Atlantic Climate Pacemaker for Millennia Past, Decades Hence?

An unsteady ocean conveyor delivering heat to the far North Atlantic has been abetting everything from rising temperatures to surging hurricanes, but look for a turnaround soon

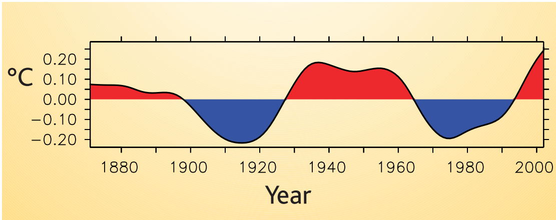
Benjamin Franklin knew about the warm Gulf Stream that flows north and east off the North American coast, ferrying more than a petawatt of heating power to the chilly far North Atlantic. But he could have had little inkling of the role that this ponderous ocean circulation has had in the climatic vicissitudes of the greater Atlantic region and even the globe.

With a longer view of climate history and long-running climate models, today's researchers are tying decades-long oscillations in the Gulf Stream and the rest of the ocean conveyor to long-recognized fluctuations in Atlantic sea-surface temperatures. These fluctuations, in turn, seem to have helped drive the recent revival of Atlantic hurricanes, the drying of the Sahel in the 1970s and '80s, and the global warming of the past few decades, among other climate trends.

The ocean conveyor "is an important source of climate variability," says meteorologist James Hurrell of the National Center for Atmospheric Research in Boulder, Colorado. "There's increasing evidence of the important role oceans have played in climate change." And there are growing signs that the conveyor may well begin to slow on its own within a decade or two, temporarily cooling the Atlantic and possibly reversing many recent climate effects. Greenhouse warming will prevail globally in both the short and long terms, but sorting out just what the coming decades of climate change will be like in your neighborhood could be a daunting challenge.

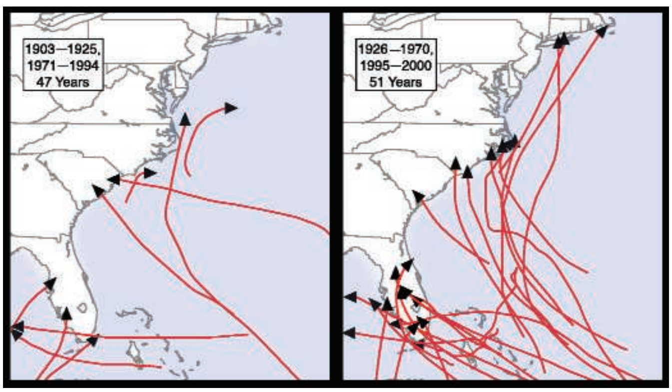
Researchers agree that the North Atlantic climate machine has been revving up and down lately (*Science*, 16 June 2000, p. 1984). From recorded temperatures and climate proxies such as tree rings, researchers could see that temperatures around the North Atlantic had risen and fallen in a roughly 60- to 80-year cycle over the past few centuries. This climate variability was dubbed the Atlantic Multidecadal Oscillation (AMO). Ocean observations suggested that a weakening of the ocean conveyor could have cooled the Atlantic region and even the entire Northern Hemisphere in the 1950s and '60s, and a subsequent strengthening could have helped warm it in the 1980s and '90s. But the records were too short to prove that the AMO is a permanent fixture of the climate system or that variations in the conveyor drive the AMO.

Taking the long view, climate modeler Jeff Knight of the Hadley Centre for Climate Prediction and Research in Exeter, U.K., and colleagues analyzed a 1400-year-long simulation on the Hadley Centre's HadCM3 model, one of the world's leading climate models. The simulations included no changes in climate drivers such as greenhouse gases that could force climate change. Any changes that appeared had to represent natural variations of the model's climate system.



Wobbly ocean. North Atlantic temperatures have wavered up and down at a roughly 60- to 80-year pace.

At April's meeting of the European Geosciences Union in Vienna, Austria, Knight and colleagues reported that the Hadley Centre model produces a rather realistic AMO with a period of 70 to 120 years. And the model AMO persists throughout the 1400-year run, they note, suggesting that the real-world AMO goes back much further than the past century of observations does. The model AMO also tends to be in step with oscillations in the strength of the model's conveyor flow, implying that real-world conveyor variability does indeed drive the AMO.



Bad warmth. The AMO's warm years favor more U.S. hurricanes (*right*).

Such strong similarities between a model and reality "suggest to me it's quite likely" that the actual Atlantic Ocean works much the same way as the model's does, says climate modeler Peter Stott of the Hadley Centre unit in Reading, who did not participate in the analysis. Hadley model simulations also support the AMO's involvement in prominent regional climate events, such as recurrent drought in North East Brazil and in the Sahel region of northern Africa, as well as variations in the formation of tropical Atlantic hurricanes, including the resurgence of such hurricanes in the 1990s.

On page 115, climate modelers Rowan Sutton and Daniel Hodson of the University of Reading, U.K., report that they could simulate the way relatively warm, dry summers in the central United States in the 1930s through the 1960s became cooler and wetter in the 1960s through 1980s. All that was needed was to insert the AMO pattern of sea-surface temperature into the Hadley atmospheric model. That implies that the AMO contributed to the multidecadal seesawing of summertime climate in the region.

If the Hadley model's AMO works as well as it seems to, Knight and his colleagues argue, it should serve as some guide to the future. For example, if North Atlantic temperatures track the conveyor's flow as well in the real world as they do in the model, then the conveyor has been accelerating during the past 35 years—not beginning to slow, as some signs had hinted (*Science*, 16 April 2004, p. 371). That acceleration could account for about 10% to 25% of the global warming seen since the mid-1970s, they calculate, meaning that rising greenhouse gases haven't been warming the world quite as fast as was thought.

Judging by the 1400-year simulation's AMO, Knight and colleagues predict that the conveyor will begin to slow within a decade or so. Subsequent slowing would offset—although only temporarily—a "fairly small fraction" of the greenhouse warming expected in the Northern Hemisphere in the next 30 years. Likewise, Sutton and Hodson predict more drought-prone summers in the central United States in the next few decades.

But don't bet on any of this just yet. The AMO "is not as regular as clockwork," says Knight; it's quasi-periodic, not strictly periodic. And no one knows what effect the

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strengthening greenhouse might have on the AMO, adds Sutton. Most helpful would be an understanding of the AMO's ultimate pacemaker. In the Hadley Centre model, report modelers Michael Vellinga and Peili Wu of the Hadley Centre in Exeter in the December *Journal of Climate*, the pulsations of the conveyor are timed by the slow wheeling of water around the North Atlantic. It takes about 50 years for fresher-than-normal water created in the tropics by the strengthened conveyor to reach the far north. There, the fresher waters, being less dense, are less inclined to sink and slide back south. The sinking—and therefore the conveyor—slows down, cooling the North Atlantic and reversing the cycle.

That may be how the Hadley AMO works, says oceanographer Jochem Marotzke of the Max Planck Institute for Meteorology in Hamburg, Germany, but it doesn't settle the mechanism question. How a model generates multidecadal Atlantic variability "seems to be dependent on the model you choose," he says. Before even tentative forecasts of future AMO behavior are taken seriously, other leading models will have to weigh in, too.

–RICHARD A. KERR

Astronomy

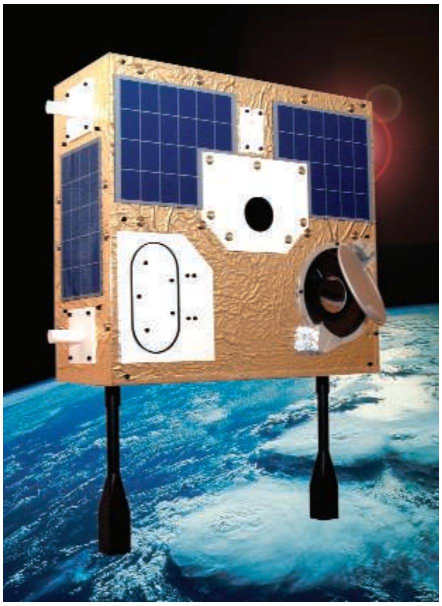
Suitcase-Sized Space Telescope Fills a Big Stellar Niche

Small but single-minded, Canada's MOST microsatellite is revealing the inner clockwork of stars and characterizing exoplanetary systems

MONTREAL, CANADA—To astronomers, bigger telescopes usually mean better telescopes. But a Canadian space-based instrument is bucking that trend. Just 2 years into monitoring subtle periodic dips in starlight, the suitcase-sized MOST (Microvariability and Oscillations of Stars) telescope is probing the hidden internal structures of sunlike stars and pinning their ages down to a greater precision than ever before. At a meeting here,* astronomers announced that MOST has also begun to provide information about the planets that orbit some of those stars, even hinting at their weather patterns. "Not bad for a space telescope with a mirror the size of a pie plate and a price tag of $10 million Canadian, eh?" says astronomer Jaymie Matthews of the University of British Columbia.

MOST blasted into space aboard a converted Russian intercontinental ballistic missile on 30 June 2003. Nicknamed "the Humble Space Telescope," Canada's first space observatory is also the world's smallest, weighing in at only 60 kg and sporting a modest 15-cm mirror. Designed and built for less than 1/20 of the projected cost of any upcoming competing mission, the single-purpose satellite does without most of the instruments found on its larger space-based cousins but still conducts science no other orbiting observatory is equipped to do.

Above the blurring effect of our atmosphere, MOST's ultraprecise photometer can detect fluctuations in stellar brightness as small as one part in a million—10 times better than ground-based telescopes can achieve. Thanks to a specially designed gyroscope, the Canadian Space Agency–run microsatellite can stare at a star around the clock for up to 2 months. The Hubble Space Telescope, by contrast, can look at a given object for only about 6 days. "MOST is pushing frontiers in stellar astronomy in terms of time sampling and light-measuring precision," Matthews says. "While this may seem more abstract than what Hubble can do, it is just as revolutionary in terms of what this tiny telescope allows us to see in stars and their planets."



Packed with potential. Boxy MOST focuses on doing one thing very well.

CREDIT: E. KOELEMEYER/MACMILLIAN SPACE CENTRE

Using methods of asteroseismology—the study of starquakes—MOST monitors optical pulsations caused by vibrations of sound waves coursing through a stars' deep interior. Just as geologists can map Earth's interior from earthquake signals, astronomers can probe a star's hidden structure by tracking minute oscillations in its luminosity. As the star contracts, its internal pressure increases, heating its gases and temporarily increasing its brightness. The MOST team hopes the technique will lead to better theories about how stars evolve with age.

"Most of the research is being done on sunlike stars, because we know how to interpret the data using our sun as a model," says starquake hunter Jørgen Christensen-Dalsgaard of the University of Aarhus in Denmark. According to astrophysical models, stars between 80% and 170% as massive as the sun pass through the same basic life cycles as the sun does and should show similar upper atmosphere turbulence and micromagnitude oscillations. But whereas short, subtle changes in brightness are relatively easy to detect on the sun, they are much trickier to spot in more-distant sunlike stars.

Not until 2000 did ground-based telescopes become sensitive enough to confirm them in a few dozen solar-type stars. Those observations used spectroscopes to detect shifts in the color of light, from which astronomers could calculate the radial velocity of the stellar surface as it moves up and down. Now MOST—which makes it possible to draw similar inferences from much smaller changes in brightness—is opening a new chapter in the field, says astronomer Travis Metcalfe of the High Altitude Observatory in Boulder, Colorado: "This modest instrument is bound to have a great impact on our understanding of stellar evolution."

In July 2004—a year into its observations—MOST's science team, led by Matthews, generated their own waves in the asteroseismology community when they published their observations on the well-studied star Procyon. To the shock of everyone, the satellite found that Procyon showed none of the oscillations that ground-based measurements had seen and theoretical models had predicted for nearly 20 years. "We had 32 continuous days of data representing over a quarter of a million individual measurements and saw nothing," says Matthews.

Asteroseismologists around the world are still puzzling over those observations. Christensen-Dalsgaard, a member of one of

* CASCA 2005, Montreal, Quebec, 15–17 May.

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