Investigation of Decadal Changes of Temperature over Bihar Region (India)

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Abstract-*Climate change has influenced rainfall and temperature patterns in specific areas. As a result, it's vital to look into the trend of meteorological variables like temperature in Bihar. Other hydrological processes, such as rainfall, may be influenced by temperature variations, contributing to temperature variability.*

The objective for the present analysis was to identify trends in long- and short-term change amount of temperature in Bihar region at various spatial scales. It examines the impact of historical spatiotemporal variability of Temperature on Bihar annual and seasonal time series state over a 60-year period (1954–2013). The goal of this study was to determine long and short term changes in rainfall amounts in the Bihar region at various spatial scales.

Keywords: *Rainfall, Mann Kendall Test, Standardized Anomaly Index, ENSO, Cyclone, Climate Change.*

1. INTRODUCTION

Climate change threatens sustainable development in South Asia given the potential vulnerability associated with high population density, poverty, and limited resources for adaptation. Climate change is, thereby, set to cause huge economic, social, and environmental damage across the region, compromising growth potential and poverty-reduction efforts [1]. Agriculture is extremely vulnerable, as any change in climate influences crop growth and yield, hydrologic balances, supplies of inputs and other management practices [2]. Climate change effects on agriculture are manifold: changes in average temperatures, rainfall, and weather extremes; changes in pests and diseases conditions; changes in the nutritional quality of foods; and changes in sea level, among others [3,4]. Higher temperatures shorten crop cycles by inducing early flowering and shortening the grain-filling period, thereby reducing yield per unit area [5]. High day- and night-time temperatures are set to become more common in the near future and represent a tremendous environmental hurdle to global food production and food security [6–8]. Future climatic variability will also lead to more frequent extremes of weather in the form of erratic monsoons and increased frequency and intensity of drought and flooding [9], thereby affecting both rainfed and irrigated productions systems. Although climate change has occurred on a global scale, its impacts often vary from region to region [10] and even from location to location [11]. Moreover, considerable uncertainties remain as to when, where and how climate change will affect agricultural production in India [12]. Because of the large spatial and temporal variability in weather factors in India, the analysis of changes in climatic variables at a local level represents an important task in detecting the magnitude of climate change, identifying current and future climate risks, and designing risk-management interventions. Since decisions about climate change are complex, costly and have long-term implications, it is vital that such decisions are based on the best available evidence [13]. Bihar is one of the most climate-sensitive states in India due to its geographical setting, hydro-meteorological uncertainties, dense rural population and high level of poverty [14]. The State Government of Bihar acknowledges that climate change is one of the major challenges of agriculture in the state, and its overall strategy is to transform agriculture and its allied sectors into climate-resilient and vibrant production systems while developing their full potential and ensuring sustained food and nutritional security.

2. MATERIAL AND METHODS

In this study, the observed annual/seasonal January-February (J-F), March-April-May (MAM), June-July-August-September (JJAS), October-November- December (OND) temperature are used. Daily gridded rainfall data set (0.25° × 0.25°, latitude × longitude) procured from National Data Centre, Indian Meteorological Department (IMD), Pune.

2.1 Mann-Kendall Trend Analysis

The Mann-Kendall test, is a non-parametric approach, has been widely used for detection of trend in different fields of research including hydrology and climatology. It is used for identifying trends in time series data. If the data do not confirm to a normal distribution, the [15] test can be applied.

To perform a Mann-Kendall test, compute the difference between the later-measured value and all earlier-measured values, (yj-yi), where j>i, and assign the integer value of 1,0, or –1 to positive differences, no differences, and negative differences, respectively. The test statistic S, is then computed as the sum of the integers:

$$\sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \mathrm{sign}(y_i - y_j)$$

Where sign (y_i-y_j), is equal to +1, 0, or -1 as indicated above.When S is a large positive number, later-measured values tend to be larger than earlier values and an upward trend is indicated. When S is a large negative number, later values tend to be smaller than earlier values and a downward trend is indicated. Where *xi* and x_j the annual values in years *i* and *j*, i>*j*, respectively, and

$$\operatorname{sign}(y_i-y_j) = \begin{cases} 1 & \text{if } x_i-x_j>0 \\ 0 & \text{if } x_i-x_j=0 \\ -1 & \text{if } x_i-x_j<0 \end{cases}$$

It has been documented that when n ≥ 8, the statistic S is approximately normally distributed with the mean.

$$E(s)=0$$

The variance statistic is given as-

$$Var(s)=\left[n(n-1)(2n+5)-\sum_{P=1}^{q} t_p(t_p-1)(2t_p+5)\right]/18 \ldots\ldots \text{Eqn (1)}$$

Here *q* is the number of tied groups and *tp* is the number of data values in the *P^th^* group.

The values of *S* and *VAR(S)* are used to compute the test statistic *Z* as follows-

$$Z=\begin{cases} S-1/[Var(s)]^{1/2} & \text{if } S>0 \\ 0 & \text{if } S=0 \\ S+1/[Var(s)]^{1/2} & \text{if } S<0 \end{cases}$$

The presence of a statistically significant trend is evaluated using the *Z* value. A positive (negative) value of *Z* indicates an upward (downward) trend. The statistic *Z* has a normal distribution. To test for either an upward or a downward monotone trend (a two-tailed test) at α level of significance, *H0* is rejected if the absolute value of *Z* is greater than Z1-α/2, where Z1-*α/2* is obtained from the standard normal cumulative distribution tables.

2.2 Sen's slope estimator test

The Sen's estimator predicts the magnitude of trend. Here, the slope (T_i) of all data pairs is computed as [16]. The estimate for the magnitude of the slope of trend *b* is calculated using non-parametric Sen's method, which is the median of slopes of all data value pairs.

$$b= \text{median } [X_j-X_i/j-i] \text{ for all } i<j \ldots\ldots \quad \text{Eqn(2)}$$

where *b* is the slope between data points X_j and X_i measured at times j and i respectively.

3. RESULTS AND DISCUSSIONS

3.1 Mann-Kendall Trend Analysis of Temperature over Bihar Region

For the state of Bihar, minimum temperature showed decreasing (-0.006) trend in winter season for the period of 1954-2013 (See Table 1). For the period of 1954-2013,

Table-1: Mann-Kendall Trend analysis of temperature data Bihar (1954-2013)

1954-2013		**Min Temp.**			**Max Temp.**	
Annual/Seasonal	**Test Z**	**Significance**	**Q**	**Test Z**	**Significance**	**Q**
JF	-1.10		-0.006	-1.42		-0.008
MAM	-1.71	+	-0.009	-1.83	+	-0.013
JJAS	-2.08	*	-0.008	1.97	*	0.008
OND	0.64		0.004	1.44		0.006
ANNUAL	-1.38		-0.005	0.19		0.0006

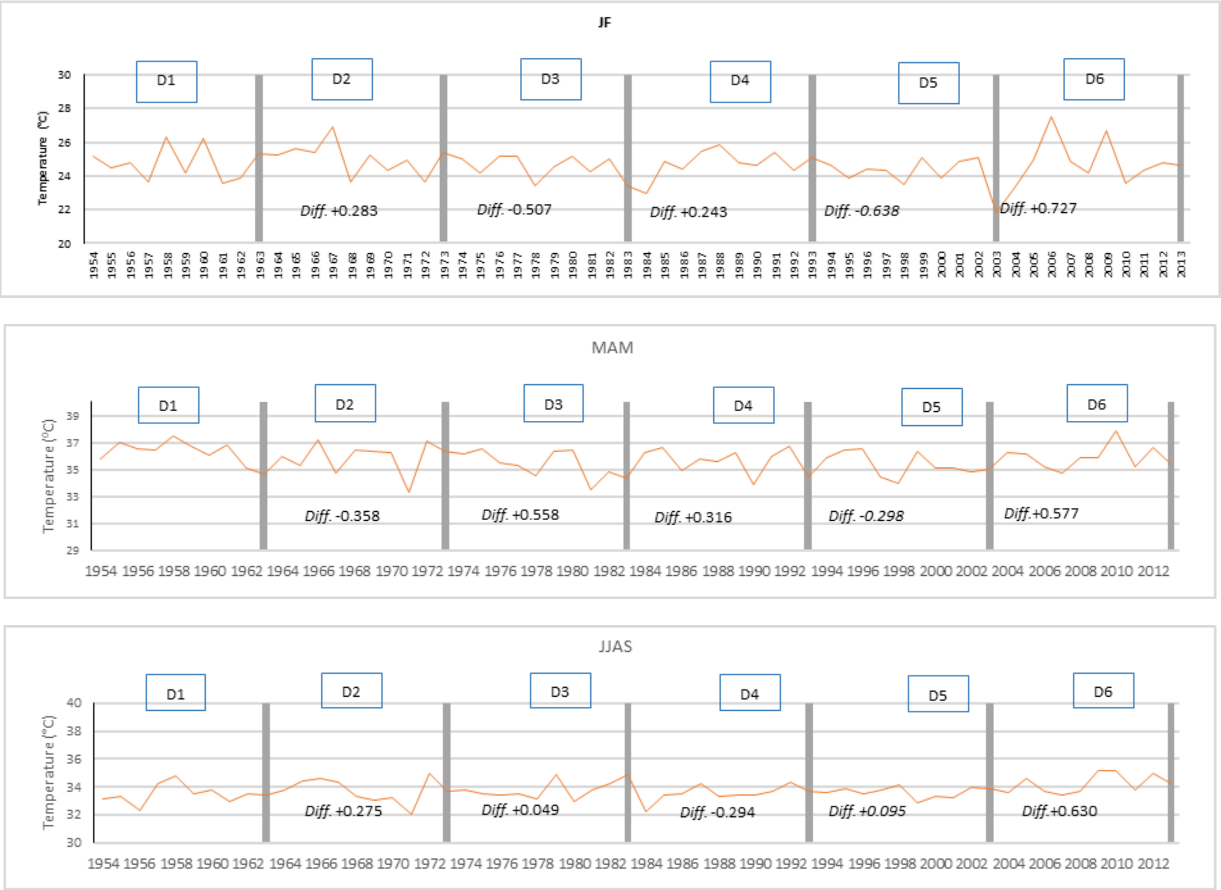
*** Statistically significant at 0.05 level.**

+ Statistically significant 0.1 level

minimum and maximum temperature shows decreasing and increasing (-0.008 and +0.008) trend and statistically significant (0.05 level) for monsoon season (Subhash *et.al*, 2010).

3.2 Results of decadal Variation in Temperature of Bihar

In the recent decade, seasonal and annual values of maximum temperature increased for the State of Bihar. In monsoon season, maximum temperature increased at 0.6°C /decade in decade VI, in comparison to decade V (shown in figure 1). Temperature increase may be due to El-Niño events [17] observed 13 drought years in the period 1901-2009, for ISMR region during monsoon season. Due to changes in the ocean climate and temperatures, there is warm water across the Pacific Ocean; both the sea surface and the thermocline flatten throughout, and particularly the sea-surface in the central and eastern Pacific Ocean becomes hotter than usual. The average water temperature in that area is typically between 1 and 3°C (approximately 2 and 5°F) warmer than normal during this event. This warming adds huge amounts of heat and moisture into the atmosphere, ultimately affecting the patterns of air pressure and rainfall across the Pacific and eventually spreading globally. As a result, the western Pacific experience droughts, while the east experience heavy resultant precipitation and sometimes even floods condition observed [18]. The annual minimum temperature data showed maximum decrease in temperature of approximately -3°C/decade in decade IV (1984-1993), in comparison to decade III. It may be due to decreased SSN in this decade (IV), as SSN is directly proportional to temperature. More sunspots deliver more energy to the atmosphere, so that global temperatures should rise [19]. This indicates cooler winter season due to excess rainfall event observed in year 1984 and 1994.In contrast, relatively less cool winter season was observed in decade V (1994-2003) with a major increase in the minimum temperature, approximately at the rate of 0.008°C/decade (shown in figure 2).



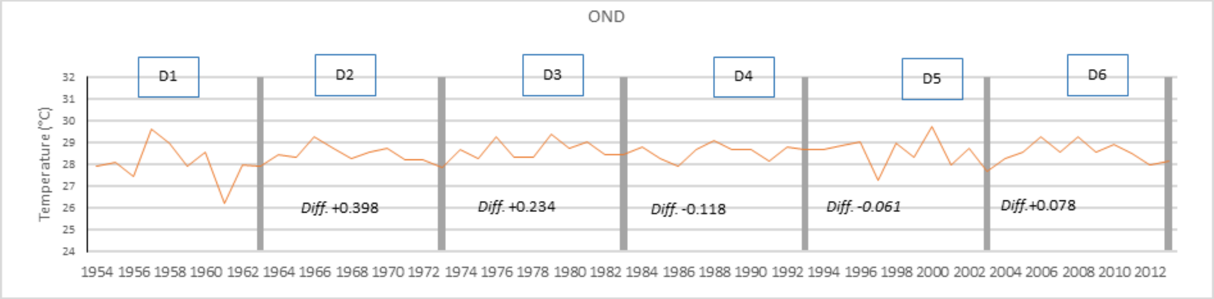


Fig -1: Decadal variation (JF, AM, JJAS, OND) of maximum temperature in Bihar

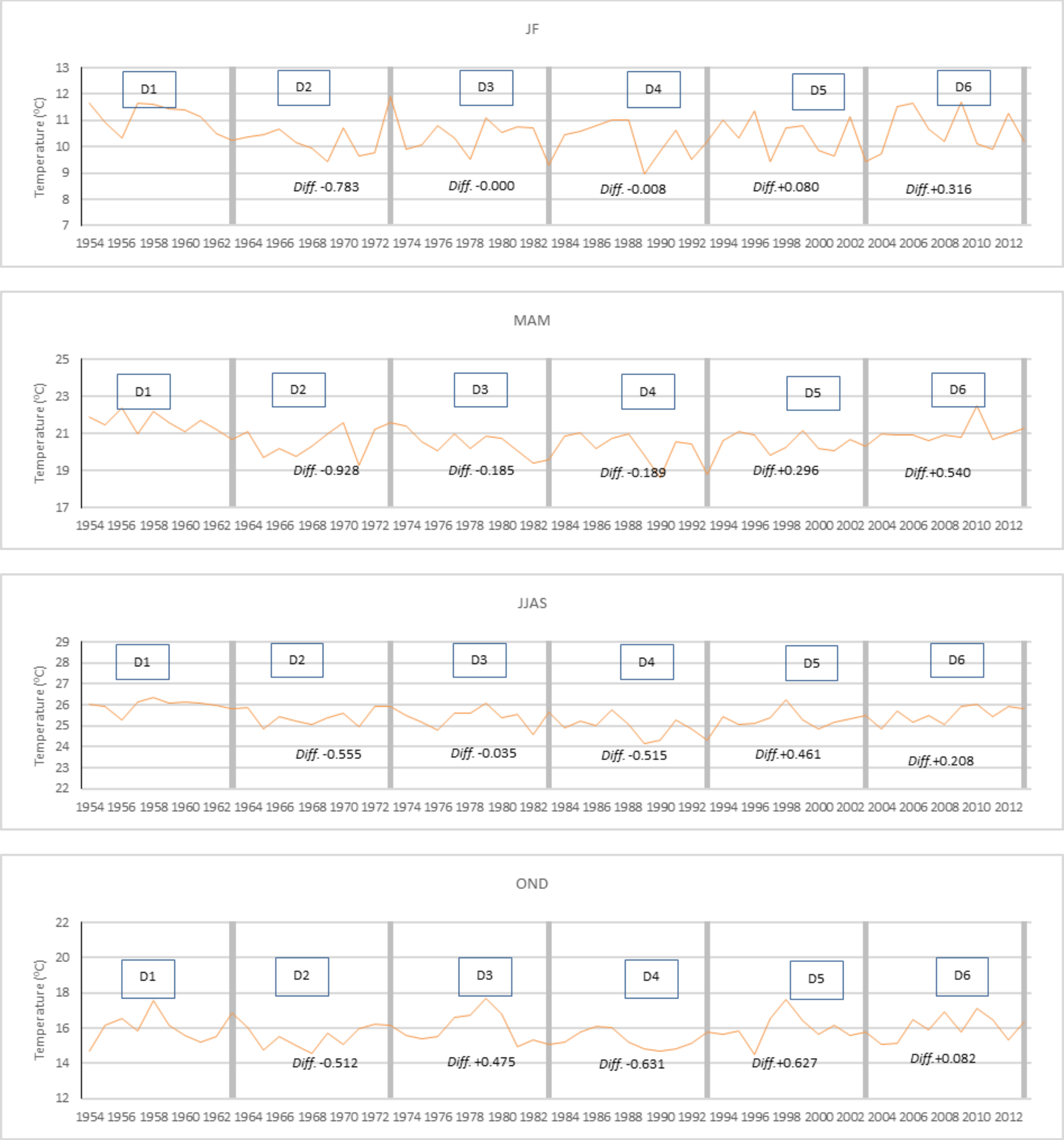


Fig -2: Decadal variation (JF, MAM, JJAS, OND) of minimum temperature in Bihar

4. CONCLUSION

In the recent decade, seasonal and annual values of maximum temperature for State of Bihar were observed to increase. In monsoon season, maximum temperature increased at 0.6˚C/decade in decade VI in comparison to decade V. The annual minimum temperature data showed maximum decrease in temperature of approximately -3˚C/decade in decade IV (1984-1993), in comparison to decade III. This indicates cooler winter season due to excess rainfall event observed in year 1984 and 1990. In contrast, relatively less cool winter season was observed in decade V (1994-2003) with a major increase in the minimum temperature, approximately at the rate of 0.008°C/decade. In post-monsoon season, the minimum temperature showed maximum decrease (-0.6°C/decade) in decade IV, in comparison to decade III. In monsoon season, maximum anomaly was seen to be positive in year 2009 (+2.0°C) and in year 2010 (+2.1°C). Maximum temperature was increased due to El-Niño event (2009, 2010).

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