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Analysis of Projected Temperature trends over Rampur at Satluj River Basin

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Abstract

This paper describes the regarding trends in temperature for the Rampur Dam sites in Satluj River Basin, the mean maximum temperature series showed a rising trend at most of the month; it showed a falling trend at some of the month. The mean minimum temperature showed a rising as well as a falling trend. At most of the month temperature a rising trend was found. Some of the month in the showed a falling trend in annual mean temperature.

Keywords: Trend; River basin; Temperature

Introduction

The surface temperatures over a given region vary seasonally and annually depending upon latitude, altitude and location with respect to geographical features such as a water body (river, lake or sea), mountains, etc. Probably one of the most widely quoted aspects of climatic change and the one that will have important ramifications on arrange of sectors, including water is the significant increase in the global mean air temperature during the past century. Since the hydrologic cycle is a thermally driven system, rise in global temperature is likely to accelerate this cycle. Identification of the temperature trends and their projection has been the subject matter of a large number of studies.

Most of the temperature trend studies in India focus on the analysis of annual and seasonal temperature data for a single station or a group of stations. Such studies date back to at least 50 years. In one of the first studies, trends in the annual mean, maximum and minimum temperatures over the whole country were studied by Pramanikand Jagannathan, who did not find any general tendency for an increase or decrease in these temperatures. The study by Srivastava et al. [1] on decadal trends in climate over India gave the first indications that the diurnal asymmetry of temperature trends over India is quite different from that over many other parts of the globe. Pant and Kumar [2] analysed seasonal and annual air temperature series for 1881-1997 and showed that there is a significant warming trend of 0.57°C per 100 years. The magnitude of warming was higher in the post-monsoon and winter seasons. The monsoon temperature did not show a significant trend in any major part of the country, except for a significant negative trend over northwest India.

Mean annual temperature was found to be increasing over the west coast, interior peninsula, and north central and north-eastern regions of India along with the whole of India during the period 1901-1982 by Hingane et al. [3]. Pant and Hingane [4] found decreasing trend in mean annual surface air temperature for 1901-1982 over the northwest Indian region consisting of the meteorological sub-divisions of Punjab, Haryana, west Rajasthan, east Rajasthan and west Madhya Pradesh. Data from seven stations for 1901-1980 showed highly significant warming trend in the mean maximum, mean minimum and average mean temperatures of the Mahanadi river basin. Trend analyses of maximum and minimum temperature data at 121 stations in India for 1901-1987 by RupaKumar et al. [5] showed increasing maximum temperature and trendless minimum temperature, resulting in rise in mean and diurnal range of temperature.

Kothyari and Singh found increasing annual maximum temperature over the Ganga basin and increasing average annual temperature for India starting around the second half of 1960s. The annual surface air temperature in IGP showed significant rising trend (0.53°C/100-yrs) during 1875-1958 and significant decreasing trend (-0.93°C/100-yrs) during 1958-1997 [6,7]. Sinha Rayand De summarized information on trends in the occurrence of extreme events over India. An increasing trend of 0.35°C over the last 100 years was observed in the temperature records. Extreme maximum and minimum temperatures showed an increasing trend in the south and a decreasing trend in the north. Temporal variation in the temperature over Pune city during the period 1901-2000 revealed significant decrease in mean annual and mean maximum temperature. Winter season experienced decrease in temperature, whereas monsoon season temperature was found to be increasing.

Arora et al. [8] analysed a series of annual and seasonal mean temperature, annual mean maximum temperature and annual mean minimum temperature using the data from 125 stations distributed throughout India. For annual series, mean maximum temperature showed a rising trend at 63 stations and a falling trend at 8 stations. The mean minimum temperature showed a rising trend at 33 stations and a falling trend at 31 stations. In the mean temperature series, a rising trend was observed at 53 stations and a falling trend at 17 stations. Most of the stations in the south, central and western parts of India showed a rising trend and some stations in the north and northeaster parts showed a falling trend in annual mean temperature. In the winter season, a rising trend in mean temperature was observed at 39 stations and a falling trend at 19 stations. Most of the stations in the coastal and southern areas showed an increasing trend, whereas a falling trend was exhibited by some stations in the north, central and eastern India. The mean pre-monsoon temperature showed a rising trend at 35 stations and a falling trend at 23 stations. Most of the stations in the eastern region and in the foothills of the Himalayas showed a falling trend. For the mean monsoon temperature series, 27 stations showed a rising trend and 18 stations a falling trend. In the mean post-monsoon temperature series, 59stations showed a rising trend and six a falling trend. Arising trend dominates all over India in this season.

Arora et al. [8] also found that the percentage of significant trends was high and there is a rising trend in most cases, except for temperatures for mean pre-monsoon, mean monsoon, pre-monsoon mean minimum and monsoon mean minimum. There was an increase of 0.42°C (100 year$)^{-1}$ in the annual mean temperature, 0.92°C (100year)$^{-1}$ in the mean maximum temperature and 0.09°C (100 year)$^{-1}$ in the mean minimum temperature. Averaged for all seasons, there was a rise of 1.1°C (100 year)$^{-1}$ in mean winter temperature, 0.94°C (100 year)-1 in mean post-monsoon temperature, and a fall of minus 0.40°C(100 year$)^{-1}$ in mean pre-monsoon temperature. Atmospheric surface temperature in India has increased in the last century by about 1°C and 1.1°C during winter and post-monsoon months respectively. Also, decrease in the minimum temperature during summer monsoon and its increase during post-monsoon months have created a large difference of about 0.8°C in the seasonal temperature anomalies. Opposite phases of increase and decrease in the minimum temperatures in the southern and northern regions, respectively, have been noticed in the inter annual variability. In north India, the minimum temperature showed a sharp decrease between 1955 and 1972, and then a sharp increase. But in south India, the minimum temperature showed a steady increase [9].

Bhutiyani et al. [10] found increasing trend in maximum, minimum, mean and diurnal temperature range over the north-western Himalayan region during the 20th century. Frequency of occurrence of hot days and hot nights showed widespread increasing trend, whereas that of cold days and cold nights showed widespread decreasing trend during the period 1970-2005 over India as a whole and seven homogeneous regions [11]. The frequency of occurrence of hot days was found to have significantly increased over the east coast, west coast and interior peninsula, whereas that of cold days showed significant decreasing trend over Western Himalaya and the west coast. The three regions, east coast, west coast and northwest, showed significant increasing trend in the frequency of hot nights.

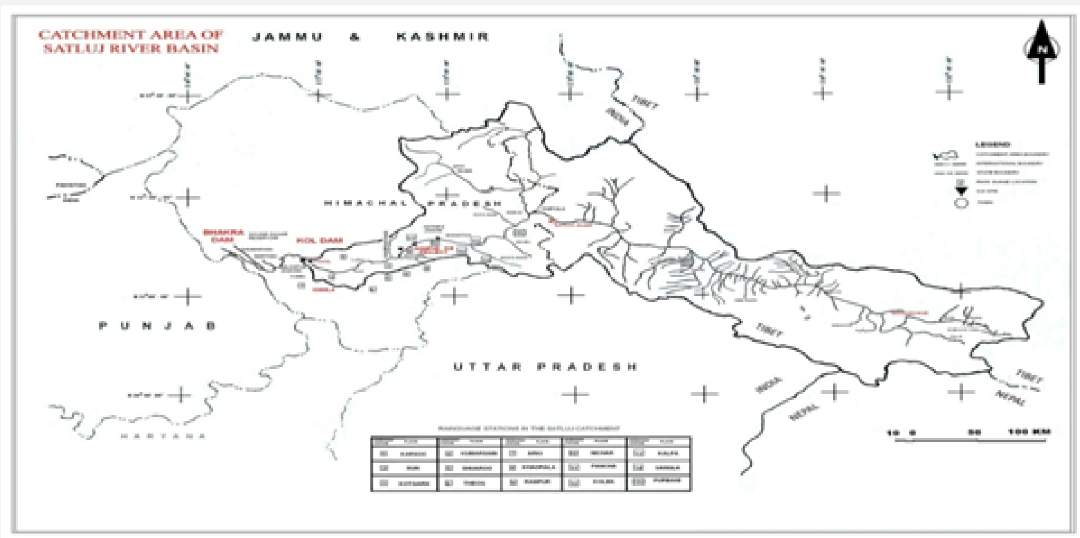

Figure 1: The schematic diagram of the Satluj River basin.

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Study Area

SJVNL has envisaged a 412 MW Rampur Hydro Electric project (RHEP), down-stream of NHJEP to tap the hydropower potential of the Satluj River between Jhakri and Bael village. The proposed project is conceived as a tailrace development from the 1500 MW Nathpa-Jhakri HE Project (NJHEP). The Rampur project is designed to divert 405 cumec of de-silted water of the Satluj from the tailrace pool of NJHEP through 15 km headrace tunnel to a surface power station near Bael. The water from Rampur Intake structure shall be conveyed to the right bank through a cut & cover Conduit, 10.50 m diameter HRT of 15.08 Km length terminating into a 140 m high, 38 m dia Surge Shaft. The length of HRT on left bank is 484 m before it crosses the river Satluj with a 43.2 m long Cut and Cover Conduit. The water will further enter into three underground penstocks 5.4 m dia. each bifurcating into six Branch Tunnels each of 3.8 m diameter, to feed six generating units in a surface Power House equipped with Francis turbines driven generating unit each of 68.67 MW capacity. The schematic diagram of satluj river basin as shown in (Figure 1).

Trend Analysis-General Methodology

Trend analysis of a time series consists of the magnitude of trend and its statistical significance. Obviously, different workers have used different methodologies for trend detection. Kundzewicz [11] has discussed the change detection methodologies for hydrologic data. In general, the magnitude of trend in a time series is determined either using regression analysis (parametric test) or using Sen's estimator method (non-parametric method [12]. Both these methods assume a linear trend in the time series. Regression analysis is conducted with time as the independent variable and rainfall/temperatures the dependent variable. The regression analysis can be carried out directly on the time series or on the anomalies (i.e. deviation from mean). A linear equation, y = mt+ c, defined by c (the intercept) and trend m (the slope), can be fitted by regression. The linear trend value represented by the slope of the simple least-square regression line provided the rate of rise/fall in the variable.

Sen's estimator has been widely used for determining Trends in annual and seasonal temperatures in the four most populated cities of India - Delhi, Kolkata, Mumbai and Chennai showed positive change with different rates indifferent seasons [13,14]. The maximum temperature at Mumbai during winter and monsoon was significantly increasing, whereas minimum temperature showed significant decrease. The remaining cities recorded significant increase in minimum temperature during winter. Analysis of maximum, minimum and mean temperatures; diurnal temperature range; and sunshine duration in eight sites in North East India by Jhajharia and Singh [11] showed decreasing trends in diurnal temperature range corresponding to annual, seasonal (pre-monsoon and monsoon) and monthly (September) timescales at three sites. Diurnal temperature range increases were also observed at three other sites in the monsoon and post-monsoon season's as well as in June, October and December. Temperature remained practically trendless in winter and pre-monsoon season and increased in the monsoon and post-monsoon seasons over NE India. Decreasing trends in sunshine duration were observed mainly on annual, seasonal (winter and pre-monsoon) and monthly (January-March) timescales.

Maximum temperature showed significant rising trend of 0.008°C/yr during monsoon season; 0.014°C/yr during post-monsoon season and 0.008°C/yr in the annual maximum temperature during the period 1914-2003 for Central Northeast India [15]. Minimum temperature showed significant rising trend of 0.012°C/yr during post-monsoon season and significant falling trend of 0.002°C/yr during monsoon season. Studies of the long-term trends and variations of the monthly maximum and minimum temperatures in various climatologically regions in India by Paland Al-Tabbaa [16] showed increasing monthly maximum temperature, though unevenly, over the last century. Minimum temperature changes were found more variable than maximum temperature changes, both temporally and spatially, with results of lesser significance.

The monthly maximum and minimum temperature data from 121 stations well distributed over the country for the period 1901-2007 were used by Kothawale et al. [17] and from these data, they computed seasonal and annual trends in surface air temperature over the country and seven homogeneous regions (western Himalaya, northwest, north-central, northeast, east coast, west coast and interior peninsula) during three periods: 1901-2007, 1971-2007 and 1998-2007 [18,19]. Key findings of this comprehensive study are described here.

a. Annual mean (average of maximum and minimum),maximum and minimum temperatures showed significant warming trends of 0.51, 0.72 and 0.27°C (100 year)-1,respectively, during 1901-2007. The temperature has increased gradually and continuously over this period. This warming was mainly due to increasing temperatures in the winter and post-monsoon seasons. During the three decades from 1971 to 2007, annual mean temperature increased by 0.20°C per decade due to significant increases in both maximum and minimum temperatures. Also, increase in minimum temperature was much steeper than the maximum temperature. On the whole, winter and summer monsoon temperatures showed a significant increasing trend over almost the entire country, whereas post-monsoon temperatures significantly increased over relatively smaller number of regions.

b. On larger spatially aggregated scales, the temperature trends in India were found to be quite consistent and in agreement with global and hemispheric trends. However,

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on smaller regional scales and for different sub periods, trends were not always consistent with Indian aggregated temperatures. Further, the trends were also influenced by the variability of rainfall in the monsoon and post-monsoon seasons. It was opined that the recent temperature changes in some parts of the country may also be due to the relative influence of greenhouse gases and aerosols

c. Accelerated warming was observed during 1971-2007 and this was attributed mainly to intense warming in the decade 1998-2007. During 1998-2007, maximum temperature was significantly higher compared to the long-term (1901-2007) mean throughout India, with a stagnated trend during this period, whereas minimum temperature showed an increasing trend, almost equal to that observed during 1971-2007. It is pertinent to note that recently, the year 2010 has been reported to rank in the top three warmest years since the beginning of instrumental climate records in 1850, according to data sources compiled by the World Meteorological organization (WMO) [20-23].

d. On the seasonal scale, maximum temperature has significantly increased in all seasons during the period1901-2007. On this scale, pronounced warming trends in mean temperature were observed in two seasons - winter and monsoon. However, for the recent period only, winter and post-monsoon temperatures showed significant warming trends and the other seasons showed a warming tendency (trend not significant). In contrast, maximum and minimum temperature showed a significant warming trend in most seasons during 1971-2007.as shown in (Figure 2).

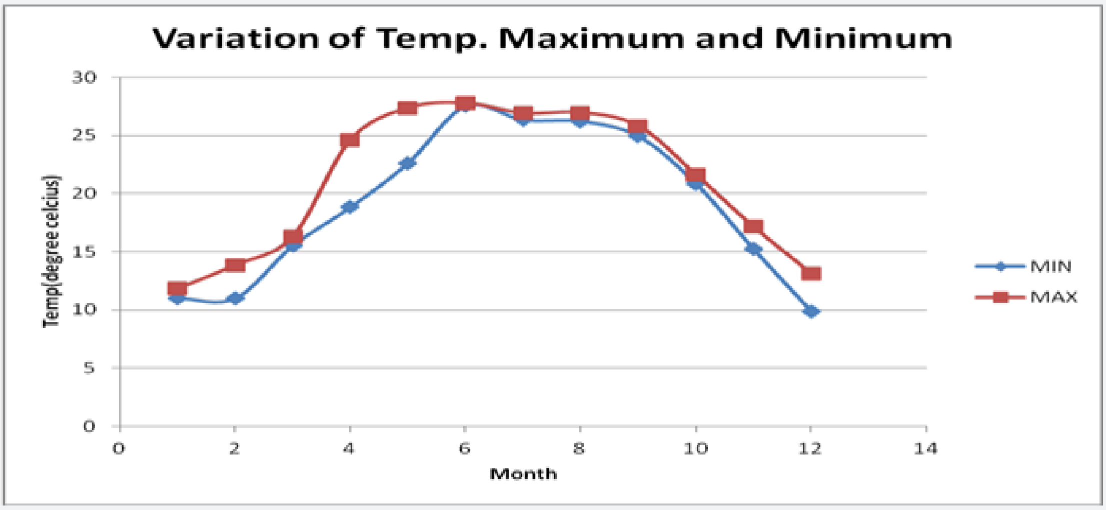

Figure 2: Variation of Temp. Maximum and Minimum.

Kothawale & Rupa Kumar [6,17] had shown a strong negative simultaneous correlation between Indian monsoon mean surface temperature and monsoon rainfall. Kothawale et al. [17] concluded that on inter annual time scales, Indian mean temperatures are strongly correlated with SST in the eastern Pacific and the equatorial Indian Ocean. A strong inter annual link between Indian temperatures and Indian Ocean SST was found. ENSO was found to be impacting Indian temperatures significantly. The composite maximum temperature anomalies of ElNiño years were statistically significant and positive during monsoon and post-monsoon seasons over large areas of the country and the composite anomalies of La Niña years were almost opposite to El Niño years. Interestingly, the year 2010 was special for climate scientists since El Niño conditions prevailed in the tropical Pacific for the first four months but it quickly changed and a LaNiña pattern had emerged by June.

Conclusion

Temperature data, however, show nearly monotonous rising trends although the behaviour of the maximum and the minimum temperature at different locations is different. In trend analysis studies, the results significantly depend upon the period of data and the stations whose data are used. There is another observation that most of the data used in trend detection pertain to the stations that are located in urban areas and these areas are a sort of heat islands. Thus, the study of trends using this data may not be the correct depiction of the reality and this aspect needs to be addressed. These concerns, in fact, highlight the importance of identifying a network of baseline stations for change detection studies. Countries, such as the USA, have identified such networks.

Existing stations with long series of good quality will be the obvious candidates for the baseline network and it will be necessary to add new stations so that the whole country is properly represented. More studies to detect tele-connections between Indian rainfall and temperatures and ENSO/SST are also needed. In a major exercise, an assessment of impact of climate change in the 2030s on four key sectors of the Indian economy, namely agriculture, water, natural ecosystems and

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biodiversity, and health in four climate sensitive regions of India, namely the Himalayan region, the Western Ghats, the coastal areas and north-eastern region has been carried out by the Ministry of Environment and forest, Government of India [24] There is a need of an integrated nation-wide adaptation and mitigation.

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