SAS/ETS® 14.2 User's Guide
The ESM Procedure

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Chapter 14
The ESM Procedure

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Overview: ESM Procedure

The ESM procedure generates forecasts by using exponential smoothing models with optimized smoothing weights for many time series or transactional data.

- For typical time series, you can use the following smoothing models:
  - simple
  - double
  - linear
  - damped trend
  - seasonal
  - Winters method (additive and multiplicative)
- Additionally, transformed versions of these models are provided:
  - log
  - square root
  - logistic
  - Box-Cox

Graphics are available with the ESM procedure. For more information, see the section "ODS Graphics" on page 850.

The exponential smoothing models supported in PROC ESM differ from those supported in PROC FORECAST since all parameters associated with the forecasting model are optimized by PROC ESM based on the data.

The ESM procedure writes the time series extrapolated by the forecasts, the series summary statistics, the forecasts and confidence limits, the parameter estimates, and the fit statistics to output data sets. The ESM procedure optionally produces printed output for these results by using the Output Delivery System (ODS).

The ESM procedure can forecast both time series data, whose observations are equally spaced by a specific time interval (for example, monthly, weekly), or transactional data, whose observations are not spaced with respect to any particular time interval. Internet, inventory, sales, and similar data are typical examples of transactional data. For transactional data, the data are accumulated based on a specified time interval to form a time series prior to modeling and forecasting.

Getting Started: ESM Procedure

The ESM procedure is simple to use and does not require in-depth knowledge of forecasting methods. It can provide results in output data sets or in other output formats by using the Output Delivery System (ODS). The following examples are more fully illustrated in "Example 14.2: Forecasting of Transactional Data" on page 853.

Given an input data set that contains numerous time series variables recorded at a specific frequency, the ESM procedure can forecast the series as follows:

```
proc esm data=<input-data-set> out=<output-data-set>;
   id <time-ID-variable> interval=<frequency>;
   forecast <time-series-variables>;
run;
```

For example, suppose that the input data set SALES contains sales data recorded monthly, the variable that represents time is DATE, and the forecasts are to be recorded in the output data set NEXTYEAR. The ESM procedure could be used as follows:

```
proc esm data=sales out=nextyear;
   id date interval=month;
   forecast _numeric_;
run;
```

The preceding statements generate forecasts for every numeric variable in the input data set SALES for the next 12 months and store these forecasts in the output data set NEXTYEAR. Other output data sets can be specified to store the parameter estimates, forecasts, statistics of fit, and summary data.

By default, PROC ESM generates no printed output. If you want to print the forecasts by using the Output Delivery System (ODS), then you need to add the PRINT=FORECASTS option to the PROC ESM statement, as shown in the following example:

```
proc esm data=sales out=nextyear print=forecasts;
   id date interval=month;
   forecast _numeric_;
run;
```

Other PRINT= options can be specified to print the parameter estimates, statistics of fit, and summary data.

The ESM procedure can forecast both time series data, whose observations are equally spaced by a specific time interval (for example, monthly, weekly), or transactional data, whose observations are not spaced with respect to any particular time interval.

Given an input data set that contains transactional variables not recorded at any specific frequency, the ESM procedure accumulates the data to a specific time interval and forecasts the accumulated series as follows:

```
proc esm data=<input-data-set> out=<output-data-set>;
   id <time-ID-variable> interval=<frequency>
                         accumulate=<accumulation>;
   forecast <time-series-variables> / model=<esm>;
run;
```

For example, suppose that the input data set WEBSITES contains three variables (BOATS, CARS, PLANES) that are Internet data recorded on no particular time interval, and the variable that represents time is TIME, which records the time of the website hit. The forecasts for the total daily values are to be recorded in the output data set NEXTWEEK. The ESM procedure could be used as follows:

```
proc esm data=websites out=nextweek lead=7;
   id time interval=dtday accumulate=total;
   forecast boats cars planes;
run;
```

The preceding statements accumulate the data into a daily time series, generate forecasts for the BOATS, CARS, and PLANES variables in the input data set (WEBSITES) for the next seven days, and store the forecasts in the output data set (NEXTWEEK). Because the MODEL= option is not specified in the FORECAST statement, a simple exponential smoothing model is fit to each series.

Syntax: ESM Procedure

The following statements are available in the ESM procedure:

PROC ESM *options* **;**
BY *variables* **;**
ID *variable* **INTERVAL=** *interval* < *options* > **;**
FORECAST *variable-list* / < *options* > **;**

Functional Summary

The statements and options that control the ESM procedure are summarized in Table 14.1.

Table 14.1 Functional Summary

Description	Statement	Option
Statements		
Specify data sets and options	PROC ESM	
Specify BY-group processing	BY	
Specify variables to forecast	FORECAST	
Specify the time ID variable	ID	
Data Set Options		
Specify the input data set	PROC ESM	DATA=
Specify to output forecasts only	PROC ESM	NOOUTALL
Specify the output data set	PROC ESM	OUT=
Specify parameter output data set	PROC ESM	OUTEST=
Specify forecast output data set	PROC ESM	OUTFOR=
Specify the forecast procedure information output data set	PROC ESM	OUTPROCINFO=
Specify statistics output data set	PROC ESM	OUTSTAT=
Specify summary output data set	PROC ESM	OUTSUM=
Replace actual values held back	FORECAST	REPLACEBACK
Replace missing values	FORECAST	REPLACEMISSING
Use forecast value to append	FORECAST	USE=
Accumulation and Seasonality Options		
Specify accumulation frequency	ID	INTERVAL=
Specify length of seasonal cycle	PROC ESM	SEASONALITY=
Specify interval alignment	ID	ALIGN=

Table 14.1 *continued*

Description	Statement	Option
Specify that time ID variable values are not sorted	ID	NOTSORTED
Specify starting time ID value	ID	START=
Specify ending time ID value	ID	END=
Specify accumulation statistic	ID, FORECAST	ACCUMULATE=
Specify missing value interpretation	ID, FORECAST	SETMISSING=
Specify zero value interpretation	ID, FORECAST	ZEROMISS=
Forecasting Horizon, Holdback Options		
Specify data to hold back	PROC ESM	BACK=
Specify forecast horizon or lead	PROC ESM	LEAD=
Specify horizon to start summation	PROC ESM	STARTSUM=
Forecasting Model Options		
Specify confidence limit width	FORECAST	ALPHA=
Specify forecast model	FORECAST	MODEL=
Specify median forecasts	FORECAST	MEDIAN
Specify backcast initialization	FORECAST	NBACKCAST=
Specify model transformation	FORECAST	TRANSFORM=
Printing and Plotting Control Options		
Specify time ID format	ID	FORMAT=
Specify graphical output	PROC ESM	PLOT=
Specify printed output	PROC ESM	PRINT=
Specify detailed printed output	PROC ESM	PRINTDETAILS
Miscellaneous Options		
Specify that analysis variables are processed in sorted order	PROC ESM	SORTNAMES
Limit error and warning messages	PROC ESM	MAXERROR=

The following sections describe the PROC ESM statement and then describe the other statements in alphabetical order.

PROC ESM Statement

PROC ESM *options* **;**

You can specify the following *options*:

BACK=*n*
specifies the number of observations before the end of the data where the multistep forecasts are to begin. By default, BACK=0.

DATA=*SAS-data-set*
names the SAS data set that contains the input data for the procedure to forecast. If the DATA= option is not specified, the most recently created SAS data set is used.

LEAD=*n*
specifies the number of periods ahead to forecast (forecast lead or horizon). By default, LEAD=12.

The LEAD= value is relative to the BACK= option specification and to the last observation in the input data set or the accumulated series, and not to the last nonmissing observation of a particular series. Thus, if a series has missing values at the end, the actual number of forecasts computed for that series is greater than the LEAD= value.

MAXERROR=*number*
limits the number of warning and error messages produced during the execution of the procedure to the specified value. This option is particularly useful in BY-group processing where it can be used to suppress the recurring messages. By default, MAXERRORS=50.

NOOUTALL
specifies that only forecasts are written to the OUT= and OUTFOR= data sets. The NOOUTALL option includes only the final forecast observations in the output data sets; it does not include the one-step forecasts for the data before the forecast period.

The OUT= and OUTFOR= data set will only contain the forecast results starting at the next period following the last observation and ending with the forecast horizon specified by the LEAD= option.

OUT=*SAS-data-set*
names the output data set to contain the forecasts of the variables specified in the subsequent FORECAST statements. If an ID variable is specified, it is also included in the OUT= data set. The values are accumulated based on the ACCUMULATE= option, and forecasts are appended to these values based on the USE= option in the FORECAST statement. The OUT= data set is particularly useful in extending the independent variables. The OUT= data set can be used as the input data set in a subsequent PROC step to forecast a dependent series by using a regression modeling procedure. If the OUT= option is not specified, a default output data set is created by using the DATA*n* convention. If you do not want the OUT= data set created, use OUT=_NULL_.

OUTEST=*SAS-data-set*
names the output data set to contain the model parameter estimates and the associated test statistics and probability values. The OUTEST= data set is useful for evaluating the significance of the model parameters and understanding the model dynamics.

OUTFOR=*SAS-data-set*
names the output data set to contain the forecast time series components (actual, predicted, lower confidence limit, upper confidence limit, prediction error, prediction standard error). The OUTFOR= data set is useful for displaying the forecasts in tabular or graphical form.

OUTPROCINFO=*SAS-data-set*
names the output data set to contain information in the SAS log, specifically the number of notes, errors, and warnings and the number of series processed, forecasts requested, and forecasts failed.

OUTSTAT=*SAS-data-set*
names the output data set to contain the statistics of fit (or goodness-of-fit statistics). The OUTSTAT= data set is useful for evaluating how well the model fits the series.

OUTSUM=*SAS-data-set*
names the output data set to contain the summary statistics and the forecast summation. The summary statistics are based on the accumulated time series when the ACCUMULATE= or SETMISSING= option is specified. The forecast summations are based on the LEAD=, STARTSUM=, and USE= options. The OUTSUM= data set is useful when forecasting large numbers of series and a summary of the results are needed.

PLOT=*option* **|** **(** *options* **)**
specifies the graphical output desired. By default, the ESM procedure produces no graphical output. The following plotting options are available:

ACF	plots prediction error autocorrelation function graphics.
ALL	is the same as specifying all of the PLOT= options.
BASIC	equivalent to specifying PLOT=(CORR ERRORS MODELFORECASTS).
CORR	plots the prediction error series graphics panel containing the ACF, IACF, PACF, and white noise probability plots.
ERRORS	plots prediction error time series graphics.
FORECASTS	plots forecast graphics.
FORECASTSONLY	plots the forecast in the forecast horizon only.
IACF	plots prediction error inverse autocorrelation function graphics.
LEVELS	plots smoothed level component graphics.
MODELFORECASTS	plots the one-step ahead model forecast and its confidence bands in the historical period; the forecast and its confidence bands over the forecast horizon.
MODELS	plots model graphics.
PACF	plots prediction error partial autocorrelation function graphics.
PERIODOGRAM	plots prediction error periodogram.
SEASONS	plots smoothed seasonal component graphics.
SPECTRUM	plots periodogram and smoothed periodogram of the prediction error series in a single graph.

TRENDS plots smoothed trend (slope) component graphics.

WN plots white noise graphics.

For example, PLOT=FORECASTS plots the forecasts for each series. The PLOT= option produces printed output for these results by using the Output Delivery System (ODS).

PRINT=*option* | **(** *options* **)**
specifies the printed output desired. By default, the ESM procedure produces no printed output. The following printing options are available:

ESTIMATES prints the results of parameter estimation.

FORECASTS prints the forecasts.

PERFORMANCE prints the performance statistics for each forecast.

PERFORMANCESUMMARY prints the performance summary for each BY group.

PERFORMANCEOVERALL prints the performance summary for all of the BY groups.

STATISTICS prints the statistics of fit.

STATES prints the backcast, initial, and final states.

SUMMARY prints the summary statistics for the accumulated time series.

ALL Same as PRINT=(ESTIMATES FORECASTS STATISTICS SUMMARY).

For example, PRINT=FORECASTS prints the forecasts, PRINT=(ESTIMATES FORECASTS) prints the parameter estimates and the forecasts, and PRINT=ALL prints all of the output.

PRINTDETAILS
specifies that output requested with the PRINT= option be printed in greater detail.

SEASONALITY=*number*
specifies the length of the seasonal cycle. For example, SEASONALITY=3 means that every group of three observations forms a seasonal cycle. The SEASONALITY= option is applicable only for seasonal forecasting models. By default, the length of the seasonal cycle is one (no seasonality) or the length implied by the INTERVAL= option specified in the ID statement. For example, INTERVAL=MONTH implies that the length of the seasonal cycle is 12.

SORTNAMES
specifies that the variables specified in the FORECAST statements are processed in sorted order.

STARTSUM=*n*
specifies the starting forecast lead (or horizon) for which to begin summation of the forecasts specified by the LEAD= option. The STARTSUM= value must be less than the LEAD= value. By default, STARTSUM=1; that is, the sum from the one-step ahead forecast (which is the first forecast in the forecast horizon) to the multistep forecast specified by the LEAD= option.

The prediction standard errors of the summation of forecasts take into account the correlation between the multistep forecasts. For more information about the STARTSUM= option, see the section "Forecast Summation" on page 843.

BY Statement

BY *variables* **;**

A BY statement can be used with PROC ESM to obtain separate dummy variable definitions for groups of observations defined by the BY variables.

When a BY statement appears, the procedure expects the input data set to be sorted in order of the BY variables.

If your input data set is not sorted in ascending order, use one of the following alternatives:

- Sort the data by using the SORT procedure with a similar BY statement.
- Specify the option NOTSORTED or DESCENDING in the BY statement for the ESM procedure. The NOTSORTED option does not mean that the data are unsorted but rather that the data are arranged in groups (according to values of the BY variables) and that these groups are not necessarily in alphabetical or increasing numeric order.
- Create an index on the BY variables by using the DATASETS procedure.

For more information about the BY statement, see *SAS Language Reference: Concepts*. For more information about the DATASETS procedure, see the discussion in the *Base SAS Procedures Guide*.

FORECAST Statement

FORECAST *variable-list* **/** < *options* > **;**

The FORECAST statement lists the numeric variables in the DATA= data set whose accumulated values represent time series to be modeled and forecast. The options specify which forecast model is to be used.

A data set variable can be specified in only one FORECAST statement. Any number of FORECAST statements can be used. You can specify the following *options*:

ACCUMULATE=*option*

specifies how the data set observations are accumulated within each time period for the variables listed in the FORECAST statement. If the ACCUMULATE= option is not specified in the FORECAST statement, accumulation is determined by the ACCUMULATE= option in the ID statement. Use the ACCUMULATE= option with multiple FORECAST statements when you want different accumulation specifications for different variables. For more information, see the ACCUMULATE= option in the ID statement.

ALPHA=*number*

specifies the significance level to use in computing the confidence limits of the forecast. The ALPHA= value must be between 0 and 1. By default, ALPHA=0.05, which produces 95% confidence intervals.

MEDIAN
specifies that the median forecast values are to be estimated. Forecasts can be based on the mean or median. By default, the mean value is provided. If no transformation is applied to the time series by using the TRANSFORM= option, the mean and median forecast values are identical.

MODEL=*model-name*
specifies the forecasting model to be used to forecast the time series. You can specify the following forecasting *model-names*:

NONE	produces no forecast, but the time series is appended with missing values in the OUT= data set. This option is useful when the results stored in the OUT= data set are used in a subsequent analysis where forecasts of the independent variables are needed to forecast the dependent variable.
SIMPLE	performs simple (single) exponential smoothing.
DOUBLE	performs double (Brown) exponential smoothing.
LINEAR	performs linear (Holt) exponential smoothing.
DAMPTREND	performs damped trend exponential smoothing.
ADDSEASONAL | SEASONAL	performs additive seasonal exponential smoothing.
MULTSEASONAL	performs multiplicative seasonal exponential smoothing.
WINTERS	uses the Winters multiplicative method.
ADDWINTERS	uses the Winters additive method.

By default, MODEL=SIMPLE.

NBACKCAST=*n*
specifies the number of observations used to initialize the backcast states. The default is the entire series.

REPLACEBACK
replaces actual values that are excluded by the BACK= option with one-step-ahead forecasts in the OUT= data set.

REPLACEMISSING
replaces embedded missing values with one-step-ahead forecasts in the OUT= data set.

SETMISSING=*option* | *number*
specifies how missing values (either input or accumulated) are assigned in the accumulated time series for variables listed in the FORECAST statement. If the SETMISSING= option is not specified in the FORECAST statement, missing values are set based on the SETMISSING= option of the ID statement. For more information, see the SETMISSING= option in the ID statement.

TRANSFORM=*option*
specifies the time series transformation to be applied to the input or accumulated time series. The following transformations are provided:

NONE	no transformation.
LOG	logarithmic transformation

SQRT	square-root transformation
LOGISTIC	logistic transformation
BOXCOX(*n*)	Box-Cox transformation with parameter number where number is between –5 and 5

By default, TRANSFORM=NONE.

When the TRANSFORM= option is specified, the time series must be strictly positive. After the time series is transformed, the model parameters are estimated by using the transformed series. The forecasts of the transformed series are then computed, and finally the transformed series forecasts are inverse transformed. The inverse transform produces either mean or median forecasts depending on whether the MEDIAN option is specified. For more information, see the sections "Transformations" on page 842 and "Inverse Transformations" on page 843.

USE=*option*

specifies which forecast values are appended to the actual values in the OUT= and OUTSUM= data sets. You can specify the following *options*:

PREDICT	appends the predicted values to the actual values.
LOWER	appends the lower confidence limit values to the actual values.
UPPER	appends the upper confidence limit values to the actual values.

By default, USE=PREDICT.

Thus, the USE= option enables the OUT= and OUTSUM= data sets to be used for worst-case, best-case, average-case, and median-case decisions.

ZEROMISS=NONE | LEFT | RIGHT | BOTH

specifies how beginning or ending zero values (either input or accumulated) are interpreted in the accumulated time series for variables listed in the FORECAST statement. If the ZEROMISS= option is not specified in the FORECAST statement, beginning or ending zero values are set to missing values based on the ZEROMISS= option in the ID statement. For more information, see the ZEROMISS= option in the ID statement.

ID Statement

ID *variable* **INTERVAL=** *interval* < *options* > **;**

The ID statement names a numeric variable that identifies observations in the input and output data sets. The ID variable's values are assumed to be SAS date or datetime values. In addition, the ID statement specifies the (desired) frequency associated with the time series. The ID statement options also specify how the observations are accumulated and how the time ID values are aligned to form the time series to be forecast. The information specified affects all variables specified in subsequent FORECAST statements. If the ID statement is specified, the INTERVAL= option must be specified. If an ID statement is not specified, the observation number, with respect to the BY group, is used as the time ID. You can specify the following *options*.

ACCUMULATE=*option*

specifies how the data set observations are accumulated within each time period. The frequency (width of each time interval) is specified by the INTERVAL= option. The ID variable contains the time ID values. Each time ID variable value corresponds to a specific time period. The accumulated values form the time series, which is used in subsequent model fitting and forecasting.

This option is particularly useful when there are gaps in the input data or when there are multiple input observations that coincide with a particular time period (for example, transactional data). The EXPAND procedure offers additional frequency conversions and transformations that can also be useful in creating a time series.

The following *options* determine how the observations are accumulated within each time period based on the ID variable and the frequency specified by the INTERVAL= option:

NONE No accumulation occurs; the ID variable values must be equally spaced with respect to the frequency.

TOTAL accumulates observations based on the total sum of their values.

AVERAGE | AVG accumulates observations based on the average of their values.

MINIMUM | MIN accumulates observations based on the minimum of their values.

MEDIAN | MED accumulates observations based on the median of their values.

MAXIMUM | MAX accumulates observations based on the maximum of their values.

N accumulates observations based on the number of nonmissing observations.

NMISS accumulates observations based on the number of missing observations.

NOBS accumulates observations based on the number of observations.

FIRST accumulates observations based on the first of their values.

LAST accumulates observations based on the last of their values.

STDDEV | STD accumulates observations based on the standard deviation of their values.

CSS accumulates observations based on the corrected sum of squares of their values.

USS accumulates observations based on the uncorrected sum of squares of their values.

By default, ACCUMULATE=NONE.

If the ACCUMULATE= option is specified, the SETMISSING= option is useful for specifying how accumulated missing values are treated. If missing values should be interpreted as zero, then SETMISSING=0 should be used. For more information about accumulation, see the section "Accumulation" on page 840.

ALIGN=*option*

controls the alignment of SAS dates used to identify output observations. The ALIGN= option accepts the following values: BEGINNING | BEG | B, MIDDLE | MID | M, and ENDING | END | E. BEGINNING is the default.

END=*date* | *datetime*

specifies a SAS date or datetime literal value that represents the end of the data. If the last time ID variable value is less than the END= value, the series is extended with missing values. If the

last time ID variable value is greater than the END= value, the series is truncated. For example, **END='1jan2008'D** specifies that data for time periods after the first of January 2008 not be used. The option **END="&sysdate"D** uses the automatic macro variable SYSDATE to extend or truncate the series to the current date. This option and the START= option can be used to ensure that data associated with each BY group contain the same number of observations.

FORMAT=*format*
specifies the SAS format for the time ID values. If the FORMAT= option is not specified, the default format is implied from the INTERVAL= option.

INTERVAL=*interval*
specifies the frequency of the input time series or for the time series to be accumulated from the input data. For example, if the input data set consists of quarterly observations, then INTERVAL=QTR should be used. If the SEASONALITY= option is not specified, the length of the seasonal cycle is implied by the INTERVAL= option. For example, INTERVAL=QTR implies a seasonal cycle of length 4. If the ACCUMULATE= option is also specified, the INTERVAL= option determines the time periods for the accumulation of observations.

The basic intervals are YEAR, SEMIYEAR, QTR, MONTH, SEMIMONTH, TENDAY, WEEK, WEEKDAY, DAY, HOUR, MINUTE, SECOND. For more information about the intervals that can be specified, see Chapter 4, "Date Intervals, Formats, and Functions."

NOTSORTED
specifies that the time ID values are not in sorted order. The ESM procedure sorts the data with respect to the time ID prior to analysis.

SETMISSING=*option* | *number*
specifies how missing values (either input or accumulated) are assigned in the accumulated time series. If a number is specified, missing values are set to that number. If a missing value in the input data set indicates an unknown value, the SETMISSING= option should not be used. If a missing value indicates no value, SETMISSING=0 should be used. You typically use SETMISSING=0 for transactional data, because no recorded data usually implies no activity. The following options can also be used to determine how missing values are assigned:

MISSING	sets missing values to missing. The missing observations are replaced with predicted values that are computed from the exponential smoothing model.
AVERAGE | AVG	sets missing values to the accumulated average value.
MINIMUM | MIN	sets missing values to the accumulated minimum value.
MEDIAN | MED	sets missing values to the accumulated median value.
MAXIMUM | MAX	sets missing values to the accumulated maximum value.
FIRST	sets missing values to the accumulated first nonmissing value.
LAST	sets missing values to the accumulated last nonmissing value.
PREVIOUS | PREV	sets missing values to the previous accumulated nonmissing value. Missing values at the beginning of the accumulated series remain missing.
NEXT	sets missing values to the next accumulated nonmissing value. Missing values at the end of the accumulated series remain missing.

By default, SETMISSING=MISSING.

START=*date* | *datetime*
specifies a SAS date or datetime literal value that represents the beginning of the data. If the first time ID variable value is greater than the START= value, the series is prefixed with missing values. If the first time ID variable value is less than the START= value, the series is truncated. This option and the END= option can be used to ensure that data associated with each BY group contain the same number of observations.

ZEROMISS=NONE | LEFT | RIGHT | BOTH
specifies how beginning and ending zero values (either input or accumulated) are interpreted in the accumulated time series. You can specify the following values:

NONE Beginning and ending zeros are unchanged.

LEFT Beginning zeros are set to missing.

RIGHT Ending zeros are set to missing.

BOTH Both beginning and ending zeros are set to missing.

By default, ZEROMISS=NONE.

If the accumulated series is all missing or zero, the series is not changed.

Details: ESM Procedure

The ESM procedure can be used to forecast time series data as well as transactional data. If the data are transactional, then the procedure must first accumulate the data into a time series before it can be forecast. The procedure uses the sequential steps in Table 14.2 to produce forecasts, with the options that control the step listed to the right.

Table 14.2 ESM Processing Steps and Control Options

Step	Operation	Option	Statements
1	Accumulation	ACCUMULATE=	ID
2	Missing value interpretation	SETMISSING=	ID, FORECAST
3	Transformations	TRANSFORM=	FORECAST
4	Parameter estimation	MODEL=	FORECAST
5	Forecasting	MODEL=, LEAD=	FORECAST, PROC ESM
6	Inverse transformation	TRANSFORM, MEDIAN	FORECAST
7	Summation of forecasts	LEAD=, STARTSUM=	PROC ESM

Each of the steps shown in Table 14.2 is described in the following sections.

Accumulation

If the ACCUMULATE= option is specified in the ID statement, data set observations are accumulated within each time period. The frequency (width of each time interval) is specified by the INTERVAL= option,

and the ID variable contains the time ID values. Each time ID value corresponds to a specific time period. Accumulation is particularly useful when the input data set contains transactional data, whose observations are not spaced with respect to any particular time interval. The accumulated values form the time series that is used in subsequent analyses by the ESM procedure.

For example, suppose a data set contains the following observations:

```
19MAR1999    10
19MAR1999    30
11MAY1999    50
12MAY1999    20
23MAY1999    20
```

If the INTERVAL=MONTH option is specified in the ID statement, all of the preceding observations fall within three time periods: March 1999, April 1999, and May 1999. The observations are accumulated within each time period as follows.

If the ACCUMULATE=NONE option is specified, an error is generated because the ID variable values are not equally spaced with respect to the specified frequency (MONTH).

If the ACCUMULATE=TOTAL option is specified, the resulting time series is

```
01MAR1999    40
01APR1999    .
01MAY1999    90
```

If the ACCUMULATE=AVERAGE option is specified, the resulting time series is

```
01MAR1999    20
01APR1999    .
01MAY1999    30
```

If the ACCUMULATE=MINIMUM option is specified, the resulting time series is

```
01MAR1999    10
01APR1999    .
01MAY1999    20
```

If the ACCUMULATE=MEDIAN option is specified, the resulting time series is

```
01MAR1999    20
01APR1999    .
01MAY1999    20
```

If the ACCUMULATE=MAXIMUM option is specified, the resulting time series is

```
01MAR1999    30
01APR1999    .
01MAY1999    50
```

If the ACCUMULATE=FIRST option is specified, the resulting time series is

```
01MAR1999    10
01APR1999    .
01MAY1999    50
```

If the ACCUMULATE=LAST option is specified, the resulting time series is

```
O1MAR1999    30
O1APR1999    .
O1MAY1999    20
```

If the ACCUMULATE=STDDEV option is specified, the resulting time series is

```
O1MAR1999    14.14
O1APR1999    .
O1MAY1999    17.32
```

As can be seen from the preceding examples, even though the data set observations contained no missing values, the accumulated time series can have missing values.

Missing Value Interpretation

Sometimes missing values should be interpreted as truly unknown values and retained as missing values in the data set. The forecasting models used by the ESM procedure can effectively handle missing values (see the section "Missing Value Modeling Issues" on page 843). However, sometimes missing values are known, such as when missing values are created from accumulation and represent no observed values for the variable. In this case, the value for the period should be interpreted as zero (no values), and the SETMISSING=0 option should be used to cause PROC ESM to recode missing values as zero. In other cases, missing values should be interpreted as global values, such as minimum or maximum values of the accumulated series. The accumulated and missing-value-recoded time series is used in subsequent analyses in PROC ESM.

Transformations

If the TRANSFORM= option is specified in the FORECAST statement, the time series is transformed prior to model parameter estimation and forecasting. Only strictly positive series can be transformed. An error is generated when the TRANSFORM= option is used with a nonpositive series. (For more information about forecasting transformed time series, see Chapter 63, "Forecasting Process Details.")

Parameter Estimation

All the parameters (smoothing weights) associated with the exponential smoothing model used to forecast the time series (as specified by the MODEL= option) are optimized based on the data, with the default parameter restrictions imposed. If the TRANSFORM= option is specified, the transformed time series data are used to estimate the model parameters.

The techniques used in the ESM procedure are identical to those used for exponential smoothing models in the Time Series Forecasting System of SAS/ETS software. For more information, see Chapter 55, "Overview of the Time Series Forecasting System."

Missing Value Modeling Issues

The treatment of missing values varies with the forecasting model. Missing values after the start of the series are replaced with one-step-ahead predicted values, and the predicted values are used in the smoothing equations.

The treatment of missing values can also be specified with the SETMISSING= option, which changes the missing values prior to modeling.

NOTE: Even if all of the observed data are nonmissing, the ACCUMULATE= option can create missing values in the accumulated series (when the data contain no observations for some of the time periods specified by the INTERVAL= option).

Forecasting

Once the model parameters are estimated, one-step-ahead forecasts are generated for the full range of the accumulated and optionally transformed time series data, and multistep forecasts are generated from the end of the time series to the future time period specified by the LEAD= option. If there are missing values at the end of the time series, the forecast horizon will be greater than that specified by the LEAD= option.

Inverse Transformations

If the TRANSFORM= option is specified in the FORECAST statement, the forecasts of the transformed time series are inverse transformed. By default, forecasts of the mean (expected value) are generated. If the MEDIAN option is specified, median forecasts are generated. (For more information about forecasting transformed time series, see Chapter 63, "Forecasting Process Details.")

Statistics of Fit

The statistics of fit are computed by comparing the time series data (after accumulation and missing value recoding, if specified) with the generated forecasts. If the TRANSFORM= option is specified, the statistics of fit are based on the inverse transformed forecasts. (For more information about statistics of fit for forecasting models, see Chapter 63, "Forecasting Process Details.")

Forecast Summation

The multistep forecasts generated by the preceding steps can optionally be summed from the STARTSUM= value to the LEAD= value. For example, if the options STARTSUM=4 and LEAD=6 are specified in the PROC ESM statement, the four-step-ahead through six-step-ahead forecasts are summed.

The forecasts are simply summed; however, the prediction error variance of this sum is computed by taking into account the correlation between the individual predictions. (These variance-related computations are performed only when no transformation is specified; that is, when TRANSFORM=NONE.) The upper and

lower confidence limits for the sum of the predictions is then computed based on the prediction error variance of the sum.

The forecast summation is particularly useful when it is desirable to model in one frequency but the forecast of interest is another frequency. For example, if a time series has a monthly frequency (INTERVAL=MONTH) and you want a forecast for the third and fourth future months, a forecast summation for the third and fourth month can be obtained by specifying STARTSUM=3 and LEAD=4.

Data Set Output

The ESM procedure can create the OUT=, OUTEST=, OUTFOR=, OUTSTAT=, and OUTSUM= data sets. These data sets contain the variables listed in the BY statement and statistics related to the variables listing in the FORECAST statement. In general, if a forecasting step related to an output data set fails, the values of this step are not recorded or are set to missing in the related output data set and appropriate error and/or warning messages are recorded in the log.

OUT= Data Set

The OUT= data set contains the variables specified in the BY, ID, and FORECAST statements. If the ID statement is specified, the ID variable values are aligned and extended based on the ALIGN= and INTERVAL= options. The values of the variables specified in the FORECAST statements are accumulated based on the ACCUMULATE= option, and missing values are interpreted based on the SETMISSING= option. If the REPLACEMISSING option is specified, embedded missing values are replaced by the one-step-ahead predicted values.

These FORECAST variables are then extrapolated based on the forecasts from the fitted models, or extended with missing values when the MODEL=NONE option is specified. If USE=LOWER is specified, the variable is extrapolated with the lower confidence limits; if USE=UPPER, the variable is extrapolated using the upper confidence limits; otherwise, the variable values are extrapolated with the predicted values. If the TRANSFORM= option is specified, the predicted values contain either mean or median forecasts depending on whether or not the MEDIAN option is specified.

If any of the forecasting steps fail for a particular variable, the variable is extended by missing values.

OUTEST= Data Set

The OUTEST= data set contains the variables specified in the BY statement as well as the variables listed below. For variables listed in FORECAST statements where the option MODEL=NONE is specified, no observations are recorded in the OUTEST= data set. For variables listed in FORECAST statements where the option MODEL=NONE is not specified, the following variables in the OUTEST= data set contain observations related to the parameter estimation step:

NAME	variable name
MODEL	forecasting model
TRANSFORM	transformation
PARM	parameter name
EST	parameter estimate

STDERR	standard errors
TVALUE	*t* values
PVALUE	probability values

If the parameter estimation step fails for a particular variable, no observations are output to the OUTEST= data set for that variable.

OUTFOR= Data Set

The OUTFOR= data set contains the variables specified in the BY statement as well as the variables listed below. For variables listed in FORECAST statements where the option MODEL=NONE is specified, no observations are recorded in the OUTFOR= data set for these variables. For variables listed in FORECAST statements where the option MODEL=NONE is not specified, the following variables in the OUTFOR= data set contain observations related to the forecasting step:

NAME	variable name
TIMEID	time ID values
ACTUAL	actual values
PREDICT	predicted values
STD	prediction standard errors
LOWER	lower confidence limits
UPPER	upper confidence limits
ERROR	prediction errors

If the forecasting step fails for a particular variable, no observations are recorded in the OUTFOR= data set for that variable. If the TRANSFORM= option is specified, the values in the preceding variables are the inverse transform forecasts. If the MEDIAN option is specified, the median forecasts are stored; otherwise, the mean forecasts are stored.

OUTPROCINFO= Data Set

The OUTPROCINFO= data set contains information about the run of the ESM procedure. The following variables are present:

SOURCE	set to the name of the procedure, in this case ESM
NAME	name of an item being reported; can be the number of errors, notes, or warnings, number of forecasts requested, and so on
LABEL	descriptive label for the item in _NAME_
STAGE	set to the current stage of the procedure; for PROC ESM this is set to ALL
VALUE	value of the item specified in _NAME_

OUTSTAT= Data Set

The OUTSTAT= data set contains the variables specified in the BY statement as well as the variables listed below. For variables listed in FORECAST statements where the option MODEL=NONE is specified, no observations are recorded for these variables in the OUTSTAT= data set. For variables listed in FORECAST statements where the option MODEL=NONE is not specified, the following variables in the OUTSTAT= data set contain observations related to the statistics of fit:

NAME	variable name
REGION	the region in which the statistics are calculated. Statistics calculated in the fit region are indicated by FIT. Statistics calculated in the forecast region, which happens only if the BACK= option is greater than zero, are indicated by FORECAST.
DFE	degrees of freedom error
N	number of observations
NOBS	number of observations used
NMISSA	number of missing actuals
NMISSP	number of missing predicted values
NPARMS	number of parameters
TSS	total sum of squares
SST	corrected total sum of squares
SSE	sum of square error
MSE	mean square error
UMSE	unbiased mean square error
RMSE	root mean square error
URMSE	unbiased root mean square error
MAPE	mean absolute percent error
MAE	mean absolute error
MASE	mean absolute scaled error
RSQUARE	R-square
ADJRSQ	adjusted R-square
AADJRSQ	Amemiya's adjusted R-square
RWRSQ	random walk R-square
AIC	Akaike's information criterion
AICC	finite sample corrected AIC
SBC	Schwarz Bayesian information criterion
APC	Amemiya's prediction criterion
MAXERR	maximum error
MINERR	minimum error

MINPE	minimum percent error
MAXPE	maximum percent error
ME	mean error
MPE	mean percent error
MDAPE	median absolute percent error
GMAPE	geometric mean absolute percent error
MINPPE	minimum predictive percent error
MAXPPE	maximum predictive percent error
MSPPE	mean predictive percent error
MAPPE	symmetric mean absolute predictive percent error
MDAPPE	median absolute predictive percent error
GMAPPE	geometric mean absolute predictive percent error
MINSPE	minimum symmetric percent error
MAXSPE	maximum symmetric percent error
MSPE	mean symmetric percent error
SMAPE	symmetric mean absolute percent error
MDASPE	median absolute symmetric percent error
GMASPE	geometric mean absolute symmetric percent error
MINRE	minimum relative error
MAXRE	maximum relative error
MRE	mean relative error
MRAE	mean relative absolute error
MDRAE	median relative absolute error
GMRAE	geometric mean relative absolute error
MINAPES	minimum absolute error percent of standard deviation
MAXAPES	maximum absolute error percent of standard deviation
MAPES	mean absolute error percent of standard deviation
MDAPES	median absolute error percent of standard deviation
GMAPES	geometric mean absolute error percent of standard deviation

If the statistics of fit cannot be computed for a particular variable, no observations are recorded in the OUTSTAT= data set for that variable. If the TRANSFORM= option is specified, the values in the preceding variables are computed based on the inverse transform forecasts. If the MEDIAN option is specified, the median forecasts are the basis; otherwise, the mean forecasts are the basis.

For more information about the calculation of forecasting statistics of fit, see Chapter 63, "Forecasting Process Details."

OUTSUM= Data Set

The OUTSUM= data set contains the variables specified in the BY statement as well as the variables listed below. The OUTSUM= data set records the summary statistics for each variable specified in a FORECAST statement. For variables listed in FORECAST statements where the option MODEL=NONE is specified, the values related to forecasts are set to missing for those variables in the OUTSUM= data set. For variables listed in FORECAST statements where the option MODEL=NONE is not specified, the forecast values are set based on the USE= option.

The following variables related to summary statistics are based on the ACCUMULATE= and SETMISSING= options:

NAME	variable name
STATUS	forecasting status. Nonzero values imply that no forecast was generated for the series.
NOBS	number of observations
N	number of nonmissing observations
NMISS	number of missing observations
MIN	minimum value
MAX	maximum value
MEAN	mean value
STDDEV	standard deviation

The following variables related to forecast summation are based on the LEAD= and STARTSUM= options:

PREDICT	forecast summation predicted values
STD	forecast summation prediction standard errors
LOWER	forecast summation lower confidence limits
UPPER	forecast summation upper confidence limits

Variance-related computations are computed only when no transformation is specified (TRANSFORM=NONE).

The following variables related to multistep forecast are based on the LEAD= and USE= options:

LEAD*n* multistep forecast (*n* ranges from one to the value of the LEAD= option). If USE=LOWER, this variable contains the lower confidence limits; if USE=UPPER, this variable contains the upper confidence limits; otherwise, this variable contains the predicted values.

If the forecast step fails for a particular variable, the variables that are related to forecasting are set to missing for that variable. The OUTSUM= data set contains both a summary of the (accumulated) time series and optionally its forecasts for all series.

Printed Output

The ESM procedure optionally produces printed output by using the Output Delivery System (ODS). By default, the procedure produces no printed output. All output is controlled by the PRINT= and PRINTDETAILS options in the PROC ESM statement. In general, if a forecasting step that is related to printed output

fails, the values of this step are not printed and appropriate error or warning messages are recorded in the log. The printed output is similar to the output data sets.

The printed output produced by the PRINT= option values is described as follows:

SUMMARY	prints the summary statistics and forecast summaries similar to the OUTSUM= data set.
ESTIMATES	prints the parameter estimates similar to the OUTEST= data set.
FORECASTS	prints the forecasts similar to the OUTFOR= data set.
PERFORMANCE	prints the performance statistics.
PERFORMANCESUMMARY	prints the performance summary for each BY group.
PERFORMANCEOVERALL	prints the performance summary for all BY groups.
STATES	prints the backcast, initial, and final smoothed states.
STATISTICS	prints the statistics of fit similar to the OUTSTAT= data set.

The PRINTDETAILS option is the opposite of the NOOUTALL option. Specifically, if PRINT=FORECASTS and the PRINTDETAILS options are specified in the PROC ESM statement, the one-step-ahead forecasts through the range of the data are printed in addition to the information related to a specific forecasting model, such as the smoothing states. If the PRINTDETAILS option is not specified, only the multistep forecasts are printed.

ODS Table Names

Table 14.3 relates the PRINT= options to ODS tables.

Table 14.3 ODS Tables Produced in PROC ESM

ODS Table Name	Description	PRINT= Option
DescStats	Descriptive statistics	SUMMARY
ForecastSummary	Forecast summary	SUMMARY
ForecastSummation	Forecast summation	SUMMARY
ParameterEstimates	Parameter estimates	ESTIMATES
Forecasts	Forecasts	FORECASTS
Performance	Performance statistics	PERFORMANCE
PerformanceSummary	Performance summary	PERFORMANCESUMMARY
PerformanceOverall	Performance overall	PERFORMANCEOVERALL
SmoothedStates	Smoothed states	STATES
FitStatistics	Evaluation statistics of fit	STATISTICS
PerformanceStatistics	Performance (out-of-sample) statistics of fit	STATISTICS

The ODS table “ForecastSummary” is related to all time series within a BY group. The other tables are related to a single series within a BY group.

ODS Graphics

Statistical procedures use ODS Graphics to create graphs as part of their output. ODS Graphics is described in detail in Chapter 21, "Statistical Graphics Using ODS" (*SAS/STAT User's Guide*).

Before you create graphs, ODS Graphics must be enabled (for example, with the ODS GRAPHICS ON statement). For more information about enabling and disabling ODS Graphics, see the section "Enabling and Disabling ODS Graphics" in that chapter.

The overall appearance of graphs is controlled by ODS styles. Styles and other aspects of using ODS Graphics are discussed in the section "A Primer on ODS Statistical Graphics" in that chapter.

This section describes the use of ODS for creating graphics with the ESM procedure. To request these graphs you must specify the PLOT= option in the PROC ESM statement.

ODS Graph Names

PROC ESM assigns a name to each graph it creates using ODS. You can use these names to reference the graphs when using ODS. The names are listed in Table 14.4.

Table 14.4 ODS Graphics Produced by the PLOT= Option in PROC ESM

ODS Graph Name	Plot Description	PLOT= Option
ErrorACFNORMPlot	Standardized autocorrelation of prediction errors	ACF
ErrorACFPlot	Autocorrelation of prediction errors	ACF
ErrorHistogram	Prediction error histogram	ERRORS
ErrorCorrelationPlots	Prediction error plot panel	CORR
ErrorIACFNORMPlot	Standardized inverse autocorrelation of prediction errors	IACF
ErrorIACFPlot	Inverse autocorrelation of prediction errors	IACF
ErrorPACFNORMPlot	Standardized partial autocorrelation of prediction errors	PACF
ErrorPACFPlot	Partial autocorrelation of prediction errors	PACF
ErrorPeriodogramPlot	Periodogram of prediction errors	PERIODOGRAM
ErrorPlot	Plot of prediction errors	ERRORS
ErrorSpectralDensityPlot	Combined periodogram and spectral density estimate plot	SPECTRUM
ErrorWhiteNoiseLogProbPlot	White noise log probability plot of prediction errors	WN
ErrorWhiteNoiseProbPlot	White noise probability plot of prediction errors	WN

Table 14.4 *continued*

ODS Graph Name	Plot Description	PLOT= Option
ForecastsOnlyPlot	Forecasts only plot	FORECASTSONLY
ForecastsPlot	Forecasts plot	FORECASTS
LevelStatePlot	Smoothed level state plot	LEVELS
ModelForecastsPlot	Model and forecasts plot	MODELFORECASTS
ModelPlot	Model plot	MODELS
SeasonStatePlot	Smoothed season state plot	SEASONS
TrendStatePlot	Smoothed trend state plot	TRENDS

Examples: ESM Procedure

Example 14.1: Forecasting of Time Series Data

This example uses retail sales data to illustrate how the ESM procedure can be used to forecast time series data.

The following DATA step creates a data set from data recorded monthly at numerous points of sale. The data set, SALES, contains a variable, DATE, that represents time and a variable for each sales item. Each value of the DATE variable is recorded in ascending order, and the values of each of the other variables represent a single time series:

```
data sales;
   format date date9.;
   input date : date9. shoes socks laces dresses
                       coats shirts ties belts hats blouses;
   datalines;
01JAN1994 3557 3718 6368.80 575  987 10.8200 15.0000 102.600 12410 15013

   ... more lines ...
```

The following ESM procedure statements forecast each of the monthly time series:

```
proc esm data=sales out=nextyear;
   id date interval=month;
   forecast _numeric_;
run;
```

The preceding statements generate forecasts for every numeric variable in the input data set SALES for the next 12 months and store these forecasts in the output data set NEXTYEAR.

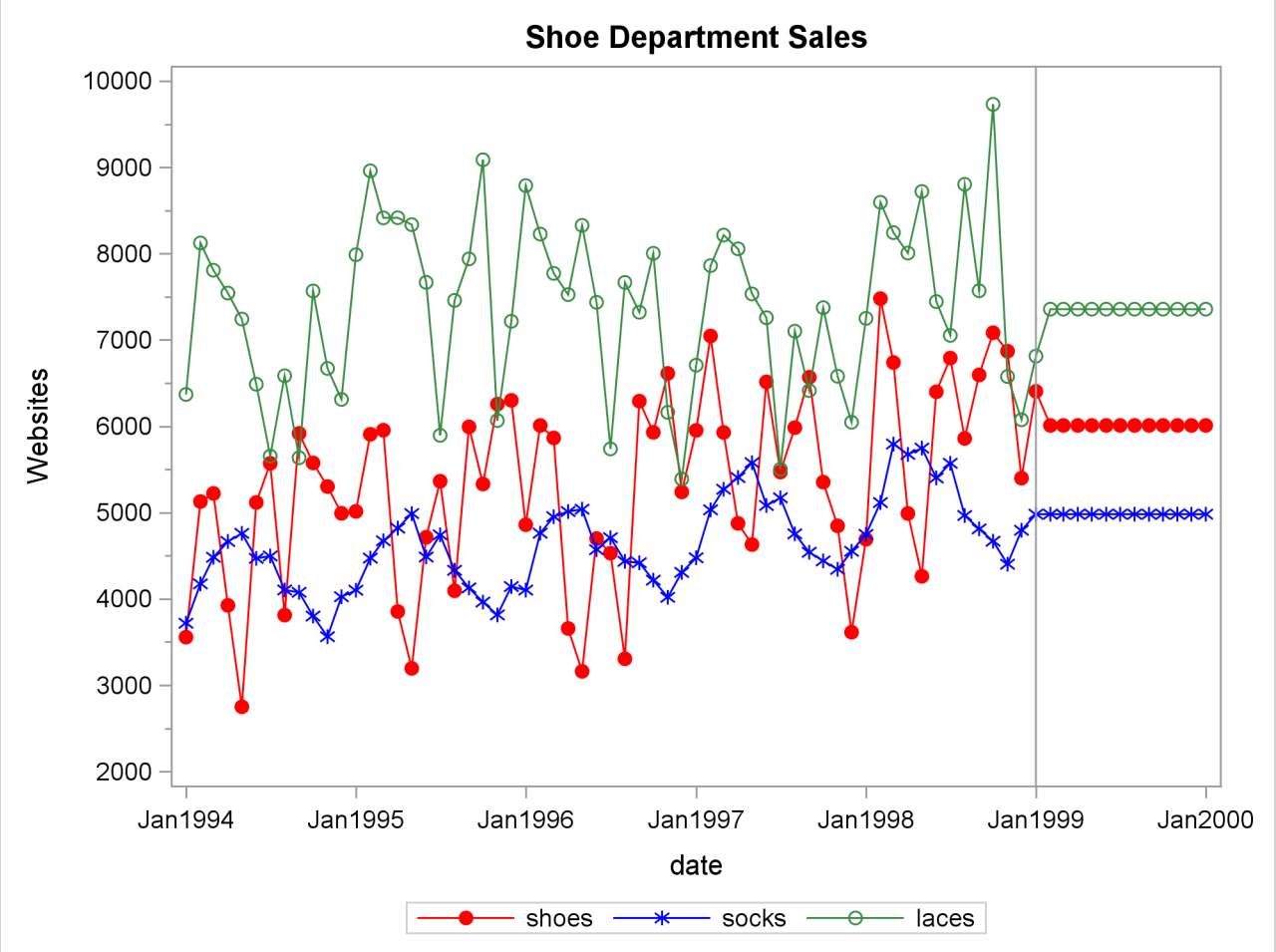
The following statements plot the forecasts:

```
title1 "Shoe Department Sales";
proc sgplot data=nextyear;
   series x=date y=shoes / markers
                           markerattrs=(symbol=circlefilled color=red)
```

```
                          lineattrs=(color=red);
    series x=date y=socks / markers
                          markerattrs=(symbol=asterisk color=blue)
                          lineattrs=(color=blue);
    series x=date y=laces / markers
                          markerattrs=(symbol=circle color=styg)
                         lineattrs=(color=styg);
    refline '01JAN1999'd / axis=x;
    xaxis values=('01JAN1994'd to '01DEC2000'd by year);
    yaxis values=(2000 to 10000 by 1000) minor label='Websites';
run;
```

The plots are shown in Output 14.1.1. The historical data are shown to the left of the reference line, and the forecasts for the next 12 monthly periods are shown to the right.

Output 14.1.1 Retail Sales Forecast Plots



The default simple exponential smoothing model is used because the MODEL= option is omitted from the FORECAST statement. Note that for simple exponential smoothing the forecasts are constant.

The following ESM procedure statements are identical to the preceding statements except that the PRINT=FORECASTS option is specified:

```
proc esm data=sales out=nextyear print=forecasts;
   id date interval=month;
   forecast _numeric_;
run;
```

In addition to forecasting each of the monthly time series, the preceding statements print the forecasts by using the Output Delivery System (ODS); the forecasts are partially shown in Output 14.1.2. This output shows the predictions, prediction standard errors, and upper and lower confidence limits for the next 12 monthly periods.

Output 14.1.2 Forecast Tables

Shoe Department Sales

The ESM Procedure

Forecasts for Variable shoes

Obs	Time	Forecasts	Standard Error	95% Confidence Limits	
62	FEB1999	6009.1986	1069.4059	3913.2016	8105.1956
63	MAR1999	6009.1986	1075.7846	3900.6996	8117.6976
64	APR1999	6009.1986	1082.1257	3888.2713	8130.1259
65	MAY1999	6009.1986	1088.4298	3875.9154	8142.4818
66	JUN1999	6009.1986	1094.6976	3863.6306	8154.7666
67	JUL1999	6009.1986	1100.9298	3851.4158	8166.9814
68	AUG1999	6009.1986	1107.1269	3839.2698	8179.1274
69	SEP1999	6009.1986	1113.2895	3827.1914	8191.2058
70	OCT1999	6009.1986	1119.4181	3815.1794	8203.2178
71	NOV1999	6009.1986	1125.5134	3803.2329	8215.1643
72	DEC1999	6009.1986	1131.5758	3791.3507	8227.0465
73	JAN2000	6009.1986	1137.6060	3779.5318	8238.8654

Example 14.2: Forecasting of Transactional Data

This example illustrates how the ESM procedure can be used to forecast transactional data.

The following DATA step creates a data set from data recorded at several Internet websites. The data set WEBSITES contains a variable, TIME, that represents time and the variables ENGINE, BOATS, CARS, and PLANES that represent Internet website data. Each value of the TIME variable is recorded in ascending order, and the values of each of the other variables represent a transactional data series.

The following ESM procedure statements forecast each of the transactional data series:

```
proc esm data=websites out=nextweek lead=7;
   id time interval=dtday accumulate=total;
   forecast boats cars planes;
run;
```

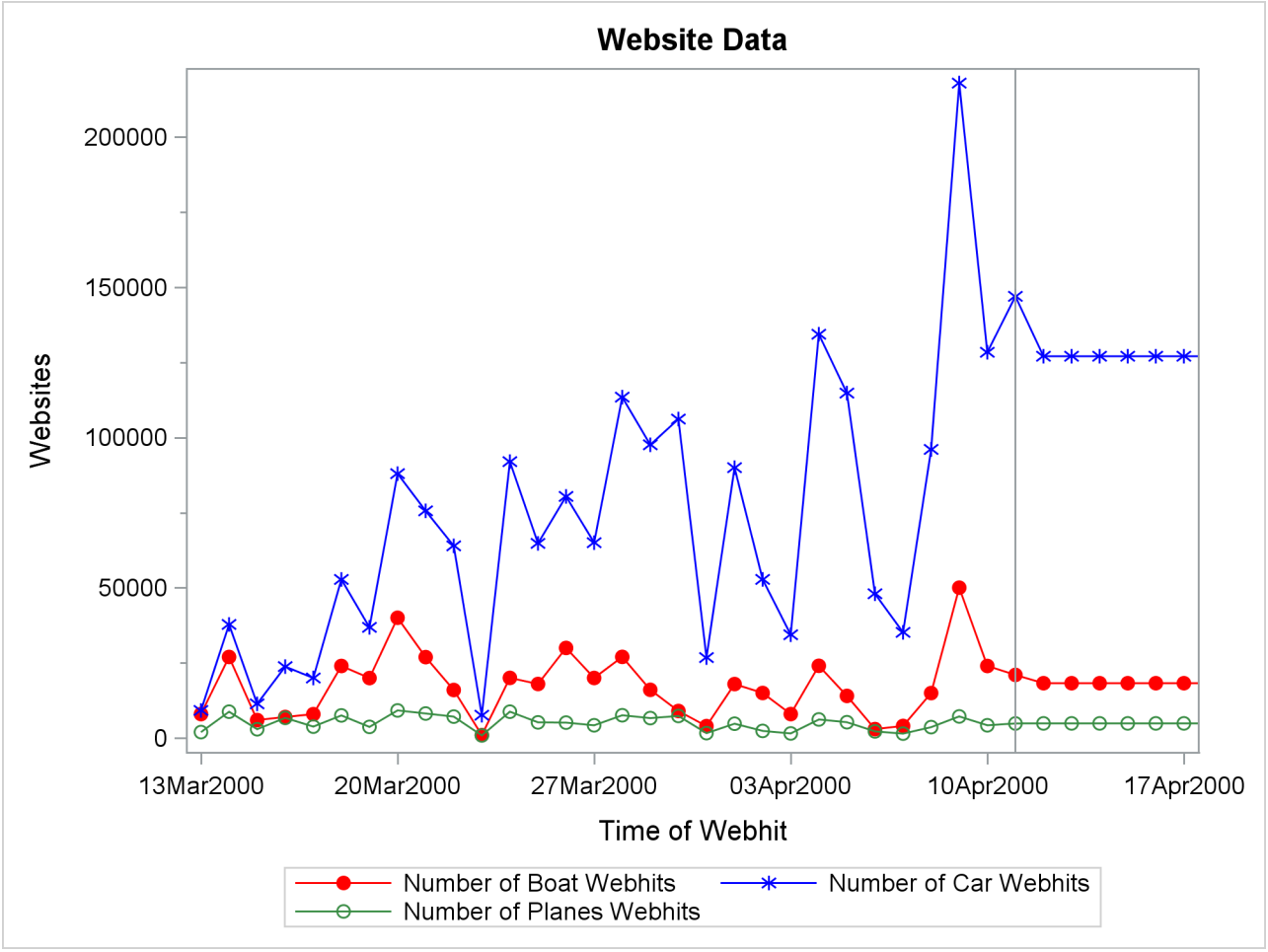
The preceding statements accumulate the data into a daily time series, generate forecasts for the BOATS, CARS, and PLANES variables in the input data set WEBSITES for the next week, and the forecasts are stored in the OUT= data set NEXTWEEK.

The following statements plot the forecasts related to the Internet data:

```
title1 "Website Data";
proc sgplot data=nextweek;
   series x=time y=boats / markers
                           markerattrs=(symbol=circlefilled color=red)
                           lineattrs=(color=red);
   series x=time y=cars / markers
                           markerattrs=(symbol=asterisk color=blue)
                           lineattrs=(color=blue);
   series x=time y=planes / markers
                           markerattrs=(symbol=circle color=styg)
                           lineattrs=(color=styg);
   refline '11APR2000:00:00:00'dt / axis=x;
   xaxis values=('13MAR2000:00:00:00'dt to '18APR2000:00:00:00'dt by dtweek);
   yaxis label='Websites' minor;
run;
```

The plots are shown in Output 14.2.1. The historical data are shown to the left of the reference line, and the forecasts for the next seven days are shown to the right.

Output 14.2.1 Internet Data Forecast Plots



Example 14.3: Specifying the Forecasting Model

This example illustrates how the ESM procedure can be used to specify different models for different series. Internet data from the previous example are used for this illustration.

This example forecasts the BOATS variable by using the seasonal exponential smoothing model (SEASONAL), the CARS variable by using the Winters (multiplicative) model (MULTWINTERS), and the PLANES variable by using the Log Winters (additive) model. The following ESM procedure statements forecast each of the transactional data series based on these requirements:

```
proc esm data=websites out=nextweek lead=7;
   id time interval=dtday accumulate=total;
   forecast boats   / model=seasonal;
   forecast cars    / model=multwinters;
   forecast planes  / model=addwinters transform=log;
run;
```

Example 14.4: Extending the Independent Variables for Multivariate Forecasts

In the previous example, the ESM procedure was used to forecast several transactional series variables by using univariate models. This example illustrates how the ESM procedure can be used to extend the independent variables that are associated with a multiple regression forecasting problem.

This example accumulates and forecasts the BOATS, CARS, and PLANES variables that were illustrated in the previous example. In addition, this example accumulates the ENGINES variable to form a time series that is then extended with missing values within the forecast horizon with the specification of MODEL=NONE.

```
proc esm data=websites out=nextweek lead=7;
   id time interval=dtday accumulate=total;
   forecast engines / model=none;
   forecast boats   / model=seasonal;
   forecast cars    / model=multwinters;
   forecast planes  / model=addwinters transform=log;
run;
```

The following AUTOREG procedure statements are used to forecast the ENGINES variable by regressing on the independent variables (BOATS, CARS, and PLANES):

```
proc autoreg data= nextweek;
   model engines = boats cars planes / noprint;
   output out=enginehits p=predicted;
run;
```

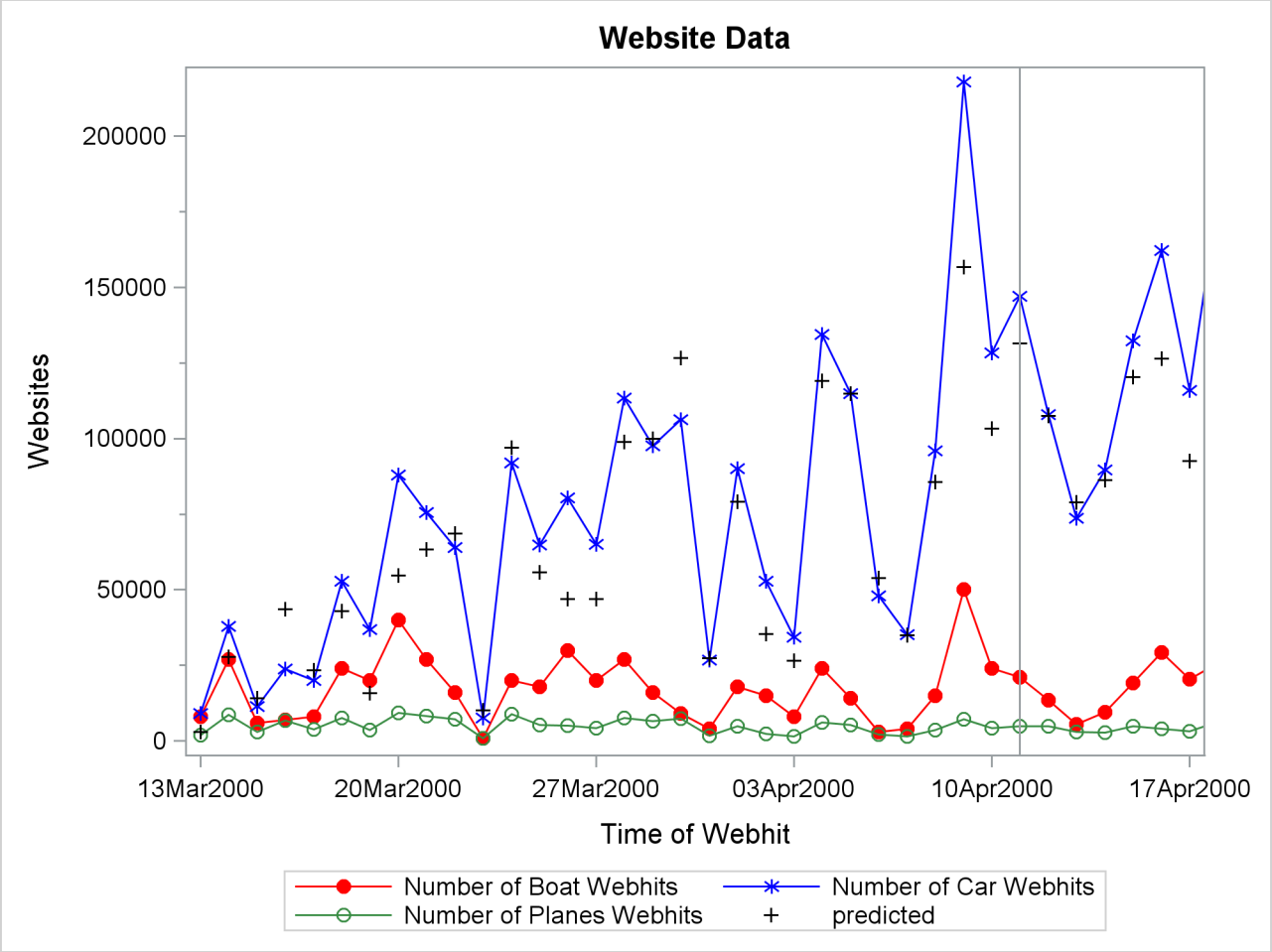
The NEXTWEEK data set created by PROC ESM is used as an input data set to PROC AUTOREG. The output data set from PROC AUTOREG contains the forecast of the variable ENGINES based on the regression model with the variables BOATS, CARS, and PLANES as regressors. For more information about autoregression models, see Chapter 8, "The AUTOREG Procedure."

The following statements plot the forecasts related to the ENGINES variable:

```
title1 "Website Data";
proc sgplot data=enginehits;
   series x=time y=boats / markers
                           markerattrs=(symbol=circlefilled color=red)
                           lineattrs=(color=red);
   series x=time y=cars / markers
                           markerattrs=(symbol=asterisk color=blue)
                           lineattrs=(color=blue);
   series x=time y=planes / markers
                           markerattrs=(symbol=circle color=styg)
                           lineattrs=(color=styg);
   scatter x=time y=predicted / markerattrs=(symbol=plus color=black);
   refline '11APR2000:00:00:00'dt / axis=x;
   xaxis values=('13MAR2000:00:00:00'dt to '18APR2000:00:00:00'dt by dtweek);
   yaxis label='Websites' minor;
run;
```

The plots are shown in Output 14.4.1. The historical data are shown to the left of the reference line, and the forecasts for the next seven daily periods are shown to the right.

Output 14.4.1 Internet Data Forecast Plots



Example 14.5: Illustration of ODS Graphics

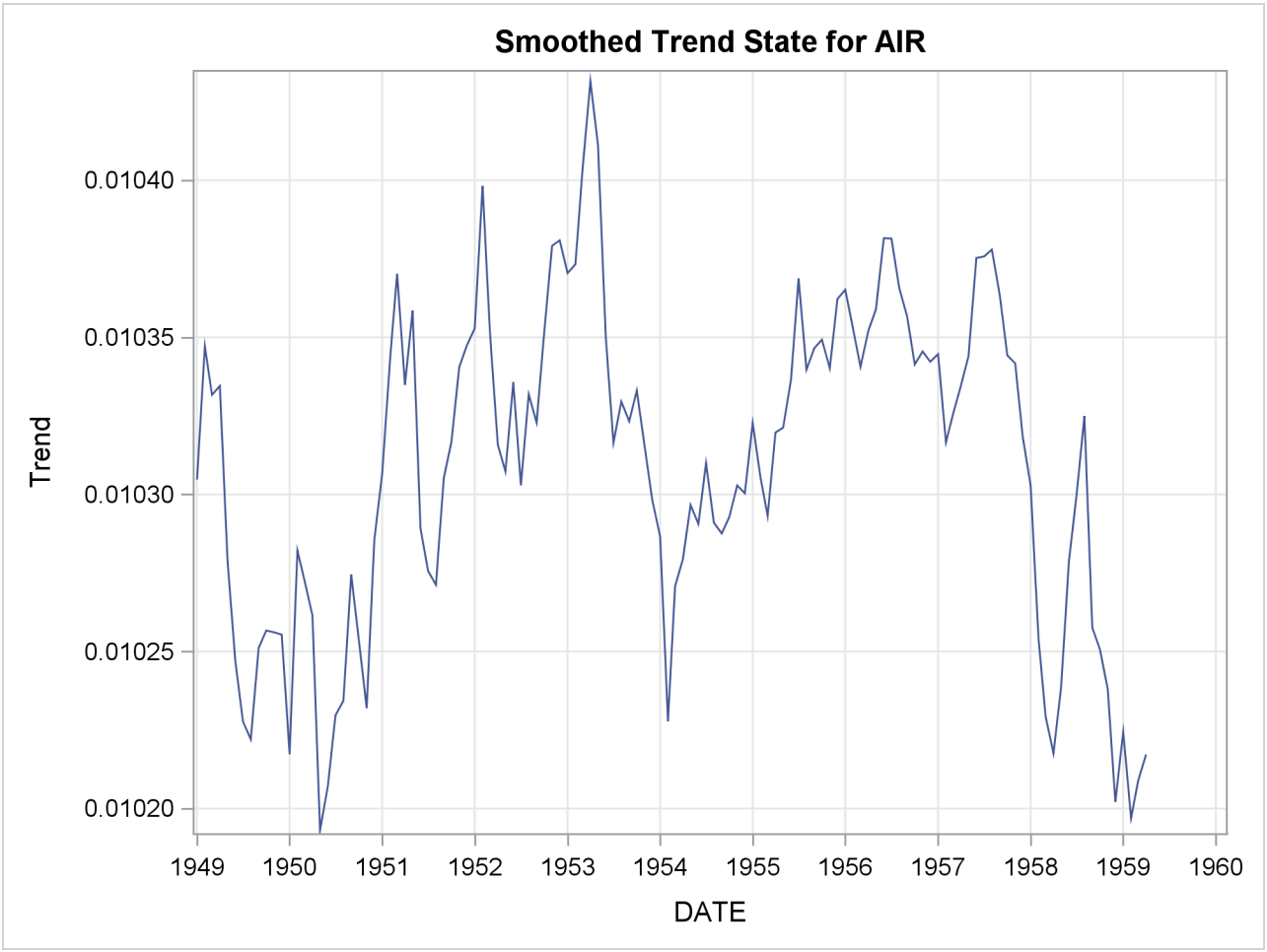
This example illustrates the use of ODS graphics in the ESM procedure and uses the SASHELP.AIR data set to forecast the time series of international airline travel.

The graphical displays are requested by specifying the PLOT= option in the PROC ESM statement. In this case, all plots are requested. Output 14.5.1 through Output 14.5.5 show a selection of the plots created.

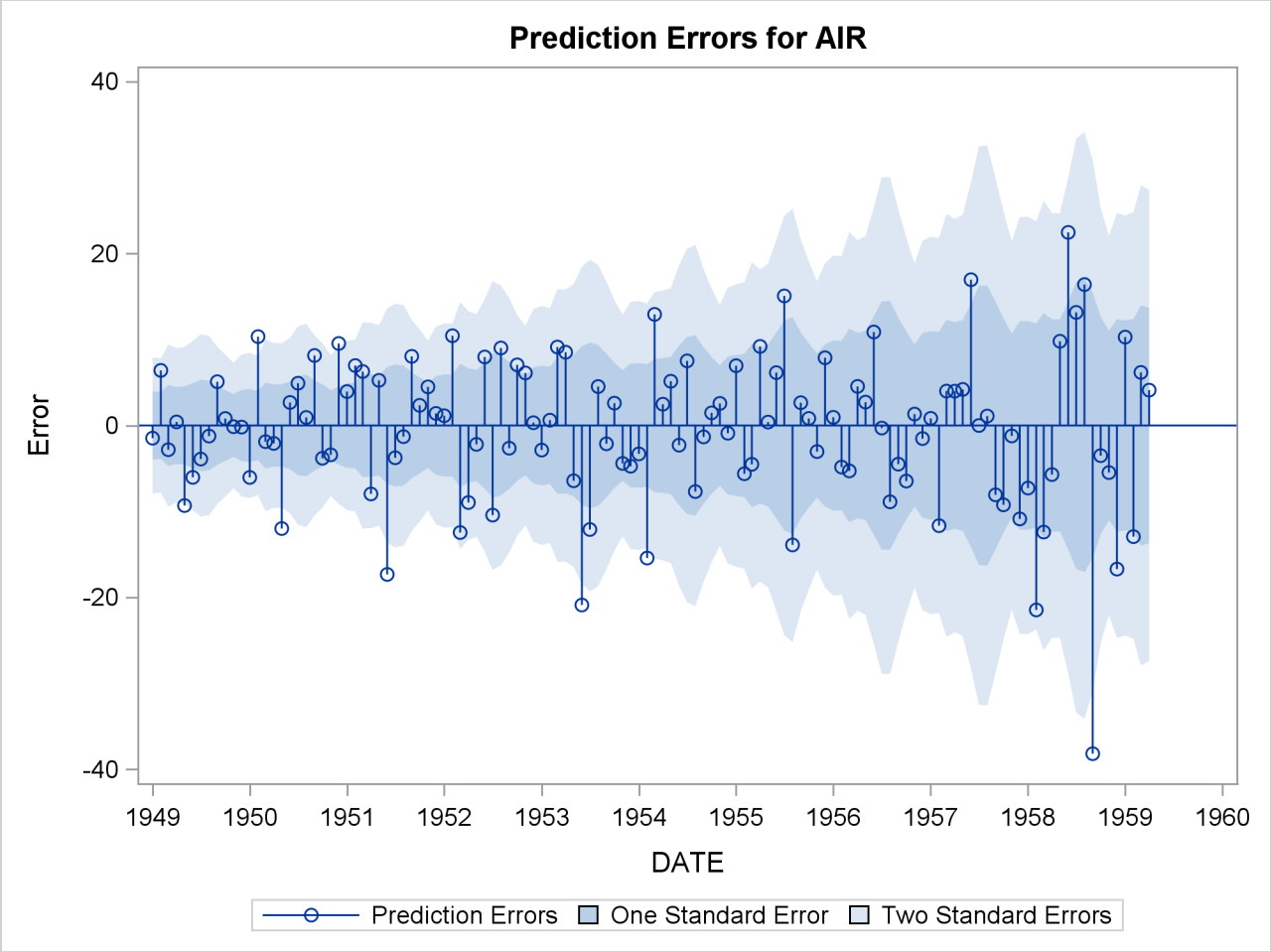
For information about the graphics available in the ESM procedure, see the section "ODS Graphics" on page 850.

```
proc esm data=sashelp.air out=_null_
         lead=20
         back=20
         print=all
         plot=all;
   id date interval=month;
   forecast air / model=addwinters transform=log;
run;
```

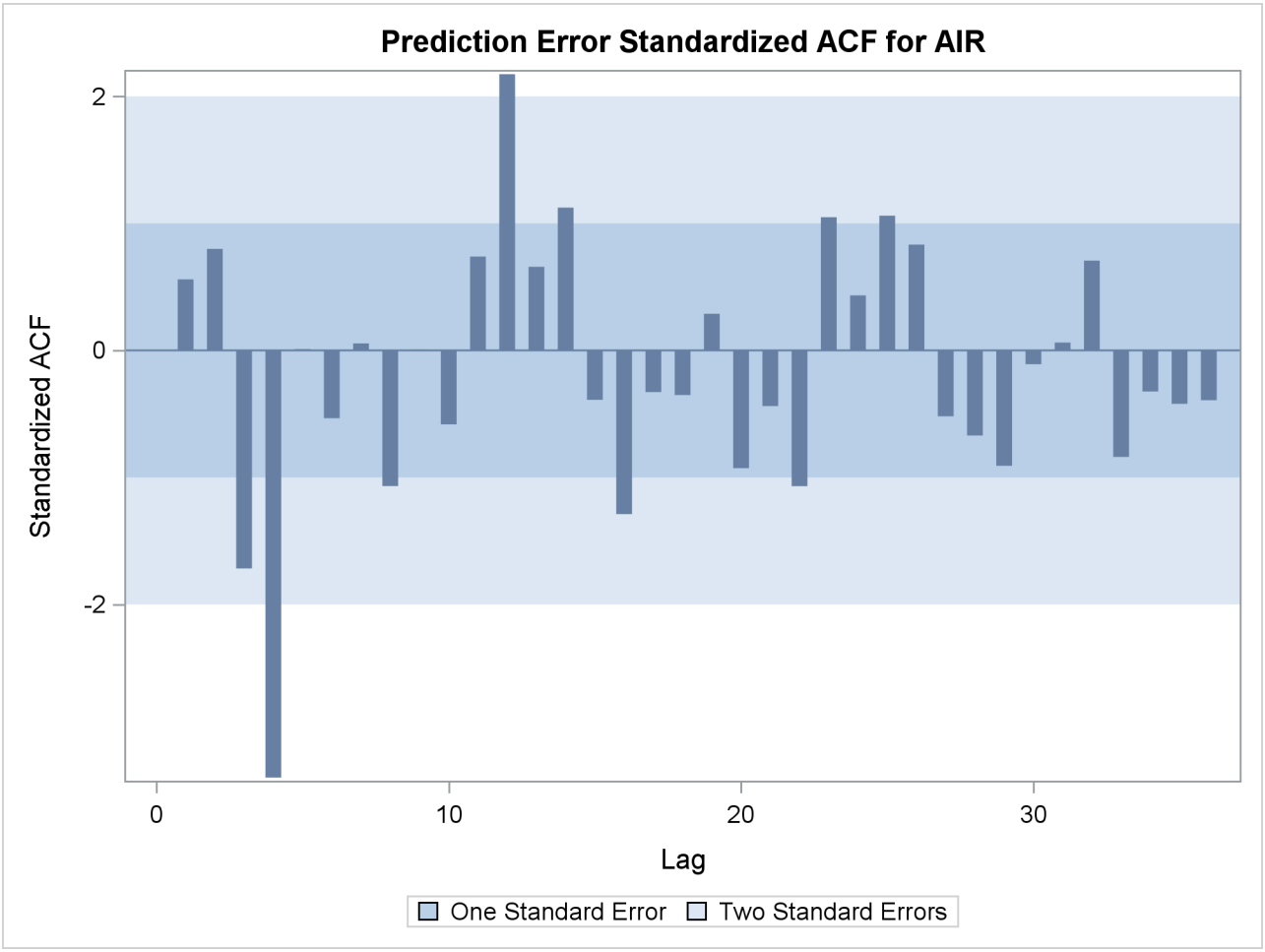
Output 14.5.1 Smoothed Trend Plot



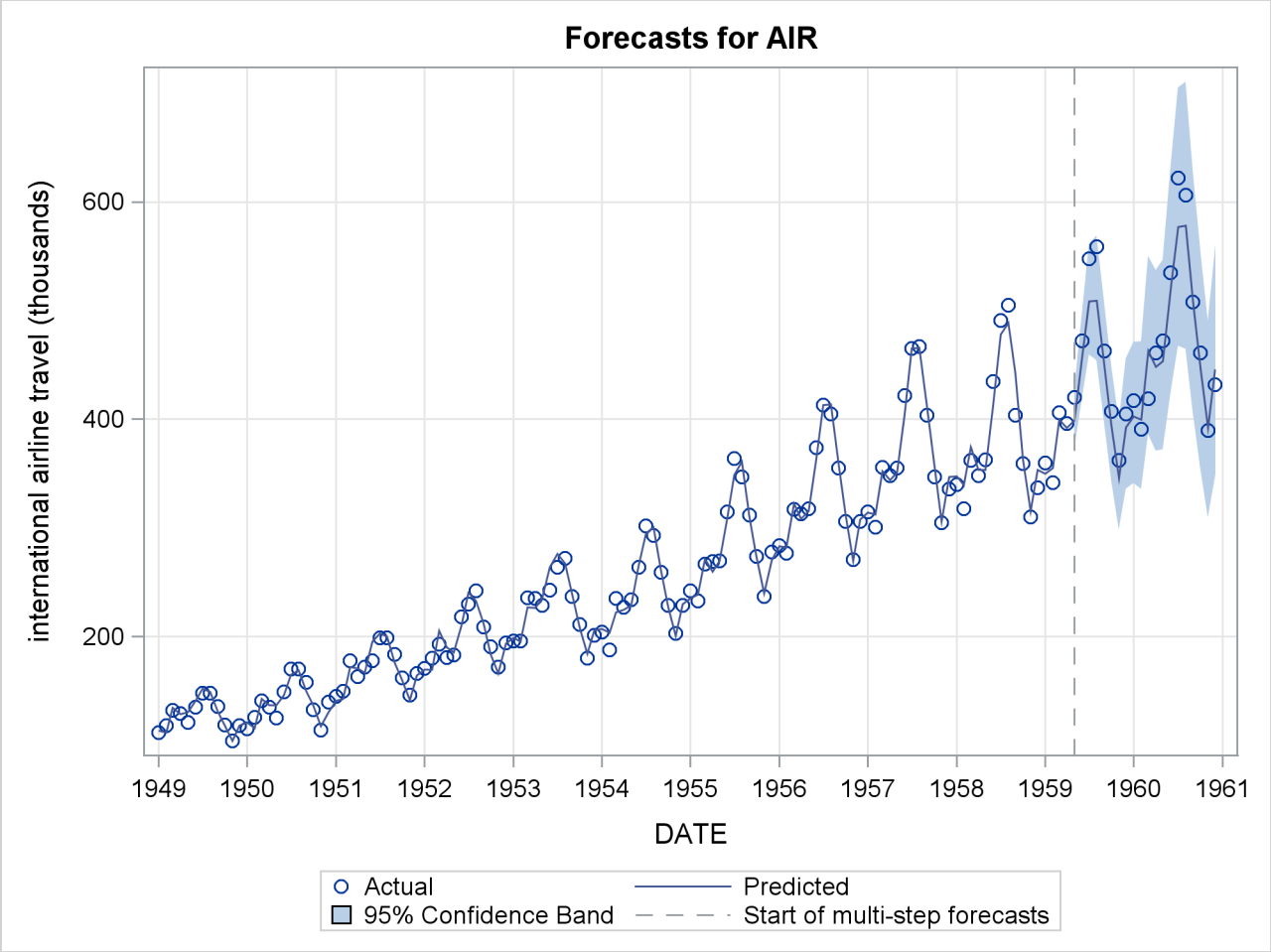
Output 14.5.2 Prediction Error Plot



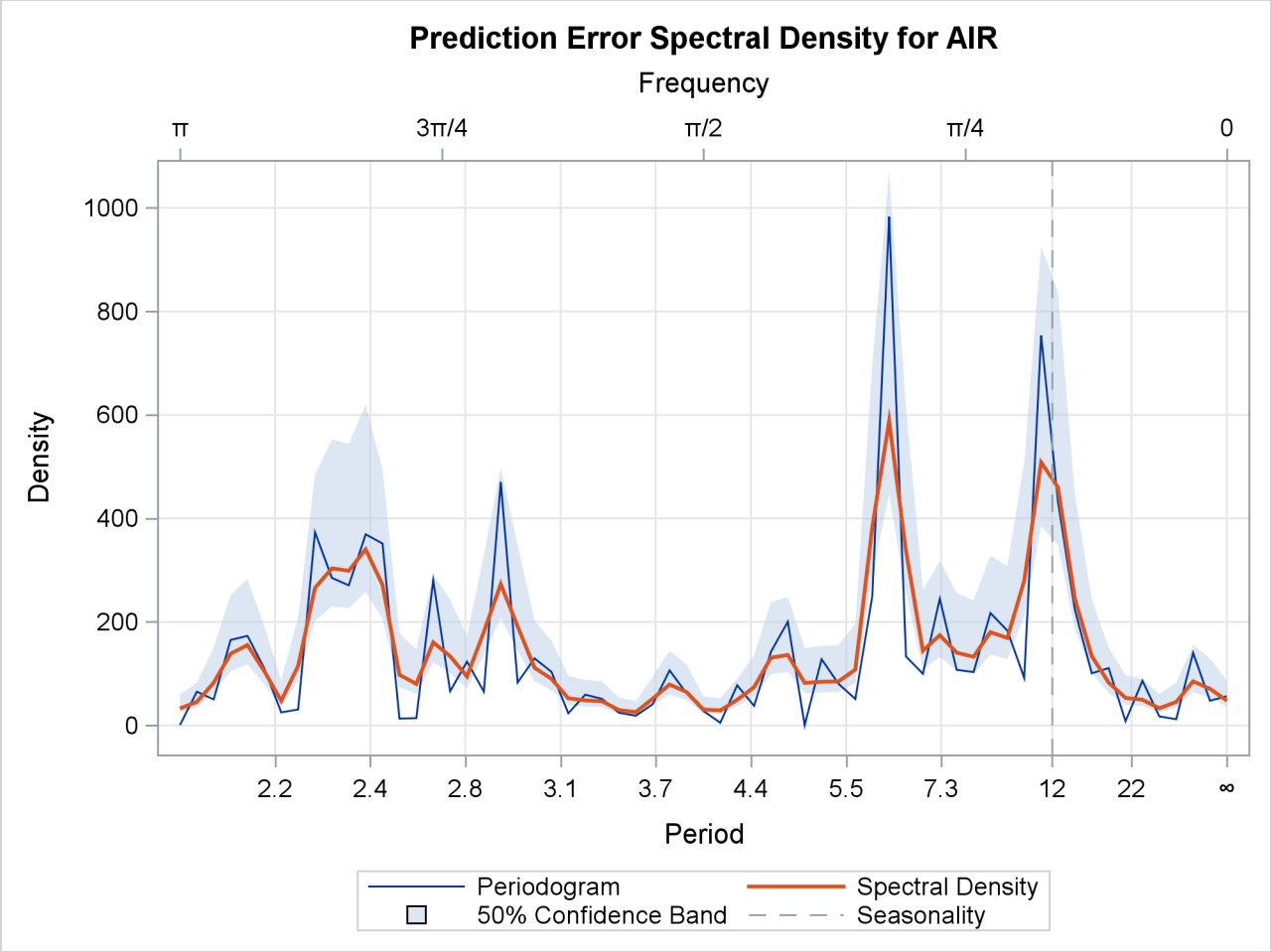
Output 14.5.3 Prediction Error Standardized ACF Plot



Output 14.5.4 Forecast Plot



Output 14.5.5 Prediction Error Spectral Density



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