The Fickleness of the Deep Sea

Crisscrossing the far northern North Atlantic in 1981, oceanographers were finding that the water thousands of meters below had changed since the last close look in 1972. Although only slightly less salty and colder than before, this water was definitely different, which ran counter to the assumptions of the past 100 years of oceanography. This first detection of changes in the presumably immutable deep sea should aid the understanding of how the ocean manages to renew the water of even its deepest recesses.

The first hint that something was different came on the fourth cruise of the Transit Tracers in the Ocean (TTO) program. TTO is a coordinated effort to follow the path of such debris as nuclear bomb fallout and aerosol propellants when they penetrate into the deep sea as the entire ocean mixes itself from top to bottom in only a few hundred years. In 1981 on the fourth TTO cruise, shipboard scientists were reinspecting a gap in the Mid-Atlantic Ridge southeast of Greenland where relatively cold, salty water had been found slipping across the ridge from the eastern to the western basin of the Atlantic. But this time it was not exactly the same kind of water—it was just a bit colder and less salty. The immediate suspicion was that something had obstructed that particular flow of deep water, which originates to the north in the Norwegian Sea just west of Norway.

The obstruction explanation did not hold up. Subsequent TTO cruises* found similar changes in all of the water below a few hundred meters depth north of 50°N (the latitude of Newfoundland) and south of Iceland. That water flows into the deep Atlantic from the Laborador Sea and the Greenland Sea (east of Greenland) as well as from the Norwegian Sea. Since the GEOSECS survey of 1972, water in the far North Atlantic from all three sources had become 0.02 part per thousand less saline and 0.15°C colder. To a physical oceanographer, these are not trivial variations. He takes a great deal of trouble to measure salinity to a few parts per million and temperature to a few millidegrees in order to detect the subtle density differences that inexorably drive the circulation of the deep sea.

The rest of the deep North Atlantic may have been affected too, but there is good evidence that at least the far North Atlantic was stable in the 1960's. James Swift of Scripps Institution of Oceanography can find no differences between the 1972 GEOSECS observations and the 1958 International Geophysical Year (IGY) survey, or among any of the surveys between them. He cannot detect any change in the far North Atlantic between 1958 and 1972. James McWilliams of the National Center for Atmospheric Research and Peter Rhines of Woods Hole Oceanographic Institution (WHOI) say that there appears to be "a weak indication of the same freshening tendency" since the IGY surveys.

"We've all been trained to imagine that the deep ocean is steady," says Rhines. "It's not so much a belief, but a practice that became a way of teaching." It had been a convenient practice to think of an ocean whose properties remained unchanged despite continuous replacement of its deep water by newly arrived water from the surface. Such a dynamic but steady-state ocean would operate something like a sink that loses water through an overflow drain as fast as new water is supplied from the faucet.

The catch in this analogy is that the supply of new water to the deep sea depends on the atmosphere, which is notoriously unstable. Swift suspects that some variation in the behavior of the atmosphere in the 1970's brought about a change in the production of new water off Laborador, Greenland, and Norway. Surface water there can sink thousands of meters and begin sliding to the south after becoming colder, saltier, or both. The atmosphere can in theory affect this deep-water formation by adding freshwater through precipitation, removing freshwater and heat through evaporation, chilling the surface with cold air, and by blowing different kinds of water toward the area. Even after leaving the surface, variations in the mixing of the new deep water with the older surrounding water could change its properties, Swift cautions.

Another sort of change, also possibly related to atmospheric behavior, has apparently occurred during the past 20 years in the central North Atlantic. Dean Roemmich of Scripps and Carl Wunsch of WHOI have analyzed temperature and salinity observations† made along latitudes 36°N and 24°N, the same tracks followed by IGY surveyors in 1957 and 1959. More than two decades later, the water at depths between 500 and 3000 meters is warmer by as much as 0.2°C. Above 500 meters and below 3000 meters to the bottom at about 5000 meters, the water tended to be colder. Unlike the situation farther north, the accompanying salinity changes tended to maintain the salinity-temperature relations characteristic of the different water masses there.

The observed changes in the central Atlantic could mean that more of the water there came from the vicinity of Antarctica, the other major source of new deep water, and less from the far North Atlantic, Roemmich says. That might reflect a change in the rate of deep water production induced by atmospheric changes. Alternatively, they may be seeing the effects of a north-south sloshing of water in the Atlantic basin. No one has looked at possible connections between the changes in the central Atlantic and those to the north.

Although the atmosphere may play a role, researchers caution that the changes in deep water are not a harbinger of dramatic climatic changes. The observed alterations of seawater are still 10 to 30 times smaller than the worldwide contrasts in temperature and salinity that drive deep-sea circulation. If the changes persist long enough, the circulation could change. The instability of the deep sea will ultimately aid in understanding it. If the system of deep water circulation is occasionally being nudged by the atmosphere, the response of the system will suggest how the system works. In a practical vein, understanding the carbon dioxide greenhouse effects on climate, for example, requires understanding the formation of new deep water, which removes carbon dioxide from the atmosphere and ultimately disposes of it at the sea floor.—RICHARD A. KERR

*Cochief scientists on the cruises were: C. Rooth, University of Miami; W. Broecker and T. Takahashi, Lamont-Doherty Geological Observatory; J. Swift, Scripps Institution of Oceanography; P. Rhines and W. Jenkins, Woods Hole Oceanographic Institution. Paper presented at the Ewing Symposium, held 25 to 27 October 1982.

†To be presented at the meeting of the American Geophysical Union in San Francisco, 7 to 15 December 1982.