International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-10, August 2019

Weather and Stochastic Forecasting Method for Generated Discharge Level Data at Sathanur Dam

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Abstract: *This article forecasts the future values using stochastic forecasting models for specified fitted values by using downscaling data, which are collected from Sathanoor Dam gauging site. Due to the demand of the water in this current scenario, this study analyzed the perdays Discharge level data collected from Sathanoor Dam where the outcome is predicted in a downscaling data sets in hydrology, extended Thomas –Fiering, ARIMA, MLE models, is used to estimate perdays discharge level data of each month. The error estimates RMSE, MAE of forecasts from above models is compared to identify the most suitable approaches for forecasting trend analysis.*

Keywords: ***Stochastic process, Thomas –Fiering, ARIMA, MLE models, Forecast.***

I. INTRODUCTION

The impact of precipitation deficit can be determined with the help of wetland (naturally deposited soil moisture of water is in rivers, lakes, etc.). Prolonged deposit will affect the groundwater, less water supply of surface and subsurface area. This may result in drought, famine or scarcity which will cause serious economic and social impact. Hydrologic management of streamflow droughts is of primary consideration in the design of municipal water systems, hydroelectric plants, navigation development, supplemental irrigation scheme, etc., (Chang and Boyer, 1977) and Sharma et al. (1997).

The generated downscaling data will lead to the analysis of hydrological evidence to benefit the upcoming period with less water level, overflow protection, water power on hydrology measuring method. The application of stochastic process, like trend on hydrology, management science, seasonal periods and climate change can be predicted with stochastic development in ARIMA, Extended Thomas-Fiering and MLE. Statistical downscaling is two-step process that evolves with the development of a statistical relationship between the variables such as climate variables and large scale predictors. The present paper is used to simulate the large scale downscaling data taken from the water levels and discharge at matralayam gauging site and predict the discharge data for future values.

Manuscript published on 30 August 2019.
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II. REVIEWS

Few previous studies working on this area with application of ARIMA/ARMA model (inclusion of both autoregressive and moving average terms) can be identifies as below:

Many types of hydrologic time series data having periodically varying components have been explained by Lewis and Ray [10]. The authors suggests that, a linear stochastic model that is commonly referred as Autoregressive Integrated Moving Average (ARIMA) can be applied for this type of data. The water quality daily data having maximum 1-hour ozone concentrations were forecasted using ARIMA model by Ahmad et al. [1]. The flood forecasting on the river Ouse using ARIMA model was worked by See and Openshaw [2]. Whereas, an ARMA model was used for the prediction of the streamflow on a medium sized basin in Mississippi (Hsu et al. [3]).Monthly data from Kelkit Stream watershed was used and forecasted using ARIMA model, by Yurekli et al. [4]. The residuals of the ARIMA models were used for the monthly streamflow data for three gauging stations located on Çekerek stream watershed was used by Yurekli et al. [5]. ARIMA model was used by Yurekli and Ozturk [6] in simulating of the annual-extreme daily discharges.

Performance of two stochastic approaches (ARIMA and Thomas-Fiering) for water quality and streamflow data from Yeşilırmak River, Turkey is evaluated by Kurunc et al. [7]. Walls and Bendel [8] pointed out that ARIMA can give a best fit for many time series data, also this model is renowned for its satisfactory predictive performances (Ho and Xie [9]).

Nonlinear Modeling by using time series analysis was worked by Lewis and Ray [10]. Watershed and climatic parameters are adequate for simulating per day data set was estimated by Chang and Boyer [11] .of low flows using. The statistical and trend analysis of water quality and quantity data for the hydrology and earth system science was provided by Antopoulos et.al [12].

The statistical and trend analysis of water quality and quantity data for the hydrology and Application of GIS for Mapping Rainwater-Harvesting Potential by [13]. The predicted data obtained from stream flow simulation approach for nonparametric method. Fernando and Jayawardena [14] generated and forecasting of monsoon rainfall data is strong model fit.

Hirsch et.al [15] determined of trend analysis for monthly water quality data set are applications related to water resources research. Sathish and Khadar Babu [16] estimate Markovian prediction of future values food grains in the economic survey using nth order Markovian process.

III. STUDY AREA DESCRIPTION

Study area of Geographical location of the studied region: The maximum discharge of the river so far measured is 8100 m3/s. Total actual dependable run off is 1215 million m3/s per year. The Sathanur Reservoir is constructed across Ponniar River near Sathanur village in Thandarampattu Taluk of Thiruvannamalai District. The location is approachable through B.T. road and is about 32 km from Tiruvannamalai Town. In the year 1926, the first proposal for the construction of a reservoir at a site 780 51' East longitude and 12011' North Latitude (which is also the present location) adjacent to the Vinnapadi Malai in the Reserved forest area in Chengam Taluk of North Arcot District. Was submitted by Sri.L.Venkatakrishna Iyengar then Executive Engineer, T.R.S. Division. 12.1834° N, 78.8504° E (2019).
Index Map of Sathanur Reservoir

Fig. 1 Study Area region at Sathanur Dam

Country	India
Latitude	12.205727
Longitude	78.888962
DMS Lat	12° 12' 20.6172'' N
DMS Long	78° 53' 20.2632'' E
UTM Easting	270,322.42
UTM Northing	1,350,197.56
UTM Zone	44P
Elevation (m)	216 m
Elevation (f)	709 feet
Category	Towns
Country Code	IN
Zoom Level	11

Fig. 2 Geographical Information at Sathanur Dam

IV. DATA AND METHODOLOGY

A. Data Collection

The data related to water level were observed from the Sathanur Dam. The location is approachable through B.T. road and is about 32 km from Thiruvannamalai District.

Table. 1: Results of Sathanur Dam Discharge level 68 perdays data identification (March to May-2019)

S.No	y	$\hat{y}_t$	S.No	y	$\hat{y}_t$
1	79.17	238.2	26	71.25	9293.2
2	78.25	600.4	27	71.25	9655.4
3	77.17	962.6	28	71.25	10017.6
4	76.32	1324.8	29	71.2	10379.8
5	75.58	1687	30	71.2	10742
6	74.83	2049.2	31	71.17	11104.2
7	74.05	2411.4	32	71.1	11466.4
8	73.17	2773.6	33	71.1	11828.6
9	72	3135.8	34	71	12190.8
10	71.5	3498	35	71	12553
11	71.5	3860.2	36	71	12915.2
12	71.5	4222.4	37	70.95	13277.4
13	71.5	4584.6	38	70.95	13639.6
14	71.5	4946.8	39	70.95	14001.8
15	71.45	5309	40	70.83	14364
16	71.45	5671`2	41	70.6	14726.2
17	71.45	6033.4	42	70.6	15088.4
18	71.4	6395.6	43	70.6	154050.6
19	71.4	6757.8	44	70.6	15812.8
20	71.4	7120	45	70.55	16175
21	71.4	7482.2	46	70.55	16537.2
22	71.36	7844.4	47	70.5	16899.4
23	71.3	8206.6	48	70.45	17261.6
24	71.3	8568.8	49	70.45	17623.8
25	71.3	8931	50	70.45	17986
51	70.4	18348.2	60	70.1	21608
52	70.4	18710.4	61	70.05	2190.2
53	70.35	19072.6	62	70	22332.4
54	70.3	1943.8	63	70	22694.6
55	70.25	19797	64	69.95	23056.8
56	70.25	20159.2	65	69.95	23419
57	70.2	20521.4	66	69.95	23781.2
58	70.2	20883.6	67	68.9	24143.4
59	70.15	21245.8	68	67.5	24505

V. OBJECTIVES OF STUDY

- To predict the discharge level data using T-F, E-T-F and ARIMA.
- To generate discharge level data for future prediction.
- To calculate daily discharge level data and Computations of out flow at Sathanur Dam

VI. METHODOLOGY

The methodology involving following applications the objectives of the study

- Thomas-Fiering model recommended as the standard statistical model for the Hydrological applications.

- Maximum Likelihood Estimation is the best prediction using parameters of water level data sets.
- ARIMA model is rely heavily on autocorrelation patterns which is used to capture the forecasting effectively.

Table. 2 Observed values Results of ACF-Perdays data

Observedvalues

Autocorrelations

Series: Observedvalues

Lag	Autocorrelation	Std. Error[a]	Box-Ljung Statistic Value	df	Sig.[b]
1	-.498	.119	17.390	1	.000
2	.000	.119	17.390	2	.000
3	.000	.118	17.390	3	.001
4	.000	.117	17.390	4	.002
5	.000	.116	17.390	5	.004
6	.001	.115	17.390	6	.008
7	.000	.114	17.390	7	.015
8	-.001	.113	17.390	8	.026
9	.000	.112	17.390	9	.043
10	.000	.111	17.390	10	.066
11	.000	.110	17.390	11	.097
12	.000	.109	17.390	12	.135
13	.000	.108	17.390	13	.182
14	.000	.107	17.390	14	.236
15	.000	.106	17.390	15	.296
16	.000	.105	17.390	16	.361

Table. 3 Observed values Results of PACF-Perdays data

Partial Autocorrelations

Series: Observedvalues

Lag	Partial Autocorrelation	Std. Error
1	-.498	.122
2	-.331	.122
3	-.246	.122
4	-.195	.122
5	-.161	.122
6	-.135	.122
7	-.116	.122
8	-.104	.122
9	-.093	.122
10	-.085	.122
11	-.077	.122
12	-.071	.122
13	-.066	.122
14	-.061	.122
15	-.057	.122
16	-.053	.122

The significance analysis of components and final estimates of the free parameters of suitable liner trend prediction for discharge levels are shown in Table 1. From Table 2 and Table 3, the water level and standard error, auto correlation and partial auto correlation for seasonal trend and stochastic forecasting methods. In view of above study location area and Geographical information about at Sathanur Dam gauge site see Fig. 1 and Fig. 2.

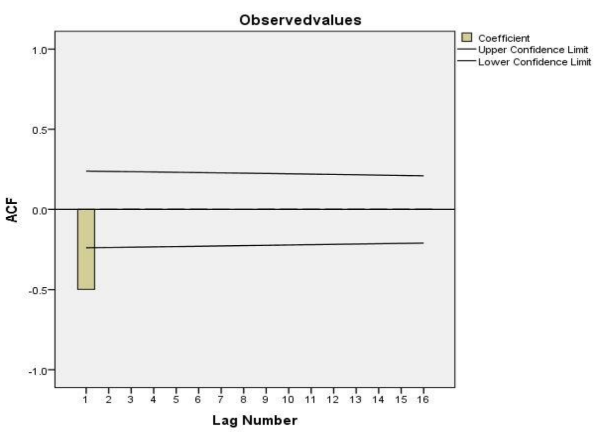

Fig. 3 ACF- Observed values Perdays data at Sathanur Dam

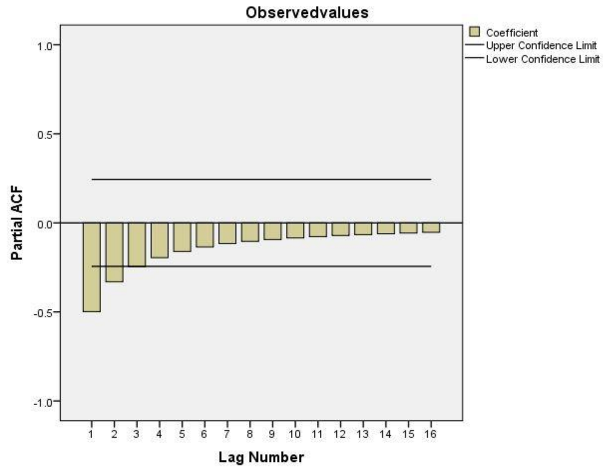

Fig. 4 PACF- Observed values Perdays data at Sathanur Dam

The Stochastic linear fitted values daily data statistics of discharge levels in the region of India at Sathanur dam gauge site monthly 68 daily days 2019 are illustrated in Fig. 3 and Fig. 4 predicted using by auto correlation function and partial auto correlation function that the suitable observed water level values has taken monthly in the March, April and May month.

Table. 4 Fitted values Std. Error of ACF Perdays data

Fittedvalues

Autocorrelations

Series: Fittedvalues

Lag	Autocorrelation	Std. Error[a]	Box-Ljung Statistic Value	df	Sig.[b]
1	-.399	.119	11.136	1	.001
2	.038	.119	11.237	2	.004
3	.029	.118	11.297	3	.010
4	.023	.117	11.336	4	.023
5	.019	.116	11.362	5	.045
6	.016	.115	11.381	6	.077
7	.013	.114	11.394	7	.122
8	.011	.113	11.404	8	.180
9	.010	.112	11.411	9	.249
10	.008	.111	11.417	10	.326
11	.007	.110	11.421	11	.409
12	.006	.109	11.424	12	.493
13	.005	.108	11.426	13	.575
14	.015	.107	11.444	14	.651
15	.003	.106	11.445	15	.720
16	.002	.105	11.446	16	.781

Table. 5 Fitted values Std. Error of PACF-Perdays data

Partial Autocorrelations

Series: Fittedvalues

Lag	Partial Autocorrelation	Std. Error
1	-.399	.122
2	-.144	.122
3	-.014	.122
4	.044	.122
5	.062	.122
6	.060	.122
7	.051	.122
8	.039	.122
9	.029	.122
10	.021	.122
11	.014	.122
12	.010	.122
13	.006	.122
14	.017	.122
15	.014	.122
16	.007	.122

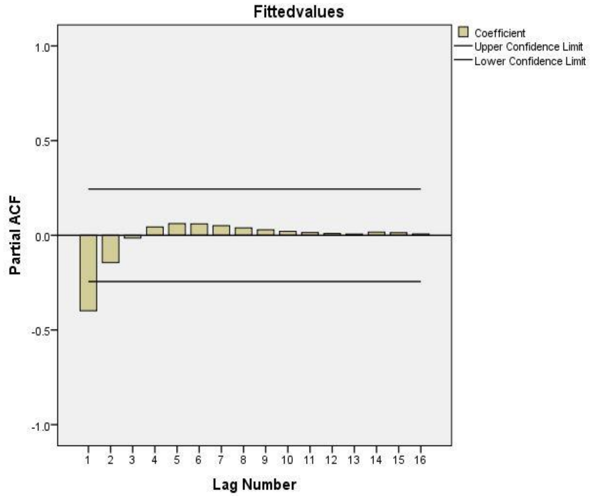

Fig. 5 PACF- Fitted values Perdays data at Sathanur Dam

Further from Table 4 and Table 5, the statistical fit based on fitted values of standard error indicates that stochastic linear trend with the seasonal and stochastic forecasting suitability in explaining the water levels by using ACF and PACF. From the graphical representations of Fig. 5, the partial auto correlation function is specific prediction for water levels at Sathanur Dam gauge site.

VII. COMPARISON AND ANALYSIS

A. Extended Thomas-Fiering Model

Thomas-Fiering Model recommended as the standard statistical model for the hydrological applications.
Russian Mathematician A.A. Markov (1856-1922) introduced the concept of a chain process called Markov process for forecasting the flow.

$$x_t - \mu = \alpha_1 \left(x_{t-1} - \mu\right) + v_t \qquad (1)$$

Thomas and Fiering (1962) used the above Markov chain model for generating monthly flows by taking into consideration the serial correlation of monthly flows.

$$Q_{p\,j+1} = Q_{av\,j+1} + b_j \left(Q_{pj} - Q_{av+j}\right) + t_p\, s_{j+1}\sqrt{1-r^2} \qquad (2)$$

Mean =12114.67, Standard deviation =7165.17, Correlation = 0.73, RMSE= 0.99 and MAE= 0.014

B. Results Maximum likelihood Estimation for discharge data using Gaussian distribution March (1/3/2019) to may (7/5/2019)

$$P(x;\mu,\sigma) = \sum_{x=1}^{68} \frac{1}{\sigma\sqrt{2\pi}} \exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right) \qquad (3)$$

$$P(68\,\text{Perdays};\mu,\sigma) = \sum_{x=1}^{68} \frac{1}{\sigma\sqrt{2\pi}} \exp\left(-\frac{(238.2-\mu)^2}{2\sigma^2}\right) \times \frac{1}{\sigma\sqrt{2\pi}} \exp\left(-\frac{(600.4-\mu)^2}{2\sigma^2}\right) \times .. \;..\times \frac{1}{\sigma\sqrt{2\pi}} \exp\left(-\frac{(24505-\mu)^2}{2\sigma^2}\right) \qquad (4)$$

Taking logs of the original expression is given us

$$\ln(P(x;\mu,\sigma)) = \sum_{x=1}^{68} \ln\left(\frac{1}{\sigma\sqrt{2\pi}}\right) - \frac{(238.2-\mu)^2}{2\sigma^2} + \ln\left(\frac{1}{\sigma\sqrt{2\pi}}\right) - \frac{(600.4-\mu)^2}{2\sigma^2} + .. \; . + \ln\left(\frac{1}{\sigma\sqrt{2\pi}}\right) - \frac{(24505-\mu)^2}{2\sigma^2} \qquad (5)$$

We can simplify above expression using the laws of logarithms to obtain

$$\ln(P(x;\mu,\sigma)) = -68\ln(\sigma) - \frac{68}{2}\ln(2\pi) - \frac{1}{2\sigma^2}\left[(238.2-\mu)^2 + (600.4-\mu)^2 + \ldots + (24505-\mu)^2\right] \qquad (6)$$

We can find the MLE of the mean μ and σ giving

$$\frac{\partial \ln(P(x;\mu,\sigma))}{\partial \mu} = \frac{1}{\sigma^2}(238.2 + 600.4 + .. + 24505\mu) \qquad (7)$$

$$Q = \tfrac{2}{3}\, Cd\, L\sqrt{2g}\left(h_2^{3/2} - h_1^{3/2}\right)$$

Finally, setting the left hand side of the equation to zero and rearranging for μ gives

$$\mu = \frac{238.2 + 600.4 + \ldots + 24505}{68} = 12114.6$$

Similarly we have to get σ

$$\frac{\partial \ln(P(x;\mu,\sigma))}{2\sigma} = \frac{1}{2\sigma}[238.2 + 600.4 + .. + 12114.6 - \mu] \qquad (8)$$

$$2\sigma = [238.2 + 600.4 + \ldots + (24505 - 12114.6]$$

$$\sigma = 7165.1$$

$$\mu = 12114.6, \quad \sigma = 7165.17$$

Table. 6 Comparison of results from at Sathanur Dam discharge level data on Extended Thomas-Fiering and MLE method (March to May -2019)

Extended Thomas - Fiering	Maximum likelihood Estimation	Error Estimates
Mean = 12114.6	Mean = 12114.6	RMSE = 0.99
Standard deviation = 7165.1	Standard deviation = 7165.1	MAE = 0.014

C. ARIMA (p , d , q) Model

p - Auto regression, d - Nonseasonal difference, q - Lagged forecast errors

$$Y_t = Q_0 + Q_1 Y_{t-1} + Q_2 Y_{t-2} + Q_3 Y_{t-3} + \ldots.. + Q_n Y_{t-n} + e_t \qquad (9)$$

$$Y_t = c(1 + Q_1)Y_{t-1} - Q_1 Y_{t-2} + e_t - h_1 e_{t-1} \qquad (10)$$

Which is equivalent to the following equation

$$(1 - Q_1 B)(1 - B)\,Y_t = C + (1 - h_1 B)\,e_t \qquad (11)$$

The general notations

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DOI: 10.35940/ijitee.J9981.0881019
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$$\left(1-Q_1B-......-Q_pB^p\right)\left(1-B\right)dY_t = C+\left(1-h_1B-.....-h_qB^q\right)e_t \quad (12)$$

Where Q_1 and h_1 are parameters to be determined.

D. Discharge Formula Adopted For Computations of out flow at Sathanur Dam

River Sluice

$$Q = \frac{2}{3} Cd\, L \sqrt{2g}\left(h_2^{3/2} - h_1^{3/2}\right) \quad (13)$$

Where Cd = 0.60, $\sqrt{2g}$ = 8.02, L= 5 Ft

h_2= Head over the lower edge of sluice height of the River Sluice

h_1= Head over the bottom edge height of the River Sluice Gate

Results

$= 78.25^{3/2} - 79.17^{3/2}$

$= \frac{2}{3} \times 0.60 \times 5 \times 8.02 \times (-12.24)$

= -196.12 c/s

Similary,

Table. 7 68 perdays predicted water level (Discharge m^3/s)

S.No	Predicted value- Q (c/s)	S.No	Predicted value- Q (c/s)
1	-196.12	18	-
2	-187.02	19	-
3	-155.5	20	-21.06
4	-184.4	21	-
5	-101.8	22	-
6	-	23	-
7	-	24	-9.6
8	-	25	-
9	9.6	26	-
10	-	27	-9.6
11	-8.02	28	-
12	-	29	-
13	-9.6	30	-9.6
14	-	31	-9.6
15	-	32	-9.6
16	-1.28	33	-
17	-20.21	34	-277.4

Table. 8 68 daily data of Parameter Estimates water level

Model Summary and Parameter Estimates

Dependent Variable: Observedvalues

Equation	Model Summary					Parameter Estimates	
	R Square	F	df1	df2	Sig.	Constant	b1
Logarithmic	.868	432.120	1	66	.000	77.985	-2.026
Exponential	.590	94.792	1	66	.000	73.963	-.001

Table 6 comparison of result Extended Thomas-Fiering and Maximum likelihood estimation, Table 7 and Table 8, the statistical model parameter estimates with Predicted value-Q (c/s) are analyzed from adopted For Computations of out flow at Sathanur Dam gauge site.

Table. 9 Least values for Best fit ARIMA Model (AR-1,1,3)

Model Fit

Fit Statistic	Mean	SE	Minimum	Maximum	Percentile		
					5	10	25
Stationary R-squared	.571	.	.571	.571	.571	.571	.571
R-squared	.982	.	.982	.982	.982	.982	.982
RMSE	.241	.	.241	.241	.241	.241	.241
MAPE	.177	.	.177	.177	.177	.177	.177
Max APE	1.463	.	1.463	1.463	1.463	1.463	1.463
MAE	.126	.	.126	.126	.126	.126	.126
Max AE	1.008	.	1.008	1.008	1.008	1.008	1.008
Normalized BIC	-2.529	.	-2.529	-2.529	-2.529	-2.529	-2.529

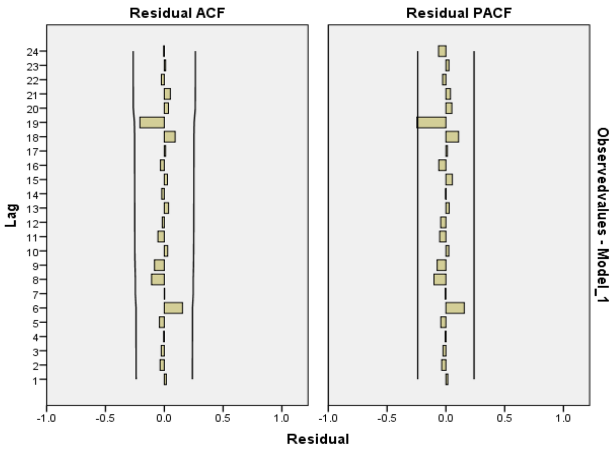

Fig. 6 Residual values for ACF and PACF daily data at Sathanur Dam

The significance of best fit model for water level using ARIMA shows in Table 9, In Fig. 6 Residuals values for ACF and PACF.

VIII. CONCLUSION

The paper investigates the linear stochastic modeling trend in discharge levels during the period at Sathanur Dam. A model-based approach is followed, generated data sets, where the components follow Extended Thomas-Fiering, ARIMA, Maximum likelihood estimation models. The model for the trend is aimed at predicting the water levels different time series by per days periods, the model for the trend should depend on the particular series being analysis i.e., on the overall ARIMA, Extended Thomas-Fiering, MLE, RMSE and MLE model. The one for which a generated formula process, α_{ij} Predicted discharge for j^{th} month from the j-1^{th} month at time i, $\overline{Q}_j$ The mean monthly discharge during month j, γ_j Correlation co-efficient for j^{th} month to j-1^{th} month, γ_{j+1} Correlation co-efficient for j+1^{th} month to j^{th} month).

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It is seen how different identification assumptions yield different application best fit the trend for the discharge levels. The Autoregressive Integrated Moving Average (ARIMA) models, or Box-Jenkins methodology, are a class of linear models which is capable of representing stationary as well as non-stationary time series. ARIMA models rely heavily on autocorrelation patterns which is used to capture the forecasting effectively. The present article conclude that the proposed method is best fit for the prediction and forecasting of the time series data analysis for different applications like Water level discharge, Rainfall flow, Wind flow etc,.

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