A North Atlantic Climate Pacemaker for the Centu

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Old trees and supercomputers are revealing a slow, multidecadal climate pulse that beats in the Atlantic Ocea around the globe

Wiggles are the bane of climate researchers, confusing records of every sort. They're jum other on time scales ranging from year-to-year to eon-to-eon. But they can also be a salv clues to how a single, repeating climate oscillation may be linked to an equally rhythmic searchers are picking through the climatic records of recent centuries to track down and gle—the first of its kind to emerge—that they hope may clarify variations in the past cent sharpen our ability to recognize greenhouse warming.

The climate swings coming into view don't officially have a name yet, but Atlantic Multic Oscillation or AMO might do. Oscillation because the climate swings one way then the o decadal because they take roughly 60 years to complete an oscillation, and Atlantic becau evident in and around the North Atlantic. Most recently, thermometers picked up a swin

Climate Prediction in Bracknell, United Kingdom. “It's very interesting, very important.” feel that the AMO might even shed light on the recent rise in global temperatures. “It is p hanced warming in the North Atlantic recently is a superposition of a natural mode plus mode,” says statistical climatologist Michael Mann of the University of Virginia in Charlo researchers, especially climate modelers, suspect that oscillations in the heat-carrying cu North Atlantic are to blame for this natural mode.

Although the AMO is a new label, what it describes was noticed by climatology's pioneers an originator of the modern concept of El Niño, observed in 1964 that a slow warming of North Atlantic in the 1910s and '20s could well have been driven by a surge of warm wate Stream. This Atlantic warming accompanied a global warming that by the 1940s had proc global temperatures to that point in the records. It was so warm that statistical techniqu 1990s to detect the “fingerprint” of greenhouse warming in climate records also show th greenhouse warming, according to work by Gabriele Hegerl of Texas A&M University in C and her colleag hat analysis is that no one believes enough greenl reached the atmosphere by then to cause much of a human-induced warming. That incor greenhouse contrarians to complain that any recent warming could just as well be natura thropogenic.

A warm 1940s gave way to a decades-long cooling that set in over the Atlantic as well as started talk of the next ice age, or at least the irrelevance of the growing load of greenho Wallace Broecker, a marine geochemist at the Lamont-Doherty Earth Observatory in Pali disputed that interpretation and suspected the cooling was just a phase. His 1975 paper i out that coring of the Greenland ice cap had retrieved a record of two climate oscillations years. In the 1970s, these natural climate variations would have counteracted greenhous by fossil fuel burning, Broecker reasoned, but not for long. “We may be in for a climatic s warned. Indeed, the North Atlantic soon began warming, the global cooling reversed itse tures set new record highs in the '80s and '90s.

The existence of as much as two full climatic swings in the last 150 years seems increasir per soon to be published in *Climate Dynamics*, climate modeler Thomas Delworth of the N and Atmospheric Administration's Geophysical Fluid Dynamics Laboratory (GFDL) in Pri Jersey, and Mann find “overwhelming evidence for a significant multidecadal variation in tem during the past 100 to 150 years, centered in the North Atlantic.”

This climate variability with a duration of 50 to 70 years—more or less equivalent to the tion seen in Greenland ice—can have some noticeable effects. Winds blowing over a warr Atlantic warm the United Kingdom, the rest of Europe, and northern Asia. Delworth and

Thomas Knutson reported recently (*Science*, 24 March, pp. 2126, 2225) that, in one out of mate model that simulates the AMO, a North Atlantic-centered warming bore a marked r the warming of the 1920s and '30s in timing, amplitude, and geographical distribution. " played a role in the 1920s-30s warming," says Delworth. On the flip side, meteorologist V Colorado State University in Fort Collins has linked a colder North Atlantic to the dearth the '70s and '80s as well as to the drought in the Sahel of northern Africa. He even sees th the North Atlantic influencing the frequency of El Niños.

Although the North Atlantic may be switching between warm and cold, one or two cycles cillation make. Meteorological standards call for a half-dozen or more. To go back before use of thermometers, climatologists have turned to so-called proxy records—the width o reflect the temperature during a growing season; a layer of snow-turned-ice in the middl Greenland glacier may record temperature in its oxygen isotopic composition; and a cora layer responds to temperature as well. In the past several years, Mann and his colleagues number of such 0 eLetters gle record that shows temperature variations aro Atlantic of several tenths of a degree, with a roughly 70-year oscillation. For comparison, warming from 1860 to the present has been about 0.6°C.

Despite the considerable uncertainties inherent in proxy records, "the pattern is significa clearly detectable," says Mann. "I think there is something going on that is important," a John Marshall of the Massachusetts Institute of Technology. And climatologist Yochanan Lamont-Doherty says that, despite all the reservations, climate is oscillating at time scal century and beyond in a way distinctly different from El Niño or decadal oscillations.

Just what is happening, however, is a matter of ongoing discussion. The proposed AMO h to the North Atlantic Oscillation (NAO) (*Science*, 7 February 1997, p. 754), in which a swi atmospheric pressure with "seats" over Iceland and Lisbon skews climate over and down Atlantic. Some meteorologists lump the NAO into a hemisphere-girdling phenomenon ca Oscillation (*Science*, 9 April 1999, p. 241), but it is still a flibbertigibbet of an oscillation, to month and year to year with little sign of a preference for an oscillation period of 50 y Such long cycles, most researchers assume, must be paced by the ocean, where massive r and ponderously slow currents might provide the required slowly ticking clock.

To sort out the ocean's role in multidecadal climate change, researchers turn to climate r forthcoming *Climate Dynamics* paper, Delworth and Mann compare the behavior of a GFD and the real world as recorded instrumentally and in a 330-year proxy record. "We see a r mode of variability in the GFDL model," Mann says, "that looks quite like the pattern of r ability in the proxy record." Both involve Atlantic-wide temperature oscillations rather th ically more complex variations of the NAO. The proxies give a period of about 70 years, w suggests 50 to 60 years. The difference is negligible, says Delworth, given the approximat ate any model.

Whereas long-term climate records are limited to Earth's surface, sophisticated climate r physics to build an ocean interior that can be probed for signs of what makes an oscillati case of the GFDL model, the AMO seen at the surface reflects a "clock" within the ocean the atmosphere's NAO. The NAO's seesawing atmospheric pressure alternately cranks up cold winds that blow out of the west across the Labrador Sea. The harder they blow, the r tract from surface waters, the denser those waters become, and the easier it becomes for the deep sea, drawing more warm water from the south through the Gulf Stream. Thus, i NAO has a hand on the control valve of the North Atlantic's so-called thermohaline circu which warm water flows north, cools, sinks, and heads back south through the deep sea.

The model's NA he THC valve, but it is with a most unsteady hand lates week to week as much as it does year to year or decade to decade, and does so unpre then, the real and model oceans pay no mind to most of the NAO's jittering. Being slow t model's North Atlantic prefers to respond only to the NAO's longest, multidecadal swing and then at a pace set by its own ponderous internal works. In particular, the added warn an accelerated THC eventually slows other currents that carry particularly salty, and ther ter northward into the regions where sinking occurs. With less salt to encourage sinking, heat transport slows, and the North Atlantic cools. Eventually, cooling will progress far e the oscillation by encouraging more salt transport that will enhance sinking and the THC herently sluggish response to the atmosphere's urgings sets the multidecadal pace of the

"The atmosphere is noisy, and the noise drives the ocean beneath it," says modeler Andr University of Victoria in British Columbia, but only at the more regular pace favored by t also recently found noise acting as a driver in a model, run with Marika Holland of the Na Atmospheric Research in Boulder, Colorado, to look at the effect of Arctic sea ice coming Atlantic. "Our work is very similar" to Delworth and Mann's, Weaver says, in that the stre of the north—a major source of fresh, less dense water to the North Atlantic—responds t tions in the overlying winds. Increased winds in the right direction drive more fresh wate and slow it.

Although some model oceans may be taking their multidecadal cue from the random jost mosphere, other models interact with the atmosphere in more of a give-and-take proces global climate model much like Delworth's GFDL model, Axel Timmermann of the Royal Meteorological Institute in De Bilt and Mojib Latif of the Max Planck Institute for Meteo

Hamburg found a two-way interaction between ocean and atmosphere that gives rise to a
tion centered on the North Atlantic. In their model, surface waters are warmed by an unu
THC. The warmth changes salinity not by altering currents but by strengthening the NA(
forces the warmth, it also gradually causes a reduction in evaporation of fresh water, so s
Eventually, the declining salinity slows the THC and cools the North Atlantic, which in tu
turns higher salinity and accelerates the THC to complete an oscillation. The model even
mospheric bridge" from the North Atlantic to the North Pacific that entrains the North P
related 35-year oscillation.

Whatever the role of the atmosphere, the temperature oscillations of the 20th century ar
sults have engendered "a strong suspicion that the thermohaline circulation is to blame,
the Hadley Center. The modeling "is a good step up," adds Timmermann, "but the model
mature to say that the thermohaline circulation is involved." A number of models are pro
decadal oscillation—within the general range of 35 to 70 years—but such obvious differe
the atmosphere ive pause, says Timmermann.

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Still, "we believe more firmly than before that this is real," says Mann of the AMO. "The e
sort of 50- to 70-year oscillation is accumulating in the instrumental observations, proxy
and the climate models." If that is correct, the pace of warming could pick up in the next
naturally warming North Atlantic combines with a stronger greenhouse warming effect. I
lot more old trees and supercomputing time to calculate how much greenhouse warming
next time the NAO swings to the cool side.

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