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Monterey, California

THESIS

AN APPLICATION OF CP/CMS

TO THE TIME SERIES ANALYSIS

by

Young Woo Lee

March 1977

Thesis Advisor: F. R. Richards

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REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER / 2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) An Application of CP/CMS to the Time Series Analysis	5. TYPE OF REPORT & PERIOD COVERED Master's Thesis; March 1977
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Young Woo Lee	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940	12. REPORT DATE March 1977 13. NUMBER OF PAGES 111
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Naval Postgraduate School Monterey, California 93940	15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

251 450

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Time Series Analysis
Box-Jenkins
Time Sharing
Interactive Computer Analysis

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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(Page 1)

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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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An Application of CP/CMS

To The Time Series Analysis

by

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
March 1977

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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.]

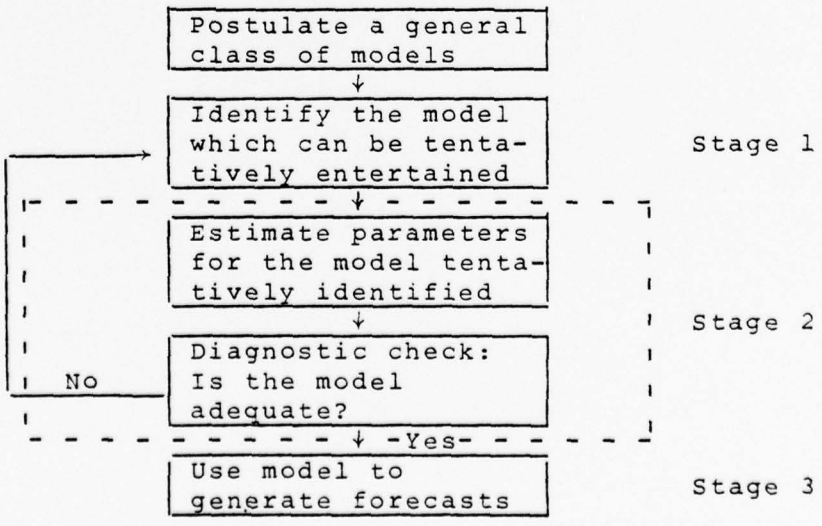

Figure 1. Box-Jenkins forecasting method.

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, ρ_k, is defined as:

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

This is estimated by the time average:

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

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 $\hat{y}_t = b_o + b_1 y_{t+1} + b_2 \cdot y_{t+2} + \ldots + b_{k-1} y_{t+k-1}$ where the b's are the least squares estimates of the linear regression coefficients (β's) in the model

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

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

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

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

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:

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

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 $\phi_1,\ldots,\phi_p$, θ_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 Δ 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 $\phi(B) = 1-\phi_1 B-\ldots-\phi_p B^p$ and $\theta(B) = 1-\theta_1 B-\ldots-\theta_q B^q$. There are p+q+2 unknown parameters, $\{\phi_1,\ldots,\phi_p,\theta_o,\theta_1..,\theta_q,\sigma_a^2\}$, 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 σ_a^2 and θ_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 $\mu_w = \theta_o/(1-\phi_1-\ldots-\phi_p)$ 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 μ_w (if $d > 0$, μ_w is usually 0) and let

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

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

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 σ_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 σ_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:

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

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

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

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

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

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

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

where the weights ψ_j are determined from

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

The variance of the forecast error is given by

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

From this, a confidence interval of z standard deviations around a forecast ℓ 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 ℓ. 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

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.

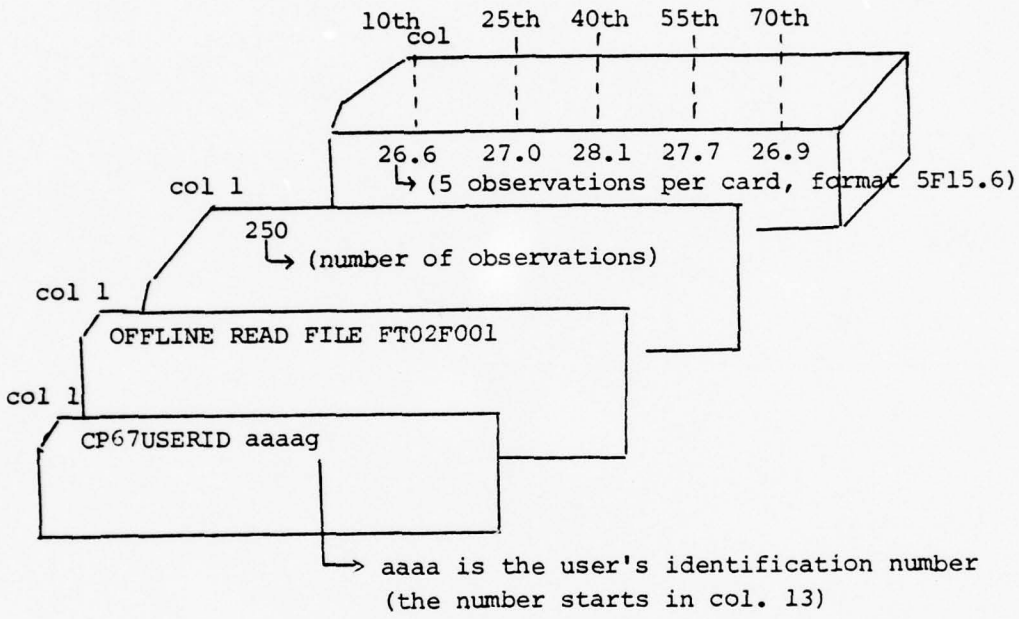

Figure 2. Card deck for offline read.

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:

χ^2 = 28.74 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;
```

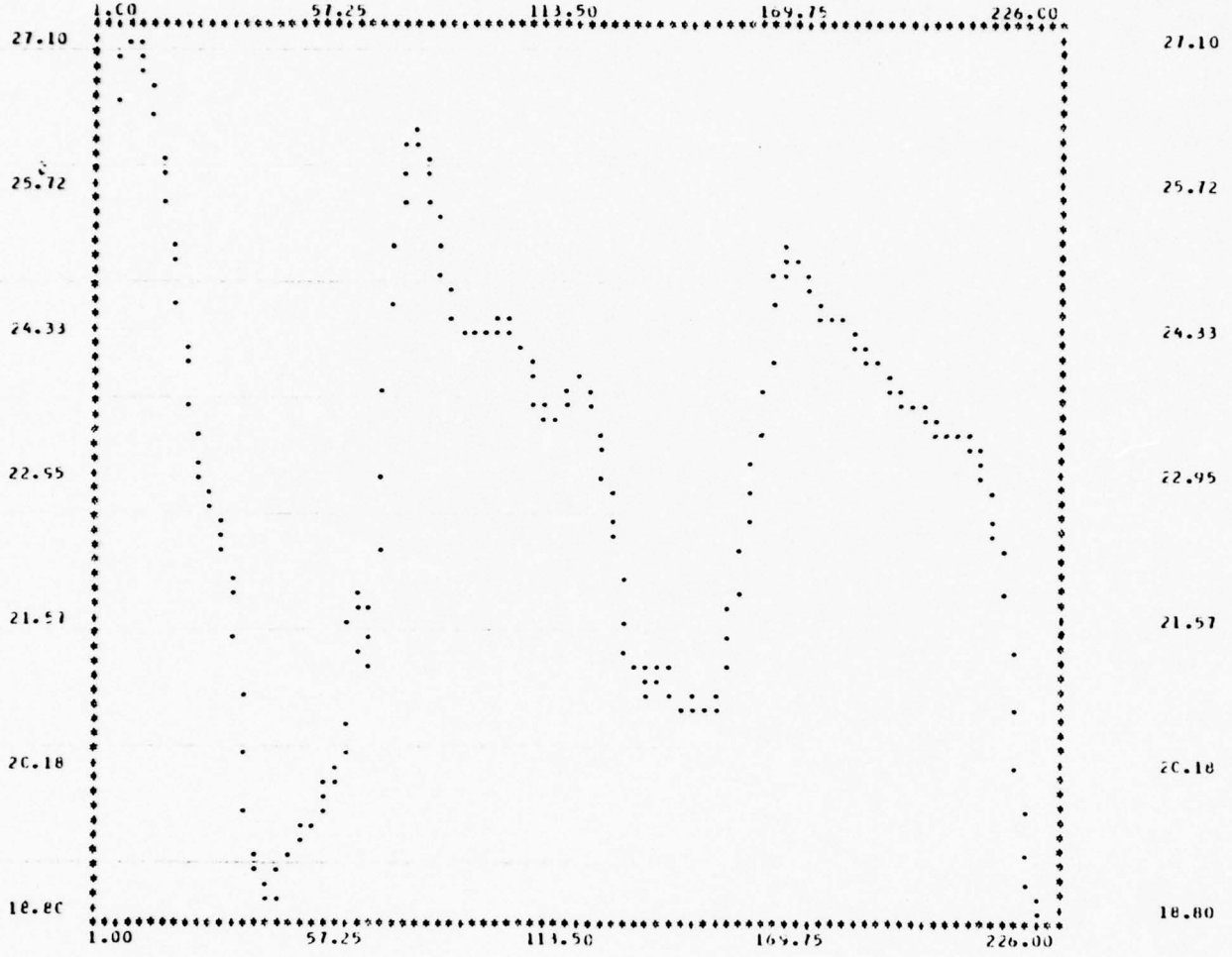

Figure 3. Plots of series C.

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	-0.053	-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= 22.5735 VARIANCE = 4.22273

Table I. Auto and partial autocorrelations of series C.

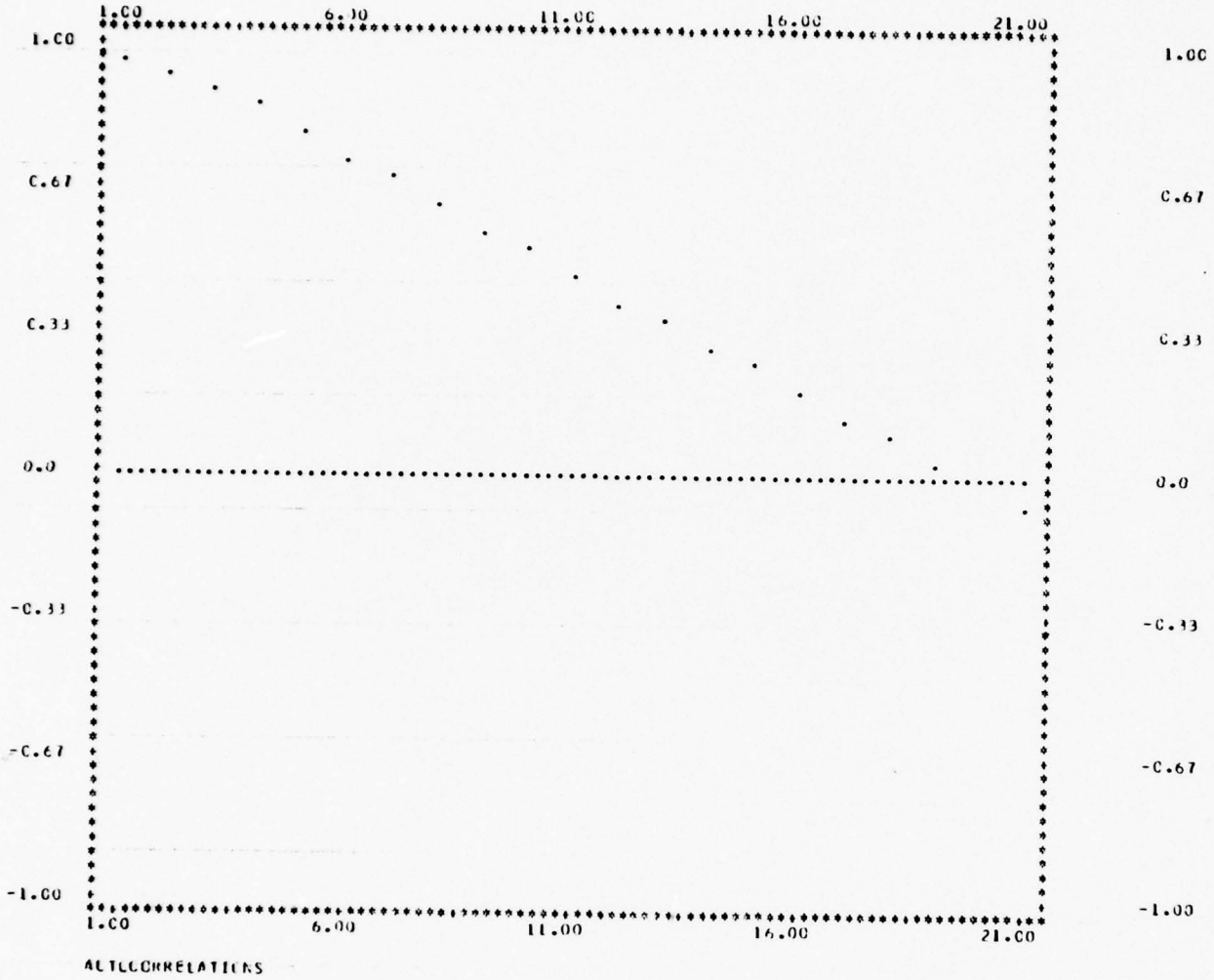

Figure 4. Plots of autocorrelations of series C.

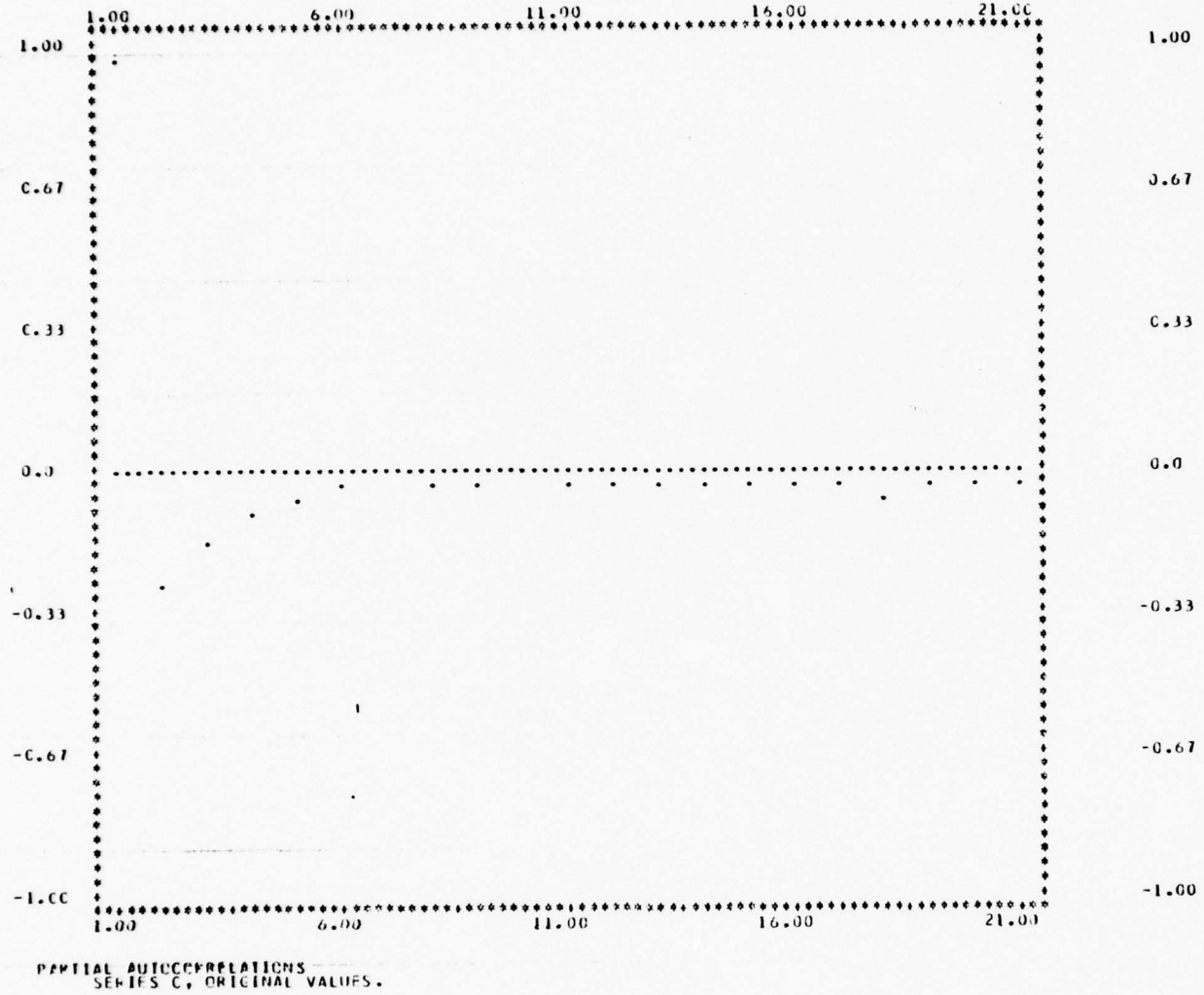

Figure 5. Plots of partial autocorrelations of series C.

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C.4000C05E CC	C.9995C8F-01	0.0	0.0	0.C	
-0.199991E 00	-0.1000006E 00	-0.999908E-01	-0.3000003E CC	-0.3999994E 00	
-C.2CCC12E CC	-C.1995571E 00	-0.3999994E 00	-0.1999997E 00	-0.4000C05E 00	
-0.3999994E CC	-0.1995571E 00	-0.3000003E CC	-C.3000003E CC	-0.3000C03E 00	
-0.1999997E 00	-0.1000006E 00	-0.999908E-01	-0.1000006E CC	-0.1999997E 00	
-0.1999997C CC	-0.1995571E CC	-0.2000012E 00	-0.3999994E CC	-0.5000C00E 00	
-0.6CCCC6E CC	-C.3999991E 00	-0.3000003E 00	-0.1000006E 00	-0.5995C8F-01	
-0.1CCCC6E 00	-C.9995C8E-01	-0.1000006E 00	0.0	0.3000C03E 00	
0.5995C8F-01	C.0	0.1000006E CC	C.1000006E 00	0.5995C8E-01	
0.0	0.0	0.0	0.0	0.1CCCC06E 00	
0.1999991E CC	C.1000006E 00	0.999908E-01	0.1000006E 00	0.5995C8E-01	
0.3000003E CC	C.1000000E 01	0.3000003E CC	-0.1999997E CC	-0.4000C04E 00	
-0.5995C8E-01	0.1999997E 00	0.3000003E 00	0.5000000E 00	0.8000C02E 00	
C.7995808E CC	0.8000C03E 00	0.5000000E 00	C.5000000E 00	0.1999997E 00	
0.3C00C03E CC	0.1999997E 00	0.0	-0.9999908E-01	-0.1999997E 00	
-0.2C00I2E CC	-C.1995571E 00	-0.1999997E 00	-0.1999997E 00	-0.3000C03E 00	
-0.1999997E CC	-0.1995571E 00	-0.1000006E CC	C.0	0.C	
0.0	0.0	-0.1000006E 00	0.1000006E 00	0.C	
0.0	C.C	0.0	0.1000006E 00	0.0	
-0.1000006E CC	-C.1000006E 00	-0.5999908E-01	0.0	-0.1999997E 00	
-0.1000006E 00	-0.1995571E 00	-0.1000006E 00	-0.9999908E-01	0.C	
0.0	0.0	0.0	0.1999997E 00	0.5995C8E-01	
0.0	0.1000006E CC	0.0	-0.1000006E 00	-0.5995C8E-01	
-0.1CCCC6E CC	-C.1995571E 00	-0.1999997E 00	-0.1999997E CC	-0.2000I2E CC	
-0.1999997E CC	-0.1995571E 00	-0.3999994E CC	-C.4000002E CC	-0.3000C03E 00	
-0.5999C8E-01	0.0	-0.1000006E 00	-0.9999908E-01	-0.1000C06E 00	
0.1CCCC6F 00	0.0	0.5999908E-01	0.1000006E 00	-0.1000C06E 00	
-0.1999997E CC	-C.1000006E 00	0.0	0.0	0.C	
0.1000C6E 00	-0.1000006E 00	0.0	-0.9999908E-01	0.C	
0.5995C8E-01	C.1000006E 00	0.3000003E 00	0.1999997E 00	0.3000C03E 00	
0.5995C8E-01	0.1000006E 00	0.3000003E 00	0.3000003E 00	0.2995808E 00	
0.3C00C3E CC	C.3000C03E 00	0.3999994E 00	0.3000003E CC	0.5000C00E 00	
0.3C00C03E CC	0.0	0.1999997E CC	-0.9999908E-01	0.C	
0.0	0.0	-0.1000006E 00	-0.1000006E 00	-0.5995C8E-01	
-C.1000C6EF CC	-0.5995C8E-01	0.0	0.0	0.0	
0.0	0.0	0.0	-0.1000006E 00	0.0	
-0.1999991E CC	0.0	-0.1000006E 00	0.0	-0.5995C8E-01	
0.0	0.0	-0.1000006E CC	-C.1000006E CC	0.0	
-0.5995C8E-01	0.0	-0.1000006E 00	0.1000006E CC	-0.1000C06E 00	
0.0	0.0	-0.9999908E-01	0.0	-0.1000C06E 00	
-0.1CCCC6E 00	0.0	0.0	C.1000006E 00	0.C	
-0.1000006E 00	-0.9999908E-01	0.9999908E-01	0.0	-0.5995C8E-01	
-0.1000006E 00	-0.1995571E 00	-0.1000006E 00	-0.1999997E 00	-0.1999997E 00	
-0.1999997E CC	-C.4CCCC5E CC	-0.5000006E 00	-0.5000000E 00	-0.5995551E 00	
-0.5CCCCCE CC	-0.4000C05E 00	-0.1999997E 00	-0.9999908E-01	-0.2000I2E 00	

Table II. Values of 1st differenced series C.

AUTOCORRELATIONS

0.865	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

0.865	0.010	-0.007	0.051	0.027	-0.019	-0.013	-0.080	0.020	0.111
-0.137	0.094	-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.

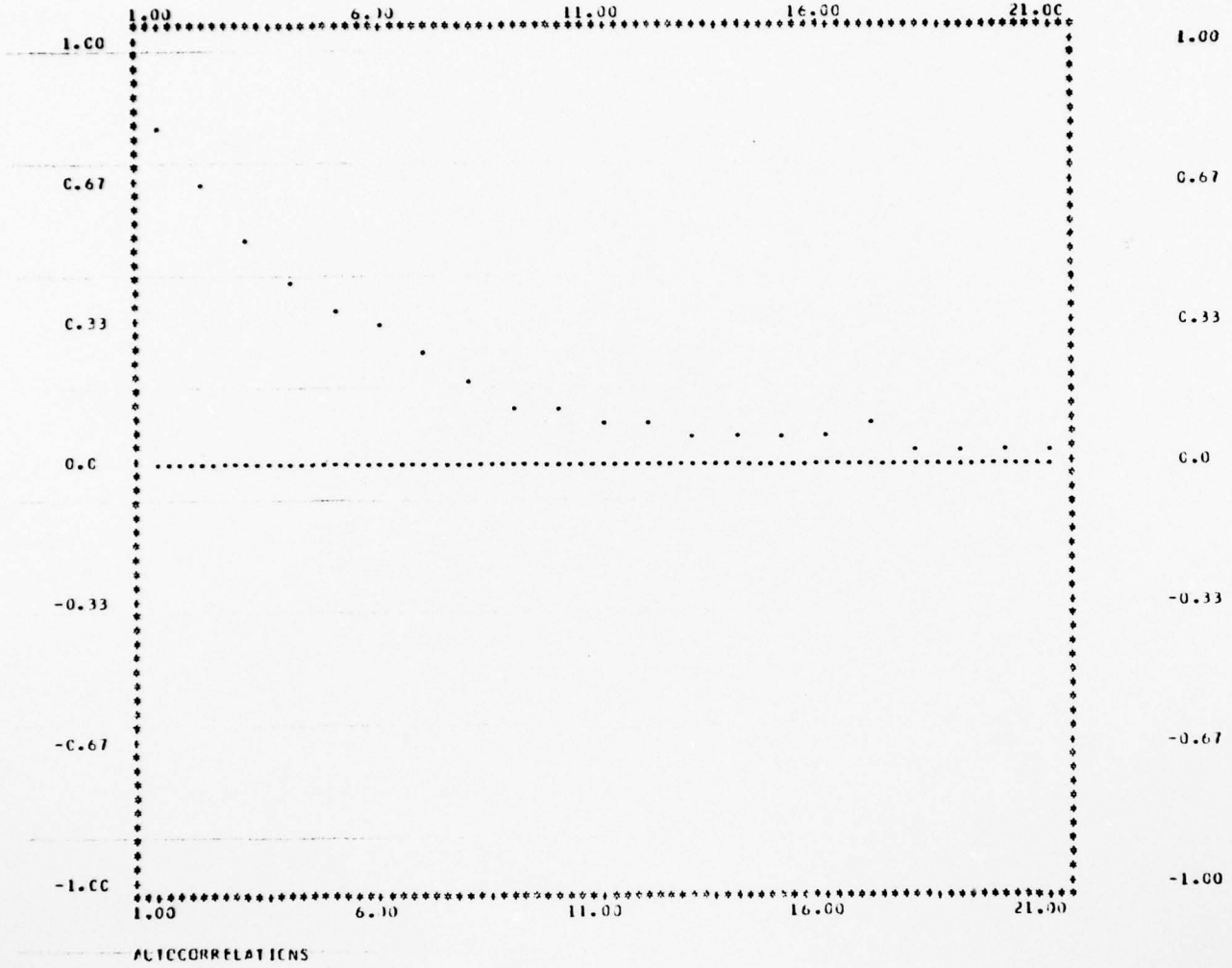


Figure 6. Plots of autocorrelations of 1st differenced series C.

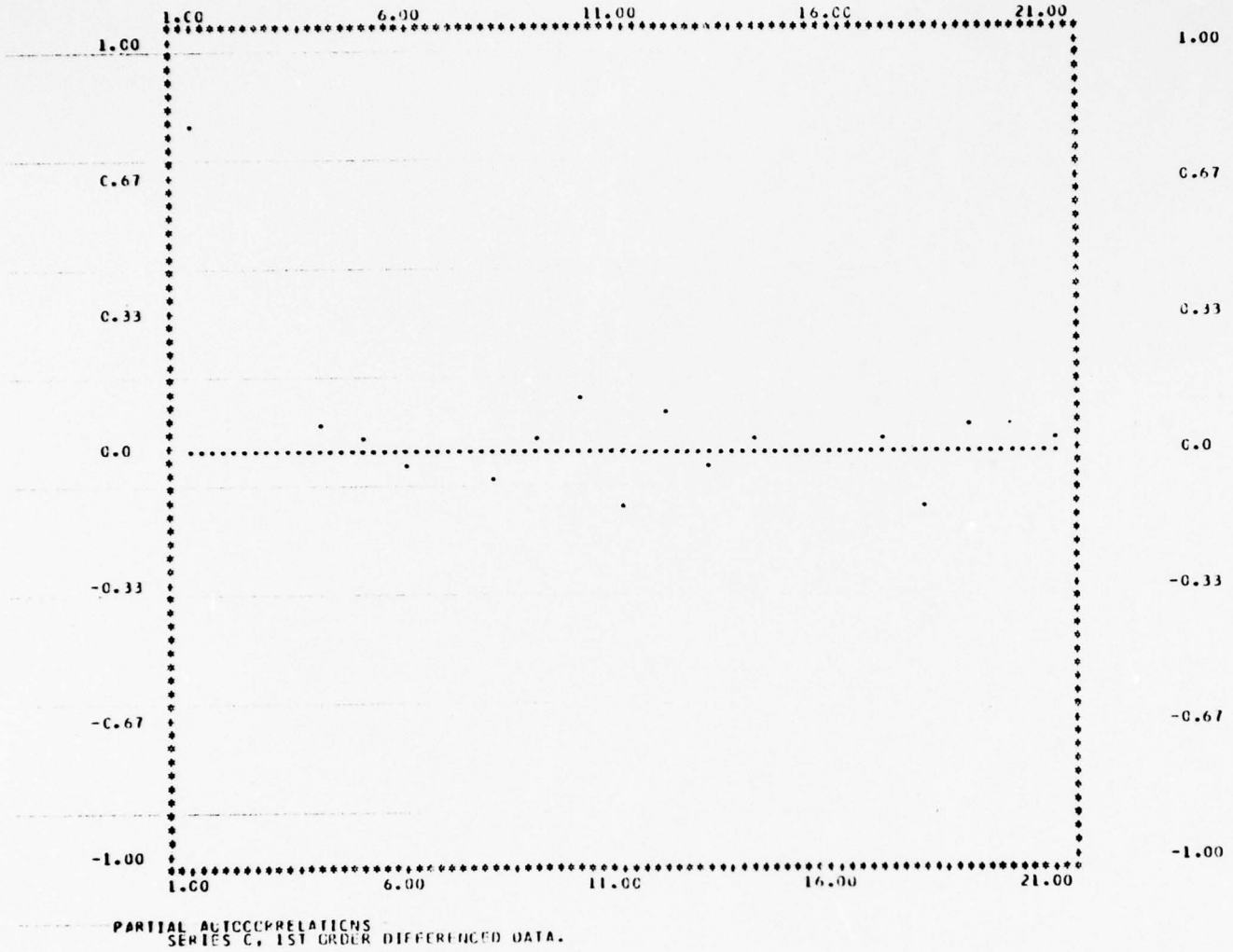


Figure 7. Plots of partial autocorrelations of 1st differenced series C.

224

-0.3C0018E CC	-0.999508E-01	0.0	0.0	-0.1999997E 00
0.999908E-01	0.152588E-04	-0.200012E 00	-0.999908E-01	0.1999982E 00
0.152588E-04	-0.1999997E 00	0.1999997E 00	-0.200012E 00	0.152588E-04
0.1999997E 00	-0.100006E 00	0.0	0.0	0.100006E 00
0.5999C8E-01	0.152588E-04	-0.152588E-04	-0.999908E-01	0.0
0.0	-0.152588E-04	-0.1999982E 00	-0.100006E 00	-0.100006E 00
0.152588E-04	0.2999588E 00	0.1999997E 00	0.152588E-04	-0.152588E-04
0.152588E-04	-0.152588E-04	0.100006E 00	0.300003E 00	-0.200012E 00
-0.5999C8E-01	0.100006E 00	0.0	-0.152588E-04	-0.5999C8E-01
0.0	0.0	0.0	0.100006E 00	0.5999C8E-01
-0.599908E-01	-0.152588E-04	0.152588E-04	-0.152588E-04	0.200012E 00
0.6999997E 00	-0.6999997E 00	-0.500003E 00	-0.200012E 00	0.300018E 00
0.2999588E 00	0.100006E 00	0.1999997E 00	0.300003E 00	-0.152588E-04
0.152588E-04	-0.300018E 00	0.0	-0.300003E 00	0.100006E 00
-0.100006E 00	-0.1999997E 00	-0.9999908E-01	-0.100006E 00	-0.152588E-04
0.152588E-04	0.0	0.0	-0.100006E 00	0.100006E 00
0.0	0.5999C8E-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	-0.1999997E 00	0.5999C8E-01
-0.5999C8E-01	0.999908E-01	0.152588E-04	0.999908E-01	0.0
0.0	0.0	0.1999997E 00	-0.100006E 00	-0.999908E-01
0.100006E 00	-0.100006E 00	-0.152588E-04	0.152588E-04	0.200012E 00
-0.100006E 00	0.0	0.152588E-04	-0.200012E 00	-0.999908E-01
0.999908E-01	0.100006E 00	0.0	0.0	0.100006E 00
0.152588E-04	-0.152588E-04	0.0	0.0	0.999908E-01
-0.300003E 00	0.1999997E 00	-0.999908E-01	0.1999997E 00	-0.1999997E 00
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	-0.1999997E 00
0.1999997E 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	0.1999982E 00	-0.999908E-01	-0.999908E-01	-0.152588E-04
-0.5999C8E-01	0.5999C8E-01	-0.999908E-01	0.0	0.0
-0.200012E 00	-0.999908E-01	0.0	-0.999908E-01	0.5999C8E-01
0.5999C8E-01	0.200012E 00	0.100006E 00	-0.100021E 00	

Values of 2nd differenced series C.

AUTOCORRELATIONS

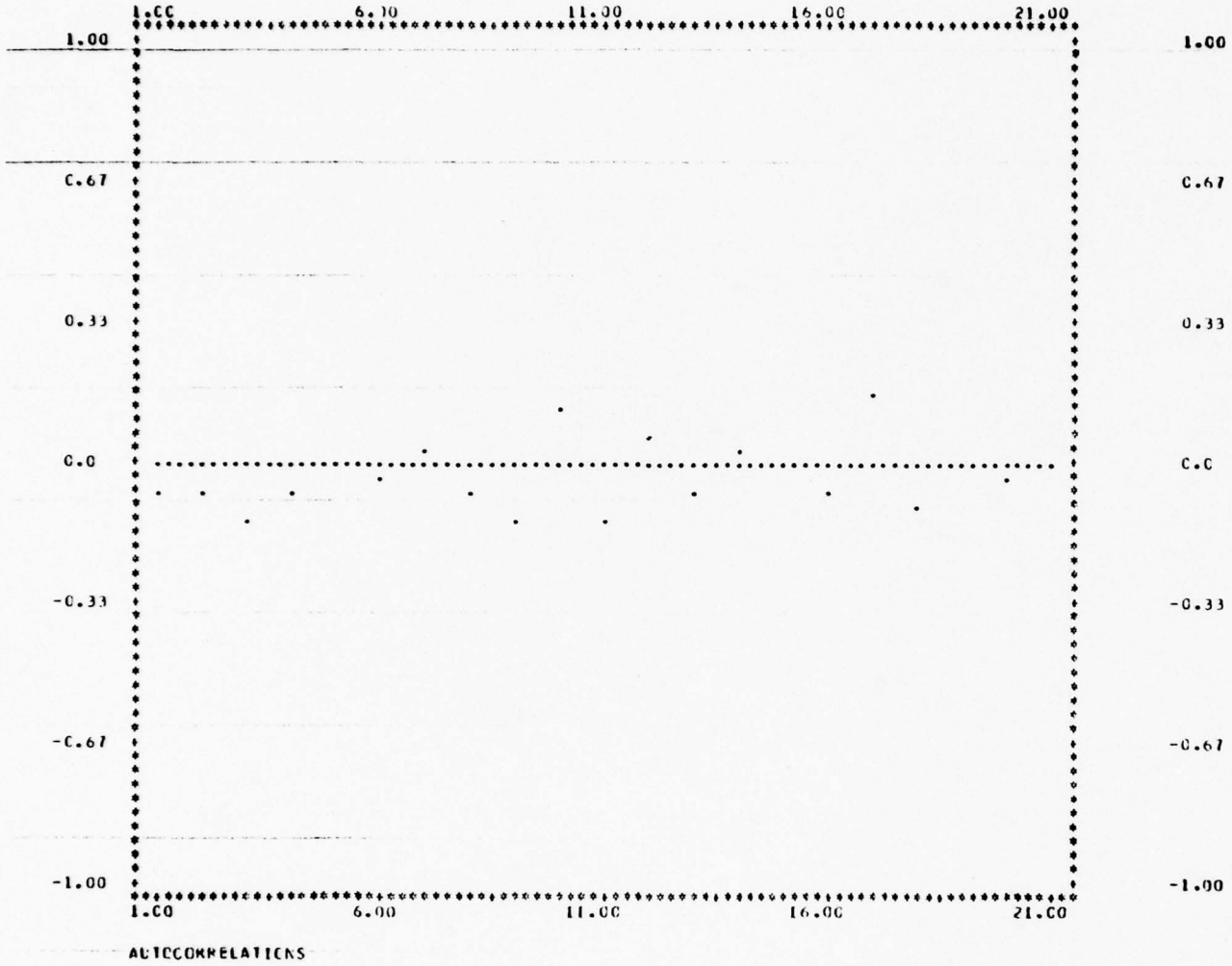
-0.079	-0.065	-0.122	-0.063	0.013	-0.018	0.049	-0.052	-0.124	0.122
-0.122	0.072	-0.077	0.029	-0.011	-0.058	0.171	-0.101	-0.013	-0.020

PARTIAL AUTOCORRELATIONS

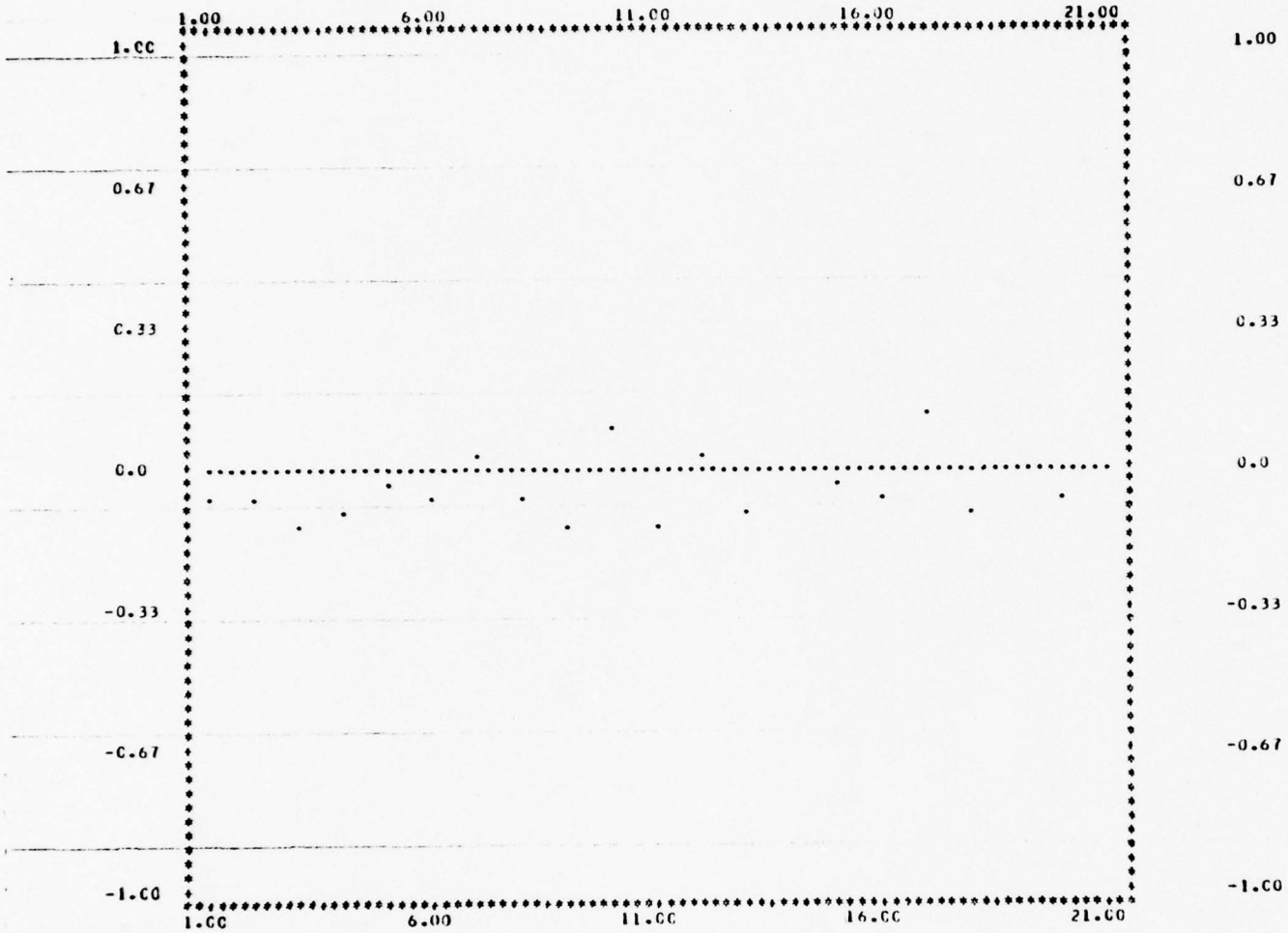
-0.079	-0.072	-0.135	-0.094	-0.022	-0.051	0.022	-0.060	-0.145	0.094
-0.143	0.023	-0.089	-0.005	-0.039	-0.074	0.130	-0.105	-0.014	-0.053

MEAN=-.267866E-02 VARIANCE = 0.1981435-01

Auto and partial autocorrelations of 2nd differenced series C.



Plots of autocorrelations of 2nd differenced series C.



PARTIAL AUTOCORRELATIONS
SERIES C, 2ND ORDER DIFFERENCED DATA.

225

0.0	-0.225262E 00	-0.813040E-01	0.0	0.0
-0.199997E 00	0.626142E-01	-0.186745E-01	-0.218699E 00	-0.156C57E 00
0.12522EE C0	-0.313642E-01	-0.237374E CC	0.125244E CC	-0.237385E CC
-0.7474CEE-01	0.125244E CC	-0.137383E 00	-0.560663E-01	-0.560EE3E-01
0.439358E-01	0.626142E-01	-0.186745E-01	-0.187021E-01	-0.118681E 00
-0.373766E-01	-0.373766F-01	-0.373919E-01	-0.237361E CC	-0.174759E CC
-0.193445E C0	-0.112117E 00	0.187858E 00	0.143931E C0	-0.186745E-01
-0.187C21E-01	-0.186745E-01	-0.187021F-01	0.813164E-01	0.300CC3E 0C
-0.143946E C0	-0.813040F-01	0.100006E 00	0.186897E-01	0.186745E-01
-0.813C4CE-01	0.0	0.C	C.0	0.10CCC6E 00
0.118681E 00	-0.626142E-01	0.186745E-01	0.187021E-01	0.186745E-01
C.21E655E CC	0.756C63E C0	-0.513111E 00	-0.443934F C0	-0.237389E 0C
0.225262E C0	0.281301E CC	0.137383E CC	C.256063E CC	0.393444E 00
0.149454E C0	0.149522E C0	-0.150494E 00	0.334429E-01	-0.206556E CC
0.137383E CC	-0.439395EE-01	-0.1626C0E CC	-0.999908E-01	-0.118693E 00
-0.373919E-01	-0.373642E-01	-0.373766E-01	-0.373766E-01	-0.373383E 0C
C.439395E-01	-0.373766E-01	0.626142E-01	C.813164E-01	0.0
0.0	0.0	-0.100006E CC	C.181322E CC	-0.813164E-01
0.0	0.0	0.0	0.100006E C0	-0.813164F-01
-0.100CC6E C0	-0.186E57E-01	-0.186745E-01	0.813040E-01	-0.199997E 0C
0.626142E-01	-0.118681F C0	0.626142E-01	-0.186745E-01	0.813C40E-01
0.0	0.0	0.0	0.199997E CC	-0.626255E-01
-0.813040E-01	0.10CCC6E C0	-0.813164E-01	-0.100006E C0	-0.186745E-01
-0.187C21F-01	-0.118681E 00	-0.373765E-01	-0.373766E-01	-0.373515E-01
-0.373642E-01	-0.373766E-01	-0.237374F C0	-0.747684E-01	0.252EC0E-01
0.143946E C0	0.813C4CE-01	-0.100006E 00	-0.186745E-01	-0.187C21E-01
0.181322E CC	-0.813164F-01	0.999908E-01	0.187021F-01	-0.181322E C0
-0.118681F CC	0.626142E-01	0.813164E-01	0.0	0.C
0.1C0006E 00	-0.181322E 00	0.813164E-01	-0.999908E-01	0.813C4CE-01
C.5555C8E-01	0.187C21E-01	0.218687E 00	-0.439398E-01	0.137383E 0C
-0.143946F C0	0.187C21E-01	0.218687E CC	C.560C63E-01	0.560511F-01
0.560787E-01	0.560CC3E-01	0.156057E 00	-0.252376E-01	0.256C63E CC
-0.106554E C0	-0.243537F CC	0.199997E 00	-0.262611E CC	0.813C40F-01
0.0	0.0	-0.100006E C0	-0.186897E-01	-0.186745F-01
-0.187C21E-01	-0.186745F-01	0.813040E-01	0.0	0.0
0.0	0.0	0.C	-0.100006E C0	0.813164E-01
-0.199997E 00	0.162620E 00	-0.100006E 00	0.813164E-01	-0.5555C8E-01
0.813040F-01	0.0	-0.100006E 00	-0.186897E-01	0.813164F-01
-0.5555C8E-01	0.813C4CE-01	-0.100006E 00	0.181322E CC	-0.181322E 0C
0.813164E-01	0.0	-0.999908E-01	0.813040F-01	-0.10CCC6E 0C
-0.166E57E-01	0.813164E-01	0.0	C.100006E C0	-0.813164E-01
-0.100006E 00	-0.186745E-01	0.181295E 0C	-0.813040F-01	-0.5555C8F-01
-0.187C21E-01	-0.118681F C0	0.626142E-01	-0.118681F 00	-0.373766E-01
-0.373766F-01	-0.237385E CC	-0.174747E 0C	-0.934429E-01	-0.193434F C0
-0.121390E-01	0.654790E-02	0.125256E 00	0.626255E-01	-0.118IC8E 0C

RESIDUAL VALUES.

Residuals of (1.1.0) model of series C.

AUTOCORRELATIONS

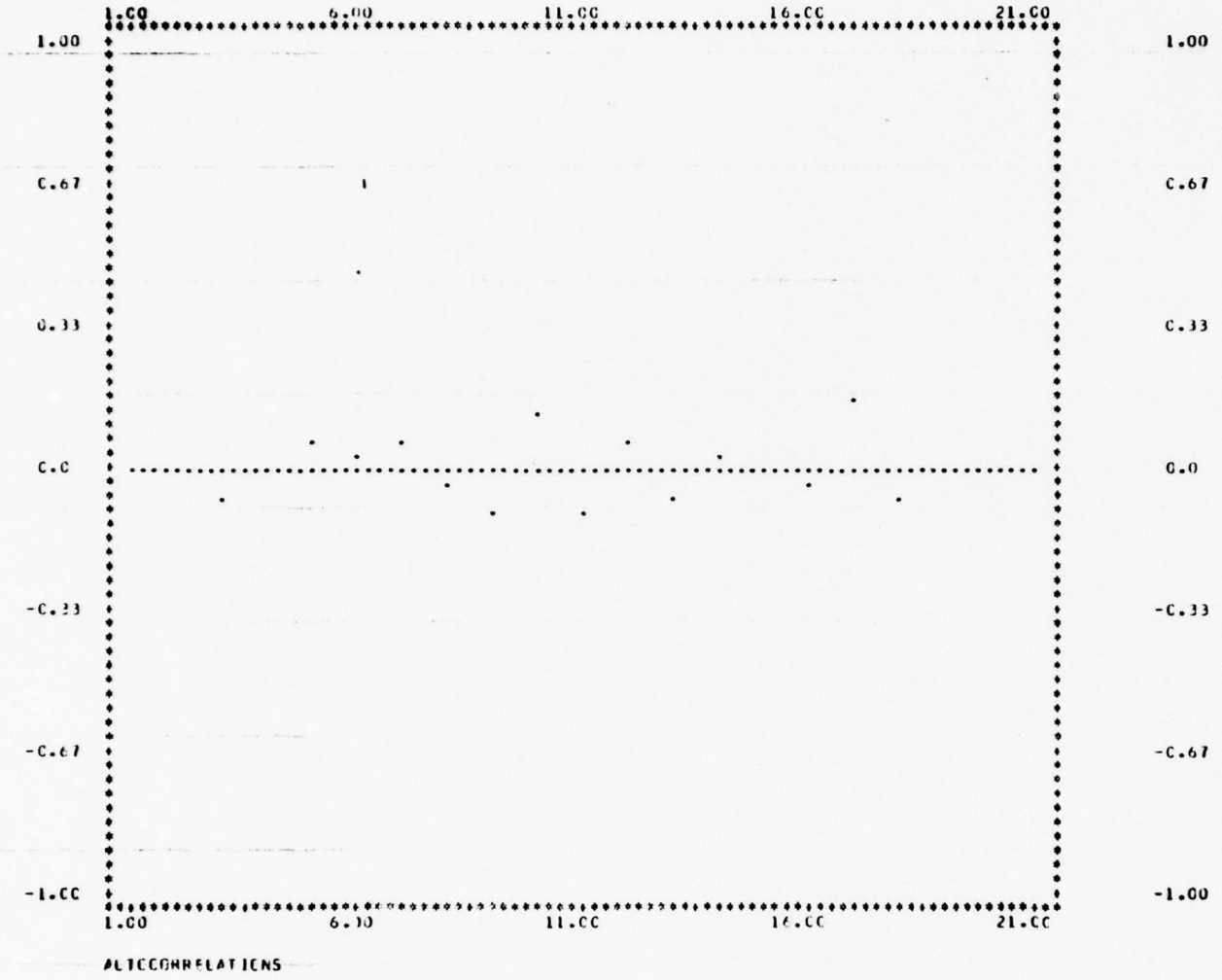
0.010	0.009	-0.053	-0.009	0.058	0.021	0.016	-0.020	-0.089	0.130
-0.095	0.083	-0.056	0.042	0.006	-0.041	0.169	-0.080	-0.001	-0.010

PARTIAL AUTOCORRELATIONS

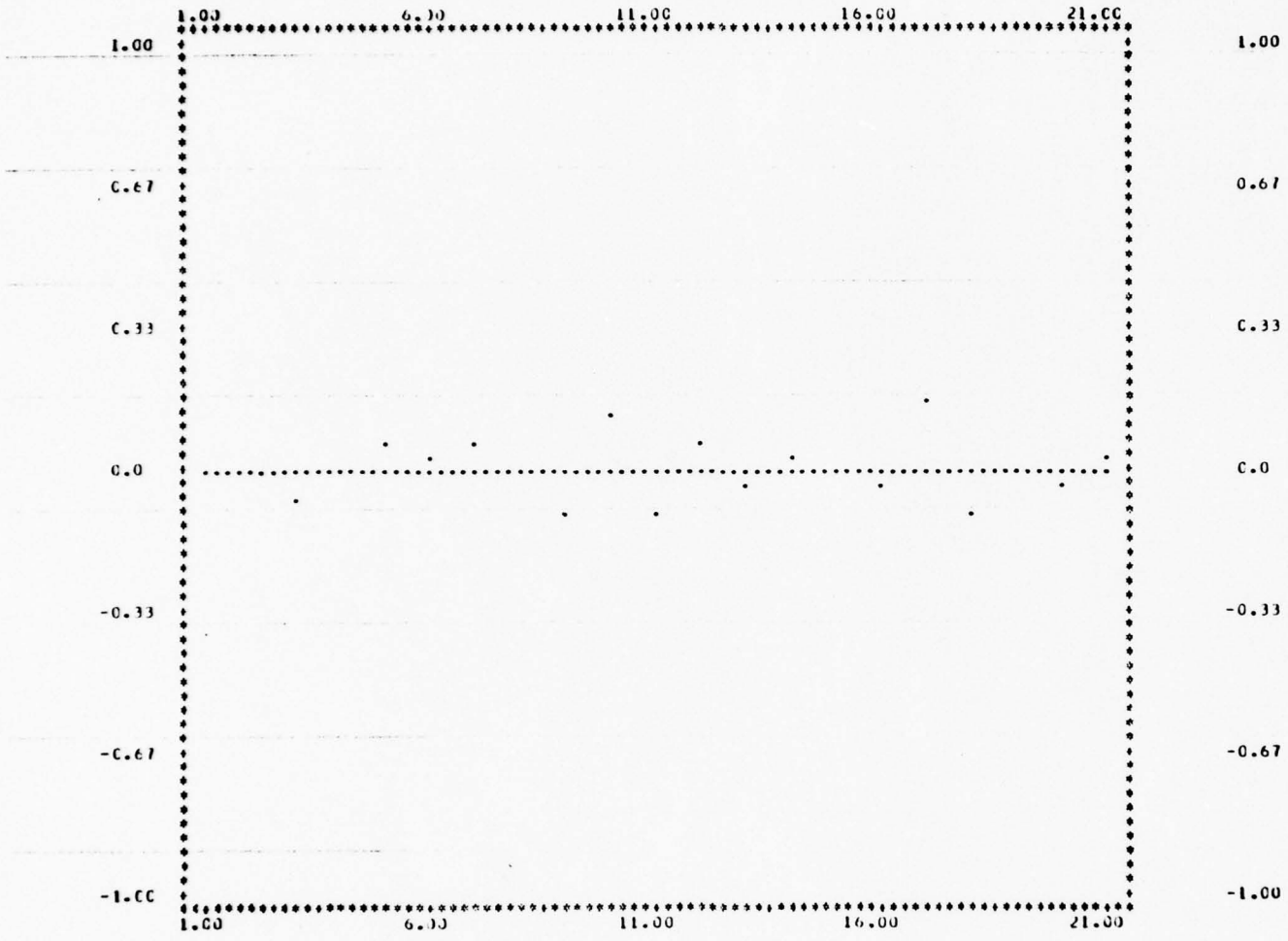
0.010	0.009	-0.054	-0.008	0.060	0.018	0.074	-0.016	-0.088	0.140
-0.104	0.069	-0.048	0.041	0.003	-0.030	0.157	-0.087	0.013	-0.025

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

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).

224

0.0	0.0	0.0	0.0	-0.155557E 00
0.723531E-01	-0.199755E-01	-0.192817E 00	-0.128713E 00	0.157135E 00
0.500111E-02	-0.179883E 00	0.175927E 00	-0.178950E 00	-0.461277E-02
0.173502E 00	-0.766292E-01	0.119634E-01	-0.830658E-02	0.130413E 00
0.112783E 00	0.286519E-01	0.186030E-01	-0.936962E-01	-0.105201E-01
-0.136327E-01	-0.326776E-02	-0.202205E 00	-0.126374E 00	-0.144026E 00
-0.365724E-01	0.279215E 00	0.233414E 00	0.681791E-01	0.357417E-01
0.143672E-01	0.713542E-02	0.102859E 00	0.315145E 00	-0.143094E 00
-0.788061E-01	0.705181E-01	-0.477377E-03	0.908115E-02	-0.588655E-01
-0.124730E-01	-0.145646E-01	-0.363380E-02	0.776110E-01	0.112076E 00
-0.116879E-01	0.476557E-02	-0.864336E-02	-0.590315E-03	0.198807E 00
0.227354E 00	-0.573635E 00	-0.484733E 00	-0.341553E 00	0.165815E 00
0.281828E 00	0.163624E 00	0.259237E 00	0.357093E 00	0.830242E-01
0.516553E-01	-0.281211E 00	-0.313357E-01	-0.346882E 00	0.488268E-01
-0.137503E 00	-0.412661E 00	-0.147257E 00	-0.147995E 00	-0.395656E-01
-0.246526E-01	-0.855577E-02	-0.439214E-02	-0.191726E 00	0.853777E-01
-0.142273E-02	0.110655E 00	0.113145E 00	0.303243E-01	0.191556E-01
0.658836E-02	-0.966060E-01	0.187518E 00	-0.966495E-01	0.123575E-01
-0.954837E-02	0.291791E-03	0.588054E-01	-0.863141E-01	-0.590522E-01
-0.249118E-01	-0.163062E-01	0.344997E-01	-0.185057E 00	0.861465E-01
-0.112658E 00	0.956190E-01	-0.141305E-02	0.112223E 00	0.153245E-01
0.167032E-01	0.422553E-02	0.202762E 00	-0.714274E-01	-0.835087E-01
0.751826E-01	-0.399173E-01	-0.103522E 00	-0.272767E-01	-0.172253E-01
-0.105918E 00	-0.168775E-01	-0.160984E-01	-0.443344E-02	-0.268568E-02
-0.547857E-03	-0.203477E 00	-0.278426E-01	0.701027E-01	0.206181E 00
0.137508E 00	-0.542057E-01	0.104051E-01	-0.562293E-02	0.200588E 00
-0.730175E-01	0.115571E 00	0.655131E-02	-0.184034E 00	-0.124571E 00
0.585576E-01	0.915463E-01	0.203562E-01	0.147636E-01	0.104652E 00
-0.182624E 00	0.882375E-01	-0.111663E 00	0.960281E-01	0.587403E-01
0.261420E-01	0.214444E 00	-0.666983E-01	0.118920E 00	-0.152247E 00
-0.110556E-01	0.133477E 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	0.134E37E 00	-0.320236E 00	0.732618E-01	-0.214565E-01
0.516921E-02	-0.103985E 00	-0.136150E-01	-0.153031E-01	-0.386553E-02
-0.251254E-02	0.991368E-01	0.133732E-01	0.147322E-01	0.377462E-02
0.243033E-02	0.827182E-03	-0.995751E-01	0.863532E-01	-0.201C05E 00
0.183443E 00	-0.1CC78CE 00	0.109921E 00	-0.978990E-01	0.1CC748E 00
0.115868E-02	-0.467463E-01	-0.118317E-01	0.870968E-01	-0.894526E-01
0.585436E-01	-0.975642E-01	0.109334E 00	-0.185198E 00	0.100221E 00
-0.102066E-01	-0.883628E-01	0.864534E-01	-0.995434E-01	-0.251574E-02
0.667203E-01	0.116505E-01	0.112888E 00	-0.828910E-01	-0.567E85E-01
-0.241333E-01	0.184CE7E 00	-0.776910E-01	-0.868040E-01	-0.221C82E-01
-0.114328E 00	0.813184E-01	-0.103612E 00	-0.374941E-02	-0.135E45E-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

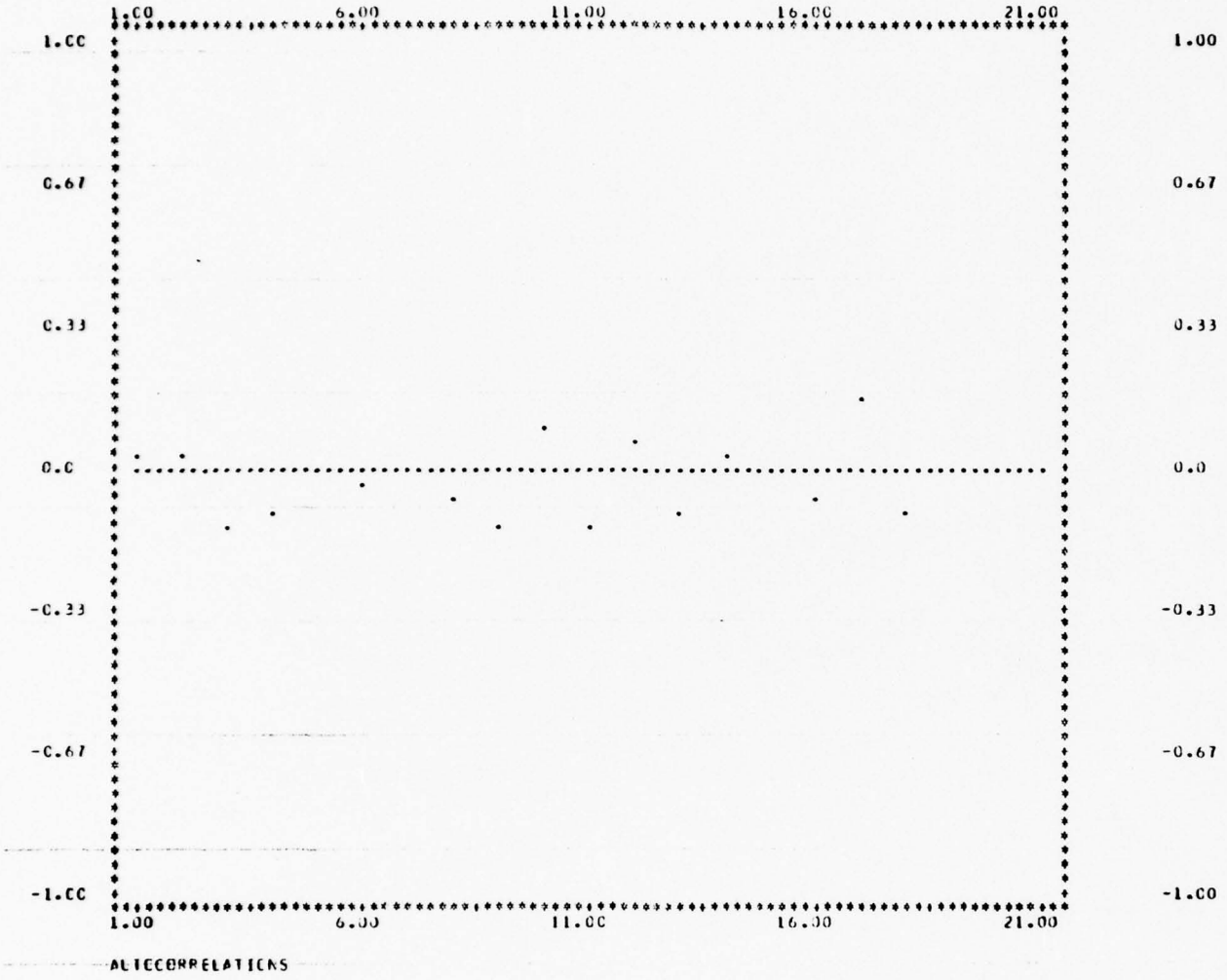
0.020	0.034	-0.134	-0.054	-0.012	-0.043	0.004	-0.063	-0.125	0.088
-0.142	0.069	-0.098	0.025	0.004	-0.055	0.157	-0.089	0.006	-0.006

PARTIAL AUTOCORRELATIONS

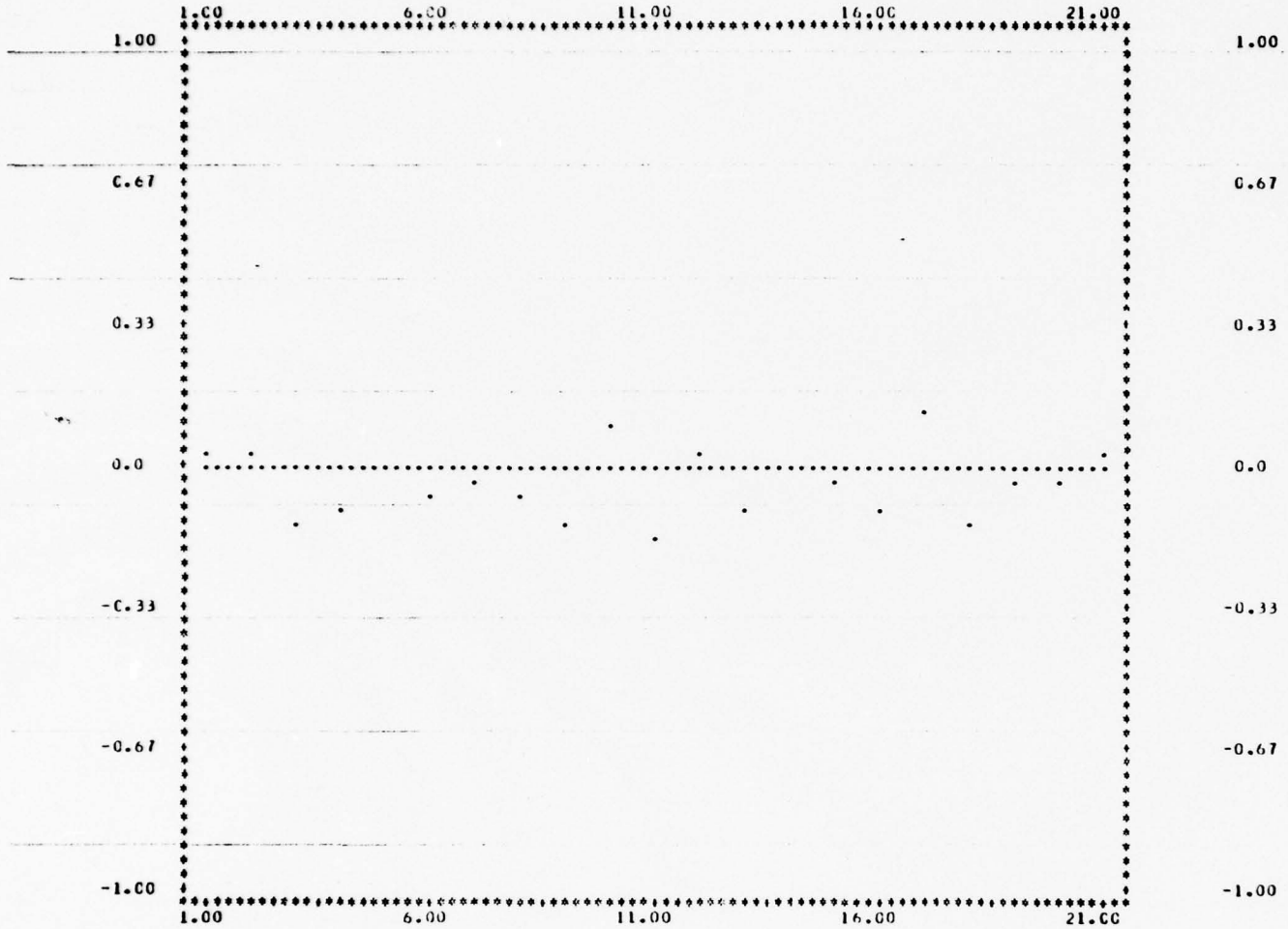
0.020	0.034	-0.135	-0.050	0.001	-0.055	-0.019	-0.071	-0.143	0.081
-0.166	0.017	-0.104	-0.012	-0.025	-0.090	0.123	-0.123	-0.021	-0.025

MEAN=-.124575E-02 VARIANCE = 0.182499E-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).

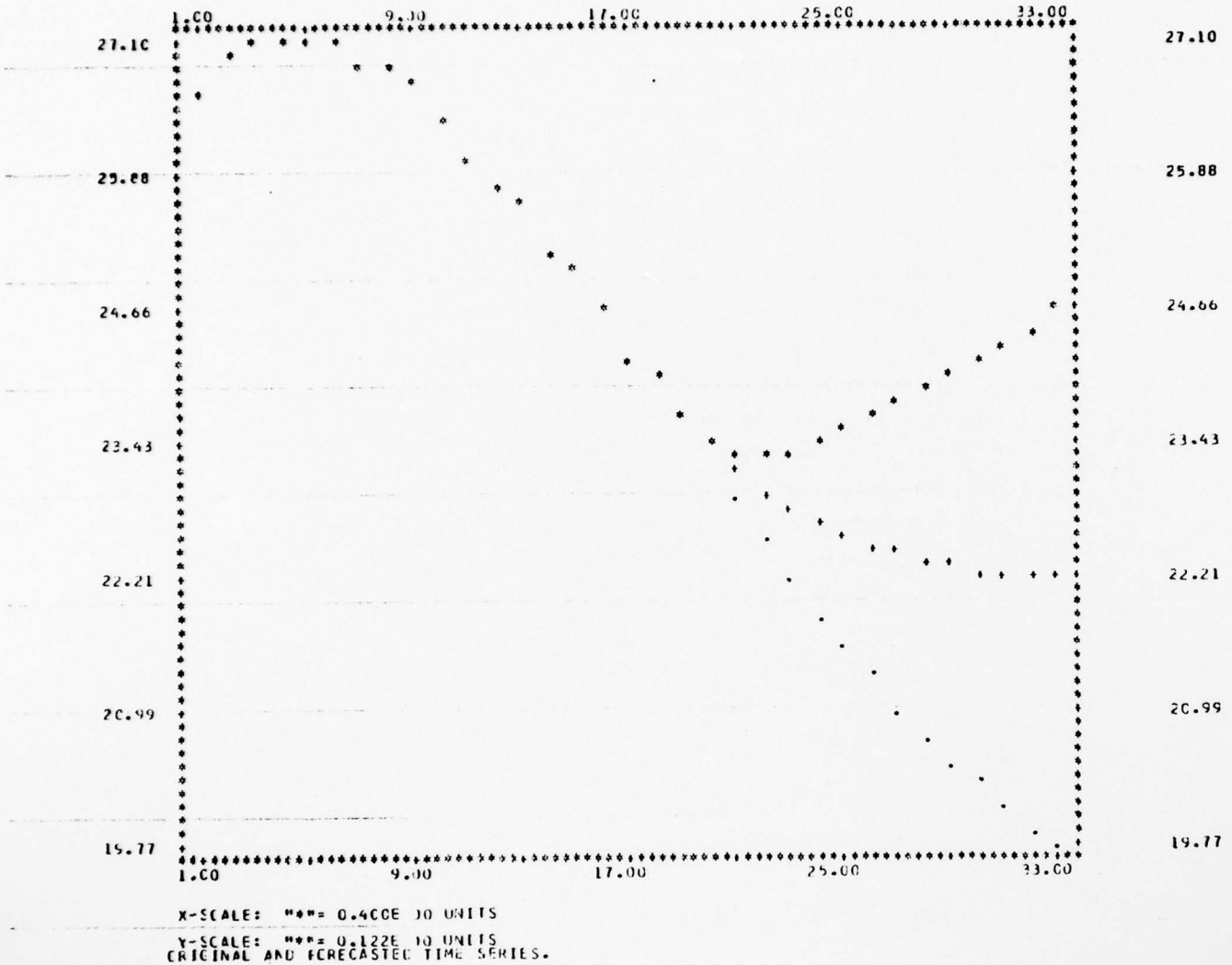


Figure 8. Plots of the forecasted values adjoined to the original series C with 80% confidence limits about the forecasts.

65

0.1864C3E C2	0.1851208E C2	0.1863116 02	0.1862688E C2	0.1878768E C2
0.1896398E C2	0.1907418E C2	0.1920508E 02	0.1926118E 02	0.1963338E 02
0.1982148E C2	C.2CC422BE C2	C.2010668E 02	0.2034768E C2	0.2036958E C2
0.2021658E C2	0.2013328E 02	C.2011748E C2	0.2029798E C2	0.2024188E 02
C.2C0E78E C2	C.198C58CE C2	0.1948758E C2	0.1963418E C2	0.1881368E 02
0.1846C3E C2	0.1756228E 02	C.1729578E 02	0.1659388E C2	0.1595708E 02
0.1546118E C2	C.1515698E 02	C.1506738E 02	0.1495298E C2	0.1496098E 02
0.1495658E C2	0.151CCC8E C2	0.1554888E C2	C.1584658E C2	0.160E778E 02
0.1635848E C2	0.1656268E 02	0.1663198E 02	0.1670408E C2	0.1623EEE C2
0.1686228E C2	C.1741728E C2	0.1741578C 02	0.1750338E 02	0.1772388E 02
0.1787358E 02	0.1811088E 02	0.1827718E 02	0.1848358E C2	0.1846568E 02
0.1E3454E C2	0.1822718E C2	0.1809298E 02	C.1805608E C2	0.1781758E 02
0.1168718E C2	0.175C218E C2	0.1731918E C2	C.1689728E C2	0.1672718E 02

65

0.1E71C5E C2	C.1835068E 02	0.1739748E 02	0.1739638E 02	0.1651108E 02
0.1646558E C2	0.1597C1E 02	0.1575188E C2	0.1574298E C2	0.1577698E 02
0.1574158E C2	0.15E33CE 02	0.1595488E 02	0.1552368E C2	0.1576328E C2
0.1554478E C2	0.1545558E 02	0.1574968E 02	0.1613928E 02	0.1649008E 02
0.1685448E C2	C.17C2668E 02	0.1730778E 02	0.1743398E C2	0.1735648E 02
0.1745438E C2	C.1744C58E C2	0.1733828E 02	C.1707608E 02	0.1676668E 02
0.1646568E C2	0.1615108E C2	0.1618678E 02	0.1619308E 02	0.1606C48E 02
0.1590288E 02	0.1573628E 02	0.1555578E 02	0.1534808E C2	0.1525918E 02
C.15CC358E C2	0.1454898E 02	0.1507978E 02	0.1493978E 02	0.1476328E 02
0.1450208E C2	0.142E748E 02	C.1400258E C2	0.1384328E C2	0.1374828E 02
0.135778E C2	0.1327C8E C2	0.1314928E 02	0.1290388E 02	0.1281C28E C2
C.1289C2E C2	C.127C19E C2	0.1269118E 02	0.1254468E 02	0.1242978E 02
0.1217CEE C2	0.1194758E 02	0.1230518E 02	0.1205818E C2	0.1212C18E 02

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

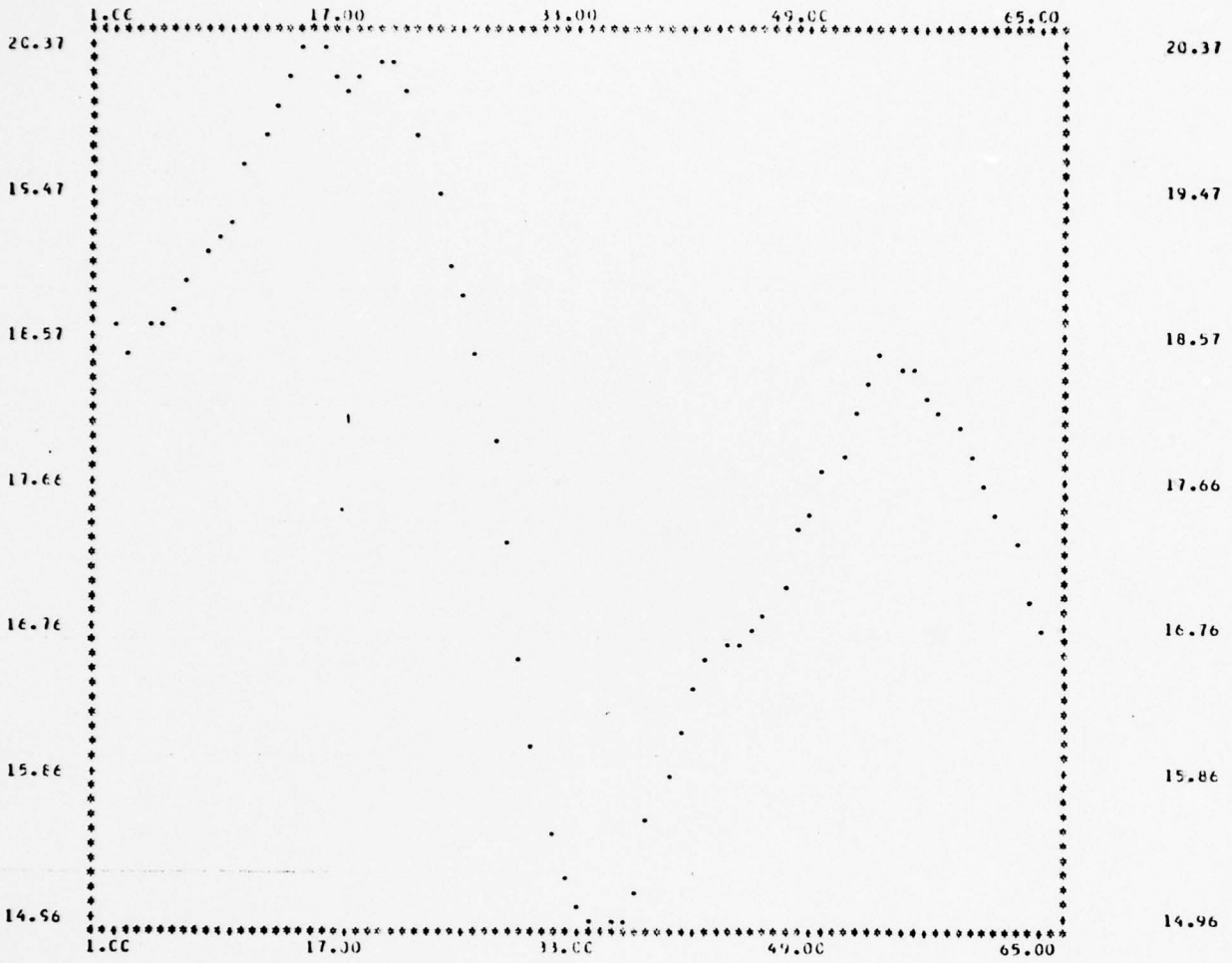


Figure 9. Plots of simulated series with model (1,1,0) of series C.

APPENDIX C

PROGRAM LISTINGS

```
&TYPECL1 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 -PRINTX
-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 F &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
-RLSS &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 P &GOTO -LOAD8
-LOAD1 LOAD GENERATE (CLEAR XEQ NOMAP)
C PRINT FILE FT01F001
&GOTO -QUES
-LOAD2 LOAD ALTC (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 ALTC (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 FTC3FCC1
ALTER FILE FTC2F001 P1 FILE FTC3F001 P1
ALTER FILE FTC3FCC1 P1 FILE FTC2F001 P1
LOAD ALTC (CLEAR XEQ NOMAP)
OFFLINE PRINTCC FILE FTC9FCC1
ALTER FILE FTC2FCC1 P1 FILE FTC3F001 P1
ALTER FILE FTC9FCC1 P1 FILE FTC2F001 P1
&UPRINT DO YOU WANT TO CHECK RESIDUALS?
&READ ARGS &ERROR &GOTO -QUES
&IF &1 NE Y &GOTO -QUES
LOAD TESTGCCC (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 FTCAF001
&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 FTC3F001
ALTER FILE FTC2FCC1 P1 FILE FTC9F001 P1
ALTER FILE FTC3FCC1 P1 FILE FTC2F001 P1
LOAD PLOT (CLEAR XEQ NOMAP)
OFFLINE PRINTCC FILE FTC8FCC1
ALTER FILE FTC2F301 P1 FILE FTC3F031 P1
ALTER FILE FTC9FCC1 P1 FILE FTC2F001 P1
&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 OFFLINE AND RETURN.
&GOTO -END
-PCH PRINTF ENTER PARA
&GOTO -LEE
-END &PRINT CONTROL RETURNED TO CMS
&EXIT
```

```
 03/22/77  18.20.23
FILE: TS       EXEC     P1                  NAVAL POSTGRADUATE SCHOOL                          PAGE 001

&TYPECLI 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 F &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 P &GOTO -LOAD8
&SPACE 1 &PRINT ILLEGAL OPTION.
&SPACE 1 &GOTO -ASK
-LOAD1 LOAD GENERATE (CLEAR XEQ NOMAP)
O PRINT FILE FTO1F001
&SPACE 1
&GOTO -CLES
-LOAD2 LOAD ALTO (CLEAR XEQ NOMAP)
O PRINTCC FILE FTO8F001
&SPACE 1
&GOTO -CLES
-LOAD3 LOAD PLOT (CLEAR XEQ NOMAP)
O PRINTCC FILE FTO8F001
&SPACE 1
&GOTO -CLES
-LOAD4 LOAD DIFF (CLEAR XEQ NOMAP)
&UPRINT DO YOU WANT TO PLOT AUTO AND PAUTO OF TRANSFORMED DATA?
&READ ARGS &ERROR &GOTO -CLES
&IF &1 NE Y &GOTO -QUES
OFFLINE PRINT FILE FTO3F001
ALTER FILE FTO2FCC1 P1 FILE FTO9F001 P1
ALTER FILE FTO3FCC1 P1 FILE FTO2F001 P1
LOAD ALTO (CLEAR XEQ NOMAP)
OFFLINE PRINTCC FILE FTO8FCC1
ALTER FILE FTO2FCC1 P1 FILE FTO3F001 P1
ALTER FILE FTO9FC01 P1 FILE FTO2F001 P1
&SPACE 1
&GOTO -CLES
-LOAD5 LOAD ESTIMATE (CLEAR XEQ NOMAP)
&UPRINT DO YOU WANT TO PLOT AUTO AND PAUTO OF RESIDUALS?
&READ ARGS &ERROR &GOTO -CLES
&IF &1 NE Y &GOTO -QUES
OFFLINE PRINT FILE FTO3FCC1
ALTER FILE FTO2FCC1 P1 FILE FTO9F001 P1
ALTER FILE FTO3FCC1 P1 FILE FTO2F001 P1
LOAD ALTO (CLEAR XEQ NOMAP)
OFFLINE PRINTCC FILE FTO8FCC1
ALTER FILE FTO2FC01 P1 FILE FTO3F001 P1
ALTER FILE FTO9FC01 P1 FILE FTO2F001 P1
&UPRINT DO YOU WANT TO CHECK RESIDUALS?
&READ ARGS &ERROR &GOTO -CLES
&IF &1 NE Y &GOTO -QUES
LOAD TESTGOOD (CLEAR XEQ NOMAP)
&SPACE 1
&GOTO -CLES
-LOAD6 LOAD FORECAST (CLEAR XEQ NOMAP)
&UPRINT DO YOU REALLY WANT TO PLOT FORECASTS?
&READ ARGS &ERROR &GOTO -CLES
&IF &1 NE Y &GOTO -QUES
OFFLINE PRINTCC FILE FTO8FC01
&UPRINT YOUR TIME SERIES AND FORECASTS ARE PLOTTED OFFLINE.
&SPACE 1
&GOTO -CLES
-LOAD7 LOAD SIMULATE (CLEAR XEQ NOMAP)
&UPRINT DO YOU WANT TO PLOT SIMULATED VALUES?
&READ ARGS &ERROR &GOTO -CLES
&IF &1 NE Y &GOTO -QUES
```

```
CFFLINE PRINT FILE FT03F001
ALTER FILE FTC2F001 P1 FILE FTC9F001 P1
ALTER FILE FTC3F001 P1 FILE FT02F001 P1
LOAD PLOT (CLEAR XEQ NOMAP)
CFFLINE PRINTCC FILE FTC8F001
ALTER FILE FT02F001 P1 FILE FT03F001 P1
ALTER FILE FTC9F001 P1 FILE FT02F001 P1
&SPACE 1
&GOTO -CLES
-LOAD LOAD REGRESS (CLEAR XEQ NOMAP)
&SPACE 1
-CLES &PRINT AGAIN?
&READ ARCS
&ERROR
&IF &1 EQ Y &GOTO -ASK
&PRINT CONTROL RETURNED TO CMS.
&EXIT
```

```
      DIMENSION X(400),Z(400),TITLE(60)                                 PLC00010
      DATA Y/'Y'/                                                       PLC00020
      READ(2,200) N                                                     PLC00030
  200 FORMAT(I3)                                                        PLC00040
      READ(2,201) (Z(I),I=1,N)                                          PLC00050
  201 FORMAT(8E15.6)                                                    PLC00060
      DO 10 I=1,N                                                       PLC00070
   10 X(I) = I                                                          PLC00080
    9 FORMAT('1')                                                       PLC00090
      WRITE(8,9)                                                        PLC00100
      CALL PLOTP(X,Z,N,C)                                               PLC00110
      WRITE(6,63)                                                       PLC00120
      READ(5,53) TITLE                                                  PLC00130
   63 FORMAT(2X,'ENTER TITLE FOR PLOT.')                                PLC00140
   53 FORMAT(60A1)                                                      PLC00150
      WRITE(8,81) TITLE                                                 PLC00160
   81 FORMAT(15X,60A1)                                                  PLC00170
      WRITE(6,64)                                                       PLC00180
   64 FORMAT(2X,'TIME SERIES PLOTS HAVE BEEN PRINTED OFFLINE.')         PLC00190
      STOP                                                              PLC00200
      END                                                               PLC00210
```

```
      DIMENSION W(400),ACV(21),PACV(21),WKAREA(21),RANGE(4),T(21),AC(21)AUTC0010
      DIMENSION TITLE(60)                                               AUTC0020
      DATA Y/'Y'/                                                       AUTC0030
      READ(2,307) LW                                                    AUTC0040
  307 FORMAT(I3)                                                        AUTC0050
      READ(2,802)  (W(I),I=1,LW)                                        AUTC0060
  802 FORMAT(5E15.6)                                                    AUTC0070
      CALL FTAUTC(W,LW,21,21,7,AMEAN,VAR,ACV,AC,PACV,WKAREA)            AUTC0080
    4 FORMAT(//5X,'MEAN=',G12.6,5X,'VARIANCE = ',G12.6,/)               AUTC0090
      WRITE(6,5)                                                        AUTC0100
      WRITE(8,*)                                                        AUTC0110
    5 FORMAT(15X,'AUTOCORRELATIONS',/)                                  AUTC0120
      WRITE(6,6) (AC(I),I=1,20)                                         AUTC0130
      WRITE(8,6) (AC(I),I=1,20)                                         AUTC0140
    6 FORMAT(1CF7.3)                                                    AUTC0150
      WRITE(6,7)                                                        AUTC0160
      WRITE(8,7)                                                        AUTC0170
    7 FORMAT(//1CX,'PARTIAL AUTOCORRELATIONS',/)                        AUTC0180
      WRITE(6,6) (PACV(I),I=1,20)                                       AUTC0190
      WRITE(8,6) (PACV(I),I=1,20)                                       AUTC0200
      WRITE(8,4) AMEAN,VAR                                              AUTC0210
      WRITE(6,4) AMEAN,VAR                                              AUTC0220
      RANGE(1)=21                                                       AUTC0230
      RANGE(2)=1                                                        AUTC0240
      RANGE(3)=1.C                                                      AUTC0250
      RANGE(4)=-1.0                                                     AUTC0260
      DO 8 I=1,21                                                       AUTC0270
    8 T(I)=I                                                            AUTC0280
      WRITE(8,9)                                                        AUTC0290
    9 FORMAT('1')                                                       AUTC0300
      CALL CTPLOT(T,AC,21,RANGE,1,C)                                    AUTC0310
      WRITE(8,10)                                                       AUTC0320
   10 FORMAT(15X,'AUTOCORRELATIONS')                                    AUTC0330
      WRITE(8,9)                                                        AUTC0340
      CALL CTPLOT(T,PACV,21,RANGE,1,0)                                  AUTC0350
      WRITE(8,11)                                                       AUTC0360
   11 FORMAT(10X,'PARTIAL AUTOCORRELATIONS')                            AUTC0370
      WRITE(6,61)                                                       AUTC0380
   61 FORMAT(2X,'ENTER TITLE FOR PLOTS.')                               AUTC0390
      READ(5,51) TITLE                                                  AUTC0400
   51 FORMAT(60A1)                                                      AUTC0410
      WRITE(8,62) TITLE                                                 AUTC0420
   62 FORMAT(15X,60A1)                                                  AUTC0430
      WRITE(6,15)                                                       AUTC0440
   15 FORMAT(' YOUR AUTO AND PAUTO PLOTS HAVE BEEN PRINTED OFFLINE.'/   AUTC0450
     *'  PICK UP IN ROOM 1140 UNDER YOUR USER ID NUMBER.')              AUTC0460
      STOP                                                              AUTC0470
      END                                                               AUTC0480
```

```
      DIMENSION  Z(400)                                                 DIFC0010
      DATA  Y/'Y'/                                                      DIFC0020
      READ(2,200)  LZ                                                   DIFC0030
  200 FORMAT(I3)                                                        DIFC0040
      READ(2,201)  (Z(I),I=1,LZ)                                        DIFC0050
  201 FORMAT(5E15.6)                                                    DIFC0060
      IS=1                                                              DIFC0070
      ID2=0                                                             DIFC0080
      ID1=0                                                             DIFC0090
      WRITE(6,605)                                                      DIFC0100
  609 FORMAT(2X,'IS YOUR TIME SERIES SEASONAL?')                        DIFC0110
      READ(5,502) ANS                                                   DIFC0120
      IF(ANS.NE.Y) GO TO 1000                                           DIFC0130
   20 WRITE(6,601)                                                      DIFC0140
  601 FORMAT(2X,'ENTER ORDER OF SEASONAL DIFFERENCING.')                DIFC0150
      READ(5,503) ID2                                                   DIFC0160
  503 FORMAT(I1)                                                        DIFC0170
   10 WRITE(6,604)                                                      DIFC0180
  604 FORMAT(2X,'ENTER LENGTH OF SEASONAL PERIOD VIA I2.')              DIFC0190
      READ(5,504) IS                                                    DIFC0200
  504 FORMAT(I2)                                                        DIFC0210
      WRITE(6,605) IS                                                   DIFC0220
  605 FORMAT(2X,'YOUR INPUT SEASONAL PERIOD=',I2,'.    IS IT OK?')      DIFC0230
      READ(5,502) ANS                                                   DIFC0240
      IF(ANS.NE.Y) GO TO 10                                             DIFC0250
 1000 WRITE(6,600)                                                      DIFC0260
  600 FORMAT(2X,'ENTER NUMBER OF NONSEASONAL DIFFERENCES.')             DIFC0270
      READ(5,603) ID1                                                   DIFC0280
      WRITE(6,602)                                                      DIFC0290
  602 FORMAT(2X,'DO YOU WANT A LOG TRANSFORMATION?')                    DIFC0300
      READ(5,502) ANS                                                   DIFC0310
  502 FORMAT(A1)                                                        DIFC0320
      IP=0                                                              DIFC0330
      IF(ANS.EQ.Y) GO TO 50                                             DIFC0340
      WRITE(6,610)                                                      DIFC0350
  610 FORMAT(2X,'DO YOU WANT AN EXPONENTIAL TRANSFORMATION?')           DIFC0360
      READ(5,502) ANS                                                   DIFC0370
      IP=1                                                              DIFC0380
      IF(ANS.NE.Y) GO TO 50                                             DIFC0390
      WRITE(6,603)                                                      DIFC0400
  603 FORMAT(2X,'ENTER POWER OF EXPONENTIAL TRANSFORMATION VIA I1.')    DIFC0410
      READ(5,503) IP                                                    DIFC0420
   50 CALL FTRDIF(ID1,ID2,IP,IS,LZ,Z,SHIFT,LW,IER)                      DIFC0430
      M=LW                                                              DIFC0440
      WRITE(6,500)                                                      DIFC0450
  900 FORMAT(2X,'YOUR TRANSFORMED TIME SERIES HAS BEEN STORED IN FILE', DIFC0460
     *' FT03F001.'/2X,'DO YOU WANT A PRINTOUT OF THE FIRST TEN VALUES?')DIFC0470
      READ(5,502) ANS                                                   DIFC0480
      IF(ANS.NE.Y) GO TO 525                                            DIFC0490
      WRITE(6,606)                                                      DIFC0500
  606 FORMAT(2X,'THE FIRST 10 VALUES OF THE TRANSFORMED SERIES ARE:')   DIFC0510
      JJ=M                                                              DIFC0520
      IF(M.GT.10)  JJ=10                                                DIFC0530
      WRITE(6,607) (Z(I),I=1,JJ)                                        DIFC0540
  607 FORMAT(5F15.6)                                                    DIFC0550
  525 WRITE(3,60) M                                                     DIFC0560
   60 FORMAT(I3)                                                        DIFC0570
      WRITE(3,61) (Z(I),I=1,M)                                          DIFC0580
   61 FORMAT(5E15.6)                                                    DIFC0590
      IF(IER.EQ.0) GO TO 70                                             DIFC0600
      WRITE(6,608) IER                                                  DIFC0610
  608 FORMAT(2X,'ERROR PARAM=',I3,' SEE EXPLANATION IN SUBROUTINE FTRDIFDIFC0620
     *.')                                                               DIFC0630
   70 STOP                                                              DIFC0640
      END                                                               DIFC0650
```

```
      DIMENSION X(400),IND(8),ARPS(10),PMAS(10),GR(40),AA(400)          ESTC0010
      EQUIVALENCE(A,B)                                                  ESTC0020
      REAL*8 B(499)                                                     ESTC0030
      REAL*4 B(558)                                                     ESTC0040
      DO 1 I=1,10                                                       ESTC0050
      ARPS(I)=.0                                                        ESTC0060
      PMAS(I)=.0                                                        ESTC0070
    1 CONTINUE                                                          ESTC0080
      READ(2,200) IND(1)                                                ESTC0090
  200 FORMAT(I3)                                                        ESTC0100
      L=IND(1)                                                          ESTC0110
      READ(2,201) (X(I),I=1,L)                                          ESTC0120
  201 FORMAT(5E15.6)                                                    ESTC0130
      WRITE(6,600)                                                      ESTC0140
  600 FORMAT(2X,'ENTER NUMBER OF AR PARAMETERS.')                       ESTC0150
      READ(5,500) IND(2)                                                ESTC0160
  500 FORMAT(I1)                                                        ESTC0170
      WRITE(6,601)                                                      ESTC0180
  601 FORMAT(2X,'ENTER NUMBER OF MA PARAMETERS.')                       ESTC0190
      READ(5,500) IND(3)                                                ESTC0200
      WRITE(6,602)                                                      ESTC0210
  602 FORMAT(2X,'ENTER NUMBER OF DIFFERENCES.')                         ESTC0220
      READ(5,500) IND(4)                                                ESTC0230
      IND(5)=100                                                        ESTC0240
      IND(6)=3                                                          ESTC0250
      IND(7)=0                                                          ESTC0260
      IND(8)=3                                                          ESTC0270
      CALL FIMAXL(X,IND,ARPS,PMAS,PMAC,WNV,GR,A,IER)                    ESTC0280
      WRITE(6,603) IND(1),IND(2),IND(3),IND(4)                          ESTC0290
  603 FORMAT(2X,'LENGTH OF TIME SERIES =',I4//2X,I1,' AR PARAMETERS',4X, ESTC0300
     *I1,' MA PARAMETERS',4X,I1,' DIFFERENCES.',/)                      ESTC0310
      KK=IND(1)-IND(4)                                                  ESTC0320
      WRITE(3,614) KK                                                   ESTC0330
  614 FORMAT(I3)                                                        ESTC0340
      WRITE(3,613)  (B(I),I=1,KK)                                       ESTC0350
  613 FORMAT(5E15.6)                                                    ESTC0360
      WRITE(3,615)                                                      ESTC0370
  615 FORMAT(/,3X,'RESIDUAL VALUES.')                                   ESTC0380
      N=IND(2)+IND(4)                                                   ESTC0390
      IF (N.EQ.0) GO TO 3002                                            ESTC0400
      WRITE(6,605) (I,ARPS(I),I=1,N)                                    ESTC0410
  605 FORMAT(2X,'ESTIMATED AR PARAMETERS (UNDIFFERENCED FORM) ARE:',/(2X ESTC0420
     *,'PHI(',I1,') =',F9.4),/)                                         ESTC0430
 3002 M=IND(3)                                                          ESTC0440
      IF(M.EQ.0) GO TO 3001                                             ESTC0450
      WRITE(6,607) (I,PMAS(I),I=1,M)                                    ESTC0460
  607 FORMAT(2X,'ESTIMATED MA PARAMETERS ARE:',/,                       ESTC0470
     *(2X,'THETA(',I1,') =',F9.4),/)                                    ESTC0480
 3001 WRITE(6,608) PMAC,WNV                                             ESTC0490
  608 FORMAT(2X,'MA CONSTANT= ',E13.5,5X,'WHITE NOISE VARIANCE= ',      ESTC0500
     *E15.6/)                                                           ESTC0510
      IF(IER.EQ.0) GO TO 616                                            ESTC0520
      WRITE(6,610) IER                                                  ESTC0530
  610 FORMAT(2X,'ERROR NUMBER= ',I3,'.  SEE EXPLANATION IN SUBROUTINE FI ESTC0540
     *MAXL (IMSL).')                                                    ESTC0550
  616 STOP                                                              ESTC0560
      END                                                               ESTC0570
```

```
      DIMENSION Z(400),ARPS(10),PMAS(20),LV(5),BARPS(20),FCST(3,20)     FOR00010
      DIMENSION X(400),T(400),W(400),V(400),G(400)                      FOR00020
      DATA Y,'Y'/                                                       FOR00030
      READ(2,200)  LENGTH                                               FOR00040
  200 FORMAT(I3)                                                        FOR00050
      LV(4)=0                                                           FOR00060
      IFLAG=0                                                           FOR00070
      WRITE(6,5001)                                                     FOR00080
 5001 FORMAT(2X,'ARE YOUR AR PARAMETERS IN DIFFERENCED FORM?')          FOR00090
      READ(5,395) ANS                                                   FOR00100
      IF(ANS.EQ.Y) GO TO 5005                                           FOR00110
      WRITE(6,5002)                                                     FOR00120
 5002 FORMAT(2X,'ENTER NO. AR PARAMETERS (UNDIFF. FORM).')              FOR00130
      READ(5,500) LV(2)                                                 FOR00140
  500 FORMAT(I1)                                                        FOR00150
      GO TO 5007                                                        FOR00160
 5005 WRITE(6,5006)                                                     FOR00170
 5006 FORMAT(2X,'ENTER NO. AR PARAMETERS (DIFF. FORM).')                FOR00180
      READ(5,500) LV(2)                                                 FOR00190
      IFLAG=1                                                           FOR00200
 5007 IP=LV(2)                                                          FOR00210
      IF(IP.LE.0) GO TO 300                                             FOR00220
   51 DO 52 I=1,IP                                                      FOR00230
      WRITE(6,314)  I                                                   FOR00240
  314 FORMAT(2X,'ENTER AR PARAMETER PHI(',I1,').')                      FOR00250
   52 READ(5,302)  ARPS(I)                                              FOR00260
  302 FORMAT(F15.6)                                                     FOR00270
      WRITE(6,505)  (ARPS(I),I=1,IP)                                    FOR00280
  505 FORMAT(2X,'AR PARAMETERS ARE:',/,(3X,F8.4))                       FOR00290
      WRITE(6,206)                                                      FOR00300
  206 FORMAT(2X,'ARE THESE OK?')                                        FOR00310
      READ(5,395) ANS                                                   FOR00320
  395 FORMAT(A1)                                                        FOR00330
      IF(ANS.EQ.Y) GO TO 300                                            FOR00340
      GO TO 51                                                          FOR00350
  300 WRITE(6,601)                                                      FOR00360
  601 FORMAT(2X,'ENTER NUMBER OF MA PARAMETERS.')                       FOR00370
      READ(5,500)  LV(3)                                                FOR00380
   53 IQ=LV(3)                                                          FOR00390
      IF(IQ.LE.0) GO TO 55                                              FOR00400
   56 DO 402 I=1,IQ                                                     FOR00410
      WRITE(6,401) I                                                    FOR00420
  401 FORMAT(2X,'ENTER MA PARAMETER THETA(',I1,').')                    FOR00430
  402 READ(5,302)  PMAS(I)                                              FOR00440
      WRITE(6,403)  (PMAS(I),I=1,IQ)                                    FOR00450
  403 FORMAT(2X,'MA PARAMETERS ARE:',/,(3X,F9.4))                       FOR00460
      WRITE(6,406)                                                      FOR00470
  406 FORMAT(2X,'ARE THESE OK?')                                        FOR00480
      READ(5,395) ANS                                                   FOR00490
      IF(ANS.EQ.Y) GO TO 55                                             FOR00500
      GO TO 56                                                          FOR00510
   55 WRITE(6,704)                                                      FOR00520
  704 FORMAT(2X,'ENTER OVERALL MA CONSTANT')                            FOR00530
      READ(5,705) PMAC                                                  FOR00540
  705 FORMAT(E15.6)                                                     FOR00550
      IF(IFLAG.EQ.0) GO TO 6000                                         FOR00560
      WRITE(6,602)                                                      FOR00570
  602 FORMAT(2X,'ENTER THE NUMBER OF DIFFERENCES.')                     FOR00580
      READ(5,500) LV(4)                                                 FOR00590
 6000 WRITE(6,6100)                                                     FOR00600
 6100 FORMAT(2X,'ENTER INDEX FOR FORECAST ORIGIN VIA I3.')              FOR00610
 6050 READ(5,200) LV(1)                                                 FOR00620
      L=LV(1)                                                           FOR00630
      IF(L.LE.LENGTH) GO TO 6150                                        FOR00640
      WRITE(6,6160) L,LENGTH                                            FOR00650
 6160 FORMAT(2X,'FORECAST ORIGIN OF',I4,' EXCEEDS LENGTH OF SERIES',I4,'FOR00660
     *.',/2X,'ENTER NEW ORIGIN.')                                       FOR00670
      GO TO 6050                                                        FOR00680
 6150 READ(2,201) (Z(I),I=1,L)                                          FOR00690
  201 FORMAT(5E15.6)                                                    FOR00700
```

```
      WRITE(6,603)                                                      FOR00710
  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 FCAST(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)                                                          FORC0920
      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:')         FORC0970
      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 SUBROUTINEFORC1060
     *E FCAST (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                                            FORC1110
      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)                                                  FORC1220
      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(1).GT.T(N)) GO TO 999                                        FORC1270
      CALL PLCTP(X,V,N,1)                                               FORC1280
      CALL PLCTP(X,T,N,2)                                               FORC1290
      CALL PLCTP(X,G,N,3)                                               FORC1300
      WRITE(6,81)                                                       FORC1310
   81 FORMAT(14X,'ORIGINAL AND FORECASTED TIME SERIES.')                FORC1320
      STOP                                                              FORC1330
  999 CALL PLCTP(X,G,N,1)                                               FORC1340
      CALL PLCTP(X,T,N,2)                                               FORC1350
      CALL PLCTP(X,V,N,3)                                               FORC1360
      WRITE(6,81)                                                       FORC1370
  622 STOP                                                              FORC1380
      END                                                               FORC1390
```

AD-A041 178 NAVAL POSTGRADUATE SCHOOL MONTEREY CALIF F/G 9/2
AN APPLICATION OF CP/CMS TO THE TIME SERIES ANALYSIS.(U)
MAR 77 Y W LEE

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2 OF 2
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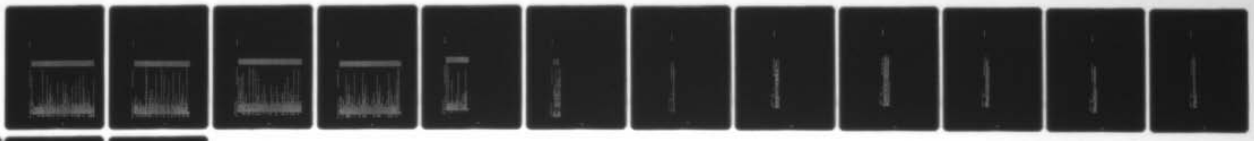

END

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```
      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 55
      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
   54 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 54
   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(6,1C55)
 1C55 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 2CCC
      DO 2001 I = 1,IP
      WRITE(6,2CC2) I
 2002 FORMAT(2X,'ENTER START(',I1,')')
      READ(5,2003) START(I)
 2C03 FORMAT(G1E.5)
 2001 CONTINUE
      GO TO 420
 2CCC WRITE(6,1C56)
 1C56 FORMAT(2X,'ENTER INDEX OF STARTING VALUE VIA I3.')
```

```
      READ(5,200) K                                                     SIMC0710
      IF(IP.EQ.0) GO TO 416                                             SIMC0720
      IF(K-1+IP.GT.L) GO TO 417                                         SIMC0730
      DO 413 I=1,IP                                                     SIMC0740
  413 START(I)=Z(K-1+I)                                                 SIMC0750
      GO TO 419                                                         SIMC0760
  414 IF(IP.EQ.0) GO TO 416                                             SIMC0770
      DO 415 I=1,IP                                                     SIMC0780
  415 START(I)=Z(L-IP+I)                                                SIMC0790
      GO TO 419                                                         SIMC0800
  416 START(1)=Z(K)                                                     SIMC0810
      GO TO 415                                                         SIMC0820
  417 WRITE(6,418)                                                      SIMC0830
  418 FORMAT(2X,'INVALID STARTING VALUE. SEE IF ANY STARTING VALUE WAS PSIMC0840
     *ICKED UP OUTSIDE OF RANGE OF INPUT DATA, VECTOR Z(I)')            SIMC0850
      GO TO 400                                                         SIMC0860
  419 DO 420 I=1,IP                                                     SIMC0870
  420 WRITE(6,421) I,START(I)                                           SIMC0880
  421 FORMAT(2X,'START(',I1,')=',F15.6)                                 SIMC0890
      WRITE(6,422)                                                      SIMC0900
  422 FORMAT(2X,'STARTING VALUE(S) OK?')                                SIMC0910
      READ(5,395) ANS                                                   SIMC0920
      IF(ANS.NE.Y) GO TO 400                                            SIMC0930
      WRITE(6,603)                                                      SIMC0940
  603 FORMAT(2X,'ENTER RANDOM NUMBER SEED (BETWEEN 0 AND 1).')          SIMC0950
      READ(5,503) SEED                                                  SIMC0960
  503 FORMAT(F15.12)                                                    SIMC0970
      SEED = SEED * 1000000000.                                         SIMC0980
      ISEED = SEED                                                      SIMC0990
      WRITE(6,604)                                                      SIMC1000
  604 FORMAT(2X,'ENTER NUMBER OF VALUES YOU WANT TO SIMULATE VIA (3.')  SIMC1010
      READ(5,200) LW                                                    SIMC1020
      WRITE(6,1000)                                                     SIMC1030
 1000 FORMAT(2X,'DO YOU WANT MORE THAN ONE SIMULATED SERIES?')          SIMC1040
      READ(5,395) ANS                                                   SIMC1050
      M=1                                                               SIMC1060
      IF(ANS.NE.Y) GO TO 1010                                           SIMC1070
      WRITE(6,1020)                                                     SIMC1080
 1020 FORMAT(2X,'HOW MANY SERIES DO YOU WANT (LE.9)?')                  SIMC1090
      READ(5,500) M                                                     SIMC1100
      JJ=20                                                             SIMC1110
      IF(LW.LT.20) JJ=LW                                                SIMC1120
 1010 DO 125 K=1,M                                                      SIMC1130
      CALL FIGEN(ARPS,FMAS,FMAC,START,WNV,ISEED,IP,IQ,LW,SIM,WA)        SIMC1140
      WRITE(3,60) LW                                                    SIMC1150
   60 FORMAT(I3)                                                        SIMC1160
      WRITE(3,61) (SIM(I),I=1,LW)                                       SIMC1170
   61 FORMAT(5E15.6)                                                    SIMC1180
      IF(K.NE.1) GO TO 125                                              SIMC1190
      WRITE(6,3010)                                                     SIMC1200
 3010 FORMAT(2X,'DO YOU WANT A PRINTOUT OF THE FIRST 20 VALUES?')       SIMC1210
      READ(5,395) ANS                                                   SIMC1220
      IF(ANS.NE.Y) GO TO 125                                            SIMC1230
      WRITE(6,606) (SIM(I),I=1,JJ)                                      SIMC1240
  606 FORMAT(2X,'SIMULATED VALUES ARE:'/(5E15.6))                       SIMC1250
  125 CONTINUE                                                          SIMC1260
      IF(IER.EQ.0) GO TO 610                                            SIMC1270
      WRITE(6,607) IER                                                  SIMC1280
  607 FORMAT(2X,'ERROR PARAMETER= ',I3,' SEE EXPLANATION IN SUBROUTINE FSIMC1290
     *TGEN1 (IMSL).')                                                   SIMC1300
  610 STOP                                                              SIMC1310
      END                                                               SIMC1320
```

```
      DIMENSION PHI(6),THETA(6),START(6),W(400),WA(410)                 TIM00010
      REAL*8 SEED                                                       TIM00020
      DATA IC1/'Y'/,IP4/'Y'/,IP5/'C'/                                   TIM00030
      DATA PHI/6*0.0/,THETA/6*0.0/,START/6*0.0/,CONS/0.0/               TIM00040
      WRITE(6,301)                                                      TIM00050
  301 FORMAT(1X,'ENTER RANDOM NUMBER SEED (BETWEEN 0 AND 1).')          TIM00060
   66 READ(5,777) SEED                                                  TIM00070
  777 FORMAT(F15.12)                                                    TIM00080
      SEED = SEED * 1000000000.                                         TIM00090
      ISEED = SEED                                                      TIM00100
  302 FORMAT(G15.6)                                                     TIM00110
   70 WRITE(6,71)                                                       TIM00120
   71 FORMAT(' ENTER IP, THE ORDER OF THE AUTOREGRESSIVE OPERATOR.')    TIM00130
      READ(5,72) IP                                                     TIM00140
   72 FORMAT(I1)                                                        TIM00150
      WRITE(6,360)                                                      TIM00160
  360 FORMAT(' ENTER IQ, THE ORDER OF THE MOVING AVERAGE OPERATOR.')    TIM00170
      READ(5,72) IQ                                                     TIM00180
      WRITE(6,361)                                                      TIM00190
  361 FORMAT(' ENTER LW, THE LENGTH OF THE TIME SERIES VIA I3.')        TIM00200
      READ(5,303) LW                                                    TIM00210
  320 WRITE(6,304)  IP,IQ,LW                                            TIM00220
  304 FORMAT(1X,'IP= ',I1,3X,'IQ= ',I1,3X,'LW = ',I3)                   TIM00230
      WRITE(6,206)                                                      TIM00240
      READ(5,395) IANS                                                  TIM00250
  395 FORMAT(A1)                                                        TIM00260
      IF(IANS.EQ.IC1) GO TO 401                                         TIM00270
      WRITE(6,306)                                                      TIM00280
  306 FORMAT(1X,'DO YOU WISH TO CHANGE LW?')                            TIM00290
      READ(5,395) IANS                                                  TIM00300
      IF(IANS.NE.IC1) GO TO 310                                         TIM00310
      WRITE(6,404)                                                      TIM00320
      READ(5,303) LW                                                    TIM00330
  303 FORMAT(I3)                                                        TIM00340
      GO TO 320                                                         TIM00350
  310 WRITE(6,311)                                                      TIM00360
  311 FORMAT(1X,'DO YOU WANT TO CHANGE IP?')                            TIM00370
      READ(5,395) IANS                                                  TIM00380
      IF(IANS.NE.IC1) GO TO 644                                         TIM00390
      WRITE(6,404)                                                      TIM00400
      READ(5,72) IP                                                     TIM00410
  644 WRITE(6,645)                                                      TIM00420
  645 FORMAT(' DO YOU WANT TO CHANGE IQ?')                              TIM00430
      READ(5,395) IANS                                                  TIM00440
      IF(IANS.NE.IC1) GO TO 401                                         TIM00450
      WRITE(6,404)                                                      TIM00460
      READ(5,72) IQ                                                     TIM00470
      GO TO 320                                                         TIM00480
  404 FORMAT(1X,'ENTER NEW VALUE')                                      TIM00490
  401 WRITE(1,304) IP,IQ,LW                                             TIM00500
      WRITE(6,202)                                                      TIM00510
  203 FORMAT(1X,'ENTER ERROR VARIANCE, VAR.')                           TIM00520
      READ(5,302) VAR                                                   TIM00530
      WRITE(6,204)                                                      TIM00540
  204 FORMAT(1X,'DO YOU WANT A NONZERO CONSTANT TERM?')                 TIM00550
      READ(5,395) IANS                                                  TIM00560
      IF(IANS.NE.IC1) GO TO 331                                         TIM00570
      WRITE(6,205)                                                      TIM00580
  205 FORMAT(1X,'ENTER CONSTANT TERM.')                                 TIM00590
      READ(5,302) CONS                                                  TIM00600
  331 WRITE(6,402) VAR,CONS                                             TIM00610
  402 FORMAT(1X,'ERROR VARIANCE=',G15.6,5X,'CONSTANT TERM=',G15.6)      TIM00620
      WRITE(6,206)                                                      TIM00630
      READ(5,395) IANS                                                  TIM00640
      IF(IANS.EQ.IC1) GO TO 531                                         TIM00650
      WRITE(6,403)                                                      TIM00660
  403 FORMAT(1X,'WHICH VARIABLE TO CHANGE, VARIANCE OR CONSTANT?')      TIM00670
      READ(5,395) IANS                                                  TIM00680
      WRITE(6,404)                                                      TIM00690
      READ(5,302) XANS                                                  TIM00700
```

```
      IF(IANS.EQ.IP4) VAR=XANS                                          TIMCC710
      IF(IANS.EQ.IP5) CONS=XANS                                         TIMCC720
      GO TO 331                                                         TIMCC730
  331 WRITE(1,4C2) VAR,CONS                                             TIMCC740
      IF(IP.LE.C) GO TO 831                                             TIMCC750
      DO 502 I=1,IP                                                     TIMCC760
      WRITE(6,514) I                                                    TIMCC770
  514 FORMAT(1X,'ENTER AUTOREGRESSIVE PARAMETER PHI(',I1,').')          TIMCC780
  502 READ(5,302) PHI(I)                                                TIMCC790
  504 WRITE(6,505) (PHI(I),I=1,IP)                                      TIMCC8C0
  505 FORMAT(1X,'AR PARAMETERS ARE',4(3X,F10.4))                        TIMCC810
      WRITE(6,2C6)                                                      TIMCC820
  206 FORMAT(1X,'ARE THESE OK?')                                        TIMCC830
      READ(5,395) IANS                                                  TIMCC840
      IF(IANS.EQ.IC1) GO TO 600                                         TIMCC850
      WRITE(6,2C7)                                                      TIMCC860
  207 FORMAT(1X,'ENTER INDEX, I, FOR VALUE YOU WANT TO CHANGE.')        TIMCC870
      READ(5,71) I                                                      TIMCC880
      WRITE(6,4C4)                                                      TIMCC890
      READ(5,302) PHI(I)                                                TIMCC9CC
      GO TO 504                                                         TIMCC910
  600 WRITE(1,9C5) (PHI(I),I=1,IP)                                      TIMCC920
  631 IF(IQ.LE.C) GO TO 731                                             TIMCC930
      DO 602 I=1,IQ                                                     TIMCC940
      WRITE(6,601) I                                                    TIMCC950
  601 FORMAT(1X,'ENTER MOVING AVERAGE PARAMETER THETA(',I1,').')        TIMCC960
  602 READ(5,302) THETA(I)                                              TIMCC970
  610 WRITE(6,6C3) (THETA(I),I=1,IQ)                                    TIMCC9E0
  603 FORMAT(1X,'MA PARAMETERS ARE',4(3X,F10.4))                        TIMCC990
      WRITE(6,2C6)                                                      TIMC1000
      READ(5,395) IANS                                                  TIMC1010
      IF(IANS.EQ.IC1) GO TO 700                                         TIMC1020
      WRITE(6,2C7)                                                      TIMC1030
      READ(5,71) I                                                      TIMC1040
      WRITE(6,404)                                                      TIMC1050
      READ(5,302) THETA(I)                                              TIMC1060
      GO TO 610                                                         TIMC1070
  700 WRITE(1,603) (THETA(I),I=1,IQ)                                    TIMC1080
  731 IF(IP.LE.C) GO TO 831                                             TIMC1090
      DO 7C2 I=1,IP                                                     TIMC1100
      WRITE(6,701) I                                                    TIMC1110
  701 FORMAT(1X,'ENTER INITIAL STARTING VALUE START(',I1,').')          TIMC1120
  702 READ(5,3C2) START(I)                                              TIMC1130
  71C WRITE(6,703) (START(I),I=1,IP)                                    TIMC1140
  703 FORMAT(1X,'START VALUES ARE',4(2X,F11.3))                         TIMC1150
      WRITE(6,2C6)                                                      TIMC1160
      READ(5,395) IANS                                                  TIMC1170
      IF(IANS.EQ.IC1) GO TO 800                                         TIMC1180
      WRITE(6,2C7)                                                      TIMC1190
      READ(5,71) I                                                      TIMC1200
      WRITE(6,404)                                                      TIMC1210
      READ(5,302) START(I)                                              TIMC1220
      GO TO 710                                                         TIMC1230
  800 WRITE(1,703) (START(I), I=1,IP)                                   TIMC1240
  831 CALL FTGEN1(PHI,THETA,CONS,START,VAR,ISEED,IP,IQ,LW,W,WA)         TIMC1250
      WRITE(1,8C1)                                                      TIMC1260
  801 FORMAT(/1CX,'GENERATED TIME SERIES')                              TIMC1270
      WRITE(1,8C2) (W(I),I=1,LW)                                        TIMC1280
  802 FORMAT(5E15.6)                                                    TIMC1290
      WRITE(2,3C2) LW                                                   TIMC1300
      WRITE(2,802) (W(I),I=1,LW)                                        TIMC1310
      WRITE(6,853)                                                      TIMC1320
  853 FORMAT(1X,'YOUR TIME SERIES HAS BEEN GENERATED.'/                 TIMC1330
     *' IT WAS BEEN PRINTED OFFLINE.'/                                  TIMC1340
     *' YOU MAY PICK IT UP IN ROOM I-140 UNDER YOUR USER IC NUMBER.'/    TIMC1350
     *' THE TIME SERIES IS IN FILE FT02F001 IF YOU WANT TO SEE IT.')     TIMC1360
      STOP                                                              TIMC1370
      END                                                               TIMC1380
```

```
      DIMENSION W(400),ACV(21),PACV(21),WKAREA(21),RANGE(4),T(21),AC(21)TESC0010
      WRITE(6,9)                                                        TESC0020
    9 FORMAT(2X,'ENTER IP, NO OF AR PARAMETERS(DIFFERENCED FORM).')     TESC0030
      READ(5,10) IP                                                     TESC0040
   10 FORMAT(I1)                                                        TESC0050
      WRITE(6,11)                                                       TESC0060
   11 FORMAT(2X,'ENTER IQ, NO OF MA PARAMETERS.')                       TESC0070
      READ(5,10) IQ                                                     TESC0080
      NDF=2C-IP-1C                                                      TESC0090
      READ(3,5) K                                                       TESC0100
    5 FORMAT(I3)                                                        TESC0110
      READ(3,6) (W(I),I=1,K)                                            TESC0120
    6 FORMAT(5E15.6)                                                    TESC0130
      CALL FTAUTC(W,K,21,21,7,AMEAN,VAR,ACV,AC,PACV,WKAREA)             TESC0140
      C=0.                                                              TESC0150
      DC 1 I=1,2C                                                       TESC0160
    1 C=C+(AC(I))**2                                                    TESC0170
      C=C*K                                                             TESC0180
      CALL MDCDFI(Q,NDF,P,IER)                                          TESC0190
      SIGNIF=P                                                          TESC0200
      WRITE(6,7) C,NDF,SIGNIF                                           TESC0210
    7 FORMAT(2X,'CHI SQUARE LACK OF FIT VALUE =',F7.2,3X,'DF =',        TESC0220
     *I3,3X,'SIGNIFICANCE =',F7.4)                                      TESC0230
      STOP                                                              TESC0240
      END                                                               TESC0250
```

03/22/77 09.41.25

FILE: OPTIONS FORA P5 NAVAL POSTGRADUATE SCHOOL PAGE 001

OPTION	DESCRIPTION	
GENERATE	-----GENERATE ANY ARIMA TIME SERIES	TIMG2020 TIMG2030
AUTO	---------CALCULATE AUTOCORRELATIONS, PARTS, MEAN AND VARIANCE	
PLOT	---------PLOT A TIME SERIES	TIMG2050
DIFF	---------TRANSFORM AND DIFFERENCE A TIME SERIES	TIMG2060
ESTIMATE	-----CALCULATE MAX LIKELIHOOD ESTIMATES OF ARMA PARAMETERS	TIMG2070
SIMULATE	-----SIMULATE TIME SERIES FROM A GIVEN MODEL	
FORECAST	-----FORECAST FUTURE VALUES, CONSTRUCT CONFIDENCE INTERVALS	

PLOT --------THIS PROGRAM PLOTS A GIVEN TIME SERIES WHICH RESIDES IN
FILE FTC2FCCL. IT USES THE PLOTP PROGRAM IN THE IBM SSPLIB.

```
AUTO --------THIS PROGRAM CALCULATES AUTOCORRELATIONS, PARTIAL
ALTOCORRELATIONS, THE MEAN AND THE VARIANCE FOR A GIVEN TIME SERIES
WHICH MUST RESIDE IN FILE FTCC2F001.  THE PROGRAM USES
FTAUTC IN THE IMSL LIBRARY.  THE AUTOCORRELATIONS AND PARTIALS CAN BE      S
PLOTTED OFFLINE.
```

03/16/77 15.15.55

FILE: D PARA PS NAVAL POSTGRADUATE SCHOOL PAGE 001

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.

03/22/77 09.41.36

FILE: E FARA P5 NAVAL POSTGRADUATE SCHOOL PAGE 001

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.

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 FTGEN.

```
GENERATE ----THIS PROGRAM GENERATES A TIME SERIES SPECIFIED BY THE USER.M02120
IT CAN HANDLE ANY ARIMA MODEL WITH NUMBER OF AR TERMS AT MOST 6 AND NUM.TIMC2130
OF MA TERMS AT MOST 6.  THE TIME SERIES CAN BE STATIONARY OR HOMOGENECUSTIMO2140
NONSTATIONARY.  THE PROGRAM USES FTGFNI FROM THE IMSL LIBRARY. THE USER TIMO2150
SPECIFIES ALL PARAMETERS AND STARTING CONDITIONS.  THE PROGRAM TAKES THETIMC2160
GIVEN MODEL, GENERATES RANDOM NOISE TERMS AND CALCULATES AS MANY VALUES TIMO2170
AS REQUESTED.
                                                                      TIMC2
```

```
 03/16/77  15.24.00
FILE: ENTER     PARA     P1                  NAVAL POSTGRADUATE SCHOOL                  PAGE 001

THE FIRST TWO CARDS ARE OFFLINE READ CONTROL CARDS:

CP67USERID  XXXXE      (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 (5F15.4))
(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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2. Box, G. E.P. and Jenkins, G. M., Time Series Analysis, Forecasting and Control, Holden-Day, San Francisco, 1970.

3. Control Program-67/Cambridge Monitor System (CP-67/CMS) User's Guide, IBM Corporation, White Plains, New York, 1972.

4. The IMSL Library Vol. 1, International Mathematical and Statistical Libraries, Inc., Houston, Texas, 1975.

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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