International Journal of Recent Engineering Research and Development (IJRERD)
ISSN: 2455-8761
www.ijrerd.com || Volume 04 – Issue 05 || May 2019 || PP. 72-75

Spatio-Temporal Trend Analysis of Rainfall and Temperature- A Review

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Abstract: Climate change has disrupted the major climatic parameters at a global level. However, the changes having localized intensity are not equal for all regions especially in India. These changes must be quantified locally to manage the natural water resources more effectively. Precipitation and Temperature are one of the most important climatic parameters. The purpose of this study is to observe the temporal variability of rainfall and temperature for the period of 1901–2017 (117 years), of Garhwal and Kumaon region districts of Uttarakhand. The aim of the study is to determine the trend in annual precipitation and temperature time series using the Mann-Kendall and Sen's T tests. The magnitudes of trend in precipitation and temperature have been estimated by Sen's estimator method. Auto correlation effect is reduced before applying the Mann-Kendall test for the trend in precipitation and temperature. On the annual basis, analysis of Mann-Kendall test shows increasing (positive) non-significance trend in rainfall and temperature time series over the 13 districts of Uttarakhand.

Keywords: Climate Change, Mann-Kendall Test, Sen's T tests, Rainfall, Temperature and Time Series

Introduction:

Climate change, also refers to global warming, is the phenomena on the earth in which there is increase/rise in average surface temperature. Studies have shown that global surface warming is happening at a rate of 0.74 ± 0.18 °C more than 1906– 2005 (IPCC, 2007). Effect of environmental change in future is very serious as given by IPCC reports which imply that there will be decrease in the freshwater accessibility in view of environmental change. Temperature and precipitation are fundamental component of climate. Changes in both these two component can affect human lives, ecosystem, plants and animals. It was observed that within 10° N to 30° N, precipitation has increased quite noticeably from 1900 to 1950, but it again declined after 1970. A decreasing trend was also found within the tropical areas of 10° N to 10° S. The eastern parts of North and South America, Northern and Central Asia and Northern Europe have become wetter, while the Mediterranean, the Sahel, Southern Africa and parts of Southern Asia have become drier. The seasonal and spatial change in the precipitation pattern is extremely variable in comparison to the change in temperature, and it is also consistent with the stream flow changes. The temperature increase is also evident since there is a reduction in the total number of frost days in the mid latitudes and an increase in the number of extreme warm days. Droughts have increased in the tropical and sub-tropical regions since the 1970s. Decreasing precipitation over land with increasing temperatures and evapotranspiration have caused drying and contributed to droughts in many regions. The tropics are getting immensely affected from the droughts. Global climate changes can affect long-term rainfall patterns impacting the availability of water, along with the danger of increasing occurrences of droughts and floods.

In India the southwest (SW) monsoon, which brings about 80% of the total precipitation over the country, is critical for the availability of freshwater for drinking and irrigation. Changes in climate over the Indian region, particularly the SW monsoon, would have a significant impact on agricultural production, water resources management and overall economy of the country. Temperature and its changes impact a number of hydrological processes including rainfall and these processes, in turn, also impact temperature (e.g., cooling due to rain/snow). Due to the uneven distribution of rainfall and the mismatch between water availability and demand, large storage reservoirs are required to redistribute the natural flow in accordance with the requirements of specific regions. The design of hydro-infrastructure is generally based on the assumption that climate is stationary. Changes in rainfall due to global warming will influence the hydrological cycle and the pattern of stream-flows and demands (particularly agricultural), requiring a review of hydrologic design and management practices. Changes in run-off and its distribution will depend on likely future climate scenarios.

There are number of parametric and non-parametric statistical test available to examine the trend of hydro meteorological parameters**.** Parametric tests are more powerful as compared to non-parametric test but they require independent and normally distributed data series while non-parametric test requires only data to be independent data and they also have the ability to remove outliers. Most important and frequently test used for the analysis of rainfall and temperature trend is Mann Kendal (MK) Trend Test.

Literature Review:

On study of basin-wise trend analysis of India, 15 basins shows decreasing trend in annual rainfall; only one basin showed significant decreasing trend at 95% confidence level. Among six basins showing increasing trend, one basin showed significant positive trend. Trends in temperature, the mean maximum temperature series showed a rising trend at most of the stations; it showed a falling trend at some stations. The mean minimum temperature showed a rising as well as a falling trend. At most of the stations in the south, central and western parts of India a rising trend was found. Some stations located in the north and northeastern India showed a falling trend in annual mean temperature. (Sharad K. Jain and Vijay Kumar,2012)

Study is about changes in rainfall trend in India for 141 years (1871–2011) and temperature trend for 107 years (1901–2007). The annual, seasonal and monthly changes were studied and the net excess or deficit of rainfall and temperature in India was obtained. Results shows decreasing annual and monsoon rainfall of India in most of the sub-divisions, and temperature fluctuations were observed in all the places. Temperatures (minimum, maximum and mean) were showing a significant increase, particularly in the winter and post-monsoon time. Wide variation was noticed all over India in the case of the minimum temperature. (Arun Mondal et.al 2015)

Trend analysis of rainfall data series for 1871–2008 did not show any clear trend for the northeast region as a whole, although there are seasonal trends for some seasons and for some hydro-meteorological subdivisions. Temperature data showed that all the four temperature variables (maximum, minimum, and mean temperatures and temperature range) had rising trend. For the post-monsoon season, the Sen's estimator of slope (°C/year) was 0.019, 0.011, and 0.015 for the maximum, minimum, and mean temperature, respectively. (Sharad K. Jain, Vijay Kumar and M. Sahariad, 2013)

Changing trend of rainfall of a river basin of Orissa near the coastal region. There are rising rates of precipitation in some months and decreasing trend in some other months suggesting overall insignificant changes in the area. (Arun Mondal et.al 2012)

Analysis of seasonal and annual trends in rainfall and rainy days over Himachal Pradesh.Based upon rainfall data of 37 stations for the period 1951-2005, it is found that the contribution of monsoon rainfall for the lower southwest part of the state is in the range of 60 to 80% of the annual total, while it is only around 35% for the higher elevation stations in the northern parts of the state. State averaged rainfall is decreasing significantly at 95% level for January (-0.61 mm/year), July (-1.83 mm/year), August (-.49 mm/year) and October (-0.90 mm/year). On seasonal scale, rainfall and rainy days are showing significantly decreasing trends for monsoon (-3.68 mm/year and -0.09 days/year respectively) and post monsoon (-0.98 mm/year and -0.03 days/year respectively). Annual rainfall and rainy days are showing significantly decreasing trends by -4.58 mm/year and -0.13 days/year respectively. Spatial patterns of monsoon rainfall and rainy days indicate significant decrease in southern and eastern parts of Himachal Pradesh, particularly in the Shivaliks and the middle Himalayas. Stations showing significant increasing trends in summer rainfall and rainy days are spatially coherent in the Shivaliks and the middle Himalaya. Seasonal rainfall is showing significantly increasing trend in winter (+1.47 mm/year) and summer (+1.77 mm/year) and significantly decreasing trend in monsoon (-3.71 mm/year) for Shimla, the capital of Himachal Pradesh. The daily heaviest rainfall is showing significantly decreasing trends in the southern parts of Himachal Pradesh (Hamirpur, Kotkhai, Nahan, Nurpur, Renuka (Rainka) and Pachhad. Stations showing significant increasing trends in annual daily heaviest rainfall are located in middle Himalayas Chini (Kalpa) and Palampur. (A.K. Jaswal, S.C.Bhan, A.S.Karandikar and M.K.Gujar,2015)

Study about the potential trend of rainfall and assess its significance in Kangra district of Himachal Pradesh.The falling trend is significant for the month of August for Dharamshala (0.05 level of significance). Interestingly the month of June shows rising trend of rainfall in all the stations, however, at Dharamshala the trend is significant (0.01 level of significance). The winter rainfall in the month of January and February record decreasing trend, with Dera Gobipur and Kangra recording significant decreasing trend for the month of January at 0.01 level of significance and 0.05 level of significance respectively. Trend analysis for annual rainfall data shows significant negative trend for Dharamshala. (Arijit Ganguly, Ranjana Ray Chaudhuri, Prateek Sharma,2015)

To study the temporal trend of meteorological parameters, 32 years (1971-2002) monthly meteorological data were collected for 133 selected stations over different agro-ecological regions of India. Both the maximum and minimum temperatures were found to be rising. A significant increasing trend in the relative humidity and a consistent significant decreasing trend in the wind speed all over the country were found.

However, a general increase in rainfall was not found in recent years (Arnab Bandyopadhyay, Anubhab Pal, and Subhajit Debnath,2011).

A study of the variability of the extreme rainfall events in Bangladesh during the time period 1958–2007 has been carried out.A total of 15 annual and seasonal indices of rainfall are examined. Variability of annual and seasonal rainfall trends is also assessed. A significant increase of annual and pre-monsoon rainfall in Bangladesh is observed. In general, an increasing trend in heavy precipitation days and decreasing trends in consecutive dry days are observed. Significant change in most of the extreme rainfall indices are observed in Northwest Bangladesh. (Shamsuddin Shahid,2010)

Mean annual precipitation varied from 694 mm (at West Nimar) 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. (Darshana duhan,Ashish Pandey,2013)

The study shows that the most probable year of change in annual as well as monsoon rainfall in the Indian Himalayas region is 1964. There was an increasing trend upto 1964 (corroborating with all India and nearby plains), followed by a decreasing trend in 1965–1980 (exclusive to this region). In the entire region, changes are most conspicuous over the Shivaliks and the southern part of the Lesser Himalayas. (Ashoke Basistha, D. S. Arya and N. K. Goel,2008)

Temperature and precipitation records from 1949 to 1998 were examined for 25 stations throughout the State of Alaska. Mean, maxima, and minima temperatures, diurnal temperature range, and total precipitation were analyzed for linear trends using least squares regressions. Annual and seasonal mean temperature increases were found throughout the entire state, and the majority were found to be statistically significant at the 95% level or better. The highest increases were found in winter in the Interior region (2.2 _C) for the 50 year period of record. Decreases in annual and seasonal mean diurnal temperature range were also found, of which only about half were statistically significant. A state-wide decrease in annual mean diurnal temperature range was found to be 0.3 _C, with substantially higher decreases in the South/Southeastern region in winter. Increases were found in total precipitation for 3 of the 4 seasons throughout most of Alaska, while summer precipitation showed decreases at many stations. Few of the precipitation trends were found to be statistically significant, due to high interannual variability. Barrow, our only station in the Arctic region, shows statistically significant decreases in annual and winter total precipitation. These findings are largely in agreement with existing literature, although they do contradict some of the precipitation trends predicted by the CO2-doubling GCM's (J. M. Stafford, G. Wendler, and J. Curtis,2000)

Trend analyses have been made by using both nonparametric (Mann–Kendall test) and parametric (linear regression analysis) procedures. The long historical series of monthly rainfall data employed in this work have been previously processed through a pre-whitening (PW) technique in order to reduce the autocorrelation of rainfall series and its effects on outcomes of trend detection. The application of the above mentioned procedures has shown a decreasing trendfor annual and winter–autumn rainfall and an increasing trend for summer precipitation. Moreover the Mann–Whitney test has been used to evidence the possible change points in the data. The higher percentages of rainfall series show possible year changes during decade 1960–1970 for almost all of the temporal aggregation rainfall (Tommaso Caloiero,Roberto Coscarelli, Ennio Ferrari and Marco Mancini,2009)

For the purpose of detecting the possible long-term trends of Japanese precipitation, both parametric *t*-test and nonparametric Mann–Kendall and Mann–Whitney techniques are applied to the spatially averaged precipitation time series over Japan. The results indicate that although several step changes occurred in Japanese precipitation, the time series did not exhibit significant evidence of monotonic trend during the past century. When a step change is present, the number of observations required for detecting the trend of a given magnitude at a specified significance and power level is investigated with the power function of the *t*-test. Results indicate that if the magnitude of the step change reaches one or two times of its standard deviation, the previous 50-year of record together with 5 years or more of new data will be available for detecting the possible trend. This conclusion may be helpful for the detection of step changes in the regions where the precipitation has near-normal distributions (K.Takeuchi,H.Ishidaira,2003)

Conclusion:

The study analyzed the rainfall data of 117 years from 1901–2017 to determine the trend of rainfall and temperature (minimum and maximum) in the Uttarakhand region. As this region is rapidly growing, any change in the rainfall trend pattern may have considerable impact on the people of this region. The Z value of Mann-

Kendall Test revealed increasing trend in rainfall and increasing trend in temperature also so it can be concluded that there may be an impact of climate change is present which is contributing to the prolonged and heavy rainfall that is rising with time. Similarly, Sen's slope has also estimated increasing magnitude of slope for rainfall and temperature data. This study is to find out the annual trend for rainfall which is found to be increasing (positive) with level of significance trend, pre-monsoon trend increasing with different level of confidence for different region, monsoon trend is increasing with different level of confidence for different region while post- monsoon is decreasing and winter trend is increasing and pre-monsoon maximum temperature showing increasing trend and monsoon showing decreasing trend. Annual Minimum temperature is increasing, pre-monsoon is increasing but monsoon and post monsoon showing a decreasing trend.

Acknowledgment:

The authors thankfully acknowledge all authors and publishers for providing all the necessary information and the research done by them which has made the study achievable.

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