

Turbulent Times for Climate Model

Researchers are running out of time to finish updating an important U.S. climate change model that has been hamstrung by the budget woes of its home institution, the National Center for Atmospheric Research

Every June, U.S. climate scientists descend upon Breckenridge, Colorado, to kick the tires on the nation's foremost academic global climate model. Some years there is added pressure, as scientists try to tune up the Community Climate System Model (CCSM) for simulations that will feed into the next report of the Intergovernmental Panel on Climate Change (IPCC). This is one of those years, and scientists are more worried than usual.

The question is whether they can meet a 1 October deadline for completing a critical part of their increasingly complex simulation of the interplay of Earth's atmosphere, oceans, land, and ice. "We're all very nervous," says atmospheric modeler Philip Rasch, who works remotely for the National Center for Atmospheric Research (NCAR) in nearby Boulder and who oversees the atmospheric component of the model. A big reason for the concern is the condition of the

center, which hosts and manages CCSM.

In 2004, NCAR's then-director, Timothy Killeen, had launched a major restructuring that included expanding the lab, banking on a 2002 congressional promise of a 5-year doubling of the budget of its main funder, the National Science Foundation (NSF). But Congress failed to keep its promise, and NSF's contribution to NCAR, instead of rising by double-digit percentages, has grown by only 2.6% annually in the past 5 years. The resulting belt-tightening has meant pink slips for 55 employees since 2003 (out of a workforce that has averaged 800 since then) and not replacing 77 others who retired or left.

Those losses have affected CCSM. In the past 2 years, seven accomplished climate scientists among 50 researchers

heavily involved in CCSM have left or announced plans to leave NCAR, including Rasch, a 27-year veteran who begins a new job this fall at Pacific Northwest National Laboratory in Richland, Washington. None has been replaced, although six scientists with less experience have been brought on since 2006 to bolster the effort.

Some climate scientists say that CCSM should have been better protected from the budget turmoil. "This hub of the nation's climate strategy has apparently not received the priority it deserves and needs," wrote members of the model's independent scientific advisory board on 8 July in an unsolicited letter to Eric Barron, who last month succeeded Killeen. Although computers are critical for climate simulation, they say, in the end it's NCAR's staff who must incorporate thousands of complex elements into a code that simulates everything from hurricanes to droughts to ocean currents.

Any erosion of CCSM's projected capabilities threatens what modeler David Randall of Colorado State University in Fort Collins calls "the closest thing we have to a national model." What sets CCSM apart from rival U.S. models at NASA and the National Oceanic and Atmospheric Administration is its widespread use by academic researchers, who also build it in partnership with NCAR. So whereas the other models rely on the expertise of teams of federal experts, CCSM's health reflects the state of overall U.S. climate research.

Although IPCC won't issue its next report until 2013, it has asked for data in 2011 from

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A towering challenge.
The majestic peaks outside NCAR's windows contrast with pancake-high budget increases for the center from NSF.

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roughly two dozen models scattered around the world. Working backward, CCSM scientists gave themselves the October deadline to finalize the atmosphere, the central element of the million-line code, as well as the other segments. NCAR's deadline for connecting the pieces is 1 January 2009.

The changes will fix some flaws in the previous version of CCSM and add new features. In particular, scientists want to make tropical temperature patterns more realistic, depict ice sheets, clouds, and cycles such as El Niño more accurately, and better simulate the turbulent movement of air between the ground and an altitude of 1 km. IPCC scientists would also like models to incorporate an active carbon cycle that simulates how Earth's biological life—say, algae or swamps—shapes the biosphere.

Will NCAR come through? "CCSM is in danger of not being able to make scientifically credible contributions to [IPCC] and the climate science community," the board wrote in its July letter. Barron disagrees, saying CCSM will remain one of the world's top models. But he acknowledges that fewer bodies will mean "not being able to do as much."

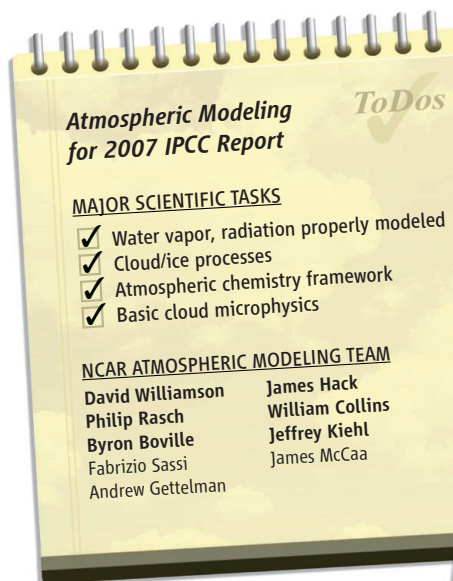
Gambling on growth

Nestled at the foot of the Rocky Mountains in Boulder, NCAR was established in 1960 with NSF funding to advance climate and weather science. Its researchers have developed some of the world's best tools for predicting storms, droughts, and rising global temperatures, built on work by meteorologists, physicists, and modelers alike. In addition, NCAR provides planes, balloons, and computers to academic scientists across the country and around the world. NSF still supplies about three-fifths of its budget, \$88 million of a total \$149 million, including money for operations, buildings and equipment, and major facilities. The rest comes from competitive grants awarded by other government agencies and industry.

The precursor to CCSM was developed in 1983 at NCAR, and the model remains a unique partnership between academic and government scientists. Its paleoclimate runs and future projections have been the basis for hundreds of studies referenced by IPCC. The model is run out of the Earth and Sun Systems Laboratory (ESSL), the largest of five so-called laboratories at NCAR.

Along with an equally renowned short-term weather model, CCSM helped establish NCAR's reputation as the go-to resource for academic atmospheric research. But Killeen, who became director in 2000, wanted NCAR to do more, including increasingly detailed

forecasts of the impacts of climate change and interdisciplinary studies on weather. So in 2004, he regrouped existing divisions into ESSL and labs for Earth observations, computing, and airborne-weather projects. He created a fifth lab to respond to growing interest in the societal impacts of climate change. Within the labs, Killeen also set up institutes devoted to interdisciplinary work and to the



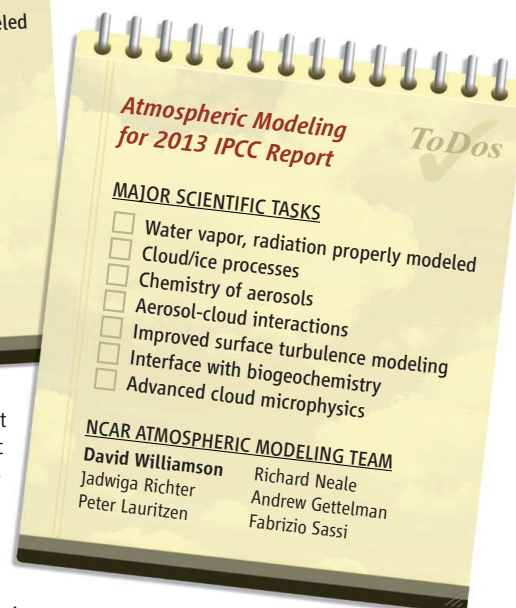
Doing more with less. The next IPCC report poses a bigger challenge for NCAR's atmospheric modelers, who have fewer senior scientists (names in bold) on hand.

application of modeling and mathematical methods in geoscience. "It was a bold new initiative," says Richard Anthes, president of the University Corporation for Atmospheric Research in Boulder, which operates NCAR for NSF.

Killeen hoped that NSF would finance the expansion as its overall budget grew. NSF's contribution to NCAR did rise by 19% between 2001 and 2004, but in the past 5 years it has increased by only 10%. That below-inflationary rise has triggered "chronic wasting disease" at NCAR, says Anthes. It also spawned fears among some scientists about the cost of the new bureaucracy. Managers estimate that the reorganization has added \$5 million in staffing and other administrative costs over 4 years. "Shouldn't we really be about putting the money instead into scientific programs?" NCAR veteran scientist Peter Gilman recalls asking an assembly at NCAR in 2004. But without a growing contribution from NSF, Killeen was forced to ask NCAR managers to tighten their belts, including dipping into research funds to meet other expenses.

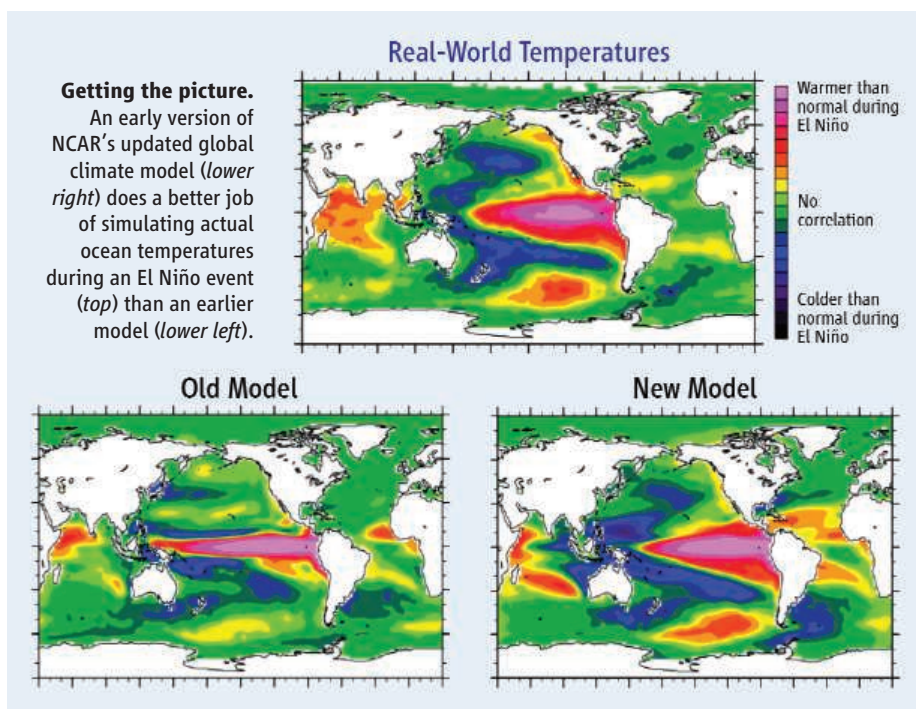
The modeling effort has also been affected by a program that Killeen began in 2001 that pays half the salaries of new hires for 2 years. ESSL used the optional funds to hire four young scientists in the climate division between 2001 and 2007, says William Large, who heads ESSL's climate division, and managers also hired five young scientists through the normal mechanism. But without a rising budget, the lab couldn't afford to replace senior modeling polymath Byron Boville, who died in 2006, or Jeffrey Kiehl, who moved from atmospheric to paleoclimate studies within ESSL. Kiehl called the hirings "a gamble" that ESSL lost.

Other parts of NCAR have also suffered



from the budget shortfall. A fledgling extrasolar planets program was shuttered in 2004, and a light-detection-and-ranging station that measures aerosols will be closed next year. Before he left in June, Killeen also dissolved the lab for societal impacts that he created. (Beyond a short interview conducted before he left NCAR, Killeen declined comment for this article, citing conflict-of-interest rules related to his new job as director of NSF's geosciences division, which funds NCAR.)

The pruning has continued under Barron. This month, he ended a program run by a senior political scientist that conducted public policy research on the impacts of climate change on developing countries. The decision prompted an outcry from social scientists. But Barron says that he had no choice and that cutting it, along with the societal-impacts lab, will save NCAR \$2 million annually. "We have not hurt CCSM nearly as much as other parts of NCAR," says deputy lab director C. Larrabee "Larry" Winter.



The main impact of the budget squeeze on climate modeling has been on the workload of scientists. Pressured to coordinate an increasingly complex model with fewer colleagues, Rasch says that he and others couldn't explore "the ideas they found fascinating." He says that's a big reason he left. James Hack decamped for the Department of Energy's Oak Ridge National Laboratory in Tennessee because, he says, "I had a better opportunity to build a program [there] than I did at NCAR." Joining the recent exodus of atmospheric modelers is William Collins, who went to Lawrence Berkeley National Laboratory in California. "Each in their own way found that something else was better," says Gilman. In addition, four scientists who worked on CCSM's land and chemistry components have left since last year and have not been replaced.

Modeler David Bader of Lawrence Livermore National Laboratory in California says a few million dollars spent over the past 5 years on personnel could "have made a big difference" in attracting and retaining seasoned talent. Last year, NCAR brass moved roughly \$1.5 million—culled from reshuffled NCAR funds and a small NSF boost—to support the research group that does climate modeling. But that just paid the salaries of software engineers moved into that group from within NCAR. The lab is trying to hire a senior and junior atmospheric modeler.

Despite the negligible growth of NSF's contribution, NCAR has spent roughly \$5 million since 2004 on equipment, includ-

ing a balloon system, a mobile radar facility, and outfitting a high-altitude research jet that was completed in 2006. "It simply doesn't make sense to have a \$100 million plane sitting in the hangar not doing science," says Anthes, explaining why the money wasn't spent on science and modeling efforts.

Down to the wire

Not all the news at Breckenridge was bad. Scientists there applauded, for example, a much-improved simulation of the seasonal global climate phenomenon known as El Niño–Southern Oscillation (above). The previous version depicted an unrealistic 2-year El Niño cycle; the new version offers a more realistic cycle of 3 to 6 years. Along with promising new land, ice dynamics, and depictions of the North Atlantic, CCSM's overhauled atmosphere includes new physics to describe the way clouds move heat and shift winds. "It'll be a much better model," Killeen says, thanks in part to the contributions from young researchers hired under his program.

But many of the proposed additions to the model have yet to be fully tested, making scientists uneasy. One important improvement that's behind schedule, says modeler Richard Rood of the University of Michigan, Ann Arbor, a CCSM advisory board member, is a better depiction of the turbulent movement of air from the ground to an altitude of 1 km. "I would personally worry about the fact that they're still doing major tuning [on that]," he says. Another important change would add biogeochemistry, including the complex rela-

tionship between the carbon and nitrogen cycles. Attempts to simulate dynamic nutrient cycles can lead to big crashes during testing, such as when forests in the model die unexpectedly. Progress has been slow, says Scott Doney of Woods Hole Oceanographic Institution in Massachusetts, a member of the model's biogeochemistry team, and the recent departure of two NCAR experts—Natalie Mahowald and Peter Thornton—hasn't helped. "We're going to be lucky to get a stable climate biogeochemistry system," he says.

Knitting together the model's many promising additions by January poses an even greater challenge. Researchers would like to simulate local clouds better. But when scientists inserted new parameters to do that into the full working atmosphere, polar clouds blocked too much sunlight and created excessive sea ice. The team expects to work the physics into the full atmosphere, says Rasch, but it's unclear whether the feature will work when coupled to the ocean.

The loss of seasoned modelers will be especially noticeable during the coming integration phase, says Rood. NCAR's young modelers are talented, he says, but lack valuable experience taming new parts of an unpredictable code. But NCAR atmospheric modeler Andrew Gettelman, who joined the CCSM team in 2003, says the departed veterans "are all there when we need them," reachable by e-mail or phone. And the 38-year-old modeler says the fact that he wrote some of the overhauled code will help him make the pieces fit.

Atmospheric scientists are cautiously optimistic that Barron, a paleoclimate modeler, recognizes the importance of CCSM. "There's no one else I would rather have at the helm," says atmospheric scientist Marvin Geller of Stony Brook University in New York, citing Barron's leadership of several national climate-related panels. Barron says his recent moves show that he's serious about protecting "core" activities such as CCSM, noting that he used an early version of the model for his 1980 Ph.D. thesis at the University of Miami.

Despite proposals by the White House and lawmakers to give NSF a double-digit increase in 2009, Anthes thinks that political gridlock could leave NCAR with another flat budget. So he demurs when asked if he sees light at the end of the tunnel. "I see hope," he muses. "It may be moonlight." For all his confidence about the next version of CCSM, Barron says continued flat budgets could devastate his lab's modeling efforts. "That's the real threat," he says.

—ELI KINTISCH

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