# AN APPLICATION OF CP/CMS TO THE TIME SERIES ANALYSIS

Young Woo Lee

# NAVAL POSTGRADUATE SCHOOL

## Monterey, California

# THESIS

AN APPLICATION OF CP/CMS

TO THE TIME SERIES ANALYSIS

by

Young Woo Lee

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# An Application of CP/CMS
# To The Time Series Analysis

by

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# ABSTRACT

An interactive package of computer programs has been developed for the analysis of time series data. The package, called the Time Series Editor, is designed around the Box-Jenkins' statistical methodology of time series analysis. The Time Series Editor was developed for time-shared use on the Controlled Program/Cambridge Monitor System (CP/CMS) but could be easily modified to accommodate other time-sharing systems. The Time Series Editor assists in data preparation, entry, analysis and diagnostic testing. Utilization of the package requires only a limited knowledge of the computer system with all required user responses prompted by the Editor.

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# I. INTRODUCTION

Operations researchers, statisticians, economists, marketing personnel, managers and many others are frequently faced with the need to analyze time series data. In most cases their objective is to discover patterns or recognizable behavior in historical data that can be used to construct mathematical models of the time series from which forecasts of future behavior can be obtained. The importance of being able to forecast future behavior accurately cannot be overemphasized. Whether the data be budget expenditures, populations, natural resource consumption, prices, demands, economic indicators, stock-market prices, manpower levels or whatever, decision makers concerned with planning for the future must base their decisions on their best predictions about the future behavior of the time series.

Until the late 1960's, the analysis techniques were primarily those of spectral analysis with heavy application of harmonic analysis and mathematical transform theory. Because of the mathematical sophistication required by the spectral approach, the analysis capability resided fairly exclusively in the hands of mathematicians and engineers. Consequently, many naive forecasting methods such as moving averages, exponential smoothing and decomposition analyses were adopted by the majority of the decision makers. Since the late 1960's the statistical analysis of time series, embodied primarily

in the methodology developed by Box and Jenkins [Ref. 2], has received widespread acceptance. Because the Box-Jenkins approach is described in a vocabulary more familiar to operations researchers, statisticians, economists and managers, more and more business and government decision makers are building models from past data to use for planning into the future.

Many algorithms and computer programs for performing the analyses required by the Box-Jenkins approach have been developed and are readily available from many sources. One of the best sources is the collection of FORTRAN computer subroutines which resides in the International Mathematical and Statistical Library (IMSL) [Ref. 4]. The major problem with using the available computer resources lies not with any deficiency of the algorithms or the programs, but with the very nature of the Box-Jenkins approach. The Box-Jenkins method is an iterative approach which is described in Figure 1. [See Wheelwright and Makridakis, ref. 7.]

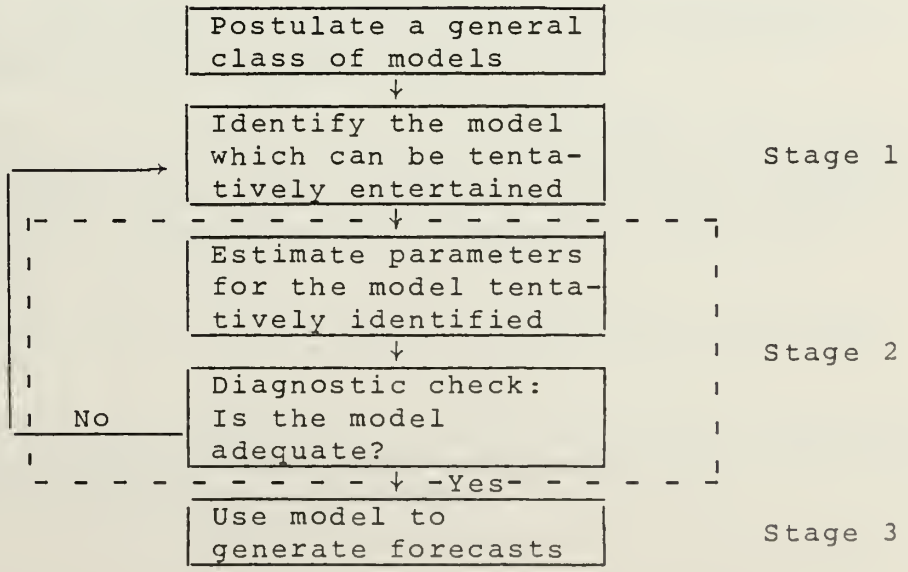


Figure 1. Box-Jenkins forecasting method.

Figure 1 shows that the Box-Jenkins method is a multi-stage, iterative process. It begins with the postulation of general class of models which has been found, experimentally to be extremely rich. Thereafter, the modeling procedure continues as a trial-and-error process with several decision points where the analyst is required to select the next direction based on the best information available to him. Each stage of the process outlined in Figure 1 may consist of several steps, and, even with the existing computer software resources, the modeling process is usually very time consuming. For example, a typical Box-Jenkins time series analyst using a batch processing computer system with access to the IMSL library of subroutines might perform the following sequence of tasks:

1. Prepare time series data.

2. Plot and visually examine the time series looking for nonstationarity, trends, deterministic patterns, etc.

3. Write a program to call the IMSL subroutine that calculates the mean, the variance, the autocorrelations and the partial autocorrelations.

4. Plot the autocorrelations and partial autocorrelations. This provides the major information needed for identification of the time series.

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 by the class of models postulated.

6. Repeat steps 2) through 4) using the transformed data.

7. Review the statistical properties of the autocorrelations and partial autocorrelations for tentative identification of the model.

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.

10. Analyze the residuals following steps 1) through 9) just as was done with the original time series.

11. Refine the model using the information obtained by the analysis of the residuals.

12. Repeat steps 8) through 10).

13. When an adequate model is obtained, write a program to call the IMSL subroutine which forecasts and determines confidence intervals for future values of the time series.

Between each pair of steps the user must manually intervene and make a subjective decision based on the information available. Thus, a great deal of user interaction is required in order to determine a mathematical model and a forecast equation. Even with rapid computer turnaround time, the process can easily consume a day or more of calendar time.

This report describes an effort to alleviate some of the problems involved with modeling time series using the Box-Jenkins approach. An interactive computer package which provides easy user access to the computational computer subroutines available in IMSL and similar subroutine libraries was developed. The package, called the Time Series Editor, was written for time-shared use on the Naval Postgraduate School's Controlled Program/Cambridge Monitor System (CP/CMS). Since all programs except the executive routine are written in FORTRAN, the Time Series Editor could be easily modified to accommodate other time-sharing systems. The Time Series Editor assists the user in data preparation,

entry, model construction, diagnostic testing and forecasting. Utilization of the package requires only a limited knowledge of CP/CMS. In fact, with the User's Guide provided in this report, a complete Box-Jenkins time series analysis can be performed in a short time by even a naive computer user. For this reason, the Time Series Editor should be valuable as an instructional aid for laboratory use in a time series class.

A brief description of the Box-Jenkins methodology is given in Chapter 2 to serve as a point of reference for the remaining material. Chapter 3 contains descriptions of each of the programs contained in the Time Series Editor. The use of the Time Series Editor is illustrated with an example time series which is given in Chapter 4.

Chapter 5 contains a summary and recommendations for additions to the Time Series Editor. A User's Guide which includes an explanation of CP/CMS sufficient for utilization of the Time Series Editor is given in Appendix A. Sample user sessions, sample outputs and complete computer listings are also included in appendices.

## II. BOX-JENKINS METHODOLOGY

In this chapter a brief description of the Box-Jenkins time series modeling methodology is given. For a more detailed discussion the reader is referred to the texts by Anderson [Ref. 1], Box and Jenkins [Ref. 2], Pindyck and Rubinfeld [Ref. 6], and Nelson [Ref. 5]. The material presented here is included primarily to serve as a point of reference for the program descriptions that follow in later chapters. It is also included here to aid the user in understanding the computer output and the questions asked by the Time Series Editor.

### A. PROPERTIES OF STATIONARY PROCESSES

A discrete stochastic time series is a set of observations $y_1, y_2, \ldots, y_T$ generated sequentially in time by a set of jointly distributed random variables; i.e., the data $y_1, \ldots, y_T$ represents a particular realization of a joint probability distribution $f(y_1, y_2, \ldots, y_T)$. A future observation, $y_{T+k}$ can be thought of as being generated by a conditional probability distribution function $f(y_{T+k} | y_1, \ldots, y_T)$ given the realization through time T. The stochastic process which generates the time series is said to be stationary if its properties are unaffected by a change of time origin; that is, if the joint probability distribution associated with m observations $y_{t_1}, y_{t_2}, \ldots, y_{t_m}$, made at any

set of times $t_1, t_2, \ldots t_m$ is the same as that distribution associated with m observations $y_{t_1+k}, y_{t_2+k}, \ldots, y_{t_m+k}$ made at times $t_1+k, \ldots, t_m+k$.

If a process is stationary, the probability distribution $f(y_t)$ is the same for all times t. Thus the process has a constant mean

$$\mu = E[y_t] = \int_{-\infty}^{\infty} yf(y)dy$$

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

$$\sigma^2 = E[(y_t-\mu)^2] = \int_{-\infty}^{\infty} (y-\mu)^2 f(y)dy$$

which measures its variability about the mean level. Since the probability distribution $f(y_t)$ is the same for all times t, the mean and the variance can be estimated by the averages taken over time:

$$\bar{y} = \frac{1}{N}\sum_{t=1}^{N} y_t \quad \text{and} \quad \hat{\sigma}^2 = \frac{1}{N}\sum_{t=1}^{N} (y_t-\bar{y})^2$$

The stationarity assumption also implies that the bivariate distribution $f(y_{t_1}, y_{t_2})$ is the same for all times $t_1$ and $t_2$ such that $|t_2-t_1|$ is constant. The autocorrelation at lag k, $\rho_k$, is defined as:

$$\rho_k = \frac{E[(y_t-\mu)(y_{t+k}-\mu]}{\sigma^2}$$

This is estimated by the time average:

$$r_k = (\frac{1}{N}\sum_{t=1}^{N-k} (y_t-\bar{y})(y_{t+k}-\bar{y}))/\hat{\sigma}^2$$

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

Another function which is important for purposes of identifying the appropriate linear time series model is the partial autocorrelation function. Let $\hat{y}_t = b_o + b_1 y_{t+1} + b_2 \cdot y_{t+2} + \dots + b_{k-1} y_{t+k-1}$ where the b's are the least squares estimates of the linear regression coefficients ($\beta$'s) in the model

$$y_t = \beta_o + \beta_1 y_{t+1} + \dots + \beta_{k-1} y_{t+k-1} + e_t .$$

Let $z_t$ be the residual of $y_t$ after removing the linear effect of $y_{t+1}, \dots y_{t+k-1}$ from $y_t$; i.e.

$$z_t = y_t - \hat{y}_t .$$

The partial autocorrelation of lag k, denoted $\phi_{kk}$, is defined to be the simple correlation of lag k for the adjusted series $z_1, z_2, \dots$ .

## B. AUTOREGRESSIVE-MOVING AVERAGE MODELS

The general class of models postulated by Box and Jenkins for stationary time series is the class of linear models defined by:

$$y_t = \phi_1 y_{t-1} + \phi_2 y_{t-2} + \dots + \phi_p y_{t-p} + \theta_o + a_t - \theta_1 a_{t-1} - \theta_2 a_{t-2} - \dots - \theta_q a_{t-q} \qquad (1)$$

where $\{a_t\}$ is a sequence of observations from a white noise process ($E[a_t] = 0$, $var[a_t] = \sigma_a^2$ and $E[a_t a_{t+k}] = 0$ for all $k > 0$) and $\phi_1,\ldots,\phi_p$, $\theta_o$, $\theta_1,\ldots,\theta_q$ are p+q+1 parameters that are to be estimated from the data. The model above is called a mixed autoregressive-moving average (ARMA) model of order (p,q). If q=0, the model is called an autoregressive model of order p, $AR_p$; and if p=0, the model is called a moving average model of order q, $MA_q$. Thus, the general linear model of Box-Jenkins represents the current observation $y_t$ as a weighted sum of past observations and present and past random shock terms. The model is usually expressed in abbreviated form using operator and transfer function notation:

$$\phi(B)y_t = \theta_o + \Theta(B)a_t \qquad (2)$$

where $\phi(B) = 1-\phi_1 B-\phi_2 B^2-\ldots-\phi_p B^p$, $\Theta(B) = 1-\theta_1 B-\ldots-\theta_q B^q$ and B is the operator defined by $B^k_{y_t} = y_{t-k}$. In order to guarantee stationarity it is necessary that the autoregressive parameters satisfy certain conditions. The conditions can be summarized by stating that all roots of the polynomial equation $\phi(B) = 0$ (treating B as a dummy variable) must lie outside the unit circle.

The tentative identification of the appropriate member of the general class (the identification of p and q) is accomplished by comparing the sample autocorrelation and partial autocorrelation functions of the given time series with the theoretical autocorrelation and partial autocorrelation 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.

## C. HOMOGENEOUS NONSTATIONARY SERIES

In many cases the time series of interest is not stationary. Instead, the probabilistic structure of the process which generates the time series may change with time. For example, there may be some sort of trend or seasonal pattern in the time series. If the process does, nevertheless, exhibit behavior which is somewhat homogeneous then the original time series can often be transformed into a stationary series that can be described by an ARMA model.

A time series is said to be homogeneous nonstationary of order d if $w_t = \Delta^d y_t$ is a stationary series. Here $\Delta$ denotes the differencing operator:

$$\Delta y_t = y_t - y_{t-1} = (1-B)y_t$$

$$\Delta^k y_t = \Delta(\Delta^{k-1} y_t)$$

That a time series is nonstationary is indicated by a plot of the time series itself (e.g. a nonconstant mean) and by the autocorrelation function. Characteristic of the correlogram of a nonstationary series is the very slow damping out of the autocorrelation. When this property of the correlogram is observed, the user should difference the series one time and compute the correlogram for the series $w_t = \Delta y_t$. The user should continue to difference the series until the resulting series appears stationary or until the procedure

appears not to improve the series. The transformed series $w_t = \Delta^d z_t$ is then modeled as an ARMA model. The resulting model, in terms of the original time series is:

$$\phi(B)\nabla^d y_t = \theta_o + \theta(B)a_t \ . \qquad (3)$$

In this form of the model, the transfer function $\phi(B)$ is assumed to be stationary; i.e., all roots of $\phi(B) = 0$ are outside the unit circle. It is sometimes written in the equivalent form

$$\psi(B)y_t = \theta_o + \theta(B)a_t \qquad (4)$$

where $\psi(B) = \phi(B)\nabla^d = \phi(B)(1-B)^d$ and, clearly, $\psi(B)$ is not a transfer function of a stationary series ($\psi(B) = 0$ has d roots on the unit circle). The ARMA model for the differenced series is called an autoregressive integrated moving average (ARIMA) model of order (p,d,q). For the purpose of distinguishing between the two forms of the ARIMA model, equation (3) is referred to as the differenced form and (4) as the undifferenced form.

D. SEASONAL TIME SERIES

Seasonality is defined as cyclical behavior that occurs on a regular calendar basis. For example, a highly seasonal time series would be the sales of Christmas ornaments which exhibit a strong peak every December. Rainfall, crop yields, livestock production, energy consumption, and many other time series that are influenced by the weather all exhibit

seasonal patterns. Seasonal patterns are often easy to spot simply by observing the time series directly. However, many times, if the variability in the time series is large, seasonal patterns will not be distinguishable from the other fluctuations. Recognition of seasonality is important since it provides information that can aid in modeling and forecasting. The autocorrelation function makes recognition of seasonal patterns easier.

Suppose, for example, that a monthly series has an annual seasonal pattern. Then the realizations should show some special correlation with other realizations which lead or lag by 12 months; i.e., there should be some correlation between $y_t$ and $y_{t+12}$, $y_t$ and $y_{t+24}$, $y_t$ and $y_{t+36}$, etc. These correlations should manifest themselves in the autocorrelation function which should show peaks at k = 12, 24, 36, etc.

The Box-Jenkins modeling approach for seasonal (nonstationary) time series is to first transform the seasonal series to a new series which is stationary. This can often be accomplished by taking seasonal differences $\Delta_s^d y_t$ defined as follows:

$$\Delta_s y_t = y_t - y_{t-s} = (1-B^s)y_t$$

$$\Delta_s^d y_t = \Delta_s(\Delta_s^{d-1} y_t) = (1-B^s)^d y_t$$

The transformed time series $\{w_t\}$ ($w_t = \Delta_s^d y_t$) is then analyzed as a stationary time series. (It may be necessary to perform more than one seasonal and/or differencing transformation before the resulting series is stationary.) Suppose that

the resulting ARMA model for the transformed series is

$$\phi(B)w_t = \theta_o + \theta(B)a_t$$

The model for the original series is then

$$\phi(B)(1-B^s)^d y_t = \theta_o + \theta(B)a_t \ .$$

## E. PARAMETER ESTIMATION

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

$$\phi(B)\Delta^d y_t = \theta_o + \theta(B)a_t \qquad (5)$$

where $\phi(B) = 1-\phi_1 B-...-\phi_p B^p$ and $\theta(B) = 1-\theta_1 B-...-\theta_q B^q$. There are p+q+2 unknown parameters, $\{\phi_1,...,\phi_p,\theta_o,\theta_1..,\theta_q,\sigma_a^2\}$, that must be estimated. The Box-Jenkins procedure separates the estimation problem into two parts. First estimates are obtained for the autoregressive-moving average parameters $\underline{\phi}$ and $\underline{\theta}$, and the estimates are then made of $\sigma_a^2$ and $\theta_o$ which are functions of the ARMA parameters. The usual procedure is to select those parameter values $\hat{\underline{\phi}}$ and $\hat{\underline{\theta}}$ that minimize the sum of squared errors. Let $\mu_w = \theta_o/(1-\phi_1-...-\phi_p)$ and $\tilde{w}_t = \Delta^d y_t - \mu_w$. Then, it can be easily shown that $\mu_w = E[w_t]$ and that (5) can be rewritten as:

$$\phi(B)(w_t-\mu_w) = \theta(B)a_t$$

or

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

Let $\bar{w}$, the sample mean, be the estimate of $\mu_w$ (if $d > 0$, $\mu_w$ is usually 0) and let

$$\hat{a}_t = \hat{\theta}^{-1}(B)\phi(B)(w_t - \bar{w}) \quad . \qquad (6)$$

Let

$$S(\hat{\underline{\phi}}, \hat{\underline{\theta}}) = \sum_t \hat{a}_t^{\,2} \; .$$

The objective is to select those parameters $\hat{\underline{\phi}}$ and $\hat{\underline{\theta}}$ that minimize $S(\hat{\underline{\phi}}, \hat{\underline{\theta}})$. Since the equation S is nonlinear in the parameters, iterative search methods must usually be used in the minimization. An estimate of $\sigma_a^2$ is provided by

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

F. DIAGNOSTIC CHECKING

After the model has been tentatively identified and parameter estimates have been obtained, the next task is to test whether or not the original specification was correct and the model is adequate. The process of testing the model takes many forms, but usually involves at least the following two steps:

1. Generate a simulated series from the estimated model and compare the simulated series and its autocorrelation functions with the original series and its respective autocorrelation and partial autocorrelation functions. The comparison is primarily subjective.

2. Compute the residuals of the estimated model from (6) 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. There are many quantitative statistical tests that can be used to test hypotheses about normality and zero correlation.

A plot of the autocorrelation and partial autocorrelation functions of the residuals provides not only a test of whether or not the residuals are uncorrelated, but, if they are correlated, the plots suggest modifications to the model. For example, suppose the model was tentatively specified as the ARMA(1,1) model: $(1-0.5B)(y_t-2) = (1+0.7B)a_t$ and the autocorrelations and partial autocorrelations of the residuals suggest the model

$$(1-0.3B)a_t = u_t$$

where the u's are white noise (uncorrelated with variance $\sigma_u^2$). Then, the next model entertained for the original time series should be the ARMA(2,1) model:

$$(1-0.3B)(1-0.5B)(y_t-2) = (1+0.7B)u_t \; .$$

G. FORECASTING

The objective of forecasting is to predict future values with as little error as possible. The criterion most often used for selection of the best forecast is that forecast which has minimum mean square forecast error. Thus, if

$\hat{y}_T(\ell)$ represents the forecast at origin T of the value $y_{T+\ell}$, the objective is to select $\hat{y}_T(\ell)$ so that

$$E[(y_{T+\ell} - \hat{y}_T(\ell))^2]$$

is minimized. This forecast is given by taking $\hat{y}_T(\ell)$ as the conditional expectation of $y_{T+\ell}$:

$$\hat{y}_T(\ell) = E[y_{T+\ell} | y_T, y_{T-1}, \ldots, y_1] \qquad (7)$$

The forecasts can be easily generated recursively from the mathematical model utilizing the fact that

$$E[y_{T-j}] = y_{T-j} \quad \text{for } j=0,1,2 \text{ (T is current time)}$$

and

$$E[a_t] = \begin{cases} 0 & \text{if } t > T \\ a_t & \text{if } t \leq T \end{cases} .$$

For example, suppose the estimated model is:

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

or, equivalently,

$$y_t = 0.5y_{t-1} - 0.6y_{t-2} + a_t + 0.3a_{t-1}$$

where $y_{100} = 1.4$, $y_{99} = 1.0$, and $a_{100} = 0.2$. The forecasts of $y_{101}$, $y_{102}$, and $y_{103}$ made at time $t = 100$ are found as follows:

$$\begin{aligned}\hat{y}_{100}(1) &= E[y_{101}|y_{100},y_{99},\ldots,y_1] \\ &= E[0.5y_{100}-0.6y_{99}+a_{101}+0.3a_{100}] \\ &= 0.5y_{100} - 0.6y_{99} + 0.3a_{100}\end{aligned}$$

$$\hat{y}_{100}(1) = 0.16$$

$$\begin{aligned}\hat{y}_{100}(2) &= E[y_{102}|y_{101},y_{100},\ldots,y_1] \\ &= E[0.5y_{101}-0.6y_{100}+a_{102}+0.3a_{101}] \\ &= 0.5\hat{y}_{100}(1) - 0.6y_{100}\end{aligned}$$

$$\hat{y}_{100}(2) = -0.76$$

$$\begin{aligned}\hat{y}_{100}(3) &= E[0.5y_{102}-0.6y_{101}+a_{103}+0.3a_{102}] \\ &= 0.5\hat{y}_{100}(2) - 0.6\hat{y}_{100}(1) \\ &= -0.48\end{aligned}$$

Let $e_T(\ell) = y_{T+\ell} - \hat{y}_T(\ell)$ be the forecast error $\ell$ periods ahead. It can be shown that $e_T(\ell)$ is given by

$$e_T(\ell) = a_{T+\ell}+\psi_1 a_{T+\ell-1}+\ldots+\psi_{\ell-1}a_{T+1} \qquad (8)$$

where the weights $\psi_j$ are determined from

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

The variance of the forecast error is given by

$$E[e_T^2(\ell)] = (1 + \psi_1^2+\ldots+ \psi_{\ell-1}^2)\sigma_a^2 \qquad (9)$$

From this, a confidence interval of z standard deviations around a forecast $\ell$ periods ahead would be given by

$$C_z(\hat{y}_T(\ell)) = \hat{y}_T(\ell) \pm z(1 + \sum_{j=1}^{\ell-1} \psi_j^2)^{1/2} \hat{\sigma}_a \qquad (10)$$

Note from expression (8) that the one-step ahead forecast error, $e_T(1)$, is simply $a_{T+1}$, i.e.

$$y_{T+1} - \hat{y}_T(1) = a_{T+1} .$$

This explains the common use of the word residual to refer to the random shock terms. Also, from expressions (9) and (10) it is clear that the forecast error variance is a non-decreasing function of the length of the forecast period $\ell$. Thus, the confidence bands must get wider as the forecast period gets larger.

# III. DESCRIPTION OF THE TIME SERIES EDITOR

In this chapter, descriptions are given of each program in the Time Series Editor that interacts with the user. There are eight separate program modules that are currently included in the Editor. In addition, there are a few other programs that reside in the Editor, but which are completely transparent to the user. The latter programs serve useful functions in conjunction with the other eight modules, but they are not described here.

No attempt is made to describe the actual mathematical calculations or algorithms that are performed by the programs. Rather, the objective is to give general descriptions about what each program can do for the user and how the user interacts with the programs. The eight programs described in this chapter are TIMESER EXEC, PLOT, DIFF, AUTO, ESTIMATE, FORECAST, SIMULATE and GENERATE.

## A. THE EXECUTIVE PROGRAM

The Time Series Editor contains a master program, called TIMESER EXEC, that provides file control of all of the other programs, controls input and output, takes care of the necessary CP/CMS protocol and provides instructions to the user as to what is in the Time Series Editor and how each program can be used. TIMESER is written in a special CP/CMS Exec language. It is the only program in the Editor that is not

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written in FORTRAN, and, consequently, it should be the only program that would need modification if the Editor were to be adapted to another time sharing system.

After the user has logged into CP/CMS and linked to the files containing the Time Series Editor (a user's guide for this is given in Appendix A) the entire Editor package is made available to the user by his command, TIMESER EXEC.[1] On entry of this command, the EXEC provides a guided tour through the Editor. It tells the user what the Editor can provide; it asks the user what tasks he wants to do; and, on the basis of the user's answers, it instructs the user as to what data is required and how it must be entered. When the user selects an option for execution, the EXEC loads the appropriate program(s) and automatically manipulates any required input and output files.

## B. DATA ENTRY AND PROGRAM OUTPUT

Whenever data is required, the user is prompted by either the EXEC or the program module being executed. In most cases, the necessary user response is a single alphanumeric character input during execution by keyboard. However, in some cases, the amount of data required is too bulky for keyboard entry, and the data is entered more efficiently offline via cards or tapes. Similarly, most of the output is typed out

---

[1]There is a second executive routine, called TS EXEC, that can be used by the more experienced analysts who wish to suppress some of the user instructions. This abbreviated program provides the same basic services as TIMESER EXEC.

right at the user's terminal, but, in some cases, the output is printed offline for conservation of time and to provide a hard copy of the results.

Detailed descriptions are given of the input and output requirements of each program in the individual program write-ups. However, there are some general principles of data input that apply for all programs. These are described in this section.

1. Offline Card Input

When a large volume of data, such as a time series of a hundred or more observations, is required, the data can be entered more efficiently through mechanisms other than keyboard entry. Keyboard entry would be not only much slower, but also more likely to contain errors than other input mediums. Thus, the Time Series Editor requires that the time series data be entered offline via cards. The data are read offline and stored in the user's file FT02F001 which is read automatically when required by the Time Series Editor. An example of an input data deck for use in the Editor is shown in Figure 2.

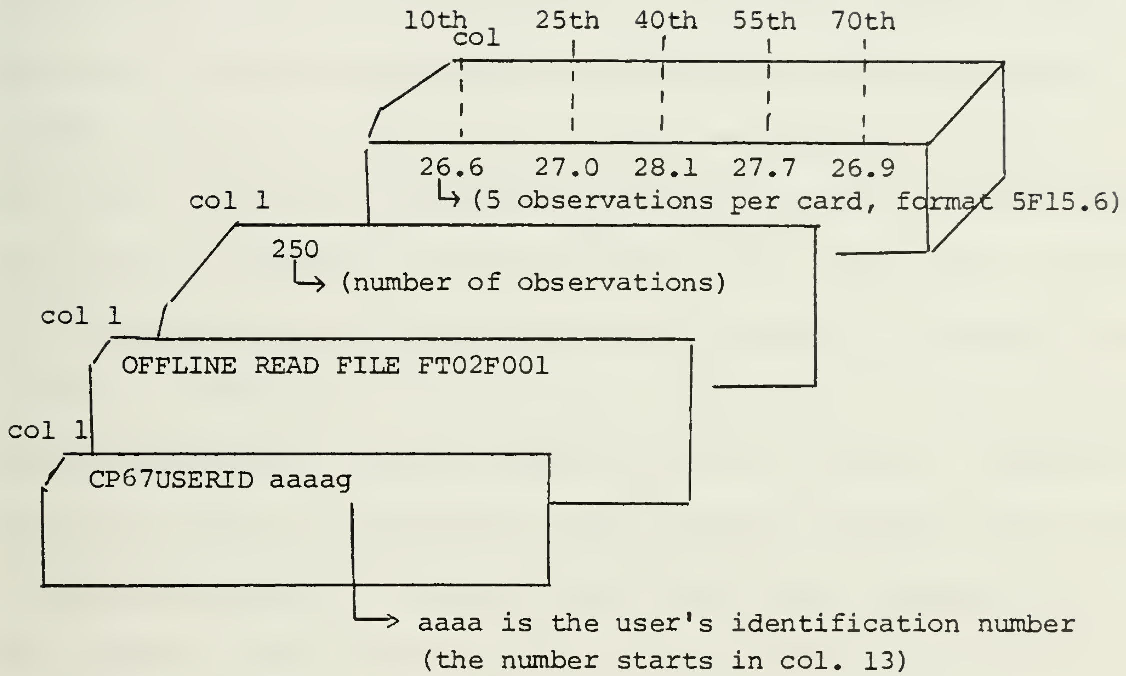



Figure 2. Card deck for offline read.

2. Numeric Keyboard Input

When the user is prompted to enter numerical values such as the number of observations, the number of parameters, parameter estimates or starting conditions, he must enter those values before program execution can continue. The user should enter the data according to standard FORTRAN practice. That is, integer data should be entered (without decimal) for counts and names beginning with the letters I through N; floating data should be entered with decimal point for all other variables. Because a typed decimal point overrides a floating format it is not necessary for the user to concern himself with the format for floating data (the user is never asked to enter more than a single observation on a line). However, some care must be exercised when entering integer data because integer data must be right justified in its format field. The user is told whenever the integer format is anything other than I1. For example, suppose the user wants to analyze a time series having only 65 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, L, VIA I3.

The user should then enter:

```
col.    123
        b65  (b represents a blank space)
```

If the blank were omitted, the program would read the length as 650 and many problems would occur.

### 3. Alphabetic Keyboard Input

The Time Series Editor often requests the user to respond with alphabetic input. For example, it may ask him a question that requires a yes or no answer, or it may ask him what option he wants to execute. The editor has been programmed to read only the first letter of the user's response. Thus, he need only enter a single letter for each such inquiry. For example, he should enter Y for yes, N for no, P for the PLOT option, E for the ESTIMATE option, etc.

### 4. Output

Most of the results are written out right at the user's terminal. In some cases, however, the output is printed offline to conserve time. Such results as plots and transformed time series are written onto various files (FT03F001, FT08F001, FT01F001) and the EXEC program prints them offline under the user's identification number. The files can also be printed out at the user's terminal at his request.

## C. PLOT PROGRAM

The PLOT program plots any given time series which resides in file FT02F001. Other than the time series, which is entered offline, the program requires only that an identification title for the plot be entered by the user during execution. The plot is automatically printed offline and is also found in file FT08F001. The PLOT program uses the subroutine PLOTP in the IBM Scientific Subroutine Package Library (SSPLIB).

## D. DIFF PROGRAM

The DIFF program performs seasonal and/or nonseasonal differences and it allows the user to transform a given time series using logarithmic or exponential transformations. The program requires the given time series to reside in file FT02F001, and it requires the user to input the following information during program execution:

(1) Type of time series (seasonal, nonseasonal)

(2) Order of differencing (for stationarity)

(3) Length of seasonal period (for seasonal series only)

(4) Type of transformation (none, exponential, logarithmic)

(5) Transform parameters (if log or exponential transform is desired)

(6) Yes or no responses to questions about plotting of autocorrelations and partial autocorrelations of transformed/differenced series.

The transformed/differenced series is written out into file FT03F001 and can be printed out at the user's terminal if he requests a printout. Plots of the transformed/differenced series, its autocorrelations, and its partial autocorrelations can be printed offline.

This program is used to transform a given series that may be seasonal and/or nonstationary or nonhomogeneous into a stationary series of the type possible for analysis using the Box-Jenkins methodology. The program utilizes the IMSL subroutine, FTRDIF.

## E. AUTO PROGRAM

AUTO calculates summary statistics from a given time series. The summary statistics include the sample mean,

variance, autocorrelations, and partial autocorrelations of logs one through 20. All of the statistics are printed out at the user's terminal, and, in addition, plots of the autocorrelations and partial autocorrelations are printed out offline. Furthermore, the plots reside in the user's file FT08F001 so that they may also be printed at the user's terminal. That is, however, a very time consuming process. AUTO provides the major information about stationarity, seasonality and model identification. With the Box-Jenkins procedure, the second moments (autocorrelations and partial autocorrelations) are the primary tools for tentative model identification. In addition, AUTO is used in the diagnostic checkout phase of model building to test the residuals.

The time series (original, transformed or differenced, or residuals) must reside in file FT02F001. (When a series is transformed or the residuals are calculated, those values are automatically stored in file FT02F001 temporarily for further analysis.) The program uses the IMSL subroutine FTAUTO.

## F. ESTIMATE PROGRAM

After the user has tentatively identified a model, the Editor program ESTIMATE should be executed to calculate maximum likelihood estimates of the model parameters. It estimates the autoregressive parameters, the moving average parameters, the constant term and the variance of the shock terms. It also determines the residuals which are so important for the diagnostic checkout phase of model building.

ESTIMATE uses the IMSL subroutine FTMAXL to estimate the parameters.

ESTIMATE needs the time series in file FT02F001 prior to execution. During program execution the user will be prompted with the following requests:

1) Enter number of autoregressive (AR) parameters.

2) Enter number of moving average (MA) parameters.

3) Enter the number of differences.

ESTIMATE then provides the following output:

1) Estimated AR parameters for the undifferenced form of the model.

2) Estimated MA parameters.

3) Estimated overall MA constant and white noise variance.

4) Auto- and partial correlations of residuals.

5) Plots of (4).

6) Values of residuals printed out offline and residuals stored in file FT03F001.

7) Chi-square goodness of fit value for estimated model.

## G. FORECAST PROGRAM

The Editor program, FORECAST, uses the estimated mathematical model to compute forecasts of future values of the time series. It also computes $(1-\alpha)$ 100% probability limits for the forecasted values. The program utilizes the IMSL subroutine FTCAST.

The time series must reside in file FT02F001 before execution begins. During execution, the user is required to enter the following inputs:

1) Origin of forecasts

2) Number of AR parameters

3) Estimated values of AR parameters

4) Number of MA parameters

5) Estimated values of MA parameters

6) Overall MA constant and white noise variance

7) Maximum lead time for a forecast

8) Order of differencing in model

9) Significance level for forecast confidence limits

The program then provides the following output:

1) AR parameters in undifferenced form[2]

2) Forecasts for lead times $\ell = 1,2,\ldots,max$

3) Deviations from each forecast for the $(1-\alpha)$ 100% confidence limits

4) Plots of forecasts and corresponding deviations joined with the original time series. This is plotted offline.

## H. SIMULATE AND GENERATE PROGRAMS

Because of their similarities the Editor programs SIMULATE and GENERATE are described together. GENERATE allows the user to generate a time series from any ARIMA model that he specifies. The user must identify the model and give values for its parameters and starting conditions. The program takes the specified model, generates random noise terms, and calculates as many values of the time series as desired.

---

[2] Suppose the identified model was ARIMA (1,1,0). The differenced form is $(1-\phi_1 B)\Delta y_t = \theta_o + a_t$. The undifferenced form is $(1-(1+\phi_1)B+\phi_1 B^2)y_t = \theta_o + a_t$, found by multiplying $(1-\phi_1 B)$ by $(1-B)$.

This program is useful for purposes of classroom instruction for the generation of a wide variety of time series examples for model identification. It is also useful for the diagnostic phase of model checkout. A time series can be generated from the estimated model and its properties can be compared with those of the original series. If large discrepancies occur the estimated model may be inadequate.

The program requires the user to enter the following inputs during execution:

1) A randum number seed
2) Number of AR parameters (undifferenced form)
3) Number of MA parameters
4) Length of time series
5) White noise variance
6) Values of AR and MA parameters
7) Initial starting values

The program output is the generated time series.

The SIMULATE program provides the capability of generating any number of simulated time series'. This is useful for predicting what might happen in the future and to demonstrate that, even within a given model, the actual observed time series' can differ substantially. This program uses GENERATE but also requires as input the number of simulated series the user wishes to generate. Furthermore, the SIMULATE program allows the user to select values of the original time series as starting values for the simulated series'. Output consists of the simulated series' and plots.

This completes the descriptions of the programs contained in the Time Series Editor. The actual program listings are given in Appendix C and sample user sessions are shown in Appendix B. In the next chapter, an example is given of an entire time series analysis from plotting to diagnostic testing and forecasting.

# IV. EXAMPLE TIME SERIES ANALYSIS

In this chapter a description is given of a complete analysis of a time series using the Box-Jenkins procedure and the Time Series Editor. The time series analyzed is series C (Chemical Process Temperature Readings) from Box and Jenkins [Ref. 2, p. 528]. This time series was selected because it is analyzed completely in Ref. 2 so that the user can compare the results found there with the results given by the Time Series Editor.

The first step in the analysis of series C is to plot the time series. This is shown in Figure 3. The plot reveals rather wide fluctuations in the series but not the sort of explosive nonstationary behavior that would render a modeling attempt 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). This is characteristic of ARIMA models with one or two differences.

Second, the autocorrelations, partial autocorrelations, mean, and variance of the series were estimated using AUTO. The numerical values are printed out in Table I and plots of the autocorrelations and partial autocorrelations are given in Figures 4 and 5. Figure 4 shows that the autocorrelations dampen out slowly in a near linear fashion. This is an indication that the series is nonstationary and that

one or more differences are needed to make it stationary. The partial autocorrelation plot is not informative when the autocorrelations fail to dampen out rapidly.

As suggested by the plots of original series and its autocorrelations, the program DIFF was executed to transform the series $\{y_t\}$ to the series $\{w_t\}$ where $w_t = \Delta y_t = y_t - y_{t-1}$. The values of the series $\{w_t\}$ are tabulated in Table II. The autocorrelations and the partial autocorrelations of the differenced series were then calculated and plotted. The values are given in Table III and the correlation plots are shown in Figures 6 and 7. The correlation plots suggest that the first differenced series is either ARMA(1,0) with the AR parameter near unity (the autocorrelations of the first differences also dampen out slowly) or a second difference is required. Thus, two candidates are suggested:

1) ARIMA(1,1,0): $(1-\phi_1 B)(1-B)y_t = \theta_o + a_t$

and 2) ARIMA(0,2,0): $(1-B)^2 y_t = \theta_o + a_t$.

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

1) $(1-\phi_1 B)\Delta y_t = \theta_o + a_t$ ARIMA(1,1,0)

and 2) $\Delta^2 y_t = \theta_o + (1-\theta_1 B - \theta_2 B^2)a_t$ ARIMA(0,2,2)

The next step is to calculate maximum likelihood estimates of the model parameters. The program ESTIMATE was

used to do this. The estimated parameters for the ARIMA (1,1,0) are:

$$\hat{\phi}_1 = 0.8131$$
$$\hat{\theta}_o = 0.0$$
$$\hat{\sigma}_a^2 = 0.0178396$$

The autocorrelation and partial autocorrelations of the residuals were calculated and plotted to test the model. The correlations should appear to be estimates of a pure white noise process if the model is adequate. The model passed that test. A goodness-of-fit test was also performed to test the model. The chi-square value was $\chi^2 = 21.51$ with 19 df and a significance level of 0.3082. Thus, there is no strong evidence to suggest that the (1,1,0) model:

$$(1-1.8131B + 0.8131B^2)y_t = a_t \qquad (11)$$

is inadequate.

Parameter estimates were also obtained for the ARIMA (0,2,2) model using ESTIMATE. The parameter estimates were:

$$\hat{\theta}_o = 0.0$$
$$\hat{\theta}_1 = 0.1382$$
$$\hat{\theta}_2 = 0.1300$$
$$\hat{\sigma}_a^2 = 0.0189515$$

As before, the correlation plots of the residuals fail to suggest any inadequacy of the model. However, the chi-square lack of fit test yielded:

$$\chi^2 = 28.74 \text{ with 18 df and a significance level of } 0.0516.$$

Thus, if the ARIMA(0,2,2) model were the correct model a chi-square value as large as 28.74 would occur by chance with a probability of only 0.0516. There is some ground here for questioning the ARIMA(0,2,2) model. Because of its simplicity (parsimony is a very desirable feature for all models) and its better fit, the ARIMA(1,1,0) model, equation (11), was selected.

The estimated model, equation (11), for series C was used to calculate forecasts and confidence limits for those forecasts. The forecasts were made for 13 periods into the future at origin t=20 using the observed values of the original time series as starting conditions. Figure 8 shows a plot of the forecasted values adjoined to the original series with 80% confidence limits about those forecasts. The forecasted values and the probability deviations are tabulated on page 59. The plot shows that the confidence limits are very wide for lags far into the future.

Finally, program SIMULATE was utilized to generate two simulated series from eq. (11). Values of these two simulations are given in Table IV. Plots of those simulated series are shown in Figure 9. The general shape of those curves is like that of the original time series, thus confirming the estimated model.

The keyboard printout of the user session that generated the analysis above is included in Appendix B. The entire session lasted approximately one and a half clock hours including checkout of plots and consumed less than one minute of CPU time.

# V. SUMMARY AND RECOMMENDATIONS

There is a growing need for an efficient unified collection of computer programs for aiding operations researchers, statisticians, economists, managers, and other people who must analyze time series. The Box-Jenkins methodology has opened the doors of time series analysis to an expanding population of analysts. Many computational algorithms have been developed and are available in many forms. The problem has been the iterative nature of the Box-Jenkins' model building procedure. Such a procedure is straightforward but can be very time consuming. The Time Series Editor that has been described in this report provides a unified collection of computer programs in an interactive time-sharing mode that can aid the user in all phases of the model building procedure from the plotting of the time series to the forecasting of future values. The Editor does not develop new computational algorithms. Rather, it makes those that are available easier and faster to use. With its simple input requirements which are all prompted by written instructions, the Editor can easily be used by the most naive computer use.

The Box-Jenkins methodology has been described in Chapter 2 and descriptions of the modules of the Time Series Editor have been given in Chapter 3. These descriptions were given not as a substitute for study of the Box-Jenkins technique,

but as a communication device to explain to the potential user of the Time Series Editor what happens in the various stages of the computational process, and to explain what the Editor requests mean. An example time series analysis covering all stages of the Box-Jenkins model building procedure was covered in Chapter 5. Appendices contain a User's Guide to the Time Series Editor, sample user sessions and program output, and program listings.

Although the Editor covers the entire model building process, as described by Box and Jenkins, from the plotting of the series to diagnostic testing and forecasting, much more could be added to improve the Editor's capability and utility. Listed below are several options that are recommended for addition to the Time Series Editor.

1. Extend the diagnostic ability to include a periodogram analysis or other tests related to the spectral analysis of time series.

2. Include an option that will determine all roots of the characteristic equation and give the general solution to the autocorrelation function and to the eventual forecast function.

3. Modify the FORECAST option to allow forecasts for seasonal nonstationary series'.

4. Modify the ESTIMATE option to provide parameter estimates for seasonal stationary series'.

5. Expand the univariate model building capability to linear transfer function model building.

6. Expand the Time Series Editor to include multivariate models such as multiple regression.

# APPENDIX A

# USER'S GUIDE TO TIME SERIES EDITOR

## APPENDIX A: USER'S GUIDE TO TIME SERIES EDITOR

In order to use the Time Series Editor, the user must log onto CP, link to the disk storage area where the Time Series Editor resides, implement CMS, log into the general user and Time Series Editor disk areas, and enter the EXEC routine. It is also necessary to log out of the system at the completion of execution. The material which follows will enable the user to perform the above steps on the NPS CP/CMS system. Commands marked with an asterisk (*) are entered by the user (the asterisk itself is omitted). Those without an asterisk and those in all capital letters are system responses. Numbered sentences are comments which will not appear during an actual user session. The instructions and system responses assume an IBM 2741 Input/Output Terminal. Some modifications may be necessary if other terminals are used.

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

   CP-67 online   xd.65   qsyosu

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

   *login xxxxgnn

3. xxxx is the user's identification number, and nn is the terminal number (written on the right-hand-side of the terminal. For example, if the user's ID is 0655 and the terminal number is 07 the input would be: login 0655g07

4. The system will respond with the statement:

   ENTER PASSWORD:

5. The user then enters his password (most users at NPS have the password npg):

   *npg

6. The system will then respond:

   ENTER 4-DIGIT PROJECT NUMBER FOLLOWED BY 4-CHARACTER COST CENTER CODE:

7. The user then enters:

   *aaaabbbb

8. aaaa is the assigned project number and bbbb is the user's section designator or faculty code.

9. The system will respond with the message of the day such as:

   CP/CMS HRS.. 0930-2200(MON-THURS)..0930-1800(FRI) OUTPUT RETAINED 4 DAYS
   CMS VERSION 3.2

10. At this point the user is in CMS. He must then get into CP. This is done by hitting the ATTN key. The system will respond:

    CP

11. The user must then link to the TIME SERIES EDITOR. This is accomplished by entering:

    *link 1969p 191 192

12. The system will respond with the instruction:

    ENTER PASSWORD:

13. The user then enters:

    *rfrr

14. The system will respond:

    SET TO READ ONLY

15. The user must now implement CMS by entering:

    *ipl cms

16. The system will respond:

    CMS VERSION 3.2

17. Now the user must log into both his general user and the Time Series Editor area by entering:

```
*login 191
```

18. The system will respond with a message about the status of the file such as:

```
P(191):49 FILES; 225 REC IN USE, 71 LEFT (OF 296),
76% FULL (2 CYL)
R;
```

19. The user should then enter the command:

```
*login 192 t,p
R;
```

20. The system will respond:

```
T(192) R/O
R;
```

21. The user can then enter the Time Series Editor by issuing the command:

```
*timeser exec
```

22. The system will respond:

```
YOU HAVE ENTERED THE TIME SERIES EDITOR
PLEASE RESPOND TO EACH INQUIRY
etc.
```

23. The user is then on his own, guided by the Exec routine. See the notes that appear at the end of this Appendix 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. A no will take the user out of the Time Series Editor. The system response will be:

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

25. The user then can log out by entering:

```
*cp logout
```

26. The system will respond:

```
     CONNECT= 01.17.24 VIRTCPU= 001.03.37 TOTCPU= 001.30.14
     LOGOUT AT 17.19.08  ON 3/21/77
```

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

A sample of the procedure is shown below:

```
cp-67 online   xd.65 qsyosu

login 0655g07
ENTER PASSWORD:
npg
ENTER 4-DIGIT PROJECT NUMBER FOLLOWED BY 4-CHARACTER COST
 CENTER CODE:
0986rk54
CP/CMS HRS,MONDAY THRU THURSDAY,0930-2200,FRIDAY,0930-1800.
OUTPUT RETAINED 5 DAYS
READY AT 16.13.22 ON 03/22/77
CMS VERSION 3.2

offline read *
P (191): 49 FILES; 225 REC IN USE, 71 LEFT (OF 296), 76% FULL
(2 CYL)

OFFLINE READ FILE FT02F001
R;
CP
link 1969p  191  192
ENTER PASSWORD:
rfrr
SET TO READ ONLY

ipl cms
CMS VERSION 3.2

login 191
P (191): 49 FILES; 225 REC IN USE, 71 LEFT (OF 296), 76% FULL
(2 CYL)
R;
login 192 t,p
T (192) R/O
R;
timeser exec

YOU HAVE ENTERED THE TIME SERIES EDITOR
.
.
.
.
DO YOU WANT TO TRY AGAIN?
n
CONTROL RETURNED TO CMS
```

```
R;
cp log
CONNECT= 00.03.38 VIRTCPU= 000.00.34 TOTCPU= 000.01.30
LOGOUT AT 13.48.56  ON 3/11/77
```

NOTES:

a. A typing error in CP/CMS can be corrected by typing the @ character as many times as is required to backup and then type the correct values. For example, the command exec timesre could be corrected by typing two @ signs followed by the correct letters er as follows:

   exec timesre@@er

b. An entire line can be deleted by typing the character ¢.

c. The user should exercise care before depressing the return key. If an input is required and the return key is depressed before any character is entered, the user may get tossed out of the Editor. Before the return key is depressed, any errors can be corrected. After the return is hit there are only selected cases that can later be corrected.

d. When asked to enter integer data, the user should always right justify the data within the allowed region.

e. ** If at any time the user encounters a debug condition (probably caused by errors in entering data) and he cannot determine what needs to be done, he can get out of the debug condition by depressing the ATTN key twice. This puts the user back into CP from which he can link back to the Time Series Editor or logout.

APPENDIX B

SAMPLE USER SESSION AND PROGRAM OUTPUT

## APPENDIX B: SAMPLE USER SESSION AND PROGRAM OUTPUT

```
cp-67 online   xd.65 qsyosu

login 9655g07
ENTER PASSWORD:
npg
ENTER 4-DIGIT PROJECT NUMBER FOLLOWED BY 4-CHARACTER COST CENTER CODE:
0986rk54
CP/CMS HRS,MONDAY THRU THURSDAY,0930-2200,FRIDAY,0930-1800.
OUTPUT RETAINED 5 DAYS.
FILES:- 01 RDR, NO PRT, NO PUN
READY AT 16.13.22 ON 03/22/77
CMS VERSION 3.2

offline read *
P (191): 49 FILES; 225 REC IN USE, 71 LEFT (OF 296), 76% FULL (2 CYL)

OFFLINE READ FILE FT02F001
R;
CP
link 1969p 191 192
ENTER PASSWORD:
rfrr
SET TO READ ONLY

ipl cms
CMS VERSION 3.2

login 191
P (191): 49 FILES; 225 REC IN USE, 71 LEFT (OF 296), 76% FULL (2 CYL)

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

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 FOR NAMES STARTING WITH I THRU N.
TYPE INTEGER VALUES FOR COUNTS.  TYPE FLOATING
VALUES WITH DECIMAL FOR ALL OTHER NAMES.

DO YOU WANT A LIST OF OPTIONS?
y
```

```
OPTION                       DESCRIPTION
GENERATE -----GENERATE ANY ARIMA TIME SERIES
AUTO ---------CALCULATE AUTOCORRELATIONS, PAUTOS, MEAN AND VARIANCE
PLOT ---------PLOT A TIME SERIES
DIFF ---------TRANSFORM AND DIFFERENCE A TIME SERIES
ESTIMATE -----CALCULATE MAX LIKELIHOOD ESTIMATES OF ARMA PARAMETERS
SIMULATE -----SIMULATE TIME SERIES FROM A GIVEN MODEL
FORECAST -----FORECAST FUTURE VALUES, CONSTRUCT CONFIDENCE INTERVALS

WOULD YOU LIKE MORE INFO?
y

ENTER OPTION YOU WANT INFO ABOUT.
d

DIFF --------THIS PROGRAM TRANSFORMS A GIVEN TIME SERIES WITH A LOG
OR AN EXPONENTIAL TRANSFORMATION (OR NO TRANSFORMATION IF DESIRED), AND
THEN TAKES SEASONAL AND/OR SIMPLE DIFFERENCES OF ANY SPECIFIED ORDERS.
IT THEN OUTPUTS THE TRANSFORMED AND DIFFERENCED TIME SERIES.  THIS
PROGRAM IS USED TO ATTEMPT TO MAKE A SEASONAL OR A NONSTATIONARY TIME
SERIES OF THE FORM THAT CAN BE HANDLED VIA BOX-JENKINS TECHNIQUES.  IT
USES FTRDIF FROM THE IMSL LIBRARY.

DO YOU WANT TO TRY A SESSION?
y

ENTER THE LETTER FOR OPTION YOU WANT.
p
IS YOUR DATA IN FILE FT02F001?
y
EXECUTION BEGINS...
ENTER TITLE FOR PLOT.
series c, original values.
TIME SERIES PLOTS HAVE BEEN PRINTED OFFLINE.
DO YOU WANT TO TRY 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  0.570  0.523
 0.468  0.413  0.359  0.305  0.253  0.201  0.150  0.098  0.047 -0.003

         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
```

```
    MEAN= 22.9739          VARIANCE = 4.22273

ENTER TITLE FOR PLOTS.
series C, original values.
YOUR AUTO AND PAUTO PLOTS HAVE BEEN PRINTED OFFLINE.
PICK UP IN ROOM I140 UNDER YOUR USED ID NUMBER.
DO YOU WANT TO TRY 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 A LOG TRANSFORMATION?
n
DO YOU WANT AN EXPONENTIAL TRANSFORMATION?
n
YOUR TRANSFORMED TIME SERIES HAS BEEN STORED IN FILE FT03F001.
DO YOU WANT A PRINTOUT OF THE FIRST TEN VALUES?
y
THE FIRST 10 VALUES OF THE TRANSFORMED SERIES ARE:
     0.400009       0.099991       0.0            0.0            0.0
    -0.199997      -0.100006      -0.099991      -0.300003      -0.399994
DO YOU WANT TO PLOT AUTO ANDPAUTO 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  0.043  0.041  0.040

        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

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

ENTER TITLE FOR PLOTS.
series C, 1st order differenced data.
YOUR AUTO AND PAUTO PLOTS HAVE BEEN PRINTED OFFLINE.
PICK UP IN ROOM I140 UNDER YOUR USED ID NUMBER.

DO YOU WANT TO TRY 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 A LOG TRANSFORMATION?
n
DO YOU WANT AN EXPONENTIAL TRANSFORMATION?
n
YOUR TRANSFORMED TIME SERIES HAS BEEN STORED IN FILE FT03F001.
DO YOU WANT A PRINTOUT OF THE FIRST TEN VALUES?
y
THE FIRST 10 VALUES OF THE TRANSFORMED SERIES ARE:
    -0.300018      -0.099991       0.0            0.0           -0.199997
     0.099991       0.000015      -0.200012      -0.099991       0.199982
DO YOU WANT TO PLOT AUTO AND PAUTO OF TRANSFORMED DATA?
y
EXECUTION BEGINS...
              AUTOCORRELATIONS

-0.079 -0.065 -0.022 -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

         PARTIAL AUTOCORELLATIONS

-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

    MEAN=-.267866E-02     VARIANCE = 0.198143E-01
ENTER TITLE FOR PLOTS.
series C, 2nd order differenced data.
YOUR AUTO AND PAUTO PLOTS HAVE BEEN PRINTED OFFLINE.
PICK UP IN ROOM I140 UNDER YOUR USER ID NUMBER.

DO YOU WANT TO TRY AGAIN?
y
ENTER LETTER FOR OPTION YOU WANT.
e
*IS YOUR DATA IN FILE FT02F001?
y
EXECUTION BEGINS...
ENTER NUMBER OF AR PARAMETERS.
0
ENTER NUMBER OF MA PARAMETERS.
2
ENTER NUMBER OF DIFFERENCES.
2
* LENGTH OF TIME SERIES = 226
0 AR PARAMETERS    2 MA PARAMETERS    2 DIFFERENCES.
```

```
ESTIMATED AR PARAMETERS (UNDIFFERENCED FORM) ARE:
PHI(1) =   2.0000

PHI(2) =  -1.0000

ESTIMATED MA PARAMETERS ARE:
THETA(1) = 0.1382

THETA(2) = 0.1300

MA CONSTANT= 0.0         WHITE NOISE VARIANCE= 0.189515E-01

DO YOU WANT TO PLOT AUTO AND PAUTO OF RESIDUALS?
y
EXECUTION BEGINS...
              AUTOCORRELATIONS

 0.020  0.034 -0.134 -0.093 -0.012 -0.043  0.004 -0.063 -0.125  0.088
-0.142  0.069 -0.098  0.025  0.004 -0.055  0.157 -0.089  0.006 -0.006

         PARTIAL AUTOCORRELATIONS

 0.020  0.034 -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 -0.090  0.123 -0.123 -0.021 -0.025

   MEAN=-.124975E-02      VARIANCE = 0.189499E-01

ENTER TITLE FOR PLOTS.
series C, residuals of (0,2,2).
YOUR AUTO AND PAUTO PLOTS HAVE BEEN PRINTED OFFLINE.
PICK UP IN ROOM I140 UNDER YOUR USER ID NUMBER.
DO YOU WANT TO CHECK RESIDUALS?
y
EXECUTION BEGINS...
ENTER IP, NO OF AR PARAMETERS (DIFFERENCED FORM).
0
ENTER IQ, NO OF MA PARAMETERS.
2
* CHI SQUARE LACK OF FIT VALUE = 28.74 DF = 18   SIGNIFICANCE = 0.0516

DO YOU WANT TO TRY AGAIN?
y
ENTER LETTER FOR OPTION YOU WANT.
e
IS YOUR DATA IN FILE FT02F001?
y
EXECUTION BEGINS...
ENTER NUMBER OF AR PARAMETERS.
1
ENTER NUMBER OF MA PARAMETERS.
0
ENTER NUMBER OF DIFFERENCES.
1
```

```
LENGTH OF TIME SERIES = 226
1 AR PARAMETERS    0 MA PARAMETERS    1 DIFFERENCES.

ESTIMATED AR PARAMETERS (UNDIFFERENCED FORM) ARE:
PHI(1) =    1.8131

PHI(2) =   -0.8131

MA CONSTANT=  0.0          WHITE NOISE VARIANCE= 0.178396E-01

DO YOU WANT TO PLOT AUTO AND PAUTO OF RESIDUALS?
y
EXECUTION BEGINS...
              AUTOCORRELATIONS

 0.010  0.009 -0.053 -0.009  0.058  0.021  0.076 -0.020 -0.089  0.130
-0.095  0.083 -0.056  0.042  0.006 -0.041  0.169 -0.080 -0.001 -0.010

         PARTIAL AUTOCORRELATIONS

 0.010  0.009 -0.054 -0.008  0.060  0.018  0.074 -0.016 -0.088  0.140
-0.104  0.069 -0.048  0.041  0.003 -0.030  0.157 -0.087  0.013 -0.025

   MEAN=-.897935E-02       VARIANCE = 0.177590E-01

ENTER TITLE FOR PLOTS.
series C, residuals of (1,1,0).
YOUR AUTO AND PAUTO PLOTS HAVE BEEN PRINTED OFFLINE.
PICK UP IN ROOM I140 UNDER YOUR USER ID NUMBER.
DO YOU WANT TO CHECK RESIDUALS?
y
EXECUTION BEGINS...
ENTER IP, NO OF AR PARAMETERS (DIFFERENCED FORM).
1
ENTER IQ, NO OF MA PARAMETERS.
0
* CHI SQUARE LACK OF FIT VALUE = 21.53  DF = 19  SIGNIFICANCE = 0.3082

DO YOU WANT TO TRY AGAIN?
y
ENTER LETTER FOR OPTION YOU WANT.
f
IS YOUR DATA IN FILE FT02F001?
y
EXECUTION BEGINS...
ARE YOUR PARAMETERS IN DIFFERENCED FORM?
y
ENTER NO. AR PARAMETERS (DIFF. FORM).
1
ENTER AR PARAMETER PHI(1).
0.8131
AR PARAMETERS ARE:
0.8131
```

```
ARE THESE OK?
y
ENTER NUMBER OF MA PARAMETERS.
0
ENTER OVERALL MA CONSTANT
0
ENTER THE NUMBER OF DIFFERENCES.
1
ENTER INDEX FOR FORECAST ORIGIN VIA I3.
020
ENTER FORECAST LEAD TIME VIA I2.
13
ENTER SIGNIFICANCE LEVEL, ALPHA.
.2
MA CONSTANT = 0.0        NUMBER OF DIFFERENCES = 1
FORECAST LEAD TIME = 13   ALPHA = 0.200
ARE THESE OK?
y
AR PARAMETERS IN UNDIFFERENCED FORM ARE:
 1.8131
-0.8131

THE FORECASTS ARE:

  23.1561       22.9577       22.7964       22.6653       22.5586
  22.4719       22.4014       22.3440       22.2974       22.2594
  22.2286       22.2035       22.1831
80.0% CONFIDENCE LIMITS FOR FORECASTS ARE:
0.172546       0.357271       0.556689       0.761553       0.966487
 1.16832        1.36521        1.55613        1.74057        1.91838
 2.08959        2.25439        2.41304
PSI WEIGHTS FOR FORECAST ERROR ARE:
 1.81310        2.47423        3.01180        3.44889        3.80429
 4.09326        4.32822        4.51927        4.67461        4.80092
 4.90362        4.98712        5.05501
WHITE NOISE VARIANCE = 0.18127E-01
DO YOU WANT TO PLOT FORECASTS?
y
*DO YOU REALLY WANT TO PLOT FORECASTS?
y
YOUR TIME SERIES AND FORECASTS ARE PLOTTED OFFLINE.

DO YOU WANT TO TRY AGAIN?
y

ENTER LETTER FOR OPTION YOU WANT.
s
IS YOUR DATA IN FILE FT02F001?
y
*EXECUTION BEGINS...
ENTER NUMBER OF AR PARAMETERS (UNDIFFERENCED FORM).
2
```

```
ENTER ESTIMATED AR PARAMETER PHI(1).
1.8131
ENTER ESTIMATED AR PARAMETER PHI(2).
-0.8131
AR PARAMETERS ARE          1.8131      -0.8131
ARE THESE OK?
y
ENTER NUMBER OF MA PARAMETERS
0
ENTER OVERALL MA CONSTANT
0
ENTER ESTIMATED WHITE NOISE VAR
0.0178
DO YOU WANT TO INPUT STARTING VALUES?
n
START(1)=      19.000000
START(2)=      18.799988
STARTING VALUE(S) OK?
y
ENTER RANDOM NUMBER SEED (BETWEEN 0 AND 1).
0.7659376
ENTER NUMBER OF VALUES YOU WANT TO SIMULATE VIA 13.
065
DO YOU WANT MORE THAN ONE SIMULATED SERIES?
y
HOW MANY SERIES DO YOU WANT (LE.9)?
2
DO YOU WANT A PRINTOUT OF THE FIRST 20 VALUES?
y
SIMULATED VALUES ARE:
    18.640320      18.511963      18.631088      18.626831      18.787552
    18.963882      19.074707      19.205811      19.261063      19.633331
    19.821411      20.042175      20.166321      20.347610      20.369507
    20.216507      20.133179      20.174332      20.287857      20.241806
DO YOU WANT TO PLOT SIMULATED VALUES?
y
EXECUTION BEGINS...
ENTER TITLE FOR PLOT.
simulations with model (1,1,0), series C.
TIME SERIES PLOTS HAVE BEEN PRINTED OFFLINE.

DO YOU WANT TO TRY AGAIN?
n
CONTROL RETURNED TO CMS
R;
```


X-SCALE: "*"= 0.281E 01 UNITS

Y-SCALE: "*"= 0.138E 00 UNITS
SERIES C, ORIGINAL VALUES.

Figure 3. Plots of series C.

AUTOCORRELATIONS

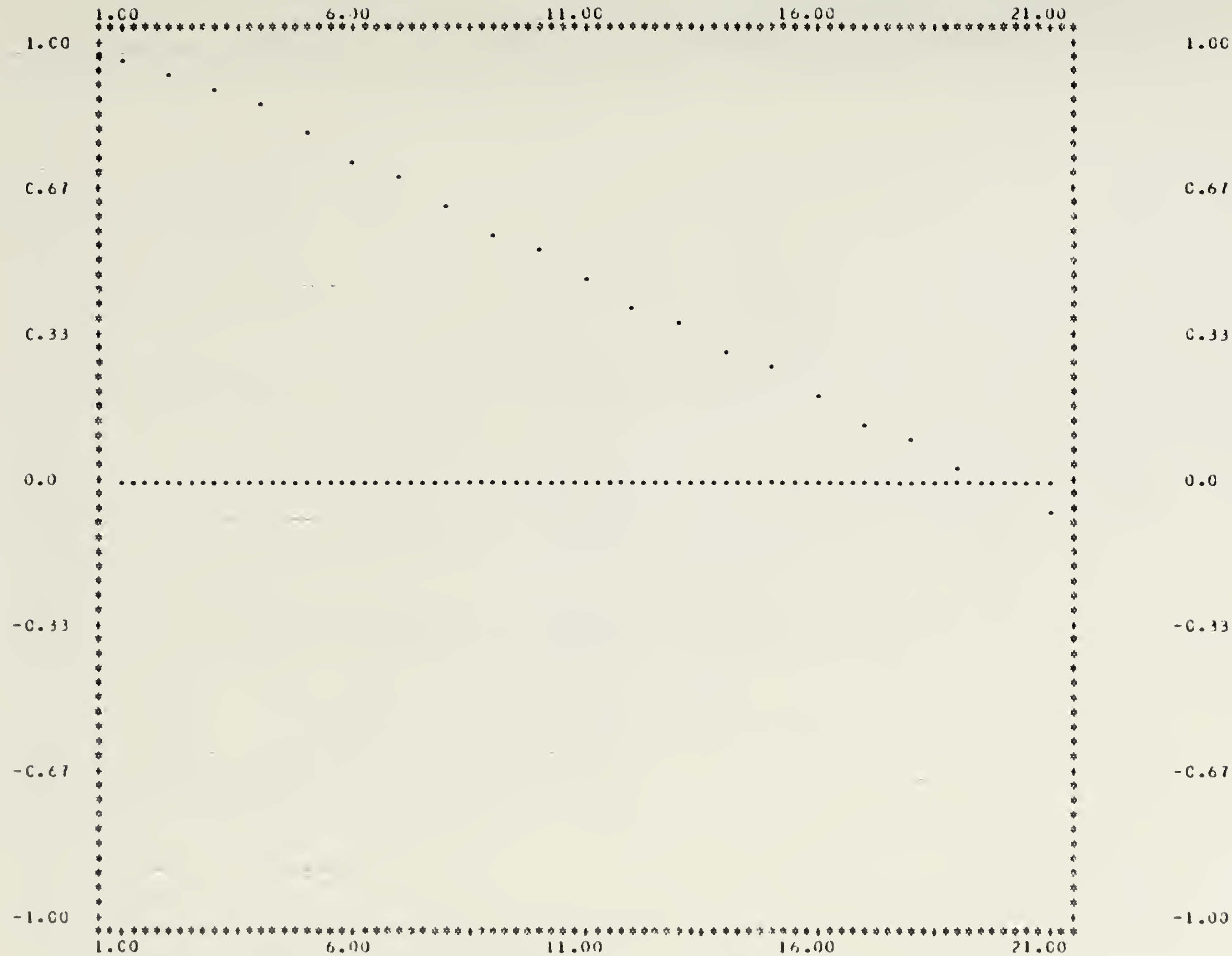
| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0.978 | 0.944 | 0.902 | 0.854 | 0.802 | 0.748 | 0.692 | 0.635 | 0.579 | 0.523 |
| 0.468 | 0.413 | 0.359 | 0.305 | 0.253 | 0.201 | 0.150 | 0.098 | 0.047 | -0.003 |

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 |

MEAN= 22.9735 VARIANCE = 4.22273

Table I. Auto and partial autocorrelations of series C.




AUTOCORRELATIONS

Figure 4. Plots of autocorrelations of series C.

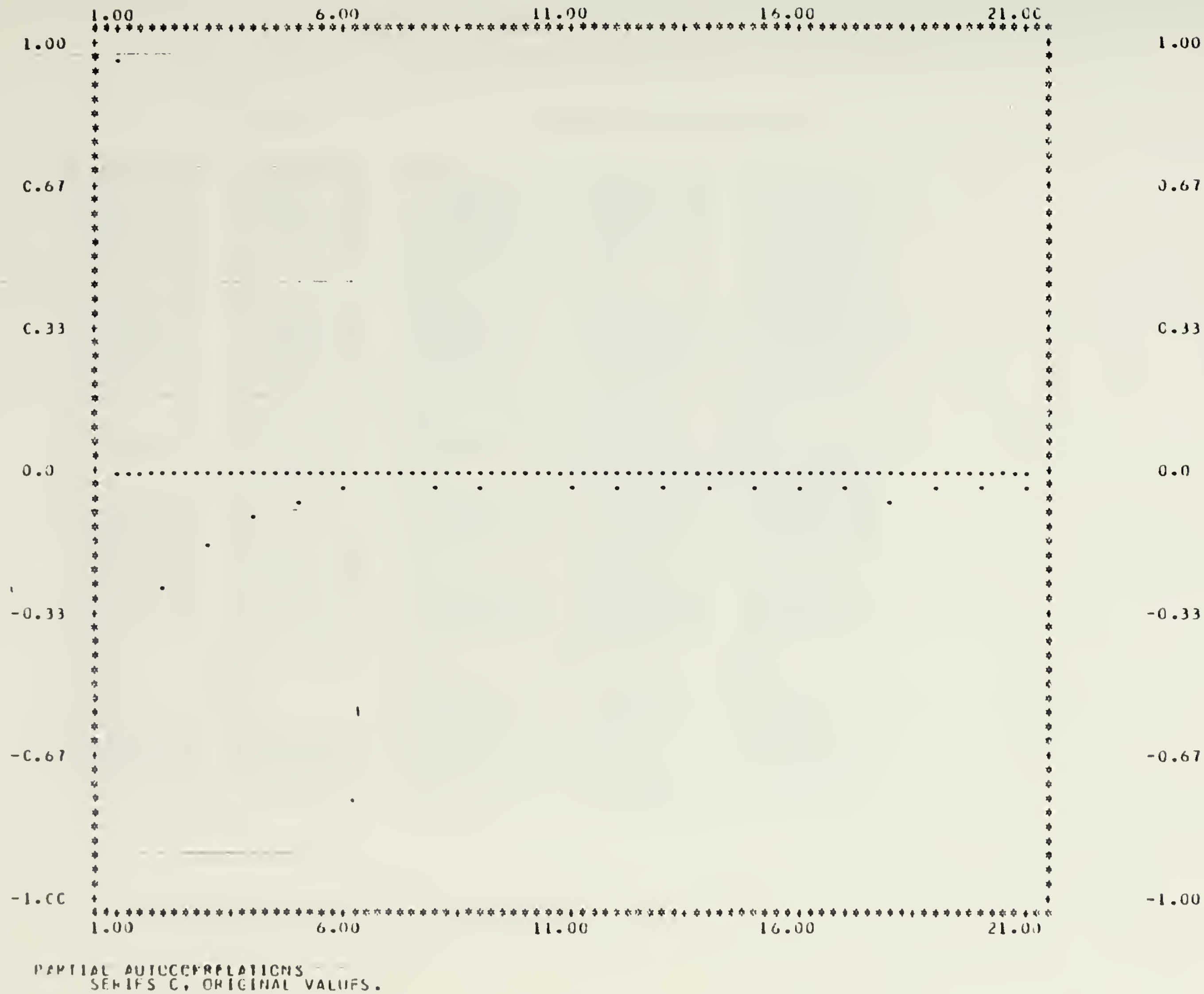



Figure 5. Plots of partial autocorrelations of series C.

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| | | | | |
|---|---|---|---|---|
| 0.400009E 00 | 0.999908E-01 | 0.0 | 0.0 | 0.0 |
| -0.199997E 00 | -0.100006E 00 | -0.999908E-01 | -0.300003E 00 | -0.399994E 00 |
| -0.200012E 00 | -0.199997E 00 | -0.399994E 00 | -0.199997E 00 | -0.400009E 00 |
| -0.399994E 00 | -0.199997E 00 | -0.300003E 00 | -0.300003E 00 | -0.300003E 00 |
| -0.199997E 00 | -0.100006E 00 | -0.999908E-01 | -0.100006E 00 | -0.199997E 00 |
| -0.199997E 00 | -0.199997E 00 | -0.200012E 00 | -0.399994E 00 | -0.500000E 00 |
| -0.600006E 00 | -0.599991E 00 | -0.300003E 00 | -0.100006E 00 | -0.999908E-01 |
| -0.100006E 00 | -0.999908E-01 | -0.100006E 00 | 0.0 | 0.300003E 00 |
| 0.999908E-01 | 0.0 | 0.100006E 00 | 0.100006E 00 | 0.999908E-01 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.100006E 00 |
| 0.199997E 00 | 0.100006E 00 | 0.999908E-01 | 0.100006E 00 | 0.999908E-01 |
| 0.300003E 00 | 0.100000E 01 | 0.300003E 00 | -0.199997E 00 | -0.400009E 00 |
| -0.999908E-01 | 0.199997E 00 | 0.300003E 00 | 0.500000E 00 | 0.800003E 00 |
| 0.799988E 00 | 0.800003E 00 | 0.500000E 00 | 0.500000E 00 | 0.199997E 00 |
| 0.300003E 00 | 0.199997E 00 | 0.0 | -0.999908E-01 | -0.199997E 00 |
| -0.200012E 00 | -0.199997E 00 | -0.199997E 00 | -0.199997E 00 | -0.300003E 00 |
| -0.199997E 00 | -0.199997E 00 | -0.100006E 00 | 0.0 | 0.0 |
| 0.0 | 0.0 | -0.100006E 00 | 0.100006E 00 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.100006E 00 | 0.0 |
| -0.100006E 00 | -0.100006E 00 | -0.999908E-01 | 0.0 | -0.199997E 00 |
| -0.100006E 00 | -0.199997E 00 | -0.100006E 00 | -0.999908E-01 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.199997E 00 | 0.999908E-01 |
| 0.0 | 0.100006E 00 | 0.0 | -0.100006E 00 | -0.999908E-01 |
| -0.100006E 00 | -0.199997E 00 | -0.199997E 00 | -0.199997E 00 | -0.200012E 00 |
| -0.199997E 00 | -0.199997E 00 | -0.399994E 00 | -0.400009E 00 | -0.300003E 00 |
| -0.999908E-01 | 0.0 | -0.100006E 00 | -0.999908E-01 | -0.100006E 00 |
| 0.100006E 00 | 0.0 | 0.999908E-01 | 0.100006E 00 | -0.100006E 00 |
| -0.199997E 00 | -0.100006E 00 | 0.0 | 0.0 | 0.0 |
| 0.100006E 00 | -0.100006E 00 | 0.0 | -0.999908E-01 | 0.0 |
| 0.999908E-01 | 0.100006E 00 | 0.300003E 00 | 0.199997E 00 | 0.300003E 00 |
| 0.999908E-01 | 0.100006E 00 | 0.300003E 00 | 0.300003E 00 | 0.299988E 00 |
| 0.300003E 00 | 0.300003E 00 | 0.399994E 00 | 0.300003E 00 | 0.500000E 00 |
| 0.300003E 00 | 0.0 | 0.199997E 00 | -0.999908E-01 | 0.0 |
| 0.0 | 0.0 | -0.100006E 00 | -0.100006E 00 | -0.999908E-01 |
| -0.100006E 00 | -0.999908E-01 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | -0.100006E 00 | 0.0 |
| -0.199997E 00 | 0.0 | -0.100006E 00 | 0.0 | -0.999908E-01 |
| 0.0 | 0.0 | -0.100006E 00 | -0.100006E 00 | 0.0 |
| -0.999908E-01 | 0.0 | -0.100006E 00 | 0.100006E 00 | -0.100006E 00 |
| 0.0 | 0.0 | -0.999908E-01 | 0.0 | -0.100006E 00 |
| -0.100006E 00 | 0.0 | 0.0 | 0.100006E 00 | 0.0 |
| -0.100006E 00 | -0.999908E-01 | 0.999908E-01 | 0.0 | -0.999908E-01 |
| -0.100006E 00 | -0.199997E 00 | -0.100006E 00 | -0.199997E 00 | -0.199997E 00 |
| -0.199997E 00 | -0.400009E 00 | -0.500000E 00 | -0.500000E 00 | -0.599991E 00 |
| -0.500000E 00 | -0.400009E 00 | -0.199997E 00 | -0.999908E-01 | -0.200012E 00 |

Table 11. Values of 1st differenced series C.

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 |

PARTIAL AUTOCORRELATIONS

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0.805 | 0.010 | -0.007 | 0.051 | 0.027 | -0.019 | -0.013 | -0.080 | 0.020 | 0.117 |
| -0.137 | 0.054 | -0.027 | 0.034 | 0.006 | 0.012 | 0.043 | -0.121 | 0.050 | -0.005 |

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

Table III. Auto and partial autocorrelations of 1st differenced series C.

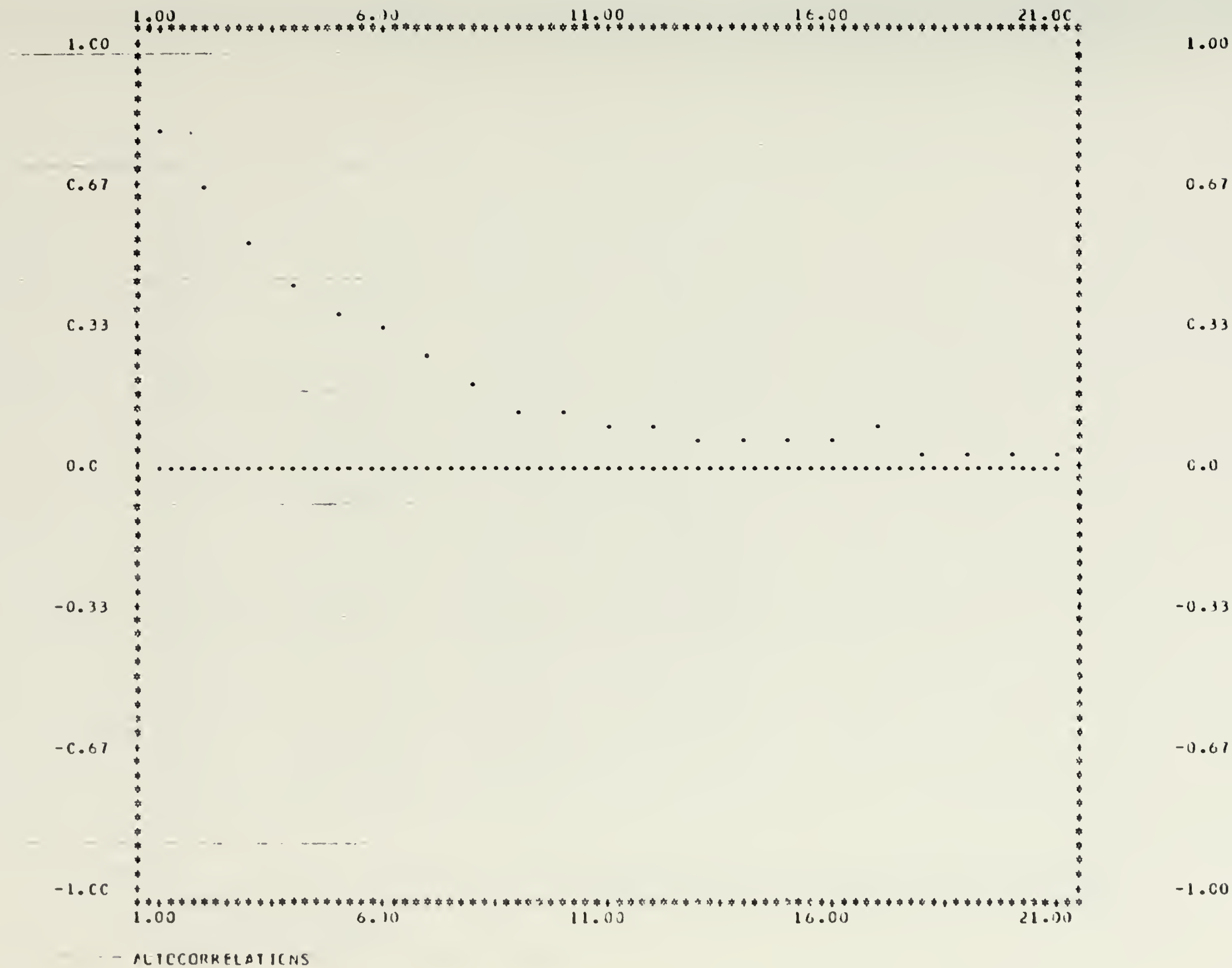


Figure 6. Plots of autocorrelations of 1st differenced series C.


PARTIAL AUTOCORRELATIONS
SERIES C, 1ST ORDER DIFFERENCED DATA.

Figure 7. Plots of partial autocorrelations of 1st differenced series C.

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| | | | | |
|---|---|---|---|---|
| -0.300018E 00 | -0.999908E-01 | 0.0 | 0.0 | -0.199997E 00 |
| 0.999908E-01 | 0.152588E-04 | -0.200012E 00 | -0.999908E-01 | 0.199982E 00 |
| 0.152588E-04 | -0.199997E 00 | 0.199997E 00 | -0.200012E 00 | 0.152588E-04 |
| 0.199997E 00 | -0.100006E 00 | 0.0 | 0.0 | 0.100006E 00 |
| 0.999908E-01 | 0.152588E-04 | -0.152588E-04 | -0.999908E-01 | 0.0 |
| 0.0 | -0.152588E-04 | -0.199982E 00 | -0.100006E 00 | -0.100006E 00 |
| 0.152588E-04 | 0.299988E 00 | 0.199997E 00 | 0.152588E-04 | -0.152588E-04 |
| 0.152588E-04 | -0.152588E-04 | 0.100006E 00 | 0.300003E 00 | -0.200012E 00 |
| -0.999908E-01 | 0.100006E 00 | 0.0 | -0.152588E-04 | -0.999908E-01 |
| 0.0 | 0.0 | 0.0 | 0.100006E 00 | 0.999908E-01 |
| -0.999908E-01 | -0.152588E-04 | 0.152588E-04 | -0.152588E-04 | 0.200012E 00 |
| 0.699997E 00 | -0.699997E 00 | -0.500000E 00 | -0.200012E 00 | 0.300018E 00 |
| 0.299988E 00 | 0.100006E 00 | 0.199997E 00 | 0.300003E 00 | -0.152588E-04 |
| 0.152588E-04 | -0.300003E 00 | 0.0 | -0.300003E 00 | 0.100006E 00 |
| -0.100006E 00 | -0.199997E 00 | -0.999908E-01 | -0.100006E 00 | -0.152588E-04 |
| 0.152588E-04 | 0.0 | 0.0 | -0.100006E 00 | 0.100006E 00 |
| 0.0 | 0.999908E-01 | 0.100006E 00 | 0.0 | 0.0 |
| 0.0 | -0.100006E 00 | 0.200012E 00 | -0.100006E 00 | 0.0 |
| 0.0 | 0.0 | 0.100006E 00 | -0.100006E 00 | -0.100006E 00 |
| 0.0 | 0.152588E-04 | 0.999908E-01 | -0.199997E 00 | 0.999908E-01 |
| -0.999908E-01 | 0.999908E-01 | 0.152588E-04 | 0.999908E-01 | 0.0 |
| 0.0 | 0.0 | 0.199997E 00 | -0.100006E 00 | -0.999908E-01 |
| 0.100006E 00 | -0.100006E 00 | -0.100006E 00 | 0.152588E-04 | -0.152588E-04 |
| -0.999908E-01 | 0.0 | 0.0 | -0.152588E-04 | 0.152588E-04 |
| 0.0 | -0.199997E 00 | -0.152588E-04 | 0.100006E 00 | 0.200012E 00 |
| 0.999908E-01 | -0.100006E 00 | 0.152588E-04 | -0.152588E-04 | 0.200012E 00 |
| -0.100006E 00 | 0.999908E-01 | 0.152588E-04 | -0.200012E 00 | -0.999908E-01 |
| 0.999908E-01 | 0.100006E 00 | 0.0 | 0.0 | 0.100006E 00 |
| -0.200012E 00 | 0.100006E 00 | -0.999908E-01 | 0.999908E-01 | 0.999908E-01 |
| 0.152588E-04 | 0.199997E 00 | -0.100006E 00 | 0.100006E 00 | -0.200012E 00 |
| 0.152588E-04 | 0.199997E 00 | 0.0 | -0.152588E-04 | 0.152588E-04 |
| 0.0 | 0.999908E-01 | -0.999908E-01 | 0.199997E 00 | -0.199997E 00 |
| -0.300003E 00 | 0.199997E 00 | -0.299988E 00 | 0.999908E-01 | 0.0 |
| 0.0 | -0.100006E 00 | 0.0 | 0.152588E-04 | -0.152588E-04 |
| 0.152588E-04 | 0.999908E-01 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | -0.100006E 00 | 0.100006E 00 | -0.199997E 00 |
| 0.199997E 00 | -0.100006E 00 | 0.100006E 00 | -0.999908E-01 | 0.999908E-01 |
| 0.0 | -0.100006E 00 | 0.0 | 0.100006E 00 | -0.999908E-01 |
| 0.999908E-01 | -0.100006E 00 | 0.200012E 00 | -0.200012E 00 | 0.100006E 00 |
| 0.0 | -0.999908E-01 | 0.999908E-01 | -0.100006E 00 | 0.0 |
| 0.100006E 00 | 0.0 | 0.100006E 00 | -0.100006E 00 | -0.100006E 00 |
| 0.152588E-04 | 0.199982E 00 | -0.999908E-01 | -0.999908E-01 | -0.152588E-04 |
| -0.999908E-01 | 0.999908E-01 | -0.999908E-01 | 0.0 | 0.0 |
| -0.200012E 00 | -0.999908E-01 | 0.0 | -0.999908E-01 | 0.999908E-01 |
| 0.999908E-01 | 0.200012E 00 | 0.100006E 00 | -0.100021E 00 | |

Values of 2nd differenced series C.

AUTOCORRELATIONS

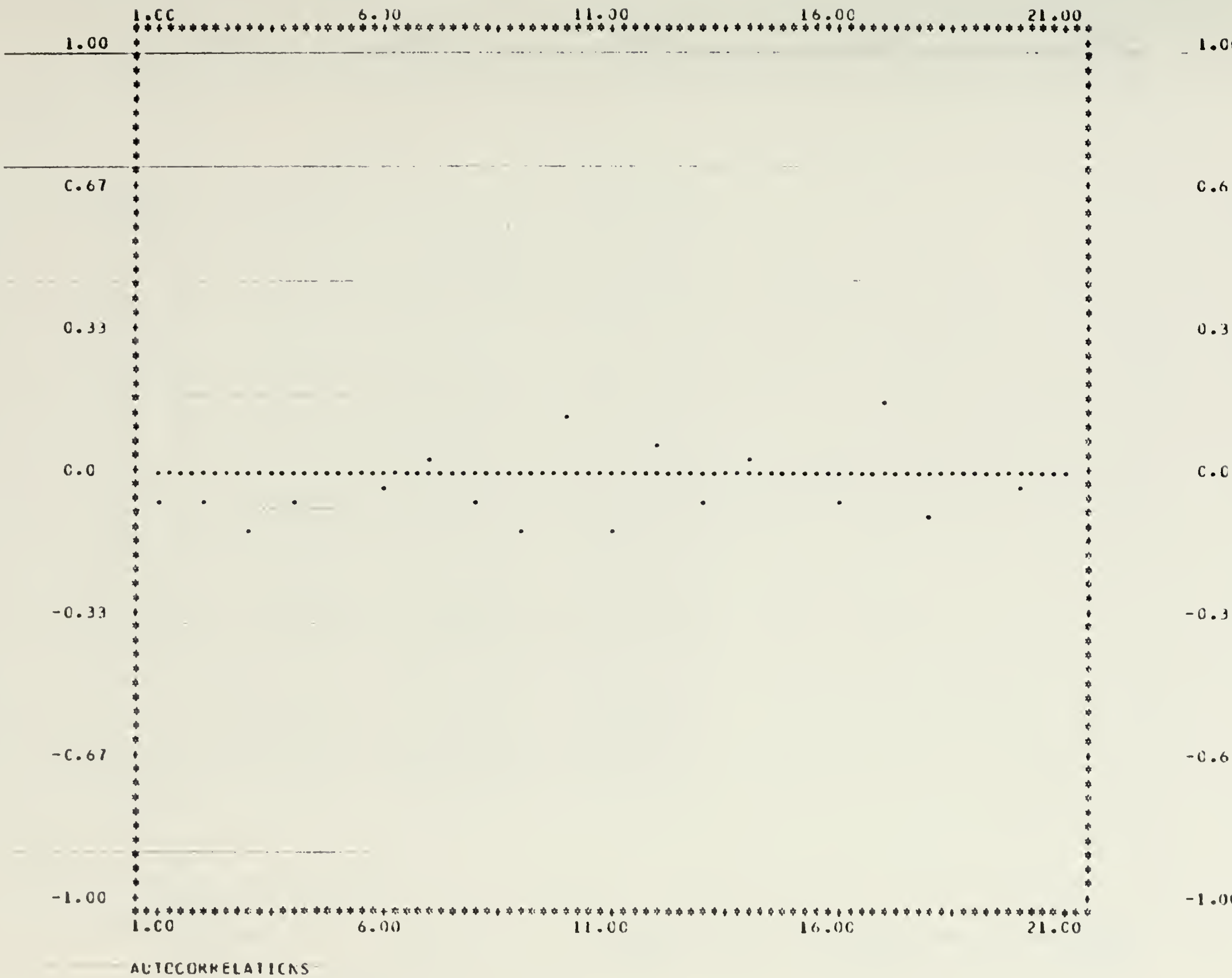
```
-0.079 -0.065 -0.122 -0.063  0.013 -0.018  0.049 -0.052 -0.124  0.122
-0.122  0.072 -0.077  0.029 -0.011 -0.058  0.171 -0.101 -0.013 -0.020
```

PARTIAL AUTOCORRELATIONS

```
-0.079 -0.072 -0.135 -0.054 -0.022 -0.051  0.022 -0.060 -0.145  0.054
-0.143  0.023 -0.089 -0.005 -0.039 -0.074  0.130 -0.105 -0.014 -0.053
```

MEAN=-.2678666E-02     VARIANCE = 0.198143E-01

Auto and partial autocorrelations of 2nd differenced series C.




Plots of autocorrelations of 2nd differenced series C.


PARTIAL AUTOCORRELATIONS
SERIES C, 2NC CRDER DIFFERENCED DATA.

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| | | | | |
|---|---|---|---|---|
| 0.0 | -0.225262E 00 | -0.813040E-01 | 0.0 | 0.0 |
| -0.199997E 00 | 0.626142E-01 | -0.186745E-01 | -0.218699E 00 | -0.156057E 00 |
| 0.125226E 00 | -0.373642E-01 | -0.237374E 00 | 0.125244E 00 | -0.237389E 00 |
| -0.747406E-01 | 0.125244E 00 | -0.137383E 00 | -0.560663E-01 | -0.560663E-01 |
| 0.439398E-01 | 0.626142E-01 | -0.186745E-01 | -0.187021E-01 | -0.118681E 00 |
| -0.373766E-01 | -0.373766E-01 | -0.373919E-01 | -0.237361E 00 | -0.174759E 00 |
| -0.193449E 00 | -0.112117E 00 | 0.187858E 00 | 0.143931E 00 | -0.186745E-01 |
| -0.187021E-01 | -0.186745E-01 | -0.187021E-01 | 0.813164E-01 | 0.300003E 00 |
| -0.143946E 00 | -0.813040E-01 | 0.100006E 00 | 0.186897E-01 | 0.186745E-01 |
| -0.813040E-01 | 0.0 | 0.0 | 0.0 | 0.100006E 00 |
| 0.118681E 00 | -0.626142E-01 | 0.186745E-01 | 0.187021E-01 | 0.186745E-01 |
| 0.218659E 00 | 0.756063E 00 | -0.513111E 00 | -0.443934E 00 | -0.237289E 00 |
| 0.225262E 00 | 0.281301E 00 | 0.137383E 00 | 0.256063E 00 | 0.393446E 00 |
| 0.149494E 00 | 0.143522E 00 | -0.150494E 00 | 0.934429E-01 | -0.206560E 00 |
| 0.137383E 00 | -0.439398E-01 | -0.162620E 00 | -0.999908E-01 | -0.118693E 00 |
| -0.373919E-01 | -0.373642E-01 | -0.373766E-01 | -0.373766E-01 | -0.137383E 00 |
| 0.439398E-01 | -0.373766E-01 | 0.626142E-01 | 0.813164E-01 | 0.0 |
| 0.0 | 0.0 | -0.100006E 00 | 0.181322E 00 | -0.813164E-01 |
| 0.0 | 0.0 | 0.0 | 0.100006E 00 | -0.813164E-01 |
| -0.100006E 00 | -0.186897E-01 | -0.186745E-01 | 0.813040E-01 | -0.199997E 00 |
| 0.626142E-01 | -0.118681E 00 | 0.626142E-01 | -0.186745E-01 | 0.813040E-01 |
| 0.0 | 0.0 | 0.0 | 0.199997E 00 | -0.626255E-01 |
| -0.813040E-01 | 0.100006E 00 | -0.813164E-01 | -0.100006E 00 | -0.186745E-01 |
| -0.187021E-01 | -0.118681E 00 | -0.373765E-01 | -0.373766E-01 | -0.373919E-01 |
| -0.373642E-01 | -0.373766E-01 | -0.237374E 00 | -0.747684E-01 | 0.252500E-01 |
| 0.143946E 00 | 0.813040E-01 | -0.100006E 00 | -0.186745E-01 | -0.187021E-01 |
| 0.181322E 00 | -0.813164E-01 | 0.999908E-01 | 0.187021E-01 | -0.181322E 00 |
| -0.118681E 00 | 0.626142E-01 | 0.813164E-01 | 0.0 | 0.0 |
| 0.100006E 00 | -0.181322E 00 | 0.813164E-01 | -0.999908E-01 | 0.813040E-01 |
| 0.999908E-01 | 0.187021E-01 | 0.218687E 00 | -0.439398E-01 | 0.137383E 00 |
| -0.143946E 00 | 0.187021E-01 | 0.218687E 00 | 0.560663E-01 | 0.560511E-01 |
| 0.560787E-01 | 0.560663E-01 | 0.156057E 00 | -0.252376E-01 | 0.256063E 00 |
| -0.106554E 00 | -0.243937E 00 | 0.199997E 00 | -0.262611E 00 | 0.813040E-01 |
| 0.0 | 0.0 | -0.100006E 00 | -0.186897E-01 | -0.186745E-01 |
| -0.187021E-01 | -0.186745E-01 | 0.813040E-01 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | -0.100006E 00 | 0.813164E-01 |
| -0.199997E 00 | 0.162620E 00 | -0.100006E 00 | 0.813164E-01 | -0.999908E-01 |
| 0.813040E-01 | 0.0 | -0.100006E 00 | -0.186897E-01 | 0.813164E-01 |
| -0.999908E-01 | 0.813040E-01 | -0.100006E 00 | 0.181322E 00 | -0.181322E 00 |
| 0.813164E-01 | 0.0 | -0.999908E-01 | 0.813040E-01 | -0.100006E 00 |
| -0.186897E-01 | 0.813164E-01 | 0.0 | 0.100006E 00 | -0.813164E-01 |
| -0.100006E 00 | -0.186745E-01 | 0.181295E 00 | -0.813040E-01 | -0.999908E-01 |
| -0.187021E-01 | -0.118681E 00 | 0.626142E-01 | -0.118681E 00 | -0.373766E-01 |
| -0.373766E-01 | -0.237389E 00 | -0.174747E 00 | -0.934429E-01 | -0.193434E 00 |
| -0.121390E-01 | 0.654790E-02 | 0.125256E 00 | 0.626295E-01 | -0.118708E 00 |

RESIDUAL VALUES.

Residuals of (1.1.0) model of series C.

AUTOCORRELATIONS

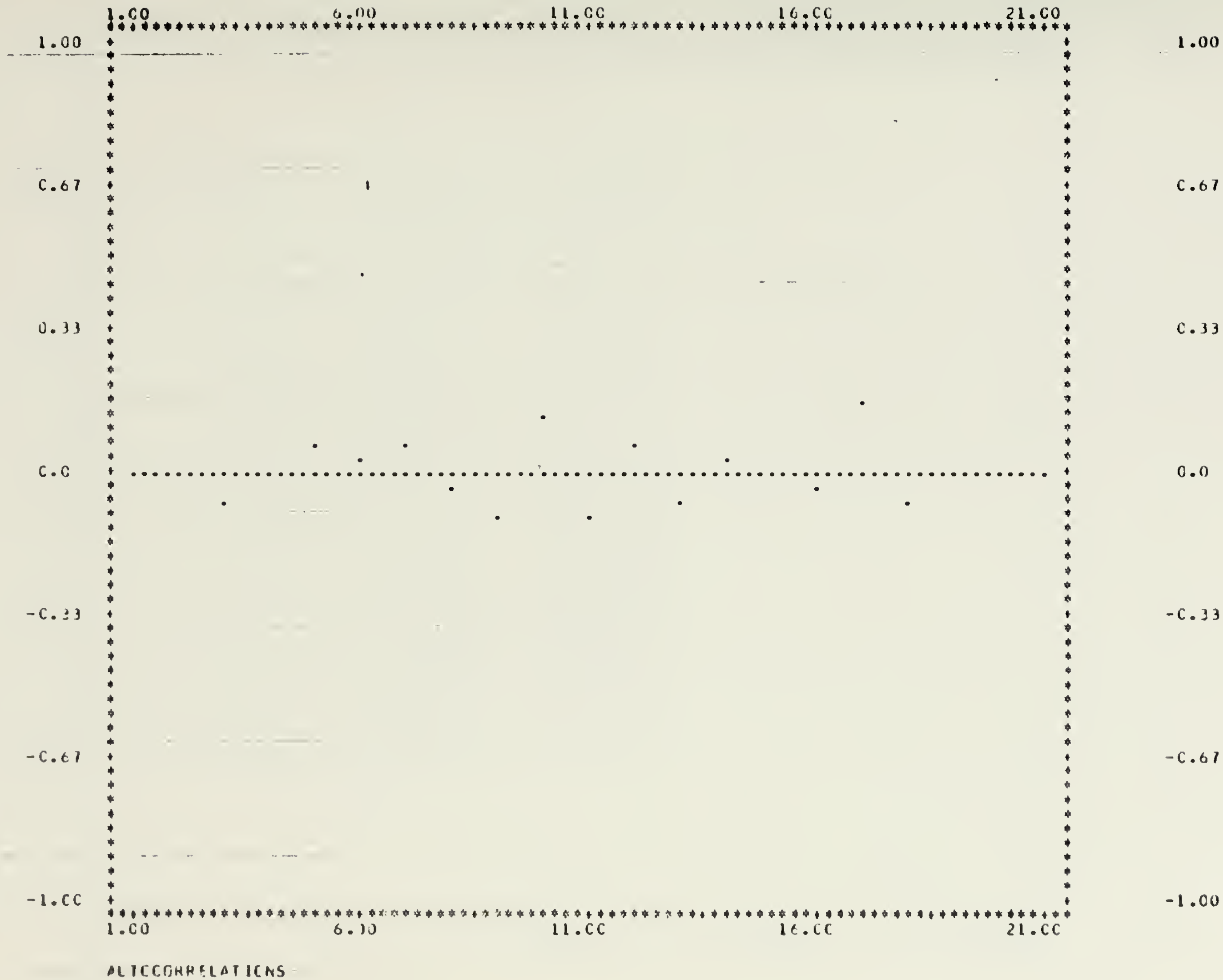
```
 0.010  0.009 -0.053 -0.009  0.058  0.021  0.076 -0.020 -0.089  0.130
-0.095  0.083 -0.056  0.042  0.006 -0.041  0.169 -0.080 -0.001 -0.010
```

PARTIAL AUTOCORRELATIONS

```
 0.010  0.009 -0.054 -0.008  0.060  0.018  0.074 -0.016 -0.088  0.140
-0.104  0.069 -0.048  0.041  0.003 -0.030  0.157 -0.087  0.013 -0.025
```

MEAN=-.8979335E-02    VARIANCE = 0.1775900E-01

Auto and partial autocorrelations of residuals of (1,1,0) model.




Plots of autocorrelations of residuals, model (1,1,0) of series C.


PARTIAL AUTOCORRELATIONS
SERIES C, RESIDUALS OF (1,1,0).

C3/22/77 16.23.43

FILE: FILE FTC3F001 P1 NAVAL POSTGRADUATE SCHOOL PAGE 001

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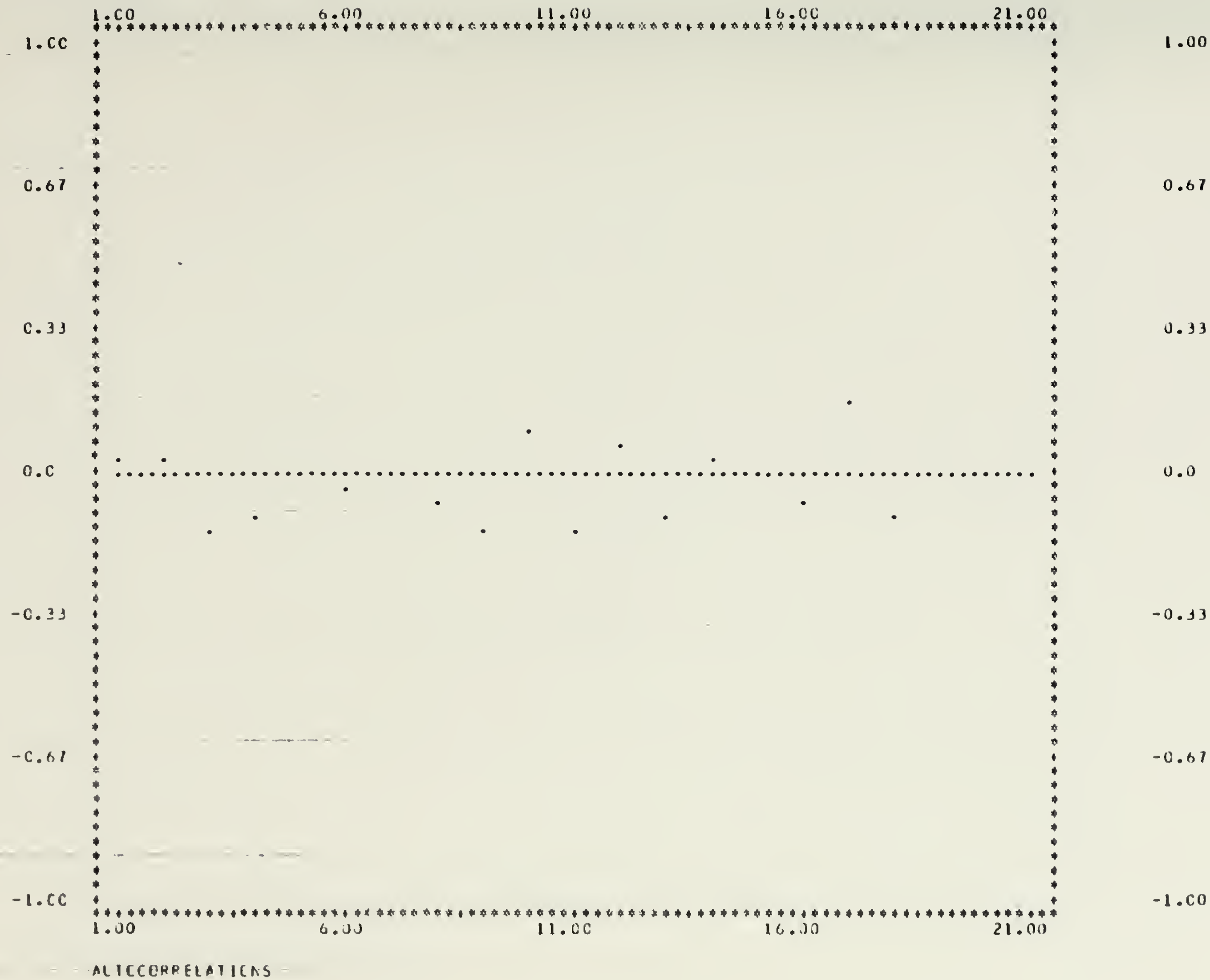
| | | | | |
|---|---|---|---|---|
| 0.0 | 0.0 | 0.0 | 0.0 | -0.199957E 00 |
| 0.723531E-01 | -0.199795E-01 | -0.192817E 00 | -0.128713E 00 | 0.157135E 00 |
| 0.500111E-02 | -0.178883E 00 | 0.175927E 00 | -0.198950E 00 | -0.461277E-02 |
| 0.173502E 00 | -0.766292E-01 | 0.119604E-01 | -0.830658E-02 | 0.100413E 00 |
| 0.112787E 00 | 0.286519E-01 | 0.186030E-01 | -0.936962E-01 | -0.105301E-01 |
| -0.136327E-01 | -0.326776E-02 | -0.202205E 00 | -0.128374E 00 | -0.144026E 00 |
| -0.365724E-01 | 0.276215E 00 | 0.233414E 00 | 0.681701E-01 | 0.397417E-01 |
| 0.143672E-01 | 0.713532E-02 | 0.102859E 00 | 0.315145E 00 | -0.143094E 00 |
| -0.788061E-01 | 0.705181E-01 | -0.497377E-03 | 0.908115E-02 | -0.988005E-01 |
| -0.124730E-01 | -0.145646E-01 | -0.363380E-02 | 0.976110E-01 | 0.113007E 00 |
| -0.716879E-01 | 0.476557E-02 | -0.864336E-02 | -0.590315E-03 | 0.198807E 00 |
| 0.727394E 00 | -0.573639E 00 | -0.484733E 00 | -0.341553E 00 | 0.189815E 00 |
| 0.281828E 00 | 0.163622E 00 | 0.259237E 00 | 0.357093E 00 | 0.830243E-01 |
| 0.578553E-01 | -0.281211E 00 | -0.313357E-01 | -0.340882E 00 | 0.488268E-01 |
| -0.137563E 00 | -0.212661E 00 | -0.147257E 00 | -0.147995E 00 | -0.396056E-01 |
| -0.246926E-01 | -0.855977E-02 | -0.439214E-02 | -0.101726E 00 | 0.853777E-01 |
| -0.142273E-02 | 0.110891E 00 | 0.115145E 00 | 0.303243E-01 | 0.191558E-01 |
| 0.658836E-02 | -0.966606E-01 | 0.187518E 00 | -0.366485E-01 | 0.123975E-01 |
| -0.954837E-02 | 0.291791E-03 | 0.988054E-01 | -0.863141E-01 | -0.990922E-01 |
| -0.249118E-01 | -0.163062E-01 | 0.944997E-01 | -0.189057E 00 | 0.861469E-01 |
| -0.112658E 00 | 0.956190E-01 | -0.141305E-02 | 0.112223E 00 | 0.153245E-01 |
| 0.167032E-01 | 0.423553E-02 | 0.202762E 00 | -0.714274E-01 | -0.835087E-01 |
| 0.791826E-01 | -0.999173E-01 | -0.103522E 00 | -0.272767E-01 | -0.172393E-01 |
| -0.105918E 00 | -0.168775E-01 | -0.160984E-01 | -0.443344E-02 | -0.268568E-02 |
| -0.947857E-03 | -0.200477E 00 | -0.278426E-01 | 0.701027E-01 | 0.206081E 00 |
| 0.137580E 00 | -0.542097E-01 | 0.104051E-01 | -0.562293E-02 | 0.200588E 00 |
| -0.730175E-01 | 0.115971E 00 | 0.655131E-02 | -0.184034E 00 | -0.124971E 00 |
| 0.586576E-01 | 0.919493E-01 | 0.203562E-01 | 0.147636E-01 | 0.104692E 00 |
| -0.183626E 00 | 0.882373E-01 | -0.111663E 00 | 0.960281E-01 | 0.987483E-01 |
| 0.261420E-01 | 0.216444E 00 | -0.666980E-01 | 0.118920E 00 | -0.152247E 00 |
| -0.110956E-01 | 0.173477E 00 | 0.225309E-01 | 0.256449E-01 | 0.648745E-02 |
| 0.422954E-02 | 0.101418E 00 | -0.854260E-01 | 0.201373E 00 | -0.183272E 00 |
| -0.259157E 00 | 0.134637E 00 | -0.320236E 00 | 0.732618E-01 | -0.314965E-01 |
| 0.516921E-02 | -0.100385E 00 | -0.136150E-01 | -0.153031E-01 | -0.389553E-02 |
| -0.251254E-02 | 0.991368E-01 | 0.133732E-01 | 0.147327E-01 | 0.377402E-02 |
| 0.243633E-02 | 0.827182E-03 | -0.995751E-01 | 0.863532E-01 | -0.201005E 00 |
| 0.183443E 00 | -0.100780E 00 | 0.109921E 00 | -0.978990E-01 | 0.100748E 00 |
| 0.119868E-02 | -0.867463E-01 | -0.118317E-01 | 0.870968E-01 | -0.894926E-01 |
| 0.989436E-01 | -0.979642E-01 | 0.199334E 00 | -0.185198E 00 | 0.100321E 00 |
| -0.102066E-01 | -0.883628E-01 | 0.864534E-01 | -0.995434E-01 | -0.251974E-02 |
| 0.867203E-01 | 0.116565E-01 | 0.112888E 00 | -0.828910E-01 | -0.967895E-01 |
| -0.241333E-01 | 0.184067E 00 | -0.776910E-01 | -0.868040E-01 | -0.221082E-01 |
| -0.114328E 00 | 0.813184E-01 | -0.103612E 00 | -0.374941E-02 | -0.139645E-01 |
| -0.202432E 00 | -0.125783E 00 | -0.442445E-01 | -0.122973E 00 | 0.772467E-01 |
| 0.946830E-01 | 0.223136E 00 | 0.143147E 00 | -0.512391E-01 | |

RESIDUAL VALUES.

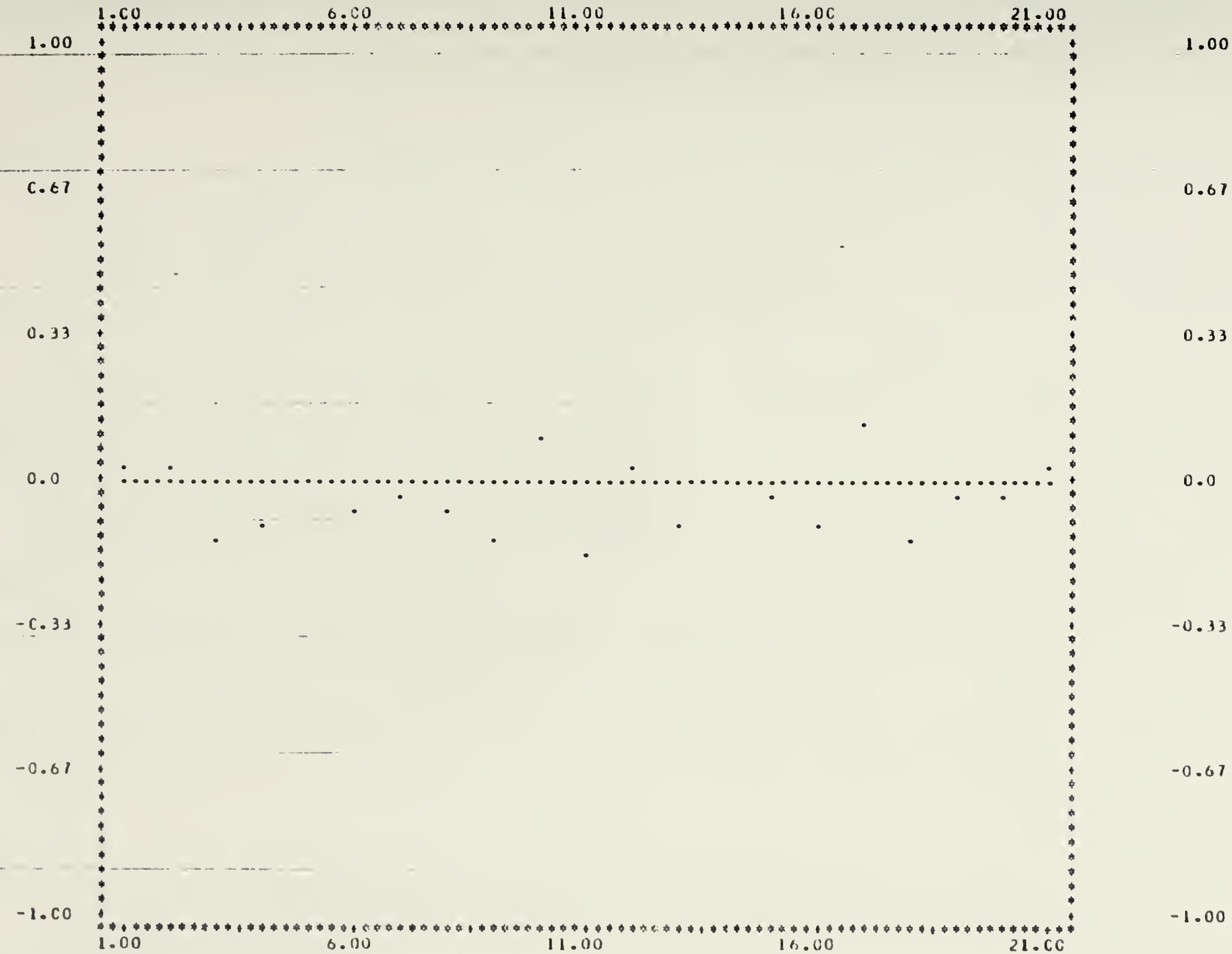
Residuals of (0,2,2) model of series C.

```
                AUTOCORRELATIONS

 0.020  0.034 -0.134 -0.053 -0.012 -0.043  0.004 -0.063 -0.125  0.088
-0.142  0.069 -0.098  0.025  0.004 -0.055  0.157 -0.089  0.006 -0.006

          PARTIAL AUTOCORRELATIONS

 0.020  0.034 -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 -0.090  0.123 -0.123 -0.021 -0.025

    MEAN=-.124575E-02      VARIANCE = 0.189499E-01
```

Auto and partial autocorrelations of residuals, model (0.2.2) of series C.




Plots of autocorrelations of residuals, model (0,2,2) of series C.




PARTIAL AUTOCORRELATIONS
SERIES C,RESIDUALS OF (0,2,2).


X-SCALE: "*"= 0.400E 00 UNITS

Y-SCALE: "*"= 0.122E 00 UNITS

ORIGINAL AND FORECASTED TIME SERIES.

Figure 8. Plots of the forecasted values adjoined to the original series C with 80% confidence limits about the forecasts.

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| | | | | |
|---|---|---|---|---|
| 0.186403E 02 | 0.185120E 02 | 0.186311E 02 | 0.186268E 02 | 0.187876E 02 |
| 0.189639E 02 | 0.190747E 02 | 0.192058E 02 | 0.192611E 02 | 0.196333E 02 |
| 0.198214E 02 | 0.200422E 02 | 0.201663E 02 | 0.203476E 02 | 0.203695E 02 |
| 0.202165E 02 | 0.201332E 02 | 0.201743E 02 | 0.202879E 02 | 0.202418E 02 |
| 0.200675E 02 | 0.198090E 02 | 0.194875E 02 | 0.190391E 02 | 0.188136E 02 |
| 0.184630E 02 | 0.175632E 02 | 0.172959E 02 | 0.165938E 02 | 0.159970E 02 |
| 0.154617E 02 | 0.151969E 02 | 0.150473E 02 | 0.149599E 02 | 0.149809E 02 |
| 0.149569E 02 | 0.151000E 02 | 0.155488E 02 | 0.158465E 02 | 0.160877E 02 |
| 0.163584E 02 | 0.165626E 02 | 0.166319E 02 | 0.167048E 02 | 0.167338E 02 |
| 0.168622E 02 | 0.170720E 02 | 0.174137E 02 | 0.175033E 02 | 0.177238E 02 |
| 0.178735E 02 | 0.181108E 02 | 0.182771E 02 | 0.134835E 02 | 0.184096E 02 |
| 0.183494E 02 | 0.182271E 02 | 0.180929E 02 | 0.180560E 02 | 0.178175E 02 |
| 0.176871E 02 | 0.179021E 02 | 0.173191E 02 | 0.168972E 02 | 0.167271E 02 |

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| | | | | |
|---|---|---|---|---|
| 0.187105E 02 | 0.183506E 02 | 0.179974E 02 | 0.173963E 02 | 0.165110E 02 |
| 0.164655E 02 | 0.159701E 02 | 0.157518E 02 | 0.157429E 02 | 0.157769E 02 |
| 0.157419E 02 | 0.158330E 02 | 0.159648E 02 | 0.159236E 02 | 0.157632E 02 |
| 0.155447E 02 | 0.154595E 02 | 0.157496E 02 | 0.161392E 02 | 0.164900E 02 |
| 0.168544E 02 | 0.170366E 02 | 0.173077E 02 | 0.174339E 02 | 0.173964E 02 |
| 0.174543E 02 | 0.174405E 02 | 0.173382E 02 | 0.170760E 02 | 0.167666E 02 |
| 0.164696E 02 | 0.161510E 02 | 0.161867E 02 | 0.161930E 02 | 0.160604E 02 |
| 0.159028E 02 | 0.157362E 02 | 0.155557E 02 | 0.153480E 02 | 0.152531E 02 |
| 0.150635E 02 | 0.149489E 02 | 0.150797E 02 | 0.149397E 02 | 0.147632E 02 |
| 0.145020E 02 | 0.142774E 02 | 0.140025E 02 | 0.138432E 02 | 0.137482E 02 |
| 0.135777E 02 | 0.132720E 02 | 0.131492E 02 | 0.129038E 02 | 0.128702E 02 |
| 0.128902E 02 | 0.127619E 02 | 0.126931E 02 | 0.125446E 02 | 0.124297E 02 |
| 0.121708E 02 | 0.119479E 02 | 0.120051E 02 | 0.120581E 02 | 0.121201E 02 |

Table IV. Values of simulations for model (1,1,0) of series C.

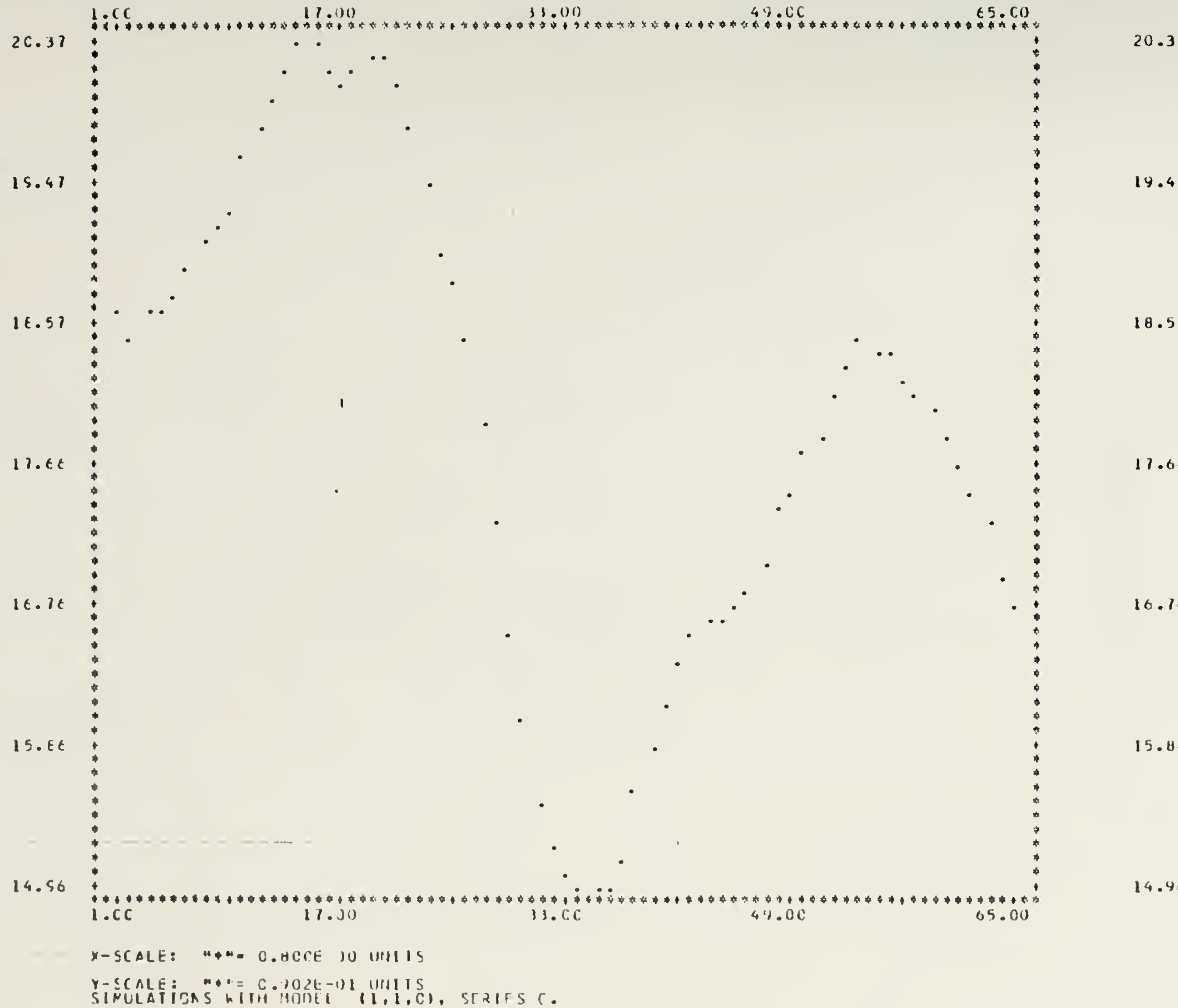


Figure 9. Plots of simulated series with model (1,1,0) of series C.

# APPENDIX C

# PROGRAM LISTINGS

```
&TYPEOUT OFF
GLOBAL T SYSLIB IMSLSP SSPLIB
&SPACE 1
&PRINT YOU HAVE ENTERED THE TIME SERIES EDITOR.
&SPACE 1
&UPRINT PLEASE RESPOND TO EACH QUERY WITH AN INPUT AT THE TERMINAL.
&UPRINT ENTER ONLY THE FIRST LETTER FOR A WORD RESPONSE.
&UPRINT ENTER NUMERICAL VALUES VIA FORTRAN FORMAT.
&SPACE 1
&PRINT TYPE INTEGER VALUES FOR NAMES STARTING WITH I THRU N.
&UPRINT TYPE INTEGER VALUES FOR COUNTS.  TYPE FLOATING
&UPRINT VALUES WITH DECIMAL FOR ALL OTHER NAMES.
&SPACE 1
-ST &PRINT DO YOU WANT A LIST OF THE OPTIONS?
&READ ARGS
&ERROR &CONTINUE
&IF &1 EQ Y &GOTO -PRINIX
-ST2 &SPACE 1
&PRINT ENTER LETTER FOR OPTION YOU WANT.
&READ ARGS
&ERROR &CONTINUE
&IF &1 EQ G &GOTO -LOAD1
&OPTION = &1
&IF &1 EQ A &GOTO -MESS
&IF &1 EQ P &GOTO -MESS
&IF &1 EQ D &GOTO -MESS
&IF &1 EQ E &GOTO -MESS
&IF &1 EQ F &GOTO -MESS
&IF &1 EQ S &GOTO -MESS
&IF &1 EQ R &GOTO -MESS
-BUSS &SPACE 1
&PRINT ILLEGAL OPTION. CHECK VALID OPTIONS.
&GOTO -QUES
-MESS &CONTINUE
&UPRINT IS YOUR DATA IN FILE FT02F001?
&READ ARGS
&ERROR &CONTINUE
&IF &1 EQ Y &GOTO -CHECK
&UPRINT HAVE YOU ALREADY SUBMITTED YOUR DATA TO BE READ OFFLINE INTO CP/CMS?
&READ ARGS
&ERROR &CONTINUE
&IF &1 EQ N &GOTO -ENTER
C READ *
-CHECK &IF &OPTION EQ A &GOTO -LOAD2
&IF &OPTION EQ P &GOTO -LOAD3
&IF &OPTION EQ D &GOTO -LOAD4
&IF &OPTION EQ E &GOTO -LOAD5
&IF &OPTION EQ F &GOTO -LOAD6
&IF &OPTION EQ S &GOTO -LOAD7
&IF &OPTION EQ R &GOTO -LOAD8
-LOAD1 LOAD GENERATE (CLEAR XEQ NOMAP)
C PRINT FILE FT01F001
&GOTO -QUES
-LOAD2 LOAD ALTO (CLEAR XEQ NOMAP)
C PRINTCC FILE FT08F001
&GOTO -QUES
-LOAD3 LOAD PLOT (CLEAR XEQ NOMAP)
C PRINTCC FILE FT08F001
&GOTO -QUES
-LOAD4 LOAD DIFF (CLEAR XEQ NOMAP)
&UPRINT DO YOU WANT TO PLOT AUTO AND PAUTO OF TRANSFORMED DATA?
&READ ARGS &ERROR &GOTO -QUES
&IF &1 NE Y &GOTO -QUES
OFFLINE PRINT FILE FT03F001
ALTER FILE FT02F001 P1 FILE FT09F001 P1
ALTER FILE FT03F001 P1 FILE FT02F001 P1
LOAD ALTO (CLEAR XEQ NOMAP)
OFFLINE PRINTCC FILE FT08F001
ALTER FILE FT02F001 P1 FILE FT03F001 P1
ALTER FILE FT09F001 P1 FILE FT02F001 P1
```

```
&SPACE 1
&GOTO -QUES
-LOAD5 LOAD ESTIMATE (CLEAR XEQ NOMAP)
&UPRINT DO YOU WANT TO PLOT AUTO AND PAUTO OF RESIDUALS?
&READ ARGS &ERROR &GOTO -QUES
&IF &1 NE Y &GOTO -QUES
OFFLINE PRINT FILE FT03F001
ALTER FILE FT02F001 PI FILE FT09F001 PI
ALTER FILE FT03F001 PI FILE FT02F001 PI
LOAD AUTO (CLEAR XEQ NOMAP)
OFFLINE PRINTCC FILE FT08F001
ALTER FILE FT02F001 PI FILE FT03F001 PI
ALTER FILE FT09F001 PI FILE FT02F001 PI
&UPRINT DO YOU WANT TO CHECK RESIDUALS?
&READ ARGS &ERROR &GOTO -QUES
&IF &1 NE Y &GOTO -QUES
LOAD TEST0000 (CLEAR XEQ NOMAP)
&SPACE 1
&GOTO -QUES
-LOAD6 LOAD FORECAST (CLEAR XEQ NOMAP)
&UPRINT DO YOU REALLY WANT TO PLOT FORECASTS?
&READ ARGS &ERROR &GOTO -QUES
&IF &1 NE Y &GOTO -QUES
OFFLINE PRINTCC FILE FT08F001
&UPRINT YOUR TIME SERIES AND FORECASTS ARE PLOTTED OFFLINE.
&SPACE 1
&GOTO -QUES
-LOAD7 LOAD SIMULATE (CLEAR XEQ NOMAP)
&UPRINT DO YOU WANT TO PLOT SIMULATED VALUES?
&READ ARGS &ERROR &GOTO -QUES
&IF &1 NE Y &GOTO -QUES
OFFLINE PRINT FILE FT03F001
ALTER FILE FT02F001 PI FILE FT09F001 PI
ALTER FILE FT03F001 PI FILE FT02F001 PI
LOAD PLOT (CLEAR XEQ NOMAP)
OFFLINE PRINTCC FILE FT08F001
ALTER FILE FT02F001 PI FILE FT03F001 PI
ALTER FILE FT09F001 PI FILE FT02F001 PI
&SPACE 1
&GOTO -QUES
-LOAD8 LOAD REGRESS (CLEAR XEQ NOMAP)
&SPACE 1
-QUES &PRINT DO YOU WANT TO TRY AGAIN?
&READ ARGS
&ERROR &GOTO -QUES
&IF &1 EQ N &GOTO -END
&GOTO -ST2
-PRINTX &CONTINUE
PRINTF OPTIONS PARA
-NEWS &SPACE 1
&PRINT WOULD YOU LIKE MORE INFO?
&READ ARGS
&ERROR &CONTINUE
&IF &1 NE Y &GOTO -ST2
&SPACE 1
&PRINT ENTER OPTION YOU WANT INFO ABOUT.
&READ ARGS
&ERROR &GOTO -NEWS
PRINTF &1 PARA
&ERROR &GOTO -RLSS
&SPACE 1
-LEE &PRINT DO YOU WANT TO TRY A SESSION?
&READ ARGS
&ERROR &GOTO -END
&IF &1 EQ N &GOTO -END
&GOTO -ST2
-ENTER &PRINT DO YOU WANT INFO ON HOW TO ENTER YOUR SERIES?
&READ ARGS
&ERROR &CONTINUE
&IF &1 EQ Y &GOTO -HOW
```

```
&PRINT ENTER SERIES CFFLINE AND RETURN.
&GCTO -END
-FCW FFINTF ENTER PARA
&GCTO -LEE
-END &PRINT CONTROL RETLRNED TO CMS
&EXIT
```

```
&TYPEOUT OFF
GLOBAL T SYSLIB IMSLSP SSPLIB
-OFFLINE READ *
-ASK &PRINT WHICH OPTION?
&READ ARGS
&ERROR
&IF &1 EQ G &GOTO -LOAD1
&IF &1 EQ A &GOTO -LOAD2
&IF &1 EQ P &GOTO -LOAD3
&IF &1 EQ D &GOTO -LOAD4
&IF &1 EQ E &GOTO -LOAD5
&IF &1 EQ F &GOTO -LOAD6
&IF &1 EQ S &GOTO -LOAD7
&IF &1 EQ R &GOTO -LOAD8
&SPACE 1 &PRINT ILLEGAL OPTION.
&SPACE 1 &GOTO -ASK
-LOAD1 LOAD GENERATE (CLEAR XEQ NOMAP)
O PRINT FILE FT01F001
&SPACE 1
&GOTO -QUES
-LOAD2 LOAD AUTO (CLEAR XEQ NOMAP)
O PRINTCC FILE FT08F001
&SPACE 1
&GOTO -QUES
-LOAD3 LOAD PLOT (CLEAR XEQ NOMAP)
O PRINTCC FILE FT08F001
&SPACE 1
&GOTO -QUES
-LOAD4 LOAD DIFF (CLEAR XEQ NOMAP)
&UPRINT DO YOU WANT TO PLOT AUTO AND PAUTO OF TRANSFORMED DATA?
&READ ARGS &ERROR &GOTO -QUES
&IF &1 NE Y &GOTO -QUES
OFFLINE PRINT FILE FT03F001
ALTER FILE FT02F001 P1 FILE FT09F001 P1
ALTER FILE FT03F001 P1 FILE FT02F001 P1
LOAD AUTO (CLEAR XEQ NOMAP)
OFFLINE PRINTCC FILE FT08F001
ALTER FILE FT02F001 P1 FILE FT03F001 P1
ALTER FILE FT09F001 P1 FILE FT02F001 P1
&SPACE 1
&GOTO -QUES
-LOAD5 LOAD ESTIMATE (CLEAR XEQ NOMAP)
&UPRINT DO YOU WANT TO PLOT AUTO AND PAUTO OF RESIDUALS?
&READ ARGS &ERROR &GOTO -QUES
&IF &1 NE Y &GOTO -QUES
OFFLINE PRINT FILE FT03F001
ALTER FILE FT02F001 P1 FILE FT09F001 P1
ALTER FILE FT03F001 P1 FILE FT02F001 P1
LOAD AUTO (CLEAR XEQ NOMAP)
OFFLINE PRINTCC FILE FT08F001
ALTER FILE FT02F001 P1 FILE FT03F001 P1
ALTER FILE FT09F001 P1 FILE FT02F001 P1
&UPRINT DO YOU WANT TO CHECK RESIDUALS?
&READ ARGS &ERROR &GOTO -QUES
&IF &1 NE Y &GOTO -QUES
LOAD TESTGOOD (CLEAR XEQ NOMAP)
&SPACE 1
&GOTO -QUES
-LOAD6 LOAD FORECAST (CLEAR XEQ NOMAP)
&UPRINT DO YOU REALLY WANT TO PLOT FORECASTS?
&READ ARGS &ERROR &GOTO -QUES
&IF &1 NE Y &GOTO -QUES
OFFLINE PRINTCC FILE FT08F001
&UPRINT YOUR TIME SERIES AND FORECASTS ARE PLOTTED OFFLINE.
&SPACE 1
&GOTO -QUES
-LOAD7 LOAD SIMULATE (CLEAR XEQ NOMAP)
&UPRINT DO YOU WANT TO PLOT SIMULATED VALUES?
&READ ARGS &ERROR &GOTO -QUES
&IF &1 NE Y &GOTO -QUES
```

```
OFFLINE PRINT FILE FT03F001
ALTER FILE FT02F001 P1 FILE FT09F001 P1
ALTER FILE FT03F001 P1 FILE FT02F001 P1
LOAD PLOT (CLEAR XEQ NOMAP)
OFFLINE PRINTCC FILE FT08F001
ALTER FILE FT02F001 P1 FILE FT03F001 P1
ALTER FILE FT09F001 P1 FILE FT02F001 P1
&SPACE 1
&GOTO -CLES
-LOAD8 LOAD REGRESS (CLEAR XEQ NOMAP)
&SPACE 1
-CLES &PRINT AGAIN?
&READ ARGS
&ERROR
&IF &1 EQ Y &GOTO -ASK
&PRINT CONTROL RETURNED TO CMS.
&EXIT
```

```
      DIMENSICN  X(400),Z(4C0),TITLE(60)                    PLCOOC10
      CATA  Y/'Y'/                                          PLCC0020
      READ(2,2CC)  N                                        PLCCCC3C
  200 FORMAT(I3)                                            PLCCC040
      READ(2,201)  (Z(I),I=1,N)                             PLCCC050
  201 FORMAT(5E15.6)                                        PLCCCC60
      DC 1C I=1,N                                           PLCCCC70
   10 X(I) = I                                              PLCCCCEC
    9 FCRMAT('1')                                           PLCCC090
      WRITE(8,9)                                            PLCC01C0
      CALL FLCTP(X,Z,N,C)                                   PLCCC110
      WRITE(6,63)                                           PLCC0120
      READ(5,53) TITLE                                      PLCCC130
   63 FCRMAT(2X,'ENTER TITLE FCR PLCT.')                    PLOCC14C
   53 FORMAT(60A1)                                          PLCC0150
      WRITE(8,81) TITLE                                     PLCC0160
   81 FORMAT(15X,60A1)                                      PLOCC170
      WRITE(6,64)                                           PLCC0180
   64 FCRMAT(2X,'TIME SERIES PLCTS HAVE BEEN PRINTEC CFFLINE.')  PLCCC190
      STCP                                                  PLCC02C0
      END                                                   PLCC0210
```

```
      DIMENSION W(400),ACV(21),PACV(21),WKAREA(21),RANGE(4),T(21),AC(21)AUTO0010
      DIMENSION TITLE(60)                                               AUTO0020
      DATA  Y/'Y'/                                                      AUTO0030
      READ(2,307) LW                                                    AUTO0040
  307 FORMAT(I3)                                                        AUTO0050
      READ(2,802)   (W(I),I=1,LW)                                       AUTO0060
  802 FORMAT(5E15.6)                                                    AUTO0070
      CALL FTAUTC(W,LW,21,21,7,AMEAN,VAR,ACV,AC,PACV,WKAREA)            AUTO0080
    4 FORMAT(//5X,'MEAN=',G12.6,5X,'VARIANCE = ',G12.6,/)               AUTO0090
      WRITE(6,5)                                                        AUTO0100
      WRITE(8,5)                                                        AUTO0110
    5 FORMAT(15X,'AUTOCORRELATIONS',/)                                  AUTO0120
      WRITE(6,6)  (AC(I),I=1,20)                                        AUTO0130
      WRITE(8,6)  (AC(I),I=1,20)                                        AUTO0140
    6 FORMAT(10F7.3)                                                    AUTO0150
      WRITE(6,7)                                                        AUTO0160
      WRITE(8,7)                                                        AUTO0170
    7 FORMAT(//10X,'PARTIAL AUTOCORRELATIONS',/)                        AUTO0180
      WRITE(6,6)  (PACV(I),I=1,20)                                      AUTO0190
      WRITE(8,6)  (PACV(I),I=1,20)                                      AUTO0200
      WRITE(8,4)  AMEAN,VAR                                             AUTO0210
      WRITE(6,4)  AMEAN,VAR                                             AUTO0220
      RANGE(1)=21                                                       AUTO0230
      RANGE(2)=1                                                        AUTO0240
      RANGE(3)=1.0                                                      AUTO0250
      RANGE(4)=-1.0                                                     AUTO0260
      DO 8  I=1,21                                                      AUTO0270
    8 T(I)=I                                                            AUTO0280
      WRITE(8,9)                                                        AUTO0290
    9 FORMAT('1')                                                       AUTO0300
      CALL UTPLOT(T,AC,21,RANGE,1,0)                                    AUTO0310
      WRITE(8,10)                                                       AUTO0320
   10 FORMAT(15X,'AUTOCORRELATIONS')                                    AUTO0330
      WRITE(8,9)                                                        AUTO0340
      CALL UTPLOT(T,PACV,21,RANGE,1,0)                                  AUTO0350
      WRITE(8,11)                                                       AUTO0360
   11 FORMAT(10X,'PARTIAL AUTOCORRELATIONS')                            AUTO0370
      WRITE(6,61)                                                       AUTO0380
   61 FORMAT(2X,'ENTER TITLE FOR PLOTS.')                               AUTO0390
      READ(5,51) TITLE                                                  AUTO0400
   51 FORMAT(60A1)                                                      AUTO0410
      WRITE(8,62) TITLE                                                 AUTO0420
   62 FORMAT(15X,65A1)                                                  AUTO0430
      WRITE(6,15)                                                       AUTO0440
   15 FORMAT('  YOUR AUTO AND PAUTO PLOTS HAVE BEEN PRINTED OFFLINE.'/  AUTO0450
     *'  PICK UP IN ROOM 1140 UNDER YOUR USER ID NUMBER.')              AUTO0460
      STOP                                                              AUTO0470
      END                                                               AUTO0480
```

```
      DIMENSION  Z(400)
      DATA  Y/'Y'/
      READ(12,200) LZ
  200 FORMAT(I3)
      READ(12,201)  (Z(I),I=1,LZ)
  201 FORMAT(5E15.6)
      IS=1
      ID2=0
      ID1=0
      WRITE(6,609)
  609 FORMAT(2X,'IS YOUR TIME SERIES SEASONAL?')
      READ(5,502) ANS
      IF(ANS.NE.Y) GO TO 1000
   20 WRITE(6,601)
  601 FORMAT(2X,'ENTER ORDER OF SEASONAL DIFFERENCING.')
      READ(5,503) ID2
  503 FORMAT(I1)
   10 WRITE(6,604)
  604 FORMAT(2X,'ENTER LENGTH OF SEASONAL PERIOD VIA I2.')
      READ(5,504) IS
  504 FORMAT(I2)
      WRITE(6,605) IS
  605 FORMAT(2X,'YOUR INPUT SEASONAL PERIOD=',I2,'.     IS IT OK?')
      READ(5,502) ANS
      IF(ANS.NE.Y) GO TO 10
 1000 WRITE(6,600)
  600 FORMAT(2X,'ENTER NUMBER OF NONSEASONAL DIFFERENCES.')
      READ(5,503) ID1
      WRITE(6,602)
  602 FORMAT(2X,'DO YOU WANT A LOG TRANSFORMATION?')
      READ(5,502) ANS
  502 FORMAT(A1)
      IP=0
      IF(ANS.EQ.Y) GO TO 50
      WRITE(6,610)
  610 FORMAT(2X,'DO YOU WANT AN EXPONENTIAL TRANSFORMATION?')
      READ(5,502) ANS
      IP=1
      IF(ANS.NE.Y) GO TO 50
      WRITE(6,603)
  603 FORMAT(2X,'ENTER POWER OF EXPONENTIAL TRANSFORMATION VIA I1.')
      READ(5,503) IP
   50 CALL FTRDIF(ID1,ID2,IP,IS,LZ,Z,SHIFT,LW,IER)
      M=LW
      WRITE(6,900)
  900 FORMAT(2X,'YOUR TRANSFORMED TIME SERIES HAS BEEN STORED IN FILE',
     *' FT03F001.'/2X,'DO YOU WANT A PRINTOUT OF THE FIRST TEN VALUES?')
      READ(5,502) ANS
      IF(ANS.NE.Y) GO TO 525
      WRITE(6,606)
  606 FORMAT(2X,'THE FIRST 10 VALUES OF THE TRANSFORMED SERIES ARE:')
      JJ=M
      IF(M.GT.10)  JJ=10
      WRITE(6,607) (Z(I),I=1,JJ)
  607 FORMAT(5F15.6)
  525 WRITE(3,60) M
   60 FORMAT(I3)
      WRITE(3,61) (Z(I),I=1,M)
   61 FORMAT(5E15.6)
      IF(IER.EQ.0) GO TO 70
      WRITE(6,608) IER
  608 FORMAT(2X,'ERROR PARAM=',I3,' SEE EXPLANATION IN SUBROUTINE FTRDIF
     *.')
   70 STOP
      END
```

```
      DIMENSION X(400),IND(8),ARPS(10),PMAS(10),GR(401),AA(400)
      EQUIVALENCE(A,B)
      REAL*8 A(499)
      REAL*4 B(998)
      DO 1 I=1,10
      ARPS(I)=.0
      PMAS(I)=.0
    1 CONTINUE
      READ(2,200) IND(1)
  200 FORMAT(I3)
      L=IND(1)
      READ(2,201) (X(I),I=1,L)
  201 FORMAT(5E15.6)
      WRITE(6,600)
  600 FORMAT(2X,'ENTER NUMBER OF AR PARAMETERS.')
      READ(5,500) IND(2)
  500 FORMAT(I1)
      WRITE(6,601)
  601 FORMAT(2X,'ENTER NUMBER OF MA PARAMETERS:')
      READ(5,500) IND(3)
      WRITE(6,602)
  602 FORMAT(2X,'ENTER NUMBER OF DIFFERENCES.')
      READ(5,500) IND(4)
      IND(5)=100
      IND(6)=3
      IND(7)=0
      IND(8)=3
      CALL FTMAXL(X,IND,ARPS,PMAS,PMAC,WNV,GR,A,IER)
      WRITE(6,603) IND(1),IND(2),IND(3),IND(4)
  603 FORMAT(2X,'LENGTH OF TIME SERIES =',I4/2X,I1,' AR PARAMETERS',4X,
     *I1,' MA PARAMETERS',4X,I1,' DIFFERENCES.',/)
      KK=IND(1)-IND(4)
      WRITE(3,614) KK
  614 FORMAT(I3)
      WRITE(3,613)  (B(I),I=1,KK)
  613 FORMAT(5E15.6)
      WRITE(3,615)
  615 FORMAT(/,3X,'RESIDUAL VALUES.')
      N=IND(2)+IND(4)
      IF (N.EQ.0) GO TO 3002
      WRITE(6,605) (I,ARPS(I),I=1,N)
  605 FORMAT(2X,'ESTIMATED AR PARAMETERS (UNDIFFERENCED FORM) ARE:',/(2X
     *,'PHI(',I1,') =',F9.4),/)
 3002 M=IND(3)
      IF(M.EQ.0) GO TO 3001
      WRITE(6,607) (I,PMAS(I),I=1,M)
  607 FORMAT(2X,'ESTIMATED MA PARAMETERS ARE:',/,
     *(2X,'THETA(',I1,') =',F9.4),/)
 3001 WRITE(6,608) PMAC,WNV
  608 FORMAT(2X,'MA CONSTANT= ',E13.5,5X,'WHITE NOISE VARIANCE= ',
     *E15.6/)
      IF(IER.EQ.0) GO TO 616
      WRITE(6,610) IER
  610 FORMAT(2X,'ERROR NUMBER= ',I3,'.  SEE EXPLANATION IN SUBROUTINE FT
     *MAXL (IMSL).')
  616 STOP
      END
```

```
      DIMENSION Z(400),ARPS(10),PMAS(20),LV(5),DARPS(20),FCST(3,20)
      DIMENSION X(400),T(400),W(400),V(400),G(400)
      DATA Y/'Y'/
      READ(2,200) LENGTH
  200 FORMAT(I3)
      LV(4)=0
      IFLAG=0
      WRITE(6,5001)
 5001 FORMAT(2X,'ARE YOUR AR PARAMETERS IN DIFFERENCED FORM?')
      READ(5,395) ANS
      IF(ANS.EQ.Y) GO TO 5005
      WRITE(6,5002)
 5002 FORMAT(2X,'ENTER NO. AR PARAMETERS (UNDIFF. FORM).')
      READ(5,500) LV(2)
  500 FORMAT(I1)
      GO TO 5007
 5005 WRITE(6,5006)
 5006 FORMAT(2X,'ENTER NO. AR PARAMETERS (DIFF. FORM).')
      READ(5,500) LV(2)
      IFLAG=1
 5007 IP=LV(2)
      IF(IP.LE.0) GO TO 300
   51 DO 52 I=1,IP
      WRITE(6,314) I
  314 FORMAT(2X,'ENTER AR PARAMETER PHI(',I1,').')
   52 READ(5,302) ARPS(I)
  302 FORMAT(F15.6)
      WRITE(6,505) (ARPS(I),I=1,IP)
  505 FORMAT(2X,'AR PARAMETERS ARE:',/,(3X,F8.4))
      WRITE(6,206)
  206 FORMAT(2X,'ARE THESE OK?')
      READ(5,395) ANS
  395 FORMAT(A1)
      IF(ANS.EQ.Y) GO TO 300
      GO TO 51
  300 WRITE(6,601)
  601 FORMAT(2X,'ENTER NUMBER OF MA PARAMETERS.')
      READ(5,500) LV(3)
   53 IQ=LV(3)
      IF(IQ.LE.0) GO TO 55
   56 DO 402 I=1,IQ
      WRITE(6,401) I
  401 FORMAT(2X,'ENTER MA PARAMETER THETA(',I1,').')
  402 READ(5,302) PMAS(I)
      WRITE(6,403) (PMAS(I),I=1,IQ)
  403 FORMAT(2X,'MA PARAMETERS ARE:',/,(3X,F9.4))
      WRITE(6,406)
  406 FORMAT(2X,'ARE THESE OK?')
      READ(5,395) ANS
      IF(ANS.EQ.Y) GO TO 55
      GO TO 56
   55 WRITE(6,704)
  704 FORMAT(2X,'ENTER OVERALL MA CONSTANT')
      READ(5,705) PMAC
  705 FORMAT(E15.6)
      IF(IFLAG.EQ.0) GO TO 6000
      WRITE(6,602)
  602 FORMAT(2X,'ENTER THE NUMBER OF DIFFERENCES.')
      READ(5,500) LV(4)
 6000 WRITE(6,6100)
 6100 FORMAT(2X,'ENTER INDEX FOR FORECAST ORIGIN VIA I3.')
 6050 READ(5,200) LV(1)
      L=LV(1)
      IF(L.LE.LENGTH) GO TO 6150
      WRITE(6,6160) L,LENGTH
 6160 FORMAT(2X,'FORECAST ORIGIN OF',I4,' EXCEEDS LENGTH OF SERIES',I4,'
     *.'/2X,'ENTER NEW ORIGIN.')
      GO TO 6050
 6150 READ(2,201) (Z(I),I=1,L)
  201 FORMAT(5E15.6)
```

```
      WRITE(6,603)                                                      FORO0710
  603 FORMAT(2X,'ENTER FORECAST LEAD TIME VIA I2.')                     FORC0720
      READ(5,503) LV(5)                                                 FORC0730
  503 FORMAT(I2)                                                        FORC0740
      WRITE(6,627)                                                      FORC0750
  627 FORMAT(2X,'ENTER SIGNIFICANCE LEVEL,ALPHA.')                      FORC0760
      READ(5,705) ALPHA                                                 FORC0770
      WRITE(6,605) PMAC,LV(4),LV(5),ALPHA                               FORC0780
  605 FORMAT(2X,'MA CONSTANT =',G15.6,4X,'NUMBER OF DIFFERENCES =',1X,I1FORC0790
     *,/,2X,'FORECAST LEAD TIME = ',I2,4X,'ALPHA =',F7.3)               FORC0800
      WRITE(6,606)                                                      FORC0810
  606 FORMAT(2X,'ARE THESE OK?')                                        FORC0820
      READ(5,395) ANS                                                   FORC0830
      IF(ANS.EQ.Y) GO TO 57                                             FORC0840
      GO TO 55                                                          FORC0850
   57 CALL FTCAST(Z,ARPS,PMAS,PMAC,ALPHA,LV,DARPS,FCST,WNV,IER)         FORC0860
      M=LV(2)+LV(4)                                                     FORC0870
      WRITE(6,610) (DARPS(I),I=1,M)                                     FORC0880
  610 FORMAT(2X,'AR PARAMETERS IN UNDIFFERENCED FORM ARE:',/,(3X,F8.4)) FORC0890
      WRITE(6,611)                                                      FORC0900
  611 FORMAT(/,2X,'THE FORECASTS ARE:',/)                               FORC0910
      KK=LV(5)                                                          FORO0920
      WRITE(6,612)  (FCST(2,J),J=1,KK)                                  FORC0930
  612 FORMAT(5G15.6)                                                    FORC0940
      SIGLEV=(1.0-ALPHA)*100.                                           FORC0950
      WRITE(6,613) SIGLEV                                               FORC0960
  613 FORMAT(2X,F5.1,'% CONFIDENCE LIMITS FOR FORECASTS ARE:')          FORO0970
      WRITE(6,612) (FCST(3,J),J=1,KK)                                   FORC0980
      WRITE(6,614)                                                      FORC0990
  614 FORMAT(2X,'PSI WEIGHTS FOR FORECAST ERROR ARE:')                  FORC1000
      WRITE(6,612) (FCST(1,J),J=1,KK)                                   FORC1010
      WRITE(6,615)  WNV                                                 FORC1020
  615 FORMAT(2X,'WHITE NOISE VARIANCE = ',G15.5)                        FORC1030
      IF(IER.EQ.0) GO TO 620                                            FORC1040
      WRITE(6,616) IER                                                  FORC1050
  616 FORMAT(2X,'ERROR PARAMETER = ',I3,3X,'SEE EXPLANATION IN SUBROUTINFORC1060
     *E FTCAST (IMSL).')                                                FORC1070
  620 WRITE(6,621)                                                      FORC1080
  621 FORMAT(2X,'DO YOU WANT TO PLOT FORECASTS?')                       FORC1090
      READ(5,395) ANS                                                   FORC1100
      IF(ANS.NE.Y) GO TO 622                                            FORO1110
      N=L+KK                                                            FORC1120
      J=L+1                                                             FORC1130
      DO 1 I=1,L                                                        FORC1140
      T(I)=Z(I)                                                         FORC1150
      V(I)=Z(I)                                                         FORC1160
      G(I)=Z(I)                                                         FORC1170
      W(I)=0.                                                           FORC1180
    1 X(I)=I                                                            FORC1190
      DO 2 I=1,KK                                                       FORC1200
      T(L+I)=FCST(2,I)                                                  FORC1210
    2 W(L+I)=FCST(3,I)                                                  FORO1220
      DO 3 I=J,N                                                        FORC1230
      V(I)=T(I)+W(I)                                                    FORC1240
      G(I)=T(I)-W(I)                                                    FORC1250
    3 X(I)=I                                                            FORC1260
      IF(T(I).GT.TIN)) GO TO 999                                        FORC1270
      CALL FLCTP(X,V,N,1)                                               FORC1280
      CALL FLCTP(X,T,N,2)                                               FORC1290
      CALL FLCTP(X,G,N,3)                                               FORC1300
      WRITE(8,81)                                                       FORC1310
   81 FORMAT(14X,'ORIGINAL AND FORECASTED TIME SERIES.')                FORC1320
      STOP                                                              FORO1330
  999 CALL FLCTP(X,G,N,1)                                               FORC1340
      CALL FLCTP(X,T,N,2)                                               FORC1350
      CALL FLCTP(X,V,N,3)                                               FORC1360
      WRITE(8,81)                                                       FORO1370
  622 STOP                                                              FORC1380
      END                                                               FORC1390
```

```
      DIMENSION  Z(400),ARPS(10),PMAS(10),SIM(150),START(6)
      REAL*8      WA(995)
      DATA  Y/'Y'/
      DO 1 I=1,10
      ARPS(I)=0.
    1 PMAS(I)=0.
      READ(2,200)  L
  200 FORMAT(I3)
      READ(2,201) (Z(I),I=1,L)
  201 FORMAT(5E15.6)
      WRITE(6,600)
      READ(5,500) IP
  600 FORMAT(2X,'ENTER NUMBER OF AR PARAMETERS (UNDIFFERENCED FORM)')
  500 FORMAT(I1)
      IF(IP.LE.0) GO TO 53
   51 DO 52 I=1,IP
      WRITE(6,314) I
  314 FORMAT(2X,'ENTER ESTIMATED AR PARAMETER PHI(',I1,').')
   52 READ(5,302)  ARPS(I)
  302 FORMAT(F15.6)
      WRITE(6,505)  (ARPS(I),I=1,IP)
  505 FORMAT(2X,'AR PARAMETERS ARE',4(3X,F10.4))
      WRITE(6,206)
  206 FORMAT(2X,'ARE THESE OK?')
      READ(5,395) ANS
  395 FORMAT(A1)
      IF(ANS.EQ.Y) GO TO 53
      GO TO 51
   53 WRITE(6,601)
  601 FORMAT(2X,'ENTER  NUMBER OF MA PARAMETERS')
      READ(5,501) IQ
  501 FORMAT(I1)
      IF(IQ.LE.0) GO TO 55
   56 DO 402 I=1,IQ
      WRITE(6,401) I
  401 FORMAT(2X,'ENTER MA PARAMETER THETA(',I1,').')
  402 READ(5,302)  PMAS(I)
      WRITE(6,403)  (PMAS(I),I=1,IQ)
  403 FORMAT(2X,'MA PARAMETERS ARE',4(3X,F10.4))
      WRITE(6,406)
  406 FORMAT(2X,'ARE THESE OK?')
      READ(5,395) ANS
      IF(ANS.EQ.Y) GO TO 55
      GO TO 56
   55 WRITE(6,704)
  704 FORMAT(2X,'ENTER OVERALL MA CONSTANT')
      READ(5,705) PMAC
  705 FORMAT(E15.6)
      WRITE(6,602)
  602 FORMAT(2X,'ENTER ESTIMATED WHITE NOISE VAR')
      READ(5,502) WNV
  502 FORMAT(F15.6)
  400 WRITE(6,411)
  411 FORMAT(2X,'DO YOU WANT TO INPUT STARTING VALUES?')
      READ(5,395) ANS
      IF(ANS.NE.Y) GO TO 414
      WRITE(6,1055)
 1055 FORMAT(2X,'DO YOU WANT TO SELECT INDEX OF TIME SERIES',/
     *'VALUE WHERE SIMULATION WILL BEGIN?')
      READ(5,395) ANS
      IF(ANS.EQ.Y) GO TO 2000
      DO 2001 I = 1,IP
      WRITE(6,2002) I
 2002 FORMAT(2X,'ENTER START(',I1,')')
      READ(5,2003) START(I)
 2003 FORMAT(G16.5)
 2001 CONTINUE
      GO TO 420
 2000 WRITE(6,1056)
 1056 FORMAT(2X,'ENTER INDEX OF STARTING VALUE VIA I3.')
```

```
      READ(5,200) K
      IF(IP.EQ.0) GO TO 416
      IF(K-1+IP.GT.L) GO TO 417
      DO 413 I=1,IP
  413 START(I)=Z(K-1+I)
      GO TO 419
  414 IF(IP.EQ.0) GO TO 416
      DO 415 I=1,IP
  415 START(I)=Z(L-IP+I)
      GO TO 419
  416 START(1)=Z(K)
      GO TO 419
  417 WRITE(6,418)
  418 FORMAT(2X,'INVALID STARTING VALUE. SEE IF ANY STARTING VALUE WAS P
     *ICKED UP OUTSIDE OF RANGE OF INPUT DATA, VECTOR Z(I)')
      GO TO 400
  419 DO 420 I=1,IP
  420 WRITE(6,421) I,START(I)
  421 FORMAT(2X,'START(',I1,')=',F15.6)
      WRITE(6,422)
  422 FORMAT(2X,'STARTING VALUE(S) OK?')
      READ(5,395) ANS
      IF(ANS.NE.Y) GO TO 400
      WRITE(6,603)
  603 FORMAT(2X,'ENTER RANDOM NUMBER SEED (BETWEEN 0 AND 1).')
      READ(5,503) SEED
  503 FORMAT(F15.12)
      SEED = SEED * 1000000000.
      ISEED = SEED
      WRITE(6,604)
  604 FORMAT(2X,'ENTER NUMBER OF VALUES YOU WANT TO SIMULATE VIA I3.')
      READ(5,200) LW
      WRITE(6,1000)
 1000 FORMAT(2X,'DO YOU WANT MORE THAN ONE SIMULATED SERIES?')
      READ(5,395) ANS
      M=1
      IF(ANS.NE.Y) GO TO 1010
      WRITE(6,1020)
 1020 FORMAT(2X,'HOW MANY SERIES DO YOU WANT (I1.9)?')
      READ(5,500) M
      JJ=20
      IF(LW.LT.20) JJ=LW
 1010 DO 125 K=1,M
      CALL FTGEN1(ARPS,PMAS,PMAC,START,WNV,ISEED,IP,IQ,LW,SIM,WA)
      WRITE(3,60) LW
   60 FORMAT(I3)
      WRITE(3,61) (SIM(I),I=1,LW)
   61 FORMAT(5E15.6)
      IF(K.NE.1) GO TO 125
      WRITE(6,3010)
 3010 FORMAT(2X,'DO YOU WANT A PRINTOUT OF THE FIRST 20 VALUES?')
      READ(5,395) ANS
      IF(ANS.NE.Y) GO TO 125
      WRITE(6,608) (SIM(I),I=1,JJ)
  608 FORMAT(2X,'SIMULATED VALUES ARE:'/15F15.6))
  125 CONTINUE
      IF(IER.EQ.0) GO TO 610
      WRITE(6,607) IER
  607 FORMAT(2X,'ERROR PARAMETER= ',I3,' SEE EXPLANATION IN SUBROUTINE F
     *TGEN1 (IMSL).')
  610 STOP
      END
```

```
      DIMENSION PHI(6),THETA(6),START(6),W(400),WA(410)
      REAL*8 SEED
      DATA IC1/'Y'/,IP4/'V'/,IP5/'C'/
      DATA PHI/6*0.0/,THETA/6*0.0/,START/6*0.0/,CONS/0.0/
      WRITE(6,301)
  301 FORMAT(1X,'ENTER RANDOM NUMBER SEED (BETWEEN 0 AND 1).')
   60 READ(5,777) SEED
  777 FORMAT(F15.12)
      SEED = SEED * 1000000000.
      ISEED = SEED
  302 FORMAT(G15.6)
   70 WRITE(6,71)
   71 FORMAT(' ENTER IP, THE ORDER OF THE AUTOREGRESSIVE OPERATOR.')
      READ(5,72) IP
   72 FORMAT(I1)
      WRITE(6,360)
  360 FORMAT(' ENTER IQ, THE ORDER OF THE MOVING AVERAGE OPERATOR.')
      READ(5,72) IQ
      WRITE(6,361)
  361 FORMAT(' ENTER LW, THE LENGTH OF THE TIME SERIES VIA I3.')
      READ(5,307) LW
  320 WRITE(6,304) IP,IQ,LW
  304 FORMAT(1X,'IP= ',I1,3X,'IQ= ',I1,3X,'LW = ',I3)
      WRITE(6,206)
      READ(5,395) IANS
  395 FORMAT(A1)
      IF(IANS.EQ.IC1) GO TO 401
      WRITE(6,306)
  306 FORMAT(1X,'DO YOU WISH TO CHANGE LW?')
      READ(5,395) IANS
      IF(IANS.NE.IC1) GO TO 310
      WRITE(6,404)
      READ(5,307) LW
  307 FORMAT(I3)
      GO TO 320
  310 WRITE(6,311)
  311 FORMAT(1X,'DO YOU WANT TO CHANGE IP?')
      READ(5,395) IANS
      IF(IANS.NE.IC1) GO TO 644
      WRITE(6,404)
      READ(5,72) IP
  644 WRITE(6,645)
  645 FORMAT(' DO YOU WANT TO CHANGE IQ?')
      READ(5,395) IANS
      IF(IANS.NE.IC1) GO TO 401
      WRITE(6,404)
      READ(5,72) IQ
      GO TO 320
  404 FORMAT(1X,'ENTER NEW VALUE')
  401 WRITE(6,304) IP,IQ,LW
      WRITE(6,203)
  203 FORMAT(1X,'ENTER ERROR VARIANCE, VAR.')
      READ(5,302) VAR
      WRITE(6,204)
  204 FORMAT(1X,'DO YOU WANT A NONZERO CONSTANT TERM?')
      READ(5,395) IANS
      IF(IANS.NE.IC1) GO TO 231
      WRITE(6,205)
  205 FORMAT(1X,'ENTER CONSTANT TERM.')
      READ(5,302) CONS
  231 WRITE(6,402) VAR,CONS
  402 FORMAT(1X,'ERROR VARIANCE=',G15.6,5X,'CONSTANT TERM=',G15.6)
      WRITE(6,206)
      READ(5,395) IANS
      IF(IANS.EQ.IC1) GO TO 531
      WRITE(6,403)
  403 FORMAT(1X,'WHICH VARIABLE TO CHANGE, VARIANCE OR CONSTANT?')
      READ(5,395) IANS
      WRITE(6,404)
      READ(5,302) XANS
```

```
      IF(IANS.EQ.IP4) VAR=XANS
      IF(IANS.EQ.IP5) CONS=XANS
      GO TO 331
 531  WRITE(1,402) VAR,CONS
      IF(IP.LE.0) GO TO 631
      DO 502 I=1,IP
      WRITE(6,514) I
 514  FORMAT(1X,'ENTER AUTOREGRESSIVE PARAMETER PHI(',I1,').')
 502  READ(5,302) PHI(I)
 504  WRITE(6,505) (PHI(I),I=1,IP)
 505  FORMAT(1X,'AR PARAMETERS ARE',4(3X,F10.4))
      WRITE(6,206)
 206  FORMAT(1X,'ARE THESE OK?')
      READ(5,395) IANS
      IF(IANS.EQ.IC1) GO TO 600
      WRITE(6,207)
 207  FORMAT(1X,'ENTER INDEX, I, FOR VALUE YOU WANT TO CHANGE.')
      READ(5,71) I
      WRITE(6,404)
      READ(5,302) PHI(I)
      GO TO 504
 600  WRITE(1,905) (PHI(I),I=1,IP)
 631  IF(IQ.LE.0) GO TO 731
      DO 602 I=1,IQ
      WRITE(6,601) I
 601  FORMAT(1X,'ENTER MOVING AVERAGE PARAMETER THETA(',I1,').')
 602  READ(5,302) THETA(I)
 610  WRITE(6,603) (THETA(I),I=1,IQ)
 603  FORMAT(1X,'MA PARAMETERS ARE',4(3X,F10.4))
      WRITE(6,206)
      READ(5,395) IANS
      IF(IANS.EQ.IC1) GO TO 700
      WRITE(6,207)
      READ(5,71) I
      WRITE(6,404)
      READ(5,302) THETA(I)
      GO TO 610
 700  WRITE(1,603) (THETA(I),I=1,IQ)
 731  IF(IP.LE.0) GO TO 831
      DO 702 I=1,IP
      WRITE(6,701) I
 701  FORMAT(1X,'ENTER INITIAL STARTING VALUE START(',I1,').')
 702  READ(5,302) START(I)
 710  WRITE(6,703) (START(I),I=1,IP)
 703  FORMAT(1X,'START VALUES ARE',4(2X,F11.3))
      WRITE(6,206)
      READ(5,395) IANS
      IF(IANS.EQ.IC1) GO TO 800
      WRITE(6,207)
      READ(5,71) I
      WRITE(6,404)
      READ(5,302) START(I)
      GO TO 710
 800  WRITE(1,703) (START(I), I=1,IP)
 831  CALL FTGEN(IPHI,THETA,CONS,START,VAR,ISEED,IP,IQ,LW,W,WA)
      WRITE(1,801)
 801  FORMAT(/10X,'GENERATED TIME SERIES')
      WRITE(1,802) (W(I),I=1,LW)
 802  FORMAT(5E15.6)
      WRITE(2,307) LW
      WRITE(2,802) (W(I),I=1,LW)
      WRITE(6,853)
 853  FORMAT(1X,'YOUR TIME SERIES HAS BEEN GENERATED.'/
     *' IT HAS BEEN PRINTED OFFLINE.'/
     *' YOU MAY PICK IT UP IN ROOM I-140 UNDER YOUR USER ID NUMBER.'/
     *' THE TIME SERIES IS IN FILE FT02F001 IF YOU WANT TO SEE IT.')
      STOP
      END
```

```
      DIMENSION W(400),ACV(21),PACV(21),WKAREA(21),RANGE(4),T(21),AC(21)
      WRITE(6,9)
    9 FORMAT(2X,'ENTER IP, NO OF AR PARAMETERS(DIFFERENCED FORM).')
      READ(5,10) IP
   10 FORMAT(I1)
      WRITE(6,11)
   11 FORMAT(2X,'ENTER IQ, NO OF MA PARAMETERS.')
      READ(5,10) IQ
      NDF=20-IP-IQ
      READ(3,5) K
    5 FORMAT(I3)
      READ(3,6) (W(I),I=1,K)
    6 FORMAT(5E15.6)
      CALL FTAUTO(W,K,21,21,7,AMEAN,VAR,ACV,AC,PACV,WKAREA)
      Q=0.
      DO 1 I=1,20
    1 Q=Q+(AC(I))**2
      Q=Q*K
      CALL MDCHI(Q,NDF,P,IER)
      SIGNIF=P
      WRITE(6,7) Q,NDF,SIGNIF
    7 FORMAT(2X,'CHI SQUARE LACK OF FIT VALUE =',F7.2,3X,'DF =',
     *I3,3X,'SIGNIFICANCE =',F7.4)
      STOP
      END
```

```
03/22/77  09.47.25
FILE: OPTIONS  PARA    P5                    NAVAL POSTGRADUATE SCHOOL                                   PAGE 001
OPTION                 DESCRIPTION
GENERATE -----GENERATE ANY ARIMA TIME SERIES                                          TIMC2020
AUTO ---------CALCULATE AUTOCORRELATIONS, PAUTOS, MEAN AND VARIANCE                   TIMC2030
PLOT ---------PLOT A TIME SERIES
DIFF ---------TRANSFORM AND DIFFERENCE A TIME SERIES                                  TIMC2050
ESTIMATE -----CALCULATE MAX LIKELIHOOD ESTIMATES OF ARMA PARAMETERS                   TIMC2060
SIMULATE -----SIMULATE TIME SERIES FROM A GIVEN MODEL                                 TIMC2070
FORECAST -----FORECAST FUTURE VALUES, CONSTRUCT CONFIDENCE INTERVALS
```

```
03/16/77  15.20.17
FILE: P        PARA     P5                 NAVAL POSTGRADUATE SCHOOL                              PAGE 001
PLOT --------THIS PROGRAM PLOTS A GIVEN TIME SERIES WHICH RESIDES IN
FILE FT02F001.  IT USES THE PLOTP PROGRAM IN THE IBM SSPLIB.
```

```
AUTO --------THIS PROGRAM CALCULATES AUTOCORRELATIONS, PARTIAL
AUTOCORRELATIONS, THE MEAN AND THE VARIANCE FOR A GIVEN TIME SERIES
WHICH MUST RESIDE IN FILE FT00ZF001.  THE PROGRAM USES
FTAUTO IN THE IMSL LIBRARY.  THE AUTOCORRELATIONS AND PAUTOS CAN BE      S
PLOTTED OFFLINE.
```

```
DIFF --------THIS PROGRAM TRANSFORMS A GIVEN TIME SERIES WITH A LOG
OR AN EXPONENTIAL TRANSFORMATION (OR NO TRANSFORMATION IF DESIRED), AND
THEN TAKES SEASONAL AND/OR SIMPLE DIFFERENCES OF ANY SPECIFIED ORDERS.
IT THEN OUTPUTS THE TRANSFORMED AND DIFFERENCED TIME SERIES.  THIS
PROGRAM IS USED TO ATTEMPT TO MAKE A SEASONAL OR A NONSTATIONARY TIME
SERIES OF THE FORM THAT CAN BE HANDLED VIA BOX-JENKINS TECHNIQUES.  IT
USES FIRDIF FROM THE IMSL LIBRARY.
```

```
ESTIMATE ----THIS PROGRAM CALCULATES MAXIMUM LIKELIHOOD ESTIMATES OF THE
AUTOREGRESSIVE AND THE MOVING AVERAGE PARAMETERS OF AN ARMA MODEL.
IT ALSO DETERMINES THE RESIDUALS WHICH CAN BE USED TO CHECK OUT THE
MODEL. IT USES THE PROGRAM FTMAXL FROM THE IMSL LIBRARY.
```

```
  03/22/77  09.47.45
FILE: F         PARA      P1                    NAVAL POSTGRADUATE SCHOOL                      PAGE 001
FORECAST -----THIS PROGRAM TAKES A GIVEN ARIMA MODEL WITH PARA-
METERS THAT HAVE ALREADY BEEN ESTIMATED AND CALCULATES FORECASTS
OF FUTURE VALUES.  IT ALSO DETERMINES CONFIDENCE LIMITS FOR THE
VALUES THAT HAVE BEEN FORECASTED.
```

```
03/16/77  19.20.13

FILE: S        PARA     P1                    NAVAL POSTGRADUATE SCHOOL                         PAGE 001

SIMULATE -----THIS PROGRAM WILL SIMULATE ADDITIONAL VALUES USING ANY
GIVEN ARIMA MODEL.  IT WILL TAKE AS STARTING CONDITIONS THE LAST VALUES OF A
OF A GIVEN TIME SERIES OR VALUES INPUT BY THE USER.  IT UTILIZES THE
IMSL PROGRAM FTCEN.
```

```
GENERATE ----THIS PROGRAM GENERATES A TIME SERIES SPECIFIED BY THE USER.MO2120
IT CAN HANDLE ANY ARIMA MODEL WITH NUMBER OF AR TERMS AT MOST 6 AND NUM.TIMO2130
OF MA TERMS AT MOST 6.  THE TIME SERIES CAN BE STATIONARY OR HOMOGENEOUSTIMO2140
NONSTATIONARY.  THE PROGRAM USES FTGEN1 FROM THE IMSL LIBRARY. THE USER TIMO2150
SPECIFIES ALL PARAMETERS AND STARTING CONDITIONS.  THE PROGRAM TAKES THETIMO2160
GIVEN MODEL, GENERATES RANDOM NOISE TERMS AND CALCULATES AS MANY VALUES TIMO2170
AS REQUESTED.                                                           TIMO2
```

```
03/16/77  15.24.00
FILE: ENTER    PARA     P1                    NAVAL POSTGRADUATE SCHOOL                    PAGE 001
THE FIRST TWO CARDS ARE OFFLINE READ CONTROL CARDS:

CP E7USERID  XXXXC     (WHERE XXXX IS USER ID NUMBER)
OFFLINE READ FILE FT02F001

THESE TWO CARDS ARE THEN FOLLOWED BY THE DATA CARDS:

XXX            (WHERE XXX IS THE LENGTH OF THE TIME SERIES)
(NOW ENTER THE TIME SERIES DATA VIA FORMAT (5F15.6))
(USE AS MANY CARDS AS NECESSARY TO ENTER THE TIME SERIES)

SUBMIT THIS DECK WITH NO ADDITIONAL CARDS TO THE OPERATOR TO BE
READ INTO CP/CMS.  THEN RETURN FOR ANOTHER SESSION.
```

## LIST OF REFERENCES


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5. Nelson, Charles R., Applied Time Series Analysis for Managerial Forecasting, Holden-Day, 1973.

6. Pindyck, Robert S. and Rubinfeld, Daniel L., Econometric Models and Economic Forecasts, McGraw-Hill, New York, 1976.

7. Wheelwright, Steven C. and Makridakis, Spyros, Forecasting Methods for Management, John Wiley & Sons, New York, 1973.

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Thesis 170314
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CP/CMS to the time se-
ries analysis.