

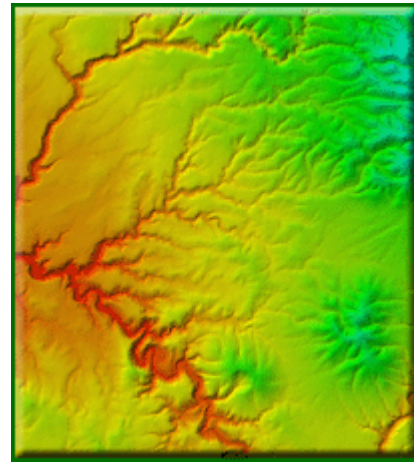
**NAME:** Grid Tools (Jenness Enterprises), v. 1.7

**Aka:** grid\_tools\_jen.avx

**Last modified:** July 9, 2006

**TOPICS:** statistics, neighborhood, legend, clip, merge, mosaic, combine, ramp, rainbow, color, GTheme, slope, aspect, hillshade, curvature

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**DESCRIPTION:** This extension offers several assorted tools for analyzing, displaying, clipping and combining grids:

**Neighborhood Statistics:** Advanced options for generating neighborhood statistics, including a tool to generate custom neighborhoods.

**Grid Statistics:** A report of grid statistics, including mean, min, max, SD, etc., plus details on the size and extent of the grid.

**Standardize Grid:** An option to convert a grid into a standardized grid, with Mean = 0 and Standard Deviation = 1.

**Aspect and Slope Graphics:** Specialized graphics to describe aspect and slope grids, plus a report of descriptive statistics.

**Curvature Grids:** Generate 3 types of curvature grids (Profile, Planiform and/or General).

**Advanced Slope Grids:** Calculate slope in either degrees or percent, and use a z-value adjustment to correct for unprojected grids.

**Advanced Aspect Grids:** Calculate aspect with options for avoiding flat areas, applying a directional adjustment and generating specialized aspect grids that reflect how much the aspect value deviates from a direction of interest.

**Advanced Hillshade Grids:** Calculate hillshade grids with additional aesthetic options, and use a z-factor adjustment to correct for unprojected grids.

**Rainbow Legend:** Apply a ramped rainbow color scheme to the legend, with as many levels as you like. You can ramp through the spectrum in either direction (i.e. from Red to Violet or from Violet to Red).

**Custom Legend:** Develop a customized multi-color legend with as many color levels as you like, and ramp between all colors.

**Graphic Color Bars:** Create ramped graphic color bars to enhance legends and layouts.

**Clip Grids:** Advanced grid-clipping tools, with options to clip based on the view extent, a theme extent, polygon features, polygon graphics and selected grid cells. Also options to clip outside or inside the clipping objects.

**Combine Grids:** Tools for various methods of combining grids, including *Merge*, *Mosaic*, and *Combine*. The Merge tool includes a way to sort your grids.

**REQUIRES:** Spatial Analyst

This extension requires that the file "avdlog.dll" be present in the ArcView/BIN32 directory (or \$AVBIN/avdlog.dll) and that the Dialog Designer extension be located in your ArcView/ext32

directory, which they usually are if you're running AV 3.1 or better. The Dialog Designer doesn't have to be loaded; it just has to be available. If you are running AV 3.0a, you can download the appropriate files for free from ESRI at:

<http://www.esri.com/software/arcview/extensions/dialog/index.html>

**REVISIONS:** Version 1.1 (January 27, 2004) repairs a bug in the Rectangle Neighborhood Statistics which produced a "Error in grid\_tools\_jen.TPIDialogOK at 6233" message.

Version 1.2 (June 24, 2005) adds the option to make color bars either vertical or horizontal.

Version 1.3 (July 9, 2005) adds a function to make general color bars for any existing grid or feature theme, based on that theme's current legend.

Version 1.4 (April 29, 2006) adds functions to make graphic symbols describing slope and aspect data, and modifies the method for choosing colors.

Version 1.5 (May 23, 2006) adds functions for generating 3 types of curvature grids (profile, planiform and general).

Version 1.6 (May 25, 2006) adds advanced functions for generating slopes and hillshades.

Version 1.7 (July 9, 2006) adds advanced functions for calculating aspect.

**Recommended Citation Format:** For those who wish to cite this extension, the author recommends something similar to:

Jenness, J. 2006. Grid Tools (Jenness Enterprises) v. 1.7 (grid\_tools\_jen.avx) extension for ArcView 3.x. Jenness Enterprises. Available at:  
[http://www.jennessent.com/arcview/grid\\_tools.htm](http://www.jennessent.com/arcview/grid_tools.htm).

Please let me know if you cite this extension in a publication ([jeffj@jennessent.com](mailto:jeffj@jennessent.com)). I will update the citation list to include any publications that I am told about.

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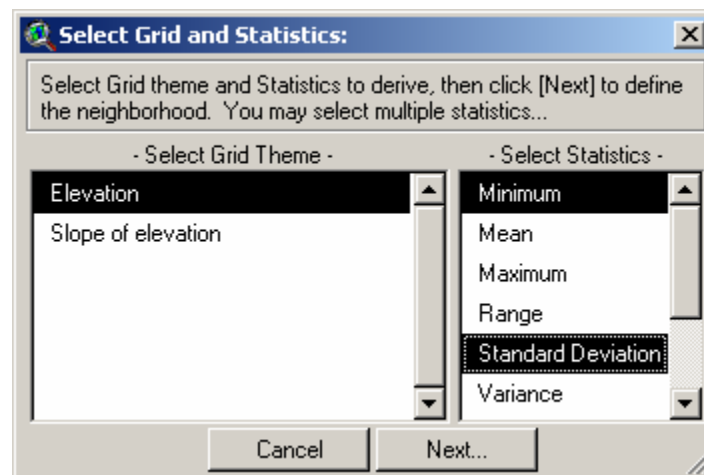
## General Instructions:

- 1) Begin by placing the "**grid\_tools\_jen.avx**" file into the ArcView extensions directory (../Av\_gis30/Arcview/ext32/).
- 2) After starting ArcView, load the extension by clicking on **File --> Extensions...**, scrolling down through the list of available extensions, and then clicking on the checkbox next to the extension called "**Grid Tools (Jenness Enterprises)**"
- 3) Most tools are found in the "Grid Tools" menu in the View Menu Bar. The General Color Bar function is found in the View "Theme" menu.

## Neighborhood Statistics:

This option generates a new grid representing neighborhood statistics from an existing grid. Each cell value in the new grid represents some statistic (i.e. mean, min, max, standard deviation, etc.) from some region of cells surrounding the original cell in the original grid, where the region is called a Neighborhood and can come in a variety of shapes and sizes. The standard Spatial Analyst Neighborhood Statistics function includes options for rectangles, circles, wedges and doughnuts (see ArcView Help files for more information; especially "FocalStats Discussion"). The Neighborhood Statistics function included with this extension is very similar to the original Spatial Analyst function except that this tool allows you to generate custom-shaped neighborhoods and also generate multiple sets of statistics with one operation.

Click the "Neighborhood Statistics" menu item to start the process. You will be asked to identify the grid theme you wish to analyze and the statistics you wish to generate. You may select multiple statistics. This window is resizable by dragging on a corner.



## Statistic Options:

If your Grid Theme is a Floating Point theme (i.e. with decimal numbers, and therefore without an attribute table), then your statistics options will include:

1. Minimum: Each cell value in the new grid will reflect the lowest value in the neighborhood around the original cell.
2. Mean: Each cell value in the new grid will reflect the average value in the neighborhood.
3. Maximum: Each cell value in the new grid will reflect the maximum value in the neighborhood.

4. Range: Each cell value in the new grid will reflect the range of values (i.e. the maximum – the minimum) in the neighborhood.
5. Standard Deviation: Each cell value in the new grid will reflect the standard deviation of values in the neighborhood.
6. Variance: Each cell value in the new grid will reflect the variance of values in the neighborhood.
7. Sum: Each cell value in the new grid will reflect the sum of values in the neighborhood.

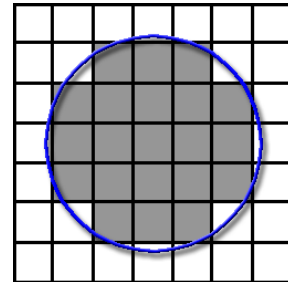
If your Grid Theme is an Integer theme, you have a few more options:

- a) Majority: Each cell value in the new grid will reflect the value that occurs most often in the neighborhood.
- b) Minority: Each cell value in the new grid will reflect the value that occurs least often in the neighborhood.
- c) Median: Each cell value in the new grid will reflect the median value in the neighborhood.
- d) Variety: Each cell value in the new grid will reflect the number of unique values in the neighborhood.

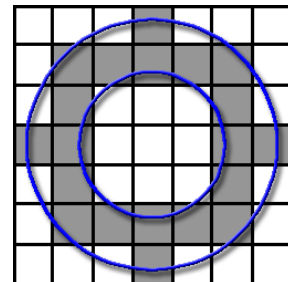
### ***Neighborhood Options:***

You will next be asked to define your neighborhood. You can choose between a circle, annulus (doughnut-shape), rectangle, wedge, or custom shape. You can also enter your neighborhood parameters in units of either grid cells or map units (i.e. meters, feet, etc.).

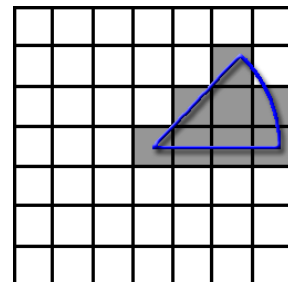
- a) Circle: A circular neighborhood defined by a radius length extending outward from the cell center. In theory, this neighborhood should be composed of all grid cells whose cell centers lie within that distance of the focal cell center, but Spatial Analyst appears to have some kind of number rounding issue that sometimes includes or excludes cells that do not exactly fit this definition. If possible, test the neighborhood function to make sure it is including the all the cells you need it to. If not, you may be able to use the Custom Neighborhood function to create a correct neighborhood.



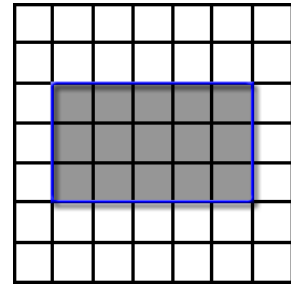
- b) Annulus: An annular neighborhood looks like a ring or doughnut defined by an inner and outer radius length extending outward from the cell center. This neighborhood should be composed of all cells whose cell centers lie within this ring, but this can also be affected by the rounding issues that affect the Circular neighborhood. If testing reveals that the annular neighborhood is not working exactly as desired, you may be able to generate a custom neighborhood that will work correctly.



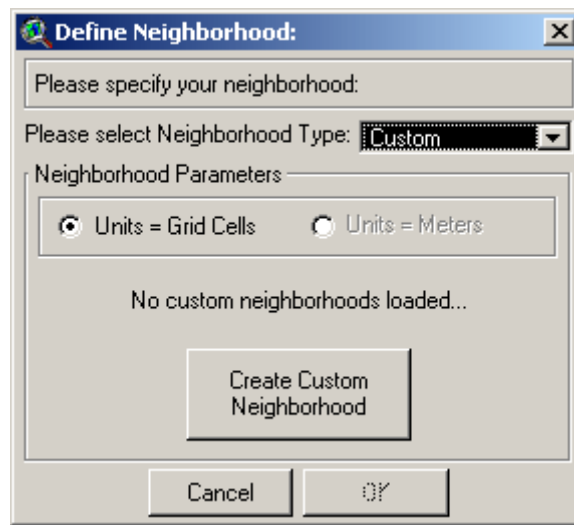
- c) Wedge: A wedge-shaped neighborhood looks like a slice of pie cut out of a circular neighborhood and is defined by a starting angle, and ending angle, and a radius. As always, it is advisable to test and confirm that your neighborhood is correct, and possibly generate a custom neighborhood if necessary.



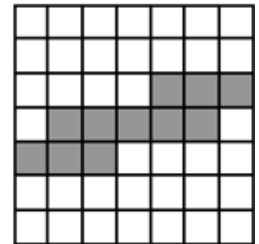
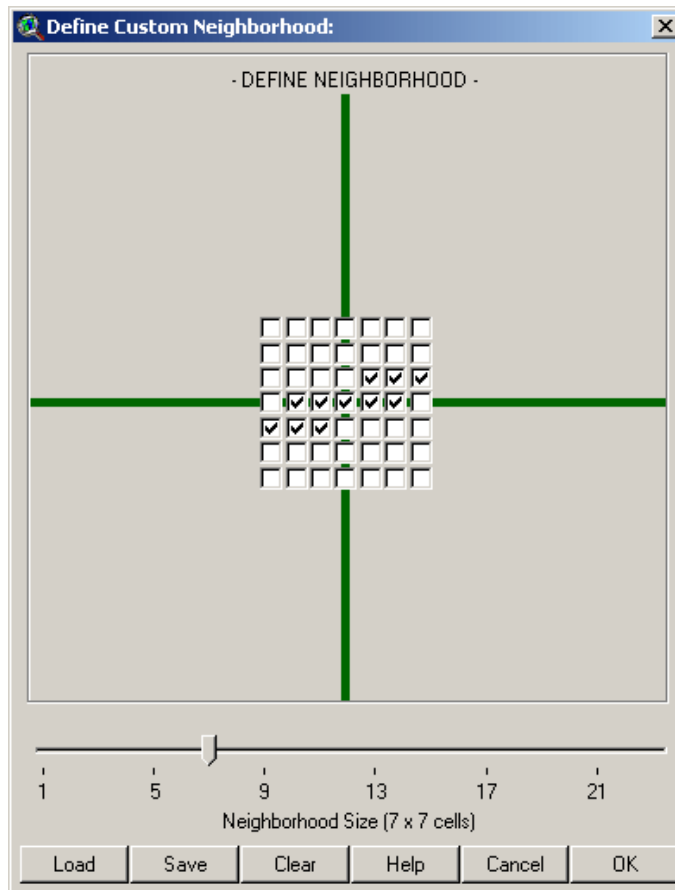
- d) Rectangle: A square or rectangular neighborhood defined by width and height, which will be centered around your focal cell center. Cells will be included in the neighborhood if the cell centers lie within this rectangle.



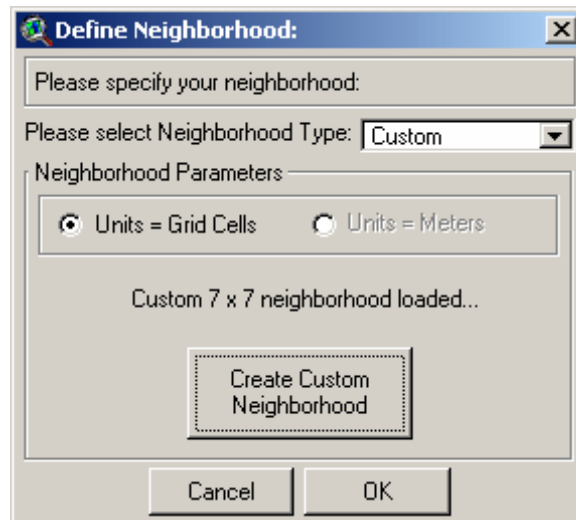
- e) Custom: Custom neighborhoods can be of any shape or arrangement and are defined by explicitly stating which cells, relative to the focal cell, will be included in the neighborhood. To generate a custom neighborhood, first select the “Custom” option from the drop-down list of Neighborhood Types:



Next click the “Create Custom Neighborhood” button to open the custom neighborhood definition window. Select your general neighborhood size by moving the slider to the correct value, and then click in the boxes to specify which cells you wish to be included in the analysis:



Click OK to go back to the “Define Neighborhood” window and notice that it now says “Custom 7 x 7 Neighborhood Loaded...”.

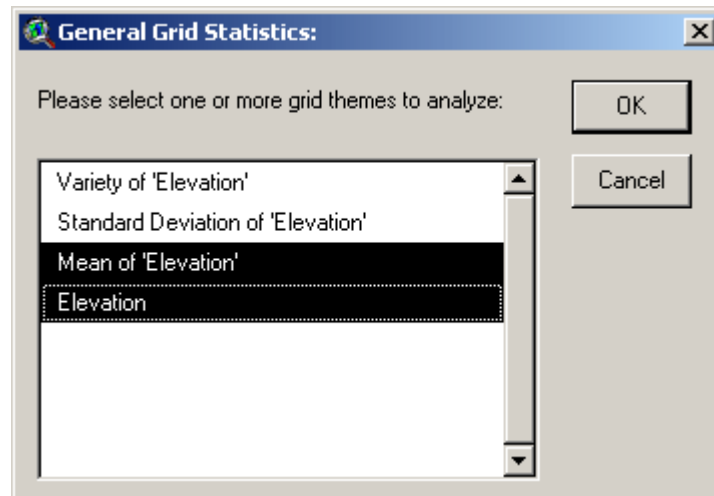


You can now click ‘OK’ and generate your neighborhood statistics grid(s).

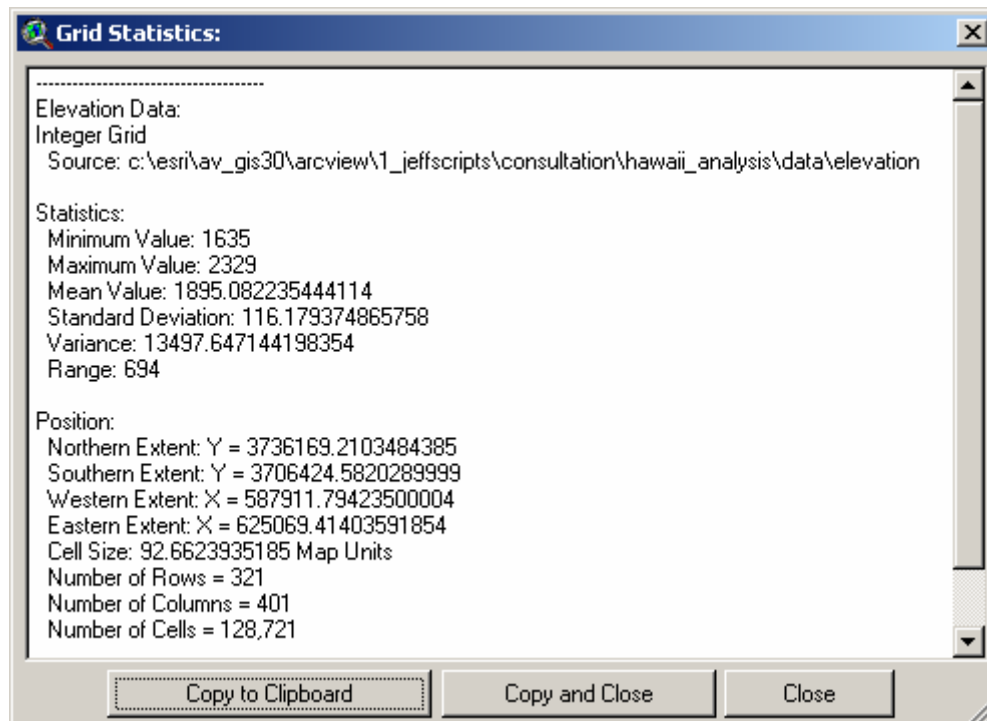
## Grid Descriptive Statistics:

This function produces a report detailing some general statistics for grid themes, including the *minimum*, *maximum*, *mean*, *standard deviation*, *variance* and *range* for all grid cell values in the grid. The report also describes the geographic extent, the number of rows, columns and cells, and the hard drive location of the grid.

Select the “Grid Descriptive Statistics” menu item and then select the grids you would like to describe:



Click 'OK' and you will see a report window with the grid description:



## Standardize Grids:

In this case, to standardize a grid means to transform the grid cell values such that the grid has a mean = 0 and a standard deviation = 1. This may be useful in some analyses where the grids



may have widely different numeric scales. For example, Andrew Weiss, in a discussion of Topographic Position Indices, describes how it may be desirable to standardize TPI grids before using them for landform identification. This process is described in a poster presented at the 2001 ESRI User Conference.

Technically, all that happens in this operation is that the original grid is subtracted from the grid mean, then divided by grid standard deviation:

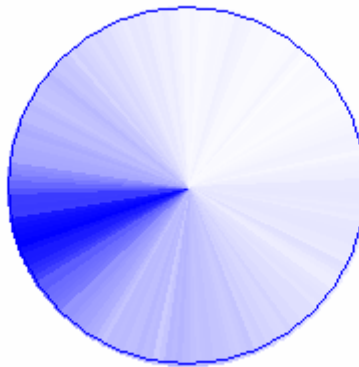
$$\text{Standardized Grid} = \frac{\text{Original Grid} - \text{Grid Mean}}{\text{Grid Standard Deviation}}$$

### Analyzing and Symbolizing Aspect:

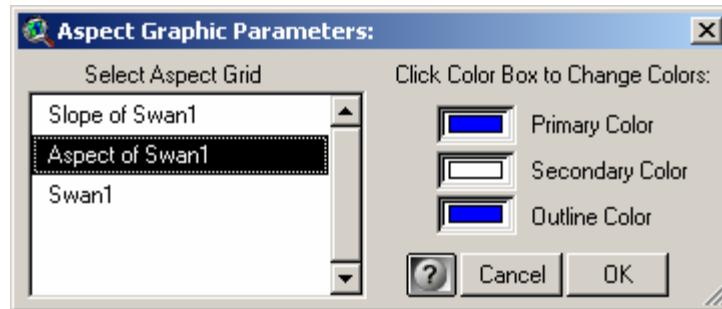
Aspect is often difficult to analyze and display because it is a circular variable. The fact that the distance between 1° and 2° is the same as the distance between 1° and 360° means that measures of central tendency and dispersion are more complicated to calculate and communicate. Please see the references for some good sources for analyzing circular data, and [Some Thoughts on Analyzing Topographic Habitat Characteristics](#) (Jenness 2006) for a discussion on analyzing aspect in particular.

This extension includes a tool to summarize aspect using standard statistical descriptors, as well as with an interesting graphical display. This function requires that an Aspect Grid be available in your view. It will not generate the aspect grid on-the-fly. If you do not have an aspect grid available, you will need to create it by clicking the 'Surface' menu in your View, then 'Derive Aspect'.

This function will generate a Pie Chart-type graphic with 180 slices. Each slice will be colored in such a way as to illustrate how much of the landscape faces that direction. The final graphic provides a powerful method of visually determining whether there appears to be a predominant aspect direction. For example, the figure below describes a region in which aspect predominately faces the southwest, with very few places facing the northeast.



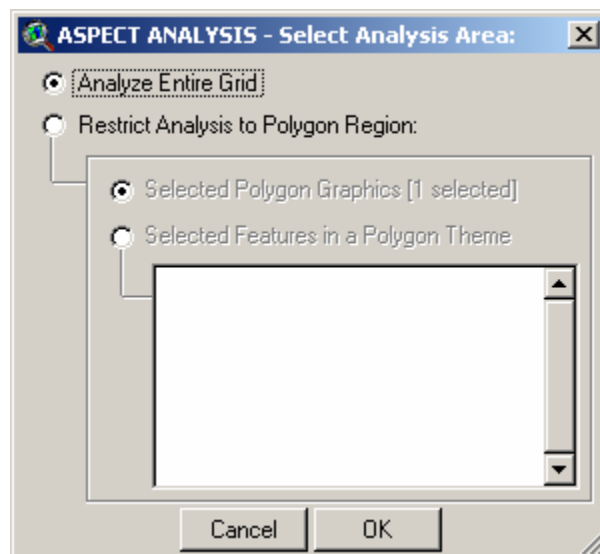
Click the menu item "Aspect: Analyze and Make Graphic" in the "Grid Tools" menu. You will first be prompted to set your graphic parameters:



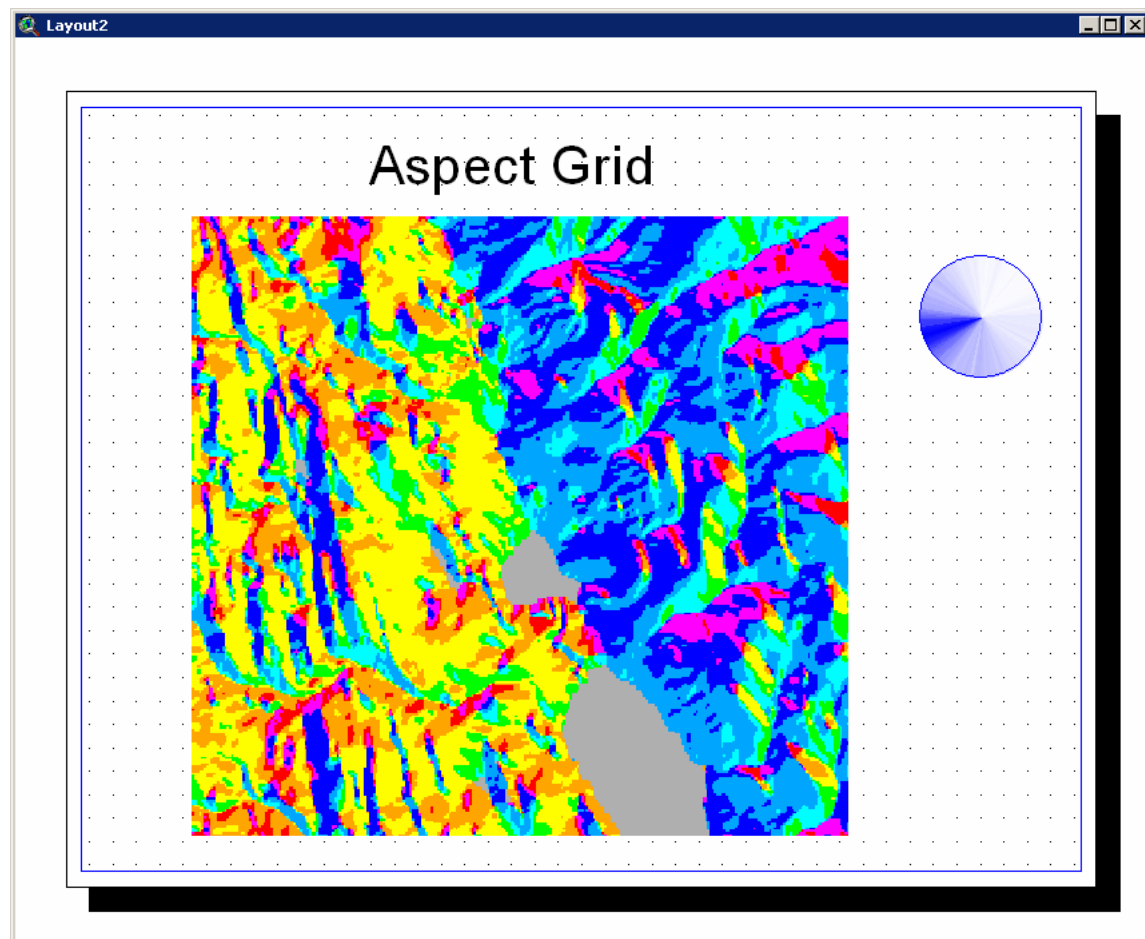
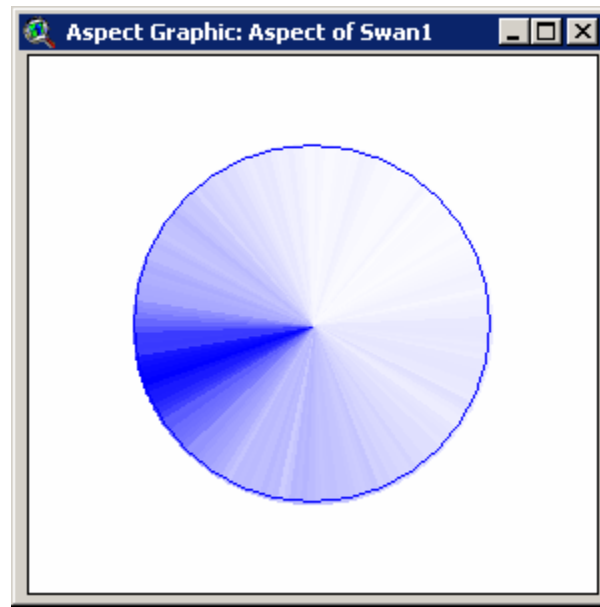
- The 'Primary Color' represents the amount of aspect grid cells that face any particular direction. The pie chart slice representing the greatest number of aspect cells will be shaded exactly this primary color.
- The 'Secondary Color' is that color which the primary color transitions to. Pie chart slices that represent fewer aspect cells will have less of the primary color, and more of the secondary color. If any pie chart slices represent zero aspect grid cells, then those slices will be colored with exactly this secondary color.
- The 'Outline Color' is the color of the circular border surrounding the pie chart slices.

As a suggestion, the author recommends a dark 'Primary' color and a white 'Secondary' color, so that the directions with greater numbers of aspect cells will stand out distinctly.

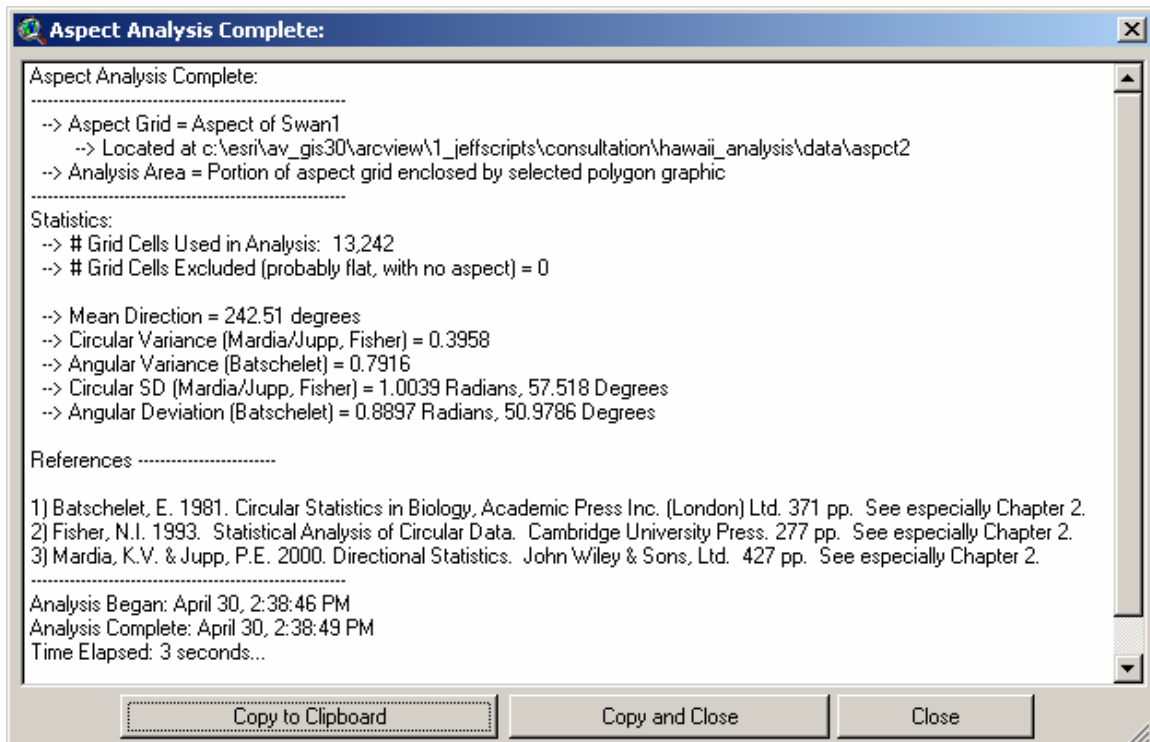
After setting the Aspect Graphic parameters, you will next be prompted to specify the region you want to analyze. You may analyze an entire aspect grid at one time, or you may restrict your analysis to a smaller region using either selected polygons in a polygon theme, or selected graphic polygons in your view:



Click 'OK' and the tool will go to work. Upon completion, it will generate a new view with your Aspect graphic, plus a report providing several aspect-related statistics. Because the Aspect Graphic is generated in a "View" document, it can easily be added to a layout by simply creating a view frame in the layout and linking it to the aspect graphic view.



The function will also give you a report containing several aspect-related statistics:



The statistics are based on texts by Mardia & Jupp, Fisher and Batschelet (see references). The formulas used are:

$$\text{Where: } C = \sum_{i=1}^n \cos \theta_i, \quad S = \sum_{i=1}^n \sin \theta_i, \quad R^2 = C^2 + S^2, \quad \bar{R} = \frac{R}{n}$$

$$\text{Mean Direction: } \bar{\theta} = \begin{cases} \tan^{-1}(S/C) & S > 0, C > 0 \\ \tan^{-1}(S/C) + \pi & C < 0 \\ \tan^{-1}(S/C) + 2\pi & S < 0, C > 0 \end{cases}$$

$$\text{Circular Variance: } V = 1 - \bar{R} \quad (\text{Mardia \& Jupp, Fisher})$$

$$\text{Angular Variance: } s^2 = 2(1 - \bar{R}) \quad (\text{Batschelet})$$

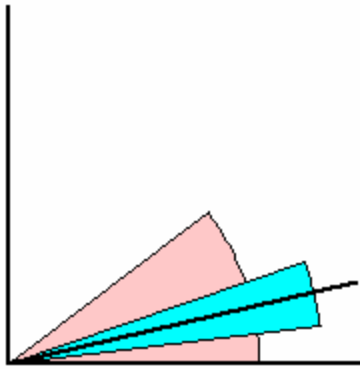
$$\text{Circular Standard Deviation: } v = \sqrt{-2 \ln \bar{R}} \quad (\text{In Radians}) \quad (\text{Mardia \& Jupp, Fisher})$$

$$\text{Angular Deviation: } s = \sqrt{s^2} = \sqrt{2(1 - \bar{R})} \quad (\text{In Radians}) \quad (\text{Batschelet})$$

$$\text{Radians to Degrees: } \text{Degrees} = \frac{180}{\pi} (\text{Radians})$$

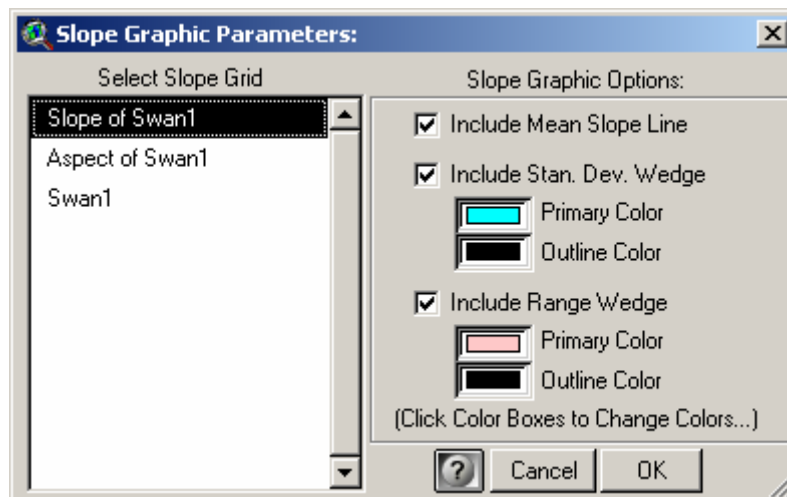
### Analyzing and Symbolizing Slope:

This extension also includes a function to generate a descriptive slope graphic that visually communicates the mean, standard deviation and range of slope values in an area. The figure below shows the average slope as a straight black line, the +/- standard deviation in the cyan wedge, and the full range of slope values in the light red wedge. This visual depiction of slope statistics is more intuitively understandable than numeric statistics of slope.



This function requires that a Slope Grid (in Degrees) be available in your view. It will not generate the slope grid on-the-fly. If you do not have a slope grid available, you will need to create it by clicking the 'Surface' menu in your View, then 'Derive Slope'.

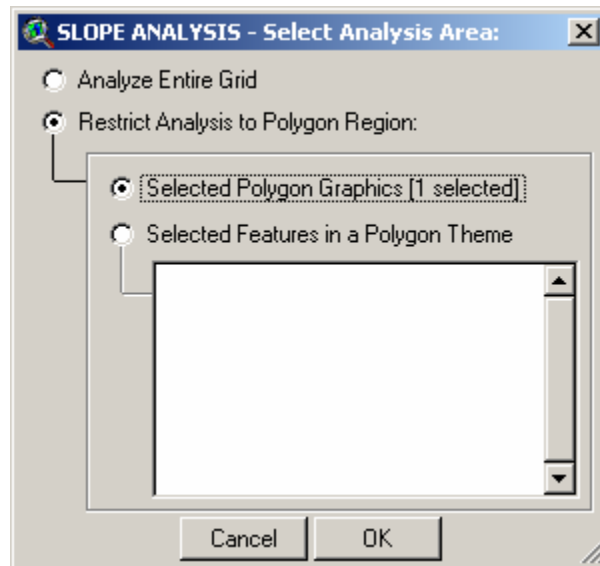
Click the menu item "Slope: Analyze and Make Graphic" in the "Grid Tools" menu. You will first be prompted to set your graphic parameters:



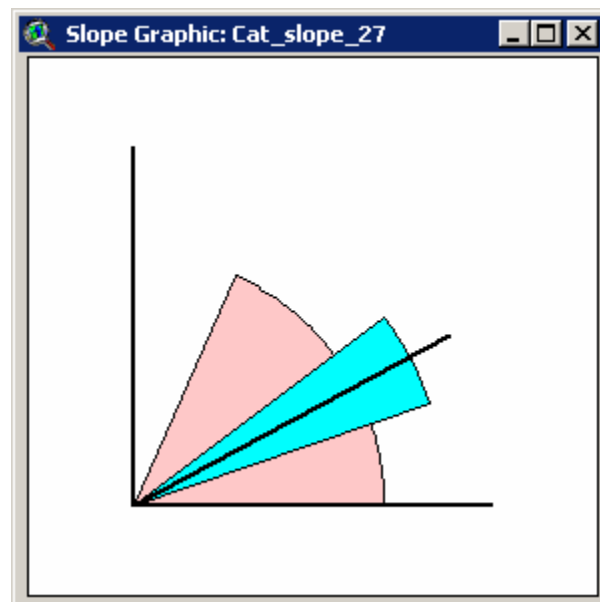
Note that you have the option to generate any or all of the three statistics (mean, standard deviation and range). If you do not wish to one or two of the statistics, simply uncheck the box.

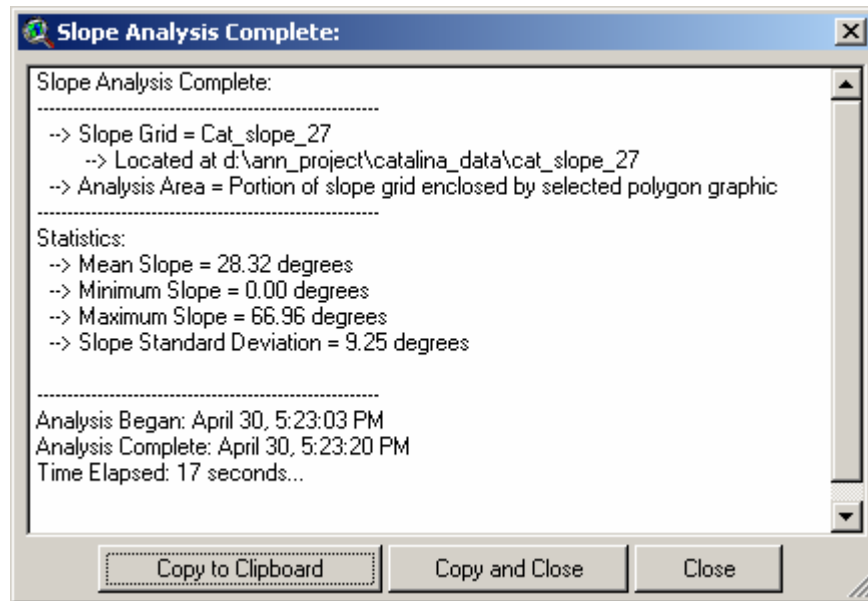
- The 'Mean Slope Line' is a black line angled at the actual average slope. It has a width of 2 points. If you wish to change the color or width of this line, you may do so after generating the graphic by double-clicking on the line and using the Symbol Window to change the line characteristics.
- The 'Standard Deviation Wedge' is a rounded wedge shape defining the range of slope values that lie within 1 standard deviation of the mean slope. The width of this wedge corresponds with the amount of variability in slope. You may set the color and outline color of the wedge, and you may change it later by double-clicking on wedge polygon and using the Symbol Window to change the polygon characteristics.
- The 'Range Wedge' is a rounded wedge shape defining the full range of slope values in the analysis area. As with the Standard Deviation wedge, you may set the color and outline color of the wedge using this dialog, and you may change it later by double-clicking on it and using the Symbol Window to change the polygon characteristics.

After setting the Slope Graphic parameters, you will next be prompted to specify the region you want to analyze. You may analyze an entire slope grid at one time, or you may restrict your analysis to a smaller region using either selected polygons in a polygon theme, or selected graphic polygons in your view:

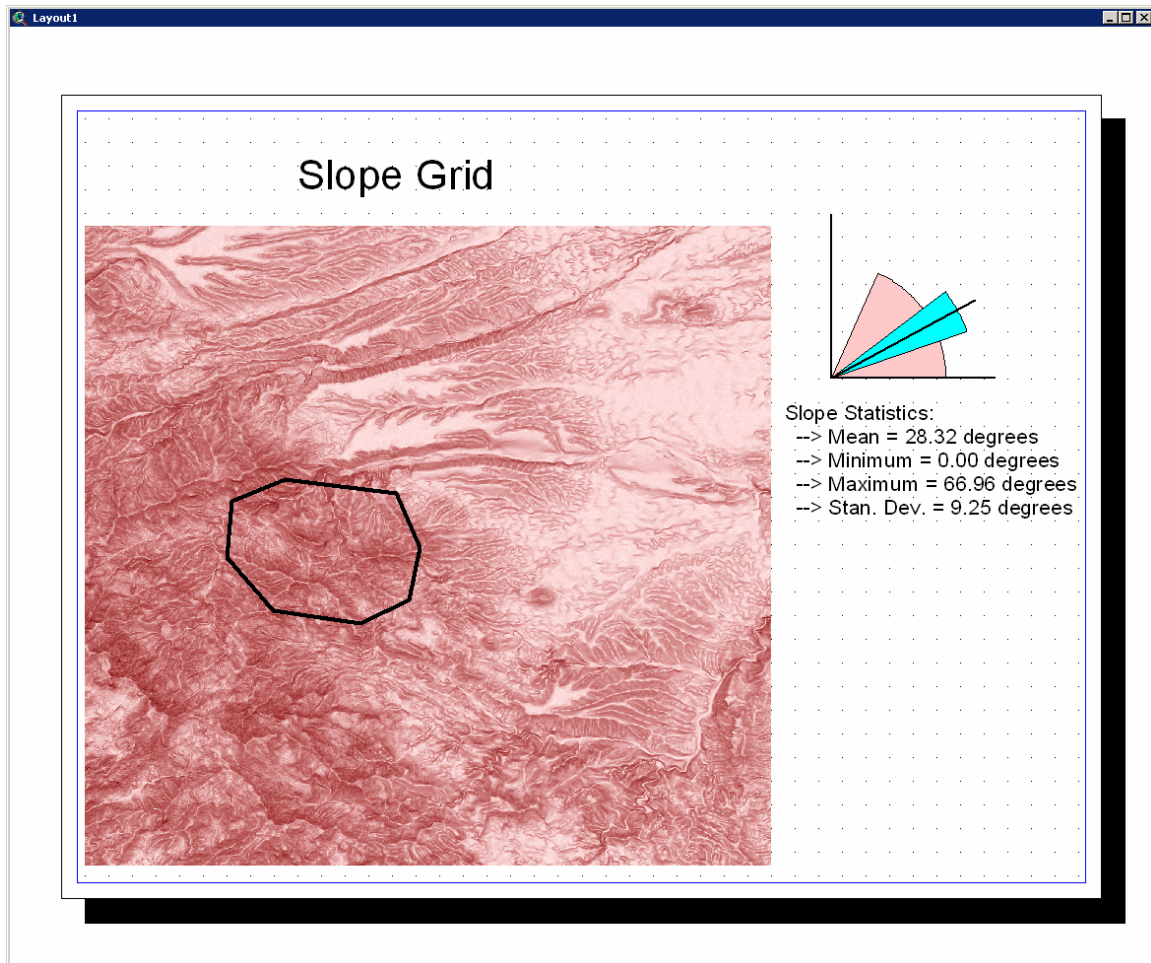


Click 'OK' and the tool will go to work. Upon completion, it will generate a new view with your Slope graphic, plus a report providing several slope-related statistics.





Because the Slope Graphic is generated in a "View" document, it can easily be added to a layout by simply creating a view frame in the layout and linking it to the aspect graphic view. In the example below, I also pasted in a few of the slope statistics from the report.

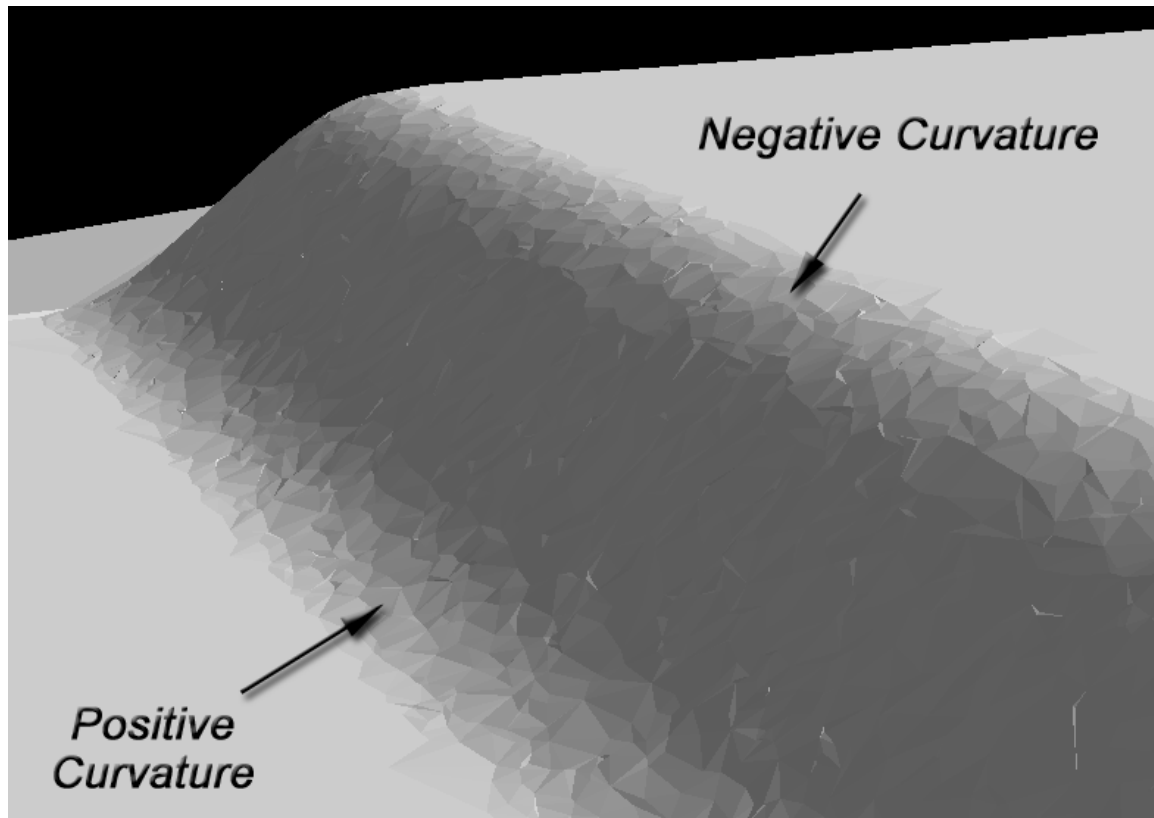


## Calculating Landscape Curvature

Landscape curvature, defined as the derivative of the rate of change of the landscape, helps to quantify the shape of the landscape surface. It is especially useful in hydrologic modeling because it influences downstream runoff behavior. **IMPORTANT:** The Curvature functions assume that the vertical (elevation) units of your grid are the same as the horizontal units (i.e. if your elevation units are in meters, then your X- and Y-Coordinates should also be in meters). If your elevation grid is unprojected, then you should project the grid before running this tool.

### ***Profile Curvature***

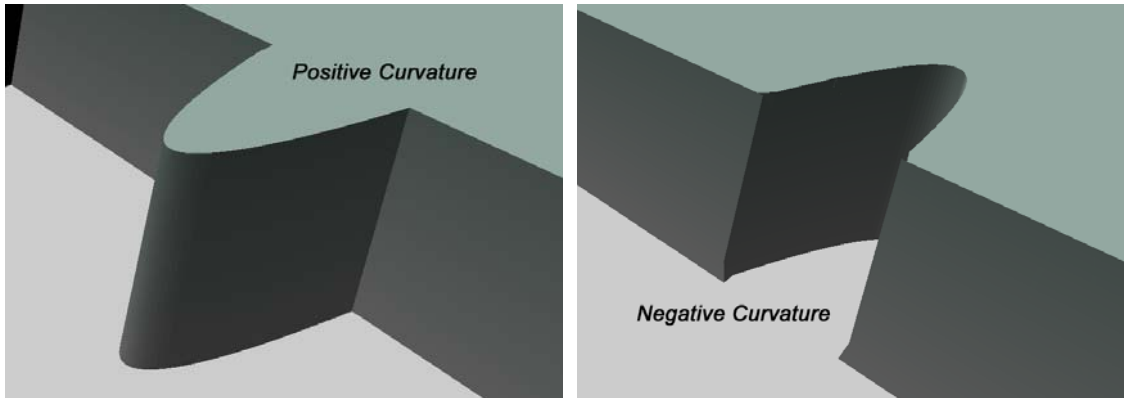
Profile curvature is calculated in the direction of slope, which would affect how water speeds up or slows down as it flows over the cell. Convex areas, where water would accelerate, have negative profile values. Concave areas, where water would slow down, have positive values.



### ***Planiform Curvature***

Planiform curvature is calculated perpendicular to the direction of slope, which would affect how water converges or diverges as it flows over the cell. Convex areas, where water would diverge, have positive planiform values. Concave areas, where water would converge, have negative values.



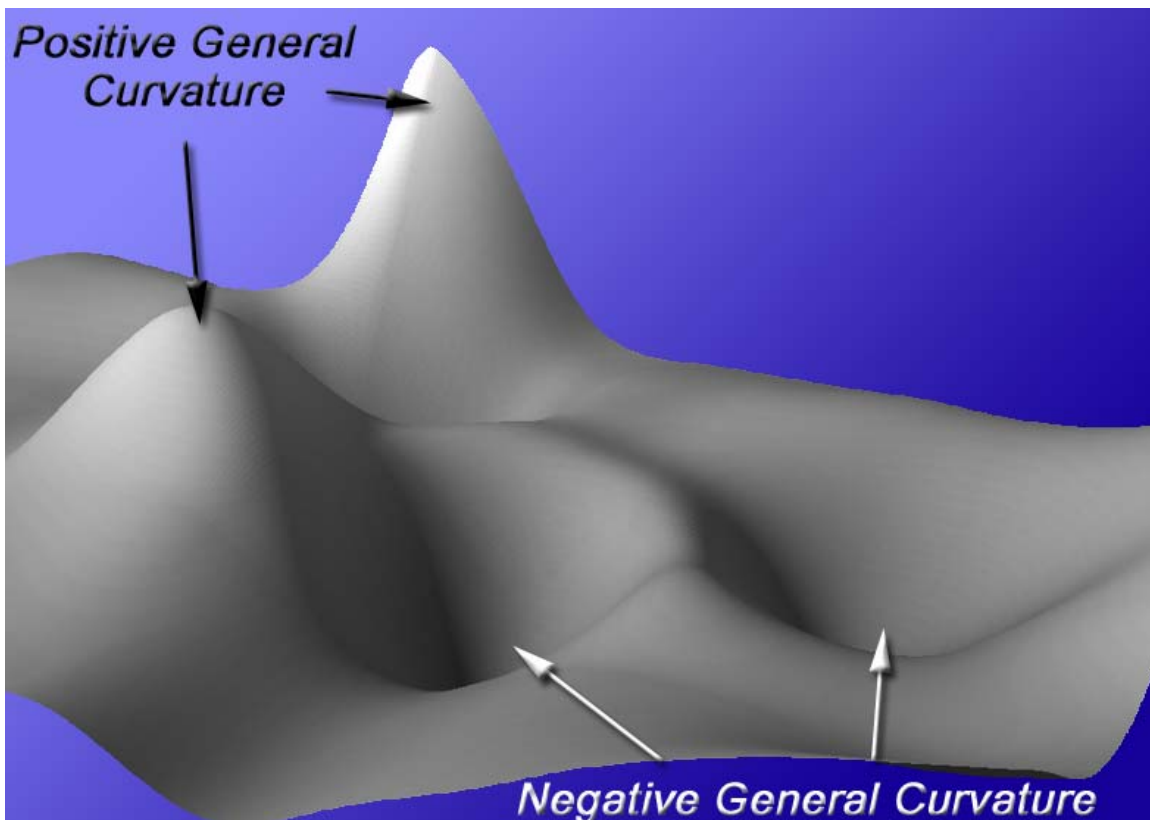


### **Overall General Curvature**

Overall curvature is a combination of profile and planiform curvature, and is useful for determining local high and low points. In general, the values derived by the "Overall Curvature" request are almost always equal to:

$$[\text{the Planiform curvature}] - [\text{the Profile curvature}]$$

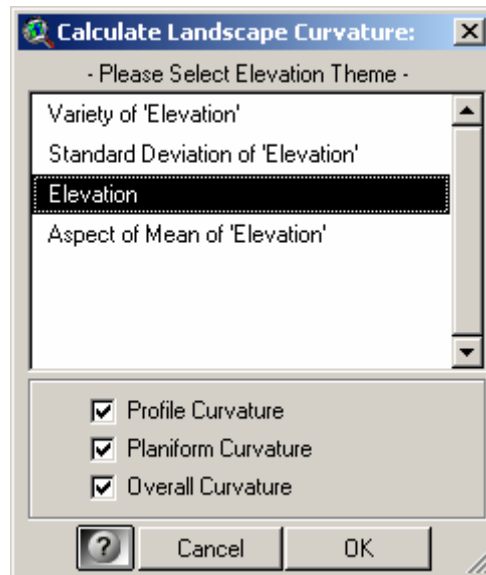
except when planiform and profile curvature are both equal to 0. In those cases, the overall curvature is some other value, with no pattern that is obvious to the author.



Local curvature values may also reflect how "protected" a site may be from weather and wind. Areas with extreme local curvature values may reflect either exposed areas (if planimetric curvature values are positive and/or profile curvature is negative) or protected nooks and crannies (if planimetric curvature is negative and/or profile curvature is positive) in areas with complex topography. However, this ready-made curvature function can also be of limited utility

because it always uses only the 8 grid cells immediately surrounding a cell to determine the local curvature and therefore gives you no flexibility regarding the scale or landscape extent you wish to analyze. If you wish to examine local curvature at a different scale or over a larger area around each cell, you will need to resample your elevation grid to a coarser resolution or use a different method.

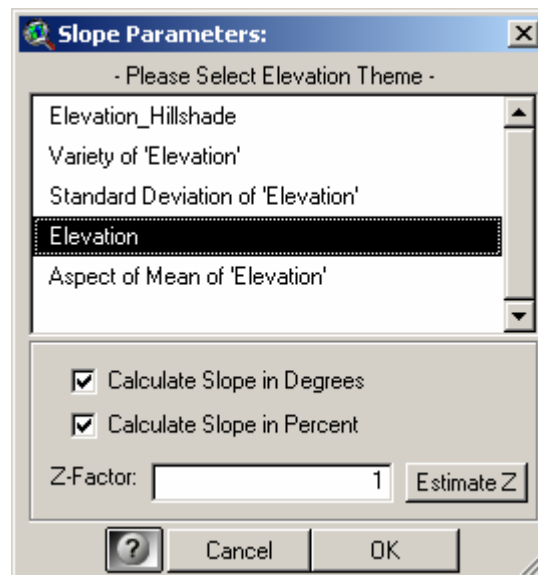
To calculate the curvature, simply click the “Calculate Landscape Curvature” menu item in the “Grid Tools” menu. You will be prompted to identify your elevation grid and curvature options:



Click 'OK' and the tool will generate the curvature grids and add them to your view.

### Calculating Slope (Advanced):

This tool allows you to generate hillshades with a few options that are unavailable in the standard Hillshade dialog. These options allow you to generate accurate hillshades for unprojected grids, and allow you to incorporate some additional aesthetic effects.



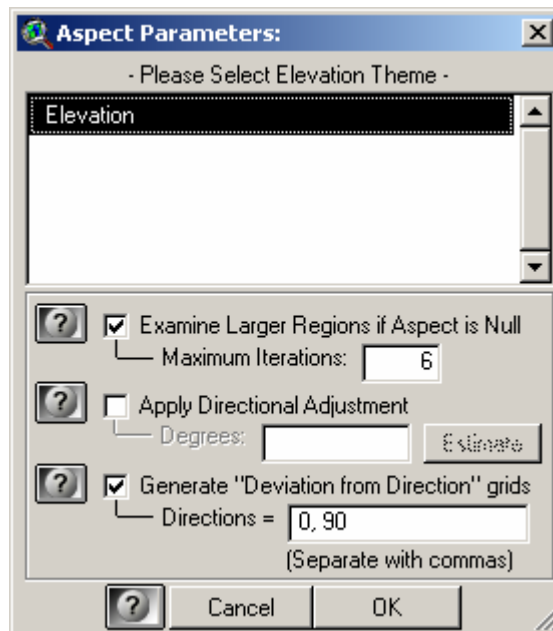
1) Calculate Slope in Degrees: This is the standard slope function offered by ArcView.

- 2) Calculate Slope in Percent: Percent slope is equal to (Horizontal Distance) / (Vertical Distance) and can range from 0 to infinity. A slope of 45 degrees is equal to a 100% Slope.
- 3) Z-Factor: The ratio of the vertical units over the horizontal units. The basic slope function assumes that the vertical distance units are the same as the horizontal units, which is often the case when the data are projected. If, for example, the elevation values are in meters and the horizontal coordinates are in meters, then the Z-factor would be equal to 1. Unprojected elevation grids present a problem because the horizontal coordinates are in degrees while the elevation units are generally in meters or feet. A degree is much larger than a meter or foot, so an appropriate Z-factor must be calculated to adjust for the difference. Z-factors for unprojected grids are typically somewhere around 0.00001.
- 3a) Estimate Z Button: This button will analyze your grid and make an estimate of what the appropriate Z-factor should be. If the extent of your grid extends past the range of geographic coordinates (i.e.  $[-180 \leq X \leq 180]$ ,  $[-90 \leq Y \leq 90]$ ), then the tool will assume that the grid is projected and will generate a Z-factor = 1. If the grid lies within the range of geographic coordinates, then the tool will assume the grid is not projected and will estimate the Z-factor for the centerpoint of your grid using the following logic:
  - a) Identify the centerpoint of your grid.
  - b) Identify the cell size of your grid.
  - c) Generate a new point exactly 1 cell width to the east of the centerpoint.
  - d) Estimate the real-world distance (in meters) between the two points, using the Haversine formula (Wikipedia 2006) and assuming a sphere with radius of 6371 km.
  - e) Z-factor = the real-world distance divided by the cell size.

### Calculating Aspect (Advanced):

This tool allows you to generate Aspect values from an elevation grid with a few options that are unavailable in the standard Aspect function. These options allow you to:

- 1) Attempt to avoid null aspect values (i.e. flat areas where aspect = -1) by examining progressively larger regions until a valid aspect value is found.
- 2) Apply a directional adjustment to the aspect values by shifting them either clockwise or counterclockwise by some specified amount.
- 3) Generate specialized aspect grids that reflect how much the aspect value deviates from a direction of interest.

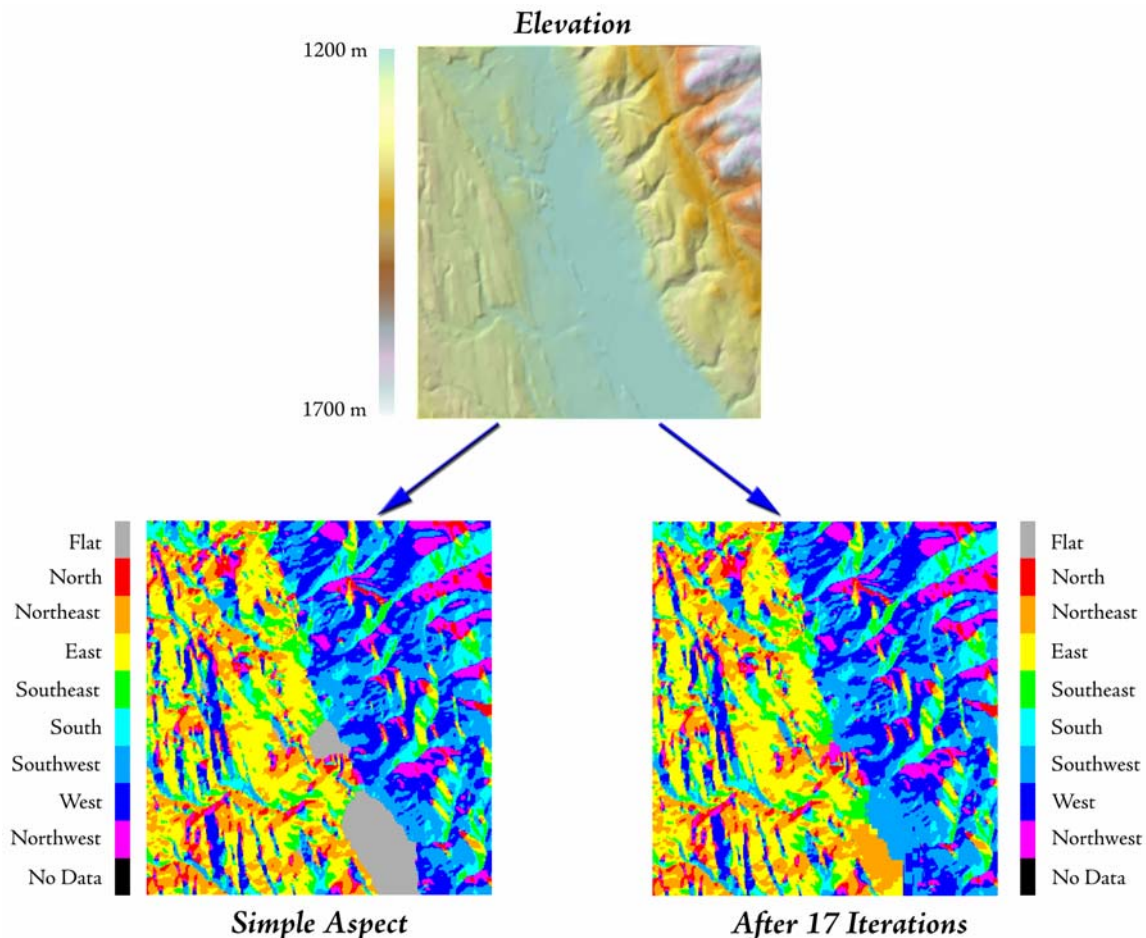


### ***Avoiding Null Aspect Values (i.e. flat areas)***

This option attempts to produce an aspect grid with a minimal number of flat areas, which may be useful if you are conducting a statistical analysis of aspect and you wish to include those flat areas in the analysis.

Recall that aspect is always calculated from the elevation at the central cell and the elevation in the 8 surrounding cells. Assuming there is any significant topography in your area, there is a good chance that you can find a true aspect value if you look at a larger region around each “null” cell. Therefore, this function minimizes the amount of flat area by recalculating aspect for “null” cells at progressively coarser scales. This function will continue recalculating aspect at increasingly coarser scales until either (a) you have reached the maximum number of iterations, or (b) you have produced a grid with no null aspect values.

**IMPORTANT:** The final aspect grid will contain aspect values for the finest scale possible. The only cells containing aspect values generated at coarser scales will be those which were “null” at finer scales. Therefore this function will produce a final aspect grid which will likely contain aspect values generated at a variety of scales.

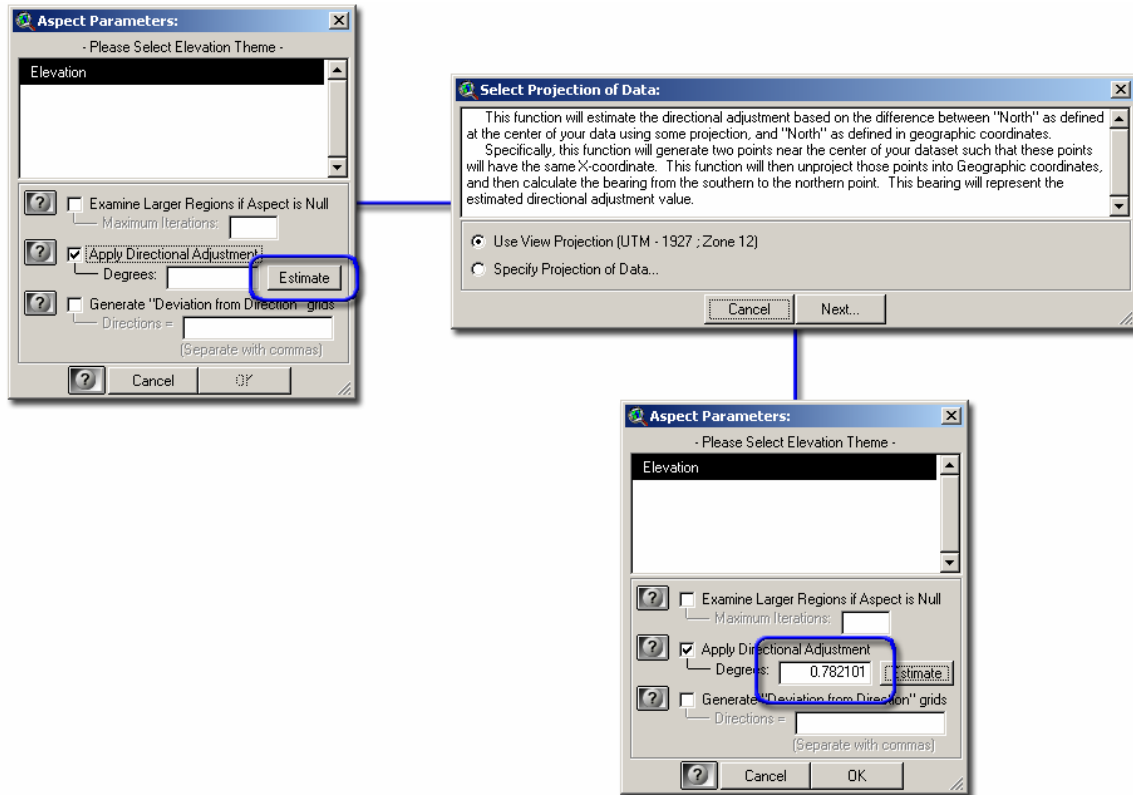


### ***Apply a Directional Adjustment***

This option is intended for projected elevation grids, and specifically for cases in which “North” in that projection deviates a significant amount from true north. This phenomenon is common for many projections, and especially in those areas where the projection distortion is greatest.

This function allows you to compensate for the projection distortion by applying a directional adjustment to the aspect grid. Whatever value is entered into the textbox will be added to the final aspect grid. The final aspect grid will still have aspect values ranging from 0 – 360 degrees, and any flat areas (i.e. “null” aspect values) will stay flat after the directional adjustment is applied.

This option also provides a function to estimate what the appropriate adjustment value should be. The “Estimate” button will ask you for the projection of your data, then it will generate two points near the center of your dataset such that these points will have the same projected X-coordinate. This function will then unproject those points into Geographic coordinates, and then calculate the bearing from the southern to the northern point. This bearing will represent the estimated directional adjustment value.



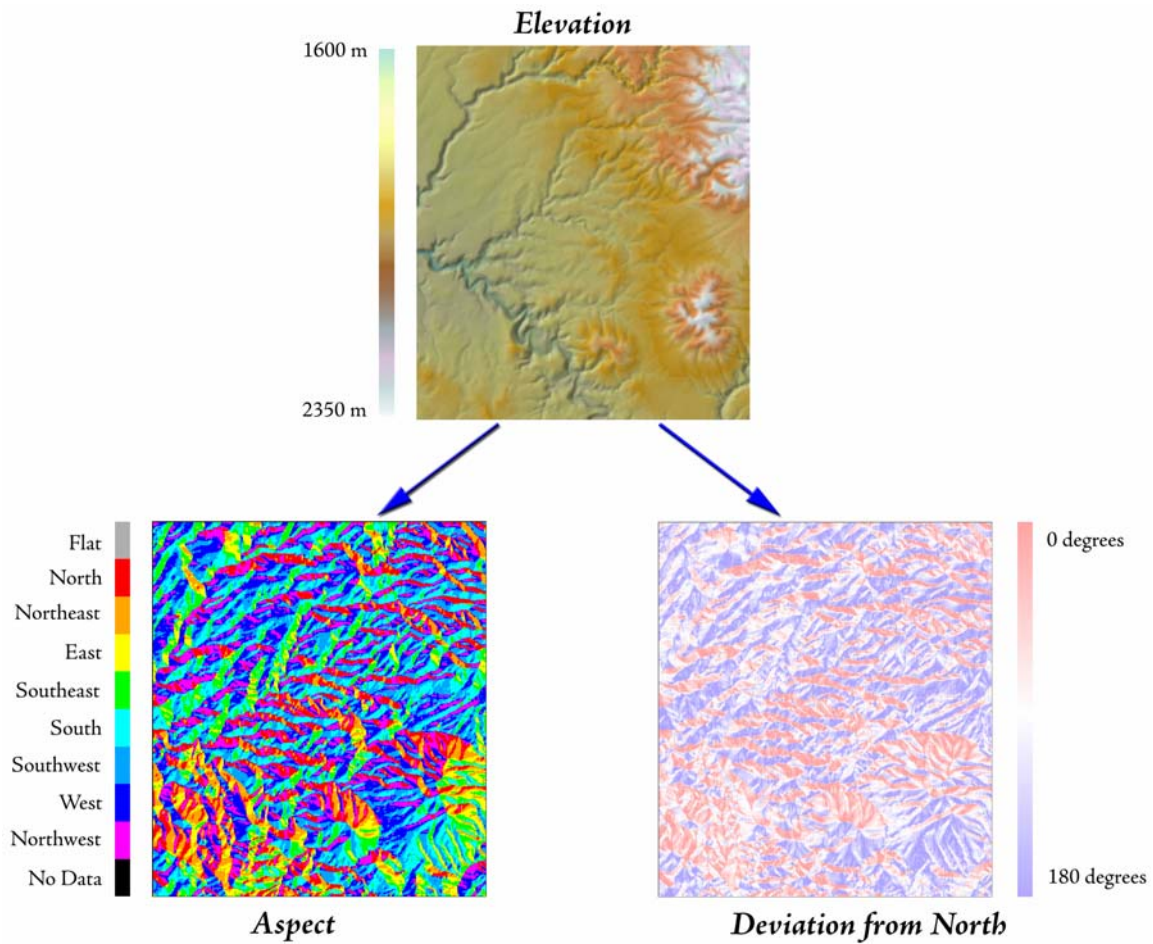
### ***Generate ‘Deviation from Direction’ grids***

Aspect is an intuitively valuable habitat variable. North-facing slopes are typically cooler and more mesic while south-facing slopes are generally warmer and more xeric (at least in the northern hemisphere), and habitats can be dramatically different depending on which side of a hill you stand on. Aspect can be difficult to analyze, though, because of its circular nature. The difference between 1 degree and 360 degrees is the same as the difference between 1 degree and 2 degrees, making it difficult to plug into a typical statistical model.

This function allows you to analyze aspect in terms of how much the landscape deviates from some direction of interest. If you are interested in the north-facing vs. south-facing habitat phenomenon, then it may be useful to convert the raw aspect data into a “deviation from North” grid, such that all values lie between 0 (where the terrain faces due north) to 180 (where the terrain faces due south).

You may enter multiple compass directions if you wish. Separate multiple direction values with commas. The dialog will let you know if it is not able to understand any compass directions you have entered.

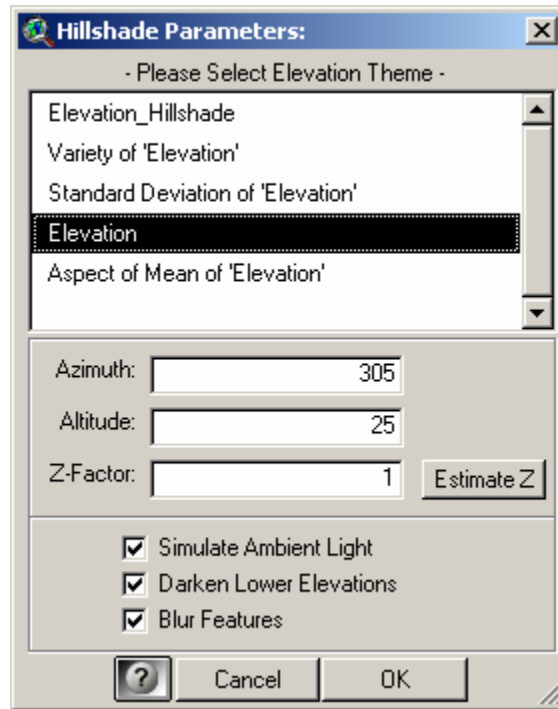
Trimble & Weitzman (1956) and Beers et al. (1966) discuss using an optimum bearing of 45 degrees, and then taking the sine of the rescaled values, which they put to extensive use in site productivity research for timber stands. Please refer to Jenness (2006: p. 6-7) for a discussion of sine transformations of aspect values.





### Calculating Hillshade (Advanced):

This tool allows you to generate slopes with a few options that are unavailable in the standard Slope function dialog. These options allow you to generate accurate slopes for unprojected grids, as well as generate slopes in either degrees or percent.



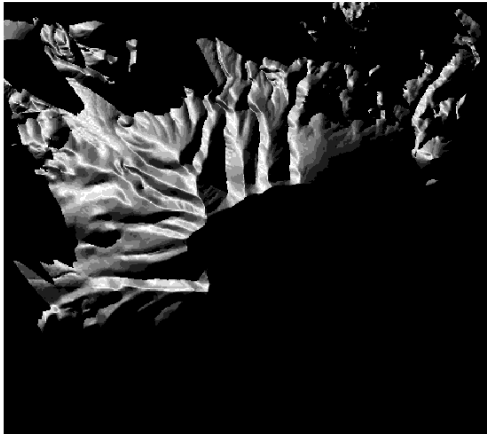
- 1) Azimuth: The compass direction of the sun.
- 2) Altitude: The angle of elevation to the sun, in degrees.
- 3) Z-Factor: The ratio of the vertical units over the horizontal units. The basic slope function assumes that the vertical distance units are the same as the horizontal units, which is often the case when the data are projected. If, for example, the elevation values are in meters and the horizontal coordinates are in meters, then the Z-factor would be equal to 1. Unprojected elevation grids present a problem because the horizontal coordinates are in degrees while the elevation units are generally in meters or feet. A degree is much larger than a meter or foot, so an appropriate Z-factor must be calculated to adjust for the difference. Z-factors for unprojected grids are typically somewhere around 0.00001.
- 3a) Estimate Z Button: This button will analyze your grid and make an estimate of what the appropriate Z-factor should be. If the extent of your grid extends past the range of geographic coordinates (i.e.  $[-180 \leq X \leq 180]$ ,  $[-90 \leq Y \leq 90]$ ), then the tool will assume that the grid is projected and will generate a Z-factor = 1. If the grid lies within the range of geographic coordinates, then the tool will assume the grid is not projected and will estimate the Z-factor for the centerpoint of your grid using the following logic:
  - a) Identify the centerpoint of your grid.
  - b) Identify the cell size of your grid.
  - c) Generate a new point exactly 1 cell width to the east of the centerpoint.
  - d) Estimate the real-world distance (in meters) between the two points, using the Haversine formula (Wikipedia 2006) and assuming a sphere with radius of 6371 km.
  - e) Z-factor = the real-world distance divided by the cell size.



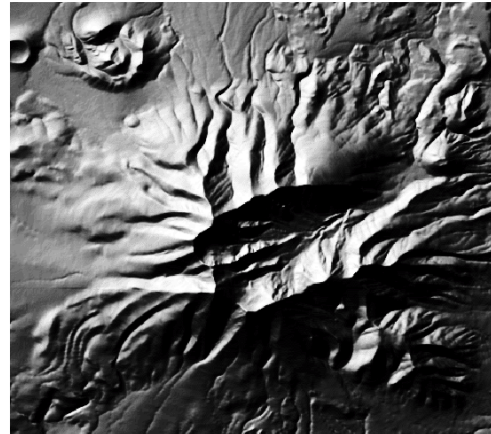
- 4) Simulate Ambient Light: This option prevents complete shading/shadowing (where landscape is completely black because of shadow) by producing several hillshades from different angles and combining them:
  - a) 40% of hillshade is from specified direction.
  - b) 20% is from 50 degrees clockwise of specified direction.
  - c) 20% is from 50 degrees counterclockwise of specified direction.
  - d) 20% is from 180 degrees (directly opposite) of specified direction.
- 5) Darken Lower Elevations: This option is good when you want valley bottoms to be darker than mountain tops, regardless of how directly they face the sun. This is also a good method of simulating bathymetric darkening as water depth increases. It is calculated as  $(\text{Elevation} / 5) + \text{Hillshade}$ , and then rescaled to 0-254.
- 6) Blur Features: This option is intended to smooth out the landscape a bit, de-emphasizing minor topographic features. It is calculated by generating the focal mean of the hillshade, using a circular neighborhood of with a radius of 2 pixels.

**NOTE:** Ambient Light, Darkening Lower Elevations and Blurring Features are all based on ideas discussed by Buckley and Barnes (2005) and are variations on the "Swiss Method" of relief shading.

Effect of Z-Factor on Unprojected Grid:

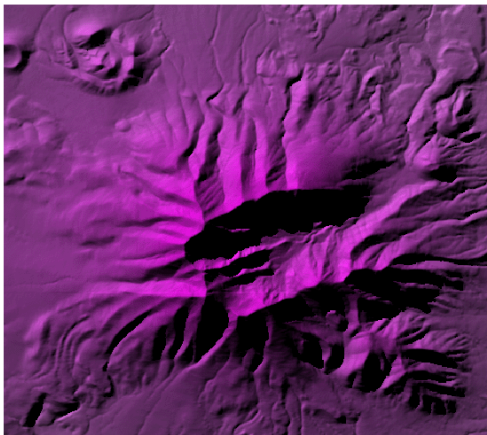


Z-factor = 1

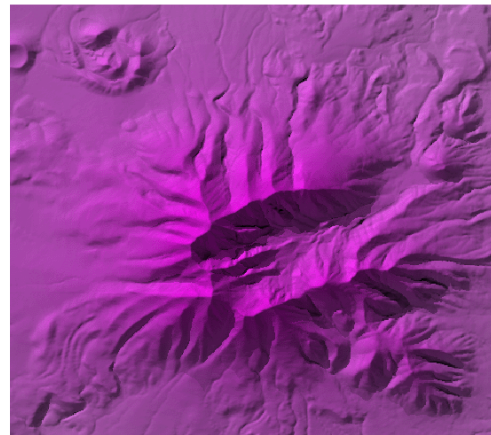


Z-factor = 0.000011028622

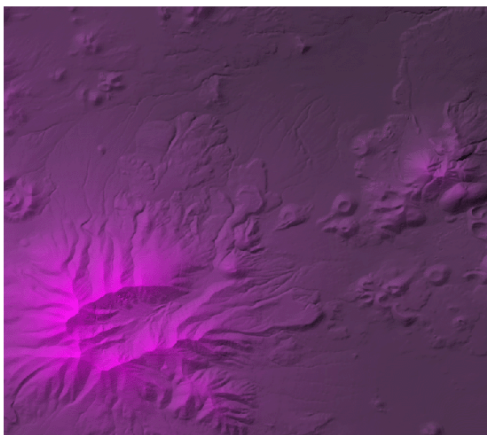
Hillshade Effects:



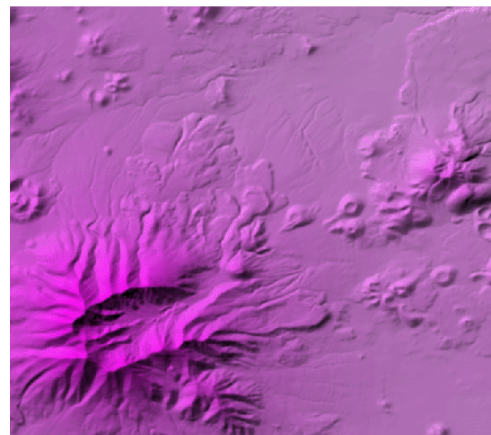
Basic Hillshade



Hillshade with Ambient Light



Hillshade with Deepening Effect



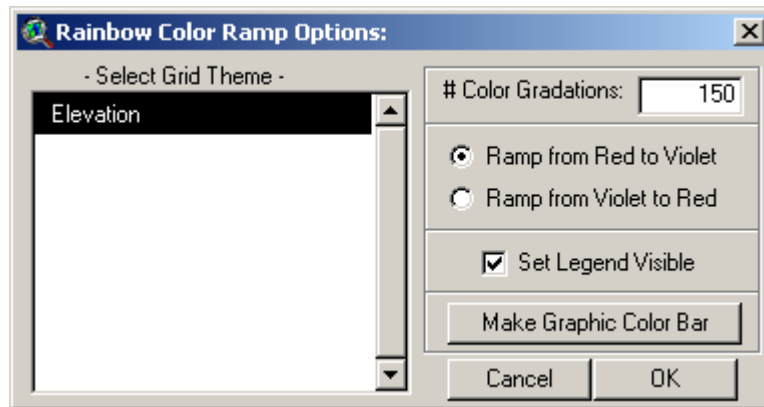
Hillshade with Blurring Effect

## Multi-Color Ramping Tools for Legends:

This extension offers two tools to generate customized color ramps for grid legends, enabling you to ramp between multiple colors and generate a large number of color levels. The tools also produce graphic color bars which can be used as attractive legends in layouts or other software.

### ***Rainbow Color Ramps:***

This tool generates an array of colors which replicate the visible color spectrum. Click the “Apply Rainbow Color Ramp...” menu item to open the Rainbow Color Ramp Options window:



Select your grid theme and the number of color gradations. This number will reflect the number of classification levels, or individual colors, in your new legend.

You have the option to ramp from Red to Violet or from Violet to Red. In either case the colors will ramp through the visible spectrum:

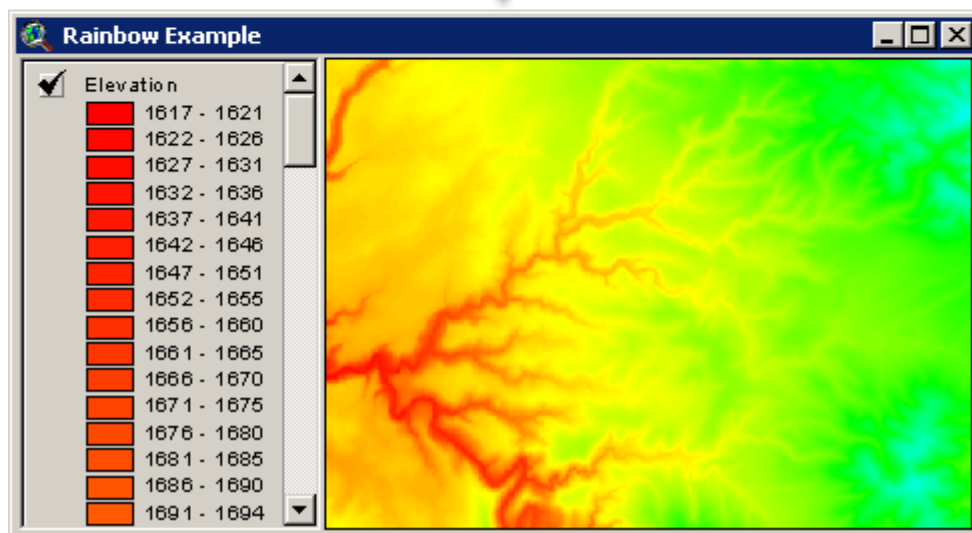
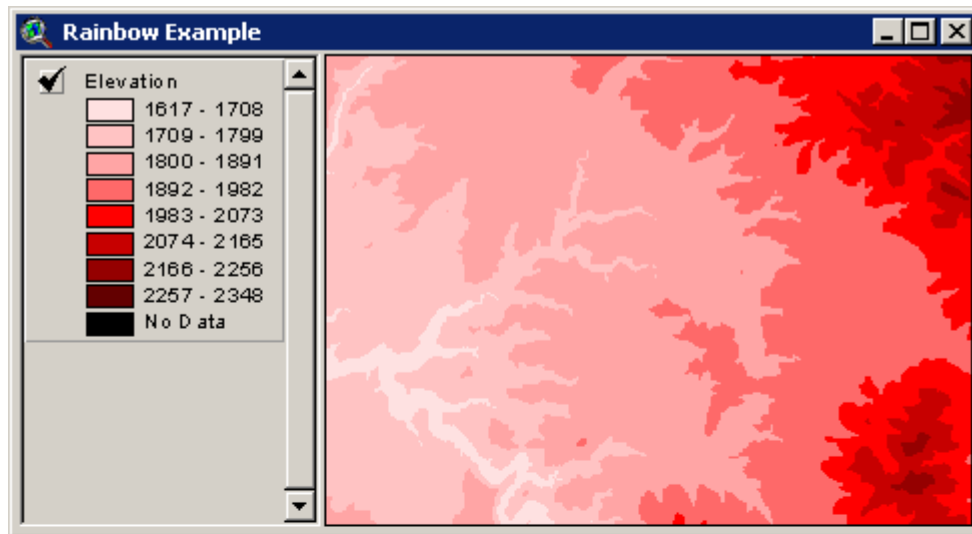
Red to Violet



Violet to Red

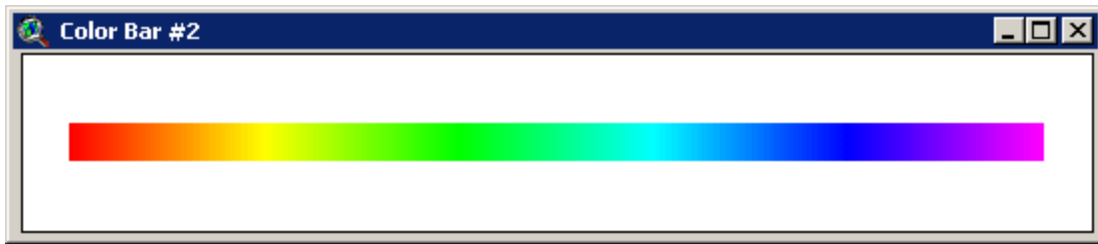



Click 'OK' to generate your new legend:

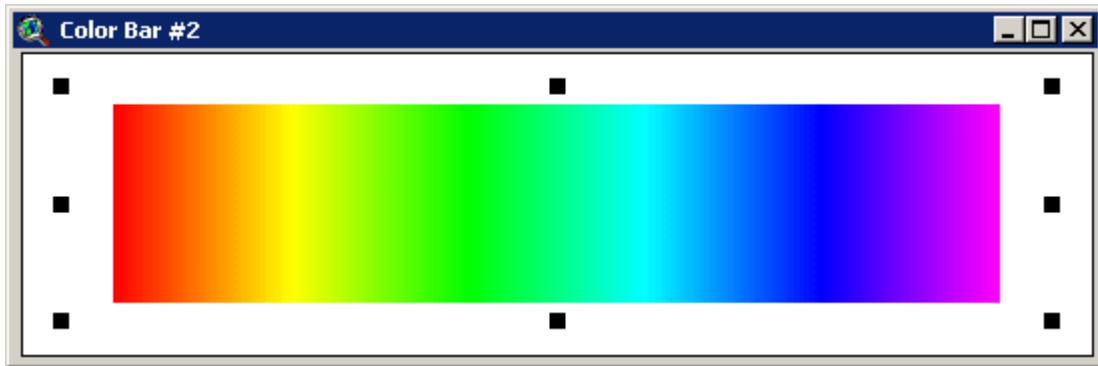


You also have the option to set your new legend visible or not. In cases where you generate large numbers of classification levels (150 in the example above), it may be useful to set your legend invisible so that it doesn't take up the entire View table of contents area. You can also set the legend visibility in the "Theme" menu, but setting the visibility directly with this tool may be more convenient.

Finally, you can generate a graphic rainbow color ramp bar by clicking the "Make Graphic Color Bar" button. This option generates a new view, labeled something like "Color Bar" (possibly with a number after it) and will contain a single graphic object. This color bar can be generated either horizontally (as shown below) or vertically:



This graphic can be resized by selecting it with the  button and stretching it by dragging on one of the handles:

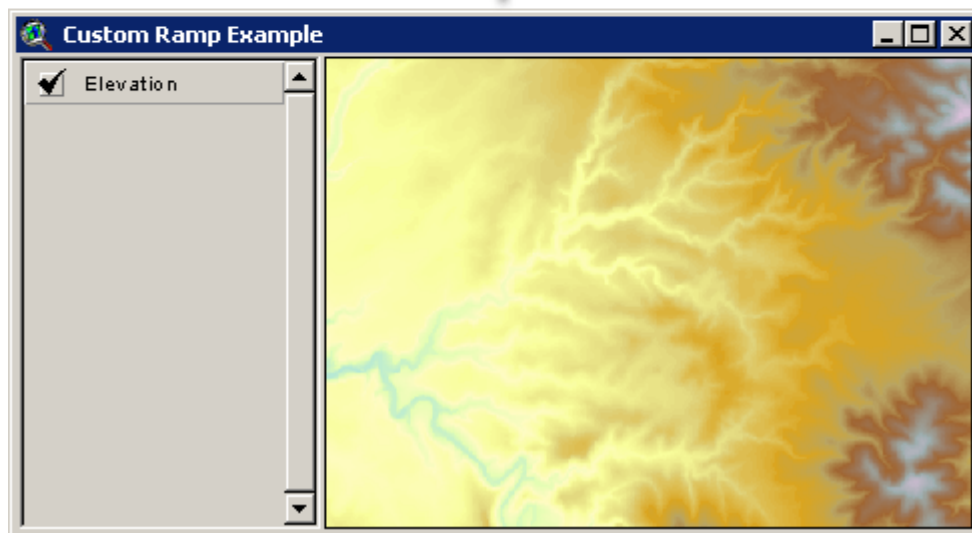
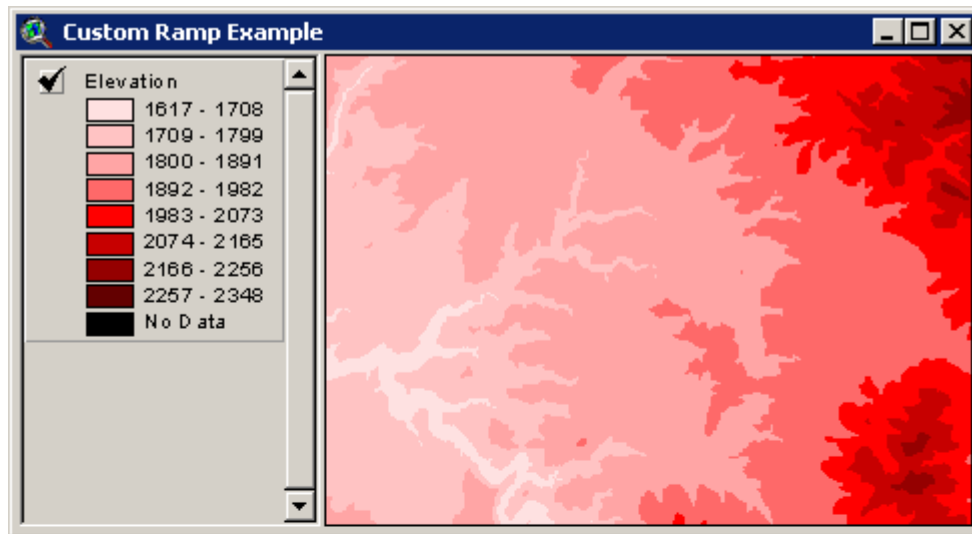


This color bar can then be added to a layout using the standard Layout functions. Remember that this color bar is actually a View document, so you add it to your layout as you would any other view. Alternatively, you could copy and paste this graphic directly into your view. If so, you will almost certainly need to reposition and resize the graphic. The original graphic coordinates extend from (0, 0) to (500, 20).

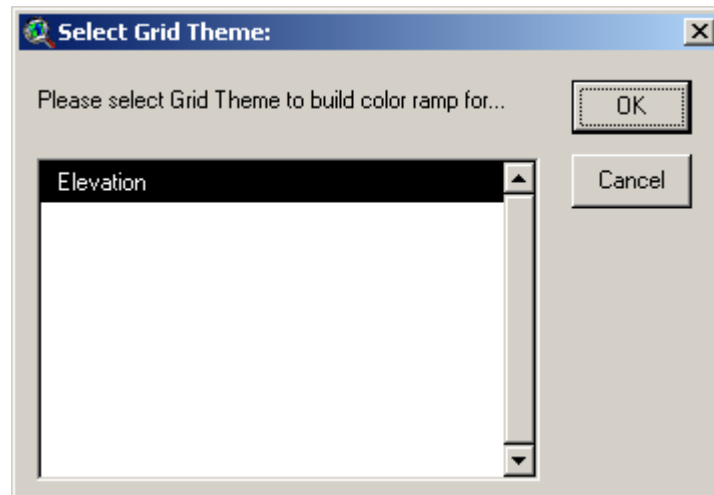
You can also take a screenshot of the color bar to paste it into graphic-editing software (i.e. Photoshop, Photopaint, etc.). Click [Alt]-Print Screen to copy the image to the clipboard, then [Control]-V to paste the image into your graphics software.

### ***Custom Color Ramps:***

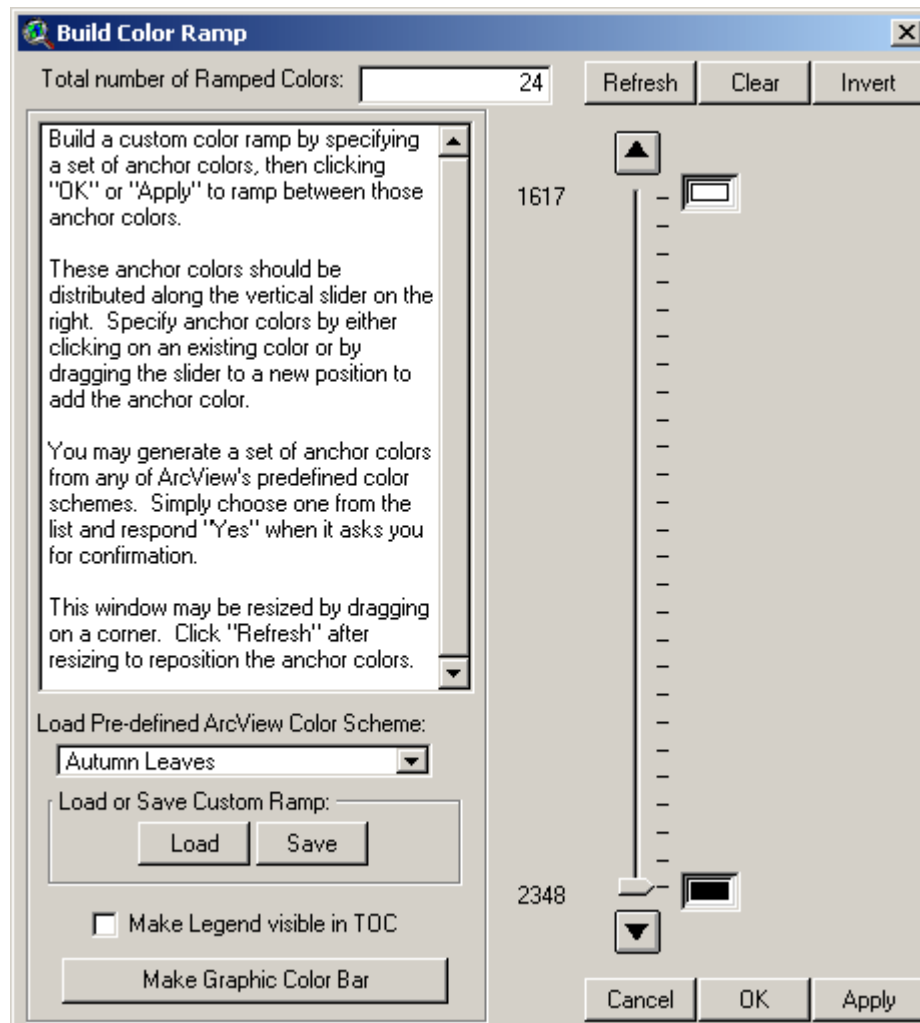
This tool is intended to generate grid legends that ramp (or blend) between multiple colors, and to give you the ability to set the colors and ramp anchor points. **IMPORTANT:** This tool is not designed to do any type of classification analysis. It only ramps colors smoothly between anchor points.



Click the “Build Custom Color Ramp...” menu item to start the process. You will first be asked to identify the grid theme to build a custom legend for:



Select your grid and click 'OK' to open the "Build Color Ramp" window:

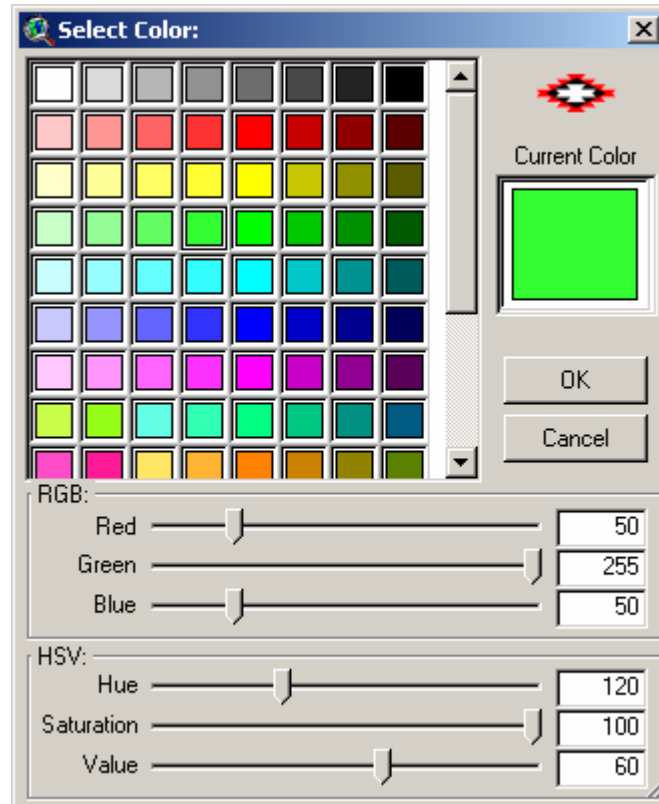


The vertical slider on the right of the window shows how the colors will be ramped, and the number box at the top of the window shows how many total color levels to include in the ramp. The color boxes on the right side of the slider show the color anchors, and the numbers on the

left side of the slider show the values associated with those colors. In this case, the tool will generate a legend with 24 shades of gray, ranging from White at Value=1617 to Black at 2348.

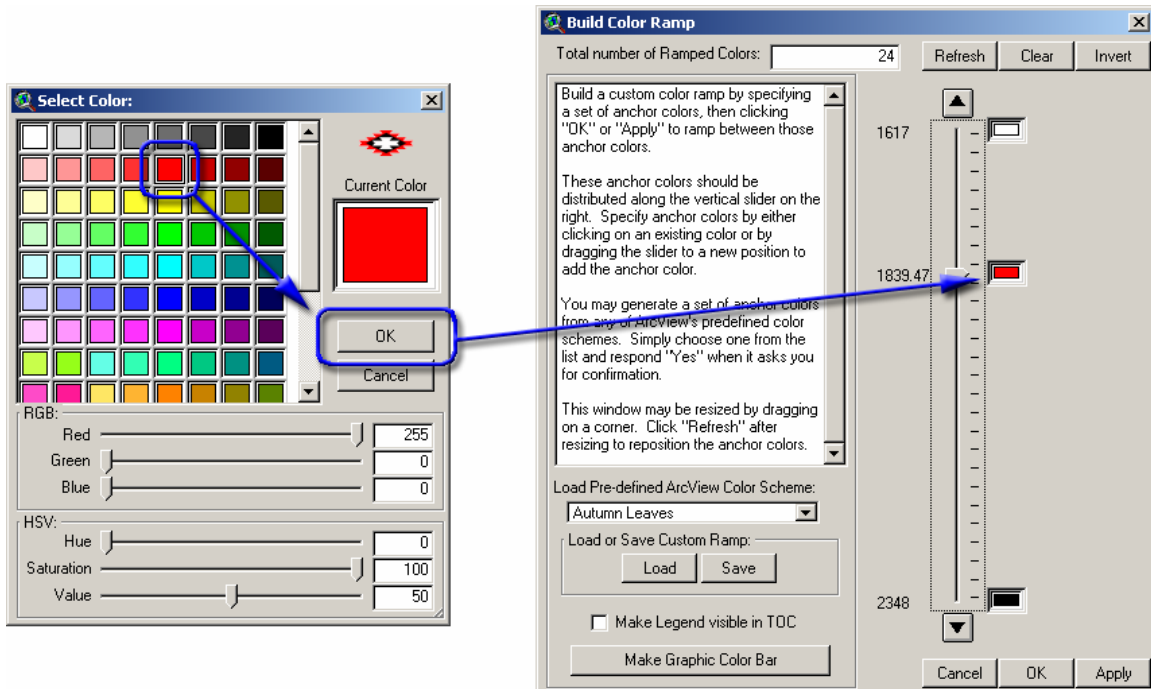
### **Adding, Deleting and Changing Color Anchors:**

You can add a midpoint color anchor by dragging the slider to the appropriate point and choosing a color. For example, to ramp from White to Red to Black, you would drag the slider to the appropriate point and enter a Red color. As soon as you move the slider, the Color Palette window and a "Select Color" window will open:



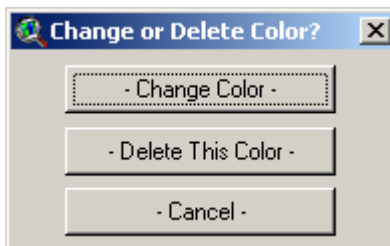
Select the desired color and click 'OK' to add your new color anchor. Note that you can adjust the selected color by dragging any of the slider bars at the bottom of the dialog. You may adjust your color using either RGB (Red/Green/Blue) or HSV (Hue/Saturation/Value) settings.





**Apply, OK and Clear:** You can test your new color ramp by clicking the 'Apply' button. This will apply the new color ramp to your theme while leaving the window open. Clicking the 'OK' button will apply the color ramp and close the window. The 'Cancel' button will close the dialog and reset the theme legend to the original condition.

**Changing or Deleting Anchor Colors:** You can change the colors of any of the anchor points, or delete any of the internal anchor points, by clicking on the color box. You will be prompted to either delete that color anchor or to change the color:



You cannot delete either of the end anchor points.

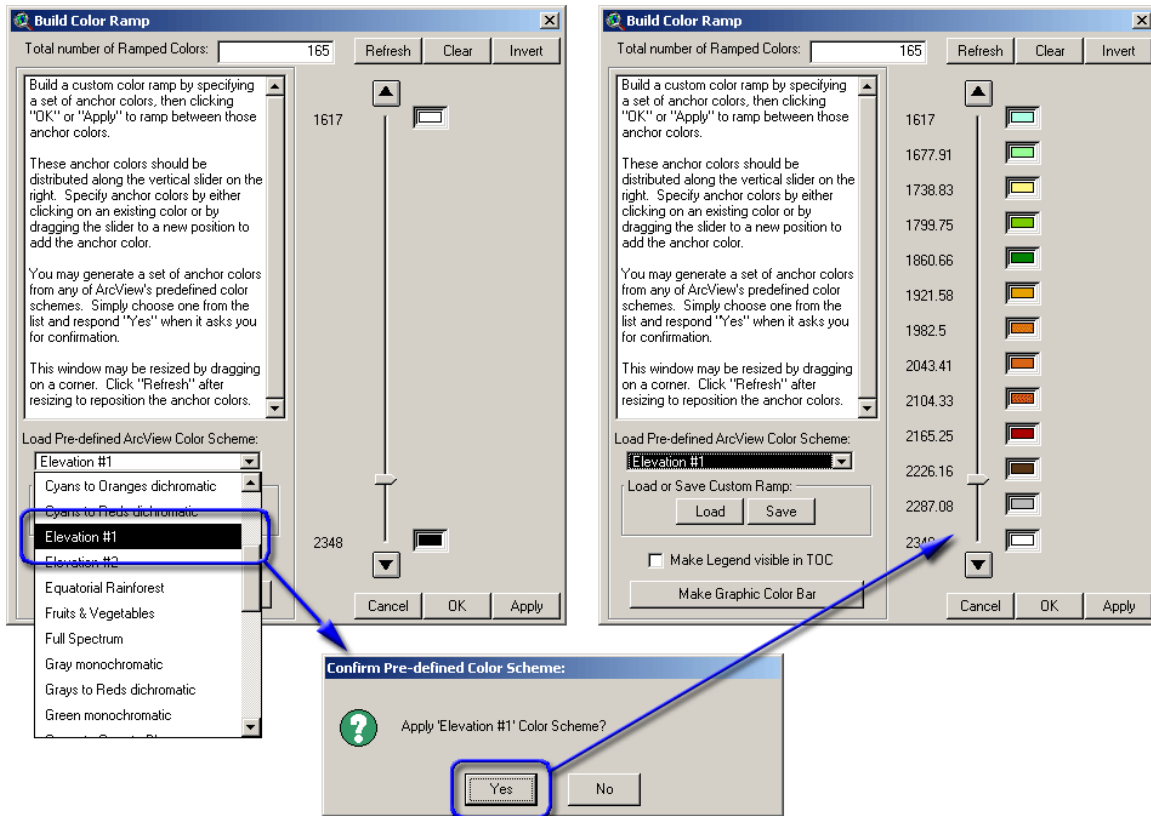
**Clear:** At any point you can clear and reset your custom ramp by clicking the 'Clear' button. This button clears all internal color anchors and resets the endpoints to White and Black. It does not change the current number of ramped colors.

**Invert:** The 'Invert' button reverses the order of the colors.

**Refresh:** The "Refresh" button redraws the slider and the color anchors. The window is resizable by dragging on a corner, but unfortunately the slider does not change size with the window. If you change the size of the window, you must click the 'Refresh' button to redraw everything.

### **Loading Pre-Defined Color Schemes:**

ArcView includes a number of pre-defined color schemes that are available in the Legend Editor (i.e. "Red Monochromatic", "Elevation #1", "Autumn Leaves", etc.). This custom color ramp tool also gives you access to these color schemes, plus gives you the ability to ramp between all colors. Choose a scheme from the drop-down list and confirm that you wish to apply it:



### **Loading and Saving Custom Color Schemes:**

This tool provides a way to save custom color ramps so they can be used with other themes. This tool does not save ArcView legends (\*.avl) files like the Legend Editor does, but rather specialized files intended to be used specifically with this tool.

**IMPORTANT:** The saved color ramps do not reference the actual values of the data. If you build and save a custom ramp on a theme that ranges from a value of 1000 to 2000, then you will still be able to apply it to a theme that ranges from 100 to 200. The color anchor points are saved in terms of the percentage along the range of the data rather than in terms of specific data values.

**NOTE:** After you have used this tool to generate the color ramp, you can always save that legend as an ArcView legend (\*.avl) in the normal way, by opening the legend and clicking “Save” in the Legend Editor.


### **Making Graphic Color Bars:**

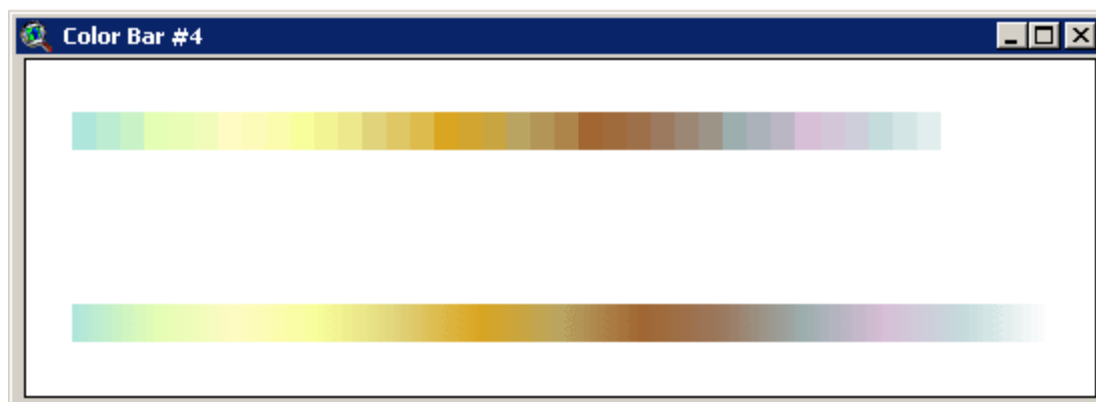
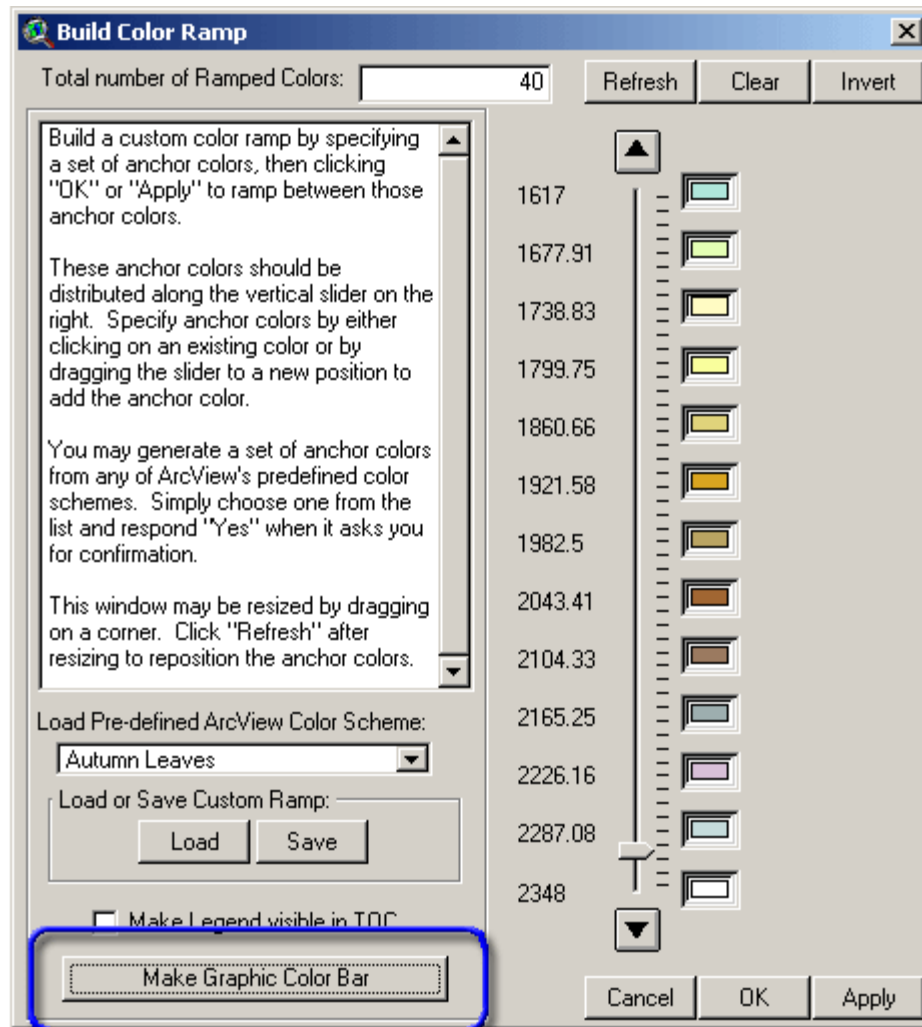
The “Make Graphic Color Bar” button will generate two graphic color bars that illustrate your color ramp, and which can be used to help make more attractive legends for your grid themes. For example, this tool was used to generate color bars for the author’s *Mahalanobis Distances* extension manual (see two illustrations at:

[http://www.jennessent.com/arcview/mahalanobis\\_description.htm](http://www.jennessent.com/arcview/mahalanobis_description.htm)

As with the rainbow color bars, these graphic color bars can be generated either vertically or horizontally.

The button makes two color bars. The first one shows only the colors that are actually used in the legends (40 in the example below), while the bottom color bar smoothly blends between colors.

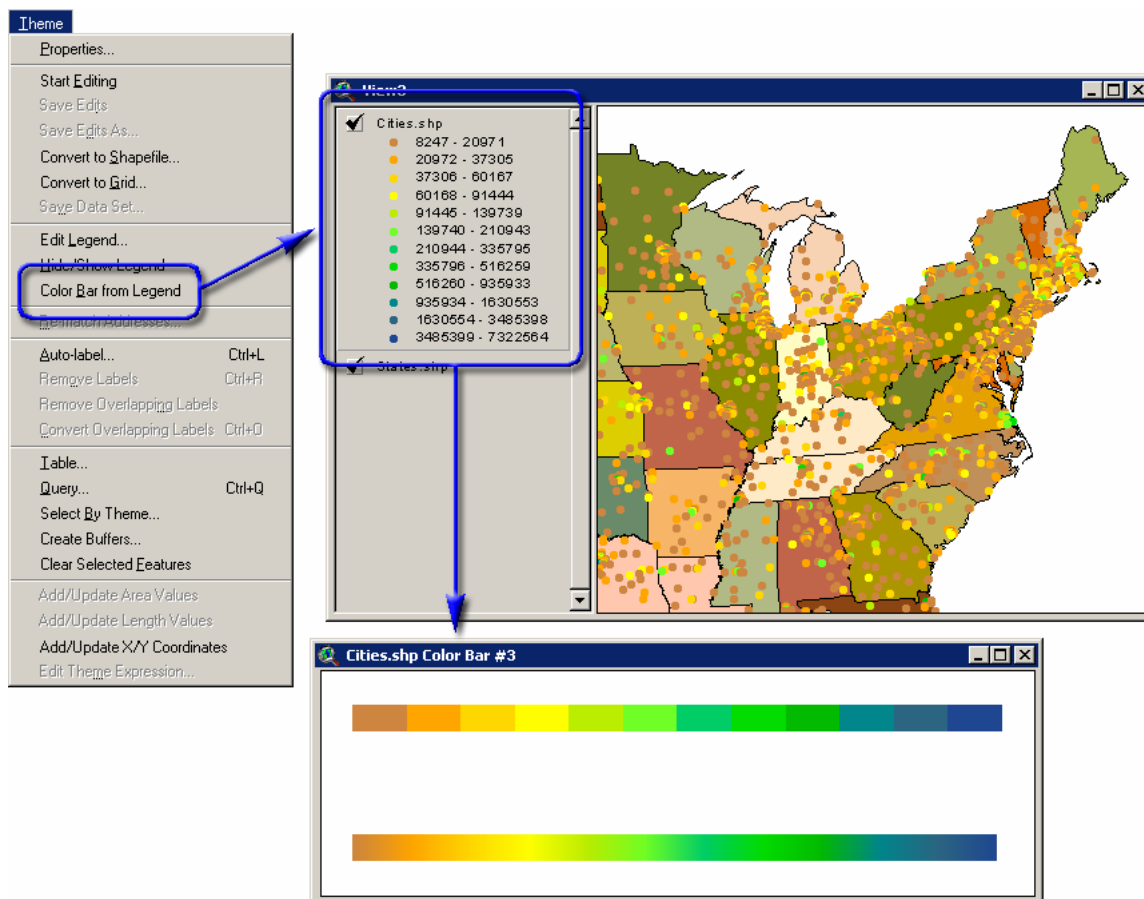
These color bars are actually in View documents, so they can be added to layouts using the “Add View Frame” function. The color bars can also be copied from the Color Bar window and pasted directly into your views, in which case they will likely need to be resized and repositioned in order to look aesthetically correct. They can be resized and repositioned the same way any other graphic shape is, by selecting it with the  button and then moving the shape or dragging one of the handles.




### Creating General Graphic Color Bars:

This extension can create graphic color bars (similar to that pictured above) for any grid or feature theme in your view, based on the current legend you have set for that theme.

This function will automatically work on all active grid or feature themes in your view, so begin by clicking on those themes to make them active. Next, simply click the “Color Bar from Legend” menu item in the “Theme” menu and specify whether you want the color bars to be vertical or horizontal.



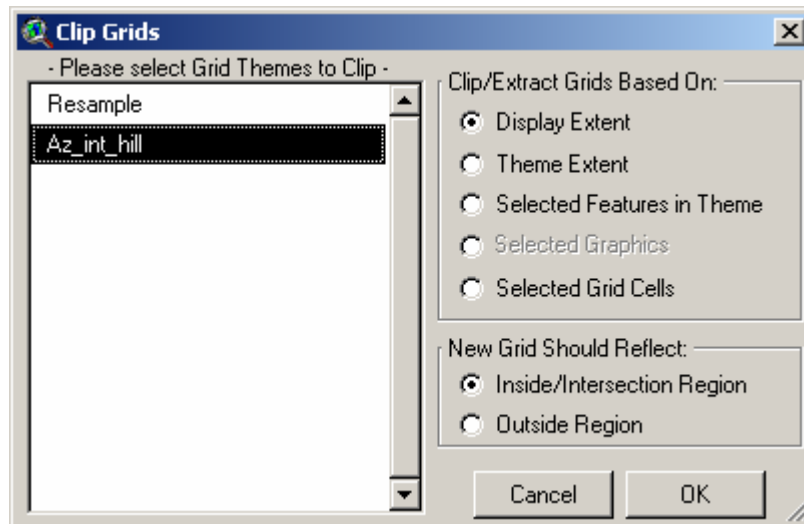
The function makes two color bars; one of which shows only the colors that are actually used in the legends (12 in the example above), while the other smoothly blends between colors. You will likely only want one of these, so you will probably want to select the other one and delete it.

These color bars are actually in View documents, so they can be added to layouts using the “Add View Frame” function. The color bars can also be copied from the Color Bar window and pasted directly into your views, in which case they will likely need to be resized and repositioned in order to look aesthetically correct. They can be resized and repositioned in the same manner as any other graphic shape by selecting it with the  button and then moving the shape or dragging one of the handles.

### Clipping Grids:

This extension allows you to clip grids according to the display extent, a theme extent, selected polygons in a polygon theme, selected polygon graphics, or selected grid cell in an integer grid. The extension also allows you to clip off the regions outside the specified area or to clip out the specified area.

Click the “Clip Grids...” menu item to open the “Clip Grids” window:



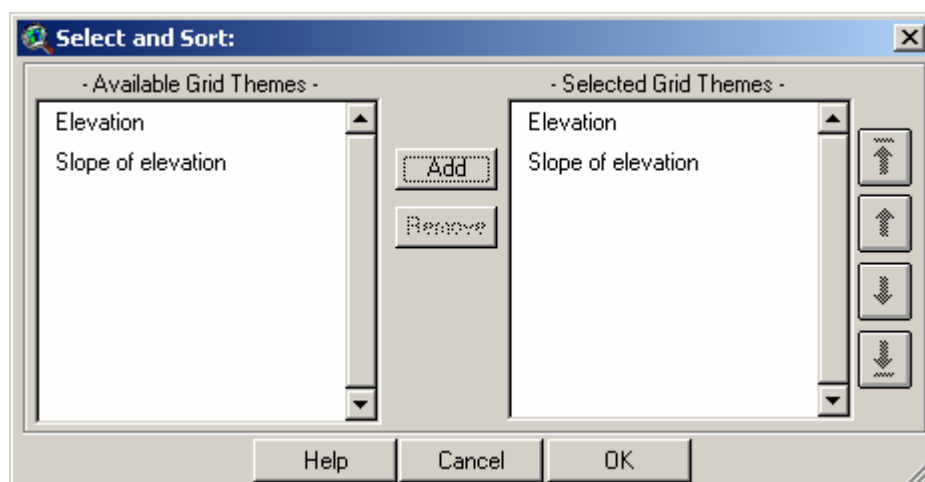
Select the grid or grids you wish to clip, the region you wish to base the clip on, and whether you want the new grid to represent only the region (Inside) or everything except the region (outside).

## Combining Grids:

ArcView offers several methods for combining multiple grids into a single grid:

1. **Merge:** The Merge request treats the set of multiple grids as a stack, where some grids may overlap others. In cases of overlapping grids, the grid which is highest in the stack will take precedence. For example, if a cell in Grid A has a value of 5, and a cell in the same location in Grid B has a value of 10, and if Grid A is higher in the stack than Grid B, then the Combined Grid cell value for that location will be 5. If Grid B was higher in the stack, then the new cell value would be 10.

To do a merge operation correctly, then, you must make sure your grids are in the right order. The Merge tool offered with this extension offers functions to sort your grids. Click the “Merge Grids...” menu item to open the “Select and Sort” window:



Select the grids you want to merge from the list on the right and click the “Add” button to add them to the list on the left. Then select any of the grids in the list on the left and use the arrow buttons to move them up or down. Once your list is sorted correctly, click the “OK” button to merge them.

2. Mosaic: The Mosaic request attempts to blend overlapping grids so that the boundary is not so sharply defined. The author recommends that you review the ArcView Help Item "Mosaic Discussion" for an explanation of what happens here.
3. Combine: The Combine request only works for Integer grids, and is a method of combining the attribute data. The combined grid will have a separate field in the attribute table for each of the input grids, and will have a separate record for every unique combination of attribute values.

## References:

- Batschelet, E. 1981. Circular Statistics in Biology, Academic Press Inc. (London) Ltd. 371 pp. See especially Chapter 2.
- Beers, T. W., P. E. Dress, and L. C. Wensel. 1966. Aspect transformation in site productivity research. *Journal of Forestry* 64:691-692.
- Buckley, A. & D. Barnes. 2005. ArcGIS ArcMap and Cartography: Advanced Cartographic Effects. 2005 ESRI International User Conference Technical Workshop.
- Fisher, N.I. 1993. Statistical Analysis of Circular Data. Cambridge University Press. 277 pp. See especially Chapter 2.
- Jenness, J. S. 2006. Some Thoughts on Analyzing Topographic Habitat Characteristics. Originally published in the June 2005 issue of Remotely Wild (newsletter of the GIS, Remote Sensing, and Telemetry Working Group of The Wildlife Society). Available at [http://www.jennessent.com/downloads/topographic\\_analysis\\_online.pdf](http://www.jennessent.com/downloads/topographic_analysis_online.pdf).
- Mardia, K.V. & Jupp, P.E. 2000. Directional Statistics. John Wiley & Sons, Ltd. 427 pp. See especially Chapter 2.
- Trimble, G. R. Jr., and S. Weitzman. 1956. Site index studies of upland oaks in the northern Appalachians. *Forest Science* 2:162-173.
- Wikipedia, 2006. Haversine Formula: [http://en.wikipedia.org/wiki/Haversine\\_formula](http://en.wikipedia.org/wiki/Haversine_formula)

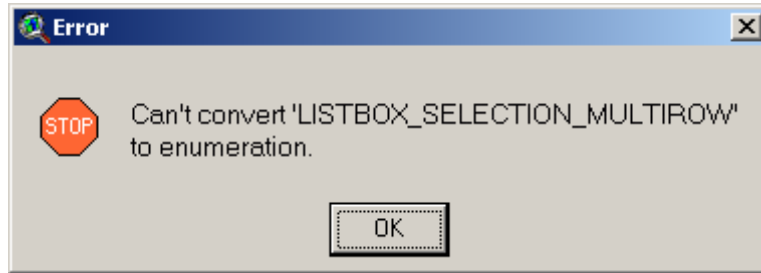
## Troubleshooting:

If you encounter some strange crash, please click the menu item "Check 'Grid Tools' Scripts" in either the View, Table or Project Help menu. Click this as soon as you are able to following the crash. With any luck, that function will generate a report with enough information for the author to find and fix the problem.

Otherwise, the problem may be found and explained below:

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**Problem:** Extension Fails to Load, with the following error message:

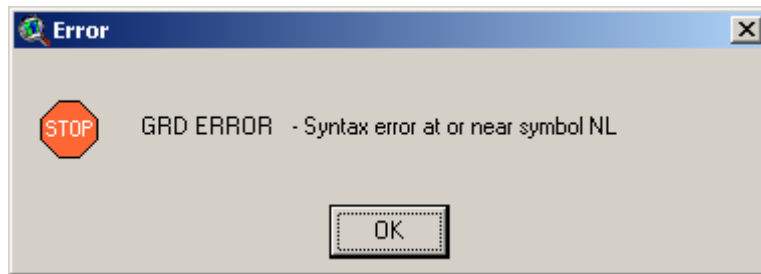


**Solution:** This problem is caused by an outdated version of the Dialog Designer. For some reason, some versions of ArcView 3 were shipped with an older version of Dialog Designer which didn't support this "LISTBOX\_SELECTION\_MULTIRROW" option (which basically means that a listbox on a dialog is set so that you can select multiple items from the list).

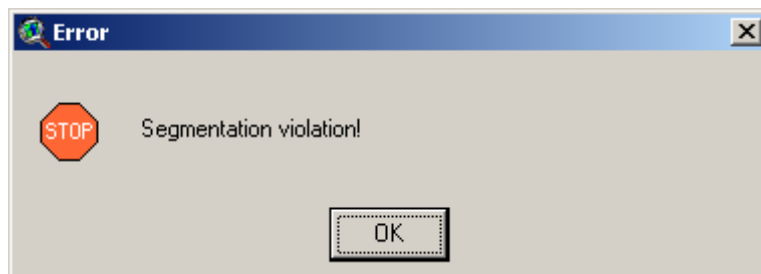
ESRI has a newer version of the Dialog Designer available on their website for free download. Please link to:

<http://support.esri.com/index.cfm?fa=downloads.patchesServicePacks.viewPatch&PID=25&MetalD=483>

**Problem:** Extension crashes in mid-operation, producing an obscure message stating that there is a syntax error at or near symbol NL:



This is sometimes followed by the infamous Segmentation Violation message:



Sometimes ArcView crashes completely and vanishes without showing these messages; while other times it vanishes after showing these messages.

**Solution:** There is no simple solution to this problem. It is due to a bug in Spatial Analyst which causes SA to crash after approximately 32,500 grid operations or if SA tries to hold > 50 grids in memory at one time. You can force the error to occur by writing a short script that checks the cell value at a particular point, then loops over 32,500 iterations. You can also trigger it by running the Zonal Statistics function on a point theme containing over 32,500 points. You would probably trigger this error if you tried to classify grids using > 50 classification values because it creates a separate grid for each classification and then merges them for the final output.

I am unaware of a simple way to work around this problem. If possible, use smaller point data sets or try to use fewer grids in your analysis. Alternatively, I hear that ArcGIS 9 was expected to fix this problem.

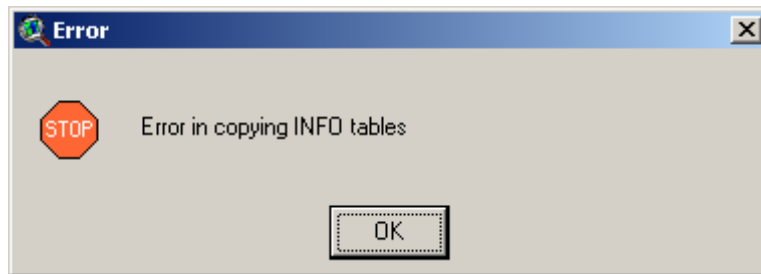
**Problem:** Unable to find grid in a directory, even though you know it is there.

**Solution:** This is probably due to a space or invalid character in the pathname. For some reason, Spatial Analyst doesn't recognize a grid if it lies in a folder with a space or period in it. For example, if you store your grids in the standard default Windows directory "My Documents," you will probably not see the grid listed in the "Add Theme" dialog at all. The "Add Theme" dialog will show you all the shapefiles and images, but no grids. The only solution is to move your grid to a different file location where it does not lie in a path with invalid characters.

**Problem:** You load your grids but you are unable to do any calculations on them. They don't act like grids.

**Solution:** You may have loaded them as images. Grids can be loaded as either images or grids, and you can't do any of the grid functions on them if you have loaded them as images. Try adding them to your view again, but make sure that you have "Grid Data Source" selected instead of "Image Data Source".

**Problem:** Extension crashes in mid-calculation, with the message:



**Solution:** This error may be caused by either a corrupt INFO directory or if your working directory pathname is too long. I am unaware of the exact pathname size that triggers the error, but I think it is around 80 characters. If you have over 80 characters in your pathname and you see this error, then you can probably avoid it by changing your work directory to someplace closer to the root.



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Enjoy! Please contact the author if you have problems or find bugs.

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Updates to this extension and an on-line version of this manual are available at

[http://www.jennessent.com/arcview/grid\\_tools.htm](http://www.jennessent.com/arcview/grid_tools.htm)

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Please visit *Jenness Enterprises* [ArcView Extensions](#) site for more ArcView Extensions and other software by the author. We also offer customized ArcView-based [GIS consultation](#) services to help you meet your specific data analysis and application development needs.

