

Dr. Matthäus Kiel - Curriculum Vitae

Jet Propulsion Laboratory/California Institute of Technology

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RESEARCH INTERESTS

Remote Sensing, Greenhouse Gases, Carbon Cycle, Air Quality, Retrieval Algorithms, Validation

EDUCATION

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| Ph.D. in Physics (Dr. rer. nat.)
Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany | May 2013 – July 2016 |
| Master of Science in Physics
Rheinische Friedrich-Wilhelms-Universität (RFWU), Bonn, Germany | Oct. 2010 – Oct. 2012 |
| Bachelor of Science in Physics
Rheinische Friedrich-Wilhelms-Universität (RFWU), Bonn, Germany | Oct. 2006 – Oct. 2010 |
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RESEARCH AND WORK EXPERIENCE

Jet Propulsion Laboratory/Caltech, Pasadena, CA June 2019 – present
Research Scientist in Earth Science Division - Tropospheric Composition

Member of the Orbiting Carbon Observatory-2 (OCO-2), Orbiting Carbon Observatory-3 (OCO-3), and Multi-Angle Imager for Aerosols (MAIA) Science Teams.

- **Validation Lead (OCO-3):** Responsible for executing the mission's validation plan; Evaluate OCO-3 observations against independent data sets including ground/air/space-borne measurements and model simulations; Coordinate validation and field campaign activities with external research partners including the Total Carbon Column Observing Network (TCCON) and the Collaborative Carbon Column Observing Network (COCCON).
- **Local Sources Lead (OCO-3):** Lead and coordinate a group of scientists to address challenges in the anthropogenic footprint of carbon and its relationship to air quality; Contribute to the development of novel methods to identify and quantify small-scale greenhouse gas sources using OCO-3's Snapshot Area Map (SAM) observations.
- **OCO-2/3 Science Team:** Contribute to the development of the Atmospheric Carbon Observations from Space (ACOS) algorithm; Develop methods to mitigate local and global-scale biases in OCO-2/3 Level 2 data; Evaluate and validate OCO-2/3 against independent data sets; Provide science support for multiple project teams including calibration, algorithm, validation, and mission planning; Coordinate meetings for the working groups associated with validation and local sources.
- **MAIA Science Team:** Conceptualize and develop quality control measures for aerosols and particulate matter (PM) observations. Validation of Level 2/4 data against the Aerosol Robotic Network (AERONET) and PM surface monitors.

Caltech, Wennberg Research Group, Pasadena, CA

Aug. 2016 – June 2019

Postdoctoral Scholar in Environmental Science and Engineering

- Studied the terrestrial carbon cycle and anthropogenic carbon dioxide emissions using satellite data, ground-based remote sensing observations, airborne in-situ measurements, and model data.
- Analyzed and calibrated data from the Total Carbon Column Observing Network (TCCON) against aircraft in-situ measurements.

KIT, Remote Sensing Research Group, Karlsruhe, Germany

May 2013 – July 2016

Graduate Research Assistant

- Identified and quantified error sources in the retrieval of atmospheric trace gas abundances using ground-based solar FTIR measurements in the Network for the Detection of Atmospheric Composition Change (NDACC) and TCCON.
- Synthesized atmospheric retrievals of trace gas abundances from NDACC and TCCON measured in different spectral regions to improve the spatial and temporal coverage over each individual network.

RESEARCH GRANTS

- **NASA ROSES A.51 Science Team for the OCO Missions (2021)**

Title: *Reducing OCO-2 regional biases through novel 3D-cloud and meteorology retrievals*

JPL Lead CO-I: Dr. Matthäus Kiel

Contribution: Implementation and evaluation of vertical water and vertical temperature retrievals in the OCO-2 retrieval system. Generating bias correction parameters for atmospheric retrievals.

AWARDS

- **JPL Voyager Award** for improving the scientific impact of OCO-3 data through validation and visualization efforts (2022).
- **JPL Voyager Award** for successfully coordinating and leading a group of scientists in the analysis of OCO-2/3 measurements over Los Angeles (2021).
- **JPL Team Bonus Award** for the successful delivery of high-quality results from the B10 Level 2 algorithm for the OCO missions (2020).
- **JPL Team Bonus Award** for the successful completion of OCO-3's In-Orbit-Checkout (2019).

SERVICE AND OUTREACH

- Review manuscripts for scientific journals (e.g. Remote Sens. Environ, Atmos. Meas. Tech., Atmos. Chem. Phys., Remote Sens., Geophys. Res. Lett.)
- Review research grant proposals (e.g. NASA, FINESST21)
- Organize sessions at domestic and international conferences (e.g. IWGGMS17)
- Present science highlights at public events chosen by NASA's JPL Speakers Bureau (e.g. at the American Institute of Aeronautics and Astronautics (AIAA) - Los Angeles/Las Vegas Section)
- Collaborate with members of ESA and JAXA on the Tri-Agency Earth Observing Dashboard with the goal to inform the public about environmental, economic, and societal challenges impacting Earth's climate.

TEACHING AND MENTORING

- Co-mentoring NASA summer internship student, starting summer 2022, JPL, Pasadena, CA, USA

LIST OF PUBLICATIONS

- 2023 Taylor, T. E., O'Dell, C. W., Baker, D., Bruegge, C., Chang, A., Chapsky, L., Chatterjee, A., Cheng, C., Chevallier, F., Crisp, D., Dang, L., Drouin, B., Eldering, A., Feng, L., Fisher, B., Fu, D., Gunson, M., Haemmerle, V., Keller, G. R., **Kiel, M.**, et al.: *Evaluating the consistency between OCO-2 and OCO-3 XCO₂ estimates derived from the NASA ACOS version 10 retrieval algorithm*, Atmos. Meas. Tech. Discuss., in review, 2023
- Laughner, J., Andrews, A., Roche S., **Kiel, M.**, Toon, G. C., Wunch, D., Baier, B., Biraud, S., Chen, H., Kivi, R., Laemmle, T., Quéhé, P.-Y., Rousogonous, C., Stephens, B. B., and Wennberg, P. O.: *A new algorithm to generate a priori trace gas profiles for the GGG2020 retrieval algorithm*, Atmos. Meas. Tech., 16, 1121–1146, 2023
- Bell, E., Taylor, T. E., Merrelli A., O'Dell C., Nelson R. R., **Kiel, M.**, Eldering A., Rosenberg R., and Fisher, B.: *Exploring OCO-3 Snapshot Area Map swath bias via geometry, surface, and aerosol effects in simulations*, Atmos. Meas. Tech., 16, 109–133, 2023
- 2022 Nassar, R., Moeini, O., Mastrogiacomo, J.-P., O'Dell, C. W., Nelson, R. R., **Kiel, M.**, Chatterjee, A., Eldering, A., and Crisp, D.: *Tracking CO₂ emission reductions from space: A case study at Europe's largest fossil fuel power plant*, Front. Remote Sens. 3:1028240, 2022
- Rißmann, M., Chen J., Osterman, G., Dietrich, F., Zhao X., Makowski, M., and **Kiel, M.**: *Comparison of OCO-2 target observations to MUCCnet - Is it possible to capture urban XCO₂ gradients from space?*, Atmos. Meas. Tech., 15, 6605–6623, 2022
- Wu, D., Liu, J., Wennberg, P. O., Palmer, P. I., Nelson, R. R., **Kiel, M.**, and Eldering, A.: *Towards sector-based attribution using intra-city variations in satellite-based emission ratios between CO₂ and CO*, Atmos. Chem. Phys., 22, 14547–14570, 2022
- Taylor, T. E., O'Dell, C. W., Crisp, D., Kuze, A., Lindqvist, H., Wennberg, P. O., Chatterjee, A., Gunson, M., Eldering, A., Fisher, B., **Kiel, M.**, Nelson, R. R., Merrelli, A., Osterman, G., Chevallier, F., Palmer, P. I., Feng, L., Deutscher, N. M., Dubey, M. K., Feist, D. G., García, O. E., Griffith, D. W. T., Hase, F., Iraci, L. T., Kivi, R., Liu, C., De Mazière, M., Morino, I., Notholt, J., Oh, Y.-S., Ohyama, H., Pollard, D. F., Rettinger, M., Schneider, M., Roehl, C. M., Sha, M. K., Shiomi, K., Strong, K., Sussmann, R., Té, Y., Velasco, V. A., Vrekoussis, M., Warneke, T. and Wunch, D.: *An 11-year record of XCO₂ estimates derived from GOSAT measurements using the NASA ACOS version 9 retrieval algorithm*, Earth System Science Data, 14, 325–360, 2022
- 2021 Nassar, R., Mastrogiacomo, J.-P., Bateman-Hemphill W., McCracken C., MacDonald C. G., Hill T., O'Dell, C. W., **Kiel, M.**, and Crisp, D.: *Advances in quantifying power plant CO₂ emissions with OCO-2*, Remote Sens. Environ., 264, 112579, 2021
- Kiel, M.**, Eldering A., Roten, D. D., Lin, J. C., Feng, S., Lei, R., Lauvaux, T., Oda, T., Roehl, C. M., Blavier, J.-F., and Iraci, L.: *Urban-focused satellite CO₂ observations from the Orbiting Carbon Observatory-3: a first look at the Los Angeles Megacity*, Remote Sens. Environ., 258, 112314, 2021
- 2020 Taylor, T. E., Eldering, A., Merrelli, A., **Kiel, M.**, Somkuti, P., Cheng, C., Rosenberg, R., Fisher, B., Crisp, D., Basilio, R., Bennett, M., Cervantes, D., Chang, A., Dang, L., Frankenberg, C., Haemmerle, V. R., Keller, G. R., Kurosu, T., Laughner, J. L., Lee, R., Marchetti, Y., Nelson, R. R., O'Dell, C. W., Osterman, G., Pavlick, R., Roehl, C., Schneider,

R., Spiers, G., To, C., Wells, C., Wennberg, P. O., Yelamanchili, A., and Yu, S.: *OCO-3 early mission operations and initial (vEarly) XCO₂ and SIF retrievals*, Remote Sens. Environ., 251, 112032, 2020

Ohyama, H., Morino, I., Velazco, V. A., Klausner T., Bagtasa G., **Kiel, M.**, Frey M., Hori A., Uchino O., Matsunaga T., Deutscher, N. M., DiGangi, J. P., Choi, Y., Diskin, G. S., Pusede, S. E., Fiehn, A., Roiger, A., Lichtenstern, M., Schlager, H., Wang, P. K., Chou C., Andrés-Hernández M. D., and Burrows, J. P.: *Validation of XCO₂ and XCH₄ retrieved from a portable Fourier transform spectrometer with those from in situ profiles from aircraft-borne instruments*, Atmos. Meas. Tech., 13, 5149–5163, 2020

Byrne, B., Liu, J., Lee, M., Baker, I., Bowman, K., Deutscher, N., Feist, D., Griffith, D., Iraci, L., **Kiel, M.**, Kimball, J., Miller, C., Morino, I., Parazoo, N., Petri, C., Roehl, C., Sha, M., Strong, K., Velazco, V., Wennberg, P., and Wunch, D.: *Improved constraints on northern extratropical CO₂ fluxes obtained by combining surface-based and space-based atmospheric CO₂ measurements*, J. Geophys. Res.-Atmos., 125, e2019JD032029, 2020

2019 Kulawik, S. S., O'Dell, C. W., Osterman, G. B., Wennberg, P. O., Wunch, D., Roehl, C. M., Deutscher, N. M., **Kiel, M.**, Griffith, D. W. T., Velazco, V. A., Notholt, J., Warneke, T., Petri, C., De Maziere, M., Sha, M. K., Sussman, R., Rettinger, M., Pollard, D., Morino, I., Uchino, O., Hase, F., Feist, D. G., Strong, K., Kivi, R., Iraci, L., Shuji, K., Dubey, M. K., Sepulveda, E., Garcia, O. E., Te, Y., Jeseck, P., Heikkinen, P., Schneider, M., Wofsy, S. C., McKain, K., Sweeney, C., Baker, D. F., and Liu, J.: *Characterization of OCO-2 biases and errors for flux estimates*, Atmos. Meas. Tech. Discuss., 2019

Hedelius, J. K., He, T.-L., Jones, D. B. A., Baier, B. C., Buchholz, R. R., De Mazière, M., Deutscher, N. M., Dubey, M. K., Feist, D. G., Griffith, D. W. T., Hase, F., Iraci, L. T., Jeseck, P., **Kiel, M.**, Kivi, R., Liu, C., Morino, I., Notholt, J., Oh, Y.-S., Ohyama, H., Pollard, D. F., Rettinger, M., Roche, S., Roehl, C. M., Schneider, M., Shiomi, K., Strong, K., Sussmann, R., Sweeney, C., Té, Y., Uchino, O., Velazco, V. A., Wang, W., Warneke, T., Wennberg, P. O., Worden, H. M., and Wunch, D.: *Evaluation of MOPITT Version 7 joint TIR–NIR XCO retrievals with TCCON*, Atmos. Meas. Tech., 12, 5547–5572, 2019

Kiel, M., O'Dell, C. W., Fisher, B., Eldering, A., Nassar, R., MacDonald, C. G., and Wennberg, P. O.: *How bias correction goes wrong: Measurement of XCO₂ affected by erroneous surface pressure estimates*, Atmos. Meas. Tech., 12, 2241–2259, 2019

Frey, M., Sha, M. K., Hase, F., **Kiel, M.**, Blumenstock, T., Harig, R., Surawicz, G., Deutscher, N. M., Shiomi, K., Franklin, J., Bösch, H., Chen, J., Grutter, M., Ohyama, H., Sun, Y., Butz, A., Mengistu Tsidu, G., Ene, D., Wunch, D., Cao, Z., Garcia, O., Ramonet, M., Vogel, F., Orphal, J.: *Building the Collaborative Carbon Column Observing Network (COCCON): Long term stability and ensemble performance of the EM27/SUN Fourier transform spectrometer*, Atmos. Meas. Tech., 12, 1513–1530, 2019

2018 O'Dell, C. W., Eldering, A., Wennberg, P. O., Crisp, D., Gunson, M. R., Fisher, B., Frankenberg, C., **Kiel, M.**, Lindqvist, H., Mandrake, L., Merrelli, A., Natraj, V., Nelson, R. R., Osterman, G. B., Payne, V. H., Taylor, T. R., Wunch, D., Drouin, B. J., Oyafuso, F., Chang, A., McDuffie, J., Smyth, M., Baker, D. F., Basu, S., Chevallier, F., Crowell, S. M. R., Feng, L., Palmer, P. I., et al.: *Improved Retrievals of Carbon Dioxide from the Orbiting Carbon Observatory-2 with the version 8 ACOS algorithm*, Atmos. Meas. Tech., 6539–6576, 2018

Borsdorff, T., aan de Brugh, J., Hu, H., Hasekamp, O., Sussmann, R., Rettinger, M., Hase, F., Gross, J., Schneider, M., Garcia, O., Stremme, W., Grutter, M., Feist, D. G., Arnold, S.

- G., De Mazière, M., Kumar Sha, M., Pollard, D. F., **Kiel, M.**, Roehl, C., Wennberg, P. O., Toon, G. C., and Landgraf, J.: *Mapping carbon monoxide pollution from space down to city scales with daily global coverage*, Atmos. Meas. Tech. Discuss., 5507-5518, 2018
- Oh, Y.-S., Kenea, S. T., Goo, T.-Y., Kim, G., Chung, K.-S., Rhee, J.-S., Ou, M.-L., Byun, Y.-H., Wennberg, P. O., **Kiel, M.**, Velazco, V. A., Oh, M.-L., and Griffith, D. W. T.: *Characteristics of the Greenhouse Gas Concentration Derived from the Ground-based FTS Spectra at Anmyeondo, Korea*, Atmos. Meas. Tech., 11, 2361-2374, 2018
- 2017 Velazco V. A., Morino, I., Uchino O., Hori A., **Kiel, M.**, Bukosa, B., Deutscher, N. M., Sakai, T., Nagai, T., Bagtasa, G., Izumim, T., Yoshida, Y., and Griffith, D. W. T.: *TCCON Philippines: First Measurement Results, Satellite Data and Model Comparisons in Southeast Asia*, Remote Sens., 9, 1228, 2017
- Wunch, D., Wennberg, P. O., Osterman G., Fisher, B., Naylor, B., Roehl, C. M., O'Dell C., Mandrake, L., Viatte, C., **Kiel, M.**, et al.: *Comparisons of the Orbiting Carbon Observatory-2 (OCO-2) XCO₂ measurements with TCCON*, Atmos. Meas. Tech., 10, 2209-2238, 2017
- 2016 Barthlott, S., Schneider, M., Hase, F., Blumenstock, T., **Kiel, M.**, Dubravica, D., Garcia O. E., Sepulveda, E., Mengistu Tsidu, G., Takele Kenea, S., Grutter, M., Stremme, W., Strong, K., Weaver, D., Palm, M., Warneke, T., Notholt, J., Mahieu, E., Jones, N., Griffith, D. W. T., Smale, D., and Robinson, J.: *Tropospheric water vapour isotopologue data (H₂¹⁶O, H₂¹⁸O and HD¹⁶O) as obtained from NDACC/FTIR solar absorption spectra*, Earth Syst. Sci. Data, 9, 15-29, 2016
- Kiel, M.**, Hase, F., Blumenstock, T., and Kirner, O.: *Comparison of XCO abundances from the Total Carbon Column Observing Network and the Network for the Detection of Atmospheric Composition Change measured in Karlsruhe*, Atmos. Meas. Tech., 9, 2223-2239, 2016
- Hase, F., Frey, M., **Kiel, M.**, Blumenstock, T., Harig, R., Keens, A., and Orphal, J.: *Addition of a channel for XCO observations to a portable FTIR spectrometer for greenhouse gas measurements*, Atmos. Meas. Tech., 9, 2303-2313, 2016
- Kiel, M.**, Wunch, D., Wennberg, P. O., Toon, G. C., Hase, F., and Blumenstock, T.: *Improved retrieval of gas abundances from near-infrared solar FTIR spectra measured at the Karlsruhe TCCON station*, Atmos. Meas. Tech., 9, 669-682, 2016
- 2015 Hase, F., Frey, M., Blumenstock, T., Groß, J., **Kiel, M.**, Kohlhepp, R., Mengistu Tsidu, G., Schäfer, K., Sha, M. K., and Orphal, J.: *Application of portable FTIR spectrometers for detecting greenhouse gas emissions of the major city Berlin*, Atmos. Meas. Tech., 8, 3059-3068, 2015
- Frey, M., Hase, F., Blumenstock, T., Groß, J., **Kiel, M.**, Mengistu Tsidu, G., Schäfer, K., Sha, M. K., and Orphal, J.: *Calibration and instrumental line shape characterization of a set of portable FTIR spectrometers for detecting greenhouse gas emissions*, Atmos. Meas. Tech., 8, 3047-3057, 2015
- 2014 Porz, S., **Kiel, M.**, and Lehnertz, K.: *Can spurious indications for phase synchronization due to superimposed signals be avoided?*, Chaos, 24, 033112, 2014

SELECTED PRESENTATIONS

- 2023 **European Geosciences Union Gen. Assembly, Vienna, Austria**
Kiel, M., O'Dell, C., Fisher, B., Nelson, R., Taylor T., Kurosu T., Rosenberg, R., Keller, Laughner, J., and Osterman, G.: *Evaluation of the OCO-2 and OCO-3 ACOS data products against TCCON*, 4/2023, Poster
- 2022 **ESA Living Planet Symposium, Bonn, Germany**
Kiel, M., Eldering, A., O'Dell, C., Fisher, B., Nelson, R., Taylor T., Kurosu T., Merrelli, A., Rosenberg, R., Keller, G., Spiers, G., Laughner, J., Bell, E., Osterman, G., Somkuti, P., Pavlick, R., Chang, A., Dang, L., Wunch, D., Crisp, D., and Wennberg, P.: *An overview of the new and improved OCO-3 ACOS V10 XCO₂ data product*, 5/2022, Oral
- 2021 **American Institute of Aeronautics and Astronautics, LA-LV Section, Los Angeles, USA**
Kiel, M., Eldering A., Roten, D. D., Lin, J. C., Feng, S., Lei, R., Lauvaux, T., Oda, T., Roehl, C. M., Blavier, J.-F., and Iraci, L.: *Urban-focused satellite CO₂ observations from OCO-3: a first look at the Los Angeles Megacity*, 8/2021, Oral, **Invited**
- European Geosciences Union Gen. Assembly (Virtual), Vienna, Austria**
Kiel, M., Eldering A., Roten, D. D., Lin, J. C., Feng, S., Lei, R., Lauvaux, T., Oda, T., Roehl, C. M., Blavier, J.-F., and Iraci, L.: *Urban-focused satellite CO₂ observations from the Orbiting Carbon Observatory-3: a first look at the Los Angeles Megacity*, 4/2021, Oral
- 2020 **Annual NDACC-IRWG and TCCON Meeting (Virtual), St. Petersburg, Russia**
Kiel, M., Laughner, J., Eldering, A., Fisher, B. M., Kurosu, T. P., Pavlick, R. P., Osterman, G. B., Nelson, R. R., O'Dell, C. W., Somkuti, P., Taylor, T. E., Roehl, C. M., and the TCCON team.: *An Overview of the First Year of the OCO-3 Mission*, 6/2020, Oral, **Invited**
- American Geophysical Union Fall Meeting (Virtual), San Francisco, CA, USA**
Kiel, M., Eldering, A., Roten, D. D., Lei, R., Feng, S., Lin, J. C., Lauvaux, T., Roehl, C., Oda, T.: *OCO-3 SAM mode: Spatiotemporal Variability of XCO₂ over the Los Angeles Megacity*, 12/2020, Oral
- 2019 **American Geophysical Union Fall Meeting, San Francisco, CA, USA**
Kiel, M., Laughner, J., Eldering, A., Fisher, B., Kurosu, T., Pavlick, R., Osterman, G., Nelson, R., O'Dell, C., Somkuti, P., Taylor, T., Roehl, C., and the TCCON team: *First Comparison of OCO-3 XCO₂ Measurements with TCCON*, 12/2019, Oral
- 2018 **Annual NDACC-IRWG and TCCON Meeting, Mexico City, Mexico**
Kiel, M., Liu, J., Wennberg O. P.: *Variations of XCO₂ anomalies over the European continent observed from OCO-2 and TCCON*, 6/2018, Oral
- 14th International Workshop on GHG Measurements from Space, Toronto, Canada**
Kiel, M., Fisher, B., Wennberg O. P.: *Correction of topography related biases in XCO₂ measurements from OCO-2*, 5/2018, Oral
- 2017 **NASA's OCO-2 Science Team Meeting, Boulder, CO, USA**
Kiel, M., and the OCO-2 Validation team.: *Analysis of V8 OCO-2 target mode measurements*, 10/2017, Oral
- Annual NDACC-IRWG and TCCON Meeting, Paris, France**

Kiel, M., Toon, G. C., Wunch, D., Mendonca, J., and Wennberg, P. O.: *Airmass dependent correction factors and Xair dependence*, 6/2017, Oral

2016 **European Geosciences Union Gen. Assembly, Vienna, Austria**

Kiel, M., Hase, F., Blumenstock, and T., Kirner, O.: *Comparison of XCO abundances measured in the MIR (NDACC) and NIR (TCCON) using Karlsruhe Fourier Transform Infrared (FTIR) measurements*, 4/2016, Poster

2015 **American Geophysical Union Fall Meeting, San Francisco, CA, USA**

Kiel, M., Hase, F., and Blumenstock, T.: *Comparison of MIR (NDACC) and NIR (TCCON) column-averaged CO from ground-based solar Fourier Transform Infrared (FTIR) measurements*, 12/2015, Poster