SHORTER CONTRIBUTION

Dynamic instability of the zonal current during a break monsoon

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Indian summer monsoon is characterised by periods of weak and strong monsoon activity. A particular example of the weak monsoon case is the so-called "break monsoon" situation. During the break the rainfall is mainly concentrated near the foot of the Himalayas and over western ghats and the remaining parts of the country experience little or no precipitation. If this type of situation continues for a long time almost all parts of the country suffer from below normal rainfall and is considered to be a calamity. This will not normally happen. Generally, a disturbance develops over the head of Bay of Bengal after a few days of break and monsoon revives to its normal activity. Thus, the break situation is shortlived and leads to the formation of disturbances. This suggests the existence of some sort of instability mechanism during a break situation.

It has been earlier shown by the author (Brahmananda Rao, 1968) that baroclinic instability does not exist in a normal monsoon situation. Even during a break the situation is not expected to be different because the vertical distribution of the zonal wind and static stability will not be different from that of the normal monsoon case. However, major changes occur in the horizontal distribution of the zonal wind during a break. There is a southward shift of the subtropical westerlies and easterlies north of the easterly jet strengthen. In some cases the easterly jet occupies a more northerly position (Koteswaram, 1958). This suggests the possi bility of barotropic instability.

Representing the mean zonal wind current U by

$$U = -c \cos 2 \text{ ly} \tag{1}$$

and the perturbation stream function ψ, by

$$\psi = a \sin \text{ly} \cos kx \tag{2}$$

the expression for the time change of perturbation kinetic energy at the initial time is given by Rao (1968) as

$$\left(\frac{\partial^2 K}{\partial t^2}\right)_0 = \frac{kc^2 a^2 \pi^2 D}{k^2 D^2 + \pi^2}\left(\frac{3\pi^2}{D^2} - k^2\right) \tag{3}$$

In expressions (1), (2) and (3), $K = \int (u^2 + v^2)/2 \, dm$, dm is the mass of an element of the atmosphere, $l = \pi / D$ and D is the channel width, K is the wave number given by $k = 2\pi / L$ where L is the wavelength. c and a are constants. It can be seen from (3) that $L = 2D/\sqrt{3}$ is the neutral wavelength (for which $(\partial^2 K/\partial t^2)_0 = 0$). Thus all waves longer than $2D/\sqrt{3}$ are unstable (i.e. $(\partial^2 K/\partial t^2)_0 > 0$) and all waves shorter than $2D/\sqrt{3}$ are stable (i.e. $(\partial^2 K/\partial t^2)_0 < 0$). This criterion is essentially the same as the one derived by Kuo (1953) and Syono & Aihara (1957).

Based on the observations of Starr & White (1954), Aihara (1959) has suggested a value of 12 000 km for D for the mean state of the atmosphere. Thus only disturbances of wavelengths larger than 13 000 km will become unstable. Since the instability occurs only in disturbances of very long wavelengths, Aihara arrived at the result that barotropic instability seldom occurs in the normal state of the atmosphere.

However, when a sharp jet concentrates over a narrow zone i.e. if D decreases considerably barotropic instability becomes important. This type of situation exists during a break monsoon.

The case selected for the study is the one which was observationally studied by Ramaswamy (1962). On August 3rd, 1957, the monsoon with associated rainfall was normal. From 4th to 7th there was a break accompanied with the usual cessation of rainfall over the country except near the foot of the Himalayas and over western ghats. On 7th a shallow depression for-

med over the head of the Bay of Bengal and by 10th the monsoon regained its normal activity.

Coming to the distribution of the zonal current, the distance between the easterly and westerly jet cores is about 35 degrees of latitude before the break on 3rd August and about 27 degrees of latitude after the break on 10th. During the break there is a remarkable extension of middle and upper troposphere westerlies equator ward and there is a strengthening of easterlies north of the easterly jet core. The latitudinal distance between easterly and westerly jet cores is about 12 degrees of latitude only!

Taking the distance between the easterly and westerly jet cores as $D/2$ we see before and after the break there is only a slight increase of instability (in the sense that the domain of instability is shifted towards shorter waves) as compared to the normal situation discussed in the previous paragraphs. But during the break the increase of instability is very predominant, waves shorter than 3 000 km are only stable and above this wavelength all disturbances are becoming unstable! On August 7th we actually notice the formation of a depression as described earlier.

Though in other break situations the distance between the westerly and easterly jets vary, similar decrease is a general feature. Thus the atmosphere is generally very unstable barotropically during a break monsoon. In many cases the revival of the monsoon after the break is accompanied by the formation of disturbances. The nearing of easterlies and westerly streams during a break monsoon and then moving apart during the normal monsoon is not unlike the barotropic phenomenon studied numerically by Arakawa (1961).

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