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ENERGY LEVELS IN THE NORTH ATLANTIC AND SHIP ROUTING

by

H.J.A. Neu

Atlantic Oceanographic Laboratory

Ocean Science and Surveys, Atlantic

Department of Fisheries and Oceans

Bedford Institute of Oceanography

P.O. Box 1006

Dartmouth, Nova Scotia

B2Y 4A2

ABSTRACT

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Applying non-dimensional energy ratios for seastate activities in the North Atlantic, the use of the Great Lakes Freighters for coastal shipping along the North American seaboard was studied and assessed. It is concluded that 'Lakers' designed for 80% strength of ocean-going vessels can navigate the coastal waters of Atlantic North America all year round without restriction.

RÉSUMÉ

Neu, H.J.A. 1982. Energy levels in the North Atlantic and ship routing. Can. Tech. Rep. Hydrogr. Ocean Sci. 10: v + 11 p.

A partir de rapports sans dimensions de niveaux énergétiques d'états de la mer dans l'Atlantique-Nord, on a étudié les possibilités d'utilisation des cargos des Grands Lacs pour le transport de marchandises le long de la côte de l'Atlantique-Nord. On a conclu que ces cargos conçus pour supporter 80% des sollicitations des navires de haute mer peuvent naviguer toute l'année sans réserve dans les eaux côtières de l'Atlantique-Nord.

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ENERGY LEVELS IN THE NORTH ATLANTIC AND SHIP ROUTING

1. Introduction

In North American waters there are basically two types of vessels, the ocean-going vessel which can also operate in the Great Lakes and the Lake freighter which is restricted to the Great Lakes and down to the western part of the Gulf of St. Lawrence.

Winter ice prohibits navigation in the Great Lakes and the St. Lawrence Seaway, and Lake freighters lie idle during each winter season. The possibility is examined here of whether these vessels could be used during this time for coastal shipping along the northwestern Atlantic from St. John's, Newfoundland, to Jamaica in the Caribbean.

2. 100% and 80% Vessels

A sea-going vessel which is unrestricted in its use in all open waters is defined as the 100% vessel; specifically, it is a vessel capable of withstanding the most severe weather conditions and the highest seas in the North Atlantic without experiencing serious damage. In this context, the worst seastate in the North Atlantic is called the 100% sea.

The restricted vessel or 'Laker' has its own strength requirement which is 20% less than that of the 100% vessel.

3. Wave Height Distribution and Wave Energy

The wave height used here is the significant height, H_{sig}. This value is not the height of an individual wave but a parameter which represents the severity of the seastate. For instance, in a storm with H_{sig} of 10 m, the heights in the wave field vary from less than 1 m to 20 m; the average is about 6.5 m; the mean of the highest one third is 10 m which is the reference wave height of the seastate; 16 to 17% of all waves or every sixth wave is higher than 10 m; the mean of the highest 10% is 12.8 m and the largest wave in a storm lasting more than 8 hours is 20 m. Therefore, the largest wave height west of Ireland in a 10 years storm with a H_{sig} of 18.6 m is about 37 m. The 100 years design wave height for oil platforms in this area is 40 m. Thus, an unrestricted or 100% vessel should survive a seastate with a maximum wave of 40 m (130 feet).

The most critical wave period for a vessel or any other structure in this sea is the breaking period. For a 37 m wave, the breaking period is 15 to 16 seconds.

The energy of the sea is determined by the following equation:

$$E = 1/8\ \gamma\ H^2\ \lambda\ \text{(m ton/m)}$$

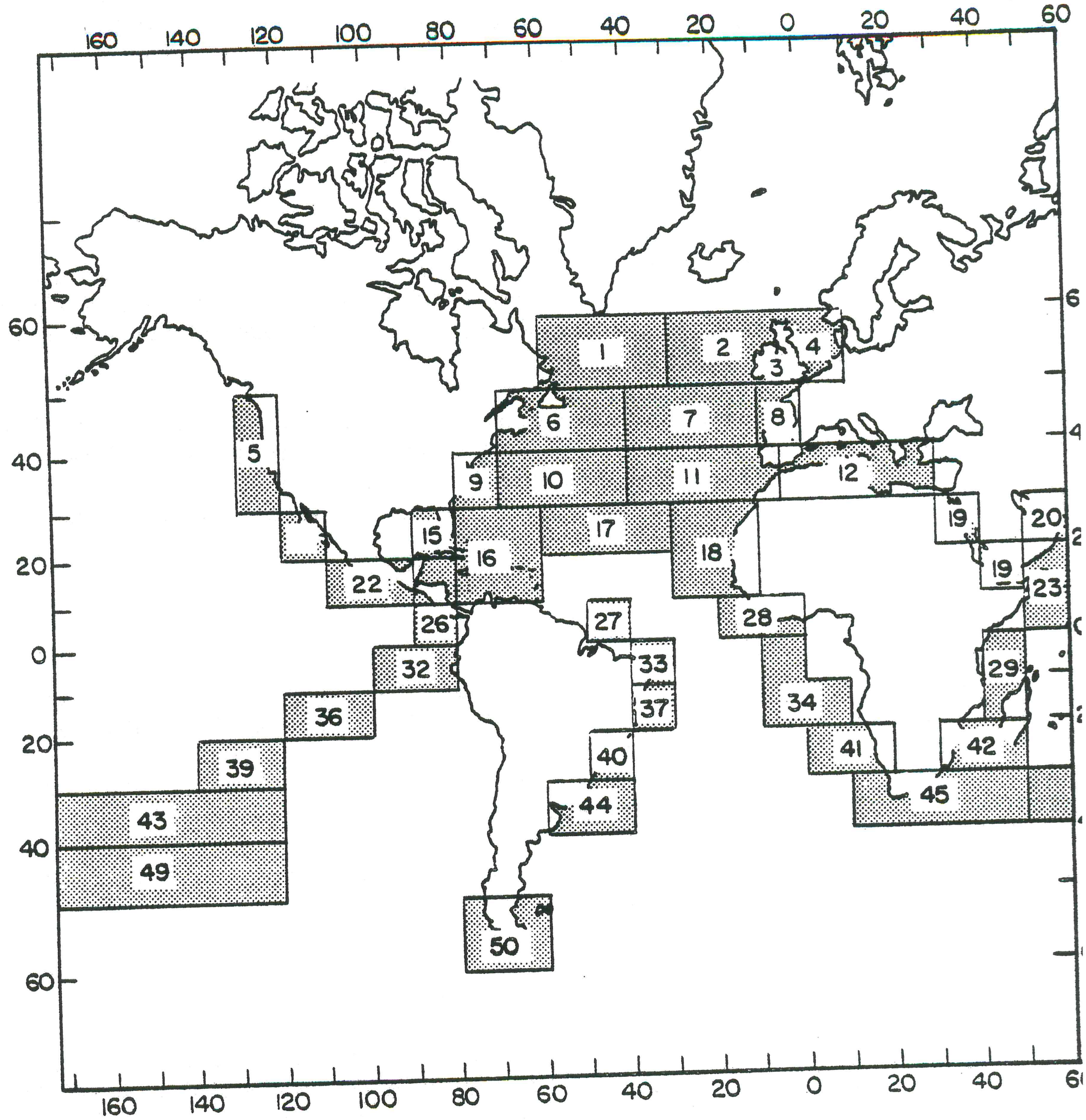


Figure 1 Layout of Areas of Hogben's wave atlas (after Hogben and Lumb, 1967)

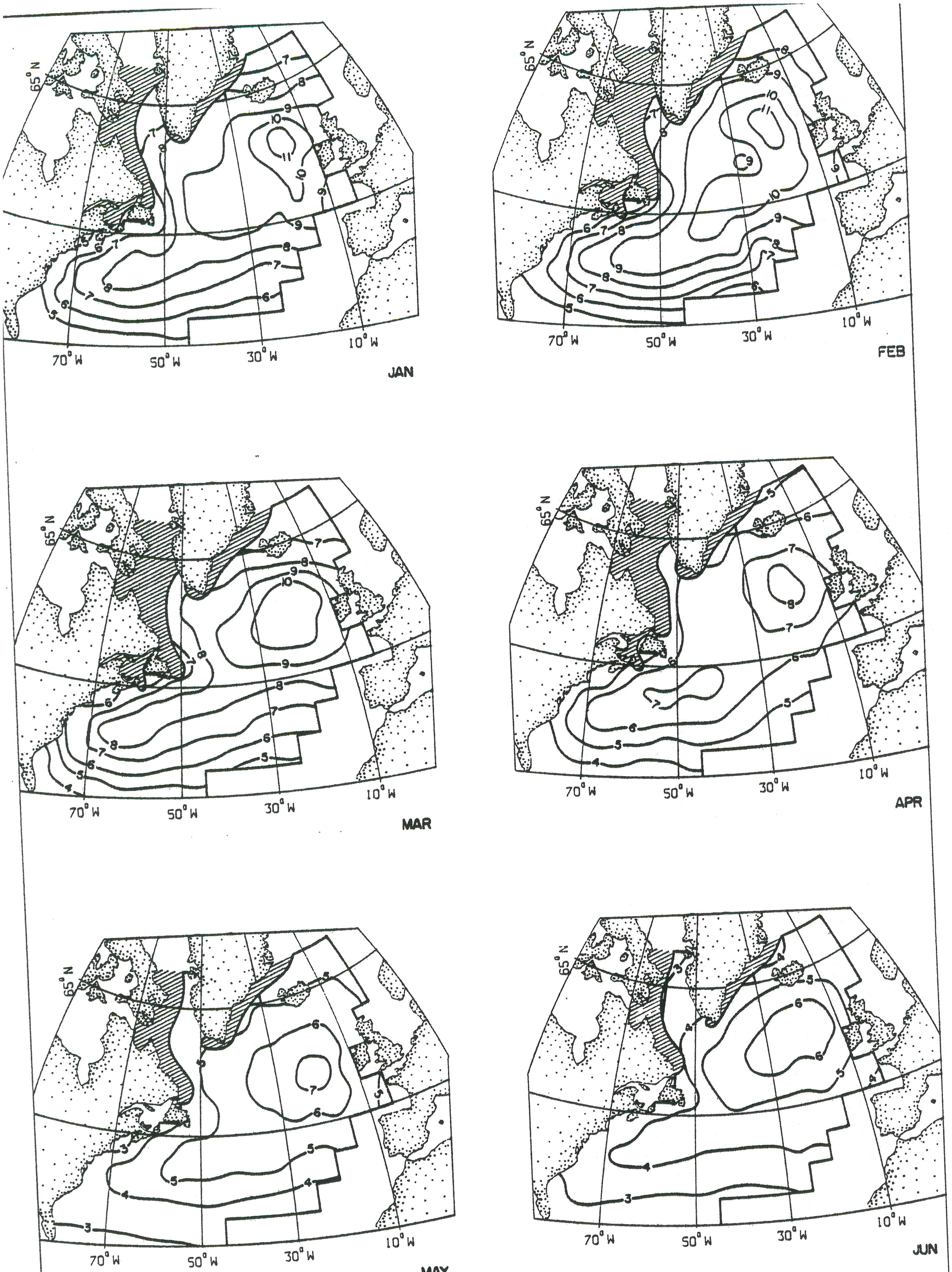
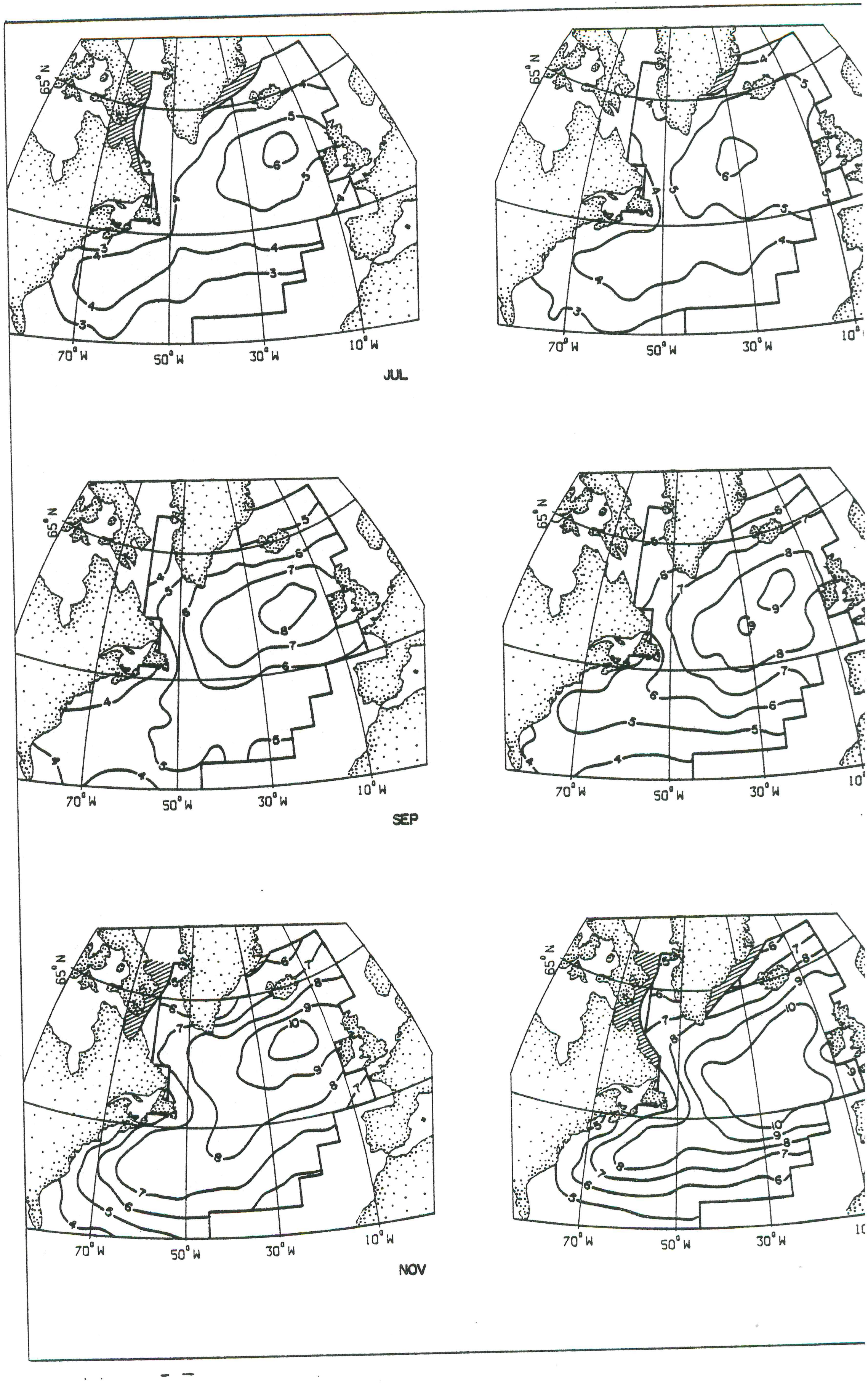


Figure 2 a. Largest monthly H_{sig} (January to June) of a normal year based on 11 years data (1970-1980)


65° N
70° W
50° W
30° W
10° W
JUL
SEP
NOV

where E is the energy per wave length and per unit width of wave crest, γ is the specific weight of sea water (approximately 1.025 [ton/m^3]), and λ is the wave length (1.56T^2[m] in deep water, where T is the wave period in seconds). Thus, the energy per metre wave crest per second simplifies to:

$$E = 0.2H^2T(\text{m ton})$$

Since the periods of larger waves in deep water do not differ from each other greatly - only by about 2 seconds - the energy of these waves is primarily dependent on the square of the wave height. The squared wave height is used here to determine the relative energy levels in the North Atlantic.

4. Lloyd's Analysis

Lloy'ds Register of Shipping assessed the strength requirements of 'Lakers' for the lower part of the Gulf of St. Lawrence and for possible use along the Atlantic Seaboard. Not being aware of the BIO wave climate, Lloyd's used Hogben's (Hogben and Lumb, 1967) wave atlas data (Fig. 1). These data are random observations not a time series and therefore cannot be used for time related investigations such as long-term estimates for annual, ten year and 100 year wave heights. Furthermore, the areas chosen are far too large for a reasonable description of the spatial variability of wave energy in the North Atlantic. Averaging the wave heights of Areas 1, 2, 6 and 7 provides an energy level too low to be representative for the peak energy of the North Atlantic. A more realistic value would have been achieved if Lloyd's had taken only Area 2 as the reference area for the energy comparison.

5. BIO Analysis

In the late sixties, the Bedford Institute of Oceanography (BIO) initiated a wave study of the coastal waters and continental shelf of Atlantic Canada (Neu 1971, 1972) and later expanded it to cover the entire North Atlantic (Neu 1976, Walker 1976, 1977, 1978). The study was based on wave charts issued every twelve hours by the Canadian Forces Meteorologic and Oceanographic Centre (METOC) in Halifax, Nova Scotia who compiled them mainly from visual observations contained in ship weather reports and some instrumental records.

It was noted that variations in wave activity occurred from year to year which greatly influenced long-term statistics. Therefore an 11 years (1970 to 1980) data bank was established from which monthly, annual and long-term statistics were developed. The monthly largest wave heights of a normal year are shown on Figures 2a and 2b. As can be seen the largest wave heights in the North Atlantic are always west of Ireland. From there the wave heights fall off in all directions with the smallest waves being in the southern North Atantic and along the coast of North America. In the region with the highest wave activity, H_{sig} for the largest monthly storm waves varies from more than 6 m in June to over 11 m in January. The largest 10 years H_{sig} was 18.6 m.

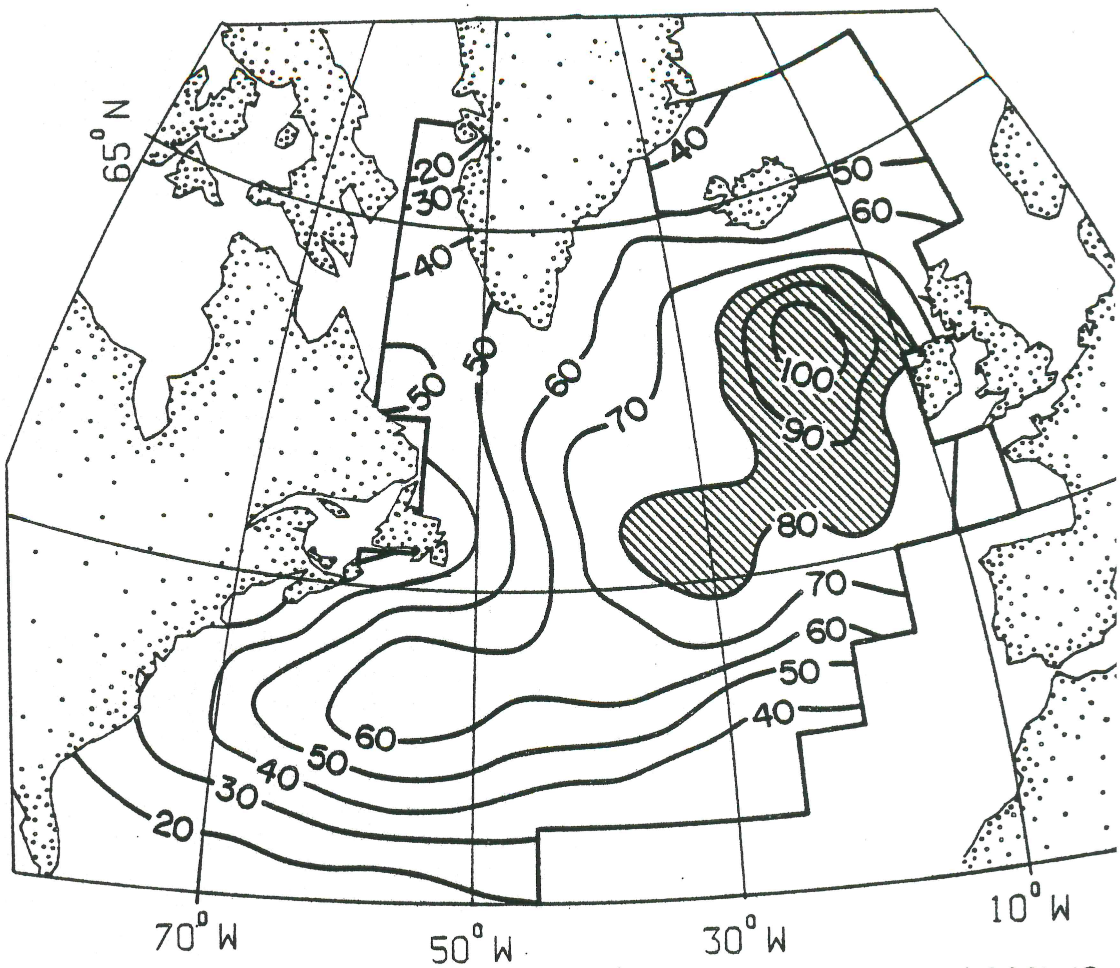


Figure 3 Wave energy distribution in % of peak wave energy of Atlantic, based on 11 years largest wave height (197C

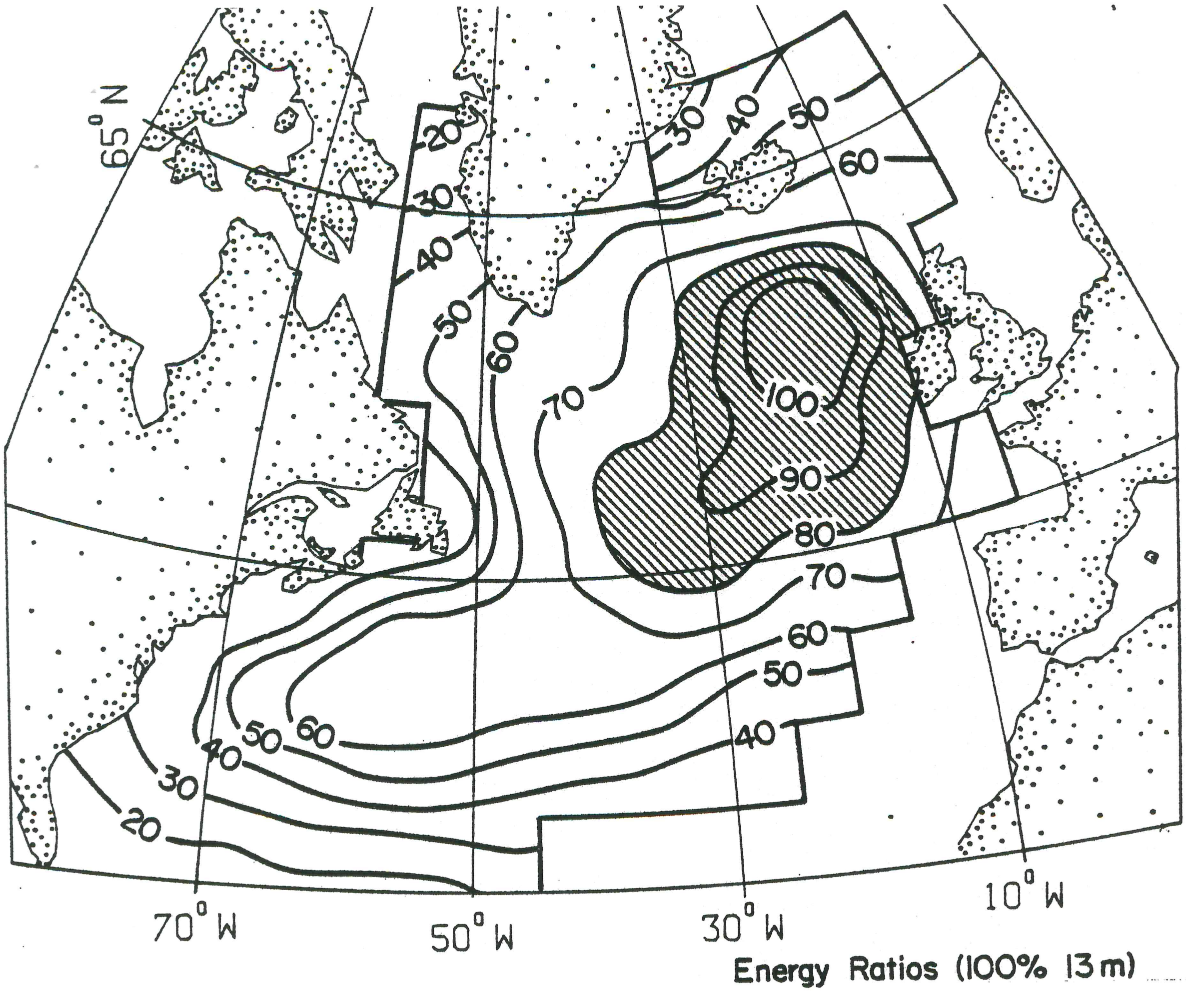


Figure 4 Wave energy distribution in % of peak wave energy of North Atlantic, based on the largest wave height of a normal year

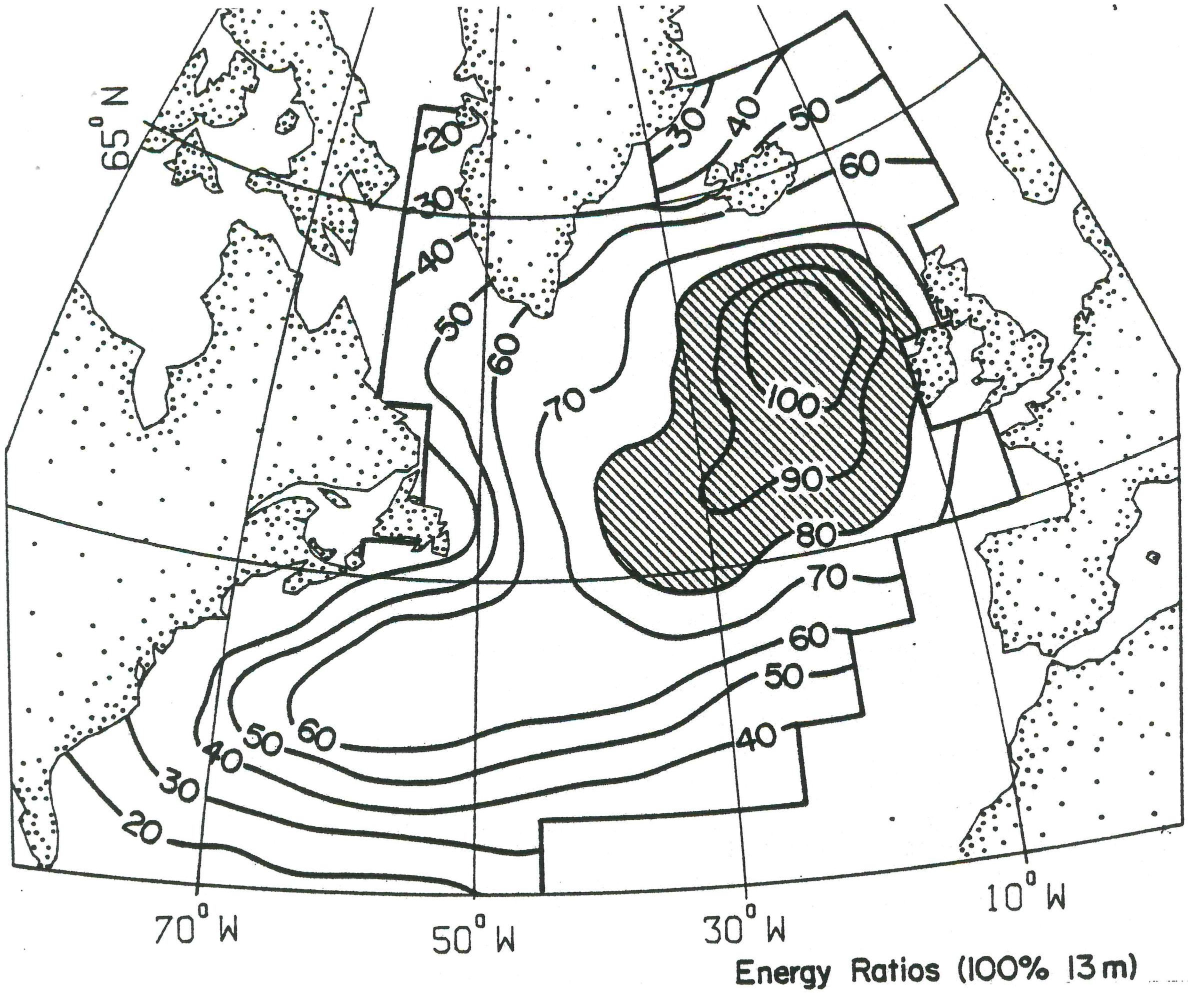


Figure 4 Wave energy distribution in % of peak wave energy of North Atlantic, based on the largest wave height of a normal year

For estimating the energy distribution in the North Atlantic, three sets of data were utilized, first the largest 11 years H_{sig}, second the largest H_{sig} of a normal year and third, the largest January H_{sig} of 11 years. The percentage distribution relative to the highest level of wave energy located west of Ireland are given in Figures 3, 4 and 5 respectively. The results of the three approaches are very similar and the 100% peaks are very much in the same location. The area exceeding 80% extends through about 15 degrees of latitude and longitude but tending generally to the south and west of the 100% area. The remainder of the North Atlantic is below the 80% energy level. Along the North American seaboard (Fig. 6), the energy declines from a level of about 50% at St. John's, Newfoundland, to about 30% at Cape Hatteras and below 20% along the coast of Florida.

6. Conclusion

Based on the energy distributions from the BIO wave climate study, and the assumption that the 100% vessel is designed to withstand the most severe ocean and storm conditions, the 80% vessel can safely navigate in most of the North Atlantic through the year, except for the area shaded in Figures 3, 4 and 5 west of Ireland where the energy level is higher than 80% from October to March. Therefore, theoretically, using a southern or northern route, a 'Laker' could sail to Europe during all the year.

With regard to navigation along the American seaboard, the energies are well below the danger level at any season.

To our knowledge, there is no monthly wave climate available for the Gulf of Mexico. However, it can be assumed that, with the exception of hurricanes, the wave energy in these waters will be less than that of the Florida Atlantic waters, or, well below the 20% level.

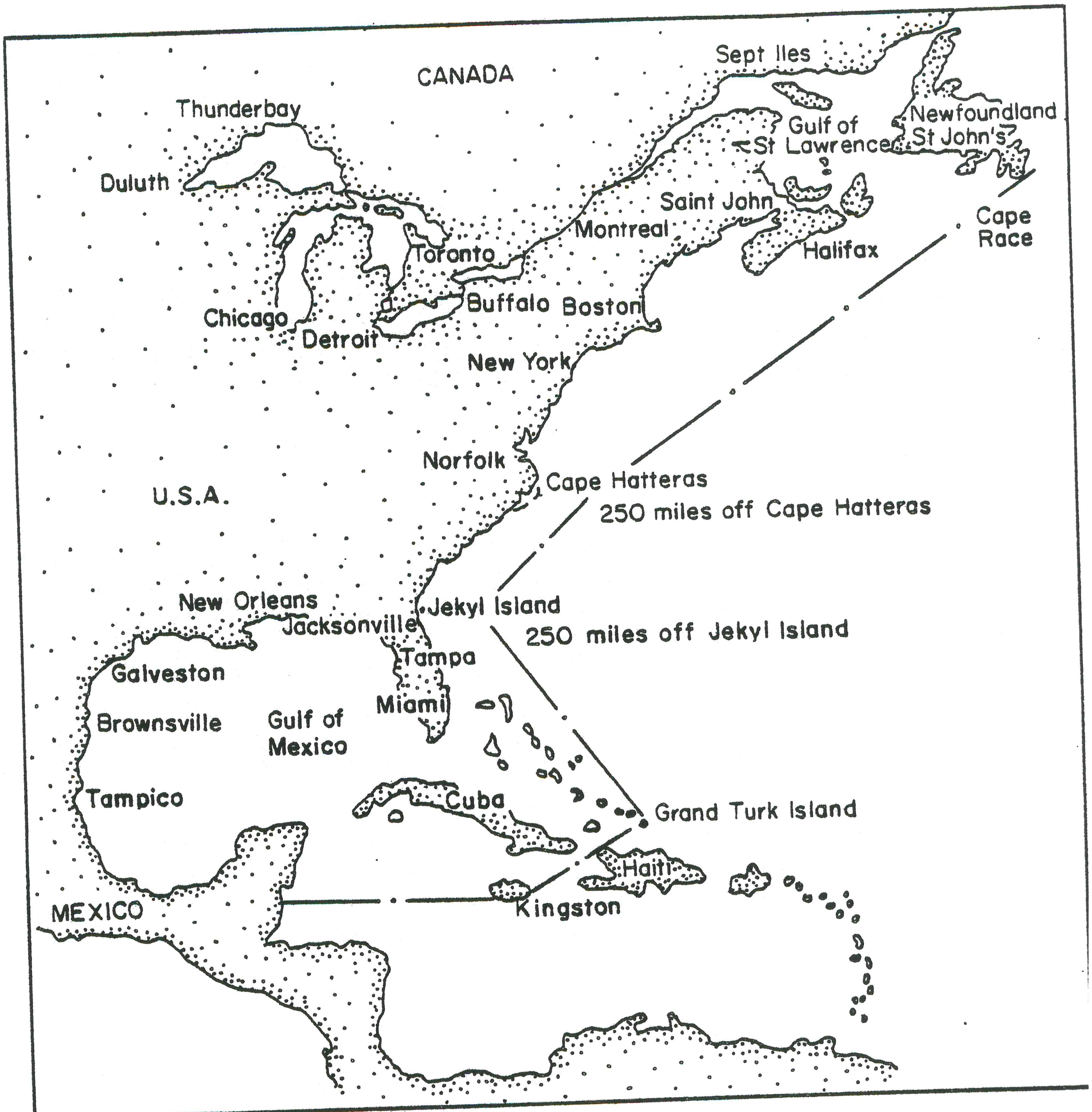


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Figure 6 Extension of 80% modulus vessel

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