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Prediction of monthly mean Inflow to Dez Dam reservoir using time series models (Box-jenkins)

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Abstract. The optimal exploitation of water from a dam reservoir requires a comprehensive knowledge of future availability of water resources. In this case the amount of water that will be available in the future is important. Also, we need to examine the flows at the dam from a short-term perspective. This is necessary to avoid overflowing and to minimize damage. In order to facilitate forecasting of the water resources, many different techniques have been developed through the years.
In this paper, using yearly data (since 1988-2007) obtained from Hydrometric station at Dez (upstream of Dez Dam), the Auto Regressive Integrated Moving average (ARIMA) model, for prediction of monthly mean inflow to Dez Dam reservoir was accomplished. On the basic of comparison the results of the model with measured data, the performance of ARIMA(1,1,0)(1,0,0)12 model is acceptable.

Keywords: ARIMA, reservoir, time series model, Inflow prediction, Dez Dam.

1. Introduction

Increased need to water resources with proper quality and quantity besides possessing temporal and spatial distribution adapted with operation needs required engineers and investigators of water sources to make more efficient managerial systems for hydro-systems. It is needless telling that accuracy in predicting the streams of forthcoming periods has valuable effect on the efficiency of decision support systems for operating the reservoir. Prediction includes approximating the future situation of a parameter with four dimensions: quality, quantity, space and time [3]. Regarding to the statistics in Iran, it seems that time series models are acceptable variants for developing the flow prediction model. The basic theory for developing mentioned models is that the future is a reflection of past and any statistical relation that could be found in the historical statistics can be generalized to the future.

The main development of time series models and its concepts resulting in vast application of these models conducted by Box and Jenkins (1970 & 1976) [6]. The method used by these investigators later called Box- Jenkins method and attracted the hydrologist.

In a study, the average monthly temperature of Tabriz station studied based on Box- Jenkins ARIMA model and using above mentioned model, the monthly temperature of Tabriz for a 40 years statistical period (1959-98) has been studied based on auto correlation and partial auto correlation [2]. In another study, the ground water level changes of Nishabor desert predicted for next 5 years, using Box- Jenkins, Holt- Winters models as well as extrapolation of trend curve from provided data [8].

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In another study, for examining the climate of Synoptic station of Birjand and recognizing the climate fluctuations, particularly drought and wet years, and providing a proper model for predicting the climate fluctuations, using statistical methods and Box- Jenkins models, the time series of precipitation and temperature was studied and best fitting model has been provided [1]. Modarres studied the time series of monthly precipitation of Ghale Shahrokh Station, one of the upstream basins of Zayande Rood River for modeling by Box- Jenkins method. According to the auto correlation function of studied series, it is determined that related series possesses a seasonal behavior lacking main statistical property. Studied series stabled by differencing. For simulating and modeling the drought of Pars province, using Box- Jenkins method, based on auto correlation and partial auto correlation, evaluating the models based on being static and examining types of models, the ARIMA model has been selected and most suitable model based provided based on AIC measure for simulating the drought in any region [5]. Most studies conducted based on this model include cases such as determining the proper model, estimating the parameters of extracted model with maximum accuracy and simulating the considered variables with minimum error.

1.1. Case study

In this study, there has been provided a time series model for predicting the monthly inflow to Dez dam reservoir. Dez dam is of concrete type with two arcs and 203 m in height, 5.4m in width and and 27 m in foundation with 212 m in crown length. The size of reservoir is 3.3 billion square meter. This dam is located in geographic longitudinal and transversal 48^{o}- 28' east and 36^{o}-32' north, respectively. The objectives for erecting Shahid Abbaspour Reservoir dam:

- Controlling the devastating floods of Dez stream;
- Regulating the water for irrigation usage;
- Providing required force for power supply.

2. Materials and Methods

Along with modeling a time series, or on the other hand describing the behavior of a time series mathematically, there are considered three main stages [5] (Box and Jenkins, 1976).

- Recognizing the initial model;
- Estimating the parameters of recognized model;
- Properly studying the model.

Before dealing with modeling, related series must be examined by normal test. If related series is normal, one can analyze it. If studied series is not normal, it is necessary to take necessary action to normalize the series.

The statistical period of arable year is 1988 to 2007. Initially the homogeneity of data verified using run test statistical method. Then, based on the series of the observations and behavior of the phenomenon in the past, a proper model of prediction made using time series analysis. Along with modeling the data, after providing the inflow to Dam reservoir based on time series, there took action to make data static.

2.1 Methodology for making the model

Method of this study is conducted by time series analysis, one of these methods called ARIMA method or Box- Jenkins model or (p,d,q) mode [7]. In any (p,d,q) model, p indicates the number of autoregressive, q is the number of mobile mean and d is the order of differencing as well as indicating the number of orders needed for attaining the series to a kind of statistical balance. In the first stage, the analysis of initial values of p, d and q is determined by auto correlation (ACF) and partial auto correlation (PACF). By accurately studying the ACF and PACF charts and their components, the general view for presence of time series with trend and its properties is obtained. Then in the second stage, it is examined if p and q values, indicating the autoregressive and mobile mean, remain in the model or must be removed from. In the third stage, it is reviewed whether the residual values, residual error are random and with normal distribution or not. In this case, one can say that this model enjoys proper fitness. When time series is of type seasonal, in this state, modeling is dimensional and in the season, a part of time series changes is for changes in any season and other part to changes between different seasons. A special type of seasonal models indicating the proper results and adapted to the general structure of ARIMA models according o Box- Jenkins (1976) called

multiplied seasonal model. This model is ARIMA (pdq) (PDQ). Then for ideal model, it must be used models for testing the model and comparing them to select best model for prediction [5].

2.2 Criterion for choosing the model

During time series analysis or generally in data analysis, it may be used several proper model for indicating a given data set. When applying the ARIMA model, the Akaike Information Criterion (AIC) has higher accuracy and it acts better comparing two ARIMA model for selecting the best fitting function [4]. In this study there was used ARIMA model using ITSM software and AIC test for modeling the inflow to reservoir and studying their effects on each other. According this test any order with minimum AIC value is ideal based on prediction and adaption. After determining the type of model and its parameters as well as determining the proper AIC value, for validating the model, arable years 2004-2005 to 2007 to 2009 considered as control and actual values were compared with predicted values.

3. Results and Discussion

Time series diagram for inflow to Dez Dam reservoir indicated in figure (1).

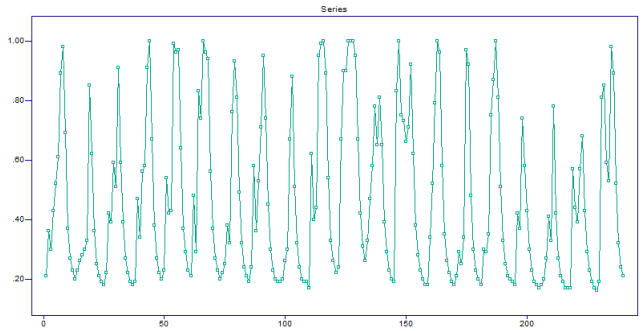

Fig. 1: Time series for the inflow to dam reservoir.

ACF and PACF diagrams have drawn using ITSM software to determine the initial model figure (2). The regular seasonal changes are indicated by these diagrams.

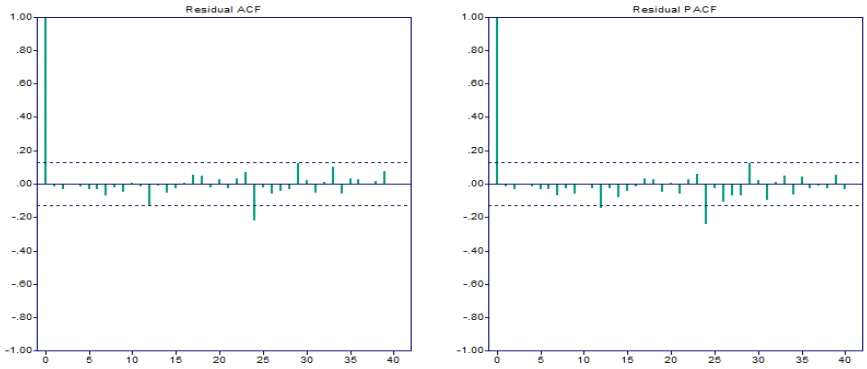

Fig. 2: Diagram for ACF and PACF function of time series of inflow to dam reservoir.

By any 12 times observations, the pattern of time series changes is repeated. Consequently, the series is not static and possesses seasonal changes12. Because the variability of time series will be increased over the time, therefore, data series is not static in variance and it could become static by Box- Cox method and seasonal changes 12. For modeling by ACF and PACF method, the best model for predicting the values of inflow to Dez reservoir is ARIMA (1,1,0)(1,0,0)12. For verifying the model there was used ACF and PACF diagram figure (3) where the auto correlations were in the range of zero and the assumption for independency and stochastic data was accepted. For validating the model, the correlation between actual values and predicted values indicated in figure (4).

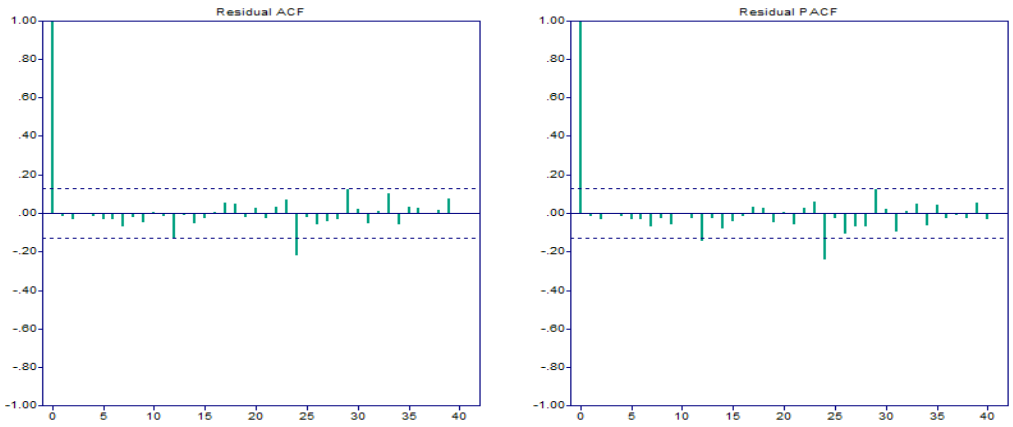

Fig. 3: ACF and PACF diagram for residuals of inflow to dam reservoir

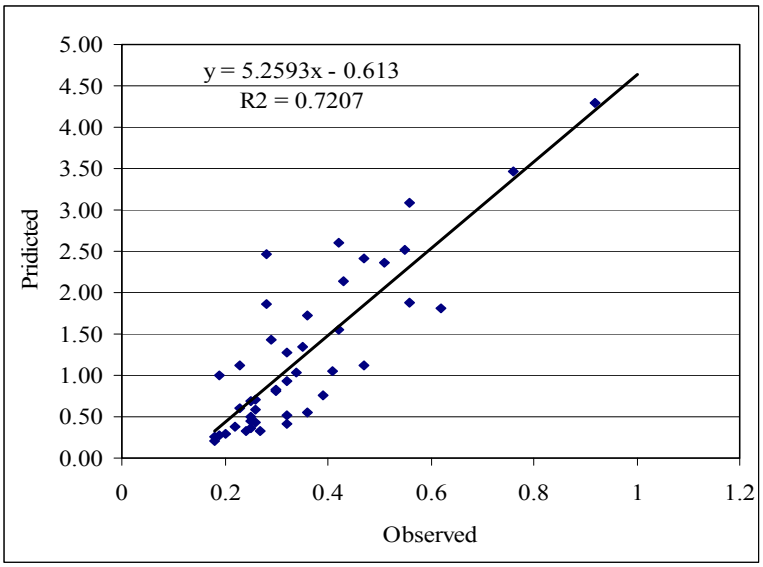

Fig. 4: Correlation between actual values and predicted values of inflow to dam reservoir.

4. Conclusion

Recognizing these fluctuations during statistical period and predicting them are necessary for planning. Results from reviewing the climatic parameters of moisture and average monthly temperature with reviewing the diagrams indicated that:

- In order for predicting the studied parameters, there was used Box- Jenkins model and finally they assessed by providing final model. The correlation coefficient for inflow to dam reservoir obtained about 0.72. Therefore, considering the higher accuracy of model, one can use it for anticipating the average monthly temperature and moisture.

- There was used AIC criterion for choosing the model. According to Akaike Information criterion, $AIC(p,q) = N\ln(\sigma_\varepsilon^2) + 2(p+q)$, ARIMA (1,1,0)(1,0,0)12 model for inflow to dam reservoir and it has lower Akaike vales than other models and can be chosen as models better than other seasonal models of Box- Jenkins.

- The diagram for actual and predicted values for inflow to dam reservoir for 2011 and 2012 was anticipated for time modeling and one can use such statistics for these years.

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