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# Forecasting rainfull using transfer function

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ABSTRACT

This research includes the application of some statistical techniques for studying the time series of the average monthly rainfall as an output series with two of the variables which affect on to, which are the series of the average monthly relative temperature and humidity as an input which is measured at the meteorological station of Ninavah. The techniques used are the modeling by an(ARIMA) model as well as the dynamic regression model. So that the perfect dynamic regression model selected was suitable for determining the future forecasting values.

**KEYWORDS:***Output,series,input ,ARIMA ,dynamic, regression,forecasting.*

## التكهن بالأمطار باستخدام الدالة التحولية

**الملخص**

يتضمن هذا البحث تطبيق لبعض التقنيات الاحصائية في دراسة السلسلة الزمنية لمعدلات الامطار الشهرية كسلسلة مخرجات مع سلسلتى المدخلات التي تؤثر فيها وهما سلسلة معدلات الرطوبة الشهرية ودرجة الحرارة التي تم قياسها في محطة نينوى للانواء الجوية باستخدام الانحدار الحركي . حصل الباحث على هذا الاستنتاج وهو ان يكون نموذج الانحدار الحركي التام المختار ملائماً لايجاد القيم التنبوئية للقيم المستقبلية.

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## INTRODUCTION

The series of the rainfall and relative temperature and humidity were examined and determined that they ware stationary in the mean and the variance, also both the autocorrelation and partial autocorrelation function were studied for the rainfall and relative temperature and humidity series and determined that there is an observed correlation for these phenomena; therefore, a suitable model was determined there three series from order AR(1). Relative to the dynamic regression models (it is that model which takes the time into account)is the modeling of the dynamic regression which shows how that output results from the input and that is depends upon:

1- The relation of the lag time with the input and output.
2- The time composition for the turbulence series.

Then the model which was identified by the statistical measures as well as the cross correlation function for the residual between the residual series ($\alpha_t$) of the input series, it was found that these two series are independent and the model of the transformation function was suitable . As well as the examination of the autocorrelation for the residuals series ($a_t$) by the statistical test shows that all values were insignificant and it is prove that the turbulence series ($a_t$).

## 1- Dynamic Regression (DR)

### 1.1 transfer function:[1],[3],[7]

For simplicity we will discuss just one input. The ideas we develop here are easily extended to multiple inputs if $Y_t$ depends on $X_t$ in some way we may write this as

$Y_t= f(X_t)$ (1)

Where f(.) is some mathematical function. The function f(.) is called a transfer function. The effect of a change in $X_t$is transferred to $Y_t$ in some way specified by the function f(.).In general, there are other factors causing variation in $Y_t$ besides changes in the specified input, we capture those other factors with an additives stochastic disturbance ($N_t$) that may be autocorrelated.

$N_t$ represents the effects of all excluded inputs on the variability of $Y_t$. The input – output relationship may also have an additive the constant term(C) .This is a buffer term that captures the effect of excluded inputs on the overall level of $Y_t$, thus we are considering models of the form

$Y_t = C + f(X_t) + N_t$ (2)

Where $Y_t$: is the output

$X_t$: is the input

C: is the constant term.

$f(X_t)$: is the transfer function

$N_t$: is the stochastic disturbance which may be autocorrelated and it is assumed to be independent of $X_t$

Input $N_t$ output

$X_t \rightarrow$[ transfer function] $\rightarrow Y_t$

**1-2 IMPULSE RESPONSE FUNCTION:**[6],[7]

We can write a linearly distributed lag transfer function in back shift form by defining v(B) as

$v(B) = v_0 + v_1B + v_2B^2 + v_3B^3 + \dots$ (3)

Where B is the backshift operator defined such that

$B^kX_t = X_{t-k}$

We can write the transfer function $f(X_t)$ as a liner combination of current and past $X_t$ value:

$Y_t = f(X_t) = v_0X_t + v_1 X_{t-1} + v_2 X_{t-2} + v_3 X_{t-3} + \dots$(4)

Using equation (3),(4) may be rewritten as

$Y_t = v(B) X_t$ (5)

Equation (5) is a compact way of saying that there is a linearly distributed lag relationship between change in $X_t$ and changes in $Y_t$ .The individual $v_k$ weights in v(B), ($v_0$ , $v_1$, $v_2$, $v_3$, … ) are called the impulse response weights ,we can estimate that the $v_k$ weights as follows

$V_k = \frac{\hat{\sigma}_\beta}{\hat{\sigma}_\alpha} \hat{\rho}_{\alpha\beta}(k)$ (6)

Where $\hat{\rho}_{\alpha\beta}(k)$ :estimates the cross correlation between $\alpha, \beta$

$\hat{\sigma}_\beta$: standard deviation of $\beta$ & $\hat{\sigma}_\alpha$: standard deviation of $\alpha$

## 1-3 Dead Time:[6],[7]

$Y_t$ might not react immediately to a change in $X_t$, some initial v weights may be zero. The number of v weights equal to zero (starting with $v_0$) is called dead time denoted as b, starting with $v_0$, if there is one v weight equal to zero ($v_0 = 0$), so b=1.Alternatively if $v_0 = v_1 = v_2 = 0$ and $v_3 \neq 0$ then b=3 .

## 1-4The rational distributed lag family:[2],[6],[7]

The Koyck impulse response function is just one member of the family of rational polynomial distributed lag models. This family is a set of impulse response functions v(B) given by

$v(B) = \frac{w(B)B^b}{\delta(B)}$ (7)

Where $w(B) = w_0 + w_1 B + w_2 B^2 + \cdots + w_h B^h$ (8)

$\delta(B) = 1 - \delta_1 B - \delta_2 B^2 - \cdots - \delta_r B^r$(9)

Where h: represents the order of ($w$)

r: represents the order of ($\delta$)

Extending this frame work to m inputs, i=1,2,…,M, is straight forward. The result may be written compactly as

$$Y_t = \sum_{i=1}^{m} v_i(B) X_{i,t}$$

$$= \sum_{i=1}^{m} \frac{w_i(B)B^{bi}}{\delta_i(B)} X_{i,t}$$

(10)

## 1-5 BUILDING DYNAMIC REGRESSION MODELS (DR).[4],[6] ,[7].

A Dynamic Regression (DR) model with two inputs consists of a transfer function plus a disturbance. This may be written as

$Y_t = c + v_1(B)X_{1,t} + v_2(B)X_{2,t} + N_t$

$$= \frac{w_1(B)B^{b_1}}{\delta_1(B)} X_{1,t} + \frac{w_2(B)B^{b_2}}{\delta_2(B)} X_{2,t} + N_t$$

Where

$N_t = \frac{\theta(B^s)\theta(B)}{\phi(B^s)\phi(B)\Delta_s^D \Delta^d} a_t$ , and

$a_t$ : is zero mean and normally distributed white noise

**1-6 preparation and prewhitening of the inputs and outputs series:**[1],[3]

Rewriting the process, we may think of AR and MA operators as a filter that, when applied to $X_t$,

produces an uncorrelated residual series

$\alpha_t = \theta_x^{-1}(B)\phi_x(B)X_t$

The series $\alpha_t$ (in practice $\hat{\alpha}_t$) is called the prewhitened $X_t$ series ,known suppose we apply the

same filter to $Y_t$: this will produce another residual series

$\beta_t = \theta_x^{-1}(B)\phi_x(B)Y_t$

**1-7 IDENTIFICTION**

**a) Estimation of the impulse response weights:**[2],[6]

Equation (7) shows that if we prewhiten the input, and apply the same filter to the output, then the v weights are proportion to the cross correlations of the residuals from these two filtering procedures. In practice, we don't know the parameters on the right side of equation (7).Instead we substitute estimates of these parameters obtained from the data to arrive at the following estimated v weights

$$\hat{v}_k = \frac{r_{\alpha\beta}(k)\hat{\sigma}_\beta}{\hat{\sigma}_\alpha}$$

**b) Identification of (r,s,b) for the transfer function:**[2],[7]

We obtain the identity

$v_j = 0$ ;  j<b

$v_j = \delta_1 v_{j-1} + \delta_2 v_{j-2} + \ldots \delta_r v_{j-r} + w_0$ ;j = b

$v_j = \delta_1 v_{j-1} + \delta_2 v_{j-2} + \ldots \delta_r v_{j-r} - w_{j-b}$ ;j = b +1, b+2, …,b+s

$v_j = \delta_1 v_{j-1} + \delta_2 v_{j-2} + \ldots \delta_r v_{j-r}$ ;j> b + s

**c)Disturbance series:**[6]

We generate an estimate of the $N_t$ series denoted by $\hat{N}_t$ , the estimate disturbance series and it is computed as:

$\hat{N}_t = Y_t - v_1(B)X_{1,t} - v_2(B)X_{2,t}$

$= Y_t - \frac{w_1(B)B^{b_1}}{\delta_1(B)}X_{1,t} - \frac{w_2(B)B^{b_2}}{\delta_2(B)}X_{2,t}$

This disturbance series ( $N_t$ ) in a dynamic regression will often be autocorrelated.

$\phi_N(B)N_t = \theta_N(B)a_t$

where $a_t$ : is zero mean and normally distributed white noise

**1-8 Estimation:**[3],[4],[5]

At the identification stage we tentatively specify a rational from transfer function model of orders(b,r,s), and a disturbance series ARIMA model of orders (p,d,q) We identified the following DR model

$$Y_t = \frac{w_1(B)B^{b_1}}{\delta_1(B)} X_{1,t} + \frac{w_2(B)B^{b_2}}{\delta_2(B)} X_{2,t} + \frac{\theta_N(B)B^b}{\varphi_N(B)} a_t \qquad (11)$$

At the second stage of our modeling strategy we estimate the parameters of the identified DR model using the available data .To estimate the coefficients in w(B) and $\delta(B)$ the next step in estimation is to compute the SSR(sum of squared residual)

$$SSR = \sum_{i=1}^{n} a_i^2$$

is used to choose better model coefficients, by taking the minimum SSR

**1-9 Diagnostic Check:**[1],[6]

We can Diagnose Check time series model by examining

a)Residuals Cross Correlation function (RCCF) $r_{k(\hat{a})}$

where $r_{k(\hat{a})} = \frac{\rho_{\alpha a(k)}}{\hat{\sigma}_a \hat{\sigma}_\alpha}$ k=1,2,3,… (12)

Where $\rho_{\alpha a(k)}$ : the cross correlation between a , $\alpha$

$\hat{\sigma}_a$: standard deviation of a

$\sigma_{\hat{\alpha}}$: standard deviation of $\alpha$

$$\rho_{\alpha a(k)} = \frac{\sum_{t=1}^{n-k}(\hat{\alpha}_t - \bar{\alpha})(\hat{a}_{t+k} - \bar{a})}{n} \quad k=1,2,3,\ldots \qquad (13)$$

Where $\hat{r}_k$ is only an estimate of parameter $\rho_k$ , we may test the null hypothesis

$H_o: \rho_k = 0$

$H_A: \rho_k \neq 0$

If $\alpha_t$ and $a_t$ are uncorrelated and normally distributed, and one of these two series is white noise, then $\hat{r}_k$ has the following approximate standard error

$S(\hat{r}_k) = n^{-1/2}$ (14)

Where n is smaller number of observation for $\hat{\alpha}_t$ or $\hat{\alpha}_t$.

Another useful statistic involves a test on all K residual CCF coefficients as a set. Consider the joint null hypothesis

$H_{o:}$: $\rho_1 = \rho_2 = \rho_3 = \ldots = \rho_k = 0$

$H_A$ : $\rho_1 \neq \rho_2 \neq \rho_3 \ldots \neq \rho_k \neq 0$

By using Ljung and Box(1978) below

$$s = n^2 \sum_{k=0}^{K} (n-k)^{-1} (r_k)^2 \quad (15)$$

Where n: is smaller number of observation for $\hat{\alpha}_t$ or $\hat{\alpha}_t$

$s \sim \chi^2$ for degree of freedom (K+1-m)
m: is the number of parameters estimated in the transfer function part of the DR model.
If the critical value is less than the $\chi^2$ for degree of freedom (K+1-m) , we accept the $H_0$ .it means that the two series $\hat{\alpha}_t$ and $\hat{\alpha}_t$ are independent.
b) Autocorrelation Check
We also check the adequacy of the ARIMA model for the disturbance series in the DR model by examining autocorrelation and partial autocorrelation of series $\hat{a}_t$ we test the null hypothesis

$H_{o:}$: $\rho_k = 0$

$H_A$ : $\rho_k \neq 0$ k=1,2,3,…K

Wrong transfer function model will also tend to produce significant residual autocorrelations, even if the disturbance ARIMA model is correct.

We may also perform a joint test with the null hypothesis

$H_{o:}$: $\rho_0(a) = \rho_1(a) = \rho_2(a) = \rho_3(a) = \ldots = \rho_k(a) = 0$

$H_A$ : $\rho_0(a) \neq \rho_1(a) \neq \rho_2(a) \neq \rho_3(a) \ldots \neq \rho_k(a) \neq 0$

The test statistic proposed by Ljung and Box (1978) is

$$Q^* = n(n+2) \sum_{k=1}^{K} (n-k)^{-1} r_k^2(\hat{a}) \qquad (16)$$

Under the null hypothesis $Q^*$ is approximately $\chi^2$ distributed with K-m degrees of freedom, where m is the total number of parameters estimated in the disturbance ARIMA model. After calculating the Critical value we compare it with the tabulated value if the Critical value is less than the tabulated value it means that will be a good model

## 1-11 forecasting:[1] ,[7]

*We* explain how forecasts of future value of $Y_t$ are produced from the following DR model with M=2 input: $Y_t = v_1(B)X_{1,t} + v_2(B)X_{2,t}$

$$Y_t = \frac{w_1(B)B^{b_1}}{\delta_1(B)}X_{1,t} + \frac{w_2(B)B^{b_2}}{\delta_2(B)}X_{2,t} \qquad (17)$$

Now equation(17 ) may be written

$v_i(B) = v_{i,0} + v_{i,1}B + v_{i,2}B^2 + \cdots = w_i(B)B^{b_i}/\delta_i(B)$ i=1,2

$b_i = dead\ time\ for\ input$ i=1,2

$w_i(B) = w_{i,0} + w_{i,1}B + \cdots + w_{i,h_i}B^{h_i}$ for i=1,2

$\delta_i(B) = 1 - \delta_{i,1}B - \delta_{i,2}B^2 - \cdots - \delta_{i,r_i}B^{r_i}$ for i=1,2

$h_i$=order of $w_i(B)$ i=1,2

$r_i$=order of $\delta_i(B)$i=1,2

Extending this framework to M inputs, i=1,2,…,m ,is straightforward. The result may be written compactly as :

$$Y_t = \sum_{i=1}^{M} v_i(B)X_{I,t}$$

$$= \sum_{i=1}^{M} \frac{w_i(B)B^{b_i}}{\delta_i(B)}X_{i,t}$$

Equation (17) shows the rational form of a model with M inputs and M transfer functions. A complete dynamic may also include a constant term (C),and it has a disturbance series $(N_t)$

$$Y_t = C + \sum_{i=1}^{M} \frac{w_i(B)B^{b_i}}{\delta_i(B)}X_{i,t} + N_t \quad (18)$$

The disturbance may have a time structure that can be described by an ARIMA mechanism. This is written as

$$\phi(B^s)\phi(B)\nabla_s^D\nabla^d N_t = \theta(B^s)\theta(B)a_t \quad \text{or}$$

$$N_t = \frac{\theta(B^s)\theta(B)}{\phi(B^s)\phi(B)\nabla_s^D\nabla^d}a_t \quad (19)$$

Substitute (19) into (18); then the combined multiple input transfer function plus disturbance model (i.e. the complete dynamic regression model) is

$$Y_t = C + \sum_{i=1}^{m} \frac{w_i(B)B^{b_i}}{\delta_i(B)} X_{i,t} + \frac{\theta(B^s)\theta(B)}{\emptyset(B^s)\emptyset(B)\nabla_s^D \nabla^d} a_t \quad (20)$$

Using the initial values, recursively compute (for periods t, t+1, t+2) the following two series:

$y_{1,t}^* = [w_1(B)B^{b_1}/\delta_1(B)]x_{1,t}$

$=\delta_{1,1}y_{1,t-1}^* + \cdots + \delta_{1,r1}y_{1,t-r1}^* + w_{1,0}x_{1,t-b1} + \cdots + w_{1,h1}x_{1,t-b1-h1}$ (21)

$y_{2,t}^* = [w_2(B)B^{b_2}/\delta_2(B)]x_{2,t}$

$=\delta_{2,1}y_{2,t-1}^* + \cdots + \delta_{2,r2}y_{2,t-r2}^* + w_{2,0}x_{2,t-b2} + \cdots + w_{2,h2}x_{2,t-b2-h2}$ (22)

These two series are the outputs from the M=2 transfer function components of model (18), given the initial values of the coefficients. In other words, $y_{1,t}^*$ is the set of values predicted by the transfer function $[w_1(B)B^{b_1}/\delta_1(B)]x_{1,t}$ in (20), conditional on the initial coefficient values ; and $y_{2,t}^*$ is the set of values predicted by the transfer function $[w_2(B)B^{b_2}/\delta_2(B)]x_{2,t}$ in (18), also conditional on the initial coefficient values.

Because of the recursive nature of (20), computation of $y_{1,t}^*$ requires $r_1$ starting values of $y_{1,t}^*$ prior to t=$k_1$, where $k_1 = \max[r_1 + 1, b_1 + h_1 + 1]$.Similarly, computation of $y_{2,t}^*$ in (20) requires $r_2$ starting values for $y_{2,t}^*$ prior to t=$k_2$, where $k_2$=max[$r_2$ +1,$b_2 + h_2 + 1$].

F = C( 1-$\sum_{i=1}^{p}\varphi_i)(1 - \sum_{i=1}^{p}\varphi_{is})(1 - \sum_{i=1}^{r1}\delta_{i1}) \ldots (1 - \sum_{i=1}^{rm}\delta_{im}) \ldots$ (21)

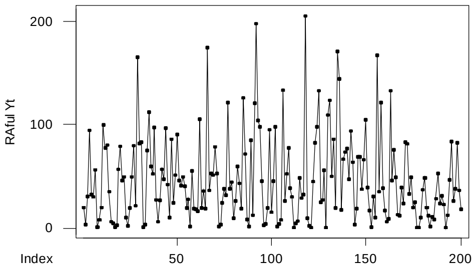
## .2)Application

### 2-1 Introduction

This section deals with the application of section one. The first method is testing of cross-correlation function between prewhitening of the input denoted by humidity (RH)and temperature and of the output denoted by rainfall. We take the monthly average of the meteorological station of Ninavah for the period (1976) to (2000), all data are shown appendix (A). The second method is used to test $\chi^2$between two series of input and output by using equations(15), (16)

### 2.2 preparation and prewhitening of the inputs and outputs series

**1)**cross-correlation between output rainfall ($Y_t$) and input temperature ($X_{1t}$),.RH ($X_{2t}$),.We plot the time series of it by using software of Minitab (13.2) as in figures(1),(2),(3), respectively We show that the series is stationary in mean and variance




**Figure(1):**the time series plot of rainfull

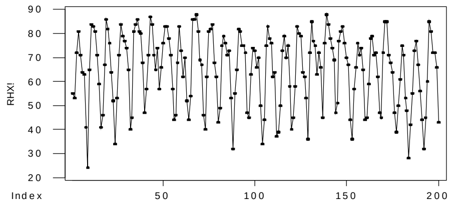
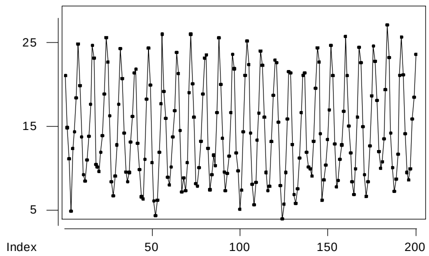
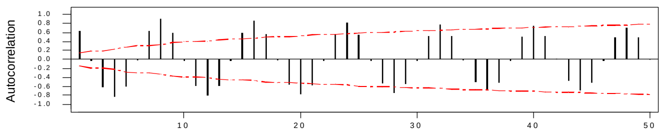


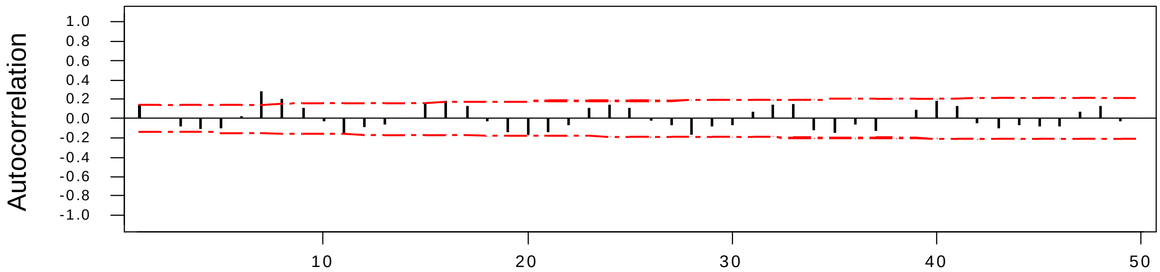

**Figure (2):**the time series plot of temperature



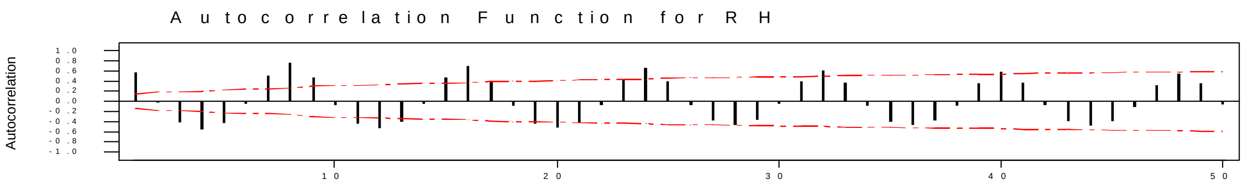

**Figure(3**):the time series plot of (RH**)**




**Figure(4)**: ACF for the rainfall

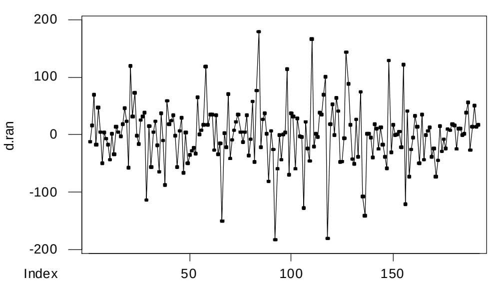


**Figure(5):** ACF for the temperature




**Figure(6)** :ACF for the RH

We plot above (Autocorrelation function) ACF for the rainfall, temperature and RH series in figures (4),(5),(6) we show that the seasonality period is(8) months.
We take the first difference for the data as shown in the figures(7),(8) ,(9) and plot ACF again for the difference time series about temperature and RH in figures(10,11) and (PACF) in figures(12,13)



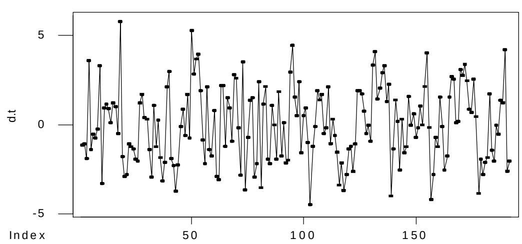




**Figure (7)**: the plot for difference time series of(rainfull)

**Figure (8)**: the plot for difference time series of (temperature)

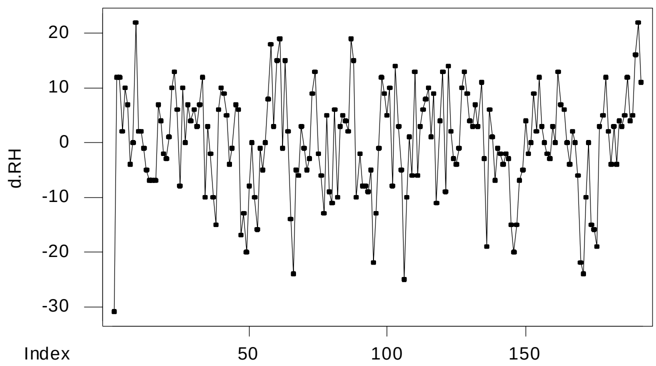



**Figure (9):** The plot for difference time series of(RH)

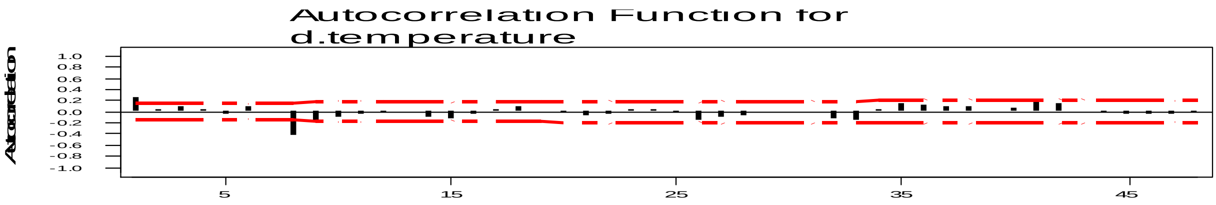



**Figure (10):** ACF for differenced time series of**(temperature)**

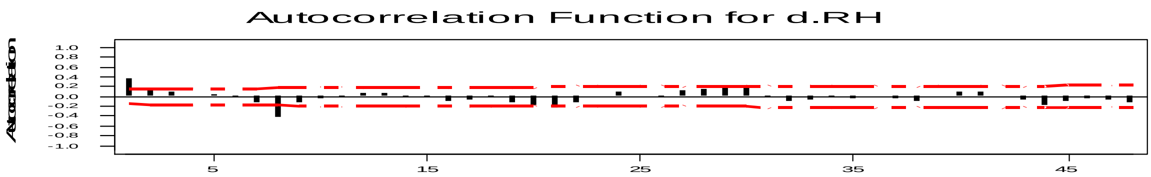



**Figure (11)**:(ACF)differenced time series of(RH)

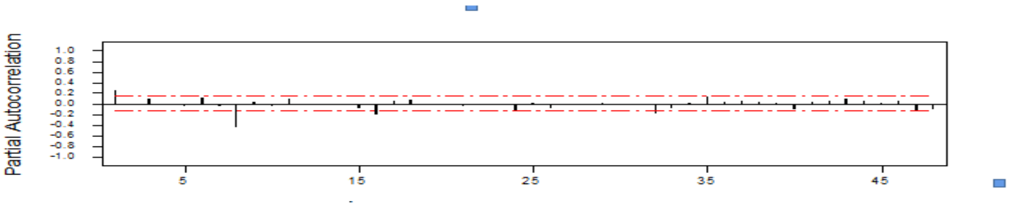



**Figure (12)**:(PACF)differenced time series of **temperature)**

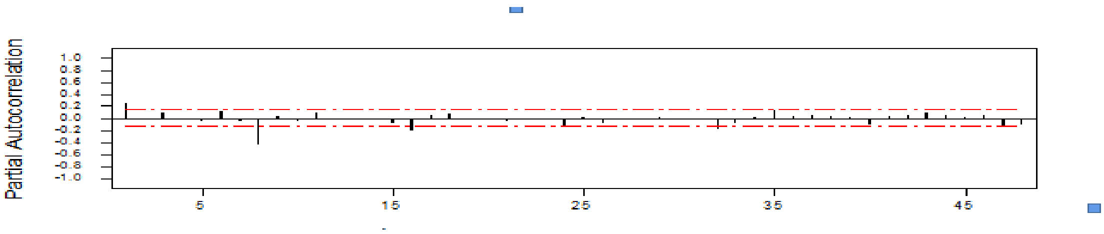



**Figure (13)**:(PACF)differenced time series of(RH)

The figures (10) and (12),by using (AIC=-2logL +2m) we suggest that the tentative model for the differenced series is AR(1) as shown in the equation below:

$\propto_t = (1-\varphi B)X_{1,t}$

$\beta_t = (1-\ \varphi B)Y_t$

The researcher writes the program through the use of macro within Minitab just as program (1) in the appendix (B).we can find that the results of series( $\alpha_t^{\wedge}$ ) are the same as in the table (1).

**Table(1)** :the values of ( $\alpha_t^{\wedge}$ ) variable input (temperature) with ( $\phi$ =0.2518)

| T | $\alpha_t^{\wedge}$ | t | $\alpha_t^{\wedge}$ | T | $\alpha_t^{\wedge}$ | T | $\alpha_t^{\wedge}$ | T | $\alpha_t^{\wedge}$ | t | $\alpha_t^{\wedge}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -1.15000 | 33 | 1.84281 | 65 | -1.75396 | 97 | 0.10971 | 129 | 0.07590 | 161 | 1.86475 |
| 2 | -0.81043 | 34 | -1.52698 | 66 | 1.80216 | 98 | 2.27410 | 130 | -0.93741 | 162 | -0.49029 |
| 3 | -1.62302 | 35 | 0.56475 | 67 | 0.57230 | 99 | -2.20432 | 131 | 3.58921 | 163 | -2.52482 |
| 4 | 4.07842 | 36 | -1.91295 | 68 | -1.18921 | 100 | 0.90288 | 132 | 3.25647 | 164 | -1.10791 |
| 5 | -2.30648 | 37 | -2.68417 | 69 | 3.03921 | 101 | 0.82410 | 133 | 0.41762 | 165 | 1.99065 |
| 6 | -0.19748 | 38 | -1.30683 | 70 | 1.89496 | 102 | -1.23921 | 134 | 1.68489 | 166 | 2.30971 |
| 7 | -0.61151 | 39 | 2.62878 | 71 | -0.85468 | 103 | -4.24820 | 135 | 2.38381 | 167 | 1.87014 |
| 8 | -0.06115 | 40 | 2.47122 | 72 | -2.79964 | 104 | -0.06690 | 136 | 2.56978 | 168 | -0.54209 |
| 9 | 3.36295 | 41 | -2.65540 | 73 | 4.21763 | 105 | 0.20216 | 137 | 0.46906 | 169 | 0.17482 |
| 10 | -4.13094 | 42 | -1.82158 | 74 | -4.53130 | 106 | 1.92518 | 138 | 1.92266 | 170 | 3.04964 |
| 11 | 1.78094 | 43 | -3.17086 | 75 | 0.21907 | 107 | 0.92158 | 139 | -4.56655 | 171 | 1.96942 |
| 12 | 0.91079 | 44 | -1.30575 | 76 | 1.52626 | 108 | 1.34748 | 140 | -0.34280 | 172 | 2.70755 |
| 13 | 0.61043 | 45 | 0.46655 | 77 | 1.16007 | 109 | -0.92806 | 141 | 1.73993 | 173 | 1.59388 |
| 14 | -0.12662 | 46 | 0.87518 | 78 | -3.32770 | 110 | -0.07410 | 142 | -0.15252 | 174 | 0.23309 |
| 15 | 1.17482 | 47 | -0.81403 | 79 | -1.45719 | 111 | 2.15036 | 143 | -2.60036 | 175 | 0.48597 |
| 16 | 0.69784 | 48 | 1.85108 | 80 | 2.95396 | 112 | -1.57878 | 144 | 0.94209 | 176 | 2.37374 |
| 17 | -0.75180 | 49 | -1.17806 | 81 | -4.15432 | 113 | 0.56439 | 145 | -1.67554 | 177 | -0.19209 |
| 18 | 5.92590 | 50 | 5.48885 | 82 | 2.04389 | 114 | -0.67554 | 146 | -0.84712 | 178 | -3.96331 |
| 19 | -3.26044 | 51 | 1.51546 | 83 | 1.86043 | 115 | -1.39892 | 147 | 1.91475 | 179 | -0.98057 |
| 20 | -2.44676 | 52 | 2.98237 | 84 | -2.49137 | 116 | -3.00971 | 148 | -0.45288 | 180 | -2.30899 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 21 | -2.06978 | 53 | 3.01834 | 85 | -1.70899 | 117 | -1.29388 | 149 | 0.61259 | 181 | -1.39496 |
| 22 | -0.39496 | 54 | 0.90539 | 86 | 1.65396 | 118 | -3.15863 | 150 | -0.85108 | 182 | -1.32122 |
| 23 | -0.97302 | 55 | -1.32842 | 87 | -0.27698 | 119 | -1.86834 | 151 | -0.02374 | 183 | 2.21583 |
| 24 | -1.03525 | 56 | -1.98597 | 88 | -1.95000 | 120 | -0.64496 | 152 | 1.10036 | 184 | -1.89065 |
| 25 | -1.61007 | 57 | 2.65396 | 89 | 2.34101 | 121 | -0.86007 | 153 | -0.26439 | 185 | -1.68489 |
| 26 | -1.55899 | 58 | -1.92878 | 90 | -2.21583 | 122 | -2.34784 | 154 | 2.15000 | 186 | 0.46619 |
| 27 | 1.71619 | 59 | -1.39748 | 91 | 0.54065 | 123 | -0.43273 | 155 | 3.50863 | 187 | -0.53741 |
| 28 | 1.39784 | 60 | 1.24065 | 92 | -2.17518 | 124 | 2.17698 | 156 | -1.16979 | 188 | 1.48849 |
| 29 | -0.02806 | 61 | -3.10144 | 93 | -1.45863 | 125 | 1.42158 | 157 | -4.16223 | 189 | 0.91007 |
| 30 | 0.19928 | 62 | -2.36978 | 94 | 3.45360 | 126 | 1.27158 | 158 | -1.74244 | 190 | 3.88525 |
| 31 | -1.47554 | 63 | 2.98058 | 95 | 3.70719 | 127 | 0.30935 | 159 | 0.00504 | 191 | -3.65756 |
| 32 | -2.59748 | 64 | 1.64604 | 96 | 0.42949 | 128 | -0.68885 | 160 | -1.07374 | 192 | -1.39532 |

And We can find the series ( $\hat{\beta}_t$ ) by using program (2) in the appendix (B).

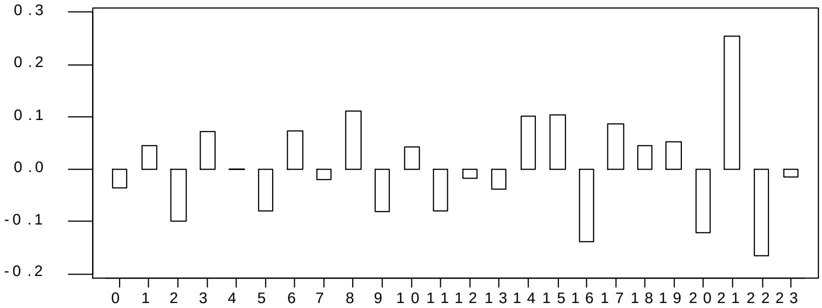
**Table (2):** values ( $\hat{\beta}_t$ ) for output (rainfall)

| T | ( $\hat{\beta}_t$ ) | T | ( $\hat{\beta}_t$ ) | T | ( $\hat{\beta}_t$ ) | T | ( $\hat{\beta}_t$ ) | T | ( $\hat{\beta}_t$ ) | t | ( $\hat{\beta}_t$ ) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -12.000 | 33 | 22.216 | 65 | -6.864 | 97 | 11.954 | 129 | -5.235 | 161 | 34.059 |
| 2 | 19.522 | 34 | -24.517 | 66 | -146.622 | 98 | 3.473 | 130 | -46.806 | 162 | 6.341 |
| 3 | 65.145 | 35 | -60.117 | 67 | 39.996 | 99 | 113.768 | 131 | -40.099 | 163 | -53.576 |
| 4 | -34.350 | 36 | 53.917 | 68 | -21.529 | 100 | -98.381 | 132 | 39.491 | 164 | 48.065 |
| 5 | 52.055 | 37 | -19.668 | 69 | 75.988 | 101 | 55.000 | 133 | -45.323 | 165 | -52.239 |
| 6 | -6.936 | 38 | -84.732 | 70 | -58.802 | 102 | 22.557 | 134 | 84.719 | 166 | 10.703 |
| 7 | -51.584 | 39 | 80.782 | 71 | 1.524 | 103 | -67.358 | 135 | -126.585 | 167 | 6.650 |
| 8 | 16.066 | 40 | 3.794 | 72 | 10.116 | 104 | 43.332 | 136 | -114.081 | 168 | 11.638 |
| 9 | -7.456 | 41 | 19.717 | 73 | 21.011 | 105 | -10.251 | 137 | 36.654 | 169 | -42.149 |
| 10 | -15.538 | 42 | 27.656 | 74 | 29.709 | 106 | -2.519 | 138 | 1.623 | 170 | -13.430 |
| 11 | -39.069 | 43 | -9.811 | 75 | -3.739 | 107 | -126.469 | 139 | -4.978 | 171 | -67.458 |
| 12 | 12.328 | 44 | -56.173 | 76 | -14.509 | 108 | 54.154 | 140 | -38.167 | 172 | -25.843 |
| 13 | -34.653 | 45 | 21.527 | 77 | 7.924 | 109 | -29.465 | 141 | 28.296 | 173 | 26.755 |
| 14 | 22.937 | 46 | 28.362 | 78 | 32.842 | 110 | -39.482 | 142 | 6.267 | 174 | -32.628 |
| 15 | 0.599 | 47 | -74.604 | 79 | -44.261 | 111 | 178.457 | 143 | -27.445 | 175 | -0.573 |
| 16 | -3.458 | 48 | 20.171 | 80 | 0.889 | 112 | -62.751 | 144 | 19.819 | 176 | -21.636 |
| 17 | 19.004 | 49 | -50.831 | 81 | 60.740 | 113 | 7.012 | 145 | -20.924 | 177 | 16.342 |
| 18 | 42.467 | 50 | -22.910 | 82 | -62.181 | 114 | -4.253 | 146 | -33.993 | 178 | 5.481 |
| 19 | 11.540 | 51 | -18.861 | 83 | 89.435 | 115 | 39.357 | 147 | -48.831 | 179 | 16.260 |
| 20 | -63.392 | 52 | -15.700 | 84 | 160.486 | 116 | 25.031 | 148 | 144.430 | 180 | 11.192 |
| 21 | 134.279 | 53 | -27.584 | 85 | -67.224 | 117 | 60.563 | 149 | -63.458 | 181 | -28.478 |
| 22 | 2.334 | 54 | 73.685 | 86 | 32.114 | 118 | 83.350 | 150 | 24.655 | 182 | 17.469 |
| 23 | 64.816 | 55 | -16.443 | 87 | 30.102 | 119 | -206.381 | 151 | -4.555 | 183 | 7.755 |
| 24 | -19.481 | 56 | 7.700 | 88 | -8.066 | 120 | 63.776 | 152 | 0.076 | 184 | -3.569 |
| 25 | -15.823 | 57 | 15.461 | 89 | -81.402 | 121 | 48.717 | 153 | 5.400 | 185 | 2.127 |
| 26 | 29.754 | 58 | 115.219 | 90 | 27.221 | 122 | -13.621 | 154 | -22.860 | 186 | 38.022 |
| 27 | 25.729 | 59 | -12.315 | 91 | -27.212 | 123 | 64.650 | 155 | 128.214 | 187 | 46.006 |
| 28 | 29.992 | 60 | 30.218 | 92 | -176.979 | 124 | 25.034 | 156 | -152.221 | 188 | -40.725 |
| 29 | -122.994 | 61 | 26.263 | 93 | -12.620 | 125 | -58.399 | 157 | 71.543 | 189 | 20.923 |
| 30 | 43.754 | 62 | -35.513 | 94 | 14.506 | 126 | -34.814 | 158 | -83.224 | 190 | 47.824 |
| 31 | -59.827 | 63 | 40.723 | 95 | -43.824 | 127 | 6.009 | 159 | -7.444 | 191 | 0.957 |
| 32 | 19.201 | 64 | -42.461 | 96 | 11.954 | 128 | 145.660 | 160 | 1.496 | 192 | 13.800 |

Correlation coefficient values between ( $\hat{\alpha}_t$ )and( $\hat{\beta}_t$ )can be found by using equation (12)as in table(3).

**Table (3):** the values of correlation coefficient between ( $\hat{\alpha}_t$ ) and ( $\hat{\beta}_t$ )

| T | $r_{\alpha\beta}$ | T | $r_{\alpha\beta}$ | T | $r_{\alpha\beta}$ | T | $r_{\alpha\beta}$ |
|---|---|---|---|---|---|---|---|
| 0 | -0.036 | 6 | 0.073 | 12 | -0.018 | 18 | 0.045 |
| 1 | 0.045 | 7 | -0.020 | 13 | -0.038 | 19 | 0.052 |
| 2 | -0.100 | 8 | 0.111 | 14 | 0.102 | 20 | -0.122 |
| 3 | 0.071 | 9 | -0.082 | 15 | 0.105 | 21 | 0.256 |
| 4 | -0.001 | 10 | 0.043 | 16 | -0.140 | 22 | -0.166 |
| 5 | -0.080 | 11 | -0.080 | 17 | 0.087 | 23 | -0.015 |




**Figure(14)**: cross correlation coefficient between ( $\hat{\alpha}_t$ ) and ( $\hat{\beta}_t$ )

It is clear from figure (14)that the dead time is (b=0) close to zero which explains $\rho_{\alpha\beta}(0) \neq 0$, reading the graph from left to right ,there are no initial zero value v weights(because $v_0 \neq 0$),and there is an eventual simple exponential decay pattern.

## 2.3 Identification for $y_t$ and $x_{1t}$

### a- Estimation of the impulse response weights

We estimate the impulse response weights between input ($X_t$) and output series ($Y_t$) in the table (4) below

**Table (4):** The values of the impulse response of input variable (temperature $X_{1,t}$)

| T | V | t | V | T | V | t | V |
|---|---|---|---|---|---|---|---|
| 0 | -0.980 | 6 | 1.988 | 12 | -0.490 | 18 | 1.220 |
| 1 | 1.220 | 7 | -0.540 | 13 | -1.030 | 19 | 1.410 |
| 2 | -2.700 | 8 | 3.020 | 14 | 2.770 | 20 | -3.320 |
| 3 | 1.900 | 9 | -2.230 | 15 | 2.800 | 21 | 6.970 |
| 4 | -0.027 | 10 | 1.170 | 16 | -3.810 | 22 | -4.520 |
| 5 | -2.170 | 11 | -2.170 | 17 | 2.370 | 23 | -0.400 |

### b)Identification of (r,s,b) for the transfer function

It is clear from the figure (14) of(r,s,b) equal(2,2,0) .the pattern can be written as:

$$Y_t = \frac{(w_0 - w_1 B - w_2 B^2)}{(1-\delta_1 B - \delta_2 B^2)} X_{1t} + a_t \qquad (31)$$

### c) Disturbance series

We find disturbance series by using the equation

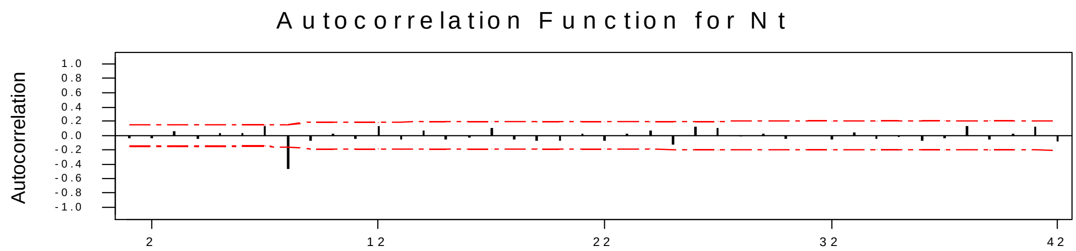
$$N_t = Y_t - v_0 X_t - v_1 X_{t-1} - \cdots - v_{23} X_{t-23} \quad (32)$$

By using equation (32) we can obtain the number of disturbance series which their values are less than the input and output series values(t=23) so, we can apply them in program (3) in appendix(B) ,the values are in table (5)

**Table(5)** :estimate values of disturbance series $N_t$

| T | $N_t^{\wedge}$ | T | $N_t^{\wedge}$ | T | $N_t^{\wedge}$ | t | $N_t^{\wedge}$ | t | $N_t^{\wedge}$ | t | $N_t^{\wedge}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 13.365 | 31 | 10.901 | 61 | 147.725 | 91 | 29.868 | 121 | 2.03 | 151 | -21.446 |
| 2 | -31.641 | 32 | 35.253 | 62 | -30.333 | 92 | -3.813 | 122 | -35.799 | 152 | -4.474 |
| 3 | 6.611 | 33 | -0.382 | 63 | 52.868 | 93 | 46.077 | 123 | -51.845 | 153 | -41.222 |
| 4 | 54.277 | 34 | 33.167 | 64 | 18.616 | 94 | 127.691 | 124 | -38.218 | 154 | 40.844 |
| 5 | 31.804 | 35 | 108.622 | 65 | -17.067 | 95 | -156.801 | 125 | 124.675 | 155 | 45.27 |
| 6 | -80.144 | 36 | 38.022 | 66 | -24.033 | 96 | -11.406 | 126 | -21.48 | 156 | 9.855 |
| 7 | -31.143 | 37 | -0.049 | 67 | -55.589 | 97 | 80.595 | 127 | -22.942 | 157 | -29.622 |
| 8 | -17.244 | 38 | 24.683 | 68 | -17.151 | 98 | -14.855 | 128 | 7.415 | 158 | -5.815 |
| 9 | -28.431 | 39 | 23.632 | 69 | -182.988 | 99 | 71.533 | 129 | -29.11 | 159 | -1.084 |
| 10 | -0.27 | 40 | 34.248 | 70 | 0.591 | 100 | 34.748 | 130 | -5.655 | 160 | 17.514 |
| 11 | 0.871 | 41 | -18.947 | 71 | -61.522 | 101 | -13.25 | 131 | 11.296 | 161 | -5.045 |
| 12 | -59.391 | 42 | -32.597 | 72 | -14.96 | 102 | -73.314 | 132 | 92.202 | 162 | -0.353 |
| 13 | 13.981 | 43 | -147.168 | 73 | 32.97 | 103 | -1.652 | 133 | -125.625 | 163 | 24.038 |
| 14 | -25.183 | 44 | -46.851 | 74 | -37.958 | 104 | 132.26 | 134 | 50.583 | 164 | 35.708 |
| 15 | -43.969 | 45 | -10.365 | 75 | 116.984 | 105 | 81.207 | 135 | -15.209 | 165 | -13.952 |
| 16 | 24.472 | 46 | 56.519 | 76 | -37.351 | 106 | 12.39 | 136 | -59.037 | 166 | 4.87 |
| 17 | 74.275 | 47 | -25.199 | 77 | 67.257 | 107 | -30.118 | 137 | 48.495 | 167 | 47.988 |
| 18 | -5.746 | 48 | -52.361 | 78 | -35.903 | 108 | -33.99 | 138 | 28.447 | 168 | -35.856 |
| 19 | 36.336 | 49 | -2.244 | 79 | -12.999 | 109 | 0.865 | 139 | -23.989 | 169 | 44.456 |
| 20 | -29.206 | 50 | 40.356 | 80 | 9.85 | 110 | -2.283 | 140 | -45.368 | | |
| 21 | -39.696 | 51 | 11.621 | 81 | -41.741 | 111 | 74.674 | 141 | 62.079 | | |
| 22 | 4.019 | 52 | 36.622 | 82 | 22.486 | 112 | -102.218 | 142 | -51.065 | | |
| 23 | 36.398 | 53 | 4.295 | 83 | -107.222 | 113 | -107.77 | 143 | 14.645 | | |
| 24 | -69.85 | 54 | 14.151 | 84 | 36.119 | 114 | 38.386 | 144 | 21.651 | | |
| 25 | -27.85 | 55 | 3.439 | 85 | -40.364 | 115 | -4.607 | 145 | -8.623 | | |
| 26 | -12.357 | 56 | -20.087 | 86 | -35.045 | 116 | -20.542 | 146 | -61.668 | | |
| 27 | -13.303 | 57 | 24.121 | 87 | 144.68 | 117 | -30.373 | 147 | -33.479 | | |
| 28 | -4.782 | 58 | 7.383 | 88 | 21.282 | 118 | -3.758 | 148 | -46.209 | | |
| 29 | 2.524 | 59 | 10.358 | 89 | -32.411 | 119 | 3.314 | 149 | -22.5 | | |
| 30 | -20.55 | 60 | 51.908 | 90 | 3.156 | 120 | -7.261 | 150 | -14.829 | | |

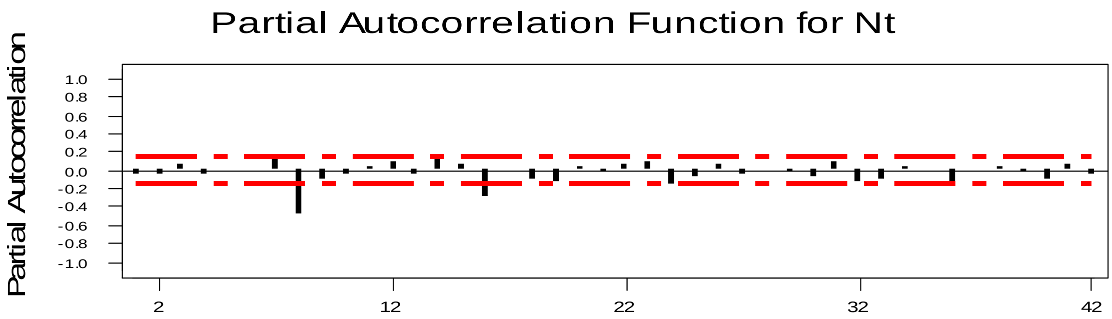
We plot ACF and PACF from the disturbance series ($\hat{N}_t$), as in the figures (15) and (16)




| Lag | Corr | T | LBQ | Lag | Corr | T | LBQ | Lag | Corr | T | LBQ | Lag | Corr | T | LBQ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -0.04 | -0.52 | 0.27 | 13 | -0.06 | -0.59 | 50.39 | 25 | -0.14 | -1.37 | 62.92 | 37 | -0.04 | -0.40 | 71.68 |
| 2 | -0.04 | -0.48 | 0.51 | 14 | 0.07 | 0.75 | 51.37 | 26 | 0.12 | 1.19 | 65.77 | 38 | 0.14 | 1.34 | 75.83 |
| 3 | 0.06 | 0.80 | 1.18 | 15 | -0.06 | -0.60 | 52.01 | 27 | 0.10 | 0.97 | 67.72 | 39 | -0.06 | -0.57 | 76.61 |
| 4 | -0.05 | -0.68 | 1.67 | 16 | -0.03 | -0.34 | 52.22 | 28 | -0.01 | -0.05 | 67.72 | 40 | 0.02 | 0.19 | 76.70 |
| 5 | 0.03 | 0.33 | 1.79 | 17 | 0.11 | 1.09 | 54.34 | 29 | 0.02 | 0.18 | 67.79 | 41 | 0.12 | 1.19 | 80.16 |
| 6 | 0.03 | 0.33 | 1.90 | 18 | -0.07 | -0.67 | 55.15 | 30 | -0.05 | -0.50 | 68.32 | 42 | -0.08 | -0.74 | 81.51 |
| 7 | 0.13 | 1.69 | 4.99 | 19 | -0.07 | -0.72 | 56.10 | 31 | -0.00 | -0.04 | 68.33 | | | | |
| 8 | -0.47 | -5.98 | 45.11 | 20 | -0.07 | -0.75 | 57.16 | 32 | -0.06 | -0.62 | 69.16 | | | | |
| 9 | -0.07 | -0.72 | 45.96 | 21 | 0.02 | 0.23 | 57.26 | 33 | 0.04 | 0.38 | 69.48 | | | | |
| 10 | 0.02 | 0.24 | 46.05 | 22 | -0.07 | -0.68 | 58.14 | 34 | -0.05 | -0.53 | 70.11 | | | | |
| 11 | -0.05 | -0.50 | 46.46 | 23 | 0.02 | 0.18 | 58.20 | 35 | -0.03 | -0.25 | 70.25 | | | | |
| 12 | 0.13 | 1.42 | 49.79 | 24 | 0.07 | 0.73 | 59.23 | 36 | -0.07 | -0.69 | 71.32 | | | | |

**Figure (15):** ACF and from the disturbance series ($\hat{N}_t$)

Figure(15) Shos the outline because we have the value (-59.39) in table(5) outlier.




| Lag | PAC | T | Lag | PAC | T | Lag | PAC | T | Lag | PAC | T |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -0.04 | -0.52 | 13 | -0.04 | -0.51 | 25 | -0.08 | -1.02 | 37 | 0.01 | 0.10 |
| 2 | -0.04 | -0.50 | 14 | 0.12 | 1.52 | 26 | 0.07 | 0.88 | 38 | 0.04 | 0.54 |
| 3 | 0.06 | 0.77 | 15 | 0.06 | 0.77 | 27 | -0.03 | -0.40 | 39 | -0.01 | -0.17 |
| 4 | -0.05 | -0.64 | 16 | -0.29 | -3.83 | 28 | 0.00 | 0.06 | 40 | -0.09 | -1.13 |
| 5 | 0.03 | 0.35 | 17 | 0.00 | 0.05 | 29 | -0.02 | -0.30 | 41 | 0.07 | 0.86 |
| 6 | 0.02 | 0.26 | 18 | -0.10 | -1.36 | 30 | -0.06 | -0.81 | 42 | -0.04 | -0.51 |
| 7 | 0.14 | 1.85 | 19 | -0.13 | -1.64 | 31 | 0.09 | 1.19 | | | |
| 8 | -0.48 | -6.26 | 20 | 0.03 | 0.45 | 32 | -0.13 | -1.67 | | | |
| 9 | -0.08 | -1.07 | 21 | -0.01 | -0.09 | 33 | -0.09 | -1.19 | | | |
| 10 | -0.03 | -0.45 | 22 | 0.06 | 0.84 | 34 | 0.04 | 0.54 | | | |
| 11 | 0.04 | 0.54 | 23 | 0.10 | 1.36 | 35 | 0.02 | 0.23 | | | |
| 12 | 0.10 | 1.27 | 24 | -0.15 | -1.93 | 36 | -0.11 | -1.42 | | | |

**Figure (16):** PACF and from the disturbance series ($\hat{N}_t$)

It is clear from figure (16) that the disturbance series ($\hat{N}_t$) is equal residual series $N_t = a_t$(the series $N_t$ does not follow any model because it is independent random) , thus the model of dynamic regression is as shown in the equation below

$$Y_t = \frac{(w_0 - w_1 B - w_2 B^2)}{(1 - \delta_1 B - \delta_2 B^2)} X_{1t} + a_t \qquad (33)$$

We estimate the values of the model by using equation (33)

$v_0 = w_0$

$v_1 = \delta_1 v_0 - w_1$

$v_2 = \delta_1 v_1 + \delta_2 v_0 - w_2$ $\qquad$ $j = b+1, \ldots, b+s$

$v_3 = \delta_1 v_2 + \delta_2 v_1$

$v_4 = \delta_1 v_3 + \delta_2 v_2$

The next step in estimation is to compute the SSR (Sum of Squared Residuals)

$$SSR = \sum_{t=1}^{n} a_t^2$$

$$Y_t = \frac{(-2.667 + 1.422B + 4.451B^2)}{(1 - 1.048B - 0.7266B^2)} X_{1t} + a_t$$

$\hat{a}_t = Y_t - 1.048Y_{t-1} - 0.7266Y_{t-2} + 2.667X_{1,t} - 1.422\, X_{1,t-1} - 4.451\, X_{1,t-2} + 1.048a_{t-1} + 0.7266\, a_{t-2}$ (34)

We find the values of series ($\hat{a}_t$) by using equation (34) and program (4) in appendix (B),We have shown that all value of series ($\hat{a}_t$)is equal to zero

**d)Diagnostic Check**

a) Residuals Cross Correlation Function(RCCF)$r_{k(\bar{a})}$.We that the cross correlation between series ($\hat{\alpha}_t$) and ($\hat{a}_t$**)**, It is clear that there are no correlation between two series ($\hat{\alpha}_t$) and series ($\hat{a}_t$**)**.We can find the cross correlation between rainfall and RH as the same way between rainfall and temperature.

The figures (11) and (13) suggest that the tentative model for the differenced series is AR(1) as shown in the equation below:

$\alpha_t = (1 - \varphi B)X_{2,t}$

$\beta_t = (1 - \varphi B)Y_t$

The researcher writes the program through the use of macro within Minitab just as program (1) in the appendix (B).We can find that the results of series($\hat{\alpha}_t$) are the same as in table (6).

**Table(6)** :the values of ($\hat{\alpha}_t$) variable input (RH) with ($\phi$=0.3882)

| T | $\hat{\alpha}_t$ | T | $\hat{\alpha}_t$ | T | $\hat{\alpha}_t$ | t | $\hat{\alpha}_t$ | T | $\hat{\alpha}_t$ | t | $\hat{\alpha}_t$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -31.0000 | 33 | 9.2826 | 65 | -14.7764 | 97 | -20.0590 | 129 | 3.9534 | 161 | -1.1646 |
| 2 | 24.0342 | 34 | -14.6584 | 66 | -18.5652 | 98 | -4.4596 | 130 | 0.5062 | 162 | 13.0000 |
| 3 | 7.3416 | 35 | 6.8820 | 67 | 4.3168 | 99 | 4.0466 | 131 | 1.4472 | 163 | 1.9534 |
| 4 | -2.6584 | 36 | -3.1646 | 68 | -4.0590 | 100 | 12.3882 | 132 | 5.8354 | 164 | 3.2826 |
| 5 | 9.2236 | 37 | -9.2236 | 69 | 5.3292 | 101 | 4.3416 | 133 | 0.2826 | 165 | -2.3292 |
| 6 | 3.1180 | 38 | -11.1180 | 70 | -2.1646 | 102 | 1.5062 | 134 | 9.8354 | 166 | -4.0000 |
| 7 | -6.7174 | 39 | 11.8230 | 71 | -4.6118 | 103 | 8.0590 | 135 | -7.2702 | 167 | 3.5528 |
| 8 | 1.5528 | 40 | 7.6708 | 72 | -1.0590 | 104 | -11.8820 | 136 | -17.8354 | 168 | -0.7764 |
| 9 | 22.0000 | 41 | 5.1180 | 73 | 10.1646 | 105 | 17.1056 | 137 | 13.3758 | 169 | -6.0000 |
| 10 | -6.5404 | 42 | 1.5062 | 74 | 9.5062 | 106 | -2.4348 | 138 | -1.3292 | 170 | -19.6708 |
| 11 | 1.2236 | 43 | -5.9410 | 75 | -7.0466 | 107 | -6.1646 | 139 | -7.3882 | 171 | -15.4596 |
| 12 | -1.7764 | 44 | 0.5528 | 76 | -5.2236 | 108 | -23.0590 | 140 | 1.7174 | 172 | -0.6832 |
| 13 | -4.6118 | 45 | 7.3882 | 77 | -10.6708 | 109 | -0.2950 | 141 | -1.6118 | 173 | 3.8820 |
| 14 | -5.0590 | 46 | 3.2826 | 78 | 10.0466 | 110 | 4.8820 | 142 | -3.2236 | 174 | -15.0000 |
| 15 | -4.2826 | 47 | -19.3292 | 79 | -10.9410 | 111 | -6.3882 | 143 | -0.4472 | 175 | -10.1770 |
| 16 | -4.2826 | 48 | -6.4006 | 80 | -7.5062 | 112 | 15.3292 | 144 | -2.2236 | 176 | -12.7888 |
| 17 | 9.7174 | 49 | -14.9534 | 81 | 10.2702 | 113 | -11.0466 | 145 | -13.8354 | 177 | 10.3758 |
| 18 | 1.2826 | 50 | -0.2360 | 82 | -12.3292 | 114 | 5.3292 | 146 | -14.1770 | 178 | 3.8354 |
| 19 | -3.5528 | 51 | 3.1056 | 83 | 6.8820 | 115 | 4.8354 | 147 | -7.2360 | 179 | 10.0590 |
| 20 | -2.2236 | 52 | -10.0000 | 84 | 3.8354 | 116 | 5.6708 | 148 | -1.1770 | 180 | -2.6584 |
| 21 | 2.1646 | 53 | -12.1180 | 85 | 2.0590 | 117 | 6.8944 | 149 | -2.2826 | 181 | -4.7764 |
| 22 | 9.6118 | 54 | 5.2112 | 86 | 0.4472 | 118 | -2.8820 | 150 | 5.9410 | 182 | 4.5528 |
| 23 | 9.1180 | 55 | -4.6118 | 87 | 18.2236 | 119 | 8.6118 | 151 | -3.5528 | 183 | -5.1646 |
| 24 | 0.9534 | 56 | 1.9410 | 88 | 7.6242 | 120 | -14.4938 | 152 | 0.7764 | 184 | 5.5528 |
| 25 | -10.3292 | 57 | 8.0000 | 89 | -15.8230 | 121 | 8.2702 | 153 | 9.0000 | 185 | 1.4472 |
| 26 | 13.1056 | 58 | 14.8944 | 90 | 1.8820 | 122 | 11.4472 | 154 | -1.4938 | 186 | 3.8354 |
| 27 | -3.8820 | 59 | -3.9876 | 91 | -7.2236 | 123 | -14.0466 | 155 | 11.2236 | 187 | 10.0590 |
| 28 | 7.0000 | 60 | 13.8354 | 92 | -4.8944 | 124 | 17.4938 | 156 | -1.6584 | 188 | -0.6584 |
| 29 | 1.2826 | 61 | 13.1770 | 93 | -5.8944 | 125 | -3.4348 | 157 | -1.1646 | 189 | 3.4472 |
| 30 | 4.4472 | 62 | -8.3758 | 94 | -1.5062 | 126 | -3.7764 | 158 | -2.0000 | 190 | 14.0590 |
| 31 | 0.6708 | 63 | 15.3882 | 95 | -14.7764 | 127 | -2.8354 | 159 | -2.2236 | 191 | 15.7888 |
| 32 | 5.8354 | 64 | -3.8230 | 96 | -18.5652 | 128 | 0.5528 | 160 | 4.1646 | 192 | 2.4596 |

And we can find the series ( $\hat{\beta}_t$ ) by using program (2) in the appendix (B)

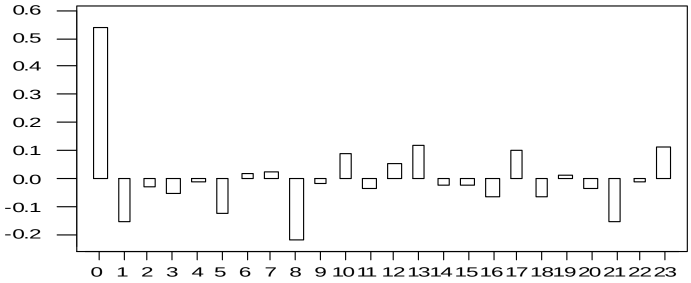
**Table (7):** values ( $\hat{\beta}_t$ ) for output (rainfall)

| T | ( $\hat{\beta}_t$ ) | T | ( $\hat{\beta}_t$ ) | T | ( $\hat{\beta}_t$ ) | t | ( $\hat{\beta}_t$ ) | T | ( $\hat{\beta}_t$ ) | t | ( $\hat{\beta}_t$ ) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -12.000 | 33 | 21.520 | 65 | 21.520 | 97 | 3.351 | 129 | -17.333 | 161 | 34.741 |
| 2 | 21.158 | 34 | -27.723 | 66 | -27.723 | 98 | 113.264 | 130 | -49.138 | 162 | 1.867 |
| 3 | 62.895 | 35 | -57.579 | 67 | -57.579 | 99 | -114.027 | 131 | -34.302 | 163 | -55.568 |
| 4 | -43.802 | 36 | 62.755 | 68 | 62.755 | 100 | 64.480 | 132 | 46.421 | 164 | 54.871 |
| 5 | 54.361 | 37 | -24.796 | 69 | -24.796 | 101 | 17.443 | 133 | -48.965 | 165 | -57.081 |
| 6 | -13.456 | 38 | -83.340 | 70 | -83.340 | 102 | -71.722 | 134 | 89.985 | 166 | 16.609 |
| 7 | -52.280 | 39 | 92.690 | 71 | 92.690 | 103 | 51.420 | 135 | -136.815 | 167 | 6.678 |
| 8 | 22.926 | 40 | -4.226 | 72 | -4.226 | 104 | -14.125 | 136 | -99.391 | 168 | 10.738 |
| 9 | -7.920 | 41 | 17.179 | 73 | 17.179 | 105 | -2.097 | 137 | 55.914 | 169 | -43.963 |
| 10 | -14.638 | 42 | 24.328 | 74 | 24.328 | 106 | -126.019 | 138 | 1.473 | 170 | -8.138 |
| 11 | -36.723 | 43 | -14.421 | 75 | -14.421 | 107 | 71.518 | 139 | -5.238 | 171 | -64.294 |
| 12 | 18.248 | 44 | -55.995 | 76 | -55.995 | 108 | -32.479 | 140 | -37.553 | 172 | -15.845 |
| 13 | -34.843 | 45 | 29.233 | 77 | 29.233 | 109 | -36.222 | 141 | 33.656 | 173 | 32.797 |
| 14 | 27.615 | 46 | 27.366 | 78 | 27.366 | 110 | 184.663 | 142 | 3.757 | 174 | -34.756 |
| 15 | -1.351 | 47 | -78.724 | 79 | -78.724 | 111 | -85.529 | 143 | -28.931 | 175 | 3.341 |
| 16 | -4.030 | 48 | 29.309 | 80 | 29.309 | 112 | 9.836 | 144 | 23.189 | 176 | -20.572 |
| 17 | 19.332 | 49 | -51.281 | 81 | -51.281 | 113 | -4.499 | 145 | -22.780 | 177 | 19.562 |
| 18 | 39.957 | 50 | -16.090 | 82 | -16.090 | 114 | 39.875 | 146 | -31.606 | 178 | 4.063 |
| 19 | 5.116 | 51 | -14.019 | 83 | -14.019 | 115 | 19.793 | 147 | -43.593 | 179 | 15.156 |
| 20 | -66.584 | 52 | -11.908 | 84 | -11.908 | 116 | 55.829 | 148 | 152.410 | 180 | 8.696 |
| 21 | 142.122 | 53 | -24.488 | 85 | -24.488 | 117 | 73.898 | 149 | -81.150 | 181 | -30.634 |
| 22 | -14.006 | 54 | 78.227 | 86 | 78.227 | 118 | -220.131 | 150 | 28.857 | 182 | 20.811 |
| 23 | 60.383 | 55 | -25.349 | 87 | -25.349 | 119 | 88.464 | 151 | -6.861 | 183 | 6.213 |
| 24 | -29.439 | 56 | 7.700 | 88 | 7.700 | 120 | 46.235 | 152 | 0.116 | 184 | -5.015 |
| 25 | -15.673 | 57 | 14.411 | 89 | 14.411 | 121 | -20.891 | 153 | 5.400 | 185 | 2.249 |
| 26 | 31.950 | 58 | 112.845 | 90 | 112.845 | 122 | 64.678 | 154 | -23.596 | 186 | 37.762 |
| 27 | 22.223 | 59 | -28.629 | 91 | -28.629 | 123 | 16.222 | 155 | 131.146 | 187 | 40.754 |
| 28 | 25.600 | 60 | 27.790 | 92 | 27.790 | 124 | -64.033 | 156 | -168.971 | 188 | -48.323 |
| 29 | -128.190 | 61 | 21.529 | 93 | 21.529 | 125 | -28.266 | 157 | 88.089 | 189 | 24.565 |
| 30 | 59.222 | 62 | -40.287 | 94 | -40.287 | 126 | 12.407 | 158 | -88.816 | 190 | 45.888 |
| 31 | -61.901 | 63 | 44.365 | 95 | 44.365 | 127 | 146.452 | 159 | 2.500 | 191 | -6.053 |
| 32 | 26.839 | 64 | -47.099 | 96 | -47.099 | 128 | 32.722 | 160 | 5.016 | 192 | 11.904 |

**e)**Correlation coefficient between ( $\hat{\alpha}_t$ )and ( $\hat{\beta}_t$ ) by using equation (12) we can find the values of correlation coefficient in the table (8)

**Table (8):** the values of correlation coefficient between ( $\hat{\alpha}_t$ ) and ( $\hat{\beta}_t$ )

| T | $r_{\alpha\beta}$ | t | $r_{\alpha\beta}$ | t | $r_{\alpha\beta}$ | t | $r_{\alpha\beta}$ |
|---|---|---|---|---|---|---|---|
| 0 | 0.541 | 6 | 0.017 | 12 | 0.056 | 18 | -0.064 |
| 1 | -0.154 | 7 | 0.026 | 13 | 0.120 | 19 | 0.012 |
| 2 | -0.032 | 8 | -0.221 | 14 | -0.022 | 20 | -0.038 |
| 3 | -0.056 | 9 | -0.021 | 15 | -0.022 | 21 | -0.155 |
| 4 | -0.012 | 10 | 0.089 | 16 | -0.064 | 22 | -0.014 |
| 5 | -0.126 | 11 | -0.038 | 17 | 0.101 | 23 | 0.115 |




**Figure(17)**:cross correlation coefficient between ( $\hat{\alpha}_t$ ) and ( $\hat{\beta}_t$ )

It is clear from figure (17) that the dead time is (b=0) close to zero which explains $\rho_{\alpha\beta}(0) \neq 0$, reading the graph from left to right ,there are no initial zero value v weights(because $v_0 \neq 0$) ,and there is an eventual simple exponential decay pattern.

### 2.4)Identification for $Y_t$and $x_{2t}$

### a) Estimation of the impulse response weights

We estimate of the impulse response weights between input ($X_{2t}$) and output series ($Y_t$) in table (9) below

**Table (9):** the values of the impulse response of input variable (RH $X_{2,t}$)

| T | V | T | V | t | V | t | V |
|---|---|---|---|---|---|---|---|
| 0 | 3.4868 | 6 | 0.078 | 12 | 0.3519 | 18 | -0.443 |
| 1 | -1.016 | 7 | 0.215 | 13 | 0.769 | 19 | 0.0782 |
| 2 | -0.267 | 8 | -1.466 | 14 | -0.1042 | 20 | -0.247 |
| 3 | -0.306 | 9 | -0.130 | 15 | -0.221 | 21 | -0.990 |
| 4 | -0.052 | 10 | 0.606 | 16 | -0.351 | 22 | -0.1042 |
| 5 | -0.827 | 11 | -0.2990 | 17 | 0.651 | 23 | 0.775 |

### b)Identification of (r,s,b) for the transfer function

It is clear from figure (17) of(r,s,b) equals(1,4,0) the pattern can be written as:

$$Y_t = \frac{(w_0 - w_1B - w_2B^2 - w_3B^3 - w_4B^4)}{(1-\delta_1 B)} X_{2,t} + N_t \qquad (35)$$

### c)Disturbance series

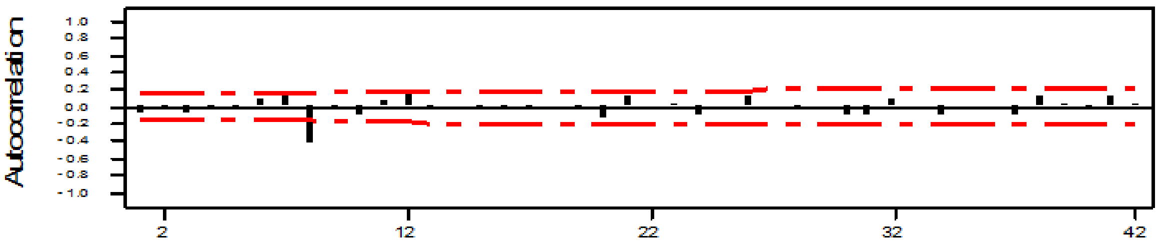
We find disturbance series by using the equation

$$N_t = Y_t - v_0X_t - v_1X_{t-1} - \cdots - v_{23}X_{t-23} \qquad (36)$$

By using equation (36) we can obtain the number of disturbance series which their values is less than the input and output series values(t=23) so, we can apply them in program (3) in appendix(B), the values are in the table (10)

**Table(10)** :estimate values of disturbance series $N_t$

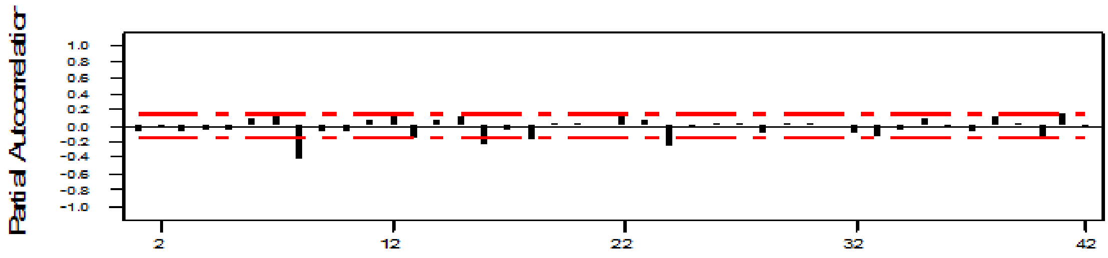
| T | $N_t^{\wedge}$ | T | $N_t^{\wedge}$ | t | $N_t^{\wedge}$ | t | $N_t^{\wedge}$ | t | $N_t^{\wedge}$ | t | $N_t^{\wedge}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 28.613 | 31 | 48.29 | 61 | 142.505 | 91 | -27.889 | 121 | -15.644 | 151 | 5.353 |
| 2 | 37.799 | 32 | -26.884 | 62 | -53.047 | 92 | 1.357 | 122 | 20.184 | 152 | 9.002 |
| 3 | -4.912 | 33 | -29.15 | 63 | -6.867 | 93 | 61.531 | 123 | 16.92 | 153 | 9.528 |
| 4 | 64.620 | 34 | -35.358 | 64 | -73.859 | 94 | 56.834 | 124 | -54.694 | 154 | -42.586 |
| 5 | 11.535 | 35 | 14.585 | 65 | -41.58 | 95 | -83.122 | 125 | 155.17 | 155 | -43.309 |
| 6 | -112.436 | 36 | 24.826 | 66 | 23.028 | 96 | 59.807 | 126 | -2.326 | 156 | -76.594 |
| 7 | 23.379 | 37 | 14.483 | 67 | 16.817 | 97 | 15.616 | 127 | -28.331 | 157 | 2.882 |
| 8 | -29.135 | 38 | 6.115 | 68 | -5.876 | 98 | 54.553 | 128 | -24.571 | 158 | -4.407 |
| 9 | -18.565 | 39 | 29.213 | 69 | -131.606 | 99 | 18.965 | 129 | -8.101 | 159 | 4.887 |
| 10 | -17.032 | 40 | -4.362 | 70 | -23.163 | 100 | 48.033 | 130 | -30.087 | 160 | 47.208 |
| 11 | 29.12 | 41 | -28.575 | 71 | 10.271 | 101 | -26.102 | 131 | -56.512 | 161 | -6.14 |
| 12 | -89.822 | 42 | 64.341 | 72 | 54.304 | 102 | -7.176 | 132 | 83.506 | 162 | -2.095 |
| 13 | 37.059 | 43 | -7.306 | 73 | 31.851 | 103 | -48.157 | 133 | -124.696 | 163 | 21.646 |
| 14 | 37.423 | 44 | -11.606 | 74 | -64.811 | 104 | 63.41 | 134 | 19.564 | 164 | 43.923 |
| 15 | -11.027 | 45 | -23.646 | 75 | 23.724 | 105 | 80.266 | 135 | -24.15 | 165 | -4.469 |
| 16 | 14.801 | 46 | 52.51 | 76 | -86.81 | 106 | -8.572 | 136 | 17.788 | 166 | 5.317 |
| 17 | -21.378 | 47 | -78.918 | 77 | -23.933 | 107 | -26.532 | 137 | -19.742 | 167 | -15.377 |
| 18 | -29.934 | 48 | -19.443 | 78 | -29.27 | 108 | -17.112 | 138 | 45.418 | 168 | -78.165 |
| 19 | 14.658 | 49 | 37.887 | 79 | 5.893 | 109 | -5.346 | 139 | -27.959 | 169 | -16.994 |
| 20 | 11.552 | 50 | -62.899 | 80 | -27.532 | 110 | -41.305 | 140 | -57.219 | | |
| 21 | -18.165 | 51 | -60.43 | 81 | -14.486 | 111 | 54.457 | 141 | 29.328 | | |
| 22 | -40.238 | 52 | 22.992 | 82 | 45.548 | 112 | -55.424 | 142 | -43.046 | | |
| 23 | -17.26 | 53 | 17.84 | 83 | 3.863 | 113 | -52.061 | 143 | -6.476 | | |
| 24 | 25.547 | 54 | 49.121 | 84 | 39.841 | 114 | -27.107 | 144 | -28.45 | | |
| 25 | 62.791 | 55 | 44.317 | 85 | 6.302 | 115 | 20.879 | 145 | 12.916 | | |
| 26 | 48.802 | 56 | 46.758 | 86 | 0.832 | 116 | 0.277 | 146 | -8.207 | | |
| 27 | -14.201 | 57 | 1.702 | 87 | 61.255 | 117 | -44.527 | 147 | 67.796 | | |
| 28 | -27.227 | 58 | 37.108 | 88 | -34.269 | 118 | 17.533 | 148 | 13.316 | | |
| 29 | -32.854 | 59 | 13.342 | 89 | -6.008 | 119 | 29.546 | 149 | -40.976 | | |
| 30 | 4.071 | 60 | 55.595 | 90 | -44.886 | 120 | -15.576 | 150 | -7.83 | | |




| Lag | Corr | T | LBQ | Lag | Corr | T | LBQ | Lag | Corr | T | LBQ | Lag | Corr | T | LBQ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -0.06 | -0.77 | 0.60 | 13 | -0.05 | -0.50 | 48.01 | 25 | 0.00 | 0.05 | 56.81 | 37 | -0.08 | -0.84 | 69.38 |
| 2 | -0.01 | -0.17 | 0.63 | 14 | 0.00 | 0.03 | 48.01 | 26 | 0.12 | 1.18 | 59.50 | 38 | 0.13 | 1.32 | 73.36 |
| 3 | -0.06 | -0.79 | 1.28 | 15 | -0.05 | -0.50 | 48.43 | 27 | 0.00 | 0.03 | 59.50 | 39 | 0.03 | 0.33 | 73.62 |
| 4 | -0.04 | -0.52 | 1.56 | 16 | -0.03 | -0.35 | 48.64 | 28 | -0.01 | -0.15 | 59.54 | 40 | -0.05 | -0.45 | 74.10 |
| 5 | -0.03 | -0.39 | 1.72 | 17 | -0.01 | -0.12 | 48.66 | 29 | 0.01 | 0.07 | 59.55 | 41 | 0.12 | 1.13 | 77.16 |
| 6 | 0.11 | 1.36 | 3.71 | 18 | 0.01 | 0.05 | 48.67 | 30 | -0.08 | -0.86 | 61.05 | 42 | 0.03 | 0.30 | 77.39 |
| 7 | 0.15 | 1.87 | 7.57 | 19 | -0.00 | -0.02 | 48.67 | 31 | -0.10 | -1.03 | 63.25 | | | | |
| 8 | -0.43 | -5.33 | 40.30 | 20 | -0.13 | -1.39 | 52.10 | 32 | 0.09 | 0.94 | 65.12 | | | | |
| 9 | -0.04 | -0.42 | 40.58 | 21 | 0.12 | 1.24 | 54.90 | 33 | 0.03 | 0.25 | 65.26 | | | | |
| 10 | -0.09 | -0.99 | 42.12 | 22 | 0.01 | 0.09 | 54.91 | 34 | -0.11 | -1.05 | 67.65 | | | | |
| 11 | 0.08 | 0.87 | 43.32 | 23 | 0.04 | 0.41 | 55.23 | 35 | 0.01 | 0.10 | 67.67 | | | | |
| 12 | 0.15 | 1.62 | 47.58 | 24 | -0.09 | -0.91 | 56.80 | 36 | 0.03 | 0.26 | 67.82 | | | | |

**Figure (18):** ACF of disturbance series ($\hat{N}_t$)

We figure(18) shows the outline we have the value (-89.822) in table(6) outlier




| Lag | PAC | T | Lag | PAC | T | Lag | PAC | T | Lag | PAC | T |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -0.06 | -0.77 | 13 | -0.15 | -1.99 | 25 | -0.00 | -0.05 | 37 | -0.05 | -0.71 |
| 2 | -0.02 | -0.22 | 14 | 0.07 | 0.87 | 26 | 0.05 | 0.66 | 38 | 0.12 | 1.53 |
| 3 | -0.06 | -0.82 | 15 | 0.12 | 1.61 | 27 | 0.03 | 0.37 | 39 | 0.05 | 0.61 |
| 4 | -0.05 | -0.63 | 16 | -0.24 | -3.08 | 28 | -0.11 | -1.38 | 40 | -0.11 | -1.46 |
| 5 | -0.04 | -0.49 | 17 | -0.05 | -0.65 | 29 | 0.05 | 0.64 | 41 | 0.15 | 2.00 |
| 6 | 0.10 | 1.26 | 18 | -0.18 | -2.28 | 30 | 0.03 | 0.42 | 42 | -0.00 | -0.04 |
| 7 | 0.16 | 2.03 | 19 | 0.04 | 0.46 | 31 | 0.01 | 0.19 | | | |
| 8 | -0.43 | -5.56 | 20 | 0.04 | 0.53 | 32 | -0.10 | -1.36 | | | |
| 9 | -0.08 | -1.04 | 21 | 0.01 | 0.15 | 33 | -0.13 | -1.69 | | | |
| 10 | -0.08 | -1.04 | 22 | 0.12 | 1.51 | 34 | -0.05 | -0.59 | | | |
| 11 | 0.06 | 0.78 | 23 | 0.07 | 0.97 | 35 | 0.09 | 1.20 | | | |
| 12 | 0.15 | 1.94 | 24 | -0.25 | -3.29 | 36 | -0.02 | -0.23 | | | |

**Figure (19):** PACF of disturbance series ($\hat{N}_t$)

It is clear from figure (18) that the disturbance series ($\hat{N}_t$) is equal residual series

$N_t = a_t$(because $N_t$ independent no model to thus the model of dynamic regression as shown in the equation below:

$$Y_t = \frac{(w_0 - w_1 B - w_2 B^2 - w_3 B^3 - w_4 B^4)}{(1-\delta_1 B)} X_{2,t} + a_t$$

The next step in estimation is to compute the SSR (Sum of Squared Residuals)

$$SSR = \sum_{t=1}^{n} a_t^2$$

$$Y_t = \frac{(3.911 - 2.228B + 1.291B^2 + 1.077B^3 + 0.4532B^4)}{(1 - 0.9309B)} X_{2,t} + a_t$$

$\hat{a}_t = Y_t - 0.9309Y_{t-1} - 3.911X_{2,t} + 2.228X_{2,t-1} - 1.291X_{2,t-2} - 1.077X_{2,t-3} - 0.4532X_{2,t-4} - 0.9309a_{t-1}$ (37)

We find the values of series ($\hat{a}_t$) by using equation (37) and program (4) in appendix(B),

The value is as in table(11)

**Table (11):** the values of series ($\hat{a}_t$)

| T | $\hat{a}_t$ | T | $\hat{a}_t$ | T | $\hat{a}_t$ | T | $\hat{a}_t$ | t | $\hat{a}_t$ | T | $\hat{a}_t$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 50.365 | 32 | 17.214 | 63 | 1.672 | 94 | 48.311 | 125 | 37.305 | 156 | -82.711 |
| 2 | -90.235 | 33 | 9.267 | 64 | 27.954 | 95 | -7.721 | 126 | -36.165 | 157 | -11.085 |
| 3 | -70.627 | 34 | -4.637 | 65 | 25.321 | 96 | -38.909 | 127 | 22.769 | 158 | -36.029 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | -92.189 | 35 | 27.389 | 66 | -46.286 | 97 | -48.405 | 128 | -92.528 | 159 | 39.536 |
| 5 | 70.200 | 36 | -10.187 | 67 | -20.277 | 98 | -0.497 | 129 | -60.434 | 160 | 34.025 |
| 6 | -114.237 | 37 | -70.976 | 68 | -12.659 | 99 | 8.282 | 130 | -2.785 | 161 | 17.844 |
| 7 | 160.600 | 38 | -26.341 | 69 | 56.899 | 100 | 80.297 | 131 | -10.002 | 162 | -36.150 |
| 8 | 280.070 | 39 | 30.149 | 70 | 77.632 | 101 | -25.895 | 132 | -3.329 | 163 | 50.648 |
| 9 | 61.636 | 40 | 25.470 | 71 | 13.540 | 102 | -70.116 | 133 | -58.201 | 164 | 19.161 |
| 10 | -159.349 | 41 | 65.383 | 72 | -52.913 | 103 | 91.315 | 134 | 28.313 | 165 | -7.360 |
| 11 | 95.367 | 42 | 13.519 | 73 | 9.592 | 104 | 6.997 | 135 | 36.838 | 166 | 0.953 |
| 12 | 143.262 | 43 | -53.584 | 74 | 41.188 | 105 | 7.823 | 136 | -7.920 | 167 | 10.333 |
| 13 | -30.895 | 44 | -20.828 | 75 | -12.424 | 106 | -0.698 | 137 | 10.690 | 168 | 38.846 |
| 14 | 181.607 | 45 | 6.230 | 76 | 89.463 | 107 | -2.385 | 138 | 30.009 | 169 | 46.669 |
| 15 | -130.834 | 46 | 67.477 | 77 | 171.036 | 108 | -8.595 | 139 | 11.914 | 170 | -23.288 |
| 16 | 240.304 | 47 | 62.504 | 78 | -71.415 | 109 | 48.501 | 140 | -6.551 | 171 | -36.614 |
| 17 | 10.798 | 48 | -3.787 | 79 | 12.279 | 110 | 63.762 | 141 | 140.643 | 172 | -66.124 |
| 18 | 40.784 | 49 | -54.902 | 80 | -30.939 | 111 | -129.493 | 142 | -22.666 | 173 | 28.415 |
| 19 | -12.151 | 50 | -11.923 | 81 | -34.212 | 112 | -5.555 | 143 | -10.967 | 174 | -5.426 |
| 20 | 23.883 | 51 | 62.623 | 82 | -23.518 | 113 | 15.895 | 144 | 2.907 | 175 | -90.206 |
| 21 | 0.118 | 52 | 41.013 | 83 | 46.625 | 114 | 20.722 | 145 | -1.762 | 176 | -16.801 |
| 22 | -10.565 | 53 | -6.733 | 84 | -12.270 | 115 | 20.300 | 146 | -16.224 | 177 | 12.358 |
| 23 | -6.392 | 54 | -18.974 | 85 | -185.105 | 116 | 33.982 | 147 | -26.870 | 178 | -5.054 |
| 24 | -40.202 | 55 | -58.342 | 86 | -55.763 | 117 | -35.398 | 148 | 101.249 | 179 | 3.947 |
| 25 | -46.941 | 56 | -7.003 | 87 | 19.832 | 118 | 4.818 | 149 | -112.047 | 180 | 3.069 |
| 26 | -18.892 | 57 | -3.776 | 88 | 77.998 | 119 | 0.314 | 150 | 19.355 | 181 | 2.609 |
| 27 | 27.512 | 58 | 61.987 | 89 | 67.879 | 120 | 104.485 | 151 | -88.526 | 182 | 8.366 |
| 28 | -51.267 | 59 | -47.600 | 90 | -11.399 | 121 | 16.639 | 152 | -33.098 | 183 | 3.916 |
| 29 | 57.579 | 60 | -4.957 | 91 | 13.581 | 122 | -16.085 | 153 | -3.738 | 184 | 3.656 |
| 30 | -8.086 | 61 | -42.081 | 92 | -119.634 | 123 | -41.270 | 154 | 52.494 | 185 | 11.909 |
| 31 | -42.822 | 62 | 27.025 | 93 | 20.001 | 124 | -28.408 | 155 | -11.893 | 186 | 19.877 |

By using Ljung and Box(1978) below

$$s_{x_2}^2 = n^2 \sum_{k=0}^{K} (n-k)^{-1} (r_k)^2$$

$= 20.1225$

The value is less than the $\chi^2$ critical value(31.4) for K+1-m=24+1-5=20 degrees of freedom at the 5% level. Therefore we do not reject the stated $H_0$ ($H_0$:the two series $a_t$ and $\alpha_t$ are independent)

**d- Autocorrelation Check**

The statistic test proposed by Ljung and Box(1978) is

$$Q_{x_2}^2 = n\,(n+2)\sum_{k=1}^{K}(n-k)^{-1}\, r_k^2(\hat{a})$$

$$= 34.43$$

We get the value (34.43) by using software of Minitab (13.2)

This value is less than the $\chi^2$ critical value (55.8) for K - m=41-1= 40 degrees of freedom at the 5% level. Therefore we do not reject the stated $H_0$. ($H_0$: series $a_t$ independent)

The next step to compute two input temperature and RH and compute the SSR (Sum of Squared Residuals)

$$\text{SSR} = \sum_{t=1}^{n} a_t^2$$

$$Y_t = \frac{(-2.667 + 1.422B + 4.451B^2)}{(1 - 1.048B - 0.7266B^2)} X_{1,t} + \frac{(3.911 - 2.228B + 1.291B^2 + 1.077B^3 + 0.4532B^4)}{(1 - 0.9309B)} X_{2,t} + a_t$$

**Table (12):** the values of series ( $\hat{a}_t$ )

| T | $\hat{a}_t$ | t | $\hat{a}_t$ | t | $\hat{a}_t$ | T | $\hat{a}_t$ | t | $\hat{a}_t$ | T | $\hat{a}_t$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 30.365 | 32 | 17.214 | 63 | 1.672 | 94 | 48.311 | 125 | 37.305 | 156 | -82.711 |
| 2 | -86.235 | 33 | 9.267 | 64 | 27.954 | 95 | -7.721 | 126 | -36.165 | 157 | -11.085 |
| 3 | -36.627 | 34 | -4.637 | 65 | 25.321 | 96 | -38.909 | 127 | 22.769 | 158 | -36.029 |
| 4 | -77.189 | 35 | 27.389 | 66 | -46.286 | 97 | -48.405 | 128 | -92.528 | 159 | 39.536 |
| 5 | 146.200 | 36 | -10.187 | 67 | -20.277 | 98 | -0.497 | 129 | -60.434 | 160 | 34.025 |
| 6 | -142.237 | 37 | -70.976 | 68 | -12.659 | 99 | 8.282 | 130 | -2.785 | 161 | 17.844 |
| 7 | 66.600 | 38 | -26.341 | 69 | 56.899 | 100 | 80.297 | 131 | -10.002 | 162 | -36.150 |
| 8 | 80.070 | 39 | 30.149 | 70 | 77.632 | 101 | -25.895 | 132 | -3.329 | 163 | 50.648 |
| 9 | 211.636 | 40 | 25.470 | 71 | 13.540 | 102 | -70.116 | 133 | -58.201 | 164 | 19.161 |
| 10 | -39.349 | 41 | 65.383 | 72 | -52.913 | 103 | 91.315 | 134 | 28.313 | 165 | -7.360 |
| 11 | 50.367 | 42 | 13.519 | 73 | 9.592 | 104 | 6.997 | 135 | 36.838 | 166 | 0.953 |
| 12 | 48.262 | 43 | -53.584 | 74 | 41.188 | 105 | 7.823 | 136 | -7.920 | 167 | 10.333 |
| 13 | -45.895 | 44 | -20.828 | 75 | -12.424 | 106 | -0.698 | 137 | 10.690 | 168 | 38.846 |
| 14 | 86.607 | 45 | 6.230 | 76 | 89.463 | 107 | -2.385 | 138 | 30.009 | 169 | 46.669 |
| 15 | -31.834 | 46 | 67.477 | 77 | 171.036 | 108 | -8.595 | 139 | 11.914 | 170 | -23.288 |
| 16 | 24.304 | 47 | 62.504 | 78 | -71.415 | 109 | 48.501 | 140 | -6.551 | 171 | -36.614 |
| 17 | 0.798 | 48 | -3.787 | 79 | 12.279 | 110 | 63.762 | 141 | 140.643 | 172 | -66.124 |
| 18 | 44.784 | 49 | -54.902 | 80 | -30.939 | 111 | -129.493 | 142 | -22.666 | 173 | 28.415 |
| 19 | -12.151 | 50 | -11.923 | 81 | -34.212 | 112 | -5.555 | 143 | -10.967 | 174 | -5.426 |
| 20 | 23.883 | 51 | 62.623 | 82 | -23.518 | 113 | 15.895 | 144 | 2.907 | 175 | 347 |
| 21 | 0.118 | 52 | 41.013 | 83 | 46.625 | 114 | 20.722 | 145 | -1.762 | 176 | -235 |
| 22 | -100.565 | 53 | -6.733 | 84 | -12.270 | 115 | 20.300 | 146 | -16.224 | 177 | -127 |
| 23 | -6.392 | 54 | -18.974 | 85 | -185.105 | 116 | 33.982 | 147 | -26.870 | 178 | |
| 24 | -49.202 | 55 | -58.342 | 86 | -55.763 | 117 | -35.398 | 148 | 101.249 | 179 | |
| 25 | -46.941 | 56 | -7.003 | 87 | 19.832 | 118 | 4.818 | 149 | -112.047 | 180 | |
| 26 | -18.892 | 57 | -3.776 | 88 | 77.998 | 119 | 0.314 | 150 | 19.355 | 181 | |
| 27 | 27.512 | 58 | 61.987 | 89 | 67.879 | 120 | 104.485 | 151 | -88.526 | 182 | |
| 28 | -59.267 | 59 | -47.600 | 90 | -11.399 | 121 | 16.639 | 152 | -33.098 | 183 | |
| 29 | 57.579 | 60 | -4.957 | 91 | 13.581 | 122 | -16.085 | 153 | -3.738 | 184 | |
| 30 | -8.086 | 61 | -42.081 | 92 | -119.634 | 123 | -41.270 | 154 | 52.494 | 185 | |
| 31 | -44.822 | 62 | 27.025 | 93 | 20.001 | 124 | -28.408 | 155 | -11.893 | 186 | |

By using equation (15) Ljung and Box(1978) below

$s^2 = 19.6743$

The value is less than the $\chi^2$ critical value(27.6) for K+1-m=24+1-8=17 degrees of freedom at the 5% level. Therefore we do not reject the stated $H_0$ ($H_0$:the two series $a_t$ and $\alpha_t$ are independent)

**e)Autocorrelation Check**

The statistic test proposed by equation (16) Ljung and Box(1978) is

$Q^2 = 40.16$

this value is less than the $\chi^2$ critical value (55.8) for K - m=41-1= 40 degrees of freedom at the 5% level. Therefore we do not reject the stated $H_0$ ($H_0$: series $a_t$ is independent).

**Forecasting** $\hat{y}_{201}$

We explain how forecasts of future value of $Y_t$ are produced from the following DR model with equation below ,where t=n = 200

for I = 1, the forecast is

$$\hat{y}_{201}=$$
$$0.978y_{200}+0.0723y_{199}-0.6726y_{198}-2.667x_{1,201}-3.904x_{1,200}+3.126x_{1,199}-0.124x_{1,198}+3.911x_{2,201}-0.87x_{2,200}-0.5067x_{2,199}+1.342x_{2,198}+0.643x_{2,197}-0.252x_{2,196}-0.329x_{2,195}+a_{200}-0.978a_{200}-0.0723a_{19}+0.672a_{198}=8.2$$

$$a_t=$$
$$y_t-0.978y_{t-1}-0.0723y_{t-2}+0.6726y_{t-3}+2.667x_{1,t}+3.904x_{1,t-1}-3.126x_{1,t-2}+0.124x_{1t-3}-3.911x_{2,t}+0.87x_{2,t-1}+0.5067x_{2,t-2}-1.342x_{2,t-3}-0.643x_{2,t-4}+0.252x_{2,t-5}+0.329x_{2,t-6}+0.978a_{t-1}+0.0723a_{t-2}-0.672a_{t-3}$$

The forecast for $x_t$ is
$X_{t+I}=\alpha_{t+I}+\emptyset X_{t+I-1}$
AndThe forecast for $Y_t$ is
$Y_{t+I}=\beta_{t+I}+\emptyset Y_{t+I-1}$
We find the values of forecasting $X_{t+I}$and$Y_{t+I}$

Table (13): forecasting $X_{t+I}$and$Y_{t+I}$ and Dynamic regression

| Year | Time | Forecasting temperature | Forecasting RH | Forecasting dynamic $y_t$ |
|---|---|---|---|---|
| 2001-2002 | Oct. | 20.5395 | 52.0114 | 8.2 |
| | Nov. | 18.5030 | 57.2962 | 25.4 |
| | Des. | 17.1697 | 60.3956 | 91.656 |
| | Jan. | 16.2968 | 62.2133 | 149 |
| | Feb. | 15.7254 | 63.2793 | 58 |
| | Mar. | 15.3512 | 63.9045 | 196 |
| | Apr. | 15.1063 | 64.2712 | 75.4 |
| | May. | 14.9459 | 64.4862 | 8.3 |

## Conclusions

1) ACF for the rainfall from series temperature and RH , we show that the seasonality period (8)is months, we suggest that the tentative model for the differenced series is AR(1)

2)After using cross- correlation between series ($\hat{\alpha}_t$) and series ($\hat{a}_t$), it is clear that there are significant values, which mean that the correlation between the two series ($\hat{\alpha}_t$) and series ($\hat{a}_t$)is significant ,we suggest the best way to forecast using dynamic regression.

3)To examine that the value is less than the $\chi^2$ critical value for K - m degrees of freedom
at the 5% level. Therefore we do not reject the stated $H_0$.

## References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**Appendix(A)**:monthly average of the humidity and rainfall of the meteorological station of Nineveh for the period (1976) to (2001)

| Year | Month | RH | rainfall | Tm | year | month | RH | rainfall | tm | Year | month | RH | rainfall | Tm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 76-77 | Oct. | 55 | 19.4 | 21.05 | | Feb. | 81 | 50.9 | 7.25 | | Oct. | 45 | 17.1 | 21.35 |
| | Nov. | 53 | 3.0 | 14.85 | | Mar. | 69 | 78.6 | 10.65 | | Nov. | 76 | 66.7 | 11.90 |
| | Des. | 72 | 30.6 | 11.10 | | Apr. | 67 | 52.9 | 19.05 | | Des. | 88 | 73.1 | 10.15 |
| | Jan. | 81 | 94.3 | 4.85 | | May. | 46 | 1.5 | 26.05 | | Jan. | 84 | 76.5 | 9.90 |
| | Feb. | 71 | 32.2 | 12.35 | 85-86 | Oct. | 40 | 3.0 | 20.10 | | Feb. | 78 | 47.3 | 9.00 |
| | Mar. | 64 | 30.0 | 14.35 | | Nov. | 62 | 23.9 | 16.05 | | Mar. | 74 | 93.8 | 13.25 |
| | Apr. | 63 | 56.2 | 18.40 | | Des. | 81 | 38.1 | 8.10 | 94-95 | Apr. | 69 | 63.7 | 19.55 |
| | May. | 41 | 0.8 | 24.90 | | Jan. | 82 | 31.5 | 7.85 | | May. | 47 | 2.9 | 24.40 |
| 77-78 | Oct. | 24 | 7.4 | 19.90 | | Feb. | 84 | 121.6 | 10.05 | | Oct. | 51 | 18.2 | 22.65 |
| | Nov. | 65 | 19.5 | 13.75 | | Mar. | 68 | 37.6 | 13.25 | | Nov. | 77 | 68.6 | 14.15 |
| | Des. | 84 | 99.9 | 9.20 | | Apr. | 62 | 44.1 | 18.85 | | Des. | 81 | 68.6 | 6.15 |
| | Jan. | 83 | 77.4 | 8.45 | | May. | 43 | 9.4 | 23.20 | | Jan. | 83 | 37.2 | 8.55 |
| | Feb. | 81 | 80.0 | 10.95 | 86-87 | Oct. | 49 | 26.0 | 23.60 | | Feb. | 76 | 65.7 | 10.40 |
| | Mar. | 71 | 35.1 | 13.80 | | Nov. | 75 | 59.4 | 12.40 | | Mar. | 70 | 104.7 | 13.45 |
| | Apr. | 59 | 5.9 | 17.65 | | Des. | 79 | 43.3 | 7.40 | 95-96 | Apr. | 67 | 39.0 | 17.00 |
| | May. | 41 | 4.2 | 24.65 | | Jan. | 76 | 18.3 | 9.20 | | May. | 44 | 16.5 | 24.70 |
| 78-79 | Oct. | 46 | 0.8 | 23.20 | | Feb. | 71 | 126.2 | 11.55 | | Oct. | 36 | 0.7 | 21.05 |
| | Nov. | 67 | 2.3 | 10.45 | | Mar. | 73 | 71.6 | 10.30 | | Nov. | 57 | 30.2 | 12.90 |
| | Des. | 86 | 56.5 | 10.15 | | Apr. | 53 | 8.4 | 16.65 | | Des. | 66 | 10.1 | 7.75 |
| | Jan. | 82 | 78.8 | 9.60 | | May. | 32 | 1.3 | 25.60 | | Jan. | 76 | 166.9 | 8.50 |
| | Feb. | 76 | 45.7 | 11.85 | 87-88 | Oct. | 55 | 84.7 | 20.05 | | Feb. | 71 | 34.9 | 11.00 |
| | Mar. | 64 | 49.4 | 13.90 | | Nov. | 65 | 12.0 | 13.55 | | Mar. | 74 | 121.6 | 12.75 |
| | Apr. | 52 | 10.1 | 18.85 | | Des. | 82 | 120.8 | 9.55 | 96-97 | Apr. | 65 | 38.7 | 16.80 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **May.** | **34** | **1.8** | **25.65** | | **Jan.** | **81** | **198.3** | **7.25** | | **May.** | **44** | **16.5** | **25.75** |
| **79-80** | **Oct.** | **53** | **19.2** | **22.70** | | **Feb.** | **75** | **104.3** | **9.35** | | **Oct.** | **45** | **6.1** | **21.05** |
| | **Nov.** | **71** | **49.4** | **16.25** | | **Mar.** | **75** | **98.2** | **11.40** | | **Nov.** | **59** | **8.7** | **15.05** |
| | **Des.** | **84** | **79.9** | **8.35** | | **Apr.** | **72** | **45.2** | **16.65** | | **Des.** | **78** | **132.9** | **11.80** |
| | **Jan.** | **79** | **21.3** | **6.70** | | **May.** | **47** | **2.5** | **23.65** | | **Jan.** | **79** | **45.6** | **8.35** |
| | **Feb.** | **77** | **165.5** | **9.05** | **88-89** | **Oct.** | **45** | **3.6** | **21.90** | | **Feb.** | **71** | **75.9** | **6.80** |
| | **Mar.** | **74** | **81.9** | **12.80** | | **Nov.** | **63** | **18.8** | **11.80** | | **Mar.** | **72** | **48.7** | **9.95** |
| | **Apr.** | **65** | **83.1** | **17.60** | | **Des.** | **74** | **95.3** | **9.65** | **97-98** | **Apr.** | **62** | **12.9** | **16.10** |
| | **May.** | **40** | **0.7** | **24.30** | | **Jan.** | **73** | **14.9** | **5.10** | | **May.** | **47** | **11.5** | **24.50** |
| **80-81** | **Oct.** | **45** | **3.1** | **20.75** | | **Feb.** | **66** | **45.5** | **7.35** | | **Oct.** | **45** | **38.9** | **22.60** |
| | **Nov.** | **81** | **75.1** | **14.20** | | **Mar.** | **70** | **97.9** | **14.35** | | **Nov.** | **72** | **23.3** | **14.95** |
| | **Des.** | **84** | **112.1** | **9.55** | | **Apr.** | **50** | **1.3** | **21.10** | | **Des.** | **85** | **83.0** | **9.25** |
| | **Jan.** | **86** | **59.4** | **8.40** | | **May.** | **34** | **3.4** | **25.20** | | **Jan.** | **85** | **81.1** | **6.60** |
| | **Feb.** | **81** | **52.1** | **9.45** | **89-90** | **Oct.** | **44** | **7.3** | **22.40** | | **Feb.** | **71** | **32.6** | **8.35** |
| | **Mar.** | **80** | **97.1** | **13.10** | | **Nov.** | **75** | **133.5** | **14.20** | | **Mar.** | **68** | **48.5** | **12.65** |
| | **Apr.** | **68** | **27.1** | **16.20** | | **Des.** | **83** | **25.8** | **8.05** | **98-99** | **Apr.** | **64** | **19.5** | **18.65** |
| | **May.** | **47** | **5.8** | **21.35** | | **Jan.** | **78** | **52.4** | **5.60** | | **May.** | **47** | **24.8** | **24.60** |
| **81-82** | **Oct.** | **57** | **26.6** | **21.85** | | **Feb.** | **76** | **77.5** | **8.30** | | **Oct.** | **39** | **0.1** | **22.80** |
| | **Nov.** | **71** | **56.5** | **12.95** | | **Mar.** | **62** | **38.6** | **13.35** | | **Nov.** | **50** | **0.1** | **18.05** |
| | **Des.** | **87** | **47.3** | **9.80** | | **Apr.** | **64** | **29.7** | **16.60** | | **Des.** | **61** | **9.7** | **12.00** |
| | **Jan.** | **84** | **97.0** | **6.55** | | **May.** | **37** | **0.3** | **24.00** | | **Jan.** | **75** | **36.8** | **10.00** |
| | **Feb.** | **71** | **41.9** | **6.30** | **90-91** | **Oct.** | **39** | **4.0** | **22.30** | | **Feb.** | **71** | **48.2** | **10.80** |
| | **Mar.** | **65** | **9.8** | **11.00** | | **Nov.** | **50** | **6.2** | **16.10** | | **Mar.** | **53** | **19.8** | **13.50** |
| | **Apr.** | **74** | **85.9** | **18.30** | | **Des.** | **73** | **47.9** | **9.45** | | **Apr.** | **48** | **11.7** | **19.35** |
| | **May.** | **57** | **24.4** | **24.35** | | **Jan.** | **79** | **28.5** | **7.30** | | **May.** | **28** | **1.2** | **27.15** |
| **82-83** | **Oct.** | **66** | **51.0** | **19.95** | | **Feb.** | **70** | **32.0** | **7.80** | | **Oct.** | **42** | **10.5** | **23.25** |
| | **Nov.** | **76** | **90.3** | **10.65** | | **Mar.** | **75** | **205.6** | **13.15** | **2000** | **Nov.** | **55** | **8.2** | **14.20** |
| | **Des.** | **83** | **46.0** | **6.05** | | **Apr.** | **58** | **9.0** | **18.70** | | **Des.** | **73** | **28.0** | **10.05** |
| | **Jan.** | **83** | **40.5** | **4.30** | | **May.** | **40** | **2.1** | **22.95** | | **Jan.** | **77** | **52.6** | **7.20** |
| | **Feb.** | **78** | **49.2** | **6.20** | **91-92** | **Oct.** | **45** | **0.2** | **22.60** | | **Feb.** | **67** | **23.7** | **8.70** |
| | **Mar.** | **71** | **40.0** | **11.85** | | **Nov.** | **58** | **44.6** | **15.50** | | **Mar.** | **56** | **31.1** | **11.65** |
| | **Apr.** | **57** | **18.9** | **17.70** | | **Des.** | **83** | **82.6** | **7.90** | | **Apr.** | **44** | **22.3** | **21.10** |
| | **May.** | **44** | **27.7** | **26.05** | | **Jan.** | **80** | **97.8** | **3.90** | | **May.** | **32** | **0.3** | **25.70** |
| **83-84** | **Oct.** | **46** | **1.0** | **19.20** | | **Feb.** | **79** | **132.8** | **5.65** | | **Oct.** | 45 | 12.4 | 21.20 |
| | **Nov.** | **68** | **54.8** | **15.95** | | **Mar.** | **64** | **24.6** | **9.45** | **2001** | **Nov.** | 60 | 46.7 | 14.15 |
| | **Des.** | **83** | **18.2** | **8.90** | | **Apr.** | **62** | **27.2** | **15.90** | | **Des.** | 85 | 83.7 | 9.50 |
| | **Jan.** | **73** | **17.8** | **8.00** | | **May.** | **53** | **55.4** | **21.60** | | **Jan.** | 81 | 25.9 | 8.55 |
| | **Feb.** | **62** | **15.9** | **10.15** | **92-93** | **Oct.** | **36** | **0.0** | **21.40** | | **Feb.** | 72 | 37.9 | 9.95 |
| | **Mar.** | **70** | **105.3** | **13.75** | | **Nov.** | **72** | **109.2** | **12.85** | | **Mar.** | 72 | 82.5 | 15.85 |
| | **Apr.** | **52** | **18.9** | **16.85** | | **Des.** | **85** | **123.9** | **6.80** | | **Apr.** | 66 | 36.2 | 18.50 |
| | **May.** | **44** | **35.4** | **23.85** | | **Jan.** | **77** | **49.8** | **5.80** | | **May.** | 43 | 17.6 | 23.65 |
| **84-85** | **Oct.** | **54** | **18.4** | **21.30** | | **Feb.** | **75** | **85.9** | **7.55** | | | | | |
| | **Nov.** | **86** | **174.4** | **14.55** | | **Mar.** | **63** | **18.8** | **11.20** | | | | | |
| | **Des.** | **86** | **36.0** | **7.15** | **93-94** | **Apr.** | **72** | **171.4** | **16.65** | | | | | |
| | **Jan.** | **88** | **52.5** | **8.80** | | **May.** | **66** | **144.1** | **21.10** | | | | | |

## Appendix (B)

he software Minitab(13.) is used in the following macro programs.

Program (1): the values of ( $\hat{\alpha}_t$ ) variable input (temperature)

```
gmacro
aa.macro
let c4(1)=-1.15
do k3=2:192
let c4(k3)=c2(k3)- 0.2518*c2(k3-1)
enddo
endmacro
```

Program (2): values ( $\hat{\beta}_t$ ) for output (Rainfall)

```
gmacro
aa.macro
let c5(1)=-12
do k3=2:192
let c5(k3)=c1(k3)- 0.2518*c1(k3-1)
enddo
endmacro
```

Program (3): estimate values of disturbance series $N_t$by using matlab program

```
For i=1:192
For k=1:23
Z(I,k)= v(k)*ul(i+21)-k);
end;
end
fori=1:192
s(i)=0;
for j=1:21
s(i)=s(i)-z(i,j);
end
end
fori=24:192
n(i)=y(i)+s(i-20)
end
```

program (4): the values of series ( $\hat{a}_t$ )

```
gmacro
aa.macro
let c3(8)=0
do k1=9:192
let c3(k1)=c1(k1)-1.048*c1(k1-1)- 0.7266*c1(k1-2)+2.667*c2(k1)-
1.422*c2(k1-1)-4.451*c2(k1-2)+1.04*c3(k1-1)+0.7266*c3(k1-2)
enddo
let k4=sum(c3(k1)**2)
print k4
endmacro
```