IJIREEICE

ISSN (Online) 2321-2004
ISSN (Print) 2321-5526

International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering

Vol. 7, Issue 4, April 2019

Trend Detection in Annual Temperature to Assess Climate Change on Selected Regions in India

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Abstract: The impact of climate change on annual air temperature has received a great deal of attention by scholars worldwide. Many studies have been conducted to illustrate that changes in annual temperature is becoming evident on a global scale. This study focuses on detecting trends in annual temperature for the five major city regions in the India. For this study, the widely used modified Mann-Kendall test was run at 5% significance level on time series data for each of five major city regions for the time period, 1982 to 2018. Mann-Kendall trend statistics is used to show the trend and Sen's estimator of slope is used to depict the magnitude of the trend. Lastly, a simple co-relation among the weather variables has been done to show the impact of temperature in changing hydrological conditions of the Country.

Keywords: Rainfall Trend, Season, Mann-Kendall Trend Statistics, Sen's Slope, Cross-correlation

I. INTRODUCTION

Climate change and global warming are recognized worldwide as the most crucial environmental dilemma that the world is experiencing today [1], [2], [3]. Concern in climate change and global warming by the international community, non-government organizations and governments has brought great interest to climate scientists leading to several studies on climate trend detection at global, hemispherical and regional scales [4],[5]. Nowadays, study of long-term temperature variability has been a topic of particular attention for climate researchers as temperature affects straightaway human activities in all domains. Increase in anthropogenic greenhouse gases' concentrations in the atmosphere is mainly due to human activities such as deforestation, burning of fossil fuel and the conversion of the Earth's land to urban uses driven largely by the rapid growth of the human population that are major causes of warming of the climate system and of the process of climate change [5],[6]. Several studies of long-term time series of temperatures have been done [7],[8],[9]. Results have shown that the Earth's surface air temperature has increased by 0.6˚C - 0.8˚C during the 20th century, along with changes in the hydrologic cycle. Temperatures in the lower troposphere have augmented between 0.13˚C and 0.22˚C per decade since 1979, according to satellite temperature measurements [10]. In an analysis of a time series combining global land and marine surface temperature records from 1850 to 2010 developed by the Climate Research Unit (CRU), the year 2005 was seen as the second warmest year, behind 1998 with 2003 and 2010 tied for third warmest year [8],[9],[10],[11],14] . The two most recent decades were compared with the period 1979-1990. Warming has been observed to be concentrated in the most recent decade, from 2001 to 2010. The results were attributed to natural variability of the climate and/or to human activity but not to the El Niño-Southern Oscillation as previously suggested by other authors [12],[13], and [15]. Generally, there is consent among scientists that most of the observed increase in globally averaged temperatures since the mid-20th century is unequivocal and very likely due to the observed increase in anthropogenic greenhouse gas concentrations. The 10 warmest years of the 20th century all occurred in the last 15 years of the century, 1998 being the warmest. The Intergovernmental Panel on Climate Change (IPCC, 2007) projected that the average global surface temperature will continue to increase to between 1.4˚C and 5.8˚C above 1990 levels, by 2100 [2]. To some extent, other factors, such as variations in solar radiation [8] and land use at regional scale, are also considered to be among the causes of the observed global warming [16 to 22]. Though some studies have been done on climate change in different regions of India and whole of the adjacent sub-continent, the lack of reliable surface observational climate data still constitute a foremost gap affecting the detection capacity of impacts resulting from long-term climate changes. An effort is, therefore, required in maintaining existing observatories and increasing networks, and cooperation between countries. Regardless of the limited surface observational climate data, results from those studies indicate, in general, an increasing trend in temperature and a decreasing trend in rainfall during the last century. But key sources of errors in the detection of abrupt changes in climate data habitually consist of change of location of observatory; changes of instruments, change in observation times, missing data, and methods used to calculate daily means and increased

IJIREEICE
ISSN (Online) 2321-2004
ISSN (Print) 2321-5526
International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering
Vol. 7, Issue 4, April 2019

urbanized and/or industrialized areas. In homogeneities in climate data time series can bring inaccuracies and make possible misinterpretation in the investigation of climate change over a region when analysing a given climate parameter. Hence, there is a need for detecting change points in temperature time series and adjustment of data thereby.

II. STUDY AREA

India is a country in South Asia. It is the seventh largest country by area and with more than 1.3 billion people; it is the second most populous country as well as the most populous democracy in the world. Bounded by the Indian Ocean on the south, the Arabian Sea on the southwest, and the Bay of Bengal on the southeast, it shares land borders with Pakistan to the west; China, Nepal, and Bhutan to the northeast; and Bangladesh and Myanmar to the east. In the Indian Ocean, India is in the vicinity of Sri Lanka and the Maldives, while it's Andaman and Nicobar Islands share a maritime border with Thailand and Indonesia. The Country's capital is Delhi.

India is home to an extraordinary variety of climatic regions, ranging from tropical in the south to temperate and alpine in the Himalayan north, where elevated regions receive sustained winter snowfall. The nation's climate is strongly influenced by the Himalayas and the Thar Desert.

Figure 1: Study Area Map

III. MATERIALS & METHODS

A. Materials Used

The data used in this study were collected from the Eastern Regional Centre of Indian Meteorological Department, Kolkata. They consisted of time series of year wise monthly average of maximum and minimum surface air temperature for the period ranging from 1982 to 2018 for the India weather observatory. Those data were statistically processed and then condensed to annual mean values for further analysis. Studies of long-term climate change require that data be homogenous. Observed climate abrupt changes in a homogenous climate time series are caused only by variations in weather and climate [23]. Several studies have been conducted on quality control and homogenization of climatologically data for the detection of climate trends [24 to 27].

ISSN (Online) 2321-2004
ISSN (Print) 2321-5526
Vol. 7, Issue 4, April 2019

Figure 2: Temperature variation in India.

B. Methodology Followed

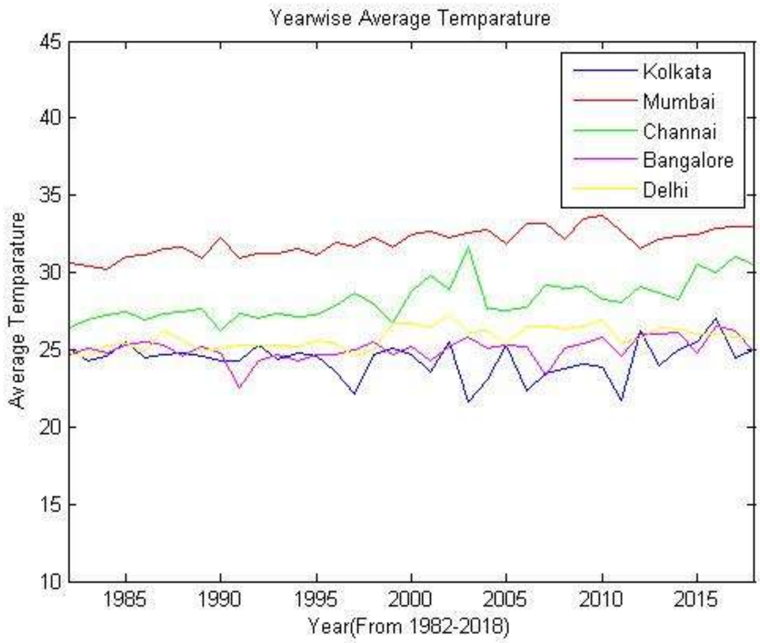

Figure 3: Year wise Average temperature in different cities

DOI 10.17148/IJIREEICE.2019.7404

ISSN (Online) 2321-2004
ISSN (Print) 2321-5526

IJIREEICE

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Electrical, Electronics, Instrumentation and Control Engineering

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The temperature trend analysis of India has been done here using Mann-Kendall trend statistics, which is a non-parametric statistical method for time series analysis (Mann, 1945, Kendall, 1975, Yu et al. 1993, Lettenmaier et al. 1994, Douglas et al. 2000, U.S. Army Corps of Engineers 2004, Burn et al. 2004, Mandal et al. 2013).

The Mann Kendall Trend Test

The Mann Kendall Trend Test (sometimes called the M-K test) is used to analyse data collected over time for consistently increasing or decreasing trends ("monotonic trends") in Y values. It is a non-parametric test, which means it works for all distributions (i.e. your data doesn't have to meet the assumption), but your data should have no serial correlation. If your data does follow a normal distribution, you can run simple linear regression instead.
The Mann-Kendall trend statistics is calculated by them as-

$$S = \sum_{k=1}^{n-1} \sum_{j=k+n}^{n} \mathrm{sgn}(Xj - Xk) \ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

Where, S = Mann-Kendall Trend Statistics
n = Number of Data Points
Xj, Xk = Data Values at the time period of j & k respectively
sgn (Xj-Xk) = sign function and is equal to 1, 0 or -1
whether (Xj-Xk) is positive, zero or negative respectively.

In the absence of ties, the variance of S under the null hypothesis is-

$$\mathrm{var}(S) = \frac{n(n-1)(2n+5)}{18} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(2)$$

Kendall's tau has been also calculated to show the nature of trend using the software. The positive and negative 'tau' value indicates the increasing and decreasing trends respectively (Mann 1945, Kendall 1975, Lettenmaier et al. 1994). Here 'p' value is generated which will identify the significance of the trend. It is done at the 95% level of significance. The 'p' values that will not significant at the 95% level of significance are showing no trend in the data series.

Sen's Slope Estimator

Now, for determining the hydro-meteorological magnitude of trend, Sen's slope estimator is used which is widely applied (Sen 1968, Yue and Hashino, 2003, Partal and Kahya, 2006, Jain and Kumar, 2012, Mandal et al. 2013). In this method, firstly the slopes (Ti) of all data pairs are calculated by the following equation-

$$Ti = \frac{Xj - Xk}{j - k} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots...(3)$$

Where, i = 1, 2…………………., n.
Xj & Xk=the data values at time j & k (j > k)
Now, the median of these n values of 'Ti' is the Sen's estimator of slope (β) which will determine the magnitude of trend (Sen, 1968, Jain and Kumar, 2012). It is calculated as-

$$\beta = T_{\frac{n+1}{2}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots. \text{ when "n" is even.}$$

$$\beta = \frac{1}{2}\left(T_{\frac{n}{2}} + T_{\frac{n+2}{2}}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots. \text{ when "n" is even.}$$

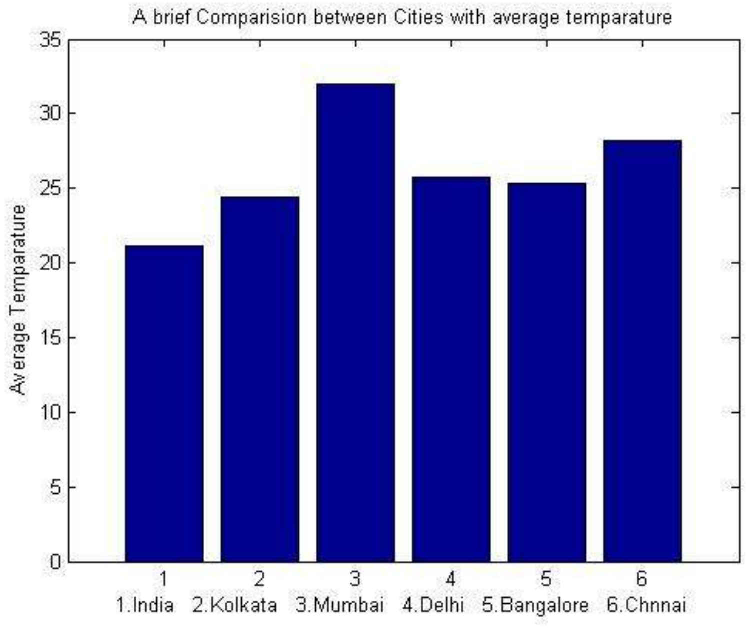
The positive β value indicates increasing trend whereas the negative β value indicates decreasing trend. After all these trend analysis, a simple co-relation has been done using the software among the climatic varia-bles to show the influence of rainfall on other parameters.

IV.RESULTS & DISCUSSION

The Mann-Kendall trend statistics are performed for five major cities of India in varying seasonal conditions for the last century (1982-2018). The outcome of such operations are shown in the following tables-

Table 1.Mann-Kendall Trend Test Table:

Score	India(1982-2018)	Kolkata(1982-2018)	Mumbai(1982-2018)	Delhi(1982-2018)	Bengalore(1982-2018)	Channai(1982-2018)
Minimum	12.826	9.6	15.7	3.9	12.2	16.6
Maximum	28.095	43	40.8	46.4	36.5	45
Mean	21.140	24.362	31.992	25.76	25.295	28.235
Median	21.961	24.3	32.45	25.65	32.3	27.75
Mode	15.271	14.4	32.9	19.7	16.3	19
Avg of Standard Deviation	1.436	3.556	1.558	1.475	2.501	2.666
Variance	2.061	12.647	2.427	2.175	6.257	7.109
Mann-Kendall Statistic (S)	-63	367	200	-174	224	216
Ken-dall's tau	-0.8109	0.047869	0.02602	0.02426	0.02916	0.02512
P Value	0.0727	0.0003	0.0032	0.013	0.0032	0.0032
Sen's Slope (β)	-0.002	0.0514	0.0176	-0.0197	0.0025	0.0032
Skewness	-1.114	0.2502	0.2692	0.6815	1.7407	0.8824
Kurtosis	5.6172	1.6324	2.2471	2.9036	6.5633	4.0860
Remarks	Increasing	Increasing	Increasing	Decreasing	Increasing	Increasing



India is an agrarian economy based country and rice is the major crop. In the Eastern, Western and central part along the river-line flood plain, agriculture is highly practiced. But summer temperature is increasing more in this area whereas North Indian temperature is decreasing. So, crop calendar must be revised for this part of the country. During summer, temperature is increasing in the all other part of India whereas it is decreasing in the North India. So, we can understand that Boro cultivation will be preferable in the central and Eastern part of India than the North India. If we have to do it in the fertile plains of East India then irrigation facility must be provided in this season. In case of annual average temperature trend, For these unusual occurrences of temperature in that area, the agricultural fields are decreasing and it is converted into millet as per the viewpoint of the local farmers. Same kind of situation is also seen in the parts of South India. Such fluctuating trend is very much significant for the economy of the whole part of India.

IV. CONCLUSION

As per the above study, it is quite evident that there is a mixed scenario of temperature trend in India. Although majority of cities are having increasing trend of temperature. As summer temperature has prime significance in the production of crops, therefore the different major regions of India which are suffering from increasing trend must think about alternative measures like irrigation. Similarly, increasing trend in the post-monsoon rainfall over entire state except the Delhi region has to be become concern for snow-fall probability and crop loss. In conclusion, it may be said that the long term temperature trend analysis during the past century (20th century) will definitely give the idea about the temperature pattern and hydro-economic conditions of the country in the present century (21st century).

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