Analysis of rainfall and temperature trends of selected stations over North East India during last century

S. I. LASKAR, S. D. KOTAL and S. K. ROY BHOWMIK

India Meteorological Department, New Delhi – 110 003, India

(*Received 24 March 2014, Modified 8 August 2014*)

e mail : drsebul@gmail.com

सार – इस शोध पत्र में वर्ष 1913 से 2012 की अवधि के पूर्वोत्तर भारत के नौ चुनिंदा स्टेशनों के उपलब्ध आँकड़ों के आधार पर ऋतुनिष्ठ अधिकतम और न्यूनतम तापमानों की प्रवृत्तियों और वर्षा की समय श्रृंखलाओं का परीक्षण किया गया है।

इस शोध की अवधि के दौरान पूर्वोत्तर भारत के लगभग सभी स्टेशनों के न्यूनतम तापमान में वृद्धि की प्रवृत्ति देखी गई है; केवल चेरापूँजी स्टेशन पर वर्ष में सभी ऋतुओं में न्यूनतम तापमान में गिरावट की प्रवृत्ति रही है। जबकि चेरापूँजी, गुवाहाटी और इम्फाल में सभी ऋतुओं में अधिकतम तापमान में वृद्धि की प्रवृत्ति पाई गई है। अगरतला और शिलांग में मॉनसून और मॉनसूनोत्तर ऋतु में अधिकतम तापमान में वृद्धि की प्रवृत्ति पाई गई है। डिब्रूगढ़ और पासिघाट में मॉनसून पूर्व ऋतु में गिरावट और वर्ष के अन्य ऋतुओं में वृद्धि की प्रवृत्ति पाई गई है। गंगटोक में सभी ऋतुओं में अधिकतम तापमान में गिरावट की प्रवृत्ति पाई गई है जबकि सिल्चर में अधिकतम तापमान के संबंध में कोई प्रवृत्ति नहीं पाई गई है।

चयन किए गए सभी नौ स्टेशनों में से अधिकांश स्टेशन वर्षा के या तो घटती हुई प्रवृत्ति को दर्शाते हैं या कोई प्रवृत्ति को नहीं दर्शाते हैं। इनमें गुवाहाटी का स्टेशन अपवाद है जो मॉनसूनोत्तर ऋतु के दौरान वर्षा में महत्वपूर्ण रूप से वृद्धि की प्रवृत्ति को प्रदर्शित करता है।

ABSTRACT. In this study, the trends of seasonal maximum and minimum temperatures and rainfall time series were investigated for 9 selected stations in the north eastern India with the available data stretching between the years 1913-2012.

During the period under study the minimum temperature has increasing trends in almost all the stations of north east India except Cherrapunji where it shows decreasing trend in all the season of the year. In case of maximum temperature Cherrapunji, Guwahati and Imphal show increasing trends during all the seasons. Agartala and Shillong show increasing trend of maximum temperature during monsoon and post monsoon season. Dibrugarh and Pasighat show decreasing trend during pre monsoon season and increasing trend during all other seasons of the year. Gangtok shows decreasing trend of maximum temperature during all the seasons where as Silchar shows no trend in maximum temperature.

Out of all the selected nine stations, most of the stations show either decreasing trend or no trend of rainfall except Guwahati which shows significant increasing trend of rainfall during post monsoon season.

Key words – Maximum temperature, Minimum temperature, Rainfall, Trend.

1. Introduction

Emergence of global warming due to climate change is the new and most talked subject of today's world as it being 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. It is mostly due to temporal and spatial distribution of precipitation, rather than the total amount which causes the water scarcity problem to Indian

subcontinent. The changes in precipitation pattern have occurred all over the world during most of this century and are predicted to change further. Such climatic changes may entail the occurrence of specific effects in the hydrological cycle. Precipitation is a vital part of the hydrologic cycle and changes in its pattern would directly influence the water resources of the concerned region. Changes in rainfall quantity and frequency would alter the pattern of stream flows and demands (particularly agricultural), spatial and temporal distribution of runoff, soil moisture and groundwater reserves. This will necessitate a review of our reservoir operation and water resources management policies. Trend analysis of rainfall in different spatial scales will lead to a better understanding of the problems associated with floods, droughts and the availability of water for various uses with respect to future climate scenarios. Air temperature is also considered a good indication of the state of climate because of its ability to represent the energy exchange process over the earth's surface with reasonable accuracy (Vinnikov *et al.*, 1990; Thapliyal and Kulshrestha, 1991). Atmospheric carbon dioxide levels have recorded continual increases since 1950s, a phenomenon that may significantly alter global and local climate characteristics such as temperature and precipitation (Yu *et al.* 2002).

It is noted that the change in precipitation and temperature is not globally uniform. Regional variations can be much larger and considerable spatial and temporal variations may exist between climatically different regions (Yue and Hashino 2003). A comprehensive knowledge of characteristics of rainfall and temperature of a region including their variation both in time and space is very essential for proper planning and overall development of an area. NE India can be considered a separate macro-region within the Indian landmass (Winstanley, 1973 Parthasarathy *et al.*, 1987). Agriculture products form important inputs to the economy of NE India and any changes in the spatial and temporal pattern of rainfall directly affects the monsoon-reliant agriculture ecosystem. The climate is subtropical and the region is characterized by wide variation of weather and climate. The Northeastern Region of India is expected to be highly prone to the consequences of climate change because of its geo-ecological fragility, strategic location *vis-à-vis* the eastern Himalayan landscape, its trans-boundary river basins and its inherent socio-economic instabilities. Environmental security and sustainability of the region are affected by these impacts. The impact of climate change on the region like north east India are less explored and less known till now making the future scenarios more uncertain for vulnerability assessment and risk management. However, certain indicators point to impacts being already visible in the region. Therefore the present

study aimed to analyze seasonal trends of temperature and rainfall over North Eastern parts of India during last century on the basis of available data of nine stations of the region to understand the local climatic fluctuations as the North Eastern region has distinct climate variations. The rapid changes in topography in the area result in climate changes within short distance.

2.   Previous studies

Trends in monthly, seasonal and annual rainfall and temperature on the sub-division and regional scale for the North Eastern region were examined by Jain *et al.* (2012) by analyzing the data season-wise as well as year-wise for temperature (1901-2003) and rainfall (1871-2008). To detect local trends in the long time series for rainfall and temperature, they have also analyzed the data by dividing them into smaller timescales - for rainfall, it is 1871-1950 and 1951-2008, and for maximum, minimum, and diurnal temperatures, it is 1901-1950 and 1951-2003. In their study they found that the Trend analysis of rainfall data series for 1871-2008 did not show any clear trend for the region as a whole, although there are seasonal trends for some seasons and for some hydro-meteorological sub-divisions. Similar analysis for temperature data showed that all the four temperature variables (maximum, minimum, and mean temperatures and temperature range) had rising trend.

Ravindranath *et al.* (2011), have developed Climate change vulnerability profiles are at the district level for agriculture, water and forest sectors for the North East region of India for the current and projected future climates. They have used an index-based approach by selecting a set of indicators that represent key sectors of vulnerability (agriculture, forest, water) using the statistical technique principal component analysis. The impacts of climate change on key sectors as represented by the changes in the indicators were derived from impact assessment models. These impacted indicators were utilized for the calculation of the future vulnerability to climate change. The result of their study indicate that majority of the districts in North East India are subject to climate induced vulnerability currently and in the near future.

Choudhury *et al.* (2012) analyzed weather variables for the period (1983-2010 to detect trend changes using non-parametric Mann Kendall test in mid altitude of Meghalaya (Umiam : 25° 41′ N / latitude, 91° 55′ E longitude, 1010 mmsl). Results of their study revealed that total annual rainfall trend increased non-significantly at

the rate of 3.72 mm/year. Contribution of monsoon months (JJAS) declined marginally at the rate of 1.70 mm while pre - (MAM) and post-monsoon (ONDJF) months increased non-significantly at an annual rate of 3.18 mm and 1.16 mm, respectively. Probability analysis showed a high frequency of anomalies (p>0.6) of either deficit or excess in occurrence of normal monsoon rainfall. Maximum temperature reflected a linear, significant rising trend (+0.086 °C / year) while minimum temperature enumerated a non-significant decreasing trend (-0.011 °C / year).

3.   General climatological features of the study area

The North Eastern region of India consists of the states of Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura, covering an area of 255168 km^2. These states consist of a part of the east Himalayan region, which extends from Arunachal Pradesh eastwards to the Darjeeling hills of West Bengal. The area is characterized by rich biodiversity, heavy precipitation and high seismicity. The climate is predominantly humid subtropical with hot, humid summers, severe monsoons and mild winters. Along with the west coast of India, this region has some of the Indian subcontinent's last remaining rain forests (Jain *et al.*, 2012). Out of the total geographical area 28.3% has an elevation more than 1200 m, 17.9% between 600 and 1200 m and about 10.8% between 300 m and 600 m above mean sea level. The region has about 72% area under hilly ecosystems. The region has inaccessible terrain, fragility, marginality, excessive sloping land with rolling topography, rich biodiversity, unique ethnicity and socio-ecological set up. The North Eastern region received high rainfall and therefore clothed with diverse and dense vegetation. Beyond the transitional pre-glacial region with increasing altitude, there appears the greater Himalayan region devoid of significant vegetative cover. Rocky surface, alpine vegetation and snowcapped high peaks dominate the physical landscape of this area. The altitudinal pattern of north east varies from place to place. The plains mainly comprises of Brahmaputra and Barak valleys. The adjoining areas of Barak river are active flood plains with marshy lands subjected to extreme annual inundation and erosive nature. The region has about 60% area under forest with Arunachal Pradesh having about 80% of its area under different kinds of forest, while Assam has the minimum percentage of forest area (30%). The varied physiological features and altitudinal differences gives rise to various types of climate ranging from near tropical to temperate and alpine.

Both the minimum as well as maximum temperature is found to be lowest over Gangtok in all the season whereas the highest during all season is found either

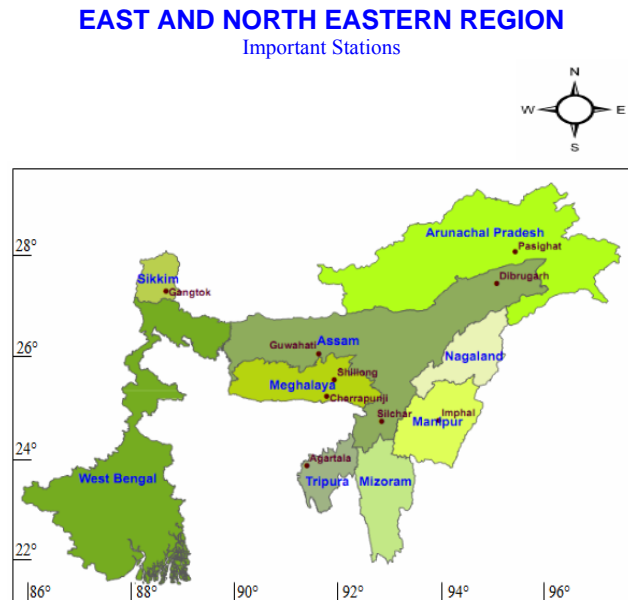**EAST AND NORTH EASTERN REGION**
Important Stations

Fig. 1. Location of the selected stations

over Silchar or over Agartala. Cherrapunji recorded highest rainfall during all the seasons. During the period of study for each of the individual stations Agartala in five occasion, Cherrapunji, Guwahati and Silchar in three occasions each and Shillong in one occasion recorded no rainfall in winter season. In the year 1960 Cherrapunji recorded no rainfall during post monsoon season.

In this paper the seasonal trends of temperature and rainfall over North Eastern parts of India during last century are analyzed on the basis of the available data of nine stations, *viz.*, Agartala, Cherrapunji, Dibrugarh, Gangtok, Guwahati, Imphal, Pasighat, Shillong and Silchar. The geographical location of the selected stations is shown in the Fig. 1. The stations are selected in such a manner that they are well representative of most of the North Eastern states.

4.   Data and methodology

For this study, seasonal data of maximum, minimum temperature and rainfall of the selected nine stations were obtained from India Meteorological Department (IMD). The seasonal maximum and minimum temperature and rainfall data have been collected for the period 1913-2012 for the stations Cherrapunji, Silchar and Shillong and only rainfall for Guwahati. Temperature data of Guwahati for the period 1951-2012, Agartala and Dibrugarh for the
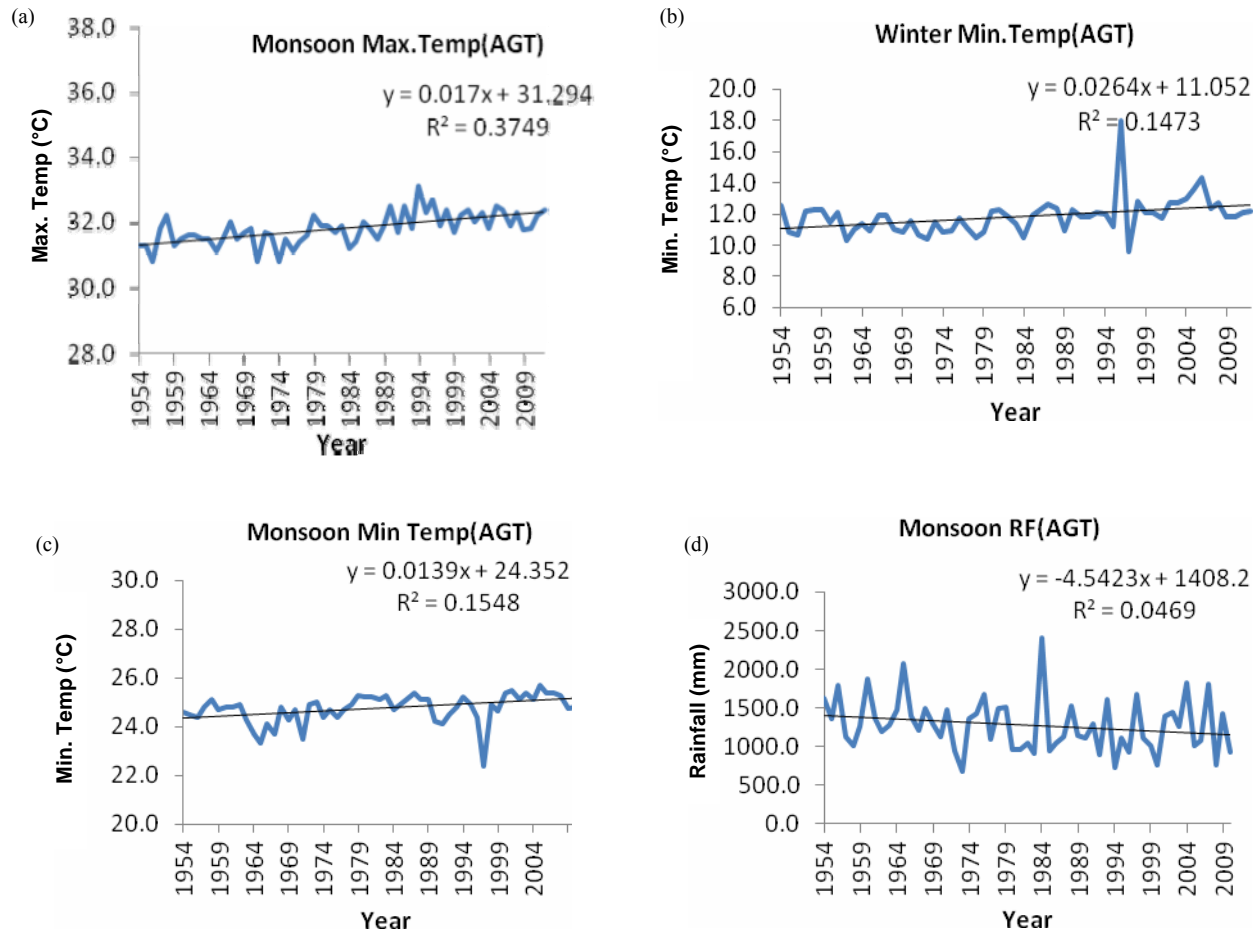
Figs. 2(a-d).   Time series and linear trend for the most significant trends over Agartala for the parameter (a) Maximum
temperature(significant at 99%) during monsoon, (b) Minimum temperature (significant at 99%) during winter, (c) Minimum
temperature(significant at 99%) during monsoon and (d) Rainfall (significant at 95%) during monsoon season

period 1953-2012, Imphal for the period 1954-2012, Pasighat for 1958-2012 and Gangtok for 1966-2007 have been considered for this study due to non-availability of the data for other periods. In this study, analyses of the temperature and rainfall data were carried out to find the seasonal trend. The four meteorological seasons considered in this study are winter (January-February), pre-monsoon (March-May), Monsoon (June-September) and Post-monsoon (October-December) as defined by India Meteorological Department.   In this study, statistical significance of the trend in the time series was analyzed by using Mann - Kendall (MK) test (Mann, 1945; Kendall, 1975). In this paper the significance was tested at 95% and 99% levels of confidence. The time series and linear trends of maximum, minimum temperature and rainfall at the stations with the most significant trends (99% levels of confidence for temperature and 95% for rainfall) are shown in Fig. 2 to Fig. 10.
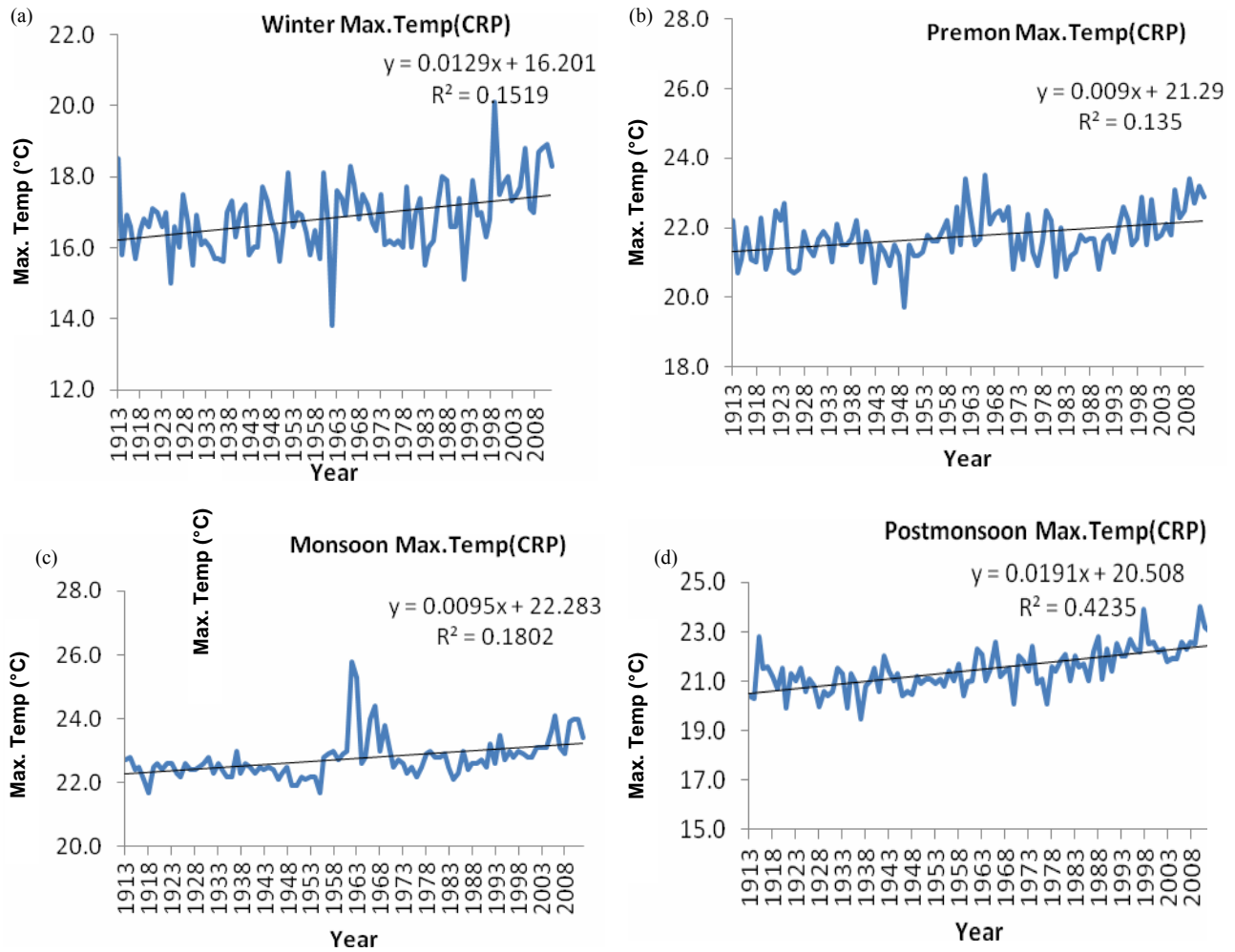
4.1. *Mann-Kendall test*

The Mann-Kendall statistics given by:

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

where n is the length of the data set, x_i and x_j are two generic sequential data values.

The function sgn $(x_i - x_j)$ assumes the following values:

$$\text{sgn}(x_i - x_j) = \begin{cases} +1, \ if \ (x_i - x_j) > 0 \\ \ \ 0, \ if \ (x_i - x_j) = 0 \\ -1, \ if \ (x_i - x_j) < 0 \end{cases} \tag{2}$$

Figs. 3(a-d). Time series and linear trend for the most significant trends over Cherrapunji for maximum temperature (significant at 99%) during (a) winter, (b) pre-monsoon, (c) monsoon and (d) post monsoon season

Under the hypothesis of independent and randomly distributed variables when n ≥ 8, the statistic S is approximately normally distributed with zero mean and the variance Var(S) as follows:

$$\text{Var}(S)= \frac{1}{18}\big[n(n-1)(2n+5)\big] \qquad (3)$$

where, n is the length of the times-series. The standardized test statistic Z is given by:

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{Var\ (S)}} & if\ \ S\ >\ 0 \\[2mm] 0 & if\ \ S\ =\ 0 \\[2mm] \dfrac{S+1}{\sqrt{Var\ (S)}} & if\ \ S\ <\ 0. \end{cases} \qquad (4)$$

The presence of a statistically significant trend is evaluated using the Z value. This statistic is used to test the null hypothesis such that no trend exists. A positive Z indicates an increasing trend in the time-series, while a negative Z indicates a decreasing trend. In this study, the significance levels of 95% and 99% are applied for each analyzed time-series.

5. Results and discussion

5.1. *Agartala*

The time series and linear trends of maximum and minimum temperature with most significant trends (99% level of confidence) and that of rainfall at 95% level of confidence over the station Agartala are shown in Figs. 2 (a-d).
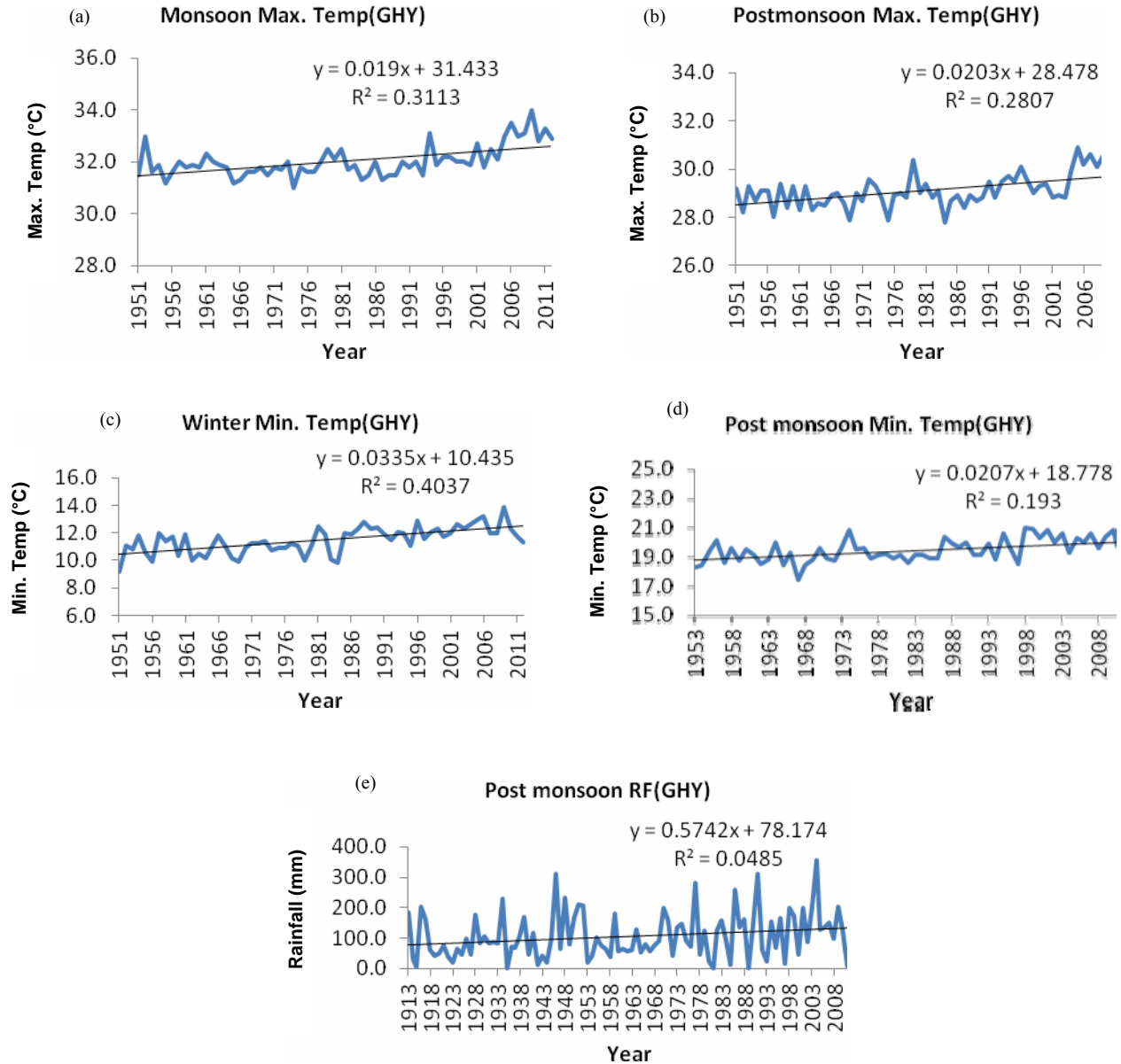
(a)

(b)

(c)

(d)

(e)
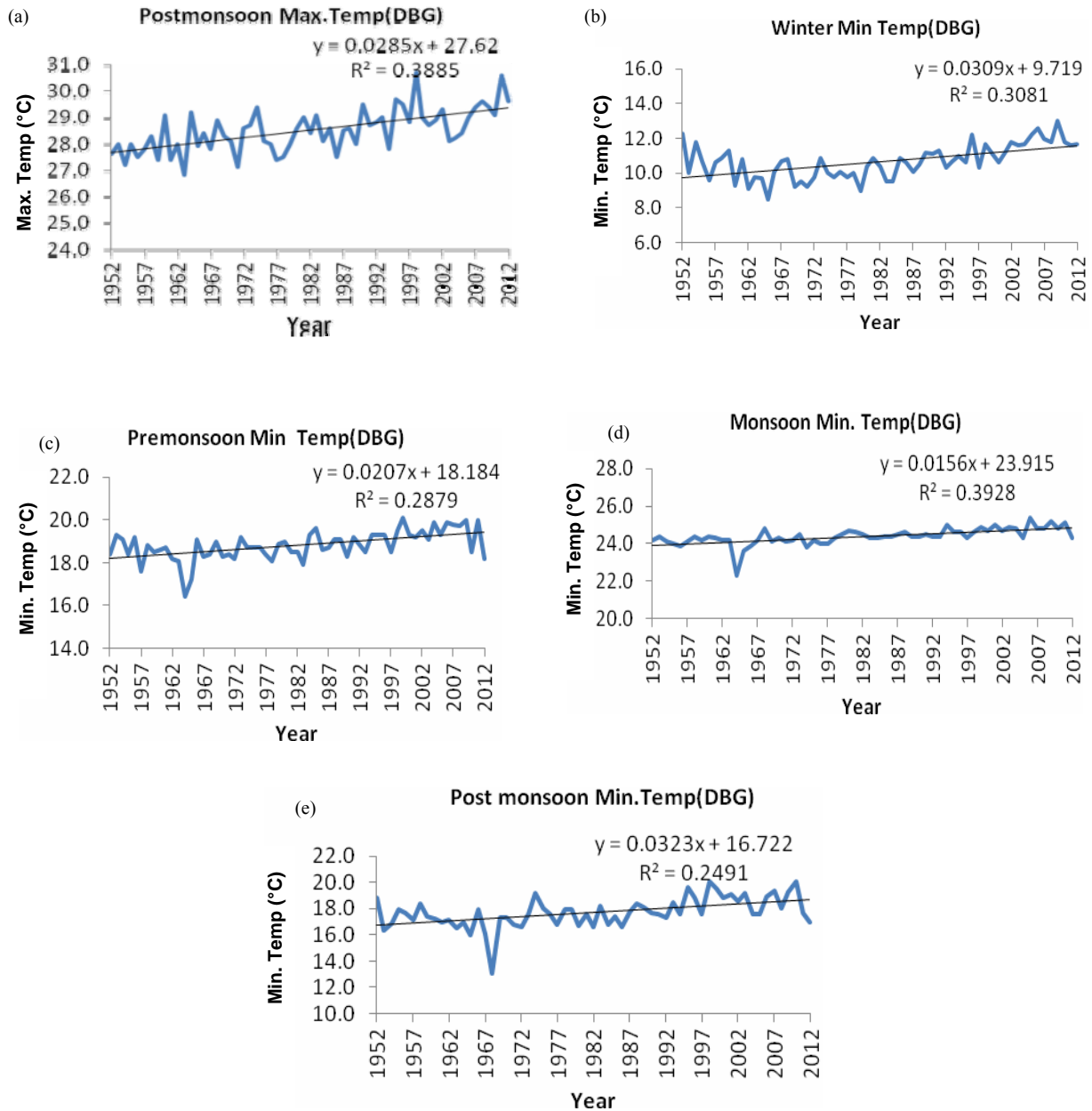
Figs. 4(a-e). Time series and linear trend for the most significant trends over Dibrugarh for the parameter (a) Maximum temperature (significant at 99%) during post -monsoon, minimum temperature (significant at 99%) during(b) winter, (c) pre-monsoon, (d) monsoon and (e) post-monsoon season

Maximum temperature over Agartala shows significant decreasing trend during pre-monsoon season and significant increasing trend during monsoon season and no significant trend in maximum temperature has been observed during winter and post monsoon season. The minimum temperature shows increasing trend during winter and monsoon season whereas it shows no significant trend during pre-monsoon and post monsoon season.

The monsoon season analysis of rainfall data during the period under study shows significant decreasing trend whereas no significant trend has been observed during other season of the year.

Figs. 5(a-e). Time series and linear trend for the most significant trends over Guwahati for maximum temperature(significant at 99%) during (a) monsoon and (b) post-monsoon, minimum temperature (significant at 99%) during (c) winter and (d) post- monsoon and (e) rainfall (significant at 95%) during post-monsoon season

5.2. *Cherrapunji*

The time series and linear trends of maximum temperature with most significant trends at 99% level of confidence over the station Cherrapunji are shown in Figs. 3 (a-d).

During the period the maximum temperature shows significant increasing trend during all the four season whereas the minimum temperature shows significant decreasing trend during winter season. The minimum

temperature over Cherrapunji shows no significant trend during rest season of the year. Rainfall data of Cherrapunji shows no significant trend during all the season of the year.

5.3. *Dibrugarh*

The time series and linear trends of maximum and minimum temperature with most significant trends over the station Dibrugarh are shown in Figs. 4 (a-e).
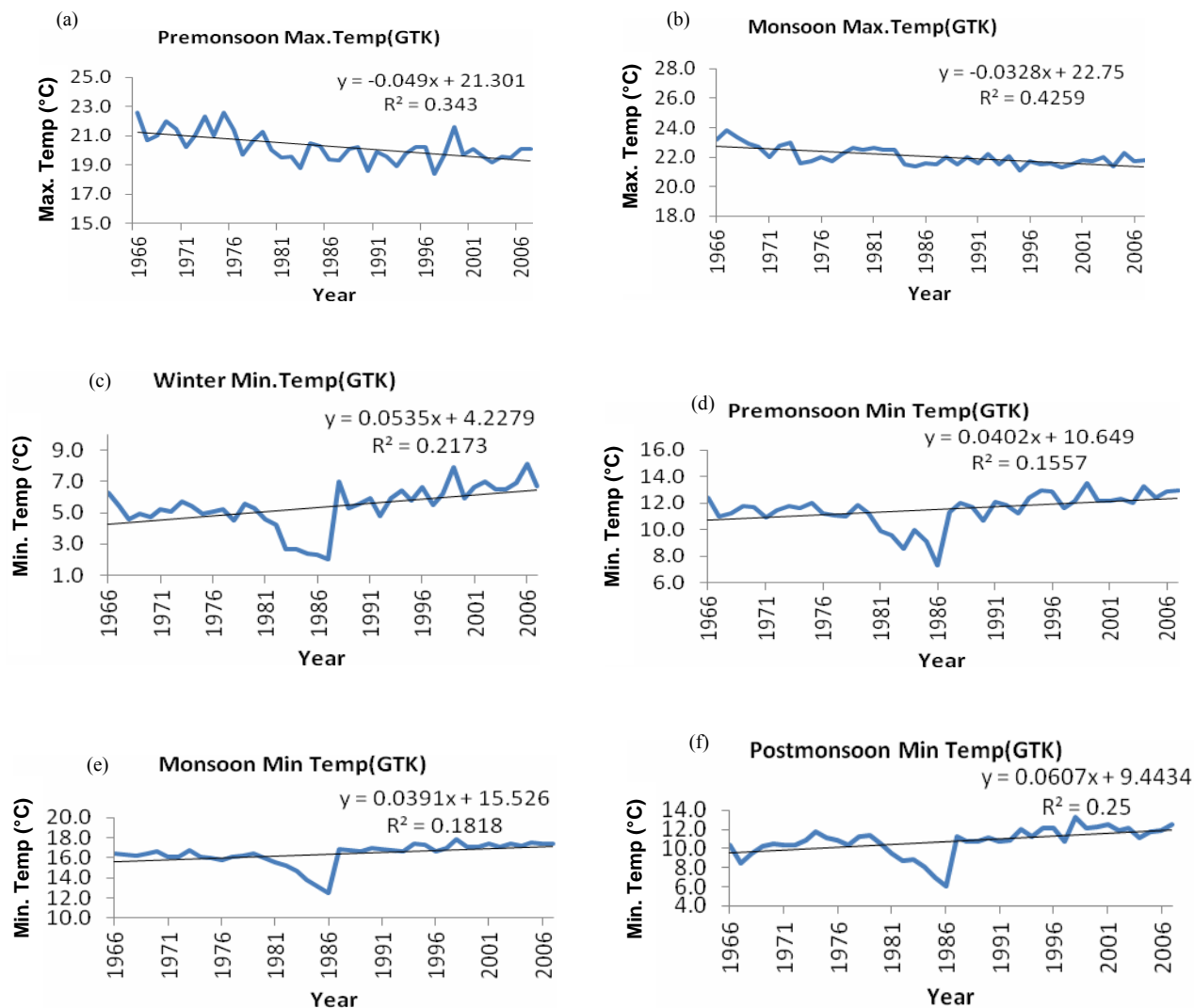
Figs. 6(a-f).   Time series and linear trend for the most significant trends (at 99% confidence level) over Gangtok for the parameter Maximum temperature during (a) pre-monsoon and (b) monsoon and minimum temperature during (c) winter, (d) pre-monsoon (e) monsoon and (f) post-monsoon season

Significant increasing trends in the maximum temperature have been observed during winter and post-monsoon season whereas during pre-monsoon and monsoon seasons no significant trends have been noticed in the maximum temperature. Minimum temperature shows significant increasing trends during all the season of the year. No significant trend of rainfall has been observed during all the season of the year.

5.4. *Guwahati*

The time series and linear trends of maximum and minimum temperature with most significant trends and that of rainfall at 95% level of confidence over Guwahati are shown in Figs. 5 (a-e).

The analysis of temperature data over Guwahati shows significant increasing trend of minimum temperature during all the season and that of maximum temperature during monsoon and post-monsoon season whereas no significant trend for the maximum temperature has been observed during winter and pre-monsoon season. Rainfall data shows significant increasing trend during post-monsoon season whereas no significant trend has been observed during other three season of the year.
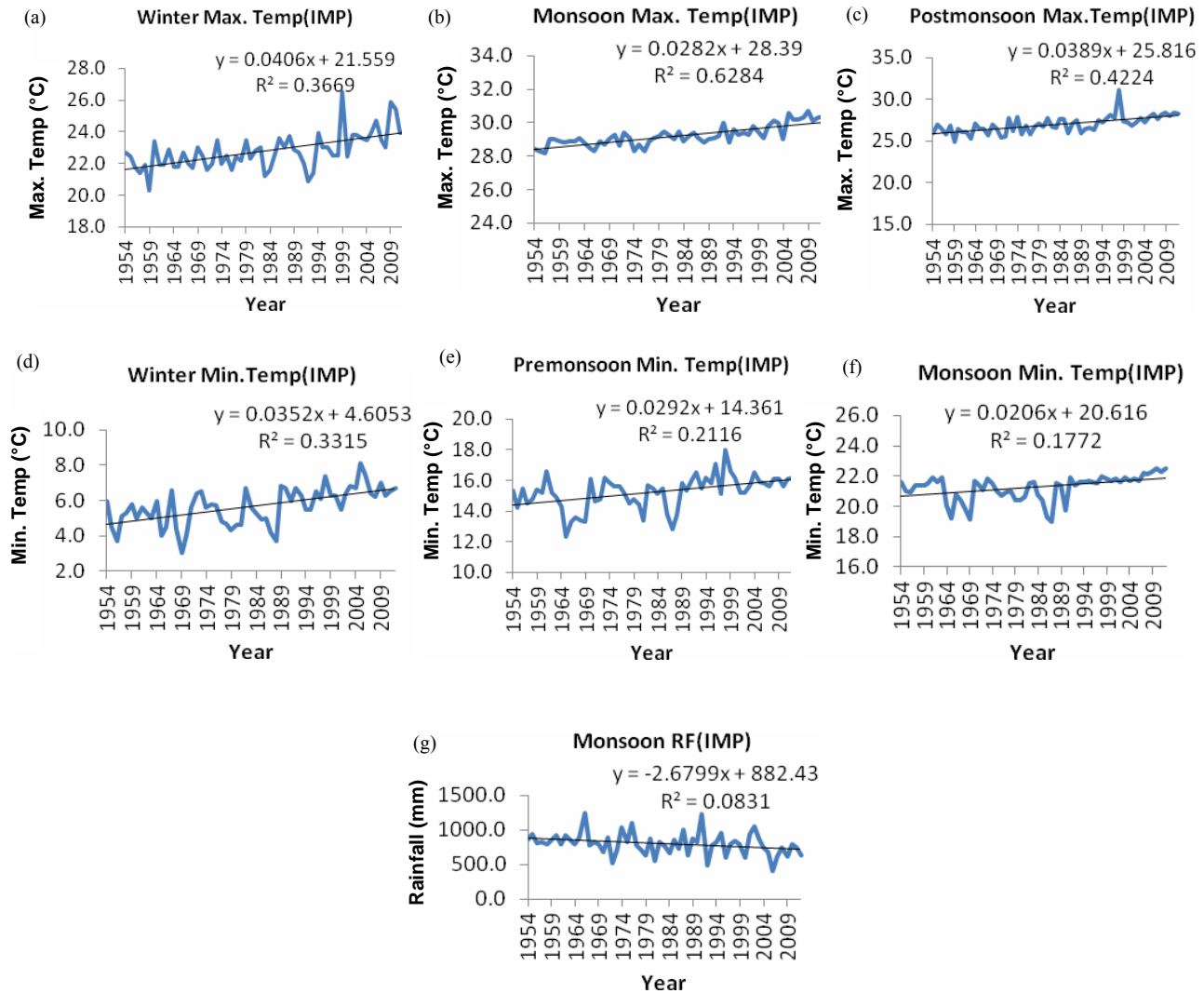
Figs. 7(a-g).   Time series and linear trend for the most significant trends over Imphal for the parameter maximum temperature(significant at 99%) during (a) winter, (b) monsoon and (c) post-monsoon , minimum temperature (significant at 99%) during (d) winter, (e) pre-monsoon and (f) monsoon and (g) rainfall (significant at 95%) during monsoon season
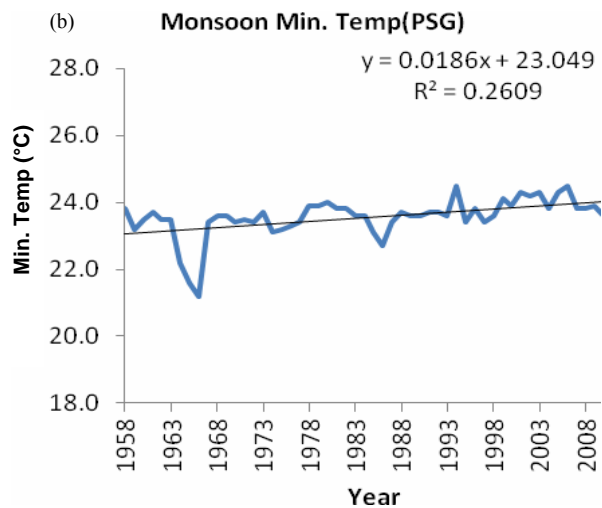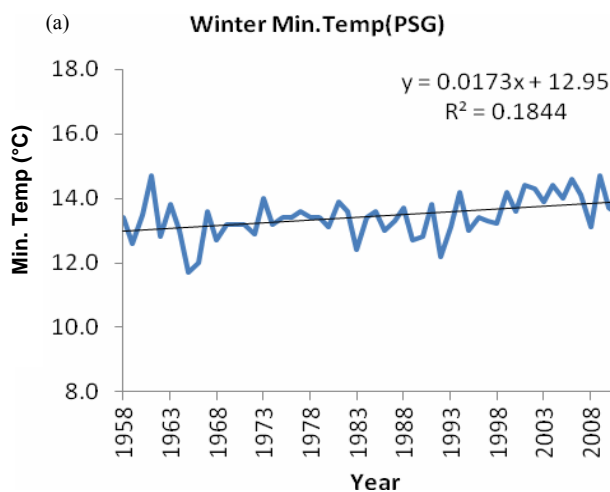
5.5. *Gangtok*

The time series and linear trends of maximum and minimum temperature with most significant trends over Gangtok are shown in Figs. 6 (a-f).

For all the four seasons of the year the maximum temperature over Gangtok during the period under study shows significant decreasing trend whereas in case of minimum temperature significant increasing trend has been observed during all the season of the year. The rainfall data shows no significant trend during any of the seasons.

5.6. *Imphal*

The time series and linear trends of maximum and minimum temperature with most significant trends and that of rainfall at 95% level of confidence over the station Imphal are shown in Figs. 7 (a-g).

For the station Imphal both the maximum and minimum temperature show significant increasing trend for all the four season of the year during the period under study. During monsoon season the rainfall over Imphal shows significant decreasing trend whereas it shows no significant trend during other season of the year.
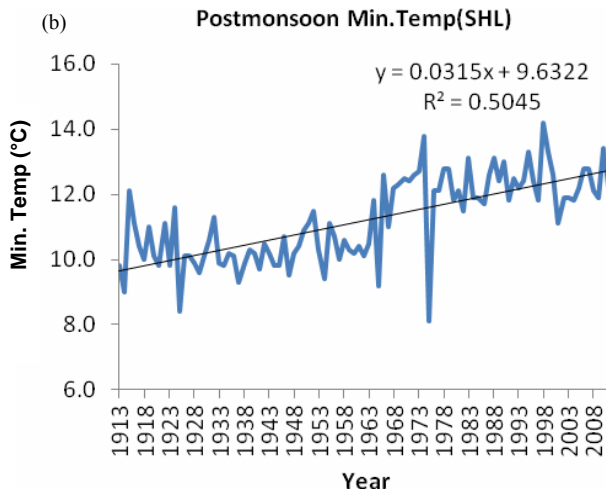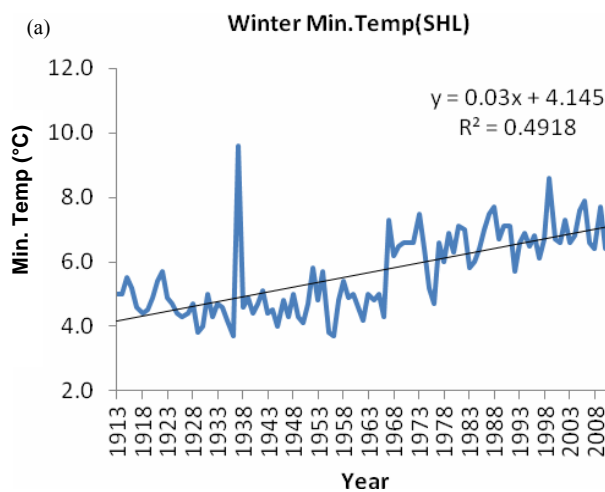
Figs. 8(a&b). Time series and linear trend for the most significant trends (at 99% confidence level) over Pasighat for the parameter minimum temperature during (a) winter and (b) monsoon season

Figs. 9(a&b). Time series and linear trend for the most significant trends (at 99% confidence level) over Shillong for the parameter minimum temperature during (a) winter and (b) post-monsoon season
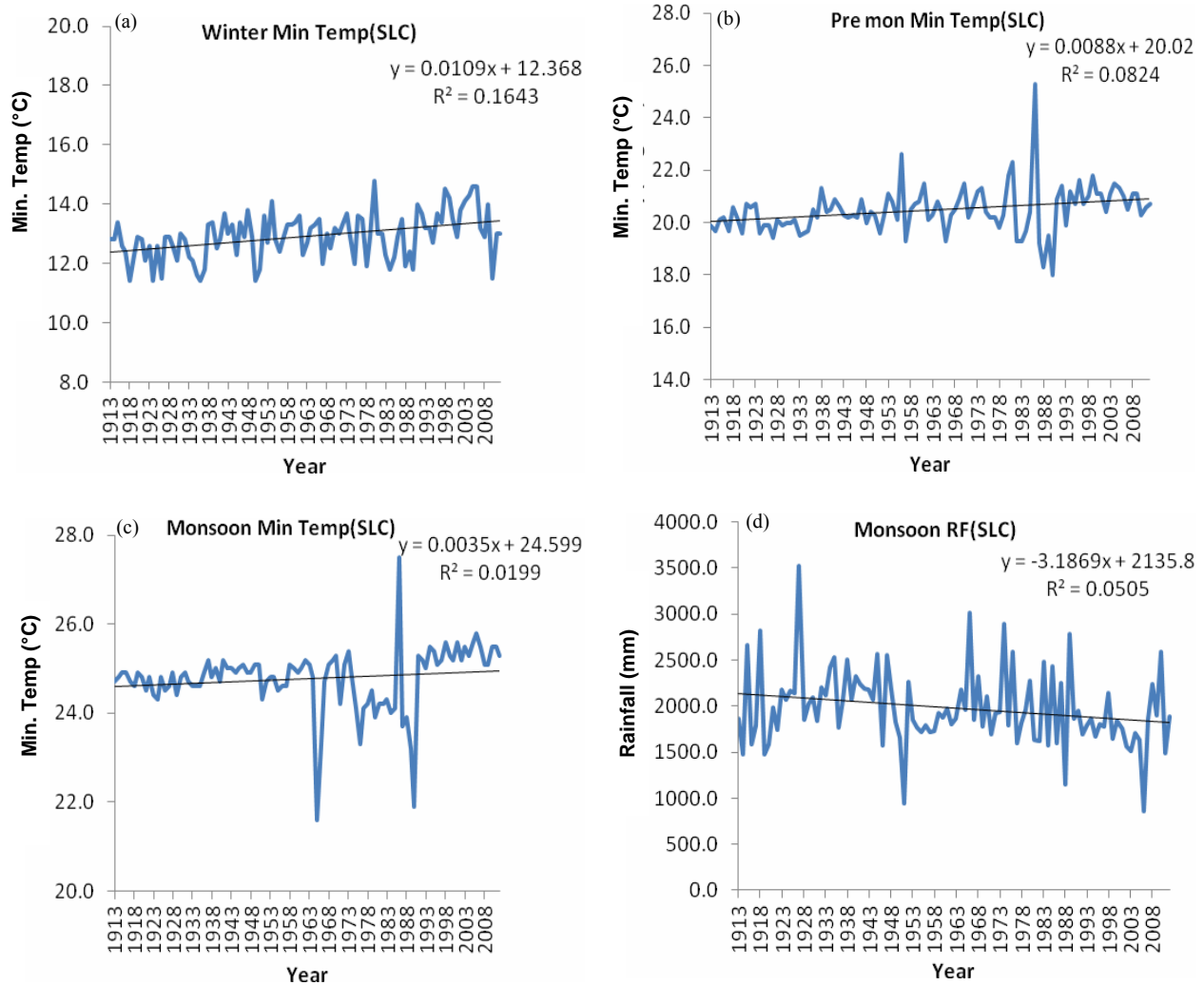
5.7. *Pasighat*

The time series and linear trends of minimum temperature with most significant trends over the station Pasighat are shown in Figs. 8 (a&b).

The maximum temperature over Pasighat shows significant increasing trend during winter and post-monsoon season whereas during pre monsoon and monsoon season it shows no significant trend. The minimum temperature over Pasighat shows significant increasing trend in all the four season of the year. No significant trend has been observed for the rainfall data during any of the seasons.

5.8. *Shillong*

The time series and linear trends of minimum temperature with most significant trends over Shillong are shown in Figs. 9 (a&b).

During the period under study the maximum temperature and the rainfall over Shillong shows no significant trend for all the seasons of the year but it shows significant increasing trend in case of minimum temperature.

5.9. *Silchar*

The time series and linear trends of minimum temperature with most significant trends and that of

Figs. 10(a-d). Time series and linear trend for the most significant trends over Silchar for the parameter minimum temperature (significant at 99%) during (a) winter, (b) pre-monsoon and (c) monsoon and (d) rainfall (significant at 95%) during monsoon season

rainfall at 95% level of confidence over the station Silchar are shown in Figs. 10 (a-d).

During monsoon season the maximum temperature over Silchar shows significant increasing trend (95% level of confidence) whereas in other season it shows no significant trend. The minimum temperature over Silchar shows significant increasing trend during winter, pre-monsoon and monsoon season and in post-monsoon season no significant trend has been observed for the minimum temperature.

Significant decreasing trend of rainfall has been observed over Silchar during monsoon season. The rainfall data analysis shows no significant trend during other season of the year.

6. Conclusions

Significant increasing trend has been observed for minimum temperature for all the selected nine stations of North Eastern region except Cherrapunji where it shows non-significant decreasing trend of minimum temperature during pre monsoon, monsoon and post monsoon season and significant decreasing trend at 99% level of confidence during winter season.

The maximum temperature for all the stations shows generally increasing trend or no significant trend except Gangtok during all the four season and Agartala during pre monsoon season where it shows significant decreasing trend.

The analysis of the rainfall data of all the selected nine stations revealed that all most all the stations show either decreasing trend of rainfall or there is no significant trend except Guwahati during post monsoon season where it shows significant increasing trend.

Though the analyzed trends might be statistically insignificant in nature, it has high practically significant effects in managing resources and agricultural activities over the region

The rate of increase of maximum temperature is found to be highest over Imphal during winter and monsoon season, in pre monsoon season highest rate of increase in maximum temperature has been observed over Cherrapunji and it is over both the Imphal and Cherrapunji during post monsoon season.

During winter and post monsoon season the rate of increase in minimum temperature has been found to be highest over Shillong whereas during pre monsoon and monsoon season it is highest over Dibrugarh.

References

Choudhury, B. U., Das, Anup, Ngachan, S. V., Slong, A., Bordoloi, L. J. and Chowdhury, P., 2012, "Trend analysis of long term weather variables in mid altitude Meghalaya, North-East India", *Journal of Agricultural Physics*, **12**, 1, 12-22.

Jain, S. K., Kumar, Vijay and Sahariad, M., 2012, "Analysis of rainfall and temperature trends in northeast India", *Int. J. Climatol.*, Published online in Wiley Online Library, (wileyonlinelibrary.com) DOI: 10.1002/joc.3483.

Kendall, M. G., 1975, "Rank Correlation Methods". Charles Griffin: London, UK.

Mann, H. B., 1945, "Nonparametric tests against trend", *Econometrica*, **13**, 245-259.

Parthasarathy, B., Sontakke, N. A., Munot, A. A., Kothawale, D. R., 1987, "Droughts/floods in the summer monsoon season over different meteorological subdivisions of India for period 1871-1984", *Journal of Climatology*, **7**, 57-70.

Ravindranath, N. H., Rao, Sandhya, Sharma, Nitasha, Nair, Malini, Gopalakrishnan, Ranjith, S. Rao, Ananya, Malaviya, Sumedha, Tiwari, Rakesh, Sagadevan, Anitha, Munsi, Madhushree, Krishna, Niharika and Bala, Govindasamy, 2011, "Climate change vulnerability profiles for North East India", *Current Science*, **101**, 3, 10, August 2011.

Thapliyal, V. and Kulshrestha, S. M., 1991 "Decadal changes and trends over India", *Mausam*, **42**, 333-338.

Vinnikov, K., Graisman, P. Y. and Lugina, K. M., 1990, "Empirical data on contemporary global climatic changes (temperature and precipitation)" *Journal of Climate*, **3**, 662-677.

Winstanley, D., 1973, "Recent rainfall trends in Africa, the Middle East and India", *Nature*, **243**, 464-465.

Yu, P. S., Yang, T. C. and Wu, C. K., 2002, "Impact of climate change on water resources in southern Taiwan", *J. Hydrol.*, **260**, 161-175.

Yue, S. and Hashino, M., 2003, "Temperature trends in Japan: 1900-1996", *Theor. Appl. Climatol.*, **75**, 15-27.