

Accuracy of precipitation network in different geophysical regions in India

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सार — किसी भी प्रकार के जल मौसम विज्ञान संबंधी अध्ययन के लिए यह अनिवार्य है कि विशेष उद्देश्य, जिसके लिए ऐसे अभिकल्पों का ध्यान रखा जाता है, को प्रभावित करने वाले विभिन्न लक्षणों पर विचार करते हुए वर्षा स्टेशन के संजाल के लिए श्रेष्ठ अभिकल्प का निर्धारण किया जाए। इस शोधपत्र में विश्व मौसम संगठन द्वारा निर्धारित मानक की तुलना में सामान्य क्षेत्रीय वर्षण के आकलन के लिए अभिकल्पित वर्षण संजाल के अनुपाती यथार्थता को निर्धारित करने का प्रयास किया गया है। यह प्रेक्षित किया गया है कि प्रस्तावित संजाल, उस उद्देश्य जिसके लिए यह अभिकल्पित किया गया है, के मामले में पूर्ण रूप से सही है।

ABSTRACT. For any type of hydrometeorological studies it is imperative that an optimum design of network of raingauge stations is determined taking into consideration various factors influencing specific purpose for which such designs are envisaged. In the present paper an attempt has been made to determine the relative accuracy of the precipitation network designed for estimation of normal areal precipitation in comparison to the standard prescribed by World Meteorological Organisation. It is observed that in the present case the proposed network is fairly accurate for the purpose for which it has been designed.

Key words — Precipitation network, Areal rainfall, Mean correlation, Error in precipitation estimation

1. Introduction

India has an area of about 3.28 million sq km. This comprises various types of humid zones classified by Thornthwaite (1948). Consequently for any type of hydrometeorological or agricultural planning involving water management, it is imperative that an optimum design of network of stations for meteorological observations is determined taking into consideration all the factors influencing specific purpose for which such designs are envisaged. It will be appreciated that what are observed in such cases are point precipitation whereas the input used for hydrometeorological studies is areal precipitation which is an estimated parameter. It is obvious that the accuracy of observed phenomena will vary from the accuracy of estimation made from these phenomena since the nature of areal representation of observed phenomena, point precipitation in this particular case, is not very clearly understood. Miller (1977) observed "areal rainfall is less easily measured than is point rainfall. The hope that was raised in 1945, that one radar set located on a ridge near the centre of a mountainous drainage basin would read out the integrated input of atmospheric water into any sub-basin or into the whole basin itself is slow in coming". The situation in this regard has not improved substantially

till now and the importance of an optimum precipitation network design for estimation of areal rainfall for various purposes remains undiminished. In this paper an attempt has been made to determine the level of accuracy attainable with the present network in comparison to international standard prescribed by World Meteorological Organisation for different types of region.

2. Methodology

In case of long term rainfall process, the long term mean rainfall over an area may be expressed as

$$\bar{P} = \frac{1}{AT} \sum_{t=0}^T \int_A P(x,y,t) dA,$$

where $P(x,y,t)$ is the point rainfall of duration t .

This is estimated by rainfall data of n observing stations in the area A for a period of T years and is given by

$$\bar{P} = \frac{1}{nT} \sum_{i=1}^n \sum_{t=0}^T P_{it}$$

TABLE 1

Comparative study of rainfall distribution meteorological sub-divisionwise & districtwise

| Year | Sub-divisions with excess/normal rainfall | | Districts within sub-divisions given in col. (2) having rainfall less than 0.75 of normal rainfall | | Area (%) |
|------|---|-------------------------|--|-------------------------|----------|
| | No. | Area (km ²) | No. | Area (km ²) | |
| | | | | | |
| 1985 | 16 | 1775987 | 38 | 279164 | 16 |
| 1986 | 16 | 1940629 | 45 | 457462 | 23 |
| 1987 | 6 | 681719 | 26 | 197112 | 29 |
| 1988 | 9 | 1104902 | 16 | 114662 | 10 |

where, P_{it} is the rainfall of i th recording station in t th period of time.

Rodriguez-Iturbe & Mejia (1974) has given the variance of estimate of \bar{P} as

$$V\left(\frac{\Delta}{\bar{P}}\right) = \sigma_p^2 \phi(T, \rho) \Psi(n, r)$$

$$\text{where } \phi(T, \rho) = \frac{1}{T} \cdot \frac{1+\rho}{1-\rho}$$

$$\Psi(n, r) = \frac{1+(n-1)r}{n}$$

σ_p = Standard deviation for precipitation

\bar{r} = Mean correlation in the area A

ρ = First auto-correlation coefficient

The error in estimation of \bar{P} is given by

$$e = \frac{\sqrt{V(\bar{P})}}{\bar{P}} = \frac{\sigma_p}{\bar{P}} \sqrt{\frac{1}{T} \cdot \frac{1+\rho}{1-\rho} \cdot \frac{1+(n-1)r}{n}}$$

$$= CV \sqrt{\frac{1}{T} \cdot \frac{1+\rho}{1-\rho} \cdot \frac{1+(n-1)r}{n}}$$

where, CV is coefficient of variation of precipitation.

3. Analysis

As indicated earlier, the accuracy of estimation of areal rainfall is directly proportional to the number of

TABLE 2

Percentage error in computation of areal rainfall

| State | Area (km ²) | Mean corr. (\bar{r}) | Expected No. of stations in the network as per WMO criteria (n') | Actual No. of stns. in precipitation network (n) | Coeff. of variation (CV) | Percentage error(e) | |
|------------------|-------------------------|--------------------------|--|--|--------------------------|-------------------------|--------------|
| | | | | | | corr. to n' | corr. to n |
| Orissa | 155782 | 0.60 | 210 | 94 | 20.3 | 3.71 | 3.72 |
| Rajasthan | 342214 | 0.45 | 228 | 138 | 43.9 | 6.96 | 6.97 |
| Himachal Pradesh | 55673 | 0.26 | 165 | 47 | 21.2 | 1.99 | 2.03 |

gauges in the network of stations in the region. This type of variation in accuracy is also observed when the basic unit of area for which this estimation is made is also varied. This can be clearly seen in case of consideration of area affected by meteorological drought in the country. Though meteorological drought is largely based on rainfall departure and/or aridity anomaly, it is basically presumed that a minimum area is also included in this definition. Hence, the conclusion based on meteorological sub-divisionwise chart and that based on meteorological districtwise chart are likely to defer. For this purpose five years (1984-1988), districtwise rainfall data were analysed for a sample study. The results are given in Table 1.

It may be seen from the table that during this period there were 66 such cases when the distribution (excess or normal) of rainfall estimated on meteorological sub-division basis differed from that estimated on meteorological district basis. The amount of area involved varied from 10% in 1988 to 29% in 1987. Presuming 20% of the area to be accepted for variation there were three years, i.e., 1984, 1986 and 1987 when the variation which were 22%, 23% and 29% to be re-assessed. This again demonstrates that smaller the basic area for which areal estimates are made, greater is the accuracy of the result obtained therefrom. World Meteorological Organization (1983) has recommended minimum density of rain gauges for determination of areal rainfall in different region.

For the present study, in consonance with WMO criterion, three States in India having typical geophysical features were selected. These are —

- (a) Orissa — which is a flat area in tropical zone,
- (b) Rajasthan — which is in arid zone and
- (c) Himachal Pradesh — which is in mountain areas in tropical zone.

As stated earlier a denser network of raingauges about two thousand five hundred stations spread over the country according to meteorological and geophysical conditions for monitoring districtwise rainfall statistics on a realtime basis has been identified. In this network there are 94, 138 and 47 raingauge stations in Orissa, Rajasthan and Himachal Pradesh respectively. An attempt has been made to assess the accuracy of these networks and compare the result with those recommended by WMO. For this purpose error in areal rainfall estimation from the network was computed from the formula

$$e = CV \sqrt{\frac{1}{T} \cdot \frac{1+\rho}{1-\rho} \cdot \frac{1+(n-1)\bar{r}}{n}}$$

where,

T = Period of data for 30 years

n = Number of raingauge stations in the network

ρ = First auto-correlation coefficient (0.25 for Orissa and Rajasthan, 0 for Himachal Pradesh)

Upadhyay *et al.* (1990) have computed the mean correlation coefficient \bar{r} for all the states in the country. Values of \bar{r} for Orissa, Rajasthan and Himachal Pradesh were obtained therefrom and utilised for determining 'e'. The results of computation are given in Table 2.

From Table 2 it will be seen that though the density of raingauge stations in the country is different from that prescribed by WMO, the error involved in these two different networks are not significantly different. This is due to the effect of other two factors, *e.g.*, \bar{r} and ρ utilised in the computation of 'e'. The increase in 'e' due to variation of n is compensated by decrease in 'e' due to the influence of \bar{r} and ρ on 'e'.

The above analysis demonstrates that the raingauge stations in the proposed precipitation network when activated will meet the requirement of project for which it has been designed.

4. Conclusions

(i) Proper location and re-adjustment of gauges in precipitation network can reduce the number of gauges required for estimation of normal areal rainfall over the region.

(ii) Smaller the basic area for which areal rainfall estimates are computed, greater is the accuracy of results obtained therefrom.

(iii) Precipitation network designed for estimation of normal areal rainfall for the purpose of monitoring districtwise rainfall statistics meets the requirement of the project for which it has been envisaged.

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