



WIND FIELDS OF STORMS FROM SURFACE ISOBARS FOR WAVE HINDCASTING

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SYNOPSIS : Marine operations of various types are critically linked to mean and extreme wave statistics. In the Indian seas extreme wave conditions are caused by cyclones and steady strong monsoon winds. Wave data from cyclone areas are not directly available in plenty. The situation can be improved by hindcasting waves using wind fields of past storms. A method to hindcast storm wind fields is presented in this paper. The method is based on the standard Hydromet pressure profile. The input variables are, (1) radius of maximum wind, (2) central pressure, (3) storm speed, (4) direction of storm movement, (5) latitude and (6) longitude. These are obtained from charts prepared by the India Meteorological Department. The computed wind fields agreed well with other published results.

INTRODUCTION

Severe storms happen in the Bay of Bengal and Arabian Sea generally during and after the summer monsoon. These storms cause very strong winds, sometimes more than 100 knots in the oceanic areas. They give rise to very high seas, even though, during the summer monsoon seas are generally rough. These high waves are not noted in plenty by the voluntary reporting ships, since ships usually avoid storms.

Long term wave data is a necessity for computing extreme wave conditions or design wave statistics. As far as the Indian seas are concerned recorded wave data is available for short periods for some places along the coasts, e.g., port areas. This deficiency can be overcome by hindcasting storm seas using past storm wind fields. For this study a storm which happened in the Bay of Bengal during November 14-20 (1977) was selected due to good documentation (Pant et al, 1980). Input storm variables were delineated using isobaric charts from the archives of the India Meteorological Department at 3 hours intervals.

STORM MODEL

Storms are very diverse in their intensity, movement patterns, life period etc. Hence patterning all types into one model is not desirable. Different storm models are available in literature (Wilson, 1957; Schwerdt et al, 1979 and Overland, 1977). The purpose of the computed wind field decides mostly the model selection. In this study the wind field is for use in hindcasting the storm waves on a large grid system. Hence, emphasis is given to arrive at the strongest winds in the storm in a finely resolved grid system ($\Delta x = 10$ km) from centre upto 200 km radius.

For this study the Hydromet Profile (Eq. 1) is adopted as the standard (Schwerdt et al, 1979).

$$P_r = P_o + (P_n - P_o) e^{-R/r} \quad (1)$$

where P_r = pressure at radius r , P_n = peripheral pressure, P_o = central pressure and R = radius of maximum velocity. This, when substituted into the horizontal equation of motion (Holton, 1972) with curved isobars and forward movement results in

$$U_r = (-\lambda/2) \pm [(\lambda/2)^2 + \Delta P \cdot (R/\rho r)]$$

$$e^{-R/r}]^{1/2} \quad (2)$$

where U_r = tangential velocity at radius r , $\lambda = (f r + V_s \sin \theta)$, f = Coriolis parameter, V_s = Storm speed, θ = anticlockwise bearing angle of the radial point from the direction of movement, $\Delta P = P_n - P_o$ and ρ = air density. Hence the gradient velocity at R is

$$U_R = (-Rf/2) + (\Delta P / \rho e)^{1/2} - (V_s \sin \theta) / 2 \quad (3)$$

Here, U_R is instantaneous gradient velocity at a level where boundary effects are insignificant. U_R can be reduced to a level 10 m above the sea surface as an average of 10 minutes periods (Schwerdt et al, 1979; Overland, 1977 and Bretschneider, 1976) by

$$U_R(10) = 0.90 \times U_R \quad (4)$$

The wind field at any radius around the storm is related to this mean velocity. Different relationships had been worked out by various workers (Dube et al, 1981) for specific purposes. Jalesnianski's formula is adopted here as below (Jalesnianski, 1972 and Overland, 1977).

$$U_r = U_R(10) \cdot (2 \cdot R \cdot r / (R^2 + r^2)) \quad (5)$$

The surface winds, due to boundary effects, are slightly inclined inwards towards the centre of the storm and this inflow angles depend on r and intensity of storm. Various methods are available for specifying this (Overland, 1977 and Schwerdt et al, 1979). In this study inflow angles are specified as shown in Fig. 1 for an R value of 56 km. (The radius of maximum velocity for this storm at low intensity is 55 km). Hence, inflow angle = $0 - 10^\circ$ (for $r = 0$ to R), = $10 - 25^\circ$ (for $r >$

R to $2R$ and = 25° (for $r > 2R$).

EVALUATION OF STORM VARIABLES

Even though isobaric charts were available at 3 hr intervals, only charts at 0830 hr were used for this pilot study. From these charts P_o and R were evaluated using Wilson's (1957) method and hourly values were interpolated. Distribution of these variables are shown in Fig. 2 and 3. The peripheral pressure (P_n) was taken as 1012 mb after a study of pressure fields of many past storms in the Bay of Bengal. (See Varkey (1985) for more details on Wilson's method of evaluation of P_o and R).

COMPUTING GRID

The hourly values of the different storm variables were input into the numerical version of the storm model (Varkey, 1985) and wind fields over 1000 sq. km area for 52 hrs of the intense phase of the storm were computed. A five-level grid system with 5 grid intervals ($\Delta x = 10, 20, 30, 40$ & 50 km) was used to resolve the wind field at the core of the storm finely and coarsely at outer areas away from the core. Here an area of 200 km^2 around the core is resolved at 10 km intervals in the first level of gridding; in the second level of gridding an area of 400 km^2 around the core is resolved at 20 km intervals and so on. In the fifth level the full area of 1000 km^2 is resolved only at 50 km intervals.

DISCUSSION

Wind speeds and directions during the mature phase ($R = 40 \text{ km}$ & $P_o = 915 \text{ mb}$) of the storm are shown in Fig. 4 and 5. The computed wind field (Fig. 4 & 5) showed good agreement with published results involving estimates of maximum velocity using T-numbers (Pant et al, 1980). The computed maximum velocity is 90 kn whereas pant et al (1980) in their velocity composite showed 100 kn as maximum

velocity. Here it is to be understood that the present value is estimated at 10 m as an average for 10 minutes. The Joint Typhoon Warning Centre at Guam estimated the maximum velocity as 115 kn on 18.11.1977 from satellite pictures. But this difference is not to be taken seriously as estimates from T-numbers can vary much depending on satellite pictures. The assymetry of the velocity field (Fig. 4) is due to the forward motion of the storm. Some modifications in the inflow angle specifications are planned in the model for its use in different storms of different intensities.

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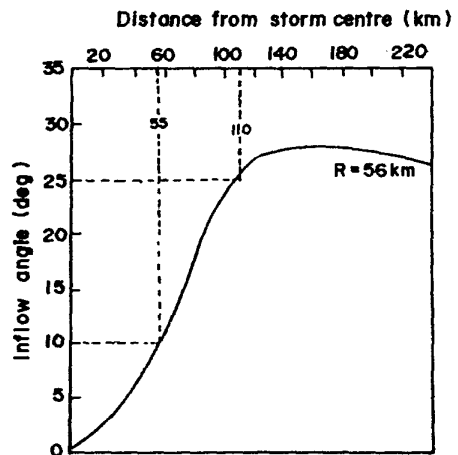


Fig.1 Specification of inflow angles (adapted from Schwerdt et al, 1979)

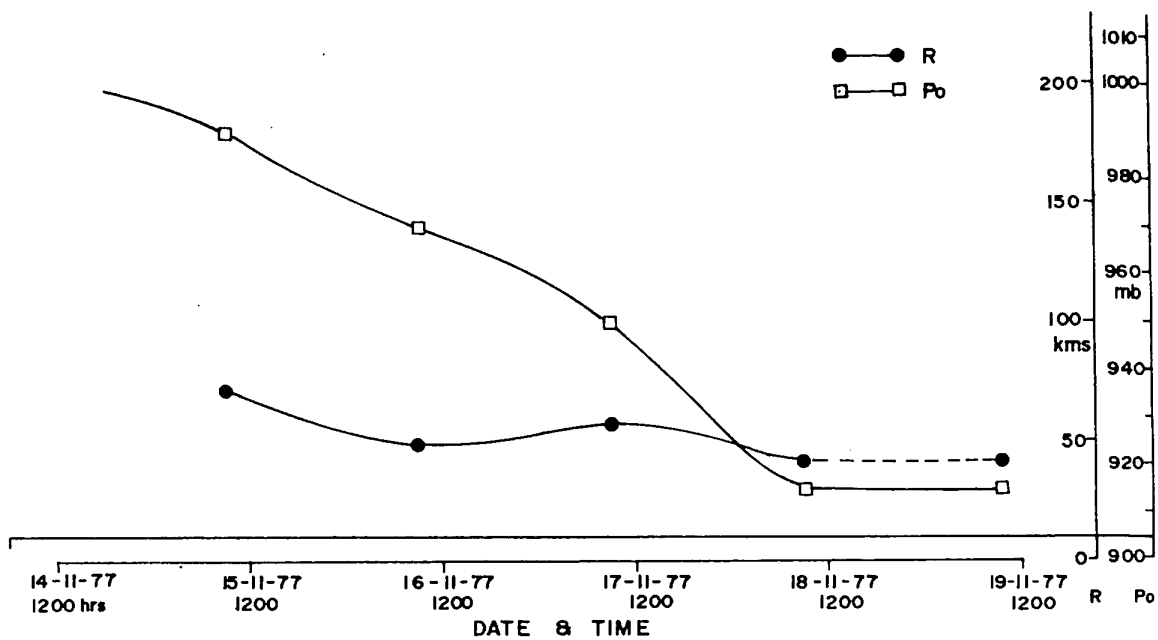


Fig. 2. Distribution of R and Po

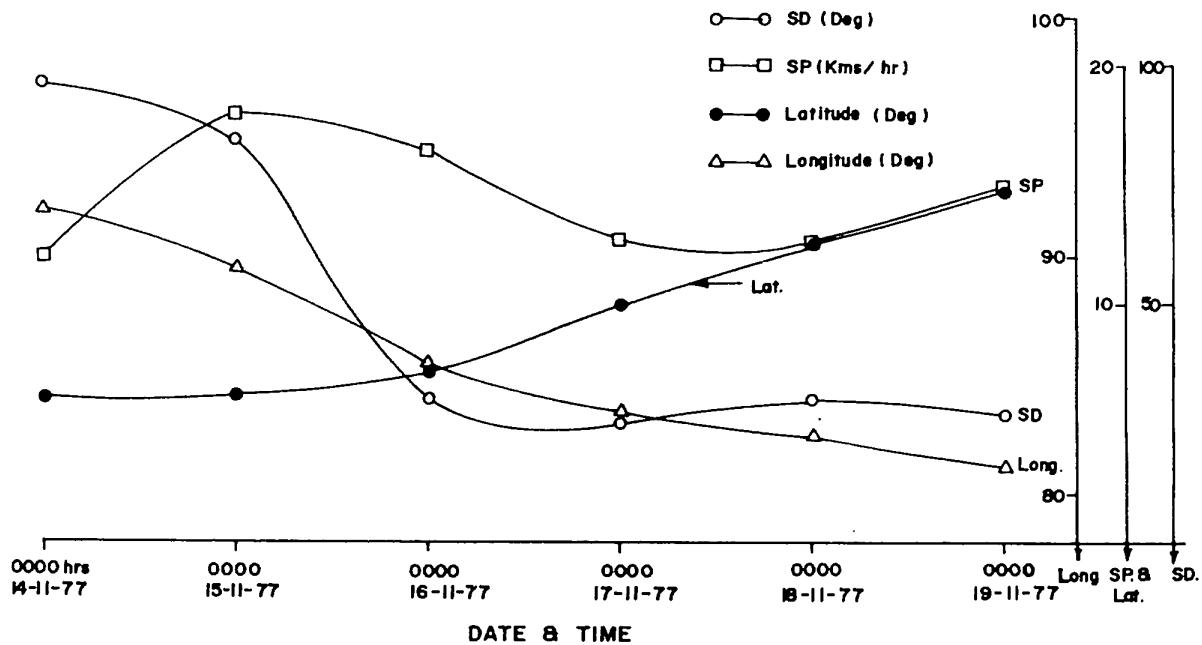


Fig. 3. Distribution of other variables

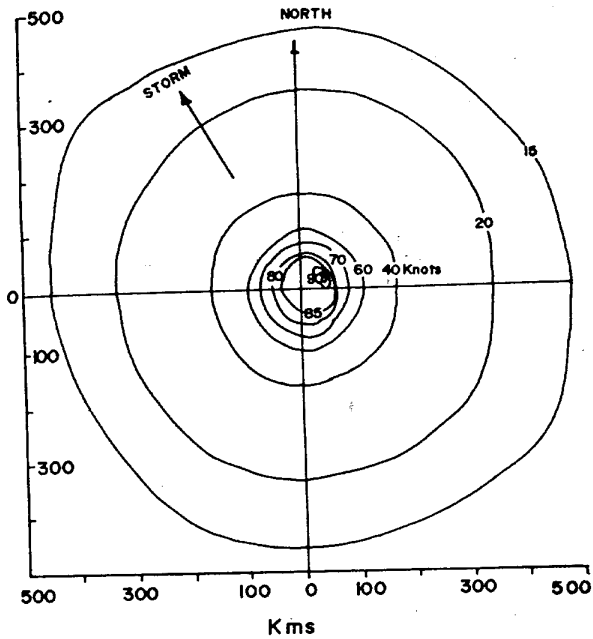


Fig. 4. Wind speeds at maximum intensity

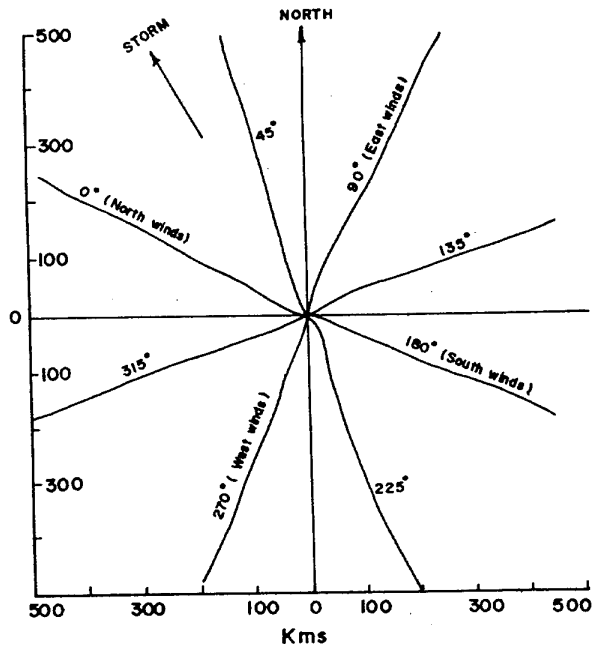


Fig. 5. Directions at maximum intensity