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RESEARCH ARTICLE

TREND DETECTION IN PM 10 AND METEOROLOGICAL PARAMETERS USING MANN KENDALL TEST –A CASE STUDY CHENNAI CITY

*Najma Nikkath S. and Samuel Selvaraj, R.

Bhaktavatsalam Memorial College for Women, Presidency College of Arts and Science, Chennai, India

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ABSTRACT

The impact of climate change on annual air temperature and precipitation has received a great deal of attention by scholars worldwide. Many studies have been conducted to illustrate that changes in annual temperature and precipitation are becoming evident on a global scale. This study focuses on detecting trends in annual temperature and precipitation and Aerosols (PM10)for Chennai city For this study, the widely used modified Mann-Kendall test was run at 5% significance level on time series data for the yearr2014. The resultant Mann Kendall test statistic (S) indicates how strong the trend in temperature, PM10 and precipitation is and whether it is increasing or decreasing. There is a increasing trend in the rainfall and PM10 measured at T. Nagar, whereas decreasing trend in the temperature and PM10 of Kilpauk regions of Chennai.

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INTRODUCTION

Atmosphere consists of gases and minute particles of solid and liquid matter (particulate matter known as atmospheric aerosols) in concentrations that can affect environment and health. Atmospheric aerosols are particles of solid or liquid phase dispersed in the atmosphere Jung1963) Seinfeld (2006). Aerosols can vary in size from $10^{-3}$to 10^{2}μmdepending upon the source and production mechanism. Small aerosols (<1 μm in size) are produced mainly by the nucleation of volatile gases, a process known as gas-to-particle conversion, in the atmosphere. Small aerosols often grow in size due to coagulation and by condensation of water vapor. Large aerosols (>1 μm in size) are produced directly by mechanical processes (e.g. action of winds). Aerosols of different size ranges are important for different atmospheric processes. While sub-micron aerosols (< 1 μm) are important in atmospheric optics, super-micron particles have important role as cloud condensation nuclei. The aerosols are of natural and anthropogenic in origin and the latter are more significant. There effects on climate are more uncertain than the greenhouse gases despite their shorter life span there effect is not well pronounced due to poor data base. The anthropogenic emission of aerosol precursors has increased considerably because of the increase in industrial activities (Cheng *et al.,* 2005, *Gong et al.,* 2007). The corresponding increase in anthropogenic aerosol would act as a super fluous superfluous forcing to alter atmospheric physical process such as radiation, the size spectrum of cloud particles, cloud cover, atmospheric stability, and precipitation (Youg-Sang 2007, Ramanatha *et al.,* 2001, Kaufman *et al*. 2005 Temperature and precipitation are fundamental components of climate and changes in their pattern can effect human health, ecosystems, plants, and animals. (Andreae, 2005) An increase in Earth's temperature leads to more evaporation and cloud formation to occur, which in turn, increases precipitation. (Chand, 2009),

Corresponding author: Najma Nikkath S.,
Bhaktavatsalam Memorial College for Women, Presidency College of Arts and Science, Chennai, India.

According to (Mark Z. Jacobson 2006) increase in aerosol concentrations, may affect the long-term variations in precipitation in conjunction with other climatic conditions such as global warming. Hence aerosol concentration and precipitation are closely related with each other. Available observational evidence indicates that regional changes in climate and particularly increases in temperature have already affected a diverse set of physical and biological systems in many parts of the world (IPCC 2001). Potential changes in the monsoon pattern are due to significant impacts of climate change According to (Parikh *et al.,* 2013) coastal cities, like Chennai are vulnerable to cyclones and associated hazards such as storm surges, high winds and heavy rainfall.

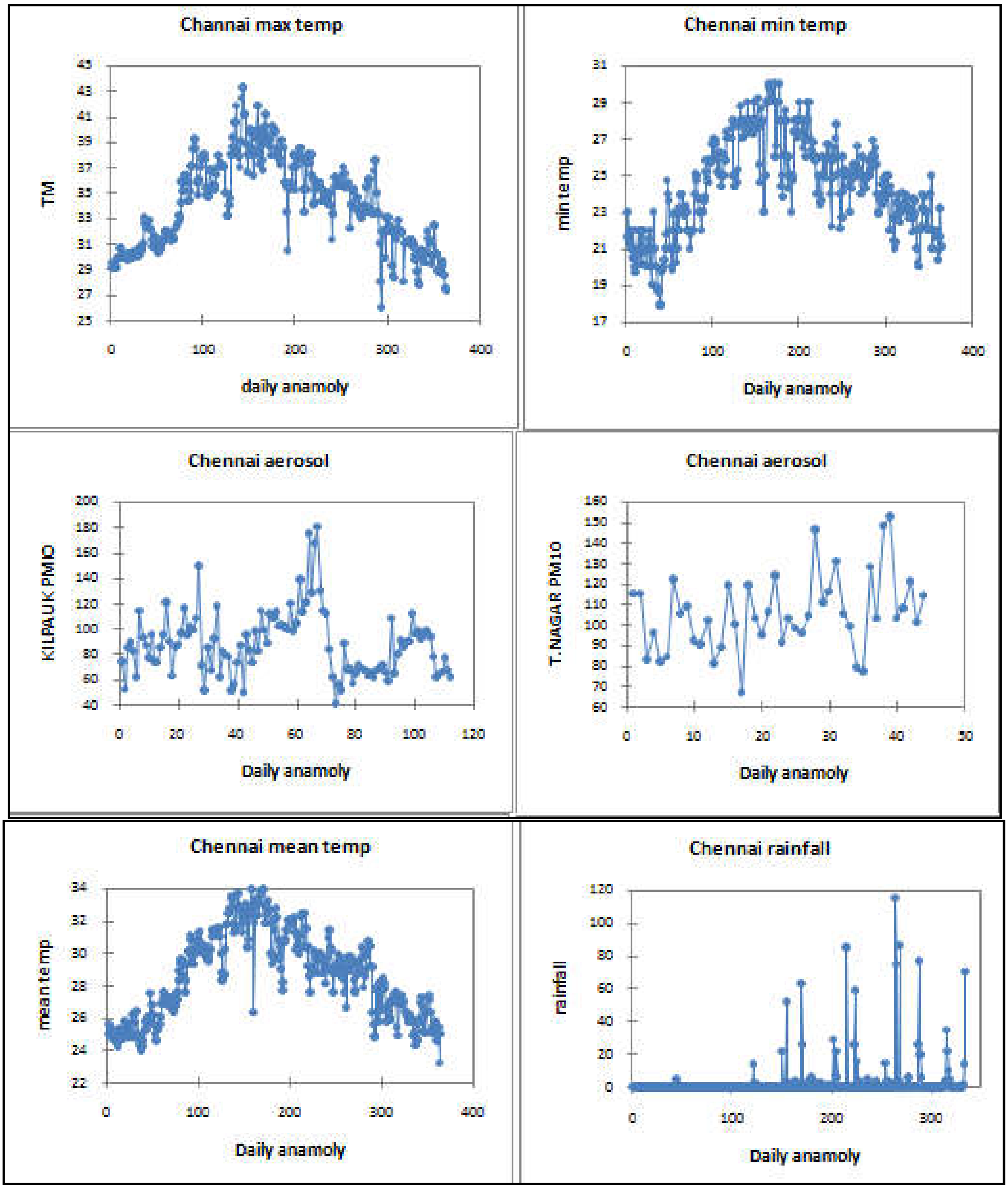

Figure 1. Plot of variation in temperature aerosol and rainfall for Chennai region 2014

The frequency of extreme rainfall (rainfall ≥ 124.4mm) shows an increasing trend and is significant at the 98 per cent level (Attri and Tyagi, 2010). Chennai city is the 4th largest city in India and having 2nd largest beach in the world. Chennai district is a district in the State of Tamilnadu out of 32 districts. It is the smallest of the entire district in the state, but has the highest human density. The most significant phenomenon in Chennai city is massive urbanization. Chennai city Metropolitan Area covers 174 sq kms. The population of Chennai city which was 14.16 lakh in1951, increased 24.69 lakh in 1971, and further it was 38.41 lakh in 1991.

Now in 2011 the population of the Chennai. Rapid urbanization in the State exceeds the national rate and with over 48.4 percent of the State population living in urban areas. While (Simpson *et al* 2008) reports large amounts of rainfall occur near Chennai due to sea breeze induced convection. Simpson *et al.,* 2007 reports, Anthropogenic heating over urban regions increases near surface air temperatures and decreases stability. According to Pillai (1999), there are long term trends in temperature, aerosols and rainfall. Urbanisation and industrialisation have resulted increased vehicular traffic in cities, resulting in increase in automobile emissions and toxic smoke emissions. (Anon, 2005),

Table 1. Summary statistics

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
Rainfall	367	33	334	0.0000	115.0600	3.2891	13.2293
Temp Mean	365	1	364	23.2000	33.900	28.5742	2.6229
TempMax	365	1	364	26.0000	43.2000	34.1753	3.5013
TempMin	365	1	364	17.8000	30.0000	24.3981	2.3136
PM10 T.Nagar	54	10	44	67.0000	153.0000	105.2955	18.6717
PM 10 Kilpauk	139	27	112	41.0000	180.0000	88.0804	25.6048

Table 2. Mann-Kendall trend test / Two-tailed test

Variable	Kendall's tau	S	Var(S)	p-value (Two-tailed)	alpha	Sen's slope	Test interpretation:
Rainfall	0.02237	7879.0	2238960.33	<.0001	.05	0	H_0 Rejected
Temp Mean	-0.0264	-1733.0	5379307.00	0.4552	.05	-.0011	H_1 Rejected
TempMax	0.0991	-.0991	5379382.6667	.0052	.05	-.0059	H_1 Rejected
TempMin	0.0505	3283.0	5370459.6667	.1567	.05	.0015	H_1 Rejected
PM10 T.Nagar	0.2104	198.0	9762.667	0.0462	0.05	0.4464	H_0 Rejected
PM 10 Kilpauk	-0.0570	-352.0	158068.0	0.3733	0.05	-0.0621	H_1 Rejected

Table 3. Seasonal Mann-Kendall Test / Period = 3 / Serial independence / Two-tailed test

Variable	Kendall's tau	S	p-value
Rainfall	0.2178	2526.0	<.0001
Temp Mean	-0.0240	-521.0	0.5011
TempMax	-0.0944	-2046.0	0.0082
TempMin	0.0547	1174.0	0.1288
PM10 T.Nagar	0.2656	72.0	0.0244
PM 10 Kilpauk	-0.0392	-78.0	0.5607

According to a report from IIT, Pollutants in Chennai are from diesel based engines and vehicles, gasoline based vehicles, LPG and soil dust.

MATERIALS AND METHODS

A 12 month data of precipitation and temperature of Chennai region for the year 2014 was used for the study. The data for PM10 was collected from the central pollution control board, Chennai for the regions T. Nagar and Kilpauk.. Rainfall data was obtained from Regional Meteorological Centre, Chennai. In this study, statistical method was used for trend detection in the rainfall and temperature series and PM10. Mann Kendall test is a statistical test widely used for the analysis of trend in climatologic Mavromatis (2011) and in hydrologic time series (Yue and Wang, 2004).

There are two advantages of using this test. First, it is an on-parametric test and does not require the data to be normally distributed. Second, the test has low sensitivity to abrupt breaks due to inhomogeneous time series Tabari, (2011). Any data reported as non-detects are included by assigning them a common value that is smaller than the smallest measured value in the data set (Blackwell Publishing 2012). According to this test, the null hypothesis H_0 assumes that there is no trend (the data is independent and randomly ordered) and this is tested against the alternative hypothesis H_1, which assumes that there is a trend Onoz 2012. The computational procedure for the Mann Kendall test considers the time series of n data points and Ti and Tj as two subsets of data where i = 1,2,3,…, n-1 and j = i+1, i+2,i+3, …, n. The data values are evaluated as an ordered time series. Each data value is compared with all subsequent data values. If a data value from a later time period is higher than a data value from anearlier time period, the statistic *S* is incremented by 1. On the other hand, if the data value from a later time period is lower than a data value sampled earlier, *S*is decremented by 1. The net result of all such increments and decrements yields the final value of *S* (Drap *et al.,* 2011). The Mann-Kendall S Statistic is computed as follows:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sign\,(T_j - T_i)$$

$$Sign\,(T_j - T_i) = \begin{cases} 1\, if\, T_j - T_i > 0 \\ 0\, if\, T_j - T_i = 0 \\ -1\, if\, T_j - T_i < 0 \end{cases}$$

where T_j and T_i are the annual values in years j and i, j > i, respectively. [10]

If n < 10, the value of |S| is compared directly to the theoretical distribution of S derived by Mann and Kendall. The two tailed test is used. At certain probability level H_0 is rejected in favor of H_1 if the absolute value of S equals or exceeds a specified value Sα/2,where Sα/2 is the smallest S which has the probability less than α/2 to appear in case of no trend. A positive (negative) value of S indicates an upward (downward) trend. (5) For n ≥ 10, the statistics is approximately normally distributed with the mean and variance as follows:

$$E(S) = 0$$

The variance (σ^2) for the S-statistic is defined by:

$$\sigma^2 = \frac{n(n-1)(2n+5) - \sum t_i(i)(i-1)(2i+5)}{18}$$

In which it denotes the number of ties to extent i. The summation term in the numerator is used only if the data series contains tied values. The standard test statistic Zs is calculated as follows:

$$Z_s = \begin{cases} \frac{S-1}{\sigma} for\ S > 0 \\ 0\ for\ S = 0 \\ \frac{S+1}{\sigma} for\ S < 0 \end{cases}$$

The test statistic Zs is used a measure of significance of trend. In fact, this test statistic is used to test the null hypothesis, H_0. If | Zs| is greater than Zα/2, where α represents the chosen significance level (eg: 5% with Z 0.025 = 1.96) then the null hypothesis is invalid implying that the trend is significant. (Motiee, 2009) Another statistic obtained on running the Mann-Kendall test is Kendall's tau, which is a measure of correlation and therefore measures the strength of the relationship between the two variables. Kendall's tau, like Spearman's rank correlation, is carried out on the ranks of the data. That is, for each variable separately, the values are put in order and numbered, 1 for the lowest value, 2for the next lowest and so on.

In common with other measures of correlation, Kendall's tau will take values between ±1 and +1, with a positive correlation indicating that the ranks of both variables increase together whilst a negative Correlation indicates that as the rank of one variable increases, the other decreases. (Blackwell Publishing 2012). In time Series analysis it is essential to consider autocorrelation or serial correlation, defined as the correlation of a variable with itself over successive time intervals, prior to testing for trends. Autocorrelation increases the chances of detecting significant trends even if they are absent and vice versa. In order to consider the effect of auto correlation, Hamed and Rao (1998) suggest a modified Mann-Kendall test, which calculates the autocorrelation between the ranks of the data after removing the apparent trend. The adjusted variance is given by:

$$Var\,[S] = \frac{1}{18}[N(N-1)(2N+5)]\frac{N}{NS^*}$$

Where $\frac{N}{NS^*} = 1 + \frac{2}{N(N-1)(N-2)}\sum_{i=1}^{p}(N-i)(N-i-1)(N-i-2)p_s(i)$

Where N is the number of observations in the sample, NS* is the effective number of observations to account for autocorrelation in the data, ps (i) is the autocorrelation between ranks of the observations for lagi, and p is the maximum time lag under consideration (Sinha 2007). The null hypothesis is tested at 95% confidence level for both, temperature and precipitation and Aerosol data for the Chennai region. The Statistical results are given in the Table 1.The results of Mankendall trend tests are given below in Table 2 and Table 3.

RESULTS AND DISCUSSION

On running the Mann-Kendall test on temperature maximum, minimum, mean, rainfall and PM 10 (T Nagar and Kilpauk) of Chennai Region daily data for the year 2014, the following results were obtained. If the p value is less than the significance level α (alpha) = 0.05, H_0 is rejected. Rejecting H_0 indicates that there is a trend In the time series, while accepting H_0 indicates no trend was detected. On rejecting the null hypothesis, the result is said to be statistically significant. Table 1 indicates statistical results whereas the Table 2 and Table 3 give Mann-Kendall trend test/ Two-tailed test and Seasonal Mann-Kendall Test. From the result is observed that for the Chennai Region there is trend in rainfall and PM 10, though there was no trend seen in the temperature time series. The aerosols play a significant role in the cloud microphysics. The positive value for Sen's slope also indicates a positive trend in the rainfall and PM10.

Conclusion

Changes in temperature and precipitation can also tell us something scientifically useful about how larger-scale atmospheric changes may influence temperature and precipitation .Another atmospheric concern accompanied by the urbanization is the air pollution and its effects on climate. It is significant to understand here that these estimates should be analysed for a longer time and no conclusions should be drawn without considering the spatial distribution of time series. In other words, the trend in PM 10 and precipitation seen for the Chennai Region could imply that it agrees well with the trend in the rainfall and Aerosol, of the cities, as reported in literature, no conclusion can be drawn with limited data.

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