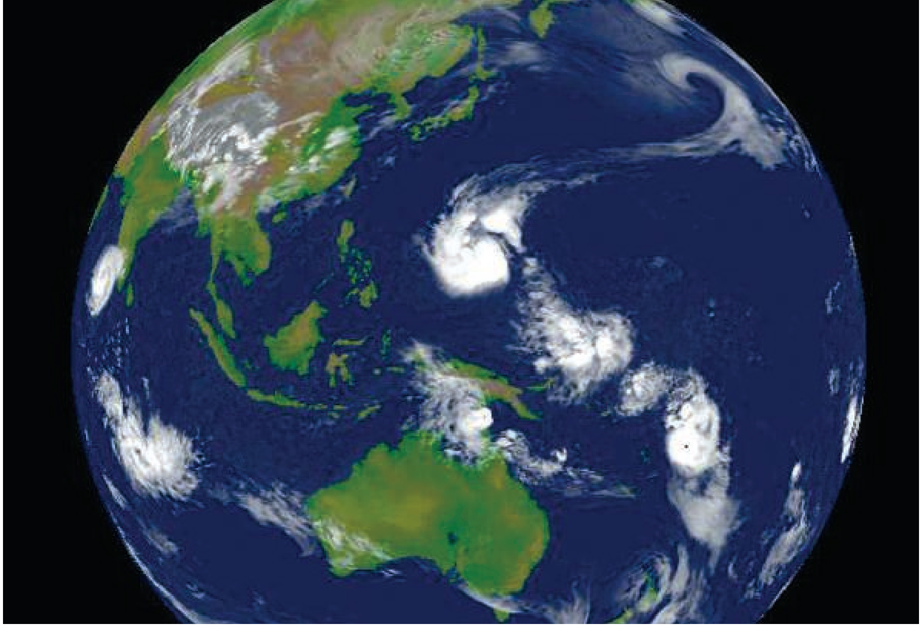

Sharper still. Typhoon Suda (*center*) looks almost real in this 3.5-kilometer simulation.

METEOROLOGY

Sharpening Up Models for a Better View of the Atmosphere

The exponential rise of computing power and the 2002 arrival of the great Earth Simulator computer have driven atmospheric models to extremes

Machines simulating Earth's atmosphere are producing ever-more-detailed pictures of weather and climate, thanks to ever-increasing computer power. And that new detail is now beginning to let researchers shed some of the approximations and downright fabrications they once needed to get anything useful out of their models. The new view of the atmosphere "looks very, very different" from that of less detailed model simulations, says modeler Jerry D. Mahlman of the National Center for Atmospheric Research in Boulder, Colorado. "It's a very important thing to do."

Supercomputers now run at once-undreamed-of speeds—many tens of teraflops (tens of trillions of floating point operations per second). In weather forecasting models, part of this exponentially improving computing power has always gone into increasing model resolution. Modelers do that by moving the isolated points at which atmospheric properties are calculated—the model's grid points—closer together. It's like a pointillist painter going from big splotches of color to smaller and smaller dabs that show greater and greater detail. Global weather-forecasting models are down to grid-point spacing of a few tens of kilometers in the horizontal. Climate modelers, in contrast, have favored a spacing of about 200 kilometers, says modeler Kevin Hamilton of the University of Hawaii, Manoa. That gave them simulations that bore some resemblance to real weather maps but that run for not just a week but centuries.

Then, in 2002, Japanese researchers turned on the 40-teraflops Earth Simulator. "The Japanese had two advantages," says Hamilton. "They were willing to invest an enormous amount of money, on the order of a billion [U.S.] dollars." And they had some very clever engineers figuring out how to build a unique, hybrid supercomputer that efficiently combines the conventional approach of simultaneously running large numbers of cheap processors with processors specially designed to accelerate atmospheric model calculations.

Spurred by the Earth Simulator, climate and meteorology researchers in Japan and around the world are pushing the resolution of their global models to new extremes. In a *Geophysical Research Letters* paper published 14 July, modeler Bo-Wen Shen of NASA's Goddard Space Flight Center in Greenbelt, Maryland, and colleagues report how they simulated 5 days in the life of Hurricane Katrina on NASA's newer, 61-teraflops Columbia supercomputer at the Ames Research Center in Mountain View, California. Global models have generally failed to produce intense tropical storms, but when the resolution was dropped from 20 kilometers to 10 kilometers, the simulated Katrina intensified to about the same extremely low central pressure as the real Katrina. It had winds nearly as strong spiraling around a suitably compact eye.

Shen and his colleagues then turned off the model's convective parameterization, the part of the model that tells it how, where, and when buoyant air will rise in puffy clouds and thunderheads. Even without that guidance, the simulated storm bore the same strong resemblance to the real thing. Apparently, the higher-resolution model was producing realistic convection—which powers tropical cyclones—all by itself from the smaller details of hurricane workings, without being told what to do.

In another high-resolution tropical cyclone study, reported last April, modeler Kazuyoshi Oouchi of the Earth Simulator Center in Yokohama, Japan, and colleagues simulated 10 years of global tropical cyclone activity both under present conditions and under warmer, greenhouse conditions. On the Earth Simulator, they ran a 20-kilometer-resolution model. Under present conditions, the model produced a reasonable rendition of the number, strength, and geographic distribution of storms. Under greenhouse warmth, the number of tropical cyclones around the world actually decreased 30%, but the number of more intense storms increased substantially. That supports upward trends in storm intensity recently reported from analyses of observations (*Science*, 5 May, p. 676).

Global simulations have driven resolution to even smaller scales. Modeler Hiroaki Miura and colleagues at the Frontier Research Center for Global Change in Yokohama, Japan, have been running a model called NICAM—Nonhydrostatic Icosahedral Atmosphere Model—on the Earth Simulator at resolutions of 7 and 3.5 kilometers. That is nearly fine enough to resolve individual clouds. When run without convective parameterization, the 7-kilometer-resolution version of NICAM showed signs of being less sensitive than a lower-resolution model to rising greenhouse gases.

The new high-resolution work is producing intriguing hypotheses, says Mahlman. But he and others still have reservations. "Is new science being produced or just really cool pictures?" he asks. With computing resources growing exponentially and staffing not, he says, computer power might overwhelm the available brainpower. All the more reason to remember that a model—no matter how super—is only a model.

–RICHARD A. KERR

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