Summer 2022

GFDL BULLETIN

Research Highlights from the Geophysical Fluid Dynamics Laboratory Community

Advancing the Modeling, Understanding, and Prediction of Weather and Climate

SKILLFUL SEASONAL PREDICTION OF NORTH AMERICAN HEAT EXTREMES

Journal of Climate *L. Jia[1,2], T. L. Delworth[1], S. Kapnick[1], X. Yang[1], N.C. Johnson[1], W. Cooke[1], F. Lu[1,3], M. Harrison[1], A. Rosati[1,2], F. Zeng[1], C. McHugh[1,4], A.T. Wittenberg[1], L. Zhang[1,2], H. Murakami[1,2], and Kai-Chih Tseng[1,3]*

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Heat extremes have profound ecological, societal, and economic impacts. Predicting heat extremes on seasonal time scales is crucial in developing early warning systems to improve preparedness. Little progress has been made thus far in forecasting heat extremes on seasonal scales; historically, it has been challenging to predict extremes on such long time scales. This study shows that the frequency of North American summertime (June–August) heat extremes is skillfully predicted several months in advance with GFDL's Seamless System for Prediction and Earth System Research (SPEAR) seasonal forecast system.

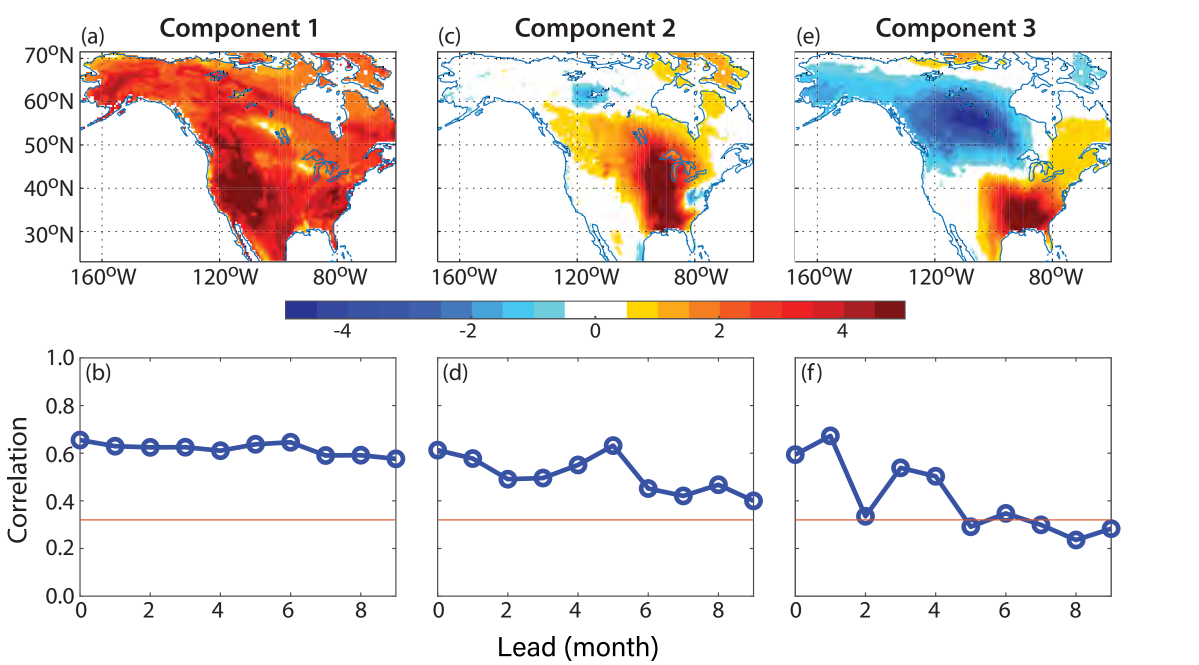
Using a statistical optimization method, the authors identified three predictable large-scale components of the frequency of North American summer hot days that are skillfully predictable on seasonal time scales. One component, related to a secular warming trend, shows a continent-wide increase in the frequency of summer hot days and is highly predictable at least 9 months in advance. This is likely a response to external radiative forcing.

The second component is largely driven by the sea surface temperatures in the North Pacific and North Atlantic and is significantly correlated with central U.S. soil moisture. It shows the largest loadings over the central U.S. and is significantly predictable 9 months in advance. The third component, related to the central Pacific El Niño, displays a dipole structure over North America and is predictable up to 4 months.

This study has potential implications for advancing seasonal predictions of North American summertime heat extremes.

OAR Goals: Make Forecasts Better

Three predictable components of the frequency of summer hot days in North America



The spatial patterns and rank correlation skill of three predictable components of the frequency of summer hot days over North American land areas. The horizontal lines in b), d) and f) indicate the 95% confidence level.

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[4]Science Applications International Corporation, Reston, VA

TRIPLING OF WESTERN US PARTICULATE POLLUTION FROM WILDFIRES IN A WARMING CLIMATE

Proceedings of the National Academy of Sciences

Y. Xie[1,2], M. Lin[1,2], B. Decharme[3], C. Delire[3], L.W. Horowitz[1], D.M. Lawrence[4], F. Li[5], R. Séférian[3]

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Record-setting fires in the Western U.S. over the last decade caused severe air pollution, loss of human life, and property damage. Enhanced drought and increased biomass in a warmer climate may fuel larger, more frequent wildfires in the future. This research combined projections of wildfires in three Earth system models with an empirical statistical model, to predict fine particulate pollution in the late 21st century.

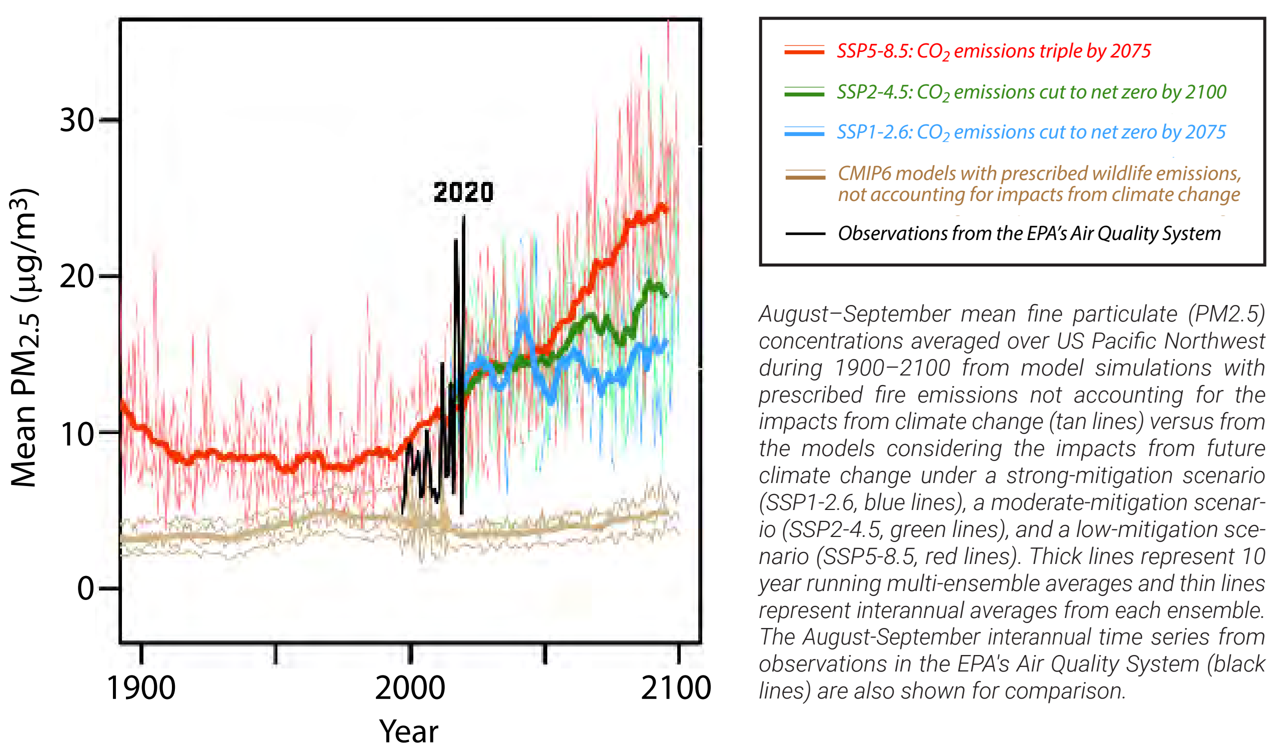
Experiments with the models, including GFDL's ESM4, used several different possible scenarios of how socioeconomic factors, as well as mitigation efforts, may change in the future. The authors found that smoke pollution from Western U.S. wildfires during late summer and fall would double to triple by 2100 under intermediate- and low-mitigation climate scenarios. The increase is reduced to a 40-60% increase in a strong-mitigation scenario with global CO_2 emissions cut to net zero around 2075. Without strong climate change mitigation, events like the consequential 2020 wildfire season could recur every 3 to 5 years in the late 21st century accompanied by particulate pollution.

This study suggests that multi-agency collaborations, addressing climate mitigation, air quality, and forest management, are needed to minimize the adverse health impacts projected to result from fire smoke.

OAR Goals: Drive Innovative Science

Tripling of Western United States particulate pollution from wildfires in a warming climate

August - September, US Pacific Northwest



August–September mean fine particulate (PM2.5) concentrations averaged over US Pacific Northwest during 1900–2100 from model simulations with prescribed fire emissions not accounting for the impacts from climate change (tan lines) versus from the models considering the impacts from future climate change under a strong-mitigation scenario (SSP1-2.6, blue lines), a moderate-mitigation scenario (SSP2-4.5, green lines), and a low-mitigation scenario (SSP5-8.5, red lines). Thick lines represent 10 year running multi-ensemble averages and thin lines represent interannual averages from each ensemble. The August-September interannual time series from observations in the EPA's Air Quality System (black lines) are also shown for comparison.

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SUBSTANTIAL GLOBAL INFLUENCE OF ANTHROPOGENIC AEROSOLS ON TROPICAL CYCLONES OVER THE PAST 40 YEARS

Science Advances *H. Murakami*[1,2]

DOI: 10.1126/sciadv.abn9493

Based on experiments with GFDL's SPEAR model, this study reveals that reducing particulate air pollution in Europe and North America has contributed to an increase in the number of tropical cyclones in the North Atlantic basin and a decrease in the number of these storms in the Southern Hemisphere. The research also determined that the growth of particulate pollution in Asia has contributed to fewer tropical cyclones in the western North Pacific basin.

Pollution control measures in Europe and the U.S. over the past 40 years led to significantly decreased anthropogenic aerosols. An estimated 50-percent drop in concentration of human-caused air pollution in the Northern Hemisphere has led to surface warming over the tropical Atlantic Ocean, which contributes to more frequent tropical cyclones. With reduced amounts of particulate pollution to reflect sunlight, the ocean absorbs more heat and warms faster. A warming Atlantic Ocean has been a key ingredient to a 33-percent increase in the number of tropical cyclones during this 40-year period.

This study shows that anthropogenic aerosols exert a substantial impact on the spatial occurrence of global tropical cyclones, a result of changes in large-scale circulations as well as local cooling/warming induced by the changes in aerosol emissions. The impact is substantially different from the effects of increased greenhouse gases, underscoring the importance of examining multiple consequences induced by anthropogenic activity.

Over the next decades human-caused particulate air pollution is projected to remain stable in the North Atlantic, with increased greenhouse gases becoming a more significant influence on tropical cyclones. Fewer numbers of tropical cyclones are projected, but those that occur are likely to be more intense.

OAR Goals: Drive Innovative Science

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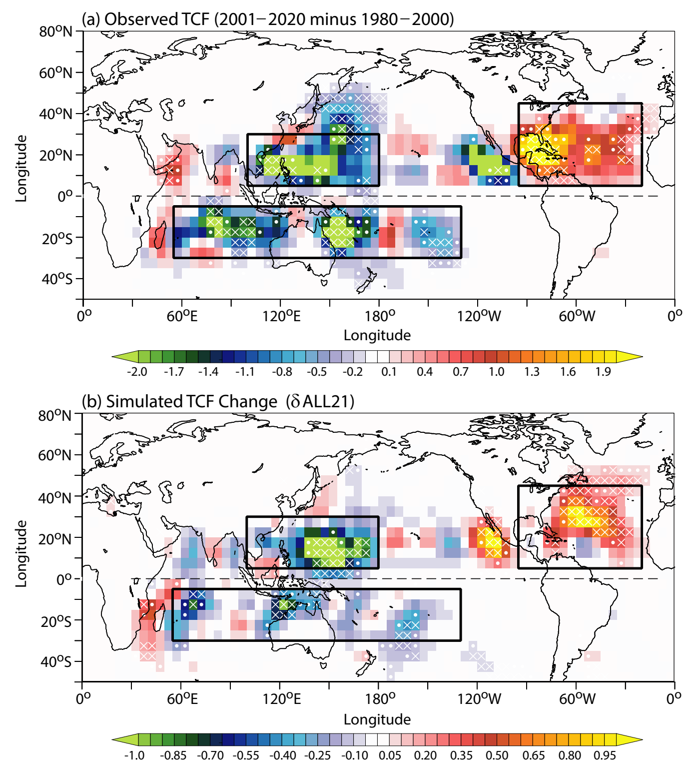
Changes in Tropical Cyclone Spatial Distributions



(a) The global pattern of locations where the frequency of tropical cyclones (TCF) has increased and where it has decreased in 2001–2020 relative to 1980–2000. (b) SPEAR's simulated response of tropical cyclone frequency to the changes in anthropogenic aerosols between 1980–2000 and 2001–2020. White crosses (dots) indicate the difference is statistically significant at the 95% (90%) level. Units: number per year per 5° × 5° grid box.

https://www.noaa.gov/news/study-climate-change-has-been-influencing-where-tropical-cyclones-rage

REGIONAL SENSITIVITY PATTERNS OF ARCTIC OCEAN ACIDIFICATION REVEALED WITH MACHINE LEARNING

Communications Earth & Environment (a Nature journal)

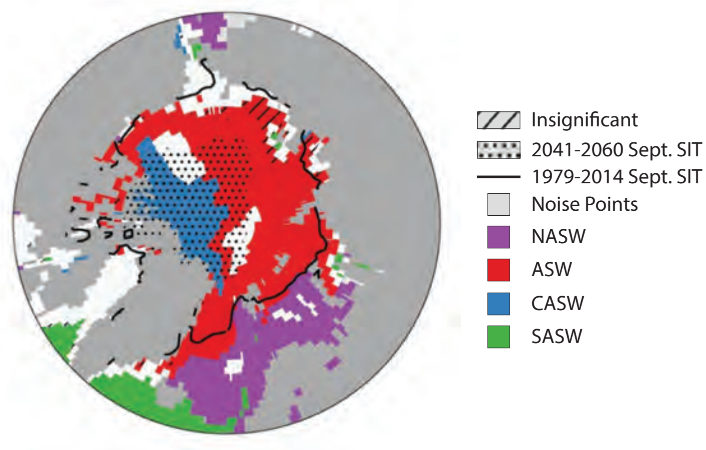
J. P. Krasting[1], M. De Palma[2,3], M. Sonnewald[3], J.P. Dunne[1], J.G. John[1]

DOI: 10.1038/s43247-022-00419-4

Ocean acidification (OA) is a direct consequence of the absorption of anthropogenic carbon emissions and it profoundly impacts marine life. Arctic regions are particularly vulnerable to rapid pH changes due to low ocean buffering capacities and high stratification. This research applied a machine learning workflow to simulations of surface Arctic acidification.

Distinct clusters of surface ocean acidification in the Arctic were identified which were robust across two state-of-the-art coupled climate models developed at GFDL, CM4 and ESM4, and across a low and high emissions future climate scenario. Changes in the surface freshwater balance of the Arctic Ocean drive reductions in salinity and in total alkalinity, the main differentiators of the clusters. Stronger trends toward corrosive surface waters in the central Arctic Ocean are driven by early summer warming in regions of annual ice cover and late summer freshening in regions of perennial ice cover. Sea surface salinity and total alkalinity reductions dominate the Arctic pH changes, highlighting the importance of objective sub-regional identification and subsequent analysis of surface water mass properties.

Regimes of Acidification in GFDL-CM4



Machine Learning clustering reveals ***different regimes*** *of Arctic ocean acidification (OA) that are linked to patterns of* ***present day and future sea ice thickness (SIT)****: Central Arctic Surface Waters (CASW, blue), more general Arctic Surface Waters (ASW, red), North Atlantic Surface Waters (NASW, purple), and Sub-Arctic Surface Waters (SASW, green).*

The regimes are robust across two different GFDL models and across different climate change scenarios.

Both models used in this study reproduce the observed patterns of global anthropogenic carbon uptake. ESM4 performs the best in overall global integrated uptake, while the higher resolution CM4 better represents the pattern distributions of anthropogenic carbon in the central Arctic Ocean.

Climate variability delays the emergence of climate change signals for other properties of the Earth system, but the high signal-to-noise ratio of OA is a clear indicator of the effects of anthropogenic carbon emissions on the ocean surface. For more than 95% of the world's oceans, the OA signal has already emerged from background natural variability. The Arctic Ocean is particularly vulnerable to acidification as melting sea ice exposes the surface to increasing carbon dioxide in the atmosphere. Freshwater from ice melt also contributes to reductions in sea surface salinity and total alkalinity. These accelerate declines in both pH and the carbonate ion saturation states, making the water increasingly corrosive with adverse effects on the ecosystem.

OAR Goals: Drive Innovative Science

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OCEANIC AND ATMOSPHERIC DRIVERS OF POST-EL-NIÑO CHLOROPHYLL REBOUND IN THE EQUATORIAL PACIFIC

Geophysical Research Letters *H-G Lim[1], J.P. Dunne[2], C.A. Stock[2], P. Ginoux[2], J.G. John[2,3], J. Krasting[2]*

DOI: 10.1029/2021GL096113

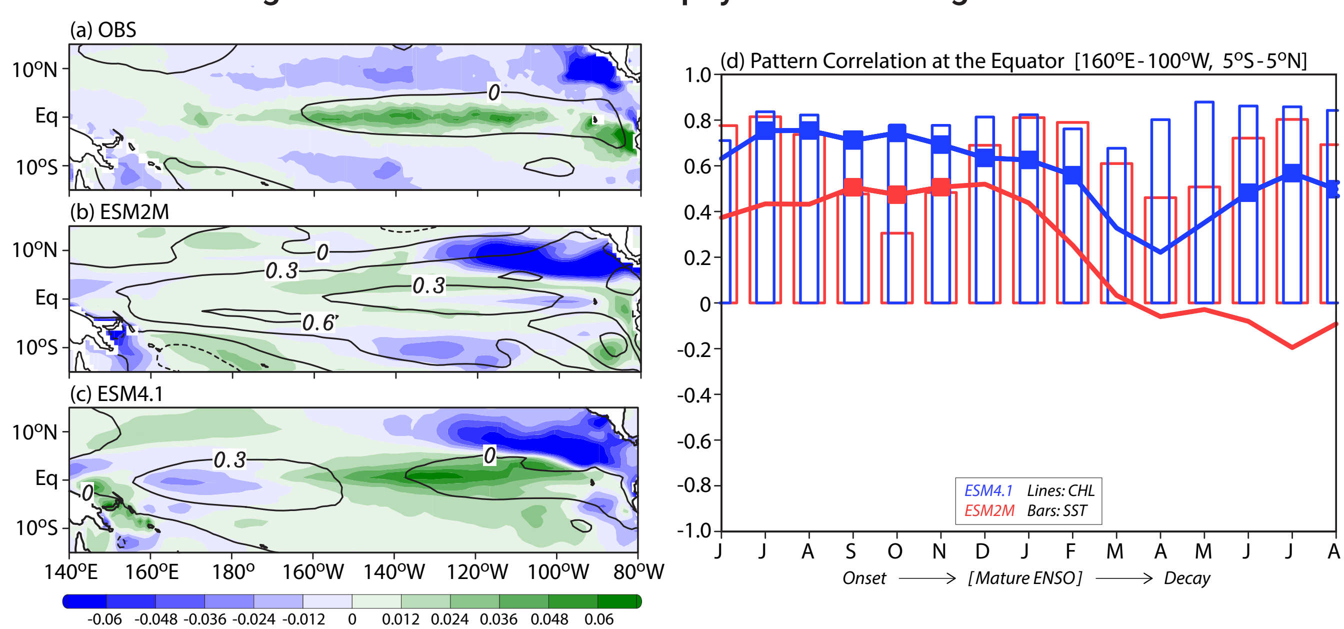
In the tropical Pacific, year-to-year changes in chlorophyll, a proxy for the phytoplankton base of ocean food webs, is dominated by the El Niño–Southern Oscillation. Triggered by westerly wind anomalies and subsequent redistributions of upper ocean heat content, El Niño can sharply reduce the regional supply of nutrients, limiting phytoplankton growth. GFDL's new Earth System Model (ESM4.1) captures not only the onset and extent of chlorophyll anomalies during El Niño events, but also a pronounced post-El Niño "chlorophyll rebound" that produces positive equatorial Pacific chlorophyll anomalies in the summer following El Niño events.

This research demonstrates that the post-El Niño chlorophyll rebound occurs as a natural, delayed response following El Niño rather than requiring any physical La-Niña response. It is primarily driven by positive western Pacific iron anomalies (associated with anomalously sluggish ocean circulation and subsequent biogeochemical responses during El Niño) impacting the Eastern Pacific surface waters via the Equatorial Undercurrent. High dust deposition anomalies arising from dry land conditions in Central and South America augment the post-El Niño chlorophyll rebound.

The chlorophyll rebound provides a key source of resilience to marine ecosystems in the equatorial Pacific, and this research informs improved ecosystem-based management of living marine resources.

OAR Goals: Explore the Marine Environment, Detect Changes in the Ocean and Atmosphere

Regression of SST and chlorophyll anomalies against ENSO



Spatially resolved ENSO-regression of temperature (contours, °C/°C) and chlorophyll concentration (shading, mgm3/°C) anomalies against ENSO in (a) satellite, Simple Ocean Data Assimilation (SODA), (b) ESM2M, and (c) ESM4.1.

Values are shown for the ENSO decay state one year after the peak (JJA+1); (d) pattern correlations of ESM2M (red) and ESM4.1 (blue) regression coefficients (i.e., panels (b) and (c)) with SODA (bars) and satellite chlorophyll (lines; square symbols denote the Student's t-test statistical significance at 95% confidence level) regression coefficients (i.e., panel (a)) in the EP (160°E–100°W, 5°N–5°S).

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SARAH KAPNICK NAMED NOAA CHIEF SCIENTIST

The former GFDL scientist was named NOAA's Chief Scientist in early July.

Sarah Kapnick, Ph.D. serves as the senior scientist for the agency, advancing policy and program direction for NOAA's science and technology priorities. She is the third woman in NOAA's history to be appointed to this role.

Dr. Kapnick brings 18 years of experience at the intersection of climate science and economics, most recently as managing director at J.P. Morgan in the role of senior climate scientist and sustainability strategist for asset and wealth management. Before joining J.P. Morgan in 2021, Kapnick was a deputy division leader for seasonal to decadal variability and predictability at GFDL. From 2011-2021, her work at GFDL included research on seasonal climate prediction, mountain snowpack, extreme storms, water security and climate impacts, including landslides and the market impacts of climate change.

Kapnick is a member of the American Geophysical Union, American Meteorological Society and American Association for the Advancement of Science. She received a Ph.D. in Atmospheric and Oceanic Sciences with a Certificate in Leaders in Sustainability from the University of California, Los Angeles, and an A.B. in Mathematics with a Certificate in Finance from Princeton University.

GFDL Scientists' Service for Professional Societies and External Organizations

Alistair Adcroft
- CLIVAR Ocean Model Development Panel

Mitch Bushuk
- American Meteorological Society Committee on Polar Meteorology and Oceanography

Tom Delworth
- Science Advisory Board, IBS Center for Climate Physics, Busan, Korea

Leo Donner
- American Meteorological Society Fellows Committee
- Department of Energy Biological and Environmental Research Advisory Committee
- Earth and Biological Sciences Directorate Advisory Committee at Pacific Northwest National Laboratory

John Dunne
- External Advisory Committee, Global Ocean Biogeochemistry Array

Kirsten Findell
- Co-chair, Global Water and Energy Exchanges project's Global Land/Atmosphere System Study Panel
- Co-chair, WCRP Lighthouse Activity on Explaining and Predicting Earth System Change

Stephen Griffies
- Chair, Awards Committee, EGU Fridtjof Nansen Medal for Oceanographic Excellence

Larry Horowitz
- NCAR ACOM Advisory Panel for Model Development
- NCAR System for the Integrated Modeling of the Atmosphere Advisory Board

Nadir Jeevanjee
- Topical Group on the Physics of Climate of the American Physical Society

Sonya Legg
- Co-Chair, CLIVAR Scientific Steering Group

Pu Lin
- American Meteorological Society, Committee on Middle Atmosphere

Feiyu Lu
- Working Group 1, WCRP Explaining and Predicting Earth System Change Lighthouse Activity

Vaishali Naik
- AerChemMIP Scientific Steering Group
- NCAR/CESM Advisory Board

Fabien Paulot
- WMO Measurement-Model Fusion for Global Total Atmospheric Deposition Task Force
- CICERO initiative to quantify the indirect climate impact of atmospheric H2

David Paynter
- American Meteorological Society, Committee on Atmospheric Radiation

Elena Shevliakova
- Interagency Council on Advancing Meteorological Services Committee on Research and Innovation
- Social Cost of Greenhouse Gases Interagency Working Group, Climate Science Technical Group

(Part 2 of the GFDL Scientists' Service list to appear in the Fall 2022 Issue.)