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An objective technique to forecast movement of vorticity centres

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सार – सूक्ष्म तीव्रता वाले निम्नदाब (अवदाब) केन्द्रों की गमन की प्रगुति की समस्या प्राचलनी पूर्वानुमानकों के समाने आती रहती है, जो कि मौसम का कारक बनने में सक्षम होती है। मूलधारा से परिचालन की परिकल्पना का उपयोग करके 'परिचालन धारा' को ज्ञात करने की तीन विधियों को उपयोग में लाया गया है। इस शोध पत्र में मार्च से मई 1981 तक की अवधि के अभिवहन तंत्रों को दिया गया है।

ABSTRACT. The prediction of movement of low pressure centres of small intensity, which are capable of causing weather is a problem faced by the operational forecaster. Using the concept of steering by the basic current, three methods to evaluate the 'Steering Current' were attempted. This paper gives the results of advection of systems during March-May 1981.

1. Introduction

Predicting the movement of tropical depressions and weaker disturbances is an important and difficult problem faced by the meteorologists. Although, a number of objective and semi-objective techniques have been evolved for tracking intense or moderately intense disturbances, this is not true for weaker systems of the type of western disturbances which affect the northern parts of India. In the post-monsoon (October - December) months, the southern peninsula is also traversed by diffused low pressure systems. The significant features associated with these pressure systems is that they are generally of shorter wavelengths, and of weak intensity such that the circulation may exist on occasions at only lower levels below 1.5 km (850 mb). Existing numerical models, therefore, often fail to capture these systems. Nevertheless, the prediction of such pressure systems is important because they are capable of generating substantial rainfall.

The concept of an upper steering current has been used by research workers to predict the movement of tropical cyclones (Sherman 1950, Jordan 1952, Miller 1958, Baghere and Datta 1970) with considerable success. They used different techniques to evaluate the basic current. This paper is an attempt to predict the movement of small scale, shallow tropical disturbances using the concept of a steering wind.

The vorticity field based on wind observations is prepared for different levels from 850 mb upwards. Assuming that the vorticity field resembles the synoptic circulation patterns, the location of vorticity maxima are advected by the steering wind. We have tried three methods to compute the basic current to provide a forecast position. In this paper we have discussed these methods in brief, and the results for the months of March to May 1981 are presented.

2. Method

As mentioned, the vorticity field was computed from the wind field analysed by fitting of 2nd degree polynomial (Singh *et al.* 1981) to the observed wind data. The area of analysis is 25 deg. E to 120 deg. E and equator to 60 deg. N. In the region of sparse data (especially over oceanic region), additional information was provided by experienced analysts based on latest satellite imagery and other relevant information keeping space and time continuity. Centres of positive vorticity maxima related to circulation features were delineated and advected by the basic flow.

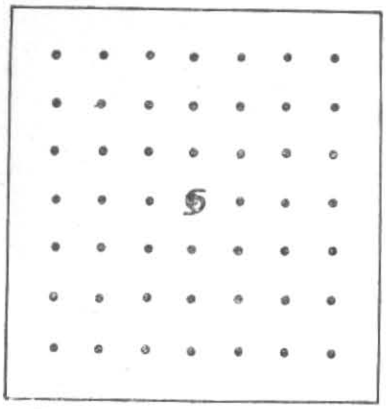

Fig. 1

The basic flow was computed by the following techniques:

2.1. *Advection by 700 mb mean wind*

This consists in computations of mean wind field $\bar{V}$ around the vorticity centre. The wind field is averaged for the surrounding grid points upto 2 to 3 grid lengths (Fig. 1) from the centre depending on the extent of the circulations. The grid length is 2.5 degree Lat./Long. The vorticity maxima are then advected by $\bar{V}$. The vorticity maxima more than 2×10^{-5}/sec. only were considered for advection. In the systems, under consideration, the vorticity maximum is of the order of 2 to 5×10^{-5}/sec.

We also tried advection by mean wind at 850 mb and 500 mb.

2.2. *Wind errors and vorticity values*

In order to study the impact of the errors in the wind observations on the magnitude of the vorticity maximum, experiments were conducted by introducing random errors in the reported wind data lying within a radius of 10 deg. from the centre of the system. Errors to the order of 0 to $\pm$20 deg. in the direction and 0 to $\pm$5 kt in the wind speed were introduced randomly in all the stations around the centre and the vorticity field was calculated. This experiment was repeated thrice to avoid any bias in the introduction of the errors. The results are given in Table 1. It is noticed that, even after introducing these errors in the data, the vorticity maximum remain unchanged in its magnitude as well as in its location. The values at the neighbouring grid points changed a little.

Another experiment was conducted with a view to find out the changes if any, in the vorticity maximum in the absence of winds in a particular direction. For this the winds in the north west, south and eastern directions were removed : (*i*) one at a time and (*ii*) two at a time, in turn and the vorticity was calculated. In all the cases, the location ef the maixmum remain unchanged. However the magnitude of the vorticity at the centre as well as at the neighbouring grid points were lower than the original and the lowest values were obtained when the winds in the eastern and western grid points were removed; simultaneously. The Central value decreased by as much as 27 per cent.

2.3. *Advection by shear wind* 500-850 *mb*

In this case, the procedure is same except that the mean field is computed for the shear wind between 500-850 mb ($\bar{V}_T$). The advection of the vorticity centre is then done with ($\bar{V}_T$).

2.4. *Advection by weighted pressure*

Based on the experience of advecting vorticity centre by $\bar{V}_{700}$ or $\bar{V}_T$ as well by 850 mb wind field, it was noticed that whereas movement by $\bar{V}_{850}$ was slow it was generally fast by $\bar{V}_{500}$ as well as $\bar{V}_T$. $\bar{V}_{700}$ definitely provided better prediction but not always so. An attempt was made to compute vertically integrated winds giving suitable weights to the mean winds at different levels upto a level where the circulation extends. This incidentally corresponds to the definition of steering current given by Jordan (1952). These weights are empirically chosen after trying different combinations. The weights given to different levels are as follows :

Level (mb)	850	700	500	300	200
Weight	.85	.7	.5	.3	.2

The vertical mean *u* and *v* components are calculated by the relation :

$$U_{\text{Mean}} = \Sigma\, \bar{u}_i\, w_i \,/\, \Sigma w_i$$

$$V_{\text{Mean}} = \Sigma\, \bar{v}_i\, w_i \,/\, \Sigma w_i$$

where, $\bar{u}_i$ & $\bar{v}_i$ are the averaged wind components at different pressure levels and w_i are the weights given to the appropriate pressure levels. The lower limit of *i* is 850 mb and the upper limit is the one corresponding to the level upto which the circulation extends.

3. Discussions and results

The prediction was made in the case of 24 synoptic situations during the period March-May 1981 by all the three methods. The results are presented in Tables 2 to 4. The salient features are:

(*i*) The angular deviation of the predicted centres is within 10 deg. in as many as 58 per cent of the cases, by the pressure weighted advection method. In as many as 87 per cent of the cases, the angular deviation is within 20 deg. and in no case the deviation is more than 30 deg. The position error of the predicted centres is within 50 km (about a half a degree) in 42 per cent of the cases while in

TABLE I

Centre of the system 85° E 25° N, 28 March 1981 850 mb

	42189 BRL	42886 JRG	42971 BWN	42809 CAL	42701 RNC	42397 BGD	42875 RPR	42498 BGP	42369 LKN	42475 ALB	42379 GRK	42410 GHT	41861 MYM	42675 JBP	Vort. at grid points in 10^{-5} /sec E	W	C	N	S
Original																			
D (°)	015	280	225	240	300	090	290	110	290	310	100	070	260	355	2.9	2.3	3.3	1.8	2.4
S (kt)	13	15	18	17	12	07	23	20	13	05	05	10	10	11					
Trial I (Random error given)																			
D (°)	+20	0	—20	—20	0	—20	20	—10	—20	20	0	20	0	0	2.8	2.2	3.3	1.6	2.9
S (kt)	5	4	—3	5	—4	0	—3	—4	—5	5	4	—3	—5	—2					
Trial II (Random error given)																			
D (°)	10	—20	—10	20	0	0	0	—10	0	—10	0	0	0	—10	2.7	2.5	3.2	1.5	2.0
S (kt)	—4	4	—3	—3	—4	0	—3	—2	2	—3	2	—3	—3	4					
Trial III (Random error given)																			
D (°)	—10	0	10	20	20	0	0	10	10	20	—10	—20	10	—20	2.9	2.2	3.3	1.8	1.8
S (kt)	4	—3	—3	—5	4	2	—4	—2	—5	4	—3	0	4	5					

Note : D = Direction, S = Speed.

TABLE 2

Percentage distribution of angular deviation

Method	Range 0°-10° (%)	11°-20° (%)	21°-30° (%)	>30° (%)
*I	58	29	13	Nil
*II	43	22	19	16
*III	14	29	29	28

TABLE 3

Position errors (km)

Method	Range (km) Average	Highest	Lowest
*I	115	440	0
*II	219	600	50
*III	545	1200	100

TABLE 4

Percentage of position errors (km)

Method	Range (km) 0-50 (%)	51-100 (%)	101-150 (%)	151-200 (%)	>200 (%)
*I	42	17	21	8	12
*II	7	29	7	7	50
*III	Nil	7	5	10	78

*I Pressure weighted wind Advection Method
*II 700 mb wind Advection method
*III Thermal Advection Method

80 per cent of the cases it is within 150 km. The average position error is 115 km.

(*ii*) In the case of advection by 700 mb winds, the angular deviation of less than 10 deg. occurred in 43 per cent of cases, whereas the deviation is within 20 deg. in 65 per cent of the cases and 16 per cent of the predicted centres deviated by more than 30 deg. The average position error by this method worked out to be 219 km while in nearly 7 per cent of the cases the position error is less than 50 km. In 50 per cent of the cases, the position error is more than 200 km.

(*iii*) The advection by thermal wind technique did not give satisfactory results. While the angular deviation is within 10 deg. in only 14 per cent of the cases, there are as many as 28 per cent of the cases where the deviation is more than 30 deg. The average position error is the largest by this method, 545 km and there is no case in which it is less than 50 km. The poor performance of this technique can easily be seen from the fact that in as many as 78 per cent of the total cases, the position error is more than 200 km.

Thus by examining the Tables 2 to 4 it can be inferred that the pressure-weighted wind technique is superior to the other two methods.

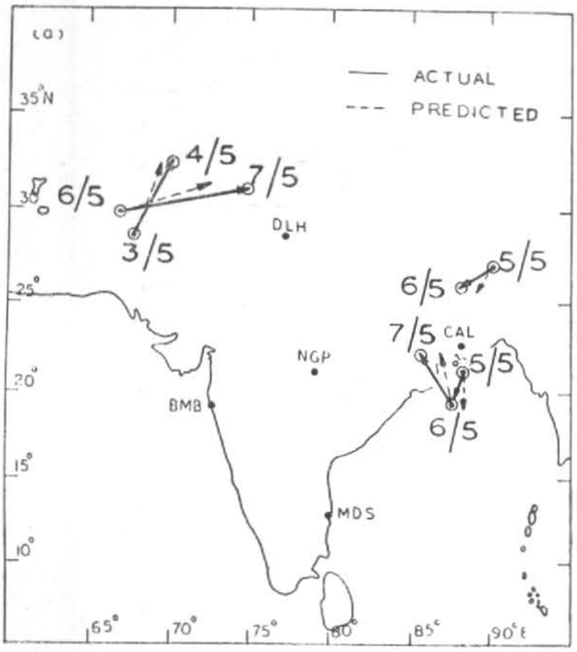

Fig. 2(a). Advection by pressure weighted meanwind method

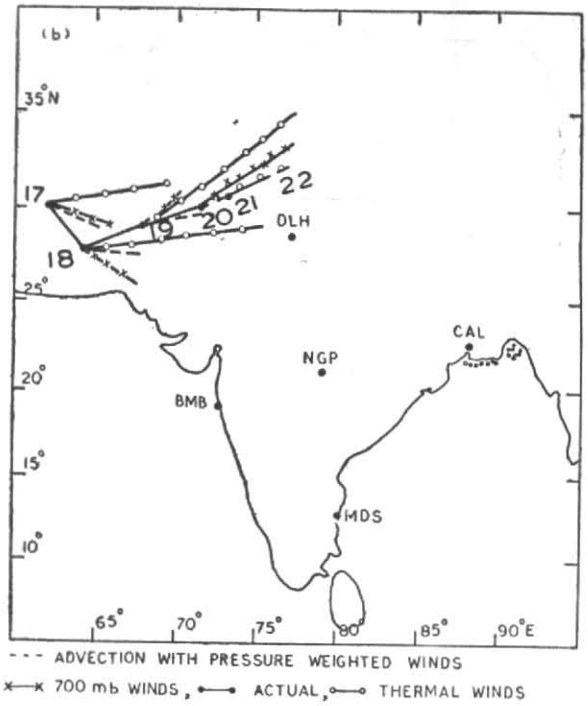

Fig. 2(b). Advection of W.D. during 17-22 March 1981

For the purpose of illustration in Fig. 2(b) we have presented the prediction produced by three methods in the case of a typical western disturbance which moved across north-west India during 17-22 March 1981. In Fig. 2(a) we have also presented some of the results by pressure weighted advection method, which are quite encouraging.

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