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Statistical Modelling of Maximum and Minimum Temperature in Thiruvananthapuram District

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Abstract: ***Time series analysis on maximum and minimum temperature using ARIMA model was done separately with the monthly mean temperature for the period from 1985-86 to 2013-14. The best fit ARIMA model for forecasting was selected based on different selection criteria viz., AIC (Akaike Information Criterion), BIC (Bayesian Information Criterion), Hannan-Quinn etc. In case of maximum temperature, ARIMA (101) (111) was the best fit one whereas ARIMA (011) (011) was best fit for minimum temperature. Mean absolute error for the forecasted maximum and minimum temperature were only 0.034 and 0.14, respectively, which showed the forecasted value and original values differ least.***
Keywords: ARIMA, Forecast, Temperature, Time series

I. INTRODUCTION

Climate change is the most important topics which is the greatest ecological, economic and social challenge of our time. Weather parameters such as temperature, rainfall, relative humidity etc. could be mainly useful for making decision and its prediction could be used for risk management. Time series analysis method have been applied to a large number of practical problems including modeling and predicting the future data according to the past.

The aim of this study is to modeling and prediction of maximum and minimum temperature of Trivandrum district in Kerala based on Box & Jenkins ARIMA model. Time-series models are better suited for predicting response to precipitation than temperature, whereas panel or cross-section models are better suited for temperature. (Lobell and Burke, 2010). A study by Unnikrishnan *et al.* (2018) on forecasting weather parameters showed that ARIMA (011) (011) is the most commonly fitted ARIMA model for seasonal parameters. Similar study by Murat *et al.* (2018) on forecasting meteorological time series data found that ARIMA models is best fit for air temperature studies.

In the study by El-Mallah and Elsharkawy (2016) on time series modelling and short term forecast of yearly temperature disclosed that the quadratic ARIMA model and linear ARIMA model had the best overall performance in making short-term forecasts of yearly total temperature in Libya. Muhammet (2012) used the ARIMA method to predict the temperature and rainfall in Afyonkarahisar Province, Turkey, until the year 2025, and found an increase in temperature according to the quadratic and linear trend models. Khedhiri (2014) studied the statistical properties of time series temperature data in Canada for the period 1913-2013 and determined a seasonal ARIMA model for the series to predict future temperature records as ARIMA modelling is found to be good fit for time series air temperature studies.

II. MATERIALS AND METHODS

The study is based on secondary data. Data on maximum and minimum temperature for Thiruvananthapuram district of Kerala was used for the analysis. Daily data corresponds to maximum and minimum temperature were recorded and maintained by the Department of Agricultural Meteorology, College of Agriculture, Vellayani were collected for the period from 1985 to 2013. Monthly mean was worked our using the daily data. An attempt was made to develop the ARIMA model for monthly mean data for forecasting separately for maximum and minimum temperature of Thiruvananthapuram district of Kerala. Descriptive statistics was done using mean, standard deviation (SD) and coefficient of variation (CV). ARIMA (Auto Regressive Integrated Moving Average) model or Box- Jenkins model, being called as (p, d, q) model, where p and q denotes the number of auto-regressive and moving average terms and d is the order of differencing, which can be expressed in the following form

$$Y_t = \theta + \alpha_1 Y_{t-1} + \alpha_2 Y_{t-2} + \cdots \alpha_p Y_{t-p} + \beta_0 u_1 + \beta_1 u_{t-1} + \beta_2 u_{t-2} + \cdots + \beta_q u_{t-q} + e_t$$

where, Y_t = Actual value, u_t= Error terms, α_i (i = 1, 2,…,p) and β_j (j =1, 2,…,q) are model parameters. (Gujarati *et al.,* 2012).

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A. Analysis Of Time Series Has Several Stages

1) Identifying the appropriate values of p, d and q.

2) Estimate the parameters of autoregressive and moving average terms

3) A careful study on the residuals of Autocorrelation (ACF) function and Partial Autocorrelation (PACF) function. If the residuals estimated from this model are white noise, we can accept the model.

4) The final stage is forecasting from the appropriate model.

There are numerous criteria available for choosing the model in analysis of time series *viz.*, AIC (Akaike Informa tion Criterion), BIC (Bayesian Information Criterion), Hannan-Quinn, SBC (Schwartz-Bayesian Criterion), Mean Percent Error (MPE) method, the Mean Square Error (MSE), the Mean Absolute Value Error (MAE), and the Mean Absolute Value Percent Error (MAPE). The model, in which the above statistics are the least, is chosen as the appropriate model. In using ARIMA model, the AIC and BIC are more accurate.

III. RESULTS AND DISCUSSION

A. Descriptive Statistics

Mean, standard deviation (SD) and coefficient of variation (CV) of maximum and minimum temperature were found out and it was given in the table 1. The highest mean value of maximum temperature was found in the year 1987 and lowest in the year 1999. In case of minimum temperature, mean value was highest during 2011 and lowest during 1997. Coefficient of variation for maximum temperature was in the range between 2.69 and 5.36 whereas for minimum temperature between 2.78 and 7.26 which shows that there was a high coefficient of variation for minimum temperature.

Table 1. Descriptive statistics of maximum and minimum temperature

Year	Maximum temperature			Minimum temperature		
	Mean	SD	CV	Mean	SD	CV
1985	30.99	1.26	4.05	23.00	0.64	2.78
1986	31.61	1.36	4.30	22.14	1.04	4.70
1987	31.71	1.15	3.61	23.35	1.69	7.26
1988	31.57	1.01	3.20	23.50	1.26	5.36
1989	30.96	1.31	4.24	23.20	1.14	4.94
1990	31.13	1.23	3.96	23.55	1.16	4.94
1991	31.00	1.27	4.10	23.56	1.30	5.52
1992	30.58	1.10	3.60	23.14	1.36	5.89
1993	30.67	1.11	3.61	23.20	1.25	5.41
1994	30.81	0.83	2.70	23.49	0.87	3.72
1995	31.25	0.97	3.11	23.65	1.35	5.69
1996	30.58	1.08	3.52	22.06	1.11	5.02
1997	30.68	1.65	5.36	21.60	0.75	3.48
1998	31.18	1.63	5.23	24.16	1.04	4.32
1999	30.47	1.09	3.58	23.44	0.93	3.95
2000	30.52	1.14	3.74	22.39	1.26	5.63
2001	31.13	1.08	3.45	22.00	1.27	5.78
2002	31.13	1.08	3.45	23.23	1.05	4.50
2003	31.48	0.83	2.65	23.58	1.18	5.00
2004	31.15	1.19	3.81	23.18	1.04	4.50
2005	31.61	1.02	3.22	23.61	1.06	4.49
2006	31.10	1.03	3.32	23.64	1.19	5.03
2007	31.17	0.94	3.00	23.06	0.98	4.26
2008	30.93	0.91	2.93	23.26	0.98	4.20
2009	31.01	1.42	4.57	24.23	1.14	4.69
2010	31.52	1.55	4.92	23.40	1.06	4.55
2011	30.88	1.10	3.57	24.25	0.71	2.93
2012	30.59	0.82	2.69	23.63	1.28	5.44
2013	30.66	1.38	4.49	23.36	1.12	4.80

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B. Modelling of Maximum Temperature

For time series temperature data, Autoregressive Integrated Moving Average (ARIMA) models are the best fitted models. ARIMA modelling was carried out separately for maximum and minimum temperature. By trial and error method the best model was chosen on the basis of model selection criteria. Model with least Akaike Information Criteria (AIC) and least Bayesian Information Criteria (BIC) and least Hannan-Quinn value will be best fit.

Table 2. ARIMA model for maximum temperature

ARIMA model	Coefficient		p-value	AIC	BIC	Hannan-Quinn
(001)(111)	Phi-1 theta-1 Theta-1	0.22 0.33 −1.00	7.63e-05 *** 4.48e-014 *** 4.54e-071 ***	717.24	732.51	723.32
(010)(111)	Phi-1 Theta-1	0.16 −0.98	0.01 ** 6.08e-011 ***	804.67	816.11	809.23
(100)(111)	phi-1 Phi-1 Theta-1	0.43 0.19 −1.00	1.66e-018 *** 0.001 *** 2.08e-046 ***	697.64	712.91	703.72
(110)(111)	phi-1 Phi-1 Theta-1	−0.38 0.16 −1.00	2.59e-014 *** 0.004 *** 3.19e-017 ***	753.22	768.48	759.30
(101)(111)	phi-1 Phi-1 theta-1 Theta-1	0.69 0.19 −0.32 −1.00	7.52e-018 *** 0.001 *** 0.002 *** 1.26e-048 ***	692.19	711.28	699.80
(011)(111)	Phi-1 theta-1 Theta-1	0.18 −0.63 −1.00	0.001 *** 1.15e-020 *** 1.09e-061 ***	724.75	740.00	730.83
(011)(011)	theta-1 Theta-1	−0.46 −0.91	1.09e-021 *** 1.01e-128 ***	768.10	779.54	772.66
(011)(101)	Phi-1 theta-1 Theta-1	0.99 −0.45 −0.908	0.00*** 2.11e-020 *** 3.46e-125 ***	800.74	816.13	806.87

Table 2 shows the different ARIMA models for maximum temperature and the least AIC, BIC and Hannan-Quinn values are shown by model (101)(111). Therefore best fit model for maximum temperature is ARIMA (101) (111).

Forecasting of time series data is another feature of ARIMA modelling. Based on the model ARIMA (101) (111), forecasting of maximum temperature was done for 2014. Table 3 shows the forecasted maximum temperature based on ARIMA (101) (111). Mean absolute error for the forecasted maximum temperature is only 0.034, which shows the forecasted value and original value differ least. The forecasted temperature trend is shown in figure 1. The forecasted temperature and original temperature shows similar trend.

Table 3. Forecast of maximum temperature based on ARIMA (101) (111)

Month	Forecasted maximum temperature	Standard error	Maximum temperature	Variation from predicted value
January	30.9	0.63	30.62	0.28
February	31.5	0.67	31.34	0.16
March	32.4	0.69	32.44	-0.04
April	32.8	0.70	32.40	0.4
May	31.9	0.70	31.88	0.02
June	29.9	0.70	30.76	-0.86
July	29.6	0.71	29.99	-0.39
August	29.8	0.71	29.55	0.25
September	30.1	0.71	30.21	-0.11
October	30.5	0.71	30.53	-0.03
November	30.4	0.71	30.18	0.22
December	30.7	0.71	30.19	0.51

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C. Modelling of Minimum Temperature

ARIMA modelling was carried out for minimum temperature. By trial and error method the best model was chosen on the basis of model selection criteria. Model with least Akaike Information Criteria (AIC) and least Baesian Information Criteria (BIC) and least Hannan-Quinn value will be best fit.

Table 4. ARIMA model for minimum temperature

ARIMA model	Coefficient		p-value	AIC	BIC	Hannan-Quinn
(001)(111)	Phi-1 theta-1 Theta-1	0.07 0.44 −0.92	0.29 2.48e-031 *** 9.61e-072 ***	827.75	843.02	833.84
(010)(111)	Phi-1 theta-1 Theta-1	0.07 0.45 −0.93	0.29 2.48e-31 *** 9.61e-72 ***	827.75	843.02	833.84
(100)(111)	phi-1 Phi-1 Theta-1	0.63 0.03 −0.93	4.89e-51 *** 0.62 4.45e-60 ***	759.32	774.589	765.41
(110)(111)	phi-1 Phi-1 Theta-1	−0.34 0.01 −0.91	3.80e-11 *** 0.87 3.21e-71 ***	783.51	798.76	789.59
(011)(011)	theta-1 Theta-1	−0.46 −0.91	9.35e-16 *** 1.23e-108 ***	768.10	779.54	772.66
(011)(111)	Phi-1 theta-1 Theta-1	0.02 −0.46 −0.92	0.82 1.17e-21 *** 1.10e-99 ***	770.05	785.31	776.13
(111)(111)	phi-1 Phi-1 theta-1 Theta-1	0.41 0.001 −0.82 −0.93	2.91e-7 *** 0.98 4.27e-58 *** 3.45e-87 ***	768.59	784.67	773.19

Table 4 shows the different ARIMA models for minimum temperature and in that least AIC, BIC and Hannan-Quinn values are shown by model (011)(011). Therefore best fit model for minimum temperature is ARIMA (011) (011).

Based on the model ARIMA (011) (011) minimum temperature forecasting was done for 2014. Table 5 shows the forecasted minimum temperature based on ARIMA (011) (011). Mean absolute error for the forecasted minimum temperature is only 0.14, which shows the forecasted value and original value differ least. The forecasted temperature trend is shown in figure 2. The forecasted temperature and original temperature shows similar trend.

Table 5. Forecast of minimum temperature based on ARIMA (011) (011)

2014-Month	Forecasted minimum temperature	Standard error	Minimum temperature	Variation from predicted value
January	21.8	0.73	21.53	0.27
February	22.4	0.83	22.33	0.07
March	23.6	0.92	22.88	0.72
April	24.8	1.00	24.47	0.33
May	24.8	1.07	24.73	0.07
June	23.5	1.14	23.21	0.29
July	23.1	1.21	23.31	-0.21
August	23.2	1.27	23.74	-0.54
September	23.4	1.33	24.01	-0.61
October	23.3	1.39	23.82	-0.52
November	22.9	1.44	23.38	-0.48
December	22.2	1.49	23.29	-1.09

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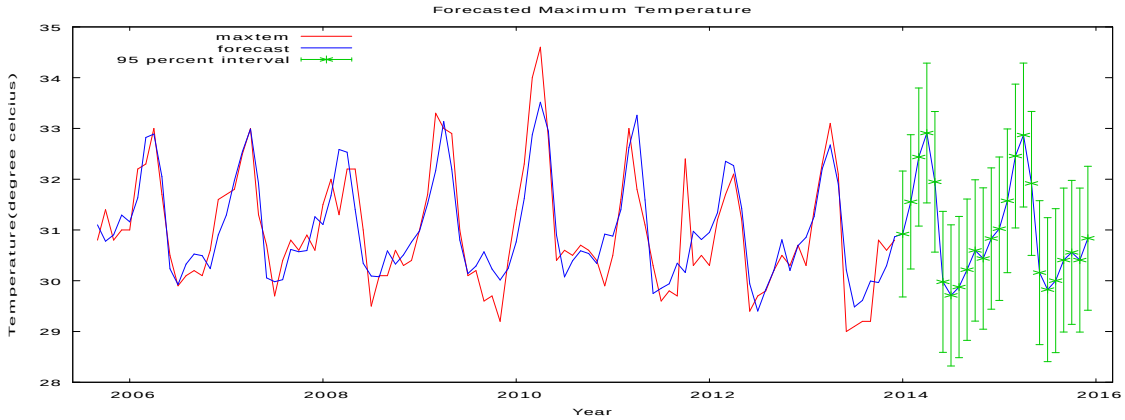


Figure 14.Trend of forecasted maximum temperature

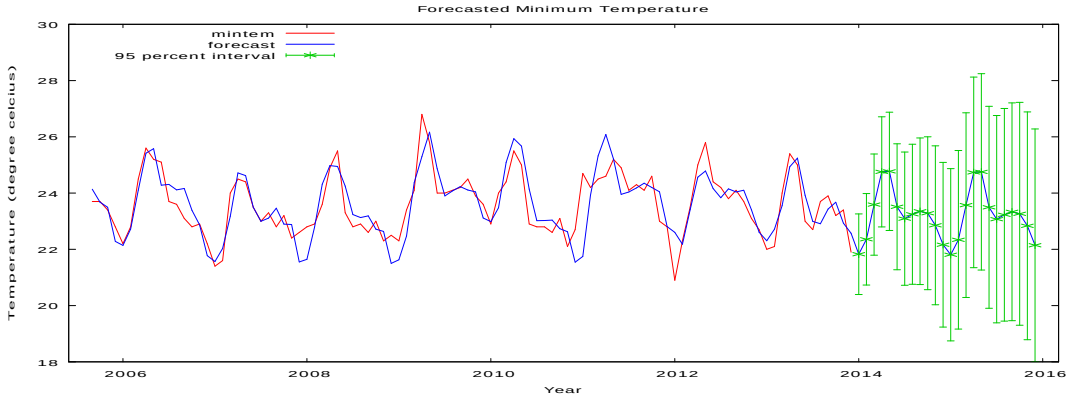


Figure 15.Trend of forecasted minimum temperature

IV. CONCLUSIONS

ARIMA model has gained a greater popularity in time series prediction because of its simplicity and reliability. The study has shown that the best ARIMA model (p, d, q) to forecast the monthly maximum and minimum temperature for the year 2014 in Thiruvananthapuram of Kerala. Good fits such ARIMA (101)(111) and ARIMA(011) (011**)** were obtained for maximum and minimum temperature, respectively.

V. ACKNOWLEDGEMENT

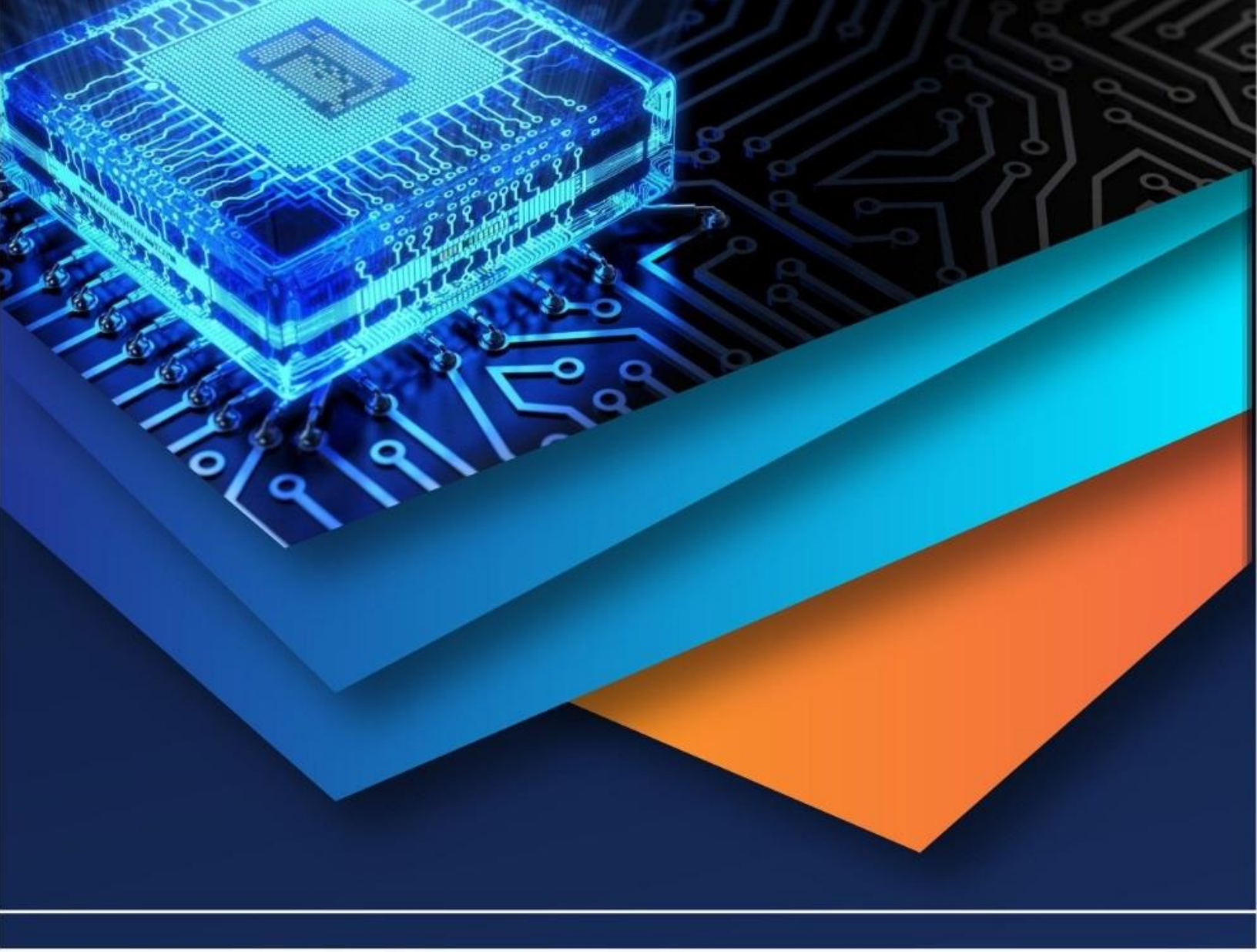
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