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Certain aspects of monsoon depressions as revealed by satellite pictures*

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ABSTRACT. The cloud distribution around typical monsoon depressions is studied with the aid of satellite cloud pictures. The depressions have asymmetric cloud distribution with the main overcast to the west and southwest of centre. The thermal structure of these depressions is studied with the help of thickness charts. They show that the well-marked depressions are associated with considerable thermal advection. The energetics of monsoon depressions has been discussed in relation to the observed thermal structure of the depressions.

1. Introduction

Satellite cloud pictures give a real synoptic view of disturbances. Much light has been thrown on the structure of tropical systems by satellite cloud data. Tropical storms have the characteristic central overcast, often the cirrus outflow and sometimes the visible eye; these features can be easily identified without too much skill. In contrast, the weaker disturbances of the tropics do not have well-organised cloud systems associated with them.

Monsoon depressions are the most important of rain-producing systems of the Indian southwest monsoon and have been extensively studied. Kulshrestha and Gupta (1964) and Keshavamurty (1966) studied the cloud structure of monsoon depressions with the help of satellite cloud data.

2. Cloud distribution

Since the installation of the APT receiving equipment at Bombay, the author has had the opportunity to examine the cloud pictures in relation to daily synoptic charts. Well-marked or deep depressions have a typical cloud structure. Figs. 1(a), 2(a) and 3(a) show the clouds around three such typical depressions. The pictures show these large-scale features. The main overcast area is to the west and southwest of the centre of the depression (marked with a dot and C), the centre of the depression being outside this overcast. In pictures of good quality, low level cumulus spirals are seen near the centre of the depression (This feature has not been very well brought out in the reproduction). These pictures conform to the well-known type C⊕ of satellite meteorology. In the other parts of the tropics, this type of clouds structure is associated with pre-hurricane depressions. Koteswaram (1961), using Tiros I data, stressed this asymmetric distribution of clouding and the clearance near the centre in the formative stage of a storm in the Arabian Sea. Pre-storm stage depressions of the pre and post monsoon seasons in the Indian Seas exhibit this feature.

The asymmetric cloud distribution around monsoon depressions observed in the satellite pictures agrees with the well-known rainfall distribution. Most of the heavy rainfall in association with monsoon depressions falls in the southwest sector (Pisharoty and Asnani 1957). Raman and Banerji (1970) found that heavy rainfall around Nagpur occurs when monsoon depressions are far to the east and the flow over Nagpur is northerly.

3. Thermal structure

Pre-hurricane depressions which have a cloud structure similar to that of monsoon depressions are known to be cold-cored: the transformation of a cold-cored into a warm-cored disturbance is an important stage in the development of a tropical storm. Again, when tropical storms weaken, the central overcast weakens and the low level spirals appear outside the overcast. Monsoon depressions rarely develop into warm-core tropical storms (which acquire a central overcast), either due to lack of long sea-travel or due to other inhibiting factors.

Now, the interesting question arises — Are monsoon depressions cold-cored similar to pre-storm

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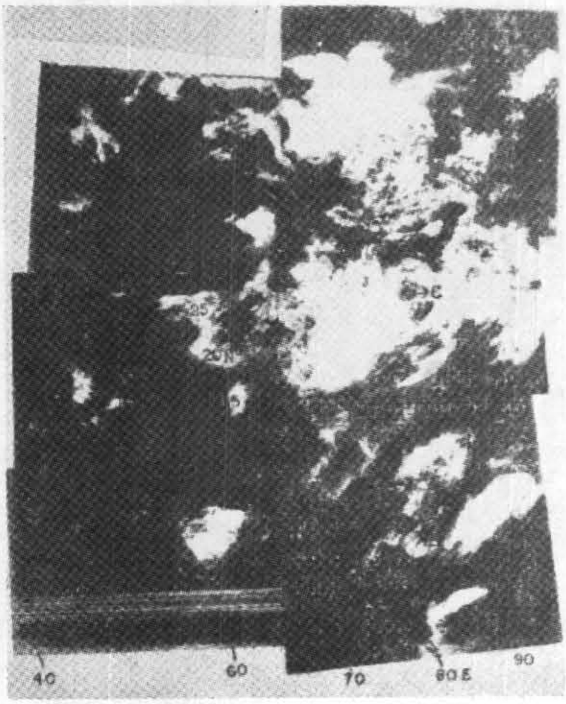

Fig. 1(a)

29 July 1969

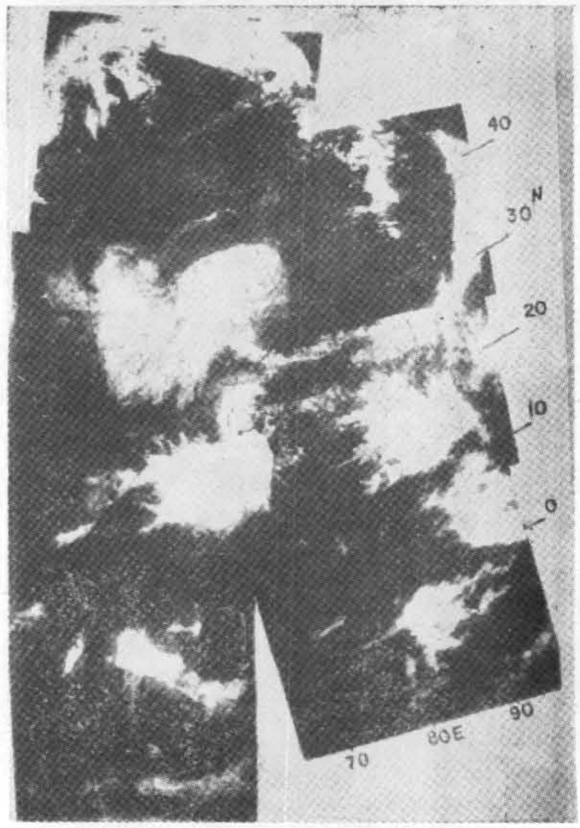

Fig. 2(a)

6 Aug 1968

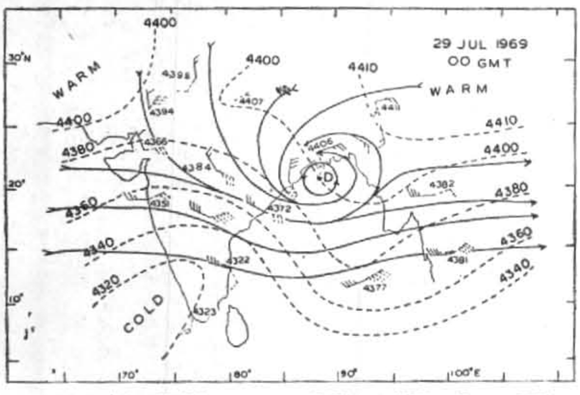

Fig. 1(b)

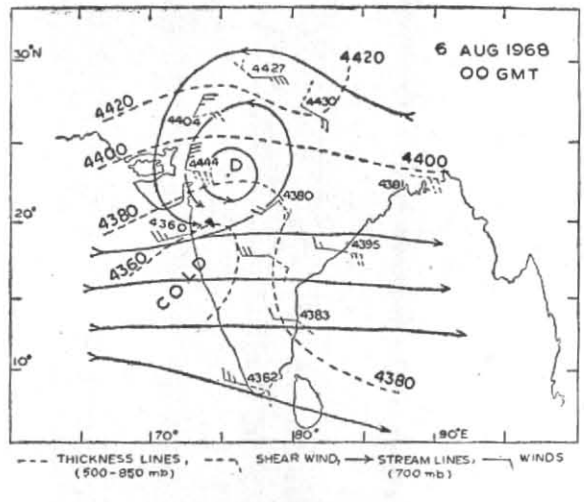

Fig. 2(b)

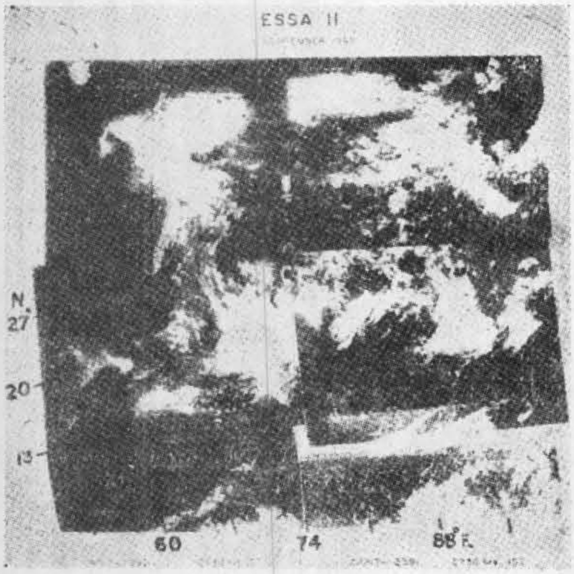

Fig. 3(a)

[5 September 1966]

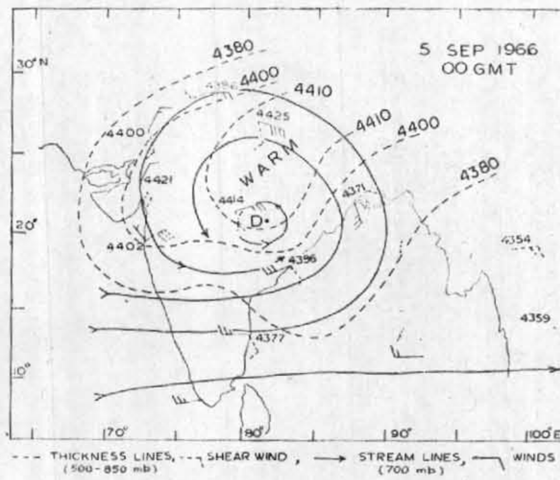

Fig. 3(b)

depressions? Koteswaram and George (1958) studied the thermal structure of a typical monsoon depression. They found warm advection ahead of the depression and cold advection in the rear. Figs. 1(b), 2(b), 3(b), show the thermal structure of the three typical depressions whose cloud pictures were discussed in the earlier section. These cases confirm the observations of Koteswaram and George. The figures show that monsoon depressions are neither cold-cored nor warm-cored but have considerable thermal advection associated with them.

4. Bearing on the energetics of monsoon depressions

Let us consider the well-marked depression on 6 Aug 1968 which caused heavy rains in central and western India during its westward travel (Figs. 2a and 2b). It is seen that there is marked cold advection in the rear. The western sector of the depression is warmer than the eastern sector. The northerlies in the western sector are associated with higher temperature than the southerlies to the east. Therefore the depression transports sensible heat from north to south.

The conversion from zonal available potential energy (A_Z) into eddy available potential energy (A_E) is given by,

$$C\,(A_Z, A_E) = -R^2 \int \frac{1}{\sigma p^2} \left[v^* \; T^* \right] \frac{\partial\,[T]}{\partial y}\, dm$$

where, v = meridional component of wind

T = temperature

dm = element of mass

R = gas constant

$$\sigma = -\frac{\alpha}{\theta}\,\frac{\partial\theta}{\partial p} = \text{ static stability}$$

p = pressure

and the square bracket indicates a zonal average, and the star denotes the deviation from this average. The monsoon depression (of 6 Aug 1968) transports sensible heat from north to south, *i.e.*, $[v^*\,T^*]$ is negative. In the southwest monsoon, zonal mean temperature increases from south to north, *i.e.*, $\partial[T]/\partial y$ is positive. Therefore, in the case of the depression on 6 Aug 1968 there is conversion from zonal available potential energy into eddy available potential energy [$C\,(A_Z, A_E)$ is positive].

The conversion from eddy available potential energy (A_E) into eddy kinetic energy (K_E) is given by:

$$C\,(A_E, K_E) = -\int [\omega^*\,\alpha^*]\, dm$$

where, $\omega = \dfrac{dp}{dt}$ and α is specific volume.

There is conversion from A_E into K_E when there is rising of warm air and sinking of cold air in the x–p plane.

As seen in Section 2, monsoon depressions are associated with overcast clouding and heavy rainfall in the western sector and relative clearing to the east. Rao and Rajamani (1968) computed quasi-geostrophic 'ω' in the field of a monsoon depression and found upward motion in the western sector. In the case of the depression on 6 Aug 1968 the temperature in the region of overcast clouding and rainfall (and hence of upward motion) in the western sector is higher than in the clear region to the east. Thus we have rising of warm air and sinking of cold air in the x–p plane and thus conversion from eddy available potential energy into eddy kinetic energy as found by Rao and Rajamani (1968). We do not have such conversions in the case of the developing depression on 29 July 1969. Koteswaram and George (1958) found that warm advection in the front and cold advection to the rear of monsoon depressions are not marked in the initial stages and develop only in the later stages.

5. Conclusions

(*i*) Monsoon depressions have asymmetric cloud distribution with the main overcast to the west and southwest.

(*ii*) Well-marked monsoon depressions have considerable thermal advection associated with them.

(*iii*) In the later stages well-marked depressions can be sustained by large-scale baroclinic conversions.

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