JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 92, NO. C7, PAGES 6716–6718, JUNE 30, 1987

Introduction: Summer Marginal Ice Zone Experiments During 1983 and 1984 in Fram Strait and the Greenland Sea

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A marginal ice zone (MIZ) occurs where polar and temperate climate systems interact to form a transition between open ocean and pack ice regimes. This transition is characterized by large horizontal gradients in the properties of the ice, ocean, and atmosphere. As a geophysical boundary, the MIZ is unique in the complexity of the vertical and horizontal air-sea-ice interactions which take place there. Over a seasonal cycle, the ice edge can migrate hundreds of kilometers north and south to produce large variations in maximum and minimum extent. The MIZ is most extensive (more than 20×10^3 km during winter) in the southern ocean, where it forms a continuous, roughly circular annulus around the continent. The geographical distribution of the MIZ in the northern hemisphere is complicated by numerous land masses which largely confine it during the winter to the Sea of Okhotsk and to the Bering, Labrador, and Greenland-Norwegian seas. During the spring and summer the MIZ retreats from the peripheral seas. Generally, the total extent of the northern MIZ is less than one-half that of the southern. Numerous studies have demonstrated the sensitivity of weather and climate to the state of the polar ice cover, and it is of fundamental importance to understand how annual and interannual variations in ice extent are related to large-scale and mesoscale circulations in the atmosphere and ocean. Successful modeling and parameterization of processes which govern the location and state of the MIZ are important not only for predicting the impact of sea ice on global climate but also for furthering man's activities in the MIZ regions (e.g., offshore oil exploration, seaborne transport of Arctic resources, development of the rich fisheries close to the ice margin, and naval operations).

In recent years, realization of the scientific and economic significance of the MIZ has focused attention on the need for coordinated, multidisciplinary studies of conditions and processes near ice–open ocean boundaries, and has led to the development of the Marginal Ice Zone Experiment (MIZEX). Although of substantial interest, the remoteness of the vast Antarctic MIZ poses serious logistic difficulties, and MIZEX efforts to date have concentrated on the more accessible northern MIZ. Considerable work has been carried out in the Bering Sea (MIZEX West) where thin first-year ice overlies shallow water. Papers describing some of these studies have appeared in a previous marginal ice zone issue (*Journal of Geophysical Research*, volume 88, number C5, 1983). The most ambitious efforts, however, have taken place in the Fram Strait and Greenland Sea (MIZEX East), where most of the heat and water exchange between the Arctic Ocean and the rest of the world ocean occurs. The MIZEX East program included two summer field experiments, MIZEX '83 (June–August) and MIZEX '84 (June–July), in the Fram Strait region between Svalbard and Greenland (Figure 1). MIZEX '84 was the largest research program ever conducted in a marginal ice zone. Integrating the interests and the resources of 11 nations, MIZEX '84 utilized seven ships, 45 satellite-tracked buoys, eight remote sensing and meteorological aircraft, and four helicopters plus the output of four satellite systems to support a multidisciplinary team of over 200 scientists. Investigators, equipment, and support came from Canada, Denmark, the Federal Republic of Germany, Finland, France, Ireland, Norway, Sweden, Switzerland, the United Kingdom, and the United States.

The goal of MIZEX East was to gain an understanding of mesoscale physical processes by which the ice, ocean, and atmosphere interact in a complicated deepwater MIZ area and to define which of these processes control the location and movement of the ice edge. Complementing this goal were efforts to determine how the MIZ affects biological and acoustical activity. The scientific program was divided into seven disciplines: ice, oceanography, meteorology, remote sensing, modeling, acoustics, and biology. Objectives of the ice program were to monitor regional changes in the state and physical properties of the ice cover, to define the dynamic and kinematic behavior of the ice both at the extreme edge and in the interior MIZ, and to study processes which affect the thermal interaction of the ice with the ocean and atmosphere. The major emphasis of the oceanographic program was to derive a synoptic picture of ocean currents and structure to assess the role of fronts, eddies, and large-scale currents in the movement and decay of the MIZ. Other studies considered (1) vertical transport of heat, mass, and momentum in the upper ocean, (2) the relationship of these fluxes to changes in mixed layer structure and ice conditions, and (3) the nature of the internal wave field and oceanic fine structure in the summer MIZ. The meteorology program determined how the atmospheric boundary layer and surface heat fluxes respond to changes in ice conditions, and the extent to which synoptic wind patterns are modified by the presence of the ice edge. Remote sensing objectives were to obtain a synoptic picture of the ice morphology and evolution of the experimental area and to gain understanding of the interaction of electromagnetic radiation with ice and ocean surfaces. The ocean acoustics program focused on the propagation of acoustic signals through the highly variable oceanographic and ice conditions of the MIZ and on ambient noise generation within the MIZ. Biological observations considered the distribution of nutrients, phytoplankton and zooplankton, and rate processes associated with each tropic level.

Several types of operations were required to support the objectives of the MIZEX East program. Experiments related

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Paper number 7C0336.
0148-0227/87/007C-0336$02.00

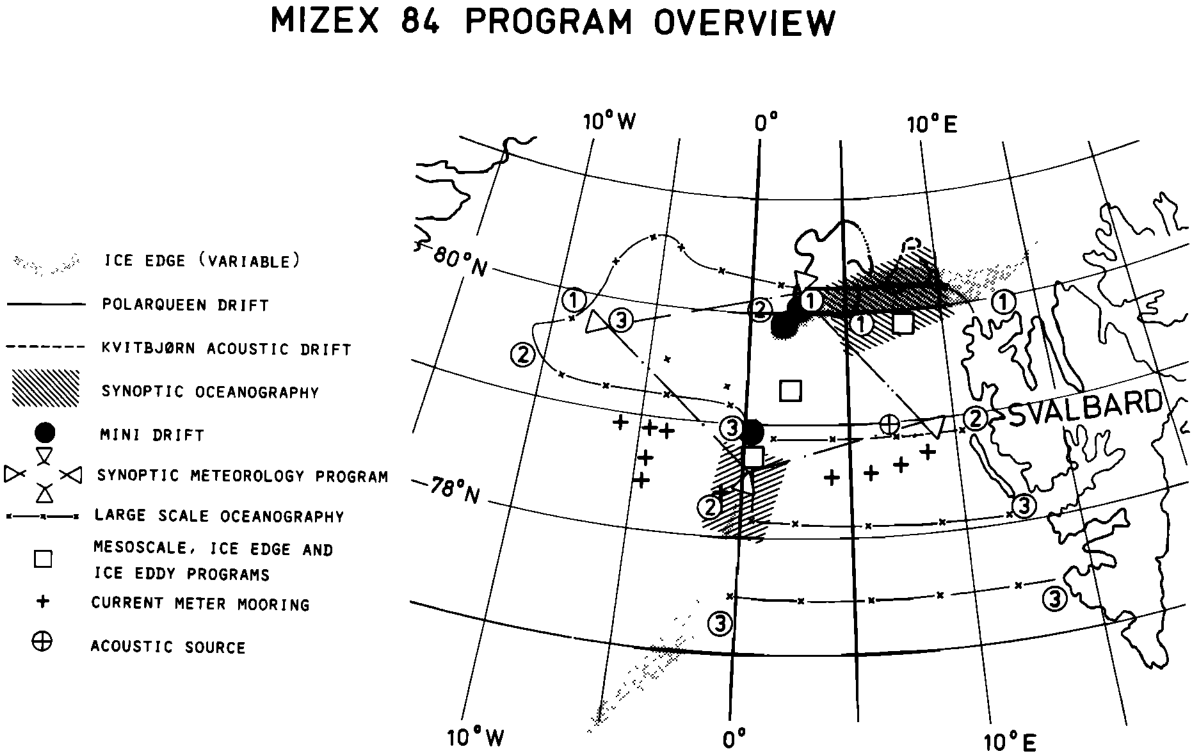

Fig. 1. MIZEX '84 program overview. The *Polarqueen* drift in the ice pack was divided into two segments during the experimental period of June–July 1984. The *Kvitbjorn* acoustic drift took place east of *Polarqueen* during June. Two synoptic conductivity-temperature-depth (CTD) surveys were conducted from the ice edge and openwater ships. Mesoscale sea ice and ocean eddy studies were supported by repeated remote sensing aircraft overflights. A mini drift experiment was designed to obtain data on ice kinematics near the extreme edge. The synoptic meteorology program involved four ships (separated by as much as 200 km) and several aircraft in an intensive study of changes in atmospheric conditions across the MIZ. Large-scale CTD transects and current meter moorings provided basic information on large-scale, long-term oceanographic conditions. Circled numbers 1, 2, and 3 indicate coordinated phases or projects of field operations.

to the oceanic and atmospheric boundary layers, heat and mass balance of the ice, internal waves, high-resolution ice kinematics, and acoustics required a stable platform stationary with respect to the ice. This platform was provided by a drifting ship, the M/V *Polarqueen*, during MIZEX '84. Supplementing the *Polarqueen* was the R/V *Kvitbjorn* and F/S *Polarstern*, which assumed the role of short-term drift stations for periods of intensive acoustic and ice edge kinematics studies. Operating in the open water were the USNS *Lynch*, the M/S *Hakon Mosby*, and the F/S *Valdivia*, which made extended hydrographic sections and deployed current meter arrays outside the ice edge. Acoustics studies were also carried out by the M/S *H. V. Sverdrup*, which was anchored off the west coast of Svalbard. Hydrographic surveys beneath the ice were carried out from the ice edge survey ships *Polarstern* and *Kvitbjorn*. These ships played a key role in a wide variety of studies related to eddies, ice properties, meteorology, remote sensing, and biological activity. One of the largest coordinated activities was a 5-day (July 9–14) synoptic meteorology experiment involving four ships (*Polarqueen, Polarstern, Mosby*, and *Valdivia*) and several meteorological aircraft (German Falcon and NOAA P-3) (Figure 1). In addition to the ships, extensive use was made of helicopter surveys, SOFAR floats, and various types of automated drifting buoys.

One important aspect of MIZEX '84 was the use of remote sensing aircraft and satellites to obtain sequential observations of many highly variable ice-ocean phenomena (e.g., ice edge position, ice concentration, eddy position and structure, wave height, and ocean surface wind) during all weather conditions. Active and passive microwave observations were used to select the initial site of the experiment, to aid in emplacement of buoys, and to direct the ships to transient ice-ocean events. Research aircraft of varying types (French B-17; Canadian Convair 580; Norwegian P-3; and U.S. NASA Convair 990, NOAA P-3, German Falcon, Danish Twin Otter, and U.S. Navy P-3) combined to make MIZEX '84 the most comprehensive remote sensing experiment performed in the Arctic. The goal of obtaining sequential, simultaneous active and passive microwave observations of a mesoscale ice-ocean area was finally achieved.

More detailed information on scientific questions, experiment design and field operations is found in works by *Johannessen et al.* [1983] and the *MIZEX Group* [1986].

The MIZEX East papers in this issue represent a systematic presentation of results from the summer experiments. It is emphasized that physical processes are significantly different during the freezing season and that one must understand both seasons to model the interannual variability of the MIZ. A complimentary winter program was started in the Greenland Sea during March and April 1987, with a major investigation planned for winter 1989.

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(Received April 2, 1987;
accepted April 6, 1987.)