551·577·21 : 551·509·518

An objective method of prognosticating the five-day mean 700-mb chart two to four days ahead

P. S. PANT, S. K. DAS and T. R. NATARAJAN

Meteorological Office, Poona

(*Received 30 May 1963*)

ABSTRACT. A few grid points representing different portions of the area covered by the latitudes 35°N and 5°N and longitudes 65°E and 95°E were chosen. For each selected grid point, prognostic equations based on linear regression were obtained for predicting the mean 700-mb contour anomaly for a pentad from the corresponding contour anomaly for the first and middle days of the same pentad. Data for the 5-year period 1957-61 were utilised for obtaining the regression equations for July and data for the period 1958-62 for obtaining corresponding equations for January.

The above prognostic equations were applied to a few situations in January 1963 and July 1962, in order to obtain the prognostic 5-day mean 700-mb charts two to four days ahead. The prognostic charts so obtained were compared with the actual charts and good agreement was noticed between them.

1. Introduction

Earlier studies (Pant 1964a, 1964b) revealed that certain synoptic features on the five-day mean 700-mb charts are closely associated with the five-day total precipitation that occurred during the same five-day period over India during winter and monsoon seasons. It was found that many of these features have a gradual evolution. Having identified the features of large scale circulation associated with the precipitation over periods of five days, the next important step towards issuing medium range weather forecasts in India involves development of suitable methods for prognosticating the five-day mean 700-mb charts sufficiently in advance.

Before the Numerical Methods were introduced into the Extended Range Forecasting practices of the U.S. Weather Bureau (Namias *et al.* 1958), some other objective methods of prognosticating the mean pressure pattern were tried (Namias 1947). The basis for these methods is the existence of serial correlation in pressure. Till models of the atmosphere suitable to the tropics are evolved and the necessary facilities for introducing numerical methods into the forecasting practices of the India Meteorological Department become available, it is necessary to evolve such objective methods for arriving at prognostic five-day mean 700-mb charts. The charts so derived may have to be modified from considerations of continuity, climatology etc. In the present study, an attempt was made to evolve an objective method for forecasting the five-day mean 700-mb contour pattern in winter and monsoon seasons (January and July).

2. The Problem

On any day the five-day mean chart that could be prepared with the latest available observations will be centred two days behind. So the first step in prognostication is to derive the five-day mean chart centred on the day of issue of the medium range forecast. Such a chart may be called the "Current Mean Chart". This would be made up of observed values for 3 days and forecasted values for the next 2 days. The current mean chart can be arrived at by estimating the values for the next two days from the latest available observations,

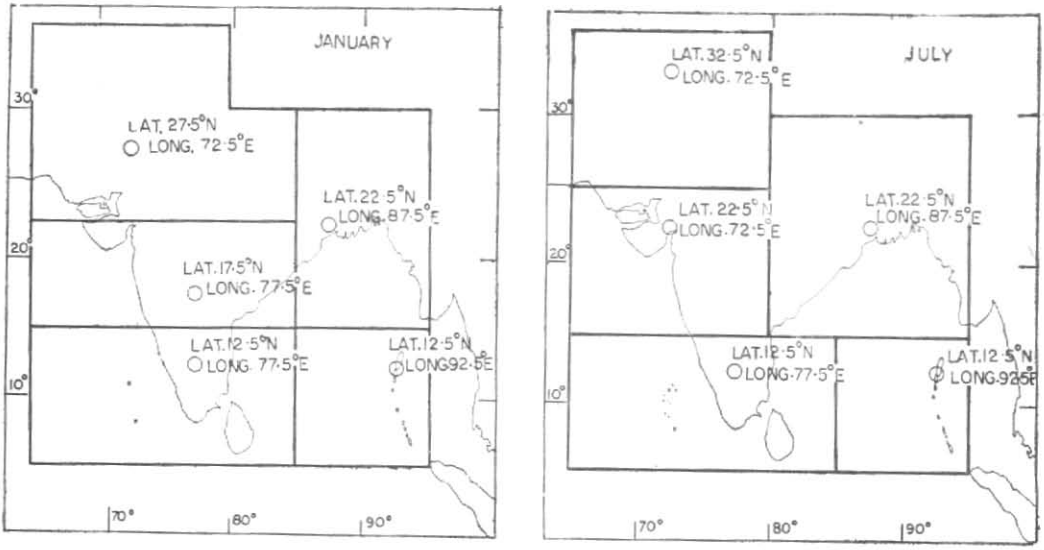

Fig. 1. The regions covering India and neighbourhood and the grid points representing each region

It can be expected that the average (of morning and evening observations) 700-mb contour value for the middle day of a pentad will have the maximum correlation with the corresponding mean for the pentad as compared to the values for other days of the pentad for the simple reason that it (among the values for different days constituting the pentad) will have the highest correlation with the values for the rest of the days constituting the pentad (Namias 1947). Existence of a good correlation between the middle day's value and the mean for the pentad will enable one to prognosticate 2 days ahead the five-day mean 700-mb contour value.

It would also be worthwhile to examine as to how well the first day's average value of 700-mb contour for a grid point is correlated with corresponding mean for the five-day period starting with that day. It can be expected that such a correlation will be less than the previous one. But if it is at least significantly high, it may be possible to utilise the first day's average value for estimating the five-day mean 700-mb contour value 4 days ahead, *i.e.*, on the first day of a pentad, the mean chart for that pentad can be prepared.

3. Choice of grid points and the area of their representation

The selected grid points and the areas they are taken to represent for January and July are shown separately in Fig. 1. The areas covered by the present study is bound by 30°N and 35°N in the north and 5°N in the south, by 65°E in the west and 95°E in the east. The investigation was limited to this areas mainly because daily values of 700-mb contour height are readily available for this region for a period of 5 years. The selection of grid points and the areas of their representation was to some extent arbitrary but the following considerations were given due weightage. The grid points were chosen so that they represent the major seasonal features observed on the relevant normal 700-mb charts. Another consideration was that the grid points should be as close as possible to one or more radiosonde stations, so that the interpolated values obtained for those grid points would be based on sufficient observations.

4. Correlation Coefficients

The coefficients of correlation between the 700-mb contour value (average of 00 and 12 GMT data) for (*i*) the first day of a pentad and the corresponding mean for the same pentad and (*ii*) for the middle day of a pentad and the mean for the same pentad were worked out for the selected grid points for January and July. In actual computation, the respective anomalies (departures from normal) were utilised. These C.Cs. are shown in Table 1.

A critical examination of these shows that for the same grid point and in the same month, values are higher for the middle day as compared to the first day and this is as should be expected. In January the C.Cs. for the first day value are lower for grid points in north India (north of 20°N) as compared to those for the south Indian grid points. One probable reason for this is that apart from troughs in the westerlies which regularly move over the region from further west, a few form *in-situ* over the region (Pant and Natarajan 1963). Sudden *in-situ* development of troughs will have the effect of reducing the C.C. Over north India the C.C. for the first day's contour value is generally higher in July than in January, whereas in the south they are either the same or slightly lower in July than in January. Another interesting observation made is that C.C. for the first day's value is lowest for the northwest grid point (27·5°N, 72·5°E) in January whereas it is lowest for the southeast grid point (12·5°N, 92·5°E) in July, probably because these are the regions of sudden development or fast movement in the large scale circulation pattern in the respective seasons.

In Table 1 the number of pairs of observations utilised for the computation of the C.Cs. are also shown. It may be mentioned here that all these pairs are not independent for some of them refer to overlapping pentads. But they can be treated as equivalent to 30 (for the five-year periods 1958—62 for January and 1957—61 for July), independent pairs referring to 30 independent pentads. It was found that the lowest among the C.Cs. will be significant at $P = \cdot 01$ level if it is based on 15 or more observations and the highest among them will be significant at the same level if it is based on 5 or more observations as per Fisher's Table (Fisher 1938). Thus all the C. Cs. shown in the above table are statistically significant even if it is considered that they are based only on 30 pairs of observations. It is thus seen that there is a statistically significant correlation between the 700-mb contour value for the first and middle days of a pentad and the corresponding mean for the same pentad. An attempt was, therefore, made to formulate linear regression equations for prognosticating five-day mean 700-mb contour anomaly for a pentad from the corresponding values for the middle day and the first day of the same pentad.

TABLE 1

Correlation Coefficients

Grid point	No. of pairs of obsn.	C.C. between first day's value and the pentad mean	C.C. between third day's value and the pentad mean
	JANUARY		
27·5°N, 72·5°E	61	0·60	0·88
22·5°N, 87·5°E	63	0·67	0·84
17·5°N, 77·5°E	59	0·74	0·89
12·5°N, 77·5°E	63	0·76	0·88
12·5°N, 92·5°E	61	0·82	0·85
	JULY		
32·5°N, 72·5°E	65	0·79	0·81
22·5°N, 72·5°E	65	0·74	0·81
22·5°N, 87·5°E	64	0·75	0·87
12·5°N, 77·5°E	64	0·72	0·72
12·5°N, 92·5°E	64	0·63	0·71

5. Prognostic equations

In Table 2 are shown prognostic equations based on linear regression for predicting the five-day mean 700-mb contour anomaly from the contour anomaly for the first day and the middle day of a pentad. These equations are given for different grid points in January and July along with the corresponding 'Scatter' (Panofsky and Brier 1958).

TABLE 2

Regression equations and scatter

Grid point	No. of pairs of obsns.	Linear regression equation between first day's value and pentad mean of 700-mb contour anomaly	Scatter S	Linear regression equation between third day's value and pentad mean of 700-mb contour anomaly	Scatter S
		JANUARY			
27·5°N, 72·5°E	61	$Xm = 0{\cdot}49X_1+1{\cdot}76$	19·4	$Xm = 0{\cdot}71X_3+1{\cdot}90$	12·0
22·5°N, 87·5°E	63	$Xm = 0{\cdot}50X_1-1{\cdot}13$	13·6	$Xm = 0{\cdot}71X_3-0{\cdot}43$	9·9
17·5°N, 77·5°E	59	$Xm = 0{\cdot}65X_1+1{\cdot}26$	10·5	$Xm = 0{\cdot}80X_3-0{\cdot}08$	6·7
12·5°N, 77·5°E	63	$Xm = 0{\cdot}65X_1-1{\cdot}03$	8·4	$Xm = 0{\cdot}78X_3-2{\cdot}04$	6·3
12·5°N, 92·5°E	61	$Xm = 0{\cdot}68X_1-2{\cdot}70$	8·1	$Xm = 0{\cdot}67X_3-3{\cdot}30$	8·0
		JULY			
32·5°N, 72·5°E	65	$Xm = 0{\cdot}45X_1-6{\cdot}88$	10·1	$Xm = 0{\cdot}53X_3-6{\cdot}14$	7·8
22·5°N, 72·5°E	65	$Xm = 0{\cdot}62X_1-2{\cdot}81$	13·1	$Xm = 0{\cdot}69X_3-4{\cdot}32$	11·8
22·5°N, 87·5°E	64	$Xm = 0{\cdot}65X_1-4{\cdot}70$	14·5	$Xm = 0{\cdot}63X_3+2{\cdot}10$	10·3
12·5°N, 77·5°E	63	$Xm = 0{\cdot}56X_1-1{\cdot}58$	6·9	$Xm = 0{\cdot}50X_3-2{\cdot}20$	6·0
12·5°N, 92·5°E	64	$Xm = 0{\cdot}41X_1-3{\cdot}38$	8·0	$Xm = 0{\cdot}50X_3-3{\cdot}23$	8·5

X_1 = First day's value of the 700-mb contour anomaly
Xm = Pentad mean value of the 700-mb contour anomaly
X_3 = Third day's value of the 700-mb contour anomaly

An examination of the scatter values reveals that they are generally higher for the estimates made from first day's value as compared to those for the estimates from middle day's value. Further, as in the case of the correlation coefficients, the prognostic equations give better estimates for grid points in south India than for those in the north. The goodness of estimate for any grid point does not seem to depend on the season. The largest scatter is about 19 gpm, whereas the smallest is 6 gpm.

6. Preparation of prognostic charts

Data for the 5-year period 1957—61 were utilised for arriving at the regression equations for July and data for the period 1958—62 for obtaining the corresponding equations for January. Therefore, to test the usefulness of these equations for prognosticating the five-day mean 700-mb pattern, they were applied to a few situations during January 1963 and July 1962, data for which were not utilised for arriving at the equations (independent sample of data). Nomograms were prepared for each selected grid point and for January and July from which knowing the first day's and middle day's value of the 700-mb contour anomaly, the corresponding five-day mean 700-mb contour anomaly can be obtained for the relevant pentad. Charts depicting the average 700-mb contour height at different grid points (at the four corners and centre of five degree squares) on the first and middle days of the pentads, for which mean prognostic charts were to be prepared, were got ready. On two separate transparent overlays the normal 700-mb contour values for all grid points for January and July were plotted. These were utilised to obtain the 700-mb contour anomaly charts corresponding to the above mentioned daily charts. Making use of the nomograms mentioned above the

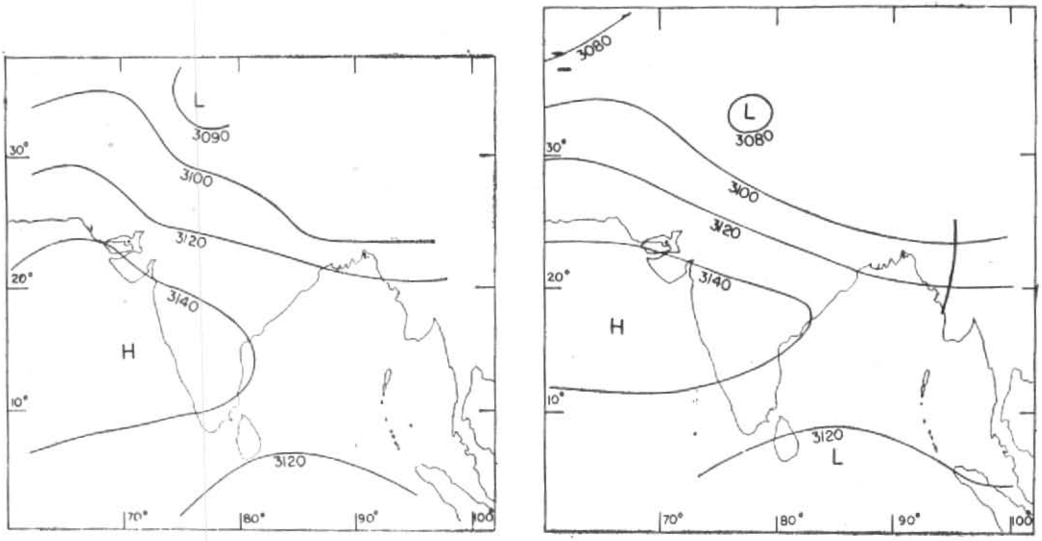

Fig. 2(a). Prognostic Chart **Fig. 2 (b). Observed Chart**

5-day mean 700-mb charts for the pentad 15—19 January 1963

Prognostic 5-day mean chart obtained from the observed chart for the middle day of the pentad

corresponding prognostic five-day mean 700-mb contour anomalies were obtained and plotted. To these the normal 700-mb contour values were added to get the prognostic five-day mean 700-mb contour values and these were plotted on separate charts and analysed. The prognostic charts so prepared were compared with the actual five-day mean charts for the same period. The purpose of the comparison was to judge whether this method could prognosticate the major features of large scale circulation, which are closely associated with the total precipitation during five-day periods in winter and monsoon seasons.

7. Prognostic five-day mean 700-mb charts derived from the daily chart for the middle day of the pentad

In Figs. 2—5 are presented the prognostic five-day mean charts derived from the middle day of the respective pentad for two pentads in January 1963 and two pentads in July 1962. The corresponding observed mean charts are also shown. The prognostic patterns show a striking resemblance to the actual pattern. Features like troughs in winter and the orientation of the axis of the monsoon low in the monsoon season are very well brought out. It can, however, be seen that there is difference in the prognostic and actual contour values as revealed by the lowest contour drawn around the 'Lows' on the prognostic and actual charts shown in Figs. 4 and 5. The purpose in obtaining the time-mean chart is to remove the smaller scale fast moving disturbances and to highlight the large scale slow-evolving synoptic systems. The trials so far made with independent data indicate that this objective method of deriving the five-day mean 700-mb charts from the chart for the central day of the pentad is quite satisfactory, especially to prognosticate large scale features. Some of the limitations of the foregoing method and the important considerations that one has to keep in mind while applying this method in practice will be discussed later.

8. Prognostic five-day mean 700-mb charts derived from the daily chart for the first day of the respective pentad

The prognostic charts along with the observed charts for four pentads in January 1963 and July 1962 are presented in Figs. 6—9. The January prognostic charts shown in Figs. 6 and 7 depict the troughs in

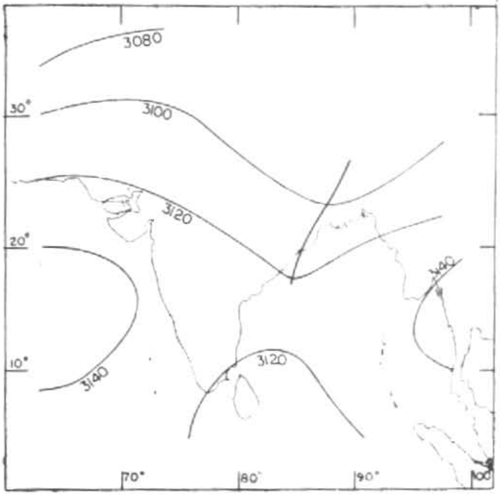

Fig. 3(a). Prognostic Chart

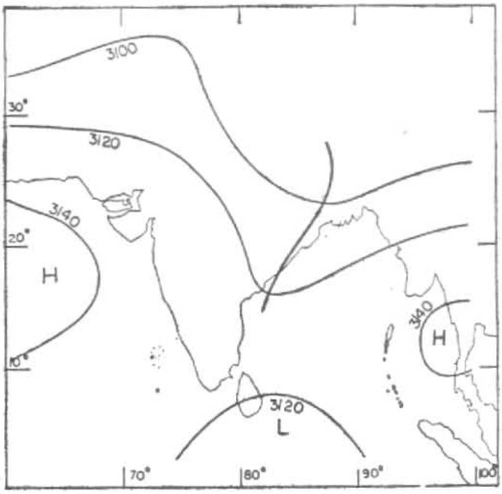

Fig. 3(b). Observed Chart

5-day mean 700-mb charts for the pentad 29 Jan to 2 Feb 1963

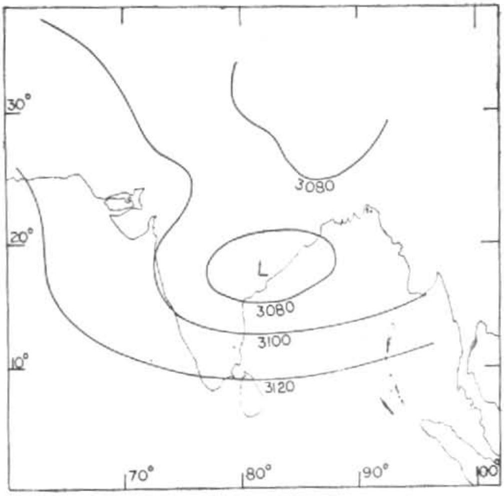

Fig. 4(a). Prognostic Chart

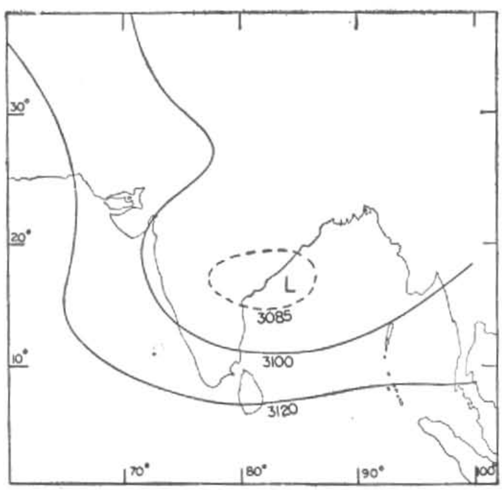

Fig. 4(b). Observed Chart

5-day mean 700-mb charts for the pentad 30 June to 4 July 1962

Figs. 3—4 Prognostic 5-day mean chart obtained from the observed chart for the middle day of the pentad

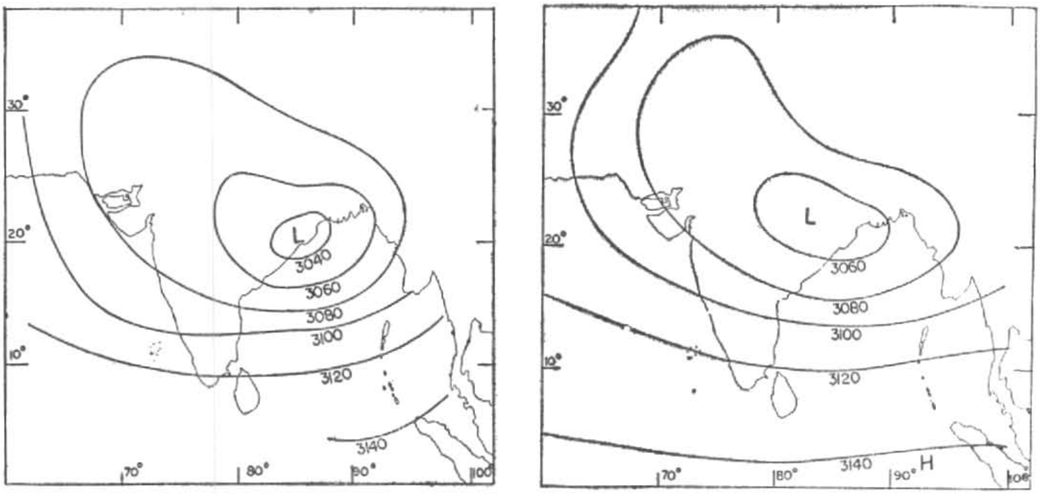

Fig. 5(a). Prognostic Chart

Fig. 5(b). Observed Chart

5-day mean 700-mb charts for the pentad 19-23 July 1962

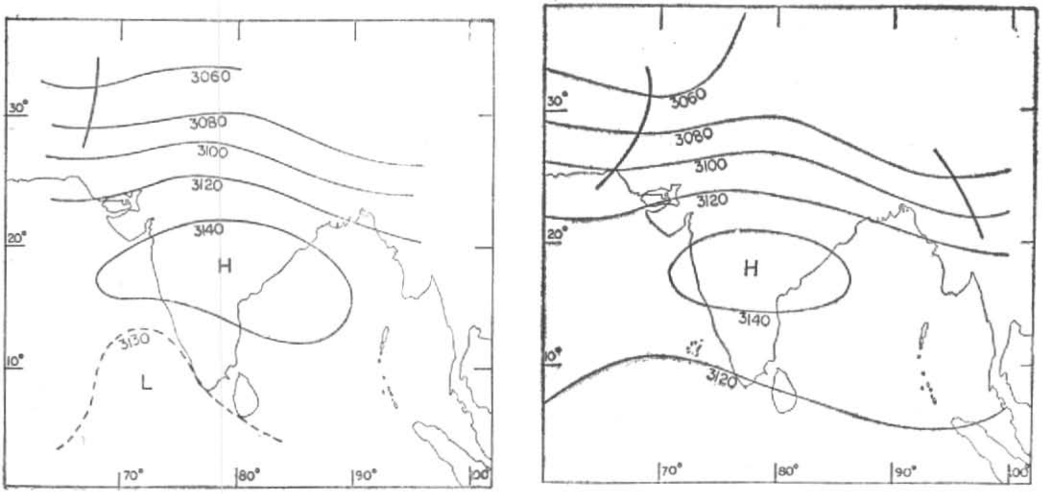

Fig. 6(a). Prognostic Chart

Fig. 6(b). Observed Chart

5-day mean 700-mb charts for the pentad 10-14 January 1963

Figs. 5–6. Prognostic 5-day mean chart obtained from the observed chart for the middle day (Fig. 5)/first day (Fig. 6) of the pentad

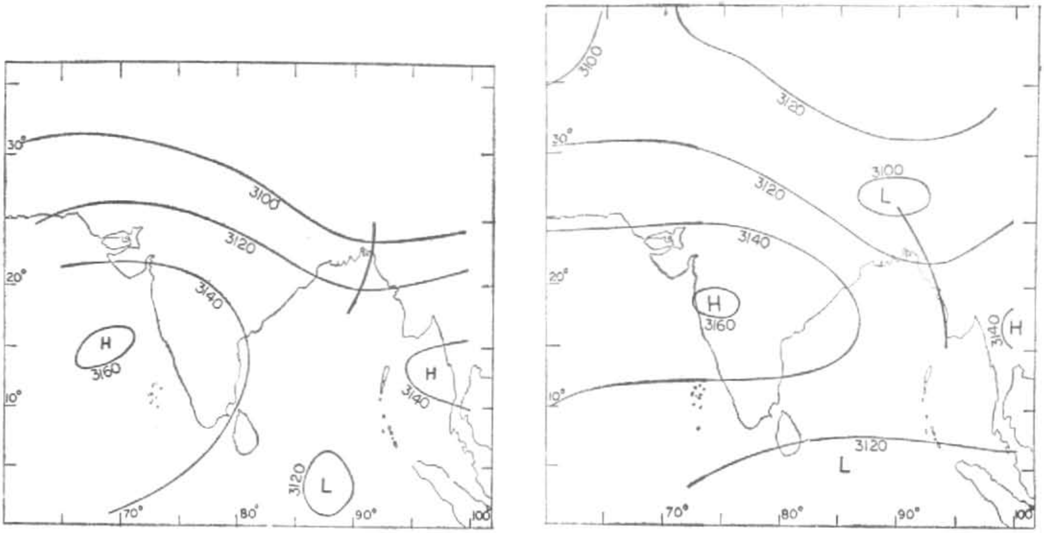

Fig. 7(a). Prognostic Chart

Fig. 7(b). Observed Chart

5-day mean 700-mb charts for the pentad 22-26 January 1963

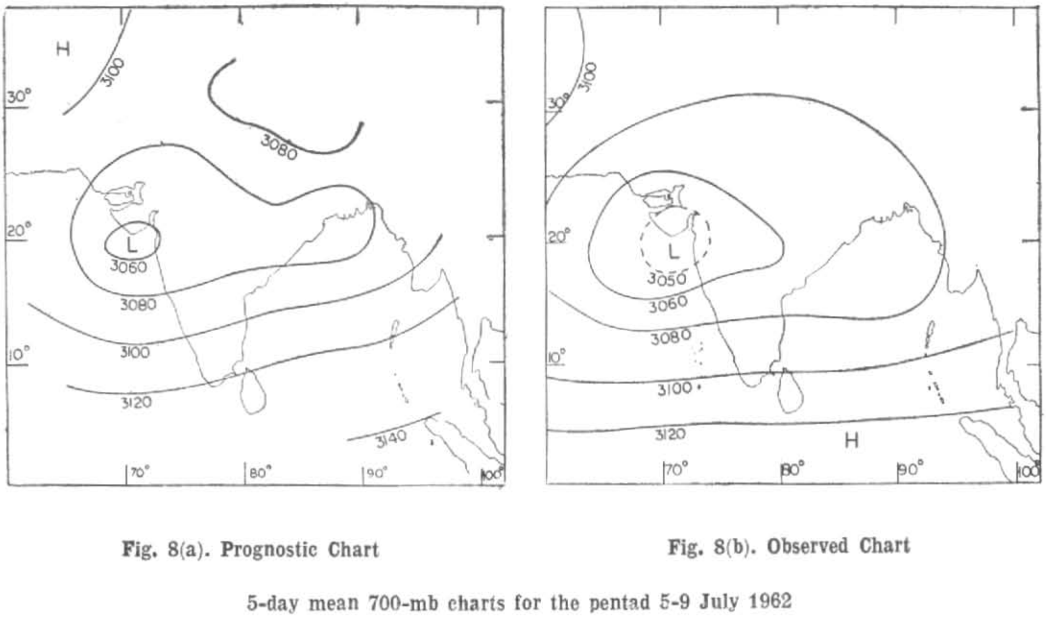

Fig. 8(a). Prognostic Chart

Fig. 8(b). Observed Chart

5-day mean 700-mb charts for the pentad 5-9 July 1962

Figs. 7-8. Prognostic 5-day mean chart obtained from the observed chart for the first day of the pentad

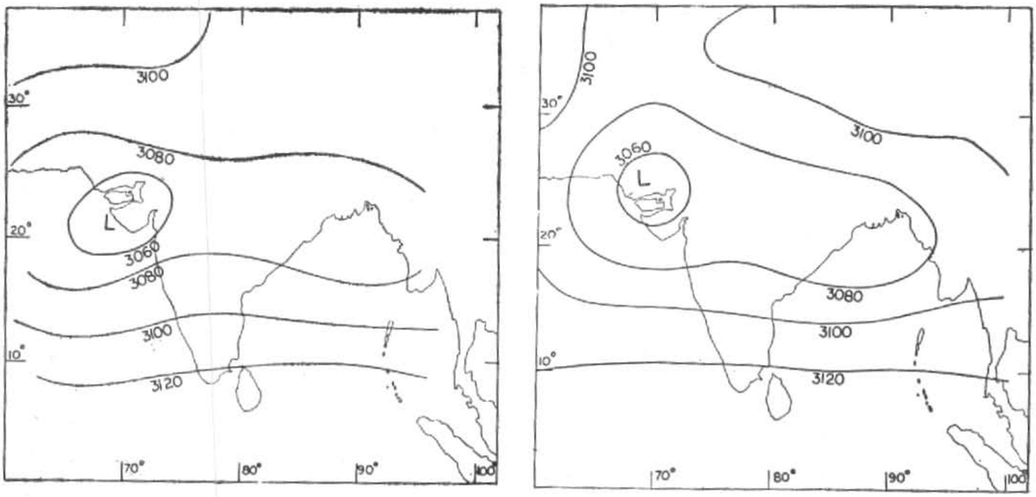

Fig. 9(a). Prognostic Chart **Fig. 9(b). Observed Chart**

5-day mean 700-mb charts for the pentad 14-18 July 1962

Prognostic 5-day mean chart obtained from the observed chart for the first day of the pentad

the westerlies and the strength of the subtropical high fairly well. But the prognosis south of 10°N is not as good. The high cell over the country extends too far to the south in the prognostic chart and the trough in the easterlies is slightly exaggerated as compared to the same features in the observed charts. But the resemblance between the two contour patterns is very good inspite of the deficiencies pointed out above.

In the July charts the orientation of axis of the monsoon low is predicted well and the positions of lows are accurate. The general agreement between the predicted and actual contour patterns is even better in July than in January. There are some differences in the predicted and actual contour values in some parts of the charts. However, these do not come in the way of revealing the major features of the contour pattern. A comparison of the predicted and observed anomaly patterns corresponding to the mean contour charts presented in Figs. 2 to 8 reveals that the important anomaly centres are predicted well by the method evolved here and there is good agreement between the two anomaly patterns.

9. Conclusion

It can be concluded that the objective method of prognosticating the five-day mean 700-mb charts discussed above is quite useful in providing a reasonably good prognostic chart two to four days ahead. This brings into focus the fact that great advantage could be taken of the high persistence that seems to be present in pressure at higher levels over India. The method was tested only on independent data for one month each for January and July. This could not be helped, because as much of the available data as possible had to be used for deriving the prognostic equations. But it can be expected that this method will work equally well when applied in future.

One important point that has to be kept in mind while applying this method in practice is that the regression coefficients and constants occurring in the prognostic equations may themselves have a time variation, as it often happens with many meteorological statistics (Panofsky and Brier 1958). The only solution to this problem is to recompute these constants after some more data accumulate and see whether they need any revision. As most methods of prognosis which cannot take sudden development into consideration fail, this method may also fail on occasions of sudden development. Such a situation can only be taken care of by modifying the prognosis issued earlier, the moment any new development is expected or actually observed.

10. Acknowledgement

The authors are grateful to Dr. R. Ananthakrishnan for the interest he took in this investigation and the facilities he provided for completing it.

REFERENCES

Fisher, R. A.	1938	*Statistical Methods for Research Workers* (Seventh Ed.), p. 214.
Namias, J.	1947	*Extended Forecasting by mean circulation methods*, U.S. Weath. Bur.
Namias, J. *et al.*	1958	*Mon. Weath. Rev.*, **86**, pp. 467-476.
Panofsky, H. A. and Brier, G. W.	1958	*Some applications of Statistics to Meteorology*, pp. 87, 88.
Pant, P. S.	1964a	*Indian J. Met. Geophys.*, **15**, p. 347.
	1964b	*Ibid.*, p. 375.
Pant ,P. S. and Natarajan, T. R.	1963	*Ibid.*, p. 595.