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Some characteristics of troughs observed on 5-day mean 700-mb charts during winter season

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ABSTRACT. The slow moving waves observed on 5-day mean 700-mb charts were identified by Namias and Clapp (1944) as long waves in the westerlies. In an earlier study (Pant 1964) it was found that some of these troughs affect weather over north India during winter and that they have an influence on the behaviour of the short wave systems observed on daily synoptic charts. Some of the characteristics of these slow moving troughs observed on 5-day mean 700-mb charts like their speed of movement, frequency of occurrence etc, are studied on the basis of mean charts for the period 1957—62. The troughs are classified into three broad types and their characteristics studied. The results of this study would form useful background information to a medium range forecaster.

1. Introduction

The wave systems observed in middle latitudes on 5-day mean 700-mb contour charts were identified as long waves in the westerlies and their properties were studied in great detail by Namias and Clapp (1944). The speed of these troughs is about one-fifth the speed of short waves observed on daily synoptic charts. Though the choice of a 5-day period for averaging is somewhat arbitrary, the five-day mean charts were found to reveal "the major planetary waves and the related sea-level centres of action, whose evolution dominates the circulation and weather over periods of approximately one week". The smaller scale systems are filtered out by this process. The 5-day mean charts were, therefore, found to be useful for studying and predicting medium range circulation changes.

These waves observed on 5-day mean charts occupy an important place in the medium range forecasting practices of the U. S. Weather Bureau (Namias 1947, Winston 1960). Frequencies of the mean (five-day and monthly) troughs at 700-mb level over the northern hemisphere were studied by Klein and Winston (1958). Information about frequencies of mean troughs in different regions will form a very useful background for medium range forecasts of the position of 5-day mean troughs.

In an earlier study, Pant (1964) found that during winter the occurrence of widespread above normal precipitation over large parts of north India is usually associated with the movement across the country of troughs in the westerlies on the 5-day mean 700-mb contour charts. It was, therefore, felt necessary to study the various characteristics of these troughs, such as their speed of movement, frequency of occurrence etc to prognosticate winter precipitation over north India about a week ahead. The present study was, therefore, undertaken, and for this purpose 5-day mean 700-mb contour charts for the six year period 1957—1962 were utilised.

The method of preparation of the 5-day mean 700-mb charts and the charts showing the 5-day total precipitation and its anomaly was described in an earlier paper (Pant 1964).

For the purpose of this study troughs in the westerlies were objectively defined as lines connecting points of minimum latitude reached by each contour in westerly flow or, alternatively as lines joining adjacent

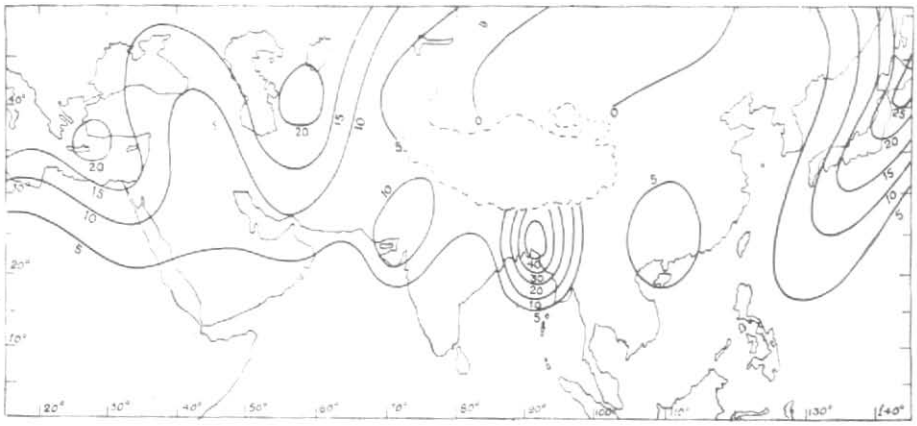


Fig. 1. Precentage frequency of 5-day mean troughs at 700-mb level in winter, December-February

points at each latitude circle where minimum height values are reached.

2. Frequencies of 5-day mean troughs at 700 mb in and around India

The trough and ridge frequency charts for the northern hemisphere published by Klein and Winston (1958) do not extend south of 30°N and they refer to a standard latitude 50°N. They are, thus, inadequate for the purpose of the present study. Therefore, percentage frequencies of troughs on 5-day mean 700-mb charts were computed for the winter season (December—February) utilising the method adopted by Klein and Winston and taking 30°N as the standard latitude for applying the latitudinal correction. A total number of 192 mean charts for the period 1957—1962 were examined for this purpose.

Among the prominent regions of high trough frequency in winter (Fig. 1) are—(*i*) the Caspian Sea region (55°E—60°E) where troughs are observed on more than 20 per cent of the occasions, (*ii*) the region off the east coast of Asia and near Japan where they occur on more than 25 per cent of occasions and (*iii*) northeast India where a weak semi-permanent trough, which is largely due to the effect of orography on westerly flow, is observed on more than 40 per cent of the occasions. On the normal 700-mb contour charts for winter, troughs are noticed in all the above three regions. The trough frequency is also high over the Mediterranean.

Another important, though less prominent, region of occurrence of mean troughs is the Indo-Pakistan area between 70°E and 75°E, where normally a ridge is noticed in winter. The troughs, which are observed in this region are relatively weak compared to the ridge that occurs more frequently.

The frequencies of mean troughs at 700-mb level clearly show that the Caspian Sea region is one of the important source regions for troughs which affect India and that most of the other troughs that affect this region form *in-situ*. The sub-tropical belt of high pressure is practically free of these mean troughs. Some of the characteristics of these troughs will be presented and discussed here.

To illustrate the discussion of different types of mean troughs, the following charts for the relevant periods are presented —

(*i*) Charts showing the 5-day mean 700-mb contours and the corresponding regions of above normal (A) and sub-normal (S) precipitation (shaded portions). The unshaded portions over India had normal precipitation.

(*ii*) Graphs showing the progression of 5-day mean troughs at 700-mb level along either 30°N or 27·5°N.

For the purpose of classification of rainfall as above normal, normal or below normal, the rainfall during each one of the standard pentads for the past 30 years at each station is arranged separately in the decreasing order of magnitude. The middle one-third of the values is considered as normal, the top one-third as above normal and the bottom one-third as below normal. The lower limit of the above normal values and the upper limit of the below normal values are obtained for different stations. These limits for intermediate pentads are obtained by graphical interpolation. By comparison of any particular 5-day total precipitation of a station with the corresponding limits, the former is classified as above normal (A), normal (N) or sub-normal (S).

3. Types of mean troughs

The mean troughs that affect India can be classified into three types, based on their place of origin. They are — (*i*) troughs which form near the Caspian Sea area (near 60°E), (*ii*) troughs which form over the Indo-Pakistan region (70°E—75°E) and (*iii*) troughs which approach India from the Mediterranean Sea or further west. Among these, the most frequent are those which form in the Caspian Sea region and move eastwards. Those which form over the Indo-Pakistan region are less frequent and very few troughs which affect north India come from the Mediterranean or further west. Many of the troughs which approach India are confined to south of 40°N and not all of these move all the way across the country and cause rainfall. Some of the troughs fill up soon after they reach the Indo-Pakistan region, whereas others move right across the country. A detailed discussion of the different types of troughs is presented below.

4. Mean troughs which form in the Caspian Sea region and move eastwards

Most of the mean troughs which affect weather over north India in winter are those which form near the Caspian Sea region and move eastwards. These troughs can again be classified into two types—(*a*) troughs which move regularly eastwards across the country and merge with the semi-permanent trough near 90°E, causing above normal precipitation over large parts of north India as far east as Assam and (*b*) the troughs that weaken and disappear as soon as they reach the Indo-Pakistan region (near about 75°E) causing above normal precipitation only over the extreme north of the country. Precipitation over India starts when the troughs move east of 65°E. The first type of trough is found to move at an average rate of about 4 degrees longitude per day at 25°—30°N and cause above normal rainfall over large parts of north India.

In Fig. 2 is presented the case of a mean trough which formed near the Caspian Sea and moved right across the country at an average speed of over 4 degrees longitude per day. Precipitation started over India when the trough moved east of 65°E. The sub-tropical high showed the usual weakening and strengthening. This trough merged with the semi-permanent trough near about 90°E. Above normal precipitation occurred over large parts of north India and this spread as far as Assam.

It was observed that the above type of troughs which progressed all the way across north India and merged with the semi-permanent trough near 90°E moved at an average speed of about 4 degrees longitude per day. In the particular case illustrated here and in a few other cases of fast movement of troughs, it was noticed that another trough formed in quick succession behind this trough and also moved eastwards. Another common feature among all such cases of fast movement is that the High over the country is exceedingly weak.

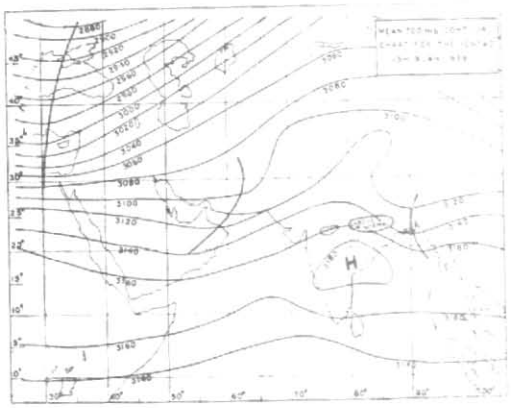


Fig. 2(a)

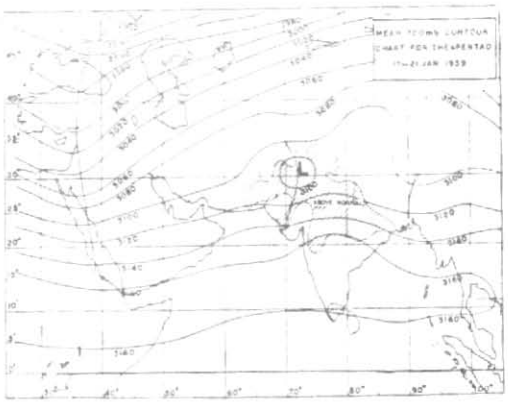


Fig. 2(b)

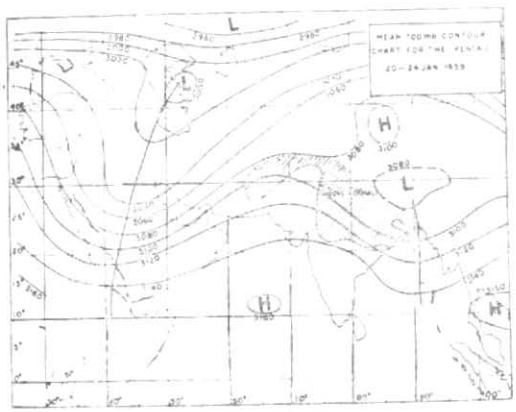


Fig. 2 (c)

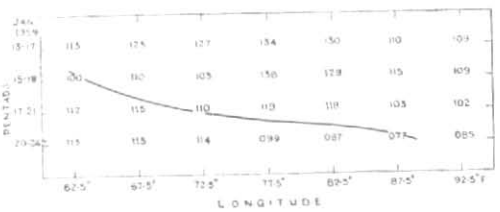


Fig. 2(d). Progression of 5-day mean trough at 700-mb level (along 27·5°N)

It is possible that in some of these cases, a system in the easterlies moving westwards across the region might have weakened the high and thus contributed to the fast movement of the mean trough in the westerlies. Though some evidence, in terms of progression westwards of weather, exists for the movement westwards of low pressure systems, the mean 700-mb contour charts are not quite adequate for identifying and following these systems in the easterlies.

The second type of troughs which form in the Caspian Sea area approach the Indo-Pakistan region at an average speed of 2-3 degrees longitude per day and break up near 75°E. Precipitation associated with these troughs is usually confined to Jammu and Kashmir, Punjab (I) and west Uttar Pradesh and Rajasthan.

Fig. 3 illustrates the case of a trough which formed near the southeast corner of the Caspian Sea near 55°E and extended up to the Persian Gulf. But during the entire period of its movement eastwards, the strength of high over India did not fall below normal, and the trough disappeared near 70°E. Its average speed was 2·6 degrees longitude per day at 30°N and it moved relatively faster between 60°—65°E. Precipitation occurred largely in the hills of Kashmir and the plains had very little rain.

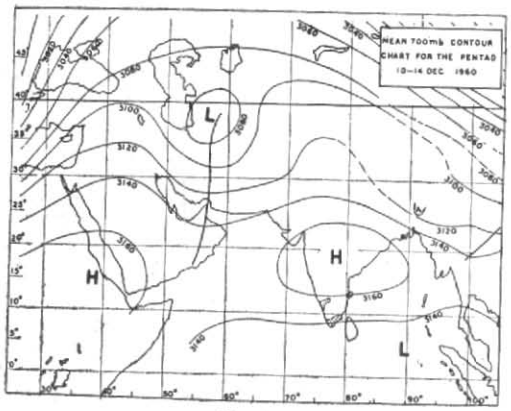


Fig. 3(a)

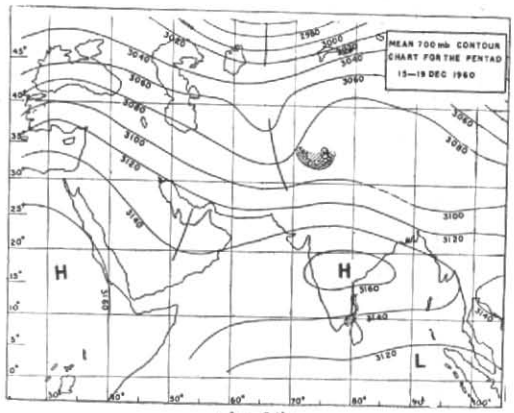


Fig. 3(b)

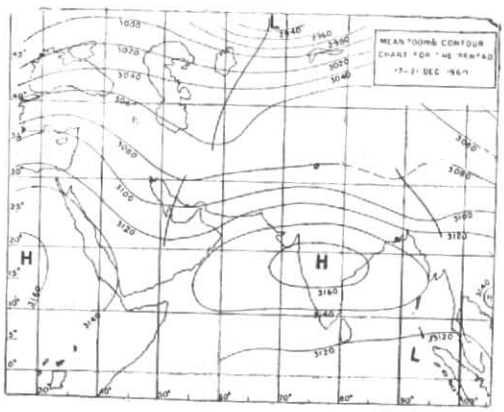


Fig. 3(c)

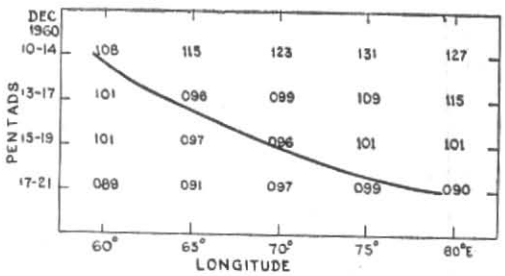


Fig. 3(d). Progression of 5-day mean trough at 700-mb level (along 30°N)

5. Mean troughs which form *in situ* over the Indo-Pakistan region

These form in the region 70°E—75°E and most of them, at least at the 700-mb level, do not move much and disappear at their origin or near about 80°E. Precipitation associated with these troughs is considerable mostly in the hills of Punjab and Jammu and Kashmir and does not normally extend south of 25°N or east of 80°E. In a few cases, central parts of the country also get precipitation.

Fig. 4 shows the trough which formed in between 30°N—35°N and 70°E—75°E, during 7—11 January 1960 and remained between 75°E—80°E for a fairly long period. This gave precipitation over Jammu and Kashmir and over central parts of the country. It disappeared around 80°E during the pentad 21—25 January 1960.

There are a few other mean troughs which formed over the Indo-Pakistan region, but which moved rapidly eastwards and merged with the semi-permanent trough near 90°E. The precipitation associated with these troughs extends all the way up to extreme east of the country. The major difference between the first and second type of troughs which form *in-situ* over the region is that in the former case the sub-tropical high remains more or less of normal or even above normal strength and the ridge does

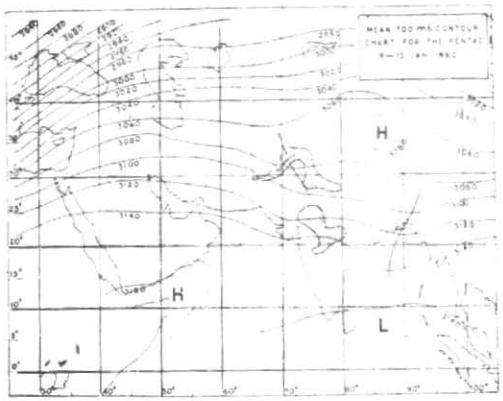
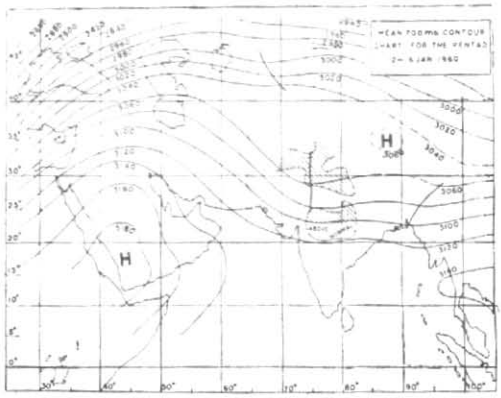


Fig. 4(a)



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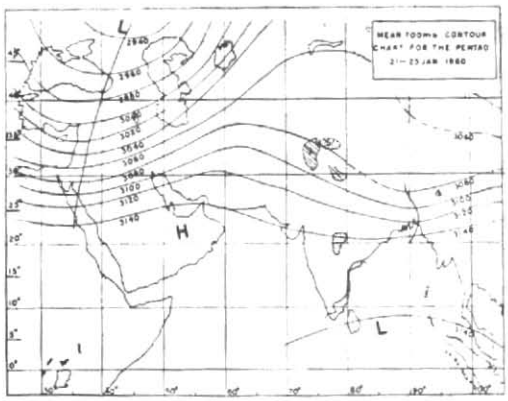

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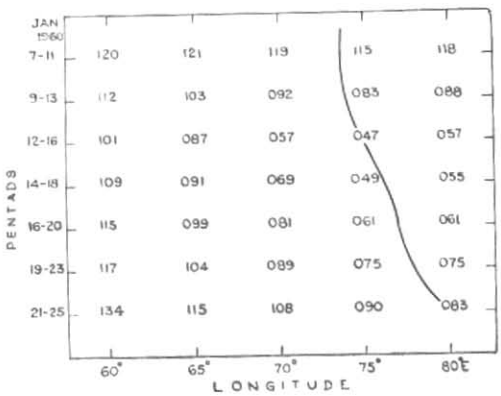


Fig. 4(d). Progression of 5-day mean trough at 700-mb level (along 30°N)

not permit the eastward movement of the mean trough. In the second case, however, the high shows considerable weakening prior to the arrival of the trough and strengthening after its passage eastwards.

A trough formed over Jammu and Kashmir during 16—20 January 1962, due to the extension southwards of a higher latitude trough and intensified during 18—22 January (Fig. 5a). This did not move initially, but later moved quite fast at the rate of about 4 degrees longitude per day and merged with the semi-permanent trough in the east by 27 January 1962. Precipitation associated with this spread all the way to northeast India and had the maximum spread when the high over the country was at its weakest, *i.e.*, during 25—29 January 1962 (Fig. 5b).

During this period, a patch of above normal rainfall moved from east to west across the extreme south Peninsula, indicating that a system in the easterlies might have moved across the Peninsula during this period. But the 700-mb charts are not quite adequate for following these systems in the easterlies.

Apart from the types of troughs discussed above, there was one trough which moved from over the Mediterranean Sea and affected weather over India. This type of trough is very infrequent. In Figs. 2(b) and 2(c) is seen an extended trough which has moved

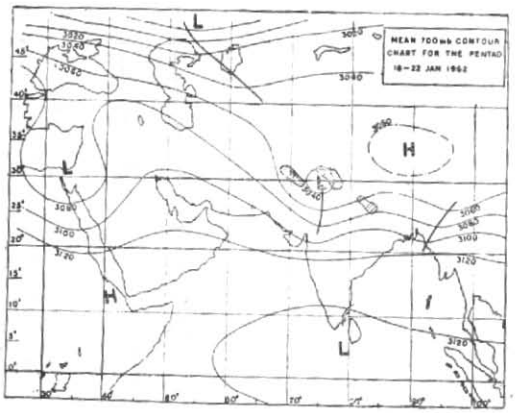
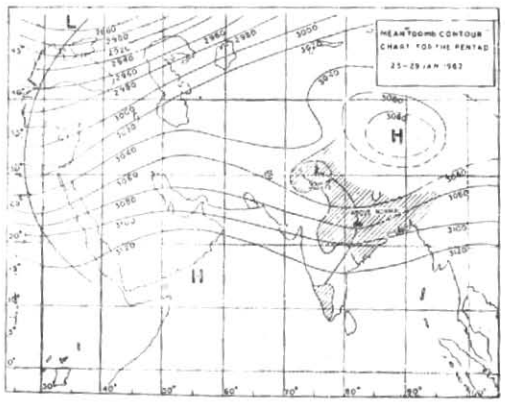


Fig. 5(a)



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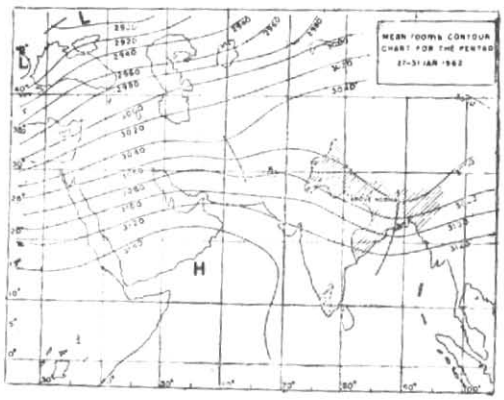

Fig. 5(c)

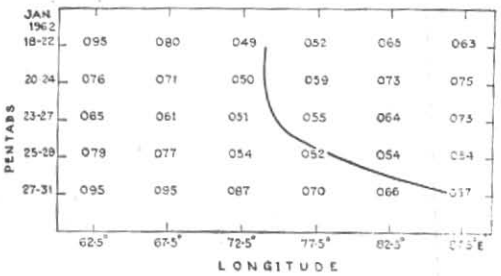

Fig. 5(d). Progression of 5-day mean trough at 700-mb level (along 27·5°N)

to the middle east from the Mediterranean Sea. During 22—26 January 1959 (Fig. 6a), this trough was near 53°E at 30°N and moved at an average speed of about 4 degrees longitude per day. It moved very fast between 22—26 and 24—28 January 1959 (Fig. 6b) and merged with the seasonal trough near 90°E during 31 January to 4 February 1959. In association with the movement of this trough above normal precipitation occurred over large parts of north India.

It can be summarised that the troughs on 5-day mean 700-mb contour charts which affect weather over north India during winter usually have their origin in (*i*) the Caspian Sea region near 60°E and (*ii*) over the Indo-Pakistan region near 70°E—75°E. Among these troughs, some move all the way across the country and finally merge with the semi-permanent trough near 90°E causing widespread above normal precipitation over large parts of north India, whereas others break up near 75°E—80°E. The former moves fast at the rate of about 4 degrees longitude per day.

The troughs which disappear near 70°E—75°E are associated with a high over the country which is either of normal or even of above normal strength. Among these, those which form near the Caspian Sea region move at a speed of 2–3 degrees longitude per day, whereas those which form over the Indo-Pakistan region do

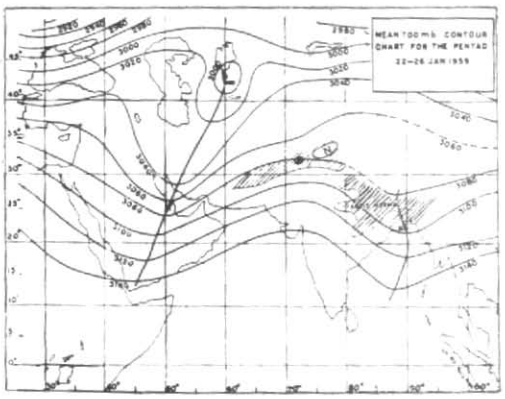

Fig. 6(a)

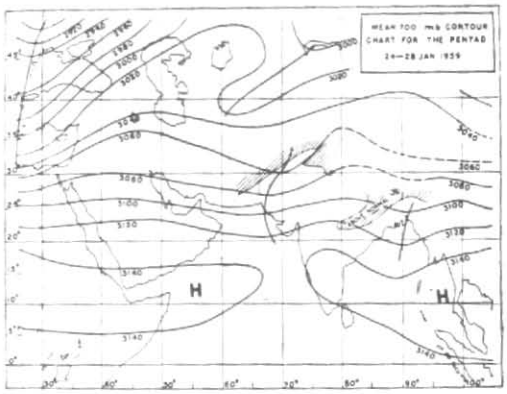

Fig. 6(b)

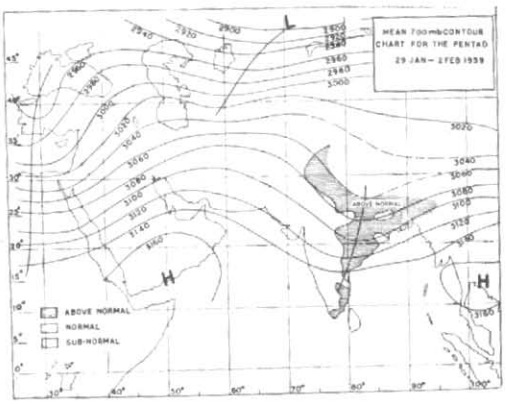

Fig. 6(c)

not move much. But, even when they move, the speed is only of the order of 1 degree longitude per day.

6. Acknowledgements

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