that abrupt shifts “have something to do with ice,” noting that all of the Northern Hemisphere’s glacial ice melted away shortly after the last abrupt climate event 8200 years ago. Ice might have done its work by producing fresh meltwater fast enough to put a lid on the North Atlantic. Or, as Wunsch suggests, the mountains of it sticking up into the prevailing winds at high latitudes could have skewed atmospheric circulation the way the Rockies do today. In either case, vast amounts of it seem to have been required.

**Unmoved models**

If the past is not a good analog for the future, computer models might serve as guides to global warming’s effect on the MOC. Lately, the most sophisticated and realistic model simulations of a warmer world have failed to drive the MOC anywhere near collapse. For example, climate modeler Peter Gent of the National Center for Atmospheric Research (NCAR) in Boulder, Colorado, told the workshop how the latest version of the NCAR climate model responded to greenhouse gas increases like those expected in the next century or two. Over a range of rates of greenhouse strengthening, the model’s MOC slowed by an average of 25% to 30%.

“That is not a collapse,” said Gent.

Modeler Jonathan Gregory of the University of Reading, U.K., and 17 colleagues got similar results in an international comparison of models. They ran 11 different models—six of the most sophisticated sort, including an earlier version of NCAR’s, and five “intermediate complexity” models—for 140 simulation years, quadrupling the concentration of greenhouse gases in the process. None led to a collapse of the MOC; instead, they slowed it gradually by 10% to 50%.

Not that model MOCs can’t collapse. “If you really hit the North Atlantic with fresh water,” says Gent, “you can make it collapse.” But the flow needs to be something like 10 times faster than current greenhouse simulations, says Gent. That’s also the only way to chill Europe in greenhouse models. None of the models in Gregory’s intercomparison showed a cooling anywhere; greenhouse warming always prevailed.

Not everyone is ready to consign the MOC collapse threat to the back burner, however. Climate modeler Michael Schlesinger of the University of Illinois, Urbana-Champaign, an organizer of the workshop, notes that model simulations are not entirely realistic. For one, they have yet to include meltwater from a warming Greenland. And, as geochemist Daniel Schrag of Harvard University has pointed out, models cannot yet simulate other climate extremes known from the geologic record, such as the extreme warming that occurred 55 million years ago.

By the end of the workshop, the threat of a MOC collapse seemed to have receded, at least relative to other climate threats. “The [scientific] community is way, way overfocused on the MOC,” said ice core geochemist Jeffrey Severinghaus of the Scripps Institution of Oceanography (SIO) in San Diego, California. Tropical oceanographer George Philander of Princeton University agreed: “The last 6 months, every computer center has been tied up pouring fresh water on the North Atlantic. That’s not good. How do we get off this bandwagon?”

A looming MOC collapse “has inspired a Hollywood movie and a lot of fear,” said statistical economist Richard Tol of Hamburg University in Germany. “It’s everyone’s favorite bogeyman, but they may be barking up the wrong tree.” Tol would direct more attention toward the prospect of rising sea levels, possibly sharply rising if the ice of West Antarctica accelerates its slipping into the sea (Science, 24 September 2004, p. 1897).

Others pointed to the possibility of sudden “regime shifts.” In these, the slowly strengthening greenhouse could abruptly snap climate patterns into new configurations. Such climatic switches have happened in the past, Severinghaus noted. The central United States seems to go through centuries-long intervals of longer and more frequent droughts separated by periods of less drought-prone climate. And there are signs that the recent western U.S. drought was intensified by the warming of tropical waters (Science, 31 January 2003, p. 636). Other climate regimes, such as the monsoons, might be susceptible to greenhouse-triggered shifts as well, noted physical oceanographer Lynne Talley of SIO. Abrupt surprises, it seems, may yet be found far beyond the North Atlantic.

—**RICHARD A. KERR**