MAUSAM, **53**, 2 (April 2002), 233-248

Letters to the Editor

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SOME ASPECTS OF INTER-ANNUAL VARIABILITY OF RAINFALL OVER GODAVARI RIVER BASIN

1. Over the Indian region summer monsoon rainfall (June to September) contributes 75 to 80 % to the annual rainfall. The summer monsoon rainfall as well as annual rainfall exhibit considerable interannual to decadal scale variability which may lead to major alterations in the regional hydrological cycle. Study of inter annual variations of rainfall on river basins scale rather than regional scale becomes important from the hydrological point of view. There are few studies available on basin scale *viz*. Rao (1992) has studied secular variation of rainfall over Mahanadi basin. Nageshwara Rao (1999) has studied year to year variations of monsoon rainfall for Godavari basin, however he has considered only 30 years *i.e*. 1962-91 rainfall data. Godavari being the largest river basin in peninsular India, in this study an attempt is made to study the interannual variability of summer monsoon rainfall over the Godavari river basin.

Among the peninsular river basins of India, the Godavari is the largest and has total catchment area of the order of 3,12,812 km^2 which is about 10 % of the total Indian area. The major tributaries of this rivers are : the Manjara from the southwest, the Penganga and the Wardha from the west, the Wainganga form the north and the Indravati and the Sabri from the east . Throughout its entire course of about 1465 km from west to east, the catchment area of the Godavari is spread over the five adjoining peninsular states of which 48.6 % lies in Maharashtra, 20.7 % in Madhya Pradesh, 1.4 % in Karnataka, 5.5 % in Orissa and 23.8 % in Andhra Pradesh, (Rao, 1975). The basin plan of the Godavari river is depicted in Fig.1.

2. The validity of any statistical analysis depends primarily on the quality of the data used in the analysis. The number of raingauges in the Godavari basin has increased from about 20 prior to 1900 to more than 200 in 1990. To avoid inhomogeneity a network of raingauges has been selected in such way that in the plane areas of the basin at least one station per district gets included. However in the orographic region a dense network is

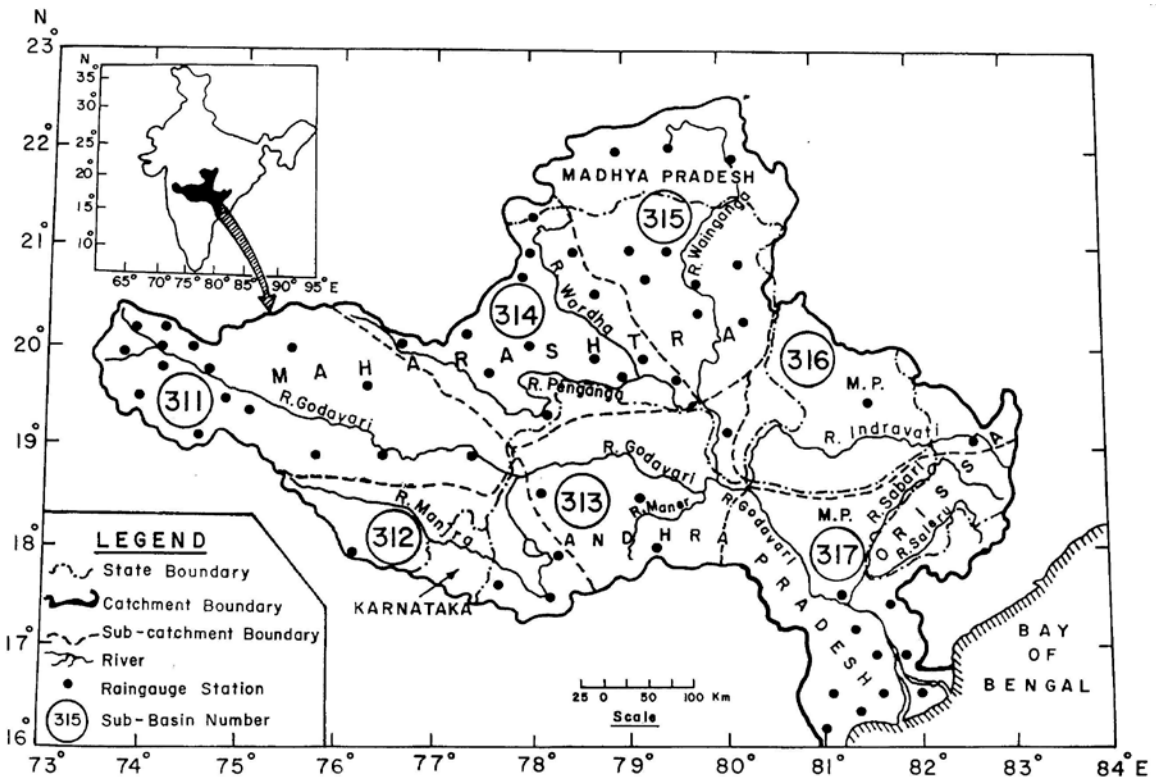

Fig. 1. Basin plan of Godavari river

used. The length and quality of data also has been considered while selecting the rainfall stations.

For studies pertaining to trends and periodicity, the required data length as indicated by Rao and Jagannathan (1963) and WMO (1966) should be 80 years or more. Considering the above aspect, we have selected 64 rainfall stations within the basin whose rainfall data is continuously available for the period 1901 to 1990. Fig.1 shows location of these rainfall stations.

The relevant rainfall data for selected raingauge stations were collected for the period 1901-1990 from the records of the Additional Director General of Meteorology (Research), India Meteorological Department, Pune.

3. *Seasonal and annual rainfall of Godavari basin* - A knowledge of mean monthly seasonal, and annual rainfall of Godavari basin and its sub-basins is essential for purpose of planning and design of water resources and agricultural operations. For this study Godavari basin is further subdivided into seven sub-basins (Khosla,1949) *viz*. Catchment No.311 (Upper Godavari), Catchment No.312 (River Manjra), Catchment No.313 (Middle Godavari), Catchment No. 314 (Penganga and Wardha), Catchment No.315 (River Wainganga), Catchment No. 316 (River Indravati) and Catchment No.317 (River Sabri). Area weighted rainfall series for monsoon, post-monsoon and annual have been derived for the Godavari basin and sub-catchments of Godavari basin. To assign weights to the raingauges construction of Thiessen Polygon method (Wiesener, 1970) has been employed.

Table 1 gives the statistical details like mean, standard deviation and coefficient variation and lag-1 autocorrelation coefficient of monsoon, post-monsoon and annual rainfall of seven sub-basins as well as Godavari basin as a whole. The mean annual rainfall of Godavari basin varies from about 1400 mm or more over extreme eastern sub-basin (*viz*. Catchment No. 316, River Indravati) to about 775 mm over western part of the basin (*viz*. Catchment No. 311, Upper Godavari). The southwest monsoon season is the principal rainy season in which the basin as whole receives 835 mm *i.e*. about 78 % of its annual rainfall. The coefficient of variation of the basin for the monsoon season is 17.3 %. Variability of monsoon rain is highest over Manjra river basin (Catchment No. 312) with coefficient of variation 27% and lowest over Sabri river basin (Catchment No. 317) with coefficient of variation 17%.

4. *Statistical analysis of rainfall series* - To understand the behaviour of rainfall on Godavari basin, the rainfall series of monsoon, post-monsoon and annual have been subjected to further detailed statistical analysis. The

TABLE 1

Statistical details of Godavari basin and sub-basins for different seasons for the year 1901-1990

S. No.	Basin No.	Season	Mean (mm)	S.D. (mm)	C. V. (%)	Auto.Corr. Lag-1
	Godavari	JJAS	835.4	144.3	17.3	0.01
1.	Basin as a	OND	153.6	70.6	46.0	0.20
	unit	Annual	1075.2	166.6	15.5	0.07
		JJAS	649.60	160.8	24.8	0.16
2.	311	OND	90.1	59.1	65.6	0.00
		Annual	777.7	183.9	23.7	0.26*
		JJAS	753.4	205.4	27.3	0.20
3.	312	OND	94.9	60.5	63.8	0.10
		Annual	914.3	225.0	24.6	0.25*
		JJAS	846.7	197.3	23.3	-0.09
4.	313	OND	90.3	60.6	67.2	0.11
		Annual	1011.0	214.3	21.2	-0.10
		JJAS	870.7	181.1	20.8	-0.13
5.	314	OND	78.8	52.4	66.5	0.00
		Annual	1010.2	199.7	19.8	-0.10
		JJAS	1181.9	206.6	17.5	-0.13
6.	315	OND	80.0	59.7	74.7	0.05
		Annual	1345.1	238.2	17.7	-0.08
		JJAS	1194.4	215.0	18.0	0.04
7.	316	OND	105.0	69.8	66.4	0.03
		Annual	1402.8	249.1	17.8	0.04
		JJAS	956.9	161.7	16.9	-0.20
8.	317	OND	176.5	83.2	47.1	0.10
		Annual	1251.0	184.5	14.8	-0.14

* Significant at 5 % level

monsoon, post-monsoon and annual rainfall series of Godavari basin are tested for homogeneity by applying Swed-Eisenhart's runs test (WMO Technical note 1966) for runs above and below the median.

According to the statistical tables by Owen(1962) for data length of 90, the number of runs less than 37 suggest trend, and more than 54 suggests oscillation at 5 % level. On examination of all 24 rainfall series considered in this study [Godavari basin as a unit and 7 sub-basins for three seasons, *viz*. monsoon (JJAS), post-monsoon (OND) and annual , total 24 rainfall series] it has been found that for 22 series the number of runs lie between 37 and 52. There is one series (Catchment No. 311, annual rainfall), for which number of runs is 36 suggesting possible trend. However application of Mann-Kandal rank statistics test did not confirm presence of trend. Similarly for catchment No. 317 (Lower Godavari), for JJAS number of runs is 60 indicating significance presence of oscillation. However,

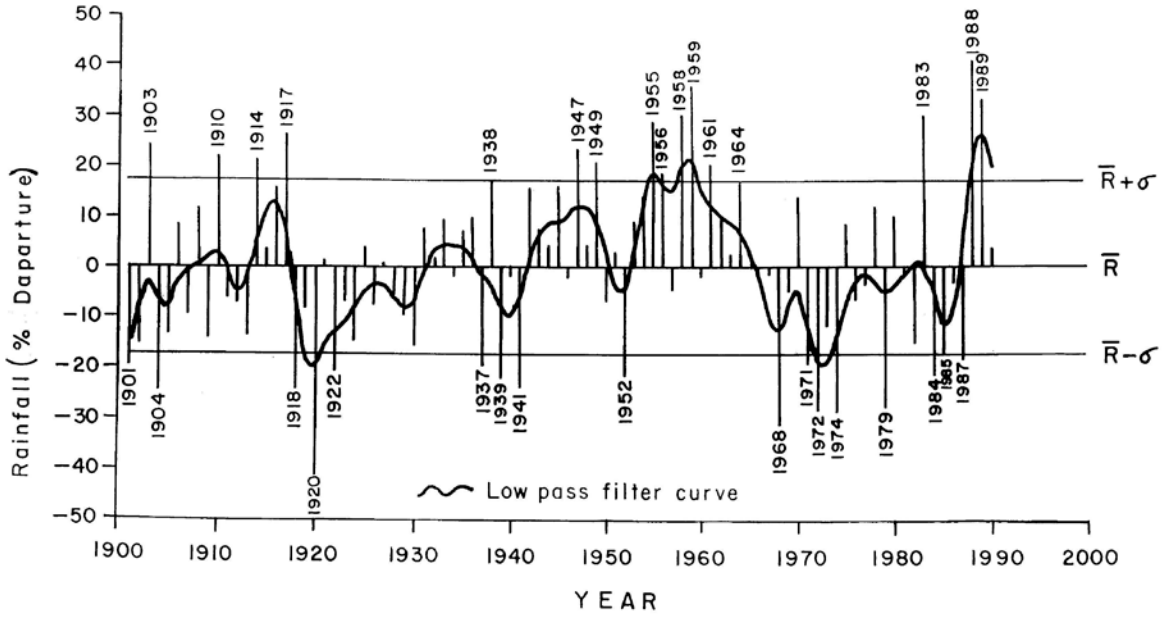

Fig. 2. Monsoon (JJAS) rainfall series for entire Godavari basin as a unit

no other sub-catchment of Godavari basin suggests an oscillation and as Catchment No. 317 is a part of Godavari basin, this presence of oscillation may be considered to be by chance. Thus the rainfall series considered for this study can be taken to be homogeneous.

The presence of persistence in the rainfall series is tested by lag-1 autocorrelation coefficient. It is seen from Table 1 that lag-1 autocorrelation coefficients are significant for annual rainfall series of Catchment No. 311 and Catchment No. 312 which suggest persistence in respective rainfall series. There is no persistence in any other rainfall series. The frequency distribution of all the rainfall series were tested for normality by using Chi-square test with ten equal probability class intervals as suggested by Cochran (1952). It is found that rainfall series for Godavari basin and its sub-catchments can be considered as Gaussian, having minor deviations.

From the above analysis it can be seen that the rainfall series for the basin are homogeneous, free from persistence and generally Gaussian-distributed. To identify if any cycles are present in the summer monsoon, post-monsoon and annual rainfall of Godavari basin and it sub-basins, the rainfall series are subjected to power spectrum analysis by following the method of Blackman and Tucky (1958) as given in the WMO Technical note 79 (1966) . It is found from this analysis that the quasi-biennial oscillation significant at 5% level and 30-year and 60-year cycles significant at 10% level are observed in monsoon rainfall of Godavari basin as a whole. In post-monsoon rainfall series of Godavari basin weak 2 to 3 year and 7.5 year cycles (significant at 10% level) are observed. There is no significant periodicity in annual rainfall series of Godavari basin.

5. *Excess and deficient rainfall over the basin in the summer monsoon season* - Agriculture in India is heavily dependent on the performance of the summer monsoon (June to September) rainfall, which provides 75 to 90 percent of the annual rainwater potential over most parts of the country. Abnormalities in the monsoon, manifested as droughts and floods, can have a disastrous affect on annual food production, causing severe strain on national economy. It is proposed to examine the incidence of drought/deficient and flood/excess rainfall over Godavari basin as a whole only during the 90- year period of study *viz*. 1901-1990.

Parthsarthy *et al*. (1992) have brought out the impact of excess (wet) and deficient (dry) monsoon rainfall on Kharif foodgrain production on All - India scale. They classified a year as wet/excess year if $Ri \geq \overline{R} + \sigma$ and dry/ deficient year if $Ri \leq R - \sigma$, where Ri is the monsoon rainfall of the i th year, $\overline{R}$ = mean of the series and σ = the standard deviation of the series. We have followed a similar procedure in classifying the excess and deficient rainfall years over entire Godavari

basin. The excess and deficient rainfall years identified using these criteria are as follows:

Excess rainfall years : 1903,1910, 1914, 1917, 1938, 1947, 1949, 1955, 1956, 1958, 1959, 1961, 1964, 1983, 1988, 1989.

Deficient rainfall years : 1901, 1904, 1918, 1920, 1922, 1937, 1939, 1941, 1952, 1968, 1971, 1972, 1974, 1979, 1984, 1985, 1987.

As seen the number of excess and deficient rainfall years are respectively 16 and 17 amounting to 18 and 19% respectively. The Godavari Basin experienced more frequent deficient rainfall years during the period 1971 to 1990 and more frequent excess years during the period 1941 to 1970. In Fig. 2, rainfall series for entire Godavari basin is presented. In this Fig. rainfall is expressed as percentage departure (vertical bars), $\overline{R}$ represents the mean rainfall and σ represents the standard deviation. The years marked above and below the vertical bars excess and deficient rainfall years respectively. Smooth line represents low pass filter curve. As rainfall is expressed as percentage departure, standard deviation correspondence to coefficient of variation which is 17.3%.

6. (*i*) Summer monsoon rainfall series of Godavari Basin and its sub-basins are homogeneous, Gaussian distributed and free from persistence.

(*ii*) The normal monsoon rainfall of the entire Godavari catchment is 835 mm (78 % of annual). The range is 705 mm (From the lowest 490 mm to the highest 1185 mm) which is 83 % of normal.

(*iii*) The minimum normal monsoon rainfall of 650 mm is over Catchment No. 311 (Upper Godavari) and maximum of the order of 1195 mm, over Catchment No. 316 (River Indravati sub-basin).

(*iv*) Power spectrum analysis reveals that there is strong QBO (2-3) year cycle and weak 30 and 60 year cycles in the summer monsoon rainfall over entire Godavari basin. Similarly weak 2-3 year and 7.5 year cycles are observed in post-monsoon rainfall series of entire Godavari basin.

(*v*) The number of excess and deficient rainfall years experienced by the basin are 16 and 17 respectively during the period 1901 to 1990. The Godavari basin and its sub-basins experienced more frequent deficient rainfall years during the period 1971 to 1990 and more frequent excess years during the period 1941 to 1970. The highest maximum number of deficient years were observed in the decade 1971 to 1980, where as number of excess years observed in 1951 to 1960.

The authors are grateful to Dr. G. B. Pant, Director, Indian Institute of Tropical Meteorology, Pune for providing necessary facilities for completing this study, to Dr. K. Rupa Kumar, Head Climatology and Hydrometeorology Division of the Institute for encouragement.

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8 December 1999, Modified 25 April 2001