# Efficiency of Severe Recorded Rainstorms over Maharashtra State

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ABSTRACT

12 severe rainstorms have been experienced by different meteorological sub-divisions of Maharashtra State during the last 100-year period from 1891-1990. For each of the rainstorms efficiency factors (i.e. P / M ratios) were worked out for maximum one-day duration and for three standard areas of 1000, 5000, and 10,000 km$^2$. Comparison of these ratios with the past has shown that the most efficient rainstorm over Maharashtra was the rainstorm of June, 1908 over the Vidarbha region whose full DAD data as well as isohyetal pattern have been given.

**Key words:** Rainstorm, Depth-area -duration (DAD), Efficiency factor of rainstorms, Probable Maximum Precipitation (PMP)

## I. INTRODUCTION

Over a plain area, besides maximum moisture contents in the inflowing winds, rainfall in an intense rainstorms mainly results from optimum combination of the following factors: i) Convergence, ii) Vertical velocities and iii) Condensation into cloud particles. These factors collectively are termed as rainstorm efficiency (Miller, 1969). Even today there are no satisfactory methods available to estimate these factors. However, maximum moisture content over an area can be estimated from a study of appropriate climatological data of the region (WMO, 1969 and Miller, 1969).

An indirect approach has been made to estimate rainstorm efficiency based upon the observed rates of rainfall in a rainstorm over a non-orographic region.Wiesner (1970) used this approach to work out efficiencies of several USA rainstorms. Dhar et al (1973, 1984, 1987) have used this approach to work out storm efficiencies of intense rainstorms of India.

In this study an attempt has been made to estimate the storm efficiency factors of the severe rainstorms which have occurred during last 100 yaers (1891-1990) over different meteorological sub-divisions of Maharashtra state.

## II. SEVERE RAINSTORMS OF MAHARASHTRA

On the basis of daily rainfall data of about 350 stations located in and around the Maharashtra state, Dhar et al (1989) and Kulkarni (1991) estimated that the state experienced about 12 severe rainstorms during the last 100-year period from 1891 to 1990. They have analyzed these severe rainstorms by Depth-Area-Duration (DAD) method (WMO, 1986; IMD Manual, 1972) and obtained maximum average raindepths for 1 to 3-day durations. Fig. 1 shows the locations of heavy rain centers of these 12 severe rainstorms. It can be seen from this figure that most of the rain centers are located in and near Vidarbha sub-division of Maharashtra. Normally, this sub-division falls in the south-western sector of cyclonic disturbances, which after originating from the Bay of Bengal during the monsoon months of

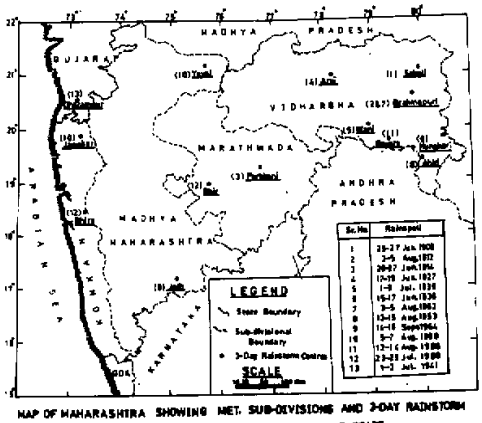


Fig. 1. The locations of heavy rain centers of 12 severe rainstorms.

June to September, travel in a northwesterly to westerly direction over the central parts of the country. As such, heavy to very heavy rainfall occur in this region with the passage of these moving tropical disturbances.

It may however, be mentioned that in this study only those rainstorms were considered whose heavy rain centers were located in Maharashtra state although their associated isohyetal patterns may have extended over the neighbouring states. In order to estimate efficiencies of these severe rainstorms maximum one–day DAD raindepths have been considered for different standard areas of 1000, 5000 and 10,000 km$^2$.

## III. EFFICIENCY FACTORS FOR THE SEVERE RAINSTORMS OF MAHARASHTRA

The efficiency ($E$) of a rainstorm is defined as the ratio of observed rainfall ($P$) in a rainstorm over a given area to the precipitable water ($M$) present in the moist air over the storm area during a given duration. In other words, efficiency ($E$) of a rainstorm is

$$E = P / M \ , \tag{1}$$

$P / M$ ratio is thus, an index of the dynamic processes which take place in a storm to convert water vapour present in the atmosphere over the storm area into precipitation. However, the storm area should be a plain area and free from any orography.

Using the Eq.(1) $P / M$ ratios for severe rainstorms of Maharashtra state were determined. Table 1 gives DAD raindepth values obtained for 12 severe rainstorms of Maharashtra state for maximum 1–day duration, i.e. the day on which the maximum rainfall was received over the storm area. From this sample of 12 rainstorms, 7 most severe rainstorms were selected (having central value > 30 cms) for determining $P / M$ ratios. Moisture available to these rainstorms on the day of maximum rainfall was determined with the help of maximum 24–hr persisting storm dew point temperatures for a number of India Meteorological Department (IMD) observatory stations available in the up–wind path of moisture bearing winds to the storm areas. For each of the most severe rainstorms at least 3 to 4 dew point stations were selected for obtaining fairly representative value of moisture ($M$) over the storm area. To obtain the value for $P$ in the Eq.(1) for a given area, the method followed

**Table 1.** DAD Raindepths (cm) for Maximum 1–day Duration of Severe Rainstorms over Plain Areas of Maharashtra

| Sr. No. | Rainspell | Storm Center (District) | Area in hundreds of square kilometers | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Point | 1 | 5 | 10 | 20 | 50 | 100 | 150 | 200 | 300 | 500 |
| 1. | 26 June, 1908 | Sakoli (Bhandara) | 38.0 | 37.7 | 37.0 | 36.4 | 35.2 | 31.9 | 28.2 | 25.0 | 22.5 | 19.0 | 15.4 |
| 2. | 4 Aug., 1912 | Armori (Chandrapur) | 27.2 | 27.4 | 26.9 | 26.3 | 25.4 | 23.3 | 21.0 | 19.0 | 17.6 | | |
| 3. | 27 June, 1914 | Parbhani (Parbhani) | 40.1 | 39.8 | 38.5 | 36.7 | 34.0 | 28.6 | 24.2 | 22.3 | 21.1 | 19.7 | 17.3 |
| 4. | 17 June, 1927 | Arvi (Wardha) | 29.1 | 28.7 | 28.2 | 27.5 | 26.2 | 22.1 | 17.8 | 15.7 | 14.5 | 12.9 | 10.5 |
| 5. | 2 July, 1930 | Wani (Yeotmal) | 36.0 | 35.6 | 33.5 | 31.5 | 27.8 | 22.1 | 18.8 | 17.2 | 16.5 | 15.0 | |
| 6. | 16 June, 1936 | Umrer (Nagpur) | 20.0 | 19.9 | 19.7 | 19.5 | 19.0 | 17.8 | 16.7 | 16.2 | 15.8 | 15.0 | 13.5 |
| 7. | 3 Aug., 1953 | Brahmapuri (Chandrapur) | 30.5 | 29.5 | 27.7 | 27.0 | 24.5 | 20.0 | 17.9 | 17.1 | 16.8 | 16.2 | 15.2 |
| 8. | 14 Aug., 1953 | Ahiri (Chandrapur) | 32.0 | 31.5 | 31.0 | 30.6 | 29.6 | 26.8 | 23.8 | 21.1 | 19.2 | 16.2 | 13.5 |
| 9. | 15 Sept., 1964 | Jath (Sangli) | 14.6 | 14.5 | 13.8 | 13.3 | 12.2 | 10.1 | 8.3 | 7.5 | 7.2 | 6.8 | 6.0 |
| 10. | 6 Aug., 1968 | Yaval (Jalgaon) | 26.0 | 25.9 | 25.7 | 25.2 | 24.6 | 22.6 | 20.6 | 18.9 | 17.6 | 16.0 | 13.4 |
| 11. | 13 Aug., 1986 | Rajura (Chandrapur) | 31.0 | 30.5 | 29.4 | 28.4 | 27.3 | 25.5 | 23.5 | 22.3 | 22.0 | 19.6 | 18.1 |
| 12. | 24 July, 1989 | Bhir (Bhir) | 34.6 | 34.0 | 31.9 | 28.6 | 24.5 | 20.7 | 18.6 | 17.6 | 17.0 | 16.3 | 15.3 |
| Envelope values | | | 40.1 | 39.8 | 38.5 | 36.7 | 35.2 | 31.9 | 28.2 | 25.0 | 22.5 | 19.7 | 18.1 |

by Wiesner (1970) and Dhar et al (1973) was used. The $P/M$ ratios were then worked out for each of the standard areas of 1000, 5000, and 10,000 km$^2$ for each of the 7 most severe rainstorms and this information is given in Table 2.

It is seen from Table 2 that of all the severe rainstorms considered, up to an area of 10,000 km$^2$, June, 1908 rainstorm was found to be the most efficient rainstorm over Maharashtra having efficiency factor of 18 for 10,000 km$^2$ area. Next to this were the rainstorms of June, 1914 and August, 1986 and their efficiency factors were 15% and 13% respectively.

The efficiency factor of June, 1908 rainstorm was compared with the efficiency factor of some of the severe rainstorms that occurred over different parts of the country (Dhar et al., 1973). Table 3 gives a list of 7 severe rainstorms of India and their respective efficiency factors for an area of 10,000 km$^2$ area.

**Table 2.** Efficiency Factors (in Percent) of Severe Rainstorms of Maharashtra on the Day of Maximum Rainfall

| Area (km$^2$) | Efficiency factors (%) of severe rainstorms | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1908 (26/6)* | 1914 (27/6) | 1930 (2/7) | 1953 (3/8) | 1953 (14/8) | 1986 (13/8) | 1989 (22/7) |
| 1000 | 23.2 | 22.4 | 19.7 | 14.9 | 16.9 | 16.4 | 17.8 |
| 5000 | 20.3 | 17.4 | 13.8 | 11.1 | 14.9 | 14.0 | 12.8 |
| 10,000 | 17.9 | 14.8 | 11.7 | 10.0 | 13.2 | 13.3 | 11.6 |

Note: * Figures in brackets indicate the date of maximum rainfall day for each rainstorm of Maharashtra

**Table 3.** Severe Rainstorms of India and Their Efficiency Factors on the Day of Maximum Rainfall

| State / region | Rainstorm period | Day of Maximum rainfall | Location of Rainstorm center | Central Value (cm) | Efficiency factor (%) over 10,000 km$^2$ of areas |
|---|---|---|---|---|---|
| Punjab | 3–5 Oct., 1955 | 5 October | Aliwal | 49.5 | 22.2 |
| Uttar Pradesh | 27–30 Sep., 1924 | 28 September | Lansdowne | 35.1 | 16.2 |
| Bihar | 1–3 Oct., 1961 | 30 October | Shaikhpura | 37.3 | 15.8 |
| West Bengal | 11–13 Jun., 1950 | 12 June | Mangpoo | 54.6 | 15.0 |
| Orissa | 28–30 Jul., 1927 | 30 July | Champua | 56.4 | 18.6 |
| Madhya Pradesh | 18–22 Sep., 1926 | 21 September | Bichhia | 40.6 | 17.2 |
| Gujarat | 26–28 Jul., 1927 | 28 July | Dakor | 54.1 | 20.8 |
| North Konkan–South Gujarat | 1–3 Jul., 1941 | 2 July | Dharampur | 98.8 | 23.0 |
| Rajasthan | 26–28 Jul., 1913 | 27 July | Kusalgarh | 37.1 | 14.5 |

It can be seen from Table 3 that the July, 1941 rainstorms over north Konkan–south Gujarat coast, which is considered to be the most severe rainstorm of India, has got the highest efficiency factor of 23% (Dhar et al., 1985) for 10,000 km$^2$ area among all the most severe rainstorms of the country.

It is thus seen that so far most severe rainstorms of Maharashtra plains are concerned, June 1908 rainstorm was found to be the most efficient rainstorm of this region (vide Table 2), but its efficiency factor compared to the most severe rainstorms of India was far low (vide Table 3). The attendant meteorological situation responsible for causing the June, 1908 rainstorm has been briefly described below:

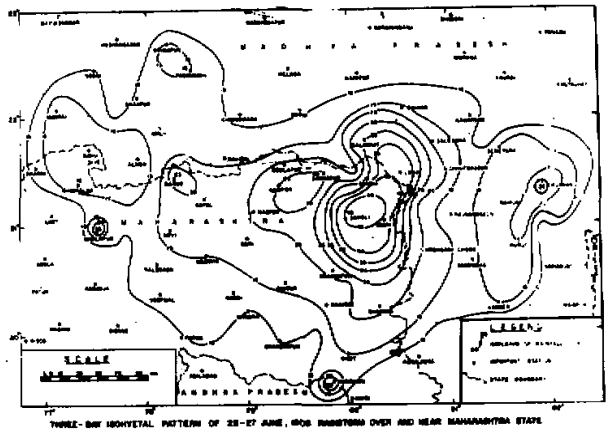

Fig. 2. The isohyetal map of the rainstorm for the period 25–27 June, 1908.

**Rainstorm of 25–27 June, 1908**

The rainstorm was associated with a depression which was located over southwest Bengal with its center near Sagar Island on 23 June. Continuing to move in a westerly direction the depression was centered to the west of Balasore on 24 June and in between Sambalpur and Pendra on 25 June. Moving further westward, the depression lay over Madhya Pradesh and neighbourhood on 26 June. It got filled up on 27 June over the same region. The isohyetal map of this rainstorm for the period 25–27 June, 1908 is shown in Fig. 2. The depth–area–duration (DAD) raindepth values of this rainstorm for different standard areas and for 1–3 durations are given in Table 4.

## IV. SUMMARY AND CONCLUSIONS

Maximum 1–day DAD raindepths of the 12 severe rainstorms of Maharashtra which occurred during the period 1891–1990 were examined for storm efficiency. It was found that June, 1908 rainstorm with its center at Sakoli (Vidarbha region) was the most severe rainstorm of Maharashtra plains with an efficiency factor of 18% for 10,000 $km^2$ area. Next to this rainstorm, June, 1914 and Aug., 1986 rainstorms were found to be efficient with efficiency factors of 15% and 13% respectively. This information can be useful to design engineers and hydrologists for calculating probable maximum precipitation (PMP) over this region.

**Table 4.** DAD Raindepths (cm) of 25–27 June Rainstorms

| Standard areas ($km^2$) | Depth–area–duration values for durations of | | |
|---|---|---|---|
| | 1–day (26 June) | 2–day (25–26 June) | 3–day (25–27 June) |
| Point | 38.0 | 43.0 | 46.3 |
| 100 | 37.7 | 42.7 | 46.2 |
| 500 | 37.0 | 42.2 | 46.0 |
| 1000 | 36.4 | 41.2 | 46.0 |
| 5,000 | 31.9 | 36.4 | 42.5 |
| 10,000 | 28.2 | 31.8 | 38.4 |
| 20,000 | 22.5 | 26.0 | 32.0 |
| 50,000 | 15.4 | 20.3 | 23.8 |

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