

SEA ICE STUDIES

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ALTHOUGH there is a considerable literature (U.S.A., 1945) on sea ice, its structure and behaviour is still very imperfectly known. Until twenty-five years or so ago, study of the physical properties of ice was concentrated, for practical reasons, more upon freshwater ice. The greater part of the sea ice literature has been concerned with distribution, and description of the various sorts of sea ice and their classification. One may mention as one of the outstanding works Wright and Priestley's memoir (1922). Several notable contributions were also made to sea ice physics, particularly by Malmgren (1927).

The remarkable growth of interest in the polar regions over the last two or three decades has led to greater attention to sea ice problems. The reason is of course that study of sea ice is fundamental to the movement of shipping into the polar regions, and this in turn is fundamental to development of almost all kinds. So the main application of sea ice studies is to shipping. There are other applications: to aircraft seeking to land on ice, to vehicles seeking to cross a frozen strait, to climatologists wishing to use ice conditions as an index to climatic change, and to synoptic meteorologists interested in the effect of ice on the dynamics of air masses. But none of these is likely in the foreseeable future to eclipse the need of the shipmaster, so that most research will be conducted with this end in view.

Ice studies today tend to fall into several subdivisions. First of all there is pure research, which is concerned with the fundamentals of structure and behaviour. It is the direct continuation of the earlier work: description and classification, leading to detailed study of the physics of sea ice. This work has been carried out in many countries, notably the U.S.S.R., the Scandinavian countries, the U.S.A., Canada, Britain, Germany, and latterly Japan. Published work is widely scattered and not easy to assemble. The only attempt to bring it together has been that by Zubov (1945); his book is most useful, but the author insists it is not to be thought of as a textbook since it contains many of his own views which still require confirmation. The text is entirely in Russian, but a translation of parts has been made by the U.S. Navy Department. Current work in the U.S.S.R. on sea ice physics is not known. A summary published just after the war by Laktionov (1945) indicates its extent,

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and leading specialists such as Zubov, Somov, Gakkel', Gordiyenko, and Volkov have been active in planning and carrying out the work of drifting stations on the ice of the Arctic Ocean from 1948 to the time when this account was written in 1955. So it is to be assumed that much work is being undertaken. Outside the U.S.S.R. the most active centre is the U.S. Navy Electronics Laboratory's Arctic and Submarine Branch, which embarked in 1954 on a comprehensive long-term program of research. A point worth underlining is the change from individual to team-work. In contrast to the quite recent past, ice physics can no longer be importantly advanced by the gifted amateur studying the natural history of sea ice.

Research on the fundamentals naturally affects the other branches of sea ice study. But the latter are sufficiently distinct to be considered separately. They are closely linked with practical demands of ship navigation, and may therefore be called applied research.

At its simplest, the provision of ice information for ships consists in issuing statements as to where ice was last observed. This is comparatively straightforward, and is done today by many agencies in many parts of the world where ships may meet ice. Two main problems are posed by the sending and the receiving of these messages: terminology, and methods of transmission.

Terminology has been most confused. Quite apart from linguistic differences, there have been numerous duplications and overlaps of definition in the English terms. Glossaries attempting to clarify the position have recently been produced by the U.S. Navy Hydrographic Office (U.S.A., 1952), by the Admiralty Hydrographic Department with the help of the Scott Polar Research Institute (G.B., 1953), and by the World Meteorological Organization (Switzerland, 1952). The last two are quite closely similar. But the W.M.O. glossary has been published as a draft only. As such it has already formed the basis for usage in Scandinavia and elsewhere, but it is now likely to be revised owing to the recent belated agreement of a Soviet representative to join the working group. Thus the terminological problem has not yet been solved. But there seems a good chance that agreement among English-speakers may not be too far distant; and once this is achieved, it should not be difficult to link in the other languages by means of linguistic equivalents. Work on this is proceeding.

The chief problem of transmitting ice information is in the use of codes. Codes are necessary in order to economize signal time, but it is difficult to adapt them to ice information. Solutions have been found for areas where the ice is not complex—the Baltic, for instance—but the problem as a whole is not as near solution as the terminological question may perhaps be. International agreement must be the ultimate goal; but at the moment such ice codes as the World Meteorological Organization has approved do not meet the need in the polar regions. Remedies are under consideration, however. Meanwhile, most ice messages to shipping are given in plain language. But the U.S. Navy in 1953 adopted facsimile transmission of ice charts by radio. This is by so much the best solution that its use must ultimately become general.

The next stage beyond reporting the present state of the ice is forecasting. Here one may distinguish the same division which exists in meteorology between climatology and synoptic meteorology. On the one hand there is the use of past records to assess, say, the probability of access to a given place at a given time of year; such researches may be termed ice probability studies. On the other hand, there is the use of present observations to predict the movement of the ice a short time ahead—synoptic ice studies. Both lines of approach have been investigated.

Ice probability studies have led to the publication of ice atlases, in which the likelihood of meeting ice at particular places is shown for different times of the year. The U.S. Navy Hydrographic Office produced one of the northern hemisphere (U.S.A., 1946), and Deutsches Hydrographisches Institut another, which included both polar regions (Büdel, 1950). These give, as intended, a very general picture, which is constructed from the comparatively few known facts with much interpolation. An attempt to give a picture which avoids interpolation and in which the factual basis is clearly set out has been made by the writer and is in course of publication (Armstrong, in press). Studies, which will be broadly similar to this is conception, are about to be undertaken for two more areas: Canadian arctic waters north of Hudson Bay and Strait, and the Graham Land region in the Antarctic.

Synoptic ice studies may be divided into the technique of forecasting and the organization of ice observing. In the technique of forecasting, by far the most work has been done by Soviet research. Since about 1935 more than a dozen Soviet scientists have been examining in detail the factors influencing drift, growth, and decay. A summary in English of their progress up to about 1941 (which is the most recent information available outside the U.S.S.R.) has been published (Armstrong, 1955). Since 1952 the U.S. Navy Hydrographic Office, which has been responsible for ice forecasting in North American arctic waters, has been developing its own techniques, which are largely based on what is known of the Soviet work. Meanwhile for Finnish waters Jurva (1937) studied the pattern of ice development in past years and was able to distinguish trends which could be used for forecasting. In general, the technique of ice forecasting is still in its very early stages (outside the U.S.S.R., where recent progress cannot be evaluated). Further development is likely to be closely linked to advances in sea ice physics.

The organization of ice observing presents a somewhat similar picture. The most highly developed system is the Soviet, as is clear from a work on aerial ice reconnaissance by Karelin *et al.* (1946), and from a more recent book by Deryugin and Karelin (1954). The U.S. Navy Hydrographic Office has successfully developed its own systems (Bates *et al.*, 1954), in general designed for use by less highly trained observers than the Soviet. In the Baltic, where the problem is limited, a system based on rather different principles has been working effectively for many years. The main problems for the polar regions are how to make the best use of aircraft, together with the training of observers to work from them; how to collect the information speedily enough to be usable synoptically, and how to transmit it to the user

in his ship. This last is of course an extension of the problem of transmission discussed above. The whole problem has been under recent review by the Canadian Defence Research Board.

In very brief outline, that is the present position in sea ice studies. Wider knowledge of fundamental sea ice physics is now a cardinal need; the U.S. Navy Electronics Laboratory's program will help here, and one must hope that more of the recent Soviet work will become available. Recently initiated research at McGill University is another useful step. Ice probability studies should be made for all regions to which ships may be required to go, and in such a way as to reflect past records as faithfully as possible in order to get the greatest value from them. Ultimately, perfected forecasting techniques will provide more reliable answers to some of the ship navigator's questions; but probability studies will retain their usefulness as aids to the broad planning of shipping movements. On the synoptic side, there is an urgent need for more exact knowledge of the factors controlling the movement of floes. North American progress in this field appeared in 1954 to have reached the level achieved in the U.S.S.R. in 1939. Organization of the collection of observations and the dissemination of information must go forward on the basis of extensive use of facsimile reproduction.

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