# Image Processing Lab Exercise #5:

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## Spectral Indices, Masking, and Zonal Statistics

**Objectives:**

1. Learn the basics of band math and apply this to vegetation spectral indices
2. Calculate zonal statistics
3. Learn to put the pieces together in terms of preprocessing, then analysis, and lastly presenting results.

*About Images Used in the Lab*

*avhrr.dat* – subset of a full AVHRR scene with 1.1 km pixel size, collected around 2:00 AM local time in mid-April 1997
*new_zeal_wv2_sub.dat* – an atmospherically corrected WorldView-2 image subset
*NW_zonal.shp* – a shapefile with three zones – water, agriculture and pasture, developed.

*Background*

**Band Ratioing**

It is possible to perform mathematical operations on multi-spectral bands. In general, addition and multiplication operators tend to enhance correlated information between bands, while subtractions and division operators tend to enhance uncorrelated information between bands.

Image division or band ratioing is one of the most common applications when working with multi-spectral images. Ratio images are calculated as the division of digital number (DN) values in one spectral band by the corresponding pixel value in another band(s).
Ratio operations are ideal for reducing environmentally induced variation in a single band's DN. Such brightness variation in the DN can be caused by topographic slope and aspect, shadows, or seasonal changes in sunlight angle or intensity. Therefore, band ratioing tends to emphasize and highlight subtle variations in the actual spectral responses of various surface covers and reduce the effects of sun angle and seasonality.

**Vegetation Indices**

Vegetation indices (VIs) are an improved version of simple band ratio methods for studying vegetation. These, long tried and tested, indices have been created by researchers to highlight different environmental properties. The biophysical basis of the indices is that vegetation absorbs and reflects EM radiation differently in different wavelengths, and the reflection and absorption varies with environmental conditions. Specifically, vegetation absorbs strongly in the red (visible), which is used as an energy source for photosynthesis,

and reflects very efficiently in the near infrared because of the cellular structure of plant tissues. When plants are healthy, much of the red is absorbed and NIR is reflected. When plants suffer from drought or insufficient nutrients, then less red is absorbed and NIR is reflected, changing any VI that is based on these two wavelengths.

*Why do we use VIs?*

- There is an empirical relationship with a range of vegetation and climatological and other environmental factors
- They are simple to understand and implement
- They are fast to calculate
- They allow researchers to track temporal changes, including seasonality
- Their use can reduce sensitivity to (while maintaining sensitivity to vegetation): topographic effects, soil background, sun angle, atmosphere

*Some of the more common indices include:*

- Normalized Difference Vegetation Index (NDVI)
- Soil Adjusted Vegetation Index (SAVI)
- Enhanced Vegetation Index (EVI)
- Modified Soil Adjusted Vegetation Index 2 (MSAVI2)
- Simple Ratio (SR)
- Difference Vegetation Index (DVI)

There are limitations to some VI usage, even NDVI. While it is the most common index, NDVI and other indices are affected by atmospheric effects, saturation problems in dense forest canopies, background effects, non-linear relationships to some vegetation variables, canopy structure effects, and topographic effects. See the lecture notes and the Jensen textbook for more detail on these topics.

**Premise of lab:**

**In this lab you are going to be shown the general steps to perform band ratioing / calculate vegetation indices and perform zonal statistics. The data created in this lab will be used again in future labs. Correct completion of this lab is essential.**

To complete this project you should first run through the tutorial below, showing how to perform band ratioing, masking, and statistics. Additionally, you may need to refer to previous labs to assist with map making and other key portions of the lab.

## Part I: Band Ratioing / Calculating NDVI

ENVI's Band Math and Spectral Math functions are particularly useful for quickly and flexibly manipulating image data. To use these tools, enter a mathematical expression and assign its variables to image bands. Band Math and Spectral Math operate with only three basic limitations:

-Your expression must return a 2D image array, meaning the mathematical expression is feasibly calculated (ex. **no divide by 0**).

-The image bands assigned to each variable in the expression must have the same projection and subset. In other words, all of the bands must have the same number of samples and lines.

-All variables must be named B1, B2, B3... and each of these variables must be assigned to one band.

Because of their broad nature, these tools are often useful for quickly analyzing or combining different data sources. For example, Band Math can be useful for calculating a *difference image* for change detection, or for computing custom *indices*.

### *Exercise 1: Difference Image*

1. From the ENVI main menu bar, select **File -- Open**... Navigate to your lab 5 folder and open the file *avhrr.dat*

This image is a NOAA AVHRR scene with 1.1 km pixel size, collected around 2:00 AM local time in mid-April 1997. The scene covers a section of the East Coast of the USA from approximately New York City to the North Carolina border. It extends out into the Atlantic Ocean about 1,000 km.
Note the spiral feature centered near image location (1030,1030). This is a warm eddy in the Gulf Stream current.

2. Open the **Data Manager** by selecting its icon, or activating it from the **File** menu. Right click on the **SST Image** band and select **Load Grayscale**. Also note the wavelengths of the other three bands. Answer in your own mind the question of "where along the EM spectrum do these bands sense, i.e. what would you call the bands?"

3. Create a second viewer (learned in lab 1). Make sure the second view is active, then right click on **AVHRR Band 5 (12.000)** in the Data Manager and click **Load Grayscale**.

The first View contains sea surface temperature (SST) data in degrees Celsius, calculated from three thermal AVHRR bands. The second View contains SST data calibrated in Kelvin, calculated from one thermal band (at 12 μm). Even though it is named band 5 it is a SST measurement.

These two images represent separate SST estimates in the scene. One dataset is well-suited for SST estimates, and the other is more general. To examine the differences between these two datasets, you have to create a difference image and also account for the different temperature units in the two images. You can easily accomplish this with Band Math. While we are using the following way to show the difference in temperature estimate:

4. Select **Views→ One View**.

5. From the ENVI Toolbox Search Window, begin typing "Band Math" or select **Band Algebra → Band Math**. A Band Math dialog appears.

6. In the **Enter an expression field**, type the following: *b1 - (b2 - 273.16).* Think about what this formula is doing.

7. Click **OK**. The Variables to Bands Pairings dialog appears.

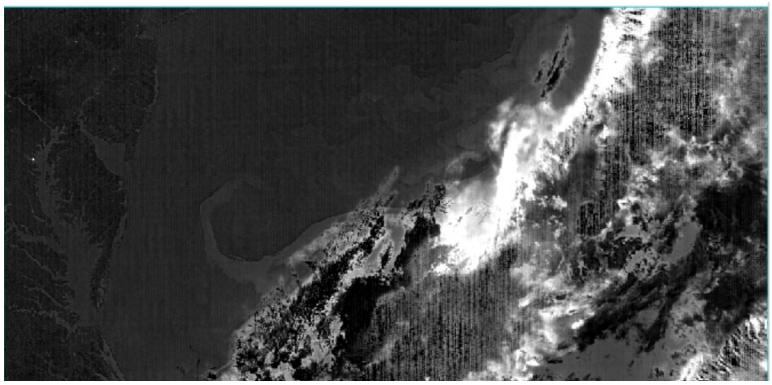
8. The variable **B1 – [undefined]** is selected by default. Map this variable to a specific band by selecting **SST Image** in the **Available Bands List** in the Variables to Bands Pairings dialog. The Variables used in expression window shows this assignment.

   **Note**: You can also apply a Band Math variable to an entire file instead of a single band by clicking Map Variable to Input File. This can be useful if, for example, you want to subtract one image band from all of the bands in a multi-band image.

9. Select **B2 – [undefined],** then click **AVHRR Band 5** to associate that band to the variable.

10. The bottom of the Variables to Bands Pairings dialog now provides options to output to file or memory. File is already selected by default. Enter an output filename of sst_thermal_diff.dat (**MAKE SURE IT IS BEING SAVED TO YOUR LAB FOLDER!!!** Check this by hitting CHOOSE in the Variables to Band Pairings dialog).

11. Click **OK**. The Band Math result appears in the Data Manager and it may also be displayed (if it is not displayed, right click on the Band Math result in the Data Manager and select Load Grayscale). Looking at the difference image, you should immediately see where the largest discrepancies occur in the two temperature estimates.



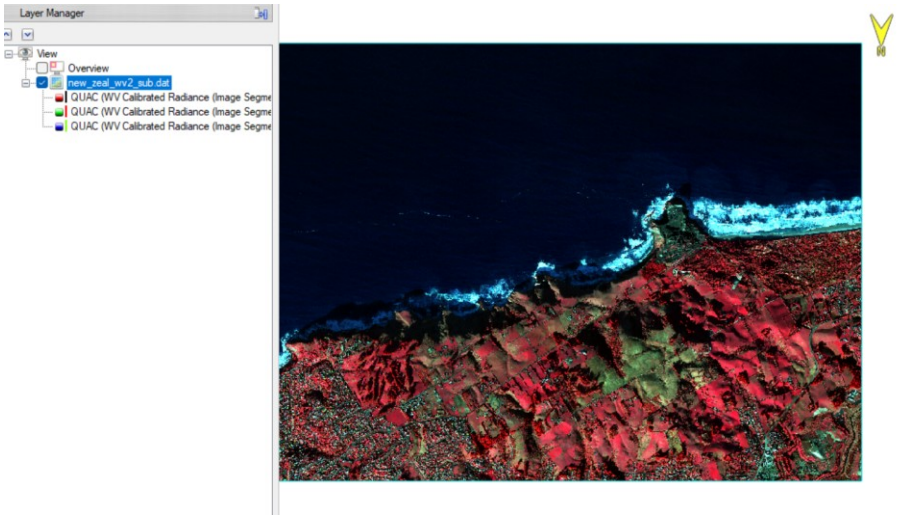
Can you identify the features emphasized in the difference image? These are areas where the ocean surface is obstructed by clouds.

12. Right click on the **View** item in the Layer Manager and select **Remove all Layers**.

*Note:* Any Band Math expressions you enter during an ENVI session are available throughout the session, and they appear in the Previous Band Math Expressions list of the Band Math dialog. You can save expressions that you use regularly to a file, so that you do not have to re-enter them in the Band Math dialog each time you need them. Give the current expression list a filename with an .exp extension and click Save in the Band Math dialog. Then, you can restore the expressions later when you need them.

## *Exercise 2: NDVI*

1. Restart ENVI. Once restarted, select **File** -- **Open** then select new_zeal_wv2_sub.dat and click **Open**.



2. Click on the **Zoom To Full Extent** icon. Search the Toolbox for "Band Math." Alternatively, navigate to **Band Algebra -- Band Math**. Double click the **Band Math** tool to start it. Enter the formula for normalized difference indices described in the section previous.

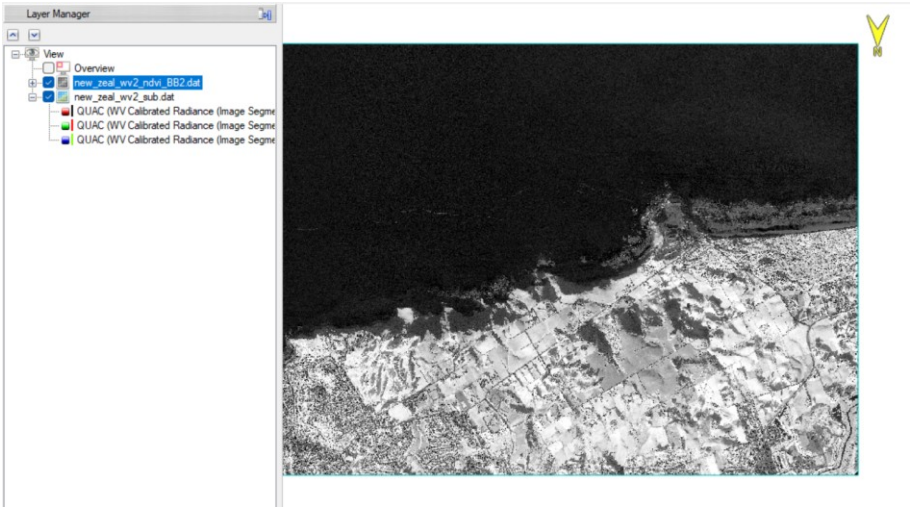
   (float(b1)-b2)/(float(b1)+b2)

   Answer in your own mind why the float() must be specified.

3. When the formula is entered / typed, click **OK**.

4. Map B1 to the NIR Band by clicking **B1** and then clicking the band 8 (wavelength 949.300 micrometers). Then click **B2** followed by the Red band, band 5.

5. For the output navigate to your **lab 5** folder and name the file new_zeal_wv2_ndvi.dat, then click **OK**. You have just calculated the Normalized Difference Vegetation Index (NDVI) of this image by using Band Math.




*****It is VERY important to include the .dat in your naming. Otherwise ENVI uses a native raster structure that is not readable in other programs such as Arc**.

6. The result will be displayed. Adjust the transparency slider to investigate the relationship between the index and the original image. Also, use the data cursor tool to examine the image. How do NDVI values vary from water to pasture to developed areas?

7. You could have calculated the NDVI using Band Algebra: Spectral Indices, and specifying the Normalized Difference Vegetation Index. Just for fun, do

the calculations using Spectral Indices to see if there are any differences. If you find differences, why do you suppose they exist? Hint: maybe the Band Algebra Spectral Images uses a different NIR band! Try to re-calculate the NDVI with band 7 and 5 through band math one more time and compare the output with the NDVI calculated by Band Algebra: Spectral Indices.

### *Alternative: calculating NDVI in ArcMap*

1. Launch the ArcMap software on your computer
2. Connect the Lab5 data folder where your data are located and add new_zeal_wv2_sub.dat raster image.
3. Double click on the image. The image will split into 8 bands. Click and drag Band 5 and Band 8 into the Arcmap window. After adding Bands 8 and 5 to the ArcMap Table of Contents, rename them to **Band 8** and **Band 5**. Using short layer names will make it easier to write and read the NDVI formula in the next step. You will notice that the image seems to be displayed upside down. Can you guess why? It won't matter for the zonal analysis so we won't reproject the data.

   ***You do not need to include all the bands for use in calculating NDVI. The important bands are selected to achieve needed result**

4. Locate the search bar on the toolbox and click on it. Type in Raster calculator and hit enter.

5. In the opened dialogue box, enter the following expression;

   **Float(***band 8 – band 5***) / Float(***Band 8 + Band 5***)**:

   (Note: Float can be found under math category by the right-hand pane – place the cursor in the expression field and click on Float, then click on Band 8 and Band 5, in the proper order, in the list of available layers. Be sure that all parentheses are in the correct location.

6. Output raster: Navigate to the folder where you wish to save. Name the file file new_zeal_wv2_ndvi_GIS.dat

## Part II: Zonal Statistics in ArcGIS

1. Close ENVI. Open ArcMap and use the **Add Data** button (plus sign in the toolbar) to add your new_zeal_wv2_ndvi.dat file. Also add the NW_zonal shapefile. You will notice again that the image appears to be displayed upside down. This will not affect the zonal analysis, so there is no need to reproject the data.
2. Before performing the zonal analysis, create a new floating-point raster from the ENVI-derived NDVI image. Open **Raster Calculator** (Toolbox → Spatial Analyst Tools → Map Algebra → Raster Calculator) and enter the following expression:

Float("new_zeal_wv2_ndvi")

Save the output as new_zeal_wv2_ndvi_float.

**Note:** In some cases, NDVI images generated in ENVI may cause the Zonal Statistics tool to return invalid values (e.g., NaN) for some classes, even though the raster displays correctly. Creating a new raster using the Float() function forces ArcGIS to rewrite the raster using its own floating-point format, which resolves this issue.

3. On the ArcMap toolbox, click the **Search** icon and in the Search window, type **Zonal Statistics as Table**.

4. Open the **Zonal Statistics as Table** tool.
5. In the **Input raster or feature zone data** field, select the NW_zonal shapefile from your Lab 5 folder.
6. For the **Zone field**, select the **Desript** field (note the spelling error in the shapefile; it should be "Descript"). You may wish to open the attribute table first to examine the available fields.

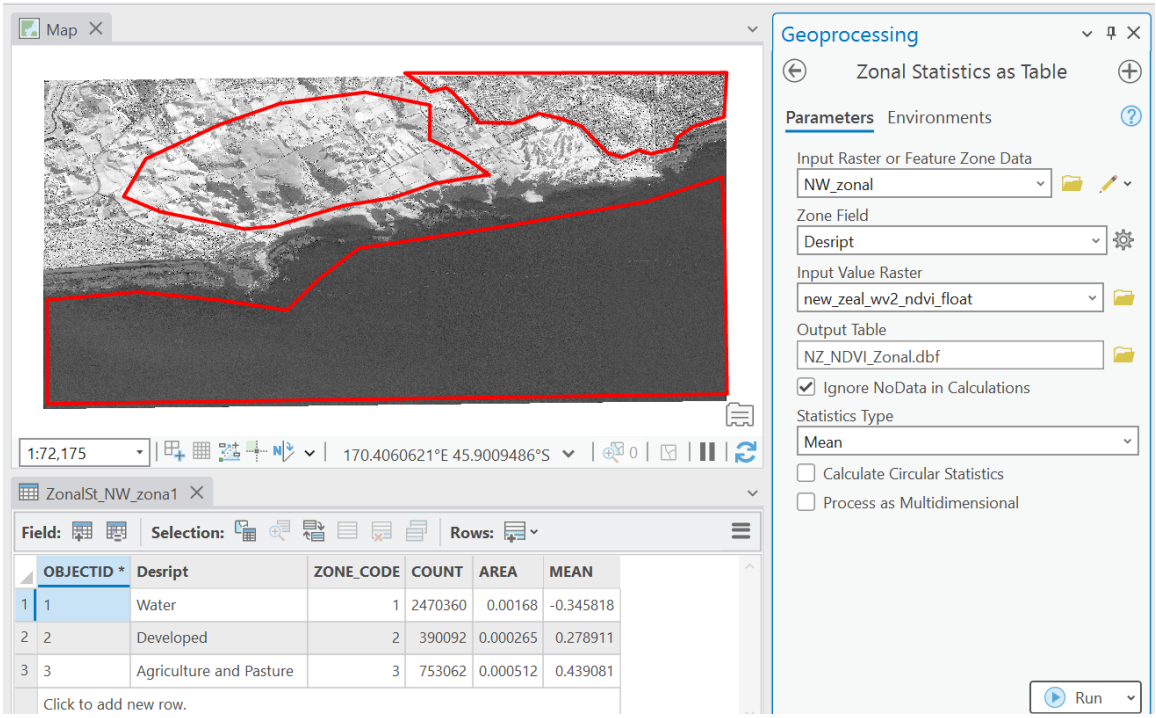
7. For the **Input value raster**, select the newly created raster new_zeal_wv2_ndvi_float.

8. In the **Output table** field, browse to your Lab 5 folder and save the output as: NZ_NDVI_Zonal.dbf

While the .dbf extension is not required, it will make subsequent steps easier.

9. For **Statistics type**, select **MEAN**. Explore the other options available in the drop-down menu. Also check **Ignore NoData in calculations**.

10. Click **OK** to run the tool. The process may take a minute to complete. Once finished, open the output table from the Table of Contents and examine the results.




Well done on completing the exercise. Congratulations!