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Vijay P. Singh
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Climate Change Impacts

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Preface

Fundamental to sustainable economic development, functioning of healthy ecosystems, reliable agricultural productivity, dependable power generation, maintenance of desirable environmental quality, continuing industrial growth, enjoyment of quality lifestyle, and renewal of land and air resources is water. With growing population, demands for water for agriculture and industry are skyrocketing. On the other hand, freshwater resources per capita are decreasing. There is therefore a need for effective water resources management strategies. These strategies must also consider the nexus between water, energy, environment, food, and society. With these considerations in mind, the International Conference on Water, Environment, Energy and Society (WEES-2016) was organized at AISECT University in Bhopal, MP, India, from March 15–18, 2016. The conference was fifth in the series and had several objectives.

The first objective was to provide a forum to not only engineers, scientists, and researchers, but also practitioners, planners, managers, administrators, and policy makers from around the world for discussion of problems pertaining to water, environment, and energy that are vital for the sustenance and development of society.

Second, the Government of India has embarked upon two large projects one on cleaning of River Ganga and the other on cleaning River Yamuna. Further, it is allocating large funds for irrigation projects with the aim to bring sufficient good quality water to all farmers. These are huge ambitious projects and require consideration of all aspects of water, environment, and energy as well as society, including economics, culture, religion, politics, administration, law, and so on.

Third, when water resources projects are developed, it is important to ensure that these projects achieve their intended objectives without causing deleterious environmental consequences, such as water logging, salinization, loss of wetlands, sedimentation of reservoirs, loss of biodiversity, etc.

Fourth, the combination of rising demand for water and increasing concern for environmental quality compels that water resources projects are planned, designed, executed and managed, keeping changing conditions in mind, especially climate change and social and economic changes.

Fifth, water resources projects are investment intensive and it is therefore important to take a stock of how the built projects have fared and the lessons that can be learnt so that future projects are even better. This requires an open and frank discussion among all sectors and stakeholders.

Sixth, we wanted to reinforce that water, environment, energy, and society constitute a continuum and water is central to this continuum. Water resources projects are therefore inherently interdisciplinary and must be so dealt with.

Seventh, a conference like this offers an opportunity to renew old friendships and make new ones, exchange ideas and experiences, develop collaborations, and enrich ourselves both socially and intellectually. We have much to learn from each other.

Now the question may be: Why India and why Bhopal? India has had a long tradition of excellence spanning several millennia in the construction of water resources projects. Because of her vast size, high climatic variability encompassing six seasons, extreme landscape variability from flat plains to the highest mountains in the world, and large river systems, India offers a rich natural laboratory for water resources investigations.

India is a vast country, full of contrasts. She is diverse yet harmonious, mysterious yet charming, old yet beautiful, ancient yet modern. Nowhere can we find as high mountains as snow-capped Himalayas in the north, the confluence of three seas and large temples in the south, long and fine sand beaches in the east as well as architectural gems in the west. The entire country is dotted with unsurpassable monuments, temples, mosques, palaces, and forts and fortresses that offer a glimpse of India's past and present.

Bhopal is located in almost the centre of India and is situated between Narmada River and Betwa River. It is a capital of Madhya Pradesh and has a rich, several century-long history. It is a fascinating amalgam of scenic beauty, old historic city, and modern urban planning. All things considered, the venue of the conference could not have been better.

We received an overwhelming response to our call for papers. The number of abstracts received exceeded 450. Each abstract was reviewed and about two-thirds of them, deemed appropriate to the theme of the conference, were selected. This led to the submission of about 300 full length papers. The subject matter of the papers was divided into more than 40 topics, encompassing virtually all major aspects of water and environment as well energy. Each topic comprised a number of contributed papers and in some cases state-of-the art papers. These papers provided a natural blend to reflect a coherent body of knowledge on that topic.

The papers contained in this volume, "Climate Change Impacts," represent one part of the conference proceedings. The other parts are embodied in six companion volumes entitled, "Hydrologic Modelling," "Groundwater," "Environmental Pollution," "Water Quality Management," "Energy and Environment," and "Water Resources Management." Arrangement of contributions in these seven books was a natural consequence of the diversity of papers presented at the conference and the topics covered. These books can be treated almost independently, although significant interconnectedness exists amongst them.

This volume contains four parts. The first part deals with some aspects of climatic characteristics ranging from changes in temperature and sunshine hours to downscaling to global climate patterns and effects of ENSO and IOD on extreme rainfall. Part II covers rainfall analysis, including changes in regional rainfall series, analysis of non-stationarity, summer monsoon, and rainfall scenarios. Impacts of climate change are treated in Part III. Change point analysis, greenhouse gas emissions, rainfall variability, water resources variability, and water resources sustainability are discussed in this part. The concluding Part IV is on low flow and drought. It deals with the SPI concept and assessment of drought.

The book will be of interest to researchers and practitioners in the field of water resources, hydrology, environmental resources, agricultural engineering, watershed management, earth sciences, as well as those engaged in natural resources planning and management. Graduate students and those wishing to conduct further research in water and environment and their development and management may find the book to be of value.

WEES-16 attracted a large number of nationally and internationally well-known people who have long been at the forefront of environmental and water resources education, research, teaching, planning, development, management, and practice. It is hoped that long and productive personal associations and friendships will be developed as a result of this conference.

College Station, USA — Vijay P. Singh, Conference Chair
Bhopal, India — Shalini Yadav, Conference Organizing Secretary
Hazaribagh/Bhopal, India — Ram Narayan Yadava, Conference Co-Chair

Acknowledgements

We express our sincere gratitude to Shri Santosh Choubey, Chancellor, and Dr. V.K. Verma, Vice Chancellor, Board of Governing Body, and Board of Management of the AISECT University, Bhopal, India, for providing their continuous guidance and full organizational support in successfully organizing this international conference on Water, Environment, Energy and Society on the AISECT University campus in Bhopal, India.

We are also grateful to the Department of Biological and Agricultural Engineering, and Zachry Department of Civil Engineering, Texas A&M University, College Station, Texas, U.S.A., and International Centre of Excellence in Water Management (ICE WaRM), Australia, for their institutional cooperation and support in organizing the ICWEES-2016.

We wish to take this opportunity to express our sincere appreciation to all the members of the Local Organization Committee for helping with transportation, lodging, food, and a whole host of other logistics. We must express our appreciation to the Members of Advisory Committee, Members of the National and International Technical Committees for sharing their pearls of wisdom with us during the course of the Conference.

Numerous other people contributed to the conference in one way or another, and lack of space does not allow us to list all of them here. We are also immensely grateful to all the invited Keynote Speakers, and Directors/Heads of Institutions for supporting and permitting research scholars, scientists and faculty members from their organizations for delivering keynote lectures and participating in the conference, submitting and presenting technical papers. The success of the conference is the direct result of their collective efforts. The session chairmen and co-chairmen administered the sessions in a positive, constructive, and professional manner. We owe our deep gratitude to all of these individuals and their organizations.

We are thankful to Shri Amitabh Saxena, Pro-Vice Chancellor, Dr. Vijay Singh, Registrar, and Dr. Basant Singh, School of Engineering and Technology, AISECT University, who provided expertise that greatly helped with the conference organization. We are also thankful to all the Heads of other Schools, Faculty Members and Staff of the AISECT University for the highly appreciable assistance in different organizing committees of the conference. We also express our sincere thanks to all the reviewers at national and international levels who reviewed and moderated the papers submitted to the conference. Their constructive evaluation and suggestions improved the manuscripts significantly.

Sponsors and Co-sponsors

The International Conference on Water, Environment, Energy and Society was Jointly organized by the AISECT University, Bhopal (M.P.), India and Texas A&M University, Texas, USA in association with ICE WaRM, Adelaide, Australia. It was partially supported by the International Atomic Energy Agency (IAEA), Vienna, Austria; AISECT University, Bhopal; M.P. Council of Science and Technology (MPCOST); Environmental Planning and Coordination Organization (EPCO), Government of Madhya Pradesh; National Bank for Agriculture and Rural Development (NABARD), Mumbai; Maulana Azad National Institute of Technology (MANIT), Bhopal; and National Thermal Power Corporation (NTPC), Noida, India. We are grateful to all these sponsors for their cooperation and providing partial financial support that led to the grand success to the ICWEES-2016.

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About the Editors

Prof. Vijay P. Singh is a University Distinguished Professor, a Regents Professor, and the inaugural holder of the Caroline and William N. Lehrer Distinguished Chair in Water Engineering in the Department of Biological and Agricultural Engineering and Zachry Department of Civil Engineering at Texas A&M University. He received his B.S., M.S., Ph.D. and D.Sc. degrees in engineering. He is a registered professional engineer, a registered professional hydrologist, and an Honorary Diplomate of American Academy of Water Resources Engineers.

Professor Singh has extensively published the results of an extraordinary range of his scientific pursuits. He has published more than 900 journal articles; 25 textbooks; 60 edited reference books, including the massive Encyclopedia of Snow, Ice and Glaciers and Handbook of Applied Hydrology; 104 book chapters; 314 conference papers; and 72 technical reports in the areas of hydrology, ground water, hydraulics, irrigation engineering, environmental engineering, and water resources.

For his scientific contributions to the development and management of water resources and promoting the cause of their conservation and sustainable use, he has received more than 90 national and international awards and numerous honors, including the Arid Lands Hydraulic Engineering Award, Ven Te Chow Award, Richard R. Torrens Award, Norman Medal, and EWRI Lifetime Achievement Award, all given by American Society of Civil Engineers; Ray K. Linsley Award and Founder's Award, given by American Institute of Hydrology; Crystal Drop Award, given by International Water Resources Association; and Outstanding Distinguished Scientist Award given by Sigma Xi, among others. He has received three honorary doctorates. He is a Distinguished Member of ASCE, and a fellow of EWRI, AWRA, IWRS, ISAE, IASWC, and IE and holds membership in 16 additional professional associations. He is a fellow/member of 10 international science/engineering academies. He has served as President and Senior Vice President of the American Institute of Hydrology (AIH). Currently he is editor-in-chief of two book series and three journals and serves on editorial boards of 20 other journals.

Professor Singh has visited and delivered invited lectures in all most all parts of the world but just a sample: Switzerland, the Czech Republic, Hungary, Austria, India, Italy, France, England, China, Singapore, Brazil, and Australia.

Prof. Shalini Yadav is a Professor and Head of the Department of Civil Engineering, AISECT University, Bhopal, India. Her research interests include Solid and Hazardous Waste Management, Construction Management, Environmental Quality, and Water Resources. She has executed a variety of research projects/consultancy in Environmental and Water Science and Technology and has got rich experience in Planning, formulating, organizing, executing, and management of R&D Programs, Seminars, and Conferences at National and International level. She has got to her credit guiding an appreciable number of M.Tech. and Ph.D. students. She has published more than 10 journal articles and 30 technical reports. Dr. Shalini has also visited and delivered invited lectures at different Institutes/Universities in India and abroad, such as Australia, South Korea, Kenya.

Professor Shalini Yadav graduated with a B.Sc. in Science from the Bhopal University. She earned her M.Sc. in Applied Chemistry with specialization in Environmental Science from Bhopal University and M.Tech. in Civil Engineering with specialization in Environmental Engineering from Malaviya National Institute of Technology, Jaipur, India in 2000. Then she pursued the degree of Ph.D. in Civil Engineering from Rajiv Gandhi Technical University, Bhopal, India in 2011. Also, she is a recipient of national fellowships and awards. She is a reviewer in many International journals. She has been recognized for one and half decades of leadership in research, teaching, and service to the Environmental Engineering Profession.

Dr. Ram Narayan Yadava holds position of Vice Chancellor of the AISECT University, Hazaribag, Jharkhand. His research interests include Solid Mechanics, Environmental Quality and Water Resources, Hydrologic Modelling, Environmental Sciences and R&D Planning and Management. Yadava has executed a variety of research/consultancy projects in the area of Water Resources Planning and Management, Environment, Remote Sensing, Mathematical Modelling, Technology Forecasting, etc.

He has got adequate experience in Establishing Institutes/Organizations, Planning, Formulating, Organizing, Executing and Management of R&D Programs, Seminars, Symposia, Conferences at National and International level. He has got to his credit guiding a number of M.Tech. and Ph.D. students in the area of Mathematical Sciences and Earth Sciences. Dr. Yadava has visited and delivered invited lectures at different Institutes/Universities in India and abroad, such as USA, Canada, United Kingdom, Thailand, Germany, South Korea, Malaysia, Singapore, South Africa, Costa Rica, and Australia.

He earned an M.Sc. in Mathematics with specialization in Special Functions and Relativity from Banaras Hindu University, India in 1970 and a Ph.D. in Mathematics with specialization in Fracture Mechanics from Indian Institute of Technology, Bombay, India in 1975. Also, he is recipient of Raman Research Fellowship and other awards. Dr. Yadava has been recognized for three and half decades of leadership in research and service to the hydrologic and water resources profession. Dr. Yadava's contribution to the state of the art has been significant in many different specialty areas, including water resources management, environmental sciences, irrigation science, soil and water conservation engineering, and mathematical modeling. He has published more than 90 journal articles; four textbooks; seven edited reference books.

Part I
Climatic Characteristics

Trends in Temperature for the Himalayan Environment of Leh (Jammu and Kashmir), India

Rohitashw Kumar, Zeenat Farooq, Deepak Jhajharia and V.P. Singh

Abstract Climate parameters variability affects significantly on water resources, and therefore on the livelihood of the common people, especially in water scarce countries. The aim of this study was to explore changes in the maximum, minimum, and mean temperatures using the monthly data of Leh taking last 15 years from 2000 to 2014, which is situated in the western Indian Himalaya. Trends analyses were performed with nonparametric statistics proposed by Mann-Kendall at different time scales in arid environments of Leh. On monthly basis, a significant falling trend in maximum temperature and minimum temperature has been observed at 5% significance level in the month of July at the rate of 1.7 °C per decade and in the month of August at the rate of 1.3 °C per decade, respectively. However, no trend has been observed in other time scales at 5% level of significance. The observed change in temperature will affect all biochemical reactions of photosynthesis thus in turn will have negative impact on plant growth.

Keywords Trend · Mann-Kendall · Maximum and minimum temperature Himalayan region, Leh

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Introduction

Climate change has brought in unexpected changes not only in India but all over the regions across the world. Emergence of global warming due to climate change is the new and most talked subject of today's world as it is the most threatening issue for very existence of life on the earth. One of the consequences of climate change is the alteration of rainfall patterns and increase in temperature. According to Intergovernmental Panel on Climate Change (IPCC 2001) reports, the surface temperature of the earth has risen by 0.6 ± 0.2 °C over the twentieth century. Also in the last 50 years, the rise in temperature has been 0.13 ± 0.07 °C per decade. As the warming depends on emissions of greenhouse gases in the atmosphere, the IPCC has projected a warming of about 0.2 °C per decade. Further, surface air temperature could rise by between 1.1 and 6.4 °C over twenty-first century. In case of India, the climate change expected to adversely affect its natural resources, forestry, agriculture, and change in precipitation, temperature, monsoon timing, and extreme events. Due to global warming, precipitation amount, type and timing are changing or expected to change because of increased evaporation, especially in the tropics.

The pattern and amount of rainfall are among the most important factors that affect agricultural production (Jhajharia et al. 2015). Agriculture is vital to India's economy and the livelihood of its people. Agriculture is contributing 21% to the country's GDP, accounting for 115 of total export, employing 56.4% of the total workforce, and supporting 600 million people directly and indirectly (Beena 2010; McVicar et al. 2010, 2012). Temperature drives the hydrological cycle, influencing hydrological processes in a direct or indirect way. A warmer climate leads to intensification of the hydrological cycle, resulting in higher rates of evaporation and increase of liquid precipitation. These processes, in association with a shifting pattern of precipitation, will affect the spatial and temporal distribution of runoff, soil moisture, groundwater reserves, and increase the frequency of droughts and floods. The future climatic change, though, will have its impact globally and will be felt severely in developing countries with agrarian economies, such as India. Surging population and associated demands for freshwater, food, and energy would be areas of concern in the changing climate. Changes in extreme climatic events are of great consequence owing to the high vulnerability of the region to these changes. Parry et al. (2001) have shown that there is a steep rise in the water shortage curve when plotted against rise in temperature. They reported that this is due to large urban populations in China and India being newly exposed to risk. There has not been conducted previous study on behavior of temperature for the Himalayan environment of Leh, this study was carried out to analyze the temperature trend of Leh using Mann-Kendall test for the year 2000–2014.

Materials and Methods

Study Area

The Indian Himalayan Region (IHR) is spreading to 10 states (administrative regions) namely, Jammu & Kashmir, Himachal Pradesh, Uttaranchal, Sikkim, Arunachal Pradesh, Meghalaya, Nagaland, Manipur, Mizoram, Tripura, and hill regions of two states viz. Assam and West Bengal of Indian Republic. It contributes about 16.2% of India's total geographical area, and most of the area is covered by snow-clad peaks, glaciers of higher Himalaya, dense forest cover of mid-Himalaya. The IHR shows a thin and dispersed human population as compared to the national figures due to its physiographic condition and poor infrastructure development, but the growth rate is much higher than the national average.

In this study Himalayan region of Leh was taken into consideration. Mountains dominate the landscape around the Leh as it is at an altitude of 3,500 m. Leh has a cold desert climate with long, harsh winters, with minimum temperatures well below freezing for most of the winter. The city gets occasional snowfall during winter. The weather in the remaining months is generally fine and warm during the day. Average annual rainfall is only 102 mm. The temperature can range from −42 °C in winter to 33 °C in summer. In 2010, the Leh city experienced flash floods which killed more than 100 people. The study area of Himalayan region is shown in Fig. 1.

The data sets used in this study was obtained from High Mountain Research Station Leh, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir for the period of 15 years from 2000 to 2014 of cold desert.

The trend analysis of temperature at monthly, annual and seasonal (winter, spring, summer and autumn) basis was carried out. Trends in data can be identified by using

Fig. 1 Study area of Leh

either parametric or nonparametric methods. In the recent past, both methods have been widely used for the detection of trends (WMO 1997; Mitosek 1992; Chiew and McMahon 1993; Burn and Elnur 2002). Then parametric tests are more suitable for non-normally distributed, censored data, including missing values, which are frequently encountered in hydrological time series (Hirsch et al. 1984).

Mann-Kendall Test

Mann-Kendall test is a statistical test widely used for the analysis of trend in climatologic and in hydrologic time series. There are two advantages of using this test. First, it is a nonparametric test and does not require the data to be normally distributed. Second, the test has low sensitivity to abrupt breaks due to inhomogeneous time series. According to this test, the null hypothesis H_0 assumes that there is no trend (the data is independent and randomly ordered) and this is tested against the alternative hypothesis H_1, which assumes that there is a trend. Mann-Kendall test is a nonparametric test for identifying trends in time series data. This test compares the relative magnitudes of data rather than the data values themselves (Gilbert 1987). This test assumes that there exists only one data value for a time period. When multiple data points exist for a single time period, the median value will be used. The initial value of the Mann-Kendall statistic S is assumed to be 0. If a data value from a later time period is higher than a data value from an earlier time period, S is increased by 1. On the other hand, if the data value from the later time period is lower than a data valued sampled earlier, it is decreased by 1. The net result of increments and decrements yields the final value of S. This method is more suitable for non-normally distributed and censored data, and is less influenced by the presence of outliers in the data (Mann 1945; Kendall 1975).

Let $x_1, x_2, x_3, \ldots, x_n$ represent n data points, then the Mann-Kendall test statistic S is given by

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

where n is the number of observations and x_j is the jth observation and sgn (θ) is the sign function which can be defined as follows:

$$\operatorname{sgn}(\theta) = \begin{bmatrix} 1 & \text{if} & \theta > 0 \\ 0 & \text{if} & \theta = 0 \\ -1 & \text{if} & \theta < 0 \end{bmatrix} \tag{2}$$

Under the assumption that the data are independent and identically distributed, the mean and variance of the S statistic are given by (Kendall 1975)

$$E(S) = 0 \tag{3}$$

$$\frac{n(n-1)(2n+5) - \sum_{i=0}^{m} t_i(t_i - 1)(2t_i + 5)}{18} = V_S, \tag{4}$$

where m is the number of groups of tied ranks, each with tied observations.

The Z-statistic can be computed as follows:

$$Z = \frac{S-1}{\sqrt{(\mathrm{var}(S))}} \quad \text{IF} \ \ S > 0 \tag{5}$$

$$Z = 0 \quad \text{If} \ \ S = 0 \tag{6}$$

$$Z = \frac{S+1}{\sqrt{(\mathrm{var}(S))}} \quad \text{if} \ \ S < 0 \tag{7}$$

Estimation of Magnitude of Trends

The magnitude of the identified trends in the meteorological parameters was obtained through the parametric linear regression test, a commonly used parametric method.

The linear relationship between two variables is represented by a straight line, which is given as

$$y = m \times x + c$$

x denote the time variable
m slope of regression line
c intercept

Results and Discussion

The value of Z statistics with p-value in parenthesis obtained by Mann-Kendall test for all the parameters on monthly and annual time scales are tabulated below. The value test Statistics (z) is summarized in Table 1.

It is witnessed from Table 1 that the statistically significant falling trends are witnessed in maximum temperature in the month of July at the rate of 1.70 °C/decade, at 5% level of significance as the values of Z (test statistics) obtained through the MK

Table 1 The value of test statistics (z) obtained through Mann-Kendall test on monthly and annual basis

Month	Maximum temperature	Minimum temperature
January	*0.291 (0.923)*	*0.132 (0.846)*
February	*−0.172 (0.254)*	*−0.357 (0.282)*
March	*0.306 (0.495)*	*0.325 (0.328)*
April	*0.363 (0.282)*	*0.254 (0.298)*
May	*0.038 (0.814)*	*0.166 (0.457)*
June	*0.097 (0.697)*	*0.073 (0.435)*
July	**−2.114 (0.032)**	*0.122 (0.656)*
August	*0.116 (0.137)*	**−1.999 (0.015)**
September	*0.068 (0.657)*	*−0.139 (0.495)*
October	*0.032 (1.000)*	*−0.132 (0.770)*
November	*0.320 (0.804)*	*0.132 (0.626)*
December	*0.052 (0.298)*	*−0.138 (0.499)*
Annual	*0.014 (0.846)*	*0.138 (0.770)*

Note: *Bold values* denote statistically significant at 5% level of significance. *Italic values* are cases of no trends (statistically non-significant even at 10% level of significance)

test are more than −1.96 (Table 1). However, the remaining months witnessed no statistically significant trends in maximum temperature at 5% level of significance as the Z values are between +1.96 and −1.96 (or at 10% level of significance as the Z values are between +1.65 and −1.65). The monthly trend in maximum temperature during 2000–2014 is shown in Fig. 2a–d.

It is evident from Table 1 that in case of minimum temperature MK test revealed that statistically significant falling trend at 5% level of significance, as the values of Z (test statistics) obtained, is more than −1.96 and was witnessed in the month of August at the rate of 1.31 °C/decade (Fig. 3a–d). Statistically significant falling trend was witnessed in the month of December at the rate of 1.74 °C/decade at 10% significance level as the Z value is more than 1.65 and less than 1.96. However, the remaining months witnessed no significant trends at 5% level of significance as the Z values are between +1.96 and −1.96 (or at 10% level of significance as the Z values are between +1.65 and −1.65).

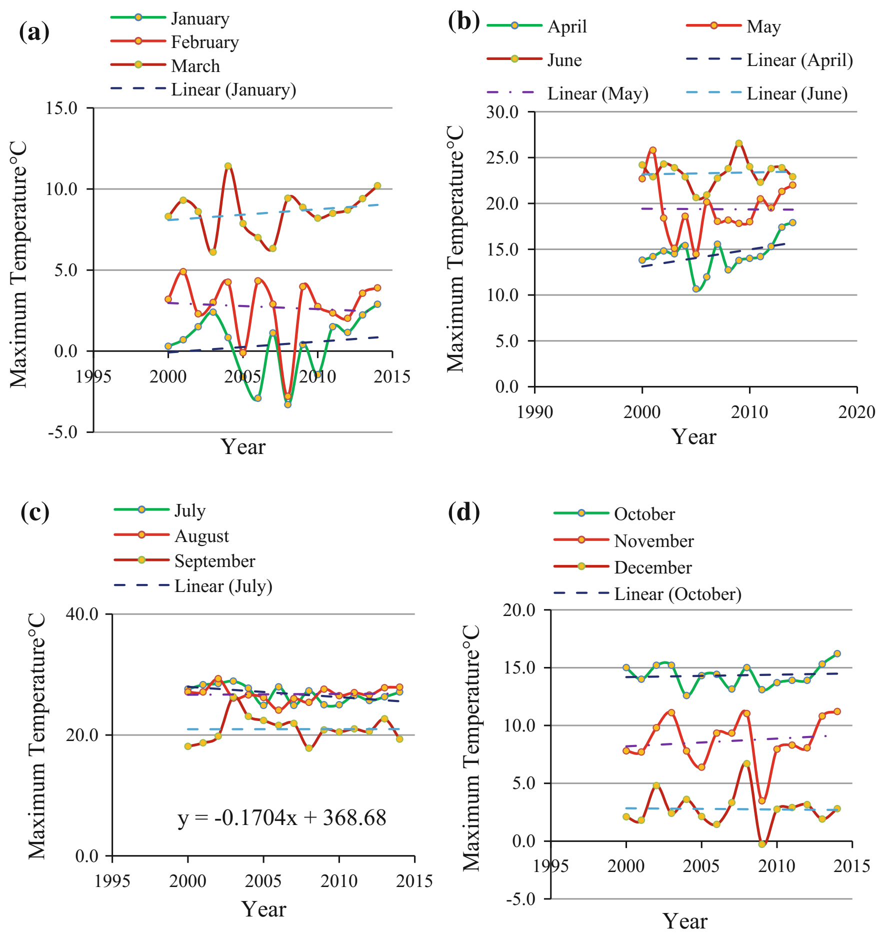

Fig. 2 **a–d** Time series of maximum temperature on monthly basis with linear trend lines

On annual basis, no significant trend was witnessed in case of maximum and minimum temperature at 5% level of significance as the Z values are between +1.96 and −1.96 (or at 10% level of significance as the Z values are between +1.65 and −1.65). The annual trend of maximum and minimum temperature is shown in Fig. 4a–b.

Test statistics (Z) values with p-value in parenthesis obtained through the Mann-Kendall test on seasonal basis is tabulated and shown in Table 2.

It is evident from Table 2 that on seasonal basis no significant trend was witnessed in case of maximum and minimum temperature at 5% level of significance

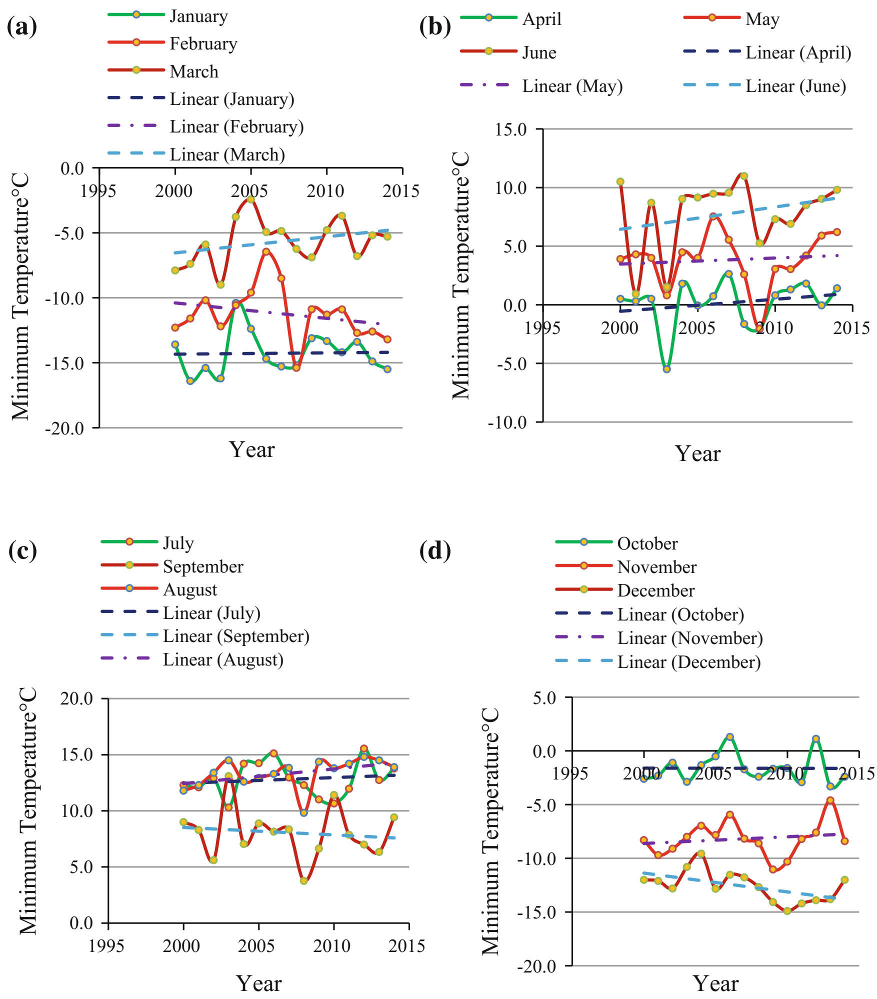

Fig. 3 **a–d** Time series of minimum temperature on monthly basis with linear trend lines

as the Z values are between +1.96 and −1.96 (or at 10% level of significance as the Z values are between +1.65 and −1.65). The graphical representation of seasonal basis between maximum temperature is shown in Fig. 5a–b.

The seasonal trend in minimum temperature in different years was also carried. The graphical representation of seasonal basis between minimum temperatures is shown in Fig. 6a–b.

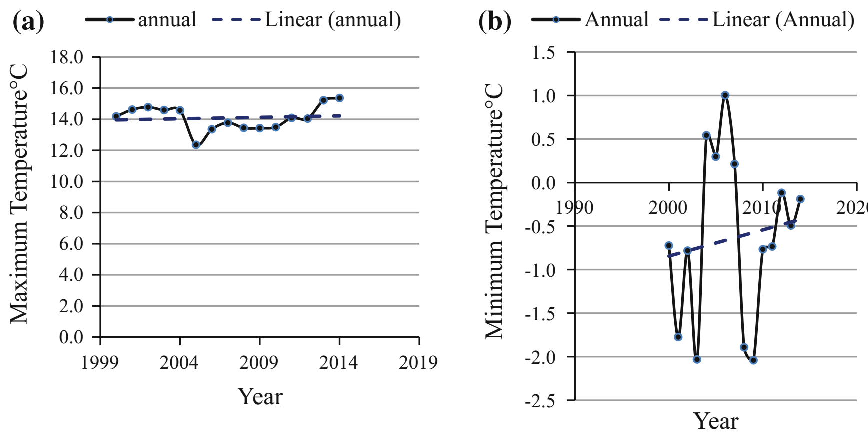

Fig. 4 **a–b** Time series of different weather parameters on annual basis

Table 2 Value of *Z* statistics with *p*-value in parenthesis on seasonal basis

Season	Maximum temperature	Minimum temperature
Spring	0.306 (0.179)	0.261 (0.667)
Summer	−0.135 (0.667)	0.370 (0.114)
Autumn	0.198 (1.000)	0.058 (0.923)
Winter	−0.017 (0.590)	−0.452 (0.659)

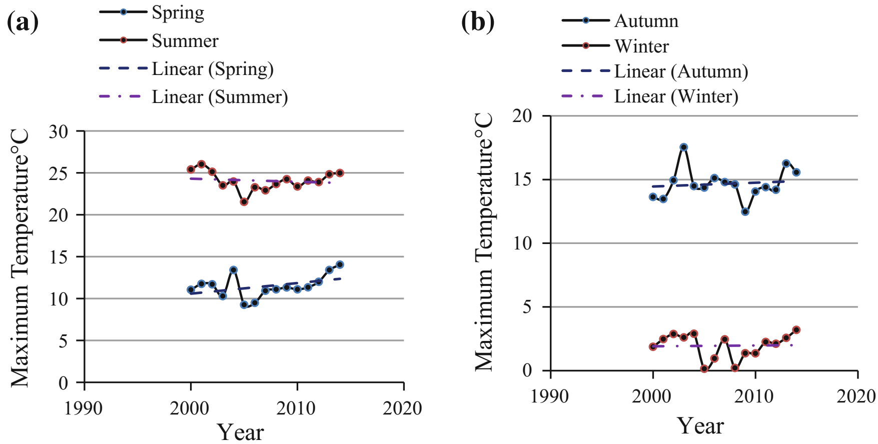

Fig. 5 **a–b** Maximum temperature on seasonal with linear trend lines

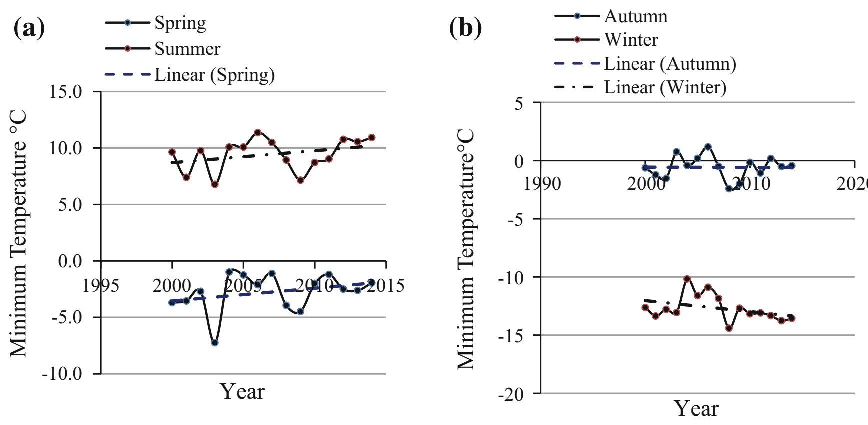

Fig. 6 **a–b** Minimum Temperature on seasonal with linear trend lines

Conclusions

The weather is a continuous, data-intensive, multidimensional, dynamic and complex process and these properties make weather forecasting a formidable challenge. Thus an attempt has been made in is study to estimate the trends of maximum and minimum temperature, on monthly, seasonal, and annual basis over climatic conditions of Himalayas because of the importance of these parameters in water balance studies, irrigation planning, planning, and operation of reservoirs. The trends in different climatic parameters were investigated using the nonparametric Mann-Kendall (MK) test. The conclusions drawn from the study are summarized as follows:

1. In case of maximum temperature a significant falling trend has been observed at 5% significance level in the month of July.
2. In case of minimum temperature a significant falling trend has been observed at 5% significance level in the month of August and at 10% significance level in the month of December.
3. On annual and seasonal basis, it was witnessed that neither maximum nor minimum temperature showed significant falling trend at 10% significance level.

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Changes in Sunshine Duration in Humid Environments of Agartala (Tripura), India

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Abstract Study of changes in the global solar radiation is one of the key factors in sustainable agricultural production and management. Therefore, we investigated trends in the solar radiation using sunshine duration as a suitable alternative, based on the recommendation of the FAO Irrigation and Drainage—Paper No. 56, by using the Mann-Kendall (MK) test at different time scales in the humid environments of Northeast India. The average annual bright sunshine hours over Agartala is found to be 6.6 hours (h) with a standard deviation of 0.4 h and coefficient of variation of 6.4%. On annual (seasonal) time scale, statistically significant decreasing trends in bright sunshine duration through the MK test were observed at 5% level of significance at the rate of 0.245 h/decade (0.545 and 0.118 h/decade in winter and monsoon) over Agartala. Similarly, sunshine decreases were observed in the months of January, February, March, May, September, October, and December in the range of 0.237–0.688 h/decade. The observed decreases in sunshine duration

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