Historical Trend Investigation Of Temperature Variation In Indira Sagar Canal Command Area In Madhya Pradesh (1901–2005)

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Abstract

Trend investigation in Temperature variable and evaluation of their statistical significance has recently recognized a great concern to explain whether or not, there is a noticeable climate change. In this study the historical trends of air Temperature variation of Indira Sagar canal command area located at Madhya Pradesh, in India for a period of 105 years (1901–2005) were analyzed in annual and seasonal basis using the Mann–Kendall test. Result of serial correlations was identified and random error is removed from the data by the single pre-whitening method previous to the trend analysis. It was found that annual (Average, Maximum and Minimum) air temperature series were increasing significant for all three stations at α = 0.001 level of significance over Indira Sagar canal command area. The magnitude of the temperature trends was derived from the Theil– Sen's slope estimator. The highest magnitudes of the warming trends in the annual average temperature series were found at Barwani, East Nimar and West Nimar stations at the rates of 0.004, 0.005 and 0.005°C/year. Moreover, the strongest rising trends and growing shift changes were observed in Annual (Average, Maximum and Minimum) temperature variation sequence.

***Keywords*:** Temperature, Trend analysis, Lag-1 serial correlation, Mann–Kendall, Single pre-whitening method, Sen's slope estimator, Monotonic trend

I INTRODUCTION

Temperature is the important meteorological variable after precipitation because it can be related to evapotranspiration processes which represent the main phase of the hydrologic cycle. In the twenty-first century, an earth temperature increases a few degrees higher than the previous century, and it is accepted that the global climate is changed. According to the best present estimates, the increase of the global temperature during the twenty-first century will be in the range of 1.4– 5.8°C, but what is happening on regional and seasonal scale is less clear. Having sufficient information about the climatic changes in the recent past is extremely important for improving the certainty of estimations about the future (Soltani and Soltani 2008).

Recently IPCC Fourth Assessment Report (2007), 11 of the last 12 years rank amongst the 12 warmest years in the globe since 1850. The last 100-year (1906–2005) linear trend is 0.74°C, which is higher than the corresponding trend in 1901–2000 given in the Third Assessment Report (Bernstein et al. 2007).

Hence, impact appraisals require information on changes in climatic variability at a regional and local scale and the analysis of not only mean changes but also trends in unpredictability of climatic variables, because variability is also an imperative part of climate change (Hasanean and Basset 2006). Trend investigation have been most commonly used statistical techniques is applied for identifying climatic changes on a regional and local basis Tabari H et al (2011a); Tabari H et al (2011b); Andrighetti et al. 2009; Gadgil and Dhorde 2005; Feidas et al. 2004; Turkes and Sumer 2004; Yue and Hashino 2003; Ventura et al. 2002; Hasanean 2001

A few studies in India have been carried out on changes in temperature and their alliance with climate change. A temporal and spatial change of seasonal and annual temperature in India was conducted by researchers including: Revadekar et al. (2011) Indrani Pal et al. (2009), Jhajharia et al, (2009), Bhutiyani et al. (2007), Kothawale et al (2005) and Arora et al. (2005).

Revadekar et al. (2011) done the observational analysis by taking 121 stations spread all over India showed that widespread warming through an increase in intensity and occurrence of warm events and also by a decrease in occurrence of cold actions.

Indrani Pal et al. (2009) reported that the long-term trends and variations of the monthly maximum and minimum temperatures and their effects on seasonal fluctuations in various climatological regions in India. The magnitude of the trends and their statistical significance were determined by parametric ordinary least square regression techniques and the variations were determined by the respective coefficient of variations. The results showed that the monthly maximum temperature increased, though unevenly, over the last century. Minimum temperature changes were more variable than maximum temperature changes, both temporally and spatially, with results of lesser significance. The results of this study are good indicators of Indian climate variability and its changes over the last century.

Jhajharia et al, (2009) investigated that the mean temperature varies from 5 to 30^{o}C and the mean relative humidity ruins between 70% and 85% for most part of the year in northeast India.Jhajharia and Singh (2010) observed declining trends in DTR (DTR = Tmax − Tmin) at four station in NE for almost all timescales. On the other hand, the DTR trends were significant mainly at annual, seasonal (pre-monsoon and monsoon), and monthly (May, June, August, September, and November) timescales. Significant rising trends in DTR are observed at three station in the month of October and in the monsoon and post-monsoon seasons as well. Four sites showed significant increasing trends in T_{mean} in monsoon and post-monsoon seasons. Post-monsoon changes in T_{max} and T_{min} were more than the monsoon changes, indicating an element of a seasonal cycle. Significant decreasing trends in the sunshine duration were observed at annual, seasonal (winter and pre-monsoon), and monthly (January–March) timescales. Lately, Kothawale et al. (2010) informed that from the period 1901–2007, all-India mean, maximum, and minimum temperatures have significantly amplified by 0.51, 0.71, and 0.27 °C per 100 years, respectively. And also from year 1971 to 2007 the accelerated warming was observed.

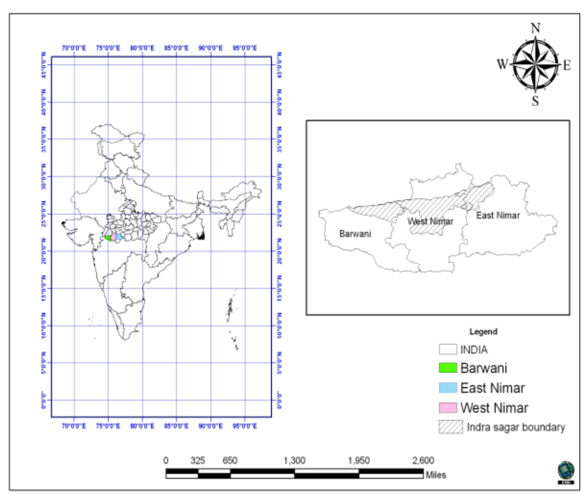
Bhutiyani et al. (2007) has demonstrated that the existence of possible teleconnections between the precipitation and temperature variation in the NWH till late-1960s in the last century. However, post-1970, these connections appear to have grown weaker considerably. It points towards the presence of other factors, which could also be playing a role. One of these could be the increasing concentration of greenhouse gases in the atmosphere.

The main intention of this study was to explore the monotonic trends and abrupt changes in the annual, and seasonal air temperature series for three stations in Indira Sagar canal command area located at Madhya Pradesh, in India during 1901–2005 using MK tests. In addition, the pre-whitening (PW) approach was used to eliminate the powers of significant lag-1 serial correlation on the MK tests.

II STUDY AREA AND DATA DESCRIPTION

The Indira Sagar Region is mainly situated in three district of Madhya Pradesh, namely: Barwani, East Nimar and West Nimar. The study area enlarges between 74° 46' to 76° 29' E longitude and 21° 46' and 22° 19' of north latitude and covers area is about 3550 km². The elevation of study area varies from 84 to 320-meter Mean Sea Level (MSL) pressure. In Indira Sagar Region, the construction of canal (Indira Sagar Pariyojana) began in April 2002. Due to rises in air temperature the region get dehydrated and drought condition arises in summer season and during irrigation period the problem of depletion of ground water arises therefore it is necessary to construct the canal, in this region. Therefore, a lined gravity canal takes off from the reservoir with FSL of 239.15 m through a 3.67 Kms long tunnel named Punasa tunnel.

In this study, Annual and monthly temperature data of three stations were obtained from India Water Portal Meteorological Organization (IWPMO). The seasonal mean temperatures were calculated by averaging the monthly values. Seasons were defined as follows: winter (December, January, and February), Pre-monsoon (March, April, and May), Monsoon (June, July, August and September), and Post-monsoon (October, and November). The missing value was also surrogated by the average between the values of the previous and the following year.



"Fig.1" Location of Study area

III METHODOLOGY

Our view of climatic changes over the Indira Sagar Region was based on the evaluation of available meteorological and hydrological time series using the statistical tools. We tested the hypothesis that the observed historical climatic trends in the Indira Sagar Region reflected a significant change in climate.

A. Serial correlation effect

Presence of positive or negative autocorrelation affects the trend in a series (Hamed and Rao, 1998). The autocorrelation (also known as serial correlation coefficients) test was performed to check the randomness and periodicity if any in the time series of all data (Madarres and Silva, 2007). If randomness is found, or in other words if lag-1 serial correlation coefficients are statistically insignificant then, Mann-Kendall (MK) test is applied without altering the original data. Otherwise, Modified Mann-Kendall (MMK) test is applied after removing the effect of serial correlation (randomness) from the time series (Karpouzos et al. 2010). The autocorrelation coefficient r_k of a discrete time series for lag-*k* is estimated as follows:

$$r_k = \frac{\sum_{k=1}^{n-k}(X_t - \overline{X_t})(X_{t+k} - \overline{X_{t+k}})}{\left[\sum_{k=1}^{n-k}(X_t - \overline{X_t})^2 (X_{t+k} - \overline{X_{t+k}})^2\right]^{0.5}} \tag{1}$$

Where, r_k is the lag-*k* serial correlation coefficient of the series. The hypothesis of serial independence is then tested by the lag-1 autocorrelation coefficient as H_0 : r_1 = 0 against H_1 : $|r_1| > 0$ using the test of significance of serial correlation (Yevjevich, 1971) following Rai et al. 2010,

$$(r_k)_{t_g} = \frac{-1 \pm t_g(n-k-1)^{1/2}}{n-k} \tag{2}$$

Where, $(r_k)_{t_g}$ is the normally distributed value of r_k, t_g is the normally distributed statistic at g level of significance. The value of t_g are 1.645, 1.965 and 2.326 at significance level of 0.10, 0.05 and 0.01 respectively. If $|r_k| \geq (r_k)_{t_g}$, the null hypothesis about serial independence is rejected at the significance level α (here 0.05). For the non-normal series, MK test is appropriate choice for the trend analysis (Yue and Pilon 2004, Basistha et al. 2008). Therefore, the MK test has been used wherever the autocorrelation is not significant at 5% significance level.

B. Pre-whitening

The method of Pre-whiting is applied to eliminate the effect of Serial correlation on the non parametric test. Lettenmaier et al. (1994) suggested that the effects of serial correlation upon trend tests in such applications could be assumed negligible, concern about the potential impacts of autoregressive processes upon trend analysis nevertheless appears to be gaining momentum.

$$^{pw}x_i = x_i - cx_{i-1} \tag{3}$$

Where, ^{PW}X is the prewhitened data to be used in the subsequent trend analysis and c is the lag-1 serial correlation coefficient as determined directly from the data using Equation 3. Pre-whitening is utilized only if observed r is greater than some critical value, C_{criti} taken to be 0.1 by von Storch (1995). This method is known as single-stage pre-whitening.

C. Analysis of trend

Common statistical methods used to test the hypothesis of the existence of a long-term trend are parametric and nonparametric. Several methods are available in both of these categories (Helsel and Hirsch, 1992). The following sections describe the nonparametric (Mann-Kendal) methods used to assess trends over Indira Sagar Region.

C.1 Mann-Kendall method

Trend analysis has been done by using non-parametric Man- Kendall test. It is a statistical method used for studying the temporal trends and spatial variation of hydro-climatic series. As in Smith (2000) it is mentioned that a non parametric test is considered over the parametric one because it can avoid the problem roused by data skew. Man-Kendall test is preferred when various stations are tested in a single study (Hirsch et al., 1991). Mann-Kendall test was formulated as non-parametric test by Mann (1945) for trend detection and test statistic distribution was given by Kendall (1975) for testing non-linear trend and turning point.The Mann-Kendall statistic *S* is formulated as

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \mathrm{sgn}(x_j - x_i) \tag{4}$$

The application of trend test is done to a time series x_i which is ranked from i = 1,2,………n-1 and x_j is ranked from j = i+1,2,……….n. Each of the data point x_i is considered as a reference point which is compared with all the rest of the data points x_j so that

$$Sgn(x_j - x_i) = \begin{cases} +1, > (x_j - x_i) \\ 0, = (x_j - x_i) \\ -1, < (x_j - x_i) \end{cases} \quad (5)$$

The variance statistic is computed as

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{n} t_i(i)(i-1)(2i+5)}{18} \quad (6)$$

where t_i represents the number of ties up to sample i. The test statistics Z_c is estimated as

$$Z_c = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} \\ 0, S = 0 \\ \frac{S+1}{\sqrt{Var(S)}}, S < 0 \end{cases} \quad (7)$$

In which Z_c follows a standard normal distribution. A positive (negative) value of Z indicates an upward (downward) trend. A significance level α is also used to test for either an upward or downward monotone trend (a two-tailed test). If Z_c is greater than $Z_{\alpha/2}$ where α denotes the significance level, then the trend is significant.

C.2 Sen's Slope Estimator Test

The magnitude of trend is estimated with the help of Sen's estimator. In this case linear trend is present and hence the true slope is estimated by this method. Here, the slope (T_i) of all data pairs is first computed as (Sen, 1968)

$$T_i = \frac{x_j - x_k}{j-k} \qquad \text{For i = 1,2,……..,N} \quad (8)$$

In which x_j and x_k are represented as data values at time j and k (j>k) correspondingly. The median of these N values of T_i is considered as Sen's estimator of slope which is given as

$$Qi = \begin{cases} T_{\frac{N+1}{2}} & N \text{ is odd} \\ \frac{1}{2}\left(T_{\frac{N}{2}} + T_{\frac{N+2}{2}}\right) & N \text{ is even} \end{cases} \quad (9)$$

Sen's estimator is calculated as Q_{med}=T(N+1)/2 if N is odd, and it is computed as $Q_{med}=[T_{N/2}+T_{(N+2)/2}]/2$ if N is even. Lastly Q_{med} is estimated by a two sided test at 100 (1-α)% confidence interval and then a true slope can be derived by the non-parametric test. Q_i with a positive value indicates an upward or increasing trend and a negative value of Q_i signifies a downward or decreasing trend in the time series.

IV RESULTS AND DISCUSSION

Lag-1 Serial correlation coefficients of the Annual and seasonal (Average, Maximum and Minimum) Temperature series for Indira Sagar region are represented in Table 1. The annual and seasonal temperature series almost all three stations had a positive lag-1 serial correlation coefficient. The positive correlations were found to be significant in the annual and post monsoon series, for all three stations correspondingly. As revealed earlier, the existence of positive serial correlation will increase the risk of rejecting the null hypothesis of no trend in the MK test. Annual and seasonal (Average, Maximum and Minimum) temperature time series for Indira Sagar region are shown in table 3. The MK test results shows that the monotonic trends in the annual temperature time series were positively significant for all three stations at 99.5% confidence level for Indira Sagar region. Darshana et.al. (2012) reported that the Mean annual precipitation varied from 694 mm (at Westnimar) to 1416 mm (at Mandla). Maximum decrease in annual precipitation was found at Balaghat (-11.99%) and minimum at Shahdol (-8.52%) district. The most probable year of change was 1978 in annual precipitation. Change in percentage in mean of 1901-1978 over the mean of 1979-2002 showed the decrease in precipitation in almost all the stations. Again, the decrease in annual precipitation was 2.59 % over the entire Madhya Pradesh in 102 years. West MP showed more increase in annual precipitation than East MP during the period of 1901-1978. However, the East MP showed more decrease than west MP during the period of 1979-2002. After review her study, we concluded that there is decrease in precipitation in Indira Sagar region over a century. In this study, we accomplished that there is increases in (Average, Maximum and Minimum) annual temperature time series at West Nimar Station. It means that in Indira Sagar region precipitation is decreased and air temperature increased over a century.

Results of Mk test on the annual average temperature series for all three stations are illustrated in Fig.2. The results showed that the monotonic trends in average temperature time series were positive for all three stations A, B and C namely; Barwani, East Nimar and West Nimar respectively. Although the annual average temperature trend in the region, statistically significant at α = 0.001 level of significance. Sen's estimator of slope following the MK test, was employed to figure out the change per unit time of the trends observed in annual average temperature time series. Sen's estimates with the resultant residuals are shown in Fig.2

Seasonal (Average, Maximum and Minimum) temperature time series at all three stations show the positive monotonic direction with increasing significant trends for Pre-monsoon, Post- monsoon and winter seasons expect monsoon season shows the rising insignificant trend but in upward direction. According to the Theil–Sen's slope estimator (Table.2), the highest magnitudes of the warming trends in the annual average temperature series were found at Barwani, East Nimar and West Nimar stations at the rates of 0.004, 0.005 and 0.005°C/year, respectively. On seasonal basis peak magnitude of the humid trend in temperature, series were found at post- monsoon for whole region

V SUMMARY AND CONCLUSIONS

The main conclusions from the present analysis of temperature data of 105 years at three stations in Indira sagar region are as pursues:

1) The annual and seasonal temperature series almost all three stations had a positive lag-1 serial correlation coefficient. The positive correlations were found to be significant in the annual and post monsoon series, for all three stations correspondingly.
2) Result of MK test confirm that most of the monotonic trends in the annual temperature time series were positively significant for all three stations at 99.5% confidence level for Indira Sagar region.
3) For seasonal temperature series increasing significant monotonic trend were found over the region.
4) The magnitudes of the significant increasing warming trends in the annual average temperature series were found at Barwani, east Nimar and West Nimar stations at the rates of 0.004, 0.005 and 0.005°C/year, respectively.

VI Acknowledgment

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TABLE 1**.** Lag-1 serial correlation coefficients of the Annual and seasonal Temperature series for Indira Sagar region (1901-2005)

STATION	TEMPERATURE	ANNUAL	PRE-MONSOON	MONSOON	POST-MONSOON	WINTER
BARWANI	AVG	**0.527**	0.181	0.089	**0.333**	0.257
	MAX	**0.524**	0.186	0.084	**0.325**	0.260
	MIN	**0.533**	0.175	0.090	**0.339**	0.254
EAST NIMAR	AVG	**0.439**	0.072	0.008	**0.312**	0.204
	MAX	**0.434**	0.088	0.008	**0.302**	0.210
	MIN	**0.447**	0.053	0.007	**0.322**	0.199
WEST NIMAR	AVG	**0.510**	0.147	0.053	**0.334**	0.238
	MAX	**0.504**	0.159	0.051	**0.322**	0.242
	MIN	**0.517**	0.135	0.055	**0.344**	0.235

*Bold value indicate the significant correlation

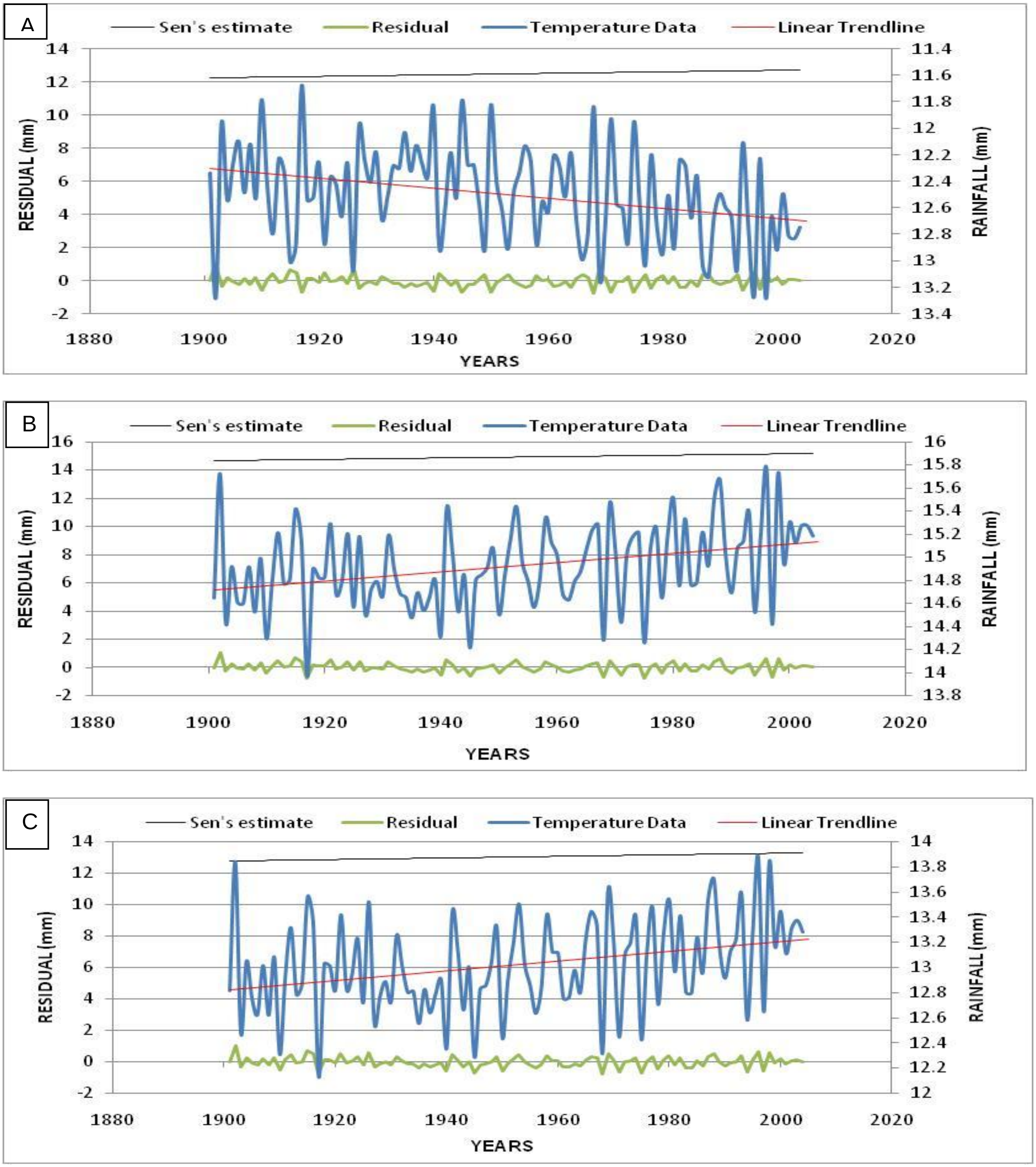
TABLE 2. Values of slope β (°C/year) for the monthly air temperature series (1901–2005)

STATIONS	BARWANI			EAST NIMAR			WEST NIMAR		
MONTHS	AVG	MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN
ANNUAL	0.004	0.004	0.009	0.005	0.005	0.008	0.005	0.005	0.009
PRE-MONSOON	0.009	0.009	0.010	0.008	0.008	0.008	0.009	0.009	0.009
MONSOON	0.002	0.002	0.002	0.001	0.001	0.001	0.002	0.002	0.002
POST-MONSOON	0.010	0.011	0.016	0.010	0.011	0.016	0.011	0.011	0.017
WINTER	0.009	0.009	0.011	0.009	0.009	0.011	0.009	0.009	0.012

TABLE 3**.** Shows Z value obtained by Mann- Kendall Test (1901-2005)

STATIONS	BARWANI						EAST NIMAR						WEST NIMAR					
TEMPERATURE	AVG		MAX		MIN		AVG		MAX		MIN		AVG		MAX		MIN	
TIME SERIES	**test z**	**signific.**	**test z**	**signific.**	**test z**	**signific.**	**test z**	**signific.**	**test z**	**Signific.**	**test z**	**signific.**	**test z**	**signific.**	**test z**	**signific.**	**test z**	**signific.**
Annual	3.57	***	3.57	***	6.28	***	3.74	***	3.77	***	5.89	***	3.64	***	3.66	***	6.21	***
Pre_monsoon	3.76	***	3.64	***	4.26	***	3.41	***	3.35	***	3.51	***	3.62	***	3.59	***	4.07	***
Monsoon	1.31		1.30		1.05		0.58		0.56		0.60		1.14		1.15		0.93	
Post_monsoon	3.28	**	3.31	***	4.91	***	3.19	**	3.33	***	4.71	***	3.21	**	3.27	**	4.93	***
Winter	4.13	***	4.18	***	5.44	***	4.22	***	4.11	***	5.10	***	4.29	***	4.27	***	5.47	***

Note: - *** if trend at α = 0.001 level of significance, **if trend at α = 0.01 level of significance



"Fig.2" A, B and C namely; (Barwani, East Nimar and West Nimar)shows average annual temperature trend over Indira sagar region (1901–2005). with Sen's estimator for a linear trend and with their residuals for three stations (a. Barwani, b. East Nimar and c. West Nimar).

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