Land Remote Sensing
Lab 4: Classification and Change Detection

Assigned: October 15, 2017
Due: October 27, 2017

In this lab, you will generate several figures. Please sensibly name these images, save them as .png or similar, collect them into a single .zip file named `xxxxxx_lab04.zip` where xxxxxx is your last name, and e-mail them to `gleggers@gatech.edu` with the subject line of "`[EAS 8803] Lab 04 Products.`"

Any files you need are at: http://wray.eas.gatech.edu/remotesensing2017/RS_lab04_files.zip.

1 Classification

Classification is a process by which the pixels of a raster image are assigned to land cover types based on the spectral radiometric response of the ground cover type within that pixel. It is a summary of remote sensing images and can be used to monitor land use, change over time, etc. Land cover assignments can be done by hand, but this is laborious for modern imagery. To automate the classification process, many algorithms have been developed, some of which will be explored in this lab.

The USGS Landsat satellite family is often used to assess land cover. For this section, use the data in file `ls5_1936_19910928.tiff`, which is 30 m/pixel multispectral imagery over Hall County, Georgia. This scene is chipped from a larger North Georgia image captured by Landsat-5 on September 28, 1991. The Landsat-5 spectral bands, along with the currently operating Landsat-7, are given in Table 1.

		Landsat-5 TM	**Landsat-7 ETM+**
Band	Color	Wavelength (μm)	Wavelength (μm)
1	Blue	0.45–0.52	0.45–0.52
2	Green	0.52–0.60	0.52–0.60
3	Red	0.63–0.69	0.63–0.69
4	NIR	0.76–0.90	0.77–0.90
5	SWIR 1	1.55–1.75	1.55–1.75
7	SWIR 2	2.08–2.35	2.09–2.35

Table 1: The 30 m/pixel bands for the Landsat-5 and Landsat-7 thematic mapping instruments. They are similar wavelengths because the Landsat family is designed to provide continuous and comparable coverage.

To begin, take time to study the 1991 image. It may be useful to generate RGB composite images with the individual bands, such as previously discussed true color or IR enhanced color images, or to compare the scene with a geographic reference such as an atlas or Google Earth.

1. Name any identifying or landmark features in this scene (e.g. cities, water bodies, etc.)?

2. Based on your initial survey, what land cover types do you observe? How do they appear in this scene?

1.1 Unsupervised Classification

Unsupervised classification is a system of methods that operate with no a priori knowledge about what classes are present in a scene. Instead, the user specifies broad operational parameters, such as number of classes, number of iterations, etc., that serve as guidelines for the algorithm to uncover statistical patterns in pixel spectra. ENVI offers two unsupervised methods—K-means and isodata. We will focus on the former.

3. In your own words, describe the K-means classification algorithm.

To implement the K-means classification algorithm:

(i) From the ENVI Classic main menu toolbar, select *Classification → Unsupervised → K-Means*.

(ii) In the image selection dialog, select the 1991 Landsat-5 image.

(iii) In the K-Means Parameters dialog, accept the default values (5 classes, 5% change threshold, and 1 iteration), select *Output Result to File*, and press *OK*.

The result should be an image with every pixel assigned a color and class name (Class 1, Class 2, etc.). The important next step is to verify the classification—to check how well the automated classification represents observed land covers. Important questions to ask include: does each class only contain a single land cover or multiple? are any single land covers split among multiple classes? if there is evidence of misclassification, are land covers at least misclassified consistently?

A basic strategy for verification is:

(i) Right-click and select *Link Displays* to link the original and classified images.

(ii) Right-click and select *Cursor Location/Value*. Now, hovering over a pixel gives its class.

(iii) It may be useful to view statistics for each class. On the main ENVI toolbar, select *Post Classification → Class Statistics*. In the dialog, select your classified image as the *Classification Input File*, press *OK*, select the 1991 Landsat-5 image as the *Statistics Input File*, and press *OK*. In the new dialog, choose *Select All Items* and press *OK*, followed by another *OK*.

(iv) Pan across the linked images and see how land covers and classes correspond.

(v) As each class is verified, it may be convenient to change the class name (e.g., "Class X" to "Water") or color (e.g., change a "Water" class to blue). From the classified image Display Window, select *Tools → Color Mapping → Class Color Mapping*. In the new dialog, each class can be modified. To save the changes, select *Options → Save Changes*.

(vi) For a final figure, a classification legend is useful. From the Display Window, select *Overlay → Annotation*. In the dialog, select *Object → Map Key*. Modify the options as desired, and then left-click in the image window to preliminarily place the legend and then right-click to finalize the selection. The annotation can be saved in the dialog by selecting *File → Save Annotation*.

4. Do the assigned classes match observed land covers? Is there evidence of misclassification, such as disparate covers grouped together? If so, give examples. E-mail your classified image with a legend.

Remember that the K-means method is an iterative algorithm and that the default parameters above only included one iteration. Furthermore, it is possible that the default of five classes was not appropriate. Run a new K-means classification and experiment with the parameter settings. Compare the old and new classifications. Questions to consider are: what correlation between old and new classes is observed? were any old classes split into new ones? were elements of old classes split off and combined into new classes?

5. What custom parameters were used, and how does your new classification differ from the old? Does it better represent the observed land covers? E-mail your classified image with a new legend.

1.2 Supervised Classification

Unsupervised classification may be quick, easy to run, and objective, but it requires identification and labeling afterwards. Furthermore, the calculated spectral classes do not always correspond to "real" informational classes. Supervised classification seeks to overcome this by providing a priori knowledge about what classes are present in a scene and what those classes look like spectrally. This is done by providing a given classification algorithm a "training set" in the form of groups of hand-selected pixels that represent desired classes. The algorithm compares the spectrum of each pixel in the image to the training set and select the training set member and class that best matches. ENVI offers several supervised classification methods, but this lab will focus on the Spectral Angle Mapper (SAM) method.

6. In your own words, describe the SAM classification algorithm. What specific advantages does it offer?

In ENVI, training sets can be defined as a set of Regions of Interest (ROIs) drawn on the image. A supervised classification is only as good as the training set it utilizes, so take a moment to decide the principle land cover types to be classified. Examples could include water, urban, bare ground, grass, or forest (or even deciduous vs. pine!). Consider, however, that the spectra of these land covers are not always consistent. A building and a road might both be considered "urban" land cover, but they do not always look spectrally similar. The same might be true for shallow and deep water, forests of different tree types, etc.

For this reason, it is best to err on the side of drawing many ROIs, each featuring various "subclasses" of the identified principle land covers. After classification, these subclasses can be combined into major classes to make a classification image of just the principle land covers.

A basic strategy for defining a training set of ROIs is:

(i) Determine the principle land covers on which the supervised classification scheme will focus. Study the scene for spectral variation in those principle land covers. These varied areas will make up the subclasses defined by ROIs.

(ii) To open the ROI menu, image toolbar select *Tools → Region of Interest → ROI Tool.*

(iii) Choose the *Window* on which to draw ROIs (Image, Zoom, etc.). Under *ROI_ Type* are options for the ROI shape (*Polygon*, *Rectangle*, etc.).

(iv) Draw the ROI with left-clicks (or left-click and dragging, as may be appropriate) and finish it with right-click(s).

(v) The ROI name and color is customizable by double-clicking the default *ROI Name* or right-clicking the default *Color*. For future convenience, this is recommended.

(vi) Select *New Region* and repeat (iii) to (iv) for more ROIs. It is recommended to have at least 2–3 (sub)classes (as appropriate) defined for each principle land cover.

(vii) When finished, save the ROIs. In the ROI Tool dialog, select *File → Save ROIs.* Select the ROIs to save, give a file name, and then save.

7. What principle land covers did you choose, and what variation is observed in each? How many (sub)classes did you define for each? E-mail your ROIs overlain on the 1991 scene.

To implement the Spectral Angle Mapper classification algorithm:

(i) From the ENVI Classic main menu toolbar, select *Classification → Supervised → Spectral Angle Mapper.*

(ii) In the Classification Input File dialog, select the 1991 Landsat-5 image.

(iii) In the Endmember Collection: SAM dialog, select *Import → from ROI/EVF from input file.*

(iv) In the Select Regions for Stats Calculation dialog, ROIs may be present already if previously worked with in this session. If not, select *Open ROI/EVF file* and choose the appropriate ROI file.

(v) Highlight the appropriate ROIs and then press *OK.*

(vi) Back in the Endmember Collection: SAM dialog, select the same ROIs and then press *Apply.*

(vii) In the Spectral Angle Mapper Parameters dialog, set the *Set Maximum Angle* to *None.* Output the classification to *File.* For *Output Rule Images?*, select *Yes* and output it to *File.* Press *OK.*

(viii) Once the algorithm has run, close the Endmember Collection: SAM dialog.

The result is a classified image informed by the ROI training set provided. Search through the image, and apply the previously discussed verification process. It may be helpful to use the produced Rule image, which shows the pixel values used in creating the classified image. The Rule image has a labeled band for every ROI in the training set, and can be used to generate a gray scale image. For the SAM algorithm, each pixel value in a given Rule image band is the spectral angle in radians between the source image pixel spectrum and the band ROI average spectrum.

Looking forward, once the classification has been verified, it should be recoded by grouping the various (sub)classes into the major classes representing principle land covers. A basic strategy for recoding is:

(i) For each group of (sub)classes, choose one to represent the major class.

(ii) From the ENVI Classic main menu toolbar, select *Classification → Post Classification → Combine Classes.*

(iii) In the Combine Classes Input File dialog, choose the SAM-classified 1991 image.

(iv) In the Combine Classes Parameters dialog, for an *Input Class*, select a (sub)class not designated as the major class, and for an *Output Class*, select the corresponding (sub)class designated as the major class. Press *Add Combination.*

(v) Under *Combined Classes*, a relation showing "(Sub)class → Major class" should appear. Repeat (iii) until all (sub)classes have been grouped with the corresponding major class. Press *Okay*.

(vi) In the Combine Classes Output dialog, choose *Yes* for *Remote Empty Classes?*, output the result to *File*, and press *OK*.

(vii) Compare the recoded image to the original SAM classified image and check that no mistakes were made in combining classes.

(viii) On the Image menu, select *Tools* → *Color Mapping* → *Class Color Mapping*. In the Class Color Mapping dialog, the classes can be renamed to something simpler and have their color modified.

8. Are the training set land covers well-represented? Is there still evidence of misclassification? If so, where are the main error sources? Email your original and recoded classified images with legends.

9. Compare your experiences with the unsupervised K-means and the supervised SAM methods. What are the strengths and weaknesses of both? In your opinion, which did a better job of classification?

2 Change Detection

A principal use of land cover classification is change detection, or the monitoring of how land cover and use changes over time. In this section, you will explore how the environs of Hall County, Georgia have changed from 1991 to 2001. For 1991, use the scene you have already classified via SAM. For 2001, use the data in the file `ls7_1936_20010307.tiff`, which was imaged by Landsat-7 on March 3, 2001 at a resolution of 30 m/pixel. Importantly, two images need to be georectified and resampled to one another's projection and resolution when conducting a change detection analysis. This has been done for you.

10. Link the 1991 and 2001 scenes and evaluate the changes over the intervening decade. What differences do you observe? <u>In addition to your own observations</u>, comment on these areas:

(a) $34^\circ\ 5'\ 16''$ N, $83^\circ\ 3'\ 43''$ W

(b) $34^\circ\ 24'\ 44''$ N, $83^\circ\ 58'\ 25''$ W

(c) $34^\circ\ 16'\ 45''$ N, $83^\circ\ 34'\ 13''$ W

For change detection, both the initial and final state images must be classified. Repeat the steps you took to classify and recode the 1991 scene but for the 2001 Landsat-7 image. Since it is best if training sets are derived from the image being classified, this requires defining a new set of training ROIs for the 2001 scene. This is not to say, however, that the ROIs of the new training set cannot be derived from the same geographic areas as the old. Finally, since change detection works by one-to-one correlation of classes, your classification of the 2001 scene should eventually be recoded to the same major classes of the 1991 scene.

11. How is the 2001 classification similar to or different from the 1991 classification? Are the observations made in Question 10 borne out in the classification? E-mail an image of your ROIs overlain on the original 2001 scene and your recoded 2001 classification image with a legend.

With both classified scenes in hand, a strategy for change detection is:

(i) From the ENVI Classic main menu toolbar, select *Basic Tools* → *Change Detection* → *Change Detection Statistics*.

(ii) In the Select 'Initial State' Image dialog, choose the recoded 1991 image.

(iii) In the Select 'Final State' Image dialog, choose the recoded 2001 image.

(iv) In the Define Equivalent Classes dialog, associate every *Initial State Class* with its corresponding *Final State Class* by selecting them and pressing *Add Pair*. If your 1991 and 2001 classes were similarly named and ordered, they may already be paired. In this case, verify that they are paired correctly, and, if not, remove the pairs and associate them correctly. When finished, press *OK*.

(v) In the Change Detection Statistics Output, choose *Yes* for *Output Classification Mask Images?* and output the result to *File*. Choose *No* for *Save Auto-Coregistered Input Images?*. Press *OK*.

(vi) In the Change Detection Statistics main menu, select *Options* → *Convert Area Units*. In the new window, choose *Square Km* for the *New Units* and press *OK*.

(vii) In the Change Detection Statistics main menu, select *File* → *Save to Text File*. In the new dialog, give the output a name and press *OK*.

The change detection statistics table gives a summary view of how the classifications changed from 1991 to 2001. Specifically, it tells you how many pixels of a 1991 class became a different class in 2001 (or, as it may be, remained the same). These pixel counts are also converted to percentages or area (the tabs above the table). The produced Classification Mask images illustrate where these changes took place geographically. The mask image has bands for each class used in the change detection. When a given class band is loaded, any black pixels experienced no change for that given class: either the pixel was classified as the class in both 1991 and 2001, or it was not classified as the class in either 1991 or 2001. Colored pixels are those that were classified as that given class in 1991 but whose classification changed in 2001. The color of the pixel corresponds to the new 2001 class.

Using these two tools, evaluate the decadal change in Hall County from 1991 to 2001. Compare these changes to those inferred by your earlier visual inspection.

12. Based on the change detection, what appear to be the major trends in Hall County from 1991 to 2001? E-mail your change detection table.

13. Do these trends match your visual observations from Question 10?

14. The two Landsat images used were captured on different calendar dates. Which of your observed changes are secular and which are seasonal? What are the advantages and disadvantages to varying the season of the initial and final state images when doing change detection?

15. What are the main error sources in the change detection? How do these relate to the classification of the 1991 and 2001 scenes? Knowing these errors, how could the classification be improved?