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RELIABILITY STUDY OF WWATCH III MODEL DURING 21st TO 29th MAY 2001 CYCLONE OVER THE ARABIAN SEA

1. The extensive drilling and oil exploration activities are regular and continuous by various agencies over off shore areas of Bombay and help to boost the country's economy. Such activities are largely influenced by the prevailing winds and generated waves. Though the incidences of development of weather system are less in the Arabian Sea but when they are present, largely affect the generation of winds and waves. The prediction of strong winds and associated high waves are the main aim for the safety of the manpower deployed at various rigs/platforms in the Arabian Sea.

Extensive offshore drilling and exploration operation in the Arabian Sea necessitate a comprehensive understanding of wave and wind regime of the area. Wave characteristics in open sea depend upon the strength of wind, its fetch and duration. According to Bhandari (1980) wave should not exceed 1.5 to 2.0 m (5-7 feet) for smooth operation and safe movement of the rigs. Thiruvengadathan (1984) and Sivaramakrishnan (1984) have suggested an empirical relationship of wind speed of 20 knots is the corresponding limit to generate wave height of 1.6 to 2.4 m. Mukherjee and Sivaramakrishnan (1980 and 1982) have studied some aspects of wave over Bombay High Area (BHA) based on observational data received from various rigs during monsoon season of 1976 and 1978. Thiruvengadathan *et al*. (1984) have studied the climatological aspect of wave over the Arabian Sea by using wave reports from Russian research vessels during monsoon season. Shyamala and Iyer (1989) have tried to evolve a relationship between wind speed and wave height during monsoon season. Bhan *et al.* (1994) applied graphical regression method for predicting wind over BHA, they could not develop a regression equation between predictants and predictor because their correlation coefficients were very low. Nandankar *et al.* (2002) had studied the temporal distribution of wind and wave over BHA during the cyclone period by using ten years data (1990-99). Rajkumar *et al*. (2000) had studied the sensitivity of the wave model (WAM) towards different parameters over Indian region and tested for error in wind speed and direction. Sarkar *et al*. (1997) had studied the intercomparison of model predicted wave heights with satellite altimeter measurements in the North India ocean.

Although, the development of the cyclone over the Arabian sea is a rare occasion and thus they deserve specific attention. 194 storms formed during 1900-1999 over the Arabian Sea; majority of them originates near Lakshadweep area in the region bound by Lat. 5° N to 12° N and east of Long. 65° E. Of these, 38 storms had formed in the Bay of Bengal and emerged into the Arabian Sea. Gujarat coast is vulnerable to cyclones with almost 2 cyclones crossing every decade (India Meteorological Department 1979 and 1996). Wind and wave associated with cyclone over the Arabian Sea as well as BHA are not adequately documented. Therefore it is difficult to get an estimation of wind and wave over the Arabian Sea and BHA under the influence of the cyclonic storm. In view of operational requirements, wave prediction in the Arabian Sea under the influence of cyclonic storm is a critical and complex. Thus, this study aimed on the prediction of wave parameter upto 72 hours at every three hours interval by using National Centre for Environment Prediction (NCEP) reanalysis surface wind (10m) as an input and reliability test has been carried out by using three hourly output based on 72 hours output.

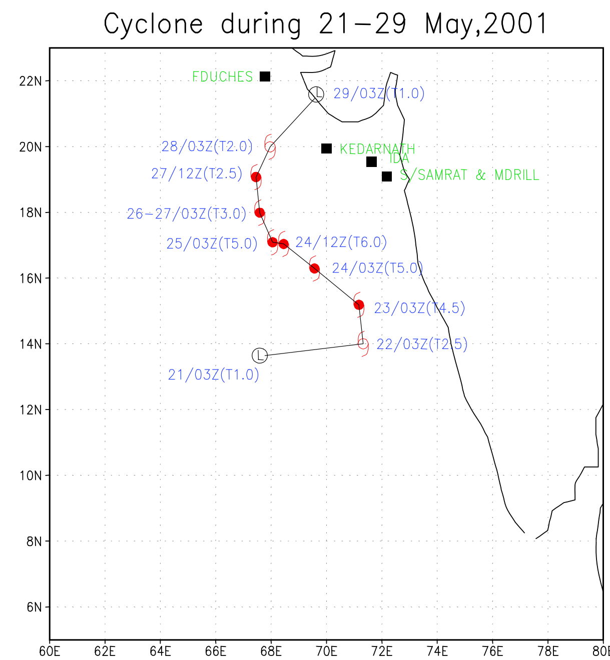

Fig. 1. Cyclone track and positions of rigs

2. The model used in this study is a full spectral third generation ocean wind wave model (Tolmann, 1999) called as WAVE WATCH III (WWATCH III). This model has developed at Ocean Modeling Branch (OMB) of the Environmental Modeling Centre (EMC) of National Centre for Environmental Prediction (NCEP).

3.1. The present study has been designed for the oceanic region around the India extending from Lat. 0° N to 25° N and Long. 60° E to 90° E. The special resolution of the model has been chosen as 2° × 2° grid and time step

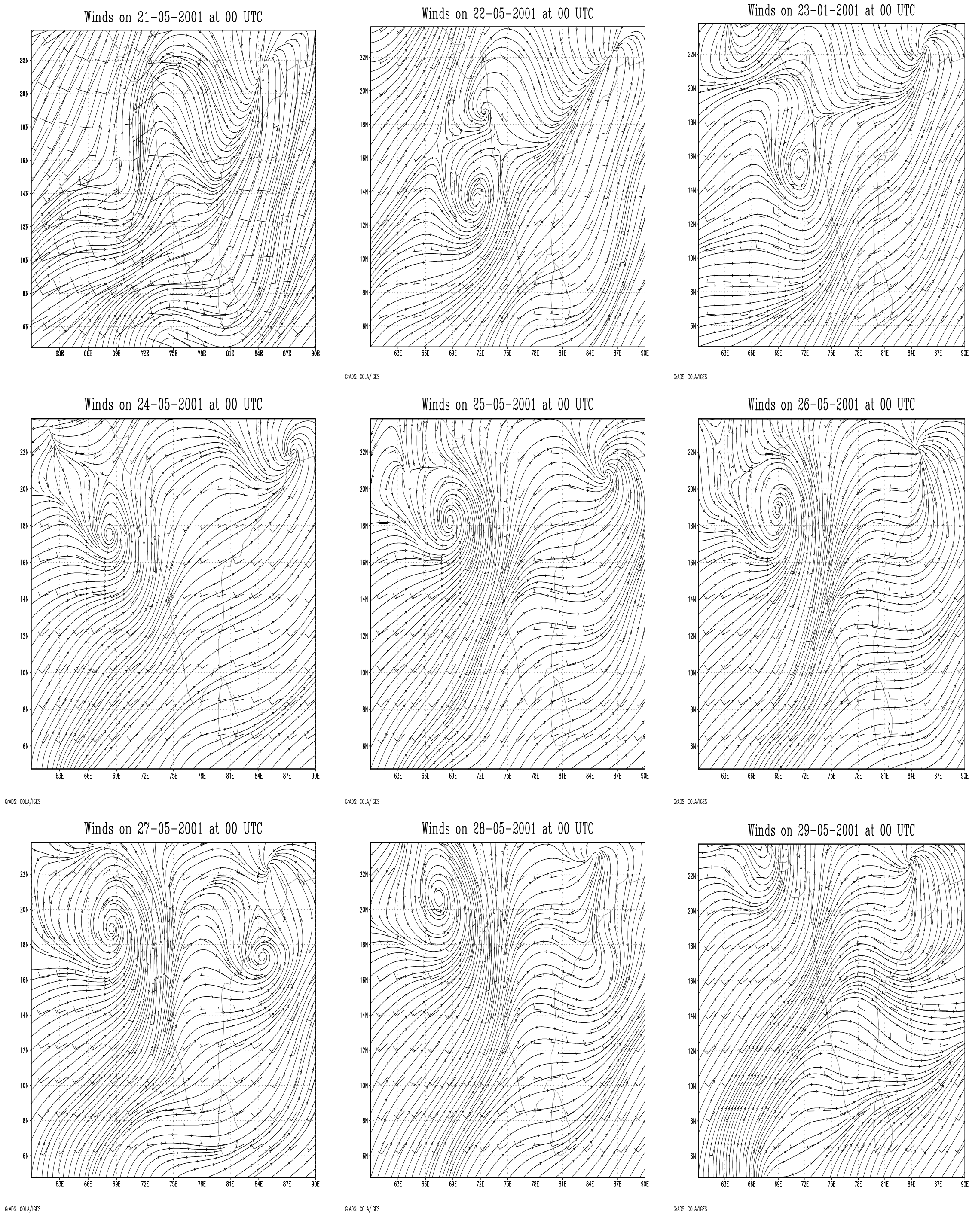

Fig. 2. Daily wind during 21st to 29th May, 2001

as 60 minutes. The depth data has been derived from NGDC (USA) which is a world wide bathymetry data set within 5 × 5 min resolution. The depth in the Indian region varies from 10 to 6000 m.

The analysis has been carried out for the validation of model output associated with the cyclonic storm over the Arabian sea during 21st to 29th May, 2001. Wind fields (u & v components at 10 m) from NCEP reanalysis have

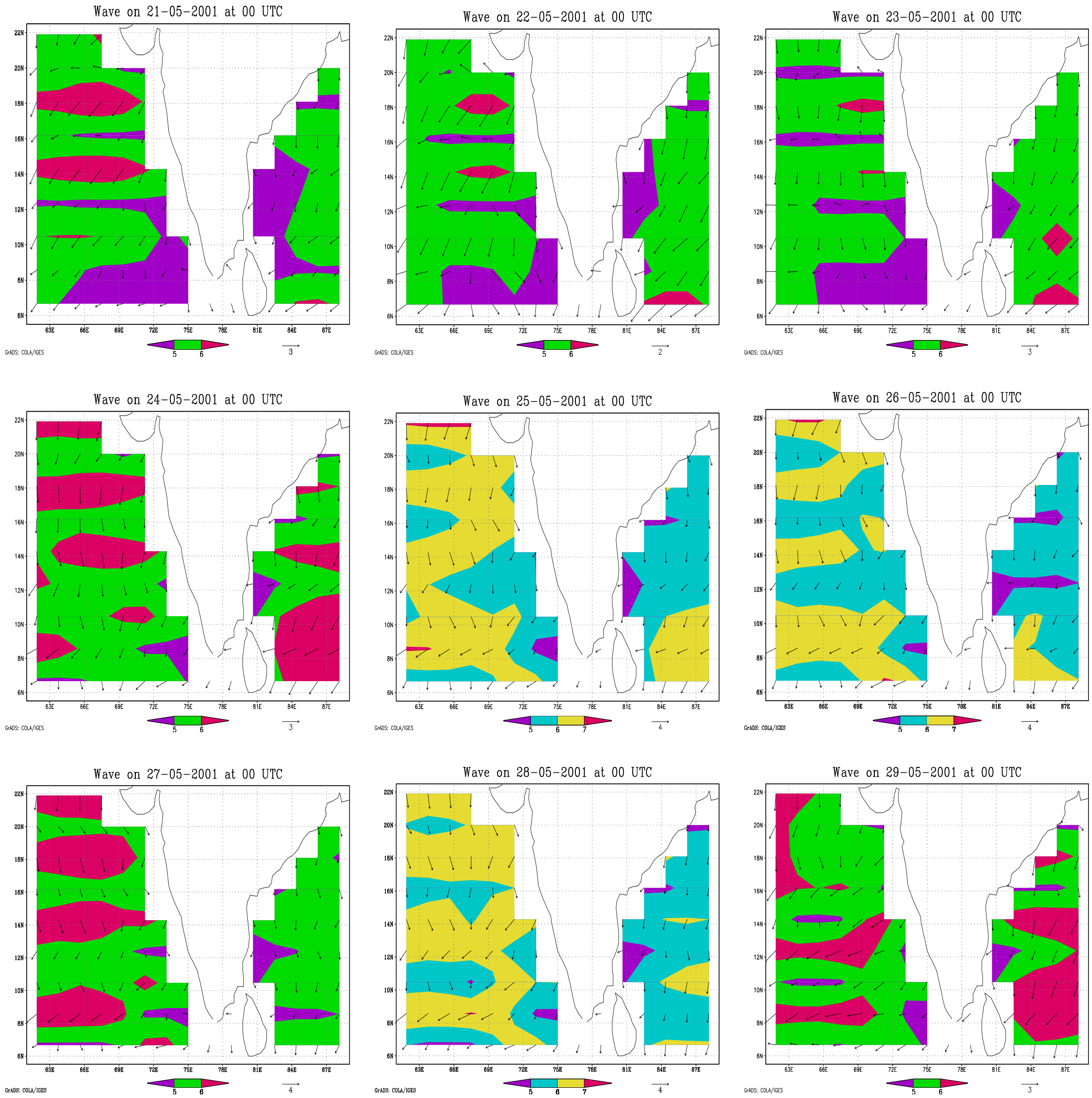

Fig. 3. Daily wave distribution (Direction, height and period) during 21st to 29th May,2001

been used in this study. The wave parameters have been extracted at every six hours interval by running the model for 72 hours daily. The model forecast is attempted to check the reliability with observed data received from various rigs in the Arabian Sea. The rig positions are shown in Fig. 1.

3.2. The track of the cyclonic storm is shown in Fig. 1. A low pressure had formed over southern parts of central Arabian Sea near Lat. 13.5° N / Long. 67.5° E with intensity T1.0 on 21st at 0000 UTC. It intensified into the cyclonic storm on 22nd at 0000 UTC near Lat. 14.8° N / Long. 71.5° E with intensity T2.5. It moved in a northerly direction and lay centered at Lat. 15.0° N / Long. 71.5° E on 23rd at 0000 UTC. The eye of the cyclone was visible at 0700 UTC of 23rd near Lat. 15.8° N / Long. 70.9° E. It moved in a north northwesterly direction and lay centered at Lat. 16.5° N / Long. 69.5° E on 24th at 0000 UTC as severe cyclonic storm with intensity T5.0. It further intensified into a very severe cyclonic storm on 24th at 1200 UTC centered at Lat. 17.0° N / Long. 68.5° E with intensity T6.0. Suddenly, it weakened slightly on 25th at 0000 UTC and lay centered at Lat. 17.0° N / Long. 68.0° E with intensity T5.0. It further weakened over the

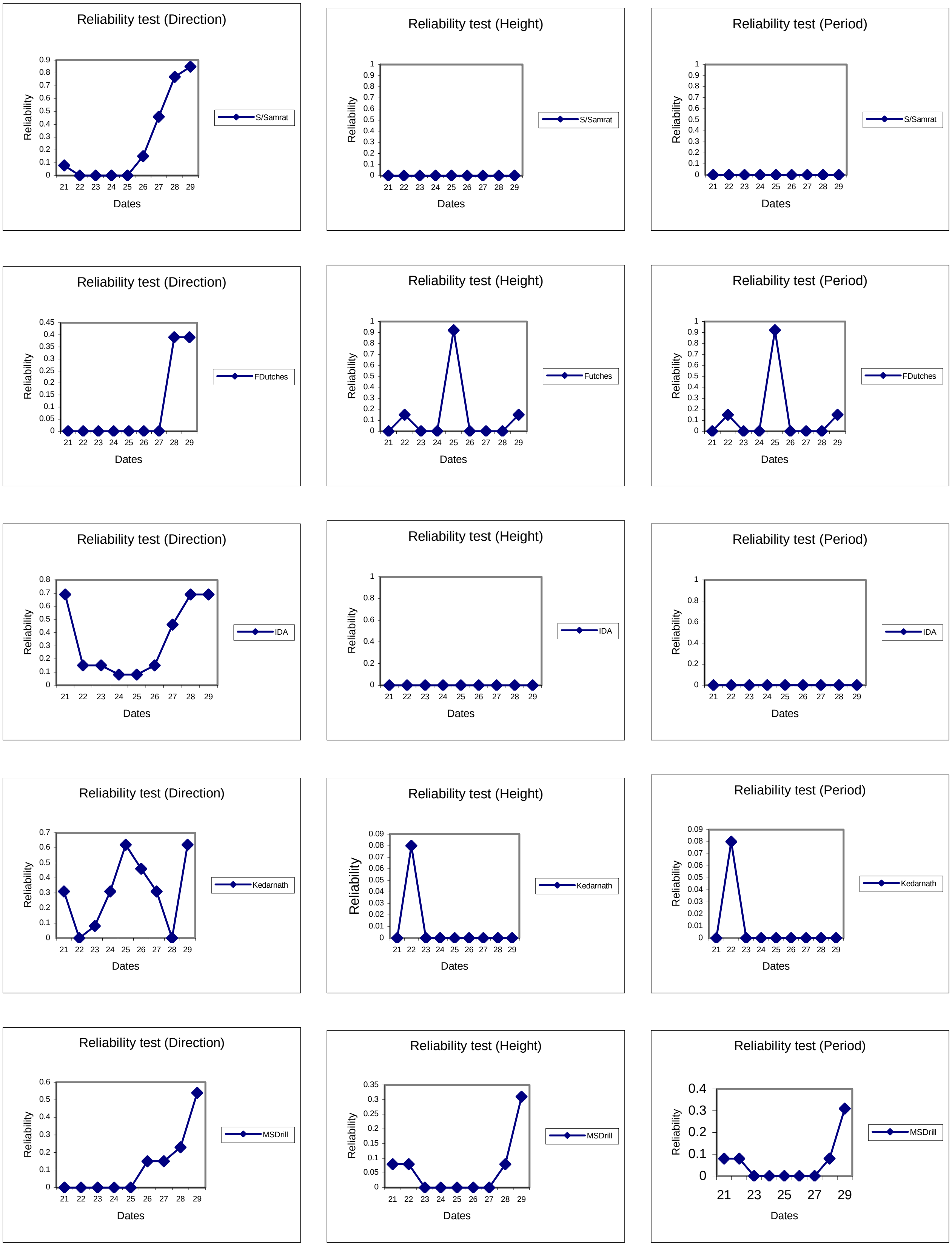

Fig. 4. Reliability test for wave direction, height and period

same region and remained stationary near Lat. 17.0° N / Long. 68.0° E upto 0000 UTC of 26th. It continued to weakened into a cyclonic storm on 28th at 0000 UTC and centered at Lat. 20.0° N / Long. 68.0° E. It rapidly weakens into a low-pressure area on 29th.

3.3. The NCEP wind (at 10 m) distribution at 0000 UTC from 21st to 29th are shown in Fig. 2. The wind analysis shows the trough in westerly over the central parts of the Arabian Sea on 21st and developed into a cyclonic circulation on 22nd. It slightly moved in a northerly direction on 23rd .The wind analysis continued to depict the circulation on 24th, 25th and 26th with northerly movement. The analysis depicted the cyclonic circulation over the northeast Arabian Sea and neighborhood on 27th. It further moved northward and located over the northern parts of the northeast Arabian Sea and neighborhood on 28th. The cyclonic circulation completely disappears on 29th and analysis has depicted the trough. This indicates that the NCEP wind distribution is perfectly matching the daily prevailing synoptic condition over the Arabian Sea. Therefore this data has been used in the model for 72 hours wave forecast.

Associated swell wave distribution at 0000 UTC from 21st to 29th are shown in Fig. 3. Vector arrows pointing toward the representative direction from where the swell wave approaches at the point and length as height. Wave period is shown in various colours as indicated in colour bars. The wave analysis shows that the swell waves are southwesterly with 2-3 m height and period ranging from 2-5 second on 21st and 22nd. The analysis has accurately depicted the changes in wave distribution on 23rd and 24th due to northward movement of the cyclonic circulation as per the NCEP wind analysis. The wave has changed from southwest to south direction, whereas, no significant change in wave height and period has been noticed. Wave analysis depicts significant changes on 25th and 26th due to intensification of the cyclonic storm and its continued northward movement. The changes in wave direction with more height and period have been again observed. The wave direction has changed from south to southwest with height 3-4 m and period 6-7 sec on 25th and 26th. The analysis depicted insignificant variation of wave distribution on 27th. The analysis has also depicted further changes in wave distribution on 28th due to the northward movement of the cyclonic storm. Wave direction has changed from south to southwest but the wave height and period remained the same as observed on 27th. Analysis also accurately depicts the significant changes in wave distribution on 29th due to weakening of the cyclonic storm. The wave analysis shows the less wave height and period on 29th. However, wave continued to travel from southwesterly direction. This suggests that the model has accurately identified the daily variations in wave distribution as per the prevailing synoptic condition and NCEP wind analysis. Therefore, it can be inferred that this wave model predicts the wave parameters and depicts its variations in space and time depending on the prevailing synoptic condition, track and intensity of the cyclonic storm.

4. The concept of reliability has been known for a number of years but it has assumed greater significance and importance during past decade particularly due to impact of automation, development of complex weather prediction models in the tropics. The reliability of the product is very important aspect of its consistent performance over its expected life span.

The reliability is calculated (Mahajan, 2001) by using the following equation

$$R_e = 1 - P_f$$

Where, $P_f = n_i / n$ = probability of failure, n_i and n are the number of occasions in which the predicted values are not matching with observed data and total number of observations respectively.

The reliability test of the model result has been carried out by using observed wave data of five rigs namely S/Samrat, Fdutches, IDA, Kedarnath and MSDrill in the Arabian Sea. The rig positions are depicted in Fig. 1.

Daily reliability test has been worked out and presented in Fig. 4 in respect of wave direction, height and period. The wave direction is more reliable on 27th, 28th and 29th and less reliable during 21st to 26th at the location of Sagar Samrat. However, wave height and period is unreliable on all the days. No significant changes/ variations has been noticed in reliability test in respect of wave height and period at all the locations of the rigs. At the location of FDutches, the wave direction is highly reliable on 28th and 29th and less reliable during 21st to 27. The wave height and period is also highly reliable on 25th and less reliable during all the remaining days. The wave direction has been highly reliable on 21st,became lesser reliable on 22nd. It continued to be less reliable up to 26th. It again switched over towards the highly reliable side on 27th, 28th and 29th at IDA. The wave height and period has been unreliable during 21st to 29th. The wave direction has been highly reliable at Kedarnath on all the days except on 22nd, 23rd and 28th and height and period are unreliable on all the days except on 22nd. Significantly, high reliability in wave direction has been observed at Mdrill during 26th to 29th and less significant during 21st to 25th. Significant difference has been observed in the reliability test in respect of wave height/period compared to wave direction. The height/period has been slightly reliable on 21st, 22nd and 28th and highly reliable on 29th, whereas, unreliable during all remaining days.

This analysis inferred that the model is unable to predict the realistic values of the wave parameters. High variations in the reliability analysis have been observed on daily basis at all the locations of the rigs. Thus, model may predict unrealistic wave parameters on operational basis in time and space. This study also reveals that the model can predict wave directions accurately depending on the intensity of the cyclone.

5. It is concluded that the model is able to predict the realistic value of wave direction in space and time depending on the center of the cyclonic storm, its track and intensity. However, this model is unable to predict the realistic values of the other wave parameters *viz*., wave height and period. Thus, it is expected that the model may predict unrealistic wave parameters on the operational basis. Therefore, many cases of the cyclonic storm have to be tested for getting realistic values of the wave parameters before utilizing this model on the operational basis.

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