Makoto M. Kelp

CONTACT
INFORMATION

29 Oxford St.
Harvard University
Cambridge, MA 02138

mkelp@g.harvard.edu
makotokelp.com

EDUCATION

Harvard University, Cambridge, Massachusetts USA

Ph.D., Earth and Planetary Sciences   May 2023
S.M., Environmental Science and Engineering   March 2022

Dissertation: Expanding the Capabilities of Atmospheric Chemistry Models and Datasets using Machine Learning and Data-Driven Methods
Advisors: Daniel Jacob and Loretta Mickley

Reed College, Portland, Oregon USA

B.A., Chemistry   May 2016

Thesis: Tropospheric Particle Formation in Forests: Global Modeling of Secondary Organic Aerosol Production from Reaction of NO_3 Radical with Speciated Monoterpenes
Advisor: Juliane Fry

RESEARCH
INTERESTS

My research centers on applying data-driven methods, including machine learning and compressed sensing, to uncover new perspectives in atmospheric chemistry, air quality engineering, and land-climate interactions. I place a special emphasis on exploring the interplay among fires, climate, and society while seeking solutions to issues of environmental injustice.

RESEARCH
EXPERIENCE

Graduate Research Assistant, Postdoctoral Fellow   **Sep 2018-Aug 2023**
With Prof. Daniel Jacob and Dr. Loretta Mickley
Harvard University Department of Earth and Planetary Sciences
- Developed a machine learning chemical solver for the GEOS-Chem chemical transport model
- Created method to identify the optimal and equitable placement of air pollution sensors
- Investigated the potential for prescribed fires to abate wildfire smoke exposures in the western US
- With Dr. Christoph Keller at NASA GSFC: Chemical data assimilation in GEOS-CF forecast model
- Revisited estimates of mortality and morbidity attributable to smoke exposure in the US
- Machine learning and data science subgroup co-leader within the Atmos. Chem. Modeling Group

Jr. Research Scientist with Prof. Julian Marshall   **June 2016-Aug 2018**
University of Washington Department of Civil and Environmental Engineering
- Developed a machine-learning neural network solver to emulate the CBM-Z chemical mechanism
- Analyzed household air pollution from field studies conducted in Koppal, India
- With Prof. Timothy Larson: analysis of area-wide, vehicle emission factors in Los Angeles

Undergraduate Senior Research Thesis with Prof. Juliane Fry   **Sep 2015-May 2016**
Reed College Department of Chemistry
- Implemented a speciated NO_3-Terpene VBS scheme in GEOS-Chem to investigate the regional/global distribution of secondary organic aerosols; with Dr. Havala Pye (EPA) and Prof. Emily Fischer (CSU)

Undergraduate Research Assistant with Prof. Emily Fischer   **Summer 2015**
Colorado State University Department of Atmospheric Science
- Evaluated importance of monoterpene-derived acetone production in GEOS-Chem

Undergraduate Research Assistant with Prof. Juliane Fry   **Summer 2014-May 2015**
Reed College Department of Chemistry
- Analyzed effects of black carbon from coal trains in the Columbia River Gorge; collaborated on field campaign with Prof. Dan Jaffe (University of Washington)
- Maintained Reed College and Brooklyn Rail Yard monitoring sites; modeled ambient air pollution in SE Portland with data from field sites in conjunction with Oregon DEQ

Peer-Reviewed Publications	h-index: 8 (as of June 2023, Google Scholar); as first author (7), as co-author (4) * Note: authors who are students I mentored are double starred

[10] **Kelp, M.**, M. Carroll, T. Liu, R.M. Yantosca, H.E. Hockenberry, and L.J. Mickley (2023). Prescribed burns as a tool to mitigate future wildfire smoke exposure: Lessons for states and environmental justice communities. *Earth's Future*, 11, e2022EF003468, DOI: 10.1029/2022EF003468
- Harvard press release

[9] **Kelp, M.**, D.J. Jacob, H. Lin, and M.P. Sulprizio (2022). An online-learned neural network chemical solver for stable long-term global simulations of atmospheric chemistry. *JAMES*, 14, e2021MS002926, DOI: 10.1029/2021MS002926
- Editor's Highlight in JAMES, Special Collection on "Machine learning application to Earth system modeling"

[8] Yang, L. H., D.H. Hagan, J.C. Rivera-Rios, **M. Kelp**, E.S. Cross, C.Y. Peng, J. Kaiser, L.R. Williams, P. L. Croteau, J.T. Jayne, N.L. Ng (2022). Investigating the sources of urban air pollution using low-cost air quality sensors at an urban Atlanta site. *Environ. Sci. Technol.*, 56, 11, 7063–7073, DOI: 10.1021/acs.est.1c07005
- Special Issue on "Urban Air Pollution and Human Health"

[7] **Kelp, M.**, S. Lin**, J.N. Kutz, and L.J. Mickley (2022). A new approach for optimal placement of $PM_{2.5}$ air quality sensors: case study for the contiguous United States. *Env. Res. Letters*, 17, 034034, DOI: 10.1088/1748-9326/ac548f

[6] **Kelp, M.**, D.J. Jacob, J.N. Kutz, J.D. Marshall, and C.Tessum (2020). Toward stable, general machine-learned models of the atmospheric chemical system. *JGR: Atmospheres*, 125, e2020JD032759, DOI: 10.1029/2020JD032759

[5] **Kelp, M.**, T. Gould, E. Austin, J.D. Marshall, M. Yost, C. Simpson, and T. Larson (2020). Sensitivity analysis of area-wide, mobile source emission factors to high-emitter vehicles in Los Angeles. *Atmospheric Environment*, 223, 117212, DOI: 10.1016/j.atmosenv.2019.117212

[4] Wen, Y., H. Wang, T. Larson, **M. Kelp**, S. Zhang, Y. Wu, and J.D. Marshall (2019). On-highway vehicle emission factors, and spatial patterns, based on mobile monitoring and absolute principal component score. *Science of The Total Environment*, 676, 242-251, DOI: 10.1016/j.scitotenv.2019.04.185

[3] **Kelp, M.**, A.P. Grieshop, C.O. Reynolds, J. Baumgartner, G. Jain, K. Sethuramanand, and J.D. Marshall (2018). Real-time indoor measurement of health and climate-relevant air pollution concentrations during a carbon-finance-approved cookstove intervention in rural India. *Development Engineering*, 3, 125-132, DOI: 10.1016/j.deveng.2018.05.001

[2] Brewer, J. F., M. Bishop, **M. Kelp**, C. Keller, A.R. Ravishankara, and E.V. Fischer (2017). A sensitivity analysis of key factors in the modeled global acetone budget. *J. Geophys. Res.*, 122, DOI: 10.1002/2016JD025935

[1] Jaffe, D., J. Putz, G. Hof, G. Hof, J. Hee, D.A. Lommers-Johnson, F. Gabela, J. Fry, B. Ayres, **M. Kelp**, and M. Minsk (2015). Diesel particulate matter and coal dust from trains in the Columbia River Gorge, Washington state, USA. *Atmospheric Pollution Research*, 6, 946-952, DOI: 10.1016/j.apr.2015.04.004

Other Publications	[3] **Kelp, M.**, 2023. "Expanding the Capabilities of Atmospheric Chemistry Models and Datasets Using Machine Learning and Data-Driven Methods", Harvard University.

[2] **Kelp, M.**, C. Tessum, and J.D. Marshall (2018). Orders-of-magnitude speedup in atmospheric chemistry modeling through neural network-based emulation. arXiv:1808.03874

[1] **Kelp, M.**, 2016. "Tropospheric particle formation in forests: global modeling of secondary organic aerosol production from reaction of NO₃ radical with speciated monoterpenes", Reed College.

PUBLICATIONS IN-PREP, IN-REVIEW	• **Kelp, M.**, T. C. Fargiano**, S. Lin**, T. Liu, J.R. Turner, J. N. Kutz, and L.J. Mickley. Data-driven placement of PM$_{2.5}$ air quality sensors in the United States: an approach to target urban environmental injustice, (In Review at *GeoHealth*) • **Kelp, M.**, C. A. Keller, K. Wargan, B.M. Karpowicz, and D. J. Jacob. Tropospheric ozone data assimilation in the NASA GEOS Composition Forecast modeling system (GEOS-CF v2.0) using satellite data for ozone vertical profiles (MLS), total ozone columns (OMI), and thermal infrared radiances (AIRS, IASI), ((In Review at *Environ. Res. Lett.*) • Balasus, N., D. J. Jacob, A. Lorente, J. D. Maasakkers, R. J. Parker, H. Boesch, Z. Chen, **M., Kelp**, H. Nesser, and D. J. Varon. A blended TROPOMI+GOSAT satellite data product for atmospheric methane using machine learning to correct retrieval biases, ((In Review at *Atmos. Meas. Tech.*):

INVITED TALKS	[17] Meteorology and Climate - Modeling for Air Quality Conference, UC Davis, Sep 13-15 2023 [16] Atmospheric Chemistry Colloquium for Emerging Senior Scientists (ACCESS) XVII, Brookhaven National Lab, July 2023 [15] NASA GISS, June 2023 [14] Columbia University, June 2023 [13] Science in the News, Harvard University, April 2023 [12] AGU/AMS GeoHealth Showcase, March 2023 [11] MIT Atmospheric Chemistry Colloquium, Feb 2023 [10] Stanford University, Jan 2023 [9] Royal Meteorological Society Atmospheric Chemistry Special Interest Conference, Dec 2022 [8] Atmospheric Chemical Mechanisms Conference, UC Davis, Dec 2022 [7] Pennsylvania Dept. of Env. Protection Air Monitoring Committee Workshop, Dec 2022 [6] Karlsruhe Institute of Technology, Nov 2022 [5] University of Washington, July 2022 [4] ECMWF Machine Learning Workshop, Mar 2022 [3] University of Illinois at Urbana-Champaign Advanced Env. Engineering Seminar, Feb 2022 [2] EPA Model Applications Team Meeting, Jan 2022 [1] AGU Virtual Fall Meeting, Dec 2020

SELECT CONFERENCE PRESENTATIONS	[12] **M. Kelp**, C. A. Keller, K. Wargan, B.M. Karpowicz, and D. J. Jacob. Tropospheric ozone data assimilation in the NASA GEOS Composition Forecast Modeling System GEOS-CF v2.0 including direct assimilation of thermal infra-red radiances. *AMS Annual Meeting*, Denver, CO, January 12, 2023 *Talk* [11] **M. Kelp**, T. Liu, and L.J. Mickley. Sensitivity of population-weighted smoke exposure to wildfires in the western United States: implications for prescribed burning at the state level and in rural environmental justice communities. *AGU Fall Meeting*, Chicago, IL, December 14, 2022 *Talk* [10] **M. Kelp**, T. C. Fargiano, S. Lin, T. Liu, J. N. Kutz, and L.J. Mickley. Data-driven placement of PM$_{2.5}$ air quality sensors in the United States: an approach to target urban environmental injustice. *AGU Fall Meeting*, Chicago, IL, December 12, 2022 *Talk* [9] **M. Kelp**, D.J. Jacob, and H. Lin. An Online-Learned Neural Network Chemical Solver for Stable and Long-Term Global Simulations of Atmospheric Chemistry in S2S Applications. *AMS Annual Meeting*, January 26, 2022 *Talk* [8] **M. Kelp** and D.J. Jacob. A recursive neural network chemical solver for fast long-term global

simulations of atmospheric composition. *AMS Annual Meeting*, Virtual, January 13, 2021 *Talk*

[7] **M. Kelp**, J. N. Kutz, J.D. Marshall, and C.W. Tessum. Toward stable, general machine-learned models of the atmospheric chemical system. *AGU Virtual Fall Meeting*, Virtual, December 7, 2020 *Invited Talk*

[6] **M. Kelp** and D.J. Jacob. A recursive neural network chemical solver for fast long-term global simulations of atmospheric composition. *Atmospheric Chemical Mechanisms Conference*, Virtual, November 18, 2020 *Lightning talk*

[5] **M. Kelp**, J. N. Kutz, J.D. Marshall, and C.Tessum. Deep Learning Emulation and Compression of an Atmospheric Chemical System using a Chained Training Regime. *AGU Fall Meeting*, San Francisco, CA, December 13, 2019

[4] **M. Kelp**, C.W. Tessum, and J.D. Marshall. Orders-of-Magnitude Speedup in Atmospheric Chemistry Modeling through Neural Network-Based Emulation. *AGU Fall Meeting*, Washington D.C, December 12, 2018

[3] **M. Kelp**, A.P. Grieshop, C.O. Reynolds, J. Baumgartner, G. Jain, K. Sethuramanand, and J.D. Marshall. Investigating Health-Relevant Air Pollution Concentration Linkages Across Multiple Seasons During Indoor Cookstove Campaign in Rural India. *ISES-ISEE Joint Annual Meeting*, Ottawa, CA, August 25, 2018

[2] **M. Kelp**, H.O.T. Pye, E.V. Fischer, J. Brewer, and J. Fry. Global Modeling of Secondary Organic Aerosol Production from Reaction of NO_3 Radical with Speciated Monoterpenes. *AAAR Annual Conference*, Portland, OR, October 18, 2016

[1] **M. Kelp**, J. Brewer, C. Keller, and E.V. Fischer. Evaluating the Potential Importance of Monoterpene Degradation for Global Acetone Production. *AGU Fall Meeting*, San Francisco, CA, December 16, 2015

TEACHING EXPERIENCE	**Teaching Certificate**, Harvard University, Derek Bok Center for Education & Learning, 2023

Harvard University Department of Earth and Planetary Sciences
Teaching Fellow **Fall 2019, Fall 2020, Fall 2022**
Guest Lecturer **Fall 2022**
- EPS 200: Graduate-level Atmospheric Chemistry and Physics

Reed College Department of Chemistry
Laboratory Teaching Assistant **2015-2016**
- Chem 101: Molecular Structure and Properties
- Chem 102: Chemical Reactivity

Tutor, Grader **2013-2016**
- Chem 101: Molecular Structure and Properties
- Chem 102: Chemical Reactivity
- Chem 230: Environmental Chemistry

MENTORING

Christian Chiu, Harvard University, Summer 2023
- Project: Data-driven $PM_{2.5}$ air pollution sensor placement for the top 25 most segregated cities in the United States
- HUCE Summer Undergraduate Research Program (co-mentor with Dr. Loretta Mickley)

Greta Schultz, University of Wisconsin-Madison, Summer 2023
- Project: Emergency mobile monitoring for California wildfire smoke
- Summer Program at Harvard in Earth and Environmental Research (SPHEER) (co-mentor with Drew Pendergrass and Dr. Loretta Mickley)

Karina Chung, Harvard University, Summer 2023
- Project: Google Earth Engine applications for wildfire smoke in the Western United States
- Harvard Program for Research in Science and Engineering (PRISE) (co-mentor with Dr. Tina Liu and Dr. Loretta Mickley)

Timothy Fargiano, Harvard University, Summer 2022 - Fall 2022
- Project: Optimal placement of $PM_{2.5}$ air quality sensors in the US: An approach to target environmental injustice
- HUCE Summer Undergraduate Research Program (co-mentor with Dr. Loretta Mickley)

Margaret Schultz, Harvard University, January 2022 - December 2022
- Project: Real-time high-resolution downscaling of fine particulate matter ($PM_{2.5}$) air quality in the United States using machine learning
- Harvard ESE senior research thesis (co-mentor with Drew Pendergrass and Dr. Loretta Mickley)

Sanjna Kedia, Harvard University, Summer 2022
- Project: Machine learning for automated detection of wildfire smoke in the US
- HUCE Summer Undergraduate Research Program (co-mentor with Drew Pendergrass and Dr. Loretta Mickley)

Samuel Lin, Harvard University, Summer 2021-Fall 2021
- Project: Optimal air quality sensor placement in the United States
- HUCE Summer Undergraduate Research Program (co-mentor with Dr. Loretta Mickley)

Marie Panday, University of Maryland, Summer 2021
- Project: Trends in and Reconstruction of Smoke Days across the United States
- Department of Organismic and Evolutionary Biology (OEB) REU (co-mentor with Tina Liu, Drew Pendergrass, and Dr. Loretta Mickley)

Kent Toshima, Harvard University, Summer 2020 - Summer 2021
- Project: Application of deep learning to detection of wildfire smoke in HMS over North America
- HUCE Summer Undergraduate Research Program (co-mentor with Tina Liu, Drew Pendergrass, and Dr. Loretta Mickley)

Miah Caine, Harvard University, Summer 2020 - Spring 2021
- Project: Agreement between the HMS Product and Ground-Level Smoke in the Pacific Northwest
- HUCE Summer Undergraduate Research Program (co-mentor with Tina Liu, Drew Pendergrass, and Dr. Loretta Mickley)

PROFESSIONAL SERVICE AND AFFILIATIONS

- **Co-Convener, Co-Session Chair** at American Geophysical Union Fall Meeting *(Dec 2023)* "Prescribed Fires and Land Management in North America"
  - Primary convener
  - With Tianjia Liu, Miriam Marlier, and Loretta Mickley as co-conveners
- **Co-Chair** for Tropospheric Ozone Assessment Report, Phase II (TOAR-II) Machine Learning for Tropospheric Ozone (ML4O3) Working Group *(March 2023 -)*
- **Proposal review panelist** for *NASA Earth Science ROSES Program (Nov 2022)*
- **Co-leader** of Statistical Learning in Atmos. Chem. (SLAC) group (Oct 2022 – Present)
- **Peer reviewer** for *Atmos. Chem. and Phys., Env. Res. Comm., Atmospheric Pollution Research, Geoscientific Model Development, Env. Res. Letters, JAMES, GeoHealth, Environ. Sci. Technol.*
- **Memberships:** AGU, AAAR, AMS
- Air Quality Sample Assistant (Fall 2015) at Oregon DEQ: installed and collected BGI filters and maintained an EPA validated method sampling site and helped create statewide attention towards arsenic and cadmium concentrations in SE Portland, which resulted in the Bullseye Glass Co. suspending its use of chromium

COMMUNITY ENGAGEMENT

Harvard University Jazz Band	**2019-Present**
Dudley Graduate Student Jazz Band	**2018-2019**
NPR Philosophy Talk Guest Jazz Musician	**Aired Nov 29 2015**
Reed College Jazz Ensemble and Conference Musician	**2012-2016**

TECHNICAL SKILLS

Computer languages: Fortran 90, IDL, R, Go, Python, Matlab, Unix environments
Software: GEOS-Chem, TensorFlow, LaTeX, RStudio
Operating Systems: Linux, Mac OS X