Indian J. Met. Geophys. (1973), **24**, 1, 31-34

551·515·2 : 551·509·3(267)

An objective method for the prediction of tropical storm movement in Indian Seas

SURENDRA KUMAR and KANTI PRASAD

Northern Hemisphere Analysis Centre, New Delhi

(Received 22 May 1972)

ABSTRACT. Regression equations for prediction of 24-hourly movement of cyclonic storms in Indian Seas are formulated. The predictors used are persistence (twice the storm movement in past 12 hours) and differences of 700 mb contour heights ($Z_\lambda = Z_S - Z_N$, $Z_\phi = Z_E - Z_W$) at selected grid points located $7\frac{1}{2}°$ to the north, south, east and west of the storm centre. The subsequent 24-hour meridional and zonal displacements of the storm in degrees latitude and longitude are used as predictands. The method was tested on storms developed during 1971. This gave an average error of 80 n.m. which compares favourably well with other objective methods.

1. Introduction

A number of objective methods have been developed to provide reliable 24-hour prediction of tropical storm movement. Most of these studies were evolved for storms in Pacific and Atlantic regions. Riehl, Haggard and Sanborn (1956) developed an objective technique based on geostrophic field at 500 mb. Veigas and Miller (1958) derived prediction equations using sea level barometric pressure and 24-hour persistence as predictors. Miller and Moore (1960) compared the steering levels at 300, 500 and 700 mb and inferred that 700-mb level was at least as good as 500 mb and both were better than 300 mb. They developed a forecast method by using geostrophic component at 700 mb and the past 12 hours motion of the storm as predictors and found that this combination appeared to result in slightly better forecasts than the standard techniques applied at sea level and at 500 mb. Wang (1956, 1960) formulated regression equations for forecasting the movement of typhoons by using four predictors at 700 mb. TSe (1966) developed forecasting technique of typhoon movement by combining the overall synoptic pattern at 700 mb with other predictors at that level.

In the present study we have aimed at providing an objective method for reliable 24-hour forecasts of storms movements in Bay of Bengal and Arabian Sea. Two regression equations are derived using longitudinal and latitudinal displacement of the storm as predictands, persistence (twice the past 12-hour movement) and differences of 700 mb contour heights ($Z_\lambda = Z_S - Z_N$, $Z_\phi = Z_E - Z_W$) at grid points located $7\frac{1}{2}°$ to the north, south, east and west of storm centre as predictors.

2. Basic data

The study is based on six year's storm data (1965-1970). The positions of storms at 00 and 12 GMT were extracted from surface charts of Northern Hemisphere Analysis Centre at New Delhi. 700 mb contour heights correct upto 5 gpm at the selected grid points were picked up from 00 GMT 700 mb charts during the storm periods 1965-1970. The data were often scanty to the south of the storm centre, but as far as possible continuity of the pattern was maintained using all available data.

3. Analysis and Computation

It is obvious from the work of Jordon (1952), Miller (1958), Riehl and Burgner (1950) that the motion of tropical storm is not determined by forces acting at any one level. The actual motion is related to the mean wind flow integrated through a deep layer and over a substantial area surrounding the cyclone, to the internal forces within the storm and asymmetry in the field of horizontal divergence around the storm. The success of any one level in predicting cyclone movement largely depends upon the extent to which that particular level represents those factors which determine the motion of cyclone.

The findings of Miller and Moore (1960), Wang (1956, 1960) and TSe (1966) were encouraging and led to the choice of 700 mb as the working level for this study.

The 00 GMT surface positions of cyclonic storms were marked at corresponding 700-mb charts. The 700-mb charts were analysed at contour intervals of 10 gpm. The four grid points E, W, N and S were marked at a distance of $7\frac{1}{2}°$ from the centre of the storm. Values of contour heights Z_E, Z_W, Z_N, Z_S were extracted to the nearest 5 gpm. The

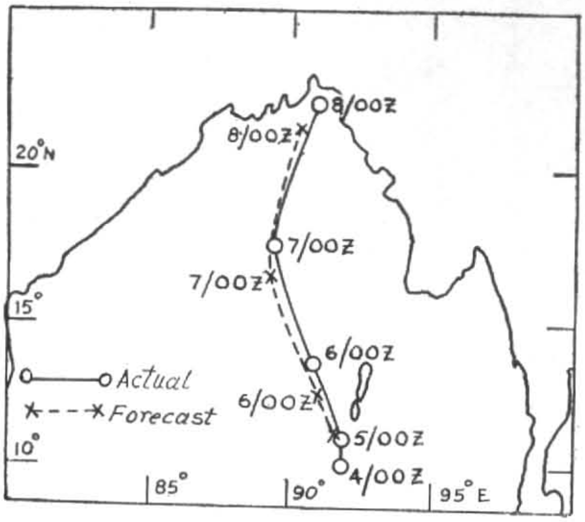

Fig. 1

Actual and forecast tracks of Cyclonic Storm, May 1971

predictors $Z\lambda = Z_S - Z_E$ and $Z\phi = Z_N - Z_W$ were worked out. The other predictors used are persistence P_X and P_Y, twice the longitudinal and latitudinal movement during past 12 hours. These were chosen on the assumption that the forces operating on the storm in the preceding 12 hours, would continue to play some role in the subsequent movement. P_X and P_Y were computed by taking 2 times the zonal and meridional components in degree longitude and latitude of the past 12 hours movement. The subsequent 24-hour zonal and meridional displacements ($Y\lambda$ and $Y\phi$) of storm centres from 00 GMT of date to 00 GMT of next day were taken as predictants. The displacement towards east and north were considered as positive.

Multiple regression equations were worked out by the method of least squares for dependent variables $Y\lambda$ and $Y\phi$ in terms of independent variables, P_X, $Z\lambda$ and P_Y, $Z\phi$ respectively. The two equations are

$$Y\lambda = \cdot 163\, P_X + \cdot 080\, Z\lambda + \cdot 020 \quad (1)$$

$$Y\phi = \cdot 163\, P_Y + \cdot 057\, Z\phi + \cdot 621 \quad (2)$$

with the multiple correlation coefficients

$$R_{Y\lambda\,,\,PXZ\lambda} = \cdot 91, \quad R_{Y\phi\,,\,PYZ\phi} = \cdot 72$$

It may be mentioned that the method outlined above is not fully objective as certain amount of subjectivity is introduced in the determination of predictors.

(*i*) The subjective fixing of storm centre at the surface may cause some error in predictors P_X and P_Y. However, it is obvious from the regression equations that contribution of these predictors towards storm movement is small.

(*ii*) The accuracy of predictors $Z\lambda$ and $Z\phi$ depends on the availability and accuracy of basic data at 700 mb and its analysis correct upto 10 gpm. The data is often scanty to the south of the storm centre.

The error involved in picking height values at the grid points to the north, east and west of the centre is negligibly small since most often two or more of these points lie over land area where observational network is good and it is possible to arrive at a unique analysis.

The uncertainty in determining the predictors $Z\lambda$ and $Z\phi$ may not always be high except in exceptional cases. The error of even 10 gpm in the predictors $Z\lambda$ and $Z\phi$ would cause an error of 0·57° in latitude and 0·8° in longitude which is not large.

4. Test of equations (1) and (2) on independent data

The method was tested on storms occurring during the year 1971. This gave an average error of 80 n. m., the range being 5 to 163 n. m.

The equations were also tested for their applicability to 24-hour predictions based on 12 GMT data during 1971. In this case the average error was 82 n. m., the range being 0 to 136 n. m.

Fig. 1 depicts the actual and forecast tracks of cyclonic storm of May 1971 which has the longest history in 1971. The storm was centred at 00 GMT of 5 May 1971 at 11°N, 92°E. The forecast position of the storm on 6 May 1971 from equations (1) and (2) is worked out as follows.

TABLE 1

Forecast based on	Average error (n. m.)
(*i*) Persistence (P)	113
(*ii*) Climatology (C)	132
(*iii*) The arithmetic mean of items (*i*) and (*ii*), namely, $\frac{1}{2}$ (P + C)	98
(*iv*) Miller and Moore's method (1960)	115
(*v*) Veigas-Miller method (1958)	100
(*vi*) TSe method (1966)	87
(*vii*) Present method	80

The contour height values (in gpm) extracted at four grid points :

$$Z_E = 3115 \quad Z_W = 3100$$
$$Z_S = 3110 \quad Z_N = 3120$$

The two predictors are

$$Z_\lambda = (Z_S - Z_N) = -10 \text{ gpm}$$
$$Z_\phi = (Z_E - Z_W) = +15 \text{ gpm}$$

The longitudinal and latitudinal displacements of the storm in past 12 hours are $-0\cdot5$ degree/longitude and $+0\cdot5$ degree/latitude respectively. The two predictors based on persistence are

$$P_X = -1\cdot0 \text{ deg./Long.} \quad P_Y = +1\cdot0 \text{ deg./Lat.}$$

The forecast values of displacements as obtained from equations (1) and (2) are

$$Y_\lambda = -0\cdot9 \text{ deg./longitude}$$
$$Y_\phi = +1\cdot6 \text{ deg./latitude.}$$

The forecast position is obtained by adding algebraically, the forecast displacement Y_λ and Y_ϕ to the initial position as

Position of storms	*Longitude*	*Latitude*
5 May 1971		
Actual position	92·0° E	11·0° N
Displacement	—0·9	+1·6
6 May 1971		
Forecast position	91·1° E	12·6° N
Actual position	91·0° E	13·5° N

The actual and forecast centres of the storm from 5-8 May, 00 GMT are given below:

Date	*Actual*	*Forecast*
5 May 1971	11° N 92° E	11·1° N 91·9° E
6 May 1971	13·5 N 91 E	12·6 N 91·2 E
7 May 1971	17·5 N 89·5 E	16·5 N 89·7 E
8 May 1971	22 N 91 E	21·1 N 90·5 E

The accuracy of forecasts by various objective methods were summarised by Bell (1962). The average errors are given in Table 1.

5. Conclusions

As indicated in the foregoing section the average error of 80 n. m. compares favourably well with the other objective methods. However, the accuracy of this method depends mainly on the accuracy of basic data at 700 mb and its analysis correct upto 10 gpm.

Acknowledgements

The authors are grateful to Dr. P. Koteswaram, Director General of Observatories and to Shri D. Krishna Rao, Director, Northern Hemisphere Analysis Centre for going through the manuscript and for their helpful suggestions.

REFERENCES

Bell, G. J. 1962 Proc. Inter regional Seminar on the tropical cyclone in Tokyo, 18-31 January 1962, Japan Met. Agency, p. 195.

Jordan, E. S. 1952 *J.Met.*, **9**, p. 340.

REFERENCES (contd)

Miller, B. I. and Moore, P. L.	1960	*Bull. Am. Met. Soc.*, **41**, pp. 59-63.
Riehl, H. and Burgner, H. M.	1950	*Ibid.*, **31**, p. 244.
Riehl, H., Haggard, W. H. and Sanborn, R. W.	1956	*J. Met.*, **13**, p. 495.
TSe, S. Y. W.	1966	*Quart. J.R. Met. Soc.*, **92**, 391, pp. 239-250.
Veigas, K. W. and Miller, R. G.	1958	The probabilistic prediction of Hurricane movements by synoptic climatology. Occasional papers in Meteorology No. 2. The Travellers Insurance Company Ltd., USA.
Wang, G.	1960	*Bull. Am. Met. Soc.*, **41**, p. 115.