CHAPTER 2

THE QUALITY OF TABULATED DECK LOG SWELL OBSERVATIONS

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INTRODUCTION

To determine the areas of data deficiencies, the totals of sea and swell observations were summarized by unit Marsden squares for the world. An interesting result of this summary was a comparison of the totals of sea and swell observations. The totals of swell observations averaged two-thirds those of sea observations. Although this ratio was fairly representative of the ocean basins, considerable variation occurred in semi-enclosed seas where swell observations averaged only one-tenth those of sea observations. A few ocean basin locations had totals of swell observations that approached those of sea observations, but no Marsden square had more swell observations than sea observations. Strangely enough, swell tabulations, in areas where the ratio of swell to sea observations were smallest (semi-enclosed basins), appeared least reliable although it was suspected at the time that this was probably due to smallness of the sample. Subsequent additions of card decks have neither changed these ratios appreciably nor the suspect reliability.

Thus, due to the relative sparseness of observations in some areas and the inexplainable ratios of swell to sea observations in others, the quality of observations contained in IBM listings have for some time been questioned.

DEFINING THE PROBLEM

An investigation of log sheets and listed observations from marine-punched card decks show that many observers never seem to make swell observations. Hundreds of sea observations will be noted in the log sheets, but the adjoining swell columns are left blank. It is probable that these sea observations are actually wave observations and include both sea and swell. A small number of swell observations may be recorded with no associated sea observations. In some instances cards contain neither a sea nor a swell observation. In many log sheets, the same code figures are recorded in both the sea and swell columns. Here the observer may have made an observation of waves and, being unable to distinguish between sea and swell, may have recorded the same code figure in each column.

By the time these sea and swell observations are included in IBM listings, little can be done to counteract these misrepresentations. Even if corrections were attempted on the original log sheets, it would be necessary to second guess the observer, something which is seldom reliable. Nevertheless, some systematic approximation is desirable to increase the reliability of such data.

THE BASIS FOR AN APPROXIMATE SOLUTION

No solution to the problem of identical data is apparent because some of these observations may be valid and others may be associated with some type of swell incorrectly coded. It can only be hoped that these errors represent a small portion of the total observations.

The cards containing neither sea nor swell observations can be eliminated immediately because they constitute no observation of the sea surface.

Sea observations are included on most marine punched cards. Nevertheless, in Marsden square 116, February, 264 out of 3,235 cards recorded a swell observation without a sea observation. More than half of these "missing" sea observations were associated with winds of Beaufort force 3 or less; therefore, it might be assumed that the sea surface was relatively smooth on these occasions. In any event this represents less than 9 percent of the total chances to observe the sea. Other Marsden squares exhibit similar ratios of "missing" sea observations, and this loss of observations probably will not materially affect the sea tabulations.

Swell, however, is considerably different. Of the Marsden squares checked the totals of swell observations were always less than those of sea observations. For example, in Marsden square 116, February, there were 2,871 sea observations and 701 swell observations. In Marsden square 149, August, there were 4,805 sea observations and 2,135 swell observations while in Marsden square 214, January, there were 981 sea observations and only 81 swell observations. At first glance this reflects what should be expected in the open ocean — a sea of some kind usually present, and a discernable swell present only part of the time. However, if no swell were present, or if swell were present but completely masked by the sea, the observer should have recorded "no swell" in the swell column; consequently, his log sheets would have shown as many swell observations as sea observations. For example, if 1,000 observations of the sea surface were made by an observer, and he observed and recorded swell only 100 times, the swell rose would be based only on these 100 observations and would not show observations of "no swell". A rose based on data of this type implies that there is always swell present and its various heights occur 100 percent of the time. Actually 1,000 observations were made, of which 900 indicated "no swell". Thus a rose made from data of this type implies that 90 percent of the time no swell occurs and the various observed swell heights occur only 10 percent of the time. In practice it can not be said with certainty that there was no swell the 900 times the swell column was left blank. The blank column only implies that the observer either saw no swell or was not sufficiently impressed by what he saw and did not complete the observation. It is also possible that the observations in the sea column are really wave observations, embodying both sea and swell.

THE QUALITY OF TABULATED DECK LOG SWELL OBSERVATIONS

Two points might explain why observers sometimes fail to record swell: 1) With winds of Beaufort force 7 or higher, 10 foot significant waves can be generated over a fetch of only 40 miles. With such winds it is difficult or impossible for an observer to distinguish any swell. Also a fully developed sea from Beaufort force 7 winds would have sea waves with heights as high as and periods as long as any swell present. 2) With winds of Beaufort force 3 or less, a fully developed sea rises to less than 2 feet. Any observer, seemingly, could detect a swell of 1 or more foot (swell code 1 and above) when seas are low and periods are less than 6 seconds (average periods of 3 seconds). When the winds are of Beaufort force 3 or less and nothing is recorded in the swell column, presumably no swell occurred.

Such arguments might also apply to the "missing" swell observations associated with Beaufort force 4, 5, and 6 winds. If the observation was taken during the onset of such winds, the seas would still have been very low and the swell present could have been seen easily; however, seas may have been nearly fully developed and high enough to obscure any swell.

The above reasons obviously cannot be valid for all the "missing" swell observations; nevertheless, when the observer fails to record swell, he implies "no swell" whatever the actual conditions might have been at the time of observation. Seemingly, all the "missing" swell observations should be considered as "no swell" if a true distribution of observations, as seen by the observers, is to be presented. To test this idea observations from a number of Marsden squares were listed by month. Examples of these listings are shown in Table I.

Table I

SUMMARY OF LISTINGS OF OBSERVATIONS FROM TWO MARSDEN SQUARES

	Marsden square 149 - August		Marsden square 116 - February	
Total number of cards	6,051		3,182	
Total sea observations	4,805		2,871	
Total swell observations	2,135		701	
No swell		216		95
Confused swell		112		23
Swell 1 to 12 feet		1,711		492
Swell greater than 12 feet		96		91
Total occurrences of sea and swell on same card	1,186		437	
Total chances to observe sea surface	5,754		3,135	
Total "missing" swell observations (assumed "no swell")	3,619		2,434	

Percentage frequencies of the various swell height categories were computed based on the actual total of swell observations and th total number of chances to observe the sea surface. Examples of these results are presented in Table II.

Table II

PERCENT FREQUENCY OF SWELL IN VARIOUS HEIGHT CATEGORIES BASED ON UNMODIFIED AND MODIFIED DATA

Marsden square 149 - August

	Based on 2,135 actual swell observations	Based on 5,754 chances to observe the sea surface
No swell	10.1	66.6
Confused swell	5.3	2.0
Swell 1 to 12 feet	80.1	29.7
Swell > 12 feet	4.5	1.7
	100.0	100.0

Marsden square 116 - February

	Based on 701 actual swell observations	Based on 3,135 chances to observe the sea surface
No swell	13.5	80.7
Confused swell	3.3	0.7
Swell 1 to 12 feet	70.2	15.7
Swell > 12 feet	13.0	2.9
	100.0	100.0

Table II indicates quite clearly that the inclusion of the larg number of "no swell" observations radically increases the percent of time without swell, thereby decreasing the percentage of time with other swell conditions. In many studies the percentages of swell observations greater than 12 feet, within a defined area, are contoured and then spoken of as the "percent of time swell is greater than 12 feet". Actually the contours are of the percent of swell observations that record swell greater than 12 feet and are not at all representative of the percent of time. However if the observations of swell greater than 12 feet were related to the total number of chances to observe the sea surface, they would then be representa tive of the percent of time.

Except for listings covering a limited number of widely separated Marsden squares, the actual number of chances to observe the sea surface is unavailable in the data tabulations at the Hydrograph Office. Sea and swell have been summarized separately, and the only totals available are those for sea observations and those for swell observations. The true number of chances is some number that lies between the number of sea observations and the number of sea observa tions plus the number of swell observations. In the few Marsden squares checked, about one-half of the swell observations was taken at the same time as a sea observation. This would indicate that the total number of chances would be the number of sea observations plus one-half of the total number of swell observations. However, the squares checked do not constitute a large sample, and in view of the available data it is suggested that the total number of sea observations be used to determine a corrected value. In Table III the present method is compared with the three suggested methods of modification.

Table III

COMPARISON OF DERIVED PERCENTAGES OF SWELL HEIGHTS FOR MARSDEN SQUARE 149 - AUGUST

1st row: Present method — using only the swell cards as the total number of chances to observe swell.

2nd row: Using the number of sea observations as the total number of chances.

3rd row: The true number of chances, i.e., the number of cards with a sea and/or a swell observation.

4th row: Number of sea observations plus 1/2 the number of swell observations.

Row	No swell < 1 foot	Low and medium swell 1 to 12 feet	High swell > 12 feet	Confused swell
1	10.1	80.1	4.5	5.3
2	60.1	35.6	2.0	2.3
3	66.6	29.7	1.7	2.0
4	67.4	29.1	1.6	1.9

MODIFICATION OF ISOLINE PRESENTATIONS

Figures 1 through 6 were prepared to illustrate the comparison between the present method and the method of modification using the number of sea state observations as the total number of observations. On these figures isolines of the frequency of occurrence of swell greater than 12 feet are presented for a representative month of each season. The isolines are based on tabulations by 2-degree quadrangles for the entire North Atlantic Ocean and its adjacent seas. These tabulations are based upon the entire volume of punch-card observations available at National Weather Records Center, Ashville, N. C. and the U. S. Navy Hydrographic Office as of 1958. Certain portions of the area, in particular north of 50°N. and west of 50°W., parts of the Baltic and its adjacent gulfs, and the entire water area north of Iceland except for the shipping lane along the Norwegian coast, contain little data. Therefore, the analysis of these sections merits a lesser degree of confidence than elsewhere in the area. The analysis in certain remote sections is based upon as few as 20 chances to observe the sea surface per 2-degree quadrangle or as many as 8,000 per 2-degree quadrangle along the most frequently traveled routes. In general 200 to 400 chances to observe the sea surface per 2-degree quadrangle occur over the major portion of the area from 20°N. to 60°N.

Figure 1, the winter chart, is based only upon original totals of actual swell observations and shows an axis of maximum frequency of high swell along each of the major storm tacks in the North Atlantic. Throughout a large portion of the central North Atlantic, frequencies of high swell reach and exceed 40 percent. A comparison with frequencies of seas equal to and exceeding 12 feet in height for the same area and based upon the same card decks reveals that no frequency reaches 40 percent. Although this excess of swell is possible (because swell has many origins), it appears unlikely along the major storm tracks where low wind speeds are rare and where seas are almost always predominant.

Perhaps even more significant are the high frequencies of swell greater than 12 feet in the Mediterranean and especially in the Baltic. In the Baltic, for example, swells greater than 12 feet, since they must originate from local seas, should never exceed the frequencies of seas of the same height or higher. This figure shows frequencies as high as 40 percent for high swell in the Baltic while sea charts, based upon the same data sources, show only 5 to 10 percent frequencies for seas equal to or greater than 12 feet in the same area.

The swell frequencies used in Figure 1 have been modified in Figure 2 by using the total of the sea state observation as the number of chances to observe swell. The 40 percent maximum frequencies of high swell in the central North Atlantic have now been reduced to two small cells west of Ireland. Similar reductions occur almost everywhere in the North Atlantic and Mediterranean. In the Baltic, meanwhile, in view of the small ratio of swell to sea frequencies of high swell are now in the 1 to 5 percent range and well within that realm of occurrence allowed by the 5 to 10 percent frequencies of seas equal to or greater than 12 feet.

In the summer chart (Figure 4, original swell data) the storm tracks have been forced northward by the expanded North Atlantic high pressure cell. Two significant features of this map are the maximum of high swell south and east of Greenland and the ever present maximum in the Baltic. In the same month, Figure 5, based upon modified swell data, indicates a great reduction in the Greenland high swell maximum and complete destruction of the Baltic maximum.

Modified data for spring and autumn (May and November) are included to complete the series in Figures 3 and 6 respectively. These figures have undergone similar reductions in data and result in patterns that show better agreement to the climatology. Figure 6 although the result of considerable modification, is indicative of rough autumn conditions in the North Atlantic and appears to overemphasize frequencies of high swell. Although this points out the incompleteness of the approach, it is much better than the original method. Data based upon the total number of chances to observe the sea surface would probably be more representative of actual conditic

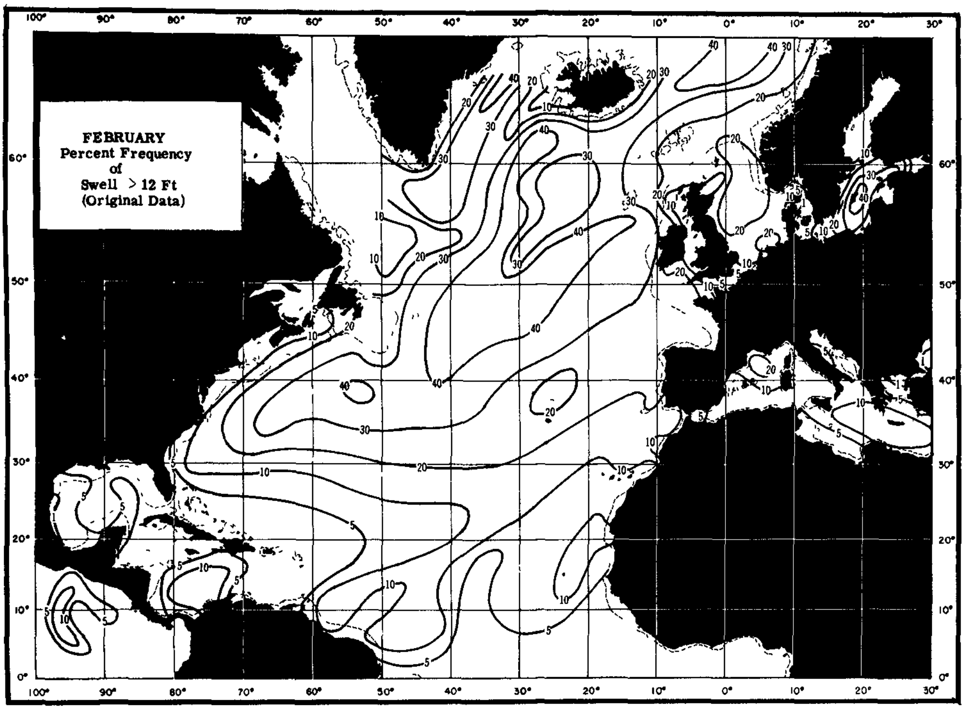

Fig. 1. Swell > 12 feet, February (Original Data)

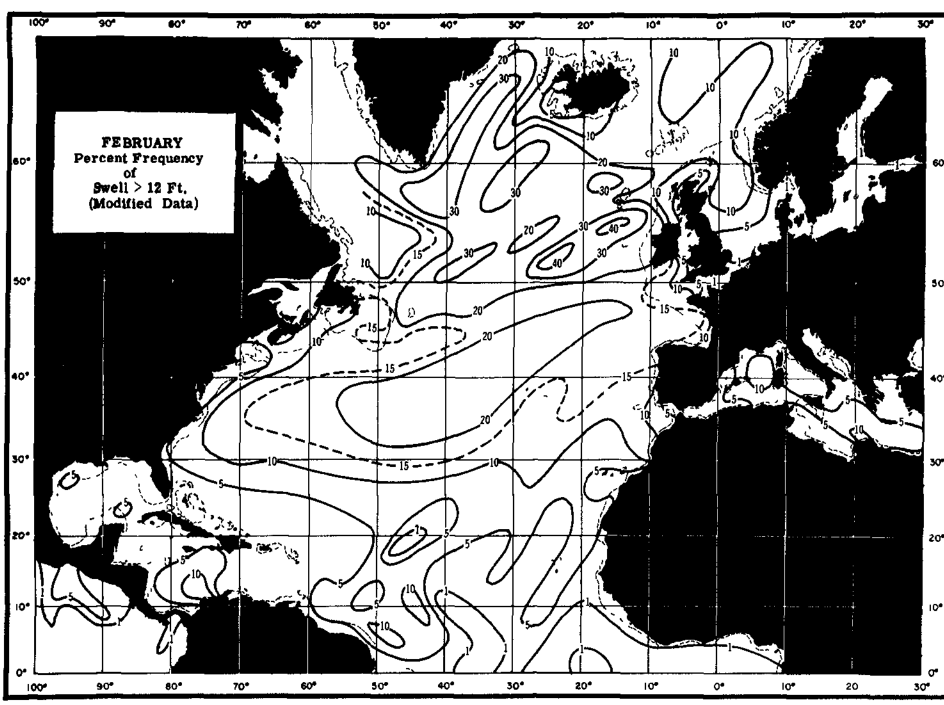

Fig. 2. Swell > 12 feet, February (Modified Data)

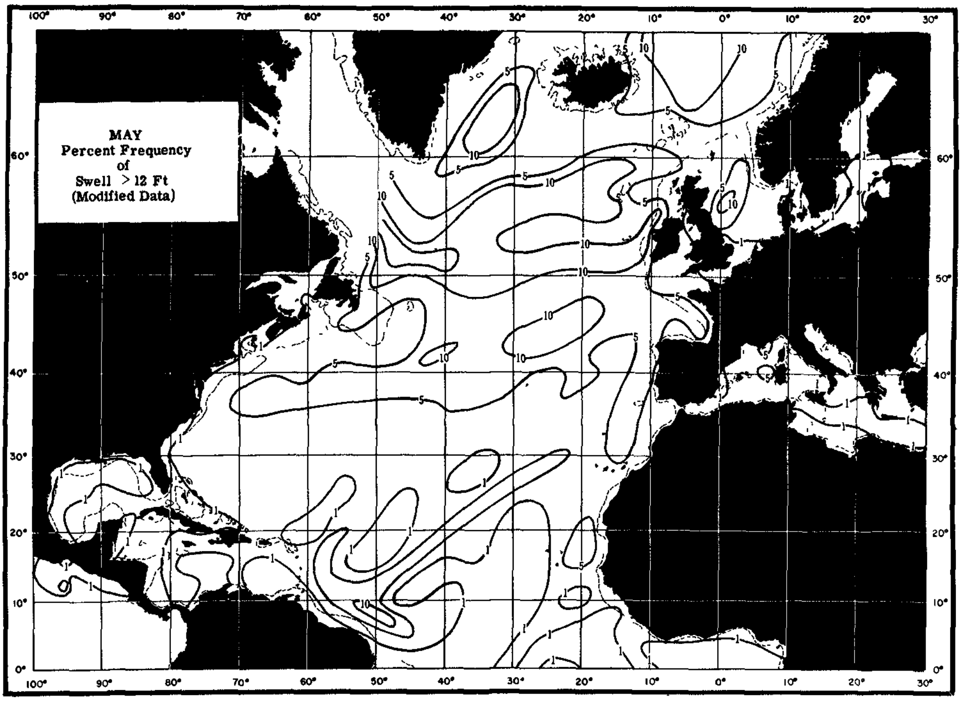

Fig. 3. Swell > 12 feet, May (Modified Data)

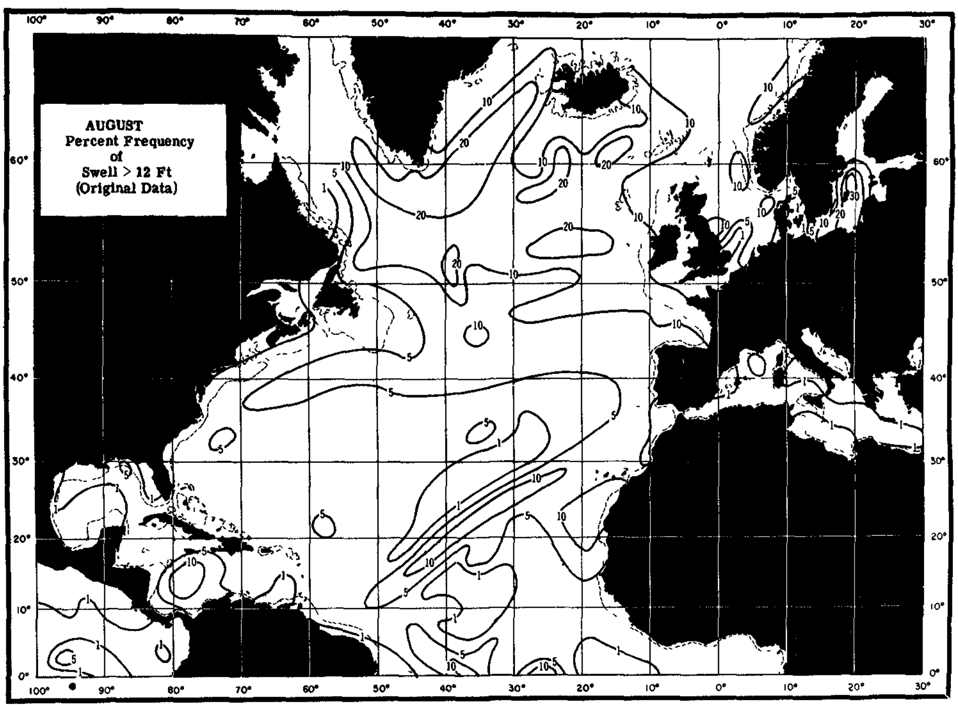

Fig. 4. Swell > 12 feet, August (Original Data)

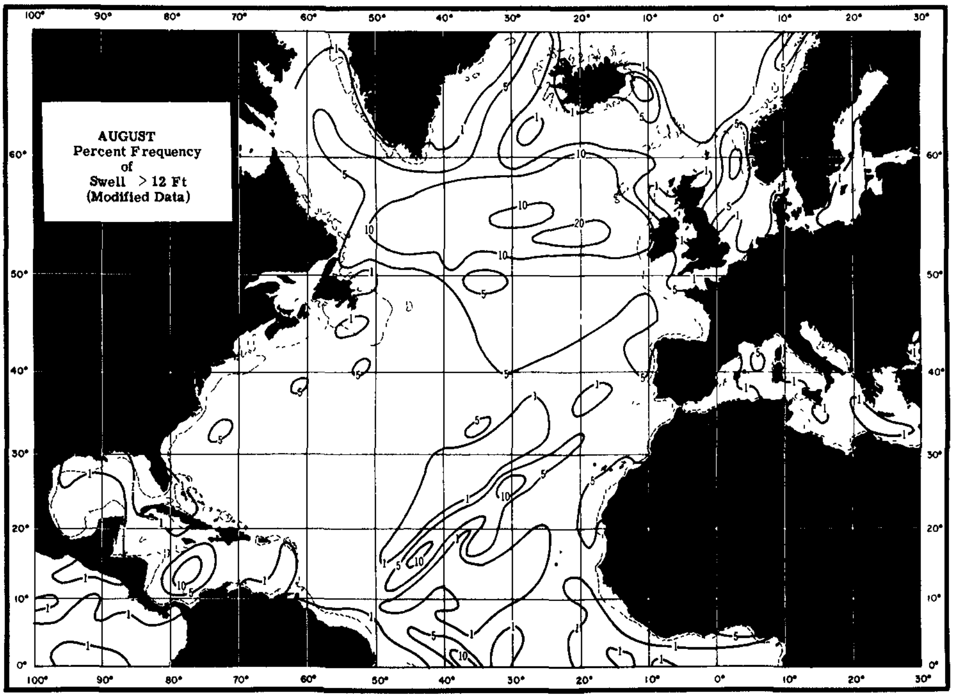

Fig. 5. Swell > 12 feet, August (Modified Data)

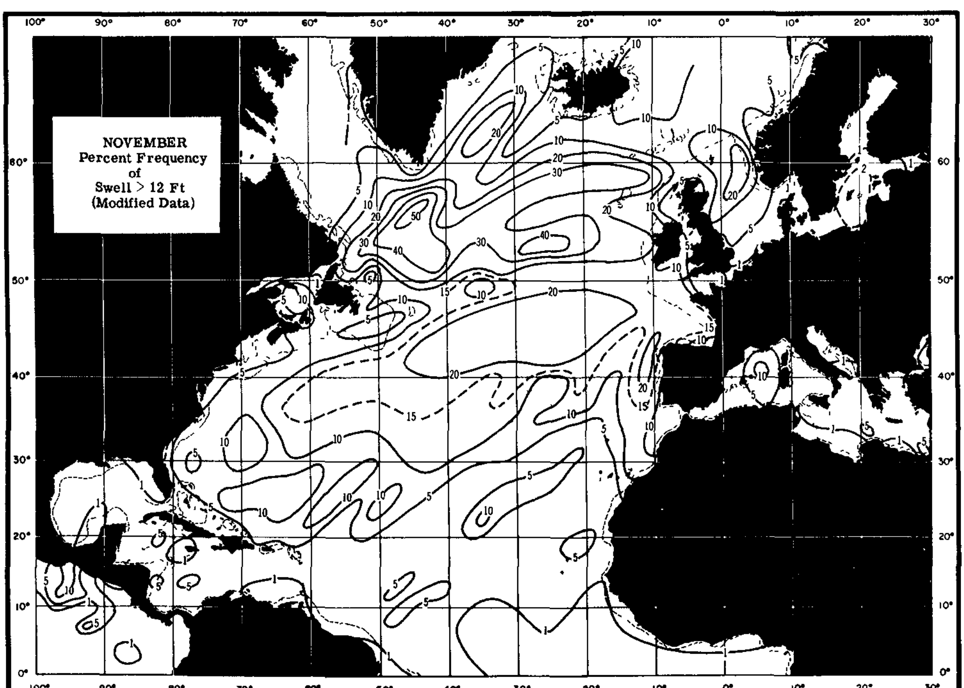

Fig. 6. Swell > 12 feet, November (Modified Data)

As a further check of this modification method, an attempt was made to locate swell data that were not included in the analysis of the charts and were taken by trained observers. NWRC, Ashville, provided microfilm records of weather ship observations covering the period 1940 through 1948. From these records only two months of observations were extracted (February and August), and only three locations had as much as three years of record in approximately the same location (Figure 7). In view of the limited number of years of record at any location, the data were totaled and averaged as a single sample for each season, comparing observed data, actual chart data, and modified chart data. The results are shown in Table IV.

Table IV

COMPARISON OF PERCENTAGE FREQUENCIES OF HIGH SWELL FROM SHIP WEATHER STATION OBSERVATIONS WITH ACTUAL AND MODIFIED MARINE DECK OBSERVATIONS

		February		
		Swell greater than 12 feet (percent)		
Ship station	Years of record*	Ship station data	Actual marine deck data	Modified marine deck data
A	3(46,47,48)	21	25	23
C	3(46,47,48)	8	40	30
1	3(42,43,44)	26	39	21
1,E	2(45,46)	18	30	20
C	1(45)	11	13	9
E	1(45)	22	25	25
B	1(46)	18	19	14
F	1(46)	4	33	22
B	1(45)	24	41	21
1	1(41)	42	33	17
1	1(40)	54	33	23
	Average	21	32	22

		August		
		Swell greater than 12 feet (percent)		
Ship station	Years of record*	Ship station data	Actual marine deck data	Modified marine deck data
A	3(46,47,48)	4	22	7
C	3(46,47,48)	2	13	13
1	2(42,43)	4	4	4
1,E	2(44,45)	0	4	3
B,F	2(44,45)	3	7	4
C,B	2(44,45)	2	18	12
1	2(40,41)	6	5	4
C	1(45)	3	10	8
	Average	3	11	7

*Data are grouped by approximate position.

This table shows large sample variations that are to be expecte in such short periods of record. The weighted averages for the two seasons present a much better comparison — here the averages are co siderably closer to those of the modified swell data than to those o

the original swell data. In general the modified swell averages show frequencies of high swell greater than those of the weather ships.

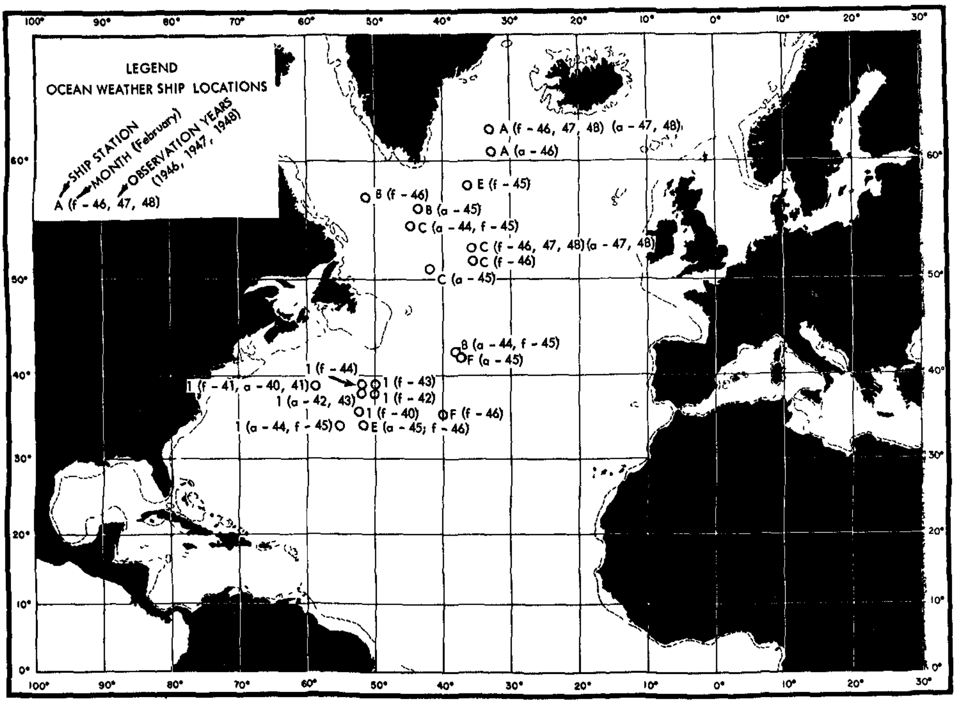

Fig. 7. Ocean weather ship locations, February and August

MODIFICATION OF SWELL ROSE CHARTS AND DATA

Some type of correction should be extended to the rose since it is still one of the most complete pictorial methods used on charts today. A complete modification based upon the total number of observation chances would often result in a significant reduction in the lengths of the arms of the swell rose, thereby providing a pattern which may be more difficult to interpret than the original rose. Besides, most data are already in a tabulated form, and without the addition of new data, a retabulation by machine would be difficult to justify. Hand tabulation of the entire rose is too time consuming and expensive. However, a simplified form of hand tabulation is a solution that involves only the computation of a factor based upon the ratio of total swell observations to total sea observations by unit rose area. This factor, included with each swell rose graphic, would provide the planner with a more complete means of interpreting ocean swell.

CONCLUSIONS AND RECOMMENDATIONS

The modification of swell data, utilizing the total number of sea observations as the number of chances to observe swell, does not provide an exact picture of ocean swell distribution. Nevertheless, all evidence indicates that this modification provides an interpreta· tion of swell distribution which is logical and reasonably similar t the actual swell distribution.

The total number of observation chances, i.e., cards with a sea and/or a swell observation, requires further study and comparison with results obtained using totals of sea observations.

Individual decks should be studied and compared to determine th sources of biased data and the possible modification by deck.

Some thought should be given to an analysis based on a simultaneous summary of both sea and swell data.

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