

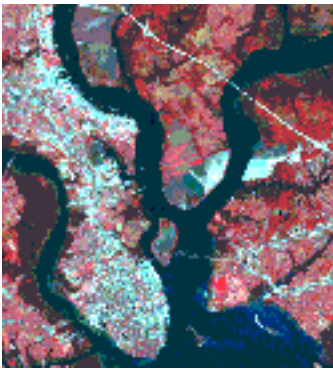
Contrast Enhancement

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Introduction

A common problem in remote sensing is that the range of reflectance values collected by a sensor may not match the capabilities of the film or color display monitor. Materials on the Earth's surface reflect and emit different amounts of energy. A sensor might record a tremendous amount of energy from a one material in a certain wavelength, while another material is recorded at much less energy in the same wavelength. Image enhancement techniques make an image easier to analyze and interpret. The range of brightness values present on an image is referred to as contrast. Contrast enhancement is a process that makes the image features stand out more clearly by making optimal use of the colors available on the display or output device.

Contrast manipulations involve changing the range of values in an image in order to increase contrast. For example, an image might start with a range of values between 40 and 90. When this is stretched to a range of 0 to 255, the differences between features is accentuated. Unfortunately, different features often reflect similar amounts of energy throughout the electromagnetic spectrum, resulting in a relatively low contrast image. In addition, besides the obvious low contrast characteristics of biophysical materials, there are cultural factors at work. For example, people in developing countries often use natural building materials (e.g., wood and soil) in the construction of urban areas (Haack et al., 1995). This results in

remotely sensed imagery with a much lower contrast as opposed to urban areas in developed countries where concrete, asphalt, and fertilized green vegetation may be more prevalent (Jensen, 1996). Thus, it is important to consider both the biophysical and human components when enhancing an image for maximum contrast.

The sensitivity of the sensor is another factor to consider when creating low-contrast remotely sensed imagery. Most sensors today are equipped with detectors that are designed to record a relatively wide range of unsaturated scene brightness values (e.g., 0 to 255). When an image becomes saturated, the radiometric sensitivity of the detector is insufficient to record the full range of intensities of reflected or emitted energy emanating from the scene. Naturally occurring materials on the earth have a wide range of spectral properties. Satellite detectors must be sensitive to low reflectance material, such as dark volcanic basalt, as well as high reflectance material such as fields of snow. However, most of real world remote sensing applications involve few scenes that are composed of brightness values which utilize the full sensitivity range of satellite detectors. Such scenes are relatively low-contrasting with brightness values ranging from 0 to 100.

As mentioned before, the contrast of an image can be increased by utilizing the entire brightness range of a display or hard-copy output device. Digital methods generally produce a more satisfactory contrast enhancement because of the precision and wide variety of processes that can be applied to the imagery. Linear and nonlinear digital techniques are two widely practiced methods of increasing the contrast of an image.

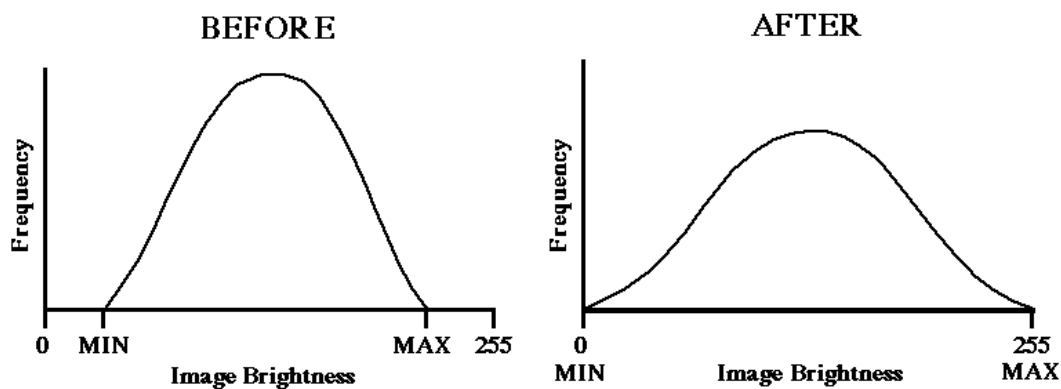
Linear Contrast Enhancement

Linear contrast enhancement, also referred to as a contrast stretching, linearly expands the original digital values of the remotely sensed data into a new distribution. By expanding the original input values of the image, the total range of sensitivity of the display device can be utilized. Linear contrast enhancement also makes subtle variations within the data more obvious. These types of enhancements are best applied to remotely sensed images with Gaussian or near-Gaussian histograms, meaning, all the brightness values fall within a narrow range of the histogram and only one mode is apparent. There are three methods of linear contrast enhancement:

- Minimum-Maximum Linear Contrast Stretch
- Percentage Linear Contrast Stretch

- Piecewise Linear Contrast Stretch

Minimum-Maximum Linear Contrast Stretch When using the minimum-maximum linear contrast stretch, the original minimum and maximum values of the data are assigned to a newly specified set of values that utilize the full range of available brightness values. Consider an image with a minimum brightness value of 45 and a maximum value of 205. When such an image is viewed without enhancements, the values of 0 to 44 and 206 to 255 are not displayed. Important spectral differences can be detected by stretching the minimum value of 45 to 0 and the maximum value of 120 to 255 (see Figure 6-3.1).



An algorithm can be used that matches the old minimum value to the new minimum value, and the old maximum value to the new maximum value. All the old intermediate values are scaled proportionately between the new minimum and maximum values. Many digital image processing systems have built-in capabilities that automatically expand the minimum and maximum values to optimize the full range of available brightness values.

Percentage Linear Contrast Stretch The percentage linear contrast stretch is similar to the minimum-maximum linear contrast stretch except this method uses a specified minimum and maximum values that lie in a certain percentage of pixels from the mean of the histogram. A standard deviation from the mean is often used to push the tails of the histogram beyond the original minimum and maximum values. Figure 6-3.2 shows the logic used in a percentage linear contrast stretch.

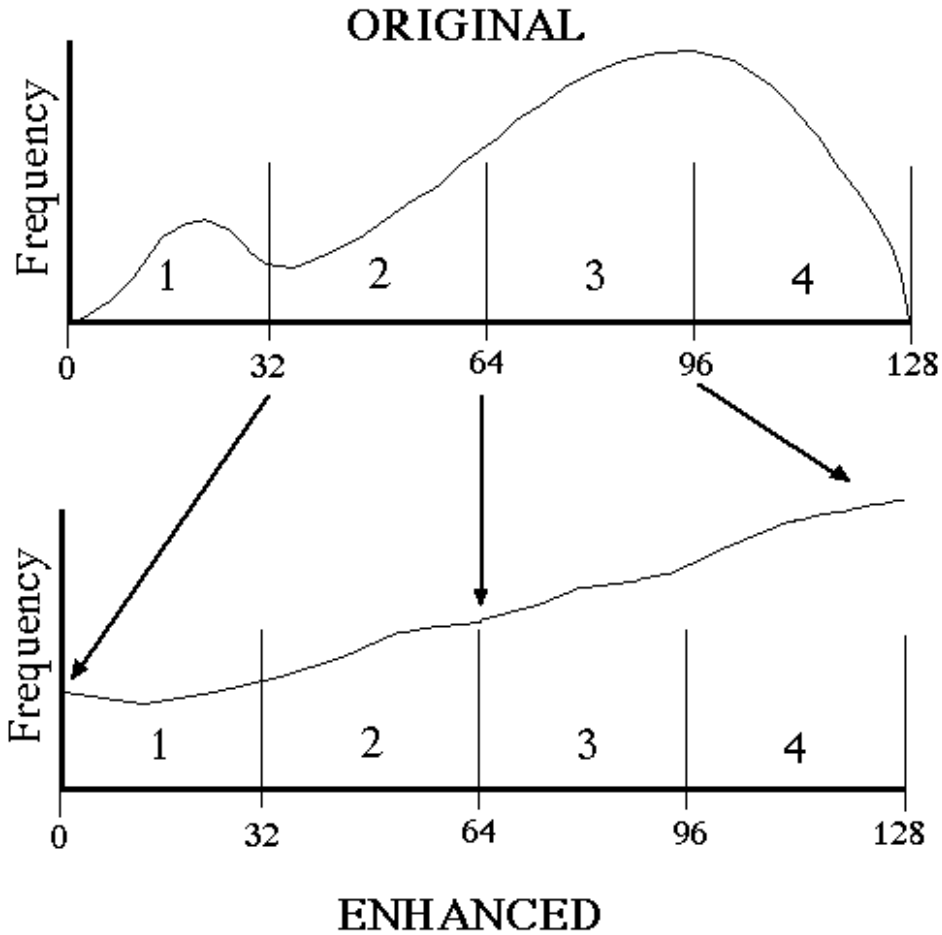


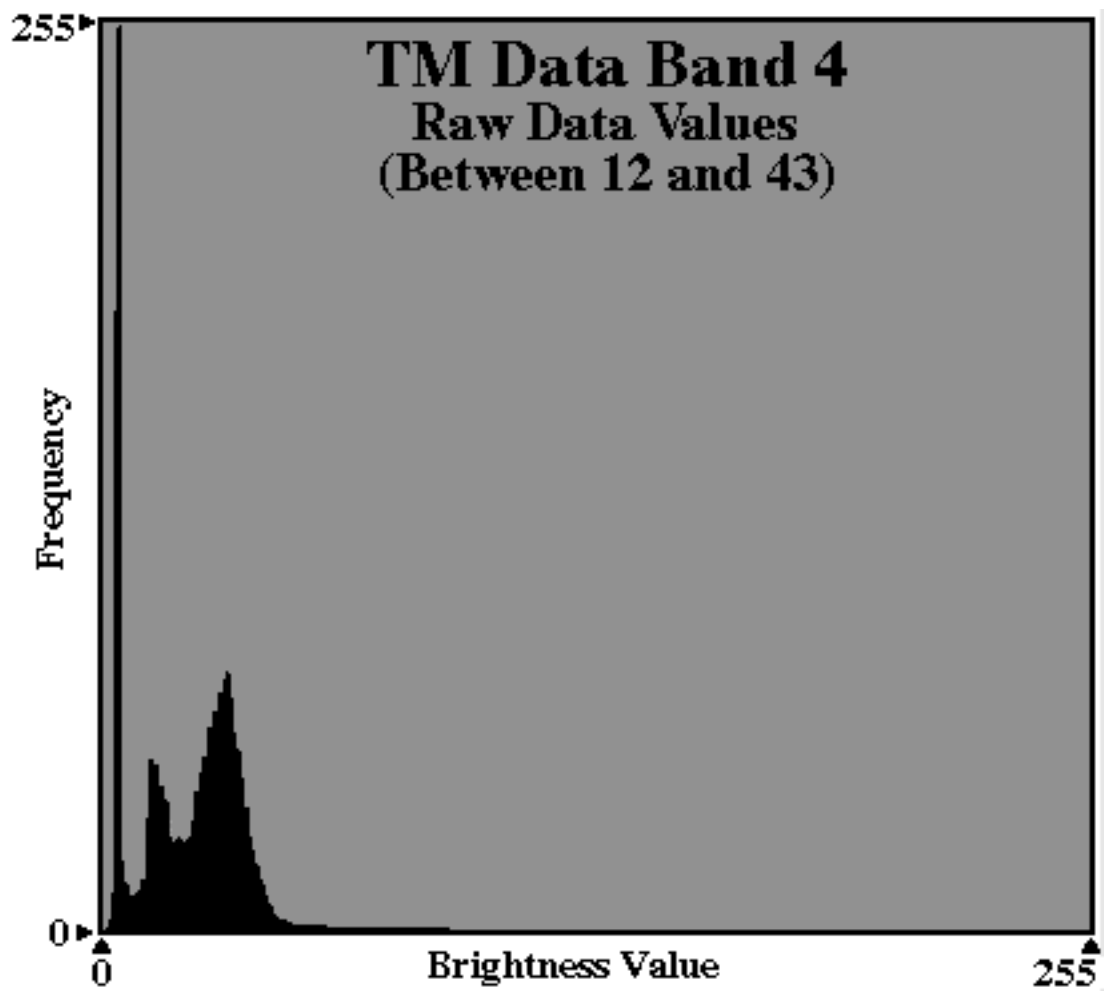
Figure 6-3.3 contains TM images of Charleston, SC and their associated histograms. The first image (a) displays the low-contrasting data in band 4 under normal conditions with no contrast stretch. The minimum brightness value is 12 and the maximum value 43. The histogram shows how the data is densely clustered between these values. In the second image (b), all values between 12 and 43 are linearly stretched using a minimum-maximum linear contrast stretch so that these values now lie within the range of 0 to 255. The minimum value 12 becomes 0 and the maximum value 43 stretches to 255. The histogram associated with this image demonstrates a wider distribution than the first histogram. This results in a pure pixel contrast that optimizes the capabilities of the display device.

The third image (c) continues to stretch the data by applying a one standard deviation percentage linear contrast stretch. The information content of the pixels that saturate at 0 and 255 is lost, yet a more detailed analysis of certain aspects of the image may be enhanced for better interpretation. The slope of a percentage linear contrast stretch is much greater than for a simple min-max stretch (refer to Figure 6-3.1). Sometimes the same percentage does not need to be applied to each

tail of the distribution. The fourth image shows how an analyst would enhance an image if only interested in delineating wetlands around Charleston Harbor. When the values between 13 and 27 are linearly stretched to 0 and 255, all values below 13 become 0 (black) and all values above 27 are set to 255 (white). This enhancement yields additional information on the smooth cord grass at the expense of the rest of the water and upland cover.

Figure III 6-3.3a







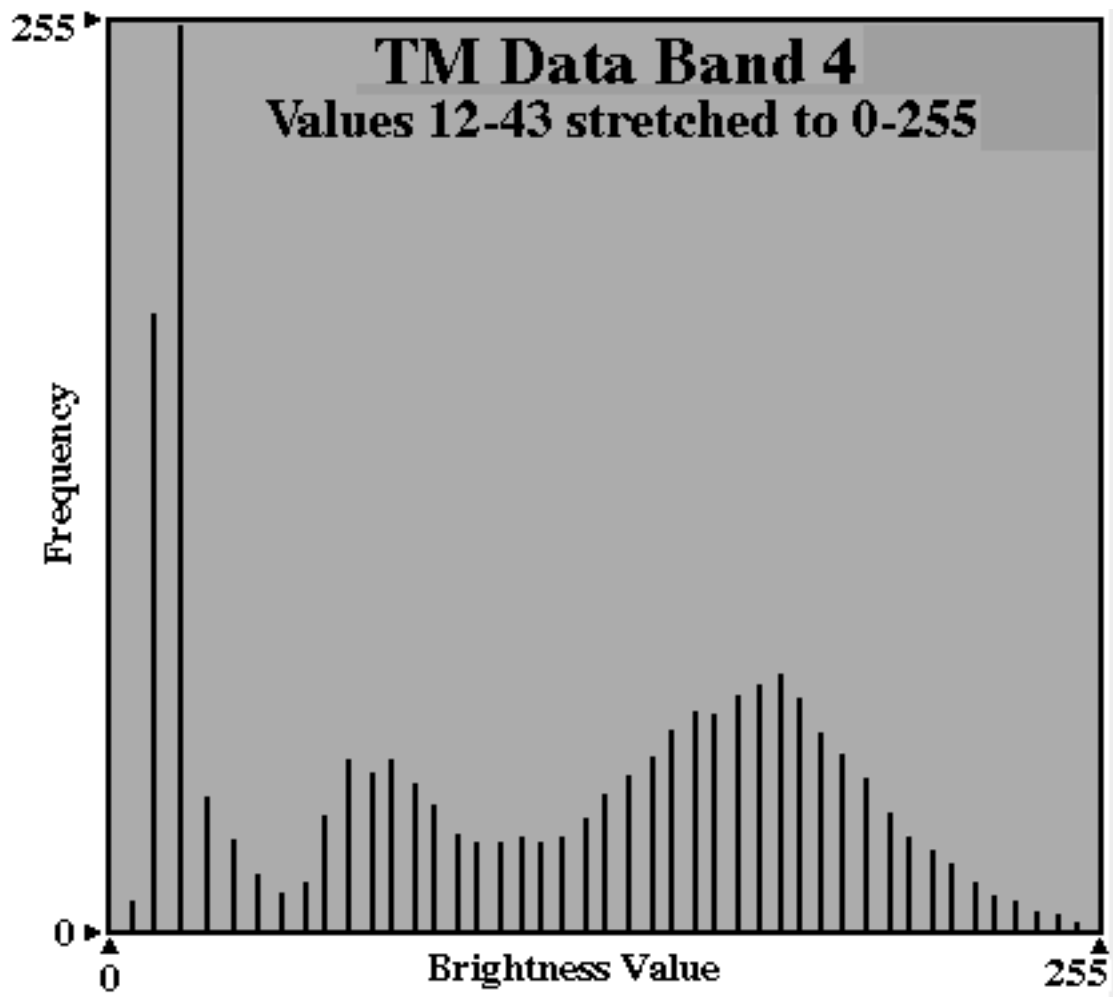
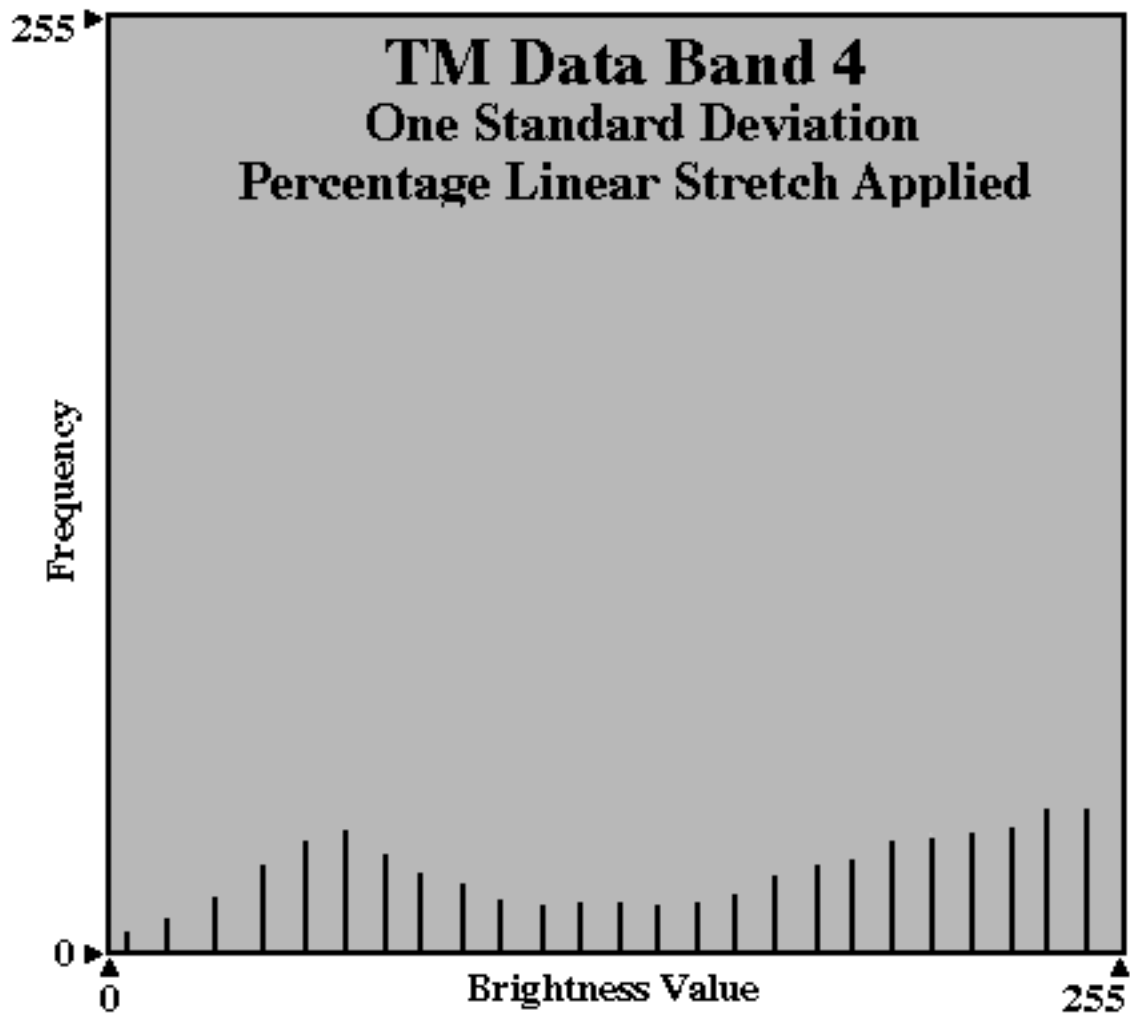
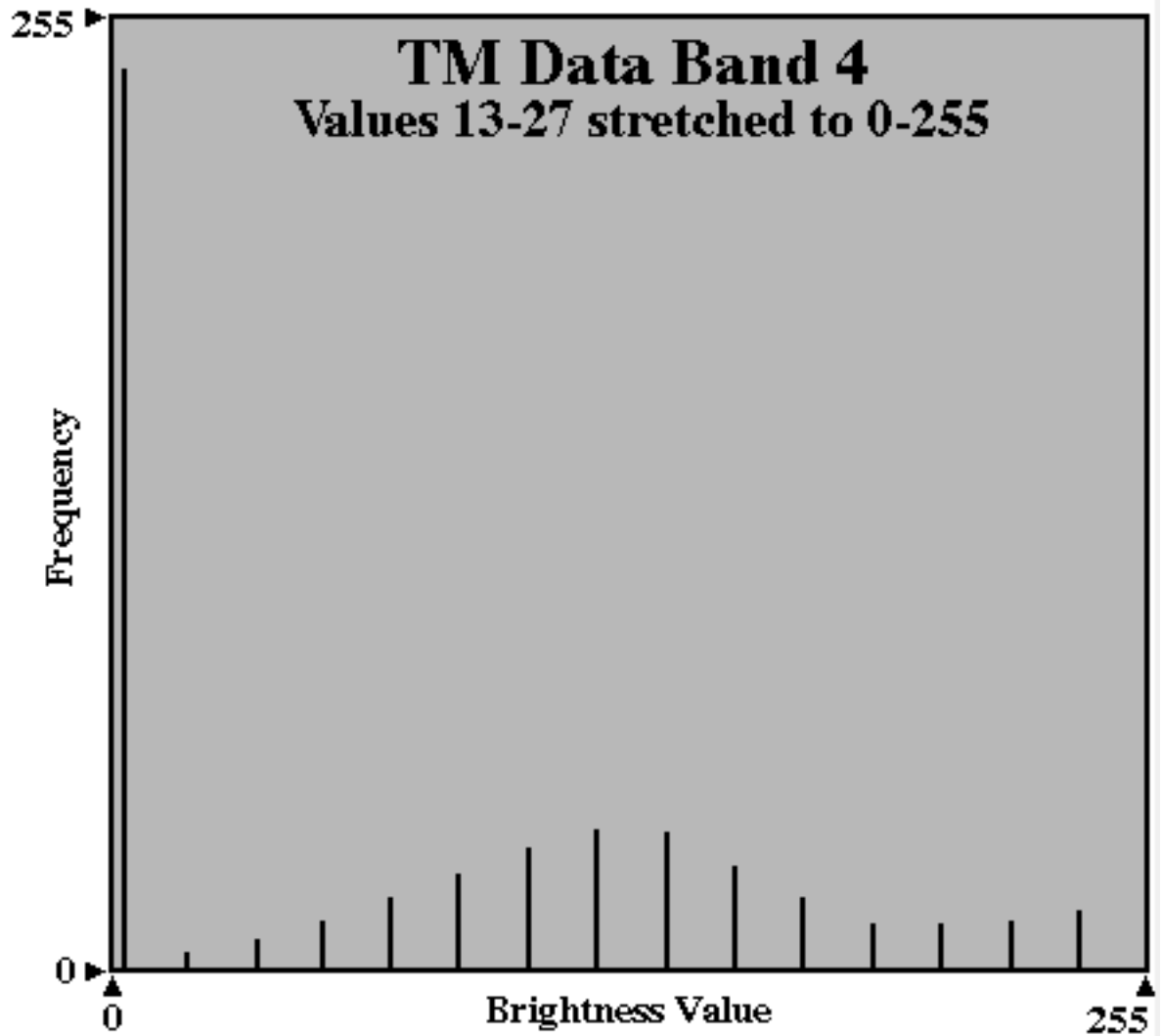


Figure III 6-3.3b







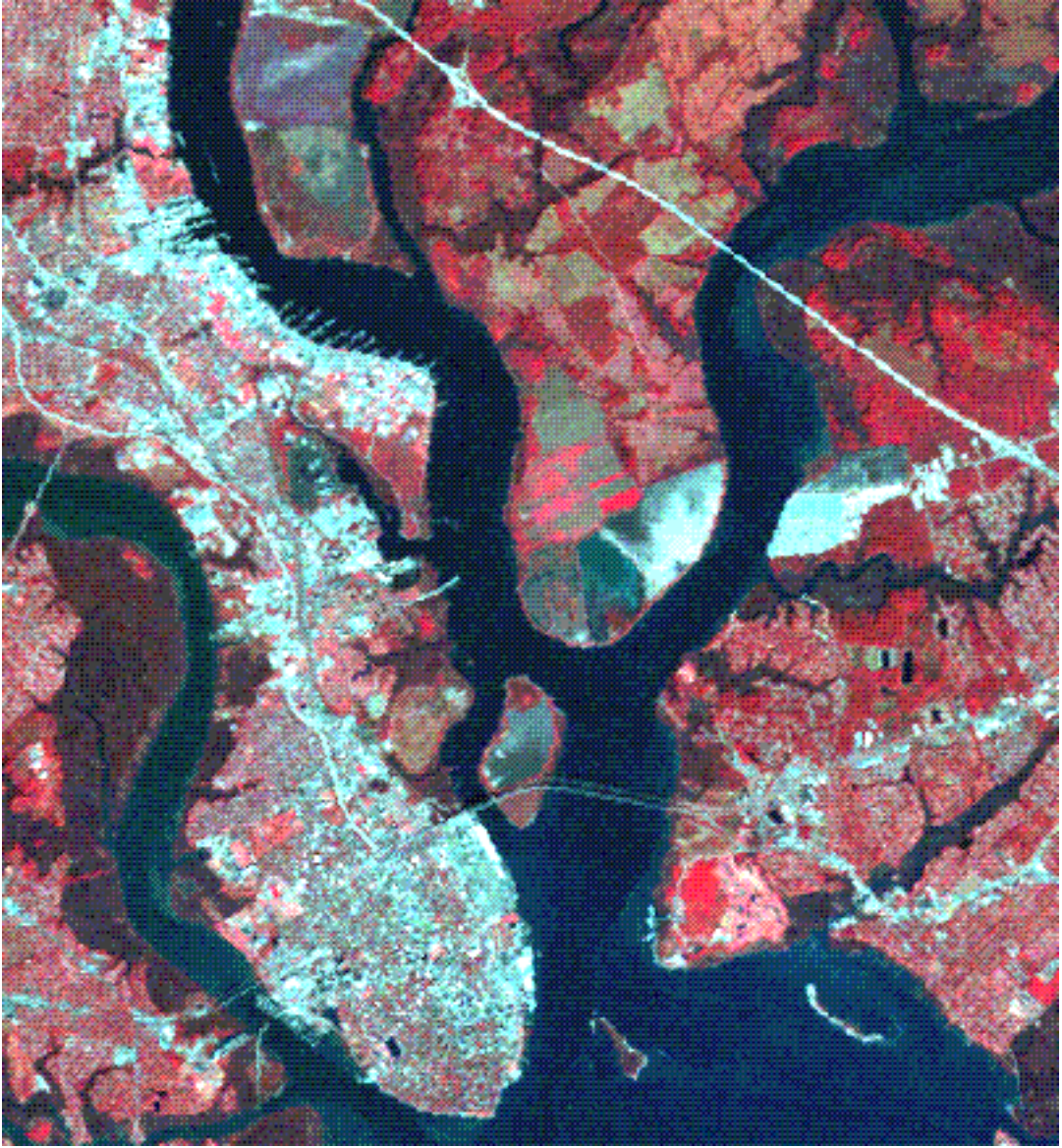


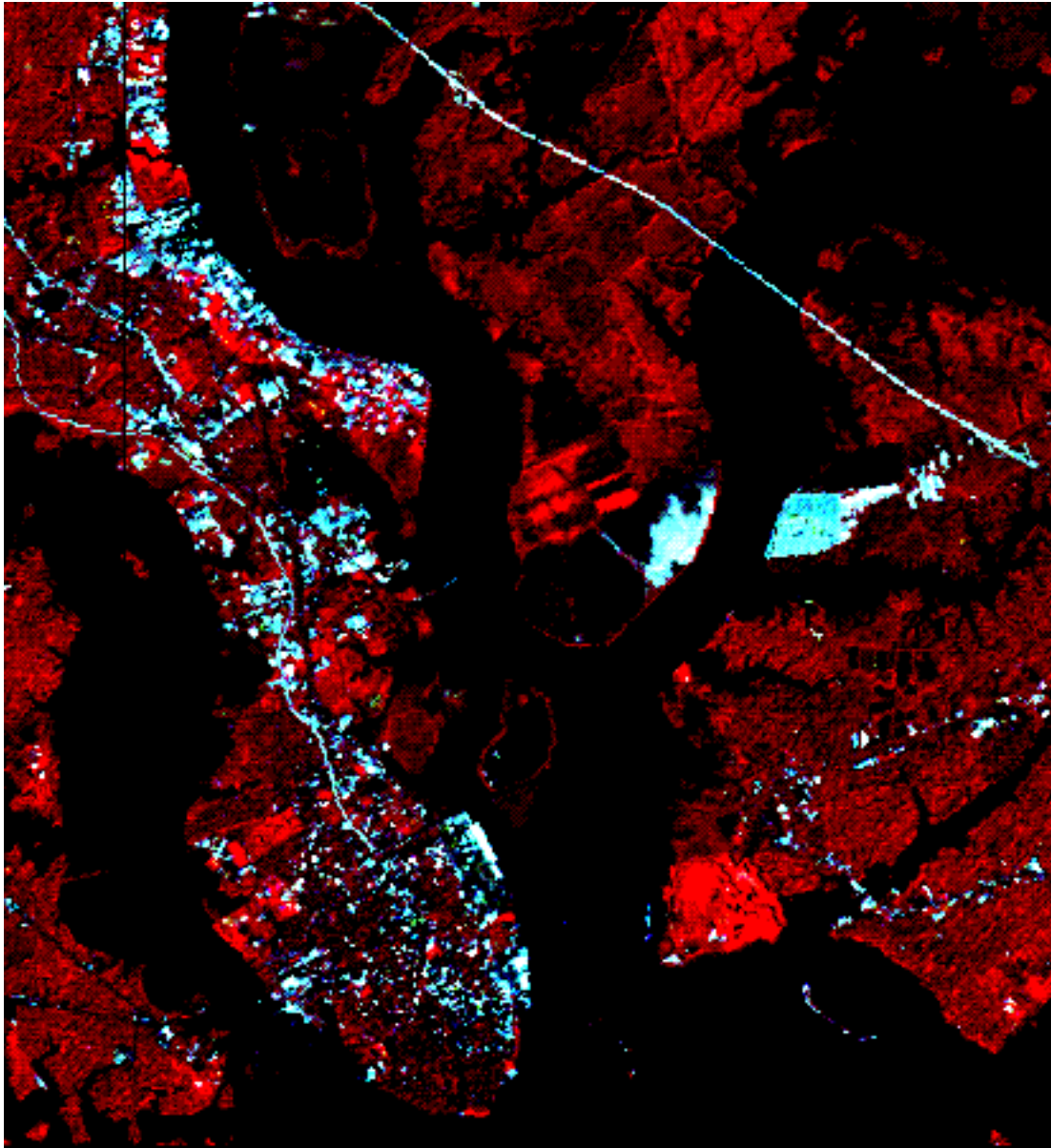
Specialized stretches

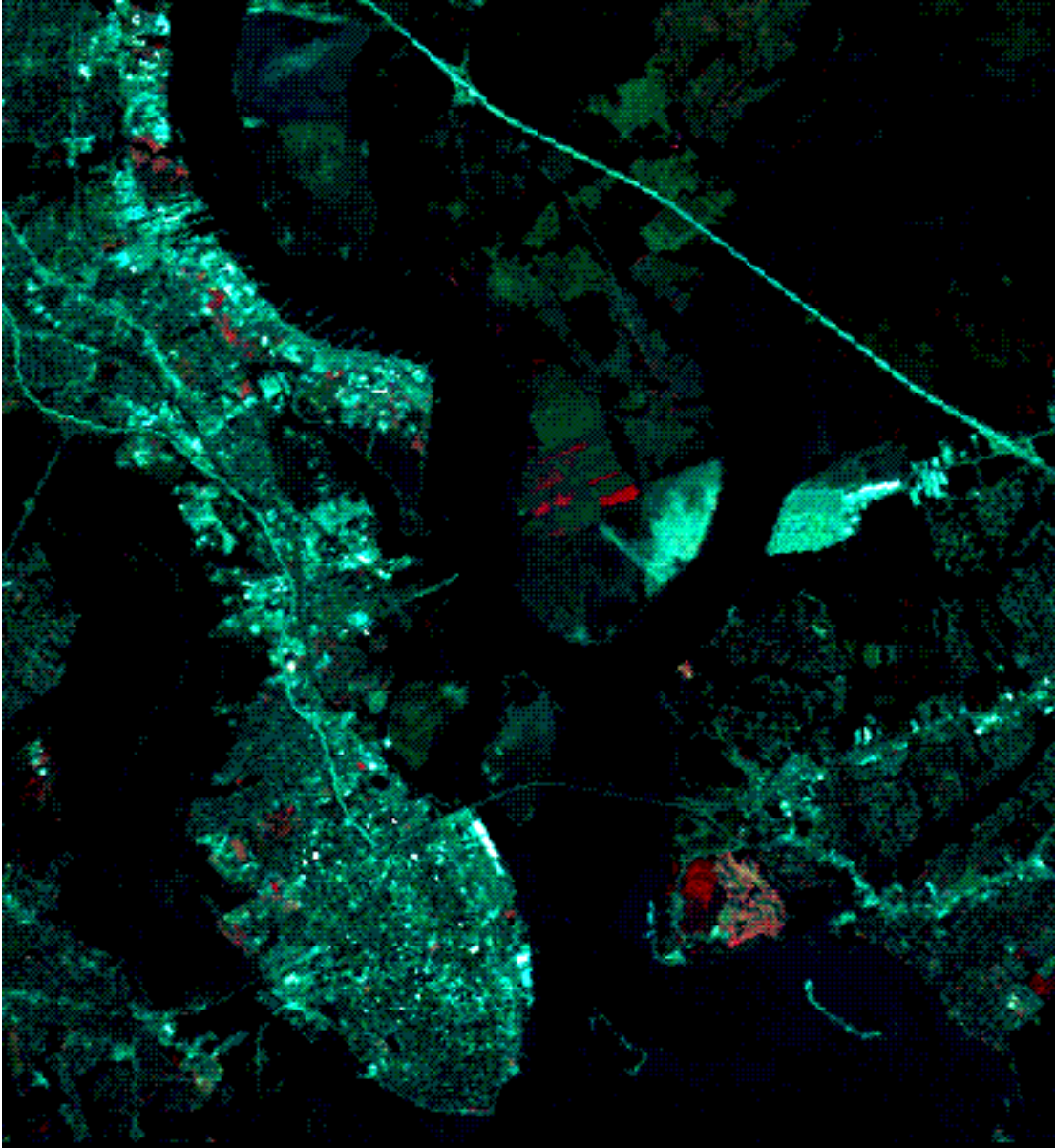
It is not necessary that the same percentage be applied to each tail of the histogram distribution. For example, image analysts often need to increase the contrast of an image only at specific portions of the electromagnetic spectrum. An analyst wanting to extract detailed marine information in an image may only be interested in values between 0 and 12. When these values are stretched to 0 and 255, subtle ocean variations can be more easily detected (see Figure 6-3.4b). A percentage stretch of the same image between values of 25 and 45 yields detailed vegetation information (see Figure 6-3.4c). This may be useful in the delineation of healthy vegetation. If an analyst is interested in image enhancement for urban features, a percentage linear stretch between the values 40 and 70 in the red gun and 15 to 45 in the green and

blue guns will increase the contrast of these features (see Figure 6-3.4d).









Piecewise Linear Contrast Stretch

When the distribution of a histogram in an image is bi or trimodal, an analyst may stretch certain values of the histogram for increased enhancement in selected areas. This method of contrast enhancement is called a piecewise linear contrast stretch. A piecewise linear contrast enhancement involves the identification of a number of linear enhancement steps that expands the brightness ranges in the modes of the histogram. Figure 6-3.5 shows the logic used in a normal linear contrast stretch compared to a piecewise linear contrast stretch. In the piecewise stretch, a series of

small min-max stretches are set up within a single histogram. Because a piecewise linear contrast stretch is a very powerful enhancement procedure, image analysts must be very familiar with the modes of the histogram and the features they represent in the real world.

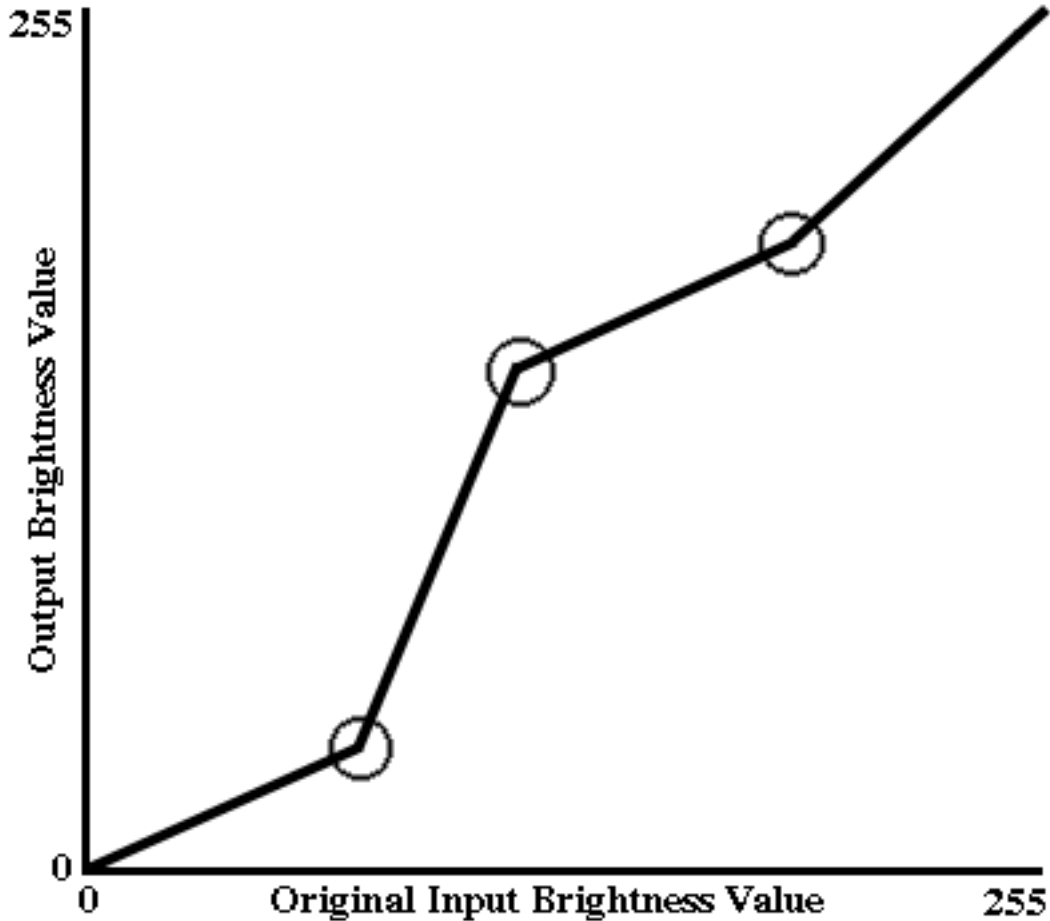


Figure 6-3.6 displays histograms generated using Erdas Imagine 8.2 image processing software. A normal linear contrast stretch compared to a piecewise linear contrast stretch. The white histogram is the histogram of the raw data values before any enhancement is applied. The red, green, and blue plots are the histograms of the displayed image after the linear stretch is applied. In the normal linear contrast stretch example, the minimum and maximum values are stretched to the values of 0 and 255 at a constant level of intensity (defined by the black line). In the piecewise linear contrast stretch, several breakpoints are defined that increase or decrease the contrast of the image for a given range of values. The higher the slope, the narrower the range of values being input from the x-axis. This results in a wider output spread for those same values and thus, increases the contrast for that range of values. A low sloping line results in a lower contrast for the same range of values. Notice the series of linear steps in each histogram that stretches intervals of

data at different levels of intensities.

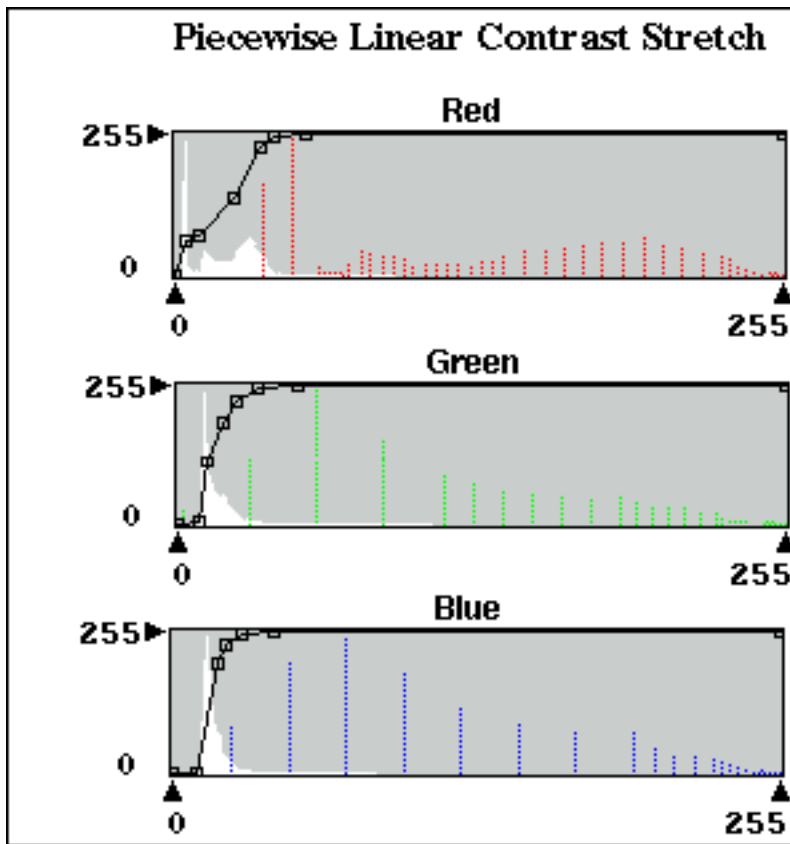


Figure 6-3.6

A normal linear contrast stretch compared to a piecewise linear contrast stretch. The white histogram is the histogram of the raw data values before any enhancement is applied. The red, green, and blue plots are the histograms of the displayed image after the linear stretch is applied. In the normal linear contrast stretch example, the minimum and maximum values are stretched to the values of 0 and 255 at a constant level of intensity (defined by the black line). In the piecewise linear contrast stretch, several breakpoints are defined that increase or decrease the contrast of the image for a given range of values. The higher the slope, the narrower the range of values being input from the x-axis. This results in a wider output spread for those same values and thus, increases the contrast for that range of values. A low sloping line results in a lower contrast for the same range of values.

Normal Linear Contrast Stretch

