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Swells over Bombay High area due to storms in the Arabian Sea

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ABSTRACT. An attempt is made to estimate the height and period of swells over 'Bombay High area' caused by the cyclones of the Arabian Sea. The calculated values are examined in the light of available observations and the results are discussed. Case studies of recent systems have also been made, regarding the suitability of the method used to forecast swells.

1. Introduction

From 1973 onwards oil exploration has started in Bombay High (B. H.) area. Fig. 1 gives the location of the area. Meteorological support on an operational basis to this exploration is to be provided by Forecasting Office at Colaba, Bombay. It is found that wind and swell are the two important parameters for which accurate forecast is needed. *Marine Climatological Atlas* published by Her Majesty's Stationary Office (1949) gives us some idea about monthly averages of swells over the Arabian Sea. The swells can be grouped into three categories, *viz.*, light, moderate and heavy. For the off-shore drilling operations of Oil and Natural Gas Commission, India, the requirement is more quantitative.

As the problem was of urgent nature forecasting was done mainly on the basis of models. It was assumed that normally swells exhibit persistence and show a marked change only when some important synoptic system develops or passes over the Arabian Sea. It is for this reason that some model situation has been assumed and the heights and periods of swells transmitted due to them over B. H. area have been calculated. This area is subject to mainly two seasons — monsoon (June to September) and non-monsoon (rest of the year). The latter can be divided into two parts:

(*i*) Months with tropical cyclones over the Arabian Sea (mid April to mid June, October, November) and

(*ii*) Months with western disturbances.

The present paper reports the results of the study of swells due to storm over the Arabian Sea.

2. Data

Two different categories of storms have been considered here.

(1) Those whose centres passed over or close to (that is within 1° latitude/longitude of) B. H. area.

(2) Those whose centres passed at a distance.

For the first category, all the storms from 1877 to 1974 were considered A monthwise distribution of storms falling in this category is shown in Figs. 2 (a-d). For the second category of storms which passed away form B. H. area, three idealised storm tracks were drawn over the map based on the study of storm tracks as published by India met. Dep. (1964, 1972). This is given in Fig. 3.

3. Methods used

Munk and Arthur (1951) developed a method for calculating the heights and periods of swells, which was modified by Wilson (1955) for storms of hurricane strength and by Bretschneider (1963) for storms with fairly regular wind field and having a slow motion. Wilson's method could not be used as most of the storms never attained hurricane strength. Darbyshire (1952) has put forward another method and Silvester (1955) has drawn graphs for Darbyshire's formulae. A comparison was made between the methods for the storm of September 1974. Fig. 4 gives the track of storm together with the positions of ships from which the data for swells were taken.

Table 1 gives the results. It is seen that while Darbyshire's method gives lower estimate of heights, both Bretschneider and Munk's methods give higher values. The method of Munk and Arthur has been used in the present study of swells. For swells of period $\leqslant$ 10 sec, the bottom is not felt at B. H. area and hence they are essentially deep water waves. For higher periods, the deep water wave concept may not be true.

4. Results and discussions

4.1. *Storms over/near B.H. area*

(a) For storms passing over/near B. H. area the maximum wind speeds in the

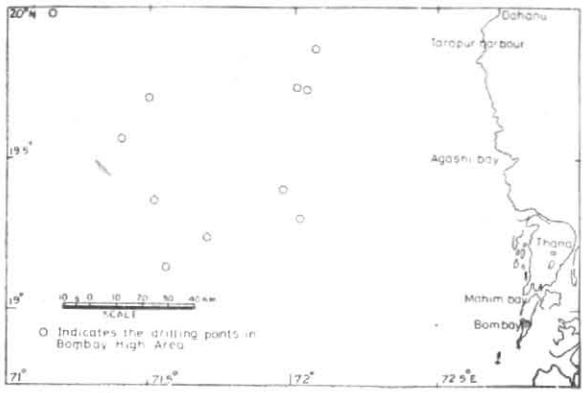

Fig. 1. Drilling points in Bombay High area

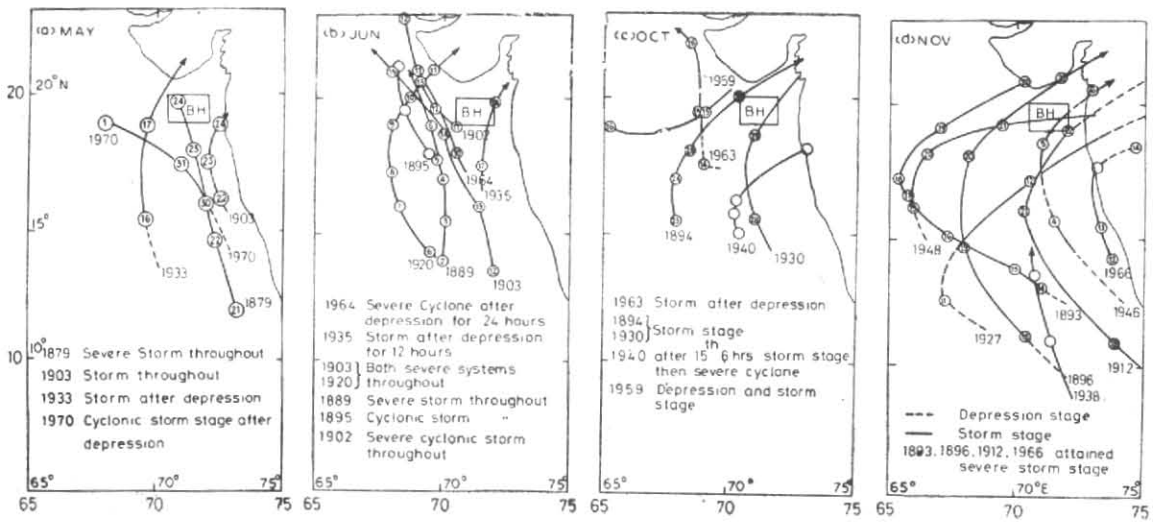

Fig. 2. (a) May, (b) June, (c) October and (d) November storms

TABLE 1

Cyclone position at GMT	Max. wind (kt)	Ship's position at GMT	Call sign	Distance (n.m.)	Calculated Bretschneider		Observed swell		Munk and Arthur		Darbyshire's method	
					Sig. height (ft)	Sig. period (sec)	Height (ft)	Period (sec)	Height (ft)	Period (sec)	Height (ft)	Period (sec)
231200	48	240000	MACS	19	11·0	7·2	9·8	6	27·6	8·2	5	7·5
191200	37	200600	ATLE	192	18·5	11·2	4·9	7	17·5	9·5	5	8·5
201200	42	210600	PFHO	124	19·0	10·5	11·5	10	21·8	9·3	6	9
201200	42	210300	PGXF	254	24·0	12·7	6·6	10	18·2	10·0	6	10
201200	42	210600	GQUH	87	16·5	9·8	6·6	6	23·8	9·0	5	9
201200	42	210430	ONGC	167	20·0	11·2	12·15	12	19·7	9·5	6	10
221200	52	230600	GXBR	229	29·0	13·5	6·6	5	30·0	11·0	8·5	13
191200	37	201200	GJEV	136	17·0	10·5	8·2	5	20·0	10·0	5	8
191200	37	201200	GJVE	174	18·0	10·8	16·4	4	18·8	10·0	4·5	8·5
201200	42	211200	GXGB	329	27·0	13·0	6·6	5	19·5	11·0	6·5	10·0
201200	42	211200	GQUH	130	19·0	10·8	6·6	6	24·6	10·0	6	9·5
191200	37	201800	GXGB	422	24·5	13·5	11·5	6	15·1	11·5	5·5	9·5
191200	37	201800	GQUH	384	23·0	13·0	6·6	6	15·6	11·5	5·5	9

central region taken for depressions, cyclones and severe cylonic storms were 30, 40 and 50 knots respectively. From the duration of wind and fetch length calculated from synoptic chart, the height and period of swells were calculated. As a preliminary check, reports for ships about sea conditions available in a few cases have been interpreted in terms of heights of waves knowing the locations of ships. On comparison, it was found that the calculated values were on the higher side. The frequency of storms affecting B. H. area or 1 degree radius area is 0·24. Occasions when the estimated wave height is between 20 ft and 40 ft are more, 21 occasions between 30 ft and 40 ft, and 27 occasions between 20 ft and 30 ft. Only on four occasions, the height exceeds 40 ft. The possibility of waves reaching greater heights is more in June followed by November as the storms of these two months are generally of sustaining nature.

(b) In general less than half the number of storms attain severe cylone stage and systems that do not attain this stage rarely give rise to waves, of height greater than 25 ft. Only two storms in these ten decades have originated in B. H. area. Hence the possibility of high waves due to formaton of storms is less over this area. Nevertheless the occasions when storms cross exactly the B. H. area are considerable. A notable point in this connection is that while waves reach greater heights in June, the frequency of storms crossing the exact area is least in this month. The prevalence of general synoptic situation not favouring much the recurvature of systems during the month may probably be the reason for this. The results are shown in Table 2.

4.2. *Storms away from the B. H. area*

It is well known that swells generated by cyclonic storms travel long distances over the surface of the sea. During the travel the swell undergoes decrease in height but increase in period as well as wave length. Mukherjee *et al.* (1961) calculated for such swells affecting Bombay, from the severe cyclonic storm of May 1959. Swells over B. H. area due to storms away from this area have been calculated, taking three idealised

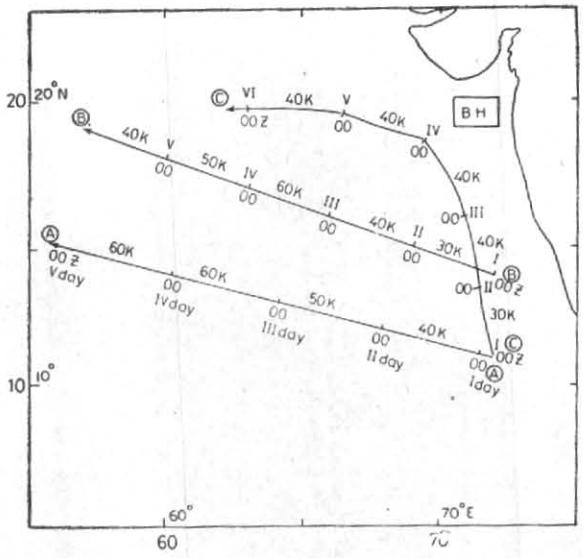

Fig. 3. Tracks of three idealised storms

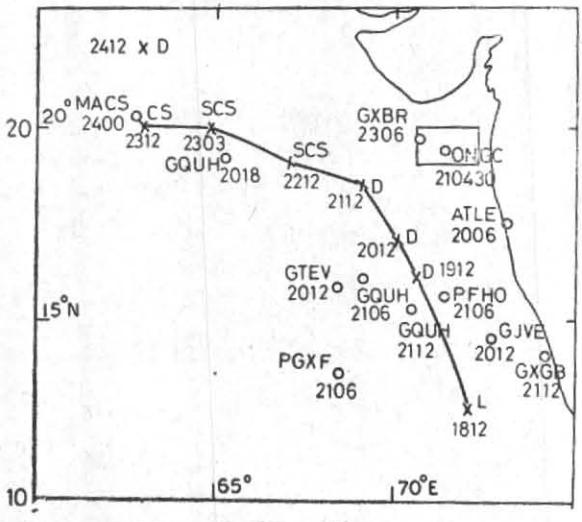

Fig. 4. Track of storm with positions of ships (September 1974)

storms (Fig. 3). Munk and Arthur's method of computation was used for this purpose. The results are shown in Figs. 5 (a-c).

4.3. *Case studies*

(A) A well marked low pressure area appeared at 0300 GMT on 30 April 1975 with centre near 9°N/71°E which subsequently became a depression with a northward movement. It was observed to have attained the cyclonic storm stage at 0300 GMT on 4 May 1975 with centre near 12°N/71°E. On 5 May it moved by 2 degrees in latitude and reached the severe cyclonic stage. The

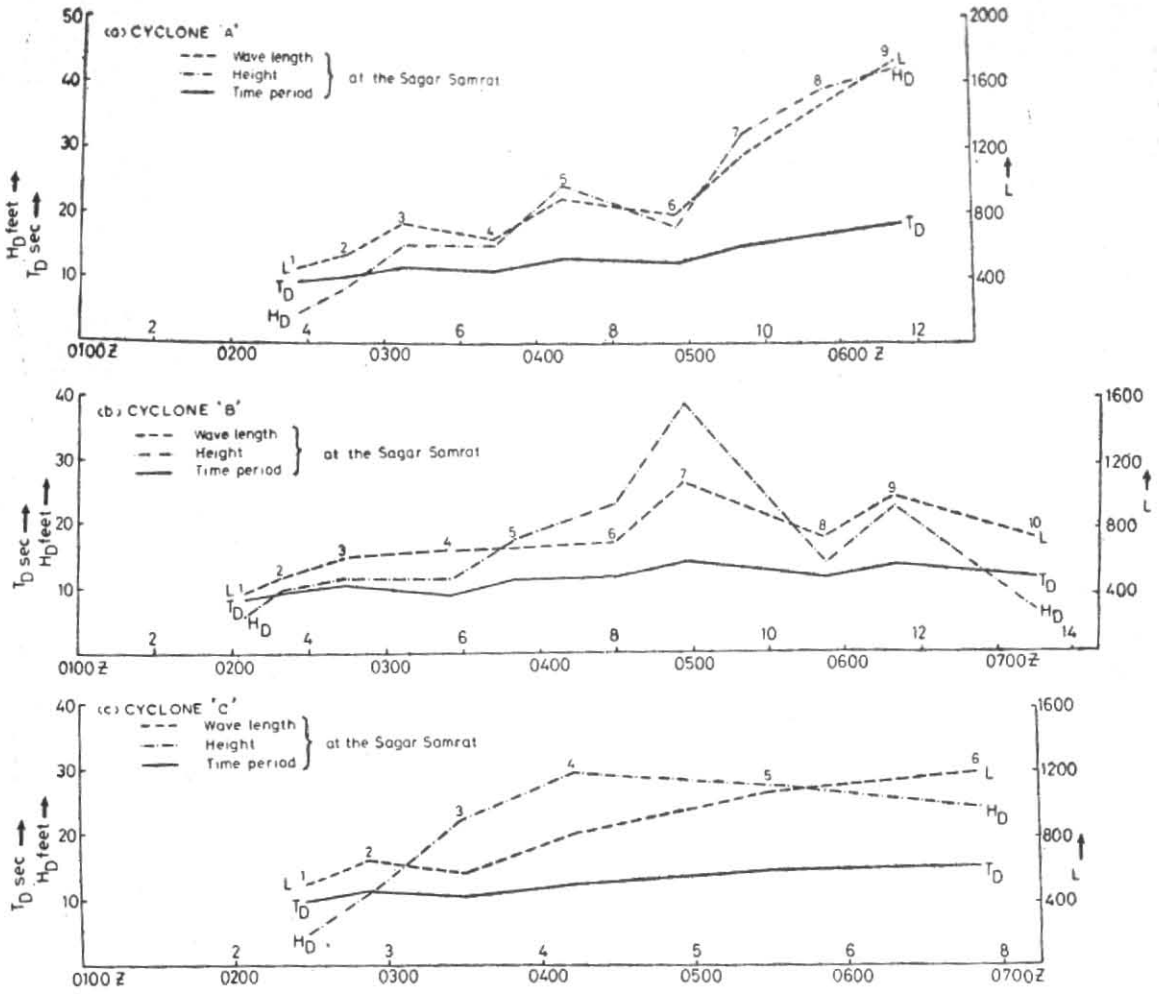

Fig. 5. Time of the swell to reach *Sagar Samrat* after generation from idealised (a) cyclone A, (b) cyclone B and (c) cyclone C

TABLE 2 (a)

Swell height

Month	Occasions when the height (ft) is			
	<20′	20′-30′	30′-40′	>40′
May	1	5	3	2
June	3	4	14	1
October	3	7	1	—
November	7	13	3	1
Total	14	29	21	4

TABLE 2 (b)

Swell period

Month	Occasions when the period is				
	<6 sec	6-8 sec	8-10 sec	10-12 sec	>12 sec
May	0	0	2	6	1
June	0	4	1	17	0
October	0	1	4	16	0
November	0	2	4	16	1
Total	0	7	11	45	2

centre was found to be around 14°N/70°E. Afterwards it weakened moving northwestwards. The track on different dates is shown in Fig. 6. The periods and heights of swells which might have come over B. H. area were calculated for this storm and the results along with observed values from *Sagar Samrat* are tabulated in Table 3. It is seen that the period agrees fairly well whereas the heights observed were much lower than those calculated.

(B) On the 29 May 1975, a trough was concentrated into a low pressure area with centre near about 7°N/70°E at 0300 GMT. At about 1200 GMT on 30 May it intensified into a depression near about 13°N/68°E. After an initial northward movement it started moving northeastwards and was observed at 1000 GMT of 31 May, 85 km/SSW from Bombay. It crossed the coast near Alibag around 1230 GMT the same day. The track is shown in Fig. 6. This storm moved within 1 degree of B. H. area. The calculated values agree well with the values of swells observed by "*Tasman Sea Horse*" (a boat belonging to O.N.G.C. stationed specially to observe swells) as seen in Table 3. The estimtes of both period and height in case (B) are comparable while in case (A) it is not. As the period exceeds 10 sec, the deep water wave concept may not be applicable for B. H. region and this may be the source for error in case (A).

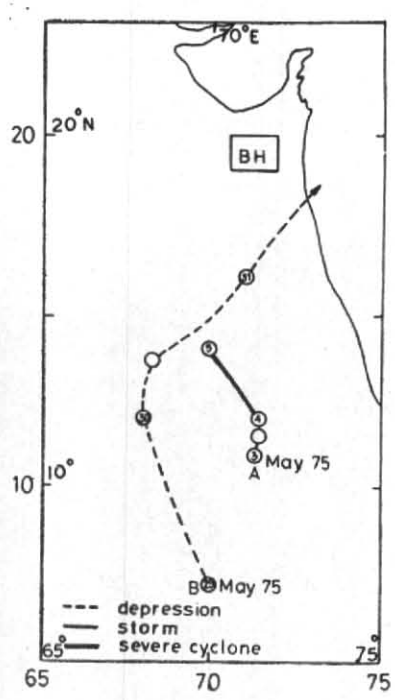

Fig. 6. Tracks of the storms under case studies A+B

TABLE 3

Date	Distance of centre from Bombay High area (n. mile)	Swell height		Swell period	
		Calculated (ft)	Observed (ft)	Calculated (sec)	Observed (sec)
	(a) Storm referred in case (A)				
3 May 75	480	8	4-5	10·8	8
4 May 75	420	17	4-5	11·8	9-10
5 May 75	300	30	5	12	9
6 May 75	250	10	4	9·3	8
	(b) Storm referred in case (B)				
0300 GMT of 30 May 75	450	6-8	8	9	8
2100 GMT 30 May 75	300	8	8-9	9	8
31 May 75	180	13	12	9	

5. Conclusions

B. H. area is affected predominantly by swells originated by cyclonic storms over the Arabian Sea. The cyclonic storms which pass over and near the B. H. area will be expected to cause high waves. The calculated and observed values of periods of swells from storms prior to 1975 agree fairly well, whereas the calculated heights appear to be overestimates. In case of the deep depression of 1975, the boat was stationed at B. H. area specially to observe swells. The observed values agreed very well with the calculated values when periods are less than 10 sec, indicating that the method adopted in the study can be used for forecasting on an operational basis within this limit.

Storms passing at a distance can also send swells to B. H. area. Here also, while the calculated values of periods agree well with observations the heights are again overestimates.

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