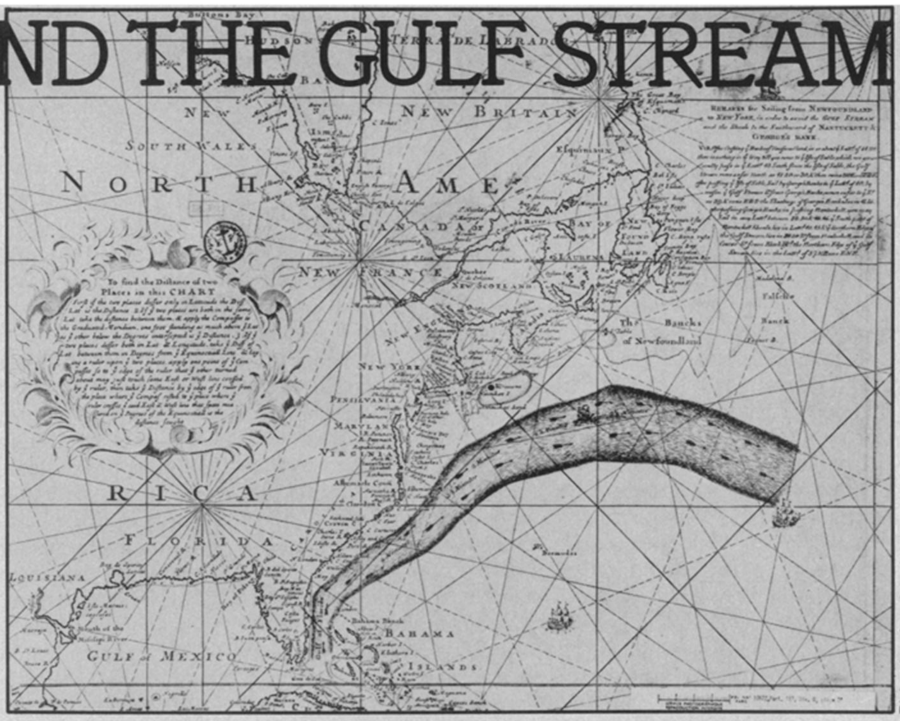
RING AROUND THE GULF STREAM

The life and times of a Gulf Stream ring, one of the most important but least understood of ocean phenomena

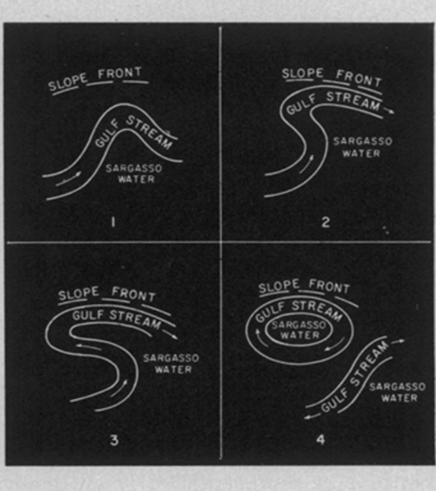
BY SUSAN WEST



Richardson/WHOI

The Gulf Stream then and now: the Gulf Stream as Franklin charted it in 1769 (right) and as seen by satellite in 1977 (below, left). The warm water of the Stream and the rotating warm rings show up dark; the rings are labeled alphabetically in the order they detach from the Stream. Schematic shows how a Gulf Stream meander pinches off, trapping warm Sargasso Sea water, and spins away as a warm core ring (below, right).

NOAA/NESS



Bisagni/NOAA

In the 1760s, Postmaster General Benjamin Franklin noticed that the English received their mail from the colonies much quicker than the colonists got theirs from England. Thinking that it might have something to do with the trans-Atlantic current first discovered by Ponce de Leon in the 16th century, Franklin enlisted the help of Timothy Folger, a Nantucket ship captain, to trace the direction and boundaries of this warm, west-to-east flow. In 1769 or 1770, Franklin published the first good chart of the Gulf Stream so that captains of the British mail ships could avoid the current or use it to their advantage.

Franklin's chart, though certainly sufficient for its purpose, hardly resembles the present picture of the Gulf Stream. Instead of the homogeneous flow seen by Franklin, the Gulf Stream is now known to be a complex of filamentary flows—like smoke rising from a cigarette — that hugs the coast from the tip of Florida to Cape Hatteras, N.C., then breaks away from the shore and wanders unpredictably toward the tip of the Grand Banks and across the North Atlantic. Not until the late 1930s and early 1940s, however, did oceanographers become aware of what may be the most important feature of the Gulf Stream—the formation of rings, or eddies, that spin off and live independently of the sinuous current. These rings, which are also spawned by other strong ocean currents, may be the primary means of transporting heat, salt and nutrients from one part of the ocean to another and may affect marine biology and the distribution of ocean pollution. Despite their importance—one researcher calls them "the aorta of the ocean circulatory system" — these massive whirls have only recently been studied intensively.

One group of researchers, however, has been tracking Gulf Stream rings for six years. Directed by J. Lockwood Chamberlin, the Atlantic Environmental Group (AEG) of the National Marine Fisheries Service in Narragansett, R.I., was initiated to monitor the effects of Gulf Stream rings on environmental conditions in the fishing grounds off New England and the Middle Atlantic states. Using weekly satellite-derived charts of the Gulf Stream from the National Oceanic and Atmospheric Administration's National Environmental Satellite Service, the AEG researchers add other available observations, watch closely those rings that approach the coast and study their environmental effects. Recently, AEG oceanographers Jayne L. Fitzgerald and R. Wylie Crist reported observations of the largest surface diameter ring to enter the Hudson Canyon area during the six years of study. Interesting in its own right, a description of the birth, life and death of this Gulf Stream ring also is a convenient means of explaining this important ocean phenomenon.

Born Sept.18, 1979, due east of Cape Cod, Mass., at 41.8°N, 63.0°W, with a diameter of 125 kilometers, eddy (or ring) 79-H — so named because it was the eighth such feature formed in 1979 — was a "warm-core" ring. (Rings come in two varieties, cold or warm, depending on the temperature of the water at their center.) Like other warm-core rings, 79-H formed when a wandering loop — called a meander — of the Gulf Stream pinched off toward the north, enclosing some of the warm water of the Sargasso Sea that lies south of the stream. At birth, 79-H was probably 8°C to 9°C warmer than the surrounding water and so was obvious to the infrared eye of satellites. Conversely, a cold-core ring forms when a southward loop of the Gulf Stream, filled with cold water from the North Atlantic, pinches off.

The more the Gulf Stream wanders, the more rings form; rings probably would not form at all if the Stream were as steady as Franklin envisioned. And the reason the Stream wanders is not well understood, says Woods Hole Oceanographic Institution researcher Philip Richardson. Noting that the stream begins to meander strongly and to form rings just over a sea floor feature called the New England Seamounts, he suggests that the deep-running Stream seems to "feel" the seamounts and be deflected by them. Whatever the ultimate physical cause, the rings form — about five of each type per year — and the warm rings go spinning clockwise to the west and south while the cold ones whirl counterclockwise into the Sargasso Sea. Only warm-core rings are tracked by the AEG, since only that type approaches the eastern U.S. coast.

Once born, life is often a tenuous thing for a Gulf Stream ring. As it moves slowly — usually about 3 to 5 km per day — it may bounce repeatedly off the Stream. On one of these encounters, it may be absorbed by the Stream or it may pull, or entrain, Stream water around itself. Ring 79-H, however, avoided the rapidly meandering current by stagnating near the northeast channel of the Gulf of Maine, Fitzgerald and Chamberlin report. By January 1980, the Stream had ceased gyrating quite so wildly, and in February, 79-H made its move south and then west along the continental slope. Twice, says Fitzgerald, it bounced off the Gulf Stream and cloaked itself with Stream water, thereby increasing its diameter. By April, it had grown to 187 km in diameter, achieving its status as the largest diameter warm-core ring to enter the Hudson Canyon area. Usually, explains Fitzgerald, large warm rings are squeezed between the coast and the Stream and absorbed before reaching that far west, but the Stream was not snaking as much as usual and 79-H "managed to sneak in." Cold rings, on the other hand, often reach 200 km diameter as they spin unconfined through the Sargasso Sea.

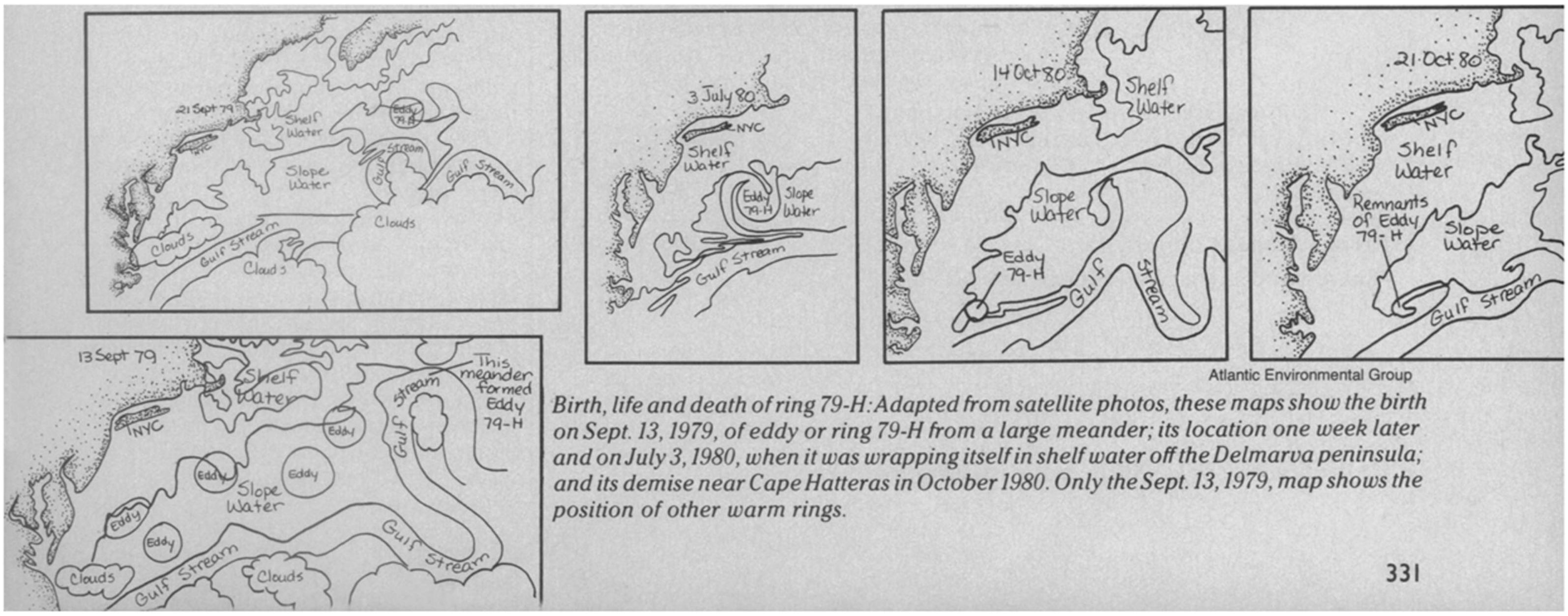
It is at this point — when a ring like 79-H nears the coast — that the watchers at the AEG perk up. At this proximity, 79-H has a number of potential effects on the coast environment. Carrying water that is warmer and more saline than that of the continental shelf and slope, containing a community of alien organisms from the Sargasso Sea and swirling at a speed of up to 5 knots, a warm ring invades the coastal water like a germ-laden tornado.

According the the AEG researchers, 79-H could have affected fisheries in two well-known ways. When the ring spun into the slope waters, the temperature contrast probably caused nutrients to rise from the depths at the edges of the ring and that attracted large predators such as swordfish, tuna and sharks. The result — instant fishing grounds. At the same time, however, 79-H's strong surface currents very likely pulled under marker floats and damaged lines to lobster and crab traps. These effects put the AEG's maps in high demand by fishermen, and the researchers alert trappers when a ring may encroach on crabbing and lobster grounds.

Other biological effects are not so well established. In June and July, 79-H pulled continental shelf water around itself. There is some suspicion, says Fitzgerald, that when this happens, the ring currents also sweep plankton and larvae off the shelf bottom. If so, says biologist Peter Wiebe of WHOI, it may explain why the commonly used technique of measuring larval production is often not a reliable predictor of future fisheries stocks.

In addition, says Wiebe, who has studied the biological communities in cold rings, little is known about the fate of the warm-water organisms that 79-H carried from the Sargasso Sea. For a time after it forms, a ring acts like an aquarium for these organisms, maintaining the nutrient, temperature and salinity characteristics of the original water while moving through chemically and biologically foreign water. Eventually, however, the ring slowly loses its identity and leaves its passengers in a hostile environment. Wiebe suspects that because warm-water marine organisms fare well in colder-than-optimal temperatures, most may survive until they remerge with the Stream and are carried back to the Sargasso Sea. There may, however, be effects on the fertility of females, he adds.

Also not fully understood is the possible effect of rings on the dispersal of wastes dumped into the ocean. In its spin along the coast, 79-H probably encountered what is called Deepwater Dumpsite 106. Located 106 nautical miles southeast of New York Harbor and occupying 450 square miles, the dumpsite receives the most industrial wastes — primarily liquid chemical wastes — of any dump in the country, according to Peter Anderson of the Environmental Protection Agency in New York City. It is also directly in the path of warm rings, and, with the recognition that the swift currents in these features may pick up pollutants, the region has been studied since 1975. According to James Bisagni of the AEG, rings occupy the area about 20 percent of the time and much of their possible effect probably depends on the age — because rings slow as they "age" or cool down — and vertical temperature profile of the ring. Tracking of dyes in waste plumes shows that the plumes may get caught up in a ring for two to three days, he says, although a satisfactory means of following plumes for longer periods has not yet been found. The rings apparently have some dispersal effects, however. WHOI researchers have noted, for example, that oil from the 1976 *Argo Merchant* spill on Nantucket Shoals was pulled into a warm core ring that later merged with the Stream, and the oil was



Atlantic Environmental Group

Birth, life and death of ring 79-H: Adapted from satellite photos, these maps show the birth on Sept. 13, 1979, of eddy or ring 79-H from a large meander; its location one week later and on July 3, 1980, when it was wrapping itself in shelf water off the Delmarva peninsula; and its demise near Cape Hatteras in October 1980. Only the Sept. 13, 1979, map shows the position of other warm rings.

carried across the Atlantic.

Even less well understood is the effect of rings like 79-H on the energy and heat balance in the ocean, says Richardson. But these and other questions will soon be addressed. A three-year project on warm rings is slated to begin next year, involving 13 institutions and directed by Terry Joyce of WHOI. According to Wiebe, who will be among the investigators, the project will use ships and buoys to examine the warm rings' chemical, biological and physical structures both horizontally and vertically.

But back to 79-H. Throughout the summer, ring 79-H continued to wend its way along the coast under the watchful eyes of satellites and researchers. At the beginning of September, says Fitzgerald, the ring bumped into a Gulf Stream meander and began to fade from satellite images as the temperature difference between its waters and those of the slope lessened. Even so, the researchers were still able to pick out the position of the shrinking ring because of the colder shelf water it pulled around itself. Finally, late in October, 79-H met the inevitable fate of all warm rings. Having survived far beyond the usual six-month lifetime of a warm ring, 79-H shrank to almost nothing and merged with the Gulf Stream near Cape Hatteras. Unusual in many respects, 79-H was certainly not the last warm ring to spin past the AEG researchers. And the more that come along, the more they will learn. □

... Saturn

Such events might well have taken place on other objects, he notes, but the evidence could be preserved on Rhea because part of the original crater population was smoothed over by ice flows from within the satellite, leaving a "clean slate" on which the later impacts could be discerned. Such multiple bombardments should be considered, Soderblom says, before calculations based on the craters of earth's moon (which lacks such a clearly defined small-craters-only patch) are applied to vastly different objects such as Jupiter's Galilean satellites.

The outermost Saturnian moon viewed by Voyager 1 was Iapetus (1,440±40 km), an oddly two-faced object with one hemisphere several times brighter than the other. Prior to the flyby, the most-heard explanation for the difference was that dark material from the moon Phoebe (still farther out) was being somehow transported to Iapetus, where it caught up with the satellite from behind and darkened the otherwise ice-covered object's trailing side as it moved in its orbit. Voyager 2 will take a closer look, but the fine details of the light-dark boundary seen in even Voyager 1's photos prompt Soderblom to believe that the dark material must have reached the surface as a result of the internal thrashings of Iapetus itself.

Besides probing the satellites, Voyager 1 continued to show new details of Saturn's spectacular rings. Even in a relatively low-resolution photo, Richard Terrile of Jet Propulsion Laboratory counted 360 individual "ringlets," and extrapolated from high-resolution coverage of small areas that the actual total is probably more than 1,000. Furthermore, he says, it is quite possible that by the time Voyager 2 takes its look in nine months, the details may have changed. If the ringlets are due to satellite resonances, the objects causing the resonances may have moved relative to one another; spiral gravitational density waves, another cited possibility (also linked by some researchers with the spiral structure of galactic arms), would tend to propagate outward, shuffling the ringlet particles some more.

Terrile also offered a tentative hypothesis regarding the strange, radial "spokes" in the wide B-ring, which have baffled researchers by seeming to ignore the fact that ring particles close to Saturn should circle the planet faster than those farther out, thus tearing such spokes apart. The spokes appear dark by back-scattered light and bright by forward-scattered light, suggesting them to consist of small particles, Terrile noted. Perhaps electrostatic charging, enhanced when the particles pass through Saturn's shadow, lifts them slightly out of the main ring plane so that their scattering characteristics show, and the thus-charged particles are then carried around by Saturn's magnetic field — which just happens to rotate at about the same speed as particles in the middle of the B-ring, the only ring in which the spokes have been seen. Electrostatic forces may also have something to do with a yet more baffling phenomenon — the "braided" and knotted structure of the multiple ringlets revealed in close-ups of the thin F-ring. But the mystery remains. Even Saturn's powerful radio emissions may originate at least in part from the rings' vicinity, says James Warwick of Radiophysics, Inc., in Colorado, who reports the apparently ring-based bursts to represent about 3 million watts of power. (Saturn's seemingly obvious ionosphere is not their source, he says, because the bursts contain low frequencies that the ionosphere would have cut off.) The rings also almost certainly include the necessary conditions (electric fields, particle collisions, etc.) for another phenomenon, lightning, Warwick adds, but their lack of a dense atmosphere probably precludes bright optical flashes — and indeed, none were initially reported in Voyager's photos, which had revealed lightning "superbolts" around Jupiter.

In the time pressure of Voyager 1's myriad close encounters, many of the project's scientists have yet even to see all of their data, and Voyager 2 will add to the file during its own flyby next August. Voyager 1, meanwhile, is now heading out of the solar system at a steep 35.5° inclination to the plane of the ecliptic, on its way to the stars. Next week: The visible and invisible Saturns. □