Image Contrast Enhancement

Images that you display may have poor inherent brightness and contrast. The Display process in TNTgis can automatically adjust the brightness and contrast of images, but you can also design and save specific contrast enhancements using the Raster Contrast Enhancement window. This window lets you create and save contrast look-up tables that translate each input raster value to an adjusted brightness value. You can design contrast tables that change the average brightness value of the display and that spread the input values over a different range of display brightness to change the contrast. For a color composite raster or an RGB display of three raster objects, contrast and brightness adjustments for each color component also improve the overall color and color balance of the display.
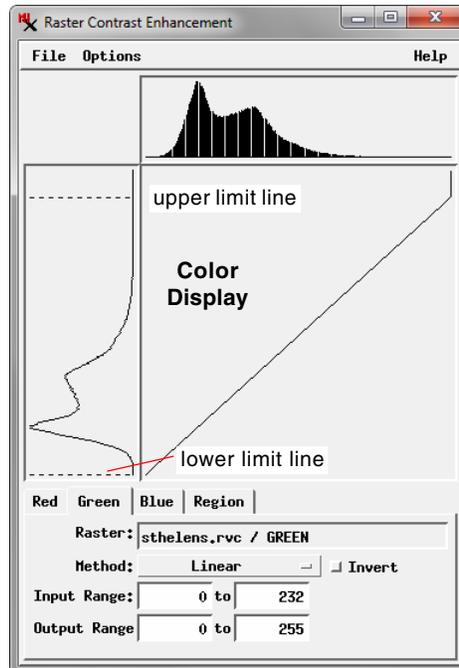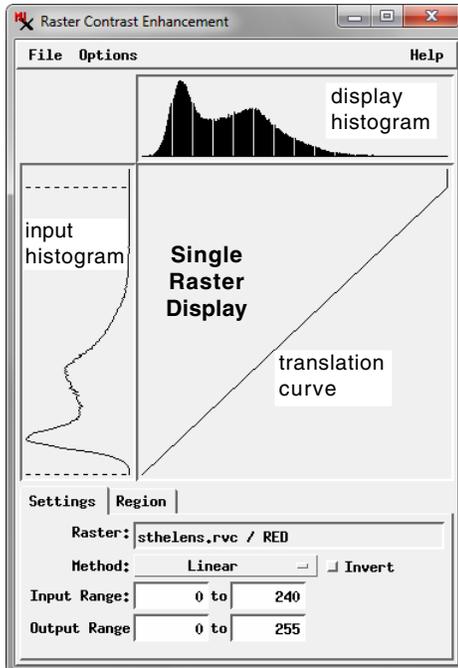
Raster Contrast Enhancement Window

The Raster Contrast Enhancement window is opened using the Enhance Contrast option on the right mouse-button menu for a raster layer listing in the Display Manager or View window sidebar. The upper part of the window (illustrated below) includes a graphical representation of the contrast adjustment. The lower portion of the window has a Settings tabbed panel (for a single grayscale raster) or Red, Green, and Blue tabbed panels that allow separate adjustments for the components in a 24-bit color-composite raster or RGB separates display. Controls on the Region tabbed panel allow you to design the contrast enhancement using only a portion of the image (see the Technical Guide entitled *Contrast Enhancement for Local Areas*).

Display of RGB image with no enhancement (left) and with contrast-enhancement (right) for the red, green, and blue components.

The Settings panel (or equivalent) includes a Method menu from which you can choose an enhancement method, which determines the shape of the translation curve. The Input Range fields show the minimum and maximum values defining the input range used to create the translation curve. The Output Range fields show the minimum and maximum output display values to be used. In most cases you should use the full range of output display values (0 to 255) and adjust brightness and contrast by varying the input range, contrast method, and (where allowed) the translation curve.

The input histogram graphic is provided with dashed lines that allow you to change the lower and upper input limits by visual comparison with the shape of the histogram. Left-click and drag either of these lines to change its position in the graphic. The values corresponding to the positions of these lines are then shown in the Input Range fields. You can also enter values manually in these fields if desired.

For an 8-bit raster component the default input range is the maximum range allowed by the raster type (*e.g.*, 0 to 255 for 8-bit unsigned). The input data values may only occupy a portion of that possible range, resulting in a low-contrast display. Moving the input limits to match the actual range of raster cell values spreads these values over the entire output display r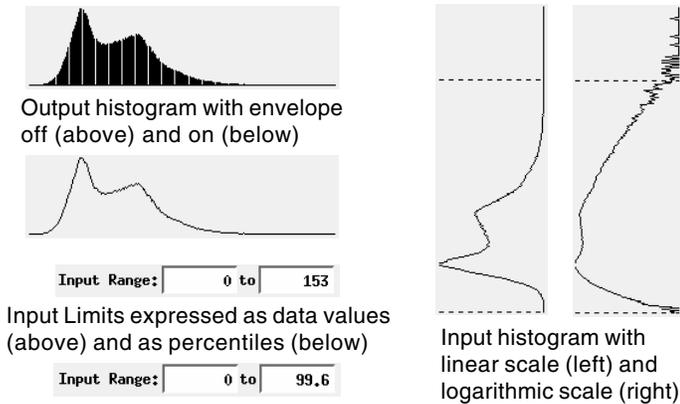ange, improving brightness and contrast. If you reduce the input range further, any input values less than the lower limit are displayed as black and any values above the upper limit are displayed as white; truncating the input histogram in this way is perfectly acceptable for many images.

The input histogram is shown vertically along the left edge of the window and the histogram of the display values is shown horizontally across the top. The *translation curve* graphs the function used to convert input raster values to display values. Some enhancement methods allow you to directly manipulate the shape of the translation curve.

The Invert toggle button reverses the translation curve so that low input values are translated to high display brightness and high input values are converted to low display brightness. This option is generally reserved for specialized applications.

Histogram Options

The Options menu provides several alternative ways to show the input and display histograms. The display histogram is shown by default as a bar graph, with one vertical bar for each histogram bin and the height of the bar representing the cell count in that bin (in many cases the bars merge together to create a solid "fill" for the graph). The Envelope toggle option changes the display histogram to a simple curve. The input histogram is only shown as an envelope.

Output histogram with envelope off (above) and on (below)

Input Range: 0 to   153

Input Limits expressed as data values (above) and as percentiles (below)

Input Range: 0 to   99.6

Input histogram with linear scale (left) and logarithmic scale (right)

The Input Limits submenu provides two options for showing the values in the Input Range fields: as Data Values (actual cell values) or as Percentiles. The Input Scale submenu provides Linear and Logarithmic options for scaling the input histogram. The Logarithmic option makes it easier to see the occurrence of low-frequency values in the tails of the histogram. Linear and Logarithmic options are also provided on the Output Scale submenu for the display histogram.

Contrast Methods

As you make adjustments using the Contrast Enhancement controls, you can press the Refresh icon button on the View window after any change to see the effect on the displayed image. Good brightness and contrast are generally achieved when the median input value is translated to the median display brightness and display brightness values are well-distributed over the entire range. A number of different contrast enhancement methods are provided to allow you to produce good brightness and contrast with a variety of different images. You should experiment to determine which methods work best for the types of images you work with.
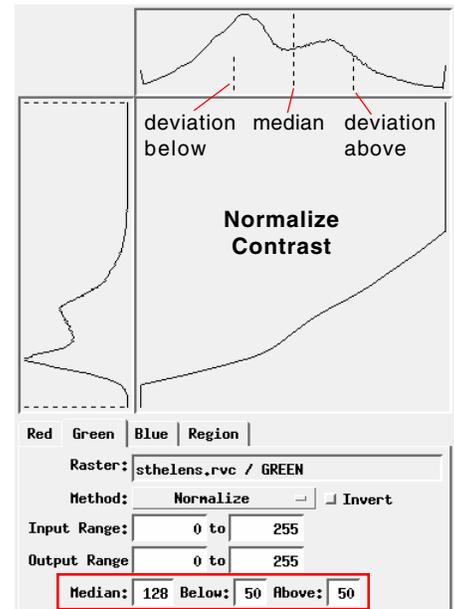
Linear: In the this method there is a linear relationship between input and display values. The translation curve is a straight line sloping upward to the right (see illustrations on the previous page). You cannot adjust this line directly in the graphic. If the input limits are set at the maximum range, the display histogram is identical to the input histogram and there is no enhancement. Restricting the input range produces a translation line with a lower slope between these narrower limits, distributing the image values over a wider display range to increase the contrast. Changing the lower and upper limits by

different amounts also shifts the mean brightness to higher or lower display values.

Normalize: The Normalize contrast method adjusts the input values to approximate a normal frequency distribution with a symmetrical bell-shaped display histogram covering the full output range. The translation curve has a variable shape and cannot be adjusted directly (see illustration below). Changing the upper and lower input limits does not affect the normalized display histogram unless actual cell values are excluded, and in most cases excluding a small percentage of high and/or low values has little affect on the normalized display histogram.

The normalized display histogram graphic is provided with three dashed vertical control lines that can be used to adjust the shape of the histogram. The middle line indicates the median brightness value, for which there are equal numbers of brighter and darker cells; its output display brightness value is shown in the Median field at the bottom of the window. The default position of the median line is at the midpoint of the output range, which is 128 for an 8-bit unsigned raster object. You can drag the median control line to the left (or enter a lower Median value) to make the display darker and to the right (or enter a higher Median value) to make it brighter.

The two *deviation* lines control the distribution of display brightness values on either side of the median. By default these lines are placed at display brightness values 50 units below and above the median display brightness; these distances are shown in the Below and Above numeric fields. Moving the Above deviation line farther to the right broadens the distribution of values above the median, stretching the contrast for the brighter parts of the image. Conversely, dragging the Below deviation line to the left stretches the contrast for the darker portions of the image. The current Below and Above distances are maintained when you change the median position of the normalized histogram. You can quickly restore the median and deviation lines to their default positions by choosing Reset from the Options menu.
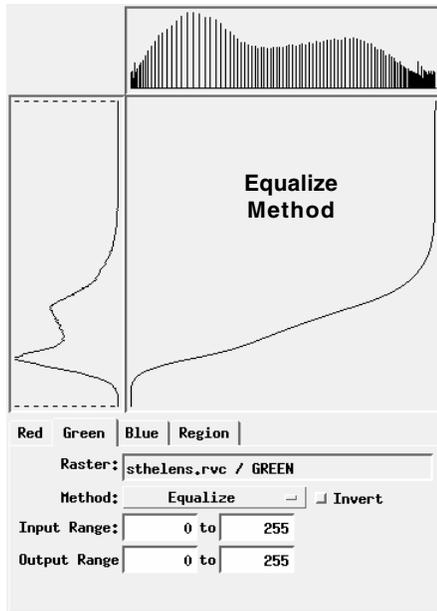
The normalize method works well for many images that have low inherent contrast. For images requiring only modest contrast enhancement, however, the normalize method may boost the image contrast too much and produce harsh colors.

Equalize: The Equalize method attempts to produce a flat display histogram, with equal numbers of cells at each display
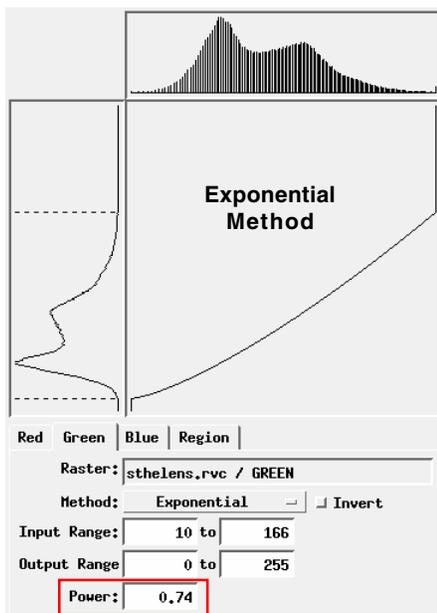
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brightness level. However, with most input images this goal cannot be achieved because real images have varying numbers of cells at each brightness value and all input cells with the same value must be assigned the same output display value. The equalized display histogram for most images resembles a broader, flatter version of the normalized histogram (see illustration below). The translation curve has a variable shape and cannot be adjusted directly. The result is little affected by modest adjustments to the input range.

Histogram equalization greatly increases the number of input values that are displayed at the low and high ends of the display brightness range, as can be seen by the crowding of the display histogram bars at the left and right sides of the histogram. The result can be a display with even greater contrast than a normalized display.
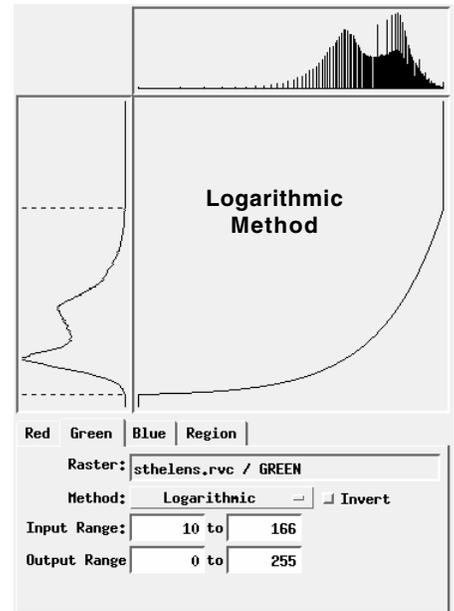
Equalize Method

Red Green Blue Region
Raster: sthelens.rvc / GREEN
Method: Equalize ⌐ ⌐ Invert
Input Range: 0 to 255
Output Range 0 to 255

Exponential: The Exponential contrast method creates a translation curve that is an exponential function of the input value. The function is computed from the lower and upper input limits you set and the magnitude of the exponent used in the function, which is shown in the Power field. At the default Power value of 1.00, the translation curve is a straight line between the minimum and maximum input values. You can change the shape of the translation curve by changing the input limits and by dragging the translation curve, which changes the Power value. Dragging the curve to the right decreases the Power to values below 1.00, resulting in a curve that is concave toward the upper left and which shifts the median display brightness to higher values. Dragging the curve to the left increases the Power to values greater than 1.00, resulting in a curve that is convex to-

Exponential Method

Red Green Blue Region
Raster: sthelens.rvc / GREEN
Method: Exponential ⌐ ⌐ Invert
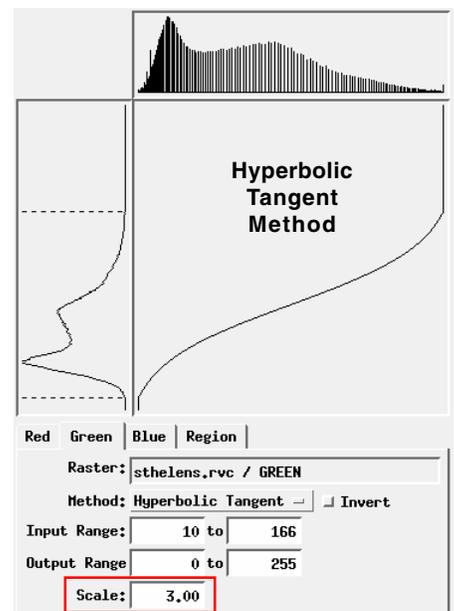Input Range: 10 to 166
Output Range 0 to 255
Power: 0.74

ward the upper left and which shifts the median display brightness to lower values. The Exponential method thus lets you easily change the overall brightness of the image while limiting the effects to the specific input range you specify.

Logarithmic: The Logarithmic method creates a translation curve that is a logarithmic function of the input value. The translation curve is not adjustable except for setting the lower and upper limits. This method is most useful for images with a high proportion of low cell values, which is common in many images from imaging radar systems. However, an approximately logarithmic translation can also be set up using the Exponential method, in which you can adjust the Power to make fine changes to the enhancement.

Logarithmic Method

Red Green Blue Region
Raster: sthelens.rvc / GREEN
Method: Logarithmic ⌐ ⌐ Invert
Input Range: 10 to 166
Output Range 0 to 255

Hyperbolic Tangent: This method uses the hyperbolic tangent trigonometric function to produce a nonlinear translation of input values (within the specified range) to display values. The method provides an adjustable Scale factor (default value = 1.0) that can be used to adjust the enhancement. At low values of the Scale Factor (less than 1) the translation curve is close to linear. Increasing the scale factor flattens the middle portion of the translation curve while steepening either end, which stretches contrast in the middle portion of the input range at the expense of low and high values. Illustrations of the effects of this method are included in the TechGuide entitled *Hyperbolic Tangent Contrast Enhancement*.

Hyperbolic Tangent Method

Red Green Blue Region
Raster: sthelens.rvc / GREEN
Method: Hyperbolic Tangent ⌐ ⌐ Invert
Input Range: 10 to 166
Output Range 0 to 255
Scale: 3.00

User-Drawn: When you choose the User-Drawn method, it initially inherits the previous translation curve. You can then
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freely adjust the enhancement in two ways. You can drag the mouse cursor along the translation curve to redraw the curve, or manually redraw the display histogram in the same way. You can use this method to selectively stretch some parts of the input range while compressing others to fine-tune a previous enhancement or to create special effects in the display.
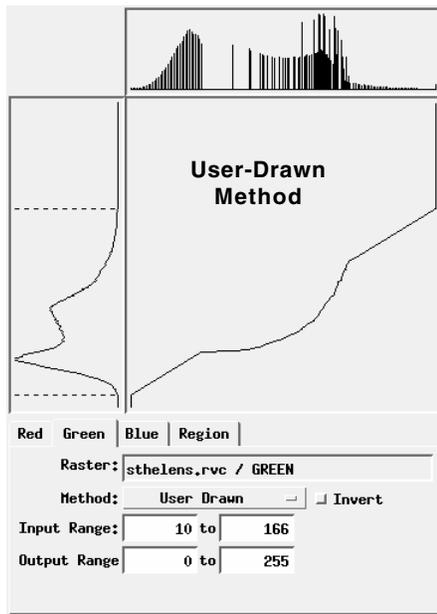

Saving and Opening Contrast Tables

A contrast table is saved as a subobject of the raster object it applies to. You can create multiple contrast tables for the same raster object for different uses. For a band in a multispectral image, for example, you might create a contrast table for grayscale display of the band by itself, and one or more contrast tables for the band when used as a color component in an RGB separates display. The File menu in the Raster Contrast Enhancement window provides options to Save, Save As, and to Open an existing contrast table. When you are adjusting contrast for a color display, you save separate contrast tables for each of the three color components.

Using Contrast Tables

When you display an image, the Raster Layer Controls window provides a Contrast menu (on the Object tabbed panel) for each of the color components in the layer. This menu lists each of the contrast tables that have been saved with the raster, allowing you to choose the table to use for the current session. Your selection is saved with the other display parameters for

this raster object so it will be used by default the next time the raster is displayed. The menu also lists a number of automatic contrast methods (Auto Linear, Auto Normalize, etc.) that enhance the contrast using default parameters for the method. If no contrast table has been saved for the raster, you can use any of the Auto Contrast methods to display it. If you then open the Raster Contrast Enhancement window, the corresponding method is automatically set, allowing you to make and save further refinements.
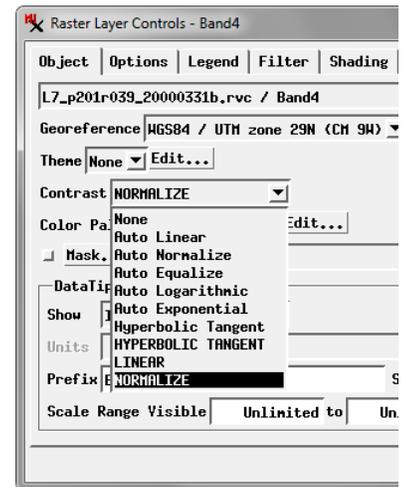
The Contrast menu for an 8-bit unsigned raster object also includes the option None, which you can use to display the raster directly with no translation of the raster values. This option is not available for raster data types that can have values outside the range 0 to 255 (*e.g.*, signed integer, 16- and 32-bit integer, and floating point) since values in these data ranges require rescaling to the 0-255 display range.

If no contrast table has been saved with a raster object, and it has not been displayed previously with the None option, then one of the auto-contrast enhancement options is automatically applied. The method used by default can be set in the Options window opened from the Display Manager (Options / View Options). The Raster tabbed panel in this window includes a set of menus under the heading *Default contrast when none previously set*. You can set different auto-contrast default options for different raster data types: 8 bits or less, 16 bits or more, and hyperspectral.