Remote Sensing 4113
Lab09: Spectral Unmixing and ROIs.
April 4, 2018

In this lab we will explore **Spectral Unmixing** techniques. Rather than simply trying to classify different pixels, these techniques attempt to estimate the amount of different minerals present in a given pixel. The first step in Spectral Unmixing is to determine the spectra of the "Endmembers" – those components which when averaged together in the right amount can produce all the observed spectra. We will explore two techniques for obtaining endmembers. With the first we will select certain Regions of Interest (ROIs) in the image which we hope are composed of "pure" endmembers, and then use the spectra of those pixels. Finding the right endmembers is usually a time consuming process so for this lab I have preselected certain regions. With the second technique we will importing mineral spectra from the USGS spectral library.

For convenience we will again use the Como Bluff Aster data. However be aware that the 9 visible through short-wavelength IR bands available are not really enough for detailed unmixing modeling. Much better results would be obtained with hyperspectral data.

Because we will be comparing the observations to laboratory spectra we need true reflectivity data. I've produced a more-or-less calibrated reflectance version of the data for use this week. Be sure to use that file rather than the raw DN data from last week. The calibrated version was obtained by applying ASTER sensitivity information to obtain radiance at the sensor, then dividing that result by the expected spectrum of the sun. This data has not yet been corrected for atmospheric transparency, so the values for some filters (in particular Band 9) will be slightly too low.

As usual, use a temporary directory within **`c:\tmp`** on your local machine for all your files, and copy the **`lab_09 data`** zip file from the class website to your local machine and unzip it. You should see the following files: the **`aster_como_bluff_reflectance`** image and **`hdr`** files and the **`como_bluff_predefined.roi`** file. Save any files you want to keep on your **`Home Drive`**.

Part I: Spectral Linear Unmixing using ROIs

I have selected eight "Regions of Interest" (ROIs) in the Como Bluff image. We will find the spectra of those regions then attempt to model the rest of the image assuming the other pixels are a linear mixture of those eight types.

1. **Defining Regions of Interest (ROIs)**
   Open the Como Bluffs image (**`File->Open Image File`**), and load **`Bands 3,2, 1`** as RGB. Click on the image's **`Maximize`** button (on the title bar) to make the image large enough that the **`Scroll`** window disappears. Save a copy for inclusion in your report.

   To see how to define a ROI, from the **`Image`** window menu select **`Tools->Regions of Interest->ROI Tool...`**. A **`ROI Tool`** window will appear, and a **`Region #1`** will appear in the list of ROIs. Initially it should contain 0 pixels. Near the top of the window there will be a set of "radio buttons" which let you select whether to draw the ROI in the **`Image`**, **`Scroll`**, or **`Zoom`** window, or turn the tool off to use the cursor

for other tasks. Select **Zoom** if it is not already selected. From the **ROI Tool**'s menu select **ROI_Type** and be sure that **Polygon** is checked. (The other options are **polyline** and **point**.) Drag the red zoom box in the main image to an interesting area. Left-click the mouse in the **Zoom** window to define the corners of a polygon which outlines a region of interest. (You may want to enlarge the zoom window.) When finished selecting corners, right-click the mouse to close the polygon. A small diamond will appear in the polygon. You can drag with the left mouse button to move the polygon. When it is located correctly, right-click the mouse again. The ROI will then be filled with a preselected color and the total number of pixels will be indicated in the **ROI Tool** window. You could then click on the name there to change it to something meaningful, and you could also change the color. You would normally select ROIs for all the different Endmember components you would use in the modeling. Because that is a time consuming process we'll start by using ROI's that have already been defined, and will delete the ROI you just created after reading in those predefined ones.

2. **Reading predefined ROIs.**
In the **ROI Tool** menu select **File->Restore ROIs...** and in the file selection box which opens select **como_bluff_predefined.roi** then click **OK**. Click **OK** again on the confirmation box which will open. The ROIs should now appear in the **ROI tool** window. Go to that window, click on the **Region #1** entry to select it, then click on the **Delete** button to remove it.

   To see where the ROIs are located select each one in the **ROI Tool** window list then click **Goto**. The red zoom box will jump to the ROI. If a ROI consists of more than one polygon, each time you click **Goto** it jumps to the next polygon.

3. **Computing average spectra and statistics for the ROIs.**
Select all the ROIs with the **Select All** button in the **ROI Tool** window, then click the **Stats** button. A **ROI Statistics** window will open showing the average ROI spectra and various statistical information. By holding the left mouse down in the plot window you can examine the numerical values for each of the spectra. You should be able to recognize at least the vegetation spectrum. The differences between the others will be subtle, suggesting that we may not be able to completely unmix the spectra given the limited data available.

4. **Applying Spectral Linear Unmixing.**
From the main ENVI window select **Spectral->Mapping Methods->Linear Spectral Unmixing**. A window will open to select the input file. Select the **aster_como_bluffs_reflectance** file and click **OK**. Next an **Endmember Collection** window will appear. From its menu select **Import->From ROI/EVF from input file**. Another window titled **Select Regions for Stats Calculation** will appear listing all the predefined ROIs. Click the **Select All Items** then click **OK**. The spectra of the ROIs will finally be entered into the **Endmember Collection** window. Clicking **Plot** will display those spectra in a new window. On the **Plot Window** menu select **Options->Plot Key** to add the key. Enlarge the window to a reasonable size and save it for inclusion in your report. To perform the unmixing, in the **Endmember Collection** window click the **Apply** button. An **Unmixing Parameters** window will appear. For now leave the "**Apply a unit sum constraint**" at the default **NO**. **Choose** an output file name in your directory then click **OK**. After calculations are finished a set of new entries should appear in your **Available Bands List**, one for each component plus an RMS error image.

Load the Vegetation component in a new display window by right clicking on that entry in the band list then selecting **Load band to new display** in the pop-up menu. (This is a short cut for the longer steps of opening then loading a new window.) Maximize that new image window to make the **Scroll** window disappear then use **Tools->Link** commands to link this window to your original display. Pressing the left mouse button in the new image window will temporarily show the linked image, allowing easy comparison. How well did the unmixing select the vegetation? To determine this quantitatively use **Tools->Cursor Location/Value** to open a window displaying this. What are typical minimum and maximum values for **Disp #2** data – the fraction of the pixel thought to be occupied by vegetation? Record this range, and save a copy of the image for inclusion in your report.

Successively examine the other component images and save copies for your report. You can just load them to the current (#2) display. The short cut to load them in this **Display #2** is to right-click on them in the **Available Band List** then select **Load band to current display**. Examine the typical fraction occupied numbers. Discuss in a few sentences how well the unmixing worked. For some components it will work well but for other ones it fails badly. Besides providing a poor match, some components will show fractions less than zero or greater than one. Most likely we are missing some endmember spectra, and we also have noise present in our data. In addition, microscopic mixing is inherently non-linear, so it cannot be modeled with these simple techniques. You don't need to discuss each component in detail. But do report a couple of the best and the worst fraction numbers for each.

5. **Matched Filtering.**
   A more sophisticated variant of Spectral Linear Unmixing is **Matched Filtering**. As described in the ENVI User Guide, when you have unknown endmembers "This technique maximizes the response of the known endmember and suppresses the response of the composite unknown background, thus matching the known signature."
   In the **Endmember Collection** window menu select **Algorithm->Matched Filtering** then click **Apply**. In the window which opens select a name for the statistics and the output image files in your own directory, then click OK. After calculations are finished a series of MF score bands will appear in your band list. Once again, selectively load these into **Display #2**, save them to your report, and comment on the quality of the match and also the range of the data values. For example for the Vegetation band, what values do you obtain over vegetation, and what do you obtain over bare regions?

Part II: Resampling and Convolution of Laboratory Spectra

6. **Restart ENVI.**
   To be sure ENVI is in a well defined state, exit it, restart it, then reload the Como Bluff image with Band #3, 2, 1 as RGB, and again maximize the main image window.

7. **Obtaining USGS Laboratory Spectra.**
   Many laboratory spectra in libraries were obtained at much higher resolution than can be expected in remote sensing data. In using the laboratory spectra we often need to

"convolve" or average the spectra over the relatively broad filters in which our remote observations are obtained. We may also need to interpolate the laboratory data to match wavelengths. ENVI calls this process **resampling**. It knows how to do much of this automatically, but in this Part II we'll following a slightly indirect procedure so we can see those convolution steps.

To use a Spectral Library (an **sli** file) we first need to open it so it appears in the **Available Bands List.** From the main ENVI window select **Spectral->Spectral Libraries->Spectral Library Viewer**. In the **Spectral Library Input File** window which appears, at the bottom click the **Open>** button, then select **Spectral Library...** . A file selection box will open. You should be positioned in the **ENVI spec_lib** directory. Select the **usgs_min** subdirectory. Select the **usgs_min.sli** file and click **OK**. You may need to click **OK** in the previous window which now reappears. **USGS Mineral Spectral Library** should now appear in the **Available Bands List**.

A **Spectral Library Viewer** window listing many minerals should now appear. (If it doesn't, from the main ENVI window again select **Spectral->Spectral Libraries->Spectral Library Viewer** and in the **Spectral Library Input File** window which appears, select the **usgs_min.sli** file and click **OK**.) This is an earlier version of the on-line USGS spectral library which we have been using.

For simplicity we will use two minerals we've seen before even if they may not be the best choice for matching this particular scene. Click on **Alunite (HS295.3B)** and a **Spectral Library Plots** window will appear containing its spectrum. Enlarge it to a reasonable size. Back in the **Spectral Library Viewer** window scroll to **Kaolinite CM3** and click on it to display its spectrum. Note that these spectra are at the full resolution of the library, but the filters for the Aster bands are wide enough that they would not resolve all the detail present. We must average the spectra over the Aster bandpasses. (Technically, we "convolve" the mineral spectrum with the spectrum of the filter's transmission, just as in homework we convolved an image with a spatial filter kernel.)

8. **Convolving the spectrum with filter transmission curves.**
From the main ENVI menu select **Spectral->Spectral Libraries->Spectral Library Resampling**. In the window which appears select the **usgs_min.sli** file and click **OK**. In the **Spectral Resampling Parameters** window select **Pre Defined Filter Functions**. A sensor button will appear, probably reading the default **Landsat TM4**. Right click on it and select **Aster** from the list which should appear. (In some versions of ENVI you instead left click on the down-arrow at the right of the sensor button.) In the lower part of the window specify an output file name like **resampled_spectra** (in your directory) and click **OK**. . ENVI will probably warn you that 5 of the 14 points are outside the wavelength range of the input spectrum. It is just telling you that our spectrum doesn't extend out to the wavelength of the ASTER TIR filters. That's OK since we will not be using those filters. Just click **OK** to ignore the warning. The **resampled spectra**, and also an entry for the aster filter transmissions, should appear in the **Available Bands List**.

To display the convolved spectra, go to the **Spectral Library Plots** window showing the existing plots and select **File->Input Data->Spectral Library...** and in the

window which opens select **resampled spectra** then click **OK**. From the spectral list in the window which opens again click on **Alunite (HS295.3B).** Scroll to **Kaolinite CM3.** While holding **CTRL** down click on it to select it too, then click on **OK**. In the plot window you should now see additional spectra, consisting of only 9 points (at the ASTER band center wavelengths), with straight line segments between then. To display the 9 spectral points more clearly, from the plot window menu select **Edit->Data Parameters**. In the window which opens find the entry which corresponds to your convolved spectra and change the **Symbol** from **None** to **Diamond**. You can also adjust line colors if you wish. When done close the **Data Parameters** window.

Finally, to plot the transmission spectra of the ASTER filters, repeat the above procedure. From the **Spectral Plots** menu select **File->Input Data->Spectral Library...** and in the window which opens select **aster.sli** then click **OK.** In the next window which opens select **Bands 1** through **9** by holding **CTRL** down while clicking on them, then click **OK**. The nine relevant Aster filters will be plotted. If you examine the plots carefully, you will see that the resampled mineral spectra do corresponds to the original spectra, averaged over the width of the ASTER filters. Add a key to you plot with **Options->Plot Key** then save a copy of this plot for inclusion in your report.

When done go to the Available Bands List, right click **resampled spectra**, and click **Close Selected File**. In the following work ENVI will automatically resample and convolve the spectra we select, based on the filter wavelength and bandwidth information stored in our data file. The above exercise was just to see the relationship of the original spectra and the resampled ones. In the following it's best not to confuse ENVI by giving it already resampled spectra.

Part III. Spectral Unmixing using laboratory spectra

9. **Unmixing the Como Bluff image with USGS spectra.**
Lets see how successful Unmixing will be using a few spectral endmembers from the USGS library. A brief look at the coarse nature of the convolved spectra should convince you that the results will not be very trustworthy. With only 9 bands there are a large number of minerals which would easily be confused. However the general class of minerals might be determined more reliably. Once again, with hyperspectral data the results would be much better.

From the main ENVI menu select **Classification->Endmember Collection** and in the **Classification Input File** window which opens select **aster_como_bluff_reflectance** and click **OK**. In the **Endmember Collection** window which then opens select **Import->from Spectral library file** and in the window which opens select **usgs_min.sli** then **OK**. Select **Alunite HS295.3B**, scroll to **Kaolinite CM3** then while holding **CTRL** down, select it, then click **OK**.

Lets add one final component, a type of vegetation. For that we will need to load the USGS vegetation library. From the **Endmember Collection** window select **Import->from Spectral library file.** In the **Spectral Library Input File** window which appears click the **OPEN>** button at the bottom, then select **Spectral Library...** .. A file selection box should open and you will either be in the main ENVI spectra directory, or in the usgs_min one you last used. If the latter, move up to the main spectral directory. You should see a **veg_lib** directory. Navigate to it and select the **usgs_veg.sli** file. Click **OK** in that window and the next higher level one. An **Input**

Spectral Library window should appear giving a list of vegetation. From that list select **Rabbitbrush** and click **OK**. That third spectrum should appear in the **Endmembers** list.

Finally, back in the **Endmember Collection** window, click **Select All** then from its menu select **Algorithm->Matched Filtering** then click **Apply**. In the next window to appear pick reasonable output names (**usgs_mix**) for your statistics and output files and click **OK**. The resulting MF Scores should appear in the **Available Bands List**.

As you did above, display those MF scores in a new window linked to your original image. Save copies of the three images for your report. The match will probably be marginal, as we haven't put much work into choosing an appropriate set of end embers. Despite that, discuss in a few sentences whether the regions showing Alunite and Kaolinite corresponds at all to those formations which you might expect to contain more clays and hydrated materials. Is the modeling capturing the location of the vegetation?

Finally, in the **Endmembers Collection** window click on the **Plot** button to display the spectra of the endmembers. From the **Plot** window menu select **Options->Plot Key** to add a label key. Use **Edit->Data Parameters** to show symbols at the nine spectral points per plot. You can also use **Edit->Data Parameters** or **Edit->Plot Parameters** to clean up your plot, for example changing unreadably light colors to something more useful, or changing the scaling. When finished, save a copy for your report.

In summary your report should include

1) A copy of the original RGB (Band 3, 2, 1) image for comparison with the other ones.

2) A plot of the spectra from the preselected ROI's, with key.

3) Eight images from the **Linear Spectral Unmixing** routine for the ROI spectra, plus a discussion of those results.

4) Eight images from the **Matched Filtering** routine for the ROI spectra, plus a discussion of those results.

4) The spectral plot showing the original Alunite and Kaolinite spectra, the ASTER filters, and the convolved spectra.

5) Three images from the **Matched Filtering** routine for the USGS spectra, plus a discussion of those results

6) The Endmember USGS spectra with key.