*Mausam*, (1979), **30**, 1, 85-90

551.577.21 : 519.25 : 551.582 (547.6)

# Does precipitation pattern foretell Gujarat climate becoming arid ?

A. CHOWDHURY and V. P. ABHYANKAR

*Meteorological Office, Pune*

(*Received 28 April 1977*)

ABSTRACT. In recent years, on account of the anomalous behaviour of southwest monsoon, drought conditions were reported from many parts of the country, Gujarat State in particular. An attempt has been made in this paper to determine, if Gujarat is turning drier.

Southwest monsoon (seasonal) and the annual rainfall series of nearly 70 years were subjected to sophisticated statistical analyses. Rainfall data over Gujarat was found to constitute a random series and did not exhibit presence of trend, cycle or persistence. The precipitation pattern does not indicate that arid conditions are gradually increasing over Gujarat State. It is also not feasible to anticipate years of poor rainfall from the past occurrences in the rainfall series.

## 1. Introduction

In the past few years, southwest monsoon rainfall over Gujarat State was consecutively below normal, the departures being even 50 per cent or more and prolonged drought conditions were reported.

It is worth mentioning in this context that considerable speculation is being made by reknowned climatologists in other parts of the globe to suggest that India is undergoing climatic changes and is threatened by drought and famine.

One of the methods to determine climatic shifts and to project a time series into future is the statistical analysis of the past behaviour of the sample. Now in the application of statistics it may be assumed that the series is composed of combination of two components, *viz*., non-deterministic component (when the data contain random past which can be handled by probability concept) and deterministic component like trend, cycles or persistence. The latter component is dealt in the paper.

The aim of the present study is, therefore, to determine the predictivity, if any, existing in the rainfall series for Gujarat State. Raman *et al.* (1972) adopting Friedman's (1957) methodology for Texas, confirmed absence of trend, cycles or persistence in the rainfall series in Bihar State. Apart from a few tests mentioned in these papers some recent sophisticated tests have also been introduced in the present analyses.

## 2. Basic data

The most important factor which is essential for a quantitative evaluation and understanding the characteristics of drought and the climatic shift, is the availability of continuous rainfall data for a very long period. In the present investigation 11 rain recording stations in Gujarat State representing different agroclimatic regimes, were selected. The monsoon (June to September) and annual rainfall data for nearly 70 years generally ranging from 1895 to 1970 was available for most of the stations. The data was subjected to various statistical analyses to determine presence, if any, of trend, cycles and persistence in the rainfall series in Gujarat.

## 3. Trend in rainfall

Computation of trend values provides with a tool to ascertain, if a locality is getting drier or wetter. In case the rainfall series show a positive trend, the area could be considered to be getting wetter year by year, and if it is negative, they would imply possible approach of drier conditions. To determine presence of trend, if any in Gujarat, the following test were applied :

(a) *Hart's test for independence of successive observation*

A method of testing the independence of successive observation is to compute Von Neumann ratio as defined below and test its significance :

$$\text{Von Neumann ratio}\ (\mu) = \frac{\sum_{t=1}^{N-1} (X_{t+1} - X_t)^2/(N-1)}{\sum_{t=1}^{N} (X_t - \overline{X})^2/N}$$

where, $X_t$ is the observed value at time $t$ and $\overline{X}$ is the mean.

This ratio was computed for all the stations and results presented in Table 1. At 5 per cent level of significance, no evidence of trend was noticed for any of the stations for both the monsoon and annual rainfall series except at Veraval for which the rainfall showed presence of some trend.

(b) *Linear time trend and correlation*

In this method, a linear time scale regression to the rainfall series in the form of :

$$Y = a + bt$$

(where $Y$ is the rainfall at the time $t$, $a$ and $b$ are constants, $b$ gives the slope of the regression) is fitted. The slope and the coefficent of linear regression both provide a basis to probe the presence of trend. The slope and coefficient are depicted in Table 2. The slope in rainfall series for Veraval and Surat appears to be quite steep. In case of Porbandar, though the slope is not as marked as in the above two stations, it was quite large.

The linear correlation coefficient for the rainfall (seasonal and annual) at Veraval alone was found significant at 5 per cent level. Surat and Porbandar also registered a high, though not significant correlation.

#### 4. Test for recurring cycles

There are two tests for locating the presence of cycle in a time series sample. The first test compares the observed length of runs in the sample with that of expected ones. The second test compares the number of runs in the sample with the number expected in a random sample.

(a) *Length of runs*

The sample distribution of the test was derived by Wallace and Moore and is based on chi-square distribtution.

$$\chi_P^2 = \frac{(u_1 - U_1)^2}{U_1} + \frac{(u_2 - U_2)^2}{U_2} + \frac{(w_3 - W_3)^2}{W_3}$$

where $u_1$, $u_2$ and $w_3$ represent respectively the observed number of runs of length 1, 2 and 3 or more in empirical sample and $U_1$, $U_2$, and $W_3$ are expec-

TABLE 1

Von-Neumann ratio

| S. No. | Station | Neumann ratio of rainfall: (Jun-Sep) Seasonal | Neumann ratio of rainfall: Annual |
|---|---|---|---|
| 1 | Deesa | 2·224 | 2·171 |
| 2 | Rajkot | 2·154 | 2·142 |
| 3 | Bhuj | 2·364 | 2·399 |
| 4 | Ahmedabad | 1·841 | 1·869 |
| 5 | Veraval | 1·449* | 1·472* |
| 6 | Kaira | 2·035 | 2·168 |
| 7 | Dohad | 1·904 | 1·989 |
| 8 | Surat | 1·988 | 2·019 |
| 9 | Baroda | 2·078 | 2·126 |
| 10 | Porbandar | 2·062 | 2·108 |
| 11 | Morvi | 2·308 | 2·366 |

*Significant at 5 per cent level

TABLE 2

Slope and linear time scale correlation coefficient

| Station | Slope: Seasonal | Slope: Annual | Linear correlation coeff.: Seasonal | Linear correlation coeff.: Annual |
|---|---|---|---|---|
| Deesa | —0·046 | —0·056 | —0·032 | —0·037 |
| Rajkot | 0·150 | 0·164 | 0·125 | 0·123 |
| Bhuj | 0·002 | 0·012 | 0·070 | 0·063 |
| Ahmedabad | 0·107 | 0·108 | 0·073 | 0·072 |
| Veraval | *0·657 | *0·680 | *0·424 | *0·417 |
| Kaira | 0·262 | 0·247 | 0·149 | 0·133 |
| Dohad | 0·128 | 0·156 | 0·055 | 0·062 |
| Surat | *0·539 | *0·535 | 0·271 | 0·261 |
| Baroda | —0·042 | —0·190 | 0·015 | —0·042 |
| Porbandar | 0·385 | 0·368 | 0·265 | 0·248 |
| Morvi | —0·050 | —0·050 | —0·036 | —0·035 |

*Significant at 5 per cent level

TABLE 3

Number of runs of various lengths

| Station | Seasonal length: 1 | 2 | ≥3 | Total | Annual length: 1 | 2 | ≥3 | Total |
|---|---|---|---|---|---|---|---|---|
| Deesa | 31 | 12 | 4 | 47 | 32 | 11 | 4 | 47 |
| Rajkot | 33 | 16 | 3 | 52 | 32 | 18 | 2 | 52 |
| Bhuj | 25 | 20 | 3 | 48 | 24 | 22 | 2 | 48 |
| Ahmedabad | 28 | 11 | 6 | 45 | 27 | 12 | 6 | 45 |
| Veraval | 24 | 9 | 7 | 40 | 24 | 9 | 7 | 40 |
| Kaira | 24 | 13 | 3 | 40 | 30 | 13 | 1 | 44 |
| Dohad | 23 | 5 | 1 | 29 | 19 | 4 | 2 | 25 |
| Surat | 30 | 13 | 3 | 46 | 31 | 11 | 4 | 46 |
| Baroda | 12 | 5 | 4 | 21 | 11 | 8 | 2 | 21 |
| Porbandar | 29 | 15 | 2 | 46 | 30 | 14 | 2 | 46 |
| Morvi | 25 | 13 | 3 | 41 | 26 | 12 | 3 | 41 |

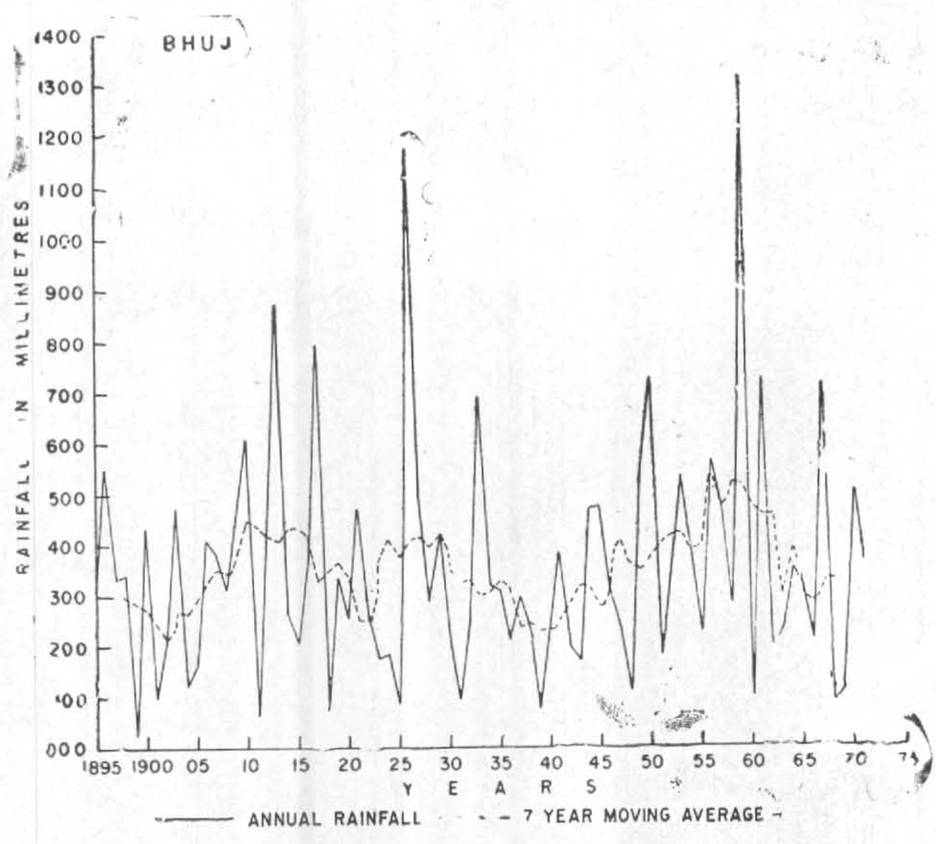


Fig. 1. Annual rainfall and moving average

ted number of runs of length 1, 2, and 3 or more, each of which being a function of $N$, the sample size, and expressed as below :

$$U^1 = \frac{5(N-3)}{12}, U_2 = \frac{11(N-4)}{60}, W_3 = \frac{4N-11}{60}$$

Now a series with well defined cycle would have a small number of up and down runs of considrable length. On the other hand, a large number of runs of length 1 and 2 are indicative of random variation.

The number of runs of various length is shown in Table 3, columns 1 and 2 of the table show that there is a large variation in the number of runs of length 1 and 2 over Gujarat in the time series. The presence of cycles in the data would also be revealed by the long runs of upward movement (positive sign) and downward movement (negative sign). An indication of this tendency is given in column 3 of Table 3. The number of runs of length 3 or more varies considerably from station to station. However, the total number of runs (column 4) is generally of the same order for different stations except for Dohad and Baroda for which the sample size itself was very limited.

(b) *The number of runs*

The general expression in the number of runs of length $d$ or more is :

$$W_d = \frac{2}{(d+2)} \left[ N(d+1) - (d^2+d-1) \right]$$

Putting $d=1$ the total number of runs of length 1 or more becomes :

$$W_1 = \frac{2N-1}{3}$$

This expression provides basis for a test of total number of runs in a random sample by computing the statistic,

$$t = \frac{r - (2N-1)/3}{\sqrt{(16N-29)/90}}$$

where $r$ is the total number of runs in the sample. Value of this parameter and the magnitude of $\chi_p{}^2$ the quantity for testing the significance of length of runs is shown in Table 4. In none of the cases, barring annual rainfall of Bhuj, the value found was significant. Also no station in

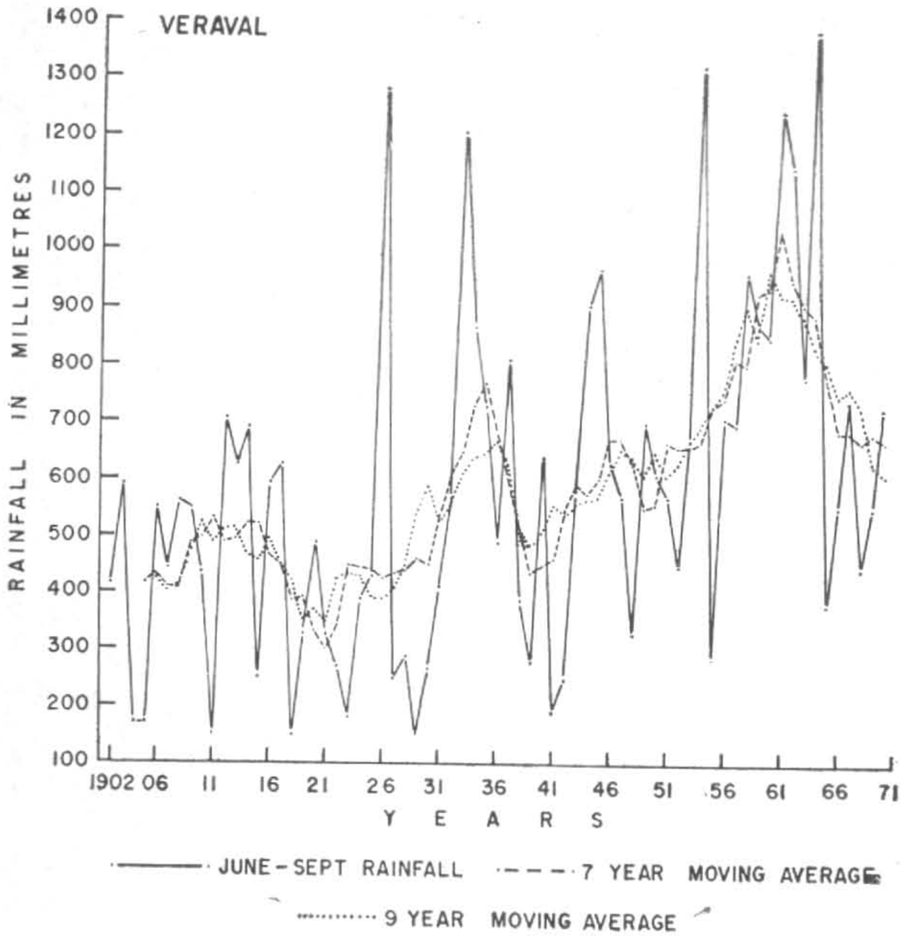


Fig. 2(a). Seasonal rainfall and moving averages

this case shows value of $t$ significant in annual and seasonal rainfall series.

At each of the stations in the series (except Bhuj where the statistical significance appears to be localised), the null hypothesis is accepted, the length of runs in up and down movement in the series and the number of runs offer no general evidence of regularly recurring cycles in the seasonal and annual rainfall data.

The annual rainfall at Bhuj when analysed for the length of runs showed some presence of cycles in data series. It was, therefore, considered worthwhile to check and confirm this result by some independent method. For this sake, seven years running average was worked out. The actual and the average values are depicted in Fig. 1. The illustration brings out a gross picture on the presence of cyclic pattern in the rainfall. The period and amplitude of the cycle, was, however, fluctuating.

**5. Test for persistence**

A non-parametric test for persistence in time series is given by serial correlation coefficient.

**TABLE 4**

**Magnitude of quantities used for testing (a) length of runs (b) number of runs**

| Station | Length of runs $\chi_p^2$ | | Number of runs '$t$' | |
|---|---|---|---|---|
| | Seasonal | Annual | Seasonal | Annual |
| Deesa | 0·323 | 0·749 | 0·000 | 0·191 |
| Rajkot | 1·539 | 3·530 | 0·458 | 0·458 |
| Bhuj | 5·143 | 8·922* | —0·820 | —0·642 |
| Ahmedabad | 0·736 | 0·670 | —1·293 | —1·293 |
| Veraval | 2·602 | 2·602 | —1·457 | —1·457 |
| Kaira | 0·824 | 4·171 | —0·102 | 1·130 |
| Dohad | 5·409 | 2·378 | 1·296 | 0·266 |
| Surat | 0·780 | 0·555 | 0·096 | 0·096 |
| Baroda | 1·804 | 1·346 | —1·332 | —1·081 |
| Porbandar | 2·451 | 2·311 | 0·489 | 0·690 |
| Morvi | 0·698 | 0·485 | —0·202 | 0·000 |

*Significant at 5 per cent level

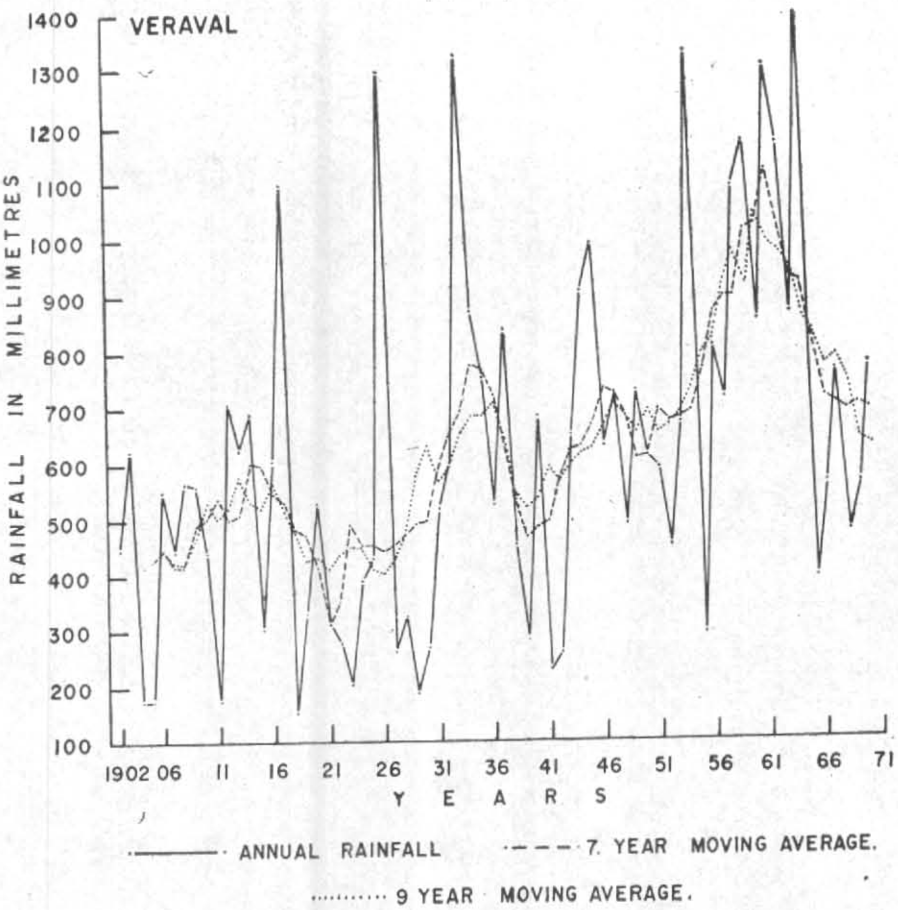


Fig. 2(b). Annual rainfall and moving averages

$$r_1 = \frac{(N-1)\sum_{i=1}^{N-1} X_i .\ X_{i+1} - \left(\sum_{i=1}^{N-1} X_i\right)\left(\sum_{i=2}^{N} X_i\right)}{\left[(N-1)\sum_{i=1}^{N-1} X_i^2 - \left(\sum_{i=1}^{N-1} X_i\right)^2\right]^{\frac{1}{2}} \left[(N-1)\sum_{i=2}^{N} X_i^2 - \left(\sum_{i=2}^{N} X_i\right)^2\right]^{\frac{1}{2}}}$$

The statistical significance of $r_1$ for null hypothesis is tested from the equation :

$$(r_1)_t = \frac{-1 + t_g \sqrt{N-2}}{N-1}$$

where $N$ is the length of the series, and $t_g$ is the Students' $t$ value for appropriate degree of freedom (5 per cent level). The results of the computations have been shown in Table 5. As in case of trend, the seasonal and annual rainfall series of only one station, *viz.*, Veraval revealed presence of serial correlation.

## 6. Discussion on trend of Veraval rainfall

In the earlier paragraphs, it is said that the station Veraval displayed presence of trend in all the tests in the seasonal and annual rainfall series. With a view to investigate further into this aspect, the rainfall data of nearby stations within the districts was collected and analysed. Unfortunately, in the district in which Veraval is located, only one station, *i.e.*, Junagarh had comparable length of data. Consequently, the data of another nearby coastal station Diu was considered and data of these two stations were subjected to statistical analysis. Both the Junagarh and Diu rainfall series (seasonal and annual) did not reveal presence of any trend.

An additional test in identifying the presence of trend in the Veraval data was adopted by computing the 7 and 9 year's sliding means.

**TABLE 5**

**Testing serial correlation coefficient**

| Station | $r_1$ | | $(r_1)t$ | |
|---|---|---|---|---|
| | Seasonal | Annual | Seasonal | Annual |
| Deesa | —0·109 | —0·083 | 0·223 | 0·224 |
| Rajkot | —0·095 | —0·081 | 0·215 | 0·215 |
| Bhuj | —0·161 | —0·183 | 0·214 | 0·215 |
| Ahmedabad | 0·062 | 0·049 | 0·217 | 0·217 |
| Veraval | *0·282 | *0·271 | 0·227 | 0·227 |
| Kaira | —0·026 | —0·077 | 0·239 | 0·239 |
| Dohad | 0·037 | 0·003 | 0·298 | 0·306 |
| Surat | —0·014 | —0·025 | 0·226 | 0·226 |
| Baroda | 0·044 | 0·014 | 0·306 | 0·310 |
| Porbandar | —0·041 | —0·066 | 0·229 | 0·231 |
| Morvi | —0·159 | —0·191 | 0·236 | 0·238 |

*Significant at 5 per cent level

The same was plotted and illustrated in Fig. 2· A definite positive trend in both seasonal and annual rainfall of Veraval from 1921 to 1935 and again from 1939 to 1961 is striking. After 1961 a downward trend is noticed. However, as this was not supported by data from other nearby stations, the trend in case of Veraval appear to be purely localised.

### 7. Conclusions

On the basis of the rigorous and latest statistical tests to which the rainfall series in Gujarat was subjected to, the following broad conclusions may be drawn :

(*i*) Hardly any evidence was revealed to suggest that rainfall was successively decreasing.

(*ii*) Regularly recurring cycles of wet spell (connoting floods) and dry spell (years of drought) were not observed in the rainfall series.

(*iii*) Very little persistence in the successive values of seasonal and annual rainfall was noticed.

(*iv*) Indirectly the results do not justify the gloom and despair echoed elsewhere that climatic shift, for the worst is occurring in India.

*Acknowledgement*

The authors wish to express their sincere thanks to Shri C. R. V. Raman, Deputy Director General of Observatories (Climatology & Geophysics) and Dr. R. P. Sarker, Director, Agrimet. Division, Pune for their encouragement and valuable suggestions in the study.

**References**

Friedman, Don G., 1957, The prediction of long continuing drought in south and southwest Texas. The Travellers Weather Research Centre—Occasional papers in Met. No. 1.

Raman, C.R.V., George, C. J. and Abhyankar, V.P., 1972, Preliminary attempt to forecast drought over Bihar State—India met. Dep. Pre-publ. Sci. Rep. 186.

Winstanley, Derek, 1973, Rainfall Patterns and General Atmospheric Circulation, *Nature*, **245**, pp. 190-194.

W. M. O., 1966, *Climatic change*, W. M. O. Technical Note 79, pp. 60-66.