An analysis of radar ice reports submitted by Hudson Bay shipping (1953)

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AN ANALYSIS OF RADAR ICE REPORTS SUBMITTED BY HUDSON BAY SHIPPING (1953)

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ABSTRACT

Ice reports received from Hudson Bay shipping were analysed to determine whether or not satisfactory radar results are being achieved by merchant marine radar operators when navigating in ice-infested waters. On all ice formations of berg size, the ranges recorded were found to be in reasonably close agreement with theoretical and experimental data. There was not a sufficient number of floes and growlers reported to arrive at any definite conclusion regarding the smaller types of ice. A survey of the reported ice locations reveals that 90 per cent of the ice encountered by a ship on the Port Churchill route occurs between Charles Island and the eastern approaches to Hudson Strait. This area lies between Long. W. 63° and Long. W. 73°, and covers a distance of 600 miles. The forms used for tabulating ice reports will be amended so that more specific data will be recorded for a future analysis.

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INTRODUCTION

The data for this survey was drawn from the reports on "Radar Detection of Ice at Sea" submitted to the Supervisor of Nautical Services, Department of Transport, by the masters of 13 vessels which loaded grain at Port Churchill on Hudson Bay during the summer of 1953. Also included were the "Masters Voyage Reports" from 10 other ships not submitting the standard ice report forms.

The 13 reports on radar detection of ice contained data on 141 ice formations. The location of all ice formations charted by the 13 ships is shown on a tracing of Chart 5000 (see Fig. 1). There were, of necessity, several duplications where more than one vessel reported the same ice formation. These duplications appear in Fig. 1, and, though they may be misleading, they comprise valuable information for a radar analysis. The complete concentration of ice in eastern Hudson Strait and its approaches is shown. Nothing was reported west of Longitude 75°, with the exception of a field of pack ice off Port Churchill, which was fairly extensive early in the season. The shipping lanes in Hudson Bay proper, from Port Churchill to Nottingham Island, were completely free of ice for the whole season. A few bergs were picked up in the North Atlantic east of Longitude 50°, but these were all large and were reported at extreme radar ranges.

There are seven classifications of ice formations listed in the report sheets, and the data submitted was grouped as follows:

CLASS	DESCRIPTION	NUMBER
1	Large Bergs	55
2	Medium Bergs	41
3	Small	24
4	Bergy Bits	7
5	Growlers	12
6	Heavy Floes	2
7	Light Floes	0
	Total	141

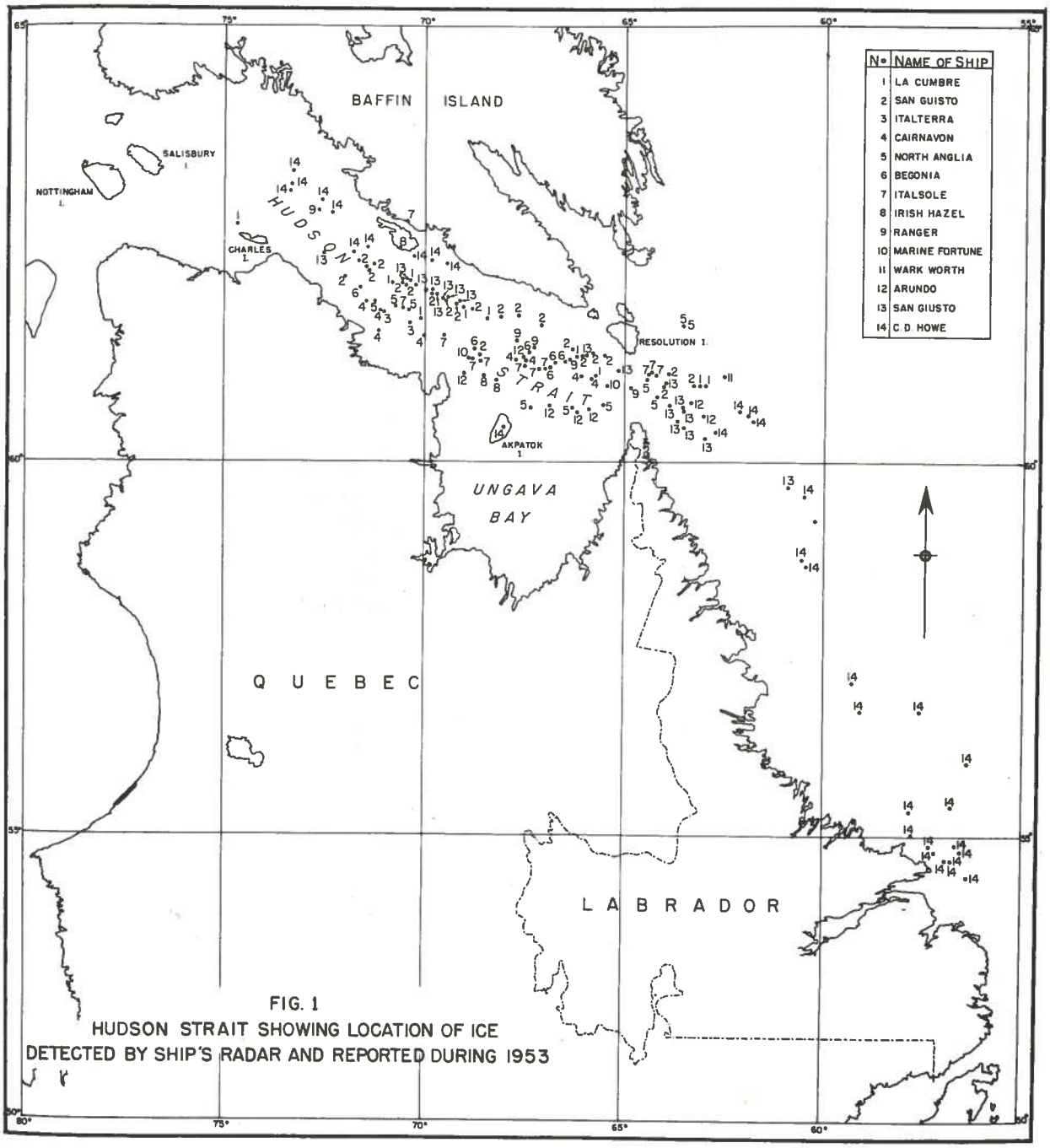

FIG. 1
HUDSON STRAIT SHOWING LOCATION OF ICE
DETECTED BY SHIP'S RADAR AND REPORTED DURING 1953

Bergs (Class 1 and 2) comprise 70 per cent of the reported ice. Of all classes of ice formation, these two present the least hazard to navigation. Bergs classed as large or medium are always of sufficient cross-sectional area to give a good radar echo in any type of sea condition. Small bergs, from 15 to 30 feet in height, make up an additional 15 per cent of the data, and again they are not classified as dangerous to a radar-equipped ship, although they will be seen at a reduced range. The remaining four classes of ice formations, which could be lost on entering the sea clutter region or escape radar detection entirely, present the greatest danger to a ship navigating in ice-infested waters. Since these classifications represent only 15 per cent of the data, it is not possible to prepare any statistics on small ice formations in sea clutter.

ANALYSIS

Of the 141 bergs reported, the information supplied on 68 was sufficiently complete for analytical purposes. From the dimensions and the general shape of the berg, it was possible to arrive at a reasonable estimate of the cross-sectional area presented to the radar. This area is modified by the contours of the ice and the nature of the surface reflecting the radar beam. This modified area is called the radar cross-sectional area of the target. For any specific ice formation, the maximum range of detection is a function of the target area, and this relationship can be seen from the radar equation:

$$S = P_o \frac{G^2 \lambda^2 \sigma}{(4\pi)^3 R^4},$$

where S = signal strength, or the power received from the target,

P_o = peak power output of the radar,

G = gain of the antenna

λ = wavelength (3 cm. for most marine radar),

σ = radar cross-sectional area of the target, and

R = range of the target.

If S is the minimum signal that the radar receiver will detect, then R is the maximum range of detection of a target of cross-sectional area σ .

Rearranging the terms:

$$R = \frac{P_o G \lambda^2}{(4\pi)^3 S} \cdot \sigma .$$

For a given radar, the terms P_o, G, λ , and S are known quantities and can be replaced in the equation by a constant K.

Then $R^4 = K\sigma$, or $R^4 \propto \sigma$;

that is, the fourth power of the maximum detection range is proportional to the radar cross-sectional area of the target.

This relationship was applied to the data contained in the ice reports in the following manner. A berg reported by the S.S. "North Anglia" was 400 feet long and 230 feet high, with a bold perpendicular surface. The overall cross section was 92,000 square feet, and the range of detection was $9\frac{1}{4}$ miles. Assuming the radar cross section of this berg to be 50 per cent of the overall cross section, then σ is 46,000 square feet, and the maximum range of detection was 18,500 yards, as actually recorded by radar and plotted in Fig. 2. Each berg that was reported with sufficient information to enable an estimate of radar cross section to be made, was treated as above. The locus shown in the figure is not necessarily the best, but the slope is the fourth power line as plotted from the radar equation.

The considerable scatter of the points in Fig. 2 is partially due to:

a) the approximation of the radar cross-sectional area that must be made from the limited data available, and
b) the use of results taken from 13 separate radars manufactured by 6 different firms.

With few exceptions, the ranges achieved on the various ice formations are of the proper order of magnitude, and the radar results agree very well with the theoretical expectations.

A survey of the radars from which this data was taken, with their rated power outputs, is as follows:

Type	Number	Power Output (kw)
Decca	6	7
Kelvin Hughes	2	7
Type-268	2	25
Raytheon	1	20
RCA	1	-
Marconi	1	26

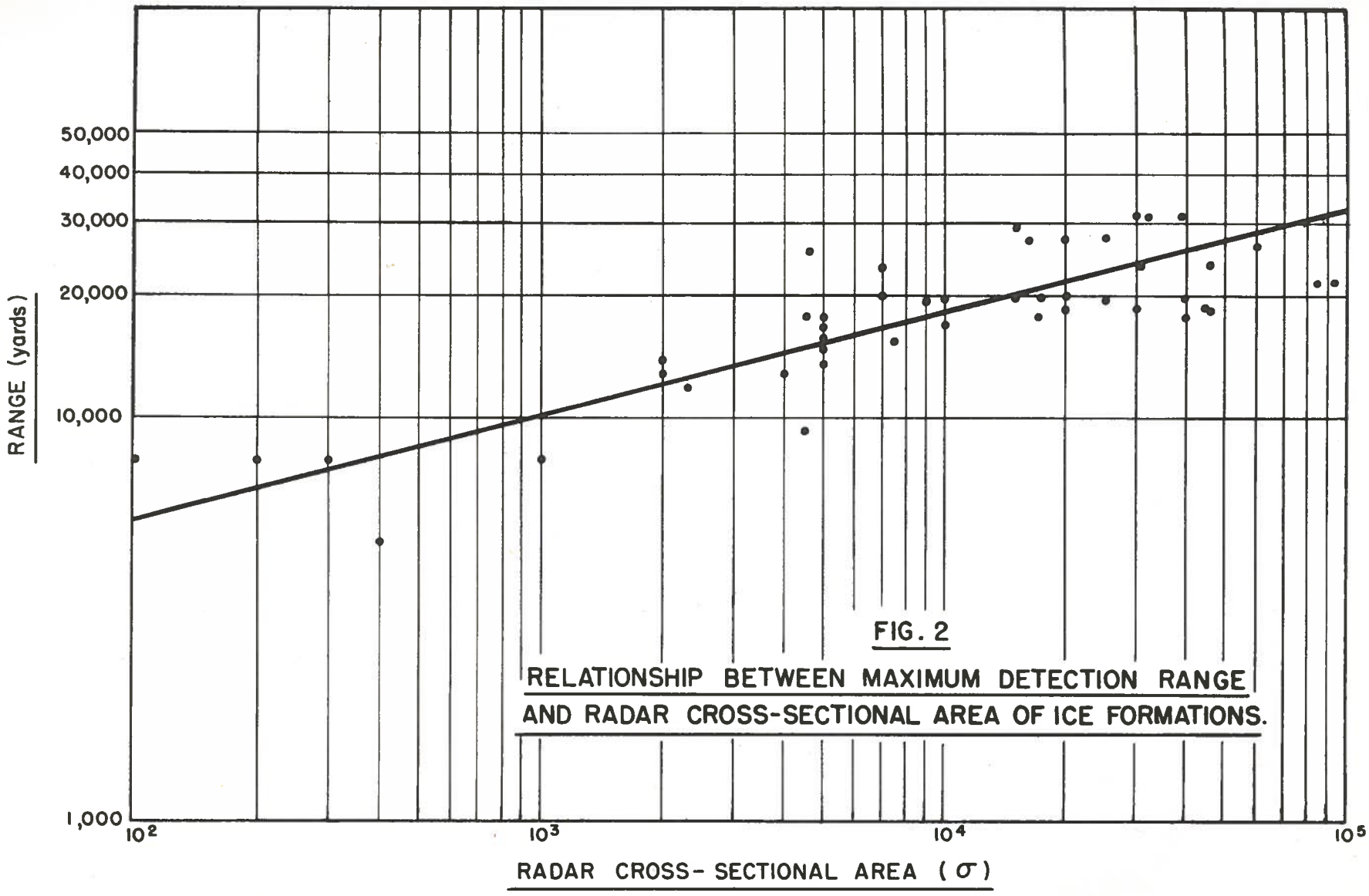

FIG. 2

RELATIONSHIP BETWEEN MAXIMUM DETECTION RANGE AND RADAR CROSS-SECTIONAL AREA OF ICE FORMATIONS.

The rated peak power outputs vary from 7 to 26 kilowatts, but this discrepancy does not affect the results seriously, since power output must be increased 16 times in order to double the detection range, R, of a given target.

RECOMMENDATIONS

The results of this analysis indicate that some modification of the ice report forms in current use would be desirable. These changes have been discussed with officials of the Department of Transport, and the following suggestions will be used by them as a guide in making the modifications. It has been well established by Canadian and British research workers that atmospheric effects have little or no effect on the range obtained by a modern radar in the detection of ice in Arctic waters. It would seem advisable, therefore, to omit records of air and sea temperature, as well as barometric pressure, from ice reports. With a view to a more extensive future analysis of ice reports, the term "sea and swell" would be a great deal more useful if changed to "radar range of sea clutter". This information was requested in a footnote under the subscript "sea", but was not given in any of the completed ice reports. Another valuable addition to the data would be a sketch of the overall contours of the ice formation. This would enable a more accurate estimate of the radar cross-sectional area to be made. Sketches were included in some of the reports even though they were not requested. It appears necessary that some notation be made on the report blanks to stress the importance of the more dangerous types of ice included in the last four categories. To obtain the maximum value from the ice report data, at least 50 per cent of the reported ice formations should be bergy bits, growlers, and floes.