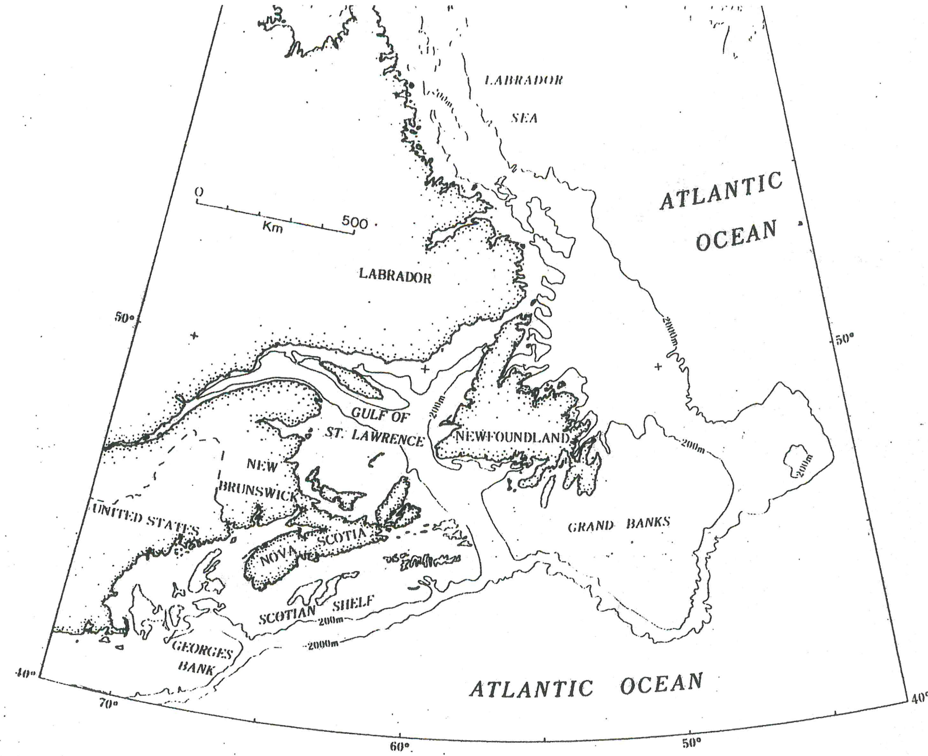

Fig. 1—Canadian Atlantic Coast and Continental Shelf.

Extreme wave height distribution along the Canadian Atlantic Coast

A rig built for a 20-meter design wave may withstand sea conditions on Scotian Shelf, but would probably fail over Grand Banks or off the Labrador Coast

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In recent years oil exploration has greatly increased on the Continental Shelf of the Canadian Atlantic Coast. All available exploration permits have been acquired and several oil rigs and ships are drilling on the Nova Scotian Shelf, on the Grand Banks and on the Labrador Shelf.

This exploration is faced with exceptional technological problems unique to the aquatic environment, especially the sea state. As in other coastal areas, available wave information was inadequate for the design of oil rigs, marine structures, safety standards and planning offshore operations. A solution therefore had to be found to provide information required, particularly with respect to the seasonal occurrence and distribution of extreme wave heights along the seaboard.

This investigation covers the offshore region from the Gulf of Maine to Hudson Strait and seaward to the 2,000-meter depth contour (Fig. 1). The depth over the Continental Shelf is generally between 75 meters and 250 meters except for some shallower areas on Georges Bank, Sable Island Bank and on the south tip of the Grand Banks, where depths are less than 50 meters. Thus, over most of the shelf, with the exception of the nearshore region and shallow areas mentioned, waves propagate as "deep water" waves, their motion being unaffected by the bottom topography.

Wave Observation, Processing

Wave data were obtained primarily by visual observations from ships. Some information was derived from the wave gages on oil exploration rigs. Twice daily, wave and weather obser-

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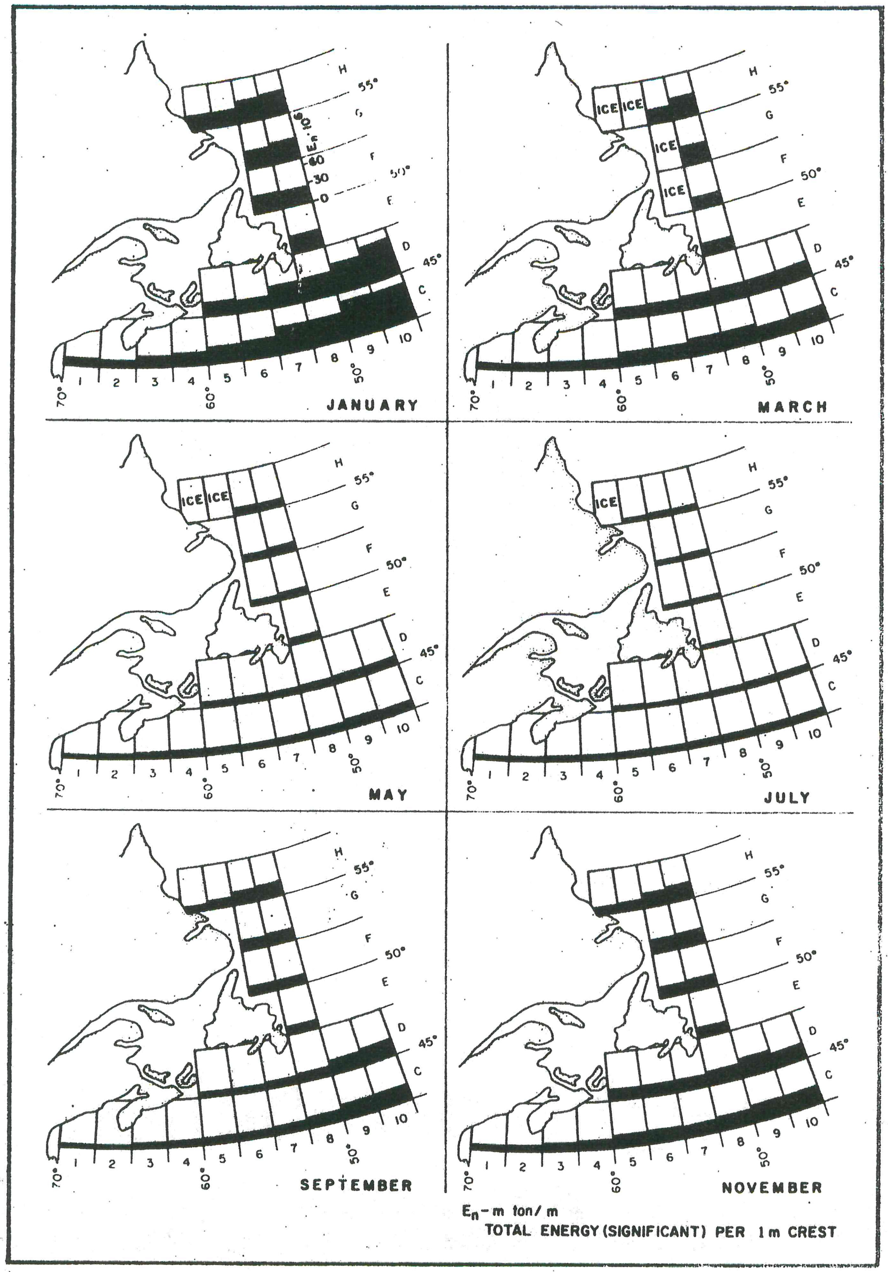

Fig. 2—Bimonthly nondirectional energy spectra.

vations of 30 to 40 stations consisting of weather ships, Canadian and U.S. government and Navy ships, merchant ships and oil rigs are radioed to the Maritime Forces Weather Center. Here, the data are reviewed on a 24-hour basis, and related continuously to the preceding and present wave and wind environment by meteorologically trained personnel. Information which does not fit into the developing pattern is checked for errors in observing, reporting or communication and, if found faulty, discarded. By this process, wave data are subjected to a large measure of quality control. The data are plotted on charts and then lines of equal wave height are drawn. The resultant information is issued twice dai-

It has been stated by Wiegel[1] and Ippen[2] that wave properties obtained by visual observations are equivalent, for practical purposes, to those defined as "significant waves"; the height (H_{sig}) being the mean height of the highest third of all the waves in a wave train. The significant wave used was considered to be representative of the sea state for a 6-hour time interval. The maximum wave height (H_{max}) is related to the significant wave height in a Rayleigh relationship. According to Wiegel[1], Ippen[2] and Thom[3], the ratio between the extreme wave heights and the significant wave height can be assumed to be about 1.8:1.

In coastal and offshore operations, annual and longer term

year maximum are of utmost importance. The statistical treatment for long-term maxima described by Draper,[4] has been applied to the maximum wave heights of each 6-hour period for the entire year of 1970 and plotted on probability paper against percentage exceedance. The long-term maximum wave heights are then extrapolated.

To evaluate energy distribution and its seasonal and directional variation along the coast and over the shelf, the energy of the six-hourly significant wave was calculated. The energy per wave length and per unit width of wave crest in the m-ton-sec system is given by:

$$E = (1/8)\, \gamma H_{sig}^2 \cdot \lambda [m\ ton/m]$$

where γ is the specific weight of sea water (approximately 1.025 [ton/m^3]) and λ is the wavelength (1.56 T^2 [m] in deep water, where T is the wave period in seconds). For a 6-hour period, the number of waves which occurs is: $n = 6 \cdot 3600/T$, and the total energy per meter of wave crest is:

$$E_n = 4.32 \cdot 10^3\, H_{sig}^2 \cdot [m\ ton/m]$$

Results

The results are presented as follows:

(a) Bimonthly nondirectional energy distribution for the entire region (Fig. 2)

(b) Three representative samples of monthly directional energy spectra, (1) the region off the Labrador coast, (2) the outer region of Grand Banks, (3) the Scotian Shelf (Fig. 3)

(c) Long-term, i.e., 10 and 100-year most probable maximum wave height for selected areas (Fig. 4)

(d) Maximum wave height distribution along the coast and over the shelf for 1970 (Fig. 5)

(e) "Design wave" (100-year maximum wave height) distribution along the coast and over the shelf (Fig. 6).

Conclusion

The results in Figs. 2, 3 and 4 demonstrate clearly that the sea state along the coast was highly non-uniform with respect to time and space. During the winter, the monthly energy level was approximately five times greater than during the summer. Energy concentration on the Grand Banks and along the coast of Labrador was three to four times that over the Scotian Shelf. The reason for this lies in the seasonal vari-

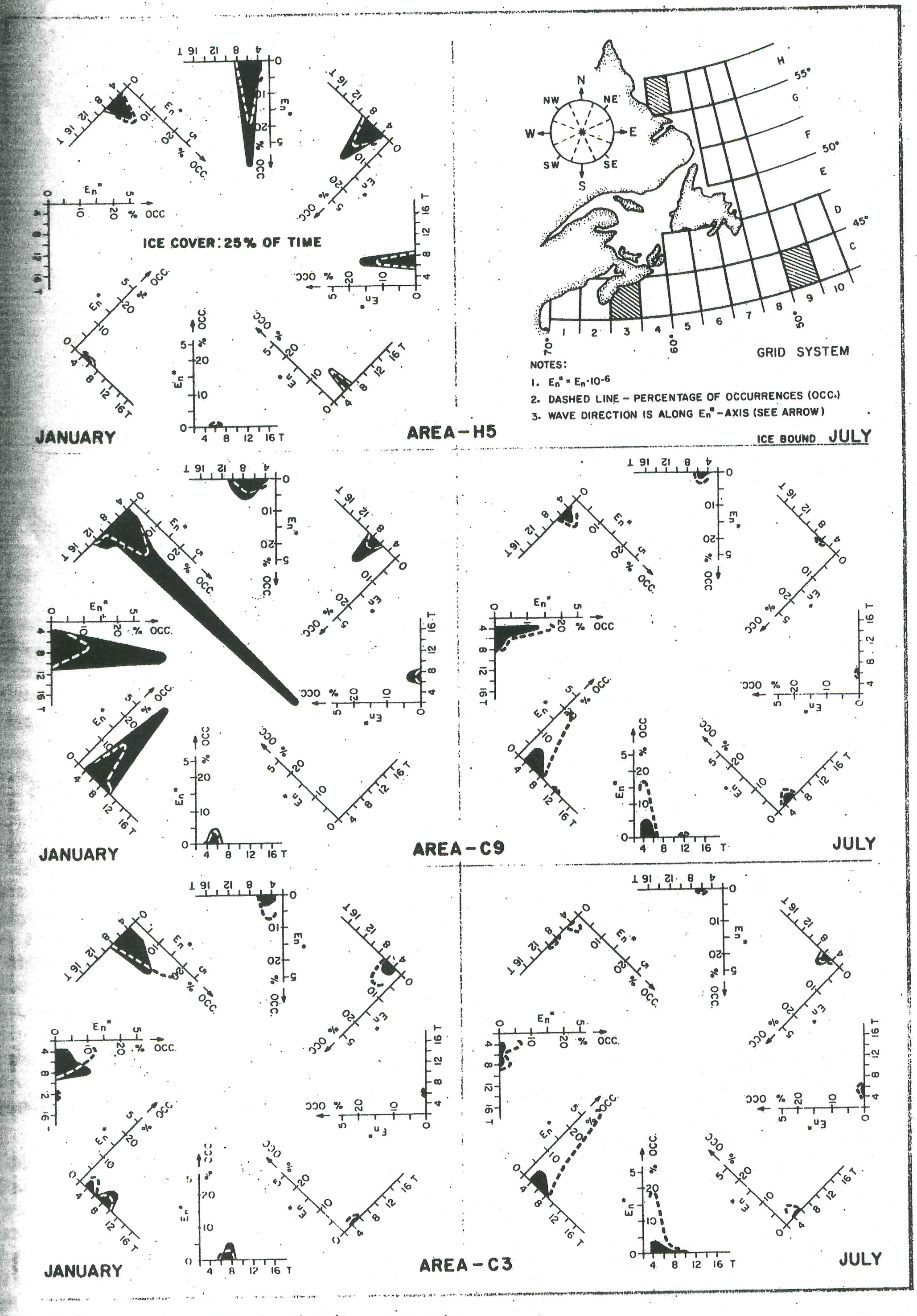

Fig. 3—Samples of monthly directional energy spectra.

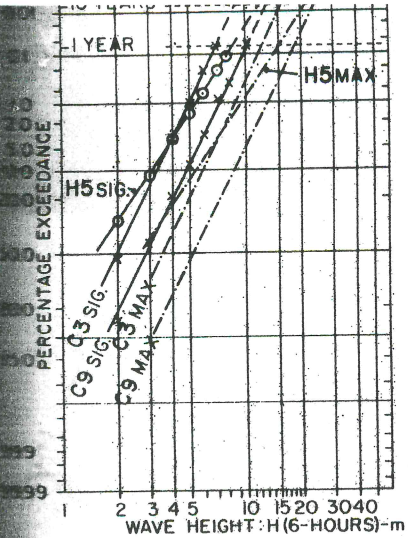

Fig. 4—Long-term significant and maximum wave height prediction.

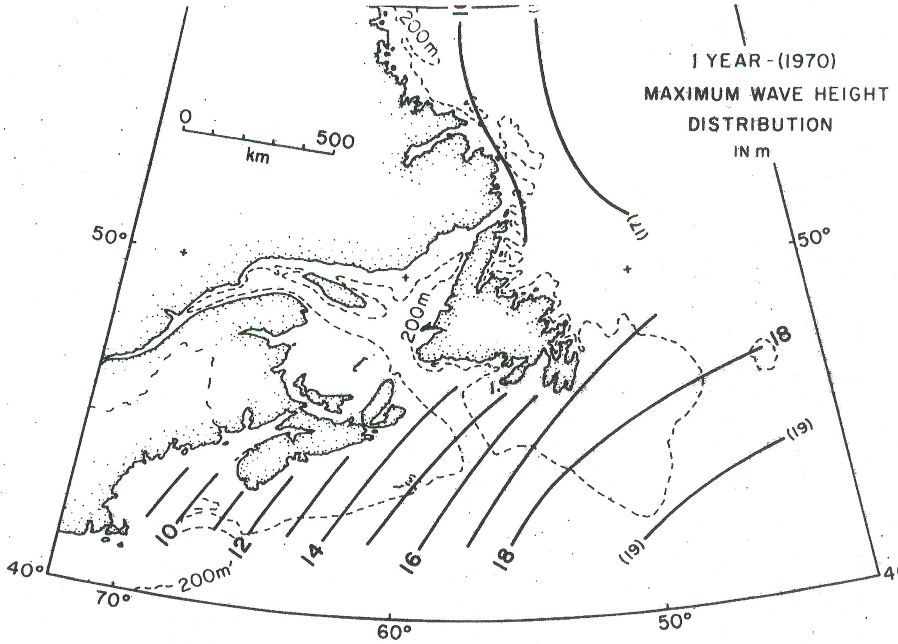

Fig 5—One-year (1970) maximum wave height distribution.

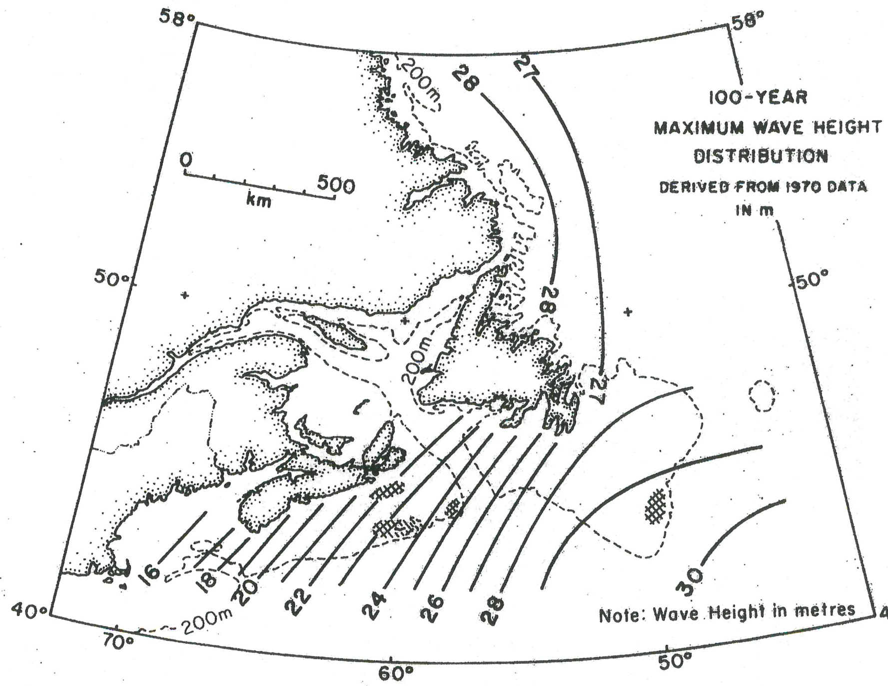

Fig. 6—"Design wave" (100-year wave) distribution.

rthwest winds are offshore relative the southern coast thereby reducing sea state by opposing the mid-Attic waves, and are parallel to the stern seaboard where they generate ge seas along the coast of Labrador over Grand Banks. During the mmer, winds are primarily from thwest along the southern coast away from the eastern seaboard. ce these winds are light, wave acn along both coastlines is very low.

In 1970 extreme wave heights var along the coast and over the shelf shown on Fig. 5. They increased m 9 meters (30 ft.) in the Gulf of aine to about 13 meters (43 ft.) on Scotian Shelf and reached a maxium of 19 meters (62 ft.) on the rand Banks. Off the coast of Labrador they were slightly lower, in the order of 17 meters (56 ft.). The 1971 ta, which in the meantime are being alyzed, show the same wave height d distribution pattern, except at the trance to the Bay of Fundy and ong the coast of Labrador, where the treme wave heights of 1971 were about one meter higher than during 1970.

In designing oil rigs the "lifetime" r "design-wave" is usually the 100-year wave. As shown on Fig. 6, this wave varies from 16 meters (52 ft.) in the Gulf of Maine at the U.S.-Canada border to 30 meters (98 ft.) at the outer region of Grand Banks. Along the coasts of eastern Newfoundland and Labrador the "design wave" is quite constant and almost of the same magnitude as over Grand Banks. The shaded areas on Fig. 6 indicate that in these regions the "design wave" may be still greater than designated, due to shoaling and refraction.

Extreme value statistics were also applied to obtain long-term maximum wave periods. It was surprising to find that the maximum 100-year significant wave period, in the order of 20 seconds, was very much the same along the entire coast. No attempt was made to relate this period to the absolute maximum wave period.

From these results, the conclusion must be drawn that a drilling rig which has been built for a "design wave" of, say, 20 meters may withstand successfully all sea conditions on Scotian Shelf, but would probably fail over Grand Banks or off the Labrador coast.

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