

# Panoply

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*netCDF Visualization Software*

v. 1.5.1

**Panoply v. 1.5**  
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Although Panoply was produced at a U.S. Government research institute, the complete Panoply application cannot be considered public domain because it includes libraries provided by third parties which have individual copyrights and licenses.

The following Java libraries and classes are used with permission under the GNU Lesser General Public License (<http://www.gnu.org/copyleft/lesser.html>):

- netCDF Java library by Unidata  
(<http://my.unidata.ucar.edu/content/software/netcdf/index.html>)
- HTTPClient Java library by Innovation Gmbh  
(<http://www.innovation.ch/java/HTTPClient/>)
- PngEncoder class by J. David Eisenberg  
(<http://catcode.com/pngencoder/>)

We gratefully acknowledge use of the following Java libraries and classes, used under the terms of a modified General Public License available at the library website:

GNU JAXP and AElfried2 parser by the GNU Classpath Extensions Project  
(<http://www.gnu.org/software/classpathx/jaxp/>)

We also gratefully acknowledge use of the following Java libraries and classes:

- QuantizeFilter class by Jerry Huxtable  
(<http://www.jhlab.com/ip/>)
- JDOM by the JDOM Project  
(<http://www.jdom.org/>)

Source code and compiled Java bytecode for these libraries and classes are available at the URLs provided.

Additional copies and/or updated versions of Panoply may be downloaded from <http://www.giss.nasa.gov/tools/panoply/>.

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# Introduction

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*panoply* \PAN-uh-plee\, noun: 1. A splendid or impressive array. ...

Panoply is a Java application that enables the user to plot raster images of geo-gridded (geo-referenced) data from datasets in netCDF format (see Appendix 1). Depending on the type of data available, Panoply can be used to create displays in a variety of ways:

- Plot longitude-latitude data as global maps or zonal averages, using any of over 40 global map projections
- Overlay continent outlines or masks on longitude-latitude plots, or just plot a particular region
- Display specific latitude-longitude or latitude-vertical arrays from larger multidimensional variables as slices

Panoply also functions as a tool for graphical data analysis and reporting of results by allowing the user to:

- Combine two arrays in one plot by differencing, summing or averaging
- Use any of the 30 scale colorbars provided (based on PAL, ACT or CWC color tables), or add a custom colorbar
- Save plots to disk as PNG or GIF images

Your computer must have a Java 1.3 virtual machine or better installed prior to the installation of Panoply. For the latest version of Java, visit <http://www.java.com>.

## Contact Information

If you wish to be notified when new versions of Panoply are released, or if you would like to report a bug, please contact the author at:

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## Installation Notes

After uncompressing the Panoply package, you should be able to run it “as is” from the location where you’ve placed the application.

### *Install and Run Panoply for Mac OS X*

The Panoply package for Mac OS X comes as a StuffIt archive (PanoplyOSX.sit), which can be uncompressed using the free StuffIt Expander utility from Allume Systems (<http://www.stuffit.com>). The package contains a folder holding the following items:

- Panoply application
- Colorbars (color tables) in a folder called “colorbars”
- Continent masks and outlines in a folder called “overlays”
- Sample netCDF datasets in a folder “sample\_data”
- A README file

To run Panoply on Mac OS X, just double-click on the Panoply application.

(Note: Panoply is not compatible with the “classic” Mac OS.)

If you find that Panoply quits immediately when you try to run it for the first time by double-clicking on its desktop icon, it may be that the program’s permissions were corrupted when StuffIt Expander opened up the PanoplyOSX.sit archive. This problem can occur if you have StuffIt 8.0.0 on your machine and have not updated to a later StuffIt 8.0.x version. Try updating StuffIt and then downloading and installing a fresh Panoply package.

### *Install and Run Panoply for Windows*

The Panoply package for Windows comes as a zipped archive (PanoplyWin.zip). You must manually extract this archive, using WinZip, StuffIt Expander or some other ZIP-compatible program. Some versions of Windows allow you to run programs from a zipped archive without extraction, but that won’t work with Panoply.

Extracting the archive creates a folder called “PanoplyWin” which holds the following items:

- Panoply.exe application
- Java application files in a folder called “jars”
- Colorbars (color tables) in a folder called “colorbars”

- Continent masks and outlines in a folder called “overlays”
- Sample netCDF datasets in a folder “sample\_data”
- A README file

To run Panoply, just double-click on the Panoply.exe application.

Windows computers often do not have Java automatically installed. To ensure that you have an appropriate version of Java on your machine, use the Sun utility that looks for it on your desktop and automatically downloads it if necessary. Go to the Java.com website and click on the “Free Download” button at the top right of the page. Note: It is possible to have a Java plugin enabled in your web browser that allows you to run applets, but not have a JRE installed which allows you to run Java applications.

The folder called “jars” must remain in the same location as the Panoply.exe application. Also, all .jar files in the jars folder must remain there. If you move or remove that folder or any of its contents, Panoply will not work.

### *Install and Run Panoply “Generic”*

The “standard” Panoply package comes as either a (a) zipped archive (PanoplyJ.zip) or (b) tarred and gzipped archive (PanoplyJ.tar.gz), either of which can be uncompressed by many freeware uncompression utilities. Both archive types contain a directory, “PanoplyJ”, holding the following items:

- Java application in a jar file called “Panoply.jar”
- Several other Java “.jar” files
- Sample colorbars (color tables) in a directory called “colorbars”
- Sample continent overlays and outlines in a directory called “continents”
- Sample netCDF datasets in a directory called “sample\_data”
- A README file

On many platforms, you should be able to launch Panoply by double-clicking on the Panoply.jar file icon. If your computer does not permit that, you should still be able to launch Panoply from the command line; simply cd into the directory where Panoply.jar is located and then type `java -jar Panoply.jar`

In addition to the Panoply.jar file included in the generic Panoply package, there are five other Java .jar files. You must keep these in the same directory as the Panoply.jar file, or Panoply will not run.





# Quick Start Guide

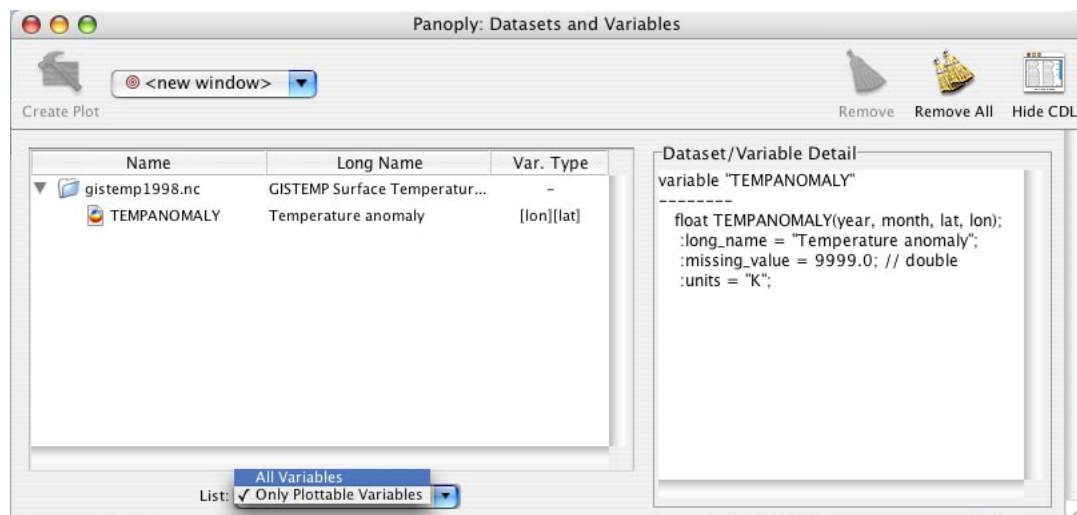
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## Creating Data Plots in Panoply

Once you have Panoply installed, double-click on the Panoply icon to launch the program. You will be immediately asked to select a netCDF dataset; navigate to the “sample\_data” folder included with Panoply, and select the “gistemp1998.nc” file.

## Datasets and Variables (The Data Browser)

Opening the gistemp1998.nc file will bring up a window, called the data browser. This window displays the dataset file name as a folder. Double-clicking the folder name opens it to show individual variables listed by their abbreviated name in the file; the long name of each variable (usually more descriptive than the abbreviated name); and the type of variable (whether latitude-longitude or latitude-vertical). By default, only plottable variables are shown initially, but you can opt to see all variables in the dataset by selecting “All Variables” from the drop-down menu at the bottom of the window.

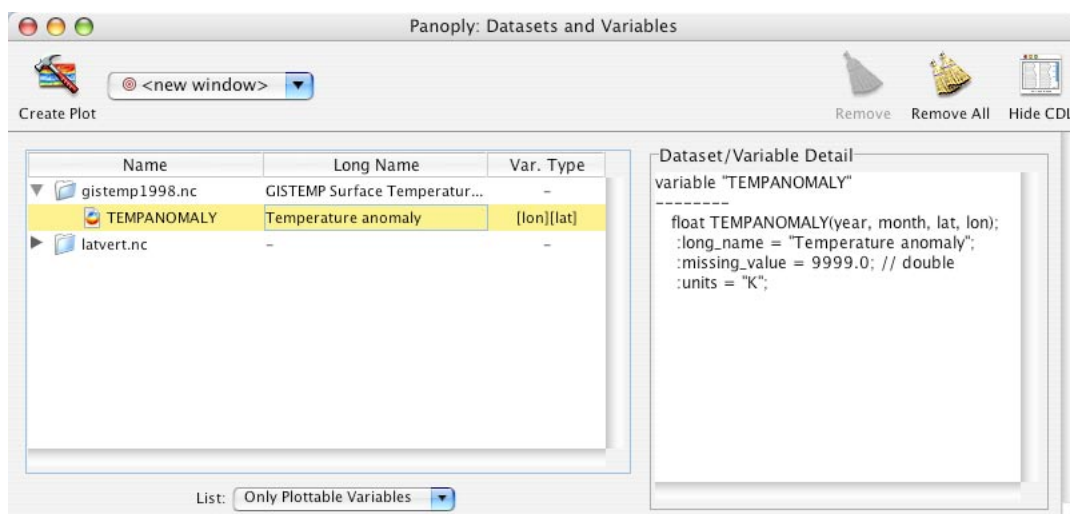


*The data browser displays the names and characteristics of the variables within the datasets selected.*

The details of a given variable within the dataset are shown on the right side of the data browser. If you don’t wish to see these details, simply click on the “Hide CDL” icon in the upper right corner of the data browser.

Multiple datasets can be opened in the data browser, which is especially useful if you plan to compare the same variable in different datasets. To add more datasets, simply open them in the same way you opened the initial dataset. The new dataset files will appear as new folders within the data browser. To remove an extra dataset at any point, simply select the folder name and click on the “Remove” whiskbroom icon in the upper right corner of the data browser. If you have already made plots and want to delete any unused datasets at that point, click instead on the “Remove All” whiskbroom icon.

When you are ready to create a plot, select a single variable from the list. At that point, the “Create Plot” icon in the upper right corner of the data browser becomes available. Click once on this icon, or else double-click the name of the specific variable you want, to create a plot.

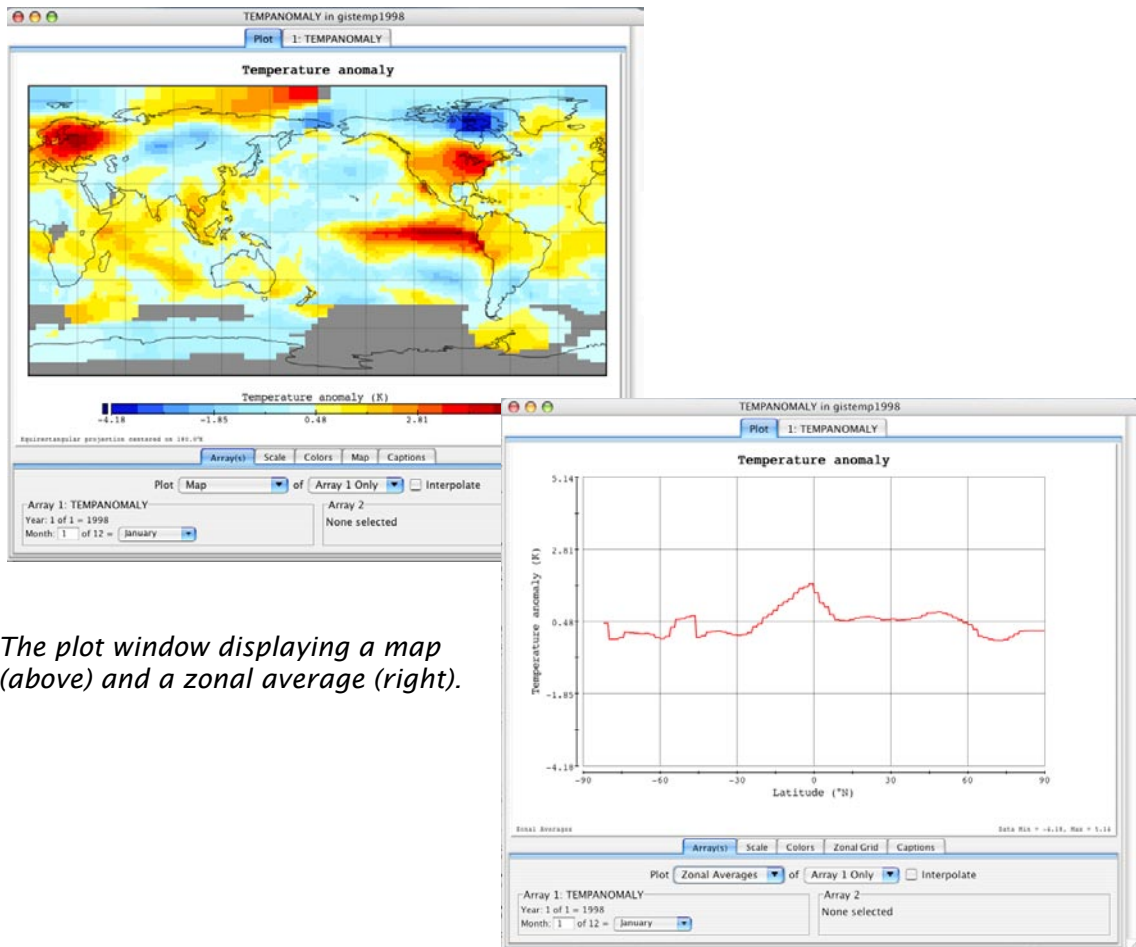


*Selecting a variable enables the plotting function in the data browser.*

## The Plot Window

This is the window in which you can adjust all aspects of a plot to suit your needs. There are a number of components to this window, any of which may be selected by clicking on individual tabs either near the top of the window (to toggle between the plot image and tables showing dataset values for a given variable), or at the bottom of the window for the Plot tab (to modify different attributes of a given plot).

Every time you choose to create a plot in a new window (from the data browser), a large window labeled with the VARIABLE\_NAME and the dataset file name will open first to a map view of the data. Note that you can set your own preferences regarding which map projection, colorbar, etc., Panoply should use each time you create a plot.



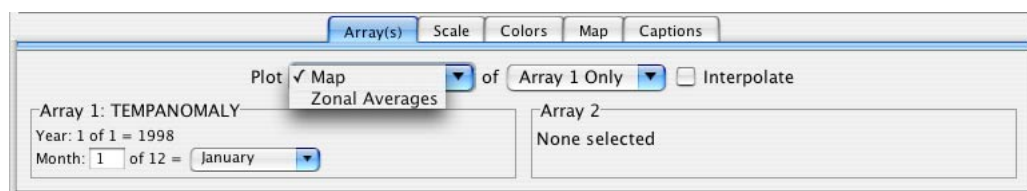
*The plot window displaying a map (above) and a zonal average (right).*

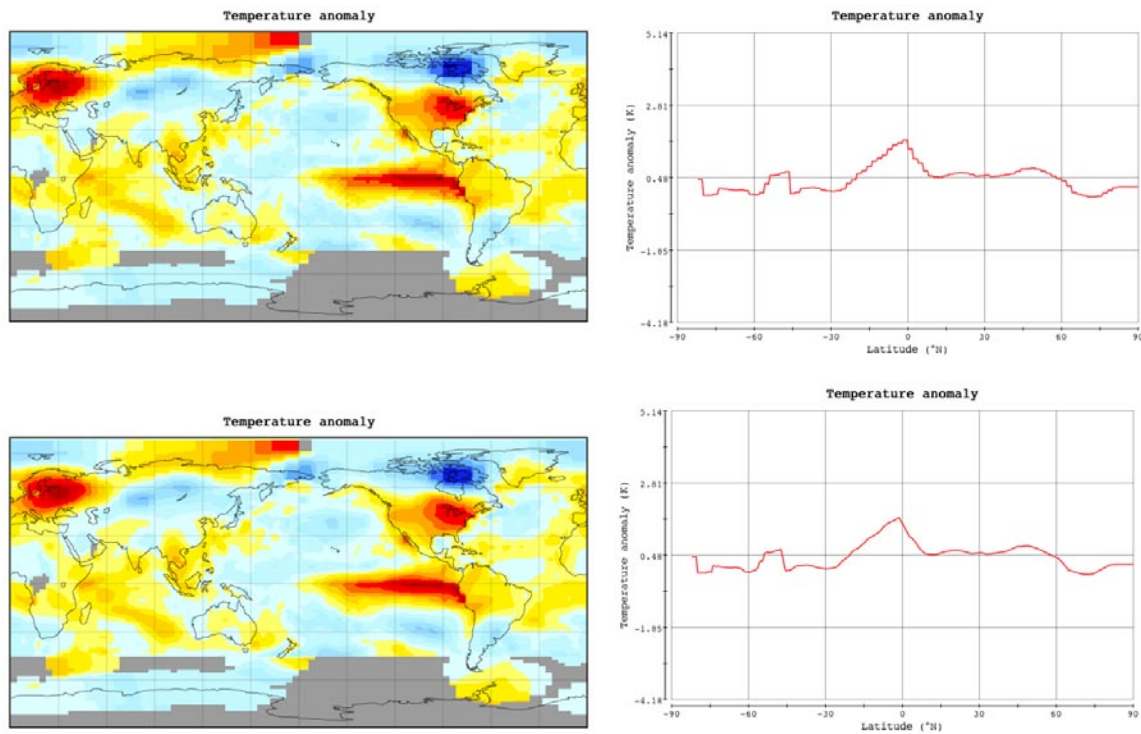
First, let's look at how to modify a plot of a single variable.

### *The Array(s) Tab*

In the plot tab for a dataset, the first attribute that can be modified is the array of data that you wish to show. The plot toggle menu allows you to switch back and forth between a map plot and a zonal average (the average variable value across a given latitude).

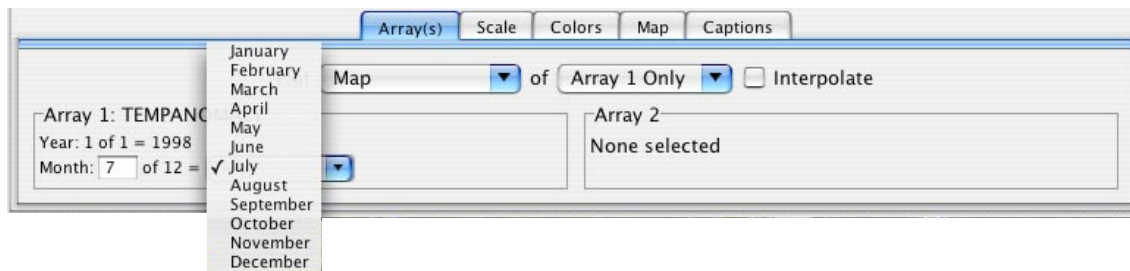
The interpolate checkbox to the right allows you to show the data as gridded cells or smoothly transitioning between values.





Map plots and zonal averages displayed in gridded (top row) and interpolated (bottom row) form.

Within the Array(s) tab, you can also change the time interval of interest according to the data available in the dataset. In the example below, you can select the month of the year you want to see plotted by either typing in a month number or selecting a month from the drop-down menu.



If you are plotting more than one array in a single plot (e.g., if you are differencing two datasets), the properties for the second array can be modified in the same way as for the first array. Make sure that you have the appropriate array selected in the drop-down menu of the array(s) tab before you begin changing plot properties.

## *The Scale Tab*

This tab controls the way the colorbar scale is displayed below the plot. You may or may not have the ability to modify some of these settings, depending upon the type of data in your dataset. The settings within the Scale tab include:

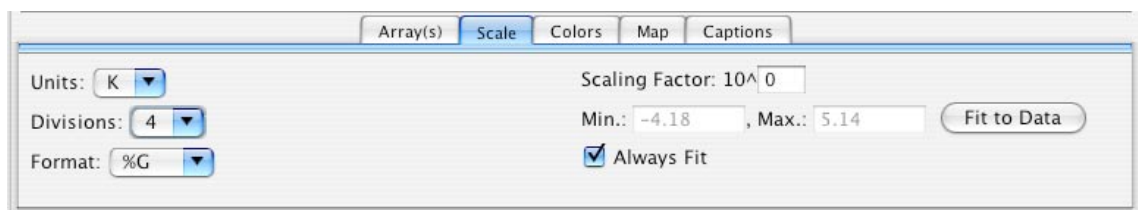
*Units:* The unit selection depends upon the units assigned to variables in the dataset. In the example below, units are given in degrees Kelvin (K).

*Divisions:* This setting refers to the number of major segments on the map colorbar scale or the major y-axis labels of a zonal average plot. There can be between two and six labeled divisions.

*Format:* This setting refers to the display of numeric labels as real numbers in decimal form (%f), numbers in scientific notation (%E), or the option to display in either form (%G). The labels f, E and G are standard Fortran variable formats; the other choices in the drop-down menu (ranging e.g. from %.0f to %.6f) denote the number of significant digits to be displayed for a particular format. For the average user, %G is a reasonable format selection.

*Scaling Factor:* For datasets where the range in values is quite small, a scaling factor, or exaggeration, expressed in exponential form can be useful in underscoring variability.

*Min., Max./Fit to Data:* This setting can be used to impose a scale of a certain range, for example, if a user wanted to have a scale with minima and maxima rounded to whole numbers. If the “Always Fit” checkbox is selected, however, the scale will be fitted precisely to the data, and no modification of the scale endpoints will be possible.



*The Scale tab allows flexibility in the labeling of scales for map colorbars and zonal average plots.*

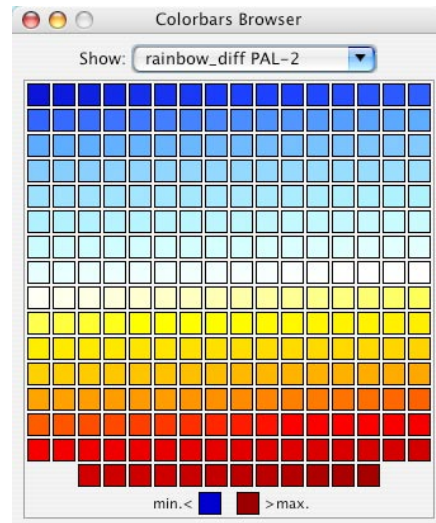


## The Colors Tab

This tab is primarily for use with map plots, as it is in this tab that you can select which colorbar you want to use.

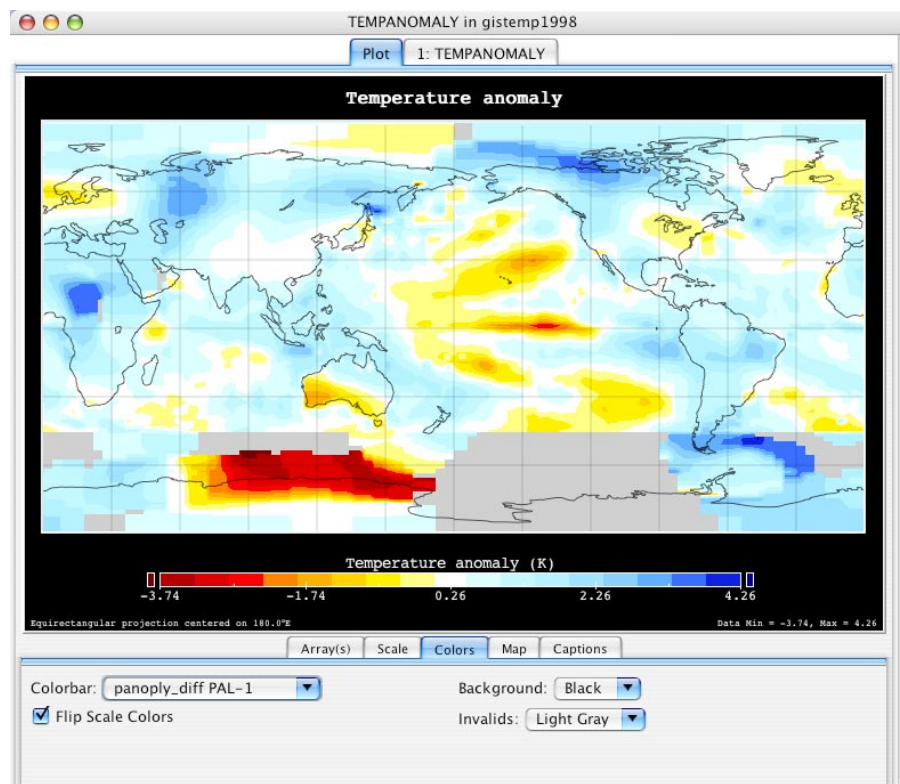
**Colorbar:** Thirty different colorbars have been included in Panoply, and each is listed in the “Colorbar” drop-down menu; you can, however, use a custom colorbar if you wish (see Appendix 2 for details). The “Flip Scale” checkbox allows you to reverse the order of colors in a colorbar selected from the list.

If at any point you would like to see the spectrum of colors that would be displayed for a given color bar, go into the Panoply Windows menu and select “Colorbars Browser” (shown at right).



**Background:** This setting can be used for both map plots and zonal average plots. It allows you to make the plot background either white or black.

**Invalids:** This setting allows you to indicate areas without data in a map plot by selecting a particular color (black, dark gray, gray, light gray, or white) that will contrast appropriately with your Colorbar selection.

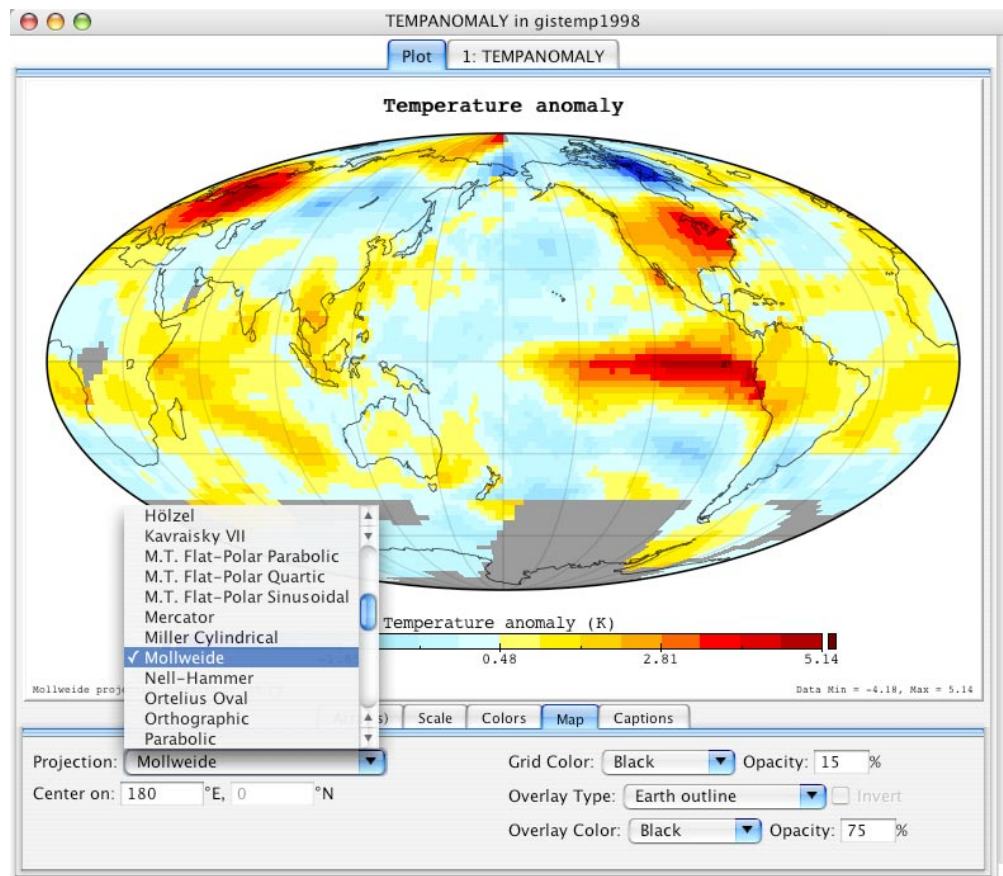


*The Colors tab is the tool for altering the visual impact of a map plot.*

### *The Maps Tab/Zonal Grid Tab*

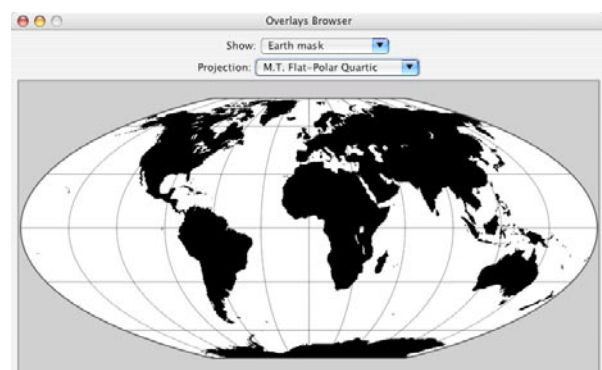
Whether you are working with a map plot or a zonal average plot, the fourth tab at the bottom of the plot window will display controls for modifying the gridded view of the data.

Map plots have a greater number of settings that can be adjusted:



*The Maps tab provides the major control for the appearance of your map.*

**Projection:** Over 40 different map projections have been included in Panoply, each with varying properties that make them suitable for different purposes (see Appendix 3). To preview the projections available, go into the Panoply Windows menu and select the “Continent Overlays Browser” (shown at right).



Some of the more commonly used map projections are:

*Equirectangular:* This is a cylindrical map projection, which means it has straight meridians and parallels that intersect at right angles. Scale is true at the equator, and along any pair of parallels equidistant from the equator. While is useful for comparison of narrow regions at similar latitudes, the increasing distortion of scale toward the polar regions makes it a less-than-ideal choice for world maps.

*Mercator:* This projection is perhaps the most famous of the cylindrical map projections. It differs from other types of cylindrical projections in that it is conformal: it preserves angles, so that any two lines in the map follow the same angle as the corresponding original lines on the Earth, even though shapes become increasingly distorted toward the poles. For this reason, the Mercator projection is often used in marine navigation.

*Mollweide:* This is a pseudocylindrical map projection, which means that it has straight and parallel latitude lines and equally spaced meridians, but all but the centermost meridian are curved. This projection is often used for world maps.

*Orthographic:* This azimuthal projection is used for perspective views of hemispheres, and so is especially useful for viewing polar regions. Area and shape are distorted, but distances along lines of latitude are true.

*Azimuthal Equal Area:* This azimuthal projection has the distinction of being able to show areas in true proportion to the same areas on Earth. Scale decreases gradually away from the center point, while distortion increases. This projection is useful for displaying large regions, such as the Pacific Ocean, that extend equally in all directions from a center point.

*Stereographic:* Yet another azimuthal projection, this one is also useful for polar regions, and in fact is often used for navigation there. Directions are true from the center point and scale increases away from the center, and area and shapes are increasingly distorted toward the outer edge of the map.

*Center on:* You can select a particular point on the globe to be placed at the center of the map, a useful feature for highlighting locations that are typically close a map edge.

*Grid color:* The default selection is black, but you can select from a range of colors to emphasize grid lines or to make them more subtle. You can also adjust the opacity of the grid lines by typing a different percentage in the adjacent box.



**Overlay type:** You can display continents as outlines or solid shapes in realistic form (Earth mask/outline) or in stylized form according to different model grid cell sizes (10x8 degrees or 5x4 degrees). You may also choose not to show any continents at all.

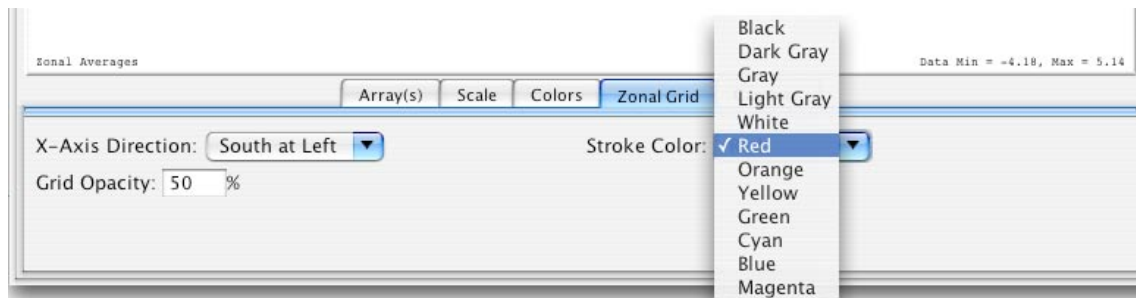
**Overlay color:** As with grid color, the default selection is black, but you can select from a range of colors to emphasize continent overlays or to make them more subtle. You can also adjust the opacity of the continents by typing a different percentage in the adjacent box.

Zonal average grids have just a few options available:

**X-Axis Direction:** This setting allows you to put the North or South Pole on the left side of the plot.

**Grid opacity:** You can adjust the visibility of grid lines on the plot.

**Stroke color:** The default color is red, but there are a range of colors available for highlighting the data itself on the plot.

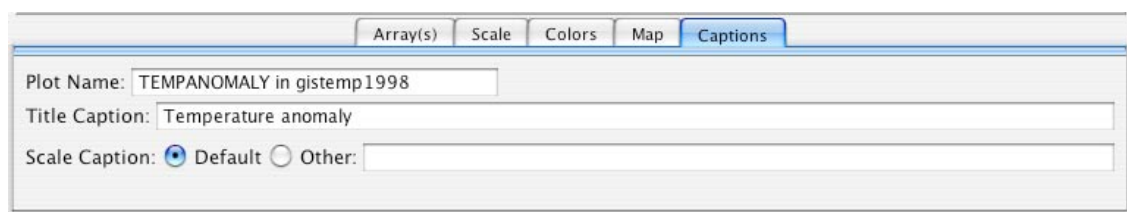


*The Zonal Grid tab permits limited customization of your line plot.*

### *The Captions Tab*

This tab, the same for both map plots and zonal average plots, allows you to change the name of the plot window, the plot title (which will be carried over to any exported images), and the scale caption. The scale caption by default is the long variable name plus the appropriate units.

Custom title and scale captions are permitted to be quite long, but you should aim to keep them concise so as to avoid cluttering your plot.

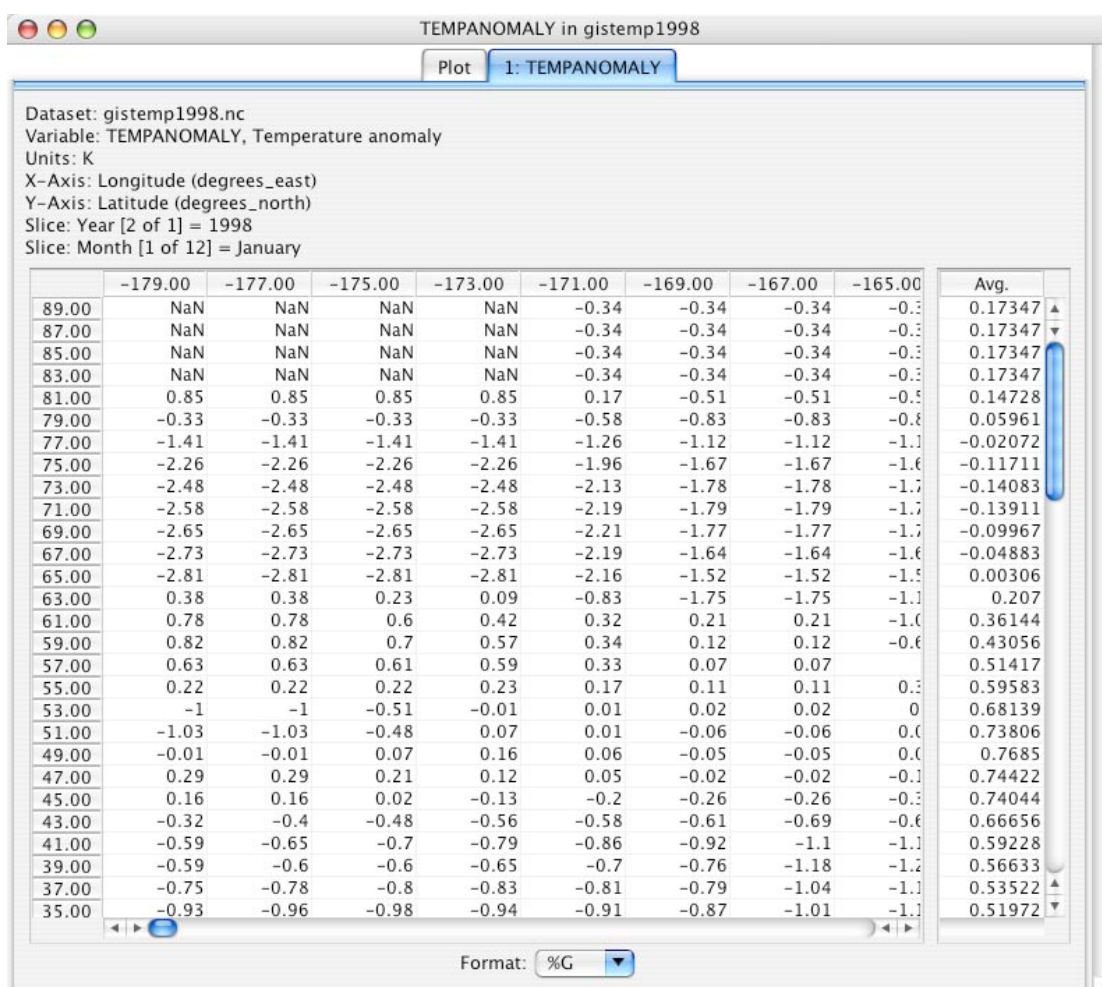


*The Captions tab permits customized labeling of your plot.*

## The Data Window

Tucked behind the map tab in the plot window is the array of data used to generate the map and zonal average plots, appropriately called the data window (shown below). Metadata (including the dataset name, long variable name, units, grid numbering and time slice) are listed at the top of the window.

Values for individual grid cells are listed by lat/long or lat/vert coordinates, with the zonal average value listed in a separate column to the right. The value “NaN” (“not a number”) is given for grid cells that have no available data (i.e., the “invalid” cells that are assigned a color outside the colorbar spectrum). The format of the numeric values can also be changed at the bottom of the window, in lieu of making a selection on the scale tab in the map window.



## Plotting Multiple Variables (Difference Plotting)

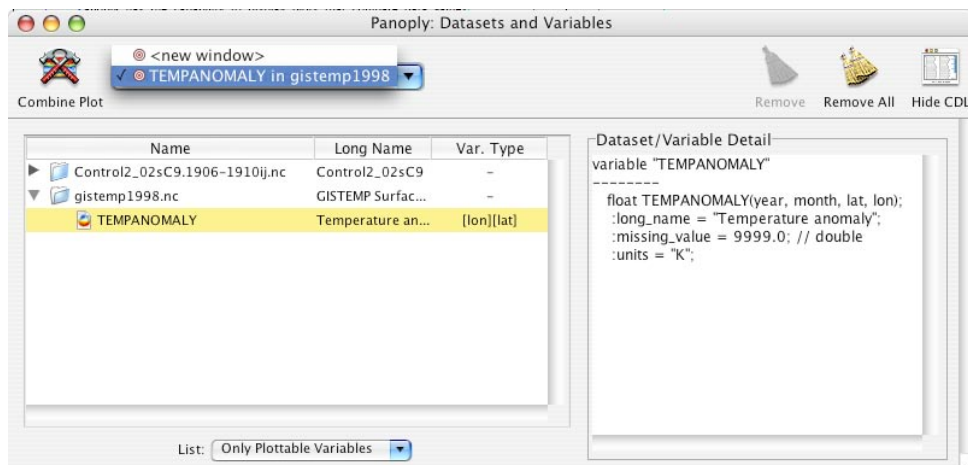
Panoply has the capability to display plots that compare data values between arrays. The compared arrays may be different time intervals for a single variable within one dataset, or they can be the same variable from two different datasets (e.g., comparing annual average temperatures for two different climate simulations).

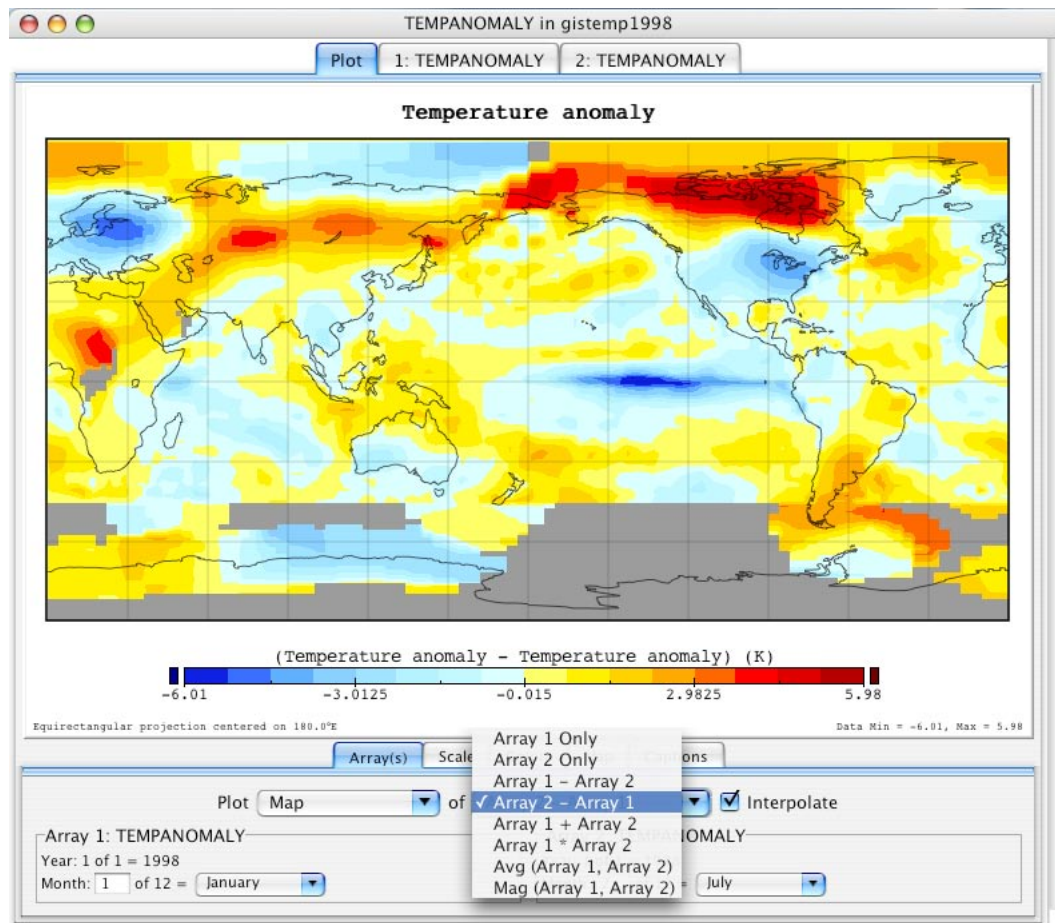
**WARNING:** *Especially when comparing variables between datasets, make sure that you are actually selecting the same variable for both arrays.* Panoply can determine to some extent whether two arrays have compatible units (e.g., Celsius and Kelvin), and will allow you to choose which unit you want in the Scale tab. However, it will not double-check to make sure that you are not contrasting temperature with precipitation.

In order to compare data arrays, you need to “open” a second dataset within the data browser. You can do this in one of two ways:

*1. Differencing two time intervals for a single variable within a single dataset:* With one array already open and mapped, go back to the data browser and select the same variable you have already plotted. In the “target” drop-down menu at the top, instead of selecting “new plot,” select the option named after the variable. When you do, you will see the icon to the left change to “Combine Plot”; click this icon to add the second array to the plot.

*2. Differencing the same variable from two different datasets:* With one array already open and mapped, go back to the data browser. Go into the Panoply File menu to open a new dataset. In the data browser, double-click on the dataset folder to display all the variables, and select the same variable name you have already plotted. In the drop-down menu at the top, instead of selecting “new plot” select the option named after the variable already plotted. When you do, you will see the icon to the left change to “Combine Plot”; click this icon to add the second array to the plot.





*Adding a second array to an existing plot creates a new data window behind the first one, and enables the comparison drop-down menu in the Array(s) tab.*

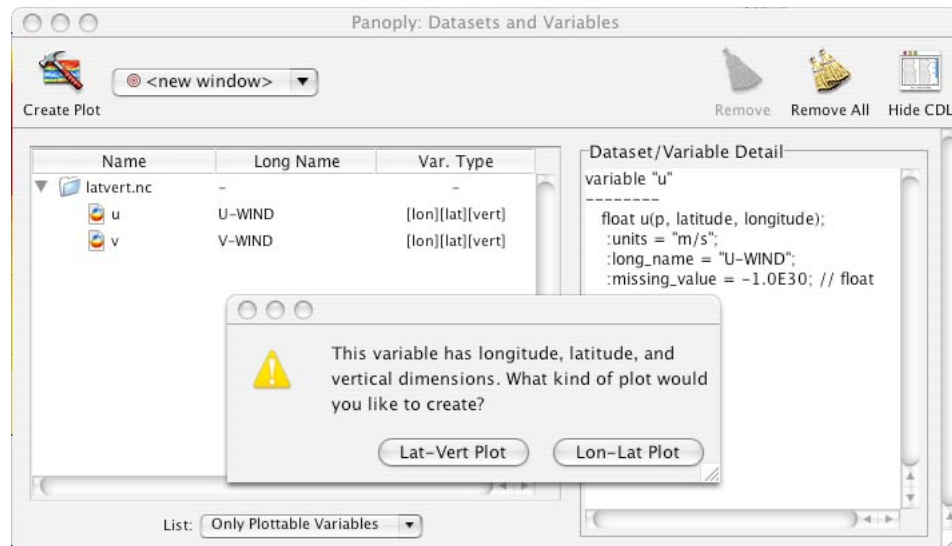
Once you have a second array opened, you will see that the comparison drop-down menu has become enabled in the Array(s) tab of the map plot. The menu allows you to examine each array individually as well as difference them (array 1 – array 2 and vice versa), add them, multiply them, and average them.

### *Hint: Choosing the Right Color Bar*

When plotting differences, always choose a colorbar (in the Colors tab) that has white in the exact center of the bar (e.g., panoply\_diff PAL-1). In this way, white = no difference. Then, within the Scale tab, uncheck the “Always fit” box and set your scale so that the Max = -1 x Min (e.g., Max = 5.0 when Min = -5.0). This creates a color bar with a symmetric scale, so that it is easy to distinguish positive anomalies (e.g., colors to the right of white are regions that warmed) and negative anomalies (e.g., colors to the left of white are regions that cooled).

## Creating a Latitude vs. Altitude Plot (Vertical Plot)

If the data are available in your dataset, Panoply has the ability to display vertical slices for a given line of longitude (meridian). The vertical dimension may be either positive (altitude) or negative (depth). As an example, open the sample dataset called “latvert.nc” included with Panoply. The data browser indicates that the plottable variables in this dataset have latitude, longitude, and vertical dimensions. When you select one of the variables and click on the “Create Plot” icon in the upper left corner of the data browser, you will be asked what kind of plot you would like to create. To plot a vertical slice, click on the “Lat-Vert Plot” button.



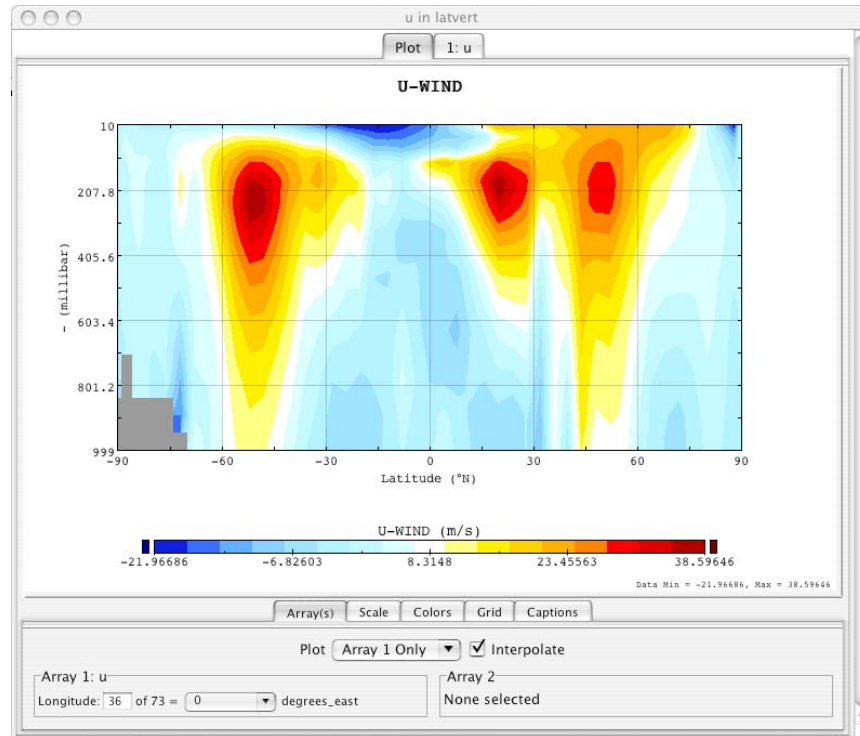
The vertical plot you create shows the changes in the variable “u-wind” with altitude for each latitude between the north and south poles. The controls in the tabs across the bottom of the vertical plot window are similar to those for a zonal average plot, with the exception of the Array(s) tab. For vertical plots, the “Longitude” control allows you to specify which meridian slice you would like to see displayed (in degrees east), or zonal average for each line of latitude (the choice “Average” from the “Longitude” drop-down menu).

Another minor difference between the controls for zonal average plots and vertical plots is in the Grid tab. For vertical plots, you can use the controls here to adjust the Y-axis units and numeric format, and the grid color and opacity, in addition to the X-axis orientation (North or South Pole to left).

Just as with map plots, you can open a second array of lat-vert data to create difference plots comparing a variable along two different meridians in the same dataset, or a variable along the same meridian in two different datasets.



*Vertical plots allow you to display data along a single meridian (in this case, the Prime Meridian).*



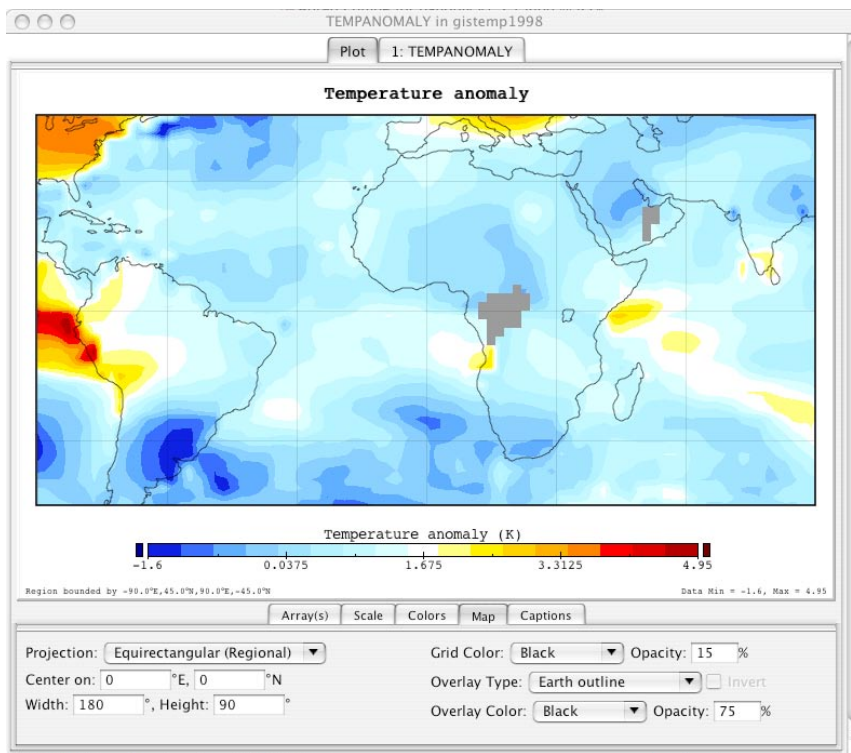
## Special Map Plots (Regional and Vertical Perspective)

For cases in which you would like to plot only a limited portion of the globe, or perhaps offer a “bird’s-eye view” of a given area, Panoply includes two special map projections that can be used to present a different perspective.

### *Equirectangular Regional Projection*

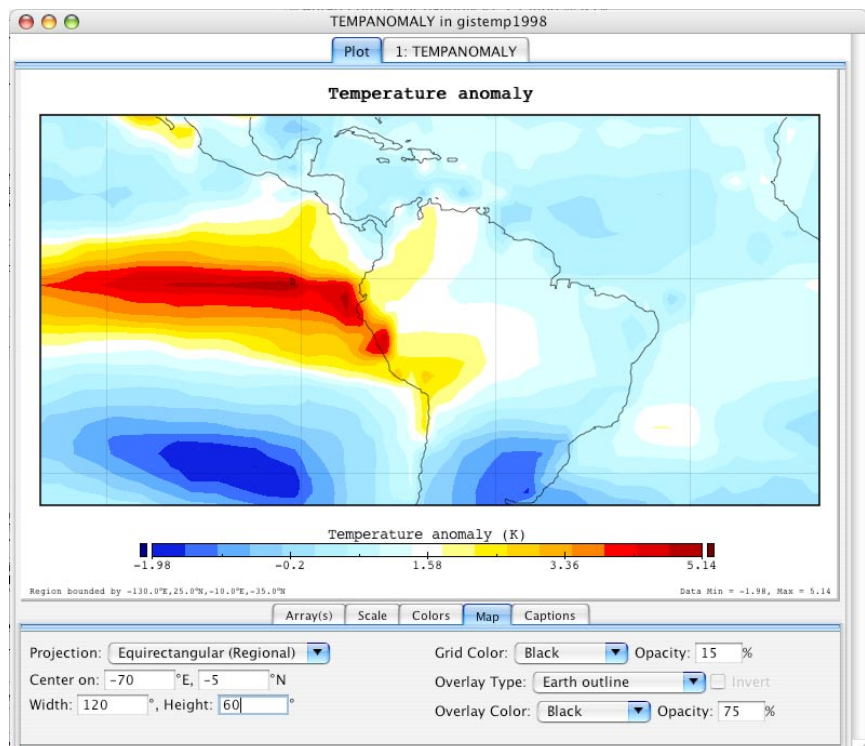
To limit the area displayed in your map plot, select the Maps tab and choose the “Equirectangular Regional” projection. Note that when you do, an additional pair of settings appears in the tab: width (in degrees longitude) and height (in degrees latitude).

The default display for the Equirectangular Regional projection is half the area of a regular Equirectangular projection, i.e., the field of view is 180 degrees wide and 90 degrees high, centered on 0° latitude, 0° longitude. To adjust the field of view to encompass a particular region, first enter the new coordinates in the “Center on” field. (Make sure your desired values are accepted either by clicking the cursor into a new field, or by hitting the enter key after typing in a value.) Then enter appropriate values for the width and height of your regional map. Note that Panoply will not force your map to be proportional; you may have to adjust width and height several times to produce a proportional map.



*The default settings for the Equirectangular Regional projection cover half the globe.*

*Recentring the map and limiting the height and width of the map produces a regional perspective.*

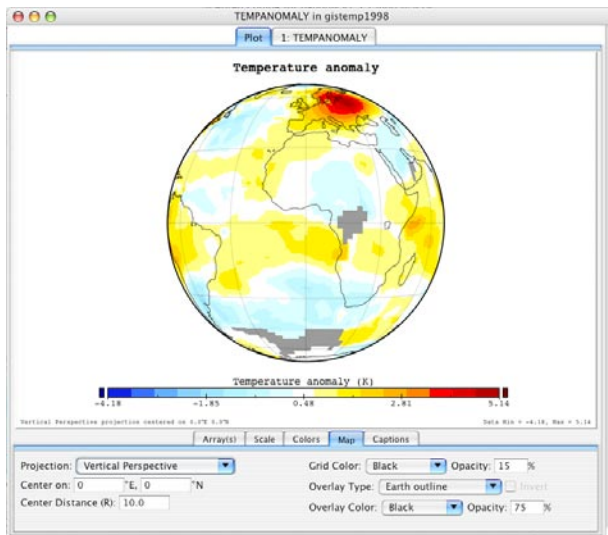


## Vertical Perspective

To create a bird's-eye view of your map plot, select the Maps tab and choose the "Vertical Perspective" projection. Note that when you do, a new setting appears: "Center Distance (R)," which alters the map viewer's perspective to varying "heights" above a point that you select.

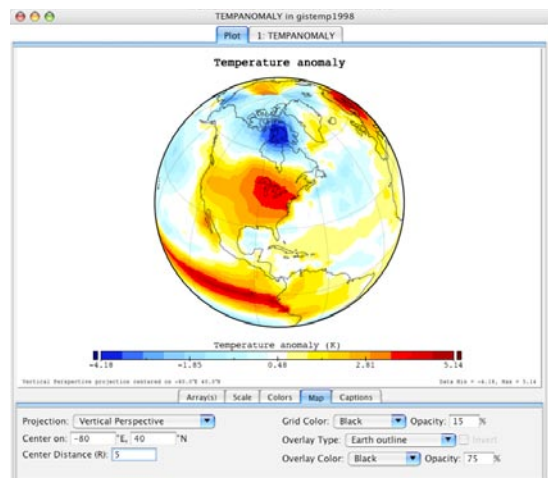
The default display for the Vertical Perspective projection is an orthographic projection centered on 0° latitude, 0° longitude, with a perspective from  $R=10$ . To adjust the field of view to display a new perspective, first enter the new coordinates in the "Center on" field. (Make sure your desired values are accepted either by clicking the cursor into a new field, or pressing the enter key after typing in a value.) Then enter a value for the "height" of your perspective.

Note: A value of  $R=1$  should put you at the surface, but values of  $R \leq 1$  may not display correctly. In addition, any value of  $R \geq 500$  is essentially a regular orthographic projection.



*The default settings for the Vertical Perspective projection display an orthographic projection at the height of  $R=10$ .*

*The Vertical Perspective projection can be adjusted to produce a map with a regional focus yet still retains a "global" context.*



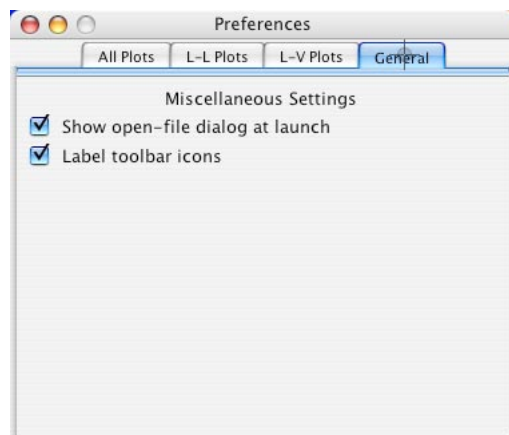
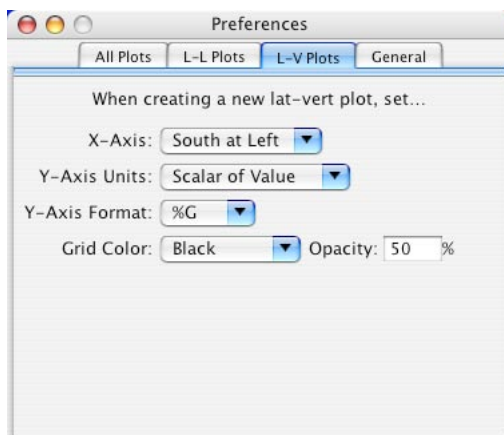
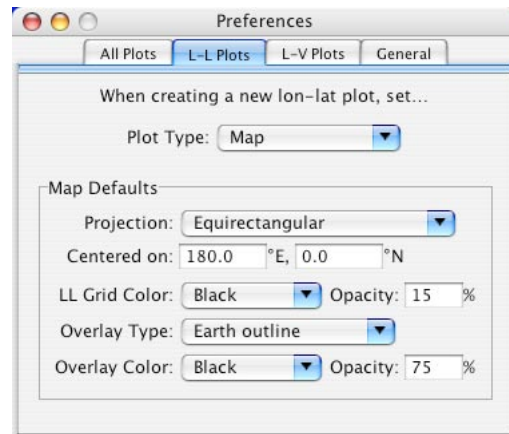
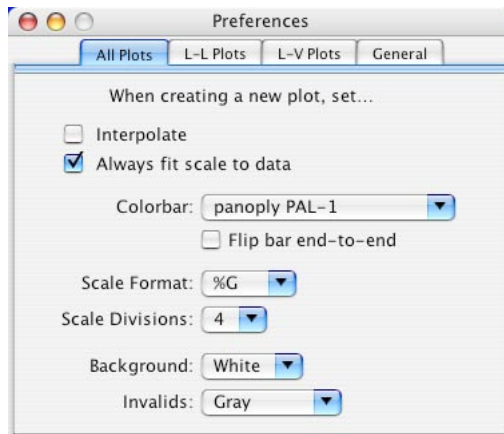


## Exporting Plots

Once you have produced an image you are happy with, exporting the plot is quite simple. Go into the Panoply File menu, select “Save” or “Save as...” and name the file as you wish. The default file format of plots exported from Panoply is PNG. To save a file in GIF format, simply add .GIF to the end of the output file name.

## Saving Preferences

If you would like to have your plots default to a particular set of characteristics, you can set these within the Panoply preference windows. Any of the characteristics you previously set in the tabs within the plot window can also be set here.





# Appendix 1

## netCDF Data Files

---

The netCDF (network Common Data Form) file format was developed to assist in the creation, access and sharing of scientific datasets. A detailed description of the netCDF format is available from the UCAR Unidata Program Center (<http://my.unidata.ucar.edu/content/software/netcdf/index.html>). The following discussion concerns what information Panoply requires in order to work with the contents of a netCDF dataset.

In general, Panoply works best with netCDF datasets that have been tagged according to one of the more common defined netCDF conventions, such as CF, COARDS, and GDT.

### Coordinate Variables

When examining the variables in a netCDF dataset, Panoply looks for certain information to determine whether each variable is “plottable,” and if so, how to plot it.

For longitude-latitude plots, the variable must have at least two dimensions, and the last two dimensions must be the latitude and longitude (in that order). In addition, the latitude dimension must be named either lat or latitude, and the longitude dimension named lon or longitude.

Values of the longitude coordinate variable must run eastward and be monotonically increasing. They should have units of “degrees\_east.” For example, a grid that has 10° spacing and is centered on the prime meridian might have longitude values running from -175.0 up to 175.0. Alternatively, a grid that has the prime meridian as its left edge would have longitude values that run from 5.0 to 355.0.

Values of the latitude coordinate variable may run either north to south or south to north, but they should have units of “degrees\_north.” Northern hemisphere latitudes must be positive, and southern hemisphere latitudes must be negative.

For latitude-vertical plots, the variable must again have at least two dimensions. The vertical and latitude dimensions need not be the last two dimensions of the variable, as Panoply is capable of dealing with variables that have three dimensions in the vertical, latitude and longitude.

There are two ways of tagging the vertical dimension so that it may be recognized by Panoply. The easiest to recognize is when the dimension has units of pressure, and the units should be a string recognized by UDUNITS (the Unidata units library). If the dimension has units of bars or millibars, the full unit name should be spelled out rather than abbreviated.

The alternative form of vertical dimension that may be recognized is a dimension that has a positive attribute, with value of either “up” or “down.” In the case of a vertical dimension with units of meters, the positive attribute is necessary to identify that the units indicate either altitude or depth. Similarly, a vertical dimension which has units of “level” needs the positive attribute to indicate whether the first level is the top or bottom.

Additionally, for each variable dimension there must be an associated coordinate variable which has the same name as the dimension. In other words, if the latitude dimension is called lat then the dataset must have a variable called lat.

## Boundary Variables

In addition to using the coordinate variables to identify the grid points on which the data are placed, Panoply needs to determine the area each point in the latitude-longitude grid represents. Consequently, it also checks the netCDF dataset for associated boundary variables. This checking is done by testing whether the pertinent coordinate variable has an attribute called `bounds`, which identifies another variable containing the boundaries of the grid cells. A boundary variable will have one more dimension than its associated coordinate variable, with the second dimension having two possible values, i.e., the two boundaries.

If a coordinate variable does not have an associated boundary variable, Panoply will use values halfway between the grid points.

## Relative Time Coordinates

A coordinate variable which has units of form `<something>`, since `<something>` (e.g., “hours since 1901-01-01 00:00:00”) is recognized by Panoply as being of variable type “relative time.”

Panoply understands how to treat relative-time coordinate variables if they use a recognized calendar. The calendar must be identified, either in the variable’s `calendar` attribute or the dataset’s `calendar` attribute. If both attributes are present, then the variable attribute has priority. The types of recognized calendars include:

*gregorian*: The standard calendar used today. However, for dates in the past it is actually a hybrid Julian/Gregorian calendar, with a 10-day gap in October 1582 when much of Europe first switched from the Julian calendar to the Gregorian.

*proleptic\_gregorian*: A pure Gregorian calendar, representing today's dates accurately but also extending indefinitely back into the past.

*julian*: A pure Julian calendar.

*noleap*: A 365-day calendar in which February always has 28 days and a year always 365 days. Might also be denoted *no\_leap*, *common\_year*, or *365\_day*.

*all\_leap*: A 366-day calendar in which February always has 29 days and a year always 365 days. Might also be denoted *no\_leap*, *common\_year*, or *366\_day*.

*360\_day*: A 360-day calendar in which all 12 months each have exactly 30 days. Might also be denoted *360*, but such usage is deprecated.

The last three of these calendar schemes are non-astronomical calendars used by various climate models.

## Absolute Time Coordinates

A coordinate variable that has units of form <time unit> as <format string> (e.g., “days as %Y%m%d.%f”) is recognized by Panoply as being of variable type “absolute time.”

For example, a dataset that includes a collection of monthly averages beginning at the start of the 21st century might specify the coordinate variable as having units “months as %Y%m” and contain values 200101, 200102, 200103, etc.

## Special Values

If a variable has invalid or missing values, then the appropriate attributes *valid\_min*, *valid\_max*, *valid\_range*, and/or *missing\_value* should be specified so that Panoply treats them correctly.

Panoply treats all missing or invalid values the same and, when rendering a plot, draws them all using a single “invalids color.”




## Scale Labels

Panoply uses the variable's `long_name` and `units` attributes, if they are provided, for the default labeling of the scale in a plot. If the `long_name` is missing, Panoply checks to see if a `standard_name` has been provided instead.

## Appendix 2

# Colorbars (a.k.a. Palettes or Color Tables)



When rendering a global map from a data array, Panoply uses color table information to translate the data values into colors. A scale indicating the relation between colors and data values is rendered on the plot as a colorbar.

The color information is stored in separate files, two of which are bundled into the Panoply application itself, with another 30 provided in the sample colorbars folder. When launched, Panoply will attempt to open all the colorbars in the sample folder. If there are colorbars in that folder that you don't need, you can remove them and Panoply will not list them as options. Likewise, you can add your own favorite colorbars to the folder and they will be automatically opened if they are in a recognized format. You can also use the Open... item in the File menu to open other colorbars from other locations on your computer.

There are basically three types of colorbars that Panoply recognizes, each identified by the filename extension.

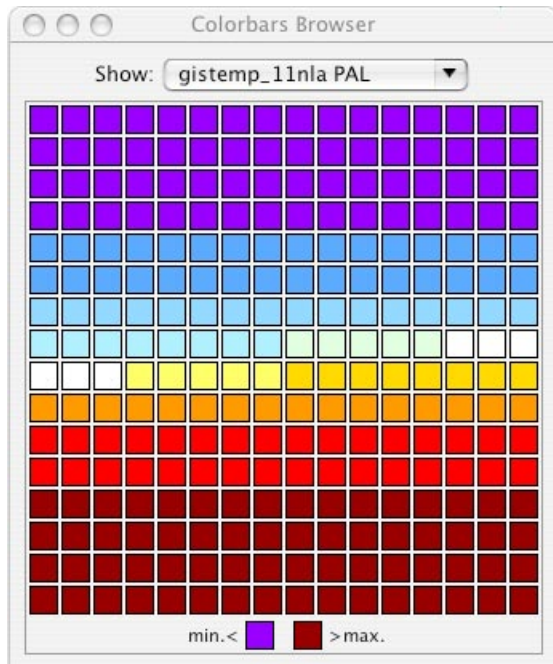
### **PAL Color Tables**

This is a fairly common color table format, which specifies 256 colors and is identified by the .PAL filename extension. Panoply treats the first color in the table as corresponding to the minimum of the plot scale and the 256th color as corresponding to the maximum (or vice versa if you opt to "Flip Scale Colorbar" when plotting).

When specifying plot options, you may have specified scale extrema such that there are "outliers," data values which are outside the minimum-maximum range. In such cases Panoply uses the color value corresponding to the minimum value on the scale for all values less than that minimum. Similarly, any values greater than the scale maximum would be rendered using the color corresponding to the maximum.

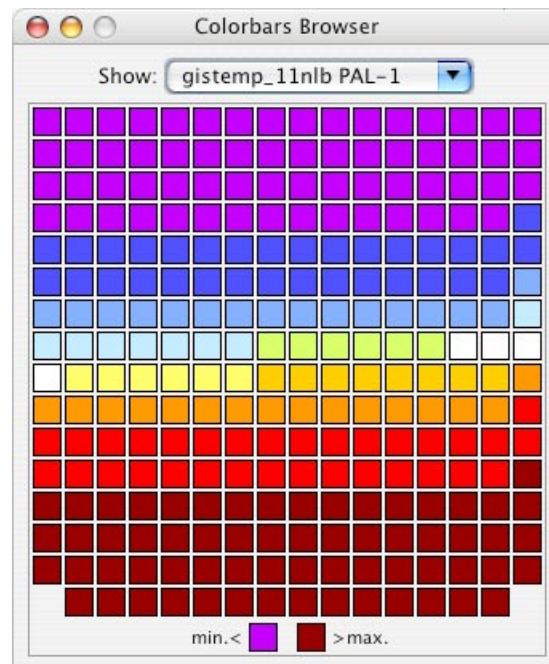
A PAL file is 768 bytes long, with the first 256 bytes specifying the red values, the middle 256 bytes specifying green values, and the final 256 bytes blue values. This means then that if a data value is identified by

Panoply as corresponding to the first color value, then the matching RGB color value is found by combining bytes 1, 257, and 513 of the file.



*An example of a PAL color table (left), showing the 256 colors available.*

*At right is a PAL-1 variation on the PAL color table shown above. Note that only 254 colors are available with this table. Many of the color tables included with Panoply are PAL-1 tables.*



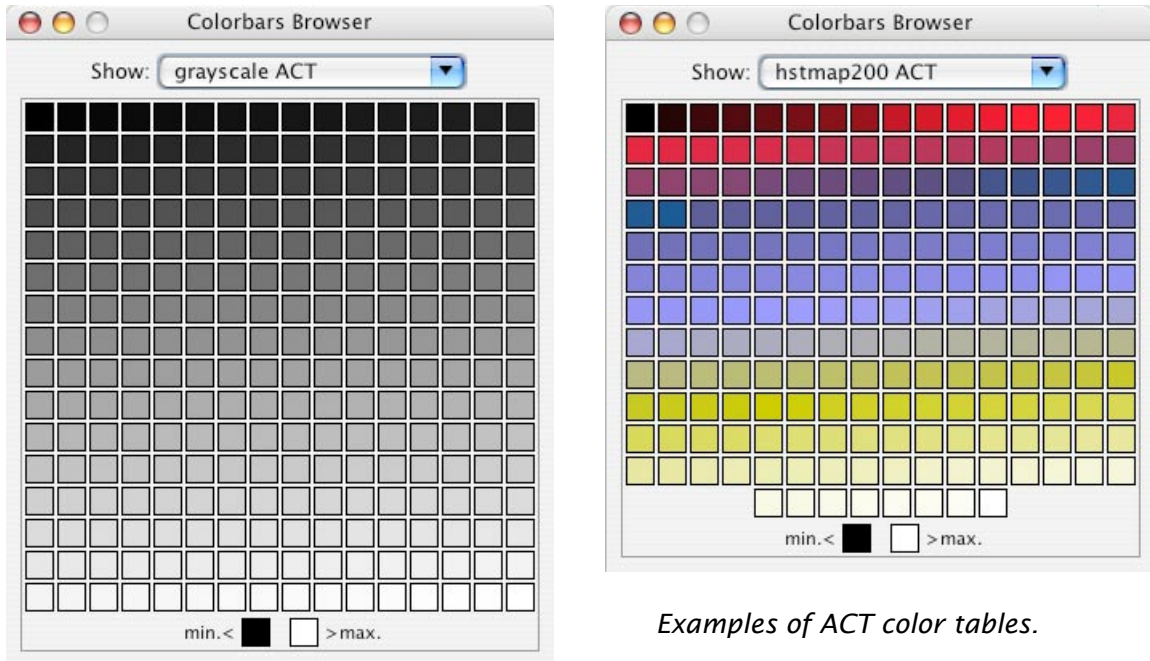
## PAL-1 Color Tables

A PAL-1 color table is a special case of a PAL color table. It is identified by a .PA1 filename extension (that's a numeral one at the end, not a lowercase L) so that Panoply can distinguish between them. A PAL-1 file is structurally the same as a PAL file, but Panoply treats the first and 256th colors in a PAL-1 file as being special and only uses colors 2-255 to draw the scale itself (i.e., a 254-color scale). The first color value in the file is treated as corresponding to all values in the plot less than the specified scale minimum; the 256th color is similarly used for all values greater than the scale maximum.



## ACT Color Tables

The .ACT extension stands for Adobe Color Table, and indicates a type of color file used in some graphics programs from Adobe Systems. An ACT file usually defines 256 color values, but the format allows for defining a smaller number. As with a PAL color table, Panoply treats the first color of an ACT table as representing the scale minimum and also all less-than-minimum values, and the last color as representing the scale maximum and all greater-than-maximum values.



*Examples of ACT color tables.*

## CWC Color Tables

The .CWC extension indicates a color file format most commonly used in Apple Computer's AppleWorks application (once known as ClarisWorks). This type of color table has 256 color values. As with a PAL color table, Panoply treats the first color of a CWC table as representing the scale minimum and also all less-than-minimum values, and the 256th color as representing the scale maximum and greater-than-maximum values.

## Color Table Software

If you are using Mac OS X, you may find the application ColorBarTender (<http://macupdate.com/info.php/id/11678>) useful for creating and editing color table files. As of its version 2.0 (May 2003), it works with PAL-1 and CWC colorbars.





# Appendix 3

## Map Projections

---

Panoply can plot a global map of longitude-latitude data using numerous different projections. Although the average user may only ever avail themselves of one or two of the most common projections, a different map projection can literally provide a different perspective on the graphical interpretation of data.

The projections available in Panoply can be classified by aspect (layout) as follows:

*Azimuthal:* Azimuthal maps can be thought of as projections to a plane placed tangent to the globe at a given point, with distortion increasing away from the tangent point. Projections in this category include Aitoff, Azimuthal Equal-Area, Azimuthal Equidistant, Eckert-Greifendorff, Hammer, Orthographic, Stereographic, Vertical Perspective, Wagner VII, Wagner VIII, and Winkel Tripel.

*Cylindrical:* Maps of this type have straight and parallel lines of latitude as well as meridians, and the parallels and meridians meet at right angles. Panoply projections in this category include Equirectangular, Gall, Mercator, and Miller Cylindrical.

*Pseudocylindrical:* Maps of this type have straight and parallel lines of latitude, but the scale along them varies such that meridians are no longer perpendicular to latitude, and may not even be straight lines. Panoply projections in this category include Apian Globular II, Eckert III, Eckert IV, Eckert V, Eckert VI, Hölzel, Kavraisky VII, McBride-Thomas Flat-Polar Parabolic, McBride-Thomas Flat-Polar Quartic, McBride-Thomas Plat-Polar Sinusoidal, Mollweide, Nell-Hammer, Parabolic, Putninš P1, Putninš P1', Putninš P3, Putninš P3', Putninš P4', Putninš P5, Putninš P5', Quartic-Authalic, Sinusoidal (equal area), Wagner I, Wagner II, Wagner IV, Wagner V, Wagner VI, and Winkel I.

Some Panoply projections do not fit a particular classification, and are grouped together in a Miscellaneous category. These projections include Ortellius Oval and Van Der Grinten I.

Below are a series of charts of the available global and hemispheric projections, along with alternative names. Each projection name is shown with a simple black-and-white map of Earth (centered on 0°E 0°N) using that projection.



1. Aitoff



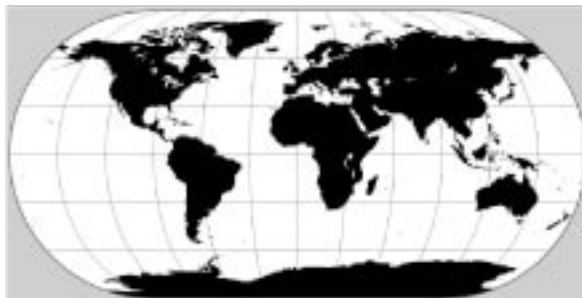
2. Apian Globular II



3. Azimuthal Equal-Area



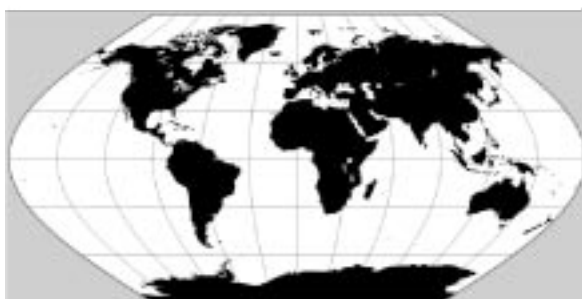
4. Azimuthal Equidistant



5. Eckert III



6. Eckert IV



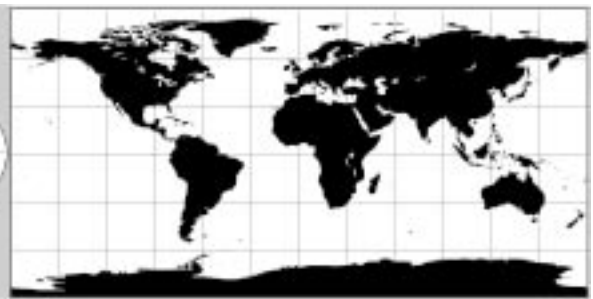
7. Eckert V



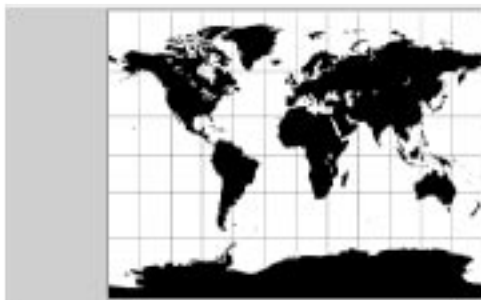
8. Eckert VI



9. Eckert-Greifendorff



10. Equirectangular  
( $\Phi_{ts} = 0^\circ$ , aka Plate Carrée)



11. Gall



12. Hammer  
(aka Hammer-Aitoff)



13. Hölzel



14. Kavraisky VII



15. McBride-Thomas  
Flat-Polar Parabolic



16. McBride-Thomas  
Flat-Polar Quartic

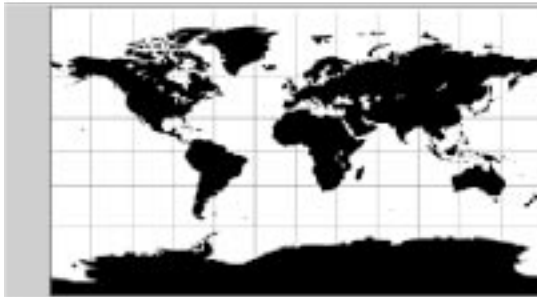




17. McBride-Thomas  
Flat-Polar Sinusoidal



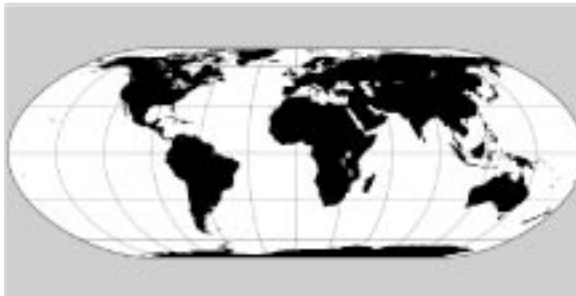
18. Mercator



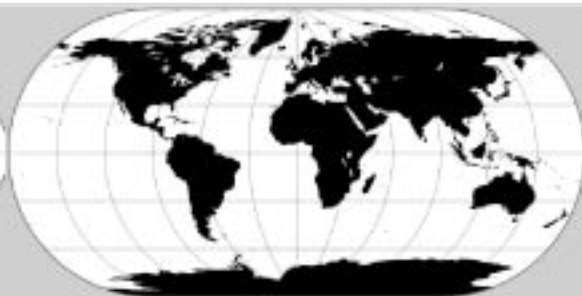
19. Miller Cylindrical



20. Mollweide



21. Nell-Hammer



22. Ortellius Oval

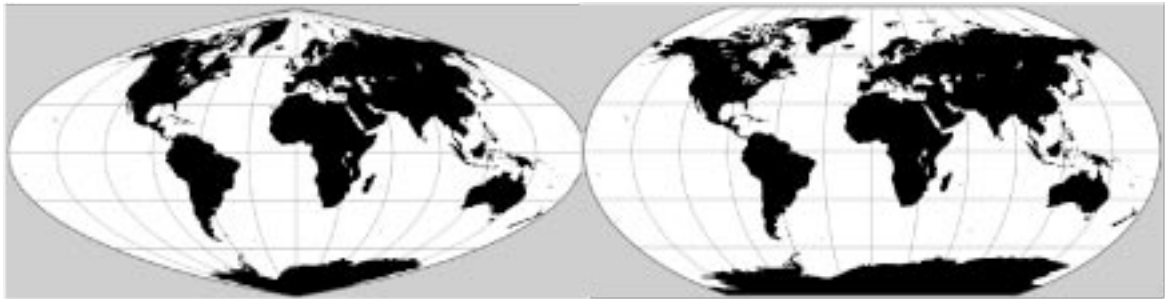


23. Orthographic



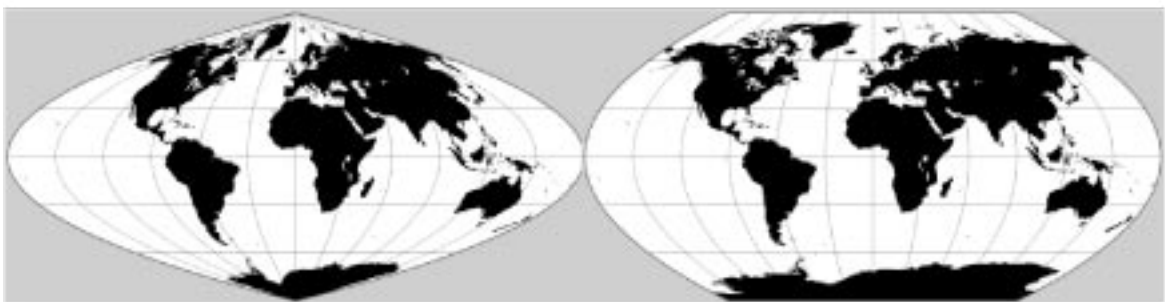
24. Parabolic  
(aka Craster Parabolic / Putninš P4)





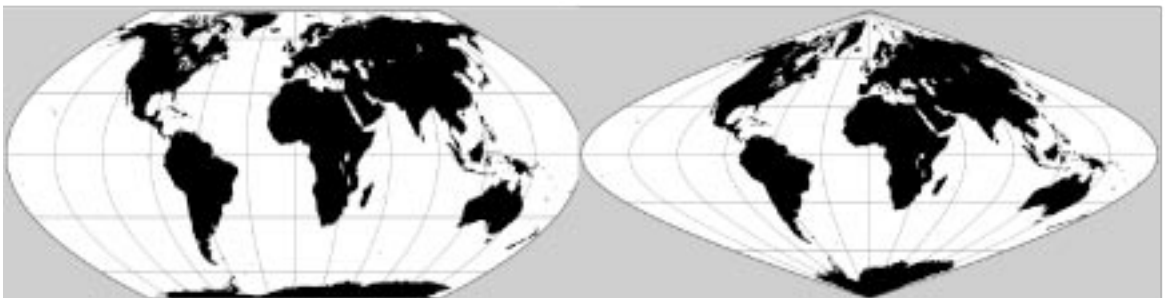
25. Putninsk P1

26. Putninsk P1'



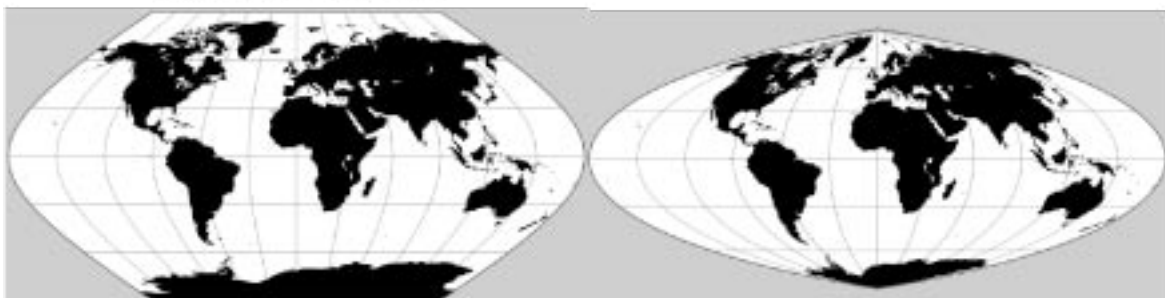
27. Putninsk P3

28. Putninsk P3'



29. Putninsk P4'  
(aka Werenskiold I)

30. Putninsk P5



31. Putninsk P5'

32. Quartic-Authalic





33. Sinusoidal  
(aka Sanson-Flamsteed)



34. Stereographic



35. Van Der Grinten I



36. Vertical Perspective  
(P = 10xR shown)



37. Wagner I  
(aka Kavraisky VI)



38. Wagner II



39. Wagner IV  
(aka Putninš P2')



40. Wagner V





41. Wagner VI



42. Wagner VII  
(aka Hammer-Wagner)



43. Wagner VIII



44. Winkel I  
( $\phi_{ts} = 50^\circ 28'$ )



45. Winkel Tripel

For further reading:

Bugayevskiy, Lev M. and John P. Snyder. 1995. *Map Projections: A Reference Manual*. London: Taylor and Francis.

Muehrcke, Phillip C. and Juliana O. Muehrcke. 1998. *Map Use: Reading-Analysis-Interpretation*, 4th ed. Madison, WI: JP Publications.

Snyder, John P. 1987. *Map Projections: A Working Manual*. USGS Professional Paper 1395. Washington, DC: United States Government Printing Office.



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