
# Advancing a Systems Approach to Studying the Earth: A Strategy for the National Science Foundation

## Workshop on Education and Workforce for Earth Systems Science: Framing Session
## November 13, 2020; 11:00 am – 2:00 pm ET

The National Academies of
SCIENCES • ENGINEERING • MEDICINE

***Advancing a Systems Approach to Studying the Earth:***
***A Strategy for the National Science Foundation***

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# *Workshop on Education and Workforce for Earth Systems Science*

## *Framing Session*

### *Public Agenda*

**Friday November 13, 2020**

**Start time: 11am ET / 10am CT / 9am MT / 8am PT**
**End time: 2pm ET / 1pm CT / 12pm MT / 11am PT**

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| **11:00 - 11:20 am ET** | **Welcome and Purpose for the Workshop**<br><br>*Ruth DeFries, Columbia University, Committee Co-Chair*<br>*Kristen St. John, James Madison University, Committee Member*<br>*Melissa Burt, Colorado State University, Committee Member* |
| **11:20 - 11:45 am ET** | **Speaker: DEI Issues in the Earth Systems Workforce to Better Serve Earth and Its People**<br>Q&A and Discussion<br><br>*Raj Pandya, Thriving Earth Exchange* |
| **11:45 am - 12:30 pm ET** | **Panel: Creating Earth Systems Sciences Learning and Working Environments for All**<br>Moderator: *Asmeret Asefaw Berhe, University of California, Merced, Committee Member*<br><br>*Diana Dalbotten, University of Minnesota*<br>*Anita Stone Marshall, University of Florida*<br>*Kaatje Kraft, Whatcom Community College*<br>*Lisa White, University of California*<br>*Reginald Archer, Tennessee State University*<br><br>Key questions/points to be addressed:<br>• *How could the vision for Earth system science increase diversity and inclusion in the future workforce?*<br>• *How can we create welcoming environments that support a sense of belonging by people of diverse backgrounds?* |
| **12:30 - 1:00 pm ET** | *BREAK* |

# Advancing a Systems Approach to Studying the Earth:
# A Strategy for the National Science Foundation

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| **1:00 - 1:10 pm ET** | **Speaker: Statistics and Data on the Geoscience Workforce**<br><br>*Sharon Mosher, University of Texas at Austin* |
| **1:10 - 1:50 pm ET** | **Panel: Thinking about the Future of Earth Systems Science Education and Training**<br>Moderator: *Fiamma Straneo, Scripps Institution of Oceanography, Committee Member*<br><br>*Kim Kastens, Lamont Doherty*<br>*Anne Egger, Central Washington University*<br>*Brandon Jones, National Science Foundation*<br>*Wendy Smythe, University of Minnesota*<br>*Cynthia Hall, West Chester University*<br><br>Key questions/points to be addressed:<br>• *Increasing relevance and experiential learning while teaching content knowledge and skills*<br>• *How do people learn?*<br>• *What are the resources and how/why to apply them?* |
| **1:50 - 2:00 pm ET** | **Wrap Up and Closing Remarks** |

# Advancing a Systems Approach to Studying the Earth: A Strategy for the National Science Foundation

**Speaker Biographies**

**Reginald Archer** is an Assistant Professor of Applied GIS in the Department of Agricultural and Environmental sciences at Tennessee State University (TSU). He applies Geographic Information Systems/Science & Remote Sensing to analyze spatial data, and use the "science of where" to conduct research, specifically environmental change related to sustainability, public health, hazards, vulnerability, disaster recovery and environmental justice. He teaches multiple courses related to Geospatial applications at both undergraduate and graduate level. Reginald actively engages in campus wide activities to increase STEM participation and is a Lifetime member of the National Society of Black Engineers (NSBE) and TSU Chapter advisor, as well as an advisor for Minorities in Agriculture, Natural Resources and Related Sciences (MANNRS) chapter. He is also an active member of the National Association of Geoscience Teachers (NAGT) and the HBCU Geosciences working group. He is dedicated to increasing the number of underrepresented students in STEM and regularly participates as a mentor in programs such as Tennessee Achieves, and STEM related summer camps. Education: PhD in Geography from the University of California Santa Barbara, MS in Civil Engineering and BS in Surveying and Mapping, both from the University of Florida.

**Diana Dalbotten** is the director of Diversity and Broader Impacts for the St. Anthony Falls Laboratory, University of Minnesota. The focus of her research has been on supporting greater diversity in Science, Technology, Engineering, and Mathematics fields via Community-Engaged Research. Dr. Dalbotten is the founder and directs the Geoscience Alliance, a national alliance for broadening participation of Native Americans in the geosciences. She directs the Research Experience for Undergraduates on Sustainable Land and Water Resources.

**Anne Egger** is an Associate Professor with a joint appointment in Geological Sciences and Science and Math Education at Central Washington University, and the Executive Director of the National Association of Geoscience Teachers. She was co-PI of the InTeGrate project, a seven-year community effort to enhance interdisciplinary teaching of Earth for a sustainable future, and helped lead the development of rigorously tested, freely available curricular materials to increase Earth literacy across the undergraduate curriculum. Her ongoing work involves exploring the results of the National Geoscience Faculty Survey to better understand the landscape of undergraduate geoscience education and to sue those results to inform professional development opportunities and future research directions.

**Cynthia A. Hall** is an environmental geochemist and farmer. She obtained a BS in Chemistry from Howard University in Washington, DC. Following the completion of her degree, she headed to the Georgia Institute of Technology in Atlanta, GA and enrolled in a Ph.D. program in the School of Earth and Atmospheric Sciences. Her dissertation research was focused on marine nitrogen cycling, which allowed her to participate in several expeditions at sea to collect sediment samples from the sea floor. Dr. Hall defended her dissertation in 2008 and landed a faculty position at West Chester University of Pennsylvania. After relocating to Philadelphia, PA, she began to study the chemistry of the soil in the city and became aware of the lead contamination that plagues the city. She has devoted the last 12 years to testing soil throughout Philadelphia and developing plans of action to decrease risk and exposure to local residents. Until 2019, she was an Associate Professor of Geosciences in the Department of Earth

and Space Sciences at West Chester University. Dr. Cynthia Hall now co-owns and operates Free Haven Farms in her hometown of Lawnside, N.J. with her husband, Micaiah Hall, and the help of their three children (sometimes). At Free Haven Farms, the couple grows high-quality, seasonal vegetables and fruits as well as facilitates educational programs such as a summer science camp and school garden clubs. She continues to teach part-time at West Chester University. Dr. Hall also recently started a non-profit organization, Free Haven Institute of Science and Agriculture, Inc. (FHISA, Inc.), that will allow her to focus on training the next generation of scientists from underserved populations.

**Brandon Jones** is the Program Director for education and broadening participation efforts in the National Science Foundation's Directorate for Geosciences. At NSF, he oversees programs that focus on undergraduate and graduate workforce preparation for the Geosciences and supports initiatives related to increasing diversity and enhancing inclusion and belonging in STEM. Brandon received a BA in biology from The Lincoln University (PA) in 1991 and his MS & PhD degrees in Marine Biology and Biochemistry from the University of Delaware's College of Earth, Ocean and Environment. He taught five years of high school science in the interim between his MS and PhD matriculation. Brandon currently serves on the board of directors for the American Geophysical Union and the Environmental Leadership Program. He is also a member of the Dean's Advisory Council for the University of Delaware's College of Earth, Ocean and Environment. He continues to be an active mentor for historically underrepresented students interested in STEM.

**Kim Kastens** is a Special Research Scientist at Lamont-Doherty Earth Observatory of Columbia University. Her training and early career were in marine geology, focusing on the geological evolution of the Mediterranean region and the structure and tectonics of transform faults. About twenty-five years ago, Kastens shifted her focus towards improving the public's understanding of the Earth and environment, through training of environmental journalists, development of instructional materials, professional development for teachers, innovative use of information technology, and discipline-based education research. Her current research focuses on how students understand and reason about feedback loops, a poorly understood and foundational aspect of Earth System thinking.

**Kaatje van der Hoeven Kraft** is a professor of geology and oceanography at Whatcom Community College. Her expertise lies in applying and implementing research-based strategies for effective and inclusive learning in content-based courses. She is driven to create spaces that optimize learning for students traditionally underrepresented in the geosciences and works with faculty (particularly community college) across the country with that focus.

**Anita M. Stone Marshall** is a Lecturer and researcher in the Department of Geological Sciences at the University of Florida, Gainesville. Her primary research area focuses on engagement and accessibility in geoscience classrooms and field learning environments. As the Director of Operations for the non-profit International Association for Geoscience Diversity (theIAGD.org), she works with academic departments and professional societies to address accessibility barriers, and serves as a mentor and advocate for geoscience students and professionals with disabilities.

**Sharon Mosher** is the William Stamps Farish Chair and Professor at The University of Texas at Austin. She was Dean of the Jackson School of Geosciences (2009-2020), department chair (2007-2009) and on the faculty since 1978. Dr. Mosher's expertise is in structural geology, structural petrology, and tectonics. Since 2014 she has spearheaded two National Science Foundation sponsored initiatives, one on the Future of Undergraduate Geoscience Education and since 2017 on graduate preparation for the workforce. Mosher was President of the American Geoscience Institute (AGI) in 2012-13, President of

the Geological Society of America (GSA) in 2000-2001, and 2004 Chair of the Council of Scientific Society Presidents. She is a founder and past Chair of the Board for GeoScienceWorld, an international journal aggregation for geoscientists. She is the 2020 Marcus Milling Legendary Geoscientist Medalist awarded by the American Geoscience Institute. In 2016 she was awarded the College of Liberal Arts and Sciences Alumni Achievement Award from the University of Illinois at Champaign/Urbana. She is a fellow of the Geological Society of America, receiving the Distinguished Service Award in 2003, an honorary fellow of the Geological Society of London, and recipient of the Association of Women Geologists Outstanding Educator Award (1990). She received her Ph.D. from the University of Illinois at Urbana in 1978 and M.Sc. from Brown University in 1975.

**Raj Pandya** directs AGU's Thriving Earth Exchange, a program connecting scientists and communities, including historically marginalized communities, and helps them work together to design and lead science that addresses community priorities. He is interested in how the sciences can be more participatory, how inclusivity contributes to scientific innovation and societal relevance, and how the sciences can be allies in advancing equity in society. Raj chaired the National Academies committee on "Designing Citizen Science to Support Science Learning," and has or is serving on the board for Cornell Lab of Ornithology, Public Lab, the Citizen Science Association, the Anthropocene Alliance, and ISET International. His PhD investigated how large thunderstorms grow and persist.

**Wendy F. Smythe** is an Assistant Professor at the University of Minnesota Duluth (UMD), she holds a joint appointment between the Departments of American Indian Studies and Earth & Environmental Sciences. She was named the 2019 Professional of the Year by the American Indian Science and Engineering Society (AISES) for her interdisciplinary research in geoscience, Native Education, and policy. In 2020 Dr. Smythe was elected to the AISES Board of Directors. She is a geoscientist and oceanographer whose research focuses on examining microbial ecology and molecular diversity, biogeochemistry, and biomineralization in metalliferous, iron and manganese rich groundwater and marine ecosystems from deep-sea hydrothermal volcanoes to hydrothermal springs in Southeast Alaska and Yellowstone National Park. Dr. Smythe also works with tribal communities working to couple STEM disciplines with Traditional Knowledge in K-12 education by incorporating language and cultural values.

**Lisa D. White** is Director of Education at the Museum of Paleontology at the University of California, Berkeley. Past positions held during a 22 year career at San Francisco State University include Professor of Geosciences, Geosciences Department Chair, Associate Dean of the Graduate Division, and Associate Dean of the College of Science and Engineering. She has extensive experience with science education programs for underrepresented students and she leads multiple efforts to increase diversity in the geosciences. A micropaleontologist by training and Fellow of the California Academy of Sciences and the Geological Society of America, Dr. White was the inaugural recipient of the GSA Bromery Award for Minorities. As Chair of the American Geophysical Union Diversity and Inclusion Advisory Committee, she works to create a culture that embraces diversity and inclusiveness in the Earth and space sciences. As the education director at the UC Museum of Paleontology, she develops and disseminates learning materials on evolution and the fossil record, virtual geological field experiences, and the nature and process of science. She holds degrees from San Francisco State University (B.A. in Geology) and the University of California at Santa Cruz (Ph.D. in Earth Sciences).

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

The National Academies of Sciences, Engineering, and Medicine (NASEM) are committed to the principles of diversity, 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 commitment 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, 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
- 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 June 7, 2018*

# Committee on Advancing a Systems Approach to Studying the Earth: A Strategy for the National Science Foundation


**Ruth S. DeFries (NAS)**, *Co-Chair*
Columbia University

**George M. Hornberger (NAE)**, *Co-Chair*
Vanderbilt University

**Claudia Benitez-Nelson**,
University of South Carolina

**Asmeret Asefaw Berhe**
University of California Merced

**Melissa A. Burt**
Colorado State University

**James J. Elser (NAS)**
University of Montana

**Courtney G. Flint**
Utah State University

**Royce A. Francis**
George Washington University

**Inez Y. Fung (NAS)**
University of California Berkeley

**William D. Gropp (NAE)**
University of Illinois at Urbana-Champaign

**Melissa A. Kenney**
University of Minnesota

**Jerry X. Mitrovica**
Harvard University

**Constantine Samaras**
Carnegie Mellon University

**Kristen St. John**
James Madison University

**Fiamma Straneo**
Scripps Institution of Oceanography, UCSD

**Duane E. Waliser**
Jet Propulsion Laboratory


***NASEM "Hub & Spokes" Staff Team***

**Kerry Brenner**, Board on Science Education; Education spoke
**Maria Dahlberg**, Board on Higher Education and Workforce; Workforce spoke
**Tamara Dawson**, Board on Environmental Studies and Toxicology; Hub
**Lauren Everett**, Board on Atmospheric Sciences and Climate & Polar Research Board; Hub, atmosphere and polar spoke
**Deb Glickson**, Board on Earth Sciences and Resources & Water Science and Technology Board; Hub
**Rob Greenway**, Board on Atmospheric Sciences and Climate & Polar Research Board; Hub
**Brent Heard**, Board on Energy and Environmental Systems; Engineering spoke
**Anne Linn**, Board on Earth Sciences and Resources; Hub, solid earth and water cycle spoke
**Lynette Millett**, Computer Science and Telecommunications Board; Computation and data spoke
**Keegan Sawyer**, Board on Life Sciences; Biology, ecology, and natural resources spoke
**Emily Twigg**, Ocean Studies Board; Ocean spoke
**Jenell Walsh-Thomas**, Board on Environmental Change and Society; Hub, social and behavioral sciences spoke

**Ruth S. DeFries** is a professor of ecology and sustainable development at Columbia University in New York. She uses images from satellites and field surveys to examine how the world's demands for food and other resources are changing land use throughout the tropics. Her research quantifies how these land use changes affect climate, biodiversity and other ecosystem services, as well as human development. She has also developed innovate education programs in sustainable development. Dr. DeFries was elected as a member of the U.S. National Academy of Sciences, received a MacArthur "genius" award, and is the recipient of many other honors for her scientific research. In addition to over 100 scientific papers, she is committed to communicating the nuances and complexities of sustainable development to popular audiences through her books "The Big Ratchet: How Humanity Thrives in the Face of Natural Crisis" and "What Would Nature Do?: A Guide for Our Complex World". Dr. DeFries is committed to linking science with policy, for example through her involvement with the Environmental Defense Fund, Science for Nature and People, World Wildlife Fund, and reconciling conservation and development in central India. Dr. DeFries received her Ph.D. in 1980 from the Department of Geography and Environmental Engineering at Johns Hopkins University. She currently serves on the NAS council.

**George M. Hornberger** is Distinguished University Professor at Vanderbilt University, where he is the Director of the Vanderbilt Institute for Energy and the Environment. He has a shared appointment as the Craig E. Philip Professor of Engineering and as Professor of Earth and Environmental Sciences there. He previously was a professor at the University of Virginia for many years where he held the Ernest H. Ern Chair of Environmental Sciences. He also has been a visiting scholar at the Australian National University, Lancaster University, Stanford University, the United States Geological Survey (USGS), the University of Colorado, and the University of California at Berkeley. His current work focuses on coupled natural-human systems and aims to understand how climate, groundwater, surface water, energy production, food production, and human abstraction of water interact in complex ways. Hornberger is a fellow of the American Geophysical Union (AGU), a fellow of the Geological Society of America, and a fellow of the Association for Women in Science. Dr. Hornberger won the Robert E. Horton Award (Hydrology Section) from the AGU in 1993. In 1995, he received the John Wesley Powell Award from the USGS. In 1999, he was presented with the Excellence in Geophysical Education Award by the AGU and in 2007 he was selected Virginia Outstanding Scientist. He was elected to the American Academy of Arts and Sciences in 2020. He has served on numerous boards and committees of the National Academies, including as chair of the Commission on Geosciences, Environment, and Resources (1996-2000), chair of the Board on Earth Sciences and Resources (2003-2009), and chair of the Water Science and Technology Board (2013-2017). Dr. Hornberger is a member of the U.S. National Academy of Engineering, having been elected in 1996.

**Claudia Benitez-Nelson** is the Associate Dean Associate Dean for Instruction, Community Engagement, & Research and Carolina Distinguished Professor & Endowed Chair in Marine Studies in the College of Arts & Sciences at the University of South Carolina. As an Associate Dean, Dr. Benitez-Nelson has direct oversight of five departments (Biological Sciences, Mathematics, School of the Earth, Ocean & Environment, Psychology, and Statistics) that encompass over 300 faculty and staff, 300 graduate students, and over 2500 undergraduate majors. Dr. Benitez-Nelson's research focuses on the biogeochemical cycling of phosphorus and carbon and how these elements are influenced by both natural and anthropogenic processes. She is a diverse scientist, with expertise ranging from radiochemistry to harmful algal bloom toxins and is highly regarded for her cross-disciplinary research. Over the past two decades, Dr. Benitez-Nelson has authored or co-authored more than 100 articles, including lead author publications in the journals Science and Nature. She has been continuously supported by substantial, multi-year research and education grants from the National Science Foundation and the National Aeronautics and Space Administration, among others. Her many research

honors include the Early Career Award in Oceanography from AGU and Fulbright and Marie Curie Fellowships. In 2015 she was named an AAAS Fellow, and in 2017, was named an ASLO Sustaining Fellow. Dr. Benitez-Nelson is also highly regarded as a teacher and mentor, having received the National Faculty of the Year Award from the National Society of Collegiate Scholars and the University of South Carolina's Distinguished Professor of the Year Award, SEC Faculty Achievement Award, and Outstanding Faculty Advisor of the Year. In 2014, she received the Sulzman Award for Excellence in Education and Mentoring from the Biogeosciences Section of AGU. Dr. Benitez-Nelson is regularly called upon by national and international scientific and policy agencies for her expertise and currently serves or has served as a member of the Advisory Committee to the Geoscience Directorate of NSF, the EPA Science Advisory Board, and the National Academy of Science's Ocean Studies Board. Dr. Benitez-Nelson earned a B.S. in chemistry and oceanography from the University of Washington and a Ph.D. in oceanography from the Woods Hole Oceanographic Institute/Massachusetts Institute of Technology Joint Program in 1999.

**Asmeret Asefaw Berhe** is a professor of Soil Biogeochemistry, and Falasco Chair in Earth Sciences at the Department of in the Life and Environmental Sciences at University of California, Merced. In addition, she serves as the Interim Dean of the Graduate Division at UC Merced; Associate Editor of Journal of Geophysical Research – Biogeosciences and Elementa. Her research focus lies at the intersection of soil science and global change science. In its most general sense, her research seeks to elucidate how bio-physical and socio-political changes in the environment affect different soil processes and land management. Within in this framework, she is exploring two general issues: (a) how geomorphic processes, anthropogenic disturbances, and climate change affect the dynamics of biogeochemical processes (esp. carbon, nitrogen, and phosphorus biogeochemical cycles) in the pedosphere, and its interactions with the atmosphere and hydrosphere on one hand, and (b) how the landuse choices that humans make and their relations with land are influenced by complex dynamics between socio-politico-economic factors on the other. Her research approaches range from lab- and field-intensive data collection to quantitative analyses and qualitative research methods that attempt to unravel the many facets, causal links, interactions, and feedback mechanisms among different processes in the earth system. In her work, she combines insights from various disciplines. Concepts and methods that she employs in her research are grounded in biogeochemistry, soil science, geomorphology, plant ecology, surface and isotope geochemistry, analytical and atmospheric chemistry, and political ecology. She is the Past Chair and current ex-officio member of the US National Committee on Soil Science at the National Academies; Current member of the Board of International Scientific Organizations; and she is a member of the inaugural class of the US National Academies of Science, Engineering and Medicine's New Voices in Science, Engineering, and Medicine. Asmeret holds a Ph.D. in Biogeochemistry from the University of California, Berkeley, M. Sc. in Resource Development (Political Ecology) from Michigan State University; and B. Sc. in Soil and Water Conservation from University of Asmara, Eritrea. Prior to joining the faculty at UC Merced, Asmeret was a University of California President's Postdoctoral Fellow (2006-2008) at the University of California, Berkeley and at the University of California, Davis.

**Melissa A. Burt** is the Assistant Dean for Diversity and Inclusion in the Walter Scott, Jr. College of Engineering at Colorado State University. In this position, Dr. Burt, oversees and leads the strategic and implementation efforts for diversity, inclusion, and equity goals across the College. The Office of the Assistant Dean for Diversity and Inclusion focuses on recruitment, retention, and engagement of faculty/staff, and supports the college-wide recruitment and retention efforts of undergraduate and graduate students from historically underrepresented groups. Dr. Burt is also a Research Scientist in the Department of Atmospheric Science at Colorado State University. Her research focuses on the interactions of Arctic clouds, radiation, and sea ice, with interests ranging from cloud-radiation

feedbacks, hydrological and energy cycles in climate, and climate change feedbacks. Melissa has a B.S. degree in Meteorology from Millersville University and a M.S. and Ph.D. in Atmospheric Science from Colorado State University.

**James J. Elser** is Bierman Professor of Ecology of the University of Montana (UM) and since March 2016 has been Director of UM's Flathead Lake Biological Station at Yellow Bay. He also holds a part-time research faculty position in the School of Life Sciences at Arizona State University. Trained as a limnologist, Dr. Elser is best known for his role in developing and testing the theory of ecological stoichiometry, the study of the balance of energy and multiple chemical elements in ecological systems. Currently, Dr. Elser's research focuses most intensively on Flathead Lake as well as mountain lakes of western Montana and western China. Specific studies involve observational and experimental studies at various scales, including laboratory cultures, short-term field experiments and sustained whole-ecosystem manipulations. Previous field sites have included the Experimental Lakes Area in Ontario, Canada; lakes of the Arctic and of Patagonia; lakes, forests, and grasslands of the upper Midwest; and desert springs in Mexico's Chihuahuan Desert. In recognition of his research accomplishments, in 2019 Dr. Elser was elected to the National Academy of Sciences. He has also been named a Fellow of the American Association for the Advancement of Science (AAAS) as well as a foreign member of the Norwegian Academy of Arts and Sciences. In 2012, Elser received the G.E. Hutchinson Award of the Association for the Sciences of Limnology and Oceanography (ASLO), the world's largest scientific association dedicated to aquatic sciences.

**Courtney G. Flint** is a Professor of Natural Resource Sociology at Utah State University. Her work focuses on the perspectives and collective actions of people in changing landscapes and social and natural resource conditions. She strives to provide sound data to support local and regional decisions on land use, natural resource management, and wellbeing. Her research is highly interdisciplinary as she has worked closely with researchers from water science, engineering, forestry, biogeochemistry, plant phytochemistry, agricultural science and engineering, systems ecology, landscape planning, and other sciences as well as local leaders and representatives of citizen action groups to address complex social-environmental changes. Her current research and engagement efforts emphasize inquiry and assessments related to individual and community wellbeing, as well as the social ecology of rivers in the US Intermountain West. She serves on the Board of Scientific Counselors for the U.S. Environmental Protection Agency as the chair of the subcommittee on Sustainable and Healthy Communities as well as on other advisory boards in Austria and South Africa. Her bachelor's degree is in geography from Northern Arizona University, her master's degree is in geography from the University of Colorado at Boulder, and her PhD is in rural sociology from Penn State University where she also enjoyed a strong working relationship with the US Forest Service's Pacific Northwest Research Station that extended into her post-doctoral research and tenure track position at the University of Illinois at Urbana-Champaign. She moved to Utah State University in 2013 where she is now a Professor of Sociology and a Community Resource Specialist for USU Extension. She directs the Institute of Social Science Research on Natural Resources and serves on the leadership team for the NSF-funded Climate Adaptation Science Graduate Training Program at USU.

**Royce A. Francis** is an associate professor in the Department of Engineering Management and Systems Engineering at George Washington University. His overall research vision is to conduct research, teaching, and service that facilitates sustainable habitation of the built environment. This vision involves three thrusts: 1.) infrastructure management, including sustainability assessment and risk analysis; 2.) regulatory risk assessment and policy-focused research, especially for environmental contaminants and infrastructure systems; and, 3.) statistical/mathematical modeling approaches to decision support. He

unifies these multi-disciplinary interests under the Earth Systems Engineering and Management (ESEM) paradigm for civil/environmental systems design and analysis. In the past year, Dr. Francis's research program has incorporated two new thrusts: i.) Investigating macrocognitive decision making processes for infrastructure resilience; and ii.) Characterizing engineer identity and engineering judgment situated in low-cost air quality sensor network design. Dr. Francis earned the Ph.D. from Engineering and Public Policy and Civil and Environmental Engineering at Carnegie Mellon University, M.S. in Civil and Environmental Engineering from Carnegie Mellon University, and the B.S. in Civil Engineering from Howard University.

**Inez Y. Fung** is a Professor of Atmospheric Science in the Department of Earth and Planetary Science and the Department of Environmental Science, Policy and Management at the University of California, Berkeley. She studies climate change and the carbon cycle using global-scale numerical models of the Earth System and its components. Fung received her S.B. in Applied Mathematics (1971) and her Sc.D. in Meteorology (1977) from MIT. Among her numerous honors are membership of the US National Academy of Sciences, the Royal Society, London, and Academia Sinica (Taiwan). She was the US lead for the 2014 joint NAS-Royal Society study "Climate Change: Evidence and Causes" and its 2020 update. Fung is a subject in a biography series for middle-school-aged readers, "Women's Adventures in Science", launched by the National Academy of Sciences. The title of her biography is "Forecast Earth". She was also featured in a short YouTube video sponsored by WIRED magazine: "What could happen in a world that's 4 degrees warmer?".

**William "Bill" D. Gropp** is Director of the National Center for Supercomputing Applications and holds the Thomas M. Siebel Chair in the Department of Computer Science at the University of Illinois at Urbana-Champaign. His research interests are in parallel and high performance computing, software for scientific computing, and numerical methods for partial differential equations. He has played a major role in the development of the MPI message-passing standard. He is co-author of one of the most widely used implementation of MPI, MPICH, and was involved in the MPI Forum as a chapter author for both MPI-1 and MPI-2. He has written many books and papers on MPI including "Using MPI" and "Using MPI-2." He is also one of the designers of the PETSc parallel numerical library and has developed efficient and scalable parallel algorithms for the solution of linear and nonlinear equations. Gropp is a Fellow of AAAS, ACM, IEEE, and SIAM and received the Sidney Fernbach Award from the IEEE Computer Society in 2008. In 2016, the Association for Computing Machinery (ACM) and IEEE Computer Society named Gropp, a professor of computer science at the University of Illinois at Urbana-Champaign the recipient of the 2016 ACM/IEEE Computer Society Ken Kennedy Award for highly influential contributions to the programmability of high-performance parallel and distributed computers. Gropp is a member of the National Academy of Engineering. William Gropp received his B.S. in Mathematics from Case Western Reserve University in 1977, an MS in Physics from the University of Washington in 1978, and a Ph.D. in Computer Science from Stanford in 1982. Gropp has served on several panels and a study for the National Academies, including the Panel on Digitization and Communications Science (2008--2010), the Study Committee (co-chair): Future Directions for NSF Advanced Computing Infrastructure to support US Science in 2017-2020 (2013-2015), the Panel on Computational Sciences at the Army Research Laboratory (2017), and the Panel on Review of Extramural Basic Research at the Army Research Laboratory (2018-2019).

**Melissa A. Kenney** is the Associate Director of Knowledge Initiatives at the University of Minnesota's Institute on the Environment (IonE) where she directs efforts to build synergy across IonE's broad scientific research portfolio. To achieve this goal, she collaborates with faculty, community partners, the University of Minnesota's systemwide campuses, and the IonE management team to sustain existing

and launch new research efforts in support of the strategic plan. Dr. Kenney is an environmental decision scientist with expertise in multidisciplinary, team-based science approaches to solving sustainability and Earth system challenges. Her research program broadly addresses how to integrate both scientific knowledge and societal values into policy decision-making under uncertainty. Her research expertise includes conceptual modeling and decision structuring, indicators, systems analysis, multi-attribute methods, and evaluation of decision support to address environmental policy decisions. These decision support tool and collaborative decision-making processes methods have been applied to a range of topics including participatory global change indicators, setting environmental policy criteria, economic analyses for restoration alternatives assessment, expert elicitation, value of information of indicators, and improving ecological forecasts. Over the past decade, this work has led to more than 50 publications; over $5M in grants awarded; more than 100 invited talks; multiple invited White House events integrating her research findings; and opportunities to translate scientific findings as policy memos or decision support prototypes to federal agencies and the highest levels of government. She was an invited presenter to the National Academies of Science, Engineering, and Medicine (NASEM) Roundtable on Science and Technology for Sustainability on Measuring Progress toward Sustainability and an invited roundtable participant for the Measures of Community Resilience workshop as part of the Resilient America Program. In addition to Dr. Kenney's multidisciplinary scientific research, she has extensive experience in high-level science policy coordination and relationship building between Federal and academic institutions. In her former role as an AAAS Science and Technology Policy Fellow, she played a role in visioning a transboundary climate early warning system in the Columbia River basin, facilitated academic center collaborations via an NOAA and NSF partnership, advised several federal agencies on enhancing their social science research agendas, and recommended methods to quantify the value of Federal programs. In recognition of her public engagement leadership, she was part of the inaugural cohort of AAAS Leshner Leadership Institute Public Engagement Fellows, where she focused on enhancing stakeholder-engaged research to create climate-resilient solutions in the U.S. and Chesapeake Bay region. Previously, Dr. Kenney was an Associate Research Professor in Environmental Decision Science at the University of Maryland and research faculty in the Department of Geography and Environmental Engineering at Johns Hopkins University. She was a postdoctoral scholar with the National Center for Earth-surface Dynamics at the University of Minnesota and Johns Hopkins University. She received a B.A. with Distinction in environmental sciences from the University of Virginia in 2002, and she earned a Ph.D. from Duke University in 2007, focused on integrating water quality and decision models.

**Jerry X. Mitrovica** is the Frank B. Baird, Jr., Professor of Science at Harvard University. His work focuses on the Earth's response to processes that have time scales ranging from seconds to billions of years. He has written extensively on topics ranging from the connection of mantle convective flow to the geological record, the rotational stability of the Earth and other terrestrial planets, ice age dynamics, and the geodetic and geophysical signatures of ice sheet melting in our progressively warming world. Sea-level change has served as the major, unifying theme of these studies, with a particular emphasis on critical events in ice age climate and on the sea-level fingerprints of modern polar ice sheet collapse. Dr. Mitrovica is a former Director of the Earth Systems Evolution Program of the Canadian Institute for Advanced Research and J. Tuzo Wilson Professor in the Department of Physics at the University of Toronto. He is the recipient of the Arthur L. Day Medal from the Geological Society of America, the W.S Jardetsky Medal from Columbia University, the A.E.H. Love Medal from the European Geosciences Union and the Rutherford Memorial Medal from the Royal Society of Canada. He was recently named (2019) a Fellow of the MacArthur Foundation. He is also a Fellow of American Geophysical Union and the

Geological Society of America, as well as a past Fellow of the John Simon Guggenheim Memorial Foundation.

**Constantine (Costa) Samaras** is an associate professor at Carnegie Mellon University in the Department of Civil and Environmental Engineering. Dr. Samaras's research spans energy, climate change, automation, and defense analysis, and he directs the Center for Engineering and Resilience for Climate Adaptation. He assesses how technology, policy, and infrastructure system designs affect energy use, system resilience to climate change impacts, economic and equity outcomes, and life cycle environmental emissions and other externalities under uncertainty. He currently serves as the Chair of the ASCE Committee on Adaptation to a Changing Climate. Dr. Samaras is also an adjunct senior researcher at the RAND Corporation. From 2009 to 2014, he was a researcher at the RAND Corporation, and from 1999-2004 was a megaprojects engineer in New York. Dr. Samaras received his Ph.D. in civil and environmental engineering and engineering and public policy from Carnegie Mellon University in 2008, and earlier received a MPA from New York University and a BS from Bucknell University. He has previously served on the National Academies Review of the U.S. DRIVE Research Program–Phase 4 Committee, and on the Committee on Enhancing Air Mobility¬¬–A National Blueprint.

**Kristen St. John** is a Professor of Geology at James Madison University. She earned her B.S. in Geology at Furman University (1992), and her M.S. (1995) and a Ph.D. (1998) in Geological Sciences from The Ohio State University. Her research extends across two areas: (1) undergraduate geoscience curriculum design and community development and (2) marine sedimentology/paleoceanography. She was the Editor-in-Chief of the *Journal of Geoscience Education* from 2012-2017. She delivered the presentation on the future of geoscience education research in the 2019 *AGU Centennial Plenary: Inspire the Future for the Benefit of Humanity*. She was the lead researcher and editor of the vision and planning report: A Community Framework for Geoscience Education Research. An active researcher in the International Ocean Discovery Program (IODP), she was a marine sedimentologist for several expeditions, and worked on samples from the Arctic, North Atlantic, and North Pacific to investigate the marine record of iceberg and sea ice changes through time. She is the co-chief scientist for the future Arctic Ocean Paleoceanography expedition (Arc-OP, IODP Exp. 377). Her work in scientific ocean drilling and education intersect in two books projects; she is the lead author on *Reconstructing Earth's Climate History: Inquiry Exercises for Lab and Class*, and is collaboratively preparing a new introductory textbook, *Climate Change: A Geosciences Perspective*. She served on the U.S. Steering Committee for Scientific Ocean Drilling, was a co-leader of the IODP NEXT workshop and the IODP workshop on Scientific Exploration of the Arctic and North Pacific. Currently, she is on the U.S. IODP Education and Outreach Committee and the National Academies of Science Polar Research Board. At JMU, she received the General Education Distinguished Teacher Award in 2013, the College of Science and Math Outstanding Teaching Award in 2014, the Research and Scholarship Lifetime Achievement Award in 2017, and the Roberts Endowment for Faculty Excellence Award in 2019. She was recognized as Geological Society of America (GSA) Fellow in 2016.

**Fiamma Straneo** is a Professor in Polar Climate and Oceans at the Scripps Institution of Oceanography of the University of California San Diego. Prior to joining Scripps, she was a Senior Scientist at the Woods Hole Oceanographic Institution until 2017. She studies the high latitude North Atlantic and Arctic Oceans and their interaction with the atmosphere, sea-ice and the Greenland Ice Sheet. Much of her research has focused on obtaining and interpreting data from the challenging regions at the glaciers' margins. Straneo has led over a dozen field expeditions to the Arctic and Greenland. She has collaborated extensively with glaciologists and ice sheet modelers, and recently chaired the Ocean Forcing Working Group for the Ice Sheet Modeling Intercomparison Project. Straneo is co-chair of the Climate and

Cryosphere Program of the World Climate Research Program, co-chair and founder of the Greenland Ice Sheet/Ocean Science Network (GRISO), a member of the Atlantic Meridional Overturning Circulation Science Team and of the ASOF (Arctic-Subarctic Ocean Fluxes). She is also a fellow of the Leopold Leadership Program and was awarded the Sverdrup Lecture by the Ocean Sciences Section of the American Geophysical Union in 2016. Straneo obtained her Ph.D. in Physical Oceanography in 1999 from the University of Washington, USA, following a Laurea cum Laude in Physics in 1993 from the University of Milan, Italy.

**Duane E. Waliser** is Chief Scientist of the Earth Science and Technology Directorate at the Jet Propulsion Laboratory (JPL) in Pasadena, California, which formulates, develops, and operates of a wide range of Earth science remote sensing instruments for NASA's airborne and satellite program. His principal research interests lie in Earth system processes, observations and modeling; weather-climate linkages, particularly subseasonal to seasonal (S2S) variability; prediction and predictability; and the Earth's water cycle. His recent foci at JPL involves working within NASA and across agencies to enable and enhance societal benefits from our growing understanding, observing and modeling capabilities of the Earth System. He received a B.S. in physics and a B.S. in computer science from Oregon State University in 1985, an M.S. in physics from UC San Diego in 1987, and his Ph.D. in physical oceanography from the Scripps Institution of Oceanography at UC San Diego in 1992. Past interactions with the Academies include membership in the following three studies: 2010 Assessment of Intraseasonal to Interannual Climate Prediction and Predictability, 2016 Next Generation Earth System Prediction: Strategies for Subseasonal to Seasonal Forecasts, and 2018 Thriving on Our Changing Planet: A Decadal Strategy for Earth Observation from Space, as well as current membership on the on the Board on Atmospheric Science and Climate and the Committee on Earth Science and Applications from Space.

# Advancing a Systems Approach to Studying the Earth: A Strategy for the National Science Foundation

https://www.nationalacademies.org/our-work/advancing-a-systems-approach-to-studying-the-earth-a-strategy-for-the-national-science-foundation


**Summary**

The Earth is a complex system, with myriad interactions and feedbacks among the atmosphere, hydrosphere, geosphere, cryosphere, biosphere, and the individuals, institutions, and technologies that respond to and influence these dynamics. Earth systems research has been conducted for decades. Making further progress will require lowering institutional and cultural barriers to engagement across traditional scientific disciplines and advancing transdisciplinary efforts that foster greater understanding of the interdependencies among the Earth system components. The National Science Foundation (NSF)—including the directorates of Geosciences, Biology, Engineering, Computer and Information Science and Engineering, Education and Human Resources, and Social, Behavioral, and Economics Sciences—seeks to build bridges across these disciplines to significantly advance a systems-level, integrated understanding of the Earth.


**Statement of Task**

An ad hoc committee of the National Academies of Sciences, Engineering, and Medicine will undertake a study that develops a compelling vision for a systems approach to studying the Earth and identifies facilities, infrastructure, coordinating mechanisms, computing, and workforce development needed to support that vision. All major components of the Earth system will be considered including the atmosphere, hydrosphere, geosphere, cryosphere, biosphere, and the individuals, institutions, and technologies that respond to and influence these dynamics as will their interactions and feedbacks through time. With input from virtual workshops and lessons learned from previous and current approaches to integrated research at NSF, the committee also will provide advice on how NSF can support the research community in meeting the vision and identifying overarching capabilities needed to support a systems approach to studying the Earth.

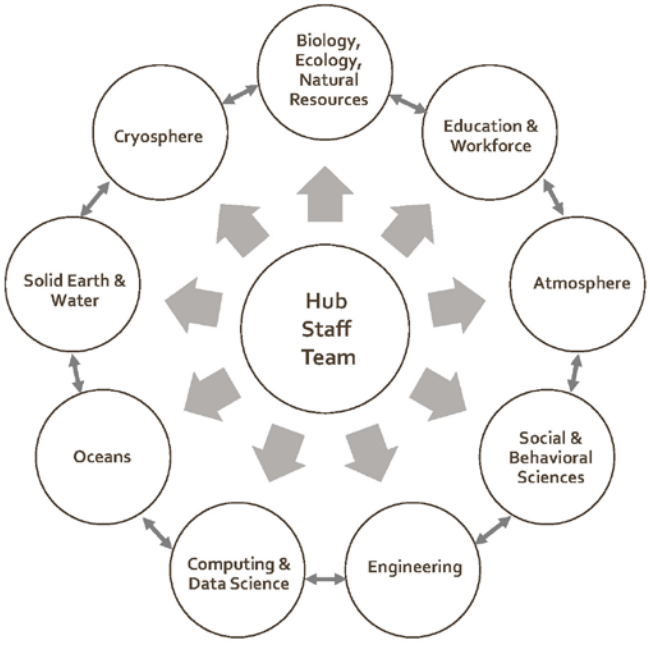
The committee's report will:

1. Describe the potential value and key characteristics of a robust, integrated approach for studying the Earth system.
2. Discuss emerging opportunities and barriers to progress for achieving this vision, including consideration of the interdependencies and synergies among all components.
3. Identify potential synergistic opportunities within current facilities, infrastructure, and coordinating mechanisms to address the overarching capabilities, and recommend ways to leverage these efforts for Earth systems research. Ideas for new approaches, facilities, infrastructure, and coordinating mechanisms may also be considered.
4. Discuss computational, data, and analytic support for Earth systems research, including guidance on harnessing existing, planned, and future NSF-supported cyberinfrastructure.
5. Discuss workforce development to support the personnel needed to advance Earth systems research. This could include undergraduate and graduate education, technical training to support facilities and infrastructure, and increasing diversity and inclusion in the future workforce. This will draw upon scholarship related to workforce development and broadening participation to consider new and existing approaches.

**Work Plan**

This activity will be carried out by an ad hoc committee of 16 members with expertise in atmospheric science, behavioral and social sciences, biology and ecology, climate science, computer and data science, education and workforce development, engineering, geology and geophysics, hydrology, and oceanography. Members have experience working on integrated research questions and teams, and in taking a systems approach to research. Members have expertise covering both fundamental questions and applications of science. Finally, members who have experience working with major facilities, infrastructure, and mechanisms that support integrated research were selected.

The project is supported by staff from relevant program units across the National Academies, using a hub-and-spokes team design. The "hub" will support overall coordination of the project, ensure cross-Academies engagements, and support report development. The "spokes", in partnership with committee members with relevant expertise, will be the primary conduits among designated expert communities, relevant parts of NSF, and the study.




The spokes will ensure that information and perspectives from each NSF division/directorate are considered and that their NSF points of contact are kept informed throughout the study process. Likewise, spokes will ensure that their relevant expert communities are apprised of the study, have opportunities to engage in the process (e.g., disseminating the call for nominations and requests to provide input to the committee, participating in the workshops), and to learn about the report after it is released (e.g., organizing briefing sessions at relevant conferences, board meetings). Staff serving as spokes may also have other roles during the study, as part of the hub team or as leads for specific parts of workshop planning.

The committee will convene five meetings and a series of virtual workshops. The first few committee meetings were focused primarily on developing the report vision, development of draft report text, and

preparation for the workshops. The committee will continue to gather additional information and deliberate in virtual meetings as needed. The committee will also solicit community input on the statement of task through a structured online questionnaire. The questionnaire has been widely distributed to relevant Earth system communities. The questionnaire is available through December 2020: https://www.surveygizmo.com/s3/5888023/ess.

The committee will organize virtual workshops to engage scientists from a range of institutions, disciplines, and career stages. The committee's report may include syntheses of key presentations or discussions from the workshops. Presentation materials and video recordings of the workshop will be made available on the Academies' website, but workshop proceedings will not be produced.

Virtual workshop sessions will provide an opportunity for additional discussion of the draft vision as well as strategies for implementation. Workshop sessions will address crosscutting aspects of implementation, including:

- Education and Workforce Development for Earth Systems Science
- Integrating Earth Systems Science and Engineering
- Accelerating Integration of the Social Sciences in the Study of Earth System Interactions
- Computing, Data, and Cyberinfrastructure for a Systems Approach to Studying the Earth
- Facilities, Infrastructure, and Coordinating Mechanisms for Supporting Integrated Research

The committee, with support from National Academies' staff, will prepare a report addressing the vision and implementation sections of the statement of task. The full report will be subject to standard Academies' review procedures.

# Advancing a Systems Approach to Studying the Earth: A Strategy for the National Science Foundation

## Draft Committee Vision

***Vision. To explore interactions among natural and social systems that effect Earth's ability for sustaining life and to provide the scientific foundation for navigating our future.***

A research framework to accelerate integrative understanding of Earth systems would incorporate both discovery and use-inspired research on interactions among all Earth system components across all temporal and spatial scales. It would also enable research teams to work seamlessly across NSF's natural and social science, engineering, computing, and education and workforce directorates.

* Discovery science includes prediction
* Use-inspired research includes decision making at individual to societal levels
* Earth system components include the atmosphere, hydrosphere, cryosphere, geosphere, biosphere, and human institutions and infrastructure
* Spatial scales of Earth system processes range from molecules to global, and temporal scales range from milliseconds to millennia, over periods from the geologic past to far into the future.