

Cloud systems associated with western disturbances : A preliminary study

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ABSTRACT. During the winter season cloud and precipitation belts are seen to move from west to east over northern India. The cause of these cloud and precipitation systems came to be referred to as 'western disturbances'. In this study the cloud systems have been classified into five broad categories. Typical examples of these cloud patterns and synoptic conditions most commonly associated with each category of cloud systems are presented in this paper.

1. Introduction

During the winter season cloud and precipitation belts are seen to move from west to east over northern India. The cause of these cloud and precipitation systems came to be referred to as 'western disturbances' (Rao and Srinivasan 1969). Even a casual glance at the satellite pictures of the winter months shows that cloud patterns associated with these systems are of a large variety. However, on closer examination we find that, they can broadly be classified into certain categories in terms of the geometry of the clouded area as seen on the satellite pictures. In this study we have classified the cloud systems into five broad categories. Typical examples of these cloud patterns and synoptic conditions most commonly associated with each category of cloud systems are presented in this paper.

The extent of the geographical area covered by this study is from 40°E to 90°E and from 15°N to 60°N. The period of study was confined to the winter halves (namely, January, February and March and October, November and December) for the years 1967 and 1968. Charts of the Indian Ocean and Southern Hemisphere Analysis Centre, Poona were generally used for studying the synoptic conditions associated with the cloud systems. As the coverage of these charts extends only upto 45°N, northern hemisphere charts published by Hydro-Meteorological Service of U.S.S.R. were utilised whenever necessary. Satellite cloud data were taken from A.P.T. pictures received at Bombay, the catalogue of meteorological satellite television cloud photography published by Environmental Science Service Administration (ESSA) of U.S.A. and also the digitised television microfilms prepared by the same agency.

2. Cloud patterns and associated synoptic conditions

On scrutinising a large number of satellite cloud pictures, it was seen that the various cloud forms which move eastwards across the area under consideration during the winter months could be broadly classified into certain types. These are enumerated below—

- | | |
|-----------------------------------|------|
| (1) Systems with a Vortex | (V) |
| (2) Latitudinal Bands | (LB) |
| (3) Meridional Bands | (MB) |
| (4) Overcast cloud Masses | (OM) |
| (5) Broken amorphous clouded Area | (BA) |

Typical examples of different types are shown and the synoptic conditions associated with each type are discussed below. To conserve space, discussions and presentation of data are confined to surface and 300-mb levels.

The vortex type is typical of the extra tropical cyclones of middle latitudes. An example is shown in Fig. 1. The date of the picture is 13 October, 1967. The vortex cloud system can be seen just to the east of Caspian Sea and the frontal cloud system further to the east. This type generally develops just to the east of the Caspian Sea, moves eastwards and breaks up over the Pamirs and adjoining mountains. Formation of such vortex systems is not seen to the south of the chain of mountain ranges which stretches eastwards from Elbruz to the Pamirs. However, the southern fringes of the frontal clouds affect North Afghanistan, and Jammu and Kashmir. The surface chart of that day is shown in Fig. 2(a). The sea-level low and the front at the surface, fit fairly well with the cloud system observed in the satellite picture. A trough in the upper tropospheric westerlies



Fig. 1

Digitised satellite picture of 13 Oct 1967 showing a system with a vortex (V)

lay slightly to the west of the cloud system as can be seen from the 300-mb contour analysis shown in Fig. 2(b).

The second type can be justifiably called the latitudinal band type (LB). The cloud band is generally oriented in a west-south-west to east-north-east direction. A typical example is shown in Fig. 3. The date of the picture is 19 November 1967. The associated surface isobars and the 300 mb winds on that day are shown in Figs. 4(a) and 4(b) respectively. As can be seen, one cannot easily explain this band from the surface pattern or from the upper tropospheric flow. A survey of the synoptic situations associated with a number of such cases showed that such long bands form when the waves in the upper tropospheric westerlies have large lengths. The cloud band lies roughly in the section of the wave from the trough to downstream ridge. It is also observed that the cloud band lies almost parallel to and just to the south of axis of the westerly jet, if it is present. However, such bands do not form on all days when waves with large lengths are present in the upper levels.

The longest bands of this type encountered in this study extended from the eastern Sahara to Kashmir. But such cases were rare, most of the bands being much smaller in length. These bands seem to form *insitu*. Their movement after formation is also very small (about 2° in a day) and

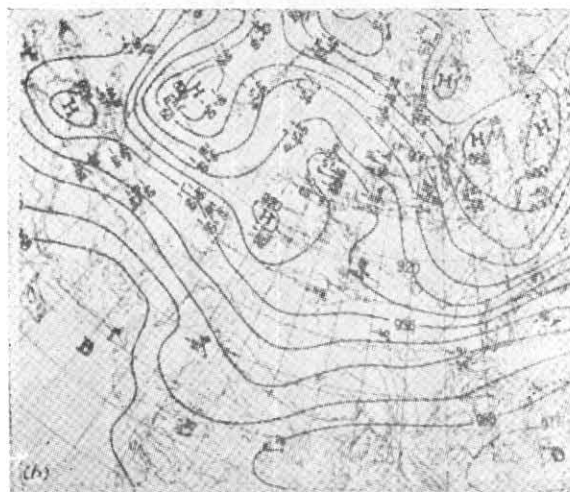


Fig. 2

(a) Surface and (b) 300 mb chart at 00 GMT of 13 October 1967

(Reproduced from northern hemisphere charts published by Hydrometeorological Service of USSR. 'B' on the charts indicates 'High' and 'H' indicates 'Low')

is normal to their orientation. They dissipate after 2 or 3 days and we may find traces of the system for a couple of days more.

Bands of smaller lengths are found to form on a number of other occasions also, especially over the Arabian Sea and the Iranian Plateau. But due to lack of adequate upper air data from these regions, it has not been possible to study the synoptic patterns associated with them.

An example of a cloud system of meridional band type (MB) is shown in Fig. 5. The date is 24 December 1967. The surface isobaric pattern and the 300 mb winds on that day are shown in

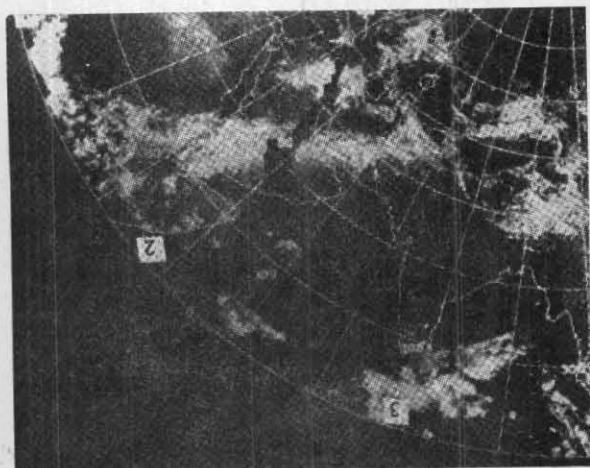


Fig. 3

Digitised satellite picture of 19 Nov 1967 showing a cloud system of Latitudinal Band (LB) type

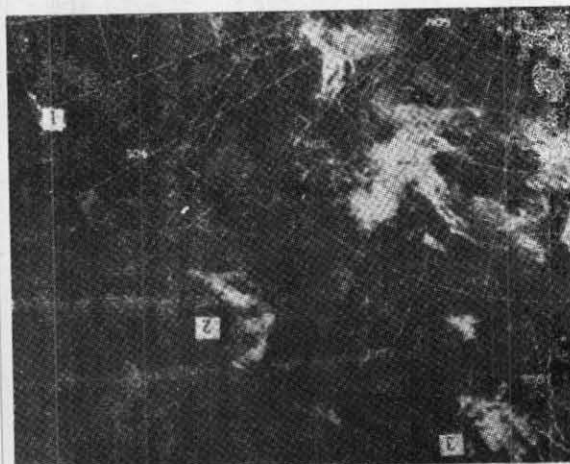
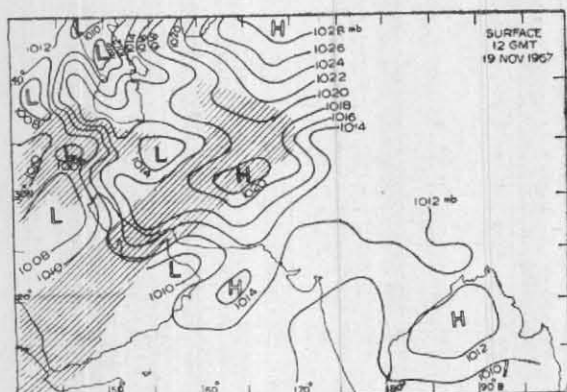
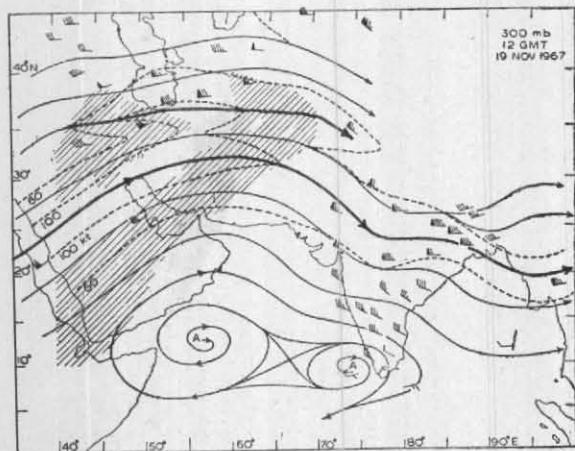


Fig. 5

Digitised satellite picture of 24 Dec 1967 showing a cloud system of Meridional Band (MB) type



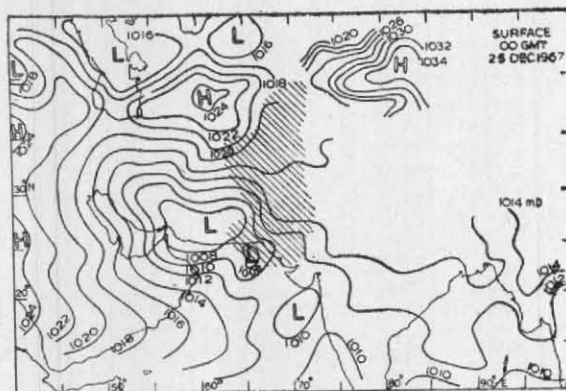
(a)



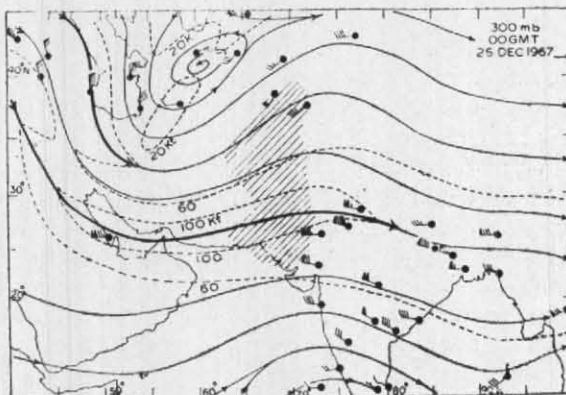
(b)

Fig. 4

The shaded area corresponds to the cloud systems in Fig. 3



(a)



(b)

Fig. 6

The shaded area corresponds to the cloud systems in Fig. 5

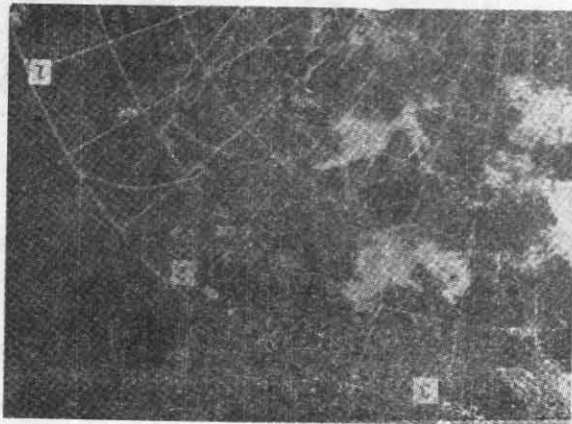


Fig. 7. 7 December 1967

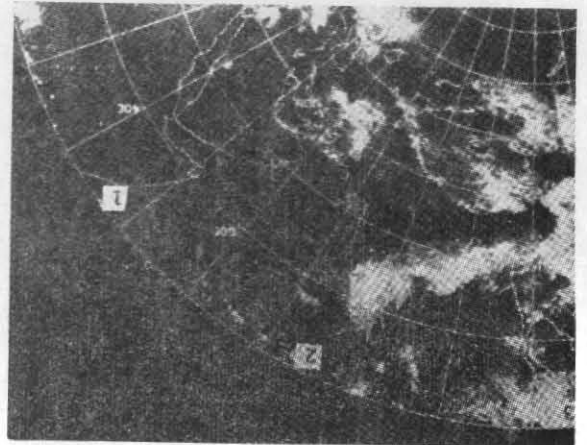


Fig. 8. 8 December 1967

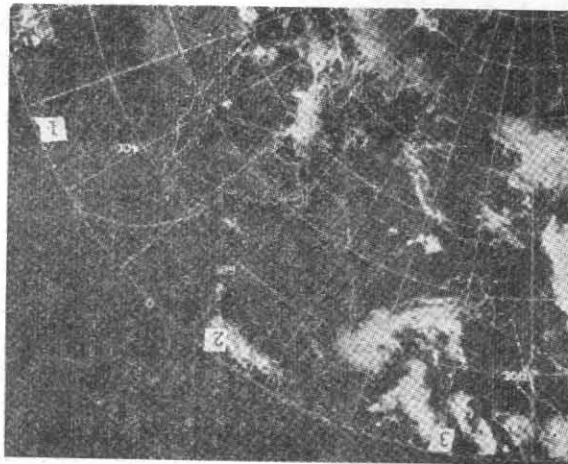


Fig. 9. 9 December 1967

Digitised satellite pictures showing cloud system of overcast cloud mass type (OM) during 7-9 December 1967

Figs. 6(a) and 6(b) respectively. The significant synoptic features associated with this type seem to be rare. This band generally lies to the east of a surface low. In most cases, a well marked trough-ridge system in the upper tropospheric westerlies is present, and the band lies at some position between the trough line and the downstream ridge line, indicating that vorticity advection associated with the upper system has a favourable influence in the formation of this type of cloud system. These meridional bands generally form between 25°N and 35°N , in the area under consideration. Their movement is often erratic. Orography seems to play a significant role in their movement and their degeneration. Ranges of mountains stretching north to south seem to play the decisive role. In the area chosen for this study,

there are three such ranges— (1) Mountain ranges of Western Iran near Long. 45°E , (2) The Kirthar and Sulaiman ranges near Long. 68°E and (3) The Western Himalayas. When this type of cloud system reaches one of these barriers, it generally stagnates for a day or two and seems to disintegrate there. An amorphous cloud mass can be traced next day to the east of the range. But on many occasions a new cloud band is seen, which forms at some distance down-stream usually the day after and which for all practical purposes appears as a fresh formation *insitu*.

A typical example of overcast mass (OM) type of cloud system is shown in Fig. 7. This formed on 7 December 1967 near the Persian Gulf, and moved northeastwards and was over Baluchistan on the



Fig. 10(a)

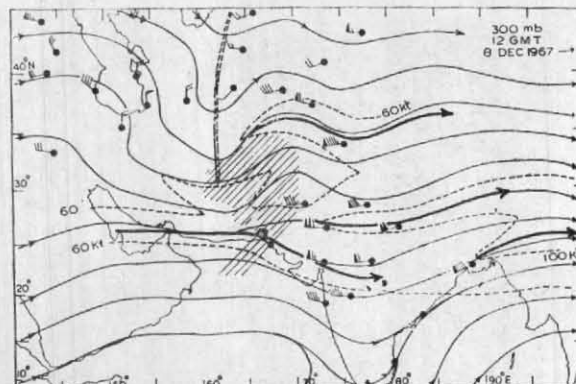


Fig. 10(b)

The shaded area corresponds to the cloud systems of Fig. 8

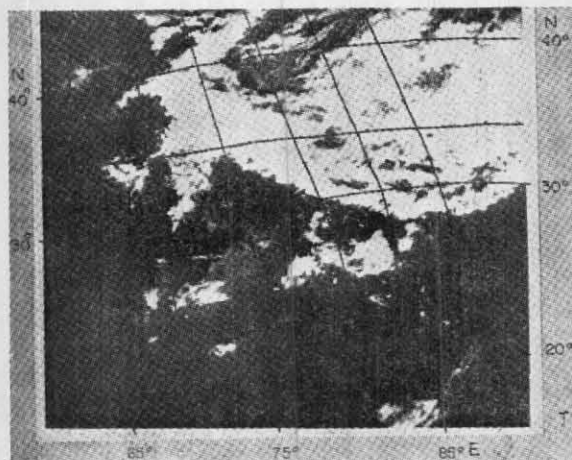


Fig. 11. 23 Nov 1967

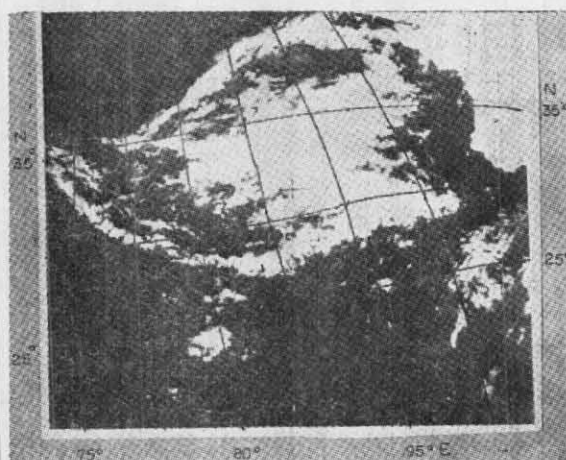


Fig. 12. 24 Nov 1967

APT pictures of ESSA-6 (Please see text)

next day (Fig. 8). It moved further northeast by 9th (Fig. 9). This type was seen on a large number of occasions at one place or another in the area under study. The surface isobaric chart and 300mb wind pattern associated with the system on the 8th are shown in Figs. 10(a) and 10(b) respectively. In most cases, a sea level 'low' lies beneath the overcast mass or just to the west of it. An upper trough to the west of the overcast mass is also present on most occasions. The wave length of the upper perturbation is generally small.

The cloud systems of the broken amorphous type take varied forms and sizes. The synoptic conditions associated with them also vary considerably with the result that no typical example can be given. However, on many occasions their movement from day to day can be followed. Figs. 11 to 13 show one such case. Hence, they can be

described as being associated with western disturbances as defined at the beginning of this chapter.

3. Statistics of occurrence of different types

To get an idea of the frequency of occurrence of different types of cloud systems, statistics were collected for the winter half of the years 1967 and 1968. The data was mainly collected from the APT pictures received at Bombay. For this purpose the first appearance of the cloud system evolves from or degenerates into a different type of cloud system by the next day, then the new form is taken as a fresh count. The number of first occurrences of each type within the area under consideration is shown month-wise in Table 1.

Due to the inherent limitations in counting the number of occurrences as outlined above the data

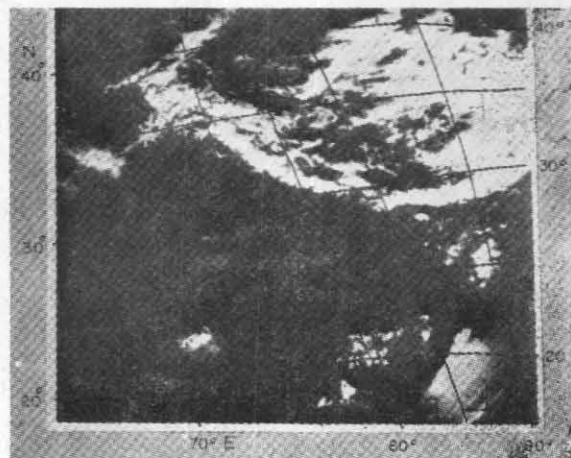


Fig. 13. 25 Nov 1967
APT picture of ESSA-6 (Please see text)

TABLE 1
Area 40°E to 90°E, 15°N to 60°N

	Type of Cloud System					Total
	V	LB	MB	OM	BA	
1971						
Jan	0	0	3	4	2	9
Feb	0	2	6	5	4	17
Mar	1	4	1	2	4	12
Oct	2	0	1	2	3	8
Nov	1	1	4	1	4	11
Dec	0	3	1	3	7	14
1968						
Jan	0	0	1	7	6	14
Feb	1	3	2	3	7	16
Mar	0	0	0	4	8	12
Oct	2	0	0	2	4	8
Nov	2	0	2	1	8	13
Dec	2	0	0	6	9	17
Total	11	13	21	40	66	151

V—Systems with a vortex, LB—Latitudinal bands, MB—Meridional bands, OM—Overcast cloud masses, BA—Broken amorphous clouded area.

in Table 1 does not give the frequency of the western disturbances in different months. It only gives an idea of the frequency of formation of a given type of cloud system in different months. However, certain interesting features are shown by the data.

(1) Cloud type most commonly associated with the western disturbances is the broken amor-

phous type, and the least common one is the vortex type.

(2) Overcast mass type appears twice as frequently as the meridional band type.

4. Diagnostic studies

Some diagnostic studies for explaining the formation and structure of the cloud systems associated with the western disturbances have been taken up. As can be seen from the evidence in Figs. 4(b), 6(b) and 10(b), vorticity advection resulting from the trough-ridge systems in the fast upper tropospheric westerlies seem to play an important role in the development of these cloud systems. Thus, there appears to be some similarity between these and the extratropical cyclonic systems, which develop under favourable upper tropospheric flow patterns (Bjerknes 1951). For the Indian area, the part played by upper divergence in the case of thunderstorm activity in the pre-monsoon months has been pointed out by Ramaswamy (1956) and Koteswaram and Srinivasan (1958). Objective assessment of such divergence fields in upper tropospheric levels are being worked out by numerical methods and their correlation with the winter cloud systems are under study.

Another aspect noticed in a qualitative way in this preliminary study is that the areas of cloud cover agree to a large extent with the areas of warm advection at 850 and/or 700-mb levels. Numerical computations for such advection fields have also been undertaken.

The results from the above studies will be presented in a later paper.

5. Conclusions

These preliminary results indicate that the clouded areas associated with western disturbances seem to fall into certain broad types in terms of the general geometry of the clouded area. Each type of cloud system is usually associated with certain specific synoptic conditions both in the upper level as well as in the lower tropospheric levels, even though exceptions are noticed on rare occasions. The associations presented in the paper may provide clues for diagnostic studies for the formation and movement of the different types of cloud systems.

Even from these preliminary results, it is apparent that in a majority of cases, vorticity advection in upper tropospheric levels and effect

of mountainous terrain play an important part in the development and movement of the cloud systems of the winter season, which affect the Southwest Asian region and India. Studies on middle and lower tropospheric flow will reveal the other favourable conditions like moisture feed and warm advection. Marked frontal activity is not noticed in areas south of the mountain ranges stretching from the Elburz mountains to the Himalayas.

Acknowledgements

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REFERENCES

- | | | |
|-----------------------------------|------|--|
| Bjerknes, J. | 1951 | <i>Compendium of Meteorology</i> , Amer. Met. Soc., pp. 577-598. |
| Koteswaram, P. and Srinivasan, V. | 1958 | <i>Indian J. Met. Geophys.</i> , 9 , pp. 301-312. |
| Ramaswamy, C. | 1956 | <i>Tellus</i> , 8 , pp. 26-60. |
| Rao, Y. P. and Srinivasan, V. | 1969 | Forecasting Manual Part III, 1.1. Winter-western disturbances and their associated features, India met. Dep. |

DISCUSSION

(Presented by P. E. Moray)

SHRI B.R.D. GUPTA (B.H.U.) : Are the cloud patterns associated with typical upper air features ?

SHRI P.E. MORAY : The latitudinal band (LB) type is associated with upper air long wave pattern, the vortex (V), meridional band (MB) and overcast cloud mass (OM) with short wave troughs.

DR. C. RAMASWAMY remarked that in a few cases shown the schematic cloud pattern is to the rear of a ridge as should be expected from vorticity advection considerations.

SHRI R.K. DATTA : Sometimes it is observed that marked clouding near 28°N and 60°E persists for the first two days, disappears on third day and reappears over northwest India on fourth day. Is this due to orography or is there any physical reason ?

SHRI MORAY : Similar behaviour is seen in the case of MB. Orography seems to play a part. There are three ranges running north to south in the area, viz., (i) over Western Iran, (ii) The Kirtar and Sulaiman mountains and (iii) the Western Himalayas. The meridional band which generally develops between 25°N and 35°N stagnates for a day or two when they reach the western side of one of the above ranges and the next day a degenerated amorphous cloud mass is seen to the east of the mountain ranges. But again a fresh MB is noticed on the subsequent day, some distance down stream.

DR. A.S. RAMANATHAN : Did you find predominance of any one type during any particular month ?

SHRI MORAY : During March the vortex pattern was not observed.

DR. R. ANANTHAKRISHAN : Does a single disturbance undergo evolution from one type to another ?

SHRI MORAY : The first four types degenerate into amorphous masses when they cross mountains. In addition both meridional and latitudinal bands develop out of amorphous masses.

SHRI D.R. SIKKA : Were the meridional bands and overcast masses associated with short wave troughs in the westerlies at 500 mb ?

SHRI MORAY : Yes.

SHRI JAGAN MOHAN RAO (A.U.) : What was the position of the upper air trough with respect to the surface low associated with the different types of clouding ?

SHRI MORAY : In the first four types the upper air trough was generally to the west of the surface low.