Kevin W. Bowman

Senior Technical Staff

Jet Propulsion Laboratory
California Institute of Technology

MS 183-601
4800 Oak Grove Dr.
Pasadena, CA 91109
T «Phone»
F «Phone»
«Email»
science.jpl.nasa.gov

Experience

Principal Investigator, Tropospheric Emission Spectrometer (TES), Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, 2014-Present

Deputy Principal Investigator, TES, 2010-2014

Principal Investigator, Carbon Monitoring System Flux Pilot Project, 2010-present

Visiting Associate Researcher, Joint-Institute for Regional Earth System Science and Engineering (JIFRESSE), University of California, Los Angeles, 2009-Present

Scientist, Jet Propulsion Laboratory, Pasadena, CA - 1997-Present

- Integration of ocean, terrestrial, anthropogenic, and atmospheric models to attribute climate forcing from CO_2 to spatially resolved surface fluxes.
- Assimilation and inverse modeling of atmospheric composition including ozone, carbon monoxide, and CO_2 observations into global chemistry and transport models
- Observational constraints on ozone radiative forcing in chemistry-climate models
- Observing system simulation experiments (OSSE) to support mission formulation for atmospheric composition
- Conception and development of non-linear optimal estimation and error analysis algorithms for vertical trace gas retrievals.

NASA Graduate Student Researcher's Program Fellow, Georgia Institute of Technology, 1993-1997

- Wavelet-based algorithms for wavefront estimation and reconstruction in adaptive optical systems.
- Developed wavelet-based Wiener filtering techniques for stationary and non-stationary stochastic processes.

Education

Georgia Institute of Technology, Georgia - Phd in Electrical Engineering, 1997
Thesis: Application of Wavelets to Adaptive Optical Systems and Multiresolution Wiener Filtering

Georgia Institute of Technology, Georgia - MSEE, 1992
Concentrations: Optics and Signal Processing

Ecole Supérieure d'Electricité (SUPELEC), Metz, FRANCE - Diplôme de Spécialisation en Traitement et Transmission des Informations, 1993

Auburn University, Alabama - Bachelor of Electrical Engineering, 1991

MS 183-601
4800 Oak Grove Dr.
Pasadena, CA 91109
T «Phone»
F «Phone»
«Email»
science.jpl.nasa.gov

Awards

NASA JPL Voyager Award (2015)

NASA Langley, Henry J. Reid Award (2015)

NASA Group Achievement Award-Observations for Climate Model Intercomparison (2015)

NASA Group Achievement Award-Aura Tropospheric Emission Spectrometer Team (2014)

NASA Group Achievement Award-Carbon Monitoring System Flux Project (2013)

NASA Group Achievement Award-Aura Project (2005)

NASA Group Achievement Award – Aura Tropospheric Emission Spectrometer instrument team and the ground data system development teams (2005)

Goddard Space Flight Center Group Achievement Award as a member of the Aura Team (2005)

Field Campaigns

INTEX-B/MILAGRO (NASA/NSF) satellite team member (2006)

TexAQS/GoMACCS (Texas Air Quality Study/Gulf of Mexico Atmospheric Composition and Climate Study) (NOAA/NASA/Texas) Rapid Science Synthesis (RSS) panel member (2006)

Professional Activities

Carbon Monitoring System Science-Frameworks Working Group Team Leader

GEOS-Chem Steering Committee Adjoint Model and Data Assimilation Chair (2009-present)

JPL Earth system assimilation working group lead (ESAWG) (2007-08)

AGU Fall Meeting (2007). Presiding: Evaluation of Air Quality Models and Assessment of Emissions Inventories Using Bottom-Up and Top-Down Approaches III: Source and State Data Assimilation of Satellite and in Situ Measurements in Atmospheric Chemistry

Educational Contributions

Guest Lecturer, "Inverse Methods" as part of ESE/GE 152 ATMOSPHERIC RADIATION, Division of Geological and Planetary Sciences, California Institute of Technology, 2008-Present

Lecturer, "Inverse Methods and Data Assimilation", JPL Summer Climate School, 2011

Scientific Advisor to iPhone/iPad game "Offset", https://itunes.apple.com/us/app/offset/id895952566?mt=8

Selected Conference Presentations and Invited Talks

"Observational Constraints on Climate Forcing: Perspectives from satellites, models, and assimilation", Invited Seminar, Nicolas School of the Environment, Duke University, Durham, NC, 2015

"Climate Forcing in the Earth System: Contributions from the Carbon Monitoring System Flux Project", Invited Seminar, Jackson School of Geosciences, University of Texas, Austin, TX, 2015

"Observational Constraints on Climate Forcing: Perspectives from satellites, models, and assimilation", Invited Seminar, Department of Physics, University of Toronto, Toronto, Canada, 2014

K. Bowman, T. Walker, H. Worden, L. Kuai, "Attribution of ozone and methane radiative forcing to spatially resolved emissions", International Radiation Symposium, Auckland, New Zealand, 2016

K. Bowman, "NASA Carbon Monitoring System Flux Project", 3rd Carbon Carbon Workshop from Space, Exeter, UK, 2016

K. Bowman, *et al,* "Tropical controls on the CO2 atmospheric growth rate in response to the historic El Modoki ENSO event (2010-2011): Implications from carbon-climate feedbacks", EM-BRACE-CMIP6 Workshop, Dubrovnik, Croatia, 2015

MS 183-601
4800 Oak Grove Dr.
Pasadena, CA 91109
T «Phone»
F «Phone»
«Email»
science.jpl.nasa.gov

Publications

Submitted/in press

D. Schimel et al, K. **Bowman**, Observing the Carbon-Climate System, Bulletin of the American Meterological Society, *submitted*

Fu, D., **Bowman**, K. W., Worden, H. M., Natraj, V., Worden, J. R., Yu, S., Veefkind, P., Aben, I., Landgraf, J., Strow, L., and Han, Y.: High Resolution Tropospheric Carbon Monoxide Profiles Retrieved from CrIS and TROPOMI, Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2015-404, in review, 2016.

A. Bloom, J. Worden, A. Eldering, H. Worden, J. Liu, Z Jiang, M Lee, K **Bowman** , OCO-detection of southern Africa fire CO2 emissions, GRL, *in revision*

Published

Liu, J., and K. **Bowman** (2016), A method for independent validation of surface fluxes from atmospheric inversion: Application to CO2, Geophysical Research Letters, doi: 10.1002/2016GL067828.

Liu, J., K. W. **Bowman**, and D. K. Henze (2015), Source-receptor relationships of column-average CO2 and implications for the impact of observations on flux inversions, Journal of Geophysical Research: Atmospheres, 120(10), 5214–5236, doi:10.1002/2014JD022914.

Verstraeten, W. W., J. L. Neu, J. E. Williams, K. W. **Bowman**, J. R. Worden, and K. F. Boersma (2015), Rapid increases in tropospheric ozone production and export from Chi-

na, Nature Geosci, 8(9), 690–695.

Brix, H., D. Menemenlis, C. Hill, S. Dutkiewicz, O. Jahn, D. Wang, K. **Bowman**, and H. Zhang (2015), Using Green's Functions to initialize and adjust a global, eddying ocean biogeochemistry general circulation model, Ocean Modelling, 95, 1–14, doi:http://dx.doi.org/10.1016/j.ocemod.2015.07.008

N. Bousserez, D. K. Henze, A. Perkins, K. W. **Bowman**, M. Lee, J. Liu, F. Deng, and D. B. A. Jones (2015), Improved analysis-error covariance matrix for high-dimensional variational inversions: application to source estimation using a 3D atmospheric transport model, Quarterly Journal of the Royal Meteorological Society, 141(690), 1906–1921, doi:10.1002/qj.2495.

Matheou, G., and K. **Bowman** (2015), A recycling method for the large-eddy simulation of plumes in the atmospheric boundary layer, Environmental Fluid Mechanics, pp. 1–17, doi:10.1007/s10652-015-9413-4.

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4800 Oak Grove Dr.
Pasadena, CA 91109
T «Phone»
F «Phone»
«Email»
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Turner, A. J., D. J. Jacob, K. J. Wecht, J. D. Maasakkers, E. Lundgren, A. E. Andrews, S. C. Biraud, H. Boesch, K. W. **Bowman**, N. M. Deutscher, M. K. Dubey, D. W. T. Griffith, F. Hase, A. Kuze, J. Notholt, H. Ohyama, R. Parker, V. H. Payne, R. Sussmann, C. Sweeney, V. A. Velazco, T. Warneke, P. O. Wennberg, and D. Wunch (2015), Estimating global and North American methane emissions with high spatial resolution using GOSAT satellite data, Atmos. Chem. Phys., 15(12), 7049–7069, doi:10.5194/acp-15-7049-2015.

Worden, J. R., A. J. Turner, A. Bloom, S. S. Kulawik, J. Liu, M. Lee, R. Weidner, K. **Bowman**, C. Frankenberg, R. Parker, and V. H. Payne (2015), Quantifying lower tropospheric methane concentrations using GOSAT near-IR and TES thermal IR measurements, Atmos. Meas. Tech., 8(8), 3433–3445, doi:10.5194/amt-8-3433-2015.

Schwalm, C. R., D. N. Huntzinger, J. B. Fisher, A. M. Michalak, K. Bowman, P. Ciais, R. Cook, B. El-Masri, D. Hayes, M. Huang, A. Ito, A. Jain, A. W. King, H. Lei, J. Liu, C. Lu, J. Mao, S. Peng, B. Poulter, D. Ricciuto, K. Schaefer, X. Shi, B. Tao, H. Tian, W. Wang, Y. Wei, J. Yang, and N. Zeng (2015), Toward "optimal" integration of terrestrial biosphere models, Geophysical Research Letters, 42(11), 2015GL064,002, doi:10.1002/2015GL064002.

Ott, L. E., S. Pawson, G. J. Collatz, W. W. Gregg, D. Menemenlis, H. Brix, C. S. Rousseaux, K. W. **Bowman**, J. Liu, A. Eldering, M. R. Gunson, and S. R. Kawa (2015), Assessing the magnitude of CO2 flux uncertainty in atmospheric CO2 records using products from NASA's Carbon Monitoring Flux Pilot Project, Journal of Geophysical Research: Atmospheres, 120(2), 734–765, doi:10.1002/2014JD022411, 2014JD022411.

Deng, F., D. B. A. Jones, T. W. Walker, M. Keller, K. W. **Bowman**, D. K. Henze, R. Nassar, E. A. Kort, S. C. Wofsy, K. A. Walker, A. E. Bourassa, and D. A. Degenstein (2015), Sensitivity analysis of the potential impact of discrepancies in stratosphere-troposphere exchange on inferred sources and sinks of CO2, Atmos. Chem. Phys., 15(20), 11,773–11,788, doi:10.5194/acp-15-11773-2015.

Deng, F., D. B. A. Jones, D. K. Henze, N. Bousserez, K. W. **Bowman**, J. B. Fisher, R. Nassar, C. O'Dell, D. Wunch, P. O. Wennberg, E. A. Kort, S. C. Wofsy, T. Blumenstock, N. M. Deutscher, D. W. T. Griffith, F. Hase, P. Heikkinen, V. Sherlock, K. Strong, R. Sussmann, and T. Warneke (2014), Inferring regional sources and sinks of atmospheric CO2 from GOSAT XCO2 data, Atmos. Chem. Phys., 14(7), 3703–3727, doi:10.5194/acp-14-3703-2014.

Doniki, S., D. Hurtmans, L. Clarisse, C. Clerbaux, H. M. Worden, K. W. **Bowman**, and P. F. Coheur (2015), Instantaneous longwave radiative impact of ozone: an application on IASI/MetOp observations, Atmos. Chem. Phys., 15(22), 12,971–12,987, doi:10.5194/acp-15-12971-2015.

Hamer, P. D., K. W. **Bowman**, D. K. Henze, J. L. Attié, and V. Marécal (2015), The impact of observing characteristics on the ability to predict ozone under varying polluted photochemical regimes, Atmos. Chem. Phys., 15(18), 10,645–10,667, doi:10.5194/acp-15-10645-2015.

Parazoo, N. C., E. Barnes, J. Worden, A. B. Harper, K. B. **Bowman**, C. Frankenberg, S. Wolf, M. Litvak, and T. F. Keenan (2015), Influence of ENSO and the NAO on terrestrial carbon uptake in the Texas-northern Mexico region, Global Biogeochemical Cycles, 29(8), 1247–1265, doi:10.1002/2015GB005125.

Huang, M., K. W. **Bowman**, G. R. Carmichael, M. Lee, T. Chai, S. N. Spak, D. K. Henze, A. S. Darmenov, and A. M. da Silva (2015), Improved western U.S. background ozone estimates via constraining nonlocal and local source contributions using Aura TES and OMI observations, Journal of Geophysical Research: Atmospheres, 120(8), 3572–3592, doi:10.1002/2014JD022993.

Kuai, L., J. R. Worden, J. E. Campbell, S. S. Kulawik, K.-F. Li, M. Lee, R. J. Weidner, S. A. Montzka, F. L. Moore, J. A. Berry, I. Baker, A. S. Denning, H. Bian, K. W. **Bowman**, J. Liu, and Y. L. Yung (2015), Estimate of carbonyl sulfide tropical oceanic surface fluxes using Aura Tropospheric Emission Spectrometer observations, Journal of Geophysical Research: Atmospheres, 120(20), 11,012–11,023, doi:10.1002/2015JD023493.

Lapina, K., D. K. Henze, J. B. Milford, M. Huang, M. Lin, A. M. Fiore, G. Carmichael, G. G. Pfister, and K. **Bowman** (2014), Assessment of source contributions to seasonal vegetative exposure to ozone in the U.S., Journal of Geophysical Research: Atmospheres, 119(1), 324–340, doi:10.1002/2013JD020905.

Parazoo, N. C., K. **Bowman**, J. B. Fisher, C. Frankenberg, D. B. A. Jones, A. Cescatti, O. Pérez-Priego, G. Wohlfahrt, and L. Montagnani (2014), Terrestrial gross primary production inferred from satellite fluorescence and vegetation models, Global Change Biology, 20(10), 3103–3121, doi:10.1111/gcb.12652.

Kahn, B. H., F. W. Irion, V. T. Dang, E. M. Manning, S. L. Nasiri, C. M. Naud, J. M. Blaisdell, M. M. Schreier, Q. Yue, K. W. **Bowman**, E. J. Fetzer, G. C. Hulley, K. N. Liou, D. Lubin, S. C. Ou, J. Susskind, Y. Takano, B. Tian, and J. R. Worden (2014), The Atmospheric Infrared Sounder version 6 cloud products, Atmos. Chem. Phys., 14(1), 399–426, doi:10.5194/acp-14-399-2014.

Liu, J., K. **Bowman**, M. Lee, D. Henze, N. Bousserez, H. Brix, G. J. Collatz, D. Menemenlis, L. Ott, S. Pawson, D. Jones, and R. Nassar (2014), Carbon monitoring system flux estimation and attribution: Impact of ACOS-GOSAT XCO2 sampling on the inference of terrestrial biospheric sources and sinks, Tellus B, 66(0), doi:http://dx.doi.org/10.3402/tellusb.v66.22486.

MS 183-601
4800 Oak Grove Dr.
Pasadena, CA 91109
T «Phone»
F «Phone»
«Email»
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Bowman, K. W. (2013), Toward the next generation of air quality monitoring: Ozone, Atmos. Environ., 80(0), 571–583, doi:http://dx.doi.org/10.1016/j.atmosenv.2013.07.007.

Parazoo, N. C., K. **Bowman**, C. Frankenberg, J.-E. Lee, J. B. Fisher, J. Worden, D. B. A. Jones, J. Berry, G. James Collatz, I. T. Baker, M. Jung, J. Liu, G. Osterman, C. O'Dell, A. Sparks, A. Butz, S. Guerlet, Y. Yoshida, H. Chen, and C. Gerbig (2013), Interpreting Seasonal Changes in the Carbon Balance of Southern Amazonia Using Measurements of XCO2 and Chlorophyll Fluorescence from GOSAT, Geophysical Research Letters, doi:10.1002/grl.50452.

Shindell, D., G. Faluvegi, L. Nazarenko, K. **Bowman**, J.-F. Lamarque, A. Voulgarakis, G. A. Schmidt, O. Pechony, and R. Ruedy (2013), Attribution of historical ozone forcing to anthropogenic emissions, Nat. Clim. Change, 3(6), 567–570.

Shindell, D. T., O. Pechony, A. Voulgarakis, G. Faluvegi, L. Nazarenko, J. F. Lamarque, K. **Bowman**, G. Milly, B. Kovari, R. Ruedy, and G. A. Schmidt (2013), Interactive ozone and methane chemistry in GISS-E2 historical and future climate simulations, Atmos. Chem. Phys., 13(5), 2653–2689, doi:10.5194/acp-13-2653-2013.

Bowman, K. W., D. T. Shindell, H. M. Worden, J. F. Lamarque, P. J. Young, D. S. Stevenson, Z. Qu, M. de la Torre, D. Bergmann, P. J. Cameron-Smith, W. J. Collins, R. Doherty, S. B. Dalsø ren, G. Faluvegi, G. Folberth, L. W. Horowitz, B. M. Josse, Y. H. Lee, I. A. MacKenzie, G. Myhre, T. Nagashima, V. Naik, D. A. Plummer, S. T. Rumbold, R. B. Skeie, S. A. Strode, K. Sudo, S. Szopa, A. Voulgarakis, G. Zeng, S. S. Kulawik, A. M. Aghedo, and J. R. Worden (2013), Evaluation of ACCMIP outgoing longwave radiation from tropospheric ozone using TES satellite observations, *Atmos. Chem. Phys.*, *13*(8), 4057–4072, 10.5194/acp-13-4057-2013.

Young, P. J., A. T. Archibald, K. W. **Bowman**, J. F. Lamarque, V. Naik, D. S. Stevenson, S. Tilmes, A. Voulgarakis, O. Wild, D. Bergmann, P. Cameron-Smith, I. Cionni, W. J. Collins, S. B. Dalsøren, R. M. Doherty, V. Eyring, G. Faluvegi, L. W. Horowitz, B. Josse, Y. H. Lee, I. A. MacKenzie, T. Nagashima, D. A. Plummer, M. Righi, S. T. Rumbold, R. B. Skeie, D. T. Shindell, S. A. Strode, K. Sudo, S. Szopa, and G. Zeng (2013), Pre-industrial to end 21st century projections of tropospheric ozone from the atmospheric chemistry and climate model intercomparison project (ACCMIP), *Atmos. Chem. Phys.*, *13*(4), 2063–2090, 10.5194/acp-13-2063-2013.

Stevenson, D. S., P. J. Young, V. Naik, J. F. Lamarque, D. T. Shindell, A. Voulgarakis, R. B. Skeie, S. B. Dalsoren, G. Myhre, T. K. Berntsen, G. A. Folberth, S. T. Rumbold, W. J. Collins, I. A. MacKenzie, R. M. Doherty, G. Zeng, T. P. C. van Noije, A. Strunk, D. Bergmann, P. Cameron- Smith, D. A. Plummer, S. A. Strode, L. Horowitz, Y. H. Lee, S. Szopa, K. Sudo, T. Nagashima, B. Josse, I. Cionni, M. Righi, V. Eyring, A. Conley, K. W. **Bowman**, O. Wild, and A. Archibald (2013), Tropospheric ozone changes, radiative forcing and attribution to emissions in the atmospheric chemistry and climate model intercomparison project (accmip), Atmos. Chem. Phys., 13(6), 3063–3085, doi:10.5194/acp-13-3063-2013.

MS 183-601
4800 Oak Grove Dr.
Pasadena, CA 91109
T «Phone»
F «Phone»
«Email»
science.jpl.nasa.gov

Worden, H. M., M. N. Deeter, C. Frankenberg, M. George, F. Nichitiu, J. Worden, I. Aben, K. W. **Bowman**, C. Clerbaux, P. F. Coheur, A. T. J. de Laat, R. Detweiler, J. R. Drummond, D. P. Edwards, J. C. Gille, D. Hurtmans, M. Luo, S. Martinez Alonso, S. Massie, G. Pfister, and J. X. Warner (2013), Decadal record of satellite carbon monoxide observations, *Atmos. Chem. Phys.*, *13*(2), 837–850, 10.5194/acp-13-837-2013.

Verstraeten, W. W., K. F. Boersma, J. Z örner, M. A. F. Allaart, K. W. **Bowman**, and J. R. Worden (2013), Validation of six years of tes tropospheric ozone retrievals with ozonesonde measurements: implications for spatial patterns and temporal stability in the bias, Atmos. Meas. Tech., 6(5), 1413–1423, doi:10.5194/amt-6-1413-2013.

Wielicki, B. A., D. F. Young, M. G. Mlynczak, K. J. Thome, S. Leroy, J. Corliss, J. G. Anderson, C. O. Ao, R. Bantges, F. Best, K. **Bowman**, H. Brindley, J. J. Butler, W. Collins, J. A. Dykema, D. R. Doelling, D. R. Feldman, N. Fox, X. Huang, R. Holz, Y. Huang, Z. Jin, D. Jennings, D. G. Johnson, K. Jucks, S. Kato, D. B. Kirk-Davidoff, R. Knuteson, G. Kopp, D. P. Kratz, X. Liu, C. Lukashin, A. J. Mannucci, N. Phojanamongkolkij, P. Pilewskie, V. Ramaswamy, H. Revercomb, J. Rice, Y. Roberts, C. M. Roithmayr, F. Rose, S. Sandford, E. L. Shirley, W. L. Smith, B. Soden, P. W. Speth, W. Sun, P. C. Taylor, D. Tobin, and X. Xiong (2013), Achieving climate change absolute accuracy in orbit, Bulletin of the American Meteorological Society, 94(10), 1519–1539, doi:10.1175/BAMS-D-12-00149.1.

MS 183-601
4800 Oak Grove Dr.
Pasadena, CA 91109
T «Phone»
F «Phone»
«Email»
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Worden, J., K. Wecht, C. Frankenberg, M. Alvarado, K. **Bowman**, E. Kort, S. Kulawik, M. Lee, V. Payne, and H. Worden (2013), CH4 and CO distributions over tropical fires during October 2006 as observed by the Aura TES satellite instrument and modeled by GEOS-Chem, *Atmos. Chem. Phys.*, *13*(7), 3679–3692, 10.5194/acp-13-3679-2013.

Singh, K., A. Sandu, M. Jardak, K. **Bowman**, and M. Lee (2013), A practical method to estimate information content in the context of 4d-var data assimilation, SIAM/ASA Journal on Uncertainty Quantification, 1 (1), 106–138, doi:10.1137/120884523.

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Huang, M., G. R. Carmichael, T. Chai, R. B. Pierce, S. J. Oltmans, D. A. Jaffe, K. W. **Bowman**, A. Kaduwela, C. Cai, S. N. Spak, A. J. Weinheimer, L. G. Huey, and G. S. Diskin (2013), Impacts of transported background pollutants on summertime western us air quality: model evaluation, sensitivity analysis and data assimilation, *Atmos. Chem. Phys.*, *13*(1), 359–391, 10.5194/acp-13-359-2013.

Jiang, Z., D. B. A. Jones, H. M. Worden, M. N. Deeter, D. K. Henze, J. Worden, K. W. **Bowman**, C. A. M. Brenninkmeijer, and T. J. Schuck (2013), Impact of model errors in convective transport on co source estimates inferred from mopitt co retrievals, *Journal of Geophysical Research: Atmospheres*, *118*(4), 2073–2083, 10.1002/jgrd.50216

Fu, D., J. R. Worden, X. Liu, S. S. Kulawik, K. W. **Bowman**, and V. Natraj (2013), Characterization of ozone profiles derived from aura tes and omi radiances, *Atmos. Chem. Phys.*, *13*(6), 3445–3462, 10.5194/acp-13-3445-2013.

Luo, M., W. Read, S. Kulawik, J. Worden, N. Livesey, K. **Bowman**, and R. Herman (2013), Carbon monoxide (CO) vertical pro- files derived from joined TES and MLS measurements, Journal of Geophysical Research: Atmospheres, 118(18), 10,601–10,613, doi:10.1002/jgrd.50800.

Bowman, K., and D. K. Henze (2012), Attribution of direct ozone radiative forcing to spatially resolved emissions, *Geophys. Res. Lett.*, *39*(22), L22,704, 10.1029/2012GL053274

Walker, T. W., D. B. A. Jones, M. Parrington, D. K. Henze, L. T. Murray, J. W. Bottenheim, K. Anlauf, J. R. Worden, K. W. **Bowman**, C. Shim, K. Singh, M. Kopacz, D. W. Tarasick, J. Davies, P. von der Gathen, A. M. Thompson, and C. C. Carouge (2012), Impacts of midlatitude precursor emissions and local photochemistry on ozone abundances in the arctic, *J. Geophys. Res.*, *117*(D1), D01,305, 10.1029/2011JD016370

Parrington, M., P. I. Palmer, D. K. Henze, D. W. Tarasick, E. J. Hyer, R. C. Owen, D. Helmig, C. Clerbaux, K. W. **Bowman**, M. N. Deeter, E. M. Barratt, P. F. Coheur, D. Hurtmans, Z. Jiang, M. George, and J. R. Worden (2012), The influence of boreal biomass burning emissions on the distribution of tropospheric ozone over North America and the North Atlantic during 2010, *Atmos. Chem. Phys.*, *12*(4), 2077–2098, 10.5194/acp-12-2077-2012.

Worden, J., S. Kulawik, C. Frankenberg, V. Payne, K. **Bowman**, K. Cady-Peirara, K. Wecht, J. E. Lee, and D. Noone (2012), Profiles of CH_4, HDO, H_2O, and N_2O with improved lower tropospheric vertical resolution from Aura TES radiances, *Atmos. Meas. Tech.*, *5*(2), 397–411, 10.5194/amt-5-397-2012.

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A. M. Aghedo, K. W. **Bowman**, H. M. Worden, S. S. Kulawik, D. T. Shindell, J. F. Lamarque, G. Faluvegi, M. Parrington, D. B. A. Jones, and S. Rast. The vertical distribution of ozone instantaneous radiative forcing from satellite and chemistry climate models. J. Geophys. Res., 116(D1), 01 2011.

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