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EFFECT OF VERTICAL WIND SHEAR ON RAINFALL AT POONA DURING SOUTHWEST MONSOON

An objective method of forecasting rain at Poona during southwest monsoon has been suggested in a recent note by Rao (1955). Two parameters—the difference between the sea level pressures at Honavar and Bombay (A) and the difference between the one gpkm pressures at Mahabaleshwar and Poona (B) are taken and the criteria obtained are—

If $A > B$, greater chances of rain.
If $A < B$, chances of rain small.

Though providing a helpful method for the local forecasting, the author (Rao 1955) has not mentioned anything by way of explaining the result. The object of this note is to suggest an explanation in the light of the 'Theory of air flow over mountains'.

Before giving the explanation, the second parameter used by Rao—pressure differences at one gpkm between Poona and Mahabaleshwar—has to be rejected as physically unrepresentative. The distance between Bombay and Honavar is five times that between Poona and Mahabaleshwar. It appears impossible that the pressure gradient at one gpkm level can be five times that at sea level on many occasions as would be required if B is greater than A. A more physically representative parameter was, however, obtained by considering Gadag pressure reduced to one gpkm instead of Mahabaleshwar pressure. The anomaly in Rao's parameter B is probably arising from the fact that one gpkm level is higher than Poona station level but lower than that of Mahabaleshwar. Both Gadag and Poona are approximately at the same elevation. Table 1 gives a comparison of the results obtained with Gadag and Rao's results. (The monsoon season of the year 1953, *i.e.*, the period 15 June to 30 September, has been examined. Only days with ten cents or more have been taken as rainy days and no discrimination made for cyclonic circulation over Kutch and Kathiawar or over head Bay of Bengal). The

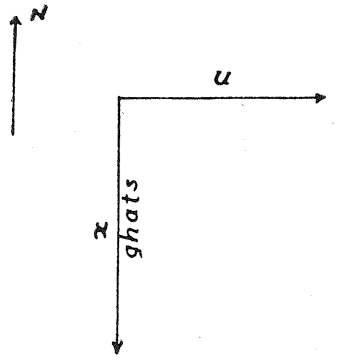
TABLE 1

Total No. of days	No. of successes taking 1 gpkm Mahabaleshwar pressure	No. of successes taking 1 gpkm Gadag pressure
108	81	79

explanation given hereafter, has, therefore, been developed with reference to one gpkm pressure difference between Gadag and Poona.

It has been known that an air stream flowing across a mountain ridge is greatly affected and is modified by the presence of the ridge. Depending upon the wind and temperature variation in the vertical, the effect in general is either to produce an organised deformation of the air stream giving rise to what are termed 'lee waves' or to make the flow chaotic producing turbulence. It can be shown (Scorer 1953, 1954) that for a stable air stream the criterion for the formation of lee waves reduces to the requirement for a strong forward wind shear. With identical temperature distribution, if a reverse wind shear is present, the steady laminar flow breaks down and a completely disorganised flow pattern is obtained. Forchtgott's (1949) field studies reveal the presence of heavy turbulence on such occasions.

During the southwest monsoon a deep westerly stream blows across the Ghats. The air is generally in the condition of neutral stability for saturated air and there are no large discontinuities in the lapse rate through a considerable depth. With a forward wind shear lee waves can be expected but their amplitude may not be sufficient (unless the shear is very marked) to give vertical velocities high enough to have any significant effect on rainfall. Furthermore, the effect of the irregular mountainous terrain would be to smooth out the waves. On the other hand when a reverse wind shear is present the turbulence generated may reach considerable heights creating favourable conditions for increase in rainfall. Thus, criteria for increase or decrease of rain



on the lee side of the Ghats may be put as—

Forward wind shear, *i.e.*,

$$\frac{\partial u}{\partial z} > 0 \quad : \quad \text{decrease in rain.}$$

Reverse wind shear, *i.e.*,

$$\frac{\partial u}{\partial z} < 0 \quad : \quad \text{increase in rain.}$$

We may consider the pressure difference between the two coastal places as representative of the conditions at sea level. Similarly the one gpkm pressure difference between the stations to the east of the Ghats may be taken as representative of the conditions of one gpkm. The winds are generally westerly in the southwest monsoon and pressure decreases to the north at both the levels. The pressure differences mentioned earlier are obtained by subtracting the pressure at the northern station from that in the south, so that the quantities are positive.

Let p denote pressure and x distance parallel to the Ghats (Fig. 1). Primed quantities refer to a height z and unprimed to sea level. If $\triangle p$ is the pressure difference between stations at a distance x (coastal stations) and $\triangle p'$ at a distance x' (stations to the east of Ghats)

$$\triangle p = \frac{\partial p}{\partial x} x \quad \text{and} \quad \triangle p' = \frac{\partial p'}{\partial x} x'$$

$$\therefore \triangle p - \triangle p' = \frac{\partial p}{\partial x} x - \frac{\partial p'}{\partial x} x'$$

If u and u' are the winds normal to hill range at sea level and at the height z respectively, then

$$u = k \frac{\partial p}{\partial x} \text{ and } u' = k' \frac{\partial p'}{\partial x}$$

The difference between k and k' arising out of density variation will be very small and may be neglected for practical purposes in this case. Hence $k \approx k'$ and

$$\triangle p - \triangle p' = \frac{1}{k}(ux - u'x')$$

In the cases chosen, *i.e.*, Poona and Gadag at one gpkm level and Bombay and Honavar at sea level, $x \approx x'$.

$$\therefore \triangle p - \triangle p' \approx \frac{x}{k}(u - u')$$

$$\frac{\partial u}{\partial z} = \frac{u' - u}{z} \approx \frac{k}{xz}(\triangle p' - \triangle p)$$

For the west wind taken as positive in this co-ordinate system k is positive. Hence

$$\frac{\partial u}{\partial z} > 0 \quad \text{when } \triangle p' > \triangle p$$

and $$\frac{\partial u}{\partial z} < 0 \quad \text{when } \triangle p' < \triangle p$$

It, therefore, follows that when the pressure difference between Gadag and Poona is less than that between Honavar and Bombay there should be increase of rain and *vice versa*.

It may be seen that the condition A—B=0 corresponds to the case of uniform air stream, *i.e.*, $\partial u/\partial z = 0$. Under such conditions the air stream remains undisturbed except just over the ridge itself and rainfall on the lee side will be governed solely by factors other than the effect on the mountain ridge.

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February 9, 1956.

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