PRECIPITATION ON MOUNTAIN SLOPES.

By S. K. BANERJI, *O.B.E., D.Sc., Director-General of Observatories, India Meteorological Department, New Delhi.*

Pockels (1901) has computed the rainfall distribution on mountain slopes. The mountain profile is represented by

$$\eta = C \sin mx\, e^{-r\eta},$$

where—

x is the horizontal distance measured normal to the mountain-range,

η gives the height of the mountain profile,

$m = \frac{\pi}{\lambda}$, λ being the horizontal distance between the centre of the valley and the summit of the mountain,

$r = \sqrt{m^2+q^2/4}$,

q being a constant equal to 1/8000. C determines the height of the range. The values of C and m are so chosen that the equation roughly represents the profile of the particular mountain.

Correspondingly, the vertical velocity (v) of the wind is given by the expression,

$$v = Cam \cos mx\, e^{-nY},$$

where Y is the vertical co-ordinate.

The constant a is related to the horizontal velocity of wind (u) by the expression

$$u = a(1+C\frac{m^2}{n} \sin mx\, e^{-nY}).$$

We also have

$$n = -\frac{q}{2}+r.$$

The rate of precipitation (W) is given by

$$W = -\int_{Y^0}^{Y'} v\epsilon F'(Y)\, dY,$$

ϵ being the air density.

$F(Y)$ is the specific humidity of saturated air at the altitude Y.

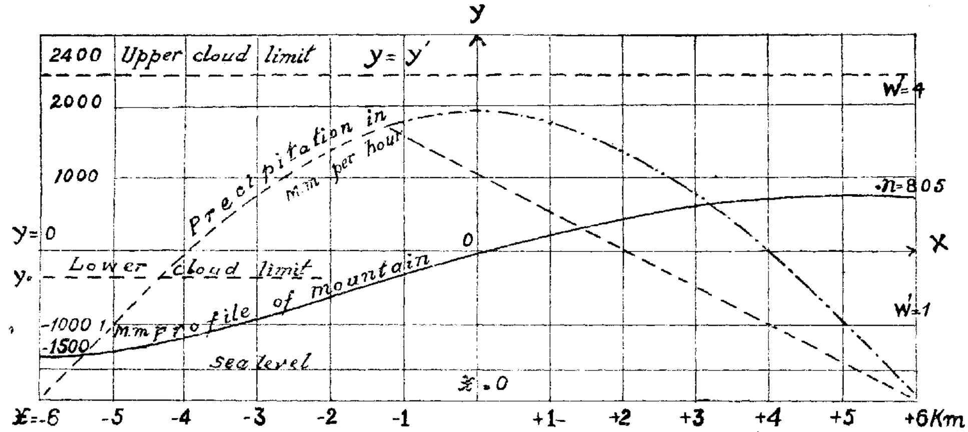
Y^0 and Y' are respectively the heights of the cloud base and cloud top.

In computing the rate of precipitation Pockels assumes that the products of condensation simply fall vertically without being carried along by the horizontal current of air. The diagram on the next page shows the variation in the precipitation rate along a mountain slope for a case computed by Pockels.

In applying Pockels's theory to the Satpura range, the following values have been used :—

Horizontal distance from the valley to the summit (λ) = 80 kms.

The present height of the top of the range, above the centre of the valley is taken as 800 metres or 2,600 feet. The corresponding value of C is 400 metres. (The hill



tops of the Satpuras are about 3,600 feet above sea-level and the surrounding valley is about 1,000 feet above sea-level. Hence the hill tops are 2,600 feet above the valley level). The monsoon air is taken as having an average temperature of 80°F. and relative humidity of 80%. The amount of precipitation depends on the thickness of the cloud layer. The monsoon clouds may be taken to have the base at 400 metres and the top at 4,000 metres or 5,000 metres depending on the region under examination and state of the monsoon. Assuming that the cloud base is at 400 metres and cloud top at 4,000 metres above the valley, the maximum rate of precipitation (W_1) for the above conditions, is found to be $10a/g$, where g is the acceleration due to gravity. This will be at a height of about 2,400 feet above sea-level. Judging from the existing observatories it appears that the highest normal value of the monsoon rain on the Satpuras is 70″ which occurs at Pachmarhi, its height above sea-level being 3,528 feet. If we assume that 70″ determines the maximum rate of rainfall on this mountain slope during the monsoon period which we call W_1, we get

$$10a/g \propto 70 \quad \text{or} \quad 10ak/g = 70 \quad \text{or} \quad \frac{ak}{g} = 7$$

where k is a constant.

It may reasonably be assumed that the value of a depends only on the general airflow and will not be affected by any limited changes in the height of the range. a can therefore be regarded as a constant.

The equation $\frac{ak}{g} = 7$ can thus be used for computing the likely monsoon rainfall when the height of the range is altered.

By similar computation, it is found that when $C = 800$ metres, i.e. when the height of the range is 5,300 feet above the valley or 6,300 feet above sea-level, the maximum rate of precipitation is 30 a/g. The cloud top is now taken as at about 5,000 metres. The corresponding monsoon rainfall will be 22 $\frac{ak}{g}$. Substituting $\frac{ak}{g} = 7$, we get the total monsoon rainfall as 154″. Thus, if the Satpuras are about 6,000 feet high above sea-level, the monsoon rainfall is likely to be about 150″ at a height of 4,000 feet above sea-level on the hill slopes.

When $C = 1,100$ metres, i.e. when the height of the range is 7,300 feet above the valley or 8,300 feet above sea-level, the maximum rate of precipitation is 27 a/g.

The cloud top is again taken as at 7,000 metres above the valley. The corresponding monsoon rainfall will be $27\,\frac{ak}{g} = 27 \times 7 = 189$.

If the Satpuras are of a height of about 8,000 feet above sea-level, the monsoon rainfall is likely to be about 200″ at a height of 5,000 feet above sea-level on the hill slopes. We thus get the following results:—

Height.	*Rainfall.*
For the present height of 3,600′ a.s.l.	70″
If the height is 6,000′ a.s.l.	150″
If the height is 8,000′ a.s.l.	200″

Therefore, if the height of the Satpura range be extended to 8,000 feet, one could expect on theoretical consideration a maximum possible precipitation of 200″ per annum. Taking this to represent roughly the average rainfall over Western Ghats, it would appear that the Satpura range will have to be raised to about 8,000′ to get this precipitation.

The above values should be regarded as indicating orders of magnitude only. These are the maximum possible values given by theory. In practice, the whole of it may not be realized, although a large part of it will be realized. The rainfall in other than monsoon months is small in this area and the values of monsoon rainfall given here may be taken to be very nearly equal to the annual rainfall.

Reference.

Pockels, F. (1901). The theory of formation of precipitation on Mountain Slopes, *Ann. d. Physik*, (4) **4**, 459–480.