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FOR TIME SERIES ANALYSIS.

by

⑩ Stephen Russell/Woodall

⑪ Sep ~~1978~~ 1978      ⑫ 242p.

Thesis Co-Advisors:      F.R. Richards  
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An Interactive Software Package  
for Time Series Analysis

by

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Submitted in partial fulfillment of the  
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### ABSTRACT

An expanded package of interactive FORTRAN computer programs has been developed for the analysis and forecasting of time series data. The package, called the Time Series Editor, is designed to employ the iterative Box-Jenkins methodology of time series analysis. The Time Series Editor was developed for time-shared use on the Control Program/Cambridge Monitor System (CP/CMS) at the U.S. Naval Postgraduate School, but can be modified for use on other time-sharing systems with a FORTRAN capability. The Time Series Editor assists in data preparation and entry, analysis, modeling, forecasting and diagnostic testing. Utilization of the package, following the included User's Guide, requires only a limited knowledge of the computer system, with all required user responses interactively prompted by the Editor.

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## I. INTRODUCTION

Operations researchers, military planners and programmers, statisticians, economists, marketing personnel, managers and others are often faced with the need to analyze data in the form of a time series, which can be thought of as a sequence of observations of either a deterministic or stochastic process. In most cases, the objective of the analysis is to determine patterns or other recognizable behavior apparent in the data, and to then formulate a suitable mathematical model for the time series from which forecasts of future behavior can be obtained. The value to a decision maker of being able to predict the future with some reasonable and statistically quantifiable degree of accuracy can not be overstated. For example, in areas such as budget expenditures, recruiting performance, commodity prices, population levels, resource consumption, manpower levels and consumer demand for products, decision makers charged with planning for the future should base their decisions at least in part on the best available predictions about the future behavior of the time series in question.

Until the late 1960's, the techniques employed in time series analysis were primarily those of spectral analysis, with applications of harmonic analysis and mathematical transform theory. For an introduction to these topics, the reader is referred to Anderson [Ref. 2], Lewis [Ref. 7] and Jenkins [Ref. 10]. Due to the high degree of mathematical

sophistication required by the spectral analysis approach, the capability to perform time series analysis resided nearly exclusively with mathematicians and electrical engineers. As a consequence, the majority of decision makers came to use more understandable (and far less powerful) methods such as simple moving averages or exponential smoothing. However, in the late 1960's and early 1970's, the statistical analysis of time series by the methods developed by Box and Jenkins [Ref. 4] has gained widespread acceptance. Although these methods are mathematically nearly equivalent to the spectral approach (there are transformations that interconnect the two methodologies), the Box-Jenkins approach is described in vocabulary more familiar to operations researchers, statisticians, economists and managers, and is therefore being used more and more by them in building models from measurements of the past.

Many algorithms and computer programs for performing the analyses required by the Box-Jenkins approach have been developed and are available from several sources. Perhaps the best source is the collection of FORTRAN computer subroutines which resides in the International Mathematical and Statistical Library (IMSL) [Ref. 9]. The primary problem with using the available computer resources lies not in any deficiency of the programs themselves, but with the very nature of the Box-Jenkins methodology itself. The Box-Jenkins method is an iterative approach to time series

analysis, which is briefly described in Figure 1. [See Wheelwright and Makridakis, Ref. 16.]

As indicated by Figure 1, the Box-Jenkins method is a multi-stage, iterative process. It begins with the postulation of a general class of time series models which has been found, experimentally, to be extremely rich. Thereafter, the procedure continues as a trial-and-error process, with decision points where the analyst is required to select the next direction based on the best information available to him. Since each stage of the process outlined in Figure 1 may consist of several sub-steps, the modeling process itself can become quite time-consuming, even with the ready availability of the IMSL software resources. For example, an analyst employing the IMSL subroutines in a batch processing computer system to perform Box-Jenkins modeling of a time series might perform the following sequence of tasks:

1. Prepare the time series data in the proper format.
2. Plot and visually examine the time series, checking for nonstationarity, trends, seasonality, patterns, etc.
3. Write a program to call the IMSL subroutine that will calculate the mean, variance, autocorrelations and partial autocorrelations of the series.
4. Plot the autocorrelations and partial autocorrelations; this provides much of the information required for identifying the correct model for the series.

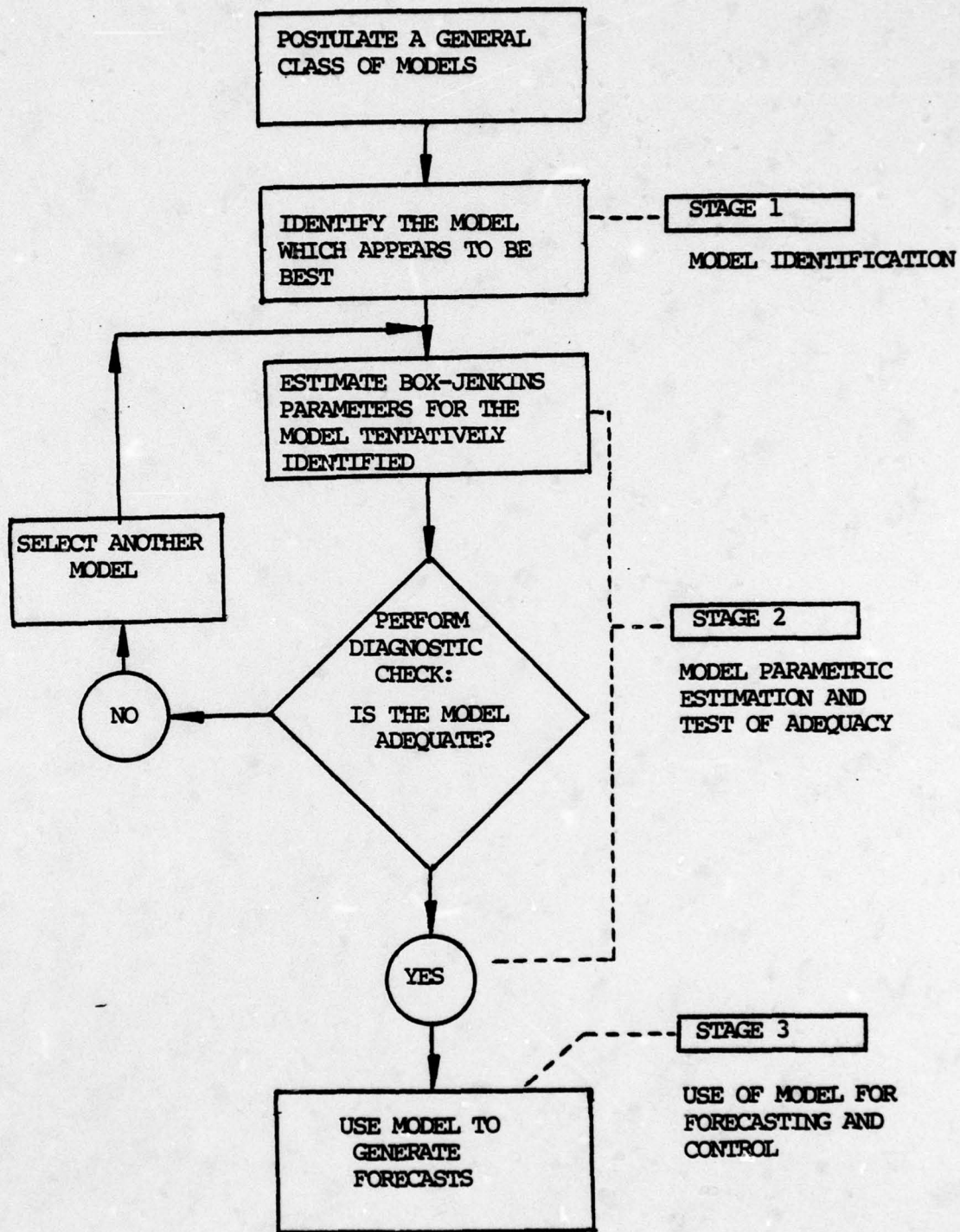


FIGURE 1. The Box-Jenkins Forecasting Methodology

5. Write a program to call the IMSL subroutine which transforms the time series to adjust for seasonal patterns, nonstationary behavior or other behavior which deviates from that assumed for the class of models postulated.
6. Repeat steps (2) through (4) with the transformed data.
7. Review the statistical properties of the autocorrelations and partial autocorrelations for tentative model identification.
8. Write a program to call the IMSL program that estimates the model parameters and computes the residuals.
9. Write a program to perform goodness-of-fit tests for the model.
10. Analyze the model residuals, using steps (1) through (9), as with the original time series.
11. Refine the model using information gained by examination for any structure in the residuals.
12. Repeat the preceding process until no structure remains in the residuals.
13. When an adequate model has been obtained, write a program to call the IMSL subroutine which forecasts and determines confidence intervals for future values of the time series.

Between each successive pair of steps, the analyst must manually intervene in the analysis process, making a decision

subjectively based on the information then available. Thus, much analyst interaction is necessary in order to determine a suitable mathematical model and forecast equation. Even with rapid computer job turnaround time, the process described above could easily consume a full working day or more.

This paper describes an effort to alleviate some of the organizational problems inherent in the modeling of time series using the Box-Jenkins iterative approach. This effort consists of an interactive computer program package which provides access in a structured way to the most useful IMSL and other subroutines necessary for Box-Jenkins time series analysis. This package, called the Time Series Editor, is written for use with the Naval Postgraduate School's Control Program/Cambridge Monitor System (CP/CMS). Since all working programs with the exception of the executive routine itself are written in FORTRAN, the Time Series Editor should be adaptable for use on other FORTRAN-capable time-sharing systems. The Time Series Editor assists the analyst in data preparation and entry, model construction and diagnostic testing, and time series forecasting. In fact, with the User's Guide provided as an Appendix to this report, a complete Box-Jenkins time series analysis can be performed in a short time by even a novice computer user. For this reason, the Time Series Editor could be a valuable instructional tool for laboratory use in a time series course.

A brief overview of Box-Jenkins methodology is provided in Chapter II, to serve as a point of reference for the material which follows. Chapter III contains a description of the algorithm employed to estimate non-linear least-squares parameters for a generalized (seasonal, nonseasonal, stationary, or nonstationary) Box-Jenkins model. Chapter IV contains descriptions of each of the major programs in the Time Series Editor. Chapters V and VI contain examples of actual use of the Time Series Editor, using a non-seasonal and a seasonal series, respectively. Chapter VII includes a summary of the report, and recommendations for future additions to the Time Series Editor. The Appendices include a User's Guide to the Time Series Editor, with instructions, sample user sessions and sample outputs, as well as listings of the Editor itself and all primary subprogram packages.

## II. BOX-JENKINS METHODOLOGY: A PRIMER

This chapter provides a brief overview of the methodology developed for the analysis of time series data by G.E.P. Box and G.M. Jenkins, in order to facilitate understanding of the models and programs employed in the Time Series Editor. For more detail on the material covered in this chapter, the interested reader is referred to the texts by Anderson [Ref. 1], Box and Jenkins [Ref. 4], Pindyck and Rubinfeld [Ref. 15], Nelson [Ref. 14], and Mabert [Ref. 12].

### A. LISTING OF NOTATION

The following is a listing of the notation employed in this chapter and in the remainder of this report. Each symbol is provided with a brief title or explanation of its use.

$\{z_t\}$	a time series
$N$	the length of the time series (number of terms)
$\bar{z}, \hat{\sigma}_z^2$	estimates of the mean and variance of the time series $\{z_t\}$
$\{z'_t\}$	transform of $\{z_t\}$ , where $z'_t = (z_t + \zeta)^\lambda$ or $z'_t = \ln(z_t + \zeta)$
$\{W_t\}$	differenced series from $\{z_t\}$ , where $W_t = \nabla^d \nabla_s^D z'_t$
$\rho_k$	autocorrelation of lag $k$
$r_K$	estimate of autocorrelation at lag $k$
$\nabla^d$	backward difference operator of order $d$

$\nabla_s^D$	seasonal backward difference operator of order D with season s
$B^s$	backward shift operator of order s
s	length of the time series' season
$\phi$	non-seasonal autoregressive parameters (estimates, $\hat{\phi}$ )
$\Phi$	seasonal autoregressive parameters (estimates, $\hat{\Phi}$ )
$\theta$	non-seasonal moving average parameters (estimates, $\hat{\theta}$ )
$\Theta$	seasonal moving average parameters (estimates, $\hat{\Theta}$ )
$\{a_t\}$	series of white noise terms of the process
$\sigma_a^2$	variance of the white noise process
$S(\hat{\phi}, \hat{\theta})$	sum of squared residuals of the model
p	number of non-seasonal autoregressive parameters
P	number of seasonal autoregressive parameters
q	number of non-seasonal moving average parameters
Q	number of seasonal moving average parameters
$\psi(B)$	transfer function of a linear filter
$\phi_{kk}$	partial autocorrelation of log k

## B. TIME SERIES, STOCHASTIC MODELS AND STATIONARITY

A distinguishing feature of modern time series analysis is that the sequence of observations of a given variable is considered to be a realization of jointly distributed

random variables, such that the time series itself can be viewed as a stochastic process. A discrete stochastic time series, then, is a set of observations  $(z_1, z_2, \dots, z_t)$  generated sequentially in time by a set of jointly distributed random variables, where the actual data  $(z_1, z_2, \dots, z_t)$  represents a particular realization of some joint probability distribution function  $f(z_1, z_2, \dots, z_t)$ . With this function determined in some way, a forecast  $z_{t+k}$  can be thought of as having been generated by a conditional probability distribution  $f(z_{t+k} | z_1, z_2, \dots, z_t)$ . Now, the stochastic process which generates the time series  $(z_1, z_2, \dots, z_t)$  is said to be stationary if its properties are unaffected by a change in time origin; that is, the process has reached a particular state of statistical equilibrium. This implies that the joint probability distribution associated with the  $m$  observations  $(z_{t_1}, z_{t_2}, \dots, z_{t_m})$ , made at any set of times  $(t_1, t_2, \dots, t_m)$ , is identical to that distribution associated with the  $m$  observations  $(z_{t_1+k}, z_{t_2+k}, \dots, z_{t_m+k})$  made at times  $(t_1+k, t_2+k, \dots, t_m+k)$ .

For stationary discrete time series, the marginal probability distribution  $p(z_t)$  is the same for all times  $t$ . Hence, the stochastic process embodied in the time series has a constant mean

$$\mu = E[z_t] = \int_{-\infty}^{\infty} zP(z)dz ,$$

which defines the level about which it fluctuates in time, and a constant variance

$$\sigma_z^2 = E[(z_t - \mu)^2] = \int_{-\infty}^{\infty} (z - \mu)^2 p(z) dz ,$$

which measures its variability about the level of the mean. Since the probability distribution  $p(z)$  is the same for all times  $t$ , its form can be discovered by plotting a histogram or relative frequency plot of the set of observations  $(z_1, z_2, \dots, z_t)$ . Additionally, the mean and variance of the stochastic process can be estimated by the sample averages taken over time:

$$\bar{z} = \frac{1}{N} \sum_{t=1}^N z_t$$

and

$$\hat{\sigma}_z^2 = \frac{1}{N} \sum_{t=1}^N (z_t - \bar{z})^2 .$$

### C. THE BASICS OF DIFFERENCE OPERATORS AND LINEAR FILTER MODELS

This section provides a brief discussion of the difference operators currently employed in writing Box-Jenkins models. Those most commonly used are described below in Table I.

Operator	Name	Definition
$B^m$	Backward Shift Operator of order m	$Bz_t = z_{t-1}$ $B^s z_t = z_{t-s}$
$F^m$	Forward Shift Operator of order m	$F = B^{-1}$ $Fz_t = z_{t+1}$ $F^m z_t = z_{t+m}$
$\nabla_s^D$	Backward Difference Operator of order D and season s	$\nabla^D = (1 - B)^D$ $\nabla_s^D = (1 - B^s)^D$ $\nabla z_t = z_t - z_{t-1}$

Table I. Basic difference operators.

It is noted here that  $\nabla^D z_t$  could be written as a binomial expansion; that is,

$$\begin{aligned} \nabla^D z_t &= (1 - B)^D z_t = \left( \sum_{j=0}^D \binom{D}{j} (1)^j (-B)^{D-j} \right) z_t \\ &= \sum_{j=0}^D \binom{D}{j} (-1)^{D-j} z_{t-D+j} \end{aligned}$$

The stochastic models employed in the Box-Jenkins method are based on the idea that a time series in which successive

values are highly dependent can be regarded as having been generated from a series of independent "shocks"  $a_t$ . These shock terms, sometimes referred to as white noise terms, are random drawings from some fixed distribution, generally assumed Normal with mean zero and variance  $\sigma_a^2$ . The white noise process  $a_t$  is supposed transformed to the process  $z_t$  by what is known as a linear filter, shown in Figure 2 below [Ref. 4, p. 8]. The linear filtering operation takes a

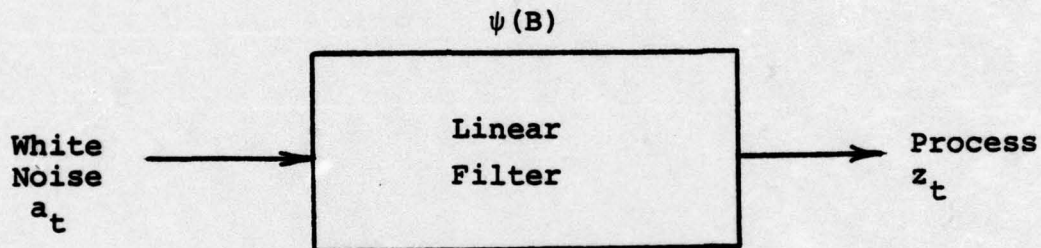


Figure 2. Representation of a time series as the output from a linear filter.

weighted sum of previous observations, such that  $z_t$  can be written

$$\begin{aligned}
 z_t &= \mu + a_t + \psi_1 a_{t-1} + \psi_2 a_{t-2} + \dots \\
 &= \mu + \psi(B) a_t .
 \end{aligned}$$

In general,  $\mu$  is the parameter that determines the "level" of the process, and

$$\psi(B) = 1 + \psi_1 B + \psi_2 B^2 + \dots$$

is the linear operator that transforms  $a_t$  into  $z_t$ , called the transfer function of the filter. The sequence  $\psi_1, \psi_2, \dots$  formed by the weights may be (theoretically) finite or infinite; if this sequence is finite, or infinite and converges, the filter is said to be stable and the process  $z_t$  stationary. The parameter  $\mu$  is then the value about which the process varies. Otherwise,  $z_t$  is called nonstationary, and  $\mu$  has no specific meaning except as a reference point for the level of the process.

#### D. HOMOGENEOUS NON-STATIONARY AND SEASONAL PROCESSES

In many cases of interest to the time series analyst, the process being examined is not stationary. Instead, the probabilistic structure of the process generating the time series changes with time. For example, there may be a trend or seasonal pattern in the time series. However, if the series can be found to exhibit behavior which is somewhat homogeneous, then the series can frequently be transformed into a stationary series that can be described by Box-Jenkins models.

A series is said to be homogeneous nonstationary of order  $d$  if  $w_t = \nabla^d z_t$  is a stationary series for some integer  $d$ . Here  $\nabla = (1 - B)$  denotes the difference operator such that  $\nabla^1 a_t = z_t - z_{t-1}$ . The fact that a given series is nonstationary can be determined quickly by examination of

the autocorrelation function, to be discussed later. The series to be modeled should be differenced until the resulting series appears stationary or until the procedure appears to be making no improvement.

A time series is called seasonal when it exhibits cyclical behavior over time, showing a regular period. Examples of seasonal processes include monthly rainfall, monthly crop yields, sale volume of bathing suits, livestock production rates and energy consumption. Seasonal patterns are often easy to spot simply by observing a plot of the series, or through knowledge of the process that generated the series. However, in many cases where the variability of the series is large, seasonal patterns will be difficult to distinguish from other fluctuations. Recognition of seasonality in a series is important, since it provides information useful in modeling and forecasting; as will be shown, the autocorrelation function can assist in recognizing seasonality. The Box-Jenkins modeling approach for seasonal nonstationary time series of season length  $s$  is to first transform the series using an appropriate seasonal differencing operator to "sweep out" the seasonal effect; that is, take

$$W_t = \nabla_s^D z_t .$$

If there is a trend or other types of non-stationarity present, as well as the seasonal effect, the series can be

differenced again with the ordinary difference operator until stationarity is achieved. This transform would be written

$$W_t = \nabla^d \nabla_s^D z_t$$

The transformed series  $W_t$  is then modeled as a stationary series. For seasonal series where complete stationarity can not be achieved, a class of seasonal models is available; these are discussed later in this Chapter.

#### E. GENERAL CLASSES OF BOX-JENKINS MODELS

This section will provide brief descriptions of several of the most commonly used classes of Box-Jenkins models, including autoregressive (AR) models, moving average (MA) models, mixed and integrated autoregressive-moving average (ARMA/ARIMA) models, and a generalized seasonal ARIMA model.

##### 1. Autoregressive Models

In autoregressive (AR) models, the current value of the series under study is expressed as a linear combination of previous series values that explain the current observation, plus an unexplained random (white noise) term  $a_t$ . For a stationary series, or one that has been transformed to stationarity, the deviation from the mean value for each period,  $\tilde{z}_t = z_t - \mu$ , can be modeled as dependent on weighted values of the previous deviations from the mean. The AR model can be written

$$\tilde{z}_t = \phi_1 \tilde{z}_{t-1} + \phi_2 \tilde{z}_{t-2} + \dots + \phi_p \tilde{z}_{t-p} + a_t .$$

In the expressions which follow the tilde will be dropped, but it is to be understood that the mean has already been subtracted from each observation. This equation is called an autoregressive process of order  $p$ , where  $\phi_j$  represents a scalar weighting coefficient for the  $j^{\text{th}}$  previous period. The model can also be written in more compact form as

$$\phi(B)z_t = a_t ,$$

where

$$\phi(B) = (1 - \phi_1 B - \phi_2 B^2 - \dots - \phi_p B^p),$$

a polynomial in the operator  $B$ . Then,  $\phi(B)$  represents a general non-seasonal AR operator. The reason these models are called autoregressive can be seen from recalling regression analysis; here the model relates the dependent variable  $z_t$  to a set of explanatory variables ( $z_{t-1}, z_{t-2}, \dots, z_{t-p}$ ), which are previous values of the time series. Therefore, the model is autoregressive. For example, when the value of the time series at time  $t$  depends only on the value at time  $t-1$ , the model becomes an autoregressive model of order 1, denoted AR(1). Similarly, if the value in period  $t$  depends on the values in periods  $t-1$ ,  $t-2$  and  $t-3$ ,

the model is AR(3). The following equations are the mathematical representation of those two examples:

$$\text{AR}(1) : z_t = \phi_1 z_{t-1} + a_t ;$$

$$\text{AR}(3) : z_t = \phi_1 z_{t-1} + \phi_2 z_{t-2} + \phi_3 z_{t-3} + a_t .$$

## 2. Moving Average Models

In moving average (MA) models, the assumption is made that the current value of the time series at period  $t$  can be expressed as a linear combination of the previous forecast errors (or, residuals),  $a_t = z_t - \hat{z}_t$ . The general equation for this model can be written

$$z_t = a_t - \theta_1 a_{t-1} - \theta_2 a_{t-2} - \dots - \theta_q a_{t-q} ,$$

which is called a moving average model of order  $q$ , where  $\theta_q$  represents the scalar weighting coefficient for the  $q^{\text{th}}$  previous period. Like the AR model, the MA model can be written in more compact operator notation as follows:

$$z_t = \theta(B) a_t ,$$

where

$$\theta(B) = (1 - \theta_1 B - \theta_2 B^2 - \dots - \theta_q B^q) ,$$

a polynomial in the operator B. The MA model implies that the analyst can gain valuable information for future predictions by consideration of the weighted sum of a number of previous forecast errors or residuals. The following are examples of MA models of order 1 and order 3, MA(1) and MA(3):

$$\text{MA}(1) : z_t = (1 - \theta_1 B)a_t = a_t - \theta_1 a_{t-1} ;$$

$$\begin{aligned} \text{MA}(3) : z_t &= (1 - \theta_1 B - \theta_2 B^2 - \theta_3 B^3)a_t \\ &= a_t - \theta_1 a_{t-1} - \theta_2 a_{t-2} - \theta_3 a_{t-3} . \end{aligned}$$

### 3. Mixed and Integrated Autoregressive-Moving Average Models

A natural extension of the autoregressive and moving average models is to construct a combination of the two. Such mixed processes are called autoregressive-moving average (ARMA) processes, of orders p and q, often written as ARMA(p,q). Box and Jenkins [Ref. 4] notes that for many series encountered in practice, the inclusion of both AR and MA terms in a model results in fewer total parameters than would be required for either a pure AR or pure MA process. The ARMA(p,q) model may be written in the usual form as

$$z_t = \phi_1 z_{t-1} + \phi_2 z_{t-2} + \dots + \phi_p z_{t-p} + a_t - \theta_1 a_{t-1} - \theta_2 a_{t-2} - \dots - \theta_q a_{t-q} ;$$

in the more compact operator notation, the same model is written

$$\phi(B)z_t = \theta(B)a_t .$$

As an example, an ARMA(2,2) model would be written as:

$$(1 - \phi_1 B - \phi_2 B^2)z_t = (1 - \theta_1 B - \theta_2 B^2)a_t ,$$

or expanded, as:

$$z_t = \phi_1 z_{t-1} + \phi_2 z_{t-2} + a_t - \theta_1 a_{t-1} - \theta_2 a_{t-2} .$$

Recall that with differencing or other transformation techniques, a stationary series can be obtained from a homogeneous (seasonal or non-seasonal) non-stationary series. When the differencing technique is integrated directly into the ARMA model, the result is an integrated autoregressive-moving average (ARIMA) model. The model is often written ARIMA(p,d,q), where p and q retain their previous meanings, and d represents the order of (non-seasonal) differencing. The model may also be generalized by including an additional constant term  $\theta_0$  that will have the effect of adding a deterministic polynomial trend of order d. The value of  $\theta_0$  may be found in general by the formula

$$\hat{\theta}_0 = \hat{\mu} G ,$$

where

$$G = [1 - \sum_{i=1}^P \hat{\phi}_i] [1 - \sum_{j=1}^P \hat{\phi}_j] .$$

The general ARIMA(p,d,q) model can be written compactly as

$$(1) \quad \phi(B) \nabla^d z_t = \theta_0 + \theta(B) a_t .$$

An equivalent form for ARIMA(p,d,q) models that is sometimes seen is called undifferenced form:

$$\Psi(B) z_t = \theta_0 + \theta(B) a_t ,$$

where

$$\Psi(B) = \phi(B) \nabla^d = \phi(B) (1 - B)^d .$$

The "differenced" form, equation (1), is the form usually seen. In the differenced form, the transfer function  $\phi(B)$  is assumed to be stable; that is, all the roots of the difference equation  $\phi(B) = 0$  are outside the unit circle. Clearly,  $\Psi(B)$  is not a transfer function of a stationary series when  $d > 0$ , since  $\Psi(B)$  has  $d$  roots on the unit circle.

#### 4. Seasonal ARIMA Models

The general class of ARIMA models previously discussed can be further generalized to allow for the modeling of seasonal models with the addition of appropriate seasonal operators and parameters. The seasonal model is called an ARIMA model of order  $(p,d,q) \times (P,D,Q)_s$ , where  $p,d,$  and  $q$  retain their previous meanings, and  $P, D, Q$  and  $s$  are as defined in Section A of this chapter, page 17. The ARIMA  $(p,d,q) \times (P,D,Q)_s$  model can be written as the product of nonseasonal and seasonal operators:

$$\phi(B)\phi(B^s)\nabla_s^D\nabla^d z_t = \theta_0 + \theta(B)\theta(B^s)a_t.$$

As an example, consider the ARIMA  $(1,2,1) \times (1,2,1)_{12}$  model:

$$(1-\phi_1 B)(1-\phi_{1,12} B^{12})\nabla^2\nabla_{12}^2 z_t = \theta_0 + (1-\theta_1 B)(1-\theta_{1,12} B^{12})a_t.$$

#### F. THE AUTOCORRELATION AND PARTIAL AUTOCORRELATION FUNCTIONS

Mathematically, the autocorrelation at lag  $k$ , denoted  $\rho_k$ , is defined as:

$$\rho_k = \frac{E[(z_t - \mu)(z_{t+k} - \mu)]}{\sigma_z^2}.$$

The autocorrelation function of a time series describes the association (mutual dependence) among values of the same

series taken at different time periods, the difference in time being referred to as the lag, denoted  $k$ . Autocorrelation of itself implies nothing about a change in one variable causing a change in another. However, the autocorrelations may provide important information about the structure of a data set and its pattern. In a set of completely random data the theoretical autocorrelations among successive values will always be zero, whereas data values of strong seasonal or cyclical behavior will be highly autocorrelated. This  $\rho_k$  can be estimated using the time-averaged sample autocorrelation, denoted  $r_k$ , defined as:

$$r_k = \frac{\frac{1}{N} \sum_{t=1}^{N-k} (z_t - \bar{z})(z_{t+k} - \bar{z})}{\hat{\sigma}_z^2}$$

A plot of the autocorrelation function versus the lag  $k$ , called a correlogram, is very useful for the purpose of determining if a process is stationary and for identifying the appropriate model.

Another function useful in identifying the appropriate model for a given series is the partial autocorrelation function, often called the pauto function. Partial autocorrelations are analogous to autocorrelations in that they indicate the relationship of the values of a time series to various time-lagged values of the same series. However, they differ from autocorrelations in that they measure the

strength of the relationship between values of the series of various lags after the effects of other lags have been removed. In effect, they show the relative strength of the relationship that exists for varying time lags. For time series models of the types to be considered, the partial autocorrelation coefficients can be calculated several ways. One method of calculation, described by Box and Jenkins [Ref. 4, Sec. 3.2.5] begins with the following equation, satisfied by the autocorrelation function, where the  $\phi_k$  are autoregressive parameters:

$$\rho_j = \phi_{k1}\rho_{j-1} + \dots + \phi_{k,k-1}\rho_{j-k+1} + \phi_{kk}\rho_{j-k}, \quad j = 1, 2, \dots, k$$

This leads to what are known as the Yule-Walker equations, which may be written

$$\begin{bmatrix} 1 & \rho_1 & \rho_2 & \dots & \rho_{k-1} \\ \rho_1 & 1 & \rho_1 & \dots & \rho_{k-2} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \rho_{k-1} & \rho_{k-2} & \rho_{k-3} & \dots & 1 \end{bmatrix} \begin{bmatrix} \phi_{k1} \\ \phi_{k2} \\ \vdots \\ \phi_{kk} \end{bmatrix} = \begin{bmatrix} \rho_1 \\ \rho_2 \\ \vdots \\ \rho_k \end{bmatrix}$$

Solving these equations for  $k = 1, 2, 3, \dots$ , successively, we obtain

$$\phi_{11} = \rho_1,$$

$$\phi_{22} = \frac{\begin{vmatrix} 1 & \rho_1 \\ \rho_1 & \rho_2 \end{vmatrix}}{\begin{vmatrix} 1 & \rho_1 \\ \rho_1 & 1 \end{vmatrix}} = \frac{\rho_2 - \rho_1^2}{1 - \rho_1^2},$$

$$\phi_{32} = \frac{\begin{vmatrix} 1 & \rho_1 & \rho_1 \\ \rho_1 & 1 & \rho_2 \\ \rho_2 & \rho_1 & \rho_3 \end{vmatrix}}{\begin{vmatrix} 1 & \rho_1 & \rho_2 \\ \rho_1 & 1 & \rho_1 \\ \rho_2 & \rho_1 & 1 \end{vmatrix}}, \text{ etc.}$$

In general, for  $\phi_{kk}$ , the determinant in the numerator has the same elements as that in the denominator, but with the last column replaced with  $\rho_k$ . The quantity  $\phi_{kk}$ , a function of the lag  $k$ , is called the partial autocorrelation function. Other methods for calculating partial autocorrelations include successively fitting autoregressive processes of orders 1, 2, ...,  $k$  by least squares and picking off estimates of  $\hat{\phi}_{11}$ ,  $\hat{\phi}_{22}$ , ...,  $\hat{\phi}_{kk}$  of the last coefficient fitted at each stage. Another method, discussed in Appendix A3.2 of Ref. 4 and due to Durbin, generates estimates of an autoregressive process of order  $k+1$  recursively from estimates of autoregressive processed orders  $k$  and less. It is derived by observing recursive relationships from the Yule-Walker equations. The recursive formulas are:

$$\hat{\phi}_{k+1,j} = \hat{\phi}_{k,j} - \hat{\phi}_{k+1,k+1} \hat{\phi}_{k,k-j+1}$$

$j = 1, 2, \dots, k$ , and

$$\hat{\phi}_{k+1,k+1} = \frac{r_{k+1} - \sum_{j=1}^k \hat{\phi}_{k,j} r_{k+1-j}}{1 - \sum_{j=1}^k \hat{\phi}_{k,j} r_j}$$

Another way of looking at partial autocorrelations is to consider a time series  $\{z_t\}$  and the model

$$\hat{z}_t = b_0 + b_1 z_{t-1} + b_2 z_{t-2} + \dots + b_{k-1} z_{t-(k-1)}$$

where the  $b$  values are the least squares estimates of the linear regression coefficients ( $\beta$ 's) in the model

$$z_t = \beta_0 + \beta_1 z_{t-1} + \dots + \beta_{k-1} z_{t-(k-1)} + e_t$$

Let  $\tilde{z}_t$  be the residual of  $z_t$  after removing the linear effect of  $z_{t-1}, \dots, z_{t-k+1}$  from  $z_t$ , such that  $\tilde{z}_t = z_t - \hat{z}_t$ . Then, the partial autocorrelation of lag  $k$ , denoted  $\phi_{kk}$ , is defined to be the simple autocorrelation of lag  $k$  for the adjusted series  $(\tilde{z}_1, \tilde{z}_2, \dots, \tilde{z}_n)$ .

The exact expression for partial autocorrelations of a moving average process is complicated, but an approximate duality between autocorrelations of an autoregressive

process and partials of a moving average process implies that the partials of a moving average process would have the same general behavior as the autocorrelations of an autoregressive process of the same order. This approximate duality also implies that the partials of an autoregressive process of order  $p$  will have the same general behavior as the autocorrelations of a moving average process of order  $p$ . Thus, one function can be examined and used to confirm the other, and may be of use in model identification, discussed in section G of this chapter.

#### G. COMMENTS ON MODEL SELECTION EMPLOYING AUTOCORRELATIONS AND PARTIAL AUTOCORRELATIONS

The purpose of this section is to provide a brief overview of the methodology for selecting the proper model for a given time series, through both examination or prior knowledge of the data itself and examination of plots of the autocorrelation and partial autocorrelation functions.

A not yet stationary series should first be differenced or transformed until it appears to be stationary; characteristic of the autocorrelation plot (correlogram) of a non-stationary series is a very slow damping out of the autocorrelations. When this property of the correlogram is observed, the analyst should difference the series until no further improvement is reached. For ARMA( $p,q$ ) models, the tentative identification of the model class, that is, the determination of  $p$  and  $q$ , can be done by examining the

sample autocorrelation and sample partial autocorrelation functions of the given time series with the theoretical auto and pauto functions of members of the general linear class. For most stationary time series, an adequate fit can be found in a model with  $p$  and  $q$  relatively small, say three or less.

The following figure displays examples of autocorrelation and partial autocorrelation versus lag plots for several basic model types, described in Ref. 17.

Figure 3. Examples of Auto and Pauto Plots

Figure 3(a). Auto and Pauto vs. Lag for AR(1) Model

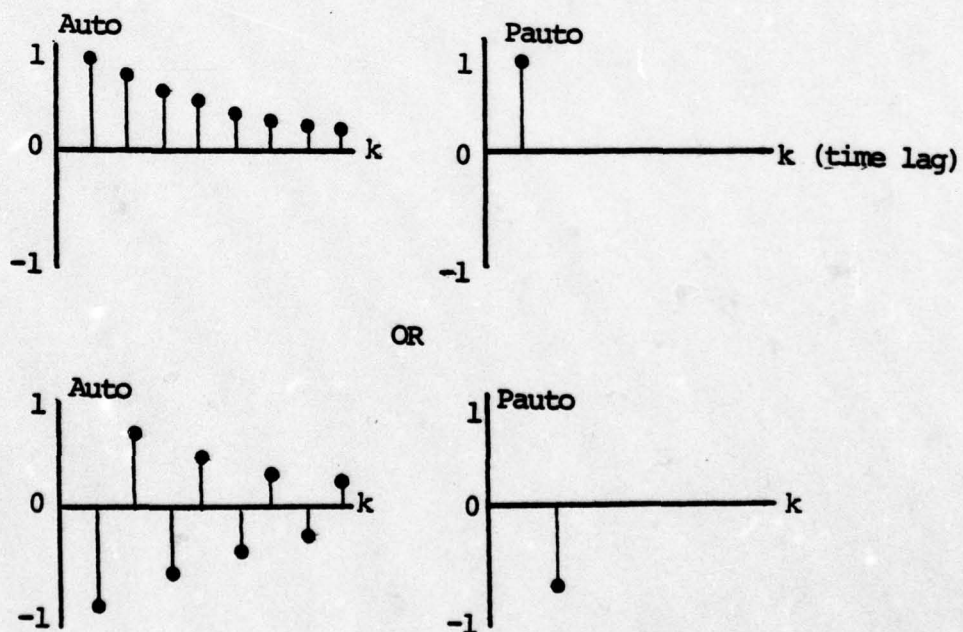


Figure 3(b). Auto and Pauto vs. Lag for AR(2) Model

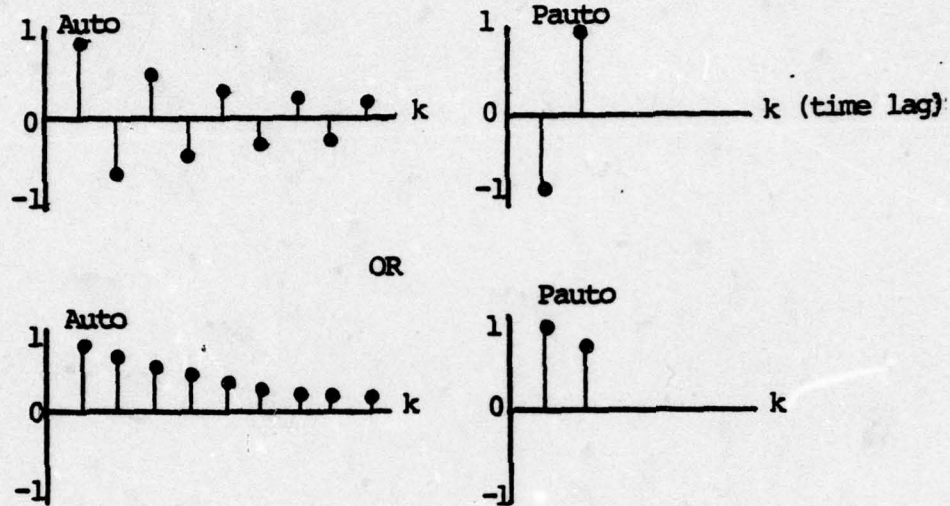


Figure 3(c). Auto and Pauto vs. Lag for MA(1) Model

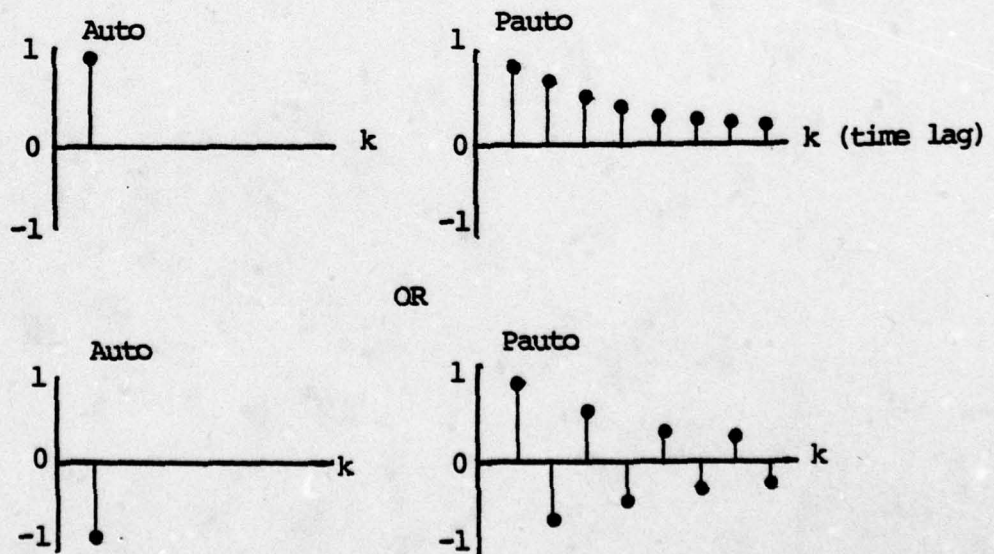


Figure 3(d). Auto and Pauto vs. Lag for MA(2) Model

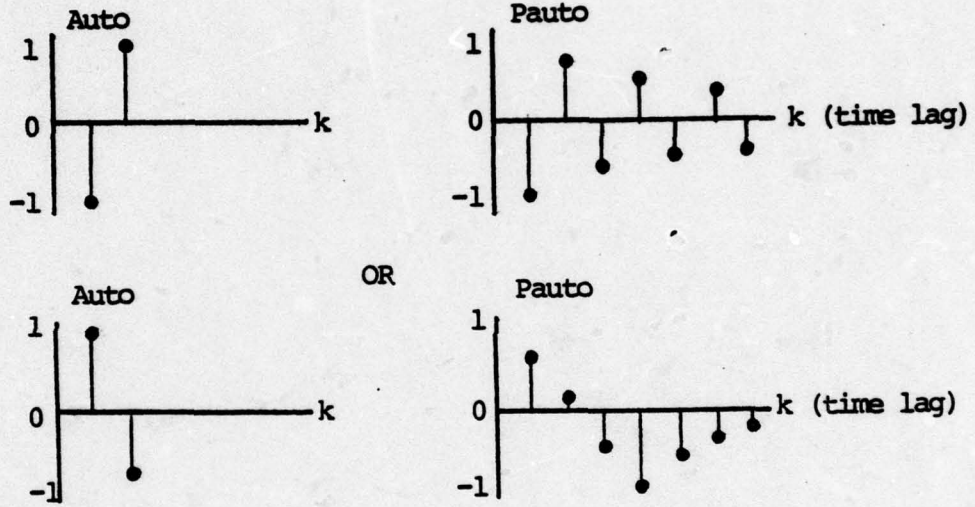
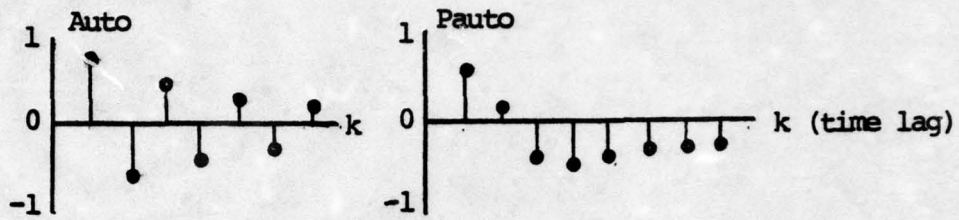
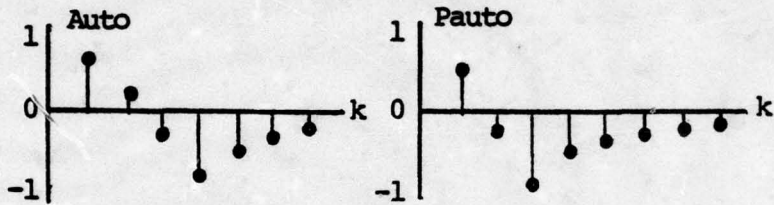


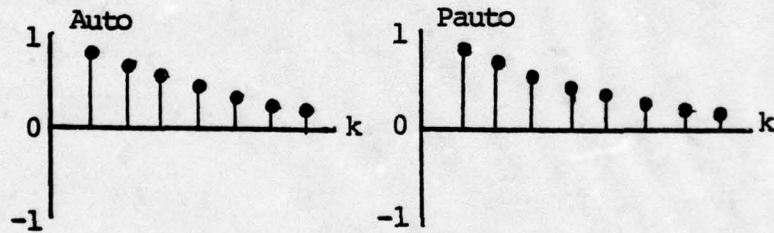
Figure 3(e). Example Auto and Pauto vs. Lag for Mixed ARMA(1,1) Model



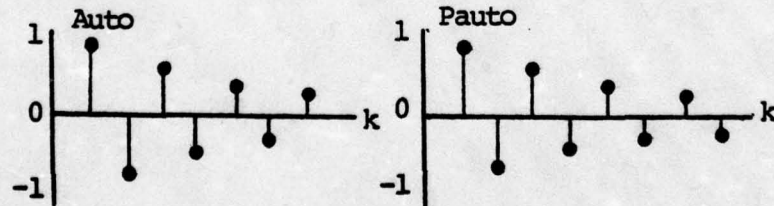
OR



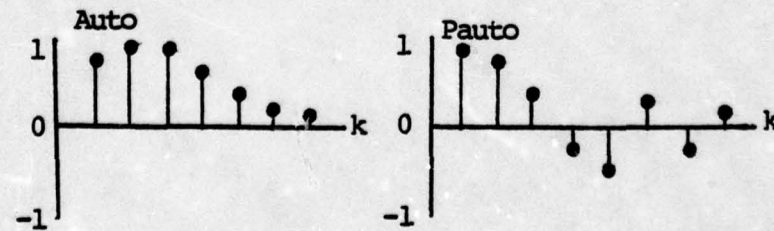
OR



OR



OR



As can be seen from the figures, there is a wide variety of possibilities for appearance of the correlogram and partial autocorrelation plots for even the simplest of models. Sometimes the pattern of estimated autos and pautos can be quickly classified in terms of one of the simpler basic models; however, most real data will generate auto and pauto plots that resemble those of Figure 3(e), those of a mixed model. Here some free association may be required to infer a pattern from the correlogram, or more than one pattern may be implied. However, most of the time a selection of something is possible. As is evident, this is a somewhat subjective process, where the quality of identification will improve with experience.

The following table, adapted from Box and Jenkins [Ref. 4], summarizes the properties of autoregressive, moving average and mixed ARMA processes; an understanding of its contents will be helpful as thumbrules for initial model identification.

It can be noted from examination of Table II that there exists what can be termed a "duality" relationship between the autocorrelations and partial autocorrelations of pure autoregressive and moving average processes. For example, the plot of autocorrelation versus lag for an AR(p) process would appear the same as the plot of partial autocorrelation versus lag for an MA(q) process, for  $p = q$ . Similarly, the plot of partial autocorrelation versus lag for the AR(p)

	Autoregressive Process	Moving Average Process	Mixed Process
Model in terms of previous $z_t$ values	$\phi(B)\tilde{z}_t = a_t$	$\tilde{z}_t = \theta(B)a_t$	$\phi(B)\tilde{z}_t = \theta(B)z_t$
Autocorrelation Function	Infinite and tails off; composed of damped exponentials and/or damped sine waves	finite; that is, there will be $q$ non-zero autocorrelations	Infinite and tails off; composed of damped exponentials and/or damped sine waves after the first $q-p$ lags
Partial Autocorrelation Function	finite; that is, there will be $p$ non-zero partial autocorrelations	Infinite and tails off; dominated by damped exponentials and/or sine waves	Infinite and tails off; composed of damped exponentials and/or sine waves after the first $p-q$ lags

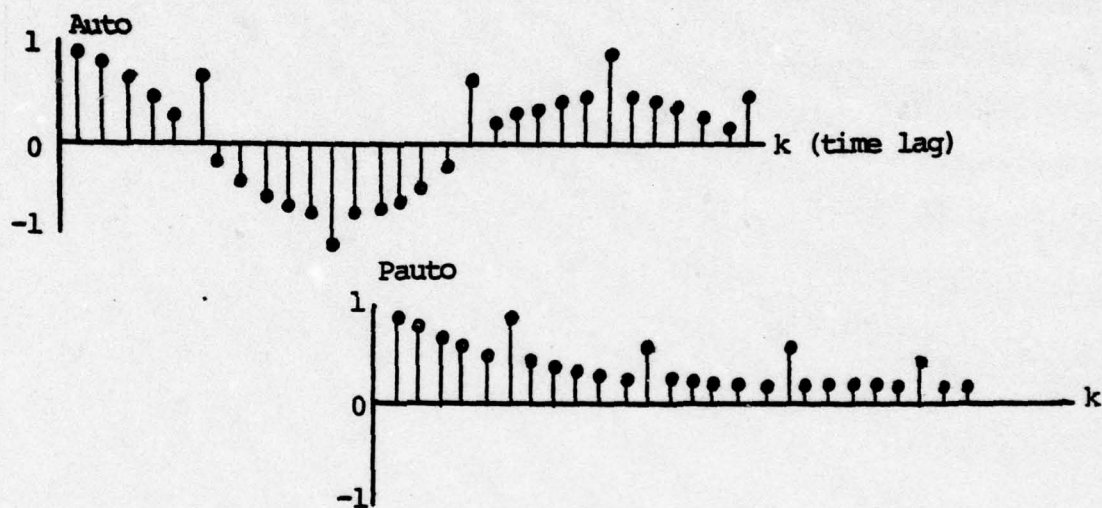
Table II. Properties of Basic ARMA Processes

process would appear the same as the plot of autocorrelation versus lag for an MA( $q$ ) process, where  $p = q$ .

For seasonal series, where differencing has been unable to remove all the nonstationary seasonal behavior, the autocorrelation and partial autocorrelation plots will generally exhibit a "spike" at lags equal to integer multiples of the period of seasonality. For example, if the data are seasonal with a period of 12, then the autocorrelations

$r_{12}, r_{24}, r_{36}, \dots$  and the partial autocorrelations  $\phi_{12,12}, \phi_{24,24}, \phi_{36,36}, \dots$  would be amplified. This would indicate a need for one or more seasonal parameters to be included in the model. The following figure is an illustration of such an auto/pauto plot.

Figure 4. Example Auto and Pauto versus lag for mixed ARMA(p,q), with seasonality remaining of period  $s = 6$ .



#### H. ESTIMATION OF MODEL PARAMETERS

Suppose a time series has been tentatively identified as an ARIMA(p,d,q) model:

$$\phi(B) \nabla^d z_t = \theta_0 + \theta(B) a_t.$$

There are then  $p+q+2$  unknown parameters of the model to be estimated,  $(\phi_1, \phi_2, \dots, \phi_p, \theta_0, \theta_1, \theta_2, \dots, \theta_q, \sigma_a^2)$ . The

Box-Jenkins procedure separates this estimation into two parts. First, estimates are obtained for the AR and MA parameters  $\hat{\phi} = (\phi_1, \phi_2, \dots, \phi_p)$  and  $\hat{\theta} = (\theta_1, \theta_2, \dots, \theta_q)$ ; then estimates are calculated for  $\theta_0$  and  $\sigma_a^2$ , which are functions of  $\hat{\phi}$  and  $\hat{\theta}$ .

The usual procedure is to select those parameter values  $\hat{\phi}$  and  $\hat{\theta}$  that minimize the sum of squared model errors (residuals). Let  $\mu_w = \theta_0 / (1 - \phi_1 - \phi_2 - \dots - \phi_p)$  and  $\tilde{W}_t = \nabla^d (z_t - \mu_w)$ . Then, it can be shown that  $\mu_w = E[W_t]$  and that the model can be rewritten as

$$\phi(B) (W_t - \mu_w) = \theta(B) a_t,$$

or

$$a_t = \theta^{-1}(B) \phi(B) (W_t - \mu_w).$$

Now, let  $\bar{W}$ , the sample mean, be the estimate of  $\mu_w$  (if  $d > 0$ , then  $\mu_w$  is usually zero). Also, let

$$a_t = \hat{\theta}^{-1}(B) \hat{\phi}(B) (W_t - \bar{W}).$$

Set

$$S(\hat{\phi}, \hat{\theta}) = \sum_{t=1}^N a_t^2,$$

where  $N = n-d$  is the length of the differenced series. The

objective is to select those parameters  $\hat{\phi}$  and  $\hat{\theta}$  such that  $S(\hat{\phi}, \hat{\theta})$  is minimized over all values of the  $(p+q)$ -dimensioned parameter space. Since the equation in  $S$  is nonlinear in the parameters, iterative search methods are generally used to determine optimal model parameters. Having found these optimal parameters and the minimum  $S$ ,  $\sigma_a^2$  can be estimated using

$$\hat{\sigma}_a^2 = S(\hat{\phi}, \hat{\theta}) / N - p - q .$$

Chapter III contains a more detailed description of a nonlinear algorithm to estimate parameters of a generalized seasonal or nonseasonal ARIMA model.

#### I. DIAGNOSTIC CHECKING OF MODELS

After the model has been tentatively identified and parameter estimates have been calculated, the next task is to test whether or not the original model specification was correct and that the model itself is adequate in forecasting power. The process of testing the model can take many forms, but will usually include at least the following two steps:

1. Generate a simulated series from the estimated model and compare the simulated series and its auto and pauto functions with the original series and its respective auto and pauto functions. This comparison is essentially subjective.

2. Calculate the residuals of the estimated model, the  $\hat{a}_t$ 's, and compare the properties of the residuals with those assumed for the shock terms of the actual process. The residuals should be normally distributed and uncorrelated with each other; that is, there should be no discernable structure in the residuals. There are many quantitative statistical tests and data analytic tools that can be applied to the residuals to test hypotheses of normality and zero autocorrelation.

A plot of the autocorrelation and partial autocorrelation functions of the residuals will provide not only a test of whether or not the residuals are uncorrelated, but, if they are correlated, the plots can be used to suggest improvements to the model. For example, suppose the model was tentatively specified as the ARMA(1,1) model below:

$$(1 - 0.5B)(z_t - 2) = (1 + 0.7B) a_t .$$

Suppose also that the autos and pautos of the model residuals suggested the model  $(1 - 0.3B) a_t = u_t$ , where the  $u_t$ 's are white noise, uncorrelated with variance  $\sigma_u^2$ . Then, these two models can be combined into the ARMA(2,1) model:

$$(1 - 0.3B)(1 - 0.5B)(z_t - 2) = (1 + 0.7B) u_t .$$

This should be a refinement over the original model.

## J. FORECASTING

The objective in forecasting is to predict future values of the time series with as little error as possible. The criterion most often used for forecasting is to calculate that forecast which minimizes the expected mean square forecast error. Therefore, if  $\hat{z}_t(\ell)$  denotes the forecast for lead time  $\ell$  from time origin  $t$  of the value  $z_{t+\ell}$ , the objective is to find  $\hat{z}_t(\ell)$  such that the objective function

$$E[(z_{t+\ell} - \hat{z}_t(\ell))^2]$$

is a minimum. This forecast is given by taking  $\hat{z}_t(\ell)$  as the conditional expectation of  $z_{t+\ell}$ , given  $z_1, \dots, z_t$ :

$$\hat{z}_t(\ell) = E[z_{t+\ell} | z_t, z_{t-1}, \dots, z_1] .$$

The forecast can be easily generated recursively from the mathematical model, utilizing the facts that

$$E[z_{t-j} | z_t, \dots, z_1] = z_{t-j} ,$$

for  $j = 0, 1, 2, \dots$  (where  $t$  is the current time), and

$$E[z_{t+j} | z_t, \dots, z_1] = \hat{z}_t(j), \text{ for } j = 1, 2, \dots$$

and

$$E[a_t] = \begin{cases} 0 & \text{for times } > t \\ a_t & \text{for times } \leq t \end{cases}$$

For example, consider the Box-Jenkins model

$$(1 - 0.5B + 0.6B^2) z_t = (1 + 0.3B) a_t$$

which could be written in the expanded form as

$$z_t = 0.5z_{t-1} - 0.6z_{t-2} + a_t + 0.3 a_{t-1} .$$

Now, assume it is known that  $z_{100}$  is 1.4,  $z_{99}$  is 1.0, and the calculation has been made to obtain the residual  $\hat{a}_{100} = 0.2$ . Then the forecasts of  $z_{101}$ ,  $z_{102}$  and  $z_{103}$  made from an origin of  $t = 100$  can be calculated from the model as follows:

first, for  $l = 1$ , set

$$\hat{z}_{100}(1) = E[z_{101} | z_{100}, z_{99}, \dots, z_1] ,$$

$$\hat{z}_{100}(1) = E[0.5z_{100} - 0.6z_{99} + \hat{a}_{101} + 0.3\hat{a}_{100}] ,$$

and

$$\hat{z}_{100}(1) = (0.5)(1.4) - (0.6)(1.0) + 0 + (0.3)(0.2) ;$$

then our forecast

$$\hat{z}_{100}(1) = .0.7 - 0.6 + 0.06 = 0.16 ;$$

Next, for  $l = 2$ , set

$$\hat{z}_{100}(2) = E[z_{102} | \hat{z}_{101}, z_{100}, z_{99}, \dots, z_1] ,$$

$$\hat{z}_{100}(2) = E[0.5\hat{z}_{101} - 0.6z_{100} + a_{102} + 0.3a_{101} \\ | z_{100}, z_{99}, \dots, z_1] ,$$

$$\hat{z}_{100}(2) = (0.5)(\hat{z}_{100}(1)) - (0.6)(z_{100}) + 0 + 0 ,$$

$$\hat{z}_{100}(2) = (0.5)(0.16) - (0.6)(1.4) = -0.76 ;$$

similarly, for  $l = 3$ , set

$$\hat{z}_{100}(3) = E[z_{103} | \hat{z}_{102}, \hat{z}_{101}, z_{100}, z_{99}, \dots, z_1] ,$$

$$\hat{z}_{100}(3) = E[0.5\hat{z}_{102} - 0.6\hat{z}_{101} + a_{103} + 0.3a_{102} \\ | z_{100}, z_{99}, \dots, z_1]$$

$$\hat{z}_{100}(3) = (0.5)(\hat{z}_{100}(2)) - (0.6)(\hat{z}_{100}(1)) + 0 + 0 ,$$

and then

$$\hat{z}_{100}(3) = (0.5)(-0.76) - (0.6)(0.16) = -0.48 .$$

Clearly, this process can be continued into the future as long as desired, recognizing that the expected forecast accuracy will decrease as  $l$  increases.

Let

$$e_t(l) = (z_{t+l} - \hat{z}_t(l))$$

denote the forecast error for lead time  $l$  beyond the forecast time origin  $t$ . It can be shown that  $e_t(l)$  is given by the relation

$$e_t(l) = a_{t+l} + \psi_1 a_{t+l-1} + \dots + \psi_{l-1} a_{t+1} ,$$

where the scalar weights  $\psi_j$  are determined from the equation

$$\psi(B) = \hat{\phi}^{-1}(B) (1 - B)^{-d} \hat{\theta}(B)$$

using the known parameter values. The variance of the forecast error is given by

$$E[(e_t^2(l))] = (1 + \psi_1^2 + \dots + \psi_{l-1}^2) (\sigma_a^2) = \left\{ 1 + \sum_{j=1}^{l-1} \psi_j^2 \right\} \sigma_a^2 .$$

From these relationships, a confidence interval of  $n$  standard deviations about a forecast of lead time  $l$  would be given by:

$$c_n(\hat{z}_t(l)) = \hat{z}_t(l) \pm n \left[ 1 + \sum_{j=1}^{l-1} \psi_j^2 \right]^{1/2} \hat{\sigma}_a .$$

The value of  $n$  could also be thought of as the percentage point for the desired level of confidence using the Normal distribution [Ref. 4]. It can be noted from the definition of  $e_t(l)$  above that the one-step-ahead forecast error,  $e_t(1)$  is simply the value  $a_{t+1}$ ; that is,

$$z_{t+1} - \hat{z}_t(1) = e_t(1) = a_{t+1} .$$

This is an explanation for the use of the term "residual" to refer to the white noise or shock terms. Additionally, from the foregoing it is evident that the forecast error variance is a non-decreasing function of the length of the forecast lead time  $l$ ; therefore, the confidence bands must become wider as the forecast lead time increases.

### III. GENERALIZED ARIMA MODEL PARAMETER ESTIMATION

The purpose of this chapter is to describe the computational details of the algorithm WMARQRDT, employed with appropriate subroutines to estimate Box-Jenkins parameters of a generalized seasonal (or non-seasonal) ARIMA model. This generalized model can be written parsimoniously as follows:

$$\phi(B)\phi(B^S)W_t = \theta_0 + \theta(B)\theta(B^S)a_t,$$

where

$$W_t \text{ is } \nabla^d \nabla_d^D z'_t,$$

and

$z'_t$  is the transformed time series (for example,

$$z'_t = \ln z_t \text{ or } z'_t = \sqrt{z_t} \text{ .}$$

The model employs a Marquardt-type [see Ref. 13] non-linear least squares algorithm for determination of the model parameters, searching in the parameter space for the set of parameters which minimizes the sum of the squared model residuals.

#### A. MATHEMATICAL DISCUSSION OF THE MARQUARDT ALGORITHM

Reference 13 describes Marquardt's methodology for development of a general algorithm for least-squares estimation of nonlinear parameters. Most algorithms for least-squares estimation of nonlinear parameters have been centered about either a pure linear iterative model based on a Taylor series expansion or using some form of the method of steepest descent (maximum negative gradient). Since both methods have severe potential pitfalls (Taylor series due to divergence of the iterates due to an unfortunate choice of initial values, the steepest descent due to slow convergence after the first few iterations), a method termed "Maximum neighborhood" method was developed by Marquardt which, in effect, performs an optimum interpolation between the Taylor series method and the method of steepest descent, the interpolation being based upon the maximum neighborhood in which the truncated Taylor series gives an adequate representation of the nonlinear model.

As discussed in Ref. 14, the idea of Marquardt's method can be briefly explained as follows. Assume the algorithm begins with a vector of initial parameters  $(\phi_0, \phi_0, \theta_0, \theta_0)$ . If the method of steepest descent is applied, a certain vector direction  $h_g$ , where the subscript  $g$  represents the gradient (which gives the direction in which the rate of change is the greatest), is obtained for movement away from the initial point values in the parameter space. Due to potential nonlinearities in the sum-of-squared-residuals

surface,  $S(\phi_0, \phi_0, \theta_0, \theta_0)$ , in the parameter space,  $h_g$  may be the best local direction in which to move toward optimality (minimal sum of squared model residuals), but may not be the best direction. However, the best direction must be within 90 degrees [Ref. 8] of  $h_g$ , or else the value of  $S(\phi, \phi, \theta, \theta)$  will increase locally. Now, the linearization, or Taylor series method, may result in a different correction vector,  $h_t$ . Marquardt found experimentally that for a number of practical problems, the angle, say  $\xi$ , between the vectors  $h_g$  and  $h_t$ , fell in the range 80 degrees  $< \xi < 90$  degrees. In other words, the two directions were nearly normal in most cases. The Marquardt algorithm then, provides a method for interpolation between the vectors  $h_g$  and  $h_t$ , employing a suitable step size, which, in general, converges more quickly than either of the two "parent" methods alone. The remainder of this section describes the mechanics of the algorithm, as applied to the estimation of Box-Jenkins parameters.

#### B. MODEL INPUT INFORMATION

The following is the required input information to the `WMARQRDT` parameter estimation model:

$\{W'_t\}$	the transformed time series (for example, $W'_t = \ln z_t$ , or $W'_t = \sqrt{z_t}$ )
N	the length of the time series
s	the length of the seasonal period (for no seasonality, $s = 1$ )

P	the number of seasonal AR parameters, $P \geq 0$
p	the number of non-seasonal AR parameters, $p \geq 0$
Q	the number of seasonal MA parameters, $Q \geq 0$
q	the number of non-seasonal MA parameters, $q \geq 0$
NDIFNS	the number of non-seasonal differences to be taken
NDIFS	the number of seasonal differences to be taken
$\hat{\phi} = (\hat{\phi}_{1,s}, \dots, \hat{\phi}_{P,s})$	initial estimates of seasonal AR parameters
$\hat{\phi} = (\hat{\phi}_1, \hat{\phi}_2, \dots, \hat{\phi}_p)$	initial estimates of non-seasonal AR parameters
$\hat{\theta} = (\hat{\theta}_{1,s}, \hat{\theta}_{2,s}, \dots, \hat{\theta}_{Q,s})$	initial estimates of seasonal MA parameters
$\hat{\theta} = (\hat{\theta}_1, \hat{\theta}_2, \dots, \hat{\theta}_q)$	initial estimate of non-seasonal MA parameters

### C. ALGORITHM DESCRIPTION

Initially, the model accepts inputs of the time series length and the (transformed, but undifferenced) time series itself from the user's disc, where it is stored in File FT02F001. The remainder of the input data is then entered interactively on the terminal as prompted by the model. The model then forms the initial parameter estimates into vectors of lengths p, P, q, and Q, and employs them to calculate an initial model residual sum of squares.

Prior to initiating the sum of squares calculation process, the model unravels the polynomial of AR and MA operators, and forms a vector of coefficients for both the AR and MA sides of the model. For example, consider the relatively simple  $(2,1) \times (2,1)_{12}$  ARIMA model, written

$$(1 - \phi_1 B - \phi_2 B^2)(1 - \phi_{1,12} B^{12}) W_t = (1 - \theta_1 B - \theta_2 B^2)(1 - \theta_{1,12} B^{12}) a_t.$$

Unraveling, the model becomes first:

$$(1 - \phi_1 B - \phi_2 B^2)(W_t - \phi_{1,12} W_{t-12}) = (1 - \theta_1 B - \theta_2 B^2)(a_t - \theta_{1,12} a_{t-12}),$$

and then takes the form:

$$\begin{aligned} W_t - \phi_{1,12} W_{t-12} - \phi_1 W_{t-1} + \phi_1 \phi_{1,12} W_{t-13} - \phi_2 W_{t-2} + \phi_2 \phi_{1,12} W_{t-14} \\ = z_t^{-\theta_1} \theta_{1,12} a_{t-12} - \theta_1 a_{t-1} + \theta_1 \theta_{1,12} a_{t-13} - \theta_2 a_{t-2} + \theta_2 \theta_{1,12} a_{t-14}. \end{aligned}$$

This is represented in the computer as four vectors: two vectors,  $\pi$  and  $\gamma$ , composed of the expansion AR and MA coefficients respectively, and two vectors composed of the indices of the time series terms associated with the coefficients. For the model in the example above, these vectors would be written as follows:

$$\pi = (1, \phi_{1,12}, \phi_1, (\phi_1)(\phi_{1,12}), \phi_2, (\phi_2)(\phi_{1,12}))$$

$$\text{INDEX}_{\text{AR}} = (0, 12, 1, 13, 2, 14)$$

$$\gamma = (1, \theta_{1,12}, \theta_1, (\theta_1)(\theta_{1,12}), \theta_2, (\theta_2)(\theta_{1,12}))$$

$$\text{INDEX}_{MA} = (0, 12, 1, 13, 2, 14).$$

This format for unraveling of a generalized product of polynomials of seasonal and non-seasonal parameters permits simplified calculations in the determination of the sum of squared residuals, since the arithmetic need only be performed for the non-zero parameter values, those contained in the  $\pi$  and  $\gamma$  vectors. In the actual calculations, performed in FORTRAN, the index vector origin is translated to the right by the amount  $p + Ps + q + Qs$ , called IADDIT in the model, in order to prevent obtaining zero or negative subscripts.

The calculation of the residual sum of squares is a three stage process. First, the model calculates ten values of  $e_t$ , the "forward" white noise terms, using the following relationship:

$$e_t = W_t - \sum_{i=2}^{p+Ps} \pi_i W_{t-i} + \sum_{j=2}^{q+Qs} \gamma_j e_{t+j}$$

The assumption is made that  $(e_{11}, e_{12}, \dots, e_N)$  are all equal to zero. Having found the desired values for  $(e_{10}, e_9, \dots, e_1)$ , we can now backcast the necessary values of  $W_t$ , in order to enable us to calculate the required white noise terms  $a_t$ , as follows:

$$W_t = e_t + \sum_{i=2}^{p+Ps} \pi_i W_{t+i} - \sum_{j=2}^{q+Qs} \gamma_j e_{t+j} ,$$

solving for  $(W_0, W_{-1}, W_{-2}, \dots, W_{1-(p+Ps+q+Qs)})$ . Now, with the  $W_t$ 's backcast, we can proceed to calculate the estimated white noise terms (residuals) using this relationship:

$$a_t = W_t - \sum_{i=2}^{p+Ps} \pi_i W_{t-i} + \sum_{j=2}^{q+Qs} \gamma_j a_{t-j} .$$

The values of  $a_t$  are calculated for  $t = 1, \dots, N$ . Once the  $a_t$ 's are calculated, it is a simple matter to calculate the sum of squares, using

$$S(\phi, \phi, \theta, \theta) = \sum_{t=1}^N a_t^2 .$$

Having calculated the residual sum of squares for the initial parameter estimates, we form the parameters into a vector  $\hat{\beta}$ , such that

$$\hat{\beta} = (\beta_1, \beta_2, \dots, \beta_k) ,$$

where  $k = p+P+q+Q$  ; that is,

$$\hat{\beta} = (\phi_1, \dots, \phi_p, \phi_{1,s}, \dots, \phi_{p,s}, \theta_1, \dots, \theta_q, \theta_{d,s}, \dots, \theta_{Q,s}) .$$

The subroutine PARSH then calculates the derivatives

$$x_{i,t} = - \frac{\partial a_t}{\partial \beta_i},$$

over all values of  $t = 1, \dots, N$  and  $i = 1, \dots, k$ . Using the residuals  $\{a_t\}$  calculated earlier, the derivatives are estimated numerically using a perturbation of each parameter of amount  $\delta$ , such that

$$x_{i,t} = \{a_t(\beta_1, \dots, \beta_k) - a_t(\beta_1, \dots, \beta_i + \delta, \dots, \beta_k)\} / \delta.$$

Then with  $\{a_t\}$  and  $x_{i,t}$  supplied for the current parameter values, the following quantities are formed:

1. The  $k \times k$  matrix  $A = \{A_{ij}\}$ , where

$$A_{ij} = \sum_{t=1}^N (x_{i,t})(x_{j,t})$$

2. the vector  $G = \{g_i\}$ , where

$$g_i = \sum_{t=1}^N (x_{i,t})(a_t)$$

3. the scaling quantities  $D_i = \sqrt{A_{ii}}$ .

Then, the modified (scaled and constrained) linearized equations

$$[A^*] [h^*] = [g^*]$$

are formed, where

$$A_{ij}^* = A_{ij}/D_i D_j, \quad i \neq j,$$

$$A_{ii}^* = A_{ii} + \xi, \quad \xi = .01,$$

and

$$g_i^* = g_i/D_i.$$

It can be noted here that the  $[A_{ij}^*]$  matrix is in fact a correlation matrix for the model parameters. Those equations are then solved for  $h^*$ , which is scaled back to give the parameter correction vector  $h_j$ , where

$$h_j = h_j^*/D_j.$$

Then, the new parameter values are formed from the  $h$  vector, such that

$$\beta_{NEW} = \beta_{OLD} + h,$$

and the sum of squared residuals for the  $\beta_{\text{NEW}}$  set of parameters is calculated.

Now, if  $S(\beta_{\text{NEW}}) < S(\beta_{\text{OLD}})$ , the parameter corrections  $h$  are tested. If all elements of the  $h$  vector are smaller than some epsilon, say .0001, then convergence is assumed and the  $k \times k$  matrix  $[A^*]^{-1}$  is used to calculate the covariance matrix of the estimates; otherwise,  $\beta_{\text{OLD}}$  is reset to  $\beta_{\text{NEW}}$ , the constant  $\xi$  is reduced by a factor  $F$ , say .1, and computation returns to the calculation of a new set of derivatives.

However, if  $S(\beta_{\text{NEW}}) > S(\beta_{\text{OLD}})$ , the constraint parameter  $\xi$  is increased by the factor  $F$ , and computation is returned to the stage where the  $A$  matrix is formed. In all but unusual cases, a minimal sum of squares will be found. However, an upper bound can be placed on  $\xi$ , and when it is exceeded, the search is terminated. When convergence is reached, the desired output information is calculated.

#### D. MODEL OUTPUT AND DIAGNOSTIC CHECKS

The output includes:

1.  $\beta = (\beta_1, \dots, \beta_k)$  the least-squares estimates of

$$\phi_1, \dots, \phi_p$$

$$\phi_1, \dots, \phi_p$$

$$\theta_1, \dots, \theta_q$$

$$\theta_1, \dots, \theta_q$$

2.  $\hat{\sigma}_a^2$  the residual variance,  $\frac{1}{N-p-q-P-Q} S(\hat{\phi}, \hat{\phi}, \hat{\delta}, \hat{\theta})$

3.  $V$  the covariance matrix of the parameter estimates, formed from

$$V = \{V_{ij}\} = (A^T A)^{-1} \hat{\sigma}_a^2$$

4.  $s_i$  the standard errors of the parameter estimates,

$$s_i = \sqrt{V_{ii}}, \quad i = 1, \dots, p+q+P+Q$$

5.  $R_{ij}$  the correlation matrix, obtained from

$$R_{ij} = V_{ij} / \sqrt{V_{ii} V_{jj}}$$

6.  $\hat{\theta}_0$  the overall constant term, where  $\hat{\theta}_0 = \hat{\mu} G$ , for

$$G = (1 - \sum_{i=1}^P \hat{\phi}_i) (1 - \sum_{j=1}^P \hat{\phi}_j) \quad \text{and}$$

$$\hat{\mu} = \frac{1}{N} \sum_{t=1}^N W_t$$

Finally, diagnostic checks on the model are performed. This includes calculation of residual autocorrelations  $r_{aa}^{\hat{\hat{}}}(k)$ , obtained from these formulas:

$$r_{aa}^{\hat{\hat{}}}(k) = c_{aa}^{\hat{\hat{}}}(k) / c_{aa}^{\hat{\hat{}}}(0),$$

where

$$c_{aa}^{\wedge\wedge}(k) = \frac{1}{N} \sum_{t=1}^{N-k} (\hat{a}_t - \bar{a})(\hat{a}_{t+k} - \bar{a}) ,$$

$$\bar{a} = \frac{1}{N} \sum_{t=1}^N a_t ,$$

and  $k$  goes from 1 to the maximum desired lag  $K$ , usually 40. Additionally, a chi-square statistic is calculated from

$$\chi_{(v)}^2 = N \sum_{k=1}^K r_{aa}^{\wedge\wedge}(k) ,$$

and is compared with a chi-square distribution with  $v = K - p - q - P - Q$  degrees of freedom.

Examples of input methodology and appearance of output for this model are contained in later chapters of this paper.

#### IV. DESCRIPTION OF THE TIME SERIES EDITOR

In this chapter, descriptions are given for each of those programs in the Time Series Editor which interact with the user. There are fifteen separate program modules currently included in the Editor; there are other programs utilized by the Editor that are completely transparent to the user, and are not described here. However, listings for all programs contained in the Editor are provided in Appendix D to this report.

No attempt is made in this chapter to describe the actual mathematical calculations or algorithms that are performed by the programs. Rather, the objective is to provide general descriptions of what each program can do for the user, and how the user interacts with the programs. The programs described in this chapter are, in the order presented: TIMESER EXEC, ZFORMAT, CMSWORK, TRANS, DIFF, PLOT, AUTO, ESTIMATE, YESTSEAS, WMARQRT, XSUMSQ, FORECAST, ROOTS, SIMULATE and GENERATE, and HELP.

##### A. THE EXECUTIVE PROGRAM

The heart of the Time Series Editor is a master program called TIMESER EXEC which provides file control for all of the other program modules, controls input and output, supervises the necessary CP/CMS protocol and provides instructions interactively to the user concerning the contents of the

Time Series Editor and how each program can be used.

The TIMESER EXEC program is written in the IBM-360 CP/CMS Executive language. It is the only program in the package not written in FORTRAN; consequently, it should be the only program that would need modification if the Editor were to be adapted to another FORTRAN-capable time-sharing system.

After the user has logged into CP/CMS and linked to the disc space containing the Time Series Editor (instructions for this procedure are provided in detail in the User's Guide to the Time Series Editor, included as Appendix A to this report), the entire Editor package is made available to the user by the command TIMESER. On entry of this comand, the executive routine, TIMESER EXEC, can provide a guided tour through the Editor. It will briefly describe what the Editor can provide and asks the user what option he wants to use. On the basis of the user's response, the Editor then advises the user what input data is required and how it should be entered, either through a data file entered offline or parametric data entered interactively at the terminal. When the user selects an option for execution, the TIMESER EXEC routine loads the appropriate program package and automatically manipulates the required input and output data files. For the more experienced user who does not require detailed user instructions, there is a shortened version of the TIMESER EXEC. Upon entry into the shortened version, the user is immediately asked which

option he desires. This version of the Editor is entered by adding the argument "s" when logging into the Editor; that is, type TIMESER S when logging in. The TIMESER S (shortened) version of the Editor provides exactly the same program options to the user as the longer TIMESER version.

## B. DATA AND FILE MANAGEMENT

Whenever data is required, the user is prompted at the terminal by either the TIMESER EXEC or the program module being executed. In most cases, the necessary user response is a short alphanumeric character input during execution using the terminal keyboard. However, when the time series data itself is entered, the user may enter the data by card deck offline. Similarly, most output is provided right at the user's terminal. Output such as listings of transformed series or plots are sent to the offline printer to conserve time and provide hard copies of the results. Detailed descriptions of the input and output requirements of each program module are provided in this chapter, and also in abbreviated tabular form in Appendix A, the User's Guide. However, there are some general principles of data management that apply to all programs. These are described in this section.

### 1. Offline Data Entry

The Time Series Editor requires that the user's time reside in FILE FT02F001. The data can be read offline

via cards and directed to FILE FT02F001. An example of the required format for the input card deck for the Time Series Editor is provided in Figure 5. It is noted here that the data format expected by all programs is FORMAT(5F15.6), preceded by a card containing the length of the time series in FORMAT(I3).

## 2. ZFORMAT Program

In many cases, the user will want to analyze time series data that are already available in a format other than that required by the Editor. To spare the user the tedious task of retyping his deck in the required format, the ZFORMAT program was written. This program converts a time series data file (FILE FT03001) written in any FORTRAN format into the proper FORMAT(5F15.6) onto FILE FT02F001. The length of the series is entered as an input on the terminal. The data are then ready to use in the Editor, with the original file left in FILE FT03F001. Figure 6 shows a sample input deck for such non-standard data. Figure 7 gives a sample session where ZFORMAT is used.

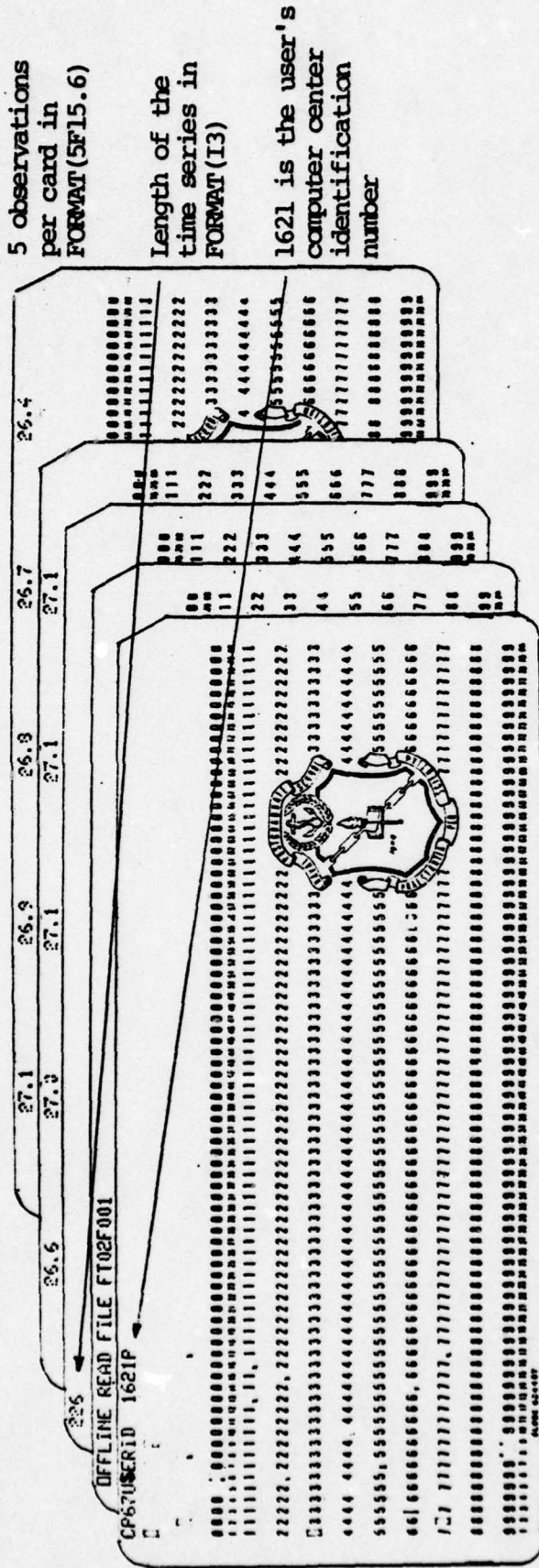


Figure 5. Card deck arrangement for OFFLINE READ of time series input data in FORMAT(5F16.5)



timeser s

ENTER LETTER FOR OPTION YOU WANT.

z

IS YOUR DATA IN FILE FT03F001?

y

EXECUTION BEGINS...

IS YOUR TIME SERIES DATA NOW IN FILE FT03F001?

y

ENTER THE LENGTH OF YOUR TIME SERIES VIA FORMAT I3.

010

NOW ENTER THE FORTRAN FORMAT FOR YOUR TIME SERIES DATA,  
INCLUDING PARENTHESES; FOR EXAMPLE, TYPE: (5F15.7).

f10.2

YOUR FORMAT IS:

FORMATF10.2

IS THIS CORRECT?

n

NOW ENTER THE FORTRAN FORMAT FOR YOUR TIME SERIES DATA,  
INCLUDING PARENTHESES; FOR EXAMPLE, TYPE: (5F15.7).

(f10.2)

YOUR FORMAT IS:

FORMAT(F10.2)

IS THIS CORRECT?

y

YOUR DATA IS NOW TRANSFORMED INTO THE PROPER FORMAT  
FOR USE IN THE TIME SERIES EDITOR, LOCATED IN FILE  
FT02F001. YOUR ORIGINAL DATA IS IN FILE FT03F001.

DO YOU WANT TO GO AGAIN?

n

CONTROL RETURNED TO CMS

R;

Figure 7. Sample user session with ZFORMAT program

### 3. Interactive Keyboard Input

#### a. Numeric Input

When the user is prompted at the terminal to enter such numerical values as the number of AR parameters, estimates of parameters or the number of differences to be taken, he must enter these values before program execution can continue. The user should enter the data according to standard FORTRAN practice. For example, integer data should be entered (without a decimal point) for counts, such as the length of a seasonal period, and for names beginning with the letters I through N; floating-point data, such as initial estimates of parameters, should be entered with a decimal point. Because a typed decimal point overrides a floating-point format, it is not necessary for the user to concern himself with the format for floating-point input data. However, care must be taken when entering integer data because it must be right-justified in its format field. The user is advised in each case when the format is other than I1. For example, suppose the user desires to perform analysis on a series having only 90 observations. If the program that he is executing requires the length of the time series, the user will receive the following request:

ENTER LENGTH OF THE TIME SERIES VIA FORMAT I3

The user would then enter:

column 123

b90 (where b represents a blank space).

If the blank were omitted, the program would read the series length as 900, and problems in execution would occur.

b. Alphabetic Input

The Editor often asks the user to respond with alphabetic input. Generally, this is in the form of the response to a question requiring a yes or no answer, or a response to the question of which program to execute. The editor has been programmed to read only the first letter of such responses. Therefore, the user need only enter the first letter of the response for each such inquiry. For example, the user should enter Y for yes, N for no, P for the PLOT option, X for the XSUMSQ option, W for the WMARQRDT option, etc. The other alphabetic input is generally entry of titles to plots; these can be any combination of numeric and alphabetic characters, as long as they do not exceed 72 columns in length. For example, a suitable title would be:

PLOT OF AUTOS AND PAUTOS FOR SERIES C DATA (2 ORDINARY DIFFERENCES).

4. Output

Most of the results are written out at the user's terminal. However, in some cases the output is printed

offline to conserve time. Such results as plots and transformed time series are written onto various files (FT03F001, FT09F001, FT08F001), and the TIMESER EXEC program causes them to be automatically printed offline under the user's identification number (USERID). The plots and files can also be printed out at the terminal using the usual CMS commands in the CMS mode, outside the Editor, or in the CMSWORK program (see next section). However, the user should be aware that plotting graphs at the terminal is generally quite a slow process.

#### 5. CMSWORK Program

This program permits the user to enter the CMS environment to perform routine CMS functions without leaving the Time Series Editor. Commonly used CMS commands include file name alteration, file erasure, file offline printing or punching, obtaining a disc status, and listing all disc-resident files. However, essentially all CMS commands can be issued while in CMSWORK. Figure 8 provides an example of the use of the CMSWORK program.

#### C. TRANS PROGRAM

The TRANS program takes a given time series in File F102F001 and performs a transformation upon each data element. The options include a change of scale, a power transformation, a shift of the origin, and a natural logarithm transformation. The original data is written onto a file

timeser s

ENTER LETTER FOR OPTION YOU WANT.

C

ENTER DESIRED CP/CMS COMMANDS, ONE PER LINE.

WHEN FINISHED TYPE: &GOTO -QUES

stat

P (191): 30 FILES; 263 REC IN USE, 33 LEFT (of 296), 89% FULL (2 CYL)

listf \* ft02f002

FILE NOT FOUND

17.14.13 LISTF \* FT02F002

!!! E(00002) !!!

listf \* ft02f001

FILENAME FILETYPE MODE NO.REC. DATE

SERG FT02F001 P1 3 9/16

SERC FT02F001 P1 5 9/16

LNSERG FT02F001 P1 3 9/16

FILE FT02F001 P1 3 9/16

cp q f

FILES:- NO RDR, NO PRT, NO PUN

erase file ft08f001

offline print file ft02f001

offline print serg ft02f001

offline print serc ft02f001

erase file ft02f001

stat

P (191): 28 FILES; 240 REC IN USE, 56 LEFT (of 296), 81% FULL (2 CYL)

&goto -ques

DO YOU WANT TO GO AGAIN?

n

CONTROL RETURNED TO CMS

R;

Figure 8. Sample user session with CMSWORK program

called DATA FT02F001, while the transformed series is written onto FILE FT02F001. The parameters of the transform itself are written onto FILE FT07F001. The TRANS program is self-contained, using no other programs.

#### D. DIFF PROGRAM

The DIFF program takes a given time series in FILE FT02F001, and performs non-seasonal and/or seasonal differencing operations on the series in order to help achieve stationarity for proper modeling. The user must indicate if seasonal differences are required; if so, the length of the season is input. The user is then required to enter the number of seasonal and nonseasonal differences. After execution of DIFF, the original data are in FILE FT02F001, and the differenced data are written onto FILE FT03F001. To use the differenced data in any other program, CMSWORK program must be entered and the files altered to save the original data (if desired) and to transfer the differenced data to FILE FT02F001. The CMS commands to perform this shift of files would look like:

```
ALTER FILE FT02F001 P1.SAVEDATA FT02F001 P1
R;
ALTER FILE FT03F001 P1 FILE FT02F001 P1
R;
```

The DIFF program uses the IMSL subroutine called FTRDIF.

#### E. PLOT PROGRAM

The PLOT program plots any given time series which resides in FILE FT02F001. Other than the time series, which must be on the user's disc or entered offline, the program requires only that an identification title for the plot itself be entered during execution. The plot is automatically printed offline. The PLOT program uses a modified PLOTP subroutine called PLOT8 from the IBM Scientific Subroutine Package Library (SSPLIB).

#### F. AUTO PROGRAM

The AUTO program takes a given time series in FILE FT02F001 and calculates summary statistics of utility in Box-Jenkins modeling. The statistics include the sample mean, variance, autocorrelations and partial autocorrelations for lags one through 40. Part of those statistics are printed out at the user's terminal, while plots of the autocorrelations and partial autocorrelations versus lag are printed offline. These plots will also be written onto the user's disc in FILE FT08F001, and may be plotted at the terminal in CMS outside the Editor or in the CMSWORK program; recall that this is a time-consuming process. The AUTO program provides the user with essential information about stationarity, seasonality and model identification. With the Box-Jenkins procedures, the second moments (autocorrelations and partial autocorrelations) are valuable tools in tentative model identification. Additionally, AUTO

is useful in the diagnostic checkout phase of model building, when examining the model residuals for structure. The AUTO program uses the IMSL subroutine FTAUTO.

#### G. ESTIMATE PROGRAM

After the user has tentatively identified a model for a series through analysis of the series plot, autocorrelations and partial autocorrelations, ESTIMATE should be executed to calculate maximum likelihood estimates of the model parameters. ESTIMATE is written to calculate parameters for non-seasonal models only; for seasonal models, the programs YESTSEAS and WMARQRDT should be used for parameter estimation. The ESTIMATE program requires that the series to be modeled (already transformed and differenced to achieve stationarity) reside in FILE FT02F001; additionally, the program will instruct the user to input the number of MA and AR parameters in the model, as well as the number of differences taken. The general model for which ESTIMATE calculates parameters is:

$$\phi(B) W'_t = \theta_0 + \theta(B) a_t$$

where  $W'_t = \nabla^d z'_t$  and  $z'_t$  is the transformed value of  $z_t$ .

ESTIMATE calculates estimates of the AR parameters for the undifferenced form of the model, the estimated MA parameters and MA constant term, the residual variance, autocorrelations and partial autocorrelations of the residuals, plots of

these autocorrelations and partial autocorrelations, and a Chi-square goodness-of-fit statistic for the model. The original series to be modeled remains in FILE FT02F001 and the residuals of the model are stored in FILE FT02F001. ESTIMATE uses the IMSL subroutine FTMAXL (a nonlinear gradient search algorithm) to estimate the model parameters.

#### H. YESTSEAS PROGRAM

The YESTSEAS program is used to calculate initial estimates of autoregressive and moving average parameters for a generalized seasonal Box-Jenkins model. These initial estimates are used as inputs to the program WMARQRTD, which then refines them to determine the parameter estimates that minimize the sum of the squared residuals. The general model assumed in YESTSEAS is

$$\phi(B) \phi(B^S) \nabla^d \nabla_s^D z_t = \theta(B) \theta(B^S) a_t .$$

The YESTSEAS program requires that the seasonal time series for which initial parameter estimates are required is located in FILE FT02F001; it should be transformed, if desired, but generally not differenced, since YESTSEAS performs the required (seasonal and/or non-seasonal) differencing.

Terminal inputs required by the program include the number of seasonal and non-seasonal differences to be taken (if data is already differenced, enter zero for these values), the length of the seasonal period and the number of each

type of parameter to be estimated (that is, the number of each of the seasonal and non-seasonal AR and MA parameters). The output of the model, initial estimates for the requested parameters, is printed out at the terminal. YESTSEAS uses the IMSL subroutines FTRDIF, FTMAXL, FTAUTO and FTARPS, as well as a modified version of FTMAPS.

#### I. WMARQRDT PROGRAM

The WMARQRDT program uses the initial parameter estimates calculated by YESTSEAS or other means as starting points for calculation of parameters of a generalized seasonal Box-Jenkins model which minimize the sum of the squared residuals. The general seasonal model assumed by WMARQRDT can be written:

$$\phi(B)\phi(B^S)\nabla^d\nabla_S^D z_t = \theta_0 + \theta(B)\theta(B^S)a_t.$$

Details of the Marquardt-type non-linear least squares algorithm employed in this program are provided in Chapter III of this report. WMARQRDT requires that the series to be modeled reside in FILE FT02F001; it should be transformed, if desired, but generally not yet differenced, since the program performs differencing. Inputs at the terminal include number of seasonal and non-seasonal differences, length of the seasonal period, number and type of parameters desired, and initial estimates of those parameters. The program then calculates the least-squares parameter estimates,

the standard error of these estimates, the MA constant term, the residual variance, the autocorrelations and partial autocorrelations of the residuals, the final model sum of squared residuals and a Chi-square goodness-of-fit statistic (the portmanteau test). Additionally, it plots offline the autocorrelations and partial autocorrelations of the residuals. WMARQRT uses the IMSL subroutines FTRDIF, FTAUTO, LINVLF and MDCDFI, the SSPLIB routine PLOT8, and the Time Series Editor resident subroutines PARSH, MARQRT, SUMSQ, SWAPB and FORMB. The calculations are performed in double-precision arithmetic.

#### J. XSUMSQ PROGRAM

The XSUMSQ program accepts an already transformed and differenced series in FILE FT02F001 and general seasonal and non-seasonal Box-Jenkins parameter values for a general seasonal model from the terminal. The program then calculates the residual sum of squares for these parameters, giving the user a feel for the "goodness-of-fit" the parameter estimates provide in modeling the given time series. XSUMSQ uses the Time Series Editor resident subprogram XSUMSQ. All output is printed at the terminal. The calculations are performed in double-precision arithmetic.

#### K. FORECAST PROGRAM

The FORECAST program uses the estimated Box-Jenkins (seasonal or non-seasonal) model to compute forecasts of

the transformed and differenced time series. FORECAST requires that the time series to be forecasted reside in FILE FT02F001 in transformed form. During execution the input required at the terminal includes the forecast origin, the numbers and estimated values of the AR and MA parameters of the model, the overall MA constant, the plot origin index, the maximum forecast lead time, the order of differencing in the model, and a level of significance for the forecast confidence limits. The program needs the transformation parameters from FILE FT07F001, created when using program TRANS, and performs the inverse transform to return the data to its original form. FORECAST also undifferences differenced data. The program output includes the forecasts up to the given maximum lead time, the deviations from each forecast for the confidence limits, and plots of forecasts and confidence limits plotted offline. The FORECAST program uses IMSL subroutine FTCAST and the special IBM SSPLIB subroutine UTPLT8. The plot itself and output data are written onto FILE FT08F001 on the user's disc; since this plot file takes considerable space, it is usually best to erase it after execution of the program is completed and the plot itself has been printed offline.

#### L. ROOTS PROGRAM

The ROOTS program is used to determine the roots of the characteristic equation for a general ARIMA model. The roots are useful for testing for stationarity and for

determining the form of the forecast function. ROOTS uses the IMSL subroutine ZPOLR to calculate the roots; it requires as input the number of AR parameters in undifferenced form,<sup>1</sup> and the actual values of these parameters, as determined from the ESTIMATE or WMARQRDT programs. The roots are printed out at the terminal. If desired, roots can also be obtained for the MA polynomial, simply by substituting the appropriate MA values for the AR values as input.

#### M. GENERATE AND SIMULATE PROGRAMS

Because of their similarities, the GENERATE and SIMULATE programs are described together. The GENERATE program permits the user to generate a time series from any non-seasonal ARIMA model he specifies. The user must identify the model and give values for the model parameters and starting conditions; a random number seed must also be input. The program takes the specified model, generates random noise terms, and calculates as many values of the time series as desired. The GENERATE program can be useful for purposes of classroom instruction in the generation of a wide variety of time series examples for model identification exercises.

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<sup>1</sup>Suppose the model was ARIMA(1,1,0). The differenced form would be  $(1-\phi_1 B)\nabla^1 z_t = \theta_0 + a_t$ . Then, the undifferenced form would be written  $(1-(1+\phi_1)B + \phi_1 B^2)z_t = \theta_0 + a_t$ , where the left-hand side was found by multiplying  $(1-\phi_1 B)$  by  $(1-B) = \nabla^1$ .

It could also be useful in the diagnostic phase of model checkout; a time series could be generated from the estimated model, and its properties compared with those of the original series. If large discrepancies occur in this comparison, this may be evidence that the model is inadequate. The model output, the generated time series, is written in FILE FT02F001 as well as being printed offline. The GENERATE program uses IMSL subroutine FTGEN1.

The SIMULATE program provides the capability of generating any number of simulated time series. This program is useful for prediction of what might happen in the future; it also demonstrates that within a given model, the time series actually observed can vary considerably. This program uses GENERATE, but also requires as input the actual series in FILE FT02F001<sup>1</sup> and the number of simulated series the user wishes to generate. The series should be already transformed and differenced. Additionally, SIMULATE allows the user to select values of the original time series as starting values for the simulated series. The output consists of the simulated series printed at the terminal. The SIMULATE program uses IMSL subroutine FTGEN1.

#### N. HELP OPTION

The HELP option is a modification to the Time Series Editor CP/CMS program itself that allows the user to obtain

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<sup>1</sup>If desired, the user may choose to input his own starting values, and not use the actual time series values.

information about Editor programs after the initial introductory phase has been completed.

#### O. SUMMARY

This chapter has provided brief descriptions of the options available for analysis of time series data in the Time Series Editor. The following two chapters contain detailed examples of time series analysis for both a non-seasonal and a seasonal series; the accompanying terminal sessions and computer output for analysis of these series are contained in full in Appendices B and C. Appendix A to this report contains a User's Guide for the Time Series Editor, while Appendix D contains a complete listing of the Time Series Editor and resident programs. Appendix E contains listings of the data sets used in the analyses of the next two chapters.

## V. EXAMPLE NON-SEASONAL TIME SERIES ANALYSIS

This chapter provides a description of a complete analysis of a non-seasonal time series using the Time Series Editor. The time series analyzed is Series C (Chemical Process Temperature Readings), taken from Box and Jenkins [Ref. 4, p. 528]. This time series was selected since it is fully analyzed and discussed in Reference 4, so that the interested user can compare for himself the results presented there with the results given by the Time Series Editor. After reading this overview of the analysis, the reader can follow the actual user session and associated user session Editor program output contained in Appendix B to this report.

The first step in the analysis of series C is to plot the series using program PLOT. The plot reveals rather wide fluctuations in the series, but not the sort of explosive nonstationary behavior that would render an attempt to model fruitless. The plot also reveals that the time series has a large amount of momentum (movements of the series tend to resist changes of direction over time). This is characteristic of ARIMA models with two or more differences.

As a second step, the autocorrelations (autos) and partial autocorrelations (pautos), mean, and variance of the series were estimated using AUTO. The plot shows that the autos dampen out slowly in a nearly linear fashion.

This is an indication that the process is nonstationary and that one or more differences are required to make it stationary. The pauto plot is not informative when the autos fail to dampen out rapidly.

As suggested by the plots of the original series and its auto and pautos, the program DIFF was used to examine the series with both one and two non-seasonal differences; i.e., the series  $z'_t = \nabla^1 z_t$  and  $z''_t = \nabla^2 z_t$  were derived. The plots suggest that two differences might be required to achieve stationarity in the series. However, one might be able to get by with a single difference and an AR parameter near unity, since the autos of  $z'_t$  dampen out slowly. Thus, two possible model candidates are suggested:

1. ARIMA(1,1,0):  $(1 - \phi_1 B) \nabla^1 z_t = \theta_0 + a_t$ ,

and

2. ARIMA(0,2,2):  $\nabla^2 z_t = \theta_0 + (1 - \theta_1 B - \theta_2 B^2) a_t$ .

For purposes of estimation, the second model was extended to two moving average parameters. Such overfitting is often done to see if the estimated moving average parameters turn out to be near zero, thus confirming the tentative identification.

The next step in the analysis process is to calculate the maximum likelihood estimates of the model parameters.

The program ESTIMATE was used to do this. The estimated parameters for the ARIMA(1,1,0) model were:

$$\begin{aligned}\hat{\phi}_1 &= 0.8073 \\ \hat{\theta}_0 &= -0.006789 \\ \hat{\sigma}_a^2 &= 0.0177633\end{aligned}$$

The autos and pautos of the residuals were calculated to test the model. The correlations should appear to be estimates of a pure white noise process if the model is adequate; the (1,1,0) model seemed to pass that test. The chi-square goodness-of-fit test results in a  $\chi^2 = 28.88$  with 24 df and a significance level of 0.2247. Thus, there is no strong evidence to suggest that the (1,1,0) model is inadequate. The model can be written, in undifferenced form:

$$(1 - 1.8073B + 0.8073B^2)z_t = a_t .$$

The  $\theta_0$  is omitted here since it is nearly zero in value.

The estimated parameters for the (0,2,2) model were

$$\begin{aligned}\hat{\theta}_1 &= 0.1378 \\ \hat{\theta}_2 &= 0.1296 \\ \hat{\theta}_0 &= -0.0026787 \\ \hat{\sigma}_a^2 &= 0.0189559\end{aligned}$$

As before, the correlation plots of the residuals fail to suggest any inadequacy of the model. However, the chi-square goodness-of-fit test for this model yielded a  $\chi^2 = 36.75$  with 23 df and a significance level of 0.0346. Therefore,

if the ARIMA(0,2,2) model were a "correct" one, a chi-square value as large as 36.75 would occur by chance with a probability of only 0.0346. Due to its simplicity (parsimony is a desirable feature in time series models) and better fit, the ARIMA(1,1,0) model was chosen as the "best" of the two alternatives originally selected.

The ARIMA(1,1,0) model calculated was then used to make forecasts and confidence limits for these forecasts, using program FORECAST. The forecasts were made for 25 periods into the future, with plot origin 200 and forecast origin 220. The length of the series C itself is 226; with one difference, it becomes 225. The plot in Appendix B shows the forecasted values, along with the confidence limits at level of significance 0.10; the plot shows that the width of the confidence limits increases substantially as the lag gets large.

Finally the program ROOTS was used to calculate the roots of the characteristic equation for the ARIMA(1,1,0) model, which can be written:

$$1 - 1.8073B - 0.8073B^2 = 0$$

The roots calculated by ROOTS were 1.239 and 1.0. Also, the program SIMULATE was used to generate a simulated series from the ARIMA(1,1,0) model, using the last two values of the actual series as starting values. The entire session lasted about two hours, including checkout of plots and consumed less than a minute of CPU time.

## VI. EXAMPLE SEASONAL TIME SERIES ANALYSIS

This chapter provides a description of a complete analysis of a seasonal time series using the Box-Jenkins technique through the Time Series Editor. The time series analyzed is Series G (International Airline Passengers: Monthly Totals (Thousands of Passengers) January 1949 - December 1960), taken from Box and Jenkins [Ref. 4, p. 531]. This time series was selected since it was fully analyzed and discussed in Chapter 9 of Reference 4; again, the interested reader can compare for himself the results presented by Box and Jenkins with those given by the Time Series Editor programs. After reading this overview of the analysis, the reader can follow the actual user session and associated Editor program output contained in Appendix C to this report.

The plot shows both annual seasonality and an increasing trend. This suggests that a seasonal model with differencing may be needed. The autocorrelations (autos) and partial autocorrelations (pautos) were then calculated and plotted using AUTO. The plot of the autos shows very slow damping out with peaks at intervals of 12, indicating strong non-stationarity and a seasonal period of 12 months. Again, here the pauto plot is not informative, due to the slow damping out of the autos. As it is sometimes useful in dealing with seasonal models, a natural log transform was

made on the series G data using program TRANS. The plot of the logged data shows little change in non-stationarity, and the autos and pautos of the logged data still indicate seasonality and non-stationarity.

Next, differencing to achieve stationarity was tried, using program DIFF; both one seasonal and one non-seasonal difference of the logged data was taken. The autos and pautos of the data  $\nabla^1 \nabla_{12}^1 (\ln z_t)$  appear much improved, rapidly damping out. They also exhibit sharp peaks at the periods of seasonality, indicating the need for seasonal parameterization in the model. Since positive identification of the model type from the auto and pauto plots was not possible, two were postulated as close candidates:

1. ARIMA (0,1,1) x (0,1,1)<sup>12</sup>, written:

$$\nabla^1 \nabla_{12}^1 (\ln z_t) = \theta_0 + (1-\theta_1 B)(1-\theta_{1,12} B^{12}) a_t,$$

and

2. ARIMA (1,1,1) x (0,1,1)<sup>12</sup>, written:

$$(1-\theta_1 B) \nabla^1 \nabla_{12}^1 (\ln z_t) = \theta_0 + (1-\theta_1 B)(1-\theta_{1,12} B^{12}) a_t.$$

The next step in the analysis was to calculate the parameter estimates for both models. YESTSEAS was used to

obtain initial parameter estimates. For the model  
ARIMA (0,1,1) x (0,1,1)<sup>12</sup>, YESTSEAS yielded starting values:

$$\hat{\theta}_{1(s)} = 0.390425$$

$$\hat{\theta}_{1,12(s)} = 0.534397 .$$

For this model, calculation of final parameter estimates  
in WMARQRDT using the starting values above yielded the  
following in seven iterations:

$$\hat{\theta}_1 = 0.377152$$

$$\hat{\theta}_{1,12} = 0.572387$$

$$\hat{\theta}_0 = 0.000291 ;$$

the chi-square statistic for residual lack of fit of the  
model was  $\chi^2 = 29.713571$ , with  $df = 38$  and a probability  
of exceeding the  $\chi^2$  value of .829.

For the ARIMA (1,1,1) x (0,1,1)<sup>12</sup> model YESTSEAS calcu-  
lated starting values:

$$\hat{\phi}_{1(s)} = 0.112699$$

$$\hat{\theta}_1(s) = 0.490883$$

$$\hat{\theta}_{1,12(s)} = 0.533679 ;$$

for this model, WMARQRTD yielded the following parameter values in ten iterations:

$$\hat{\phi}_1 = 0.146667$$

$$\hat{\theta}_1 = 0.509816$$

$$\hat{\theta}_{1,12} = 0.573388 .$$

The chi-square statistic for residual lack of fit of the model was  $\chi^2 = 28.302543$ , with  $df = 37$  and a probability of exceeding the  $\chi^2$  value of :847.

Next, the plots of autos and pautos of the residual for both models were examined; both models have autos and pautos that dampen out rapidly, and essentially appear to be "white noise", with the exception of a small peak at auto and pauto of lag 12, corresponding to the seasonal period. The chi-square statistics indicate that both models have "about" the same goodness of fit to the data. Consequently, both models were used to make forecasts of the series.

Program FORECAST was used to forecast series G into the future for 30 time periods, with a forecast origin of 131; the plot origin selected was index 100. As expected, both models do about the same job of forecasting the series.

The significance level for the confidence limits for both plots was 90%.

As a final check of both models, the program XSUMSQ was used to calculate the sum of squared residuals for models. The results were as follows:

1. For ARIMA (0,1,1) x (0,1,1)<sup>12</sup>,

$$s^2(\hat{\theta}_0, \hat{\theta}_1, \hat{\theta}_{1,12}, \hat{\sigma}_a^2) = 0.181929$$

2. For ARIMA (1,1,1) x (0,1,1)<sup>12</sup>,

$$s^2(\hat{\phi}_1, \hat{\theta}_0, \hat{\theta}_1, \hat{\theta}_{1,12}, \hat{\sigma}_a^2) = 0.181643 .$$

It can be seen here that both models are nearly equally "good", and either could be used with a reasonable amount of confidence for forecasting series G.

## VII. SUMMARY

There has been an increasing need in military applications, as well as in the general business area, for a computer-aided time series analysis and forecasting capability that is both powerful and easy to use. Current military-associated functions in which time series techniques are valuable include material inventory management, recruiting, personnel management, budget analysis, force level projections, and perhaps even short-term weather prediction.

The Time Series Editor that has been described in this report provides a unified collection of programs that greatly facilitate the conduct of a complete time series analysis and forecasting evolution using Box-Jenkins methodology. The routines guide the user from the data input stage, through the data analysis and parameter estimation stages, and finally through the model building, diagnostic checking and forecasting stages. With its simple input requirements, the Editor can be quickly mastered by even a beginning computer user, who has a basic understanding of Box-Jenkins methodology.

The Box-Jenkins methodology has been described broadly in Chapter II and descriptions of the programs resident in the Time Series Editor have been given in Chapter IV. Example analyses of both non-seasonal and seasonal time series are provided in Chapters V and VI, with complete

user sessions and output packages for these analyses included as Appendices B and C. The Appendices also contain a Time Series Editor User's Guide, as well as complete program listings.

Although the Time Series Editor in its present form provides an excellent capability for interactive time series analysis using the Box-Jenkins methodology, there are additions to the program set that might be made in the future which would improve the Editor's capability and utility. It is first recommended that the model diagnostic testing capability be extended to include a periodogram analysis, and/or other tests related to the spectral analysis of time series [see Ref. 4, p. 294]. Another useful addition might be to include in the Time Series Editor a package capable of improving the ease of entering data and simplifying the input error correction problem.

## APPENDIX A

### USER'S GUIDE TO THE TIME SERIES EDITOR

The Time Series Editor is a collection of FORTRAN programs driven by a control program called TIMESER EXEC in the CP/CMS executive language that has been designed specifically for the analysis and forecasting of time series data using the general Box-Jenkins methodology. This Guide contains information essential for the user to access the Time Series Editor, enter time series data, build a model and obtain the desired output.

#### I. DATA INPUT

The Time Series Editor requires that time series data be entered into the sequential FORTRAN input/output file named FILE FT02F001. This can be done either online or via cards read offline. The following diagram illustrates the proper card deck arrangement. When your deck is ready for input, give it to a computer center system operator to direct it to your disc space.

If the user has a data deck already punched up in a format other than 5F15.6, he may enter the series as above into FILE FT03F001 (without the length of series card) and use the Editor program ZFORMAT to transform it into the FILE FT02F001 in the proper format, without destroying his original file. This program is described in the next section.

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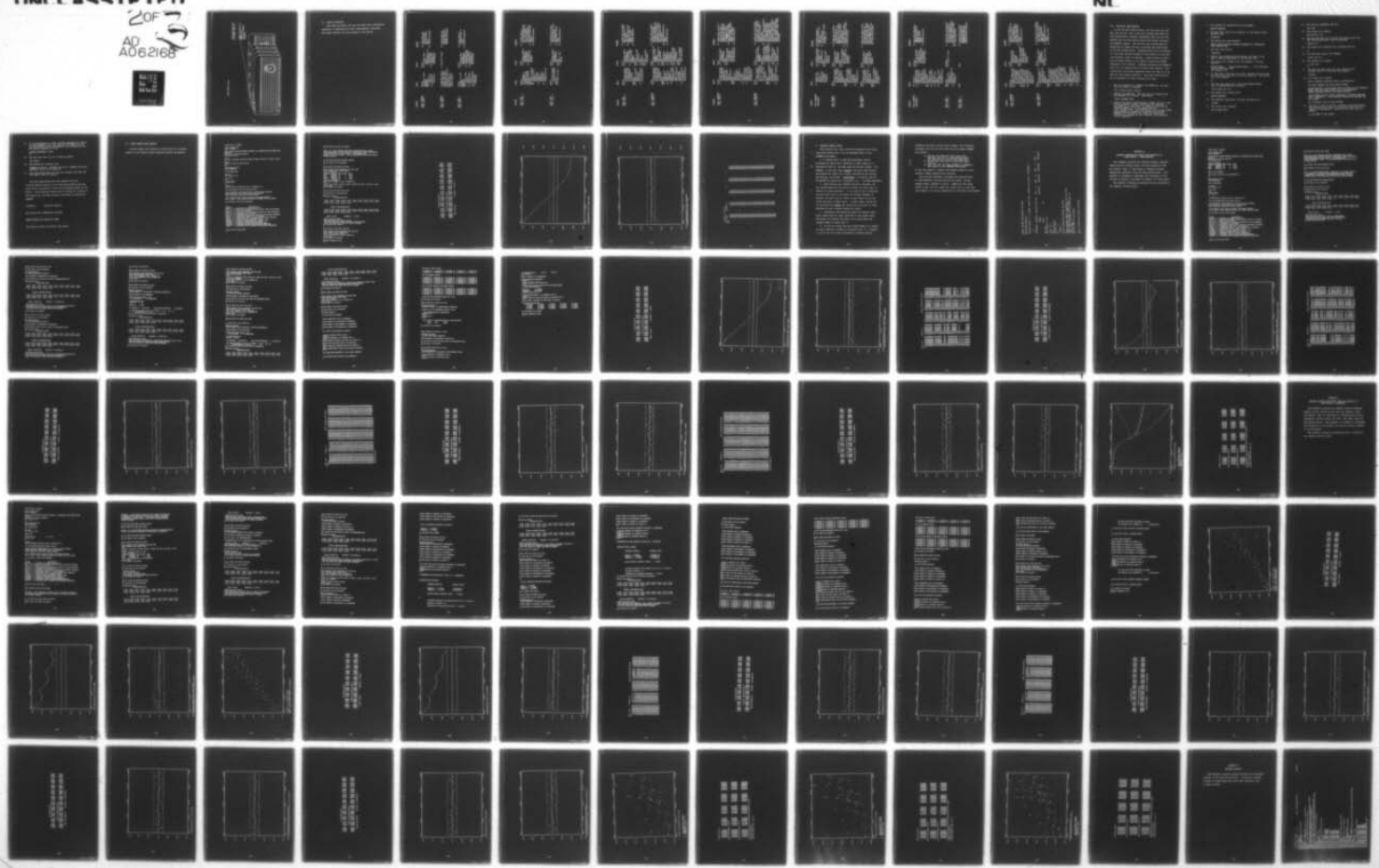
NAVAL POSTGRADUATE SCHOOL MONTEREY CALIF  
AN INTERACTIVE SOFTWARE PACKAGE FOR TIME SERIES ANALYSIS. (U)  
SEP 78 S R WOODALL

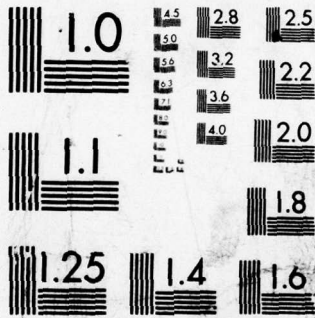
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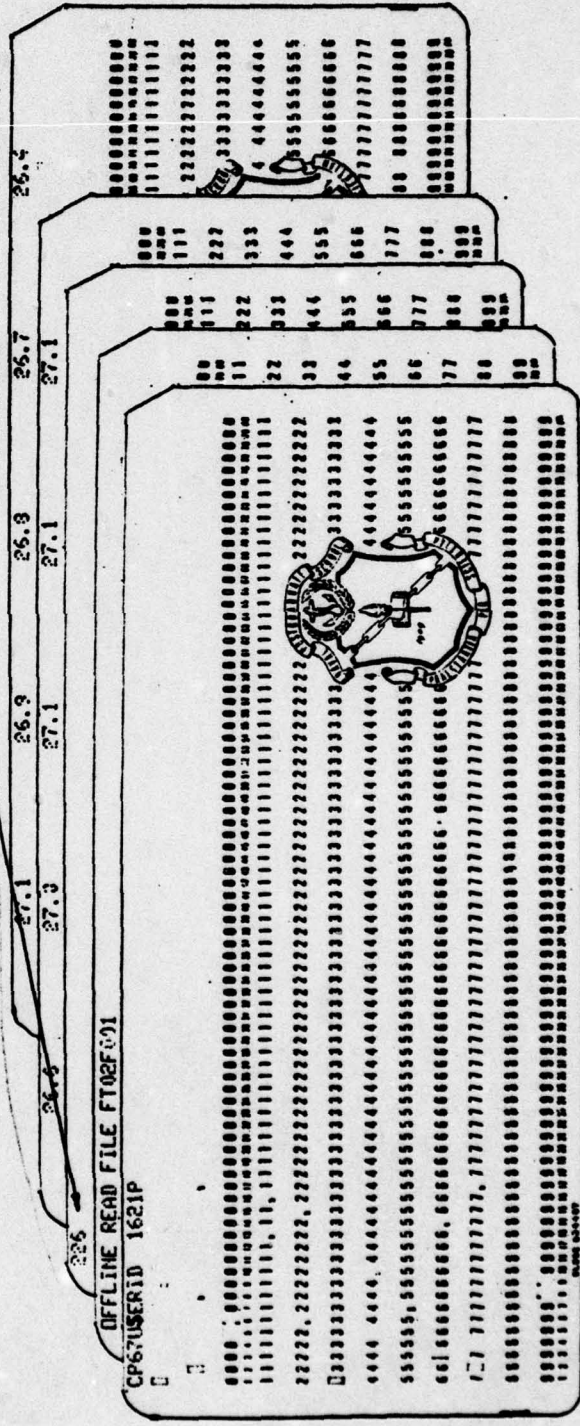


MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS-1963-A

DATA ENTRY DECK

time saver data deck  
in FORMAT (5F15.6)

length of series in  
FORMAT (I3)  
(omit for ZFORMAT  
program)



## II. TABLE OF OPTIONS

This Table provides the user with the basic information necessary to understand the data requirements, functions and output options for each program in the Editor.

PROGRAM	INPUT	OUTPUT	REMARKS
Name: ZFORMAT Entry Code: z	Files: (1) data in FILE FT03F001 Keyboard: (1) length of time series (2) format of time series	Files: (1) original data put in FORMAT(5F15.6) in FILE FT02F001 (2) original data unchanged in FILE FT03F001	(1) puts date into proper format for Time Series Editor (2) single precision
Name: CMSWORK Entry Code: C	no specific input; normal usage would include file name alteration, obtaining disc status, or erasing files no longer required	no specific output	(1) allows users to perform CMS admin actions while in TIMESER environment
Name: TRANS Entry Code: T	Files: (1) data in FILE FT02F001 Keyboard: (1) origin transformation? (2) scale change factor? (3) log transform? (4) power/root transform?	Files: (1) original data unchanged in DATA FT02F001 (2) transformed data in FILE FT02F001 (3) transformation parameters in FILE FT07F001	(1) allows user to transform data in a file (2) single precision

PROGRAM	INPUT	OUTPUT	REMARKS
Name: DIFF Entry Code: D	Files: (1) original (transformed if desired) series in FILE FT02F001 Keyboard: (1) series seasonal? (2) number of non- seasonal differences (3) number of seasonal differences (4) length of seasonal period	Files: (1) original series unchanged in FILE FT02F001 (2) differenced series in FILE FT03F001	(1) allows user to perform differencing of a time series, in order to achieve series stationarity (2) uses IMSL subroutine FT0DIF (3) single precision
Name: PLOT Entry Code: P	Files: (1) original series in FILE FT02F001 Keyboard: (1) title for plot	Files: (1) original series unchanged in FILE FT02F001 Offline: (1) plot of time series	(1) allows user to plot any time series using offline printer (2) uses SSPLIB routine PLOT8 (3) single precision

PROGRAM	INPUT	OUTPUT	REMARKS
Name: AUTO Entry Code: A	<p>Files:</p> <p>(1) original series in FILE FT02F001 transformed and/or differenced if desired</p> <p>Keyboard:</p> <p>(1) number of autos/pautos to be calculated</p> <p>(2) title for plots of autos/pautos</p>	<p>Files:</p> <p>(1) original series unchanged in FILE FT02F001</p> <p>(2) plots of autos/pautos in FILE FT08F001</p> <p>Terminal:</p> <p>(1) values of autos and pautos</p> <p>(2) mean</p> <p>(3) variance</p> <p>Offline:</p> <p>(1) plots of autos and pautos</p>	<p>(1) allows user to obtain basic statistics for time series</p> <p>(2) uses IMSL subroutine FTAUTO, as well as UTPLT8 routine</p> <p>(3) single precision</p>
Name: ESTIMATE Entry Code: E	<p>Files:</p> <p>(1) original series in FILE FT02F001; transformed and/or differenced as desired.</p> <p>Keyboard:</p> <p>(1) number of AR parameters</p> <p>(2) number of MA parameters</p> <p>(3) number of (non-seasonal) differences to be taken, if series not already differenced</p> <p>(4) titles for plots of residual autos and pautos</p>	<p>Files:</p> <p>(1) original series unchanged in FILE FT02F001</p> <p>(2) model residuals in FILE FT02F001</p> <p>Terminal:</p> <p>(1) estimated AR parameters</p> <p>(2) estimated MA parameters</p> <p>(3) MA constant</p> <p>(4) residual variance</p> <p>(5) portmanteau test of residuals</p> <p>Offline:</p> <p>(1) plots of residual autos and pautos</p>	<p>(1) allows user to obtain maximum likelihood parameter estimates for a general non-seasonal ARIMA model, as well as data concerning model sufficiency</p> <p>(2) uses IMSL subroutine FIMAXL</p> <p>(3) single precision</p>

PROGRAM	INPUT	OUTPUT	REMARKS
Name: YESTSEAS Entry Code: Y	Files: (1) original series in FILE FT02F001 transformed if desired; and either differenced or undifferenced Keyboard: (1) number of seasonal and non-seasonal differences to be taken (2) length of seasonal period (3) numbers of both seasonal and non-seasonal AR and MA parameters	Files: (1) original series unchanged in FILE FT02F001 Terminal: (1) estimated values for requested seasonal and non-seasonal AR and MA parameters	(1) allows user to calculate initial non-seasonal and seasonal ARIMA model parameter estimates as input to WVARQRT routine (2) uses IMSL subroutines FTXDIF, FTMAXL, FTAUTO, FTARPS and FTMAPS (3) single precision
Name: WVARQRT Entry Code: W	Files: (1) original series in FILE FT02F001; may be transformed but not differenced (either diff or nondiff) Keyboard: (1) number of seasonal and non-seasonal differences to be taken (2) length of seasonal period	Files: (1) original series unchanged in FILE FT02F001 Terminal: (1) seasonal and non-seasonal AR and MA parameter estimates (2) parameter standard errors (3) MA constant term (4) sum of squared residuals (5) residual variance	(1) allows user to estimate non-linear least squares parameters for a general seasonal Box-Jenkins ARIMA model (2) requires initial parameter estimates, obtainable using YESTSEAS program (3) uses IMSL subroutines FTXDIF, FTAUTO, LINVIF, and MCDIFI, SSPLIB routine DPLOIP, and Time Series Editor resident subroutine PARSH, MARQRT, SUMSQ, SWAPB and FORMB

PROGRAM	INPUT	OUTPUT	REMARKS
Name: WVARQDRT (CONTINUED)	(3) number and initial estimates of seasonal and non-seasonal AR and MA parameters	(6) residual variance (7) portmanteau test for model goodness-of-fit Offline: (1) plots of autos/pautos of residuals	(4) double precision (5) requires LOGIN with 450k core (6) if non-seasonal modeling, input length of season = 1
Name: XSUMSQ Entry Code: X	Files: (1) original series in FILE FT02F001; should be transformed and/or differenced as desired Keyboard: (1) number and estimates of seasonal and non-seasonal AR and MA parameters (2) length of seasonal period	Files: (1) original series unchanged in FILE FT02F001 Terminal: (1) value of residual sum of squares for the model and parameters specified	(1) allows user to obtain a residual sum of squares value for any seasonal or non-seasonal ARIMA model with specified parameters (2) uses Time Series Editor resident subroutine SUMSQ (3) double precision
Name: FORECAST Entry Code: F	Files: (1) original series in FILE FT02F001; transformed as desired, but not differenced Keyboard: (1) number of seasonal and non-seasonal differences to be taken	Files: (1) original series unchanged in FILE FT02F001 (2) forecast values and plot FILE FT08F001	(1) allows the user to forecast any seasonal or non-seasonal time series using a previously determined seasonal or non-seasonal ARIMA model and the time series itself

PROGRAM	INPUT	OUTPUT	REMARKS
Name: FORECAST (CONTINUED)	(2) length of seasonal period (3) number and estimated values of seasonal and non-seasonal AR and MA parameters (4) MA constant (5) index for forecast origin (6) maximum forecast lead time (7) index for plot origin (8) confidence level for forecast confidence units	Offline: (1) plot of forecast of series, including listing of forecast values and confidence interval values	(2) uses IMSL subroutine FTDFLF and modified SSPLTB routine UTPLOT called UTPLTB (3) single precision
Name: ROOTS Entry Code: R	Keyboard: (1) number of AR parameters in undifferenced form (2) values of AR parameters  None	Terminal: (1) values of roots  None	(1) allows user to calculate the roots of the characteristic equation for non-seasonal ARIMA models (2) uses IMSL routine ZPOLR (3) single precision  (1) allows user to access program information paragraphs after the TIMESER introduction phase has been completed
Name: HELP Entry Code: H			

PROGRAM

Name: GENERATE  
Entry Code: G

INPUT

Keyboard:  
(1) random number seed  
(2) number and values  
for non-seasonal  
AR and MA ARIMA  
model parameters  
(3) MA constant term  
(4) residual variance  
(5) length of series  
to be generated  
(6) initial starting  
value for time  
series to be  
generated

OUTPUT

Files:  
(1) generated time  
series written  
onto FILE  
FT02F001  
Offline:  
(1) length of generated  
series and series  
values themselves  
are printed  
offline

REMARKS

(1) allows the user to  
generate a time series  
from a given non-  
seasonal ARIMA model,  
previously determined  
(2) uses IMSL subroutine  
FTGENI  
(3) single precision

Name: SIMULATE  
Entry Code: S

INPUT

Files:  
(1) original series in  
FILE FT02F001,  
transformed and/or  
differenced as  
desired  
Keyboard:  
(1) number and values  
for non-seasonal  
AR and MA ARIMA  
model parameters  
(2) MA constant term  
(3) residual variance  
(4) index value of time  
series where simu-  
lation is to begin  
(5) starting values of  
series to be  
simulated  
(6) random number seed  
(7) number of values to  
be simulated in  
each series  
(8) number of series to  
be generated

OUTPUT

Files:  
(1) original series  
unchanged in  
FILE FT02F001  
Terminal:  
(1) Simulated series

(1) allows user to produce  
any number of simulated  
time series from a  
given non-seasonal  
ARIMA model  
(2) uses IMSL subroutine  
FTGENI  
(3) single precision

### III. THE BASIC USER SESSION

To use the Time Series Editor, the user must log into CMS, get into CP, link to the disc storage area where the Time Series Editor resides, reimplement CMS, log into the general user and Time Series Editor disc areas, and enter the TIMESER routine. This section will provide explicit guidelines to enable the user to perform the above steps on the NPS CP/CMS system. Commands marked with an asterisk (\*) are those actually entered on the terminal by the user (the asterisk itself is omitted). Those without an asterisk and those written in all capital letters are system responses at the terminal. Numbered sentences are comments, which will not appear during an actual user session. The instructions and system responses assure the user is on an IBM 2741 Input/Output Terminal. Some minor modifications may be necessary if other terminals are used.

1. Turn the terminal on, depress the BREAK key, and wait for the system to respond:

```
CP-67 online xd.65 gsyosu
```

2. Depress the ATTN key. The roll bar will advance and the keyboard will unlock. Then enter:

```
*login aaaapbb 450k
```

3. aaaa is the user's identification number, and nn is the terminal number (usually written on the terminal). For example, if the user's ID number is 1621 and the terminal number is 44, the input would be:  
login 1621p44 450k. The addition of 450 k to the normal login command is necessary to execute the program WMARQRDT in the Editor; for users not planning to execute this program during a session, this addition is not necessary.

4. The system will respond with the statement:  
ENTER PASSWORD:
5. The user then enters his password, or the general users password npg;  
\*password
6. The system will then respond:  
ENTER 4-DIGIT PROJECT NUMBER FOLLOWED BY 4-CHARACTER  
COST CENTER CODE:
7. The user then enters:  
\*gggghhhh
8. gggg is the assigned project number, and hhhh is the user's section designator or the faculty code.
9. The system will respond with the message of the day, such as:  
  
CP/CMS HOURS ... 0930=2200 (MON-THURS) ... 0930-1800 (FRI)  
OUTPUT RETAINED 5 DAYS  
Cms Version 3.25
10. At this point, the user is in CMS. He must then get into CP; this can be done by hitting the ATTN key. The system will then respond:  
  
CP
11. The user must then link to the TIME SERIES EDITOR; this is accomplished by entering:  
  
\*link 2069p 191 192
12. The system will respond with:  
  
ENTER PASSWORD:
13. The password (read only) to enter the Editor is:  
  
\*timser
14. The system then responds:  
  
SET TO READ ONLY

15. The user now implements CMS by:  
\*ipl cms
16. The system will respond:  
CMS Version 3.25
17. Now the user must log into both the general user and the Time Series Editor area by entering:  
\*login 191
18. The system will respond with a message such as:  
R;
19. The user then enters the command:  
\*login 192 t,p
20. The system will respond:  
T (192) R/O  
R;
21. The user can then enter the Time Series Editor (guided version) by entering the command:  
\*timeser
22. The system will respond:  
EACH 2 SECONDS EXECUTION TIME IS INDICATED BY \*  
YOU HAVE ENTERED THE TIME SERIES EDITOR  
PLEASE RESPOND TO EACH QUERY WITH AN INPUT AT THE TERMINAL.  
ENTER ONLY THE FIRST LETTER FOR A WORD RESPONSE.  
ENTER NUMERICAL VALUES VIA FORTRAN FORMAT.  
TYPE INTEGER VALUES (RIGHT JUSTIFIED) FOR NAMES STARTING WITH I THROUGH N. TYPE FLOATING VALUES WITH DECIMAL FOR ALL OTHERS.  
DO YOU WANT A LIST OF THE OPTIONS?
23. The user is then on his own, guided by the Exec routine. See the notes that appear at the end of this guide for additional information. Eventually the user will be asked:  
DO YOU WANT TO TRY AGAIN?

24. If a yes response is given, another sequence will begin; if the response is no, the user will be taken out of the Time Series Editor environment and returned to CMS. The system response will be:

```
CONTROL RETURNED TO CMS  
R;
```

25. The user can then log out of CMS by typing:

```
*cp logout
```

26. The system will respond with:

```
CONNECT= 00:08:02  VIRTCPU= 000:07.98  TOTCPU= 000.10.94  
LOGOUT AT 14.22.04 on 10/16/78
```

27. The user should then turn off his terminal and tear off the output from his session.

The more experienced user can dispense with the "welcome aboard" section of the Time Series Editor and get right down to business by using the shortened version of the Editor. This shortened version may be entered by linking in the normal way, and then entering the Editor by typing the COMMAND

```
*timeser s      (asterisk omitted).
```

The system will immediately respond:

```
ENTER LETTER FOR OPTION YOU WANT.
```

The session inside the Editor then begins.

#### IV. BRIEF SAMPLE USER SESSION

A brief sample user session is given below; it includes copies of the offline output generated during the session.

repeat login nur@pne

login 1621p44 450k  
ENTER PASSWORD:

ENTER 4-DIGIT, PROJECT NUMBER FOLLOWED BY 4-CHARACTER COST CENTER CODE:  
0444r172  
READY AT 17.24.38 ON 09/16/78  
CMS Version 3.25

stat  
P (191): 29 FILES; 241 REC IN USE, 55 LEFT (of 296), 81% FULL (2 CYL)

R;  
cp q f  
FILES:- NO RDR, NO PRT, NO PUN

R;  
CP  
link 2069p 191 192  
ENTER PASSWORD:

SET TO READ ONLY

ipl cms  
CMS Version 3.25

login 191  
R;  
login 192 t,p  
T (192) R/O  
R;

timeser  
EACH 2 SECONDS EXECUTION TIME IS INDICATED BY \*.

YOU HAVE ENTERED THE TIME SERIES EDITOR.

PLEASE RESPOND TO EACH QUERY WITH AN INPUT AT THE TERMINAL:  
ENTER ONLY THE FIRST LETTER FOR A WORD RESPONSE.  
ENTER NUMERICAL VALUES VIA FORTRAN FORMAT.

TYPE INTEGER VALUES (RIGHT JUSTIFIED) FOR NAMES STARTING  
WITH I THRU N. TYPE FLOATING VALUES WITH DECIMAL FOR ALL OTHERS.

DO YOU WANT A LIST OF THE OPTIONS?  
Y

OPTION	DESCRIPTION
GENERATE	-----GENERATE ANY ARIMA TIME SERIES
AUTO	-----CALCULATE AUTOCORRELATIONS, PAUTOS, MEAN AND VARIANCE
PLOT	-----PLOT A TIME SERIES
ESTIMATE	-----CALCULATE MAX LIKELIHOOD ESTIMATES OF ARMA PARAMETERS
DIFF	-----DIFFERENCE A TIME SERIES
FORECAST	-----FORECAST FUTURE VALUES, CONSTRUCT CONFIDENCE INTERVALS
TRANS	-----TRANSFORMS VALUES OF A TIME SERIES
ROOTS	-----DETERMINES ROOTS OF ARIMA CHARACTERISTIC EQUATION
ZFORMAT	-----ALTER DATA FILE TO FORMAT 5F15.6
CMSWORK	-----PERFORM CP/CMS COMMANDS IN TIMESER EXEC
SIMULATE	-----SIMULATE NONSEASONAL TIME SERIES
YESTSEAS	-----CALCULATE INITIAL SEASONAL PARAMETERS
WMARQDRT	-----MARQUARDT SOLUTION FOR PARAMETER ESTIMATES
XSUMSQ	-----CALCULATE SUM OF SQUARES FOR ARBITRARY PARAMETERS

WOULD YOU LIKE MORE INFO?  
Y

ENTER OPTION YOU WANT INFO ABOUT.

a

AUTO -----THIS PROGRAM CALCULATES AUTOCORRELATIONS, PARTIAL  
AUTOCORRELATIONS, THE MEAN AND THE VARIANCE FOR A GIVEN TIME SERIES  
WHICH MUST RESIDE IN FILE FT02F001. THE PROGRAM USES  
FTAUTO IN THE INSL LIBRARY. THE AUTOCORRELATIONS AND PAUTOS CAN BE  
PLOTTED OFFLINE.

DO YOU WANT INFO ABOUT ANOTHER OPTION?

n

DO YOU WANT TO TRY A SESSION?

y

ENTER LETTER FOR OPTION YOU WANT.

c

ENTER DESIRED CP/CMS COMMANDS, ONE PER LINE.

WHEN FINISHED TYPE: &GOTO -QUES

listf \* ft02f001

FILENAME	FILETYPE	MODE	NO.REC.	DATE
SERG	FT02F001	P1	3	9/16
SERC	FT02F001	P1	5	9/16
LNSERG	FT02F001	P1	3	9/16
FILE	FT02F001	P1	1	9/16

erase file ft02f001

alter serc ft02f001 pl file ft02f001 pl

stat

P (191): 28 FILES; 240 REC IN USE, 56 LEFT (of 296), 81% FULL (2 CYL)

&goto -ques

DO YOU WANT TO GO AGAIN?

y

ENTER LETTER FOR OPTION YOU WANT.

a

IS YOUR DATA IN FILE FT02F001?

y

EXECUTION BEGINS...

AUTOCORRELATIONS

0.978	0.944	0.902	0.854	0.802	0.748	0.692	0.635	0.579	0.923
0.468	0.413	0.359	0.305	0.253	0.201	0.150	0.098	0.047	-0.003
-0.052	-0.101	-0.151	-0.200	-0.248					

PARTIAL AUTOCORRELATIONS

0.978	-0.260	-0.157	-0.093	-0.058	-0.045	-0.012	-0.038	-0.022	-0.010
-0.036	-0.041	-0.038	-0.024	-0.037	-0.027	-0.032	-0.070	-0.048	-0.024
-0.034	-0.061	-0.079	-0.048	-0.037					

MEAN= 22.9739

VARIANCE = 4.22273

ENTER TITLE FOR PLOTS.

autos and pautos for series c data

YOUR AUTO AND PAUTO PLOTS HAVE BEEN PRINTED OFFLINE.

PICK UP IN ROOM I140 UNDER YOUR USER ID NUMBER.

DO YOU WANT TO GO AGAIN?

y

ENTER LETTER FOR OPTION YOU WANT.

c

ENTER DESIRED CP/CMS COMMANDS, ONE PER LINE.

WHEN FINISHED TYPE: &GOTO -QUES

offline print file ft02f001

alter file ft02f001 pl serc ft02f001 pl

&goto -ques

DO YOU WANT TO GO AGAIN?

n

CONTROL RETURNED TO CMS

R;

AUTOCORRELATIONS

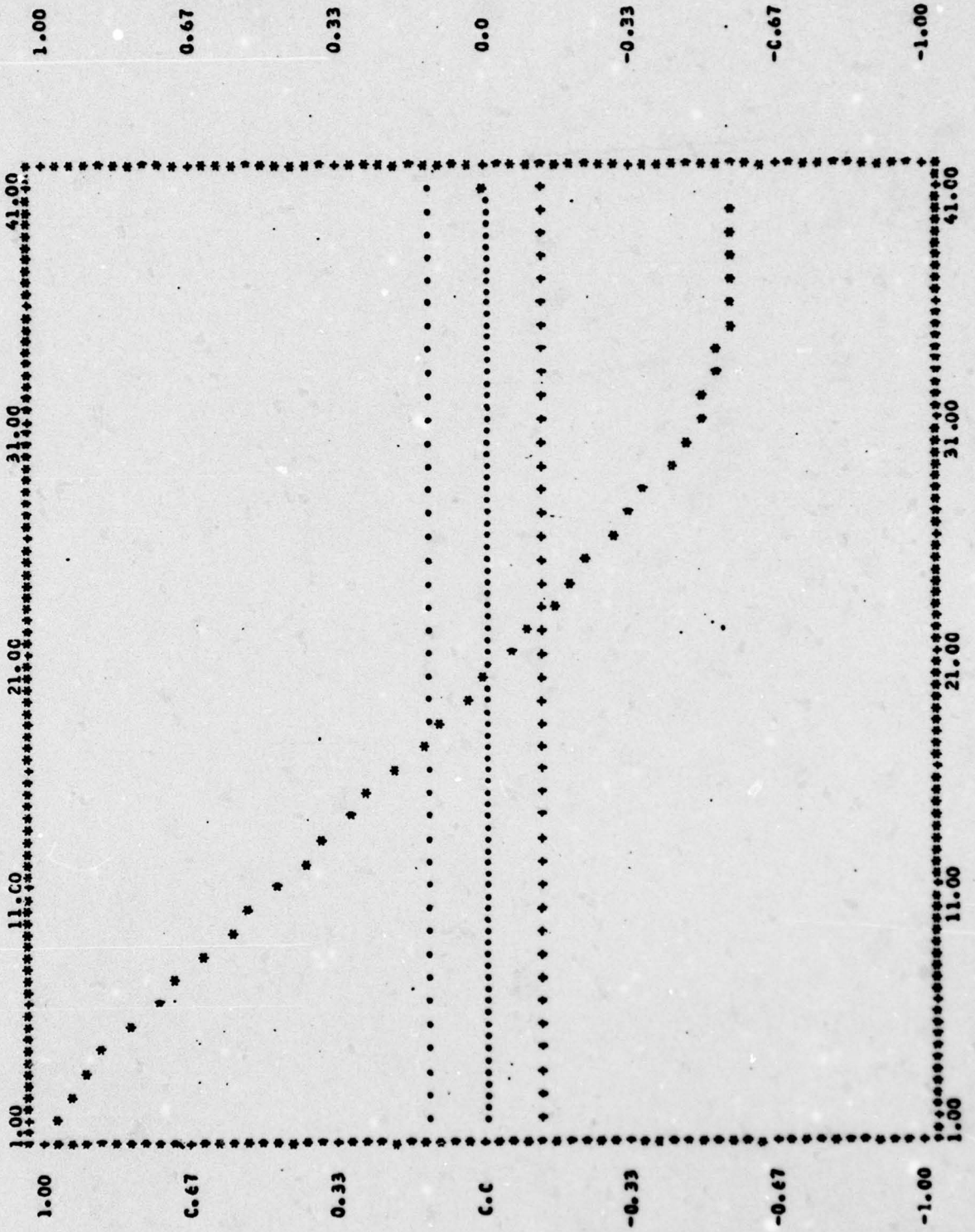
C. 578	C. 544	C. 502	C. 854	C. 802	C. 748	C. 692	C. 635	C. 579	C. 523
0.466	0.413	0.359	0.305	0.258	0.201	0.150	0.098	0.047	0.003
-0.052	-0.101	-0.151	-0.200	-0.248	-0.294	-0.337	-0.379	-0.418	-0.454
-0.486	-0.512	-0.534	-0.550	-0.562	-0.570	-0.573	-0.573	-0.568	-0.562

PARTIAL AUTOCORRELATIONS

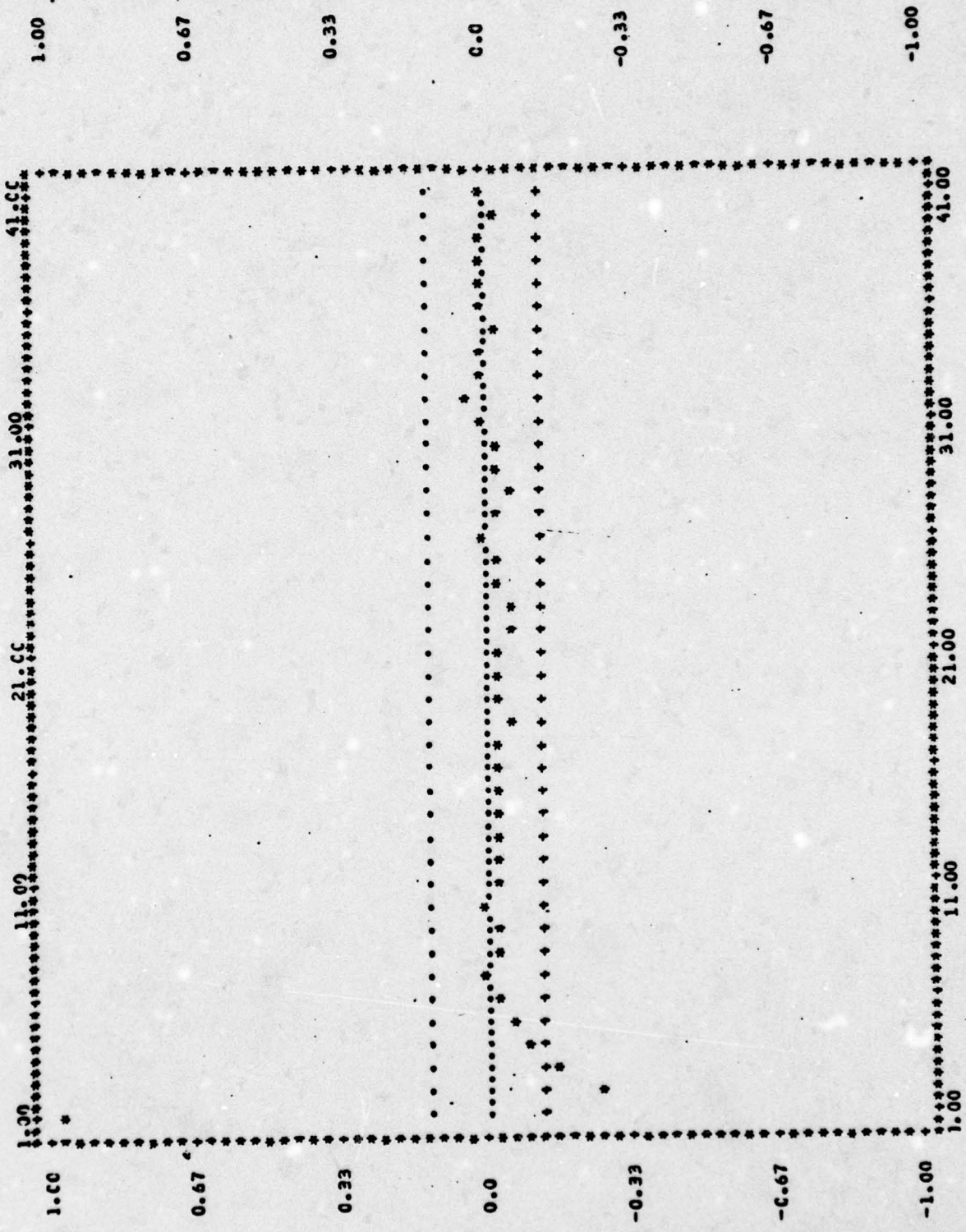
C. 578	C. 260	C. 157	C. 093	C. 058	C. 045	C. 012	C. 018	C. 022	C. 010
-0.036	-0.041	-0.038	-0.024	-0.037	-0.027	-0.032	-0.070	-0.048	-0.024
-0.002	0.022	-0.014	-0.006	-0.024	0.006	-0.016	-0.004	-0.010	-0.032

MEAN = 22.9739

VARIANCE = 4.22273



AUTCCRRFLATIGNS WITH 2 SIGMA BANDS.



PARTIAL AUTOCCORRELATIONS WITH 2 SIGMA BANDS.  
 ALTOS AND PAUTOS PCR SERIES C DATA



## V. PROBLEM CONTROL NOTES

24  
This section will cover corrective measures that can be taken when things fail to go as expected while in the TIMESER environment.

25  
a. A typing error in the CMS environment can be corrected by typing the @ character as many times as is required to back up and then type the correct values. For example, if the user typed timesre, the user could correct the mistake by typing two @ signs, followed by the correct spelling er, as follows: timesre@@re. An entire line can be deleted by typing the ¢ character (or [ on some terminals).

26  
b. When working with TIMESER executive programs, the user should exercise care before hitting the return key (or control s on some terminals). If an input value is required and the return key is hit before the proper response is entered, the user will be likely to get thrown out of the editor and have to begin again. In most cases, errors can be corrected only before the return key is struck (in some programs you get a second chance for input).

c. Particular care should be taken for integer value input, which must be right justified in the format field. The editor will advise the user in all cases where the integer format is other than I1.

d. If for any reason the user finds himself in a debug or error condition (caused by erroneous data, or a "blowup" in one of the non-linear optimization routines usually

caused by very poor initial input values), the following procedure will get the user back into the normal TIMESER environment:

- (1) depress the ATTN key twice; this gets the user into CP; hit the ATTN key again, and then type kx to kill the execution.
- (2) re-ipl CMS, and login 191 and then login 192 t,p.
- (3) then the user can type TIMESER or TIMESER S, and return to the TIMESER environment

On the next page is a sample user session where an error causing a debug condition has occurred.

Here the user executed a program that required data in FILE FT02F001, and the FILE did not exist. As the example shows, recovery is quick. Simply hit the break button to get into CP, login 191, login 192 t,p, and then type timeser s to return immediately to the Editor environment.

ENTER LETTER FOR OPTION YOU WANT.  
d  
EXECUTION BEGINS...

IHC218I FIOCS - I/O ERROR BSAM INPUT ERROR 01 ON FILE: "FT02F001" /

8

TRACEBACK ROUTINE CALLED FROM ISN REG. 14 REG. 15 REG. 0 REG. 1  
IBCOM 000131FC 000133F8 FFF93908 00014F80

DIFF CP

ipl cms  
CMS Version 3.25

login 191  
R;  
login 192 t,p  
T (192) R/O  
R;  
timeser s

ENTER LETTER FOR OPTION YOU WANT.  
C  
ENTER DESIRED CP/CMS COMMANDS, ONE PER LINE.  
WHEN FINISHED TYPE: &GOTO -QUES  
alter serc ft02f001 pl file ft02f001 pl  
&goto -ques  
DO YOU WANT TO GO AGAIN?  
Y

ENTER LETTER FOR OPTION YOU WANT.  
d

## APPENDIX B

### KEYBOARD SESSION AND OUTPUT FROM ANALYSIS OF TIME SERIES C (NON-SEASONAL)

This appendix contains the complete terminal keyboard session and all offline output from the analysis of Box and Jenkins' [Ref. 4] time series C (Chemical process temperature readings) using the Time Series Editor. This appendix is intended to supplement the discussion of the analysis of series C discussed in Chapter V of this report.

The terminal listings are presented first, followed by the computer offline output.

repeat login nur@pn@

login 1621p44 400k  
ENTER PASSWORD:

ENTER 4-DIGIT PROJECT NUMBER FOLLOWED BY 4-CHARACTER COST CENTER CODE:  
0444r172  
READY AT 14.23.02 ON 09/16/78  
CMS Version 3.25

listf \* ft02f001  
FILENAME FILETYPE MODE NO.REC. DATE  
FILE FT02F001 P1 3 9/15  
SERG FT02F001 P1 3 9/16  
SERC FT02F001 P1 5 9/16  
R;

erase file ft02f001  
R;  
alter serc ft02f001 pl file ft02f001 pl  
R;

CP  
link 2069p 191 192  
ENTER PASSWORD:

SET TO READ ONLY

ipl cms  
CMS Version 3.25

login 191  
R;  
login 192 t,p  
T (192) R/O  
R;

-----  
EACH 2 SECONDS EXECUTION TIME IS INDICATED BY \*.

YOU HAVE ENTERED THE TIME SERIES EDITOR.

PLEASE RESPOND TO EACH QUERY WITH AN INPUT AT THE TERMINAL.  
ENTER ONLY THE FIRST LETTER FOR A WORD RESPONSE.  
ENTER NUMERICAL VALUES VIA FORTRAN FORMAT.

TYPE INTEGER VALUES (RIGHT JUSTIFIED) FOR NAMES STARTING  
WITH I THRU N. TYPE FLOATING VALUES WITH DECIMAL FOR ALL OTHERS.

DO YOU WANT A LIST OF THE OPTIONS?  
Y

OPTION	DESCRIPTION
GENERATE	-----GENERATE ANY ARIMA TIME SERIES
AUTO	-----CALCULATE AUTOCORRELATIONS, PAUTOS, MEAN AND VARIANCE
PLOT	-----PLOT A TIME SERIES
ESTIMATE	-----CALCULATE MAX LIKELIHOOD ESTIMATES OF ARMA PARAMETERS
DIFF	-----DIFFERENCE A TIME SERIES
FORECAST	-----FORECAST FUTURE VALUES, CONSTRUCT CONFIDENCE INTERVALS
TRANS	-----TRANSFORMS VALUES OF A TIME SERIES
ROOTS	-----DETERMINES ROOTS OF ARIMA CHARACTERISTIC EQUATION
ZFORMAT	-----ALTER DATA FILE TO FORMAT 5F15.6
CMSWORK	-----PERFORM CP/CMS COMMANDS IN TIMESER EXEC
SIMULATE	-----SIMULATE NONSEASONAL TIME SERIES
YESTSEAS	-----CALCULATE INITIAL SEASONAL PARAMETERS
WMARQDRT	-----MARQUARDT SOLUTION FOR PARAMETER ESTIMATES
XSUMSQ	-----CALCULATE SUM OF SQUARES FOR ARBITRARY PARAMETERS

WOULD YOU LIKE MORE INFO?  
Y

ENTER OPTION YOU WANT INFO ABOUT.

a

AUTO -----THIS PROGRAM CALCULATES AUTOCORRELATIONS, PARTIAL  
AUTOCORRELATIONS, THE MEAN AND THE VARIANCE FOR A GIVEN TIME SERIES  
WHICH MUST RESIDE IN FILE FT02F001. THE PROGRAM USES  
PTAUTO IN THE IMSL LIBRARY. THE AUTOCORRELATIONS AND PAUTOS CAN BE  
PLOTTED OFFLINE.

DO YOU WANT INFO ABOUT ANOTHER OPTION?

y

ENTER OPTION YOU WANT INFO ABOUT.

d

DIFF -----THIS PROGRAM TAKES A SERIES IN FILE FT02F001, ASKS IF  
IT IS SEASONAL, AND THEN PERFORMS NONSEASONAL AND/OR SEASONAL  
DIFFERENCING, AS REQUESTED. THE ORIGINAL DATA REMAINS IN FILE  
FT02F001, WHILE THE DIFFERENCED SERIES IS PUT IN FILE FT03F001.

DO YOU WANT INFO ABOUT ANOTHER OPTION?

n

DO YOU WANT TO TRY A SESSION?

y

ENTER LETTER FOR OPTION YOU WANT.

a

IS YOUR DATA IN FILE FT02F001?

y

EXECUTION BEGINS...

AUTOCORRELATIONS

0.978	0.944	0.902	0.854	0.802	0.748	0.692	0.635	0.579	0.523
0.468	0.413	0.359	0.305	0.253	0.201	0.150	0.098	0.047	-0.003
-0.052	-0.101	-0.151	-0.200	-0.248					

PARTIAL AUTOCORRELATIONS

0.978	-0.260	-0.157	-0.093	-0.058	-0.045	-0.012	-0.038	-0.022	-0.010
-0.036	-0.041	-0.038	-0.024	-0.037	-0.027	-0.032	-0.070	-0.048	-0.024
-0.034	-0.061	-0.079	-0.048	-0.037					

MEAN= 22.9739

VARIANCE = 4.22273

ENTER TITLE FOR PLOTS.

autos and pautos of series c data / undifferenced  
YOUR AUTO AND PAUTO PLOTS HAVE BEEN PRINTED OFFLINE.  
PICK UP IN ROOM I140 UNDER YOUR USER ID NUMBER.

\*DO YOU WANT TO GO AGAIN?

y

ENTER LETTER FOR OPTION YOU WANT.

d  
IS YOUR DATA IN FILE FT02F001?

y  
EXECUTION BEGINS...

IS YOUR TIME SERIES SEASONAL?

n  
ENTER NUMBER OF NONSEASONAL DIFFERENCES.

1  
\*DO YOU WANT TO PLOT AUTO AND PAUTO OF TRANSFORMED DATA?

y  
EXECUTION BEGINS...

AUTOCORRELATIONS

0.805	0.653	0.526	0.442	0.380	0.318	0.262	0.186	0.139	0.144
0.097	0.094	0.074	0.073	0.070	0.072	0.089	0.048	0.041	0.040
0.044	0.048	0.000	-0.052	-0.097					

PARTIAL AUTOCORRELATIONS

0.805	0.010	-0.007	0.051	0.027	-0.019	-0.013	-0.080	0.020	0.117
-0.137	0.094	-0.027	0.034	0.006	0.012	0.043	-0.121	0.060	-0.005
0.038	-0.022	-0.116	-0.076	-0.008					

MEAN=-.346667E-01      VARIANCE = 0.531982E-01

ENTER TITLE FOR PLOTS.  
autos and pautos of series c data / one nonseasonal difference  
YOUR AUTO AND PAUTO PLOTS HAVE BEEN PRINTED OFFLINE.  
PICK UP IN ROOM I140 UNDER YOUR USER ID NUMBER.

DO YOU WANT TO GO AGAIN?

y

ENTER LETTER FOR OPTION YOU WANT.

d  
IS YOUR DATA IN FILE FT02F001?

y  
EXECUTION BEGINS...

IS YOUR TIME SERIES SEASONAL?

n  
ENTER NUMBER OF NONSEASONAL DIFFERENCES.

2  
DO YOU WANT TO PLOT AUTO AND PAUTO OF TRANSFORMED DATA?

y  
EXECUTION BEGINS...

AUTOCORRELATIONS

-0.079	-0.065	-0.122	-0.063	0.013	-0.018	0.049	-0.052	-0.124	0.122
-0.122	0.072	-0.077	0.029	-0.011	-0.058	0.171	-0.101	-0.013	-0.020
-0.007	0.135	0.014	-0.013	-0.135					

PARTIAL AUTOCORRELATIONS

-0.079	-0.072	-0.135	-0.094	-0.022	-0.051	0.022	-0.060	-0.145	0.094
-0.143	0.023	-0.089	-0.005	-0.039	-0.074	0.130	-0.105	-0.014	-0.053
0.004	0.081	0.056	-0.041	-0.099					

MEAN=-.267866E-02      VARIANCE = 0.198143E-01

ENTER TITLE FOR PLOTS.  
autos and pautos of series c data / two nonseasonal differences  
YOUR AUTO AND PAUTO PLOTS HAVE BEEN PRINTED OFFLINE.  
PICK UP IN ROOM I140 UNDER YOUR USER ID NUMBER.

DO YOU WANT TO GO AGAIN?

y

ENTER LETTER FOR OPTION YOU WANT.

c

ENTER DESIRED CP/CMS COMMANDS, ONE PER LINE.

WHEN FINISHED TYPE: &GOTO -QUES

alter file ft02f001 pl serc ft02f001 pl

alter file ft03f001 pl file ft02f001 pl

&goto -ques

DO YOU WANT TO GO AGAIN?

y

ENTER LETTER FOR OPTION YOU WANT.

e

IS YOUR DATA IN FILE FT02F001?

y

EXECUTION BEGINS...

ENTER NUMBER OF AR PARAMETERS (EXCLUDE DIFFERENCES).

0

ENTER NUMBER OF MA PARAMETERS.

2

LENGTH OF TIME SERIES = 224

0 AR PARAMETERS 2 MA PARAMETERS

MA PARAMETERS ARE:

THETA(1)= 0.1378

THETA(2)= 0.1296

MA CONSTANT= -0.26787E-02 WHITE NOISE VARIANCE= 0.189559E-01

CHI SQUARE RESIDUAL LACK OF FIT VALUE = 36.75 DF = 23

SIGNIFICANCE = 0.0346

DO YOU WANT TO PLOT AUTO AND PAUTO OF RESIDUALS?

y

\*EXECUTION BEGINS...

AUTOCORRELATIONS

0.019	0.034	-0.134	-0.093	-0.012	-0.043	0.005	-0.063	-0.125	0.088
-0.142	0.069	-0.098	0.025	0.004	-0.055	0.157	-0.090	0.005	-0.006
0.009	0.133	0.005	-0.015	-0.133					

PARTIAL AUTOCORRELATIONS

0.019	0.033	-0.135	-0.090	0.001	-0.055	-0.019	-0.071	-0.143	0.087
-0.166	0.017	-0.104	-0.013	-0.025	-0.089	0.123	-0.123	-0.021	-0.025
0.024	0.069	0.024	-0.069	-0.102					

MEAN=0.236684E-02 VARIANCE = 0.189503E-01

ENTER TITLE FOR PLOTS.

autos and pautos of residuals / arima(0,2,2) model of series c data

YOUR AUTO AND PAUTO PLOTS HAVE BEEN PRINTED OFFLINE.

PICK UP IN ROOM I140 UNDER YOUR USER ID NUMBER.

DO YOU WANT TO GO AGAIN?

y

ENTER LETTER FOR OPTION YOU WANT.

c  
ENTER DESIRED CP/CMS COMMANDS, ONE PER LINE.  
WHEN FINISHED TYPE: &GOTO -QUES  
erase file ft02f001

stat  
P (191): 27 FILES; 265 REC IN USE, 31 LEFT (of 296), 90% FULL (2 CYL)  
erase file ft02f001  
alter serc ft02f001 pl file ft02f001 pl  
&goto -ques  
DO YOU WANT TO GO AGAIN?  
y

ENTER LETTER FOR OPTION YOU WANT.

d  
\*IS YOUR DATA IN FILE FT02F001?

y  
EXECUTION BEGINS...  
IS YOUR TIME SERIES SEASONAL?

n  
ENTER NUMBER OF NONSEASONAL DIFFERENCES.

1  
DO YOU WANT TO PLOT AUTO AND PAUTO OF TRANSFORMED DATA?

n  
DO YOU WANT TO GO AGAIN?  
y

ENTER LETTER FOR OPTION YOU WANT.

c  
\*ENTER DESIRED CP/CMS COMMANDS, ONE PER LINE.  
WHEN FINISHED TYPE: &GOTO -QUES

alter file ft02f001 pl serc ft02f001 pl  
alter file ft03f001 pl file ft02f001 pl  
&goto -ques  
DO YOU WANT TO GO AGAIN?  
y

ENTER LETTER FOR OPTION YOU WANT.

e  
IS YOUR DATA IN FILE FT02F001?

y  
EXECUTION BEGINS...  
ENTER NUMBER OF AR PARAMETERS (EXCLUDE DIFFERENCES).

1  
ENTER NUMBER OF MA PARAMETERS.

0  
\* LENGTH OF TIME SERIES = 225  
1 AR PARAMETERS 0 MA PARAMETERS

AR PARAMETERS ARE:

PHI(1)= 0.8073

MA CONSTANT= -0.66789E-02 WHITE NOISE VARIANCE= 0.177633E-01

CHI SQUARE RESIDUAL LACK OF FIT VALUE = 28.88 DF = 24  
SIGNIFICANCE = 9.2247

DO YOU WANT TO PLOT AUTO AND PAUTO OF RESIDUALS?

y  
EXECUTION BEGINS...

AUTOCORRELATIONS

0.016	0.014	-0.049	-0.005	0.061	0.024	0.078	-0.018	-0.087	0.130
-0.093	0.084	-0.055	0.043	0.007	-0.040	0.169	-0.079	-0.001	-0.010
0.000	0.129	0.014	-0.013	-0.127					

PARTIAL AUTOCORRELATIONS

0.016	0.014	-0.050	-0.004	0.063	0.019	0.075	-0.015	-0.087	0.140
-0.104	0.070	-0.048	0.042	0.003	-0.030	0.158	-0.088	0.013	-0.025
0.030	0.086	0.039	-0.062	-0.101					

MEAN=-.252517E-02      VARIANCE = 0.177569E-01

ENTER TITLE FOR PLOTS.  
autos and pautos of residuals / arima(1,1,0) model of series c data  
YOUR AUTO AND PAUTO PLOTS HAVE BEEN PRINTED OFFLINE.  
PICK UP IN ROOM 1140 UNDER YOUR USER ID NUMBER.

DO YOU WANT TO GO AGAIN?

y

\*

ENTER LETTER FOR OPTION YOU WANT.

c

ENTER DESIRED CP/CMS COMMANDS, ONE PER LINE.

WHEN FINISHED TYPE: &GOTO -QUES

erase file ft02f001

alter serc ft02f001 pl file ft02f001 pl

tgoto -ques

DO YOU WANT TO GO AGAIN?

y

ENTER LETTER FOR OPTION YOU WANT.

f

IS YOUR DATA IN FILE FT02F001?

y

EXECUTION BEGINS...

IS YOUR SERIES SEASONAL?

n

ENTER NONSEASONAL DATA AS REQUESTED:

ENTER NUMBER OF NON-SEASONAL DIFFERENCES.

1

ENTER NUMBER OF NON-SEASONAL AR PARAMETERS.

1

ENTER NUMBER OF NON-SEASONAL MA PARAMETERS.

0

NOW INPUT YOUR PARAMETER ESTIMATES:

ENTER MA CONSTANT TERM, THETA0.

-.00667

ENTER NON-SEASONAL AR PARAMETER PHI(1).

0.8073

ENTER MAXIMUM FORECAST LEAD TIME VIA FORMAT I2.

25

ENTER INDEX FOR PLOT ORIGIN VIA FORMAT I3.

200

ENTER INDEX FOR FORECAST ORIGIN VIA FORMAT I3.

220

ENTER SIGNIFICANCE LEVEL FOR CONFIDENCE INTERVALS.

0.10

WAS YOUR DATA TRANSFORMED IN THE TRANS PROGRAM?

n

DO YOU WANT BASIC OUTPUT AT THE TERMINAL?

y

THE LAST 10 WVEC VALUES:

0.222000E 02 0.218000E 02 0.213000E 02 0.208000E 02 0.202000E 02  
0.197000E 02 0.193000E 02 0.191000E 02 0.190000E 02 0.188000E 02

THE 25 FORECAST VALUES:

0.203896E 02 0.200517E 02 0.197722E 02 0.195399E 02 0.193456E 02  
0.191821E 02 0.190434E 02 0.189248E 02 0.188223E 02 0.187329E 02  
0.186541E 02 0.185837E 02 0.185203E 02 0.184623E 02 0.184089E 02  
0.183591E 02 0.183121E 02 0.182676E 02 0.182249E 02 0.181838E 02  
0.181439E 02 0.181050E 02 0.180669E 02 0.180295E 02 0.179926E 02

THE 25 UPPER FORECAST CONFIDENCE LIMITS:

0.206094E 02 0.205056E 02 0.204779E 02 0.205033E 02 0.205662E 02  
0.206551E 02 0.207621E 02 0.208812E 02 0.210079E 02 0.211390E 02  
0.212721E 02 0.214056E 02 0.215381E 02 0.216687E 02 0.217969E 02  
0.219221E 02 0.220442E 02 0.221630E 02 0.222783E 02 0.223903E 02  
0.224989E 02 0.226043E 02 0.227064E 02 0.228055E 02 0.229016E 02

ALPHA FOR THE CONFIDENCE LIMITS IS: 0.100

DO YOU WANT TO GO AGAIN?

y

ENTER LETTER FOR OPTION YOU WANT.

r

\*EXECUTION BEGINS...

SOLVES FOR ROOTS OF CHARACTERISTIC EQUATION.

ENTER NO. OF AR PARAMETERS (UNDIFF. FORM).

2

ENTER AUTOREGRESSIVE PARAMETERS:

ENTER PHI(1).

1.8073

ENTER PHI(2).

-0.8073

THE 2 ROOTS OF CHARACTERISTIC EQ. AND NORMS ARE:

1.239	0.0	1.239
1.000	0.0	1.000

DO YOU WANT TO GO AGAIN?

y

ENTER LETTER FOR OPTION YOU WANT.

d

\*EXECUTION BEGINS...

IS YOUR TIME SERIES SEASONAL?

n

ENTER NUMBER OF NONSEASONAL DIFFERENCES.

0

DO YOU WANT TO PLOT AUTO AND PAUTO OF TRANSFORMED DATA?

n

DO YOU WANT TO GO AGAIN?

y

ENTER LETTER FOR OPTION YOU WANT.

s

\*EXECUTION BEGINS...

ENTER NUMBER OF AR PARAMETERS (UNDIFFERENCED FORM)

2

ENTER ESTIMATED AR PARAMETER PHI(1).

1.8073

ENTER ESTIMATED AR PARAMETER PHI(2).

-0.8073

AR PARAMETERS ARE 1.8073 -0.8073  
ARE THESE OK?

Y  
ENTER NUMBER OF MA PARAMETERS

0  
ENTER OVERALL MA CONSTANT  
-0.00667

ENTER ESTIMATED WHITE NOISE VAR  
0.0177

DO YOU WANT STARTING VALUES TO BE THE LAST VALUES  
OF THE ACTUAL SERIES?

Y  
START(1)= 19.000000  
START(2)= 18.799988  
STARTING VALUE(S) OK?

Y  
ENTER RANDOM NUMBER SEED (BETWEEN 0 AND 1).  
0.12345

ENTER NUMBER OF VALUES YOU WANT TO SIMULATE VIA I3.  
50

DO YOU WANT A PRINTOUT OF THE FIRST 20 VALUES?

Y  
SIMULATED VALUES ARE:

18.50224	18.33957	18.33694	18.16435	17.98804
17.85420	17.69398	17.58267	17.50722	17.26422
16.94655	16.68689	16.43227	16.42499	16.26595
16.31497	16.64629	17.04015	17.47137	17.62828

DO YOU WANT TO GO AGAIN?

n  
CONTROL RETURNED TO CMS  
R;

AUTOCORRELATIONS

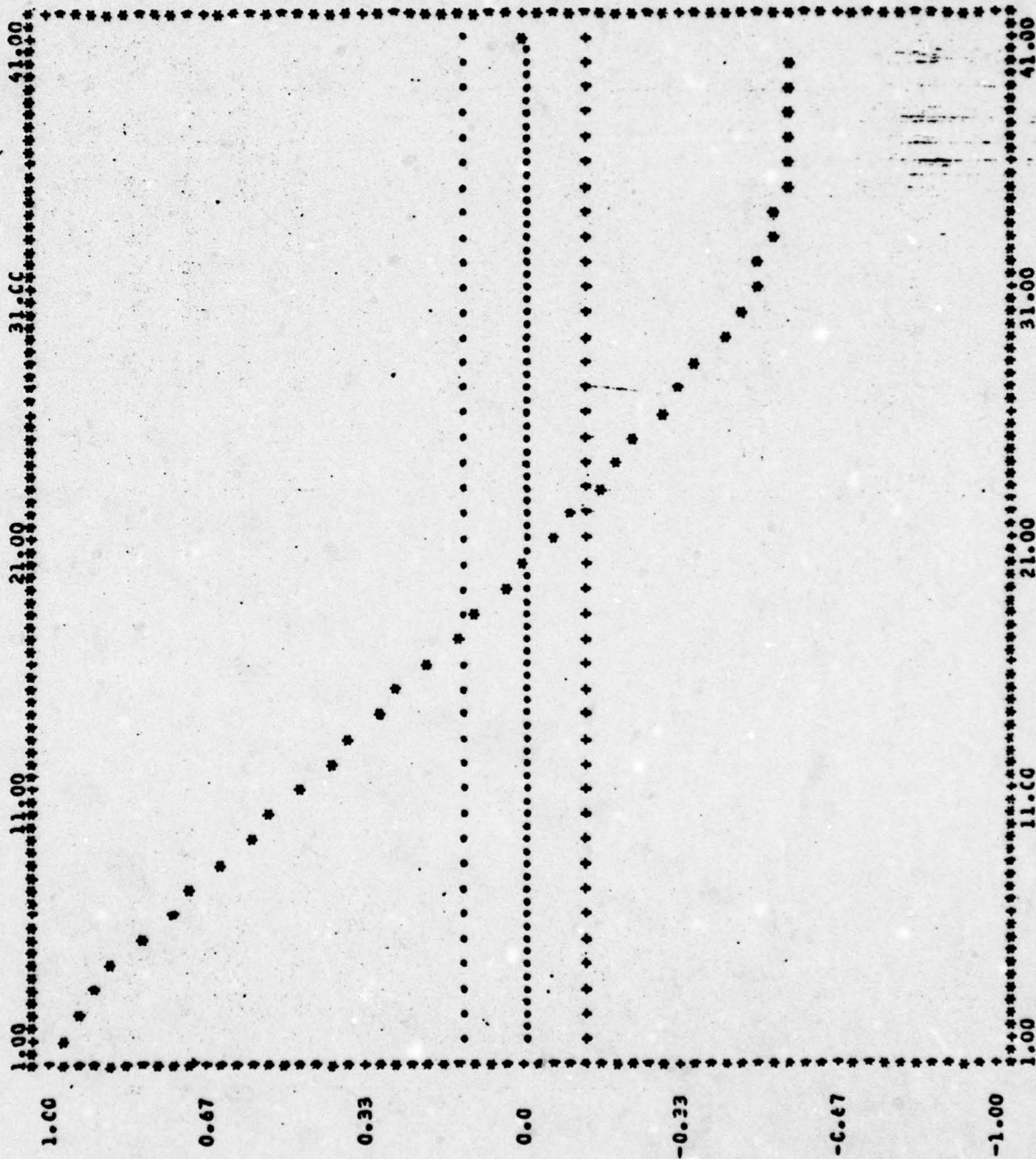
0.978	0.944	0.902	0.854	0.802	0.748	0.692	0.635	0.579	0.523
0.668	0.713	0.759	0.803	0.848	0.894	0.939	0.983	0.979	0.975
-0.052	-0.101	-0.151	-0.200	-0.248	-0.297	-0.345	-0.393	-0.441	-0.489
-0.486	-0.512	-0.534	-0.550	-0.562	-0.570	-0.573	-0.573	-0.568	-0.562

PARTIAL AUTOCORRELATIONS

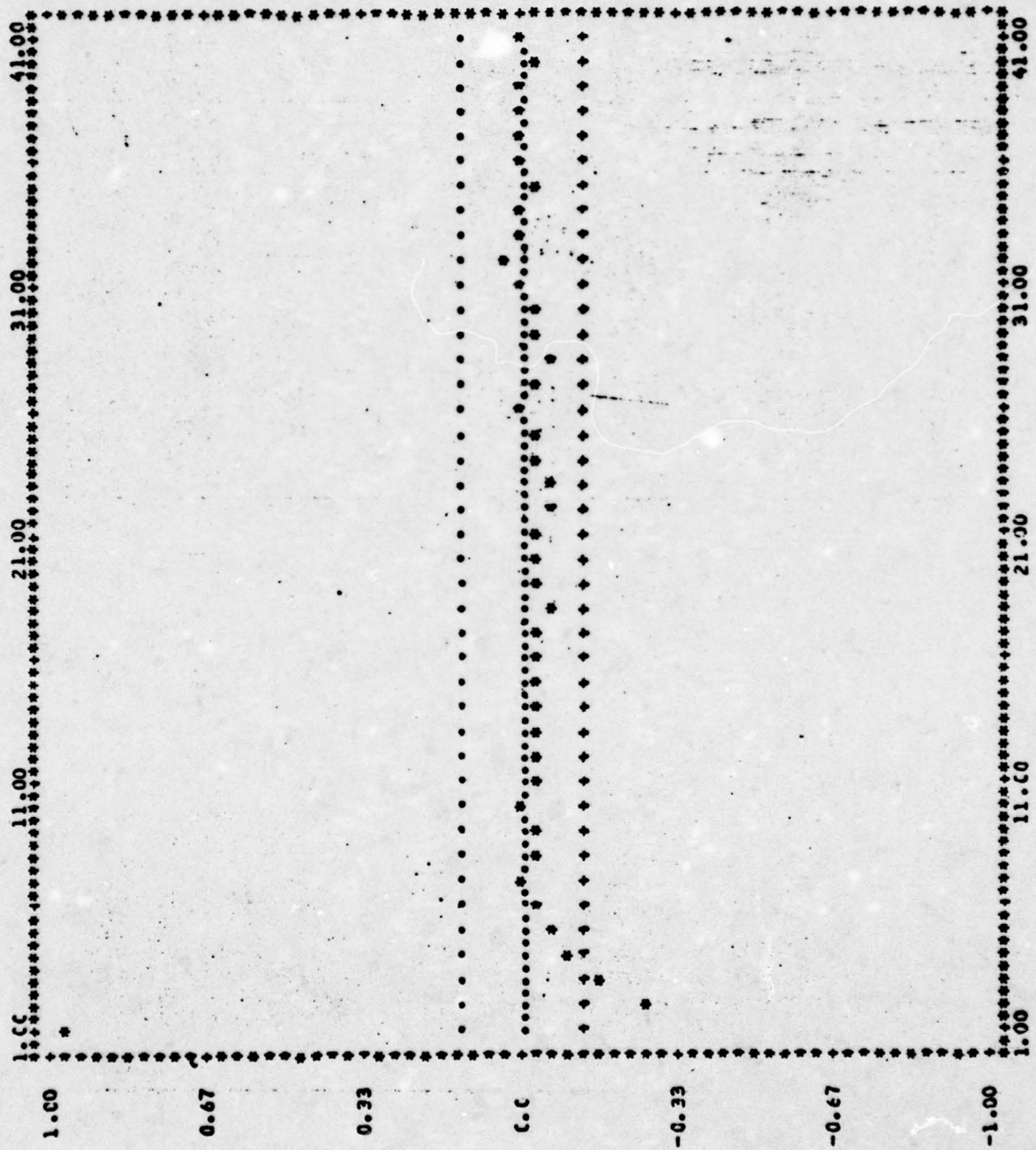
0.878	0.160	-0.157	-0.092	-0.058	-0.045	-0.012	-0.038	0.022	0.010
-0.034	-0.641	-0.039	-0.024	-0.037	-0.027	-0.032	-0.054	-0.038	-0.024
-0.002	-0.022	-0.014	-0.008	-0.024	0.006	-0.016	-0.004	-0.010	-0.036

MEAN = 22.9739

VARIANCE = 4.22273



AUTOCORRELATIONS WITH 2 SIGMA BANDS.



PARTIAL AUTOCORRELATIONS WITH 2 SIGMA BANDS, AUTOS AND PARTIALS OF SERIES C DATA / UNDIFFERENCED



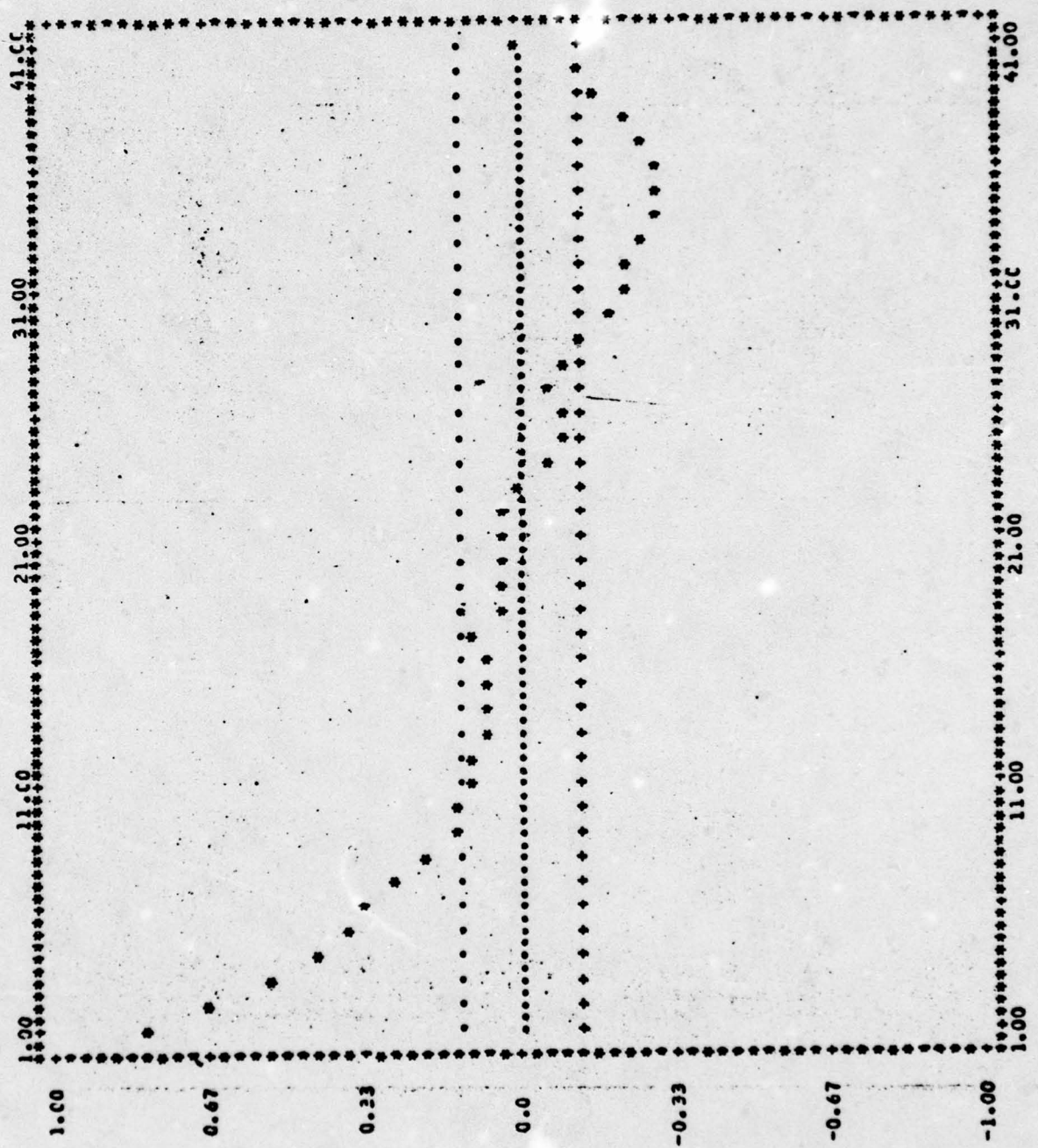
AUTOCORRELATIONS

0.859	0.653	0.526	0.442	0.390	0.318	0.262	0.186	0.119	0.140
0.094	0.549	0.070	0.073	0.070	0.072	0.083	0.048	0.019	0.184
-0.226	-0.223	-0.261	-0.285	-0.313	-0.284	-0.258	-0.219	-0.166	-0.134

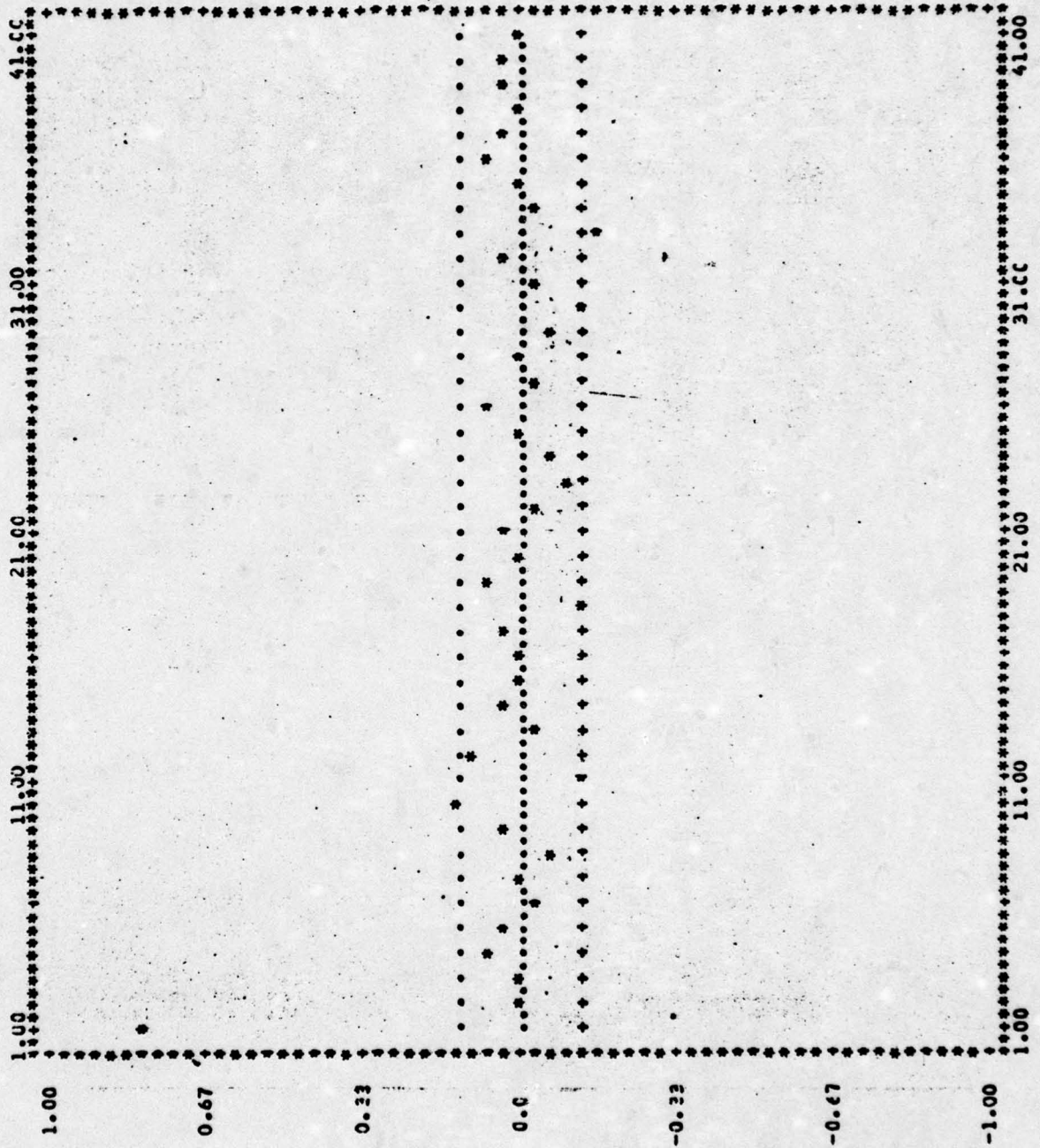
PARTIAL AUTOCORRELATIONS

0.807	0.610	-0.007	0.051	0.027	-0.015	-0.013	-0.089	0.080	0.117
-0.137	0.099	-0.027	0.034	0.006	0.012	0.013	0.021	0.080	-0.071
-0.038	0.044	-0.154	-0.076	-0.009	0.071	-0.019	0.013	-0.008	0.123

MEAN--.34667E-01      VARIANCE = 0.531982E-01



AUTOCORRELATIONS WITH 2 SIGMA BANDS.



PARTIAL AUTOCORRELATIONS WITH 2 SIGMA BANDS:  
 AUTOS AND PAUTOS OF SERIES C DATA / ONE NONSEASONAL CIPHEREN



AUTCORRELATIONS

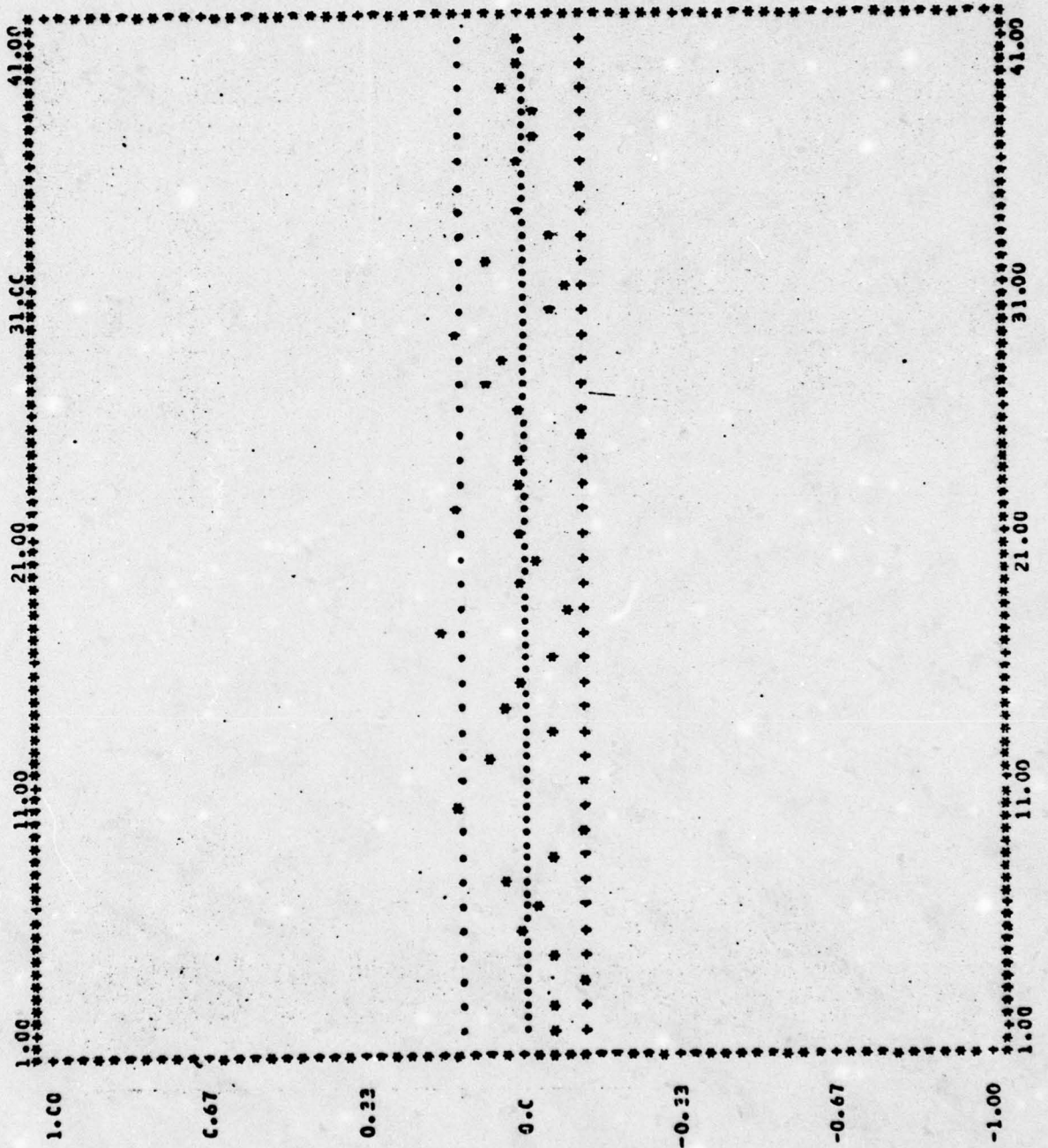
-0.079	-0.095	-0.122	-0.063	0.013	-0.018	0.049	-0.052	-0.124	0.120
-0.122	0.012	-0.077	0.023	-0.011	-0.058	0.171	-0.091	-0.043	-0.058
-0.007	0.170	-0.014	-0.013	0.009	-0.002	-0.034	-0.043	0.125	0.005

PARTIAL AUTOCORRELATIONS

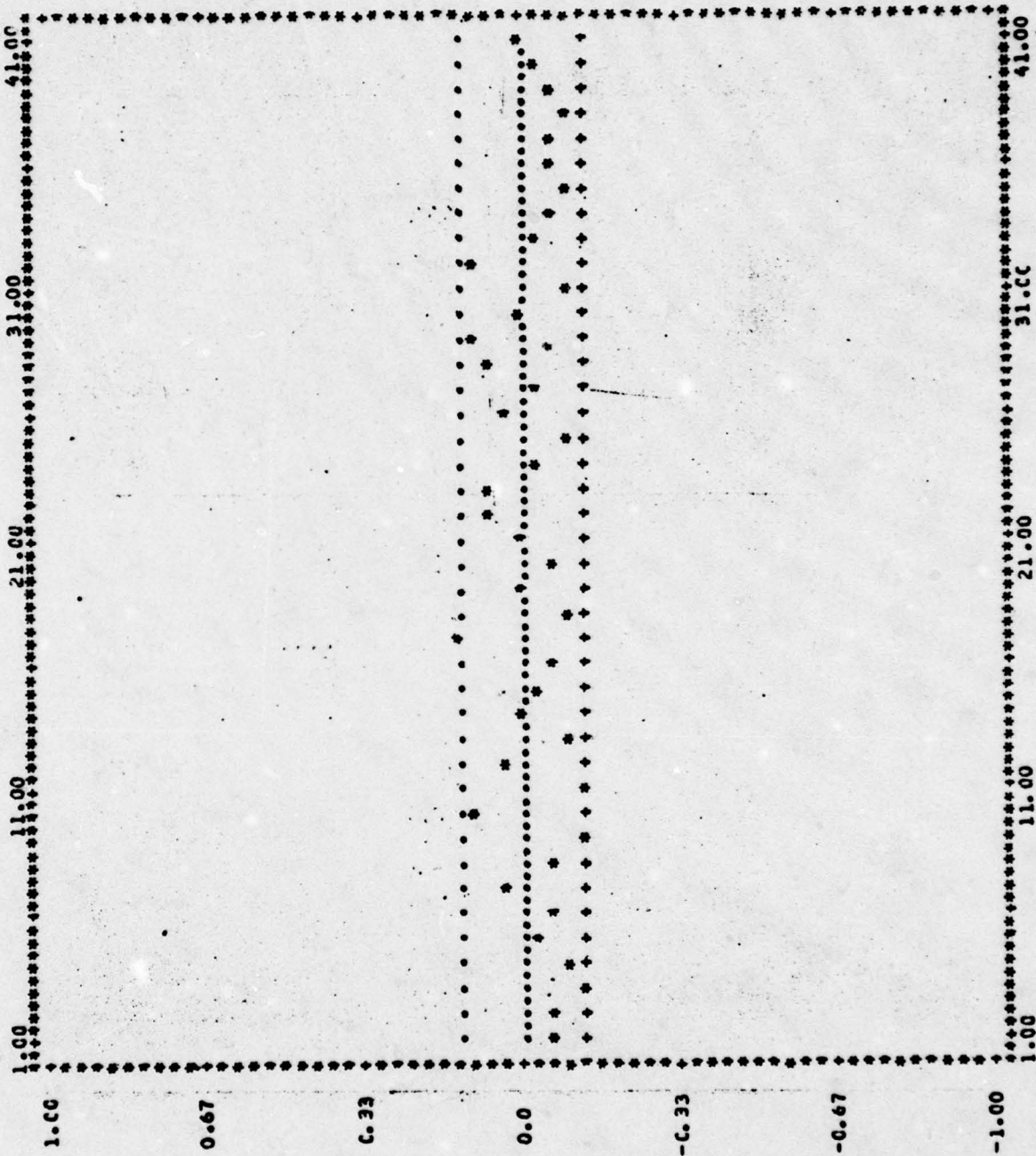
-0.079	-0.072	-0.135	-0.054	-0.032	-0.051	0.022	-0.069	-0.145	0.094
0.122	0.023	-0.089	-0.003	-0.059	-0.074	-0.122	-0.029	-0.069	-0.023
0.009	0.101	-0.038	-0.041	-0.059	-0.025	-0.023	-0.052	-0.069	-0.013

MEAN = -.21866E-02

VARIANCE = 0.198143E-01



AUTOCORRELATIONS WITH 2 SIGMA BANDS.



PARTIAL AUTOCORRELATIONS WITH 2 SIGMA BANDS;  
 AUTOS AND PARTIALS OF SERIES C DATA / TWO NONSEASONAL DIFFEREN



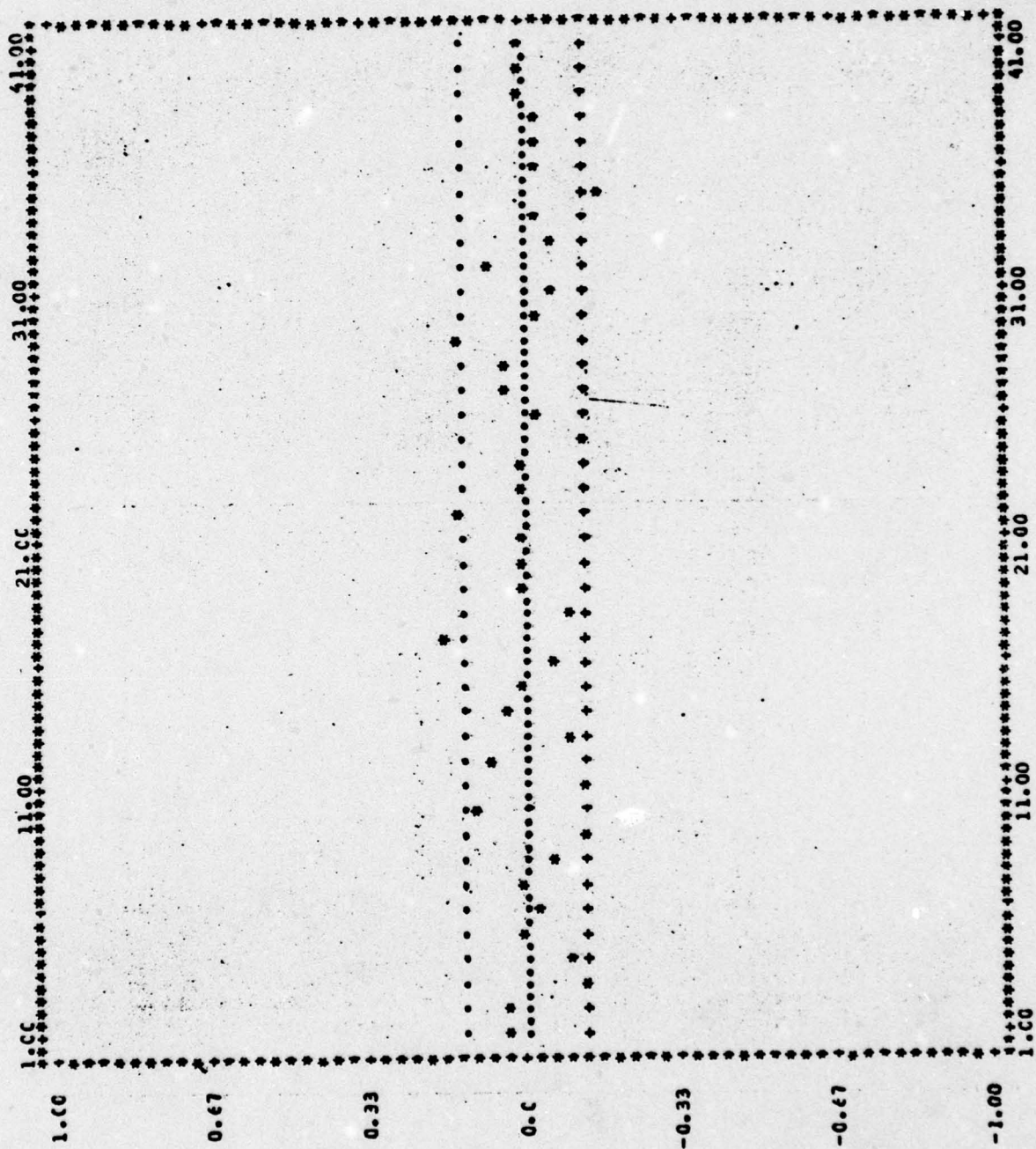
AUTOCORRELATIONS

0.019	0.024	-0.134	-0.053	-0.212	-0.043	0.005	-0.063	-0.125	0.086
-0.142	0.069	-0.098	0.021	-0.004	-0.053	0.157	-0.090	0.125	-0.006
-0.009	0.133	0.655	-0.015	-0.133	-0.019	0.049	0.043	0.123	-0.071
-0.078	0.058	-0.078	-0.015	-0.171	-0.028	-0.049	-0.035	0.033	0.006

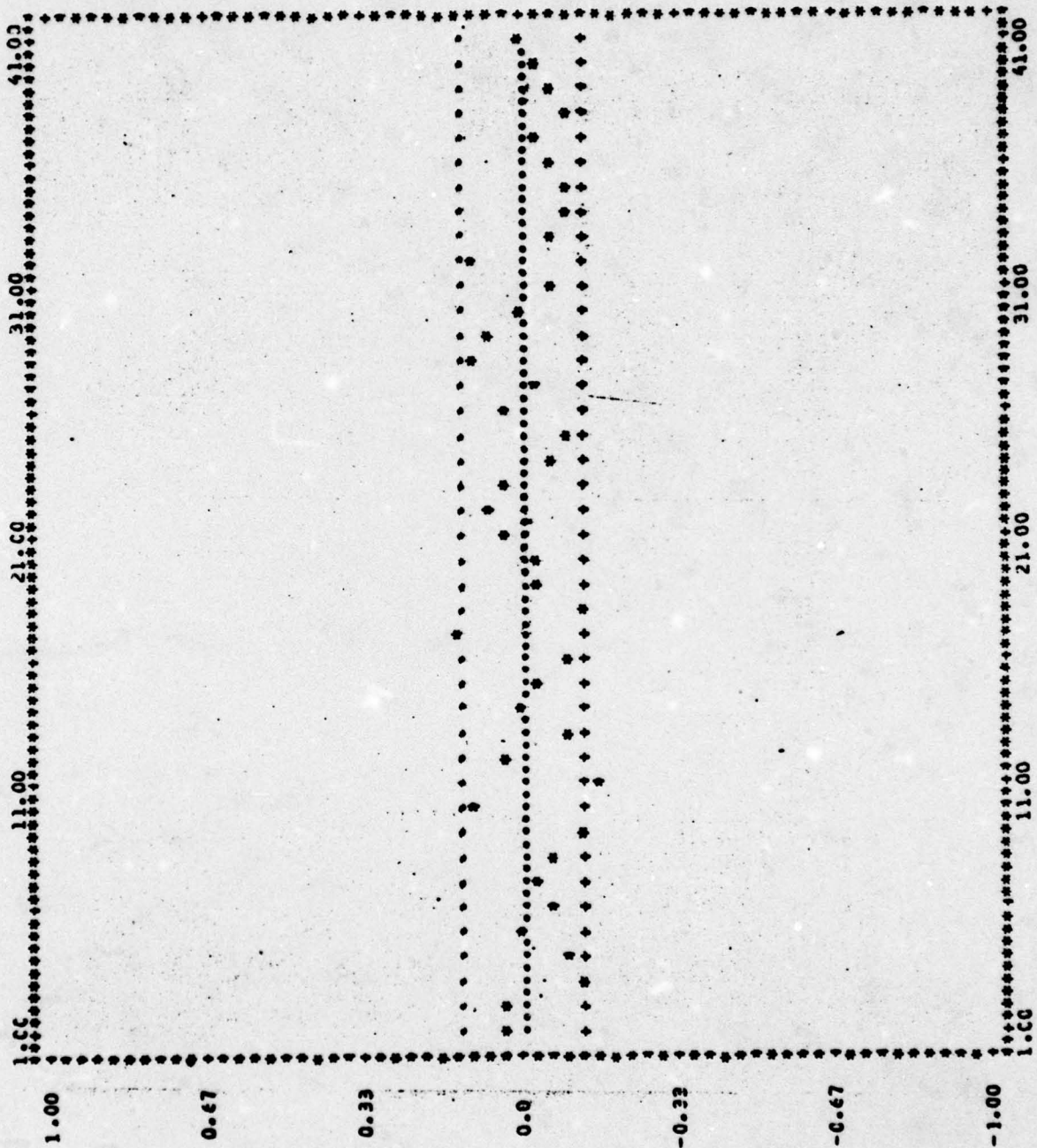
PARTIAL AUTOCORRELATIONS

0.019	0.033	-0.135	-0.090	0.001	-0.055	-0.019	-0.071	-0.143	0.087
-0.166	0.017	-0.104	-0.113	-0.025	-0.089	0.123	-0.123	-0.021	-0.023
-0.024	0.065	0.024	-0.065	-0.102	0.040	-0.019	0.083	0.056	0.005
-0.079	0.103	-0.056	-0.088	-0.112	-0.067	-0.043	-0.101	-0.078	-0.036

MEAN=C.236684E-02      VARIANCE = 0.169503E-01



AUTOCORRELATIONS WITH 2 SIGMA BANDS.



PARTIAL AUTOCORRELATIONS WITH 2 SIGMA BANDS  
 ALTOS AND PAUTOS OF RESTOJALS / ARIMA(0,2,2) MODEL OF SERIES



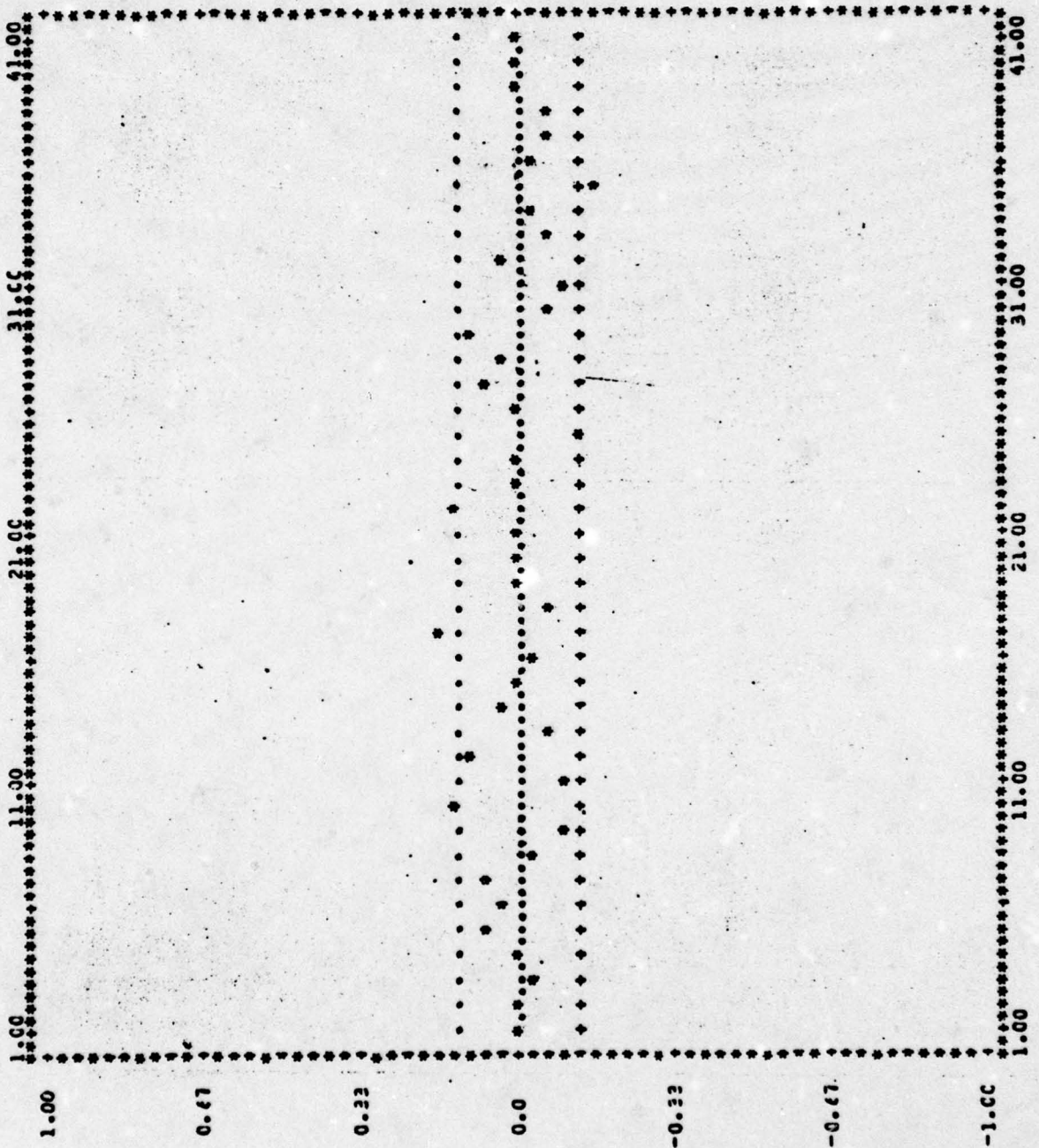
AUTCCORRELATIONS

0.016	0.014	0.049	-0.095	0.061	0.024	0.078	-0.018	-0.087	0.130
-0.003	0.084	-0.012	0.043	0.007	-0.040	0.129	-0.075	-0.001	-0.010
-0.000	0.125	0.014	-0.013	-0.127	0.014	0.052	0.032	0.115	-0.060
-0.112	0.045	-0.073	-0.023	-0.166	-0.027	-0.056	-0.062	-0.002	-0.008

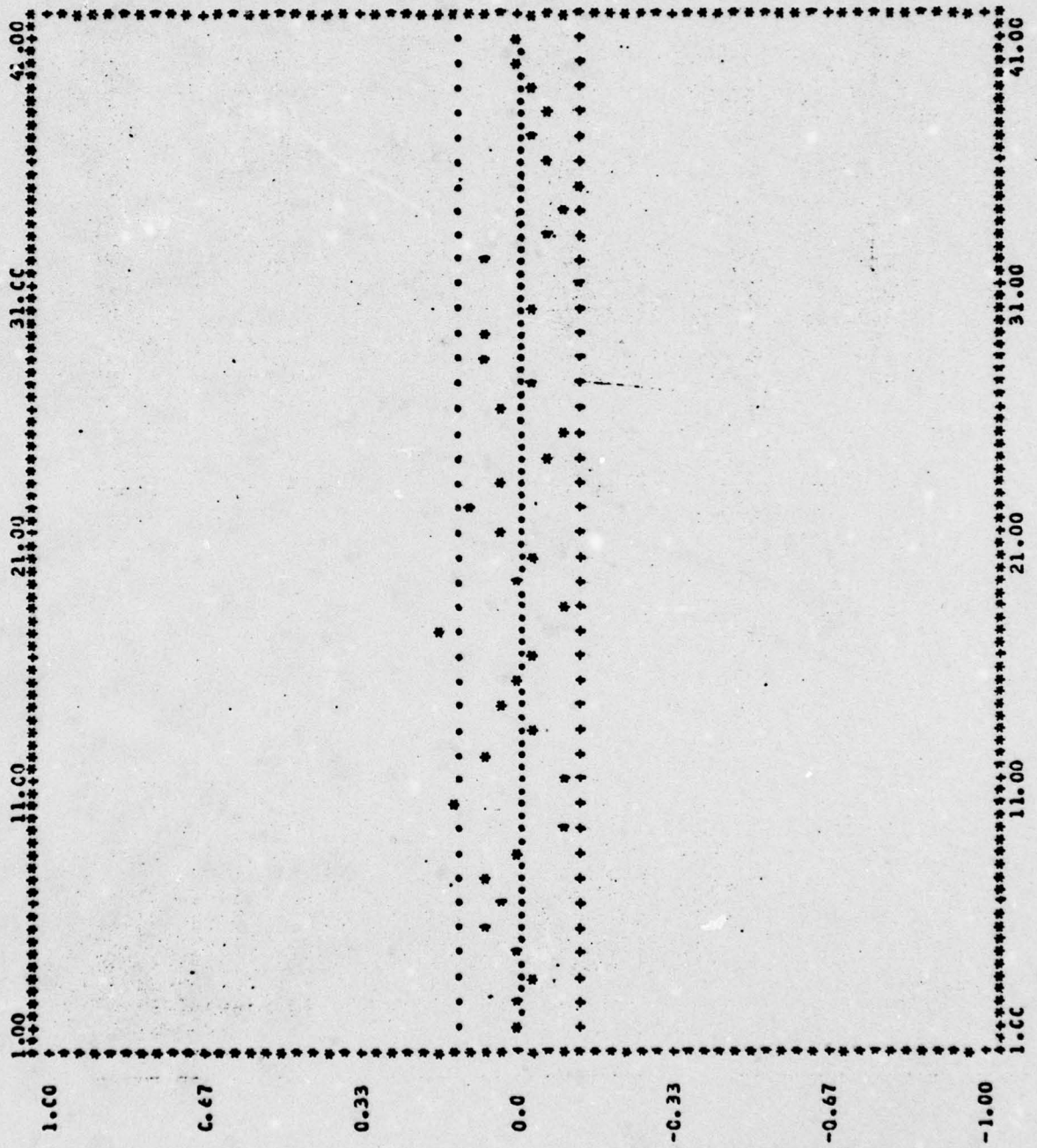
PARTIAL AUTCCORRELATIONS

0.016	0.014	-0.050	-0.004	0.063	0.019	0.075	-0.015	-0.087	0.145
-0.104	0.070	-0.048	0.032	0.003	-0.030	0.158	-0.088	0.013	-0.025
0.030	0.086	0.035	-0.022	-0.101	0.031	-0.021	0.077	-0.058	-0.026
-0.117	0.070	-0.082	-0.032	-0.121	-0.059	-0.029	-0.063	-0.032	0.010

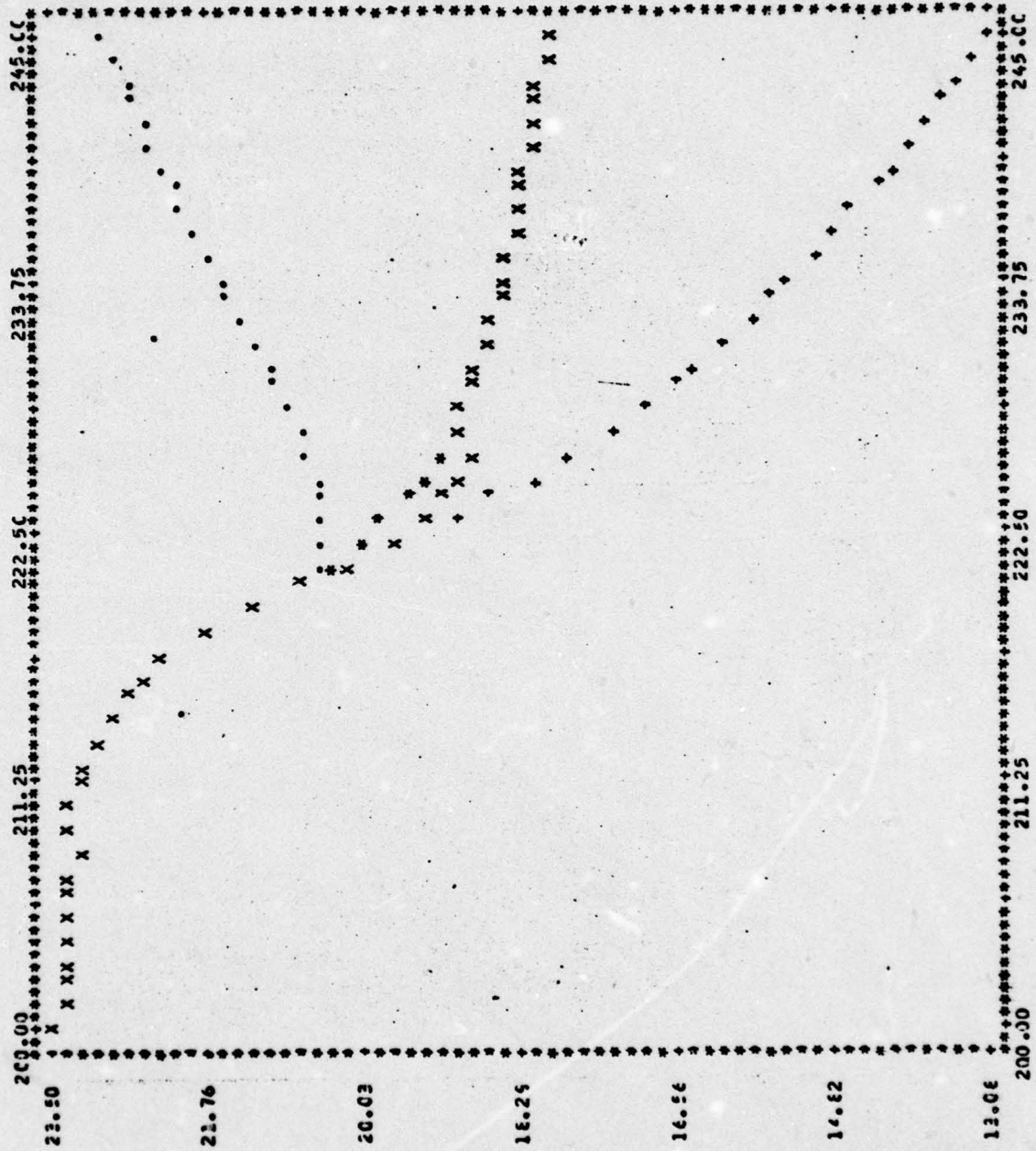
MEAN = -.252517E-02      VARIANCE = 0.177569E-01



AUTOCORRELATIONS WITH 2 SIGMA BANDS.



PARTIAL AUTOCCORRELATIONS WITH 2 SIGMA BANDS  
 AUTCS AND PARTCS OF RESIDUALS / ARIMA(1,1,0) MODEL OF SERIES



ORIGINAL AND FORECASTED TIME SERIES.

FORECAST VALUES:

20: 155648	20: 051457	19: 772186	19: 322556	19: 432561
19: 130074	18: 082742	18: 224905	18: 222431	18: 420977
18: 359522	18: 112511	18: 203563	18: 224899	18: 420977
18: 143850	18: 105111	18: 066940	18: 029526	17: 512263

UPPER CONFIDENCE LIMITS:

20: 609390	20: 505569	20: 477855	20: 503826	20: 669162
20: 551131	20: 403334	20: 111022	20: 068032	20: 520990
20: 228152	20: 403334	20: 538022	20: 068032	20: 520990
20: 498532	20: 604263	20: 106421	20: 229548	20: 520990

LOWER CONFIDENCE LIMITS:

20: 158841	19: 557898	15: 066498	18: 576370	15: 125046
19: 700076	17: 324167	15: 08427	15: 63910	15: 125046
19: 025011	15: 760735	15: 50427	15: 25938	15: 125046
15: 78884	13: 20545	13: 37248	13: 253	15: 125046

SIGNIFICANCE LEVEL FOR CONFIDENCE INTERVALS: 90.000

FORECAST CRIGIN: 220

MAXIMUM FORECAST LEAD TIME: 25

## APPENDIX C

### KEYBOARD SESSION AND OUTPUT FROM THE ANALYSIS OF TIME SERIES G (SEASONAL)

This appendix contains the complete terminal keyboard session and all offline output from the analysis of Box and Jenkins' [Ref. 4] time series G (International airline passengers, monthly totals, Jan 1949 - Dec 1960) using the Time Series Editor. This appendix is intended to supplement the discussion of the analysis of series G given in Chapter VI of this report.

The terminal listings are presented first, followed by the computer offline output.

repeat login nur@pn@

login 162lp44 400k  
ENTER PASSWORD:

ENTER 4-DIGIT PROJECT NUMBER FOLLOWED BY 4-CHARACTER COST CENTER CODE:  
0444r172  
READY AT 15.12.34 ON 09/16/78  
CMS Version 3.25

CP  
link 2069p 191 192  
ENTER PASSWORD:

SET TO READ ONLY

ipl cms  
CMS Version 3.25

login 191  
R;  
login 192 t.p  
T (192) R/O  
R;

timeser  
EACH 2 SECONDS EXECUTION TIME IS INDICATED BY \*.

YOU HAVE ENTERED THE TIME SERIES EDITOR.

PLEASE RESPOND TO EACH QUERY WITH AN INPUT AT THE TERMINAL.  
ENTER ONLY THE FIRST LETTER FOR A WORD RESPONSE.  
ENTER NUMERICAL VALUES VIA FORTRAN FORMAT.

TYPE INTEGER VALUES (RIGHT JUSTIFIED) FOR NAMES STARTING  
WITH I THRU N. TYPE FLOATING VALUES WITH DECIMAL FOR ALL OTHERS.

DO YOU WANT A LIST OF THE OPTIONS?  
Y

OPTION	DESCRIPTION
GENERATE	-----GENERATE ANY ARIMA TIME SERIES
AUTO	-----CALCULATE AUTOCORRELATIONS, PAUTOS, MEAN AND VARIANCE
PLOT	-----PLOT A TIME SERIES
ESTIMATE	-----CALCULATE MAX LIKELIHOOD ESTIMATES OF ARMA PARAMETERS
DIFF	-----DIFFERENCE A TIME SERIES
FORECAST	-----FORECAST FUTURE VALUES, CONSTRUCT CONFIDENCE INTERVALS
TRANS	-----TRANSFORMS VALUES OF A TIME SERIES
ROOTS	-----DETERMINES ROOTS OF ARIMA CHARACTERISTIC EQUATION
ZFORMAT	-----ALTER DATA FILE TO FORMAT 5F15.6
CMSWORK	-----PERFORM CP/CMS COMMANDS IN TIMESER EXEC
SIMULATE	-----SIMULATE NONSEASONAL TIME SERIES
YESTSEAS	-----CALCULATE INITIAL SEASONAL PARAMETERS
WMARQDRT	-----MARQUARDT SOLUTION FOR PARAMETER ESTIMATES
XSUMSQ	-----CALCULATE SUM OF SQUARES FOR ARBITRARY PARAMETERS

WOULD YOU LIKE MORE INFO?  
Y

ENTER OPTION YOU WANT INFO ABOUT.  
Y

YESTSEAS ----THIS PROGRAM CALCULATES INITIAL PARAMETER ESTIMATES  
FOR SEASONAL AND NONSEASONAL ARIMA MODELS, TO BE USED AS INPUTS TO  
THE WMARQDRT PROGRAM.

DO YOU WANT INFO ABOUT ANOTHER OPTION?  
Y  
ENTER OPTION YOU WANT INFO ABOUT.  
W

WMARQRTD ----THIS PROGRAM CALCULATES NON-LINEAR LEAST SQUARES ESTIMATES OF BOX-JENKINS PARAMETERS FOR A GENERAL (SEASONAL OR NONSEASONAL) ARIMA MODEL. IT REQUIRES INITIAL PARAMETER ESTIMATES AS STARTING VALUES; THESE MAY BE CALCULATED USING PROGRAM YESTSEAS.

DO YOU WANT INFO ABOUT ANOTHER OPTION?

y

ENTER OPTION YOU WANT INFO ABOUT.

x

XSUMSQ -----THIS PROGRAM CALCULATES THE SUM OF SQUARED RESIDUALS FOR ANY SET OF ARIMA (SEASONAL OR NONSEASONAL) PARAMETERS.

DO YOU WANT INFO ABOUT ANOTHER OPTION?

n

\*DO YOU WANT TO TRY A SESSION?

y

ENTER LETTER FOR OPTION YOU WANT.

c

ENTER DESIRED CP/CMS COMMANDS, ONE PER LINE.

WHEN FINISHED TYPE: &GOTO -QUES

stat

P (191): 26 FILES; 235 REC IN USE, 61 LEFT (of 296), 79% FULL (2 CYL)

cp q f

FILES:- NO RDR, NO PRT, NO PUN

listf \* ft02f001

FILENAME FILETYPE MODE NO.REC. DATE

SERG FT02F001 P1 3 9/16

SERC FT02F001 P1 .5 9/16

alter serg ft02f001 pl file ft02f001 pl

&goto -ques

DO YOU WANT TO GO AGAIN?

y

ENTER LETTER FOR OPTION YOU WANT.

p

IS YOUR DATA IN FILE FT02F001?

y

EXECUTION BEGINS...

ENTER TITLE FOR PLOT

series q data / undifferenced

TIME SERIES PLOTS HAVE BEEN PRINTED OFFLINE

DO YOU WANT TO GO AGAIN?

y

ENTER LETTER FOR OPTION YOU WANT.

a

IS YOUR DATA IN FILE FT02F001?

y

EXECUTION BEGINS...

#### AUTOCORRELATIONS

0.948	0.876	0.807	0.753	0.714	0.682	0.663	0.656	0.671	0.703
0.743	0.760	0.713	0.646	0.586	0.538	0.500	0.469	0.450	0.442
0.457	0.482	0.517	0.532	0.494					

#### PARTIAL AUTOCORRELATIONS

0.948	-0.229	0.038	0.094	0.074	0.008	0.126	0.090	0.232	0.166
0.171	-0.135	-0.540	-0.027	0.091	0.025	0.032	0.077	0.048	-0.046
0.046	-0.100	0.052	0.048	-0.163					

MEAN= 280.299

VARIANCE = 14292.0

ENTER TITLE FOR PLOTS.  
autos and pautos of series g data / undifferenced  
YOUR AUTO AND PAUTO PLOTS HAVE BEEN PRINTED OFFLINE.  
PICK UP IN ROOM I140 UNDER YOUR USER ID NUMBER.  
DO YOU WANT TO GO AGAIN?  
y

ENTER LETTER FOR OPTION YOU WANT.

t  
IS YOUR DATA IN FILE FT02F001?

y  
EXECUTION BEGINS...

DO YOU WANT TO TRANSLATE THE ORIGIN: W=Z-SHIFT?

n  
DO YOU WANT TO RESCALE THE VALUES: W=Z\*SCALE?

n  
DO YOU WANT A LOG TRANSFORMATION?

y  
TRANSFORMATION IS  $W(I) = \text{LOG}(\text{SCALE} * (\text{Z}(I) - \text{SHIFT}) - \text{FACTOR})$  WHERE:

SCALE= 1.00000      SHIFT=0.0      FACTOR=0.0  
YOUR ORIGINAL SERIES IS IN DATA FT02F001 P1.  
YOUR TRANSFORMED SERIES IS IN FILE FT02F001 P1.

DO YOU WANT TO PLOT THE TRANSFORMED VALUES?

y  
EXECUTION BEGINS...

\* ENTER TITLE FOR PLOT  
plot of series g data / natural log transform  
TIME SERIES PLOTS HAVE BEEN PRINTED OFFLINE

DO YOU WANT TO GO AGAIN?

y

ENTER LETTER FOR OPTION YOU WANT.

a  
IS YOUR DATA IN FILE FT02F001?

y  
EXECUTION BEGINS...

AUTOCORRELATIONS

0.954	0.899	0.851	0.808	0.779	0.756	0.738	0.727	0.734	0.744
0.758	0.762	0.717	0.663	0.618	0.576	0.544	0.519	0.501	0.490
0.498	0.506	0.517	0.520	0.484					

PARTIAL AUTOCORRELATIONS

0.954	-0.118	0.054	0.024	0.116	0.044	0.038	0.100	0.204	0.064
0.106	-0.042	-0.485	-0.034	0.042	-0.044	0.028	0.037	0.042	0.014
0.073	-0.033	0.061	0.031	-0.194					

MEAN= 5.54218

VARIANCE = 0.193531

ENTER TITLE FOR PLOTS.  
autos and pautos of series g data / natural log transform  
YOUR AUTO AND PAUTO PLOTS HAVE BEEN PRINTED OFFLINE.  
PICK UP IN ROOM I140 UNDER YOUR USER ID NUMBER.  
DO YOU WANT TO GO AGAIN?  
y

ENTER LETTER FOR OPTION YOU WANT.

d  
IS YOUR DATA IN FILE FT02F001?

y  
EXECUTION BEGINS...  
IS YOUR TIME SERIES SEASONAL?

y  
ENTER ORDER OF SEASONAL DIFFERENCING.

1  
ENTER LENGTH OF SEASONAL PERIOD VIA I2.

12  
ENTER NUMBER OF NONSEASONAL DIFFERENCES.

1  
DO YOU WANT TO PLOT AUTO AND PAUTO OF TRANSFORMED DATA?

y  
EXECUTION BEGINS...

AUTOCORRELATIONS

-0.341	0.105	-0.202	0.021	0.056	0.031	-0.056	-0.001	0.176	-0.076
0.064	-0.387	0.152	-0.058	0.150	-0.139	0.071	0.016	-0.011	-0.117
0.039	-0.091	0.223	-0.018	-0.100					

PARTIAL AUTOCORRELATIONS

-0.341	-0.013	-0.193	-0.125	0.033	0.035	-0.060	-0.020	0.226	0.043
0.047	-0.339	-0.109	-0.077	-0.022	-0.140	0.026	0.115	-0.013	-0.167
0.132	-0.072	0.143	-0.067	-0.103					

MEAN=0.290920E-03      VARIANCE = 0.208604E-02

ENTER TITLE FOR PLOTS.

autos and pautos for series g sedata / 1 ns diff, 1 seas diff, ln xform  
YOUR AUTO AND PAUTO PLOTS HAVE BEEN PRINTED OFFLINE.  
PICK UP IN ROOM I140 UNDER YOUR USER ID NUMBER.

DO YOU WANT TO GO AGAIN?

y

ENTER LETTER FOR OPTION YOU WANT.

c

ENTER DESIRED CP/CMS COMMANDS, ONE PER LINE.

WHEN FINISHED TYPE: %GOTO -QUES

alter file ft03f001 pl save ft03f001 pl

alter data ft02f001 pl serg ft02f001 pl

stat

P (191): 29 FILES; 267 REC IN USE, 29 LEFT (of 296), 90% FULL (2 CYL)

erase file ft08f001

cp q f

FILES:- NO RDR, NO PRT, NO PUN

%goto -ques

DO YOU WANT TO GO AGAIN?

y

ENTER LETTER FOR OPTION YOU WANT.

y

IS YOUR DATA IN FILE FT02F001?

y

EXECUTION BEGINS...

ENTER LENGTH OF SEASON VIA FORMAT I2.

12

ENTER NUMBER OF NON-SEASONAL DIFFERENCES.

1

ENTER NUMBER OF SEASONAL DIFFERENCES.

1

ENTER NUMBER OF NON-SEASONAL AR PARAMETERS.

0

ENTER NUMBER OF SEASONAL AR PARAMETERS.  
0  
ENTER NUMBER OF NON-SEASONAL MA PARAMETERS.  
1  
ENTER NUMBER OF SEASONAL MA PARAMETERS.  
1

INITIAL PARAMETER ESTIMATES FOR MARQRT :

THETA(1) = 0.390425  
THETAS(1) = 0.534397

DO YOU WANT TO GO AGAIN?  
Y

ENTER LETTER FOR OPTION YOU WANT.

W  
IS YOUR DATA IN FILE FT02F001?

Y  
EXECUTION BEGINS...  
ENTER NUMBER OF NON-SEASONAL DIFFERENCES.

1  
ENTER NUMBER OF SEASONAL DIFFERENCES.

1  
ENTER NUMBER OF NON-SEASONAL AR PARAMETERS.

0  
ENTER NUMBER OF SEASONAL AR PARAMETERS.

0  
ENTER NUMBER OF NON-SEASONAL MA PARAMETERS.

1  
ENTER NUMBER OF SEASONAL MA PARAMETERS.

1  
ENTER LENGTH OF SEASON VIA FORMAT I2.  
12

NOW INPUT YOUR INITIAL PARAMETER ESTIMATES, AS REQUESTED.

ENTER NON-SEASONAL MA PARAMETER THETA(1).  
.390425  
ENTER SEASONAL MA PARAMETER THETAS(1).  
.534397  
\*

CONVERGENCE HAS BEEN REACHED IN MAX( 7, 7) ITERATIONS.

SELECTED OUTPUT FOLLOWS:

PARAMETER ESTIMATE	STANDARD ERROR
THETA(1) = 0.377152	0.819933D-01
THETAS(1) = 0.572387	0.780252D-01

MOVING AVERAGE CONSTANT: THETA0 = 0.000291

\*\*

CHI-SQUARE STATISTIC FOR RESIDUAL LACK OF FIT = 29.713571

DEGREES OF FREEDOM = 38

PROBABILITY OF EXCEEDING STATISTIC = 0.829438

DO YOU WANT TO PLOT AUTO AND PAUTO OF RESIDUALS?

Y

EXECUTION BEGINS...

AUTOCORRELATIONS

0.009	0.026	-0.129	-0.105	0.078	0.077	-0.036	-0.033	0.103	-0.050
0.026	-0.020	0.013	0.035	0.067	-0.130	0.052	0.015	-0.093	-0.090
-0.027	-0.014	0.213	0.009	-0.042					

PARTIAL AUTOCORRELATIONS

0.009	0.026	-0.130	-0.104	0.088	0.068	-0.072	-0.029	0.151	-0.057
-0.022	0.018	0.046	0.001	0.053	-0.114	0.069	0.029	-0.129	-0.134
0.042	-0.014	0.143	-0.025	0.013					

MEAN=0.236005E-02      VARIANCE = 0.139713E-02

ENTER TITLE FOR PLOTS.

autos and pautos of residuals / (0,1,1)x(0,1,1)2 model of series g

YOUR AUTO AND PAUTO PLOTS HAVE BEEN PRINTED OFFLINE.

PICK UP IN ROOM I140 UNDER YOUR USER ID NUMBER.

\*

DO YOU WANT TO GO AGAIN?

Y

ENTER LETTER FOR OPTION YOU WANT.

Y

IS YOUR DATA IN FILE FT02F001?

Y

EXECUTION BEGINS...

ENTER LENGTH OF SEASON VIA FORMAT I2.

12

ENTER NUMBER OF NON-SEASONAL DIFFERENCES.

1

ENTER NUMBER OF SEASONAL DIFFERENCES.

1

ENTER NUMBER OF NON-SEASONAL AR PARAMETERS.

1

ENTER NUMBER OF SEASONAL AR PARAMETERS.

0

ENTER NUMBER OF NON-SEASONAL MA PARAMETERS.

1

ENTER NUMBER OF SEASONAL MA PARAMETERS.

1

\*\*\*

INITIAL PARAMETER ESTIMATES FOR MARQRT :

PHI(1) = 0.112699

THETA(1) = 0.490883

THETAS(1) = 0.533679

DO YOU WANT TO GO AGAIN?

Y

ENTER LETTER FOR OPTION YOU WANT.

W

IS YOUR DATA IN FILE FT02F001?

Y

EXECUTION BEGINS...

ENTER NUMBER OF NON-SEASONAL DIFFERENCES.

1

ENTER NUMBER OF SEASONAL DIFFERENCES.

1

ENTER NUMBER OF NON-SEASONAL AR PARAMETERS.

1

ENTER NUMBER OF SEASONAL AR PARAMETERS.

0  
ENTER NUMBER OF NON-SEASONAL MA PARAMETERS.

1  
ENTER NUMBER OF SEASONAL MA PARAMETERS.

1  
ENTER LENGTH OF SEASON VIA FORMAT I2.  
12

NOW INPUT YOUR INITIAL PARAMETER ESTIMATES, AS REQUESTED.

ENTER NON-SEASONAL AR PARAMETER PHI(1).  
0.112699

ENTER NON-SEASONAL MA PARAMETER THETA(1).  
0.490883

ENTER SEASONAL MA PARAMETER THETAS(1).  
0.533679  
\*\*\*

CONVERGENCE HAS BEEN REACHED IN MAX(10,10) ITERATIONS.

SELECTED OUTPUT FOLLOWS:

PARAMETER ESTIMATE	STANDARD ERROR
PHI(1) = 0.146667	0.224464D 00
THETA(1) = 0.509816	0.195934D 00
THETAS(1) = 0.573388	0.784896D-01

MOVING AVERAGE CONSTANT: THETA0 = 0.000248

CHI-SQUARE STATISTIC FOR RESIDUAL LACK OF FIT = 28.302543

DEGREES OF FREEDOM = 37

PROBABILITY OF EXCEEDING STATISTIC = 0.847102

DO YOU WANT TO PLOT AUTO AND PAUTO OF RESIDUALS?

Y

\*EXECUTION BEGINS...

AUTOCORRELATIONS

-0.013	0.073	-0.100	-0.088	0.077	0.073	-0.031	-0.033	0.105	-0.054
0.033	-0.018	0.014	0.027	0.070	-0.133	0.051	0.008	-0.092	-0.084
-0.020	-0.023	0.208	0.005	-0.036					

PARTIAL AUTOCORRELATIONS

-0.013	0.073	-0.098	-0.096	0.092	0.081	-0.064	-0.040	0.152	-0.050
-0.027	0.017	0.047	-0.004	0.053	-0.118	0.055	0.031	-0.123	-0.135
0.051	-0.006	0.148	-0.019	0.003					

MEAN=0.253052E-02      VARIANCE = 0.139373E-02

ENTER TITLE FOR PLOTS.

autos and pautos of residuals / (1,1,1)x(0,1,1)12 model of series g

YOUR AUTO AND PAUTO PLOTS HAVE BEEN PRINTED OFFLINE.

PICK UP IN ROOM I140 UNDER YOUR USER ID NUMBER.

DO YOU WANT TO GO AGAIN?

Y

ENTER LETTER FOR OPTION YOU WANT.

f

IS YOUR DATA IN FILE FT02F001?

y

EXECUTION BEGINS...

IS YOUR SERIES SEASONAL?

y

ENTER SEASONAL DATA AS REQUESTED:

ENTER NUMBER OF SEASONAL DIFFERENCES.

1

ENTER NUMBER OF SEASONAL AR PARAMETERS.

0

ENTER NUMBER OF SEASONAL MA PARAMETERS.

1

ENTER LENGTH OF SEASON VIA FORMAT I2.

12

ENTER NONSEASONAL DATA AS REQUESTED:

ENTER NUMBER OF NON-SEASONAL DIFFERENCES.

1

ENTER NUMBER OF NON-SEASONAL AR PARAMETERS.

0

ENTER NUMBER OF NON-SEASONAL MA PARAMETERS.

1

NOW INPUT YOUR PARAMETER ESTIMATES:

ENTER MA CONSTANT TERM, THETA0.

.000291

ENTER NON-SEASONAL MA PARAMETER THETA(1).

.377152

ENTER SEASONAL MA PARAMETER THETAS(1).

.572387

ENTER MAXIMUM FORECAST LEAD TIME VIA FORMAT I2.

30

ENTER INDEX FOR PLOT ORIGIN VIA FORMAT I3.

100

ENTER INDEX FOR FORECAST ORIGIN VIA FORMAT I3.

131

ENTER SIGNIFICANCE LEVEL FOR CONFIDENCE INTERVALS.

0.10

WAS YOUR DATA TRANSFORMED IN THE TRANS PROGRAM?

y

DO YOU WANT BASIC OUTPUT AT THE TERMINAL?

y

THE LAST 10 WVEC VALUES:

0.418999E 03 0.461001E 03 0.472000E 03 0.535001E 03 0.622000E 03  
0.606000E 03 0.507999E 03 0.461001E 03 0.390001E 03 0.432002E 03

THE 30 FORECAST VALUES:

0.398539E 03 0.415184E 03 0.395402E 03 0.462697E 03 0.450971E 03  
0.469710E 03 0.543456E 03 0.618194E 03 0.626276E 03 0.524292E 03  
0.460421E 03 0.405213E 03 0.448016E 03 0.466864E 03 0.444748E 03  
0.520593E 03 0.507548E 03 0.528791E 03 0.611991E 03 0.696357E 03  
0.705666E 03 0.590927E 03 0.519089E 03 0.456978E 03 0.505397E 03  
0.526812E 03 0.502002E 03 0.587782E 03 0.573220E 03 0.597386E 03

THE 30 UPPER FORECAST CONFIDENCE LIMITS:

0.399598E 03	0.416254E 03	0.396481E 03	0.463785E 03	0.452068E 03
0.470813E 03	0.544567E 03	0.619311E 03	0.627399E 03	0.525422E 03
0.461557E 03	0.406354E 03	0.449173E 03	0.468030E 03	0.445925E 03
0.521779E 03	0.508743E 03	0.529995E 03	0.613203E 03	0.697577E 03
0.706894E 03	0.592163E 03	0.520332E 03	0.458229E 03	0.506664E 03
0.528090E 03	0.503292E 03	0.589083E 03	0.574532E 03	0.598708E 03

ALPHA FOR THE CONFIDENCE LIMITS IS: 0.100

\*  
DO YOU WANT TO GO AGAIN?

Y

ENTER LETTER FOR OPTION YOU WANT.

F

IS YOUR DATA IN FILE FT02F001?

Y

EXECUTION BEGINS...

IS YOUR SERIES SEASONAL?

Y

ENTER SEASONAL DATA AS REQUESTED:

ENTER NUMBER OF SEASONAL DIFFERENCES.

1

ENTER NUMBER OF SEASONAL AR PARAMETERS.

0

ENTER NUMBER OF SEASONAL MA PARAMETERS.

1

ENTER LENGTH OF SEASON VIA FORMAT I2.

12

ENTER NONSEASONAL DATA AS REQUESTED:

ENTER NUMBER OF NON-SEASONAL DIFFERENCES.

1

ENTER NUMBER OF NON-SEASONAL AR PARAMETERS.

1

ENTER NUMBER OF NON-SEASONAL MA PARAMETERS.

1

NOW INPUT YOUR PARAMETER ESTIMATES:

ENTER MA CONSTANT TERM, THETA0.

.000248

ENTER NON-SEASONAL AR PARAMETER PHI(1).

0.146667

ENTER NON-SEASONAL MA PARAMETER THETA(1).

0.509816

ENTER SEASONAL MA PARAMETER THETAS(1).

0.573388

ENTER MAXIMUM FORECAST LEAD TIME VIA FORMAT I2.

30

ENTER INDEX FOR PLOT ORIGIN VIA FORMAT I3.

100

ENTER INDEX FOR FORECAST ORIGIN VIA FORMAT I3.

131

ENTER SIGNIFICANCE LEVEL FOR CONFIDENCE INTERVALS.

0.10

WAS YOUR DATA TRANSFORMED IN THE TRANS PROGRAM?

Y

DO YOU WANT BASIC OUTPUT AT THE TERMINAL?

Y

THE LAST 10 WVEC VALUES:

0.418999E 03 0.461001E 03 0.472000E 03 0.535001E 03 0.622000E 03  
0.606000E 03 0.507999E 03 0.461001E 03 0.390001E 03 0.432002E 03

THE 30 FORECAST VALUES:

0.398650E 03 0.414875E 03 0.395125E 03 0.462366E 03 0.450651E 03  
0.469348E 03 0.543045E 03 0.617700E 03 0.625753E 03 0.523897E 03  
0.460071E 03 0.404899E 03 0.447739E 03 0.466360E 03 0.444325E 03  
0.520096E 03 0.507066E 03 0.528257E 03 0.611381E 03 0.695632E 03  
0.704905E 03 0.590336E 03 0.518566E 03 0.456512E 03 0.504960E 03  
0.526113E 03 0.501400E 03 0.587074E 03 0.572532E 03 0.596632E 03

THE 30 UPPER FORECAST CONFIDENCE LIMITS:

0.399709E 03 0.415945E 03 0.396204E 03 0.463452E 03 0.451744E 03  
0.470448E 03 0.544151E 03 0.618812E 03 0.626870E 03 0.525020E 03  
0.461199E 03 0.406032E 03 0.448887E 03 0.467517E 03 0.445491E 03  
0.521270E 03 0.508249E 03 0.529448E 03 0.612579E 03 0.696837E 03  
0.706117E 03 0.591556E 03 0.519792E 03 0.457745E 03 0.506207E 03  
0.527371E 03 0.502668E 03 0.588353E 03 0.573821E 03 0.597930E 03

ALPHA FOR THE CONFIDENCE LIMITS IS: 0.100

DO YOU WANT TO GO AGAIN?

y

ENTER LETTER FOR OPTION YOU WANT.

f

IS YOUR DATA IN FILE FT02F001?

y

EXECUTION BEGINS...

IS YOUR SERIES SEASONAL?

y

ENTER SEASONAL DATA AS REQUESTED:

ENTER NUMBER OF SEASONAL DIFFERENCES.

1

ENTER NUMBER OF SEASONAL AR PARAMETERS.

0

ENTER NUMBER OF SEASONAL MA PARAMETERS.

1

ENTER LENGTH OF SEASON VIA FORMAT I2.

12

ENTER NONSEASONAL DATA AS REQUESTED:

ENTER NUMBER OF NON-SEASONAL DIFFERENCES.

1

ENTER NUMBER OF NON-SEASONAL AR PARAMETERS.

0

ENTER NUMBER OF NON-SEASONAL MA PARAMETERS.

1

NOW INPUT YOUR PARAMETER ESTIMATES:

ENTER MA CONSTANT TERM, THETA0.

.000291

ENTER NON-SEASONAL MA PARAMETER THETA(1).

.377152

ENTER SEASONAL MA PARAMETER THETAS(1).

.572387

ENTER MAXIMUM FORECAST LEAD TIME VIA FORMAT I2.

40

ENTER INDEX FOR PLOT ORIGIN VIA FORMAT I3.  
075  
ENTER INDEX FOR FORECAST ORIGIN VIA FORMAT I3.  
120  
ENTER SIGNIFICANCE LEVEL FOR CONFIDENCE INTERVALS.  
0.10

WAS YOUR DATA TRANSFORMED IN THE TRANS PROGRAM?  
y

DO YOU WANT BASIC OUTPUT AT THE TERMINAL?  
n  
\*  
DO YOU WANT TO GO AGAIN?  
y

ENTER LETTER FOR OPTION YOU WANT.

d  
IS YOUR DATA IN FILE FT02F001?

y  
EXECUTION BEGINS...  
IS YOUR TIME SERIES SEASONAL?

y  
ENTER ORDER OF SEASONAL DIFFERENCING.

1  
ENTER LENGTH OF SEASONAL PERIOD VIA I2.

12  
ENTER NUMBER OF NONSEASONAL DIFFERENCES.

1  
DO YOU WANT TO PLOT AUTO AND PAUTO OF TRANSFORMED DATA?

n  
DO YOU WANT TO GO AGAIN?  
y

ENTER LETTER FOR OPTION YOU WANT.

c  
ENTER DESIRED CP/CMS COMMANDS, ONE PER LINE.

WHEN FINISHED TYPE: &GOTO -QUES  
alter file ft02f001 pl lnsrg ft02f001 pl  
alter file ft03f001 pl file ft02f001 pl  
&goto -ques

DO YOU WANT TO GO AGAIN?  
y

ENTER LETTER FOR OPTION YOU WANT.

x  
IS YOUR DATA IN FILE FT02F001?  
y  
EXECUTION BEGINS...

IS YOUR SERIES SEASONAL?

y  
ENTER LENGTH OF SEASON VIA FORMAT I2.

12  
ENTER NUMBER OF SEASONAL AR PARAMETERS.

0  
ENTER NUMBER OF SEASONAL MA PARAMETERS.

1  
ENTER NUMBER OF NON-SEASONAL AR PARAMETERS.

0  
ENTER NUMBER OF NON-SEASONAL MA PARAMETERS.

1

NOW INPUT YOUR INITIAL PARAMETER ESTIMATES, AS REQUESTED.

ENTER NON-SEASONAL MA PARAMETER THETA(1).

.377152

ENTER SEASONAL MA PARAMETER THETAS(1).

.572387

FOR THE GIVEN INPUT PARAMETERS AND MODEL

THE RESIDUAL SUM OF SQUARES IS: 0.18192935D 00

DO YOU WANT TO TEST DIFFERENT PARAMETER VALUES?

n

DO YOU WANT TO TEST A DIFFERENT MODEL?

y

IS YOUR SERIES SEASONAL?

y

ENTER LENGTH OF SEASON VIA FORMAT I2.

12

ENTER NUMBER OF SEASONAL AR PARAMETERS.

0

ENTER NUMBER OF SEASONAL MA PARAMETERS.

1

ENTER NUMBER OF NON-SEASONAL AR PARAMETERS.

1

ENTER NUMBER OF NON-SEASONAL MA PARAMETERS.

1

NOW INPUT YOUR INITIAL PARAMETER ESTIMATES, AS REQUESTED.

ENTER NON-SEASONAL AR PARAMETER PHI(1).

.146667

ENTER NON-SEASONAL MA PARAMETER THETA(1).

.509816

ENTER SEASONAL MA PARAMETER THETAS(1).

.573388

\*

FOR THE GIVEN INPUT PARAMETERS AND MODEL

THE RESIDUAL SUM OF SQUARES IS: 0.18164378D 00

DO YOU WANT TO TEST DIFFERENT PARAMETER VALUES?

n

DO YOU WANT TO TEST A DIFFERENT MODEL?

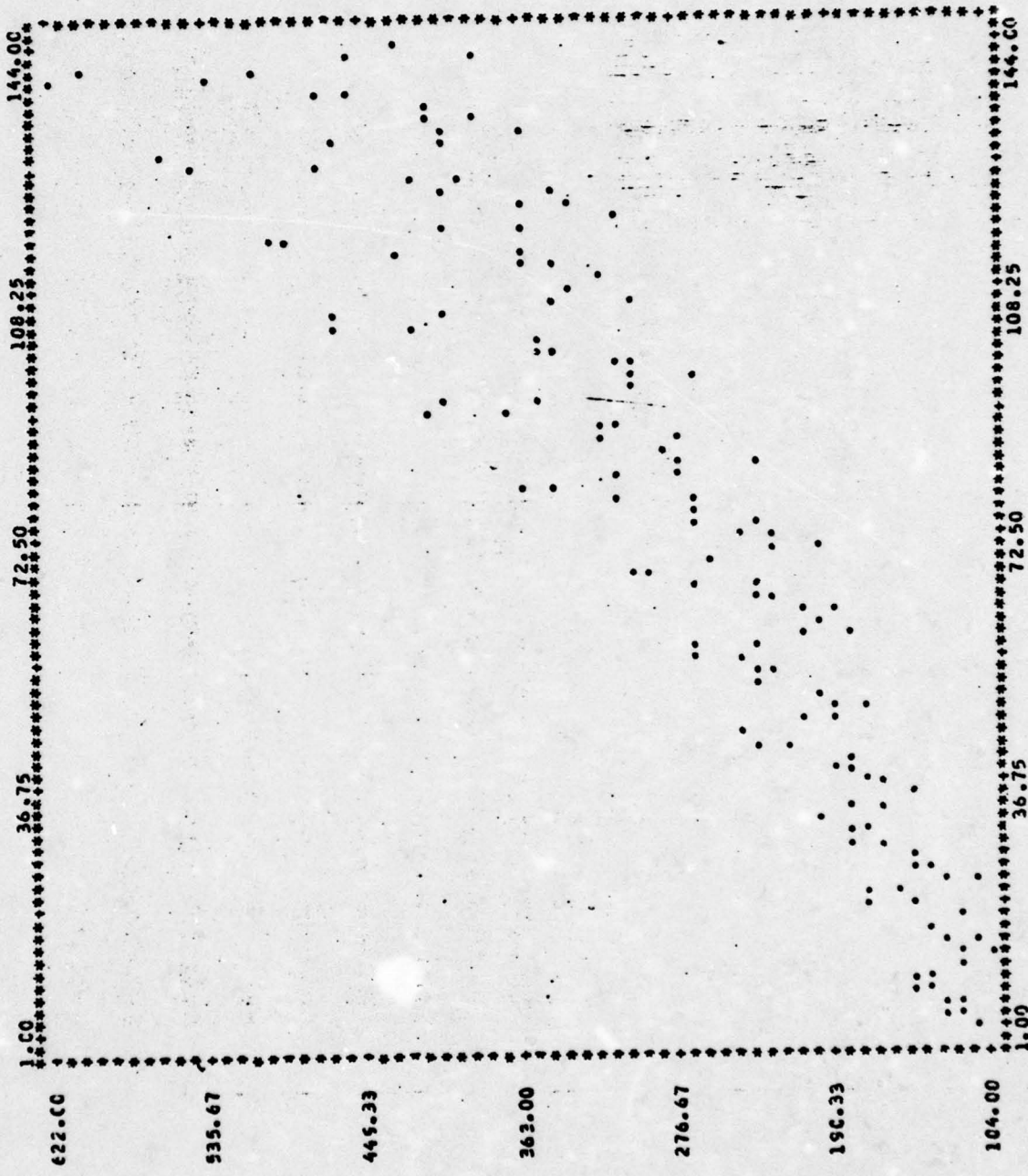
n

DO YOU WANT TO GO AGAIN?

n

CONTROL RETURNED TO CMS

R;



X-SCALE: \*\*= 0.179E 01 UNITS  
 Y-SCALE: \*\*= 0.865E 01 UNITS  
 SERIES: G DATA / UNDIFFERENCED

ALTCORRELATIONS

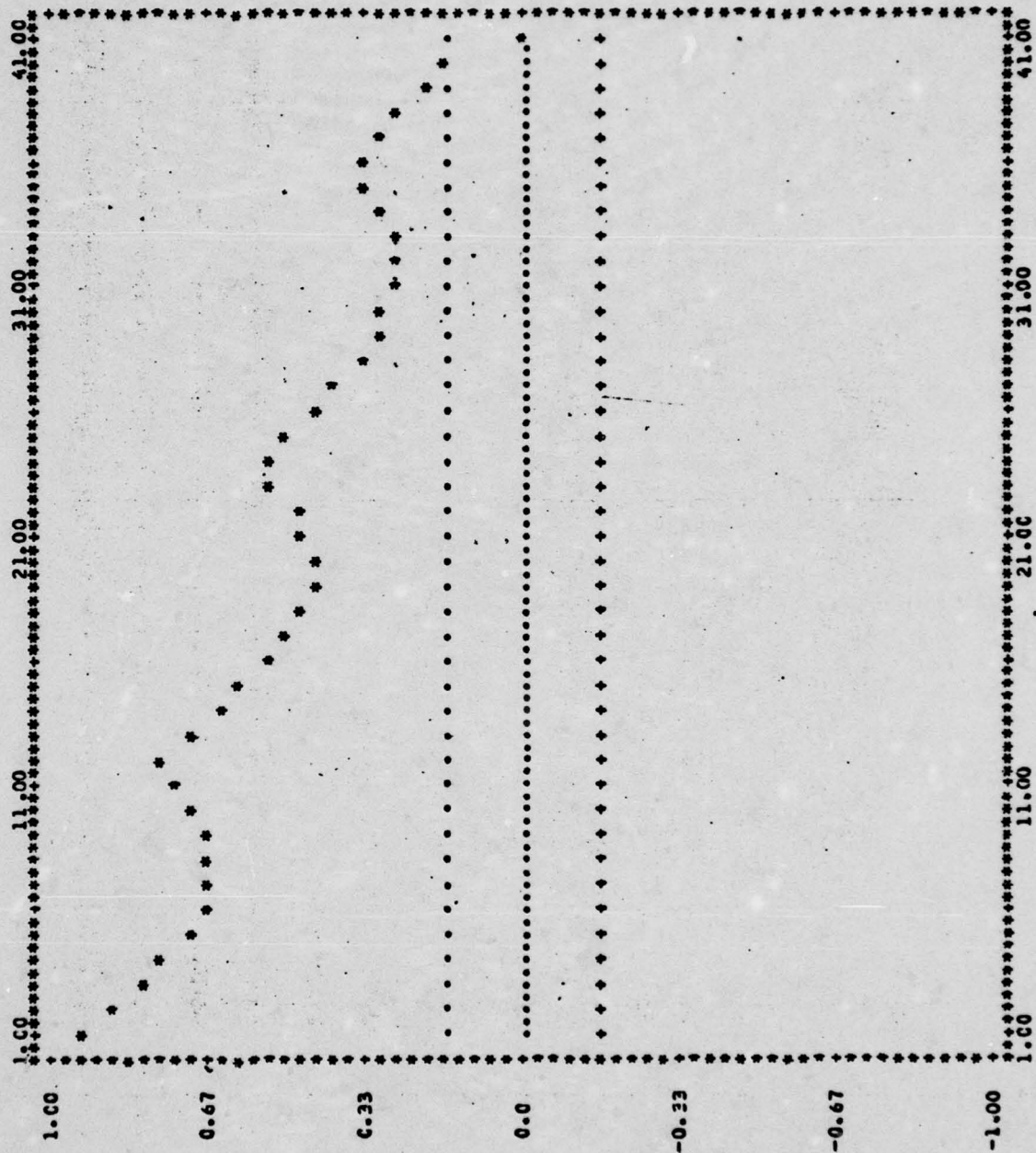
0.949	0.576	0.907	0.752	0.714	0.682	0.663	0.656	0.671	0.702
0.743	0.760	0.712	0.642	0.586	0.538	0.510	0.495	0.455	0.412
0.557	0.482	0.517	0.532	0.454	0.438	0.388	0.398	0.315	0.282
0.271	0.264	0.217	0.255	0.226	0.337	0.303	0.254	0.270	0.172

PARTIAL AUTOCORRELATIONS

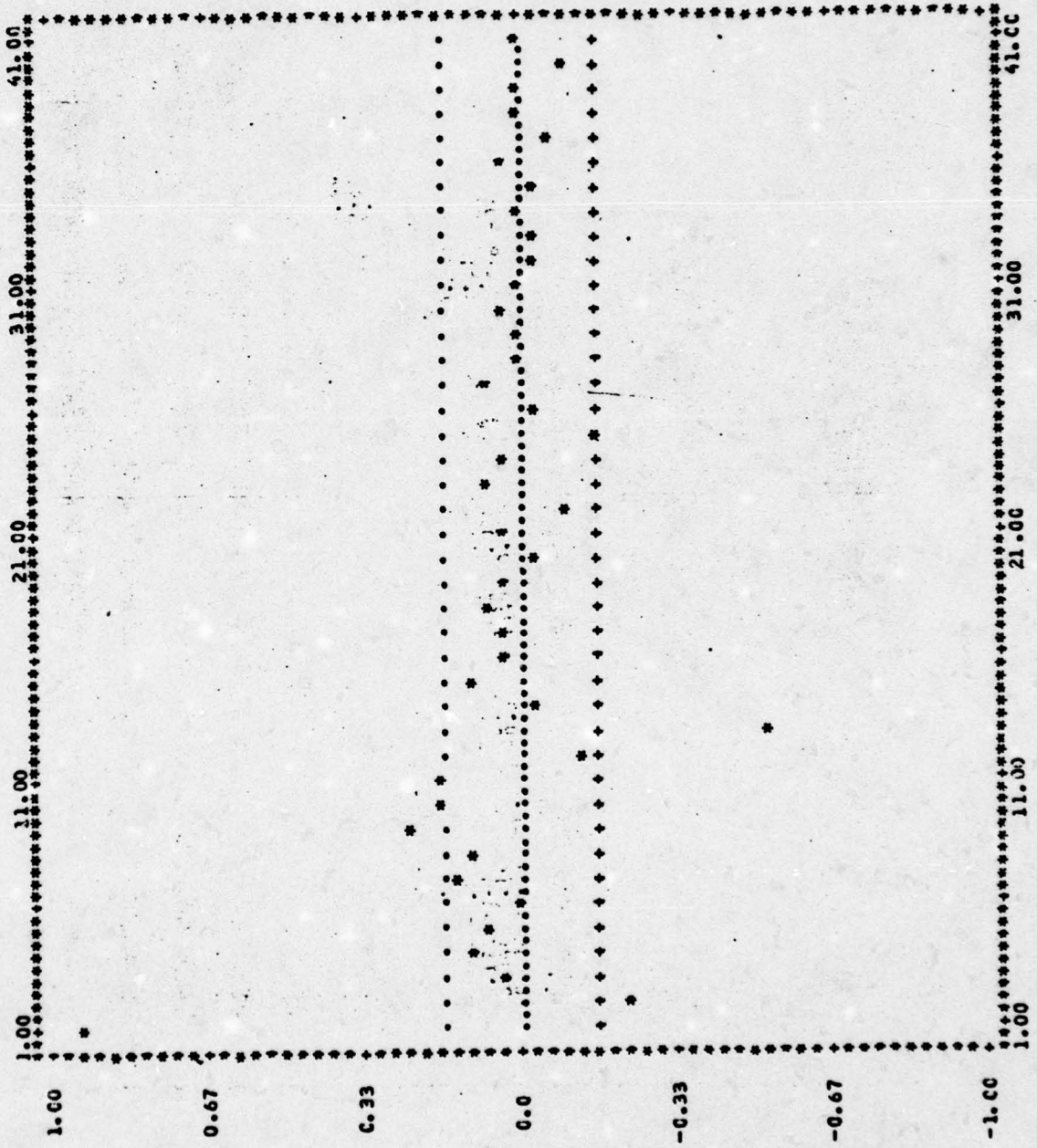
0.949	-0.225	0.038	0.094	0.074	0.008	0.126	0.090	0.232	0.166
0.171	-0.132	-0.549	-0.027	0.091	-0.025	0.032	0.073	0.048	-0.046
-0.010	-0.016	-0.025	-0.015	-0.048	-0.036	0.066	0.004	0.008	-0.019
					0.046	-0.067	-0.002	0.016	-0.088

MEAN= 280.299

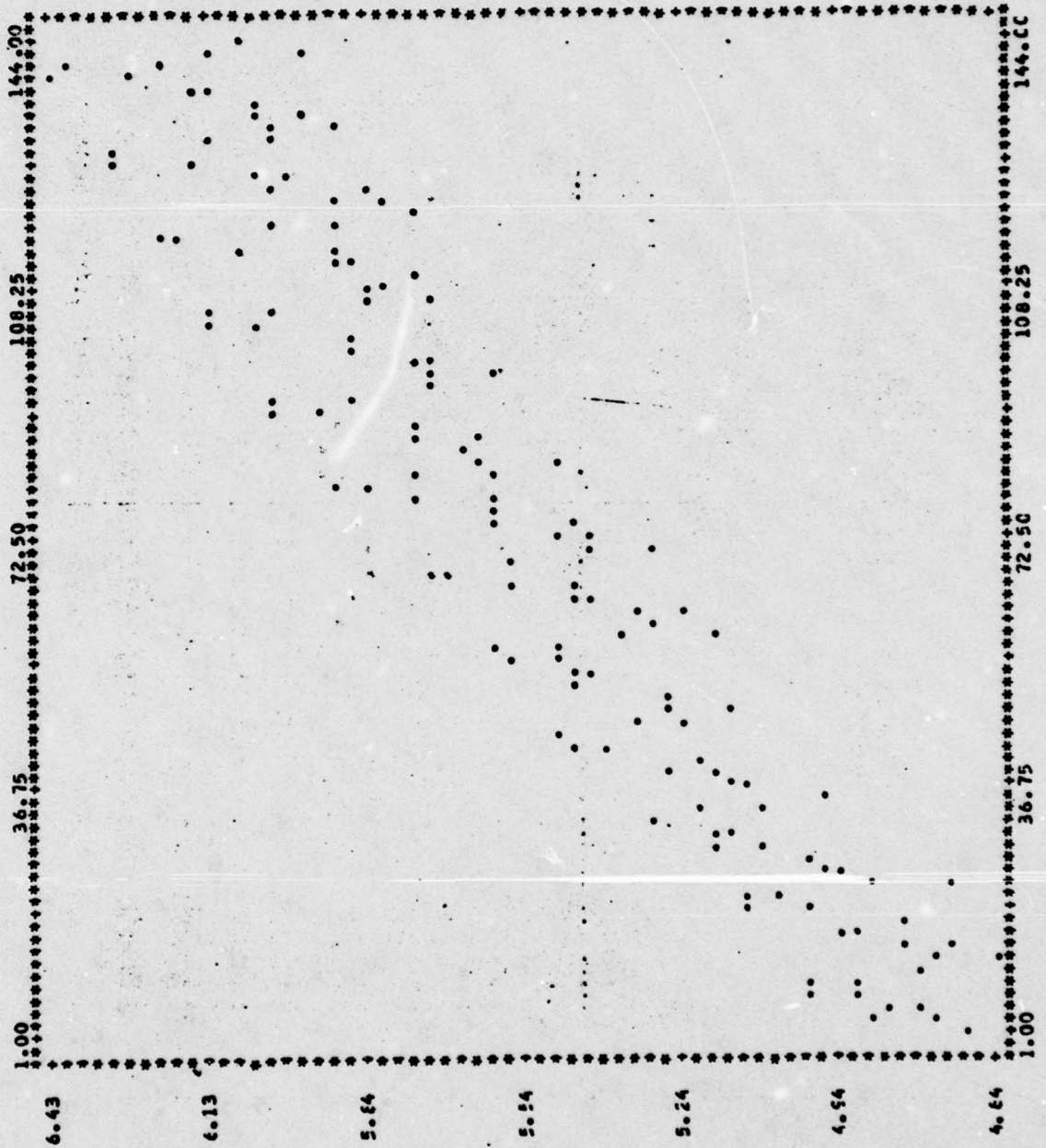
VARIANCE = 14292.0



AUTOCORRELATIONS WITH 2 SIGMA BANDS.



PARTIAL AUTOCORRELATIONS WITH 2 SIGMA BANDS.  
 AUTOS AND PACTOS OF SERIES G DAT A / UNDIFFERENCED



X-SCALE: " " " 0.179E 01 UNITS  
 Y-SCALE: " " " 0.258E-01 UNITS  
 PLOT OF SERIES G DATA 7 NATURAL LOG TRANSFORM

AUTOCORRELATIONS

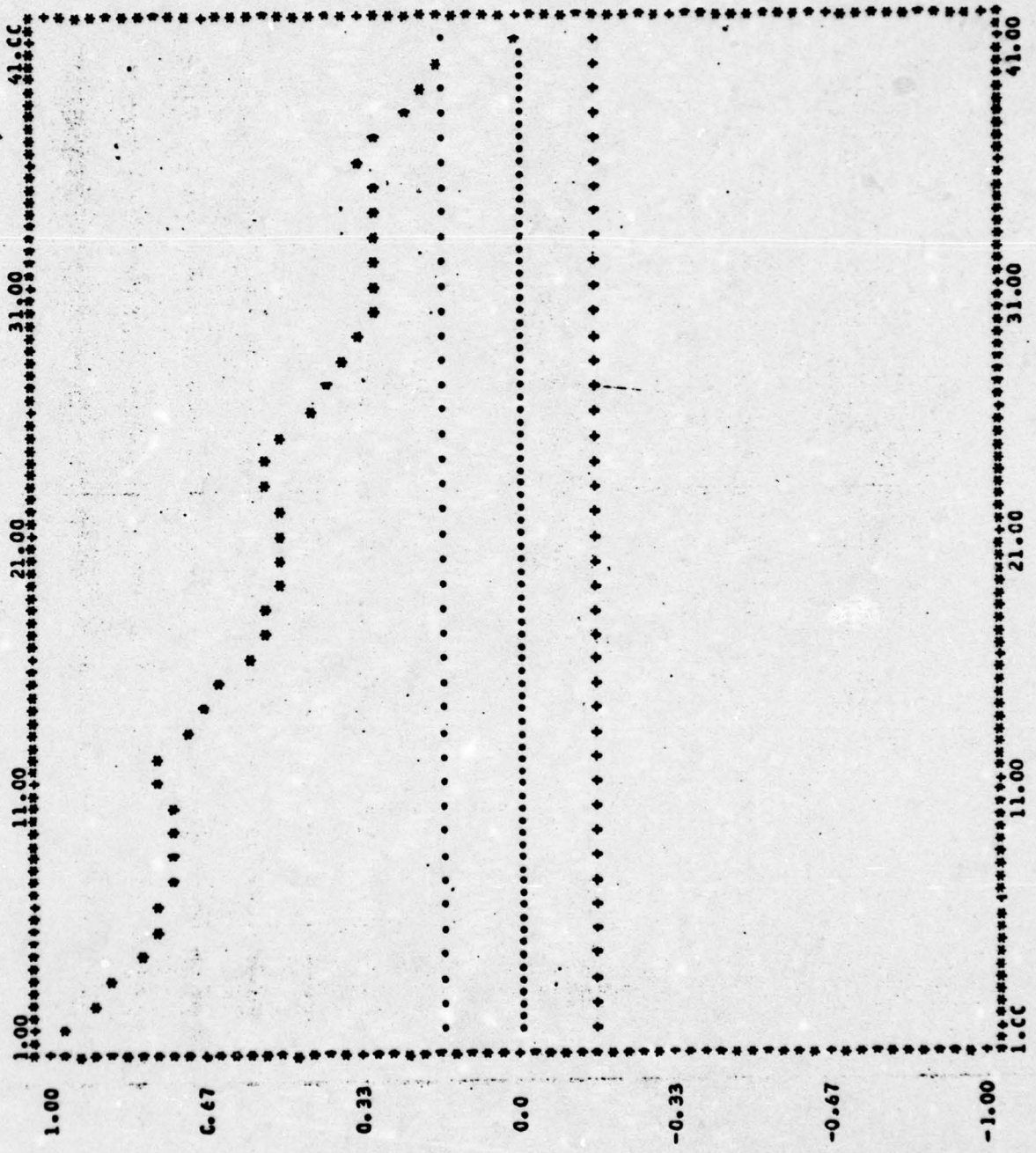
0.924	0.859	0.851	0.806	0.779	0.756	0.738	0.727	0.734	0.744
0.758	0.762	0.717	0.655	0.618	0.579	0.544	0.519	0.521	0.490
0.498	0.506	0.411	0.305	0.482	0.437	0.400	0.364	0.331	0.315
0.257	0.285	0.255	0.305	0.315	0.319	0.286	0.245	0.211	0.171

PARTIAL AUTOCORRELATIONS

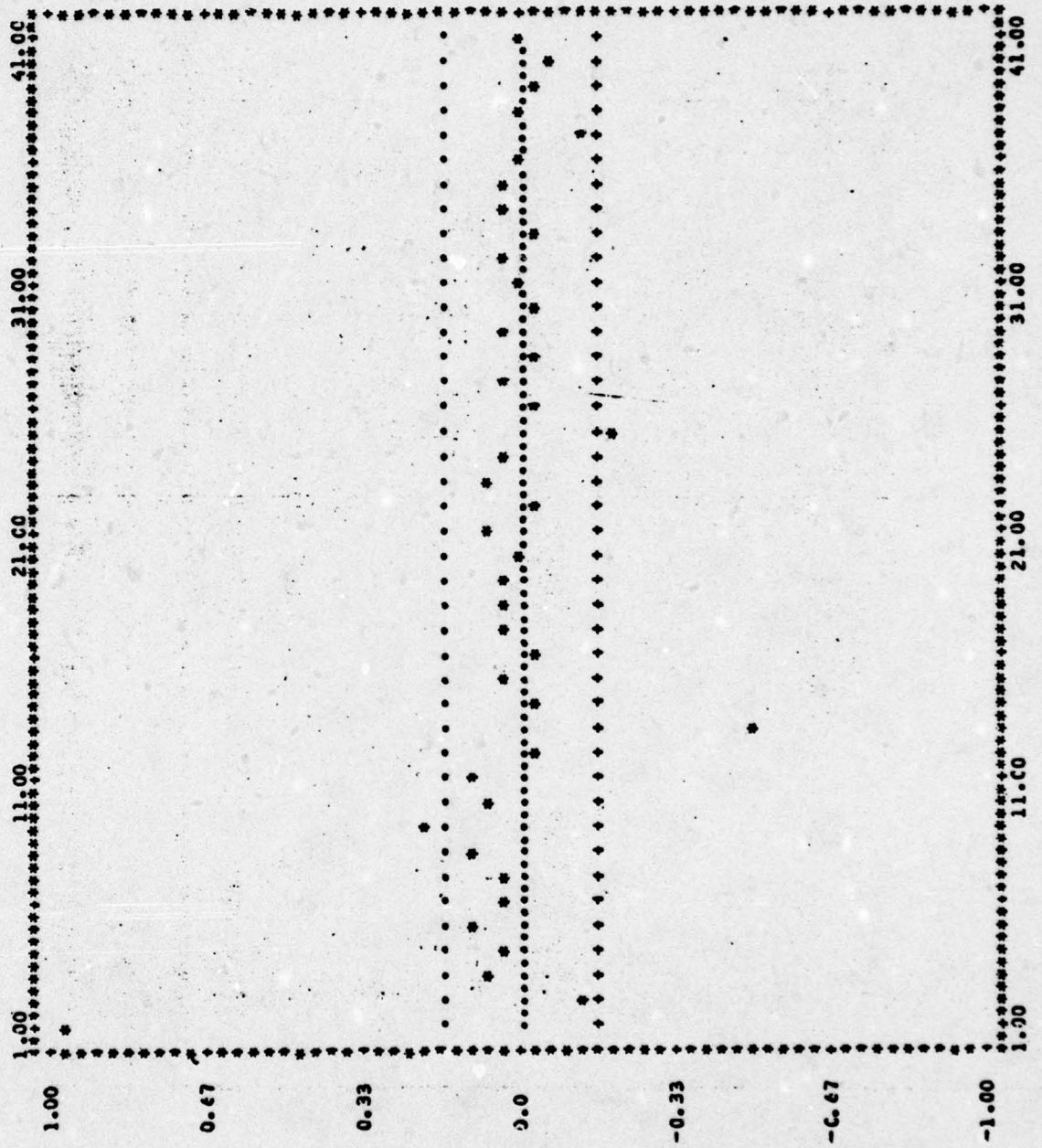
0.954	-0.118	0.054	0.224	0.115	0.044	0.038	0.100	0.204	0.064
0.106	-0.042	-0.481	-0.031	0.042	-0.044	0.028	0.037	0.042	0.011
0.003	-0.033	-0.020	0.021	-0.154	-0.035	0.036	-0.035	0.044	-0.045
	0.034	-0.028	0.028	0.029	-0.004	-0.132	-0.002	-0.025	-0.052

MEAN = 5.54218

VARIANCE = 0.193531



AUTOCORRELATIONS WITH 2 SIGMA BANDS.



PARTIAL AUTOCORRELATIONS WITH 2 SIGMA BANDS  
 AUTCS AND PALTOS OF SERIES G DATA / LOG TRANSFORMED



AUTCCRELATIONS

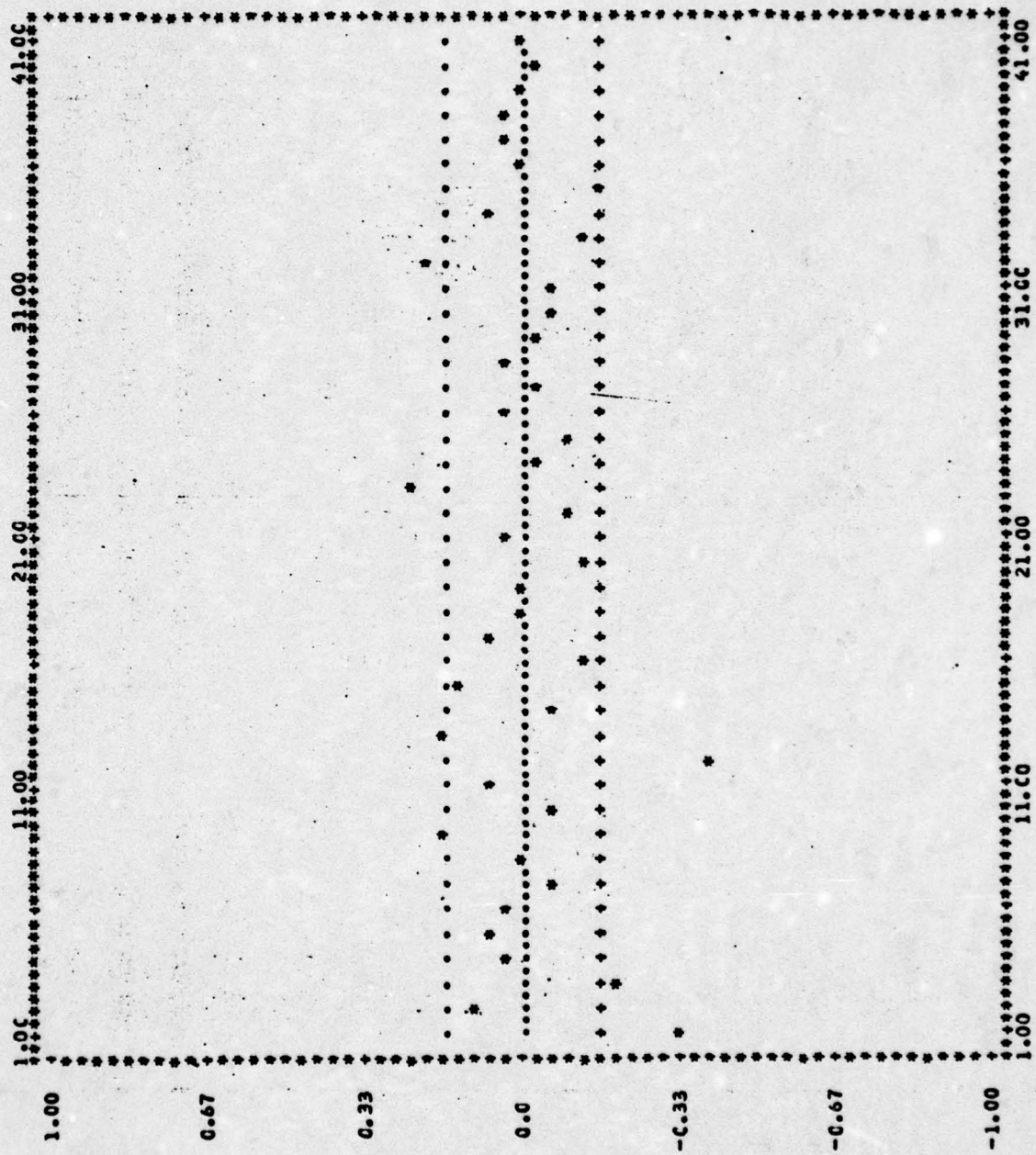
-0.341	0.105	-0.202	0.021	0.156	0.031	-0.256	-0.001	0.176	-0.075
0.064	-0.087	0.122	-0.328	0.150	-0.139	-0.071	0.019	-0.011	-0.151
-0.039	-0.051	0.222	-0.074	-0.152	0.049	-0.030	0.047	-0.016	-0.034
-0.054	0.196	-0.122	0.074	-0.152	-0.010	0.047	0.031	-0.015	

PARTIAL AUTCCRELATIONS

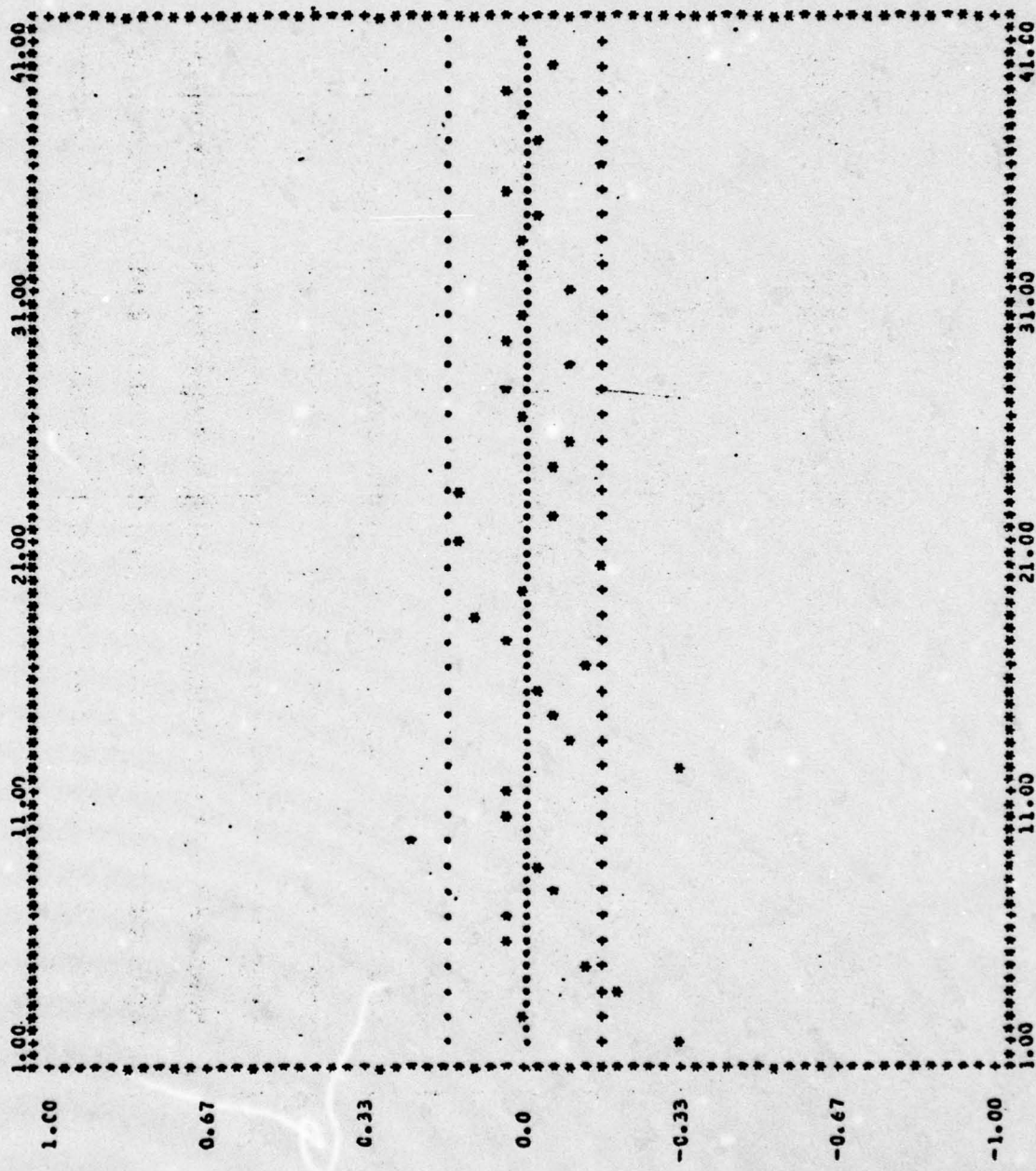
-0.341	-0.613	-0.163	-0.125	0.033	0.035	-0.040	-0.020	0.248	0.047
0.047	-0.239	-0.103	-0.077	-0.022	-0.140	0.026	-0.120	-0.043	-0.161
-0.032	-0.042	0.143	-0.067	-0.103	-0.010	0.044	-0.150	0.009	-0.077
-0.056	-0.015	0.011	-0.015	0.023	-0.165	-0.034	0.009	0.045	

MEAN=C.290920E-03

VARIANCE = 0.208604E-02



ALTCORRELATIONS WITH 2 SIGMA BANDS.



PARTIAL AUTOCORRELATION WITH 2 SIGMA BANDS.  
AL TOS AND PAUTOS OF SERIES G DAT A / 1 NS CIFF, 1 SEAS CIFF,



AUTOCORRELATICS

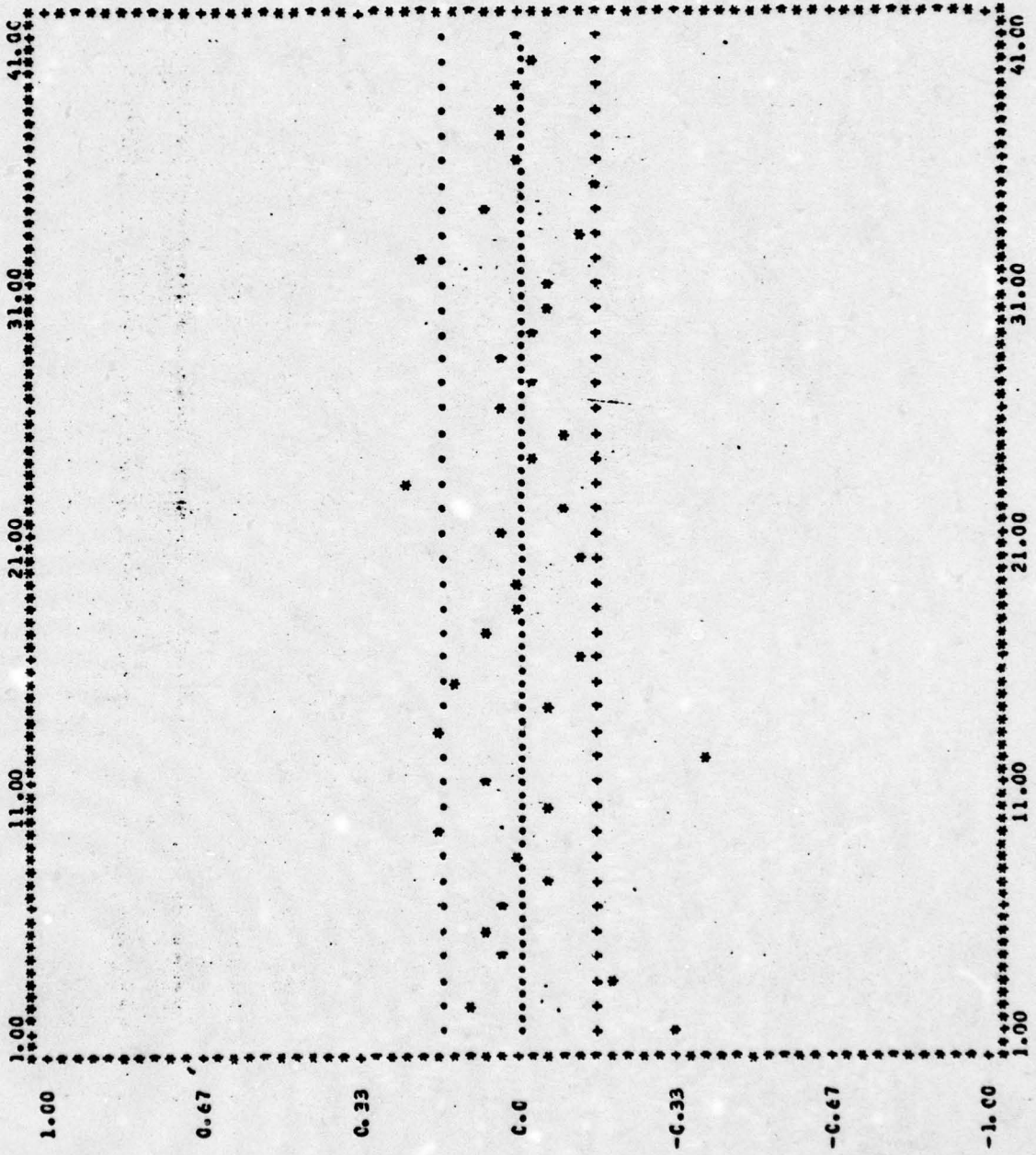
-0.341	0.155	0.202	0.021	0.056	0.031	-0.056	-0.001	0.176	-0.076
-0.204	0.152	-0.152	-0.058	0.150	-0.139	0.071	0.007	-0.011	-0.111
0.104	0.157	0.122	0.078	-0.100	0.049	-0.030	0.005	-0.015	-0.051
-0.004	0.156	-0.122	0.078	-0.152	-0.010	0.047	0.031	-0.015	-0.034

PARTIAL AUTOCORRELATIONS

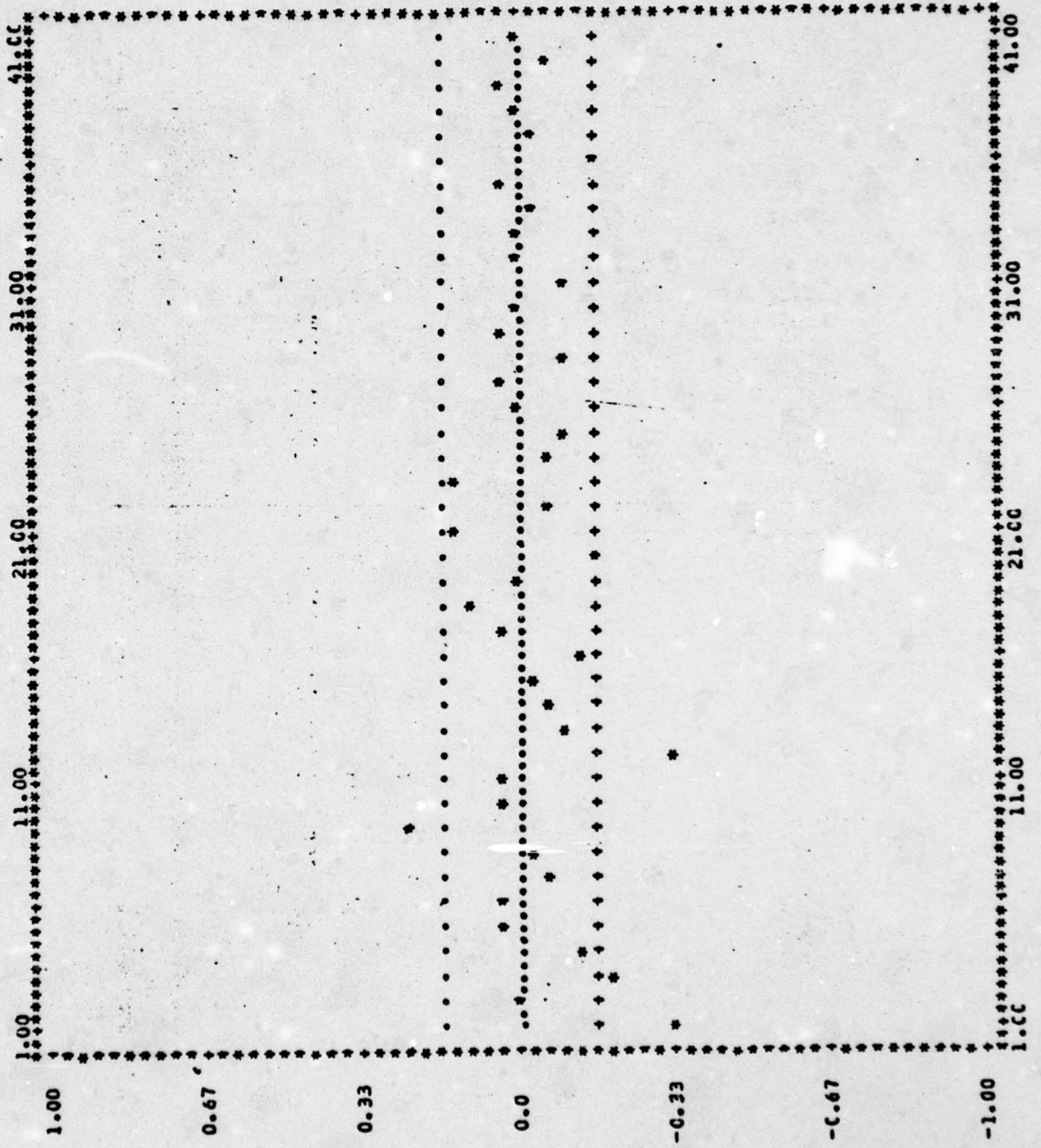
-0.341	0.013	-0.193	-0.177	0.033	0.035	-0.060	-0.020	0.126	0.047
0.047	-0.079	-0.105	-0.047	-0.022	-0.140	0.026	-0.115	-0.047	-0.167
0.032	0.072	0.143	-0.047	-0.123	-0.010	0.044	-0.009	0.045	-0.077
-0.006	-0.012	0.011	-0.015	0.023	-0.165	-0.034	0.009	0.045	-0.077

MEAN=C.290920E-03

VARIANCE = C.2086C4E-02



AUTOCORRELATIONS WITH 2 SIGMA BANDS.



PARTIAL AUTOCORRELATIONS WITH 2 SIGMA BANDS.  
 AUTOS AND PLOTS FOR SERIES: G DATA / 1 NS DIFF, 1 SEAS DIFF.

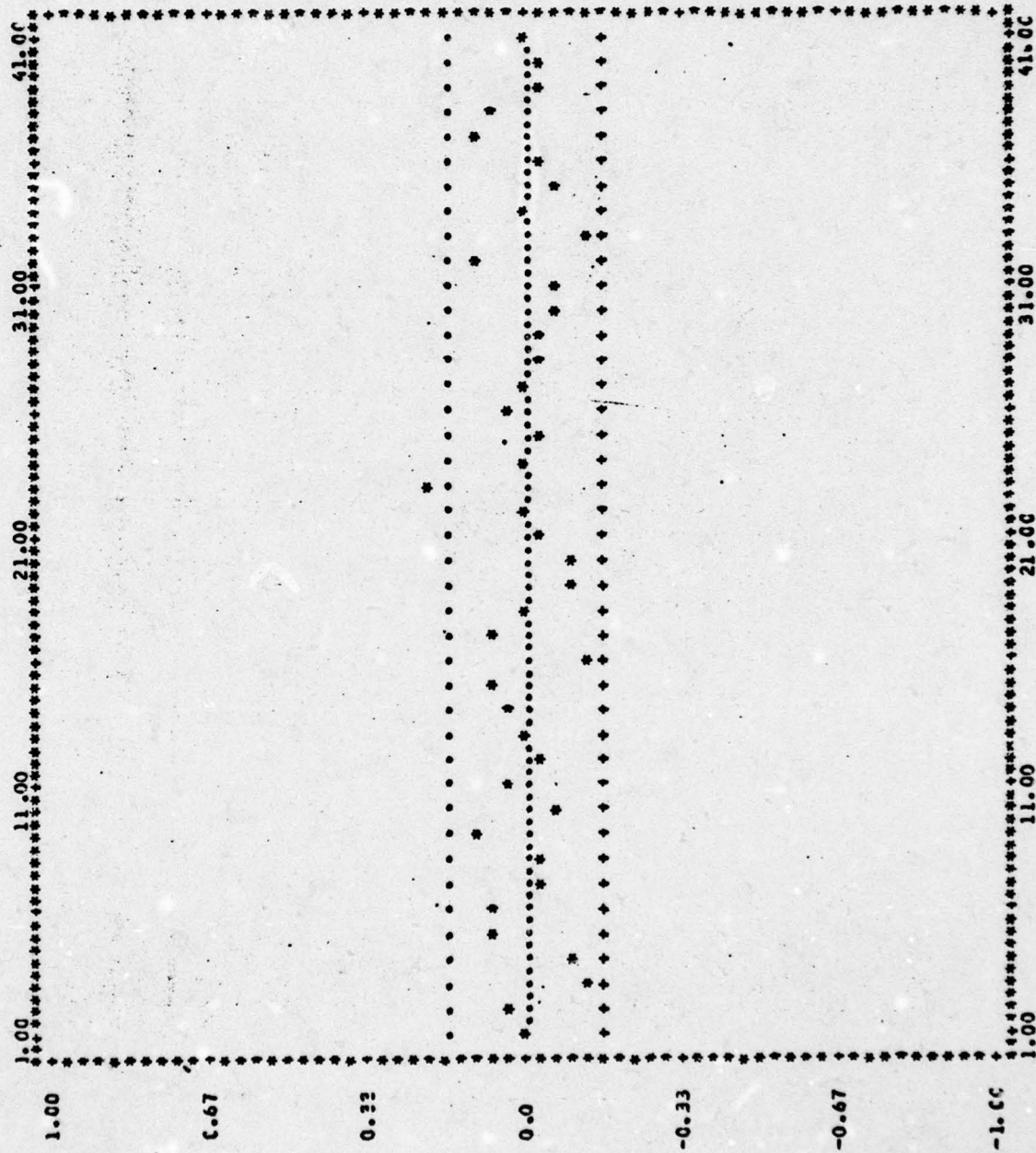
AUTOCORRELATIONS

0.055	0.129	-0.105	0.078	0.077	-0.036	-0.033	0.103	-0.050
0.029	0.213	0.005	0.067	0.130	-0.052	-0.013	-0.093	-0.050
-0.023	0.213	0.005	-0.067	0.067	-0.052	-0.013	-0.027	-0.074
	-0.142	0.000	-0.081	-0.036	0.089	0.062	-0.024	-0.033

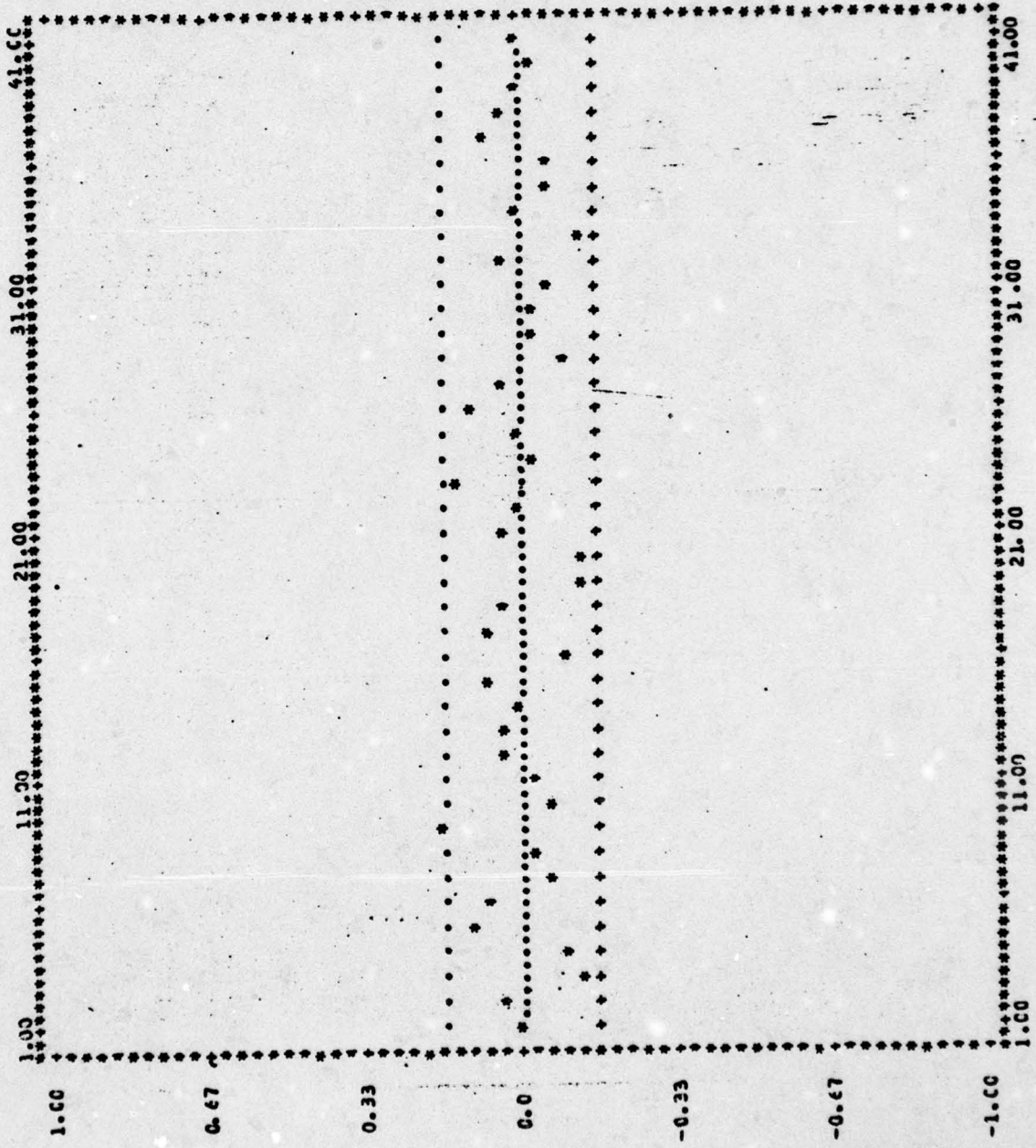
PARTIAL AUTOCORRELATIONS

0.005	0.130	-0.104	0.088	0.068	-0.072	-0.029	0.151	-0.054
-0.022	0.018	0.001	0.053	-0.114	0.049	-0.091	-0.129	-0.134
-0.028	0.025	-0.025	0.013	0.088	0.024	-0.041	-0.023	-0.042
	-0.125	0.002	-0.074	-0.074	0.002	0.041	-0.010	-0.042

MEAN=C.236005E-02      VARIANCE = 0.139713E-02



AUTOCORRELATIONS WITH 2 SIGMA BANDS.



PARTIAL AUTOCORRELATIONS WITH 2 SIGMA BANDS.  
 AUTOS AND PAULCS OF RESTOALS / (0,1,1)X(0,1,1)12 MOCEL OF S

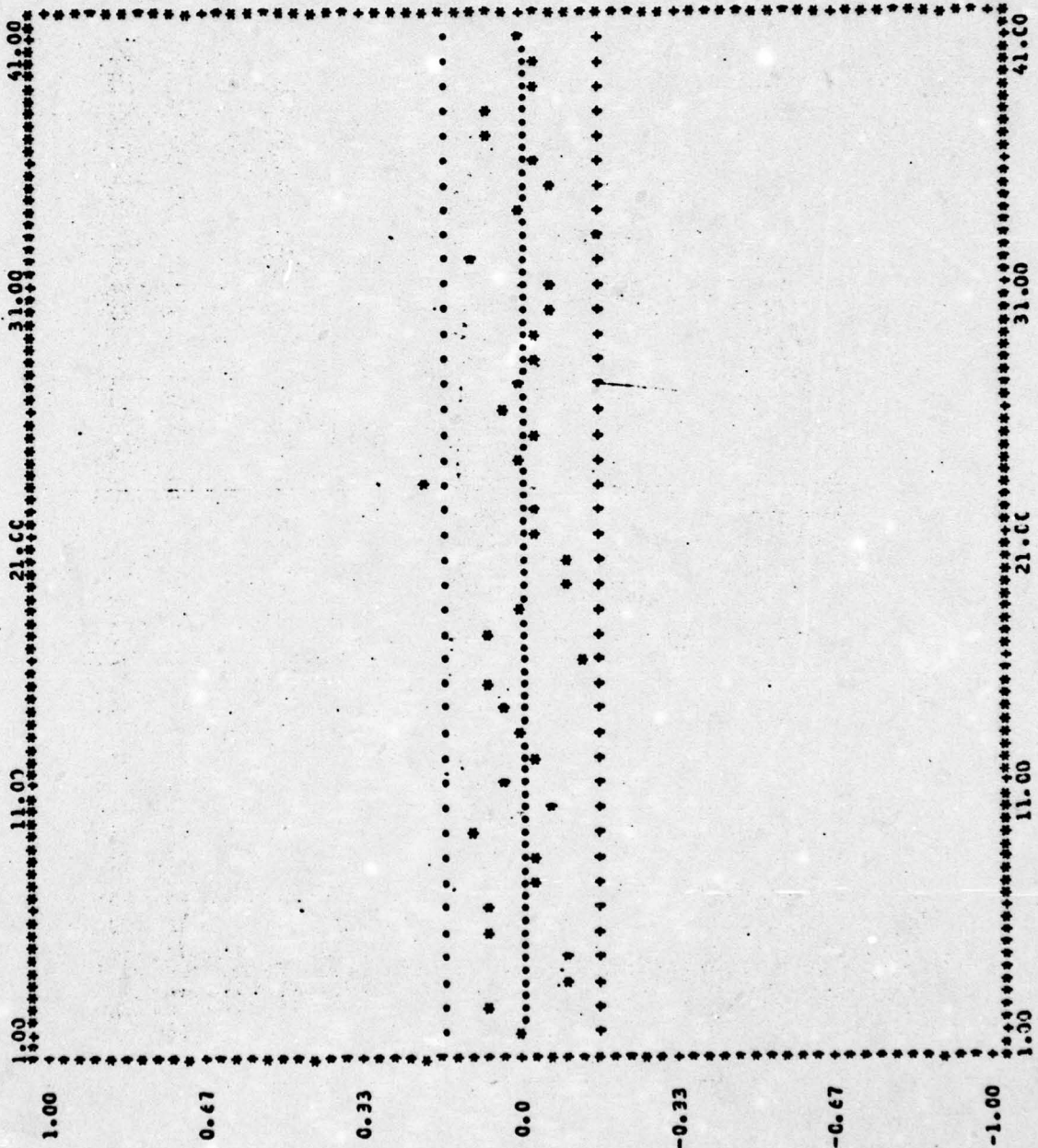
AUTOCORRELATIONS

-0.013	0.173	-0.100	-0.088	0.077	0.073	-0.231	-0.093	0.105	-0.054
-0.020	-0.018	0.014	0.027	0.070	-0.133	0.014	0.008	-0.027	-0.084
-0.074	-0.111	-0.154	0.007	-0.082	-0.048	0.080	-0.034	-0.027	-0.032

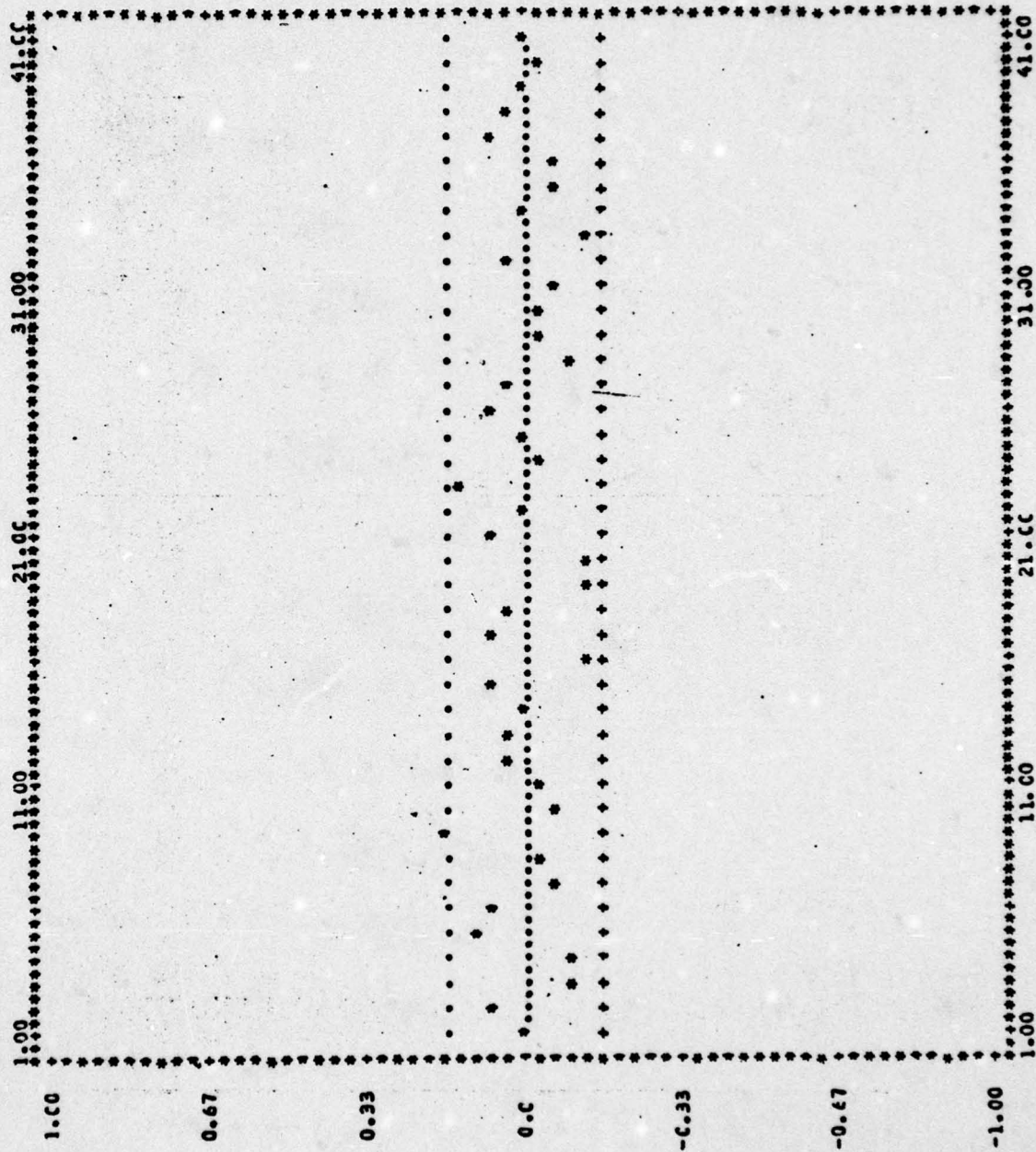
PARTIAL AUTOCORRELATIONS

-0.013	0.073	-0.098	-0.056	0.092	0.081	-0.064	-0.040	0.152	-0.050
-0.027	0.017	0.047	-0.004	0.053	-0.118	0.055	0.031	-0.123	-0.032
-0.063	-0.027	-0.130	0.008	-0.062	-0.072	0.082	-0.044	-0.012	-0.044

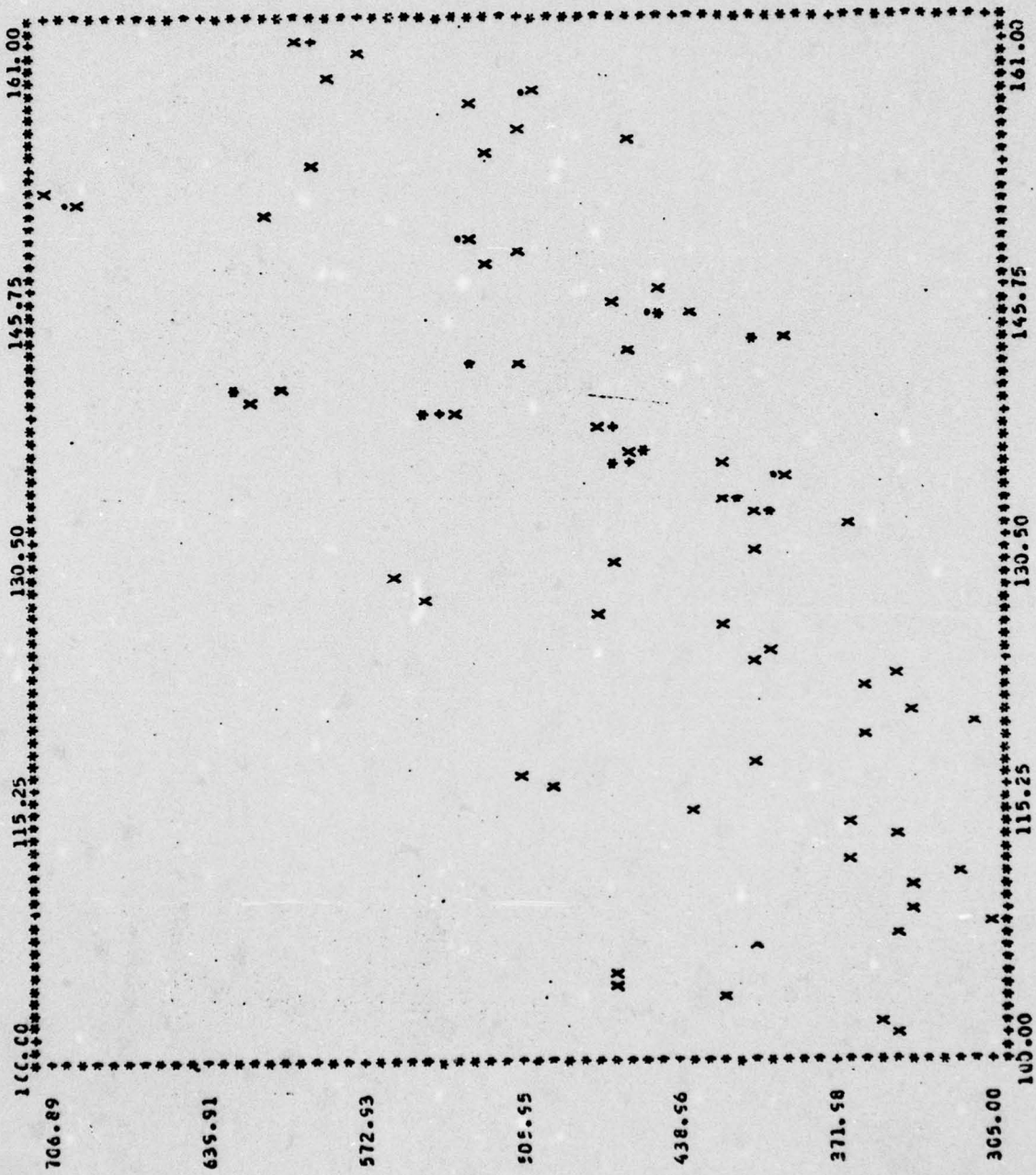
MEAN=0.253052E-02      VARIANCE = 0.139373E-02



AUTOCORRELATIONS WITH 2 SIGMA BANDS.



PARTIAL AUTOCORRELATIONS WITH 2 SIGMA BANDS.  
 AUTOS AND PLOTS OF RESIDUALS / (1.1.1)(0.1.1)12 MODEL OF S



ORIGINAL AND FORECASTED TIME SERIES.

\* UPPER CONFIDENCE INTERVAL  
 \* LOWER CONFIDENCE INTERVAL  
 \* FORECAST  
 \* ACTUAL DATA POINTS

FORECAST VALUES:

398.55062  
465.75917  
460.42197  
520.59301  
701.64123  
326.81123

415.18402  
443.45605  
465.21226  
507.54805  
590.52678  
502.60244

426.99533  
426.36325  
611.99145  
456.57827  
573.21957

450.97119  
524.52480  
444.74829  
696.56934  
597.58574

UPPER CONFIDENCE LIMITS:

399.59839  
470.51249  
461.55153  
701.65468  
528.09008

416.25425  
544.32248  
406.35420  
508.74258  
503.25223

396.48144  
619.31103  
445.17309  
529.94873  
520.33270  
589.08300

402.78454  
627.39947  
468.03023  
613.20349  
457.22317

452.55182  
525.42365  
445.92148  
697.51818  
596.70822

LOWER CONFIDENCE LIMITS:

397.47542  
466.60573  
415.25482  
704.43774  
525.53295

414.11352  
542.07105  
406.35327  
508.69067  
500.71242

394.32152  
617.07528  
446.85937  
527.58742  
517.84521  
586.40071

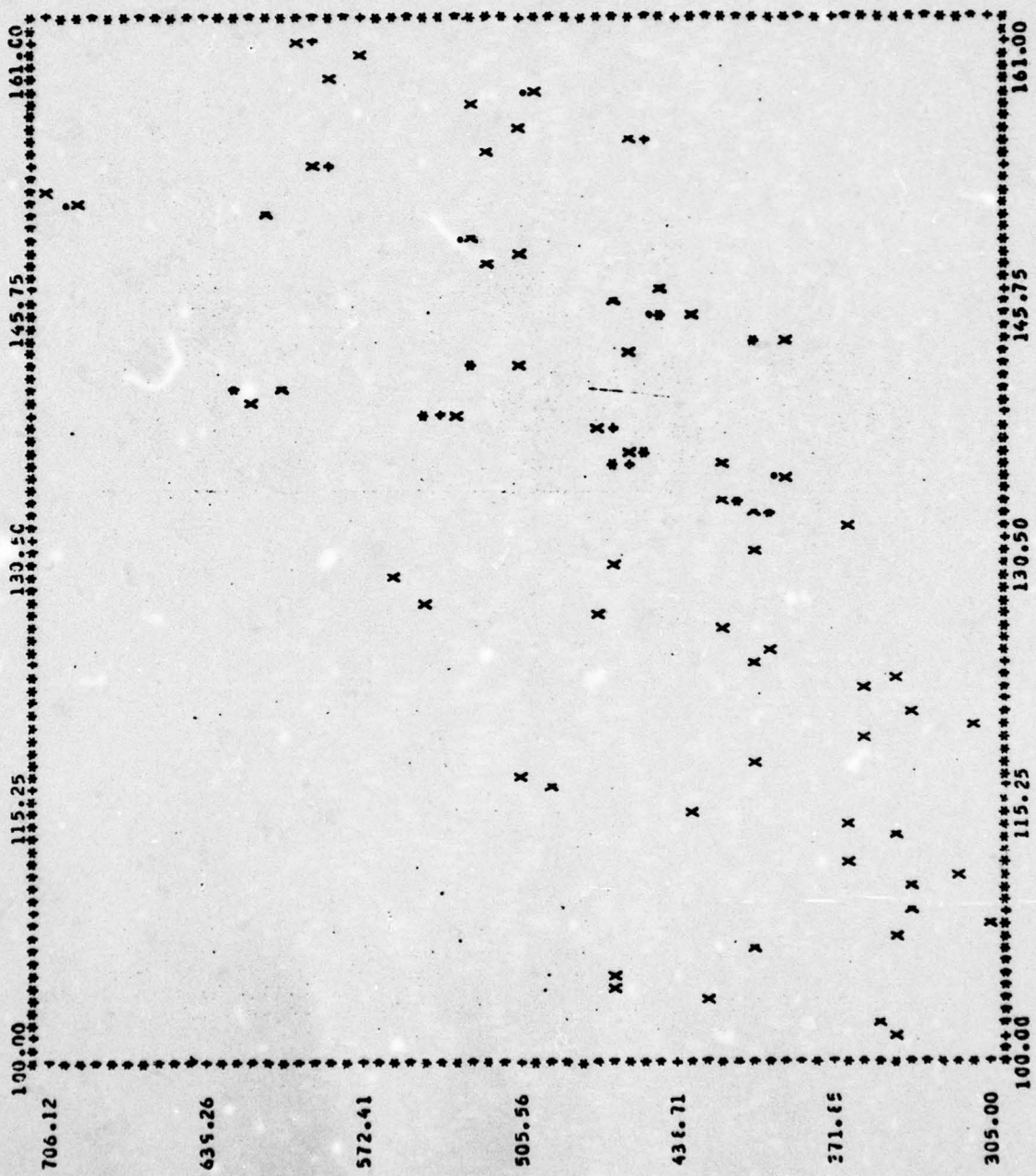
401.65751  
625.15163  
465.67523  
610.72705  
457.00795

449.87422  
523.16213  
445.16471  
604.13371  
594.13388

SIGNIFICANCE LEVEL FOR CONFIDENCE INTERVALS: 90.000

FORECAST CRIGIN: 131

MAXIMUM FORECAST LEAD TIME: 30



ORIGINAL AND FORECASTED TIME SERIES.

- UPPER CONFIDENCE INTERVAL
- LOWER CONFIDENCE INTERVAL
- FORECASTS
- ACTUAL DATA POINTS

FORECAST VALUES:

398.65655  
400.31357  
400.05703  
704.95273  
526.11245

414.874512  
404.045706  
400.899170  
507.066426  
501.355558

395.126759  
217.99707  
447.739224  
528.257324  
518.566476  
587.073975

423.395723  
425.35286  
400.355863  
611.3812451  
572.532227

450.650879  
423.696729  
444.224707  
695.632080  
506.959717  
596.632324

UPPER CONFIDENCE LIMITS:

399.70884  
470.448486  
461.158730  
521.270264  
706.11432  
527.311094

415.445458  
414.151471  
406.032475  
508.244115  
591.555694  
502.668457

396.203557  
618.81768  
442.886583  
525.447510  
519.792236  
588.352539

463.452393  
625.870381  
467.517334  
617.579117  
573.820557

451.714395  
423.019775  
443.50567  
656.837158  
506.827275  
597.530176

LOWER CONFIDENCE LIMITS:

397.55084  
466.242043  
518.520898  
703.652271  
524.855760

413.803711  
411.534211  
403.765623  
505.483545  
589.136843  
500.130615

394.045410  
616.587402  
446.591305  
527.066895  
511.340332  
585.795166

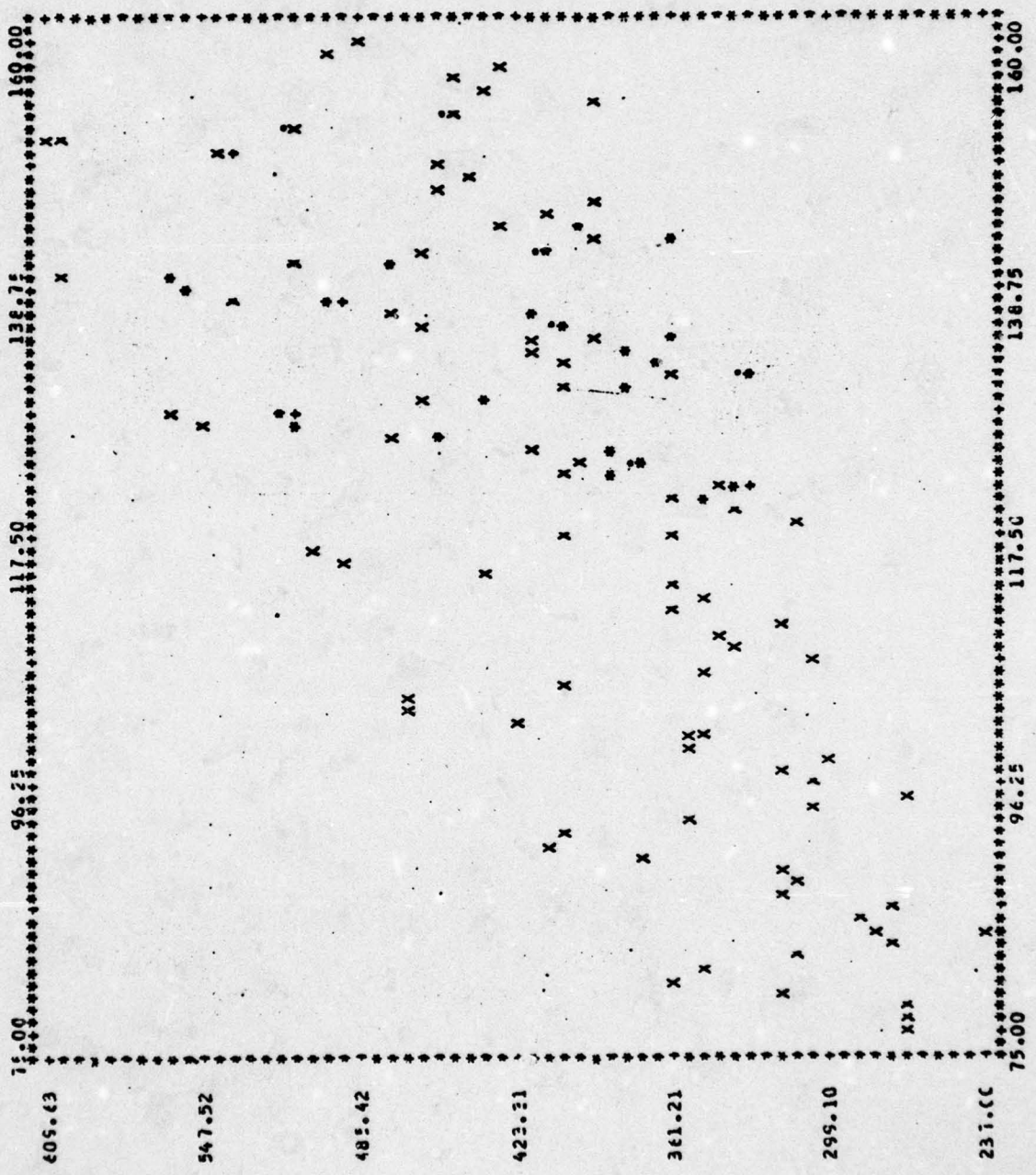
461.278805  
624.602148  
466.202350  
610.183541  
571.243652

445.577129  
422.773438  
447.136758  
503.111514  
595.114229

SIGNIFICANCE LEVEL FOR CONFIDENCE INTERVALS: 90.000

FORECAST CRIGIN: 131

MAXIMUM FORECAST LEAD TIME: 30



FORECAST VALUES:

349.764404  
456.098397  
322.143086  
407.133010  
392.994873  
403.475342  
436.366942

320.697116  
326.207148  
443.344471  
608.003566  
445.220198

385.479298  
378.392200  
494.885010  
360.791750  
443.263164  
513.338379  
422.822021

335.713064  
353.130634  
351.428234  
455.110269  
496.502693

350.943183  
387.183354  
392.17079  
371.5475  
375.5455  
392.3246  
398.4346

UPPER CONFIDENCE LIMITS:

301.225155  
459.231454  
478.605629  
438.368113  
437.760742

334.617188  
515.131227  
419.421646  
456.581057  
450.663348

387.030029  
515.579834  
386.000488  
362.094288  
444.570190  
453.002482

376.622543  
435.052451  
455.407749  
451.488744  
458.067383

387.110104  
385.101097  
345.458293  
353.170244  
387.101097  
385.101097  
345.458293

LOWER CONFIDENCE LIMITS:

345.103365  
451.511454  
316.501460  
408.101422  
353.133224  
424.572500

332.472900  
509.582254  
367.541054  
413.371051  
406.520410  
447.869873

384.865723  
313.323877  
372.583018  
351.593018  
441.97109  
427.995600

374.6664  
352.560235  
352.560235  
349.128693

375.42463  
345.4336  
375.42463  
345.4336  
375.42463  
345.4336  
375.42463

SIGNIFICANCE LEVEL FOR CONFIDENCE INTERVALS: 90.000

FORECAST CRICIN:120

MAXIMUM FORECAST LEAD TIME: 40

APPENDIX D  
PROGRAM LISTINGS

This Appendix contains program listings of all programs resident in the Time Series Editor. It does not include listings of subroutines used from other libraries, such as IMSL routines.



AD-A062 168

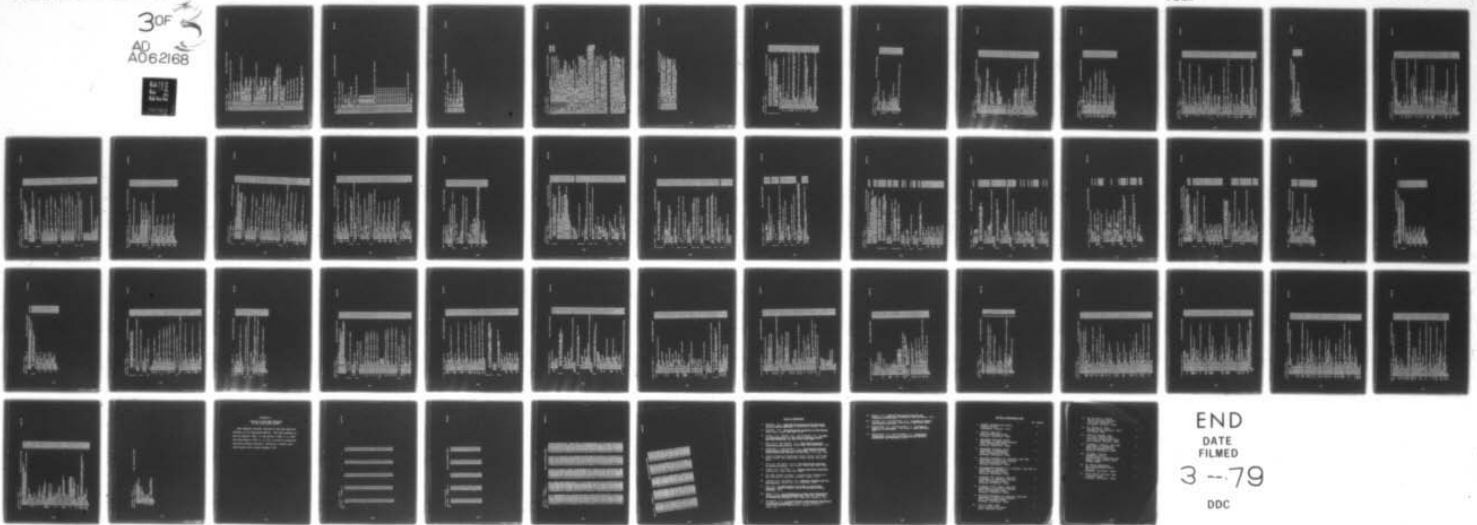
NAVAL POSTGRADUATE SCHOOL MONTEREY CALIF  
AN INTERACTIVE SOFTWARE PACKAGE FOR TIME SERIES ANALYSIS. (U)  
SEP 78 S R WOODALL

F/G 9/2

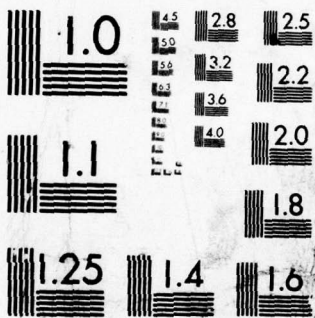
UNCLASSIFIED

3 OF 3  
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DATE  
FILMED  
3--79  
DOC



MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS-1963-A



NAVAL POSTGRADUATE SCHCOL

FILE: TIMESER EXEC P1

GREAD 2C  
 -QLES  
 -LEAD SIMULATE (CLEAR XEQ NOMAP)  
 -LEAD CC YOU WANT TC GO AGAIN?  
 -ARGC -QUES  
 -END  
 -S12  
 -CNINLE  
 -SERIES PARA 1 15  
 -SPACE  
 -YOU LIKE MORE INFO?  
 -ATINLE  
 -Y LCYC -STZ  
 -INT ENTER CPTICK YOL WANT INFO ABOUT.

-NOMS  
 -XP  
 -XD  
 -XE  
 -XF  
 -XG  
 -XH  
 -XI  
 -XJ  
 -XK  
 -XL  
 -XM  
 -XN  
 -XO  
 -XP  
 -XQ  
 -XR  
 -XS  
 -XT  
 -XU  
 -XV  
 -XW  
 -XX  
 -XY  
 -XZ  
 -LEGJL NAME.

ENTER FIRST LETTER ONLY. CHECK OPTIONS.

TSERIES PARA 48 45  
 TSERIES PARA 50 53  
 TSERIES FARA 57 6C  
 TSERIES FARA 43 47  
 TSERIES PARA 32 35  
 TSERIES PARA 28 31  
 TSERIES PARA 36 42  
 TSERIES PARA 61 62  
 TSERIES PARA 82 85  
 TSERIES PARA 71 72  
 TSERIES FARA 66 70  
 TSERIES FARA 77 81  
 TSERIES PARA 73 76  
 TSERIES PARA 64 67

YOU WANT INFV ABOUT ANOTHER OPTION?

Y LCYC -MIT

NAVAL POSTGRADUATE SCHOOL

FILE: TIMEXR EXEC P1

PRINT DO YOU WANT TO TRY A SESSION?

PRINT ARGV

PRINT OR %GCTC -END

PRINT %1 ES A %GCTC -END

%GCTC -S12

-PRINT DO YOU WANT INFO ON HOW TO ENTER YOUR SERIES?

%GCTC -CONTINUE

%GCTC -HCH

%GCTC -ENTER SERIES OFFLINE AND RETURN.

%GCTC -END

%GCTC -END OF ISERIES PARA 1727

%GCTC -PRINT CONTROL RETURNED TO CMS

%GCTC -PRINT ON

%GCTC





09/18/78 13.26.15

FILE: ZFORMAT FORTRAN P1

NAVAL POSTGRADUATE SCHOOL

PAGE 001

CCCCCCCCCCCC

THE ROUTINE ZFPT TAKES TIME SERIES DATA IN ANY FORTRAN  
FCFMT AND REWRITES IT IN THE FORMAT SUITABLE FOR  
ANALYSIS IN THE TIME SERIES EDITOR.

THE SERIES IS ENTERED ONTO THE DISC IN FILE FT03FC01.  
AND IS REWRITTEN BY THIS PROGRAM ONTO FILE FT02FC01.  
IN FORMAT SERIES REQUIRED FOR USE IN TIME SERIES EDITOR  
PROGRAMS. THE ORIGINAL DATA IS NOT DESTROYED, BUT  
REMAINS IN FILE FT03FC01.

DIPESSICA, DATA10001.FPT(18)

DATA Y7.Y7.FPT(18)

10 FORATE(1) 12X, 'IS YCLR TIME SERIES DATA NOW IN FILE FT03FC01?')

11 FORATE(1) 11A, 'Y1G0 TO 99

12 FORATE(1) 12X, 'ENTER THE LENGTH OF YOUR TIME SERIES VIA FORMAT I3.')

13 FORATE(1) 13J

14 FORATE(1) 12X, 'NOW ENTER THE FORTRAN FORMAT FOR YOUR TIME SERIES DAT

15 FORATE(1) 12X, 'INCLUDING PARENTHESES; FOR EXAMPLE, TYPE: (5F15.7).')

16 FORATE(1) 18A, 'YOUR FCFMAT IS: ', 2X, 'FCFMAT', 18A4, ', 2X, 'IS THIS CCR

17 FORATE(1) 12X, 'SIANS

18 FORATE(1) 13J

19 FORATE(1) 12X, 'YOUR DATA IS NOW TRANSFERRED INTO THE PROPER FORMAT,

20 FORATE(1) 12X, 'USE IN THE TIME SERIES EDITOR LOCATED IN FILE ', 2X,

21 FORATE(1) 12X, 'YOUR ORIGINAL DATA IS IN FILE FT03FC01.')

22 FORATE(1) 12X, 'IN DATA(1): I=1,N)

23 FORATE(1) 12X, 'IN DATA(1): I=1,N)

24 FORATE(1) 12X, 'IN DATA(1): I=1,N)

25 FORATE(1) 12X, 'IN DATA(1): I=1,N)

26 FORATE(1) 12X, 'IN DATA(1): I=1,N)

27 FORATE(1) 12X, 'IN DATA(1): I=1,N)

28 FORATE(1) 12X, 'IN DATA(1): I=1,N)

29 FORATE(1) 12X, 'IN DATA(1): I=1,N)

30 FORATE(1) 12X, 'IN DATA(1): I=1,N)

31 FORATE(1) 12X, 'IN DATA(1): I=1,N)

32 FORATE(1) 12X, 'IN DATA(1): I=1,N)

33 FORATE(1) 12X, 'IN DATA(1): I=1,N)

34 FORATE(1) 12X, 'IN DATA(1): I=1,N)

35 FORATE(1) 12X, 'IN DATA(1): I=1,N)

36 FORATE(1) 12X, 'IN DATA(1): I=1,N)

37 FORATE(1) 12X, 'IN DATA(1): I=1,N)

38 FORATE(1) 12X, 'IN DATA(1): I=1,N)

39 FORATE(1) 12X, 'IN DATA(1): I=1,N)

40 FORATE(1) 12X, 'IN DATA(1): I=1,N)

ZFMSC010  
ZFMSC020  
ZFMSC030  
ZFMSC040  
ZFMSC050  
ZFMSC060  
ZFMSC070  
ZFMSC080  
ZFMSC090  
ZFMSC100  
ZFMSC110  
ZFMSC120  
ZFMSC130  
ZFMSC140  
ZFMSC150  
ZFMSC160  
ZFMSC170  
ZFMSC180  
ZFMSC190  
ZFMSC200  
ZFMSC210  
ZFMSC220  
ZFMSC230  
ZFMSC240  
ZFMSC250  
ZFMSC260  
ZFMSC270  
ZFMSC280  
ZFMSC290  
ZFMSC300  
ZFMSC310  
ZFMSC320  
ZFMSC330  
ZFMSC340  
ZFMSC350  
ZFMSC360  
ZFMSC370  
ZFMSC380  
ZFMSC390  
ZFMSC400  
ZFMSC410  
ZFMSC420  
ZFMSC430  
ZFMSC440  
ZFMSC450  
ZFMSC460  
ZFMSC470

CS/1E/1E 11.22.4E NAVAL POSTGRADUATE SCHOOL

FILE: PLOT FORTRAN P1  
DIMENSION X(1000), Z(1000), TITLE(60)  
DATA Y(1000),  
FEAC(2,200)N

200 FORMAT(13), (Z(1), I=1, N)  
201 FORMAT(15), (.6)  
16 WRITE(1, I=1, N)  
19

CALL FLOC(1, X, Z, A, C)  
CALL FLOC(2, X, Z, A, C)  
CALL FLOC(3, X, Z, A, C)  
CALL FLOC(4, X, Z, A, C)  
CALL FLOC(5, X, Z, A, C)  
CALL FLOC(6, X, Z, A, C)  
CALL FLOC(7, X, Z, A, C)  
CALL FLOC(8, X, Z, A, C)  
CALL FLOC(9, X, Z, A, C)  
CALL FLOC(10, X, Z, A, C)  
CALL FLOC(11, X, Z, A, C)  
CALL FLOC(12, X, Z, A, C)  
CALL FLOC(13, X, Z, A, C)  
CALL FLOC(14, X, Z, A, C)  
CALL FLOC(15, X, Z, A, C)  
CALL FLOC(16, X, Z, A, C)  
CALL FLOC(17, X, Z, A, C)  
CALL FLOC(18, X, Z, A, C)  
CALL FLOC(19, X, Z, A, C)  
CALL FLOC(20, X, Z, A, C)  
CALL FLOC(21, X, Z, A, C)  
CALL FLOC(22, X, Z, A, C)  
CALL FLOC(23, X, Z, A, C)  
CALL FLOC(24, X, Z, A, C)  
CALL FLOC(25, X, Z, A, C)  
CALL FLOC(26, X, Z, A, C)  
CALL FLOC(27, X, Z, A, C)  
CALL FLOC(28, X, Z, A, C)  
CALL FLOC(29, X, Z, A, C)  
CALL FLOC(30, X, Z, A, C)  
CALL FLOC(31, X, Z, A, C)  
CALL FLOC(32, X, Z, A, C)  
CALL FLOC(33, X, Z, A, C)  
CALL FLOC(34, X, Z, A, C)  
CALL FLOC(35, X, Z, A, C)  
CALL FLOC(36, X, Z, A, C)  
CALL FLOC(37, X, Z, A, C)  
CALL FLOC(38, X, Z, A, C)  
CALL FLOC(39, X, Z, A, C)  
CALL FLOC(40, X, Z, A, C)  
CALL FLOC(41, X, Z, A, C)  
CALL FLOC(42, X, Z, A, C)  
CALL FLOC(43, X, Z, A, C)  
CALL FLOC(44, X, Z, A, C)  
CALL FLOC(45, X, Z, A, C)  
CALL FLOC(46, X, Z, A, C)  
CALL FLOC(47, X, Z, A, C)  
CALL FLOC(48, X, Z, A, C)  
CALL FLOC(49, X, Z, A, C)  
CALL FLOC(50, X, Z, A, C)  
CALL FLOC(51, X, Z, A, C)  
CALL FLOC(52, X, Z, A, C)  
CALL FLOC(53, X, Z, A, C)  
CALL FLOC(54, X, Z, A, C)  
CALL FLOC(55, X, Z, A, C)  
CALL FLOC(56, X, Z, A, C)  
CALL FLOC(57, X, Z, A, C)  
CALL FLOC(58, X, Z, A, C)  
CALL FLOC(59, X, Z, A, C)  
CALL FLOC(60, X, Z, A, C)  
CALL FLOC(61, X, Z, A, C)  
CALL FLOC(62, X, Z, A, C)  
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PAGE 002

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FILE: TRANS      FURTRAN P1      NAVAL POSTGRADUATE SCHCOL
175 FORMAT(2X,' TRANSFORMATION IS W(1)=LOG(SCALE*(Z(1)-SHIFT)),
* 1X,FACTOR), W PERCENTS, //, 3X, SCALE=1.612.6, 3X, SHIFT=1.612.6,
200 * 2X, FACTOR=, G12.6)
WRITE(3, '(3, 2X) (Z(1), I=1, 2Z)
* 1X, I=1, 2Z)
217 * 1X, I=1, 2Z)
FORMAT(11, 4E15.6)
STOP
END
```

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TRACC719
TRACC720
TRACC730
TRACC740
TRACC750
TRACC760
TRACC770
TRACC780
TRACC790
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CS/16/78 12.23.41

FILE: WAFGCT FORTRAN P1 NAVAL POSTGRADUATE SCHOOL

C INPLT PHASE

```

INTELLI REAL(1,1) C-Z1
DIMENSION BETA(5), PI(5), PHIS(5), BETA(20), X(20,1000)
DIMENSION TAN(20), PHISN(5), THETAN(5), THESN(5)
DIMENSION AVEC(100), AMAT(20,20)
DIMENSION STARR(20), SEPI(5), SETH(5), SETHS(5)
DIMENSION ACV(25), AC(25), PACV(25), WKAREA(40), WKARL(30)
DIMENSION AINVC(20)

```

C C C READ SERIES AND TIME SERIES FROM FILE FT02F001

```

READ(1,1) N
READ(1,1) INVC(I), I=1,N
FORMAT(15,6)
WRITE(1,12) ENTER NUMBER OF NON-SEASONAL DIFFERENCES.'
FORMAT(12) INCIENS
FORMAT(14) ENTER NUMBER OF SEASCNL DIFFERENCES.'
FORMAT(15) INDIENS

```

C C C INPUT NUMBER OF PARAMETERS, BY TYPE.

```

WRITE(1,20) ENTER NUMBER OF NON-SEASONAL AR PARAMETERS.'
FORMAT(12) IF
FORMAT(11) IF
FORMAT(16,2) ENTER NUMBER OF SEASONAL AR PARAMETERS.'
FORMAT(15,2) IPS
FORMAT(12,1) ENTER NUMBER OF ACN-SEASONAL MA PARAMETERS.'
FORMAT(12,1) IC
WRITE(1,24) ENTER NUMBER OF SEASCNL MA PARAMETERS.'
FORMAT(15,1) IQS
IF(1) SEAS=0,1-ANC.(ICS.EQ.0) GO TO 5
WRITE(1,25) ENTER LENGTH OF SEASON VIA FORMAT 12.'
FORMAT(15,1) ILSEAS
FORMAT(12) IF

```

C C C INPUT YOUR INITIAL PARAMETER ESTIPATES

```

WRITE(1,30)
FORMAT(7,2) X, 'NOW INPUT YOUR INITIAL PARAMETER ESTIMATES, AS REQUESTED BY THE FOLLOWING CIPHERENCING
LTC PERCENTAGE CIPHERENCING
ITRAN PERCENTAGE CIPHERENCING
CALL FPCDF (ADIFENS, ACIFS, ITRANS, LSEAS, N, WVEC, SHIFT, M, IER)
WRITE(1,41) ENTER NON-SEASONAL AR PARAMETER PHI(, , I1, , I1, , I1)
FORMAT(5,12) PHII1
FORMAT(15,6)
WRITE(1,42) ENTER NON-SEASONAL AR PARAMETER PHI(, , I1, , I1, , I1)
FORMAT(15,6)
WRITE(1,40) GO TO 500
FORMAT(15,6)
WRITE(1,51) ENTER SEASCNL AR PARAMETER PHS(, , I1, , I1, , I1)
FORMAT(15,6)
WRITE(1,52) ENTER SEASCNL AR PARAMETER PHS(, , I1, , I1, , I1)
FORMAT(15,6)
WRITE(1,50) GO TO 600
IF(1) GO TO 600

```

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NL 600010
NL 600020
NL 600030
NL 600040
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NL 600080
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NL 600100
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NL 600190
NL 600200
NL 600210
NL 600220
NL 600230
NL 600240
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NL 600270
NL 600280
NL 600290
NL 600300
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NL 600680
NL 600690
NL 600700

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09/18/78 15:24:32

FILE: PARCPT FORTRAN P1 NAVAL POSTGRADUATE SCHOOL

PAGE 001

```

SUBROUTINE PARCPT (PHI, PHIS, THETA, THETAS, AVEC, X, WVEC, BETA, IP, IPS, IQ,
1, IC, UN, LSEAS, AMAT, SUPSCA)
  NARYUART IS A NON-LINEAR LEAST-SQUARES OPTIMIZING
  ROUTINE FOR THE ESTIMATION OF PARAMETERS FOR
  A GENERALIZED SEASONAL ARIMA MODEL.
  DOUBLE PRECISION X, AMAT, ASTARN
  DOUBLE PRECISION PHIS, THETA, THETAS, PHIN, PHISN, THETAN, THESN
  DOUBLE PRECISION AVEC, WVEC, GVEC, GSTARV, WVEC, HSTARV
  DOUBLE PRECISION BETA, BETAAN, CONSP1, F, Z, EPS, SUM, SUMG
  DOUBLE PRECISION SUP, SUPCON
  DOUBLE PRECISION AMAT(20,20), DVEC(20)
  DOUBLE PRECISION GSTARV(20), WVEC(20)
  DOUBLE PRECISION BETAAN(20), THETAN(20), PHIS(20), PHISN(20)
  DOUBLE PRECISION THESN(20), WVEC(1000)
  DATA AMAT / 20, .N1 /
  CONSP1 = .0100
  EPS = .0000100
  KOUNT1 = 0
  CALL PARSH TO GET REQUIRED DERIVATIVES
  STAGE 1
30 KOUNT1 = KOUNT1 + 1
  IF (KOUNT1.EQ.10166) GO TO 999
  CALL PARSP (IP, IPS, IC, ICS, PHI, PHIS, THETA, THETAS, AVEC, X, N, WVEC, LSEAS,
1)
  CALL SUMSQ TO GET ACTUAL AVEC AND SUMSQ.
15 SUPSCA, AVEC)
  FCMP THE A MATRIX
  NPARAM = IP + IPS + IQ + IQS
  DO 1 J = 1, NPARAM
  DO 2 J = 1, NPARAM
  SUP = 0.0000
  DO 3 IJ = 1, N
  CONTINUE + X(I, IJ) * X(IJ, IJ)
  CONTINUE = SUP
  CONTINUE = SUP
  CONTINUE = SUP
  FCMP THE G VECTOR.
  DC 4 I1 = 1, NPARAM
  SUPG = 0.0000
  DO 5 J1 = 1, N
  SUMG = SUPG + X(I1, J1) * AVEC(J1)
  CONTINUE = SUPG
  GVEC(I1) = SUPG
  CONTINUE
  FCMP THE SCALING VECTOR, CALLED DVEC.
  DO 6 J1 = 1, NPARAM
  DVEC(J1) = AMAT(I1, J1) * .5
  CONTINUE

```



NAVAL POSTGRADUATE SCHOOL

FILE: MARCPT FORTRAN P1

```

C
4C DO 45 LLL=1,NPAPAM
   BETAILL) = BETAN(LLL)
4S CONTINUE
   CALL SWAPB(BETA,IP,IP5,IQ,IPHI,PHIS,T,ETA,T,ETAS)
   CALL CONSP1(IP,IPHI,PHIS,T,ETA,T,ETAS)
   IF(CC=SP1.LT.1.E-6)GO TO 995
   GC TC STAGE (1).
3C
3C GC TC 3C
3C
60 WRITE(6,(1)KOUNT,KELA)
61 FORMAT(17,2X,'CONVERGENCE HAS BEEN REACHED IN MAX(,12,.,,12,.)
   1 ITERATION(,17)
   WRITE(6,(2),,77)
62 FORMAT(17,2X,'SELECTEC OUTPUT FLLCMS:'))
3C
3C   ASSIGN FINAL BETA VALUES TO THE BETA VECTOR.
63
   DC 63 11=1,NPAPAM
   BETAIL) = BETAN(11)
   CONTINUE
3C
3C   NCH, PUT IN THE PROPER FORM FOR OUTPUT.
   CALL SWAPB(BETAN,IP,IP5,IQ,IPHI,PHIS,T,ETA,T,ETAS)
   GC TC 1CC0
3C
555 WRITE(6,596)
596 FORMAT(17,2X,'COMPUTATIONS TERMINATED; CONSP1 PARAMETER EXCEEDED B
   10UNCS:17,2X,'CHECK YOUR INITIAL ESTIMATES OF PARAPETERS AND CTME
   2H INPU CA 1A.))
   GO TO 1000
3C
999 WRITE(6,998)
998 FORMAT(12,'KOUNT, ITERATION MAX KOUNT, HAS BEEN EXCEEDED:,,/,2
   1X,TFIS KUA HAS BEEN TERMINATED.))
1000
   BETUFA
   END

```

MARCI1400  
MARC1410  
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MARC1700  
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MARC1740



NAVAL POSTGRADUATE SCHOOL

FILE: SLMSC FOR (RAN PI

114 CONTINUE = 1.000  
PHI(1) = 1.000  
THEST(1) = 1.000

LNRAVEL THE AR SIDE OF THE GENERAL MODEL;  
KAR WILL KEEP TRACK OF THE NUMBER OF NON-ZERO  
ELEMENTS OF THE PI VECTOR OF PARAMETERS.

KAR = 0  
DO 200 I = 1, IPST  
DC ICC I = 1, IPT  
KAP = KAR + 1  
K = (I - 1) \* LSEAS  
INCAR = K + IADDI  
PI(KAR) = PI(I) + PHIST(I)  
I = I + 1  
KAR = KAR + 1  
CONTINUE  
200 CONTINUE

NON LNRAVEL THE PA SIDE OF THE MODEL, FORMING THE  
NON-ZERO ELEMENTS OF THE GAMMA VECTOR.

KMA = CC  
CC 400 YI = 1, IQT  
KMA = KMA + 1 + (JJ - 1) \* LSEAS  
INCPA(KMA) = THEST(JJ)  
GAPPA(KMA) = ANL(I, EQ, 1) .OR. ((JJ.GT.1).AND.(I.GT.1)) \* PI(KAR) =  
I = I + 1  
KMA = KMA + 1  
CONTINUE  
400 CONTINUE

ACH, SOLVE FOR THE NON-ZERO ELEMENTS OF THE EVEC.

DO 210 I = 1, 10  
I = 1  
SUMPI = 0.000  
IF (I.EQ.1) .AND. (IPS.EQ.0) IGO TO 215  
DO 220 J = 2, KAR  
KMA = 1 + KMA  
I = I + 1  
CONTINUE  
220 CONTINUE  
215 IF (I.EQ.1) .AND. (IGS.EQ.0) IGO TO 225  
DC J = 2, KMA  
JJ = I + J  
SUMPI = SUMPI + GAMMA(K) \* EVEC(I, J)  
CONTINUE  
225 EVEC(I, I) = TVEC(I) + SUMPI - SUMTHE  
210 CONTINUE

ACH, BACKCAST THE REQUIRED WVEC VALUES.

DO 310 I = 1, IACCT  
I = 1  
SUMPI = 0.000  
IF (I.EQ.1) .AND. (IPS.EQ.0) IGO TO 315  
DO 320 J = 2, KAR  
KMA = 1 + KMA  
I = I + 1  
CONTINUE  
320 CONTINUE = 0.000

NLE02820

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NLE02880  
NLE02890  
NLE02900  
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NLE02940  
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NLE02960  
NLE02970

NLE02980  
NLE02990  
NLE03000  
NLE03010  
NLE03020  
NLE03030  
NLE03040  
NLE03050  
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NLE03070  
NLE03080  
NLE03090  
NLE03100  
NLE03110  
NLE03120

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NLE03160  
NLE03170  
NLE03180  
NLE03190  
NLE03200  
NLE03210

NLE03250

NLE03270

NLE03300

NLE03320

NLE03340  
NLE03350  
NLE03360  
NLE03370  
NLE03380

NLE03420

NLE03440

FILE: SUMSC FCSTRAN P1 NAVAL POSTGRADUATE SCHOOL

NLE03470  
NLE03450

NLE03510  
NLE03520  
NLE03530  
NLE03540  
NLE03550

NLE03610

NLE03660  
NLE03680  
NLE03690  
NLE03700  
NLE03710  
NLE03720

NLE03740

NLE03770  
NLE03780  
NLE03790  
NLE03800  
NLE03810  
NLE03820

NLE03840  
NLE03850  
NLE03860

IF(I)C.EQ.(J).AND.(IGS.EQ.O))GO TO 325  
CO=I-1  
JJ=INDPA(K)  
I=I+1  
SUMPI=SUMPI+I  
SUMTPE=SUMTPE+I  
CONTINUE

330 I=I+1  
325 TVECC(I)=EVECC(I)+SUMPI - SUMTPE  
310 CONTINUE

CC NCM, CALCULATE THE AVEC VALUES.

CC 415 I=1  
415 I=I+1  
SUMPI=0.0  
IF(I)P.EQ.(O).AND.(IFS.EQ.O))GO TO 415  
DO 420 J=2,N  
MK=I+J  
I=I+1  
SUMPI=SUMPI+I  
SUMTPE=SUMTPE+I  
CONTINUE

429 SUMTPE=C.COO  
415 IF(I)Q.EQ.(O).AND.(IGS.EQ.O))GO TO 425  
CC 430 K=2,NPA  
JJ=I+K  
I=I+1  
SUMTPE=SUMTPE+I  
SUMTVECC(I)=TVECC(I)+SUMPI + SUMTPE  
CONTINUE

430 SUMTVECC(I)=TVECC(I) - SUMPI + SUMTPE  
425 TAVECC(I)=TAVECC(I)  
410 CONTINUE

CCCC CALCULATE THE SUP OF SQUARES, THE AVECC(I)'S SQUARED  
AND SUMMED, OVER ALL VALUES OF THE TIME SERIES.

SUMSSA=0.0  
DO 440 I=1,N  
I4=I+I  
SUMSSA=SUMSSA+TAVECC(I)\*\*2  
CONTINUE

CCCC FOR OUTPUT PURPOSES, CORRECT THE CRIGIN FOR THE AVEC  
INDICES, SO THAT THEY WILL RUN FROM 1 TO N.

CO 1 I=1,N  
I4=I+I  
AVECC(I)=TAVECC(I+I)  
CONTINUE  
1 RETURN  
END

```

SUBROUTINE PARSH(IP,IFS,IQ,IS,FFI,PFIS,THETA,THETAS,AVEC,X,N,NVEC
1  DOUBLE PRECISION X,AVEC,TOPI,I,CF2,MVEC,DELTA,SUMSQA
2  DOUBLE PRECISION PHI,PHIS,TFETA,THETAS,PHIST,PHIST(S),THEIAT,THEST
3  COMPLEX ION,AVEC(I,1),X(20,100),PHI(S),PHIS(S),THEIAT(S),THEST(S)
4  DIMENSION ION,AVEC(I,1),X(20,100),PHI(S),PHIS(S),THEIAT(S),THEST(S)
5  DELTA = C.CC0000001C
6  DELTA = C.CC0000001C

```

THIS SUBROUTINE CALCULATES THE DERIVATIVES USED IN THE NON-LINEAR LEAST SQUARES ROUTINE.

```

CALL SUMSQ(PFIS,PHIS,THETA,THETAS,N,NVEC,IP,IPS,IQ,ICS,LSEAS,
1  COI,M,I,N
2  ICFI,M)=AVEC(K)
3  CONTINUE

```

ASSIGN ALL PARAMETER VALUES TO TEMPORARY VARIABLES.

```

IF(IP,IFS,0)GO TO 591
IC(S,I)=I,IP
PHIST(I)=PHI(I)
591 DO 10 I=1,IPS
PHIST(I)=PHIS(I)
592 CONTINUE
IF(IFS,0)GO TO 593
DO 10 I=1,IC
THEIAT(I)=THEIAT(I)
593 DO 10 I=1,ICS
DO 10 I=1,IS
THEST(I)=THEST(I)
594 CONTINUE

```

NON THE ROUTINE ICS PERTURBATIONS OF DELTA ON EACH PARAMETER, TO OBTAIN INFORMATION ON THE SEQUENT CHANGES TO THE RESIDUALS, IN ORDER TO CALCULATE THE REQUIRED PARTIAL DERIVATIVES.

THE XII(J)'S ARE THE DERIVATIVES.

```

554 IF(IFS,0)IGC TC 200
DO 10 J=1,IP
PHI(I,PHI(I,J) + CELTA
CALL SUMSQ(PHI,PHIS,THETA,THETAS,N,NVEC,IP,IPS,IQ,ICS,LSEAS
1  DO 20 J=1,N
XCF2(I,J)=XAVEC(I,J)
XCF2(I,J) = (TCPI(I,J) - TOP2(J,J))/DELTA
22 CONTINUE
XCFI(I,J)=PHI(I,J) - CELTA
20 CONTINUE
DO 10 I=1,IPS
XCFI(I)=XAVEC(I) - CELTA
206 DO 10 I=1,IP
PHI(I,PHI(I) + CELTA
CALL SUMSQ(PHI,PHIS,THETA,THETAS,N,NVEC,IP,IPS,IQ,ICS,LSEAS
1  DO 30 I=1,N
XCFI(I)=XAVEC(I)
XCFI(I) = (TCPI(I) - TOP2(II,II))/DELTA
33 CONTINUE
XCFI(I)=PHIST(I) - CELTA
300 CONTINUE
595 ICFI(I)=AVEC(I)
DO 4 M=1,10

```

NLE03880  
NLE03950  
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NLE03970  
NLE03980  
NLE03990  
NLE04000  
NLE04010  
NLE04020  
NLE04030  
NLE04040  
NLE04050  
NLE04060  
NLE04070  
NLE04080  
NLE04090  
NLE04100  
NLE04110  
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NLE04310  
NLE04320  
NLE04330  
NLE04340  
NLE04350  
NLE04360  
NLE04370  
NLE04380  
NLE04390  
NLE04400  
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NLE04440  
NLE04450  
NLE04460

NAVAL POSTGRADUATE SCHOOL

FILE: PARSH FORTRAN P1

```

1 THETA(M) = THETA(M) + DELTA
  CALL SUPSC(PH1, PH1S, IMETA, THETA, N, WVEC, IP, IPS, IG, ICS, LSEAS)
  IC = 1
  ICP2(MH1) = 1.0
  ICP2(MH1) = AVEC(MH1)
  K4 = M + IP + IPS
  X(K4, MH1) = (TOP1(IP) - TOP2(MH1))/DELTA
44 CONTINUE
  ICP2(MH1) = THETA(M) - DELTA
400 OC = 1
  CALL SUPSC(Q, Q1, IO, THETA(M), THETA, N, WVEC, IP, IPS, IO, ICS, LSEAS)
  ICP2(MH1) = 1.0
  ICP2(MH1) = AVEC(MH1)
  K5 = M + IP + IPS
  X(K5, MH1) = (TOP1(IP) - TOP2(MH1))/DELTA
55 CONTINUE
  ICP2(MH1) = THETA(M) - DELTA
500 RETURN
  END

```

```

NLEC4450
NLEC4460
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NLEC4480
NLEC4490
NLEC4500
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NLEC4530
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NLEC4560
NLEC4570
NLEC4580
NLEC4590
NLEC4600
NLEC4610
NLEC4620
NLEC4630
NLEC4640
NLEC4650
NLEC4660
NLEC4670
NLEC4680

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65/16/1E 13.22.13

FILE: FGPE FCRTAN P1

NAVAL POSTGRADUATE SCHOOL

SUBROUTINE FORMB(P1,PHIS,THETA,THEAS,IP,IPS,IQ,IQS,EETA)  
DECLARE PRECISION(P1,PHIS,THEAS,THETA,IP,IPS,IQ,IQS,EETA)  
DIMENSION BETA(20),PHIS(5),THEAS(5),THETA(5),THEIPS(5)

CC

THIS SUBROUTINE TAKES SEPARATE PARAMETER VECTORS  
ANC PUTS THEM INTO COMBINED BETA VECTOR FORM.

```

1  IF(IP=0)GO TC 10
   BETA(1)=IP(1)
   BETA(2)=IP(2)
2  IF(IPS=0)GOTO 30
   PH=J(IPS)-PHIS(J)
   BETA(3)=PH
   BETA(4)=IP(3)
3  IF(IQS=0)GOTO 40
   PHKK=L+IP(4)+IPS+IQ
   BETA(5)=PHKK
4  RETURN
   BETA(6)=THEAS(1)
   BETA(7)=THEAS(2)
   BETA(8)=THEAS(3)
   BETA(9)=THEAS(4)
   BETA(10)=THEAS(5)
   BETA(11)=THEAS(1)
   BETA(12)=THEAS(2)
   BETA(13)=THEAS(3)
   BETA(14)=THEAS(4)
   BETA(15)=THEAS(5)
   BETA(16)=THEAS(1)
   BETA(17)=THEAS(2)
   BETA(18)=THEAS(3)
   BETA(19)=THEAS(4)
   BETA(20)=THEAS(5)

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CS/16/76 13.22.27  
FILE: PSLMSQ FORTRAN P1 NAVAL POSTGRADUATE SCHCCL

THIS ROUTINE PSUPSO CALCULATES THE SUM OF  
SQUARED RESIDUALS FOR ANY ARIMA MODEL GIVEN  
A TIME SERIES AND INITIAL PARAMETER ESTIMATES.

```

      INPUT PHASE
      REAL*8 MVEC(1000),AVEC(1000),PHI(5),THETA(5),THETAS(5),
      *SUMSCA
      DATA V,V',/
      RECALSERIES AND TIME SERIES FROM FILE FT02F001
      REACIZ(10)INS
      10 FORMAT(10I1)
      11 REAC(2,1) (MVEC(I),I=1,NS)
      11 FORMAT(15F5.6)
      INPUT NUMBER OF PARAMETERS, BY TYPE.
      IPS=0
      704 WRITE(6,1) (I,705)
      705 FORMAT(10I2)
      708 IF (IPANS=1) GO TO 706
      25 IF (I=1) GO TO 705
      25 FORMAT(10I2)
      26 REAC(1,2) (I,1) IS YCLF SERIES SEASONAL?
      26 FORMAT(12I1)
      22 REAC(1,2) (I,1) ENTER LENGTH OF SEASON VIA FORMAT 12.
      24 REAC(1,2) (I,1) ENTER NUMBER OF SEASONAL AR PARAMETERS.
      20 REAC(1,2) (I,1) ENTER NUMBER OF SEASONAL MA PARAMETERS.
      21 REAC(1,2) (I,1) ENTER NUMBER OF NON-SEASONAL AR PARAMETERS.
      23 REAC(1,2) (I,1) ENTER NUMBER OF NON-SEASONAL MA PARAMETERS.
      INPUT YOUR INITIAL PARAMETER ESTIMATES
      702 WRITE(6,3)
      30 FORMAT(10X)
      30 FORC(1,1) (I,1) ENTER YOUR INITIAL PARAMETER ESTIMATES, AS REQUES
      30 FORC(1,1) (I,1) ENTER YOUR INITIAL PARAMETER ESTIMATES, AS REQUES
      41 REAC(1,2) (I,1) ENTER NON-SEASONAL AR PARAMETER PHI(1,1).
      42 REAC(1,2) (I,1) ENTER NON-SEASONAL AR PARAMETER PHI(1,1).
      400 REAC(1,2) (I,1) ENTER NON-SEASONAL AR PARAMETER PHI(1,1).
      51 REAC(1,2) (I,1) ENTER SEASONAL AR PARAMETER PHIS(1,1).
      52 REAC(1,2) (I,1) ENTER SEASONAL AR PARAMETER PHIS(1,1).
      500 REAC(1,2) (I,1) ENTER SEASONAL AR PARAMETER PHIS(1,1).
      61 REAC(1,2) (I,1) ENTER NON-SEASONAL MA PARAMETER THETA(1,1).

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NAVAL POSTGRADUATE SCHOOL

FILE: XSUMSC FCRTAN P1

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62 FCRTAN(15.6)
63 CONTINUE
64 IF (I.E.C.0160 TC 700
65 70 L=1, IQS
66 71 WRITE(2) 'ENTER SEASONAL NA PARAMETER THETAS(, .11, .1, .1)'
67 FCRTAN(2) THETAS(I)
68 READ(1) (15.6)
69 FORMAT(15.6)
70 CONTINUE
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09/16/78 13:24:55

FILE: FUFECST FORTRAN P1 NAVAL POSTGRADUATE SCHOOL

PAGE 001

```

DIPEASICA FECT(1,00),LV(15),PHIS(15),TETA(15),THETAS(15)
DIPEASICA FECT(1,00),LV(15),THE1(15),THE2(15),THE3(15)
DIPEASICA FECT(1,00),LV(15),INDIA(15),INDIA(15),INDIA(15)
DIPEASICA FECT(1,00),LV(15),INDIA(15),INDIA(15),INDIA(15)
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DIPEASICA FECT(1,00),LV(15),INDIA(15),INDIA(15),INDIA(15)
DIPEASICA FECT(1,00),LV(15),INDIA(15),INDIA(15),INDIA(15)
DIPEASICA FECT(1,00),LV(15),INDIA(15),INDIA(15),INDIA(15)
DIPEASICA FECT(1,00),LV(15),INDIA(15),INDIA(15),INDIA(15)
DIPEASICA FECT(1,00),LV(15),INDIA(15),INDIA(15),INDIA(15)

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33333
      INPUT PHASE
      READ SERIES AND TIME SERIES FROM FILE FT02.F001

```

```

10 READ(1,10)N
    FORMATT(1,10) (MVECF(1),I=1,N)

```

```

11 FCPPA(1,15.6)
    IF(FCPPA(1,15.6) .GT. 0) THEN

```

```

      INPUT NUMBER OF PARAMETERS, BY TYPE.
      WRITE(1,15)X,'IS YOUR SERIES SEASONAL?'

```

```

1  NORMAL(1,1)
2  FORMATS(1,1) YIGC TC 202

```

```

141 WRITE(1,14) 'ENTER SEASONAL DATA AS REQUESTED: ',/
14  FCFFA(1,14) 'ENTER NUMBER OF SEASONAL DIFFERENCES.'

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22  FCRTA(1,14) 'ENTER NUMBER OF SEASONAL AR PARAMETERS.'
24  FCRTA(1,14) 'ENTER NUMBER OF SEASONAL MA PARAMETERS.'

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25  FCRTA(1,14) 'ENTER LENGTH OF SEASON VIA FORMAT 12.'
    FCRTA(1,14) 'LSEAS'

```

```

26 202 FCRTA(1,14) 'YILSEAS=1'
    FCRTA(1,14) 'YILS=C'
    FCRTA(1,14) 'YILS=0'
    FCRTA(1,14) 'YINDIFS=0'

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201 FCRTA(1,14) 'ENTER NONSEASONAL DATA AS REQUESTED: ',/
12  FCRTA(1,14) 'ENTER NUMBER OF NON-SEASONAL DIFFERENCES.'

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13  FCRTA(1,14) 'ENTER NUMBER OF NCN-SEASONAL AR PARAMETERS.'
20  FCRTA(1,14) 'ENTER NUMBER OF NCN-SEASONAL MA PARAMETERS.'

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23  FCRTA(1,14) 'ENTER NUMBER OF NON-SEASONAL MA PARAMETERS.'
    FCRTA(1,14) 'ENTER YOUR PARAMETER ESTIMATES'

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30  FCRTA(1,14) 'NOW INPUT YOUR PARAMETER ESTIMATES: ',/
31  FCRTA(1,14) 'ENTER MA CONSTANT TERM, THETA.'

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41  FCRTA(1,14) 'ENTER ACH-SEASONAL AR PARAMETER PHI(1,1,1)'.
    FCRTA(1,14) 'PHI(1,1,1)'

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      READ(1,15)

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FORCCC10
FORCCC20
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09/16/76 11:21:52  
FILE: GENERATE FCRTAM P1 NAVAL POSTGRADUATE SCHOOL

```

DIMENSION PHI(10),T(ETA(1)),START(10),M(999),MA(999)
WRITE(1) ' / IP5 / V / / IP5 / C / '
CALL TIME(1) / 99.0 / 1-ETA(999) / START / 99.0 / CONS / 0.0 /
PRINT(1) ' X / '
READ(1) (X)
301 READ(1) (X)
777 SEED = 1000000000.
302 SEED = SEED * 1000000000.
71 SEED = SEED * 1000000000.
72 SEED = SEED * 1000000000.
360 SEED = SEED * 1000000000.
361 SEED = SEED * 1000000000.
320 SEED = SEED * 1000000000.
334 SEED = SEED * 1000000000.
395 SEED = SEED * 1000000000.
306 SEED = SEED * 1000000000.
307 SEED = SEED * 1000000000.
310 SEED = SEED * 1000000000.
311 SEED = SEED * 1000000000.
644 SEED = SEED * 1000000000.
645 SEED = SEED * 1000000000.
404 SEED = SEED * 1000000000.
401 SEED = SEED * 1000000000.
203 SEED = SEED * 1000000000.
204 SEED = SEED * 1000000000.
205 SEED = SEED * 1000000000.
231 SEED = SEED * 1000000000.
403 SEED = SEED * 1000000000.

```







CS/18/IE 13.25.2C  
FILE: FTMAPS FORTRAN P1 NAVAL POSTGRADUATE SCHOOL

SUBROUTINE FTMAPS(JACV, ARPS, IP, IQ, PMAS, MNV, MA, IERR)  
DIMENSION ACV(10), ARPS(10), PMAS(10), MA(10), EPS(8), IERR  
DATA ZERR, CEM, TOL, NSIG, ITMAX, EPSMAX / 0., .1, .001, 3, 100, 0.000 /

```

10  IF (CIGT) GO TO 10
20  IF (CIGT) GO TO 10
30  IF (CIGT) GO TO 10
40  IF (CIGT) GO TO 10
50  IF (CIGT) GO TO 10
60  IF (CIGT) GO TO 10
70  IF (CIGT) GO TO 10
80  IF (CIGT) GO TO 10
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970 IF (CIGT) GO TO 10
980 IF (CIGT) GO TO 10
990 IF (CIGT) GO TO 10
1000 IF (CIGT) GO TO 10

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09/16/78 12:26.45

FILE: FTFUNC FCRTAN P1

FUNCTION FIFUNC(X) (PAR)  
 DIMENSION X(1),PAR(1)  
 DOUBLES PRECISION X PAR.FTFUNC  
 COMMON /FTFCOM/ IQFI  
 PI=3.141592653589793  
 FIFUNC=--X(IQFI)  
 FIFUNC=7  
 FIFUNC=1.0  
 FIFUNC=9.5  
 FIFUNC=4.5  
 FIFUNC=MI  
 FIFUNC = FIFUNC + X(IQFI)\*X(I)  
 FIFUNC = FIFUNC + X(IQFI)\*PAR(I)  
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## APPENDIX E

### LISTING OF DATA SETS RESIDING IN THE TIME SERIES EDITOR

This appendix contains listings of the data sets now residing in the Time Series Editor. The data consists of Box and Jenkins' [Ref. 4] time series C [Ref. 4, p. 528] and time series G [Ref. 4, p. 531], as well as a data set containing monthly Monterey, California, rainfall data from January 1931 through December 1976 .

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