

A Call to Action

Developing the Capability to Explain and Predict Earth System Change

Key messages from

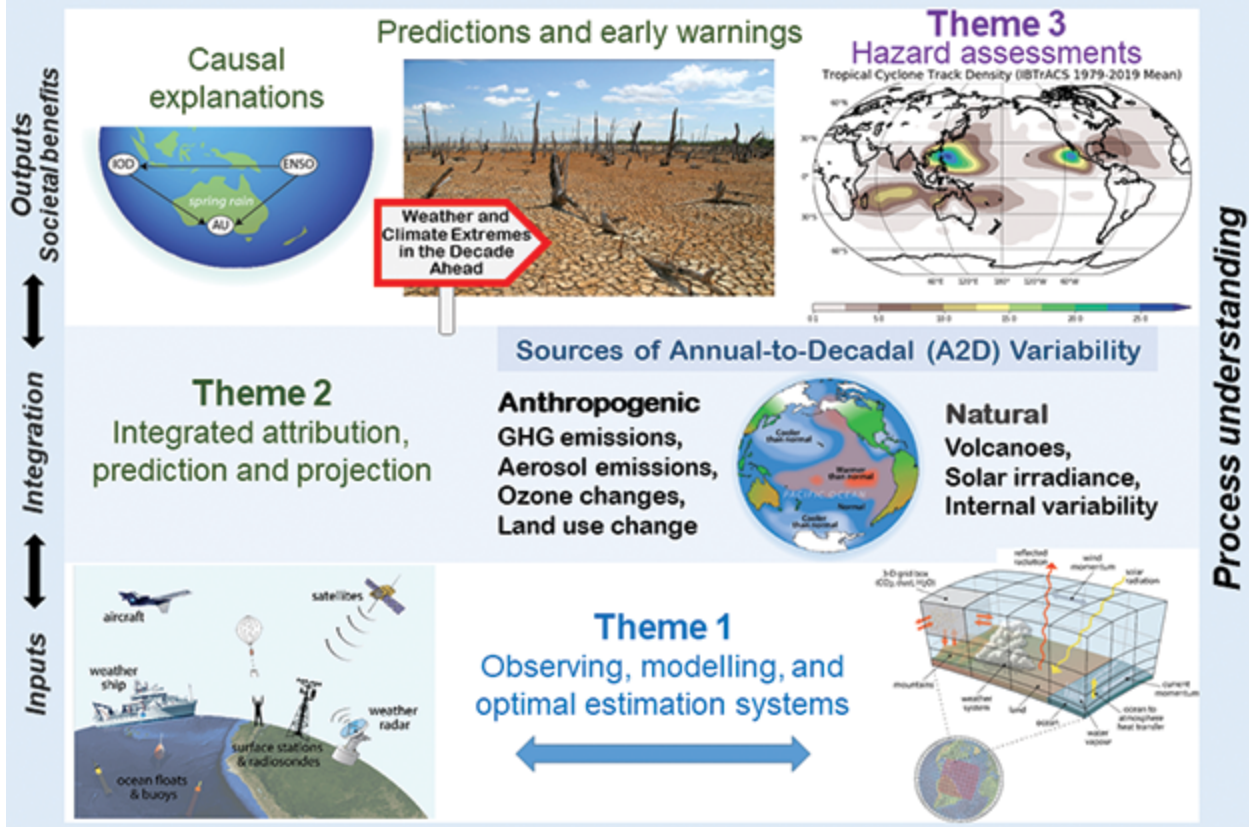
“Explaining and Predicting Earth System Change: A World Climate Research Programme Call to Action,” by Kirsten L. Findell (NOAA/Geophysical Fluid Dynamics Laboratory), Rowan Sutton, Nico Caltabiano, Anca Brookshaw, Patrick Heimbach, Masahide Kimoto, Scott Osprey, Doug Smith, James S. Risbey, Zhuo Wang, Lijing Cheng, Leandro B. Diaz, Markus G. Donat, Michael Ek, June-Yi Lee, Shoshiro Minobe, Matilde Rusticucci, Frederic Vitart, and Lin Wang. Published online in *BAMS*, January 2023. For the full, citable article, see <https://doi.org/10.1175/BAMS-D-21-0280.1>.

The formulation of robust policies for mitigation of—and adaptation to—climate change requires quantitative understanding of how and why specific changes are unfolding in the Earth system, and what might happen in the future. Quantitative explanation of observed changes—through robust process-based detection and attribution—is also fundamental to specification of confidence in climate assessments, predictions, and projections. However, the capacity to deliver these capabilities is very limited, particularly for the annual to decadal (A2D) time scales that lie between the time scales of days to seasons—the focus of numerical weather prediction (NWP) and seasonal forecasting—and the multi-decadal-to-century time scales that are the primary focus of climate projection efforts. The World Climate Research Programme (WCRP) Lighthouse Activity (LHA) on Explaining and Predicting Earth System Change (EPESC) is intended to address this need.

The overarching goal of EPESC is *to develop an integrated capability to understand, attribute, and predict annual to decadal changes in the Earth system, including capabilities for early warning of potential high impact changes and events*. This will deliver improved capabilities for early warning of impactful changes in the Earth system, more reliable assessments of meteorological hazard risks, and quantitative attribution statements to support the Global Annual to Decadal Climate Update and State of the Climate reports issued by the World Meteorological Organization.

On regional-to-global and A2D scales, changes in oceanic and atmospheric circulation and their consequent impacts are of particular interest because of their importance in shaping hazards, and because current capabilities to explain and predict changes in circulation are particularly limited. Some examples of changes of interest include rapid warming of the North Atlantic Ocean, weakening of the North Atlantic subpolar gyre, changes in the phase of the Interdecadal Pacific Oscillation, persistent marine heatwaves (e.g., North Pacific, 2013–16), persistent droughts (e.g., the Sahel, 1970s and 1980s), and the apparent slowdown in global mean surface temperature rise that was observed in the 2000s. This last example is a particularly fitting case study of how natural decadal variability

WCRP Lighthouse Activity on Explaining and Predicting Earth System Change



on top of long-term trends can combine to produce a long-lasting signal that can capture both research and public attention.

This LHA is concerned both with events that have A2D duration and with understanding how regional and larger-scale changes (e.g., broad atmospheric or oceanic circulation changes) on these time scales influence the characteristics of hazards (e.g., severe convective storms, tropical and extratropical cyclones, atmospheric rivers, terrestrial and marine heat waves, wildfires) occurring on shorter space and time scales. Examples of A2D variability influencing hazards can be found in the impact of Atlantic multidecadal variability on tropical cyclones in the Caribbean basin, or of the El Niño–Southern Oscillation (ENSO) on fire weather in Australia.

We have organized the scientific challenges and opportunities around three major themes with associated research questions and working groups:

Key elements of the Lighthouse Activity. The bottom layer shows the importance of coordinated observational and modeling efforts serving as key tools and inputs to the integrated attribution, prediction, and projection efforts in the middle layer. Both of these layers feed into the outputs and societal benefits displayed in the top layer: causal explanations, predictions and early warnings, and hazard assessments. Arrows along the left side indicate that outputs (Themes 2 and 3) and integration (Theme 2) can feedback to improve the inputs (Theme 1). Fundamental physical process understanding runs through all aspects of the Lighthouse Activity.

Theme 1: Monitoring and Modeling Earth System Change

- 1) What are the observational and modeling requirements to measure, explain, and predict changes in the Earth system on A2D and regional-to-global scales?
- 2) How can we most effectively combine observations and models to quantify,

explain, and predict changes in the Earth system on A2D and regional-to-global scales?

- 3) Which enhanced observations will offer the greatest improvements in predictive and explanatory skill, and where should those enhancements be targeted?

Theme 2: Integrated Attribution, Prediction, and Projection of Earth System Change

- 1) How can we best identify and attribute the drivers of changes in the Earth system on regional-to-global and A2D scales?
- 2) What are the requirements for an operational integrated attribution and prediction capability focused on regional-to-global and A2D scales to provide early warnings to inform decision-making?

Theme 3: Assessment of Current and Future Hazards

- 1) How do internal variability and external forcings influence the characteristics and occurrence of meteorological hazards on A2D scales in different regions?

- 2) How can we use observations, models, and process understanding to deliver robust assessments of current and future hazards for specific regions and hazard classes?

Initial steps to develop a capability to observe, explain, and predict Earth system change will focus on compelling case studies targeting climate “events” that have occurred in recent decades, such as the examples given above. Additionally, we envisage that new large ensembles of single-forcing experiments will be a key resource for each of the themes. These are essential to characterize the responses to different forcing factors (e.g., increasing concentrations of greenhouse gases in the atmosphere, changes in land use), thereby informing observing system design (Theme 1), providing quantitative process-based attribution (Theme 2), and improving our understanding of the drivers of changing hazard frequencies and intensities (Theme 3). Expertise relevant to EPESC is found in many of WCRP’s core projects and other Lighthouse Activities; active communication between EPESC and other WCRP entities is crucial to the success of this endeavor. ●●

≡ METADATA

BAMS: What would you like readers to learn from this article?

Kirsten Findell (NOAA/Geophysical Fluid Dynamics Laboratory): *This work was motivated by imagining the capabilities for annual-to-decadal attribution and prediction we expect will be available by 2050 or 2060 and then asking: How can we get there? And can we get there sooner?*

BAMS: How did you become interested in the topic of this article?

KF: *Much of my work is focused on land–atmosphere interactions, often through the lens of diurnal and subdiurnal physical processes connecting surface fluxes of heat and moisture with the growth and development of the planetary boundary layer, including implications for clouds and precipitation.*

These processes are critically important for understanding climatic conditions at the land surface, where humans, animals, and ecosystems are all grappling with the consequences of a changing climate. Understanding the large-scale forcing mechanisms creating the backdrop for these land–atmosphere interactions and influencing how they progress on individual days and in statistical aggregates is critically important. This LHA provides the opportunity for rapid and exciting community-wide progress on these topics.

BAMS: What surprised you the most about the work you document in this article?

KF: *I am awed by the determination of the scientific community to tackle really hard questions. The work laid out in this document will force us to*

confront a series of really difficult problems, hoping all the while that progress will be revolutionary, but understanding that it may be merely incremental.

BAMS: What was the biggest challenge you encountered while doing this work?

KF: *The LHAs were initially envisioned just weeks before the Covid lockdown began, which meant that the work of actually assembling the team, defining the scope, and initiating these activities had to be done virtually. This posed enormous logistical challenges and initial limitations, but clearly we were not the only people grappling with these issues. Our recent (and first) in-person meeting in March 2023 helped us to begin the next phase of the work at hand.*

AMS Journals

The world's home for
weather, water, and climate research

Journal of the Atmospheric Sciences

The *Journal of the Atmospheric Sciences (JAS)* publishes basic research related to the physics, dynamics, and chemistry of the atmosphere of Earth and other planets, with emphasis on the quantitative and deductive aspects of the subject.

Open Access option for authors. All papers publicly accessible 12 months after publication.

2019 Impact Factor: 3.194 (2019 Journal Impact Factors by Clarivate Analytics: Meteorology and Atmospheric Science category)

Editorial Board

Anne K. Smith, National Center for Atmospheric Research (Chief Editor)

Peter Bartello, McGill University

William R. Boos, University of California, Berkeley

Elie Bou-Zeid, Princeton University

Edmund Kar-Man Chang, Stony Brook University

Johannes Dahl, Texas Tech University

Jerry Harrington, The Pennsylvania State University

Yoshio Kawatani, Japan Agency for Marine-Earth Science and Technology

David Mechem, University of Kansas

Lorraine Remer, University of Maryland, Baltimore County

Christopher Rozoff, National Center for Atmospheric Research

Tiffany Shaw, University of Chicago

Daniel Stern, University Corporation for Atmospheric Research

Zhuo Wang, University of Illinois at Urbana-Champaign

Feng Xu, University of Oklahoma



Journal of the Atmospheric Sciences (JAS)
ISSN: 0022-4928; eISSN: 1520-0469