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Monsoon depression as seen in satellite pictures

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ABSTRACT. Satellite cloud pictures for the periods of monsoon depressions, from formative stage to dissipative stage, during July to September, 1967-69 were examined. Five broad types of cloud patterns could be identified in these pictures and they have been empirically correlated with the observed synoptic and upper air features. The pattern of clouding readily gives an indication of the intensity of the monsoon disturbance as well as its centre. The salient features of the five cloud patterns and the associated synoptic and upper air features are briefly discussed. The principal area of heavy rains is identified from the cloud patterns.

1. Introduction

Monsoon depressions have been studied by a number of workers from the synoptic, climatological, dynamical and thermodynamic points of view utilising the conventional data of surface and upper air observatories. With the advent of weather satellites and the availability of cloud pictures on a somewhat regular basis in recent years, we have now a new perspective of monsoon depressions. However, except for a solitary case study by Kulshrestha and Gupta (1964), no systematic study of the satellite pictures of the monsoon depressions in the Indian area has been reported so far. In this paper such a study has been attempted with a view to bring out the characteristic features of the cloud distribution in monsoon depressions.

2. Data and analysis

The satellite cloud pictures received at the APT Ground Station, Bombay, for the periods of monsoon depressions (from formative stage to dissipative stage) during July—September. 1967, 1968 and 1969 were examined (The cloud pictures of lows which subsequently did not develop into depressions were not considered). There were in all about 70 cloud pictures available for this study. These were scrutinised and the salient features of the cloud configuration—such as bands, overcast areas, centres of circulation etc— were listed. The details as gathered from the corresponding synoptic and upper air charts in respect of the intensity of the lows/depressions (central pressure, number of closed isobars, wind speed in the lower troposphere etc) and the rainfall patterns were also tabulated.

3. Classification of cloud pictures

The cloud patterns reveal certain features of interest. The most common feature is the presence of an extensive heavy overcast mass in the southern sector of the depression, in the field of lower tropospheric westerlies. The overcast could be recognised as a distinct cloud mass and is usually quite bright—relatively brighter than the other cloud masses in the neighbourhood. The heavy overcast area extends about 5-7 degrees of latitude in the north-south direction. Sometimes the area extends towards the north-west also. Cumuliform clouds are present in most cases in the northern sector, in the field of low level easterlies. They organise into bands as the low intensifies into a depression and the organisation is well-marked in the case of deep depressions. Often a rotation in the cloud mass around the centre of depression can also be recognised. The cloud patterns could be classified under five broad types. Typical examples of these are shown in Figs. 1 to 5. Table 1 gives the salient features of the different cloud patterns and the most common synoptic features associated with each of them. They are briefly discussed below.

Type I — In Type I the cumuliform clouds are either faint and meagre or altogether absent. The easterly winds are weak. The centre is not defined in the cloud picture, but in a few cases feeble rotation in the overcast areas could be noticed. Type I usually corresponds to a well-marked low in the formative stage of a depression.

Type II — A rotation in the overcast cloud mass around the centre of the depression is noticeable more clearly than in Type I. However, the centre cannot be delineated uniquely in this case also. The easterlies are moderate. Otherwise, this type of clouding is similar to Type I. Type II clouding belongs to depression stage.

Type III — The important development in Type III is that the cumuliform clouds are invariably present in the northern sector and are organised into bands which define the centre* of the depression. The centre is located in the cumuliform field close to the northern edge of the overcast mass. The easterlies in this type are strong and of speed 20—25 kt. Type III patterns is invariably a depression.

Types IV and V — In Types IV and V, the cumuliform bands in the north are quite prominent and they spiral towards the centre of the depression which is located at the northern (often northeastern edge of the overcast area in Type IV and inside the overcast in Type V. Type IV corresponds to depressions and deep depressions in almost equal numbers in the cases examined, while Type V corresponds mainly to deep depressions. The easterlies in all these cases are quite strong, of the order of 20-30 kt reaching even 40 kt or more in individual cases.

4. Rainfall patterns, pressure gradient etc

In the cumuliform field, rainfall is scattered and generally light to moderate. A few elements of the cumuliform band may be well developed and be associated with localised rather heavy falls. Rainfall is widespread over the area of overcast; but the heaviest falls in Types III, IV and V in which cumuliform bands are well-defined, are mostly confined to a small portion of the overcast in the region where the cumuliform bands from the north meet the overcast mass. This region is usually about 300—400 km west of the centre of the depression.

It has been noticed that, particularly when a low/depression is out at sea, the surface pressure gradient is strong and ships report rain, squall etc in the area of overcast.

A schematic diagram of the cloud distribution and wind field in the case of a well marked depression is shown in Fig. 6.

5. Upper air features

While they have no correlation with the strength of the westerlies in the region of overcast, the types of cloud pattern discussed in Section 3 show significant variations with changes in the easterlies in the cumuliform field. The evolution from an initial low pressure area to a depression is primarily noticed in the characteristics of the cumuliform cloud field. Thus, the degree of organisation of the cumuliform bands is an indication of the intensity of the system. In the first two types, the easterlies are light or moderate while in the other types they are strong, rising up to 40-50 kt in some cases.

An examination of the tephigrams of the stations in the field of the monsoon depressions shows that to the south of the depression (in the overcast area), high humidity extends to very high levels while to the north of the depressions (in the cumuliform cloud area) the high humidity is confined to the lower troposphere, above which there is a rapid decrease of moisture. Table 2 gives the mean values averaged for a number of depressions in 1969-1970.

6. Conclusion

Types I to V of the satellite cloud patterns are in the order of increasing intensity, from a low or a depression in the formative stage to a fully developed deep depression or even a cyclonic storm. However, all these types of clouding need not necessarily be present in the various stages of development of all depressions, though a few of them were seen to go through sequentially the various types of clouding during their growth. One such case was the depression of 26-31 July 1969 which is shown in Fig. 7.

These pictures (Fig. 7) refer to the afternoon hours. On 26th and 27th the depression was in the formative stage and the satellite pictures shown in the figure correspond to Type I. On 28th it was a depression and on 29th a deep depression. Type III cloud pattern can be easily recognised on the pictures for these two days. On 30th the deep depression moved inland and the cloud pattern on this day was close to Type IV. On 31st the depression was weakening and the satellite picture also shows the clouding getting disorganised.

The National Environmental Satellite Centre at Washington, USA (NESC) uses a system of classification of tropical and subtropical disturbances based on satellite picture (Anderson *et al.* 1969). Though the monsoon depressions show some resemblance to the stages A, B and C of NESC classification, yet it is found inadequate and not quite suitable in the case of monsoon depressions. We have identified certain patterns of clouding associated with monsoon depressions and empirically correlated them with the observed synoptic and upper air features. The pattern of clouding readily gives an indication of the intensity of the monsoon disturbnce, its centre and the associated rainfall patterns. Another important point is that we have now a better knowledge of the three dimensional structure of the monsoon depression

* Here, as well as in subsequent discussions, the 'centre' refers to the centre of depression as defined by the cloud-pattern, unless otherwise stated. There could be slight differences between this centre and the centre on the synoptic chart. But they are ignored in this paper.

in the various stages of development, through satellite pictures; this is an essential observational requirement for any theoretical study of the monsoon depressions.

REFERENCES

Anderson, R.K. Ashman, J.P., Bittner, F., Farr, G.R., Fergueson, E.W., Oliver, V. J. and Smith, A. H.	1969	Applications of Meteorological Satellite Data in Analysis and Forecasting, ESSA Tech. Rep. NESC 51, Washington, D.C. Chap. 4, Sec. E.
Kulshrestha, S. M. and Gupta, M. G.	1964	*Indian J. Met. Geophys.*, 15, 2, pp. 175-182.

DISCUSSION

(Presented by S. Raman)

Shri G. Gurunadham : Is there any distinction in the classification when the depressions are over land and sea ?

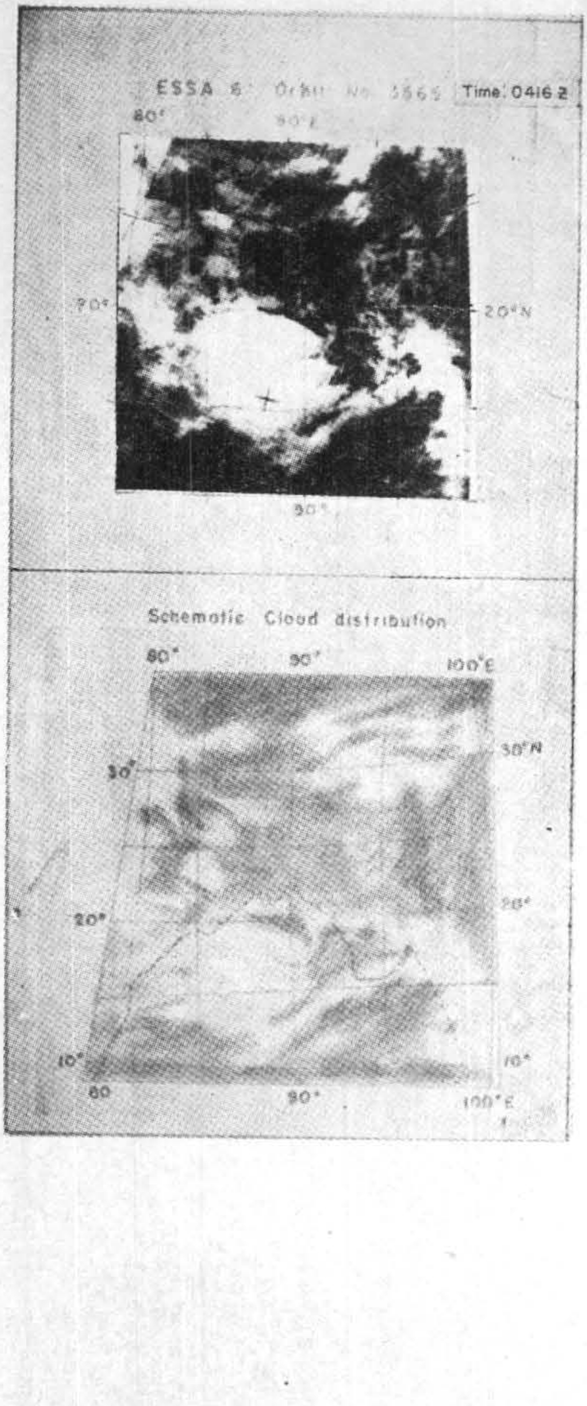
Shri S. Raman : The clouding pattern did not show any significant variation, particularly in the cumulus field, in the various categories irrespective of their location over land or sea.

Shri B. K. Majumdar (Air India) : Normally gliding operations are not undertaken on depression days. However, will this detailed wind information obtained from such satellite pictures be useful for gliding operations ?

Shri Raman : Estimation of upper wind from cloud pictures has not been attempted in our study. However, gliding may be possible in the areas of cumulus field, where we can expect good thermals.

Shri D. R. Sikka : Was there any case of depression which evolved through all the stages ?

Shri Raman : Yes, the deep depression that formed during the last week of July 1969 was one such case.



Satellite cloud pattern —Type I

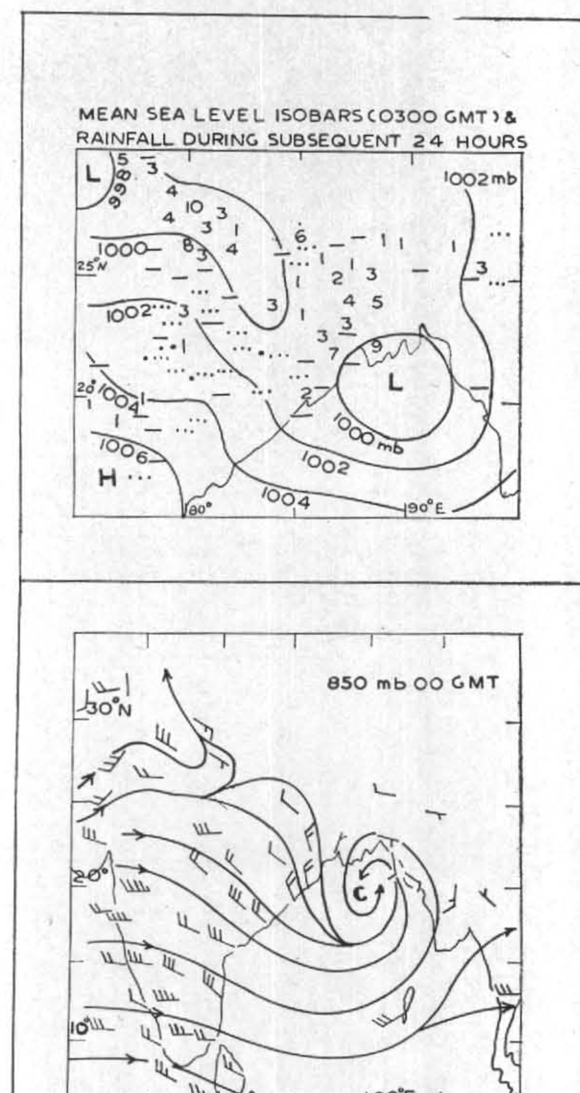
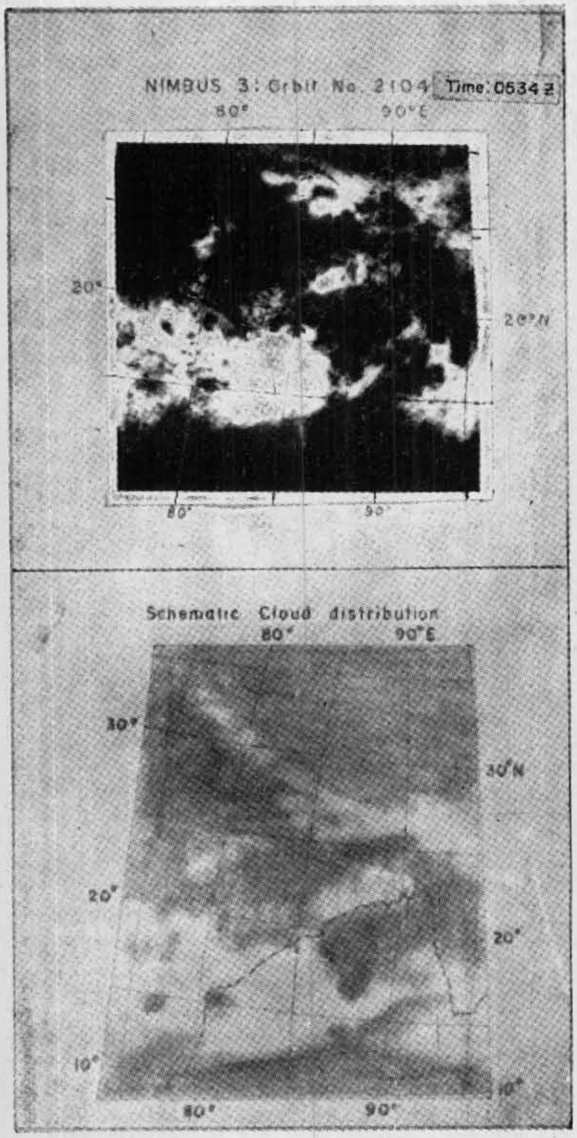
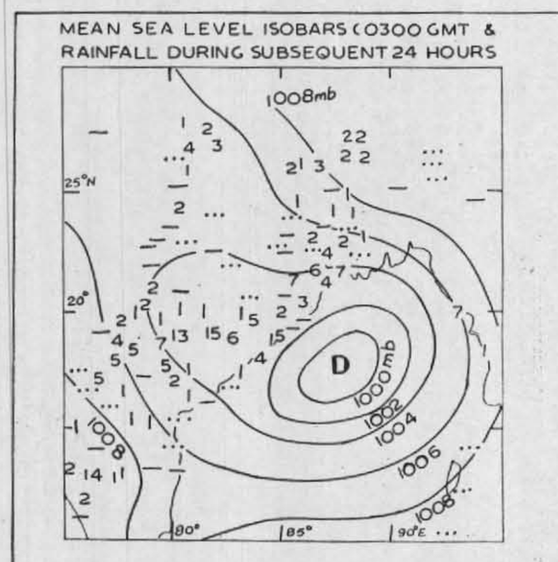


Fig. 1. 21 August 1968

Low over north Bay of Bengal developing into depression (Central pressure 1000-mb, pressure departure-4 mb)



Satellite cloud pattern — Type II



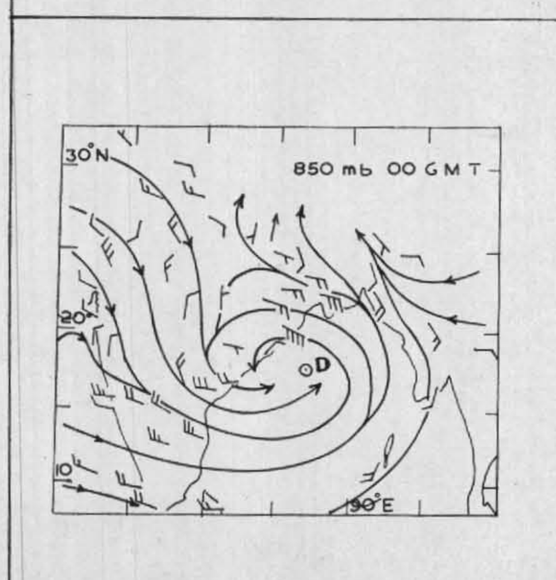
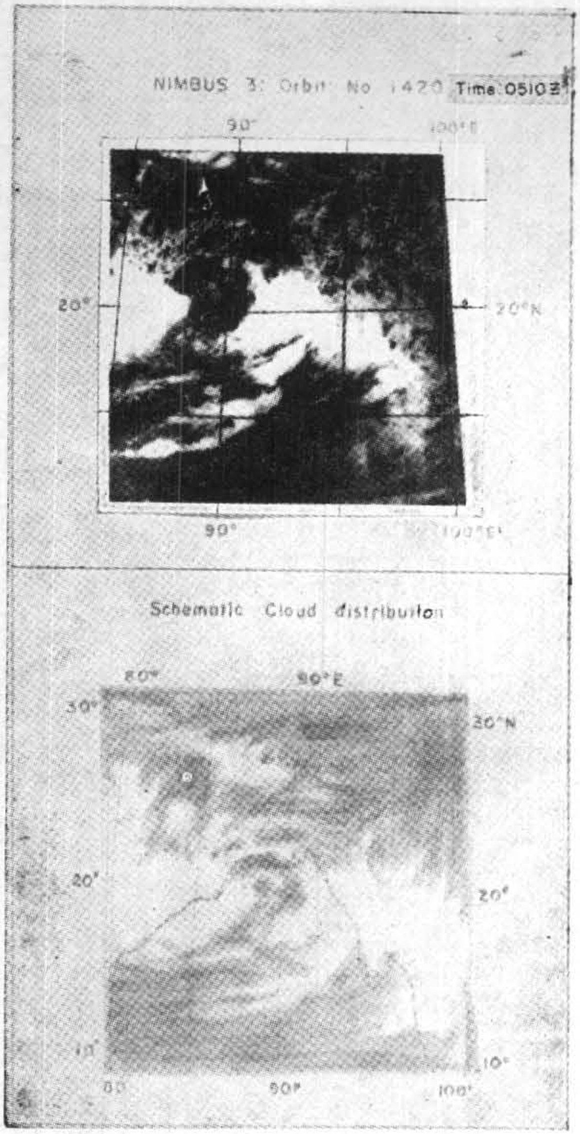
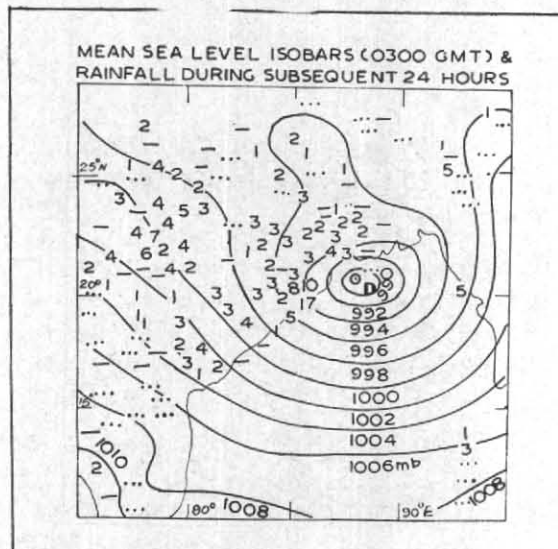


Fig. 2. 18 September 1969

Depression centred 17·5°N, 87·5°E
(Central pressure 1000 mb, pressure departure-4 mb)



Satellite cloud pattern — Type III



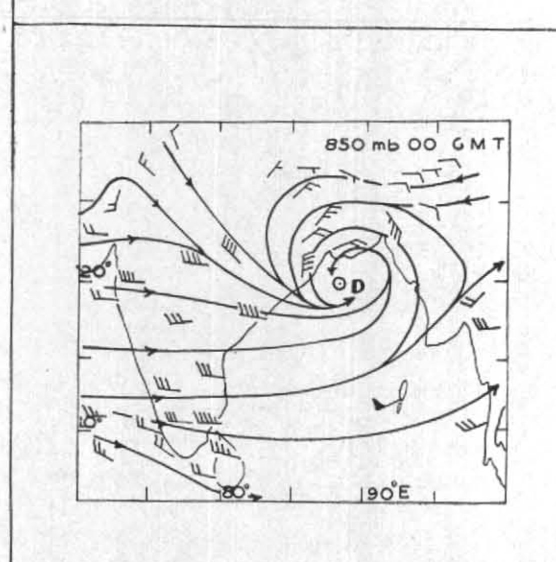
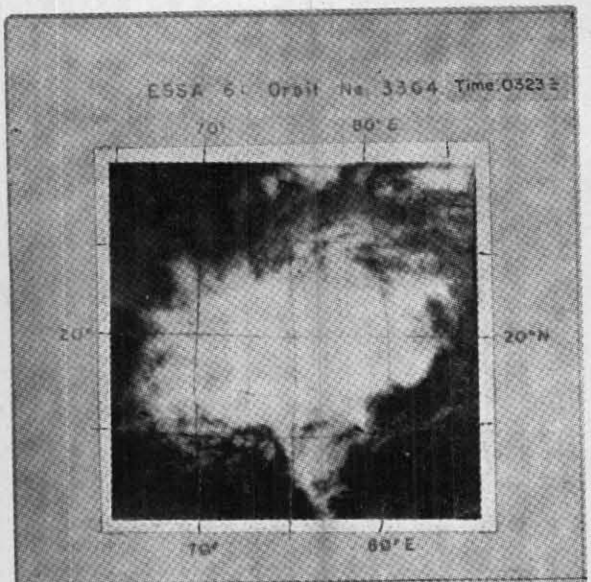
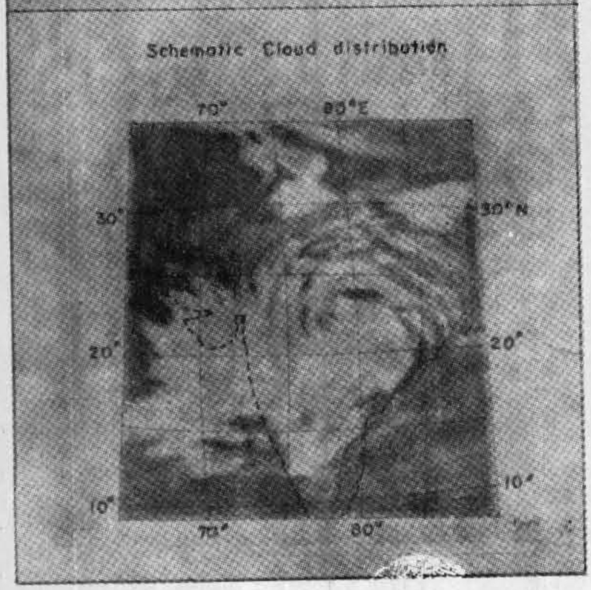


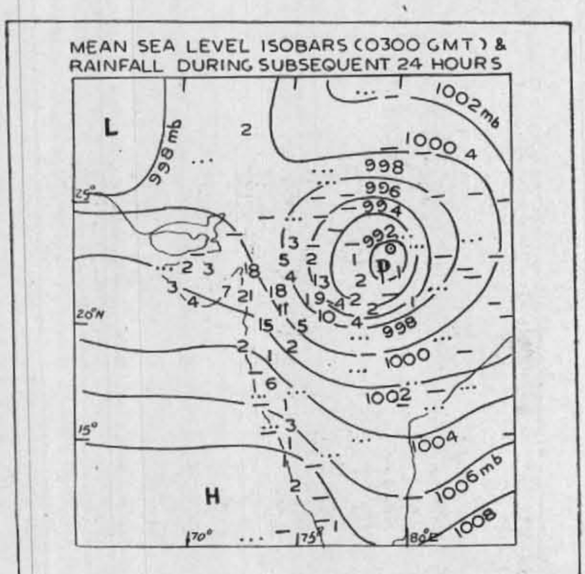
Fig. 3. 29 July 1969

Deep depression centred 20·5°N, 88·0°E
(Central pressure 990 mb, pressure departure-8 mb)



Satellite cloud pattern — Type IV





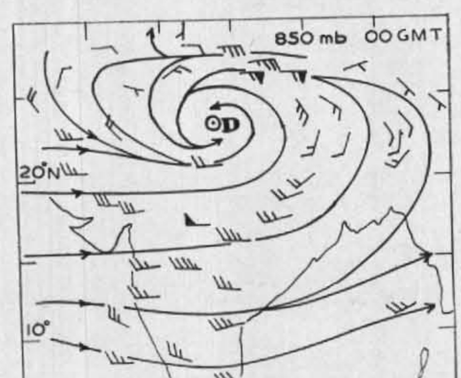
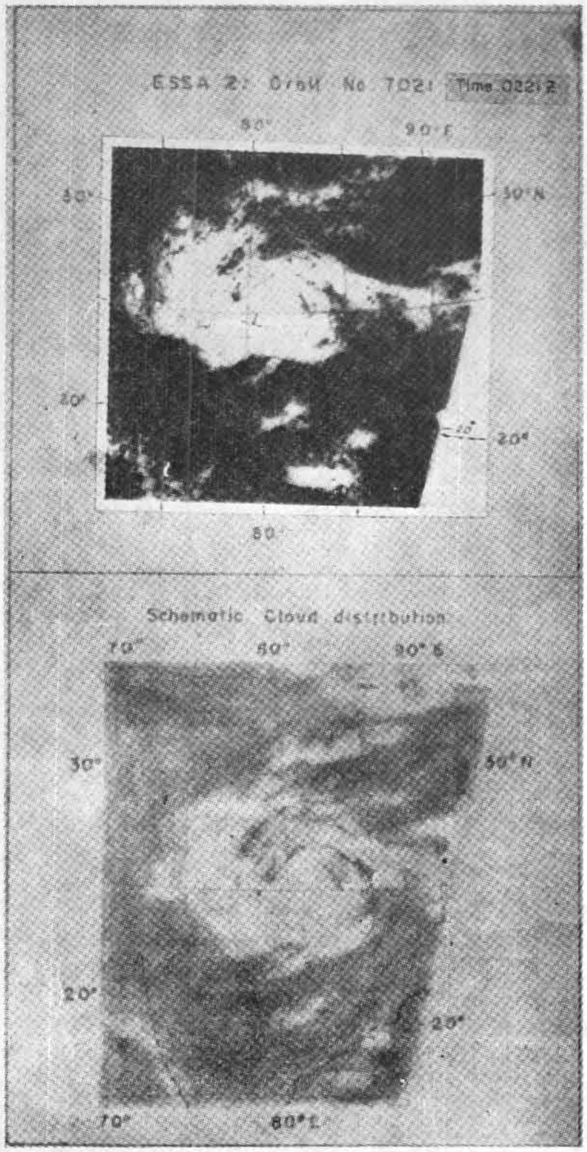


Fig. 4. 5 August 1968

Deep depression centred 22·5°N, 79·0°E
(Central pressure 992 mb, pressure departure-10 mb)



Satellite cloud pattern — Type V

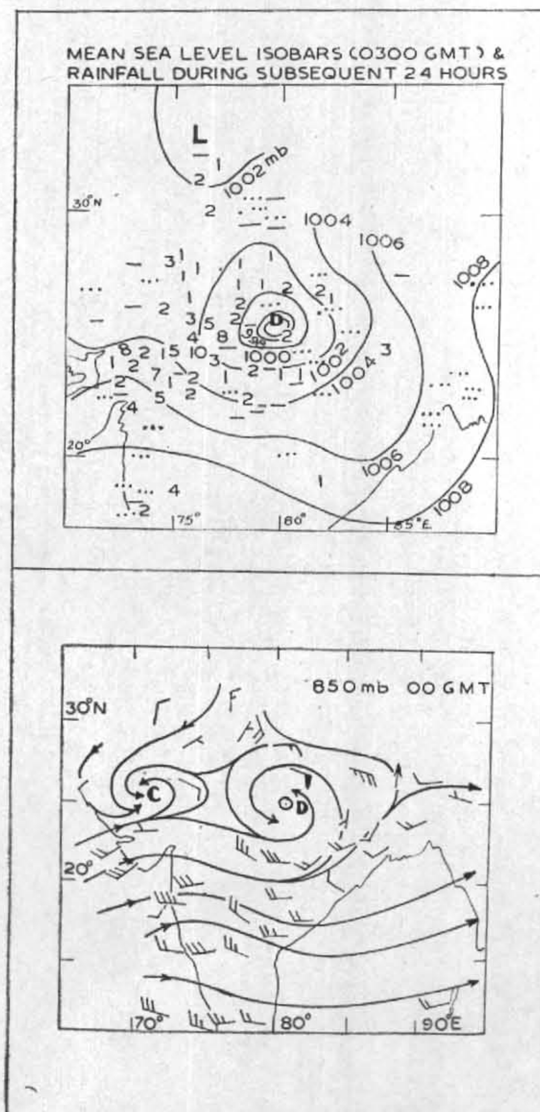


Fig. 5. 5 September 1967

Deep depression centred 25°N, 79°E
(Central pressure 994 mb, pressure departure-9 mb)

TABLE 1

Characteristics of cloud formations and associated synoptic features

Type	Clouding		Centre of Depression*	Strength of low level (between ground and 1·5 km) Easterlies in CuF field	Location of principal area of heavy rain	Synoptic classification of disturbance
	Overcast	Cumuliform				
I	Bright, separated from rest and located in the southern sector of the disturbance	Little or no CuF clouds and no bands	Centre not defined; in some cases feeble rotation in the overcast mass	Weak (10-15 kt)	Anywhere in overcast area	Well-marked low or initial stage of depression
II	Do.	Do.	Some rotation about the centre of disturbance in the overcast mass; isobaric centre at northern edge of overcast area	Moderate (20 kt or less)	Nothern portions of overcast	Mainly depression
III	Bright heavy overcast to south of centre of depression; overcast extends towards northwest also	CuF bands north of centre of depression	Centre defined by CuF bands and located in CuF field close to the northern edge of overcast area	Strong (20-25 kt)	300-400 km west of centre of depression where CuF bands meet overcast mass	Do.
IV	Do.	Do.	Centre defined by CuF bands and located at the northern edge of overcast	Strong (20-30 kt)	Do.	Depression and deep depressions (equal numbers)
V	Do.	Do.	Centre inside overcast area and defined by *CuF* bands	Strong about 30 kt or more	Do.	Mostly deep depression

*See foot-note of Sec. 3.

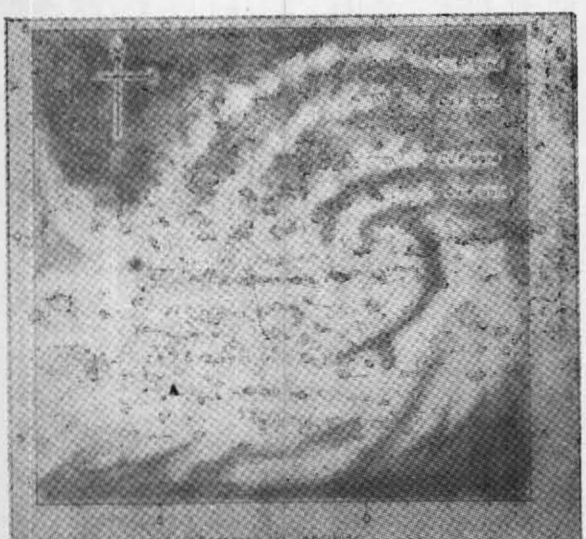


Fig. 6.
Schematic diagram of monsoon depression

TABLE 2

Mean Relative Humidity (per cent) at standard isobaric levels in the fields of monsoon depressions

	Height (mb)					
	1000	850	700	600	500	400
Cumuliform field	85	79	81	76	61	41
	(11)	(11)	(10)	(11)	(11)	(8)
Overcast area	87	85	85	87	87	76
	(20)	(20)	(19)	(19)	(13)	(9)

NOTE :1. Figures in brackets show the number of observations available.

2. Values above 400 mb are not given as the observations are too few for these levels.

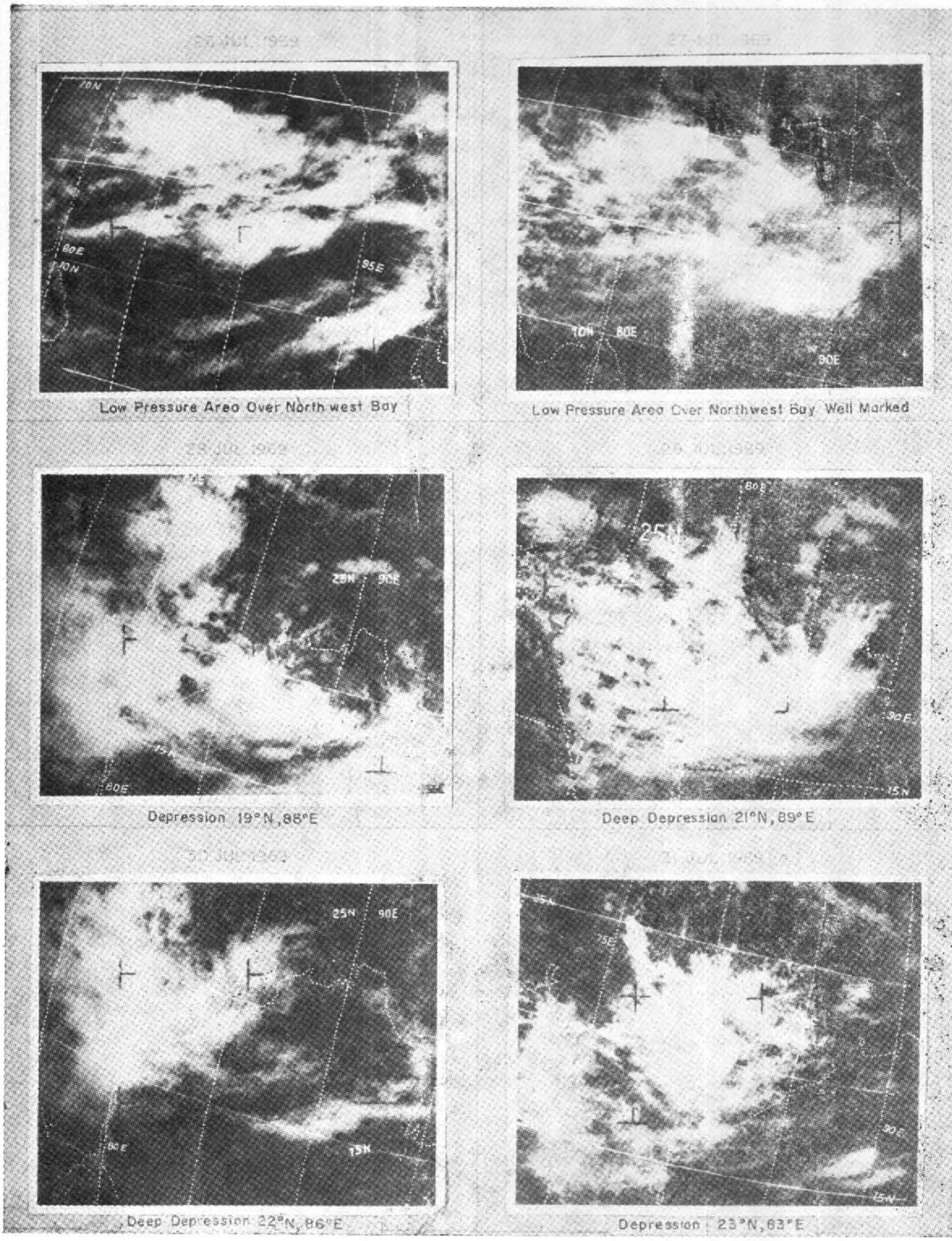


Fig. 7

Monsoon depression during 26-31 July 1969 — ESSA-9 pictures

[**Courtsey**: NESC, Washington]