2002

DOE Climate Change Prediction Program

Washington, W.; Gent, P.; Hack, J.; Kiehl, J.; Meehl, G.; Rasch, P.; Semtner, B.; Weatherly, J.

Science-of-Scale Projects

To promote the productivity of cutting-edge science, NERSC adapts its systems to provide the resources needed by data-intensive applications and provides "Red Carpet" support to large-scale strategic projects so that they can make rapid progress. These projects typically need support such as very large computing allocations, very large scratch disk, terabytes of usable memory and support for 64-bit computing, large-scale visualization, consulting support to make effective use of these resources, good bandwidth between the resources, and large archival storage.

The projects described below show how the unique resources of the IBM SP combined with excellent consulting support have produced scientific breakthroughs. They also demonstrate the size of the resources needed for rapidly growing, data-intensive projects. Three of these projects could have used all of NERSC's resources in FY 2002.

DOE Climate Change Prediction Program

Scientists in the DOE Climate Change Prediction Program recently completed a 1,000-year run of a powerful new climate system model on a supercomputer at NERSC. The millennium-long simulation of the new Community Climate System Model (CCSM2) ran for more than 200 uninterrupted days on the IBM SP supercomputer at NERSC. The lengthy run served as a kind of "shakedown cruise" for the new version of the climate model and demonstrated that its variability is stable, even when run for century-after-century simulations. The 1,000-year CCSM2 run had a total drift of just one-half of one degree Celsius, compared to older versions with two to three times as much variance.

A 1,000-year simulation demonstrates the ability of CCSM2 to produce a long-term, stable representation of the earth's climate (Figure 1). Few if any climate models in the world can make this claim, since all previous simulations contained drifts too large to allow complete, uncorrected simulations to 1,000 years. In addition, the simulation provides scientists with a database to analyze the variability of weather and climate on time scales ranging from interannual to interdecadal to inter-centennial. Few datasets exist which are as comprehensive as the one produced during this simulation.

CCSM2 tightly couples four complex models, including atmosphere and land modeling codes developed at the National Center for Atmospheric Research (NCAR) and ocean and sea ice models developed at Los Alamos National Laboratory. Computationally, the full CCSM2 code consists of five binaries which are organized to execute concurrently within a single job. The models exchange data at various frequencies appropriate to the physical, large-scale processes being simulated. CCSM2

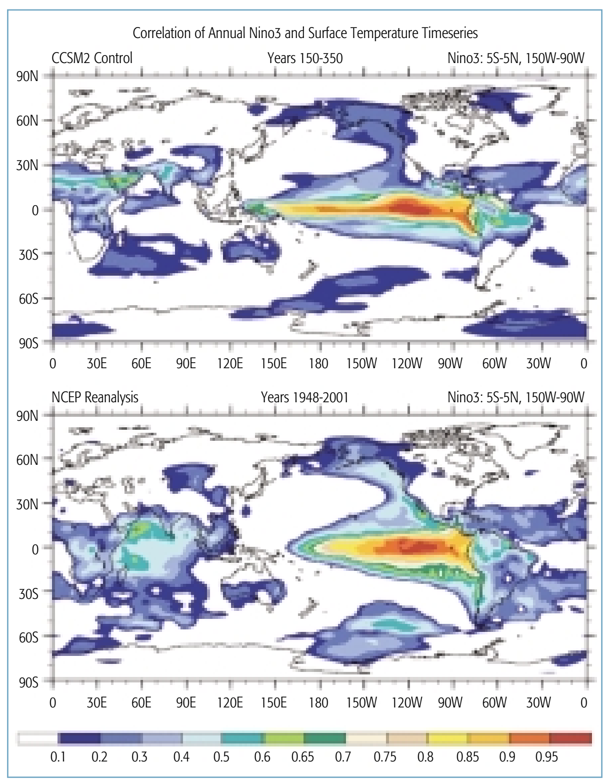

FIGURE 1 Two hundred years of modeling El Niño events and surface temperatures on the Community Climate System Model (CCSM2) closely correlate with 50 years of actual climate data.

requires 4.5 wall-clock hours on 144 1.5-Gflops CPUs of the NERSC IBM SP to complete one simulated year. NERSC gave CCSM2 special queue priority to complete this project in a timely fashion. Preliminary results of 800 model years were presented to 250 participants at the Seventh Annual CCSM Workshop held in Breckenridge, Colorado, on June 25–27, 2002.

INVESTIGATORS W. Washington, P. Gent, J. Hack, J. Kiehl, G. Meehl, and P. Rasch, National Center for Atmospheric Research; B. Semtner, Naval Postgraduate School; J. Weatherly, U.S. Army Cold Regions Research and Engineering Lab Laboratory.

PUBLICATION J. T. Kiehl and P. Gent, "The Control Climate Simulation from the Community Climate System Model (CCSM2)" (in preparation).

URL http://www.ccsm.ucar.edu/index.html

High-Resolution Global Coupled Ocean/Sea Ice Modeling

The objective of this project is to couple a high-resolution ocean general circulation model with a high-resolution dynamic-thermodynamic sea ice model in a global context. Currently, such simulations are typically performed with a horizontal grid resolution of about 1 degree. At this resolution (about 30 to 50 km in the polar regions), the ocean model cannot resolve very narrow current systems (including fronts and turbulent eddies) that play a crucial role in the transport of heat and salt in the global ocean. Similarly, lower-resolution sea ice models cannot resolve important dynamics that occur in regions of complicated topography (such as the Canadian Archipelago).

This project is running a global ocean circulation model with horizontal resolution of approximately 1/10th degree—between 11 km and 2.5 km (Figure 2). This is the highest-resolution simulation even attempted with a such a realistic model. This configuration has dimensions of $3600 \times 2400 \times 40$, resulting in 177 million active ocean grid points (some grid points are on land). The code being used is the Parallel Ocean Program (POP), developed at LANL under the Department of Energy's CHAMMP program. At NERSC, 448 processors are used to run the model. One year can be simulated in about eight wall-clock days (86,000 processor hours), generating over 500 GB of output. Eight model years have been run to date, with a goal of 30–50 years. After the ocean simulation has run for 10–15 model years, it will be coupled with a sea ice model to more accurately simulate the polar circulation.

The interaction of the ocean and overlying sea ice in global coupled numerical models is poorly understood, though very important. When ocean water freezes into sea ice, salt is released into the upper ocean, making it more dense. Conversely, when the ice melts, it creates a layer of fresh water that is less dense than the underlying ocean. This delicate balance between melting and freezing is very difficult to simulate with coarse grids. In particular, high vertical resolution is needed near the surface to simulate this salinity balance correctly. High horizontal resolution is required to properly simulate the current systems that advect these salinity anomalies into the open ocean. Inaccuracies in the surface ocean properties due to poor representation of ocean-ice interaction can have wide-ranging global consequences. Most notable is the possibility that too much fresh surface water can inhibit vertical convection in the northern seas (since it is less dense than the salty water beneath it), which then disrupts the entire global heat budget. Coarse-resolution simulations have found that the circulation and heat budget are extremely sensitive to the way sea ice is prescribed in ocean-only runs. The best tool for simulating the global circulation accurately is a high-resolution, fully coupled ocean-sea ice model.

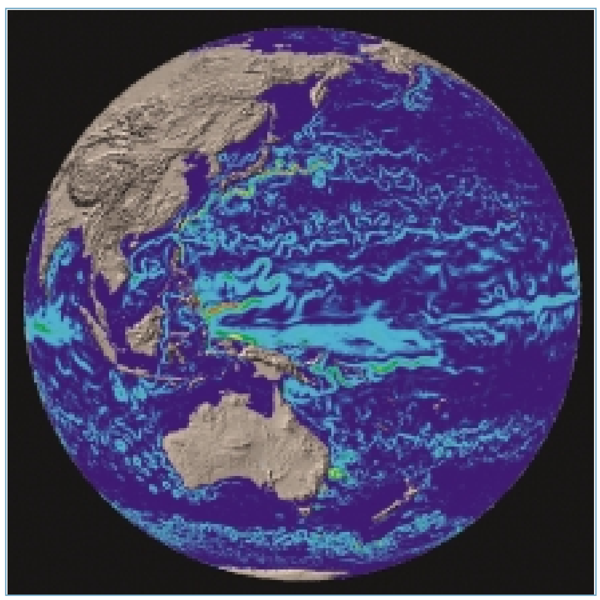

FIGURE 2 High-resolution (1/10 degree) POP ocean model currents at 50m depth. Blue = 0; red > 150 cm/s.