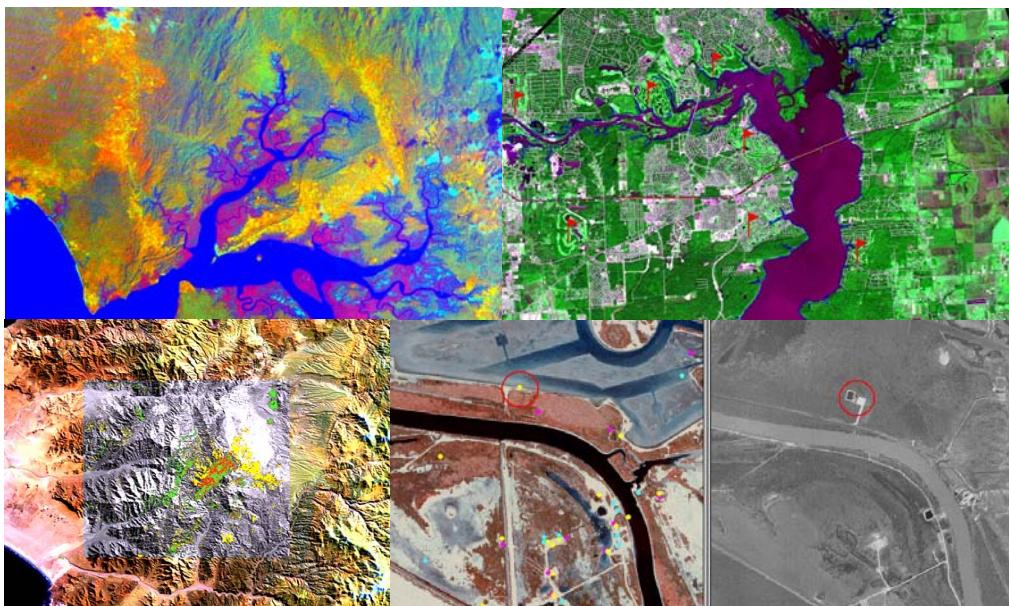


Image Analysis with ArcGIS 10



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TerraView

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Preface

The following tutorial is designed to be used by advanced GIS students within the framework of a remote sensing class or raster GIS class with a strong remote sensing component. ArcGIS 10, any level, and the Spatial Analyst Extension are required to use this tutorial. Students should be proficient in the basic functions of ArcGIS 10 including creating a new project and geodatabase, setting up a project workspace, adding data, adding and using the dockable windows, and using ArcGIS dropdown and menu tabs. The tutorial utilizes most of the functionality of the Image Analysis window. The tutorial does not, however, explain each function in detail. This is an opportunity for the student to become familiar with the excellent “Help” resources available in ArcGIS and each section contains path references to additional information (<http://resources.arcgis.com/content/web-based-help>).

Each Exercise begins with a brief statement of the purpose or concept of the Exercise. When needed, the tools and functions may also be introduced. **Start ArcMap** indicates the point at which the “hands on” instructions begin. The operation of the tools and functions is discussed as part of the “hands on” directions. Since this tutorial is intended to supplement and compliment a class focused on remote sensing, basic remote sensing concepts and discussions of sensors, data acquisition, data formats, and other aspects of remote sensing are not provided. Remote sensing online tutorials are available from:

NASA <http://rst.gsfc.nasa.gov/>

The Canadian Centre for Remote Sensing
http://www.ccrs.nrcan.gc.ca/resource/tutor/fundam/index_e.php

Experimentation is key to understanding any new tool. Please use this tutorial as an introduction and guide and then experiment with the included data set or, more importantly, acquire your own data and really enhance your experience. An outstanding archive of remote sensing and GIS Learning Units is available through the Integrated Geospatial Education & Technology Training (iGETT) site hosted by Del Mar College:

<http://www.delmar.edu/igett/LearningUnits.html>

Special thanks to the students of GISC 1491 and GISC 2411 at CyFair College for working through the exercises, finding errors, and suggesting improvements. Ann Johnson, Associate Director, GeoTech Center provided encouragement, comments, and suggestions that were critical to a useful document.

Introduction

Lawrie Jordan, Director of Imagery for Esri recently stated that “GIS users are the largest collection of imagery users in the world.” The combination of unique view (synoptic and multi-spectral), extractable information, timely acquisition, and extensive archive make imagery an important component of GIS. Formerly, image analysis (IA) and GIS were largely separate disciplines and separate software. As the bilateral integration occurs, it is logical that this convergence should be reflected in software development. Esri has addressed this need by incorporating IA tools in the ArcGIS 10 release. If you discover that you need more image data types and more sophisticated processing for your projects, IA tools are available as 3rd party toolboxes (ENVI 4.8) and extensions for ArcGIS and as separate IA software systems.

In this tutorial, you will explore most of the important functions in the Image Analysis window using images and data from the Houston, TX region. The Image Classification toolbar is only available with a Spatial Analyst license but it is important for extracting information from the image data. Several examples of classification will be given in this tutorial. References are made to ArcGIS Help throughout this tutorial. If you want to explore ArcGIS help topics using the Web, go to <http://resources.arcgis.com/content/web-based-help>. You are strongly encouraged to read through the entire Exercise before you start each one.

After completing the exercises in this tutorial, you will be able to locate and use the ArcMap and Image Analysis tools you need for basic preparation, enhancement, and analysis of aerial and satellite images.

Image Sources

Please refer to the ArcGIS Help: *Resource Center>Professional Library>Data Management>Geographic data types>Rasters and images>Supported raster data* for detailed information on supported image file formats. The list is extensive. Specialized Image Analysis software may be needed to load and convert data from other sources. **Important Note: You cannot use raster catalog layers in the Image Analysis window.**

Image access falls into three types: local, dynamic, and static. Local access refers to imagery available on a local disk or server. It is also called “direct access”. Imagery you select and download from the Web or media will be local. Dynamic service refers to images that are delivered by a remote service that assembles an image at your request and serves it back to you. You may be able to exercise some control over the image production in this environment. Esri image services are examples of dynamic service. Static services provide predefined images or tiles. ArcGIS.com, Bing (Microsoft) Maps, and Google distribute large volumes of static images over the Web. You will use local access for the images and data used in these exercises.

Exercise 1 – Starting Image Analysis

IAtutorial/Houston_TM.tif, the image we will use for this exercise, is a spatial and spectral subset of a full Landsat TM scene acquired 9/20/1999. The subset contains 6 spectral channels, more commonly referred to as bands, of Landsat data ranging from the visible (band 1 = blue, band 2 = green, and band 3 = red) to the reflected infrared (bands 4, 5, & 7). Landsat band 6, a thermal band, is not used in this tutorial and so Landsat band 7 becomes band 6 in the ArcGIS list. Landsat TM also includes a panchromatic band (band 8) with 15 meter spatial resolution. We will use the panchromatic band in Exercise 3 to create a pan-sharpened image.

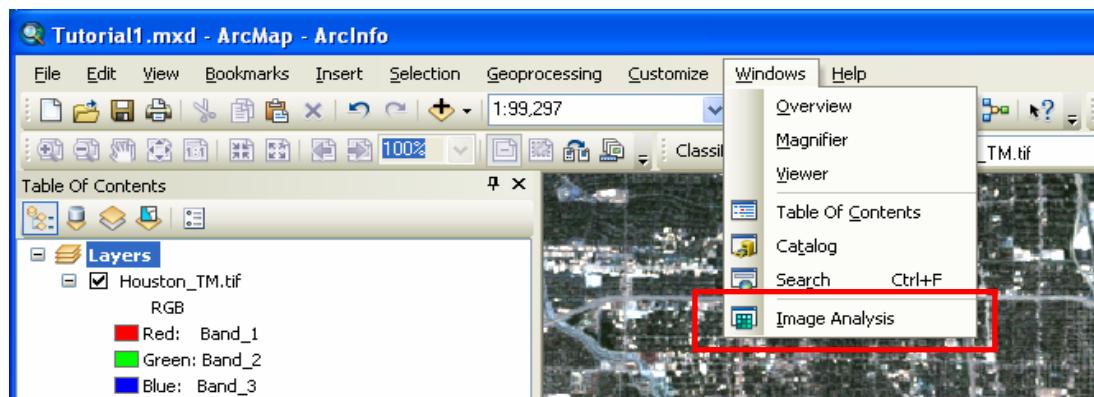
This would be an excellent time to review the properties of images and the characteristics of Landsat TM sensors. The following links to The Canadian Centre for Remote Sensing tutorial are a good place to start.

http://www.ccrs.nrcan.gc.ca/resource/tutor/fundam/chapter1/07_e.php

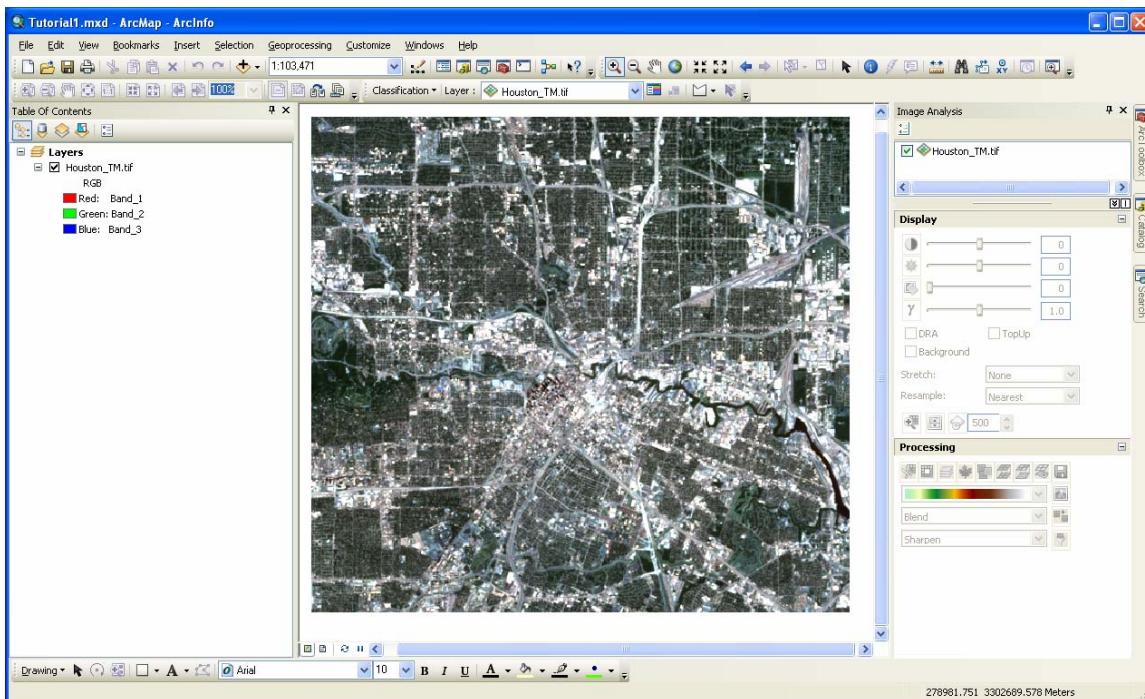
http://www.ccrs.nrcan.gc.ca/resource/tutor/fundam/chapter2/12_e.php

Start ArcMap. You can use image analysis tools in any level (ArcView, Editor, or ArcInfo) of ArcGIS 10 Desktop. Open a new map document. Add the **Houston_TM.tif** image with the Add Data button by navigating to the **IAtutorial** directory and selecting the designated file. The image will appear in the ArcMap Table of Contents. Remember that band 6 in the ArcGIS list is TM band 7.

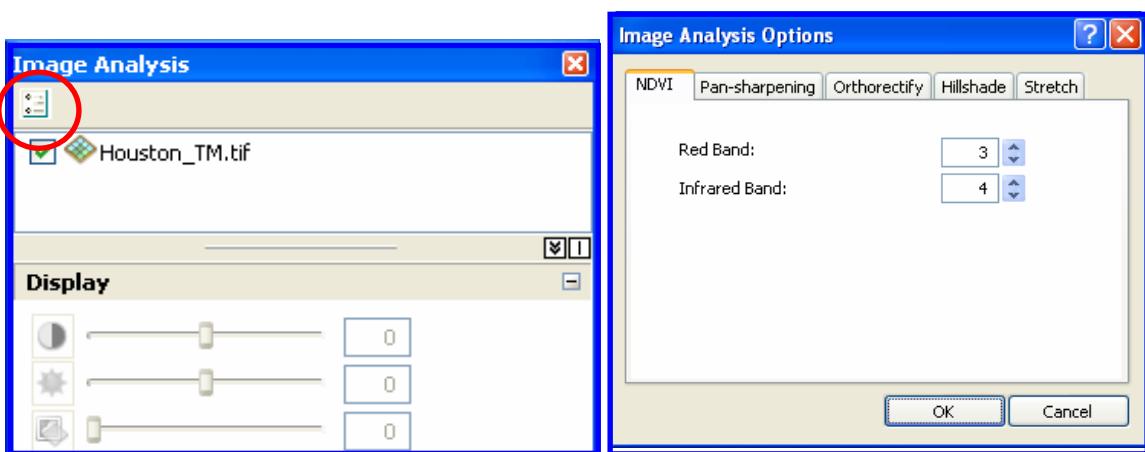
Image Analysis for ArcGIS is activated by clicking on the Image Analysis window in the Windows dropdown menu on the Main menu toolbar in ArcMap.



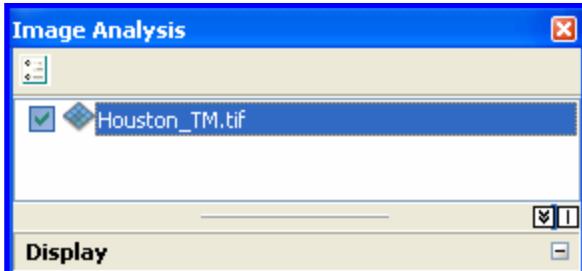
You can dock the IA window in ArcGIS 10, which is often the most convenient way to use it.



Open the Image Analysis Options at the top of the window. You will not change these now but as you become more familiar with the functions in Image Analysis, you will want to alter them for specific image types or projects.

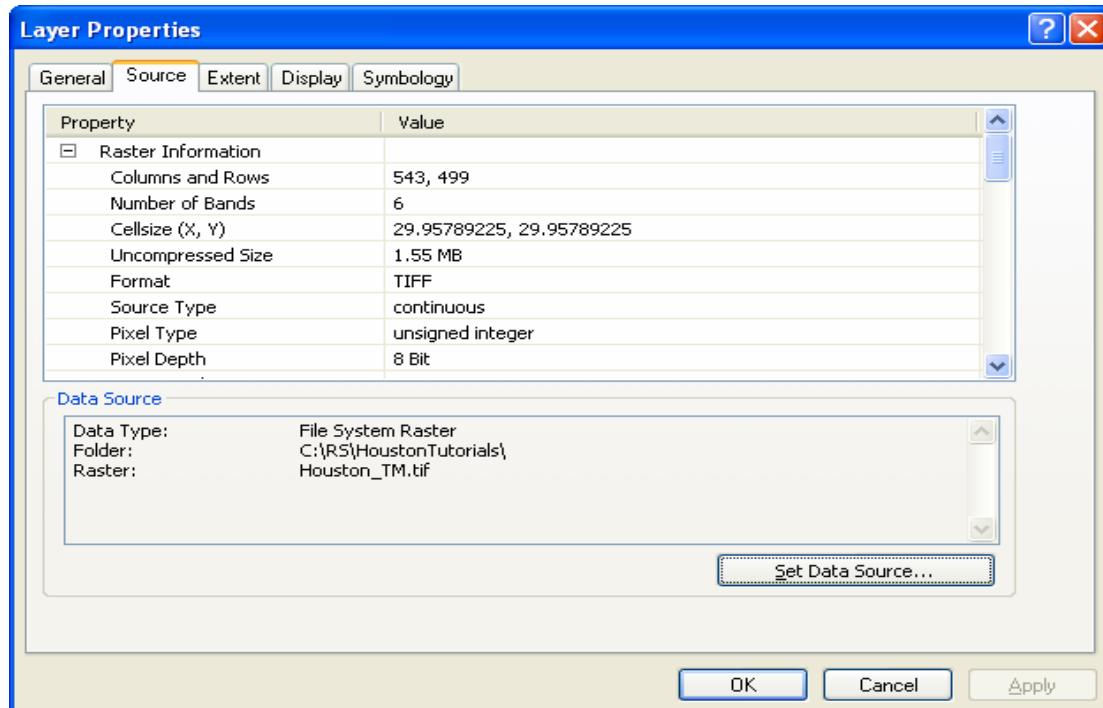


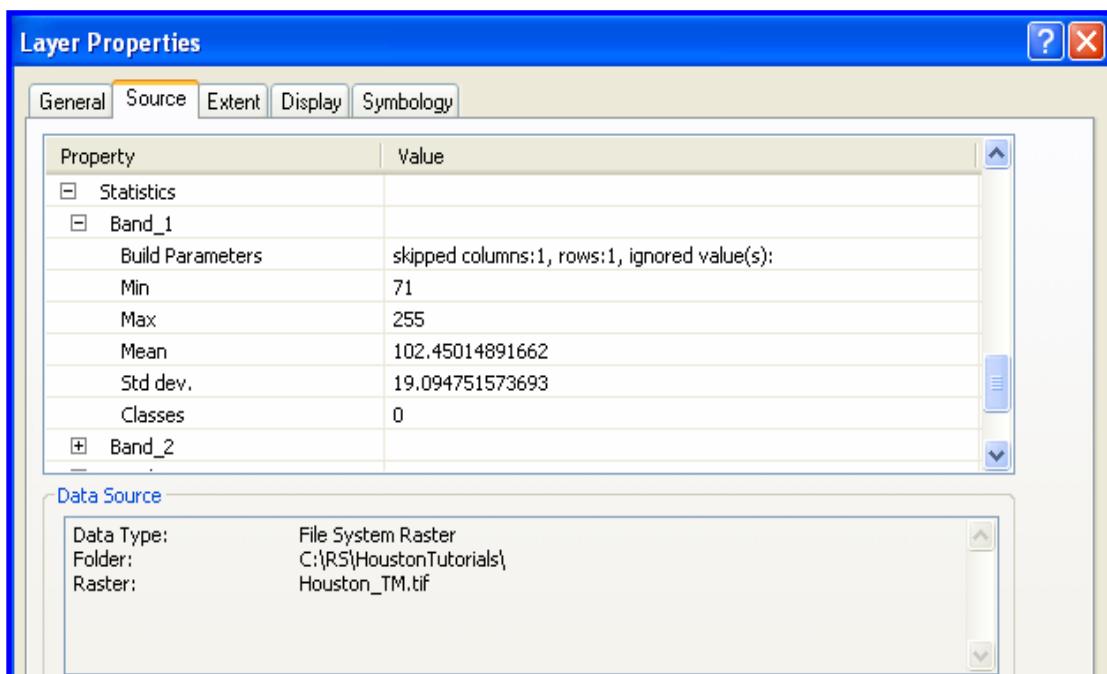
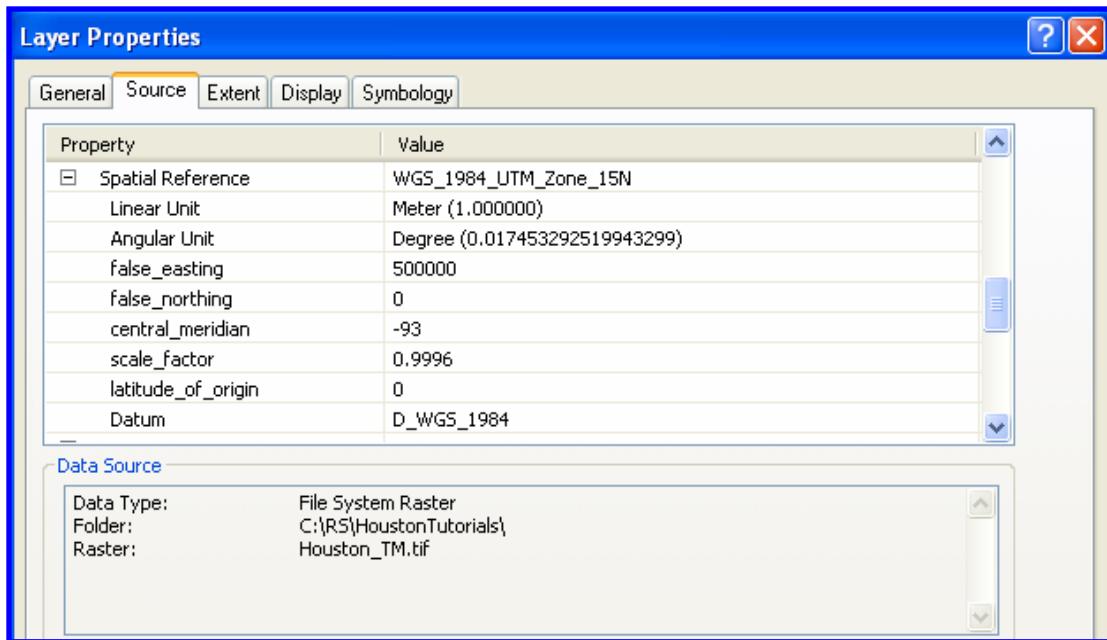
The Image Analysis window will show the **Houston_TM.tif** in the layer list at the top of the window.



Right click on the image and note that there are three options: Accelerate, Remove, and Properties. Click Properties and this will bring up the Layer Properties menu just as it would if you right clicked and selected the Properties in the Table of Contents.

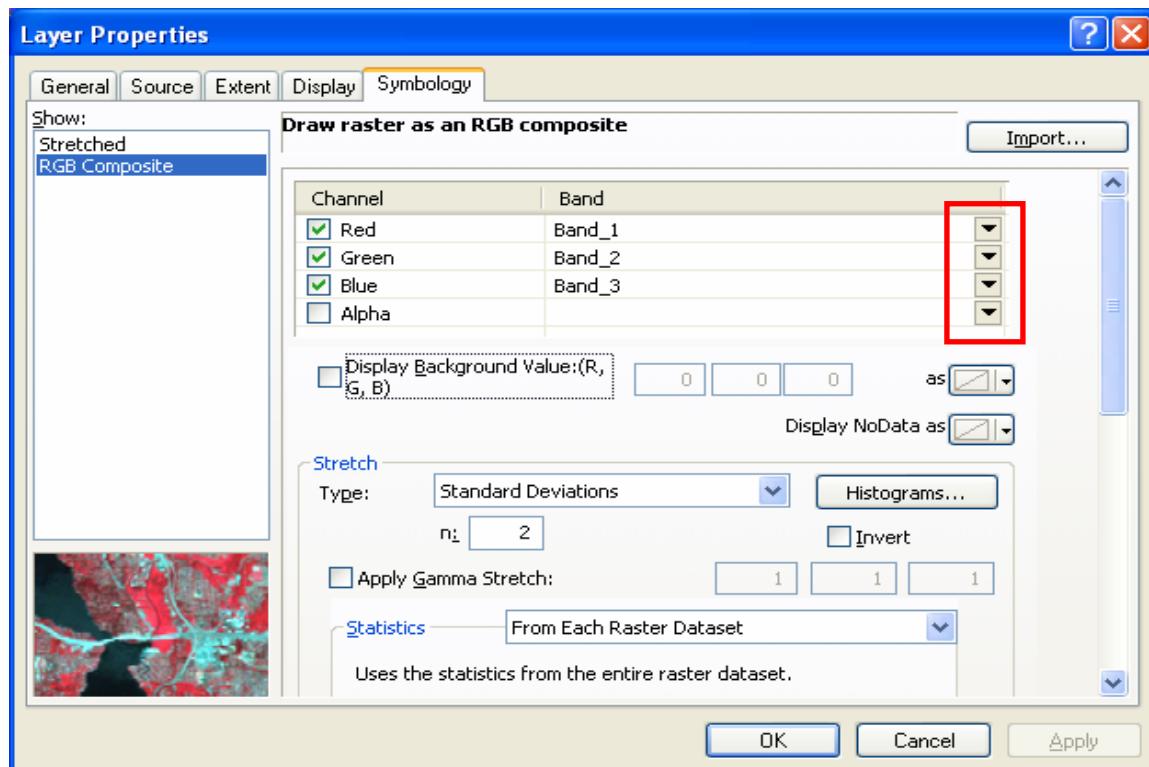
Examine each of the tabs: General, Source, Extent, Display, and Symbology. This is the time to make note of critical parameters from the Source tab for future reference in a project notebook or for producing metadata. The information includes columns and rows, cell size, pixel depth, extent, spatial reference, and statistics. You can copy the entire list or single rows to a text document but it will include all the HTML code. It is often easier to copy the information you want from the text into a pre-formatted spread sheet.





The Extent tab has similar information to the Source tab except for the listing of current extent, if zoomed in, and extent of data frame. The Display tab has options for displaying and manipulating the data but you will use the tools in the IA window at this time.

The Symbology tab allows you to select the assignment of bands to the display color channels, display of background value, stretch options, view image statistics using several sampling options, and pan-sharpening parameters (to be discussed in the Processing panel section of this tutorial).



Remember that band combinations, band color assignments, and image enhancements can have a great impact on scene visualization and interpretation. You can review the concepts and principles of image processing at:

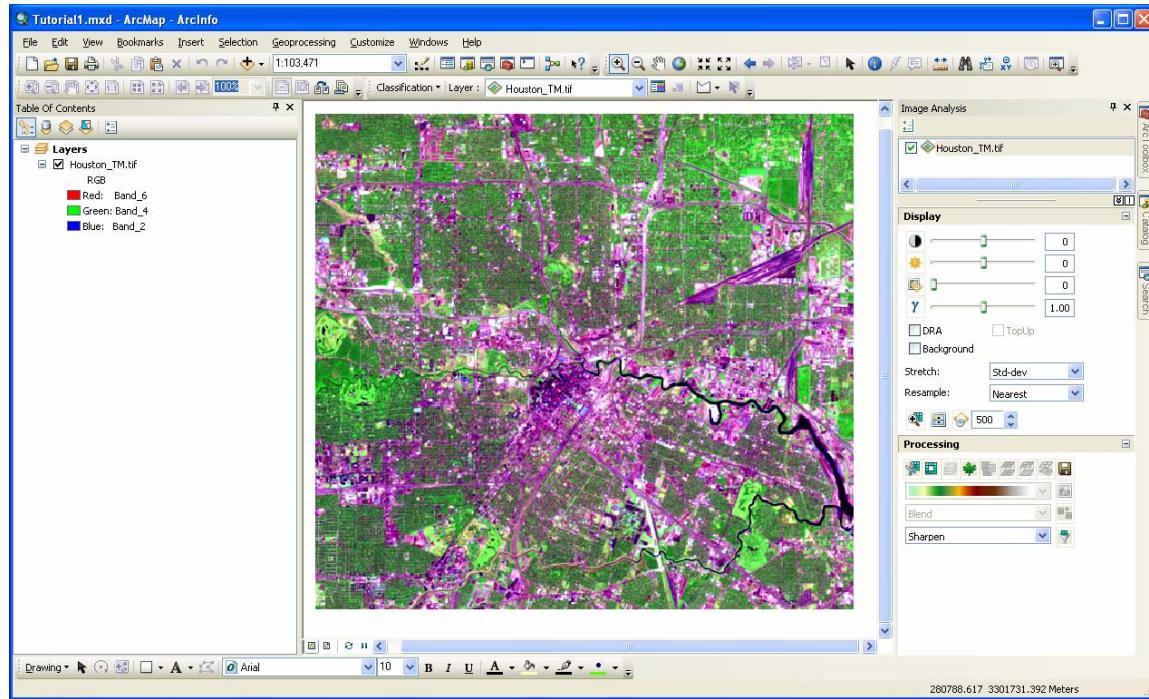
http://rst.gsfc.nasa.gov/Sect1/Sect1_1.html

http://www.ccrs.nrcan.gc.ca/resource/tutor/fundam/chapter2/12_e.php

http://www.ccrs.nrcan.gc.ca/resource/tutor/fundam/chapter4/05_e.php

Again, you will use the tools in the IA window for most of these functions. However, the default band assignments for the **Houston_TM.tif** image have produced a very poor display; almost monochromatic. First, be sure RGB Composite is selected as the Show option to display all 3 bands. Reverse the order of the bands to R = 3, G = 2, and B = 1. This will produce a true color band combination with red band 3 in the red channel. Now try an R = 6 (actually TM band 7), G = 4, and B = 2 combination. Vegetation appears green and water a dark blue. The urban areas are magenta but that is often more acceptable to the viewer than red or blue vegetation. Use the 6, 4, 2 band combination for the following exercise.

You can change the default order of band display in the Main menu>Customize>ArcMap Options>Raster tab. This is convenient for satellite images but may have an undesired affect on other picture types.



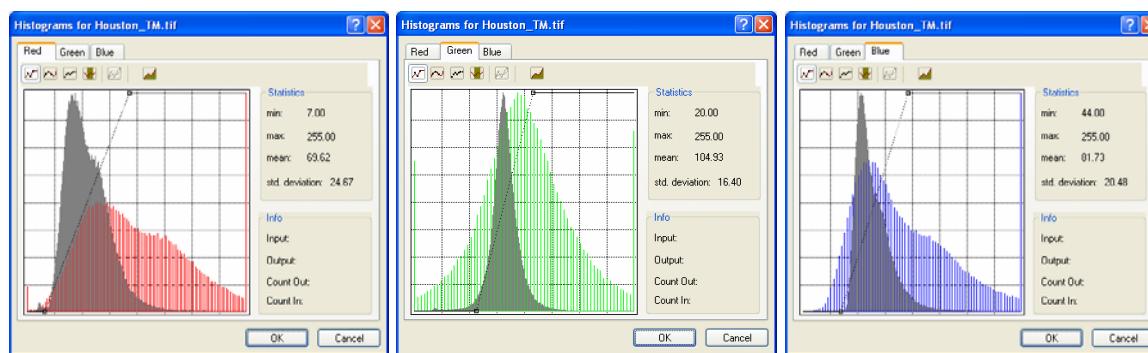
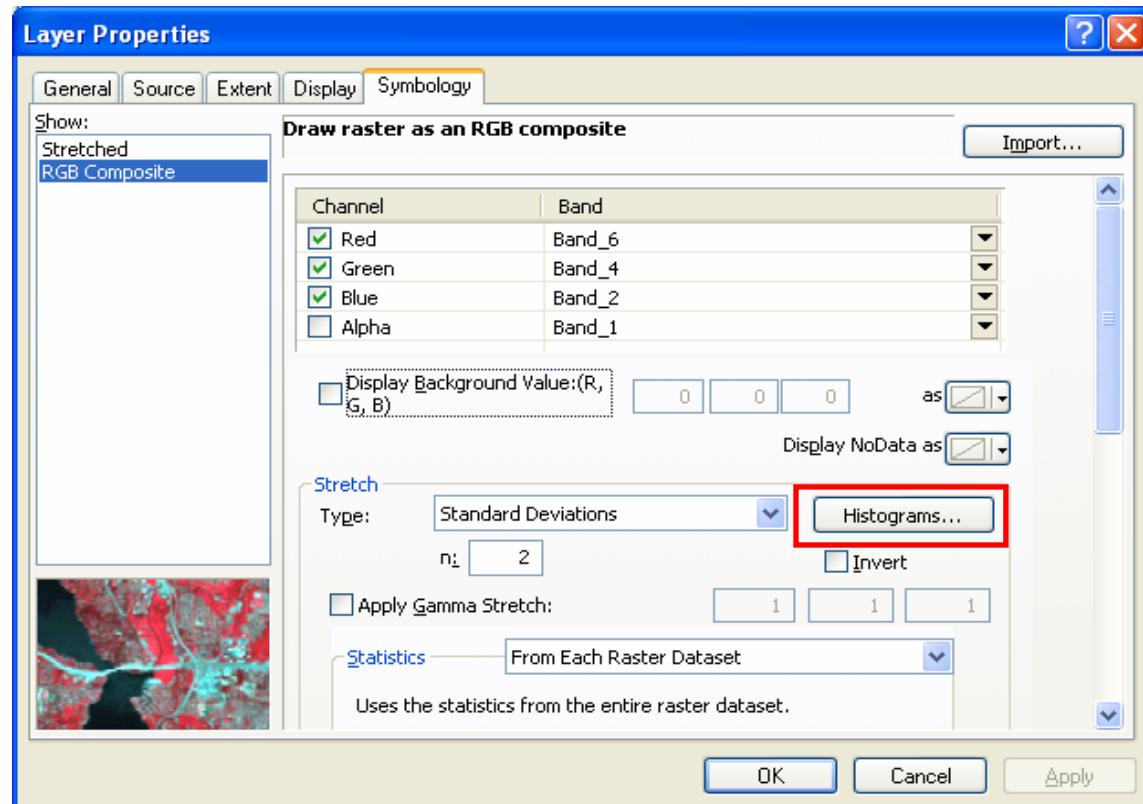
Prepare a layout to contrast the “true color” R=3, G=2, B=1 image with the R = 6 (7), G = 4, and B = 2 combination. Be sure to include the key elements of a map in your illustration; title, scale, and brief text identifying the images. Export the layout by selecting the “File” dropdown menu and selecting “Export Map”. Choose “TIFF” format, 150 dpi, and an appropriate file name (one that does not conflict with any of your other .TIF files) and location. The TIFF format is recommended for text clarity. The JPEG option creates artifacts around text that degrade appearance. Place the exported map in a Word (compatibility) document by going to Insert>Picture>From File and selecting your .TIF file. Briefly discuss the application and visualization characteristics of both combinations. ***Turn in the document for Exercise 1 credit.***

This concludes Exercise 1. If you are continuing on to Exercise 2, where you will work with the Display panel, just continue to follow the instructions. If you are stopping at this point, save this map document as **AITutorial1.mxd**.

Exercise 2 – Enhancing the image with the Layer Properties and Image Analysis window: Display panel

There are many display options in the IA window. Images in raw form are rarely optimal for viewing and interpreting. By changing the distribution of pixel values in the image histogram or “stretching” the image, the brightness and contrast of the image can be significantly improved.

Start ArcMap If you are not continuing from Exercise 1, open **AITutorial1.mxd**. Open the image properties and examine the stretches for each band by clicking on the Histograms button in the Stretch portion of the menu.

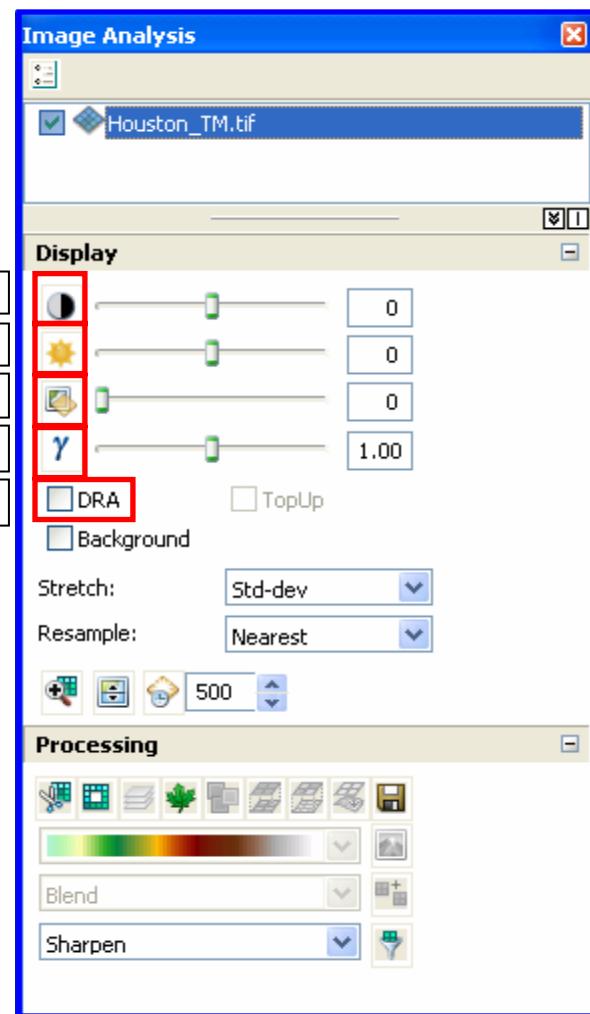


The ArcGIS default stretch uses 2 standard deviations calculated from a statistical analysis of pixel value frequency distribution. Note that the stretches are different for each band. To see what the image would look like without manipulation, set the stretch type to “none” and apply. This would be a difficult image to examine and interpret. Apply the “Histogram Equalize”, “Minimum-Maximum”, and “Percent Clip” stretches with their default settings and note the differences. Change the default min: and max: settings of 2(%) in “Percent Clip” to 10 and note the difference. There are also more interactive methods of histogram stretch that are not used in this tutorial.

It is very important to remember that you do not want to alter the original pixel values of an image permanently if you intend to subsequently perform classifications or other processes involving band calculations. Keep your original file safe.

The “Display” panel offers many tools to quickly improve the appearance of the image.

- 1 Contrast Slider
- 2 Brightness Slider
- 3 Transparency Slider
- 4 Gamma Slider
- 5 DRA (Dynamic Range Adjustment)



Please refer to the ArcGIS Help: *Resource Center>Professional Library>Data Management>Geographic data types>Rasters and images>Displaying raster data* and subtopic *>Options for improving the display of raster data* for detailed information on the Display panel of the Image Analysis window and the tools available.

Experiment with the sliders to quickly enhance an image for display and to use for data interpretation and extraction such as heads-up digitizing.

The operations of the gamma slider, DRA button and Background button require some explanation. The gamma slider controls the brightness of the middle values without affecting the values at the extreme ends of range. The gamma slider can also affect the ratios of red, green, and blue. Small variations in the gamma values can have large effects on the image. The Dynamic Range Adjustment button adjusts the stretch based only on statistics of the data contained within the data frame. Zoom in to a scale of 1:50,000, check the DRA box, and observe the changes. The Background button sets the background value to 0 and makes it transparent. This is very useful when a transformed layer is surrounded by “no data” in black and you want to see the image beneath.

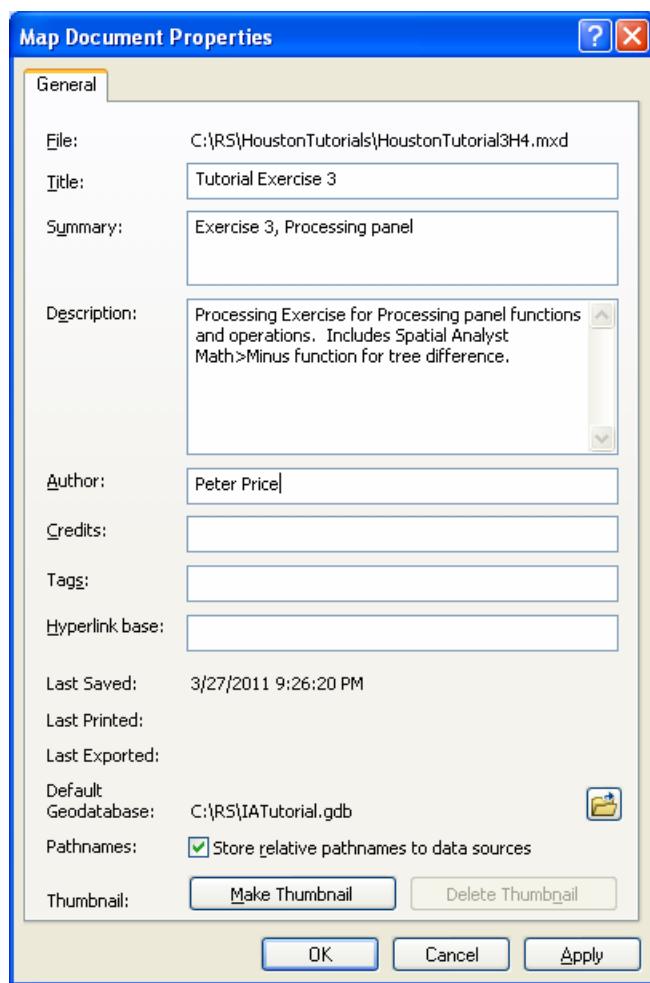
The selection of the resampling method is important because it affects the usability of the image for classification and band calculations. Nearest neighbor is the only method that does not involve alteration of the pixel value. The cubic convolution method results in the sharpest image with minimized “jaggies” in straight lines. If you are still at the 1:50,000 scale (if not, zoom in), go to the “Resample” drop-down and switch from “Nearest” to “Cubic” and note the differences in appearance.

The One-to-One button or Zoom to Raster Resolution  displays the image at its optimal resolution. The Swipe and Flicker tools  are used to view and compare two overlapping images or raster layers. You will use these tools later to help interpret Exercise results. Select the layer you want to Swipe in the Image Analysis Window and be sure it is on top.

You have now enhanced the image to improve its usability. Create a layout with your best enhancement of the **Houston_TM.tif** image, export it, and place it in a Word (compatibility) document. Describe the choices you made and parameters you set to achieve the enhanced image. ***Turn in the document for Exercise 2 credit.***

Save your enhanced image as **Houston_TMenh1.tif** and the map document as **AITutorial2.mxd**. You can save your image by right-clicking on the layer in the Table of Contents and using data>data export. You can also use the Export  button in the IA Processing panel.

This is an excellent time to organize your data and to plan for future exercises. Depending upon how you have been using ArcGIS for previous projects, you may be saving to folders or a geodatabase. ArcGIS has a default geodatabase located in C:\ Documents and Settings\ (your user name)\My Documents\ArcGIS\Default.gdb. (NOTE: If you exported data without checking the location and could not find it, this is a good place to look!) It is NOT the location for the temporary results of operations in Image Analysis. They are located in C:\ Documents and Settings\ (your user name)\Local Settings\Temp. Do not delete or alter these files because they are your temporary results. Delete them from inside your ArcGIS map document. For these exercises, it is recommended that you create a new file geodatabase and name it **IATutroials**. Set this as your default geodatabase by going to the File>Map Document Properties and making the changes as illustrated.



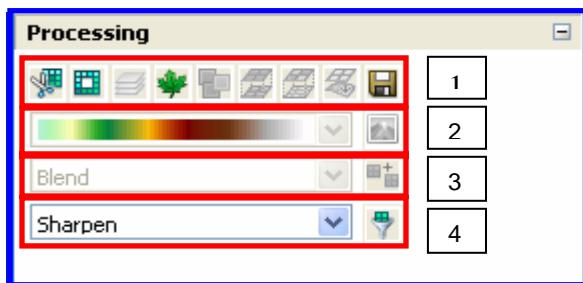
Within the geodatabase, you may want to set up feature datasets for certain sections of the Exercises. Remember, however, that feature datasets must be in the same datum, projection, and coordinate system. The data sets within this tutorial are mixed Decimal Degrees, UTM, Texas State Plane S Central, etc.

Remember, the AI tools operate on the layer(s) selected in the list. Avoid unintended consequences by selecting the target layer carefully.

Exercise 3 – The Image Analysis window: Processing panel

The Image Analysis window: Processing panel offers a suite of basic tools for performing processing and analysis techniques to single or multiple, depending upon the operation, images and raster data sets. The tools operate on one or more layers selected in the Image Analysis window layer list. One key feature of the processing in this section is that it results in the creation of temporary layers. The results must be exported to become a permanent file. The advantage to this approach is that the user does not have to manage a vast collection of intermediate files while arriving at an optimal result.

Please refer to the ArcGIS Help: *Resource Center>Professional Library>Data Management>Geographic data types>Rasters and images>Processing and analyzing raster data* and subtopic *>Analysis tools on the Image Analysis window* for detailed information on the Processing panel of the Image Analysis window and the tools available. *Resource Center>Professional Library>Data Management>Geographic data types>Rasters and images>Fundamentals of raster data* provides detailed information on the raster functions called by these buttons.



The top row (1) of buttons holds the tools (from left to right): Clip, Mask, Composite Bands, NDVI, Colormap to RGB, Difference, Pan-Sharpen, Orthorectify, and Export. Remember, the options for setting the tool parameters are found in the upper left of the Image Analysis window (see page 5).

Row 2 holds button for creating a Shaded Relief of the selected layer and symbolizing the resulting layer with various ramps.

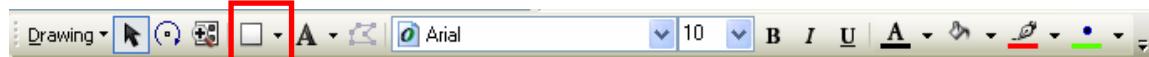
Row 3 holds the Mosaic button and a drop-down menu for handling the overlapping areas of raster layers selected in the layer list.

Row 4 holds the Filter button and a drop-down menu of preconfigured filter choices. Please refer to the ArcGIS Help: *Resource Center>Professional Library>Data Management>Geographic data types>Rasters and images>Building and managing a raster database>Mosaic datasets>Working with functions “Convolution function* for detailed information on and examples of convolution filter types.

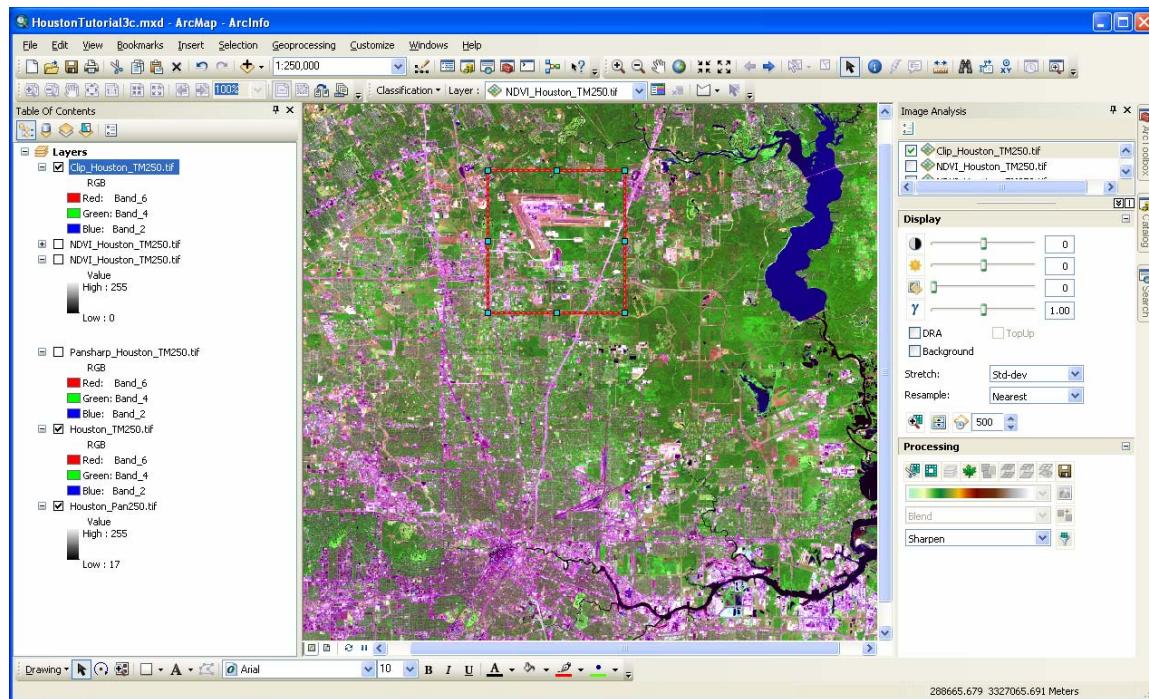
You will now apply some of these tools to produce useful enhancements and analyses to your Houston project.

Start ArcMap and open the Image Analysis window. Open a new map document. Add the **Houston_TM250.tif** image with the Add Data button by navigating to the **ITutorial** directory and selecting the designated file. This is a larger spatial subset of the 1999 Landsat TM image used in the previous Exercises.

Efficient image analysis necessitates image subsetting to use only the area that is required by the project. The Clip button  will subset the image to the data view extent or to the extent of overlap with a feature or graphic. You will want to isolate features in the area of Houston International Airport in some future project. Draw a polygon as shown around the airport. This is done by activating the Draw toolbar.



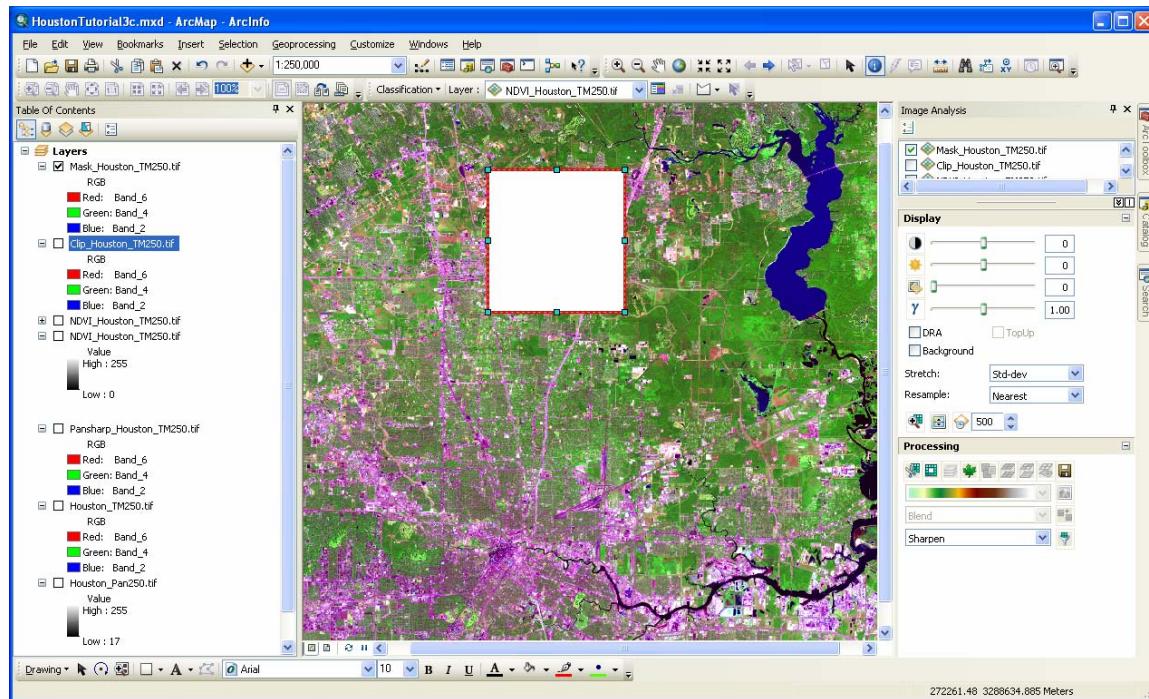
From the toolbar, select the rectangle tool and enclose the area described above. Change the polygon graphic fill to “no color” with a red outline. With the polygon **selected** and the **Houston_TM250** image selected in the image list, click the Clip button in the Processing panel of the Image Analysis window.



You should immediately see a **Clip_Houston_TM250.tif** image in the layer (image) list and the Table of Contents. One potential problem that occurs with the Clip button is that it will clip partial pixels. This can cause pixel alignment

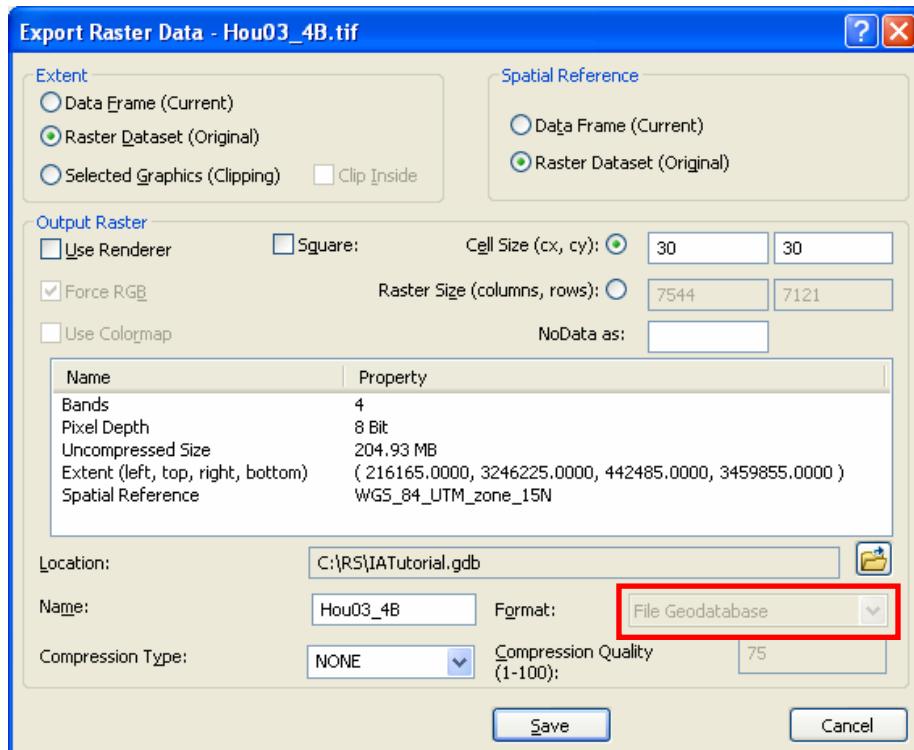
problems in subsequent operations. Remember, this is a temporary image and it must be exported using the Export button to become a permanent file. Select the Clip image in the image list and click the Export button. The Export Raster Data window will open. Review the parameters in the window and save the file as **HouAirport_TM.tif**. You can subset the available bands by using the “Make Raster Layer” tool in the Data Management Tools>Layers and Table Views.

The Mask button  is used to create a masked or hidden area or areas within a data set. The masked area values are converted to “NoData”. A graphic or a polygon feature within a feature class layer can be used to designate the areas. Masks are used to exclude data from an analysis. One common use of Mask in IA is to eliminate cloud covered areas so that they will not affect the statistics of a classification. Unsupervised classifications, in particular, can be heavily biased by cloud signatures. For simplicity, assume that Homeland Security has designated the airport as an area that must not be displayed on a map or represented in an image file. Use the same polygon you used to sub sample the **Houston_TM250.tif** image to create a mask of the airport. Click the Mask button and you should immediately see a **Mask_Houston_TM250.tif** image in the image list and the Table of Contents. Turn off all other layers.

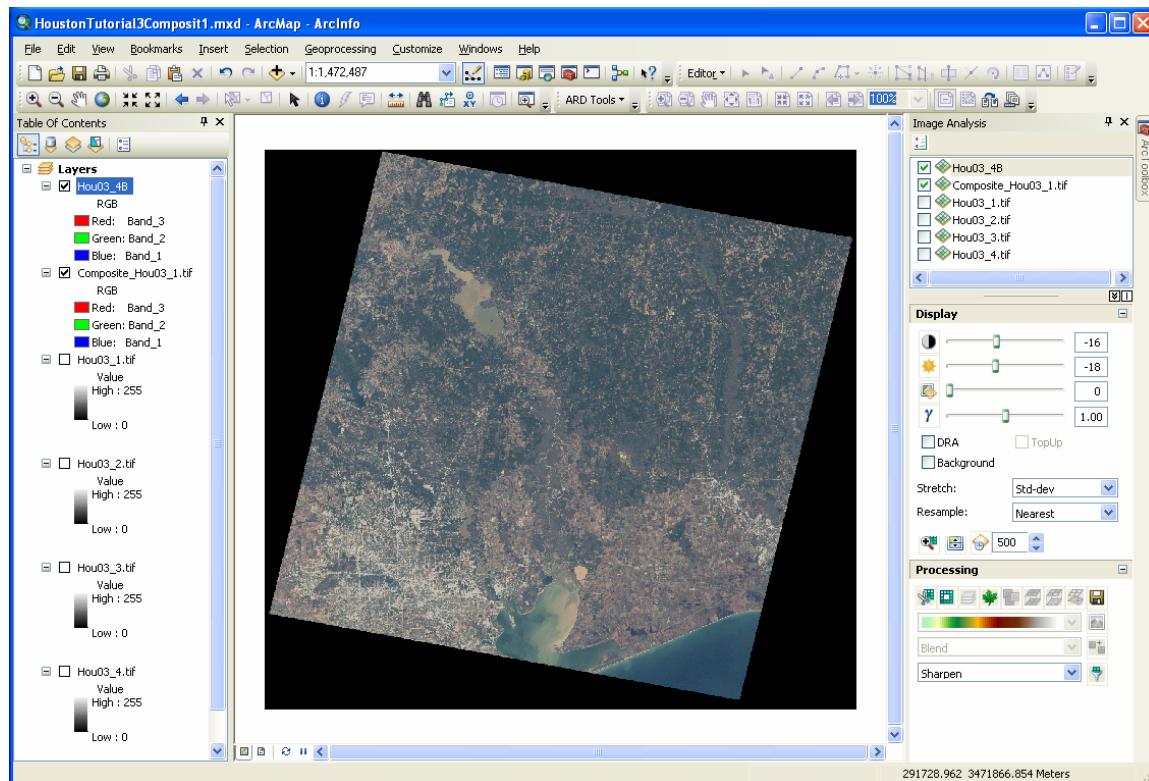


Use the Identify tool to view the values inside the masked area. The values should be “NoData” for all 3 bands. Turn on the **HouAirport_TM.tif** image and see that it fills the NoData area.

The Composite Bands button  is very important because it allows you to combine single image bands or raster layers into one multi-band raster layer. A significant component of the available image archives is imagery in single band format, usually as (geo)TIFF files. To process data as multi-band sets for functions such as classification, the bands must be combined into a single raster layer. As part of your analysis of the Houston area, you might want an image that is more current than 1999. The last Landsat 7 data that was not affected by the scan line corrector (SLC) fault was prior to April, 2003. (Research the SLC issue if you are not familiar with it; it impacts a lot of imagery that you might consider using in projects.) The available scene is in single band .TIF format. You will need to composite the bands to use the data in future analyses. The **IATutorial\Houston_03** directory contains 4 files, **Hou03_1** through **Hou03_4**, which are bands 1 through 4 of a full Landsat TM scene for path 26 row 39 from 1/18/2003. The directory also contains metadata for the image. This scene contains the same areas subset for the 1999 Landsat images. You will composite the bands by adding them to a new ArcMap document. Add the separate bands, **Hou03_1** through **Hou03_4**. Be sure they appear in numerical order in the Table of Contents and Image Analysis window. Select all 4 bands in the IA window and click the Composite Bands button. You should immediately see a **Composite_Hou03_1.tif** layer in the Table of Contents and IA window list. Export the raster layer as **Hou03_4B**. If you are using a geodatabase and the “Format” entry in the Export Raster Data window is not “File Geodatabase” (grayed out), you may have to reset the “Location” to set the geodatabase location, even if it has not changed.



Remember to “stretch” or use the Display panel options to enhance your **Hou03_4B** composite image. The final product should look something like the example below. Now that you have scenes with a temporal difference, think about how you could compare them. What might a 2003 NDVI show (coming next)?



The normalized difference vegetation index or NDVI button is used to perform image algebra on the red (band 3 for Landsat TM) and near infrared (band 4 for Landsat TM) bands of an image to produce a new single band layer that shows “greenness” or relative biomass. The brighter (higher) value indicates a higher percentage of vegetation, healthier vegetation, or plant species differences. The formula for the calculation is: $NDVI = (IR - R)/(IR + R)$. Landsat MSS uses bands 2, 4; SPOT XS 2, 3; and NOAA AVHRR 1, 2 for this transformation. Consult the Web for sensor information on other combinations. Since the NDVI is a ratio, the processing will minimize shadow effects. You will perform an NDVI analysis of the **Houston_TM250.tif** image. First, use the Options button (see page 5, this tutorial) to confirm that the default bands selected are 3 for red and 4 for IR. Select the image in the in the layer list and the NDVI button will activate if it is not already. Click the NDVI button and you should immediately see an **NDVI_Houston_TM250.tif** image in the layer list and the Table of Contents and layer list.

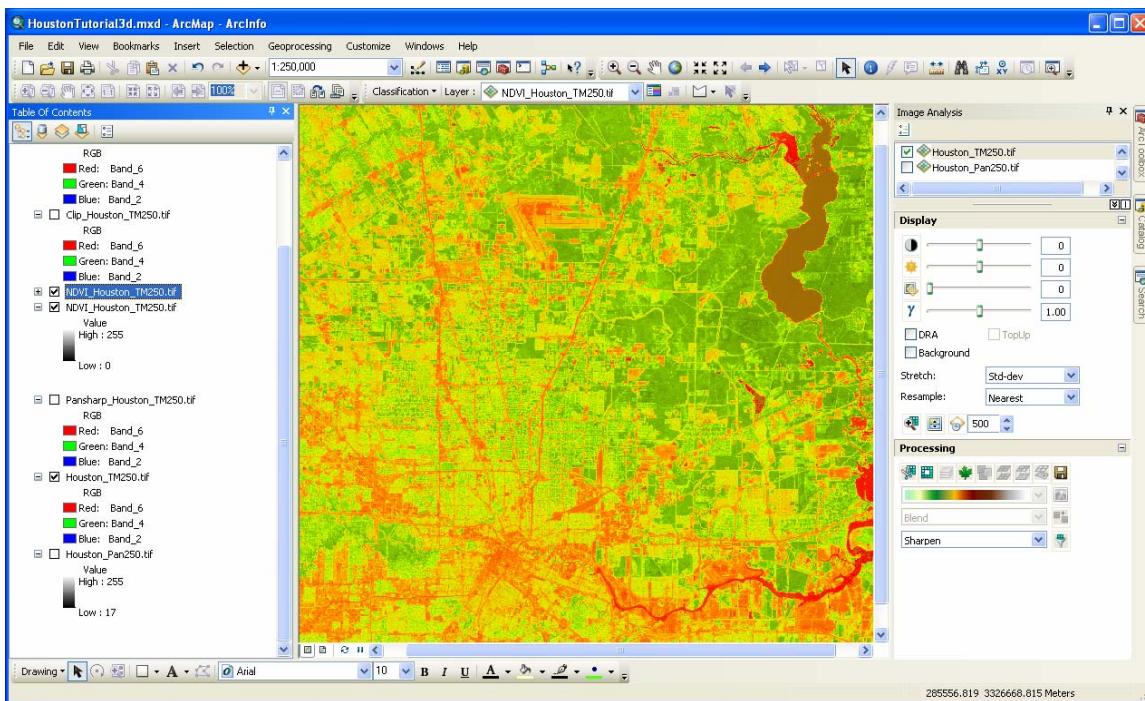
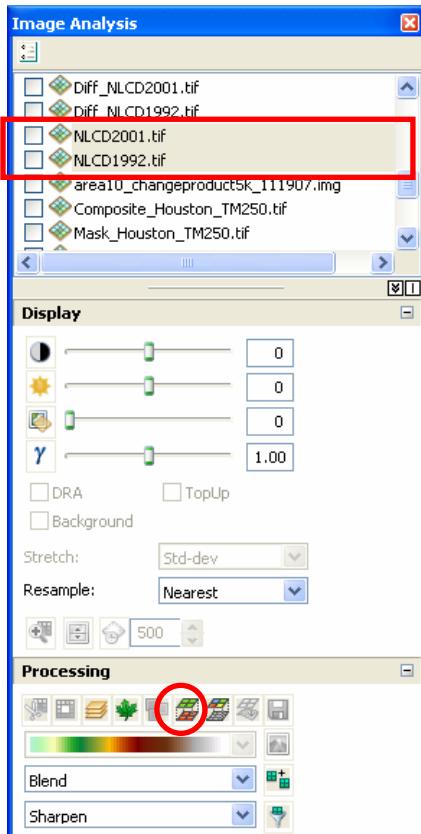


Image Analyst will apply a Colormap to the results. The greener colors indicate greater vegetation mass (or vegetation health or species) and redder colors indicate less vegetation. If you want to examine an image that will give you a better understanding of the relative pixel values, make a copy of the layer in the Table of Contents and change the color ramp to gray-scale. Carefully examine the image. Zoom in on an area containing a golf course east of the airport and examine the signatures. Use the swipe tool by selecting the NDVI image in the layer list and swiping over the TM layer. In addition to mapping vegetation, would this image be useful for identifying urban infrastructure and impervious surface?



What else, besides urban infrastructure and impervious surface, has a low NDVI signature? What masks would allow you to more easily extract an “Urban” layer without including undesired features? Answer these questions in a Word document and include useful images and illustrations.

The Difference button  can be used to compare classified images or any other single band raster file type. The difference or change detection uses the arithmetic minus function to calculate the difference between two raster layers.

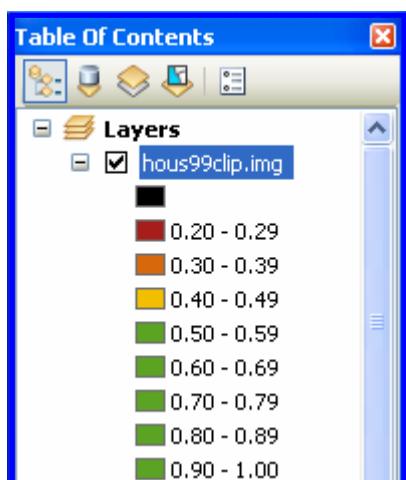


The lowest selected layer in the layer list is subtracted from the upper selected layer.

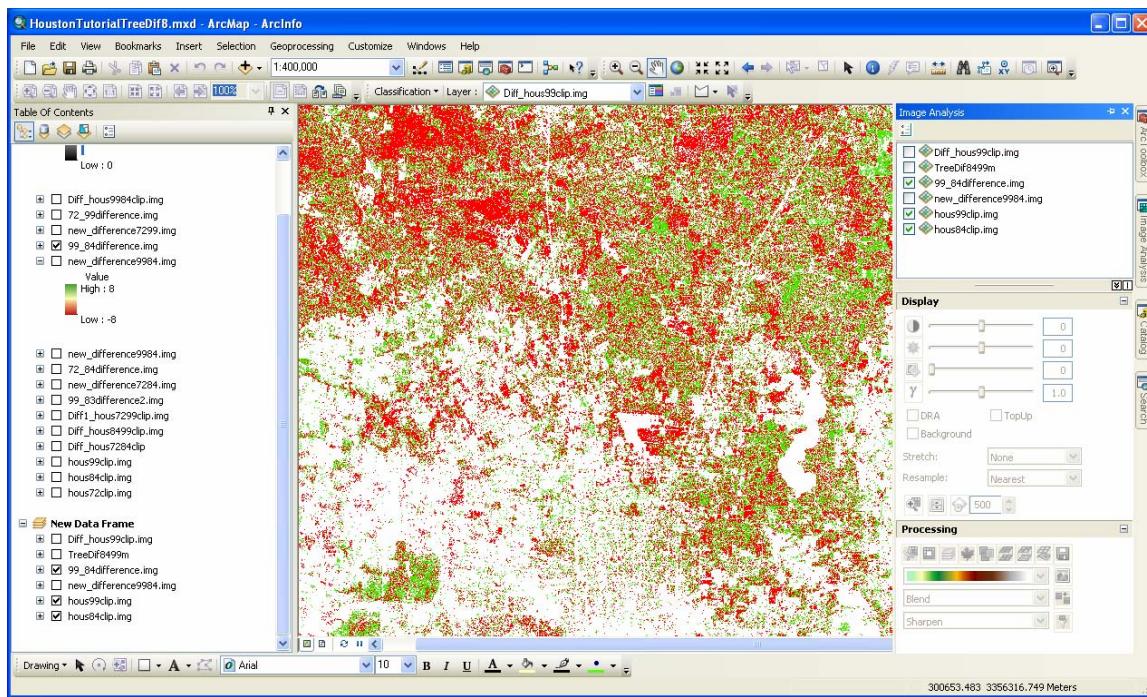
At the present time, the Difference button is producing results that are difficult to use. Esri has registered an official “bug”. Do not use this tool until the problem is corrected.

If you want to see what the Difference button is supposed to do, add the **hous84clip.img** and **hous99clip.img** layers to the layer list with the “99” image on top. These two files are classifications of percentage tree cover for Houston in 1999 and 1984 (see TOC symbology below). Use ArcToolbox>Spatial Analyst Tools>Math>Minus tool with the “99” layer as Input Raster value 1 to see the changes in tree cover between the two years. The minus numbers equal

tree cover loss and the positive numbers are tree cover gain. The values range from 8 to -8 and are the class values assigned to the original color map.

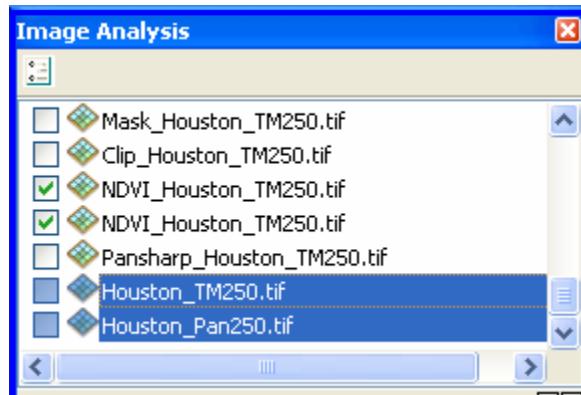


Therefore, a **+ 8** indicates a 90 to 100% increase in tree cover between the two years, a **0** equals no change, and a **- 8** indicates a 90 to 100% tree loss. This is a very significant result for the Houston area. Can you equate tree loss or gain to processes associated with the development of the Houston region? For emphasis, all tree loss is shown in red and all tree gain is shown in green in the presentation below. No change is in white. For reference, note the location of Lake Houston, the major highways, and Houston (Bush) Intercontinental Airport.

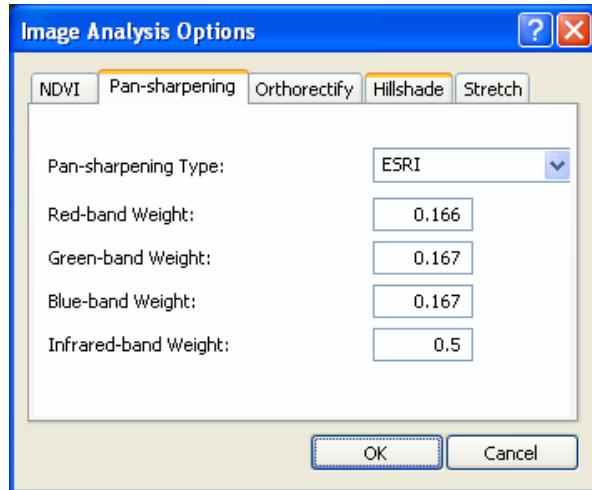


The Pan-Sharpen tool is very useful for enhancing the spatial resolution of project images. Please see *Resource Center>Professional Library>Data Management>Geographic data types>Rasters and images>Processing and analyzing raster data>Panchromatic sharpening* for detailed information on panchromatic sharpening in ArcGIS 10. The tool uses a higher-resolution panchromatic layer such as the Landsat TM Pan band (Band 8, 15 m) to combine with multi-spectral bands (TM 1-5 & 7, 28.5 m). The resulting image, in the case of Landsat TM, is a multi-spectral image with 15 m spatial resolution. Pan-sharpening is available from both the Symbology tab and the button in the

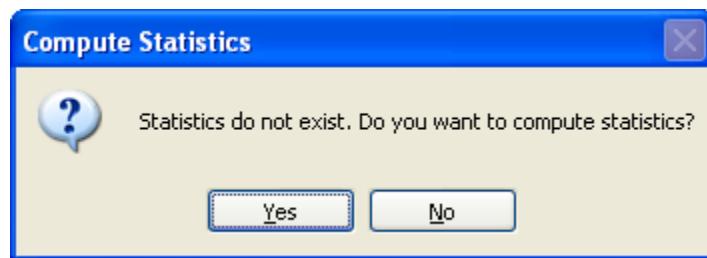
Image Analysis: Processing panel. You will use the Pan-sharpen button  in Image Analysis. Add the **Houston_Pan250.tif** image to the project. Adjust the layer order the Table of Contents and layer list so that the **Houston_TM250.tif** is above the **Houston_Pan250.tif**.



Open the Image Analysis Options and examine the available options for pan-sharpening. You will use the Esri type for this exercise but you should read about and experiment with the other color transformation options. Note that the options will also adjust the near-infrared band which can be a significant advantage.



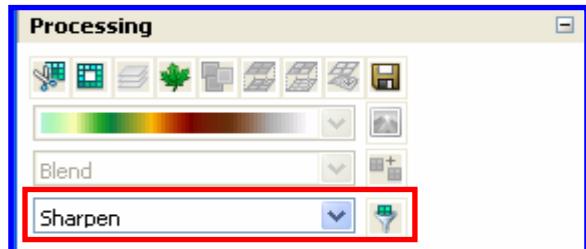
Click the Pan-sharpen button and the layer **Pansharp_Houston_TM250.tif** will appear at the top of the TOC and layer list. You will now use several of the image analysis display tools to enhance the pan-sharpened image and compare the results with the **HouAirport_TM.tif** image created earlier. First, enhance the **Pansharp_Houston_TM250.tif** image. Try the Esri default of a 2 standard deviation stretch on the RGB composite. You will probably see a request to calculate statistics. Click “yes” IA will need image statistics to apply enhancements.



When you are satisfied with this enhancement, enhance the **HouAirport_TM.tif** image. Next, use the One-to-One button to compare the resolution of both images. Note the One-to-One scales for the two images and record them. Use the Swipe tool (remember to select the layer to be swiped) to examine the differences between the images at the pan-sharpened scale and when zoomed-in to a specific area. Export images from both layers and put them in a Word document with comments on your results. Be sure to include the scale

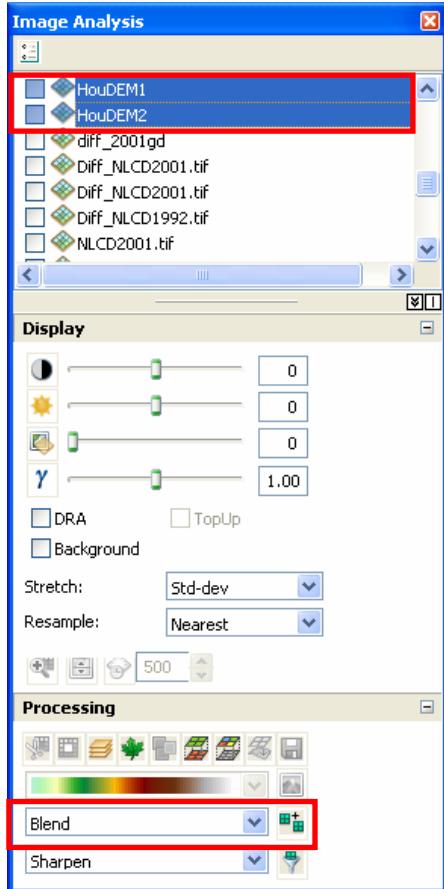
observations. You will use the pan-sharpened image in the next step to examine the results of convolution filtering.

You will now further spatially enhance your pan-sharpened image by applying a filter.



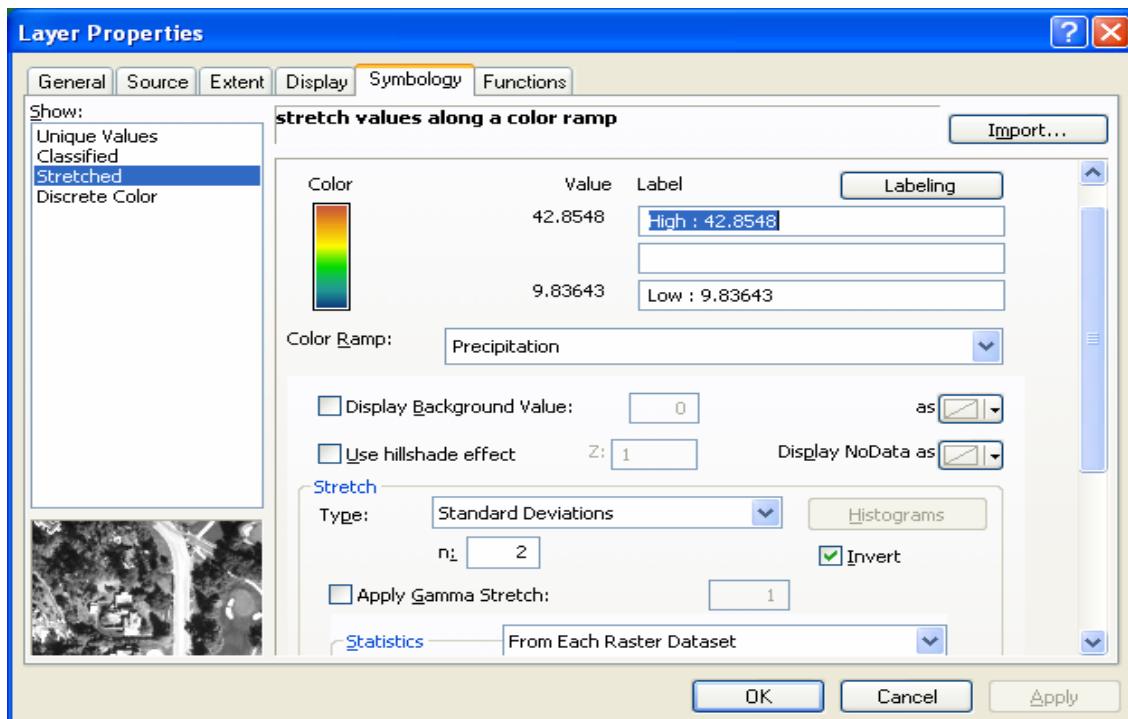
Filters can produce many different effects such as sharpening, blurring, non-directional and directional edge detection, reducing “noise” (such as the speckle in radar data), and generalization. Convolution filters perform calculations on pixel values based on different weightings of a matrix of pixels called kernels. A typical kernel is 3 x 3 pixels but kernel sizes can vary greatly depending on the results needed. However, remember that filtering alters the pixel values. The altered values may require re-stretching to achieve the best display. Filtered images may not be suitable for classification. You will now use the filter option to enhance the **Pansharp_Houston_TM250.tif**. Make sure this layer is selected in the layer list. Examine the options in the drop-down menu of filter options. Refer to convolution filter type descriptions in the Help documentation (see the “Row 4” description on page 14 for the Resource Center help and information path). Select the “sharpen” filter and click the button to apply. Apply a stretch to the resulting **Filter_Pansharp1_Houston_TM250.tif** image. Now apply the same filter again to the filtered image (**Filter_Filter_Pansharp1_Houston_TM250.tif**). Does filtering always enhance the image? Describe and illustrate the results in the document you prepared for pan-sharpening.

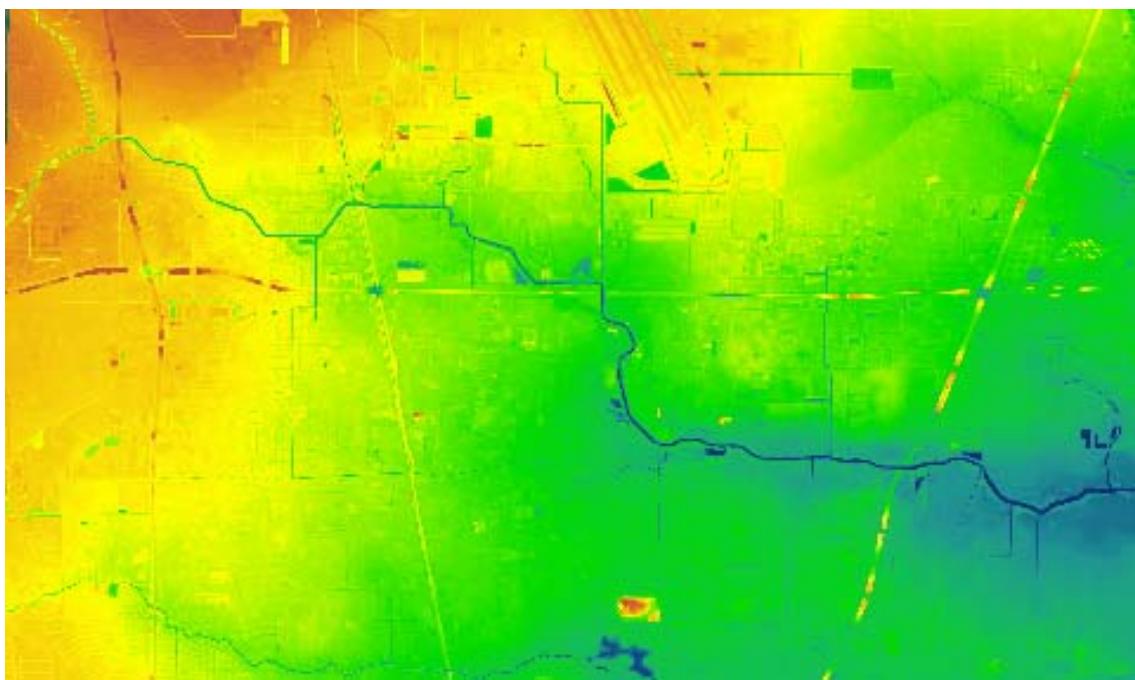
The Mosaic button gives you an opportunity to look at a different data set. The Mosaic button creates a new layer that combines selected raster layers in the layer list. For this function, you will use two digital elevation datasets extracted from the USGS Seamless Web site. **HouDEM1** (north) and **HouDEM2** (south) were created from a single request to the USGS site. Because of file size limitations, the request was split into two files dividing the area into north and south data sets. The source data is LIDAR that was flown after tropical storm Allison. It is a high resolution data set that has a ~3m spatial resolution and ~0.5 meter vertical accuracy. The data set has been processed to “bare ground” by the removal of infrastructure and vegetation. You need to combine the two files to facilitate processing and display.



Add the two layers, **HouDEM1** and **HouDEM2** to a project. You can continue with your existing project (map document) or create a new one. Begin by opening the layer Properties and examining the Source information. Note the key parameters such as file format, cell size, bit depth, and spatial reference. The two layers will display with different gray scales because the range of elevations is different for each. To combine the layers, you need to choose a method in the dropdown menu. The two layers only overlap by one pixel and the values of those pixels are identical so you do not have to be concerned about the method of handling the overlap. Choose the “First” option to use the layer that is first in the layer list. In the illustration to the left, HouDEM1 will be used to supply the overlap values. Click the Mosaic button and **Mosaic_HouDEM1** will be created. A more useful display can be created by applying a stretch and a ramp. Try a 2 Standard deviation stretch and the “precipitation” dark orange to blue ramp.

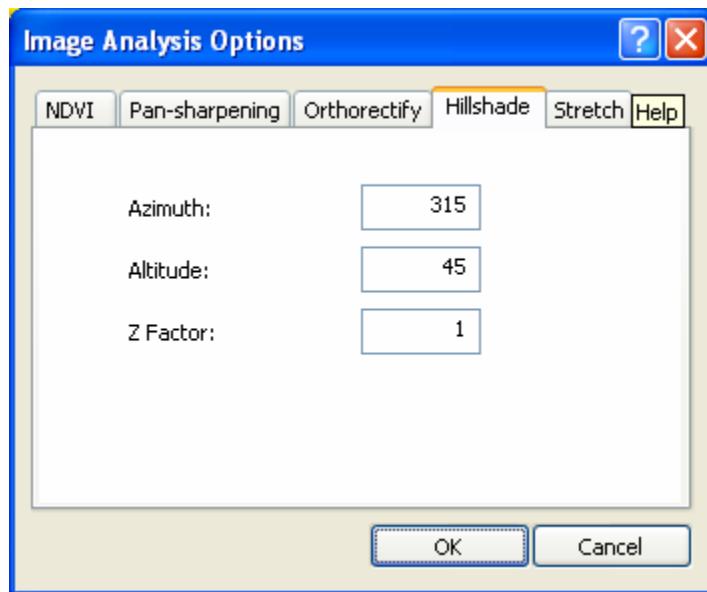
You will need to invert the ramp to make the low elevations blue. Experiment with different stretches to improve appearance.





The example above is a starting point resulting from the parameters suggested. Experiment with other stretches and ramps. Insert a map with the best results of your experimentation into a Word document and describe your procedure.

Now that you have a DEM mosaic, you can create a shaded relief from the **Mosaic_HouDEM1** layer. First, examine the Hillshade tab options in the IA window. Use the default settings for the initial processing. Be sure the correct



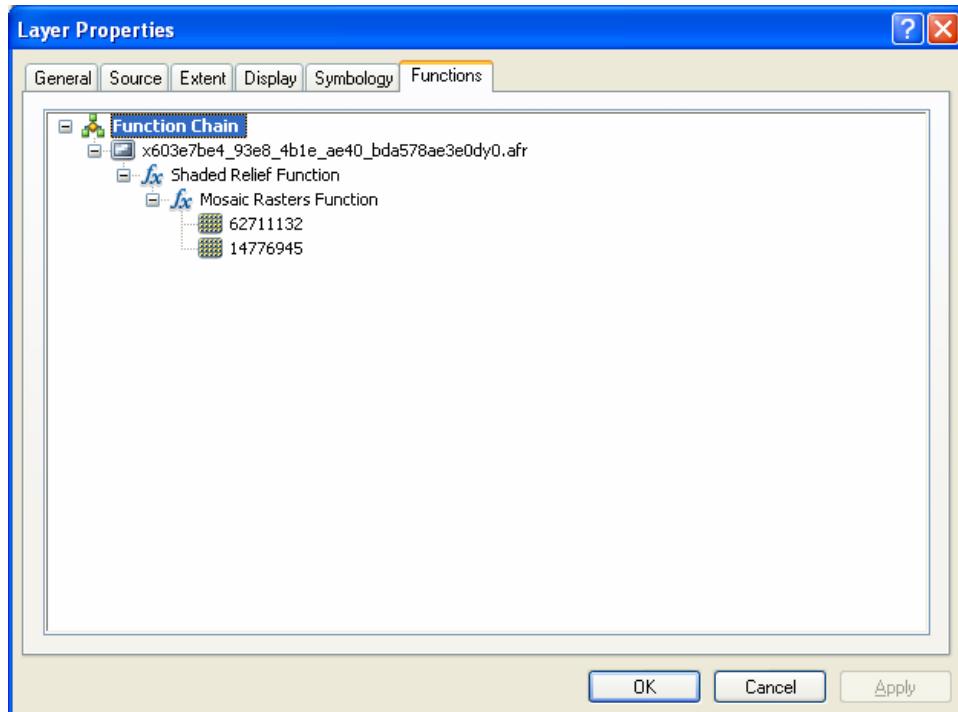
layer is selected in the Layers list. Create the shaded relief using the Shaded Relief button.



You can often improve the display of the data by selecting the new layer and changing the color ramp using the drop-down arrow in the Processing section.

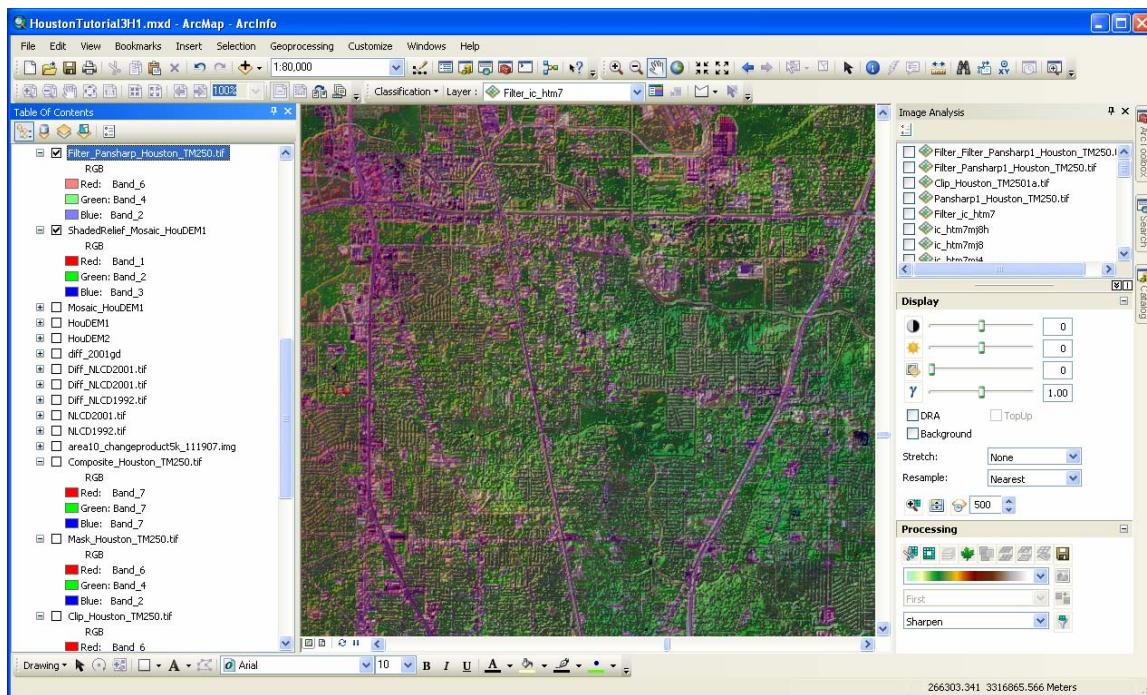


You can change the Hillshade illumination properties on the fly by right clicking on the layer name and selecting the properties option. In the Layer Properties



window, select the Functions tab. Double click the Shaded Relief function and the Raster Function Properties dialog box will allow you to make adjustments to the properties. Changes will be applied on the fly but you must click "Apply" to implement the change. Be patient. On large data sets, the change will not be instantaneous. Perform one more visualization operation. Change the ramp of your shaded relief to gray scale. To do this, you will need to go to the Properties of the layer, set the Show to "Stretched" from "RGB Composite" and use the default gray scale ramp. Adjust the layer list so that

Filter_Pansharpen1_Houston_TM250.tif is above the Shaded Relief. Change the display of this layer to 50% transparency and examine the results. On some displays a 30% value gives better results. Your result should look something like the screen capture below.



Add the results of this analysis to the Word document you began for the mosaic creation. Describe the options you chose and the results. Include map examples to illustrate your observations.

Turn in all the documents requested for Exercise 3 credit.

You have now completed Exercise 3. The Orthorectify button was not used in these exercises. This is a specialized application that is not usually included in basic analyses.

Exercise 4 – Classification with the Image Classification Toolbar

Classification is a key procedure for creating information from data.

Classification in image analysis is somewhat different from classification in GIS.

In a GIS, you create classes or groups of features through statistical analysis of the attributes. The geometry and attributes of the features are already known.

Image analysis classification identifies pixels with similar spectral signatures through statistical analysis of multi-band images. Groups of pixels with similar spectral signatures can be identified as features based on their geometric relationships and the knowledge and interpretive skills of the analyst. Image classification is a very computationally intensive process which is why you spatially and spectrally subset your image data. Below is an example of an information extraction by classification for the Houston International Airport. The classes in this example are Dry Grass in yellow, Pavement and Rooftop in gray and magenta, Tree Canopy in light green, and Healthy Grass in dark green.

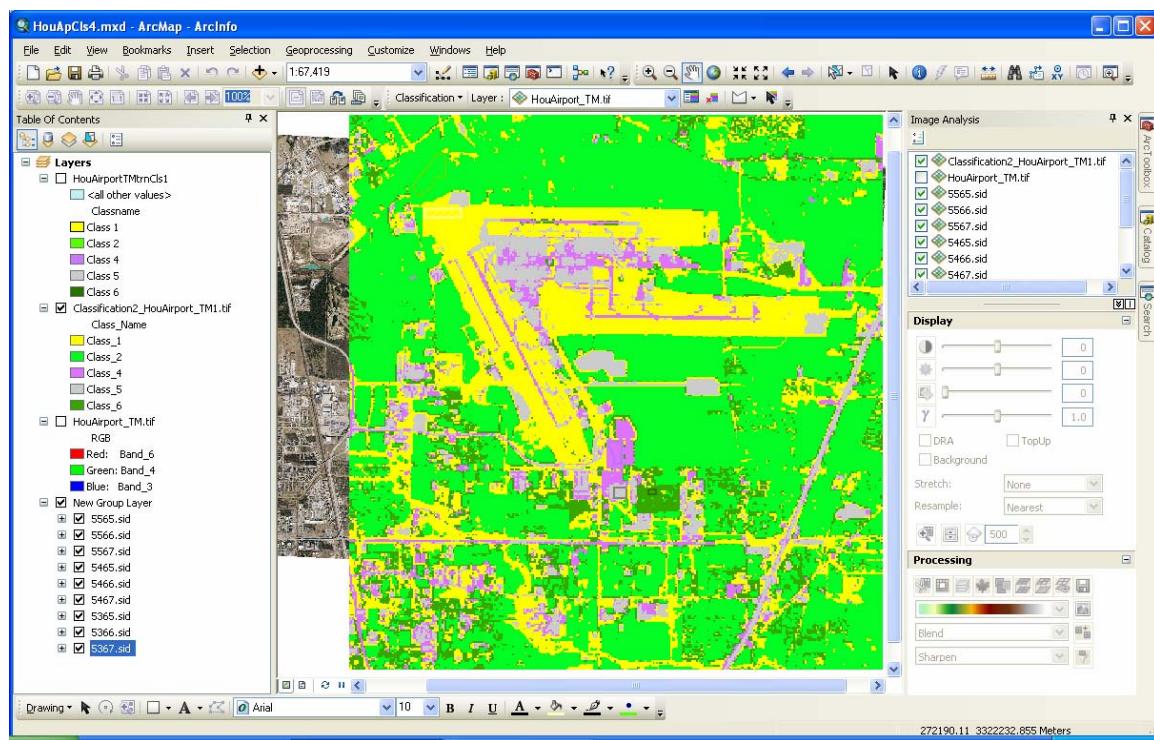


Image classification is divided into two main types; supervised and unsupervised. They both rely on statistical techniques for the assignment of pixels to classes. However, supervised classification utilizes class information input by the analyst before statistical analysis and classification of the image. The analyst selects training samples or regions of interest (ROIs). Properly selected training samples contain pixels that represent the spectral characteristics of only the feature or feature class to be identified. Several training samples can be selected and combined to make a single class. The skill and knowledge of the analyst are important to the success of a supervised classification. Once the training samples are gathered, there are a number of statistical classifiers that

can be used to process the image data. ArcGIS 10 has Interactive Supervised Classification, Maximum Likelihood Classification, and Class Probability options for supervised classification. As a final note, there are feature extraction tools for image analysis that will automatically use both spectral and spatial signatures to identify features in an image, also known as object-oriented classification, but they are not included in IA for ArcGIS 10.

Unsupervised classification uses clustering routines to create the number of pixel classes designated by the analyst. It is the responsibility of the analyst to assign meaningful identities to the classes after processing. A typical procedure would be for the analyst to specify a large number of classes and then refine and group them to produce features such as areas of land cover types. The unsupervised classification option in ArcGIS10 is the Iso Cluster Unsupervised Classification also known as ISODATA (Iterative Self-Organized Data Analysis Techniques A). Unsupervised classifications usually do not have unclassified pixels if the parameters are set correctly.

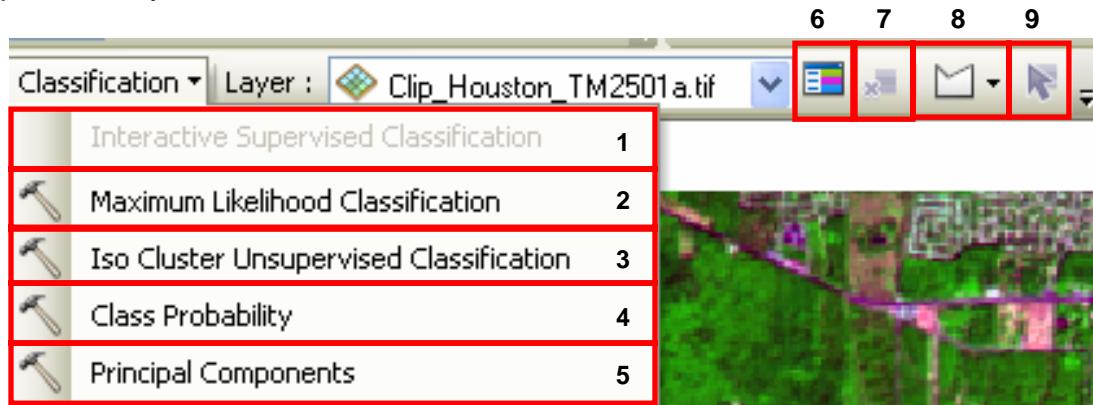
It is common practice to combine both types of classification by performing an unsupervised classification prior to a supervised classification. The unsupervised classification provides insight into the size and distribution of classes in the image and can guide the user in selecting better training samples.

You should always evaluate the results of your classification to be sure the classification functions performed as you expected. In many analyses, you will be expected to quantify the accuracy of your classification by comparison with various methods of ground truth. Tabular presentation of the accuracy assessment is called an error matrix (also contingency table or confusion matrix).

Please see *Resource Center>Professional Library>Extensions >Spatial Analyst>Image classification* and sub-topic >*The Image Classification toolbar* for detailed information on image classification. The discussion of workflow in the “Image classification using Spatial Analyst” Help document is essential reading for understanding the classification process.

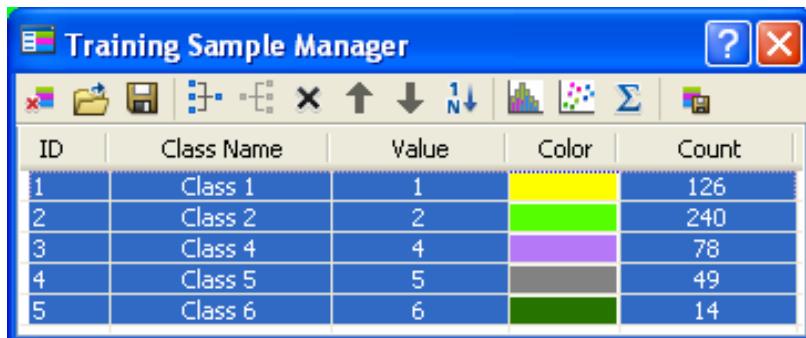
Please refer to *Remote Sensing and Image Interpretation* by Lillesand, Kiefer, and Chipman for an in-depth discussion of classification.

Image classification is accessed through the Image Classification toolbar and the Spatial Analyst Tools>Multivariate functions.



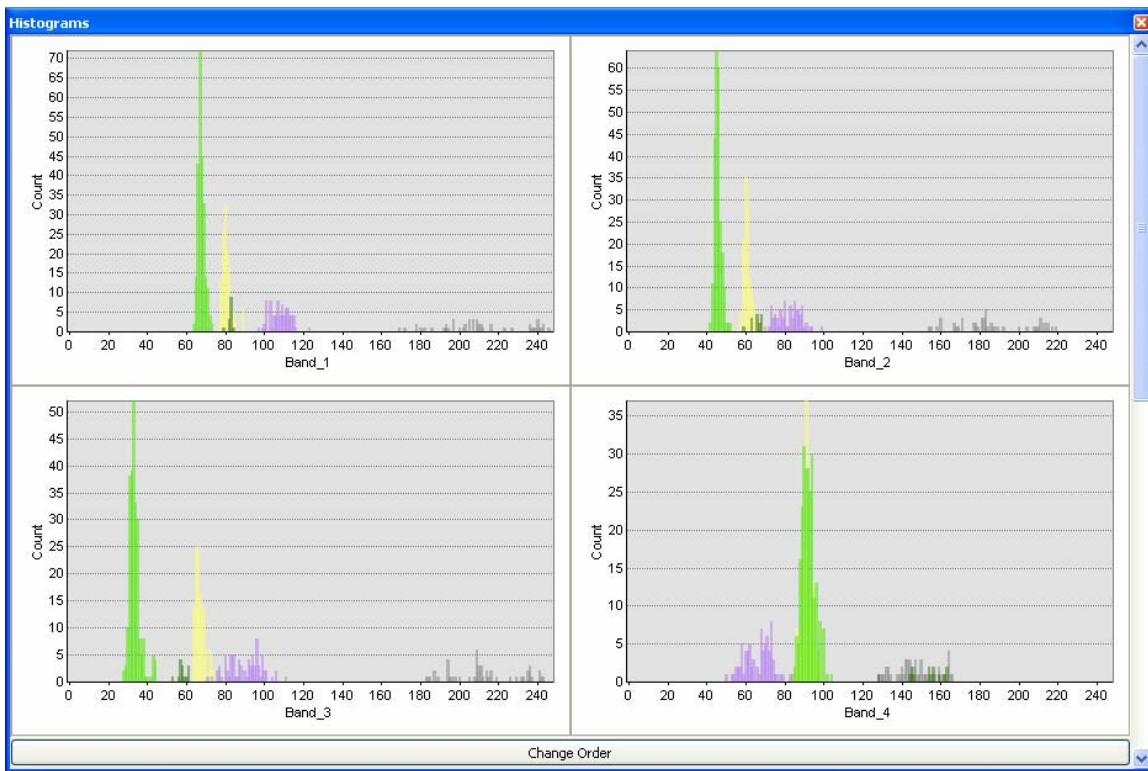
You will initially work with the Image Classification toolbar which makes some of the Multivariate functions available. Drop-down commands 1, 2, and 4 perform different types of supervised classification. Command 1, Interactive Supervised Classification, uses the Maximum Likelihood Classification tool to automatically classify a layer selected in the layer list using at least two training samples from the Training Sample Manager. Command 2, Maximum Likelihood Classification (MLC), performs a classification on an input image layer using a signature file. While MLC is generally considered a supervised classification technique, the MLC geoprocessing tool is also used to perform an unsupervised classification from a signature file (.gsg) generated by the Iso Cluster tool in the Spatial Analyst Tools>Multivariate functions. Command 4, Class Probability, creates a multi-band raster with one probability band created for each class represented in the input signature file. The probability layer ranks each pixel on the probability that it belongs to that class. Probability layers are particularly useful for identifying and resolving mixed pixel issues.

Buttons 6 through 9 are used to acquire and manage training samples for supervised classification. Button 6 opens the Training Sample Manager which is the control center for supervised classification.

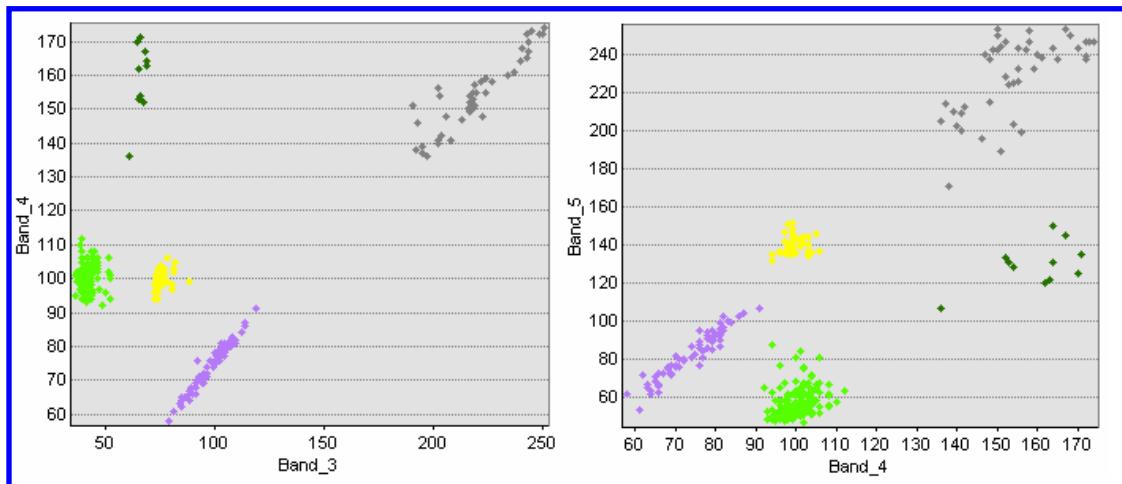


The buttons from left to right are the Clear training samples button that empties the training sample class list. The Load button adds training classes from a shapefile saved by the Save button. The Merge and Split

buttons are used to combine classes or to separate classes that have been combined. If you think you want to split classes you have merged, it is easier to save a classification list, clear the training samples, and then load the original list. The Delete  button removes a class. The Up and Down  buttons change the order of classes in the list. The Reset class value  allows you to assign a new number to a class in the Value column. The Histograms, Scatterplots, and Statistics  buttons are extremely useful in understanding your data by providing you with visual and tabular comparisons of your classes. The examples below show the separation (or lack of it) in the classes from the **HouAirport_TM.tif** image. You must select the classes for display from the list in the Training sample manager. It is obvious from the histogram plot that the signatures for Classes 1 - 2 and 5 - 6 overlap in TM band 4 but are better separated in band 3. Separating these classes is important since Class 1 (yellow) is dry grass and Class 2 (bright green) is forest and classes 5 and 6 are pavement and green grass, respectively.



You can see the statistical separation of the classes in the scatter plots as well. Note that the cross plot of bands 3 – 4 and 4 – 5 show good separation in the clusters.



The statistics table for Class 1 also shows low covariance between Band 4 and most other Bands. Lower covariance indicates better the separation of the classes.

| Statistics | | | | | | |
|---------------------------|--------|--------|--------|--------|--------|--------|
| Class 1 Statistics | Band_1 | Band_2 | Band_3 | Band_4 | Band_5 | Band_6 |
| Minimum | 85.00 | 65.00 | 72.00 | 94.00 | 132.00 | 77.00 |
| Maximum | 97.00 | 78.00 | 88.00 | 106.00 | 152.00 | 99.00 |
| Mean | 88.71 | 69.03 | 75.30 | 99.41 | 139.44 | 82.80 |
| Std.dev | 2.49 | 2.17 | 2.94 | 2.68 | 4.53 | 4.22 |
| Covariance | | | | | | |
| Band_1 | 6.22 | 4.03 | 5.46 | 0.69 | 6.47 | 7.32 |
| Band_2 | 4.03 | 4.70 | 5.40 | 2.36 | 4.83 | 6.02 |
| Band_3 | 5.46 | 5.40 | 8.64 | 2.98 | 8.49 | 9.04 |
| Band_4 | 0.69 | 2.36 | 2.98 | 7.19 | 1.72 | 0.30 |
| Band_5 | 6.47 | 4.83 | 8.49 | 1.72 | 20.53 | 17.28 |
| Band_6 | 7.32 | 6.02 | 9.04 | 0.30 | 17.28 | 17.81 |

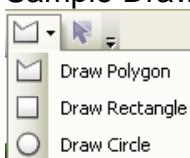
The far-right button is the Create Signature File button. The signature file contains the means and covariances of the spectral values of the training samples for the bands chosen for the analysis. The table below is an example of the signature file output for one class.

```

houairport_tm2.gsg - Notepad
File Edit Format View Help
# Signatures Produced by classsig from
#   Class-Grid __1000001
#   and stack __1000000
#
#   Number of selected grids
#       6
#   Layer-Number      Band-name
#   1      HouAirport_TM.tif\Band_1
#   2      HouAirport_TM.tif\Band_2
#   3      HouAirport_TM.tif\Band_3
#   4      HouAirport_TM.tif\Band_4
#   5      HouAirport_TM.tif\Band_5
#   6      HouAirport_TM.tif\Band_6
#
#   Type      Number of Classes      Number of Layers      Number of Parametric Layers
#   1          5                      6                      6
# -----
#   Class ID      Number of Cells      Class Name
#   1              115
#   Layers          1                2                3                4                5                6
#   Means
#   Covariance
#   1      6.34889      5.18352      7.65980      1.64622      6.85797      9.30931
#   2      5.18352      6.41373      7.99695      3.22639      6.61076      9.07704
#   3      7.65980      7.99695      13.30282      3.25515      10.72159      13.88444
#   4      1.64622      3.22639      3.25515      7.49779      2.60214      1.30092
#   5      6.85797      6.61076      10.72159      2.60214      19.75027      18.15713
#   6      9.30931      9.07704      13.88444      1.30092      18.15713      22.62624
# -----

```

As you can see, the Training Sample Manager is a key element in supervised classification. Button 7 clears the Training Sample Manager list to begin a new supervised classification session. Button 8 opens the Training Sample Drawing Tools. These tools draw shapes that select areas on the image for training sets. The draw polygon and the draw rectangle tools are generally the most useful. Button 9 selects training samples in the display and highlights them in the list.



This has been a long introduction but now you are ready to create a supervised classification. This is a good time to remember to subset image extent and multi-spectral bands as needed to achieve your desired results.

Start ArcMap and add the Image Classification Toolbar. Add the **HouAirport_TM.tif** image with the Add Data button by navigating to the **IAtutorial** directory and selecting the designated file. The image will appear in the ArcMap table of contents. **HouAirport_TM.tif** is the spatial subset you created using the Clip button in Exercise 3. This is a small area for classification but it has adequate diversity of land cover. [You are using a small area because these operations are computationally and memory intensive. Some computers, such as a laptop on which this tutorial was tested, do not have enough resources to process large scenes in ArcGIS 10. If you get unexpected results, such as fewer classes than you specified in an unsupervised classification, this is an indication of memory issues per Esri and my testing.] You will now add 9 one

foot pixel resolution aerial photographs acquired in the winter of 2010 from the **Aerials2010** directory in the **IAtutorial** directory. Create a Group Layer for the aerials to make management easier. Since this is a supervised classification, you want to select the most representative examples of the classes you want to make. Higher resolution images of your area are one of the best ways to do this. You don't need full coverage, just the areas that contain your training samples. You also need to take into consideration the dates of acquisition. In this case, changes have occurred in many areas since 1999 but you want to carefully select areas that have not had significant change.

You will now create several training samples from which you will generate the supervised classes. For this exercise, you will create 5 classes from 6 training samples. The classes of interest in the Landsat TM image are: 1) dry grass, 2) green grass, 3) impervious surfaces A, 4) impervious surfaces B, 5) and forest. Start with the dry grass training sample. Airport personnel have confirmed that the land cover between and around runways is mostly dry grass and scrub. You will see a large area of brownish-maroon at the NW end of the runway oriented NNW-SSE on the west side of the airport. Zoom to that area. Use a scale of about 1:4,000 and examine the TM and aerial images.

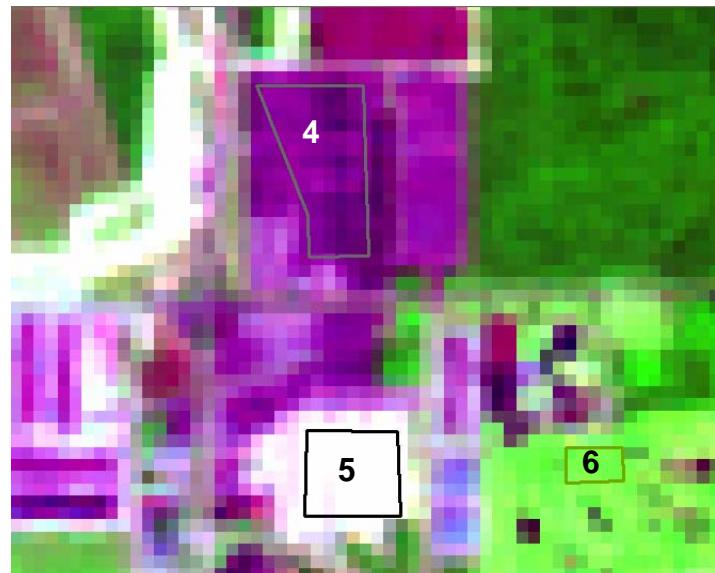
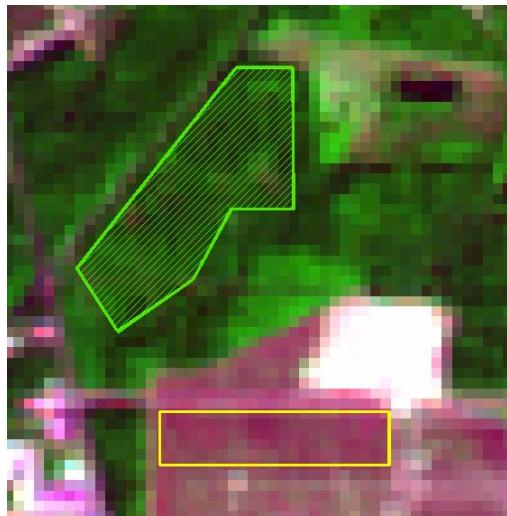


Observe the characteristics of the area such as access roads, other infrastructure, and the mowing patterns. The north half of the area looks reasonably consistent. This makes the area a good candidate for a training sample. You should also note the misregistration of Landsat and aerial images based on the positional shift of the E-W road on the north boundary. Use the measurement tool to determine the offset. Hint: use swipe or transparency to make the measurement easier. Be sure the **HouAirport_TM.tif** is selected in the layer list. Select area that looks like the one illustrated using the Draw Rectangle (Button 8 dropdown). This is your Class 1, dry grass. Now zoom out to about 1:10,000 and pan to the NW to the forest patch.

Select a new class in the forest area similar to the one shown. The new class will appear with hash marks indicating the class is selected. Because the aerials are newer (2010), part of the forested area has been cleared. (If you were going to classify a 2010 TM image, the forested area could be used to train the more recent image.) Now that you have two classes, you can use Interactive Supervised Classification to see a first approximation of the classes. Do this but delete the result and select another forested area, Class 3.

Now you will select two areas of impervious surface. In the example, a parking lot with cars is Class 4 and building roofs are Class 5. The final Class (6) is green grass. The best nearby example is the golf course east of training sample Class 5.

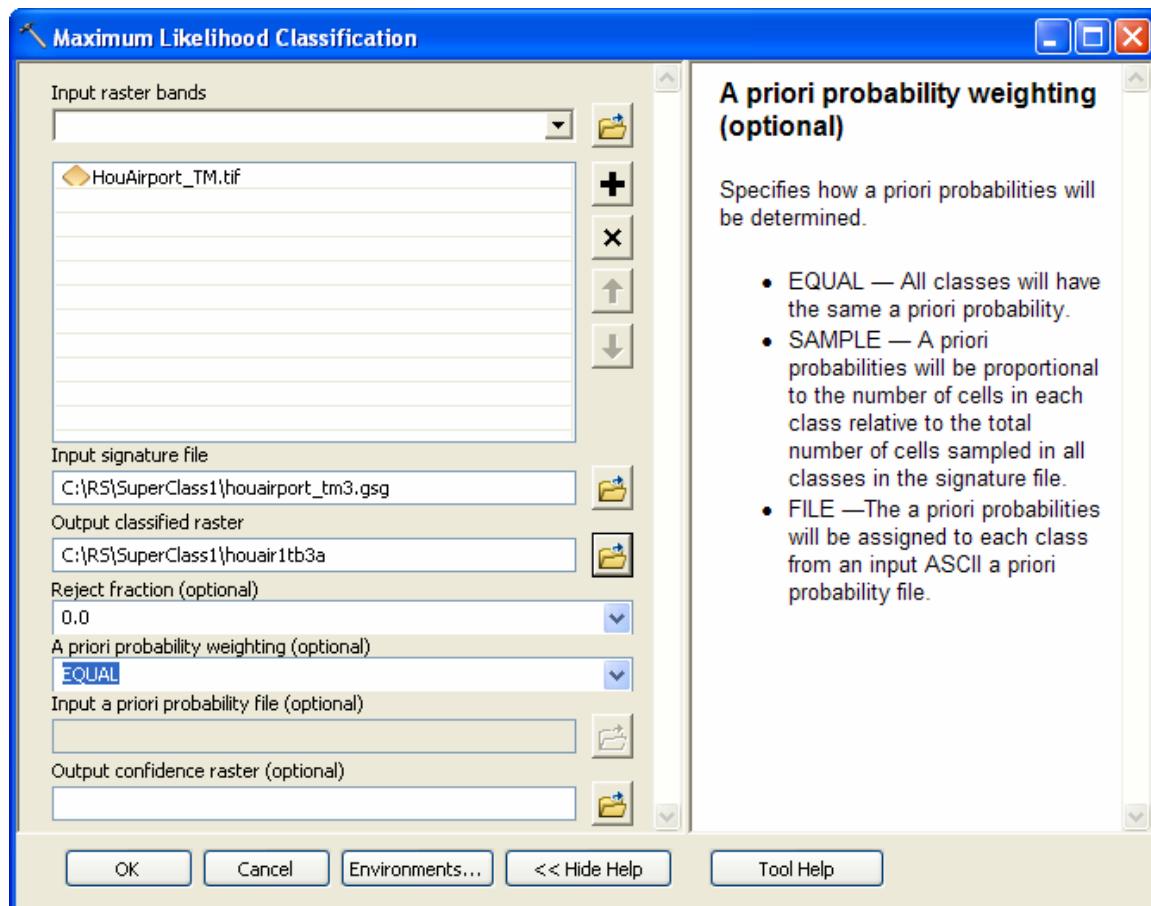
You now have training samples for all the classes needed for the project. Assign colors to your classes, in the class list, that make them representative and easily identifiable. Test your classes with the Interactive tool. If you are satisfied, it is time to save your classes. Use the Training Sample Manager to save the classes as a shape file. See the example below.



Training Sample Manager

| ID | Class Name | Value | Color | Count |
|----|------------|-------|------------|-------|
| 1 | Class 1 | 1 | Yellow | 117 |
| 2 | Class 2 | 2 | Green | 256 |
| 3 | Class 3 | 3 | Cyan | 312 |
| 4 | Class 4 | 4 | White | 91 |
| 5 | Class 5 | 5 | Black | 54 |
| 6 | Class 6 | 6 | Dark Green | 13 |

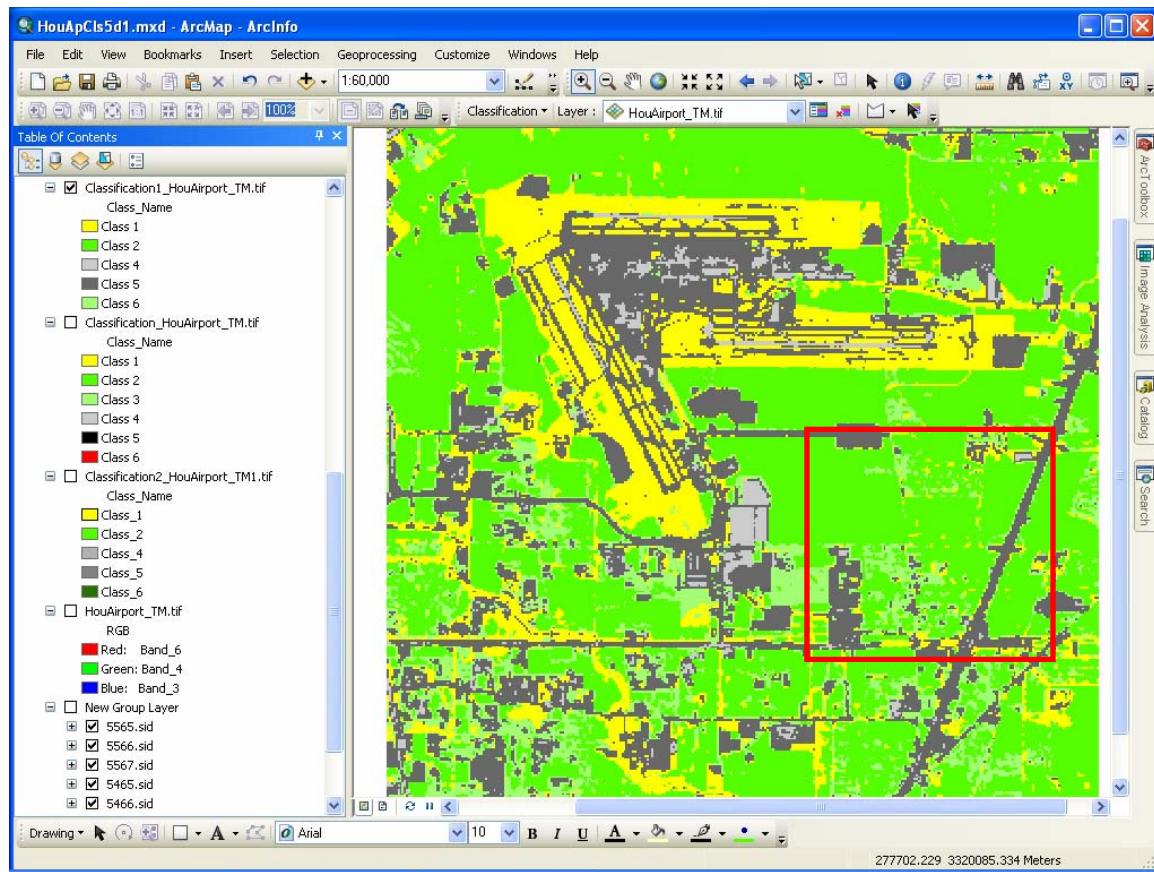
Open the shape file and choose “unique values” in the symbology tab and assign class colors. Even if your classes look good and represent reasonable differences, you need to have only one forest class. You will now use the Merge button to combine classes 2 and 3. Select those 2 classes and click the button. Class 2 will now contain the combined signatures. Be sure the **HouAirport_TM.tif** is selected. This time, “Save” the classification as a shape file and as a signature file with the “Create Signature File” button. Now you will do a supervised classification with the Maximum Likelihood Classification Drop-down command. Be sure that **HouAirport TM.tif** is selected. Input the signature file you just created. Specify a file name for the Output classified raster. Use the default settings at this time. The main drawback with the default



settings is that the “Reject fraction” is set to 0,0 which means that every cell is classified. This does not yield the best results because your original classes did not include all land cover types. There should be some unclassified cells.

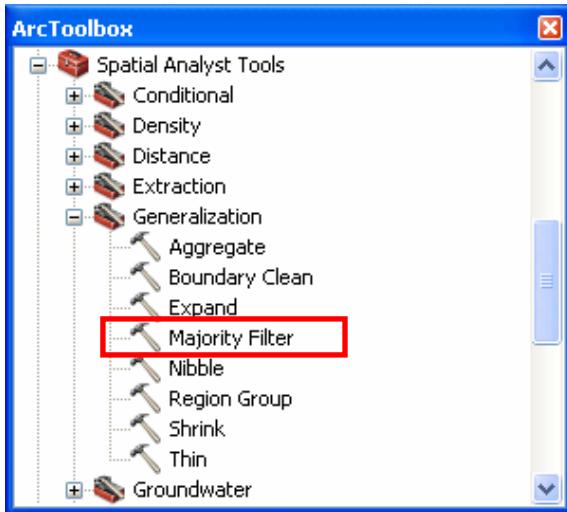
At this time there is a “bug” with this option that has been reported to Esri. Even with a high Reject fraction (.99), all cells are classified.

Your results should look something like the example below.

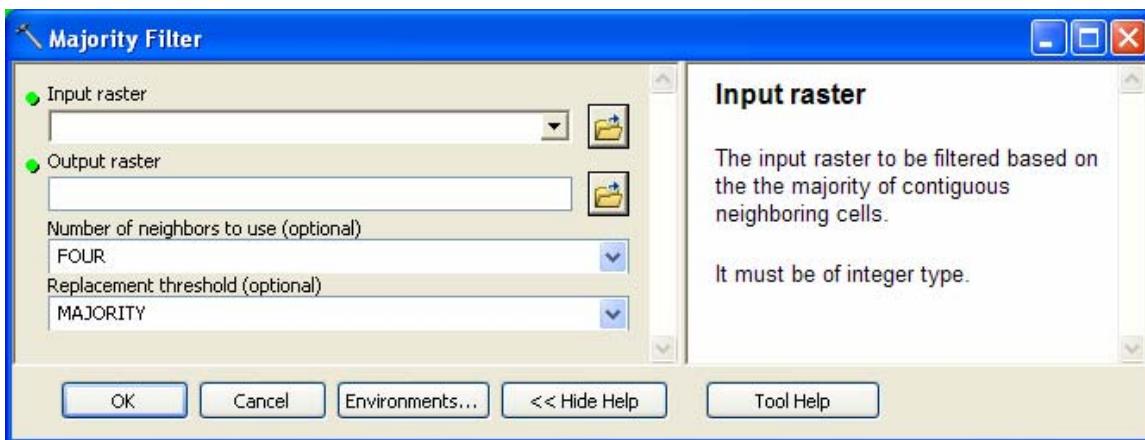


The final operation that needs to be considered is the cleaning or generalization of the data. Notice that there are many instances of isolated or very small clusters of pixels. If you were to use this classification to detect change, you would have a lot of “noise” in your analysis. Reducing the noise requires the application of one or more smoothing or generalization techniques that include filtering with the Majority Filter, smoothing class boundaries with the Boundary Clean tool, and removing isolated regions with the Region Group tool and the Nibble tool. Remember to review *Resource Center>Professional Library>Extensions >Spatial Analyst>Image classification* and sub-topic *>The Image Classification toolbar* for detailed information on this process. The discussion of workflow in the “Image classification using Spatial Analyst” Help document is essential reading for understanding the classification and cleanup process.

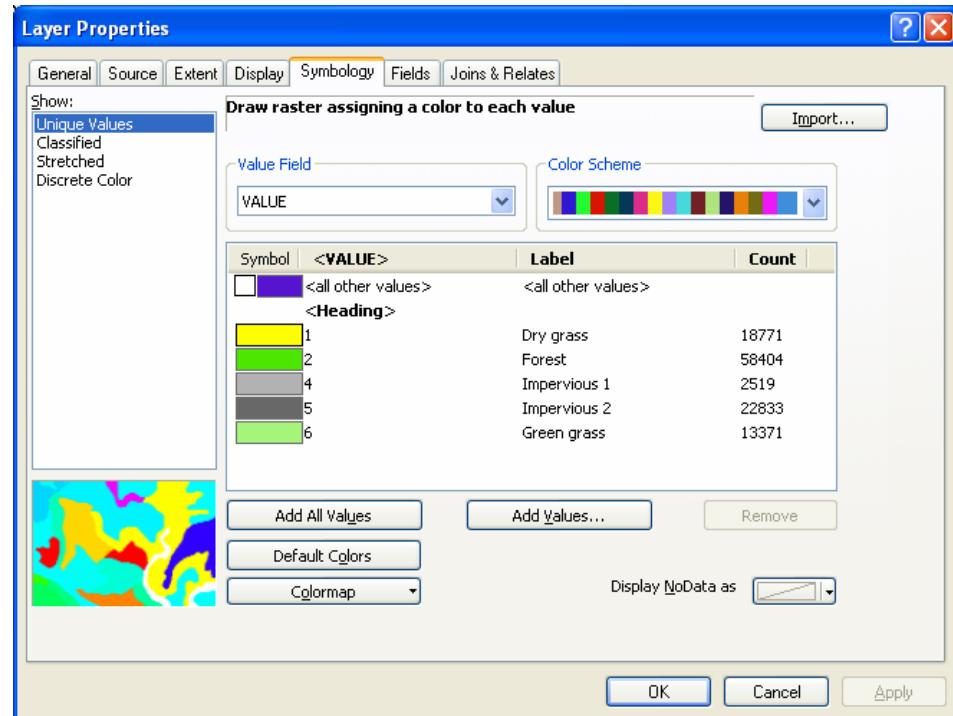
The technique we will use for this part of the exercise is the Majority Filter. Zoom into the area marked by the red box above. Hint: create a bookmark so you can easily return to the area. Open ArcToolbox and scroll to the Spatial Analyst Tools. Expand the Generalization tools and click on the Majority Filter.



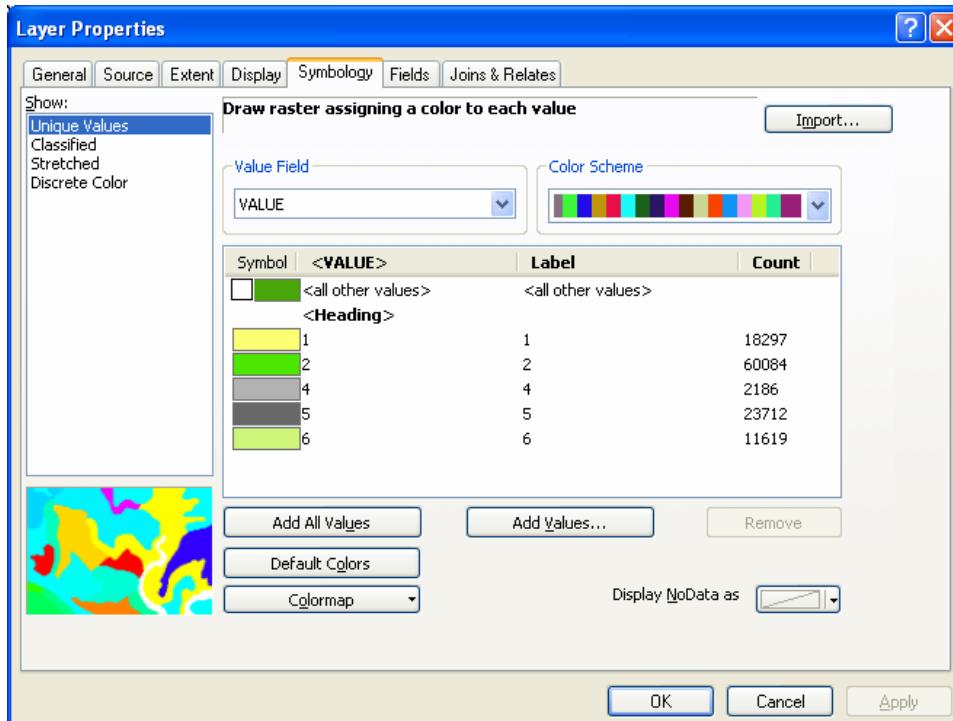
Specify the file name you gave to the results of your Maximum Likelihood classification. The majority filter has several options and you should experiment to determine the best setting for your data set and the desired result. The Number of neighbors to use sets the array of cells. “Four” uses a kernel of four orthogonal neighboring cells. “Eight” uses a full 3x3 cell kernel. The Replacement threshold specifies the number of spatially connected cells that must be the same value before



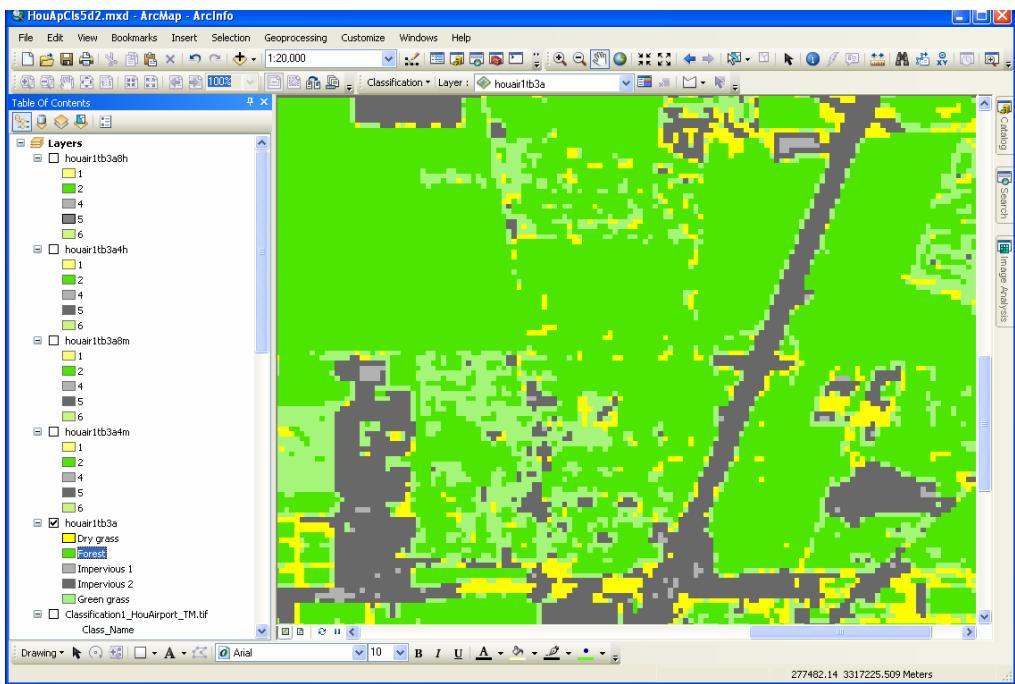
replacement occurs. Selecting “Majority” specifies that 3 of 4 or 5 of 8 connected cells must have the same value. Selecting “Half” specifies that 2 of 4 or 4 of 8 connected cells must have the same value and this option produces a smoother result. You can also apply the filter multiple times to increase the smoothing effect. Proceed carefully. At some point you will begin to lose important data. Perform the Majority filter four times using different combinations of the basic options. Give your output files names that will allow you to track the options you used per the examples below. Prepare a map layout showing the unfiltered classification and your selection of the best result. Add the layout to a Word document discussing the process you used to create the final classification. Please be detailed in your description of your filter choices. What compromises resulted from your filter choices? How would the compromises affect the use of the classification? The effects of the Majority filter on cell counts can be viewed by selecting the layer and opening the Layer Properties>Symbology tab. The examples below show the reduction in cell counts for smaller classes and the increase in cell counts for the larger classes.



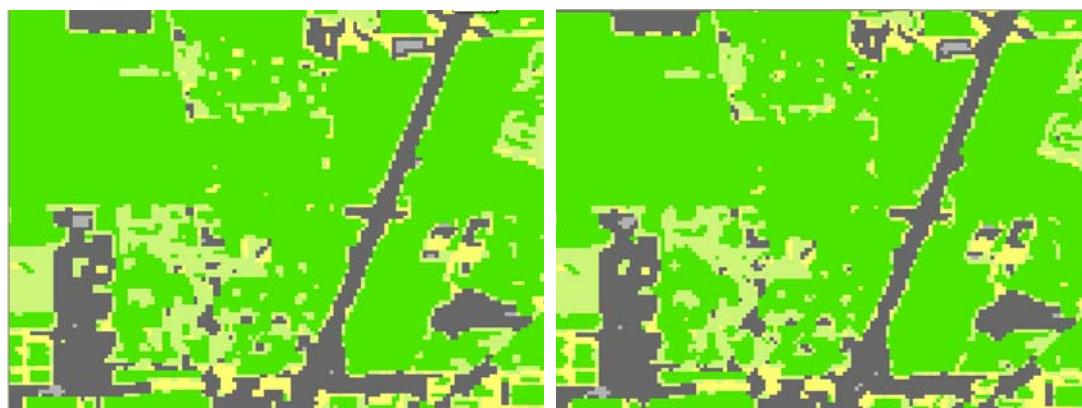
Unfiltered classification



Majority 4h filter

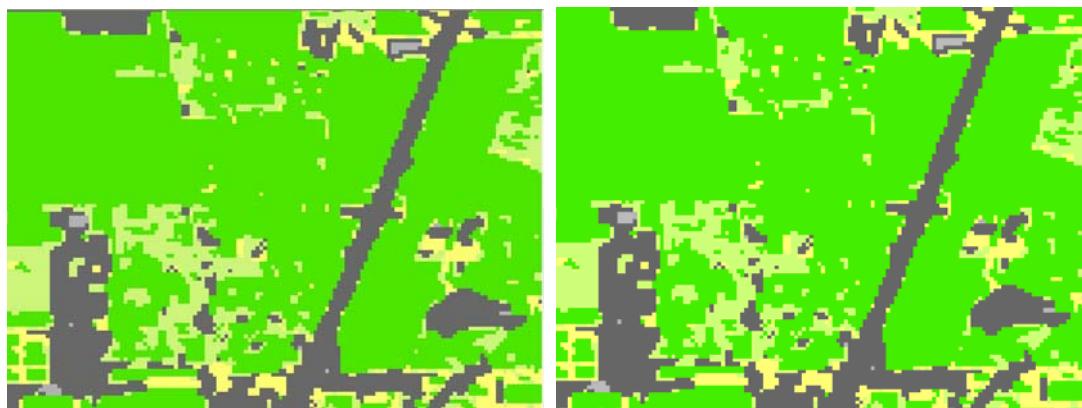


Unfiltered



4m

8m

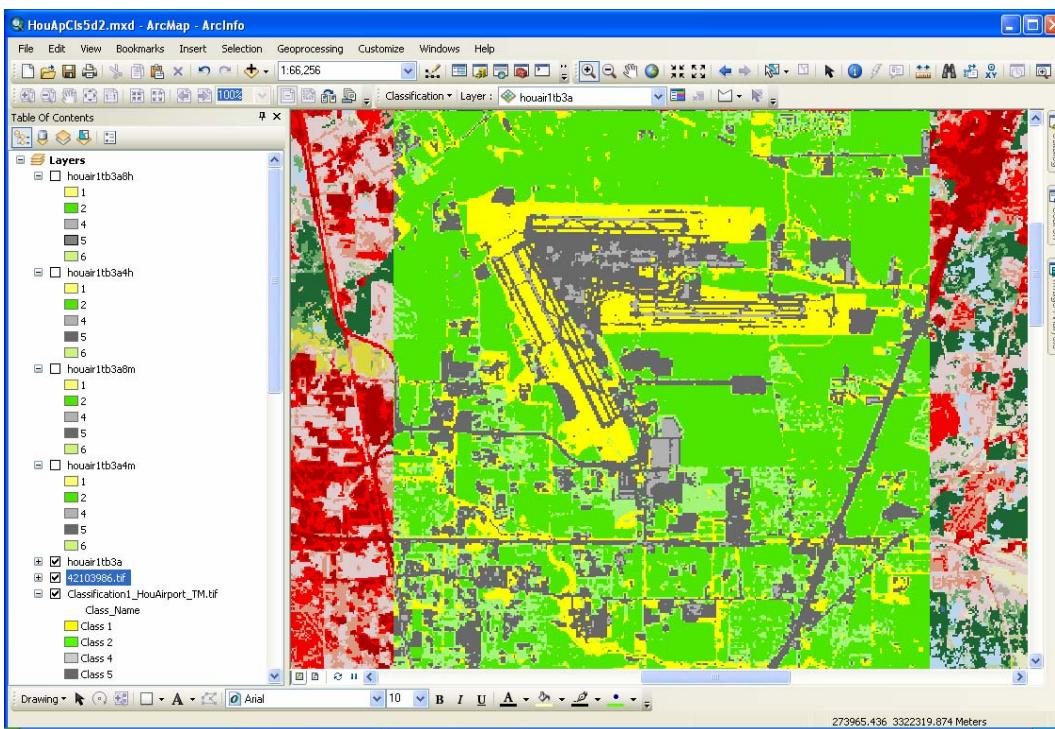
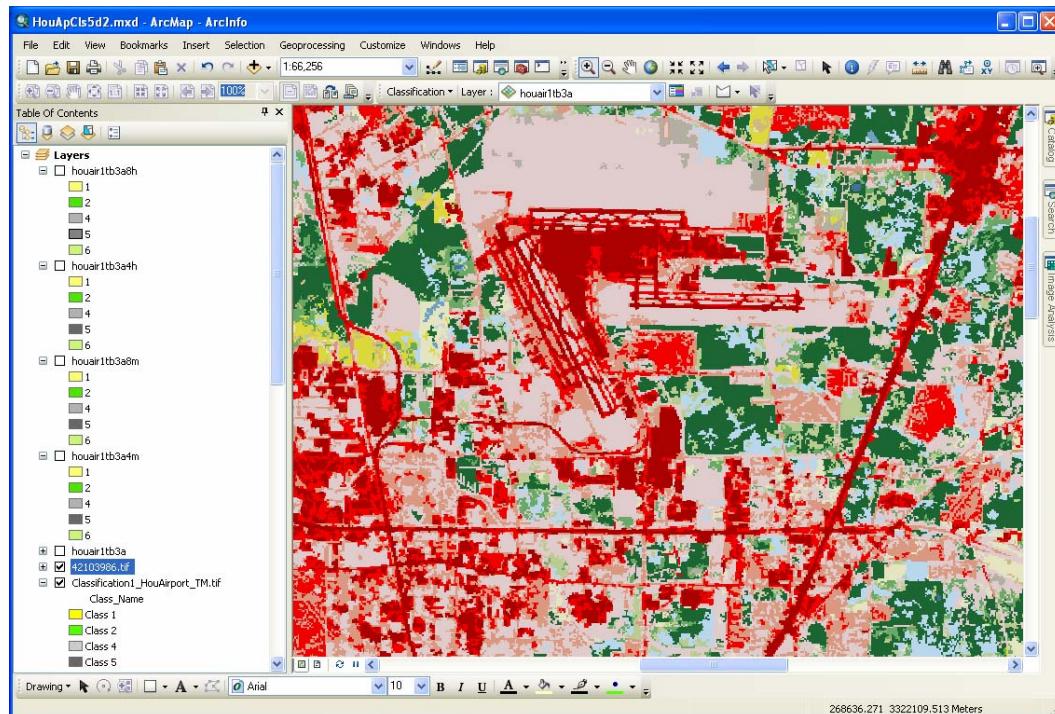


4h

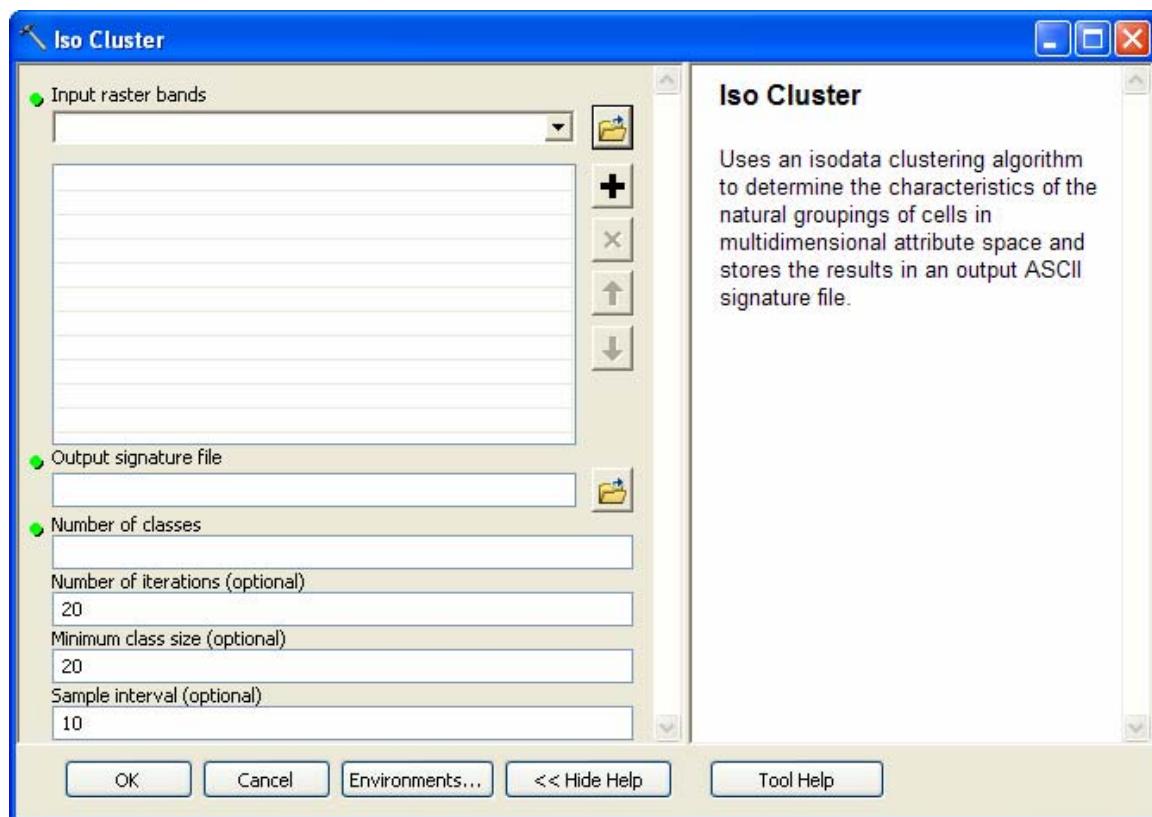
8h

Save your project for use with the next part of the Exercise.

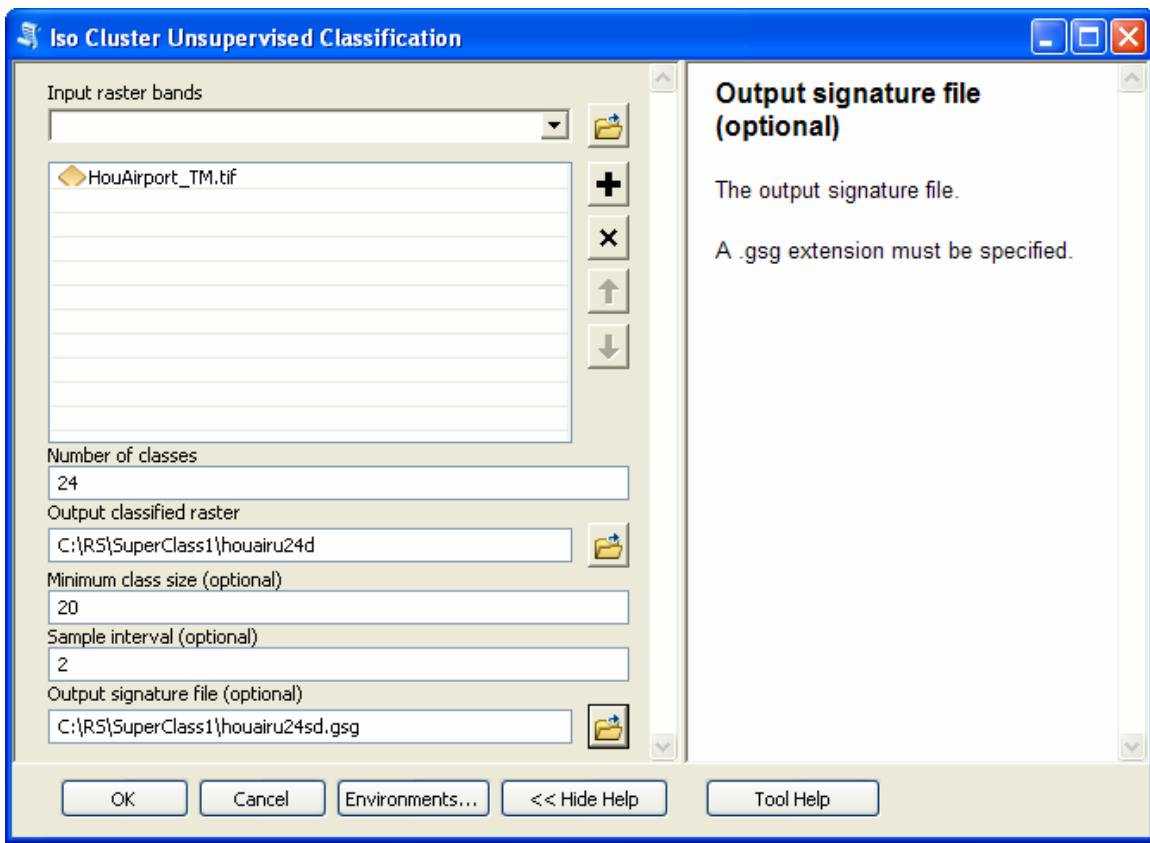
As a final step, compare your results with the 2001 National Land Cover Database using the raster **IAtutorial \LandCoverDifference\NLCD2001\42103986.tif**. There will be significant differences because of the greater number of classes used in the NLCD product (top) and the date of analysis but you should see a lot of similarity as well.



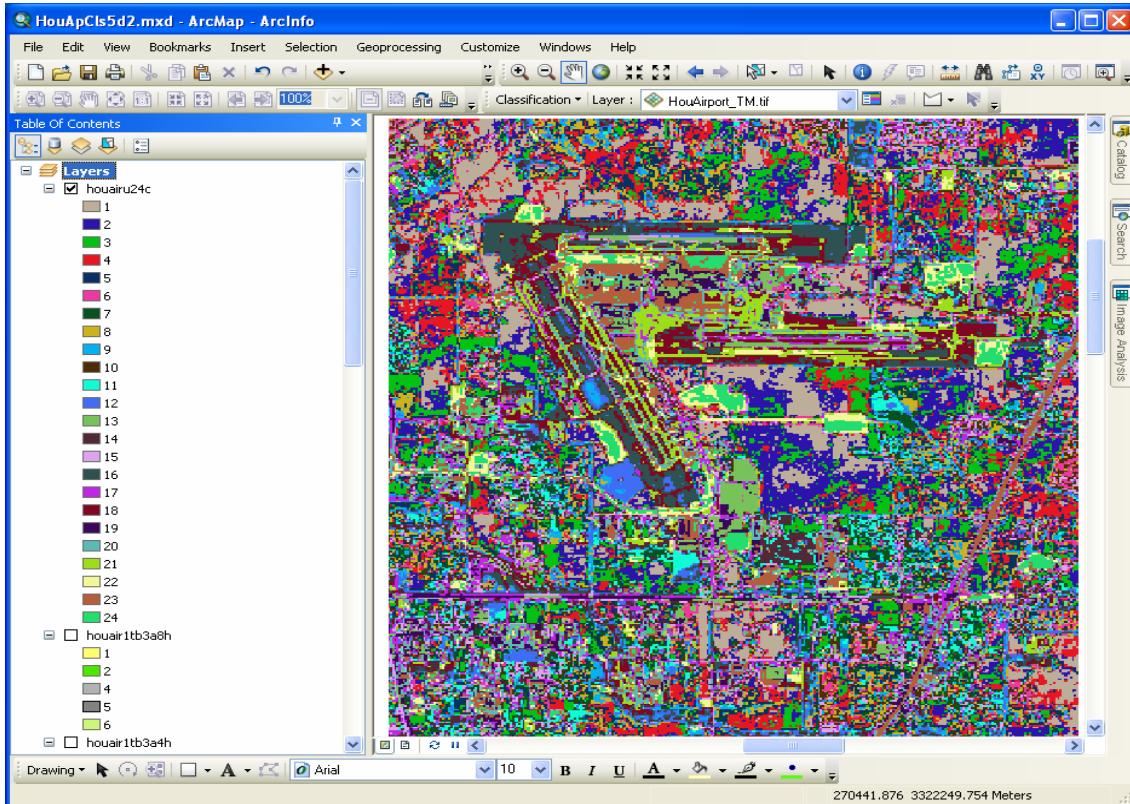
Drop-down Command 3, the Iso Cluster Unsupervised Classification, is the only unsupervised classification tool in the Image Classification toolbar. It differs from the Iso Cluster tool in the Spatial Analyst Tools in that it creates an output classified image as well as a signature file. This command, however, does not offer control over the number of iterations used to define the clusters that is found in the Iso Cluster tool in the Spatial Analyst Tools>Multivariate functions shown below.



You will now perform an unsupervised classification on the **HouAirport_TM.tif** image. Use the map document (.MXD) that you saved from the supervised classification. Clean the table of contents so that you only retain your base images and aerials, your unfiltered classification, and your best filtered result. From the Classification toolbar, select the Iso Cluster Unsupervised Classification drop-down (3). Input the **HouAirport_TM.tif** as the raster band. Specify the Number of classes as 24, name an output classified raster file, a Minimum class size (default, 20), a Sample interval of 2, and an Output signature file for future use. Your window should look like the example below. You changed the default Sample interval to 2 because, as mentioned before, some computers have insufficient memory to handle a bigger interval and will return fewer classes than specified.



The result should look something like the example below.



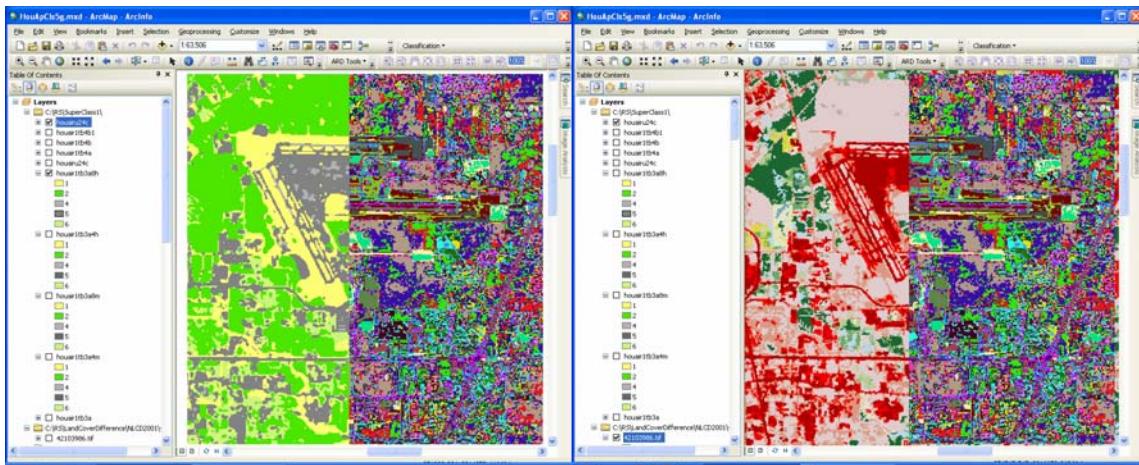
Compare the unsupervised classification with the supervised classification you did earlier, the NLCD product, and the airport aerials and TM image. The unsupervised image looks noisy but it contains a lot of valuable information.

As the analyst, it is now your job to make a useful classification from the unsupervised classes. Your assignment is to develop a set of classes that represent major groups of land cover. Go to the USGS MRLC site and examine the classification scheme that they have used that is based on the Anderson scheme www.mrlc.gov/changeproduct.php. This chart also attempts to reconcile the classes used for NLCD 1992 and NLCD 2001.

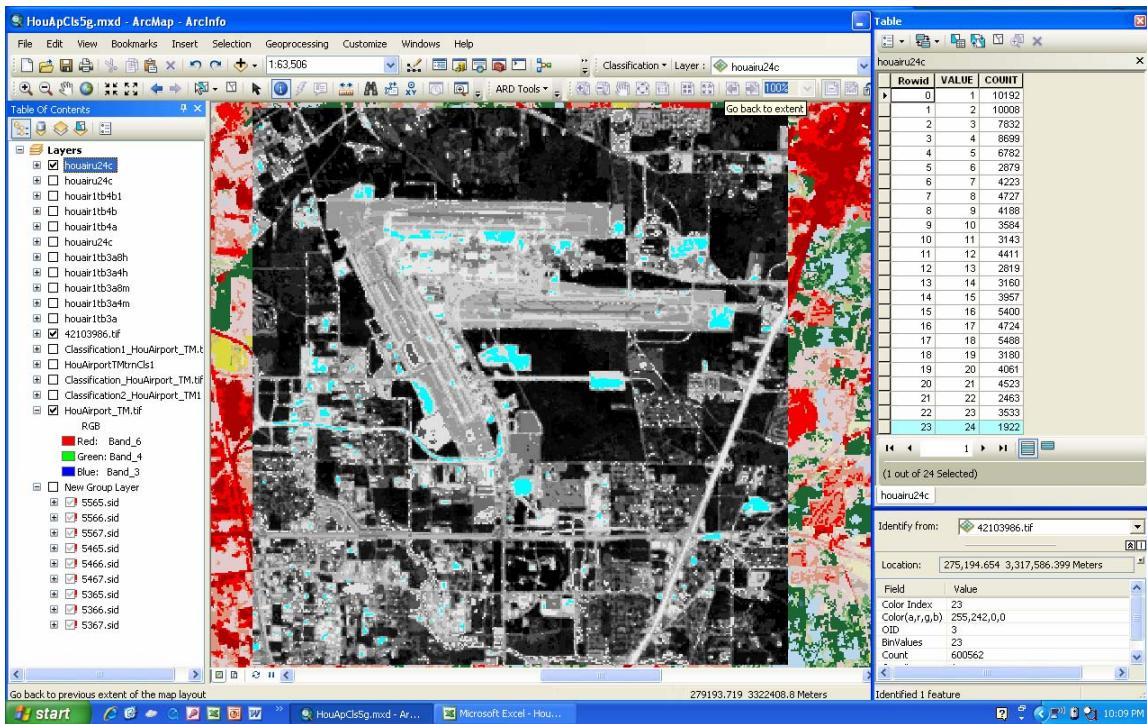
| NLCD 1992 Class Code | NLCD 1992 Description | NLCD 2001 Class Code | NLCD 2001 Description | Modified Anderson Level I |
|----------------------|--------------------------------|----------------------|---------------------------------|---------------------------|
| 11 | Open Water | 11 | Open Water | 1 |
| 12 | Perennial Ice, Snow | 12 | Perennial Ice, Snow | 8 |
| 85 | Urban, Recreational Grasses | 21 | Developed, Open Space | 2 |
| 21 | Low Intensity Residential | 22 | Developed, Low Intensity | 2 |
| 22 | High Intensity Residential | 23 | Developed, Medium Intensity | 2 |
| 23 | Commercial, Industrial, Trans. | 24 | Developed, High Intensity | 2 |
| 31 | Bare Rock, Sand | 31 | Barren Land, Rock, Sand, Clay | 3 |
| | | 32 | Unconsolidated Shore* | 3 |
| 32 | Quarry, Strip Mine, Gravel Pit | 31 | Barren Land, Rock, Sand, Clay | 3 |
| 33 | Transitional Barren | 31 | Barren Land, Rock, Sand, Clay | 3 |
| 33 | Transitional Barren | 31 | Barren Land, Rock, Sand, Clay | 3 |
| 41 | Deciduous Forest | 41 | Deciduous Forest | 4 |
| 42 | Evergreen Forest | 42 | Evergreen Forest | 4 |
| 43 | Mixed Forest | 43 | Mixed Forest | 4 |
| | | 51 | Dwarf Scrub** | 8 |
| 51 | Shrubland | 52 | Shrub, Scrub | 5 |
| 61 | Orchards, Vineyards, Other | | | 6 |
| 71 | Grasslands, Herbaceous | 71 | Grassland, Herbaceous | 5 |
| | | 72 | Sedge, Herbaceous** | 8 |
| | | 73 | Lichens** | 8 |
| | | 74 | Moss** | 8 |
| 81 | Pasture, Hay | 81 | Pasture, Hay | 6 |
| 82 | Row Crops | 82 | Cultivated Crops | 6 |
| 83 | Small Grains | 82 | Cultivated Crops | 6 |
| 84 | Fallow | 82 | Cultivated Crops | 6 |
| 85 | Urban, Recreational Grasses | 21 | Developed, Open Space | 2 |
| 91 | Woody Wetlands | 90 | Woody Wetlands | 7 |
| 92 | Emergent, Herbaceous Wetland | 95 | Emergent Herbaceous Wetlands | 7 |
| | | 91 | Palustrine Forested Wetland* | 7 |
| | | 92 | Palustrine Scrub/Shrub Wetland* | 7 |
| | | 93 | Estuarine Forested Wetland* | 7 |
| | | 94 | Estuarine Scrub/Shrub Wetland* | 7 |
| | | 96 | Palustrine Emergent Wetland* | 7 |
| | | 97 | Estuarine Emergent Wetland* | 7 |
| | | 98 | Palustrine Aquatic Bed* | 7 |
| | | 99 | Estuarine Aquatic Bed* | 7 |
| | | | * Coastal Areas Only | |
| | | | ** Alaska Only | |

You will begin by assigning real identities to the classes that were created. Use the TM image, aerials, and the NLCD product to help guide your interpretation. A

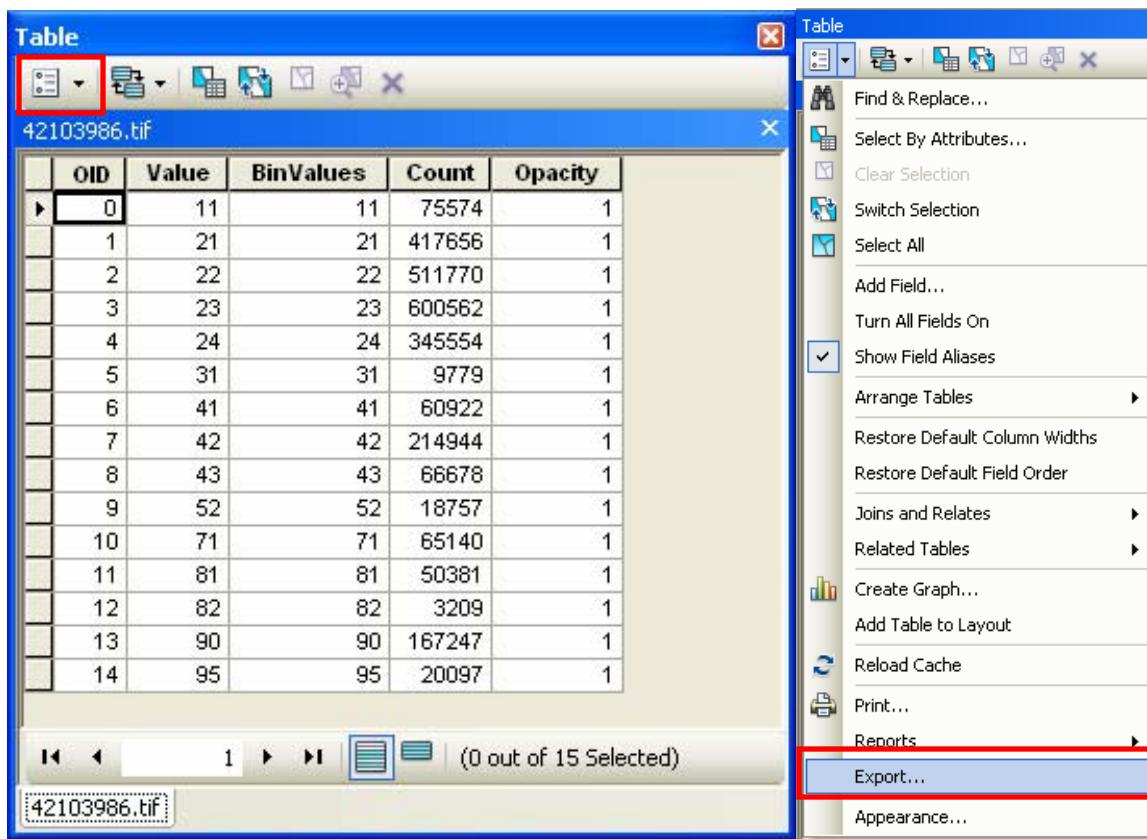
good approach to this is to use your unsupervised classification as the top layer and “Swipe” it over the other layers. An improvement on the plain “swipe” is to



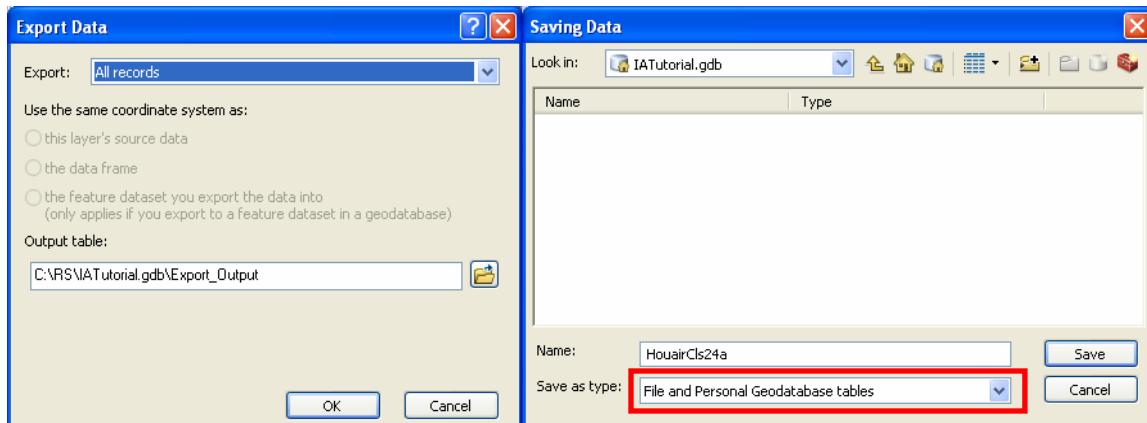
open the classification table and select a class in the unsupervised classification image. This highlights a single class and now it can be compared with the underlying images and classifications. As you see in the example, going



to a gray scale allows the selected class to be highlighted without visual clutter. Use the “Identify” tool to view the class values in the underlying layers. Another way to improve your efficiency and workflow is to export the classification table, place it in an Excel spreadsheet, and record your observations and correlations in the spreadsheet. Open the classification table and go to the drop down menu.



Select the “Export” option and save the table to the geodatabase with an appropriate file name.



Export the file using ArcCatalog to a .dbf file and open it in an Excel spreadsheet. You can also export directly to a .dbf by specifying it in the “Save as type” box. Below is an example of a spreadsheet created by the method outlined.

Microsoft Excel - HouairCls24b.xls

| | A | B | C | D | E | F |
|----|----------|------------|-------------------|-------|-----------|--------------------|
| 1 | OBJECTID | VALUE_CI24 | NCLD_Num | COUNT | SClassNum | ClassName |
| 2 | 1 | 1 | | 42 | 10192 | 2 Forest |
| 3 | 2 | 2 | | 42 | 10008 | 2 Forest |
| 4 | 3 | 3 | | 42 | 7832 | 2 Forest |
| 5 | 4 | 4 | | 42 | 8699 | 2 Forest |
| 6 | 5 | 5 | | 42 | 6782 | 2 Forest |
| 7 | 6 | 6 | 95,41,42,11,21,81 | 2879 | | 2 Woody Wetland* |
| 8 | 7 | 7 | | 81 | 4223 | 1,2,6 Dry Grass* |
| 9 | 8 | 8 | 21,23,41 | | 4727 | 2 Forest |
| 10 | 9 | 9 | | 23 | 4188 | 2,1 Forest* |
| 11 | 10 | 10 | | 21 | 3584 | 6,5 Green Grass* |
| 12 | 11 | 11 | | 21 | 3143 | 6 Green Grass |
| 13 | 12 | 12 | | 21 | 4411 | 1 Dry Grass |
| 14 | 13 | 13 | | 24 | 2819 | 4,5 Urban* |
| 15 | 14 | 14 | | 21 | 3160 | 6,1 Green Grass* |
| 16 | 15 | 15 | | 23 | 3957 | 6,5,1 Green Grass* |
| 17 | 16 | 16 | | 21 | 5400 | 1 Dry Grass |
| 18 | 17 | 17 | | 23 | 4724 | 5 Urban light |
| 19 | 18 | 18 | | 21 | 5488 | 1 Dry Grass |
| 20 | 19 | 19 | | 24 | 3180 | 4 Urban |
| 21 | 20 | 20 | | 23 | 4061 | 5 Urban light |
| 22 | 21 | 21 | 21,23 | | 4523 | 5,6,1 Urban* |
| 23 | 22 | 22 | 21,22,223 | | 2463 | 5 Urban light |
| 24 | 23 | | 23 | | 3633 | 5 Urban light |
| 25 | 24 | | 24 | | 1922 | 5 Urban light |
| 26 | | | | | * mixed | |

You can see from the spreadsheet that, as expected, there are multiple classes within the major land cover classes. For the purposes of this exercise, you only need the major classes. Merging some classes that have obvious relationships is needed. Classes 1 through 5, 8, and 9 in this example all appear to be forest. Classes can be reassigned using the “Reclassify” tool.



Use the spreadsheet to assign new classes to the layer. Open the “Reclassify” tool by going to ArcToolbox>Spatial Analyst Tools>Reclass>Reclassify. This will open the “Reclassify” menu seen below. The input is the **houairu24c** layer in this case. If the classes do not appear, be sure the Reclass field is “Value” and click the “Unique” button. Enter the new class designations in the “New values” boxes. Save the completed reclassification to an appropriate file name. For continuity, **ReclsHouair1** was used for this example.

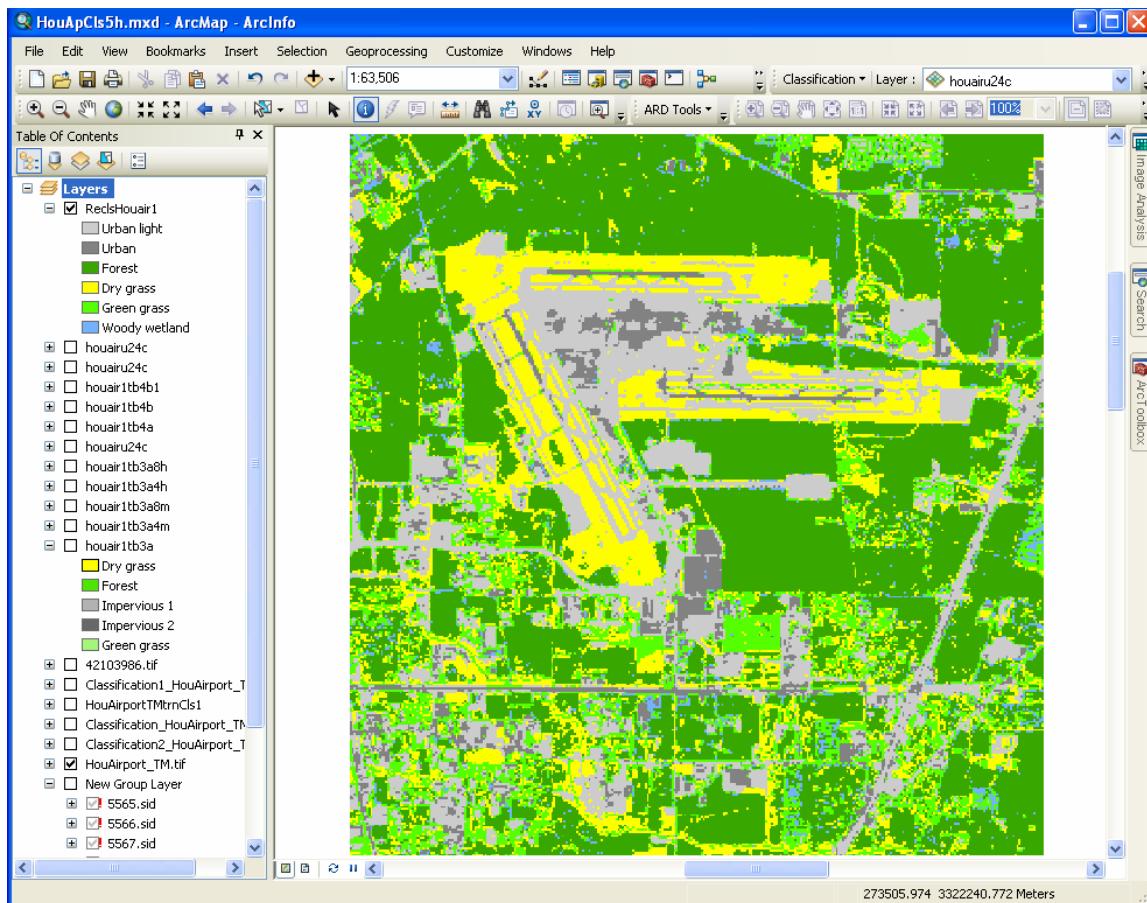
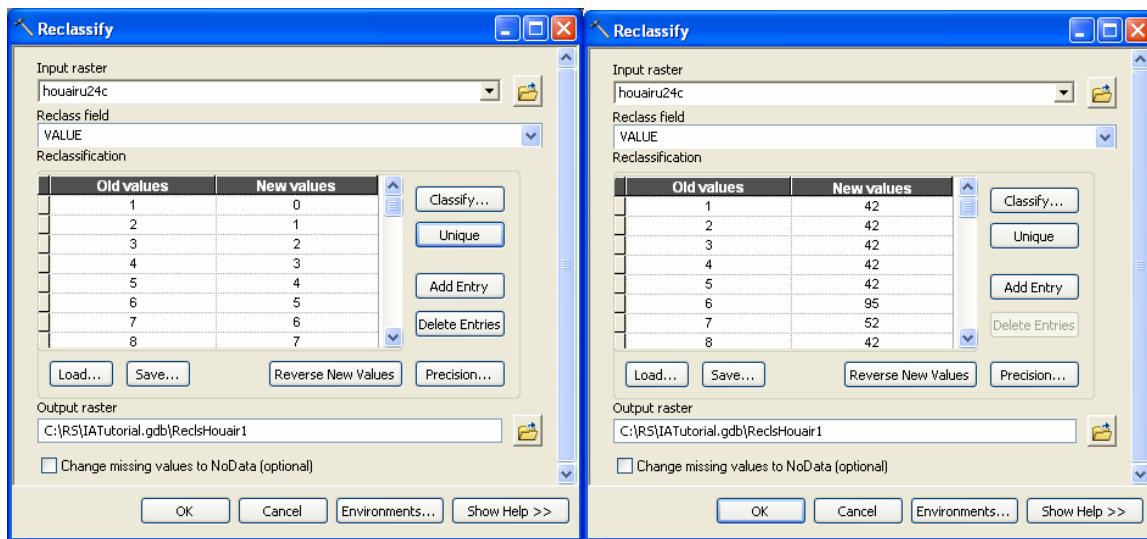
Add the reclassified image to the Table of Contents and set the symbology to display the new classes. Your results should look something like the screen capture below. Examine the **ReclsHouair1** layer table to see the numerical distribution of class pixels.

The screenshot shows the Table window with the following data:

| OBJECTID | Value | Count |
|----------|-------|-------|
| 1 | 23 | 21226 |
| 2 | 24 | 5999 |
| 3 | 42 | 52428 |
| 4 | 52 | 19522 |
| 5 | 81 | 13844 |
| 6 | 95 | 2879 |

(0 out of 6 Selected)

ReclsHouair1



You might want to remove some of the noisy pixels with the appropriate generalizing procedure (Majority filter) as you did in the supervised classification section of the exercise.

Use your skills and the tools you have explored to create a map that represents the major land cover types in this area. Place the map in a Word document with an explanation of your process and the results. Discuss the differences you observe between the NLCD layer and your classification.

Turn in all the documents requested for Exercise 4 credit.

This concludes the Exercise 4. However, we did not yet discuss or use Command 5, Principal Components. Here is a brief description to complete the Command discussion. Principal Components is an analysis that is not really a classification. Principal Components analysis transforms a multi-band image to minimize band correlation. This geoprocessing tool creates a new image with the information compressed into fewer bands or components. The first component represents the greatest variance, usually brightness. The second component represents the second greatest variance in the remaining image information. The content of the remaining components depends upon the image characteristics. According to Aronoff, "Typically, over 90% of the variability in pixel values in an image is captured in the first two or three components". Components beyond 5 are usually image noise. By enhancing the first few bands of a principal components image, you can produce an image layer that might be helpful in identifying training sets.

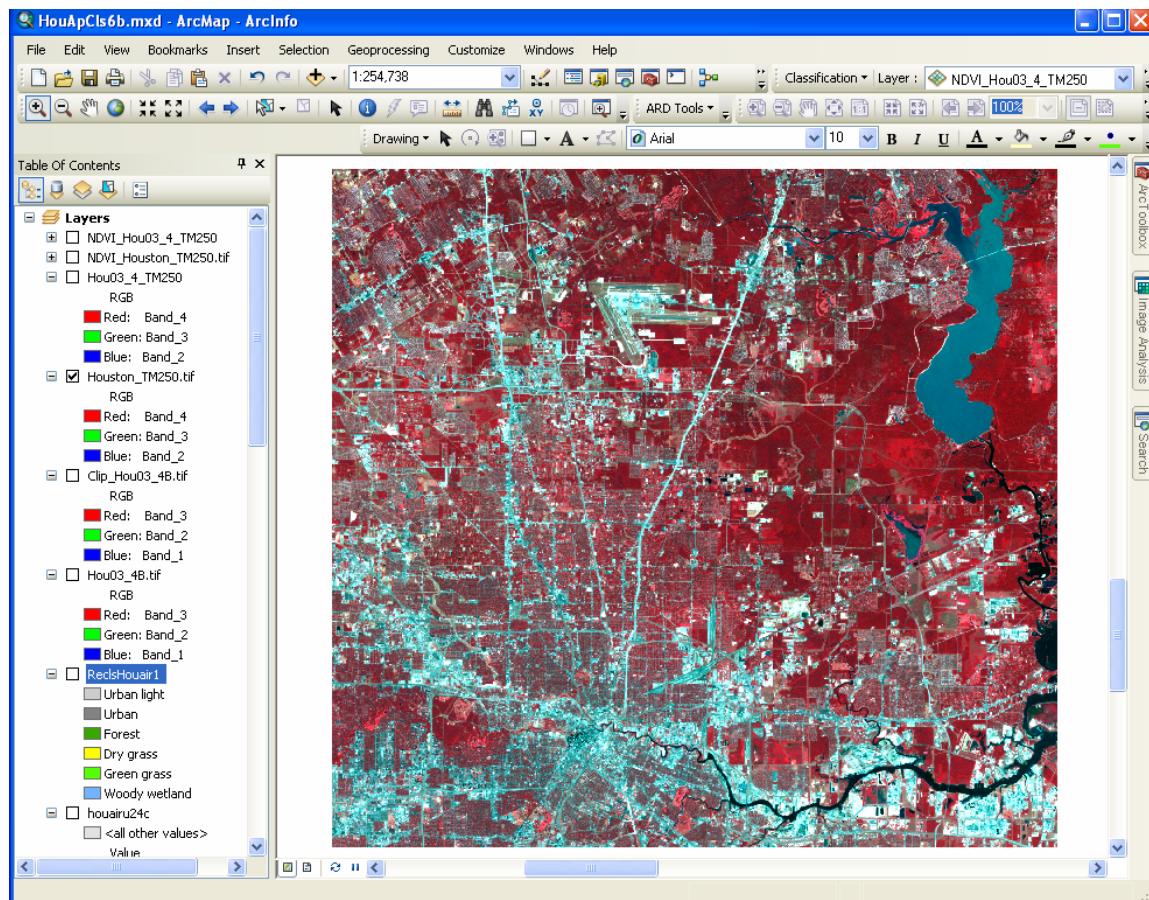
You have now completed an introduction to the basics of image analysis in ArcGIS 10. A supplementary Exercise on georeferencing photographs is planned for the near future. However, you now have the knowledge and tools to add imagery and information derived from imagery to your GIS projects. Good luck!

Optional Exercise 1 – Temporal Comparison

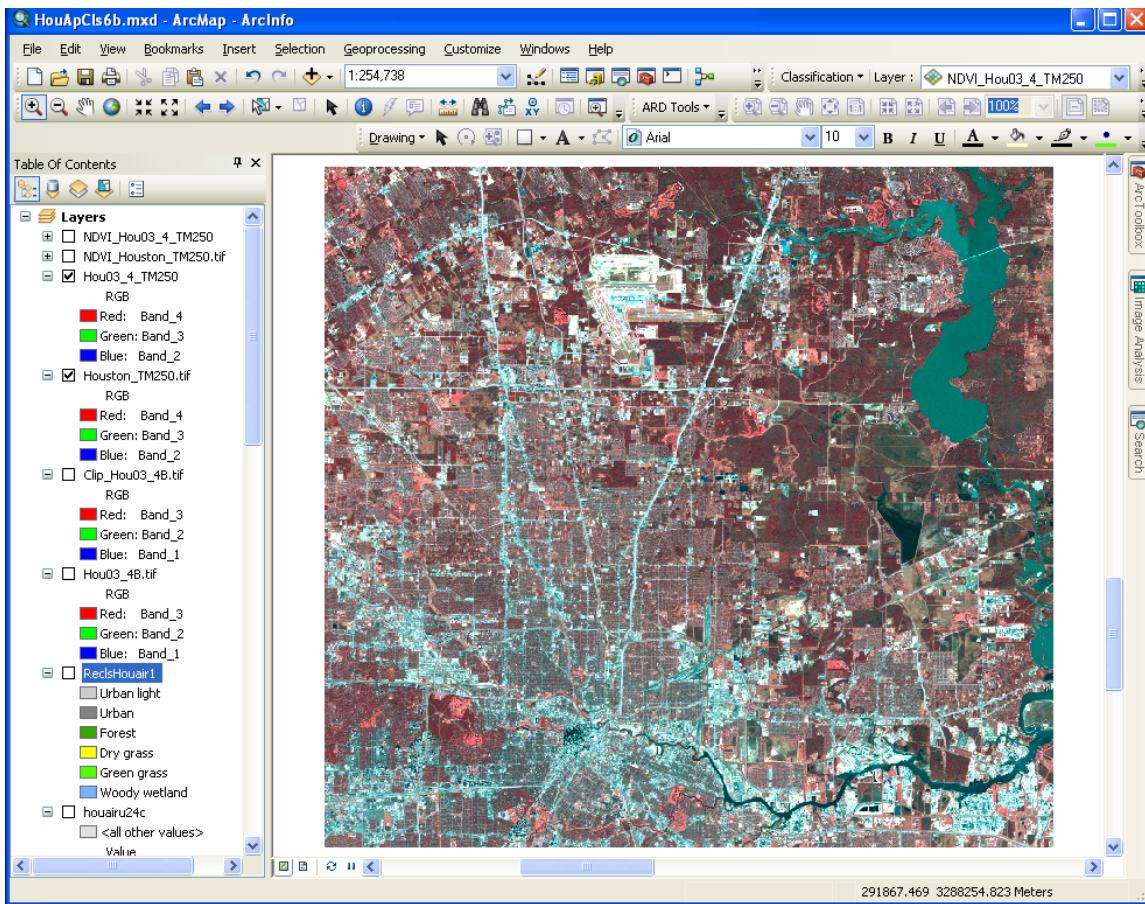
In Exercise 3, you prepared a band composite for a Landsat scene from January of 2003. You have worked extensively with the image from September of 1999. The time period between images was characterized by active development in the Houston area. There were also differences in precipitation between the two years. In this Exercise, you will process the 2003 image and compare the results with the 1999 image.

Start ArcMap. Add the **Houston_TM250.tif** layer and the **Hou03_4B** layer to the Table of Contents. Subset the **Hou03_4B** layer to the same extent as the **Houston_TM250.tif** and name it **Hou03_4_TM250**. Using a 4,3,2 band combination for both images, apply a 2 Standard Deviation stretch and Gamma stretch to both. Your results should resemble the examples below.

9/1999



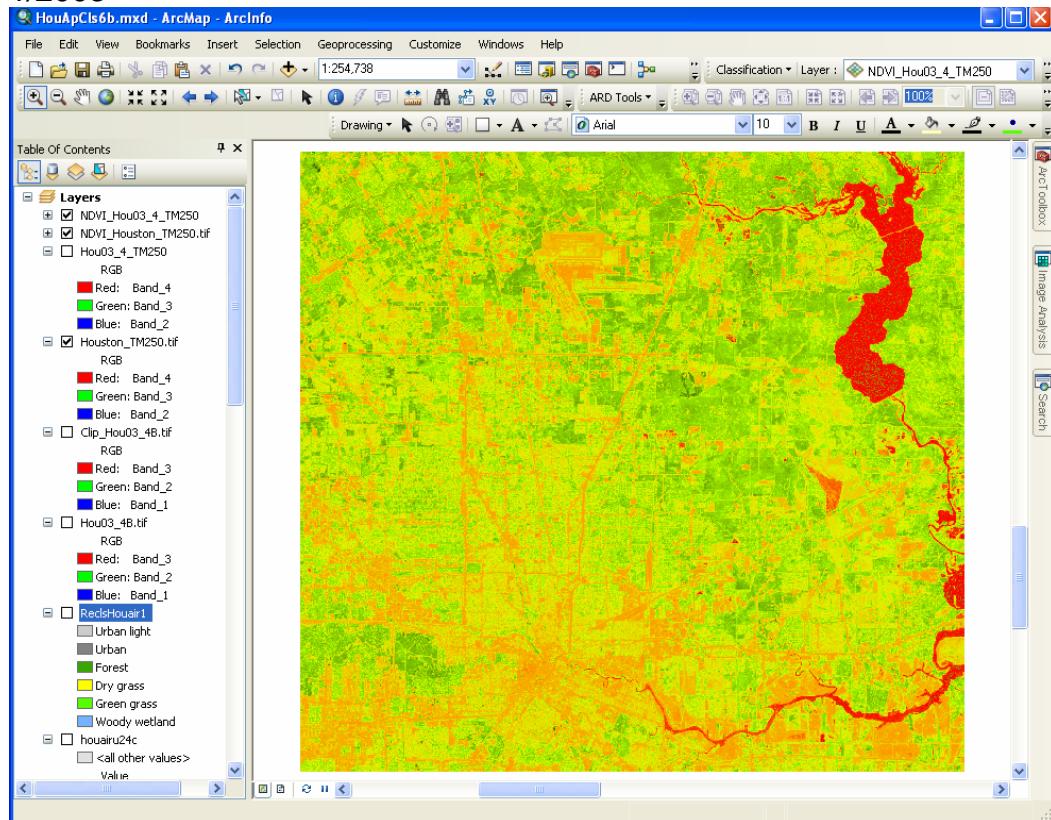
1/2003



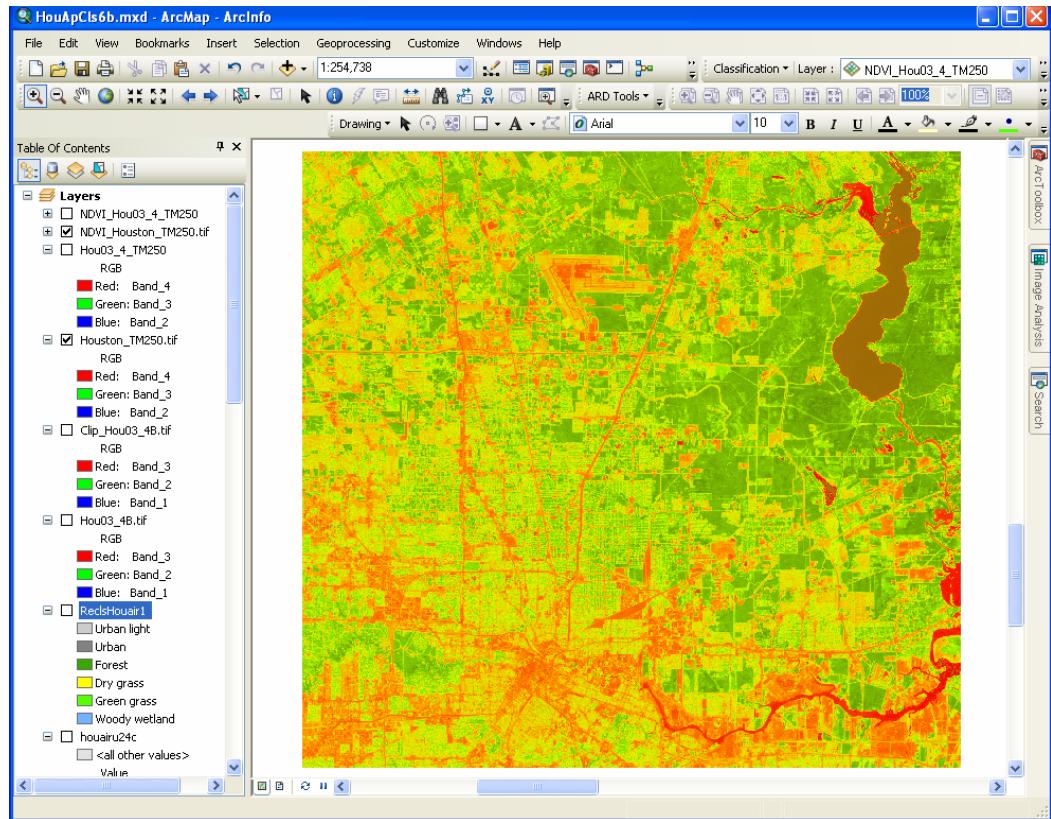
Carefully examine the results and make notes on the significant differences.

The NDVI transform does a good job of highlighting the conversion of areas of tree canopy and grassland to urban uses. Perform an NDVI transform on the **Hou03_4_TM250** image. Add the **NDVI_Houston_TM250.tif** image to the Table of Contents. Compare the NDVI results on both images. Be sure to examine the properties of the default colormap that ArcGIS applies to this product. Are they identical? Your results should resemble the examples below.

1/2003



9/1999



As the analyst and interpreter, you now have a lot of things to consider. Here are some points to help you with your analysis.

What would you expect of the vegetation conditions considering the times of year that the images were acquired? Can you compare the images directly and would a Difference function be appropriate?

Examine the bodies of water in the two scenes. What do they tell you about precipitation conditions? Apply that knowledge to your interpretation of the NDVI results.

The 4,3,2 band combination has a distinct signature for golf courses in both images. Use that signature to help you examine the NDVI signatures for those features. Are these results consistent with your conclusions regarding precipitation?

You might be able to extract an urban class from the NDVI. What functions would you use to accomplish that operation? Is there an NDVI value below which most urban features fall? We have already discussed masks in relation to extracting an urban class based on NDVI but for thoroughness, what types of features need to be masked out to produce a “clean” urban class?

Prepare a brief, professional report discussing the losses or gains in vegetation and urban land cover that you have observed between the two images. Be as quantitative as you can in your comparison. Be thorough in your evaluation of the limitations of the analysis. Include a discussion of the choice of bands and the observed signatures of land cover elements. Use maps and tables to illustrate your conclusions. The report will be written in Word (compatibility) format.