NATURE OF OCEAN CURRENTS IN THE GULF OF MEXICO *

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Oceanographic studies in the Gulf of Mexico have been relatively few and far between. I imagine that the term "oceanography" is new to a good many of you and that it might therefore be well to define it and to mention its various aspects.

We may say that it is the systematic analysis of the seas and everything that is in them, over them, around them and under them. Oceanography draws upon the techniques and principles of the basic sciences such as biology, chemistry, geology, physics, mathematics, meteorology and engineering. If a problem can be solved within one of these fields without recourse to any of the others, then that problem, even though it concerns the marine environment, would not be listed as an oceanographic problem. Only those problems which can not be solved by application of one of the basic sciences alone can properly be called oceanographic problems.

In our Department of Oceanography, which is in the School of Arts and Sciences at Texas A. & M., oceanography is considered as being made up of five major components. These are: biological oceanography, which is the study of life in the sea including both plants and animals; physical oceanography, which is the physics of the sea, including the study of ocean waves and water movements, of transformations of energy, and of the physical characteristics of sea water; geological oceanography, which deals with relationships between the land and the oceans and includes studies of beach erosion, sedimentation, bottom topographies and the interpretation of marine deposits; chemical oceanography, which is the study of the chemical composition of the sea and of chemical reactions which take place within it, and which includes determinations of the amount of various constituents present, development of methods of extraction, and studies of corrosive effects; finally, there is marine meteorology, which deals with the winds and weather over the sea, with the manner in which winds set up ocean waves and currents and with the climate as determined by evaporation and conduction from the sea surface.

An oceanographer is a person trained in one of the pertinent basic sciences who has learned to apply his specialty in the marine environment and who has an interest in and at least an elementary knowledge of the other marine sciences.

There are several features of the subject which make oceanography a distinct and specialized field. One of these is the fact that, in nearly every problem he attacks, the oceanographer is soon confronted with the necessity of applying knowledge which can only be gathered by combining several of the marine sciences. This unity of the sciences of the sea is brought about by the very nature of the oceans themselves—they being a large, continuous, active, flowing medium. A second characteristic of oceanography is that

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it deals with large quantities. Distances are measured in thousands of miles and volumes in thousands of cubic miles. The oceanographer is fortunate if the data from which he must draw his conclusions provide as much as a single sample or observation for each 250 cubic miles of water to be analyzed. He deals with large amounts of energy which make even the energy associated with an atomic bomb explosion seem insignificant. He deals with forces not present in laboratory experiments, such as the apparent force due to the earth's rotation. Although few individual methods or principles of oceanography are unique, the combination of principles and methods which must be used requires special training and experience.

A typical oceanographic problem is that of determining the currents of the seas. Sverdrup* lists three different groups of currents, each of which is represented in the Gulf of Mexico. These are:

(1) currents that are related to the distribution of density in the sea,

(2) currents that are caused directly by the stress that the wind exerts on the sea surface, and

(3) tidal currents and currents associated with internal waves.

(Information presented in this discussion is standard oceanographic knowledge and is thoroughly covered in THE OCEANS. It is presented here in somewhat elementary form for the benefit of undergraduate students in biology who may not have strong backgrounds in mathematics and physics.)

Tidal currents are caused chiefly by the gravitational attractions between the earth, the moon and the sun. These attractions are proportional to the masses of the bodies and inversely proportional to the squares of the distance between them. Because of its very short distance from the earth, the attraction of the moon is large. The sun, on the other hand, although it is at a much greater distance from the earth, is so large that it is able to exert an attraction which is 43% of the moon's attraction.

A result of gravitational attraction upon the rotating earth is to periodically raise and lower the level of the ocean's surface, i.e., to create tides. Water which is required to raise sea level at a particular location must be furnished by horizontal movements within the ocean. These are the tidal currents. Since the sun and moon change their position with respect to a given part of the earth's surface in a periodic fashion, the tides and tidal currents are periodic. Because the rotation of the earth affects movements of water, the tidal currents do not oscillate back and forth on a straight line but rotate. In the northern hemisphere this rotation is in a clockwise direction.

Along the Texas coast there are many bays and lagoons which have relatively few outlets to the sea. If the water level in these bays is to be raised by tidal action, all of the water required for the change in level must flow into the bay through a few narrow channels. Therefore the tidal currents in such channels may be quite large, particularly at certain stages of the tide.

The great width of the shallow continental shelf along the Gulf Coast results in high tidal current velocities. This is because the change of water level of this large area must be brought about by flow across the shallow shelf. Since the depth of the moving water is small, its velocity must be relatively great to provide the volume needed for change in sea level.

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* **Sverdrup, H. U., Johnson, Martin W., and Richard H. Fleming**—1946—The oceans, their physics, chemistry and general biology. x, 1087. New York. Prentice-Hall, Inc.

The high velocities and the changing direction and velocity of these tidal currents lead to turbulence and stirring which provide nutrient materials needed for plant and animal growth in the lighted upper layers.

Oscillating currents related to internal waves may be important in this region but little information now is available on this subject.

Currents caused by the stress of the wind upon the sea surface are particularly important on the Gulf Coast. The most widely known phenomena which results from the action of such currents is the storm tide or general rise in water level which precedes winds of hurricane velocities.

When a wind starts to blow over the ocean it exerts a frictional force or drag upon the sea surface. If the wind persists the surface layers of the water start to move and they in turn act upon the deeper layers and set these in motion also. The two forces which are involved in setting up such currents are the frictional force and the Coriolis force, which is the apparent force due to the rotation of the earth. If the wind blows long enough for a state of equilibrium to be reached, the surface waters will be moving in a direction approximately 45° to the right of the wind direction. A north wind sets up a surface current toward the southwest. Currents at greater depths will flow at greater angles to the wind and at velocities which decrease with depth. The surface velocities may reach 1 to 2% of the wind velocity.

Studies of currents set up by the wind are mostly based upon theoretical considerations. A few observations have been made in land locked bays to show the piling up of water by the wind. However, in the open ocean no data are available. The existence of the drilling platforms off the Gulf Coast may permit, for the first time, the accumulation of data which will enable a practical analysis to be carried out.

The currents related to the distribution of density are the major semi-permanent currents of the oceans. Little is known about these currents in the Gulf of Mexico. The chief source of information is the pilot charts of the U. S. Navy Hydrographic Office. These are based upon the navigation records of the ships sailing in the Gulf over many years. They do indicate the general drift in various regions but the individual observations upon which they are based are subject to many errors. For example, the deviation of a ship from its course may be caused by the wind rather than by the current. Also, it is difficult to determine positions at sea accurately. A survey of the pilot charts for the Gulf indicates that these may not describe all of the currents present. They show waters flowing into the western part of the area at all latitudes but no water flowing out. This situation can not exist unless there is a submarine return current of equal magnitude—which is unlikely.

In the deep waters, direct observation of current velocities has until recently been almost impossible because of difficulty in anchoring vessels. Accordingly few such observations have been made. Instead, oceanographers have developed a method based upon the principles of physics. By use of this method the ocean currents present may be inferred from the distribution of density as determined by relatively simple observations of temperature, salinity and pressure. Two forces again are involved, one of these being the Coriolis force which I have previously mentioned, and the other being the "pressure gradient" which is a force that depends upon the density of the water and the density distribution. The pressure gradient tends to make water flow from a region of high pressure toward a region of low pressure just as water poured into less dense oil will flow outward from the point at which it is poured. When the movement related to the pressure gradient has begun, the Coriolis force in the northern hemisphere acts toward the right of the movement and the resulting equilibrium between the two forces is associated with a steady current flowing almost perpendicular to a line connecting the regions of high pressure and low pressure. This flow is such that the more dense water is on the left hand of a person standing with his back to the current and the less dense water is on his right in the northern hemisphere. Since temperature is one of the major factors influencing density, it may be inferred that the cold water is on the observer's left and the warm is on his right when he is standing as described above with relation to the current. Thus, he can tell something about the currents if he knows the distribution of temperature or he can tell something about the temperature if he knows the distribution of currents.

There are a number of difficulties in applying the current computation method. However, in spite of these difficulties it has been found to be the method which provides the most information for a reasonable amount of work.

Processes by which the distribution of density is caused to change are cooling and increase of salinity by evaporation and conduction, and the movement of masses of water by the winds. Since the total transport of water due to the winds is toward the right and since this transport consists of warm waters in the surface layers, the low density waters are piled up at the right of the wind flow, which is in the center of anti-cyclones—regions of good clear weather. The warm waters are removed from the low pressure storm areas at the left by the wind action. This movement is what is called the wind driven current. Its primary effect is to pile up water of small density in areas of anti-cyclonic winds and to leave waters of greater density in areas of cyclonic winds. This leads to a secondary effect, namely the maintenance of a different ocean current related to this distribution of density. Since such currents flow nearly perpendicular to a line connecting the regions having the different water densities, the associated currents form a pattern quite similar to the pattern of the winds. This may readily be recognized from a chart showing the distribution of ocean currents and prevailing winds.

It can be seen that the study of this one particular phase of oceanography, ocean currents, involves the use of many of the basic sciences. The fundamental laws were derived from physics. The data are obtained by various measuring devices developed by engineers. The density determinations require chemical analysis to determine salinity. The computations require rigorous mathematical methods. The interpretation of the computed currents is largely based upon meteorological phenomena. The application of the information gained is of particular importance to biologists since the ocean currents provide oxygen needed to maintain life in the sea, furnish nutrient materials, remove wastes and provide for the wide dispersal of eggs and larvae necessary to maintain populations. The ocean current information is also essential to geologists for their studies of sedimentation and erosion.

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