WRITTEN STATEMENT OF
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ON THE
DEPARTMENT OF ENERGY'S ROLE IN THE FEDERAL RESEARCH ENTERPRISE

BEFORE THE
HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

1. INTRODUCTION

Chairman Lucas, Ranking Member Lofgren, and Members of the Committee, thank you for the opportunity to testify today regarding NOAA's work with the Department of Energy (DOE) on high performance computing (HPC) and Earth system modeling. My name is Dr. Michael Morgan and I am the Assistant Secretary of Commerce for Environmental Observation and Prediction. I appreciate the committee's interest in exploring successful interagency research collaborations with the Department of Energy (DOE).

NOAA is mandated to provide environmental intelligence on weather, water, and climate through data, forecasts, warnings, and impact-based decision support services for the protection of life and property and enhancement of the national economy. Communities around the country are struggling with the effects of high-impact and extreme events like hurricanes, heat waves, floods, droughts, wildfires, and fisheries collapse. The U.S. has sustained 341 weather and climate disasters from 1980 to 2022, where overall damages for each disaster reached or exceeded costs of $1 billion (including Consumer Price Index adjustment to 2022). The cumulative cost of these 341 events exceeds $2.475 trillion.[1] Due to increasing vulnerabilities and increasing demand for NOAA's environmental intelligence, there is a need for further improvements in weather and climate information and predictions.

In FY 2023, NOAA is leveraging significant investments from the Inflation Reduction Act of 2022 (P.L. 117-169) to accelerate advances and improvements in modeling and forecasting related to weather, coasts, oceans, and climate, as well as the procurement of additional HPC, data processing capacity, data management, and storage assets. Developing and delivering the next generation modeling systems for weather and climate prediction will be supported by crucial investments to maintain and expand high performance computing for research and development.

[1] NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2023). https://www.ncei.noaa.gov/access/billions/, DOI: 10.25921/stkw-7w73

2. NOAA'S APPROACH TO EARTH SYSTEM MODELING AND HIGH PERFORMANCE COMPUTING

For the past several years, NOAA has been developing and improving comprehensive climate and Earth system models (ESMs) to advance our understanding of how the Earth's biogeochemical, physical, and dynamical cycles, including human actions, interact with the climate system. The Earth system approach [2,3,4,5] includes multifaceted connections between different components of the Earth system such as the atmosphere, oceans, land and sea ice, and hydrology across short and long time scales. ESMs also incorporate interactive biogeochemistry, including the carbon cycle. Building the ESMs has been a large collaborative effort involving scientists from multiple NOAA laboratories, academic and private sector partners, and other federal agencies to study climate and ecosystem interactions and their potential changes, from both natural and anthropogenic causes. Substantial improvements in Earth system modeling will require the incorporation of these processes and interactions that are not already present in current models.

Complex environmental prediction models provide foundational tools for providing accurate and reliable guidance on various spatial and temporal scales to meet NOAA's core mission requirements. Adequate HPC capabilities are central to developing state-of-the-art and next generation numerical models to conduct research, validate, and transition to operations. In order for NOAA to meet current and future requirements for computing capability and services, there must be continual enhancement and investment in NOAA's core enterprise, including post-processing, product generation, real-time dissemination, and data storage. Optimization, modernization, and exploitation of emerging HPC technologies, as well as prioritization of available computing resources, are critical for the development of the next generation of models as well as highly reliable operational models.

NOAA's HPC strategy embraces the need to adopt the latest HPC technologies and plan for emerging uses of HPC. NOAA maintains strong relationships with interagency partners, including DOE and NSF, and participates in coordination activities with the National Science and Technology Council. Coordination occurs across initiatives, such as the Future Advanced Computing Ecosystem, Networking and Information Technology Research and Development,

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[2] Shapiro et al. (2010): An Earth-system prediction initiative for the twenty-first century, Bulletin of the American Meteorological Society, 91, 1377-1388.

[3] IPCC, 2021: *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, In press, doi:10.1017/9781009157896.

[4] NOAA Science Advisory Board, 2021: A Report on Priorities for Weather Research. NOAA Science Advisory Board Report, 119 pp. https://sab.noaa.gov/wp-content/uploads/2021/12/PWR-Report_Final_12-9-21.pdf

[5] NOAA Science Advisory Board, 2021: Advancing Earth System Prediction. NOAA Science Advisory White Paper, 22 pp. https://sab.noaa.gov/wp-content/uploads/2021/08/SAB_Report_Advancing-ESP_02April2021_Final.pdf

and Interagency Council on Advancing Meteorological Services, which are essential to advancing Earth system modeling as a whole by ensuring that NOAA's requirements are represented within national computing strategies.

NOAA's HPC approach provides opportunities for innovation using cutting-edge technology that leverages other computing resources such as DOE's Innovative and Novel Computational Impact on Theory and Experiment program and the National Science Foundation's Advanced Cyberinfrastructure Coordination Ecosystem Services and Support Program. NOAA's HPC environment enables NOAA scientists to apply and obtain grant hours on DOE and National Science Foundation systems by providing appropriate connectivity and support for use of these systems. These opportunities enable NOAA to gain competence and experience in the novel architectures provided by DOE and fosters interagency collaboration while allowing NOAA's traditional computing assets to carry out NOAA's research and operational mission.

3. RESEARCH AND DEVELOPMENT WITH GAEA SUPERCOMPUTER

NOAA already benefits from DOE's supercomputing resources by leveraging the Oak Ridge National Laboratory's expertise. NOAA's Office for Oceanic and Atmospheric Research has an Interagency Agreement with DOE for HPC Collaborative Services for Climate Modeling through 2025. The Oak Ridge National Laboratory has been procuring, hosting, and operating Gaea, NOAA's largest research and development HPC, under this agreement since 2009. This agreement focuses on sustained access to NOAA-funded computing in collaboration with DOE's leading computing facilities and computational science expertise enabling NOAA to undertake Earth system modeling research and development efforts that span multiple years to complete.

The Gaea HPC system supports research and development activities across NOAA's mission areas. Gaea is capable of more than 10,223 trillion calculations each second, or 10.2 petaFLOPS, making it the largest of the four NOAA research and development systems. This computing capacity allows NOAA researchers to develop and refine advanced climate models, enhances scientific understanding of climate variability and change, and improves the accuracy of global and regional climate model projections at a finer resolution and on a timeframe that is more useful for decision makers and sectors such as agriculture, energy, and transportation. For example, Gaea powers research into the relationship between climate change and extreme weather, such as flooding.

Gaea has been instrumental in the application of NOAA's Flexible Modeling System, a key software framework, for the development of world-class global models and scientific interpretation of the climate and earth system across timescales. Included in this are high fidelity models representing Earth and climate system variability and change. Seasonal real-time experimental predictions from the Flexible Modeling System-based Seamless System for Prediction and EArth System Research (SPEAR) are performed every month on the Gaea

computer, and fed into the North American MultiModel Ensemble climate predictions that are freely available to private and public U.S.-based and international entities to make regional or tailored forecasts. SPEAR is also a next generation model for making multi seasonal to multi decadal predictions and projections under climate change. SPEAR predictions for El Niño-Southern Oscillation, as well as decadal predictions for the World Meteorological Organization, are additionally performed on Gaea. Decadal forecasts produced by SPEAR will be made available as part of an international decadal prediction program through the United Kingdom Met Office.

Gaea also supports the development of operational numerical weather prediction systems based on the Unified Forecast System, a community-based, coupled, comprehensive Earth modeling system. The United Forecast System numerical applications span local to global domains and predictive time scales from sub-hourly analyses to seasonal predictions. It is designed to support the Weather Enterprise and to be the source system for NOAA‘s operational numerical weather prediction applications.

Additionally, the Earth System Model 4 (ESM4) was developed and run primarily on the Gaea HPC system. This model marks the culmination of NOAA’s 4th generation climate model development effort that unifies advances across several past development efforts and highlights chemistry, carbon, and ecosystem comprehensiveness. These efforts were merged into NOAA’s first coupled carbon-chemistry-climate model with state-of-the-art representation of each, along with comprehensive interactions between components. Over 50 simulations from ESM4.1 have been made publicly available. Analyses of these simulations will serve as the basis for research in years to come, helping to improve our understanding of coupled carbon-chemistry-climate interactions, and reducing uncertainty in projections of future climate change and its impacts and feedbacks. ESM4.1 is also a key contributor to the 6th Coupled Model Intercomparison Project, which aims through a multi model context to better understand past, present and future climate changes arising from natural, unforced variability or in response to changes in radiative forcing.

4. FUTURE OF NOAA-DOE PARTNERSHIP

NOAA’s Interagency Agreement with DOE’s Oak Ridge National Laboratory for HPC Collaborative Services for Climate Modeling has proven to be beneficial. NOAA’s access to DOE’s cutting edge leadership-class HPC has been ad-hoc largely through the Innovative and Novel Computational Impact on Theory and Experiment program grant process. NOAA would benefit from partnerships that more consistently leverage DOE’s leadership in computing platforms and expertise in computational sciences to explore and develop new HPC infrastructure for NOAA. Running NOAA models on DOE’s different computing platforms and technologies could allow for innovation and advancement of new HPC technologies and cutting-edge NOAA models that maximize performance on large-scale HPC systems. These include

simulations with large ensembles, more realistic representation of Earth system processes and interactions, and high-spatial-resolution (horizontal and vertical) predictions of extremes and abrupt changes at the county and finer spatial scales. Increasing resolution allows capture of smaller-scale processes and features, which can lead to better representation of severe weather, which could lead to more timely warnings, predictions of extremes and their duration, and climate projections. Furthermore, the application of artificial intelligence and machine learning methodologies to Earth system modeling is a high value area for a future NOAA-DOE HPC partnership. The potential for discovery is large, and NOAA would benefit from DOE's expertise.

In addition, using DOE's computing resources and expertise could lead to improvements in data assimilation by using NOAA's growing collection of high-quality environmental data while also improving model performance (both speed and accuracy), harnessing complex interactions within the models that are often computationally expensive, and leveraging machine learning concepts that could reduce the cost to run high-resolution global models for both research and operations. Collaboration between NOAA and DOE will not only reduce duplication of efforts, but also allow a cost-effective approach to generating additional computational capability for both agencies, resulting in sound decision-making on issues of national importance, such as future energy use and technology options.

5. CONCLUSION

For over two decades, NOAA scientists have defined the leading edge of climate and Earth system modeling. NOAA is the authoritative source of advanced development of Earth system modeling for the purposes of atmospheric, oceanic, and biogeochemical modeling for understanding, and predictions seamlessly across timescales, from short-term weather to decadal and centennial climate simulations.[6] NOAA's partnership with DOE has enabled our scientists to access larger computing capacities using leadership-class technology and services, aiding in the advancement of Earth system modeling. Further collaboration could result in numerous additional benefits such as improved HPC infrastructure, data assimilation, and model performance. Interagency agreements, like those with DOE, and other partnerships with academia and industry provide critical opportunities for NOAA to advance Earth system modeling in order to save lives and property and support the national economy. Strengthening the exchange of information and scientific capabilities with partners will enable NOAA to continue to meet our core mission of understanding and predicting changes in climate, weather, ocean and coasts to protect lives and property.

[6] NOAA Administrative Order (NAO) 216-115B: Research and Development in NOAA, effective June 2022. https://www.noaa.gov/organization/administration/nao-216-115b-research-and-development-in-noaa