MathSoft

Getting Started with S-PLUS 2000

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TUTORIAL 1

QUICK TOUR

S-PLUS is designed to work seamlessly with the software you already use. You can import data from and export data to many sources, including spreadsheets such as Excel and Lotus, databases such as Access, analytical software such as SAS and SPSS, and the financial databases Bloomberg, LIM, and FAME.

Once you have accessed your data, you can analyze and explore it. In this quick tour, you will perform the following tasks:

- Open a data set.
- Create several two-dimensional plots.
- Identify and label points in those plots.
- Edit a plot.
- View objects in the **Object Explorer**.
- Create a three-dimensional plot.

This quick tour briefly introduces you to many of the most commonly used procedures in S-PLUS.

Getting Data

Let's walk through a sample session using some data to help you decide which new car you should buy.

1. From the main menu, select **File ► Open**.
2. Navigate to the **samples** directory (a subdirectory of your S-PLUS installation directory) and select **exfuel.sdd**.
3. Click **Open** to load the file into a **Data** window.

The `exfuel` data set consists of five data columns plus a column of row names:

- `Weight`: Automobile weight
- `Disp.`: Engine displacement (6 liter, 8 liter, etc.)
- `Mileage`: Mileage in miles per gallon
- `Fuel`: 100/mileage
- `Type`: Category of vehicle (`Large`, `Medium`, `Small`, `Compact`, `Sporty`, `Van`)

To see a description of any column, hold the cursor over the column name. To see the column type, hold the cursor over the column number.

S-PLUS provides 8 different column types: character, complex, dates, double, factor, integer, logical, and single. Notice that `Type` is a factor column representing *categorical* data.

Creating a 2D Graph

You can create a graph by selecting data columns and choosing a plot type.

1. Select all the columns of `exfuel` (from `Weight` to `Type`) by dragging the mouse across the column headers.
2. Click the **2D Plots** button on the **Standard** toolbar to open a palette of available 2D plot types.

Figure 1.1: *The 2D Plots and 3D Plots buttons on the Standard toolbar.*

3. Click the **Scatter Matrix** button on the palette.

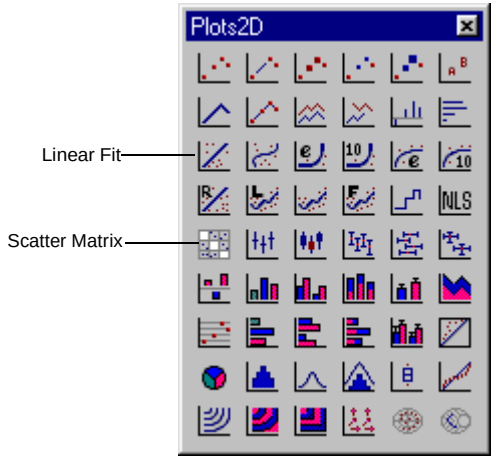


Figure 1.2: *The Plots 2D palette.*

The scatterplot matrix displays each column of data against the other selected columns. For example, to see how `Mileage` and `Fuel` are related, read across from `Mileage` and above `Fuel` to see the plot. The plot shows that `Mileage` and `Fuel` are directly related. You can also see a strong relationship between `Mileage` and `Weight`: heavier cars have lower mileage.

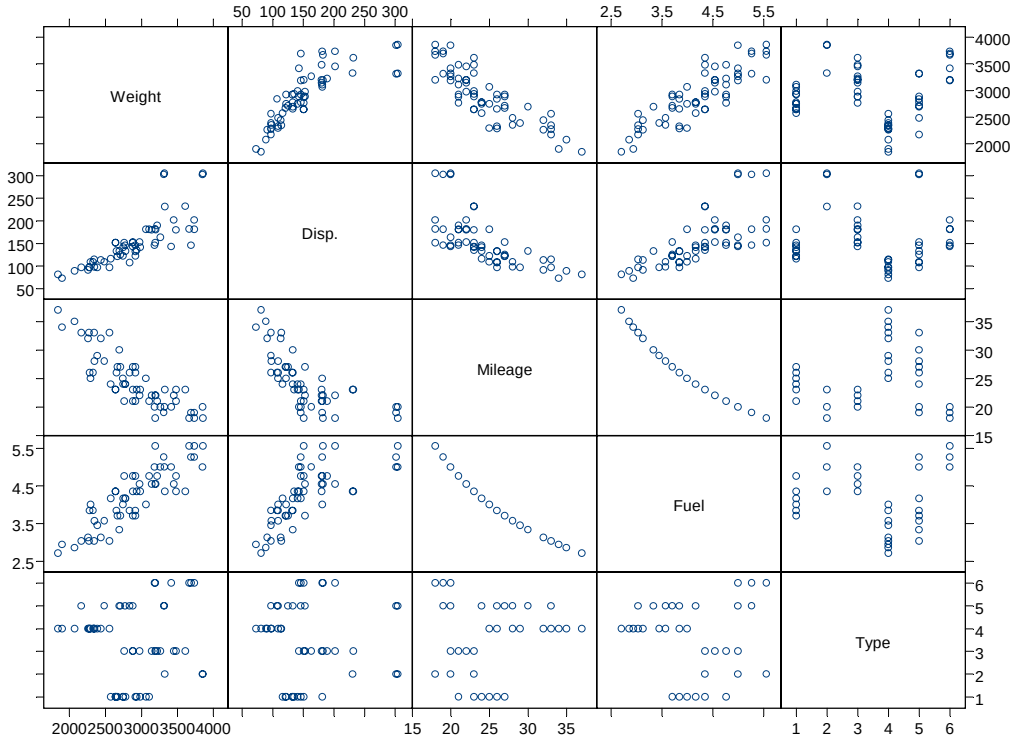


Figure 1.3: *The scatterplot matrix shows a number of strong relationships.*

Linear Regression

Now that you're familiar with your data, let's examine the relationship between `Weight` and `Mileage` a bit more extensively.

1. Close the **Graph Sheet** containing the scatterplot matrix. You do not need to save it.
2. Click the header of `Weight` and then CTRL-click the header of `Mileage` in the **Data** window.

3. Click the **Linear Fit** button (see Figure 1.2) on the **Plots 2D** palette. This linear fit shows an obvious relationship between an increase in `Weight` and a decrease in `Mileage` (see Figure 1.4).

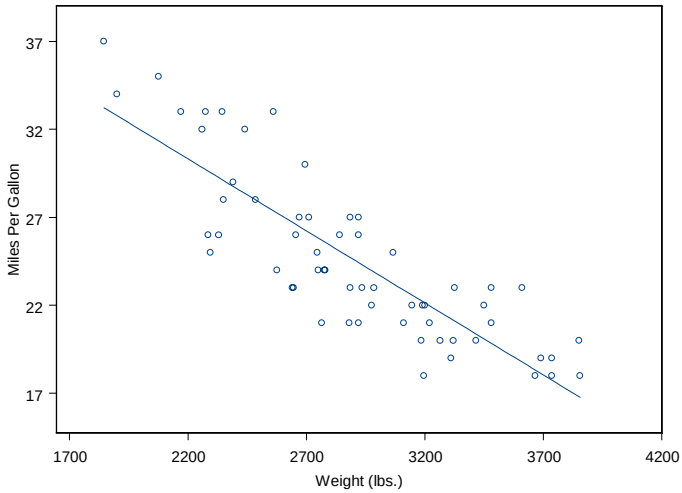


Figure 1.4: *Linear fit of* `Mileage` *vs.* `Weight`.

To examine how `Vans` or `Compact` cars fit into this example, you can use MathSoft's exclusive Trellis graphics to condition `Weight` and `Mileage` on a third variable, `Type`.

4. Minimize any open windows except the **Data** window and **Graph Sheet**. You may need to minimize the **Graph Sheet** and **Data** windows first and then restore them after minimizing the other windows. Choose **Window ► Tile Vertical** (or press CTRL-SHIFT-V) to vertically tile the **Graph Sheet** and **Data** windows side by side.

5. Select the `Type` column by clicking on its header. You may have to use the slider at the bottom of the **Data** window to locate the `Type` column. Then position the mouse somewhere within the data so that the pointer arrow appears, not the down arrow of the column header. Click and drag the data column to the top of the **Graph Sheet** where a rectangle

marked by dashed lines appears. A plus sign appears beneath the mouse cursor when you have positioned the cursor correctly, as in Figure 1.5. To create the Trellis graph, release the mouse button to drop the data column into this rectangle.

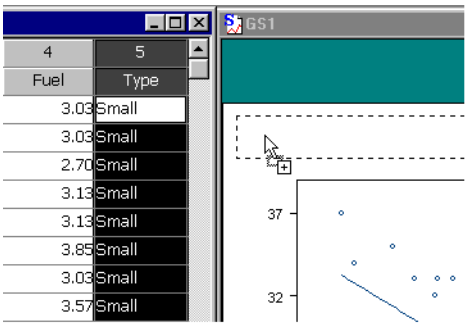


Figure 1.5: *Drag-and-drop to create Trellis graphs.*

The resulting plot is shown in Figure 1.6. The data are divided into subsamples and conditioned by `Type`. Now you can see additional relationships:

- `Sporty` cars, normally assumed to be gas guzzlers, actually have among the highest mileage, along with `Small` cars.

- `Compact` and `Medium` cars, often touted for higher mileage, get gas mileage similar to `Large` cars.

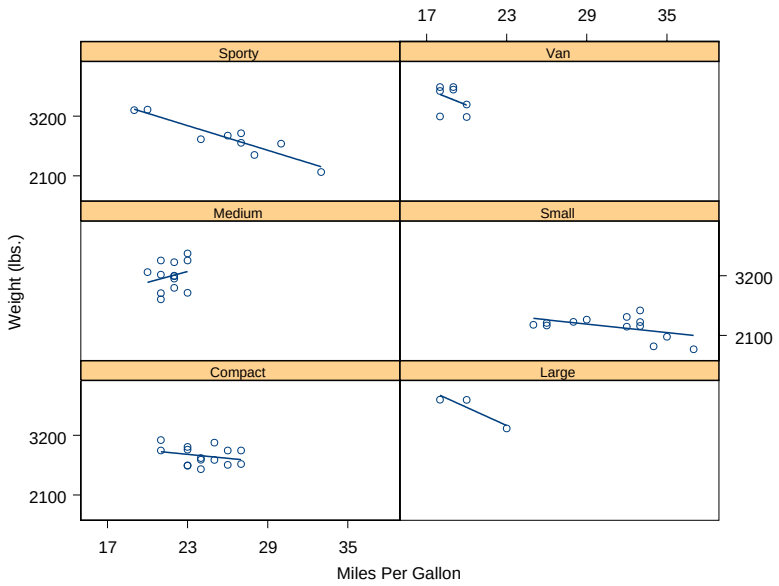


Figure 1.6: *A Trellis view of the fuel data.*

Identifying and Labeling Data Points

Now we can identify which cars have the best and worst mileage by labeling the data points.

1. Point the mouse cursor at any data point in the graph. A DataTip appears, similar to a ToolTip, showing you the vehicle's model, weight, and mileage.

2. To label the point, click the **Graph Tools** toolbar button  on the **Graph** toolbar. To see the **Graph** toolbar, make sure the graph sheet is in focus. On the **Graph Tools** palette, click the **Label Point** button  .

3. Click on the data point you want to label. The data point is labeled with the car description (the row name) and the values of the plotted columns at that point. For example, if you click on the uppermost data point in the `Sporty` cars panel, you'll see the following label:

   ```
   Honda Civic CRX Si 4.
   Weight = 2170.00
   Mileage = 33.00
   ```

   SHIFT-click on additional points to label multiple points at once.

4. Click on the **Select Tool** button  from the **Graph Tools** palette. Delete the labels by selecting them and pressing the DELETE key.

Now we'll change the contents of the DataTips and labels:

1. In the plot, right-click on any data point, and choose **Data to Plot** from the shortcut menu.
2. Under **DataTips and Point Labels**, expand the column list. Click on **<ROWNAMES>**, then CTRL-click on **Disp.** Press **OK**. The model name and engine displacement are now shown in the DataTips.

Editing the Graph

Now imagine that you want to include your graph in a report or presentation. You might want to modify its attributes further.

In S-PLUS graphics are object-oriented, which means you have complete control over every detail. You can easily modify graph objects using shortcut menus, dialogs, or the toolbar.

1. Click on the X axis title, then SHIFT-click on the Y axis title on the graph to select them. (Both axis titles are surrounded by green knobs indicating that they are selected). Change the font size to 20 using the **Graph** toolbar (see Figure 1.7).

2. Click on any data point to select the plot. A single green square will appear at the bottom center. Change the plot color to **Red** using the dropdown **Color** menu by clicking on the **Line Color** button on the **Graph** toolbar (see Figure 1.7).

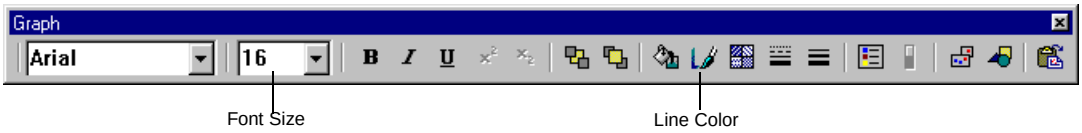


Figure 1.7: *The Line Color button on the Graph toolbar changes text as well as line colors.*

Databases and the Object Explorer

S-PLUS does not operate on data files directly. Instead, S-PLUS stores objects representing the data sets in an internal database. This means that the original data file is not modified, and changes made to the object stored in the database persist from session to session. (However, you can choose to delete your changes at the end of each session). S-PLUS also keeps track of any graphs or other documents that you have open during a session (**Report** windows, **Script** windows). To see the contents of your current session, click on the **Object Explorer** button on the standard toolbar.

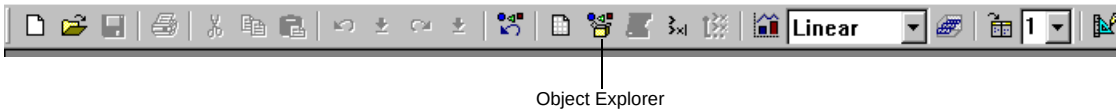


Figure 1.8: *The Object Explorer button on the Standard toolbar.*

The **Object Explorer** uses folders to organize the documents and data objects in your working database. Click on the **Data** folder and notice that `exfuel` appears in the right pane of the **Object Explorer**. Click on the **Graphs** folder to see the **Graph Sheet** windows open in your current session. Now let's create a folder to contain those objects associated with our current analysis.

1. Right-click on the left pane of the **Object Explorer** and choose **Insert Folder** from the shortcut menu.
2. Name the folder `Car type analysis`.

3. Expand the **Data** folder by clicking on the **+** sign associated with it.
4. Click on the **exfuel** object and drag it into the new folder you created.
5. Expand the **Graphs** folder by clicking on the **+** sign associated with it.
6. Click on the **GS1** object and drag it into the new folder.
7. Expand the **Car type analysis** folder to view its contents.

You can customize your folder further by right-clicking on it and choosing **Folder**, **Objects**, or **Advanced** from the shortcut menu. Document objects (**Graph Sheets, Reports, Scripts)** that appear in the **Object Explorer** are transient objects existing in your current session, rather than permanent objects residing on disk. To save your current session, including document objects and your customized **Object Explorer**, use the menu option **File ► Workspace ► Save**.

Creating a 3D Graph

S-PLUS offers a variety of 3D plot types for powerful data visualization. First let's load some 3D data. The `exgalaxy` data set contains measurements of the radial velocity of a spiral galaxy measured at 323 points in the sky.

1. Choose **File ► Open** and navigate to the **samples** directory. (You can close all other windows. You do not need to save any **Graph Sheets**.)
2. Type `exgalaxy.sdd` in the **File name** field and click **Open**.
3. Select the data columns `east.west`, `north.south`, and `velocity` by CTRL-clicking on each column.
4. Click the **3D Plots** button  on the **Standard** toolbar (see Figure 1.1) to open a palette of available 3D plot types.

5. Click the **3D Scatter** button on the palette.

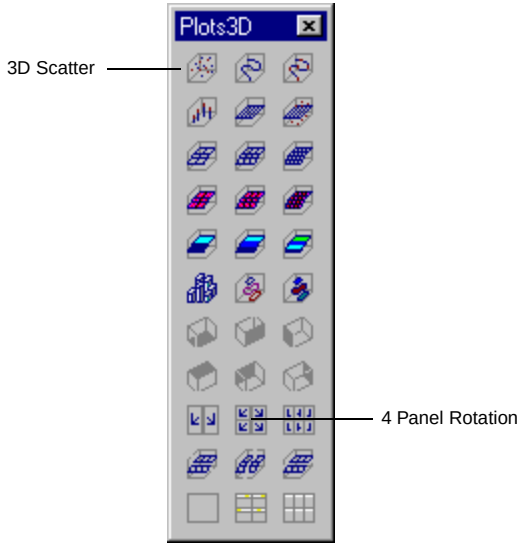


Figure 1.9: *The Plots 3D palette.*

6. You can interactively rotate the 3D graph. Click outside the surface plot but inside the 3D workbox area to select the invisible 3D workbox (several green knobs should appear). Drag horizontally on one of the green circles. When you release the mouse, the graph is redrawn at the new perspective. The green triangle can be dragged up and down to rotate the graph vertically.

7. Click the plotted points of the graph to select the scatter plot. A single green knob should appear. Then click the **4 Panel Rotation** button  on the **Plots 3D** palette. Now you can rotate the graph using the lower left panel. The panels will rotate together so you can view your graph from different angles.

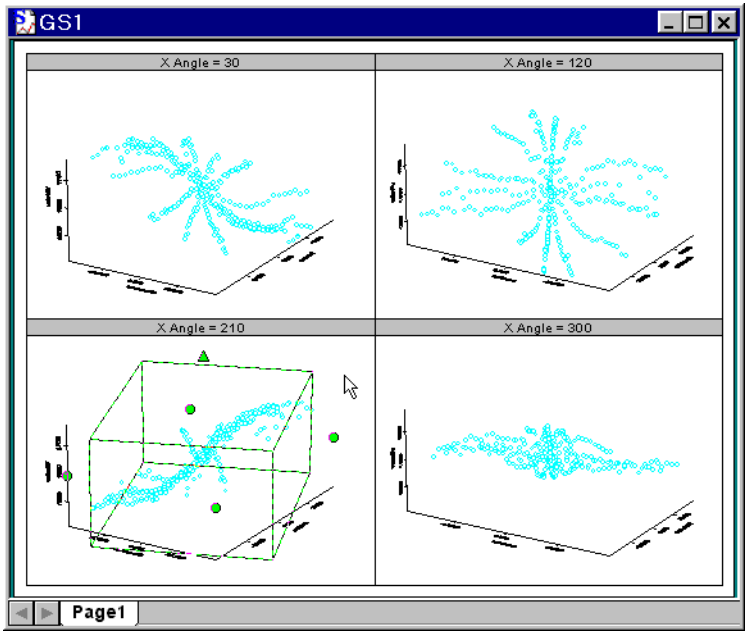


Figure 1.10: *Four-panel rotation; note the circles and triangle used for controlling the rotation in the lower left plot.*

EXTENDED TOUR: EXAMINING ENVIRONMENTAL DATA

In this extended example, we will import data from a SAS file and edit the data. The data set contains measurements on ozone concentration, solar radiation, daily maximum temperature, and wind speed on 111 days in 1973 in the New York metropolitan area. After editing, we visually explore the data with standard and Trellis plots. We then fit a linear model to the data. We also edit the plots for possible use in a presentation.

Importing a File

To import the data:

1. If you have any windows open from the preceding tutorial, close them before continuing.
2. Choose **File ► Import Data ► From File**. S-PLUS lists the files in the current directory. We use **File ► Import Data** instead of **File ► Open** because we are opening a SAS file instead of an S-PLUS file.
3. Under **Files of type**, choose **SAS Files (*.sd2)**.
4. Navigate to the **samples** directory and select **Exenvirn.sd2**.
5. Click **Open** to load the file into a **Data** window.

Editing Variable Names

Note that the imported SAS file has variable names all in uppercase and at most eight characters long. In S-PLUS variable names are highly flexible, so let's modify the variable names before creating a graph.

1. In the **Data** window, double-click the column name for column 2 and change `RADIATIO` to `RADIATION`.
2. Double-click on the column name for column 3 and change `TEMPERAT` to `TEMPERATURE`.

Adding Column Descriptions

You can store more detailed information about your data set in the column descriptions. These column descriptions are automatically used as axis titles when graphing the data.

1. Right-click anywhere on the column `RADIATION`.
2. Choose **Properties** from the shortcut menu.

3. Enter `Solar Radiation (langleys)` in the **Description**.
4. Click **OK**.

Saving the Data as an S-PLUS Data Set

We can now save our changes in an S-PLUS data file. You store S-PLUS data files using the **.sdd** extension:

1. Choose **File ► Save**.
2. Accept the default **samples** directory and the default name, **Exenvirn.sdd**.
3. Click **OK**.

Creating a 2D Graph

Now we are ready to visualize the data. We first create a local regression plot of the data:

1. In the **Data** window, select the data columns for `RADIATION`, then CTRL-click `OZONE`. The first column will be the X data, and the second will be the Y data.
2. Click the **2D Plots** button to open a palette of available 2D plot types.
3. Click the **Loess** button  on the palette. A locally weighted, least squares regression is calculated and the plot is created.
4. Close the **Plots 2D** palette.
5. Click the maximize button in the upper right-hand corner of the **Graph Sheet**.
6. Right-click on the smoothed line or any data point to access the plot's shortcut menu. Select **Smooth/Sort** to try different levels of smoothing. Enter values between 0.1 and 0.9 in the **Span** field and click **Apply**. Reset the **Span** to **Auto**, and click **OK**.

Note

If you do not see a **Smooth/Sort** dialog option, you probably selected some other graph object. Try again and make sure you click on a data point and not on an axis or axis label. S-PLUS indicates with green knobs what object you have selected. Try clicking on different parts of the graph (axis, labels, data, etc.) to see how different graph objects get highlighted with green knobs when they have been selected.

Changing Graph Features

S-PLUS gives you unparalleled control over every detail of your graph—right down to the thickness of tick marks. You can control all individual line thicknesses, symbol sizes, fonts, colors, titles, tick marks, and axis labels. Additionally, you can create multiple lines of text for comments, titles, and tick labels. Superscript and subscript options are conveniently located on a toolbar for quick access, so editing any text or equation is easy.

Axes and Labels

1. Click on the y-axis to select it (a square green knob appears on the center of the axis if you have properly selected it).
2. CTRL-click on the x-axis to select it.
3. Choose **Format ► Selected Objects**. The **Modify All Selected Objects (if applicable)** dialog appears.
4. In the **Display/Scale** page, specify **Color: Lt Gray** and **Frame: With ticks**.
5. Click on the **Grids/Ticks** tab. Under **Major Ticks**, specify **Weight: 1** and **Tick Position: In**.
6. Click **OK**.
7. Change the y-axis title by clicking once to select the axis title (green knobs surround the axis title when it is selected) and once more to get an in-place edit box.
8. In the text edit box, type `Ozone Concentration`. Do not press ENTER. Click outside the box to make the change.

Plot Properties

1. Double-click a point in the plot to display the **Line/Scatter Plot** dialog. A green knob appears at the bottom of the graph indicating the plot object was selected.
2. On the **Line** page, specify the **Line Color** as **Black** and the **Weight** as **2**. On the **Symbol** page, specify **Circle, Solid** as the **Symbol Style** and **Red** as the **Symbol Color**. Click **OK**.

Titles

1. Now we can insert a main title at the top of our graph. Choose **Insert ► Titles ► Main**.
2. Type `The Relationship Between Radiation and Ozone` into the text box that appears. Do not press ENTER. Click outside the title to close the text box.

3. Select the main title and use the toolbar to specify a font size of 20. Use the **Line Color** button to change the text color to **Blue**. You can use the toolbar to change the font, font size, and color of any text objects in your graph. Do not close the **Graph Sheet** or **Data** window; we will use them again shortly.

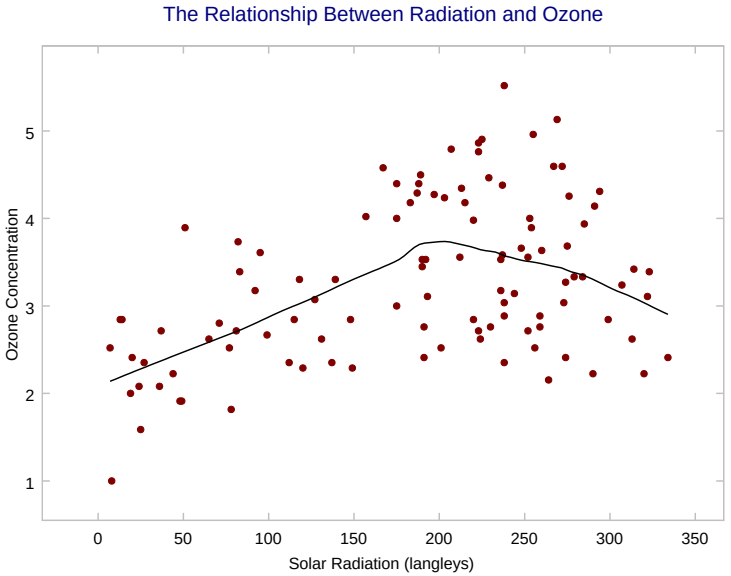


Figure 1.11: *After making all the changes to our graph, it now looks like this.*

Using Trellis Graphics for Multipanel Conditioning

Suppose you have a data set with multiple variables and you want to see how plots of two variables change with variations in one or more conditioning variables. Exclusive to MathSoft, Trellis graphics are designed to display your data in a series of panels using conditioning options. Each panel contains a subset of the original data corresponding to intervals of the conditioning variables.

Most graphs can be conditioned. The data columns used for each plot and for the conditioning variable(s) must be of equal length. The axis specifications and panel display attributes (for example, fill color) by default are identical for each panel.

Now we will apply multipanel conditioning to our previously created loess plot.

1. Make sure that only the windows containing the `Exenvirn` data and your **Graph Sheet** are open. Select **Tile Vertical** in the **Window** menu.
2. In the **Data** window, select `TEMPERATURE`, then CTRL-click `WIND`.
3. Click and hold the mouse over the data in the columns until the rectangular shadow appears, then drag-and-drop on the rectangular drop target (the long bar) that appears at the top of the graph.

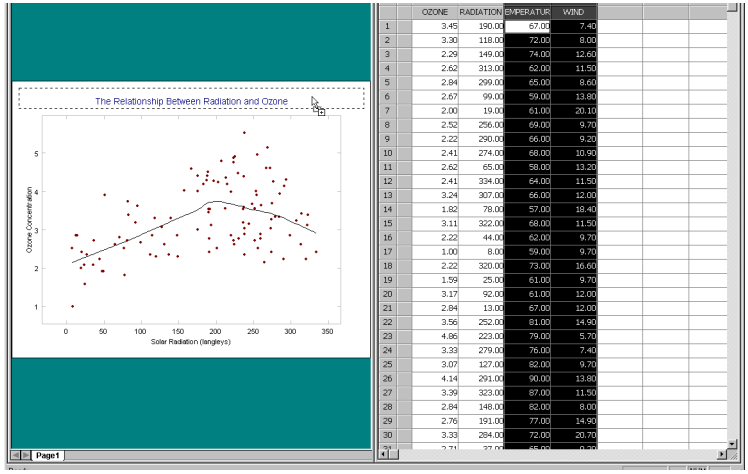


Figure 1.12: *`TEMPERATURE` and `WIND` are dragged to the rectangular drop target at the top of the graph.*

The Trellis graph in Figure 1.13 shows how the dependence of `OZONE` on `RADIATION` varies according to levels of `WIND` and `TEMPERATURE`.

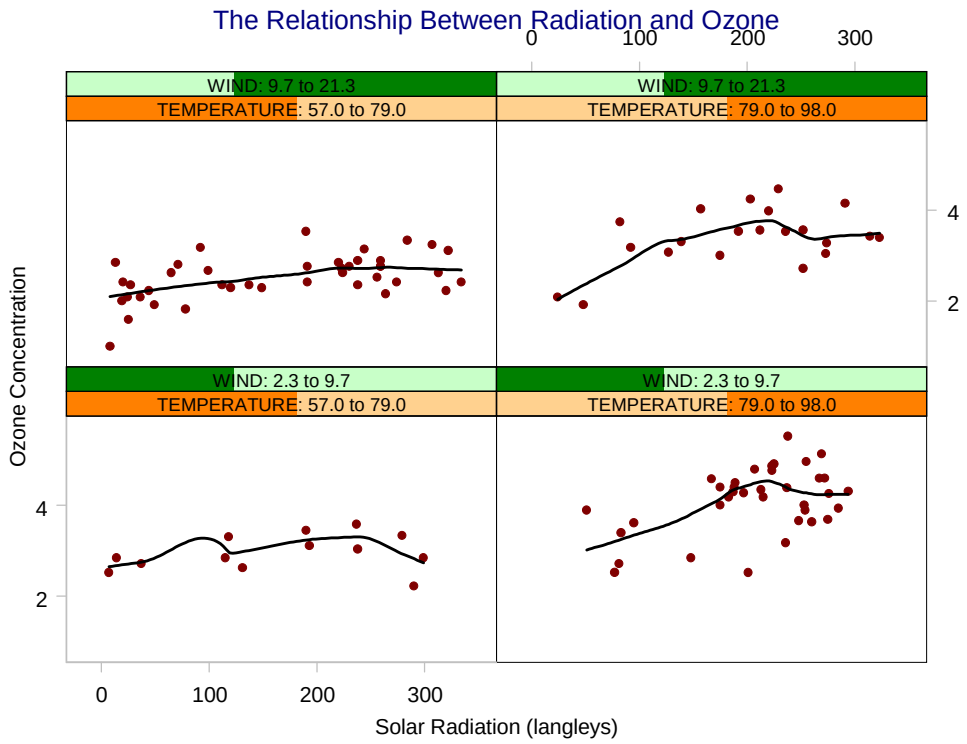


Figure 1.13: *Ozone concentration and solar radiation: This graph shows that radiation explains variation in ozone levels beyond that explained by wind speed and temperature.*

Select the plot by clicking the line or symbols in any one of the panels. Open the **Plots 2D** palette and click on the **Linear Fit** button. A linear regression line will replace the loess curve in each panel, as shown in Figure 1.14. This graph suggests that high temperatures with less wind result in the strongest dependence of ozone on radiation.

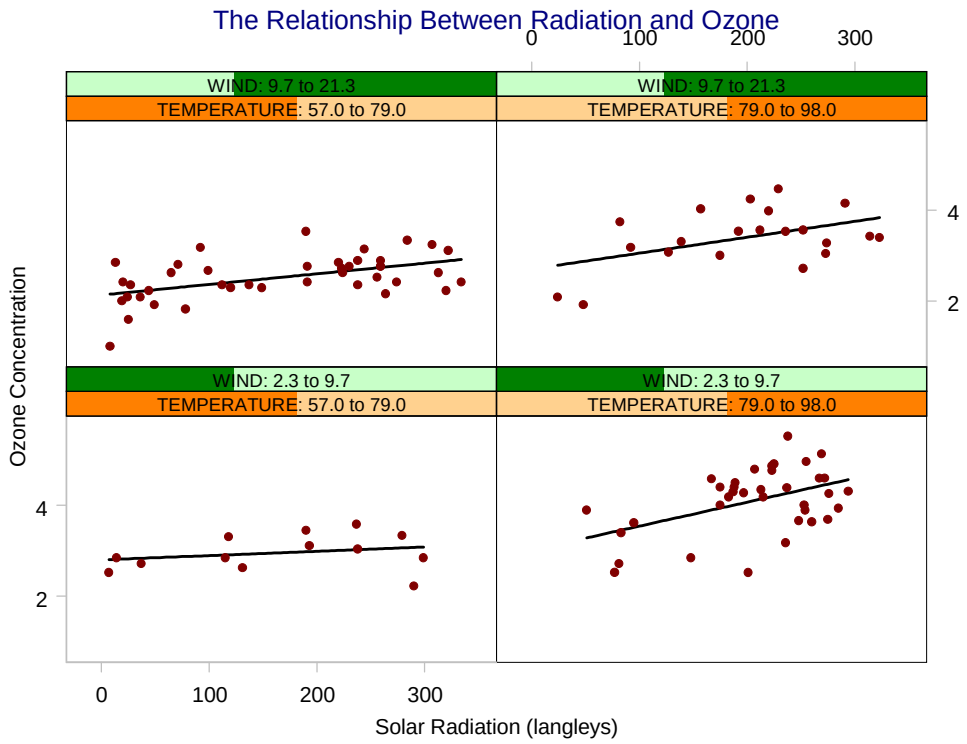


Figure 1.14: *A linear regression has replaced the loess curve in each panel.*

Highlighting Data Points

We can highlight data points in our graph and have the same points highlighted in other graphs and the **Data** window.

1. Open the **Graph Tools** palette by clicking the button in the **Graph** toolbar.
2. Click on the **Select Data Points** button .
3. Drag around a selection of points in the upper right panel of the graph.

Notice that the selected points are highlighted in both the graph and the **Data** window. If we had other graphs based on this highlighted data, the points would be highlighted in all graphs.

4. Click on an empty part of the panel to remove the selection.

Extracting Graph Panels

You can "drill-down" into a Trellis graph panel using the **Graph Tools**.

1. Select the **Extract Panel** button on the **Graph Tools** palette.
2. Click on the upper right panel of the Trellis graph.

   The panel is extracted and is displayed as a full-size graph.

3. Click the **Show All Panels** button to restore the Trellis graph.

Save the multipanel plot as **mpanel.sgr**, using **File ► Save As**, and close the **Data** window, the **Graph Sheet**, and any open palettes.

Note

The data set is not saved with the **Graph Sheet**. When the **Graph Sheet** is reopened, it will redraw using the current data set named `Exenvirn`. To embed the data set within the **Graph Sheet** before saving, choose **Graph ► Embed Data** from the main menu.

Applying Statistics Models

S-PLUS provides a vast array of statistical techniques, with the most widely used techniques accessible through dialogs launched from the **Data** and **Statistics** menus.

All techniques available on the menus are available through the S-PLUS language. Commands may be issued interactively in the **Commands** window or as a script in a **Script** window. In the course of an analysis, the user may begin by fitting a model through a convenient dialog, then proceed to analyze the model and perform diagnostics through the flexible and powerful S language.

In this section, we will fit linear regression models to predict ozone using temperature, radiation, and wind.

Summaries

First we will look at simple summaries of the data in the `Exenvirn` data.

1. Choose **File ► Open** and navigate to the **samples** directory.
2. Enter `Exenvirn.sdd` as the **File name** and click **Open**.
3. Choose **Statistics ► Data Summaries ► Summary Statistics**.
4. The **Summary Statistics** dialog appears with `Exenvirn` in the **Data Set** field. Click **OK**. Summaries for the columns appear in the **Report** window.
5. Choose **Statistics ► Data Summaries ► Correlations**.
6. The **Correlations and Covariances** dialog appears with `Exenvirn` in the **Data Set** field. Click **OK**. Correlations for the columns appear in the **Report** window.

Linear Model

Next we will use the **Linear Regression** dialog to fit a linear model predicting `ozone` from the other variables.

Simple model from a dialog

1. In the **Data** window for `Exenvirn`, select `OZONE`, `RADIATION`, `TEMPERATURE`, and `WIND`, in that order, by dragging across the column headers.
2. Choose **Statistics ► Regression ► Linear**. The **Linear Regression** dialog opens.
3. In the **Data Set** field, `Exenvirn` is listed.
4. In the **Formula** field, the formula expression `OZONE ~ RADIATION + TEMPERATURE + WIND` appears. The response, or *dependent*, variable is `OZONE` and is listed first. The predictors, or *independent* variables, are shown after the tilde (**~**).
5. On the **Plot** page, check the box beside **Residuals vs. Fit**, then click **OK**.

The regression results appear in the **Report** window. In addition, a new **Graph Sheet** is created showing the diagnostic plots. The data used in this plot are embedded within the **Graph Sheet**; subsequent

changes in the `Exenvirn` data set will not affect these plots. See the section Embedding and Extracting Data in Graph Sheets (page 27) for more information.

The Formula Builder

The **Formula Builder** lets you describe complex regression models by selecting variables and indicating how they are used in the model. For example, you might want to add an interaction term to the model. The **Formula Builder** lets you do this easily.

To use the Formula Builder

1. Close the **Graph Sheet**. Again choose **Statistics ► Regression ► Linear**. Select **OZONE** as the dependent variable from the dropdown list. Then select **RADIATION**, **TEMPERATURE**, and **WIND** (using CTRL-click) as the independent variables. Notice that the formula reflects your changes.
2. Now click the **Create Formula** button.
3. Select **RADIATION** and **TEMPERATURE** in the variable list. Click on **Add Interaction** to include the interaction between radiation and temperature as a predictor.
4. Click **OK** to exit the **Formula Builder** dialog. The formula you generated is placed in the **Formula** field of the **Linear Regression** dialog.
5. Click **OK** to generate the model.

More detailed results

1. Choose **Statistics ► Regression ► Linear**.
2. Use the **Dialog Rollback** button at the bottom center of the page (to the right of **Apply**) to select the previous dialog state. The previous values for **Data Set** and **Formula** will be filled in.
3. On the **Results** page, check the **ANOVA Table** check box. This will provide an analysis of variance table for the linear model.

4. Click **OK**. The ANOVA table for the fit will appear in the **Report** window.
5. When you are done looking at the results, close the **Report** window and the `Exenvirn` **Data** window.

DOING MORE WITH GRAPHICS

Varying 2D Axis Types

By default, 2D plots are drawn on linear x and y axes. Sometimes it is useful to create plots using a logarithmic or probability scale on one or both axes. You can most easily create such plots by selecting your 2D axis type from the toolbar *before* selecting your plot type.

1. Select **File ► Open**, and navigate to the **samples** directory. Change the **Files of type** dropdown to **Data Sets (*.sdd, *.axd)**.
2. Select **expuro.sdd**.
3. Click **Open** to load the file into a **Data** window.
4. Select the columns `conc`, `vel`, and `state` by dragging the mouse across the column headers.

This data set is from a biochemical experiment testing the drug Puromycin. The column `conc` gives the enzyme concentration of the substrate and `vel` is the initial velocity of the reaction. The `state` variable indicates whether or not the cell had been treated with Puromycin.

5. Choose **Log X** from the **Default 2D Axis Type** dropdown in the standard toolbar.

Figure 1.15: *Choosing the Default 2D Axis Type.*

6. Click the **Color** plot button in the **Plots2D** palette. The treated and untreated cell observations appear in different colors.
7. Make sure your graph is not selected, then change the **Default 2D Axis Type** back to **Linear**. The **Default 2D Axis Type** control specifies the *default* axis type; if you don't change it back to **Linear**, subsequent plots are created on a

log scale as well. If your graph is selected when you change the default axis type, the axis type of your selected graph is also changed.

8. Close the **Graph Sheet** and **Data** window.

Creating Graphics With Multiple Axes

You can create plots showing different data series, with varying scales, against a single x or y variable. This is often useful in plotting, for example, revenue and profit against time. You can see at a glance whether revenue and profit are rising and falling together, or if some more complicated relationship holds.

As a simple example, we'll plot housing starts and manufacturing shipments on a time scale.

1. Select **File ► Open**, and navigate to the **samples** directory. Change the **Files of type** dropdown to **Data Sets (*.sdd, *.axd)**.
2. Select **execon.sdd**.
3. Click **Open** to load the file into a **Data** window.
4. Select the columns `years`, `hstart`, and `ship` by dragging the mouse across the column headers.
5. Choose **Graph ► 2D Plot**. The **Insert Graph** dialog appears.
6. Under **Axes Type**, choose **Multiple Y**. Under **Plot Type**, choose **Scatter**. Accept the default **Graph Sheet**, GS1, then click OK. A plot appears with `hstart` plotted along the left y axis, `ship` along the right y axis, both plotted against `years` along the x axis.

7. Choose **Insert ► Legend**. Drag the legend to the upper left of the plot, to create the plot shown in Figure 1.16.

Figure 1.16: *A plot with multiple y axes.*

Another way to show data series with varying scales is to put the series in separate panels:

8. Select the rectangular plot area defined by the axes. Change the **Default 2D Axes** on the **Standard** toolbar to **Vary Y Panel**. The graph is redrawn, placing each plot in a separate panel. The y axis is scaled separately in each panel.
9. Close the **Graph Sheet**. Save it as **execon.sgr**. Close the **Data** window as well.
10. Change the **Default 2D Axes** back to **Linear**.

Embedding and Extracting Data in Graph Sheets

You can store the data used to create any graph within the **Graph Sheet**. This lets you provide a fully editable graph to friends or colleagues, without having to provide a separate data file. You can also extract the data used to create the graph from any **Graph Sheet**, and then analyze and manipulate the data.

To embed the **execon** data in the **Graph Sheet**:

1. Open the **Graph Sheet execon.sgr**.
2. Choose **Graph ► Embed Data**.

The data used to create the graph (but no other data) are embedded in the **Graph Sheet**.

To extract the data used to create a graph:

1. Select the **Graph Sheet** from which you want to extract the data.
2. Choose **Graph ► Extract Data**. The **Extract Data** dialog appears.
3. Specify a name (such as `execon2`) for the extracted data set, and click **OK**.

Before proceeding, close all open **Graph Sheets** and **Data** windows.

Creating a Graph Using the Object Explorer

The Object Explorer is particularly useful when creating graphs from a data set with many columns. First load the data set `exstate`.

1. Choose **File ► Open** and navigate to the **samples** directory.
2. Type `exstate.sdd` in the **File name** field and click **Open**.

The `exstate` data set has many columns showing information about states in the United States. To get a visual summary of the data set, use the **Object Explorer**.

1. Bring the **Object Explorer** into focus. Expand the **Data** folder in the left pane. Notice that the data set `exstate` is now there.
2. Click on the button representing `exstate` in the left pane of the **Object Explorer**. All of the columns are listed in the right pane.

3. Click on the column icon for **Income**, then CTRL-click on **Illiteracy**, then **Area**. These columns are now also selected in the **Data** window. Close the **Data** window since we will use the **Object Explorer** for graphing.
4. Open the **2D Plots** palette, and click on the **Loess** button. Two loess plots are created in a **Graph Sheet**, both scaled to the same set of axes. (We assume in the next procedure this **Graph Sheet** is named **GS1**.)

Editing a Plot in the Object Explorer

Using the **Object Explorer** and properties dialogs, you can edit any open **Graph Sheet**. As an example, we will change the format of the X axis labels.

1. Bring the **Object Explorer** into focus, and expand the **Graphs** folder.
2. Expand **GS1** (or whichever corresponds to the plot you just created) in the left pane of the **Object Explorer**.
3. Expand **Graph2D**, then click on **Axis2dX1**, both in the left pane.
4. Double-click on **Axis2DLabelX** in the right pane to bring up the **X Axis Labels** properties dialog.
5. On the **Label1** tab, change the **Label1Type** to **Decimal** and set the **Precision** to **1**.

Viewing Plots in Separate Panels

The relationships between the variables can be seen much more clearly if they are scaled to different Y axes. One way to do this is to view the plots in separate panels, keeping the X axis scaling the same.

1. Click on a blank spot anywhere inside of the axes region to select the graph.
2. Open the **Graph Tools** palette.
3. Click on the  button in the lower left corner, labeled **Separate Panels with Varying Y Axes**. Your plots appear in two panels, stacked one over the other.

Removing Outliers

Notice that there is one data point far from the others. If you point your cursor at the data point you will see that it represents Alaska. Let's remove this outlier from the plots.

1. Click on the **Select Data Points** button  on the **Graph Tools** palette.
2. Drag a rectangle around the point representing Alaska to select it.
3. Choose **Format ► Exclude Selected Points** from the menu.
4. The loess smoothing is recalculated and the points representing Alaska are removed from the plots.
5. Click the **Select Tool** button  to return to the selection cursor.
6. Close the **Graph Sheet** and **Object Explorer**.

Creating a 3D Graph

Now we will use the data set `ex3dsurf` to create a 3D plot. Close any open **Graph Sheets** or **Data** windows.

1. Select **File ► Open**, and navigate to the **samples** directory. Change the **Files of type** dropdown to **Data Sets (*.sdd, *.axd)**.
2. Select **ex3dsurf.sdd**.
3. Click **Open** to load the file into a **Data** window.
4. Select the columns `V1`, `V2`, and `V3` by dragging the mouse across the column headers.
5. Click the **3D Plots** button to open a palette of available 3D plot types.
6. Click the **Spline Surface** button  on the palette. The graph shown in Figure 1.17 appears.

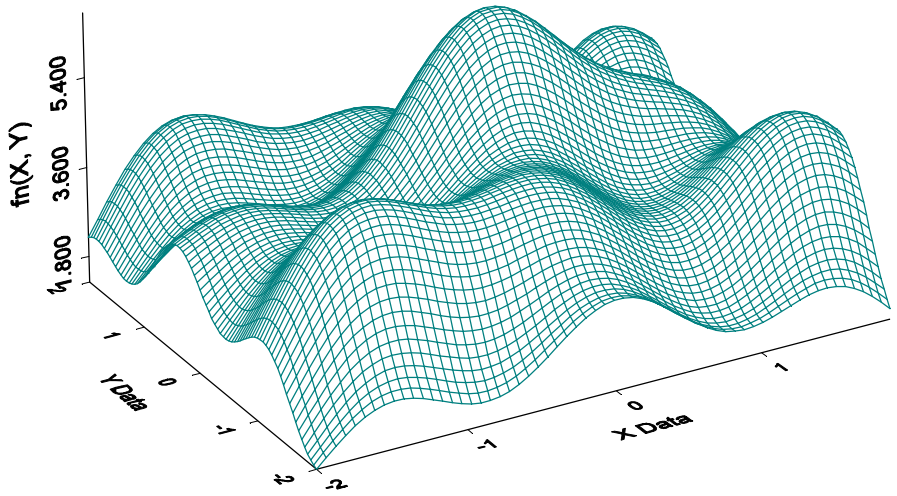


Figure 1.17: *3D spline plot.*

Adding Color Draping

Now we will add color draping to the spline plot.

1. Click on the maximize button in the upper right-hand corner of the **Graph Sheet**.
2. Click on the mesh of the surface plot to select it. On the **Plots 3D** palette, click the **32 Color Surface** button . The graph redraws with the new format.

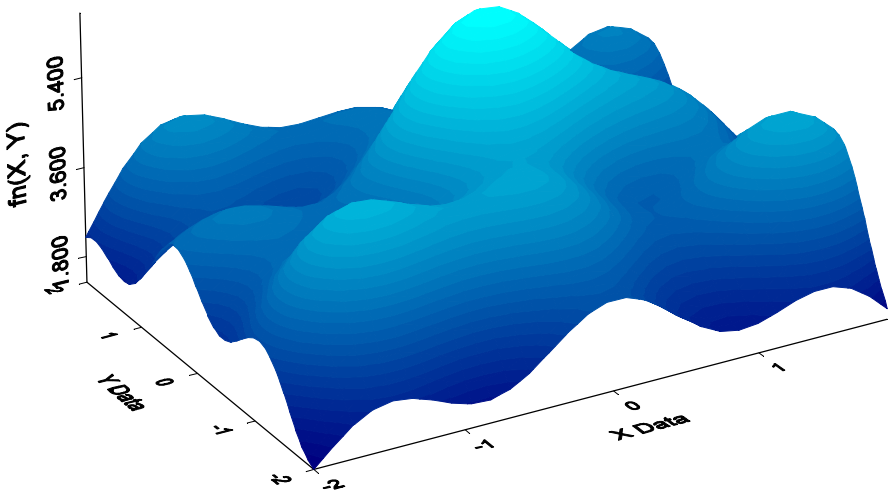


Figure 1.18: *Color draping can be done with up to 64 colors.*

CREATING POWERPOINT SLIDES AUTOMATICALLY

You can automatically create a PowerPoint presentation from your graphs. We will use the graphs we have created during this demonstration to create a PowerPoint presentation (assuming you have PowerPoint installed).

1. Click the **PowerPoint Presentation** button  on the **Standard** toolbar. You will see the **Welcome** screen of the **PowerPoint Presentation Wizard**. Click **Next**.
2. You can now add saved graphs to the PowerPoint presentation. Click the **Add Graph** button to find your graphs and add them to the list for your presentation or, from the standard **File ► Open** dialog, select one or more graphs to add to the presentation. Click **Next** to move to the next page of the wizard.
3. Click **Finish**. PowerPoint is started and the graphs you chose are inserted as slides in a new PowerPoint presentation. They are inserted in the order you specified in the presentation list in the wizard.

MANAGING YOUR DATA

There are two ways to save data in S-PLUS: in a *file* or in a *database.*

As with other standard Windows products, you can create, open, and save your data sets through the **File** menu. In addition, S-PLUS automatically saves your data sets in an internal S-PLUS database. This database, called the *working data*, is the database in which all S-PLUS data objects are stored by default. Data objects can be removed from the database at any time using the **Object Explorer**. Simply select the data object and press DELETE.

Saving a Data Set to the Working Data

At the end of every S-PLUS session, a dialog prompt appears, listing all the data objects that you have created or modified during the current session. Use this dialog to tell S-PLUS which changes to keep and which to ignore for each data set.

1. To end the current S-PLUS session and display the **Save Database Changes** dialog, click on the **x** in the upper right-hand corner of the S-PLUS window.

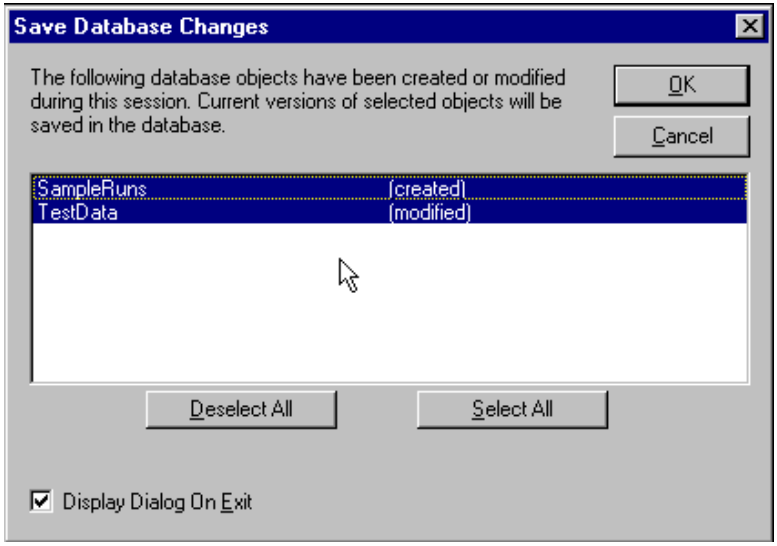


Figure 1.19: *The Save Database Changes dialog.*

By default, all objects created or modified during the current session are selected in the dialog.

2. To save a new data set or a changed version of an existing data set in the internal database, leave its name highlighted.
3. To discard a new data set or any changes made to an existing data set, CTRL-click on its name in the dialog.
4. Click **OK**.

USING THE COMMANDS WINDOW

For some analyses, it is more convenient to work with an interactive data analysis language than to maneuver through a series of dialogs. We will use the **Commands** window to fit another linear model and perform some diagnostics. If it is not already open, open the **Commands** window using the **Commands Window** button on the **Standard** toolbar. Close all other windows.

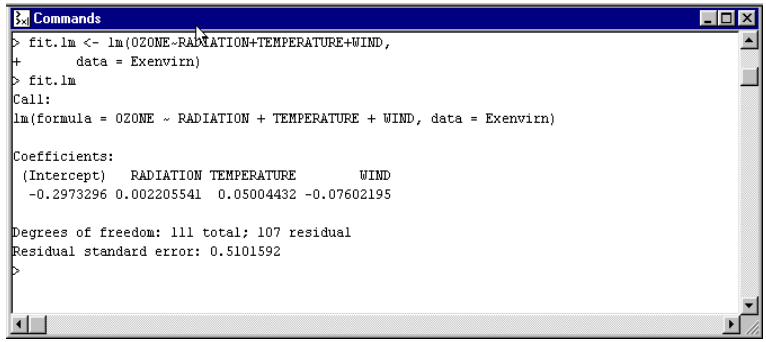


Figure 1.20: *The Commands window.*

The **Commands** window gives you interactive access to the **S-PLUS** language. Everything you type in **S-PLUS** is an *expression*. Expressions are evaluated when you press the ENTER key. If you press ENTER after an expression that is syntactically incomplete, it is not evaluated; however, it does not result in an error, either. Instead, S-PLUS prompts you to continue the expression with the + continuation prompt.

You can type several expressions on the same line by separating them with semicolons (;). S-PLUS evaluates each in succession when you press ENTER. A semicolon is not required at the end of each line; only between multiple expressions on a single line. You can include comments in S-PLUS expressions following a # symbol. Anything after the # on a line is interpreted as a comment, and is not evaluated.

The result of any expression is an *object* that may be saved by assigning it a name using the assignment operator <-. (The assignment operator is typed by typing a “Less than” character

followed immediately by a "hyphen"; do not put any spaces between the two characters.) All data used in S-PLUS is represented as some type of S-PLUS data object.

Most S-PLUS expressions are *function calls*, since S-PLUS is a functional language. To call a function, type the name of the function followed by a set of parentheses containing any arguments to the function.

S-PLUS commands are case-sensitive. S-PLUS ignores most spaces, so you can include or omit spaces in typing your expressions as you prefer. Do not place extra spaces within the name of an object, however, or between the digits of a single number, or between the < and - in the assignment operator.

The **Commands** window uses a > prompt. In this document, text starting with > is to be typed at this prompt. Do not type the >.

Listing Objects

1. If you have not already done so, use **File ► Open** to load **Exenvirn.sdd** from the **samples** directory.
2. To replicate the regression results and store them in an object named `fit.lm`, type the following (remember that the S-PLUS language is case-sensitive):

```
> fit.lm <- lm(OZONE~RADIATION+TEMPERATURE+WIND,
+      data = Exenvirn)
```

3. To see a brief summary for the model, type:

```
> fit.lm
```

Fitting a Linear Model

When fitting the model using dialogs, we added one interaction term to examine the interaction between temperature and radiation in determining ozone level. We now fit a model containing interactions and explore whether the interactions are significant.

1. To fit a linear model with all two-way interactions, type:

```
> fit.int <- lm(OZONE ~ (RADIATION + TEMPERATURE +
+      WIND) ^ 2, data = Exenvirn)
```

2. For a brief summary of the fit:

```
> fit.int
```

3. For a detailed summary:

```
> summary(fit.int)
```

4. For an F-test comparing this model to the model fit above:

```
> anova(fit.lm, fit.int)
```

Getting Help for Commands

To get help for a command, such as anova, when working in the **Commands** window, type

```
> help(anova)
```

USING THE SCRIPT WINDOW

The **Script** window makes it easy to edit and run several lines of commands. To open a **Script** window, choose **File ► New** to bring up the **New** dialog, then choose **Script File**. To run the script, click the **Run** button , or press F10. To run only selected commands, first highlight them and then click the **Run** button or press F10. There is no prompt in the **Script** window. If no output appears in the lower pane, choose **Options ► Text Output Routing** and click **Script Output** in both columns.

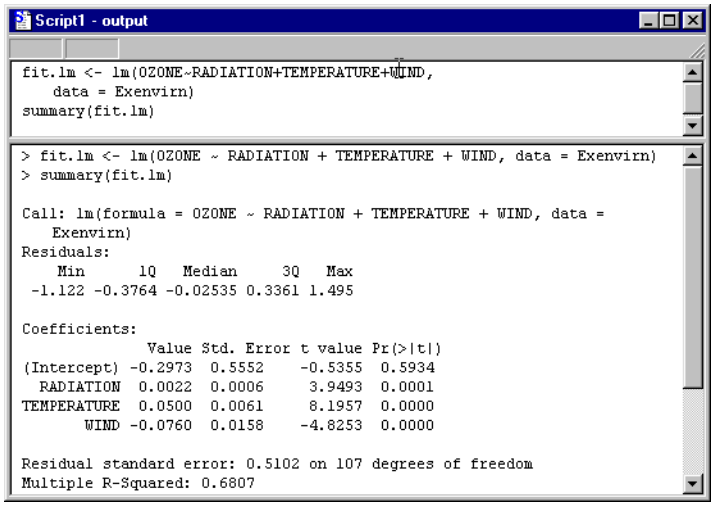


Figure 1.21: *The Script window showing an S-PLUS language script and regression output.*

Getting Help for Commands

To get help for an S-PLUS language command when working in the **Script** window, highlight the command and press F1.

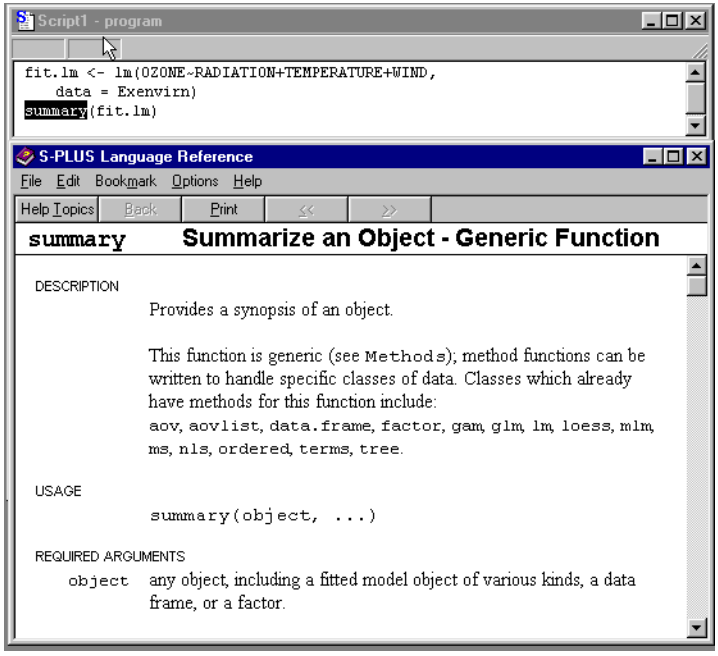


Figure 1.22: *Getting help for the* `summary` *function when working in the Script window.*

Running an S-PLUS Language Script

To run an S-PLUS language script:

1. Choose **File ► Open** and navigate to the **samples** directory.
2. Enter `exhypbl1.ssc` as the **File name** and click **Open**. A **Script** window opens with the script in the top pane.
3. Click the **Run** button . The script output appears in the bottom pane.
4. Go to the bottom of the top pane of the **Script** window and, using the mouse, highlight the function name `nls`. Press F1 to see a complete description of this function.
5. Close the **Script** window.

SUMMARY: BASIC PROCEDURES

In this tutorial, you have used virtually all of the basic procedures you need to use S-PLUS effectively. This section summarizes those basic procedures.

Using Main Menus

S-PLUS menus change, depending on the type of window you are working on. For example, if the active window (the highlighted window) contains a **Data** window, the menus display options useful for operating on **Data** windows. **Graph Sheet** and programming options are absent or dimmed.

Menu options with a ► symbol at the end of the line display a submenu when selected. Menu commands with an ellipsis (...) after the command display a dialog when selected. To cancel a menu, click outside the menu or press ESC.

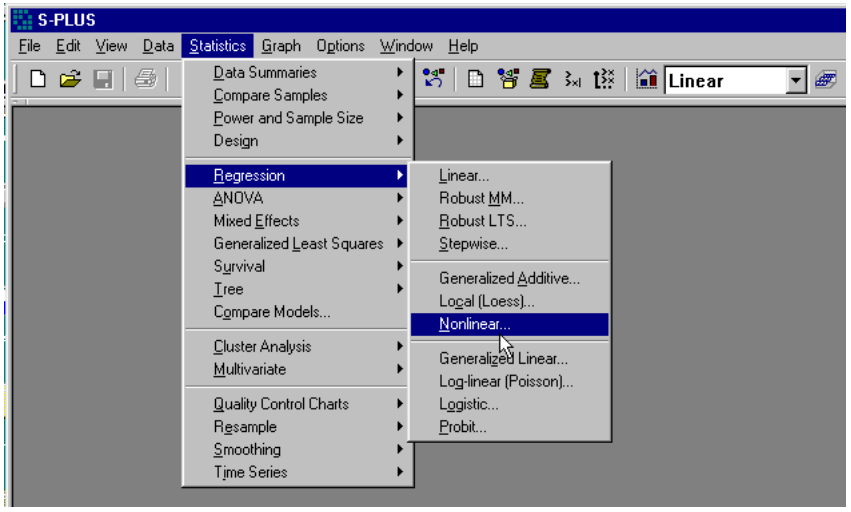


Figure 1.23: *Choosing Nonlinear Regression from the Statistics menu.*

Using Shortcut (Right-Click) Menus

When you click the right mouse button, a shortcut menu for the selected object is displayed. Shortcut menus contain options specific to the selected object. The shortcut menu appears to the right or left of the mouse pointer.

To close a shortcut menu without choosing an option, click outside the menu or press ESC.

Dialogs

Sometimes choosing a menu option or clicking the mouse displays a dialog. You can use dialogs to specify information about a particular action. There are two types of dialogs: action dialogs and properties dialogs. Action dialogs carry out commands, such as copying a column. Properties dialogs display and allow you to modify the properties (characteristics) of the selected object.

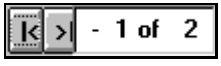
Dialogs can contain multiple, tabbed pages of options. To see the options on a different page of the dialog, click the page name or press CTRL-TAB to move from page to page. When you choose **OK** or **Apply** (or press ENTER), any changes made on any of the tabbed pages are applied to the selected object.

Most of the dialogs are *modeless*. They can be moved around on the screen, and they remain open until you choose to close them. This means you can make changes in a dialog and see the effect without closing the dialog. This is useful when you are experimenting with changes to an object and want to see the effect of each change.

The Apply Button

Modeless dialogs have an **Apply** button. The **Apply** button acts much like an **OK** button except that it does not close the dialog. You can specify changes in the dialog and then choose the **Apply** button or press CTRL-ENTER to see your changes, keeping the dialog open so that you can make more changes without having to reselect the dialog. If no changes have been made to the dialog since it was last opened or "applied," the **Apply** button is dimmed. When you are ready to close the dialog, you can choose **Cancel** or just double-click the close box on the dialog.

The Dialog Rollback Buttons



The **Dialog Rollback** buttons let you restore a dialog to a prior state. You can scroll back through each of the prior states until you find the set of values you want. Then you can modify any of these values and choose **Apply** or **OK** to accept the entire current state of the dialog (that is, to change the corresponding object or issue the corresponding command, depending upon the type of dialog). One use of **Dialog**

Rollback is to restore an object to a previous state. This is different from **Undo** in that rollback can be applied selectively to an individual object.

Typing and Editing in Dialogs

The following tasks can be performed in dialogs using the special keys listed below.

Table 1.1: *Shortcut keys when using dialogs.*

Action	Special Keys
Move to the next option in the dialog	TAB
Move to the previous option in the dialog	SHIFT-TAB
Move between pages in a multipage dialog	CTRL-TAB
Move to a specific option and select it	ALT-underlined letter in the option name: Press again to move to additional options with the same underlined letter.
Display a dropdown list	ALT-down arrow
Select an item from a list	Up or down arrow to move, ALT-down arrow to close the list
Close a list without selecting any items	ALT-down arrow

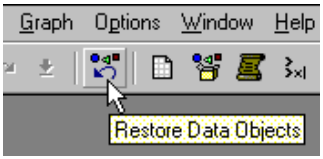
Using Toolbars and Palettes

Toolbars contain buttons that are shortcuts to menu selections. You can use toolbar buttons to perform file operations, such as opening a file or saving a file. You can also use toolbar buttons to make immediate changes to selected objects, such as font or color changes.

S-PLUS displays two toolbars: the **Standard** toolbar and a special toolbar that changes depending on the type of sheet being edited. You cannot turn off the display of **Standard** and special toolbars.

ToolTips

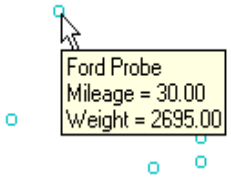
When you pause the mouse over a toolbar or palette button, helpful ToolTips appear:



You can control whether ToolTips are enabled in the **General Settings** dialog. Select **Options ► General Settings** to see the dialog. If **Enable ToolTips** is checked, tip windows will appear.

DataTips

DataTips are like ToolTips, except that they display information about the current data set in a **Data** window or **Graph Sheet**. They are displayed, for example, when you hover over a point in a scatter plot, or over the column number in a **Data** window.



You control whether DataTips are enabled using **Options ► General Settings**.

Using Toolbar Buttons

When you position the mouse pointer over a toolbar button, a description appears at the bottom of the screen in the status bar. Like menu options, some toolbar buttons may not be available at all times. Inactive toolbar buttons are dimmed (for example, the **Undo** button is dimmed if there is nothing to undo).

Displaying Palette Buttons

Several buttons display a palette of options when selected. For example, the **2D Plots** button will display a palette of 2D plot types. Tool palettes remain in view until you click the toolbar button again or click the palette's close box. Leaving a tool palette in view is convenient when you are experimenting with different options.

Selecting, Opening, or Importing Data

The first step in virtually any S-PLUS task is to select, open, or import a data set to work on. Each of these terms has a specific meaning in S-PLUS. *Selecting* a data set means choosing one data set from among the data objects stored in S-PLUS's internal databases. *Opening* a data set means choosing an S-PLUS data file from your hard disk or network file system and opening it in S-PLUS. *Importing* a data set means choosing a data file in any of S-PLUS's supported file formats (for example, Excel) and opening it in S-PLUS. In general, the result of each of these tasks is to open a **Data** window displaying the selected, opened, or imported data.

Selecting Data

You can select data either from the **Select Data** dialog or from the **Object Explorer**. If you want to look at the data in a **Data** window, and want to have the data visible as you proceed with your tasks, the **Select Data** dialog is probably simplest and fastest. If you want to work with many separate data objects with which you are already somewhat familiar, the **Object Explorer** can be much more efficient.

To select data from the **Select Data** dialog:

1. Choose **Data ► Select Data**. The **Select Data** dialog appears.
2. In the **Source** group of radio buttons, select **Existing Data**.
3. In the **Existing Data** group, type a data object name or select a data object from the dropdown menu in the **Name** combo box.
4. Click **OK**. The selected data appears in a **Data** window.

To select data from the **Object Explorer**:

1. Click the **Object Explorer** button  on the standard toolbar to open the **Object Explorer.**
2. Double-click the **Data** icon in the left pane, or equivalently, click the "+" sign to the left of the **Data** icon. The **Data** folder expands to show the currently filtered data objects in the left pane.
3. Click a data object to select it. The right pane displays a listing of the data object's variables. Double-click the item to show the data object in a **Data** window.

Opening Data

To open a data set:

1. Click the **Open** button  on the **Standard** toolbar, or equivalently, choose **File ► Open**. The **Open** dialog appears.
2. Navigate to the directory containing the desired file.
3. Select the desired file.
4. Click **Open**.

Importing Data

You can import data from a file, from the major financial databases LIM, FAME, and Bloomberg, or via an ODBC connection. ODBC connections allow you to extract data sets from enterprise databases. In all cases, there are numerous options you can specify; the procedures given here are for the simple case where you want to read an entire data file. See the section Importing and Exporting Data (page 52) in the *User's Guide* for additional details.

To import a data set from a file:

1. Choose **File ► Import Data ► From File**. The **Import Data** dialog appears.
2. Navigate to the directory containing the desired file.
3. Select the desired file.
4. Click **Open**.

To import data from the financial databases, see the section Importing Data From Financial Databases (page 61) in the *User's Guide*. To import a data set from an ODBC connection, see the online help.

Selecting Variables to Plot

Once you've chosen a data set, you create plots by selecting variables from the data set and then choosing a plot type from a plot palette or the **Insert Graph** dialog. You can select variables in either a **Data** window or the **Object Explorer**.

To select variables in a **Data** window:

- Drag your mouse across the column header to select one or more contiguous variables.

- Click in one column header, then SHIFT-click in another to select a range of variables. All the variables between the variable in which you first click and the variable in which you SHIFT-click are selected.
- Click in one column header, then CTRL-click in one or more other columns to select noncontiguous variables.

To select variables in the **Object Explorer**:

- Click one variable name, then SHIFT-click another to select a range of variables. All the variables between the variable you first click and the variable you SHIFT-click are selected.
- Click one variable name, then CTRL-click one or more other variable names to select noncontiguous variables.

Creating Plots

Once you have selected one or more variables to plot, you can create plots easily by clicking on one of the plot buttons in the **Plots2D** or **Plots3D** palette. Table 1.2 shows the plot types most commonly associated with a given number of selected variables. Plots appear in a **Graph Sheet** window.

Table 1.2: *Common plots associated with a given number of variables.*

Number of Selected Variables	Plots
1	Boxplot, histogram, density, histogram density, QQ normal with line, dot, bar, pie.
2	Scatter, line, line/scatter, isolated points, high density, horizontal high density, step, curve fit (linear, robust linear, polynomial, nonlinear, exponential, natural log, power, log 10, spline, supersmooth, loess), QQ, Y series.

Table 1.2: *Common plots associated with a given number of variables.*

Number of Selected Variables	Plots
3	Bubble, color, text-as-symbol, scatterplot matrix, grouped bar, stacked bar, grouped bar with error, stacked bar with error, contour (line or filled), 3D scatter, 3D line, 3D line scatter, 3D dropline.
4 or more	XY pairs, scatterplot matrix, grouped bar, stacked bar, high-low-close, error bar.

Editing Graphics

You edit your graphics by selecting specific objects within the **Graph Sheet** and either directly manipulating the object, or using menus, dialogs, and toolbars to edit the selected object. As an example of direct manipulation, consider the 3D rotation described in the section Creating PowerPoint Slides Automatically (page 32). As an example of using menus, dialogs, and toolbars, consider the plot editing described in the section Changing Graph Features (page 15).

The Graph Sheet

In S-PLUS we distinguish between the **Graph Sheet**, the graph area, and the plot area. The **Graph Sheet** is best described as the sheet of paper on which we draw our plots. When you print, you print one or more pages of a **Graph Sheet**. A **Graph Sheet** can contain more than one graph. The graph area refers to the rectangle surrounding

the data points, axes, legends, graph title, etc. The plot area is the rectangular area within the graph where the data are plotted. See Figure 1.24 for an illustration.

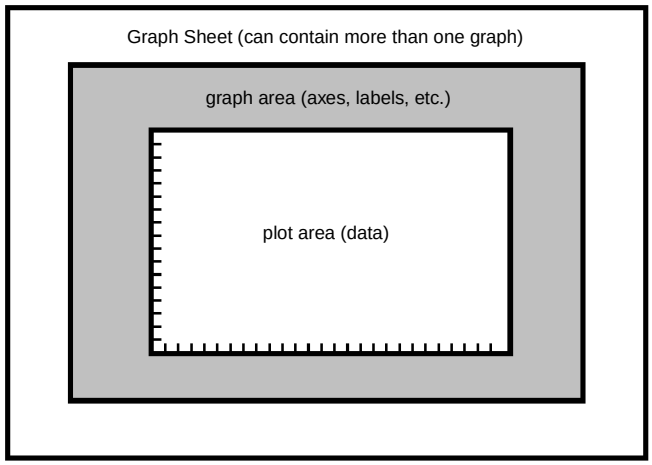


Figure 1.24: *A Graph Sheet with graph area (gray) and plot area (center).*

Within the plot area, you can select either the plot area itself or the plot within.

- To select the plot area, click a blank area within the plot area.
- To select the plot, click any plotted element (line, symbol, filled region, etc.).

Axes and axis titles are editable and selectable separately on 2D graphs. Axis labels are formatted per axis.

- To select an axis, click the axis itself or within the tick marks.
- To select an axis title, click it.
- To select an axis' labels, click any label.

To select the plot, click any plotted data (points, lines, filled regions) within the plot area. Figure 1.25 shows the difference in the two methods of selection.

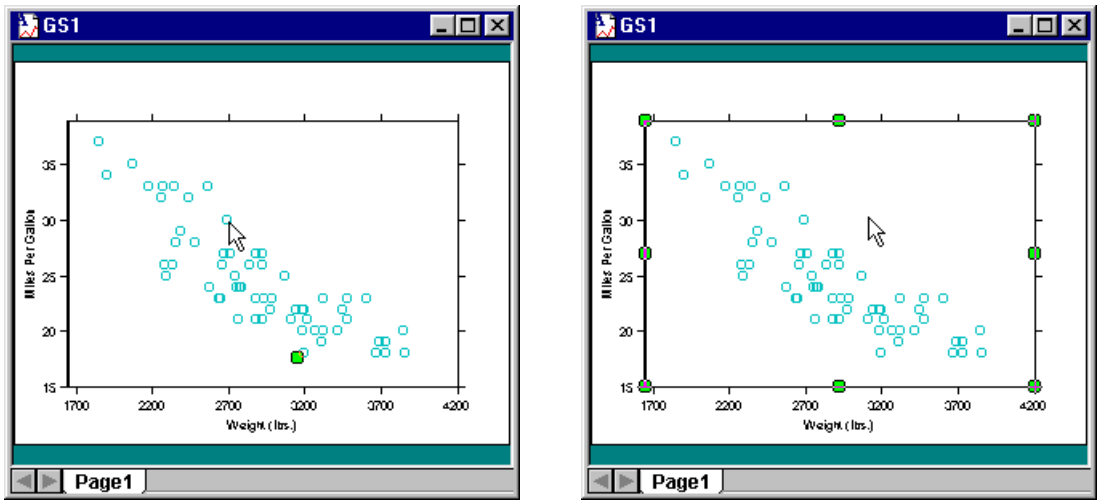


Figure 1.25: *Selecting the plot vs. selecting plot area.*

WHAT'S NEW IN S-PLUS 2000

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S-PLUS 2000 is a major upgrade of S-PLUS, including the following new or enhanced features:

1. Statistics

   - New easier-to-use statistics dialogs, including a new **Variables** group for simple model specification. See the Statistics chapter in the *User's Guide*.
   - Enhanced discriminant analysis (homoscedastic (linear), heteroscedastic (quadratic), proportional covariances, equal correlation, common principal components, canonical discriminant function), with a new dialog. See the chapter Discriminant Analysis in the *Guide to Statistics, Volume 2*.
   - Enhanced LME/NLME. New, state-of-the-art code, contributed by Doug Bates of the University of Wisconsin–Madison and José Pinhiero of Lucent Technologies, is included. There are dialogs for linear and nonlinear mixed-effects models, and linear and nonlinear models fit with generalized least squares. See the chapter Linear and Nonlinear Mixed-Effects Models in the *Guide to Statistics, Volume 1*.
   - Enhanced Survival Analysis. This includes a new survival library from Terry Therneau at the Mayo Clinic, along with some enhancements to the accelerated life testing (censorReg) functionality, plus revised and enhanced dialogs. See the chapters on survival analysis in the *Guide to Statistics, Volume 2*.
   - Enhanced Quality Control charts now include a number of moving average charts, and there are new dialogs for creating these charts. See the chapter Quality Control Charts in the *Guide to Statistics, Volume 2*.

2. Data

   - Import data from the leading financial databases: Bloomberg, FAME, and LIM. See the section **Importing Data From Financial Databases** (page 61) in the *User's Guide*.
   - Data manipulation capabilities and dialogs have been greatly enhanced:

   i. Block operations (copy, move, transpose, clear, remove)

   ii. Operations on rows and columns (copy, move, transpose, clear, remove, pack, append, stack, unstack). Noncontiguous and conditional sets of rows and columns can be specified.

   iii. **Data Fill**, **Create Categories**, and **Subset Builder** dialogs

   - DataTips now show column type and column description. Just point the mouse cursor at the column number to see the column type, or at the column name to see the column description.
   - New `data.sheet` data object has been added. Similar to a data frame, the data sheet object type provides increased flexibility. Most importantly, you can have data columns of different lengths stored in a data sheet.
   - Save, load, and create data objects via the **File** menu.

4. New **Object Explorer** (see the chapter Organizing Your Work in the *User's Guide*.)

   - View an outline of your data objects and your documents in the left pane. Expand and contract the outline as you do in the Windows Explorer.
   - View the contents of any object in the right pane, along with explanatory information.
   - Add your own folders to the **Object Explorer**. Add objects to it by filtering or by drag-and-drop.
   - Select data columns from the right pane of the **Object Explorer** and graph them with the plot palettes.
   - View and manipulate time series objects.

5. Graphics (see the chapter Creating Plots in the *User's Guide*).

   - DataTips and labeling have been added to scatter plots. Point your mouse cursor at a data point in a scatter plot. A DataTip appears showing the values of your data for that point. Customize the contents of the DataTip for each plot on the **Data to Plot** page of the plot's dialog. Use the **Label Data Points** tool to create a comment with the contents of the tip.

   - New plot types have been added to the 2D plot palette. The first five plot types are completely new to S-PLUS. The remaining plots have been added to the 2D plot palette for easy accessibility.

     i. Combined vertical/horizontal error bar charts. Draw graphs showing errors for both the x and y directions.

     ii. High-low-open-close plots. Plot financial data showing not only the high and low values for the day, but also a marker showing the open and close values. Alternatively, draw a candlestick plot to show the open-close region.

     iii. Multiple x-y pairs. Plot two or more pairs of x-y data series on the same plot by selecting the data columns and clicking on a plot button.

     iv. Nonlinear curve fitting plots. Specify your own model, and the fitted line will be calculated and drawn.

     v. Smith Charts. A new plot type most often used by engineers.

     vi. Vector Plots

     vii. Polar Plots

     viii. Power Fit

     ix. Ln Fit

     x. Log 10 Fit

     xi. Friedman's Supersmooth

     xii. Horizontal High Density

     xiii. Horizontal Step Plots

xiv. Horizontal Error Bar Charts

xv. Grouped Horizontal Bar Charts.

- New **Default 2D Axis** toolbar option and new **Insert Graph** dialog let you specify 2D axis types before you create your plot, as well as showing you a clear picture of the type of plot you're creating. For example, select three columns of data, then choose **Multiple Y** axes and a scatter plot. Two plots are created, and the second plot is scaled to an automatically created right y-axis. Or, choose **Log Y** to have the scaling on your y-axis automatically set to Log scaling.
- Embed data into your **Graph Sheet** so that it can be saved as a single file.
- Extract data from a **Graph Sheet** to link the plots to data. For example, if you've created a graph from the command line, you can later extract the data used within in it and have it put into a data set. Examine the data, edit it, draw other graphs with it, and interactively select data points on the graph.

16. Saving and Loading the Workspace (see the chapter Organizing Your Work in the *User's Guide*.)
    - Workspace files can be saved and loaded. Each workspace file contains a complete description of the workspace, including sizes and positions of open documents and user-specified paths.
17. Enhanced History Log
    - By default, the history log is now condensed, showing quick summaries of your actions. You can choose to see full commands, if you prefer.
18. Automation (see the chapter Automation in the *Programmer's Guide*.)
    - Greatly enhanced automation server capabilities, especially for using C++ and Java to write automation clients for S-PLUS.
    - Enhanced automation client capabilities.

- New automation help capabilities. Generate HTML files containing entire object hierarchy in S-PLUS, including all internal objects and methods and user-defined functions.

19. GUI customization and deployment
    - Drill down capability in **Object Explorer** for **FunctionInfo** objects and for properties makes dialog creation much easier.
20. Interacting with other products
    - New S-PLUS component for Mathcad
21. Improved speed
    - Start-up speed up to 50% faster (depending on machine)
22. Y2K compliance.
    - S-PLUS 2000 for Windows/NT has had complete Y2K test coverage
23. User-contributed libraries from Brian Ripley and William Venables, and from Frank Harrell.
24. Documentation
    - The documentation set has been revised and expanded.
    - Tips of the Day to improve your efficiency have been added.
    - New sample files have been added to the **samples** directory:

    i. Many sample graphs and data sets

    ii. New automation examples

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