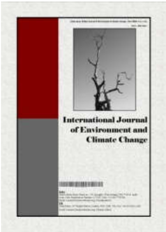

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Modelling and Forecasting of Monthly Rainfall and Temperature Time Series Using SARIMA for Trend Detection- A Case Study of Umiam, Meghalaya (India)

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Seasonal Auto Regressive Integrative Moving Average Models (SARIMA) were developed for monthly rainfall, mean monthly maximum and minimum temperature time series for Umiam (Barapani), Meghalaya (India). The best model was selected based on the minimum values of AIC and BIC criteria as well as based on observing the ACF and PACF plot of residuals. SARIMA (5,1,2) x $(1,1,1)_{12}$, SARIMA (2,1,2) x $(2,1,1)_{12}$, SARIMA (6,1,4) x $(2,1,3)_{12}$ models were found to be the best fit model for the monthly rainfall, mean monthly maximum and minimum temperatures time series respectively. The adequacy of the SARIMA models was also verified using the Ljung-Box (Q) statistic test. McLeod-Li test and Engle's ARCH LM test were carried out for residuals. The results indicated that there was no Arch effect in the established SARIMA models and models can be used for forecasting the future values for the year 2013 to 2028. The determination of trend in monthly rainfall, mean maximum and minimum temperatures in the forecasted series were done using different trend analysis techniques. For monthly rainfall and mean monthly minimum

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temperature time series, all the selected methods supported no significant trend. However, in the case of mean monthly maximum temperature time series, three selected methods supported falling trend.

Keywords: Time series; monthly rainfall; mean monthly maximum and minimum temperatures; SARIMA model; Umiam; Meghalaya.

1. INTRODUCTION

Modelling and forecasting of the hydrological variable may be done using soft computing techniques, physically based model, downscaling technique and stochastic time series models. Many stochastic models have been developed in the past for modelling of hydrological series such as runoff, rainfall, temperature, evaporation, monthly stream flows and wind velocity using AR, MA, ARIMA and SARIMA [1-17]. Dabral and Murry [17] discussed in length the advantage of SARIMA model for modelling and forecasting of hydrological variables over other methods. SARIMA models are known for their simple mathematical structure and estimate of small number of parameters and may be applied to stationary as well as non-stationary process [18]. SARIMA models can also be used for long-term forecasting of weather parameters.

Barapani (presently Umiam) lies in the state of Meghalaya (India) located at 25°41'N latitude and between 91°54'and 91°63'E longitude and 20 km away from Shillong, Meghalaya(India). The area is a part of Ri-Bhoi district and comprises rolling terrace and steep slopes with valleys and plateaus. The area consists of typically hilly undulating terrain with altitude varying between 952 m and 1082 m above mean sea level. The mean rainfall is 2390 mm with more than 88% occurring during the period May to October. The daily temperature varies from 1° to 32.5°C. The climate of Umiam is changing because of population explosion, urbanization, industrialization and various other land uses. The variables rainfall pattern, the maximum and minimum temperatures effect much on climate variability and these parameters may be modelled accurately using SARIMA model. In this study an attempt has been made to model and forecast monthly rainfall, mean monthly maximum and minimum temperatures of Umiam, Meghalaya (India) using SARIMA model. Detection of trend has also been made in the forecasted time series of monthly rainfall and mean monthly maximum and minimum.

2. METHODS AND MATERIALS

2.1 Collection of Data and Study Area

The study place Umiam (Barapani), Meghalaya is located at 25°41'21" N latitude, 91°55'25" E longitude and altitude of 1010 m (Fig. 1). Umiam lies in the central part of Meghalaya in the east Khasi hills which is 22 km away from Shillong byroad.For this study, monthly rainfall data (1983-2012) and mean monthly maximum and minimum temperatures data (1985-2012) for Umiam were collected from the same meteorological observatory established by, IMD (Indian Meteorological Department), Poona (collaboration with ICAR) in ICAR Research complex at Umiam. Monthly rainfall data for the years 1983 to 2008 were taken for time series model development and remaining data from the years 2009 to 2012 were used for model validation. The mean monthly maximum and minimum temperatures data for the years 1985 to 2008 were taken for time series modelling and remaining data from the years 2009 to 2012 were used for model validation.

The place of study is a true representative of the state, except few places in it where extreme climate events take place. The mean annual rainfall is 2390 mm of which 88% occurring during the period from May to October. The daily temperature during a year varies widely between 1° to 32.5°C. The relative humidity remains between 75 to 83% during the most of the year.The bright sunshine varies from 9 to 11 hours during the months of November to April and remains in the range of 2 to 8 hours during the months May to October.

2.2 Methodology for SARIMA Modelling

The first step in time series modelling is to establish stationary time series either by transformation of data or differencing or by both. For determining the value of λ (Power parameter in Box-Transformation) seven goodness of fit tests for normality were applied. The best value for λ was selected based on its minimum value for each series. For transformation of data, the

Box-Cox transformation was used. A detailed description of the seven goodness of fit test for normality, the Box–Cox transformation and differencing technique can be found in the work of Dabral and Murry [17]. The flow chart (Fig. 2) shows the methodology followed for SARIMA modelling.

2.2.1 SARIMA model

$SARIMA(p,d,q) \times (P,D,Q)_S$ model for time series y_t may be expressed in the following expression [19]:

$$\Phi(L^S)\phi(L)\Delta^d \Delta_s{}^D y_t = \theta_0 + \Theta(L^S)\theta(L)\varepsilon_t \quad (1)$$

Where, ϕ is Autoregressive Parameter, ɵ is Moving Average Parameter, Φ is Seasonal Autoregressive Parameter and Θ is Seasonal Moving Average Parameter and details of other symbols used in the above equation is described in the work of Dabral and Murry [17].

2.2.2 Estimation of model parameters

In the present study R software was used to estimate autocorrelation, partial autocorrelation functions and their standard errors, model parameters. The adequacy of the model was tested by examining the ACF and PACF of the residual of the SARIMA model.

2.2.3 Development of SARIMA with H-K algorithm

The Hyndman-Khandakar (HK) algorithm (Hyndman and Khandkar, 2008), is suitable for application in R with the function autoarima in the forecast package. Their algorithm processes an iterative strategy procedure that saves time, and allows the model which has the smallest value of the selected information criterions (AIC =Akaike Information Criteria and BIC= Bayesian Information Criterion) to be found much quicker, without going through the process of making a comparison with every possible model.

2.2.4 Ljung-Box Q statistic test

Ljung-Box Q statistic test was carried for the residuals first developed by Ljung-Box in 1978. It is applied to the residuals of a fitted SARIMA model with the test hypothesis that the residuals do not have any autocorrelation. A detailed description of Ljung-Box Q statistic test can be found in Dabral and Murry [17].If the residuals of any selected model were not passed through Ljung-Box test, another model of the different order was tried.

2.2.5 Testing for the ARCH effect

Mcleod-Li test [20], and Engle's Lagrange Multiplier test [21] were applied in this study to check the presence of ARCH effect in the monthly rainfall, mean monthly maximum and minimum temperatures residual series using R Software.

2.3 Model Performance Assessment

Model performance was measured by estimating absolute error, relative error, Nash-Sutcliffe coefficient, root mean square error and mean relative error. The mean and standard deviation were also calculated to assess the model fitting.

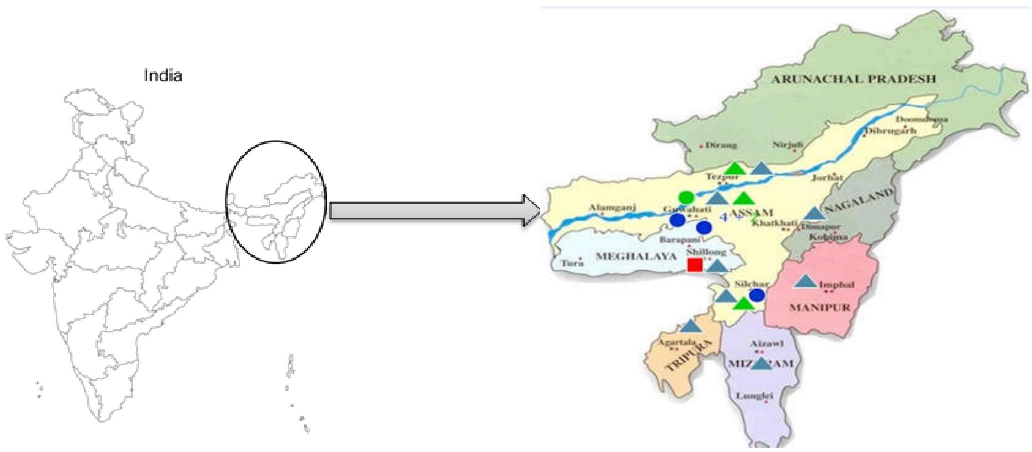

Fig. 1. Location map of the study area

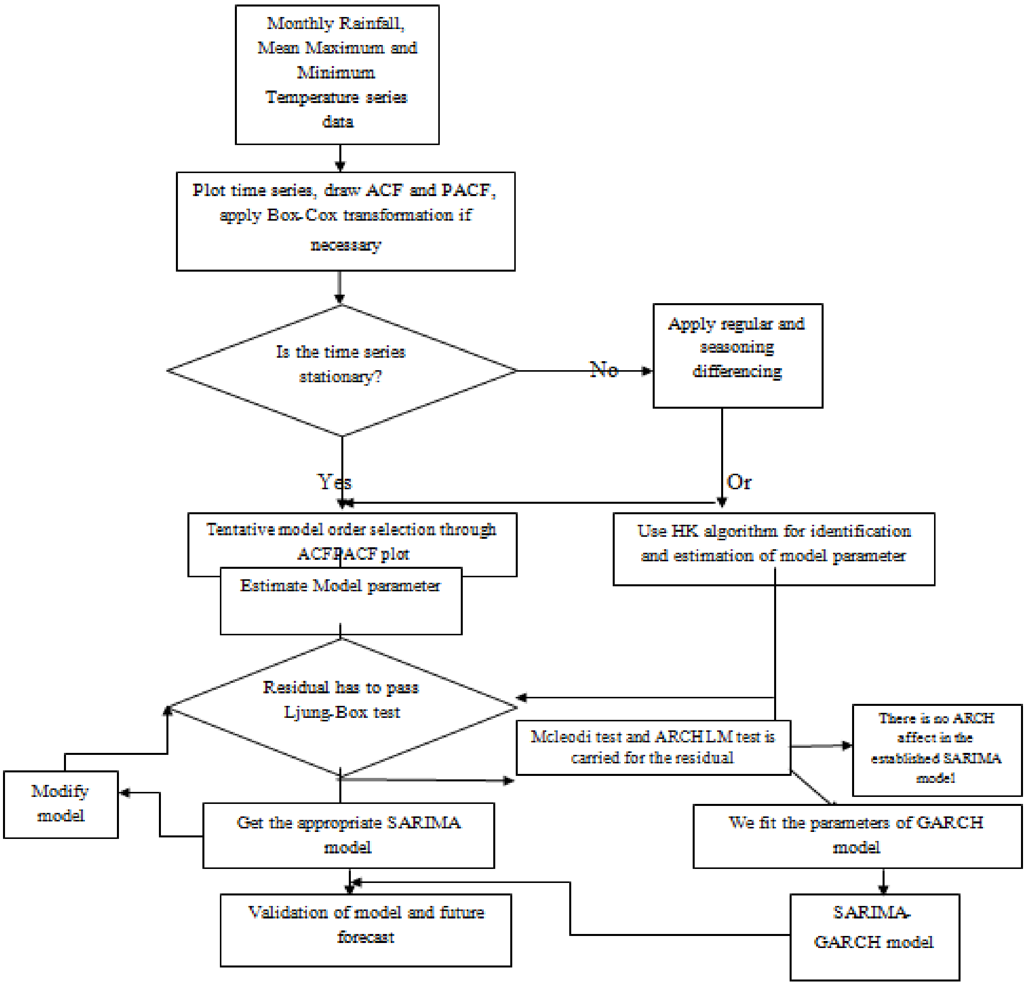

Fig. 2. Process flow diagram for SARIMA model

2.4 Detection of Climate Change in Forecasted Series of Monthly Rainfall, Mean Monthly Maximum and Minimum Temperatures

For detection of climate change in monthly rainfall and mean monthly maximum and minimum temperatures forecasted series; four tests were carried out i.e: Least squares linear regression test, Innovative trend analysis technique [22], Mann–Kendall test, Sen's slope (SS) estimator.

3. RESULTS AND DISCUSSION

3.1 SARIMA Modelling of Monthly Rainfall Time Series

The monthly rainfall time series data (1983-2012) was plotted (Fig. 3) and the series was found to be non-stationary in nature. Based on normality tests, the value of λ was found to be 0.337.The Box-Cox transformation was applied for non-stationary monthly rainfall time series and further differencing at lag 1 and once at lag 12 and it was found to be stationary. HK algorithm was applied for identification and estimation of model parameters. The best fit model obtained was SARIMA $(5,1,2)x(1,1,1)_{12}$, which was selected based on the minimum value of AIC= 1581.68 and BIC = 1618.69 (Table 1). The adequacy of the SARIMA $(5,1,2)x(1,1,1)_{12}$, was verified using the Ljung-Box (Q) statistic test (Table 1). As the p-value of Ljung-Box statistic exceeded the critical value (p=0.05) therefore, the null hypothesis of autocorrelation in the SARIMA $(5,1,2)x(1,1,1)_{12}$, model residuals were rejected. The ACF and PACF of the residuals also verified this (Fig. 4). For the residuals, McLeod-Li test and Engle's ARCH LM test were also carried out.The results indicated that there was no Arch effect in the established SARIMA model and it can be used for forecasting the future values (Table 1).

3.2 Assessment of Developed SARIMA Model for Monthly Rainfall Time Series

For comparing observed and predicted data, the mean monthly rainfall values from the years 1983 to 2008 were used. Fig. 5 shows the value of observed and predicted monthly rainfall for the years 1983 to 2008. The absolute errors for the twelve months were computed as shown in Table 4. The absolute error for the observed data was found in the range of 0.1 mm to 6.8 mm. The low value of absolute error was observed for the months of March, April and December. Relative error was found in the range of 0 % to 3.3%. The low value of relative error was observed for the months of March, April, August, September, and October (Table 2).

The mean of the observed and predicted monthly time series were observed to be 192.2 mm and 200.9 mm respectively. The correlation coefficient and Nash-Sutcliff coefficient and mean relative error were found to be 0.84, 0.70 and 0.001 mm respectively indicating a good model fitness (Table 2).

3.3 Validation of Developed Monthly Rainfall Time Series Model

The SARIMA $(5,1,2)x(1,1,1)_{12}$ model was used for predicting 4 years of monthly rainfall (2009-2012). Fig. 6 shows the value of observed and predicted monthly rainfall for the years 2009 to 2012. The mean of the observed and predicted data was found to be 192.5 mm and 198.9 mm respectively.The absolute error was found to be in the range of 1.1 mm to 29.8 mm. The low value of absolute error was observed in the months of January, February, March and December. The relative error was found in the range of 2.1% to 25%. The low value of relative error was observed for the months

Table 1. Details of developed SARIMA model and other statistics for monthly rainfall at Umiam, Meghalaya

SARIMA	Parameter	ϕ_1	ϕ_2	ϕ_3	ϕ_4	ϕ_5	θ_1	θ_2	Φ_1	Θ_1
(5,1,2) x	Estimate	-0.97	-0.041	-0.030	-0.096	-0.141	-0.0007	-0.938	-0.0002	-1.00
$(1,1,1)_{12}$	SE	0.07	0.095	0.094	0.093	0.064	0.048	0.045	0.0651	0.082
	AIC	1581.68								
	BIC	1618.69								
	Ljung Box (Q) statistic test=12.2, χ2 (20) p value=0.905									
	Engle's ARCH LM test of standardized residuals (SRs) χ2 (24) = 25.8, p value=0.36									
	Li- McLeod test of standardized residuals (SRs) χ2 (24) = 12.6, p value=0.943									

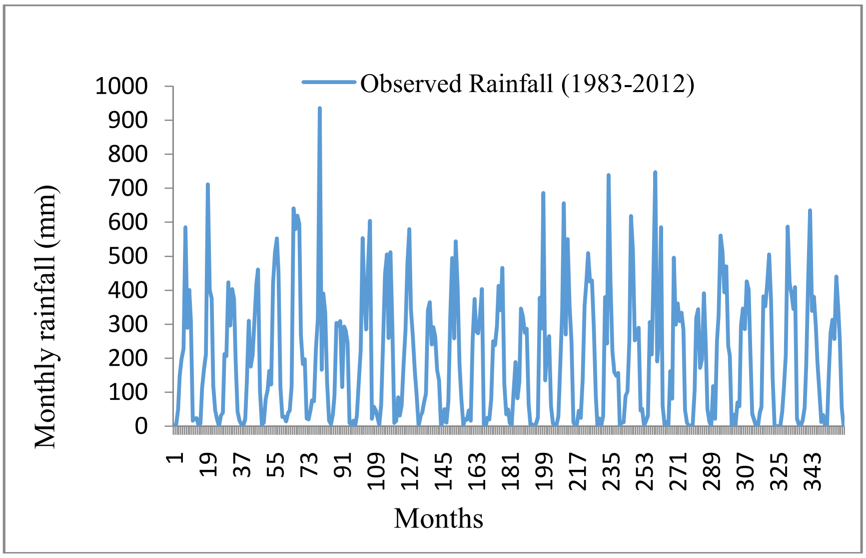

Fig. 3. Monthly rainfall time series at Umiam (1983-2012)

of March, May, July, August and September. The correlation coefficient, Nash-Sutcliff coefficient and mean relative error were estimated 0.91,0.82 and 0.124 mm respectively indicating a good model fitness (Table 3).

3.4 SARIMA Modelling of Mean Monthly Maximum Temperature Time Series

The original mean monthly maximum temperature time series was plotted (Fig. 7) and the series was found to be non-stationary in nature. Based on normality test, the value of λ was found to be 3.62. The Box-Cox transformation was applied for non-stationary monthly rainfall time series and further differencing at lag 1 and once at lag 12 and it was found to be stationary. HK algorithm was applied for identification and estimation of model parameters. SARIMA (2,1,2) x$(2,1,1)_{12}$, was found as the best fit model, for the mean monthly maximum temperature time series, based on the minimum value of AIC= 5466.3 and BIC = 5495.23 (Table 4). The adequacy of the SARIMA (2,1,2)x$(2,1,1)_{12}$, was verified using the Ljung-Box (Q) statistic test for which the p-value is shown in Table 4. As the p-value of Ljung-Box

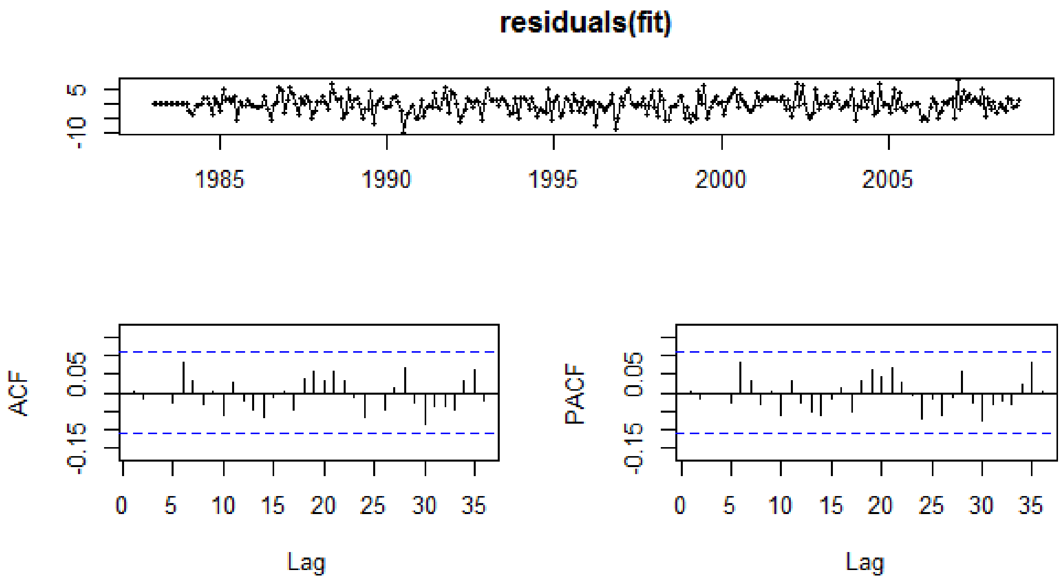

Fig. 4. ACF and PACF of residuals of monthly rainfall SARIMA model at Umiam, Meghalaya

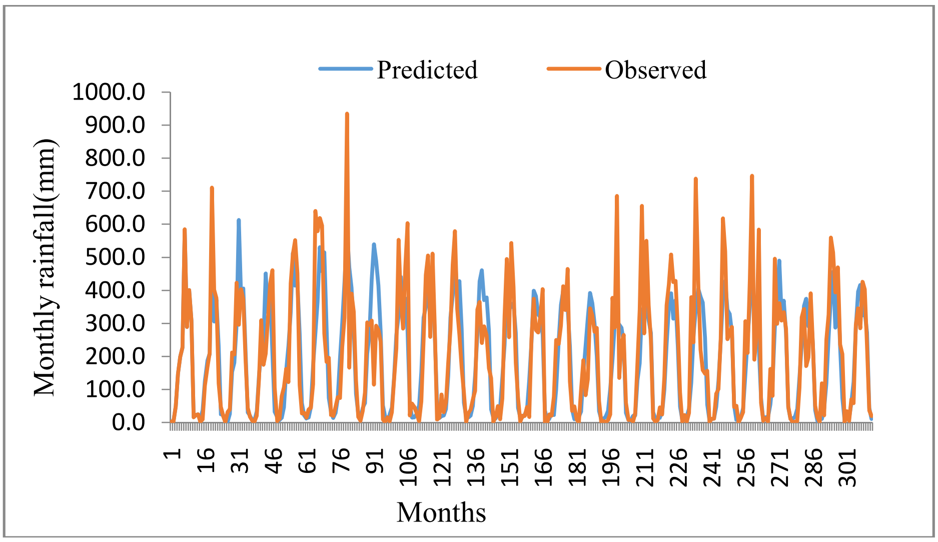

Fig. 5. Observed and predicted monthly rainfall for assessment period 1983-2008

statistic exceeded the critical value (p=0.05) therefore, the null hypothesis of autocorrelation in the SARIMA $(2,1,2)x(2,1,1)_{12}$ model residuals were rejected. This was also verified from the ACF and PACF of the residuals (Fig. 8). For the residuals, McLeod-Li test and Engle's ARCH LM test were also carried out. The results indicated that there was no Arch effect in the developedSARIMA model which can be used for forecasting the mean monthly maximum temperature(Table 4).

3.5 Assessment of Developed SARIMA Model for Mean Monthly Maximum Temperature Time Series

For comparing observed and predicted data, the mean monthly maximum temperature values for the years 1985 to 2008 were used. Fig. 9 shows the value of observed and predicted monthly rainfall for the years 1985 to 2008.The absolute errors for the twelve months were computed as shown in Table 5. The mean of the observed and predicted monthly data were observed to be 24.3°C and 24.3°C respectively. The absolute error for the observed data was found in the range of 0.01°C to 0.06°C.The low value of absolute error was found in the months of January and December. The relative error value was found in the range of 0.04 % to 0.28%. The low value of relative error was observed for the months of January, September, and December. The correlation coefficient, Nash-Sutcliff coefficient and mean relative error were estimated 0.95, 0.90 and 0.001°C respectivelyshowing a high degree of model fitness (Table 5).

Table 2. Mean monthly rainfall of observed and predicted data (1983-2008) along with errors

Month	Average observed data (mm)	Average predicted data (mm)	Error		Mean absolute error (mm)	Correlation	Nash Sutcliffe coefficient
			Absolute error (mm)	Relative error (%)			
January	16.4	16.9	0.5	3.2			
February	24.3	25.1	0.8	3.3	0.001	0.84	0.70
March	50.1	50.1	0.1	0.1			
April	149.2	149.3	0.1	0.0			
May	283.5	286.8	3.3	1.1			
June	403.6	410.4	6.8	1.7			
July	440.5	435.0	5.5	1.3			
August	337.2	339.0	1.8	0.5			
September	355.9	354.1	1.7	0.5			
October	268.3	266.7	1.6	0.6			
November	68.0	70.0	2.0	2.9			
December	14.2	13.9	0.3	2.1			

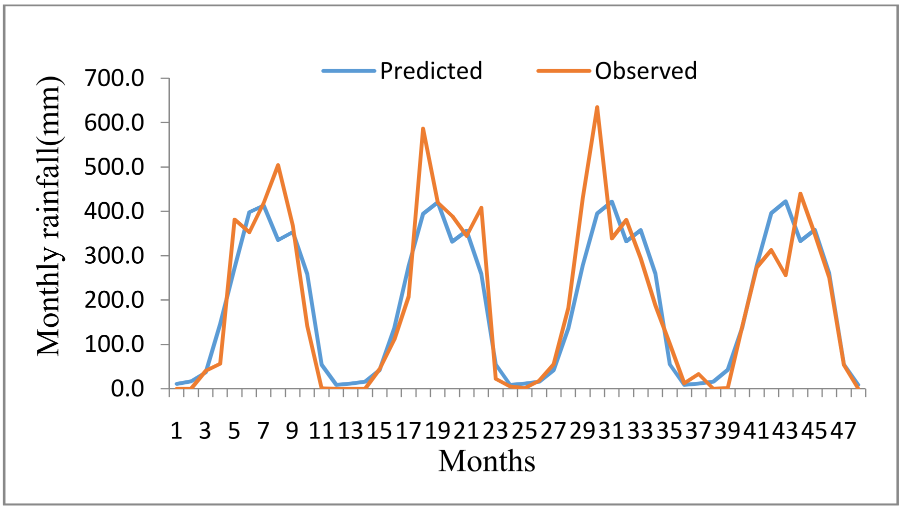

Fig. 6. Observed and predicted value of monthly rainfall (2009-2012)

Table 3. Mean monthly rainfall of observed and predicted data (2009-2012) along with errors

Month	Average observed data(mm)	Average predicted data(mm)	Error		Mean relative error (mm)	Correlation	Nash Sutcliffe coefficient
			Absolute error (mm)	Relative error (%)			
January	8.6	10.8	2.2	25	0.124	0.91	0.82
February	4.5	5.6	1.1	25			
March	35.3	34.0	1.3	3.5			
April	122.2	138.7	16.5	13.5			
May	323.3	308.7	14.6	4.5			
June	471.7	501.5	29.8	6.3			
July	358.3	343.2	15.1	4.2			
August	428.6	409.6	19.0	4.4			
September	338.7	331.5	7.2	2.1			
October	247.3	273.7	26.4	10.7			
November	44.6	55.5	10.9	24.6			
December	4.3	5.3	1.0	25			

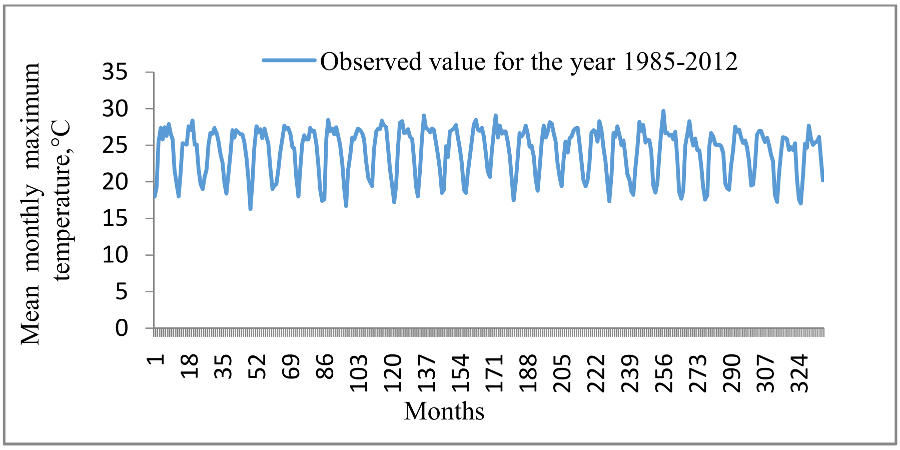

Fig. 7. Observed mean monthly maximum temperature series

Table 4. Details of developed SARIMA model and other statistics for mean monthly maximum temperature at Umiam, Meghalaya

SARIMA	Parameter	ϕ_1	ϕ_2	θ_1	θ_2	Φ_1	Φ_2	Θ_1
(5,1,2)x (1,1,1)$_{12}$	Estimate	1.326	-0.367	-1.976	-0.980	-0.109	-0.233	-0.83
	SE	0.065	0.061	0.025	0.025	0.076	0.070	0.070
	AIC	5466.3						
	BIC	5495.23						
	Ljung Box (Q) statistic test=14.45, χ2 (20) p value=0.807							
	Engle's ARCH LM test of standardized residuals (SRs) χ2 (24) = 25.79, p value=0.36							
	Li- McLeod test of standardized residuals (SRs) χ2 (24) = 14.6, p value=0.879							

3.6 Validation of Developed Mean Monthly Maximum Temperature Time Series Model

The SARIMA(6,1,4)x(2,1,3)$_{12}$ model, for mean monthly maximum temperature series, was used for predicting 4 years of monthly rainfall (2009-2012). Fig. 10 shows the value of predicted and observed monthly rainfall from the years 2009 to 2012. For comparing the observed and the predicted data, the mean monthly rainfall values for the years 2009 to 2012 were used.The mean of the observed and predicted data was found to be 23.7°C and 23.9°C respectively. The absolute error was lying in the range of 0°C to 0.2°C. The relative error was lying in the range of 0% to 1.1%. The correlation coefficient, Nash-Sutcliff coefficient and mean relative error were estimated 0.95,0.88 and 0.01°C indicatinga good degree of model fitness (Table 6).

3.7 SARIMA Modelling of Mean Monthly Minimum Temperature Time Series

The monthly minimum temperature observed data for the year 1985-2012 were plotted (Fig. 11) and it was observed to be non-stationary in nature. Based on normality tests, the value of λ was found to be 1.4. The Box-Cox transformation was applied for non-stationary monthly rainfall time series and further differencing at lag 1 and once at lag 12 and it was found to be stationary.HK algorithm was applied for identification and estimation of model parameters. The best fit model obtained was SARIMA(6,1,4) x $(2,1,3)_{12}$, for mean monthly minimum temperature series, which was selected based on the minimum value of AIC= 1444.4 and BIC = 1502.27 (Table 7). The adequacy of the SARIMA(6,1,4) x $(2,1,3)_{12}$, was verified using the Ljung-Box (Q) statistic test for which the p-values are shown in Table 7. As the p-value of Ljung-Box statistic exceeded the critical value (p=0.05), the null hypothesis of autocorrelation in the SARIMA $(6,1,4)x(2,1,3)_{12}$, model residuals were rejected. This was also verified from the ACF and PACF of the residuals (Fig. 12). The results indicated that there was no Arch effect in the developed SARIMA model which can be used for forecasting monthly minimum temperature (Table 7).

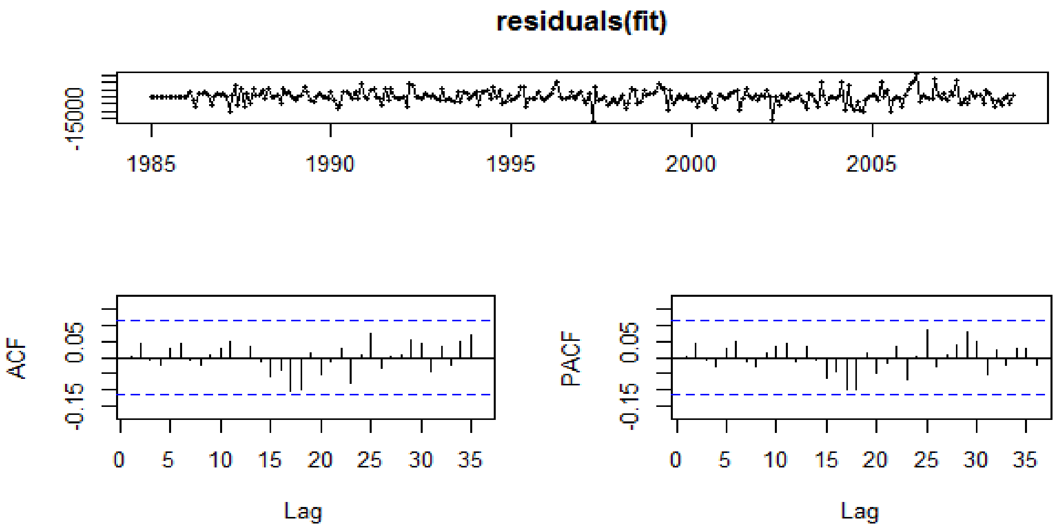

Fig. 8. ACF and PACF of residuals of monthly SARIMA model of mean maximum temperature at Umiam, Meghalaya

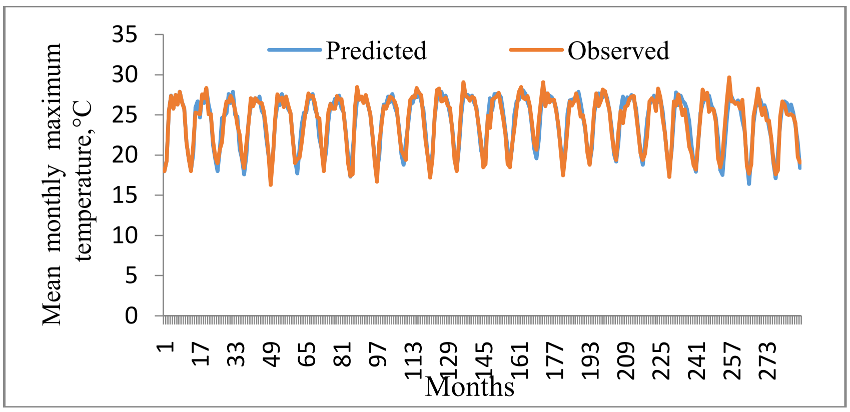

Fig. 9. Observed and predicted mean monthly maximum temperature for the assessment period 1985-2008

Table 5. Mean monthly maximum temperature of observed and predicted data (1985-2008) along with errors

Month	Average observed data(°C)	Average predicted data(°C)	Error		Mean relative error(°C)	Correlation	Nash Sutcliffe coefficient
			Absolute error(°C)	Relative error(%)			
January	18.3	18.4	0.01	0.08	0.001	0.95	0.90
February	20.7	20.8	0.06	0.28			
March	24.7	24.7	0.03	0.13			
April	26.8	26.7	0.03	0.10			
May	26.7	26.7	0.04	0.14			
June	26.9	26.9	0.02	0.09			
July	26.7	26.7	0.02	0.06			
August	27.0	27.0	0.04	0.13			
September	26.2	26.2	0.02	0.07			
October	25.0	24.9	0.03	0.14			
November	22.5	22.5	0.04	0.16			
December	19.8	19.8	0.01	0.04			

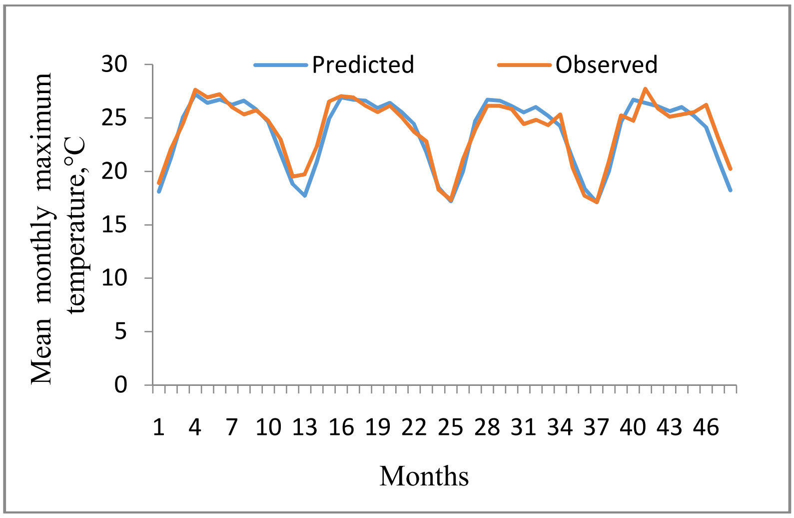

Fig. 10. Observed and predicted value of mean monthly maximum (temperature) 2009-2012

Table 6. Mean monthly maximum temperature of observed and predicted data (2009-2012) along with errors

Month	Average observed data(°C)	Average predicted data (°C)	Error		Mean absolute error(°C)	Correlation	Nash Sutcliffe coefficient
			Absolute error (°C)	Relative error (%)			
January	18.2	18	0.20	1.1	0.01	0.96	0.89
February	21.6	21.5	0.10	0.5			
March	25	25.2	0.20	0.8			
April	26.3	26	0.30	1.1			
May	26.9	26.9	0.00	0.0			
June	26.2	26	0.20	0.8			
July	25.2	25	0.20	0.8			
August	25.4	25.4	0.00	0.0			
September	25.1	25	0.10	0.4			
October	25	25	0.00	0.0			
November	22.3	22.2	0.10	0.4			
December	18.9	18.8	0.10	0.5			

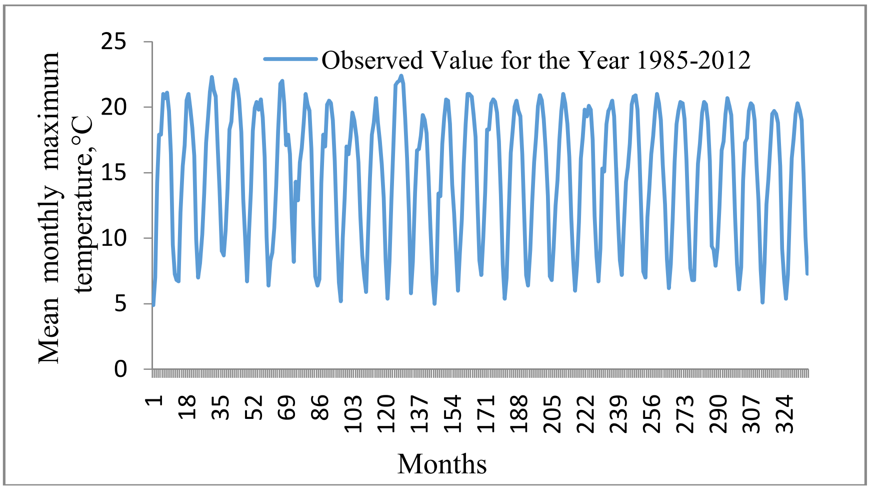

Fig. 11. Observed mean monthly minimum temperature series

Table 7. Details of developed monthly SARIMA model and other statistics for minimum temperature at Umiam, Meghalaya

SARIMA(6,1,4)x(2,1,3)$_{12}$	**Parameter**	**Estimates**	**SE**	**AIC**	**BIC**
	ϕ_1	-0.3417	0.2335	1444.4	1502.27
	ϕ_2	-0.5697	0.1332		
	ϕ_3	0.0456	0.1807		
	ϕ_4	0.3057	0.1339		
	ϕ_5	0.1446	0.0644		
	ϕ_6	0.2460	0.0682		
	Θ_1	-0.1848	0.2364		
	Θ_2	0.1459	0.1965		
	Θ_3	-0.5029	0.1628		
	Θ_4	-0.4582	0.2233		
	Φ_1	-0.2073	0.0408		
	Φ_2	-0.9982	0.0018		
	Θ_1	-0.8137	0.0921		
	Θ_2	0.8065	0.1166		
	Θ_3	-0.9922	0.0103		
	Ljung Box (Q) statistic test=13.42, $\chi2$ (20) p value=0.8586				
	Engle's ARCH LM test of standardized residuals (SRs) $\chi2$ (24) = 53.35, p value=0.0005				
	Li- McLeod test of standardized residuals (SRs) $\chi2$ (24) = 13.59, p value=0.915				

3.8 Assessment of Developed SARIMA Model for Mean Monthly Minimum Temperature Time Series

For comparing observed and predicted data, the mean monthly minimum temperature values for the years 1985 to 2008 were used. Fig. 13 shows the graphical representation of the value of observed and predicted the monthly minimum temperature for the years1985 to 2008.The mean of the observed and predicted monthly data were observed to be 15.0°C and 15.0°C respectively. The absolute errors for the twelve months were computed as shown in Table 8. The absolute errors for the observed series were lying in the range of 0.01°C to 0.11°C. The low value of absolute error was observed for the months of September and October. Relative error value was found in between the range of 0.01% to 1.07%.The low value of relative error was observed for the months of May, July, and October (Table 8). The estimated value of correlation coefficient, Nash-Sutcliff coefficient and mean relative were found 0.98,0.96 and 0.004°C respectively indicating a high degree of model fitness (Table 8).

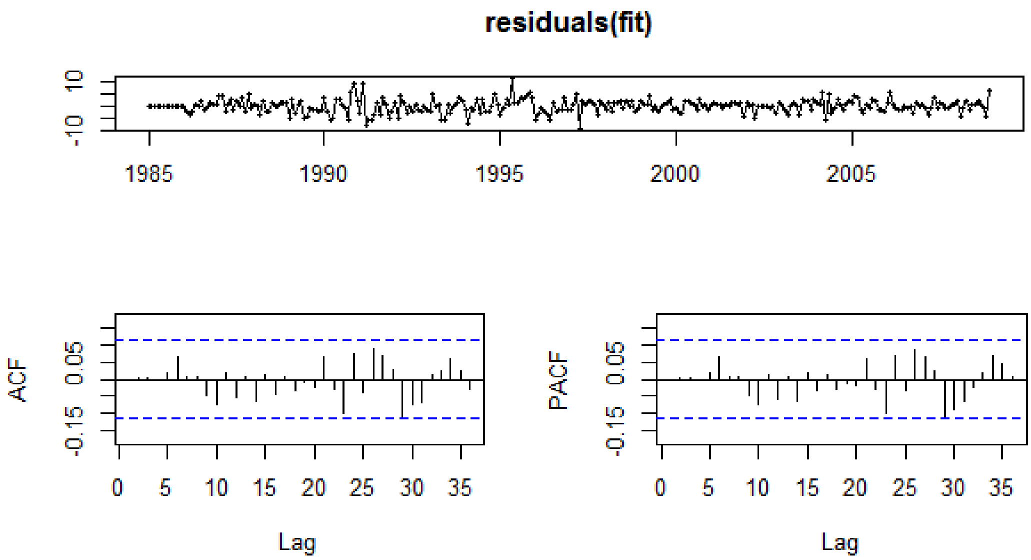

Fig. 12. ACF and PACF of residuals of monthly SARIMA model of mean monthly minimum temperature at Umiam, Meghalaya

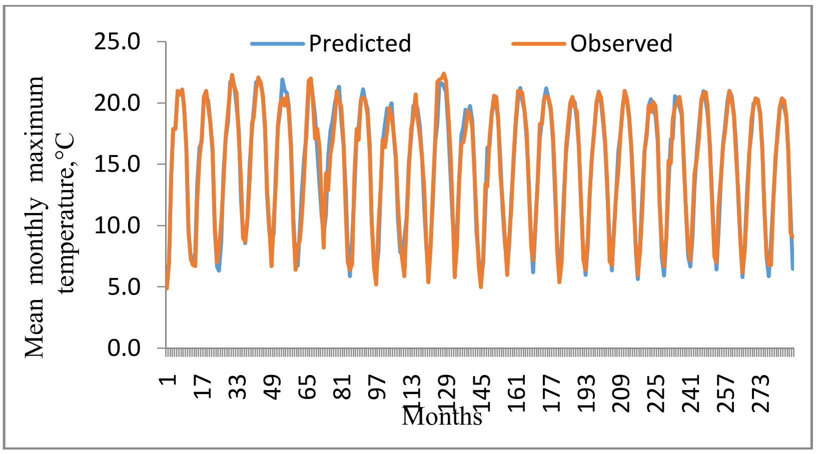

Fig. 13. Observed and predicted mean monthly minimum temperature for the period 1985-2008

Table 8. Mean monthly minimum temperature of observed and predicted series (1985-2008) along with errors

Month	Average observed data (°C)	Average predicted data(°C)	Error		Mean absolute error (°C)	Correlation	Nash Sutcliffe coefficient
			Absolute error(°C)	Relative error(%)			
January	6.6	6.7	0.07	1.07	0.004	0.98	0.96
February	8.9	9.0	0.08	0.88			
March	12.8	12.8	0.06	0.45			
April	16.2	16.1	0.07	0.44			
May	18.0	18.0	0.01	0.03			
June	20.0	20.0	0.04	0.21			
July	20.7	20.7	0.00	0.01			
August	20.4	20.3	0.03	0.15			
September	19.2	19.1	0.02	0.12			
October	16.5	16.5	0.00	0.02			
November	12.0	12.1	0.11	0.88			
December	8.2	8.3	0.04	0.48			

3.9 Validation of Developed Mean Monthly Minimum Temperature Time Series Model

The SARIMA (6,1,4)x(2,1,3)$_{12}$ model, for mean monthly minimum temperature, was used for predicting 4 years of monthly rainfall (2009-2012). For comparing the observed and predicted data, the mean monthly minimum temperature values for the years 2009 to 2012 were used. Fig. 14 shows the value of predicted and observed monthly data for the years 2009 to 2012. The mean of the observed and predicted data was found to be 14.7°C and 14.4°Crespectively. The absolute error was lying in the range of 0°C to 0.4°C.Relative error was lying in the range of 0% to 7.2% (Table 9).The correlation coefficient, Nash-Sutcliff coefficient and mean relative error were calculated as 0.98, 0.99 and 0.015 °C respectively showing a good degree of model fitness (Table 9).

3.10 Forecasting of Monthly Rainfall, Mean Monthly Maximum and Minimum Temperature

Forecasting of monthly rainfall, mean monthly maximum and minimum temperature for the year 2013-2028 was done using the developed modelsand presented in Figs.15 to 17.

3.11 Trend Detection in Monthly Rainfall, Mean Monthly Maximum and Minimum Temperature Forecasted Time Series

Using the forecasted values of monthly rainfall, mean monthly maximum and minimum temperatures for the years 2013 to 2028, detection of trend in monthly rainfall and mean monthly maximum and minimum temperature forecasted time series was carried out using four methods as described in section 2.5.

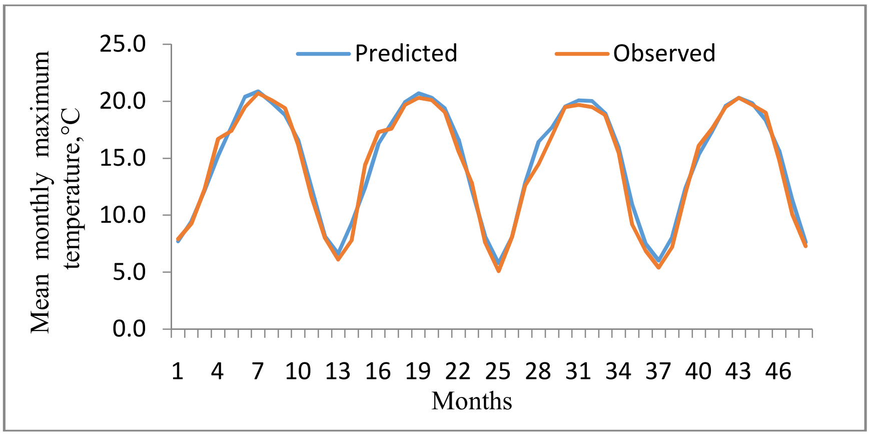

Fig. 14. Observed and predicted value of mean monthly minimum temperature (2009-2012)

Table 9. Mean monthly minimum temperature of observed and predicted data series (2009-2012) along with errors

Month	Average observed data(°C)	Average predicted data(°C)	Error		Mean absolute error(°C)	Correlation	Nash Sutcliff coefficient
			Absolute error(°C)	Relative error(%)			
January	6.125	5.7	0.4	7.2	0.015	0.99	0.98
February	8.1	7.8	0.3	3.7			
March	12.825	13.0	0.1	1.0			
April	16.15	16.0	0.1	0.9			
May	17.4	17.4	0.0	0.0			
June	19.55	19.6	0.0	0.1			
July	20.25	20.1	0.1	0.6			
August	19.85	19.8	0.1	0.3			
September	19.05	19.0	0.1	0.5			
October	15.55	15.4	0.2	1.0			
November	10.95	10.8	0.2	1.5			
December	7.45	7.3	0.1	1.8			

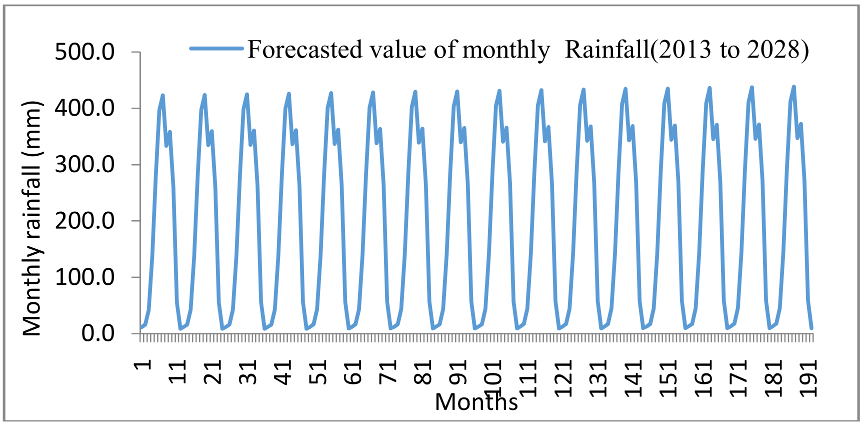

Fig. 15. Forecasted value of monthly rainfall (2013-2028)

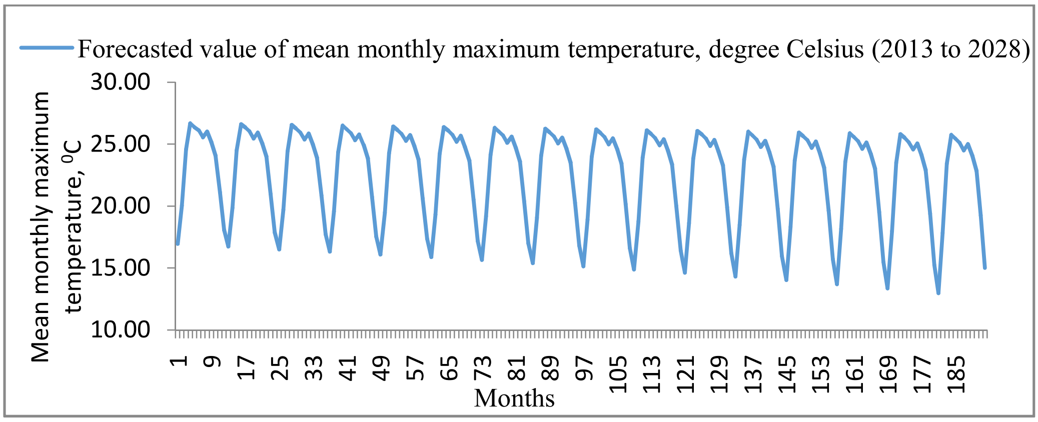

Fig. 16. Forecasted value of mean monthly maximum temperature (2013-2028)

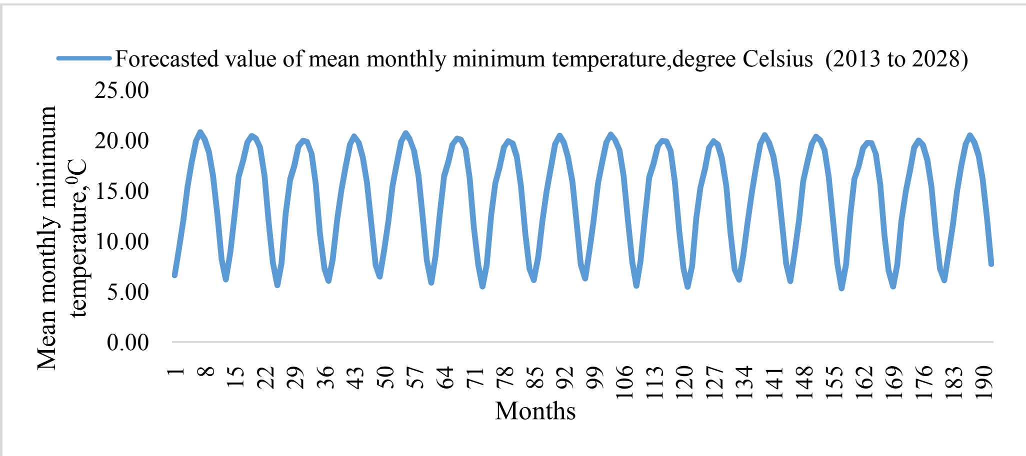

Fig. 17. Forecasted value of mean monthly minimum temperature (2013-2028)

3.11.1 Innovative trend analysis technique (Sen 2012)

The first half of forecasted time series (January 2013 to December 2020) was plotted against the second half of forecasted time series (January 2021 to December 2028) for monthly rainfall, mean monthly maximum and minimum temperature and then 1:1 line was drawn. For monthly rainfall and mean monthly minimum temperature, all the data points lie on 1:1 line, indicating that there is no trend present in forecasted time series of monthly rainfall and mean monthly minimum temperature. Whereas, for the mean monthly maximum temperature, all the data point lie below the 1:1 line and they are closer, depicting a minor falling monotonic trend in the forecasted time series of the mean monthly maximum temperature (Figs. 18 to 20).

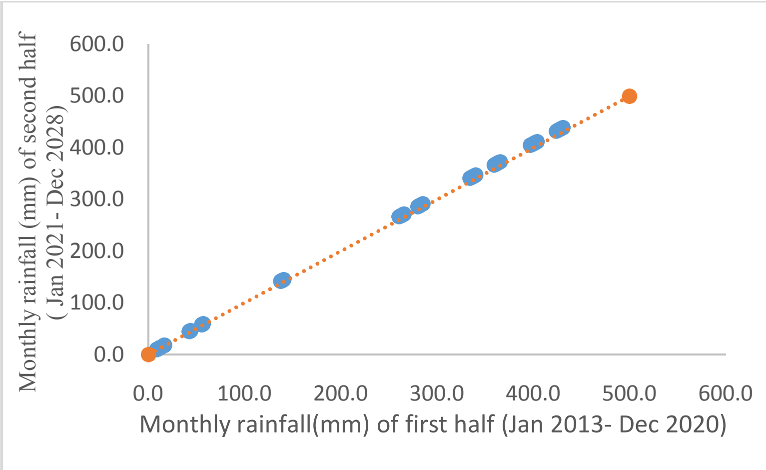

Fig. 18. Innovative trend analysis result for forecasted monthly rainfall time series (2013-2028)

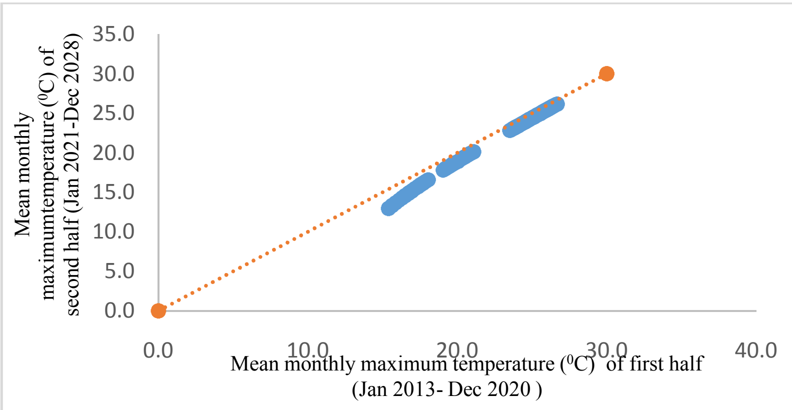

Fig. 19. Innovative trend analysis result for forecasted mean monthly maximum temperature time series (2013-2028)

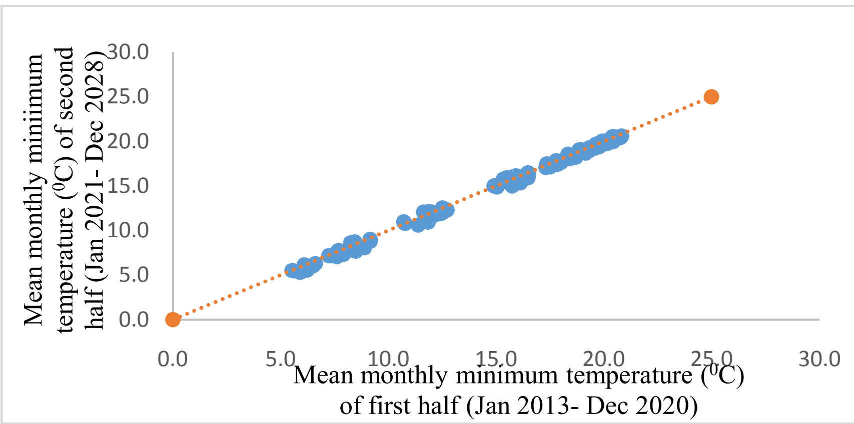

Fig. 20. Innovative trend analysis result for forecasted mean monthly minimum temperature time series (2013-2028)

Table 10. Linear regression analysis

Parameter	Equation	Slope	Intercept
Monthly rainfall	Y=0.090t+189.274	0.090	189.274*,**
Mean monthly maximum temperature	Y=-0.009t+23.443	-0.009	23.443*,**
Mean monthly minimum temperature	Y=-0.001t+14.557	-0.001	14.557*,**

***= significant at 1% level and **= significant at 5% level*

Table 11. Mann-Kendall Trend test statistics and magnitude of trend indicator (Sen's slope parameter) for forecasted monthly rainfall, mean monthly maximum temperature and minimum temperature

Parameter	Z_{MK}	b	Trend	Trend at 5% significance level
Monthly rainfall	1.83	.04174	No	No
Mean monthly maximum temperature	-3.14	-0.00673	Falling	Yes
Mean monthly minimum temperature	-0.46	-0.00218	Falling	No

3.11.2 Least squares linear regression test

The slopes and intercept obtained from linear regression analysis of monthly series of rainfall, mean monthly maximum and minimum temperature are shown in Table 10. Results revealed that all the three slopes are insignificant at 1% and 5% level which indicates no trend in forecasted monthly series of rainfall, mean monthly maximum temperature and minimum temperature.

3.11.3 Mann-Kendall test statistic (Z_{MK}) and Sen's slope (b) parameter

The summary of Mann-Kendall test statistic and Sen's slope parameter for forecasted monthly rainfall, mean monthly maximum temperature and minimum temperature series is presented in Table 11 .For monthly rainfall and mean monthly minimum temperature forecasted series, the computed Z_{MK} statistic was not found significant at 5% significance level. The value of Sen's slope parameter for monthly rainfall and mean monthly minimum temperature forecasted series was obtained 0.04174 and -0.00218. For mean monthly maximum temperature forecasted series, computed Z_{MK} statistics indicated that there is a falling trend at 5% significant level. The value of Sen's slope parameter was estimated -0.00673 (Table 11).

3.11.4 Inter comparison among selected trend analysis tests

For inter comparison of trends in monthly rainfall, mean monthly minimum and maximum temperatures; innovative analysis technique, the linear regression method, Mann-Kendall method, and Sen's slope method were applied.For monthly rainfall and mean monthly minimum temperature time series, all the selected method supported no significant trend present in the forecasted time series. However, in case of mean monthly maximum temperature time series, three methods supported falling trend in the forecasted values. Hence, mean monthly maximum temperature has the falling trend in the forecasted series. This might be due to less receipt of incident energy/radiation over the earth surface of the study area. The reason of less receipt of incident energy/ radiation might be due to increase in forest cover area in the study area. However, after the ban on forest cutting by the Supreme Court of India , the forest cover area has increased from 16988 km^2 (year 2005) to 17, 288 km^2 (year 2013) in the state of Megalaya, India.

4. CONCLUSION

The determination of trend in monthly rainfall, mean maximum and minimum temperatures in the forecasted series were done using different trend analysis techniques. For monthly rainfall and mean monthly minimum temperature time series, all the selected methods supported no significant trend. However, in the case of mean monthly maximum temperature time series, three selected methods supported falling trend.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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