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Time series analysis model for forecasting of temperature at Allahabad region

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Abstract
The prediction of temperature on monthly and seasonal time scales is not only scientifically Challenging but is also important for planning and devising agricultural strategies. Various research groups attempted to predict temperature on a seasonal time scales using different techniques. This paper describes the Box-Jenkins time series seasonal ARIMA (Auto Regression Integrated Moving Average) approach for prediction of temperature on monthly scales. seasonal ARIMA (1, 0, 0) (0, 1, 1) maximum temperature (1,0,1) (0,1,1) minimum temperature was identified the best model to forecast temperature for next 5 year's with confidence level of 95 percent by analyzing last 31 year's data(1985-20015). Previous years data is used to formulate the seasonal ARIMA model and in determination of model parameters. The performance evaluations of the adopted models are carried out on the basis of correlation coefficient (R^2) and root mean square error (RMSE).The study conducted at Allahabad, Uttar Pradesh (India).The results indicate that the seasonal ARIMA model provide consistent and satis factory predictions for temperature parameters on monthly scale.

Keywords: temperature, time series, SARIMA model

Introduction

A Time Series is a data set which describes a function or property that varies or changes overtime. Time Series Analysis examines this changing data, often with the objective of predicting the future occurrences (David Corliss, 2009) [8]. Analyzing time series data and forecasting its future values are among the most significant challenges in many fields like agriculture, meteorology, finance, economics, engineering, industrial production, and various environmental studies. The gradual rise in the mean temperature of the Earth's atmosphere and its oceans is referred to as Global warming. It is widely believed that the changing temperature due to global warming is permanently changing the entire Earth's climate. For a long time the biggest debate in a number of local and international forums worldwide has been whether global warming is real. Some people think that global warming is not real. However several climate scientists have carried out researches and have come to a conclusion that the globe is gradually warming. People perceive the impacts of global warming differently with some taking the necessary precautions to help reduce the rates of the rising temperatures. In the past century alone, studies have shown that the globe's mean temperature has risen by between 0.4 °C and 0.8 °C. According to a study by IPCC (2007) [7], the temperatures could rise by between 1.4 °C and 5.8 °C by the end of the 21st century.

This increase in temperature may seem to be minute but the impacts are great. Increase in temperatures are likely to lead to a global increase in drought conditions, decreased water supplies due to evapotranspiration and an increase in urban and agricultural demand. The prediction of temperature has been made using auto regressive integrated moving average method and is examined using data for the period of 1985-2015. The modeling and prediction of temperature is done through the statistical method based on autoregressive integrated moving average (ARIMA). In this paper, modeling and forecasting of temperature is made through the conventional method called box-jerkins seasonal ARIMA model.

Materials and Methods

Study area

The district of Allahabad is located between 24° 47´ N and 25° 43´ N latitudes and between 81° 31´ E to 82° 21´ E longitudes. The climate of Allahabad district is typical humid subtropical it has three seasons: hot dry summer, warm humid monsoon and cool dry winter. The winter usually extends from mid-November to February and is followed by the summer which continues till about the middle of June. Allahabad experiences severe fog in January resulting in massive traffic and travel delays. The summer season is long and hot with the maximum temperatures ranging from 40 °C (104 °F) to 45 °C (113 °F) accompanied by hot local winds called as “loo”. The monsoon season starts from mid of June to September. About 88 percent of the annual rainfall is received during the monsoon season July and August being the months of maximum rainfall. The normal rainfall in the district is 975.4 mm. (38.40 inches) but the variation from year to year is appreciable.

Data Collection

Daily temperature data for the past 31 year’s from 1985 to 2009 was collected from IMD, while data from 2010 to 2015 was collected from the agro meteorological observatory of College of Forestry, SHUATS, Allahabad**,** for forecasting.

Software used: SPSS

SEASONAL Auto Regressive Integrated Moving Average (ARIMA) models were selected using SPSS software to find the best fit of a time series to past values of this time series in order to make forecasts.

Methodology

A time series is defined as a set of observations arranged chronologically i.e. asequence of observations usually ordered in time. The principal aim of a time series analysis is to describe the history of movements in time of some variable at aparticular site. The objective is to generate data having properties of the observed historical record. To compute properties of ahistorical record, the historical record or time series is broken into separate components and analyzed individually to understand the casual mechanism of different components. Once properties of these components are understood, these can be generated with similar properties and combined together to give a generated future time series. Analysis of a continuously recorded temperature data time series is performed by transforming the continuous series into adiscrete time series of finite time interval. Mathematical modeling of temperature data is a stochastic process. Several mathematical models based on the probability concept are available. These models help in knowing the probable weekly, monthly or annually temperature. Over the past decade or so, a number of models have been developed to generate rainfall, temperature and runoff. Monthly temperatures were analyzed using time series analysis. Time series models have been extensively studied by Box and Jenkins (1976) [1] and as their names have frequently been used with synonymously with general ARIMA process applied to time series analysis and forecasting. Auto Regressive (AR) models were first introduced and later generalized by while Moving Average (MA) models were first introduced by Slutzky (1937). Wold (1938) provided theoretical foundation for combined Auto Regressive Moving Average (ARMA) process. Box and Jenkins (1976) [1] have effectively put together in a comprehensive manner, the relevant information required to understand and use time series ARIMA models. Adetailed strategy for the construction of linear stochastic equation describing the behavior of time series was examined. Consider the function Z_t represents forecasted temperature at time t month. Y_t is series of observed data of temperature at time t. If series is stationary then a ARIMA process can berepresented as

$$\nabla^p Z_t = \nabla^q Y_t \ldots. \quad (1)$$

Where ∇ is a back shift operator. If series Y is not stationary then it can bereduced to a stationary series by differencing a finite number of times.

$$\nabla^p Z_t = \nabla^q (1-B)^d Y_t \ldots. \quad (2)$$

Where d is a positive integer, and B is back shift operator on the index of time series so that

$BY_t = Y_t\text{-}1$; $B^2 Y_t = Y_{t-2}$ and so on. Thus further equation (2) can be simplified into following equation.

$$(1-\Phi_1 B-\Phi_2 B^2-\ldots\ldots.-\Phi_p B^p)\ Z_t = \theta_0 + (1-\theta_1 B-\theta_2 B^2-\ldots\ldots\ldots-\theta_q B^q)\ a_t \ldots.. \quad (3)$$

Where a_t’s a sequence of identically distributed uncorrelated deviates, referred to as “white noise”.

Combining equations (2) and (3) yields the basic Box-Jenkins models for non stationary time series

$$(1-\Phi_1 B-\Phi_2 B^2-\ldots\ldots.-\Phi_p B^p)\ (1-B)^d Y_t = \theta_0 + (1-\theta_1 B-\theta_2 B^2-\ldots\ldots\ldots-\theta_q B^q)\ a_t \ldots. \quad (4)$$

Equation (4) represents an ARIMA process of order (p, d, q). Seasonal ARIMA model represented as follows for a stationary series i.e. differencing parameters (d &d_s = 0) equal to Zero, used for forecasting rainfall and temperature.

$$\nabla^{ps} \nabla^p Z_t = \nabla^{qs} \nabla^q Y_t \ldots. \quad (5)$$

Where p_s and q_s are the seasonal parameters corresponding to AR and MA process. Model of type of equation (5) was fitted to given set of data using an approach consists of mainly three steps (a) identification (b) estimation (c) application (forecasting) or diagnostic checking. At the identification stage tentative values of p, d, q and p_s, d_s, q_s were chosen. Coefficients of variables used in model were estimated. Finally diagnostic checks were made to determine, whether the model fitted adequately describes the given time series. Any inadequacies discovered might suggestan alternative form of the model, and whole iterative cycle of identification, estimation and application was repeated until satisfactory model was obtained.

Results and Discussion

The model that represent the behaviour of the series is searched, by the means of autocorrelation function (ACF) and partial auto correlation function (PACF), for further investigation and parameter estimation. The behaviour of ACF and PACF is to see whether the series is stationary or not. For modelling by ACF and PACF methods, examination of values relative to auto regression and moving average were made. An appropriate model for estimation of monthly temperature for Allahabad station was finally found. Many models for Allahabad station, according to the ACF and PACF of the data, were examined to determine the best model. The model that gives the minimum BIC is selected as best fit model, as shown in Table 1. Obviously, model for temperature SARIMA (1, 0, 0) (0, 1, 1) maximum temperature (1,0,1) (0,1,1) minimum temperature has the smallest values of BIC. Observed and predicted values of next five years are determined and plotted as shown in figure**:** 6, 7.

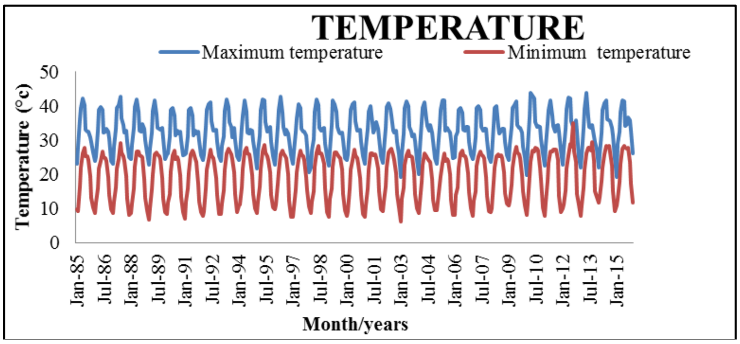

Fig 1: Observed temperature (maximum, minimum) in Allahabad district (Jan. 1985-Dec. 15)

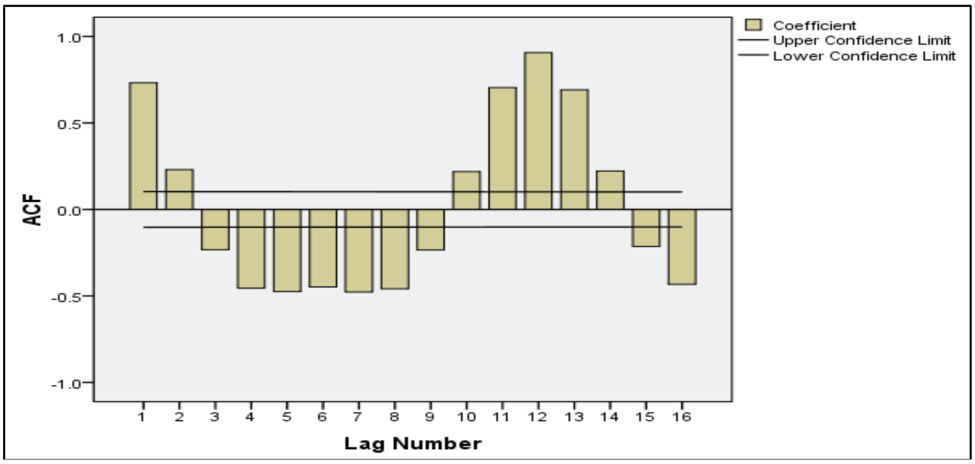

Fig 2: Autocorrelation function of Maximum temperature

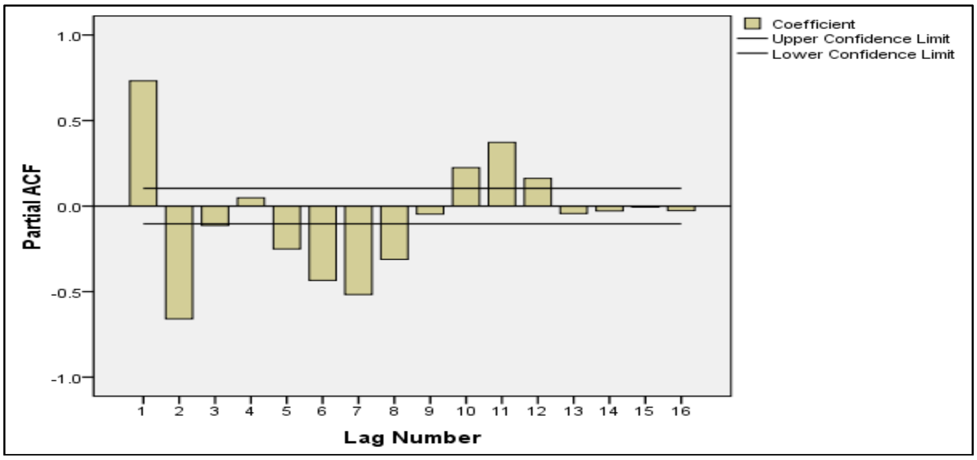

Fig 3: Partial autocorrelation function of Maximum temperature

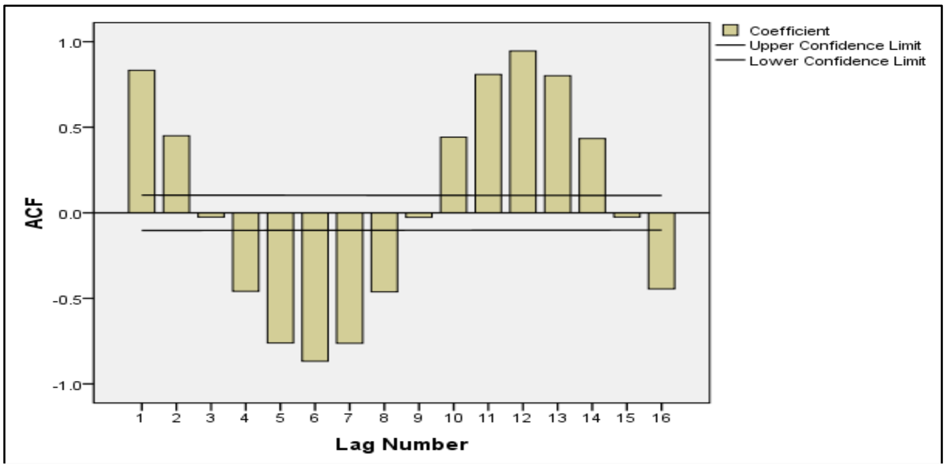

Fig 4: Autocorrelation of Minimum temperature.

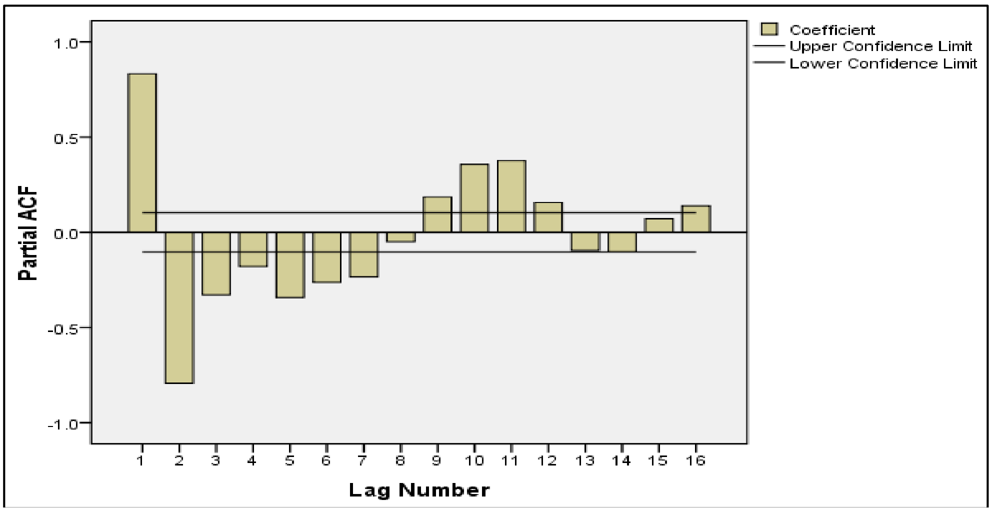

Fig 5: Partial autocorrelation function of Minimum temperature

Table 1: Obviously, model for temperature

Parameters	Seasonal ARIMA model (PDQ, PSDSQS)	R2	RMSE
Minimum Temperature	(1,0,1)(0,1,1)	0.974	1.102
Maximum Temperature	(1,0,0)(0,1,1)	0.938	1.387

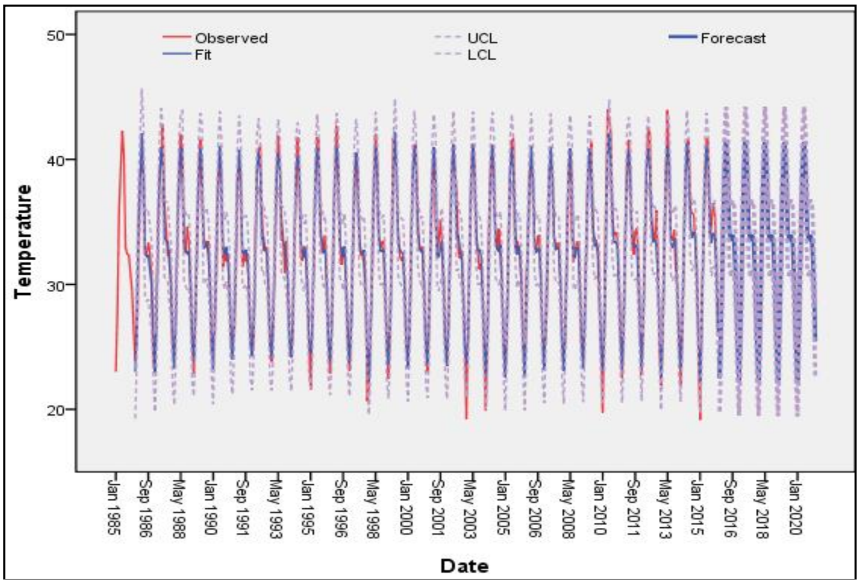

Fig 6: Observed and fitted values of Maximum temperature series.

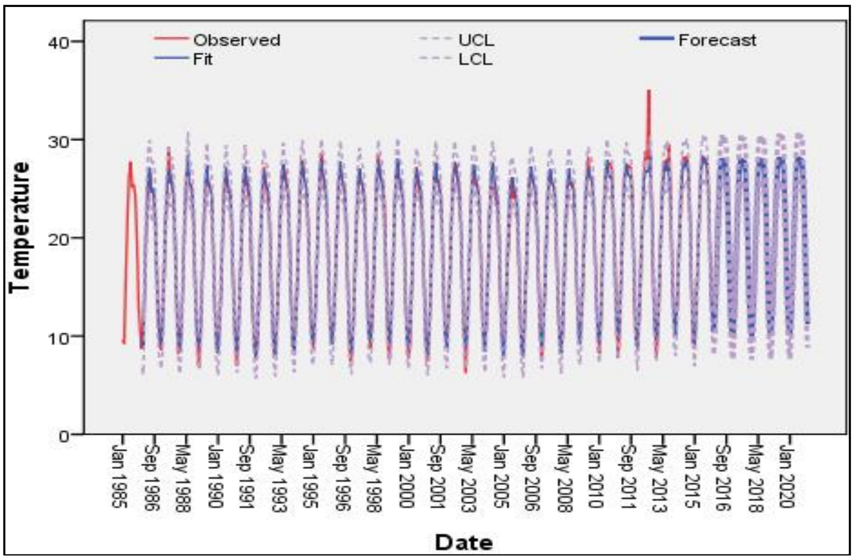

Fig 7: Observed and fitted values of Minimum temperature series

Conclusion

The Box-Jenkins ARIMA methodology was used to develop monthly temperature of Allahabad. The performance of resulting ARIMA model was evaluated by using the data from the year 1985-2015 through graphical comparison between the forecasted and observed data. In ARIMA model the forecasted and observed data of temperature showed good results. The study reveals that Box-Jenkins methodology can be used as an appropriate tool to forecast temperature in Allahabad for upcoming years.

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