Mausam, (1986), 37, 3, 365-367

551.553.21 : 551.511.3

Study of energetics in strong and break monsoon

D. S. DESAI
Meteorological Office, Pune

(*Received 6 May 1983*)

सार — व्यवधानी तथा प्रबल मानसून दौरों को विपरीत वर्षा बंटन तथा विशिष्ट सिनॉप्टिक परिस्थितियों द्वारा पहचाना जाता है। व्यवधानी तथा प्रबल मानसून दिनों के ऊर्जा विज्ञान का एजेड, एई, केजेड, केई, सी (एजेड, एई), सी (ऐई, केई), सी (केजेड, केई) तथा सी (एजेड, केजेड) जैसी मात्राओं की जांच के लिए अध्ययन किया गया है। भंवरें क्षेत्रीय प्रवाहों को ऊर्जा प्रदान करती है जिससे, ऐसा पाया गया है, व्यवधानी मानसून में वायुमण्डल दाब घनत्व की दृष्टि से स्थिर रहता है जबकि भंवर क्षेत्रीय प्रवाह में ऊर्जा छोड़ती हैं। प्रबल मानसून में, जब कि भंवर क्षेत्रीय प्रवाह से ऊर्जा प्राप्त करती है, वायुमंडल दाब घनत्व की दृष्टि से अस्थिर रहता है।

ABSTRACT. Break and strong monsoon periods are characterised by contrasting rainfall distributions and typical synoptic situations. The study of the energetics of break and strong monsoon days is undertaken to examine the quantities like A_Z, A_E, K_Z, K_E, $C\,(A_Z, A_E)$, $C\,(A_E, K_E)$, $C\,(K_Z, K_E)$ and $C\,(A_Z, K_Z)$. It is found that the atmosphere in break monsoon is barotropically stable as eddies lose energy to the zonal flow, and atmosphere in strong monsoon is barotropically unstable as eddies gain energy from the zonal flow.

1. Introduction

The southwest monsoon rainfall over India fluctuates in its intensity and spatial distributions. There are periods of strong and break monsoon characterised by contrasting rainfall distributions and associated synoptic situations. The position and intensity of monsoon trough has strong influence on the rainfall distribution and decides strong or break monsoon conditions. In break monsoon, rainfall is confined to sub-montane districts of Himalayas, northeast India, and southeastern Peninsular India and rest of India gets very less rainfall. In contrast, in strong monsoon, rainfall is confined over India outside the regions where it rains in break monsoon. In strong monsoon, the monsoon trough is south of the normal position and is active and in break monsoon, the monsoon trough is north of the normal position near the foot hills of Himalayas, apart from the other associated synoptic features. During break monsoon, the axis of the monsoon trough lies close to the foot of the Himalayas or in some cases, not seen at all in the surface chart. If this situation continues for two days or more, it is observed most frequently, that, a secondary trough forms over Peninsular India along latitude 13°N and there is a reversal of north-south temperature gradient over India as compared to the strong monsoon situations. This will influence the energy parameters and energy conversions. Energetics of such a contrasting synoptic situation in break and strong monsoon will help in comparing the magnitudes of the energy terms and understanding the energy conversions taking place.

2. Computation of energetics and discussion

Synoptic weather situation at 1200 GMT of 25 July 1972 representing typical break monsoon situation and at 1200 GMT of 5 July 1977, representing typical strong monsoon situation were selected on the basis of rainfall distribution and typical synoptic situations. Contour charts for 1000 mb, 850 mb, 700 mb, 500 mb and 200 mb levels for these two days are prepared and analysed. The grid point values of geopotential height at every 5-degree latitude-longitude grid were picked out over the region from 45° E to 105°E and 5°N to 30°N. All the energy terms and their conversions were calculated from these data based on geostrophic assumption.

The geostrophic wind components U and V have been calculated from the geopotential heights using the Eqns. (1) and (2) and zonal kinetic energy (K_Z) and eddy kinetic energy (K_E) have been calculated using Eqns. (3) and (4).

$$U = -\frac{g}{f}\frac{\partial Z}{\partial y} \tag{1}$$

$$V = \frac{g}{f}\frac{\partial Z}{\partial x} \tag{2}$$

$$K_Z = \frac{1}{2}\int_M \left(\left[\,U\,\right]^2 + \left[\,V\,\right]^2\right) dM \tag{3}$$

TABLE 1

Energy terms (KJM^{-2}) and conversion terms ($10^{-2}\ JM^{-2}\ sec^{-1}$)

S. No.	Term	Strong monsoon day (5 July 1977)			Break monsoon day (25 July 1972)		
		1000-500 mb	500-200 mb	1000-200 mb	1000-500 mb	500-200 mb	1000-200 mb
1	A_Z	1241.6	1284.1	2525.7	1477.3	1361.6	2838.9
2	A_E	22.8	6.9	29.7	19.2	15.4	34.6
3	K_Z	103.1	340.2	443.3	208.0	346.7	554.7
4	K_E	196.3	97.1	293.4	161.9	75.9	237.8
5	$C(A_Z, A_E)$	15.1	4.5	19.6	5.8	5.6	11.4
6	$C(A_E, K_E)$	13.3	8.8	22.1	5.3	8.5	13.8
7	$C(K_Z, K_E)$	24.7	9.5	34.2	−18.1	−8.6	−26.7
8	$C(A_Z, K_Z)$	31.2	16.3	47.5	9.1	17.2	26.3

$$K_E=\frac{1}{2}\int_M\left(\left[U^{*2}\right]+\left[V^{*2}\right]\right)dM \qquad (4)$$

where g = Acceleration due to gravity, f = Coriolis parameter, [ ] = Zonal mean, M = Mass of the atmosphere between two pressure levels, $U^* = U - [U]$, $V^* = V - [V]$.

An expression for the total available potential energy as given by Wiin Nielsen (1968) is given in Eqn. (5) :

$$A=\int_M \frac{1}{2\tilde{\sigma}}\left(\frac{\partial\varphi}{\partial p}-\frac{\partial\tilde{\varphi}}{\partial p}\right)^2 \qquad (5)$$

The Eqn. (5) can be resolved into zonal (A_Z) and eddy (A_E) components of total available potential energy as in Eqns. (6) and (7) :

$$A_Z=\int_M \frac{1}{2\tilde{\sigma}}\left(\frac{\partial[\varphi]}{\partial p}-\frac{\partial\tilde{\varphi}}{\partial p}\right)^2 \qquad (6)$$

$$A_E=\int_M \frac{1}{2\tilde{\sigma}}\left(\frac{\partial\varphi}{\partial p}-\frac{\partial[\varphi]}{\partial p}\right)^2 \qquad (7)$$

where M = Mass of the atmosphere from 1000 mb to 200 mb over the area under study, σ = Static stability parameter $= -\alpha\frac{\partial}{\partial p}(\ln\theta)$, α = Specific volume, θ = Potential temperature, $\tilde{\sigma} = -\tilde{\alpha}\frac{\partial}{\partial p}(\ln\tilde{\theta})$, φ = Geopotential, $(\sim)$ = Hemispherical mean, [ ] = Zonal mean. $\tilde{\varphi}$ and $\tilde{\sigma}$ have been calculated using upper air data for all stations over northern hemisphere. The zonal and eddy available potential energy have been calculated using Eqns. (6) and (7).

The details of energetics of the atmosphere are given by Lorenz (1967) and Rajamani (1978). The expressions for energy conversion as derived by Oort (1964) after simplifying and neglecting small order terms have been used here. Oort (1964) derived these equations, using basic equations of motion and thermodynamic energy equations. The notation $C(X_1\ X_2)$ represents the energy conversion from X_1 to X_2 The Eqns. (8)-(11) have been used for calculating energy conversion terms.

$$C\left(A_Z, K_Z\right) = -\int_M [\omega]''[\alpha]''\, dM \qquad (8)$$

$$C\left(A_E, K_E\right) = -\int_M [\omega^*\alpha^*]\, dM \qquad (9)$$

$$C\left(A_Z, A_E\right) = -c_p\int_M \gamma\,[v^*T^*]\,\frac{\partial[T]}{a\,\partial A}\, dM \qquad (10)$$

$$C\left(K_E, K_Z\right) = \int_M [u^*v^*]\cos A\,\frac{\partial}{a\,\partial A}\left(\frac{[u]}{\cos A}\right)dM \qquad (11)$$

where, A = Latitude, ω = Vertical velocity, α = Specific volume.

a = Radius of the earth, $\omega^*=\omega-[\omega]$, $\alpha^*=\alpha-[\alpha]$ $T^*=T-[T]$,

$[\ ]''$ = Deviation of the zonal mean from hemispherical mean,

$$\gamma = -\left(\frac{\theta}{T}\right)\frac{R}{c_p\,p}\left(\frac{\partial\tilde{\varphi}}{\partial p}\right)^{-1}.$$

θ = Potential temperature, c_p = Specific heat at constant pressure and R = Gas constant for dry air.

The vertical velocity has been calculated by using equation of continuity in pressure co-ordinate system with the assumption that $\omega = 0$ at 1000 mb and 200 mb. All the energy terms and conversion terms were calculated for layers 1000-850 mb, 850-700 mb, 700-500 mb and 500-200 mb and for the entire layer 1000-200 mb. The energy terms and conversion terms for break monsoon and strong monsoon day have been given in Table 1. The energy terms have been expressed in KJM^{-2} and conversion terms in 10^{-2} JM^{-2} sec^{-1}.

The values of A_Z, A_E and K_Z are more on break monsoon day than the strong monsoon day. This is an agreement with the prevailing synoptic situation where in break monsoon, the winds are mainly westerlies upto 500 mb level and the axis of monsoon trough is absent (or to the foot hills of Himalayas) in lower levels. The value of K_E is more on strong monsoon day as the monsoon trough is active in the surface with an embedded low pressure area in it.

On strong monsoon day, $C(A_Z, A_E)$ is positive and more and also $C(K_Z, K_E)$ and sum of these two is positive and more. This means that the eddies receive energy from the zonal flow and intensify. That is the monsoon trough being active during strong monsoon and receiving energy from the zonal flow remains active and circulations/lows form over this trough. On this strong monsoon day eddy gained energy of the order of 53.8 KJM^{-2} from the zonal flow. Thus, eddy gains energy from the zonal flow on strong monsoon day, the atmosphere is barotropically unstable.

On break monsoon day, $C(A_Z, A_E)$ is less and positive and also $C(K_Z, K_E)$ is less but is negative. The sum of $C(A_Z, A_E)$ and $C(K_Z, K_E)$ is negative. This means that eddies, instead of receiving energy from zonal flow, lose energy to the zonal flow. In other words, the zonal flow receives energy from the eddy flow and strengthen in break monsoon period. On this break monsoon day, eddies lost energy to the zonal flow of the order of 15.3 KJM^{-2}. Thus, the eddy loses energy to the zonal flow in break monsoon and the atmosphere is barotropically stable.

When we examine the magnitudes of energy terms and energy conversion terms in the lower troposphere (1000-500 mb) and upper troposphere (500-200 mb) in Table 1, we find tentatively the following :

(*a*) In the lower troposphere (1000-500 mb) magnitude of A_E, K_E are more in magnitudes and that of K_Z is less on both the days.

(*b*) In the lower troposphere all energy conversion terms are more on strong monsoon day and are less on break monsoon day except $C(A_Z, A_E)$ which is marginal.

3. Conclusions

In break monsoon, atmosphere is barotropically stable as eddy flow loses energy to the zonal flow and in strong monsoon, atmosphere is barotropically unstable as eddy flow gains energy from the zonal flow.

Acknowledgement

The author is thankful to Dr. G.C. Asnani for useful discussion and his constant encouragement. He is also thankful to Shri N. B. Thade for his help in collecting data and Mr. R. K. Nayar for typing the manuscript.

References

Lorenz, E.N., 1967, 'The nature and theory of General Circulation of the atmosphere', Geneva, WMO., Note 218, Chapt. V, pp. 97-113

Oort, A.H., 1964, 'On estimates of the atmospheric energy cycle', *Mon. Weath. Rev.*, **92**, pp. 433-443.

Rajamani, S., 1978, Ph D. thesis of University of Pune, Chapts., I & II, pp. 2-111.

Wiin-Nielsen, A., 1968, 'On the intensity of the general circulation of the atmosphere', *Rev. Geophys.*, **16**, pp. 559-579.