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Atmospheric energetics over India during drought and normal monsoons

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ABSTRACT. Energetics of the atmosphere during a drought and normal southwest monsoons over India based on upper air data have been computed. The parameters considered are sensible heat, latent heat, kinetic energy and angular momentum. The mean and eddy components due to meridional circulation are separated and the differences between the two contrasting years are highlighted. The present results are compared with the earlier ones obtained over India.

1. Introduction

In the global atmosphere-ocean system, there always exists some imbalances between different latitudes. For example, the incoming and outgoing solar radiation at low and high latitudes are not the same. Similar is the case for energy, water vapour and angular momentum. These imbalances are maintained by a strong poleward transports.

Problems of general circulation were studied by many scientists in detail. Important among them are Priestly (1949); Starr & White (1951, 1952 a, b) and Parker (1970). With the availability of reliable long term data and fast computers, atmospheric statistics on hemispheric basis were worked out by Murray *et al.* 1969), Kidson *et al.* (1972) and Newell *et al.* (1974).

Most of the studies are confined to mid or high latitudes only, though the general circulation of tropics differs from extra-tropics in several respects. One reason may be due to lack of good network of data. Alaka (1964) stressed the importance of Asian summer monsoon and its specific role in general circulation of tropics. The summer or southwest monsoon over India and neighbourhood is an unique phenomenon. It is the largest local perturbation embedded in the general circulation of the atmosphere and most important among the seasonal standing eddies. During the monsoon period, over India and neighbourhood, heat and angular momentum source is disturbed due to large scale cloudiness.

Angular momentum is lost by the atmosphere to the earth due to strong low level westerlies. Thus the study of meridional fluxes of heat, energy and angular momentum over Indian monsoon area became important.

Rao (1961) observed that considerable amount of angular momentum, though not heat, is transported into Indian monsoon area. Sankar Rao (1962), Sankar Rao and Ramanadham (1963) noted with limited data coverage over India that transient local eddies play a minor role in heat and momentum transports. Anjaneyulu (1969) found that monsoon trough area acts as a heat source with a strong vertical convection from lower to upper troposphere in July and August. Bunker (1965) observed that the monsoon air picks up moisture and heat during its travel over the Arabian Sea.

During the decade 1961-1970, India received below normal rainfall in 1965, 1966 and 1968 resulting in drought. In between, the rainfall was normal in 1967 (Parthasarathy & Mooley 1978). The years 1966 and 1967 are selected as drought and normal years for the analysis. During these two years the onset and withdrawal of monsoon took place more or less on normal dates, but the activity was sub-normal in 1966 and was normal in 1967. In 1966, rainfall was normal to above

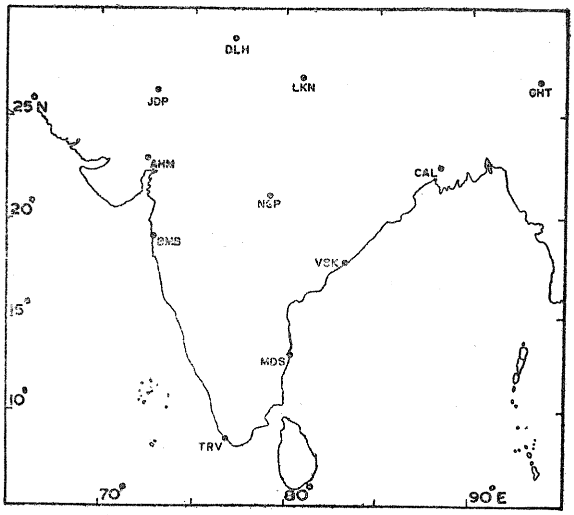

Fig. 1. Locator map of radiosonde station

normal over half of the country and was below normal over rest, whereas it was normal to above normal over the whole country except in one meteorological sub-division during 1967.

2. Data used in the study

The daily upper air data upto 650 mb by steps of 50 mb for 00 GMT of the 11 available radiosonde stations (Fig. 1) in the country, were used to obtain the meridional fluxes of sensible heat, latent heat, relative angular momentum and kinetic energy by mean and transient eddies. The parameters were calculated levelwise for the two monsoon seasons of 1966 and 1967 (June to September) from 950 mb to 650 mb. Surface level was omitted in order to avoid radiation and topographical effects. Computations were restricted upto 650 mb level only. It is well known that the steadiness factor of winds is least in between 600 mb to 400 mb and during monsoon period the lower and middle tropospheric westerlies are replaced by easterlies at higher levels over most of the areas. Thus, if the integration is extended beyond 600 mb the net result will be very much different. Hence computations were restricted for lower levels of monsoon cell only, where westerlies are predominent.

Mean values (seasonal) of zonal and meridional winds, temperatures and humidity mixing ratios at 50 mb intervals from 950 mb to 650 mb are computed at all the stations. Time departures are obtained from the the daily values and used for calculation of eddy terms.

3. Evaluation of parameters and discussion of results

Utilising stationwise data, meridional fluxes (Mean and Eddy) are computed at each level, which are later integrated. These values are analysed by drawing suitable isopleths over the country.

Results of two monsoons, both for integrated and some selected zones are discussed. The three zones selected are mean of 950 and 900, 850 and 800, and 700 and 650 mb and termed as zone one, two and three respectively. Diagrams for these zones are not given due to lack of space. The individual fluxes for the three vertical zones at all the stations, are given separately in the tables. The important inferences obtained from the diagrams and tables are included in the discussion at appropriate places.

List of symbols used are given below:

t = time
u = zonal component of wind
v = meridional component of wind
ϕ = geopotential
a = radius of earth
f = coriolis parameter
λ = longitude
$F\lambda$ = frictional force in zonal direction
$F\phi$ = frictional force in meridional direction
w = vertical velocity
φ = latitude
T = temperature
$K = R/c_p$
R = gas constant for dry air
c_p = specific heat of air at constant pressure
p = pressure
Q = rate of diabatic heating
ρ = density

(a) *Sensible heat flux*

The total meridional energy in the atmosphere is proportional to sensible heat and geopotential, which is given by:

$$[\overline{c_pT + \phi}\,]\,V = \overline{c_p\,TV} + \overline{\phi V}$$

The small contribution by kinetic energy term is neglected and the flux due to sensible heat is computed as

$$\underset{(SH)}{F} = \frac{c_p}{g}\int_{p_1}^{p_2} \overline{VT}\,dp \ \text{cal/sec}$$

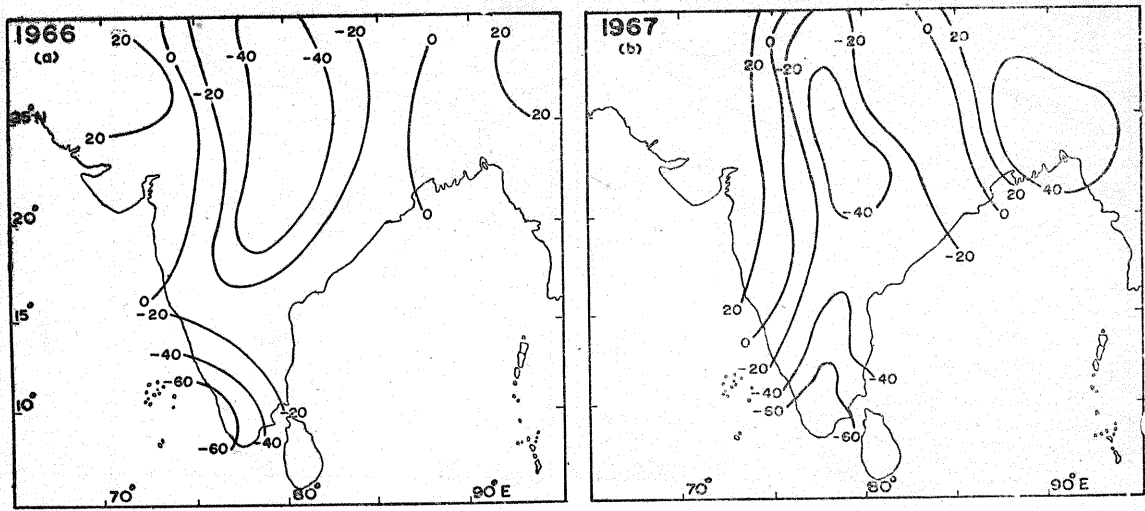

Fig. 2. Meridonal flux of sensible heat (10^5 cal/sec/mb/°Long.) due to mean flow during monsoon

TABLE 1

Meridional flux (in 10^5 cal/sec/mb) of sensible heat by mean component at different stations during summer monsoon period (June to September)

Station	1966 — Layers (mb)				1967 — Layers (mb)			
	950-900	850-800	700-650	950-650	950-900	850-800	700-650	950-650
Delhi	—1.2	—7.2	—8.8	—40.0	—0.6	—5.9	—7.9	—33.0
Jodhpur	13.0	8.3	—6.0	29.0	10.0	6.4	—5.7	21.0
Lucknow	—	—	—	—	2.5	—0.7	—2.2	—4.9
Gauhati	0.4	4.5	5.6	24.0	0.8	6.6	6.3	32.0
Ahmedabad	3.3	7.2	—3.4	17.0	5.8	7.8	—0.5	28.0
Nagpur	—11.0	—11.0	—6.7	—58.0	—9.4	—9.0	—7.1	—51.0
Calcutta	4.5	1.5	—1.5	12.0	12.0	7.6	4.4	45.0
Bombay	5.6	5.3	—1.2	19.9	9.5	7.6	4.2	38.1
Visakhapatnam	3.9	—1.1	—6.1	—10.0	4.6	—5.0	—7.6	—24.0
Madras	3.3	—5.6	—1.0	—14.0	—2.9	—8.2	—3.7	—36.0
Trivandrum	—19.0	—13.0	—2.3	—67.0	—18.0	—16.0	—5.8	—78.0

between the layer p_1 and p_2. This flux is further splitted up into mean and transient eddy as

$$F_{(SH)} = \frac{C_p}{g} \int_{p_1}^{p_2} [\overline{V}\,\overline{T} + \overline{V'\,T'}]\, dp \ \text{cal/sec}$$

The individual values are computed and discussed later separately.

(*i*) *Mean motion*

The integrated picture indicated a southward flux, Fig. 2 (a & b) over the whole country except eastern and western parts, north of 20 deg. N where it is northward. Maximum values occurred in central and extreme south-western parts of the country. In case of individual zones, the pattern is almost similar to that of integrated one, with maximum contribution from zone one and two.

Among the two years under study, even though the patterns are more or less similar, values are generally higher during 1967 over 1966. In particular, there is an increase of nearly 100 per cent values in eastern India, north of

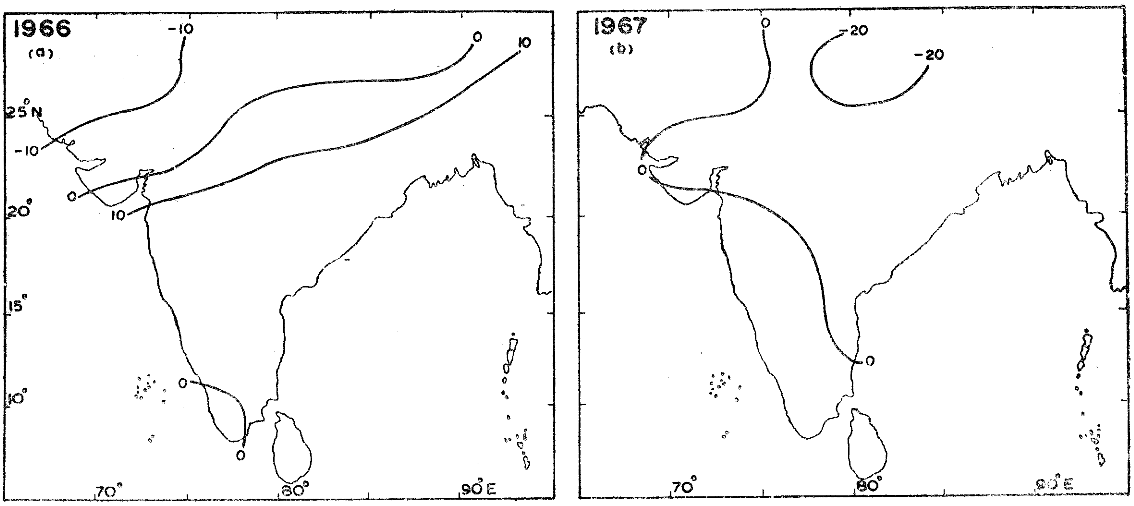

Fig. 3. Meridional flux of sensible heat (10^3 cal/sec/mb/°Long.) due to eddy during monsoon

TABLE 2

Meridional flux (in 10^3 cal/sec/mb) of sensible heat by eddy component at different stations during summer monsoon period (June to September)

Station	1966 — Layers (mb)				1967 — Layers			
	950-900	850-800	700-650	950-650	950-900	850-800	700-650	950-650
Delhi	—2.9	—3.1	1.7	—8.9	—1.7	—5.5	—0.3	—17.0
Jodhpur	—4.2	—3.1	0.8	—12.0	0.6	0.1	3.0	7.5
Lucknow	—	—	—	—	—4.7	—6.4	—0.2	—25.0
Gauhati	—0.3	1.0	—0.2	2.0	0.0	—0.5	0.8	—0.4
Ahmedabad	—2.5	—2.0	1.2	—5.6	—1.8	—1.0	0.7	—5.6
Nagpur	4.1	3.4	—0.4	12.0	—3.4	—2.1	0.9	—7.3
Calcutta	0.0	1.5	1.0	1.0	—0.7	—1.6	1.7	—1.4
Bombay	—0.9	—2.9	—1.8	12.9	1.0	—0.3	0.4	1.9
Visakhapatnam	—0.3	0.2	1.5	3.0	—0.9	—1.9	—1.0	—1.1
Madras	1.3	1.3	3.3	6.1	0.4	—0.3	—0.2	—0.4
Trivandrum	—0.8	—7.0	—7.5	—3.6	0.3	—0.1	0.6	1.0

20 deg. N. Zone one showed slightly higher values over central and about twice over north-east India. Values at other two levels did not differ much in the two years. Except at Jodhpur and Nagpur, all other stations indicated higher values in 1967 (Table 1).

(ii) *Eddy motion*

The flux by eddy motion is quite small when compared to mean (Fig. 3a & 3b).

Integrated picture of 1966 indicated southward flux over northwestern parts and northward flux over rest of the country. In the same year, zone two indicated southward flux west of 80 deg. E and northward in the east running from north to south. Zone three showed strong southward flux over southwestern Peninsula and northward flux over east coast south of 20 deg. N. During 1967, the patterns are altogether different. Integrated (Fig. 3b) values indicated a pocket of strong southward flux north of

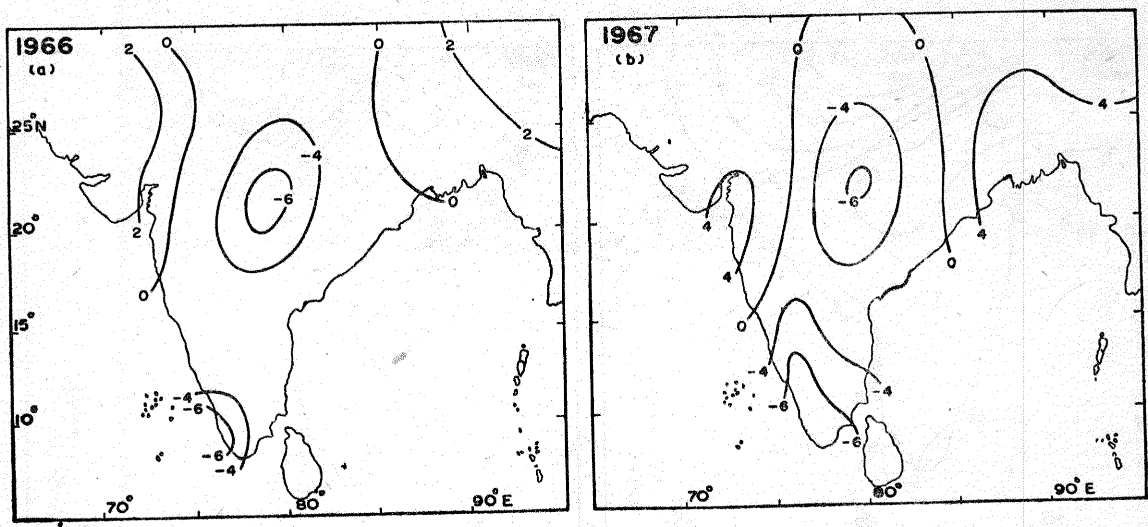

Fig. 4. Meridional flux of latent heat (10^5 cal/sec/mb/° Long.) due to mean flow during monsoon

TABLE 3

Meridional flux (in 10^5 cal/sec/mb) of latent heat by mean component at different stations during summer monsoon period (June to September)

Stations	1966—Layers (mb)				1967—Layers (mb)			
	950-900	850-800	700-650	950-650	950-900	850-800	750-650	950-650
Delhi	—0.2	—0.7	—0.6	—3.5	—0.1	—0.6	—0.6	—3.0
Jodhpur	1.6	0.8	—0.4	3.6	1.4	0.7	—0.3	2.9
Lucknow	—	—	—	—	0.3	—0.1	—0.2	—0.3
Gauhati	0.1	0.6	0.5	2.7	0.1	0.8	0.6	3.6
Ahmedabad	0.4	0.7	0.2	2.0	0.8	0.8	—1.5	3.1
Nagpur	—1.6	—1.3	—0.5	—6.6	—1.3	—1.1	—0.6	—5.9
Calcutta	0.5	—0.8	0.3	0.6	1.9	0.9	0.4	5.6
Bombay	0.8	0.6	—0.1	2.3	1.3	0.8	0.4	4.1
Visakhapatnam	0.5	—0.1	—0.5	—0.7	0.7	—0.6	—0.6	—2.0
Madras	0.4	—0.6	—0.1	—1.2	—0.4	—0.9	—0.3	—3.5
Trivandrum	—2.4	—1.4	—0.2	—7.3	—2.3	—1.6	—0.4	—8.0

25 deg. N along 80 deg. E. In zone one northerly flux is noticed over more than half of the country, and in zone two over the whole country and in zone three over whole country except a small area running from north to south along 85 deg. E.

Generally, eddy values are stronger in zone two compared to other zones and Delhi showed higher value (integrated) in 1967 over 1966.

(b) *Latent heat flux*

On similar lines of sensitive heat flux, the latent heat flux $F_{(LH)}$ can be written as :

$$F_{(LH)} = \frac{L}{g} \int_{p_1}^{p_2} [\overline{qv} + \overline{q'v'}] \, dp \ \text{cal/sec}$$

where, L = latent heat of vaporisation and
q = humidity mixing ratio.

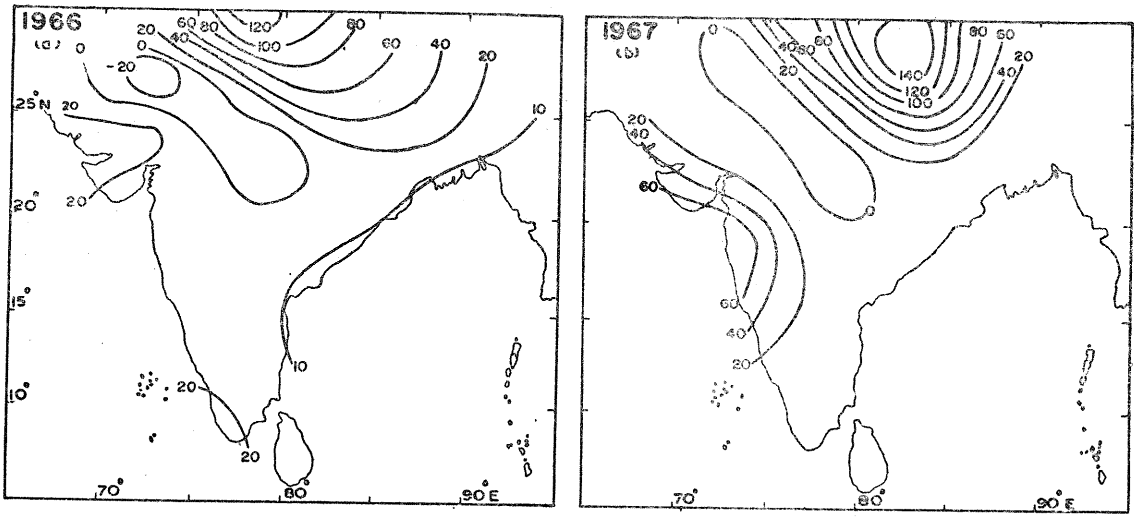

Fig. 5. Meridional flux of latent heat (10^3 cal/sec/mb/°Long.) due to eddy during monsoon

TABLE 4

Meridional flux (in 10^3 cal/sec/mb) of latent heat by eddy component at different stations during summer monsoon period (June to September)

Station	1966 — Layers (mb)				1967—Layers (mb)			
	950-900	850-800	700-650	950-650	950-900	850-800	700-650	950-650
Delhi	27.0	21.0	13.0	120.0	13.0	14.0	10.0	79.0
Jodhpur	—1.3	—9.5	—1.9	—36.0	—2.5	—1.0	2.6	—7.6
Lucknow	—	—	—	—	25.0	27.0	17.0	140.0
Gauhati	—0.2	—4.3	2.8	14.0	1.0	—0.9	0.6	1.6
Ahmedabad	10.0	2.1	1.3	23.0	5.7	0.4	2.2	13.0
Nagpur	—2.6	—2.0	—0.5	—6.8	3.3	—1.4	—2.0	—7.1
Calcutta	1.5	2.5	3.0	10.5	1.4	0.6	5.6	14.0
Bombay	6.2	2.8	1.4	18.6	8.7	13.0	9.4	62.5
Visakhapatnam	2.6	3.4	1.8	16.0	4.7	—0.9	—2.8	2.3
Madras	4.6	0.2	1.8	11.0	2.4	2.4	2.4	12.0
Trivandrum	5.1	2.6	3.7	21.0	2.3	0	0.9	5.1

As usual, the fluxes by mean and eddy components are computed and discussed.

(i) *Mean motion*

The integrated patterns resemble in both the years that of sensible heat flux (Fig. 4a & 4b). Most of the country is covered by southward flux except eastern and western areas north of 20 deg. N. Areas of maximum values are noticed over central and extreme southern parts of the country.

During 1967 integrated values are higher compared to 1966 over the whole country, particularly over eastern and western parts. Maximum contribution is from zone one in both the years except some small values in zone two during 1966 along the foot hills of Himalayas.

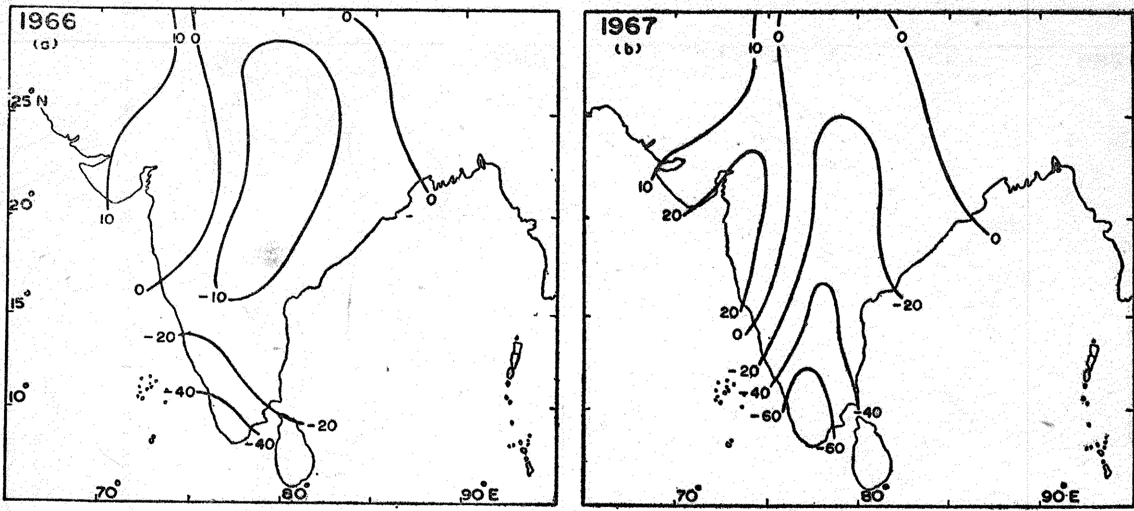

Fig. 6. Northward flux of angular momentum (10^{15} gm cm^2/sec^2/mb/°Long.) due to mean flow during monsoon

(ii) *Eddy motion*

Integrated eddy flux patterns (Fig. 5a & 5b) are quite different from those of mean patterns. Northward flux covered the whole country except a small southward flux area extending from northwest to southeast central India. The strongest fields are along monsoon trough and west coast.

In 1967 the integrated picture showed higher values along west coast (thrice of 1966) and along monsoon trough. But the northward flux was stronger over northwest India in 1966 over 1967.

The individual zones indicated that eddy activity is almost of the same order in both the years. During 1967, the values are slightly higher in zone two compared to one and three at Delhi, Lucknow and Bombay (Table 4).

(c) *Flux of relative angular momentum*

The meridional flux of relative angular momentum is given by :

$$J\varphi = a^2 \cos^2 \varphi \Omega \overline{V} + a \cos \varphi [\, \overline{uv} + \overline{u'v'} \,]$$

where Ω is angular velocity of earth. But the flux of relative angular momentum $F_{(AM)}$ between the two levels is given as :

$$F_{(AM)} = -\frac{a^2 \cos^2\varphi \Omega}{g} \int_{p_1}^{p_2} V . dp - \frac{a \cos \varphi}{g} \int_{p_1}^{p_2} [\overline{u\, v} + \overline{u'v'}\,]\, dp \ \text{ gm cm}^2/\text{sec}^2$$

Generally the term involving $\overline{V}.dp$ is very small compared to other terms due to Hadley circulation (Tucker 1959 and 1970) and is neglected. Then :

$$F_{(AM)} = \frac{-a \cos \varphi}{g} \int_{p_1}^{p_2} [\overline{u\, v} + \overline{u'\, v'}] dp \ \text{ gm cm}^2/\text{sec}^2$$

As in previous cases, fluxes due to mean and eddy components are computed and discussed.

(i) *Mean motion*

Integrated picture of 1966 and 1967 (Fig. 6a & 6b) respectively indicated a sink of angular momentum (negative values) over the whole country except eastern and western parts. Maximum negative values occurred over southwestern areas of Peninsula.

Integrated picture of 1967 (Fig. 6b) indicated stronger values of either sign with higher values along west coast. Eastern and western areas, north of 20 deg. N did not show any large increase in 1967 over 1966 unlike other fluxes.

Contribution by the three zones (Table 5) is significant during 1967, whereas in 1966 it is due to zone one and two only.

(ii) *Eddy motion*

The integrated patterns are different in two years. During 1966 (Fig. 7a) most of the country is covered by positive values except north of 25 deg. N along 80 deg. E.

1967 pattern (Fig. 7b) showed negative values over the whole country except areas west of 75 deg. E and a small area over extreme northeast India. Higher values are noticed along the monsoon trough.

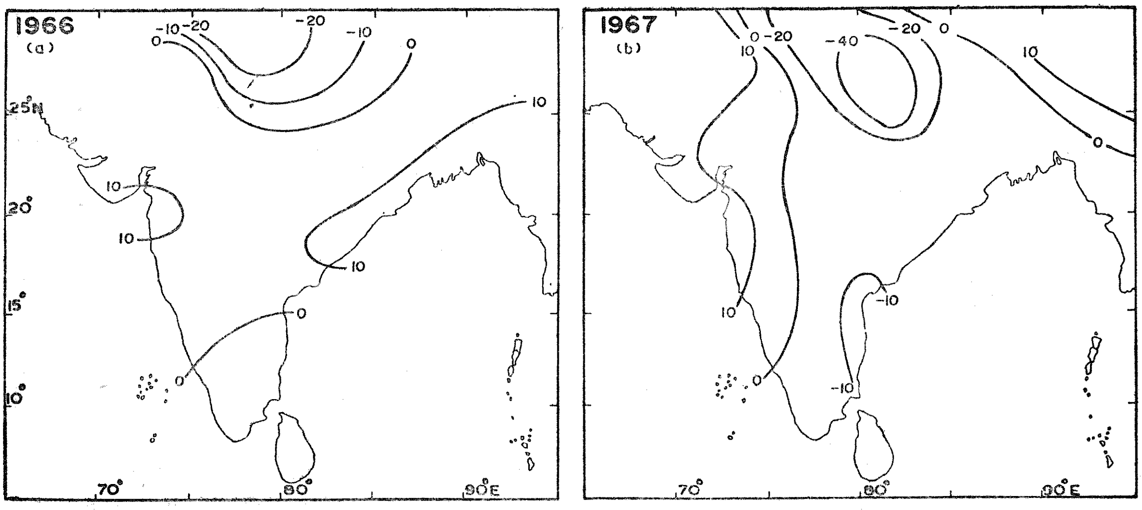

Fig. 7. Northward flux of angular momentum (10^{15} gm cm^2/sec^2/mb/°Long.) due to eddy during monsoon

TABLE 5

Meridional flux (in 10^{15} gm cm^2/sec^2/mb) of angular momentum by mean component at different stations during summer monsoon period (June-September)

Stations	1966—Layers (mb)				1967—Layers (mb)			
	950-900	850-800	700-650	950-650	950-900	850-800	700-650	950-650
Delhi	—0.3	—1.6	—1.3	—7.4	—0.2	—0.9	—0.1	—3.4
Jodhpur	7.1	2.7	0.8	18.0	5.0	1.8	1.1	13.0
Lucknow	—	—	—	—	0	—0.1	—0.2	—0.6
Gauhati	0	0.1	0.8	2.8	0.1	1.0	1.0	4.7
Ahmedabad	1.9	3.0	—0.2	9.1	2.6	2.5	0.1	9.3
Nagpur	—3.9	—2.7	—0.6	—14.0	—4.7	—3.9	—1.2	—20.0
Calcutta	—2.1	0.2	—0.5	0.8	1.5	0.8	0.1	4.4
Bombay	2.8	2.4	—0.4	9.6	5.9	4.5	2.1	22.2
Visakhapatnam	1.8	—0.6	—1.8	—3.4	3.0	—3.2	—3.0	—12.0
Madras	2.1	—3.1	—0.5	—6.9	—2.5	—5.8	—2.2	—25.0
Trivandrum	—12.0	—12.0	—1.2	—46.0	—12.0	—14.0	—4.3	—63.0

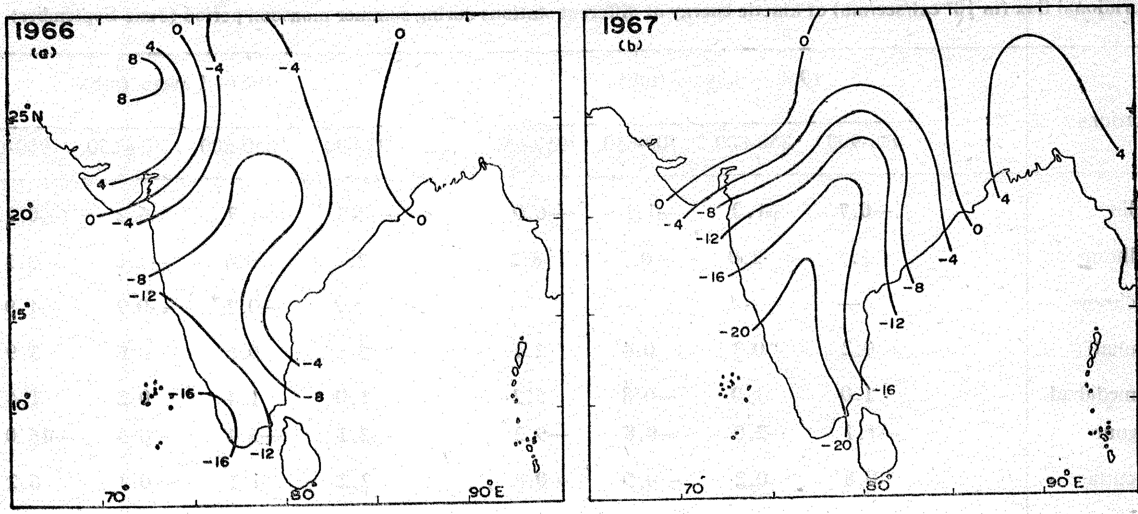

Fig. 8. Northward flux of kinetic energy (10^2 cal/sec/mb/°Long.) due to mean flow dwing monsoon

TABLE 6

Meridional flux (in 10^{15} gm cm^2/sec^2/mb) of angular momentum by iddy component at different stations during summer monsoon period (June-September)

Stations	1966 — Layers (mb)				1967 — Layers (mb)			
	950-900	850-800	700-650	950-650	950-900	850-800	700-650	950-650
Delhi	—4.1	—5.0	—3.5	—26.0	—3.5	—5.5	—6.8	—31.8
Jodhpur	2.7	3.1	0.8	12.0	0.7	2.9	1.0	10.0
Lucknow	—	—	—	—	—4.3	—8.2	—6.6	—41.0
Gauhati	0.6	2.1	1.3	9.5	1.5	2.1	1.5	12.0
Ahmedabad	1.0	1.7	0.7	8.3	0.0	0.6	1.3	7.1
Nagpur	0.1	0.2	1.0	3.8	—0.6	—2.3	0.4	—4.3
Calcutta	1.8	2.3	1.0	5.0	1.4	—0.2	—2.2	—3.1
Bombay	2.5	2.8	0.1	11.7	2.8	2.7	1.2	12.0
Visakhapatnam	4.0	3.1	0.8	14.0	1.9	—0.4	—0.8	—1.0
Madras	—0.5	—0.6	0.9	—0.5	—2.8	—3.2	—0.9	—14.0
Trivandrum	—0.3	—1.8	—0.6	—5.9	—0.2	—1.1	—1.4	—6.4

From Table 6 it can be seen that contribution of zone two to the total is significant. In 1967, values from zone three are equally important.

(d) *Northward flux of kinetic energy*

The instantaneous flux of horizontal kinetic energy $F_{(KE)}$ in a vertical column from surface to a height z along an unit latitudinal distance is given by:

$$F_{(KE)} = \int_0^z \tfrac{1}{2}\,\sigma\, V\,[u^2+v^2]\,dz \quad \text{cal/sec}$$

TABLE 7

Meridional flux (in 10^2 cal/sec/mb) of kinetic energy at different stations during summer monsoon period (June-September)

Stations	1966 — Layers (mb)				1967—Layers (mb)			
	950-900	850-800	700-650	950-650	950-900	850-800	700-650	950-650
Delhi	−0.7	−1.0	−1.1	−6.0	−0.5	−1.7	6.2	−0.2
Jodhour	3.1	2.0	−0.7	8.2	2.1	0.6	−1.0	3.3
Lucknow	—	—	—	—	0.2	−0.2	−0.7	−1.9
Gauhati	0.2	0.3	0.4	2.1	0.1	0.8	0.6	3.9
Ahmedabad	1.0	1.9	−0.8	5.2	1.0	1.4	0.2	1.4
Nagpur	−1.7	−2.0	−0.8	−9.2	−2.1	−5.4	−0.9	−16.0
Calcutta	0.8	0.2	−0.5	−0.8	2.2	1.1	0.3	6.2
Bombay	1.3	1.0	−0.2	−4.2	2.8	2.0	−1.5	−12.9
Visakhapatnam	1.0	0.3	−1.1	−0.4	1.6	−1.7	−1.6	−6.3
Madras	0.4	−1.2	−0.1	−3.0	−1.5	−3.0	−1.1	−13.0
Trivandrum	−4.2	−4.0	−1.1	−18.0	−3.6	−4.6	−1.6	−21.0

It can be rewritten after using hydrostatic equation as :

$$F_{(KE)} = \frac{1}{2gJ}\int_{p_1}^{p_2} [V(u^{2}+v^{2})]\, dp \text{ cal/sec}$$

where J is equal to mechanical equivalent of heat. Unlike the other fluxes, kinetic energy values are small and as such they are not separated into mean and eddy components.

The integrated pictures of 1966 and 1967, Fig. 8(a) and 8(b) respectively, revealed that the patterns are more or less similar to those of angular momentum to some extent, having southward flux over the whole country except eastern and western areas north of 22 deg. N. The southward flux decreased in strength with increasing latitude.

During 1967 the fluxes are stronger over the whole country except northwest India, as compared to 1966. Table 7 indicated that contribution of zones two and three to total is significant. In 1967, one or two stations showed even higher values at zone three.

4. Comparison of present results with earlier ones

(a) *Heat fluxes*

White (1951) observed that the mean fluxes are southward at very low latitudes with seasonal variation in them. Parker (1970) obtained during June at 30 deg. N Lat. that the flux of sensible heat by mean is southward and greater compared to eddies, whereas flux of latent heat by eddies is higher and northward compared to mean. In the Indian monsoon area, Sankar Rao (1962) noted that eddies play a minor role and is connected with pulsating nature of monsoon. Rao (1961) suggested the possibility of heat transport into monsoon area from outside.

The present analysis indicated that the fluxes of sensible and latent heat by mean is southward over the whole country except eastern and western areas, north of 20 deg. N. To some extent it resembled the meridional wind flow pattern obtained by Rao (1961). Eddy fluxes are small and significant, with different patterns in the two monsoons unlike mean flow. Most of the flux contributions are from lower levels and particularly for latent heat, due to high values of specific humidity. A normal monsoon year is associated with higher values both in mean and eddies, particularly along the west coast and monsoon trough area.

(b) *Angular momentum fluxes*

Widger (1949) showed the important role played by Hadley cell in the maintenance of angular momentum budget of the atmosphere. At low latitudes, the transports are northward by mean component. Eddies play a minor role. In the tropical upper atmosphere, Newell *et al.* (1974) noticed that the concentration by mean and eddy motions are varied with seasonal changes. They observed large momentum fluxes in the monsoon regions. Rao (1961) found that the monsoon region is a sink rather than a source. The present analysis supported this except in eastern and western areas of north India, north of 20 deg. N where it is a source. There is no major variation in the mean flow patterns from one year to another, but the eddy patterns differed much. The eddy contribution is as important as that of mean when compared to the provisional results of Sankar Rao and Ramanadham (1963). Activity of eddies along west coast and monsoon trough is higher in a normal monsoon year 1967.

(c) *Northward flux of kinetic energy*

Parker (1970) noticed that the flux is northward, reaching maximum at maximum wind level. Anjaneyulu (1971) obtained that the Indian monsoon trough zone is an exporter of kinetic energy in the upper troposphere. The present study showed that the whole country is covered by southward transport except over eastern and western parts of India. Normal monsoon year is characterised by higher values.

5. Summary of the main results obtained from the study

(a) *Flux of sensible heat*

The integrated flux of sensible heat over India during southwest monsoon period is southward except eastern and western areas north of 20 deg. N. Flux variations between two monsoons, 1966 and 1967, by mean is least but not in eddy. The magnitude of eddy fluxes is small compared to mean values. Most of the contribution to the integrated values is from lower tropospheric levels, due to strong monsoon winds. Year of normal monsoon rainfall (1967) is associated with higher fluxes.

(b) *Flux of latent heat*

The integrated flux of latent heat resembled that of sensible heat in all aspects. Most of the contribution to total flux is from lowest levels, due to high moisture content and strong winds. Higher rainfall activity is associated with higher fluxes.

(c) *Flux of angular momentum*

The integrated flux of angular momentum over India during two monsoons by mean flow is negative except over certain preferred areas, where it is positive. Contribution by mean and eddy flow are of the same order. Variation between two monsoons by mean flow is least but not in eddies.

(d) *Flux of kinetic energy*

The total integrated flux of kinetic energy is small compared to other fluxes in both the monsoons, with small variations between two years. India, as a whole, is covered by negative values except certain preferred regions.

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