Lab 4: Return to Earth

ENVI Intro and Classification with Landsat

A PDF of the lab report must be uploaded to Gradescope by 10 am on Tuesday, February 22, 2022 (see submission instructions on Brightspace, and check Brightspace for due date updates).

Setup

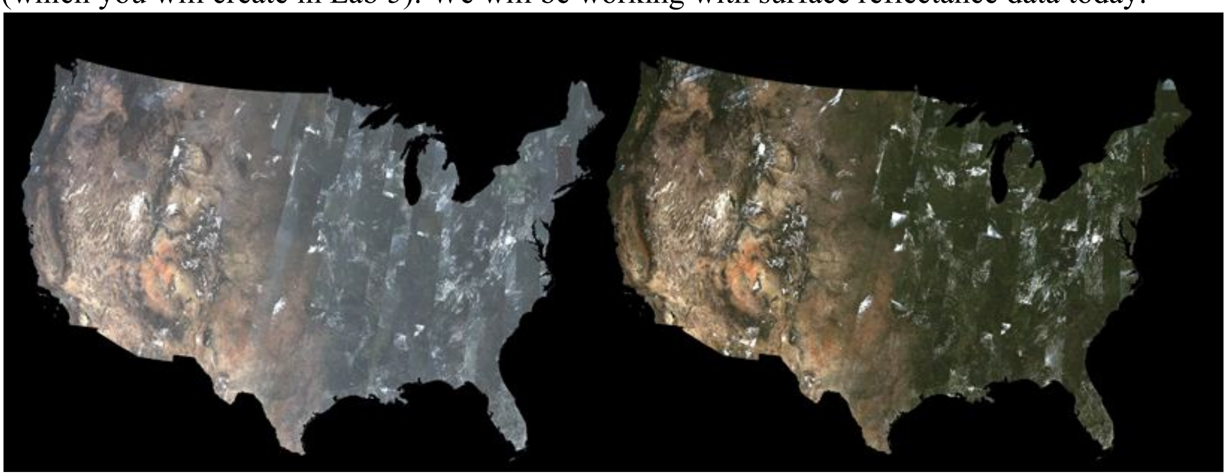
Back on your lab computer, navigate to your home directory from the icon on the Desktop, and create a working directory for the lab called lab04 in your EAPS577 folder. Download all of the files for the lab from this folder into your working directory (remember that unzipping is much faster in the downloads folder before you move the files):
https://www.dropbox.com/sh/fdik776jagb2ipa/AAAqWCjpR_WLGFITE5LB1FuRa?dl=0

There are two key documents for this lab - this document gives instructions for the lab, but make sure to also fill out the lab report. You should open and edit this file, and write your answers in all the indicated areas.

Lab Intro

Today we'll be looking at a Landsat 7 image over Arches and Canyonlands National Park in Utah. Your ultimate goal will be to make an image highlighting bedrock in the area, which are an analog for many different surfaces on Mars.

Just because it's cool, here's a mosaic of the USA made using Landsat 8 images. The left mosaic uses calibrated radiance data (like you created with your pipeline in Lab 3), and the right mosaic is actual derived surface reflectance, where atmospheric scattering has been suppressed (which you will create in Lab 5). We will be working with surface reflectance data today.



Some history of Landsat with very cool mosaics: http://www.codex99.com/cartography/103.html

Key Concepts/Skills in this Lab:

- Getting to know the ENVI display windows
- Opening and manipulating Landsat images
- Creating color images in ENVI
- Band math and creating masks in ENVI

Acquiring Landsat data

Your data for lab today is provided at the link above, but here is some info for downloading your own data for future reference. This website lists the different ways that you can access Landsat data online: https://www.usgs.gov/land-resources/nli/landsat/landsat-data-access?qt-science_support_page_related_con=0#qt-science_support_page_related_con

The Landsat data that you will be using in the lab today was obtained using GloVis, which is the simplest option for accessing Landsat data: https://glovis.usgs.gov/ *Pro tip:* Select the GeoTiff option so that you get all of the data associated with the Landsat image. This is packaged as a zipped tar.gz file, which you must unzip prior to use.

Alternatively, you could use the USGS Earth Explorer, linked from the USGS page above. This site allows access to all publicly available remote sensing datasets, including ASTER, Landsat, MODIS, etc. I normally find images in Earth Explorer and then download them in GloVis.

1. Displaying Images in ENVI

ENVI is an image and spectral analysis software package that is commonly used in industry, research, and government remote sensing labs. We'll use ENVI Classic in this course because it has a much simpler interface, but many people use the modernized ENVI as well.

ENVI is composed of a graphical user interface (GUI) built on top of IDL, so ENVI can be opened either by opening ***ENVI Classic + IDL*** through the Windows interface, or from the IDL command line by entering: **`envi`**. When you open ENVI, both a menu bar and a command line will show up – the command line is actually an IDL command line, and can perform any functions that IDL can.

To open the image data for today's lab, go to ***File -> Open Image File***, and navigate to the "data" folder in your lab03 directory.

You'll see a long list of files in this folder, including a tif file for every Landsat band associated with this one observation. We could open each of these individually and combine them into one data product, but ENVI knows how to deal with Landsat data in this folder format. So, just open the filename ending in **`MTL.txt`** instead.

- *Note 1: Windows hides extensions, so you may need to open the version of this file without an extension.*

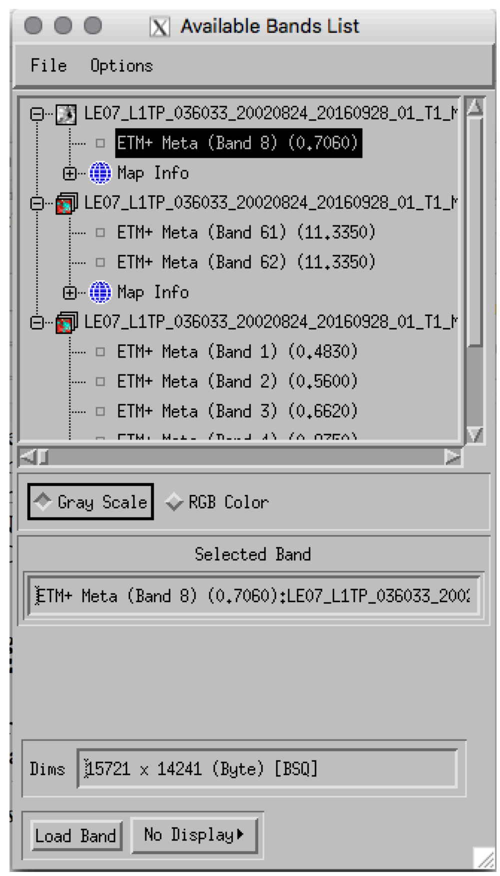


Figure 1: *Available bands list that should open in ENVI when you open a new image.*

- *Note 2: ENVI classic has some issues with Landsat 8, so you would need to use normal ENVI to look at that data set.*

A window titled "Available Bands List" will pop up as shown in ***Figure 1***, this shows all open data files and their contents. The numbers in parentheses indicate the center wavelength of the filter. The first file is the panchromatic image.

Standard image data files come with "headers", these are either text at the beginning of the data file (hence to name) or a separate file that contains info about the observation, image, processing, etc. You can see the header in ENVI by ***right-clicking*** on the image name and then going to ***Edit header.*** This will bring up additional information about the file, including the file size and the number of rows (ENVI calls these "lines") and columns (ENVI calls these "samples") in the image.

You can also click the + button next to the Map Info entry in the Available Bands List to show the geographic information for the image. GeoTiff's are different from normal images in that they this contain map and projection info.

Now display the images. Click on the band 8 image to select it as shown in ***Figure 1***, and then click the ***Load Band*** button in the lower left corner. This will open a new image display like shown in ***Figure 2***, and because we've only selected one band, it will be in grayscale.

The large window is the "image" window, make this bigger for easier viewing. The "scroll" window on the lower left shows your location in the full image, and you can click around within it to change your location, as indicated by the red box. Click in the middle of the image to make the image window not just black.

The "zoom" window on the lower right shows a close up of the red box area in the image, typically at the scale of individual pixels. You can move the location of the zoom area in either the scroll or image windows either by dragging it with your mouse or using the arrow keys on the keyboard. You can also choose to eliminate one or more of these displays by right-clicking in any of the windows and going to ***Display window style.***

Your zoom display may or may not show the cross-hairs that are in my example. Click the empty box on the right at the bottom of the image to turn it on. The default display setting is for these to be red - to change this, go to the Image window (the big window) and select *File-Preferences*. At the bottom of the Display Preferences dialog box, click on *Display Graphic Color* box to toggle through all of the color choices until you get something that shows up, then close the Display Preferences dialog box.

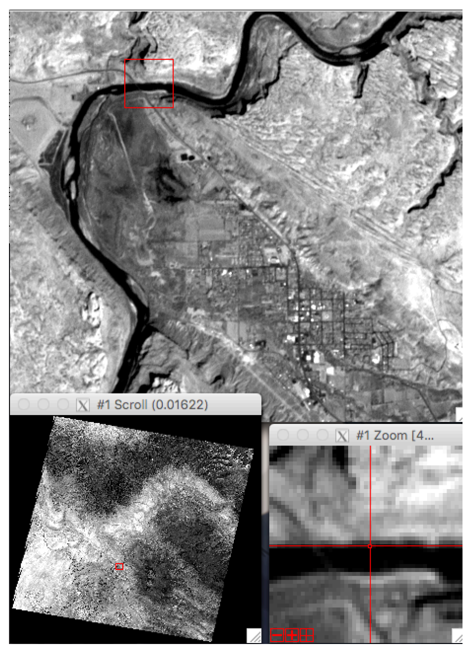


Figure 2: *ENVI image display windows, a set of three showing context (scroll, bottom left), higher resolution (image, top), and pixel scale (zoom, bottom right).*

2. Scales and pixels

Pixel Size: The sinuous channel that extends from the northeast corner of the image to the bottom middle is the main channel of Colorado River. Use the zoom image to find the edge of the river as shown above. Click the + button on the right of the zoom image until you begin to see the appearance of the image degraded and the individual pixels that make up the image. You should also see a box appear in the middle of the cross hairs, which is showing the size of one pixel.

When you start to work with any image data set, one of the first things you want to determine is the pixel size. In ENVI, you can obtain this information in the Available Bands List dialog box by clicking on the + next to the Map Info. Knowing the pixel size will give you a sense of scale and will be essential for enabling you to calculate areas and distances in your image.

Determine the size of the pixels in the panchromatic image. What is the approximate width (east-west) of the Colorado River at the location shown in Figure 2? You can determine this by counting pixels as you move across the river using the arrow keys, and then multiplying the number of pixels by the resolution in meters/pixel.

Measurement tool: There is an easier way to get distances from your image. In the menu bar in the Image window, go to ***Tools -> Measurement Tool*** , select the Units (do you want the distance in pixels, meters, etc.) then point to one bank of the river, left-click, then point to the other bank of the river and left-click again. You can also measure multiple line segments or calculate areas using this tool. Right click once to stop drawing and twice to clear the lines.

Using the measurement tool, determine the maximum width of the Colorado River in ***at least*** three locations in the image (the image above shows where it passes through the city of Moab) and calculate the average width in the scene. *Note: if you're having a hard time finding and following the river, make the scroll window bigger.* (Question #1)

3. Color stretching in ENVI

Next, let's make an RGB image using bands 1, 2, and 3. Go back to the Available Bands List window, and click on the ***RGB color*** text or radio button. Then click on band 3, then band 2, then band 1. This will assign these bands to the red, green and blue color channels, respectively (do the wavelengths listed for those bands make sense for this assignment?). Now click Load RGB, which should bring up an image similar to the one shown in ***Figure 3***.

Figure 3: *Bands 3/2/1 image of Moab/Arches/Canyonlands.*

The color image was loaded with a default ENVI stretch for these bands. You can change the appearance of the image by trying different preset stretches listed under the ***Enhance*** menu in the Image window. Try a few of these to see the effects. The [scroll/image/zoom] descriptor tells you which window and associated range of values is being used to compute the stretch for the whole image. Try moving to different areas of the scene and changing the stretch based on the "image" window.

To understand what these different enhancements do, go to ***Enhance -> Interactive stretching.*** This brings up a histogram display that looks as shown in ***Figure 4***. This is just like the histograms that you created in Lab 2. Note that for the Landsat data, each band has already been scaled to bytes from 0-255, with the same limits applied to each band. This is shown on the Input Histogram, where the X-axis is the brightness value and the Y-axis represents the number of pixels with a given brightness value. You can click the G and B radio buttons to see the range of values for the blue and green channels.

The large number of pixels with brightness values of zero is due to the black edges around the margin of the image. To zoom in on the histogram, go to ***Options -> Histogram Parameters***, and set the min to 1. This should show a histogram like the image at bottom right.

From our three Input Histograms, we can see that the actual brightness values in our image don't "use up" the full range of shades of blue, green and red that we have available to us (especially for green/blue – does that make sense to you based on the scene?). This is where stretching comes in. The different stretches listed in the "Defaults" menu provide different ways to rescale our brightness values, for display purposes, to more effectively use up all the shades of blue, green and red that we have available to us. Watch the limits that are stated in the text boxes change as you select these different options. You can also apply your own stretch using the text boxes in the histogram window or by dragging the white dashed lines around, both of which change the min and max.

First, ***create an approximate true color image*** – look back at Lab 1 if you're not sure what this means. You can either use one of the default stretches if you think it is creating a true color image, or apply your own stretch limits. Save the image by selecting File -> Save Image As -> Image File. Make sure that the Spatial Subset is set to Full Scene, and change the output file type to JPEG. Select "Choose" to select the directory and filename for your image – make sure to save the image to your lab04 directory.

How did you create a true color image? What color is most of the bedrock in this stretch? (Question #2a-c)

Now repeat this process on the 3/2/1 image to make a false color image that emphasizes diversity in the scene.

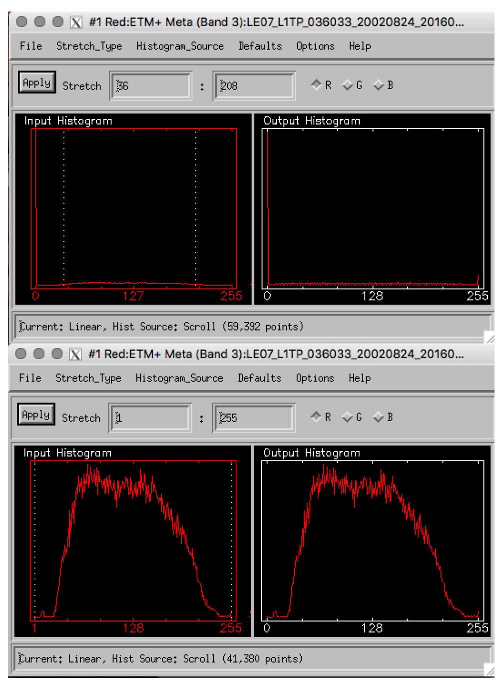


Figure 4: *Histograms of image shown in Figure 3, before and after zooming in on the y-axis.*

Explain why you chose the stretch that you did - what were you trying to emphasize or show? (Question #2d-e)

4. False color images using band combinations

Now we'll make false color band combinations like the ones we saw in class, and that are shown in ***Figure 5***.

Figure 5: *Common Landsat band combinations, as shown in class*

Bands 3/2/1 *Bands 5/4/3* *Bands 4/3/2*

For all three combinations shown above, try assigning the bands shown to the R/G/B channels in your scene. Save the two false color band combo images and put them in your report. (Question #3a-b)

Notice that out here in the desert, the colors look different due to the different types of vegetation. Using the 5/4/3 and 4/3/2 combos, you should able to see that there are at least three different types of vegetation in the scene. What colors do these correspond to in those images? Where are they located in the image? Based on ***Figure 6*** that shows some common types of vegetation along with the Landsat 7 bands, what type of vegetation do you think these areas are dominated by? (Question #3c-e)

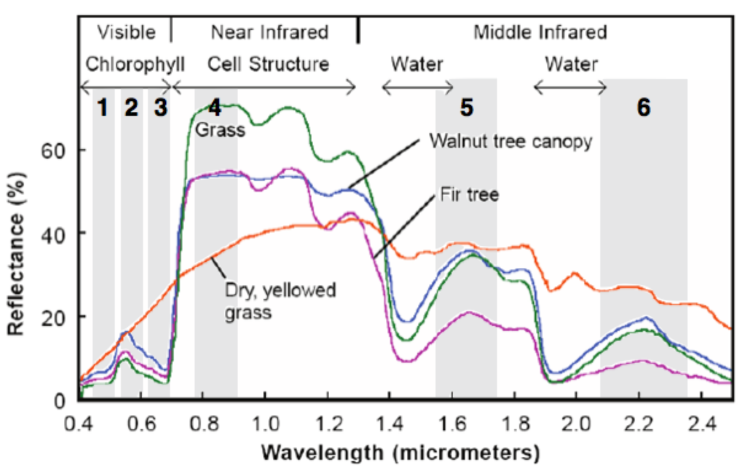


Figure 6: *Landsat VNIR bands compared to typical reflectance spectra for vegetation.*

5. Masking in ENVI

Now we would like to focus on the bedrock in the scene, but it's difficult to figure out what exactly is bedrock and what is vegetation by eye. So your goal in this section will be to create a mask that will remove vegetation and water from the scene.

Let's start by masking out just the water in the scene. ***Figure*** *7* is the one we saw in class that compares water to soil and green vegetation. Note that water is basically totally absorbing at long wavelengths, so if you open a grayscale image of e.g., band 5, you'll see that the river is black.

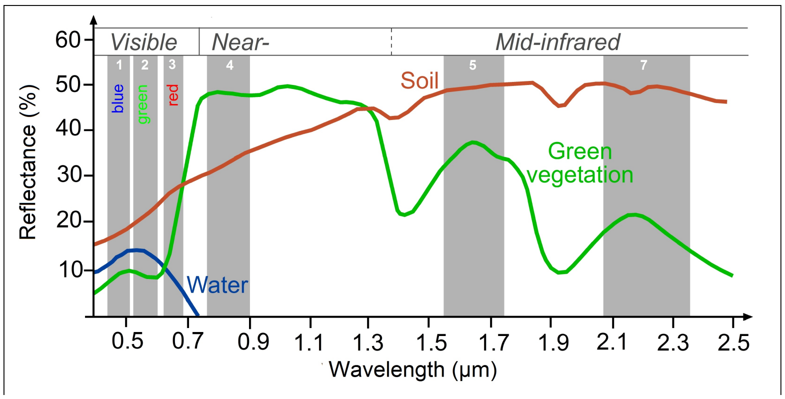


Figure 7: *Landsat bands compared to typical reflectance spectra for water/soil/plants.*

To verify this, in the image window go to ***Tools -> Cursor Location Value***. This enables you to point to a location in the image and determine the underlying pixel brightness value. The helpful number in this window is the "data" value, which is the actual value of the band at that location. Is the water actually zero bytes in band 5?

Use the histogram to figure out the approximate range of values over the river. Test this by stretching the image over those values, and save the result to put in your report. Is the river the only part of the scene that is dark? If not, what do these areas correspond to? (Question #4a-c)

We can use this range of values for the river (and the other areas we don't care about) to identify water and create a mask that will remove it from the scene. From the image window Menu Bar, select ***Tools -> Build Mask.*** From the Mask Definition dialog, go to ***Options -> Import Data Range.*** Select the Landsat image file, and then select the ***Spectral Subset*** button at lower right. This brings up the ***File Spectral Subset*** window, and here select band 5 and hit ok. This brings up the ***Input for Data Range Mask*** dialog box.

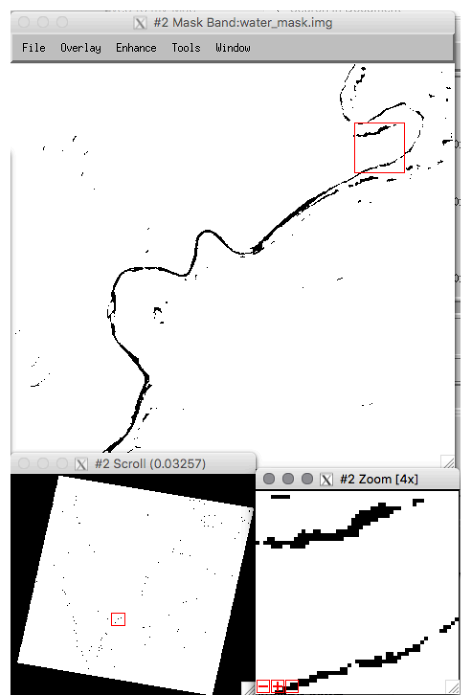


Figure 8: *Example mask to remove water from the scene.*

We want the rocks to be one and the water to be zero in this mask, so enter the minimum and maximum data value that define all areas *brighter than water* in band 5, then click OK. In the ***Mask Definition*** dialog, choose an output filename (e.g., *water_mask.img*), then click ***Apply***. Your new mask should appear in your Available Bands list. Click on it to highlight it and then click the Load Band button. This should bring up something like the image shown in ***Figure 8***. Save the image and paste it into your lab report. (Question #4d)

Now we're going to create another mask to mask out vegetation. For this we'll do some simple math to create a ***band ratio***, where we divide the values in one band by the values in another. Remember, images are just arrays that we can add, subtract, multiply, divide, etc. Based on the spectral plots above, what band ratio should you use to identify green vegetation and why? (Question #5a)

The division is done by using the ***Band Math*** tool. From the ENVI main menu bar, go to ***Basic Tools -> Band Math.*** This opens the ***Band Math*** dialog box. In ***Enter an Expression***, enter "b1*1.0 / b2" as shown in ***Figure 9***.

Why did I add a 1.0 to the equation (hint: what kind of numbers are the arrays composed of)? What would have happened if I didn't? (Question #5b). If you're not sure, try entering these commands at the IDL command line:

`print, 255/50` and **`print, 255*1./5`**
`print, 50/255` and **`print, 50*1./255`**

Then click on ***Add to List***, then ***OK.*** We just defined a generic math function: we will divide band 1 (which we called "b1") by band 2 (which we called "b2"). Now we need to assign specific bands in specific image files to our two variables; b1 and b2. As soon as you clicked OK, the ***Variables to Band Pairings*** dialog box should have appeared, as shown at right.

This dialog indicates that b1 and b2 are currently undefined. Now you'll need to assign the bands that you chose above to identify vegetation to these variables. Select b1, click ***Map Variable to Input File***, open the Landsat image, and select your numerator band. Hit ok and repeat for b2. Create a filename (e.g., *veg_ratio.img*) and hit ok to execute. The image is large so it may take a minute. The output from your ***Band Math*** function should then appear in your ***Available Bands List.*** Click on it and then click on ***Load Band*** to view the result. It will appear as a gray scale image. Save the image and paste it into your report. (Question #5c).

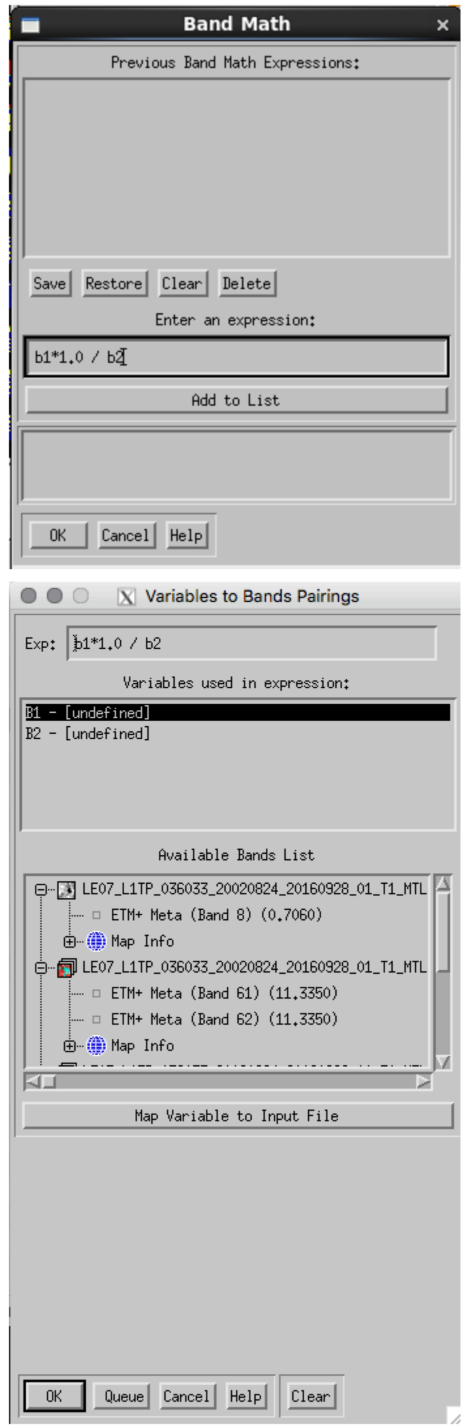


Figure 9: *Band math dialog windows, with example band ratio.*

Did you successfully map vegetation? What does the strength of the parameter correspond to? What are the ranges of values of this parameter that correspond to relatively dense vegetation (this is a little subjective)? (Question #5d-e).

Now we can use our handy new ratio parameter to identify and mask out (remove) vegetation from our image. Repeat the steps that you used above to create a water mask in order to create a vegetation mask based on your ratio image. Save the mask image, and paste it into your lab report. (Question #5f).

6. Rocks, glorious rocks

Now we'll create an image that highlights bedrock in the scene. Frist, we need to decide which bands are best for showing the diversity in the rocks. You can do this either by trying different band combinations and stretches to see what works, or by using this handy Landsat spectra website: https://landsat.usgs.gov/spectral-characteristics-viewer

On this site, you can load **Landsat 7** bandpasses and compare them to many different materials (click Bands/Spectra/Convolve). For our purposes, try comparing them to the rocks listed under the Spectra tab. What bands would be best for highlighting these differences?

Create your favorite rock stretch band combination, stretch it to highlight variability, and paste it into your lab report. Why did you choose this combination? What kind of variability do you see in the scene? (Question #6a-c in the Lab Report).

Now we can do band math again to apply the mask to our image to highlight only bedrock in the scene. Open the band math dialog, and this time enter a simple multiplication: b1 * b2 * b3. b1 corresponds to your water mask, b2 corresponds to your vegetation mask, and b3 corresponds to your band of interest. Try applying this to one of the bands from your rock image to see what happens. To make an RGB, you'll have to repeat this for each band and then combine them using the RGB dialog.

Finalize your rock image with your favorite stretch to emphasize diversity in the rocks (this should be easier now that the vegetation and water are gone) and paste it into your lab report. Did the mask help you stretch the image more accurately? (Question #6c-d in the Lab Report).

If you want to blow your mind, open up this area in Google Maps and zoom around the satellite imagery at high res. Glorious, glorious rocks!

Written by Briony Horgan (Purdue University)