Bedford Institute of Oceanography

L'Institut océanographique de Bedford

Dartmouth / Nova Scotia / Canada

Sea State During the Breakup of the Oil Tanker Kurdistan

Hans J.A. Neu

Report Series / BI-R-81-11 / July 1981

The Bedford Institute of Oceanography is a Government of Canada establishment whose staff conduct oceanographic research and hydrographic surveys in a wide range of marine environments. Various government organizations are represented at the Institute including: the Atlantic Region of the Canadian Hydrographic Service, Atlantic Oceanographic Laboratory, Institute Facilities, Marine Ecology Laboratory, and Marine Fish Division of the Department of Fisheries and Oceans; the Seabird Research Unit of the Canadian Wildlife Service, Department of Encironment; the Atlantic Geoscience Centre of the Geological Survey of Canada, Department of Energy, Mines and Resources; and several other smaller groups.

L'Institut océanographique de Bedford est un éstablissement du governement du Canada; son personnel s'occupe de recherches océanographiques et d'études hydrographiques dans divers milieux marins. L'Institut regroupe, dans ses installations, divers organismes gouvernementaux, y compris la Région de l'atlantique du Service hydrographique du Canada, le Laboratoire océanographique de l'Atlantique, les Ressources de l'institut, le Laboratoire d'écologie marine, et la Division des poissons d'eau de mer du ministère des Pêches et Océans; la Soussection de recherche sur les oiseaux marins du Service canadien de la faune, ministère de l'Environnement; et le Centre géoscientifique de l'Atlantique de la Commission géologique du Canada, ministère de l'energie, des Mines et des Ressources, ainsi que plusieurs autres plus petits groupes.

BEDFORD INSTITUTE OF OCEANOGRAPHY
Dartmouth, Nova Scotia
Canada B2Y 4A2

SEA STATE DURING BREAKUP OF THE OIL TANKER KURDISTAN

by
Hans J.A. Neu

Department of Fisheries and Oceans
Ocean Science and Surveys, Atlantic

JULY 1981 REPORT SERIES BI-R-81-11

ABSTRACT

The sea state prior to and during the breakup of the oil tanker Kurdistan in Cabot Strait on 15 March 1979 is analyzed and described. A North Atlantic winter cyclone, with a severity similar to that which normally occurs once every month from November to March, passed the region. During the height of the storm and in the open water to the approach of Cabot Strait, H_{sig} was generally between 7 and 7.5 m with H_{max} between 12.5 and 13.5 m. Along the edge of the ice field H_{sig} was amplified probably to 8 m with H_{max} in the order of 14.5 m. The tanker entered the ice pack in Cabot Strait during the latter part of the storm when waves were still high. The crack in the hull of the vessel was noticed when the sea state in the open water had declined, and the tanker broke apart when the wave height was only two-thirds of that at the peak of the storm, that means when the energy in the wave field was reduced to about 50%.

RÉSUMÉ

L'auteur analyse et decrit l'état de la mer avant et pendant la rupture du pétrolier Kurdistan dans le détroit de Cabot le 15 mars 1979. Un cyclone hivernal de l'Atlantique Nord, d'une violence comparable â ceux qui se produisent normalement une fois par mois de novembre â mars, passait dans la région. Pendant le plus fort de la tempête, et dand l'eau libre aux approches du détroit de Cabot, H_{sig} se situait en général entre 7 et 7,5 m et H_{max} entre 12,5 et 13,5 m. En bordure du champ de glace, H_{sig} était probablement de 8 m et H_{max} de l'ordre de 14,5 m. Le pétrolier pénétra dans les glaces dans le détroit de Cabot pendant la deuxième moitif de an tempête alors que les vagues étaient encore élevées. La fissure dans la coque du navire fut remarquée lorsque l'état de la mer dans les eaux libres était moins violent, et le

pétrolier se brisa en deux lorsque la hauteur des vagues n'était que les deux liers de qu'elle de ce qu'elle avait été au plus fort de la tempête, c'est-à-dire lorsque l'énergie dans le champ d'ondes avait dimiue de 50% environ.

TABLE OF CONTENTS

LIST OF FIGURES

1. INTRODUCTION

The tanker Kurdistan, carrying about 30,000 tons of Bunker-C oil, left Point Tupper in the Strait of Canso in the early hours of 15 March 1979 for Sept Iles in the Gulf of St. Lawrence. Sailing along the coast of Cape Breton (Fig. 1) in a stormy sea, the vessel entered a heavy ice field in Cabot Strait at about noon the same day. Several hours later, after leaving the ice the Kurdistan reported cracks developing in its hull and later in the evening, the tanker split into two sections. This study was made at the request of the Canadian Coast Guard (Transport Canada) to review the sea state experienced by the Kurdistan at this time.

2. WEATHER AND WIND

During the winter, the weather in the North Atlantic is largely controlled by the Icelandic Low and Azores High. The pressure difference between the two locations generates the 'Westerlies' that dominate the wind pattern between 35° and 60°N. Superimposed on this prevailing condition are the North Atlantic cyclones which occur when cold Canadian continental air encounters the moist warm air over the Atlantic, bringing large day-to-day fluctuations in atmospheric pressure and thus in wind strength and direction. During the course of a winter more than 200 of these cyclones, sometimes in groups of 2 to 3, can travel along the coasts of the New England states and Atlantic Canada and then head towards Iceland where they usually reach their greatest intensity. Some of these storms, usually the smaller size, turn landward and spend their energy over Newfoundland and the Labrador Sea. This latter storm is the type that the Kurdistan encountered along the coast of Cape Breton and in Cabot Strait.

Figure 2 shows the atmospheric sea-level pressure on 15 March 1979 at 0200 AST (0600Z). This pattern is representative of the general condition

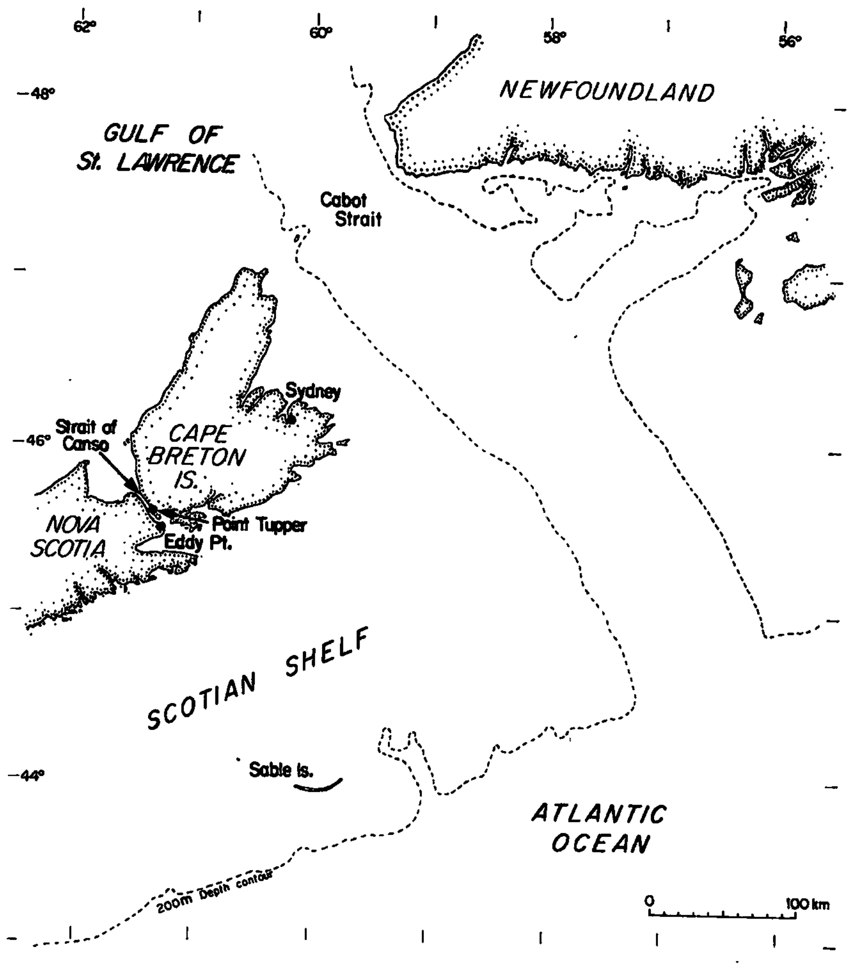


Figure 1. Map of the Cabot Strait region

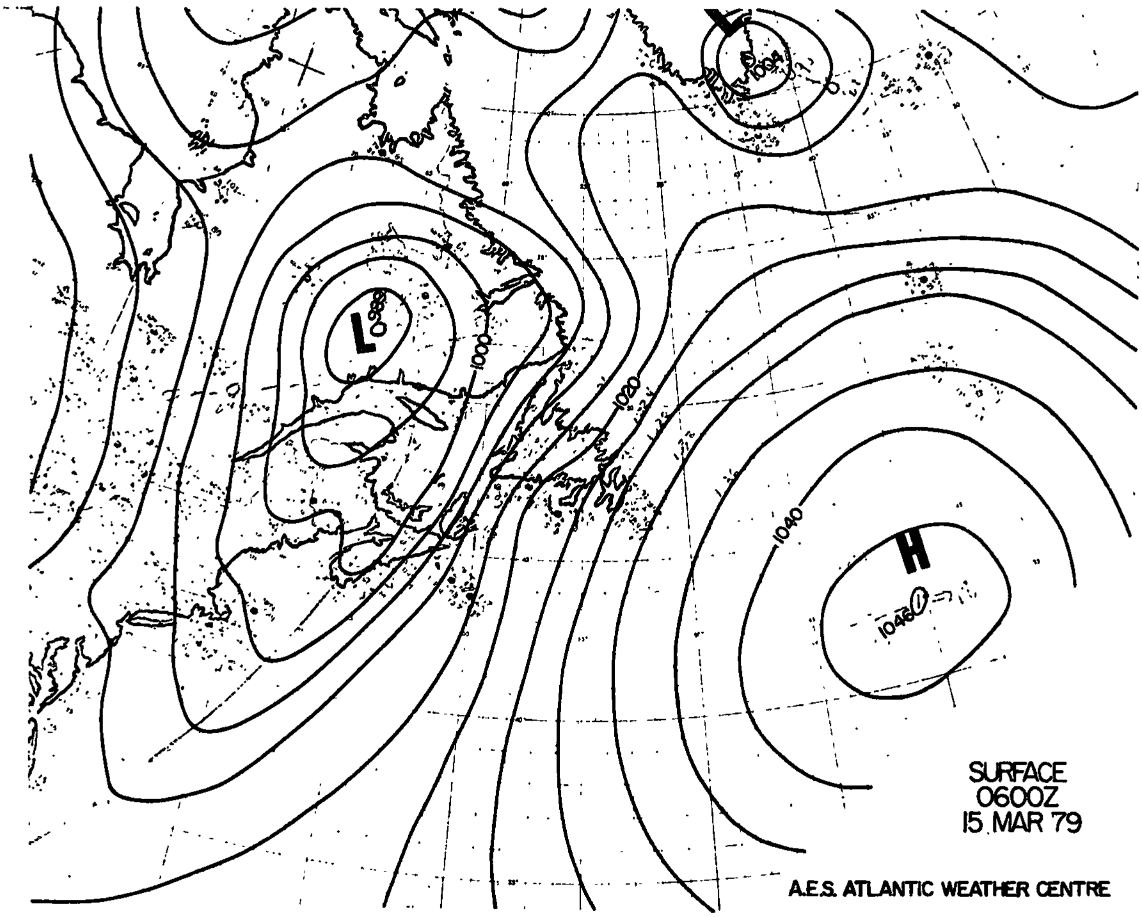


Figure 2. Sea-level pressure in millibars on 15 March 1979, 0600Z

(from AES Atlantic Weather Chart)

which prevailed when the major part of the wave field was generated. During this period there was a large High halfway out to the Azores and two Lows - one over the Laurentian Highlands north of the St. Lawrence estuary and the other at the south tip of Greenland. As indicated by the spacing of the isobars, the largest pressure gradient and thus the strongest winds were along the coast of Nova Scotia and Gulf coast of Newfoundland, with directions from the south-southwest. The fetch length of this wind field was between 800 and 1400 km. The strength of the wind recorded at the coastal station in Sydney (Fig. 3) was between 45 and 60 km/hr and on Sable Island between 40 and 50 km/hr, the latter having been located more toward the edge of the stronger wind field. Over the open water between Sable Island and the mainland, ships reported winds of 55 km/hr (30 knots).

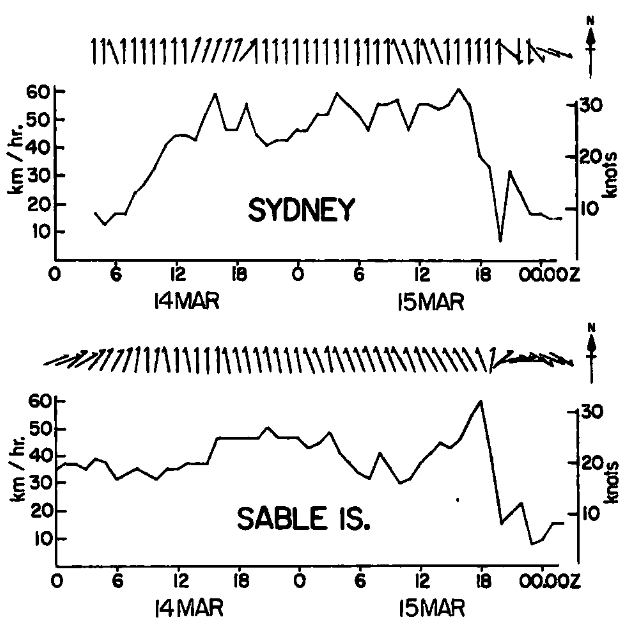


Figure 3. Wind records of Sydney and Sable Island (from AES Atlantic Region)

3. GENERAL WAVE INFORMATION

Data for a sea state description can be obtained by four methods, they are: hind-casting from wind, measurements with gauges, aerial surveys, and visual observations from ships. As reasoned by Neu (1976), the latter method is the most practical and reliable method for the Canadian waters and the North Atlantic. The data are provided by the Canadian Forces METOC Centre in Halifax, in the form of synoptic wave charts.

Four times daily, wave and weather observations at 40 to 100 stations consisting of weather ships, Canadian and U.S. government and navy ships, merchant ships, and oil drilling platforms, are radioed to the METOC Centre where they are reviewed on a 6-hour basis by personnel trained in meteorology and wave climatology. Information which does not fit in the developing pattern is checked for errors in observing, reporting, or communicating and, if found faulty, discarded. By this process, the initial data are subjected to a large degree of quality control. It is obvious that individual observations taken from a ship may not always be very accurate; but with the application of the control, and by reviewing the data constantly in time series and spatially, the data become highly consistent. From these data long-term statistics, have been established and a 3-year (1970-1972) wave climate for the North Atlantic, a 2-year wave climate for Canadian waters including Gulf of St. Lawrence, Bay of Fundy, and Labrador Sea, and a 10-year climate for the Scotian Shelf have been developed. The results proved to be very reliable and accurate to be better than $\pm\frac{1}{2}$ metre.

The METOC charts were used to reconstruct and analyze the seastate during the Kurdistan incident.

The data given in the charts are visually observed wave heights and wave periods. The relationship between visual observations, significant wave height (H_{sig}) and maximum wave height (H_{max}), and the period at the peak of the power spectrum (T_p), has been addressed by a number of researchers (Wiegel, 1964; Ippen, 1966) who have established from short-term comparison that the visual observed wave height (H_v) is for all practical purposes identical to H_{sig}, which is the mean height of the highest one-third of the waves in a record. This was verified by Neu (1976) for long-term comparisons (more than 6 months) on the Scotian Shelf. H_{sig}, however, is not an individual wave, but a value which represents the severity of a sea state. For instance, in a storm with H_{sig} of 7 m, the waves in the wave field vary in height from 1 m to 13 m; the average height H_{av} is about 4.4 m; the mean of the highest 10% is 9 m; 16 to 17% of all the waves or every sixth wave is higher than 7 m. Similarly, for the periods there is also a variety or spectrum of values. A visually observed period (T_v) of 10 s represents a range from about 4 s to 18 s with an average (T_{av}) of about 8 s and a period at the peak of the power spectrum (T_p) of about 12 to 13 sec. Larger periods can occur, but do not necessarily coincide with the highest waves in the wave field. To summarize, the values given on the charts and in the analysis are not the largest or extreme values of the wave field, but are figures which represent the sea state as a whole for the time interval specified. As a general rule, maximum wave heights (H_{max}) can be obtained by multiplying H_{sig} by a factor of 1.8, and the period at the peak of the power spectrum (T_p) can be obtained by multiplying the visual observed period (T_v) by a factor of 1.2 to 1.3.

4. WAVES OF THE STORM

Prior to 14 March, waves along the Atlantic coast from North Carolina to Newfoundland were between 2 and 3 m in height and with periods of 6 to 7 s. This is typical for the winter season with no storm active in the region. During the course of the day a storm started to develop near Cape Hatteras, N.C., which increased the sea state to 4 m (H_{sig}) as seen on Figure 4. Twelve hours later at 0000Z, 15 March 1979, the wave field had grown to 6 m height at its centre and progressed northeastward with a speed of about 20 km/hr. From here on, while passing along the coast of Nova Scotia, the speed of the wave field increased to between 40 and 45 km/hr, and the sea state intensified offshore to a significant wave height of 7 m which contains, as described in the previous chapter, waves of up to 13 m height. The apex of the wave field was heading directly for Cabot Strait and the south shore of Newfoundland. The peak of the storm reached the Strait about 0930 AST (1230Z)(Fig.5) but waves in excess of 6 m (H_{max} = 11 m) lasted from about 0600 AST to about 1400 AST. The wave periods (T_V) during the storm and for 12 hours afterward (Fig. 6) were 10 s for the entire region. Thus, the period at the peak of the power spectrum where most of the wave activity occurred, was in the order of 12 to 13 s. After the storm had hit Newfoundland the centre of the wave field started to veer off into the easterly direction with a progressive decline in its propagation speed. On 16 March the sea state in the wave field gradually decreased and the storm decayed over the Grand Banks of Newfoundland.

While the storm was passing along the coast of Nova Scotia, the direction of the waves in the wave field changed progressively. As indicated by ship observation (Fig. 7), first (at 0000Z), waves along the entire coast, the south coast of Newfoundland included, were primarily from south-southwest, while 6 hr later this changed to more southerly. At the height of the storm the waves in Cabot strait were from south-south-east. At about 1800Z the wind

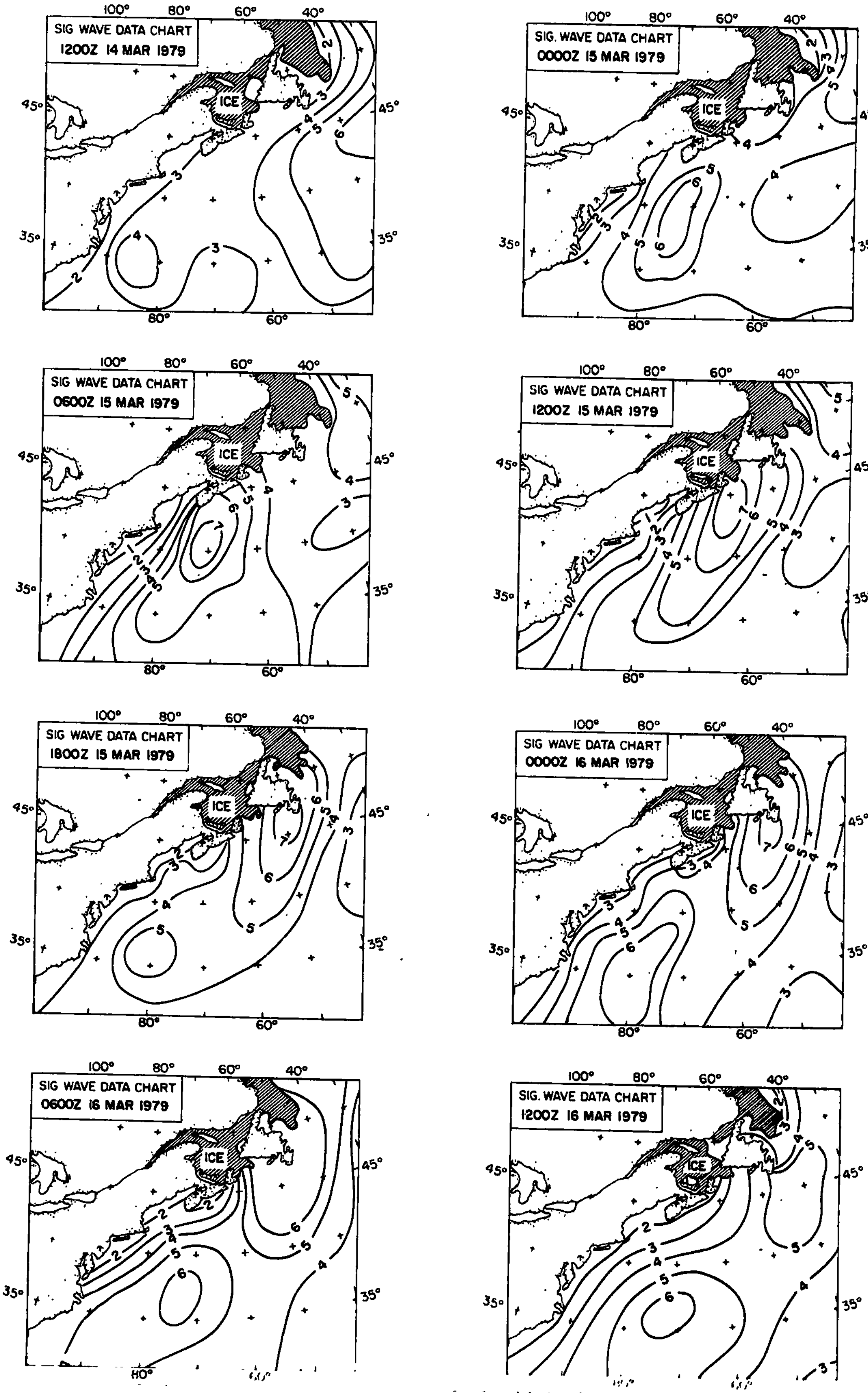


Figure 4. Wave charts from 14 March 1979, 1200Z, to 16 March 1979, 1200Z (from Canadian Forces METOC Centre)

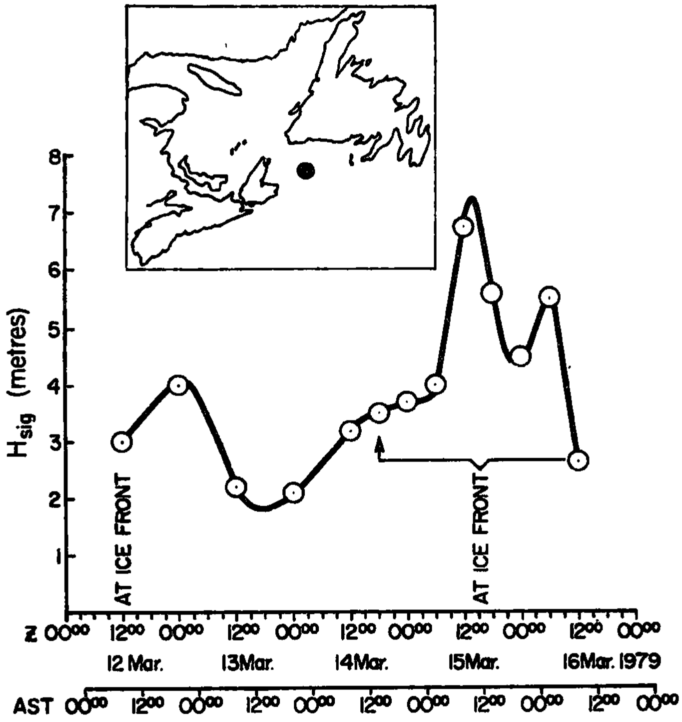


Figure 5. Time series of H_{sig} at entrance to Cabot Strait (from METOC wave charts).

changed direction (Fig. 3) from south to west and then to northwest. This new wind generated a new wave field, which was superimposed on the initial wave field from the southeast, producing a cross-sea.

Instrumental recordings of waves south of Newfoundland during the storm do not exist from which to present a power spectrum of the sea state conditions. However, a number of long-term wave-rider recordings near the region

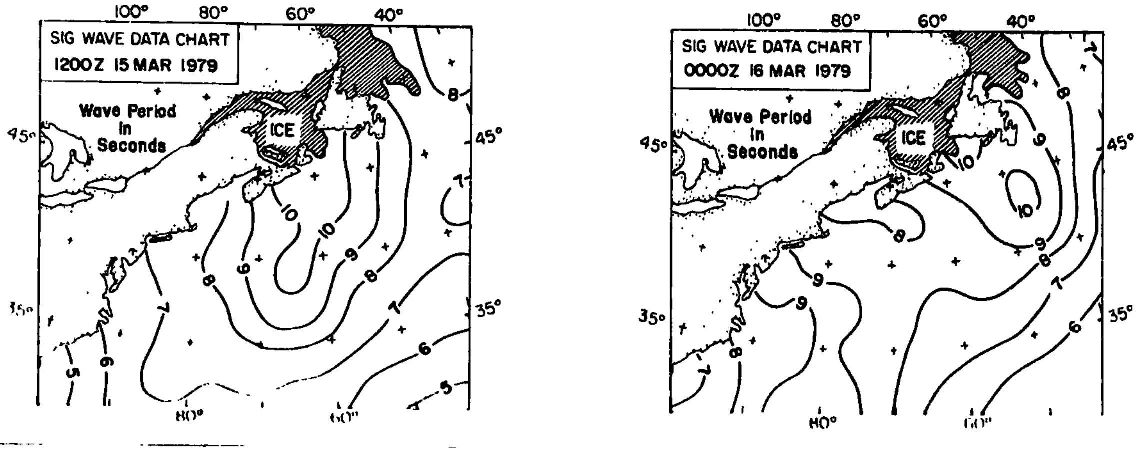


Figure 6. Visually observed wave periods on 15 March 1979, 1200Z, and 16 March 1979, 0000Z.

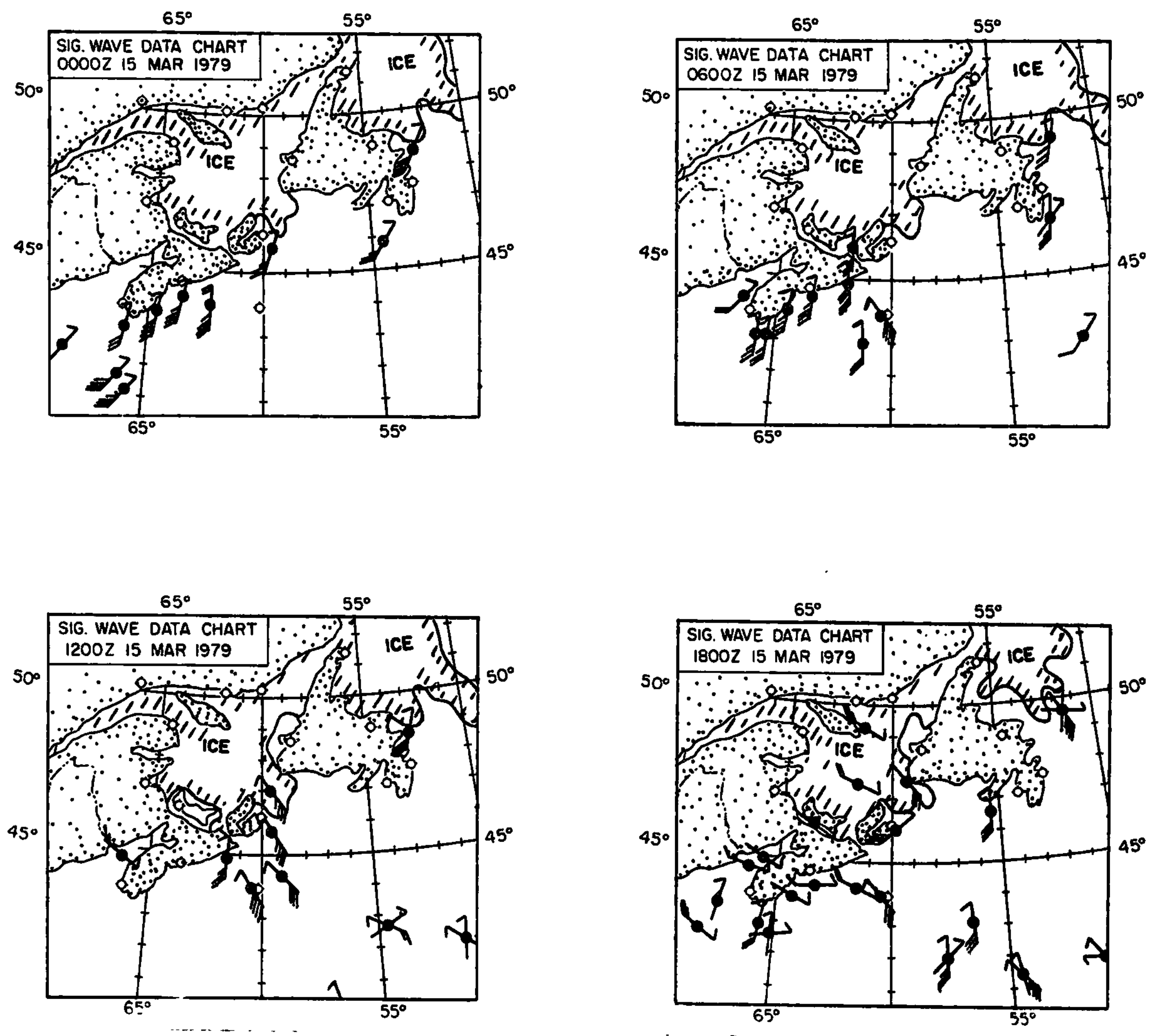


Figure . Wave directions during the storm (from Canadian Forces METOC Centre) were collected by the Marine Environmental Data Service in Ottawa, from 1973 to 1977 at Sedco H exploration platform. The spectra of seven storms (25 December 1973, 0100Z; 4 January 1974, 0900Z; 9 January 1974, 0740Z; 9 January 1974 1040Z; 23 February 1974, 1900Z; 24 February 1974, 1900Z; 18 January 1977, 0100Z) which were similar to that of the Kurdistan disaster, i.e. storms which had H_{sig} of at least 6 m (20 ft) and periods at the peak of the power spectrum (T_p) of 12 s or more, were used and an average spectrum developed. As shown on Figure 8, T_p is 12.8 s, similar to that derived from METOC data for the storm. The spectrum clearly demonstrates that there is usually a considerable portion of the energy contained in the waves with periods larger than 12 s.

Captains of Canadian Coast Guard ships have observed that the sea state in Cabot Strait is, on occasion, considerably larger than that outside in the open Atlantic. They also have noticed that wave heights build up at the edge of an ice field such as was located in Cabot Strait during the accident. There are several reasons for this behavior. It is known that when a wave field is opposed by a current, the waves become shorter and steeper and their heights increase, causing them to break earlier than usual. The currents in Cabot Strait during the storm were the result of the residual outflow from the Gulf of St. Lawrence, with varying currents arising from the tides and direct atmospheric forcing. It appears that at this time the composite current of these three forces was so weak that it did not increase the wave height significantly. Another possible reason for an increase in wave height at the Strait can be the refraction of waves around Sable Island. As shown in Figure 9, waves from the south and with a period of 14 s - this was the direction of storm and a period 2 seconds greater than that at the peak of the power spectrum - refract around Sable Island Bank and converge toward Cabot Strait.

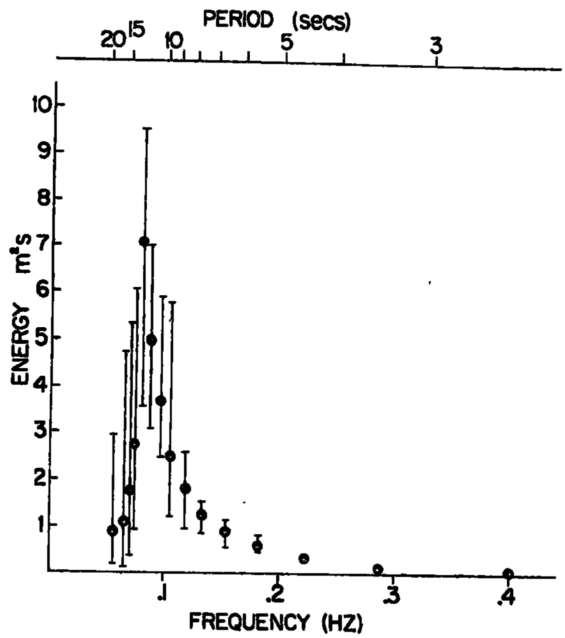


Figure 8. Averaged power spectrum south of Newfoundland (from MEDS wave recordings)

A slight change of the direction of wave fronts from the south to the west of south brings the centre of convergence to the inlet of Cabot Strait, causing the random buildup of wave peaks probably 5 to 10% higher than the normal sea. While this effect might only be felt at some points in the approach area of Cabot Strait, there is a definite increase in wave height along the edge of an ice field. In the case of a firm and well defined edge with little or no ice floes in front of it, the zone affected will be between ½ to 1 km wide. The reason for the increase in wave height is that to an advancing wave field, the pack ice acts like a barrier which is permeable to long waves with periods in excess of 8 to 10 s but reflects shorter period waves. The long waves are transmitted underneath the ice until friction and turbulence absorb their

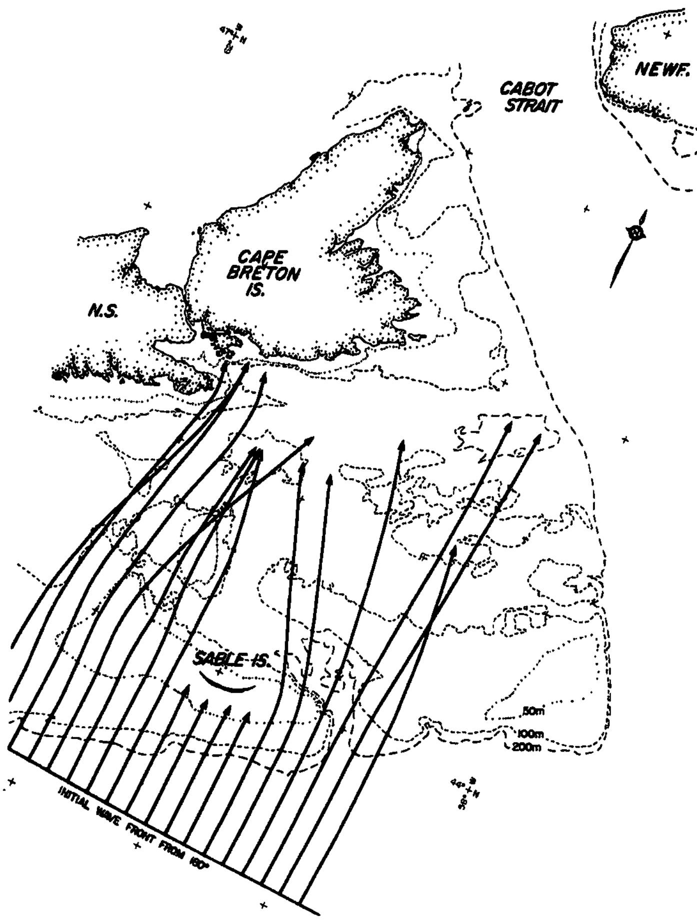


Figure 9. Refraction diagram of a wave front from the south and a wave period of 14 s

energy; shorter waves are reflected back to superimpose their height on the incoming waves, thus forming a local 'standing' wave system in front of the ice field. The amount of reflection depends on many factors, some of which are the period of the wave (the smaller the period the larger the reflection), the thickness of ice, and the condition of the pack ice with regard to being consolidated and under pressure. On the day of the accident, the pack ice in

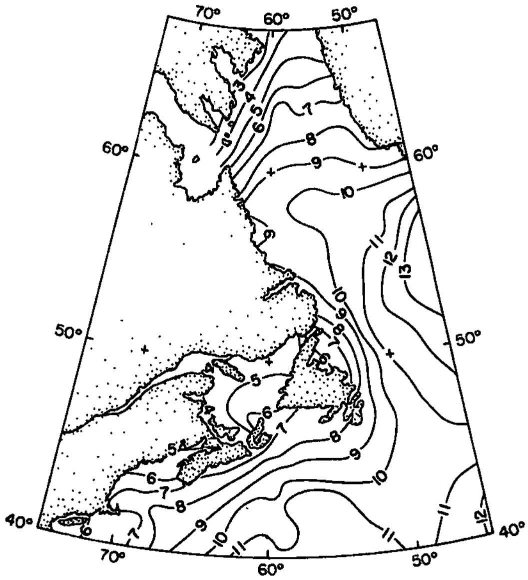
Cabot Strait was composed of cakes of pan ice with open leads between them - in spite of the wind from the south which held the ice in the Strait. Long waves could therefore propagate through the ice field without being greatly affected by the ice. Apparently, a well defined edge between the ice and the open water did not exist and the front of the ice consisted of free-floating sheets where the reflection of the shorter waves is not confined to a narrow region but spread over a wider area. As shown on Figure 8, the energy involved in reflection is relatively small. When 20% of the incident energy is reflected, the wave height in front of the pack ice would be increased by about 10%.

Thus, it can be assumed that, during the storm, waves in Cabot Strait were randomly higher than given in the charts. Along the edge of the pack ice waves were definitely higher, probably reaching 8 m and more.

Comparing the intensity of the storm, in particular its wave height, with those of other years (Fig. 10), or other months of a regular year (derived from a 10-year data bank, 1970 to 1979), it clearly shows that this type of storm with H_{sig} exceeding 7.5 m occurs once every year, mostly in December, and that storms with a wave height of 6.5 to 7 m occur in all other months of the winter from November to March. The storm of 15 March 1979 was therefore not rare and could happen any time during a winter.

5. WAVES AFFECTING THE 'KURDISTAN'

The tanker left Point Tupper in the Strait of Canso at 0542Z (0142 AST) 15 March 1979. In outer Chedabucto Bay it already encountered heavier seas from the south which increased to 6 m (H_{max} = 11 m) in the open Atlantic. While sailing along the coast of Cape Breton toward Cabot Strait, the storm



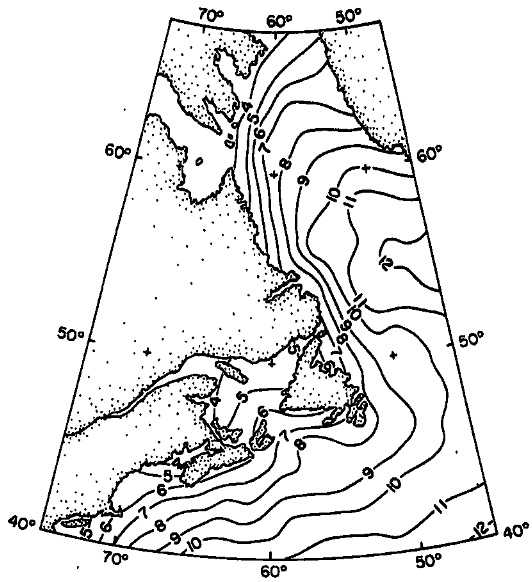


Figure 10. Largest annual H_{sig} for 1977-78 and 1978-79

intensified and waves increased to 7 m (H_{sig}) with the largest waves in the range from 12 to 13 m. The tanker arrived in Cabot Strait at noon shortly after the peak of the storm had passed with waves 7 to 7.5 m high (Fig. 5), possible peaks along the edge of the pack ice of 8 m and some extreme waves up to 14.5 m. The period with the largest wave activity was between 12 and 13 s. While entering the pack ice, the storm was still strong with waves in excess of 6 m, declining further in the following hours, so when the cracks in the vessel were noted, waves in the open water had decreased to heights between 5 and 6 m. In the late evening, when the tanker split into two parts, the significant wave height had reduced to between 4.5 and 5 m, meaning that the energy contained in this sea state was less than half of that which prevailed during the storm when the tanker entered the pack ice.

6. CONCLUSIONS

(1) The storm associated with the breaking up of the tanker was not an uncommon one, but could happen nearly every month during a normal winter season

(2) At about 0930 AST (1330Z), 15 March 1979, during the peak of the storm, in the open water of Cabot Strait, H_{sig} was between 7 and 7.5 m with some possible local increase beyond this value due to convergence of wave energy from Sable Island. The corresponding largest waves during the storm were between 12.5 and 13.5 m. The period with the greatest wave activity was between 12 and 13 s.

(3) At the peak of the storm, along the edge of the pack ice, waves were amplified to a height of 8 m (H_{max} = 14.5 m) with a lot of wave breaking being present.

(4) At 1350 AST (1750Z), H_{sig} was 5.7 m with an H_{max} of 10.2 m plus a probable increase from the ice edge and possible refraction. Thus the total wave height - H_{sig} - during this period was between 6 and 6.5 m.

(5) An analysis of power spectra of similar storms in the area indicates that a considerable amount of the energy is contained in waves with periods larger than 13 s.

7. ACKNOWLEDGEMENTS

The author acknowledges the assistance given by the Canadian Forces METOC Centre in providing additional wave data, and I am particularly grateful to R.E. Walker and F. Jordan who processed the data and assisted in the preparation of the report.

8. REFERENCES

ATMOSPHERIC ENVIRONMENT SERVICE. Monthly meteorological summary - Sydney 'A' Nova Scotia and Sable Island (W.S.A.) for March 1979.

IPPEN, A.T. (ed.) 1966. Estuary and coastline hydrodynamics, Chapter 3, by C.L. Bretschneider, McGraw-Hill Book Co., New York.

MARINE ENVIRONMENTAL DATA SERVICE. Waves recorded off SEDCO H (Shell oil rig) 13 June 1973 to 19 March 1977.

NEU, H.J.A. 1972. Extreme wave height distribution along the Csnadian Atlantic coast. Ocean Industry 7: 45-49.

NEU, H.J.A. 1976. Wave climate of the North Atlantic - 1970. Bedford Institute of Oceanography, Report Series BI-R-76-10, Dartmouth, N.S.