OCEANOGRAPHIC PROBLEMS OF THE ARCTIC OCEAN

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THE central problem in oceanography is to understand the movements of the water. This is true whether a study is primarily concerned with the physics, the chemistry, or the biology of the sea. Although the oceanographer deals with much slower movements than the meteorologist, he is beset by many of the same sorts of questions. To both, the motions observed occur within a relatively thin fluid envelope on a rotating earth. To both, the scale of the motions of interest covers a very wide range and both periodic and non-periodic motions are involved. Over most of the oceans the winds and the currents interact in many subtle ways, and it is often difficult to distinguish between cause and effect.

While it has become clear that ocean currents derive much of their energy from the winds, it is also evident that heating and cooling play a significant role. Some currents are almost pure wind currents; others are maintained largely because of regional differences in density. In most currents both causes are at work, and it is usually extremely difficult to establish their relative importance. However, much of the theoretical work in oceanography has been in connection with wind currents, as theories that can help to explain the characteristics of currents that are partly wind-driven and partly density-driven are beset by great mathematical difficulties. In the past, at any rate, theoretical studies have been most helpful in physical oceanography after the physical characteristics of the situation could be described in a reliable manner. In oceanography theory alone has seldom led to advances.

The exploratory stage of arctic oceanography is now drawing to a close. In very general terms the physical, biological, and geological characteristics of the area can be described as the result of a number of arduous and costly expeditions. To an oceanographer the Arctic Ocean is no longer an unknown sea. Ice-free waters that are just as cold are available to him elsewhere, and to be able to reach higher latitudes does not in itself hold promise of advancing his primary problems. But the arctic region[1] can make an important contribution to physical oceanography. As Worthington (1953) has shown, the

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[1]In this paper Dr. Iselin is concerned with the Arctic Ocean basin only, not with the waters of the arctic islands, Canadian coastal waters, Baffin Bay, or Hudson Bay. *Ed.*

Arctic Ocean is the only sea in which circulation occurs down to very considerable depths in the absence of any significant supply of energy from the local winds.

The circulation of the Arctic Ocean therefore presents a unique problem in physical oceanography. The winds can move the ice to some degree, as several expeditions have shown, but the frictional effect of the ice on the water must be minor compared with the regional differences of density, level for level, between the truly arctic waters and those of the Norwegian Sea. Moreover, recent knowledge of the topography of the Arctic Ocean Basin shows that the problem is even more interesting than it was previously thought to be. Only five years ago, when Sverdrup (1950) reviewed our knowledge, or rather lack of knowledge, concerning the physical oceanography of the arctic basin, he could not have realized that it was cut in half by a pronounced ridge. Worthington (1953) later suspected this, but it is only since the results of the Soviet expeditions have become known that it was certain bottom topography must profoundly influence the deep circulation (Webster, 1954).

Thus, a significant challenge faces students of oceanic circulation problems: Here is a sizable, deep basin covered with ice, one half of which is connected directly to another deep basin—the Norwegian Sea, which is largely ice-free—and the other half of which is to some extent isolated by the newly discovered Lomonosov Range. While the velocities of the currents under the ice may be weak, Worthington's (1953) calculations indicate that considerable transports are involved, even in the remote part of the basin. How can the study of the main problem that this area presents be advanced, what sorts of facilities are required, and what factors peculiar to the Arctic are favourable or unfavourable? In comparison with other large-scale aspects of the circulation problem the situation on the whole appears to be favourable, and undoubtedly many other interesting oceanographical phenomena will be encountered in the course of studies of the arctic circulation.

The primary assumption in deep sea oceanography, namely, that the flow is relatively steady so that a balance of forces exists, is probably most fully justified in the Arctic Ocean because the disturbing effects of the local winds are mostly eliminated. Thus, in the Arctic the necessity for simultaneous observations is largely removed and observed and computed currents can be compared with considerable expectation of agreement, especially since the disturbing effects of internal waves are probably largely eliminated, even though the collection of a deep network of temperature and salinity observations may have required a considerable period of time. In addition, even though the currents are relatively weak, it should be easier to obtain accurate measurements of the change of velocity with depth working from the ice, a very favourable platform for current measurements, than is ever possible from a ship. At lower latitudes an oceanographer has to study currents that he is virtually unable to measure with the desirable accuracy. Since the currents in the Arctic Ocean are probably slow, broad, and relatively steady, a rather open network of points of observation should suffice. A satisfactory analysis could emerge even though the points of observation were separated by as much as 100 miles on the average. As oceanographers have learned during the last few years, a considerably closer network of nearly simultaneous observations is essential in seas that are exposed to the winds.

Although in the Arctic a comparatively small number of points of observation may well suffice, the oceanographer is faced with a serious, but not necessarily expensive, transportation problem. An aircraft is considerably cheaper to operate per mile than a sea-going vessel, but the difficulty at present seems to be that nobody has designed an aircraft specifically for arctic oceanography. An aeronautical engineer with this purpose in view would certainly be facing a limited market, but the fact remains that reliable and economical transportation is the chief requirement of arctic oceanography. All other aspects of a productive observational program could be solved fairly quickly on the basis of existing knowledge and experience. Most of the readily available instrumentation of oceanography has been designed to withstand the normal conditions at sea, a heaving ship and a ready supply of power, rather than to operate in the ice and to meet the requirements of an airlift. But to devise oceanographic instruments in miniature and otherwise to improve them for use in the Arctic could be quickly achieved, the bottle-neck for the time-being is the transportation. To set up camps on the ice and to depend on the slow drift of the ice to gain coverage, as has usually been done in the past, does not seem the most efficient way to attack the majority of arctic oceanographic problems. The requirement is to move two trained observers and perhaps 1,000 pounds of equipment to a network of points separated by about 100 miles and to give the men a few hours at each station to make their observations. Until such transportation is available most oceanographers will find it more profitable to study problems for which advances can still be made from ships, and most of the gains in arctic oceanography will probably continue to come as a by-product of expeditions whose objectives are not limited to the classical problems of oceanography.

During the summer season many interesting studies can of course be carried out along the shallow margins of the Arctic Ocean, even from quite small craft. From the ecological standpoint especially, such expeditions will continue to be profitable for many years to come. Another possible approach for both summer and winter work would be to design radio-telemetering instruments that could be air-dropped into open leads to secure observations from the deeper parts of the Arctic Ocean, but until the problem of precise aerial navigation is solved, landing on the ice with the oceanographic instruments will be a sounder method. A reliable geographical fix is especially critical in the case of physical measurements. Nor could a submarine at present really solve this need for accurate navigation, except in so far as it were practicable to surface in open leads. Where am I? and just where is my instrument relative to my position? become increasingly important questions as oceanography emerges from the exploratory stage. These are difficult enough questions to answer with precision from a ship, even in areas where the latest navigational techniques are available. Thus, although mobility is important to an oceanographer, he must also be able to fix his location at frequent intervals.

While the difficulties of transportation may seem considerable today, the Arctic Ocean has at least two great attractions to an oceanographer: It is not nearly as large as, say, the Pacific Ocean, and the ice provides a nearly ideal platform from which to work.

References

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