The shifting world of Arctic sea ice

Cracks in the ice hasten heat loss from sea to air.

In the Arctic Ice Dynamics Joint Experiment, polar scientists will be monitoring the everchanging interactions of sea, ice and air

by Louise Purrett

About 10 percent of the world's oceans is sheathed with ice at least part of the year. Large parts of the Arctic Ocean are frequently covered by a 15- to 20-foot layer of ice.

This ice, though it lies in the far northern reaches of the globe, is far from a mere oceanographic curiosity; it has tremendous economic, strategic and climatological significance.

Through this ice lies the Northwest Passage—the long-sought short-cut around North America. The passage has stubbornly resisted attempts at navigation. It was first traversed by ship in 1903, but the trip took three years. Not until 1954 did a ship, the Canadian ship Labrador, make the entire voyage through the Northwest Passage in a single season. In 1969, the S.S. Manhattan proved that it was operationally feasible for a commercial vessel to make the trip, but the economic feasibility was still open to question, and the oil company that operates the Manhattan has since abandoned such efforts and decided to transport its product by other means (SN: 10/31/70, p. 350).

Nevertheless, the sea ice has great economic significance to such nations as the Soviet Union, Canada, Norway, Japan and the United States. Strategically, naval operations in this area, which separates the United States and the Soviet Union, require precise, up-to-date information on the extent and thickness of the Arctic ice, and submarines traveling under the ice shelf need data on under-ice contours.

The Arctic sea ice also critically affects interactions between ocean and atmosphere, influencing world climate in the process. The ice cover reduces the transfer of momentum from the air to the water, suppresses drift currents, and acts as an insulating blanket that keeps out the sun's rays in summer and prevents the water's warmth from escaping in the winter.

To complicate matters, the sea ice is an inconstant phenomenon. The thin veneer of ice is affected by environmental changes on a time scale of years or even months. The southern boundaries of the ice in the North Atlantic, for example, have shifted hundreds of miles in recent historical times. "On the whole," says Dr. Joseph O. Fletcher of the University of Washington, "it appears that sea-ice cover is one of the greatest variables in the environment of the earth's surface."

An understanding of the behavior of this ice and its interactions with its environment is thus essential to solution of many problems in navigation and meteorology. Though there have been a number of independent studies on floating ice islands, they have not been sufficient to gain an understanding of the large-scale interactions of sea, ice and air.

In the spring of 1973, a massive international effort to achieve quantitative understanding of these interactions is scheduled to begin full-scale operation. The Arctic Ice Dynamics Joint Experiment (AIDJEX) will include a number of United States Government agencies (Office of Naval Research, the Office of the Oceanographer of the Navy, the National Science Foundation, the Defense Department's Advanced Research Projects Agency, the National Oceanic and Atmospheric Administration, the U.S. Coast Guard and the National Aeronautics and Space Administration), as well as U.S. and Canadian universities, including the University of Washington and Columbia University. The Canadian Government has already joined in with considerable support, and there is hope that Russian and Japanese scientists will also cooperate. The ultimate goal of the program, says Dr. Fletcher, initial project coordinator, is to predict ice movement and deformation and heat exchange between the ocean and the atmosphere. (On Sept. 1, Dr. Fletcher will become head of the Office of Polar Programs of the National Science Foundation. Dr. Norbert Untersteiner, professor of glaciology at the University of Washington, is the new AIDJEX project coordinator.)

In 1969 the U.S. Office of Naval Research commissioned a team of scientists from the University of Washington and Columbia University to design an experiment to achieve this objective. In November of that year, Canadian and U.S. scientists met in Washington, D.C., to discuss the resulting plan. Many of these scientists had been engaged in Arctic research for many years, says Dr. Fletcher, "and were acutely aware of the limits of what can be learned from single-station observations about the interactions of macroscale fields." Thereafter, an AIDJEX coordinating office was established at the University of Washington.

So far, two pilot projects, aimed at planning the most efficient field program for 1973, have been carried out, in the spring of 1970 and 1971. This year's study, which took place off the Mackenzie River delta of northwestern Canada, involved some 30 U.S. and Canadian scientists who took measurements of water motion relative to ice, air motion, currents and relative motion of ice floes. A final pilot project is slated for next spring.

The experimental design at present calls for answers to three basic questions:

- How is large-scale ice deformation related to external stresses, such as wind and water currents?
- How does ice topography interact with these stresses and strains?
- How do ice deformation and morphology affect the heat balance?

Though sea ice has been thoroughly investigated in the laboratory, there is almost no quantitative knowledge of its large-scale properties. An array of stations, Dr. Fletcher says, would make it possible to find a causal relationship between the internal stress at a given point and regional stresses and strains. In order to take into account nonuniformities in the ice, such as pressure ridges and cracks, a detailed morphological description of the ice within the test area will also be necessary. Frequent aerial surveys, using remote sensing techniques, will provide the necessary descriptions.

Answers to this first question, however, will depend on the answers to the second. The transfer of momentum between the atmosphere and the ice, and between the ice and the ocean, is regulated by the roughness of the ice topography. But topography is in turn influenced by strains generated from wind and water stresses. One important objective of AIDJEX will be to devise methods by which the stresses on the ice can be related to simple variables that can be obtained by remote sensing. For instance, it may be possible to calculate wind stress at a given point from observations of the force and direction of wind. Likewise, water stress depends on the velocity of the ice over the water and on the roughness of the ice shelf's lower surface.

AIDJEX researchers will also need to discover the ways in which stress is transmitted through the ice pack.

The characteristics of the ice cover have obvious effects on heat balance. During the winter, the rate at which heat is transferred between ocean and atmosphere depends on the extent of open water. Heat loss from open water, exposed, for example, by cracking ice, appears to be at least two orders of magnitude more rapid than heat loss from thin ice of equal area. Break-up of ice thus causes heating of the atmosphere.

A crucial part of the heat balance studies is the question of the stability

Wind and water combine to deform the ice, often with spectacular results.

of the Arctic ice cover. If the ice is inherently unstable, concluded a National Academy of Sciences Panel of Glaciology in 1967, "removal of the sea-ice cover might be triggered by natural or human influences. Removal of an unstable sea-ice cover would, in turn, presumably have profound influences on the climate of the Northern Hemisphere." Scientists participating in the Study of Man's Impact on Climate held in Stockholm June 28 to July 16 also emphasized the "delicate balance of the processes which maintain the Arctic sea ice."

In addition to transfer of heat from open water, the researchers will also consider the transfer of heat through the pack ice itself, which is regulated not only by ice thickness but by the thickness of the snow cover.

Summer presents a new spectrum of considerations. In summer, there are only small temperature differences between ice and open water. The only morphological features known to be significant in the summer heat balance are melt ponds. Since the reflectivity of ice is different from that of water, summer melt ponds absorb more radiation than the surrounding ice.

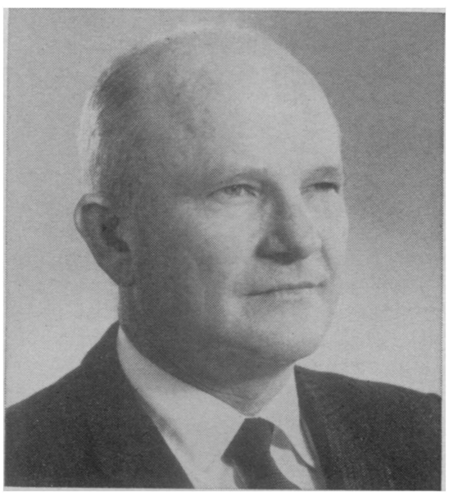
The AIDJEX experiments now envisioned will be conducted from a network of drifting stations in the Arctic Ocean. There will be a number of observation stations, five of which will be manned. The main array will consist of those five manned stations, with four arranged in a square around a central station. Major ice features, such as ridges and floes, have a scale of several kilometers, while atmospheric pressure systems may encompass thousands of kilometers. The square of stations should therefore be on an intermediate scale. The initial square of manned stations might be 100 kilometers on a side. Additional unmanned stations would be placed outside the main array, in a continuation of the 100-kilometer grid.

The researchers hope to make some measurements of ice drift on a smaller scale—say 10 kilometers. Dr. Fletcher suggests that, as a first try, there should be a square of four unmanned stations 20 kilometers on a side.

Remote sensing techniques will also play a significant role in AIDJEX. To date, aerial observations have had limited usefulness, since the ice surface is often obscured by clouds and darkness. Scientists of the National Aeronautics and Space Administration have now developed a microwave imager that will allow AIDJEX researchers to observe ice conditions through clouds and at night. The imager, says Dr. William J. Campbell of the University of Washington, can not only detect cracks in the ice but also gives an indication of the age of the ice. Such an imager will be included on Nimbus F, which will be orbiting while the main AIDJEX effort is in progress.

The main field program of AIDJEX will last at least a year, in order to observe seasonal changes in the state of the ice cover. Upon completion of the field work, AIDJEX will coordinate the reduction, distribution and analysis of the data collected. The total duration of the AIDJEX project would be about six years.

The final goal of all this is to formulate a predictive model that will yield forecasts of ice deformation and drift on the basis of a few easily measured quantities. The model the researchers hope for would compute each of the stresses in the ice from observations of wind, position, pressure and surface characteristics. Such a model, aside from providing insight into the mechanics of ice deformation, will make it possible to estimate, from a given atmospheric pressure field, what the ice conditions in a given location will be. And, beyond this, the models of ice dynamics that AIDJEX would produce would eventually be incorporated into models of atmospheric and oceanic circulation on a global scale. "Only then," says Dr. Fletcher, "will it be possible to examine the global consequences of natural or artificial modifications in the extent, thickness, or circulation of the Arctic ice cover." □



Univ. of Washington

Fletcher: The goal is prediction.