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

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...
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°C 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 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 \( \lambda \) (Power parameter in Box-Transformation) seven goodness of fit tests for normality were applied. The best value for \( \lambda \) 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

\[ \text{SARIMA}(p, d, q) \times (P, D, Q)_s \]

for time series \( y_t \) may be expressed in the following expression [19]:

\[ \Phi(L^S) \phi(L) \Delta^d \Delta_s^D y_t = \Theta(L^S) \theta(L) \varepsilon_t \]  

(1)

Where, \( \phi \) is Autoregressive Parameter, \( \varepsilon \) is Moving Average Parameter, \( \Phi \) is Seasonal Autoregressive Parameter and \( \Theta \) 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 Khandakar, 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](image-url)
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 \((5,1,2)\times(1,1,1)_12\), which was selected based on the minimum value of AIC= 1581.68 and BIC = 1618.69 (Table 1). The adequacy of the SARIMA \((5,1,2)\times(1,1,1)_12\), 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 \((5,1,2)\times(1,1,1)_12\), 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)×(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

| SARIMA | Parameter  | $\phi_1$ | $\phi_2$ | $\phi_3$ | $\phi_4$ | $\phi_5$ | $\Theta_1$ | $\Theta_2$ | $\Phi_1$ | $\Theta_1$ |
|--------|------------|---------|---------|---------|---------|---------|-----------|-----------|---------|-----------|
| (5,1,2) x (1,1,1)_{12} | Estimate | -0.97   | -0.041  | -0.030  | -0.096  | -0.141  | -0.0007   | -0.938    | -0.0002 | -1.00     |
|        | 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, $\chi^2$ (20) p value=0.905
Engle’s ARCH LM test of standardized residuals (SRs) $\chi^2$ (24) = 25.8, p value=0.36
Li- McLeod test of standardized residuals (SRs) $\chi^2$ (24) = 12.6, p value=0.943

![Observed Rainfall (1983-2012)](image)

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 $\lambda$ 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 $(2,1,2) \times (2,1,1)_12$, was found as the best fit model, for the mean monthly maximum temperature time series, based on the minimum value of $\text{AIC} = 5466.3$ and $\text{BIC} = 5495.23$ (Table 4). The adequacy of the SARIMA $(2,1,2) \times (2,1,1)_12$, 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

![residuals fit](image)

![ACF and PACF](image)

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

![Observed and predicted monthly rainfall](image)

**Fig. 5.** Observed and predicted monthly rainfall for assessment period 1983-2008
the years 1985 to 2008 were used for forecasting the mean monthly maximum temperature. 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 developed SARIMA 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 respectively showing 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 |
|-----------|----------------------------|----------------------------|-------|--------------------------|-------------|---------------------------|
|           |                            |                            |       |                          |             |                           |
| January   | 16.4                       | 16.9                       | 0.5   | 3.2                      | 0.001       | 0.84                      | 0.70                          |
| February  | 24.3                       | 25.1                       | 0.8   | 3.3                      |             |                           |
| 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 |
|---------|----------------------------|-----------------------------|-------|--------------------------|-------------|---------------------------|
| January | 8.6                       | 10.8                        | 2.2   | 0.124                    | 0.91        | 0.82                       |
| February| 4.5                       | 5.6                         | 1.1   | 0.091                    | 0.81        |                           |
| March   | 35.3                      | 34.0                        | 1.3   | 0.025                    | 0.86        |                           |
| April   | 122.2                     | 138.7                       | 16.5  | 0.135                    | 0.76        |                           |
| May     | 323.3                     | 308.7                       | 14.6  | 0.045                    | 0.94        |                           |
| June    | 471.7                     | 501.5                       | 29.8  | 0.059                    | 0.93        |                           |
| July    | 358.3                     | 343.2                       | 15.1  | 0.043                    | 0.96        |                           |
| August  | 428.6                     | 409.6                       | 19.0  | 0.047                    | 0.94        |                           |
| September| 338.7                    | 331.5                       | 7.2   | 0.022                    | 0.89        |                           |
| October | 247.3                     | 273.7                       | 26.4  | 0.103                    | 0.83        |                           |
| November| 44.6                      | 55.5                        | 10.9  | 0.246                    | 0.84        |                           |
| December| 4.3                       | 5.3                         | 1.0   | 0.25                     | 0.85        |                           |

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 (5,1,2)x (1,1,1)_12 | Parameter | \( \phi_1 \) | \( \phi_2 \) | \( \Theta_1 \) | \( \Theta_2 \) | \( \Phi_1 \) | \( \Phi_2 \) | \( \Theta_1 \) |
|----------------------------|-----------|-------------|-------------|---------------|---------------|-------------|-------------|-------------|
| 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, \( \chi^2(20) \) p value=0.807 |
| Engle’s ARCH LM test of standardized residuals (SRs) \( \chi^2(24) = 25.79, \) p value=0.36 |
| Li-McLeod test of standardized residuals (SRs) \( \chi^2(24) = 14.6, \) p value=0.879 |

3.6 Validation of Developed Mean Monthly Maximum Temperature Time Series Model

The SARIMA\((6,1,4)\times(2,1,3)_{12}\) 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 indicating a 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).

![Residuals](residuals.png)

![ACF and PACF](acf_pacf.png)

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

![Observed and Predicted](predicted_observed.png)

**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                      |             |                           |                      |
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 years 1985 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 Absolute error(°C) | Error Relative error(%) | Mean absolute error (°C) | Correlation | Nash Sutcliffe coefficient |
|----------|---------------------------|----------------------------|--------------------------|-------------------------|--------------------------|-------------|---------------------------|
| 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 \((6,1,4)(2,1,3)_{12}\) 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°C respectively. 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 models and 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.

![Predicted vs Observed Mean Monthly Minimum Temperature](image)

**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)
Dabral and Tabing; IJECC, 10(11): 155-172, 2020; Article no.IJECC.62407

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                               | ZMK     | b        | Trend   | Trend at 5% significance level |
|-----------------------------------------|---------|----------|---------|-------------------------------|
| Monthly rainfall                        | 1.83    | 0.04174  | 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 (ZMK) 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 ZMK 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 ZMK 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 km² (year 2005) to 17,288 km² (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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