Mausam, (1981), 32, 4, 401-404

551.515.13 : 551.553.21

Rain fall and energy computations within monsoon depression field

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(*Received 27 September 1980*)

ABSTRACT. Based on data of 27 depressions which formed in the Bay of Bengal during 1961-74, the mean vertical structure of the humidity field has been presented in the first instance. Radial velocity has been worked out and the resulting mean picture discussed briefly. These two parameters have been combined to obtain, theoretically possible maximum amount of rainfall within the depression field. Heat released due to condensation process has been computed and discussed.

1. Introduction

Energy released within a depression field does not appear to have attracted much attention though a few studies on the energetics of the monsoon field has been undertaken. For example Anjaneyulu (1969) computed flux of sensible heat in an elliptic area around the monsoon trough. Earlier, Bunker (1965) studied the heat balance and flux of sensible and latent heat along the trajectory of air in the low level jet over Arabian Sea. The purpose of this study is to determine mean latent heat energy released within the depression field. It is also proposed to find out theoretically possible maximum rainfall in the depression.

2. Data utilised

Data pertaining to 27 depressions which formed during July and August months of 1961-1974 and followed westerly or westnorthwesterly track have been utilised. Radiosonde data of observations within 1,000 km of the depression have been utilised. Only the morning ascents have been taken into consideration. The wind observations were supplemented by the pibal ascents. The radial velocity required in the computations is based on the technique adopted by Jordan (1952).

3. Compositing procedure

The elements composited are the radial velocity, total velocity and the specific humidity. In this procedure, each of the elements at a level, are plotted against the distance from the surface position of the depression centre. A smooth curve is then drawn so that, more or less, equal number of observations lie either side of the curve. The field has been equally divided into 10 ranges (*viz.*, 0-100, 100-200 km etc) of 100 km each. Value of the element at the mid-point of the interval is noted from the curve drawn and is assigned to that interval for the sake of analysis.

4. Theoretical assumption and computation

In the computation of the rainfall the following assumption have been made:

(*i*) Steady state,

(*ii*) No loss of moisture takes place from the top of the depression,

(*iii*) All low level moisture is precipitated,

(*iv*) No liquid water loss occurs and

(*v*) Moisture is concentrated only upto 500 mb level.

If F is the flux of moisture through a layer dp within a radius r km of the centre, v_r is the radial velocity, q_r the specific humidity at distance r then :

$$F = 2\pi r \int_{\text{Surf.}}^{500} \frac{q_r}{g}\, v_r\, dp \tag{1}$$

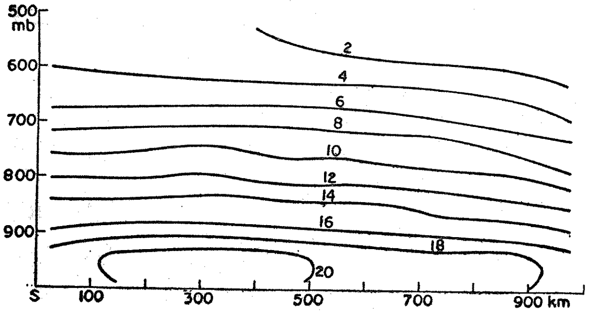

Fig. 1. Vertical section of specific humidity (g/kg)

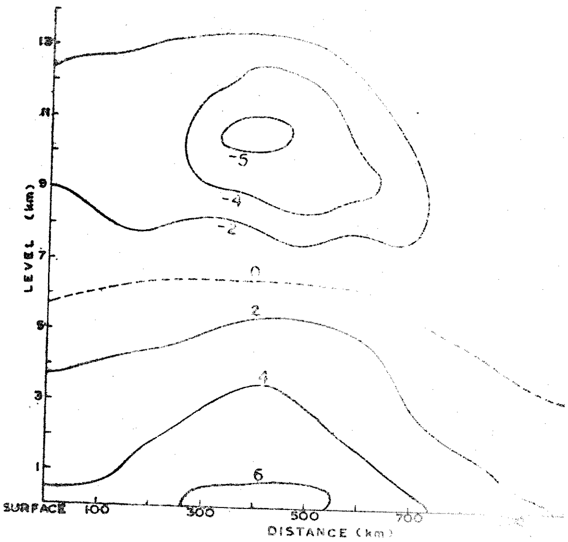

Fig. 2. Vertical cross-section of the radial velocity (m/sec)

If R is the amount of rainfall occurring in the circle then:

$$F = \pi r^2 R \tag{2}$$

$$R = \frac{2}{rg} \int_{\text{Surf.}}^{500} v_r \, q_r \, dp \tag{3}$$

Assuming that moisture is confined upto 500 mb in the depression which is a very fair assumption, integration of the right hand side of Eqn. (3) above from surface to 500 mb would yield maximum probable rainfall.

Before the actual computation of rainfall energy, it may be perhaps worthwhile to discuss, in brief, the space distribution of radial velocity and specific humidity. This has been done in the following paragraphs.

5. Specific humidity and radial velocity

The vertical cross section of the mean specific humidity (g/kg) is shown in Fig. 1.

The moisture field in terms of relative humidity was earlier worked out by Godbole (1977) based on 5 monsoon depressions of 1973. He found large concentration of moisture close to the surface. In the present study, maximum amount of moisture (about 20 g/kg) is located at the surface slightly away from the depression centre, mostly between 100 and 500 km from it. Outward of this high humidity zone, the moisture content diminishes gradually. Nevertheless, the humidity close to the surface within the area under consideration remain high (more than 18 g/kg). Above the surface position of the highly moist region, the isohygrics are parallel, suggesting that lateral variations in the humidity are not large. The humidity decreases vertically upwards and is about 4 g/kg at about 600 mb. Near the surface position of the depression, even at 500 mb, the humidity is quite high (*i.e.,* more than 2 g/kg). Only beyond 600 km at this level, the humidity falls to less than 2 g/kg. Murakami (1977) investigated monsoon lows over inland areas of northern India by spectrum analysis. He found maximum variance in the oscillations of the specific humidity at the surface, the values decreasing with height.

The vertical cross section of the radial velocity is depicted in Fig. 2. Maximum amount of the inflow, *i.e.,* about 7 mps, is observed in the lower level between 300 and 500 km from the surface position of the depression centre. Inflow is observed, from the surface vertically upto about 6 km (500 mb) upto distance 600 km from

TABLE 1

Rainfall and energy values

Radius (km)	Average rainfall (cm day^{-1})	Energy released (10^{26} ergs day^{-1})
100	28.1	2.14
200	15.9	4.84
300	13.4	9.18
400	11.0	13.40
500	8.0	15.23
600	5.4	14.80
700	3.4	12.71
800	1.8	8.77
900	1.2	7.40
1000	0.6	4.57

the centre. Thereafter, inflow gradually diminishes. No inflow is observed above 3 km, *i.e.*, 700 mb at a distance 1,000 km from the centre. Outflow occurs above the level of mass inflow. Maximum amount of outflow (about 5 mps) is observed at about 11 km, *i.e.*, 250 mb at a radial distance of 400 km. East of 700 km at this level outflow decreases to about 2 mps. Above 12 km or 200 mb, the amount of outflow decreases again.

The above observations are in general agreement with the results of Mulky and Banerjee (1960) and Sikka and Paul (1975).

6. Rainfall and energy distribution

The values of rainfall per day for different radii circles are given in Table 1. These values are such that if the storm passes directly over a station while moving in a straight line, there would be, on an average, a total rainfall about 28 cm in 24 hr. This appears to be a quite reasonable value, since rainfall amounts of such magnitude have often been reported in association with depressions. The rainfall decreases with the distance. Far away from the depression centre the amount of rainfall may be as less as 1 cm.

Multiplication of the average rainfall values by the area, the latent heat of condensation and the mechanical equivalent of heat gives the energy release per day. The energy released due to latent heat increases from the centre reaching a maximum at about 500 km. It falls off thereafter. Longley (1949) computed the latent heat released in an Atlantic hurricane and Hughes (1952) computed the same for a number of Pacific tropical cyclones. For a 3 deg. lat. circle Longley's value of 1.9×10^{26} ergs and Hughes value of 4.36×10^{26}, compares well with the value of 9.2×10^{26} for 300 km radius (Table 1). Unfortunately such computations are not available for monsoon depressions.

7. Conclusions

The following broad conclusions emerge from the study:

(*i*) Moisture is largely concentrated near the surface position of the depression centre. Outward of the centre and vertically above the ground surface, the specific humidity gradually diminishes.

(*ii*) Inflow occurs vertically up to about 6 km above sea level, the maximum occurring between 300 and 500 km from the centre.

(*iii*) Maximum amount of rainfall that can reasonably be expected, theoretically, is about 30 cm per day, near the centre. The rainfall amount at 900 km and beyond is much less, *i.e.*, about 1 cm in 24 hours.

(*iv*) Energy released due to condensation process is largest about 500 km from the centre.

Acknowledgement

The author is grateful to Dr. R. P. Sarker, Deputy Director General of Meteorology (Climatology) for inspiration and very useful suggestions.

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