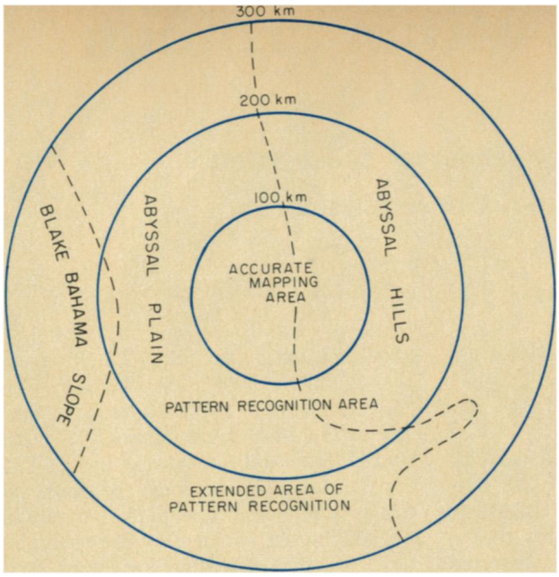


Eddies: Mysteries of the deep ocean

Scientists have staked out a 600-kilometer circle in the Atlantic to study "the weather systems of the deep sea."

by Jonathan Eberhart

John Swallow started the whole thing when his nice simple experiment ended up going every which way.

Prior to 1960 the prevailing theory was that the ocean's circulation was dominated in deep water by a slow, smooth drift of perhaps a centimeter per second. Swallow, now senior principal scientific officer of the British National Institute of Oceanography, decided to confirm the theory. In the Atlantic Ocean near Bermuda he loosed about 20 floats, ballasted to hover two kilometers below the surface, and prepared to clock them as they drifted gently northward.

To his surprise, the floats followed no such regular pattern (which had been a key element in theoretical models of the ocean's overall behavior), but wandered off in all directions. The northward drift was there, but a much greater influence was a tangle of irregular eddies which pushed the floats around with about 100 times the strength of the drift.

The lack of fixed reference points at sea and the problems of mooring deep-ocean instruments kept oceanographers from studying the eddies at the time, and a decade passed before they could agree that a really comprehensive investigation should be made. Almost three years of planning followed, but at last the program has begun, with scores of scientists, half a dozen research ships and hundreds of instruments taking part. The Mid-Ocean Dynamics Experiment, or MODE, is at sea.

It is estimated that if eddies exist throughout all the world's oceans, they may contain at least as much kinetic energy as the general ocean circulation, and possibly 10 times more. Where the energy comes from, how much there is, what it does and where it goes are among the questions being asked.

"Eddies," says Allan R. Robinson of Harvard University, co-chairman of MODE's first phase, "are the weather systems of the deep sea. . . . The eddy problem is the most important dynamical problem which must be solved in order to take a substantial step forward in our understanding of the general circulation of the ocean."

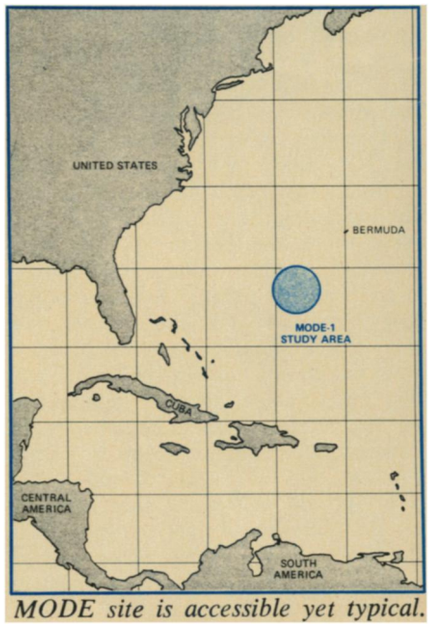
In fact, deep-ocean eddies are even more important than that. MODE is part of the International Decade of Ocean Exploration, one of whose major concerns is the present state of ignorance about the ocean's role in environmental forecasting. The behavior of the sea is related to sweeping changes in the pressure, temperature and motion of the atmosphere above it, and simplistic notions of the way either element works are obstacles to accurate prediction.

Scientists, Robinson says, used to think that the atmosphere simply flowed up at the equator and down at the poles, with some spiraling caused by the earth's rotation; in the 1930's and '40's they discovered the need to include wind systems. Eddies have the same significance for ocean studies, and the importance of such detail becomes still greater in understanding the air-sea interaction that helps to determine much of the world's climate and weather.

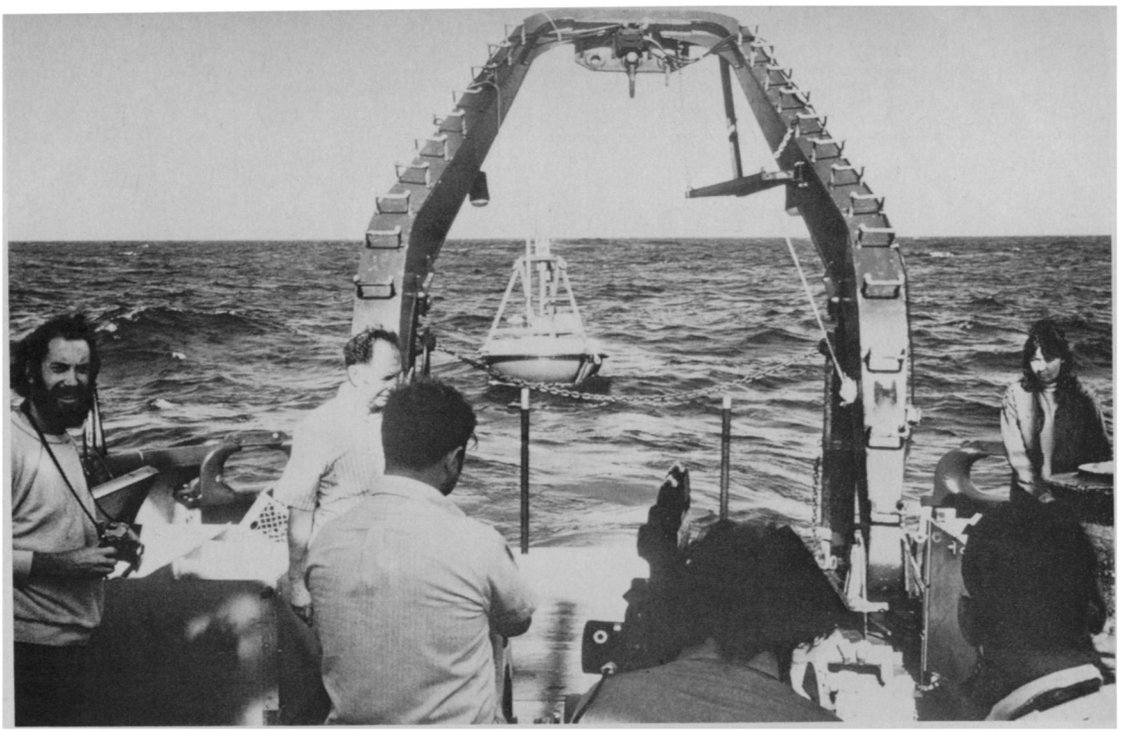
MODE's target is just that—a target, laid out in concentric circles with the most important one in the center. The site spans 600 kilometers in the Sargasso Sea, halfway between Bermuda and the Bahamas, chosen because it is easy to reach, it is fairly representative of the open ocean, and its bottom includes both mountains and flat plains.

Instruments at the site are measuring temperature, salinity, pressure, current direction and speed, and electric and magnetic fields. Some are flown overhead, while others are on shipboard or floating on the surface and at various depths. Still others are anchored on the bottom, while free floats move up, down and crossways.

There is a method to the madness, however. A key element in planning the location of the sensors was a term known as r_c, or critical radius. This is an estimate, worked out with the aid of three preliminary visits to the site and a lot of computer-assisted head-scratching, of the best way to arrange the instruments so as to be sure of detecting the gross movements of the eddies. (A Soviet experiment called Polygon, carried out over six months of 1970 near the Cape Verde Islands,



MODE site is accessible yet typical.



A buoy equipped with a wind recorder and a radar transponder is launched to help oceanographers accurately position other instruments for phase I of MODE.

Illustrations: NSF

used instruments laid out in a giant cross. This provided useful statistics about wave periods and strengths but little about the shapes and movements of the eddies of which the waves were a part.) Thus the MODE instruments are laid out in circles whose radii are multiples of r_c—about 100 kilometers.

The instruments were emplaced about three months ago, and most of them will be removed late in July. Studies of the data will probably continue well into 1974, but an elaborate communications system is already showing the investigators that they are on the right track. Radio, telephone, data links and leased undersea cables keep the MODE ships and aircraft in touch with a Hot Line Center in Bermuda, as well as with research coordinators at Harvard, Yale, Massachusetts Institute of Technology, Woods Hole Oceanographic Institution and Johns Hopkins University. The easy data exchange has revealed that the instrument network has actually "seen" eddies form within the site and move out of the area.

To study the long-term behavior of the eddies, such as their response (and perhaps contribution) to seasonal changes, the study may be extended. If funding permits, the oceanographers hope to leave some of their instruments in place for an additional full year.

And this is only MODE-I. The project can probe possible causes of eddies—instabilities in atmospheric pressure fronts, cast-off energy from major currents such as the Gulf Stream and so on—but its applicability to the whole world, which is, after all, the point, will require work on a larger scale.

There are at least two ideas afoot for MODE-II. One is simply a bigger MODE-I, with more instruments, more time and a bigger piece of ocean. The alternative is several little MODE's in varying types of ocean, such as in the Pacific, near a continental shelf or directly in a strong known current.

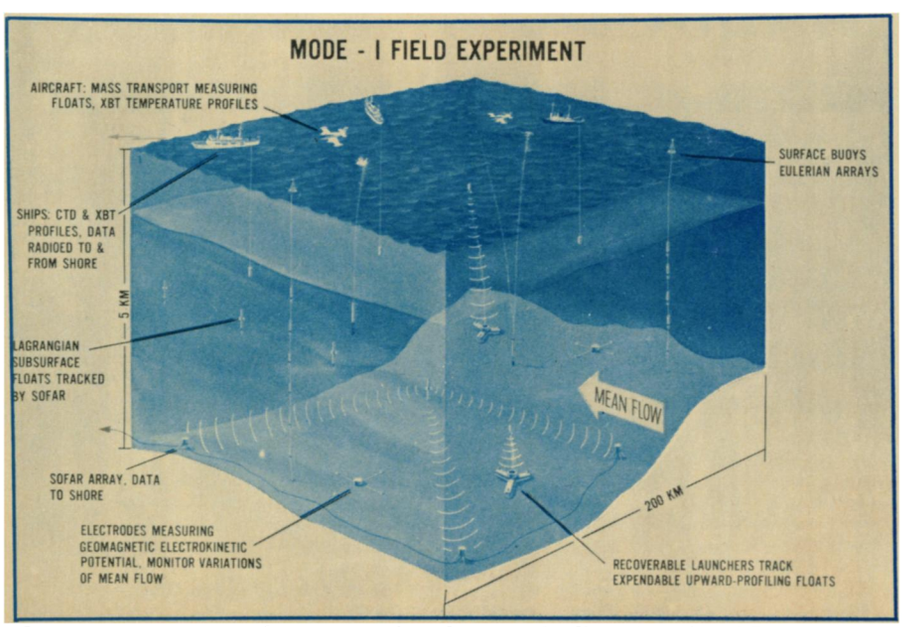
The whole MODE program is itself part of a much larger effort: the International Decade of Ocean Exploration. U.S. participation is largely guided by the National Science Foundation, but at least 32 other countries are involved. The major concerns of the IDOE are the resources of the seabed, the quality of the ocean environment and the ocean's role in environmental forecasting (of which MODE is a part).

The search for new supplies of natural resources so far includes ocean studies of the continental margins of east Africa and eastern South America, as well as of the Mid-Atlantic Ridge and of the Nazca crustal plate that includes much of western South America and was apparently a source of metal deposits in the Andes Mountains.

A vast gathering of baseline data is much of the work of the ocean quality research, though it also includes such odd studies as CEPEX, the Controlled Ecosystem Pollution Experiment, in which upright plastic tubes as much as 100 feet long are to be placed in the ocean to measure the effects of pollution on plankton.

Just added to the IDOE is a living resources program to evaluate oceanic animal and plant life, including a study of upwelling from the sea bottom.

Besides MODE, the forecasting research includes a core-sample study to see what the ocean's history can tell about where its future lies. □



Ocean cross section, shown out of scale, reveals diversity of MODE research.