Mark T. Richardson

M/S233-300, Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91101, USA
Tel: (818)354-4270 **e-mail:** markr@jpl.nasa.gov

Summary

I am interested in large-scale climate change, understanding the physics behind it and its societal impacts. I have a strong orientation to solid observations mixed with physical understanding and rigorous accounting for uncertainties.

Recent work has involved combining hyperspectral spectroscopy with other sensors in the development and use of optimal estimation cloud and atmospheric retrievals. Separately I have analysed trends in essential climate variables including temperature, precipitation and cloud properties.

My objectives are to be a leader in remote sensing of cloud processes, to identify the best measurement techniques to answer scientific questions, and then to go out and answer those questions using modern techniques to improve retrievals. In particular, I have a focus on cloud processes and cloud-aerosol interactions for the purpose of understanding climate sensitivity and feedbacks. This will mean, where possible, ensuring compatibility with past data and the program of record for ancillary data or long-term studies.

I aim to ensure that measurements we undertake will contribute to answering major questions in climate science. This will involve collaboration across different instrument teams, but also with engineers at one end and theoreticians and modellers at the other.

Employment and Internships

2022—present	**Research Scientist, Jet Propulsion Laboratory, Caltech** Projects include changes in convective risk, aerosol-low-cloud interactions, development of cloud and atmosphere retrievals, Phase A development of upcoming mission products.
2020—present	**Research Associate III, CSU (at JPL)**
2018—2020	**Research Assistant II, UCLA (at JPL)**
2015—2018	**Postdoctoral scholar, Caltech (at JPL)**
2014	**3-month Internship, Parliamentary Office of Science and Technology UK**

Education

2010—2014	**University of Reading, UK (PhD)** Snow Observations and Modelling, supervisor: Prof. Robert Gurney
2006—2010	**University of Durham, UK (MPhys)** Master of Physics, First-class Honours Masters' project in condensed matter physics, exploiting quantum tunnelling to improve electrical contacts of cadmium-telluride solar cells

Technical skills and experiences

Computing	Primary language is Python, but have worked with and modified code in FORTRAN, R and MATLAB. Experience with physical models, retrievals, machine learning and large datasets in CDF/netCDF/HDF.
Experimental	Low-temperature experiments in condensed-matter physics lab for MPhys, design and execution of spectroscopy snow fieldwork experiments for PhD.
Satellite data and retrievals	Experience with A-train satellite data from Level 1 to Level 3, including processing Level 1 radiance spectra to Level 2 cloud properties. Development of preprocessors, including machine-learning classifiers, and multiple retrieval approaches from lookup tables to optimal estimation.

Model evaluation	Produced and modified physical models, worked with CMIP5/6 outputs, including modifying a global-temperature-record emulator to simulate observational datasets such as HadCRUT and GISTEMP from CMIP output. Used COSP and large ensemble output for science applications.
Statistics	Familiarity with frequentist and Bayesian approaches, including Bayesian optimal estimation for OCO2CLD-LIDAR-AUX development. I know that uncertainty quantification is crucial, and am aware of the necessity to check assumptions behind statistical methods such as non-normality, heteroskedasticity and autocorrelation. Recent work has included order statistics and avoiding sampling biases associated with extreme event frequency trends. Prior work has required multiple regression plus non-traditional approaches to parameter estimation and uncertainty calculation, such as Monte Carlo, bootstrapping, non-parametric estimators and exploitation of climate model large ensembles.
Adaptability	With a solid physical basis, statistical grounding and range of experience with satellite & climate model data, I can easily adapt to a wide range of technical topics. Referring to the reference list numbers, I have published on hyperspectral cloud retrieval development (13,15,20,22); use of hyperspectral retrievals for analysis of boundary layer water vapour (8,10); detection of climate change in satellite records (14); precipitation remote sensing and trend analysis (9,17,29); radiative feedbacks and climate sensitivity (27,28,31); global temperature evolution and carbon budgets (11,19,24); the carbon cycle (35); the cryosphere (16,23); and scientific consensus (26,30,32,36).
Collaboration	As is common in modern science, my teams are often multidisciplinary, multi-institutional, and multinational. Our 2013 consensus paper used a modern crowdsourcing collaborative approach.
Educational	Invited lecturer to CalState LA, online course lecturer for University of Queensland EdX course, course expert for United Nations Institute of Training and Research (2016)
Outreach	Online work for climate.nasa.gov, climatefeedback.org, skepticalscience.com. Invited speaker for NASA Solar System Ambassadors and Museum Alliance. Intern at Parliamentary Office of Science and Technology.
Languages	English (mother tongue), Italian (conversational)

Reviewed publications (Total=37; first author=16; Google Scholar citations=4,261; *H* index=13; *i-10* index=17)

1. **Richardson MT** (2023) A Physical Explanation for Ocean Air-Water Warming Differences Under CO2-Forced Warming *J. Clim.* doi: 10.1175/JCLI-D-22-0215.1
2. Li JLF, Cesana GV, Xu KM, **Richardson MT**, Takahashi H, Jiang JH (2022) Comparisons of Simulated Radiation, Surface Wind Stress and SST Fields over Tropical Pacific by the GISS CMIP6 Versions of Global Climate Models with Observations *Environ. Res. Comm.* doi: 10.1088/2515-7620/aca9ab
3. **Richardson MT**, Benestad RE (2022) Erroneous use of Statistics behind Claims of a Major Solar Role in Recent Warming *Research in Astronomy and Astrophysics* doi: 10.1088/1674-4527/ac981c
4. **Richardson MT**, Roy RJ, Lebsock MD (2022) Satellites Suggest Rising Tropical High Cloud Altitude: 2002—2021 *Geophys. Res. Lett.* doi: 10.1029/2022GL098160
5. **Richardson MT** (2022) Prospects for Detecting Accelerated Global Warming *Geophys. Res. Lett.* doi: 10.1029/2021GL095782
6. **Richardson MT**, Thompson DR, Kurowski MJ, Lebsock MD (2022) New Sampling Strategy Removes Imaging Spectroscopy Solar-Smearing Bias in Sub-km Vapour Scaling Statistics *Atmos. Meas. Tech.* doi: 10.5194/amt-15-1-2022

7. Li J-L F, Xu K-M, **Richardson MT**, *et al.* (2021) Improved Ice Content, Radiation, Precipitation and Low-level Circulation over the Tropical Pacific from ECMWF ERA-Interim to ERA5 *Environ. Res. Comm.* doi: 10.1088/2515-7620/ac1bfe
8. **Richardson MT**, Thompson DR, Kurowski MJ, Lebsock MD (2021) Boundary layer water vapour statistics from high-spatial-resolution spaceborne imaging spectroscopy *Atmos. Meas. Tech.* doi: 10.5194/amt-14-5555-2021
9. Chinita MJ, **Richardson MT**, Teixeira J, Miranda PMA (2021) Global Mean Frequency Increases of Daily and Sub-daily Heavy Precipitation in ERA5 *Environ. Res. Lett.* doi: 10.1088/1748-9326/ac0caa
10. Thompson DR, Kahn BH, Brodrick PG, Lebsock MD, **Richardson MT**, Green RO (2021) Spectroscopic imaging of sub-kilometer spatial structure in lower-tropospheric water vapor *Atmos. Meas. Tech.* doi: 10.5194/amt-14-2827-2021
11. Clarke DC, **Richardson MT** (2021) The Benefits of Continuous Local Regression for Quantifying Global Warming *Earth and Space Science* doi: 10.1029/2020EA001082
12. Li J-L F, Xu K-M, **Richardson MT**, *et al.* (2020) Annual and seasonal mean tropical and subtropical precipitation bias in CMIP5 and CMIP6 models *ERL* doi: 10.1088/1748-9326/abc7dd
13. **Richardson MT**, Lebsock MD, McDuffie J, Stephens GL (2020) A new Orbiting Carbon Observatory 2 cloud flagging method and rapid retrieval of marine boundary layer cloud properties *AMT* doi: 10.5194/amt-13-4947-2020
14. Takahashi H, Lebsock MD, **Richardson MT**, Marchand R, Kay JE (2019) When Will Spaceborne Cloud Radar Detect Upward Shifts in Cloud Heights? *JGR Atmospheres* doi: 10.1029/2018JD030242
15. **Richardson MT** *et al.* (2019) Marine liquid cloud geometric thickness retrieved from OCO-2's oxygen A-band spectrometer *AMT* doi: 10.5194/amt-12-1717-2019
16. Li J-L F, **Richardson MT** *et al.* (2019) Potential faster Arctic sea ice retreat triggered by snowflakes' greenhouse effect *The Cryosphere* doi: 10.5194/tc-13-969-2019
17. Behrangi A, **Richardson MT** (2018) Observed High-Latitude Precipitation Amount and Pattern and CMIP5 Model Projections *Remote Sensing* doi: 10.3390/rs10101583
18. Chen C-A, Li J-L F, **Richardson MT** *et al.* (2018) Falling Snow Radiative Effects Enhance the Global Warming Response of the Tropical Pacific Atmosphere *JGR Atmospheres* doi: 10.1029/2018JD028655
19. **Richardson MT**, Cowtan K, Millar RJ (2018) Global temperature definition affects achievement of long-term climate goals *ERL* doi: 10.1088/1748-9326/aab305
20. **Richardson MT**, Stephens GL (2018) Information content of OCO-2 oxygen A-band channels for retrieving marine liquid cloud properties *AMT* doi: 10.5194/amt-11-1515-2018
21. Li J-L F, Suhas E, **Richardson MT** *et al.* (2018) The Impacts of Bias in Cloud-Radiation-Dynamics Interactions on Central Pacific Seasonal and El Niño Simulations in Contemporary GCMs *Earth and Space Science* doi: 10.1002/2017EA000304
22. **Richardson MT**, McDuffie J, Stephens GL, Cronk HQ, Taylor TE (2017) The OCO-2 oxygen A-band response to liquid marine cloud properties from CALIPSO and MODIS *JGR Atmospheres* doi: 10.1002/2017JD026561
23. Li J-L F, **Richardson MT** *et al.* (2017) Improved simulation of Antarctic sea ice due to the radiative effects of falling snow *ERL* doi: 10.1088/1748-9326/aa7a17
24. Hausfather Z, Cowtan K, Clarke DC, Jacobs P, **Richardson MT**, Rohde R (2017) Assessing recent warming using instrumentally homogeneous sea surface temperature records *Science Advances* doi: 10.1126/sciadv.1601207
25. Li J-L F, Lee W-L, Wang Y-H, **Richardson MT** *et al.* (2016) Assessing the radiative impacts of precipitating clouds on winter surface air temperatures and land surface properties in general circulation models using observations *JGR Atmospheres* doi: 10.1002/2016JD025175
26. Skuce AG, Cook J, **Richardson MT** *et al.* (2016) Does It Matter if the Consensus on Anthropogenic Global Warming Is 97% or 99.99%? *Bulletin of Science, Technology & Society* doi: 10.1177/0270467617702781
27. **Richardson MT**, Cowtan K, Hawkins E, Stolpe MB (2016) Reconciled climate response estimates from climate models and the energy budget of Earth *Nature Climate Change* doi: 10.1038/nclimate3066
28. Stephens GL, Kahn BH, **Richardson MT** (2016) The Super Greenhouse Effect in a Changing Climate *Journal of Climate* doi: 10.1175/JCLI-D-15-0234.1

29. Behrangi A, Christensen M, **Richardson MT** *et al.* (2016) Status of high-latitude precipitation estimates from observations and reanalyses *JGR Atmospheres* doi: 10.1002/2015JD024546
30. Cook J, Oreskes N, Doran PT, Anderegg WRL, Verheggen B, Maibach EW, Carlton JS, Lewandowsky S, Skuce AG, Green SA, Nuccitelli D, Jacobs P, **Richardson MT**, Winkler B, Painting R, Rice K (2016) Consensus on consensus: a synthesis of consensus estimates on human-caused global warming *ERL* doi: 10.1088/1748-9326/11/4/048002
31. **Richardson MT**, Hausfather Z, Nuccitelli DA, Rice K, Abraham JP (2015) Misdiagnosis of Earth climate sensitivity based on energy balance model results *Science Bulletin* doi: 10.1007/s11434-015-0806-z
32. Cook J, Nuccitelli D, Skuce A, Jacobs P, Painting R, Honeycutt R, Green SA, Lewandowsky S, **Richardson MT**, Way RG (2014) Reply to 'Quantifying the consensus on anthropogenic global warming in the scientific literature: A re-analysis' *Energy Policy* doi: 10.1016/j.enpol.2014.06.002
33. **Richardson MT**, Stolpe MB, Jacobs P, Jokimaki A, Cowtan K (2014) Comment on "Quantitatively evaluating the effects of CO2 emission on temperature rise" *Quaternary International* doi: 10.1016/j.quaint.2014.04.054
34. Nuccitelli D, Cowtan K, Jacobs P, **Richardson MT**, Way RG, Blackburn A-M, Stolpe MB, Cook J (2014) Comment on "Cosmic-ray-driven reaction and greenhouse effect of halogenated molecules: Culprits for atmospheric ozone depletion and global climate change" *International Journal of Modern Physics B* doi: 10.1142/S0217979214820037
35. **Richardson MT** (2013) Comment on "The phase relation between atmospheric carbon dioxide and global temperature" by Humlum, Stordahl and Solheim *Global and Planetary Change* doi: 10.1016/j.gloplacha.2013.03.011
36. Cook J, Nuccitelli D, Green SA, **Richardson MT** *et al.* (2013) Quantifying the consensus on anthropogenic global warming in the scientific literature *ERL* doi: 10.1088/1748-9326/8/2/024024
37. **Richardson MT**, Davenport I, Gurney R (2013) Global Snow Mass Measurements and the Effect of Stratigraphic Detail on Inversion of Microwave Brightness Temperatures *The Earth's Hydrological Cycle* doi: 10.1007/978-94-017-8789-5_14

Non-reviewed publications

1. **Richardson M** (2014) Errors in predicting snow's near-infrared optical grain size *PhD Thesis, University of Reading, UK*
2. **Richardson M** (2014) Reducing Emissions from Deforestation and Forest Degradation (REFF+) *POSTnote Number 466, Parliamentary Office of Science and Technology, UK*

Awards, Fellowships and Grants

Selected Proposals as Co-I

1. NASA ROSES NNH20ZDA001N-TASNPP (2021) Trends in thermodynamic environments of severe convection using trajectory-enhanced remote sensing (PI: Peter Kalmus, JPL)
2. NASA ROSES NNH20ZDA001N-MAP (2020) Evaluation of Tropical Cloud-Radiation-Circulation Coupling in NASA GISS ModelE3 Using Observations and Reanalysis (PI: Jui-Lin Frank Li, JPL)

Selected Proposals as Collaborator

1. NASA New Investigators Program NNH20ZDA001N-NIP (2020) Spatial Evolution of 2000—2020 TOA radiation, SST, and radiative feedbacks (PI: Maria Rugenstein, CSU)

Other

1. NERC NCEO PhD studentship 2010—2014
2. NERC Field Spectroscopy Facility equipment loan of field spectrometer for fieldwork
3. NERC-funded Parliamentary Office of Science and Technology internship

Presentations

Conferences (oral)

1. *AGU Fall Meeting, New Orleans, LA, USA* (December 2021)
2. *AGU Fall Meeting, San Francisco, CA, USA* (December 2019)
3. *OCO-2 Science Team Meeting, Boulder, CO* (October 2018)

4. *CloudSat/CALIPSO Science Team Meeting, Boulder, CO, USA* (April 2018)
5. *OCO-2 Science Team Meeting, Pasandea, CA* (March 2018)
6. *OCO-2 Science Team Meeting, Boulder, CO* (October 2017)
7. *A-Train Symposium, Pasadena, CA, USA* (April 2017)
8. *AGU Fall Meeting, San Francisco, CA, USA* (December 2016)
9. *OCO-2 Science Team Meeting, Pasadena, CA, USA* (March 2016)
10. *CloudSat/CALIPSO Science Team Meeting, Newport News, VA, USA* (February 2016)
11. *National Center for Earth Observation/CEOI Joint Annual Science Conference, Nottingham, UK* (September 2012)
12. *National Center for Earth Observation/CEOI Joint Annual Science Conference, Leicester, UK* (April 2012)
13. *National Center for Earth Observation/CEOI Joint Annual Science Conference, Warwick, UK* (September 2011)

Conferences (poster)

1. *AGU Fall Meeting*, *online* (December 2020)
2. *EGU General Assembly, online* (May 2020)
3. *AGU Fall Meeting, Washington DC, USA* (December 2018)
4. *AGU Fall Meeting, New Orleans, USA* (December 2017)
5. *OCO-2 Science Team Meeting, Pasadena, CA, USA* (March 2017)
6. *OCO-2 Science Team Meeting, Boulder, CO, USA* (October 2016)
7. *Cloud Feedback Model Intercomparison Project/WCRP/ICTP Conference, Trieste, Italy* (July 2016)
8. *AGU Fall Meeting, San Francisco, USA* (December 2015)
9. AGU *Fall Meeting, San Francisco, USA* (December 2012)
10. *Micro-DICE Summer School on Microstructures of Ice and Snow, Obergurgl, Austria* (August 2012)
11. *ESA-CliC-EGU Earth Observation and Cryosphere Science Conference, Frascati, Italy* (November 2012)

Invited talks and lectures

1. *IEEE Geoscience and Remote Sensing Society, LA Chapter webinar*, June 2021 (joint presentation with Dr. Maria Chinita, JPL)
2. *JPL Center for Climate Sciences, Friday Seminar Series*, February 2021 (joint presentation with Dr. Maria Chinita, JPL)
3. *CalState LA, Geos5100 guest lecture*, November 2018
4. *Colorado State University, CIRA Seminar*, October 2018
5. *NASA Museum Alliance, Solar System Ambassadors*, October 2017
6. *JPL Center for Climate Sciences*, *Friday Seminar Series*, May 2017
7. *University of Reading (UK), NCAS Climate Seminar,* April 2016
8. *Caltech Division of Geophysics and Planetary Sciences, YLY seminar*, June 2015

Professional Activities and Memberships

1. Member, American Geophysical Union.
2. Contributing author for IPCC Special Report on 1.5 °C warming.
3. Convener or lead-convener for AGU Fall Meeting Session "Climate Sensitivity and Feedbacks: Advances and New Paradigms" 2016—2021.
4. United Nations Institute for Training and Research course expert, 2016
5. Member of Decadal Survey teams including point-of-contact for retrieval algorithms in AOS-SBG synergy and several AOS-only teams.
6. CloudSat Algorithm Developer Working Group 2015—present as OCO2CLD-LIDAR-AUX developer
7. Reviewer: *Nature Climate Change, Nature Geoscience, Environmental Research Letters, Remote Sensing of Environment, Climatic Change, Atmospheric Measurement Techniques, Geoscientific Model Development*, *Oceanography, JGR Atmospheres, Journal of Quantitative Spectroscopy and Radiative Transfer, Geophysical Research Letters, Transactions on Geoscience and Remote*

Sensing, Surveys in Geophysics, Climate Dynamics, Remote Sensing, *Geophysical Research Letters*.

8. Contributor to climate.nasa.gov, I generated the initial code for the temperature vs solar activity graph.
9. Lecturer for University of Queensland's massive online open course on EdX, Denial101x, Making Sense of Climate Science Denial. Total enrolment >40,000 as of 2021-04.
10. Registered factchecker for climatefeedback.org, a member of Facebook's Third-Party Fact Checking initiative.
11. Public outreach includes blogging for science blog skepticalscience.com (winner of 2011 Australian Museum Eureka Award) and presentations to students at Anderson W Clark Magnet High School, Glendale and La Crescenta Presbyterian Church.

Research Experience and Objectives

My main research objective is to develop and apply novel approaches to cloud and aerosol remote sensing to answer big-picture questions about climate variability and change.

I have long focussed on applied science, with PhD fieldwork obtaining *in-situ* profiles of snowpack scattering properties to improve passive microwave snow retrievals. Post PhD, I developed the CloudSat project's OCO2CLD-LIDAR-AUX retrieval, combining CALIPSO lidar and OCO-2 hyperspectral A-band observations to retrieve cloud-top pressure (P_{top}), optical depth (τ) and geometric thickness (H). This project gives me a strong background in optimal estimation, understanding and applying radiative transfer, and handling satellite data.

The liquid marine clouds I targeted are radiatively important and sensitive to aerosol. Unfortunately, their typical height and thickness prevents retrieval of H from modern active spaceborne sensors, while other passive retrievals make many more assumptions. OCO-2 has sufficient spectral resolution to retrieve both P_{top} and H from photon path length, and the lidar P_{top} constraint helps to break the covariance between those two retrieved properties.

The retrievals imply that cloud adiabaticity correlates with atmospheric stability, hinting at an observational constraint on entrainment. Similarly, adiabaticity changed when CloudSat detected precipitation nearby. Unfortunately, I identified a retrieval bias so did not publish these results, since I am more concerned with accurate science than pure publication metrics.

In a recent OSSE based on large-eddy-simulation output, I demonstrated how to obtain information about PBL water vapour from EMIT-like instruments, and collaborated to produce an AGU poster on combining EMIT and thermal infrared for PBL applications.

These two projects gave me experience in practical problem solving, prioritisation of resource use, multi-sensor retrievals, and machine learning. I have developed practicable plans to improve both cloud and vapour retrievals. For OCO-2, I have demonstrated that my reported biases can be explained because cloud vertical extinction profiles differ from standard radiative transfer assumptions. Similarly, biases in the EMIT OSSE retrievals are related to the handling of meteorological profiles, resulting in erroneous absorption line broadening. In both cases I have proposed simple approaches to mitigate these biases in a way that could be implemented within current product pipelines.

I will continue to propose this work, which addresses questions associated with the Decadal Survey's designated observables for Aerosol and Clouds, Convection and Precipitation (ACCP, now Atmospheric Observing System AOS). I am particularly excited to work in an active flight environment and combine data sources for science applications.

For example, I contacted airborne specialists at Langley to obtain airborne campaign data with which to evaluate assumptions involved in my OSSE work, and am part of several Decadal Survey groups, including AOS multi-instrument synergy and AOS-Surface Biology and Geology. My career plan is to play a key role for this new generation of sensors, using my own expertise to drive developments in my skill area while working with other groups.

I have an enthusiasm for collaboration with demonstrated impact, at JPL I have submitted proposals working with members of the Aerosols and Clouds, Atmospheric Physics and Weather, and Sea Level and Ice groups. I have two ongoing selected ROSES proposals as Co-I; one led by Dr. Frank Li on evaluating model treatment of hydrometeor radiative effects, and another with Dr. Peter Kalmus on extending AIRS data to evaluate trends in the severe convective environment over the eastern U.S. I will continue to drive for collaboration across groups, and identify a particularly obvious link between energy-budget missions such as Libera and AOS measurement goals.

Outside of JPL, I have worked with international groups to generate high-impact papers and was a contributing author to the IPCC Special Report on 1.5 °C Warming. I contributed to the development and modification of a global-temperature-record "simulator" for CMIP output, which properly accounts for incomplete spatial coverage and blending of air- and water temperature data in observational records. One of my lead-authored studies resulted in an adjustment of approximately 25 % in climate sensitivity from energy-budget constraints, and another is repeatedly cited in both SR1.5 and the 6th Assessment Report. Furthermore, these results played some role in providers implementing or developing updates to global temperature datasets to reduce the biases we quantified.

As well as producing excellent and well-validated datasets, our primary aim must be to address open science questions. Many end users are unfamiliar with limitations related to the Level 3 products they select for high-impact research, and I see myself as taking an important role as an observational liaison to pure theoreticians and modellers. In this fashion I am a listed collaborator on a selected ROSES NIP proposal with Prof. Maria Rugenstein of CSU on the recent spatial evolution of TOA radiation, SSTs and radiative feedbacks.

I have active experience in model-observation comparison. For example, I co-authored a study on when and where W-Band radar might detect changes in upper-tropospheric cloud heights, in which we used COSP to provide like-with-like output. However, in a recent submitted study I am lead authoring, we were not able to use MODIS COSP output due to its coarse resolution, so I performed extensive sensitivity tests to identify potential instrumental drifts and to address known representation issues such as model-assumed cloud overlap.

The brevity of existing records, combined with large internal climate variability, is a major challenge for separating climate change and climate variability in satellite records. To address this, I firstly support exploiting past missions and the Program of Record to ensure longer or more-informative data products. Furthermore, I have learned statistical skills to address internal climate variability, having used Monte-Carlo, resampling and nonparametric approaches in my published work. In two recent papers I advocated for the use of climate model large ensemble output to test statistical methods for trend evaluation, in a way which is different from standard approaches but is more powerful.

I want to continue applying my skills that stretch from retrieval development and uncertainty quantification, through to understanding physical processes in the atmosphere. In addition to my ongoing ROSES-funded work in convection and hydrometeor-radiation-circulation coupling, I want to play a major role and eventually lead JPL involvement in addressing upcoming Decadal Survey science goals. I have a particular interest in understanding aerosol-cloud responses for the purposes of constraining radiative forcing and climate feedbacks, as well as anticipating responses to potential geoengineering. I also hope to continue preliminary work on changes in Earth's surface energy balance, which ties both to estimation of global-mean temperature and to the hydrological cycle.

This will require new approaches, such as potentially obtaining more than just cloud-top or integrated properties from space, and combining multiple sensors. JPL is the dream location from which to continue this journey.

Finally, it is crucial to communicate our findings. I have experience of science communication through the UK's Parliamentary Office of Science and Technology, online and in-person presentation, and media interactions. I want to continue in science as part of exciting, diverse teams, and to clearly share inspirational findings with the world.

Diversity, Equity and Inclusion

It is a tragedy when individuals are unfairly prevented from contributing to science. I am a first-generation university graduate who was born in the city that the UK government ranked 12^{th} out of 317 for "deprivation" in England in 2019, and then attended a university with one of the highest fractions of privately-schooled individuals in the UK. By comparing my social networks, I have grown to understand how hidden *de facto* barriers can drive widespread social inequity, even in the presence of *de jure* equality.
My experiences are incomplete, but I am driven to learn and ensure that I contribute to reducing barriers. Examples of how I have actively worked in this area are mainly related to easing initial access for some groups. In 2016 I worked as a course expert with the United Nations Institute for Training and Research (UNITAR), primarily targeting trainees from low-income countries. I have also presented courses for the University of Queensland's Massively Online Open Course (MOOC) DENIAL101X on the EdX platform, which provides free education for anyone with internet access.

I am fully aware that issues of equity, diversity and inclusion extend beyond initial access and include factors such as the "leaky pipeline" of talent, so these problems cannot be solved with outreach or free courses alone. A further example of applying this awareness is that, as lead convener of an AGU Fall Meeting session, I ensured that submissions were anonymised before other conveners voted on which presenters would be given a more prestigious oral slot. This decision was based on applying research showing that people can change our judgment of work based purely on names that imply membership of particular groups, rather than just quality.

At JPL I will actively work to ensure that I contribute to an equitable, diverse and inclusive workplace. As well as continuing efforts to ensure that any work I am in a position to judge is done fairly, I intend to develop research projects that will require interns and other early career scientists, and I will ensure that these positions are advertised to groups that tend to have lower access to such opportunities, and I will encourage them to apply.

CalState LA is an example of such an institution, a 2012 University of California report showed how it has one of the highest fractions of Pell Grant recipients in the state, which has encouraged me to ensure that I engage with people involved with that university. I accepted an invitation to guest lecture there in 2018, and approached and unofficially mentored CalState JPL summer interns in 2017.

References

Prof. Graeme L Stephens **Director, Center for Climate Sciences** Jet Propulsion Laboratory M/S 233-300 4800 Oak Grove Drive Pasadena CA 91109 USA **e-mail** graeme.l.stephens@jpl.nasa.gov	**Dr. David R Thompson** **Principal Technologist** Jet Propulsion Laboratory M/S 306-431 4800 Oak Grove Drive Pasadena CA 91109 USA **e-mail** david.r.thompson@jpl.nasa.gov
Dr. Christopher W O'Dell **Senior Research Scientist** Cooperative Institute for Research in the Atmosphere Colorado State University 3925 LaPorte Avenue Ft. Collins CO 80523 USA **e-mail** christopher.odell@colostate.edu	**Dr. Brian H Kahn** **Research Scientist** Jet Propulsion Laboratory M/S 233-300 4800 Oak Grove Drive Pasadena CA 91109 USA **e-mail** brian.h.kahn@jpl.nasa.gov

Appendix – Requirements Traceability Matrix

This appendix identifies where in this application I list evidence relevant to each qualification. The left column lists the page numbers within this .pdf to check, and the right column describes the precise elements. If required, my publications are cited as "(ref. X)", where X is the number of the paper in the CV "Reviewed publications" list.

Required qualifications

Source pages	Description
PhD in Atmospheric Science, Geophysics or a related technical discipline.	
Page 2	2015 PhD in Atmosphere, Oceans and Climate
Advanced knowledge of cloud remote sensing from multiple observations including active and passive observations.	
Pages 3,4,7,8	I developed the OCO2CLD-LIDAR-AUX product (ref. 11), knowledge in development and use of spectroscopy (refs. 4,11), passive microwave (ref. 33), and science applications of W-band radar (e.g. refs. 8,10,25).
Demonstrated knowledge of Bayesian methods for remote sensing, which is needed for on-going microwave (active and passive) remote sensing algorithms.	
Pages 4,7,8	OCO2CLD-LIDAR-AUX uses Bayesian iterative optimal estimation, and required an information content study (refs. 11,16)
Strong expertise in cloud radiative effects, climate sensitivity, and cloud-climate feed-backs.	
Pages 4,6,7,8	I have convened AGU Fall Meeting sessions on "Climate Sensitivity and Feedbacks". Published on cloud radiative effects (e.g. refs. 12,19), Gregory-plot feedback quantification (ref. 24), transient climate response (ref. 23) and retrieval of new properties of low marine clouds (ref. 11).
Excellent oral (including public speaking) and written communication skills.	
Pages 2,5,6	Experienced in public speaking, including invited talks, to both academic and non-expert audiences. Demonstrated written skills through publications, and a parliamentary internship included writing skills development to address a variety of audiences.
A strong record of peer-reviewed publications and presentations at major international scientific meetings and conferences.	

Pages 3,4,5,6	Oral and poster presentations at major international conferences, and session convening at AGU. 33 publications since 2013 with a total of 3,535 citations in Google Scholar.
Demonstrated familiarity with the use of computer programing languages (e.g. Python and Fortran).	
Page 2	Primary language is Python, also used FORTRAN, MATLAB, R

Preferred qualifications

Source pages	Description
At least three years of experience in remote sensing research beyond a PhD is strongly preferred.	
Page 2	7 years of post-PhD research experience in remote sensing.
Capability of writing successful proposals.	
Page 5	Co-I on two selected NASA ROSES proposals.
Eagerness to work with scientists and support staff from JPL and throughout NASA in a highly collaborative flight project environment.	
Pages 3—8	I am thoroughly eager to work in a collaborative environment with JPL, NASA and external staff. I am a member of several early Decadal Survey algorithm and synergy teams, and at JPL have worked with members from CloudSat, OCO-2, AIRS and AVIRIS-NG groups. I also took the initiative to produce a ROSES proposal with members of JPL's Sea Level and Ice Group. While unsuccessful, the review panel scored it "excellent/very good" and I am excited to continue such collaboration. I have networked as a contributing author to the IPCC SR1.5, and external groups to generate high-impact papers (e.g. refs. 15,20,23,26,32).
Familiarity with satellite observations and cloud remote sensing from spaceborne platforms.	
Pages 4,7,8	Experience using products from sensors including CPR (CloudSat), CALIOP (CALIPSO), OCO-2, CERES, MODIS, ATSR, AVHRR, TRMM, GPM, SSM/I, AMSR-E and AIRS. This includes everything from developing a cloud product (ref. 11) to inter-product comparison (ref. 25), model evaluation (e.g. ref. 8) and climate trend studies (ref. 10).