Chapter 4 Enhancing Images Spatially

This chapter, as well as the subsequent two chapters, deals with the enhancement of images. The term enhancement is used in remote sensing to imply image processing to make patterns in the data stand out more clearly. Contrast enhancement, which we already covered in Section 2.2.3, and which manipulates the look up table used for image display, is a good example of a basic enhancement technique.

In this manual, we separate enhancement techniques into two categories: spectral and spatial.

- **Spectral enhancement** is covered in Chapters 5 and 6, and involves various mathematical combinations of image bands, usually with each pixel treated independently of its neighbors.
- **Spatial enhancement**, the topic for this chapter, includes processing that explicitly focuses on the spatial properties of an image, and typically involves processing that draws on a local neighborhood of pixels.

Spatial enhancement is often performed to improve the visual quality of an image. For example, spatial filters may be employed to either increase the contrast between features, or reduce the random noise inherent in the image. Another common enhancement technique is to merge data of differing spatial resolutions.

Combining data of differing spatial resolution is of interest because many satellite-borne sensors record information in bands of different spatial resolution. A common sensor design is to include a single high spatial resolution band and a group of lower spatial resolution bands sensitive to a variety of wavelengths. The high resolution band is termed the **panchromatic** band, following the naming convention of black and white aerial film. The panchromatic band provides detailed spatial information. The lower resolution bands are termed the **multispectral** bands, and they provide the spectral information, or, by analogy, the color information. The aim in a multi-spatial resolution merge is to combine the spatial information from the panchromatic band with the spectral information from the multispectral bands, to obtain a multi-band, high resolution image.

In this chapter we will examine the ways we can spatially enhance the Hong Kong Landsat image. We will initially develop a so-called high-pass filter that enhances spatial features in a single band image. We will then merge the high-resolution panchromatic band with a combination of multispectral bands to form a multi-resolution product.

4.1 Convolution

A convolution filter is a local image processing operation, which involves the use of moving windows. A **window** is a local group of pixels, for example, one pixel and its eight immediate neighbors (Figure 4.1.a), and is by definition a subset of the image. Windows can be of any size; Figure 4.1.a shows an example of a 3x3 window, with three rows and three columns of pixels. An important part of the concept of the moving window is that the template that defines the local neighborhood can be moved sequentially across the image, so that each pixel is the center of a local group of pixels. Pixels from the edge of the image require special handling, as they do not have neighbors on all sides.

b	b	b
b	a	b
b	b	b

Figure 4.1.a A 3 x 3 window of pixels (a = center pixel, b = neighbors).

In convolution, some mathematical operation is used to combine the DN values in the window. The result of this local analysis is written to a new image, the convolution image. Specifically, the convolution value is usually written out to the new image at the pixel location equivalent to the center of the window as it was placed over the old image. The precise nature of the mathematical combination performed in the convolution operation is controlled by the relative values stored in the **matrix kernel**. Specifically, the convolution output value is the sum of the products of each pixel value and its corresponding kernel value. Then the matrix is moved by one pixel location, and the operation is repeated. The filter operation can be **normalized** by dividing the result by the sum of the kernel values.

4.1.1 Smoothing Filters

Noise suppression and/or removal can be accomplished with convolution filtering. The simplest type of smoothing filter is the **low pass filter**, also known as a **mean** filter, which simply adds all the pixel values in the matrix kernel and divides the sum by the matrix size (or number of pixels used in the summation). In this particular case, the matrix kernel has a value of 1/9 in each kernel location (Figure 4.1.1.a), since no pixel is given a greater weighting than another. Note that there is no significant difference between a 3 x 3 kernel with values of 1/9 in each location, and one with values of 1 in each location, except that the former would have DNs that were on average nine times that of the original image. It is for this reason the normalization of the filter is often applied to ensure the output image has a similar radiometric range to the input image.

1/9	1/9	1/9
1/9	1/9	1/9
1/9	1/9	1/9

Figure 4.1.1.a. A kernel for a smoothing filter.

IDRISI offers a wide variety of filters in the FILTER module. For example, the *Gaussian* filter is a more sophisticated smoothing filter than the simple uniform averaging of the type illustrated in Figure 4.1.1.a. The *Gaussian* filter fits a

Gaussian or bell curve to the kernel. The Gaussian filter thus gives the greatest weight to the value at the center of the kernel, and the pixels further out from the center are given a progressively lower weighting. Another filter offered, the *median* filter, can be useful for noise suppression, as is the *adaptive box* filter, which is good for correcting "salt-and-pepper" random noise.

We are now ready to investigate our first filter operation. The data for this chapter is the same as we used for Chapters 1-3. Therefore, if you have been working through the manual sequentially, there is no preparatory work you need to do, as the data should already be available, and the resource folder set up. If not, you will need to follow the instructions in Chapter 1 to copy the data from the CD, and set up a resource folder (see Section 1.3). You will also need to set the *Display Min* and *Display Max* in the ***etm_pan.rst*** metadata, as was described in Section 2.2.3.

Let's begin by displaying the Hong Kong Landsat panchromatic data, ***etm_pan***. If you need to, you can refer back to Section 2.2.2 to refresh your memory on how to display an image. However, be sure to display this image with a *GreyScale* palette. If, after you have displayed the file, the image has a color palette, then you forgot to set the palette file correctly, and you should simply redisplay the image with the correct *GreyScale* palette.

We will use the display of the ***etm_pan*** image to compare with our results from filtered version of the image, generated through the FILTER module.

Low pass filter
Menu Location: **Image Processing – Enhancement - FILTER**
1. Use the main menu bar to start the FILTER module. 2. The *FILTER* dialog box will open (Figure 4.1.1.b).

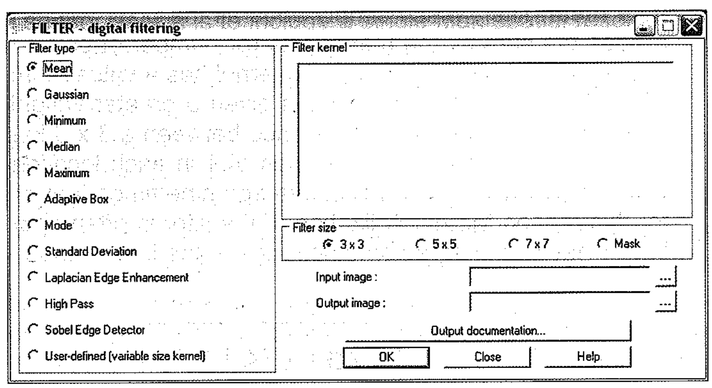


Figure 4.1.1.b The *FILTER* dialog box.

The *FILTER* dialog box shows a list of pre-defined filters on the left, on the upper right a view of the values of the matrix kernel selected (though note that initially no values are shown), and in the middle radio buttons for selecting different kernel sizes.

The default filter is the *Mean* filter. In order to see the kernel values for the *Mean* filter, click on the radio button for *Gaussian*, and then again on the button labeled *Mean*. The values should now appear in the Filter kernel window (Figure 4.1.1.c). The kernel should now be filled with 1/9 values, similar to Figure 4.1.1.a.

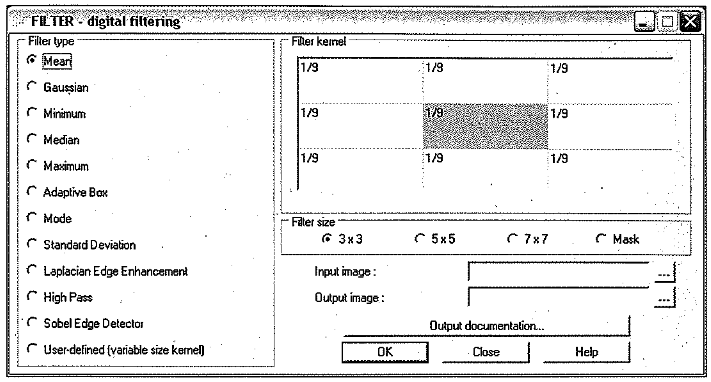


Figure 4.1.1.c The *FILTER* dialog box with the Mean filter selected.

As already discussed, mean filtering is commonly applied to smooth an image and remove some of the random noise. We will now apply the *Mean* filter to our Hong Kong panchromatic data.

Low pass filter (cont.)

3. In the FILTER dialog box, specify the *Input image* by clicking on the browse button (...) next to the appropriate textbox, and then double clicking on the ***etm_pan*** file in the *Pick list* window.
4. In the *Output image* text box, type the name of the file we will generate: **pan_mean3x3**.
5. In the *FILTER* dialog box, click on *OK* to generate the filtered image.

When the program is done, the image will be displayed automatically with the appropriate *GreyScale* palette. However, bear in mind that the program does not automatically set a contrast enhancement similar to that of the unfiltered data. You will therefore need to set the contrast enhancement for the new image.

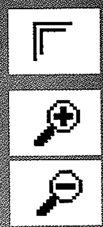
Change contrast enhancement of an image

1. Make sure the new ***pan_mean3x3*** image is the focus of the IDRISI workspace by clicking in the image.
2. Find the *Composer* window, and select the button for *Layer Properties.*
3. In the *Layer Properties* window, enter in the *Display Min* and *Display Max* text boxes the values for the contrast stretch we used for the ***etm_pan*** image, namely **18** and **73**.
4. Still in the *Layer Properties* window, click on the buttons for *Apply*, *Save* and *OK*.

Once the contrast stretch has been applied, the original ***etm_pan*** and the filtered ***pan_mean3x3*** should look fairly similar. This is in part because of the scale that we are using to look at the data. In order to see the effects of the filter operation, which is a local operation, we need to see the image in greater detail.

Zooming in to an already displayed image

1. Click on the *Zoom* icon from the main icon bar.
2. Draw a box in the ***etm_pan*** Display window around the Hong Kong airport by using the left mouse button to click on the top left corner of the desired box



and, keeping the mouse button depressed, drag the cursor to the lower right corner (Figure 4.1.1.d).

3. When you raise your finger from the mouse button, the display should automatically zoom in to the desired area. If the area is not quite what you wanted, you can either zoom in further, by selecting the zoom button again, or return the zoom to its default extent with the *Full extent normal* icon, and starting again. You can also use the *Zoom in / Center* and *Zoom out / Center* icons.

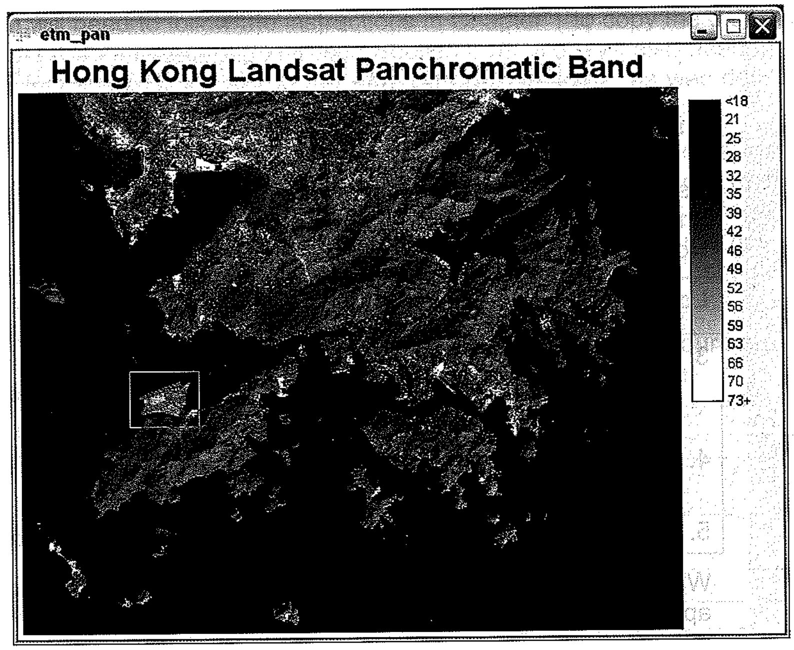


Figure 4.1.1.d Drawing the zoom box around the Hong Kong airport.

When you are satisfied with the zoomed window for the ***etm_pan*** image (Figure 4.1.1.e), repeat the zoom operation for the filtered ***pan_mean3x3*** image (Figure 4.1.1.f).

Compare the two zoomed in images (Figures 4.1.1.e and 4.1.1.f). Note the *Mean* filter reduces the grainy texture of the original image, thus reducing the internal variability in each cover class. This would be an improvement for image classification (Chapter 6). However, the reduction in variability is not without a cost: the detail of the features found within the airport, particularly associated with the terminal building, is clearly reduced.

4.1.2 High-pass and Edge Filters

Fundamentally, a **high pass** filter is a type of **edge detector** that emphasizes abrupt changes relative to regions of gradual change within the image. Specialized filters available in IDRISI that focus on edge effects include *Laplacian Edge Enhancement* and the *Sobel Edge Detector*.

4.1.2.1 High pass filter

The high pass filter generates an image that indicates where abrupt boundaries are found in an image. Other, non-spatial information, such as the average brightness information, is lost in generating a high pass image. An image with

Hong Kong Landsat Panchromatic Band

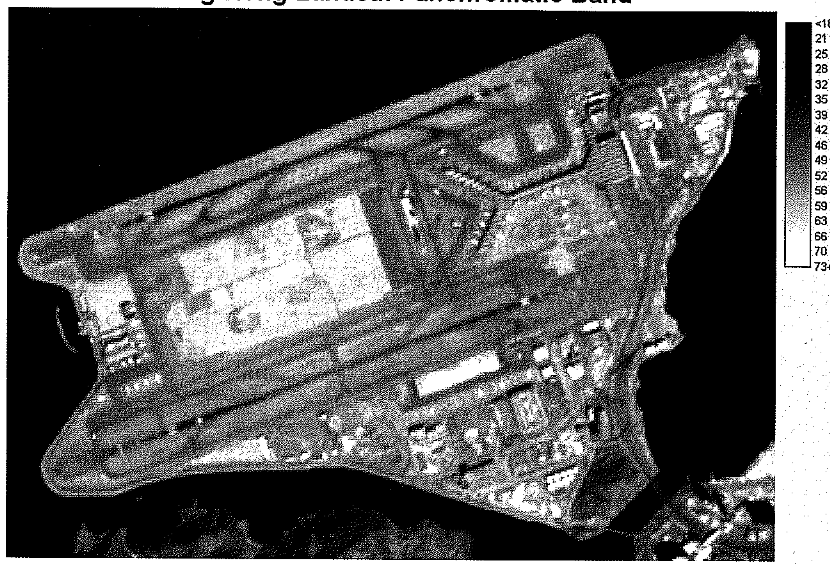


Figure 4.1.1.e Original Panchromatic image of the Hong Kong airport.

3 x 3 Mean filter of etm_pan

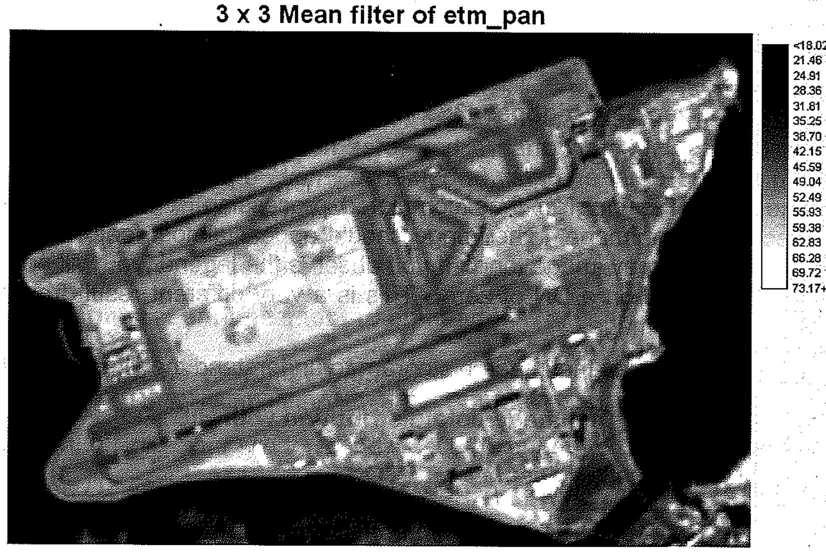


Figure 4.1.1.f *Mean* filtered Panchromatic image of the Hong Kong airport.

only the boundaries shown can be useful, however, and we will see such an example in Section 4.2, dealing with a multi-resolution merge, below. We will now try this filter, and see what it does to the Landsat Panchromatic image of Hong Kong.

High pass filter
Menu Location: **Image Processing– Enhancement - FILTER**
1. The *FILTER* dialog box should still be open from the Low Pass Filter operation. If not, use the main menu to open the *FILTER* dialog box, and specify the input file as ***etm_pan***.

2. In the *FILTER* dialog box, select the radio button for the *High Pass* filter. (Note that there is a strange quirk in this program. If *High Pass* is the first filter you click on when opening the window it may be necessary to first click on another filter, such as *Gaussian*, in order to see the kernel values.)

After you select the *High Pass* filter, note the values in the matrix kernel (Figure 4.1.2.1.a). You will see that the value of the center pixel is positive while all the other values are negative. The high pass kernel calculates the difference between the center pixel and the average of its surrounding neighbors.

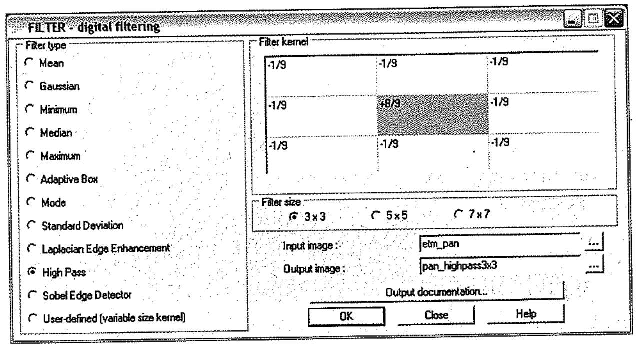


Figure 4.1.2.1.a The *FILTER* dialog box, with the *High Pass* filter selected.

High pass filter (cont.)
3. Type **pan_highpass3x3** in the *Output image* text box.
4. Click on *OK*.

After the program has completed processing, it will automatically display the resultant image. The image should appear almost featureless, with a dominant middle gray image tone. If you observe the legend, you will notice the values are centered on a DN of zero. This is a very different result from that of the *Mean* filtered image.

Let's display the image histogram to understand the filtered results better.

Analyzing the image data distribution with HISTO
Menu Location: **Display - HISTO**
1. Start the HISTO program from the main menu or the toolbar. 2. In the *HISTO* dialog box, click on the browse button (...) next to the text box for the *Input file name*. 3. The *Pick list* window will open, and use it to select ***pan_highpass3x3***. 4. Set the class width to **0.5.** 5. Click on *OK*.

The result of the HISTO program shows that the mean of the filtered image is centered on zero (Figure 4.1.2.1.b). The reason the result of the *High Pass* filter is so different from that of the *Mean* filter can be understood by looking in detail at the values of the filter kernels. Add up the kernel weights in the *Mean* filter and compare the result to the sum of the kernel weights in the *High Pass* filter. The *Mean* filter kernel sum is equal to 1 (9 x 1/9 = 1), whereas the sum of the values in the *High Pass* kernel is equal to 0 (8 x [-1/9] + 8/9 = 0).

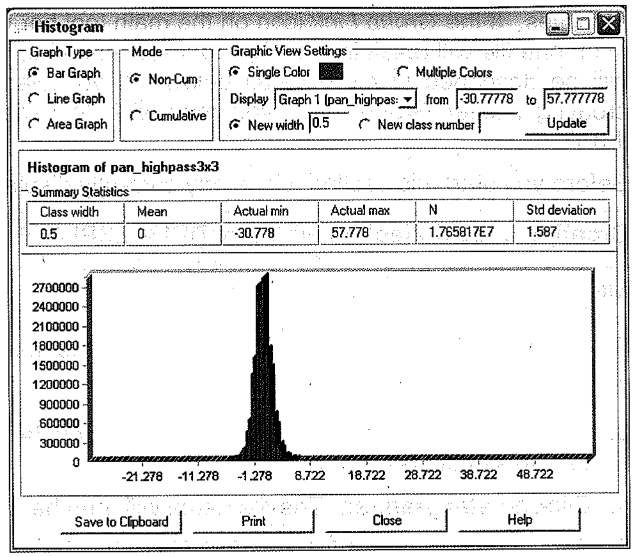


Figure 4.1.2.1.b Histogram of 3x3 *High Pass* filtered Panchromatic image.

The sum of the values in the kernel is essentially a measure of how much information of the original image is retained in the filtered result. The *Mean* filter retains most of the image statistical information – the mean and standard deviation are similar to the original image – but the image is smoothed and boundaries blurred. On the other hand, the *High Pass* filter, with its zero-sum kernel, removes most of the original image brightness information. The *High Pass* has a mean centered on zero, and a narrow standard deviation. Figure 4.1.2.1.b shows that the *High Pass* image has some large outliers (anomalous DN values), and this may partly explain the lack of contrast we observed in the displayed image. Therefore, let's adjust the contrast of the high-pass filtered image so that we can better see what the filter did to the image.

Apply a contrast enhancement to an image

1. Make sure the new ***pan_highpass3x3*** image is the focus of the IDRISI workspace by clicking in the image.
2. Find the *Composer* window, and select the button for *Layer Properties.*
3. In the *Layer Properties* window, enter in the *Display Max* and *Display Min* text boxes the values of **-7** and **7**, respectively.
4. Click on the buttons for *Apply*, *Save* and *OK*.

The result should show more contrast, but still appear to be mainly noise. In order to see the details, we need to zoom into a scale where the edges become more apparent. However, we are faced with a challenge – how do we find the airport in this rather featureless image? One way to do this is to carefully note the location of the airport in the ***etm_pan*** image, and then zoom in on the same general region in the ***pan_highpassx3*** image. Another more precise method, which we will try in the next section, zooms in on a file using the zoom of a companion image, based on the IDRISI *Group Link* concept.

4.1.2.2 IDRISI Group Link Display

In order to take advantage of the *Group Link* we need to create a *Raster Group File* that links the files. The images are displayed using their *Raster Group* identities. If the *Group Link* icon on the main tool bar is then depressed, zooming in on one file will result in a similar zoom for the other linked files. This procedure will be described in more detail below. If you want additional discussion on creating *Raster Group Files*, you may wish to review the material in Section 1.3.7.

Before you start this section, close any currently displayed images.

Creating a file dollection with the IDRISI EXPLORER

Menu Location: **File – IDRISI EXPLORER**

1. Open the *IDRISI EXPLORER* window from the menu or the main icon toolbar.
2. Click on the tab for *Files*.
3. If the files are not listed in the *Files* pane, double click on the directory name to display the files.
4. Click on ***etm_pan.rst***. The file name will then be highlighted.
5. Scroll down to ***pan_highpass3x3*** file. Now be very careful. Hold the *CTRL* key down, and click on the ***pan_highpass3x3*** file, thus highlighting it simultaneously with ***etm_pan.rst.***
6. Remove your finger from the *CTRL* button. Press the right mouse button.
7. A pop-up menu will appear. Within this menu, scroll down to *Create*, and then select *Raster Group*.
8. This will create a new file called ***Raster Group.rgf***. Click on this file name in the *Files* pane.
9. In the *Metadata* pane of the *IDRISI EXPLORER*, delete the ***Raster Group*** text in the *Name* text box, and type: **filter**, then press *Enter* on the computer keyboard.
10. Click on the *Save* icon in the bottom left hand corner of the *Metadata* pane.

Now that we have created the *Raster Group File*, we can display the two images within the context of the *Raster Group File*. IDRISI calls this displaying the images "with their full "dot-logic" filenames." The logic of these terms will become clearer in a moment.

Displaying images that form part of a Raster Group File

Menu Location: **Display – DISPLAY LAUNCHER**

1. Open the DISPLAY LAUNCHER using the main toolbar or main menu.
2. Within the *DISPLAY LAUNCHER* window, click on the browse button (…).
3. The *Pick List* will open. Scroll down to ***filter***. Click on the plus sign (+).
4. The plus sign will change to a minus (-), and the two files, ***etm_pan*** and ***pan_highpass3x3*** should both be listed below. Note that both image files are actually listed twice in the *Pick List* window, once independently, and once as part of a *Raster Group File* (Figure 4.1.2.2.a).

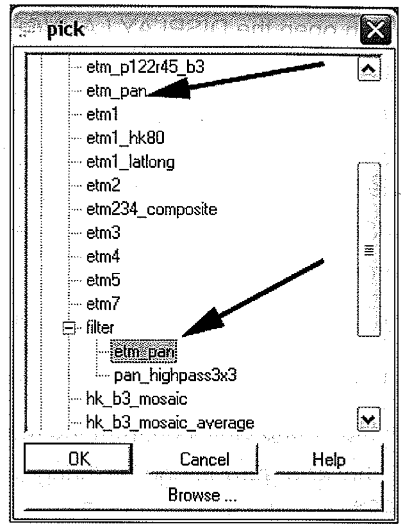


Figure 4.1.2.2.a The *Pick List* showing the image ***etm_pan*** listed independently, and also as part of the ***filter*** *Raster Group File*.

Displaying images that form part of a Raster Group File (cont.)
5. Select the ***etm_pan*** image associated with the ***filter*** *Raster Group File* from the *Pick list* window, and click on *OK*.

Observe the name of the file we have just selected, as listed in the DISPLAY LAUNCHER (Figure 4.1.2.2.b). The file is listed as ***filter.etm_pan***. Thus the format of the image is *Raster Group File name* "dot" *image file name*. The dot in this context specifically implies that the etm_pan image is a part of the raster group. When the image is identified with its full name, indicating the image and the raster group it is a part of, it is termed as the image file name "with full dot logic."

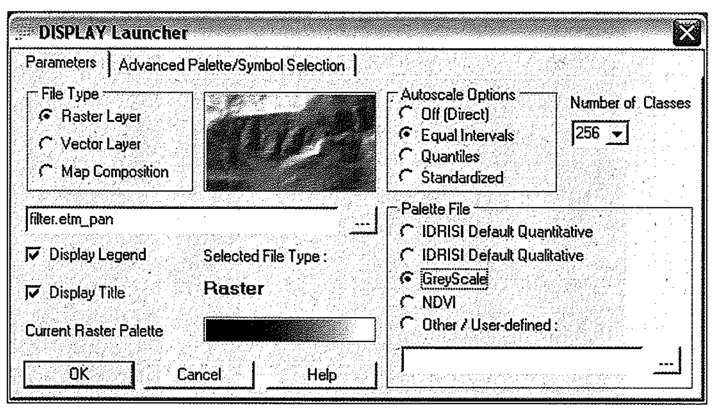


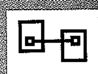
Figure 4.1.2.2.b The *DISPLAY LAUNCHER* showing the image file name associated with a *Raster Group File*.

Displaying images that form part of a Raster Group File (cont.)
6. In the *DISPLAY LAUNCHER* window, select a *GreyScale* palette.
7. Click on *OK*.

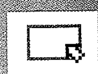
8. Once again open the DISPLAY LAUNCHER using the main toolbar.
9. Within the *DISPLAY LAUNCHER* window, click on the browse button (…).
10. The *Pick List* will open. Scroll down to ***filter***. Click on the plus sign (+).
11. The plus sign will change to a minus (-). Select the ***pan_highpass3x3*** image associated with the ***filter*** *Raster Group File*, and click on *OK*.
12. In the *DISPLAY LAUNCHER* window, select a *GreyScale* palette.
13. Click on *OK*.

We are now finally ready to apply our linked zoom.

Applying a linked zoom with Raster Group File images



1. Click on the *Group Link* icon from the main menu bar.
2. Click in the ***etm_pan*** image, to bring this window to the front of the IDRISI workspace.



3. Click on the *Zoom* icon from the main menu bar.
4. Draw a zoom box around the airport by clicking at the upper left corner of the airport, and dragging the mouse to the bottom right corner of airport.
5. Both images should zoom in to the same place and extent. You may need to move the ***etm_pan*** image display, to see the ***pan_highpass3x3*** image.

The zoomed image shows that the *High Pass* filter highlights the boundaries between features by creating contrasting negative and positive pixels (Figure 4.1.2.2.c). Look closely at the boundary between the airport and the sea. Note that the boundary is marked by a dark line, with an adjacent parallel white line. This distinctive result emphasizes the edges of the features in the image. Also, observe how image noise within the image is heightened. High-pass filters tend to enhance any noise present in the image, since any variability, especially variation that is not correlated spatially, is enhanced.

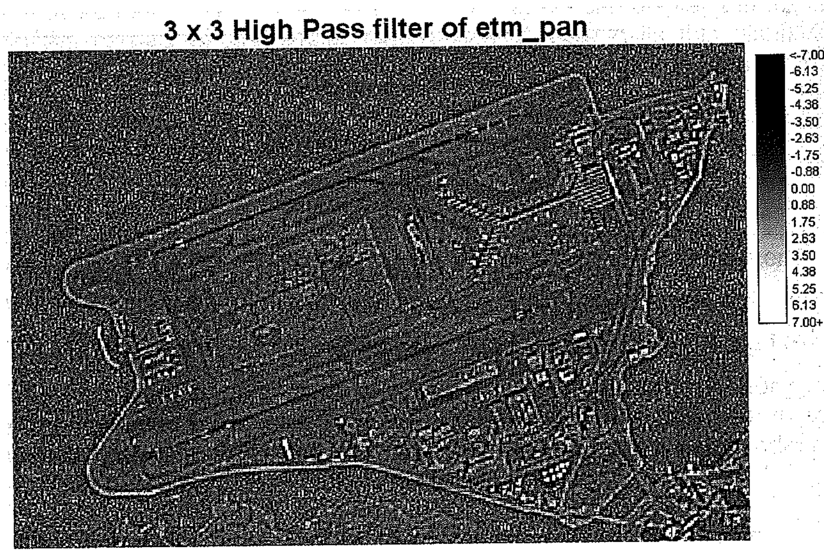


Figure 4.1.2.2.c Zoomed *High Pass* filtered image.

4.1.2.3 Sobel Edge Detector

Another edge filter, called the *Sobel Edge Detector* filter, is very useful in highlighting long continuous linear features in your imagery. Linear features in imagery, commonly called **lineaments**, are sometimes used in geological studies. Natural geomorphic features that exhibit relatively linear patterns may indicate structural features, such as faults or fracture systems controlled by joints. We will use the *Sobel Edge Detector* filter to highlight linear features found in the ***etm_pan*** image.

Sobel edge detector FILTER
Menu Location: **Image Processing– Enhancement - FILTER**
1. The *FILTER* dialog box should still be open from the Low Pass Filter operation. If not, use the main menu to open the *FILTER* dialog box, and specify the input file as ***etm_pan***. (If necessary, review Section 4.1.1.)
2. Select the *Sobel Edge Detector* radio button.
3. In the *Output Image* text box, type **pan_Sobel**.
4. Click on *OK* to generate the filtered image.

After the processing, the image is automatically displayed with an appropriate *GreyScale* palette. However, we do need to set the appropriate contrast.

Apply a contrast enhancement to an image
1. Click in the ***pan_Sobel*** window.
2. Find the *Composer* window, and click on the *Layer Properties* button.
3. In the *Layer Properties* window, type **20** in the *Display Min* text box, and **45** in the *Display Max* text box.
4. In the *Layer Properties* window, click on the buttons for *Apply*, *Save* and *OK*.

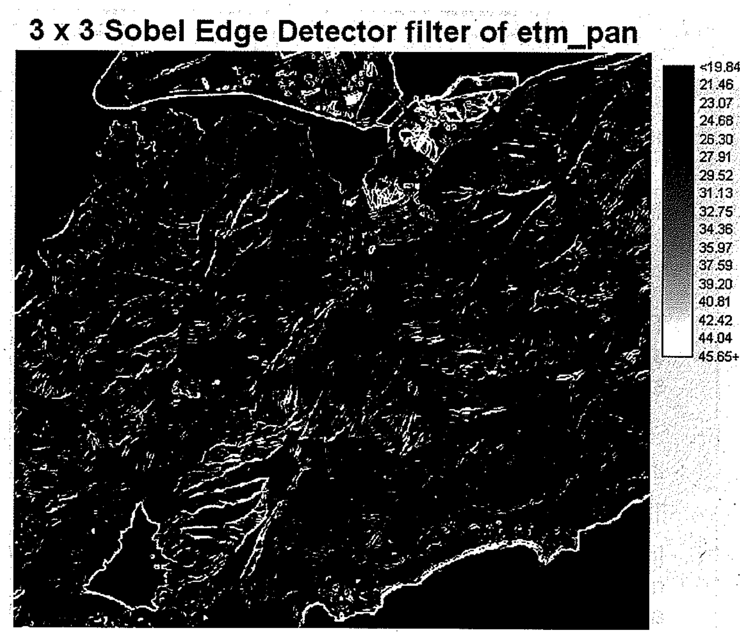


Figure 4.1.2.3.a Sobel filter of the area south of the airport.

Now zoom in on the Sobel Edge Detection image around the airport, and especially the adjacent island, Lantau (Figure 4.1.2.3.a). Note the strong NE trending linear features. These features suggest a distinctive NE structural geology trend.

Note: In working through this exercise you may have decided to redisplay one or more of the images. For example, you may have closed the ***pan_mean3x3*** image, and may wish to view it again to compare it with the subsequent images. If so, be sure to use the *GreyScale* palette each time you display the image. However, if you have saved the *Display Min* and *Display Max* settings you have entered, it should not be necessary to reapply the contrast stretch.

4.1.3 Sharpening Filters

For the satellite optical data such as Landsat data, convolution filtering is typically employed to sharpen the image. Often referred to as high-pass filtering, this operation is somewhat analogous to focusing a lens – it enhances the boundaries between features of distinctly different digital values. The difference between sharpened images and typical high-pass and edge filtered images is that most of the image information is retained in the final sharpened image.

In addition to the preset filters, IDRISI allows the user to define custom values for the kernel. We will now use this capability to define a filter that will sharpen our image without losing most of the image content. To retain the image content, we will design a matrix kernel whose sum is equal to 1 keep the results comparable with the mean filter kernel.

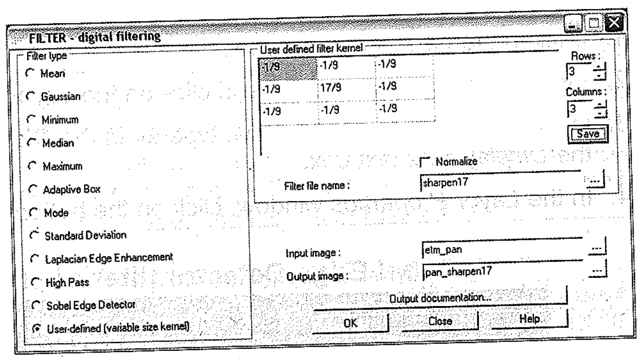


Figure 4.1.3.a *FILTER* dialog box for custom filter creation.

Custom filter

Menu Location: **Image Processing– Enhancement - FILTER**

1. The *FILTER* dialog box should still be open from the Low Pass Filter operation. If not, use the main menu to open the *FILTER* dialog box, and specify the input file as **etm_pan**.
2. Select the radio button for *User-defined filter (variable size kernel).*
3. In the *User-defined filter kernel* area, click on the center kernel position.
4. Type **17/9**
5. In the surrounding 8 kernel positions, click and type **-1/9** in each cell. You may find it easier to type the value in one cell, copy it (press the keys *Cntrl* and *c* simultaneously), and paste the value (*Cntrl* and *v)* in each subsequent cell.

6. Make sure that the normalize option is <u>not</u> selected (we have already normalized the kernel by dividing it by the number of kernel positions, i.e. 9).
7. In the *Filter file name* text box, type **sharpen17**.
8. Click on the *Save* button above and to the right of the *Filter file name* text box.
9. In the Output image text box, type **pan_sharpen17**.
10. Figure 4.1.3.a shows the *FILTER* dialog box with the parameters specified.
11. Click on *OK.*

The filtered image retains most of the image information of the original image, and shows a similar range of values. Therefore we now need to set the contrast once again.

Change contrast enhancement of an image

1. Make sure the new ***pan_sharpen17*** image is the focus of the IDRISI workspace by clicking in the image.
2. Find the *Composer* window, and select the button for *Layer Properties.*
3. In the *Layer Properties* window, enter in the *Display Min* and *Display Max* text boxes the values for the contrast stretch we used for the ***etm_pan*** image, namely **18** and **73**.
4. Still in the *Layer Properties* window, click on the buttons for *Apply*, *Save* and *OK*.

The image should now have much better contrast.

Zoom in on the airport and compare the filtered results with the original panchromatic image (Figures 4.1.3.b and 4.1.3.c). (If you need to redisplay the panchromatic image, remember to use a GreyScale palette.) The sharpen-filtered image shows better definition to the features in the airport such as the fuel tank field, the variations of the internal field, and the jets at the terminal. However, the filtered image also appears noisier.

3 x 3 sharpen17 filter of etm_pan

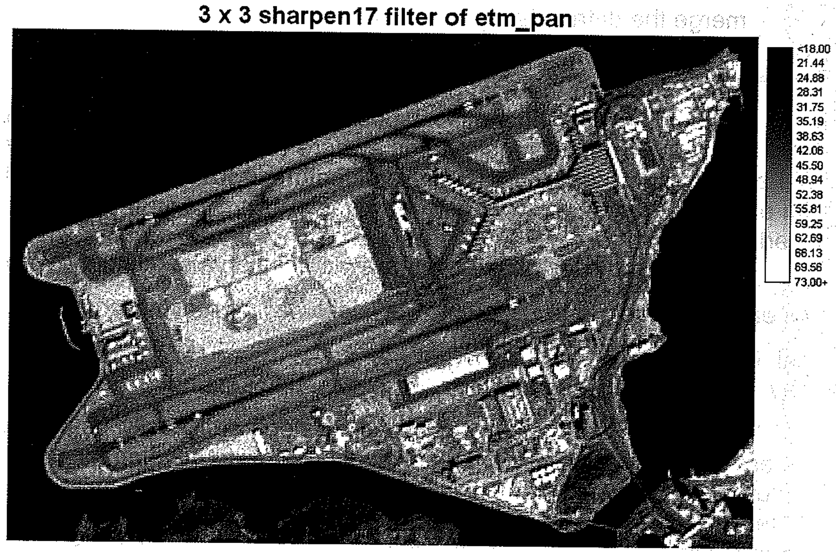


Figure 4.1.3.b Sharpened image of Hk_etm_pan.

Hong Kong Landsat Panchromatic Band

Figure 4.1.3.c Hong Kong Landsat Panchromatic data.

4.2 Multiresolution Merge

Another approach to enhancing images spatially is to merge high-resolution panchromatic data with multispectral imagery of lower spatial resolution. As noted previously in Section 2.1.1, multispectral imagery, which because of its multi-band nature can be displayed in a false color composite format, tends to have a lower spatial resolution than single band panchromatic data. An ideal merge of the two data sets would result in retaining the spectral integrity of the multispectral bands, while incorporating the spatial resolution of the panchromatic data. In this section we will learn how to use two methods to merge data of differing resolution. The first method will draw on color theory, and the second will take advantage of spatial filters and mathematical operators to merge the data sets.

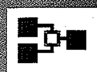
In performing this resolution enhancement, it will be necessary to perform many steps to obtain the final product. The step-by-step processing can be very time consuming and laborious, especially if we need to repeat the process due to some adjustment required somewhere along the process stream. Thus, we will learn how to employ a very useful feature of IDRISI, the MACRO MODELER.

This MACRO MODELER has a number of significant benefits:

- It provides an excellent way to develop a sequence of program steps.
- It tends to be a more efficient way of running programs, especially those that are sequential.
- It provides a record of a processing sequence.
- The sequence of processing steps can easily be adapted to apply to a new data set, thus making it possible to develop "canned" procedures.
- It is easy to repeatedly run through a processing sequence, thus facilitating scenario modeling, where for example, multiple alternative values in some key processing parameter are compared.

4.2.1 Building a simple model in the MACRO MODELER

The Macro Modeler is a graphical user interface in which the user can easily develop and execute multiple operations in a sequential fashion. In essence, the interface allows the user to plan complex operations by creating a process stream that includes data inputs, operations, temporary file outputs as well as final outputs. Let's begin and work on becoming acquainted with this interface.



MACRO MODELER
Menu Location: **Modeling – Model Deployment Tools - MACRO MODELER**
1. Start the MACRO MODELER either from the main menu or the icon bar. 2. The *MACRO MODELER* graphical interface will open (Figure 4.2.1.a).

The Macro Modeler window has a standard pull-down menu and an icon toolbar. We will be using the icon toolbar exclusively so let's see what is available. Run your cursor over each icon, and note the brief name that pops up as you read the summary information below on the groups of icons.

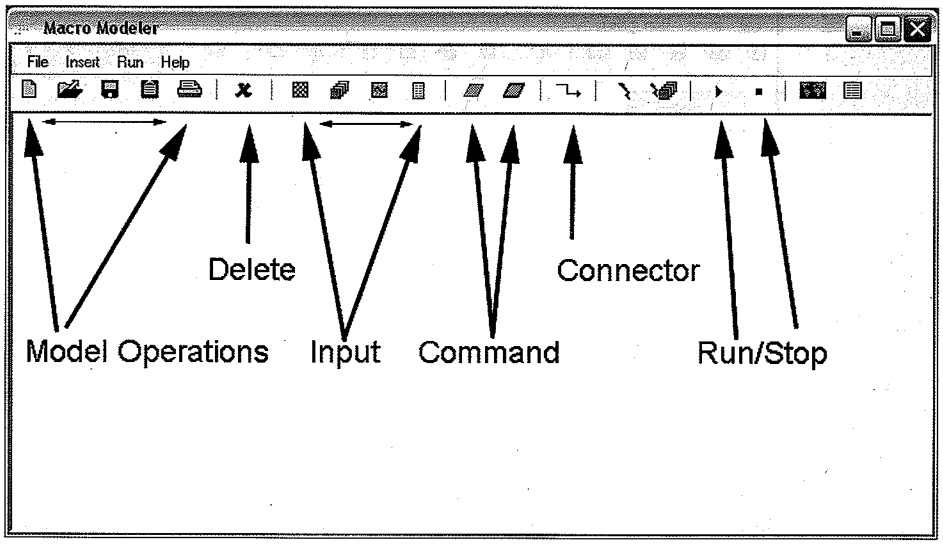


Figure 4.2.1.a *MACRO MODELER* graphical Interface.

- **Model Operations**. The blue model operations icons on the left include commands to create a new model, open a model file, save the model to a file, copy the graphical representation of the model to the windows clipboard, and print the graphic representation of the model.
- **Delete**. The red x icon allows the user to delete elements of the model.
- **Input**. The green icons are the data elements that are inputs into processing modules, including raster files, raster group files, vector files, as well as attribute data (the latter two are for GIS operations).
- **Command Elements**. The next two icons in red are the command elements of a module and a sub-model. Sub-models are previously constructed modules that can be used within a larger model. When a command element is placed into the model, an output file is automatically connected to the module of the appropriate data type and with a default temporary file name.

- **Connector**. The next icon, the blue arrow, creates connections between model elements. Connectors control the flow of input data to the command modules.
- **Start/Stop**. The red triangle and square icons are for running and stopping the model. (The other icons will not be used here.)

In order to demonstrate the Macro Modeler's capability, let's first build a simple one-step model before we attempt building more complicated models. Let's build a model that creates a color composite image from three separate data layers.

MACRO MODELER (cont.)
3. Click on the *Raster Layer* icon to insert a data input into the model. (Figure 4.2.1.b shows the icon and the result of the operation described here.)
4. In the *Pick* window, select the data layer ***etm2***.
5. Click on *OK*.

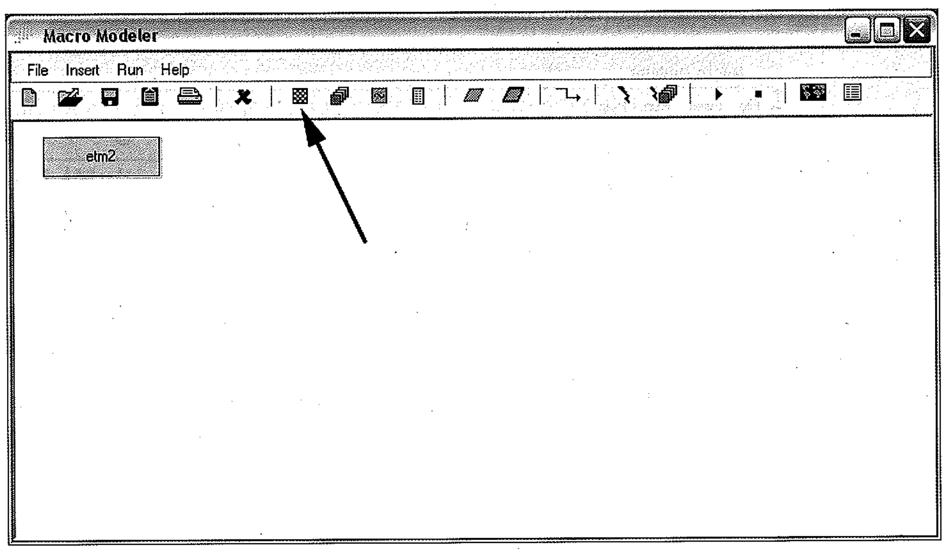


Figure 4.2.1.b A raster layer in a Macro Model, with the arrow indicating the icon to insert the layer.

The Macro Modeler creates a blue rectangle as the graphical representation of a data input layer and places the name of the input file inside the rectangle (Figure 4.2.1.b). Click on the rectangle and the rectangle's border becomes a bold line indicating that the data input is selected. You can also move the element by selecting the element, hold the mouse click down and dragging it to your desired location. Continue now to add the other two data inputs.

MACRO MODELER (cont.)
6. Click on the *Raster Layer* icon to insert a data input into the model.
7. In the *Pick* window, select the data layer ***etm4***.
8. Click on *OK*.
9. Click on the *Raster Layer* icon to insert a data input into the model.
10. In the *Pick* window, select the data layer ***etm5***.

11. Click on *OK*.

Now we will add the command module.

MACRO MODELER (cont.)
12. Click on the *Module* icon to insert a command module into the model. 13. In the *Pick* window, select the module *composite*. 14. Click on *OK*.

The MACRO MODELER adds the command module, which is represented in the model by a pink parallelogram with the label *composite* (Figure 4.2.1.c). Notice that the modeler automatically creates an output file with the name ***tmp000*** (***tmp*** followed by a series of numbers), and shows the connection from the *composite* module.

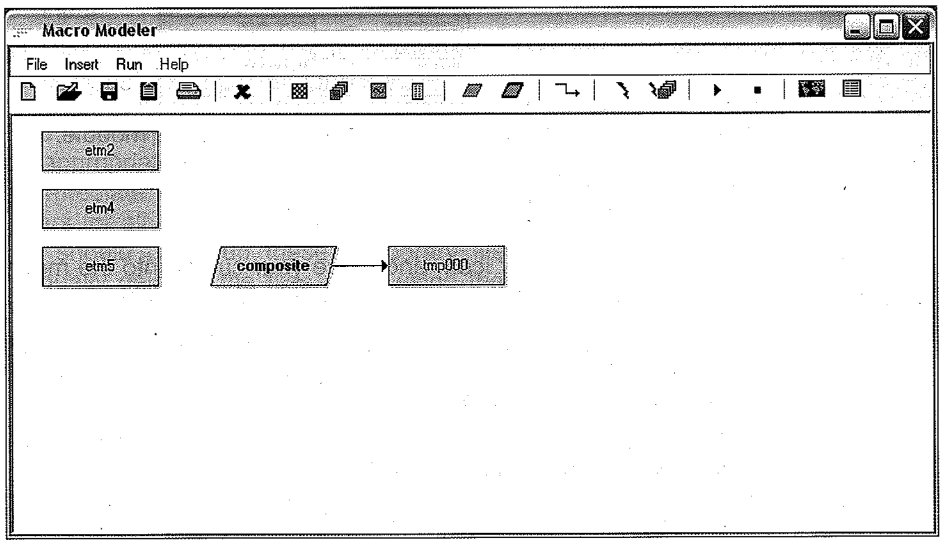


Figure 4.2.1.c The model with three input data sets and the *composite* module specified.

We will now need to establish the connection and sequence of the input files to the *composite* module. First, we must learn the order that the *composite* module expects the input files, and then we can establish the connectors. The MACRO MODELER establishes the order of the data input files into a command module by the sequence in which you connect the data to the module. So it is very important to know before what order to physically connect the inputs to the module. Let's try with the model we are building.

MACRO MODELER (cont.)
15. Place your cursor over the pink *composite* module parallelogram, and right click. 16. A *Parameter* window appears for the *composite* module (Figure 4.2.1.d). This window shows the input files, output file name, and the parameters used in creating the output.

17. Notice the inputs are arranged from top to bottom as *Blue band*, *Green band*, and *Red band*. This is the sequence that the module expects the input files to be connected.
18. Try clicking in the fields for the inputs and output. Notice that you cannot change these attributes.
19. You can, however, change the values in the section labeled *Additional parameters*. Click on each parameter attribute to view the possible options. For this exercise, leave the options unchanged (default options)
20. Click on the *OK* button to close the *Parameters* window.

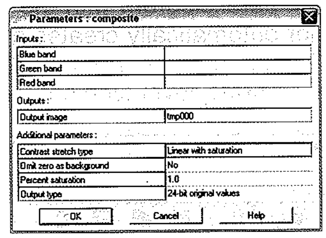
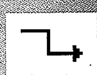


Figure 4.2.1.d *Parameters* window for the *composite* module.

MACRO MODELER (cont.)



21. Click on the *Connect* icon, and move your curser into the model. Notice that the cursor shape has changed to a hand with a pointing finger.
22. Place the cursor over the blue rectangle representing the input raster layer that we want to be the blue band for the *composite* module, namely the Landsat ETM+ band 2, ***etm2***.
23. Click, and holding the mouse button down, drag the cursor over to the *composite* module and release.
24. The model now shows the ***etm2*** data layer connecting to the *composite* module, with the arrow indicating that it is an input data file.

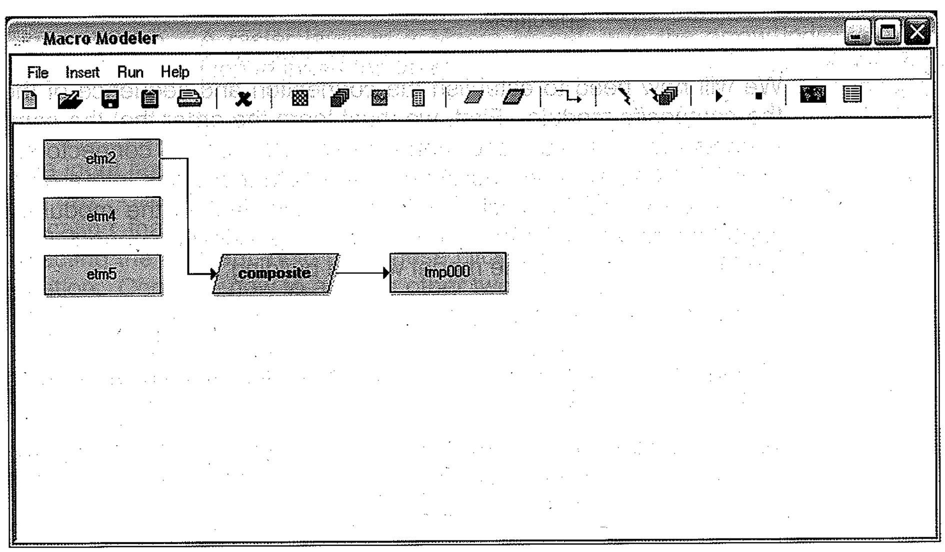


Figure 4.2.1.e The model with the first data layer connected.

MACRO MODELER (cont.)

25. Right click with the cursor over the *composite* module to bring up the *Parameters* window once again. Note that the *Blue band* field now indicates ***etm2,*** indicating that you have successfully connected the data layer to the module. Let's continue and add the other data inputs.
26. Click on the *Connect* icon and move your curser into the model.
27. Place the hand cursor over the rectangle representing the ***etm4*** raster layer input.
28. Click, and keeping the mouse button depressed, drag cursor over to the *composite* module, and release.
29. Click on the *Connect* icon and move your curser into the model.
30. Place the hand cursor over the rectangle representing the ***etm5*** raster layer input.
31. Click, and keeping the mouse button depressed, drag cursor over to the *composite* module, and release.

One final step before we will run our model is to create an output data layer with an appropriate name. The ***tmp*** (temporary) filename prefix is typically used for intermediate data layers rather than final products. The model creates data layers for all the outputs and doesn't automatically clean up the temporary files. We should clean up these temporary files after we run the model by either manually deleting the files or by using the *Delete all temporary files* command found in the *File* pull-down menu. Let's continue and name our output.

MACRO MODELER (cont.)

32. Place you cursor over the ***tmp001*** data output and right click.
33. A *Change layer name* window appears, with the original name in the field.
34. Type in new file name as **etm542**.
35. Click *OK.*

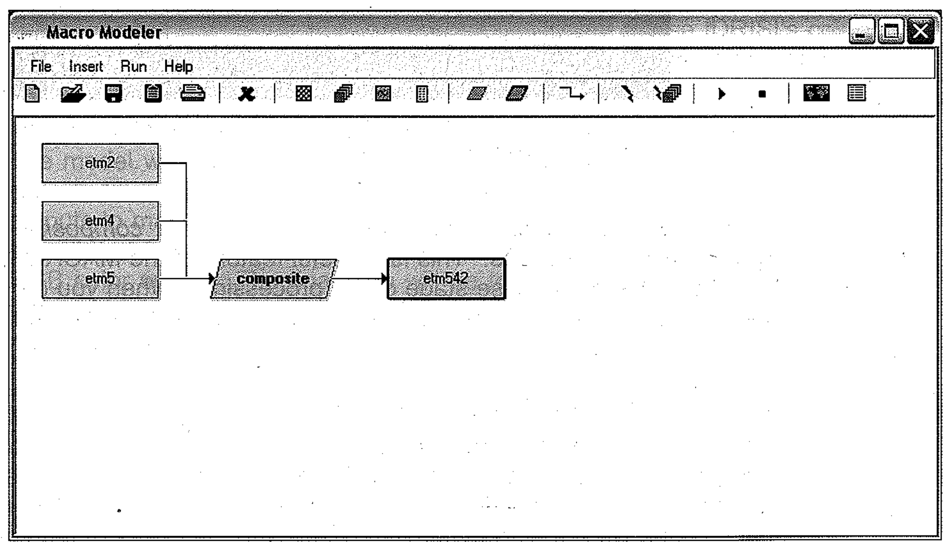
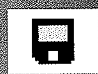


Figure 4.2.1.f The model completely specified.

One aspect of the MACRO MODELER that we need to consider is the standard output directory for all the data layers created when you run the model. All data are automatically written to the standard output directory in the *Working Folder*. One can always use the IDRISI file explorer to move the final data layers to another folder location if necessary.

Finally, let's save and run our new model.

MACRO MODELER (cont.)



36. Click on the *Save* icon.
37. Specify the Model file name **composite542**.
38. Click *OK*.

39. Click on the *run* icon.
40. A window will open in which you are warned that the files created by the model will overwrite any existing files of those names. Click on *Yes to all*.
41. Your new raster file is created and displayed (Figure 4.2.1.g).

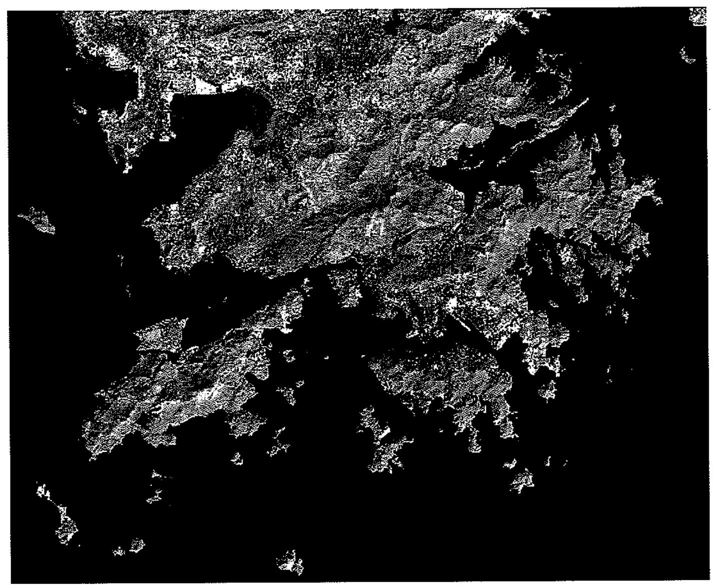


Figure 4.2.1.g Landsat 542 (RGB) composite created using the MACRO MODELER.

Notice how the pink parallelogram representing the *composite* module turns green as the module runs. This is a useful feature of the MACRO MODELER, in that it indicates the precise stage of the processing. When you combine multiple modules in a single module, you can track progress through the module in this way.

4.2.2 Color Transformation Merge

A common method to merge data uses the concept of color spaces. **Color space** is a mathematical model describing the way colors can be represented as a combination of three values. For example, the **RGB (Red, Green, Blue)** color space is one we are already familiar with. The three axes of the color space are represented by the Red, Green, and Blue components of the color. Based on fact that the impressions of almost all the colors we perceive with our eyes can be evoked by mixing these three components, a point in the RGB color space will represent a distinctive color.

RGB is not the only possible representation of color. An alternative color space is the **HLS (Hue, Lightness, Saturation)** model. In this case, Hue, Lightness, and Saturation are the axes of the color space, just as Red, Green and Blue are the axes in the RGB model.

- **Hue** refers to the characteristic tint of a color. For computer-based color, the color wheel is based on the RGB model and includes secondary colors of cyan, magenta, and yellow. Since the color wheel is circular, the number assigned to the Hue value is typically an angle, from 0° to 360° (Figure 4.2.2.a). IDRISI will normalize this 360-degree value to an 8-bit range (0-255).
- **Lightness** refers to the brightness, which extends from black to white.
- **Saturation** refers to the purity of the color, so that low saturation colors tend to gray, and have a typically pastel quality, whereas high saturation colors are the purest colors. With no saturation at all, the hue becomes a shade of gray equivalent to lightness (Figure 4.2.2.b).

Sometimes HLS system is referred to as IHS, for **intensity** (instead of lightness), **hue**, and **saturation**. Soil scientists refer to this system by the terms **hue, value** (for lightness) and **chroma** (for saturation). For this exercise we will use the terms used in IDRISI, i.e. HLS.

Interestingly, there are in fact additional color spaces, which sometimes are used in preference to either the RGB or HLS models. The reader seeking additional information about color spaces should refer to a text such as Jensen (2005).

Transformations between color spaces are essentially matrix rotations of the data between the different color space axes. The differences between the RGB and HLS color spaces can be visualized in Figure 4.2.2.b.

The Lightness component in the HLS space is the useful component for merging datasets of different resolutions. In Landsat ETM+ data, the panchromatic band has four 15 m pixels for every one 30 m pixel of the multispectral bands. The panchromatic band, which is sensitive to 0.5-0.9 µm electromagnetic radiation, gives a good average reflectance of the pixel. We will use IDRISI's color space transformation functions to merge the Landsat panchromatic band with the multispectral Landsat bands 5, 4, and 2.

We will use the MACRO MODELER to develop the multi-step merge procedure. The model will first transform three multispectral bands from RGB to HLS color space. We will then expand the resolution of the resulting Hue and Saturation outputs to match that of the panchromatic band. The panchromatic band will be substituted for the Lightness data, and then the data will be transformed back to RGB color space. The final step will be to create the color composite image to view the merged image.

HLS resolution merge with the MACRO MODELER

Menu Location: **Modeling – Model Deployment Tools - MACRO MODELER**

1. Start the MACRO MODELER either from the main menu or the icon bar.
2. In the MACRO MODELER window, use the menu to select *File* and then *Delete all temporary* files.

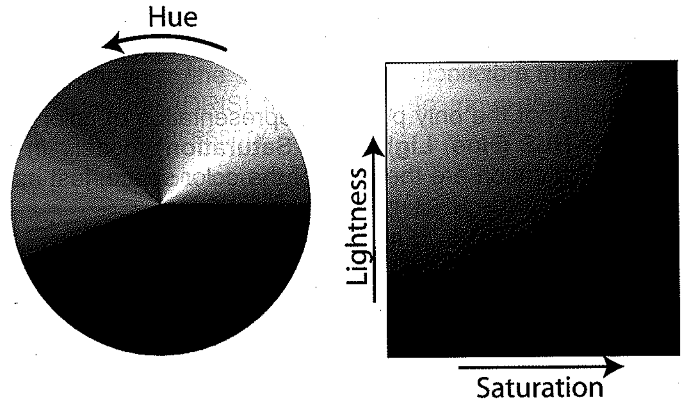


Figure 4.2.2.a Left: Hue color wheel. Right: Lightness and saturation variation associated with a red hue.

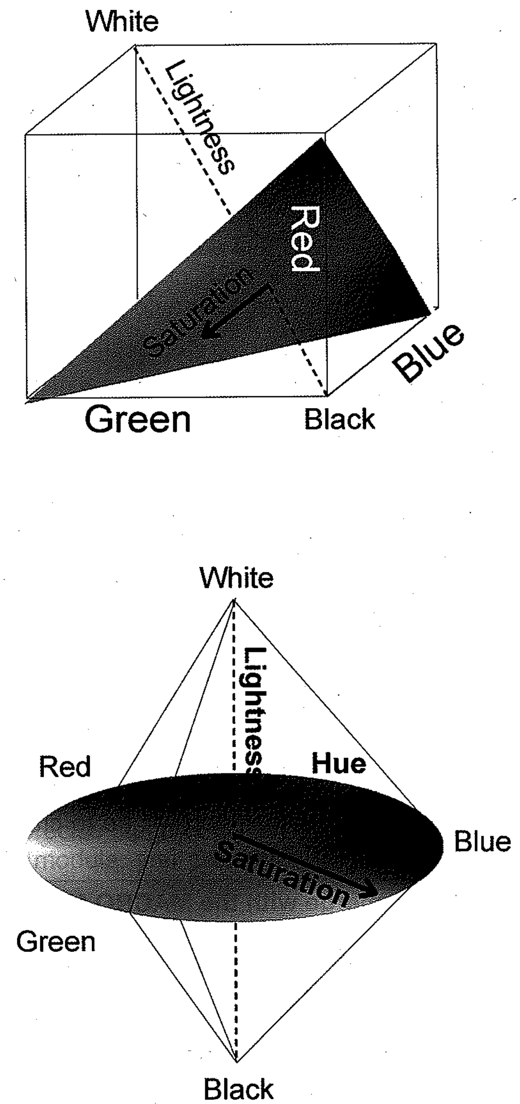
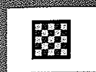


Figure 4.2.2.b RGB color space and HLS color space.

3. Click on *File* and select *Set/Reset temporary file counter*.
4. The *Set/Reset TMP File Counter* window will open. Click on *Reset*.
5. If the value for Current counter value is not *0*, change the value in the *Set next counter window* to ***0***. Click *OK* to close the *Set/Reset TMP File Counter* window.



6. Click on the *Raster Layer* icon to insert a data input into the model.
7. In the *Pick list* window, select the data layer ***etm5***.
8. Click on *OK*.
9. Repeat the above three steps to insert raster layer ***etm4***, and again to insert raster layer ***etm2***.

10. Click on the *Module* icon to insert a command module into the model.
11. In the *Pick list* window, select the module *colspace*.
12. Click on *OK*.
13. Right click with the cursor over the *colspace* module to bring up the *Parameters: colspace* window.
14. Within the *Parameters* window, note that the input images are listed as *hue image band*, *lightness image* band and *saturation image band*.
15. Find the *Additional Parameters* section. In that section, the *Conversion type* should list the default option of *HLS to RGB*.
16. Click in the *HLS to RGB* field, and select *RGB to HLS* from the popup menu (Figure 4.2.2.c).
17. Note that the input images are now listed as *Red image band*, *Green image band* and *Blue image band*, in that order (Figure 4.2.2.c). Therefore, we will want first to connect the Landsat band that will be displayed as red, then green, then blue.

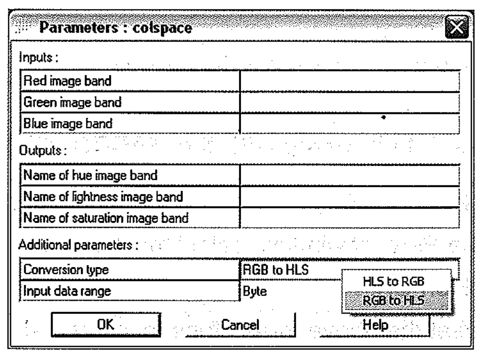


Figure 4.2.2.c The *colspace Parameters* window after the *RGB to HLS* option has been selected.

HLS resolution merge with the MACRO MODELER (cont.)

18. Click on *OK* to close the *Parameters* window.
19. Click on the *Connect* icon and move your curser into the model.

20. Place cursor over the red band for the *colspace* module, which will be ***etm5***. Click, and keeping the left mouse button depressed, drag the cursor over to the *colspace* module, and release.
21. The model now shows the ***etm5*** data layer as connecting to the *colspace* module with the arrow indicating that it is an input data file.
22. Repeat the previous three steps to connect ***etm4*** to the *colspace* module, and the ***etm2*** to the *colspace* module, in that order.

Your model should now show the three input Landsat ETM+ images connected to the *colspace* module (Figure 4.2.2.d). The colspace module provides for three outputs that currently have default names, such as ***tmp003***, ***tmp004*** and ***tmp005***. These files represent, in order, hue, lightness and saturation. We will next expand the resolution of the hue and saturation data to match the Landsat panchromatic image.

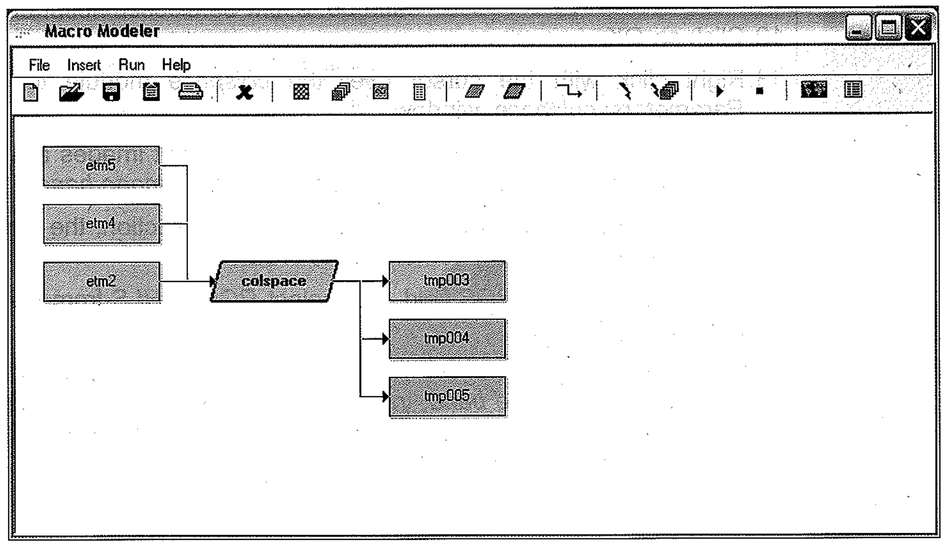
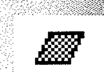
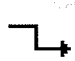


Figure 4.2.2.d The *colspace* module.

HLS resolution merge with the MACRO MODELER (cont.)



23. Click on the *Module* icon to insert a command module into the model.
24. In the *Pick list* window, select the module *expand.*
25. Click on *OK.*
26. Repeat the above three steps to insert a second *expand* module in the model. (The new module is placed in the model somewhere to the right of the existing model elements. You may need to scroll over to find them.)
27. Drag each of the *expand* modules and their outputs to line up with the first and third raster file outputs from *colspace*, which correspond to the *hue* and *saturation* outputs from the module (for example ***tmp003*** and ***tmp005*** in Figure 4.2.2.d).



28. Use the connector icon to connect the first and third raster output files from the *colspace* module to *expand* modules.
29. Right click on the first *expand* module. The *Parameters* window will open.
30. In the blank text box next to *Expansion factor*, type **2** (Figure 4.2.2.e).

31. Click *OK*.
32. Right-click on the output file icon from this expand operation, currently indicated with a temporary name such as ***tmp006***. The *Change layer name* window opens. Change the file name to **hue_expand**.
33. Repeat steps 29-31 to specify an *Expansion factor* of **2** for the second *expand* module. Rename the output file **sat_expand** (sat is short for saturation) (Figure 4.2.2.e).

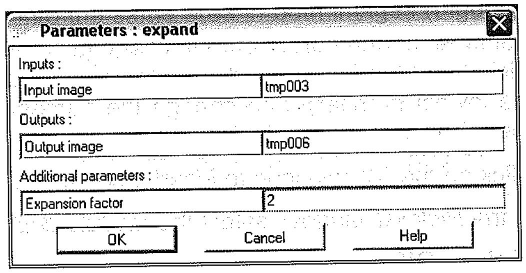


Figure 4.2.2.e Entering the expansion factor of **2** in the *expand* module.

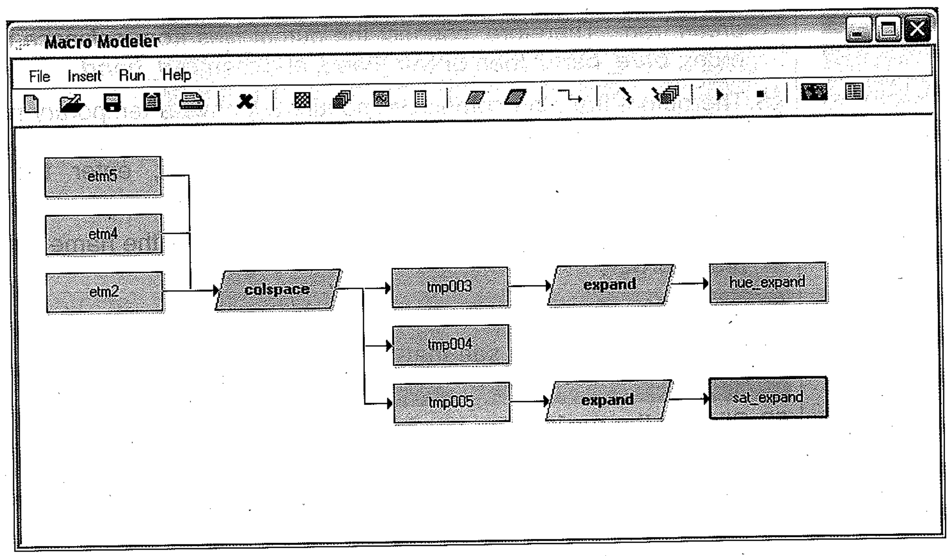
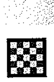


Figure 4.2.2.f The model with *colspace* and *expand* modules.

Now we will insert the panchromatic band into the model, substituting it for the lightness data in the reverse of the color space transform, from HLS back to RGB. The final step will be to construct a composite for viewing our results.

HLS resolution merge with the MACRO MODELER (cont.)

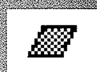


34. Click on the *Raster Layer* icon to insert a data input into the model.
35. In the *Pick list* window, select the data layer ***etm_pan***.
36. Click on *OK*.
37. Line up raster file ***etm_pan*** between the expanded *hue* and *saturation* raster files (***hue_expand*** and ***sat_expand*** in Figure 4.2.2.f).

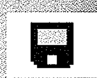
38. Click on the *Module* icon to insert a command module into the model.

39. In the pick window, select the module *colspace*.
40. Click on *OK*.
41. This time we need to convert from HLS to RGB, which we saw above was the default option in colspace. Therefore we can directly connect the input files to the new *colspace* module.

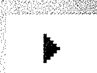
42. Use the connector icon to connect the expanded hue output (***hue_expand*** in Figure 4.2.2.f), ***etm_pan***, and the expanded saturation output (***sat_expand***), *in that order.*
43. Rename the temporary output files (e.g. **tmp008**, **tmp009**, **tmp010**), by right-clicking on the blue rectangle representing each file (starting with the file with the lowest number), and change the names to **red_band**, **green_band** and **blue_band**, respectively.



44. Click on the *Module* icon to insert a command module into the model.
45. In the *Pick list* window, select the module *composite*.
46. Click on *OK*.
47. In connecting files to modules it is very important to connect the files in the correct order. The *composite* module expects input files in the order *blue, green, red*. Therefore, connect the output files from *colspace* module in this order: ***blue_band***, then ***green_band***, and then ***red_band***.
48. The output from the composite module will have a temporary name, such as tmp011. Right click on the blue rectangle representing this temporary file, and in the *Change Layer Name* dialog box, enter the new name, **542_pan_hls_merge**.



49. Click on the *Save* icon, and when prompted, enter the name for the model as **hls_merge**.
50. Click *OK*.
51. Review the model to see that all the components are correctly linked (Figure 4.2.2.g).



52. Click on the *run* icon.
53. A window will open in which you are warned that the files created by the model will overwrite any existing files of those names. Click on *Yes to all*.

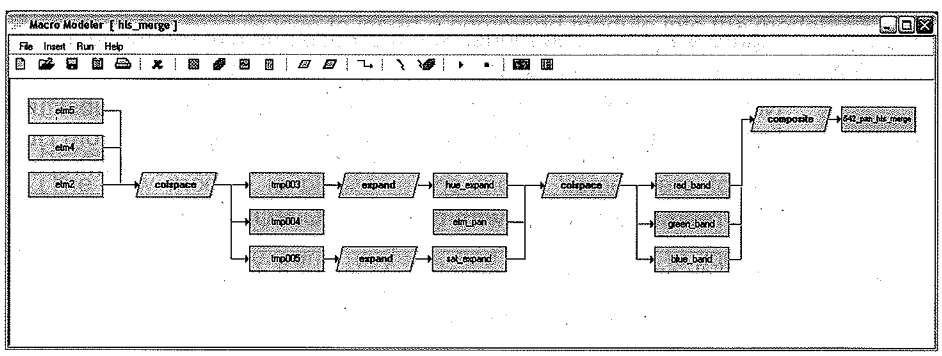


Figure 4.2.2.g HLS resolution merge model.

As the model runs, the progress through the various steps is clearly illustrated by the sequence of modules that turn green. After the program is completed, the merged image will be displayed automatically.

Let us now compare the standard false color composite of bands 2, 4 and 5 we created in Section 4.2.1 with the merged image comprising bands 2, 4 and 5 with the panchromatic band.

Use the DISPLAY LAUNCHER to display the ***etm542*** image. Select an area, for example the east end of Deep Bay (the significant embayment to the north of the airport), and zoom into the same area in both images (Figure 4.2.2.h and Figure 4.2.2.i). Note how the detail is sharpened in the merged image. The spectral quality, however, is slightly changed in the merged image. Both the water areas and agricultural areas have different shades of blue from the original. This slight mismatch in the spectral quality is due to the fact that the Landsat panchromatic data are statistically different from the 542 lightness band. The simple substitution of the panchromatic data for lightness results in a slightly different spectral character to the resulting RGB image.

Before starting the next section, close all files, including the MACRO MODELER.

Figure 4.2.2.h Landsat 5,4,2 (RGB) false color composite image of the eastern end of Deep Bay with 30 m resolution.

Figure 4.2.2.i HLS merge of Landsat bands 5,4,2 (RGB) and the panchromatic band, with approximately 15 m resolution.

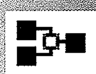
4.2.3 Multiplicative Merge

We saw in section 4.2.2 that some multiresolution merge methods change the relative spectral values, and colors are consistent between a regular false color composite and one made using the merged bands. Therefore, our aim in this section will be to develop a merge procedure that does not change the relative spectral properties. One way to do this is to use a multiplicative approach that uniformly enhances the lower resolution spectral bands with the panchromatic band.

Rather than simply multiply directly the panchromatic bands with the multispectral bands, we will first filter the panchromatic band. If you remember from our earlier exercise in filtering, a high pass filter will emphasize the edges of features, while simultaneously removing much of the average brightness signal associated with the feature. By using a high pass filtered image as an input into the image merge, we will sharpen the boundaries of features, while also retaining the integrity of the spectral characteristic of the feature. Let's create the model and compare the results to the HLS merge.

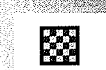
Note: In this model, we will assume you have gained familiarity with the MACRO MODELER, and therefore the instructions will be shortened somewhat for commands that we have already used a number of times. If necessary, you can always refer back to Section 4.2.2 to see more detailed instructions for these commands.

Multiplicative resolution merge with the MACRO MODELER

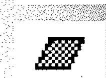


Menu Location: **Modeling – Model Deployment Tools - MACRO MODELER**

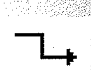
1. Start the MACRO MODELER either from the main menu or the icon bar.
2. In the MACRO MODELER window, click on *File* and select *Delete all temporary* files.
3. Click on *File* and select *Set/Reset temporary file counter*.
4. The *Set/Reset TMP File Counter* window will open. Click the *Reset* button. If the value for Current counter value is not *0*, change the value in the *Set next counter window* to ***0***. Click *OK*.



5. Use the *Raster Layer* icon to insert data layer ***etm2*** into the model. Repeat to insert ***etm4*** and ***etm5*** into the model, in that order.



6. Use the *Module* icon to insert the *expand* command module into the model. Repeat to insert two more *expand* modules, to create a total of three *expand* modules.
7. Arrange the *expand* modules, one each in front of the three input file, ***etm2***, ***etm4*** and ***etm5***.



8. Use the *Connector* icon to connect each of the three blue rectangles representing the raster layers, ***etm2***, ***etm4*** and ***etm5***, to an *expand* module (Figure 4.2.3.a) (*Note that your temporary output names may have different numbers, e.g.* ***tmp002*** *where the figure shows* ***tmp000****. This is not significant. The important issue is how the files are connected, and for some program modules, such as composite, the order in which they are combined.*)
9. Sequentially right-click in each *expand* command module, and each time the *Parameter* window opens, set the *Expansion factor* to **2**.

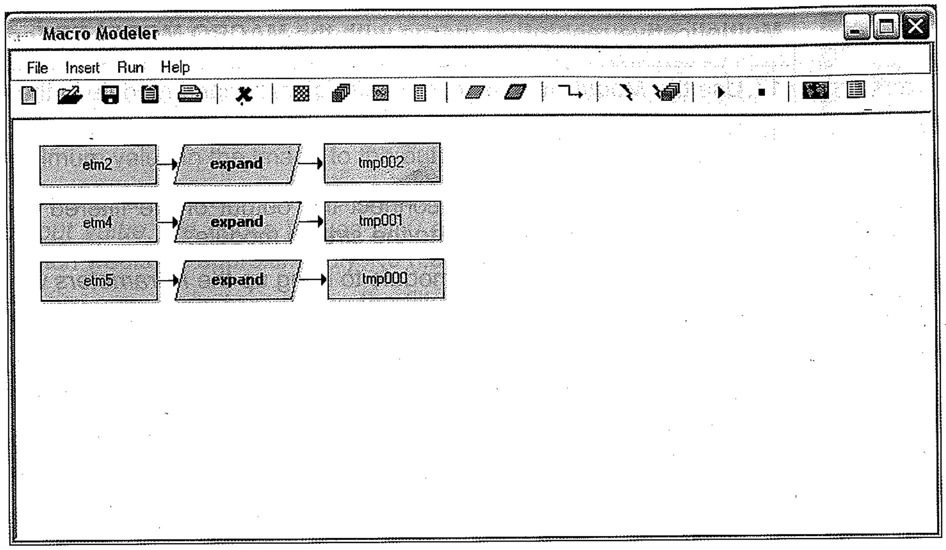
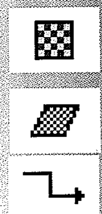


Figure 4.2.3.a The initial model with three *expand* modules.

Having added the Landsat multispectral bands and expanded them to the same resolution as the Landsat panchromatic band, we will now add the panchromatic band to the module, and filter it to highlight feature boundaries. Once we have filtered the panchromatic band, we will scale it so that its histogram and mean are centered on one.



Multiplicative resolution merge with the MACRO MODELER (cont.)

10. Use the *Raster Layer* icon to insert data layer ***etm_pan*** into the model.
11. Arrange the etm_pan rectangle, in line under the other input data layers.
12. Use the *Module* icon to insert the *filter* command module into the model.
13. Use the Connector icon to connect the ***etm_pan*** layer to the *filter* module.
14. Right-click on the *filter* module to bring up the *Parameters* window.
15. Right-click in the field to the right of the *filter-type,* and select *High-pass* (Figure 4.2.3.b) .
16. Click on *OK* to close the *Parameters* window.

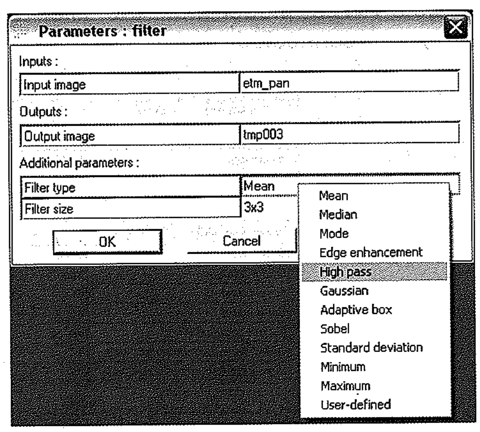
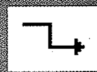


Figure 4.2.3.b Setting the *Filter type* to *High Pass.*



Multiplicative resolution merge with the MACRO MODELER (cont.)

17. Use the *Module* icon to insert a *stretch* command module in the model.
18. Move the *stretch* module and its output below the *filter* module, to save space.
19. Use the *Connect* icon to connect the output of the filtered ***etm_pan*** image (***tmp003*** in Figure 4.2.3.c) to the *stretch* module.
20. Right-click on the *stretch* module to bring up the *Parameters* window.
21. Click in the field to the right of *Output data type*, and select *Real* from the pop-up menu.
22. Click in the field to the right of *Exclude background?,* and select *No*.
23. Click in the field to the right of *Lowest non-background output value*, and enter **0**
24. Click in the field to the right of *Highest non-background output value*, and enter **2**
25. Leave the remaining fields with their default values (Figure 4.2.3.d), and close the window by clicking on *OK*.

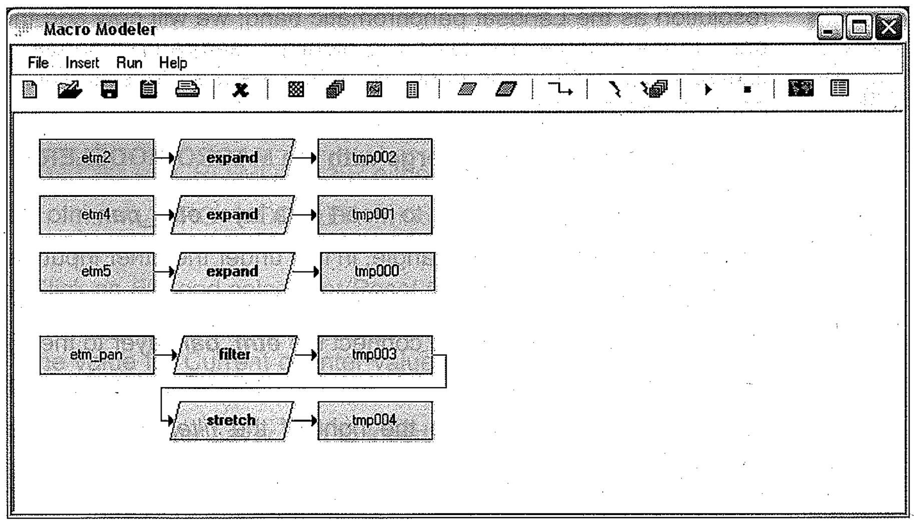


Figure 4.2.3.c The model with the *filter* and *stretch* modules added and connected.

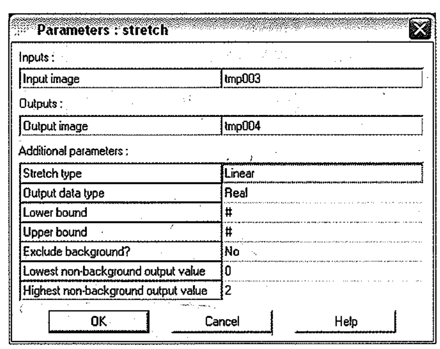


Figure 4.2.3.d The stretch module *Parameter* window.

The Parameters window for stretch (Figure 4.2.3.d) had # symbols in the fields for Lower bound and Upper bound. For this module, # is used to indicate that the program should use the appropriate values from the image itself. Thus, in this case, the input image will be queried, and the stretch will extend from the minimum value in the image to the output value.

For the fields *Lowest non-background output value* and *Highest non-background output value*, we chose values of *0* and *2*, so that the average value after the stretch would be approximately 1.0 (i.e. half way between the two extremes).

We are now ready to combine the filtered and stretched panchromatic band with the multispectral bands by a simple multiplication. Since the filtered, panchromatic band is centered on approximately 1.0, the only changes in the multispectral bands will be on the edges of features, and these will be made slowly lower or higher, thus accentuating those edges.

Multiplicative resolution merge with the MACRO MODELER (cont.)

26. Click on the *Module* icon and insert an *overlay* command module.
27. Repeat the previous step twice, to create a total of three *overlay* modules in the model.
28. Line up each pink parallelogram that represents an *overlay* module with an output temporary file from the three *expand* modules.
29. Use the *Connect* icon to connect each output temporary file from the *expand* modules to the adjacent *overlay* module.
30. Use the *Connect* icon another three times to connect the output file from the stretch module (***tmp004*** in Figure 4.2.3.e) to each *overlay* module.
31. Right-click on the first *overlay* module to bring up the *Parameters* window.
32. Click on the field to the right of *Operations*, and select *Multiply* from the pop-up menu.
33. Repeat the previous two instructions for each *overlay* module, so that each module is set to *Multiply*.

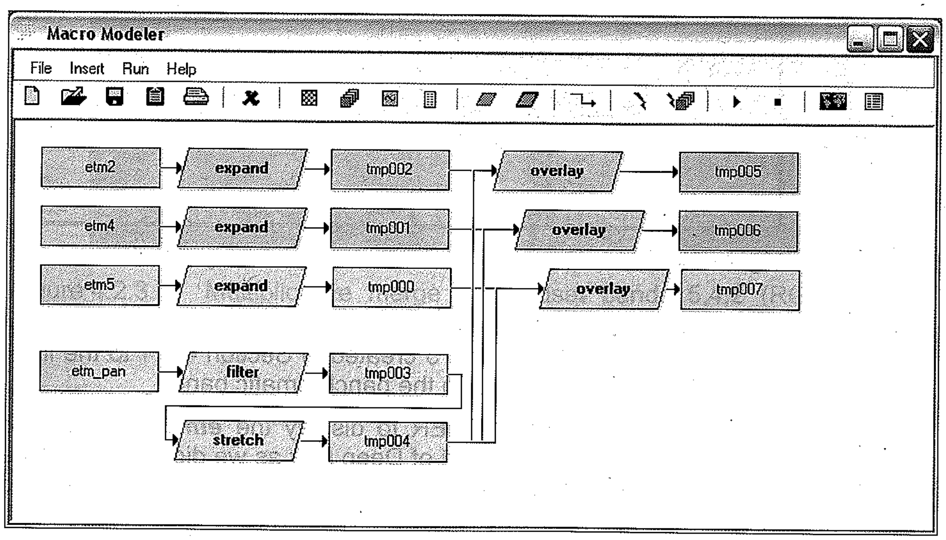


Figure 4.2.3.e The model with the three *overlay* modules connected.

We are now ready to create a false color composite image of the merged data.

Multiplicative resolution merge with the MACRO MODELER (cont.)

34. Use the *Module* icon to insert the *composite* command module in the model.
35. Connect the temporary raster files from the *overlay* modules so that if you follow along a row, the result of the expansion and overlay operation for the ***etm2*** file is connected first, then ***etm4***, and finally ***etm5***. In Figure 4.2.3.f, this would be in the order ***tmp005***, ***tmp006*** and ***tmp007***.
36. The output from the *composite* module will have a temporary name, such as ***tmp008***. Right click on the blue rectangle representing this temporary file, and in the *Change Layer Name* dialog box, enter the new name, **542_pan_mult_merge**.
37. Click on *OK*.

38. Click on the *Save* icon.
39. Specify the Model file name **mult_merge**.
40. Click on *OK*.
41. Review the model to see that all the components are correctly linked (Figure 4.2.3.g).

42. Click on the *run* icon.
43. A window will open in which you are warned that the files created by the model will overwrite any existing files of those names. Click on *Yes to all*.

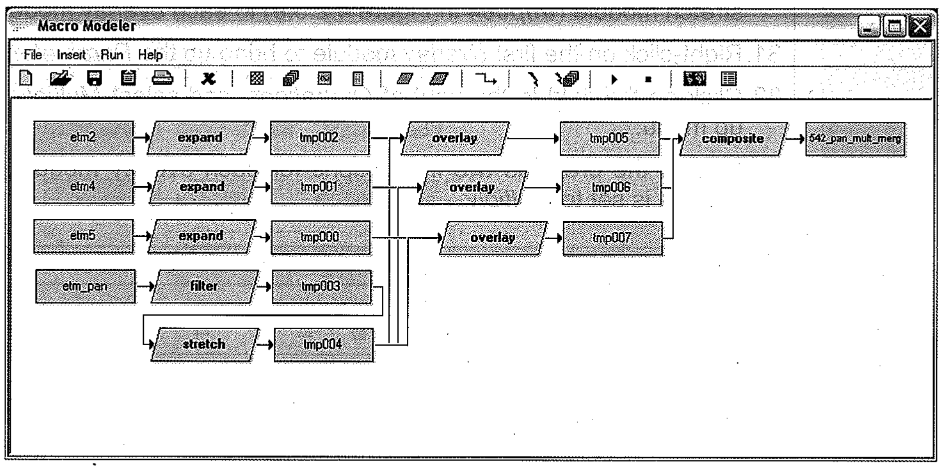


Figure 4.2.3.f The multiplicative resolution merge model.

As we did with the HLS merge, let us now compare the standard false color composite of bands 2, 4 and 5 created in Section 4.2.1 to the image comprising bands 2, 4 and 5 merged with the panchromatic band.

Use the DISPLAY LAUNCHER to display the ***etm542*** image. Zoom into the same area of the eastern end of Deep Bay as we did before (Figures 4.2.3.g and 4.2.3.h). Note that we have been able to match accurately the spectral character of the mud flats that extend into Deep Bay, as well as the spectral signature of the exposed soil on the tops of hills. We can see that we successfully retained the relative spectral characteristics of the image. Also, look at the urban areas in the zoomed images and we can see a definite sharpening of the roads and buildings.

Figure 4.3.2.g Landsat 5,4,2 (RGB) false color composite image of the eastern end of Deep Bay with 30m resolution.

Figure 4.2.3.h Multiplicative merge of Landsat bands 5,4,2 (RGB) and the panchromatic band, with approximately 15m resolution.

Chapter 5 Image Ratios

5.1 Introduction to Image Ratios

In this chapter, we will explore three different applications of band ratios. We will start with one of the most common ratios used, that of a vegetation index. We will then look at how a ratio might be designed to separate snow from clouds. In the final section of the chapter we will look at ratios in a more in-depth fashion. We will design three ratios to highlight different mineral compositions, and use the ratios in a false color composite.

5.2 Copy Data for This Chapter

Starting with this chapter, we will use different data sets for each chapter, and even for different sections within each chapter. Thus, in this chapter we will work with three different image sets, one for each for vegetation, snow and rock ratios. Therefore, you should now copy the *Chap5* folder from the CD, and paste it as a new subfolder within the *\ID Man* folder on your computer.

After you have copied the folder, you should remove the Read-Only attribute from this new folder on your computer. This is done by right-clicking on the *Chap5* folder name, selecting *Properties* from the pop-up menu. A dialog box will open, labeled *Chap5 Properties* (if you apply this procedure to the entire *ID Man* directory, then the dialog box will be labeled *ID Man Properties*). Now clear the check mark from the *Read Only* check box, by clicking in the box. You should then click on the button for *Apply*, and in the subsequent *Confirm Attribute Changes* dialog box, accept the default *Apply changes to this folder, subfolder and files*, and click on *OK*. You will need to also click on *OK* in the *Chap5 Properties* dialog box.

Note: Section 1.3.1 provides detailed instructions on how to copy the data from the CD, and also on how to remove the *Read-Only* attribute from the data. Also, the procedure for setting up the *ID Man* folder on your computer is described.

5.3 Vegetation Indices

5.3.1 Background

5.3.1.1 The normalized difference vegetation index (NDVI)

Some enhancement techniques help the analyst explore a data set, and do not require any preconceived ideas about the potential spectral properties of the objects in the scene. Sometimes, however, the analyst would like to enhance a specific land cover, such as vegetation. There is a very long history in the remote sensing literature of using ratios as a method of estimating vegetation abundance (i.e. biomass estimates) and greenness associated with the seasonal cycle of deciduous vegetation.

Green vegetation is particularly well suited for spectral enhancement because the pigment, chlorophyll, absorbs blue and red wavelengths strongly, and thus the reflectance of leaves at these wavelengths is very low (Figure 5.3.1.1). On the other hand, leaves typically reflect strongly at near infrared wavelengths, providing a very strong contrast between the red and near infrared. It is this contrast that the vegetation ratios capitalize on. In this section we will see how a contrast in spectral properties between two different wavelengths provides a much more reliable method of distinguishing a particular land cover than just a single wavelength does.

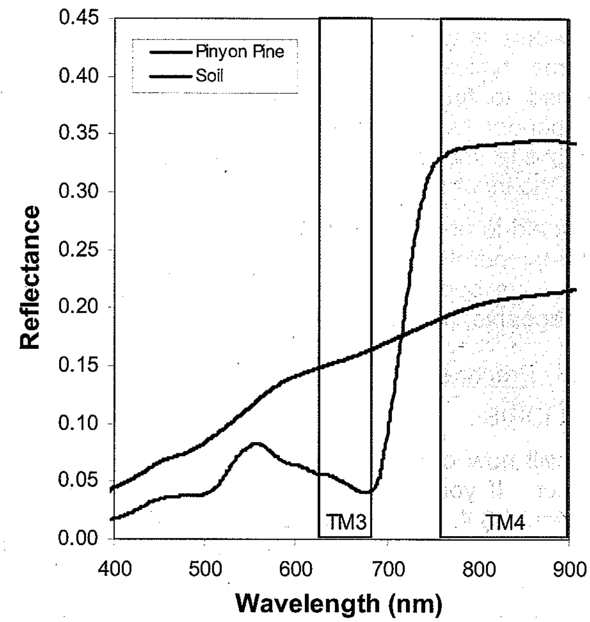


Figure 5.3.1.1.a Graph of the spectral reflectance of vegetation and soil, with the locations of TM bands 3 (red) and 4 (near infrared) shown.

The ratio we use is the **normalized difference vegetation index**, or **NDVI**. This ratio is defined:

NDVI = (Near Infrared – Red) / (Near Infrared + Red).

NDVI is a variant of the simple ratio of Near Infrared/Red. However, by constructing the ratio as the difference of the two wavelengths over the sum of the two wavelengths, NDVI is normalized, so that the range falls between -1 and +1, and the middle value is zero. Furthermore, NDVI is designed such that high values of the ratio (close to +1) indicate abundant green vegetation, and values near zero or less indicate an absence of vegetation.

5.3.1.2 Background on the data used in this exercise

The data for this exercise is from the National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR). The AVHRR sensor has been flown on NOAA satellites since the 1970s, and therefore there is a large archive of AVHRR data, providing a very rich source of information for multi-temporal studies. AVHRR data are usually classified as coarse resolution, as the nominal pixel size at nadir is 1.1 kilometer. However, the sensor has a relatively broad field of view (approximately 2400 kilometers), thus facilitating the construction of global image mosaics. Although different AVHRR sensors have had slightly different band combinations over time, all AVHRR sensors have included a red band (band 1, which measures 0.58-0.68 µm radiation) and a near infrared band (band 2, 0.72-1.10 µm), in addition to channels in the 3-5 μm and 8-12 μm ranges. For this exercise, we will only work with AVHRR bands 1 and 2.

In continental or global scale analyses of the terrestrial earth, the presence of clouds is a particular problem, because it is extremely rare that cloud free scenes are obtained over large regions. However, with coarse resolution data there is a simple solution that draws on the short revisit time of the sensor. In essence, the procedure is to overlay a large number of images acquired within a short period of time, typically one to four weeks. This multi-temporal stack of images is queried to find the image with the lowest amount of cloud, for each pixel independently. This information is then used to assemble a single multi-temporal composite image that is cloud-free, or as nearly cloud-free as can be achieved from the input data.

The data for this exercise comprises two AVHRR images of Africa. The data are multi-temporal mosaics representing the months of February and July 2001. The data have been resampled to a 20 kilometer grid, to make the file size more manageable, and reduce noise.

5.3.2 Preparation

Start IDRISI.

We will now create a new project file and specify the working folders for that project. If you find the instructions below too brief, you may need to review Section 1.3.4, which provides greater detail. However, just to remind you, the **project file** is the file used by IDRISI to keep track of the data locations for a particular exercise. The **working folder** is the specific folder where your data are found. Additional **resource folders** can also be specified.

Create a new project file and specify the working folders with the IDRISI EXPLORER

Menu Location: **File – IDRISI EXPLORER**

1. Start the IDRISI EXPLORER from the main menu or toolbar.
2. The *IDRISI EXPLORER* window will open on the left side of the IDRISI workspace. At the top left of the *IDRISI EXPLORER* window will either be a plus (+) or a minus (-) symbol. If the symbol is a plus sign, click it to expand the window.
3. Select the *Projects* tab.
4. If the *Editor* pane obscures the listing of project files, drag the boundary of the Editor pane down, to show the *Projects* pane (Figure 5.3.2.a).
5. Right click within the *Projects* pane, and select the *New Project Ins* option.
6. A *Browse For Folder* window will open. Use this window to navigate to the *ID_Man* folder, which is the folder you created on your computer for the data for this manual. Now navigate to the *Chap5_3* subfolder, within the *ID Man/Chap5* folder.
7. Click *OK* in the *Browse For Folder* window.
8. A new project file *Chap5_3*, will now be listed in the *Project* pane of the IDRISI EXPLORER. The working folder will also be listed in the Editor pane. (Figure 5.3.2.b).

9. Note that you can switch between the *Chap1-4* project and this new *Chap5-3* project by selecting the appropriate radio buttons in the *Project* pane of the IDRISI EXPLORER.
10. Close the IDRISI EXPLORER by clicking on the red *x* in the upper right corner of the *IDRISI EXPLORER* window.

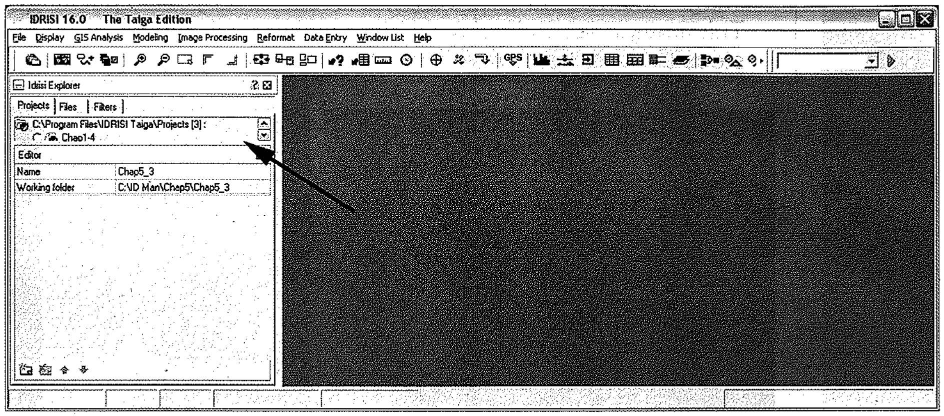


Figure 5.3.2.a *Editor* pane obscuring the *Projects* pane. Arrow points to the boundary of the *Editor* pane.

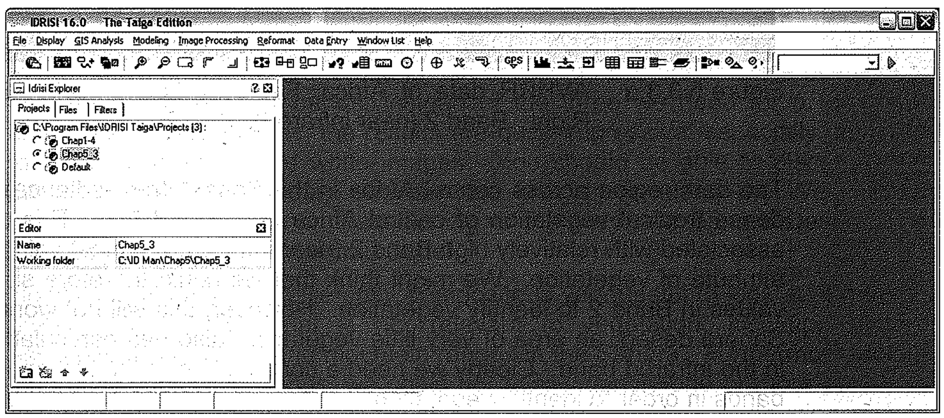


Figure 5.3.2.b *Projects* and *Editor* panes visible, new project specified.

5.3.3 <u>Exploratory investigation of the AVHRR data of Africa</u>

Initial display and enhancement of AVHRR images

1. Start the DISPLAY LAUNCHER.
2. In the *DISPLAY LAUNCHER* window, click on the browse button (…) to select the file name for display.
3. Select the ***feb_b1*** image (the AVHRR red band) from the *Pick list* window, and click on *OK* to close that window.
4. In the *DISPLAY LAUNCHER* window, select a *GreysScale* palette.
5. Click on *OK* to display the image.
6. Find the *Composer* window in the IDRISI workspace. In the *Composer* window, click on the *Layer Properties* button.

7. In the *Layer Properties* window, adjust the *Display Max* slider so that the image has more contrast, and the pattern in the Sahara Desert (North Africa) is clearer. A value of **675** appears to provide a good contrast (Figure 5.3.3.a).
8. In the Layer Properties window, click on *Save* button, and then *OK*.
9. Now repeat the above steps 1-5 to display in another viewer the ***feb_b2*** image (the near infrared band), also with a *GreyScale* palette (Figure 5.3.3.a). This image has better contrast, and does not appear to need the additional steps to specify a greater contrast.

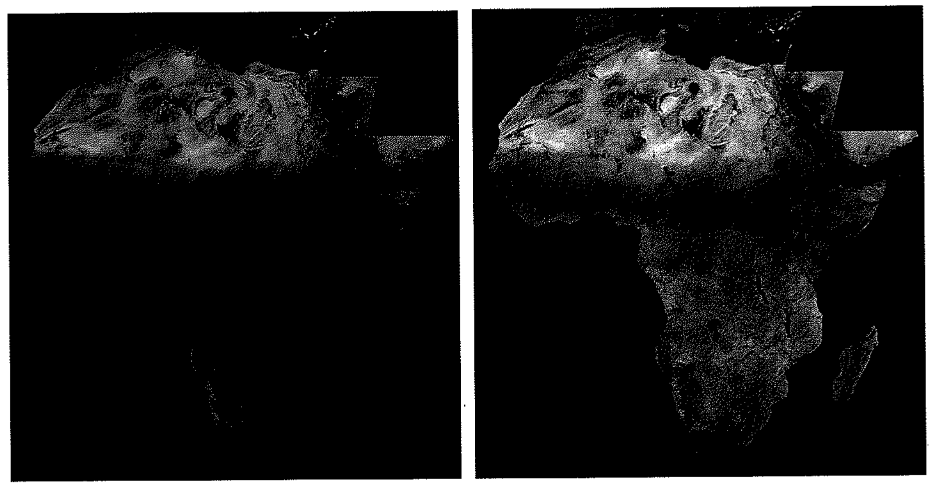


Figure 5.3.3.a AVHRR data of Africa, February 2001. Left: Band 1 (red). Right: Band 2 (near infrared).

The dark region across central Africa in the Band 1 (red radiance) image is the dense tropical vegetation of central Africa (Figure 5.3.3.a). This dark region is associated with relatively high Band 2 (near infrared radiance) values, a common attribute of vegetation. We might think that we could therefore simply use high values in Band 2 to identify vegetation. However, this will not work because the Sahara desert, an area of very little vegetation, also has particularly high values in the infrared band. Clearly we need a combination of the red and near-infrared bands in order to identify vegetation.

One simple way of combining two bands is to create a false color composite. The creation of a false color composite was introduced in detail in Section 2.2.4, and that section should be consulted if you find the instructions too brief here.

Create a false color composite image

Menu Location: **Display - COMPOSITE**

1. Start the COMPOSITE program using the main menu or tool bar.
2. In the *COMPOSITE* dialog box, specify the file name for the *Blue image band* by clicking on the adjacent browse button (…), and in the resulting *Pick list* selecting ***feb_1***. Click on *OK* to close the *Pick list.*
3. Repeat the previous step for the *Green image band*, specifying the ***feb_2*** image.
4. Again, repeat the previous step for the *Red image band*, this time specifying the ***feb_1*** image (i.e. the same as for the *Blue image band*).

5. Enter the *Output image* filename in the text box provided: **feb_fcc**.
6. Enter in the *Title* text box: **February False Color Composite (R,B = red, G = IR)** .
7. Accept all other defaults, and click *OK* to create and display the false color composite (Figure 5.3.3.b).

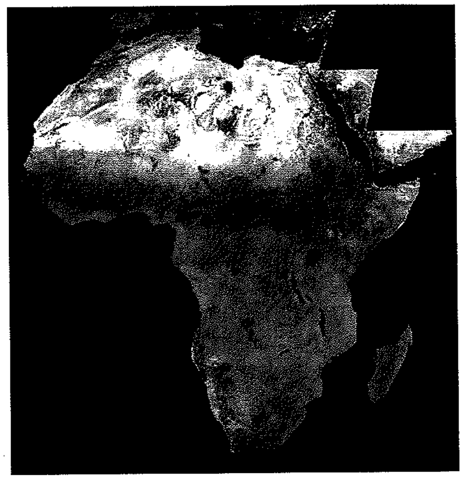


Figure 5.3.3.b Africa February AVHRR false color composite image.

In the above steps, we are forced to use one of the two bands twice because we only have two AVHRR bands, instead of the three we need for a false color composite. Nevertheless, the results are quite impressive, especially compared to the original black and white images. You should be able to discern a very distinct east-west boundary between the lush green along the West African coast, and the dry interior, transitioning to the very arid Sahara Desert. This transition region is known as the Sahel.

However, although the false color composite is very useful to look at, it retains a great deal of detail that is not relevant to vegetation, including patterns associated with dunes and mountain ranges in the Sahara. Furthermore, color is inherently subjective. Thus, we could not easily identify one or more thresholds that differentiated between relatively dense and less dense vegetation regions. On the other hand, a ratio such as NDVI is well-suited for such tasks.

5.3.4 NDVI image of Africa

IDRISI offers a built in program, VEGINDEX for calculating 19 different vegetation ratios. We will use this program to calculate one of the simplest and most enduring ratios, NDVI.

Calculating NDVI with VEGINDEX

Menu location: **Image Processing – Transformation - VEGINDEX**

1. Start VEGINDEX from the main menu.
2. The *VEGINDEX* dialog box will open.
3. Select the radio button for *NDVI*.
4. Click on the browse button (…) next to the *Red band* text box, to identify the input file ***feb_1***.

5. Click on the browse button (…) next to the *Infrared band* text box, to identify the input file as ***feb_2***.
6. In the *Output image* text box, type **feb_NDVI**.
7. Click on OK to generate and display the image.
8. After the program has finished processing, find the *VEGINDEX* dialog box again, which may be hidden by the displayed image.
9. Change the file specified for the Red band to ***july_1***.
10. Change the file specified for the Infrared band to ***july_2***.
11. Type a new *Output image* filename: **july_NDVI**.
12. Click on *OK*.

The two images should show the vegetation patterns quite well. However, to be able to compare between the images, it is necessary to adjust the display properties so that a particular DN value has the same associated color in both images. The current images have default stretches, based on the minimum and maximum values in each image. The fact that the two images have different stretches is immediately apparent when you compare the ocean background areas.

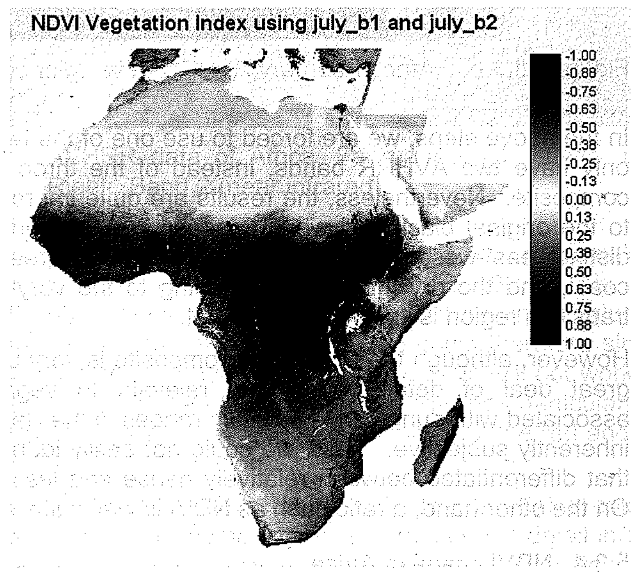


Figure 5.3.4.a Africa NDVI for February.

Setting the image contrast

1. Find the *Composer* window, which is automatically present when any image is displayed.
2. Click in the ***feb_NDVI*** image, and then click on the *Layer properties* button in the *Composer* window.
3. In the *Layer Properties* window, clear the *Display Min* text box, and then enter **-1**.
4. Clear the *Display Max* text box, and then enter **1**.
5. Click on *Apply*, and then *Save*.

6. The image should now have a legend that extends from -1 to +1.
7. Click in the ***july_NDVI*** image, and then click on the *Layer properties* button in the *Composer* window.
8. In the *Layer Properties* window, clear the *Display Min* text box, and then enter **-1**.
9. Clear the *Display Max* text box, and then enter **1**.
10. Click on *Apply*, *Save*, and then *OK*.

In comparing the February and July (Figure 5.3.4.a) data, note how the band of high values (deep green) just south of the Sahara Desert has moved north in July. In contrast, Southern Africa, with the exception of the tip of Africa, near Cape Town, is now relatively dry. These two images capture the major seasonal patterns of Africa and, in particular, show how the seasons follow the sun.

In January, the sun's rays are most intense in the southern hemisphere. The low pressure belt and heavy rainfall caused by the rising air due to intense heating is south of the equator, and the Sahel region is relatively dry. By July, however, the latitude of the sun's most intense illumination has migrated to the northern hemisphere. Likewise, the low pressure belt also moves north, bringing welcome rains to the Sahel. For the island of Madagascar, off the south east coast of Africa, only the east coast is relatively wet in July. On-shore easterly winds and local orographic precipitation bring moisture in an otherwise dry region.

5.4 Discriminating Snow from Clouds

5.4.1 Overview

One of the most basic image enhancement procedures is the false color composite. The combination of three bands, each assigned to a different primary color, is a powerful method for visualizing the spectral information in an image. As the number of spectral bands in a data set increases, the potential number of combinations of bands as false color composites increases exponentially. It is therefore important to consider what factors make a good false color composite, and how the colors in the image can be interpreted if fundamental information is available regarding the spectral properties of the surfaces in the image.

In this exercise, we will choose a band combination to separate snow and clouds, and also predict the associated colors based on the band combination and color assignment we choose. We will then develop a snow ratio, or index, and use that to set a threshold that maps snow. Thus, this exercise will start with enhancement, and end with a simple classification. The procedure we will follow is loosely based on Dozier (1989).

5.4.2 Snow and Cloud Properties

We know from everyday experience that both fresh snow and clouds are typically very bright in the visible part of the spectrum. In fact, snow and clouds have a reflectance close to 100% in the visible (Figure 5.4.2.a). However, their spectral properties beyond the visible, in the short wave infrared, are very different. Clouds are also bright in the short wave infrared, but snow has very low reflectance beyond 1.4 μm (Dozier 1989).

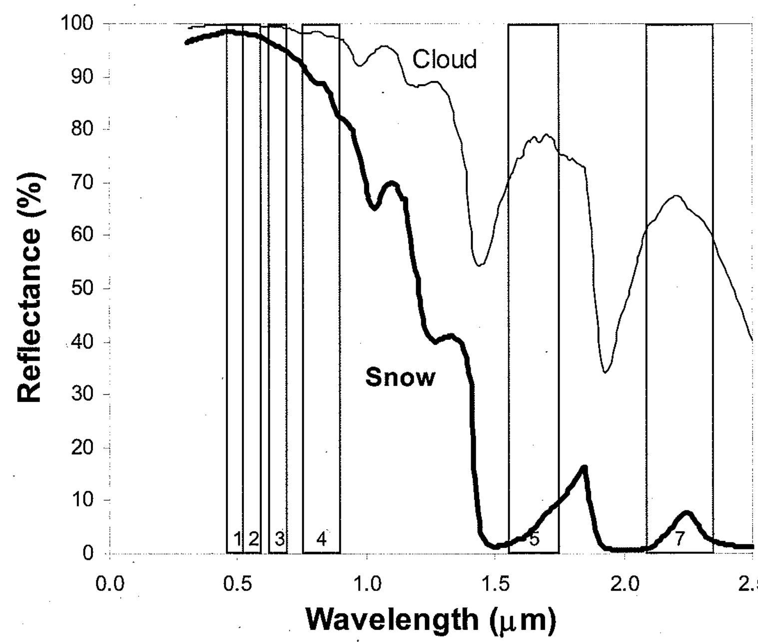


Figure 5.4.2.a Comparison of the spectral reflectance of snow and cloud, as well as the Landsat spectral band passes. (Snow modeled as 200 µm radii grains, cloud as 5 µm radii water droplets, modified from Dozier 1989).

Based on Figure 5.4.2.a, we can see that with careful selection of the spectral bands it should be possible to create a false color composite that shows snow and cloud as different colors. A false color composite has the advantage of combining information from different wavelengths. For example, although Figure 5.4.2.a appears to suggest that a single band, such as the 1.55 – 1.75 µm TM band 5, can potentially differentiate snow and clouds, we need to remember that there are usually other spectral classes that may confuse our interpretation. Thus, snow is not the only substance that has a low reflectance in band 5; water also has a low reflectance in that band. Adding further complexity is the effect of varying illumination on slopes of different steepness and topographic aspect. Furthermore, mixed pixels dilute the characteristic spectral properties of the cover classes. Combinations of bands, including both false color composites for visual interpretation, and ratios of bands for either visual or more quantitative interpretation, can in many cases overcome these problems.

5.4.3 Preparation

For this section we will use Thematic Mapper data from the Cascade Mountains of Washington State, USA. In Section 5.2 you should have already copied the data from the CD. However, we still need to set the *Project* and *Working Folders* for this new data set.

Before starting you should close any dialog boxes or displayed images in the IDRISI workspace.

Create a new project file and specify the working folders with the IDRISI EXPLORER

Menu Location: **File – IDRISI EXPLORER**

1. Start the IDRISI EXPLORER from the main menu or toolbar, if it is not already open.
2. In the *IDRISI EXPLORER* window, select the *Projects* tab.
3. Right click within the *Projects* pane, and select the *New Project Ins* option.
4. A *Browse For Folder* window will open. Use this window to navigate to the *ID_Man* folder, which is the folder you created on your computer for the data for this manual. Now navigate to the *Chap5_4* subfolder, within the *ID Man/Chap5* folder.
5. Click *OK* in the *Browse For Folder* window.
6. A new project file *Chap5_4*, will now be listed in the *Project* pane of the IDRISI EXPLORER. The working folder will also be listed in the Editor pane.
7. Close the IDRISI EXPLORER by clicking on the red *x* in the upper right corner of the *IDRISI EXPLORER* window.

5.4.4 A Color Composite to Discriminate Snow from Clouds

We will first create a simulated natural color composite of the TM data. We call this a natural color composite because it somewhat replicates the colors we might see with our eyes, if we were to fly over the landscape. We should remember, however, that the TM bands are not perfect matches for the wavelengths the eye is sensitive to, and furthermore, each band is stretched in the composite generation. Therefore the colors will not be identical to natural colors.

Create a simulated natural color composite image

Menu Location: **Display - COMPOSITE**

1. Start the COMPOSITE program using the main menu or tool bar.
2. In the *COMPOSITE* dialog box, specify the file name for the *Blue image band* by clicking on the browse button (...), and in the resulting *Pick list* selecting ***TM_casc_b1***. Click on *OK* to close the *Pick list.*
3. Repeat the previous step for the *Green image band*, specifying the ***TM_casc_b2*** image.
4. Again, repeat the previous step for the *Red image band*, this time specifying the ***TM_casc_b3*** image.
5. Enter the *Output image* filename in the text box provided: **123comp**.
6. Enter in the *Title* text box: **Simulated Natural Color Composite**.
7. Accept all other defaults, and click *OK* to create and display the false color composite (Figure 5.4.4.a).

Figure 5.4.4.a Simulated natural color Landsat TM image of a mountain with snow and clouds in places.

In the simulated natural color image (Figure 5.4.4.a), snow and clouds are both white. However, the presence of shadows to the northwest of each cloud (the image is oriented that north is approximately in the "up" direction) makes it possible for a human interpreter to differentiate the clouds from the snow. However, in this image there are some patches of snow and small clouds that make the use of shadows alone challenging for snow and cloud differentiation. Furthermore, a spatial rule is difficult to implement using automated image processing, and most remote sensing enhancement is usually spectrally based.

Referring back to the graph shown in Figure 5.4.2.a, it is apparent that the standard false color composite has a major limitation in that it does not include a short wave infrared band, where snow and clouds have contrasting reflectance. Therefore, a better choice would be a false color composite produced from bands 2, 4, and 5.

For this reason, we will now create another false color composite. This time we will assign bands 2, 4 and 5, to blue, green and red, respectively.

Create a false color composite image

Menu Location: **Display - COMPOSITE**

1. If necessary, start the COMPOSITE program using the main menu or tool bar.
2. Specify the file name for the *Blue image band* as ***TM_casc_b2***.
3. Specify the file name for the *Green image band* as ***TM_casc_b4***.
4. Specify the file name for the *Red image band* as ***TM_casc_b5***.
5. Enter the *Output image* filename in the text box provided: **245fcc**.
6. Enter in the *Title* text box: **False Color Composite (2,4,5 as BGR)**.
7. Accept all other defaults, and click *OK* to create and display the false color composite.
8. Click *Close*, to remove the *COMPOSITE* dialog box.

For this false color composite image, we can predict the colors snow and clouds should be, based on a comparison of the expected relative intensities in each of three bands used (2, 4 and 5), as shown in Figure 5.4.2.a., and the color assigned to those bands in the image (blue, green and red, respectively). In addition, we need some information about the mixing of colors of light, based on the additive mixing system that applies to computer monitors (Figure 5.4.4.b).

- Clouds, which are bright in all three bands of this false color, should be represented by high red, green and blue values in the false color composite. A combination of red, green and blue makes white in the additive color scheme used on computer monitors (Figure 5.4.4.b).
- Snow, on the other hand, is bright in only the first two bands (2 and 4, represented by blue and green in the false color composite), but not the third band (5, represented by red). The combination of blue and green makes cyan (Figure 5.4.4.b).

Thus, in summary, for the TM Bands 2, 4, 5 false color composite, we predict clouds will be white, and snow cyan.

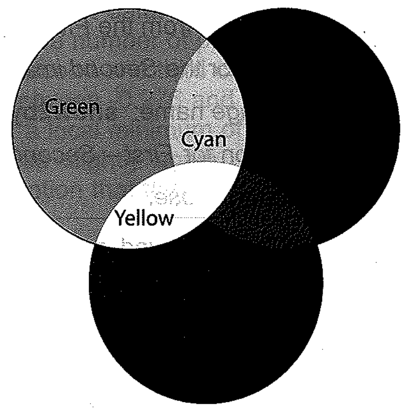


Figure 5.4.4.b Additive colors.

The non-standard false color composite (Figure 5.4.4.c) does indeed show snow in cyan, and clouds in white. In addition, vegetation is shown in green because of their strong near infrared (band 4) radiance, which is assigned to the monitor's green gun.

Figure 5.4.4.c Washington State false color composite. Bands 2,4,5 as BGR.

5.4.5 A Ratio to Discriminate Snow

The false color composite shown in Figure 5.4.4.c draws on the distinctive spectral reflectance pattern of snow: strong absorption in the short wave infrared TM band 5, and strong reflectance in the visible and near infrared, including TM bands 2 and 4. This contrast lends itself to the development of a snow ratio. One possible ratio is (Band 2 – Band 5)/ (Band 2 + Band 5) (Dozier, 1989). This is not a ratio that IDRISI offers as a prepared program. However, the program OVERLAY provides a simple way of implementing any ratio.

Calculating ratios with OVERLAY

Menu location: **GIS Analysis – Mathematical Operators – OVERLAY**

1. Start the OVERLAY program from the main menu or the icon tool bar.
2. In the *OVERLAY* dialog box, double click in the text box next to *First image*, and select ***TM_casc_b2*** from the *Pick list*. Click *OK*.
3. Select ***TM_casc_b5*** for the *Second image*, and click *OK*.
4. Enter the *Output image* name: **snow2by5**.
5. Select the radio button for *First – Second / First + Second*.
6. Click on *OK*, and then *Close*.

The ratio image will be displayed automatically (Figure 5.4.5.a). Ratio values that are high, those shown in red and yellow colors, indicate snow.

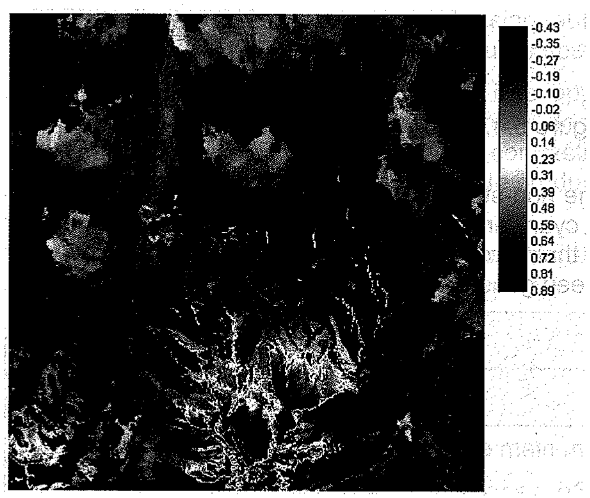


Figure 5.4.5.a TM (Band 2 – Band 5) / (Band 2 + Band 5) ratio image. The higher DN values (assigned to red colors in the figure) indicate areas of snow.

Finally, to make the location of the snow most clear, we will make a map that indicates where snow is located. This map could be used, for example, as a mask, to blank out any snow-covered areas. To create our map, we need to identify a threshold value in the snow ratio image that differentiates snow. The value we select is somewhat arbitrary, since the boundary is actually a fuzzy one; there will be a complete gradation from 100% snow-covered pixels to pixels without any snow at all. We will choose our threshold by examining the ratio image histogram. We observe that snow makes up only a relatively small proportion of the image. Therefore, in the ratio image, it should comprise the anomalously high values.

Compute the histogram of DN values with HISTO

Menu location: **GIS Analysis – Database Query – HISTO**

1. Start the HISTO program from the main menu or the toolbar.
2. Double click in the *Input file name* text box, and select ***snow2by5***. Click on *OK*.
3. Select the radio button for *Numeric*.
4. Accept all other defaults.
5. Click on *OK*.

Observe the resulting table of data. Note that the fourth column represents the histogram frequency, or the number of pixels in the image within the range of DN values specified in the second and third columns. The frequency values peak at 20,208 for DN values between -0.276 and -0.263, and then decline rapidly. The frequency values reach a local minimum of 215 between the values of 0.320 and 0.333, and then increase slightly again. We therefore will select 0.333 as a threshold, on the assumption that the slight increase is the influence of the snow pixels.

Thresholding is an operation of dividing a single band image into a small number of classes, in this case, just two. We will set up a rule, such that any input DN value below the threshold will be classed as 0, and any DN above the threshold, will be classed as 1.

Applying a threshold to an image with RECLASS

Menu location: **GIS Analysis – Database Query - RECLASS**

1. Start the RECLASS program from the main menu or toolbar.
2. The *RECLASS* dialog box will open.
3. Double click in the text box for *Input file,* select ***snow2by5*** from the *Pick list*, and click *OK.*
4. Enter a name for the *Output file*: **snowmap**.
5. Below the Output file name is the table of *Reclass parameters*. Complete the first line of the table as follows:
   Assign a new value of: **0**
   To all values from: **-1**
   To just less than: **0.333**
6. Complete the second line of the table:
   Assign a new value of: **1**
   To all values from: **0.333**
   To just less than: **1**
7. Check that the dialog box has been completed correctly (Figure 5.4.5.b).
8. Click on *OK*.
9. IDRISI will generate a warning notice: *Warning the input file contains real values. Would you like to convert the output file to integer?*
10. Click on *Yes* to accept this default of an integer output file.

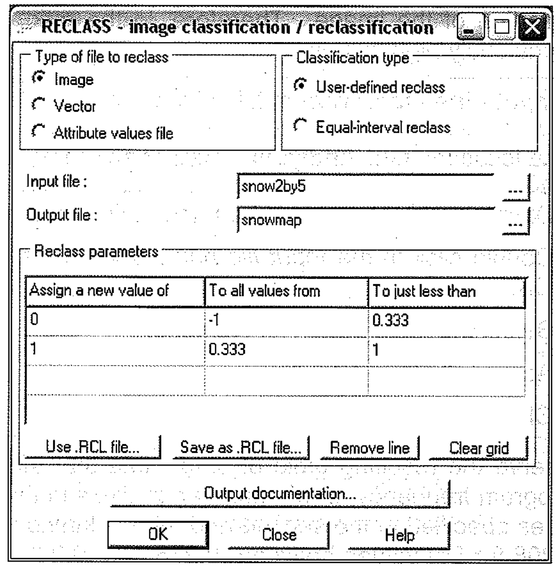


Figure 5.4.5.b *RECLASS* dialog box with parameters entered.

The output image will be displayed automatically. Compare the image to the false color composite (Figure 5.4.4.c). On the whole, the thresholded image provides a good map of the snow.

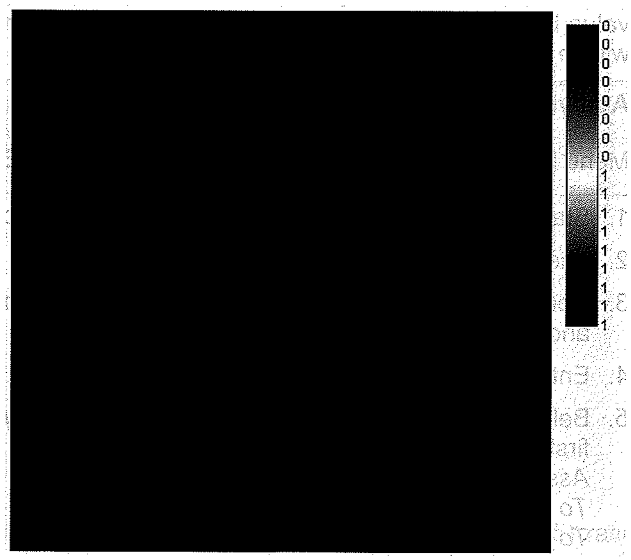


Figure 5.4.5.c Snow map from the snow ratio image.

We can calculate the area that the snow covers in this image, by using the HISTO program one more time.

Compute the histogram of DN values with HISTO
Menu location: **GIS Analysis – Database Query – HISTO**
1. Start the HISTO program from the main menu or the toolbar, if it is not already open.

2. Double click in the *Input file name* text box, and select ***snowmap***. Click on *OK*.
3. Select the radio button for *Numeric*.
4. Accept all other defaults, and click on *OK*.

Observe the resulting tabular data (Figure 5.4.5.d). The **Lower Limit** is the minimum DN value, the **Upper Limit** should be interpreted as "just less than." Since our data are integer, Class 0 will therefore only include pixels with a DN of 0, and class 1, pixels with a DN value of 1. The **Frequency** column (fourth from the left), gives information on the number of pixels in each category. Thus, we see that there are 240,140 pixels with a DN value of 0, and 10,861 with a DN value of 1. (Your numbers should be similar, unless you chose a different threshold for discriminating snow.) Summing the non-snow and snow pixels gives us 251,001. This latter sum is equal to the total number of pixels in the image, 501 rows by 501 columns (501 x 501 = 251,001).

Histogram of snow map

Class	Lower Limit	Upper Limit	Frequency	Prop.	Cum. Freq.	Cum. Prop.
0	0.000	1.000	240140	0.957	240140	0.957
1	1.000	2.000	10861	0.043	251001	1.000

Class width	=	1.000
Display minimum	=	0.000
Display maximum	=	2.000
Actual minimum	=	0.000
Actual maximum	=	1.000
Mean	=	0.043
Stand. Deviation	=	0.203
df	=	251000

Figure 5.4.5.d HISTO output for the ***snowmap*** image map.

We can now estimate the area of snow. One pixel represents 30 meters by 30 meters or 0.09 hectares (30 m x 30 m = 900 m^2, 1 hectare = 10,000 m^2). Therefore, 10,861 x 0.09 ha = **977.5 ha of snow**.

5.5 Mineral Ratios

In the Section 5.3 we saw how the NDVI index is an excellent way to enhance information about vegetation in an image, and in the previous section we saw that snow could be mapped quite reliably with a custom "snow index." In this section we will explore the idea of ratios further. We will investigate what makes a good ratio, and how ratio data can be combined to enhance different mineral types.

Our study area is a volcanic region near Puna de Atacama, Bolivia. The rocks in this region have been altered extensively by hydrothermal fluids. Hydrothermal fluids consist of hot ground water. As these hot ground waters circulate, they chemically alter the surrounding rock. Hydrothermal fluids often carry dissolved chemicals that may precipitate, and may eventually form economic mineral deposits. Thus hydrothermally altered regions make very good mineral exploration targets.

Early work using MSS data, which as just four spectral bands, showed that ratios could be used to enhance mineral alteration in Nevada (Rowan *et al*, 1974.) In addition to enhancing subtle spectral differences, ratios tend to suppress topographically-caused illumination differences in a scene. (We saw this topographic normalization to a certain extent in the snow ratio data.)

A ratio is created by dividing brightness values, pixel by pixel, of one band by another. The primary purpose of such ratios is to enhance the contrast between materials by dividing brightness values at **peaks** and **troughs** in a **spectral reflectance curve**. Specifically, the absorption feature (trough) should be used for the denominator of the ratio, and the peak brightness (peak) as the numerator. This combination of peak and trough will tend to result in higher numbers for the ratio when the class of interest is present.

It is very important that image analysts who use ratios understand the theory behind them, and have specific absorption features in mind for the analysis. Figure 5.5.a can be used to illustrate why the ratios identified in Table 5.5.a can be used to highlight the types of minerals listed. Figure 5.5.a also shows the band passes of the Landsat TM sensor, and thus serves to remind us that it is only possible to use ratios in regions for which we have data. Kaolinite has an absorption feature at 1.4 μm, but Landsat has no spectral band in this region, and thus it cannot be used in an analysis using Landsat TM data. In addition, we need to keep in mind that the bands integrate all the energy across the entire width. Thus, although the mineral jarosite has a deep absorption feature within the band pass of Landsat Band 7 (2.3 μm), the Band 7 DN value for a pixel of pure jarosite would be a single number, and would include radiance from the adjacent, relatively high reflectance regions. Therefore, the signal of jarosite in Band 7 would not be as distinctive as might be expected at first.

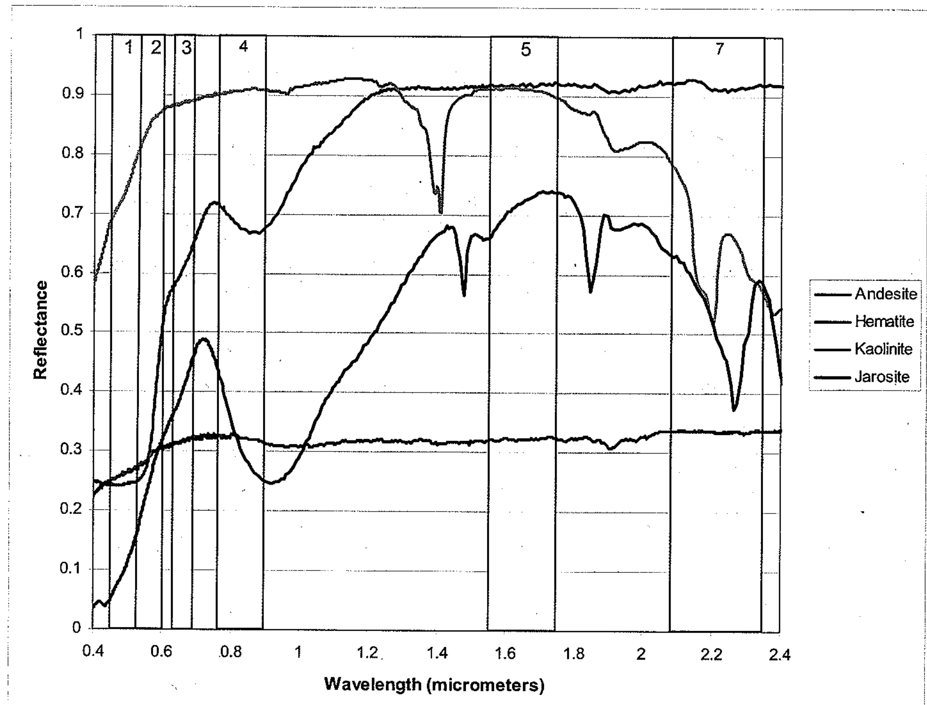


Figure 5.5.a Spectra of selected rocks and minerals and Landsat spectral band passes. (Source of spectra: Andesite: Johns Hopkins Spectral Library, Hematite & Jarosite: USGS Spectral Library (Clark *et al.* 2003), Kaolinite: JPL Spectral Library).

Table 5.5.a Typical Landsat TM Mineral Ratios

Ratio (Bands)	**Material typically highlighted**	**Example mineral**
5/7	Clay minerals	Kaolinite
5/4	Ferrous iron minerals	Jarosite
3/1	Ferric iron minerals	Hematite

The Andesite spectrum (Figure 5.5.a) is typical of the country rock in our study area in Bolivia. It is a relatively flat spectrum, with few spectral features. Therefore, the andesite might be a spectrum in contrast to which we hope to highlight the other minerals.

The spectra shown in Figure 5.5a suggest that a ratio of band 5 by band 7 will result in a relatively large value for kaolinite, and also, to a lesser extent, for jarosite. Jarosite, however, will have a very high value for a 5 by 4 ratio. Several minerals will have strong 3 by 1 ratios, but the ratio will be particularly strong for hematite, because its strong red color (high band 3 values) contrast against the lower band 1 (blue-green) values. In developing the link from Figure 5.5.a to the image we will produce in this exercise we need to remember that the spectra are library mineral spectra, and the image spectra are composites of many minerals. In some cases there are non-linear mixing effects, especially when dealing with iron minerals. Non-linear mixing effects add further to the difficulties of predicting the results.

The next section is a purely hypothetical example, to illustrate the idea of ratios further, and should be completed prior to working with the real data.

5.5.1 Hypothetical Ratio Example

Figure 5.5.1.a presents two hypothetical spectral curves that might be collected from a field spectrometer for two materials, A and B. Note that the vertical axis is on an arbitrary 8 bit scale, instead of the more normal reflectance, which has a 0-1 scale. The figure also shows the spectral band passes of a 3-band imaging sensor, with 0.1 µm wide bands centered on 0.6, 0.8 and 1.0 µm.

Now, we will investigate the ratios from the three band sensor that would give us the best separation of cover type A from B. The first step is to complete Table 5.5.1.a, estimating the value that the sensor would record for each cover type, in each band. You will simply estimate an average value for the curve, within the sensitivity region of the band you are dealing with. To provide an example, the first row, for the 0.6 µm band, has been completed for you. In the image band (or channel) centered on 0.6 µm, material A has a reflectance response that starts at 175 and peaks at about 195, but the sensor only records a single number, representing an average. In this case the average is probably close to 185. The value recorded for material B is similar, but a little higher on average.

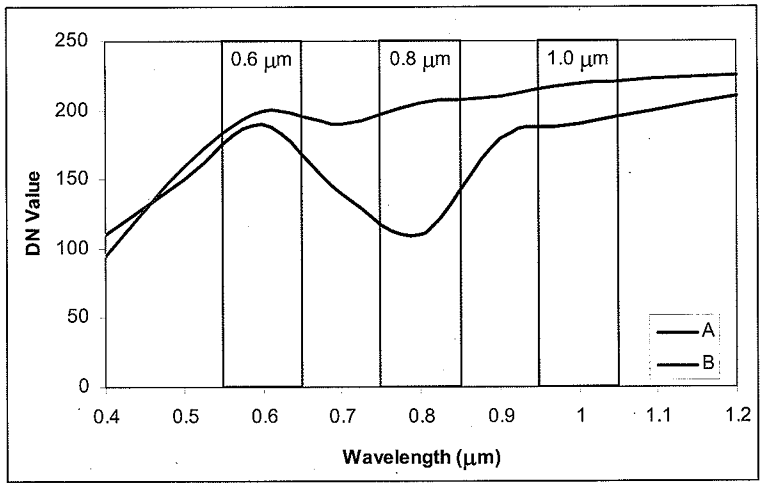


Figure 5.5.1.a Hypothetical field-collected spectral reflectance curves image sensor wavelength bands.

Table 5.5.1.a Table of expected DN values for the two cover types as imaged by the three band sensor (compare to Figure 5.4.1.a).

Band	**Integrated D.N Values for Band**	
Wavelength (μm)	Material A	Material B
0.6	185	200
0.8		
1.0		

Once you have completed the remaining two rows of Table 5.5.1.a, you are ready to try developing your own ratio by completing Table 5.5.1.b. Specifically you should try to develop a ratio *that highlights cover type **A** in bright tones, and **B** in dark tones*. As an example, the first row has been completed using the ratio **1.0 μm / 0.6 μm**. The DN values used in the figure are derived from the table you will develop of the integrated values for each band (Table 5.5.1.a).

The **1.0 μm / 0.6 μm** ratio wasn't very successful, because the values obtained are very similar, 1.0 and 1.1. If we look at Figure 5.5.1.a, we can see that this is not surprising, because at those wavelengths cover type ***A*** does not have any distinctive absorption features. Instead, we need to select two wavelengths, for one of which ***A*** has an absorption feature, and ***B*** doesn't. For the second wavelength both ***A*** and ***B*** should have relatively high reflectance. Remember to put the wavelength that has the absorption feature for cover type **A** in the denominator of the ratio you choose.

See if you can get a better result with a more carefully chosen set of band rations, *based on the absorption features in Figure 5.5.1.a.*

Hints for completing Table 5.5.1.b: There are two possible ratios that give a high value for ***A***, and a low value for ***B***. Both choices give a ratio for ***A*** that is about 50% higher than the value obtained for ***B***. If your ratio is higher for ***B*** than ***A***, then your ratio has the wrong wavelength band in the denominator.

Table 5.5.1.b Worksheet for developing a ratio that highlights A relative to B.

Band Ratio	**A**		**B**	
($Band_X$ / $Band_Y$)	DN Values DN_X / DN_Y (Obtain values from Table 5.4.1.a)	**Resulting Ratio Value**	DN Values DN_X / DN_Y (Obtain values from Table 5.4.1.a)	**Resulting Ratio Value**
1.0 µm / 0.6 µm	185 / 185	**1.0**	220 / 200	**1.1**

5.5.2 Preparation

For this section we will use Thematic Mapper data from a volcanic region in Puna de Atacama, Bolivia. In Section 5.2 you should have already copied the data from the CD. However, we still need to set the *Project* and *Working Folders* for the Bolivian data.

Before starting you should close any dialog boxes or displayed images in the IDRISI workspace.

Create a new project file and specify the working folders with the IDRISI EXPLORER

Menu Location: **File – IDRISI EXPLORER**

1. Start the IDRISI EXPLORER from the main menu or toolbar.
2. In the *IDRISI EXPLORER* window, select the *Projects* tab.
3. Right click within the *Projects* pane, and select the *New Project Ins* option.
4. A *Browse For Folder* window will open. Use this window to navigate to the *ID_Man* folder, which is the folder you created on your computer for the data for this manual. Now navigate to the *Chap5_5* subfolder, within the *ID Man/Chap5* folder.
5. Click *OK* in the *Browse For Folder* window.
6. A new project file *Chap5_5*, will now be listed in the *Project* pane of the IDRISI EXPLORER. The working folder will also be listed in the Editor pane.
7. Close the IDRISI EXPLORER by clicking on the red *x* in the upper right corner of the *IDRISI EXPLORER* window.

5.5.3 Exploratory Investigation of the Puna de Atacama TM Data

For this section we will use TM data. Table 5.5.3.a lists the wavelengths of the TM bands.

We will start by creating a simulated natural color composite of the TM data, just as we did for the Washington State image, used in Section 5.4. We will use the program COMPOSITE, and assign bands 1, 2 and 3 to blue, green and red, respectivley.

Table 5.5.3.a Thematic Mapper bands

Band Number	Wavelength Region	Wavelength Interval (μm)
1	Blue	0.45-0.52
2	Green	0.52-0.60
3	Red	0.63-0.69
4	Near Infrared	0.76-0.90
5	Mid Infrared	1.55-175
6*	Thermal	10.4-12.5
7	Mid Infrared	2.08-2.35

*Note that Band 6 is not included with the data for this exercise.

Create a simulated natural color composite image

Menu Location: **Display - COMPOSITE**

1. Start the COMPOSITE program using the main menu or tool bar.
2. In the *COMPOSITE* dialog box, specify the file name for the *Blue image band* by clicking on the browse button (...), and in the resulting *Pick list* selecting ***landsat1***. Click on *OK* to close the *Pick list*.
3. Repeat the previous step for the *Green image band*, specifying the ***landsat2*** image.
4. Again, repeat the previous step for the *Red image band*, this time specifying the ***landsat3*** image.
5. Enter the *Output image* filename in the text box provided: **123bolivia.**
6. Enter in the *Title* text box: **Simulated Natural Color Composite.**
7. Accept all other defaults, and click *OK* to create and display the false color composite (Figure 5.5.3.a).

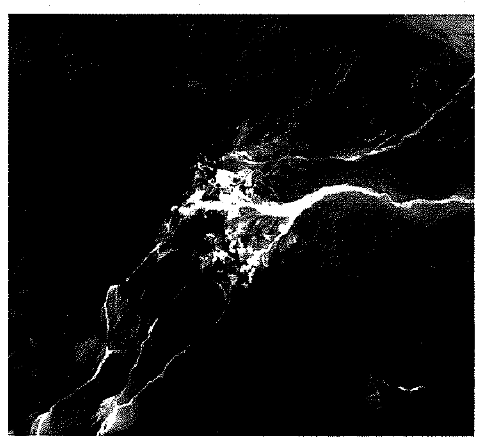


Figure 5.5.3.a Simulated natural color composite of Puna de Atacama TM data.

Figure 5.5.3 illustrates that a simulated natural color composite works well in this arid environment to show the hydrothermal alteration. Note the central bright area, which is the main region of hydrothermal alteration, and which provides a strong contrast against the dark volcanic rocks. Erosion products from the hydrothermal area are resdistributed to the northeast and southwest along stream courses.

5.5.4 <u>Calculating Ratios</u>

We will calculate three ratios to highlight the different minerals present in these rocks: Band 5 / Band7, Band 5 / Band 4, and Band 3 / Band 1 (Table 5.5.a). We will use the program OVERLAY.

As with the snow ratio of Section 5.4., we will generate a normalized difference ratio (First – Second)/(First + Second), rather than a simple ratio (First / Second), because the former gives a more balanced range of values, from -1, to +1, with 0 representing the middle value, namely a flat spectrum. For simplicity sake, however, we will refer to each ratio as if it were a simple ratio. Thus, (Band 7 – Band 5) / (Band 7 + Band 5) will be referred to as Band 7 / Band 5.

Calculating ratios with OVERLAY

Menu location: **GIS Analysis – Mathematical Operators – OVERLAY**

1. Start the OVERLAY program from the main menu or the icon tool bar.
2. In the *OVERLAY* dialog box, double click in the text box next to *First image*, and select ***landsat5*** from the *Pick list*. Click *OK*.
3. Select ***landsat7*** for the *Second image*, and click *OK*.
4. Enter the *Output image* name **5by7**.
5. Select the radio button for *First – Second / First + Second*.
6. Click on *OK*.

The resulting image does not look impressive. Partly this is because ratios are very noisy. A ratio suppresses the majority of the information, which derives from variation in illumination due to topography, and enhances a minor part of the signal, the spectral differences between bands. Another reason why the image looks rather unimpressive is that the default palette is the *quant* palette. This ratio would make more sense as a black and white image. Therefore, follow the instructions below to change the palette and increase the contrast.

Change palette and contrast enhancement of an image

1. Make sure the new ***5by7*** image is the focus of the IDRISI workspace by clicking in the image.
2. Find the *Composer* window, and select the button for *Layer Properties*.
3. In the *Layer Properties* window, select the browse button (…) next to text box blow *Palette File*.
4. In the *Pick list* window, click on the plus sign next to the *IDRISI Taiga\symbol* folder.
5. Scroll down, until you can select ***GreyScale***. Click on *OK* to close the *Pick list* window.
6. Back in the *Layer Properties* window, enter in the *Display Min* text box **-0.05**.
7. Enter in the *Display Max* text boxes **0.20**.

8. Still in the *Layer Properties* window, click on the buttons for *Apply*, *Save* and *OK*.

The resulting image (Figure 5.5.4.a) should show the central hydrothermally altered area very distinctly.

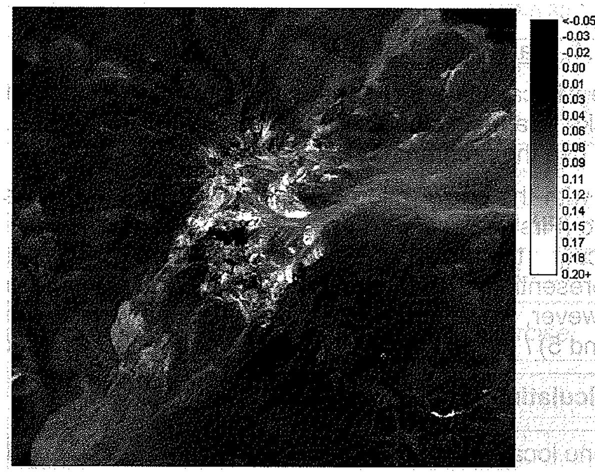


Figure 5.5.4.a Ratio of Landsat bands 5 / 7, with *greyscale* palette and contrast enhanced.

Having produced the first ratio, now run the OVERLAY operation two more times to create the remaining two ratio combinations (Band 5 / Band 4 and Band 3 / Band 1).

Calculating ratios with OVERLAY

Menu location: **GIS Analysis – Mathematical Operators – OVERLAY**

1. If necessary, start the OVERLAY program again from the main menu or the icon tool bar.
2. In the *OVERLAY* dialog box, double click in the text box next to *First image.*
3. The *Pick List* window will open. Select ***landsat5*** from the *Pick list*. If necessary, click on the plus symbol (+) to see the names of the individual bands within the *Chap5_5* folder. Click *OK* to close the *Pick list*, if necessary.
4. Select ***landsat4*** for the *Second image*, and click *OK*.
5. Enter the *Output image* name **5by4**.
6. Select the radio button for *First – Second / First + Second*.
7. Click on *OK*.
8. The image will display automatically, with a *quant* palette file.
9. Now alter the file names to create the third and last ratio.
10. In the *OVERLAY* dialog box, double click in the text box next to *First image*, and select ***landsat3*** from the *Pick list*. Click *OK*.
11. Select ***landsat1*** for the *Second image*, and click *OK*.
12. Enter the *Output image* name **3by1**.
13. Click on *OK*.

Once you have the three ratio images, you can combine them in a false color composite, with the program **COMPOSITE**. Use the Band 5 / Band 7 ratio for blue, Band 3 / Band 1 for green, and Band 5 / Band 4 as red.

Create a color composite image

Menu Location**: Display - COMPOSITE**

1. Start the COMPOSITE program using the main menu or tool bar.
2. In the *COMPOSITE* dialog box, specify the *Blue image band* as ***5by7.***
3. Specify the *Green image band* as ***3by1***.
4. Specify the *Red image band* as ***5by4***.
5. Enter the *Output image* filename in the text box provided: **ratiofcc.**
6. Enter in the *Title* text box: **5/7 as blue, 3/1 as green, and 5/4 as red.**
7. Accept all other defaults, and click *OK* to create and display the false color composite (Figure 5.5.4.b).

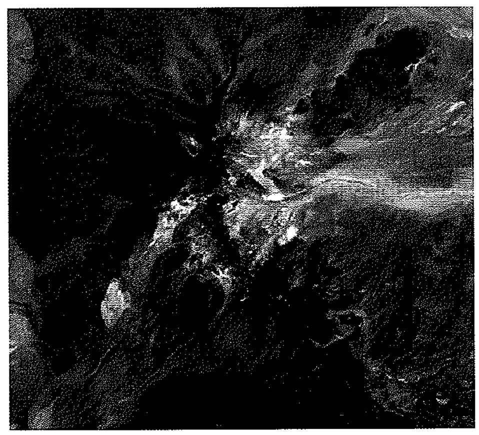


Figure 5.5.4.b Ratio false color composite. 5/7 as blue, 3/1 as green, and 5/4 as red.

With Figure 5.5.4.b to guide you, you should now be able to draw a sketch map of the main minerals present in the image. For example, the central core of the alteration zone has a blue color, indicating high values in the 5/7 ratio, which in turn indicates the presence of clay minerals. In interpreting all the colors in the image, remember the mixing of red and blue gives cyan (a light, sky blue color), green and red gives yellow, and red and blue gives magenta (purple) (see the color mixtures shown by Figure 5.4.4.b).

Chapter 6 Other Spectral Enhancement Techniques

6.1 Introduction

This chapter is a companion to Chapter 5, on ratios, and is a second chapter on spectral enhancement techniques. We will start by investigating methods for enhancing information in highly correlated bands. In highly correlated data, the colors in the image will not appear very vibrant, and we will explore techniques to address this problem. One of the techniques, principal component analysis, has very widespread use in remote sensing because it is an effective method of dealing with another problem commonly encountered, namely the need to visualize more than three bands at a time. Three bands is the maximum number that can be used in a false color composite.

After the section on highly correlated data, we then look at specialized image enhancement. We will segment an image, separating water from land. We will then apply different false color composites to the water and land features, thus providing an overall optimal image.

6.2 Copy Data for This Chapter

In this chapter we will work with two different image sets, one for the highly correlated data section (6.3) and one for the segmenting and density slice for advanced display (6.4) sections. Therefore, you should now copy the *Chap6* folder from the CD, and paste it as a new subfolder within the *\ID Man* folder on your computer.

After you have copied the folder, you should remove the Read-Only attribute from this new folder on your computer. This is done by right-clicking on the *Chap6* folder name, selecting *Properties* from the pop-up menu. A dialog box will open, labeled *Chap6 Properties* (if you apply this procedure to the entire *ID Man* directory, then the dialog box will be labeled *ID Man Properties*). Now clear the check mark from the *Read Only* check box, by clicking in the box. You should then click on the button for *Apply*, and in the subsequent *Confirm Attribute Changes* dialog box, accept the default *Apply changes to this folder, subfolder and files*, and click on *OK*. You will need to also click on *OK* in the *Chap6 Properties* dialog box.

Note: Section 1.3.1 provides detailed instructions on how to copy the data from the CD, and also on how to remove the *Read-Only* attribute from the data. Also, the procedure for setting up the *ID Man* folder on your computer is described.

6.3 Enhancing Highly Correlated Data using Data Transformations

6.3.1 Background

The NASA airborne Thermal Infrared Multispectral Scanner (TIMS) instrument collects six bands of long wavelength infrared radiation (Table 6.3.a). The thermal infrared part of the electromagnetic part of the spectrum includes an atmospheric window from 8-12 μm, which is the region where the TIMS bands are located. Thermal wavelengths are characterized by emission of energy from objects that are at approximately room temperature. The measured thermal energy also includes a reflected component, but the magnitude is generally small, and can be ignored.

Table 6.3.a. Approximate TIMS band passes.

Band	Wavelength (μm)
1	8.15 - 8.5
2	8.6 - 9.0
3	9.0 - 9.3
4	9.6 - 10.2
5	10.3 - 11.1
6	11.3 - 11.6

Each multispectral thermal band is dominated by the temperature of the surface radiating energy. This is because the total radiance is proportional to the fourth power of the temperature of the surface (the Stefan-Boltzman radiation law). Furthermore, the wavelength at which maximum radiance occurs is a function of the inverse of the temperature (Wien's displacement law). The dominant influence of temperature in multispectral thermal data has the effect of making the bands highly correlated. False color images made from highly correlated data are characterized by gray tones, and very pale colors, with low saturation. In this exercise, we shall investigate three methods of enhancing highly correlated data: principal component analysis (PCA), decorrelation stretch (which is based on PCA), and an intensity-hue-saturation (IHS) stretch. These methods, especially PCA, also have general use in image processing, for example in the analysis of Landsat imagery. Thus, for example, we will also use PCA in Chapter 8, as a change detection method.

The data we will work with is a subscene from a flight line over Mauna Loa, Hawaii, and was collected at 22:03 GMT, September 30, 1989. The image covers an area approximately 2.5 kilometers on a side. The band 3 (9.0 to 9.2 μm) radiance image is shown in Figure 6.3.a. This is a daytime image, and the image is clearly dominated by topographic effects. For example, notice the way temperature differences associated with solar heating cause the cinder cones to stand out. The cinder cones are quite distinctive because they have a conical shape, with a central depression.

Figure 6.3.a TIMS Band 3 (9.0 - 9.2 μm) image of lava flows on Mauna Loa, Hawaii.

It is apparent from Figure 6.3.a that there are slight temperature differences associated with the different lava flows. These lava flows are all historic flows, and thus the lava flows have long since cooled from their original molten state. Therefore the brightness variations are unrelated to the original molten lava temperatures. Instead, the temperature differences you can see in this image are entirely due to differences in heating, due to slope and aspect effects, as well as differences in the rate at which heat is absorbed, due to variations in surface properties. As an example of how surface properties can affect local temperature, you might think about the difference in temperatures between dark vehicles, which absorb more heat, than light or shiny vehicles.

The differences in temperature between the different lava flows are relatively small, and mapping the different lava flows from Figure 6.3.a would be quite difficult. In this exercise, we will investigate spectral enhancement methods to make the different lava flows more clear.

6.3.2 Preparation

In Section 6.2 you should have already copied the data from the CD. However, we still need to set the *Project* and *Working Folders* for the TIMS data.

Before starting you should close any dialog boxes or displayed images in the IDRISI workspace.

Create a new project file and specify the working folders with the IDRISI EXPLORER

Menu Location: **File – IDRISI EXPLORER**

1. Start the IDRISI EXPLORER from the main menu or toolbar.
2. In the *IDRISI EXPLORER* window, select the *Projects* tab.
3. Right click within the *Projects* pane, and select the *New Project Ins* option.
4. A *Browse For Folder* window will open. Use this window to navigate to the *ID_Man* folder, which is the folder you created on your computer for the data for this manual. Now navigate to the *Chap6_3* subfolder, within the *ID Man/Chap6* folder.
5. Click *OK* in the *Browse For Folder* window.
6. A new project file *Chap6_3*, will now be listed in the *Project* pane of the IDRISI EXPLORER. The working folder will also be listed in the Editor pane.
7. Close the IDRISI EXPLORER by clicking on the red *x* in the upper right corner of the *IDRISI EXPLORER* window.

Before we begin our ehancements, let's first simply look at the data. We will display two bands as single band images, and thus we will use a GreyScale palette. In addition, we will create a false color composite, using three different bands.

Initial display of images

Menu: **Display – DISPLAY LAUNCHER**

1. Start the DISPLAY LAUNCHER from the main menu or icon bar.
2. In the *DISPLAY LAUNCHER* window, double click in the text box for the file name, and select ***TIMSb1***.
3. Select a *GreyScale* palette.

4. Click on *OK* to display the image.
5. Start the DISPLAY LAUNCHER again.
6. In the *DISPLAY LAUNCHER* window, double click in the text box for the file name, and select ***TIMSb3***.
7. Select a *GreyScale* palette.
8. Click on *OK* to display the image.

Compare the two images, and note how similar, and thus how highly correlated, the two images appear to be. We will now create the false color composite. Refer to Table 6.3.a for the wavelength regions associated with each band.

Create a color composite image

Menu Location: **Display - COMPOSITE**

1. Start the COMPOSITE program using the main menu or tool bar.
2. In the *COMPOSITE* dialog box, specify the file name for the *Blue image band* ***TIMSb1***. Click on *OK* to close the *Pick list.*
3. Specify the *Green image band as* ***TIMSb3***.
4. Specify the *Red image band* as ***TIMSb5***.
5. Enter the *Output image* filename in the text box provided: **135fcc**.
6. Accept all other defaults, and click *OK* to create and display the false color composite (Figure 6.3.2.a).

Figure 6.3.2.a TIMS false color composite. Band 1 (8.15 - 8.5 µm) as blue, band 3 (9.0 - 9.3 µm) as green and band 5 (10.3 - 11.1 µm) as red.

The resulting false color composite (Figure 6.3.2.a) shows distinct differences in colors between the different lava flows, suggesting that there are chemical or weathering differences between the various flows. Although the false color composite helps a great deal in separating the different flows, it is still rather difficult to separate the different units because the colors are rather pale.

6.3.3 Principal Component Analysis (PCA)

Principal component analysis (PCA) is a statistical method for generating new, uncorrelated variables, from a data set. If you are not familiar with PCA, you should consult a remote sensing text. Most remote sensing texts, including Lillesand *et al.* 2004, and Jensen 2005, have excellent descriptions of this method. For completeness sake, however, we provide a very short reminder of the purpose and concepts of PCA.

PCA is a rotation and translation of the original band axes to produce an equal number of new bands that are orthogonal (at right angles to each other in the data space) and uncorrelated (Figure 6.3.3.a). The first principal component band, PCA band 1, is oriented to capture the maximum variance. Thus, in the case of Figure 6.3.3.a, PCA1 is oriented along the diagonal of the bispectral plot, along the direction of the main data distribution. Subsequent bands are oriented to capture the maximum remaining variance, and are perpendicular to the earlier bands. PCA produces as many new bands as there were old bands, although it usually assumed that most of the information is present in the first few new bands, which comprise most of the variance.

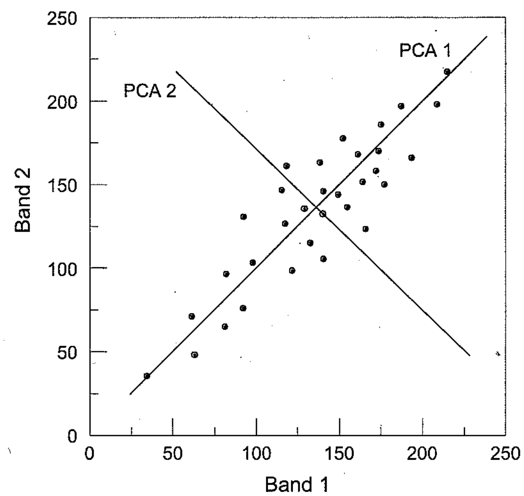


Figure 6.3.3.a Bispectral plot of two band data showing original band axes and the new axes associated with the principal components.

Apply a principal component analysis with PCA
Menu location: **Image Processing – Transformation – PCA**
1. Start the PCA program using the main menu. 2. In the *PCA* dialog box window, click on the button to *Insert layer group*. In the pick list window, select the ***tims*** raster group file. 3. Set the *Number of components to be extracted* to ***6*** (the maximum possible, if there are 6 input files) . 4. In the text box next to *Prefix for output files (can include path):*, enter ***PCA***. 5. In the *Text output option* section of the *PCA* dialog box, select the radio button for *Complete output*.

6. Accept all other defaults. (See Figure 6.3.3.b for the completed dialog box.)
7. Click on *OK*.

The *Module Results* window will display a text file of the results of the analysis (Table 6.3.3.a).

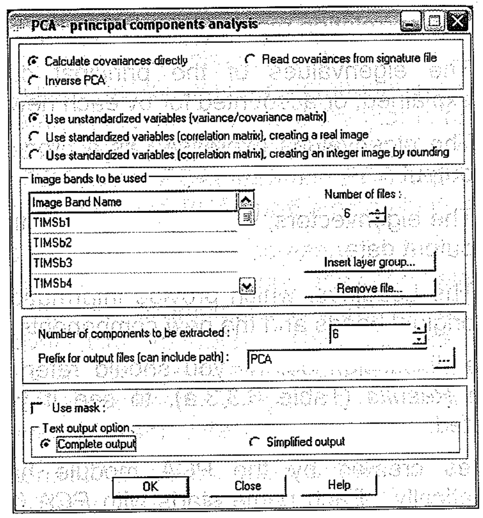


Figure 6.3.3.b The *PCA* dialog box with the TIMS data specified.

Table 6.3.3.a PCA results for TIMS data of Hawaii

VAR/COVAR	timsb1	timsb2	timsb3	timsb4	timsb5	timsb6
timsb1	3049.735087	3167.563987	2896.607208	2814.089180	2408.649538	2117.097105
timsb2	3167.563987	3328.996188	3056.881097	2940.704585	2515.199971	2206.764671
timsb3	2896.607208	3056.881097	2863.842080	2696.184573	2282.163491	1997.237795
timsb4	2814.089180	2940.704585	2696.184573	2685.575131	2347.519245	2055.336047
timsb5	2408.649538	2515.199971	2282.163491	2347.519245	2122.048568	1859.768873
timsb6	2117.097105	2206.764671	1997.237795	2055.336047	1859.768873	1649.966022

COR MATRX	timsb1	timsb2	timsb3	timsb4	timsb5	timsb6
timsb1	1.000000	0.994117	0.980131	0.983305	0.946814	0.943783
timsb2	0.994117	1.000000	0.990028	0.983504	0.946320	0.941590
timsb3	0.980131	0.990028	1.000000	0.972202	0.925752	0.918793
timsb4	0.983305	0.983504	0.972202	1.000000	0.983361	0.976398
timsb5	0.946814	0.946320	0.925752	0.983361	1.000000	0.993903
timsb6	0.943783	0.941590	0.918793	0.976398	0.993903	1.000000

COMPONENT	C 1	C 2	C 3	C 4	C 5	C 6
% var.	97.404921	2.040407	0.335480	0.112832	0.072828	0.033525
eigenval.	15292.732438	320.347217	52.670862	17.714852	11.434155	5.263552
eigvec.1	0.443114	-0.241191	-0.700588	-0.108803	0.408736	-0.275227
eigvec.2	0.463738	-0.310442	-0.146321	0.330072	-0.723611	0.186018
eigvec.3	0.425695	-0.457113	0.676808	0.095475	0.327058	-0.188894
eigvec.4	0.417582	0.164644	0.095411	-0.671154	0.021111	0.581825
eigvec.5	0.362757	0.572312	0.143408	-0.175841	-0.286340	-0.638271
eigvec.6	0.318455	0.530898	-0.005285	0.623483	0.346294	0.328718

LOADING	C 1	C 2	C 3	C 4	C 5	C 6
timsb1	0.992263	-0.078170	-0.092070	-0.008292	0.025027	-0.011434
timsb2	0.993937	-0.096302	-0.018405	0.024078	-0.042408	0.007397
timsb3	0.983709	-0.152883	0.091786	0.007509	0.020666	-0.008098
timsb4	0.996474	0.056864	0.013362	-0.054509	0.001378	0.025758
timsb5	0.973823	0.222364	0.022593	-0.016066	-0.021019	-0.031788
timsb6	0.969512	0.233929	-0.000944	0.064604	0.028828	0.018566

One of the difficulties of using PCA is that the output images can be difficult to interpret. Nevertheless, by carefully examining the output text from the PCA program (Table 6.3.3.a), some interpretation can usually be made. Therefore, these results should be saved, for example by clicking on the *Save to File* button of the bottom of the *Module Results* window.

The *Module Results* includes information on:

- The variance/covariance matrix (i.e. the variability of the bands, and how they relate to one another).
- The correlation matrix (the relationship between the bands).
- The eigenvalues of the principal components (amount of variance explained, or accounted for by each new component).
- The eigenvalues expressed as a proportion of the total ("% var.") in the output.
- The eigenvectors, which give the equation to convert the input data to the output data.
- The Loadings, which provide information on the correlation between the original bands and the new components.

For the discussion below, you should refer to the relevant images, and the *Module Results* (Table 6.3.3.a), to see if you can verify the interpretations suggested.

The files created by the PCA module have names that are generated systematically. Each name starts with *PCA* (the prefix that we specified in the program), and a suffix of *cmp#*, where the # indicates the file number.

Use the IDRISI DISPLAY LAUNCHER to display the 6 output files, each time using a GreyScale Palette, as described below.

Display the PCA images

Menu: **Display – DISPLAY LAUNCHER**

1. Start the DISPLAY LAUNCHER from the main menu or icon bar.
2. In the *DISPLAY LAUNCHER* window, double click in the text box for the file name, and select ***pcacmp1***.
3. Select a *GreyScale* palette.
4. Click on *OK* to display the image.
5. Repeat steps 1-4 above, five times, to display the five files, ***pcacmp2*** through ***pcacmp6***. Rember to use the GreyScale palette each time.

Note that principal component images 3 and 5 are very dark, and therefore you will need to change the contrast stretch for these images.

Change palette and contrast enhancement of an image

1. Make sure the ***pcacmp3*** image is the focus of the IDRISI workspace by clicking in the image.
2. Find the *Composer* window, and select the button for *Layer Properties.*
3. In the *Layer Properties* window, move the slider for *Display Max* until the display has a better contrast. (A good value appears to be about **16**, however the choice is quite subjective.)
4. Now move the *Display Min* slider to improve the contrast further. (A good value appears to be about **-30.0)**

5. Click on the buttons for *Apply*, *Save* and *OK*.
6. Repeat steps 1-5 for ***prncmp5***, selecting appropriate *Display Max* and *Display Min* values.

In interpreting the values for the TIMS data (Table 6.3.3.a), we see that the first component (C1 = ***PCAcmp1***) comprises a total of over 97.4% of the original variance. This suggests that the majority of the variability in the images is common to all the images. In this case, that common information is the temperature of the rocks. The remaining 5 components represent only 0.6% of the variance in the data. However, it is this 0.6% that is of interest to us. Note how the images appear to get progressively noisier with higher numbers. For example, notice how ***PCAcmp2***, ***PCAcmp3*** and ***PCAcmp4*** shows the pattern of lava flows well, but ***PCAcmp5*** and ***PCAcmp6*** are dominated by noise.

The eigenvectors, as explained before, represent the formula for the calculation of the new principal component bands. Thus, they can help us understand what each output band means. For example, we find that the eigenvectors for C1 are all positive, and similar (0.44 to 0.32). This suggests that C1 (the image ***PCAcmp1***) represents an average of all the bands. Indeed, the loadings, the last section of the table, show that C1 is highly correlated with all the input bands (the values vary between 0.97 and 0.99).

Likewise, we can interpret the eigenvectors of each of the remaining principal components, or output bands, in terms of the original input values. For C2, the eigenvectors are negative for the first three bands, and positive for the remaining three. This suggests that ***PCAcmp2*** can be understood to be the difference between the first three bands and the second three bands. C3, on the other hand, is generated by the difference between the first two bands, and the third band. However, without knowledge of the emittance spectra of the lava flows, interpreting the meaning of the bands is difficult. We can, however, see from the eigenvectors that C1 is an average of the input data, and that C2 – 5 are all enhancing subtle spectral features in the original images. A simple visual inspection of the images tells us that ***PCAcmp2***, ***PCAcmp3*** and ***PCAcmp4*** have some interesting information, whereas ***PCAcmp5*** and ***PCAcmp6*** have relatively little.

As a final step, the PCA components can be visualized as a false color composite, using the program COMPOSITE and principal components 2, 3 and 4 as the input bands, as described below.

Create a color composite image

Menu Location: **Display - COMPOSITE**

1. Start the COMPOSITE program using the main menu or tool bar.
2. In the *COMPOSITE* dialog box, specify the file name for the *Blue image band* **PCAcmp2**. Click on *OK* to close the *Pick list.*
3. Specify the *Green image band as* **PCAcmp3**.
4. Specify the *Red image band* as **PCAcmp4**.
5. Enter the *Output image* filename in the text box provided: **PCAfcc234**.
6. Accept all other defaults, and click *OK* to create and display the false color composite (Figure 6.3.3.c).

Figure 6.3.3.c False color composite of TIMS data. Principal components 2,3,4 as BGR.

Based on the discussion above, we can understand that by excluding ***PCAcmp1***, we are excluding the majority of the temperature information, which is of less interest to us. The false color composite without this first principal component (Figure 6.3.3.b) is remarkably impressive, given that it comprises less than 1% of the original variance. The lava flows are now very clearly differentiated.

Note, however, that the PCA false color composite does appear rather noisy, with a distinctive striping. The stripes are from the scan-lines. It is, generally speaking, inevitable that we will enhance the noise in this type of PCA operation, since we are boosting a minor part of the signal (the spectral variation) at the expense of the majority of the signal (the temperature information).

6.3.4 PCA Decorrelation Stretch

PCA is a powerful data transformation technique that has many applications and variations. One variation on PCA is the decorrelation stretch. In a decorrelation stretch, the image is first transformed with PCA. Selected principal component bands are then stretched, and a reverse PCA transformation is applied, in which the data are retransformed back to the original data space. Figure 6.3.4.a illustrates how the data shown in Figure 6.3.3.a might appear after a decorrelation stretch. In comparing the two figures, note how the data have been stretched out in the direction of PC2, thus filling the bispectral plot area to a much greater degree.

Gillespie *et al.* (1986) point out a very useful attribute of the decorrelation stretch is that if a false color composite is made of the decorrelated data, the color *saturation* will be much stronger compared to that of a false color composite of the original bands. However, the *hues* should be unchanged, thus making it possible to interpret the colors in terms of the original spectral bands. (*Hue* refers to the dominant color, such as red, or green, and *saturation* refers to the brightness of the color, for example, pink has less saturation than red.

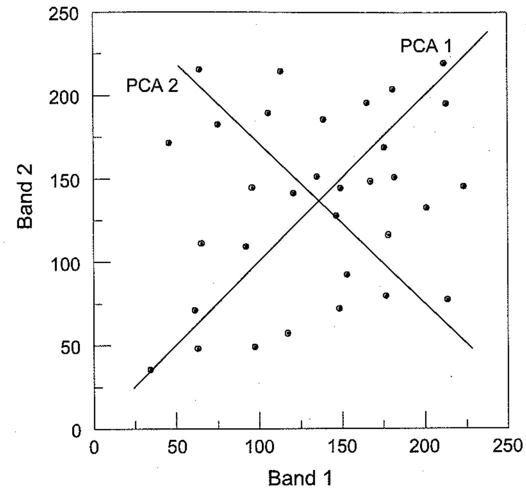


Figure 6.3.4.a Bispectral plot showing the effects of a decorrelation stretch. Compare to Figure 6.3.3.a, which shows the data prior to the stretch.

Further information on these terms is provided in Section 4.2.2, where color terminology is explained in detail.) Let us investigate whether this improvement of the colors seems to apply with the Hawaii TIMS data.

In Section 6.3.3 we already calculated the principal components for the Hawaii data. Therefore, in this exercise we only need to apply a stretch to the selected bands, and then re-transform the principal components back to the original bands. The IDRISI PCA program, which we used in Section 6.3.3, has an option to do the reverse transformation.

We will specifically only stretch principal components 2, 3 and 4, as these components appear to carry most of the spectral information. Principal component 1 is mostly temperature and will be used in the retransformation back to the original space, but it is not stretched. Principal components 4 and 5 are mainly noise, and will be excluded entirely.

The stretching is applied with the IDRISI program SCALAR, a program for applying simple arithmetic (scalar) operations to an image, including multiplication, addition, division exponentiation, and subtraction.

Multiplying an image by a number with SCALAR
Menu Location: **GIS Analysis – Mathematical Operations - SCALAR**
1. Start the SCALAR program using the main menu. 2. In the *SCALAR* dialog box, use the *pick list button* (…) to specify the name of the *Input image* as ***PCAcmp2***. Click on *OK* to close the *Pick list.* 3. In the text box labeled *Output image*, type **PCAcmp2_b**. 4. In the text box labeled *Scalar value*, type ***2.*** 5. In the *Operation* section of the window, select the radio button for *Multiply* (Figure 6.3.4.b). 6. Click *OK*.

7. The stretched image will be displayed automatically; however you can close the image, as we don't need to see it.
8. Now stretch ***PCAcmp3*** by a factor 2, to create **PCAcmp3_b** output. The simplest way to do this is to type over the number **2** in text boxes in the SCALAR window, to change the Input image ***PCAcmp2*** to ***PCAcmp3***, and output image to **PCAcmp3_b**. Click *OK*.
9. Repeat the previous procedure to stretch ***PCAcmp4*** by a factor of 2, create **PCAcmp4_b** output.

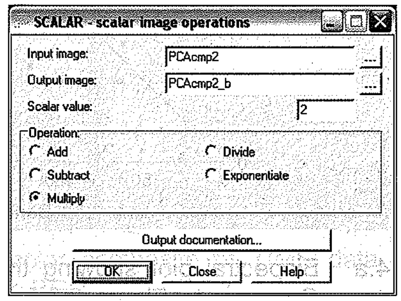


Figure 6.3.4.b The *SCALAR* dialog box, with the *Multiply* option selected.

Now that we have stretched the data, we have two minor steps to complete before we can run the inverse PCA program. First, we have to create a raster group file. A raster group file is a file that tells IDRISI that a group of files belongs together as a single group. Raster group files were introduced in Section 1.3.7, and if you have trouble with this section, you may want to review that material.

Create a raster goup file collection with the IDRISI EXPLORER

Menu Location: **File – IDRISI EXPLORER**

1. If the *IDRISI EXPLORER* window is not already open, open it again using the main menu or the icon toolbar.
2. Click on the tab for *Files*.
3. If the files are not listed in the *Files* pane, double click on the directory name to display the files.
4. If need be, slide the divider for the *Metadata* pane down, so you can see all the files we need to work with: ***PCAcmp1.rst*** through ***PCAcmp6.rst***, as well as the three new files ***PCAcmp2_b.rst, PCAcmp3_b.rst*** and ***PCA.cmp4_b.rst.***
5. Click on ***PCAcmp1.rst***, so the file is highlighted.
6. Keeping the keyboard Ctrl button pressed, now click on the following files in the order listed:
   PCAcmp2_b.rst
   PCAcmp3_b.rst
   PCAcmp4_b.rst
   PCAcmp5.rst
   PCAcmp6.rst
7. You should now have 6 files highlighted.

8. Right click in the *Files* pane. Select the menu option for *Create – Raster Group* (Figure 6.3.4.c). This will create a file ***Raster group.rgf.***
9. Click on the file ***Raster group.rgf*** in the *Files* pane. In the *Metadata* pane, below the *Files* pane, enter a new name in the right hand cell of the first row, typing over the default name of *Raster Group*. Use **PCA2** for the new name.
10. Click on the *save* (floppy disk) icon, at the bottom left hand corner of the *Metadata* pane. The name of the Raster Group File will immediately be updated in the *Files* pane.

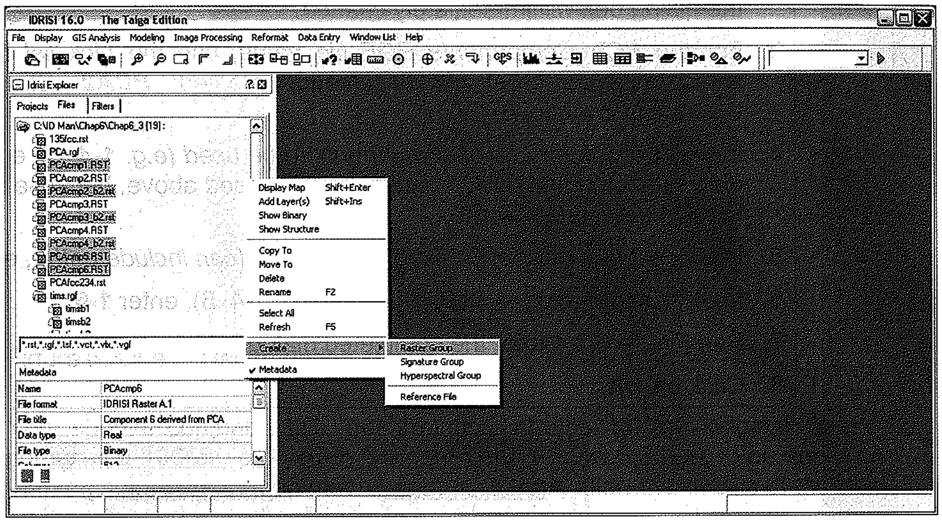


Figure 6.3.4.c Selecting the raster files to combine into a Raster Group File.

The next step is to rename the eigenvector file, associated with our original PCA raster group file, so that it matches the new raster group file name. You can use the Windows Explorer to do this, or follow the directions below to use the IDRISI EXPLORER:

Rename a file with the IDRISI EXPLORER

Menu Location: **File – IDRISI EXPLORER**

1. The *IDRISI EXPLORER* window should still be open from the last step. If you have closed it, open it again using the main menu or the icon toolbar.
8. In the *IDRISI EXPLORER* window, click on the tab for *Files*.
9. If the files are not listed in the *Files* pane, double click on the directory name to display the files.
2. The unlabeled text box at the bottom of the *Files* pane is a listing of file formats to be shown. The default is **.rst,*.rgf,*.ts,*.vct,*.vlx,*.vgf.* Use the down arrow on the right hand side of the text box to select the option for this text box of *All files (*.*)*.
3. Find the file ***PCA.eig***, and click on it to highlight it.
4. With the mouse over the highlighted text, right-click, and select *Rename* from the pop-up menu.
5. Edit the name of the file, so it reads ***PCA2.eig.***

6. Close the IDRISI Explorer.

We are ready now for the final step for retransforming the data.

Perform an inverse principal component analysis with PCA
Menu location: **Image Processing – Transformation – PCA**
1. Start the PCA program using the main menu. 2. In the *PCA* window, select the radio button for *Inverse PCA*. The options in the dialog box will immediately change. 3. For the *PCA Components RGF file name*, use the *pick list* button (…) to select the raster group file we have just created: ***PCA2***. Click *OK* to close the *Pick List* window. 4. In the text box for *List of components to be used (e.g. 1-4, 6)*, enter **1-4.** (We only select the first 4 PCA bands, as discussed above, because the remaining two are dominated by noise). 5. In the text box next to *Prefix for output files (can include path):*, enter **Decor**. 6. In the text box next to Output bands (e.g. 1-4, 6), enter **1-6**. 7. See Figure 6.3.4.d for the completed dialog box. 8. Click on *OK*.

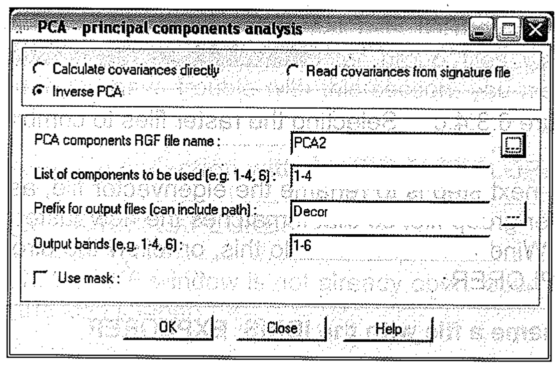
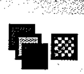


Figure 6.3.4.d Inverse PCA transformation in the *PCA* dialog box.

We can now create the false color composite, and see whether we have indeed improved the colors of the lava flows.



Create a color composite image
Menu Location: **Display - COMPOSITE**
1. Start the COMPOSITE program using the main menu or tool bar. 2. In the *COMPOSITE* dialog box, specify the file name for the *Blue image band* ***Decor1***. Click on *OK* to close the *Pick list*. 3. Specify the *Green image band* as ***Decor3***. 4. Specify the *Red image band* as ***Decor5***. 5. Enter the *Output image* filename in the text box provided: **135decor**.

6. Accept all other defaults, and click *OK* to create and display the false color composite (Figure 6.3.4.e).

Figure 6.3.4.e Decorrelation stretch of TIMS bands 1,3,5 as BGR.

You should compare this decorrelation stretch to the original false color composite, **135fcc**, created in Section 6.3.2 (Figure 6.3.2.a). You should notice that the colors are indeed much brighter. In particular, the details of the lava flow on the left hand side should now be much clearer.

6.3.5 HLS Stretch

In section 4.2.2, we introduced the concept of color transformations. We provide only the briefest summary here. If you need to be refreshed regarding color space concepts, you should review Section 4.2.2, and possibly also refer to a text such as Jensen (2005).

We saw in Section 4.2.2 that colors on a computer monitor are normally specified in terms of red, green and blue (RGB values), and therefore this a convenient system for addressing many remote sensing problems. However, in some instances, it is useful to work in the alternative hue, lightness, and saturation (HLS) color system. The term *hue* is relatively intuitive and refers to the characteristic tint. *Lightness* refers to the brightness, which extends from black to white. *Saturation* refers to the purity of the color, so that low saturation colors tend to gray, and have a typically pastel quality, whereas high saturation colors are the purest colors.

It is important to understand that HLS and RGB are equivalent ways of specifying color, and thus it is possible to move back and forth between systems. In this exercise, we will transform an image between RGB and HLS space. This will allow us to increase the saturation of the image, making the colors much purer. Since we don't alter the hue, the tints of the colors should not change at all. This will help discriminate the different lava flows in the image, but because we don't change the hues, the color tints will still be useful for interpreting the different colors in the image.

Convert three image bands from RGB to HLS space

Menu location: **Image Processing – Transformation – COLSPACE**

1. Start the COLSPACE program from the menu.
2. In the *COLSPACE* window, select the radio button for *RGB to HLS.*
3. In the section for *Input files*, note that it is a little bit confusing that IDRISI specifies the input files here in the reverse order of that used for the COMPOSITE program, namely as *Red, Green*, and then *Blue*.
4. Use the pick list button (...) next to the text box for *Red image band*, to select the original band 5 TIMS image, ***timsb5***. Click *OK* to close the *Pick List* window.
5. Repeat the previous step, to select ***timsb3*** for the *Green image band.*
6. Repeat the previous step, to select ***timsb1*** for the *Blue image band.*
7. In the section for *Output files*, type the filename in the textbox for *Hue image band*: **hue**.
8. In the textbox next to *Lightness image band*, type **lightness**.
9. In the textbox next to *Saturation image band*, type **saturation**.
10. Compare your completion of the text box options to Figure 6.3.5.a.
11. Click *OK*. Unlike most other IDRISI programs, an image is not displayed on completing the program.

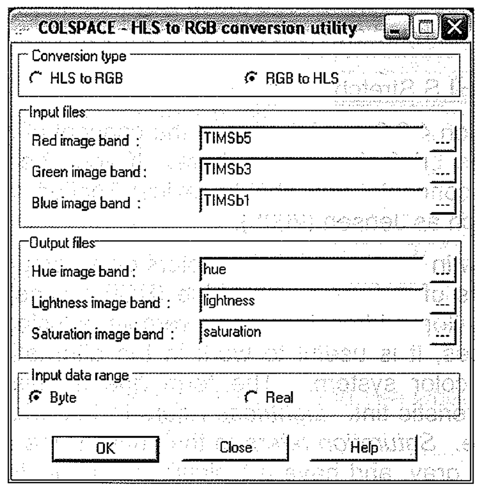


Figure 6.3.5.a. The *COLSPACE* dialog box for RGB to HLS transformation.

Use the IDRISI DISPLAY LAUNCHER to view the ***saturation*** image created by the COLSPACE program, as described below

Initial display of images

Menu: **Display – DISPLAY LAUNCHER**

1. Start the DISPLAY LAUNCHER from the main menu or icon bar.
2. In the *DISPLAY LAUNCHER* window, double click in the text box for the file name, and select ***saturation***. Click *OK* in the *Pick List* window.

3. Select a *GreyScale* palette.
4. Click on *OK* to display the image (Figure 6.3.5.b).

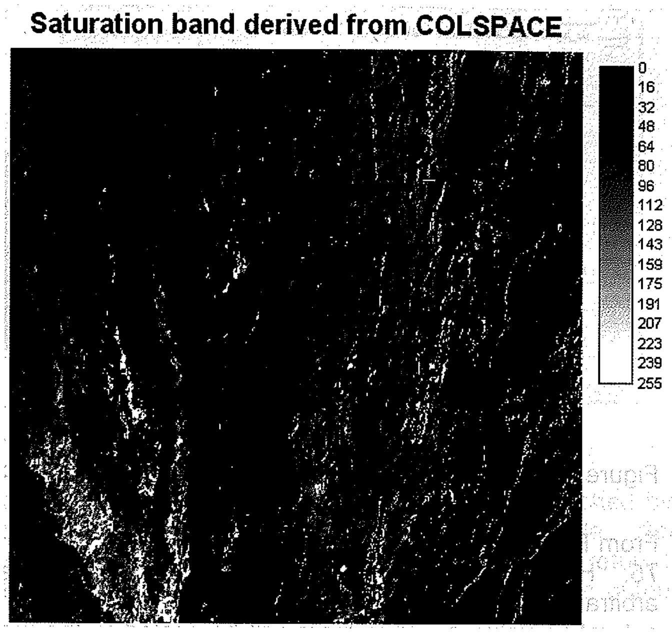


Figure 6.3.5.b Saturation image of the TIMS data.

As shown by Figure 6.3.5.b, the saturation image is very dark, and although the image is scaled over the range 0-255, most of the image values are in the lower half of the DN range, as indicated by the radiometric scale bar. This image therefore confirms what we had observed visually, namely that the saturation of this image is very low. We can improve the image by stretching the saturation, and then transforming the hue, stretched saturation, and lightness (HLS) bands back to RGB. However, first we need to decide how much to stretch the saturation, and we will do that by looking at the image histogram.

Display the image data distribution with HISTO

Menu Location: **Display - HISTO**

1. Start the HISTO program from the main menu or the toolbar.
2. In the *HISTO* dialog box, click on the browse button (…) next to the text box for the *Input file name* to select ***saturation***. Click on *OK* to close the *Pick List* window.
3. Set the class width to **1**.
4. Leave the remaining parameters set at their default values.
5. Click on *OK*.
6. The histogram will appear in a new HISTOGRAM window. In this new window, in the section labeled *Mode*, click on the option for *Cumulative*. The graph will automatically update (Figure 6.3.5.c).

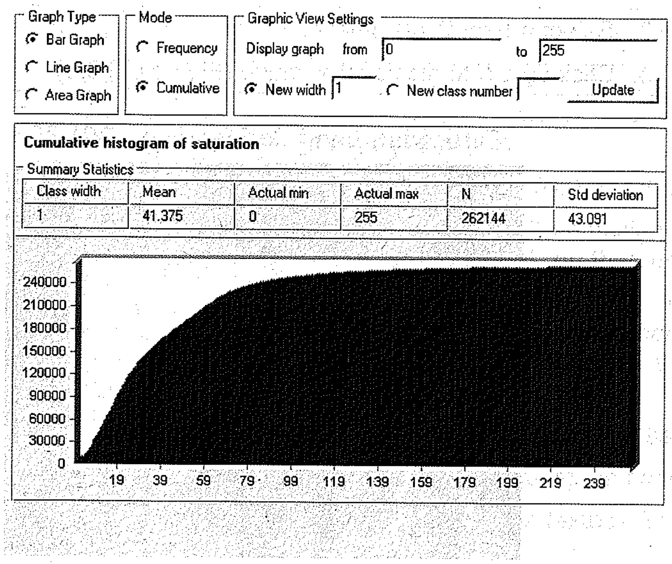


Figure 6.3.5.c Histogram of the ***saturation*** image, in *Cumulative* mode.

From Figure 6.3.5.c, we can see that the majority of the DN values are less than 75. However, to increase the saturation to give an even clearer image, we arbitrarily select 50 as the maximum for the scaling. This means that any saturation value of 50 or more will be scaled to the maximum, 255. From the graph we can see this will still leave about 75% of the image with saturation values less than the maximum of 255.

There are a variety of ways to do the rescaling of the saturation values. One simple way is through the program STRETCH. The concept of a stretch operation should be familiar to you, as a stretch operation is typically used in displaying data. This is done so that the image brightness levels are shown in an optimal manner on the screen (Chapter 2). The type of stretch applied in displaying an image is normally temporary, and does change the original file values. For this exercise, however, we need to create a new file with the stretch applied permanently.

Rescaling the DN values of an image with STRETCH

Menu location: **Image Processing – Enhancement – STRETCH**

1. Use the main menu to start the STRETCH program.
2. In the *STRETCH* window, click on the pick list button (...) next to the *Input image* text box to select the image ***saturation***. Click *OK* to close the *Pick List* window.
3. In the text box next to *Output image*, enter **sat_str**.
4. Check the box for *Specify an upper bound other than maximum.*
5. In the text box that will open to the right of the *Specify an upper bound other than maximum*, enter **50**.
6. Accept the remaining defaults (Figure 6.3.5.d), and Press OK.

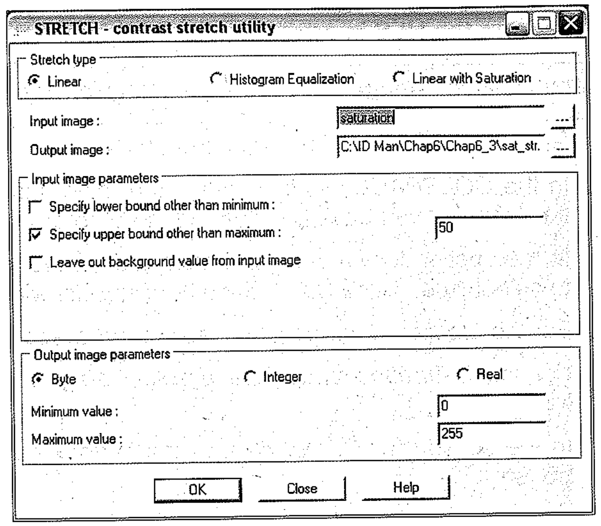


Figure 6.3.5.d The *STRETCH* dialog box.

We can now confirm that the data have indeed been stretched by running the HISTO program once again, using ***sat_str*** as the input file. See if you can complete this without instructions. If you do have problems, return to the HISTO instructions earlier in this Section. Figure 6.3.5.e shows the output you should obtain.

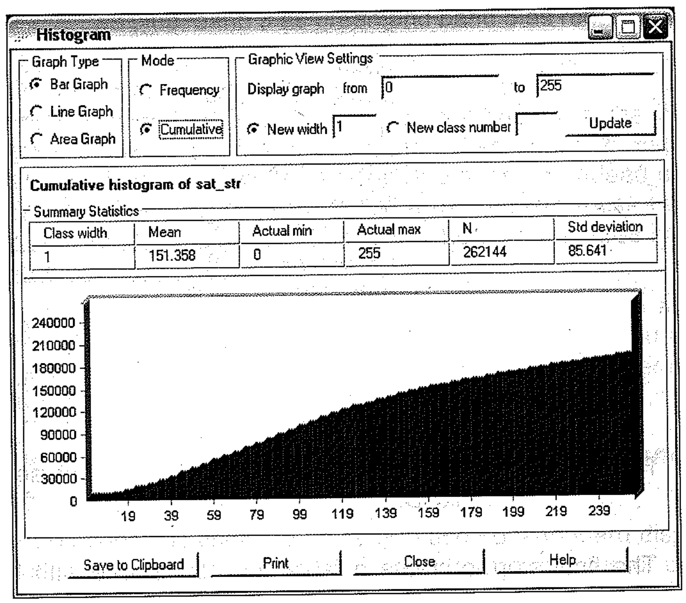


Figure 6.3.5.e Histogram of the ***sat_str*** image, in *Cumulative* mode.

In comparing the two histograms shown in Figures 6.3.5.c and 6.3.5.e, you should note that in the latter figure only a small portion of the image has low DN values, and approximately 25% of the image has the maximum DN value. This confirms that the DN values in the ***sat_str*** image are now much higher with the stretch applied.

Therefore, we are now ready to transform the HLS data back to RGB space.

Transform the HLS images back to RGB images

Menu location: **Image Processing – Transformation – COLSPACE**

1. Start the COLSPACE program from the menu.
2. In the *COLSPACE* window, select the radio button for *HLS to RGB.* (This is the default if you have just opened the program window.)
3. In the section for *Input files*, double click in the text box for *Hue Image Band*, to select ***hue***. Click *OK* to close the *Pick List* window.
4. For the *Lightness Image Band*, select ***lightness***.
5. For the *Saturation Image Band* select ***sat_str*** (i.e. the stretched saturation image).
6. In the section for *Output files*, in the textbox next to *Red image band,* enter **b5_str**.
7. In the textbox next to *Green image band*, enter **b3_str**.
8. In the textbox next to *Blue image band*, enter **b1_str**.
9. Compare your completion of the text box options to Figure 6.3.5.f.
10. Press *OK*. As before, the program will not automatically display the output file.

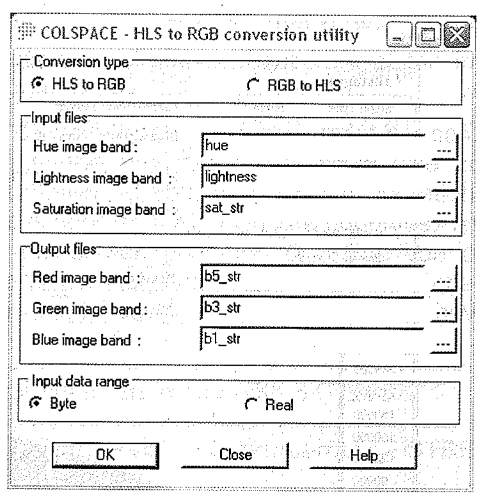


Figure 6.3.5.f *COLSPACE* dialog box for the reverse transformation of HLS to RGB.

The final step is create a false color composite with the three new saturation-stretched files with the program COMPOSITE.

Create a color composite image

Menu Location: **Display - COMPOSITE**

1. Start the COMPOSITE program using the main menu or tool bar.
2. In the *COMPOSITE* dialog box, specify the file name for the *Blue image band **b1_str**.* Click on *OK* to close the *Pick list.*
3. Specify the *Green image band as **b3_str**.*

4. Specify the *Red image band* as ***b5_str.***
5. Enter the *Output image* filename in the text box provided: **135sat_str**.
6. Accept all other defaults, and click *OK* to create and display the false color composite (Figure 6.3.5.g).

Figure 6.3.5.g TIMS false color composite of saturation-stretched data. Band 1 as blue, band 3 as green and band 5 as red.

Compare the false color composite with the stretched saturation, **135_satstr** (Figure 6.3.5.g) with the false color composite made from the original data, **135fcc** (Figure 6.3.2.a), by redisplaying the latter image if necessary. In comparing the two images, evaluate whether the hues are indeed unchanged in the saturation stretched image. You should also compare these two images to the decorrelation image, **135decorr** (Figure 6.3.4.e). Of the three images, which is the best for interpreting the lava flows?

In doing this exercise, you may have noted that in applying the stretch to the saturation image, we selected an arbitrary cut-off of 50 DN. You may want to experiment with values of 10 (an extreme stretch) and 100 (a rather mild stretch), to see whether a different value might give you better results.

6.4 Segmenting and Density Slicing Images for Advanced Display

For some applications it is useful to be able to use non-standard display options. In this section we will therefore explore some alternative ways of displaying an image, including masking of features not of interest, and density slicing.

6.4.1 Preparation

In Section 6.2 you should have already copied the data from the CD. Specifically, we will work with the data in the folder **Chap6\Chap6_4**, which like the folder for Chapters 1-4, contains ETM+ Hong Kong. However, the area we will be studying in this section is focused on the Pearl River Estuary.

In order to create a more manageable data size, the original image, with its 30 meter pixels, has been degraded by pixel averaging to produce 90 meter pixels.

If you would prefer to work with the original 30 meter pixel data, the original 30 meter data are available in the folder **Chap6\Chap6_4alt**. If you do use this alternative data set, in the instructions that follow, set the subfolder to this alternative location. When prompted to use files that have names such as hk_etm_b1, substitute the name of the files in the new directory, e.g. hk_etm_large_b1, etc.

Before starting you should close any dialog boxes or displayed images in the IDRISI workspace. Now, set the *Project* and *Working Folders* for this new data, as described below.

Create a new project file and specify the working folders with the IDRISI EXPLORER

Menu Location: **File – IDRISI EXPLORER**

1. Start the IDRISI EXPLORER from the main menu or toolbar.
2. In the *IDRISI EXPLORER* window, select the *Projects* tab.
3. Right click within the *Projects* pane, and select the *New Project Ins* option.
4. A *Browse For Folder* window will open. Use this window to navigate to the *ID_Man* folder, which is the folder you created on your computer for the data for this manual. Now navigate to the *Chap6_4* subfolder, within the *ID Man/Chap6* folder. (If you decide to work with the full resolution data set, simply navigate to the *Chap6_4alt* subfolder.)
5. Click *OK* in the *Browse For Folder* window.
6. A new project file *Chap6_4*, will now be listed in the *Project* pane of the IDRISI EXPLORER. The working folder will also be listed in the Editor pane.
7. Close the IDRISI EXPLORER by clicking on the red *x* in the upper right corner of the *IDRISI EXPLORER* window.

On starting a new project, it is always good to look at the data. We will therefore create a standard color composite, with simulated natural colors. We will increase the percent that is saturated to the extremes of the brightness range, in order to increase the image contrast.

Create a color composite image

Menu Location: **Display - COMPOSITE**

1. Start the COMPOSITE program using the main menu or tool bar.
2. In the *COMPOSITE* dialog box, double click in the text box for the *Blue image band*. The *Pick List* will open automatically. Double click on ***hk_etm_b1*** to select the blue band (band 1).
3. Repeat this selection process to specify the *Green image band as* ***hk_etm_b2***.
4. Specify the *Red image band* as ***hk_etm_b3***.
5. Enter the *Output image* filename in the text box provided: **hk123**.
6. Change the value of the *Percent to be saturated from each end of the grey scale* from *1.0* to **7.5**.
7. Accept all other defaults, and click *OK* to create and display the false color composite.

Notice how the pattern of sediment in the Pearl River Estuary is apparent in this image (Figure 6.4.1.a).

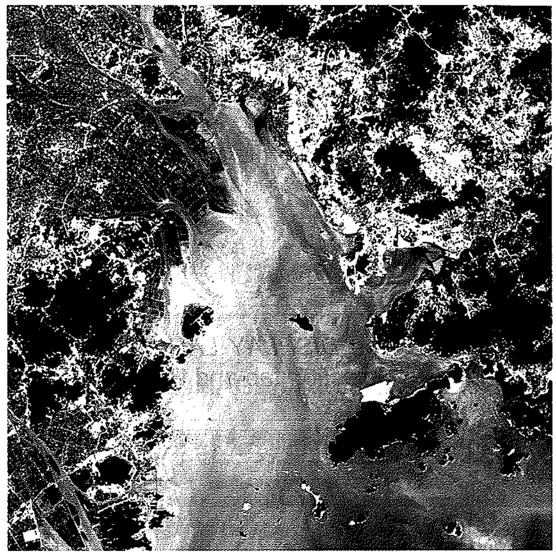


Figure 6.4.1.a Simulated natural color composite of the Pearl River Delta, using TM bands 1, 2 and 3 as blue, green and red.

6.4.2 Developing a Land Mask

In order to explore further the patterns in the water, it would be useful to develop a mask, so that we can ignore the land. A straightforward method of developing this mask is to use a threshold value in ETM+ Band 5 (1.55-1.75 µm). Water absorbs strongly in the mid infrared, and therefore we will assume that all dark pixels in the mid infrared band are water. The only difficult step is to choose the value of the threshold between water and land. In a tidal area, the boundary is obviously a zone, not an absolute line. In addition, water logged soils will tend to have similar spectral characteristics to water.

In the next step we will modify the image palette file, in order to display the image DN values around the potential threshold very clearly. Specifically, we want a clear idea of the area that would be included in the mask, for each potential threshold value.

Displaying an image with an alternative palette file

Menu Location: **Display – DISPLAY LAUNCHER**

1. Start the DISPLAY LAUNCHER from the main menu or icon bar.
2. In the *DISPLAY LAUNCHER* window, double click in the text box for the file name, and double click on ***hk_etm_b5*** in the *Pick List* window that opens automatically.
3. Click on the tab for *Advanced Palette/Symbol Selection*. This will open up additional options in the dialog box.
4. Click on the brightly colored color ramp in the bottom right column (Figure 6.4.2.a). The palette file's name, RADAR, will be displayed in the data entry line labeled *Current Selection*.
5. Accept all the remaining default options.

6. Click on *OK* to display the image (Figure 6.4.2.b).

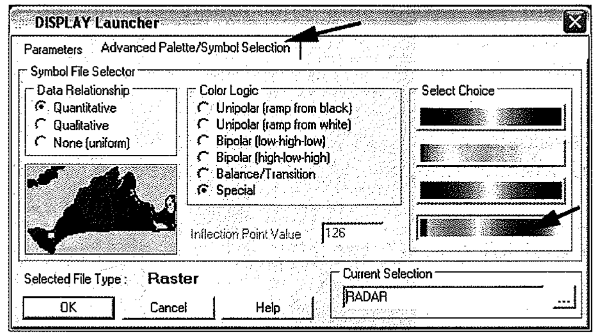


Figure 6.4.2.a. The *DISPLAY LAUNCHER*, with the *Advanced Palette/Symbol Selection* tab and the *RADAR* palette indicated by the arrows.

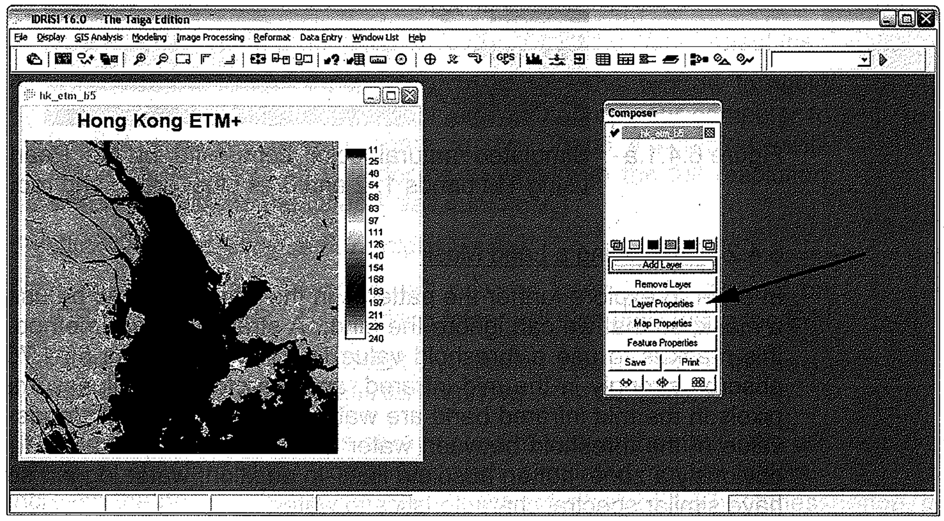


Figure 6.4.2.b ETM+ Band 5 image with the *RADAR* palette file. The *Layer properties* button in the *Composer* window is indicated by the arrow.

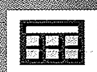
Note that in this rendition of the Band 5 image (Figure 6.4.2.b), the water is generally shown in cool colors, such as blue. We will now adjust the range of DN values over which the color ramp is applied, in order to select a precise threshold that discriminates between land and water.

Adjusting the thresholds for color ramp display in the *Composer* Window

1. Find the *Composer* window, which is automatically opened whenever an image is displayed.
2. In the *Composer* window, select *Layer Properties* (see Figure 6.4.2.b). The *Layer Properties* dialog box will open.
3. Slowly adjust the *Display max* slider to successively lower positions. Observe how, when you slide the pointer to lower values, more and more of the land area of the image is displayed as white. Stop moving the slider when you reach a DN value of between 18 and 22.

4. Now use the legend and the colors in the image to help you choose an optimum DN threshold that differentiates between the water and land. Specifically, we want a value **below** which most pixels are water. (For example, 18 might seem a good value.)
5. Make a note of the value you selected for the threshold.

Now that we have selected the threshold, we need a mechanism to apply the threshold so as to assign all pixels that have a value below the threshold as water, and all those above the threshold as land. There are at least two ways to do this in IDRISI. One way is to use the program RECLASS, which is available from the main menu from GIS Analysis – Database Query – RECLASS, and which we used in Section 5.4.5. However, we will use an alternative method, using the IMAGE CALCULATOR, a particularly powerful tool with broad application to image analysis.



Creating a land mask with the IMAGE CALCULATOR

Menu location: **GIS Analysis – Mathematical Operators – IMAGE CALCULATOR**

1. Use the main menu or the icon tool bar to open the IMAGE CALCULATOR.
2. In the *IMAGE CALCULATOR* window, click on the radio button for *Operation Type: Logical Expression.*

Before continuing, we will stop and take a moment to familiarize ourselves with the IMAGE CALCULATOR (Figure 6.4.2.c). The interface for this program is based on the concept of a hand calculator. However, unlike a hand calculator, the IMAGE CALCULATOR can operate on images.

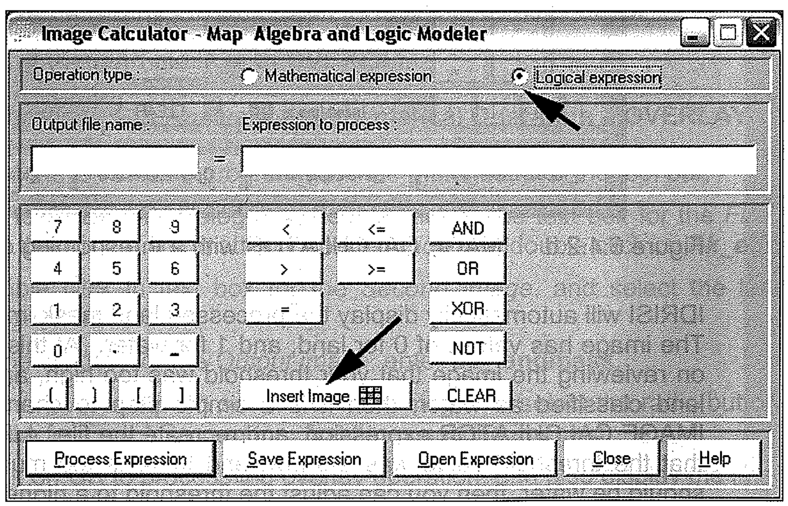


Figure 6.4.2.c *IMAGE CALCULATOR* window.

The top part of the *IMAGE CALCULATOR* window has radio buttons for specifying whether you wish to create a *Mathematical expression* or a *Logical expression.* (The latter option, *Logical expression*, is indicated by the upper arrow in Figure 6.4.2.c.) Below the radio buttons are two text boxes, on the left for the *Output file name*, and the right for the *Expression to process*. Developing an expression, or formula, is easy using the buttons in the large, main area below the two text boxes. In particular, the *Insert image* button (indicated by the lower arrow in Figure 6.4.2.c) is used to place an entire image in the expression. There are additional buttons for logical operations. At the bottom of the window are some basic commands for processing, saving, and opening expressions.

Creating a land mask with the IMAGE CALCULATOR (cont.)

3. In the *Output file name* text box, enter the file name **landmask**
4. Click on the button for *Insert Image*.
5. A *Pick List* will open. Double click on ***hk_etm_b5***.
6. The *Expression to Process* text box will now contain the image name in square brackets: **[hk_etm_b5]**.
7. Click on the button for the less than sign ("<"), and then enter the threshold you determined in the previous step. Your equation should now look something like the following: **[hk_etm_b5]<18**.
8. Figure 6.4.2.d shows the resulting IMAGE CALCULATOR expression.
9. Click on the *Process Expression* button.

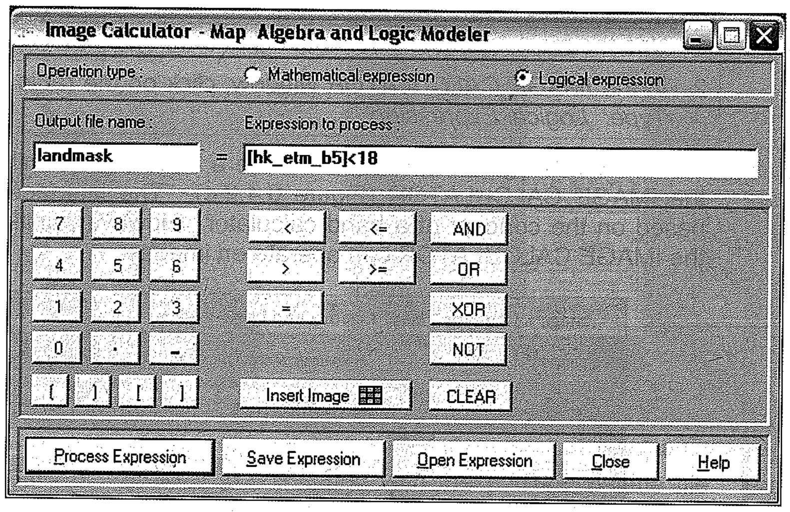


Figure 6.4.2.d IMAGE CALCULATOR with a thresholding expression.

IDRISI will automatically display the processed land mask image (Figure 6.4.2.e). The image has values of 0 for land, and 1 for water. At this stage, if you decide on reviewing the image that your threshold was too high, and there is too much land classified as water, then it is a simple step to change the value in the IMAGE CALCULATOR expression, and recreate the file. Likewise, if you decide that the threshold value was too low, and there is too much land where there should be water, then you can adjust the threshold to a higher number.

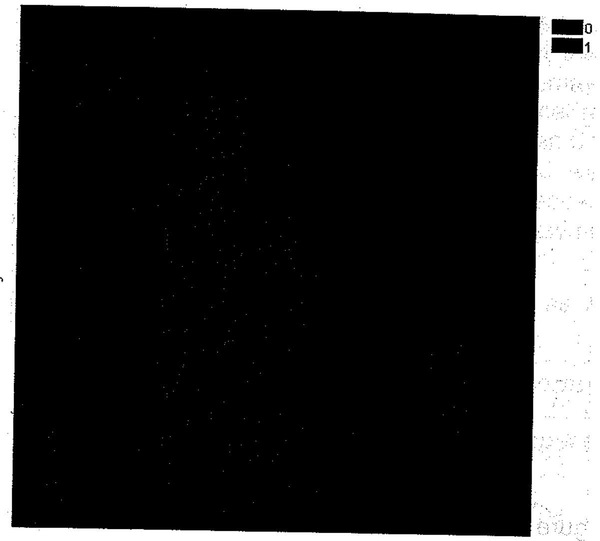


Figure 6.4.2.e The land mask image.

6.4.3 Displaying Patterns in Water

In this section we will use our mask to suppress all land area pixels, leaving only the water pixels for an image of water patterns. We will then apply a look up table (palette file) that highlights patterns of sediment in the water in the Pearl River Estuary, and the surrounding lakes.

The land mask, created in the previous section, has values of 1 in the areas interpreted to be water, and 0 elsewhere. We therefore can apply the mask simply by multiplying the land mask by a selected image band.

Applying the land mask with OVERLAY
Menu location: **GIS Analysis – Mathematical Operators – OVERLAY**
1. Start the OVERLAY program from the main menu or the tool bar. 2. In the *OVERLAY* dialog box, double click in the text box for the *First Image*, and then in the automatically opened *Pick List*, double click on ***hk_etm_b3***. 3. Double click in text box for the *Second Image*, and select the land mask image, ***landmask***. 4. In the window for the *Output image*, enter **b3_landmask**. 5. In the Overlay option section of the dialog box, select the radio button for the option for *First * Second* (i.e. first times second images). 6. Click on *OK* to process the overlay operation, and also display the image.

The masked image, with a color ramp applied by IDRISI automatically (Figure 6.4.3.a), shows the complex sediment patterns in the bay very clearly. Higher DN values, shown in oranges and reds, indicate more sediment-laden water, or shallower water. Lower values, indicated by greens, indicate clearer, deeper water.

The ETM+ thermal band also shows interesting patterns in the water. We can follow the same procedure as with the red band to mask the thermal band. Try doing this on your own using the OVERLAY program. If you have trouble, follow the instructions below.

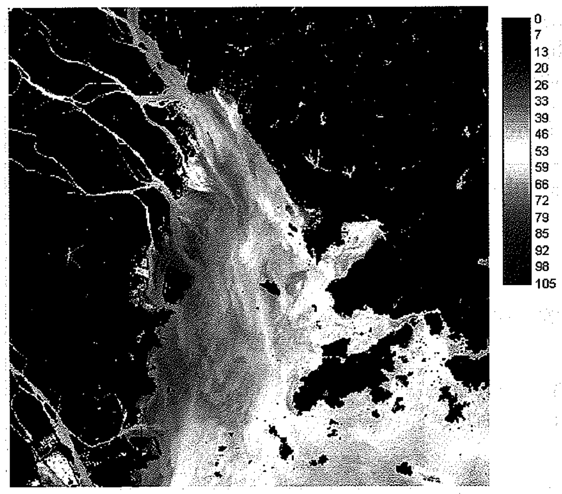


Figure 6.4.3.a ETM+ band 3 (red), with land masked out and color ramp applied.

Applying the land mask with OVERLAY
Menu location: **GIS Analysis – Mathematical Operators – OVERLAY**
1. Start the OVERLAY program from the main menu or the tool bar. 2. In the *OVERLAY* dialog box, double click in the text box for the *First Image*, and then in the automatically opened *Pick List*, double click on ***hk_etm_b6***. 3. Double click in text box for the *Second Image*, and select the land mask image, ***landmask***. 4. In the window for the *Output image*, enter **b6_landmask**. 5. In the Overlay option section of the dialog box, select the radio button for the option for *First * Second* (i.e. first times second images). 6. Click on *OK* to process the overlay operation, and also display the image (Figure 6.4.3.b).

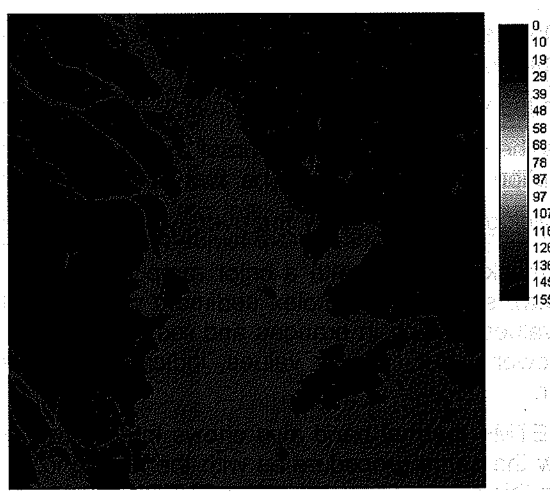


Figure 6.4.3.b ETM+ band 6 (thermal) with land masked out.

The image that is created (Figure 6.4.3.b) this time appears to be dominated by just one color value in the water, namely red. You might therefore think that there is no thermal variation in the water. However, you may notice from the legend, that the color ramp has been applied from 0, and that red encompasses a range of values. Therefore, if we select a higher value than 0 for the lower end of the color ramp, we may well see differentiation in the water. (Note that actually a similar issue applied to the red band data, processed earlier. In that case, however, the issue wasn't as noticeable, since the maximum value was so much lower.)

We will therefore adjust the thresholds for the display, just as we did in Section 6.4.2.

Adjusting the thresholds for color ramp display in the *Composer* Window

1. Find the *Composer* window, which is automatically opened whenever an image is displayed.
2. In the *Composer* window, select *Layer Properties*. The *Layer Properties* dialog box will open.
3. Slowly adjust the *Display min* slider to successively higher positions. Observe how patterns in the water appear and vary as you move the slider.
4. Slowly adjust the *Display max* slider to successively lower positions.
5. The optimal values for *Display Min* and *Display Max* are somewhat arbitrary. However, one set of values that gives a good visual representation of the patterns is **121** and **150**, respectively (Figure 6.4.3.c). You can manually enter these values in the relevant text boxes, and click on *Apply*.

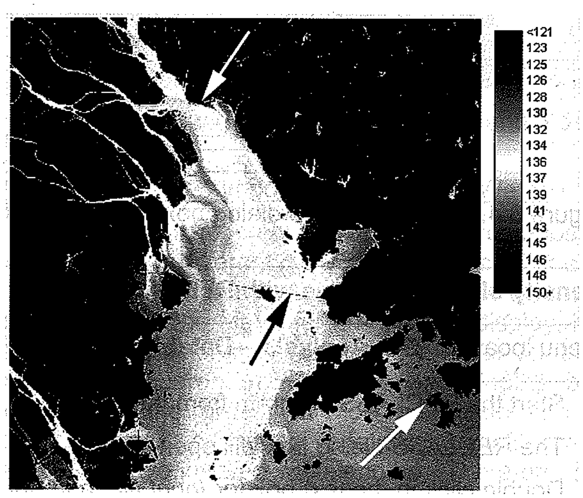


Figure 6.4.3.c ETM+ band 6 (thermal) with land masked out and modified color ramp. White arrows point to thermal pollution sources, black arrow to noise in the data.

The masked thermal image with the adjusted display range (Figure 6.4.3.c), looks very different compared to the original display of the masked data (Figure 6.4.3.b). This reminds us that the nature of the display stretch can be very important in interpreting an image.

The thermal image also has a number of interesting features, and shows patterns not evident in the red band image (Figure 4.3.a). A major source of thermal pollution is evident as a dark red (high DN value) plume extending from the island in the bottom right corner of the image (indicated by a white arrow in Figure 6.4.3.c). This source for this warm water is the discharge from a power station. A second major plume, also indicated by a white arrow, is evident where the main channel of the Pearl River becomes much narrower, at the top of the image. With careful examination, additional, smaller plumes can be made out at other locations along the coastline.

Note also that there is some noise in the data, as shown by the narrow line of warm temperatures that crosses the bay. This feature is indicated by a black arrow in Figure 6.4.3.c.

6.4.4 Density Slicing Landsat Band 3

Sometimes it may be useful to summarize the complexity of the multiple DN values into just a few discrete classes, a process termed *Density slicing*. Density slicing can be conceptualized as a simple type of classification, using just one band of data.

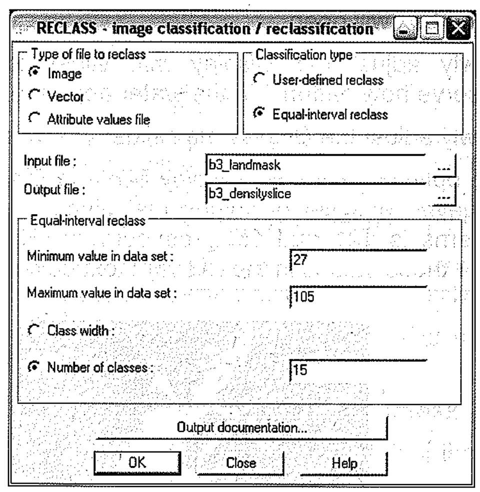


Figure 6.4.4.a *RECLASS* dialog box with options for *Equal-interval reclass.*

Density slicing an image with RECLASS

Menu location: **GIS Analysis – Database Query - RECLASS**

1. Start the RECLASS program from the main menu or toolbar.
2. The *RECLASS* dialog box will open.
3. Double click in the text box for *Input file,* and double click on ***b3_landmask*** to select that file.
4. Enter a name for the *Output file*: **b3_densityslice**.
5. In the *Classification type* section of the RECLASS dialog box, click on the radio button for *Equal-interval reclass*. The controls in the dialog box will be changed automatically to reflect this option.
6. Change the *Minimum value in data set* to **27**.
7. Leave the *Maximum value in the data set* at the default (*105* in this case).
8. Click on the *Number of classes* radio button, and enter **15** in the text box that opens to the right.

9. Figure 6.4.4.a shows the dialog box, with the parameters specified.
10. Click on *OK*.

In the above instructions, you were given a minimum value of 27 to enter, rather than the default of 0. You can verify that this is a good choice by examining the ***b3_landmask*** histogram, available with the program HISTO.

Once the RECLASS program has completed, the image will be displayed automatically (Figure 6.4.4.b). In comparing this image to the original masked band 3 data (***b3_landmask***, shown in Figure 6.4.3.a), you should note that the range of the color ramps are different. In addition, the density slicing has resulted in discrete steps in the colors, instead of the appearance of a smooth surface.

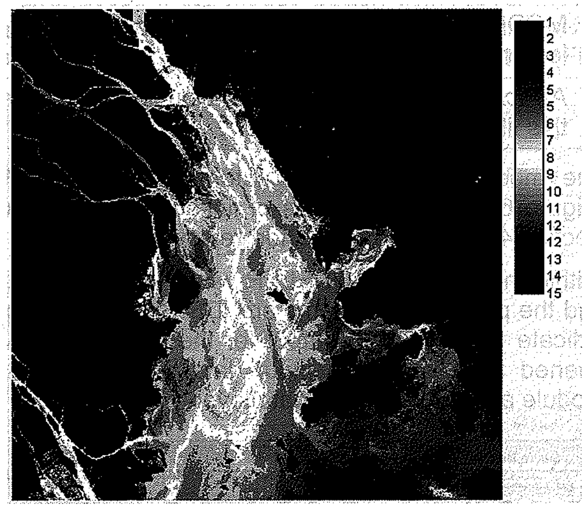


Figure 6.4.4.b Density-sliced and land-masked ETM+ band 3 data.

6.4.5 Combination False Color Composite for Land and Water

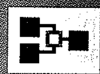
Occasionally it may be useful to create a false color composite that uses a different band combination for different parts of the image. For example, a band combination that is good for the land is not always good for water, which has very different spectral properties. Therefore, for an effective display, it may be useful to use one band combination for the water, and another for the land. Water quality patterns are most apparent in the visible wavelengths, because water's peak transmissivity is in the green part of the electromagnetic spectrum. However, land cover materials, especially vegetation, benefit from a combination of visible, near and shortwave infrared wavelengths. Therefore, for this exercise we will create a combination of Landsat bands 1, 2 and 3 (i.e. visible wavelengths) for water areas, and bands 3, 4 and 5 (i.e. red, near infrared and shortwave infrared) for the land.

It is important to note that combination false color composites such as the one we are creating here should be used with caution. A combination false color composite may be misleading to users who are not aware of the processing history of the image. In addition, unless the user has a reference image that shows the band assignments for each part of the image, even an experienced user might be misled by such a product.

The steps involved in this exercise are fairly numerous. Therefore, we will take advantage of a very powerful tool in IDRISI: the MACRO MODELER. The

MACRO MODELER has already been explained in some detail in Section 4.2, and if this section seems confusing to you, you should review that material.

For this exercise we will see an example of the use of the Macro Modeler as a way to employ "canned" programs, which have been prepared previously.



Adapting and running a previously created MACRO MODELER model

Menu location: **Modeling – MACRO MODELER**

1. Start the MACRO MODELER from the main menu or main icon bar.
2. The *MACRO MODELER* graphical interface will open.
3. In the *MACRO MODELER* window, click on the *Open* icon (second from left), or use the *MACRO MODELER* menu: *File – open*. (Note that if the MACRO MODELER window is highlighted, and you put your cursor over an icon, the icon name is shown.)
4. A *Pick List* window will open. Double click on ***segment_composite*** to select this file.

The model will be shown automatically in the *MACRO MODELER* window (Figure 6.5.4.a) as a series of linked icons. Although discussed extensively in Section 4.2, we provide a short review here.

Within the MACRO MODELER window, the blue squares represent data layers, and the pink parallelograms are IDRISI program modules. The dark blue arrows indicate the input and output for the processes. Note that the model we have opened is missing one input data layer, as well as a composite generation module and a final output data layer, all of which we will provide.

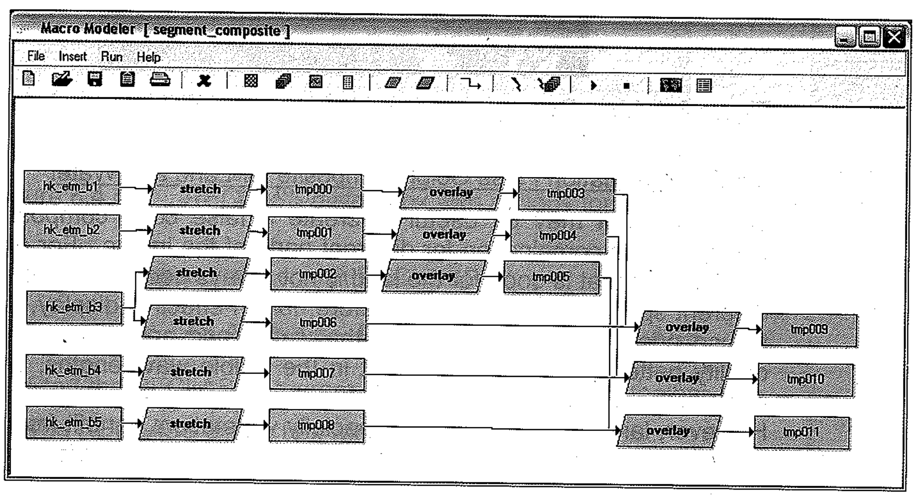


Figure 6.4.5.a MACRO MODELER, showing the model when first opened.

Models with multiple inputs, outputs and modules, such as the ***segment_composite*** model, are a bit daunting to try to interpret. However, this model is actually quite simple. The input files are all on the left, and comprise five of the seven Landsat bands. In the model, the five bands are each stretched. The first three are then each processed through an overlay operation. This is followed by a second set of overlay operations.

Note that ETM+ band 3 is linked as input for two different stretch modules. This demonstrates that it is possible for one file to serve as input for multiple modules.

Adapting and running a previously created model (cont.)

5. In the *MACRO MODELER* window, click on the *Raster Layer* icon.
6. The *Pick List* window will open. Select ***LANDMASK***, a file created in Section 6.4.2. (This image has DN values of 1 for the water areas, and 0 for land areas.)
7. A new raster layer, indicated by a blue rectangle and labeled ***LANDMASK***, will appear in your model.
8. Use the mouse to drag the ***landmask*** raster layer to a position above the second column of input files (i.e. above raster layer *tmp000*).
9. Click on the *Connect* icon (a blue bent arrow). Now click on the ***landmask***, raster layer, and, keeping the mouse button depressed, move the mouse to the top of the first *Overlay* module. Remove your finger from the mouse button. This will connect ***landmask*** to the *Overlay* function (Figure 6.4.5.b).

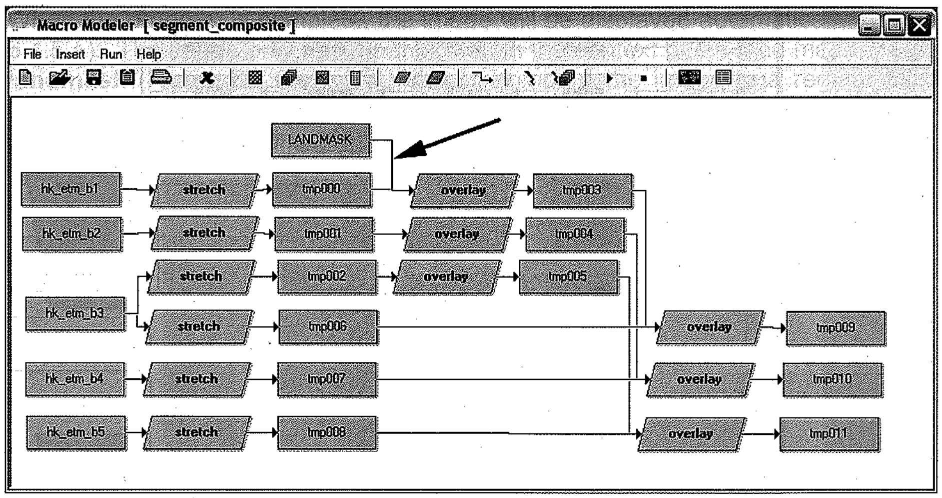


Figure 6.4.5.b MACRO MODELER with the *Landmask* raster layer added. Arrow points to the new link to the *Overlay* function.

Adapting and running a previously created model (cont.)

10. Repeat the previous step two more times, connecting the ***landmask*** raster layer to the two *Overlay* modules below the first one. The result will be that the land mask will be connected to all three *Overlay* modules.
11. The connection procedure described above automatically enters the land mask as the second layer in each of the *Overlay* module functions. To confirm that this has indeed taken place, do the following: Place the mouse over the first *Overlay* module (the one used in step 9, above). Right click. A *Parameters: Overlay* window will open (Figure 6.4.5.c), which is essentially a table showing the processing parameters for *Overlay*. Confirm that the *Second input image* is specified as ***landmask***. You should also confirm that in the bottom line of the window the overlay *Operation* parameter is specified as *Multiply*.
12. Click on *OK* to close the *Parameters: Overlay* window.

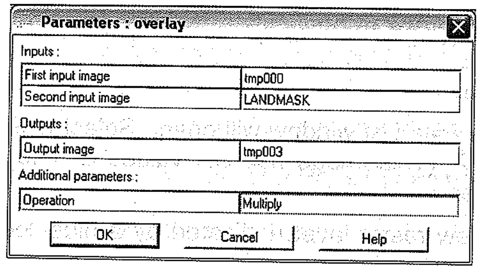


Figure 6.4.5.c *Parameters: Overlay* window showing *Landmask* as the second input image.

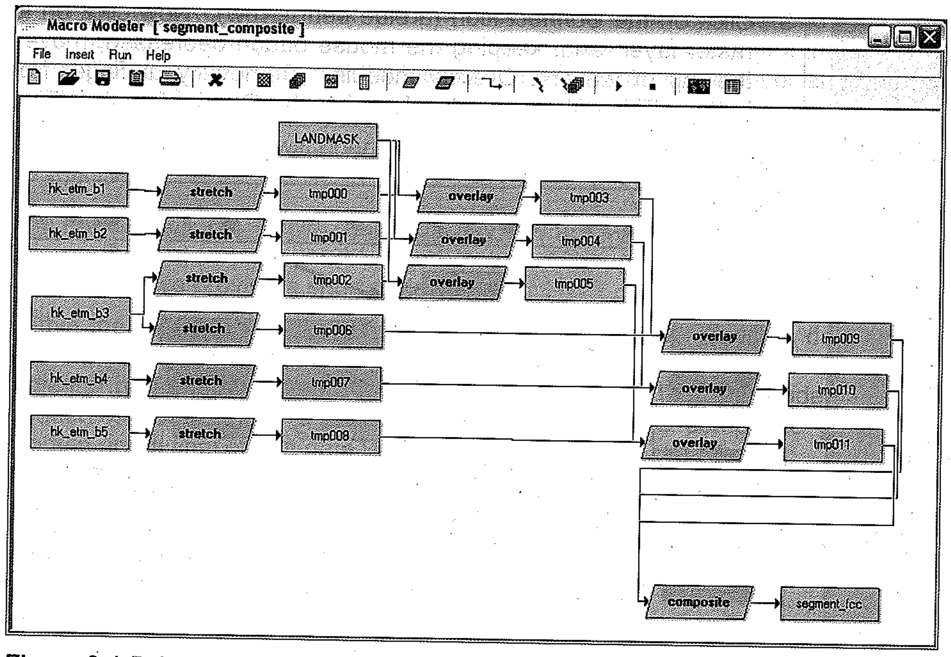


Figure 6.4.5.d MACRO MODELER with final model.

Adapting and running a previously created model (cont.)

13. Make the MACRO MODELER window a little larger, by dragging the lower frame down a short way.
14. Now add a new module to the model, by clicking on the *Module* icon.
15. A *Pick List* window will open. Double click on *Composite*.
16. A new module, labeled *Composite*, will appear in the model.
17. Use the mouse to drag the *Composite* module and its output raster layer to the bottom right corner of the *MACRO MODELER* window.
18. Click on the *Connect* icon. Click on raster layer ***tmp009***, and keeping the mouse button depressed, move the mouse until you are over the *Composite* module. Remove your finger from the mouse button. The ***tmp009*** raster layer should now be connected as one of the three inputs for the Composite Module.
19. Repeat the previous step to connect ***tmp010*** as the second input to the Composite module.

20. Repeat again to connect ***tmp011*** as the third input to the Composite module.
21. Change the output filename of the *Composite* module from the default name (which will begin with *temp*, and is followed by 3 numbers) by *right-clicking* with the mouse on that raster layer icon.
22. *A Change Layer Name* window will open. Enter the new file name: **segment_fcc**.
23. The resulting module is shown in Figure 6.4.5.d.
24. Save the model by clicking on the *Save* icon.
25. Run the model by clicking on the *Run* icon.
26. When prompted *"The layer tmp007 will be overwritten if it exists. Continue?,"* click on *Yes to All.*
27. As the model runs, you can track its progress by observing which module is highlighted in green.

When the program is complete, the image will be displayed automatically (Figure 6.4.5.e). The image only has meaning within the context of the land mask image, **landmask** (Figure 6.4.2.e). You should compare the image to a regular false color composite, such as **hk123**, to decide if you feel this combination false color composite image does indeed provide more information.

Figure 6.4.5.e Combination false color composite. Water: bands 3,2,1 (R,G,B). Land: 5,4,3 (R,G,B).