Lab 1 Introduction to ENVI Software
Utilizes Textbook's Remote Sensing Digital Database: *Chapters 1 and 2 data.*

The objectives of this lab are to learn where many key, image processing tools are located on ENVI's main display window and what these tools do. Topics that will be covered include:

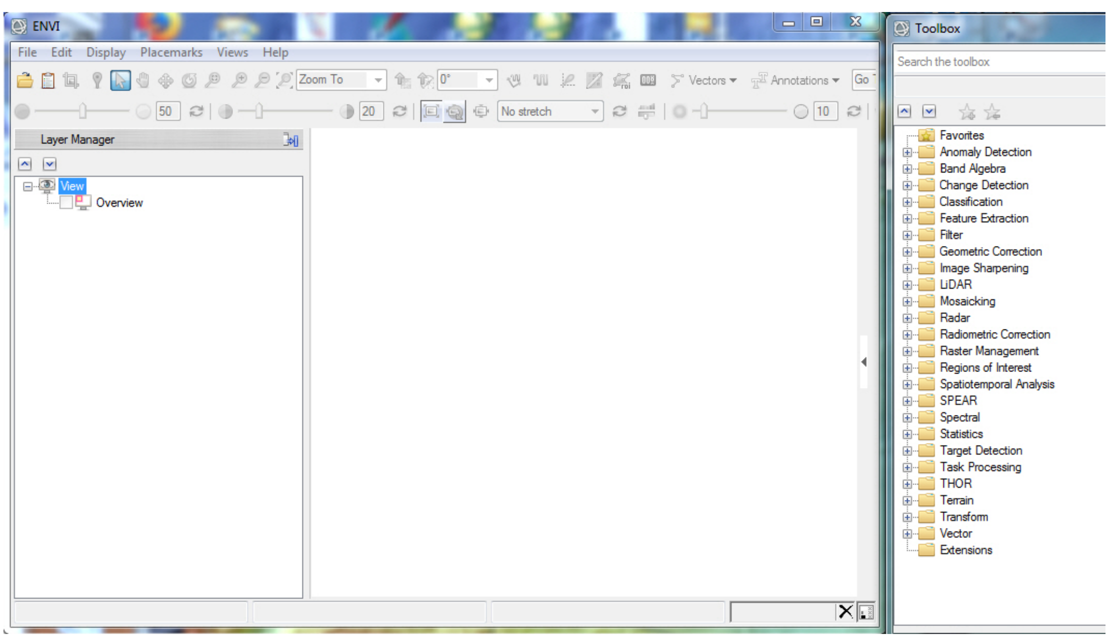
> Review drop-down menus and tools located along top margin.
> Metadata
> Radiometric and spatial resolution
> Contrast stretching
> Spectral and Arbitrary profile (transect)

You will upload one (1) digital file to the instructor. Thirteen (13) questions are asked during this lab – you are to write your answer on the sheet that is at the end of this handout.

ENVI has two formats for the Graphical User Interface (GUI).

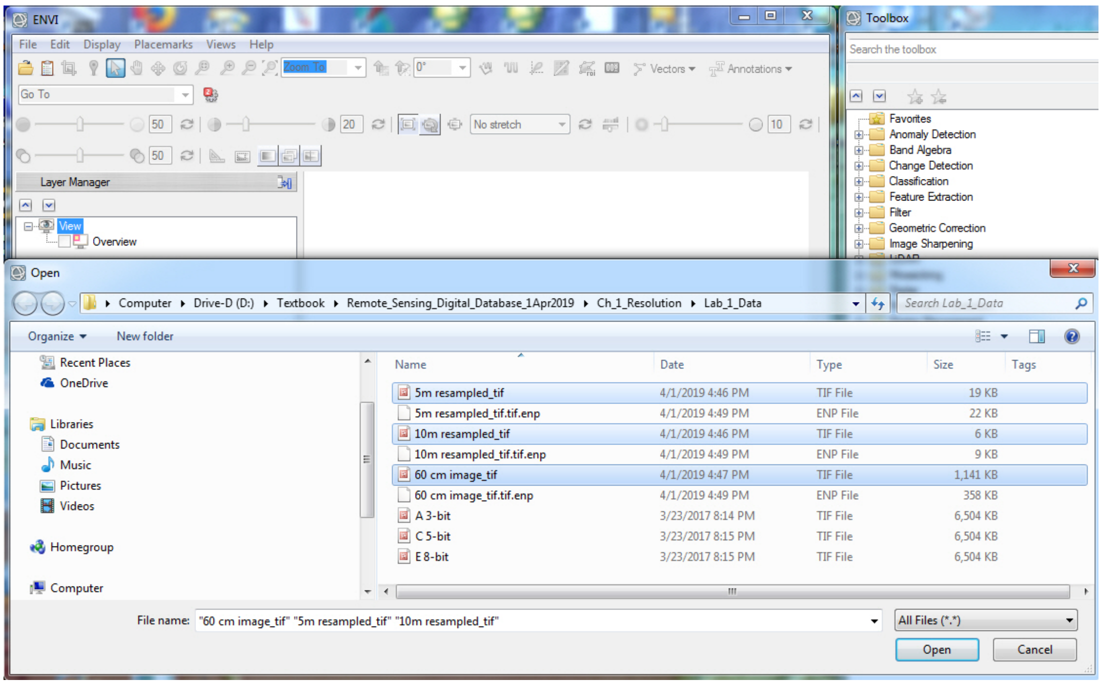
> A) "Classic" is a 3-window arrangement (Image, zoom, and scroll) for power users.
>
> B) unnamed is the latest arrangement that as has a GIS look. We'll start with the unnamed GUI (see Figure below). *Start* the ENVI software.

Layers that are loaded into the program are displayed in the left column, many tools are in the Toolbox to the right, and the image and maps are displayed in the center view.

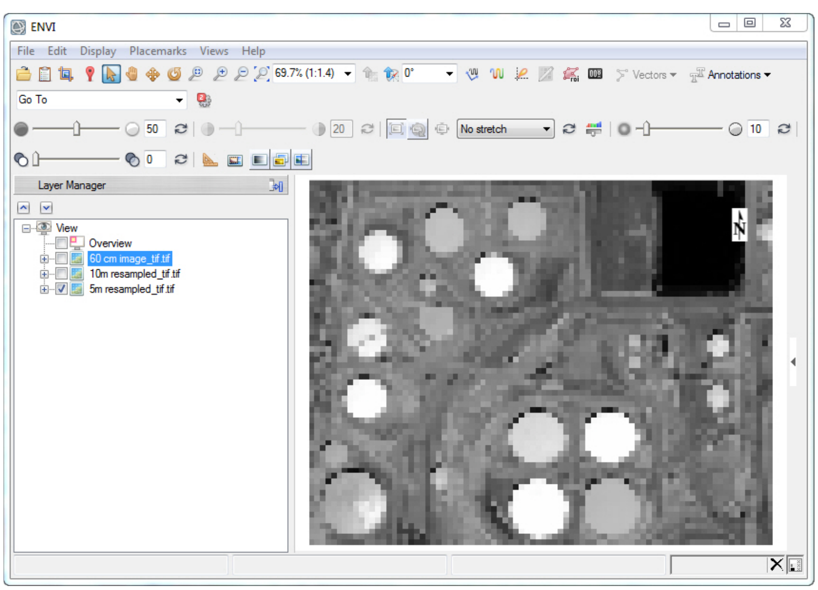


1) Let's first load the 3 spatial resolution grayscale images that have copied from the "Remote Sensing Digital Database \ Ch_1_Resolution" collection. Open the "**Lab_1_Data**" folder that was in the same folder as this Lab 1 handout and load the 3 images. These 3 images are shown in the textbook's Figure 1-5.

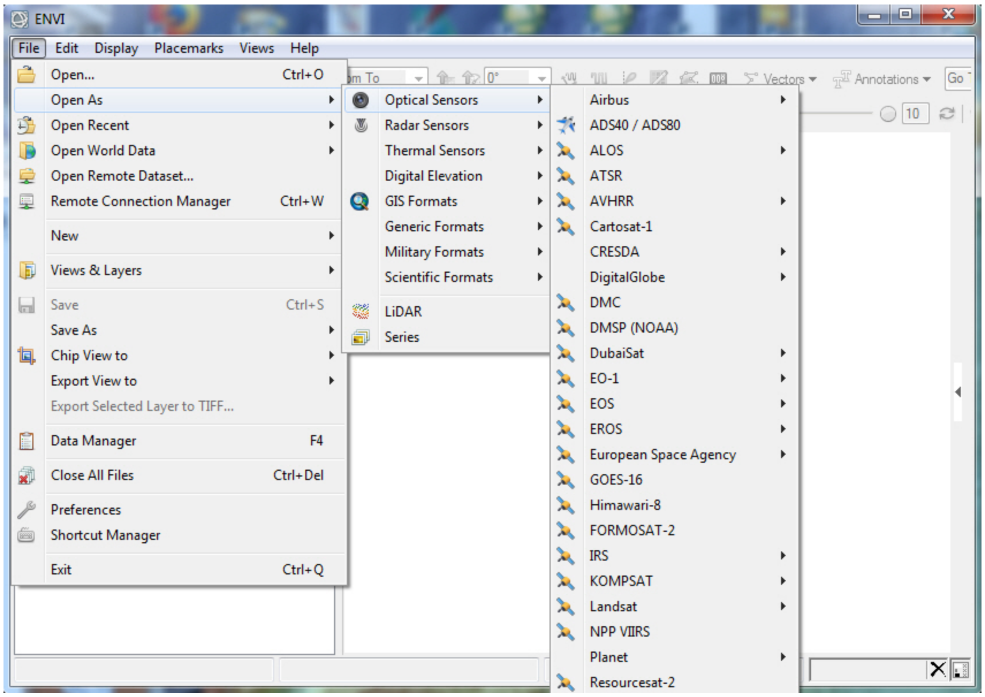
File > *Open* > Lab_1_Data\ 10m resampled_tif, 5m resampled_tif, and 60 cm image_tif. (You should see windows identical to what is below).



Zoom to Full Extent icon. *Unclick* the 60 cm and the 5 m images in the Layer Manager so only the 10 m image is displayed. (See below).



2) With the instructor, you will open the tasks located across the top of the ENVI window (File, Edit, Display, etc.) We will start with the dropdown menu under "*File > Open As.* Examine the "*Open As*" options for different types of data – discuss the advantages of this extensive capability (Optical Sensors shown below).



File > Open World Data Global data – you need to zoom out. You may be asked to approve reprojecting the images in your view so that the ENVI global vector and DEM data can be displayed.

File > Open Remote Dataset or *Remote Connection Manager* Streams in GIS layers from a server on the Internet.

File > Views and Layers > Save Enables you to save the images and maps loaded into ENVI Views so you can restore them later (data has to remain on the same path).

File > Export Selected Layer to TIFF Most useful for images being sent to a GIS.

File > Data Manager Displays all the data you have opened. Shows all the bands in a multispectral data set (Layer Manager only shows the 3 bands being displayed in color).

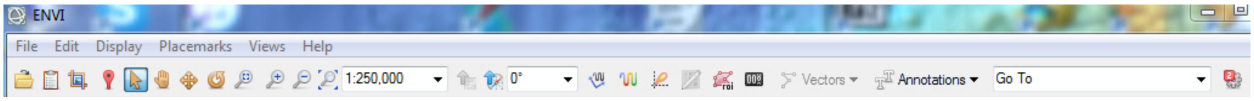
File > Preferences Important if you want to change the default display stretches

Display > You will use many of these tools, especially Cursor Value and Profiles.

Views > You can drag and drop images and maps from one view to other views. Multiple views are excellent for comparing different enhancements of the same dataset.

Help > Contents   ***Essential*** **for understanding the tools that you will be using.** Click on the "Index" tab and type in a term you want to understand in the "Search Index".

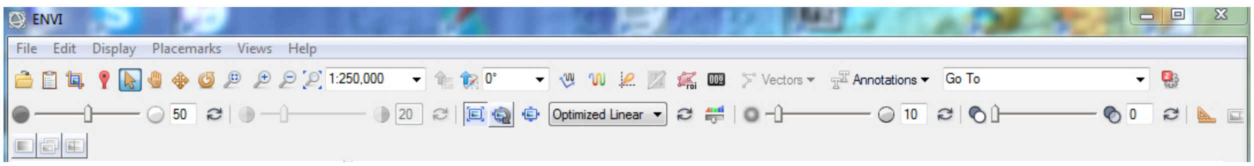
3) Top row of icons and buttons



Test out the different tools. The "*Pixel Scale*" dropdown menu is less useful than the "*Map Scale*" dropdown menu.

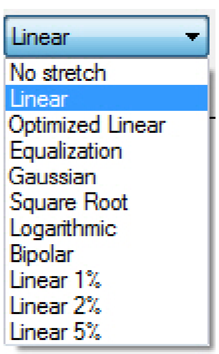
Other icons are duplicates of what is in the *Display* dropdown menu.

4) Second row of icons and sliders



The "*Contrast*" slider only works when the contrast stretch is set to "Linear" (see below).

The "*Stretch on View Extend*" is very useful for enhancing only what you see in the View – it ignores the rest of the dataset outside the view.



The "contrast stretch options in the drop-down menu are very useful.

Histogram Stretch   Enables you to broaden or narrow the digital numbers (DNs) used in the enhanced grayscale band (or image) by moving darker pixels to pure black and lighter pixels to pure white.

Sharpen is an edge enhancement tool. Zoom-in to a scale of 1:1000. Move the slider to the right to see the visible increase in edges and sharpness (this is a "high pass filter"). The vertical line in the slider represents <u>No Sharpening</u>. Move the slider to the left of the vertical line to soften the image (this is a "low pass filter").

5) *File > Preferences> Display General*   Set the Default Stretches for 8-bit imagery to "No Stretch" >   *OK*

This will load new 8-bit images without any enhancement.

6) *Right-click* on the 10m resample_tif image in the Layer Manager > *View Metadata.*

View the metadata for the 5m resampled_tif and the 60 cm image_tif

Question 1:   A. What is the map projection and datum for the 3 images?

B. How big is each image in KB, and the number of pixels in the columns and rows?

7) *Turn-on (check)* the 5 m and 60 cm images in the Layer Manager

Right-click on the "60 cm image_tif.tif"   *View Metadata.*

Export > *Selected node to a file* > *Close*

Question 2: What is the format is the exported metadata? Why is this a useful format?

8) *Display* > *Cursor Value*   Move the cross-hairs around with the "Select" arrow.

Question 3: What is the range of digital numbers (DNs) for the 60 cm image?

Question 4: can you identify the tanks on the 10 m image?

Question 5: Can you identify roads on the 5 m image? What is their characteristic?

9) *Views* > *Two Vertical View*   Activate the blank view so it has a color boundary around it and the "View" text in the Layer Manager is highlighted.

File > *Open* > A 3-bit.tif, C 5-bit.tif, and E 8-bit.tif
These 3 images are shown in Figure 1-9 (see also Figure 1-10).

Zoom to Full Extent icon.   Unclick the 5-bit and the 8-bit images.

Use the Zoom tool and enlarge the 4 tanks and ground in the southeast central portion of the image. Turn on & off the 3 images.

Question 6:   A. 3-bit images have how many levels of gray?

B. 5-bit images have how many levels of gray"?

C. Do you see much difference between the 5-bit and 8-bit images? Why?

10) *Zoom* into the same tank on the left and right view. Use the *Pan* tool to center the tank in the view.

Use the measuring tool "*Mensuration*" to measure the dimension of the tank.

Question 7: A. What are the two measurements of the same tank in the two views?

B. Why the difference?

11) *Views* > *One View* (don't save any annotation). We are going back to one view.

Right-click on "View" in the Layer Manager and "*Remove all Layers*" (don't save any annotation). The Layer Manager should be blank.

12) *File* > *Open* > Locate the folders in the Remote Sensing Digital Database named "Ch_2_Aerial_Images\Plate_3_NAIP_Aerial_Multispectral"

Open the "NAIP_CIR_432…", "NAIP_Color_321…", and "NAIP-4band…" TIFs

Highlight each tif file (the largest 3 files in the subfolder) > *Open.*

The 3 data sets are in the one view. *Move* the "NAIP_Color…" image to the bottom of the Layer Manager list (highlight and drag to bottom of the list).

NOTE: The 4 NAIP bands, along with a map are shown in the textbook's Figure 2-27. The natural color and color IR images are shown in the textbook's Plate 3.

File > *Data Manager* If not already opened, open the Data Manager so you can see how many bands are in each dataset.

Zoom to Full Extent icon. Unclick the "NAIP_CIR…" and the "NAIP_4band…" layers in the Layer Manager.

The "NAIP_Color…" image should appear with natural colors. This image was acquired in June when non-irrigated grasses that cover the hills are very dry and should appear with shades of yellow. What color is the grass on the hills in your view? If the non-irrigated grass is not yellow, the order of the bands in the color display is incorrect (See Plate 3A).

NOTE: A typical problem to solve when loading data is the order that bands are sequenced in a dataset. The USDA delivers 4-band NAIP data in the following order: reflected blue light = band 1, reflected green light = band 2, reflected red light = band 3, and reflected Near IR light = band 4. A natural color image should display in ENVI as bands 3, 2, 1 in red-green-blue.

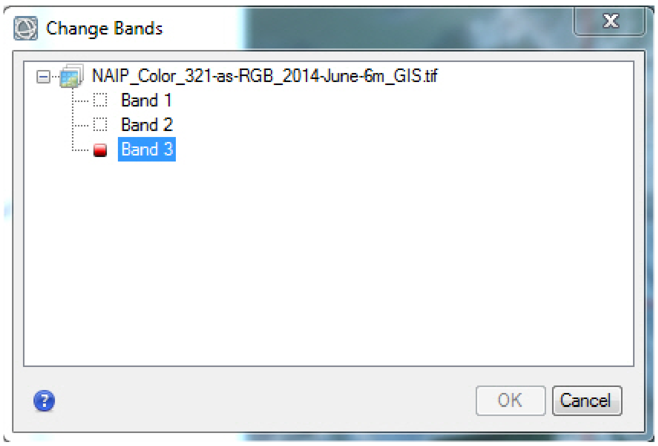
But you may see that ENVI loaded the color image with bands 1, 2, 3 as red-green-blue. That is incorrect!

The metadata that accompanies a remote sensing dataset should document the sequence of bands to help minimize the confusion.

13) We'll change the color images band order next to correct the problem.

Right-click on "NAIP_Color…" in the Layer Manager > *Change RGB Bands…*

In the Change Bands window (see below) *Click* Band 3 first (displayed with red light), Band 2 next (displayed with green light) and Band 1 last (displayed with blue light) > *OK*



Now the dry grass should appear yellow.

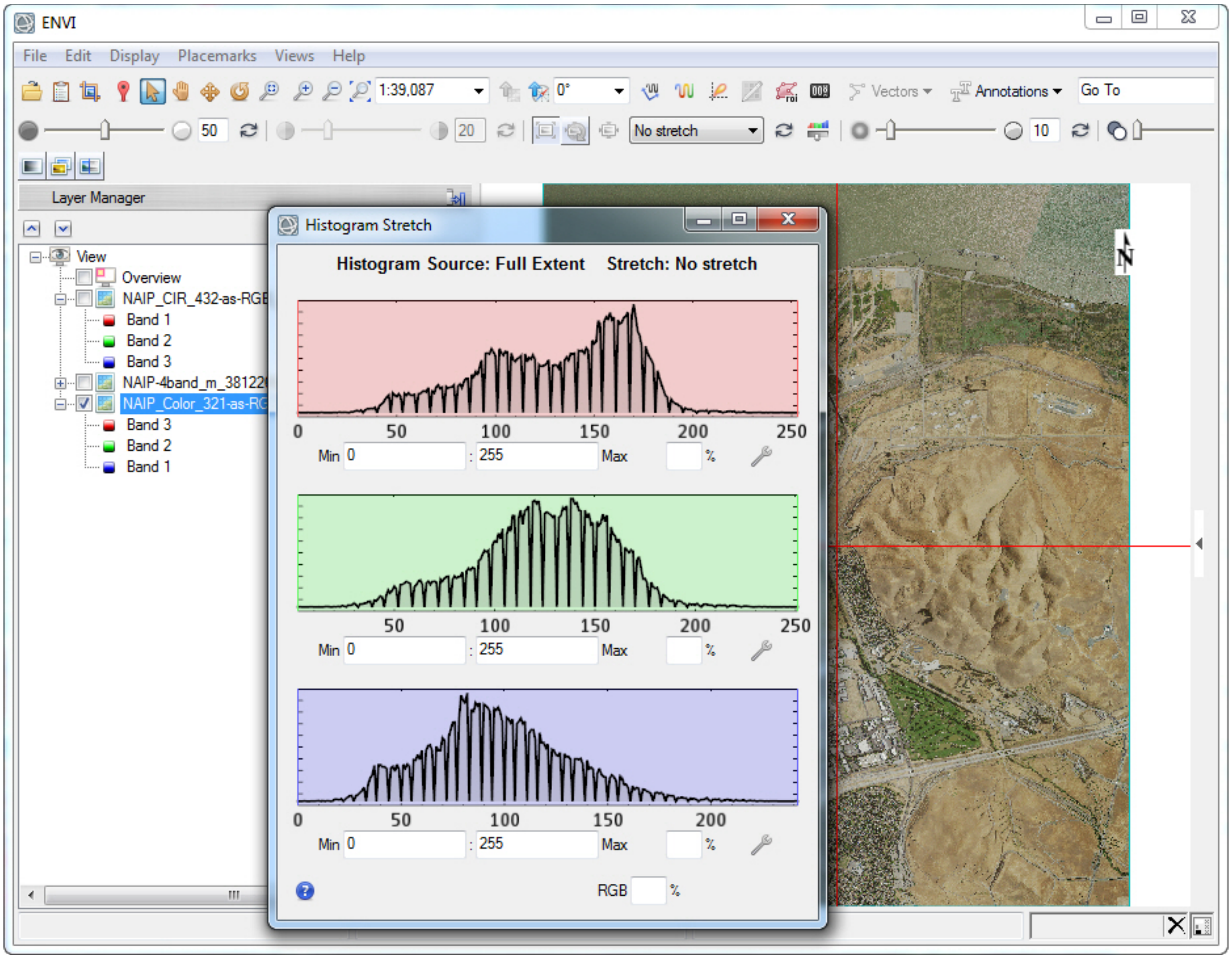
Right-click on the "NAIP_Color…" image and *View Metadata.*

14) Enhancing the image. Start with "**No stretch**". Use the Brightness slider – when done, return to 50.

Contrast stretching is discussed in the textbook's Chapter 9 Digital Image Processing. Also see textbook Figures 9-12 and 9-13.

Click on the *Histogram Stretch* icon. You will see the 3 histograms for the color image. The NAIP image is collected as 4 bands (reflected blue, green, red, and near IR as bands 1, 2, 3, and 4). The color image is bands 1-2-3 displayed in blue-green-red. The CIR (color infrared image is bands 2-3-4 displayed in blue-green-red. The 4-band multispectral data enables you to change the band combinations and color composite using the 4 bands.

The Histogram Stretch display is shown below for the 3 bands in the "NAIP_Color…" image. There is no contrast stretch applied.



Question 8: How many bits is this data? How many levels of gray?

Question 9: Between approximately what low and high DN (brightness) values (numbers along the horizontal axis) are most of the pixels in this dataset?

We can use the contrast-stretching tools to improve the range of brightness and improve the information content in the color image. First let's do the enhancement with the options provided in the contrast stretch drop-down menu.

Choose "Linear 1%" Is the image more informative? Zoom in and pan around to make your determination.

For this contrast stretch, 1 % of the pixels are moved to pure black (DN = 0) on the left side of the histogram and 1% of the pixels are moved to pure white (DN = 255) on the right side of histogram). You see the 1% vertical lines on the *Histogram Stretch* plots.

Question 10: Why did moving 1% of the dark and bright pixels to 0 and 255, respectively, improve the range of colors displayed in the color composite?

Choose "Linear 5%" What happened to the information content displayed in the industrial and developed areas?

15) Now let's manually change the % of pixels changed to pure black or pure white.

Use the Drop-down menu and choose *"No Stretch"*

Place your cursor on the left and right side of the red histogram and *move the bars inward* so that approximately 2% of the pixels are moved to pure black or DN = 0 (left side) and pure white or DN = 255 (right side).

What happens to the natural color image when you do contrast stretching only only one band – in this case the band illuminated with red light?

Repeat the 2% linear stretch on the green and blue bands. Is the image more informative? Zoom in and pan around to make your determination if a Linear 2% stretch was better than a Linear 1% stretch that we did earlier.

16) Let's save our enhanced Linear 2% contrast-stretched color image for a GIS.

Highlight the "NAIP_Color… file name in the Layer Manager.

File > Export Selected File to TIFF… Name the file "Enhanced_NAIP_Color.tif"

Question 11: A. How large is this tif file in MB?

B. How large was the original NAIP_Color_321…tif" image?

C. Is your enhanced image better looking than the original?

File > *Chip File To > Geospatial PDF…*

Fill in with your name, course ID, and a few keywords (metadata!!).

Output file name: "Your Name_Enhanced_NAIP_Color pdf"

Do you like the thumbnail image?

Upload this pdf to the instructor.

File > Chip File To > Google Earth you don't get to name the kmz…

Look at your image in Google Earth. Do you like it?

The name may be "ENVI View"… not very useful…

17) Let's reset the stretch to "No stretch". Click through the different stretches in the drop-down menu. Which one do you like the best?

Zoom into the golf course in the lower right.

Turn on the "NAIP_Color_321…" and the "NAIP_CIR_432…" image in the Layer Manager. Unclick the "NAIP-4band…" data.

Turn on the **Portal** and move it around with the **Select** arrow.

Display > Portal

Hopefully you will see the color image in the portal – and the color IR image as the background – or vice versa.

Zoom in with the Portal active. Very cool(!) – it stays the same size while you zoom in & out. Use the Select arrow to pan the Portal around.

You are looking at 1 meter digital airborne imagery.

18) Above the Layer Manager are 3 icons – Blend, Flicker, and Swipe

Touch the **Swipe** tool icon. You should see the "NAIP_Color_321…" being swiped over the "NAIP_CIR_432…"

Unclick the [p] file (Portal) in the Layer Manager so the Portal does not display while the Swipe tool is active.

Right-click on Flicker and Portal [p] files in the Layer Manager and *Remove.*

19) *Views > Two Horizontal Views*

Drag and drop the color IR image from the 1st view into the 2nd view.

Turn-off the color IR image in the 1st view. Have the color image turned on in the first view.

Views > Link Views > Geo Link >*Link All > OK*

Zoom in and pan around.

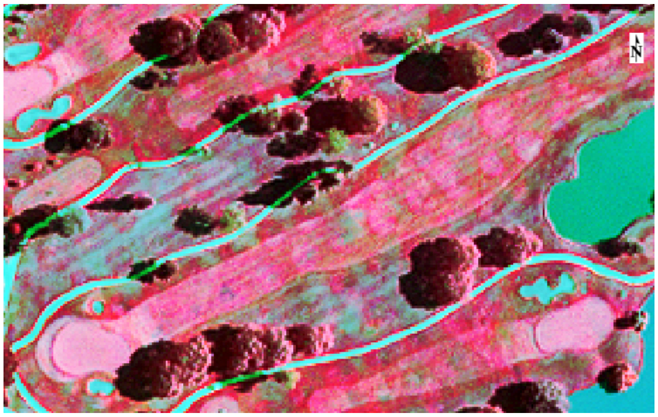
20) *Views* > *One View* > *Click on* “NAIP-4band…” multispectral data set.

The data will be in the Data Manager if it doesn’t appear in your view. Select bands 4-3-2 as red-green-blue so a Color IR image is displayed.

Use the *Equalization* contrast stretch in the drop-down menu. Click on the adjacent (to the left) icon to apply the stretch to only the view.

Stretch on View Extent

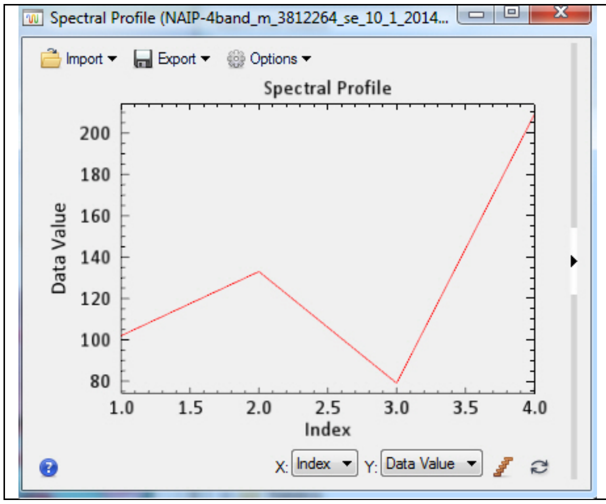
This “harsh” contrast stretch should reveal subtle irrigation patterns and dry portions of the golf course, along with strange linear patterns paralleling the fairways (due to uneven fertilizer application or mowing issues? (See below)



Zoom to a scale of 1:4000 in the drop-down menu near the top center of the ENVI window. Ensure in the view that you have a pond in the upper left and and lower right with golf fairways in between.

Display > *Profiles* > *Spectral* or *click-on* the Spectral Profile icon along the top row of tools. This tool shows the reflectance at individual pixels for the 4 bands.

Use the Select arrow to move the crosshairs around the golf course targeting water, irrigated grass in the golf course, non irrigated (dry grass) outside the golf course, concrete, building tops, asphalt, etc. (See below)



Spectral signature for healthy irrigated golf course grass.

Horizontal Axis shows bands 1 – 4:
1 = reflected blue light
2 = reflected green light
3 = reflected red light
4 = reflected Near IR light

Question 12: A. What happens to the Data Value (brightness) of Band 3 (red) and Band 4 (near IR) when you measure reflectance on irrigated grass at the golf course?

B. What happens to Band 4 when you measure the reflectance over water?

C. What are the two brightest bands when you measure reflectance over dry grass outside of the golf course?

21) Now we'll do a spectral profile (a transect or a line) of reflected near IR, red, and green light across the golf course.

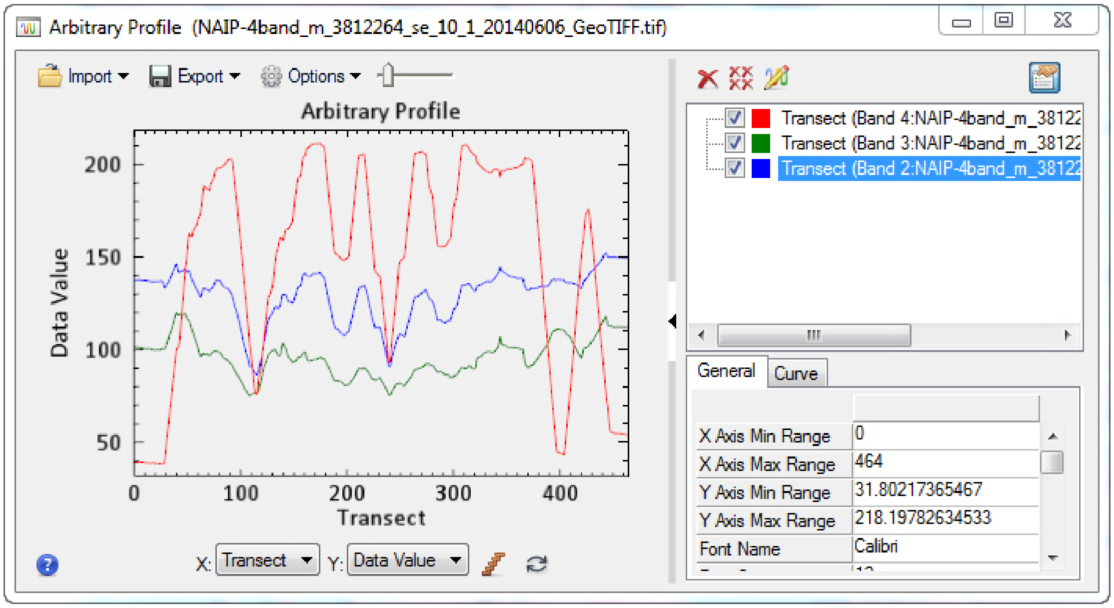
Zoom to a scale of 1:4000 in the drop-down menu near the top center of the ENVI window. Ensure in the view that you have a pond in the upper left and and lower right with golf fairways in between.

Display > Profiles > Arbitrary

Start on the lake in the upper left and move the cursor to the lake at the lower right and click to stop line – and a graph pops up. Maybe you have to click the end of the line a couple times.

In the Arbitrary Profile transect window, *click* on the black triangle in the white area of the right margin to reveal what bands are associated with what color line.

Options (drop-down menu) > Curve Smoothing (see below)



Question 13: A. What happens to the Near IR reflectance (brightness or Data Value) value (red line) in water?

B. What happens to Near IR brightness in the golf course fairways?

C. Reflected green light is brighter than reflected red light over the irrigated grass on the fairways? Why do you already know this fact?

D. Do you have any idea why green light is reflected more strongly from healthy vegetation compared with red light?

Lab 1 Introduction to ENVI Answer Sheet Name:

Upload the following file to the instructor:

(16) Your Name_Enhanced_NAIP_Color pdf” pdf

Question 1: A. What is the map projection and datum for these 3 images?

B. How big is each image in KB, and the number of pixels in the columns and rows?

	KB	columns	rows
60 cm:			
5 m:			
10 m:			

Question 2: What is the format is the exported metadata? Why is this a useful format?

Question 3: What is the range of digital numbers (DNs) for the 60 cm image?

Question 4: Can you identify oil storage tanks on the 10 m image? Why?

Question 5: Can you identify roads on the 5 m image? What is their characteristic?

Question 6: A. 3-bit images have how many levels of gray?

B. 5-bit images have how many levels of gray”?

D. Do you see much difference between the 5-bit and 8-bit images? Why?

Question 7: A. What are your two measurements of the same tank in the two views?

B. Why the difference?

Question 8: How many bits is this data? How many levels of gray?

Question 9: Between approximately what low and high DN (brightness) values (numbers along the horizontal axis) are most of the pixels in this dataset?

Question 10: Why did moving 1% of the dark and bright pixels to 0 and 255, respectively, improve the range of colors displayed in the color composite?

Question 11: A. How large is this tif file in MB?

B. How large was the original NAIP_Color_321…tif" image?

C. Is your enhanced image better looking than the original?

Question 12: A. What happens to the Data Value (brightness) of Band 3 (red) and Band 4 (near IR) when you measure reflectance on irrigated grass at the golf course?

B. What happens to Band 4 when you measure the reflectance over water?

C. What are the two brightest bands when you measure reflectance over dry grass outside of the golf course?

Question 13: A. What happens to the Near IR reflectance (brightness or Data Value) value (red line) in water?

B. What happens to Near IR brightness in the golf course fairways?

C. Reflected green light is brighter than reflected red light over the irrigated grass on the fairways? Why do you already know this fact?

D. Do you have any idea why green light is reflected more strongly from healthy vegetation compared with red light?

Lab 2 Landsat Multispectral Processing
Utilizes Textbook's Remote Sensing Digital Database: Chapter 3 data.

The objectives of this lab are to learn the processing tools on ENVI's main display window that are used to interrogate, display, and display multispectral data.

Evaluate individual bands
Quick stats (overview of dataset statistics)
Compare an enhanced image with original USGS data
Spectral profile
Evaluate different color composites in four display Views
Regions of Interest (ROIs)
Scatter plots (feature space)

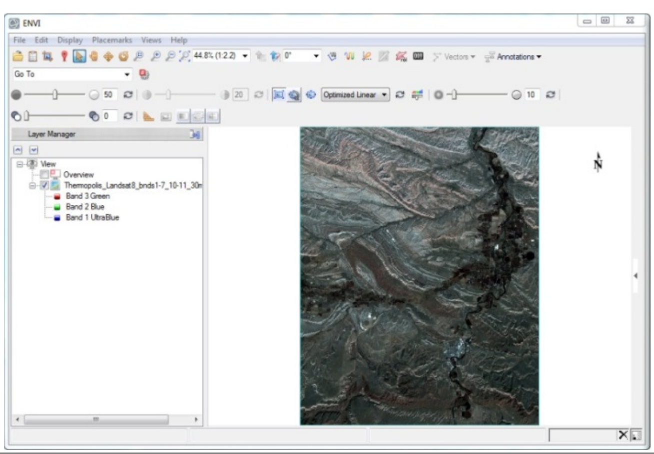
Eight questions are asked during this lab – you are to write your answer on the sheet that is at the end of this handout. Two files are to be uploaded to the instructor.

1) Open the Remote Sensing Digital Database chapter 3 folder named "Plates_7 and 27_Thermopolis". You can see that all the Landsat 8 bands and derived images that are explained in the textbook are contained within this folder. Also there is a folder named **Lab_2_Data** that has other data used in this lab.

Open ENVI (the GIS-look option) and load the 9-band Landsat data in ENVI format named: "Thermopolis_Landsat8_bnds1-7_10-11_30m_ENVI_".

NOTE: The ENVI file has more information compared with the GeoTIFF because the wavelength (blue, NIR, Thermal IR, etc.) can added to the band number and displayed in the Layer Manager and Data Manager.

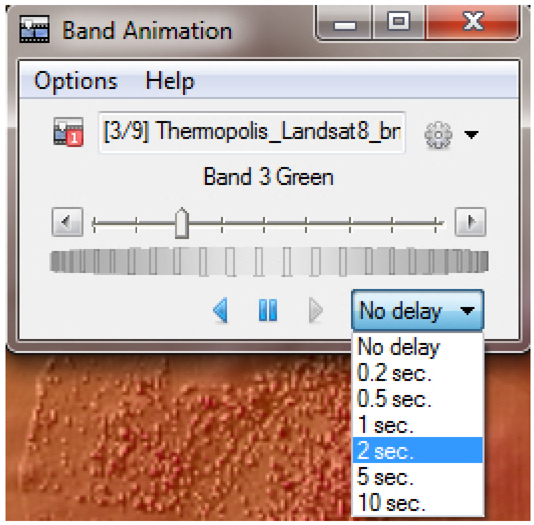
Zoom to full extent. Note that the first 3 bands are automatically displayed by the ENVI software based on the default Preferences. To see what bands are displayed you have to click on the "+" sign to the left of the file name (see below).



File > Data Manager Lists all 9 bands in this Landsat dataset

Look at Figure 3-11 A-G in the textbook. The geologic map is Figure 3-11H. Also look at Plate 7. We'll examine the spectral characteristics of the Red Rose Anticline and the agricultural fields in the upper right along the Wind River.

2) Let's examine each of the 9 bands. *Right-click* on the file name in the Layer Manager *> Band Animation.* ENVI flickers through the 9 bands rapidly(!) by default.



Slow down ENVI….Use the dropdown menu in the lower left of the Band Animation tool to choose 2 seconds or 5 seconds.

Question 1: Which band is most unlike the other 8 bands?

3) Let's load 7 of the individual bands. Open the "Bands" subfolder that is in the Remote Sensing Digital Data chapter 3 folder named "Plates_7and27_Thermopolis".

Landsat OLI bands 2-7 and 10 are available for loading into ENVI.

Highlight the seven TIFF images with the *Control (Ctrl) Key down* and click *Open*

Turn-off all the bands in the View except "Band 10 Thermal_tif.tif" in the Layer Manager View

Right-click on Band 10 in the Layer Manager and *View Metadata.*

What is the pixel size of this thermal IR band? _____

Right-click on Band 6 in the Layer Manager and *View Metadata.*

What is the pixel size of this SWIR1 band? _____

The Landsat 8 TIR sensor acquires thermal IR bands 10 and 11 with 100 x 100 m pixels. The Landsat 8 OLI sensor acquires VNIR-SWIR bands 1 to 7 with 30 x 30 m pixels. The USGS resamples the thermal IR bands to 30 x 30 m pixels for delivery to users.

Question 2: Why are the Landsat 8 thermal IR bands collected with pixels that cover an area more than 100 times larger than the VNIR-SWIR 30 x 30 m pixels?

(see Equation 1-2 and Table 3-1 in the textbook)

4) Turn on Landsat OLI band 5 NIR. *Right click* > *Quick Stats*

Select Plot > *Histogram Band 1* (Drop-down menu in upper left of Quick Stats)

This Landsat band was resampled to 8-bit from the original data delivered by the USGS and contrast-stretched for the textbook figure. You are viewing a contrast-stretched grayscale image (you would not know this unless the remote sensing analyst documented the radiometric change in the metadata).

Question 3: A. What is the Mean and Standard Deviation of all the pixels in the grayscale Band 5 NIR?

B. What percentage of pixels have values within one standard deviation of the mean? (see textbook Figure 9-3 for explanation)

C. What digital number (DN) is displayed by the most pixels (Data Value on the horizontal axis of the histogram)? How many pixels have that DN (“Count” value)? What percentage of the 256 DNs is contained by this largest DN?

5) Let’s zoom into the area shown in the textbook’s Figure 9-2. Turn on Landsat band 5 NIR. Load the UTM Zone 13 vector polygon shapefile named “Textbook Fig 9-2 Thermopolis.shp” that is in the **Lab_2_Data** folder.

File > *Open* > “Textbook Fig 9-2 Thermopolis.shp” (the type of file to load is designated “SHP”. Many files are required to support a shapefile(!)

Right click on the shapefile in the Layer Manager > *Properties* > *change* “Line Thickness” to *3* > *Change* “Line Color” to black so that the rectangular polygon is displayed more clearly.

We want to replicate some of Figure 9-2. Turn-off all images and bands except Band 5 NIR. Display the band 5 with “No Stretch”. You have to keep highlighting “Band 5 NIR” in the Layer Manager while the vector shapefile is

turned-on to use tools and to see information about the raster band 5.
Zoom-in so the polygon fills your View

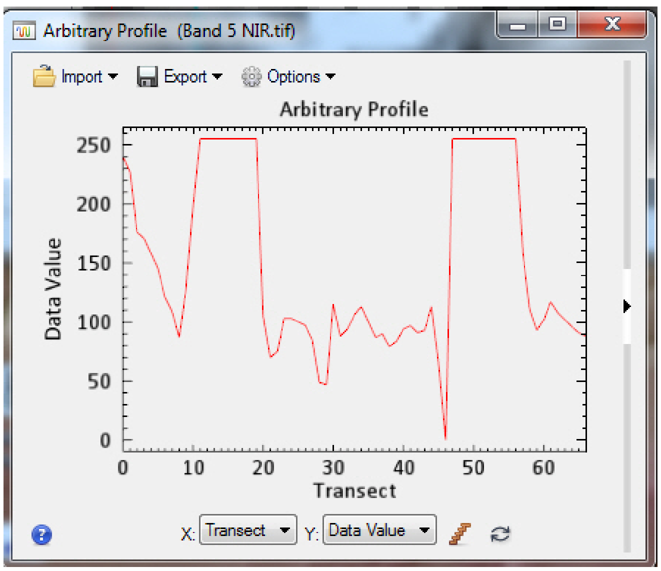
Display > Cursor Value   Move the crosshairs around the image with the Select tool (arrow)

What is the brightest DN value for band 5? What is the darkest DN value for band 5?

Turn-off the shapefile. *Highlight* Band 5 NIR in the Layer Manager

Display > Profiles > Arbitrary

Draw a profile that mimics a – a' on Figure 9-2A (keep clicking until the profile pops up in a window). What do you see as the high and low DNs (see figure below).



a- a' profile of Band 5 NIR

6) Let's look at band 5 in the 9-band dataset (Thermopolis_Landsat8_bands1-7_10-11_30m_ENVI_). Highlight this color composite in the Layer Manager. Change the band combination to a 7-5-2 as red-green-blue.

Right-click the 9-band Landsat dataset in the Layer Manager > *Change RGB Bands…*   The bands in this dataset have the original DNs delivered by the USGS.

Right click on the 9—band Landsat dataset > *Quick Stats*

Select Plot > Histogram Band 5

Question 4: A. What is the Mean and Standard Deviation of all the pixels in the 9-band Landsat dataset's Band 5 NIR?

B. Scroll down (or use the "Locate Stat" dropdown menu) and select Band 5. Computer screens can typically only display 256 levels (DNs) of brightness. So each DN on the histogram and your computer screen contains many DNs from the original USGS data. How many original DNs are contained within each DN displayed in the histogram and on the computer screen (look for "binsize =….")

C. What range of original USGS digital numbers (DN) have the highest count in band 5?

D. How many pixels (the "Count" value) in band 5 have the highest DN?

E. The USGS delivers Landsat 8 OLI and TIR bands with 16-bit radiometric resolution! How many levels of brightness is available with 16-bit data?

> **NOTE:** The Landsat 8 system collects the data with 12-bit radiometric resolution (see Textbook Table 3-3).

7) Let's examine a color IR image generated from the "Thermopolis_Landsat8_bands1-7_10-11_30m_ENVI_" dataset. The area we are evaluating continues to be within the shapefile and the textbook Figure 9-2.

Right-click on the file name in the Layer Manager and *Change RGB bands…*

Generate a color IR image (Bands 5-4-3 or NIR-red-green in R-G-B). To see what bands are displayed you have to click on the "+" sign to the left of the file name.
Zoom to Full Extent

Contrast-stretch the color IR image – use the "Linear 2%" stretch

Display > Cursor Value Move the crosshairs around the image with the Select tool (arrow). The DNs for the 3 bands are displayed in the "Data:" field.

What is the approximate brightest DN value for band 5 NIR? What is the approximate darkest DN value for band 5 NIR?

Turn-on the shapefile. *Zoom-in* to the shapefile polygon. *Highlight* the 9-band Landsat dataset in the Layer Manager

Display > Profiles > Arbitrary

Draw a profile that mimics a – a' on Figure 9-2A. Where do you see the high and low DNs for Band 5?

Question 5: A. How is the DN profile from the enhanced grayscale Band 5 NIR (shown above) compare with the DN profile from the original USGS data for Band 5 NIR (seen as a red line in the profile (not shown))?

B. What is different about the profiles? (Do not include the difference in the "Data Value" on the vertical axis)

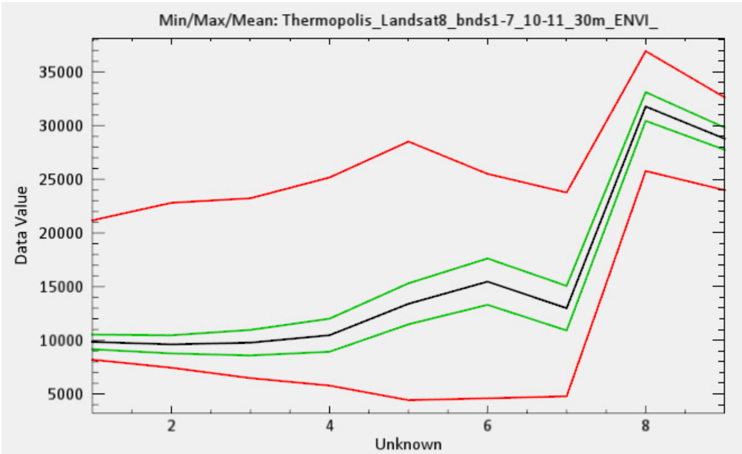
C. Why the difference in the profiles? (Hint: what is different in the image processing?)

Question 6: Reflected near IR light is very bright (high Data Value) over irrigated agricultural fields on your Arbitrary Profile across the original USGS Landsat data. On this same plot, what happens to the reflected red light (band 4) over irrigated agricultural fields in comparison to reflected green light (band 3)? Any idea why this occurs?

8) Let's look at the brightness values of the 9 bands in the "Thermopolis_Landsat8_bands1-7_10-11_30m_ENVI_" dataset. Highlight the color IR image in the Layer Manager. The bands in this dataset have the original DNs delivered by the USGS.

Right click on the 9—band Landsat dataset > *Quick Stats*

The horizontal axis labelled "Unknown" represents the band number. The visible bands are 1-4, the NIR band is 5, the SWIR bands are 6 and 7, and the thermal IR bands are 8 and 9 on the horizontal axis. The "Data Value" vertical axis represents the 16-bit DNs (brightness value) that are delivered with Landsat 8 radiance data. See below.



Question 7: A. Explain the statistical plot above. (also look at the metadata table)

B. What band has the highest mean DN?

C. What band has the highest DN range?

D. What band has the largest standard deviation?

9) Zoom out on the color IR image so that you see the Red Rose Anticline and the agricultural fields (perhaps with a map scale of 1:100,000). Let's look at a spectral profile at individual pixels.

Display > Profiles > Spectral

Move the crosshairs around with the select arrow and click on different pixels.

Examine the profile at the following features:

Irrigated agricultural field
Wind River
Airport
Different color geologic outcrops

What band varies the most? What bands vary the least?

10) Let's change the Color IR image in our View to a natural color image.

Right-click on 9-band Landsat data set in Layer Manager > *Change RGB Bands > Select* Band 4 - Band 3 - Band2 as R-G-B > *OK > Zoom to Full Extent > Contrast Stretch* to "Linear 2%"

Now let's generate 4 Views and load three other band combinations in each one, then link the four views so we can pan and zoom in and out and easily compare the different colors composites.

Views > 2 X 2 Views We'll load the empty Views using the Data Manager.

Highlight View 2 (upper right) with your cursor. *Data Manager > Select* Band 5 – Band 4 – Band 3 as R-G-B in the 9-band Landsat data set > *Load Data > Zoom to Full Extent > Contrast Stretch* to "Linear 2%"

Highlight View 3 (lower left) with your cursor. *Data Manager > Select* Band 7 – Band 5 – Band 2 as R-G-B in the 9-band Landsat data set > *Load Data > Zoom to Full Extent > Contrast Stretch* to "Linear 2%"

Highlight View 4 (lower right) with your cursor. *Data Manager* > *Select* Band 7 – Band 6 – Band 5 as R-G-B in the 9-band Landsat data set > *Load Data* > *Zoom to Full Extent* > *Contrast Stretch* to "Linear 2%"

To see what bands are displayed you have to click on the "+" sign to the left of the file name.

Turn-off all other images and shapefile in the Layer Manager . Each View should only have the color composite checked in the Layer Manager and displayed.

Now we will *link* the four Views.
Views > *Link Views* > GeoLink *active* > *Link All* > *OK*
Pan around *Zoom in & out*

Question 8: List the colors displayed with the different color composites in the agricultural fields along the Wind River. Zoom in on a field with much irrigation and vigorous crops and a field with limited irrigation and less vigorous crops to fill in the blanks on the table.

a) natural color (red-green-blue in R-G-B),

b) color IR (NIR-red-green in R-G-B)

c) enhanced color (SWIR2-NIR-blue in R-G-B)

d) total IR (SWIR2-SWIR1-NIR in R-G-B)

11) Close 3 of the 4 Views.
Right-click on "View" in the Layer Manager > *Remove View*
In the remaining View > *Zoom to Full Extent*

We will now examine the correlation between the different bands using the Scatter Plot Tool. We will be working with the same "Thermopolis_Landsat8_bands1-7_10-11_30m_ENVI_" dataset.
Change RGB Bands > *5-4-3* as red-green-blue (color IR)
Turn off other layers in your Layer Manager.
You will be doing statistical analysis using all the pixels in each band.

Display > *2D Scatter Plot* (Picture below)
Press the "Toggle Density Slice" tool (upper center) to see the pixel density scaled to color.
Click the "Full Band" box.
Change the Class 1 color from default red to <u>yellow</u>.

White areas in the scatterplot show where the highest number of pixels overlap between the two bands while black areas have the least number of overlapping pixels.

Start with bands 1 versus 2, and work your way through band combinations. Ignore the thermal bands (# 8 and 9 in the Scatter plot)

Note how band 5 NIR is significantly different from the other VNIR-SWIR bands

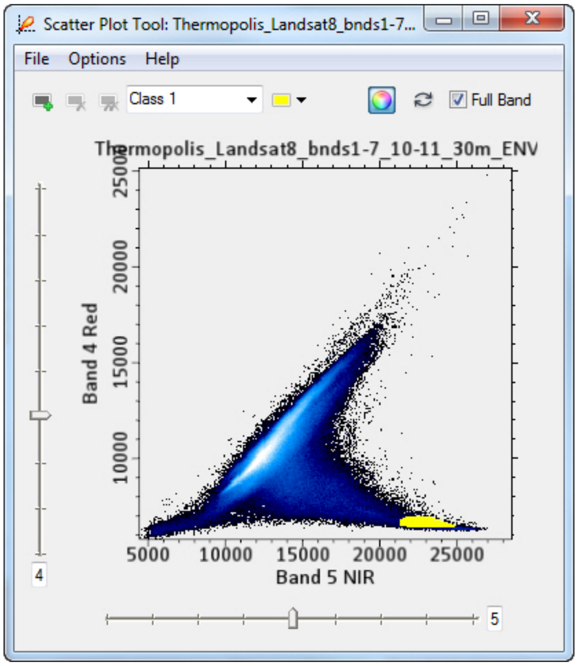
Display Band 5 NIR versus Band 4 Red in the color Scatter plot (see picture below). On the image in the ENVI View, as you move your mouse around you should see a small square.

If you don't, close the scatter plot tool, highlight the 9-band Landsat dataset in the Layer Manager and reopen the 2D scatterplot display

Display > 2D Scatterplot

As you move your mouse over irrigated agricultural fields – you will see the color IR red pixels display where the Band 5 NIR have high DN values and the Band 4 Red have low DN values in the scatterplot. The image is connected to the Scatter plot!

On the scatter plot, draw a polygon around the pixels with high Band 5 NIR DNs and low Band 4 Red DNs. This is "Class 1". (see below). You will see those pixels that have band 5 and band 4 pixels within your polygon light up on the color IR image! You have identified vigorous vegetation in the agricultural fields.



Let's upload the Landsat color image with the Class 1 pixels highlighted to the instructor as a "geospatial pdf".

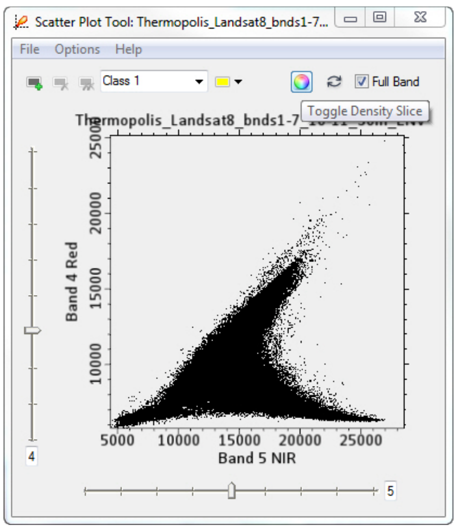
File > Export View To > GeoSpatial pdf (the pdf has coordinates!)

Briefly fill in the blanks on the form (this is metadata!)

Name the pdf "Your Name_Landsat_vig_veg"

12) Now we will use the scatter plot tool to display the spectral characteristics of select features that you will map with ENVI's ROI (region of interest) tool.

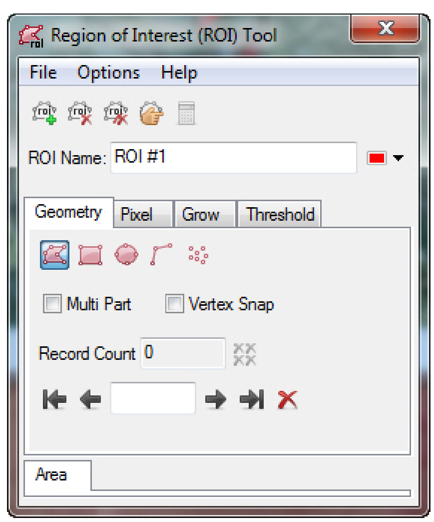
Clear the yellow Class 1 on the scatterplot. *Options > Clear Class*



Use the Toggle Density Tool (upper center) to change to a Black pattern for the pixel distribution.

Go to the main ENVI display to access the ROI tool.

File > New > Region of Interest The Region of Interest (ROI) Tool pops up



We will create 4 ROIs using the default *Geometry > polygon tool* in the menu above. The ROIs will represent:

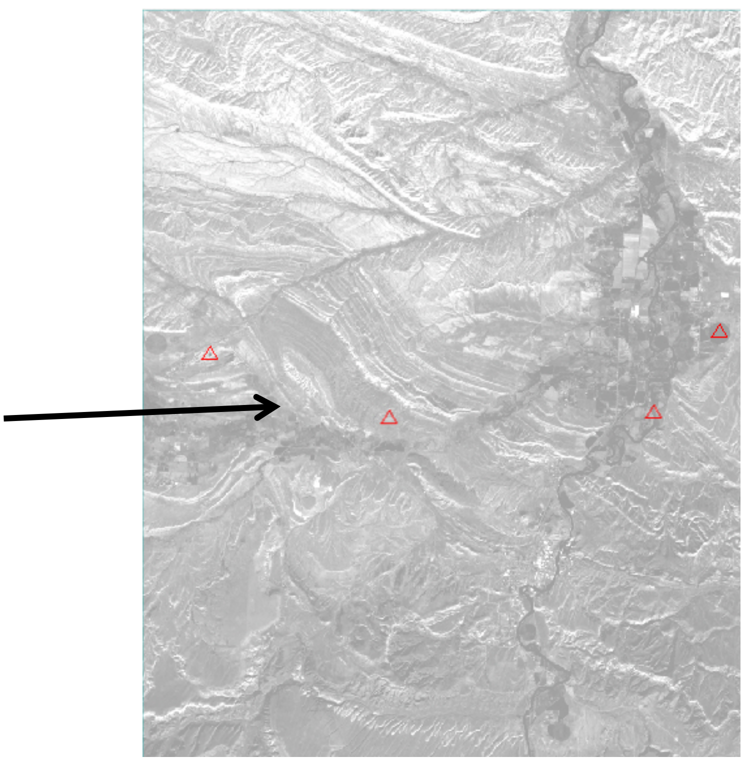
Irrigated vigorous vegetation
Water in the Wind River
Outcrop of the Chainman Shale
Airport tarmac (asphalt?)

We will display the Landsat as a 7-5-2 as R-G-B color image. Use a Linear 2% stretch.

We will use a GIS vector shapefile that has each of the four features above mapped as points. Draw your ROI polygon around those pixels near the shapefile point that are "pure" pixels for the feature of interest. Don't mix other pixels as that will degrade the spectral signature of our four features of interest.

File > Open open the "Lab_2_Data" folder and select the "ROI_sites on Thermopolis Landsat.shp" file. (the SHP File).

The four points will display on the ENVI view. The points are located across the center of the image. They are difficult to see! *Right-click* on the ROI sites shapefile in the Layer Manager and *change* the Properties – *enlarge* the "Point Size" to "20". Maybe *change* the color to "Black".



Location of shapefile points

If you can't see the shapefile points clearly, the longitude and latitude coordinates are provided below. Drive your *Zoom tool* (enables zooming in with a rectangle area of interest) to each point, zoom-in, and create a polygon ROI.

Feature of Interest	**Longitude**	**Latitude**
Irrigated Vegetation	-108.1263	43.7313
Chainman Shale	-108.2886	43.6956
Airport tarmac asphalt	-108.3788	43.7161
Water	-108.1574	43.7012

a) *Zoom* into the vigorous agricultural field and draw a ROI polygon within the bright green pixels. *Double-click* at the end of your polygon line to close the polygon and create the ROI

Rename the ROI #1 to "Irrigated vegetation".
Click-on the upper left icon "New ROI" to create a new ROI.

b) *Zoom* into the Chainman Shale outcrop and draw a ROI polygon within the yellow-orange to orange pixels.

Rename the ROI #.. to "Chainman Shale".
Click-on the upper left icon "New ROI".

NOTE: the polygons and ROIs can get mixed up. You may have to delete an ROI, edit the name (*right-click* on the ROI in the Layer Manager), and redo an ROI. Look at the Layer Manager and Data Manager to see if you are correctly making four ROIs over four areas on the Landsat image. If you get two polygons in your ROI, just use the Record Count at the bottom of the ROI Tool and delete the incorrect polygon. *PATIENCE!!*

c) *Zoom* into the Airport tarmac and draw a ROI polygon within the darkest pixels. (*change* the shapefile color from black to yellow so you can see it…)

Rename the ROI #.. to "Airport tarmac".
Click-on the upper left icon "New ROI".

d) Zoom into the Wind River water and draw a ROI polygon within the darkest pixels.

Rename the ROI #.. to "Water".

You should see the four ROIs under a folder named "Regions of Interest" in the Layer Manager. Let's rename this folder

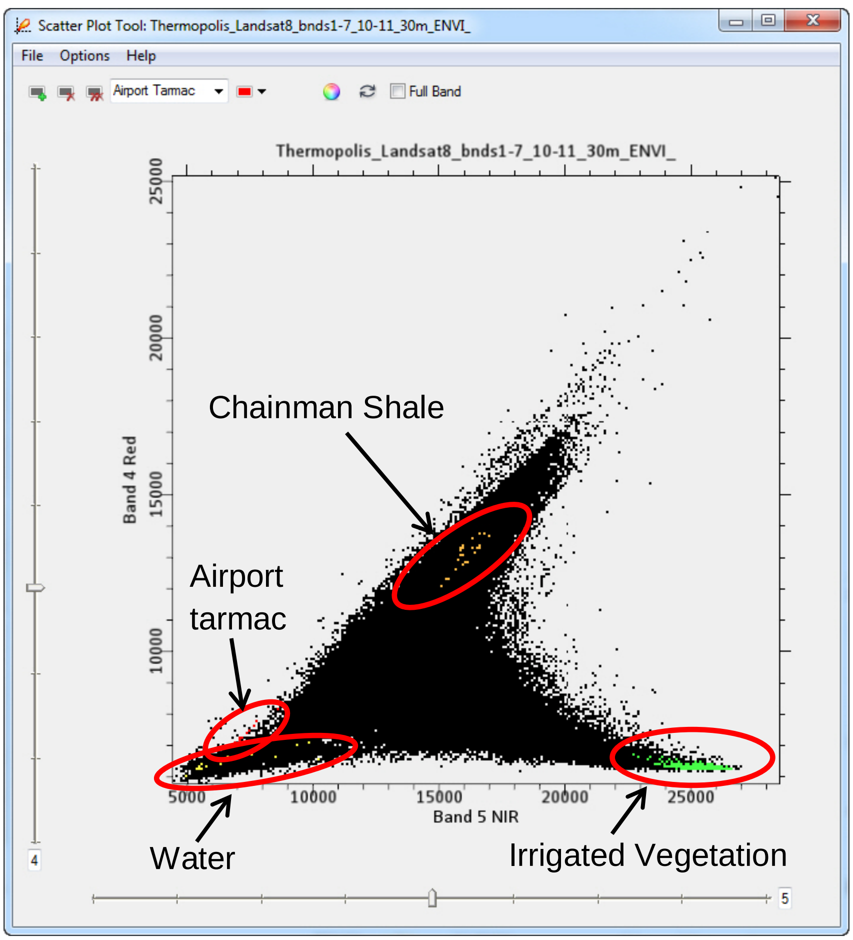
Right-click “Regions of Interest” folder > *Save As*
“Your Name_ROIs_for_ScatterPlot”

NOTE: You can also save the four ROIs using the Regions of Interest (ROI) Tool. File > Save As *Click-on* the “Select All Items” button.

13) Now let’s see where these four ROIs are located on our scatter plot.
First you have to *highlight* the 9-band Landsat data in the Layer Manager!
Display > 2D Scatter Plot (if not already opened)
Choose band 4 on the vertical axis and band 5 on the horizontal axis.

Use the *Toggle Density Slice* to make the scatter plot black.

On the Scatter Plot Tool *File > Import ROIs*
You should see the 4 ROIs you just created(!)
Push the “Select All Items” button.
You will the pixels that match your ROI spectral signatures show up on the black scatter plot with default colors. Let’s change the colors to brighter shades.



The ROIs reveal that each of the classes has a unique spectral signature that is differentiated on the band 4 (red) versus band 5 (NIR) scatter plot! You also see the same-color pixels on the image in the ENVI view. There are few asphalt pixels and no (?) water pixels outside the Wind River with the same spectral characteristics as our ROIs.

Save the scatter plot as an image *File > Save Plot As > Image.*

Name the plot “Your Name_Scatterplot_with_ROIs”

Upload the .jpg or .png image to the instructor

Lab 2 Multispectral Landsat Processing   Name:

Upload the following files to the instructor:

(11) “Your Name_Scatterplot_map.pdf”

(13) “Your Name_Scatterplot_with_ROIs.png”

Question 1: Which band is most unlike the other 9 bands?

Question 2: Why are the Landsat 8 thermal IR bands collected with pixels that cover an area more than 100 times larger than the VNIR-SWIR 30 x 30 m pixels?
(see Equation 1-2 and Table 3-1 in the textbook)

Question 3: A. What is the Mean and Standard Deviation of all the pixels in the grayscale Band 5 NIR?

B. What percentage of pixels have values within one standard deviation of the mean? (see textbook Figure 9-3 for explanation)

C. What digital number (DN) is displayed by the most pixels (Data Value on the horizontal axis of the histogram)? How many pixels have that DN (“Count” value)? What percentage of the 256 DNs is contained by this largest DN?

Question 4: A. What is the Mean and Standard Deviation of all the pixels in the 9-band Landsat dataset’s Band 5 NIR?

B. Scroll down (or use the “Locate Stat” dropdown menu) and select Band 5. Computer screens can typically only display 256 levels (DNs) of brightness. So each DN on the histogram and your computer screen contains many DNs from the original USGS data. How many original DNs are contained within each DN displayed in the histogram and on the computer screen (look for “binsize =….”)

C. What range of original USGS digital numbers (DN) have the highest count in band 5?

D. How many pixels (the “Count” value) in band 5 have the highest DN?

E. The USGS delivers Landsat 8 OLI and TIR bands with 16-bit radiometric resolution! How many levels of brightness is available with 16-bit data?

Question 5: A. How is the DN profile from the enhanced grayscale Band 5 NIR (shown above) compare with the DN profile from the original USGS data for Band 5 NIR (seen as a red line in the profile (not shown))?

B. What is different about the profiles? (Do not include the difference in the "Data Value" on the vertical axis)

C. Why the difference in the profiles? (Hint: what is different in the image processing?)

Question 6: Reflected near IR light is very bright (high Data Value) over irrigated agricultural fields on your Arbitrary Profile across the original USGS Landsat data. On this same plot, what happens to the reflected red light (band 4) over irrigated agricultural fields in comparison to reflected green light (band 3)? Any idea why this occurs?

Question 7: A. Explain the statistical plot. (also look at the metadata table)

B. What band has the highest mean DN?

C. What band has the highest DN range?

D. What band has the largest standard deviation?

Question 8: List the colors displayed with the different color composites in the agricultural fields along the Wind River. Zoom in on a field with much irrigation and vigorous crops and a field with limited irrigation and less vigorous crops to fill in the blanks on the table.

Features of Interest / OLI Bands	Agriculture fields with much irrigation and vigorous crops	Agriculture fields with limited irrigation and less vigorous crops
Natural Color OLI 4-3-2 as R-G-B		
Color IR OLI 5-4-3 as R-G-B		
Enhanced Color OLI 7-5-2 as R-G-B		
Total IR OLI 7-6-2 as R-G-B		

Lab 3 Image Processing 1
Utilizes Textbook's Remote Sensing Digital Database: *Chapters 3 and 4 data.*

The objectives of this lab are to learn the processing tools that are used for Preprocessing and Image Enhancement (see Chapter 9 Digital Image Processing for discussion). The tools used in this lab are in in the **ENVI Toolbox**:

Statistics (complete, including correlation matrix)
Resize Data
Rotate/Flip Data
Layer stacking
Edge enhancement

Some files are in the **Lab_3_Data** folder. Five questions are asked during this lab – you are to write your answer on the sheet that is at the end of this handout. Three digital files are to be uploaded to the instructor.

IMPORTANT NOTE: ENVI does not retain display enhancements for images when you use ***Save As***. These include rotating, zooming, contrast, brightness, sharpening, stretching, Portals, or viewing multiple layers. Use the ***Export View To > Image File*** to retain display enhancements and original scale (choose Zoom Factor 1.0000).

1) Statistics

We will use a Landsat 8 data set located in the "Remote Sensing Digital Database \ Ch_3_Landsat" folder. *Open* the subfolder named "Plate_6_1979-2016_Saudi_Change".
Open the subfolder "Landsat-8_2016_OLI-TIRS".

Open ENVI. *File* > *Open*

"Saudi_Landsat8_2016_Bnds1-7_10-11_Stack_Clip_ENVI_"

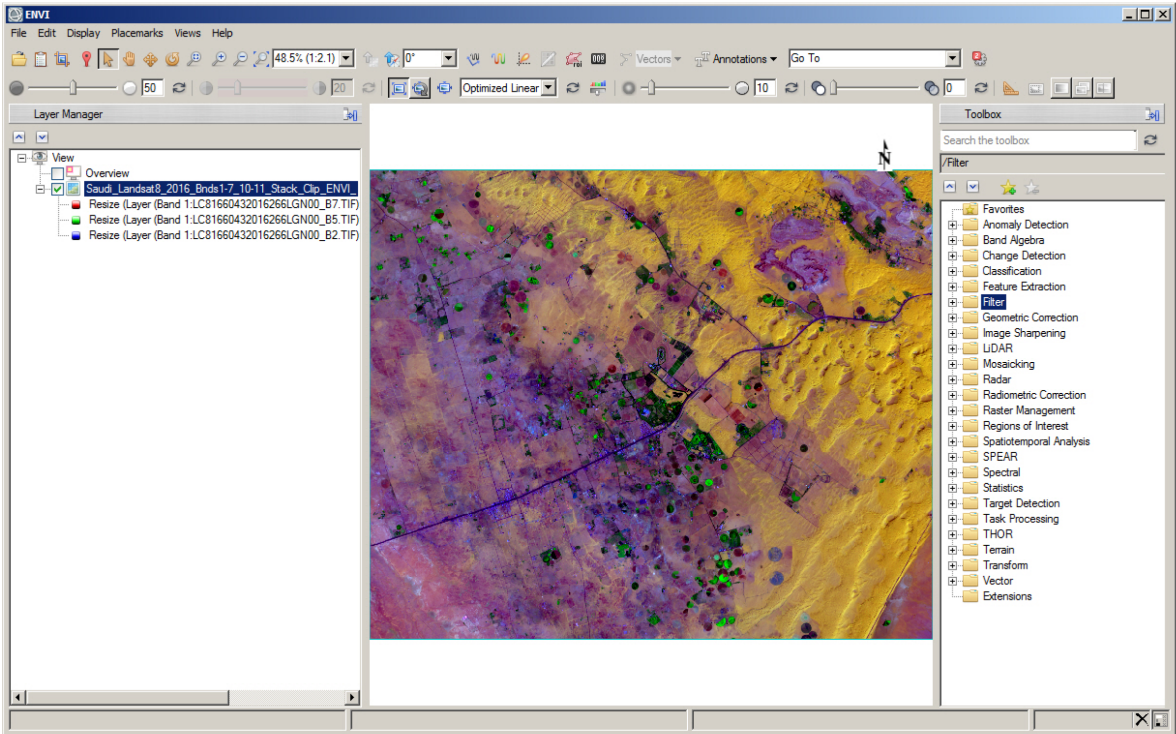
This Landsat data has 7 VNIR-SWIR bands and two TIR bands. We will evaluate the statistics for OLI bands 2-7.

Zoom to Full Extent, *File* > *Data Manager* So you can see all the bands.

Right-click on file in Layer Manager > *Change RGB Bands..*

Load 7-5-2 as R-G-B. (these are SWIR2 – NIR – Green bands)

Your display should appear as below – note the Toolbox on the right.



Toolbox > Statistics > Compute Statistics

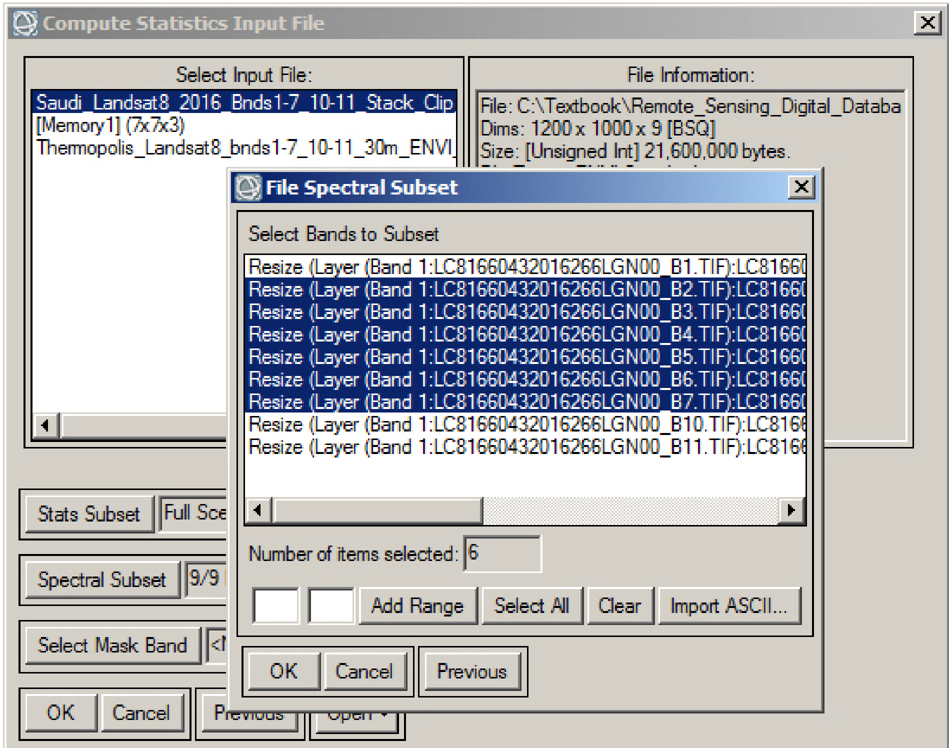
A “Compute Statistics Input File” menu pops up. Highlight the Saudi Landsat 8 input file. We want to show statistics on the **six** VNIR-SWIR bands that record reflected blue, green, red, NIR, SWIR1 and SWIR2 light (Landsat OLI bands 2 – 7). To do this, *click* on the *“Spectral Subset”* button that has “9/9 bands” displayed.

A smaller menu “File Spectral Subset” pops up. We will select bands 2 – 7 with the Shift or Ctrl key, and then press *Add Range > OK*

Note the “Spectral Subset” number changes to “6/9 Bands” on the “Compute Statistics Input File” menu.

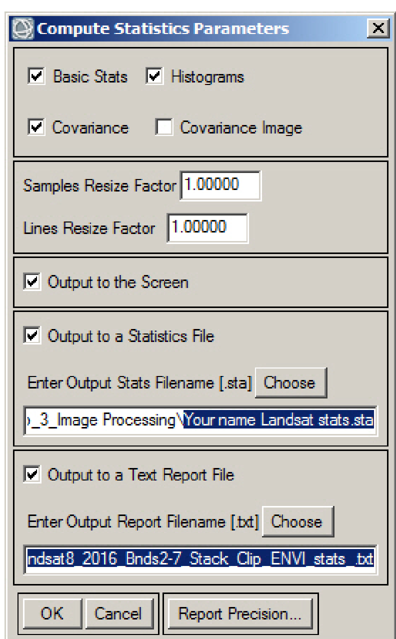
> *OK* on the “Compute Statistics Input File” window (lower left)

See menu below for selecting 6 of the 9 bands.



A "Compute Statistics Parameters" menu pops up. (see below) Check all the boxes.

Accept the default names for the ENVI statistics .sta file and the .txt Report FileName. If the default name is blank, use "VNIR-SWIR_stats…"



Click *OK* when done.

A Statistics View window pops open because the “Output to the Screen” option was checked. This Toolbox report is more complete than the Quick Stats report.

Push the triangle in the white strip on the right vertical bar next to the chart to reveal details and edit colors and data values.

At the bottom of the window are tables. *Scroll* down to the “Correlation” table.

1.000 is perfect correlation. The more highly correlated the bands, the higher the correlation value. Band have perfect 1.00 correlation to themselves in this table (also called a Correlation Matrix). Negative correlation values (-) indicate that when pixels are light in one band they are dark in the other band.

Question 1: (Provide correlation values to the nearest two decimal places).

A. What is the correlation between OLI bands 3 (green) and 2 (blue)?

B. What is the correlation between OLI bands 4 (red) and 2 (blue)?

C. What two bands have the least correlation (most difference spectrally)?

D. What two bands have the highest correlation (most similar spectrally)?

Open the text document that lists the statistics.

2) Let’s look at the image in two ENVI views that are linked. The Saudi Landsat scene has active sand dunes, some pivot irrigation plots, and stabilized barren ground without vegetation.

File > View > Two Horizontal Views
Right-click on file in Layer Manager > *Change RGB Bands..*

View 1: *Load 4-3-2 as R-G-B.* (these are the visible bands).
Drag and drop the color image from View 1 to View 2
(you can also load View 2 using the Data Manager)

View 2: *Right-click* on file in Layer Manager > *Change RGB Bands..*
Load 5-4-3 as R-G-B (this is a color IR image).

File > View > Link Views > Link All

Use the Pan to roam around both images. Zoom in and out. Interpret what is displayed in the scene

Right-click on the Landsat dataset in one of the Views in the Layer Manager

> *Band Animation.* Slow down flicker. You can pan around while flickering.

Question 2: Compare the visual gray tone of the sand dunes in the northeast and east of the band 2 (blue) and the three reflected infrared bands (5-7). Does this match the values in the correlation table? Explain.

3) Let's look at a Scatter plot of the 9-band Saudi Landsat data. *Return to one view.*
Views > One View
Only the 9-band Landsat file should be checked in the Layer Manager.
Display > 2D Scatter Plot
Compare different combinations of bands.
Save an image of the band 2 versus band 5 scatter plot.

File > Save Plot As > Image… "Your name_bands_2-5_Scatterplot" save as a jpg or png.

Upload your image of the Scatterplot to the instructor.

Question 3: How does the scatter plot of bands 2 and 3 and the plot of bands 2 and 5 compare to the correlation table values?

4) Resize Data We will clip out a subscene of Band 5 (NIR) from the 9-band Saudi dataset.

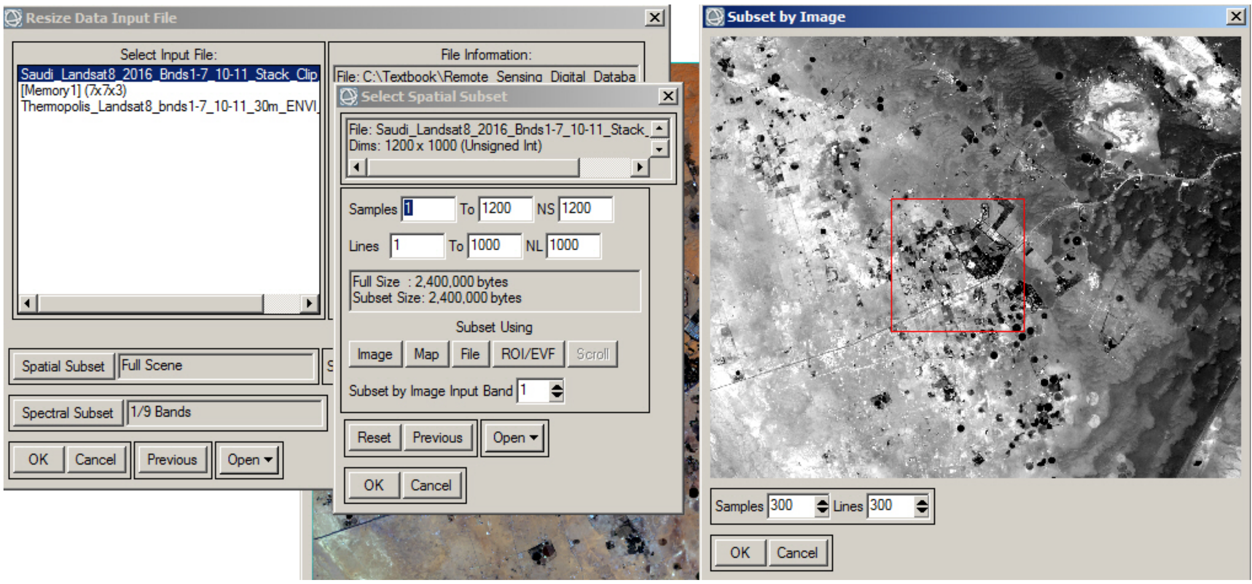
ENVI Toolbox > Raster Management > Resize Data
'Resize Data Input File" window pops up. *Highlight* the Saudi Landsat 9-band dataset if needed.

Click on ""Spectral Subset" button. "9/9 Bands" is shown next to this button. A "File Spectral Subset" window pops up. Highlight Band 5 > Add Range and "1/9" shows up in the text next to the Spectral Subset button on the Resize menu. *> OK*

Click on "Spatial Subset" button > "Select Spatial Subset" window pops up. (see screen capture below)

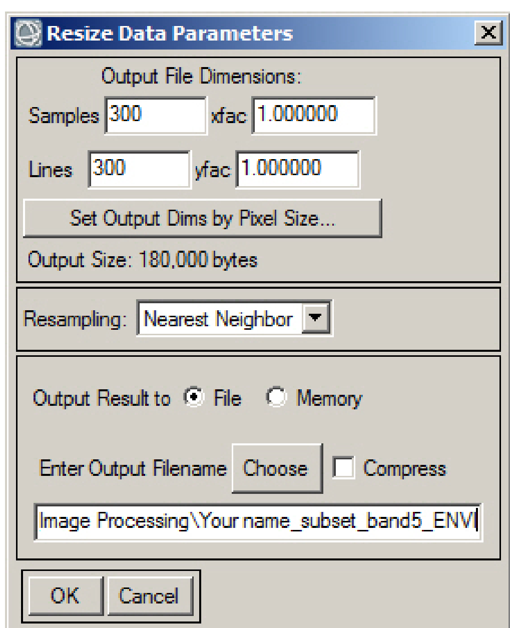
> *Click* on "Image" > "Subset by Image" window pops up.
> *change* Samples and Lines to *300 x 300*
> *move* subset box to center of image > *OK > OK > OK.*

The menus are displayed below with the 3 OK buttons.



A “Resize Data Parameters” window pops up showing the 300 x 300 dimensions of the subset area. (see below).

Name the subset image “Your name_subset_band5_ENVI”. The image will be in ENVI format (.img with .hdr file) > *OK*



Resize menu

The resized ENVI image will display in the center of the larger image in the ENVI view and will be listed in the Layer Manager.

We want to make the clipped band 5 NIR grayscale image more useful for GIS, so we will next convert the ENVI image to the universal **geotiff** format.

Highlight the resized file in the Layer Manager
File > Export Selected Layer to TIFF

NOTE: The same export tool is available with *Right-click* on the resized file in the Layer Manager > *Export Layer to TIFF*

Rename the file "Your name_subset_band5_geotiff"

Check the "Display result" box > *OK*
Upload your geotiff of the resized image to the instructor.

5) <u>Rotate/Flip Data</u> We will use an image that does not have any coordinates. This tool is useful when georeferencing scanned images and maps to place them in a position where N is approximately up.

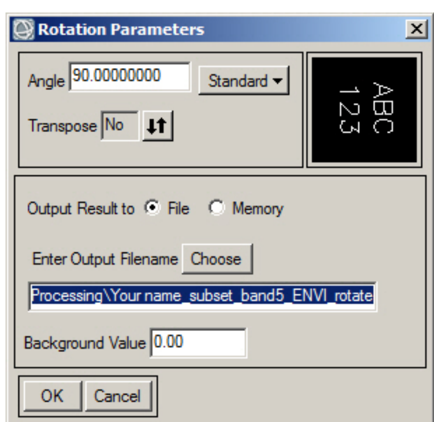
Right-click View > Remove All Layers

In the Lab_3_Data folder is a grayscale image without coordinates from Lab 1 named "E 8-bit.tif"

File > Open > "E 8bit.tif" *> Zoom to Full Extent*

Right-click "E 8bit.tif" in the Layer Manager > *View Metadata.* Does this image have any coordinate information?

Toolbox > Raster Management > Rotate/Flip Data
Select "E 8-bit.tif" in the Rotation Input File menu. *> OK*
In the "Rotation Parameters" menu, *Choose the "Standard 90"*



Rename the rotated ENVI file "Your name_rotate 90_ENVI"

The rotated file automatically displays in ENVI.
Upload the rotated image and the same-name .hdr file to the instructor

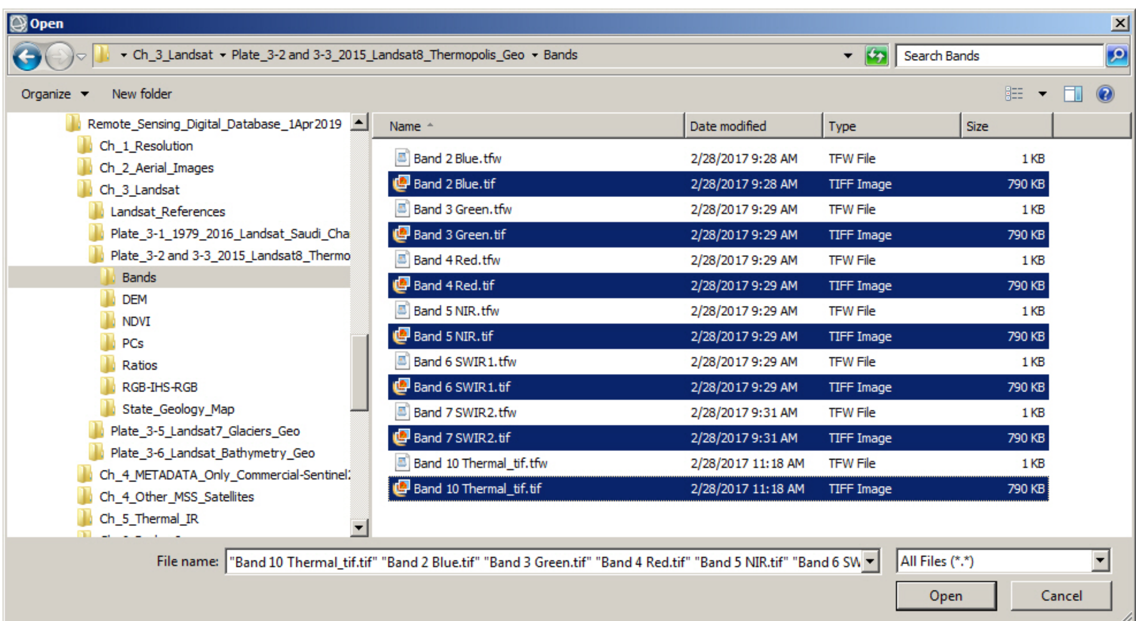
6) <u>Layer stacking</u>   Landsat and other multispectral data are delivered as individual bands. In order to generate spectral profiles, complete spectral classification, and do other image enhancement tasks, the bands have to be stacked into one database.

We will use the Landsat 8 bands of Thermopolis that are located in the "Remote Sensing Digital Database \ Ch_3_Landsat" folder. Open the subfolder "Plates_7and27_Thermopolis". Open the subfolder "Bands".

You will see bands OLI bands 2 – 7 and TIR band 10 as .tifs with .tfw files (the .tfw contains georeferencing information).

In ENVI, *Right-click View* > *Remove All Layers*

File > *Open* highlight the seven .TIFF files > *Open*   (see below)

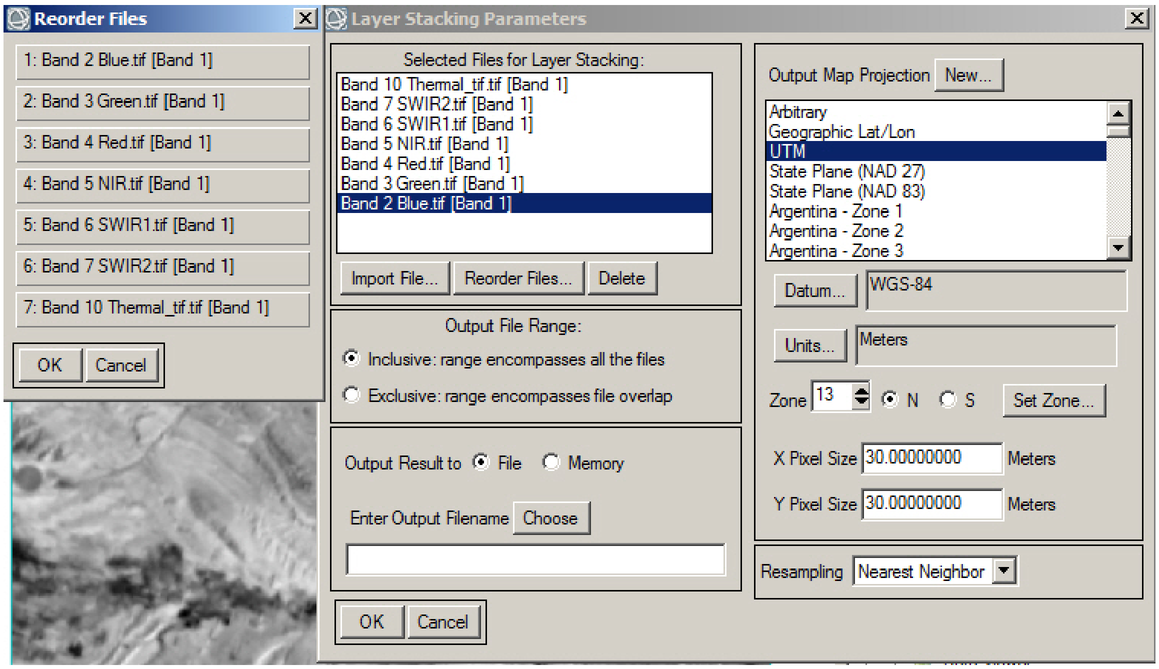


The seven bands should be displayed in ENVI. *Zoom to Full Extent*

Toolbox > *raster Management* > *Layer Stacking*
The "Layer Stacking Parameters" window pops up > *Import File…*
The "Layer Stacking Input File" window pops up.
Highlight the seven bands > *OK*

In the “Layer Stacking Parameters” window the georeferenced bands automatically fill in the map projection parameters. > *Reorder Files…*

See below. Reorder if band number are not sequential (2 to 7 and then 10) > *OK*



Name the output stack “Landsat8_Thermopolis_Stack_7 bands_ENVI”

The Data Manager will list the 7 bands.

Display different color combinations of your new stacked Landsat bands.

7) <u>Edge Enhancement</u>

Let’s remove all the layers in the view and load a commercial, high spatial resolution image discussed in the textbook Chapter 4 (see Figure 4-9). The data is provided by DigitalGlobe. The scene covers a portion of Tokyo with their Worldview-3 satellite (WV-3).

Right-click on View > *Remove* all the other images in the View.

File > *Open* > “Remote Sensing Digital Database \ Chapter_4_Other_MSS_Satellites” \ High_resolution_Satellites \ Worldview-3_pan-MSS_Tokyo” folder

Select “Tokyo_WV-3_4-bnd_30cm_pan-sharpened_MSS_11-bit_GeoTIFF” > *Open*

We'll create a natural color image with 30 cm spatial resolution. DigitalGlobe delivers data with bands 1, 2, 3, 4 as reflected blue, green, red, near IR light.

Select Band 3 – Band 2 – Band 1 as Red – Green – Blue

Zoom-in to the lower left corner so the two red & white construction cranes, the street below, and the southwest corner of the baseball stadium is in your view.

Set scale to 1:300

Let's use the Sharpen Slider in the 2nd from top row of icons to see what happens with high pass and low pass filters.

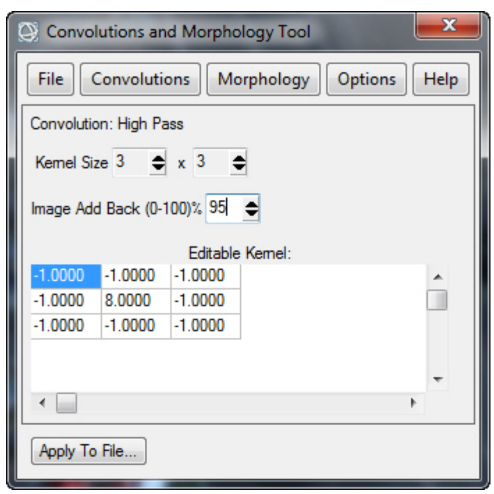
Question 4: A. Describe the change in visual appearance of the red & white construction cranes when the Sharpen slider is set to 100 and to the far left of the slider (beyond the no change vertical line on the slider).

B. What level of sharpening provides an image that you find most informative (answer with the number to the right of the slider)

To improve our understanding of edge enhancement, we will now use the **Toolbox** for high pass and low pass filtering of our Tokyo 4-band dataset.

Chapter 9 Digital Image Processing has an extensive discussion on edge enhancement (see Figures 9-14 to 9-18). We will be using a High Pass filter that is similar to the Laplacian filter shown in Figure 9-14, but the center and corner pixel values are different. See ENVI Tool below that is opened via the Toolbox.

Filter > Convolutions and Morphology



Press the buttons across the top to see the many possible variations.
Click on the Help button to obtain a better understanding of the tools.

The high-pass filter that we will use is shown above. This filter "….Removes the low frequency components of an image while retaining the high frequency (local variations)." ENVI Help.

As a recap of what is discussed in Chapter 9, let us assume that the 3 x 3 filter cell is on a pixel with a DN value of 52. The algorithm does the calculation shown below for the center cell to every pixel in the image…except along the margin of the image! The center pixel is changed from 52 to 64 in the example below.

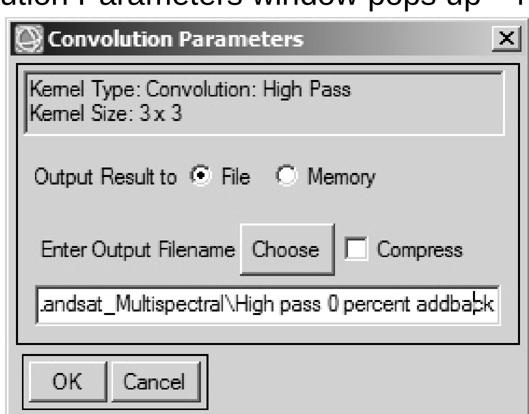
[-65 + -55 + -65 + -60 +416 + -60 +-60 + -55 + -60] = [416 + -480] = = +64

Original DNs				High Pass Filter				Edge Enhancement		
65	55	65		-1	-1	-1		65	55	65
60	52	60	→	-1	8	-1	→	60	64	60
60	55	60		-1	-1	-1		60	55	60

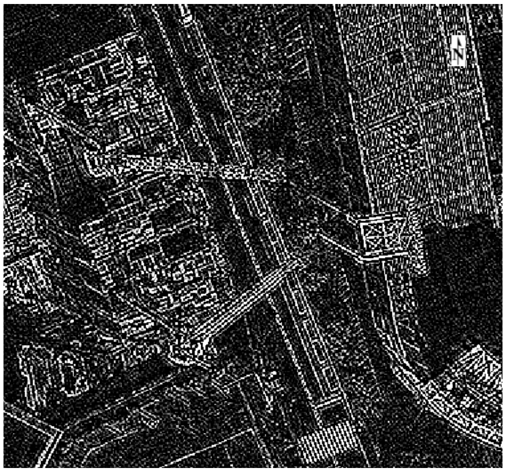
First we will do the high pass filter with 0% image add back.

Filter > Convolutions and Morphology > 0% Add Back > Apply to File

A "Convolution Input File" window pops up – *select* the Tokyo 4-bnd dataset.
Apply this high pass filter to all four bands – so just say *OK*
The Convolution Parameters window pops up – name your file



You should see something like the image below – a high pass filter applied with 0% add back on the Tokyo satellite image – edges are emphasized….maybe good for input to AI and fracture/fault/linear feature detection… but not a visually pleasing image. You usually have to do some contrast stretch to make the image appear without being oversaturated (blown out).



Repeat the Convolutions and Morphology high pass filtering, but change the Add back to 95%. Addback means the percentage of the original image added back to the edge-enhanced image. 95% Add back is often used to create a sharper image for interpretation.

> In the ENVI Layer manager compare the original color image with the image that has been edge-enhanced with a high pass filter but with 95 % image add back. Is the 95% add back more informative compared to the original?

Let's do a Low-Pass Filter. Low pass filters "…Preserves the low frequency components of an image, which smoothes it." ENVI Help. Low pass filters are useful for noisy data and used extensively in geophysics.

Toolbox > *Filter* > *Convolutions and Morphology* > *Convolutions* > *Low Pass*

Kernal size = 3   0% Image Add Back

Repeat but with Kernal size = 13   0% Image Add Back

Question 5: What is the difference in image appearance when a low pass filter with a 3 x 3 kernal is applied compared with a low pass filter with a 13 x 13 kernel?

Lab 3 Image Processing Name:

Upload the following files to the instructor:

(3) “Your name_bands_2-5_Scatterplot”

(4) “Your name_subset_band5_geotiff”

(5) “Your name_rotate 90_ENVI.img” with ENVI .hdr file (two files)

Question 1: (Provide correlation values to the nearest two decimal places).

A. What is the correlation between OLI bands 3 (green) and 2 (blue)?

B. What is the correlation between OLI bands 4 (red) and 2 (blue)?

C. What two bands have the least correlation (most difference spectrally)?

D. What two bands have the highest correlation (most similar spectrally)?

Question 2: A. Compare the visual gray tone of the sand dunes in the band 2 (blue) and the three reflected infrared bands (5-7). Does this match the values in the correlation table? Explain.

Question 3: How does the scatter plot of bands 2 and 3 and the plot of bands 2 and 5 compare to the correlation table values?

Question 4: Describe the change in visual appearance of the red & white construction cranes when the Sharpen slider is set to 100 and to the far left of the slider (beyond the no change vertical line on the slider).

B. What level of sharpening provides an image that you find most informative (answer with the number to the right of the slider).

Question 5: What is the difference in image appearance when a low pass filter with a 3 x 3 kernel is applied compared with a low pass filter with a 13 x 13 kernel?

Lab 4 Image Processing 2
Utilizes Textbook's Remote Sensing Digital Database: *Chapters 3, 5, and 8 data.*

The objectives of this lab are to use image enhancement tools (see Chapter 9 Digital Image Processing for discussion of enhancements) to process thermal IR, UAS (drone), and multispectral data and to introduce band math. The tasks we will complete with this lab are done with tools in the **ENVI Toolbox**:

Band Math
Density slice
Mosaicking
Masking

Four digital files are to be uploaded to the instructor and four questions are to be answered on the last page of this handout.

IMPORTANT NOTE: The "new" ENVI with the GIS-look does *not* retain display enhancements for images when you use ***Save As***. These include rotating, zooming, contrast, brightness, sharpening, stretching, Portals, or viewing multiple layers. Use the ***Export View To > Image File*** to retain displayed enhancements. Unfortunately, it appears that when exporting an enhanced 1-band grayscale image, ENVI generates a grayscale file that contains 3 identical grayscale bands. This is bad. Can you find a fix?

1) Band Math
In this exercise we will convert raw DNs displayed on an ASTER thermal IR surface temperature image of the Ghanzi area, Afghanistan to degrees Celsius (°C). See textbook Chapter 5 and Figure 5-6 for more background information.

Open the ENVI software. *File* > *Open*

Locate the nighttime, Level 2 ASTER TIR surface temperature image (AST- 08 product) from the Remote Sensing Digital Database following this path:

\ Ch_5_Thermal_IR \ Fig_5-6 Afghanistan_ASTER_Surface_Temp \ Nightime

Choose the TIF image in the "Nightime" subfolder: "Ghazni_AST_08_TIR_Surface_Kinetic_Temp_Nighttime_31aug2013_integer"

Zoom to Extent *Click-on the Cursor Value icon*

Use the Select Arrow to move the crosshairs around the ASTER TIR image.

Move from bright pixels to dark pixels.

View Metadata

Quick Stats

Select Plot (drop-down menu in upper left) > *Histogram Band 1*

NOTE: The Terra platform that hosts the ASTER system is moving from south to north during the nighttime orbit. The rotation of the earth is demonstrated by the wedge-shaped black margins of NO DATA on the East and West margins. The system records a null DN of 2000 in this NO DATA area. Ignore the wedge-shaped margins.

Question 1: A. What is the range in DN values (min – max)?

B. What is the DN range for the bin with the highest Count (located at the peak of the histogram)?

1a) Brilliant people at the Jet Propulsion Lab (JPL) and NASA deliver calibrated ASTER thermal IR products for a variety of applications at no cost. The original DNs of the pixels in a Level 2, AST-08 product (calibrated surface temperature) can be converted to degrees Celsius (°C) using the following formula (Gillespie and Rokugawa, 2001):

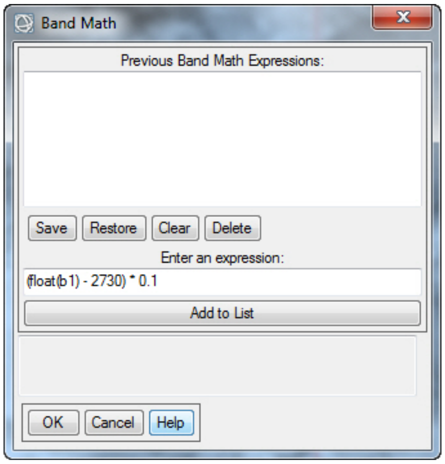
XXXX = DN of pixel on calibrated AST-08 Level 2 image
2730 = constant
YYY = Value when 2730 subtracted from DN on image (XXXX)

XXXX – 2730 = YYY * 0.1 = ZZ.Z°C

You can do this calculation on paper or with a calculator for each pixel you measured with the Cursor Value tool earlier. That is very inefficient. Fortunately, many image processing and GIS software packages include tools for you to write your own mathematical operations that can be applied to the entire image.

ENVI supplies the Band Math tool. Band Math is a powerful tool for remote sensing. Let's use it!

Toolbox > Band Algebra > Band Math



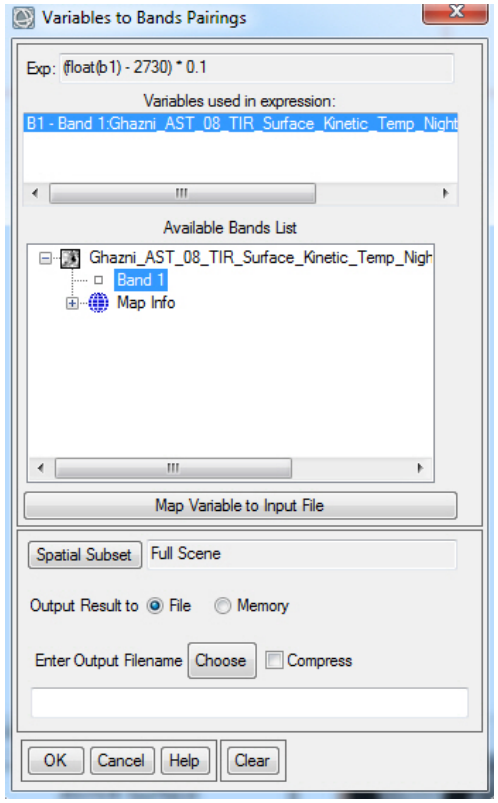
Push **Help** to see examples and better understand how band math works!!

Our formula XXXX – 2730 = YYY * 0.1 becomes (float(b1) - 2730) * 0.1

> "float" is used before each pixel's original DN value to ensure our degree Celsius result supports a decimal point.

Enter the Band Math formula into the "Enter an expression" box
> Add to List

> *Save* the Band Math formula as "ASTER TIR DN to Celsius" so you can use it again in the future.
> *> OK* The "Variables to Bands Pairings" window pops up.



Click-on the “Band 1” in the “Available Bands List”

The thermal IR band will automatically fill in the “Variables used in expression:” Name the output file “ASTER TIR Celsius_ENVI”. This new image will be in ENVI format (.img with .hdr).

The ASTER TIR °C image automatically loads into the View. The new image will be very dark if “No stretch” is set. Contrast stretch with” Linear 1%”

Roam around the image with your “Cursor Value” tool. Very dark blobs of pixels along the East margin have negative °C values. These may be clouds or errors. Best to ignore.

If you are more comfortable with Fahrenheit degrees (°F), use this formula for converting °C to °F

(32**°C** × 9/5) + 32 = 89.6**°F**

Question 2: A. What is the highest temperature in °C recorded by the ASTER TIR system? (Hint: Refer to the *Quick Stats* Histogram table)

B. Do you think you should use this highest temperature if only one pixel recorded it? YES or NO

1b) Our "ASTER TIR Celsius_ENVI" grayscale image is not useful for GIS. Let's quickly convert it to a geoTIFF format.

Right-click on "ASTER TIR Celsius_ENVI" in the Layer Manager
> Export Layer to TIFF

Name your geotiff output file "Your Name_ASTER Temp GIS.tif"

Upload to the instructor.
If you have access to a GIS, open your geoTIFF image in the GIS.

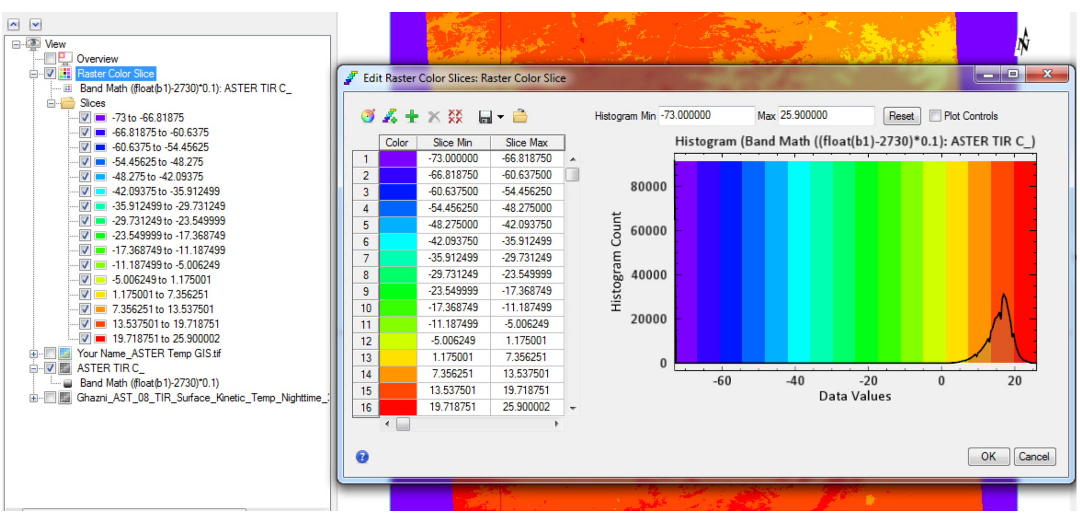
<u>2) Density Slice.</u> Use the "Raster Color Slices" tool in the ENVI Toolbox. Temperature patterns on our ASTER TIR °C grayscale image can be understood more easily if we perform a density slice on the image.

Highlight the "ASTER TIR Celsius_ENVI" image in the Layer Manager.

ENVI Toolbox > Classification > Raster Color Slices
A "Data Selection" window pops up – ensure the "Band Math (…)" entry under our "ASTER TIR Celsius_ENVI" image is highlighted. > *OK*

Automatically ENVI generates a "Raster Color Slice" image with 16 slices!

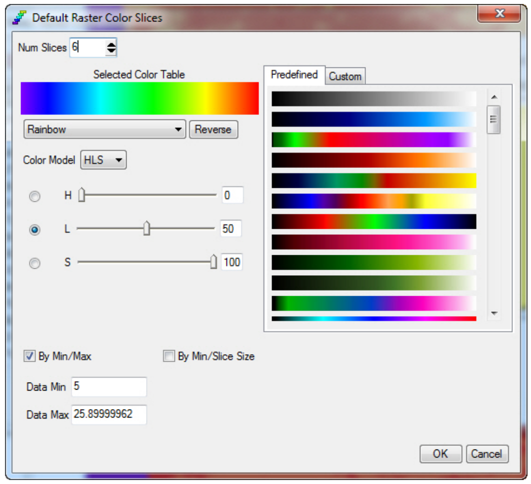
NOTE Problem*!* ENVI created 12 density slices where there is <u>no data</u> because our ASTER TIR DN histogram is not "normal" – it is skewed to the right. Image processing algorithms often <u>assume</u> a "normal" distribution of data. But often the data DNs are skewed!! Always <u>look</u> at your results to see if they are reasonable. *See below*



We MUST correct this very bad and misleading density slice image!!

Click-on the 2nd to the upper left icon *"New Default Color Slices…"*

The "Default Raster Color Slices" window pops up. (see below)



Change the *Num Slices* to "'6" and the *Data Min* to "5" > *OK*

You now see the color density slices more accurately reflect the distribution of surface temperatures on the ASTER TIR image.

In the "Edit Raster Color Slices: Raster Color Slice" window now on your screen, *save* the color density slices as a shapefile. *Drop-down* menu on diskette (6th icon from left) > Export as Shapefile…

Name your shapefile "YourName_ASTER_Temp_Density_Slice"
If you have access to a GIS, *load* this shapefile and color-code.

Upload your shapefile to the instructor.

NOTE: Converting a raster color density slice image to a vector polygon shapefile enables you to improve the symbology and legend, and fuse with other layers in your GIS. The nighttime surface temperature shapefile is awesome when faded and draped on the 30-meter SRTM DEM (available in the Remote Sensing Digital Database, Chapter 5 Thermal IR folder)

3) <u>Mosaicking.</u>
This exercise is quick and simple with ENVI. We will load two overlapping color images acquired by a USGS drone and digitally mosaic them into one image.

Remove all files from the Data Manager and Layer Manager.

The two georeferenced images are in the Remote Sensing Digital Database.

File > Open   Open the folder "Ch_8_sUAS_Manned-Aircraft" and its subfolder "UAS_USGS_West Fork Mine". The two images to load are

"dji__0260_georef_GIS.tif" and "dji__0770_georef_GIS.tif"

Zoom to Extents

With the Cursor Value, roam over the black edges around the images.

Question 3: What is the DN at the black edges of the two images?

ENVI Toolbox > Mosaicking > Seamless Mosaic > green **+** *sign (Add Scenes)*

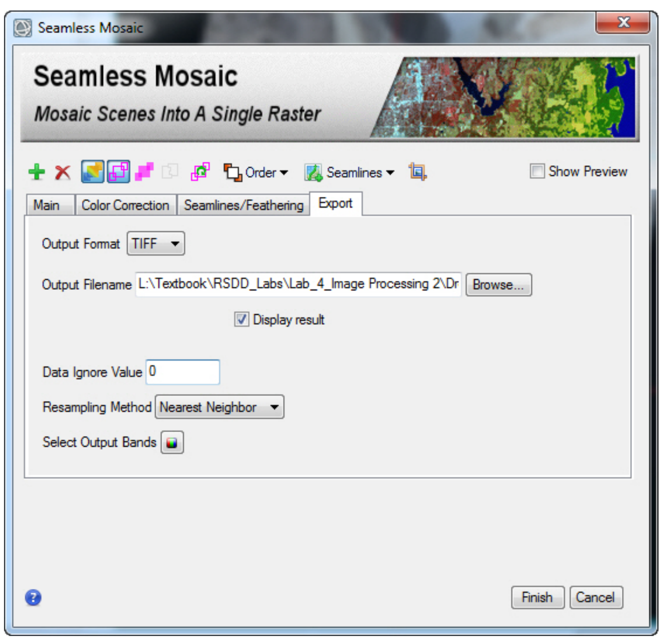
In the "Data Selection" menu, *select* both images *(ctrl key)* or *Select All > OK*

Click-on the "Color Correction" *tab > do not check* Histogram matching
(the mosaicked image is overly bright if you check this function)

Click-on the "Seamlines/Feathering" *tab > check* None

Click-on the "Export" *tab* > "Output Format" *dropdown menu* TIFF
"Output Filename" > "Drone mosaic"
"Data Ignore Value" . "0"   (zero – so the black margins that overlap are transparent)

Click "Show Preview"   (see tool and tabs below)



Check the preview. If OK, *Click* Finish

The processing could take a minute or two. The mosaic is over 160 MB.

Zoom in along the seam between the two images. (Scale 1:250).

Let's save a thumbnail jpg and upload it to the instructor.

File > Chip View To > File *Choose* "Output Format" as JPEG.

Name the file "YourName_drone_mosaic_thumbnail"

No need to display. Look at it when it is saved to your folder for this lab.
My thumbnail was tiny – 60 KB and it looked OK!

Upload thumbnail jpg to the instructor.

4) Masking.
Exit the GIS-look ENVI that we have been using, and open ENVI Classic.
I find that older ENVI Classic is much more efficient at generating a Mask from a multispectral data set compared with the new ENVI front end.
I have included the Masking exercise with the new ENVI front end as an alternative supplement at the end of the Lab Manual.

We are going to use a Landsat TM SWIR1 band (TM band 5) to **mask** water around islands in the Bahamas so we only process the features on the islands without interference or noise from the water.

The textbook Chapter 3 discusses how Landsat was used for generating a bathymetry map of the seafloor in this area. Plate 9 and Figure 3-16 show the enhanced satellite image with masks that you will be using in this exercise.

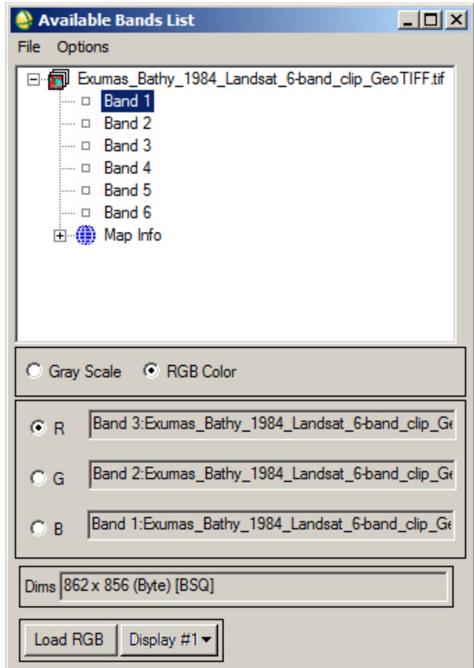
The Landsat data is in the Remote Sensing Digital Database \ Ch_3_Landsat folder.

In ENVI Classic *File > Open Image File*

Follow this path: \ Plate_9_Bathymetry \ Original_Landsat_Data

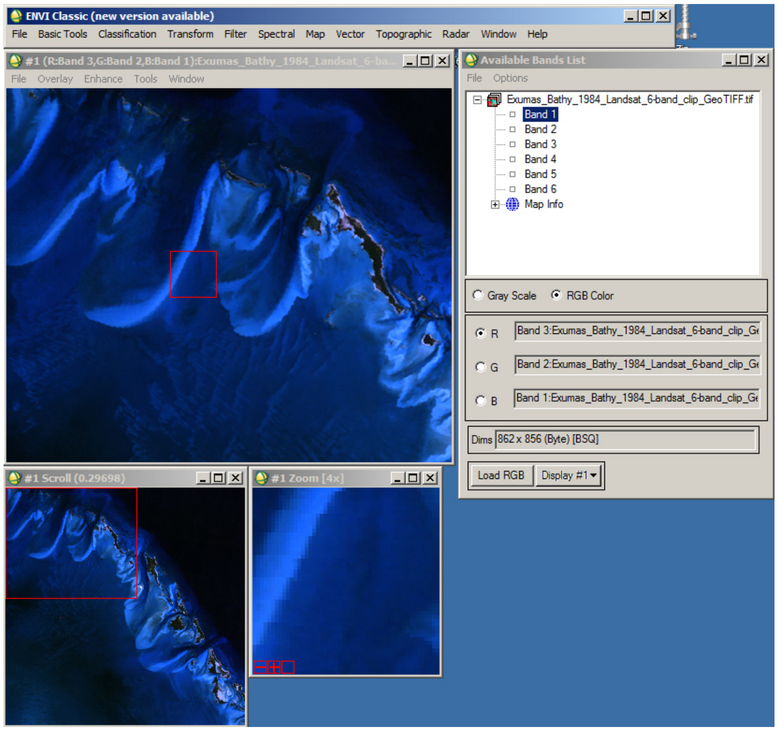
to the "Exumas_Bathy_1984_Landsat_6-band_clip_GeoTIFF" data > *Open*

An "Available Band List" window pops up with the six bands. (see below).



Click the "RGB Color" button > *Click* on Band 3 first, Band 2 second, and Band 1 last to create a natural color image (reflected red-green-blue light as R-G-B).

Click-on "Load RGB". A 3-window display pops up. The color image is automatically loaded in "Display #1" with its 3 windows.The full scene is in the lower left "Scoll", a 1:1 zoom factor image is in the large ("Image") window (outlined in red on the "Scroll" window), and an enlargement is in the "Zoom" window (outlined in red on the "Image" window. The "Available Band List" is to the right. See below.



NOTE: Remember that Landsat TM 30 m bands are numbered 1-5 and then 7 (SWIR2). See textbook Table 3-1. TM band 6 is a 60 m thermal IR band. We did not include the thermal IR band in our layer stack, so TM band 7 is listed as "band 6" by ENVI (and other image processing software).

4a) You are looking at a natural color image of the clear water, underwater sand bars in shades of blue, and white carbonate sands around the islands.

Access one "Contrast Stretch" tool in the "Image Window" by *clicking-on*
Enhance > In the Drop-down menu *Select* " [Scoll] Linear 0-255"
this will reset the displayed image to the original DNs.

In the "Image" window *Tools > Cursor Location/Value…*

A "✚" shows up in the "Image" window and a small "Cursor Location/Value" window pops up. If you are looking at the original data (not contrast-stretched) the "Scrn:" and "Data:" R-G-B DN values are identical.

Move the *Cursor Value* tool around the image to understand the range of DNs in the water and on land.

To brighten the color image *Enhance* > "[Scroll]" Linear 2%

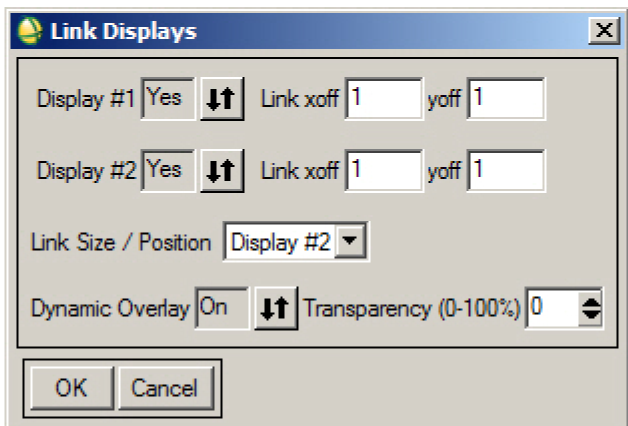
Move the *Cursor Value* tool around the image. Note how the enhanced pixels on the screen (“Scrn:”) have DNs that are different compared with the original “Data:”

Now we will compare the individual grayscale bands to the natural color image by opening up a second Display (“Display #2).

In the “Available Bands List” menu, *click-on* “Band 1” >
click-on “Gray Scale” > *click-on* “Display #2” > *New Display* >
click-on “Load Band”
Band 1 pops up in Display #2 to the right of Display #1.

4b) Let’s link the two views so we can compare the color image to the bands.
In Display #2 *Tools > Link > Link Displays*

The “Link Displays” window pops up. *> OK*



Choosing to start the link in Display #2 makes Display #2 the master when moving around the scene

Now you can move the Image rectangle outline in the “Scroll” window of Display #2 around to see different parts of the scene in color and as grayscale bands.

Sequentially display Bands 1 through 6 in Display #2. *Contrast-stretch* as needed with the *Enhance* tool. Press the Image or Scroll window with the cursor and the linked Display image is shown.

In the Cursor Location/Value tool, look at the original DN value for the grayscale bands as you roam around from shallow to deeper water. The original DN values are on the “Disp #2 Data:” line.

Question 4: A. What happens to the visibility of the underwater sand bars and ripples on the sea floor as you display the blue, then green, and then red bands? (Hint: read the textbook Chapter 3 and look at Plate 9)

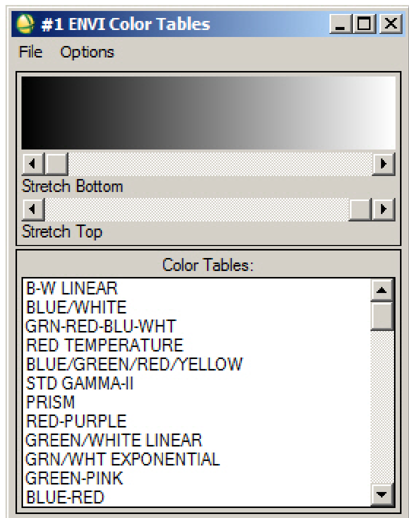
B. Why?

C. What happens to the brightness of water as you display the reflected infrared bands (Bands 4, 5, 6)? (*Contrast-stretch* each band to make the change more clear).

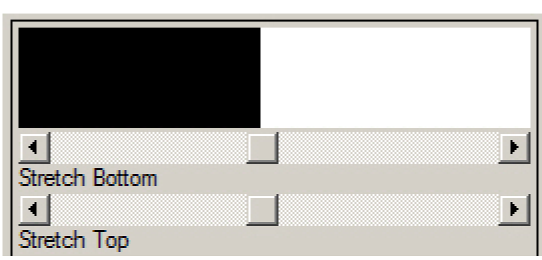
D. Why?

4c) Landsat TM band 5 (SWIR1) does a good job of differentiating water from land. Using the "Available Band List" *Load Band* > Band 5 as a "Gray Scale" into Display #2.. Now we will make a binary (black and white) image of Band 5 in Display #2.

Tools > *Color Mapping* > *ENVI Color Tables* (see below)



The B-W Linear grayscale from black to White should be displayed. (See above). Move the stretch buttons toward the center of the sliders. You are doing a linear stretch, with the top slider moving pixels toward the left side to pure black (DN = 0) and the bottom slider moving pixels toward the right side to pure white (DN = 255). Align the slider buttons so the black-white pattern has a sharp boundary (see below). This could be termed a "Linear 50%" contrast stretch.

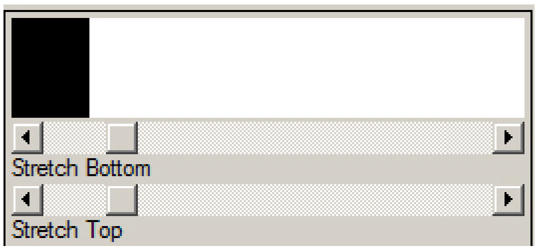


Look at the Band 5 image in Display #2. The pixels are only black or white. (See "Cursor Location / Value" "Disp #2…Scrn:" DN values).

Our goal is to display islands as white and water as black. The Linear 50% stretch is excessive - a significant portion of the land on the islands is black which should represent water.

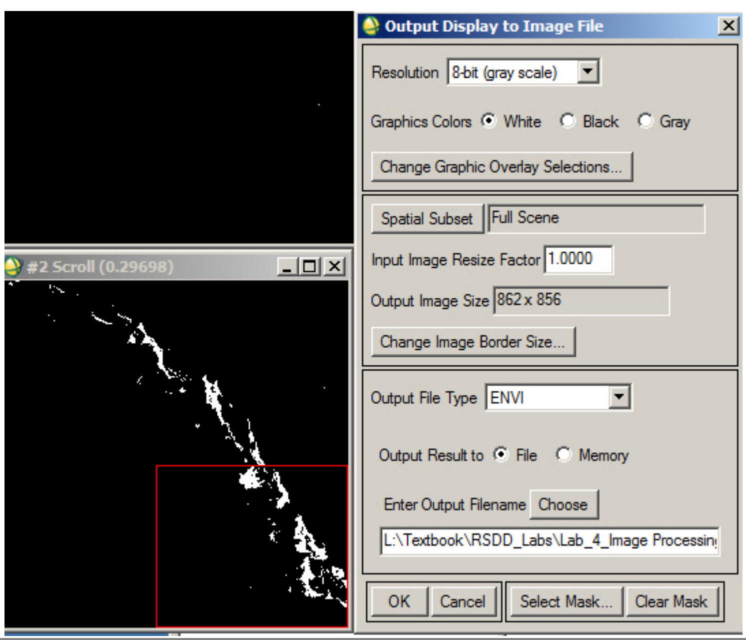
Redo the sliders on the "#2 ENVI Color Tables" window. Move the vertical Black-white boundary left so that the land on the islands is displayed as white.

Press the Image or Scroll window with the cursor and the linked Display image is shown. This will help you determine when you have an appropriate land – water boundary. I decided on the following black – white boundary.



Note that there are lakes on the islands and the white sands may be saturated – so the SWIR TM band 5 records these as dark pixels. These pixels are in the black water class.

To save our TM Band 5 Black-White image we use Display #2 Image drop-down menus *File > Save Image As > Image File* The Output Display to Image File window pops up.



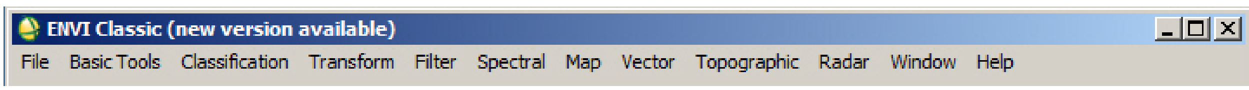
Choose the defaults. The "Resolution " is "8-bit (gray scale)" Save the image as "TM_Band5_BW_8-bit_ENVI"

The saved image automatically shows up in the "Available Band List" and is highlighted so it easily displays next.

"Available Band List" > *push* "Display #1" button > *New Display* > *push "Load Band"* Our TM Band 5 8-bit image is loaded into Display #3.

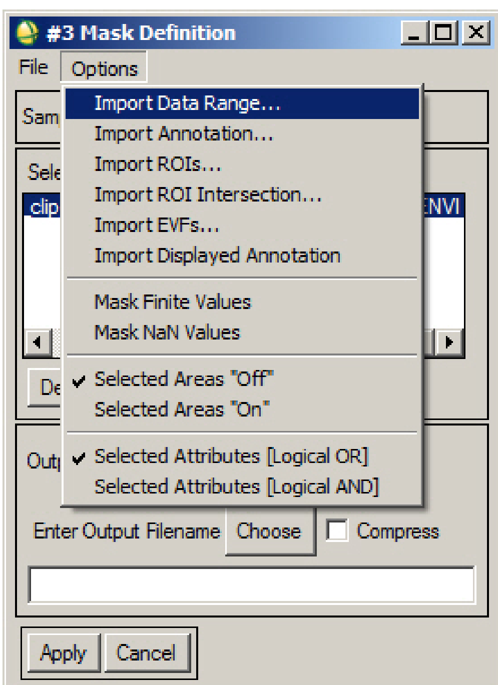
4d) Build the Mask. Now we will convert our 8-bit grayscale image (with 255 levels of gray even though only 0 and 255 are used) to a Mask with DNs of 0 and 1.

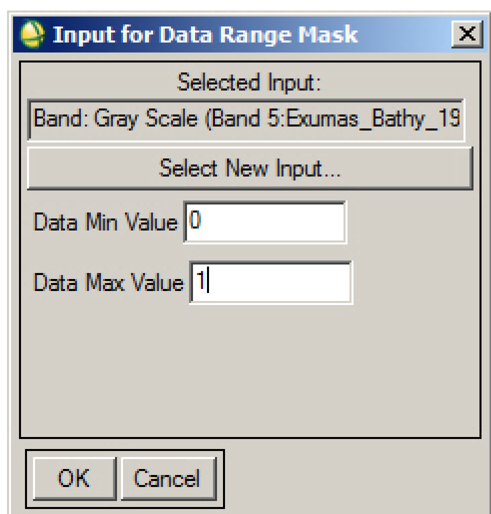
We use the drop-down menus on the ENVI Classic Toolbar (see below).



Basic Tools > Masking > Build Mask *Select* Display #3

The "#3 Mask Definition" window pops up. Our TM Band 5 8-bit image is highlighted by ENVI. *Options > Import Data Range* (shown below on left)





The "Import for Data Range Mask" menu pops up. Enter 0 and 1.
This sets the mask for "water" > *OK*

In the Options drop-down menu ensure "Selected Areas "Off"

Name the Mask "Water_Mask_0-1_Off" so that you remember you used 0-1 and "off" in the Mask Definition. *> Apply*

NOTE: The combination of 0-1 and "off" in the Mask Definition ensures that the mask will be opaque over water pixels and transparent over land pixels so water will not interfere with processing analysis of the land cover on the islands. This is always confusing and trial & error with these parameters seems to be the typical way to get the Mask you want…

The mask automatically loads into the "Available Band List" and is highlighted.

Push "Display #..." drop-down menu and *choose* "New Display"

Push "Load Band?

Move your Cursor Location/Value tool over the water and land. They should have DNs of 0 and 1, respectively.

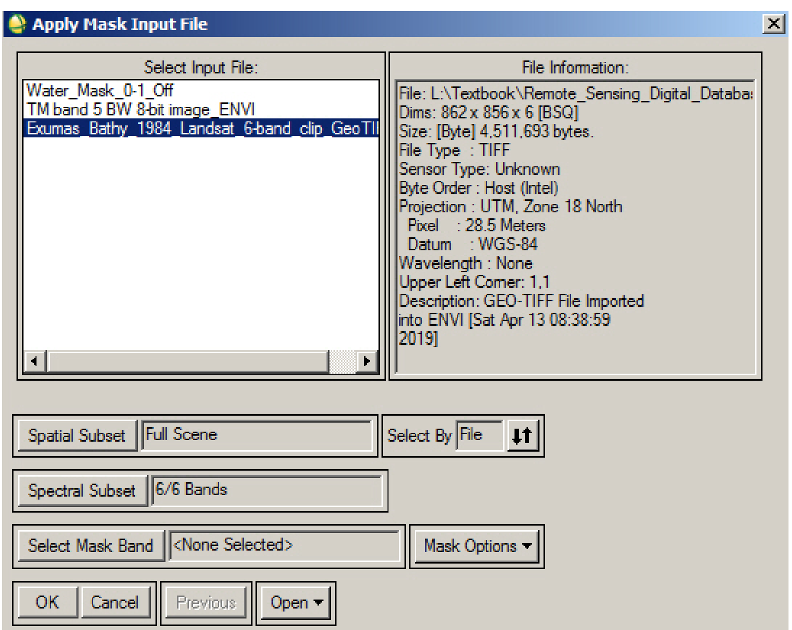
4e) Apply the Mask

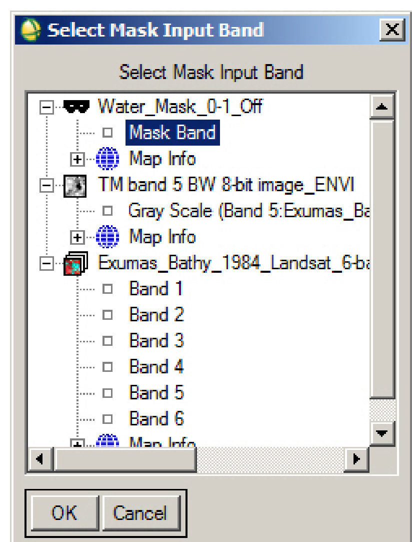
ENVI Toolbar > Basic Tools > Masking > Apply Mask

The "Apply Mask Input File" window pops up. This is the data we want to mask – the 6-band Landsat dataset.

"Select Input File:" *Select* the 6-band Landsat dataset *> OK*

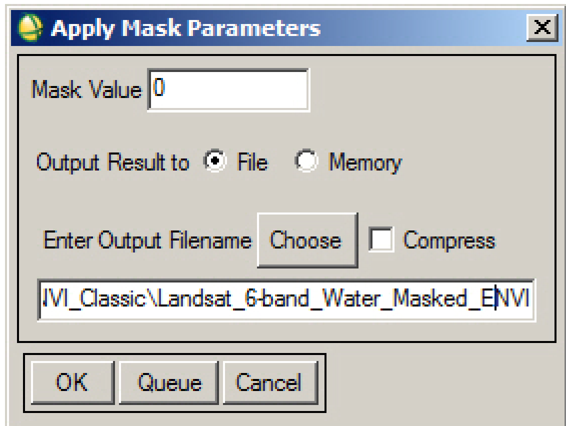
Buttons pop in on the "Apply Mask Input File" window (see below)





Click-on the "Select Mask Band" button. Our water mask shows up at the top of the "Select Mask Input Band" window (see above) *> OK > OK*

An “Apply Mask Parameters” window pops up. (see below)



Name the file “Landsat_6-band_Water_Masked_ENVI” > *OK*

The masked Landsat displays in the “Available Bands List”

Display a color IR image (TM bands 4-3-2 as R-G-B)
Click the “RGB Color” > *Push* the “Load RGB” button
Your masked color image will display in your last Display.

Move the Zoom window over a large island > *Enhance* > *[Zoom] Equalization*
You are contrast-stretching using **only** the pixels in the Zoom window.
This stretch reveals <u>significant</u> differences in the vigor of vegetation on different islands and within larger islands.

4f) Our masked ENVI color IR Landsat is more useful in GIS so others can view it – and we could import our color IR image into Google Earth if it was a geoTIFF.

We want to save the 3- band color composite so we use the ENVI <u>Image</u> menus
File > *Save Image As* > *Image File…*
Choose “Resolution” drop-down menu   “24-bit Color (BSQ)
Choose “Output File Type” drop-down menu   “TIFF/GeoTIFF

Name the GIS-ready dataset:
“YourName_Landsat_ColorIR_Masked_Water_GIS” > *OK*

Upload the 24-bit GIS-ready color IR image to the instructor.

If you have access to a GIS, load the 6-band multispectral dataset.

Lab 4 Image Processing 2 Name:

Upload the following files to the instructor:

(1) “Your Name_ASTER Temp GIS.tif” geotiff

(2) “YourName_ASTER_Temp_Density_Slice” shapefile

(3) “YourName_drone_mosaic_thumbnail” jpg

(4D) “YourName_Landsat_ColorIR_Masked_Water_GIS” geotiff

Question 1: A. What is the range in DN values (min – max)?

B. What is the DN range for the bin with the highest Count (located at the peak of the histogram)?

Question 2: A. What is the highest temperature in °C recorded by the ASTER TIR system? (Hint: Refer to the *Quick Stats* Histogram table)

B. Do you think you should use this highest temperature if only one pixel recorded it? YES or NO

Question 3: What is the DN at the black edges of the two images?

Question 4: A. What happens to the visibility of the underwater sand bars and ripples on the sea floor as you display the blue, then green, and then red bands? (Hint: read the textbook Chapter 3 and look at Plate 9).

B. Why?

C. What happens to the brightness of water as you display the reflected infrared bands (Bands 4, 5, 6)? (*Contrast-stretch* each band to make the change more clear).

D. Why?

Lab 5 Band Ratios and Principal Components
Utilizes Textbook's Remote Sensing Digital Database: Chapter 3 data.

The objective of this lab is to use Information Extraction tools (see Chapter 9 Digital Image Processing for discussion) to process multispectral Landsat data in *Reflectance***.** The tasks we will complete with this lab are done with tools in the **ENVI Toolbox**.

Three digital files are to be uploaded to the instructor and eight questions are to be answered on the last pages of this handout.

IMPORTANT NOTE: ENVI does not retain display enhancements for images when you use ***Save As***. These include rotating, zooming, contrast, brightness, sharpening, stretching, Portals, or viewing multiple layers. Use the ***Export View To > Image File*** to retain display enhancements and original scale (choose Zoom Factor 1.0000).

We will use Landsat 8 bands of Thermopolis that have been converted from radiance to reflectance to ensure our band ratios are accurate. Reflectance data are also required for spectral libraries that we will work with in a later lab. The data set is located in the "Remote Sensing Digital Database \ Ch_3_Landsat" folder.

1) *Start up ENVI*

Open the subfolder "Plates_7and27_Thermopolis". Open the subfolder "Landsat8_Reflectance_6bnds_VNIR-SWIR".

Select "OLI_Thermopolis_Sep2015_reflectance_bnds2-7_ENVI" *> Open*

> *Zoom to Extents*

If you have your ENVI Display preferences set at "No Stretch", the 12-bit bands will appear white with some of the Wind River in yellow and green?!

Click-on the Histogram Stretch tool 

With "No Stretch", the histogram low and high vertical DN bars are set to "0" and "255" (8-bit) while the data are 12-bit.
Click-on the contrast stretch drop-down menu and *select* "Linear 1%"
Analyze the stretched histograms in the Histogram Stretch tool.

Open the Data Manager. *Move* the slider all the way to the right so you can see the wavelengths of the six Landsat 8 bands. The USGS attaches the center wavelength of each band to the file name (excellent!) when they convert Landsat from radiance to reflectance. The USGS also ensures the bands are correctly labelled: OLI 2 – 7.

2) <u>Band Ratios</u>**:** Band ratios (or ratio images) are prepared by (digitally) dividing the DN

in one band by the corresponding DN in another band for each pixel in an image. In a ratio image, the darkest pixels represent the smallest ratio values and the lightest pixels represent the largest ratio values. The darkest signatures are areas where the band in the denominator (7 in the 5/7 ratio image) has a greater reflectivity (higher DN value) than the band in the numerator. The brightest signatures show pixels where the numerator is larger than the denominator. Bands should be corrected to reflectance prior to band ratioing.

Look at Figures 9-25 A and C along with textbook discussion in Chapter 9.

<u>OLI Band Ratio 4/2 (red/blue):</u>

Spectra of weathered iron-bearing (ferrous) minerals have strong reflectance in the visible red region of the electromagnetic spectrum (TM band 3 or OLI band 4) wavelengths at ~0.63 to 0.69 *u*m). Because red-colored material, or Iron-bearing minerals, have a weak reflectance in the visible blue portion of the spectrum (TM band 1 or OLI band 2) at ~0.45 to 0.52 *u*m) a ratio image of TM bands 3/1 or OLI bands 4/2 could indicate iron- stained areas. Areas with iron-staining will be bright.

<u>OLI Band Ratio 6/7 (SWIR1/SWIR2)</u>

Landsat TM band 7 (OLI band 7) is preferentially absorbed by the hydroxyl-bearing clay minerals as compared with TM band 5 (OLI band 6); therefore, a ratio image of TM bands 5/7 (OLI bands 6/7) could show anomalously high concentrations of these clay minerals as bright areas.

ENVI Toolbox > Band Algebra > Band Ratios

Select Band 4 first. ENVI automatically places Band 4 in the Numerator.
Select Band 2 next. ENVI places Band 2 in the Denominator.
Click “Enter Pair” > *OK*
The “Band Ratios Parameters” window pops up.

Enter an Output Filename: “Landsat iron ratio_ENVI”
Accept “Floating Point” as the output data type (each pixel DN will have a decimal place).

The iron ratio grayscale image needs to stretched.

ENVI Toolbox > Band Algebra > Band Ratios

Select Band 6 first. ENVI automatically places Band 6 in the Numerator.
Select Band 7 next. ENVI places Band 7 in the Denominator.
Click “Enter Pair” > *OK*
The “Band Ratios Parameters” window pops up.

Enter an Output Filename: “Landsat clay ratio_ENVI”
Accept “Floating Point” as the output data type (each pixel DN will have a decimal place).

The clay ratio grayscale image needs to stretched.

3) Let's open up four Views. *Views > 2 X 2 Views*

Slide the iron ratio image into View 2.
Slide the clay ratio image into View 3.
Turn off the iron and clay ratio images in View 1.

Zoom to Extent and *Optimized Linear* stretch for the View 1 (natural color), View 2 and View 3.

Views > Link Views > GeoLink *active* > *Link All* > *OK*
Pan around *Zoom in & out*
In the Cursor Value window,
select "Link Views" and "Display Information for All Views"

Question 1: Activate View 2 with the iron ratio image. Put your cursor on the brightest pixel you see in the Chainman Shale (Red Rose Anticline (see textbook Figure 3-11H if you don't remember where that is). (Show only two decimal places for the DN below).

A. What is the Data value (DN) for the bright pixel on the iron ratio image:

B. What is the Data value (DN) for the same pixel on the clay ratio image:

Question 2: Put your cursor on the brightest pixel you see in the clay ratio image in a Wind River agricultural field (see textbook Figure 3-11H if you don't remember where the river is). (Show only two decimal places for the DN below).

A. What is the Data value (DN) for the bright pixel on the clay ratio image:

B. What is the Data value (DN) for the same pixel on the iron ratio image:

4) You are planning field work and only want to visit sites in the field with the highest potential iron content and potential clay content. To make a useful map we can interactively determine which pixels we want to be pure white and which we want to be pure black. The pure white pixels have the highest potential iron and clay content in the Thermopolis field area. In the Layer Manager, highlight View 2 with the iron ratio image.

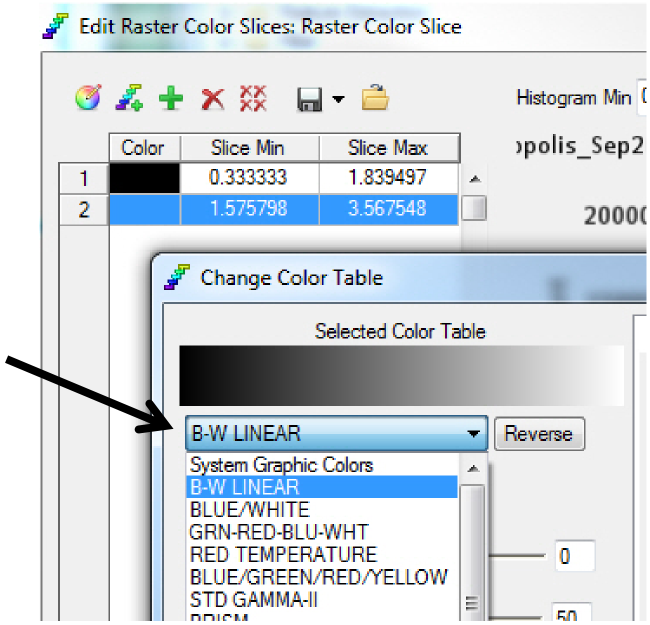
ENVI Toolbox > Classification > Raster Color Slices
The "Data Selection" window pops-up
Select your "Landsat_iron_ratio_ENVI" image first > *OK*

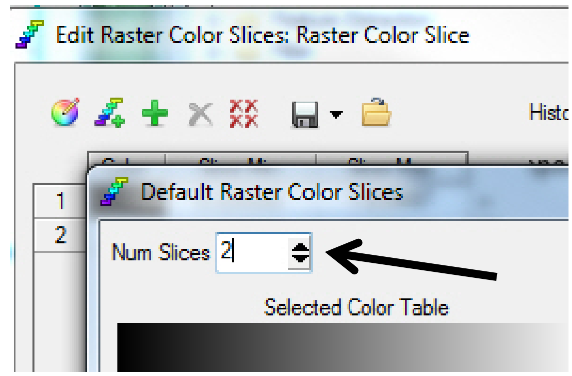
The "Edit Raster Color Slices: Raster Color Slice" window pops-up
(The default density slice has 16 levels and a rainbow color scheme)

Change the color scheme and the number of slices.

In the upper left corner of the window is the
"Change Color Table…" icon and next to it the
"New Default Color Slices…" icon.

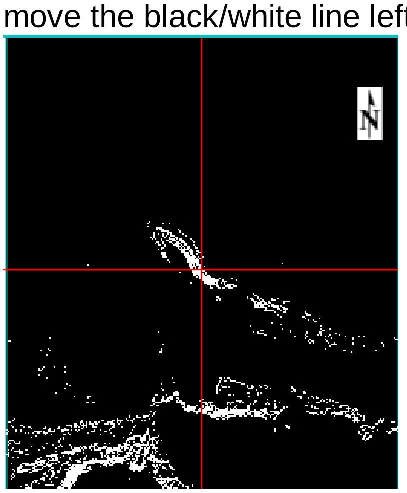
In the Change Color Table window *Select* "B-W Linear"
In the "New Default Color Slices" window *Change* 16 to 2

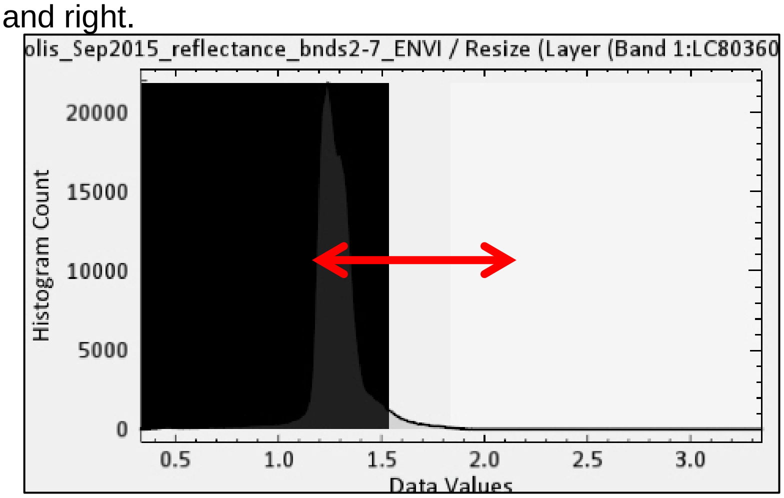




In the "Edit Raster Color Slices: Raster Color Slice" window, move the vertical line separating the black and white patterns on the histogram while looking at the grayscale ratio image. Choose a black-white dividing DN that shows <u>only</u> the most promising sites on the band ratio image for you to find iron-stained rocks at the surface – that may indicate hydrothermal alteration and mineralization! To reduce your field area (saving time and money), density-slice your iratio image so only a few areas have white pixels.

You can also *change* the "Slice Min" value in the table to the left of the histogram to move the black/white line left and right.





Let's save your Black-White prospecting image for your GIS.

Ensure that the "Raster Color Slice" is checked and highlighted in your Layer Manager (the black and white slices for the iron ratio image are in a subfolder)

File > Export Selected File to TIFF > name the image
"Your Name_Iron_Sites_GIS"
Check the "Display result" so you can see if the output identical to your black-white iron image in View 2. Upload to the instructor.

5) You are now an agricultural soil scientist and want to find sites in the Thermopolis area that have the highest potential for clay to support your proposed grape vineyard. In the Layer Manager, *highlight* View 3 with the clay ratio image. Repeat the process you did for the black-white iron image under Step 3).

Name your GIS output image "YourName_Clay_Sites_GIS". Upload to the instructor.

6) Normalized Difference Vegetation Index (NDVI)
(see textbook Figures 9-27, 9-37)

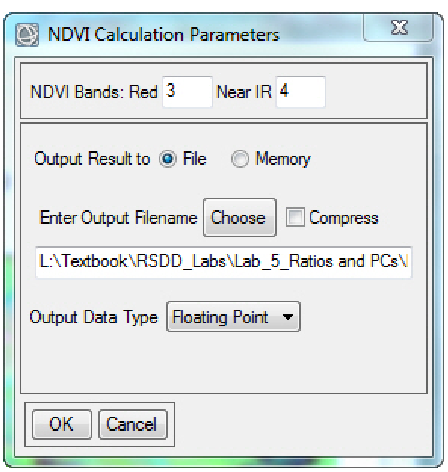
The difference in reflectance values between NIR and red wavelengths is used to map vegetation greenness (also termed vigor and stress). Healthy plants reflect NIR light but absorb red light (cholorphyll). Scientists like to have a number describe a situation – an "index".

NDVI is an index that is normalized so the value varies between -1 and +1>
NDVI = (NIR – red) / (NIR + red)
NDVI = (OLI 5 – OLI 4) / (OLI 5 + OLI 4)
= (145 – 35) / (145 + 35) = 110 / 180 = +0.61 (healthy vegetation!)

Highlight View 4 (so the NDVI image is displayed in this empty view)

6a) *ENVI Toolbox > Spectral > Vegetation > NDVI*
Select the six-band Landsat dataset as the *Input File*

The "NDVI Calculation Parameters" window pops-up.



The selection of NDVI Bands is correct – the 3rd band in the dataset is red and the 4th band is Near IR.

Name “Landsat_NDVI_ENVI”

Leave as “Floating Point” so range of DNs in the NDVI pixels should range between -1.0 and 1.0 (pixels with noise or error could be outside this range) *> OK*

6b) Zoom to Extents > Contrast stretch with “Linear 1%”

Link View 4 with the NDVI image to the other 3 Views
Views > *Link Views* *click-on* New Link *or Link All*

Turn off the density slices in Views 2 and 3. Enhance all the grayscale ratio images with “Linear 1%” *Pan* around and *zoom in & out* of the linked Views

Question 3: A. Why do you think the clay ratio image in View 3 is so similar to the NDVI image (vegetation greenness or vigor) image in View 4?

B. Roam around the linked Views. What type of feature has pixels on the clay ratio image that are bright but dark on the NDVI image?
(hint: look also at the color image in view 1 – change the bands to OLI 7-5-2 as R-G-B. Look at the iron band ratio image also).

6c) Use the *Cursor Value* tool and *click* around the NDVI grayscale image.

Question 4: A. What range of NDVI values do you find on your NDVI image?

B. Did you find any negative values?

6d) *Right-click* on the NDVI image in the Layer Manager > *Quick Stats*
Select Plot drop-down menu > “Histogram Band 1”

Question 5: A. What range of DN values (Min and Max) do you find in the metadata for the NDVI image?

B. Is the range of DNs in the image’s metadata different than what you found clicking around the image with the Cursor Value tool? YES NO

C. Approximately how many pixels have values greater than +1.0?

D. Approximately how many pixels have values less than -1.0?

E. How many pixels are in this image? (Remember Metadata?)

F. What is your opinion about those pixels in the metadata with DNs outside of the NDVI -1 to 1 range?

It is very important to use your brain and eyes - look at the image, metadata, and statistics - to help you understand the quality and technical issues with your imagery to ensure that what you are doing makes sense – and that the maps you generate are useful. We'll see the impact of blindly using all the DNs that are in the NDVI image in the final NDVI exercise below.

6e) Let's color-code the NDVI to highlight those pixels with vigorous vegetation
ENVI Tool Box > Classification > Raster Color Slices
Select the grayscale NDVI image *> OK*

The ENVI density slice program uses the DN range documented in the metadata.

The "Edit Raster Color Slices: Raster Color Slice" tool pops-up. Evaluate it!

Question 6: A. What density slice colors appear on your NDVI image in View 4?

B. Is this NDVI image what you want for a final, color-coded product?

We must modify the min and max DN values that we allow to be used by the density slice tool to reflect what we visually see in the image. The remote sensing analyst has to make a <u>decision</u> about what is most valid and what is noise and needs to be ignored. This decision should be documented in your color-coded NDVI GIS image's metadata.

Along the top right portion of the "Edit Raster Color Slices…" window are DN values for "Histogram Min" and "Max" automatically placed by ENVI based on the unedited NDVI input image.

Change the Min to -1.0 and the Max to 1.0

Click-on the "New Default Color Slices…" icon in the upper left.
Change "Num Slices" from 16 to 5.
Note "Data Min" is -1.0 and "Data Max" is 1.0 in the lower left. *> OK > OK*

How many colors do you see on your NDVI image in View 4?

There is much research documentation that in terrain such as Thermopolis (semi arid) we have a low probability of finding pixels with NDVI values below -0.2. GIS Resources indicates the following NDVI values can be expected:

1. Barren rocks, sand, or snow show very low NDVI values (-0.1 to 0.1)
2. Shurbs and grasslands or senescing crops (– 0.2 to 0.5)
3. Dense vegetation or tropical rainforest (– 0.6 to 0.9)
4. Deep water (-1)

ENVI's Help indicates vegetation typically ranges between NDVI values of 0.2 and 0.8.

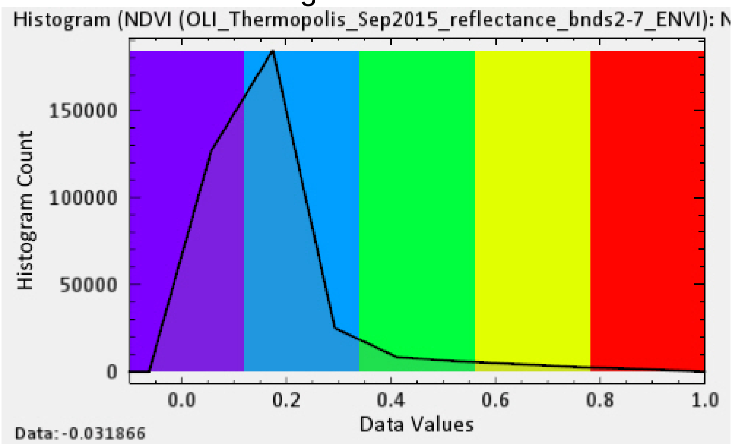
Given the above, let's change our density slice min value to -0.1 since most of us didn't find any DNs more negative than -0.1 while analyzing our NDVI image with the Cursor Value tool earlier.

6f) In the Layer Manager, *Right-click* on the "Slices" folder that contains the 5 colors and their ranges under the "Raster Color Slice" file *> Edit Color Slices…*

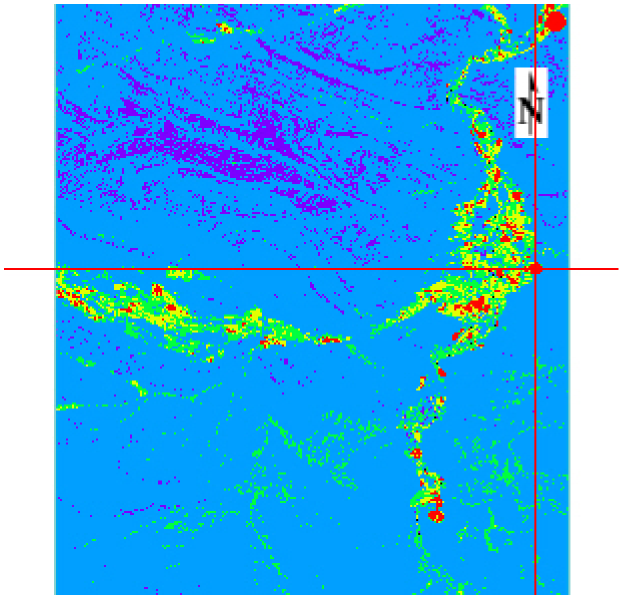
The same menu pops up that we saw in Exercise (6e) above. Update the Min value to -0.1 and the Max value to 1.0. We have to reset the number of slices also.

Click-on the "New Default Color Slices…" icon in the upper left. *Change* "Num Slices" from 16 to 5.

Your color-coded histogram should look like what is shown below:



> OK



Your 5-level density slice of the NDVI image should look like this. Agricultural fields that are heavily irrigated are displayed in red. Less vigorous (or more open) fields are displayed in yellow and green. A very useful and new product!

File > Chip View To… > Image > Select “JPEG” in the dropdown window.

Name the color-coded NDVI image “YourName_color-coded_NDVI_jpg”

Upload to the instructor.

7) <u>Principal Components</u>

Highlight Views 2, 3, 4 and for each view *File > Close All Files*
In View 1 > *Change RGB Bands* to OLI 5-3-2 (NIR-Red-Green) as R-G-B
Leave 4 Views – only View 1 has an image.

Principal Components (PCs) are covered in the textbook Chapter 9,
See Figures 9-22, 9-23 A-F, 9-24 and Plate 27. The reflectance image used in this exercise does not cover the exact same area as the textbook Landsat example which is also in radiance. So the PCs developed in this exercise will not look exactly like the ones in the textbook. PCs are specific to the dataset being processed.

Why PCs? When you compare the individual multispectral bands in a dataset there is strong visual similarity. Think back to Lab 3 and the correlation matrix for the Thermopolis Landsat bands. The high correlation means there is much redundancy of information in the multispectral data set. PCs reduce this redundancy by compressing all of the information contained in the original grayscale bands set into a new set of grayscale images named PC1, PC2, PC3, etc. Each successive PC image accounts for a progressively smaller proportion of the variation in the original data set.

Highlight View 2 (this will put the PCs into this empty View)

ENVI Toolbox > Transform > PCA Rotation > Forward PCA Rotation New Statistics and Rotate

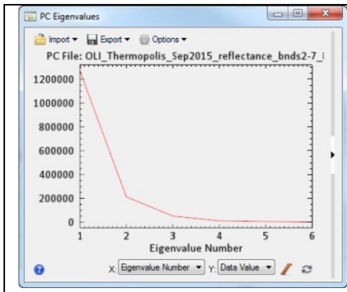
(PCA) means principal component analysis
Use **ENVI Help** to learn more about this analysis and step-by-step details

Select the 6-band Landsat data set > *OK* *Accept* Defaults for subsets & Mask > *OK*

The “Forward PC Parameters” window pops-up.

Name the output Stats file “Landsat_6PC_stats”
Name the output file “Landsat_6PC”
Accept defaults EXCEPT change “floating point” to “byte” > *OK*

The “PC Eigenvalues” window pops-up (see below) and the 6 PCs load into View 2.



Eigenvalue
PC1: 1,270,891
PC2: 212,665
PC3: 51,161
PC4: 11,321
PC5: 5048
PC6: 729

To see the Eigenvalue values (shown on the right above), you choose *Export > ASCII* in the PC Eigenvalues menu. The ASCII file is a simple .txt file that lists the PC Eigenvalues.

NOTE: PC Eigenvalues indicate the proportion of original information (total variance) in the multispectral dataset (all the bands) that each PC contains. To determine the percentage of the total variance within each PC, you sum the Eigenvalues and divide each PC Eigenvalue by the summed total.

Views > Link Views View 1 has 6 Landsat bands, View 2 has 6 PC images.
Look at the Data Manager list of bands and PCs

7a) Next we will examine the grayscale bands and PCs with "Band Animation"
Highlight View 1 > *Right-click* file in Layer Manager > *Band Animation*
Slow the flicker rate to 1 or 2 seconds
Note the high visual correlation between bands
You may have to use "Linear 1%" stretch on the bands

Highlight View 2 > *Right-click* file in Layer Manager > *Band Animation*
Note the low visual correlation between PC images
You may have to use "Linear 1%" stretch on the bands

Both Views should be in Band Animation mode, *Zoom in* to the Red Rose Anticline – band animation should still be working in both Views.

7b) Let's load a grayscale band into View 3 and a grayscale PC into View 4
Highlight View 3 > "Data Manager" > *Select* OLI Band 1 > *Load Grayscale*
OLI Band 1 will display in View 3

Highlight View 4 > "Data Manager" > *Select* PC Band 1 > *Load Grayscale*
PC Band 1 will display in View 4

Views > Link Views > Link All > OK

Zoom in to the Red Rose Anticline. In View 3 use the Data Manager to load another OLI band. Compare a few OLI bands to PC 1.

Question 7: A. Does the PC 1 image look very similar to the OLI bands, especially in areas with topographic relief (ridges, cliffs, valleys, etc.)? YES NO

B. What percentage of the variance in the 6-band Landsat data set is in PC1? (Hint: Use the values in the PC Eigenvalues table above)

C. What percentage of the variance in the 6-band Landsat data set is in PC5? (Hint: Use the values in the PC Eigenvalues table above)

7c) Zoom out so both the Red Rose Anticline and the Wind River agricultural fields are visible in the 4 views.

Highlight View 2 > Use the Data Manager > *Select* PC2 – PC3 – PC4 as R-G-B > *Load Data* > Try different stretches > last stretch “Linear 1%”

Highlight View 3 > Use the Data Manager > *Select* PC4 – PC5 – PC6 as R-G-B > *Load Data* > Try different stretches > last stretch “Linear 1%”

Highlight View 4 > Use the Data Manager > *Select* PC3 – PC4 – PC5 as R-G-B > *Load Data* > Try different stretches > last stretch “Linear 1%”

Pan over the Wind River agricultural fields and note the increased level of information available with PC color images compared with the traditional color IR image in View 1

Question 8: A. Which PC color image in Views 2, 3, and 4 provides the most information for you about the agricultural fields?

B. The PC color image generated from PC4-PC5-PC6 as R-G-B has what percentage of the total variance in the 6-band Landsat dataset?
(Hint: refer to Eigenvalue table above and use your calculator)

NOTE: If we converted our NDVI grayscale image to a Mask, we could mask out the non-vegetated terrain in the Thermopolis scene and generate more detailed and informative PCs over the agricultural and natural vegetated areas. The Mask could be inverted and vegetation eliminated from the PC analysis to extract more unique patterns on the PC images over terrain with geologic outcrops.

Principal Components provide unique and often very subtle but important information about features of interest. PCs should be applied to any multispectral data set to see what spectral patterns may be hidden in the original bands.

The Landsat 8 OLI sensor (VNIR-SWIR) is so noise-free that the PC 5 image is almost noise-free and even the PC 6 image displays unique spectral information. Awesome remote sensing technology!

Lab 5 Band Ratios and Principal Component Name:

Upload the following files to the instructor:

(4) "Your Name_Iron_Sites" geotiff

(5) "Your Name_Clay_Sites" geotiff

(6) "YourName_color-coded_NDVI_jpg" jpg

Question 1: Put your cursor on the brightest pixel in the Chainman Shale (Red Rose Anticline (see textbook Figure 3-11H if you don't remember where that is).

A. What is the Data value (DN) for the bright pixel on the iron ratio image:

B. What is the Data value (DN) for the same pixel on the clay ratio image:

Question 2: Put your cursor on the brightest pixel in a Wind River agricultural field (see textbook Figure 3-11H if you don't remember where the river is).

A. What is the Data value (DN) for the bright pixel on the clay ratio image:

B. What is the Data value (DN) for the same pixel on the iron ratio image:

Question 3: A. Why do you think the clay ratio image in View 3 is so similar to the NDVI image (vegetation greenness or vigor) image in View 4?

B. Roam around the linked What type of feature has pixels on the clay ratio image that are bright but dark on the NDVI image?
(hint: look also at the color image in view 1 – change the bands to OLI 7-5-2 as R-G-B. Look at the iron band ratio image also).

Question 4: A. What range of NDVI values do you find on your NDVI image?

B. Did you find any negative values?

Question 5: A. What range of DN values (Min and Max) do you find in the metadata for the NDVI image?

B. Is the range of DNs in the image's metadata different than what you found clicking around the image with the Cursor Value tool? YES NO

C. What is your opinion about those pixels in the metadata with DNs outside of the NDVI -1 to 1 range?

Question 6: A. What density slice colors appear on your NDVI image in View 4?

B. Is this NDVI image what you want for a final, color-coded product?

Question 7: A. Does the PC 1 image look very similar to the OLI bands, especially in areas with topographic relief (ridges, cliffs, valleys, etc.)? YES NO

B. What percentage of the variance in the 6-band Landsat data set is in PC1?

C. What percentage of the variance in the 6-band Landsat data set is in PC5?

(Hint: Use the values in the PC Eigenvalues table above)

Question 8: A. Which PC color image provides the most information for you about the agricultural fields?

B. The PC color image generated from PC4-PC5-PC6 as R-G-B has what percentage of the total variance in the 6-band Landsat dataset?

(Hint: refer to Eigenvalue table above and use your calculator)

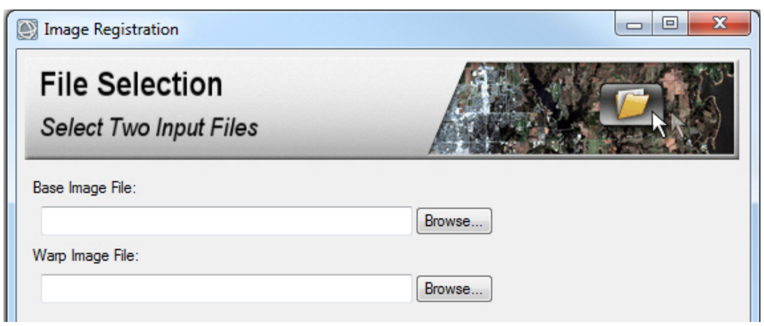
Lab 6 Georeferencing

The objective of this lab is to learn how to georeference a raster file with no coordinates (named a "warp image file" in ENVI) to a raster image (named a "base image file" in ENVI) that is in a coordinate system (see Chapter 9 Digital Image Processing for discussion). Georeferencing does not account for distortions in the input file due to topography – that requires correction with the orthorectification process which is beyond this lab. The tools for georeferencing are in the **ENVI Toolbox**.

Three georeferenced files are to be uploaded to the instructor. There are two questions at the end of the handout for you to answer.

The first exercise will use a 1959 scanned aerial photograph as the warp image file and a 2000 orthorectified aerial photograph as the base image. Portions of these aerial photographs are discussed in the textbook's Chapter 1 (Figures 1-5 and 1-9), Chapter 2 (Figure 2-20 and Plate 4), and Chapter 7 (Plate 25). Both aerial photographs are in the **Lab_6_Data** folder.

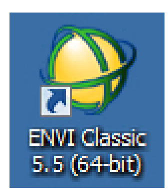
ENVI uses the term "Registration" for georeferencing. The new "GIS-look" ENVI provides a workflow wizard to simplify the process.

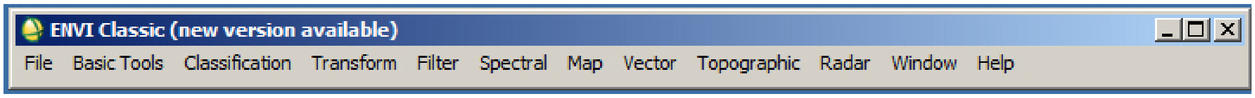


However, I was unable to make the ENVI Wizard work properly – it may be a software bug or a conflict with my Windows Operating system? Try the Wizard - it is found in the *ENVI Toolbox*

> Geometric Correction > Registration > Image Registration Workflow

Therefore, the step-by-step guidance in this lab will use the "ENVI Classic" front-end which never fails and is used by power users. The concepts and steps are very similar between the ENVI Classic and the newer "GIS-look" ENVI. The newer ENVI just displays the steps so they are easier to view and more steps are automated.

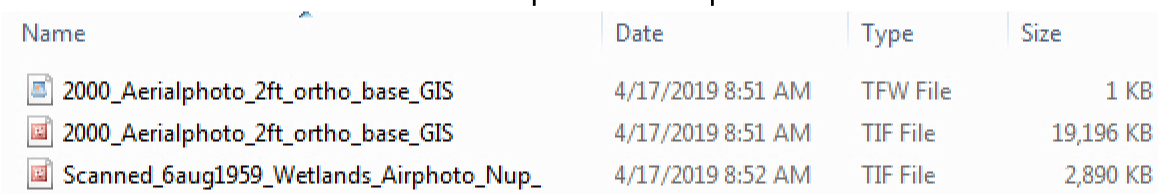




The ENVI Classic toolbar has drop-down menus that replicate the tools in the "newer" ENVI front-end that we have been using for almost all the labs.

Exercise 1. <u>Georeferencing a scanned aerial photograph to an orthorectified aerial photograph.</u>

1) Using your computer's file management system, *Open* the **Lab_6_Data** folder and its subfolder "1_Airphotos" to view the base image and the scanned image. You will see the orthorectified base image – it is a .tif file with the coordinate information in the .tfw file. Double-click on the .tfw file and open with simple software that can read .txt files.



Name	Date	Type	Size
2000_Aerialphoto_2ft_ortho_base_GIS	4/17/2019 8:51 AM	TFW File	1 KB
2000_Aerialphoto_2ft_ortho_base_GIS	4/17/2019 8:51 AM	TIF File	19,196 KB
Scanned_6aug1959_Wetlands_Airphoto_Nup_	4/17/2019 8:52 AM	TIF File	2,890 KB

.tfw files are attached to a georeferenced raster .tif with the same name so that essential coordinate information is available when the raster file is loaded into a GIS or image processing system. The .tfw file we will be using looks like this:

```
     0.60959878080000
     0.00000000000000
     0.00000000000000
    -0.60959878080000
577541.25379939040000
4209573.40820061040000
```

The 1st line is the pixel size in the x-direction in meters. The 4th line is the pixel size in the y-direction in meters. The 2nd and 3rd lines document the rotation (if any). The 5th line is the x-coordinate for the center of the upper left pixel and the 6th line is the y-coordinate for the center of the upper left pixel.

NOTE: The .tfw does <u>not</u> tell you the coordinate system which is required by a GIS. Geotiff raster files can have georeferencing information (coordinate system, map projection, ellipsoid, datum, etc.) embedded in their header but if they don't you have to make educated guesses about the geotiff's coordinate system based on the coordinates in lines 5 and 6 of the .tfw file. The guess relies on your knowledge about common coordinate systems used for the geographic area that is being mapped. If you guess correctly, the geotiff will load into the correct location using your geospatial software.

2) We are going to georeference a scanned 1959 aerial photograph to an orthorectified 2000 aerial photograph (this base image has it's map projection as UTM 10N, Datum NAD-83).

First we load these two images in separate ENVI Classic displays.
File > Open Image File Drive to the **Lab_6_Data** folder

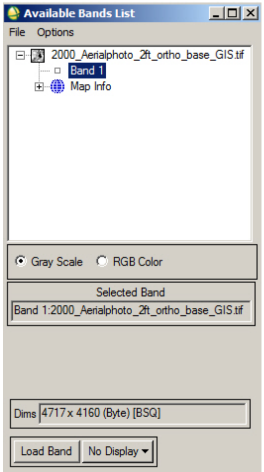
Select "2000_Aerialphoto_2ft_ortho_base_GIS" > *Open*

The "Available Bands List" window pops-up with the base image.

Accept default "Gray Scale"

Click-on "Load Band"

The base image will automatically load into Display #1.

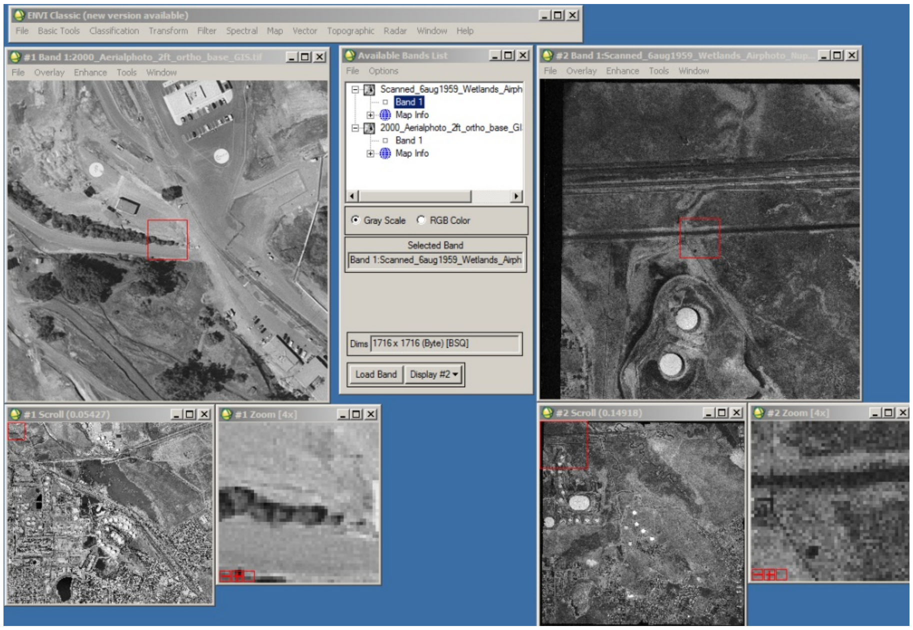


File > Open Image File *Select* "Scanned_6aug1959_Wetlands_Airphoto_Nup_"
The warp image is displayed in the "Available Band List" window.
Click-on "Display #1" drop-down menu > *Click-on* "New Display"
Click-on "Load Band". The warp file will load in Display #2.

Your ENVI Classic set-up should look like the screen-capture below. Each Display has a Scroll window with the entire scene, an Image window with the raster files displayed as 1:1, and a Zoom window. Place cross-hairs in the Zoom window by clicking on the small square with no lines at the bottom left corner of the Zoom window.

Move the red outlined square in the "Scroll" window with your cursor to pan across the scene and look at subareas in more detail in the "Image" window.

Move the red outlined square in the "Image" window to look at subareas in more detail in the "Zoom" window.



3) Before proceeding further it is important that you visually evaluate both images to understand common features between the two images, the extent of overlap, and potential GCP locations on both images. Much development and environmental change has occurred in this area along the Interstate 680 corridor between 1959 and 2000. Look at the four sites listed below for potential GCPs.

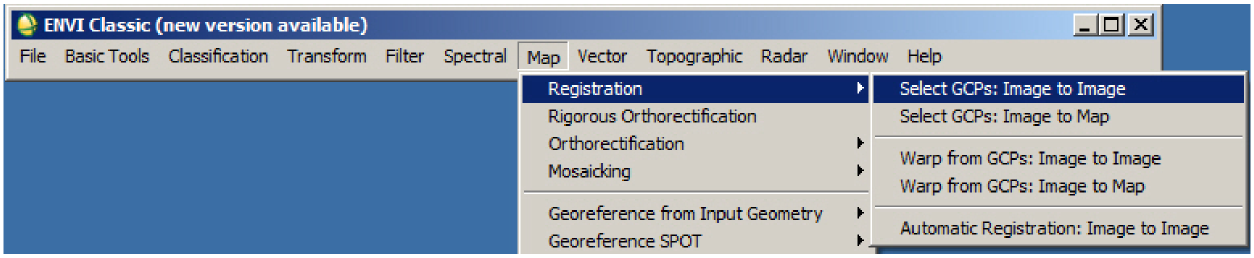
a) Storage tanks associated with a refinery are in both the 1959 and 2000 images. Look for common infrastructure in the two photographs that can be used for an initial GCP (seed-tie-point).

b) You can see a *wetlands* in the upper right portion of the two photographs. Zoom-in to the wetlands in both Views. You can see on the 1959 photograph a straight channel trending NW-SW has been dredged through the meandering stream. In the 2000 photographs remnants of the channels and levees associated with the meandering stream and dredged channel can be seen protruding through the water. The 1959 vegetated wetlands has evolved into a water body – a large pond- by 2000. Look for common features in the two photographs that you can use for an initial GCP (seed-tie-point).

c) Look at the lower right portion of the photographs. You can find common street patterns in the *subdivisions* that you can use for an initial GCP (see-tie-point)

d) Look at the lower left portion of the photographs. You can interpret a *reservoir* with a dock in the 1959 and 2000 photographs that extends into the water body – this is an excellent initial GCP (see-tie-point).

4) Look at the “Registration” options in the ENVI Classic Header Toolbox. (see below)

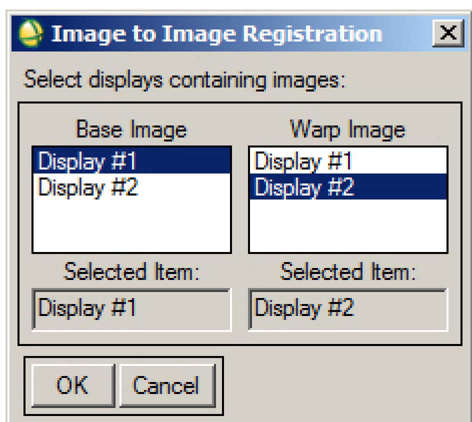


Select GCPs: Image to Image registration means pixels in the input warp image are being georeferenced to pixels in the base image by identifying ground control points (GCPs).

Select GCPs: Image to Map registration means pixels in the input warp image are being assigned coordinates based on visual correlation with the grid on a map.

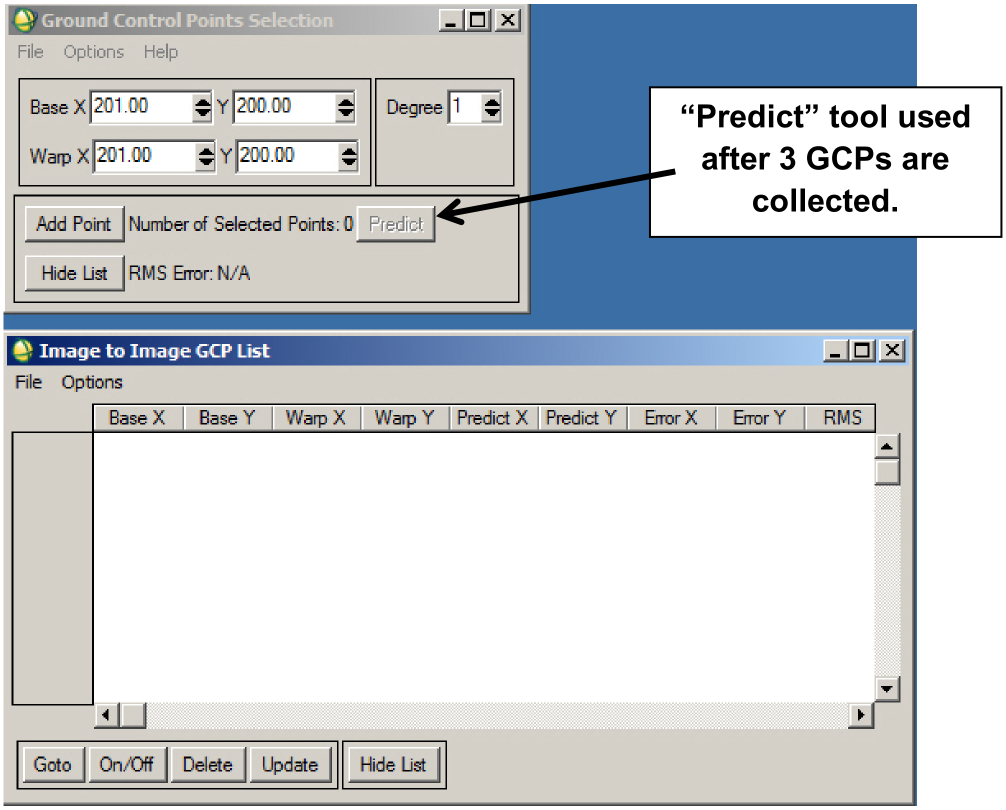
Warp from GCPs means that GCPs are already available and can be applied to a warp image – no need for the remote sensing analysts to pick new GCPs

5) We will select the “Select GCPs: Image to Image” tool from the *Map* > *Registration* drop-down menu. The “Image to Image Registration” window pops up.



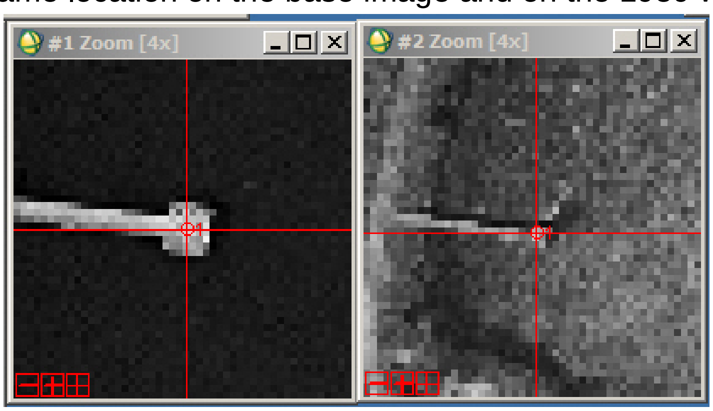
Display #1 has the Base Image. Display #2 has the Warp Image > *OK*

The “Ground Control Points Selection” window pops-up. Press on the “Show List” button in the lower left corner to open up the “Image to Image GCP List” (see below)



6) Now we will start collecting GCPs. You have to collect 3 GCPs before any automated prediction tools can be enabled by the ENVI software. Try to get these first three GCPs (also called "seed tie points) spread over the scene. Pick the GCPs using the Zoom Display and cross-hairs.

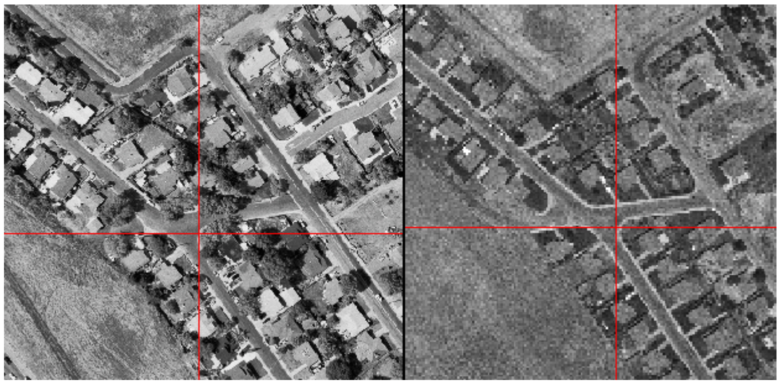
GCP #1: *Zoom-in* to the dock in the reservoir on both photographs (discussed in 3d above). In Display #1 and #2 Zoom windows place the cross-hairs on what you interpret as the same location on the base image and on the 1959 warp image.



If you don't see cross-hairs, *click on* the right "+" icon in the lower left corner of the "Zoom" window.

In the “Ground Control Points Selection” window > *press* “Add Point”. You will see your GCP #1 fills in the first row in your GCP list window.

GCP #2: Pan over the right side of the aerial photographs and find a street pattern that is identical between 1959 and 2000 (3c above). Example below.



GCP #3: Find matching features in the wetlands (3b) or in the refinery (3a).

If you make errors, just delete the GCP in the GCP list and redo the point.

NOTE: Pick GPCs at the <u>base</u> of buildings and tanks. This minimizes location errors. The tops of buildings, oil storage tanks, and tall trees can have significant offset from their location on the ground due to inherent radial distortion from the camera lens.

7) After you have entered the first 3 GCPs, you can take advantage of the “Predict” tool. You select locate a GCP in the base image with your cursor and cross-hairs, *click-on* the “Predict” button on the “Ground Control Points Selection”. ENVI will automatically use the georeferencing information in the first 3 GCPs to predict where the 4th GCP is located in the warp image. To make the location of the predicted GCP more accurate, use your cursor to move the cross-hairs in the warp image to the most correct pixel based on visual comparison of the feature in the base and warp images. After you correct the predicted GCP in the warp image > *Add Point*.

8) The rest of the GCPs that you select should be spread evenly around the warp image to ensure a more accurate georeferencing of the warp image to the base image. This is a good time to review the Georeferencing discussion in the textbook’s Chapter 9.

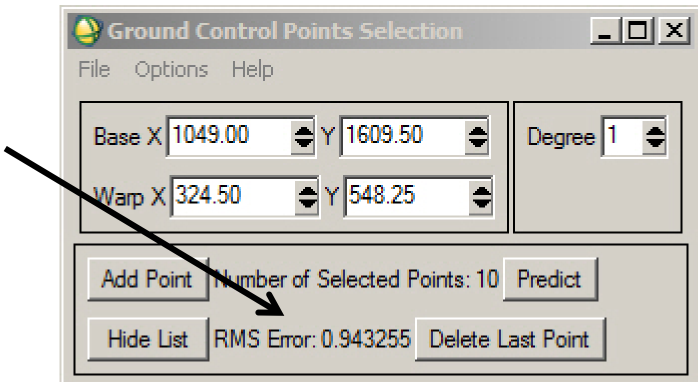
Question 1: Why should you have your GCPs distributed across the warp image and not confined to one corner or arranged along a line?

NOTE: Anytime you get confused, *click-on* **Help** in the ENVI Classic toolbar, open the Index tab, and type “Registration” in the “Search Index” window.

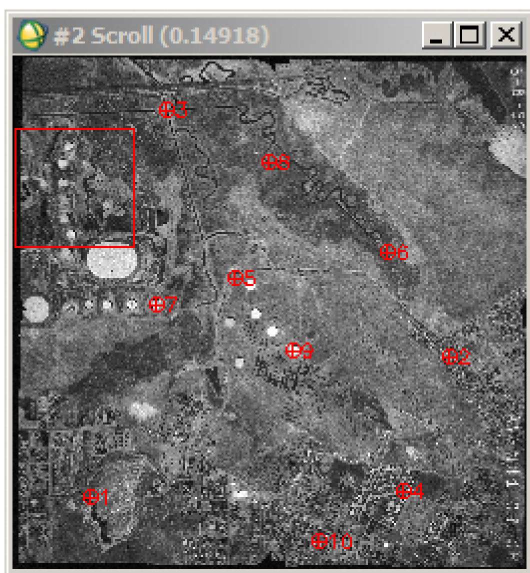
9) After you pick your 5th GCP, the GCP list fills in the cells for C and Y Error and the RMS error (root mean square). You try to minimize the RMS error by adding more and better points that are spread across the image and by deleting GCPs that have excessive error.

To see the RMS error listed in order, in the "Image to Image GCP List" *click on* the "Options" button and click on the "Order Points by Error". The GCPs will be listed in the table with the GCPs with the largest error at the top.

To see the overall RMS Error, look at the "Ground Control Points Selection" window.



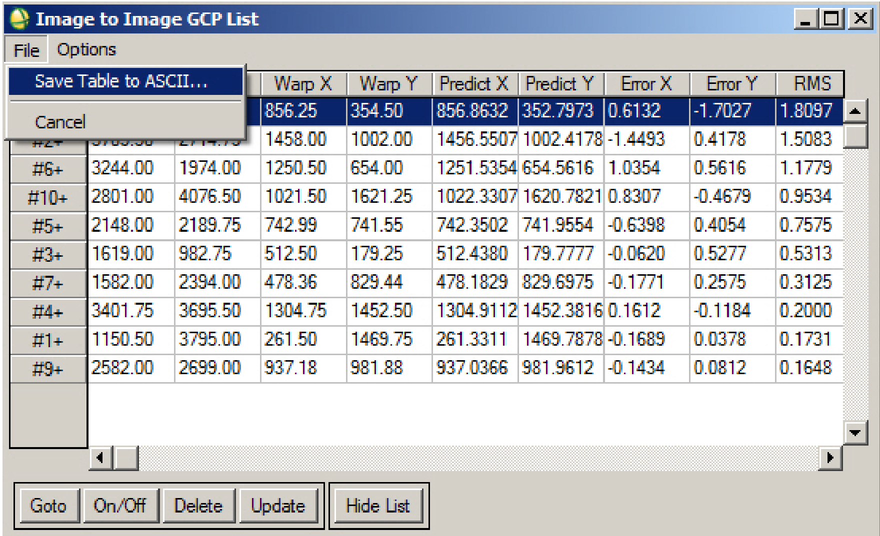
10) Pick 10 GCPs distributed across the warp image. It is very difficult to find any control in the northeast portion of the 1959 aerial photograph. See example below of 10 GCPs posted on the 1959 warp image.



Your final table should look something like this (see next page). To save your GCPs,

File > Save Table to ASCII…

Name the GCP file “1959_10pts”



			Warp X	Warp Y	Predict X	Predict Y	Error X	Error Y	RMS
[illegible]	[illegible]	[illegible]	856.25	354.50	856.8632	352.7973	0.6132	-1.7027	1.8097
[illegible]	[illegible]	[illegible]	1458.00	1002.00	1456.5507	1002.4178	-1.4493	0.4178	1.5083
#6+	3244.00	1974.00	1250.50	654.00	1251.5354	654.5616	1.0354	0.5616	1.1779
#10+	2801.00	4076.50	1021.50	1621.25	1022.3307	1620.7821	0.8307	-0.4679	0.9534
#5+	2148.00	2189.75	742.99	741.55	742.3502	741.9554	-0.6398	0.4054	0.7575
#3+	1619.00	982.75	512.50	179.25	512.4380	179.7777	-0.0620	0.5277	0.5313
#7+	1582.00	2394.00	478.36	829.44	478.1829	829.6975	-0.1771	0.2575	0.3125
#4+	3401.75	3695.50	1304.75	1452.50	1304.9112	1452.3816	0.1612	-0.1184	0.2000
#1+	1150.50	3795.00	261.50	1469.75	261.3311	1469.7878	-0.1689	0.0378	0.1731
#9+	2582.00	2699.00	937.18	981.88	937.0366	981.9612	-0.1434	0.0812	0.1648

11) As noted in the Chapter 9 “Georeferencing” section, it is often best to apply a first-order (linear) polynomial transformation to digitally georeference your warp image into the map projection of your base image. First order cannot bend the warp image – it can only change the location, scale, and skew of x and y and rotate the image. You only need 3 GCPs to do a first-order transformation, but typically one would use at least 8 GCPs.

2nd order (parabola) transformations can bend the warp image. This can cause pixels on the margins of your warp image to be digitally “rubber sheeted” far away from their true location. A 2nd order transformation can minimize the radial distortion caused by the camera lens if the GCPs are well distributed and there is minimal topographic relief. You need 6 (9 with some software) GCPs to do a second-order transformation, but 12 or more is preferred.

On the upper right corner of the “Ground Control Points Selection” window is a “Degree” window. “1” means 1st order (linear) warp – and the total RMS Error is posted at the bottom of this menu. Change the “Degree” window to “2” and you will see the RMS Error changes. A reduced RMS Error for 2nd degree compared to 1st degree does not mean the warped image will look better – there may be significant errors away from the GCPs along the margins of the warp image.

For this exercise we will use a 1st degree (linear) transformation.

12) In the “Ground Control Points Selection window”, *click-on Options > Warp File* The “Input Warp Image” window pops-up. *Select* the 1959 warp air photo > *OK*

The “Registration parameters” window pops-up. *Choose* “Resampling” as *Bilinear*
See textbook Chapter 9 for discussion of resampling

Nearest neighbor: retains spectral information in pixels, but is blocky.

Bilinear: uses DNs from 4 pixels in base image to assign DN to the corresponding warped image pixel. Smoother appearance than with nearest neighbor resampling.

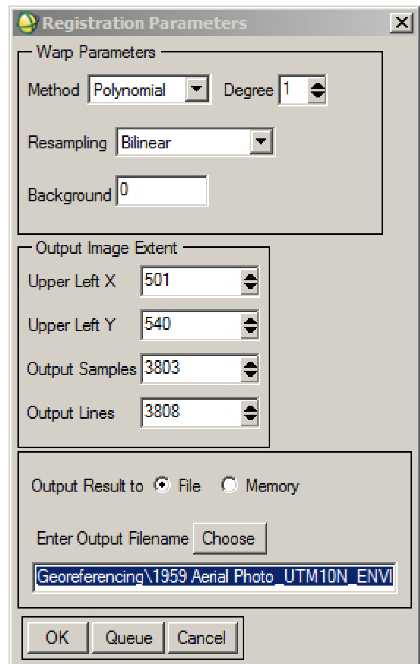
Cubic convolution: uses DNs from 16 pixels in base image to assign DN to the corresponding warped image pixel. Smoothest appearance for the warped image.

Accept defaults – Polynomial and 1st degree.

Change Resampling to Bilinear

Name the warped file
“1959_Aerial_Photo_UTM10_ENVI”

> OK



13) The warped image is resampled to the pixel size in the Base image – 0.6 m or 2 feet. The original 1959 scanned air photo was 1716 x 1716 in size. The georeferenced 1959 air photo is ~3808 x 3808 in size.

To see metadata on files, use the ENVI Classic Toolbar
> File > Edit ENVI Header and select the file of interest.
Double-click on the file and more information is revealed.

14) The 1959 warped air photo is listed and highlighted at the top of the “Available Band List”. Select “New Display” and press “Load Band”. The georeferenced 1959 air photo will be in Display #3.

15) So the warped air photo is useful for GIS, CAD, and other geospatial programs we will save it as a geoTIFF.

Display #3 > File > Save Image As > Image File >

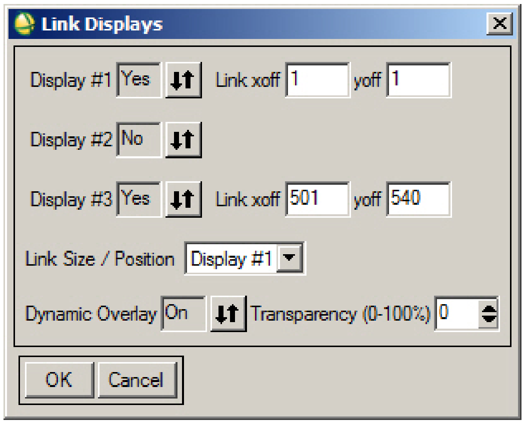
The Output Display to Image File window pops-up

Ensure Resolution is “8 bit (gray scale)
Change Output File Type to “TIFF/GeoTIFF”
Name the file **“YourName_1959_Aerial_Photo_GIS”**

Upload the georeferenced 1959 air photo to the instructor

A geoTIFF file will *not* automatically display in the “Available Band List” menu.

16) To visually evaluate how good your georeferencing was, let’s link Display #1 (Base Image) and Display #3 (georeferenced image).
Display #1 > *Tools* > *Link* > *Link Displays*
The “Link Displays” window pops-up.
Change Display #2 to “No” (see below) > OK



Roam around using the square box in the Scroll Window of either Display #1 or Display #2. Appreciate the incredible development and environmental change in this area during the late 20th century!

17) With the “newer” GIS-look ENVI front end, you can load the two georeferenced images into one view and use *Swipe* or *Flicker* to compare and note changes.

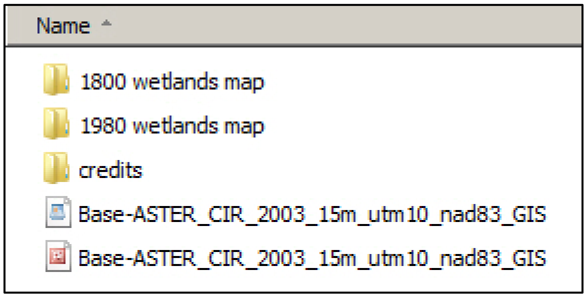
If you access to a GIS, load the two georeferenced images and open streaming vector and raster base maps to compare your georeferenced air photos with what is available online.

18) Now that you have completed one cycle of the ENVI Classic georeferencing workflow, let’s try another georeferencing exercise using a 15 m ASTER satellite image and non-georeferenced jpgs of scanned 1980 wetland and 1880 interpreted wetland

maps of the Suisun subregion, California created by the San Francisco Estuary Institute as documented below:

Production:
Science coordination, GIS and Map Design by the San Francisco Estuary Institute
Richmond, California http://www.sfei.org EcoAtlas 1.50 ©1997 SFEI

19) Using your computer's file management system, *Open* the **Lab_6_Data** folder and its subfolder named "2_ASTER_Maps" The contents are shown below:



The ASTER will be the Base Image. The 1980 and 1880 SFEIs maps are the Warp Images. We'll start our ENVI Classic georeferencing effort with the ASTER and the 1980 map of the wetlands.

20) First we close the airphoto displays. "Available Band List" > *File* > *Close All Files*

Next we load these two images in separate ENVI Classic displays.
File > *Open Image File* Drive to the **Lab_6_Data** folder

Select "Base-ASTER_CIR_2003_15m_GIS.tif" > *Open*
Load the color image into Display #1.
ENVI *automatically* loads the three bands of the color IR satellite image.

NOTE: The band sequence (R-G-B) is interpreted correctly by ENVI if the vegetation is red in the color image in Display #1. If vegetation is bluish, the sequence of bands in the ASTER geoTIFF is different from what ENVI expected, and you have to manually correct the loading of the ASTER bands to make the vegetation red.

Next *Select* "1980_SFEI_map.jpg" > *Open*
Change "Display #1" in the lower right corner to "New Display"
The SFEI map is in Display #2.

21) Roam around the image and map and look for potential GCP points. Railroad and road track intersections and other man-made infrastructure are good candidates for GCPs. Look at the legends in the 1980 and 1880 folders to understand the symbology on the SFEI maps.

22) Start the georeferencing process.

ENVI Classic Toolbar > Map > Registration > Select GCPs: Image to Image

ENVI georeferences the warp 1980 map as an ENVI file. Let's save your georeferenced 1980 wetlands map as a .tif

Display #3 > File > Save Image As > Image File >

The Output Display to Image File window pops-up

Ensure Resolution is "24-bit Color (BSQ)
Change Output File Type to "TIFF/GeoTIFF"
Name the file **"YourName_1959_Aerial_Photo_GIS"**

Name "Your name_1980_SFEI_GIS.tif"

23) Open the georeferenced 1980 map (base image) and the 1880 interpretation map (warp image) in separate Displays.

Question 2: Why did we georeference the 1980 map to the 2003 ASTER image first – and then georeference the 1880 map to the georeferenced 1980 map. (Hint: think about dates of the three files and look at the features (roads and railroads) common to the two SFEI maps).

Load the georeferenced 1980 in Display #1 and the scanned 1880 jpg map in Display #2. Repeat the georeferencing workflow.

When done, save your georeferenced 1880 interpreted wetlands map as a .tif

Name "Your name_1880_SFEI_GIS.tif"

24) If you have access to a GIS, load the ASTER, 2000 orthorectified air photo, georeferenced 1959 air photo, georeferenced 1880 wetlands map, and georeferenced 1980 wetlands map into the GIS.

You have created something new. These georeferenced images and maps can be uploaded into Google Earth, ESRI ArcGIS Globe, or any geospatial software system.

Lab 6 Georeferencing **Name:**

Upload the following files to your instructor:

(15) "YourName_1959_Aerial_Photo_GIS" .tif

(22) "Your name_1980_SFEI_GIS" .tif

(23) "Your name_1880_SFEI_GIS" .tif

Question 1: Why should you have your GCPs distributed across the warp image and not confined to one corner or arranged along a line?

Question 2: Why did we georeference the 1980 map to the 2003 ASTER image first – and then georeference the 1880 map to the georeferenced 1980 map. (Hint: think about dates of the three files and look at the features (roads and railroads) common to the two SFEI maps).

Lab 7 DEMs and Lidar

Utilizes Textbook's Remote Sensing Digital Database: Chapter 7 data.

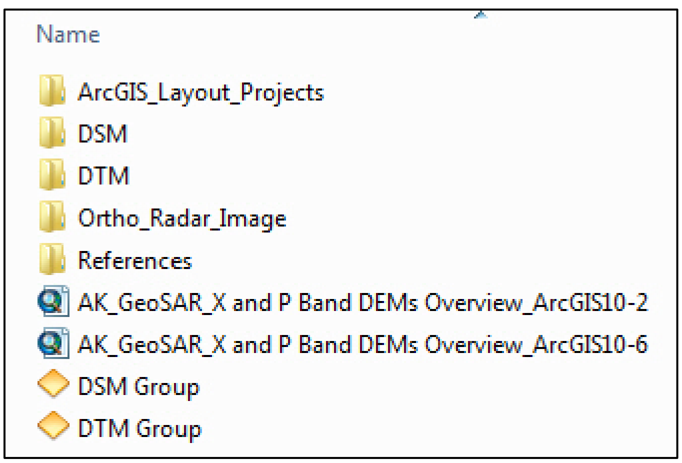
The objectives of this lab include enhancement of DEMs generated with radar and lidar using image-processing tools and visualization to improve understanding of the models. **ENVI Toolbox** contains the tasks that we will use for this lab. A short video for the lidar section that reviews the tools in the new ENVI LiDAR display is in the **Lab_7_Data** folder

Two digital files are to be uploaded to the instructor and ten questions are to be answered on the final pages of this handout.

Radar DEMs

1) Airborne L-band and P-band radar were flown over the Fairbanks, Alaska area to generate a Digital Surface Model (DSM) and a Digital Terrain Model (DTM). See discussion in the textbook Chapter 7. The data are located in the Remote Sensing Digital Database \ Ch_7_DEMs in the Chapter 7 folder. The path is:

Plate 23 P-and X-band GeoSAR_AK \
GeoSAR_DSM-DTM_ \ DSM, DTM, and Ortho_Radar_Image folders



Subfolders in "GeoSAR_DSM-DTM_" folder

2) Review the "READ ME…" pdf in the "Plate 23 P-and X-band…" folder. The READ ME file provides an overview of the technology applied and examples from the textbook of final products that can be generated with remote sensing and GIS software.

3) Open the newer ENVI "GIS-look" program > *File* > *Open* >

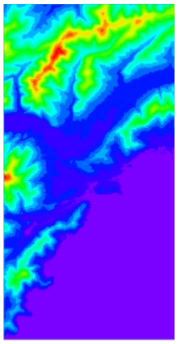
drive to the "Ortho_Radar_Image folder and *select "ORI_N6445W14800.tif"* > *Open*

> *Zoom to Full Extent* Fairbanks is on the East side of the image, North of the Chena River.

Question 1: A. In which direction is the radar beam pointing (N, S, E, or W)?

B. Why does the river south of Fairbanks have a very dark?

4) **DSM:** *Open* the DSM folder and load "DSM_N6445W14800.tif" into the View.
Right-click on this DSM layer in the Layer Manager > Quick Stats
The "Statistics View:…." window pops-up.
In the upper left, *Select Plot > Histogram Plot 1*



Question 2: What is the minimum elevation of this DSM?

4a) ENVI Toolbox > Classification > Raster Color Slices
Select the DSM in the "Data Selection" window >
Accept Defaults: 16-slices, rainbow color scheme > *OK*

4b) *ENVI Toolbox > Terrain > Create Hill Shade Image*
Select the DSM in the
"Select Hill shade Input DEM File" window > OK
The "Hill shade Image Parameters" window pops-up
Enter "25" for Sun Elevation Angle
Enter "270" for Sun Azimuth Angle
Select "B-W LINEAR" for Color Table to Apply
Change "Stretch" to "0.0" (no stretch applied)
FileName: "YourName_DSM_hs_ENVI" > *OK*

The hill shade DSM displays in the View. *Zoom to Full Extent*
Zoom-in and *pan* around

Question 3: What natural and man-made features are generating the surface on the DSM? (Hint: Turn off all layers in the Layer Manager except the hillshade DSM and the ORI radar image. Turn the top layer on & off to identify features.)

Turn on the Raster Color Slice layer in the Layer Manager. If your hillshade DSM is above this layer in the Layer Manager, use the Transparency Tool to fade the hillshade DSM so the color on the DSM can be seen.
Zoom-in to an area of interest.
Type in the scale 1:25,000 (near the top-center of the ENVI display window)

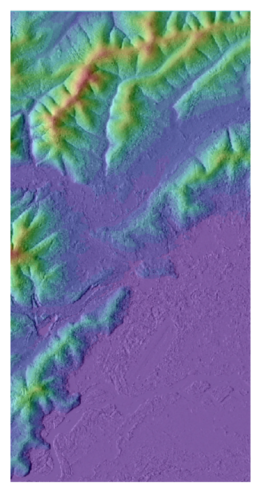
Let's save a jpg of the enlarged area (this display) for the instructor

File > Chip View To > Image
The "Chip to File Parameters" window pops-up.
Choose Output Format "JPEG"
Name the file "YourName_color-coded_25K_DSM"
Don't "display result"   We will look at the jpg outside of ENVI.

Open up your jpg. Is the quality acceptable? What's missing? Where's the scale bar, legend, coordinate grid – essential cartography elements for GIS and map-making? This is just a picture – it has very little value in the real world.

The new ENVI GIS-look front end seemingly cannot attach cartographic elements to exported images – unless you start ENVI in 32-bit mode and have an ArcGIS license…? That is not good – if this is true and there is no work-around. You can create and export images with scale, coordinate grid, N-arrow, logos, text boxes, and other cartographic elements using the older ENVI Classic and the "QuickMap" tool.

Going forward, if you use this new ENVI front end, Export your enhanced imagery and DEMs in the geoTIFF format so you can use GIS software to add symbology and critical cartographic elements.



4d) Let's create a 3D Surface View with our color-coded hill shade DSM (displayed here).

BUT first, the two files are separate in the color-coded, hillshade DSM – 1) the faded grayscale hillshade and 2) the 16-slice color DSM.

We need to <u>combine</u> these two images into one so we can use the 3D Surface View (and other visualization software).   The combined color-coded hill shade image will be draped over the DEM to enable perspective 3D viewing.

To combine the full scenes of the two files that we see on the screen into one raster image file we should "Zoom to Full Extent" to see what is going to be saved.
File > Export View To > Image File
The "Export View to Image File" window pops-up.
We want the Full scene, so click the button next to "Full"

Note the pixel size is the original data size, the Zoom Factor is 1.0000
We can output in ENVI format for this exercise.
Name the Output file: “hs_with_color-coded_DSM_ENVI” *> OK*

The “hs_with_color-coded_DSM_ENVI” image is displayed in our View.

4e) Now we can use the ENVI visualization tool!

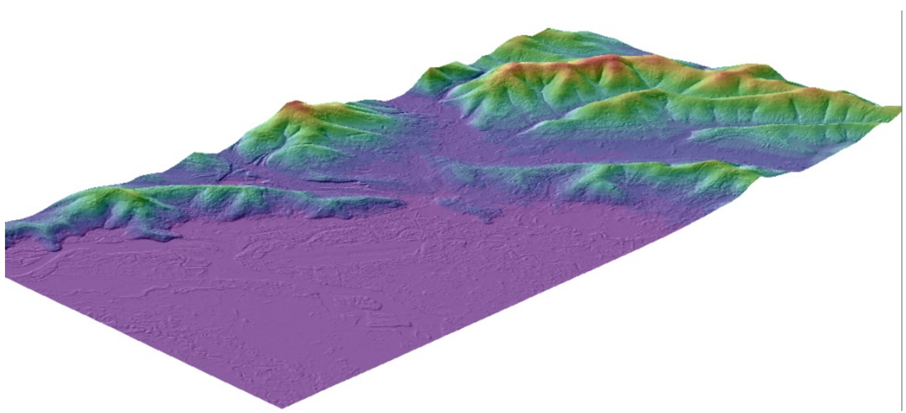
ENVI Toolbox > Terrain > 3D Surface View
The “Select 3D SurfaceView Image Bands…” window pops up

Sequentially select Band 1, Band 2, Band 3 that make up the “hs_with_color-coded_DSM_ENVI” color image so that the R, G, B buttons are filled in the correct sequence in the” Available Bands List” menu. *> OK*

Next we select the “Associated DEM Input File”.
Select > “DSM_N6445W14800.tif” *> OK*

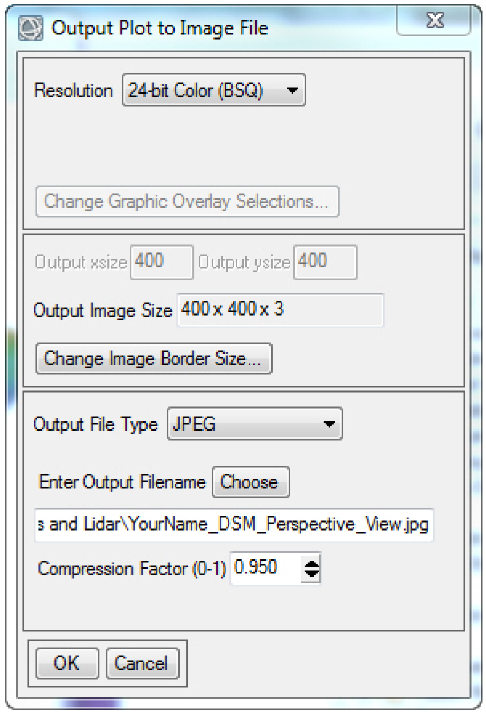
The “3D SurfaceView Input Parameters” window pops-up.
Click on “512” and accept the other defaults *> OK*

The 3D SurfaceView display pops-up with your color-coded, hill-shade DSM with 5X vertical exaggeration draped on the DSM. Many options are available in this display, including saving the surface view as a VRML file.



Let’s show this to the instructor. In the “3D SurfaceView” display,
File > Save Surface As > Image File
The “Output Plot to Image File” window pops up (see next page).

We want a color jpg of this perspective view so we set <u>Resolution</u> as “24-bit Color (BSQ)”, <u>Output File Type</u> as “JPEG”, and <u>Compression Factor</u> as “0.95”



Name the jpg "YourName_DSM_Perspective_View" > *OK*

Upload to the instructor.

Close the "3D_SurfaceView" window.

5) **DTM** Let's compare the DTM to the DSM. *Views > Two Vertical Views*

Activate View 2 by *clicking on* the empty View 2.

File > Open drive to the "DTM" folder. *Select* "DTM_N6445W14800.tif" > *Open*
Zoom to Full Extent.

5a) *ENVI Toolbox > Terrain > Create Hill Shade Image*
Select the DTM in the "Select Hill shade Input DEM File" window > OK
The "Hill shade Image Parameters" window pops-up
Enter "25" for Sun Elevation Angle
Enter "270" for Sun Azimuth Angle
Select "B-W LINEAR" for Color Table to Apply
Change "Stretch" to "0.0" (no stretch applied)
FileName: "YourName_DTM_hs_ENVI" > *OK*

5b) *Views > Link Views* "Link Views" window pops-up > *Link All > OK*

We want to use the "Cursor Value" tool to see the elevation at the same pixel on the DSM and DTM.

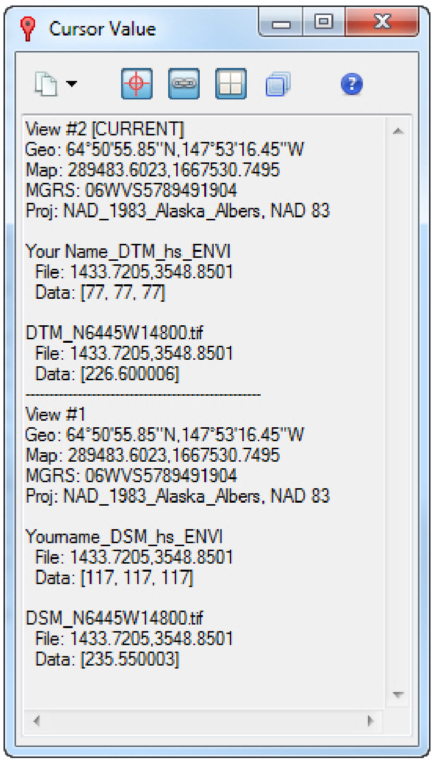
The DTM and hillshade DTM and the DSM and hillshade DSM should be turned on in the Layer Manager. Un-check all other files.

5c) In the Cursor Value menu,

press "Link Views" button and

press "Display Information for all Views" button.

Now you should see the elevation in the DTM and DSM appear in the Cursor Value window.



DTM elevation is here (226.6 m)

DSM elevation is here (235.6 m)

Question 4: A. what is the DTM and DSM elevation at the airport runway?

B. What is the elevation of the DTM and DSM about 3.5 km NW of the airport runway, along the crest of the ridge?

C. What causes the DSM and DTM to have different elevations along the crest of the ridge about 4 km NW of the airport runway?

D. Why was one radar wavelength used primarily for the DSM and the other radar wavelength used to generate the DTM?

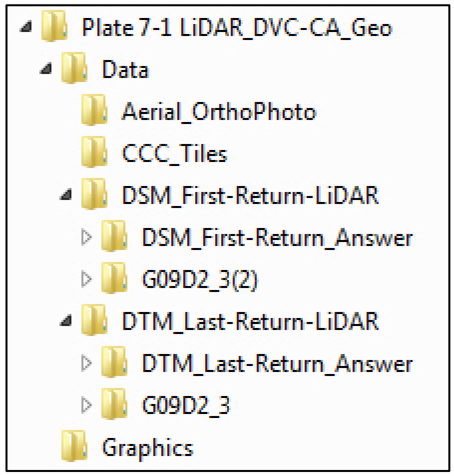
<u>Lidar</u>

6) Let's start over with a new ENVI Display. *File > Exit* to close the Radar DEMs

Using your computer's file management system,

Open the Remote Sensing Digital Database and then open the subfolder "Ch_7_DEMs". There are five DEM examples in this folder. We are going to use the lidar data in the subfolder "Plates_21-22_ LiDAR_DVC-CA".

(See file structure below)



The lidar data is in standard .las format and is located in the "DSM_First-Return-LiDAR" and "DTM_Last-return-LiDAR" folders. This .las data was processed and converted to geoTIFFs to simplify use in a GIS, CAD, or other geospatial software. These geoTIFFs are located in the "DSM_First-Return_Answer" and DTM_Last-Return_Answer"

A color orthoimage is in the "Aerial_Orthophoto" folder. Open these folders to familiarize yourself with the many files that you will be working with in this lab. Many of the files are intermediate forms that were generated by ENVI, ERDAS, and ArcGIS software as the original lidar data was processed.

6a) We will be working with lidar data of a suburban area west of Pleasant Hill, California.

The source of the lidar data is the Contra Costa County 2008 Orthophotographs & Lidar project. Available at: https://gis.cccounty.us/Downloads/Lidar/2008/ the zip is 70 GB!

The lidar and orthorectified image are in the State Plane CA III FIPS 0403 **Feet (US)** NAD-83 Coordinate System.

6b) Start up a new ENVI Display. *File > Open* the orthorectified aerial color image "g09d2_3_color_mar-apr2008_1meter" > *Open*

> *Zoom to Full Extent*

Review what and where the land cover/land use features are in this area, including single family dwellings, golf course, non-irrigated grass-covered terrain, a road network with many curves, etc.

6c) Now we will review the metadata associated with the .las lidar files
ENVI Toolbox > *LiDAR* > *View LAS Header*
Drive to the "Data" folder and *open* the "DSM_First-Return-LiDAR"
Select "G09D2_3(2).las" > *Open*
Examine the metadata in the header.

Question 5: A. What is the minimum and maximum elevation (Z) in the DSM?

ASPRS helped establish standards for lidar data. The points are classified into 9 categories as shown below. However, the metadata for our dataset lacks this classification as it notes with "0" that the lidar points were "Created, never classified"

ASPRS Standard LIDAR Point Classes

Classification Value	Description
0	Created, never classified
1	Unclassified
2	Ground
3	Low Vegetation
4	Medium Vegetation
5	High Vegetation
6	Building
7	Low Point (noise)
8	Model Key-point (mass point)
9	Water

Portion of the metadata for our lidar data

```
Points by Return [   1]    0
Points by Return [   2]    0
Points by Return [   3]    0
Points by Return [   4]    0
Points by Return [   5]    0
```

Now we will look at the metadata for the DTM.
ENVI Toolbox > *LiDAR* > *View LAS Header*
Drive to the "Data" folder and *open* the "DTM_First-Return-LiDAR"
Select "G09D2_3.las" > *Open*
Examine the metadata in the header.

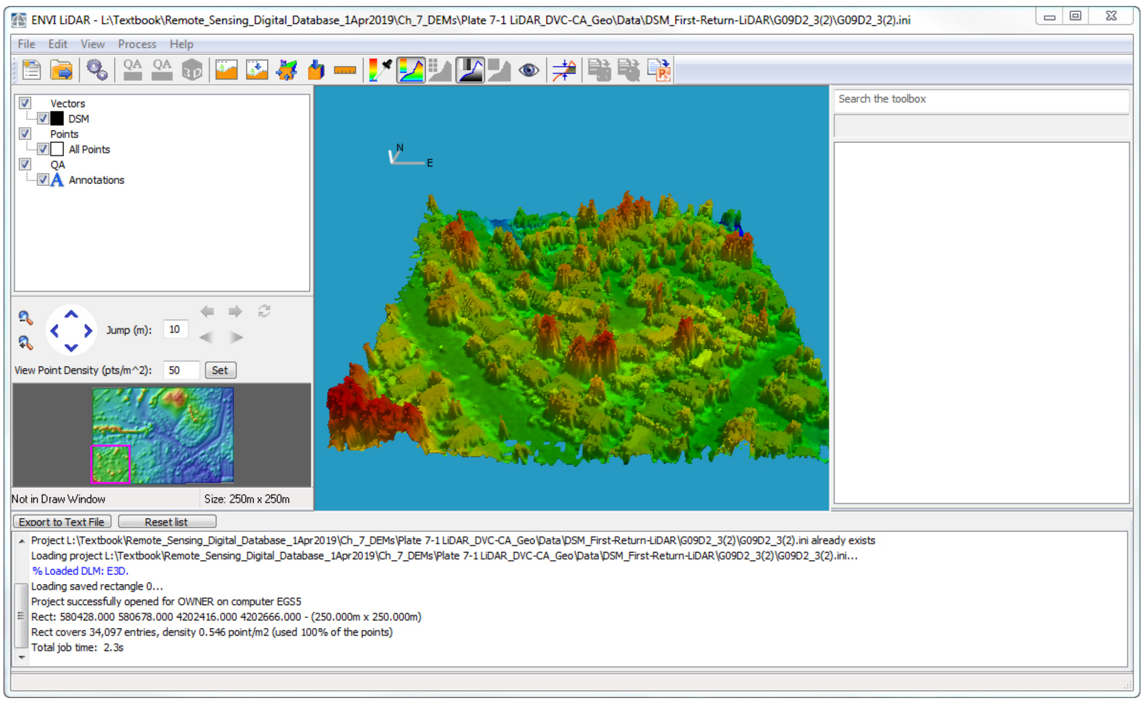
Question 6: A. What is the minimum and maximum elevation (Z) in the DTM?

B. How many lidar points are in this DTM data set?
(NUM_POINT_RECORDS)

6d) Now we will switch to a new display ENVI has created to view and interact with lidar data. A 9-minute video is included in the **Lab_7_Data_Video** folder that provides an overview of the ENVI LiDAR tools and display options to help you be more efficient working your way through the lidar portion of this lab.

ENVI Toolbox > LiDAR > Launch ENVI LiDAR
We will first load the DSM into this view. *File > Open Select* "G09D2_3(2).las" > *Open* You should see this display. The DSM is displayed as a "Solid" surface.

In the layer manager, right-click on "DSM" > *change* to "Wireframe"
Zoom-in until you see clearly see the the 1 meter grid.
In the layer manager, right-click on "DSM" > *change* to "Solid" *Zoom-out*

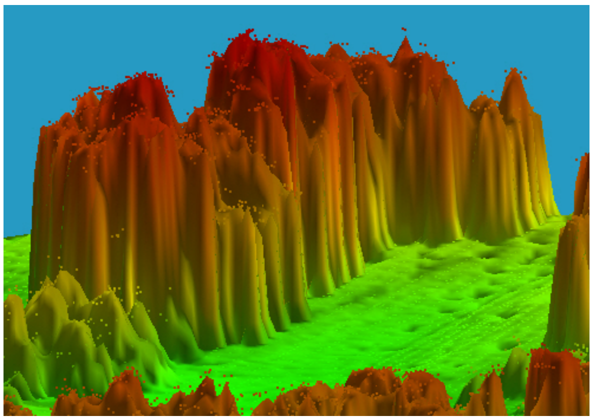


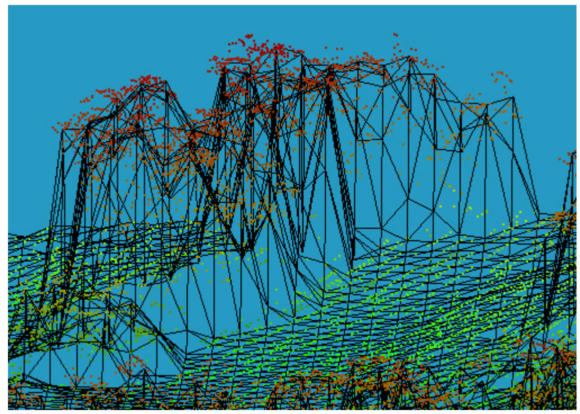
The window at the lower left shows the extent of the entire DSM. It has a rectangular outline that shows what portion of the DSM is shown in the main display. Use your cursor to *draw* an outline around the entire thumbnail image (approximately 918 x 616). The entire DSM is shown in the main display.

6e) Interrogate the drop-down menus and the ribbon of icons across the top of the ENVI LiDAR window. We'll activate a few of them.

View > Height Legend (note the units are in meters!)
Help > Help Contents (very useful to read before proceeding too far)
Reset Perspective View icon > *Move your mouse around to rotate and tilt the model*

Zoom-in on the grove of trees along the top margin of the DSM. *Change* the rendition of the model between Wire Frame to Solid (see below)





Question 7: A. Why do the trees have elongated, near-vertical sides around the extent of the tree canopy?

B. What do the red dots at the top of the canopy represent?

Reset Isometric View icon > *Click on* the model in the display *and roll your mouse wheel to zoom in and out.*
> *Click on the left and right buttons on your mouse and pan around the model.*

Reset Isometric View icon > *Click-on* the *Select Cross Section* icon.
Move your cursor to the bottom margin of the model, *click once* and move your cursor to the top of the model and *click once* to generate a N-S cross section.

7) A "Cross Section" window pops-up at the bottom of the ENVI LiDAR window. We'll interact with a few of the tools at the top of the display.

Often the width of the window automatically becomes too large. At the upper right of the “Cross Section” display is “Thickness (cm):” Change to “500”.

The “Movement” tool has up-down arrows. The default value seems to be “100”. *Clicking* on the arrows moves the cross section in a direction perpendicular to the cross section. Increase number to “500” and the cross section moves in larger increments.

The “Angle” rotates the cross-section. Increasing the number from the default of “1.000” moves the cross section in larger increments.

“Reset Position” places the cross section back to its original position (maybe? To the bottom margin of the DSM...). Click the “Movement” Arrow to move the cross section across the model at intervals of “500”.

You can *zoom* into a feature of interest in the cross section with your mouse wheel.

Question 8: What features do you see on the DSM cross section as you traverse the model? (refer to the orthophotograph in the ENVI window that we opened first)

8) Click on the “Measurement Tool” icon (a ruler) in the ENVI LiDAR window. *Measure* the height of some of the trees in the “Cross Section”.

Question 9: What is the height (in feet) of the tallest tree that you measure?

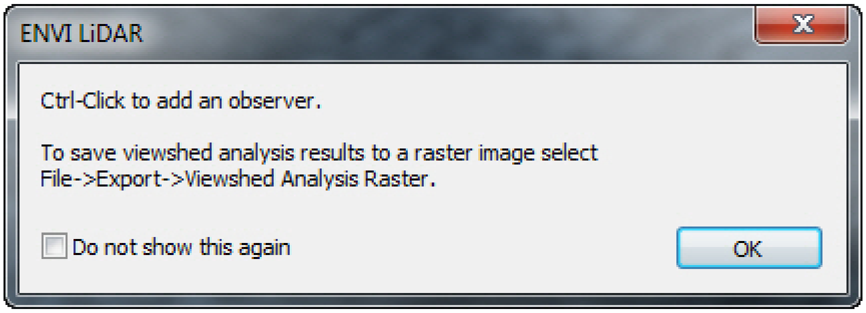
To remove the white banners with the XY and Z elevation at the measurement sites > *Right-click* on the white banner > *Delete Annotation*
To remove the Cross Section vector lines on your ENVI LiDAR display, close (X) the Cross section display.

9) The last DSM exercise will use the “Color by Viewshed Analysis” icon in the upper ribbon of the ENVI LiDAR menu.

Viewshed analysis is widely used to evaluate the visual impact to a person standing at a specific location of existing land cover/land use features, new construction, proposed logging, new hedgerows or barriers to “hide” infrastructure, etc.

Ensure you are zoomed-out so the entire DSM is displayed (use thumbnail tool in lower left corner)

Click-on the “Color by Viewshed Analysis” icon. Instructions pop-up.

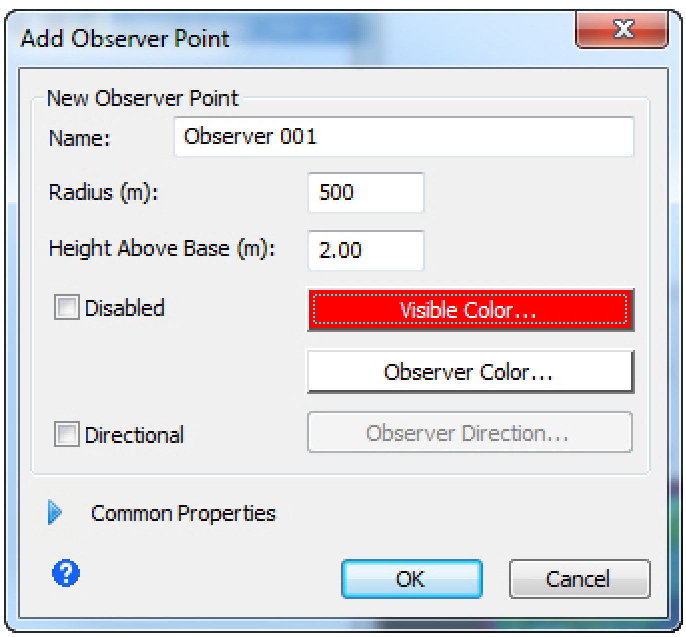


> *OK*

The DSM turns into a grayscale image.
Move your cursor to the southern slope near the top of the hill in the north margin of DSM. (imagine you are hiking up the slope toward the crest and turn around – what do you see?)

Ctrl-Click at the site for the Viewshed Analysis

Those features that you can see from this site are displayed in green (maybe). The Add Observer Point menu pops-up. *Change* Radius to “500” and Visible Color to “Red” > *OK*



The pop-up instructions above tell us how to export this analysis.

File > Export > Viewshed Analysis Raster

This Export option did not allow me to name the file, or to direct it to a specified folder…maybe you can figure out how to make the export work for you…

I'm just going to do a simple screen capture of my Viewshed perspective view using the ENVI LiDAR *File > Screenshot to Powerpoint > Save As*

"LastName_DSM Viewshed"

(If you don't have Microsoft Powerpoint software on your computer, just take a screen capture of your viewshed DSM and save it as a jpg)

Upload this graphic to the instructor.

10) We'll next look at the DTM. *File > Open* > "G09D2_3.las" *> Open*
The DSM disappears. The DTM is loaded into the display.
In the Thumbnail display of the DTM (lower left corner), *draw* a large rectangle over the East half of the DTM so you capture the red hill and dark blue terrain.

The ENVI LiDAR can only display a 2000 x 2000 area on the main display. *Accept* the program's redrawn area.

The ENVI LiDAR program displays the DTM, but in the Layer Manager it is labelled as "DSM". The software cannot identify the type of DEM being loaded.

Right-click on "DSM" in the Layer Manager and alternate between Solid and Wire Frame. *Zoom in* to see the level of detail in the DTM.

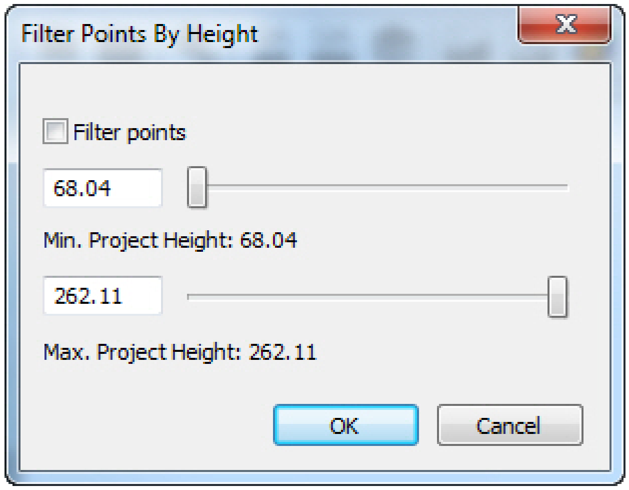
If you see a grayscale DTM in the display, *click on* the Height Palette Editor" icon and load the "Rainbow" palette (lower left corner of the menu)

Note the flat pads that have been constructed for the suburban homes with cut and fill on the sloping terrain.

Notice how the trees in the DSM have been removed from the hill in the north portion of the DTM model.

Display the "Solid" model. Click-on the "Reset Perspective View" icon.

Click on the "Filter Points By Height" icon. (see below)



Move the "Minimum (Min.) Project Height" slider to the right.
Set your minimum height at "100.00" *> OK*

Question 10. What are you simulating by raising the minimum height on the DTM?

Lab 7 DEMs and Lidar Name:

Upload the following files to the instructor:

(4) "YourName_color-coded_25K_DSM" jpg

(4) "YourName_DSM_Perspective_View"

(9) "LastName_Viewshed" Powerpoint, jpg, or other format.

Question 1: A. In which direction is the radar beam pointing (N, S, E, or W)?

B. Why does the river south of Fairbanks have a very dark?

Question 2: What is the minimum elevation of this DSM?

Question 3: What natural and man-made features are generating the surface on the DSM? (Hint: Turn off all layers in the Layer Manager except the hillshade DSM and the ORI radar image. Turn the top layer on & off to identify features.)

Question 4: A. what is the DTM and DSM elevation at the airport runway?

B. What is the elevation of the DTM and DSM about 3.5 km NW of the airport runway, along the crest of the ridge?

C. What causes the DSM and DTM to have different elevations along the crest of the ridge about 3.5 km NW of the airport runway?

D. Why was one radar wavelength used primarily for the DSM and the other radar wavelength used to generate the DTM?

Question 5: A. What is the minimum and maximum elevation (Z) in the DSM?

Question 6: A. What is the minimum and maximum elevation (Z) in the DTM?

B. How many lidar points are in this DTM data set?
(NUM_POINT_RECORDS)

Question 7: A. Why do the trees have elongated, near-vertical sides around the extent of the tree canopy?

B. What do the red dots at the top of the canopy represent?

Question 8: What features do you see on the DSM cross section as you traverse the model? (refer to the orthophotograph in the ENVI window that we opened first)

Question 9: What is the height (in feet) of the tallest tree that you measure?

Question 10. What are you simulating by raising the minimum height on the DTM?

Lab 8 RGB-IHS-RGB Transform and Image Sharpening
Utilizes Textbook's Remote Sensing Digital Database: Chapter 4 data.

The objectives of this lab include learning about RGB and IHS (or HSV) color systems, the RGB to IHS to RGB transform, and different techniques for image sharpening. The transform exercise is long & tedious, but it will teach you about different image file types and shortcomings/complicated work-arounds with ENVI software. The tasks are done with tools in the **ENVI Toolbox**.

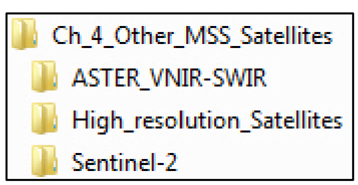
Six questions are to be answered on the last page of this handout and one digital file is to be uploaded to the instructor.

1) <u>RGB-IHS-RGB transform</u>
Chapter 2 discusses the additive and subtractive systems of primary colors Red, Green, and Blue. Chapter 9 discusses an alternative approach to color - the Intensity (Value), Hue, and Saturation system. Figure 9-19 shows the scaling used for the IHS system. IHS is equivalent to HSV (ENVI uses HSV)

Color images often have a pastel appearance because the images are undersaturated. RGB images have their saturation (purity of color) increased by transforming the RGB colors into IHS color space, and contrast-stretching the Saturation grayscale image. After the Saturation image is contrast-stretched, the IHS images are transformed back to RGB colors. See Figure 9-20 and Digital Image 9-1. Edge enhancement and the replacement of the intensity image with the panchromatic band can also be done prior to transforming the IHS images back to a RGB color composite.

We will create an ASTER color IR image from a 9-band ASTER multispectral dataset and contrast-stretch the color IR with a "Linear 1%" stretch.

1a) The 9-band ASTER data set is in the "Remote Sensing Digital Database \ Ch_4_Other MSS_Satellites" folder within the "ASTER_VNIR-SWIR" subfolder.



Start-up ENVI > *File* > *Open* > *drive* to the "ASTER_Geo" subfolder > *select* > "ASTER_2002_Reflectance_30m_9-band_ENVI_.img" > *Open*

Zoom to Full Extent > *Choose* "Linear 1%" stretch. You should see a color IR image displayed in the View. *Click-on* the 9-band file in the Layer Manager to ensure that the Bands 3N-2-1 are loaded into R-G-B. ASTER does not collect a blue band, so Band 3N = NIR, 2 = Red, and 1 = Green.

Highlight the 9-band file in the Layer Manager. We will export this enhanced color IR image using *File > Export Selected Layer to TIFF…* > Name the color IR image "ASTER_CIR_Original" and check "Display result" > *OK*

The exported color IR image should look exactly like the 3N-2-1 as R-G-B color composite made from the 9-band data set.

The Chugwater Redbeds in the Red Rose Anticline appear as yellow rocks in a Color IR image (see Figure 3-11H for location if you forgot)

Uncheck the 9-band dataset in the Layer Manager.

Let's open 4 Views. *Views > 2 x 2 Views*
The 3-band color IR image is in View 1. *Zoom to Full Extent*

Highlight View 2 (empty View in the upper right). This will ensure the IHS (HSV) color composite is displayed in View 2.

1b) First we'll use ENVI's programmed "Saturation Stretch" Tool.
ENVI Toolbox > Transform > *Saturation Stretch*
The "Saturation Stretch Input Bands" window pops up.
Select the 3-bands in our CIR original image as R-G-B > *OK*
Name the output "ENVI_Sat_Str_" > *Open* > *OK*
The ENVI saturation stretched CIR image appears in View 2

Views > Link Views > Link All > OK (empty Views don't link)

Pan and zoom around, comparing the original CIR image to the ENVI saturated stretch image.

Question 1: Discuss the differences in the colors between the original ASTER CIR image and the ENVI saturated stretched CIR image. Do you prefer the "instant" ENVI saturation stretch or your 2% saturation stretch that you created at the end of this exercise? (see page 7 below) WHY?

How was the Saturation enhancement done??? What steps are involved? Next we'll do our own saturation stretch. First we transform our RGB image to IHS (or HSV) color space.

In the Layer Manager, *drag & drop* the "ENVI_Sat_Str" CIR image into View 1 (so we don't get confused later). You can *uncheck* this image in View 1.
Right-click "ENVI_Sat_Str" image in View 2 in the Layer Manager > *Remove*

Highlight the empty View 2 so our IHS image is loaded here.

ENVI Toolbox > Transform > Color Transforms > RGB to HSV Color Transform
The "RBG to HSV Input Bands" window pops-up.
Sequentially *click-on* Band 1 to Red, Band 2 to Green, Band 3 to Blue > *OK*

The "RGB to HSV Parameters" window pops-up.
Select the Original CIR bands 1, 2, 3 as R, G, B > *OK*
Name the file "ASTER_IHS" > *OK*

The HSV color composite displays in View 3. We want to see the individual Hue, Saturation, and Value (Intensity) grayscale images in Views 2, 3, and 4.

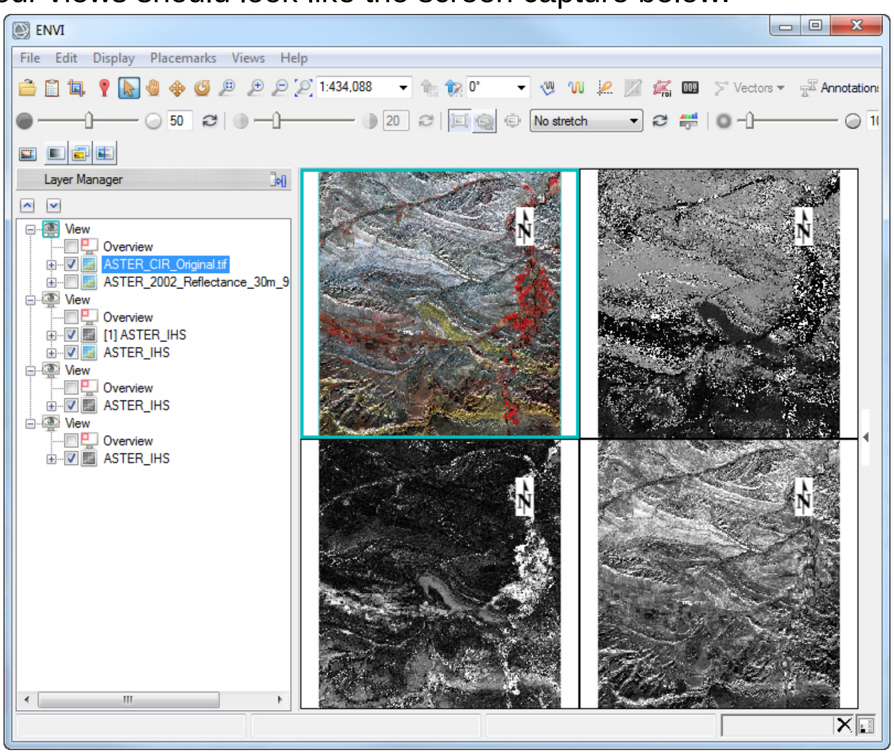
Open the "Data Manager"

The "ASTER_HS" I, H, S grayscale images are at the top of the list.
Highlight View 2
Click-on Hue > Load Grayscale > *Zoom to Full Extent > Linear 1%*

Highlight View 3
Click-on Saturation > Load Grayscale > *Zoom to Full Extent > Linear 1%*

Highlight View 4
Click-on Value (Intensity) > Load Grayscale > *Zoom to Full Extent > Linear 1%*

The four views should look like the screen capture below.



Open the Histogram Stretch icon to the right of the Contrast Stretch drop-down menu.

Click on each View and look at the histogram. Look at the horizontal scale on the histograms. The scale used on the horizontal axis (brightness) is different for the RGB image (View 1) and the Hue image (View 2). Saturation and Intensity (Value) use the same scale, which is different than the scale used by RGB images and Hue images.

Question 2: A. Which HSV grayscale image has a significant skew to the left (meaning most pixels are dark)?

B) What is the range of brightness for Hue pixels?

C) What is the range of brightness for Intensity (Value) and Saturation pixels?

D) What is the brightness value on the horizontal axis of the Saturation (View 3) histogram when you slide the vertical line to the left so that 95% of the pixels are below that brightness value (Hint: look above the vertical line for the data brightness value and percentage of pixels to the left of the vertical line).

1c) We want to pan and zoom to the same pixels in the four views.

Views > Link Views > Link All > OK

Select the Cursor Value tool and *click-on* the “Link Views” and the “Display information for all Views” icons located along the top of the tool.

Question 3: With the Cursor Value tool, *Click-on* a light brown – light orange agricultural field (fallow – no vigorous crops growing) in the color IR in View 1. The data values for each type of image are listed in the “Data:” entry space of the Cursor Value window. Write the data values you find for the same feature in the table below

View	Type of Image	Data Value (brightness)
View #1	Color IR	
View #2	Hue	
View #3	Saturation	
View #4	Intensity (Value)	

1d) We want to brighten the Saturation grayscale image, but we cannot use the "Linear 1%" because that would take the darkest 1% of the pixels and turn them black.

Highlight View 3 (Saturation) > *Zoom to Full Extent* > *Change* the contrast-stretch from "Linear 1%" to "No stretch"
Open the "Histogram Stretch"
Move the Histogram away from View so you can see how the brightness changes in the Saturation image as you send bright pixels to pure white (1.0)

Drag the maximum vertical slider (right side of the histogram) to the left so that 2% of the pixels are brightened to 1.0. (98% of the pixels are to the left of the vertical slider). The brightness value should be 0.8.

NOTE: The bright red, color IR pixels in the irrigated fields may be oversaturated and blend together with this saturation stretch (a visual loss of information).

Now we want to save the brightened Saturation grayscale image.
File > Export View > Image File > Ensure "Full" is active >
Accept the other Defaults >

Name the file "Sat_5pct_brighter_ENVI" > *Display Results > OK*

Press on the "+" sign next to the brighter Saturation image (.dat format) in the Layer Manager View 3 list
Unfortunately, ENVI created a 3-band grayscale image when we only want 1 band in the grayscale image!! This is a bad software shortcoming.

"We must save our brightened grayscale Saturation image as a NEW, 1-band grayscale image!

File > Save As > Save As (ENVI, NITF….)"
The "Data Selection" window pops-up. Ensure our brightened Saturation image is selected.

Click on "Spectral subset" button > The Spectral Subset window pops-up.
Select "Band 2" > *OK* > *OK* (all 3 bands are identical – so pick any one)

The "Save File as Parameters" window pops-up.
Name file "Sat_2pct_brighter_1band" > Check "Display results" > *OK*

Uncheck the older files in View #3 so only our "Sat_2pct_brighter_1band" is checked. >

1e) Right-click on the “Sat_1pct_brighter_1band” file in the Layer Manager.
> *View Metadata* > Raster tab
Our brightened, 1-band saturation image is a <u>Byte</u> data type. 8-bit. DN brightness ranges from 0 to 255.

Look at the histogram brightness values with the Histogram Stretch tool.
Brightness ranges from 0 to 255. (see all the pixels at 255 on the right vertical axis – we sent 5% of the pixels to pure white)

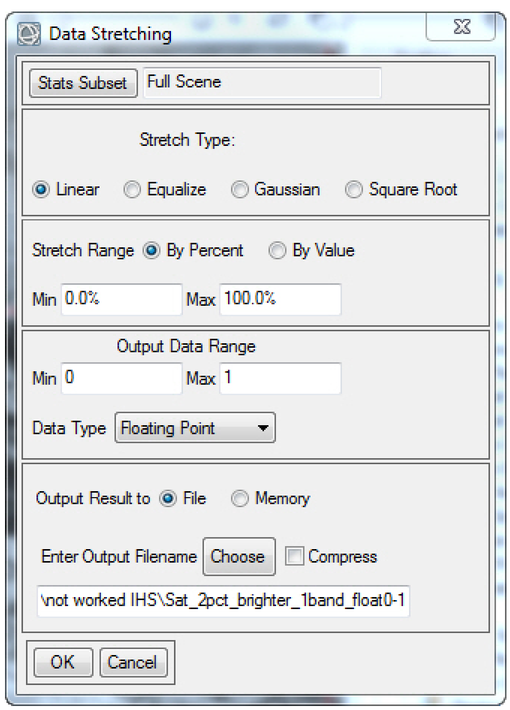
BUT our Saturation image in IHS color space was a float (decimal) grayscale image with brightness DNs that ranged from 0 to 1.

1f) So we have to convert our 8-bit image to a float image with DN range from 0 to 1.
ENVI Toolbox > Raster Management > Stretch Data
The “Data Stretch Input File” window pops-up.
Ensure our new 1-band Saturation .dat file is selected. > *OK*

The “Data Stretching” window pops up
Accept defaults.

Fill in the “Output Data Range” as Min = 0 and Max = 1
Data Type should be “Floating Point”
name the new grayscale image “Sat_2pct_brighter_1band_float0-1”

(see filled-in menu below)



> *OK*

1g) *Uncheck* other files in View #3. Only our new float grayscale Saturation image should be displayed and *checked* in the Layer Manager

View metadata for our new float image. > *Close*
Look at the histogram with the Histogram Stretch tool –
we can see 0 to 1 on brightness axis!!

We have increased the mean brightness and the standard deviation of the saturated grayscale image by our 2% clip of the brightest pixels.
The original Saturation image had a mean of 0.21 and a StdDev of 0.19

Question 4: What is the mean and StdDev of the stretched saturation grayscale image?
(Hint: Quick Stats has the answer). This confirms numerically what we see visually between the original and stretched saturation image.

1h) Now we will combine our Hue, Intensity, and our brightened float 0-1 Saturation image and transform this new IHS combination into a hopefully much more vibrant color IR image!
ENVI Toolbox > Transform > Color Transforms > HSV to RGB Color Transform
The HSV to RGB Input Bands window pops-up

The "H" is filled with our "ASTER IHS" Hue Band 1
The "S" is filled with our new brighter, float, 0-1 Saturation image at the top of the list ("Sat_5pct_brighter_1band_float0-1")
The "V" is filled with our ASTER IHS" Val Band 3 *> OK*

Name the transformed RGB color IR image "ASTER_my_sat_str_ENVI"

1i) The new color IR image in View #3 is much brighter and vibrant compared with our original color IR image in View #1!! Success!!
To make a useful GIS geoTIFF of the brighter Color IR image in View #3
File > Export Selected Layer to TIFF >
name "ASTER_CIR_my_sat_str_GIS" *click* "Display result"

1j) After all that work, let's save a chip view of the brighter Color IR image for the instructor.
Zoom to Full Extent > File > Chip View To… > File > Select JPEG
Name your output "YourName_ASTER_CIR_my_sat_str"

No need to display result *>OK*

Upload the jpg to the instructor.

2) <u>Image Sharpening</u>
This will be a short, simple exercise using DigitalGlobe's high resolution satellite imagery over Tokyo. In almost all cases a panchromatic (grayscale) image is acquired with higher spatial resolution compared with the multispectral color bands that collect a narrower wavelength range within a larger pixel. The pan and multispectral bands are collected at the same time, so alignment/registration issues are minimized.

Start up a new ENVI display. The data are in "Ch_4_Other_MSS_Satellites" folder, inside the "High_resolution_Satellites" subfolder and its "Worldview-3-pan-MSS_Tokyo" folder.

Read the pdf description of the awesome Worldview-3 satellite is in the Tokyo folder.

File > Open drive to the Tokyo folder described above
Select "Tokyo_WV-3_30cm_panchromatic_GIS" and
"Tokyo_WV-3_4-bnd_120cm_11-bit_MSS_GeoTIFF"

Views > Two Vertical Views
Drag the pan image into View #2 > *Remove* the pan image in View #1.

Views > Link Views > Link All > OK
Zoom to Full Extent > Contrast stretch
Pan around and zoom in and out –
Zoom in to the baseball field in the lower portion of the image.
Do you see a difference in the level of detail between
the 120 cm color and 30 cm pan images?

NOTE: 30 cm is the highest spatial resolution allowed by the U.S. government for civilian applications at this time (April 2019) *Brighten both Views with "Linear 2%"*
Open the "Data Manager"
DigitalGlobe's multispectral band sequence is:
Band 1, 2, 3, 4 = Blue, Green, Red, NearIR

Click on the "**+**" sign next to the multispectral data set.
Bands 3-2-1 are loaded as R-G-B

Question 5: Is the 3-band image displayed in View #1 natural color or color IR?

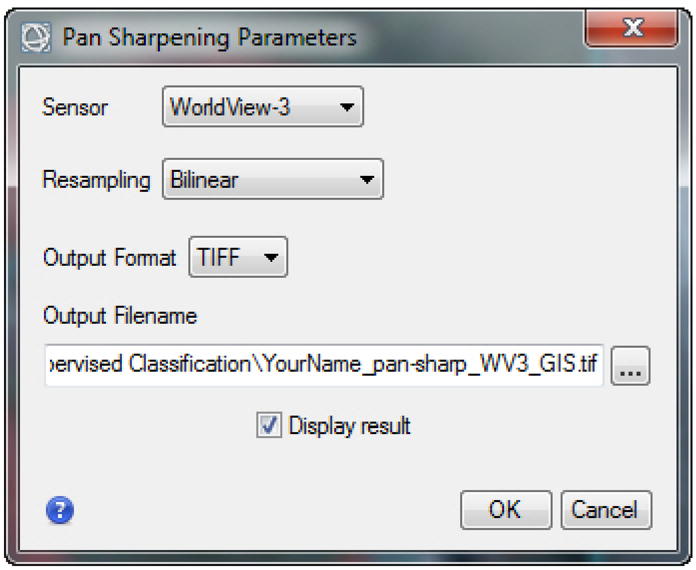
Highlight View #2 with the pan image

ENVI Toolbox > Image Sharpening > Gram-Schmidt Pan Sharpening
The "Data Selection" *window pops-up*

Select "Low Spatial Resolution Multi Band Input File:"
Select the 120 cm data set > *OK*

The "Data Selection" *window pops-up again*
Select "High Spatial Resolution Pan Band Input File:"
Select the 30 cm pan image > *OK*

The "Pan Sharpening Parameters" window pops-up
Sensor choose *WorldView-3*
Accept Resampling *Bilinear*
Output Format *TIFF* (we are going to load this into GIS)
Name "Your Name_pan-sharp_WV3_GIS"
check Display result > *OK* (The filled in menu is shown below)



The fusion or pan-sharpening process can take a long time. There is an activity indicator in the lower right of the ENVI Display window.

NOTE: Use ENVI Help and type in "sharpening" in the Index search box. Learn about the differences with the many tools ENVI offers.

2a) move the 120 cm multispectral data into one view and in the other view display our 30 cm pan-sharpened image.
Both files should default to 3-2-1 as R-G-B. The two Views should still be linked. Contrast stretch both files with "Linear 2%"

Zoom to Full Extent Evaluate the imagery and answer question 6A below.
Zoom-in to the in-field at the baseball stadium in the lower left corner of the scene and answer question 6B below.

Question 6: A. Do you see much difference in spatial detail when both the 120 cm and 30 cm images are *Zoomed to Full Extent*?

B. Describe the difference in spatial detail when zoomed-in to the baseball in-field at baseball stadium.

C. Each 120 cm pixel covers how much more area compared to each 30 cm pixel? (Can answer with cm-based measurement or a magnitude difference (for example, 5 x more area)

2b) Let's see what a color IR image looks like at the baseball field.

Right-click the pan-sharpened 4-band dataset in Layer Manager > *Change RGB Bands > select* Band 4 as R, Band 3 as G, Band 2 as *B > OK*

Right-click the 120 cm, 4-band dataset in Layer Manager > *Change RGB Bands > select* Band 4 as R, Band 3 as G, Band 2 as *B > OK*

A color IR image should be more detailed compared to a color image because the long wavelength Near IR band is not scattered as much as the short wavelength Blue band by the atmosphere.

Zoom out and then zoom in to the tennis courts in the lower right portion of the scene. The WorldView-3 imagery is discussed and the tennis court features are interpreted in the textbook's Figure 4-9.

Do you see a remarkable difference in clarity between the 30 cm Color IR image and the 120 cm color IR image?

If you have time, try out the other image-sharpening algorithms. The difference in colors and sharpness with different algorithms can be significant.

Lab 8 RGB-IHS-RGB and Image Sharpening Name:

Upload the following files to the instructor:

(1j) “YourName_ASTER_CIR_my_sat_str” .jpg

Question 1: A. Discuss the differences in the colors between the original ASTER CIR image and the ENVI saturated stretched CIR image.

B. Do you prefer the “instant” ENVI saturation stretch or your 2% saturation stretch that you created at the end of this exercise? (page 7) WHY?

Question 2: A. Which HSV grayscale image has a significant skew to the left (meaning most pixels are dark)?

B) What is the range of brightness for Hue pixels?

C) What is the range of brightness for Intensity (Value) and Saturation pixels?

D) What is the brightness value on the horizontal axis of the Saturation (View 3) histogram when you slide the vertical line to the left so that 95% of the pixels are below that brightness value (Hint: look above the vertical line for the data brightness value and percentage of pixels to the left of the vertical line).

Question 3: With the Cursor Value tool, *Click-on* a light brown agricultural field (fallow – no vigorous crops growing) in the color IR in View 1. The data values for each type of image are listed in the “Data:” entry space of the Cursor Value window. Write the data values you find for the same feature in the table below

View	**Type of Image**	**Data Value (brightness)**
View #1	Color IR	
View #2	Hue	
View #3	Saturation	
View #4	Intensity (Value)	

Question 4: What is the mean and StdDev of the stretched saturation grayscale image? (Hint: Quick Stats has the answer).

Question 5: Is the 3-band image displayed in View #1 natural color or color IR?

Question 6: A. Do you see much difference in spatial detail when both the 120 cm and 30 cm images are *Zoomed to Full Extent*?

B. Describe the difference in spatial detail when zoomed-in to the baseball in-field at baseball stadium.

C. Each 120 cm pixel covers how much more area compared to each 30 cm pixel? (Can answer with cm-based measurement or a magnitude difference (for example, 5 x more area)

Lab 9 Unsupervised Classification
Utilizes Textbook's Remote Sensing Digital Database: Chapter 3 data.

The objectives of this lab are to learn about unsupervised classification techniques, including naming classes, combining classes, converting the raster thematic map to a GIS shapefile, and the importance of apply a mask to improve your classification map. The tasks are done with tools in the **ENVI Toolbox**.

Two digital files are to be uploaded to the instructor and five questions are to be answered on the last page of this handout.

1) Unsupervised Classification

We will return to the Exumas Islands in the Bahamas where in Lab 4 we created a Mask to eliminate the impact of water on our image processing of the islands. We want to use the spectral characteristics of the six Landsat VNIR-SWIR bands to generate an unsupervised classification map of the islands.

Unsupervised classification uses the computer program to cluster the pixels into natural groupings based on the spectral characteristics of the pixels with no direction from the analyst, except for setting basic parameters such as number of classes, number of iterations performed by the program, and minimum number of pixels per class. The analyst leverages his/her experience and knowledge about the features being classified so a land use/land cover name can be attached to each class and classes can be combined. Unsupervised classification is a very fast way to evaluate the spectral richness and mapping potential of your multispectral or hyperspectral data.

The textbook Chapter 9 has an extensive discussion on unsupervised classification.

The multispectral data is located in the "Remote Sensing Digital Database \ Ch_3_Landsat" folder, inside the "Plate_9_Bathymetry" subfolder.

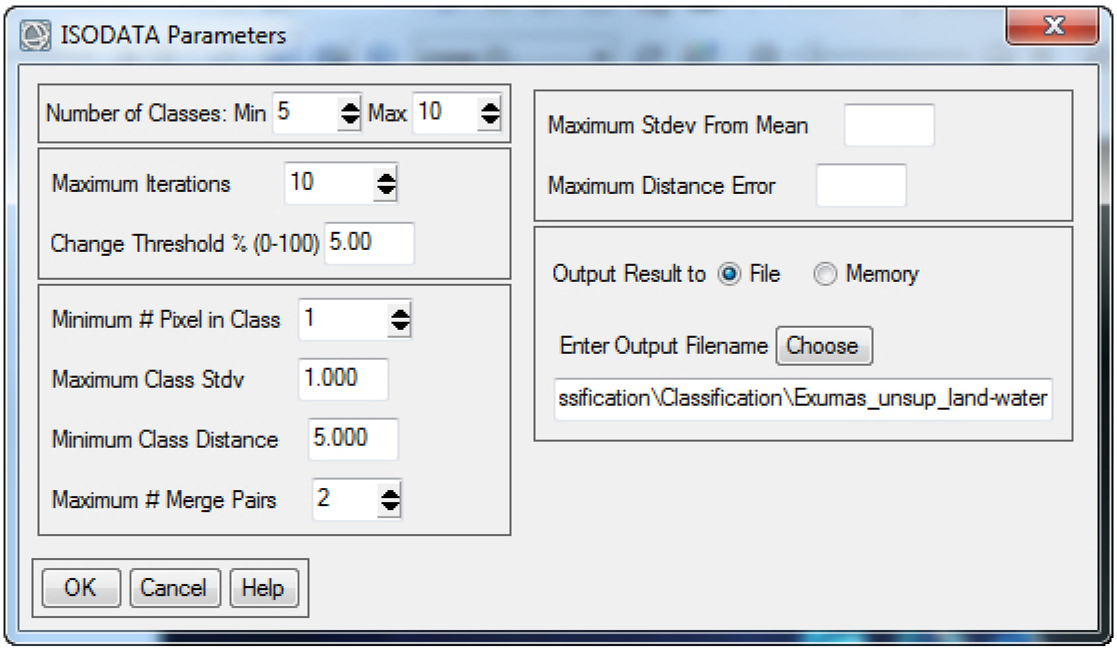
1a) *Start-up* a new ENVI display. *File > Open* drive to the
"Plate_9_Bathymetry" folder and
Open the "Original_Landsat_Data" folder >
Select > "Exumas_Bathy_1984_Landsat_6-band_clip_GeoTIFF.tif" > *Open*
A natural color image should display (TM bands 3-2-1 as R-G-B)

Zoom to Full Extent > *Contrast stretch* "Linear 2%"
Open the "Data Manager" to see the six bands.
Use the Data Manager to display a total IR color composite (4-5-6 as R-G-B)
and color IR (4-3-2 as R-G-B) > *Stretch* both "Linear 2%"

1b) We will first do an unsupervised classification on the entire 6-band scene.
ENVI Toolbox > Classification > Unsupervised Classification > IsoData Classification

ISODATA unsupervised classification calculates class means evenly distributed in the data space then iteratively clusters the remaining pixels using minimum distance techniques. Each iteration recalculates means and reclassifies pixels with respect to the new means.

The Classification Input File window pops-up > *Select* the 6-band clip > *OK*
The ISODATA Parameters window pops-up (see below)



We will accept all the defaults,
 except *change* the "Maximum Iterations" from "1" to "10".

Click-on **Help** to learn what each parameter means in the ISODATA menu.
 (this is highly recommended for class discussion in the lab)

Name the output file "Exumas_unsup_land-water" > *OK*
 The ISODATA Classifier window pops-up and you will see the iteration count being posted. The classification stops at the 10th iteration.

Examine the classification map. Use the "Swipe" tool to compare the classification map with the color images.

Question 1: How many classes do you see on the islands?

1c) The ocean water and seafloor captured most of the classes in our map. We have generated a very poor (*unacceptable*) spectral classification map for the islands.

Remove our very poor classification map from the Data Manager.

Now we will apply the water mask that we built in Lab 4. The water mask for this scene is in the **Lab_9_Data** folder.

First we will load our water mask into the Layer Manager.
File > *Open* > *drive* to the "Lab_9_Data" folder >
Select "Water_Mask_0-1_Off" > *Open*
The Black and White Mask is displayed.
Use the "Cursor Value" tool *to query* the DNs for the black and white pixels.

Question 2: What are the DN values for Black and White pixels in the Mask?

ENVI Toolbox > Classification > Unsupervised Classification > IsoData Classification

The Classification Input File window pops-up > *Select* the 6-band clip
Click-on the "Select Mask Band"
Select "Mask Band" under the "Water_Mask_0-1_Off" file name *> OK > OK*

The ISODATA Parameters window pops-up (see picture above)
We will accept all the defaults,
except *change* the "Maximum Iterations" from "1" to "10".

Name the output file "Exumas_unsup_water-masked" *> OK*
The ISODATA Classifier window pops-up and you will see the iteration count being posted. The classification stops at the 10th iteration.

Examine the classification map. Use the "Swipe" tool to compare the classification map with the color images. Y

You may see the new classification map swiping with the B-W water mask image. Move the "Water_Mask_0-1_Off" to the bottom of the files listed in the Layer Manager so that the color IR or other color image directly under the new classification will be displayed in the Swipe tool.

Zoom-in on the larger islands.

1d) Let's look at the statistics of this classification map.
Right-click on the "Classes" folder in the Layer Manager >
Select "Statistics for All Classes" > the "Data Selection" window pops-up >

Select our new classification map "Exumas_unsup_water-masked" > *OK*

The "Classification Statistics View" window pops-up

Question 3: A. What percentage of our classification map is unclassified (this is the area in the scene covered by our water mask)?

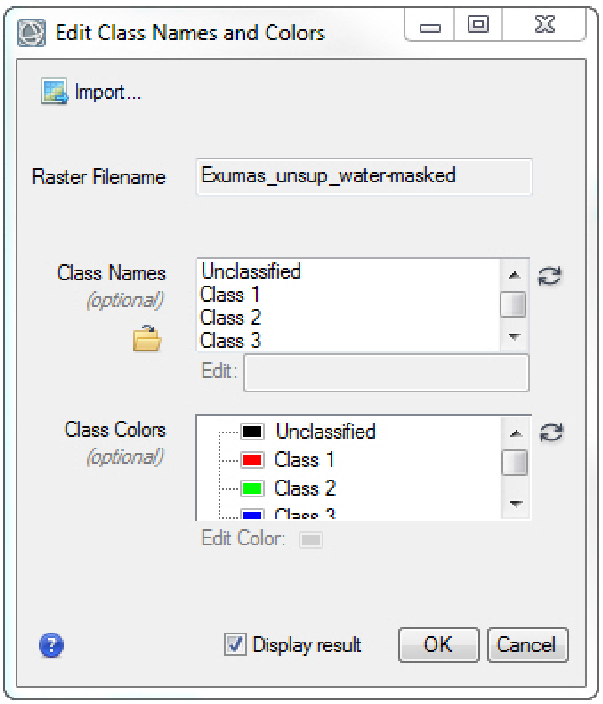
B. Which class on the islands has the highest percent coverage?

C. How many pixels are in the class with the highest percent coverage?

1e) Let's evaluate the patterns on the classification map with different color image band combinations (and contrast stretches) to help us interpret the features on the map

Let's start with the color IR image in View #2 and link the two views to help interpret the classification map. *Views > Two Vertical Views >*
Drag the color IR image in View #2 in the Layer Manager
Views > Link Views > Link All > OK
Contrast stretch the Color IR image with different stretches.

Right-click on the "Classes" folder in the Layer Manager >
Select "Edit Class Names and Colors" >
the "Edit Class Names and Colors" window pops-up (see below)



Use the "Cursor Value" tool to query the Class number. In the "Cursor Value" tool menu *Click* on the "Link" and the "Display Information for Views" icons

Click on different colors in your classification map with the “Cursor Value” tool to decide what feature they represent.
Zoom-in and *pan* to different islands.
Use the *Flicker* tool to compare classified map pixels to color image pixels.

Change the band combinations in View #2 and try different stretches on the images that bring out different patterns - these patterns may correlate with your classification map

NOTE: This is a very good class exercise with the instructor writing the class answers on a White Board so everyone participates in the decision-making.

Build a small chart and write down what you think the class represents.

Exumas_unsup_water-masked ISODATA (Exumas_Bathy_1984_La Classes	**Class interpretation**
0: Unclassified	1. Mask
1: Class 1	2. Saturated/underwater beach sands
2: Class 2	3.
3: Class 3	4.
4: Class 4	5.
5: Class 5	6.
6: Class 6	7.
7: Class 7	8.
8: Class 8	9.
9: Class 9	10.
10: Class 10	

a) Where do you see Class 5, 6, 7, 9, and 10 pixels most often?

b) There are only 378 pixels in Class 8 (dark green). Tough to find! Do you see this class in areas with very bright white sand? Maybe this is dry sand – sand on a topographic high?

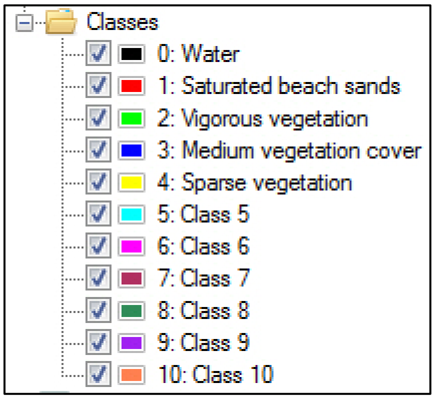
c) In the color IR and total IR images is there a trend in vegetation vigor (redder pixels may indicate more vigorous vegetation, denser vegetation cover, or different plant communities) that you can correlate with the patterns of Class 2 (green), Class 3 (blue), and Class 4 (yellow) on the islands?

Question 4: What types of other imagery, maps, and other ancillary information would help you interpret the classes with more confidence?

1f) Let's name the classes and combine those that ***maybe*** represent the same feature.

We will use the "Edit Class Names and Colors" menu.
In the "Class Name" window in the center of this menu, select Unclassified > Edit: enter the name "Water" and follow this with the next 3 entries

Unclassified = Water
Class 1 = Vigorous vegetation
Class 2 = Medium vegetation cover
Class 3 = Sparse vegetation > *OK* You will see the new names show up in the classification map legend (see below)



To open up the Edit menu again,
Right-click on the "Classes" folder in the Layer Manager >
Select "Edit Class Names and Colors" >
the "Edit Class Names and Colors" window pops-up

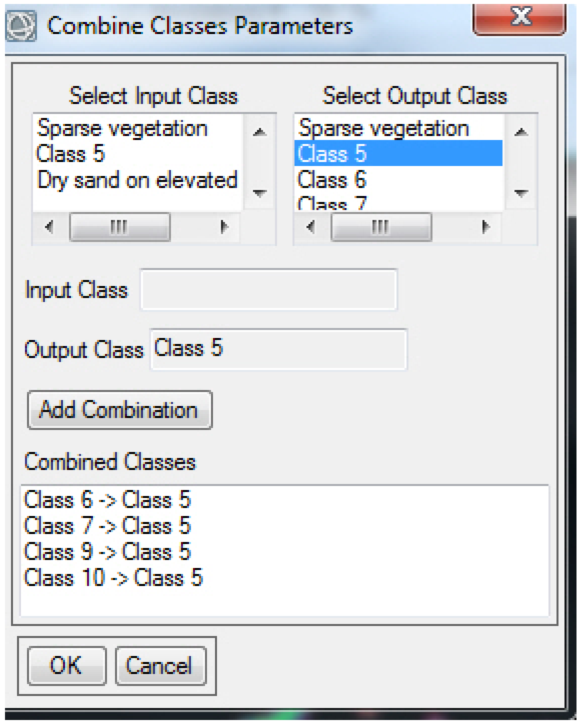
Change the name of Class 8 to "Dry sand on elevated beach" > *OK*

1g) Now let's combine classes 5, 6, 7, 9, 10 into one class.

ENVI Toolbox > Classification > Post Classification > Combine Classes
The "Combine Classes Parameters" window pops-up.

We want to sequentially *Select* Class 6, 7, 8, 10 in the "Select Input Class" list and assign each one to the "Ouput Class" 5. After we fill in the Input and Output windows we press "Add Combination" and the combined classes show up in the bottom window. (see below)

Your Combine Classes Parameters menu should look like is shown below.

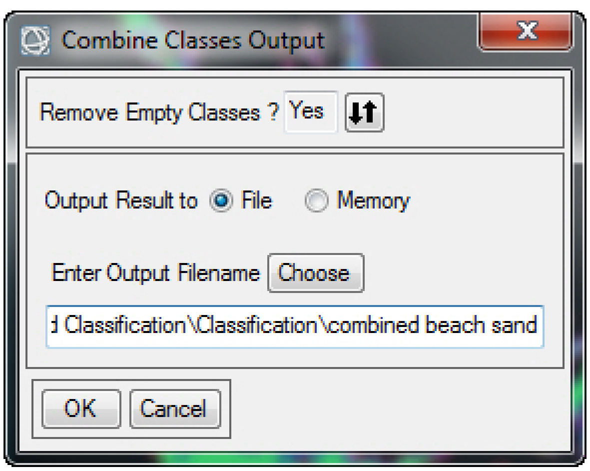


> OK

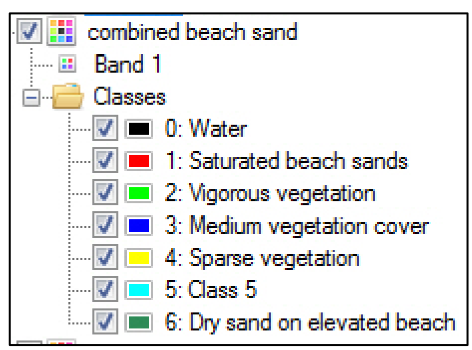
The “Combine Classes Output” window pops-up.

Remove Empty Classes? *Yes*

Name the output file “combined beach sand” (see below)



> OK



Automatically ENVI displays the classification map with the updated legend in the Layer Manager (see above).

1h) Now we want to rename “Class 5” to “beach sand” and change colors on our map.

To open up the Edit menu again,

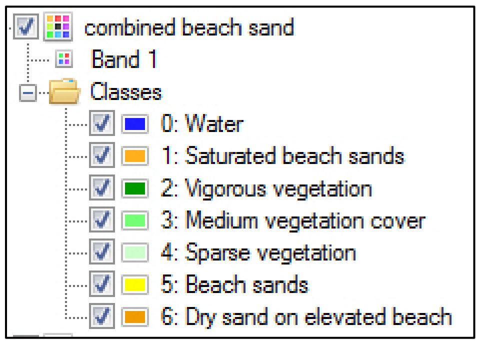
Right-click on the “Classes” folder in the Layer Manager >

Select “Edit Class Names and Colors” >

the “Edit Class Names and Colors” window pops-up
Rename “Class 5” as “beach sand”

Let’s change colors in the lower window
Just select the class and touch the color box that appears
Check “Display Result” *> OK*

1i) The new legend pops-up in the Layer Manager. Let’s rename this map
Right-click on “combined beach sand” > “Rename Item” >
Rename “Exumas Landsat Land Cover Map” *> click on* Green Checkmark
Your map name and legend should look like this in the Layer Manager



1j) Our map has a “salt and pepper” appearance with isolated pixels and narrow strings of pixels. Land cover maps are typically generalized with a “Majority” filter (see textbook Chapter 9 for explanation). The Majority filter provides a more visually appealing map.

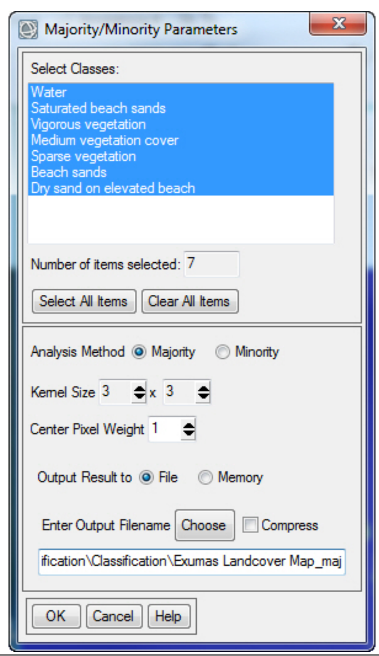
ENVI Toolbox > Classification > Post Classification > Majority/Minority Analysis

The Majority/Minority Parameters window pops-up.

Select All Items

Accept Defaults

Name the output file
“Exumas Landcover Map_maj”
> OK



The majority-filtered classification map is displayed on top of the original "salt and pepper" map.

Use the "Flicker" tool and *zoom in* on larger islands to compare the two maps.

Question 5: Which map (original or majority-filtered) do you like the most? Why?

In the Layer Manager, select (highlight) the majority filtered classification map.

File > Chip to File > File The "Chip to File Parameters" window pops-up

Select output format "JPEG"

Name the output "Your Name_unsup map_maj"
uncheck the Display result *> Save*

Upload the jpg file to the instructor.

1k) Raster classification (thematic) maps are converted to vector polygon maps to make them more useful in GIS applications. You can add more attributes to the vector polygon map and it is a much smaller file compared to a raster thematic map.

First we convert the raster map to an ENVI .evf vector file, and then we convert that .evf file into the universal shapefile format (.shp).

ENVI Toolbox > Classification > Post Classification > Classification to Vector
Select the Input file "Exumas_Landcover_Map_maj" *> OK*
Select All Items in the "Raster to Vector Parameters" menu that pops-up
Accept Defaults (Output as Single Layer)
Name the ENVI vector file "Exumas_Landcover_Map_maj_evf" *> OK*

The evf vector file may show up in the Data Manager. *Load* into the View.

ENVI Toolbox > Vector > Classic EVF to Shapefile
The "Select Input EVF files" menu pops- up.
Locate and select your "Exumas_Landcover_Map_maj_evf.evf File *> Open*

The "Output EVF Layer to Shapefile" window pops-up.
Name the shapefile "Exumas_Landcover_Map_maj_vec_GIS" *> Open* *> OK*

The .evf and .shp vector files should look like this in the folder where you are saving images and these vector files.

Exumas_Landcover_Map_GIS	4/20/2019 12:06 PM	DBF File	147 KB
Exumas_Landcover_Map_GIS	4/20/2019 12:06 PM	PRJ File	1 KB
Exumas_Landcover_Map_GIS.shp	4/20/2019 12:05 PM	SHP File	311 KB
Exumas_Landcover_Map_GIS.shx	4/20/2019 12:05 PM	SHX File	7 KB
Exumas_Landcover_Map_maj_evf	4/20/2019 12:00 PM	DBF File	147 KB
Exumas_Landcover_Map_maj_evf.evf	4/20/2019 12:00 PM	EVF File	309 KB

1l) With ENVI, you can superimpose the GIS shapefile on your final classification raster map.

File > Open drive to your folder that has the shapefile
> *select* the file that has ".shp" as the type > *Open*

Right-click on the shapefile in ENVI's Layer Manager > *View/Edit Attributes*
Use the slider to scroll across the fields in the attribute table.

Turn off (unclick) all the layers in the View with the shapefile
Zoom to Full Extent

In the Layer Manager, select (highlight) the majority filtered classification map.

File > Chip to File > File The "Chip to File Parameters" window pops-up

Select output format "JPEG"

Name the output In the Layer Manager, select (highlight) the majority filtered classification map.

File > Chip to File > File The "Chip to File Parameters" window pops-up
Select output format "JPEG"
Name the output "Your Name_unsup map_maj_shp"
uncheck the Display result > *Save*

Upload the jpg file to the instructor.

If you have access to a GIS, display your final, majority-filtered classification raster map and the vector shapefile. Right-click on the shapefile and look at the attributes.

You can import your shapefile into Google Earth and compare you map to the imagery Google Earth streams over the Exumas Island

Lab 9 Unsupervised Classification Name:

Upload the following files to the instructor:

(13j) "Your Name_unsup map_maj" jpg

(1l) "Your Name_unsup map_maj_shp" jpg

Question 1: How many classes do you see on the islands?

Question 2: What are the DN values for Black and White pixels in the Mask?

Question 3: A. What percentage of our classification map is unclassified (this is the area in the scene covered by our water mask)?

B. Which class on the islands has the highest percent coverage?

C. How many pixels are in the class with the highest percent coverage?

Question 4: What types of other imagery, maps, and other ancillary information would help you interpret the classes with more confidence?

Question 5: Which map (original or majority-filtered) do you like the most? Why?

Lab 10 Supervised Classification
Utilizes Textbook's Remote Sensing Digital Database: Chapter 9 data.

The objectives of this lab are to learn how to build training sites, understand the parameters that impact the accuracy of supervised classifications, and convert your raster classification map into a GIS vector polygon file (see Chapter 9 Digital Image Processing for discussion). The classification exercise will be done on a subscene of the Landsat 8 image used in the textbook (see Figures 9-28, 9-29, and 9-33 and Plates (29 and 30). This subscene is in the **Lab_10_Data** folder. The tasks we will complete with this lab are done with tools in the **ENVI Toolbox**.

Two digital files are to be uploaded to the instructor and six questions are to be answered on the last page of this handout.

The Landsat 8 image was acquired on September 23, 2014 of Martinez, California. The non-irrigated vegetation is dry. To successfully complete accurate supervised classification maps the analyst must have a knowledge of the types of features that are being spectrally classified.

1) *Start-up* ENVI. *File* > *Open* drive to the Lab_10_Data folder > *Select* "Martinez_Landsat8_6bnd_2PC_CLIP2_ENVI_"

A natural color image (OLI bands 4-3-2 as R-G-B) is displayed in View 1
Apply a contrast stretch to brighten the color image

Open "Data Manager" You see 6 VNIR-SWIR bands and two PC images (PC3 and PC4)
Let's look at all the bands.
Right-click on the 8-image Landsat file in the Layer Manager > *Band Animation*
Slow the flicker down…1 second delay maybe.

Question 1: Which of the 8 grayscale images are most different?

2) Let's look at the complete statistics between the 8 grayscale images
ENVI Toolbox > Statistics > Compute Statistics
Click-on "Histograms" and "Covariance" *Output to the Screen > OK*

Review the Correlation Matrix while looking at the "Band Animation"

Question 2: What features on the ground lead to the negative correlation between PC 4 image ("Band 8" in the correlation table) and Bands 1, 2, 3, and 4 (Hint: opposite graytones in the images - one has bright pixels and the other has dark pixels for the same feature).

In the upper left corner is the "Select Plot" drop-down menu. Select "Histogram 1" first, the "Histogram 2" and then "Histogram 3".

Question 3: Are these three visible band images normal or slightly skewed to the left?

In the upper left corner is the "Select Plot" drop-down menu. *Select* "Histogram 4" first, the "Histogram 5" and then "Histogram 6" – the 3 reflected IR bands.

Question 4: What is unique about the histograms for the reflected IR bands compared to the visible light bands?

3) Let's analyze the Landsat scene and define 8 land cover classes. We will then select training sites for each class using heads-up digitizing of polygons with ENVI's ROI (regions of interest) tool. 8 is an arbitrary number for this lab. (17 training sites were developed for the textbook example that used a larger Landsat scene of this area).

What land cover classes do you find on the image?
Classes should be spectrally unique.

(This is a good exercise class exercise with the instructor copying the land cover classes on a White Board and everyone voting for the top 8).

Split the ENVI display into 4 Views and fill each with a different color composite using the Data Manager and highlighting (selecting with your cursor) each View to be filled.
Views > 2X2 Views
View #2 load a color IR image
View #3 load a enhanced color (Bands 7-5-3 as R-G-B)
View #4 load PC4-PC3-Band 6 as R-G-B
Link the Views *Views > Link Views > Link All > OK*
Zoom to Full Extent > Zoom–in and pan around

<u>Placeholder Classes for processing in this exercise</u>**

1) River water
2) Ponded water
3) Irrigated grass
4) Dry grass
5) Wetlands
6) Suburbs
7) Industry
8) Trees (on western slopes with dry grass and deep shadows in valleys)

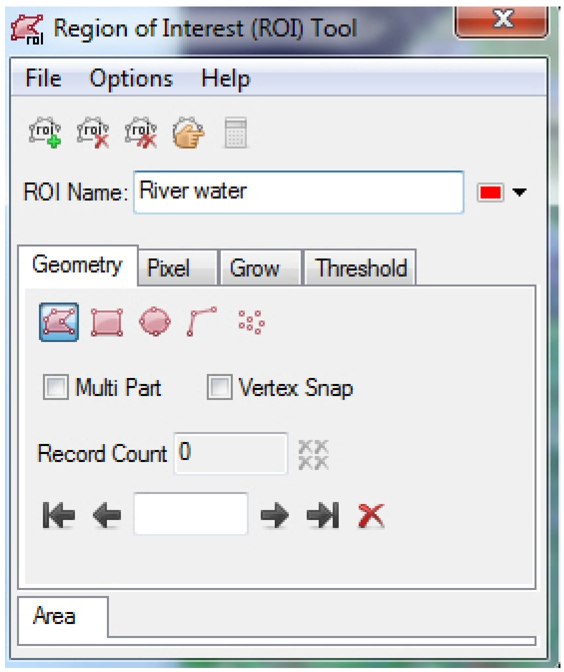
** *OK if class develops more or less classes and different classes for their processing*

4) Now we will generate training sites (ROIs) for the 8 land cover classes.

To give yourself more room to draw training sites (ROI polygons), let's Remove Views 2, 3, and 4. *Right-click* on Views 2, 3, and 4 in the layer Manager > *Remove View*

NOTE: ROIs should be neatly drawn so that the pixels inside the ROI are "pure" for the class being defined. Zoom-in and draw the polygon over only those pixels that correlate with the class being mapped. You should have more than one polygon for each training site. Try to draw ~5 polygons over pixels that represent a class.

Open the ROI tool (icon located at the top center of the ENVI display window)



Click on the "New ROI" icon, *change name* from ROI #1 to "River water".
We will accept default polygon drawing tool.
The "River Water" ROI is displayed in the Layer Manager and in the Data Manager.

Zoom-in to the feature of interest, and *draw* the around the pixels of interest. When done drawing the polygon, double-click your mouse, the polygon line will join both ends to create a closed polygon that is filled with a solid color.

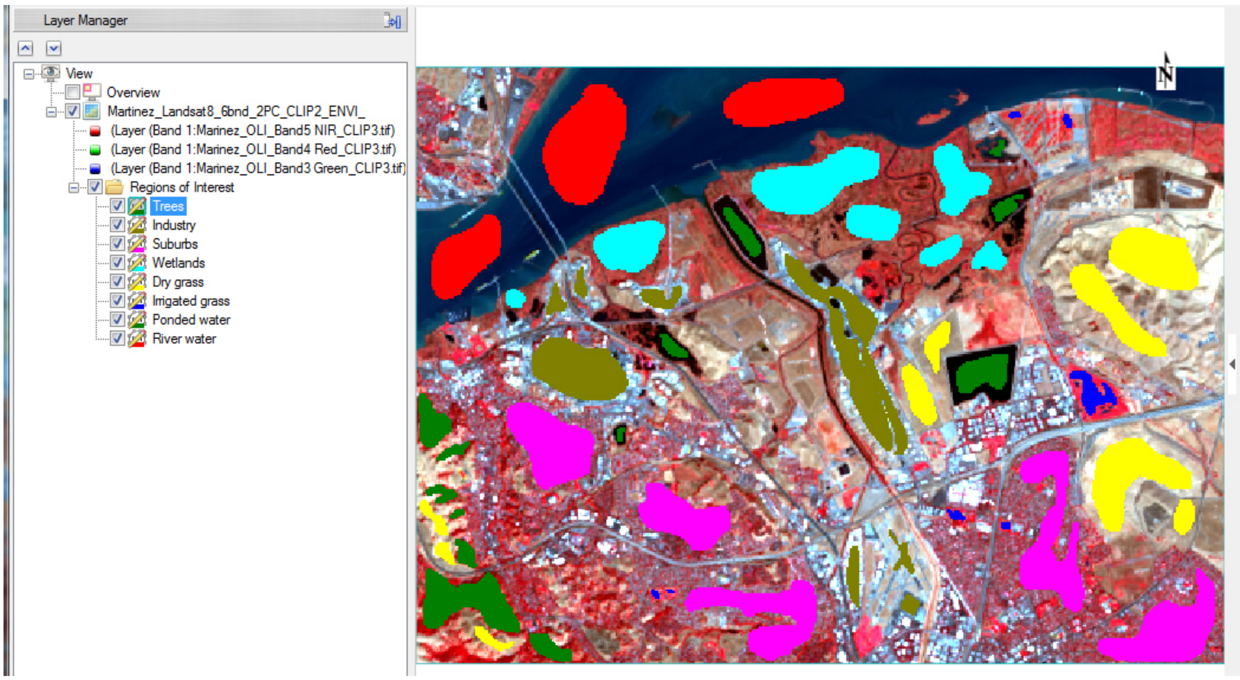
The ROI tool keeps track of the number of polygons in your class ("Record Count"). If you want to delete one of the polygons just use the counter with arrows at the bottom of the ROI tool to bring up the polygon and then you can that specific polygon using the "Delete Record" tool.

When done with one ROI, just click on "New ROI" and repeat the process.

When the "ROI Name:" turns blank while you are mapping the ROI, just click on the small down-arrow on the right to have your active ROI show up again in the tool. The name field turns blank sometimes when you use the Zoom and pan tools.

Make the polygons large in the suburbs, industry, dry grass, and river water so the program has the range of spectral values in the ROI.

As an example of training site polygons for the 8 ROIs, see below:



Let's send our training sites to the instructor.

File > Chip View To > File *Choose* Output Format "JPEG"
Name the file "YourName_TrainingSites"

<u>Upload the jpg to the instructor</u>

Now we want to save the ROI file.
Regions of Interest (ROI) Tool > *Save As > Select All Items*
Name the ROI file "Landsat8_Martinez_8_ROIs"

5) Now that we have our training sites, we can start the supervised classification program.
ENVI Toolbox > Classification > Supervised Classification >

Maximum Likelihood Classification

` The “Classification Input File” window pops-up.
Select our “…6bnd_2PC” dataset > *OK*

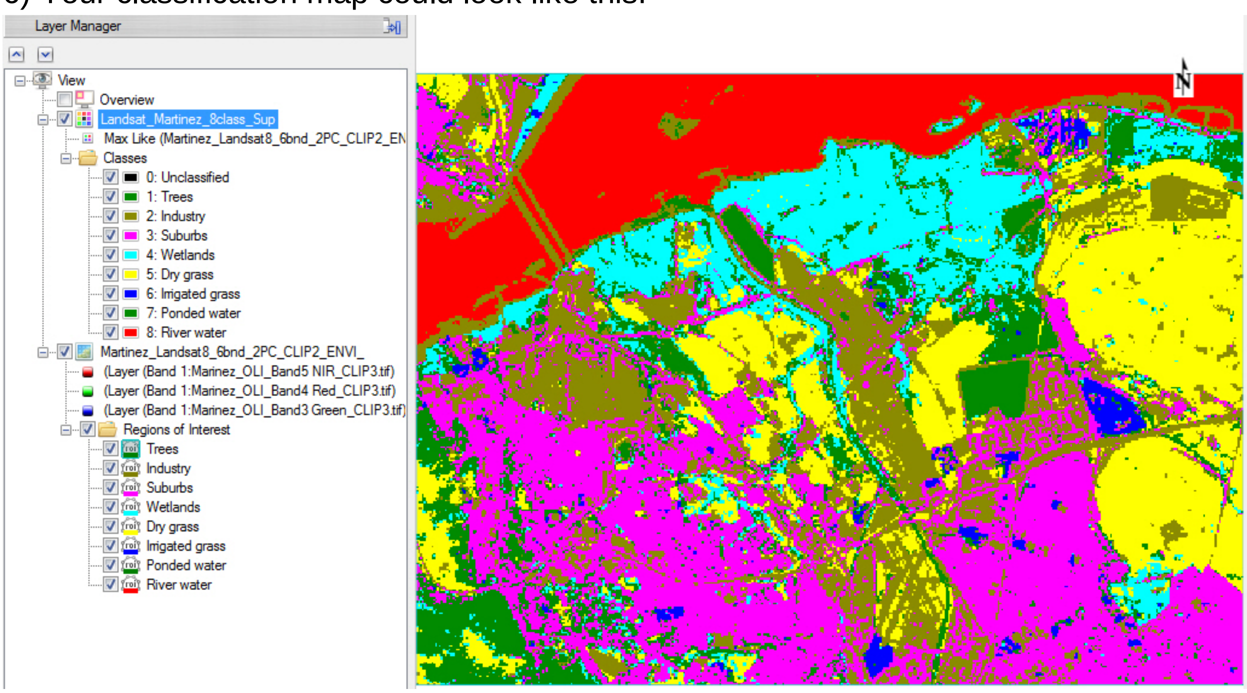
The “Maximum Likelihood Parameters” window pops-up > Click on **Help** for excellent information on the Maximum Likelihood algorithm.

Select All Items > Accept Defaults except “Output Rule Images? Change to “No” Name the output file “Landsat_Martinez_8class_Sup”

The computer crunches the numbers and displays your supervised classification map

NOTE: Maximum likelihood classification assumes that the statistics for each class in each band are normally distributed and calculates the probability that a given pixel belongs to a specific class. Unless you select a probability threshold, all pixels are classified. Each pixel is assigned to the class that has the highest probability (that is, the maximum likelihood).
The many other classification algorithms have advantages and disadvantages, just as the Maximum Likelihood does. *Open* **Help** and *search* for “Classification workflow” **Read** about the different methods and review the “Classification Tutorial”

6) Your classification map could look like this:



This is a raster thematic map. It has 9 classes (one is “unclassified”).

Let's look at the map's statistics.
Right-click on the "Classes" folder > *Statistics for All Classes….*
The "Data Selection" window pops-up *Select* our 8 class map > *OK*
*Scroll down t*o the "Class Summary" table (see below)

Class Summary	Pixel Count	Percent
Unclassified	0	0.000000
Trees	15038	10.828053
Industry	27280	19.642857
Suburbs	35315	25.428427
Wetlands	14867	10.704925
Dry grass	23858	17.178859
Irrigated grass	1976	1.422811
Ponded water	2388	1.719470
River water	18158	13.074597

Every pixel was classified.

The largest class is "Industry"

The smallest class is "Irrigated grass"

7) As with the unsupervised classification, let's minimize the "salt and pepper" appearance of this map by running a 3 X 3 majority filter across the scene.

ENVI Toolbox > Classification > Post Classification > Majority/Minority Analysis
Choose the 8-class supervised map > *Select* All items > *Accept* Defaults
Name the output file: "Landsat_Martinez_8class_Sup_maj" > *OK*

The generalized classification map displays on top of the raw map. *Swipe* to compare.
Let's look at the generalized map's statistics.
Right-click on the "Classes" folder > *Statistics for All Classes….*
The "Data Selection" window pops-up *Select* our 8 class Majority map > *OK*
*Scroll down t*o the "Class Summary" table (see below)

Class Summary	Pixel Count	Percent
Unclassified	0	0.000000
Trees	13502	9.722062
Industry	27225	19.603255
Suburbs	36491	26.275202
Wetlands	14779	10.641561
Dry grass	24333	17.520881
Irrigated grass	1884	1.356567
Ponded water	2437	1.754752
River water	18229	13.125720

Question 5: What class lost the highest percent of pixels and what class gained the highest percent of pixels when the majority filter is applied to the original classification image?

8) Move the color Landsat image beneath the majority-filtered classification map in the Layer Manager so you can compare with swipe and fade tools

Swipe the generalized map over the color Landsat image

(you

Fade the generalized map over the color Landsat image (Blend View tool)

These tools seen uncontrollable?! Too fast for analysis?

Stop the Blend Tool. Use the manual slider for transparency in the upper right corner of the ENVI display. Fade the map on and off to see what classes fit well, and what classes have errors (misclassified pixels)

To provide colors on the 8 classes that are easy to understand (i.e. dark green for trees, bright green for irrigated grass, blue for river water, etc.) *Right-click* on the majority classes folder in the layer manager > *Edit Class Names and Colors*

Display the Landsat as a grayscale image (OLI band 5 (SWIR1) is good) to provide an easy-to-understand backdrop to the faded/partially transparent color classification map.

Question 6: A. What class(es) do you interpret as least accurate?

B. What class(es) do you interpret as most accurate?

C. Why do think some classes are more accurately classified compared to others?

9) As with the unsupervised classification, this ENVI raster thematic image is not easily viewed by others. So we are going to convert it to an ENVI polygon vector file (.evf) and then convert the .evf to the universal .shp file.

ENVI Toolbox > Classification > Post Classification > Classification to Vector

Select the Input file "Landsat_Martinez_8class_Sup_maj" *> OK*

Select All Items in the "Raster to Vector Parameters" menu that pops-up

Accept Defaults (Output as Single Layer)

Name the ENVI vector file "Landsat_Martinez_8class_Sup_maj_vec" *> OK*

If the .evf file does not automatically load into the Layer Manager, *File > Open >* "…evf"

The .evf vector file should be displayed in the View. *Turn off* all the raster layers.

ENVI Toolbox > Vector > Classic EVF to Shapefile
The "Select Input EVF files" menu pops- up.
Locate and select your "Landsat_Martinez_8class_Sup_maj_vec.evf"
File > Open
The "Output EVF Layer to Shapefile" window pops-up.
Name the shapefile "Landsat_Martinez_8class_Sup_maj_GIS" *> Open > OK*

If the .shp file does not automatically load into the Layer Manager, *File > Open >* "Landsat_Martinez_8class_Sup_maj_GIS.shp"

10) Let's display the hillshade DEM of this Martinez area under our land cover shapefile in ENVI.
From the ENVI display window *File > Open*
Drive to the <u>Chapter 9</u> folder in the Remote Sensing Digital Database and open the DEM folder

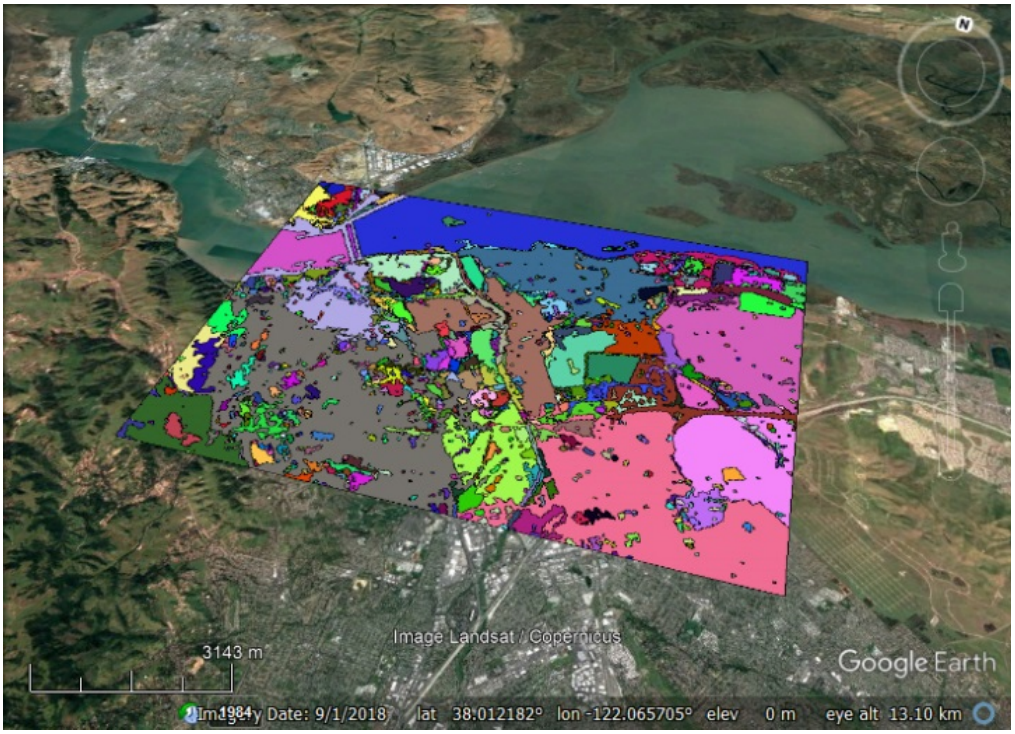
Ch_9_Image_Processing \ Plates 29-30_Spectral_Classification \ DEM

Select "DEM_Martinez_GIS_hs045_30elev.tif" *> Open*
The hillshade DEM displays in the ENVI View.
Drag the hillshade DEM below the landcover shapefile so the vectors show up on top of the DEM.

Let's send this display of vector land cover map over the hillshade DEM to the instructor
File > Chip View To > Image Select "JPEG" uncheck "Display result"

Name the vector map + hillshade DEM graphic
"YourName_landcover_hs-DEM" jpg

11) If you have access to Google Earth, *import* the land cover shapefile (see below)



Select and right-click on the imported shapefile in the Google Earth Places list > *Save Place As* > Accept default name*.* > *Save*

Your shapefile is now in the .kmz format (a universal format)
Upload the kmz to your instructor.

Lab 10 Supervised Classification Name:

Upload the following files to the instructor:

(4) “YourName_TrainingSites” jpg

(10) “YourName_landcover_hs-DEM” jpg

Question 1: Which of the 8 grayscale images are most different?

Question 2: What features on the ground lead to the negative correlation between PC 4 image (“Band 8” in the correlation table) and Bands 1, 2, 3, and 4 (Hint: opposite graytones in the images - one has bright pixels and the other has dark pixels for the same feature).

Question 3: Are these three visible band images normal or slightly skewed to the left?

Question 4: What is unique about the histograms for the reflected IR bands compared to the visible light bands?

Question 5: What class lost the highest percent of pixels and what class gained the highest percent of pixels when the majority filter is applied to the original classification image?

Question 6: A. What class(es) do you interpret as least accurate?

B. What class(es) do you interpret as most accurate?

C. Why do think some classes are more accurately classified compared to others?

Lab 11 Hyperspectral

Utilizes Textbook's Remote Sensing Digital Database: Chapter 9 data.

The objectives of this lab are to become familiar with hyperspectral data, learn about spectral libraries and different methods for processing hyperspectral data. The tasks we will complete with this lab are done with tools in the **ENVI Toolbox**.

Two hyperspectral datacubes are available to be analyzed. The first datacube has VNIR data and is analyzed for vegetation. The second datacube has SWIR data and is processed for minerals. Different image processing tools are utilized with each datacube. Lab time may be a limiting factor for both datacubes to be processed and analyzed in one session.

Therefore, this lab exercise is clearly separated into two sections – with the first section utilizing the hyperspectral VNIR datacube (pages 2 – 8) and the second section analyzing the hyperspectral SWIR datacube (pages 9 – 25).

The VNIR vegetation section has two digital uploads to be uploaded to the instructor and six questions to be answered on the last pages of this handout (page 26). The SWIR geologic section has one digital file to be uploaded to the instructor and eleven questions to be answered on the last pages of this handout (pages 27 and 28).

The VNIR vegetation section includes the following image-processing tasks:

- Normal and continuum removed spectral profiles.
- Using the chlorophyll absorption feature to document vegetation vigor.
- Editing spectral profiles for presentation.
- Building a 3D cube.
- Minimum Noise Transform (MNF).
- Unsupervised classification of select MNF bands.

The SWIR geologic section includes the following image-processing tasks:

- Using the USGS Spectral Library converted to the 50-band SWIR dataset.
- Comparing spectral profiles at select pixels with published mineral maps.
- Using the Spectral Library Viewer and adding/deleting files.
- Using ENVI's "Spectral Hourglass Wizard".
    - Data dimensionality determination,
    - Pixel Purity Index (PPI),
    - n-Dimensional Visualization,
    - Spectral Analyst tool.
    - Spectral Angle Mapper (SAM) classification.
    - SAM Rule images.

Hyperspectral VNIR Datacube for Vegetation Analysis

The first datacube was acquired over semi-arid terrain of the High Plains in central Colorado. This datacube contains 128 bands of reflected VNIR wavelengths. The data is courtesy of Galileo Group, Inc. A white paper by Galileo is included in the folder containing the datacube – it is highly recommended that you review this 22-page overview of commercial hyperspectral capabilities and case histories.

The datacube is in the Chapter 9 folder of the Remote Sensing Digital Database. The subfolder "AISA_VNIR_Hyperspectral" contains the datacube, a USGS topographic map, and metadata.

1) *Start-up* ENVI > drive to the "Ch_9_Image_Processing \ AISA_VNIR_Hyperspectral" folder > *Select* "AISA_Semiarid_Hyperspectral_VNIR_ENVI" and
"ESRI USGS TOPO Basemap_GIS.tif > *Open*

We use the ENVI version of the datacube because it displays the center wavelength of each band. The GeoTIFF version does not and you have to refer to the folder named "Table of AISA VNIR bands and wavelengths".

The datacube automatically opens as a color IR image
(Band 90 - Band 65 – Band 38 or NIR-Red-Green as R-G-B)

Drag the topo map beneath the color IR image in the View.
Zoom in so the color IR image fills your View.

Open the "Data Manager" to see the list of 128 bands with their wavelength.

2) Highlight (select) the hyperspectral file in the Layer Manager >
Display > *Profiles* > *Spectral*
With your cursor (the "Select" arrow is highlighted), *Click-on* bright red pixels and note how the spectral signature of pixels remains relatively constant.

The units of the horizontal axis are nanometers. The Data Value on the vertical axis is a measure of brightness or reflectance.

Click-on the Options drop-down menu and *select* "RGB Bars" to see where the 3 bands displayed in the ENVI View are located in the VNIR spectrum.

Click-on the small black triangle in the white band on the right side of the "Spectral Profile" menu to display properties of the plot.
Scroll down the "General" and "Curve" menus.
You can change the symbology, name, and range of wavelengths displayed with these menus.

With your cursor, *click on* the spectral profile line to see the exact wavelength and brightness (Data Value) for that part of the profile

3) Review Figure 9-37A and B and the text in the textbook's Chapter 9.

Click your cursor on a brightest red pixel (most vigorous vegetation) in the scene. This spectral profile is unique to vegetation.

Question 1: What is the name of the unique sharp increase in brightness (Data Value) between 680 and 745 nanometers?

Question 2: Why is the reflected brightness highest in the 520 – 600 nm range compared to the 400 – 520 nm and the 600 - 680 nm ranges?

There is another way to view spectral profiles named "Continuum Removed". This type of profile is generated by the algorithm fitting a "convex hull" arc over the top of the spectrum. The continuum removed spectral profile is very useful for evaluating absorption features (depth, shape, and width).

Click-on the "Y: Data Value" drop-down menu at the bottom of the Spectrum Profile window. *Choose* "Continuum Removed"
The shape of the spectral profile changes to highlight absorption features.

Question 3: What causes the unique absorption feature for healthy vegetation that is between ~600 and 680 nm? (Hint: think about what is causing the higher reflectance values at shorter and longer wavelengths).

The name of the deep absorption feature unique to vegetation that is revealed with the "continuum removed" tool is the "*chlorophyll absorption feature*".

Click-on the "Options" drop-down and select "Vegetation Index (NDVI)"

Question 4: A. What is the calculated NDVI value for your brightest (most vigorous) pixel?

B. What is the calculated NDVI value for the gray terrain (in the color IR image gray may represent dormant, dry grasses and other ground vegetation)?

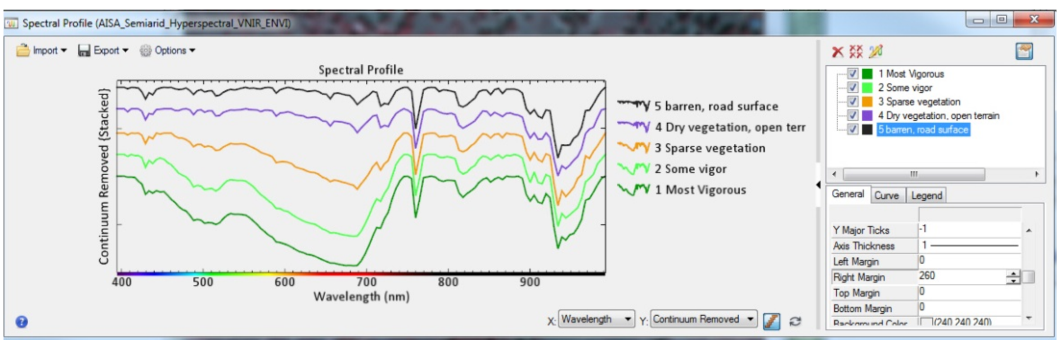
C. How did the program calculate NDVI?

4) Let’s move our cursor around the image clicking on five pixels that represent a trend from most vigorous vegetation (bright red), to less vigorous vegetation, to the gray terrain (dry vegetation?) to barren ground on the road (white pixels). Place your cursor on a bright red pixel to start this task - the deep chlorophyll absorption feature is redisplayed in the “Spectral Profile” window.

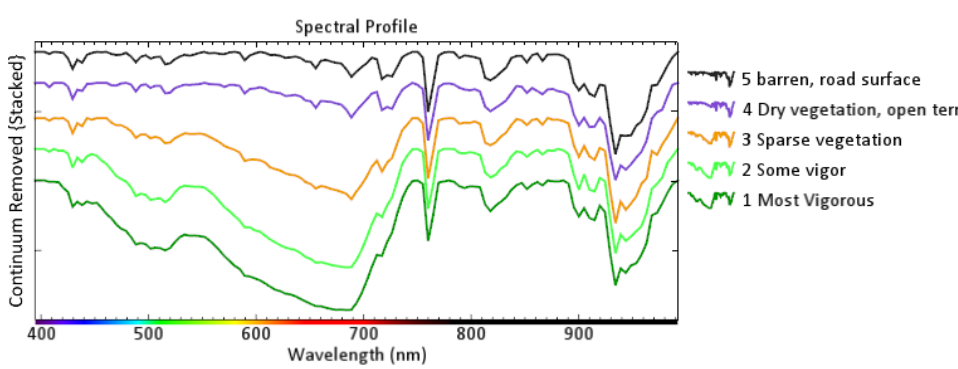
We will stack these five spectral profiles in one window so we can compare the signatures. *Click-on* the icon at the bottom of the Spectal Profile window that looks like a staircase  This stacking feature is only active when the icon is highlighted.

You have to press the Shift key on your keyboard when you *click on* the image to *collect* a spectral signature in order for the spectra to *stack* in the profile window. Have the Properties window (right side of the Spectral Profile window open so you can delete spectra you don’t like.

You can edit the names of the 5 spectra, change the line thickness, and add a legend to the side so that this change in a spectral signature as vegetation cover becomes less vigorous or is reduced for a report. An Example is below with the Properties menu open so that you can see where some changes were made.



You can Export the spectral profiles and the legend to several different graphic formats (see .png graphic below). This makes the spectral work you have done more accessible to others who don’t have or want to do image processing.



For this lab, it is an <u>option</u> to customize your 5 spectral profiles so you can learn about the symbology tools in ENVI. Use the "Curve" tab to customize your legend. Use the "General" tab to add the legend to the Export, change line thickness, etc. The symbology work takes some time…but is worth it if you are going to present your results to others.

Export > *Image* > *Name* the plot "YourName_5_Spectral_Profiles" as a .png.

Upload your png graphic to the instructor.

Question 5: Discuss in 2 or 3 sentences what happens to VNIR spectral profiles when you move from vigorous vegetation to no vegetation (barren terrain).

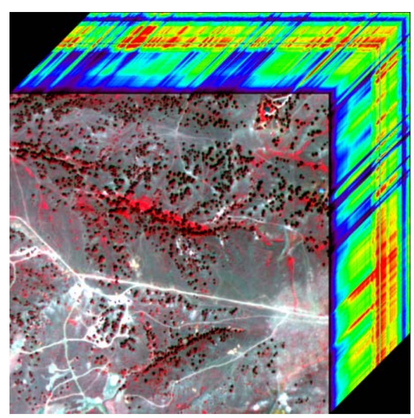
5) Let's visualize the data cube.
ENVI Toolbox > *Spectral* > *Build 3D Cube*
Select the 128 band datacube > *OK*

For the front of the datacube, let's generate a color IR image using the same bands as were automatically displayed in the View by ENVI (these three bands are designated in the metadata for automatic display). *Select* the following 3 input bands:

R = Band 90
G = Band 65
B = Band 38 > *OK* > the ""3D Cube Parameters" window pops-up

Accept defaults (rainbow color scheme and spectral scale)
Name the visualization "Colorado_3D_cube"

The processing may take 1-2 minutes.
The 3D cube is an ENVI .img file with .hdr header.
This format is *not* useful for a report graphic.
Let's *save* our 3D cube as a full resolution, .tif.



Uncheck the topo map.
Zoom in to the datacube so it fills your view.
File > *Export View To* > *Image File*
Ensure "Output Extent" is *Current"*
Leave "Zoom Factor" as 1.000
Change Output Format to "TIFF"
Uncheck "Display result"
Name the 3D cube "YourName_3D_Datacube" > *OK*
Upload your excellent graphic to the instructor.

6) To help understand the richness of the hyperspectral data, we can compress the 128 bands with an algorithm named “Minimum Noise Transform” (MNF) which is similar to Principal Components. *Open* **Help** and *search* for “MNF” to learn more – a lot more about MNF. **MNF Rotation** transforms determine the inherent dimensionality of image data, segregate noise in the data, and reduce the computational requirements for subsequent processing (Boardman and Kruse, 1994).

We will run the MNF program, select those grayscale MNF bands that contain the vast majority of variance and little noise, and then perform an unsupervised classification on the selected MNF Bands to determine if this enhancement improves our understanding, pattern recognition, and mapping of vegetation, soils, and clearings .

ENVI Toolbox > Transform > MNF Rotation > Forward MNF Estimate Noise Statistics

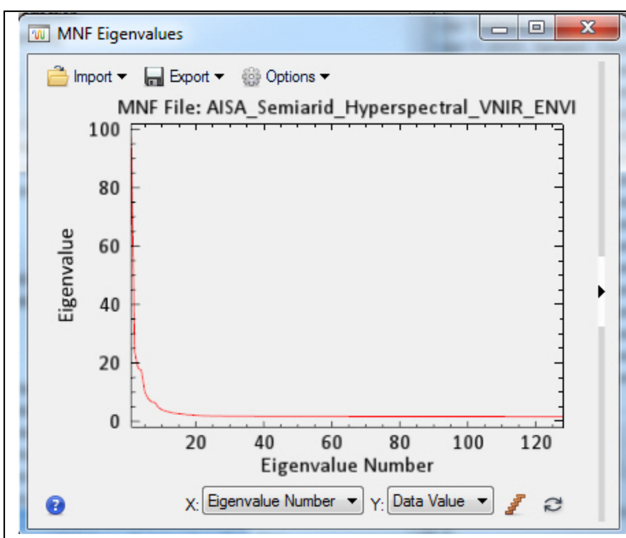
Select the AISA 128 band hyperspectral data *> Open*

Accept defaults on the MNF Transform Input File > OK

The “Forward MNF Transform Parameters” window pops-up
Output Noise Stats Filename: “VNIR_MNF_noise_”
Output MNF Stats Filename: VNIR_MNF_stats”
Output Filename: “VNIR_MNF_128bands” > *OK*

The computation of MNF bands will take some time – be patient.

When done, the 128 MNF bands appear in the Data Manager and a color composite of MNF Band 3 – 2 - 1 as R – G –B is displayed in the View.



The MNF Eigenvalues plot

Note the rapid drop-off in Eigenvalue.

This plot indicates that most of the original information in the data cube (variance) is now contained within the first 10 to 15? MNF bands.

We will use the Band Animation tool to examine the MNF bands and create color composites to determine how many MNF bands we will use going forward.

The MNF Eigenvalues plot also appears (VERY similar to the PC plot)

7) Determine the number of MNF bands for further processing. *Zoom-in* so the image fills your view.

If the MNF image in the View is *black*, click "Linear 1%"
Right-click on "VNIR_MNF_128bands" file in Layer Manager
> *Band Animation*
You may have to *stop* Band Animation and *stretch* the MNF file in the Layer Manager with "Linear 1%"
Keep *moving* the slider back to 1 after you start to see too much noise
Set timer for 1 second

MNF Band 1 has noise and all bands >10 to 15 have excessive noise?

Close the Band Animation tool > Use the Data Manager to generate color composites from MNF Band 2 to MNF Band 10. Evaluate quality.

We will create a new MNF Band dataset with bands 2-10
File > Save As > Save As (ENVI, NITF…) "Data Selection" menu pops-up
"VNIR_MNF_128 bands" should be highlighted.
> *Click* "Spectral Subset" > *Select* bands 2 – 10 > *OK* > *OK*
Name the output file "VNIR_MNF_9bands" in ENVI format > *OK*

8) The 9-band MNF dataset appears in the Data Manager. You may have to load a color MNF 4-3-2 as R-G-B using the Data Manager to have the "VNIR_MNF_9bands.dat" file appear in the Layer Manager.

9) We'll run an unsupervised classification on the 9-band MNF file to determine if new information is seen compared to the color IR and other band combinations.

ENVI Toolbox > Classification > Unsupervised Classification > IsoData Classification

Choose the "VNIR_MNF_9bands.dat file" > *OK*

The ISODATA Parameters window pops-up.
Change the Max number of classes to 15
Change Maximum Iterations to 15
Change Threshold % (0-100) to 3.00
Accept other defaults *Press* "Help" to learn what these parameters mean.

Output Filename : "VNIR_9-MNF_iso_15cla" > *OK*

10) If not already done, change to 2 vertical Views. Have the unsupervised classification in one view and the color IR image in the second view. Link the Views.

Question 6: A. Do you think there is new information and patterns in the classification map about vegetation, soils, barren ground, etc. that made our MNF and isoDATA effort worthwhile?

B. Do you see shadows in the classification map? If so, what class number represents many shadows?

C. What class number represents the most vigorous vegetation?

Close all files in the Data Manager. Return to one blank View.

Hyperspectral SWIR Datacube for Geologic Mineral Mapping

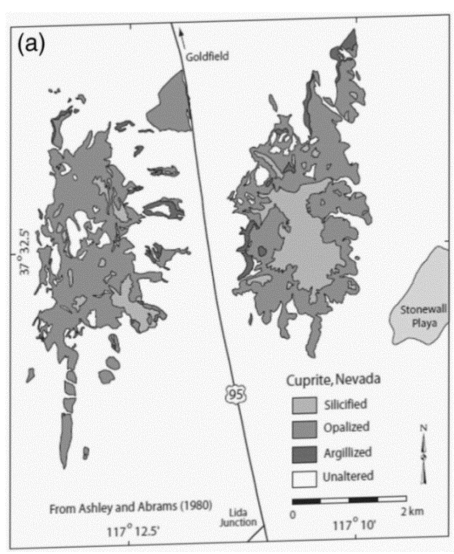
The second hyperspectral datacube is in the Chapter 9 folder of the "Remote Sensing Digital Database" in the "Ch_9_Image_Processing \ Dig_Img_1-2_Hyp-Multi_Cuprite-NV" subfolder. Digital Image 1-2 shows the Cuprite, Nevada area of interest.

File > *Open* drive to the "Dig_Img_1-2_Hyp-Multi_Cuprite-NV" folder, and open the "AVIRIS SWIR 50 bands" subfolder. We will be working with only SWIR data.
Select "cuprite_AVIRIS95_atm_50-SWIR_ENVI_" > *Open*
Apply a Linear 1% stretch

Open the Data Manager. *Select* Bands 214 – 193 – 173 as R-G-B > *Load Data*

File > *Open* return to the "Dig_Img_1-2_Hyp-Multi_Cuprite-NV" folder and open the "Cuprite_Geology_Maps" folder. We will load two geology maps.
*Select "*Field_Alteration_Zones_Ashley-Abrams_GIS.tif" and
"USGS Hyperspectral Map_GIS_JARS_9_1_0960044.tif"

1) Cuprite is in the mining district of Nevada, located about 200 km northwest of Las Vegas. Hydrothermal alteration is extensive at Cuprite. There are three mapped zones (silicified, opalized, and argillized) that include mineral assemblages (see below). The silicified zone contains abundant quartz, chalcedony, minor alunite, kaolinite and post-alteration calcite. Opalized rocks (opalite) contain opal with variable amounts of kaolinite and alunite, and minor calcite. Argillized areas are typically within or adjacent to opalized zones and contain primary quartz, unaltered sanadine, opal, montmorillonite and kaolinite. (*Kruse, Baugh, and Perry, 2015, Validation of DigitalGlobe Worldview-3 Earth Imaging satellite shortwave infrared bands for mineral mapping: Journal of Applied Remote Sensing, SPIE, v. 9, p. 096044-1 to 096044-17*).



Ashley and Abrams, 1980, USGS Open File Report 80-367.

Kruse, Baugh, and Perry (2015) also provide the USGS hyperspectral mineral map and legend (available in the Remote Sensing Digital database as “USGS Hyperspectral Map_GIS_JARS_9_1_096044.tif” and “Hyperspectral Legend” (see below).

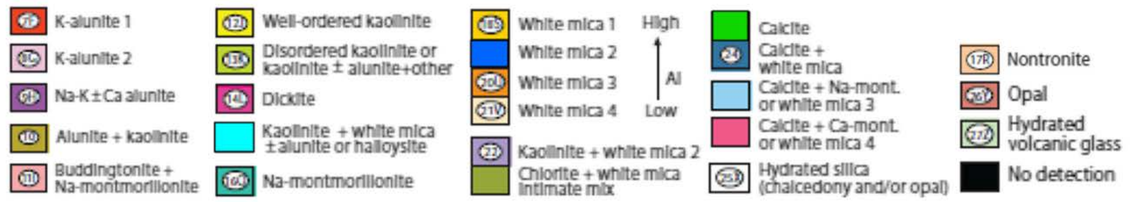


Fig. 1 (a) Cuprite field alteration map.[6] (b) U.S. Geological Survey (USGS) hyperspectral imagery mineral map of Cuprite.[13]

To see this legend picture on your screen, *drive* to the “**Lab_11_Data**” or the “Cuprite_Geology_Maps” folder and *open* “Hyperspectral_Legend.tif”. You can see and enlarge this legend on your computer screen with any computer picture viewer program while mapping in ENVI.

Next we’ll be comparing the geology maps, legend, and AVIRIS SWIR color image.

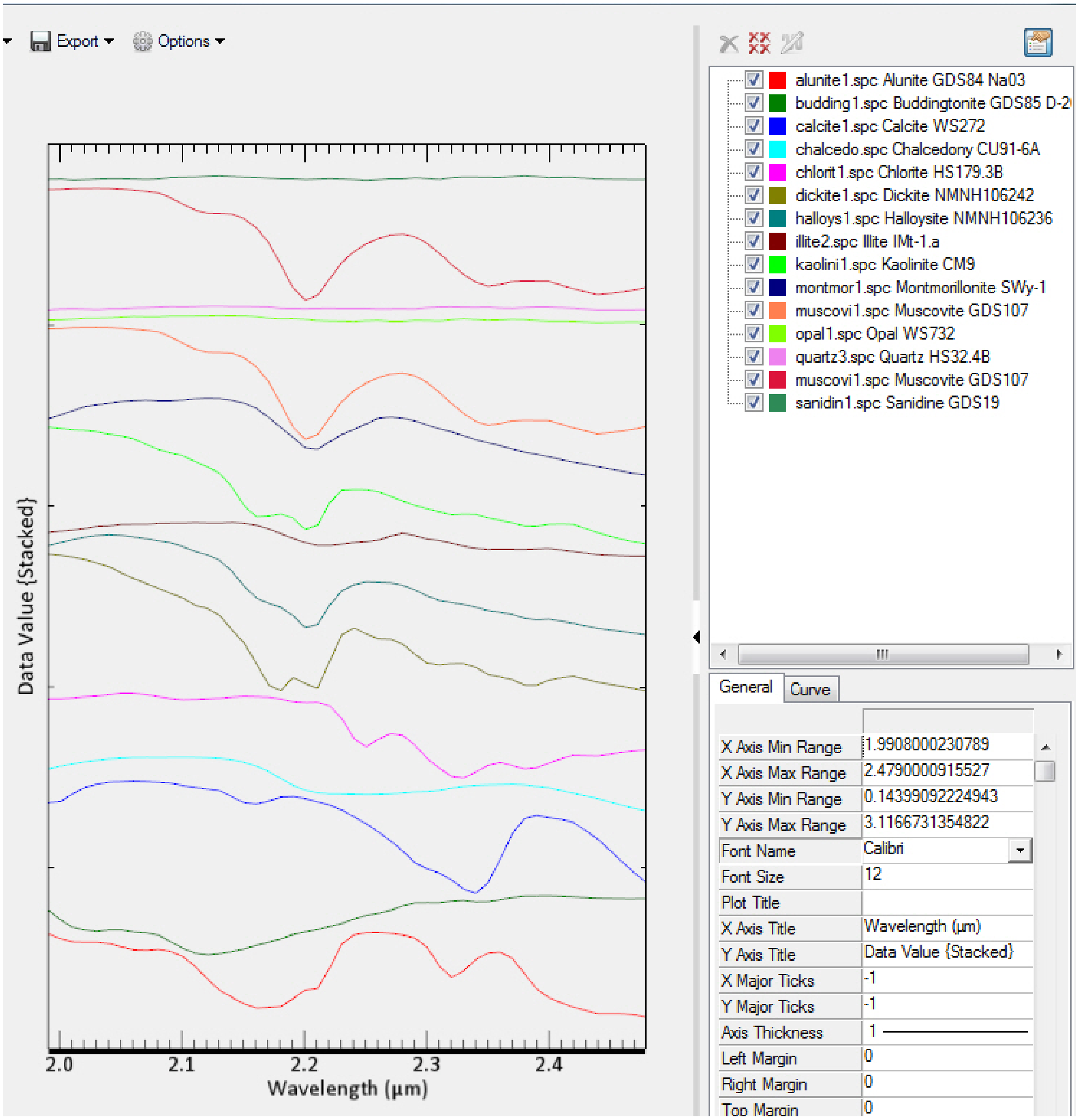
2) To expedite this lab, I used the USGS Mineral Spectral Library (available from the USGS; in ENVI available as “usgs_min.sli”) that was developed with detailed VNIR-SWIR signatures of minerals in a laboratory setting, and I converted this library to a spectral library that fits the airborne AVIRIS 50-band SWIR data. Then I extracted 14 minerals that were mapped by the USGS at Cuprite (see legend above) and created a new spectral library for this lab’s AVIRIS 50-band SWIR data.

This focused spectral library is named

“USGS_Min_Spec_Cuprite_50band_14minerals.sli”

and is found in the **Lab_11_Data** folder.

The 14-mineral Cuprite library is shown below. The list of minerals on the right is shown as spectral signatures in the reverse sequence on the left. Note the red alunite band is at the bottom of the spectral signatures and at the top of the list on the right. Many unique absorption features that are used to identify minerals occur at different wavelengths.

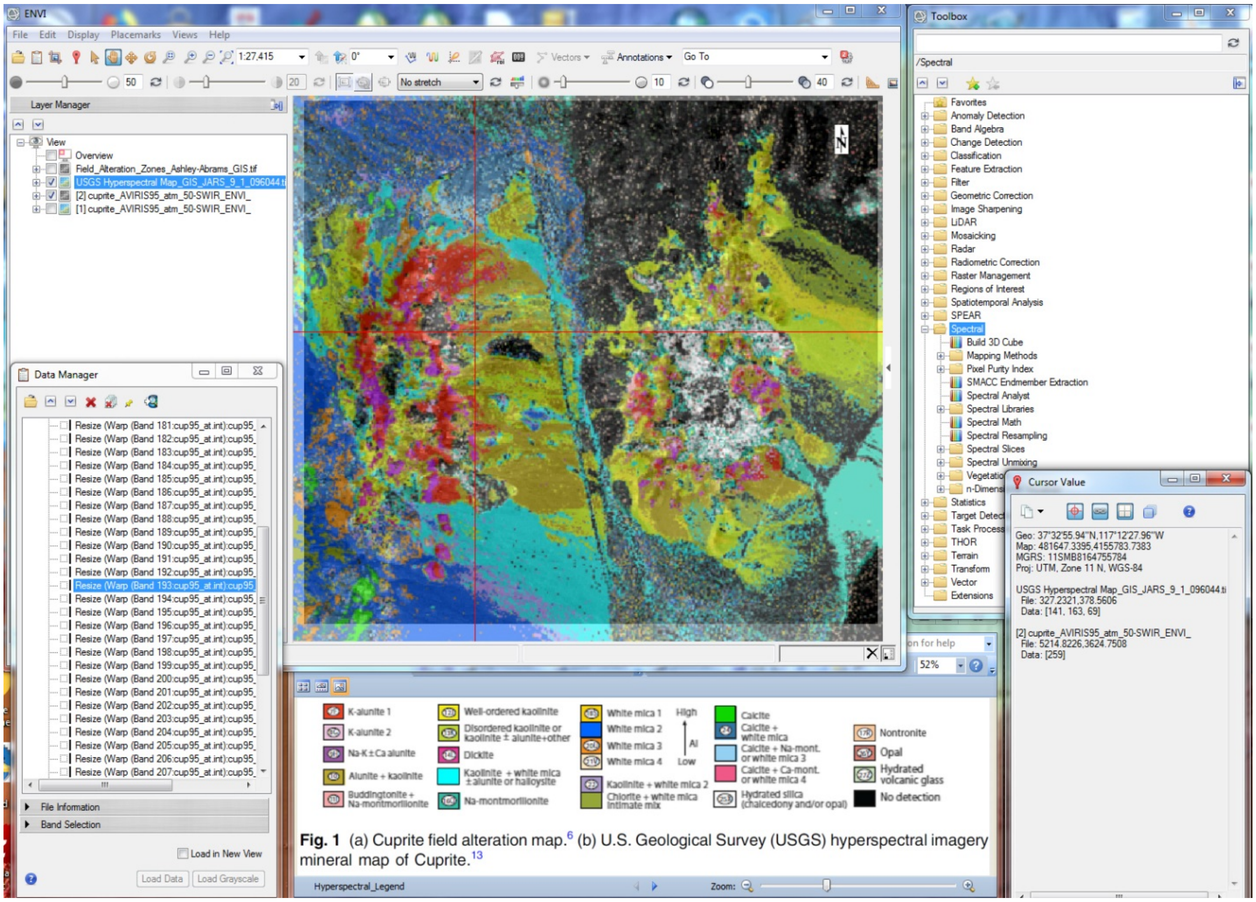


NOTE: My 14-mineral spectral library (above) has significant limitations because I did not account for differences in composition when creating the Cuprite 14 mineral spectral library. Many minerals have more than one entry in the “usgs_min.sli” spectral library because of differences in composition.

Quartz does not have a diagnostic spectral absorption feature in the SWIR wavelengths. Opal, sanadine and chalcedony also lack an absorption feature. They are included in the 14-band spectral library as field work by Ashley and Abrams (1980) confirmed their occurrence at Cuprite.

3) You should have the 50-band SWIR data, the color geologic map and the grayscale map in your ENVI display. Open the USGS color mineral legend (shown above) with a

picture viewer and place it next to the ENVI display so you can more easily correlate colors on the map displayed in ENVI with the legend.



Example of the set-up for one computer screen that includes the ENVI display, Data Manager, Toolbox, and the USGS color legend as a floating picture. The color map is interactively made transparent and opaque with the slider to help pick sites for a spectral profile.

3) Let's compare spectral profiles in our hyperspectral data to spectra in the USGS spectral library.

a) *Zoom-in* so the hyperspectral image fills your View. *Click-on* the grayscale map and *click-off* the color map. Turn the grayscale map *on & off* so you can compare the map patterns to patterns on the hyperspectral image. The "Silicified" pattern can be seen on the image.

b) Notice that the map does <u>not</u> fit the image very well – the image is not orthorectified so distortions due to topography are inherent and both maps were screen-captured from the pdf publication so they also have inherent distortions.

c) *Click-off* the grayscale map and *click-on* the color geologic map. Use the transparency slider to compare the patterns on the color map with the hyperspectral image. Use the Data Manager to load any grayscale band. The color map when partially transparent will be easier to compare with patterns on a grayscale band– it will be more apparent when the map is not aligned with the image.

d) *Set* the transparency for the color map at 40%,
Highlight the 50-band hyperspectral data in the Layer Manager.
Click-on the *Spectral Profile* tool (or use *Display > Profiles > Spectral*).

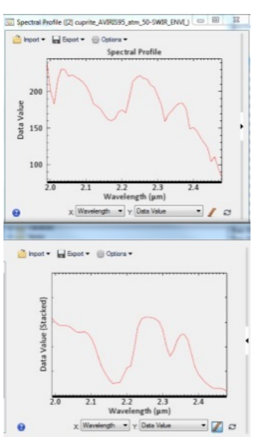
e) The Spectral Profile window pops-up.
Move your cursor to the bright red pattern (“K-alunite 1” mineral) that is mapped on the western hill. “K-alunite” and “alunite1” are the same in this lab exercise. *Move* your cursor to different locations in the red, K-alunite outcrop pattern. Notice how consistent the absorption feature is at ~2.17 µm. Place your cursor on the bottom of this absorption feature and see the wavelength value in red numbers at the bottom of the window.

To better interpret absorption feature wavelengths and shapes, *click-on* the “Data Value” drop-down menu below the spectral profile .

Choose “Continuum Removed”. Now click around the red pattern and observe the consistency and variation in the ~2.17 µm absorption feature.

Keep the Spectral Profile window open – we will *compare* the airborne AVIRIS profile in this window to the USGS spectral library profile of alunite next.

f) We open the 14-mineral spectral library that is in the **Lab_11_Data** folder.
File > Open drive to the **Lab_11_Data** folder
Select “USGS_Min_Spec_Cuprite_50band_14minerals.sli” *> Open*



The “Spectral Library Viewer” window pops-up.
The 14-band library is open on the left side of the window.
Select “alunite1…”

Move the library window with the spectral profile under the spectral AVIRIS spectral profile for alunite so the two profiles are aligned. See example to left.

Open the Properties menu (black triangle on the right side) of the Spectral Library Viewer so you can see the mineral that is displayed, and can delete profiles as needed.

Compare the shape and wavelength of the K-alunite1 (red pattern) spectral profile on the geologic map and in the USGS Spectral Library. *Click* around the alunite outcrop on the geologic map with your spectral profile tool.

Alternate profile display between “Continuum Removed” and “Data Value”

Question 7: A. Do you find the absorption feature of alunite is *relatively* consistent between the pixels in the hyperspectral data set and the USGS Spectral Library? YES NO

NOTE: Most pixels are mixtures of minerals – there are very few pixels in a scene characterized by only one mineral – pure pixels are named “end members”. So you will see variation in the shape and perhaps in the wavelength of the absorption feature for most pixels in the scene.

g) *Move* and *Click* your cursor on the bright green pattern on the color map (lower left). Your outcrop has to be within the smaller area covered by the AVIRIS image! A new spectral profile from the 50-band SWIR hyperspectral data is displayed. Click around the green pattern – is the spectral profile consistent?

In the “Spectral Library Viewer”, find the <u>one</u> mineral in the USGS library that matches the mineral represented by the bright green color on the map.

Select and *delete* the “alunite1…” and other profiles you try out in the properties menu for clarity.

Question 8: A. What mineral is represented by the green color in the USGS color map?

B. What is the wavelength of the absorption feature in both the hyperspectral data and in the spectral library?

h) Kaolinite, Dickite, and Halloysite are clay minerals with similar chemical and physical properties. They are common in hydrothermally altered terrain.

Display these three clay minerals in the Spectral Library Viewer.

Click inside the <u>yellow</u> pattern on the color map (well-ordered Kaolinite).

Question 9: A. Do you find pixels with the deepest absorption feature at ~2.21 µm? YES NO

B. Do you find pixels with the “doublet” absorption feature? (two absorption features next to each other) YES NO

B. What is the wavelength for the deepest absorption feature for dickite and halloysite in the spectral library?

i) *Add* “muscovi1” (muscovite = white mica) to the Spectral Library Viewer.

Click-on many pixels in the blue pattern (White mica 2) on the color geologic map and analyze the spectral profiles.

Click-on many pixels in the orange pattern (White mica 3) on the color geologic map and analyze the spectral profiles.

Question 10: A. What is the wavelength of the absorption feature for “muscovi1” (white mica) in the spectral library?

B. Describe the difference between the shape of the absorption feature of kaolinite and muscovi1 (white mica).

j) Remove all the minerals from the Spectral Library Viewer *except* kaolinite (“kaolini1”). Reload “alunit2” into the viewer. Think about what would happen to the absorption feature between ~ 2.15 and 2.23 µm if you mixed kaolinite and alunite.

Click around the “Alunite + kaolinite” pattern on the color map.

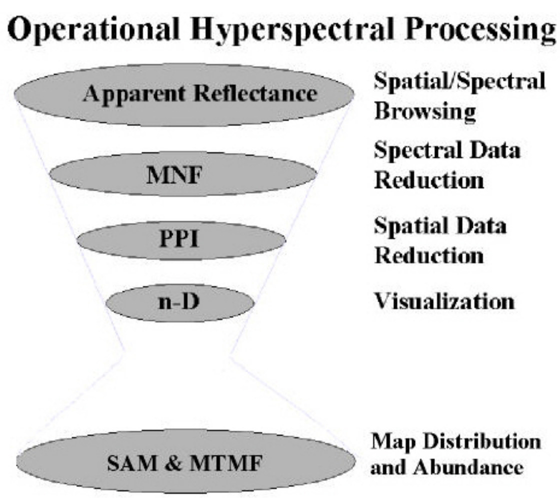
Question 11: A. What often happens to the depth of the first absorption feature in the kaolinite doublet (~2.16 µm) when alunite is mixed in?

NOTE: The spectral profiles of pure pixel end members are used to **unmix** the minerals in mixed pixels…and theoretically estimate what percentage of each mineral is in the mixed pixel. Finding pure pixels (end members) and “Unmixing” are often major goals of hyperspectral processing.

k) *Close* the Spectral Library Viewer and the Spectral Profile windows.

Uncheck all the layers in the Layer Manager except the 50-band hyperspectral data set

A good way to learn about hyperspectral processing is to use ENVI's "Spectral Hourglass Wizard" (created by J. Boardman and F. Kruse). The wizard has extensive explanations for the many processes – and many *warnings* about not letting your processing blindly follow the automated steps and results. Always <u>look</u> at the input and output data. This lab can only touch upon some of the steps – if you are interested in hyperspectral processing work with the wizard on your own.



1. Input/Output File Selection (input data are usually in reflectance)
2. MNF Transformation to reduce spectral dimensions
3. Review of MNF Results
4. Data Dimensionality determination using Spatial Coherence measures
5. Pixel Purity Index (PPI) to reduce spatial dimensions
6. Review of PPI Results
7. n-Dimensional Visualization, including auto-clustering, to select and retrieve individual endmembers
8. The option to manually add User Supplied Endmembers
9. Spectral mapping using Spectral Angle Mapper (SAM) and/or Mixture-Tuned Matched Filtering (MTMF)
10. Investigation of Mapping Results

As you gain experience with hyperspectral data, try ENVI's Toolbox's many tools in the Spectral, SPEAR and THOR Folders.

ENVI Toolbox > Spectral > Spectral Unmixing > Spectral Hourglass Wizard
<u>INTRODUCTION</u> page - *READ* the text for each step!

j) After reading the first page, press > *"Next"*
<u>SELECT INPUT/OUTPUT FILES</u> page
select our 50-band SWIR hyperspectral dataset for input.
Select an output folder for the many files that are produced.
> *Next*

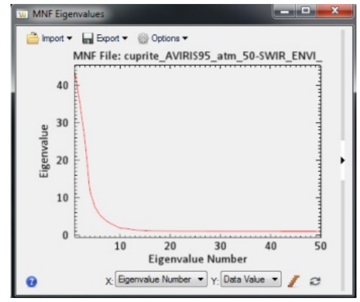
1) <u>FORWARD MNF TRANSFORM</u> page

Accept Defaults input "50" MNF bands

Do not use "Shift Difference Spatial Subset…"

 > *Next*

MNF Eigenvalues" plot pops up (see plot to right).



Do you see a flattening of the MNF curve after "10" ?
(10 of the 50 MNF Eigenvalue bands have a value above 1.8538.
The remaining 40 MNF bands have very little data variance – mostly noise).

2) > *Next*   VIEW MNF RESULTS page
"Load MNF Result to ENVI Display…."
The wizard may automatically fills the ENVI Classic 3-window display *and* the newer GIS-look display. Look for the list of MNF bands in the Data Manager.

Apply "Linear 1%" stretch if image is black.

"Load Animation of MNF Bands…" If this window does not appear, look in the Windows Taskbar at the bottom of your computer screen to display….
Slow the animation down with Speed "1" More effective to hit the "Pause" symbol and *manually* work your way back and forth through the bands with the black arrows.

Question 12: A. What do you visually see as a reasonable number of MNF bands to use going forward? (relatively clean data, not much noise).

3) > *Next*   DETERMINE DATA DIMENSIONALITY page
We see the MNF Eigenvalues plot again – with a black background.

Accept defaults (50) > Calculate Dimensionality

The "Spatial Coherence Threshold" plot shows up. Move the horizontal red line up and down number (use your cursor in the plot or the arrows). Each Threshold Level specifies the number of bands above the threshold.

Question 13: A. What “Threshold Level” did you decide to use and how many MNF bands does the ENVI program recommend using going forward?

B. Why the difference between what you saw with your eyes and what the computer program specifies as good MNF bands to use going forward?

To achieve lab class consistency, let’s type in“20” as the number of MNF bands to retain going forward. Type “20” into the Data Dimensionality window.

4) > *Next* DERIVE OR SELECT ENDMEMBERS page

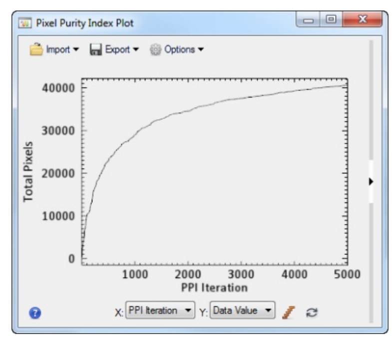
Choose to Derive Endmembers from Image “Yes” > *Next*

5) PIXEL PURITY INDEX page
Accept the PPI defaults (5,000 iterations, threshold value 2.5, memory use 10.0 Mb. > *Next*

NOTE:
I found 20,000 iterations on a fast workstation provided a curve that flattened more compared to the default 5000 iteration curve.
If you are on a fast computer, try increasing your iterations and maximum memory.

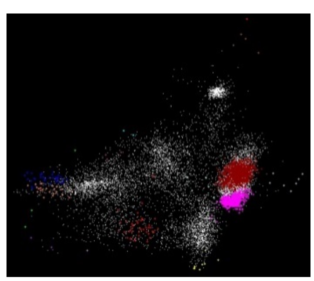
You want to flatten the curve in the upper right.

A PPI image with a grid pops up on the ENVI View.



6) EXAMINE PPI RESULTS page *Accept* 10,000 default > *Next*

7) N-DIMENSIONAL VISUALIZER page Read the discussion on this page!
Enlarge the “n-D Visualizer” window > *Start*
Reduce speed to 10. Be amazed by the cloud with end members
These are “pure” pixels color-coded by the ENVI wizard.



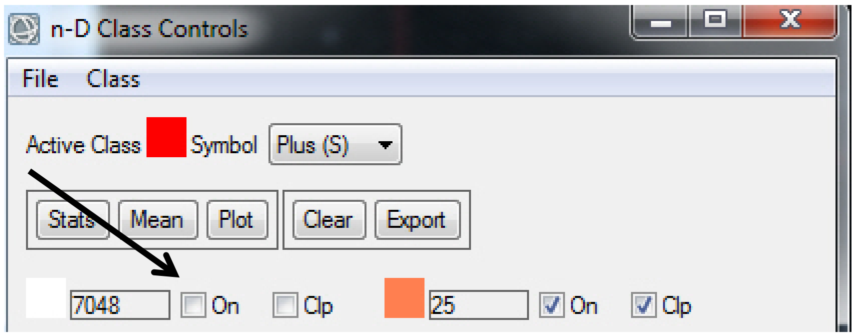
Examine the drop-down menus in the “n-D Controls” window.

Options > Show Axes

Options > Class Controls

The "n-D Class Controls" window pops-up with the 20 color-coded classes

Turn off the White pixels (I have 7048 white pixels). The white pixels are not end members (my understanding…). I see a much clearer picture of the 19 end members! Do you?



There are 20 MNF bands in the "n-D Controls" window (looks like a calendar) They are color-coded in the "n-D Class Controls" window.

Try different 3-band combinations. Turn off the active 3 bands, and then select 3 new bands. After a few combinations, try 18-19-20 > *Start*

Question 14: A. What happens to the cloud when you load MNF bands 18-19-20 into the n-D Visualizer?

B. What does the 3D shape of the 18-19-20 cloud tell you about coherent spectral information and noise in these MNF bands?

8) You can add your own end members by interpreting corners in the cloud or by importing from a Spectral Library. We will import our "alunite1" spectral profile from our 14-band spectral library.

"n-D Controls" > *Options* > *Import Library Spectra* >

"n-D Visualizer Import Spectra" window pops-up >

Import *select* "from Spectral Library File>

"Spectral Library Input File" window pops up

If you don't see our 14-band spectral library in the list, go to the "Open" drop-down menu at the bottom of this window > *choose* "Spectral Library" > drive to **Lab_11_Data** folder with our 14-band library > *Select* > *Open*

In the "Spectral Library Input File" window our 14 band library file displays at the top of the list>

Select "USGS_Min_Spec_Cuprite_50band_14minerals.sli" > *OK*

The “Input Spectral Library” window pops up.
Select “alunite…” accept defaults > *OK*

Two more windows pop-up(!).
The “alunite1…” spectra is highlighted and the profile displayed in the Spectral Library Viewer.

“alunite1…” is also highlighted in the “n-D Visualizer Import Spectra” window > *Apply* and then *the* second small window (“Import Spectra Parameters”) pops-up > *Accept* default color > *OK*

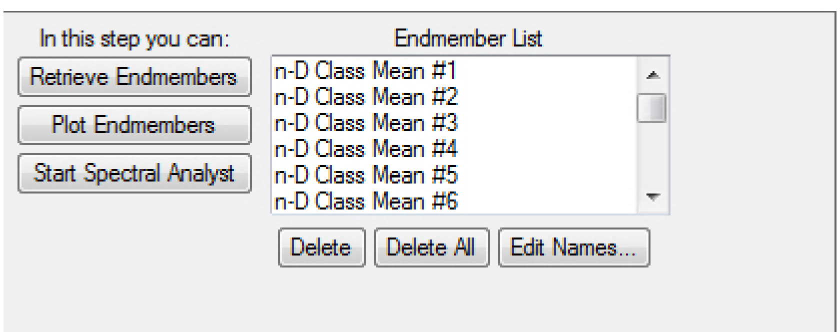
The Alunite1 position in the cloud is displayed and labelled!

Try to determine what if any PPI endmembers correlate spatially with the USGS “alunite1…” spectra. The magenta endmember (553 pixels) and the dark brown endmember (2149 pixels) are often near the USGS spectra as different bands are selected with the n-D Visualizer tool.

6) Let’s delete our Alunite1 point. “n-D Controls” > “Options” > “Delete Library Spectra” window pops-up > select “alunite1*…”* > *OK*

7) In the Wizard’s N-DIMENSIONAL VISUALIZER page
> *click on* “Retrieve Endmembers”
The 19 endmembers populate the Endmember List.

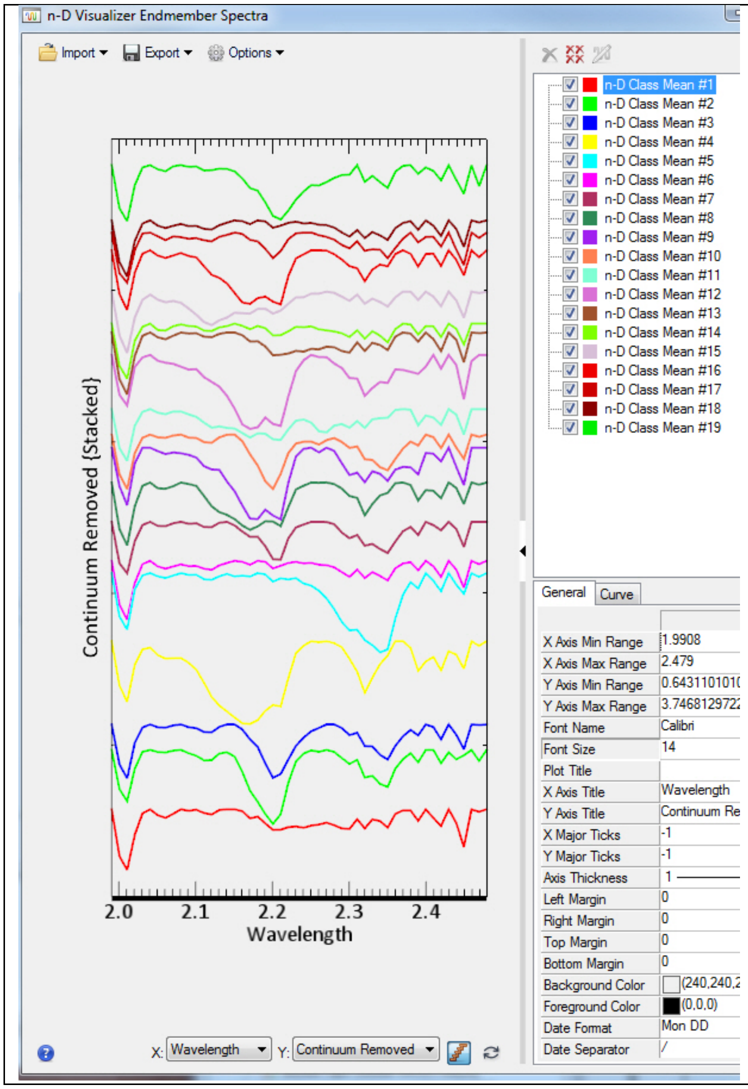
The “Plot Endmembers” and “Start Spectral Analyst” buttons are activated.



Click-on “Plot Endmembers”
The “n-D Visualizer Endmember Spectra” window pops-up.
(see window below)

Change from “Data Value” to “Continuum Removed”
Click on the “Stack Plots” icon

Read through the text on the right side of the "n-D Visualizer Endmember Spectra" window below. Note how similar these endmember spectra to some of the spectral profiles we found while clicking around the AVIRIS SWIR data set. Muscovite (white mica). Calcite.



"n-D Visualizer Endmember Spectra" window

"Data Value" changed to
"Continuum Removed"

Clicked on "Stack Plots"

What endmembers have unique spectral profiles in the SWIR wavelength range?

Experienced analysts can identify the material (minerals in our example) that is associated with a spectral profile on the left.

"n-D Class Mean #2 (green profile 2nd from the bottom) is very similar to "muscovite" or "white mica".

"n-D Class Mean #5 (cyan profile 5th from the bottom) is very similar to "calcite".

The end member spectra can be exported from this menu as a spectral library using the "Export" dropdown menu! Then you could do an excellent job comparing your endmember spectra to large spectral libraries and more accurately rename the endmembers. You could also delete those endmembers that had spectra that was not in your area (based on field work and knowledge about materials in the scene.

Also you could use the "Start Spectral Analyst" tool that is shown on the "N-Dimensional Visualizer" menu to help identify your endmember spectra.

These are very powerful tools!

The spectral signatures and names of the 19 endmembers are shown on the plot above

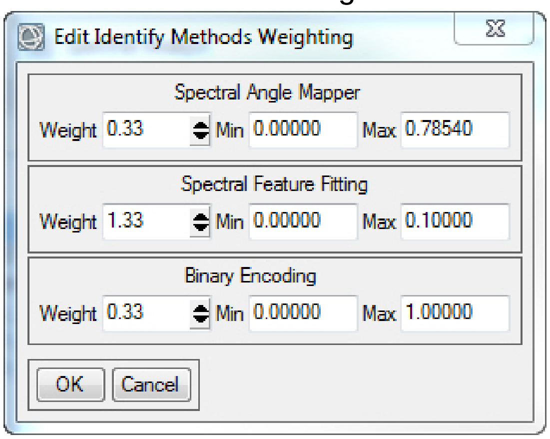
<u>The profiles and list are in reverse order</u>. "n-D-Class Mean #1" is at the bottom of the profile stack…n-D Class Mean#19 is at the top of the profile stack.

8) You should realize that several of these spectral profiles look like spectra in our 14-band Spectral Library. <u>Read the text in the box above.</u>

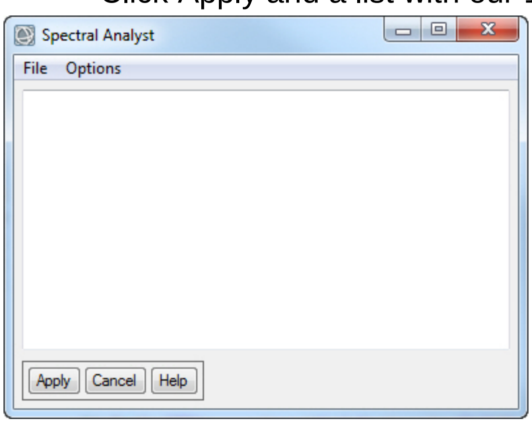
Click-on the “Start Spectral Analyst” button in the Wizard’s N-DIMENSIONAL VISUALIZER page

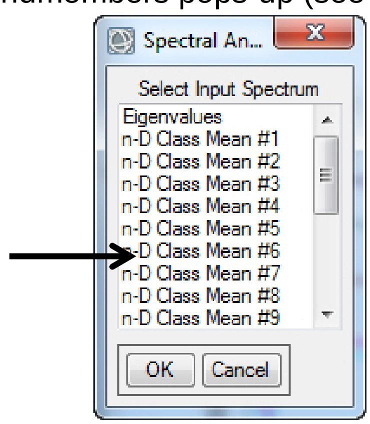
The “Spectral Analyst Input Spectral Library” window pops-up.
Select our 14-mineral Spectral Library (if it isn’t in the list, go to the drop-down menu at “Open” > Spectral Library > and drive to our library location in the **Lab_11_Data** folder and select > *OK*

The “Edit Identify Methods Weighting” window pops up.
We will use all three methods to evaluate our 19 endmember spectral profiles so enter 0.33 in the three “Weight” windows. > *OK* (see below)



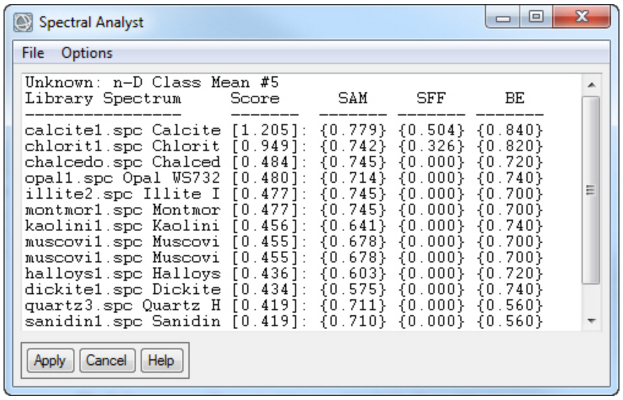
A blank “Spectral Analyst” window pops up (see below at left)
Click Apply and a list with our 19 endmembers pops-up (see below at right)





Select endmember #5 (we think this looks like Calcite) > *OK*

The “Spectral Analyst” window pops back up with a list of potential spectra that match our endmember #5 – ranked by score. (see below)



#1 fit is Calcite!

Click on **Help** at the bottom of the Spectral Analyst menu to understand the limitations and processes involved. Some Help comments below.

NOTE: Use the **Spectral Analyst** to help identify materials based on their spectral characteristics. The Spectral Analyst uses ENVI techniques such as Binary Encoding, Spectral Angle Mapper, and Spectral Feature Fitting to rank the match of an unknown spectrum to the materials in a spectral library.

The output of the Spectral Analyst is a ranked or weighted score for each of the materials in the input spectral library. The highest score indicates the closest match and indicates higher confidence in the spectral similarity. Similar materials may have relatively high scores, but unrelated materials should have low scores.

This function does not identify spectra; it only recommends likely candidates for identification.

Question 15: A. Using the “Spectral Analyst” tool, click on “Apply” and select “n-D Class Mean #9”. What three closely related clay minerals have the highest score?

B. Look at the profile of n-D Class Mean #9. What is the term used to describe the unique spectral absorption feature between 2.17 and 2.21 µm?

C. Using the “Spectral Analyst” tool, click on “Apply” and select “n-D Class Mean #4”. What mineral has the highest score?

9) “Edit Names” in the Endmember List shown in the Wizard’s the Wizard’s N-DIMENSIONAL VISUALIZER page.

Change “n-D Class Mean #5” to “Calcite”
Change “n-D Class Mean #9” to the mineral with the top score.
Change “n-D Class Mean #4” to your answer above.
Your changes will show up on our next map!! > *Next*

10) <u>USER SUPPLIED ENDMEMBERS</u> page. We won't add "User Supplied Endmembers". If you did field work and collected spectra, you could add your spectra her to improve and validate your map. *> Next*

11) <u>MAPPING METHODS</u> page. Carefully **<u>read</u>** this section – excellent review of the different methods!

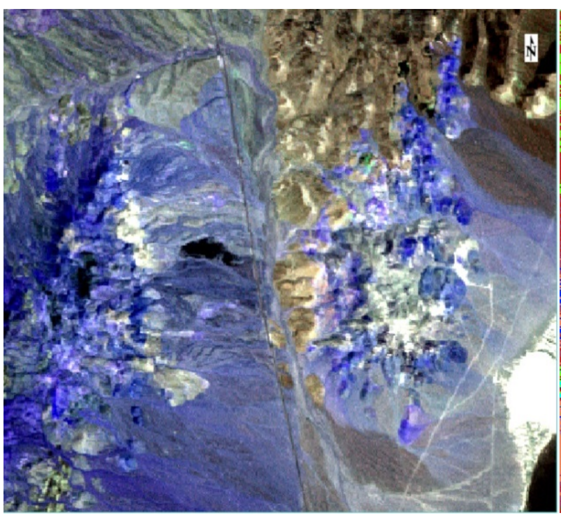
Let's just do *one* method – SAM with the default SAM Maximum Angle of 0.10 (*uncheck* MTMF and Unmixing methods) *> Next*

12) The SAM process is completed and the Wizard page <u>INVESTIGATE SAM RESULTS</u> page pops-up. **<u>Read</u>** this explanation of SAM.

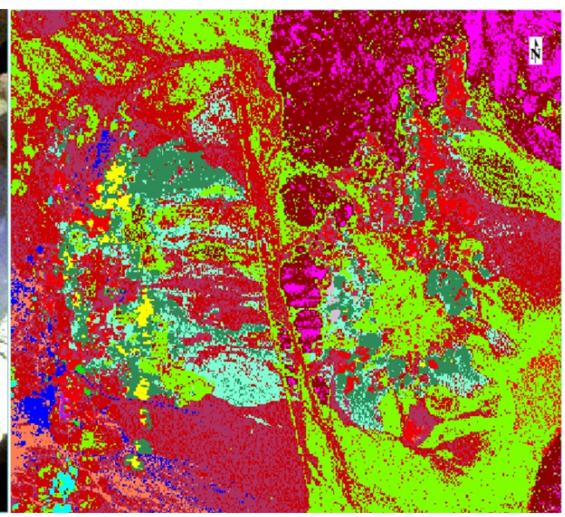
In the Data Manager you will see the SAM 19-class classification map (shown below) and the SAM 19 Rule Images (grayscale).

Turn on your SAM classification map and the USGS Hyperspectral classification map. Turn all other layers *off* in the Layer Manager.

Highlight the SAM map in the Layer Manager. Manually use the transparency slider to fade the SAM map from opaque to transparent. Answer Question 16.



Color composite of SWIR bands



SAM map with 19 classes

Question 16: Questions are based on the SAM classification map.
(Hint: Use the "Cursor Value" tool to query the class shown on your map)
A. Is Calcite located in the same place as on the USGS hyperspectral color map? YES NO

B. What is the "nD-Class Mean #3 class on the USGS hyperspectral color map?

C. Right-click on the “Classes” folder under the SAM map in the Layer Manager > *Select* “Statistics for all Classes”. In the “Data Selection” window ensure the “cuprite…_sam_class” file is *selected.*

What are the three largest classes?
What are the three smallest classes (don’t include “Unclassified”)?

D. Does your classification map show spatially coherent classes?
YES NO

13) SAM Rule images are grayscale probability images. Each endmember has a SAM Rule image. The better the fit of the pixel to the endmember’s spectral profile, the smaller the “spectral angle” and the <u>blacker</u> the pixels in the Rule image. Use the Cursor Value tool to query light and dark pixels in the Rule images.

In the Data Manager, expand the “cuprite…._sam_rule” file so that the 19 endmembers are displayed.

Select the “Rule (Calcite)” > *Load Grayscale* > *contrast stretch* “Linear 1%”
Calcite is the renamed “n-D Class Mean #5”
Use the Cursor Value tool to query the brightest and darkest pixels.
(you could also use the “Quick Stats” tool to get exact values).

Question 17: A. What is the SAM Rule value for the brightest pixel you find?

B. What is the SAM Rule for the darkest pixel you find?

C. According to the USGS color geologic map, what mineral is located where the Calcite SAM Rule map has the brightest pixels? (meaning spectra in these pixels are very different compared with calcite spectra).

C. Where are the darkest pixels located?

Turn-off all layers in the Layer Manager. *Turn-on* the colorful SAM classification map.
File > *Chip View To* > Geospatial pdf
Leave the metadata blank…bad practice but this lab is too long!
Output Filename: “YourName_SAM_map” *check* “Display Result”
Upload your geospatial pdf to the instructor.

Congratulations for completing this lab! You now have some understanding of the potential for hyperspectral remote sensing to provide unique, very informative, and very detailed maps of material on the Earth’s surface.

Lab 11 Hyperspectral Section 1 Name:

Hyperspectral VNIR Datacube for Vegetation Analysis

Upload the following files to the instructor:

"YourName_5_Spectral_Profiles" as a .png

YourName_3D_Datacube" as a .tif

Question 1: What is the name of the unique sharp increase in brightness (Data Value) between 680 and 745 nanometers?

Question 2: Why is the reflected brightness highest in the 520 – 600 nm range compared to the 400 – 520 nm and the 600 - 680 nm ranges?

Question 3: What causes the unique absorption feature for healthy vegetation that is between ~600 and 680 nm? (Hint: think about what is causing the higher reflectance values at shorter and longer wavelengths?)

Question 4: A. What is the calculated NDVI value for your brightest (most vigorous) pixel?

B. What is the calculated NDVI value for the gray terrain (in the color IR image gray may represent dormant, dry grasses and other ground vegetation)?

C. How did the program calculate NDVI?

Question 5: Discuss what happens to VNIR spectral profiles when you move from vigorous vegetation to no vegetation (barren terrain).

Question 6: A. Do you think there is new information and patterns in the classification map about vegetation, soils, barren ground, etc. that made our MNF and isoDATA effort worthwhile? YES NO

B. Do you see shadows in the classification map? If so, what class number represents many shadows?

C. What class number represents the most vigorous vegetation?

Lab 11 Hyperspectral Section 2 Name:

Hyperspectral SWIR Datacube for Geologic Mineral Mapping

Upload the following file to the instructor:

"YourName_SAM_map" as a pdf (at the end of the lab)

Question 7: A. Do you find the absorption feature of alunite is *relatively* consistent between the pixels in the hyperspectral data set and the USGS Spectral Library? YES NO

Question 8: A. What mineral is represented by the green color in the USGS color map?

B. What is the wavelength of the absorption feature in both the hyperspectral data and in the spectral library?

Question 9: A. Do you find pixels with the deepest absorption feature at ~2.21 µm? YES NO

B. Do you find pixels with the "doublet" absorption feature? (two absorption features next to each other) YES NO

B. What is the wavelength for the deepest absorption feature for dickite and halloysite in the spectral library?

Question 10: A. What is the wavelength of the absorption feature for "muscovi1" (white mica) in the spectral library?

B. Describe the difference between the shape of the absorption feature of kaolinite and muscovi1 (white mica).

Question 11: A. What often happens to the depth of the first absorption feature in the kaolinite doublet (~2.16 µm) when alunite is mixed in?

Question 12: A. What do you visually see as a reasonable number of MNF bands to use going forward? (relatively clean data, not much noise).

Question 13: A. What "Threshold Level" did you decide to use and how many MNF bands does the ENVI program recommend using going forward?

Question 14: A. What happens to the cloud when you load MNF bands 18-19-20 into the n-D Visualizer?

B. What does the 3D shape of the 18-19-20 cloud tell you about coherent spectral information and noise in these MNF bands?

Question 15: A. Using the "Spectral Analyst" tool, click on "Apply" and select "n-D Class Mean #9". What three closely related clay minerals have the highest score?

B. Look at the profile of n-D Class Mean #9. What is the term used to describe the unique spectral absorption feature between 2.17 and 2.21 µm?

C. Using the "Spectral Analyst" tool, click on "Apply" and select "n-D Class Mean #4". What mineral has the highest score?

Question 16: Questions are based on the SAM classification map.
(Hint: Use the "Cursor Value" tool to query the class shown on your map)
A. Is Calcite located in the same place as on the USGS hyperspectral color map? YES NO

B. What is the "nD-Class Mean #3 class on the USGS hyperspectral color map?

C. Right-click on the "Classes" folder under the SAM map in the Layer Manager > *Select* "Statistics for all Classes".

What are the three largest classes?

What are the three smallest classes?

D. Does your classification map show spatially coherent classes?
YES NO

Question 17: A. What is the SAM Rule value for the brightest pixel you find?

B. What is the SAM Rule for the darkest pixel you find?

C. According to the USGS color geologic map, what mineral is located where the Calcite SAM Rule map has the brightest pixels? (meaning spectra in these pixels are *very different* compared with calcite spectra).

D. Where are the darkest pixels located?

Lab 12 Change Detection and Radar Polarization
Utilizes Textbook's Remote Sensing Digital Database: Chapters 3 and 6 data.

The objectives of this lab are to learn three methods for documenting change on images over 16 days in central California and to evaluate the information provided by radar bands acquired with different polarizations.(see Chapter 9 Digital Image Processing for discussion). The change detection images and several files for the radar exercise are located in the **Lab_12_Data** folder. The tasks we will complete with this lab are done with tools in the **ENVI Toolbox**.

Three digital files are to be uploaded to the instructor and sixteen questions answered on the last pages of this handout.

Change Detection
We will analyze change at Mt. Diablo, California with Landsat images acquired before and after a fire. Much of the Mt Diablo exercise is courtesy of M.B. Quinn, Geography Dept., Diablo Valley College, Pleasant Hill, California.

NOTE: The two images used for change detection and band ratios need to have *exactly* the same number of rows and columns, and the same pixel size. When you cannot get the 2nd image to load in a change detection algorithm, check the Metadata and use the "Resize" tool to give the images the same dimension and same pixel size.

Change at Mt. Diablo, California: 7 September 2013 to 23 September 2013 (16 days)

Open ENVI
1) *Load* the two Landsat 8 TM subscenes into one View.
The datasets are in the **Lab_12_Data** folder.
mt_diablo_landsat8_7sep2013_30m_6band.tif
mt_diablo_landsat8_23sep2013_30m_6band.tif

Zoom to Full Extent
Change RGB Bands to reflected SWIR2 – NearIR – Green (Bands 6-4-2) as R-G-B so enhanced color images display
Contrast stretch with "Linear 2%" (SWIR2-NearIR-Green bands)
Perform Band Animation with the 6 bands on both Landsat images.

Load the DEM and hillshade DEM in the **Lab_12_Data** folder.
mt_diablo_30m_dem _
mt_diablo_30m_dem_shaded_
Drag the DEMs below the Landsat images in the Layer Manager.
The shaded DEM should be above the DEM.
Contrast stretch the DEM files with "Linear 1%"
Right-click the DEM > Change Color Table > Rainbow

Examine the hillshade and color-coded DEMs.
Select the hillshade DEM in the Layer Manager > "Transparency" slider > Fade the hillside DEM to 40%.

If needed, *drag* the 23 September image to the top of the Layer Manager.

Pan around the scene and *Zoom in* to the mountain. *Turn on and off* the 7 Sept and 23 Sept images so you see where features on the images are located on the color-coded hillshade DEM.

Question 1: A. What color is healthy vegetation in our enhanced color images (SWIR–Near IR–Green as R-G-B)?

B. September is a hot and dry month around Mt. Diablo, California, and typically follows many dry summer months. Based on our enhanced color images, what features around Mt. Diablo have the healthiest (most vigorous) vegetation?

C. What is the elevation at the top of Mt. Diablo? (DEM in meters)

Use the Data Manager to *load* a grayscale Band 4 (reflected near IR light) from the 7 September and 23 September Landsat data.

Zoom in to Mt. Diablo.

Contrast stretch both grayscale images "Linear 2%". *Press* on the "Stretch on View Extent" icon (next to the contrast stretch drop-down menu) so only pixels within the View are used for the histogram and contrast stretch.

Question 2: A. Compare the 7 September band 4 to the 23 September band 4. Where geographically do you see the largest difference in brightness?

B. Based on what you see and can interpret, what event has the 23 September image captured on Mt. Diablo?

C. Based on the Landsat imagery, when did this event occur?

D. What Landsat spectral evidence do you have to support your interpretation about the event on Mt. Diablo between 7 and 23 September 2013?

2) In its simplest form, the difference between two images can be determined by subtracting one from the other: *Toolbox > Band Algebra > Band Math*

Enter the expression: "float (B1) – float (B2)" then "Add to List" > *OK*

The “float” within the expression allows negative (floating point) DN values in the output image.

Assign band 4 of the Sept 7 image as “B1”; *Assign* band 4 of the Sept 23 image as “B2”

Output filename: “lastname_bandmath”

Apply various (canned) contrast stretches. Apply the stretch that best identifies the difference between the two images.

Question 3: Explain how the band math subtraction of the 23 Sept image from the 7 Sept image results in the area of change having such a significant difference in brightness (DN value) compared to the surrounding area. (Hint: think what happened to the DN value of near IR pixels in the changed area compared to the DN value of near IR pixels in the surrounding area).

File > *Chip View To* > *File* > Format JPEG > “YourName_chg_bandmath”
Upload to the instructor.

3) Now let’s try ENVI’s change detection software:
Toolbox > *Change Detection* > *Change Detection Difference Map*

For the “Initial State” image, *select* band 4 of the September 7 scene, > *OK*

Select the September 23 scene (band 4) as the “Final State” image, > *OK*
Number of classes: 5

Select “Simple Difference” and “Standardize to Unit Variance”

Name the output file: “ Lastname_CDDM” (for Change Detection Difference Map)

The output image is a raster color slice showing various states of change relative to a mean DN value. The “plus” or “minus” indicate the positive or negative direction DN values have changed for each class. If your “LastName_CDDM” image was not automatically placed at the top of the Layer Manager by ENVI, select this file in the Data Manager and > *Load Data.*

ENVI’s default (assigned) colors for classes are red (for positive values of change) and blue (for negative values of change). The user, however, can easily assign any color to each of the classes:

To change the color scheme:
Right-Click on the “Classes folder under the “lastname_CCDM” image > *Select*

"Edit Class Names and Colors" > the window pops-up
> *Change* Class Names and Class Colors as you desire.

For this exercise, let's *change* the extreme change classes, 1 and 11.
Class 1: Change (+5) to Green
Class 11: Change (-5) to Yellow

Let's save as a jpg graphic.

File > Chip View To > File > Format JPEG > "YourName_color CCDM" *> OK*

Upload to the instructor.

3a) Individual or all of the classes can be exported to a more useful GIS polygon vector file (.shp format)
Toolbox > Classification > Post Classification > Classification to Vector

Select Input Band: the "Change Detection Difference Map" *> OK*

The "Raster to Vector Parameters" window pops-up
Select Classes to Vectorize > *select* "Change (-5)" *this is Class 11*

Accept defaults (Single Layer, output results to File)

Name the output file "Yourname_event_outline" in .evf format (ENVI vector format).

If the vector .evf file does not show up automatically in your Data Manager or Layer Manager, *File > Open > drive* to the folder where you saved your .evf file and *select* "Yourname_event_outline.evf" *(you must choose the file with .evf at the end) > Open*

Turn off all the files in your Layer Manager except the hillshade DEM. Your vector file looks excellent on the hillshade DEM!

Convert the .evf to .shp: *Toolbox > Vector > Classic EVF to Shapefile*
Name your shapefile "Yourname_CCDM_map_GIS.shp"

Recall that there will be at least three files associated with each ESRI shapefile (.shp, .shx, .dbf, & possibly a .prj file); so to not allow confusion in determining the difference between ENVI and ESRI files, provide a new, distinct name for the output shapefile(s).

Click-off all the layers in the Layer Manager. *Load* the shapefile into the View using the Data Manager (the shapefile may already be loaded in your view).

If the vector shapefile does not show up automatically in your Data Manager or Layer Manager, *File* > *Open* > *drive* to the folder where you saved your shapefile and *select* "Yourname_CCDM_map_GIS.shp" *(you must choose the file with .shp at the end)* > *Open*

The shapefile map matches exactly the ENVI .evf map.

Zoom in to Mt. Diablo. Let's send this vector map to the instructor.

File > *Chip View To* > *File* > Format JPEG > "YourName_CCDM_shp" > *OK*

Upload to the instructor.

Close all files using the Data Manager.

NOTE: You can run a majority filter on the 11-class, event CCDM classified raster image to reduce the number of small polygons. There are 733 polygons in this one shapefile!

In the GIS you can edit and eliminate small polygons – or all polygons outside of the main event feature – and create an excellent map with the feature of interest faded the hillshade DEM.

If you have access to a GIS, load the shapefile, Landsat images and DEM to evaluate. Look at the attribute table and note the area and perimeter calculations are provided for every polygon. So you can quickly provide area estimates to clean-up teams and environmentalists.

There is an ENVI tool named "Image Change Workflow". This tool attempts to indicate "change" between two images by comparing differences using multiple bands rather than single bands (as were used in the examples we just completed). If you have time and want to try this alternative method of change detection, here's the tool's location.

ENVI Toolbox > *Change Detection* > *Image Change Workflow*

Close all files using the Data Manager. Start the radar exercise with a blank View.

Radar Polarization

We will analyze HH and HV polarized radar images from the Chapter 6 folder in the Digital Remote Sensing Database. We will also evaluate two ways to generate a third image from the HH and HV images so we can develop an informative color composite.

NOTE: Band ratios require the two grayscale images to have exactly the same dimension (rows and columns) and the same size pixels. If the 2nd image will not load in the band math tool or allow you to "Enter Pair" in the ENVI's Band Ratio tool, you have to *resize* one of the images so that the rows and columns have identical dimensions.

Death Valley

We will process PALSAR-2 radar data of Death Valley, California and compare the radar to a Landsat 8 enhanced color image.
The textbook has PALSAR-2 characteristics in a Chapter 6 table along with a short description. See the textbook's Figure 6-11 that shows a close-up of the PALSAR-2 HH and HV images in Death Valley.

1) *Start-up ENVI >* *Views > Two Vertical Views*
Drive to the "Plate 18_PALSAR-2_Sentinel-1_DV" folder
and open the "PALSAR-2 L-band" subfolder.

The "…GeoTIFF" HH and HV bands are the original data and have their DNs in *unsigned integer* format. We'll use these two images for band math.

The "…BW_Image_GIS" HH and HV bands were converted from the original number format to *8-bit (byte)* images that are easier to visualize in a GIS.

Highlight View #1 > *File > Open*
Select the *unsigned integer* HH GeoTIFF image:
"DeathValley_Palsar2_HH_2016_Resized_UTM12N_GeoTIFF"> *Open*

Highlight View #2 > *File > Open*
Select the *unsigned integer* HV GeoTIFF image:
: "DeathValley_Palsar2_HV_2016_clip_UTM12N_GeoTIFF" > *Open*

2) Link the Views and *Zoom in* and *pan* around Death Valley to compare the HH and HV imagery. Try different stretches. I found the obscure "Square Root" contrast stretch worked very well. See ENVI Help (definition below)

Square Root performs a square root gray scale transformation, then applies a linear stretch.

Question 5: Which polarized band carries more information to the untrained eye: HH or HV?

3) We will use the band ratio to create a third grayscale radar image from the PALSAR-2 HH and HV images.

We will divide the DN of the pixels on the HH image by the DN of the pixels on the HV image to generate a ratio grayscale image. The “Committee on Earth Observation Satellites” (CEOS) notes that the HH/HV backscatter ratio is commonly used with PALSAR (L-band) data and displayed in the blue channel as it results in a color composite image in which vegetated areas appear green.

We can use either band math or the “Band Ratios” tool.
With band math the formula becomes:
float (b1) / float (b2)

ENVI Toolbox > Band Algebra > Band Math
In the “Band Math” window:
Enter the expression above > Add to List, and then > *OK*
click on the HH image for B1 and the HV image for B2 > *OK*
Name the output: “DeathValley_HH_HV_Ratio _radar”

The ratio image will appear in one of the two vertical views.

Let’s create a 4-View display. *Views > 2 x 2 Views > OK*

Highlight the empty View #3
Drag the “DeathValley_HH_HV_Ratio _radar” to View #3
(*remove* from View 1 or 2)
or load the ratio image into View #3 from the Data Manager.

Views > Link Views > Link All > OK *Zoom to Full Extent*
Zoom in and *pan* around to compare the 3 grayscale images:
HH, HV, and HH/HV

Question 5: Describe the ratio (HH/HV) image in 10 words or less.

Now we want to stack these HH, HV and ratio images into a 3-band color image.
Highlight the empty View #4
ENVI Toolbox > Raster Management > Layer Stacking
Import the 3 files by selecting all 3 files > *OK*
Reorder if necessary:
The stack should be from top to bottom: HH, HV, HH/HV Ratio.
(or HH – HV – HH/HV Ratio Image as R – G – B (1-2-3)

Accept the defaults…. > Output Filename:
"DeathValley_HH_HV_ratio_radar" *> OK*

Load the HH-HV-ratio color composite into View #4
Views > Link Views > Link All > OK
Try different stretches on the HH-HV-ratio color composite.

4) You should have
HH in View 1,
HV in View 2,
HH / HV ratio grayscale in View 3, and
HH-HV-band ratio color composite in View 4
Views > Link Views > Link All > OK

Question 6: Do you think the color composite (View 4) tells you more information about Death Valley compared with the grayscale HH and HV? YES NO

5) *Right-click* on View #1 (HH Band) in the Layer Manager and > *Remove View*
Right-click on View #2 (HV Band) in the Layer Manager and > *Remove View*

In the View with the HH/HV ratio, load the **Landsat** color image.
Highlight this View *File > Open*
Drive to the
"Plate 18_PALSAR-2_Sentinel-1_DV \ Landsat8" subfolder
and *select*
"DeathValley Landsat8_P40R35_22Feb2017_752 Enh-Color_30m_Image_GIS"
> Open
Zoom to Full Extent The Vertical two Views should be linked.
Zoom-in and *pan* around to compare the enhanced Landsat that is generated from reflected SWIR2, Near IR, and blue light with the radar color composite that is generated from reflected radar energy.

Question 7: A. On the radar images there are dark features along the bottom of the valley. What does the dark tone indicate about the roughness of the surface?

B. On the HH-HV-Ratio color radar image of the valley bottom (ignore the mountains on the left and right) there are bright landforms with colors that grade from yellow to light purple to darker purple. What does gradation in brightness indicate what about the surface roughness of those landforms?

Close all files with the Data Manager. You should have two Views - *Select* View #1

<u>Trinity River, Texas</u>

We will close the lab with HH and HV polarized radar data collected by the European Space Agency's excellent Sentinel-1 satellite. The textbook lists characteristics of the Sentinel-1 system in a Chapter 6 table. Plate 51 (Chapter 15) in the textbook shows an interferogram generated from Sentinel-1 system that measured ground deformation caused by the 2014 Napa Valley, California earthquake.

1) *Start-up ENVI >* *Views > Two Vertical Views* *Highlight View #1.*
File > Open Drive to the Remote Sensing Digital Database \ Ch_6_Radar_Images" folder.

Open the "ESA_Sentinel-1_hh-hv-ratio" subfolder and
Select the "Galvaston_2017Apr14_Sentinel-1_hh-hv-ratio_GIS" image > *Open*
The radar image should load into View #1.

Highlight View #2.
Return to the "ESA_Sentinel-1_hh-hv-ratio" folder
Select the "Landsat_OLI_432_6Apr2017_clip_GIS" image > *Open*
The Landsat image should load into View #2.

Views > Link Views > Link All > OK
Zoom to Full Extent
You can see the overlap area of the radar and Landsat is mostly East of the Trinity River and Houston.

2) Both images were acquired within 8 days in 2017 (!) We can have some confidence that features of interest on the radar and Landsat did not markedly change over the 8-day period. We will examine the advantages of using radar in urban and coastal areas.
Zoom-in and pan around The Sentinel-1 image is <u>not</u> georeferenced very well, so offsets will be noticed by you as you zoom-in and pan around.

3) *File > Open* *Highlight* View #1 with the Sentinel-1 radar color image.

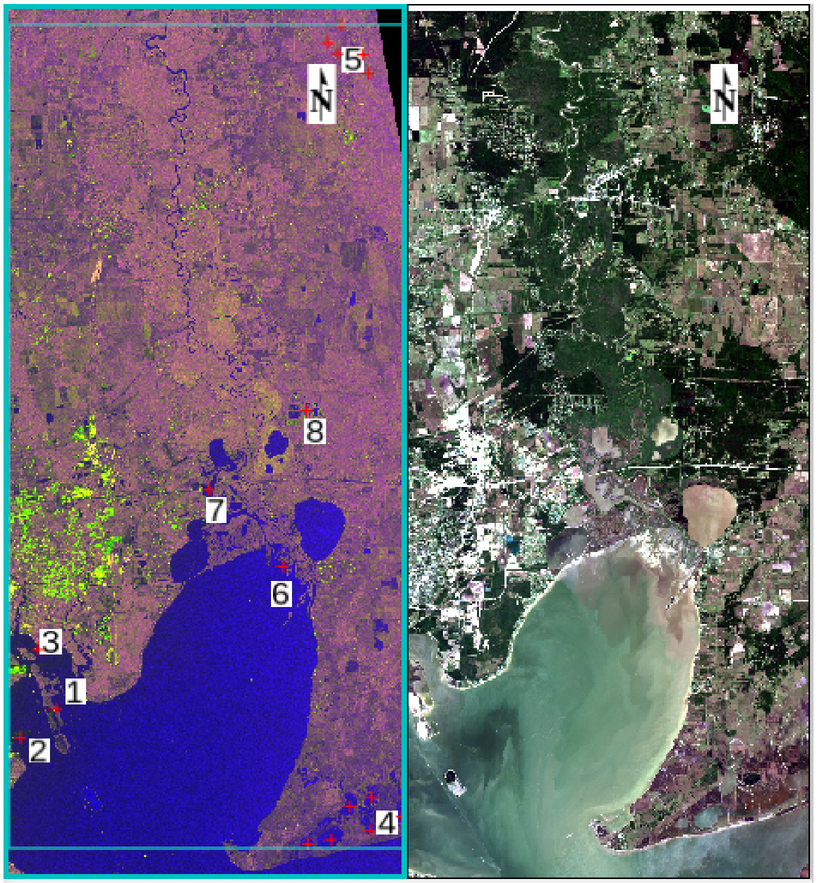
Drive to the **Lab_12_Data** folder and *select* the Shapefile and ENVI ".anz"

(8 sites are located with points and labels in the Shapefile and the .anz file).

select "Sentinel-1_Radar_Sites.shp" > *Open*
(There are at least 6 other files associated with this GIS shapefile).

Also *select* "Sentinel-1 Sites for Eval.anz" > *Open*

The shapefile is a point vector file with attributes. The ENVI .anz file is just an annotation file that posts Site numbers 1 – 8 in the View. They should be posted on the Sentinel-1 radar image in View 1 as shown below.



The shapefile's attribute table is also available as an Excel spreadsheet "Shapefile Coordinates Eval Sites.xls" in the **Lab_12_Data** folder.

The Shapefile's Attribute Table is shown below. You can copy & paste the Lat/Long numbers in each row into ENVI's *Go To* drop-down window as "29.641, -95.936" and ENVI will place the crosshairs at that location.

The Shapefile's Attribute Table from the Excel Spreadsheet.

Site	Name	Lat	Long	Y	X
1	Mouth of river	29.641	-94.936	3280587.0	312598.7
2	bright dots on radar	29.690	-94.956	3286019.9	310785.3
3	submerged pattern on radar?	29.618	-94.974	3278049.1	308854.1
4	ponded water	29.562	-94.625	3271356.9	342531.7
4	ponded water	29.569	-94.603	3272150.7	344754.2
4	ponded water	29.566	-94.556	3271674.4	349278.6
4	ponded water	29.553	-94.570	3270325.1	347849.9
4	ponded water	29.531	-94.670	3267996.7	338166.1
4	ponded water	29.598	-94.552	3275193.4	349675.5
4	ponded water	29.542	-94.604	3269108.0	344595.5
4	ponded water	29.535	-94.645	3268340.7	340573.8
5	Ag Fields	30.185	-94.649	3340383.0	341270.7
5	Ag Fields	30.176	-94.638	3339414.4	342284.4
5	Ag Fields	30.175	-94.612	3339279.2	344796.0
5	Ag Fields	30.160	-94.606	3337578.5	345359.2
5	Ag Fields	30.198	-94.634	3341903.5	342667.3
6	Tide	29.758	-94.696	3293135.1	335999.7
7	Interstate 10 Bridge pilings?	29.820	-94.774	3300160.4	328553.2
8	industrial site	29.885	-94.671	3307191.2	338601.4
				WGS-84	UTM 15N

NOTE: ENVI apparently cannot display attributes as labels (such as the Site number) in the ENVI View. And I cannot make the "Cursor Value" Tool reveal any attributes from a shapefile vector point displayed in the ENVI View. Let me know if I'm wrong. All the shapefiles have to go to a GIS to be useful and to be able to be queried?

If the vector files don't work for you, just *copy* Lat, Long coordinates (separated by a comma) from the table above, *zoom-in* to the crosshair, and answer the questions below concerning Sites 1 to 8.

4) Let's analyze what new information is available in the Sentinel-1 radar image.

Zoom-in to **Site 1** at the mouth of the Trinity River and Galveston Bay. If the large ENVI annotation numbers block your view, just *unclick* the .anz file in the Layer Manager.

You can increase the size of the shapefile's points "**+**" by *right-click* on the shapefile in the Layer Manager > *Properties* > *Point Size* > *increase* the size from default "8" to "12" or "16" or more – and you can change the color of the "**+**" > *Apply* > *OK*

Answer the following questions concerning Sites 1 to 8.

Question 8: Site 1. What different type of information is provided by the radar image versus the Landsat natural color image for the nearshore feature with many large polygonal structures?

Question 9: Site 2: Do you see the green pattern to the northwest of "2" on the Landsat? What could cause this feature – what could it be?

Question 10: Site 3: These bright dots in a line on the radar are not seen on the Landsat. What is a "corner reflector" in the science of radar?

Question 11: Site 4: A. Why is radar more reliable for visually detecting ponded water compared to Landsat that captures reflected visible light?

B. What are you seeing on the surfaces of the ponds in the Landsat image?

Question 12: Site 5: A. Why are there shadows on the west side and illuminated edges on the east side of the agricultural fields with the "red **+**" **?**

B. Are the fields higher or lower than the surrounding land cover?

Question 13: Site 6: Which image shows the tide is out (low tide): radar or Landsat?

Question 14: Site 7: This is the east-west Interstate 10. What do you think the bright dots are on the radar image?

Question 15: Site 8: Compare the radar and Landsat images of the industrial ponds and surrounding area.
A. Purple-violet on the radar image indicates what type of land cover?

B. Green – yellow green on the radar image indicates what type of land cover?

C. Why are many north-south roads clearly visible on the radar and east-west roads are more difficult to see?

This exercise hopefully shows that polarized radar imager can provide unique information in wetlands, coastal, industrial, and agricultural landscapes. There are radar systems that collect 4 polarizations and multiple wavelengths – these extract more information about the Earth's surface features. The Sentinel-1 satellite radar imagery is available for download at no cost from ESA.

Lab 12 Change Detection and Radar Polarization Name:

Upload the following files to the instructor:

(2) “Your Name_chg_bandmath” jpg

(3) “YourName_colorCCDM” jpg

(3a) “YourName_CCDM_shp” jpg

Question 1: A. What color is healthy vegetation in our enhanced color images (SWIR–Near IR–Green as R-G-B)?

B. September is a hot and dry month around Mt. Diablo, California, and typically follows many dry summer months. Based on our enhanced color images, what features around Mt. Diablo have the healthiest (most vigorous) vegetation?

C. What is the elevation at the top of Mt. Diablo? (DEM in meters)

Question 2: A. Compare the 7 September band 4 to the 23 September band 4. Where geographically do you see the largest difference in brightness?

B. Based on what you see and can interpret, what event has the 23 September image captured on Mt. Diablo?

C. Based on the Landsat imagery, when did this event occur?

D. What Landsat spectral evidence do you have to support your interpretation about the event on Mt. Diablo between 7 and 23 September 2013?

Question 3: Explain how the band math subtraction of the 23 Sept image from the 7 Sept image results in the area of change having such a significant difference in brightness (DN value) compared to the surrounding area. (Hint: think what happened to the DN value of near IR pixels in the changed area compared to the DN value of near IR pixels in the surrounding area).

Question 4: Which polarized band carries more information to the untrained eye – HH or HV?

Question 5: Describe the ratio (HH/HV) image in 10 words or less.

Question 6: Do you think the color composite (View 4) tells you more information about Death Valley compared with the grayscale HH and HV? YES NO

Question 7: A. On the radar images there are dark features along the bottom of the valley. What does the dark tone indicate about the roughness of the surface?

B. On the HH-HV-Ratio color radar image of the valley bottom (ignore the mountains on the left and right) there are bright landforms with colors that grade from yellow to light purple to darker purple. What does gradation in brightness indicate what about the surface roughness of those landforms?

Question 8: Site 1. What different type of information is provided by the radar image versus the Landsat natural color image for the nearshore feature with many large polygonal structures?

Question 9: Site 2: Do you see the green pattern to the northwest of "2" on the Landsat? What could cause this feature – what could it be?

Question 10: Site 3: The bright yellow dots on the radar that cross the river in a line in a WSW-ENE direction are not seen on the Landsat. What is a "corner reflector" in the science of radar?

Question 11: Site 4: A. Why is radar more reliable for visually detecting ponded water compared to images that capture reflected visible light?

B. What are you seeing on the surfaces of the ponds in the Landsat image?

Question 12: Site 5: A. Why are there shadows on the west side and illuminated edges on the east side of the agricultural fields with the "red ✚" ?

B. Are the fields higher or lower than the surrounding land cover?

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