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SATELLITE CLOUDING ASSOCIATED WITH THE MONSOON TROUGH*

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ABSTRACT

The ITCZ shifts much more northwards during the northern summer in the North Indian Ocean than anywhere else in the world and the axis of the low pressure belt associated with it lies over South Asia at the sea level. The other noteworthy features of the circulation over South Asia and the enclosed seas of the North Indian Ocean are (1) the existence of a broad belt of westerlies from the equator to the south of the axis extending to a height of about 6 km and (2) the southward shift of the axis of the low pressure belt with height.

The perturbations embedded in the deep and highly moist monsoon air cause plentiful rainfall, but the rainfall distribution is highly asymmetric with respect to the surface position of the disturbances. The Television cloud pictures received from satellites show clearly the areas of maximum hydrometeor activity. They appear as highly bright blobs elongated east to west. Several such blobs can often be noticed on an APT picture-mosaics and an axis can be drawn, which passes through the central areas of such blobs.

The cloud belt axis was compared with position of the axis of the monsoon trough at different levels. The results show that the cloud axis coincides best with the axis of the Monsoon trough at the 700/500 mbs and least with that at the surface under normal monsoon conditions.

INTRODUCTION

THE seasonal variations in the position of the Inter-Tropical Convergence Zone (ITCZ) are remarkably more pronounced in the North Indian Ocean than anywhere else in the World. The ITCZ shifts to an extremely northerly position during the northern summer in this area and the axis of the low pressure belt associated with it lies over South Asia during this season at the sea level. The other noteworthy features of the circulation over India and the enclosed seas of North Indian Ocean in the lower half of the troposphere are (1) The existence of a broad belt of westerlies from the Equator to the axis of the low pressure belt. This is the westerly branch of the South-west Monsoon current. These westerlies normally extend to about 500 mb and have high-moisture content. (2) The axis of the low pressure belt tilts southwards with height, the tilt being highly pronounced in the western parts of the area under consideration. Thus, the axis lies at the northernmost position at the surface and more and more to the south as we go higher up in the atmosphere upto 500 mb level.

Thus, we find that the monsoon trough is a long belt of low pressure which stretches from west to east but whose position lies at different latitudes at different levels in the lower half of the troposphere.

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On an examination of the mosaics of Satellite cloud pictures of the monsoon months, it is often observed that the long belts of clouding exist which stretch west to east. It is also noticed that these belts do not often lie near the surface positions of the monsoon trough. The present study is an attempt to find out if these belts of convergence as are revealed by the cloud pictures obtained from the satellites coincides better with the axis of the monsoon troughs at any other standard level in the lower troposphere. The results of this study are presented in this paper.

We wish to thank Shri P. V. Pathak and Shri S. S. Bhondve for the help in the preparation of their diagrams.

Data Utilized

The data utilized in this study are for the months of July and August of the years 1968, 1969 and 1970. The satellite cloud data are taken from the mosaics prepared by the Indian Ocean and Southern Hemisphere Analyses Centre (INOSHAC), Poona, from the Automatic Picture Transmission (APT) pictures received at the (APT) receiving station at Bombay. The working synoptic charts of INOSHAC, Poona, were used for obtaining the position of the monsoon trough at different levels on a daily basis.

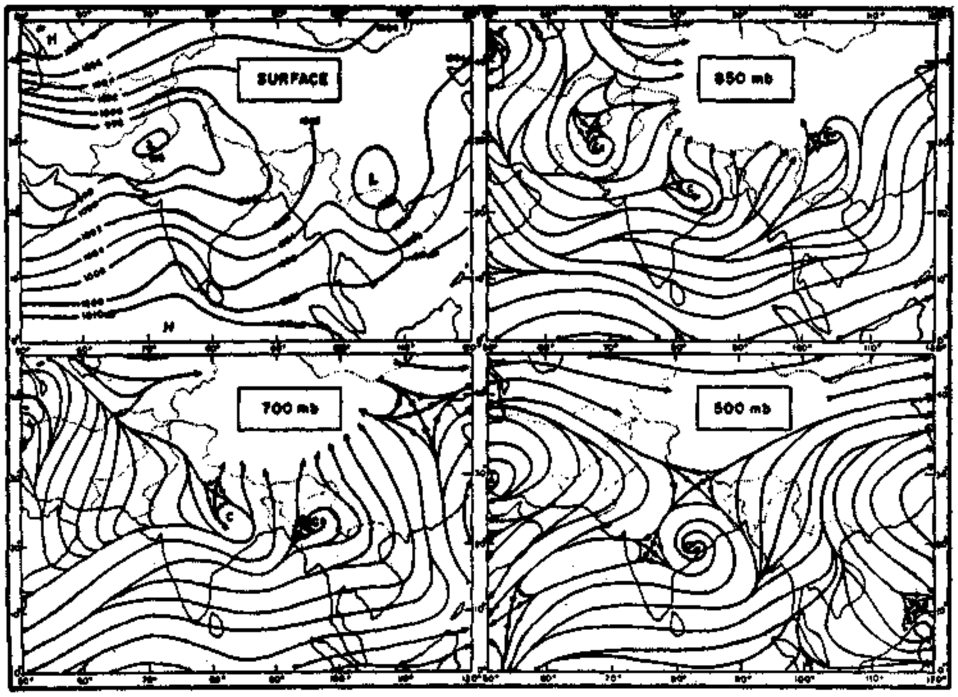


Fig. 1. Normal pressure distribution at the surface and normal streamline flow at 850, 700 and 500 mb levels.

Study and Results

Fig. 1 shows the normal isobars at the surface [I.Met.D., (1943)] and the flow patterns at 850 mb, 700 mb and 500 mb levels [Raman and Dixit, (1964)]. These charts show the tilt of the monsoon trough southward with height. It is also seen that the tilt is much greater in the western half of the area than in the eastern half.

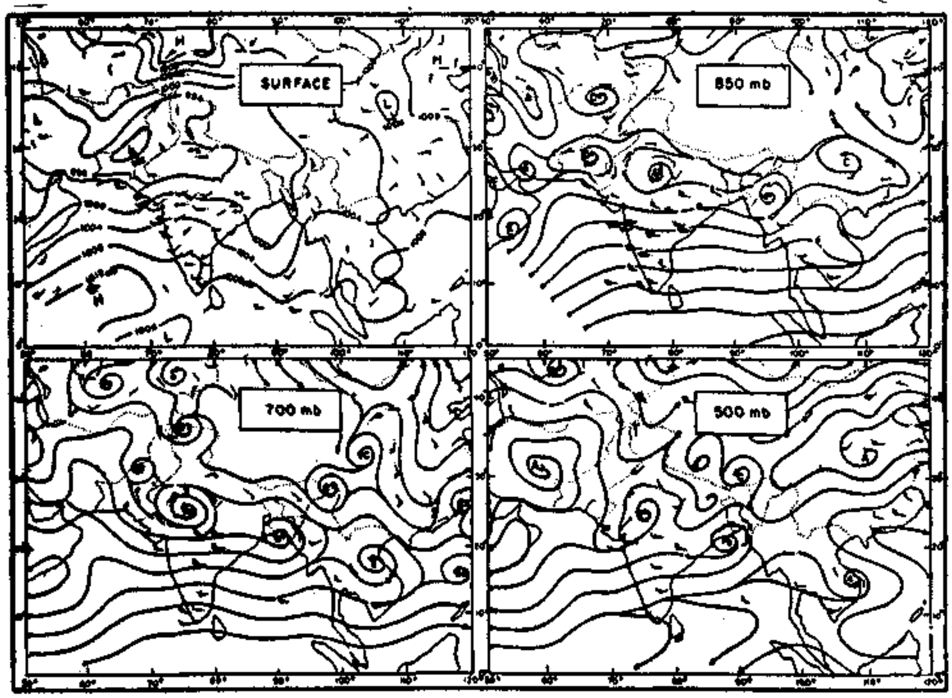


Fig. 2. The pressure distribution at the surface and the streamline flow at 850, 700 and 500 mb level on 2nd Aug., 1968, 00 G.M.T.

Fig. 2 shows the distribution of pressure at the surface and flow patterns at the 3 higher levels on 2nd August, 1968. It can be seen that a number of synoptic scale perturbations are imbedded in the general large scale circulation. It is also seen that while position of the axis of the Monsoon trough is shifted by the presence of the synoptic scale perturbations, the centres of the cyclonic perturbations in their turn tilt southwards apparently due to the effect of the large scale circulation.

Plate I shows the mosaic of the APT pictures on the same day—2nd August, 1968. A long belt of cloud systems stretches from west to east between longitudes 60°E to 110°E roughly between latitudes 15° and 25°N. This is similar in appearance to the convective activity one notices near the ITCZ, which normally lies in the Equatorial regions. Along this zone can be seen some bright patches which represent areas where active convection is taking place.

Plate II shows the same APT cloud cover with the surface isobars and the streamlines at the 850, 700 and 500 mb levels superimposed. As can be seen, the cloud belt lies far to the south of the surface position of the seasonal trough. Also the bright patches of the cloud belt do not coincide with positions of the cyclonic perturbations at the surface. On the other hand the cloud band lies almost at or near the axis of the seasonal trough on the 700 and 500 mb charts, the coincidence being slightly better with the latter.

Plate III shows another set of charts superimposed on the APT cloud cover. These charts are for 12th August, 1969. It can be seen that the relationship between the cloud axis and the positions of the Monsoon trough at different levels is similar to that shown in Fig. 4. This relationship is found generally to be valid in most cases in this season. However, the above method of comparison is laborious and time consuming as one has to transfer the cloud cover to the scale of the synoptic charts. It cannot be done for a large number of cases. So we have, for statistical purposes, processed the data in another way.

Plate IV shows the mosaic of an APT picture. Through the central position of the cloud belt one can draw a line which can be called the axis of the cloud system. The position of the axis at every five degree longitude interval starting from longitude 65°E to longitude 95°E was noticed for all days of the period under study, i.e. during July and August, 1968, 1969 and 1970. The latitudinal positions of the axis of the Monsoon trough at the four standard levels in the lower half of the troposphere were also noted on these days along each of these longitudes.

Fig. 3 shows the scatter diagrams in which the positions of the axes of Monsoon trough at different levels are plotted against the position of the axis of the cloud system along that longitude. These scatter diagrams at once reveal that there is hardly any correlation between the variations in position of the cloud cover and the variations of the positions of the surface axis. This is especially true in the case of the Western longitudes. On the other hand, it is evident from these charts that there is a much better agreement between the cloud axis and the axes of the Monsoon trough at 700/500 mb levels. On some occasions there were large differences between position of the Monsoon trough even at the 700/500 mb level and position of the axis of the cloud system. On an examination of data of such dates, it was noticed that these are days of weak or break monsoon conditions, when the general circulation in the area in the mid-tropospheric levels is widely different from the normal circulations. Such days were eliminated and data of only of those days when the general Monsoon circulation was near about the normal, were taken for comparison to the cloud cover for the purpose of this study. The main criteria used for determining whether large scale circulation on a given day was having normal features or not, is the verticle extent of the Monsoon westerlies. Days when these extended to 500 mbs were considered normal days.

Figs. 4 and 5 show the histograms of the latitudinal separation between the cloud axis and the axes of the Monsoon trough at the four levels along the different longitudes for the months of July and August respectively. (These data refer only to normal days). Positive values indicate that cloud axis is to the south of the axis of the Monsoon trough and negative values to the north. These diagrams bring out the salient features of the relationship, remarkably well. As can be seen from these figures at long. 65°E and 70°E, there is not a single case when the cloud axis coincided with the axis of the surface trough. As we go higher, the histograms come nearer the zero line. Towards the extreme eastern longitudes (90, 95°E) the histogram even at the surface are much nearer to the zero line.

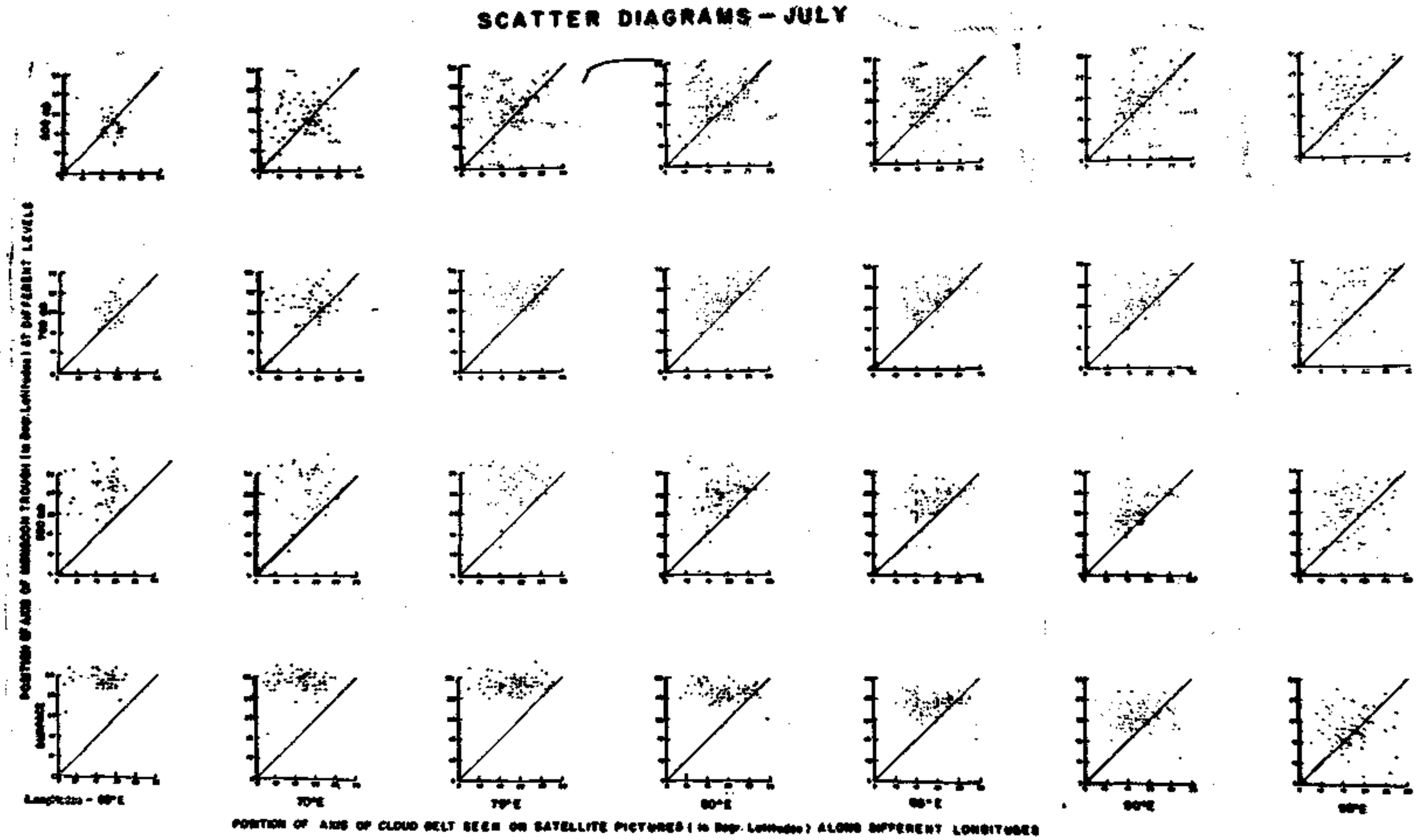
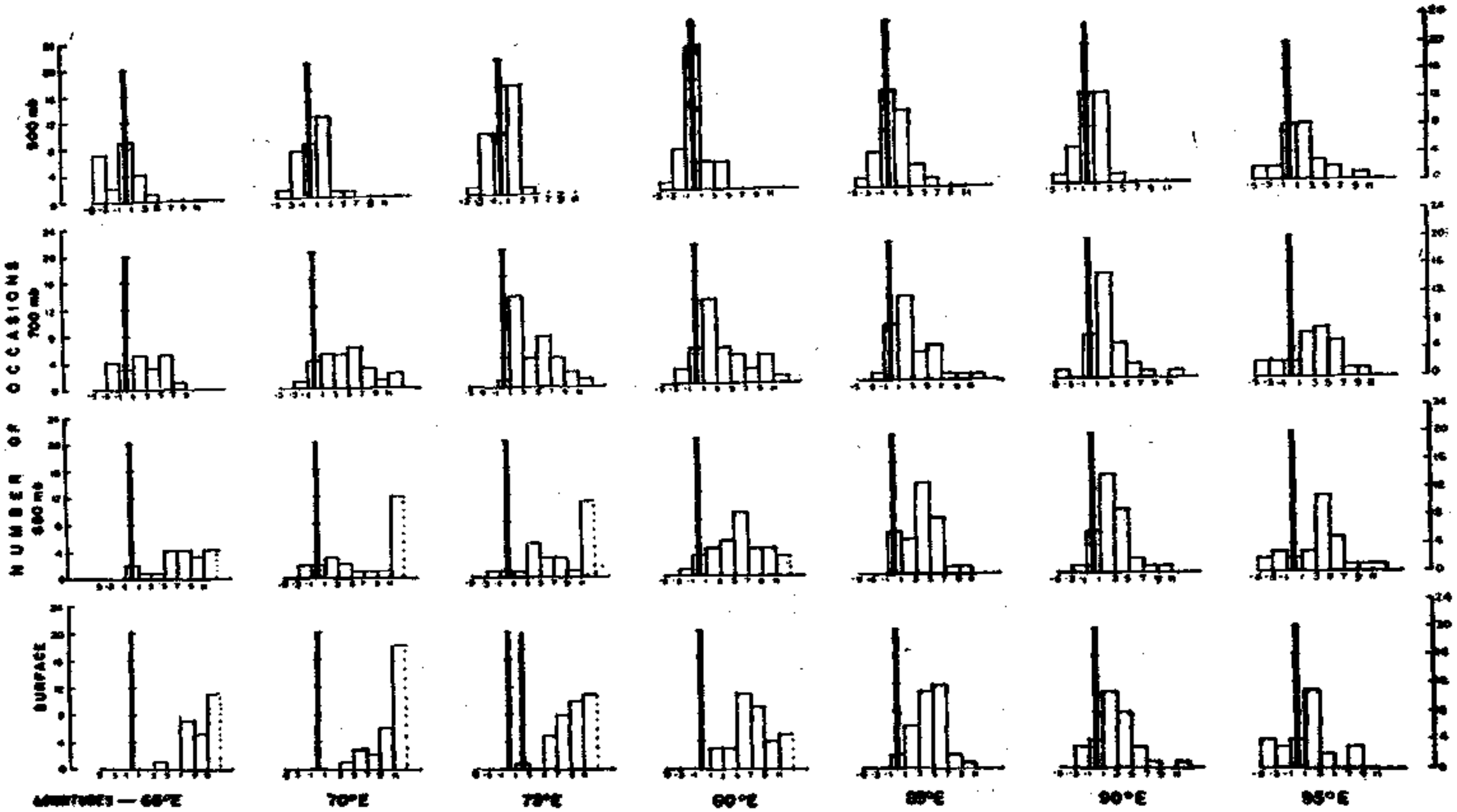


Fig. 3. Scatter diagrams drawn with the position of cloud axis on the abscissa and the position of the monsoon trough on the ordinate. Diagrams for the surface, 850, 700 and 500 mb levels along different longitudes are shown in the figure.



DIFFERENCE BETWEEN AXIS OF CLOUDING ON SATELLITE PICTURE AND MONSOON TROUGH AXIS
(IN DEGREES LATITUDE)
JULY

Fig. 4. Histograms for the month of July showing the frequency distribution of the difference in the position of the cloud axis and the position of the monsoon trough, on normal monsoon days. Positive values indicate that the cloud axis is to the south of the monsoon trough and negative values, to the north.

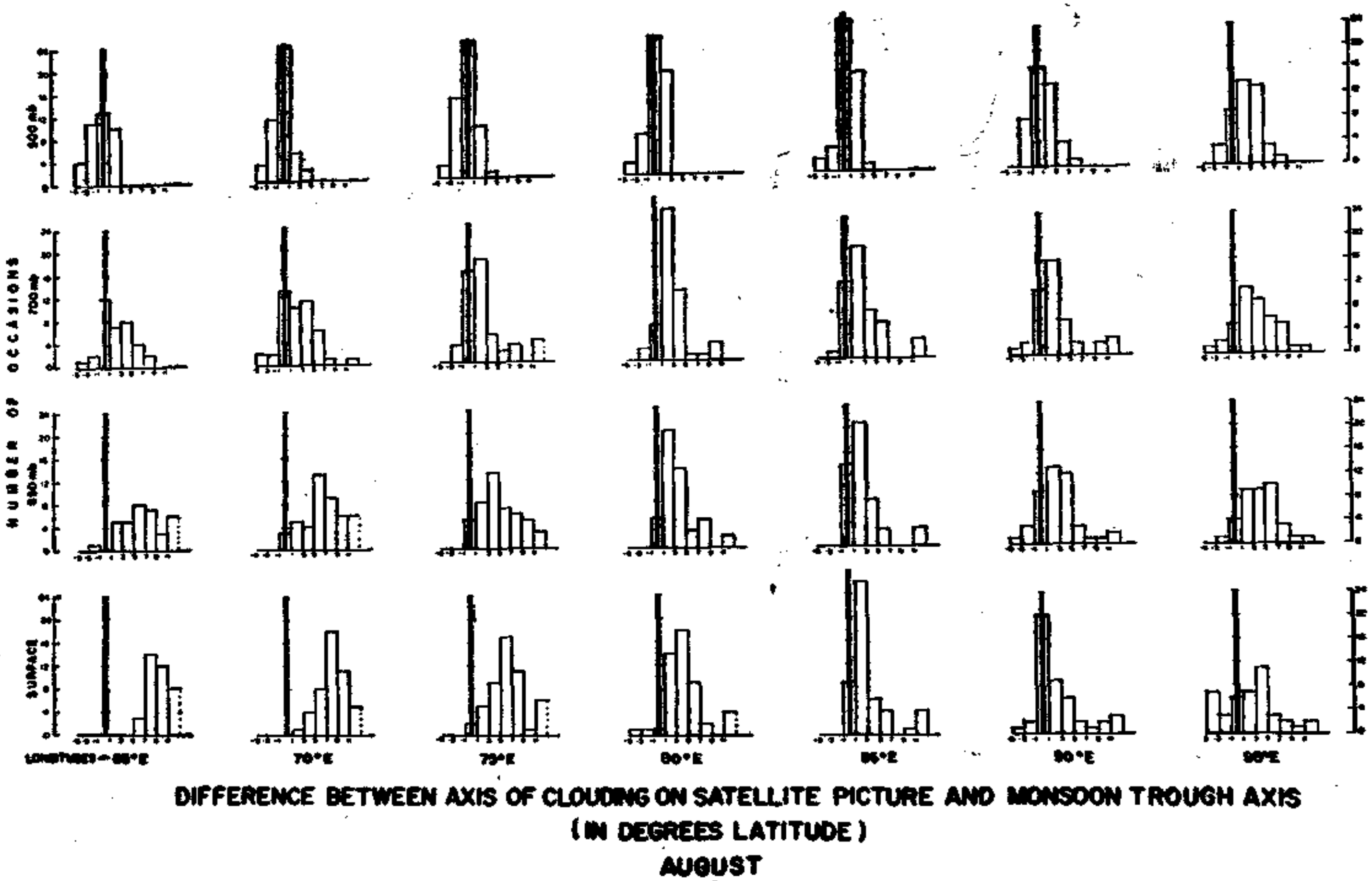


Fig. 5. Histograms for the month of August showing the frequency distribution of the difference in the position of the cloud axis and the position of monsoon trough, on normal monsoon days. Positive values ndicate that the cloud axis is to the south of the monsoon trough and the negative values, to the north.

Finally, Fig. 6 shows the average (dots) and range (lines) of the latitudinal difference of the axis of the cloud system and that of the Monsoon trough at different levels. The continuous line covers the range for roughly 90% of the data. If a line is drawn through the dots, it will show the average slope of the Monsoon axis on the days when clouding is present. The crosses on that figure indicate the normal position of the axis at different levels. A subscale for crosses is shown along the ordinate. The sub-scale is so adjusted that the 500 mb dot and cross coincide. A line through the crosses would show the normal slope of the Monsoon axis with height. Crosses on last two figs. (for 90°E and 95°E) could not be shown as it was difficult to fix the trough line on the mean charts. The more southerly position of the 'dots' as compared to 'crosses' indicates that on days of clouding the position of the Monsoon trough is at a more southerly latitude than the normal.

Discussion on the results

The above results show that the areas of convergence associated with cyclonic perturbations imbedded in the general large scale monsoon field, coincide best with the central areas of cyclonic circulations as seen at the mid tropospheric levels. Several earlier workers have drawn attention to the flow patterns at mid-levels during the monsoon season to explain the features of observed rainfall distribution and disturbed weather conditions [Yin (1949), Koteswaram (1950) and Miller and Kesavamurthy (1965) and many others]. The earlier works were mostly based on a few case-studies. The availability of satellite cloud data now enabled us to make a more systematic study of the phenomena and extend the studies to the adjacent sea areas also.

Some of the earlier workers have assumed that the cyclonic perturbation exists only in the mid-levels. However, this need not be true. La Seur (1963) describing the different types of vortices found in the Tropics in the upper air says 'It appears as a vortex only in the middle troposphere. This structure is usually due to variations in the basic current with elevation rather than a reversal in the intensity of the vortex with height. For example, a cyclonic disturbance embedded in the lower easterlies and upper westerlies frequently appears as a wave-like perturbation at low and high levels and as a vortex in the middle trophosphere where the basic flow reverses. Only by computing the vorticity at several levels can the true vertical variation of the disturbance intensity be determined'. The disturbances in the monsoon season are of this type being embedded in the basic current with strong westerlies in the lower levels and strong easterlies in the upper tropospheric level with the wind reversal in the middle level where the basic current becomes very weak. Thus the weak cyclonic systems which form in this season are able to modify the normal flow patterns in the middle levels whereas they are hardly able to make much impression on the more vigorous normal circulation in the lower levels. This need not necessarily mean that the convergence associated with the disturbance is confined only to the middle levels. It also follows that the vertical structure of the disturbance depends on the relative strengths of the large scale circulation in the area and of the imbedded system. The statistics presented in the earlier section seem to indicate, that compared to the general monsoon circulation in the lower levels, the perturbations are generally weak, eventhough these are able to produce vigorous convective activity due to their being formed in the highly moist monsoon airmass extending to great heights.

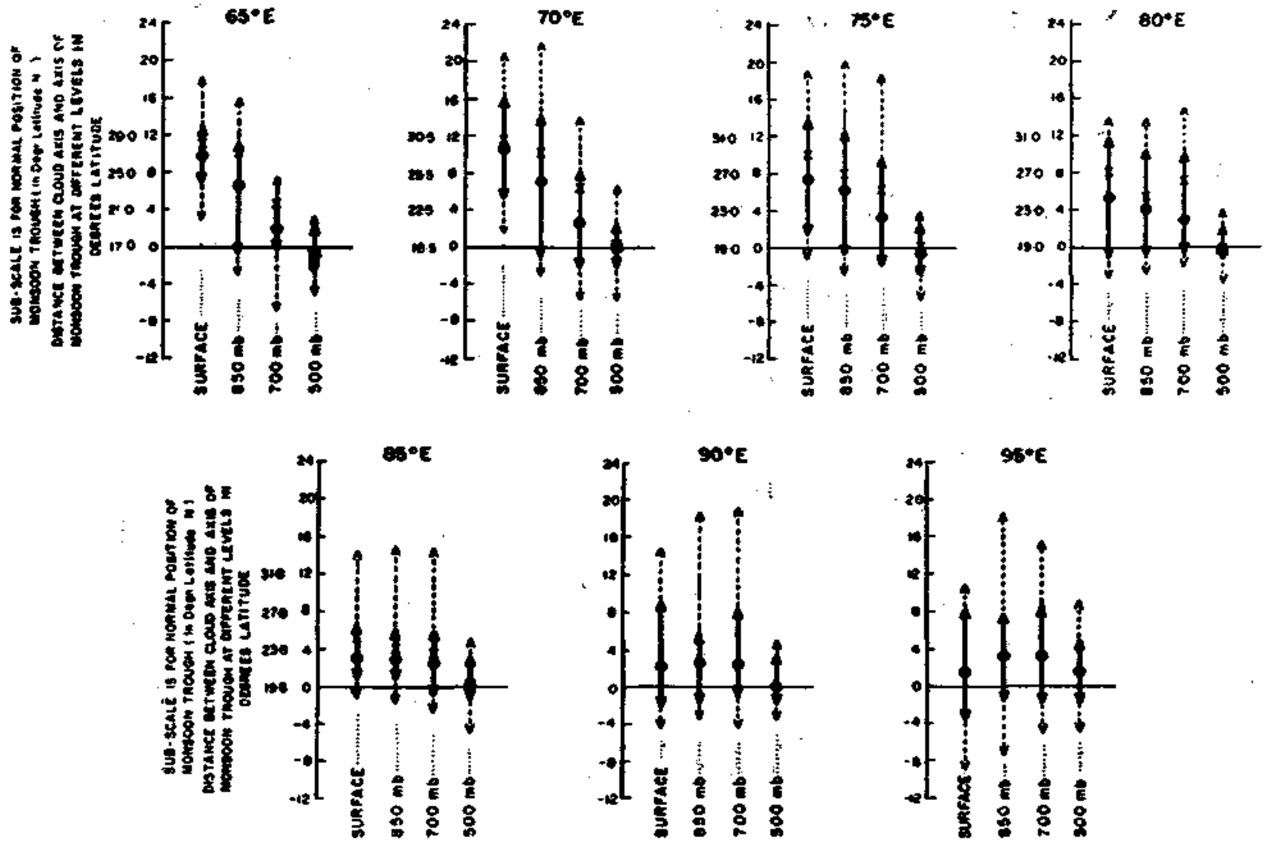


Fig. 6. Diagrams showing the latitudinal distance between the cloud axis and the axis of the monsoon trough during the months July & August combined. The lines indicate the total range of these differences. The continuous part of the line covers about 90% of the data. The dots represent the average values. The crosses along the line show the normal position of the monsoon trough. Scale for crosses is so adjusted that the dots and crosses coincide at the 500 mb level. This scale is given for each of diagram.

PLATE I. Mosaic prepared from the APT pictures received from ESSA 8 during the forenoon of 2nd Aug., 1968.

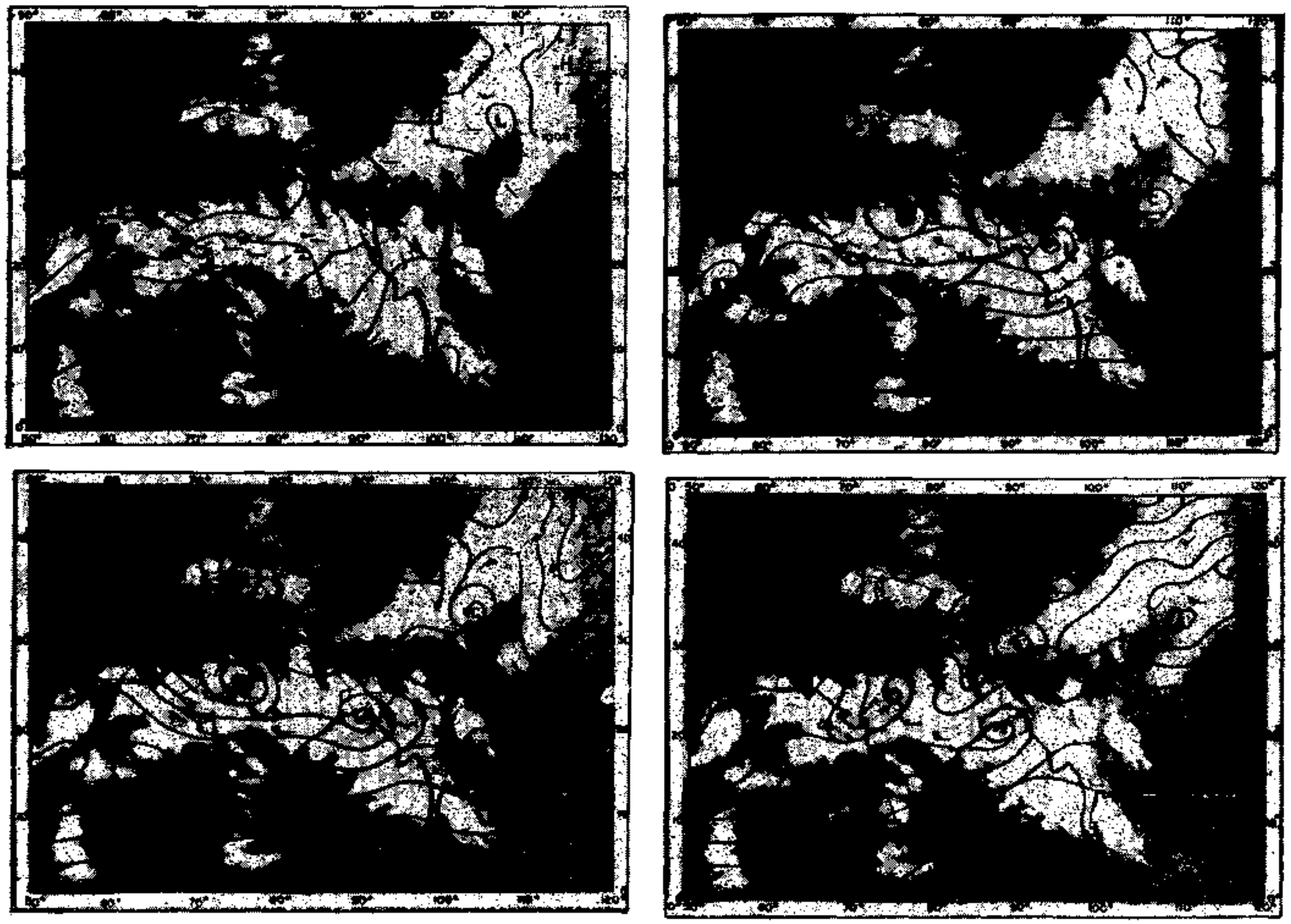


PLATE II. Synoptic charts shown in Fig. 2 with mosaic shown in Fig. 3 as underlay.

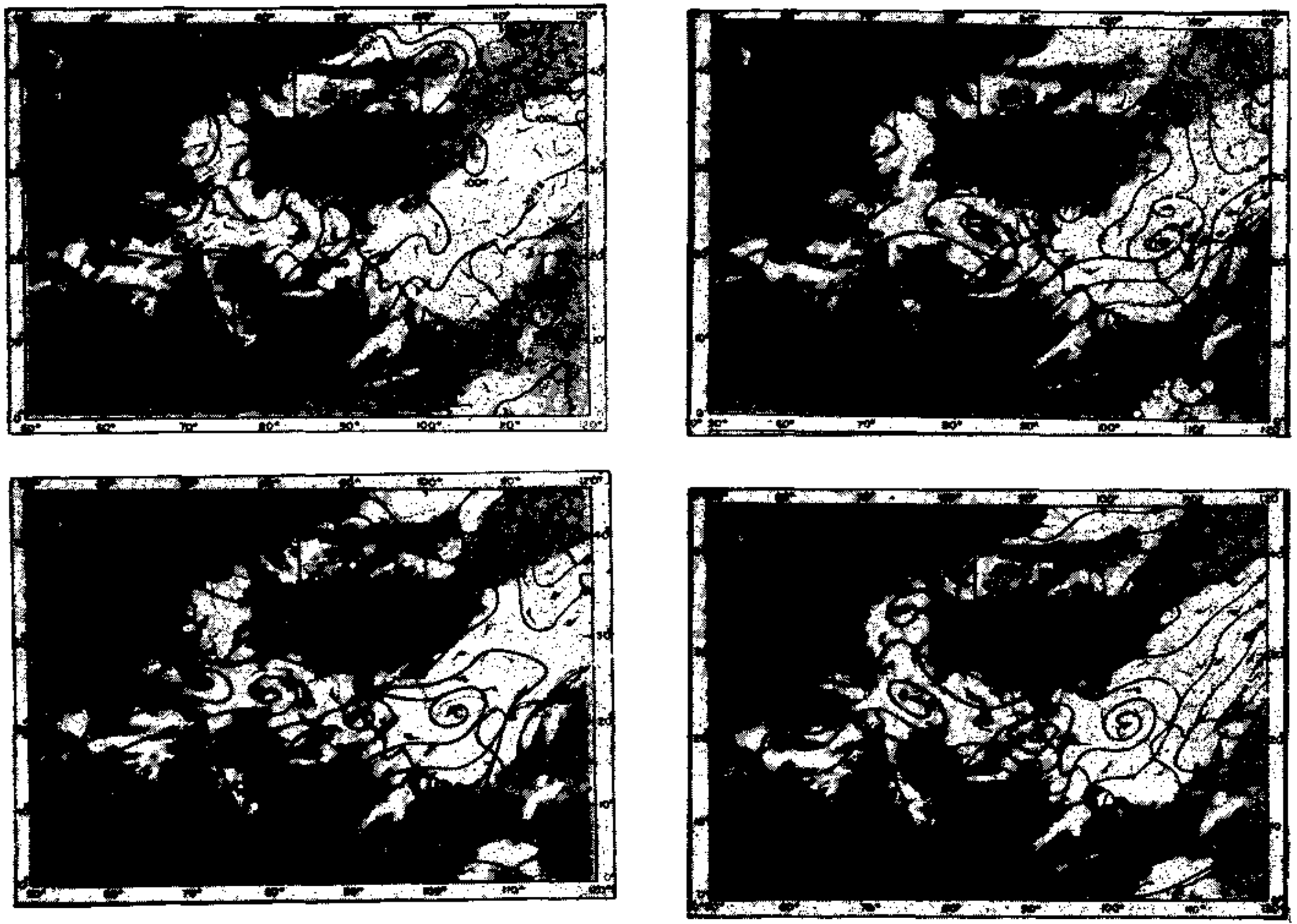


PLATE III. Synoptic charts of 12th Aug., 1969, 00 G.M.T. at the same levels as in Fig. 4 with the cloud mosaic of that date as underlay.

PLATE IV. Mosaic of APT pictures received from ESSA 8 during the forenoon of 3rd July, 1969. A long belt of bright cloud patches between lat. 70°E to lat. 110°E can be seen. A dashed line could be drawn as shown in the picture, which can be taken as the axis of the cloud belt.

As the strength of both the general monsoon circulation and the imbedded system vary considerably from day to day and from case to case, the resultant structure also take variant forms. The scatter observed on the comparison diagrams shown earlier may be mostly due to this factor.

It is noticed that on most occasions the convergent areas as revealed by the satellite cloud pictures generally falls to the south of Lat. 25°N. As this is the area where strong easterlies prevail in the upper tropospheric flow, the present results provide indirect support to findings by some earlier workers that vorticity advection associated with perturbations in the upper tropospheric easterlies play a causative role in the generation of cyclonic systems and of convergence in the lower levels in this season [Koteswaram *et al.* (1958, 1963), Srinivasan (1960)].

Finally, the present results provide a method of approximately determining from the satellite data, the axis of the monsoon trough at the mid-tropospheric levels. This would be useful in data-scanty sea areas and in clouded land areas as most of the pilot balloon flights would not reach these levels on such occasions. This would be of considerable help in analysis of mid-tropospheric charts. However, it need be mentioned here that even though a large amount of data have been studied and processed, the present results can be considered to be only of a preliminary nature. Only the broad aspects of the results have been presented here. It is possible to make many refinements both in finding the axis of the cloud belt as well as in the processing of data. These will be published elsewhere.

Conclusions

The present study reveals that the position of the axis of maximum convergence zone in the monsoon circulation coincides best with the axis of the monsoon trough in the middle levels and least with that at the surface. This feature is more marked between longitude 65° to 70°E and becomes less marked eastwards, and by 95°E, the disparity becomes very small. These observed features are similar to the tilt of the axis of the monsoon trough with height, leading one to infer that these features arise out of the interaction between the large scale monsoon circulation and the imbedded perturbations. The results also provide a method of approximately determining the axis of the monsoon trough in the middle levels which would be useful in areas where the conventional data are meagre or absent.

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DISCUSSION

R. N. KESHAVAMURTY : Is it likely that this feature that cloudiness occurs far to the south of the monsoon trough will be seen in association with equatorial trough in other regions of the tropics also.

N. S. BASKARA RAO : Yes.