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A statistical perspective on Assam’s temperature pattern from 1985-2022

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सार – यह शोधपत्र जलवायु के एक महत्वपूर्ण पैरामीटर, तापमान के परिवर्तन पर केंद्रित है। इस पैरामीटर के परिवर्तन का अध्ययन करने के लिए, असम के विभिन्न क्षेत्रों पर विचार किया गया है क्योंकि इसकी संवेदनशील संवेदनशील भू-पारिस्थितिकीय व्यवस्था और रणनीतिक स्थान के कारण जलवायु परिवर्तन के परिणामों के लिए यह अत्यधिक प्रवण होने की उम्मीद है। यह शोधपत्र न केवल इस बारे में विचार देता है कि तापमान कैसे बदल रहा है, है, बल्कि 1985-2022 के मौसम के अनुसार वृद्धि दर की गणना करके असम के चार चयनित क्षेत्रों में एक स्टेशन से दूसरे स्टेशन में विचलन की व्याख्या भी करता है। 1985-2022 की अवधि के दौरान असम के तापमान के बारे में में विशिष्ट जानकारी निकालने के लिए, मासिक औसत अधिकतम तापमान और मासिक औसत न्यूनतम तापमान पर पर विचार किया जाता है। तापमान की वृद्धि दर दर्शाती है कि अधिकतम तापमान में परिवर्तन की प्रतिशत दर धुबरी धुबरी स्टेशन में सबसे कम और डिब्रूगढ़ स्टेशन में सभी मौसमों के लिए सबसे अधिक है। लेकिन न्यूनतम तापमान के के मामले में, डिब्रूगढ़ स्टेशन में मानसून के बाद के मौसम को छोड़कर सभी मौसमों के लिए परिवर्तन दर सबसे कम है और सभी मौसमों के लिए धुबरी स्टेशन में सबसे अधिक है। इनके साथ, यह शोधपत्र 1985-2022 की अवधि अवधि के दौरान तापमान के सांख्यिकीय ढांचे को विस्तृत करने का प्रयास करता है। इनके अलावा, प्रक्षेपण के लिए सांख्यिकीय समय श्रृंखला मॉडल पर विचार किया जाता है; चरम घटनाओं के महत्व को आश्वस्त करने के लिए चरम चरम मूल्य विश्लेषण किया जाता है।

ABSTRACT. This paper focusses on the variation of a significant parameter of climate, Temperature. To study the variation of this parameter, various zones of Assam has been consideredsince it is expected to be highlyprone to consequences to climate change because of its sensitive geo-ecological set-up and strategic location. This paper gives not only the idea about how temperature is changing but also explains aberration from one station to other stations in four selected zones of Assam by calculating Growth rate from 1985-2022 season wise. To extract specific information about the temperature of Assam during the period 1985-2022, monthly mean maximum temperature and monthly mean minimum temperature is considered. Growth rate of temperature indicates that the percentage rate of change in maximum temperature is least in Dhubri station and highest in Dibrugarh station for all season. But in case of minimum temperature, variation rate is least in Dibrugarh station for all season except post-monsoon season and shows highest in Dhubri station for all seasons. Along these, this paper tries to elaborate the statistical frame of temperature during the period 1985-2022. Besides these, the statistical time series models are considered for projection; the extreme value analysis is done to assure the significance of extreme events.

Key words – Maximum Temperature, Minimum Temperature, Growth rate, Statistical model, Projection and Extreme value analysis.

1. Introduction

Changes in the climate is a global concern, it incorporates several domains beyond science, including society, economics, politics, and most significantly ethical and moral questions (Costa & Monteiro, 2017). Only a few of the several climatic parameters may be taken into consideration and these include air temperature, atmospheric pressure (barometric pressure), humidity, precipitation, solar radiation, wind, and the remaining are interpreted as a background noise. Among this temperature has much physiological significance in the natural environment and also in the laboratory. In recent decade, temperature is increasing day by day in various

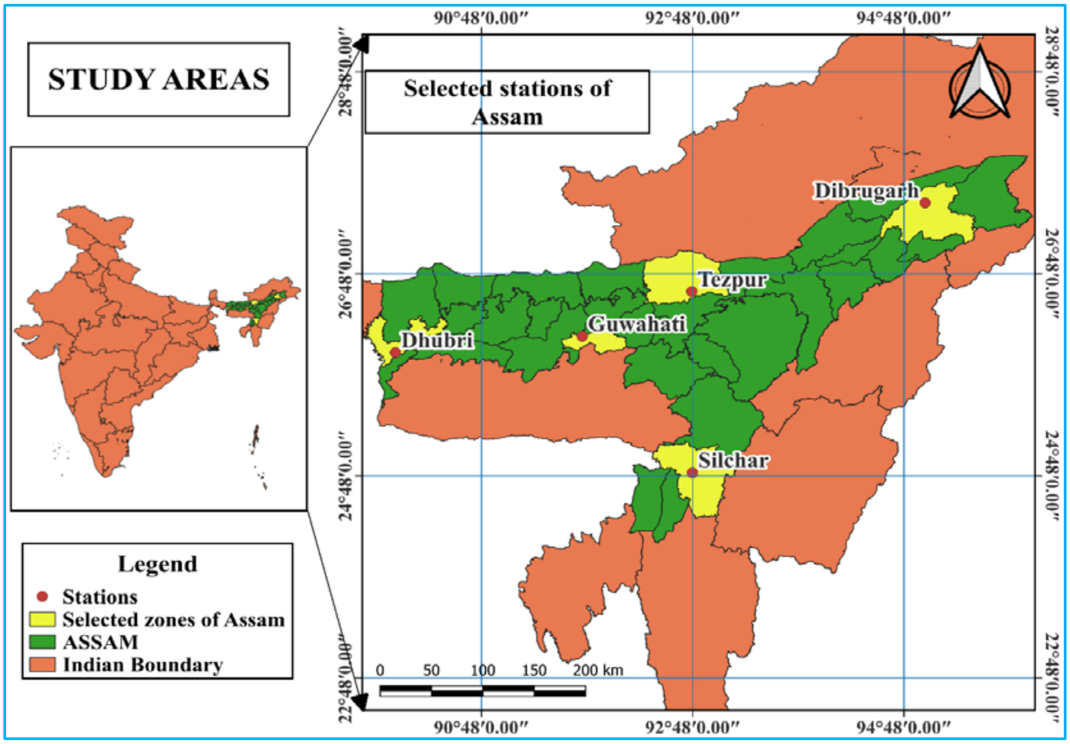


Fig. 1. Selected stations of Assam

regions of the world, having major adverse effects on society and the economy. The sensitivity of extremely high temperatures to moving thresholds in various regions throughout the world reveals a distinct performance response as the temperature rises (Cao *et al*., 2023). Temperature effects are getting worse every day as a result of climate change. It is anticipated that as a result of climate change brought on by global warming, there would be an increase in crime rates, natural disasters, and other extremely dangerous events (Awaworyi Churchill *et al*., 2022). Temperature is significantly associated with the concentration of pollutants (Basu & Samet, 2002). Researchers worldwide have examined the impacts of temperature rise on physical health in metropolitan areas. The exacerbation of pre-existing chronic diseases, particularly cardiovascular and respiratory disorders, respiratory illnesses as well as outright heat exhaustion and heat stroke are the most important impacts of temperature rise on physical health. Besides these the vector borne diseases such as malaria and dengue are greatly influenced by climate change and the ongoing pattern of increasing temperature (Wong *et al*., 2018).

Several researchers studied the variation of temperature in numerous dimensions. Temperature is one of the most important parameter of the climate change as it impacts the distribution of plant diseases (Yáñez-López *et al*., 2012). Four zones of the state Assam have been considered to study the temporal variation and its extreme pattern. Since the data points are considered at their extreme points; accordingly, the analysis of extreme pattern of temporal variation is included in this study.

2. Data source and methodology

2.1. *Source of the data and Study Area*

Assam is divided into various zones according to agro-climatic zones. Depending on the period of time and availability of the data only five stations from four zones have been considered for the study. The data covers monthly data for 38 years, from January 1985 to September 2022 and has been collected from National Data Centre (NDC), India Meteorological Department (IMD), Pune (http://dsp.imdpune.gov.in/).

The name of the stations are given below with respect to zones

Name of Zones	*Stations*
Lower Brahmaputra Valley Zone	Guwahati, Dhubri
North Bank Plain Zone	Tezpur
Upper Brahmaputra Valley Zone	Dibrugarh
Barak Valley Zone	Silchar

The data is divided into four season's Winter (January, February), Pre-Monsoon (March, April and May), Monsoon (June, July, August and September) and Post-Monsoon (October, November and December).

2.2. *General climatological features of the study area*

The North East region of India including Assam is expected to be highly prone to consequences to climate change because of its sensitive geo-ecological set-up, strategic location, presence of the Eastern Himalayan ranges, trans boundary river systems, inhabitation of ecosystem by people of different ethnic groups and inherent socio-economic differences (ASTEC, 2011).

The state Assam lies between 89° 46' - 96° 01' E longitude and 24° 03' - 27° 58' N latitude and covers an area of 78,438 km². The state is bounded in the north by Bhutan and Arunachal Pradesh, in the east by Arunachal Pradesh, Nagaland and Manipur, in the south by Meghalaya and Mizoram and in the west-by-West Bengal, Tripura and Bangladesh.

The climate of Assam is predominantly humid subtropical with hot, humid summers, severe monsoons and mild winters. The winter temperature varies from 10° C to 22° C. The summer temperature varies between 30° C to 36° C. Assam gets maximum rainfall in the month of July and August (29% of south west monsoon rainfall) followed by September (24% of south west monsoon rainfall). 66% of annual rainfall received during southwest monsoon rainfall (June - September) (Guhathakurta *et al*., 2020). Silchar station is located in Barak Valley zone within the North-East Region at 92° 51′ East (E) longitude and 24° 5′ North (N) latitude and at a height of 114.68 m above the sea level (Gupta & Biswas, 2010). In lower Brahmaputra valley zone, Guwahati is considered for the study. "The Guwahati station is located within the North-East region of India, approximately between the latitudes 91° 33′ E and 91° 52′E and longitudes 26° 4′ N and 26° 14′ N, covering an approximate area of 328 sq km spreading across both the banks of River Brahmaputra. The region has a subtropical climate, with hot humid summers, severe monsoons, and mild winters" (Sarma *et al*., 2020). Guwahati station is highly vulnerable to river bank erosion, floods and landslides (Hemani & Das, 2016).Dibrugarh station is considered for the study from upper Brahmaputra valley zone, "The total geographical area of Dibrugarh District is 3381 sq km. It extends from 27° 0' N to 27° 45' N latitude and 94° 30' E to 95° 30' E longitudes. Dibrugarh as the name suggests is a defensive town on the south bank of the river 'Dibru' centering a 'Garh' (fort) at the intersection of 27° 28' N latitude and 94° 35' E longitudes at 104.24 m above mean sea level" (Mili & Acharjee, 2014). The climate of Dibrugarh is subtropical, with pleasantly warm, dry winters from November to February and a long, hot and rainy period from April to mid-October. From lower Brahmaputra valley zone, the station Dhubri is selected for the study. "Dhubri is situated in the extreme south western part of the lower Brahmaputra valley of Assam between 25° 30' N and 26° 30' N latitude and 89° 40' E and 90°30' E longitude with an area of 675.72 sq km. Its geography is largely flat, with some slope in the eastern portion. The Brahmaputra River dominates the drainage system and runs through the area, turning abruptly south at its westernmost end" (Das & Ahmed, nd). From North bank plain zone, the station Tezpur is located on the northern bank of the Brahmaputra River, geographically positioned at 26° 63′ N and 92° 8′ E. In this area, the summer months are usually warm and muggy, whereas the months of January and February have mild winter temperatures (Deka *et al*., 2020).

From four zones only five stations out of six agro-climatic zones are considered for the study because of the non- availability of data for all the zones.

The statistical tests used to perform the analysis are explained accordingly.

2.3. *Stationary test*

The first stage in a time series forecasting model is figuring out if variations are needed to make the series stationary, as stationary time series model cannot predict on non-stationary time series data. There are various types of test to check the stationarity of the data set, which includes Augmented Dicky-Fuller test (ADF Test), Phillips-Perron test and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test (Ray *et al*., 2023).

2.4. *Statistical model diagnosis*

In regard to prediction performance, an Auto Regressive Integrated Moving Average (ARIMA) model is better than multivariate models. The overall performance of ARIMA models is also better than that of smoothing methods and naive models. ARIMA model was developed by Box and Jenkins in the 1970s and their approach of identification, estimation and diagnostics is based on the principle of parsimony. The forecasting equation for monthly mean maximum temperature is ARIMA (p, d, q) model, where p denotes the order of the autoregressive (AR) part, d, the order of integration and q, the order of the moving average (MA) part of the model (Ray *et al*., 2023).

ARIMA (p, d, q) or ARMA (p, q) is the combination of autoregressive (AR) and moving average (MA) models with or without differencing. AR (p) can be represented by an equation and it is presented below, where y_t, y_{t-1},…, y_{t-p} are stationeries and ϕ_1, ϕ_2,…, ϕ_p are constants. ε_t is a Gaussian white noise series with mean zero (Liu *et al*., 2023).

$$y_t = \phi_0 + \phi_1 y_{t-1} + \phi_2 y_{t-2} + ... + \phi_p y_{t-p} + \varepsilon_t \tag{1}$$

The equation of MA (q) is presented below, where there are q lags in the moving average and θ_1, θ_2,…, θ_p are parameters. ε_t, ε_{t-1},…, ε_{t-p} is a Gaussian white noise series with mean zero (Liu *et al*., 2023).

$$y_t = \varepsilon_t - \theta_1 \varepsilon_{t-1} - \theta_2 \varepsilon_{t-2} - ...... - \theta_q \varepsilon_{t-q} \tag{2}$$

The backshift operator (B) is introduced as $\mathrm{B}^n y_t = y_{t-n}$

Thus, based on equations (1) and (2) ARIMA (p, d, q) can be represented briefly in a equation form below, where ∇^d is the difference operator: $(1-\mathrm{B})^d$, $\Theta(\mathrm{B})$ is the moving average polynomial: $1-\theta_1\mathrm{B} - ...... - \theta_q \mathrm{B}^q$, $\Phi(\mathrm{B})$ is an auto regressive polynomial: $1-\phi_1\mathrm{B} - ...... - \phi_p \mathrm{B}^p$.

$$\Phi(\mathrm{B})\Delta^d y_t = \Theta(\mathrm{B})\varepsilon_t \tag{3}$$

The Seasonal Auto Regressive Integrated Moving Average (SARIMA) model , denoted generally as ARIMA (*p, d, q*) × ARIMA(*P, D, Q*)*S*, is presented in the equation below (Liu *et al*., 2023), where ∇^d is the difference operator : $(1-\mathrm{B})^d$, ∇_S^D is the seasonal difference operator : $(1-B^S)^D$, $\Theta(B)$ is the moving average polynomial: $1-\theta_1 B - ...... - \theta_q B^q$, $\Theta_S(B)$ is the seasonal moving average polynomial: $1-\Phi_1\mathrm{B} - ...... - \Phi_P \mathrm{B}^P$, $\Phi_S(B)$ is the seasonal autoregressive polynomial: $1-\Phi_1\mathrm{B}^S - ...... - \Phi_P \mathrm{B}^{PS}$

$$\nabla^d \nabla_S^D y_t = \frac{\Theta(B) \times \Theta_S(B)}{\Phi(B) \times \Phi_S(B)} \varepsilon_t \tag{4}$$

The atmospheric changes are thoroughly examined during the period 1985-2022 seasonally using time series model projection of temperature by determining the Growth Rate.

2.5. *Growth rate of temperature*

A quantitative measurement which studies the changes on a particular variable (Temperature) with respect to time known as Growth Rate (Chen *et al*., 2023). If G_{it} is the growth rate of t^{th} year corresponding to previous year in the i^{th} station, so that

$$G_{it} = \left(\frac{Y_{it}}{Y_{i,t-1}} - 1 \right) \times 100 \tag{5}$$

2.6. *Extreme Value Analysis*

Extreme value analysis is widely used in many disciplines, such as structural engineering, finance, earth sciences, traffic prediction, and geological engineering, environmental loads on structures, neurobiology, flood etc. The application of extreme value distribution (EVD's) can be applied to analyses extreme temperature events. Leonard Tippett (1902-1985) pioneered the principle of extreme value theory (Johnson *et al*., 1995). There are three types of extreme value distributions (EVD)

Gumbel or Type 1 EVD

If *X* follows Gumbel or Type 1 EVD with a location parameter μ and scale parameter β then the probability density function of minimum or maximum values in data set respectively can be defined as follows:

$$f(x) = \frac{1}{\beta} e^{\frac{x-\mu}{\beta}} e^{-e^{-\frac{x-\mu}{\beta}}} \;\; ; \; x > 0, \; \mu > 0, \beta > 0 \text{ or}$$

$$f(x) = \frac{1}{\beta} e^{-\frac{x-\mu}{\beta}} e^{-e^{-\frac{x-\mu}{\beta}}} \;\; ; x > 0, \; \mu > 0, \beta > 0 \tag{6}$$

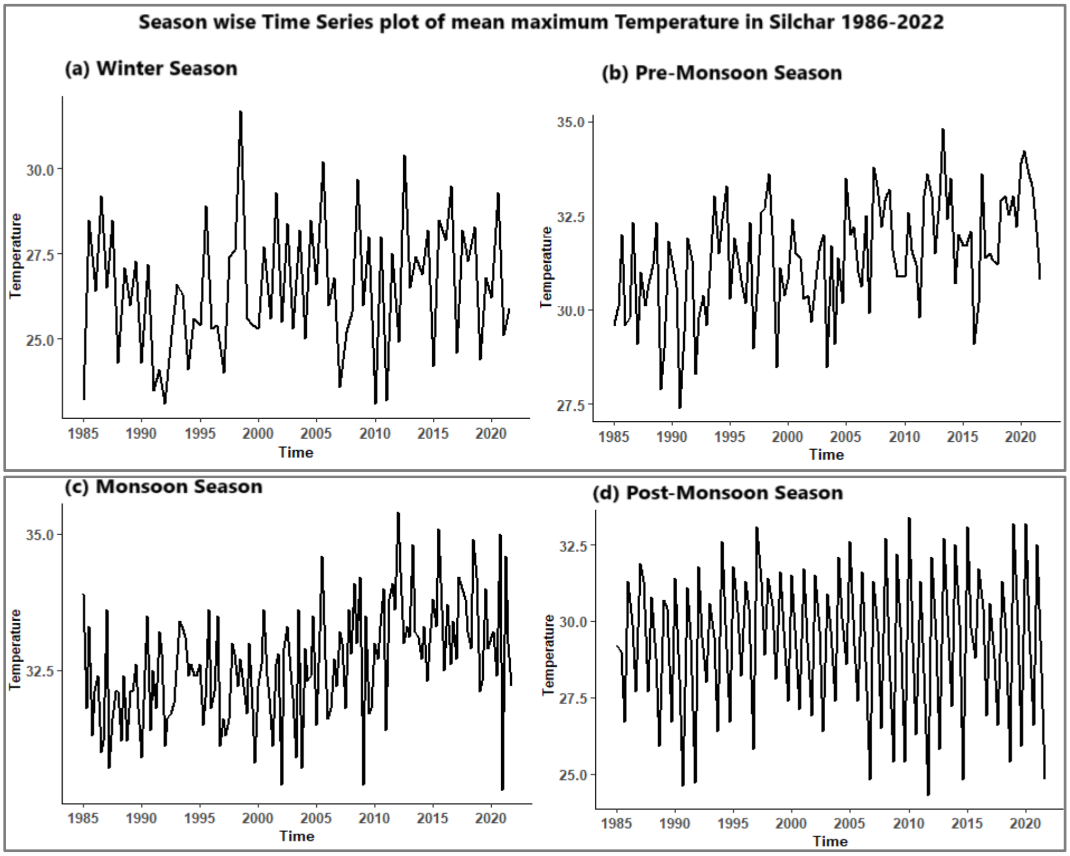
Frechet or Type 2 EVD

If *X* follows Frechet distribution with shape parameter *c* and scale parameter β with a unit location parameter then the probability density function can be defined as:

$$f(x) = c\beta \, x^{-(c+1)} e^{-\beta x^{-c}} \; , \qquad x > 0, \; c > 0, \beta > 0 \tag{7}$$

Weibull or Type 3 EVD

If *X* follows Weibull distribution with shape parameter α and scale parameter β, then the probability density function can be defined as :



Figs. 2(a-d). Season wise Time Series plot of monthly mean maximum temperature for the period of 1986-2022

$$f(x;\beta;\alpha)=\frac{\alpha}{\beta^{\alpha}}x^{\alpha-1}e^{-\left(\frac{x}{\beta}\right)^{\alpha}};\ x>0,\alpha>0,\beta>0 \quad (8)$$

Gumbel (Type 1 EVD) distribution is used in hydrology, meteorology, engineering, finance etc. Frechet (Type 2 EVD) distribution is used in the same field with a heavy tailed dataset and Weibull (Type 3 EVD) distribution is widely used in the same areas because of its flexible characteristics besides survival and reliability analysis.

3. Results and discussion

3.1. *Season wise time series model for monthly mean maximum temperature of Silchar station*

In the prediction of time series statistical model, it is necessary to check the stationarity of the data points before going to estimate statistical model. The stationary of the data set is checked by Augmented Dicky-Fuller test (ADF Test), where the null hypothesis is that the data points are not stationary and alternative hypothesis is that the data points are stationary.

The 37 years of data have been considered to study the temporal variation in Silchar station for the period 1986-2022.

Fig. 2(a-d) represents time series plots for four seasons by dividing whole data into four seasons. Statistical Time Series Model of monthly mean maximum temperature season wise for the period 1986-2022 of Silchar station are represented as follows:

Based on automatic ARIMA, which is one of the forecasting models (Awan & Aslam, 2020), it is found that SARIMA (0,1,1) $(2,1,2)^3$ is the best model for predicting values for Silchar Station in pre-monsoon season. It shows standardized residuals, the Autocorrelation Function (ACF) of the residuals and the p-value, *i.e.*, 0.2187, which depicts that there is no serial autocorrelation in residuals. Modified Ljung-Box test statistic (Q*), which explains whether there is a serial autocorrelation in residuals or not. Here the Q* statistic is

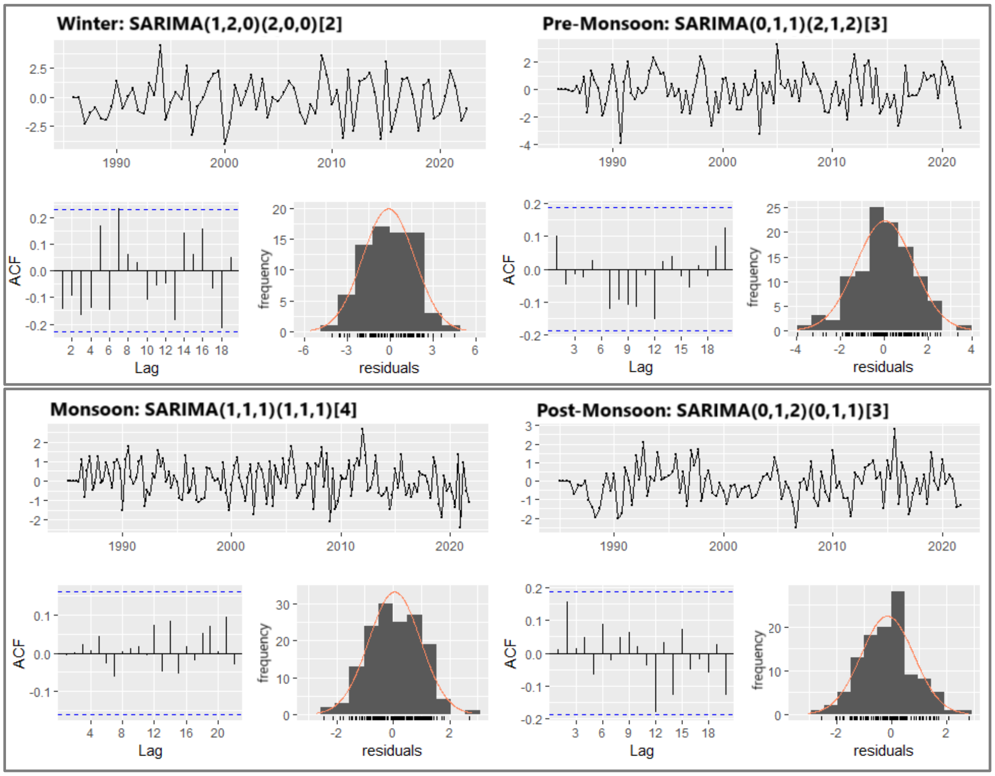


Fig. 3. Statistical models for each season in Silchar station

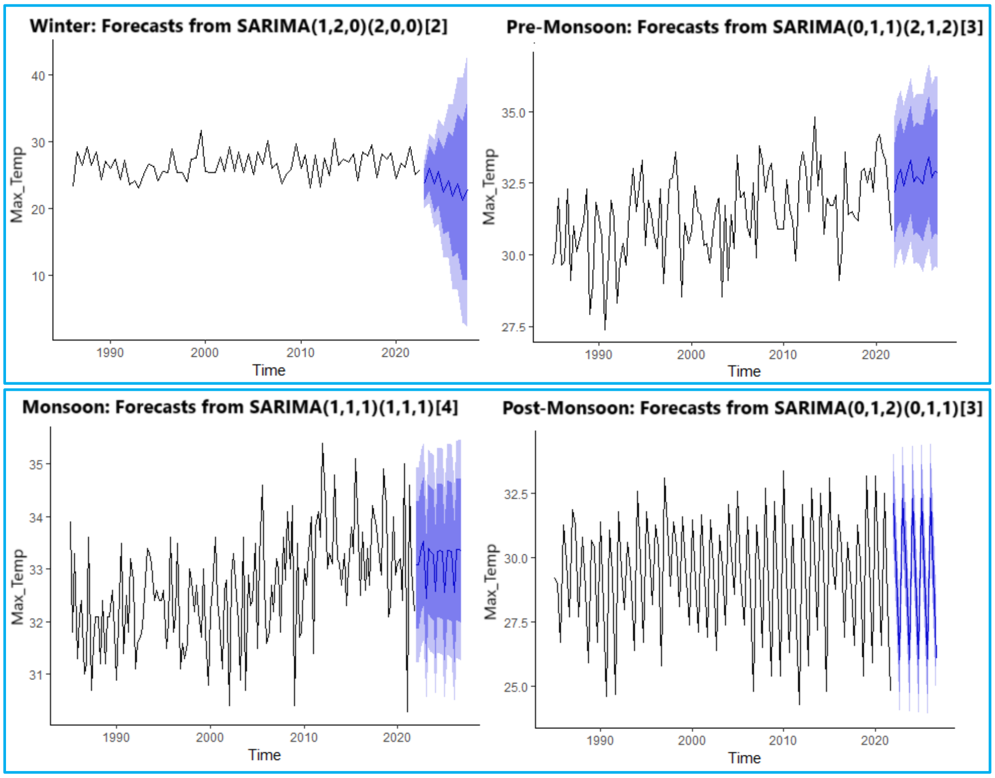


Fig. 4. Prediction of next five years for each season by defined statistical model of Silchar station

TABLE 1

Descriptive statistics of monthly mean maximum temperature (°C) for various stations of Assam

Stations	Min	Q_1	Median	Mean	Q_3	Max	SD	CV
Winter (Maximum Temperature)								
Silchar	23.10	25.23	26.45	26.50	28.00	31.70	1.990	7.511
Guwahati	21.60	23.98	25.10	25.41	27.00	29.80	2.013	7.923
Dhubri	19.30	21.70	23.95	23.81	25.75	27.20	2.193	9.215
Tezpur	21.20	23.38	24.95	24.98	26.00	29.60	1.987	7.956
Dibrugarh	20.50	22.90	24.00	24.18	25.23	29.40	1.783	7.374
Pre-Monsoon (Maximum Temperature)								
Silchar	27.40	30.40	31.50	31.41	32.40	34.80	1.473	4.692
Guwahati	26.70	30.40	31.25	31.05	32.00	35.80	1.558	5.020
Dhubri	26.40	29.30	30.40	30.22	31.00	34.60	1.398	4.625
Tezpur	25.70	29.02	30.00	29.89	30.90	34.40	1.561	5.226
Dibrugarh	23.70	26.90	28.00	28.15	29.57	32.30	1.941	6.899
Winter (Maximum Temperature)								
Silchar	23.10	25.23	26.45	26.50	28.00	31.70	1.990	7.511
Guwahati	21.60	23.98	25.10	25.41	27.00	29.80	2.013	7.923
Dhubri	19.30	21.70	23.95	23.81	25.75	27.20	2.193	9.215
Tezpur	21.20	23.38	24.95	24.98	26.00	29.60	1.987	7.956
Dibrugarh	20.50	22.90	24.00	24.18	25.23	29.40	1.783	7.374
Monsoon (Maximum Temperature)								
Silchar	30.30	31.88	32.60	32.64	33.30	35.40	1.076	3.178
Guwahati	30.40	31.90	32.60	32.66	33.40	35.90	1.072	3.284
Dhubri	28.90	30.60	31.30	31.28	31.90	34.10	0.941	3.010
Tezpur	27.80	31.10	31.90	31.88	32.50	34.30	1.012	3.177
Dibrugarh	28.80	30.70	31.40	31.43	32.10	34.50	1.086	3.456
Post-Monsoon (Maximum Temperature)								
Silchar	24.30	27.40	29.70	29.32	31.30	33.40	2.363	8.062
Guwahati	23.10	25.93	28.30	28.26	30.18	33.70	2.626	9.292
Dhubri	21.80	24.40	26.65	26.48	28.60	30.80	2.574	9.722
Tezpur	22.90	25.70	28.20	28.05	30.10	33.50	2.645	9.429
Dibrugarh	22.20	25.90	27.95	27.88	29.77	33.00	2.498	8.960

4.4287< 7.815, χ^2 value at 95% confidence interval at 3 degrees of freedom. Since the value of Q* statistic is less than χ^2 value, which also indicates that there is no autocorreltion in the residuals with least (Akaike Information Criterian) AIC = 386.57, (Corrected Akaike Information Criterian) AICC = 387.41 and (Bayesian Information Criterian) BIC = 402.6 (the criterias of goodness of fit to get best model).

From Fig. 3, it is clearly identified from the ACF plot that none of the autocorrelation coefficients up to 18 lag or may be more than 18 lag are not breaching the significant limits, *i.e.*, all the ACF values are well within the significant bounds, which indicates the better fit of data by the found model. Hence there is no non-zero autocorrelations in the forecast residuals up to 18th lag or may be more lag in the fitted model. Similarly, same interpretation can be drawn in case of other seasons.

In Fig. 4, the blue colored portion is the forecasted values of monthly mean maximum temperature in Silchar for next five years, *i.e.*, between 2023-27 season wise.

TABLE 2

Descriptive statistics of monthly mean minimum temperature for various zones of Assam

Stations	Min	Q_1	Median	Mean	Q_3	Max	SD	CV
Winter (Minimum Temperature)								
Silchar	9.70	12.20	13.15	13.17	14.10	16.90	1.435	10.895
Guwahati	9.00	10.88	11.70	11.94	13.10	15.80	1.356	11.365
Dhubri	7.40	11.25	12.85	12.65	14.55	17.20	2.472	19.551
Tezpur	9.60	11.60	12.30	12.67	14.00	15.50	1.460	11.530
Dibrugarh	7.90	10.03	11.70	11.44	12.80	15.10	1.691	14.786
Pre-Monsoon (Minimum Temperature)								
Silchar	15.10	18,82	21.05	20.72	22.80	26.30	2.418	11.670
Guwahati	15.30	17.23	20.35	19.90	22.40	24.40	2.722	13.676
Dhubri	13.00	19.30	21.20	20.66	22.55	24.70	2.615	12.662
Tezpur	14.90	17.82	20.10	19.95	22.07	24.00	2.344	11.750
Dibrugarh	14.80	16.82	19.20	19.22	21.50	24.60	2.475	12.880
Monsoon (Minimum Temperature)								
Silchar	21.60	24.80	25.30	25.14	25.70	28.40	0.990	3.938
Guwahati	23.30	25.00	25.50	25.43	25.90	26.80	0.688	0.473
Dhubri	21.00	25.00	25.60	25.58	26.40	28.20	1.050	4.107
Tezpur	22.00	24.60	25.10	25.07	26.90	26.90	0.855	3.411
Dibrugarh	21.30	24.20	24.70	24.59	25.10	25.90	0.725	2.948
Post-Monsoon (Minimum Temperature)								
Silchar	9.90	14.62	18.45	18.37	22.48	25.50	3.889	21.175
Guwahati	10.50	12.93	17.25	17.29	21.77	24.50	4.078	23.592
Dhubri	8.70	14.62	17.80	17.89	22.00	25.40	4.16	23.275
Tezpur	10.70	13.70	17.15	17.14	21.10	24.40	3.907	22.796
Dibrugarh	8.10	11.82	15.75	15.94	20.20	23.60	4.303	26.993

Table 1 shows descriptive statistics for monthly mean maximum temperature season wise. In the winter season, Dhubri shows least and Silchar shows highest maximum temperature in the period of 1985-22 among the selected stations. From the standard deviation (SD), the variation in temperature is highest in Dhubri (2.193). The station, which has least mean and highest SD, shows highest coefficient of variation (CV). As the CV is directly proportional to SD and inversely proportional to mean. In winter season Dhubri shows highest CV with highest SD (2.193). Similarly, in pre-monsoon season, Dibrugarh shows highest variation in the quantitative values of temperature. In monsoon and post-monsoon, Dibrugarh and Dhubri show highest variation in temperature respectively.

From Table 2, the variation in minimum temperature values for the period of 1985-2022 is highest in Dhubri in winter season, Guwahati in pre-monsoon season, Dhubri in monsoon season and Dibrugarh in post-monsoon season.

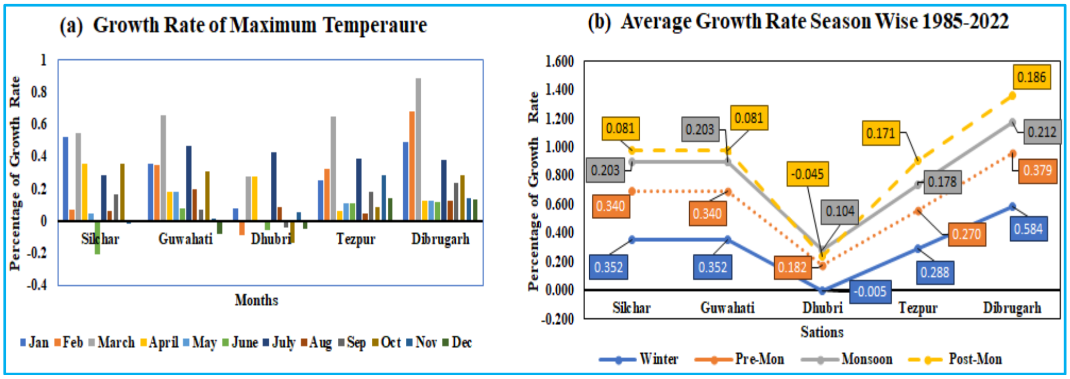
Fig. 3 represents the season wise statistical models of Silchar station for monthly maximum temperature data. Similarly, the models for monthly mean maximum temperature can be defined season wisefor the remaining stations also, *i.e.*, Dibrugarh (1985-2022), Guwahati (1985-2022), Dhubri (1985-2022) and Tezpur (1985-2022). Also, in case of monthly mean minimum temperature, the models are given in tabular form.

Table 3 represents the time series statistical model season wise for all selected station from various zones of Assam. Using these models, forecast can be done for next succeeding years; which will help in multiple dimensions of our daily life work, for example agriculture, sports,

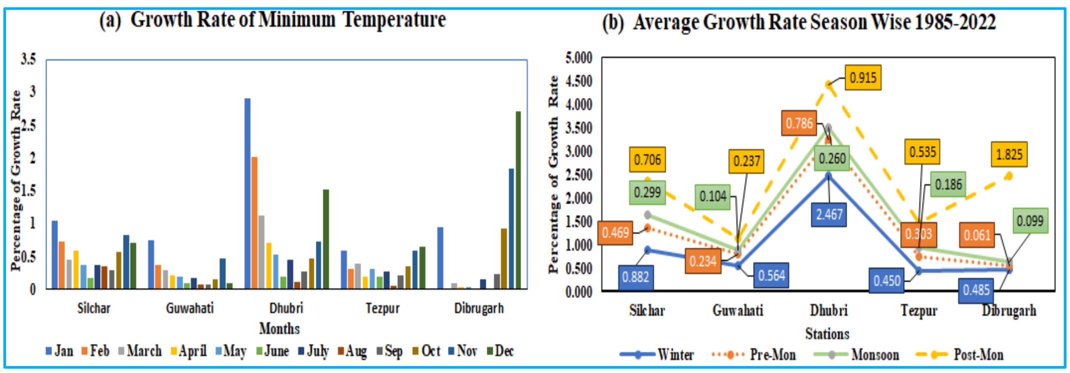
TABLE 3

Statistical models for monthly mean maximum temperature and monthly mean minimum temperature

Stations	Seasons	Models
Monthly Mean Maximum Temperature		
Guwahati (1985-2022)	Winter	SARIMA (0,0,1)(0,1,1)[2]
	Pre- Monsoon	SARIMA (1,0,0) (0,1,1) [3]
	Monsoon	SARIMA (1,1,1) (1,1,1) [4]
	Post-Monsoon	SARIMA (1,0,0) (0,1,1) [3]
Dhubri (1985-2022)	Winter	SARIMA (0,0,0) (0,1,1) [2]
	Pre- Monsoon	SARIMA (2,0,0) (2,1,0) [3]
	Monsoon	SARIMA (3,1,0) (2,1,0) [4]
	Post-Monsoon	SARIMA (0,1,1) (0,1,1) [3]
Tezpur (1985-2022)	Winter	SARIMA (1,1,0) (0,0,1) [2]
	Pre- Monsoon	SARIMA (2,1,0) (2,1,1) [3]
	Monsoon	SARIMA (0,1,1) (0,1,1) [4]
	Post-Monsoon	SARIMA (0,1,1) (0,1,2) [3]
Dibrugarh (1985-2022)	Winter	SARIMA (1,1,0) (0,0,1) [2]
	Pre- Monsoon	SARIMA (2,1,0) (2,1,1) [3]
	Monsoon	SARIMA (1,1,1) (1,1,1) [4]
	Post-Monsoon	SARIMA (0,1,1) (0,1,1) [3]
Monthly Mean Minimum Temperature		
Silchar (1986-2022)	Winter	SARIMA (1,1,0) (1,1,2) [2]
	Pre- Monsoon	SARIMA (1,0,2) (2,1,0) [3]
	Monsoon	SARIMA (2,0,0) (1,1,2) [4]
	Post-Monsoon	SARIMA (2,1,0) (0,1,2) [3]
Guwahati (1985-2022)	Winter	SARIMA (1,1,0) (2,0,2) [2]
	Pre- Monsoon	SARIMA (0,0,1) (0,1,1) [3]
	Monsoon	SARIMA (1,0,0) (2,1,0) [4]
	Post-Monsoon	SARIMA (1,0,0) (0,1,1) [3]
Dhubri (1985-2022)	Winter	SARIMA (1,1,0) (0,1,2) [2]
	Pre- Monsoon	SARIMA (0,1,2) (0,1,2) [3]
	Monsoon	SARIMA (2,0,0) (2,1,1) [4]
	Post-Monsoon	SARIMA (1,0,0) (2,1,2) [3]
Tezpur (1985-2022)	Winter	SARIMA (1,1,0) (2,1,2) [2]
	Pre- Monsoon	SARIMA (2,1,0) (1,1,2) [3]
	Monsoon	SARIMA (0,1,1) (2,1,0) [4]
	Post-Monsoon	SARIMA (1,1,1) (0,1,1) [3]
Dibrugarh (1985-2022)	Winter	SARIMA (1,1,0) (2,1,1) [2]
	Pre- Monsoon	SARIMA (0,0,1) (0,1,1) [3]
	Monsoon	SARIMA (2,0,0) (2,1,0) [4]
	Post-Monsoon	SARIMA (1,0,0) (0,1,1) [3]



Figs. 5(a&b). Growth Rate of Maximum Temperature for the period of 1985-2022



Figs. 6(a&b). Growth Rate of Minimum Temperature for the period of 1985-2022

climate studies, tourism and hospitality, construction and transportation etc.

Alteration of temperature from one year to another year can be studied by Growth Rate. Growth Rate of maximum temperature and minimum temperature is presented in both monthly and season wise for the period of 1985-2022 and are given below:

Figs. 5(a&b) represents the growth rate of maximum temperature for five stations monthly and season wise for the period of 1985-2022. From (a), it is observed that the temperature is highly increasing in the month of March for each station except Dhubri station for the period of 1985-2022. In (b), percentages of growth rate in four seasons for five stations have been presented. In the winter season, the temperature has increased at 0.352 %, 0.352%, 0.288% and 0.584% in Silchar, Guwahati, Tezpur and Dibrugarh respectively except Dhubri station. In Dhubri station, the temperature decreased at 0.005% in winter season for the period of 1985-2022. Here positive value of growth rate means increasing and negative value shows decreasing temperature for the period of 1985-2022. In all seasons, Dibrugarh station shows highest percentage of growth rate of maximum temperature, *i.e.*, 0.584%, 0.379%, 0.212% and 0.186% for winter, pre-monsoon, monsoon and post-monsoon respectively. But maximum temperature is decreasing less in Dhubri station for the period of 1985-2022 year in all seasons.

Figs. 6(a&b) depicts that the minimum temperature have increased in the month of January in each station as shown in (a). From (b), it can be elaborated that the minimum temperature decreased in Dibrugarh station and increased in Dhubri station in the period of 1985-2022 in all seasons.

3.2. *Season wise suitable extreme value distribution for monthly mean maximum temperature and minimum temperature of all station*

Table 4 shows how temperature can be explained by Extreme Value distribution (EVD's) season wise. Information about temperature for each station is divided into four seasons, the temperature data have been attempted to fit with the help of three types of extreme

TABLE 4

Best fit of Extreme Value Distributions (EVD's) in Temperature of various zones of Assam

Stations	Seasons	Best fit	Goodness of fit				K-S test	
			Estimates	Log L	AIC	BIC	Distance (D)	p-value
Monthly Mean Maximum Temperature								
Silchar (1986-2022)	Winter	Gumbel EVD	loc=275.576 (0.2129) scale=1.730 (0.1534)	309.950	313.950	318.558	0.0694	0.8674
	Pre-Monsoon	Weibull EVD	shape= 24.003 (1.7214) scale= 32.099 (0.1342)	402.368	406.368	411.787	0.0624	0.7804
	Monsoon	Gumbel EVD	loc=32.127 (0.0855) scale= 0.982 (0.0594)	445.056	449.056	455.051	0.0901	0.1799
	Post-Monsoon	Weibull EVD	shape= 14.736 (1.1042) scale= 30.381 (0.2064)	501.270	505.270	510.689	0.0763	0.5372
Guwahati (1985-2022)	Winter	Gumbel EVD	loc=24.441 (0.2109) scale=1.740 (0.1533)	320.523	324.523	329.184	0.0651	0.9040
	Pre-Monsoon	Weibull EVD	shape=21.01 (1.3827) scale= 31.765 (0.1498)	432.505	436.505	441.977	0.0855	0.3739
	Monsoon	Gumbel EVD	loc= 32.137 (0.0818) scale=0.953 (0.0585)	454.988	458.988	465.036	0.0695	0.4538
	Post-Monsoon	Weibull EVD	shape= 11.856 (0.8476) scale= 29.463 (0.2464)	549.183	553.183	558.655	0.0775	0.4986
Dhubri (1985-2022)	Winter	Weibull EVD	shape= 12.870 (1.1808) scale= 24.789 (0.2332)	332.491	336.491	341.153	0.1245	0.1892
	Pre-Monsoon	Weibull EVD	shape= 20.818 (1.3197) scale= 30.889 (0.1474)	421.323	425.323	430.795	0.1098	0.1279
	Monsoon	Gumbel EVD	loc= 30.819 (0.0739) scale= 0.8606 (0.0517)	419.940	423.940	429.987	0.0852	0.2192
	Post-Monsoon	Weibull EVD	shape= 12.006 (0.8880) scale= 27.631 (0.2276)	537.138	541.138	546.610	0.0921	0.2880
Tezpur (1985-2022)	Winter	Gumbel EVD	loc= 24.019 (0.2115) scale= 1.743 (0.1530)	320.020	324.020	328.681	0.7290	0.8140
	Pre-Monsoon	Weibull EVD	shape= 20.413 (1.3715) scale= 30.613 (0.1486)	432.446	436.446	441.918	0.0834	0.4057
	Monsoon	Weibull EVD	shape= 33.290 (1.9626) scale= 32.360 (0.0835)	447.808	451.808	457.855	0.0882	0.1876
	Post-Monsoon	Weibull EVD	shape= 12.003 (0.8685) scale= 29.248 (0.2413)	547.061	551.061	556.534	0.0821	0.4256
Dibrugarh (1985-2022)	Winter	Gumbel EVD	loc= 23.331 (0.1917) scale= 1.580 (0.1350)	303.233	307.233	311.894	0.0635	0.9191
	Pre-Monsoon	Weibull EVD	shape= 15.740 (1.1088) scale= 29.052 (0.1831)	482.117	486.117	491.590	0.1060	0.1538
	Monsoon	Gumbel EVD	loc= 30.900 (0.0841) scale= 0.890 (0.0593)	460.924	464.924	470.971	0.0679	0.4843
	Post-Monsoon	Weibull EVD	shape= 12.229 (0.8698) scale= 29.027 (0.2354)	538.428	542.428	547.901	0.0673	0.6785

TABLE 4 (*Contd.*)

Stations	Seasons	Best fit	Goodness of fit				K-S test	
			Estimates	-2Log L	AIC	BIC	Distance (D)	p-value
Monthly Mean Minimum Temperature								
Silchar (1986-2022)	Winter	Gumbel EVD	loc= 12.473 (0.1621) scale= 1.335 (0.1115)	275.156	279.155	283.817	0.0703	0.8457
	Pre-Monsoon	Weibull EVD	shape= 10.073 (0.7404) scale= 21.777 (0.2136)	521.139	525.139	530.612	0.0634	0.7484
	Monsoon			doesn't follow				
	Post-Monsoon	Gumbel EVD	loc= 16.457 (0.3420) scale= 3.451 (0.2506)	636.761	640.761	646.233	0.1165	0.0902
Guwahati (1985-2022)	Winter	Gumbel EVD	loc= 11.288 (0.1430) shape= 1.180 (0.1028)	260.706	264.706	269.367	0.0748	0.7888
	Pre- Monsoon	Weibull EVD	shape= 8.831 (0.6722) scale= 21.077 (0.2355)	545.690	549.690	555.162	0.1203	0.0737
	Monsoon	Weibull EVD	shape= 43.449 (2.7102) scale= 25.744 (0.0507)	310.620	314.620	320.668	0.0639	0.5628
	Post-Monsoon	Weibull EVD	shape= 4.861 (0.3642) scale= 18.903 (0.3847)	641.567	645.567	651.039	0.1217	0.0682
Dhubri (1985-2022)	Winter	Weibull EVD	shape= 6.010 (0.5482) scale= 13.650 (0.2746)	350.262	354.262	358.924	0.0698	0.8524
	Pre-Monsoon	Weibull EVD	shape= 10.173 (0.7802) scale= 21.746 (0.2101)	526.953	530.953	536.425	0.0805	0.4505
	Monsoon	Weibull EVD	shape= 28.295 (1.7027) scale= 26.049 (0.0788)	437.886	441.886	447.934	0.0800	0.2848
	Post-Monsoon	Gumbel EVD	loc= 15.833 (0.3813) shape= 3.843 (0.2710)	657.210	661.210	666.683	0.0888	0.3296
Tezpur (1985-2022)	Winter	Weibull EVD	shape= 9.745 (0.8676) scale= 13.317 (0.1658)	275.006	279.006	283.668	0.14396	0.0857
	Pre-Monsoon	Weibull EVD	shape= 9.854 (0.7292) scale= 20.988 (0.2107)	516.811	520.811	526.283	0.0958	0.2459
	Monsoon	Weibull EVD	shape= 33.876 (2.0525) scale= 25.460 (0.0644)	377.544	381.544	387.592	0.0659	0.5232
	Post-Monsoon	Weibull EVD	shape= 4.955 (0.3664) scale= 18.707 (0.3739)	633.498	637.498	642.971	0.1189	0.0802
Dibrugarh (1985-2022)	Winter	Weibull EVD	shape= 7.778 (0.6973) scale= 12.167 (0.1895)	294.780	298.779	303.441	0.1074	0.3443
	Pre-Monsoon	Weibull EVD	shape= 8.729 (0.6370) scale= 20.315 (0.2306)	532.895	536.895	542.368	0.1040	0.1694
	Monsoon	Weibull EVD	shape= 41.800 (2.6248) scale= 24.919 (0.0509)	315.478	319.478	325.526	0.0612	0.6195
	Post-Monsoon	Weibull EVD	shape= 4.209 (0.3142) scale= 17.585 (0.4134)	653.368	657.368	662.840	0.1189	0.1794

value distribution. In the fitting process, there are some criteria's, Kolmogorov-Smirnov (K-S) test, log likelihood (log L), AIC and BIC. Among these p-value of K-S test defines whether the data set for the particular season follow the extreme value distribution or not. The null hypothesis of this test is the data set follows the required distribution when the p-value > 0.05 (at 5% level of significance) and Kolmogorov distance (D) indicates the absolute maximum distance between the sample distribution of temperature for a particular season to the reference distribution. Smaller the value of log L, AIC (Akaike Information Criterion) and BIC(Bayesian Information Criterion) gives better fit of EVD's.

where $AIC = -2\log L\left(\hat{\theta}\right) + 2k$, $L\left(\hat{\theta}\right) = L\left(x_1, x_2, ..., x_n; \hat{\theta}\right)$ is the maximum likelihood function for the estimated model. $\hat{\theta}$ is Maximum Likelihood Estimate (MLE) of $\left(\theta_1, \theta_2, ...\theta_n\right)$ for which likelihood function is maximum, k is number of parameters of a model, n is the size of data. AIC balances the lack of fit and model complexity, so smaller the value of AIC indicates the better model. $BIC = k\log(n) - 2\log L\left(\hat{\theta}\right)$, Minimum value of BIC indicates the higher posterior probability.

Table 4 interprets, each season of each station following extreme value distribution with a p- value >0.05. It means each season of each station follows an extreme value distribution in the period of 1985-2022 in case of both monthly mean maximum temperature and monthly mean minimum temperature.

4. Conclusion

Climate changes not only in India but all over the regions across the world and the state Assam 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 (ASTEC, 2011). In this research work, the descriptive statistics of temperature for each station is defined to get a frame of dispersions in between themselves from 1985 to 2022 in both directions, *i.e.*, maximum and minimum temperature. In case of maximum temperature, Dhubri (2.193), Dibrugarh (1.941), Dibrugarh (1.086) and Tezpur (2.645) shows highest variability in winter, pre-monsoon, monsoon and post-monsoon respectively. Similarly, Dhubri (2.472), Guwahati (2.722), Dhubri (1.050) and Dibrugarh (4.303) shows highest in winter, pre-monsoon, monsoon and post-monsoon in case of minimum temperature from 1985-2022.

In the period 1985 to 2022, the temperature is highly increasing in the month of March for each station except Dhubri station in case of maximum temperature and Dibrugarh station shows highest percentage of growth rate of maximum temperature, *i.e.*, 0.584%, 0.379%, 0.212% and 0.186% in winter, pre-monsoon, monsoon and post-monsoon respectively. But Dhubri station shows least growth in the period of 1985-2022. On the other hand, in case of minimum temperature for January month, temperature is increasing for each season in each station and percentage of growth rate of temperature is highest in each season for Dhubri station and least in Dibrugarh station from 1985-2022. The time series statistical model is defined for each season in each station for predicting temperature in both dimensions for next 5 years. The best extreme value distribution is fitted in each season for all stations by calculating -2 Log L, AIC, BIC and K-S test to get idea about the temperature pattern through extreme value analysis.

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