

Land Remote Sensing
Assignment #4: Matching spectra to libraries, and atmospheric correction
Due: Oct 28, 2015

Name _____

The files you'll need are at:

http://wray.eas.gatech.edu/remotesensing2013/RS_Lab3_files.zip

ENVI has several tutorials on hyperspectral analysis that you may find useful.

Spectral library matching

In the following questions, you are given a set of unknown spectra and asked to identify the materials represented by those spectra. The goal is for you to build familiarity with which compounds absorb in which parts of the spectrum. For instance, seeing an absorption at about 2.3 μm in your unknown should get you thinking about carbonate minerals, or hydroxylated compounds (e.g., phyllosilicates).

The tool in ENVI that you'll use for this is called the *spectral library viewer* (in ENVI Classic, it's under the menu Spectral \rightarrow Spectral Libraries). As you will undoubtedly guess from its name, this tool's function is to allow you to easily view the spectra from a spectral library file. ENVI uses a special file format for spectral libraries, and files of this format end with a *.sli extension. Once you load a spectral library into the spectral library viewer, ENVI produces for you a list of spectra in the library, and all you have to do is click on one of the spectra in the list and that spectrum will be loaded into a spectral plot window for you. Using this functionality, you can visually compare a spectrum from your scene to a spectral library. There are more sophisticated tools for mathematically matching spectra, but visual matching is what the "experts" commonly do in practice (albeit sometimes with a virtual "library" in their minds).

Of course, any spectral identification you do that is based on matching to a library spectrum is only as good as the library spectrum itself. For that reason you should learn everything you can about the particular library you're using, to make sure it is valid to compare your data to that library. The spectral libraries provided for this lab have "readme" files that contain information on the libraries – you should make sure you consult these files before using the library.

Exercises

1. Look at the ACTINOLITE IN-4A spectrum that exists in each of the jpl spectral library files (jpl1.sli, jpl2.sli, & jpl3.sli). Are these spectra all the same? (You may want to combine them on a single plot: right-click in a plot window, select "Plot Key," and then click on a mineral name in the key and you can drag it into another plot window.) Explain why they are not.

2. The file ques2.sli contains three spectra taken from the jpl1.sli spectral library. Identify each of the unknowns. Which key spectral absorptions (at what wavelengths) allow you to match each spectrum? Name the electronic or vibrational process that produces one of the absorptions in each unknown.

3. The file ques3.sli contains unknown spectra from the usgs_min.sli library. Identify each of the unknowns. Which key spectral absorptions (at what wavelengths) allow you to match each spectrum?

4. The file ques4.sli contains 2 unknowns from usgs_min.sli. But this time, the spectra have been “messed up” some – they either have random noise added, or there is a contribution from some other material present (though in small amounts). These are two very common situations you’ll have to deal with in typical remote sensing analysis. Your task is to identify the mineral present in each of the two unknowns. If you can’t identify the mineral, at least tell me everything you can about it, and list some minerals/mineral groups that the sample might be.

For the following questions, you will use the spectra for a green leaf, a dry leaf, and a dollar bill from the file *spectra.xls*, which includes 3 separate measurements of the same green leaf.

5. Evaluate the repeatability of the spectra for which multiple measurements were taken (fresh green leaves). If the sample doesn't change, any variability in repeat spectra must represent instrument instability of one sort or another. With many samples (spectra), the standard deviation is a conventional measure of this precision. With only a few (three) spectra, it is not so accurate, but we can use it as an approximation. Below, explore this idea by calculating the standard deviation (STDEV) for the three green leaf spectra and making a plot or spectrum of the variation with wavelength.
 - a) Estimate the precision of the spectrometer, for example at 1000 nm (1 micron).
 - b) What do you notice about the variation with wavelength? What factors might account for the observed variations?

6. Plot the spectra of the fresh green leaf, dry leaf, and the dollar bill on the same plot. *Email this plot to me: jwray@gatech.edu*
 - a) What are the major spectral differences between the live and dead leaves? What causes these differences?
 - b) How is the dollar bill spectrally different from the green leaf?

7. Imagine that you have been chosen to design a new satellite that must enable us to map and distinguish between earth surfaces covered by live green leaves, dry senescent leaves and dollar bills, using *multispectral* data. The spectral range you can use is 0.4-2.5 μm . You are allowed only 3 spectral bands at which the satellite will make its measurements; each is to be 30 nm (i.e. 0.03 μm) wide.

At what wavelengths do you think these bands should be placed? Be sure to consider *atmospheric windows*, i.e. portions of the spectrum in which the Earth's atmosphere has high transmissivity. Explain your answer in detail.

Atmospheric correction

As you have learned, the atmosphere is not entirely transparent. The amount and type of atmospheric scattering that occurs between a satellite and the ground is variable, and can depend on the climate conditions, the time of day, the season, the type of area being sensed (marine, coastal, urban, agricultural), and numerous other factors. Generally speaking, however, the atmosphere has a relatively simple effect on radiance that passes through it. For any given ray of light in any given wavelength, the strength of the light passing through the atmosphere can be simplified as:

$$E_{\text{sensor}}(\lambda) = (E_{\text{reflected}}(\lambda) * T(\lambda)) + L(\lambda)$$

where E_{sensor} is the **energy received at the sensor**, $E_{\text{reflected}}$ is the **energy reflected from the surface**, $T(\lambda)$ is **transmissivity**, and $L(\lambda)$ is **path radiance**. Note that all of these quantities vary as a function of wavelength, λ .

Transmissivity is dependent on the observation angle, atmospheric thickness, and optical depth dependent variable, which describes how much light is absorbed while traveling through the atmosphere. **Path radiance** is an additive factor that describes the scattering of the atmosphere itself. On a thick and hazy day, less light penetrates the haze, and more light is scattered off the haze itself back to the viewer. For the purposes of this lab, we will not try to calculate transmissivity – as a multiplicative factor it is less important in

ratio images, which are the essence of vegetation indices and other analytical approaches. However, we do need to account for path radiance.

For most of remote sensing reality we are compelled to make the assumption that the atmosphere over any given scene is homogenous. This, of course, is not true. However, unless a scene includes both a very smoggy city and clear pristine mountains, usually the major atmospheric constituents (e.g. water vapor, aerosols) are, to first order, consistent across broad areas. Hence, scattering is approximately equal across a scene. We will extract and subtract the atmospheric path radiance component in this lab using a simple, commonly employed method.

8. Dark Pixel Subtraction

We will use Landsat TM data, which have the following characteristics:

Landsat TM	Band pass (μm)	Spatial res (m/pixel)
Band 1	0.45 - 0.52	30
Band 2	0.52 - 0.60	30
Band 3	0.63 - 0.69	30
Band 4	0.76 - 0.90	30
Band 5	1.55 - 1.75	30
Band 6	10.4-12.5	120
Band 7	2.08 - 2.35	30

Use ENVI to open the image file **capcod.img**. Based on the equation introduced above, if we had a perfectly dark surface (no reflection) we would expect that any radiance we detect at the sensor is only due to atmospheric path radiance. Since we are also assuming that the entire atmosphere is homogenous and acts the same over both dark and light pixels, we can therefore find the difference between dark pixel radiance and expected ground radiance at these sites (0), and assume this difference represents the atmospheric radiance of the scene. We can then subtract the derived atmospheric radiance values from the entire image for a first-order atmospheric correction.

To subtract this path radiance offset we need to find the DN of the darkest reasonable pixel in the image, or the darkest sets of pixels, or find some other way to detect the offset between the darkest pixels and zero. You can use interactive stretching (in image window menu, under **Enhance** \rightarrow **Interactive Stretching**), histogram analysis (**Basic Tools** \rightarrow **Statistics**), scatterplots, or any other way to find reasonable dark pixels used to obtain path radiance. It's best to average values from more than just one or two pixels.

Overestimating path radiance would make the radiance across the scene lower than it actually is. If we assume that the darkest coherent surface on the scene has a reflectance of zero, negative values for some pixels would suggest we have removed too much path radiance in the particular band being examined. Underestimating path radiance, on the other hand, leaves some atmospheric scatter in the image, making the radiance appear higher than it actually is.

For **capcod.img**, estimate the approximate DN values for path radiance.

a) Prepare a table of the path radiance DN values for each band and then plot these values in a graph of DN vs. wavelength. What happens to path radiance as a function of wavelength?

b) Explain the method you used to find path radiance, what you used for dark pixels, and why you think your method is valid or invalid (include graphics if this helps you to answer the question).

c) Scattering varies depending on environmental locale. Relative to this Cape Cod scene, what might you expect to observe for (1) a cold, high altitude plateau in the Himalayas or (2) a smoggy day in Los Angeles?