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Wind and waves over the Bombay High Area*

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सार — इस लेख में सागर सम्राट द्वारा 1974 से 1982 तक 9 वर्ष की अवधि में किए प्रेक्षणों के आधार पर बम्बई हाई क्षेत्र में वायु तथा लहर क्षेत्र के जलवायु लक्षणों पर चर्चा की गई है।

ABSTRACT. Based on the observations of *Sagar Samrat* for the 9-year period, 1974 to 1982, the climatological features of the wind and wave field over the Bombay High Area are discussed.

1. Introduction

During the past ten years, off-shore oil drilling operations are going on over the Bombay High Area. The wind and wave conditions over the area are of vital importance for every phase of the operations. They assumed even greater importance at the time of the unfortunate blow out in July 1982, when the possible formation of oil slick and its movement posed danger to the marine environment. Mukherjee and Sivaramakrishanan (1982) have discussed the wind and wave field over Bombay High Area during the monsoon season but their studies are based on limited data. The present study is more exhaustive, based on all available wind and wave observations of *Sagar Samrat* when it was in the Bombay High Area during the period 1974-1982.

2. Results

2.1. *Winds*

Table 1 gives the statistical information in respect of surface wind over the Bombay High Area, separately for 03 and 12 GMT. For each month and each hour of observation, the monthly mean values of the scalar wind speed, its standard deviation and the coefficient of variation and the wind direction, speed and steadiness of the mean vector wind have been tabulated.

2.1.1. *Morning hours* — In the morning hours, the mean vectorial wind is from northeasterly (041°) direction during November. With the advance of the season, it backs becoming northerly (003°) in February, northwesterly (318°) in April, westerly (280°) in May and westsouthwesterly (248-252°) in June-July. It begins to veer thereafter becoming westerly (271°) in September, northerly (005°) in October and northeasterly in November. The steadiness is lowest (only 57%) in October, when the mean vectorial wind also reaches the lowest value. Even the scalar wind is low. The steadiness is maximum in the mid-monsoon months of July and August (about 92 to 93%). The steadiness is also high, in fact highest, during January. The higher value of the steadiness factor in January is probably because the northeast trades and the local land breeze are in the same direction in the morning hours. Both the scalar and vector winds attain their maximum in July, a little less than 20 knots. The northeast trades are strongest in February when the scalar and vector winds have speeds of 11 and 13 knots respectively. The coefficient of variation of the scalar wind is minimum during July (about 31%).

2.1.2. *Afternoon hours* — During the evening hours, the winds are northnortheasterly (017°) in November. They back with season to become northerly (006°) in January, northwesterly (319°) in March, westerly (266°) in May and westnorthwesterly in June (244°)-July (248°). Later they veer to become westerly (276°) in September, and northnortheasterly (017°) in November. The maximum mean wind speed of about 17 to 20 kt is reached in July- August when the winds are also steadiest (about (95%). The lowest vector wind speed and the greatest unsteadiness occur in October. The steadiness factor decreases at 12 GMT as compared to the morning values during January to March when the sea breeze opposes the general wind. By April and May, sea breeze becomes quite prominent and pronounced and probably accounts for the increase in steadiness. Both the scalar and vector winds are minimum in March and October. The coefficient of variation of the scalar wind is minimum in July and maximum in November.

2.1.3. *Diurnal variation* — Fig. 1 shows the mean vectorial wind over Bombay High Area at 03 and 12 GMT for the different months of the year. The direction of wind low will be from the end point towards origin. The vector joining the end point of the evening to the morning wind in any particular month gives the direction of the vectorial wind change from morning to evening during that month. The diurnal variation is extremely small in the months of June, July and August. In all other months, there is an increase in the westerly component

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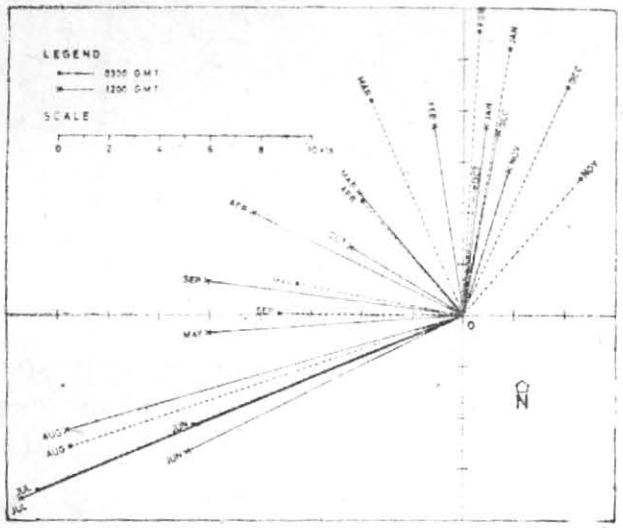

Fig. 1. Winds over Bombay High Area

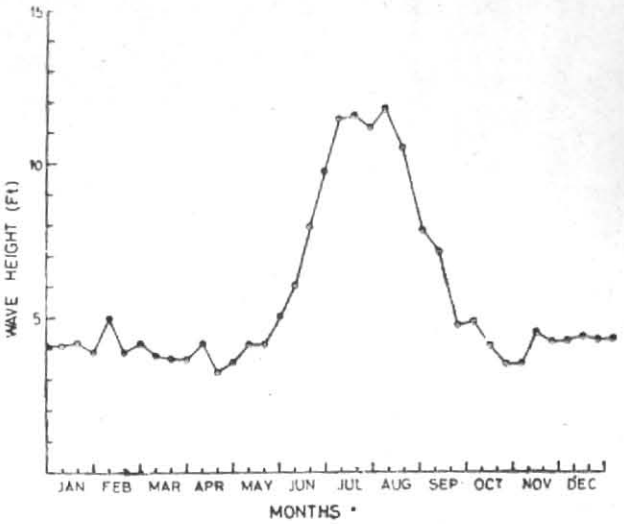

Fig. 2. Seasonal variation of wave height—Bombay High Area

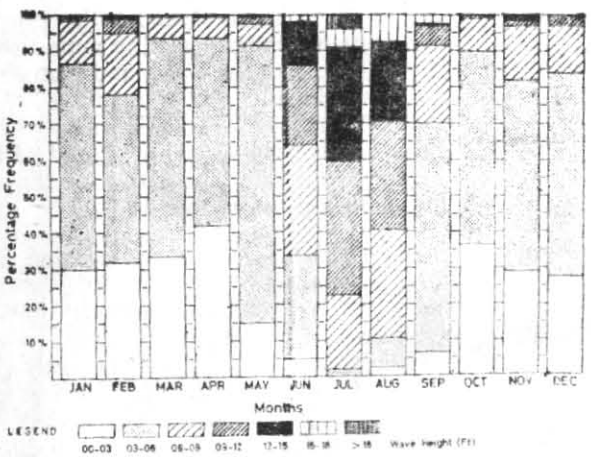

Fig. 3. Wave height — Bombay High Area (1974-1982)

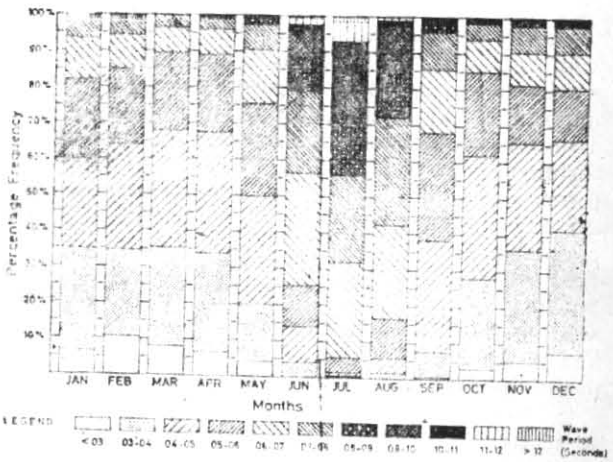

Fig. 4. Wave period — Bombay High Area (1974-1982)

(effect of sea breeze) in the 12 GMT wind as compared to the 03 GMT value. There is a small northerly component seen in September and November, while during October and from December to May, there is an increase in the southerly component at 12 GMT. The mean vectorial difference between the winds at 03 and 12 GMT is about 3 to 5 knots from September to May.

3. Waves swells

In the observation reported by *Sagar Samrat*, distinction between wave and swell has not been made in general. On most of the occasons, the total height has been reported. Hence, the statistics also refer to the total height of waves and swel.

Fig. 2 shows the annual variation of the wave height over Bombay High Area, obtained from the means calculated for three approximately equal inervals in each month (*i.e.*, about 10 days), utilising the data collected from 1974 to 1982. The mean wave height is about 4 ft from the beginning of October till the middle of May with minor fluctuations, the significant being a small rise to 5 ft by the beginning of February and the lowest values of about 3.5 ft in the middle of April and the middle of October. The wave height rises sharply from the middle of May and reaches the maximum value of 11 to 12 ft in July and first fortnight of August. It starts falling by the second half of August and reaches the minimum value of 3.5 ft by middle of October.

Fig. 3 shows the percentage frequencies of waves of different heights in the various months of the year. The heights are small in April and October, the median height being only about 3.5 ft. The median values are about 4 to 4.5 ft from November to March. They are about 7.5 ft in June, 11 ft in July and 8.5 ft in August. About 70% of the wave heights in June lie between 9 and 15 ft and 10% between 15 and 21 ft. The median wave height in November is only about 4 to 5 ft, but there is a distinct spreading towards the high values during this month, due to the presence of a few large values caused by

TABLE 1

Wind over Bombay High Area

Month	Scalar wind			Vector wind			Scalar wind			Vector wind		
	Speed (kt)	SD (kt)	CV	Drn.	Speed (kt)	Steadiness	Speed (kt)	SD	CV	Drn.	Speed (kt)	Steadiness
	0300 GMT						1200 GMT					
Jan	11.9	5.28	44.3	010	10.5	94.0	8.9	5.28	59.3	006	7.4	83.5
Feb	12.7	7.33	57.7	003	11.1	87.1	9.8	5.44	55.4	351	7.5	76.4
Mar	10.6	5.69	53.6	336	9.2	87.2	8.1	4.97	61.5	319	6.4	78.9
Apr	8.0	3.44	42.9	318	6.0	75.3	10.7	4.11	38.4	296	9.2	86.4
May	8.9	4.19	47.2	280	6.6	74.8	11.0	4.84	43.8	266	10.1	91.1
Jun	14.3	7.77	54.4	248	11.4	79.9	14.9	7.12	47.8	244	12.0	80.8
Jul	19.5	6.00	30.8	248	18.1	92.7	20.2	5.81	28.8	248	19.0	94.0
Aug	17.7	6.43	36.4	252	16.4	92.5	17.2	6.06	35.3	254	16.3	95.3
Sep	10.6	6.05	57.2	271	7.3	68.9	11.3	5.54	49.0	276	10.2	90.3
Oct	8.8	5.54	63.0	035	5.0	57.0	8.4	5.27	63.1	329	5.3	63.2
Nov	10.3	5.92	56.2	041	7.0	66.2	8.9	6.25	70.3	017	6.0	68.0
Dec	11.6	4.90	42.3	025	9.8	85.0	8.7	5.60	40.6	010	7.6	87.5

TABLE 2

Frequency distribution of wave height vis-a-vis wave period

Wave height (ft)	Total No. of obsns.	Wave period (sec)											Median (sec)
		<3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	>12	
0-3	512	119	251	103	30	4	3	1	1				3.5
6-6	1208	6	239	457	318	125	60	2	1				4.8
6-9	385		1	27	86	124	95	32	13	5	2		6.6
9-12	208		1	3	17	65	60	27	28	3	1	2	7.3
12-15	125			1	7	28	28	22	21	10	8		7.9
>15	45				1	5	5	13	11	5	4	1	8.9

TABLE 3

Wave parameters for Kruesman wave spectrum model

Wave height (mm)	Period for peak frequency T_p (sec)	Period for lower wind of frequency T_n (sec)	Period for upper wind of frequency T_n (sec)
1.0	4.26	5.92	1.97
1.5	5.22	7.25	2.41
2.0	6.03	8.38	2.78
2.5	6.74	9.36	3.11
3.0	7.39	10.26	3.41
3.5	7.98	11.08	3.68
4.0	8.53	11.85	3.94
4.5	9.05	12.56	4.18
5.0	9.54	13.24	4.40
5.5	10.00	13.89	4.62
6.0	10.45	14.51	4.8

occasional severe cylonic storms in the Arabian Sea during this month. The mean scalar wind speed in February (12.7 knots) is not far different from the mean wind speed (14.3 kt) in June; however, the wave characteristics are quite different in the two months. The median wave height is about 7.5 ft in June with nearly a third of the heights being above 9 ft, while in February the median wave height is only 4 to 4.5 ft and only about 4% of the heights exceed 9 ft. Because of the strong diurnal variation in February, the duration of the wind of the same direction and speed is reduced, leading to small accretion of wave height. In June, however, the diurnal variation is very little. Hence, continuous accretion of wave height can take place, resulting in much greater wave height.

3.2. *Period* — There is a large scatter in the period of waves in all the months (*vide* Fig. 4). The median value of the period is about 7 sec in June and August, 8 sec in July and 4.5 to 5.0 sec in the other months. The period exceeds 8 sec on about 7 days in June, 14 days in July and 9 days in August and exceeds 10 sec on 4 days in July.

Table 2 shows the fequency distribution of the wave height *vis-a-vis* wave period. The table clearly indicates the increase in the wave period with increase in wave height. The median value of the period increases from about 3.5 sec for waves less then 3 ft in height to 6.65 sec for waves in the height range 6 to 9 ft and to about 9 sec for waves with height exceeding 15 ft.

Table 3 shows the periods corresponding to the peak frequency and lower and upper boundaries of the Kruesman's (1976) wave spectrum for waves of heights ranging from 1.0 to 6.0 m. A comparison of Tables 2 and 3 will indicate that to a good degree of approximation, Kruesman's wave spectrum model seems to be applicable to the waves over Bombay High Area.

4. Conclusions

(1) Winds over Bombay High Area during the morning hours back from northeasterly in November to westsouthwesterly in June-July and later veer till November. Winds in the afternoon also back from November to June and later veer.

(2) Both the scalar and vector wind speeds reach their maximum value of about 20 kt in July when the steadiness is also maximum. The coefficient of variation of the scalar wind is minimum during this month. The northeast trades are strongest in February.

(3) The diurnal variation is small in the monsoon months June, July and August. In all other months, there is an increase in the westerly component (effect of sea breeze) in the evening hours as compared to the morning values. The vectorial difference in speed between morning and evening winds is about 3 to 5 knots from October to May.

(4) Waves over Bombay High Area have an average height of about 4 ft from middle of October to middle of May. They increase sharply from middle of May to reach the maximum value of 11 to 12 ft in July and first half of August. Later they drop down suddenly to reach the minimum value in October.

(5) The wave height lies between 9 and 15 ft on about 20 to 22 days in July and exceeds 15 ft on 3 days.

(6) Though the median wave height is only about 4 to 4.5 ft in October, a few large waves/swells occur in this month in association with severe cyclonic storms in the Arabian Sea.

(7) The median wave period is about 7 sec in June and August and 8 sec in July and 4 to 4.5 sec in the other months. It exceeds 8 sec on about 8 days in June and August and 14 days in July and 10 sec on 4 days in July.

(8) The wave period increases with height. It is observed that Kruesman's wave spectrum model fits fairly well with the observational characteristics of the waves over Bombay High Area.

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