

## ANNUAL AND WEEKLY ANALYSIS OF RAINFALL AND TEMPERATURE FOR PUNE : A MULTIPLE TIME SERIES APPROACH

Alaka Gadgil, Sharad Gore and Shridhar Gupte, Pune

**ABSTRACT :** Annual and weekly rainfall and temperature records for Pune are analysed. The data represent annual and weekly rainfall and temperature records for the periods 1901–1985 and 1946–1985, respectively. The data are smoothed and analysed for dependencies and periodicities, with a view to examining the trends and changes in the temperature and rainfall regimes. An attempt has been made to develop a model that can be employed for prediction of rainfall by considering the maximum and minimum temperature records.

### INTRODUCTION

Rainfall is a crucial agroclimatological factor in the seasonally arid parts of the world and its analysis is an important prerequisite for agricultural planning. In India, traditional analysis of rainfall data has been restricted to evaluation of trends for prediction.

Various research workers like Raghavendra (1974), Mooley (1967), etc. have analysed daily precipitation, for identification of rainfall patterns, using power spectrum and Markov chain models. These methods basically aim at establishing trends in the rainfall pattern and, under the assumption of temporal homogeneity, can at best provide estimates of the rainfall amount at specific time-points. It should be noted here that the forecasts using these methods are not predictions in real sense. The assumptions of homogeneity and stability have to be established before applying any such procedure. Even with all these precautions the only component of the error in such models is the random error. A prediction model, on the other hand, gives an additional component of deviations due to the model. This makes it necessary to

distinguish between the analytical and the predictive models employed in a study of rainfall data.

In this paper, two approaches are presented to the analysis of rainfall and temperature variations. The first approach aims at examining periodic in rainfall and temperature, and the second one is related to the prediction of rainfall with the use of multivariate statistical techniques.

The data used in the analysis presented in this paper were obtained from India Meteorological Department, Pune. The analysis were carried out on the microcomputer of the Department of Geography, University of Poona. The necessary software for the analysis was developed by the authors on this microcomputer.

The city of Pune is situated on the western margin of the Deccan Plateau at an altitude of about 600 m above sea level. Owing to its position in the rainshadow region, the climate of Pune is dry during most of the year. On account of its elevation and dryness, Pune is cool during nights, even in summer. Pune is covered by Koeppen's Bsh and Thornthwaite's Da'da'

climate, indicating semiarid and megathermal conditions with no water surplus during the year.

## METHODOLOGY

Voluminous data on observations related to daily weather conditions are provided by India Meteorological Department for a large number of stations in India. These data on weather conditions have proved to be very useful for an appreciation of changes in climatic conditions for different stations. Several research workers like Stern (1980), Singh and Kripalani (1981) and others have studied the runs of dry and wet spells for selected stations for rainfall persistency. These workers have applied one or the other model to study the persistency phenomena. They have indicated that it is possible to give an objective forecast of the probability of rainfall persisting for one or more days, based on the previous spell. These studies were limited to a few stations. Harris (1985) has adopted autocorrelation function for examining the temporal dependencies of precipitation and temperature for Durham (U. K.). However, the results indicate very weak correlations.

The study undertaken in this paper deals with the weekly and yearly temperature and rainfall analysis for Pune station. Autocorrelations for maximum temperature, minimum temperature, and rainfall have been computed separately. In addition to this, cross-correlations between temperature and rainfall, and cross-multiple-correlations of rainfall with maximum and minimum temperatures, at different lag periods, have also been worked out. Thus the objectives of the present study is to examine the trends and periodicities in temperature and rainfall and to investigate the relationships between maximum and minimum temperatures and rainfall, especially for the monsoon season.

## TRENDS IN RAINFALL VARIATION (1901-1985)

The statistical analysis carried out for

the data gives the mean annual precipitation value of 675.67 mm with a standard deviation of 170.17 mm for the series. The erratic nature of annual precipitation is clearly illustrated in Figure 1. The figure depicts the occurrences of dry years followed by wet years. For example, the lowest annual total in the series (268 mm) was recorded in 1918 and was followed by 800 mm in 1919.

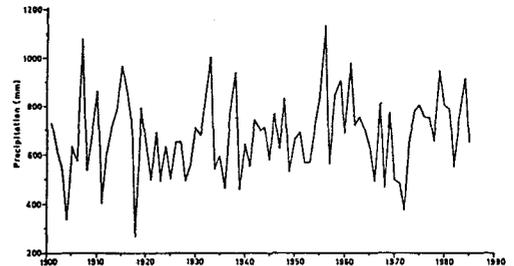


Fig. 1 : Annual precipitation (mm) 1901-1985

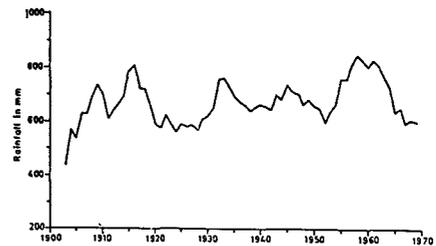


Fig. 2 : Five-year moving average of the annual rainfall

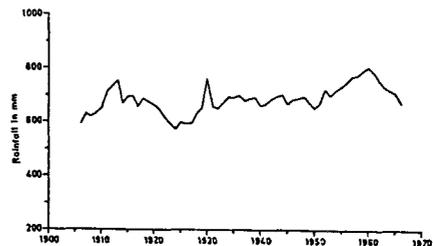


Fig. 3 : Eleven-year moving average of the annual rainfall

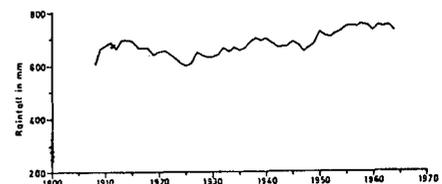


Fig. 4 : Fifteen-year moving average of the annual rainfall

In order to establish the overall trend in rainfall series, a number of smoothing operations were performed on the annual rainfall data. For this, unweighted windows of 5, 11 and 15 years were used. The series filtered with a 5 year window (Figure 2) shows an annual average rainfall maximum of 740 mm in 1908 falling to a minimum of 600 mm in 1911. During the succeeding years the average rainfall increased to reach a peak of 810 mm in 1916. Since then, the average rainfall pattern reveals a decreasing trend till the late thirties. The peak of 1933 is followed by two successive troughs covering a time span of twelve years each. Since 1958, the graph shows a gradual increase in the average rainfall amount. Smoothing through 11 years filter (Figure 3) exhibits unstable rainfall conditions upto 1930 which were followed by stability in the amount upto 1950. In the-sixties the average rainfall attained a maximum value of 800 mm and then decreased gradually in subsequent years. As against this, a 15 year window indicates a decreasing trend upto 1925, followed by a gradual increase right upto the present (Figure 4). This appears more interesting when compared with the prevailing drought conditions. However, this can be explained easily by standard deviation values which have substantially increased over the last sixteen years. Although the average rainfall amounts are normal, the higher values of standard deviation connote an erratic distribution (Table 1).

**TABLE 1 : MOVING AVERAGES WITH 15 YEARS UNWEIGHTED WINDOW**

Sl. No.	Average	Std. Dev.
1.	603.3867	237.0294
2	667.8666	191.2528
3	676.6533	196.7618
4	685.8934	196.5326
5	667.52	220.3674
6	698.1133	203.6621

Sl. No.	Average	Std. Dev.
7	698.0933	203.6685
8	693.000	207.6126
9	667.4466	179.9001
10	664.3601	182.4732
11	664.0401	182.5309
12	639.6268	178.3136
13	656.0334	166.5948
14	658.7734	166.1757
15	644.82	170.3509
16	629.14	167.6864
17	612.5134	144.0394
18	600.6601	129.8154
19	607.84	140.202
20	656.9133	141.6555
21	640.1	139.0326
22	637.0733	139.5604
23	634.92	141.9172
24	640.5133	145.9176
25	670.4066	157.8149
26	658.86	166.5248
27	668.6467	161.1211
28	659.9066	165.5164
29	666.1066	166.8591
30	692.94	169.8124
31	603.9	165.357
32	694.5734	168.2304
33	700.6335	169.3021
34	685.1068	165.21
35	673.7267	147.7692
36	672.8133	148.6068
37	677.5534	147.0664
38	692.78	135.7422
39	678.2333	137.0226
40	653.2868	120.0934
41	670.4534	108.4638
42	682.6934	115.2406

Sl. No.	Average	Std. Dev.
43	723.78	152.5303
44	711.5401	157.5791
45	707.9401	153.8205
46	720.9534	161.7108
47	730.9133	157.1297
48	744.5867	168.6868
49	750.9666	165.6557
50	745.4667	164.1734
51	756.9934	154.4655
52	748.0534	163.293
53	734.4733	175.24
54	750.9	169.9978
55	743.9933	179.2282
56	747.8466	179.1458
57	725.6067	188.0167

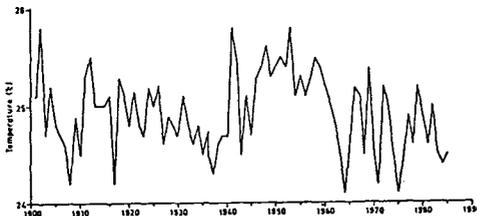


Fig. 5 : Annual mean temperature ( $^{\circ}\text{C}$ ) 1901-1985

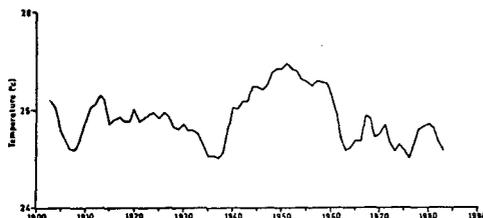


Fig. 6 : Five-year moving average of the annual mean temperature ( $^{\circ}\text{C}$ )

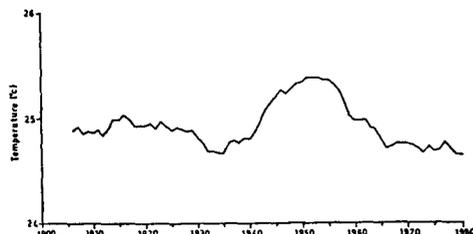


Fig. 7 : Eleven-year moving average of the annual mean temperature ( $^{\circ}\text{C}$ )

## THE PATTERN OF TEMPERATURE VARIATION (1901-1985)

The mean temperature pattern shows a gradual warming upto the fifties followed by a cooling trend as indicated in Figure 5. The graph shows annual mean temperature for the period 1901-1985. The mean for the series is  $24.92^{\circ}\text{C}$  with a standard deviation of  $0.4^{\circ}\text{C}$ . The smoothing of the same data with 5, 11 and 15 years window filters is presented in Figures 6, 7 and 8 respectively. The mean annual temperature was below  $25^{\circ}\text{C}$  for most of the time, excepting 3 to 4 years at the beginning of this century. The lowest mean of  $24.5^{\circ}\text{C}$  was recorded in 1937 followed by a rising tendency upto 1960. During this period of rise, the highest values of annual mean temperature were found to be centered around  $25.5^{\circ}\text{C}$ . In the early sixties, a marginal decrease in the annual mean temperature was observed, which dropped down upto  $24.5^{\circ}\text{C}$ . The late sixties saw a slight increase by about  $0.45^{\circ}\text{C}$ . A similar trend is also revealed with 11 and 15 year windows (Figure 7 and 8).

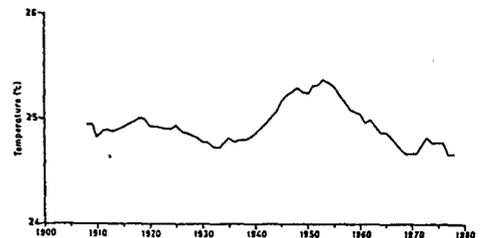


Fig. 8 : Fifteen year moving average of the annual mean temperature ( $^{\circ}\text{C}$ )

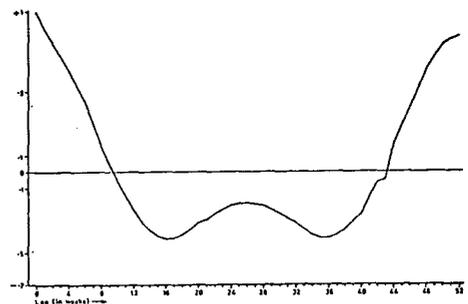


Fig. 9 : Mean maximum temperature : Auto-correlation function

## THE TEMPORAL DEPENDENCIES OF PRECIPITATION AND TEMPERATURES

The temporal dependencies of precipitation and temperature were analysed by examining autocorrelation functions (correlograms) of weekly mean maximum temperature, mean minimum temperature and rainfall. Figure 9 shows the autocorrelation function for the mean maximum temperature. The graph is W shaped. The only abnormality is seen in the decrease in the correlation co-efficient value around 26th week, i.e. at 6 months lag. This can be associated with a decrease in the mean maximum temperature for the monsoon period and with a slight increase in the parameter during the retreat of monsoon.

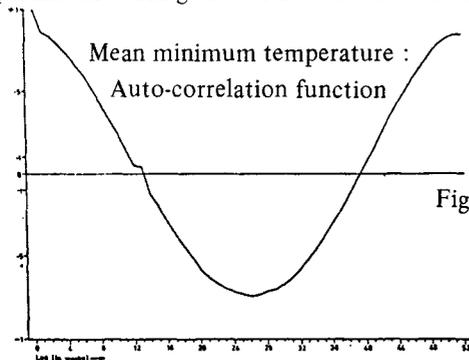


Fig. 10

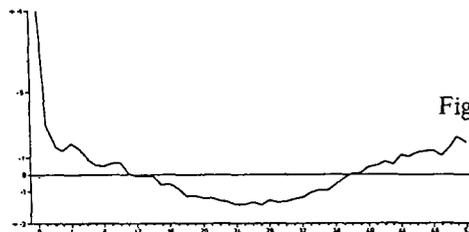


Fig. 11 :

Rainfall : Auto-correlation function

The correlogram for the mean minimum temperature, illustrated in Figure 10, resembles the alphabet 'U', with maximum negative correlation ( $-0.75$ ) around 26th week. The Figure 11 shows the autocorrelation function for rainfall, which is also more or less 'U' shaped. The shape suggests that there is no remarkable shift in the monsoon pattern.

The maximum cross-correlation ( $0.26$ ) between the mean maximum temperature and rainfall at 8 weeks lag indicates that

the former affects the latter directly after 8 weeks (Figure 12). The correlation function reaches the minimum value of  $-0.26$ , showing an inverse relationship at 39 weeks lag (Figure 12). This negative correlation conveys a high probability of good rains in the monsoon, following prolonged cold winters. The graph of cross-correlation between the mean minimum temperature and rainfall (Figure 13) is the mirror image of the previous one and may be, therefore, explained in the similar manner.

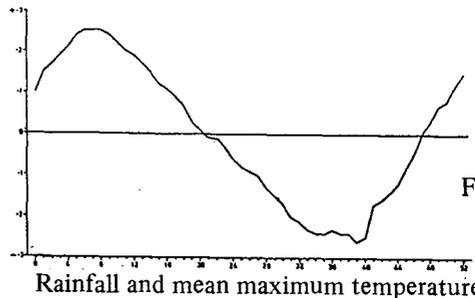


Fig. 12

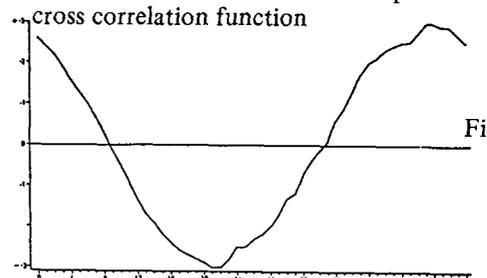


Fig. 13

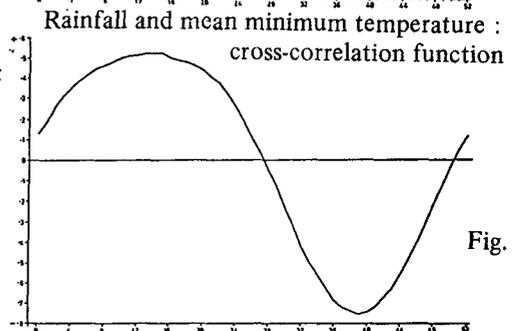


Fig. 14

Mean maximum and mean minimum temperature : cross-correlation function

Similarly, the mean maximum temperature affects the mean minimum temperature at 14 weeks lag. This observation is supported by the highest cross-correlation of  $0.53$  at 14 weeks lag. The highest negative correlation observed at 39 weeks lag implies that the mean maximum temperature is inversely related to the mean minimum temperature after 39 weeks (Figure 14).

The relation of the mean maximum and the mean minimum temperature and the rainfall at different lags is talulated in Table 2. The results can be effectively employed for predicting rainfall. The high multiple correlation coefficient values for the three parameters further support the above inference.

TABLE 2 : TABLE OF CROSS-MULTIPLE CORRELATION OF RAINFALL WITH MEAN MAXIMUM TEMPERATURE AND MEAN MINIMUM TEMPERATURE

Sr. No.	Lag for mean Maximum	Lag for mean Minimum	Multiple Correlation Coefficient	% of variation Explained
1	6	39	.7284851	53.06905
2	6	40	.7369985	54.31667
3	6	41	.7379547	54.45771
4	7	38	.7205818	51.92382
5	7	39	.7545619	56.93637
6	7	40	.7741088	59.92444
7	7	41	.746154	55.67457
8	8	38	.7357133	54.12741
9	8	39	.7817367	61.11123
10	8	40	.7722567	59.63804
11	8	41	.7269185	52.84104
12	9	38	.7573715	57.36116
13	9	39	.7745867	60.00001
14	9	40	.746983	55.79835
15	9	41	.7082158	50.15697
16	10	38	.7422959	55.10032
17	10	39	.7405761	54.84531
18	10	40	.7193513	51.74663

## DISCUSSION AND CONCLUSIONS

The importance of predictability of rainfall in an area of marginal precipitation cannot be overemphasized, especially in an agriculture-based economy. Therefore, much of the research on spatial and temporal variations in the monsoon climate are focussed on developing models for prediction of rainfall (Bedi, 1972; Singh and Mooley, 1978 etc.). The present communication is a modest attempt in this direction. This has been partially achieved by using two statistical techniques, namely:

1. Smoothing operations with unweighted windows, and
2. Correlation analysis.

The smoothing procedures, often used, have been found useful only for describing the temporal changes. Their utility for prediction is found to be limited in the present analysis. However, the smoothed series has been useful for identifying cooler and drier conditions at the turn of the

century, followed by a warmer and wetter climate towards the middle of the 20th century and a cooling trend, since then, for Pune city. Nevertheless, the analysis fails to establish any significant cyclicity or periodicity in rainfall and temperature variations.

In view of the limitations of the smoothing procedures, more sophisticated methods like autocorrelation, cross-correlation and multiple correlation were employed and were found to be more useful for developing models for rainfall prediction. The cross-correlations of the mean maximum temperature and of the mean minimum temperature with rainfall exhibit strong interdependence and hence can be used for prediction.

The following points emerge from the foregoing discussion and the preceding analysis of the data for Pune station:

1. The cross-correlation between the mean maximum temperature and rainfall indicates that prolonged cold winters assure good rains during the following monsoon.
2. The fall in the maximum temperature can be predicted 14 weeks ahead by observing the rise in the minimum temperature. For example, the fall in the maximum temperature during November is closely related with the rise in the minimum temperature during August. Therefore, duration and severity of winters is also predictable.
3. The maximum temperature during the first week of April and the minimum temperature during early August of the previous year are likely to be good indicators of the rainfall amount in the first week of June.
4. The rainfall in the second week of October (post-monsoon period) can be predicted by using the maximum

temperature during the first week of August and the minimum temperature of the second week of January.

The present study, based on the consideration of weekly mean maximum and weekly mean minimum temperatures and weekly rainfall, is an attempt to provide a new direction in search of models for predicting rainfall in tropical monsoon climate. The authors are fully aware of the limitations of the methods used. However, it is hoped that a further analysis based on daily temperatures and rainfall data over a longer period of time is likely to provide a

more reliable prediction model for monsoon rainfall.

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#### ADDRESSES OF THE AUTHORS

Alaka Gadgil  
 Sharad Gore and  
 Shridhar Gupte  
 School of Environmental Sciences  
 University of Poona  
 Pune 411 007 (India)