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SARIMA models forecasting of weather parameters for Thrissur district

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Abstract

A novel attempt has been made to construct prediction models for weather parameters of Thrissur District in Kerala using SARIMA (Seasonal Auto Regressive Integrated Moving Average) models. Assessment of trend and identification of the best SARIMA model for forecasting weather in Thrissur District were the major objectives of the study. Excellent parsimonious forecasting equations could be generated using the SARIMA technique for the parameters studied. Validity of the models was tested using standard statistical techniques. The forecasting power of SARIMA model was used to forecast six leading years and the forecasted values are recorded. The results showed good agreement between actual and predicted values.

Keywords: Seasonality, SARIMA, rainfall, temperature, wind speed, relative humidity, cloud, Kerala

Introduction

Climate change and variability in recent decades are subjects of worldwide discussion as the weather related disasters viz., droughts, floods, ice storms, dust storms, hailstorms, landslides, heat and cold waves and thunder storms are not uncommon over one or another region of the world. Warming of the climate system is unequivocal. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished and sea level has risen (IPCC, 2014) [7]. The range of temperature increase by end of the 21st century was projected to be between 1.1 to 6.4 °C across all scenarios. The report points out that if the temperature increases beyond 2.5 °C, then 20 to 30 per cent of known animal and plant species would be at increased risk of extinction. If the global average temperature increase exceeded 3.5 °C, models suggested that there would be extinctions of 40 to 70 per cent of known species (IPCC, 2014) [7]. India is one of the 27 Countries identified as most vulnerable to the impact of global warming. Lal *et al.*, (1995) [17] predicted an increase in annual mean maximum and minimum surface air temperatures of 0.7 °C and 1.0 °C over land in the 2040s with respect to the 1980s. Lonergan (1998) [19] estimates that India's climate could become warmer under conditions of increased atmospheric carbon dioxide. The average temperature change is predicted to be in the range of 2.33 °C to 4.78 °C with doubling in CO_2 concentrations. Lal *et al.*, (2001) [18], Kumar and Ashrit (2001) [16], Kumar *et al.*, (2002 and 2003) also predicted the temperature and rainfall trends over India under varied CO_2 levels. Guhathakurta and Rajeevan (2007) observed decreasing trend in almost all subdivisions except for subdivisions Himachal Pradesh, Jharkhand and Nagaland, Manipur, Mizoram and Tripura during winter. Annual rainfall showed significant decreasing trend over Chhattisgarh, Jharkhand and Kerala. During southwest monsoon, Jharkhand, Chhattisgarh and Kerala showed significant decreasing trend in rainfall. Ramesh and Goswami (2007) [9, 23] observed that decreasing trends in both early and late monsoon rainfall and number of rainy days for the period of 1951-2003, implying a shorter monsoon over India. Guhathakurta *et al.*, (2011) [5] have studied the changes in the frequency of rainy days, rain days as well as heavy rainfall days using the daily rainfall data for the period 1901-2005 all over India. It is a fact that climate change is real and is happening across the world in different magnitudes.

Thrissur is the cultural capital of Kerala and the fourth largest city in the God’s Own Country (Kerala State, India), which lies between North Latitudes 10° 10’ 22” and 10° 46’ 54” and East Longitudes 75° 57’ 20” and 76° 54’ 23”. The climate of Thrissur is typical to the climate of Kerala i.e., Tropical monsoon (humid) type. The district is characterized by dry weather during summer months (March-May) with intermittent summer showers, blessed with two rainy seasons ie., southwest monsoon (June-September) and post monsoon (October -November) and pleasant winter months (December - February). The district is blessed with pleasant and periodic wind from November fortnight to February fortnight, known as the *vrischika kaattu* (the wind blowing during the local calendar *Vrischikam though Makaram*). The wind is characterised with heavy speed and having no moisture content as it passes through the Palakkad Gap of the Western Ghats and subsequently gains momentum. The district has a tropical humid climate with an oppressive hot season and plentiful of seasonal rainfall.

Studies indicate that the State of Kerala is warming over a period of time. The India Meteorological Department has reported that the mean maximum temperature over the State has increased by 0.8 °C, mean minimum temperature by 0.2 °C and the average temperature by 0.5 °C between 1961 to 2003. Gopakumar (2017) [3] has reported that the mean annual temperature across the State of Kerala has increased by 0.65 °C (@0.011 °C/year) over a period time from 1956 to 2014. The increase in maximum temperature was 0.99 °C (@0.0169 °C/year) while that of minimum temperature was 0.31 °C(@0.0053 °C/year) during the same period (1956 to 2014). He has further reported that the rate of increase in temperature is high across the coastal belt when compared to mid and high range areas in the State. Further, the rate of increase in temperature was high during the post monsoon (0.76 °C over a period of six decades since 1956) followed by monsoon (increase of 0.732 °C over a period of six decades since 1956).

Annual rainfall across the State of Kerala is showing a declining trend since last six decades. The decline in southwest monsoon rainfall is conspicuous. Soman *et al.,* (1988) [25] reported that rainfall in Kerala showed significantly decreasing trend. Krishnakumar *et al.,* (2007) [14] have reported that the rainfall in June and July was declining while increasing in August and September across the State of Kerala after analyzing the rainfall data of the State. Krishnakumar *et al.,* (2009) [11, 12] studied the temporal variation in monthly, seasonal and annual rainfall over Kerala during the period from 1871 to 2005 and reported significant decrease in southwest monsoon rainfall and increase in post-monsoon rainfall.

Important aspect of the rainfall trend across the State of Kerala in the twentieth century was the significant decrease in the southwest monsoon rainfall and increase in post monsoon rainfall (Krishnakumar *et al.,* 2009) [11, 12]. There were large intra-regional differences in the trends in different seasons and local changes were found different from the large spatial scale averages in Kerala (Pal and Al-Tabba, 2009) [21]. Winter and autumn extreme rainfall were found to be having an increasing tendency with statistically significant changes in some regions indicating more occurrences of winter and autumn flood. Pillai *et al.* (2009) [22] analysed the trend of rainfall and the number of rainy days over 25 years and estimated regression models for Vellayani, Thiruvananthapuram. Unnikrishnan and Ajitha (2009) [26] developed a time series model for forecasting the onset of monsoon in Kerala using the data from 1870 to 2009. Gopakumar (2011) [11] revealed that the southwest monsoon rainfall in Kerala has been declining while increasing in post monsoon season. The annual rainfall exhibited a cyclic trend of 40-60 years, with a significant decline in recent decades and the moisture index across the State of Kerala indicate that the State was moving from wetness to dryness within the humid climate.

SARIMA models are the most general forecasting models with high degree of accuracy. Considering the importance and unavoidable role of seasons in Kerala, time series models were developed using Seasonal Auto Regressive Integrated Moving Average (SARIMA) for forecasting monthly parameters for the Thrissur District. No previous attempts were seen to analyse the rainfall and temperature trends in the District using SARIMA model. Hence, an attempt has been made in the present paper to analyse the rainfall and temperature trends for the Thrissur District of Kerala using the SARIMA model.

Materials and methods

The present investigation was carried out at the Department of Statistics, Farook College during the period from 2012-2017. The study analysed the maximum temperature (°C), minimum temperature (°C), humidity at 7am and 2pm, cloud hours at 7am and 2pm, total rainfall (mm), number of rainy days and wind speed (km/hr.) trends for the Thrissur District of Kerala State, India.

Daily weather data recorded at the Principal Agro-meteorological Observatory at the Main Campus of the Kerala Agricultural University and maintained by the Department of Agricultural Meteorology, College of Horticulture, Kerala Agricultural University, Vellanikkara were collected for the period from 1983 to 2015. Monthly means were worked out using the daily data. An attempt has been made to develop new statistical tools for forecasting weather of Thrissur District. The main items of observations include maximum and minimum temperature, average/mean temperature and rainfall.

Classical time series decomposition analysis was performed (Anderson, 1971) [1] for each of the weather parameters under study. Through this approach time series data were decomposed to identify four basic components, viz., the trend, seasonal fluctuations and cyclic variations and irregular. The multiplicative model of decomposition of the form $Y = T*S*C*I$, where Y denote the value corresponding to the dependent variable, S the seasonal component, C the cyclical part and I the irregular random component was used for the analysis.

Box and Jenkins method is applied to fit forecasting models. This can apply only to stationary time series data. A time series is stationary on the space $Rh+1$ if the distribution of the vector of observations $(Xt, Xt+1, Xt+2,\ldots, Xt+h)$ is independent of t, $h \in N$. Many time series in real life are not stationary. A non-stationary sequence has to be transformed to a stationary sequence before attempting to apply a model for the same. A time series Xt is said to be an ARIMA (p,d,q) process if there exists polynomials Φ and Θ of degrees p and q respectively and a white noise series Zt such that $\Phi(B)\Delta dXt = \Theta(B)Zt$ under the assumption that the time series ΔdXt is stationary on the underlying probability space, where B denote the back shift operator $B(X_t) = X_{t-1}$. When d=0, $Xt = [\Theta(B)/\Phi(B)]Zt$, is a stationary ARMA(p,q) process and in this case all the zeroes of the polynomial $\Phi(z)$ lie outside the unit circle $|z| < 1$. When it has one or more values equal to one but no value inside the unit circle, it is nonstationary but integrated. In this case the time series is an ARIMA process. In general when the function $[\Theta(B)/\Phi(B)]$ is well defined and analytic in the region $\{z \in C \mid \Phi(z) \neq 0\}$, if Φ has no roots on the circle $\{z \mid |z|=1\}$. Since it has p different roots there is an annulus $\{z/r<|z|<R\}$ with $r<1<R$ on which it has no root. On this annulus $[\Phi(B)/ \Theta(B)$ is analytic and it has a Laurent's series expansion $\Gamma(z)= \Sigma\Gamma_j B^j$ This series is uniformly and absolutely convergent on every compact subset of the annulus and the coefficients are uniquely determined by the value of Xt on the annulus. Hence the random variables Xt and Zt are defined on a probability space (Ω,U,P) and satisfying $\Phi(B)\Delta dXt(\omega) = \Theta(B)Zt\ (\omega)$ for almost every $\omega\ \varepsilon\ \Omega$.

Then the equation $\Phi(B)\Delta dXt = \Theta(B)Zt$ takes the form $Xt = \phi 1Xt\text{-}1+\phi 2Xt\text{-}2+...+\phi pXt\text{-}p + Zt+\theta 1Zt\text{-}1+\theta 2Zt\text{-}2 +...+\theta qZt\text{-}q$

For a stationary time series, the auto covariance and auto correlation at a lag $k \in Z$ are defined by $\gamma X(k) = \mathrm{cov}(Xt+k, Xt)$ and $\rho X(k)) = \rho(Xt+k, Xt) = \gamma X(k))/ \gamma X(0))$, where $\gamma X(0)= \mathrm{Var}(Xt)$ and $\rho X(0) = 1$. The partial auto correlation at a lag k is defined as the correlation between $Xk - \Pi k\text{-}1(Xk)$ and $X0 - \Pi k\text{-}1(X0)$, where Πk is the projection of the vector $y \in Rk$ on the subspace spanned by $(X1,X2,\dots Xk)$ in Rk which is a linear combination $y=\Sigma bjxj$ such that $\|y\text{-}y^\wedge\|$ is minimal. This is the correlation due to intermediate values $X1,X2,\dots Xk\text{-}1$ removed.

Seasonal ARIMA Modeling

Identification of relevant models and inclusion of suitable seasonal variables are necessary for seasonal modeling and their applications. The Seasonal ARIMA, ARIMA (p,d,q) $(P,D,Q)_s$ are defined by seven parameters. The seasonal part of an ARIMA model has the same structure as the non-seasonal part. It may have an AR factor, an MA factor and/or an order of differencing. In the seasonal part of the model, all of these factors operate across multiples of lag's' (the number of periods in a season). A seasonal ARIMA model is classified as an ARIMA (p,d,q) $(P,D,Q)_s$ model, where, P is the number of seasonal autoregressive (SAR) terms, D is the number of seasonal differences, Q is the number of seasonal moving average (SMA) terms.

A general AR model with P SAR parameters is given by $Y_t = \sum \alpha_{is} Y_{t\text{-}is\ I=1\text{ to }p.}$

Where $Y_{t\text{-}s}$ is of order s, $Y_{t\text{-}2s}$ is of order 2s and $Y_{t\text{-}ps}$, is of order ps. A model with one SAR parameter is written as $Y_t = \alpha_s Y_{t\text{-}s} + e_t$

Seasonal Moving Average (SMA) models are built with seasonal moving average (SMA) parameters, and the general SMA model with Q parameters is given by: $Y t = \sum\theta_{is} Y_{t\text{-}is} + e_t$

The general mixed SAR and SMA model is given by $Y_t = \sum \alpha_{is} Y_{t\text{-}is} +\sum\theta_{is} Y_{t\text{-}is} + e_t$

In identifying a seasonal model, the first step is to determine whether or not a seasonal difference is needed, in addition to or perhaps instead of a non-seasonal difference. By looking at the time series plots correlogram for all possible combinations of 0 or 1 non seasonal differences and 0 or 1 seasonal differences, the differences can be fixed. It is not good to use more than one seasonal and more than two non-seasonal differences. The signature of pure SAR or pure SMA behavior is similar to the signature of pure AR or pure MA behaviour, except that the pattern appears across multiples of lag's' in the ACF and PACF. For example, a pure SAR (1) process has spikes in the ACF at lags s, 2s, 3s, etc., while the PACF cuts off after lag s. Conversely, a pure SMA (1) process has spikes in the PACF at lags s, 2s, 3s, etc., while the ACF cuts off after lag s. An SAR signature usually occurs when the autocorrelation at the seasonal period is positive, whereas an SMA signature usually occurs when the seasonal autocorrelation is negative.

If the autocorrelation at the seasonal period is positive, it is good to add one SAR term to the model. If the autocorrelation at the seasonal period is negative, it is better to add an SMA term to the model. It is not a good practice to mix with SAR and SMA terms in the same model. Usually an SAR (1) or SMA (1) term is sufficient. Although a seasonal ARIMA model seems to have only a few parameters, back forecasting requires the estimation of one or two seasons' worth of implicit parameters to initialize it. Therefore, it should have at least 4 or 5 seasons of data to fit a seasonal ARIMA model. Probably the most commonly used seasonal ARIMA model is the (0, 1, 1)×(0, 1, 1) model i.e., a MA(1) * SMA(1) model with both seasonal and a non-seasonal difference. This is essentially a "seasonal exponential smoothing" model. When seasonal ARIMA models are fitted to *lag* data, they are capable of tracking a *multiplicative* seasonal pattern.

The best model is selected by using the diagnostic such as Coefficient of determination (R^2), Akaike Information Criteria (AIC)/Bayesian Information Criteria (BIC), Portmonteau tests - Box Pierce or Ljung-Box Q-tests, the Percentage Forecast Inaccuracy (PFI), Root Mean Square Error (RMSE), Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE).

Saha *et al*. (2016) [2] used SARIMA time series modelling to fit the monthly average maximum and minimum temperature data sets collected at Giridih, India for the years 1990-2011. Goswami *et al*. (2017) [9, 23] studied monthly temperature record in the Dibrugarh region using the Box-Jenkins (SARIMA) methodology. The analysis results revealed that the models' are adequately fitted to the historical data. Inderjeet Kaushik1 and Sabita Madhvi Singh (2008) observed Seasonal ARIMA models can predict minimum and maximum temperature with good accuracy as statistics of models indicate. G. Sathish *et al*. 2017 [24] used SARIMA model and found to be most suitable for forecasting total monthly rainfall over the Gangetic West Bengal. This model was considered appropriate to forecast the monthly rainfall for the next ten years in the Gangetic West Bengal region to assist policy makers to establish priorities for water demand, storage, distribution and disaster management.

The real power and attractiveness of this method is that it can handle complex patterns using a relatively well specified set of rules. The Box-Jenkins methodology of forecasting is different from most methods because it does not assume any particular pattern in the historical data of the series to be forecasted. It uses an iterative approach to identify a possible model from a general class of models. The chosen model is then checked against the historical data to see whether it accurately describes the series. The model fits well if the residuals are generally small, randomly distributed and contain no useful information. If the specified model is not satisfactory, the process is repeated using a new model designed to improve on the original one. This iterative procedure continues until a satisfactory model is found.

Results and discussion

Seasonal indices were worked out for each parameters assuming multiplicative model of decomposition given by $Y_t = T\ X\ S\ X\ C\ X\ I$, where T denote the general long term behavior of the series known as Trend, S denote the seasonality index, C denote the cyclic behavior of the time series and I the irregular random component of the series. The irregular part is identified by removing the trend, seasonality and cyclical parts. They are short term fluctuations on account of climatic deviations.

Table 1: Seasonal indices in based on Months

Month	Rainfall	Rainy Days	Wind speed	Highest maximum temp.	Lowest minimum temp.	RH I	RH II
Jan	0	2	181	101	90	85	67
Feb	4	7	128	107	94	89	63
Mar	7	14	97	111	103	97	73
Apr	34	56	82	110	105	100	93
May	82	91	80	104	105	103	104
Jun	311	222	76	97	104	109	129
Jul	275	231	72	91	103	110	131
Aug	190	198	72	92	104	110	126
Sep	119	146	67	95	105	108	117
Oct	130	145	65	98	102	106	115
Nov	41	68	107	97	96	97	100
Dec	7	21	175	97	90	87	81

From Table 1, it could be observed that the rainfall is maximum in June and July months and the wind speed is above normal during November to February. Wind speed is very low in September and October. The highest maximum temperature is high during March and April whereas the lowest minimum temperature is high during April, May, June, August and September. Relative humidity is showing high during June, July and August with very low in January and February.

Table 2: Seasonal indices if Malayalam (Regional Calendar) months are used

Month	Rainfall	Rainy Days	Average Wind speed	Highest max temp.	Lowest minimum temp.	RH I	RH II
Medam	51.0	62.6	80.3	107.4	105.6	101.1	97.4
Edavam	185.6	160.0	78.1	101.7	104.7	106.1	116.3
Midhunam	313.3	234.3	73.1	92.0	102.8	109.9	131.4
Karkitakam	244.9	222.6	71.2	91.1	103.3	110.3	130.2
Chingam	145.3	167.7	69.5	92.8	104.8	108.9	121.5
Kanni	125.0	148.1	62.5	97.3	103.4	107.0	116.6
Thulam	89.8	116.4	78.5	97.4	99.6	102.6	108.9
Vruschikam	18.1	35.2	143.0	97.0	92.6	90.4	90.1
Dhanu	2.8	10.3	186.6	98.4	89.8	85.8	75.3
Makaram	1.3	2.6	162.1	103.7	89.5	84.8	63.3
Kumbham	5.9	10.5	108.8	109.8	97.5	93.4	64.9
Meenam	16.8	29.7	86.1	111.4	106.3	99.7	84.0

From Table 2, it could be observed that the rainfall is maximum in *Midhunam* and *Karkitakam* months and the wind speed is above normal during *Vrischikam*, *Dhanu* and *Makaram*. Wind speed is very low in *Chingam* and *Kanni* months. The highest maximum temperature is high during *Kumbham* and *Meenam* whereas the lowest minimum temperature is high during *Meenam*, *Medam* and *Edavam.* Relative humidity is showing high during *Midhunam, Karkkitakam* and *Chingam* with very low in *Dhanu*, *Makaram and Kumbham.*

SARIMA Modeling

1. Highest Maximum Temperature

The software SPSS ranked SARIMA (0, 0, 2) (0, 1, 1)$_{12}$ as the best model having the lowest Normalized Bayesian Information Criteria for forecasting maximum temperature in Thrissur District. The model is having an R^2 of 0.822 indicating that 82.2 percentage of variation in the data could be explained by the model and the MAPE was 2.263 percentage with RMSE of 1.153 indicating that the forecasting error is very low. The estimates of the parameters of the model are given in Table 3.

Table 3: Parameters for SARIMA (0, 0, 2) (0, 1, 1)$_{12}$ model for highest maximum temperature

		Estimate	SE	t	Sig.
MA	Lag 1	-.220	.051	-4.348	.000
MA	Lag 2	-.184	.050	-3.664	.000
MA, Seasonal	Lag 1	.862	.033	25.997	.000

2. Minimum of Minimum temperature

SARIMA (0, 0, 2) (0, 1, 1)$_{12}$ was identified as the best model having the lowest Normalized Bayesian Information Criteria for forecasting minimum temperature in Thrissur District. The model is having an R^2 of 0.472 indicating that 47.2 percentage of variation in the data could be explained by the SARIMA (0,0,2)(0,1,1)$_{12}$ model and the MAPE was observed as 4.339 percentage with RMSE of 1.146 indicating the good forecasting power of the model. The estimates of the parameters of the model are given in Table 4.

Table 4: Parameters for SARIMA (0, 0, 2) (0, 1, 1)$_{12}$ model for lowest minimum temperature

		Estimate	SE	t	Sig.
MA	Lag 2	-.129	.050	-2.549	.011
MA, Seasonal	Lag 1	.933	.039	24.036	.000

3. Average Monthly Rainfall

SARIMA (0, 0, 0) (0, 1, $0)_{12}$ was identified as the best model for forecasting monthly average rainfall in Thrissur District. The model is having an R^2 of 0.543 indicating that 54.3 percentage of variation in the data could be explained by the model and the MAPE was 161.99 percentage. The RMSE was found to be low with 5.926. The estimates of the parameters of the model are given in Table 5.

Table 5: Parameters for SARIMA (0, 0, 0) (0, 1, $0)_{12}$ model for rainfall

	Estimate	SE	t	Sig.
Constant	.019	.302	.062	.951

4. Monthly Rainy Days

SARIMA (1, 0, 0) (0, 1, $1)_{12}$ was identified as the best model for forecasting rainy days in Thrissur District. The model is having an R^2 of 0.842 percentage indicating that 84.2 percentage of variation in the data could be explained by the model and the MAPE was 42.081 percentage with RMSE 0.138 which shows the forecasts are acceptable. The estimates of the parameters of the model are given in Table 6.

Table 6: Parameters for SARIMA (1, 0, 0) (0, 1, $1)_{12}$ model for rainy days

		Estimate	SE	t	Sig.
AR	Lag 1	.205	.050	4.087	.000
MA, Seasonal	Lag 1	.932	.035	26.544	.000

5. Average Wind Speed

SARIMA (0, 1, 1) (0, 1, $1)_{12}$ was identified as the best model for forecasting rainfall in Thrissur District. The model is having an R^2 of 0.793 indicating that 79.3 percentage of variation in the data could be explained by the model and the MAPE was 18.545 percentage and RMSE was 1.086. The estimates of the parameters of the model are given in Table 7.

Table 7: Parameters for SARIMA (0, 1, 1) (0, 1, $1)_{12}$ model for Wind speed

		Estimate	SE	t	Sig.
MA	Lag 1	.657	.039	16.778	.000
MA, Seasonal	Lag 1	.841	.034	24.747	.000

6. Average humidity

SARIMA (2, 0, 11) (0, 0, $0)_{12}$ as the best model having the lowest Normalized Bayesian Information Criteria for forecasting morning humidity in Thrissur District. The model is having an R^2 of 0.747 indicating that 74.7 percentage of variation in the data could be explained by the model and the MAPE was 3.821 percentage and RMSE was 4.116. The estimates of the parameters of the model are given in Table 8.

Table 8: Parameters for SARIMA (2, 0, 11) (0, 0, $0)_{12}$ model for morning humidity

		Estimate	SE	t	Sig.
	Constant	85.805	.415	206.694	.000
AR	Lag 1	1.494	.038	39.265	.000
	Lag 2	-.745	.034	-21.824	.000
MA	Lag 1	.720	.036	20.166	.000
	Lag 11	-.241	.030	-7.902	.000

In the case of evening relative humidity (RHII), SARIMA (0, 0, 1) (0, 1, $1)_{12}$ was the best model. The model is having an R^2 of 0.898 indicating that 89.8 percentage of variation in the data could be explained by the model and the MAPE was 6.895 percentage and RMSE was 4.726. The estimates of the parameters are given in Table 9.

Table 9: Parameters for SARIMA (0, 0, 1) (0, 1, $1)_{12}$ model for evening relative humidity (RHII)

		Estimate	SE	t	Sig.
MA	Lag 1	-.210	.050	-4.202	.000
MA, Seasonal	Lag 1	.916	.034	26.740	.000

7. Average Cloud Hours (Cloud I and Cloud II)

SARIMA $(1,0,0)(0,1,1)_{12}$ and SARIMA $(1,0,1)(0,1,1)_{12}$ were found the best models for predicting the Cloud I and Cloud II respectively. The model for cloud I is having an R^2 of 0.786 with RMSE of 0.948 and MAPE of 25.05 and Cloud II is having 0.826 of RMSE 0.815 and MAPE of 19.67. The estimates of the parameters of the model are given in Table 10 and Table 11.

Table 10: Parameters for SARIMA (1, 0, 0) (0, 1, $1)_{12}$ model for Cloud I

		Estimate	SE	t	Sig.
MA	Lag 1	.191	.071	2.699	.008
MA, Seasonal	Lag 1	.770	.054	14.134	.000

Table 11: Parameters for SARIMA (1, 0, 1) (0, 1, $1)_{12}$ model for Cloud II

		Estimate	SE	t	Sig.
AR	Lag 1	.917	.066	13.896	.000
MA	Lag 1	.792	.098	8.079	.000
MA, Seasonal	Lag 1	.835	.060	13.849	.000

Table 8: Estimated values of various weather parameters for the coming months

Month of Forecast	Highest Maximum Temperature	Average Maximum Temperature	Lowest Minimum Temperature	Average Minimum Temperature	Average RH I	Average RH II	Average Rainfall	Average Rainy Days	Average Wind speed	Average Cloud hours I	Average Cloud hours II
Jan-16	34.57	33.04	18.76	22.59	76.51	40.51	0.02	0.03	5.47	1.15	1.66
Feb-16	36.51	34.71	19.66	22.90	78.82	37.51	0.02	0.04	3.56	1.36	1.92
Mar-16	38.20	35.61	21.50	24.25	82.80	44.33	2.34	0.06	2.12	2.34	3.17
Apr-16	37.35	34.69	21.97	25.05	86.58	57.03	4.49	0.23	1.43	3.90	4.84
May-16	35.49	33.06	22.17	24.93	89.54	63.48	8.99	0.36	1.49	4.93	5.12
Jun-16	33.15	30.11	21.88	23.55	91.42	77.49	21.05	0.89	1.32	6.52	6.69
Jul-16	31.69	29.27	21.61	23.07	92.10	78.50	16.53	0.91	1.21	6.56	6.96
Aug-16	32.28	29.75	21.63	23.24	91.55	75.14	10.44	0.75	1.09	6.50	6.53
Sep-16	33.08	30.61	21.88	23.21	90.25	70.89	8.19	0.61	0.88	5.48	5.91
Oct-16	33.96	31.50	21.41	23.17	87.79	68.42	6.60	0.56	1.15	4.84	5.81
Nov-16	33.55	31.72	20.14	23.10	85.15	60.32	5.09	0.30	2.63	3.71	5.23
Dec-16	33.73	31.91	19.00	22.68	83.35	49.25	2.86	0.11	5.38	2.39	3.41
Jan-17	34.52	32.94	18.74	22.31	82.62	39.94	0.04	0.01	5.25	1.04	1.62
Feb-17	36.51	34.62	19.61	22.70	82.88	37.51	0.04	0.03	3.34	1.34	1.89
Mar-17	38.20	35.61	21.50	24.12	83.81	44.33	2.36	0.06	1.91	2.34	3.14
Apr-17	37.35	34.69	21.97	24.96	85.00	57.03	4.50	0.23	1.21	3.90	4.81
May-17	35.49	33.06	22.17	24.86	86.09	63.48	9.01	0.36	1.27	4.93	5.10
Jun-17	33.15	30.11	21.88	23.50	86.83	77.49	21.07	0.89	1.10	6.52	6.66
Jul-17	31.69	29.27	21.61	23.04	87.13	78.50	16.55	0.91	0.99	6.56	6.94
Aug-17	32.28	29.75	21.63	23.22	87.01	75.14	10.46	0.75	0.88	6.50	6.51
Sep-17	33.08	30.61	21.88	23.20	86.62	70.89	8.20	0.61	0.66	5.48	5.89
Oct-17	33.96	31.50	21.41	23.16	86.13	68.42	6.62	0.56	0.94	4.84	5.79
Nov-17	33.55	31.72	20.14	23.09	85.68	60.32	5.10	0.30	2.42	3.71	5.22
Dec-17	33.73	31.91	19.00	22.67	85.37	49.25	2.88	0.11	5.16	2.39	3.40
Jan-18	34.52	32.94	18.74	22.30	85.26	39.94	0.06	0.01	5.04	1.04	1.61
Feb-18	36.51	34.62	19.61	22.70	85.31	37.51	0.06	0.03	3.13	1.34	1.88
Mar-18	38.20	35.61	21.50	24.11	85.47	44.33	2.38	0.06	1.69	2.34	3.13
Apr-18	37.35	34.69	21.97	24.96	85.67	57.03	4.52	0.23	1.00	3.90	4.80
May-18	35.49	33.06	22.17	24.86	85.86	63.48	9.02	0.36	1.06	4.93	5.09
Jun-18	33.15	30.11	21.88	23.50	85.99	77.49	21.09	0.89	0.89	6.52	6.66
Jul-18	31.69	29.27	21.61	23.04	86.03	78.50	16.57	0.91	0.78	6.56	6.93
Aug-18	32.28	29.75	21.63	23.22	86.01	75.14	10.48	0.75	0.66	6.50	6.50
Sep-18	33.08	30.61	21.88	23.20	85.94	70.89	8.22	0.61	0.45	5.48	5.89
Oct-18	33.96	31.50	21.41	23.16	85.86	68.42	6.64	0.56	0.72	4.84	5.79
Nov-18	33.55	31.72	20.14	23.09	85.78	60.32	5.12	0.30	2.20	3.71	5.21
Dec-18	33.73	31.91	19.00	22.67	85.73	49.25	2.89	0.11	4.95	2.39	3.40
Jan-19	34.52	32.94	18.74	22.30	85.71	39.94	0.07	0.01	4.82	1.04	1.61
Feb-19	36.51	34.62	19.61	22.70	85.72	37.51	0.07	0.03	2.91	1.34	1.87
Mar-19	38.20	35.61	21.50	24.11	85.75	44.33	2.40	0.06	1.48	2.34	3.12
Apr-19	37.35	34.69	21.97	24.96	85.78	57.03	4.54	0.23	0.78	3.90	4.80
May-19	35.49	33.06	22.17	24.86	85.82	63.48	9.04	0.36	0.84	4.93	5.09
Jun-19	33.15	30.11	21.88	23.50	85.84	77.49	21.11	0.89	0.67	6.52	6.65
Jul-19	31.69	29.27	21.61	23.04	85.84	78.50	16.59	0.91	0.56	6.56	6.93
Aug-19	32.28	29.75	21.63	23.22	85.84	75.14	10.49	0.75	0.45	6.50	6.50
Sep-19	33.08	30.61	21.88	23.20	85.83	70.89	8.24	0.61	0.23	5.48	5.88
Oct-19	33.96	31.50	21.41	23.16	85.81	68.42	6.66	0.56	0.51	4.84	5.78
Nov-19	33.55	31.72	20.14	23.09	85.80	60.32	5.14	0.30	1.99	3.71	5.21
Dec-19	33.73	31.91	19.00	22.67	85.79	49.25	2.91	0.11	4.73	2.39	3.39
Jan-20	34.52	32.94	18.74	22.30	85.79	39.94	0.09	0.01	4.61	1.04	1.60
Feb-20	36.51	34.62	19.61	22.70	85.79	37.51	0.09	0.03	2.69	1.34	1.87
Mar-20	38.20	35.61	21.50	24.11	85.80	44.33	2.42	0.06	1.26	2.34	3.12
Apr-20	37.35	34.69	21.97	24.96	85.80	57.03	4.56	0.23	0.57	3.90	4.79
May-20	35.49	33.06	22.17	24.86	85.81	63.48	9.06	0.36	0.63	4.93	5.09
Jun-20	33.15	30.11	21.88	23.50	85.81	77.49	21.13	0.89	0.46	6.52	6.65
Jul-20	31.69	29.27	21.61	23.04	85.81	78.50	16.61	0.91	0.35	6.56	6.93
Aug-20	32.28	29.75	21.63	23.22	85.81	75.14	10.51	0.75	0.23	6.50	6.50
Sep-20	33.08	30.61	21.88	23.20	85.81	70.89	8.26	0.61	0.02	5.48	5.88
Oct-20	33.96	31.50	21.41	23.16	85.81	68.42	6.67	0.56	0.29	4.84	5.78
Nov-20	33.55	31.72	20.14	23.09	85.80	60.32	5.16	0.30	1.77	3.71	5.21
Dec-20	33.73	31.91	19.00	22.67	85.80	49.25	2.93	0.11	4.52	2.39	3.39

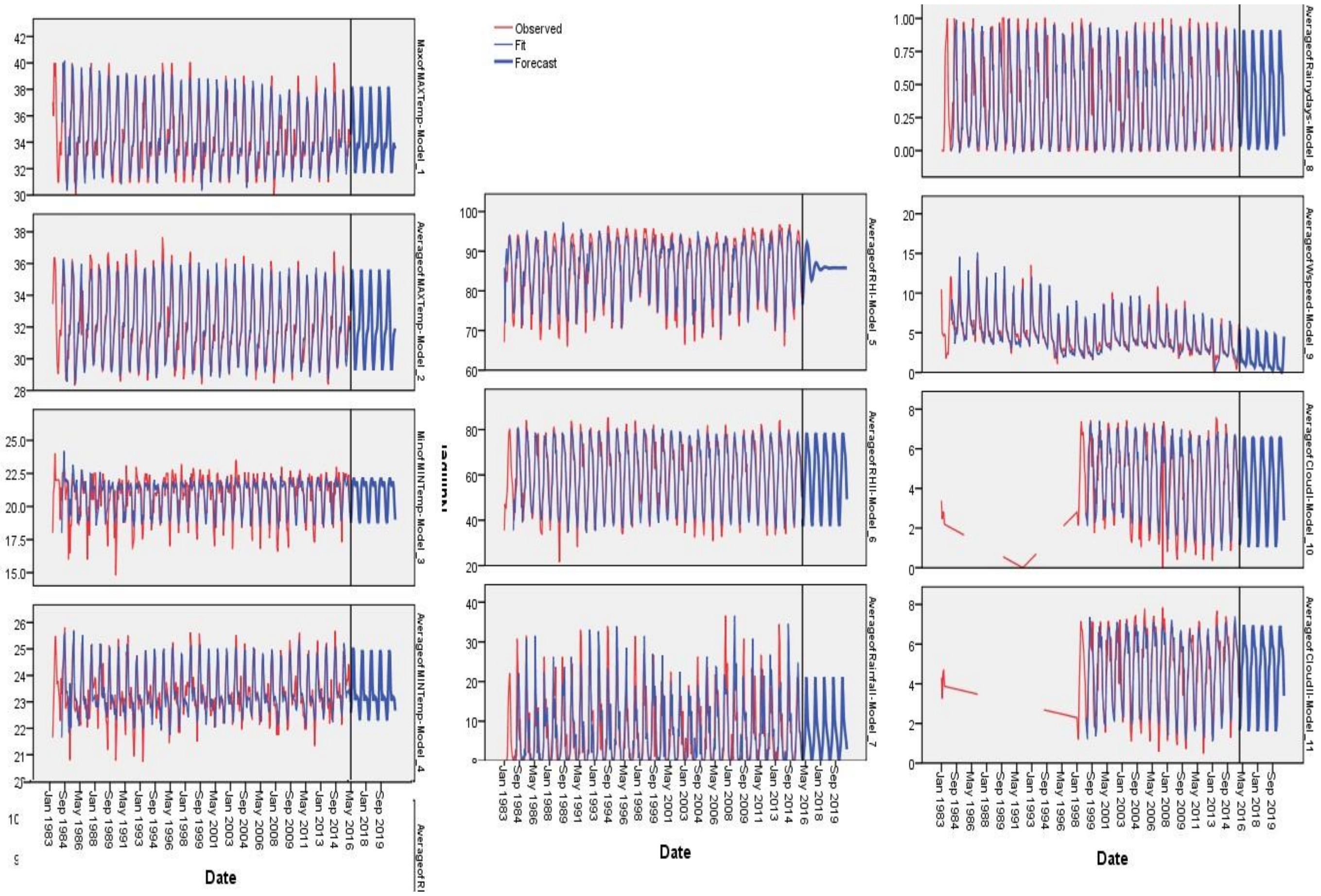

Fig 1: Observed and estimated values of various weather parameters

Conclusion

An attempt has been made to develop new statistical tools for forecasting weather in Thrissur District using SARIMA. Good fits were obtained for maximum temperature, minimum temperature, wind speed, measurements of Relative humidity at 7 am and 2pm and Average cloud hours with small MAPE and high R^2 value. In the case of rainfall and rainy days, the models were identified with a much higher MAPE and low R^2 values due to the high fluctuations in the data.

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