State of the Art Climate Modeling Research at NERSC

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inside SC09 The National Energy Research Scientific Computing Center (NERSC) is the scientific computing facility for the Office of Science in the U.S. Department of Energy. As one of the largest facilities in the world devoted to providing computational resources and expertise for basic research, NERSC is a world leader in accelerating scientific discovery through computation. NERSC is located at Lawrence Berkeley National Laboratory in Berkeley, California and currently provides supercomputing resources to more than 3,000 users at universities and national labs. Access to NERSC systems is awarded based on scientific need and computational requirements of a particular problem.

NERSC has long been meeting the complex demands of the climate modeling community, hosting a variety of projects involving researchers from DOE laboratories, universities, and other climate modeling laboratories such as the National Center for Atmospheric Research (NCAR), Scripps Institution of Oceanography, and the Geophysical Fluid Dynamics Laboratory. These projects have spanned a wide range of activities that include medium- and high-resolution production global climate simulations, ocean modeling, validation of climate models, comparisons of various climate and weather models, creation and testing of climate codes, and reconstruction of 3-D weather data for the last 150 years from sparse 2-D observational data.

NERSC Director Kathy Yelick is particularly proud of the services that NERSC has offered climate modeling researchers and of the importance of the work to the public at large.

Yelick states, "Simulations are essential to understanding global climate change and supercomputers are vital because of the complexity of the computations. The 2007 Nobel Peace prize that was awarded to the Intergovernmental Panel on Climate Change (IPCC) is recognition of the importance of this work." Many of the simulations for the IPCC Fourth Assessment Report were carried out at NERSC and researchers are planning runs at NERSC in support of the upcoming Fifth Assessment Report.

Some key highlights of climate research carried out at NERSC include the following.

- The 20th Century Reanalysis project has reconstructed weather data from the last 150 years and then run climate simulations to recreate – and explain – climate anomalies of the past. Such understanding is key to validating global climate models that will predict future behavior. In recently published work, the project, led by Gil Compo at University of Colorado, has successfully reproduced the deadly 1922 "Knickerbocker" storm and provided a comprehensive description of the 1918 El Niño event.
- Simulations at NERSC have allowed researchers at Scripps to perform over 15,000 years worth of deep ocean circulation. Led by Professor Paola Cessi, these studies are amongst the only ones working toward a parameterization of the oceanic dynamics that contribute to systematic observed warm biases of the sea surface temperature along the ocean's eastern boundaries. Insight from this work has already given researchers a better understanding of ocean circulation dynamics—how transport of heat by oceanic eddies is essential in the oceanic heat budget and how changes in the atmosphere affect these processes.
- A project led by Professor David Randall at Colorado State University has completed development of a global cloud-resolving model, one that is intended to resolve important moisture and radiation processes that are currently parameterized. The design of the model—one of only a handful in the world—is very unique, in that it uses a system of equations that filters vertically propagating sound waves, a new geodesic grid structure, and the vorticity equation rather than the momentum equation.
- Wind turbines are expected to provide a significant portion of U.S. power needs in the future. Studies at NERSC by NCAR researchers Ned Patton and Peter Sullivan are exploring how topography and vegetation in the area near turbines creates turbulence that could affect turbine efficiency. Proper characterization of this turbulence is essential for wind turbine design and deployment strategy and it requires many long-running calculations on NERSC's Cray XT4 with the NCAR Large Eddy Simulation code.

Much of the climate modeling research at NERSC is run on a Cray XT4 supercomputer named Franklin in honor of Benjamin Franklin. The Cray system has a peak rate of over 350 Teraflops and 9,572 nodes with each node having four processing cores resulting in 38,288 processing cores.

"Climate modeling is essential to advancing our understanding of climate change and supercomputers are essential because of the complexity of developing accurate and detailed global climate simulations," Yelick says. "Without this capability, we have patterns of changes to the climate but can't make scientifically valid predictions."

Although NERSC supercomputers help advance research across a wide range of scientific disciplines, climate modeling research is one of the most important areas. "Understanding and addressing climate issues is one of the most challenging and important scientific problems of our time and it literally affects each and every one of us," Yelick said.

Linda Barney owns Barney and Associates, a technical and marketing writing firm in Beaverton, Oregon that provides writing and web content for the high tech, government, medical and scientific communities. They specialize in presenting deeply technical information so that it is interesting and easy to understand. Readers can reach her at linda@barneyassoc.com.

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