<u>Image Processing Lab Exercise #3:</u>

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Map Composition, Contrast Stretching, and 3-D Viewers

Objectives:

- Continue to work with means to contrast-stretch an image using either a histogram or other preset types of stretches
- To introduce image annotation techniques
- To introduce the basics of map composition in ENVI and ArcMap
    - To refine map making skills to produce publishable quality maps
    - Exporting your complete maps / annotation to ppt, jpeg and etc.
- Creating 3-D surfaces

<u>*About Images Used in the Lab*</u>

- *SEcoast.dat*: this AVHRR (Advanced Very High Resolution Radiometer) image has several different bands, including the SST (sea surface temperature) and several but not all of the AVHRR bands. These are ~1km spatial resolution.
- *grnland*: this is a course resolution image of Greenland, but it is sufficiently resolved because the research questions and the size of the overlying glacier both covered a large extent.
- *bldr_tm.dat*: this is a Landsat Thematic Mapper (TM) scene (30m resolution) of Boulder, Colorado. This file includes the 6 bands of reflected EM radiation (TM bands 1-5 plus 7) but not the emitted thermal band (TM band 6). Thus, Band 6 in this dataset is equivalent to Band 7 in the TM data. Yes this is confusing but you will understand this as time goes by.
- *Bld_dem*: this is a digital elevation model of Boulder, Colorado. It has 30-m pixel sizes, and because the data are a single value, or band, in each pixel, is automatically displayed as greyscale.

<u>*Background*</u>

Coherent and informative map making is one of the fundamental skills a geographer or environmental researcher should obtain. While it is quick and easy to make a map in any platform (ArcGIS, ERDAS Imagine, ENVI), making a good publishable quality map takes time and usually multiple iterations. In this lab you will fine-tune your map-making skills so you can produce high quality maps.

ENVI 5.6 is not yet well integrated with ArcGIS and its suite of software packages, which makes linking between the two programs not so easy. Therefore, the easiest way is to export your map to a format readable by ArcMap, then create the map in ArcMap.

In this lab we will utilize both the ENVI and ArcMap environments to create several maps.

There are seven essential items that should probably be included in every map: title, neatline (border or frame), north arrow, legend, inset (secondary map) map, projection and source info, and scale bar. That said, sometimes some of these elements, especially the north arrow, should not be included. The title and north arrow elements are rather self-explanatory but the other elements need to be explained more explicitly. A good **title** includes reference to the point of the map, the data displayed, the location or study site, and perhaps the methods used to create the map. The **neatline** is simply a box that surrounds the map in its entirety, the fill on this box can be colored but usually is it clear. Secondly, the **legend** is the key of the map and usually the most important element outside of the map itself. This element needs to explain all symbology, colors, or gradations that appear on the map. Simply from looking at this element ANY reader should be able to understand your map. The **inset map** gives any user of the map context in terms of the larger study area. For example, if you were doing a study on just the country of Botswana the main body of your map would not show the whole of Africa, it would outline just that country. The inset map would show the whole continent of Africa. This is useful for people who are not geographically savvy. Next, the **projection and source information** is a simple text box that includes the following information: author, projection of data, source of data, date the dataset was originate / date of the image. Lastly, a **scale bar** should be included so the user can understand the distances on the map unless the map is of something so familiar that every reader will know the scale, e.g. the United States, Florida, etc. In this class the scale bar should ALWAYS be in kilometers.

For those of you have read many academic papers or even looked at maps in newspapers or news magazines you may question this list of map elements. For example, why would a map of the USA require a north arrow? A publishable map and a perfect map are actually two different things.

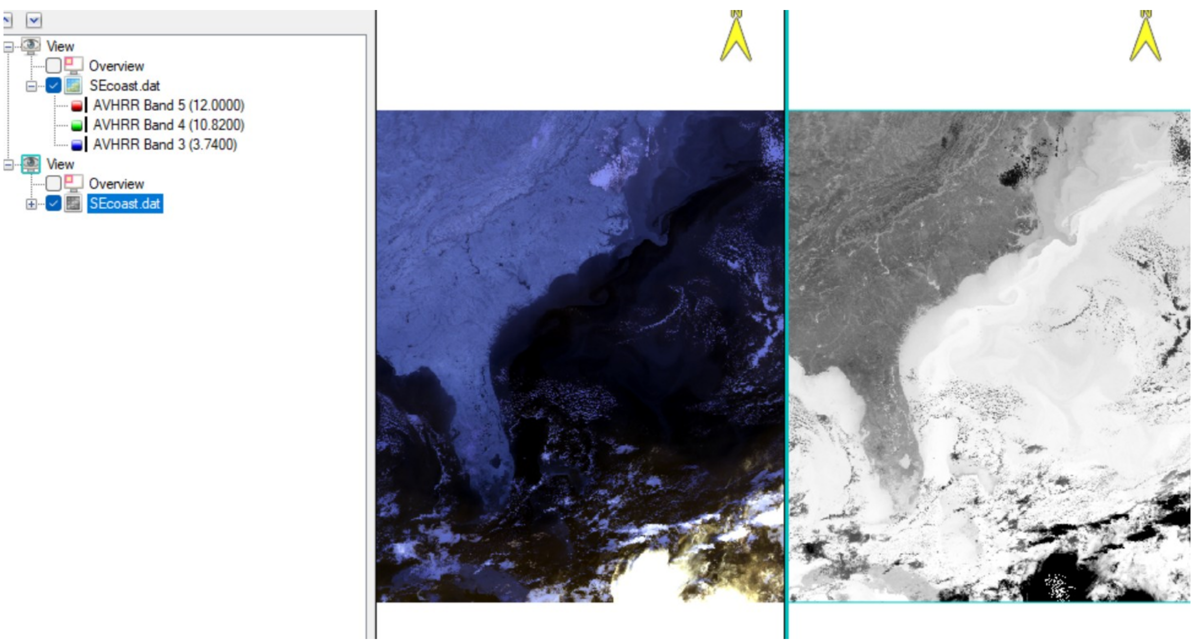
Part 1: Contrast Stretching Continued

Why are image data "contrast stretched" when making a display? The pixels in a data file that make up an image can have any value - negative, positive, integer, or floating point. When the image data are projected on screen, they are displayed as brightness values for each screen pixel. A data pixel with a larger value is brighter than one with a smaller value. However, unlike the image data, screen pixels use 256 unique brightness values for each of the red, green, and blue color components, varying as integers between 0 and 255 (where 0 is black if there is only one color value and 255 is white, or 0 is black and 255 is very bright red for the red color component). Clearly, this limitation prevents the most of the data from being displayed with brightness exactly equal to their real value. For example, how do you display a negative data value or floating-point data ranging from 0 to 1?

Stretching the image data refers to a method by which the data pixels are rescaled from their original values into a range that the monitor can display — namely, into integer values between 0 and 255. For example, if the image data were floating point values that ranged from -1.0 to 1.0, the image might be stretched such that data values of -1.0 are assigned a brightness of 0 and data with values of 1.0 are assigned a brightness of 255. All of the intermediate data values would be assigned new stretched values based on a simple model, or stretch type. Commonly, a linear stretch type is used so that the stretched data values maintain the same relationship to each other as the original data (i.e., the relative distance between two stretched values is the same as the relative distance between the two original data values). Other stretch types, such as gaussian, equalization, or square root functions use different models to assign the intermediate values.

1. From the ENVI menu bar, click on the **Open** folder, navigate to the lab 3 folder and open the image SEcoast.dat. The first band of this data set has been calibrated into sea surface temperatures (SST) in degree Celsius and is floating point data.

2. Open up the Data Manager, right click on the **SST image** band, and tick **Load in New View** and select **Load Greyscale**. A grey scale image of SST is displayed



What is meant by "contrast stretch"?

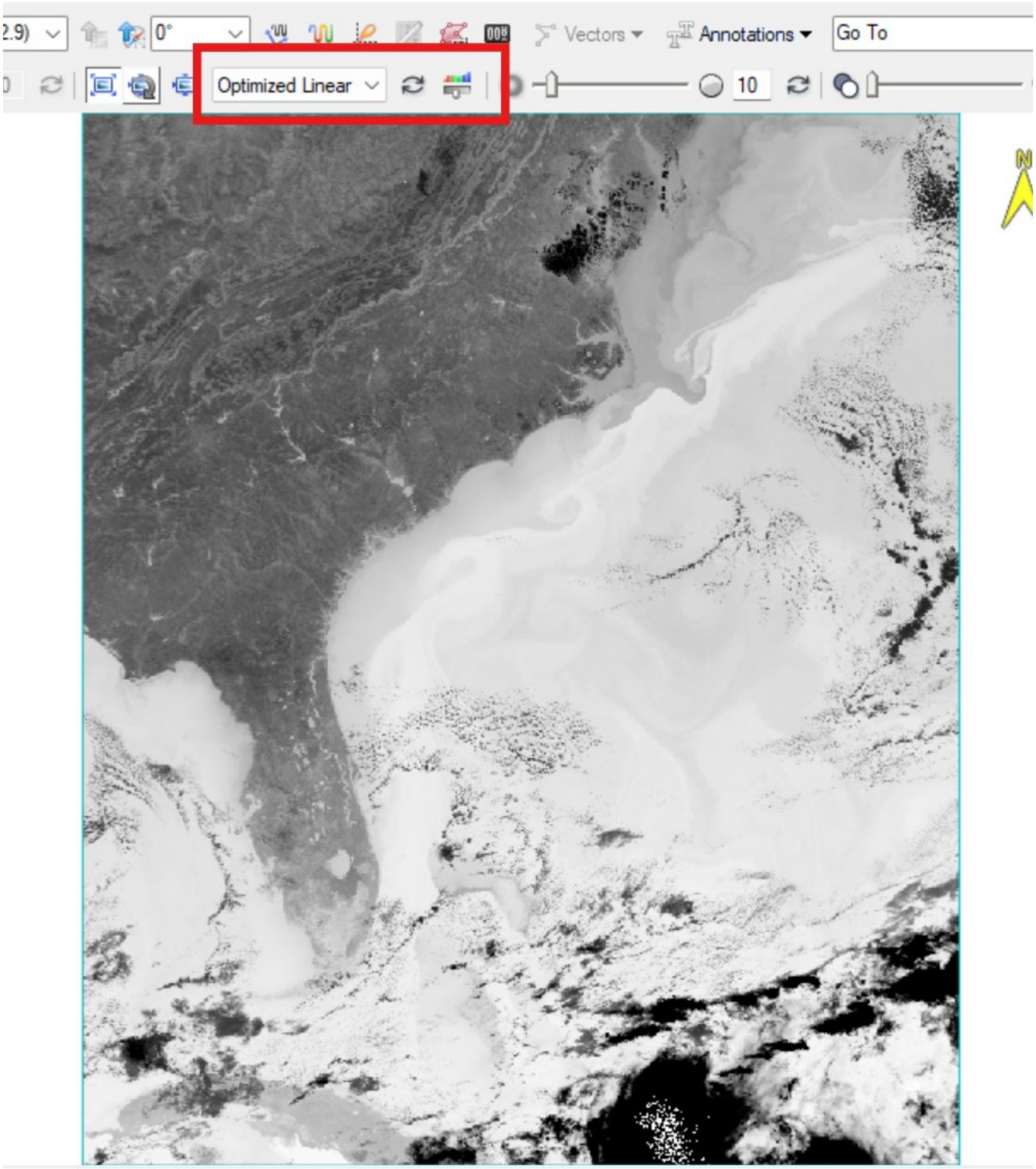
The stretch used to rescale image data into brightness values can make a drastic difference in the way that the image appears. You can adjust the parameters of the stretch to maximize the information content of the display for the features in which you are most interested. This process is referred to as contrast stretching because it changes contrast in the image, but does not change the original brightness values in the data. Contrast refers to the relative differences in the brightness of the data values in the display (i.e., increasing contrast means that the dark pixels are darker, and the bright pixels are brighter, so the brightness differences are increased).

For example, consider an image whose data numbers (DN) are integers that range between 35 and 85 (51 different data values). If this image was stretched with a simple “one-to-one” model where a data value of 0 is assigned 0 brightness, and a data value of 255 is assigned 255 brightness, then the image display is quite dim (since the brightest pixel is only a brightness of 85). This stretch produces a low-contrast image because a difference in data value of one unit is represented by a difference in brightness of one unit. Furthermore, much of the range of available screen brightness is not being used because there are only 51 different values in the image data (there are no pixels with a brightness between 85 and 255, so these brightness values are unused).

The image contrast could be maximized by assigning a brightness of 0 to the minimum data value of 35, a brightness of 255 to the maximum data value of 85, and linearly stretching the remaining 49 data values through the rest of the available brightness range. This increases the contrast because adjacent data values now differ by several units of brightness rather than just 1, making it easier to distinguish slight differences visually in the data values.

Through careful adjustment of the image stretch, it is possible to highlight certain features in an image. ENVI provides several sophisticated tools for this purpose.

3. Remove the view in layer manager that shows the AVHRR bands of SEcoast.dat image.
4. From the Contrast Stretch pull down menu, select various contrast stretches from **No stretch** to **Optimized Linear**. Open the Histogram Stretch function to examine the results of each stretch.



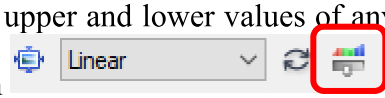
Listed below are the predefined contrast stretches that are available.

Example 1: No stretch maps a data value of 0 to a screen value of 0 and a data value of 255 to a screen value of 255, preserving the original pixel values without rescaling. Each data value corresponds directly to the same screen value.
In our case, this means:

- A pixel with a data value of 0 is displayed as 0 (black).

- A pixel with a data value of 30.2229 is displayed as 30.2229, rather than being stretched to 255 (white).

Since the maximum possible display value (255) has not been utilized, the image may appear low contrast, with the brightest pixel still far from the display's full range

- You find the upper and lower values of any stretch by clicking on the Histogram Strecth button 

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Example 2: A Linear Stretch maps the data minimum and maximum to screen values of 0 and 255, respectively, and linearly scales all other data values between those two extremes. For example, imaging the image values are changing between -4.41 and 28.42. In this case:

- The original data minimum (-4.41) is mapped to 0 (black).
- The original data maximum (28.42) is mapped to 255 (white).
- All other pixel values between -4.41 and 28.42 are proportionally stretched between 0 and 255 using a linear function.

This improves contrast by utilizing the full display range, making features in the image more distinguishable. Now, explore the SST image opened in ENVI and try the following stretch methods and fill in the blanks.

- The Linear 1% stretch sets __ to 0 and __ to 255 in the SST image
- The Linear 2% stretch sets__ to 0 and __ to 255 in the SST image
- The Linear 5% stretch sets__ to 0 and __ to 255 in the SST image
- The Equalization stretch scales__ to 0 and __ to 255 in the SST image
- The Gaussian stretch sets the data mean value __ to 0 and __ to 255 in the SST image (you may have to click on the Histogram Parameters button – a wrench)

The Square Root stretch takes the square root of the input histogram and applies a linear stretch.

- The Logarithmic stretch is a non-linear technique where the low-range brightness is enhanced. This stretch is useful for enhancing darker features.
- The Optimized Linear stretch is also known as a dynamic range adjustment. By default, 16-bit, unsigned integer data use the optimized linear stretch for display as it has a dynamic range set that is optimal for integer data. This stretch provides the maximum amount of information from the midtones and from the shadow and highlight regions.

4. Click the **Fixed Zoom In** icon once; the area of negative values is no longer in the display. Then click on the **Stretch On View Extent** icon. The contrast stretch will update because the image statistics changed.

5. With Stretch On View Extent still active zoom and pan so that you fill the display with the land. Now experiment with different contrast stretches.

6. Click on **Stretch on Full Extent** and then click on **Zoom To Full Extent** to work on and view the entire scene.

7. ENVI has a tool you can use to save a stretched image. In the ENVI Toolbox, expand Raster Management then double click on **Stretch Data**. Select SEcoast.dat, then click on Spectral Subset and select only the SST band. Click **OK** twice.

8. In the Data Stretching dialog, click on Stats Subset. In the Select Statistics Subset dialog, note that you can use histograms from part of the image, an ROI, or EVF to define your stretch. Click on **Image**.

9. In the Subset by Image window, click and drag to resize the red box and position it to cover an area over the ocean. Then click OK twice to get back to the Data Stretching dialog. For Stretch Type select Equalize.

10. For Output Data Range, type 0 for Min and 255 for Max. For Data Type, select Byte. For Output Result, choose File. Then click Enter Output Filename **Choose**. Save it to your output folder as "SST_stretch_data". Then click OK.

11. After the stretch is computed, the result will be displayed. After inspecting the result with the Cursor Value dialog, right click on the "SST_stretch_data" item in the Layer Manager and select Remove. Close the Cursor Value dialog.

Custom Stretch Tool

In this exercise you will use the Custom Stretch tool to manually manipulate contrast. Continue to use the SEcoast.dat data.

1. Click on the **Histogram Stretch** tool.

2. The Histogram Stretch dialog appears with a histogram of the data set. From the dropdown menu on the command bar experiment with the different stretches (**Linear, Equalization, Gaussian, Square Root, and Logarithmic**).

3. Choose **Linear** and then type in a value of 3 for Linear (% in the Histogram Stretch window). Hit the <Enter> key after typing so the ENVI reads your input.

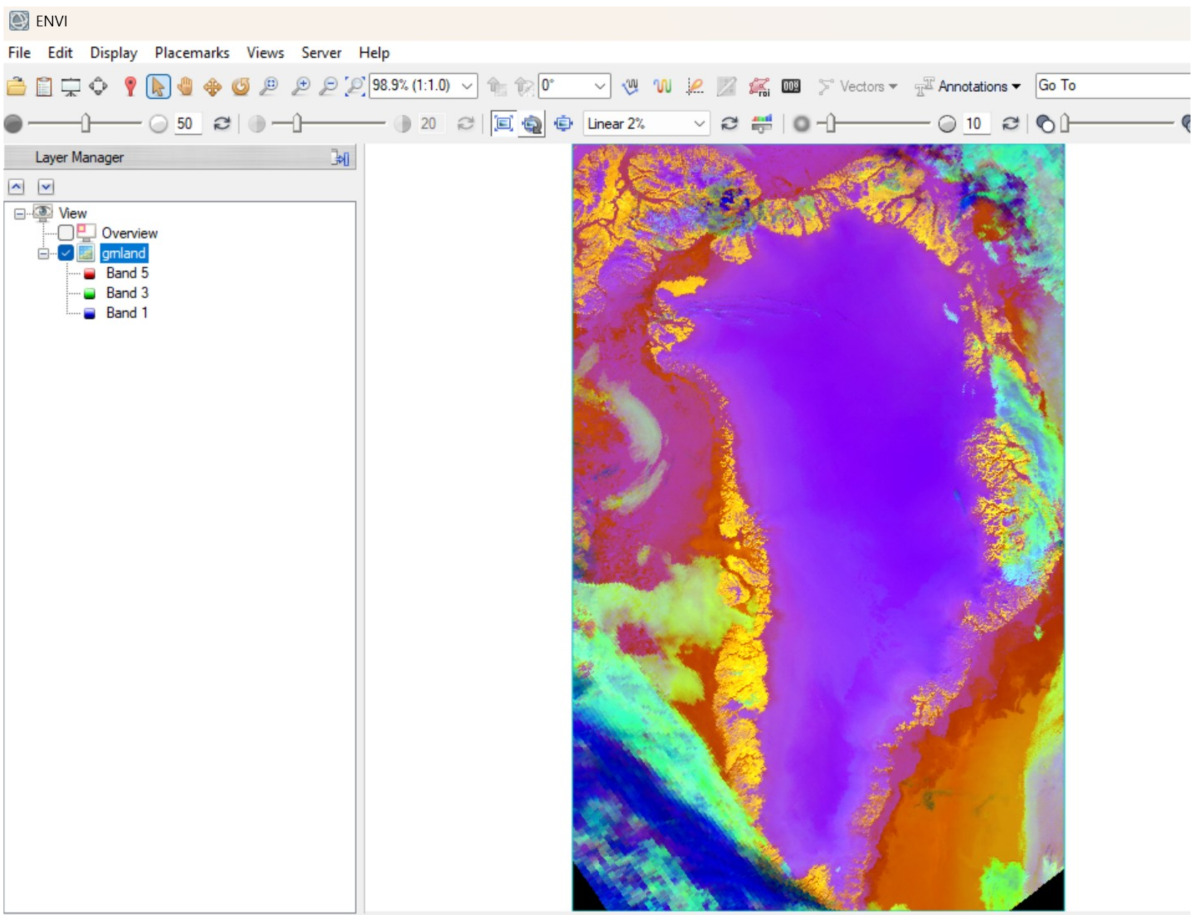
4. Type in a value of **0.5** and hit the <Enter> key.

5. Next choose **Gaussian**. For this stretch you can specify a standard deviation. Type in a value of 1 for Gaussian (Standard Deviation) and hit <Enter>.

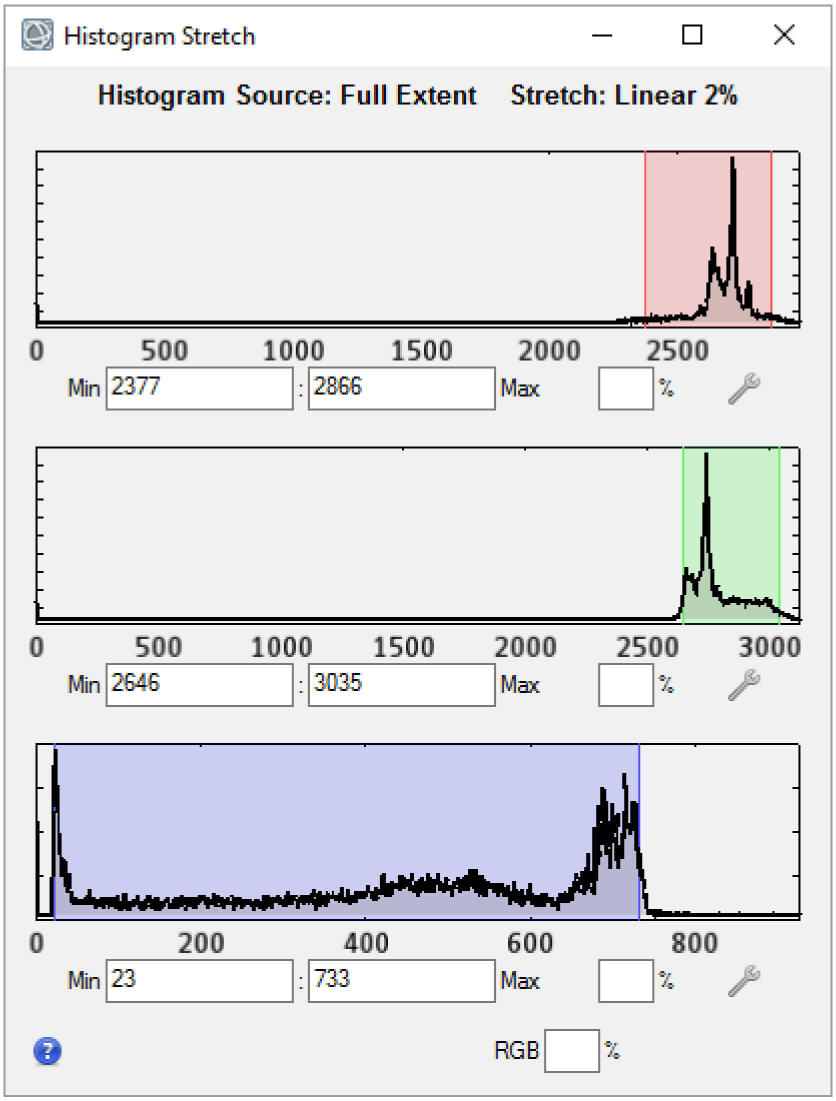
6. Next you will use the Custom stretch tool on a color image. Right click on the View listing in the Data Manager and select **Remove All Layers**.

7. Click on the **Open** folder and from the lab 3 folder choose *grnland* and click Open.

8. A strangely colored image is displayed because this data set does not have wavelengths associated with it and the ENVI default is to open a 4-3-2 RGB composite unless you have changed the default in the preferences. Open up the Data Manager and click on Bands **5**, **3**, and **1** to assign the bands' values to the R, G, and B color components, then click **Load Data**.



9. Click the **Zoom To Layer Extent** icon. Select the **Histogram Stretch** window. The Custom Stretch histogram appears with histograms for the three bands displayed as red, green, and blue. Note that the blue band has significantly lower values than the other two.
10. Notice that the DN values in this image range from 0 to 3000, not 0 to 255.



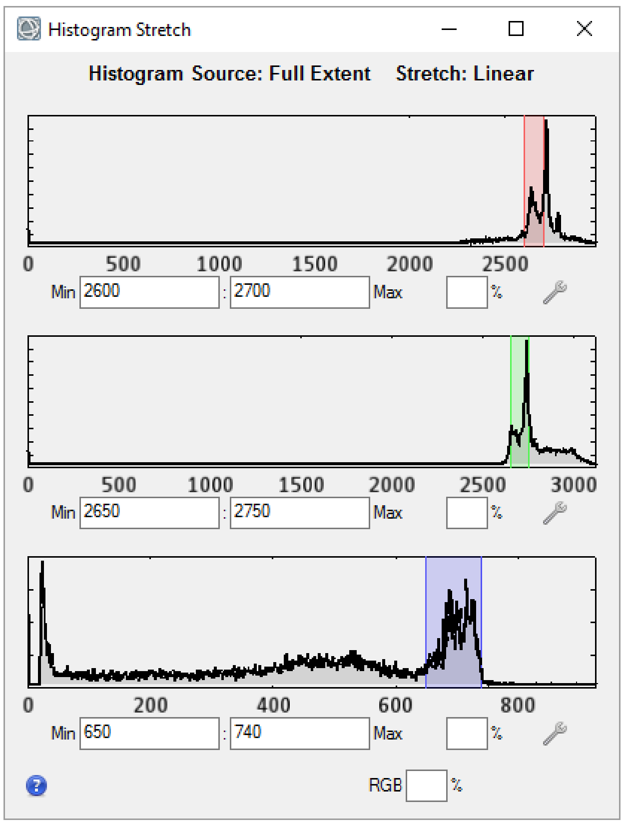
The Input Histograms are shown in the color corresponding to the color plane that is currently shown. You can stretch each color plane of the display separately.

11. You will now adjust the contrast to focus on the glacier in the middle part of the image. Click on the Cursor Value icon to bring up that tool. Then move your cursor around over the glacier and note what values you see for the displayed bands. You should get approximately 2600 to 2700 for the band displayed as red, about 2650 to 2750 for the band displayed as green and roughly 650 to 740 for the blue band.

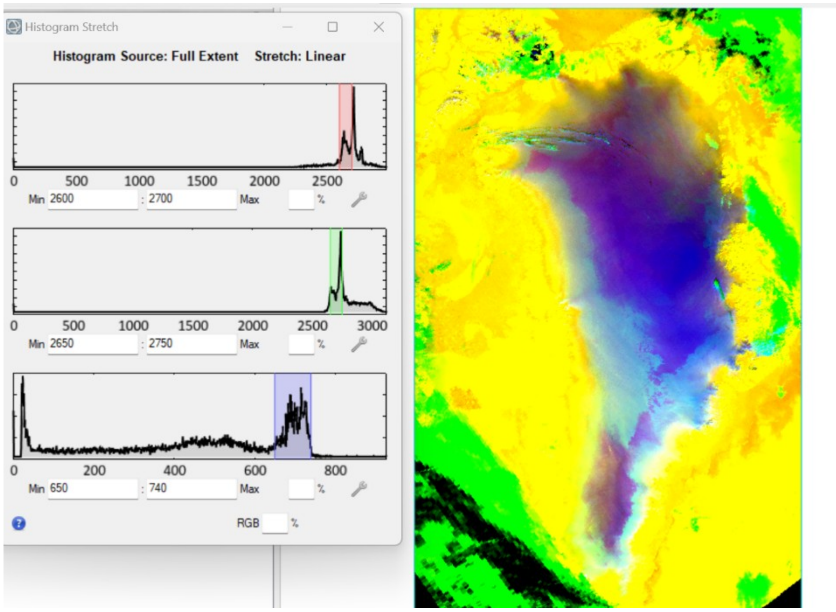
12. The Min and Max items for each band show values that reflect the last stretch that was applied. Make sure that Linear is the stretch type being used. Type in a value **2600** for the Min in the Red histogram and a value of **2700** for the Max. Note that these values delineate a particular peak in the histogram. This peak likely represents the glacier.

13. In the Green band window, move the Min threshold to about **2650** and the Max threshold to near **2750**.

14. Move the Blue Min threshold to about 650 and the Max threshold to near **740**. The resulting histograms and their stretch regions should look like this:



15. The resulting stretch should show variation in the glacier area. Look at what this did.



16. Close the Histogram Stretch and Cursor Value dialogs. Right click on the View item in the Layer Manager and select **Remove All Layers**.

Part 2: Color Slices /Tables and Image Annotation

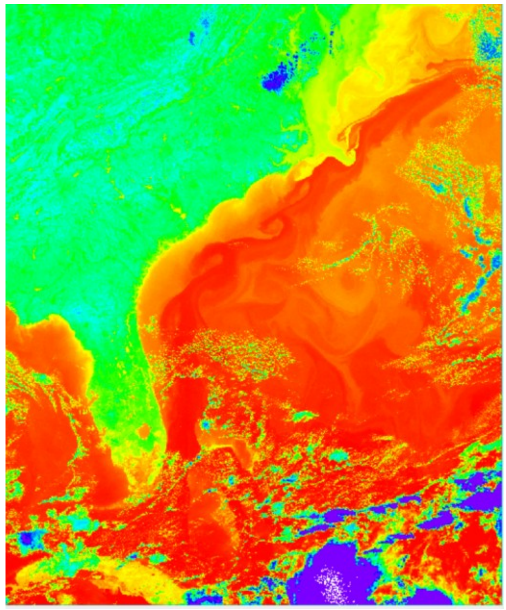
There are several ways to create color displays for images. For example, you can create a RGB color composite, where the color of each pixel is defined by its relative brightness in the three different bands. You can also use colors to accentuate features in a single band. These images, which we have previously viewed as greyscale, can at times be better interpreted in color.

Within ENVI color tables and color slices are ways to manipulate the display color. Color tables are traditionally used for one band images and color slices can be used to change the RGB composite display colors. The activity below will walk you through this.

Applying Color Tables

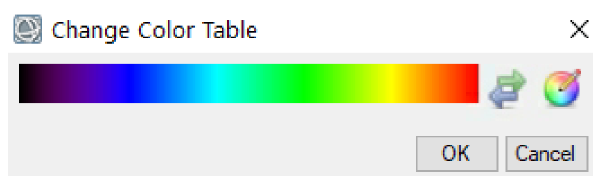
1. Open the Data Manager, open the **SST image** band of **SEcoast.dat**. Because this is a single band, the default display will be Grayscale. Adjust the zoom level so you see the entire image.

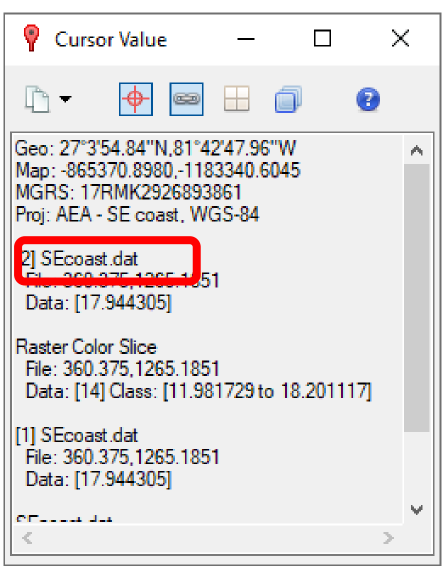
2. Right click on the file in the Layer Manager and hover over **Change Color Table--- select Rainbow**. The image is colored using this color table.



3. Experiment with different contrast stretches. As you can see, the color table responds to the contrast stretch. Whenever the stretched values change, the colors on the display also change. Adding color to a gray scale image brings a new dimension to its contrast and can help distinguish features that are otherwise hard to see because they have similar brightness values.

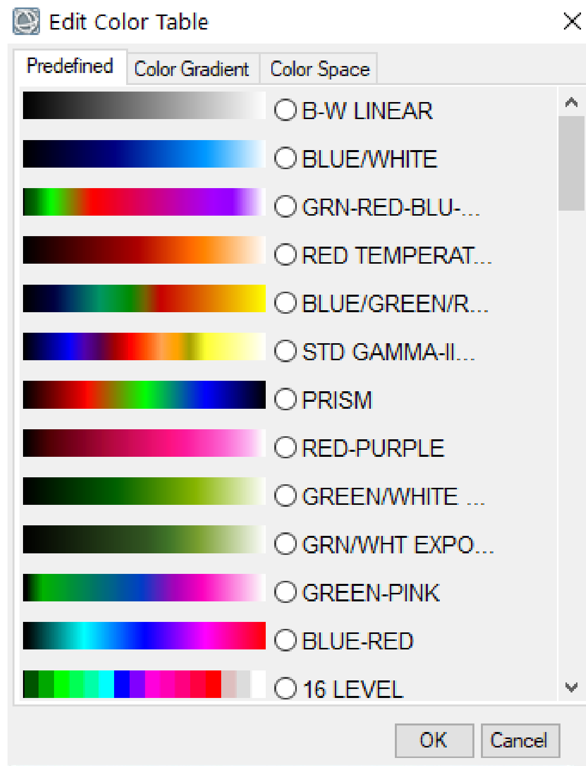
4. Right click on the SEcoast.dat file in the Layer Manager and select **Change Color Table--- More**. Click on the **Edit Color Table** icon (find this by hovering your cursor over the icons on the Change Color Table dialog box). A list of all available color tables is displayed. Experiment by selecting different color tables. Note how the image changes each time. Remember that this is simply changing the colors – ***no data in the original image are changed***, just the color assigned to a value! If you don't believe that, use the **Cursor Value** command to check the actual data values – the value denoted by Data:; in the illustration to the left, it shows a value of 17.994, which is degrees Celsius .





Note that there are several tabs at the top of the box (next page).

The horizontal color ramp in the Change Color Table box displays the currently selected color table, from minimum brightness at the left to maximum brightness at the right. Click OK in the Edit Color Table box and click on the **Reverse** icon to flip the color table so the minimum brightness color now corresponds to the maximum brightness value.



5. Click on the **Edit Color Table** selector and select **Rainbow 18**. This color table shows a lot of variation in the ocean. If you wanted to accept this color table you would click OK. However, you will continue to work with this tool in the next several steps.

6. The **Edit Color Table** dialog also allows you to define your own color table using RGB (red- green-blue), HLS (hue-lightness-saturation), HSV (hue-saturation-value), or CMY (cyan, magenta, yellow) color spaces. Click on the Color Space tab in the Edit Color Table dialog. RGB Red is selected by default, but you should click the drop-down box with RGB Red and change the entry to HLS Hue. The other two elements (Lightness and Saturation) can also be chosen. Click on each one and move the slider to see what it does. Not how each of the three affects the other two. Reset to the original settings with the Reset icon.

7. Set the HLS Hue slider all the way to the right, or type in 360 in the box. In the panel move the left-hand node up and into the dark red area. Placing the nodes in the upper part of the window produces a more saturated color. Positioning nodes near the bottom of the window produces less saturated color. Note each time how the image colors change.

8. Change the dropdown box to **HLS Light** (Lightness) and move the slider back to the center or hit the Reset button. The horizontal axis now represents Hue and the vertical axis represents Saturation. Adjust the nodes in the right-hand panel by placing them in various hues. For example you could place the left-hand node in red and the right-hand node in blue.

9. Change the dropdown box to **HLS Sat** (Saturation). The horizontal axis now represents Hue and the vertical axis represents Lightness. Don't change the nodes here but check the box to **HLS Light** again. If you are satisfied with this result, click **OK** in the Change Color Table dialog.

10. If you did not click **OK** you can continue to adjust color spaces. When you are finished experimenting close the tool by either by clicking **OK** (the last color table applied will stay), or by clicking **Cancel** (the color table will revert to whatever it was before you opened the dialog).

Raster Color Slices

1. If you have a color table applied to the SEcoast.dat scene, display the SST image band as a new grayscale image.

2. Right click on the new gray scale image in the Layer Manager and select **New Raster Color Slice**. A Select Input File dialog appears. Select the SST image band and click **OK**.

The Edit Raster Color Slices tool appears. It shows a list of colors and the histogram for the SST band. You can also start this tool by right clicking on the band in the Data Manager, or by double clicking on it under Classification in the ENVI Toolbox. By default, equally-spaced ranges are automatically calculated with a different color assigned to each data range. The icons at the top of the tool allow you to: Change Color Table (the same choices as you saw in the color table exercise), select New Default Color Slices, Add Color Slice, Remove Color Slices, Clear Color Slices, Save Color Slices to File (.dsr format), or Restore Color Slices from File.

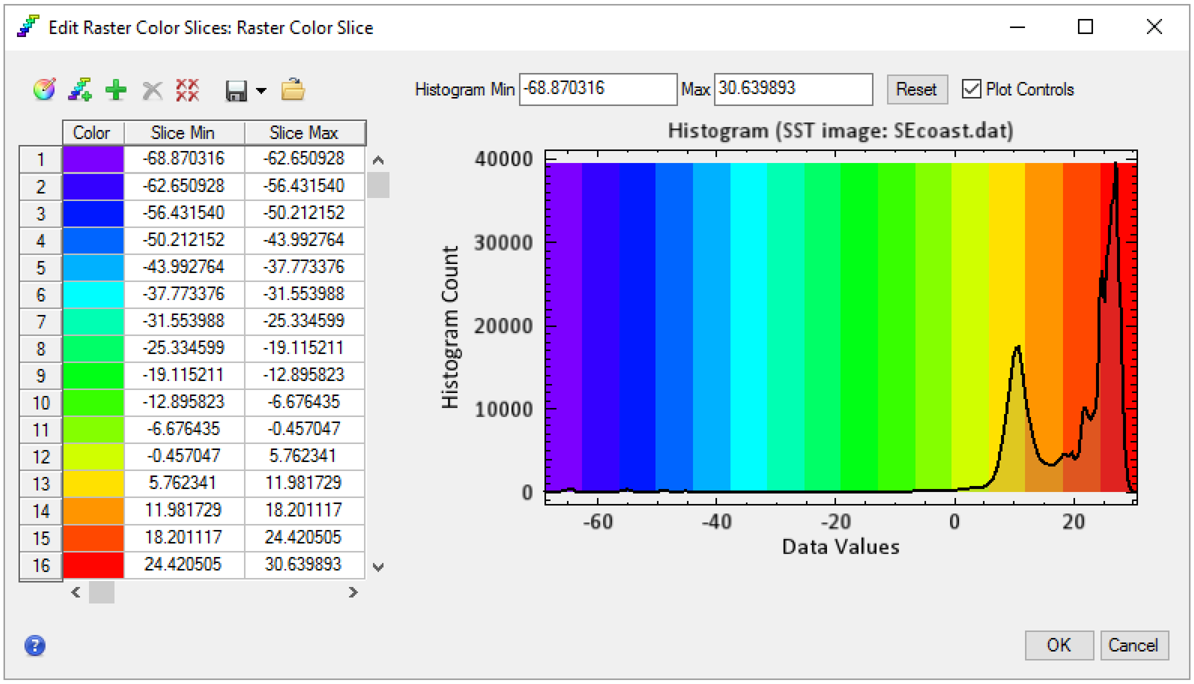
3. Select a color either by clicking on its **number** in the list or by clicking on it in the histogram plot. Then in the histogram plot, click and drag one of the sides of the color band to change the DN range for the color. Note that the DN specified at the bottom of the plot updates as you move your cursor. You can also specify color ranges by typing values in Slice Min and Slice Max in the color list.

4. Move a color band around by clicking in the middle of it and dragging it left or right.

   Reset the color ranges by clicking on the **New Default Color Slices**  icon, leaving the default values in the Default Raster Color Slices dialog and clicking **OK**.

5. The Raster Color Slices tool allows you to add color only where you want and leave the original gray scale image display elsewhere in an image. For example, next you will try to highlight the ocean by defining ranges which color codes only the data that you think are the ocean pixels. You could use the Cursor Value tool to determine what values ocean pixels have, but the Cursor Value tool cannot be accessed while the Raster Color Slices tool is open. However, you can see that ocean pixels are bright in the SST image so that means that the peak on the right side of the histogram represents ocean. To begin, first clear all the color slices by clicking the Clear Color

   Slices button.



6. You can fine tune the slices by using **Plot Controls**:
   - Enable the **Plot Controls** check box, click in the histogram, and use the mouse wheel to zoom in and out. Disable the check box again to re-enable editing functions.
   - Enable the **Plot Controls** check box, then click and hold on a curve in the plot to show the X-Y line crosshair. As you move the cursor over the curve, the crosshair snaps to the closest data point. The X and Y values of the point appear below the plot.
   - Enter **Histogram Min** and **Max** values in the fields provided to zoom to a specific range.
   - To reset the plot range to its original settings, click **Reset**.
7. To edit the data ranges:
   - Click on a color slice in the histogram, then click and drag the right or left edges of the color to resize the minimum or maximum data range for that slice.
   - Click and drag on a color slice in the histogram to redefine its range.
   - Enter a new **Slice Min** or **Slice Max** value for the slice in the table.
   - When data ranges are in floating-point data type, they can have overlap between the **Slice Max** of one range and the **Slice Min** of the next range, as shown below:

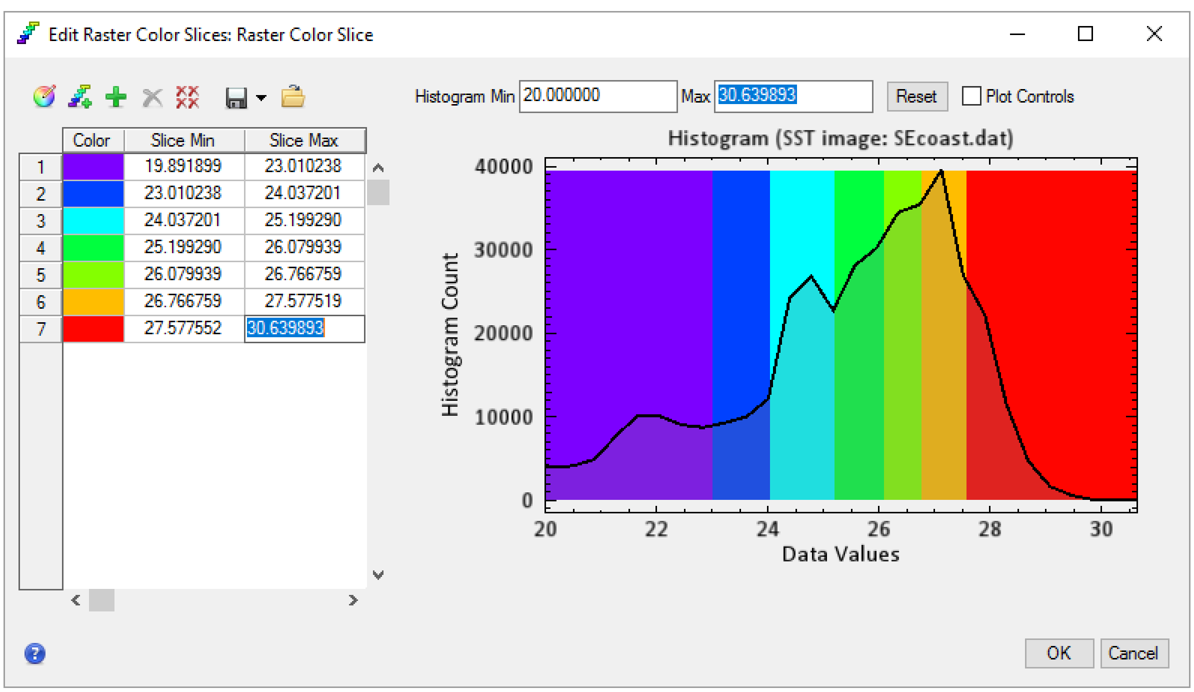
	Color	Slice Min	Slice Max
1		19.695908	20.617036
2		20.617036	21.538165
3		21.538165	22.459294

When such overlap occurs, the data are included in the later range. In the image above, the data for pixel value 20.617036 will be contained in color slice 2 (the later range), the data for pixel value 21.538165 will be contained in color slice 3, and so on.

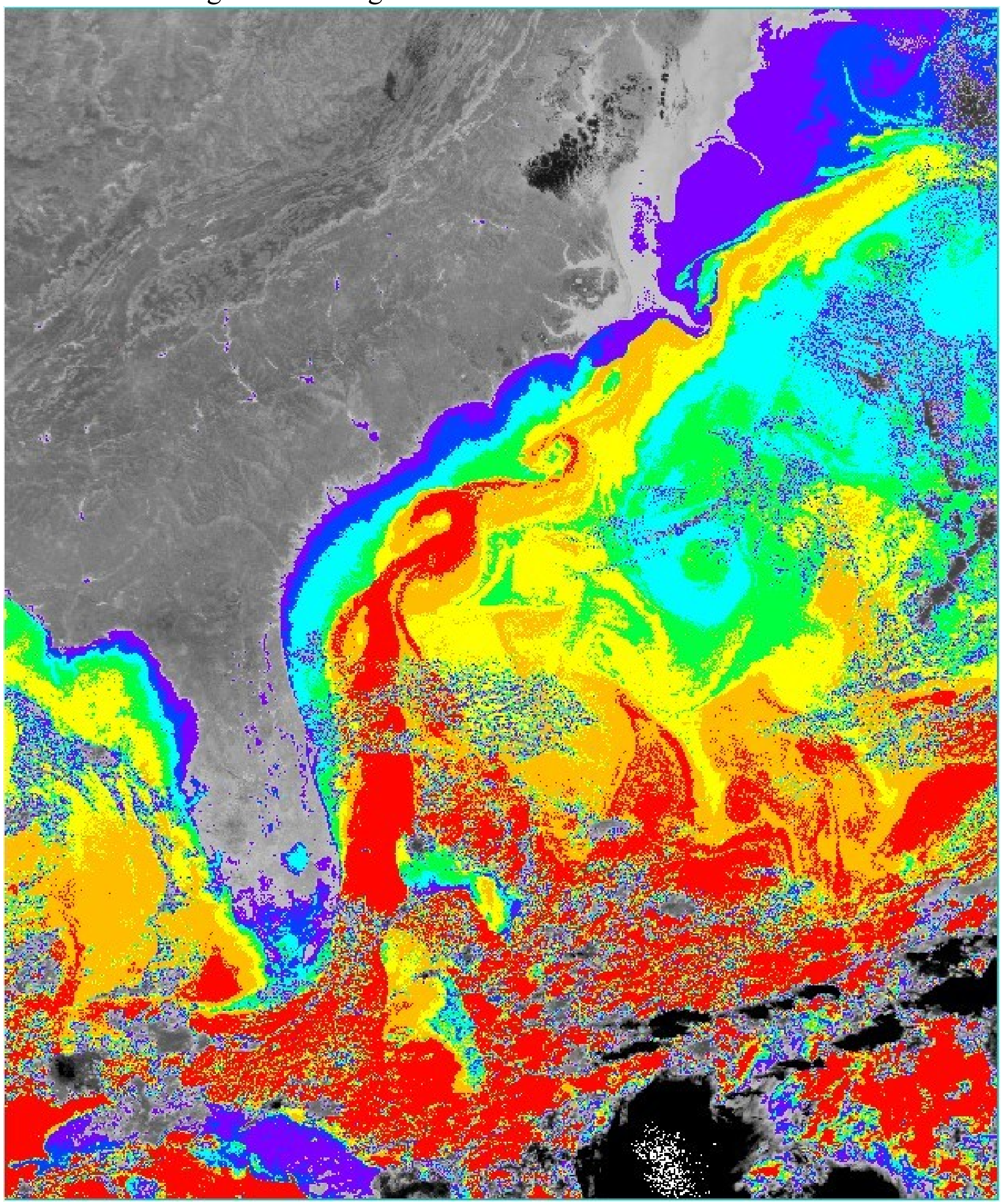
8. Move your cursor over the histogram now and note DN values between sub-peaks and at breaks in slope. Values that mark distinct changes in slope of the histogram are reasonable values to use to separate different ocean currents with different temperatures. You will use these values for setting color ranges.

9. Click on the **New Default Color Slices** button . In the Default Raster Color Slices dialog that appears, set the **Num Slices** to **7**. The Data Min and Data Max values here should reflect what histogram ranges you set previously. Let the other items default and click **OK**.

10. You can select a color from the list then type in **Slice Min** and **Slice Max** values. Try to modify the color bands so they look something like the figure below.



11. The two greens are very similar in color so in the list of colors left click on the color box for the lighter green, in the select color dialog, choose **Yellow**.
12. Once you are satisfied with your color setup, click **OK** to close the Edit Raster Color Slices dialog. The color ranges will be displayed on the image. It should look something like the image below.



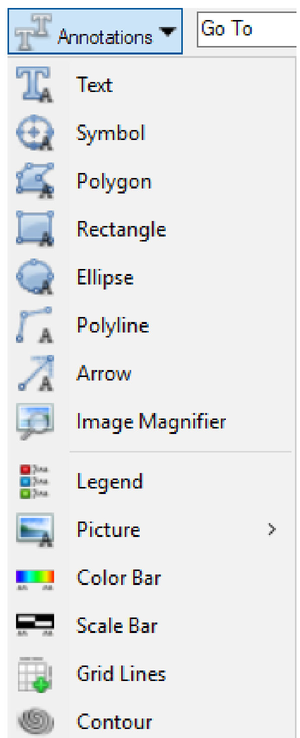
13. The color slices will also be listed in the Layer Manager. The output is actually a classification result and as such, you can uncheck color ranges so they will not be displayed. If you want to edit the color ranges, right click on the Slices folder and select Edit Color Slices. Note that you can also right click on Slices and Export Color Slices to a Classification Image or Shapefile. You also can

get statistics for all color slices. To get statistics on an individual color slice, right click on that color slice and click Color Slice Stats.

Image Annotation

1. With the previous image still open we will transition into the next portion of the lab **Image Annotation.**

2. Within the ENVI toolbar there are 8 essential annotation buttons. You will mostly use **Legend** annotation for your mapping work. The Legend function in ArcGIS will use the RGB values, which are useless in this mapping exercise because we want to map the Sea Surface Temperature.



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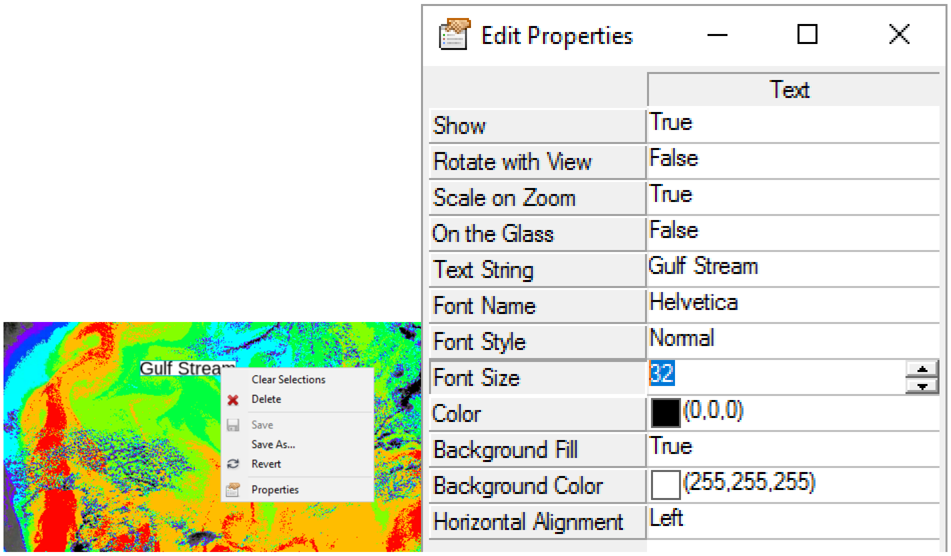
Experiment with these on the SST image that you have open. Note that all annotation functions have properties that can be changed by right clicking on the new annotation in the image, for example the font size of a text annotation can be changed by right-clicking on the text and selecting **Properties**. Put a text annotation somewhere in your image and change the font size to something readable:



3. Keep at least one layer open for the next step, then you can remove all layers.

Part 3: Map Making

Map Making with ArcMap

1. Even with the new release of ENVI 5.6 the mapping functions are rudimentary and not conducive to making good maps. In the future, when new ENVI service packs are available, it will be easier to make maps as you should be able to drag and drop data back and forth easily between ArcGIS and ENVI. Until then, we will simply export the image to a format that ArcMap can read, then use ArcMap to create the proper map.

2. There are several ways to export your image. This is the simplest. Once you have the image that you want to use to generate a good map, go File > Chip View to File > File…). Specify the Output Format as Tiff or JPEG, both of which are read by ArcMap. Give the file an output filename and specify the folder to which you will save the file.

3. Run ArcMap App on your desktop.

4. Using the Add Data button, add the file to ArcMap. Under View on the Menu Bar, click on Layout View. Then make your map.

Part 4: 3D Viewers in ENVI

1. Restart ENVI, or Close all Files with the Data Manager. Open Bldr_dem and Bldr_tm.dat from the Lab 3 Data folder

2. Load the TM image as a false-color infrared (4, 3, 2 composite). The two images will not line up 100% but we will model the overlapping surfaces with a 3D viewer

3. In the search window for the ENVI Toolbox, type 3D. Then double click **3D Surface View.**

4. In the Select 3D Surface View Image Bands Input dialog, select Bands 4,3,2 of the bldr_tm.dat image. Click **OK.**

5. In the Associated DEM Input File dialog, select the Boulder_dem (If there is a note about bad data, highlight it.) and click **OK**. The 3D Surface View Input Parameters dialog appears

6. Check the **64** and **FULL** boxes for the DEM Resolution. This is the number of pixels that will be used along the longest dimensions of the DEM in the 3D Surface View window.

7. In the **DEM min plot value** field, type **1500.** This specifies that DEM values lower than 1500 meters are not plotted.

8. Set the **Vertical Exaggeration** field to **3.0**. This exaggerates the vertical dimension by a factor of 3 so that the image will appear to have the third dimension.

9. Leave all other parameters at their default and click **OK**.

10. A new **3D SurfaceView** Window will open. You can change the size of this window as you would with any window in Windows. Enlarge it so that you can see detail.

11. Use the mouse to interactively rotate, translate and zoom into the surface.

12. Select **Options** then play with the surface controls.

13. Take a screen capture and save this

14. Remove all layers from the display. Exit ENVI. You are done with the lab for this week and deserve a short break!