The National Academies of | SCIENCES ENGINEERING MEDICINE

February 7, 10 & 11, 2022 | 1:00-4:00 pm ET

Machine Learning and Artificial Intelligence to Advance Earth System Science: Opportunities and Challenges – A Workshop

The National Academies of
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Briefing Materials

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Machine Learning and Artificial Intelligence to Advance Earth System Science: Opportunities and Challenges – A Workshop

February 7, 10, 11, 2022 | 1:00-4:00 pm (All times EST)

Final Agenda

Workshop Goal: This workshop will consider the opportunities and challenges, including the ethical development and use, of using machine learning and artificial intelligence (ML/AI) to advance Earth system science. The workshop will convene Earth system science experts, ML and AI researchers, social and behavioral scientists, ethicists, and decision-makers across sectors to explore how these approaches can contribute to improving understanding, analysis, modeling, prediction, and decision making. Workshop discussions will examine state of the art approaches for using ML/AI for Earth system science, consider challenges and ways to mitigate risks of using ML/AI, and identify future opportunities to accelerate progress.

Day 1: Monday, February 7, 2022
Emerging Approaches for Using, Interpreting, and Integrating ML/AI for Earth System Science

1:00 pm **Welcome and Opening Remarks**
Ruby Leung, Planning Committee Chair, Pacific Northwest National Laboratory

Session 1: Overview of State of the Art Use of ML/AI for Earth System Science
Moderators: Amy McGovern, University of Oklahoma and Ruby Leung, PNNL

Session 1 will provide a broad overview of how ML/AI is currently being used for Earth system science, remaining conceptual and technical challenges, and opportunities to address those challenges.

1:10 pm *20 minute talk followed by discussion*
Peter Dueben, European Centre for Medium-Range Weather Forecasts

1:40 pm Break

Session 2: Emerging Approaches for Using and Interpreting ML/AI
Moderators: Patrick Heimbach, UT Austin and Aarti Singh, CMU

Session 2 will consider unique challenges in Earth system science that emerging ML/AI approaches can help to address. Specific approaches will include integrating physics, expert knowledge, multiple modalities of data, and ML/AI techniques; explainable AI and interpretable ML; and, data assimilation.

1:45 pm *12 minute talks followed by discussion*

- **Pierre Gentine**, Columbia University
- **Elizabeth Barnes**, Colorado State University
- **Stephen Penny**, Sofar Ocean

2:45 pm Break

Session 3: Emerging Opportunities from Social and Human Engineered Systems
Moderators: Ann Bostrom, UW and Ruby Leung, PNNL

Session 3 panelists will discuss opportunities for using ML/AI to understand social and human engineered systems, and the prospects for using ML/AI to integrate social and human engineered system science into Earth system science.

3:00 pm *5 minute panelist remarks followed by discussion*

- **Auroop Ganguly**, Northeastern University
- **Abigail Snyder**, Pacific Northwest National Laboratory
- **David Rolnick**, McGill University
- **Jennifer Chayes**, UC Berkeley

3:50 pm **Closing Remarks and Plans for Day 2**
Amy McGovern, University of Oklahoma

4:00 pm Adjourn

Day 2: Thursday, February 10, 2022
Challenges and Risks of Using ML/AI for Earth System Science

1:00 pm **Welcome and Opening Remarks**
Ruby Leung, Committee Chair, Pacific Northwest National Laboratory

1:10 pm **Recap of Workshop Day 1**
Patrick Heimbach, UT Austin and Diego Melgar, U of Oregon

Session 1: Responsible and Ethical Use and JEDI Issues for ML/AI in Weather, Climate and Earth System Science
Moderators: Amy McGovern, University of Oklahoma and Ann Bostrom, UW

Session 1 panelists will consider what ethical standards should guide Earth system science, and how such standards relate to the lenses of justice, equity, diversity, and inclusion (JEDI). Panelists will also discuss potential biases in ML/AI for Earth system science and promising ways to avoid those biases.

1:20 pm *5 minute panelist remarks followed by discussion*

- **David Danks**, UC San Diego
- **Imme Ebert-Uphoff**, Colorado State University
- **Priya Donti**, Carnegie Mellon University
- **Abhishek Gupta**, Montreal Ethics AI Institute

2:10 pm Break

Session 2: Workforce Development Capacity and Skill Sets
Moderators: Diego Melgar, U of Oregon and Amy McGovern, University of Oklahoma

Session 2 conversationalists will discuss gaps in education for those working at the intersection of ML/AI and Earth system science, needs and strategies for the private sector and academia in workforce development, the role of continued education in the current workforce, and capacity building at earlier educational stages.

2:20 pm *Brief introductions followed by conversation*

- **Lak Lakshmanan**, Google
- **Hamed Alemohammad**, Radiant Earth
- **Terri Adams**, Howard University
- **Rebecca Nugent**, Carnegie Mellon University

Session 3: Challenges and Opportunities for Earth Science Technology and Data
Moderators: Patrick Heimbach, UT Austin and Laure Zanna, NYU

Session 3 panelists will consider open data, standards, and platforms to facilitate open science for ML/AI and Earth system science as well as technology development, funding models, and education challenges and opportunities for Earth system science technology and data.

3:00 pm *5 minute panelist remarks followed by discussion*

- **Ryan Abernathey**, Columbia University
- **Chelle Gentemann**, Farallon Institute
- **Jason Hickey**, Google
- **Ana Privette**, Amazon Sustainability Data Initiative
- **Katie Dagon**, National Center for Atmospheric Research

3:50 pm **Closing Remarks and Plans for Day 3**
Laure Zanna, NYU

4:00 pm Adjourn

Day 3: Friday, February 11, 2022
Identifying Future Opportunities to Accelerate Progress

1:00 pm **Welcome and Opening Remarks**
Ruby Leung, Committee Chair, Pacific Northwest National Laboratory

1:10 pm **Recap of Workshop Day 2**
Ruby Leung, PNNL and Ann Bostrom, UW

Session 1: Using ML/AI for Data-Driven Decision Making
Moderators: Ann Bostrom, UW and Diego Melgar, University of Oregon

Session 1 speakers will discuss the role of ML/AI at the interface of predictive physical models and real-time decision-making, handling uncertainties, and the remaining scientific, engineering, societal and ethical challenges in this space.

1:20 pm *12 minute talks followed by discussion*

- **Elizabeth Cochran**, US Geologic Survey
- **Pierre Lermusiaux**, MIT
- **Daniel Rothenberg**, Waymo

2:20 pm Break

Session 2: Novel Funding Mechanisms, Partnerships, and Knowledge Transfer Between Academia, Industry, Nonprofits and Government

Moderators: Aarti Singh, CMU and Laure Zanna, NYU

Session 2 conversationalists will consider funding opportunities, effective mechanisms, and creative new approaches to facilitate partnerships knowledge transfer between academia, industry, nonprofits and government to advance ML/AI for Earth system science.

2:40 pm *Brief introductions followed by conversation*

- **Lynne Parker**, White House Office of Science and Technology Policy
- **Gary Hattem**, Independent Advisor
- **Jennifer Chayes**, UC Berkeley
- **Qingkai Kong**, Lawrence Livermore National Laboratory
- **David Spergel**, Simons Foundation

3:40 pm **Summary of Workshop Day 3**
Aarti Singh, CMU and Amy McGovern, University of Oklahoma

3:50 pm **Closing Remarks**
Ruby Leung, Committee Chair, Pacific Northwest National Laboratory

4:00 pm Adjourn

TIPS FOR JOINING AND PARTICIPATING IN A ZOOM WEBINAR

Pre-requisites for attending a Zoom webinar

- Zoom desktop client
- Zoom mobile app
- Web client

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To join the webinar, click the link that the host provided you or that you received in the confirmation page after you registered. If the host sent a registration confirmation email, the link can also be found there.

How to manually join a webinar

1. Locate the meeting ID/webinar ID from your registration email. It may appear at the end of the phone dial-in information, or it will be in the join link, just after *https://zoom.us/w/*
2. Sign in to the Zoom desktop client or mobile app.
   Note: You do not need to be signed in to the Zoom client, but if not, you will need to provide a name and email address to join. If registration is required, you will need to complete registration and use the link to join the webinar.
3. Click or tap *Join*.
4. Enter the webinar ID, and click **Join** or tap *Join Meeting*.
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Audio Settings (only visible if the host hasn't granted you permission to talk): Change your **audio settings**. You can also click the upward arrow (^) next to change your speaker.

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Chat : Open **webinar chat**, allowing you to send chat messages to the host, panelists, and attendees (if permitted).

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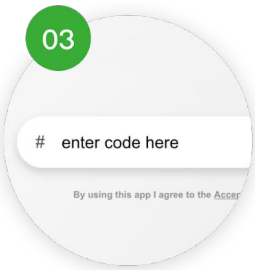

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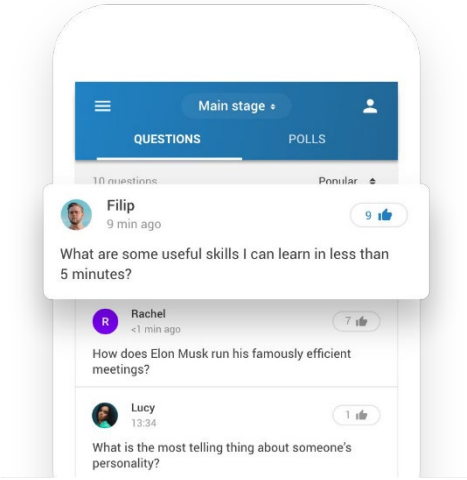
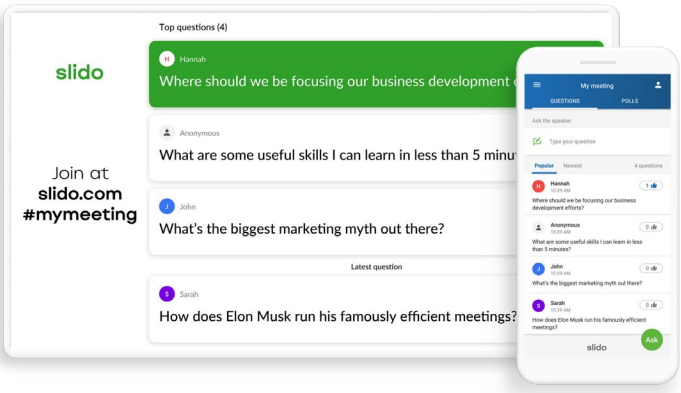


Questions and votes will appear in real-time on an interactive wall



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Machine Learning and Artificial Intelligence to Advance Earth System Science: Opportunities and Challenges - A Workshop

STATEMENT OF TASK

The National Academies of Sciences, Engineering, and Medicine will organize a workshop to bring together experts to explore the opportunities and challenges of machine learning and artificial intelligence (ML/AI) to advance Earth system science. The workshop will explore how these approaches can contribute to improving understanding, analysis, modeling, prediction, and decision making. Specific topics to be addressed could include:

- Review **current** applications of ML/AI to Earth system science.
- Survey **emerging** ML/AI technologies and approaches that could be useful for Earth system science, such as:
    - Integrating physics, expert knowledge, and ML/AI techniques to enrich models and forecasts;
    - Understanding and interpreting results produced by ML models; and
    - Bridging research and operations to support decision-making.
- Consider **challenges and risks** of using ML/AI for Earth system science, and discuss ways to mitigate these risks, such as:
    - Justice, equity, diversity, and inclusion (JEDI) and ethical implications;
    - The interface of ML/AI with existing and emerging hardware, software, tools, and approaches;
    - Workforce capacity and skillsets; and
    - Data requirements and limitations.
- Identify **future opportunities** to accelerate progress, such as:
    - Novel funding mechanisms and partnerships; and
    - Potential disruptions that could lead to rapid scientific, societal, and/or institutional progress

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SPEAKER BIOS

Ryan P. Abernathey, an Associate Professor of Earth and Environmental Science at Columbia University and Lamont Doherty Earth Observatory, is a physical oceanographer who studies large-scale ocean circulation and its relationship with Earth's climate. He received his Ph.D. from MIT in 2012 and did a postdoc at Scripps Institution of Oceanography. He has received an Alfred P. Sloan Research Fellowship in Ocean Sciences, an NSF CAREER award, The Oceanography Society Early Career Award, and the AGU Falkenberg Award. He is a member of the NASA Surface Water and Ocean Topography (SWOT) science team and Director of Data and Computing for a new NSF Science and Technology Center called Learning the Earth with Artificial Intelligence and Physics (LEAP). Prof. Abernathey is an active participant in and advocate for open source software, open data, and reproducible science.

Terri Adams is the Associate Dean of Research for the Graduate School at Howard University. Dr. Adams is also a Professor in the Department of Sociology and Criminology, and Deputy Director at the NOAA Cooperative Science Center for Atmospheric Sciences & Meteorology. She is the lead investigator of the decision-support team for the "Building Extreme Weather Resiliency Through Improved Weather and Climate Prediction and Public Response Strategies" project supported by the National Foundation's Partnerships in International Research and Education Program. Dr. Adams' research takes an interdisciplinary approach to examine issues that have both theoretical and practical implications. Her specific research interests include emergency management, policing, gender studies, and the impact of trauma and disasters on individuals and organizations. Her most recent work centers on the decision-making processes of both individuals and organizations in the face of natural disasters. In addition to her academic work, she has served as a research consultant for a number of agencies and non-profit organizations.

Hamed Alemohammad is the Chief Data Scientist and Executive Director at Radiant Earth Foundation, leading the development of Radiant MLHub- the open repository for geospatial training data and models. He has extensive expertise in machine learning and remote sensing particularly in developing new algorithms for agricultural monitoring from multispectral and microwave satellite observations. Hamed serves on the Technical Advisory Boards of Lacuna Fund and Enabling Crop Analytics At Scale (a Bill and Melinda Gates Foundation initiative). He also serves as a member of the AGU's technical committee on remote sensing. Prior to joining Radiant Earth, he was a Research Scientist at Columbia University. Hamed received his PhD in Civil and Environmental Engineering from MIT in 2014.

Elizabeth (Libby) Barnes is an associate professor of Atmospheric Science at Colorado State University. She joined the CSU faculty in 2013 after obtaining dual B.S. degrees (Honors) in Physics and Mathematics from the University of Minnesota, obtaining her Ph.D. in Atmospheric Science from the University of Washington, and spending a year as a NOAA Climate & Global Change Fellow at the Lamont-Doherty Earth Observatory. Professor Barnes' research is largely focused on climate variability and change and the data analysis tools used to understand it. Topics of interest include earth system predictability and machine learning for earth and climate science, including explainable/interpretable AI and how these tools can be used to understand, detect and predict physical signals within the earth

system. Professor Barnes is involved in a number of research community activities including being a member of the National Academies' Committee on Earth Science and Applications from Space, a funded member of the NSF AI Institute for Research on Trustworthy AI in Weather, Climate and Coastal Oceanography (AI2ES), and a member of the CESM Science Steering Committee. She recently finished being the lead of the NOAA MAPP S2S Prediction Task Force (2016-2020).

Jennifer Chayes is Associate Provost of the Division of Computing, Data Science, and Society, and Dean of the School of Information. She is Professor of EECS, Mathematics, Statistics, and the School of Information. Before joining Berkeley, she was at Microsoft for over 20 years, where she was Technical Fellow, and founder and managing director of three interdisciplinary labs: Microsoft Research New England, New York City, and Montreal. Chayes has received numerous awards for both leadership and scientific contributions, including the Anita Borg Institute Women of Vision Leadership Award, the John von Neumann Award of the Society for Industrial and Applied Mathematics, and an honorary doctorate from Leiden University. She is a member of the American Academy of Arts and Sciences and the National Academy of Sciences. Chayes' research areas include phase transitions in computer science, and structural and dynamical properties of networks including modeling and graph algorithms. Chayes is one of the inventors of the field of graphons, which are widely used for the machine learning of large-scale networks. Her recent work focuses on machine learning, including both theory and applications in cancer immunotherapy, ethical decision making, and climate change.

Elizabeth S. Cochran is a seismologist at the United States Geological Survey (USGS) in Pasadena, California. She conducts research on human-induced earthquakes, earthquake early warning, earthquake triggering, rupture processes, and seismic wave propagation. She has served as Acting Director of the USGS Earthquake Science Center (2021), Project Leader of the USGS Induced Seismicity project (2018-2021), and USGS Chief Scientist of the ShakeAlert Earthquake Early Warning project (2016-17). Elizabeth received a B.S. in geophysics from University of California, Santa Barbara and a M.Sc. and Ph.D. in geophysics and space physics from the University of California, Los Angeles. In 2010, she was recognized with a Presidential Early Career Award for Scientists and Engineers (PECASE) for her development of the Quake Catcher Network, a crowd-sourced seismic network that detected earthquakes using low-cost sensors.

Katie Dagon is a project scientist at the National Center for Atmospheric Research (NCAR) in Boulder, Colorado, working in the Climate and Global Dynamics Laboratory. Her research focuses on modeling the impacts of climate change on land-atmosphere interactions, climate variability, and extreme events. She is also interested in machine learning approaches to climate science and modeling, including quantifying uncertainty in model projections of climate change. At NCAR she co-leads the Earth System Data Science (ESDS) initiative to promote deeper collaboration centered on analysis workflows, large datasets, and open development. From 2017-2019 she was an Advanced Study Program postdoctoral fellow at NCAR. Katie obtained her Ph.D. in Earth and Planetary Sciences from Harvard University in 2017 and her B.S. in Mathematics-Physics from Brown University in 2010.

David Danks is Professor of Data Science & Philosophy and affiliate faculty in Computer Science & Engineering at University of California, San Diego. His research interests are at the intersection of philosophy, cognitive science, and machine learning, using ideas, methods, and frameworks from each to advance our understanding of complex, interdisciplinary problems. Danks has examined the ethical, psychological, and policy issues around AI and robotics in transportation, healthcare, privacy,

and security. He has also done significant research in computational cognitive science, and developed multiple novel causal discovery algorithms for complex types of observational and experimental data. Danks is the recipient of a James S. McDonnell Foundation Scholar Award, as well as an Andrew Carnegie Fellowship.

Priya Donti is a Ph.D. Candidate in Computer Science and Public Policy at Carnegie Mellon University. She is also a co-founder and chair of Climate Change AI, an initiative to catalyze impactful work in climate change and machine learning. Her work focuses on machine learning for forecasting, optimization, and control in high-renewables power grids. Specifically, her research explores methods to incorporate the physics and hard constraints associated with electric power systems into deep learning models. Priya is a recipient of the MIT Technology Review's 2021 "35 Innovators Under 35" award, the Siebel Scholarship, the U.S. Department of Energy Computational Science Graduate Fellowship, and best paper awards at ICML (honorable mention), ACM e-Energy (runner-up), PECI, the Duke Energy Data Analytics Symposium, and the NeurIPS workshop on AI for Social Good.

Peter Dueben is the AI and Machine Learning Coordinator at the European Centre for Medium-Range Weather Forecasts (ECMWF) and holds a University Research Fellowship of the Royal Society that enables him to perform research towards the use of machine learning, high-performance computing, and reduced numerical precision in weather and climate modelling. Peter is coordinator of the MAELSTROM EuroHPC-Join Undertaking project and work-package leader of the ESiWACE2 H2020 project. Before moving to ECMWF, Peter has written his PhD thesis at the Max Planck Institute for Meteorology and has worked as Postdoc at the University of Oxford.

Imme Ebert-Uphoff is a Research Professor in Electrical and Computer Engineering at Colorado State University since 2011. Her research focus for the past 10+ years has been on using data science, including causal discovery and machine learning methods, for applications in weather and climate. Since 2019, she also serves as the Machine Learning Lead of the Cooperative Institute for Research in the Atmosphere (CIRA) at Colorado State University. She is also co-PI of a $20M grant by the National Science Foundation that funds the NSF AI Institute for Research on Trustworthy AI in Weather, Climate, and Coastal Oceanography (AI2ES). She obtained the equivalent of B.S. and M.S. degrees in mathematics from the Technical University of Karlsruhe in Germany (known today as KIT), and M.S. and Ph.D. degrees in mechanical engineering from the Johns Hopkins University, in Baltimore, Maryland. Before joining Colorado State University, she was a postdoctoral researcher at Laval University in Quebec City, Canada, and an Assistant Professor, then Associate Professor, in Mechanical Engineering at the Georgia Institute of Technology in Atlanta, Georgia.

Auroop R. Ganguly is a Professor at Northeastern University, a joint Chief Scientist at the Pacific Northwest National Laboratory, and a Co-Founder of the climate analytics startup risQ that recently got successfully acquired by a Fortune 500 company. He has about 23 years of professional experience including as a Senior Scientist at the Oak Ridge National Laboratory (ORNL) and as a software developer and product manager at Oracle Corporation. Ganguly has published in interdisciplinary journals such as Nature and PNAS, won best paper awards at ML/AI or data science conferences such as ACM KDD, and has been on the program committee of KDD and AAAI, the editorial boards of Nature's Scientific Reports, PLOS ONE, AGU's Water Resources Research and ASCE's Journal of Computing in Civil Engineering, as well as on the AI Committee of the AMS and climate adaptation committee of the ASCE. He has authored a textbook on Critical Infrastructures Resilience by CRC Press. Research at his

Sustainability and Data Sciences Laboratory (SDS Lab) intersects climate extremes and water sustainability, infrastructures resilience and urban systems, as well as nonlinear dynamics, extreme value statistics, and machine learning. His PhD students, postdoctoral associates and mentees have been CEOs of startups and professors at prestigious universities internationally, as well as in federal agencies such as NASA, national laboratories such as ORNL, and in private sector companies such as Tokio Marine, AIG, Hitachi, Verizon, and Intuit. Ganguly is a Fellow of the American Society of Civil Engineers, a Senior Member of the IEEE and of the Association for Computing Machinery (ACM). He has a PhD from the Massachusetts Institute of Technology and a B.Tech.(Hons.) from the Indian Institute of Technology Kharagpur.

Chelle Gentemann is currently a senior scientist at Farallon Institute, leading research on open science, cloud computing, remote sensing, and physical oceanography. She is the science lead for NASA's Transform to Open Science (TOPS) initiative and has coordinated plans and project success for several large, international groups, and 3 field campaigns. She was principal investigator on a proposed NASA Earth Venture Mission, Butterfly. For over 20 years, she has worked on every aspect of passive microwave satellite missions, both domestically and internationally, from launch through decommission, including calibration, algorithm development, validation, data distribution, and science applications. She initiated a project to create one of the first cloud-optimized NASA datasets on AWS, a global 1-km 18 year record of SST, and sits on the open-science Pangeo project's steering committee. She was co-chair of the National Academy of Sciences and Engineering (NASEM) Committee on Best Practices for a Future Open Code Policy for NASA Space Science, co-chair of the NASEM Standing Committee on Earth Science and Applications from Space (CESAS), and testified to the House Subcommittee on Space and Aeronautics, "Discovery on the Frontiers of Space: Exploring NASA's Science Mission."

Pierre Gentine is the Maurice Ewing and J. Lamar Worzel professor of geophysics in the departments of Earth and Environmental Engineering and Earth and Environmental Sciences at Columbia University. He studies the terrestrial water and carbon cycles and their changes with climate change. Pierre Gentine is recipient of the NSF, NASA and DOE early career awards, as well as the American Geophysical Union Global Environmental Changes Early Career and American Meteorological Society Meisinger award.

Abhishek Gupta is the Founder and Principal Researcher at the Montreal AI Ethics Institute, an international non-profit research institute with a mission to democratize AI ethics literacy. He works in Machine Learning and serves on the CSE Responsible AI Board at Microsoft where his work helps solve the toughest technical challenges of Microsoft's biggest customers. Through his work as the Chair of the Standards Working Group at the Green Software Foundation, he is leading the development of a Software Carbon Intensity standard towards the comparable and interoperable measurement of the environmental impacts of AI systems. His work focuses on applied technical and policy measures for building ethical, safe, and inclusive AI systems, specializing in the operationalization of AI ethics and its deployments in organizations and assessing and mitigating the environmental impact of these systems. His work on community building has been recognized by governments from across North America, Europe, Asia, and Oceania.

Gary Hattem is an independent advisor to non- governmental organizations, social enterprises and philanthropy with a 35 year career in community development, impact investing and social finance. As managing director and head of Deutsche Bank's Social Finance Group he originated more than $3 billion in capital to advance opportunities for disadvantaged communities in the U.S., and throughout the

developing world, with direct loans and investments as well as the structuring of funds in the health, affordable housing, climate and inclusive finance sectors. As a trained city planner, Gary has focused much of his work on the regeneration of distressed urban communities and is presently a director and founder of the Cultural Heritage Finance Alliance.

Jason Hickey is a senior member of the technical staff in Google. He leads the AI for Weather team in Google Research, focusing on the use of machine learning to improve weather forecasting. Jason holds the Ph.D. and M.S. degrees in Computer Science from Cornell University, and the B.S. in Electrical Engineering from Caltech. He has worked at Google since 2008, in areas including artificial intelligence, internet of things, and global computing infrastructure. He was Assistant Professor of Computer Science at Caltech from 1999-2008, research focusing on programming languages and distributed and scientific computing. Jason is a member of the NSF AI Institute for Research on Trustworthy AI in Weather, Climate, and Coastal Oceanography (AI2ES) Industrial Advisory Board.

Qingkai Kong is currently a research scientist at Lawrence Livermore National Laboratory working on applying machine learning on seismological applications. He obtained his Ph.D. degree from University of California, Berkeley in Geophysics in 2018. Before he joins the lab, he worked as an assistant researcher at Berkeley seismology lab on building the smartphone seismic network and earthquake early warning system – MyShake. In 2019 to 2021, he also worked as a visiting researcher in Google's visiting faculty program to help them launch the Android Earthquake Alerting System.

Valliappa (Lak) Lakshmanan is the Director for Data Analytics and AI Solutions on Google Cloud where his team builds software solutions for business problems using Google Cloud's data analytics and machine learning products. Dr. Lakshmanan founded Google's Advanced Solutions Lab ML Immersion program and is the author of three O'Reilly books and several Coursera courses. Prior to joining Google, he was the Director of Data Science at Climate Corporation and a Research Scientist at NOAA. Dr. Lakshmanan has a Ph.D. in Electrical and Computer Engineering from the University of Oklahoma, a Master of Science in Biomedical Engineering from Ohio State University and a Bachelor of Technology in Electronics and Communications Engineering from the Indian Institute of Technology in Madras, India.

Pierre Lermusiaux is Professor of Mechanical Engineering and Ocean Science and Engineering at MIT. He received a Fulbright Foundation Fellowship (1992), the Wallace Prize at Harvard (1993), the Ogilvie Young Investigator Lecture in Ocean Eng. at MIT (1998), and the MIT Doherty Chair in Ocean Utilization (2009-2011). In 2010, the School of Eng. at MIT awarded him with the Ruth and Joel Spira Award for Distinguished Teaching. He has made outstanding contributions in data assimilation, as well as in ocean modeling and uncertainty predictions. His research thrusts include understanding and modeling complex physical and interdisciplinary oceanic dynamics and processes. With his group, he creates, develops and utilizes new mathematical models and computational methods for ocean predictions and dynamical diagnostics, for optimization and control of autonomous ocean systems, for uncertainty quantification and prediction, and for data assimilation and data-model comparisons. He has participated in many national and international sea exercises. He has served on numerous committees and organized large meetings and workshops. He is associate editor in three journals. He has more than hundred twenty refereed publications.

Rebecca Nugent is the Stephen E. and Joyce Fienberg Professor of Statistics & Data Science and the Department Head for the Carnegie Mellon Statistics & Data Science Department, and an affiliated

faculty member of the Block Center for Technology and Society. She received her PhD in Statistics from the University of Washington in 2006. Prior to that, she received her B.A. in Mathematics, Statistics, and Spanish from Rice University and her M.S. in Statistics from Stanford University. She has won several national and university teaching awards including the American Statistical Association Waller Award for Innovation in Statistics Education and serves as one of the co-editors of the Springer Texts in Statistics. She recently served on the National Academy of Sciences study on Envisioning the Data Science Discipline: The Undergraduate Perspective. She is the Founding Director of the Statistics & Data Science Corporate Capstone program, an experiential learning initiative that matches groups of faculty and students with data science problems in industry, non-profits, and government organizations. She has worked extensively in clustering and classification methodology with an emphasis on high-dimensional, big data problems and record linkage applications. Her current research focus is the development and deployment of low-barrier data analysis platforms that allow for adaptive instruction and the study of data science as a science.

Lynne Parker is the Founding Director of the National Artificial Intelligence Initiative Office in the White House Office of Science and Technology Policy (OSTP). She has advanced AI policy in the White House since 2018, serving an integral role in numerous landmark AI policies bolstering research, governance, education and workforce training, and international engagement. Dr. Parker is on assignment to OSTP from her role as Professor of computer science at the University of Tennessee, Knoxville (UTK). She has held numerous leadership positions, including at UTK (Interim Dean), the National Science Foundation (Division Director), and Oak Ridge National Laboratory (Distinguished R&D Staff Member and Group Leader). She is a Fellow of AAAI (Association for the Advancement of AI), AAAS (American Association for the Advancement of Science), and IEEE (Institute for Electrical and Electronic Engineers), and is also a Distinguished Member of ACM (Association for Computing Machinery). She received her PhD from the Massachusetts Institute of Technology.

Stephen G. Penny is currently the Data Assimilation Lead at Sofar Ocean Technologies, a startup company in San Francisco, California. Dr. Penny previously served as a research scientist at the Cooperative Institute for Research in Environmental Sciences (CIRES) at the University of Colorado Boulder, leading a team at the National Oceanographic and Atmospheric Administration (NOAA) Physical Sciences Laboratory (PSL) on the research and development of integrated data assimilation and AI/ML methods to enhance and improve weather forecast skill. Dr. Penny is a leading expert on coupled data assimilation, which attempts to estimate the trajectory of not only the atmospheric weather system, but also simultaneously the ocean, land, ice, and other Earth system components - which is a key capability needed for extending forecast skill beyond 2 weeks. Formerly, as a professor at the University of Maryland, Dr. Penny developed an ocean data assimilation software system that is currently being used by the NASA Global Modeling and Assimilation Office (GMAO) for initializing their subseasonal-to-seasonal global predictions. Dr. Penny has held visiting appointments at the NOAA National Centers for Environmental Prediction (NCEP) / Environmental Modeling Center (EMC), the European Centre for Medium-Range Weather Forecasts (ECMWF), Scripps Institution of Oceanography, the U.S. Naval Research Laboratory (NRL) at Stennis Space Center, the Nansen Environmental and Remote Sensing Center in Norway, and the RIKEN Center for Computational Science in Japan.

Ana Privette is a senior program manager with Amazon's Sustainability group. She joined the Sustainability Science and Innovation team in September 2017 as the program lead for the Amazon Sustainability Data Initiative (ASDI), a program that seeks to leverage Amazon's scale, technology, and

infrastructure to help create more global innovation for sustainability. ASDI is a Tech-for-Good project focused on democratizing access to key data and analytical capabilities to anyone working in the sustainability space. Ana was trained as an environmental engineer and as an earth sciences researcher at the New University of Lisbon (Portugal) and at MIT. She did her doctoral research work at NASA Goddard Space Flight Centre and as part of her project; she spent a couple of years running scientific fieldwork sites in Africa to support a NASA international field campaign. While working at NOAA, Ana worked on the US National Climate Assessment (NCA) project focusing on bringing more transparency and traceability of the data sources supporting this climate report. After spending most of her career at NASA and NOAA as a scientist, she led projects for the White House climate portfolio, including the Obama Climate Data Initiative (CDI) and the Partnership for Resilience and Preparedness (PREP), both focused on delivering better access and use of US Federal climate data to support researchers and decision makers.

David Rolnick is an Assistant Professor and Canada CIFAR AI Chair in the School of Computer Science at McGill University and at Mila Quebec AI Institute. He is a Co-founder and Chair of Climate Change AI and serves as Scientific Co-director of Sustainability in the Digital Age. Dr. Rolnick received his Ph.D. in Applied Mathematics from MIT. He is a former NSF Mathematical Sciences Postdoctoral Research Fellow, NSF Graduate Research Fellow, and Fulbright Scholar, and was named to the MIT Technology Review's 2021 list of "35 Innovators Under 35".

Daniel Rothenberg is the Technical lead for Atmospheric Science at Waymo where he broadly tackles weather and environmental challenges that affect autonomous vehicles. He previously was the Chief Scientist at Tomorrow.io, and led a team of scientists and engineers to tackle challenging problems at the interface of meteorology, data science, and software engineering. His team developed and productionized new systems and techniques for integrating novel, micro-weather observations into large-scale diagnostic systems which provided critical "weather intelligence" for their clients. Formerly Daniel was a Postdoctoral Research Associate jointly with the Center for Global Change Science and the Department of Earth, Atmospheric, and Planetary Sciences at the Massachusetts Institute of Technology (MIT) where his research interest was the interactions between aerosols, clouds, and climate, particularly the multi-scale chain of physical and chemical processes through which the three feedback on each other. Daniel received his PhD in Earth, Atmospheric and Planetary Sciences from MIT and BS in Earth and Atmospheric Sciences from Cornell University.

Abigail Snyder has been at Pacific Northwest National Laboratory's Joint Global Change Research Institute as a postdoctoral researcher and now Earth Scientist for the last five years. Her work is focused on emulation of computationally expensive process-based models for use in integrated Human-Earth System modeling, particularly for use with the Global Change Analysis Model (GCAM).

David Spergel is President of the Simons Foundation and of Simons Foundation International. He is also the Charles Young Professor of Astronomy Emeritus at Princeton University. Spergel was a member of the Princeton faculty from 1987-2019 and served as the chair of its astrophysics department for over a decade. He is a member of the National Academy of Sciences and has served as chair of the Space Studies Board. He was a panel chair for both the 2010 and 2020 astronomy decadal surveys. He serves as co-chair of the Global Coordination of Ground and Space Astrophysics working group of the International Astronomical Union. His work in cosmology and astrophysics has been recognized by a

MacArthur Fellowship, the Heinemann Prize, the Shaw Prize, the Gruber Prize and the Breakthrough Prize in Physics.

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Machine Learning and Artificial Intelligence to Advance Earth System Science: Opportunities and Challenges - A Workshop

WORKSHOP PLANNING COMMITTEE BIOS

L. Ruby Leung (*Chair*) is a Battelle Fellow at Pacific Northwest National Laboratory. Her research broadly cuts across multiple areas in modeling and analysis of climate and water cycle including orographic precipitation, monsoon climate, extreme events, land surface processes, land-atmosphere interactions, and aerosol-cloud interactions. Ruby is the Chief Scientist of the U.S. Department of Energy's Energy Exascale Earth System Model (E3SM), a major effort to develop state-of-the-art capabilities for modeling human-Earth system processes on DOE's next generation high performance computers. She has organized several workshops sponsored by Department of Energy, National Science Foundation, National Oceanic and Atmospheric Administration, and National Aeronautics and Space Administration to define gaps and priorities for climate research. She serves as a member of the Board on Atmospheric Sciences and Climate (BASC), National Academies of Sciences, Engineering, and Medicine and an editor of the AMS Journal of Hydrometeorology and AGU Journal of Geophysical Research-Atmospheres. She has published over 350 papers in peer-reviewed journals. Ruby is an elected member of the National Academy of Engineering and Washington State Academy of Sciences and a fellow of the American Meteorological Society (AMS), American Association for the Advancement of Science (AAAS), and American Geophysical Union (AGU). She is the recipient of the AGU Global Environmental Change Bert Bolin Award and Lecture in 2019 and the AGU Atmospheric Science Jacob Bjerknes Lecture in 2020.

Ann Bostrom is the Weyerhaeuser endowed Professor in Environmental Policy in the Evans School of Public Policy & Governance at the University of Washington. She studies risk perception with a focus on mental models of hazardous processes, risk and science communication, and decision making under uncertainty. Dr. Bostrom is a Fellow of the American Association for the Advancement of Science (AAAS) and of the Washington State Academy of Sciences (WSAS), and a Fellow and former President of the Society for Risk Analysis. She is also currently serving as an elected Board member for both AAAS and WSAS. She is a member of the leadership team and co-leads risk communication research in the NSF-funded AI Institute AI2ES, and is a co-PI of the Cascadia CoPes Hazards Research Hub. Dr. Bostrom completed postdoctoral studies in cognitive aspects of survey methodology at the Bureau of Labor Statistics, and in engineering and public policy at Carnegie Mellon University, after earning her Ph.D. there in policy analysis. She also holds an M.B.A. from Western Washington University, and a B.A. in English from the University of Washington. She is currently serving as a member of the national Advisory Committee on Earthquake Hazards Reduction.

Patrick Heimbach is a computational oceanographer and W. A. "Tex" Moncrief, Jr., chair III in Simulation-Based Engineering and Sciences at the University of Texas at Austin. His research focuses on ocean and ice dynamics and their role in the global climate system. He is an expert on the use of inverse methods applied to ocean and sea ice model parameter and state estimation, uncertainty quantification and observing system design. Patrick earned his Ph.D. in 1998 from the Max-Planck-Institute for Meteorology and the University of Hamburg, Germany. Among his professional activities, Patrick serves

on the National Academy of Sciences' Ocean Studies Board, NSF's Advisory Committee for the Office of Polar Programs, the CLIVAR/CliC Northern Ocean Regional Panel, and the US CLIVAR Ocean Uncertainty Quantification working group.

Amy McGovern is the Lloyd G. and Joyce Austin Presidential Professor in the School of Computer Science and School of Meteorology at the University of Oklahoma. She is also the Director of the NSF AI Institute for Research on Trustworthy AI in Weather, Climate, and Coastal Oceanography. Dr McGovern's PhD is in Computer Science from the University of Massachusetts (2002). She also has an MS in Computer Science from the University of Massachusetts Amherst (1998) and a BS (honors) in Math/Computer Science from Carnegie Mellon University (1996). She has worked in the intersection of Artificial Intelligence and meteorology since 2005, when she joined the University of Oklahoma as faculty. Dr McGovern became a fellow of the American Meteorological Society in 2021.

Diego Melgar is the Ann and Lew Williams Chair of Earth Sciences and an assistant professor of geophysics in the Department of Earth Sciences at the University of Oregon. His research focuses on large earthquakes. He works on understanding the physics of faults using many diverse kinds of on-shore and off-shore data. He researches the hazards associated with these large events, working on tsunami modeling and coastal impacts, as well as studying how strong shaking can be forecast. Prof. Melgar was awarded the 2016 Charles Richter early career award from the Seismological Society of America. He is also a member of the National Academy of Science's Committee on Solid Earth Geophysics. Prior to joining the University of Oregon he spent three years at the University of California Berkeley's Seismological Laboratory. He earned his B.Eng. in geophysics from the Universidad Nacional Autónoma de México and his M.S. and Ph.D. in geophysics from the Scripps Institution of Oceanography.

Aarti Singh is an Associate Professor in the Machine Learning Department at Carnegie Mellon University. Her research lies at the intersection of machine learning, statistics, and signal processing, and focuses on designing statistically and computationally efficient algorithms that can interactively leverage inherent structure in the data, and its application to scientific domains. She received a B.E. in electronics and communication engineering from the University of Delhi in 1997, and a M.S. and Ph.D. in electrical engineering from the University of Wisconsin-Madison in 2003 and 2008, respectively. Dr. Singh was a postdoctoral research associate at the Program in Applied and Computational Mathematics at Princeton University, before joining CMU in 2009. Her work is recognized by an NSF Career Award, a United States Air Force Young Investigator Award, A. Nico Habermann Junior Faculty Chair Award, Harold A. Peterson Best Dissertation Award, and four best student paper awards. Her service honors include serving as program chair for the International Conference on Machine Learning (ICML) 2020, program chair for Artificial Intelligence and Statistics (AISTATS) 2017 conference, associate editor for IEEE Transactions of Information Theory and IEEE Transactions on Signal and Information Processing over Networks, expert team member for ONR/NIST TMS S&T study on AI for Materials and Manufacturing innovation, steering committee for NSF innovation lab on data-driven chemistry, lead and the National Academy of Sciences (NAS) committee on Applied and Theoretical Statistics.

Laure Zanna is a Professor in Mathematics & Atmosphere/Ocean Science at the Courant Institute, New York University. Her research focuses on the dynamics of the climate system and the main emphasis of

her work is to study the influence of the ocean on local and global scales. Prior to NYU, she was a faculty member at the University of Oxford until 2019, and obtained her PhD in 2009 in Climate Dynamics from Harvard University. She was the recipient of the 2020 Nicholas P. Fofonoff Award from the American Meteorological Society “For exceptional creativity in the development and application of new concepts in ocean and climate dynamics”. She is the lead principal investigator of the NSF-NOAA Climate Process Team on Ocean Transport and Eddy Energy, and M2LInES – an international effort to improve climate models with scientific machine learning. She currently serves as an editor for the Journal of Climate, a member on the International CLIVAR Ocean Model Development Panel, and on the CESM Advisory Board.

Machine Learning and Artificial Intelligence to Advance Earth System Science: Opportunities and Challenges – A Workshop

Workshop Conduct*

We are committed to fostering a professional, respectful, inclusive environment where all participants can participate fully in an atmosphere that is free of harassment and discrimination based on any identity-based factors.

DO

- **Show respect and consideration** for all people, and do not dominate discussions;
- **Listen to others.** Make room for a diversity of voices in group discussions, on panels, and the like without pressuring those who choose not to speak;
- **Be collegial and collaborative.** Be mindful of your tone and the potential impact your position, experience, and/or privilege may have on others;
- **Show that you value differing perspectives.** Communicate openly and civilly – critique ideas, not people;
- **Be inclusive** and intentional about welcoming a diversity of individuals and their identities when leading sessions, or inviting others to share ideas;
- **Act professionally and responsibly**
- **Report concerns immediately** so that we can act quickly to address and resolve issues (see below for details on how to report concerns);
- **Respect confidentiality** of the identities of any individuals involved in a conduct concern while it is being reviewed and addressed;
- **Comply with requests to stop behavior.** If any NASEM staff, workshop committee member, or other person in a facilitation or leadership role asks you to stop a behavior deemed unacceptable, please immediately and respectfully comply.

DO NOT

- **Intentionally talk over or interrupt others;**
- **Engage in conduct or make comments that are biased, demeaning, intimidating, coercive, or harassing/hostile,** whether seriously or in jest (examples include derogatory, exclusionary behaviors or comments toward others based on gender, sexual orientation, disability, physical appearance, body size, race, religion, national origin or any identity-based factors);
- **Engage in personal attacks or bullying;**
- **Comment on personal appearance,** seriously or in jest, unless you know such comments are welcome;
- **Display nudity and/or sexual images** in public spaces or presentations;
- **Disrupt or engage in violence or abuse, threats of violence, harm, or threats of harm of any kind.** Do not create/contribute to a safety threat or unsafe or exclusionary situation.
- **Drink or use other legal intoxicants** to the extent that your ability to act professionally is compromised;
- **Take or distribute pictures or recordings without approval.**
- **Retaliate against or disadvantage anyone for reporting a concern** or cooperating in an investigation. Do not make bad faith accusations.

How to report misconduct

If you experience or witness behavior that appears to violate this Code of Conduct, please notify us immediately so we can take appropriate steps to address your concerns. Feel free to use any of the following options:

- Contact NASEM event staff: Rachel Silvern, rsilvern@nas.edu
- Contact NASEM Office of Human Resources, hrservicecenter@nas.edu

**This code of conduct was adapted from the Geological Society of America's Events Code of Conduct, found here: https://www.geosociety.org/GSA/Events/EventConductCode/GSA/Events/Conduct.aspx*

PREVENTING DISCRIMINATION, HARASSMENT, AND BULLYING:
POLICY FOR PARTICIPANTS IN NASEM ACTIVITIES

The National Academies of Sciences, Engineering, and Medicine (NASEM) are committed to the principles of diversity, inclusion, integrity, civility, and respect in all of our activities. We look to you to be a partner in this commitment by helping us to maintain a professional and cordial environment. **All forms of discrimination, harassment, and bullying are prohibited in any NASEM activity.** This policy applies to all participants in all settings and locations in which NASEM work and activities are conducted, including committee meetings, workshops, conferences, and other work and social functions where employees, volunteers, sponsors, vendors, or guests are present.

Discrimination is prejudicial treatment of individuals or groups of people based on their race, ethnicity, color, national origin, sex, sexual orientation, gender identity, age, religion, disability, veteran status, or any other characteristic protected by applicable laws.

Sexual harassment is unwelcome sexual advances, requests for sexual favors, and other verbal or physical conduct of a sexual nature that creates an intimidating, hostile, or offensive environment.

Other types of harassment include any verbal or physical conduct directed at individuals or groups of people because of their race, ethnicity, color, national origin, sex, sexual orientation, gender identity, age, religion, disability, veteran status, or any other characteristic protected by applicable laws, that creates an intimidating, hostile, or offensive environment.

Bullying is unwelcome, aggressive behavior involving the use of influence, threat, intimidation, or coercion to dominate others in the professional environment.

REPORTING AND RESOLUTION

Any violation of this policy should be reported. If you experience or witness discrimination, harassment, or bullying, you are encouraged to make your unease or disapproval known to the individual at the time the incident occurs, if you are comfortable doing so. You are also urged to report any incident by:

- Filing a complaint with the Office of Human Resources at 202-334-3400 or hrservicecenter@nas.edu, or
- Reporting the incident to an employee involved in the activity in which the member or volunteer is participating, who will then file a complaint with the Office of Human Resources.

Complaints should be filed as soon as possible after an incident. To ensure the prompt and thorough investigation of the complaint, the complainant should provide as much information as is possible, such as names, dates, locations, and steps taken. The Office of Human Resources will investigate the alleged violation in consultation with the Office of the General Counsel.

If an investigation results in a finding that an individual has committed a violation, NASEM will take the actions necessary to protect those involved in its activities from any future discrimination, harassment, or bullying, including in appropriate circumstances **the removal of an individual from current NASEM activities and a ban on participation in future activities**.

CONFIDENTIALITY

Information contained in a complaint is kept confidential, and information is revealed only on a need-to-know basis. NASEM will not retaliate or tolerate retaliation against anyone who makes a good faith report of discrimination, harassment, or bullying.

Updated December 2, 2021