A preliminary study of 5-day mean flow patterns in relation to 5-day precipitation in north India during winter season

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ABSTRACT. 5-day mean charts of surface pressures and 700-mb contours have been prepared for the winter months of the years 1956 and 1957 and studied in relation to the precipitation distribution. The typical mean patterns which were mainly associated with rainfall in north India during the above period, are illustrated and discussed in some detail. Pressure and contour anomaly charts have also been prepared and examined with reference to the precipitation distribution. The speeds and tracks of the mean lows which moved eastwards affecting the weather over northern parts of the country have also been studied and the results incorporated in the paper.

1. Introduction

At present, the forecasting offices under the India Meteorological Department usually issue weather forecasts valid for periods upto 36 or 48 hours only. These short-range forecasts, as are being issued at present, cannot fully meet the requirements of agriculturists who need more advance information for their operations. By the time these forecasts reach farmers in the remote villages, their period of validity is either over or there is hardly any time left to plan operations on the basis of these short-range forecasts. Apart from the interest of the farmers, forecasts for longer periods are also very useful for planning and execution of military operations on land, sea and air. The engineers, the Public Health Department and many other organisations are also very much interested in such forecasts. To meet these requirements the need for developing a technique for issue of medium-range forecasts for the next 5 days or so for the Indian area has been keenly felt.

In the U.S.A., Namias and his collaborators (1943, 1947 and 1953) have made a detailed study of the problem and are now issuing medium-range forecasts of rainfall and temperature on a routine basis for the whole of the United States of America with the help of 5-day mean charts. The authors of this paper have been studying data of past years to examine if the techniques used by Namias and collaborators (1943, 1947 and 1953) could be applied with reasonable success to Indian conditions also. The American methods are primarily based on two distinctly different steps, namely, (*i*) the construction of mean prognostic charts from the actual mean charts and (*ii*) the interpretation of the mean prognostic charts in terms of weather. In the present paper, the feasidility of the second step, *i.e.*, interpretation of mean charts in terms of weather, has been examined and the results discussed in some detail.

2. Details of charts and their method of preparation

The winter precipitation in north India mainly occurs under the influence of disturbances coming from the west. For the prediction of weather likely to occur over north India during the next 24 or 48 hours, it may not be very necessary to have an extended chart containing observations far beyond the western border of the subcontinent of India. However, it is very essential for a long-range forecaster to extend his vision both in time and space. The charts in the present study extend up to Long. 15°E to the west and Lat. 50°N to the north, and with these extended charts it is possible to locate a distant disturbance and study its progress and influences. The data for the wide areas outside the sub-continent of India have been extracted from the 5-day mean surface and 700-mb northern hemisphere charts prepared by the Weather Bureau, U.S.A. These American charts indicate, only in a very general way, the structure of the pressure patterns over the Indian region. The pressure and contour lines drawn over Indian area in the American charts, are generally based on observations from only a few stations. In the present study, an attempt has been made to draw the patterns over India and the neighbourhood as accurately as possible by making use of all the available data.

(*a*) *Charts prepared*—The charts prepared in connection with this study are as follows—(*i*) 5-day mean 700-mb charts, (*ii*) 5-day mean surface pressure charts, (*iii*) 5-day rainfall charts, (*iv*) 700-mb contour anomaly charts and (*v*) surface pressure anomaly charts. The study of the surface and 700-mb charts could readily be taken up as extra Indian data were available from the northern hemisphere charts. It has not, however, been possible to prepare similar extended charts of higher levels due to lack of data from areas outside India. As the northern hemisphere charts from the U.S.A. were available for only two winter seasons, *i.e.*, 1956 and 1957 the present study has been confined to this period only.

(*b*) *Method of preparation*—For the preparation of mean 700-mb charts, contour values at the corner and central points of each 5-degree latitude-longitude square were determined by interpolation from the daily working charts prepared by the Weather Central, Poona. These daily charts are constructed by the differential method. The 5-day averages of the above contour values were worked out and plotted at the relevant grid points and isolines drawn. Since data outside the Indian region had to be extracted from the American charts, it has been necessary to select the same 5-day periods as used by Namias and his collaborators. During the years 1955-57 extended forecasts were being prepared twice a week in the U.S.A. and therefore there is an overlapping period of one or more days in two successive 5-day mean charts depending upon the days of the week on which the forecasts were issued.

For the preparation of a mean surface pressure chart, 5-day averages of pressure values were worked out for about 150 stations evenly distributed over India, Burma and Pakistan. For outside areas, data from the American charts were utilised as mentioned earlier. The pressure and contour anomaly charts and also the rainfall charts have been restricted to the Indian region only. In connection with the peparation of anomaly charts for 700-mb level, 5-day normals of contour values of all the radiosonde stations in India were plotted and isolines drawn. The normals of the different stations are based on data for periods varying from five to fifteen years. From the above charts, 5-day normal values for the various grid points were determined by interpolation. By plotting the departure values at these points, the anomaly patterns for 700-mb level were obtained and these are represented by broken lines in the 700-mb charts included in the paper. The corresponding 5-day rainfall distribution is also shown in the 700-mb charts. The 5-day totals of the rainfall data (in cm) were computed for all the stations which are published in the *Indian Daily Weather Reports* and plotted against the relevant stations. The surface pressure anomaly values were determined with the help of the 5-day normals published by the India Meteorological Department and the patterns are shown by dotted lines in the corresponding surface charts.

3. Discussions

As mentioned above, the 5-day mean 700-mb contour and surface charts, and the 5-day rainfall charts were prepared for six months, namely, January, February and December of 1956 and 1957, analysed and studied with a view to find out which types of disturbances were responsible for widespread precipitation over north India. It was noticed that such precipitation was associated generally with the following types—

(1) A disturbance moving along higher latitudes (say between 40°-50°N) and inducing a secondary in lower latitudes.

(2) A disturbance moving eastwards from the Mediterranean region across northwest India (say between 30°-40°N).

(3) A disturbance developing locally over north India.

As the period of study of these weather situations was limited, there were only a few disturbances of each type which could be located on the charts prepared. An example of each of the above three types of situations has been selected and is discussed below with the help of 5-day mean 700-mb charts (also showing rainfall distribution and 700-mb contour anomaly patterns) and 5-day mean surface charts.

TYPE 1: A disturbance moving along higher latitudes and inducing a secondary in lower latitudes.

(*a*) *700-mb charts*—From the 700-mb contour chart for the period 29 December 1956 to 2 January 1957 (not shown), it was noticed that a disturbance lay over Southeast Europe near Lat. 47°N and Long. 15°E, and that a high was located to its northeast. Further, another disturbance was moving away eastwards over Kazakistan causing some light rainfall in the northern parts of the country. The disturbance which lay over Southeast Europe followed some southeasterly course and was located over the eastern part of the Black Sea in the next chart for the period 1-5 January 1957 (Fig. 1A). Its southeasterly movement was possibly due to the high which was situated to its northeast. The further progress of the above disturbance may be seen from the subsequent charts (Figs. 1B, 1C and 1D). It moved away in a northeasterly direction towards the low pressure area lying over Kazakistan and Northwest China

It is noticed that light rain had occurred at some stations over the country even when the disturbance was far away from the region (Fig. 1A). This light rain was evidently caused by some small scale atmospheric phenomena which were present in some of the daily charts but did not appear in the mean chart. When averaging is applied to day-to-day pressure data, such small scale phenomena are generally obscured. The large scale atmospheric features are, however, brought out more clearly on the mean maps. The position and intensity of such patterns usually govern the important weather phenomena for the periods which the mean charts refer to. In order that a forecaster may indicate in the medium-range forecasts the weather likely to be caused by the small scale atmospheric phenomena as mentioned above, it would be necessary for him to give due weight to the daily charts also.

During the period 5-9 January (Fig. 1C), the disturbance lay over an area near Lat. 50°N and Long. 75°E and a secondary developed over Kashmir and north Punjab. Meanwhile, another disturbance appeared near Lat. 50°N and Long. 45°E. The trough line associated with the secondary disturbance over Kashmir and north Punjab was quite well-marked and extended up to north Bihar. This caused fairly widespread rainfall over the whole of north India. During the next five days (Fig. 1D), the original disturbance moved away eastnortheastwards while the other two remained more or less stationary. The trough line associated with the secondary remained as well-marked as during the previous interval and widespread rainfall continued over the whole of north India. Later, the pressure pattern became more and more flat and the weather also gradually cleared up.

During the period up to 6 January, no major weather occurred in the country and it is seen that the height anomaly values were also generally positive over the area.

The height values began to fall below normal during the period 5-9 January and the fall was maximum during the next 5-day period (Fig. 1D) when the heaviest rainfall was recorded.

A comparative study of the two sets of charts, *viz.*, the mean surface charts and the mean 700-mb charts of the two years in question (including those not given in this paper) shows that the circulation patterns at these two levels need not necessarily be similar. Some of the disturbances which caused fairly widespread rainfall in north India could not be so clearly traced at the surface although the same could be distinctly located at 700-mb level. The rainfall distribution also seems to have a better relationship with the patterns at 700-mb level.

(*b*) *Mean surface charts*—The 5-day mean surface pressure charts for the period 1–12 January are shown in Figs. 1a—1d. It will be seen that these charts did not give any indication about the approach of the primary disturbance which moved across the Black Sea and the Caspian Sea at 700-mb level. The secondary over Kashmir and the Punjab was, however, present in the surface charts also (Figs. 1c—1d). Although the surface isobaric patterns over northwest India during the period 5-12 January could justify the rainfall over that area, it is rather difficult to explain the widespread rain over the Gangetic plains and northeast India on the basis of these charts. On the other hand, the 700-mb charts did clearly indicate the approach of the primary disturbance in question from the west, the formation of the secondary over Kashmir and Punjab and the development of the associated well-marked trough, which extended from northwest India up to upper Assam and caused widespread rainfall over that whole region.

TYPE 2 : A disturbance originating in the east Mediterranean region and moving across northwest India.

(*a*) *700-mb charts*—In this connection Figs. 2A—2D may be seen. The 700-mb chart for the period 19-23 January 1957 (Fig. 2A) shows the presence of an active disturbance over South U.S.S.R., north of the Caspian Sea and the associated trough line extended from the centre of the disturbance to the Mediterranean Sea off the Turkish coast. A shallow secondary formed near the southern end of the trough line. During the next 5-day period, the secondary (Fig. 2B) was located over Iran. It followed an eastnortheasterly course thereafter. During the periods 24th-28th and 26th-30th (Figs. 2C-2D), it lay over Afghanistan and the north Punjab respectively and later moved away eastnortheastwards. During both the above 5-day intervals, the extreme north of the country recorded moderate to heavy rainfall. With the passing away of the disturbance northeastwards weather rapidly improved there. It will be seen that unlike the previous cases no well-marked extended trough was associated with this disturbance and as such the weather was generally confined to the area across which it moved.

The anomaly patterns for the periods 19th—23rd and 22nd—26th show a fall in height values over East Iran and West Pakistan, indicating the approach of the disturbance towards northwest India. During the above intervals the height values continued above normal over northwest India and the weather also remained dry there except for a few scattered light showers. During the subsequent two 5-day periods, the departure values became negative throughout the country, being appreciably so in northwest India. It is seen that fairly widespread rain was reported from the Punjab, Kashmir and the neighbouring areas during the same period. It is further seen that the highest negative departures were recorded during the five days from 26th to 30th and the maximum rainfall also occurred during the same interval.

(*b*) *Mean surface charts*—The corresponding surface pressure charts are shown in Figs. 2a-2d. The formation and progress of the disturbance discussed above could not be traced in any of the surface charts although it was distinctly noticeable in the 700-mb charts. The primary disturbance, passing over the South U.S.S.R., north of the Caspian Sea, was very much more marked at higher levels. During the period 22-26 January 1957, there was a low pressure area at higher levels over the region north of the Indian sub-continent whereas there was a well-marked high pressure area over the same region at the surface. During the period 26th to 30th (Fig. 2d), the surface chart showed a low, quite prominent, over the Red Sea and the adjoining areas but the same was not present at 700-mb level. Again, during the same period, a fresh disturbance was moving eastwards across Southeast Europe at 700-mb level but it could not be noticed at the surface. Thus, the general pressure patterns at the two levels were quite different in this case also. The widespread rainfall that occurred in the Punjab and Kashmir during the period 22nd to 30th could also be explained more easily on the basis of the 700-mb charts.

TYPE 3 : A disturbance developing locally in north India.

(*a*) *700-mb charts*—The chart for the period 14-18 January 1956 (Fig. 3A) shows that no disturbance was approaching the country from the west. A disturbance was, however, located at a very distant place near Lat. 50°N and Long. 35°E but it slowly moved away northeastwards without affecting the weather over the country. A study of the above and the next two charts (Figs. 3B and 3C) shows that the contour gradient at 700-mb level was rapidly decreasing over north India, suggesting the probable formation of a low pressure area there. It is seen from the chart for 25th-29th (Fig. 3D) that a low, as anticipated earlier, actually developed over the above region in the course of the next five days and it caused fairly widespread precipitation in southeast Uttar Pradesh, Bihar, north Bengal and upper Assam. Later, the low became less marked and slowly moved away northeastwards.

(*b*) *Surface charts*—The mean surface pressure charts are shown in Figs. 3a-3d. It is seen that the pressure increased northwards over the country at the surface, there being generally a high pressure area over Kazakistan and Mongolia and a low pressure area over the Indian Seas. The position was, however, just the reverse at 700-mb level. During the period 25-29 January 1956 fairly widespread precipitation occurred in the Gangetic plains but the surface charts did not show any well-marked low in the vicinity of that area. It is noticed that a fairly deep low lay over Turkey at the ground level (Fig. 3d), but the 700-mb chart did not show any such low over the same area. A low was, however, located at 700-mb level over the South U.S.S.R. to the north of the Black Sea.

The surface pressure anomaly patterns in respect of the three cases are also shown in the corresponding surface charts by broken lines. It is seen that the rainfall distributions were generally more closely associated with the anomaly patterns at 700-mb level than with those at the surface.

4. Tracks of the mean disturbances

The number of disturbances which moved across Southeast Europe and middle eastern countries and of those which developed in north India are eight and five respectively. The tracks of the above disturbances are shown in Fig. 4. In drawing the track of a particular disturbance, the positions of its centre as found on the successive mean charts were plotted on a separate map and a smooth line drawn through them. The tracks shown in the above figure refer to the 700-mb level only. The speeds of the disturbances following the long tracks as shown in Fig. 4 have also been determined. It is seen that the speed of these disturbances varied from a maximum value of about 500 miles/day, to a minimum value of about 150 miles/day. The average speed for all these disturbances taken together is found to be about 300 miles per day.

5. Conclusions

It is seen from this study that the mean pattern at the surface level need not always be similar to that at the 700-mb level. The 700-mb charts are found to be more helpful in locating the disturbances which cause rainfall over north India during the winter season. A mean pattern of a particular type at the 700-mb level usually leads to a specific type of rainfall distribution over the country. It is also seen that the patterns, especially in the 700-mb charts, exhibit good continuity and the troughs and ridges in these charts undergo orderly development and movement—a feature which is essential for the purpose of prognostication of a future pattern from a given pattern. If diagrams are prepared showing the different patterns and their respective rainfall distributions after studying data of a large number of years, it is felt that these will be found very useful to a forecaster in indicating weather when the future pattern is once prognosticated by him. The present study, though limited, holds out hopes regarding the usefulness of 5-day mean charts for purposes of issuing medium-range forecasts for precipitation in north India during the winter season.

6. Acknowledgements

The authors are very grateful to the Weather Bureau, U.S.A. for kindly supplying them with micro-films and ozalith copies of 5-day mean charts of the northern hemisphere, without which it would have been very difficult to undertake a study of this kind. Their thanks are also due to Sarvashri K. Soundara Rajan, T. R. Natarajan, C. D. Patil and A.R. Joshi for assistance in computational work and preparation of charts.

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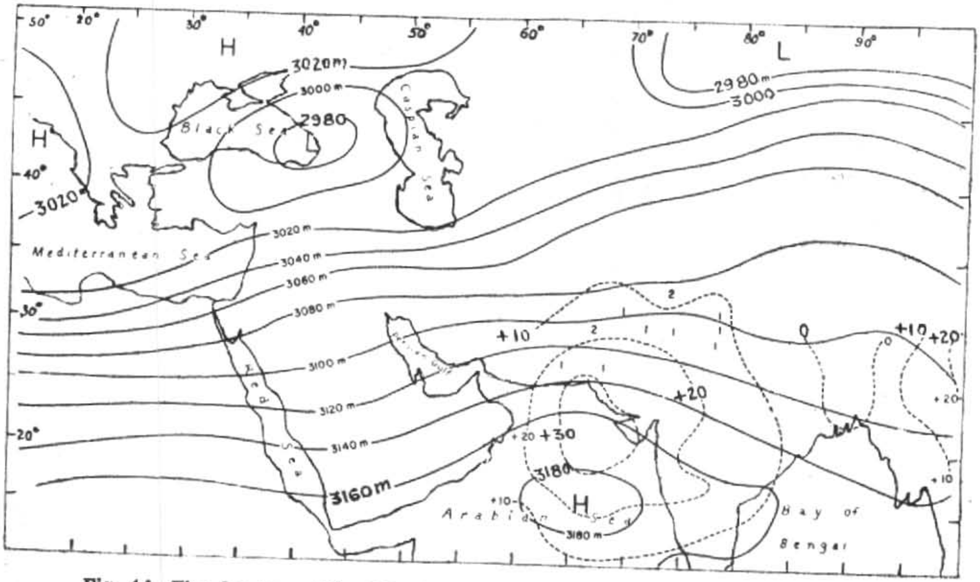

Fig. 1A. Five-day mean 700-mb level chart with height anomaly lines and rainfall (cm) for the period 1—5 Janury 1957

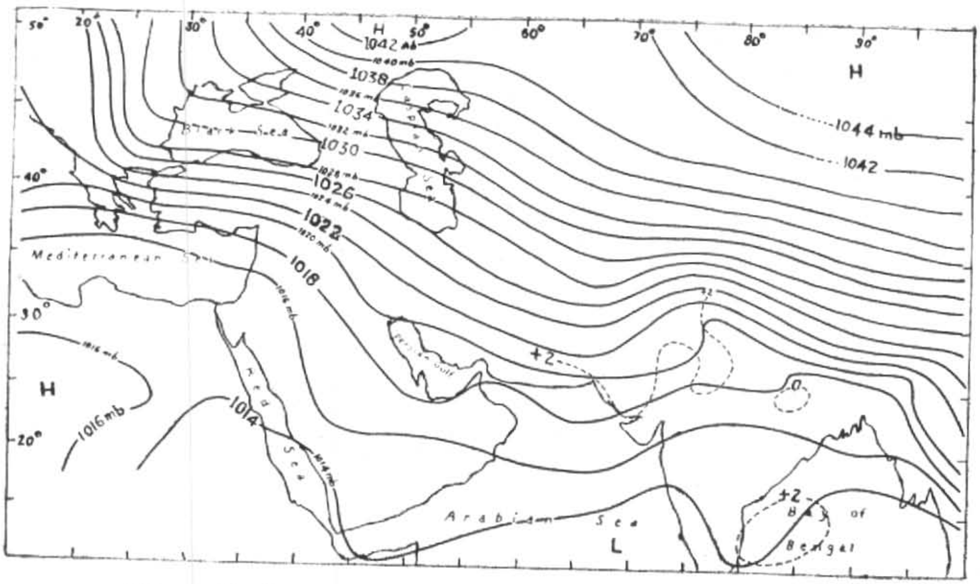

Fig. 1a. Five-day mean sea level pressure chart with pressure anomaly lines for the period 1—5 January 1957

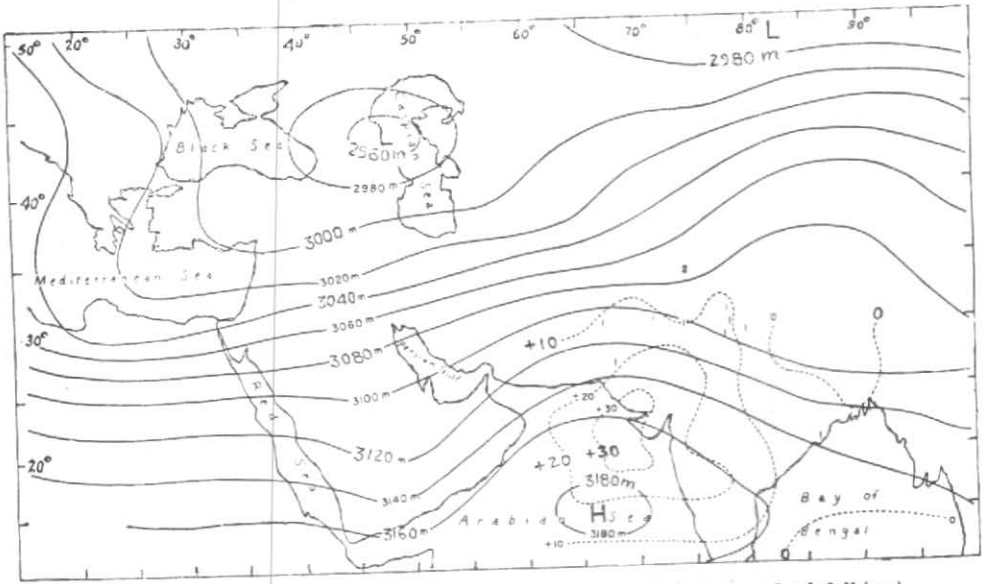

Fig. 1B. Five-day mean 700-mb level chart with height anomaly lines and rainfall (cm) for the period 2—6 January 1957

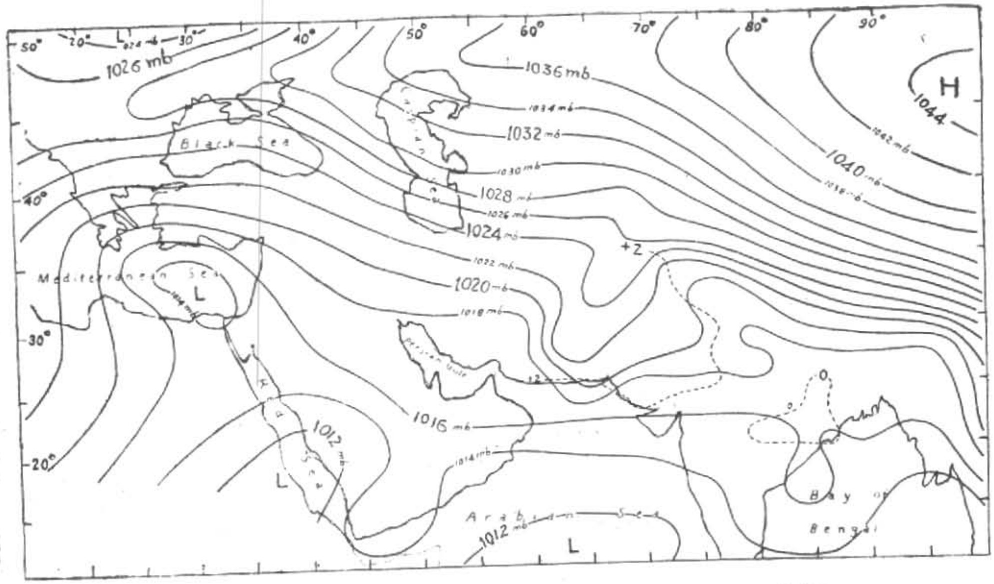

Fig. 1b. Five-day mean sea level pressure chart with pressure anomaly lines for the period 2—6 January 1957

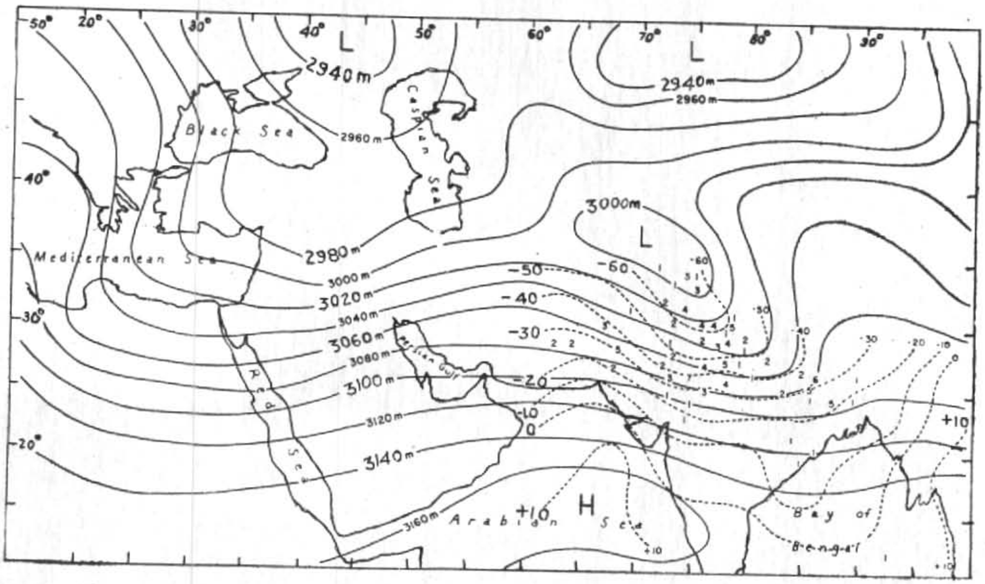

Fig. 1C. Five-day mean 700-mb level chart with height anomaly lines and rainfall (cm) for the period 5—9 January 1957

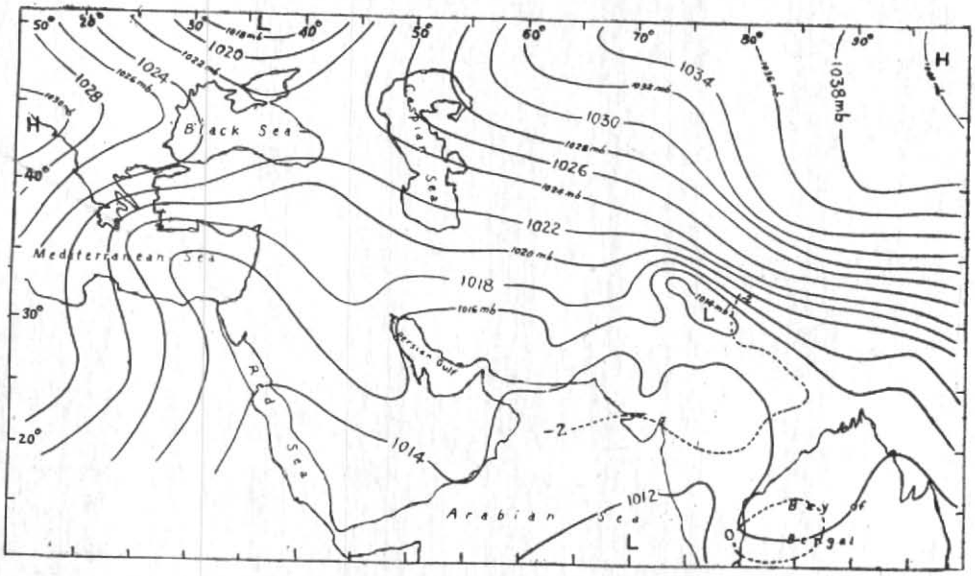

Fig. 1c. Five-day mean sea level pressure chart with pressure anomaly lines for the period 5—9 January 1957

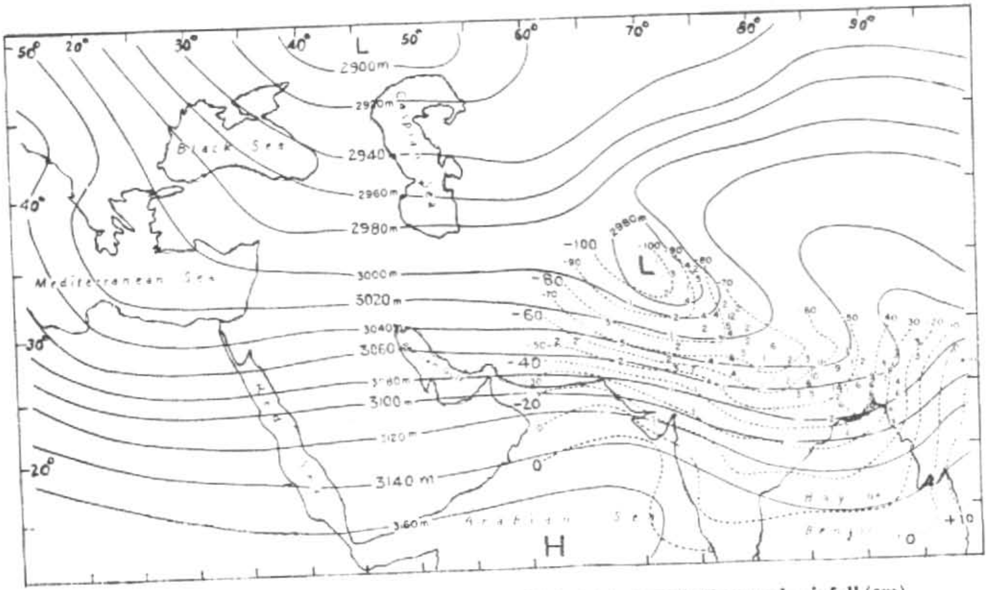

Fig. 1D. Five-day mean 700-mb level chart with height anomaly lines and rainfall (cm) for the period 8—12 January 1957

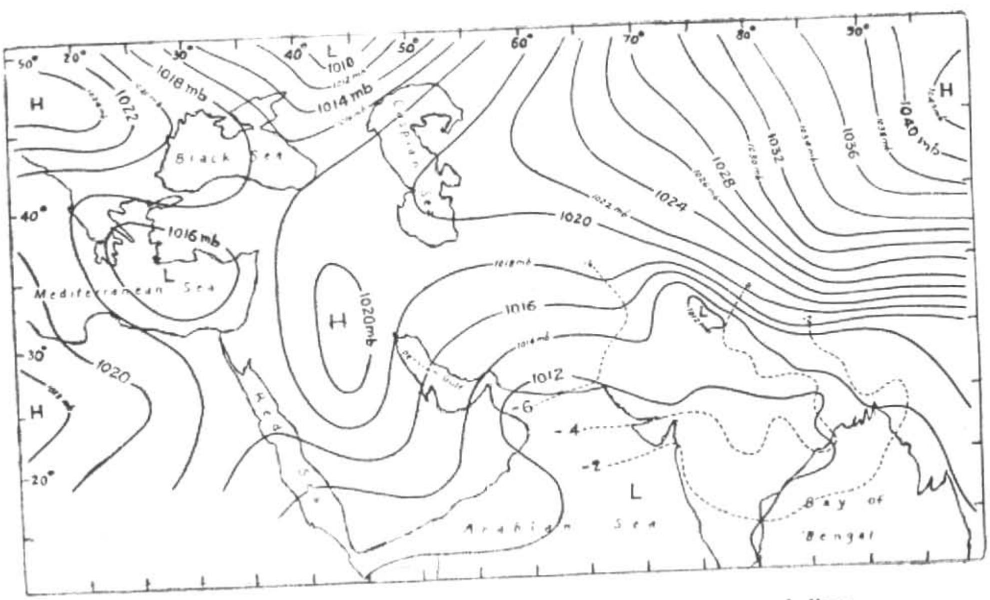

Fig. 1d. Five-day mean sea level pressure chart with pressure anomaly lines for the period 8—12 January 1957

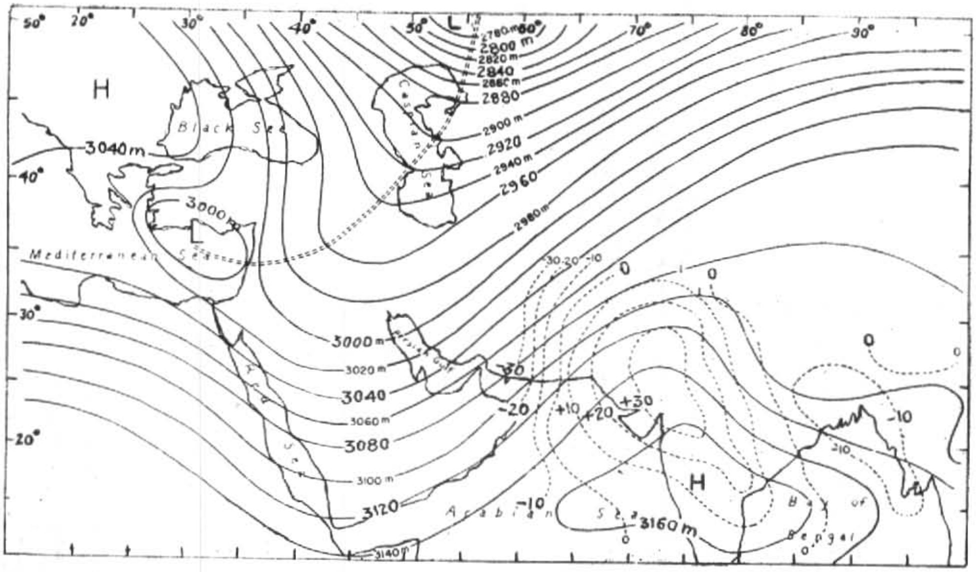

Fig. 2A. Five-day mean 700-mb level chart with height anomaly lines and rainfall (cm) for the period 19—23 January 1957

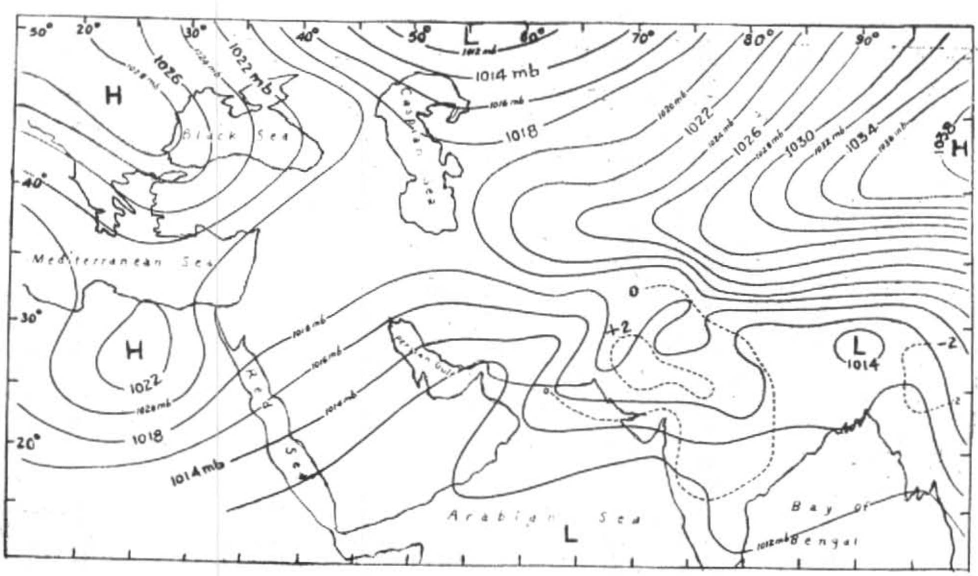

Fig. 2a. Five-day mean sea level pressure chart with pressure anomaly lines for the period 19—23 January 1957

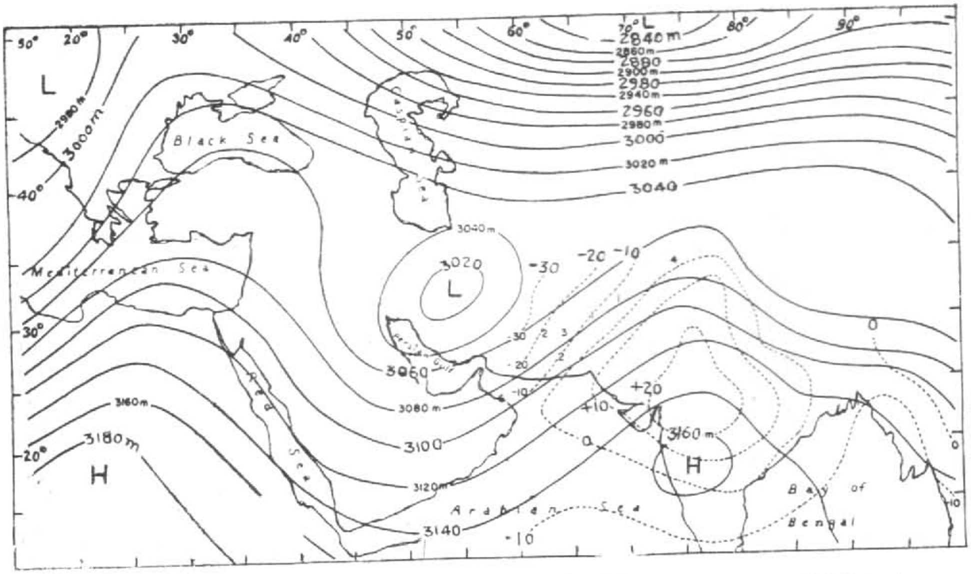

Fig. 2B. Five-day mean 700-mb level chart with height anomaly lines and rainfall (cm) for the period 22—26 January 1957

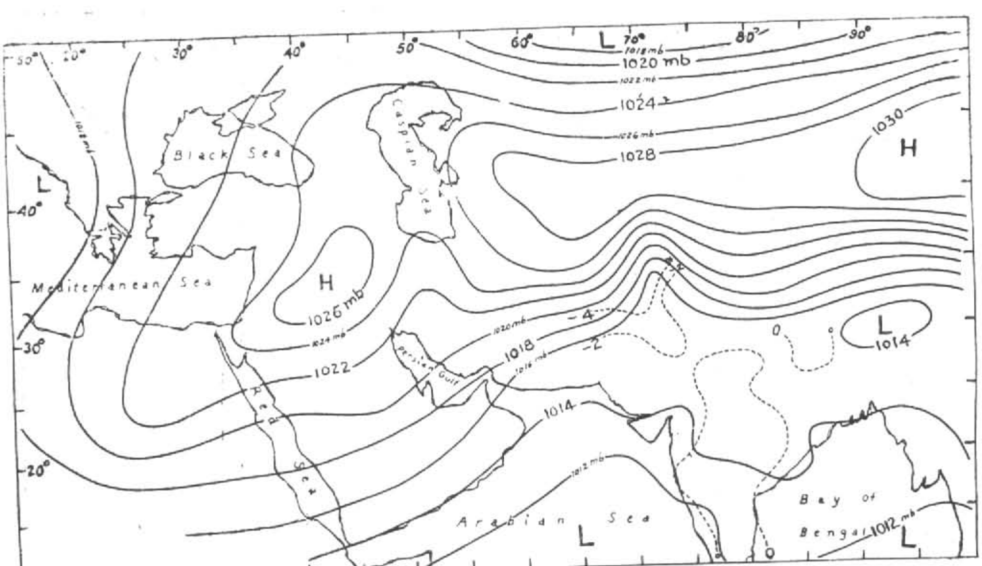

Fig. 2b. Five-day mean sea level pressure chart with pressure anomaly lines for the period 22—26 January 1957

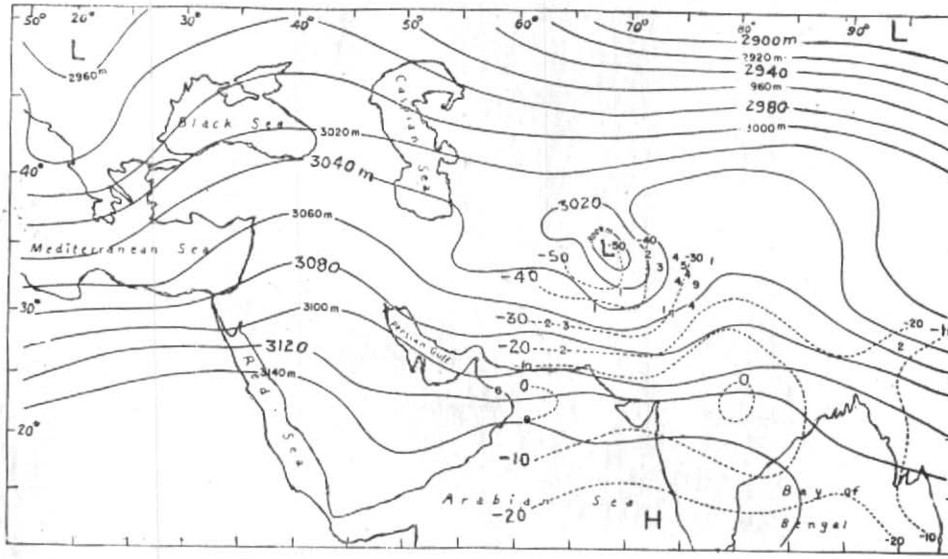

Fig. 2C. Five-day mean 700-mb level chart with height anomaly lines and rainfall (cm) for the period 24—28 January 1957

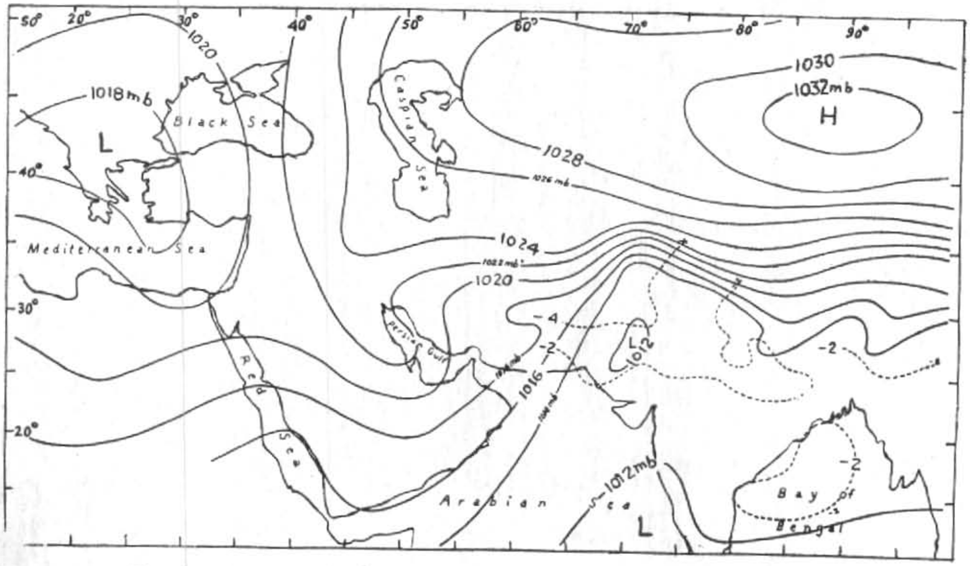

Fig. 2c. Five-day mean sea level pressure chart with pressure anomaly lines for the period 24—28 January 1957

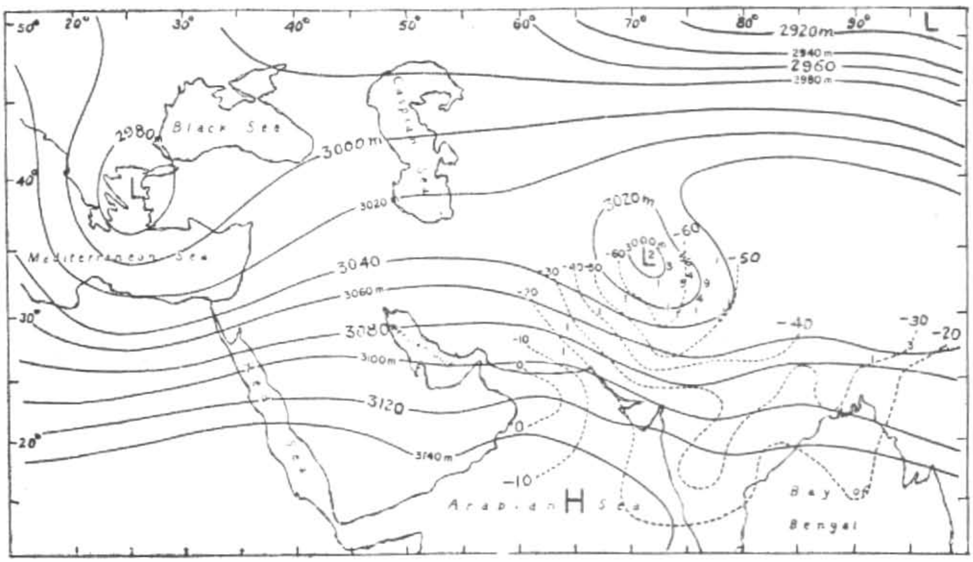

Fig. 2D. Five-day mean 700-mb level chart with height anomaly lines and rainfall (cm) for the period 26—30 January 1957

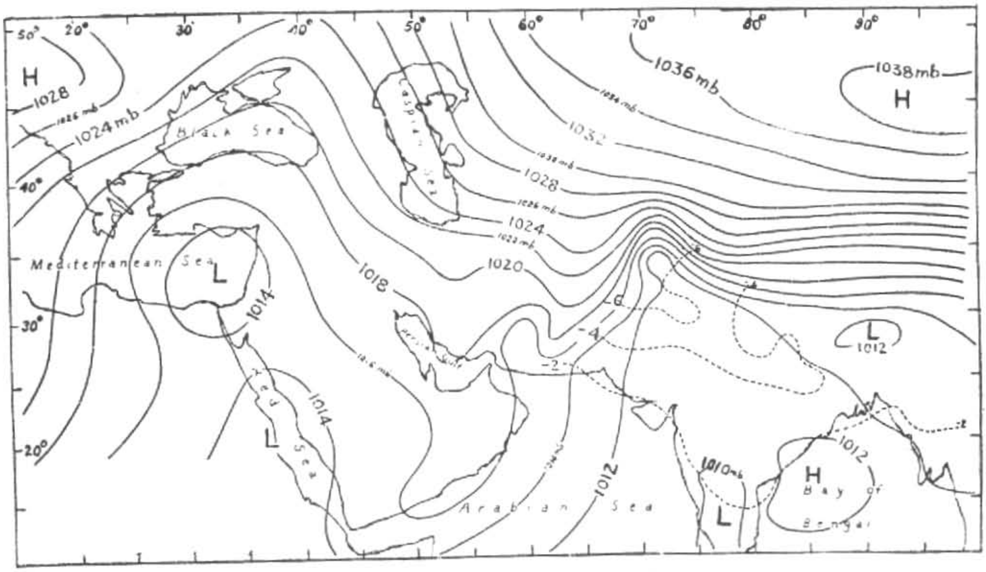

Fig. 2d. Five-day mean sea level pressure chart with pressure anomaly lines for the period 26—30 January 1957

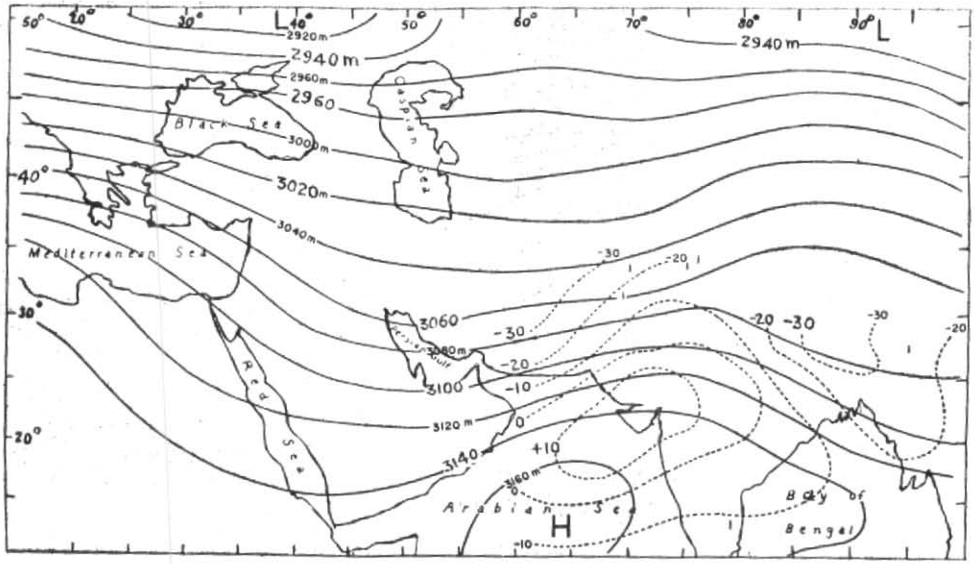

Fig. 3A. Five-day mean 700-mb level chart with height anomaly lines and rainfall (cm) for the period 14—18 January 1956

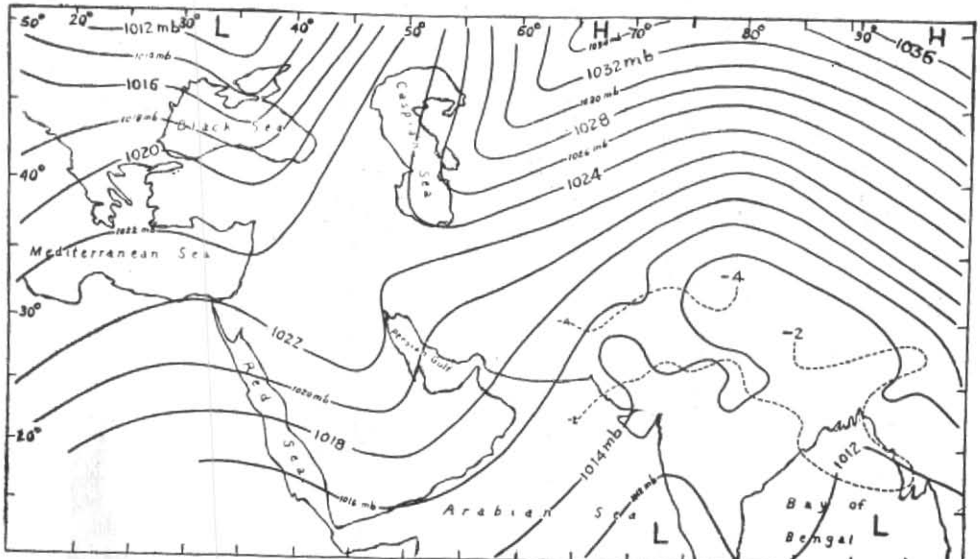

Fig. 3a. Five-day mean sea level pressure chart with pressure anomaly lines for the period 14—18 January 1956

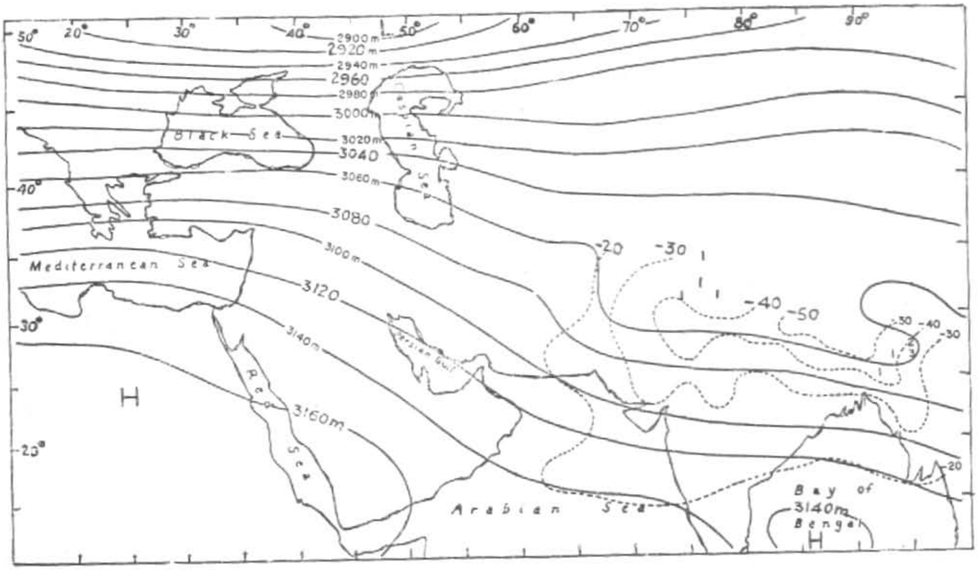

Fig. 3B. Five-day mean 700-mb level chart with height anomaly lines and rainfall (cm) for the period 18—22 January 1956

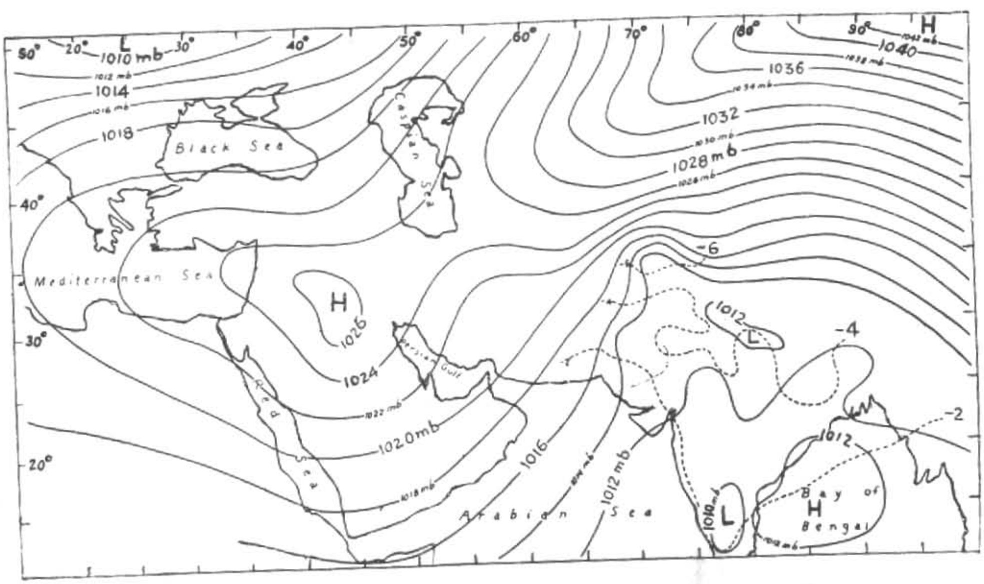

Fig. 3b. Five-day mean sea level pressure chart with pressure anomaly lines for the period 18—22 January 1956

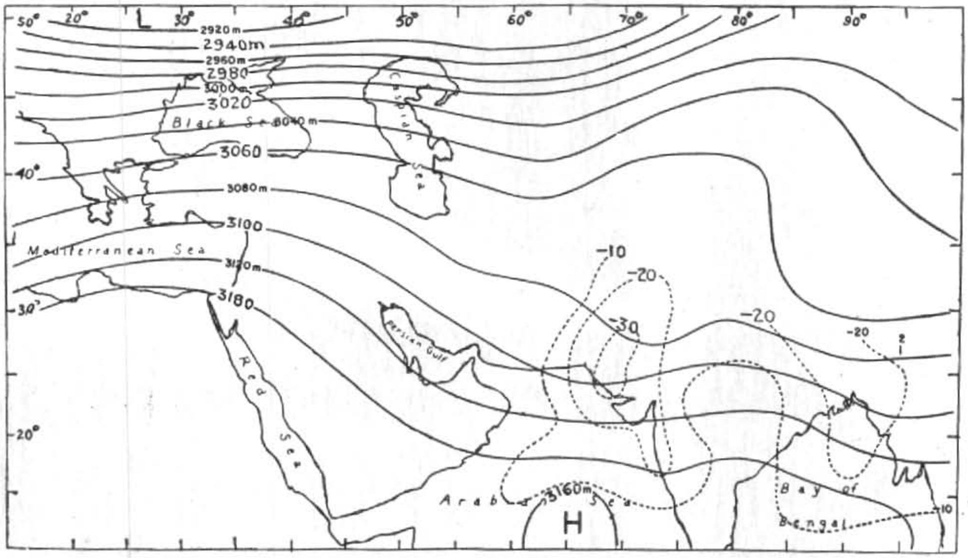

Fig. 3C. Five-day mean 700-mb level chart with height anomaly lines and rainfall (cm) for the period 21—25 January 1956

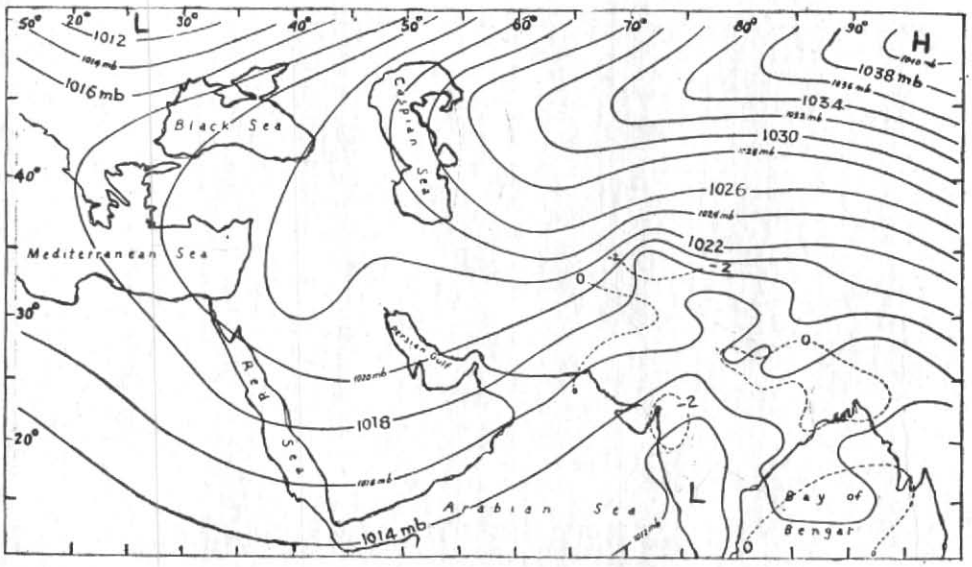

Fig. 3c. Five-day mean sea level pressure chart with pressure anomaly lines for the period 21—25 January 1956

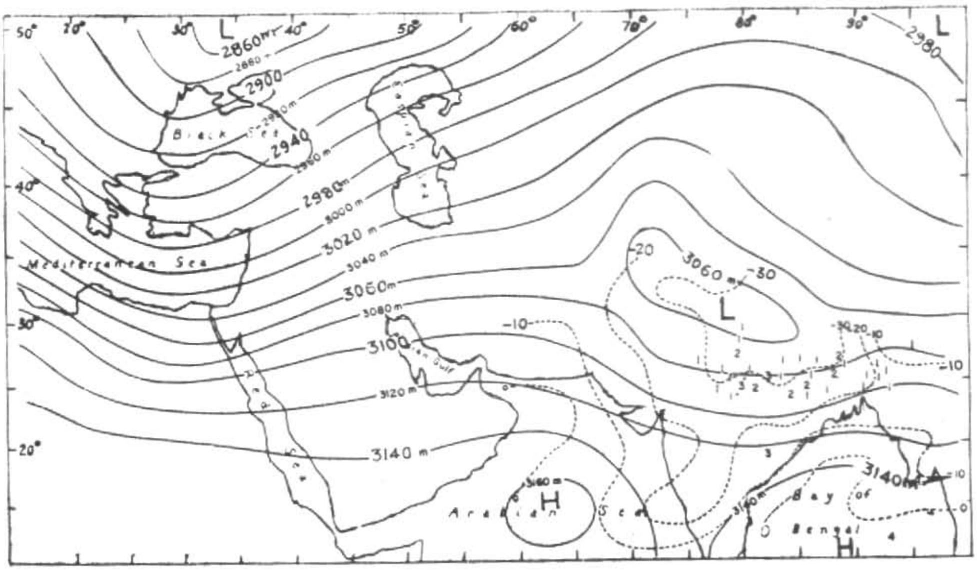

Fig 3D. Five-day mean 700-mb level chart with height anomaly lines and rainfall (cm) for the period 25—29 January 1956

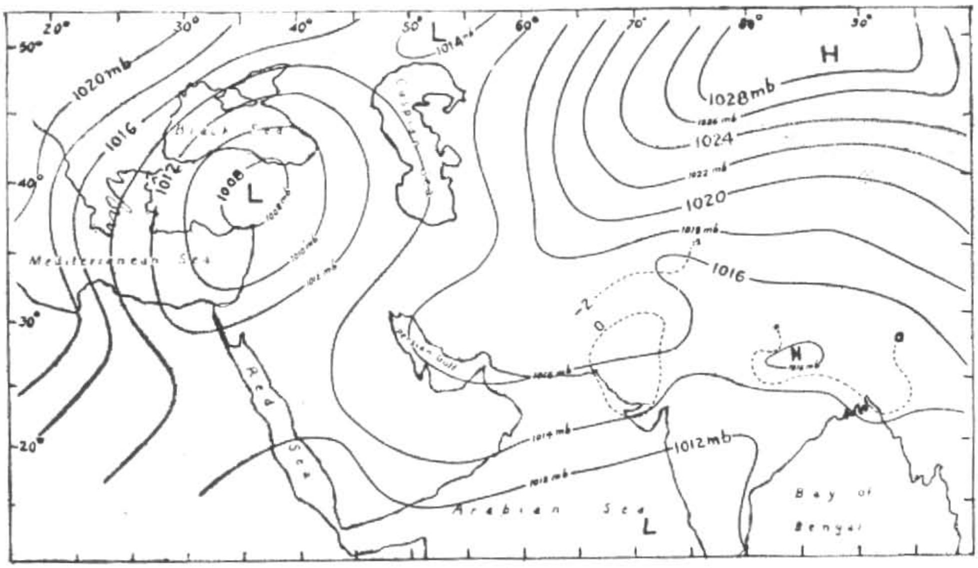

Fig. 3d. Five-day mean sea level pressure chart with pressure anomaly lines for the period 25—29 January 1956

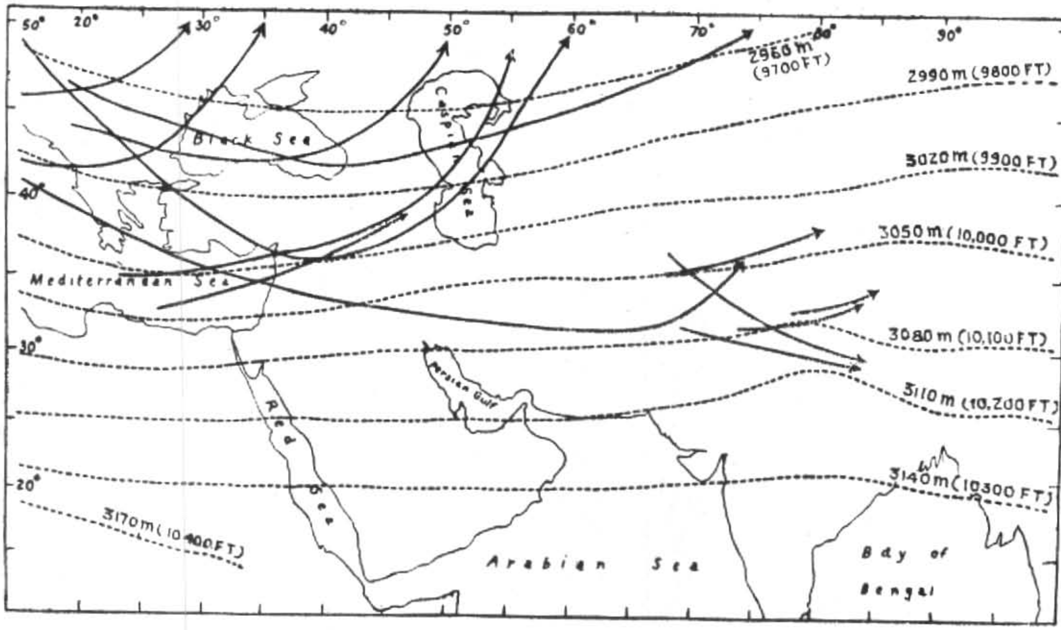

Fig. 4. Tracks of mean disturbances and normal contour lines at 700-mb level