

STUDY OF EFFECT OF CHANGE OF CLIMATE ON RAINFALL OVER AN URBANISED COASTAL CITY

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ABSTRACT

Visakhapatnam located on the east coast of India has grown into a city in the last 35 years thanks to rapid industrialisation and urbanisation. It is felt that the rapid industrialisation and urbanisation would have caused some change in the climate of the city and its environs. Towards this objective, a climatological study of the important climate indicators namely maximum and minimum temperature was undertaken. The results pointed towards warming of the environment around Visakhapatnam in the thirty nine years period (1961 - 1999). The effect of these changes on the rainfall regime was studied by considering the time series of rainfall and rainy days for the period 1901 to 1999. The results indicated that (i) Rainfall during the last thirty four years has increased in the months June, July and August while it has decreased during September and October (ii) There is some change in the mean number of rainy days in the months of August and October.

1.0 INTRODUCTION

Climate and Society together constitute and interactive loop with the climate creating significant impact on the society both in the short term and long term. At the same time there is enough evidence to show that human actions in turn influence climate through the process of climate change (Figure 1)

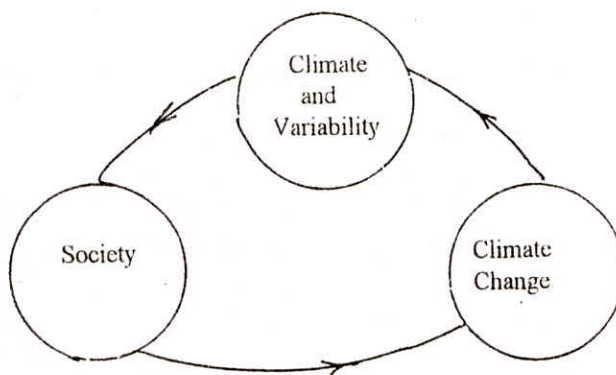


Figure 1 : Climate - Society Interaction

The fact that urbanisation and industrialisation jointly contribute to the change in the urban environment and ecosystem has received considerable attention and public exposure in the media the world over during the last 10 years. News paper reports speak of global warming being a reality and temperatures in India in the next 80 years are expected to increase by 7 degrees Celsius. The decision makers would, therefore, be interested to know about any significant shifts which are likely in the rainfall pattern and temperature regimes as a result of the warming. An objective and validated assessment would enable the urban planners and managers to evolve suitable strategies for optimal utilisation and management of the various available resources needed for the growing urban population.

Visakhapatnam located on the east coast of India has grown from a town into a city with a population of more than one million due to rapid industrialisation and urbanisation. It has been rated as one of the fast developing cities in Asia by the World Bank. A number of industries which have come up in and around the city during the last thirty five years have not only contributed to the deterioration of the surface and groundwater quality but also helped in the change of the climate of the city and its environs. A climatological study of the two important climate indicators namely maximum and minimum temperature was, therefore, undertaken with the objective to study the change of climate if any. The effect of the change of temperature if any on the rainfall regime that is rainfall amount and rainy days was also studied.

2.0 STUDY AREA

Visakhapatnam city is located between latitudes $17^{\circ} 36' 43''$ and $17^{\circ} 46' 43''$ N and longitudes $83^{\circ} 09' 17''$ and $83^{\circ} 22' E$. It has an areal extent of about 277 sq.km. The city is surrounded by Kailasa hills on the north, Yarada hills on the south and Narava - Nadupra hills on the west. Major industries like the Hindustan Petroleum Corporation Limited, Coromandel Fertiliser, Hindustan Zinc smelter plant, Bharat Heavy Plates and Vessels, Hindustan Polymers, Cement factory and Vizag Steel Plant have all come up in the southern part of the city during the period 1966 to 1995. The outer harbour facility for export of Iron ore also has come up during this period. In addition a 500 MW Thermal Power Plant is currently under construction by NTPC. The northern and north eastern areas, however, are industry free zones but with several new residential colonies. (Figure 2).

The average annual rainfall of Visakhapatnam is 980 mm. July to October is the principal rainy season. Heavy rains are also received some times during November under the influence of tropical storms. The mean annual maximum temperature is $31.0^{\circ} C$ and mean annual minimum temperature is $23.5^{\circ} C$. Summers are moderate with maximum temperatures around $33^{\circ} - 34^{\circ} C$ in May and June. Winters are mild with minimum temperatures above $17^{\circ} C$. These figures are based on 1931 - 1960 normals of India Meteorological Department.

3.0 DATA

For the purpose of the study monthly climatological data of Visakhapatnam for the period 1951 to 1999 has been analysed. However, for rainfall data for a longer duration 1901-1999 has been considered.

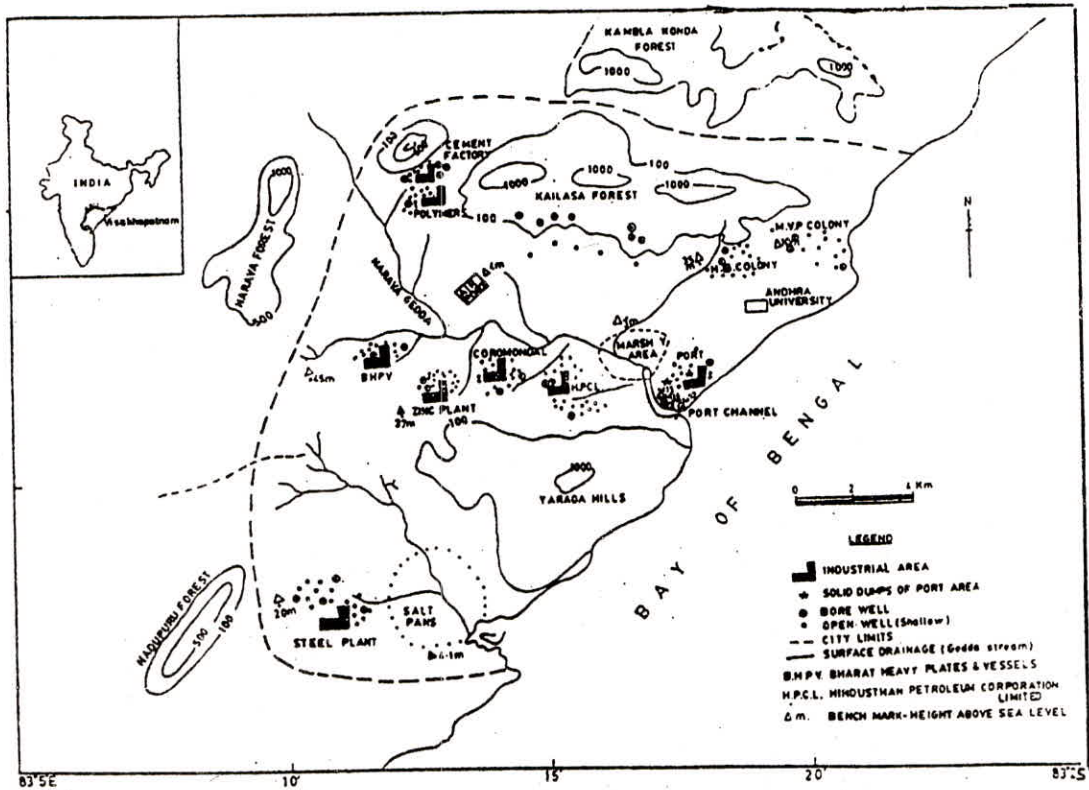


Figure 2 : Location Map of Visakhapatnam with Industrial and Residential Areas

4.0 ANALYSIS

Data of mean monthly maximum and minimum temperature of Visakhapatnam for the period 1961-1999 has been analysed to study the following:

- i. Identify any increase or decrease in temperature during the period 1961-1999 as compared to the climatological normals for the period 1931-1960 published by India Meteorological Department.
- ii. Identify any increasing or decreasing trend in temperature in the recent years that is after 1980.
- iii. Assess the effect of temperature change on the rainfall regime.

5.0 RESULTS AND DISCUSSION

The comparison of periodical means of the period 1961-1990 and 1961 - 1999 for maximum and minimum temperature in the summer and winter months with the climatological Normals of India Meteorological Department for the Standard WMO recommended period 1931-1960 is given in tables 1 (a) and 1 (b).

From the above table it may be seen that while the difference in the periodical means of the minimum temperature is negligible, there is appreciable difference in the periodical means of the maximum temperature especially in the two summer months of April and May indicating a warming. Analysis for trend in the series of the maximum and minimum temperature do not indicate any raising or falling trend in temperature in the period after 1980.

To study the effect of this local warming on the rainfall during monsoon season, trend analysis of monthly and monsoon season rainfall has been done using graphical techniques, computation of period means and statistical techniques. The period means have been determined for the two sub-periods 1901 - 1965 and 1966 - 1999 and the whole period 1901 - 1999.

Table 1 (a) : Maximum Temperature °C

Season --->	Winter	Winter	Summer	Summer	Summer
Period	<i>Dec.</i>	<i>Jan.</i>	<i>April</i>	<i>May</i>	<i>June</i>
1931-1960	27.7	27.7	32.8	34.0	33.7
1961-1990	29.0	29.0	35.2	36.3	35.4
1961-1999	29.0	29.0	35.2	36.1	35.2

Table 1 (b) : Minimum Temperature °C

Season --->	Winter	Winter	Summer	Summer	Summer
Period	<i>Dec.</i>	<i>Jan.</i>	<i>April</i>	<i>May</i>	<i>June</i>
1931-1960	18.3	17.5	25.9	27.8	27.4
1961-1990	19.0	18.3	26.1	27.7	27.4
1961-1999	18.8	18.3	26.0	27.6	27.5

The year 1965 is crucial because it is around 1965 the new industrialisation and urbanisation has started in Visakhapatnam with the establishment of Coromandel fertilisers, Bharat Heavy Plates and Vessels, Hindustan Zinc and the Creation of outer harbour facility for export of Iron ore.

Though monsoon, in general, is considered as only June to September, in this study October is also considered as a monsoon month because of the continued activity of monsoon and comparatively heavy rains received in the month of October in this region. The period means of rainfall for the five monsoon months (June to October) and the monsoon season (June - October) are given in the Table 2.

Table 2: Comparison of Period Means for Monthly and Monsoon rainfall (mm)

Month --> Period	June	July	August	September	October	Monsoon Jun- Oct
1901- 65	99.3	120.4	127.1	177.0	231.7	755.5
1966 - 99	112.1	130.0	149.7	172.7	182.1	746.6
1901 - 99	103.7	123.7	134.4	175.5	214.7	752.0

It may be seen from the table 2 that there is increase in rainfall amounts during the months July and August while there is decrease in rainfall during the month of October. The Monsoon rainfall series also indicate a decrease in rainfall during the period 1966 - 1999. The time series graphs of rainfall during August and October are shown in Figures 3 (a) and 3 (b) respectively.

To verify whether this was due to any increase or decrease in the number of rainy days, a comparative study of the number of rainy days for corresponding periods above was made. This, however, did not indicate any increase or decrease in the number of rainy days for the corresponding period of the later years i.e 1961 - 1999 in case of June, July and September. However, there is an increase in the mean number of rainy days by 1.5 in case of August and a decrease in the mean number of rainy days by 1.0 in case of October for the periods corresponding to the later years i.e 1961 - 1999.

Monsoon being a large scale phenomenon both in terms of time and space it is generally not expected that the monsoon rainfall will be affected by local phenomenon. However, the increase in dust content in the atmosphere and the heat due to the rapid industrialisation and urbanisation are expected to cause some minor changes. The prevailing wind direction in different months is also expected to contribute in a major way to the precipitation distribution. The wind roses in the different months at Visakhapatnam is shown in figure 4. It may be seen that the prevailing wind direction during June to September is south westerly to westerly and the local warming is expected

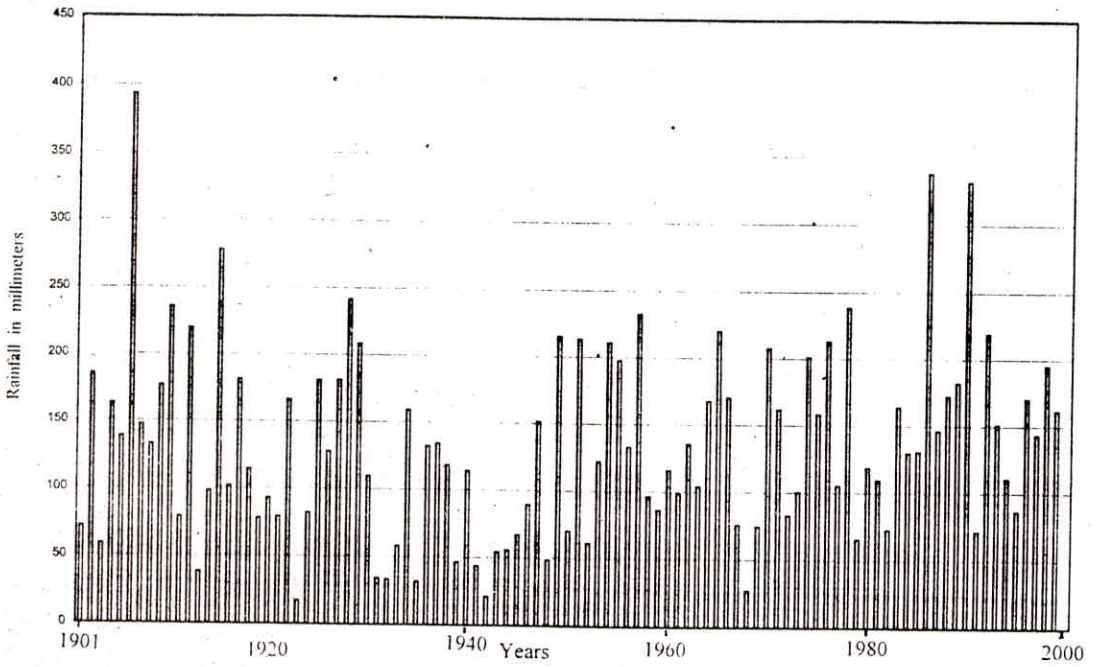


Fig. 3(a) : Time Series of August Rainfall (mm) at Visakhapatnam 1901-1999

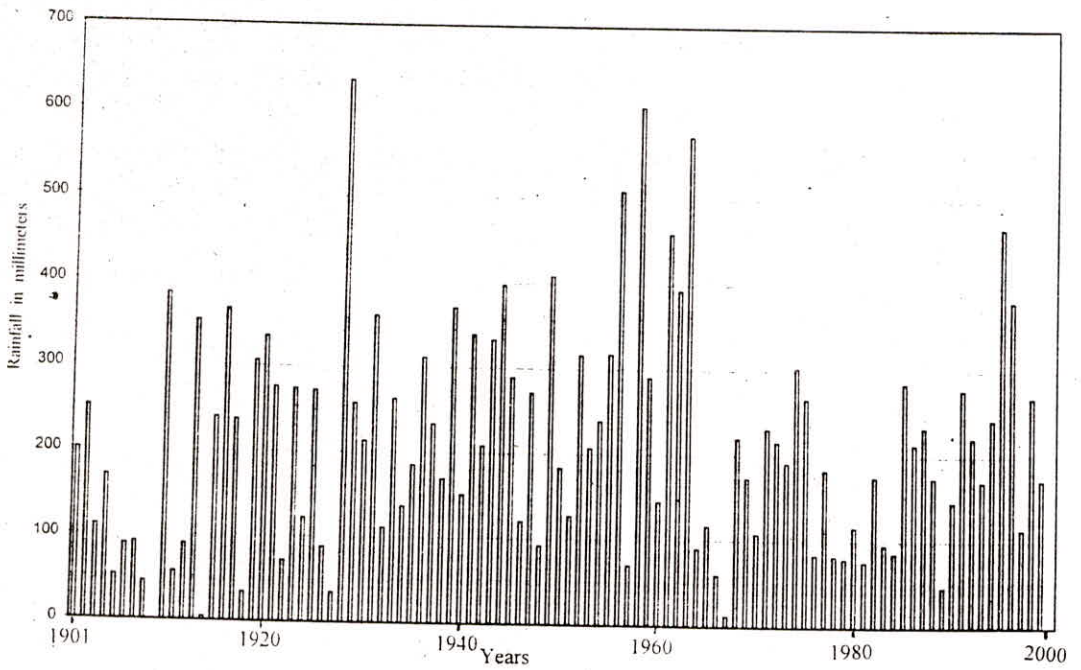


Fig. 3(b) : Time Series of October Rainfall (mm) at Visakhapatnam 1901-1999

WIND ROSES

VISAKHAPATNAM

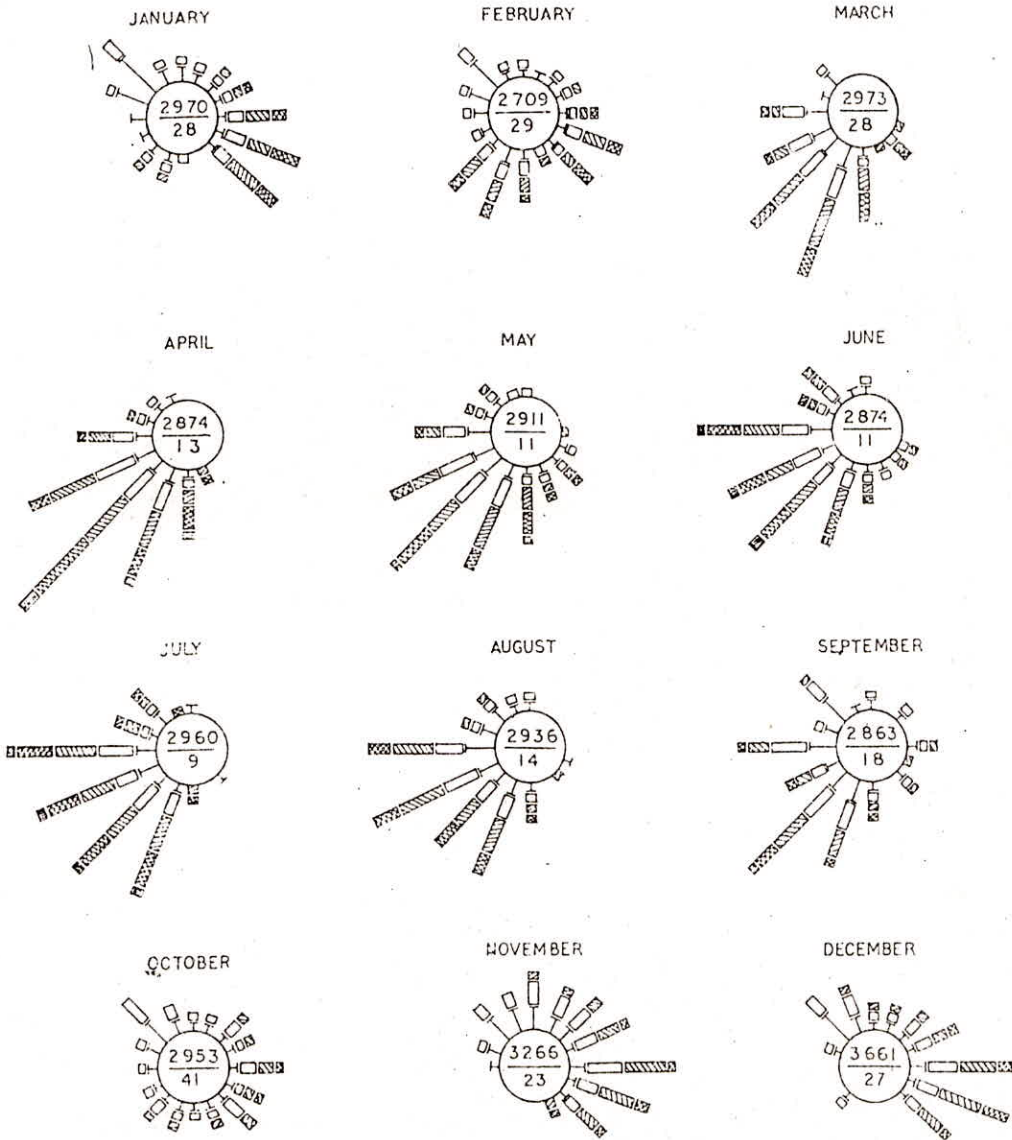
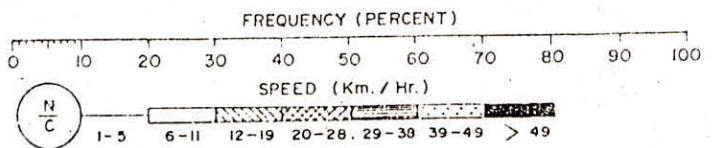


Figure 4

India Meteorological Department (1970)

N — Total number of observations.
 C — Number of calms as percentage of the total.



to increase the wind flow and might result in increase in moisture inflow facilitating more rain. In the month of October which is transition from South West monsoon to North East monsoon, the prevailing wind direction is east to south east and the winds are weak. Monsoon rain might be affected due to the increase in dust content during this period.

The possibility of increase in rain due to increase in the number of tropical storms has also been examined. The Monthly frequency of cyclonic storms during the period 1877-1990 is given in table 3.

Table 3 : Monthly frequency of cyclonic storms crossing east coast during the period 1877 - 1990

LATITUDE	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	TOTAL
17 - 18°	-	1	-	-	1	3	1	1	7
18 - 19°	-	2	-	1	4	4	1	-	12

Source : Sen, P.N and P. V. Pillai (1993) IMD Pre-Pub Sci. Rept. 1993 / 1

There has been a general increase in the number of storms crossing the east coast after 1961 as compared to the earlier decades i. e. 1941 - 1950 and 1951 - 1960 (Sen and Pillai, 1993). But it is difficult to establish how much this might have contributed to the change in precipitation pattern of the Visakhapatnam city.

6.0 SUMMARY AND CONCLUDING REMARKS

A climatological study of the important climate indicators namely maximum and minimum temperature at Visakhapatnam was undertaken with the objective of assessing the impact of rapid industrialisation and urbanisation of Visakhapatnam city. The results pointed towards warming of the environment around Visakhapatnam in the thirty nine years period (1961 - 1999). The effect of these changes on the rainfall regime was studied by considering the time series of rainfall and rainy days for the period 1901 to 1999. The results indicated that (i) Rainfall during the last thirty four years (1966 - 1999) has increased in the months June, July and August while it has decreased during September and October (ii) There is some change in the mean number of rainy days in the months of August and October. Increase in dust content in the atmosphere and the heat due to the rapid industrialisation and urbanisation are suspected to have caused some minor changes in the precipitation distribution. Further in depth studies on the micro climate of Visakhapatnam city are needed to establish the causes and corroborate the findings from the study.