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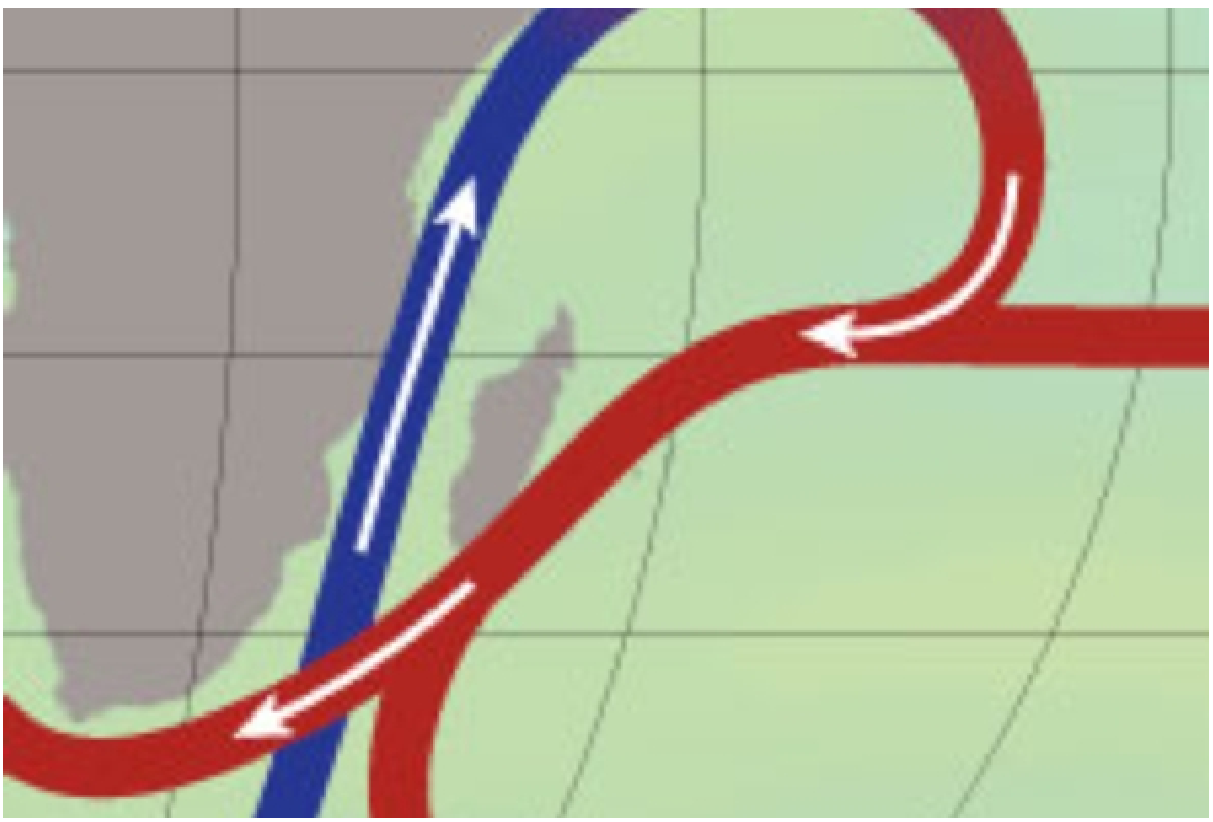
In Deep Water: Will Essential Ocean Currents Be Altered by Climate Change? [Slide Show]

Scientists are struggling to get a grasp on the huge volumes of water flowing through the world's oceans

By Nancy Bazilchuk on December 10, 2009



Credit: Wikipedia commons

Every second, a vast quantity of cold, dense seawater equal to six times the combined flow of every land river on Earth streams over an ocean-floor ridge that stretches between Greenland and Scotland. This deep southbound current, flowing from the Norwegian, Iceland and Greenland seas into the North Atlantic, is the lower limb of the Gulf Stream and its northerly extension, a great conveyor belt of ocean heat and salt that transports warm tropical water north from the equator. Most climate change models predict global warming will slow these flows, in part by altering a key component of the Atlantic's circulation, called deep-water formation. If that happens, northern Europe will cool—or warm less severely—as the rest of the globe swelters.

Understanding the role that deep-water formation plays in driving this grand circulation pattern, more formally called the Atlantic Meridional Overturning Circulation (AMOC), will help scientists predict how global warming will affect climate—both in and beyond the Northern Hemisphere. Shifts in the Atlantic's circulation patterns will alter African and Indian monsoon rainfall as well as hurricane patterns in the South Atlantic, resulting in "a profound impact on the global climate system," according to a team of international scientists asked by the U.S. government to evaluate the potential for abrupt climate change.

Oceanographers have been using moored acoustic Doppler current profilers and temperature sensors for the last decade to measure deep water as it pours over the Greenland–Scotland Ridge on its way south. They're both trying to establish the natural yearly and decadal variations in its creation as well as look for evidence of changes from human-generated temperature increases. "Our assumption is that when we are studying the exchange between the North Atlantic and the Nordic Seas, that this deep conduction and cooling of ocean water is important to the AMOC," says Svein Østerhus, an oceanographer at the Bjerknes Center for Climate Research in Bergen, Norway, who has been investigating the flows.

Deep-water formation is just what it sounds like: As the Atlantic's surface waters travel north they become cooler and denser, so that by the time they reach the Arctic they are cold enough to sink to the ocean bottom. The sinking water pulls warm surface waters like the Gulf Stream north, which in turn leaves a void that pulls deep, colder water south. If global warming inhibits the formation of deep water, the flows across the Greenland–Scotland Ridge should slow.

But it's not that simple. Between the 1950s and the 1990s, the deep water in the Nordic Seas was both warmer and increasingly less salty. As a result, "we had quite remarkable changes in deep-water formation," Østerhus says. Nevertheless, the flow of deep water headed south over the Greenland–Scotland divide has remained stubbornly stable for the past 50 years, Østerhus and his colleagues reported a paper in Nature late last year. The reasons for these counterintuitive findings are not clear, he says. It may be that deep water is pooling behind the Greenland–Scotland Ridge, providing a reservoir from which older deep water can flow when production is slowed. Østerhus's colleague, Detlef Quadfasel, an oceanographer at the University of Hamburg, thinks that part of the explanation is that "this is a nonlinear system—it can simply jump from one state to another."

Now Østerhus will travel in January to the other place on the planet where deep water forms—the Antarctic. The Weddell Sea off Antarctica is home to the coldest, densest deep water on Earth. Østerhus's mission will be to retrieve data from a string of high-tech monitors put in place there last February, with the hope of understanding how Antarctic deep-water formation affects the churning of the Atlantic's currents far to the north. There is very little information on deep-water formation in the Antarctic, and Østerhus will collect basic data on temperatures, velocities and salinity that will form the foundation for later comparisons.

"Deep-water formation in the Arctic and Antarctica are of equal importance, and they are linked," he says. "Deep water formed in the Arctic can be traced the whole way south to Antarctica and deep water formed in the Weddell Sea can be traced as far north as Ireland. A change in the Antarctic deep-water formation may have an impact on the circulation of the North Atlantic."

As Østerhus and his colleagues scramble to understand what's going on at the most distant edges of the Atlantic, roughly two dozen other projects are measuring the Atlantic's flows elsewhere, including a string of instruments from the Bahamas to Morocco. And in late September an international team proposed that the entire network be transformed into a more formal international monitoring effort in the hopes of helping humankind prepare for what global warming will bring.

"We rely on climate forecasting models to understand climate change, but not all models are in agreement," says William Johns, a University of Miami oceanographer who helped write the abrupt climate change report for the U.S. government. "We have to refine these models to get some idea of what we are going to have to get adapted to—and exactly how much warming we will get in the North Atlantic depends on how much this circulation really does slow down."

Slide Show: Deep Insights: Oceanographers plumb polar ocean depths to understand the Atlantic

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