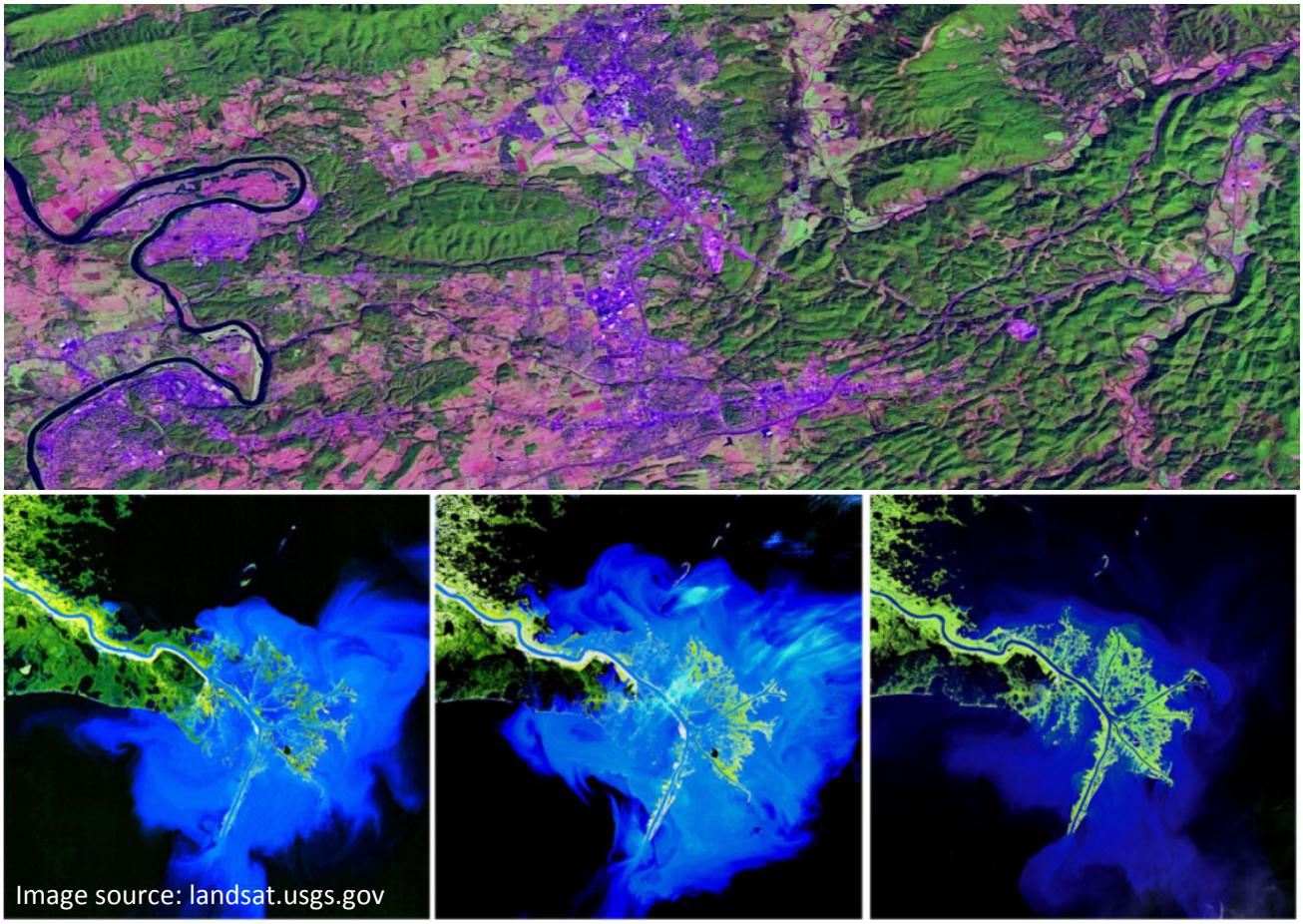
Remote Sensing in an ArcMap Environment



Tammy Parece
James Campbell
John McGee

NSF DUE 0903270; 1205110

This workbook is available online as text (.pdf's) and short video tutorials via:
http://www.virginiaview.net/education.html

The project described in this publication was supported by Grant Number G14AP00002 from the Department of the Interior, United States Geological Survey to AmericaView. Its contents are solely the responsibility of the authors; the views and conclusions contained in this document are those of the authors and should not be interpreted as representing the opinions or policies of the U.S. Government. Mention of trade names or commercial products does not constitute their endorsement by the U.S. Government.

Remote Sensing Analysis in an ArcMap Environment

Credits

This exercise was developed by:	In partnership with:
VirginiaTech College of Natural Resources and Environment VIRGINIA VIEW VirginiaView.net AMERICA VIEW	VirginiaGeospatial Extension Program gep.frec.vt.edu GeoTEd geoted.org Virginia Cooperative Extension Virginia Tech • Virginia State University NSF

Originated by:	Tutorials by:	Video design and recording by:	Funded by:
James Campbell & John McGee	Tammy Parece	Laura Johnson & Eric Guenther	VirginiaView and the AmericaView Consortium

This educational resource (and a broader collection of educational resources) is available for download (.pdf) from the VirginiaView Website. An accompanying video tutorial of this document is also available through the VirginiaView website: http://www.virginiaview.net/education

For additional information, please contact:
John McGee
jmcg@vt.edu

The instructional materials contained within these documents are copyrighted property of VirginiaView, its partners and other participating AmericaView consortium members. These materials may be reproduced and used by educators for instructional purposes. No permission is granted to use the materials for paid consulting or instruction where a fee is collected. Reproduction or translation of any part of this document beyond that permitted in Section 107 or 108 of the 1976 United States Copyright Act without the permission of the copyright owner(s) is unlawful.

The authors acknowledge the support of their academic departments—Virginia Tech Departments of Geography, and Forest Resources and Environmental Conservation.

Remote Sensing Analysis in an ArcMap Environment

1. Opening an Existing Map Document/Creating a New Map Document
How to open an existing document or create a new document in ArcGIS 10.X.
Pages 1 - 4

BASICS

2. **Adding Data to a Map Document**
Alternative data structures and how to add data to your project.
Pages 5 - 10

3. **Connecting to a Drive in ArcMap and ArcCatalog/Connecting to a GIS Server**
How to connect to different internal drives and external servers.
Pages 11 - 18

ADDING DATA

4**. Saving and Exporting Map Documents**
Steps to save a document in forms can be used effectively by other analysts.
Pages 19 - 22

5. **Repairing a Data Address**
Finding your data when it does not display in an existing map document.
Pages 23 - 28

6. **Displaying Data**
Different forms of geospatial data and ways to display them in ArcMap.
Pages 29 - 40

SAVING & DISPLAYING DATA

7. **Downloading Landsat Imagery using GloVis**
Steps to use the GloVis on-line system as a source for Landsat data.
Pages 41 - 60

8. **Downloading Landsat Imagery using Earth Explorer**
Steps to use EarthExplorer on-line system as a source for Landsat imagery.
Pages 61 - 78

9**. Information about your downloaded Landsat Data**
Interpreting metadata that accompanies a Landsat scene.
Pages 79 - 86

10a. **Displaying your Landsat Imagery**
Steps to display the different bands of your Landsat scene and introduction to the Image Analysis window.
Pages 87 – 98

10b. **Streaming and Displaying Landsat imagery**
Acquire, stream and display Landsat data using Esri's ArcGIS Landsat Archive.
Pages 99 - 118

INTRODUCING LANDSAT IMAGERY

DISPLAYING LANDSAT IMAGERY

11. **Creating a Composite Image from Landsat Imagery**
    Steps to combine different Landsat bands into one image.
    Pages 119 - 126

12. **Band Combinations using Landsat Imagery**
    Steps to display multi-band satellite images in an RGB environment and introduction to interpreting different band combinations.
    Pages 127 - 142

13. **Sub-setting Landsat Imagery**
    Steps to create composites and snapshots from multi-band satellite imagery.
    Pages 143 - 152

ENHANCING LANDSAT IMAGERY

14. **Radiometric Enhancement of Landsat Imagery**
    Transforming the values of individual pixels.
    Pages 153 - 164

15. **Spatial Enhancement of Landsat Imagery**
    Transforming the values of each pixel on a multiband basis.
    Pages 165 - 178

16. **Spectral Enhancement of Landsat Imagery**
    Transforming pixel values using neighboring pixels.
    Pages 179 - 194

ANALYZING LANDSAT IMAGERY

17. **Change Detection Using Landsat Imagery**
    Assessing changes on the earth's surface over time.
    Pages 195 - 204

18. **Classification of a Landsat Image (unsupervised)**
    Creating informational classes from satellite imagery.
    Pages 205 - 224

19. **Classification of a Landsat Image (supervised)**
    Creating informational classes from satellite imagery.
    Pages 225 - 242

20. **Accuracy Assessment**
    Evaluating the effectiveness of your image classification analysis.
    Pages 243 - 255

Introduction to this Manual

This manual, and associated videos, introduce users of ArcGIS to image analysis capabilities, now available in ESRI's ArcGIS 10.X versions. The user does not need prior knowledge of ArcGIS as we provide a review ArcMap and ArcCatalog basics, although prior knowledge of ArcGIS is helpful. This manual is an introduction; it is not a comprehensive user's manual for image analysis or for use of ArcGIS. It expands student access to remote sensing analysis by introducing students to use of ArcGIS' image analysis capabilities, thereby facilitating access to software with the ability to extract information from remotely sensed imagery. This manual does not cover remote sensing fundamentals and users of the manual should refer to remote sensing textbooks, such as suggested in the list of potential references below. Further, users of this manual should remain aware of the distinctions between GIS analysis and the practice of remote sensing, which often use similar software, but require mastery of much different knowledge bases.

These tutorials are designed to be completed in sequence as each tutorial builds on knowledge acquired from preceding tutorials. The first six tutorials introduce the user to ArcGIS**,** and later tutorials assume that readers have knowledge of these basics. These six introductory tutorials do not include information on how to download and unzip basic GIS files but users may use any point, line or polygon vector files and any elevation raster file to complete these tutorials.

We downloaded files from the U.S. Census Bureau's Tigerline data base
- http://www.census.gov/geo/maps-data/data/tiger-line.html for the mid-Atlantic States. You can also access the 2000 Tigerline files from ESRI's website
- http://arcdata.esri.com/data/tiger2000/tiger_download.cfm.

Point, line and polygons files can be downloaded from many U.S. municipalities, such as Roanoke, Virginia (ftp://ftp.roanokeva.gov/GIS/Shapefiles/), Richmond, Virginia (ftp://ftp.ci.richmond.va.us/GIS), or Chicago, Illinois (https://data.cityofchicago.org/browse?tags=gis). You can locate and access many other municipalities' GIS files from the web by using the search terms:

- downloadable GIS files for *name of municipality*, or
- *name of municipality* FTP site.

Most GIS files are downloaded as .zip files. The raster files used in the first six tutorials were downloaded from the U.S.G.S. Seamless Server at http://viewer.nationalmap.gov/viewer/.

If you have a working knowledge of ArcGIS, you can start with Tutorial 7. However, if your knowledge of ArcGIS does not include at least version 10.0, you will need to review these first six tutorials.

If you are familiar with Landsat scenes, GloVis and EarthExplorer, you can skip tutorials 7 – 9. Even if you are familiar with Landsat scenes and downloading the scenes from the web, you will need to complete Tutorial 11 – Displaying Landsat Imagery — so, you will have an understanding of using Landsat Imagery in ArcMap.

Tutorials 7 – 16, and 18 – 20 use a single Landsat scene which covers part of central and western Virginia. Tutorial 17 - Change Detection --uses Landsat scenes from Pakistan, so can be completed independently if you already know how to use GloVis or EarthExplorer.

Tutorials 11 - 13 must be completed before doing Tutorials 18 – 20. Additionally, we highly recommend that you complete Tutorials 14 – 16 before doing Tutorials 17 – 20, as we discuss the different tools used in the ArcMap image analysis window and these tools will be extremely valuable when performing change detection and image classification. You must complete Tutorials 18 and/or 19 before Tutorial 20 Accuracy Assessment.

While our main purpose is to focus upon use of Landsat imagery in ArcGIS, these tutorials do introduce techniques that prepare you to complete similar analyses using images from other sources, including IKONOS, Geoeye, AVHRR, PALSAR, Quickbird, and SPOT, (For a complete listing, see ArcGIS 10.x help). Landsat imagery is used here because it is free, and readily available for most of the earth's land surface area.

These tutorials, and associated videos, merely serve as an introduction to using ArcGIS 10.X in remote sensing analyses. These tutorials do not cover all the tools and methods available within ArcGIS. ArcGIS on-line help provides additional information on other tools and functions available. These tutorials should not substitute for remote sensing textbooks, which present the concepts and context that support application of the techniques covered here. Here we introduce some of the basic remote sensing concepts to assist students in their understanding of tools within ArcMap and their effects on the Landsat scene. We encourage students to use these tutorials in the context of a more complete program to cover the information and concepts that support the applications presented here.

Additional On-line Resources:

http://landsat.usgs.gov/

http://resources.arcgis.com/en/help/main/10.1/index.html#/

Additional Printed Resources for ArcGIS:

Getting to Know ArcGIS Desktop, Third Edition, for ArcGIS 10.1, ESRI Press.

GIS Tutorial 1: Basic Workbook, 4th Edition 10.1, ESRI Press.

GIS Tutorial 2: Spatial Analysis Workbook. 2nd Edition for ArcGIS 10, ESRI Press.

GIS Tutorial 3: Advanced Workbook for ArcGIS 10, ESRI Press.

Additional Printed Resources for Remote Sensing:

Campbell, James B. and Randolph H. Wynne. 2011. *Introduction to Remote Sensing* - 5th Edition. The Guilford Press. New York, NY. 677 p.

Jensen, John R. 2004. Introductory *Digital Image Processing: A Remote Sensing Perspective – 3rd Edition*. Pearson. Upper Saddle River, NJ. 379 p.

Keranen, Kathryn and Robert Kolvoord. 2013. *Making Spatial Decisions Using Remote Sensing.* In Press

Shellito, Bradley. 2011. *Introduction to Geospatial Technologies.* W. H. Freeman. New York. 452 p.

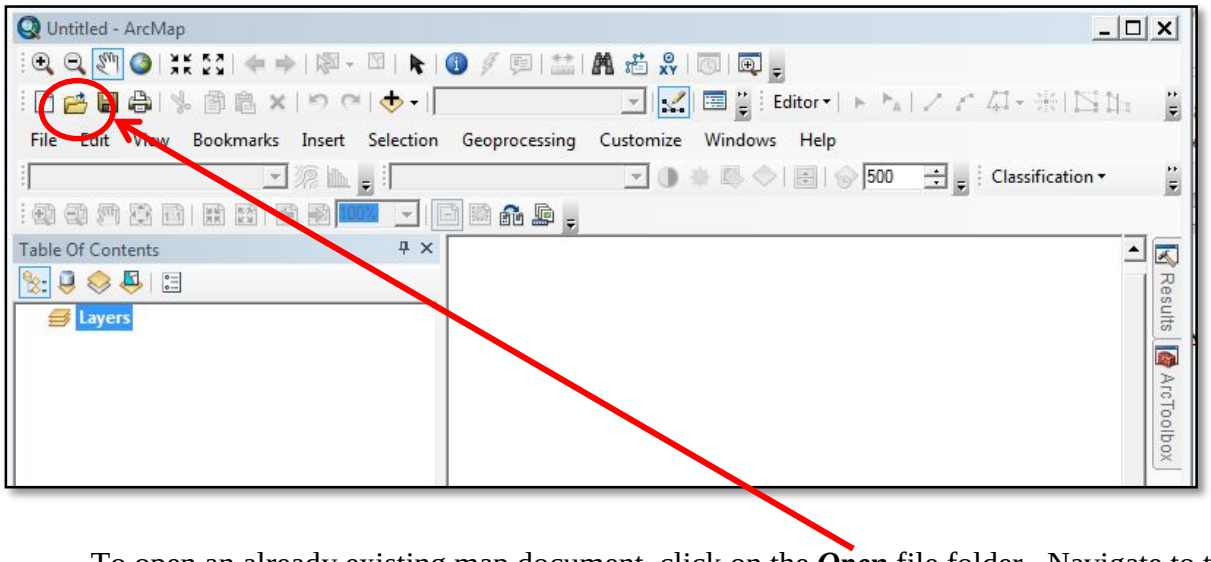
1. Opening an Existing Map Document/Creating a New Map Document

The instructional materials contained within these documents are copyrighted property of VirginiaView, its partners and other participating AmericaView consortium members. These materials may be reproduced and used by educators for instructional purposes. No permission is granted to use the materials for paid consulting or instruction where a fee is collected. Reproduction or translation of any part of this document beyond that permitted in Section 107 or 108 of the 1976 United States Copyright Act without the permission of the copyright owner(s) is unlawful.

This is the first of a set of tutorials related to image analysis using ESRI's ArcMap 10.X. You do not need to know ArcMap prior to starting these tutorials. Tutorial 1 – 6 are ArcMap basics.

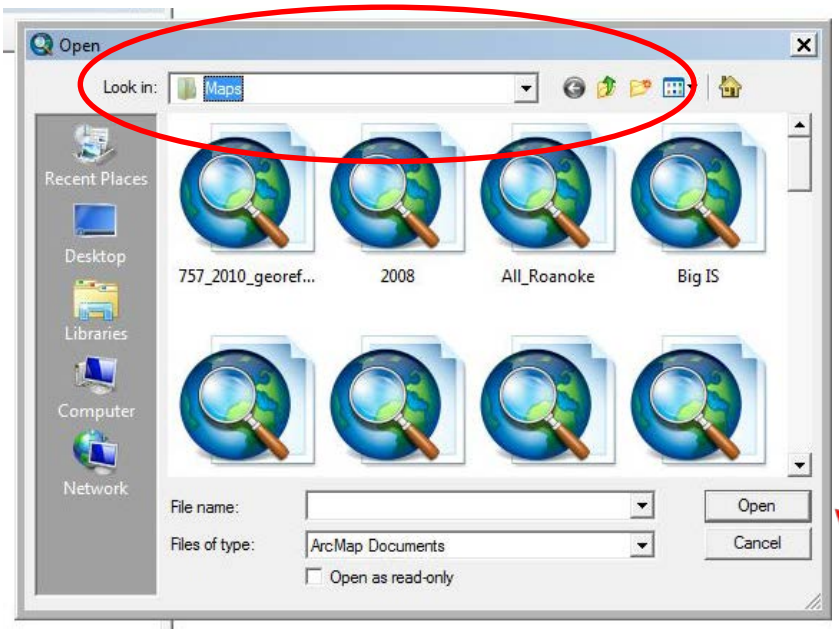
Opening a Map Document

When you open ArcMap, you get this window.



To open an already existing map document, click on the ***Open*** file folder. Navigate to the area on your hard drive where you have saved the map document & highlight the map you want.

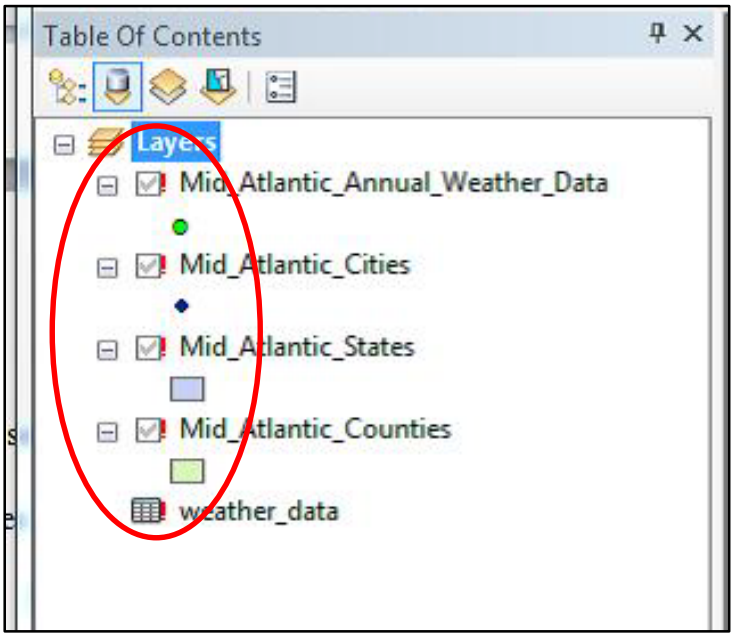
1. Opening an Existing Map Document/Creating a New Map Document



Click ***Open***

If the existing map document is blank after you open it, look at your ***Table of Contents***.

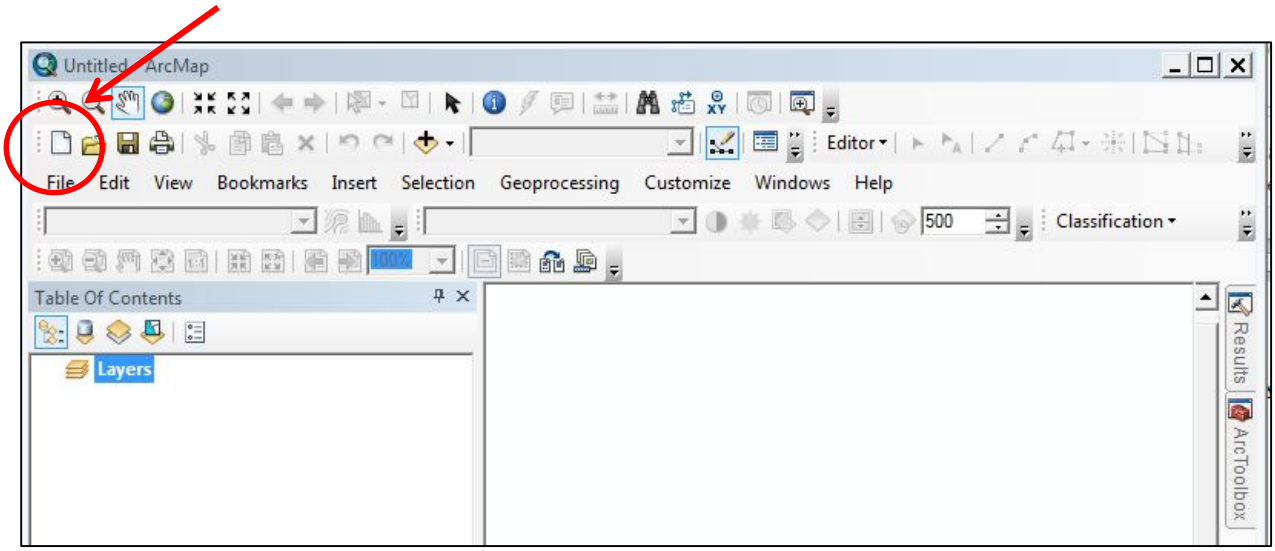
Are there red exclamation points next to the data layer names?



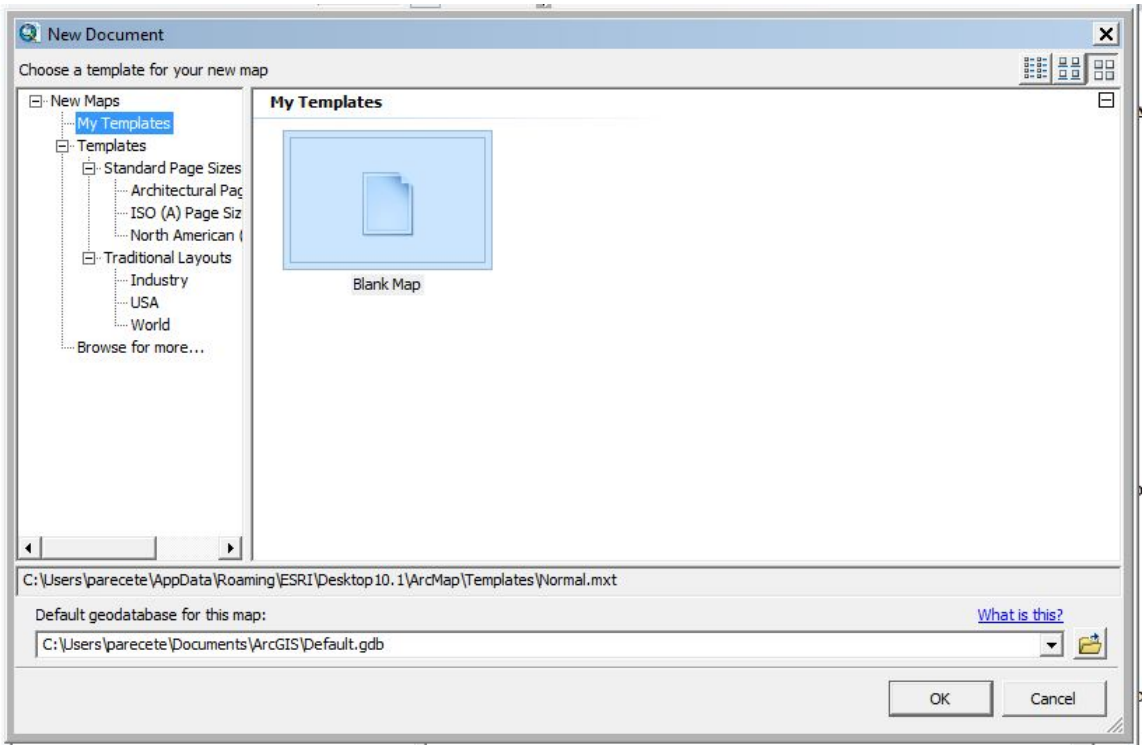
If so, you need to repair the data address – see the tutorial on repairing data address.

Creating a New Map Document

Click on ***New*** file.



You get the following window. Highlight ***Blank Map***.



Click ***OK*** and you will have a blank map document.

You are ready to proceed to the next tutorial.

1. Opening an Existing Map Document/Creating a New Map Document

Notes:

2. Adding Data to a Map Document

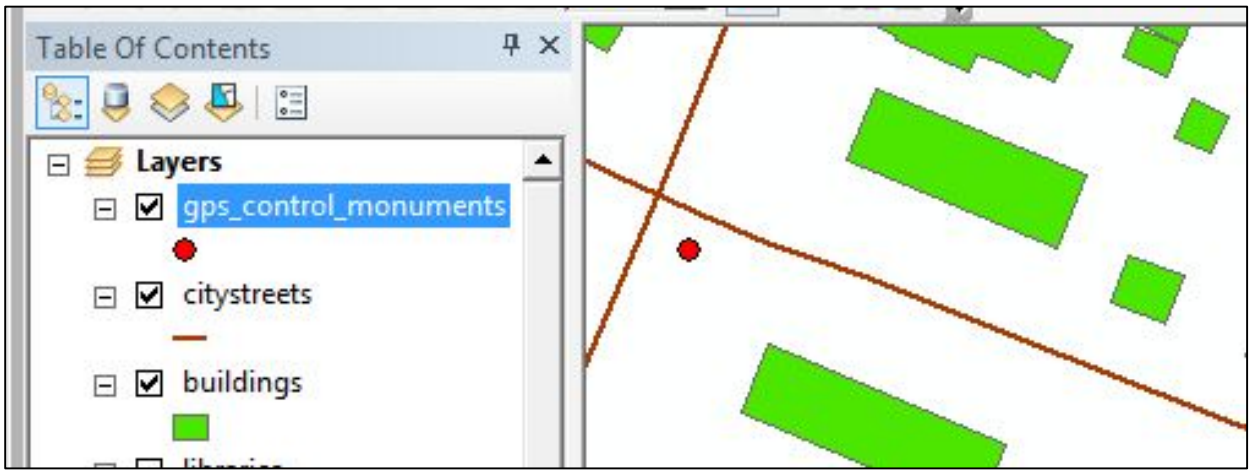
The instructional materials contained within these documents are copyrighted property of VirginiaView, its partners and other participating AmericaView consortium members. These materials may be reproduced and used by educators for instructional purposes. No permission is granted to use the materials for paid consulting or instruction where a fee is collected. Reproduction or translation of any part of this document beyond that permitted in Section 107 or 108 of the 1976 United States Copyright Act without the permission of the copyright owner(s) is unlawful.

This Tutorial covers how to add data to a map document and briefly discusses the differences between vector and raster data files.

Introduction: Types of Data Files

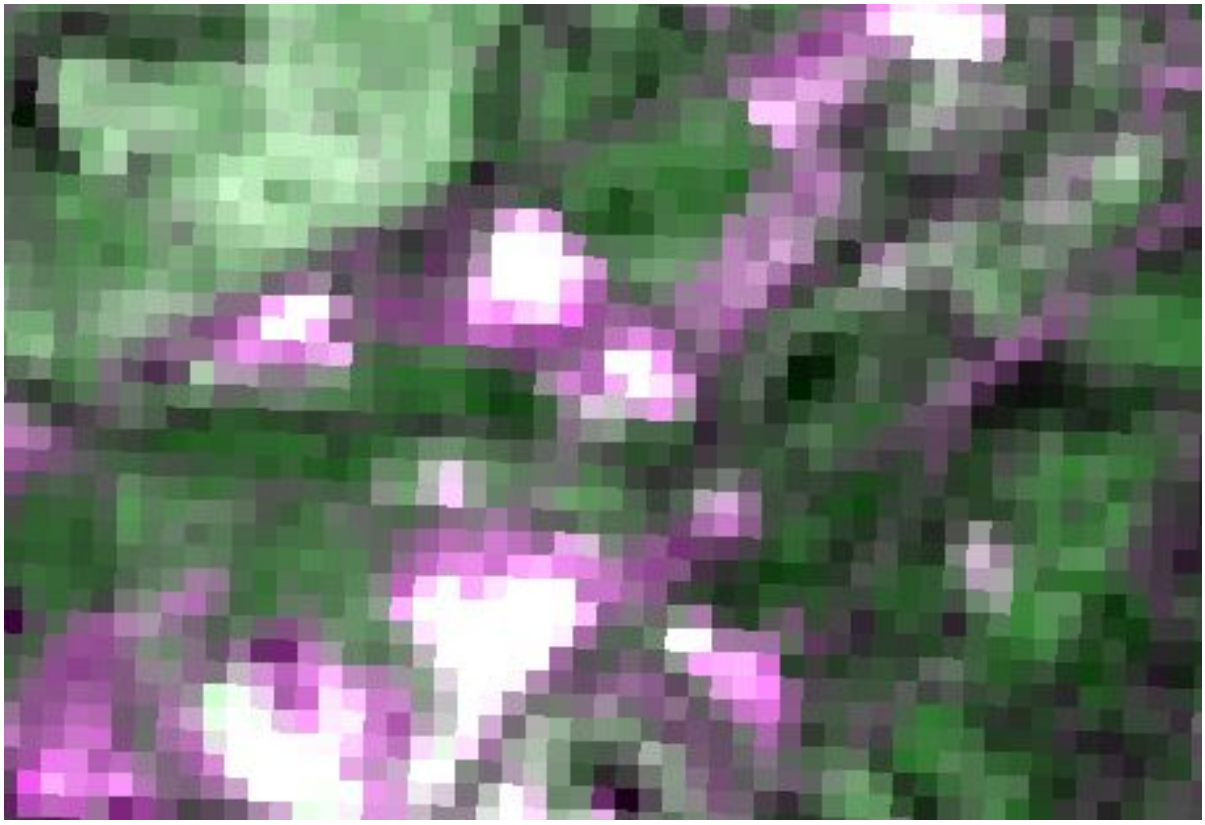
You can add different types of data to a map document in GIS. The two basic types are vector and raster files. GIS provides different tools in its toolbox which can be used to perform many different analyses using vector and raster files. You can also add JPEG, BMP, spreadsheets, word processing documents, PDFs and other file types to the map layout view -- but only for display – you cannot use perform GIS analyses with these file types.

Vector files represent discrete data and are displayed as points, lines or polygons. Points represent a specific latitude and longitude. Points do not have any length nor do they have area. When displayed in ArcMap, they can be displayed at any size but in actuality, they are just a point. Lines have length but no width, and represent things such as transects or roads. (Note – when a road is represented as a line, it has no area so it does not accurately represent the area on the ground covered by the actual road.) Polygons are anything with area – buildings, municipal boundaries, or water bodies.



Points, lines and polygon files listed in the ***Table of Contents*** and displayed in a map document

Raster files represent data as it appears across the surface of the earth. Raster data can be elevation data found in digital elevation models or weather data such as temperature gradients. Raster data can also be aerial photos or satellite images. Raster data is displayed in ArcMap as grids. Each grid file is made up of many columns and rows of pixels. Pixels are normally square and their size is dependent upon the source of the data. For instance, each pixel of Landsat imagery (with the exception of the thermal channel) is 30 meters by 30 meters. For the aerial photography of the Virginia Base Mapping Program, the pixel size ranges from ½ foot by ½ foot to 1 foot by 1 foot (depending on the municipality).

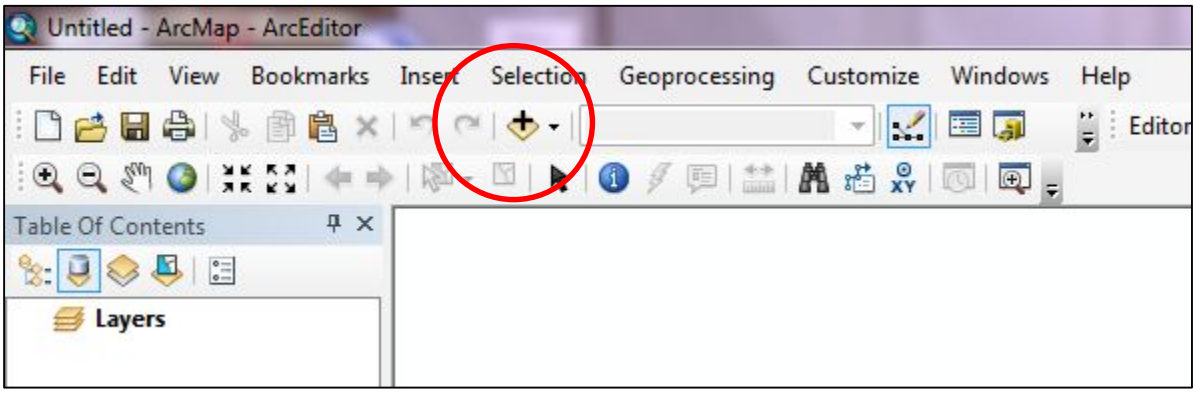


Portion of a Landsat image - you can see individual pixels. Each pixel represents an area 30 meters by 30 meters on the surface of the earth

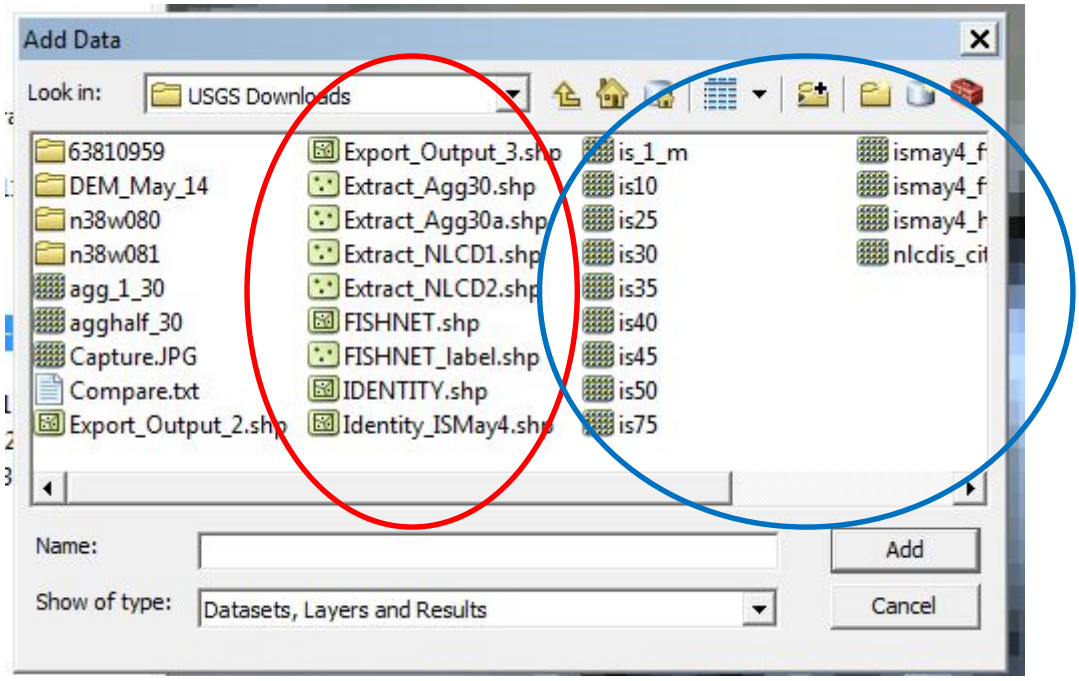
Aerial Photo from Virginia Base Mapping Program. Each pixel represents an area 1 foot by 1 foot on the surface of the earth.

Adding Data to a Map Document

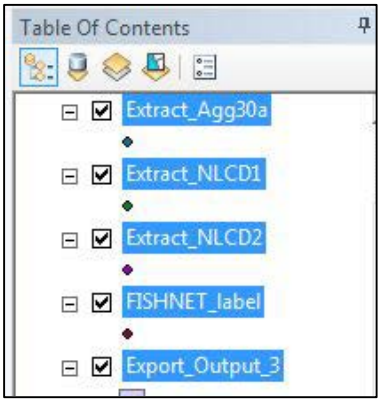
On the tool bar, click on the plus sign (***add data***) and navigate to the drive and the folder containing your data files. (If you don't see the drive on the drop down arrow list, then you will need to connect to that drive. See the tutorial on connecting to a drive in ArcMap.



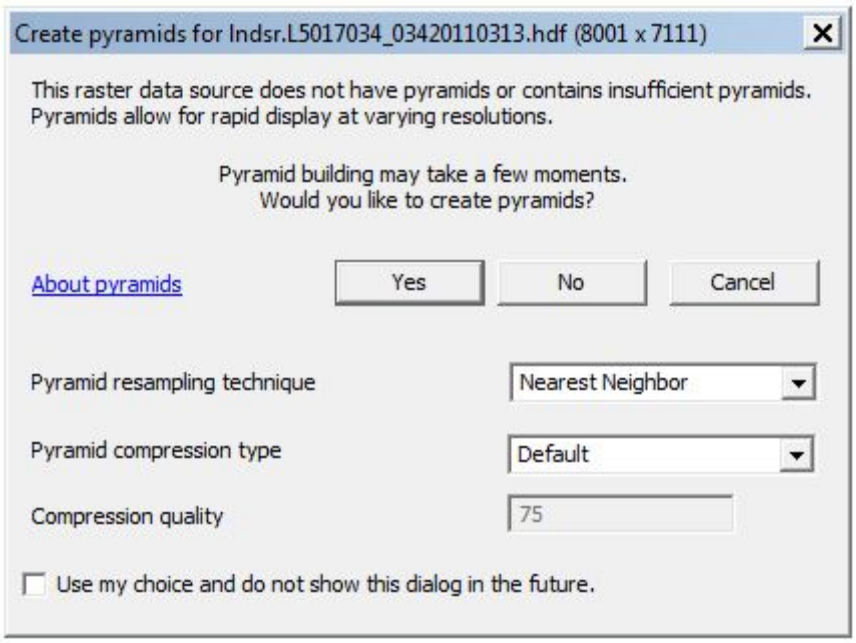
Click on the files that you wish to add to the map. If you want to add more than one file, you can hold down the control button and click on as many files as you want. You can add both vector and raster files at the same time. Vector files have icons next to the name which show if the file is a point, line or polygon file (red oval). Raster files show a grid next to their name (blue circle). Once you have chosen your files, click the ***Add*** button.



If you add multiple files at the same time, they will all appear highlighted in the ***Table of Contents***. To clear the highlights, just click (right or left) anywhere in the ***Table of Contents***.



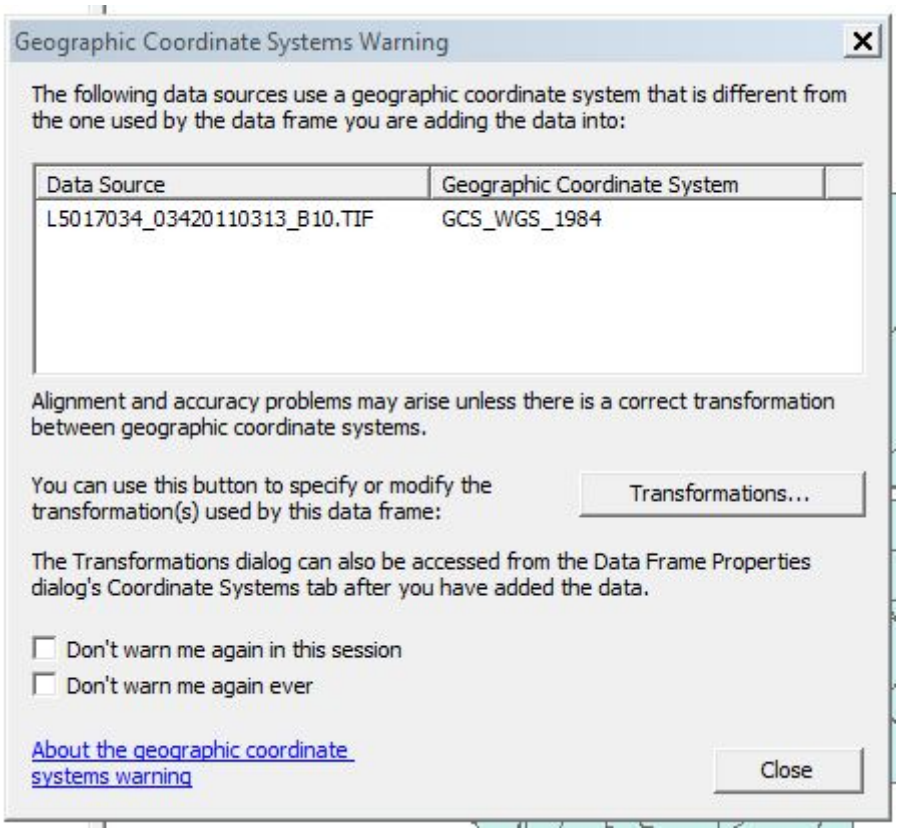
When adding a raster file for the first time, you may receive the following message:



Creating pyramids allows for faster loading of the raster dataset next time you add it to a map document. The default resampling technique is nearest neighbor, but optional resamplings are bilinear and cubic convolution *(see ArcGIS Help for additional information on resampling*).

You can add data from different file folders on your computer. You add them separately, navigating to the individual file folder housing the data file to add each one.

When adding data separately, the Data Frame's geographic coordinate system is set to the same geographic coordinate system as the first data set added. Any additional data sets added with a different geographic coordinate system, ArcMap will display a warning message:



You can do analyses with data files using different geographic coordinate systems, but your results may vary from analyses with data sets using the same geographic coordinate systems. If you change the geographic coordinate system on a dataset, this may also affect the results from your analyses. You must make an informed decision as to whether or not to close and work with the different geographic coordinate systems or change the datasets to the same geographic coordinate system.

We will discuss how ArcMap displays data in the tutorial on displaying data.

You are ready to proceed to the next tutorial.

3. Connecting to a Drive in ArcMap and ArcCatalog
Connecting to a GIS Server

The instructional materials contained within these documents are copyrighted property of VirginiaView, its partners and other participating AmericaView consortium members. These materials may be reproduced and used by educators for instructional purposes. No permission is granted to use the materials for paid consulting or instruction where a fee is collected. Reproduction or translation of any part of this document beyond that permitted in Section 107 or 108 of the 1976 United States Copyright Act without the permission of the copyright owner(s) is unlawful.

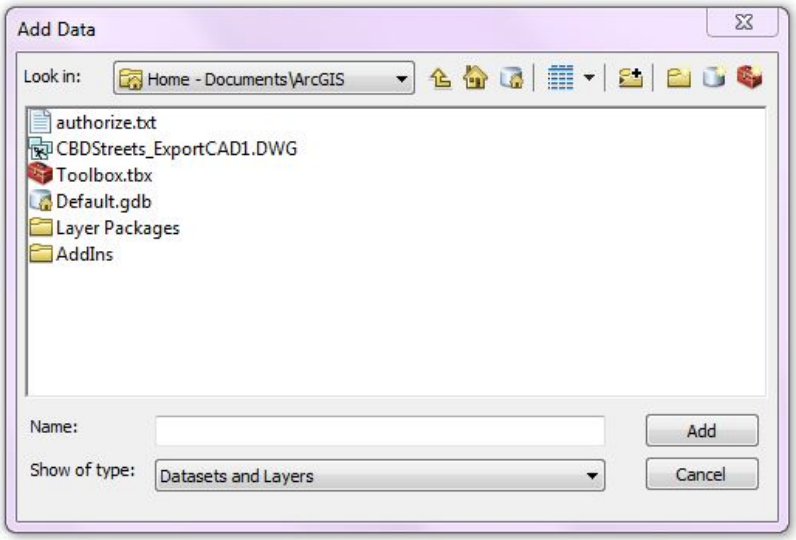
Introduction:

This tutorial covers two different topics. With the issuance of ArcGIS 10.0, you are not automatically connected to all drives on or connected to your computer. ESRI recognized that many different drive names exist and the names varied within businesses or even on personal computers. As such, you need to take steps to connect to your various drives. The first part of this tutorial explains how to connect to any drive to which your computer is connected with a hardware connection using both ArcMap and ArcCatalog.

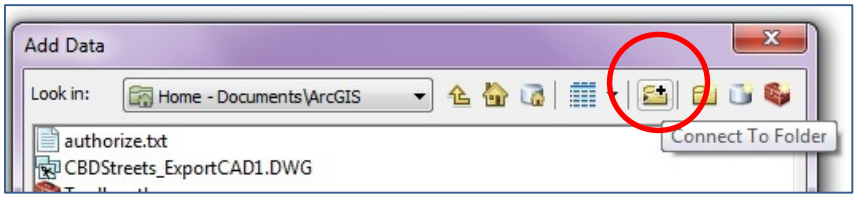
Large amounts of data have become freely available to use in GIS programs. However, some of this data is still proprietary or are extremely large files and not readily/easily downloaded. To make the data available for display, many entities, such as the U.S.D.A and the Commonwealth of Virginia make the data available via an on-line server connection. ESRI's ArcGIS has the ability to connect to these servers. The second part of this tutorial covers how to connect to such a server.

Connecting to a Drive in ArcMap

When you click on the ***Add Data*** button in ArcMap, you may see this window. You will need to connect to the drive where your data is located.



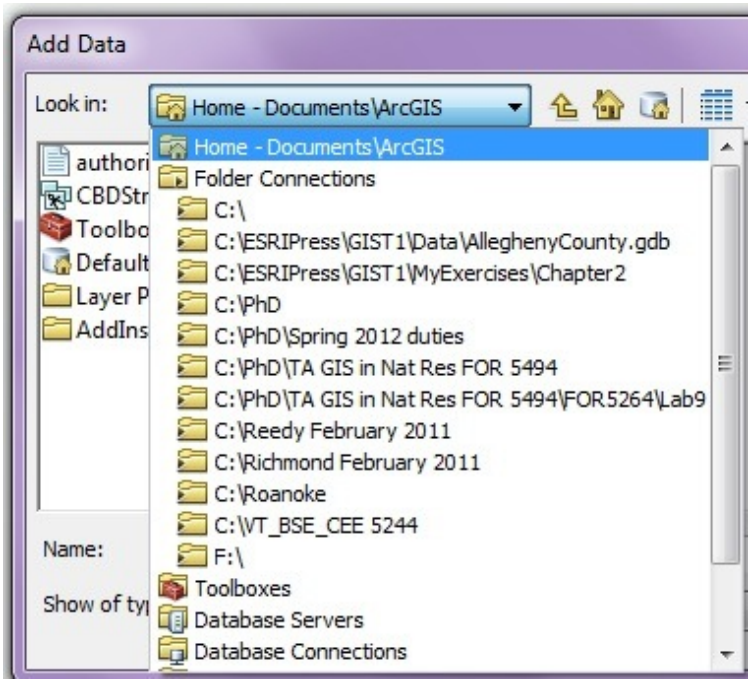
On the ***Add Data*** window tool bar, click on the ***Connect To Folder*** button.



This will take you to the ***Connect To Folder*** window:

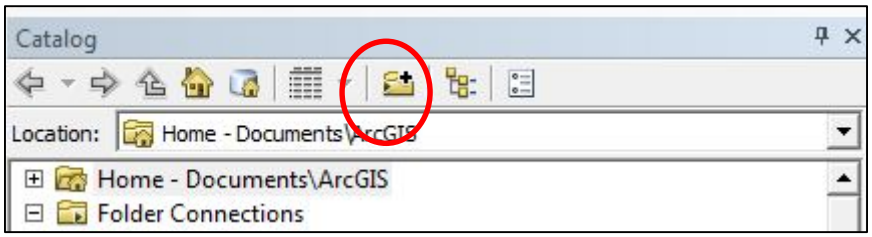
Navigate to the drive where your data is located. Once the folder is listed in the window, click okay. (You are not connected yet!) You next need to click on the down arrow in the ***Look in*** window and click on the drive and then your folder. Your chosen folder should now show in the ***Look in:*** window.

You are connected!



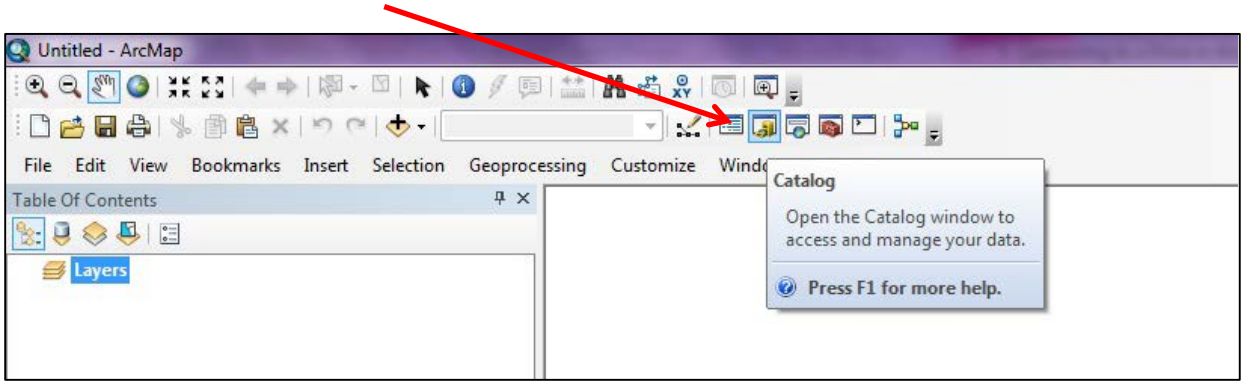
Connecting to a Folder in ArcCatalog

You connect to a drive in ArcCatalog in the same way. Open ArcCatalog, click on the ***Connect To Folder*** button and follow the same steps as above.



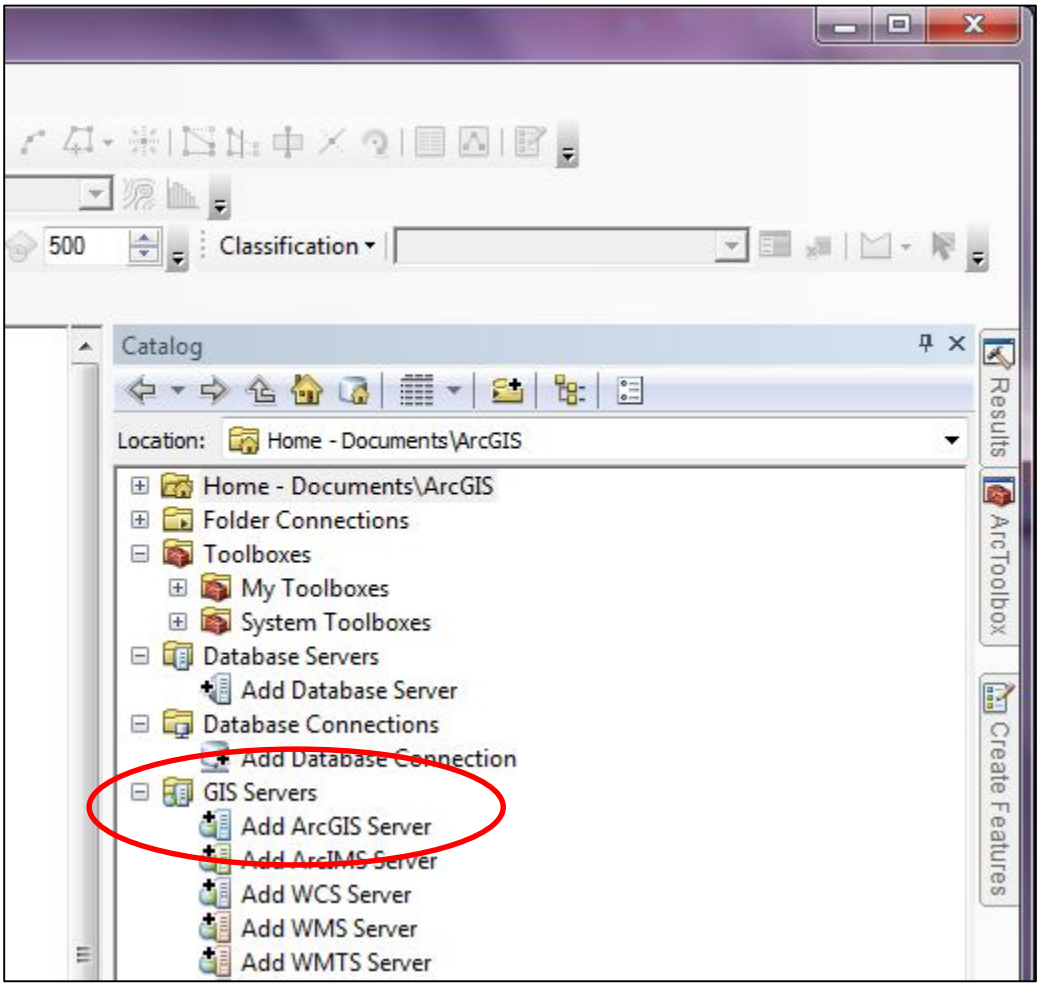
Connecting to a GIS Server in ArcCatalog and Displaying the Connection in ArcMap

To connect to an ArcGIS Server online, open ArcCatalog while in ArcMap. You do this by clicking on the ArcCatalog icon on the tool bar.

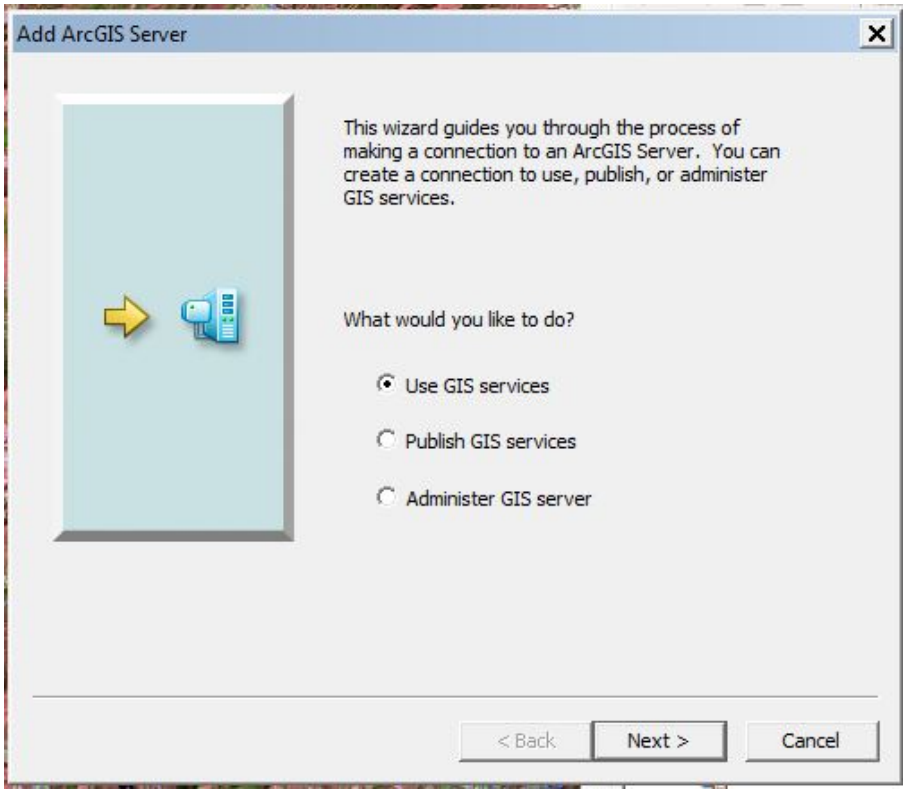


Once you click on this, ArcCatalog opens as another window within ArcMap window. To dock it to the ArcMap window, click on the pushpin (red circle).

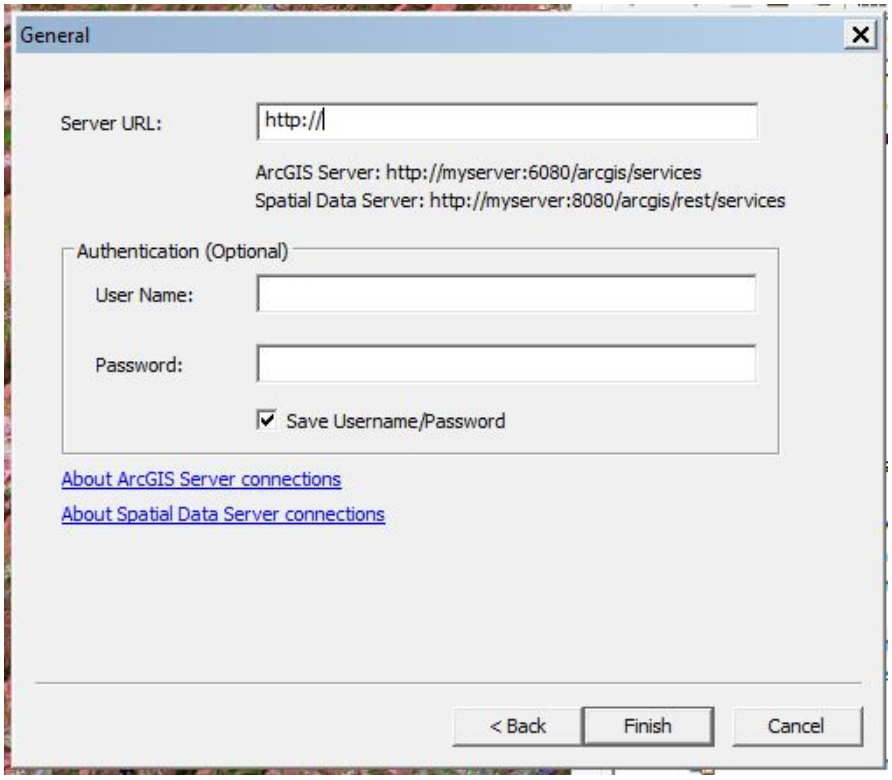
In the ArcCatalog window, under ***GIS Servers***, double click on ***Add ArcGIS*** Server.



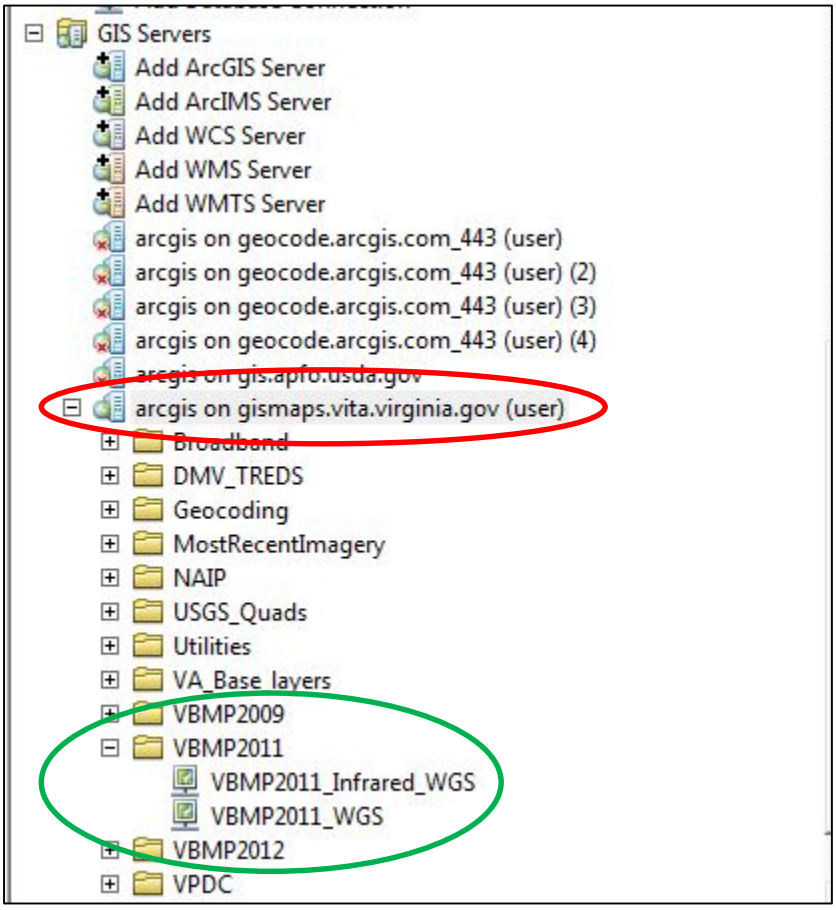
You will get this dialog box. You want ***Use GIS services***, click ***Next***.



In the ***Server URL*** box, type the URL for the ArcGIS Server to which you want to connect *(Note – the URL address will depend on the server – you can get this information by going to the website for the specific server.)* Click ***Finish***.



Now your GIS Servers in the ArcCatalog window, you will see your server connection listed. Click the + sign (red oval) next to the server and it displays all the connections for that particular server. For this particular demonstration, we are looking for the Virginia Base Mapping Program Aerial Photos for 2011 -- clicking the + sign next to VBMP 2011 lists all available data under that connection (green oval). We want VBMP2011_WGS.



To display the data from this server connection, you left click on the layer name. While holding down the mouse button, drag the mouse and file over into the ***Table of Contents*** in ArcMap. It will show as a layer and the data displayed in the map document window.

You must always have an internet connection to maintain this data within your map display. You do not have access to the data to make changes or conduct analyses. It is for display purposes only. You can create your own data files using these displays as guides.

You are ready to proceed to the next tutorial.

Notes:

4. Saving and Exporting Map Documents

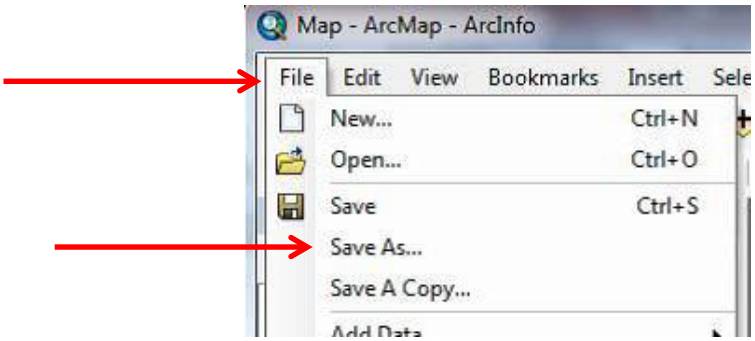
The instructional materials contained within these documents are copyrighted property of VirginiaView, its partners and other participating AmericaView consortium members. These materials may be reproduced and used by educators for instructional purposes. No permission is granted to use the materials for paid consulting or instruction where a fee is collected. Reproduction or translation of any part of this document beyond that permitted in Section 107 or 108 of the 1976 United States Copyright Act without the permission of the copyright owner(s) is unlawful.

Introduction:

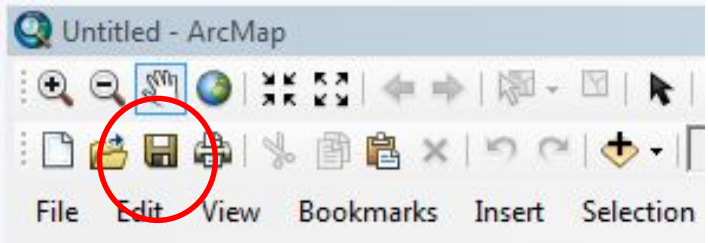
There are several things to save while working in GIS. You want to save changes while editing shapefiles or raster datasets, when you create new shapefiles or raster datasets, when you are creating map documents, and to create map documents in a form that is usable in other media. This tutorial covers saving your map document and exporting your map document as a form that is usable in other media.

Saving your Map Document

ArcMap does not automatically save map documents, so if you close your map document or ArcMap goes down, you will lose any work not saved up to that point. To save your work, left click on ***File*** in the upper left hand corner, then ***Save As***.

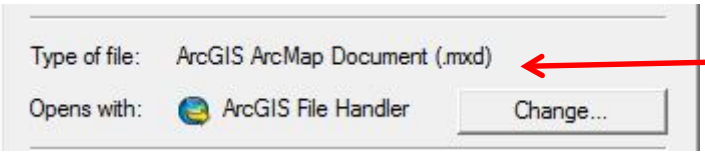


Navigate to your working directory and name your map document. Once you have done the ***Save As*** once, you can then just hit the ***Save*** button in the upper left corner of ArcMap.



You are saving the map displayed on your screen – the symbology, the location of the files listed in the ***Table of Contents***, and the extent. *(Note: this tutorial only applies to the map document itself. When you are working with shapefiles and raster data sets, many times the changes are automatically saved.)*

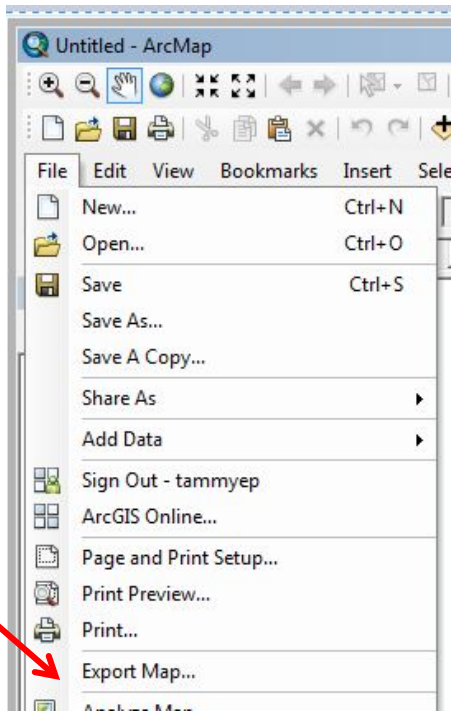
Saving your Map Document to use as a Figure in Another Document



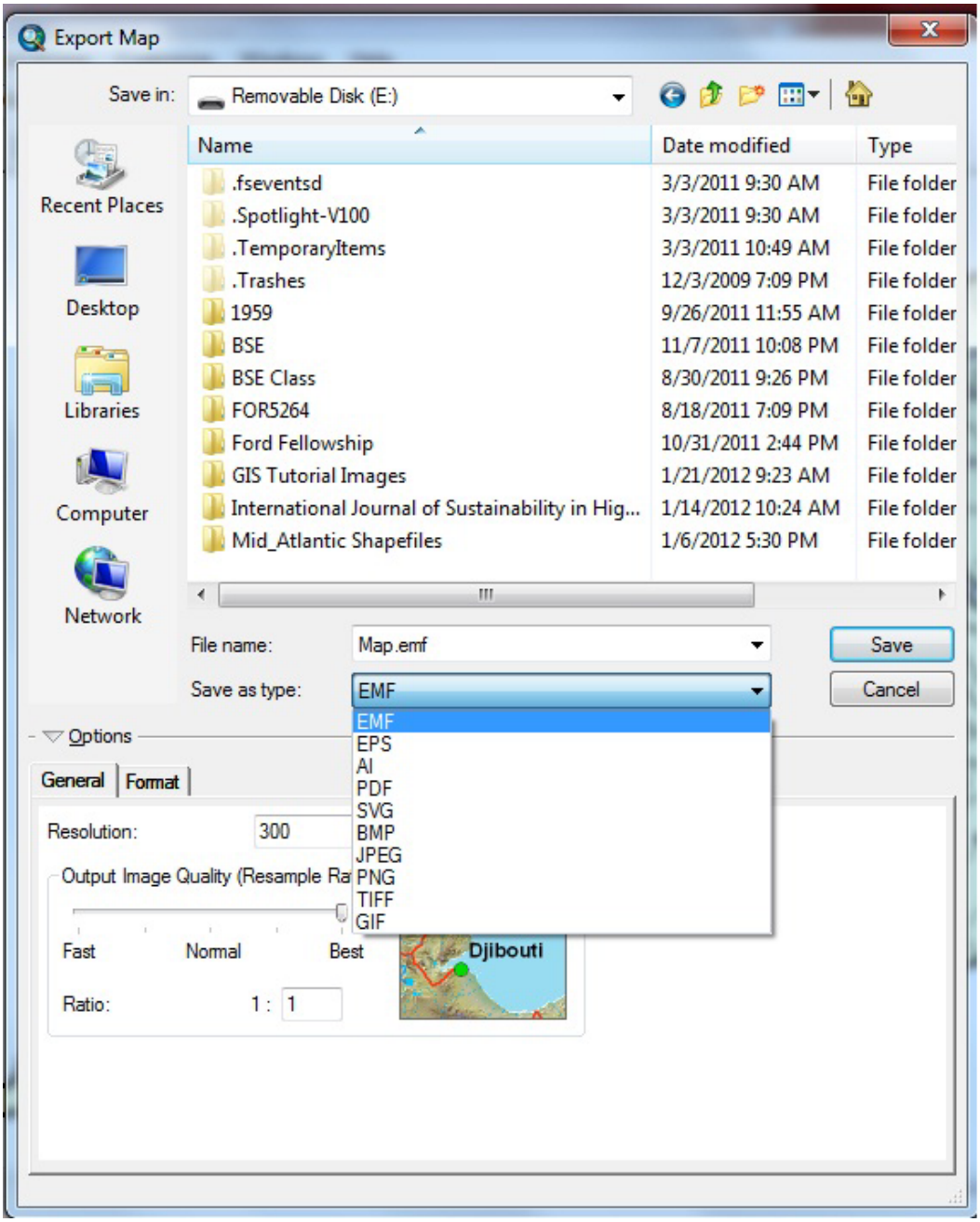
Map documents are saved as .mxd files.

If you look at the file icons using Windows, they look like this:

But, GIS is the only program that can read .mxd files. So if you want to use your map document in another document such as a presentation or a poster, you will need to save it as another type of file. To do this, Left click on ***File*** and then ***Export Map***.



You get this window and you can save the map document in any of the listed formats.



If you make changes to the map document, you will need to export the map each time to save the changes in the alternative file format. Hitting the save button in ArcMap, only saves the .mxd file.

You are ready to proceed to the next tutorial.

Notes:

5. Repairing a Data Address

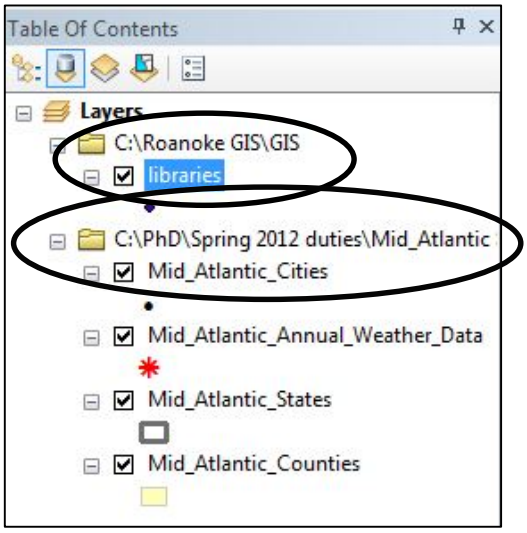
The instructional materials contained within these documents are copyrighted property of VirginiaView, its partners and other participating AmericaView consortium members. These materials may be reproduced and used by educators for instructional purposes. No permission is granted to use the materials for paid consulting or instruction where a fee is collected. Reproduction or translation of any part of this document beyond that permitted in Section 107 or 108 of the 1976 United States Copyright Act without the permission of the copyright owner(s) is unlawful.

Introduction:

ArcMap is a display mechanism. When you add data, you are only displaying the data in the map document window. The actual data file is still located in the file folder on your computer's hard drive or USB. When you save a map document, it says the data as displayed but also records the location of your data files. If you move the data files, ArcMap will not know where to find them, and when you open a specific map document, your display will be empty. You can fix this (repair the address) without rebuilding your map document.

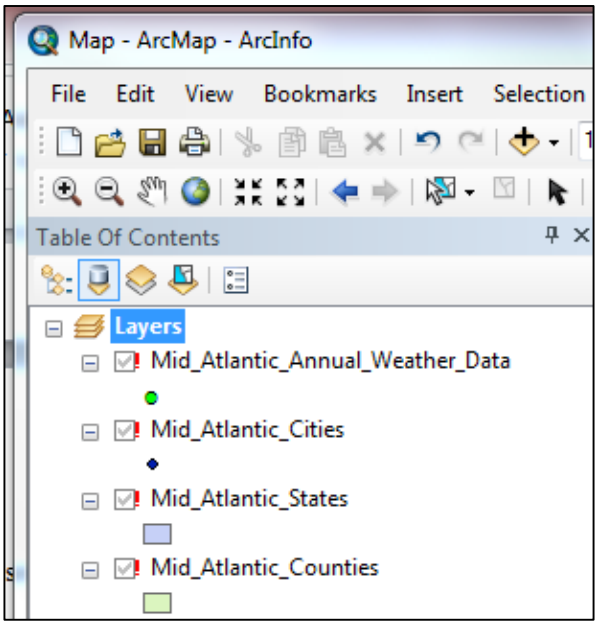
Repairing the Data Address

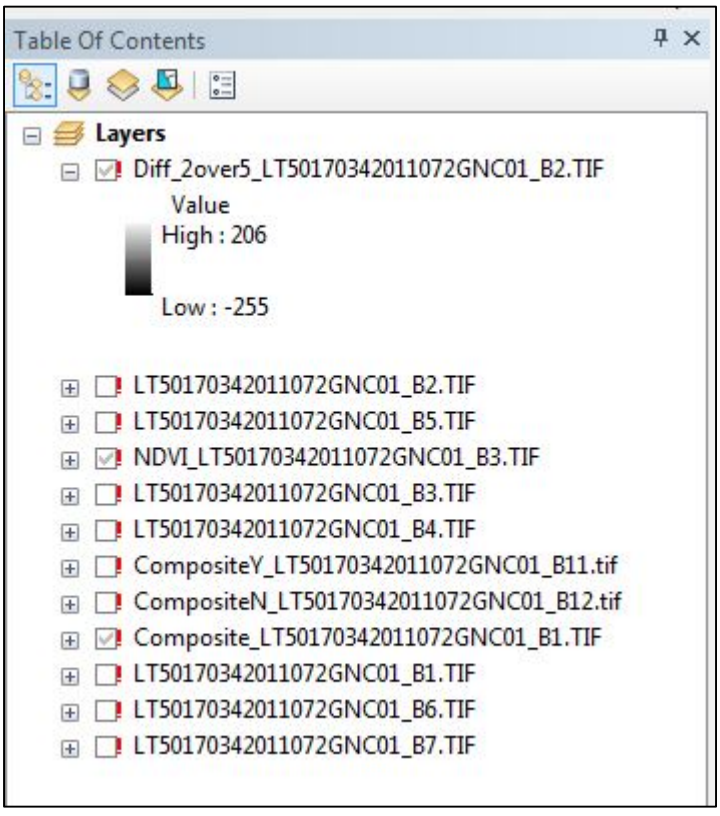
Again, the files shown in the ***Table of Contents*** of your map document are not in your map file. They are still located in the file folder where you saved them on your computer. If you look at the address under ***Layers*** in the ***Table of Contents***, it shows the reference link as to where your files are located. You can have files located in several different locations all in the same map document. ArcMap only saved the location of your files, not the data within the map document.



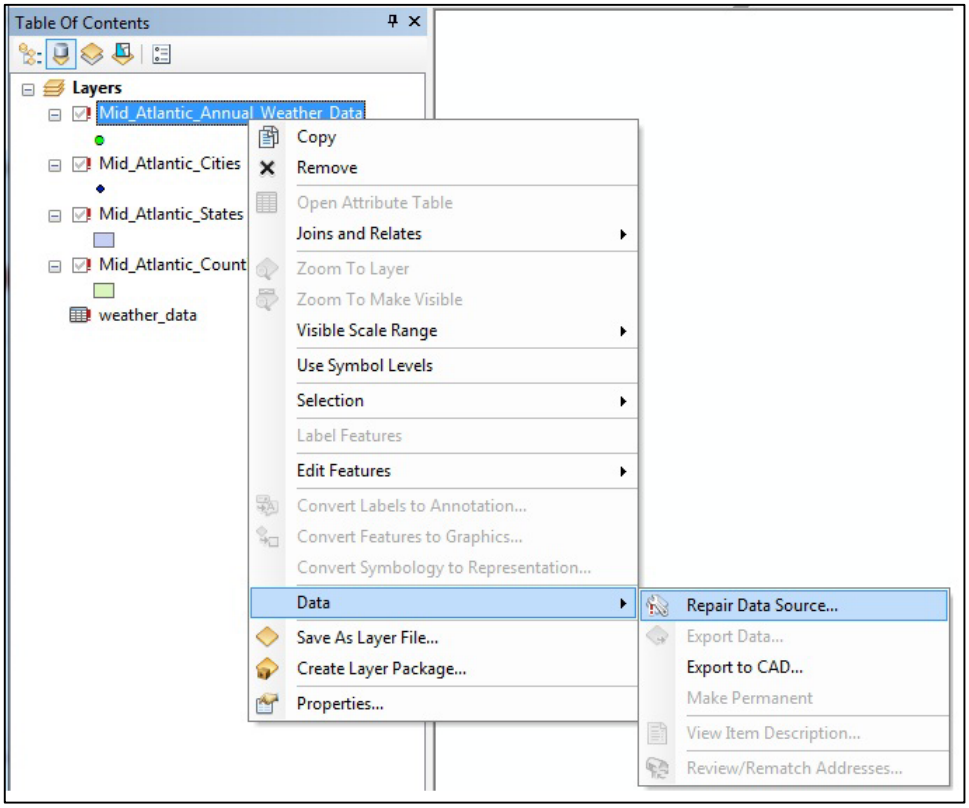
5. Repairing a Data Address

If you see red exclamation points next to your layer names when you open your map document, this means that ArcMap cannot find your data layers. This can happen with both vector and raster files. You will need to repair the data location's address.



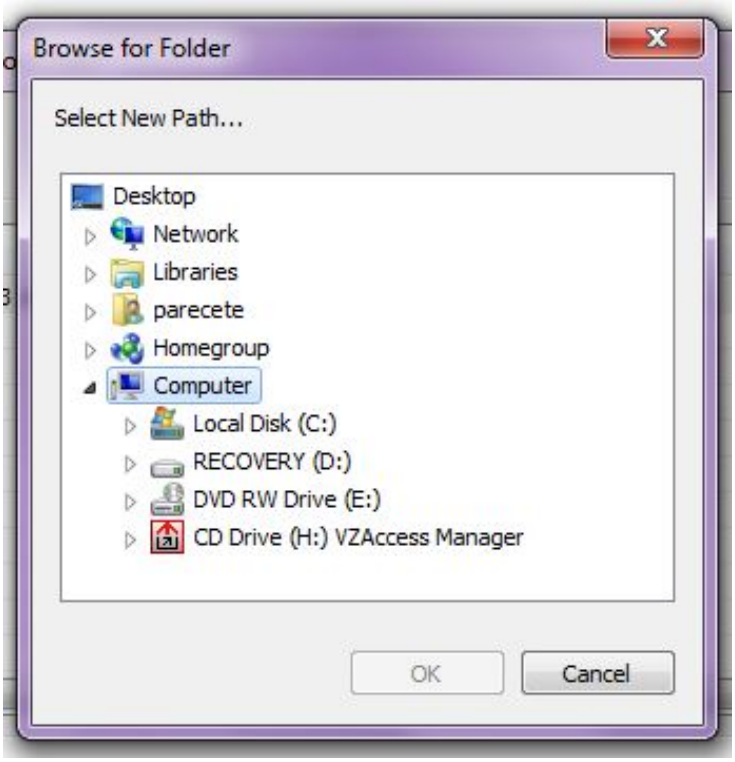


5. Repairing a Data Address



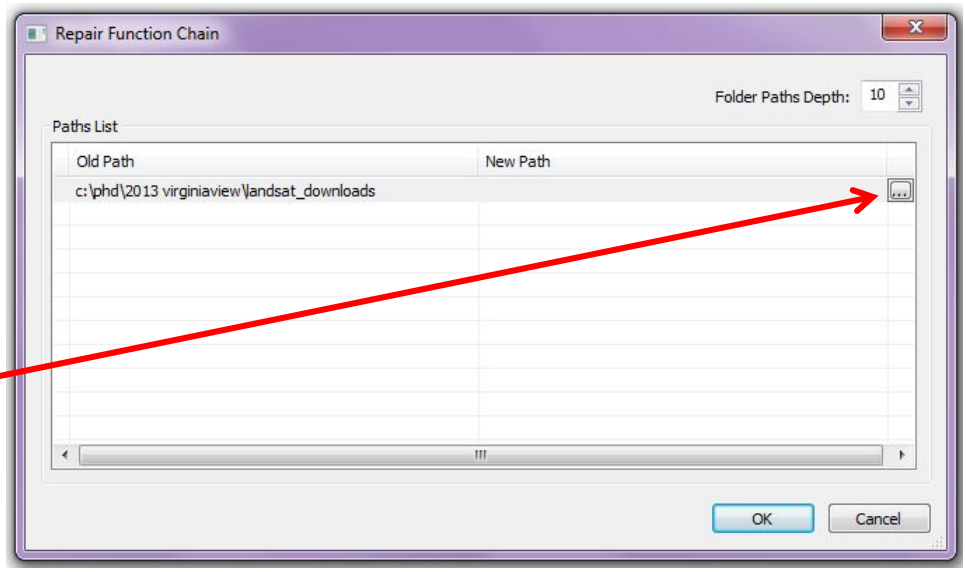
To repair the address, right click on any of the layers in the ***Table of Contents***, go to D***ata*** and ***Repair Date Source***.

This will take you to the ***Browse for Folder*** window, so you can navigate to the folder where your data is currently located. Click on the file that corresponds to the layer that you clicked on in the ***Table of Contents*** *(note – if you click on the wrong file, it alters the file that is in the map document and you will have to rebuild your map document!!).* If all of your data is located all in the same place, all layer



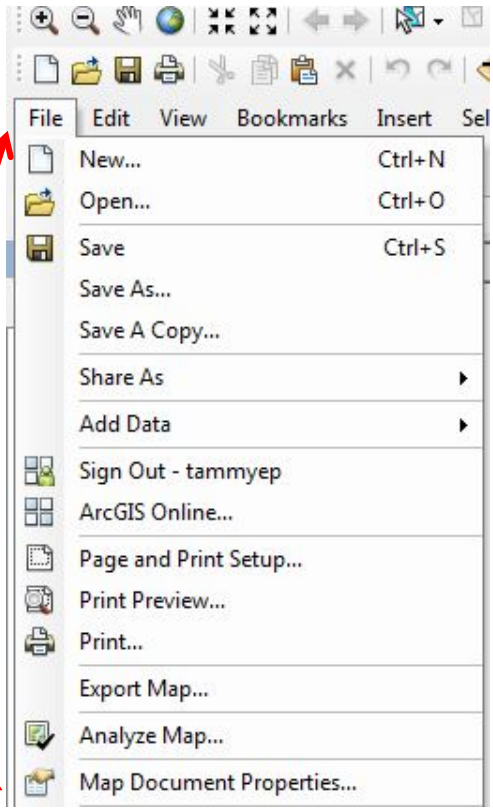
connections should be repaired. If your data is located in multiple places, you will need to do the repair this for each location.

If the file is a raster file, when you click on ***Repair Data Source***, you will get this dialog box. Click on the button at the end of the row for your file name and you will get the ***Browse for Folder*** window and can then navigate to the file folder where your data is located. Click on the file that corresponds to the file in the ***Table of Contents*** and click ***OK***.

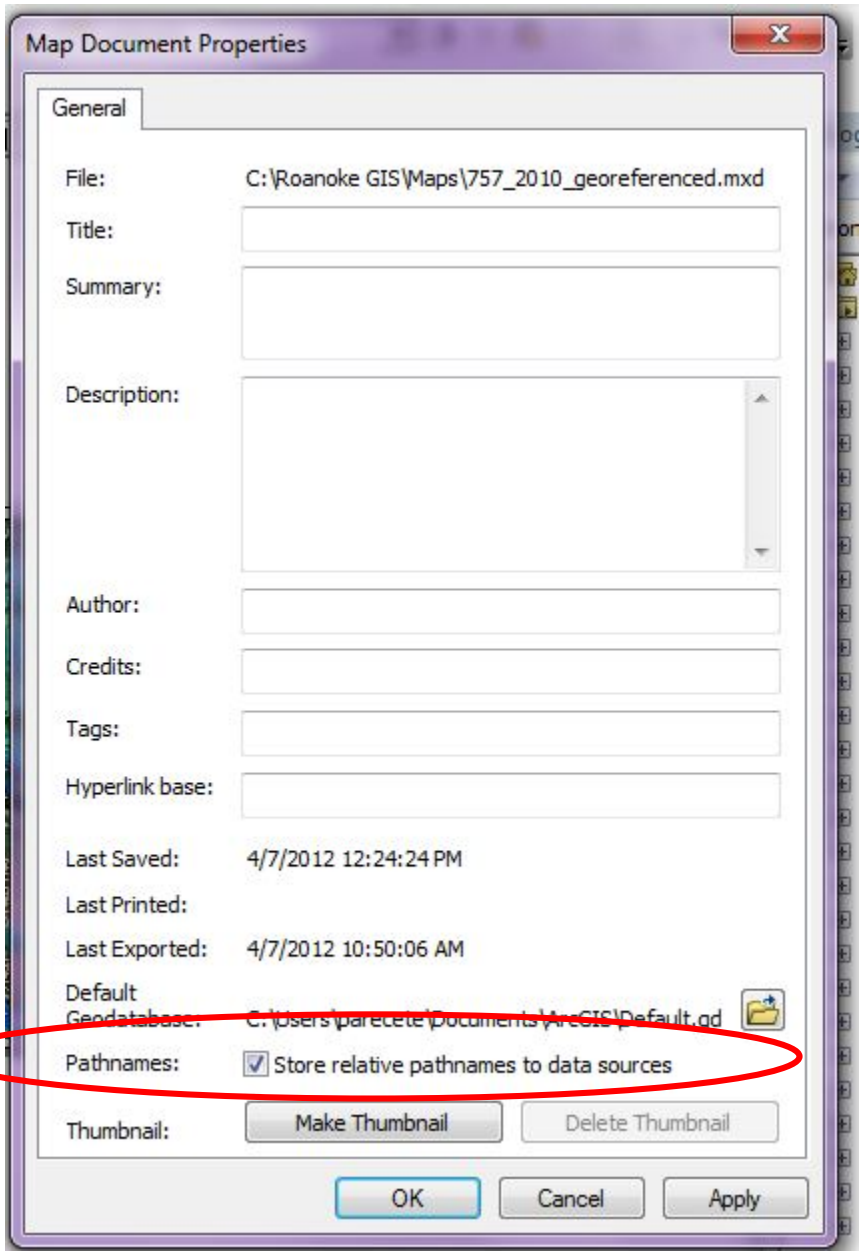


Once you have repaired all the addresses, **SAVE** your map document. Your map should now display correctly. **But you are not yet finished!**

One final step. Left click on ***File***, and then click on ***Map Document Properties***.



Click on the box next to ***Store relative pathnames to data sources***. Click ***OK***.



You are ready to proceed to the next tutorial.

5. Repairing a Data Address

Notes:

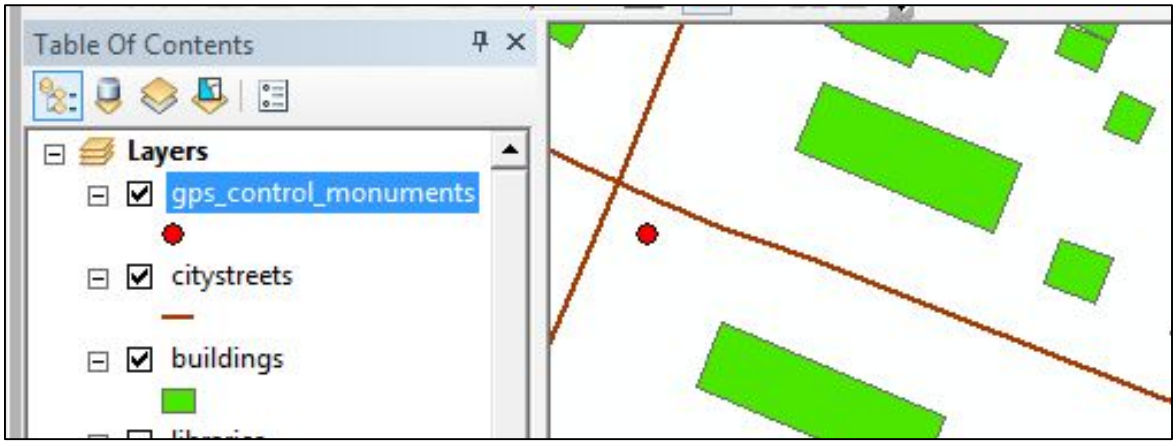
The instructional materials contained within these documents are copyrighted property of VirginiaView, its partners and other participating AmericaView consortium members. These materials may be reproduced and used by educators for instructional purposes. No permission is granted to use the materials for paid consulting or instruction where a fee is collected. Reproduction or translation of any part of this document beyond that permitted in Section 107 or 108 of the 1976 United States Copyright Act without the permission of the copyright owner(s) is unlawful.

Introduction

With the power of GIS, you have the ability to change how the data is displayed in the map document. This allows you to display multiple layers all at the same time – multiple files of the same type – for example many point files, or files of many different types – several points, several lines, and several polgyons -- and be able to visually distinguish between the different features.

Default Settings

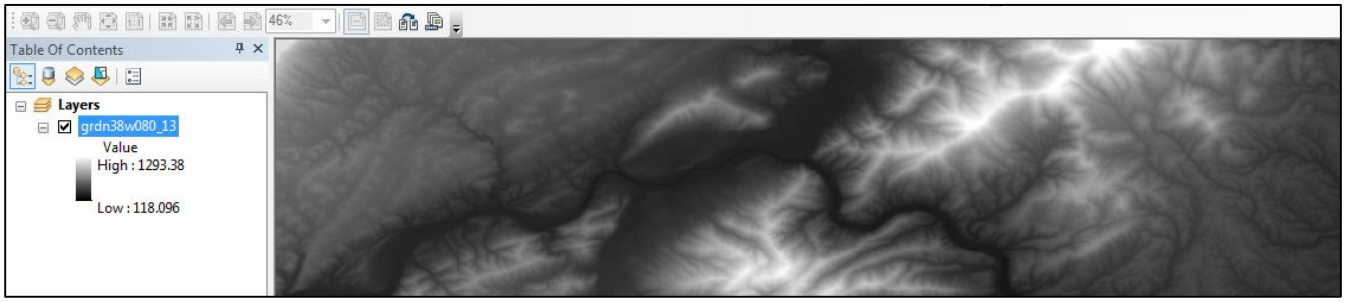
When you add vector or raster datasets to a map document, GIS selects colors to display the data. Points are always displayed as a dot, lines as a line, and polygons as a solid color outlined with a different color.



Points, lines and polygons displayed with random colors by GIS

6. Displaying Data

Raster datasets such as digital elevation models are usually displayed as a stretched grayscale.

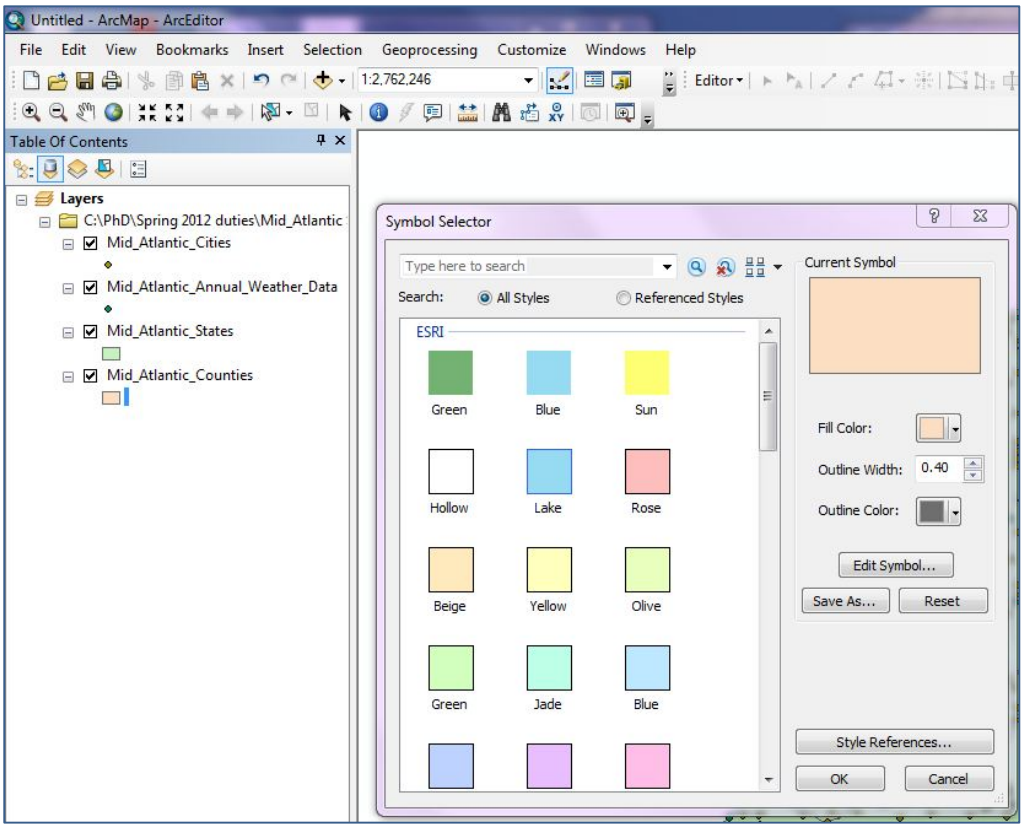


Aerial photos, such as those from the Virginia Base Mapping Program, use Red, Green, and Blue bands to display natural colors.

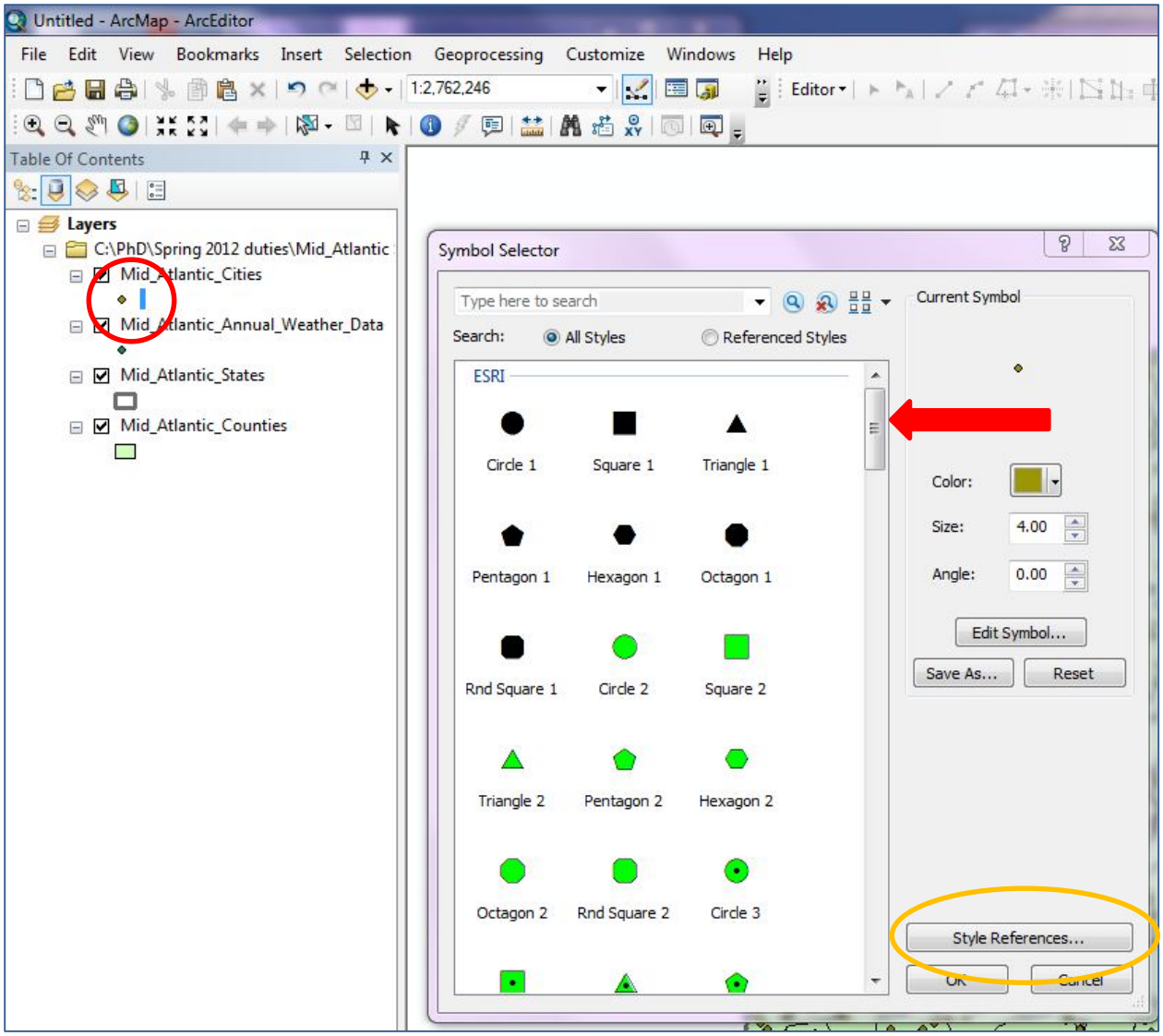
All of these types of display symbology can be changed.

Changing Symbology on Vector Files

Left click on the symbol for the layer in the ***Table of Contents*** you want to change and it brings up the ***Symbol Selector***. For polygons, you can change the color, make it hollow (only outlines are displayed), eliminate the outline, or change the width of the outline. Use the slide bar on the right side of the colored squares and you can see all the different colorizations available.

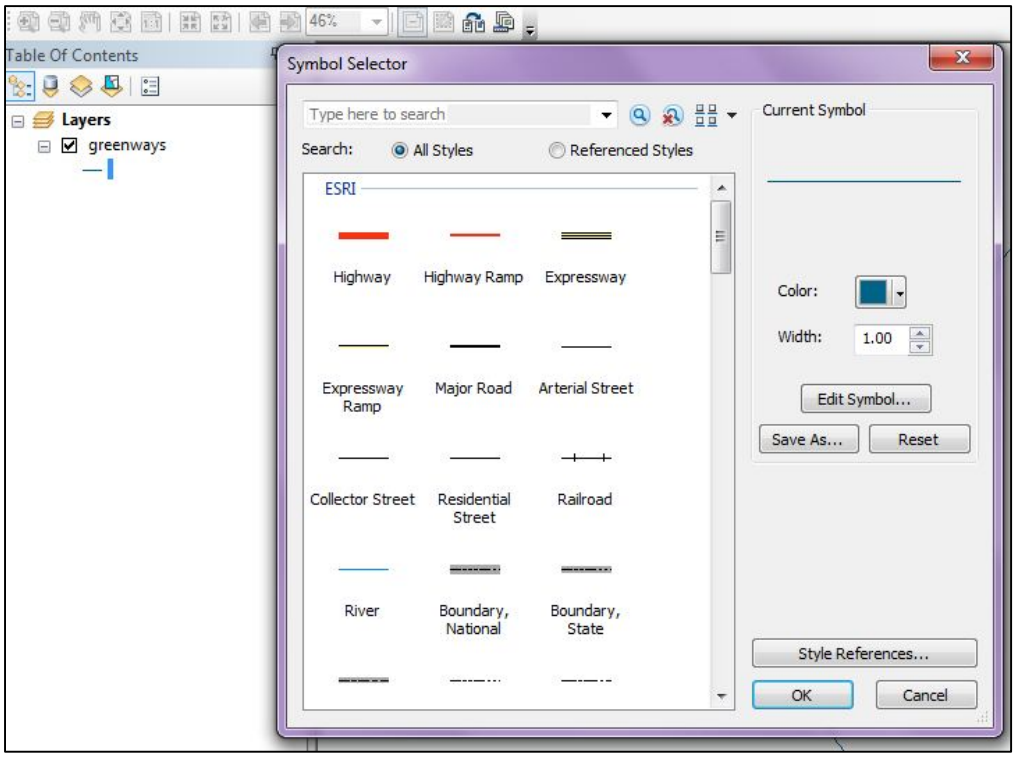


For point files, you can change the color, the size of the dot, and the type of symbol. Left click on the point symbol and it also brings up a S***ymbol Selector***.

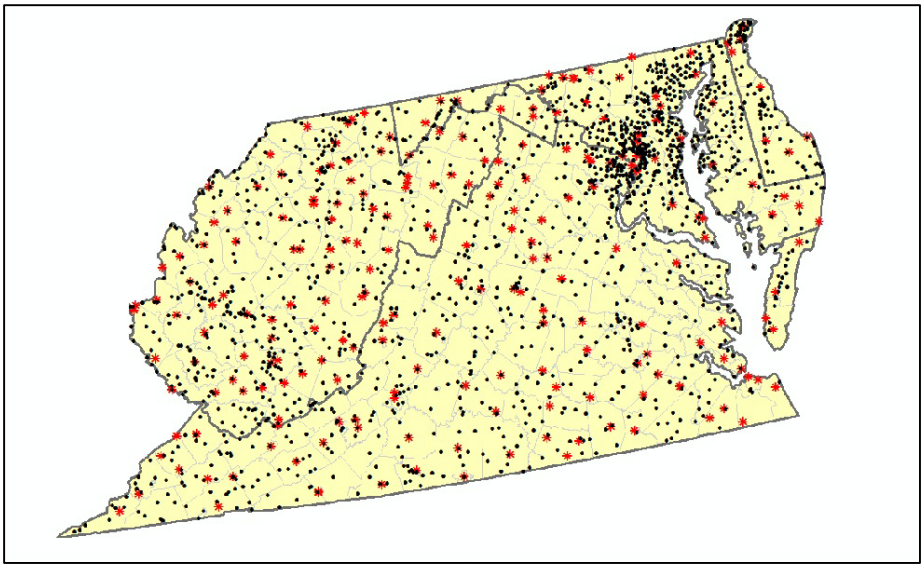


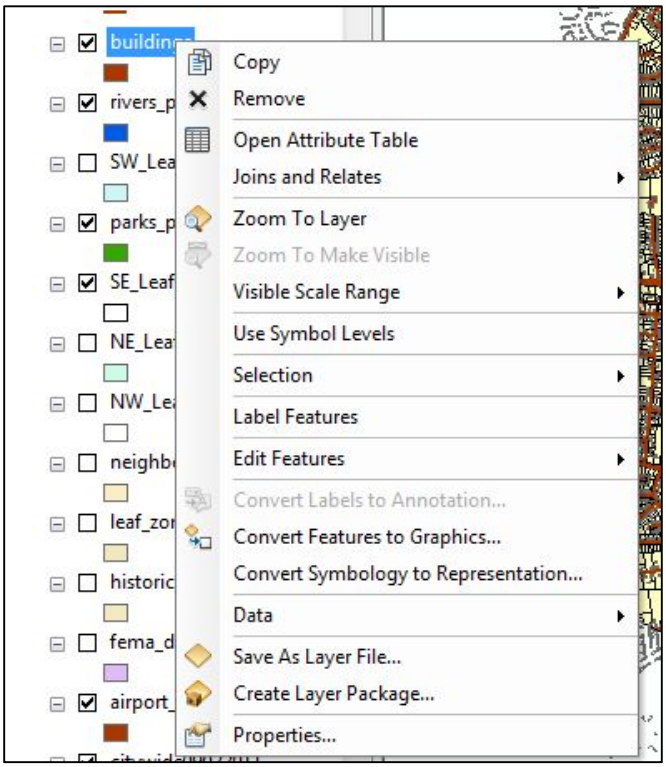
You can choose a different color, a different shape and the size of the shape. You can use the slide bar (the red arrow points to the slide bar) and see a whole variety of shapes that can be used to display points. You can also click on the ***Style References*** button (orange oval) to get many different categories of shapes.

For changes to line symbology, you access the ***Symbol Selector*** in the same manner. You can change the line color, the line width, and also the symbol itself to represent specific features.

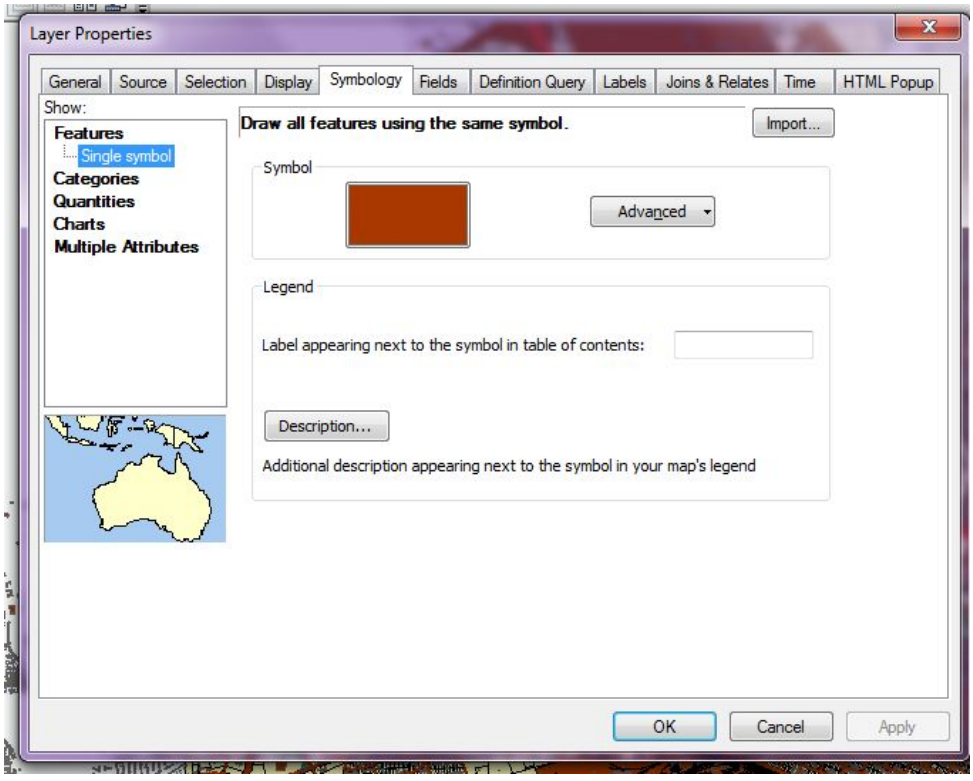


Your ultimate display in the map document needs to take in account the multiple layers and the visual representation of each on the map document. In this particular display, the counties are light yellow with light gray outlines, the states are hollow with black outlines, the cities are small black circles and the other data points are red asterisks.





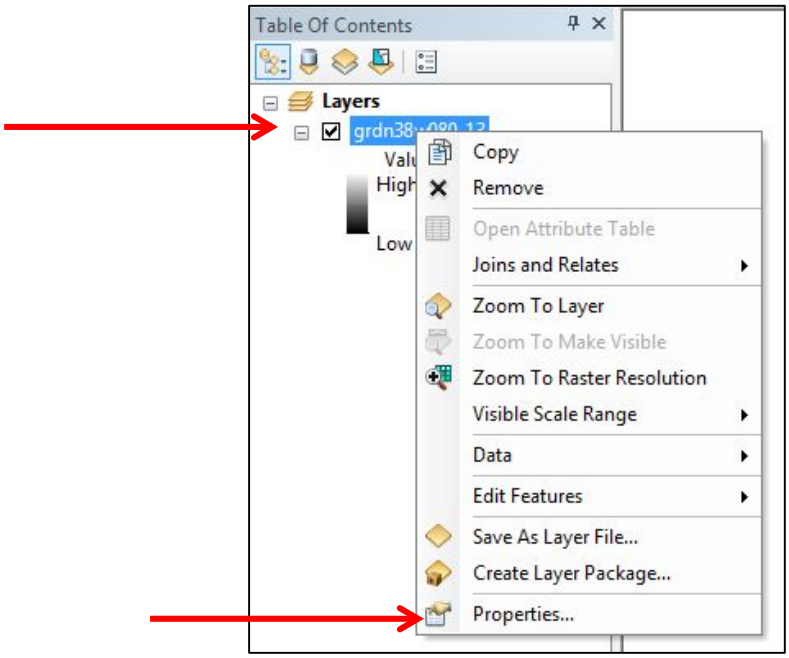
You can also change the symbology by left clicking on the layer name, and then double clicking on ***Properties.*** This method brings up the ***Layer Properties*** dialog box. Click on the ***Symbology*** tab. This method of changing symbology allows you to use some of the attributes within the layer's attribute table when displaying your data.



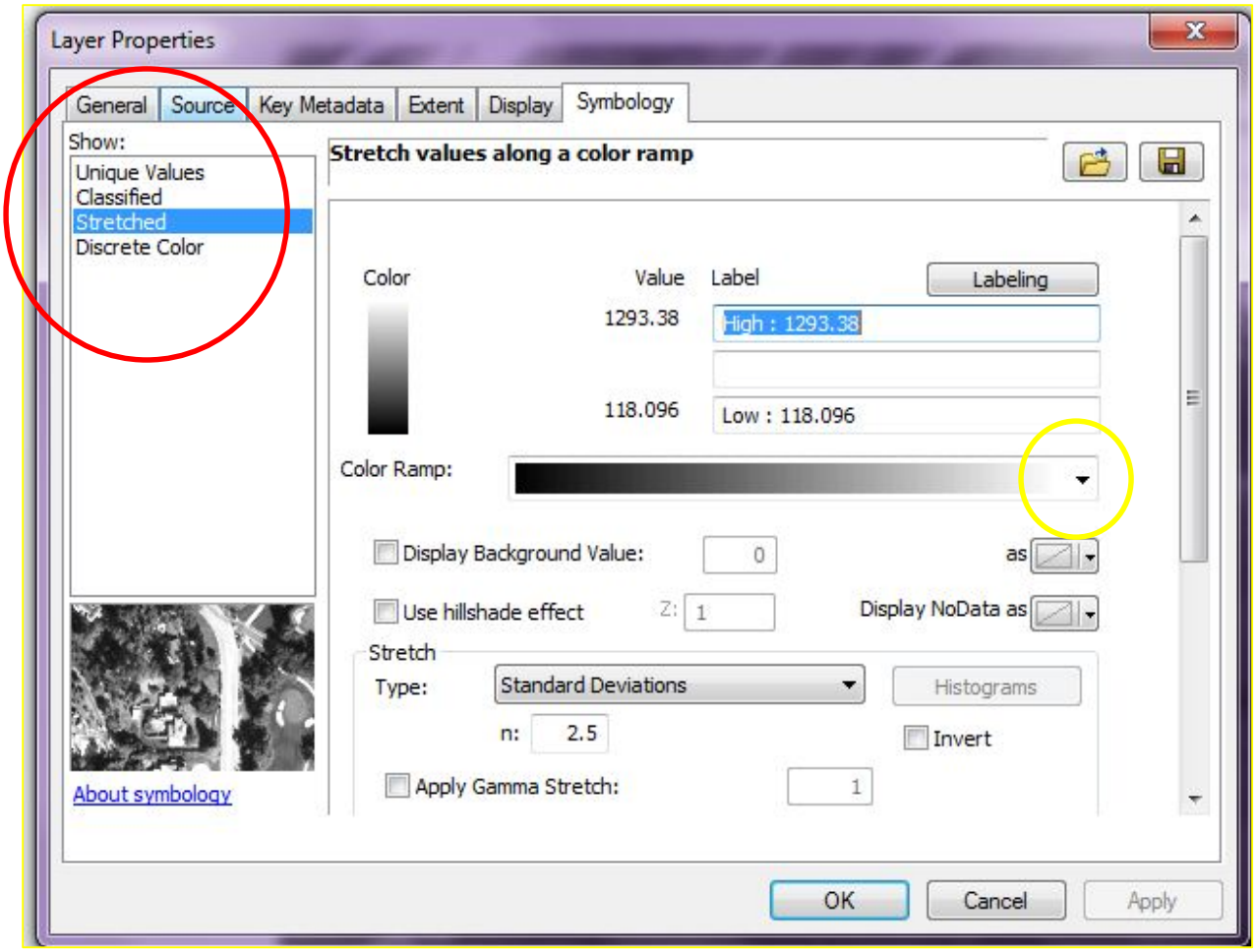
Changing Symbology on Raster Datasets

Changing the symbology on a raster dataset (such as a digital elevation model) is accomplished using the ***Layer Properties*** dialog box. Changing symbology on aerial photos and satellite imagery is more complex (see tutorials on displaying your Landsat Imagery, creating composite images and band combinations using Landsat Imagery).

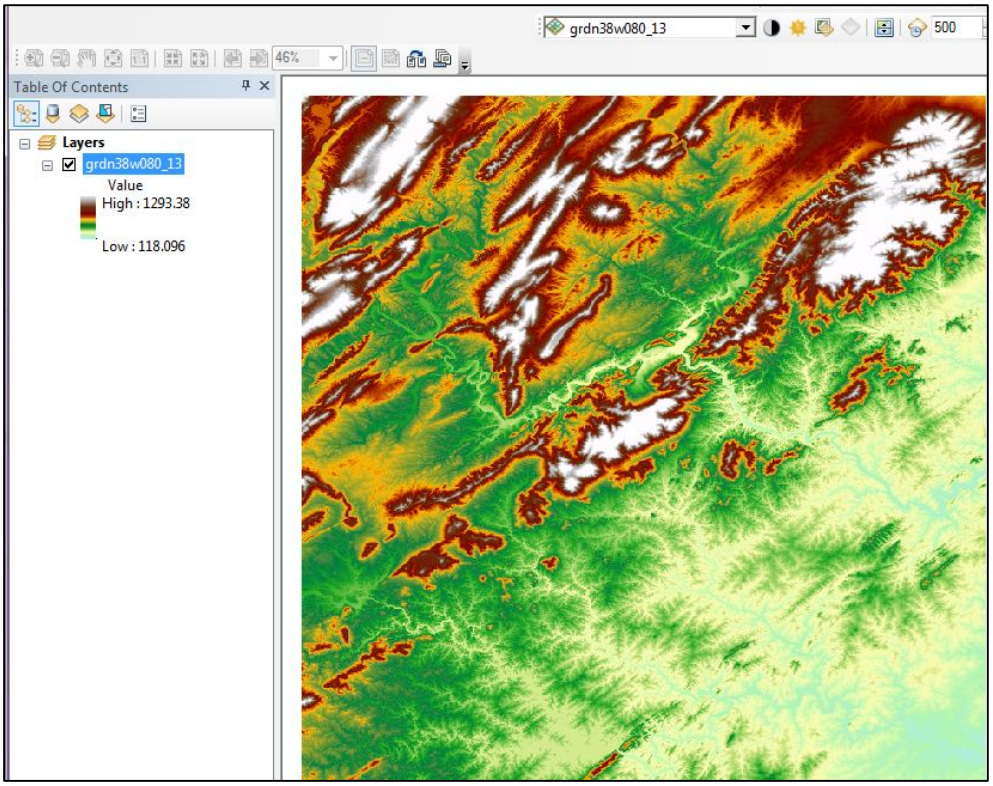
Left click on the layer name and then double click on ***Properties.***



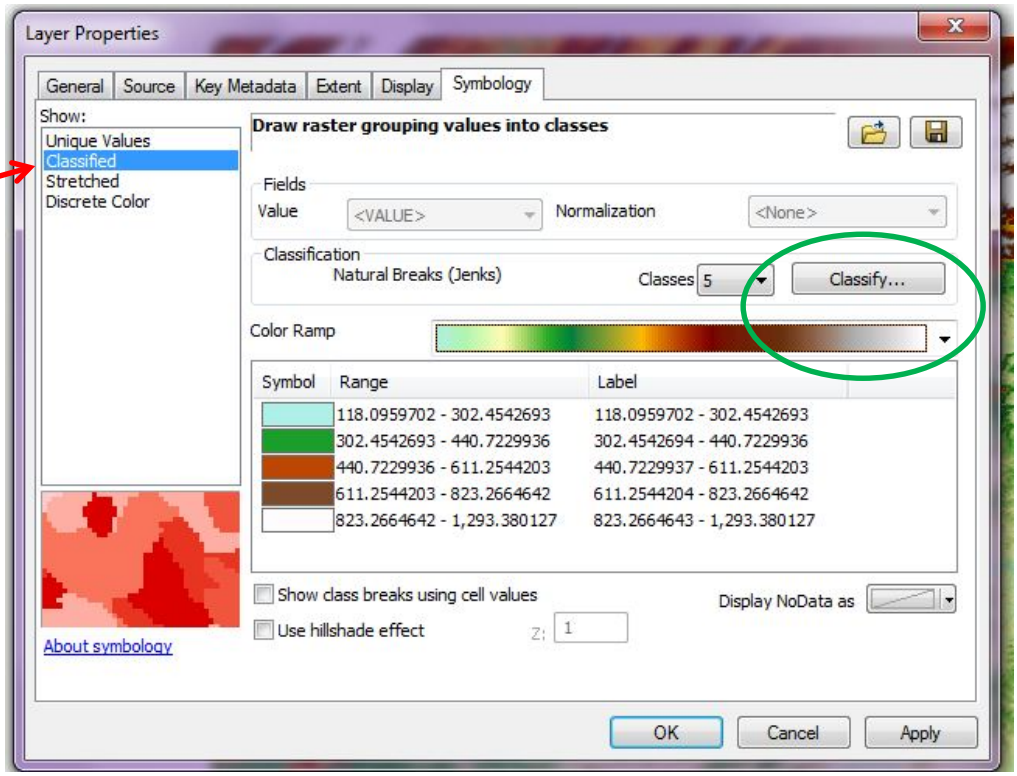
This gives you the ***Layer Properties*** dialog box. Click on the ***Symbology*** tab. The ***Symbology*** tab for a raster dataset looks slightly different than it does for a vector file. You see the types of symbology in the ***Show:*** window – ***Unique Values***, ***Classified, Stretch***, and ***Discrete Color*** (red circle). ***Stretch*** is the default because, in most instances, raster datasets represent gradients of values, not distinctive values. You can change the color from grayscale by clicking on the down arrow next to the color ramp (yellow circle)



You get a large list of different colors from which to display your data. You should choose a color ramp appropriate for the theme of your data. For this particular dataset, we have chosen elevation colorization, with the white representing higher elevations (where one might find snow) and blue for lower elevations (which might represent water). Again, these are not distinct divisions but a range of values with a range of color gradients.

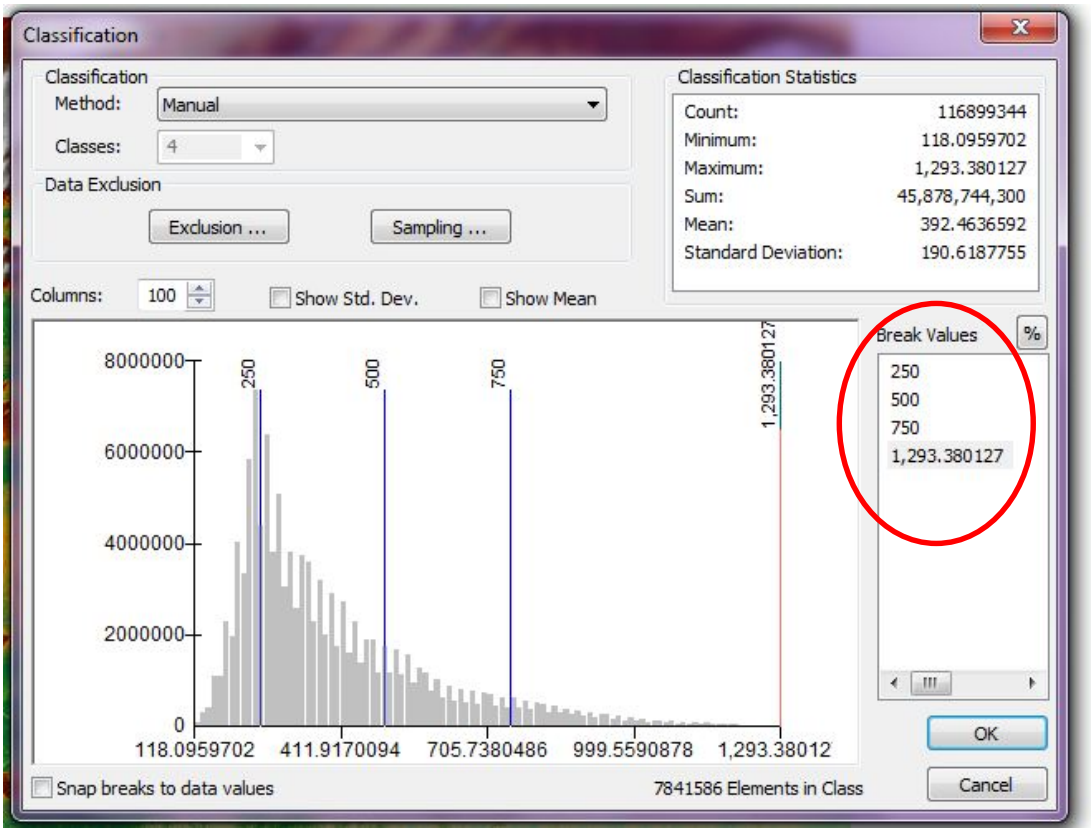


You can, however, display raster data as distinct colors for different values. Go back to the ***Symbology*** tab of ***Layer Properties*** dialog box, click to highlight ***Classified***. GIS will set some default values for each classification, but these can be changed. Click on the ***Classify*** button (green circle)

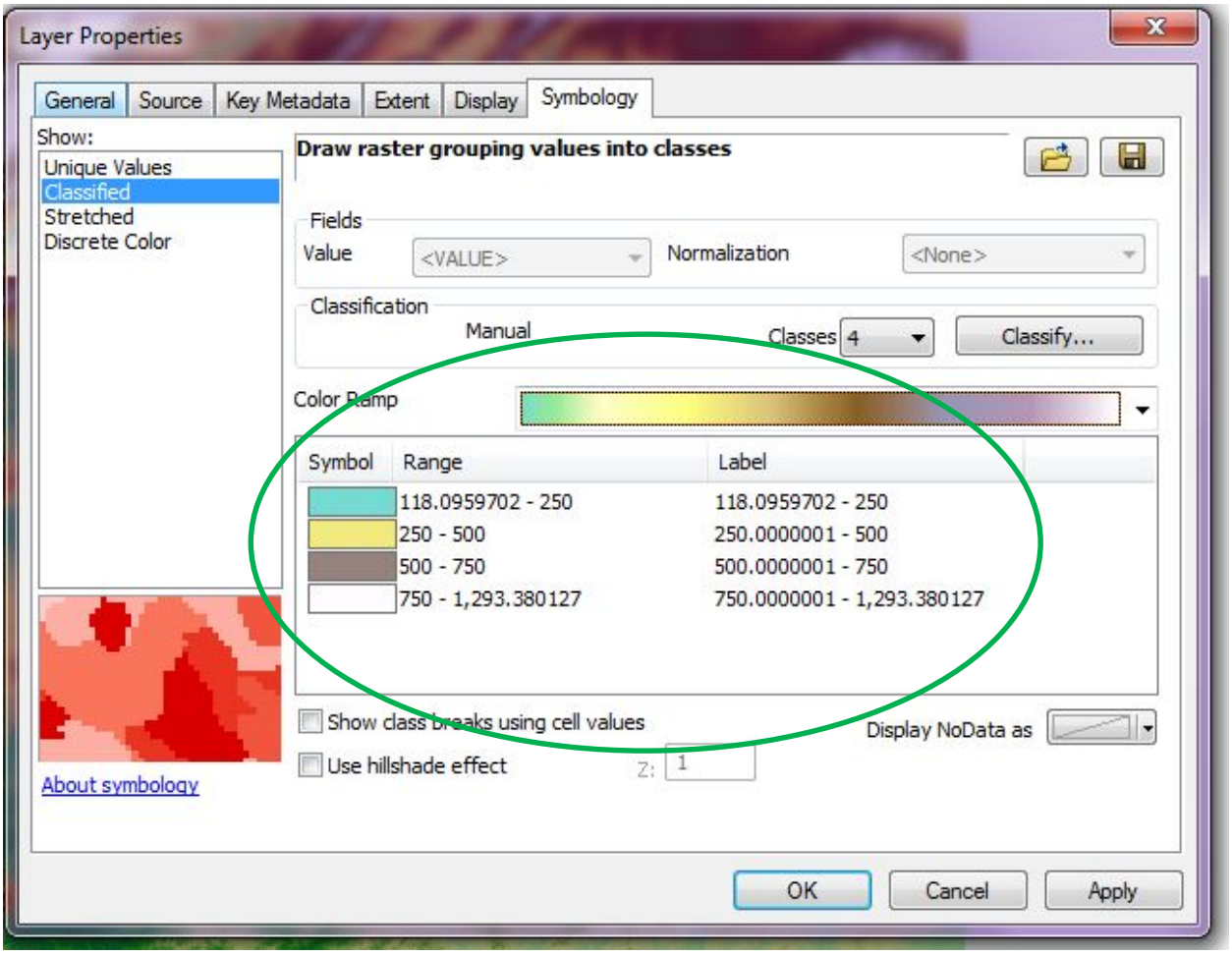


This brings up the ***Classification*** window and you can change the classification methods and matrix in many different ways.

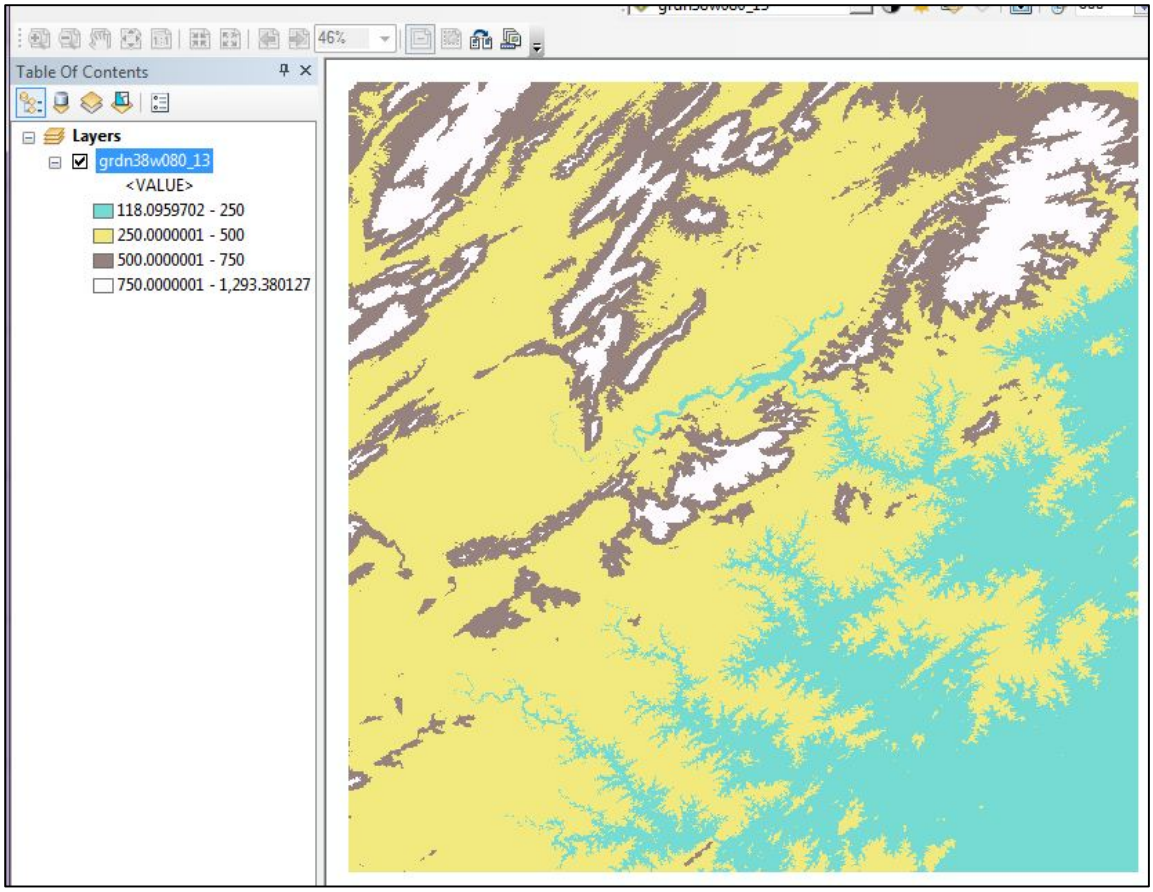
For this particular demonstration, we have manually changed the ***Break Values*** (red oval) to 250, 500, 750 -- leaving the final value as the maximum value for the dataset.



Click okay, which brings us back to the main ***Symbology*** tab. Within the main ***Symbology*** dialog box, you can see that GIS has assigned distinct colors to the four categories of elevation that we manually designated (green oval).



Clicking okay, you can see the results displayed within the map document window and the changes in the ***Table of Contents***. We have assigned an individual color to a range of elevation values.



Caution!

Be careful when changing the symbology on raster datasets. Know what you want to communicate to your audience. Do you want the display to show distinct differences in colors because of distinct breaks in the data? Or is it more appropriate to display the raster as stretched because there are no distinct borders between values (i.e. elevations changes gradually on the ground). For more information on symbology in raster datasets – please see your GIS Help windows.

After completing these first six tutorials, you should have a working knowledge of ArcGIS basics. You are now ready to learn about Landsat Imagery and Image Analysis.

The instructional materials contained within these documents are copyrighted property of VirginiaView, its partners and other participating AmericaView consortium members. These materials may be reproduced and used by educators for instructional purposes. No permission is granted to use the materials for paid consulting or instruction where a fee is collected. Reproduction or translation of any part of this document beyond that permitted in Section 107 or 108 of the 1976 United States Copyright Act without the permission of the copyright owner(s) is unlawful.

This activity introduces you to procedures for using the GloVis utility to select and download Landsat imagery to your computer as a preliminary step for analysis to extract information for specific application tasks. For this exercise, you will require a computer with an internet connection.

Introduction

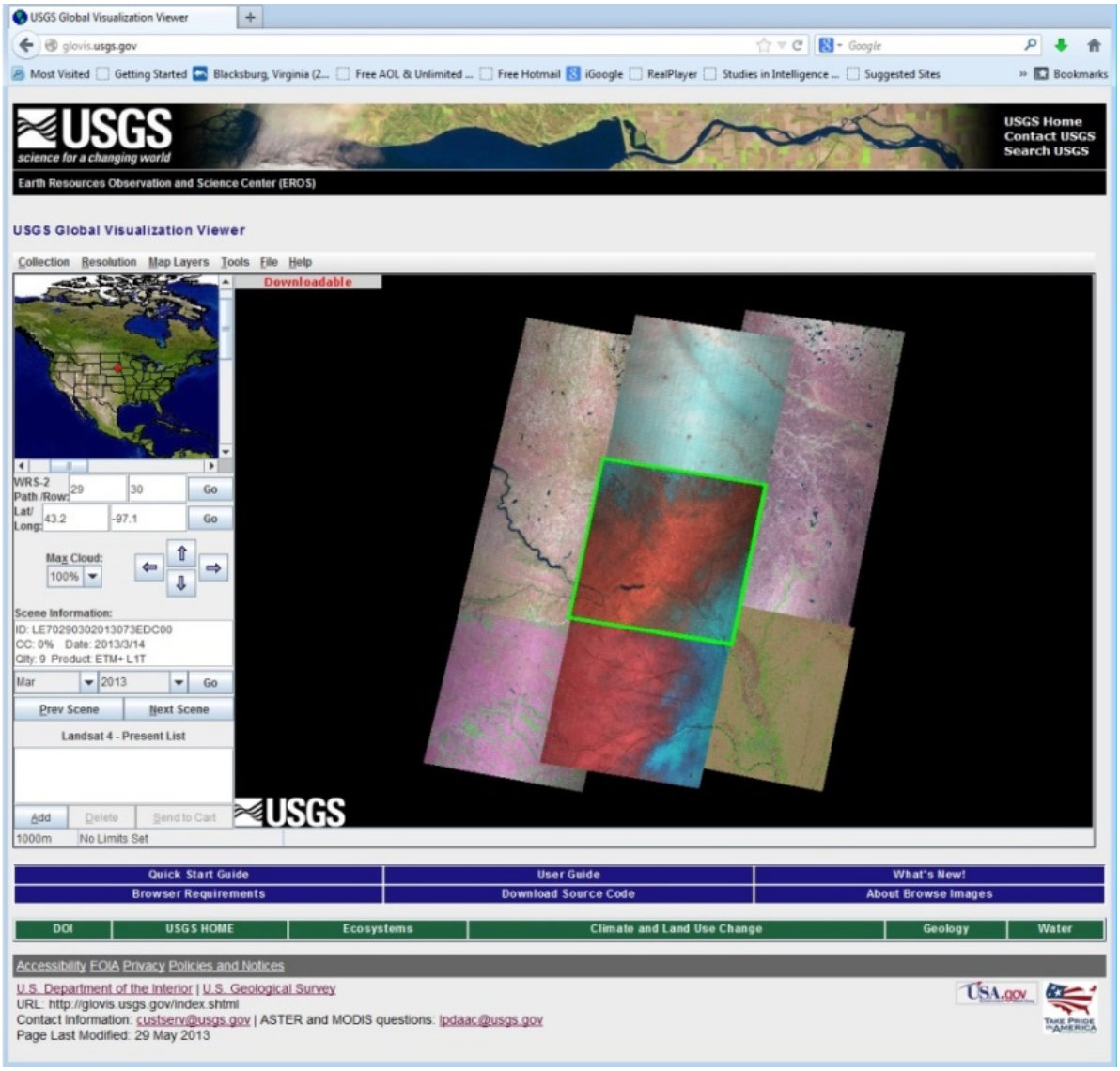
Landsat images are frequently used for land remote sensing analyses. The first Landsat Satellite was launched in 1972. The Landsat mission continues to this date with the most recent Landsat Data Continuity Mission satellite (now Landsat 8) launched in February, 2013. For more information and specific details on Landsat satellites, sensors and potential analyses using Landsat images go to: http://landsat.usgs.gov/

Landsat images are free and downloadable from the internet from http://glovis.usgs.gov/. This tutorial provides step by step instructions to download images via the internet. Decisions on exactly which specific images you need for your specific analyses cannot be answered from this tutorial.

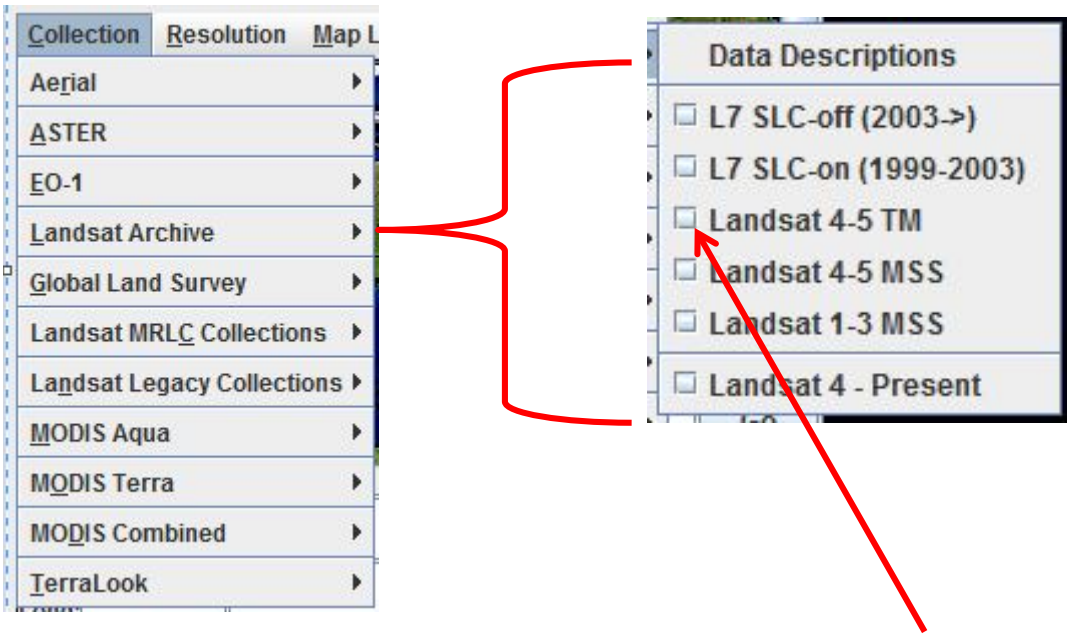
You must have the most recent version of Java (http://www.java.com/en/) to access GloVis.

Navigating to your scene

Go to http://glovis.usgs.gov/. The screen looks like this:

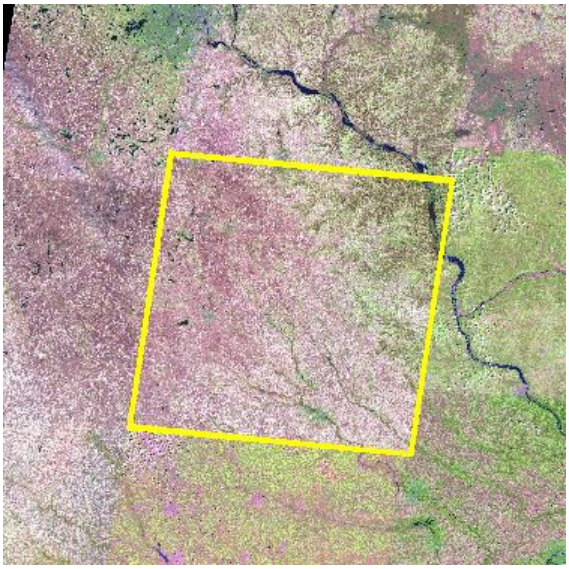


Click on ***Collection*** and you will find the images that are available for downloading from this site. We are interested in the ***Landsat Archive***. When clicking on the down arrow for the ***Landsat Archive***, you get a list of all sensors that are available for downloading. (For specifics on the different sensors, go to http://landsat.usgs.gov/.) You need to place a check next to the specific collection you want.



For this particular exercise, we are going to choose the ***Landsat 4-5 TM***.

The red square on the map of the USA shows you which Landsat scene is the current selection. The scene is highlighted in the larger window on the right. You can use the scroll bars on the right side of the map window or underneath to move the map display to other parts of the world. This does not change the scene in the window on the right.

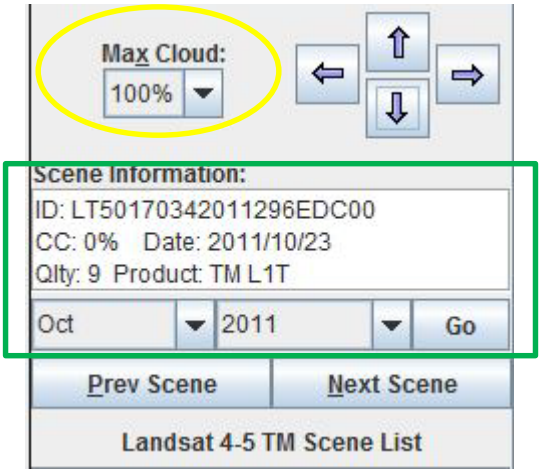


For this exercise, we want the scene which includes Roanoke, Virginia. You can move the red square to your area of interest in a number of ways: (a) double click on the area of interest in the map window, (b) enter the ***Path/Row*** numbers of the Landsat scene, or (c) the ***Latitude/Longitude*** (red rectanlge). If you enter the ***Path/Row*** or ***Lat/Long***, you must click on ***Go*** so the appropriate scene will be located. As you can see from the map, the red square moved to the scene covering Roanoke, Virginia.

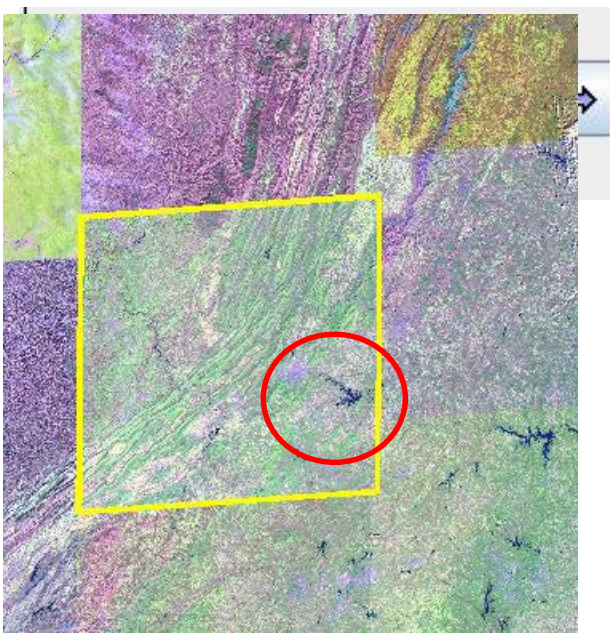
Selecting the Image Date

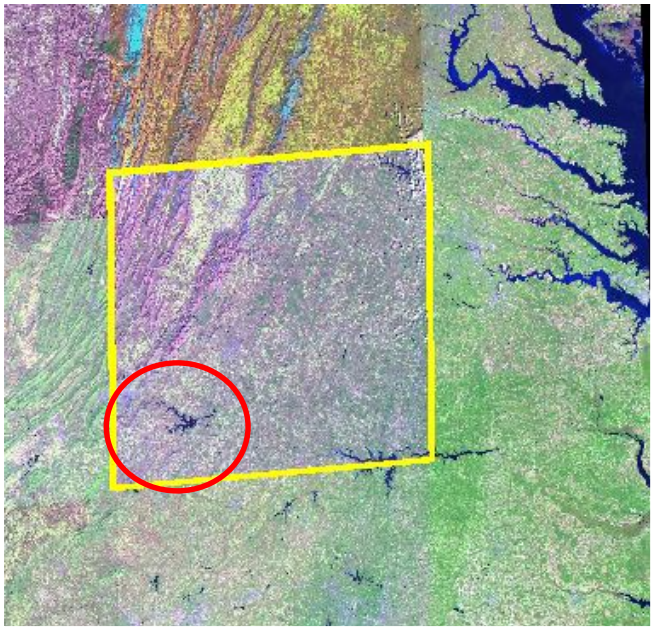
7. Downloading Landsat Imagery Using GloVis

GloVis has located a scene dated October 23, 2011 (2011/10/23 - green rectangle), we were lucky because this scene has cloud cover (***CC***) of 0%. But if we want to ensure that the scene(s) GloVis has chosen has less than 10% cloud cover, then we should change the ***Max Cloud*** percentage (yellow oval). To accomplish this, click on the down arrow and click on 10%. Then click ***Go***.



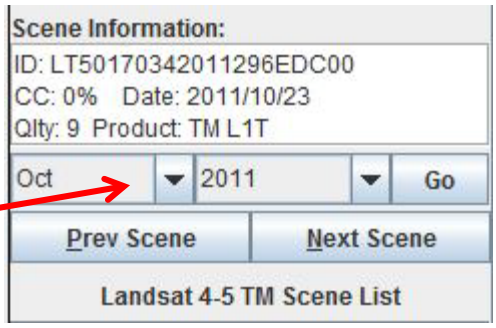
What if we discover that the scene that has been highlighted in the window on the right is actually not the correct scene? Say we want the one above, below, right, or left of the highlighted scene, we can easily chose one of these by clicking on one of the arrows next to ***Max***

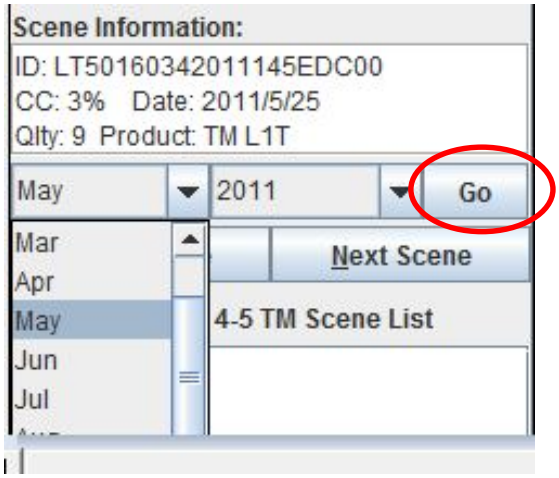


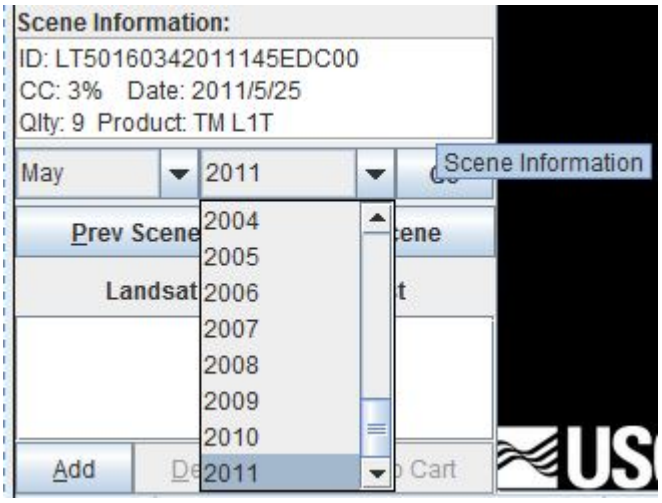


Cloud. We click on the right arrow and it moves to the scene to the east but you can see some over lapping of the scenes does occur - the lake is represented in both scenes (red ovals).

Once you are sure you have the correct scene and the appropriate level of cloud cover ***(CC)***, you need to decide if the date listed is the one you want. You can see other dates that are available by either clicking ***Prev Scene*** or ***Next Scene,*** or choosing a specific date from the down arrows next to the month and year below the ***Scene Information***.

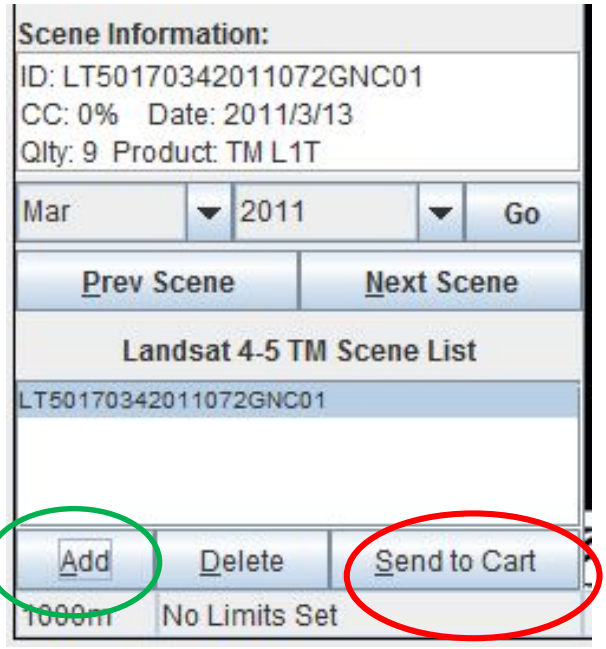






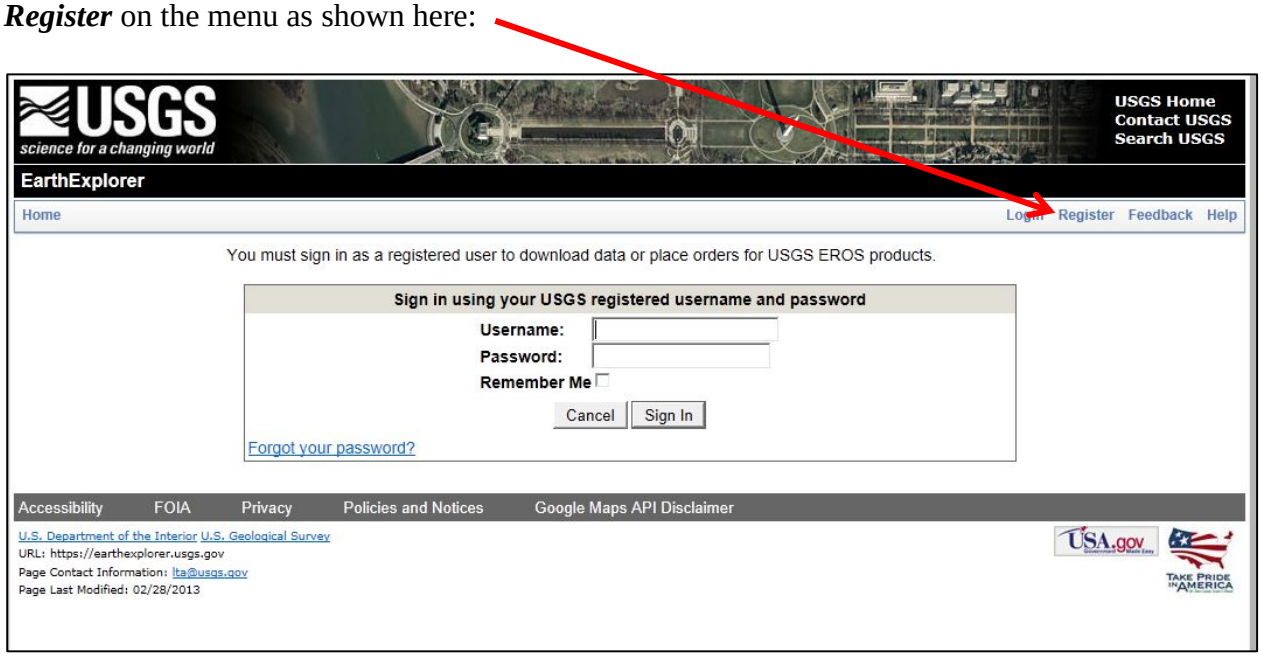
Once you have chosen the date you want, hit ***Go*** (red oval). *(Note: often, the date you choose may be determined by whether you want images collected "leaf-on" (when leaves are on the trees or ("leaf off") (after leaves have fallen in the autumn) to meet specific objectives of your project, or to match with other imagery. This is a decision that you must make depending upon the reasons for your analysis.)* For this exercise, we have chosen CC: 0% and a date of March 13, 2011. We chose this date because Virginia Base Mapping Program aerial

photos of Roanoke were taken during this same week in 2011. To order this scene, click on the ***Add*** button and it lists the scene identification number in the ***Landsat 4-5 TM Scene List.*** If you want other scenes, search for them and click ***Add*** (green oval) to put them in the ***Scene List***. Once you have chosen all the scenes you need, click on ***Send to Cart*** (red oval).

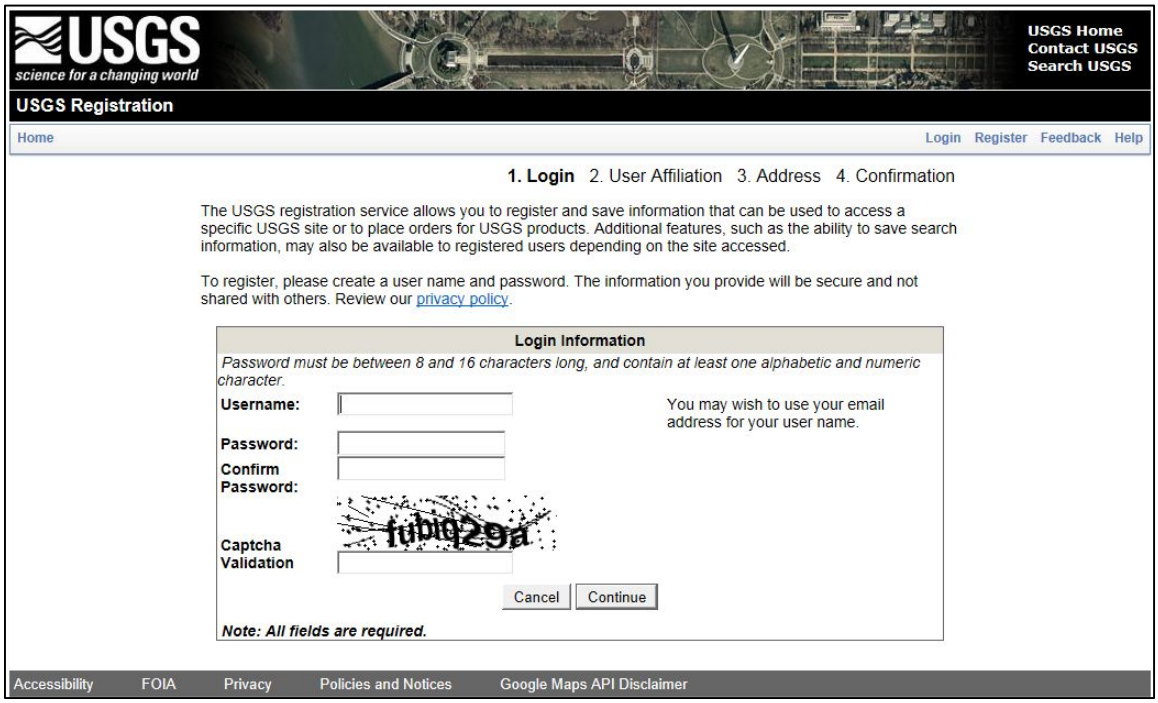


Logging in to your account and submitting your order

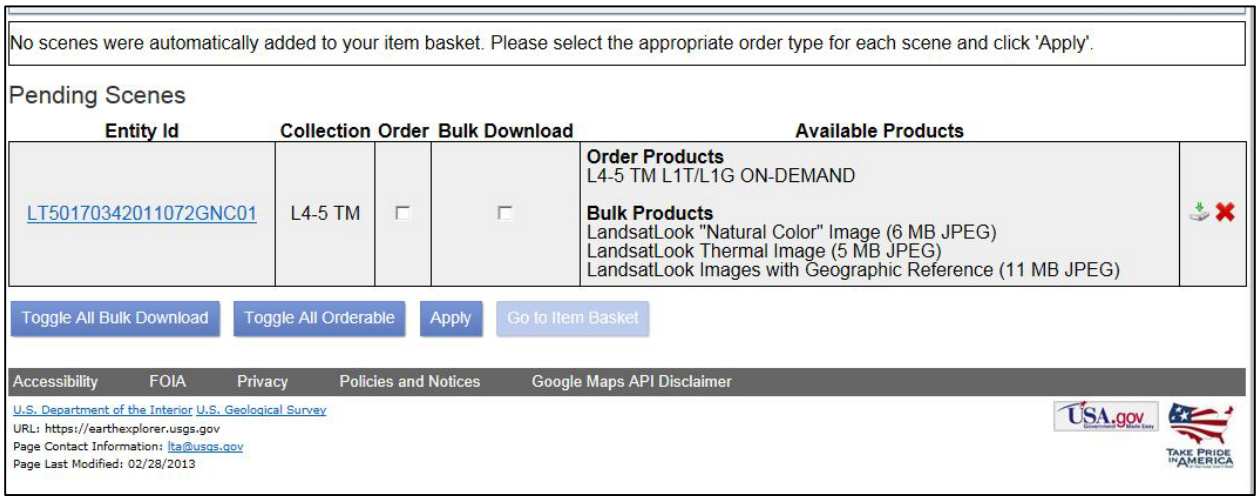
When you get to your cart, you will need to login. If you do not have a login, click on ***Register*** on the menu as shown here:



Registering online with USGS – fill in the blanks and follow the instructions and you click ***Continue***.

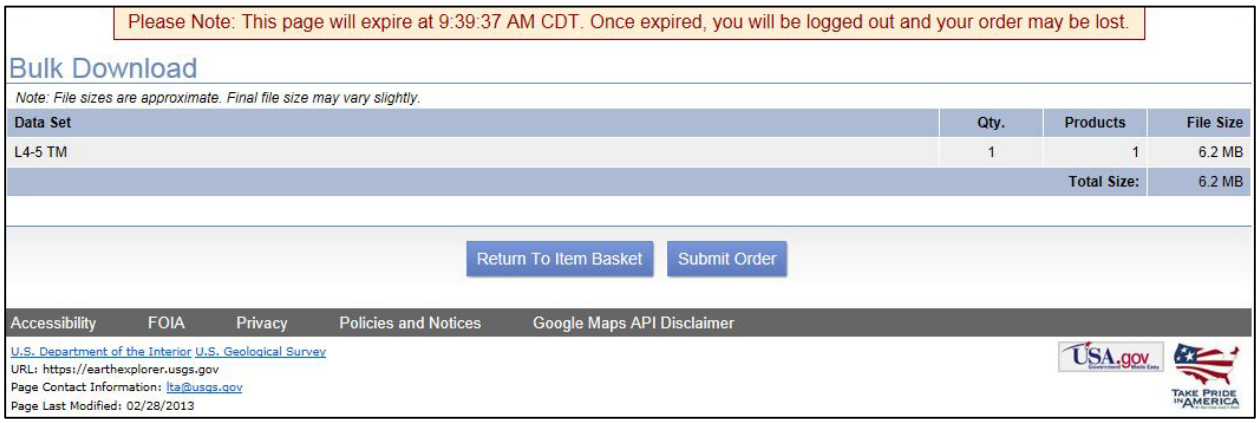


Once you have registered, it will allow you to proceed to the shopping cart for your order.

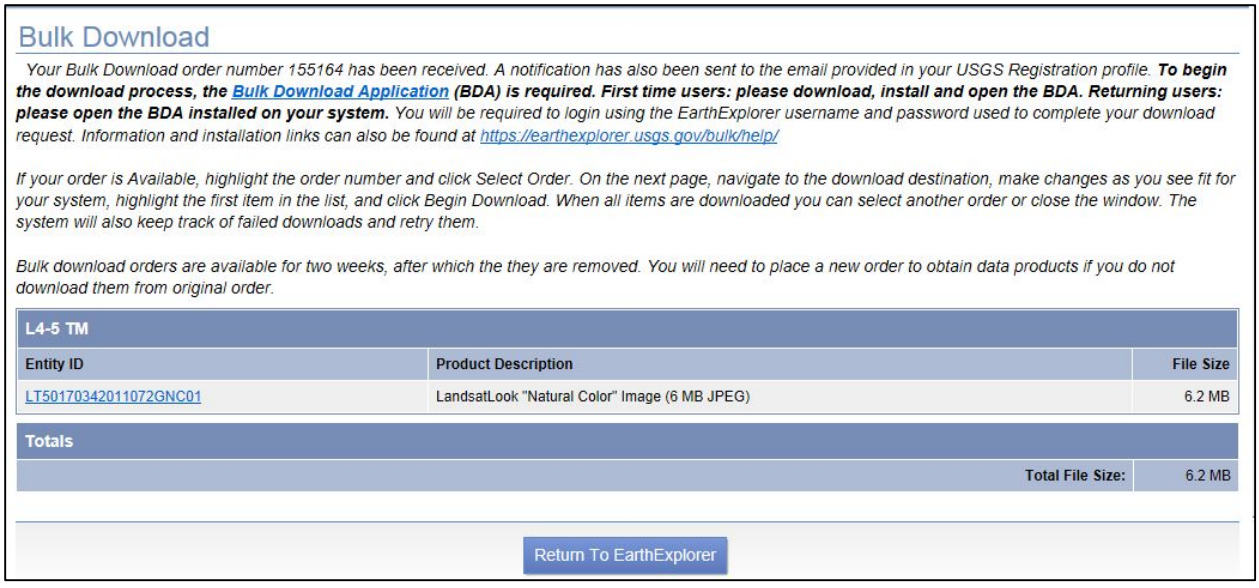


If you click on bulk download, you will get the following screen showing 6.2 MB of information. Before you actually hit Submit Order – please review the next few screen shots.

This type of order will only give you jpegs of the scene. If you only wish to have the scenes for display purposes only, proceed. If you want more than jpegs, skip to page 49.



If you have clicked ***Submit Order***, you will get the following notice. You can immediately click ***Bulk Download Application*** to download the program you will need for bulk downloading OR you can wait for the confirming email.



You will receive an ***Order Confirmation*** email from USGS. You can also click the ***Bulk Download Application*** link here to obtain the program you need for bulk downloading capability. (*Note this is not downloading the information, just accessing the program you need to do the download.*)

USGS Online Bulk Download Order Confirmation — 155164

To begin the download process, the Bulk Download Application (BDA) is required. First time users: please download, install and open the BDA. Returning users: please open the BDA installed on your system. You will be required to login using the EarthExplorer username and password used to complete your download request. Information and installation links can also be found at https://earthexplorer.usgs.gov/bulk/help/

If your order is Available, highlight the order number and click Select Order. On the next page, navigate to the download destination, make changes as you see fit for your system, highlight the first item in the list, and click Begin Download. When all items are downloaded you can select another order or close the window. The system will also keep track of failed downloads and retry them.

Bulk download orders are available for two weeks, after which the they are removed. You will need to place a new order to obtain data products if you do not download them from original order.

L4-5 TM

Entity ID	Product Description	File Size
LT50170342011072GNC01	LandsatLook "Natural Color" Image (6 MB JPEG)	6.2 MB

Totals

Total File Size: 6.2 MB

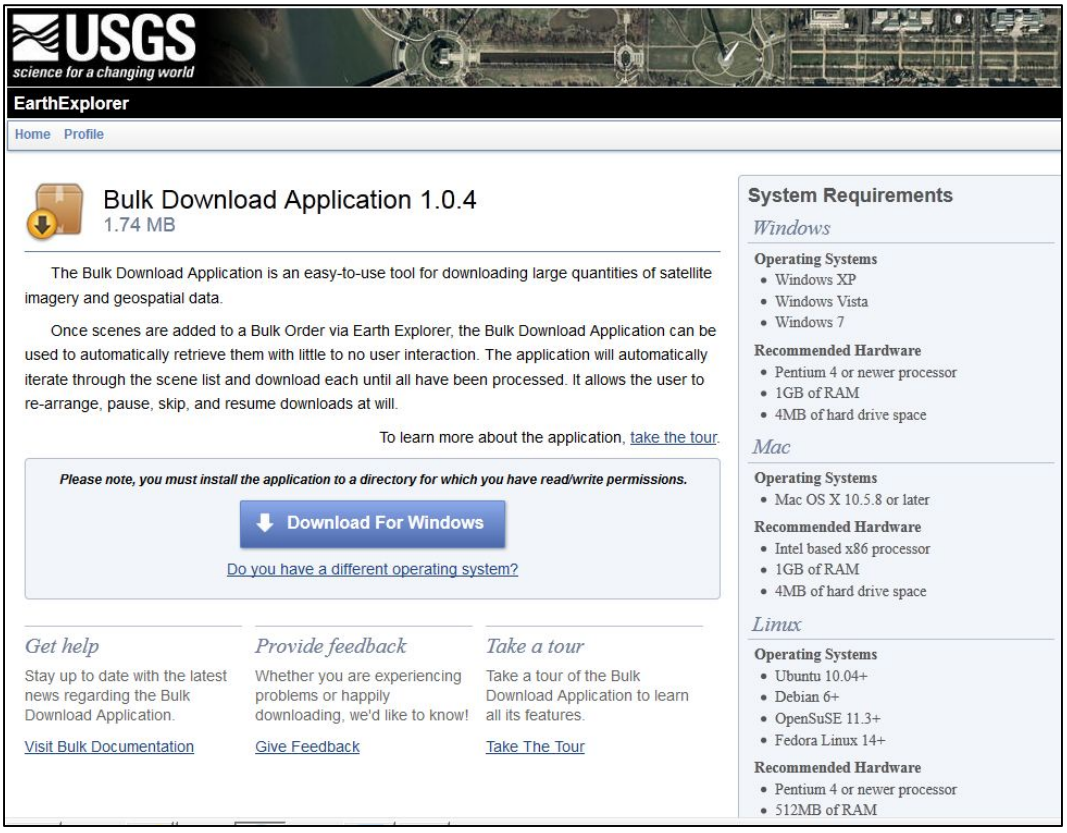
Contact Information

Customer Services
U.S. Geological Survey
Earth Resources Observation & Science Center (EROS)
47914 252nd Street
Sioux Falls, SD 57198-0001

Tel: 605-594-6151
Email: custserv@usgs.gov

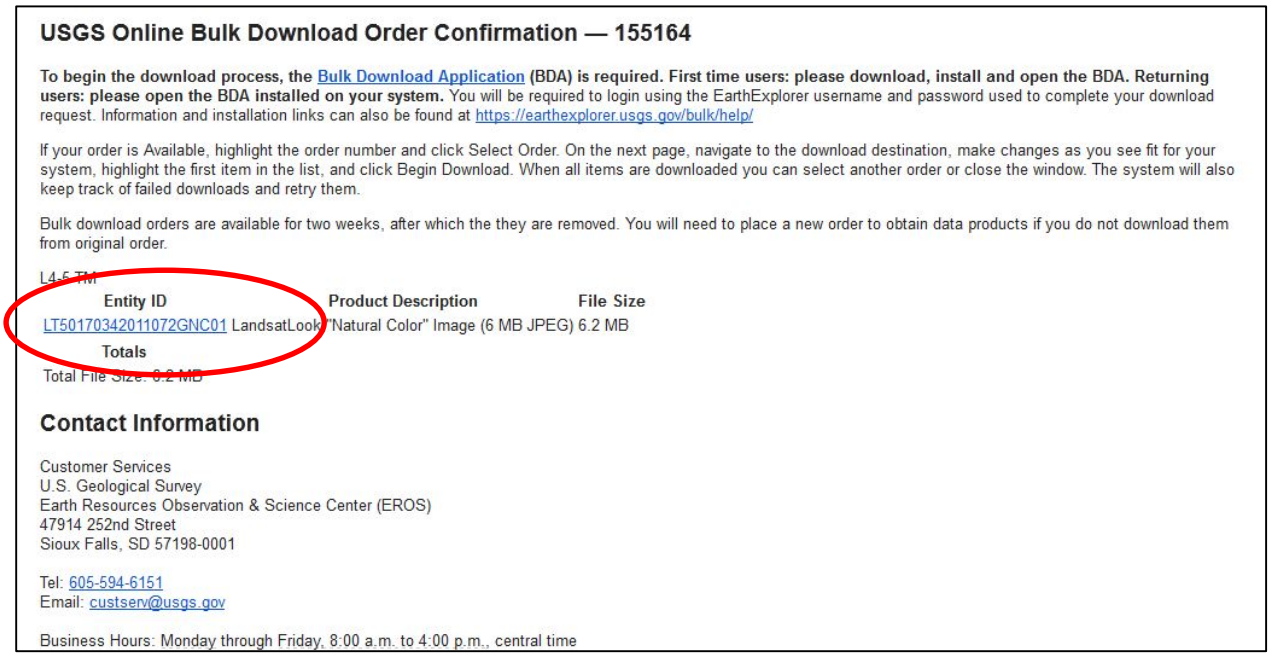
Business Hours: Monday through Friday, 8:00 a.m. to 4:00 p.m., central time

Clicking on ***Bulk Download Application*** will give you the following two screens. Click on ***Download For Windows***.



Click on ***Run*** to download the program.

Once the application has been downloaded, you go back to your email and click on the ***Entity ID*** (red oval). This will give you a screenshot of the scene and metadata about the scene.



USGS Online Bulk Download Order Confirmation — 155164

To begin the download process, the Bulk Download Application (BDA) is required. First time users: please download, install and open the BDA. Returning users: please open the BDA installed on your system. You will be required to login using the EarthExplorer username and password used to complete your download request. Information and installation links can also be found at https://earthexplorer.usgs.gov/bulk/help/

If your order is Available, highlight the order number and click Select Order. On the next page, navigate to the download destination, make changes as you see fit for your system, highlight the first item in the list, and click Begin Download. When all items are downloaded you can select another order or close the window. The system will also keep track of failed downloads and retry them.

Bulk download orders are available for two weeks, after which the they are removed. You will need to place a new order to obtain data products if you do not download them from original order.

L4-5 TM

Entity ID	Product Description	File Size
LT50170342011072GNC01	LandsatLook "Natural Color" Image (6 MB JPEG)	6.2 MB

Totals

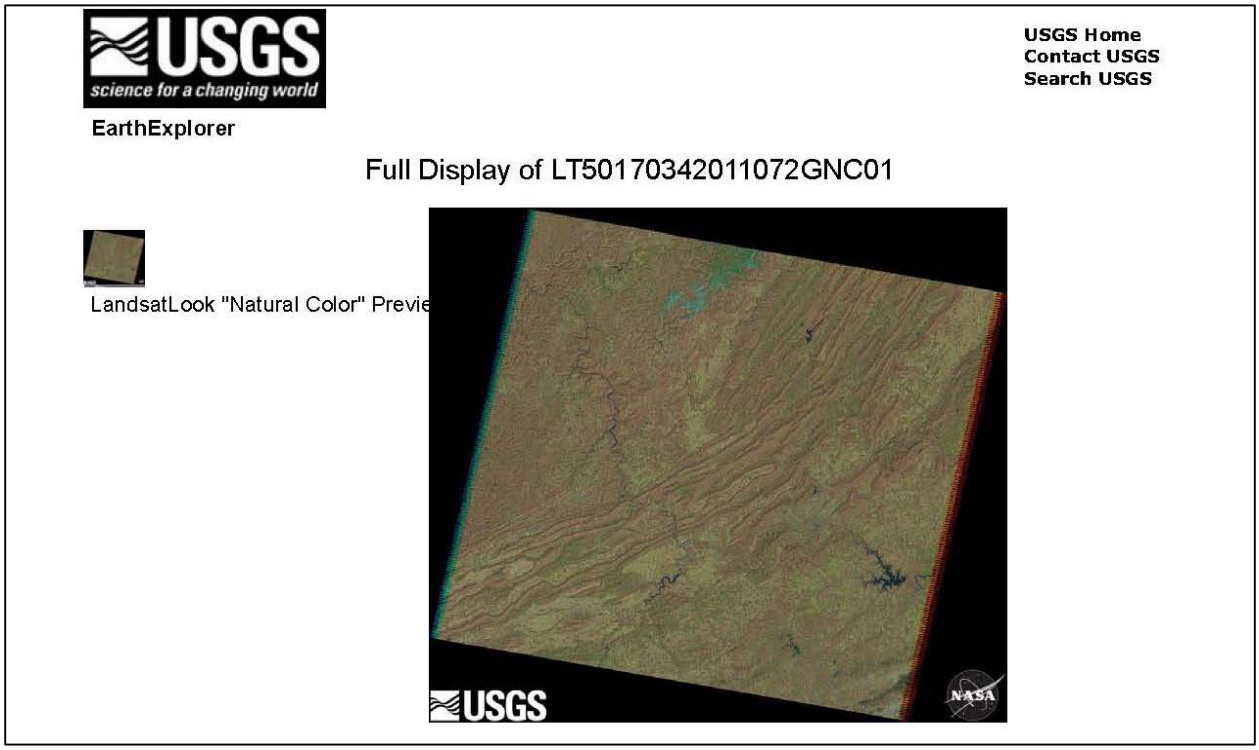
Total File Size: 6.2 MB

Contact Information

Customer Services
U.S. Geological Survey
Earth Resources Observation & Science Center (EROS)
47914 252nd Street
Sioux Falls, SD 57198-0001

Tel: 605-594-6151
Email: custserv@usgs.gov

Business Hours: Monday through Friday, 8:00 a.m. to 4:00 p.m., central time


USGS
science for a changing world
EarthExplorer
USGS Home
Contact USGS
Search USGS
Full Display of LT50170342011072GNC01
LandsatLook "Natural Color" Previe
USGS
NASA

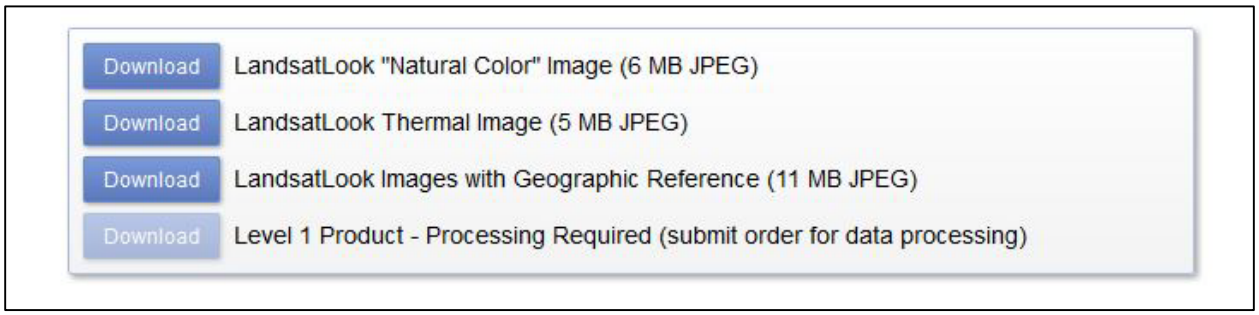
Data Set Attribute	Attribute Value
Landsat Scene Identifier	LT50170342011072GNC01
Spacecraft Identifier	LANDSAT_5
Sensor Mode	BUMPER
Station Identifier	GNC
Day/Night	DAY
WRS Path	017
WRS Row	034
WRS Type	2
Date Acquired	2011/03/13
Start Time	2011:072:15:48:53.19331
Stop Time	2011:072:15:49:19.80625
Sensor Anomalies	N
Acquisition Quality	9
Quality Band 1	9
Quality Band 2	9
Quality Band 3	9
Quality Band 4	9
Quality Band 5	9
Quality Band 6	9
Quality Band 7	9

Data Set Attribute	Attribute Value
Cloud Cover	.06
Cloud Cover Quad Upper Left	.04
Cloud Cover Quad Upper Right	0
Cloud Cover Quad Lower Left	.01
Cloud Cover Quad Lower Right	.17
Sun Elevation	43.19207936
Sun Azimuth	143.81480711
Browse Exists	Yes
Data Category	NOMINAL
Map Projection L0Ra	
Data Type L0Rp	PR
Data Type Level 1	PROCESSING REQUIRED
Corner UL Latitude Product	38.44254 (38°26'33.14"N)
Corner UL Longitude Product	-81.77234 (81°46'20.42"S)
Corner UR Latitude Product	38.42840 (38°25'42.24"N)
Corner UR Longitude Product	-79.02264 (79°01'21.50"S)
Corner LR Longitude Product	-79.07263 (79°04'21.47"S)
Corner LL Latitude Product	36.52009 (36°31'12.32"N)
Corner LL Longitude Product	-81.75280 (81°45'10.08"W)
Corner LR Latitude Product	36.50689 (36°30'24.80"N)
Center Latitude	37°29'01.86"N
Center Longitude	80°24'21.60"W
NW Corner Lat	38°25'09.08"N
NW Corner Long	81°12'34.70"W
NE Corner Lat	38°06'59.36"N
NE Corner Long	79°07'51.13"W
SE Corner Lat	36°32'32.06"N
SE Corner Long	79°37'24.56"W
SW Corner Lat	36°50'19.61"N
SW Corner Long	81°39'38.23"W
Center Latitude dec	37.48385
Center Longitude dec	-80.406
NW Corner Lat dec	38.41919
NW Corner Long dec	-81.20964
NE Corner Lat dec	38.11649
NE Corner Long dec	-79.13087
SE Corner Lat dec	36.54224
SE Corner Long dec	-79.62349
SW Corner Lat dec	36.83878
SW Corner Long dec	-81.66062

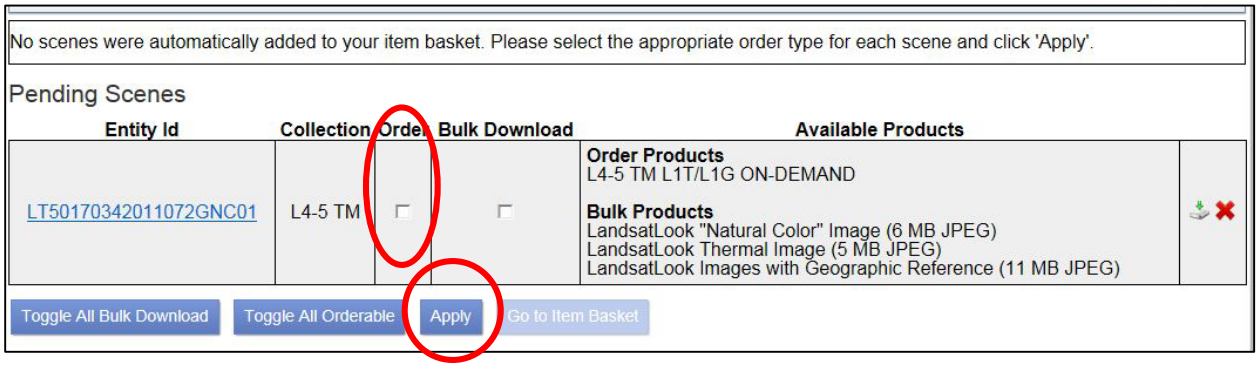
Download Order

FGDC Format Dismiss Window

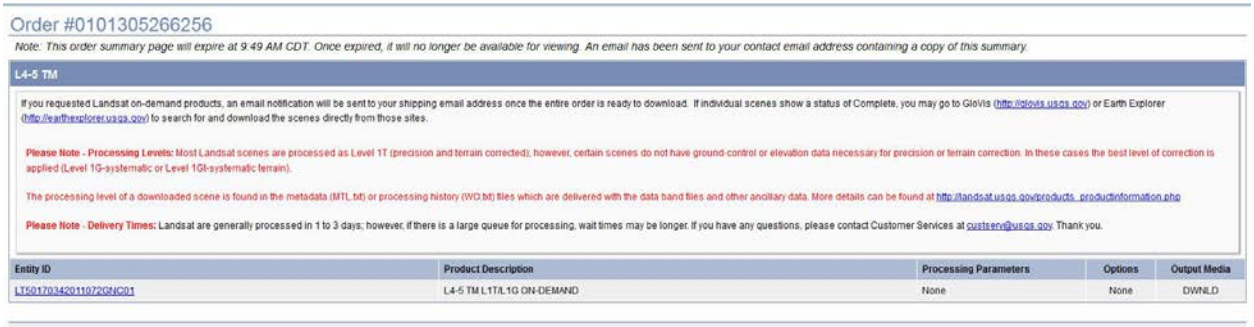
Again, this process will provide only jpegs, which will represent your area, but will not provide the data necessary for analysis. For images to use in analyses, you need the ***Level 1 Product***, which is not available for immediate direct download. If you click on ***Download***, you get the below screen. If you click on ***Order***, you can order the ***Level 1 Product***.



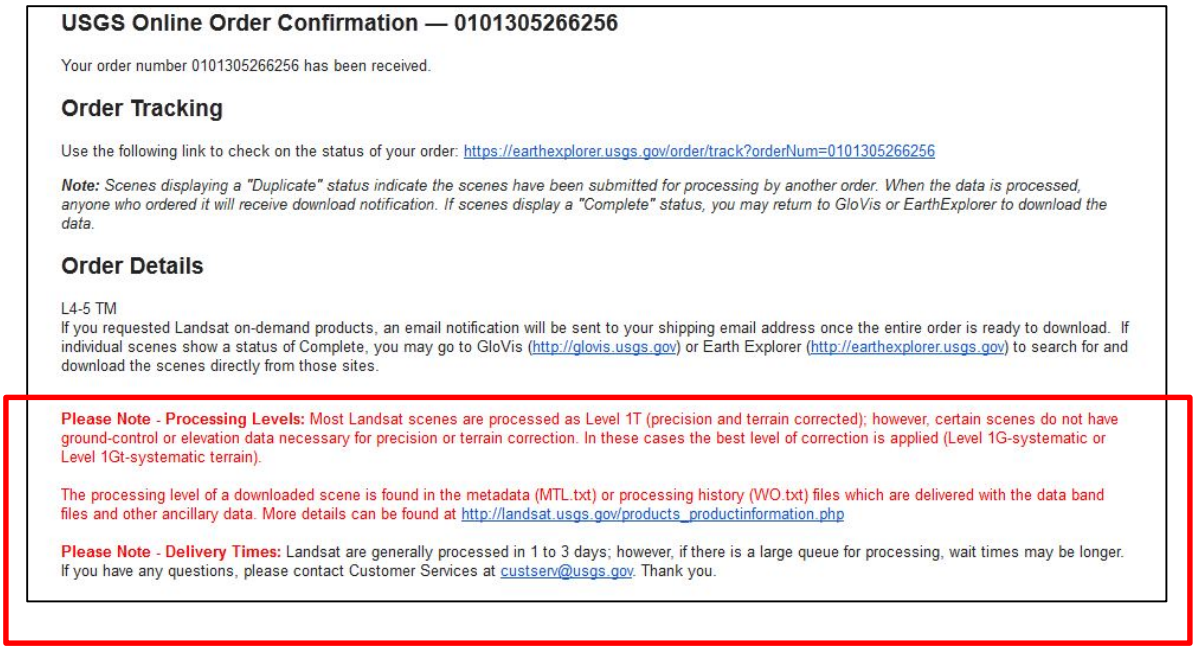
When you click on ***Order,*** you get the following screen - click on the box below ***Order*** and then click ***Apply***.



Your will get a confirmation message with an order number.



You will also get an ***Online Order Confirmation*** email *(note the processing time of 1 – 3 days)*:



USGS Online Order Confirmation — 0101305266256

Your order number 0101305266256 has been received.

Order Tracking

Use the following link to check on the status of your order: https://earthexplorer.usgs.gov/order/track?orderNum=0101305266256

Note: *Scenes displaying a "Duplicate" status indicate the scenes have been submitted for processing by another order. When the data is processed, anyone who ordered it will receive download notification. If scenes display a "Complete" status, you may return to GloVis or EarthExplorer to download the data.*

Order Details

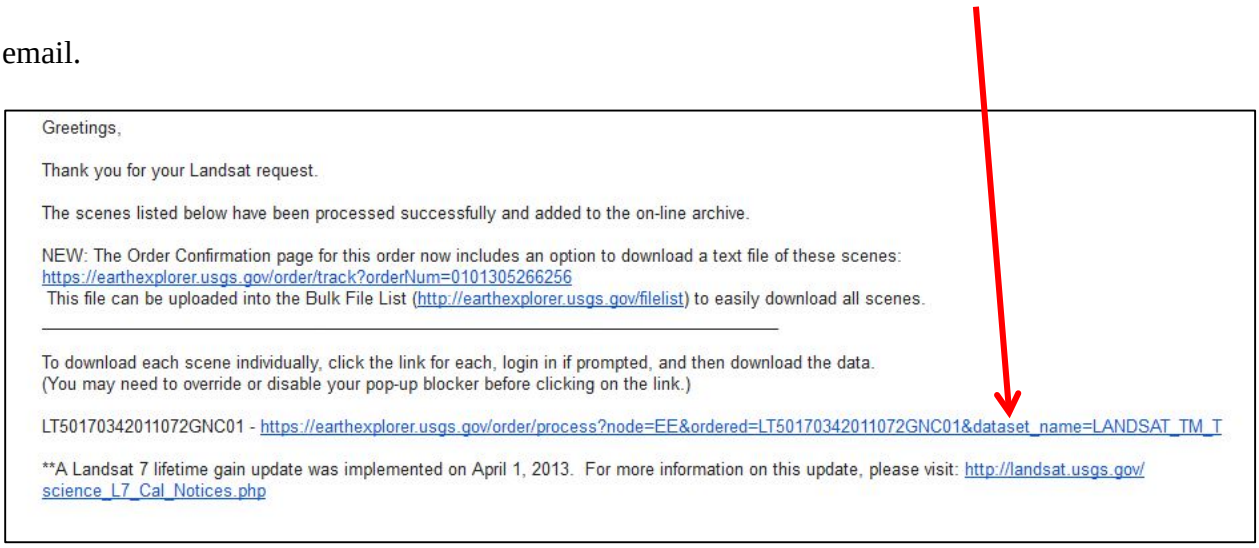
L4-5 TM
If you requested Landsat on-demand products, an email notification will be sent to your shipping email address once the entire order is ready to download. If individual scenes show a status of Complete, you may go to GloVis (http://glovis.usgs.gov) or Earth Explorer (http://earthexplorer.usgs.gov) to search for and download the scenes directly from those sites.

Please Note - Processing Levels: Most Landsat scenes are processed as Level 1T (precision and terrain corrected); however, certain scenes do not have ground-control or elevation data necessary for precision or terrain correction. In these cases the best level of correction is applied (Level 1G-systematic or Level 1Gt-systematic terrain).

The processing level of a downloaded scene is found in the metadata (MTL.txt) or processing history (WO.txt) files which are delivered with the data band files and other ancillary data. More details can be found at http://landsat.usgs.gov/products_productinformation.php

Please Note - Delivery Times: Landsat are generally processed in 1 to 3 days; however, if there is a large queue for processing, wait times may be longer. If you have any questions, please contact Customer Services at custserv@usgs.gov. Thank you.

You will get another email when the scene is ready for download. Click on the link within the email.



Greetings,

Thank you for your Landsat request.

The scenes listed below have been processed successfully and added to the on-line archive.

NEW: The Order Confirmation page for this order now includes an option to download a text file of these scenes:
https://earthexplorer.usgs.gov/order/track?orderNum=0101305266256
This file can be uploaded into the Bulk File List (http://earthexplorer.usgs.gov/filelist) to easily download all scenes.

To download each scene individually, click the link for each, login in if prompted, and then download the data.
(You may need to override or disable your pop-up blocker before clicking on the link.)

LT50170342011072GNC01 - https://earthexplorer.usgs.gov/order/process?node=EE&ordered=LT50170342011072GNC01&dataset_name=LANDSAT_TM_T

**A Landsat 7 lifetime gain update was implemented on April 1, 2013. For more information on this update, please visit: http://landsat.usgs.gov/science_L7_Cal_Notices.php

This will take you to the EarthExplorer site where you will need to Login. Once logged in, you will get the following screen. *(Note - if you did not do the **Bulk Download Application** (red oval), you will need to do those steps before downloading your Landsat scenes - see pages 45-47).* Once you have completed the ***Bulk Download Application***, you can click on the ***Entity ID*** (yellow oval).

Bulk Download

Your Bulk Download order number 155378 has been received. A notification has also been sent to the email provided in your USGS Registration profile. **To begin the download process, the Bulk Download Application (BDA) is required. First time users: please download, install and open the BDA. Returning users: please open the BDA installed on your system.** You will be required to login using the EarthExplorer username and password used to complete your download request. Information and installation links can also be found at https://earthexplorer.usgs.gov/bulk/help/

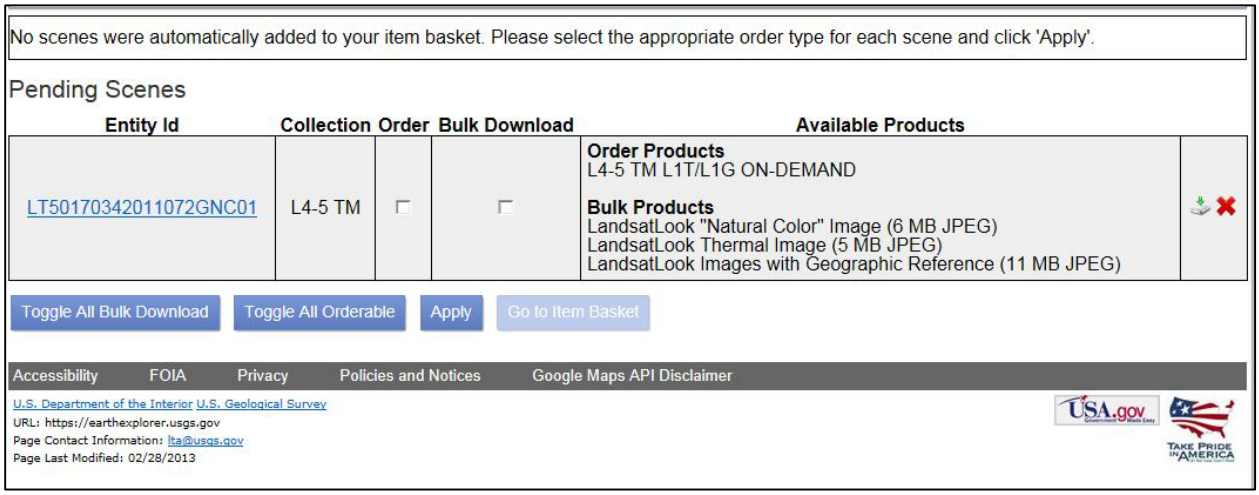
If your order is Available, highlight the order number and click Select Order. On the next page, navigate to the download destination, make changes as you see fit for your system, highlight the first item in the list, and click Begin Download. When all items are downloaded you can select another order or close the window. The system will also keep track of failed downloads and retry them.

Bulk download orders are available for two weeks, after which the they are removed. You will need to place a new order to obtain data products if you do not download them from original order.

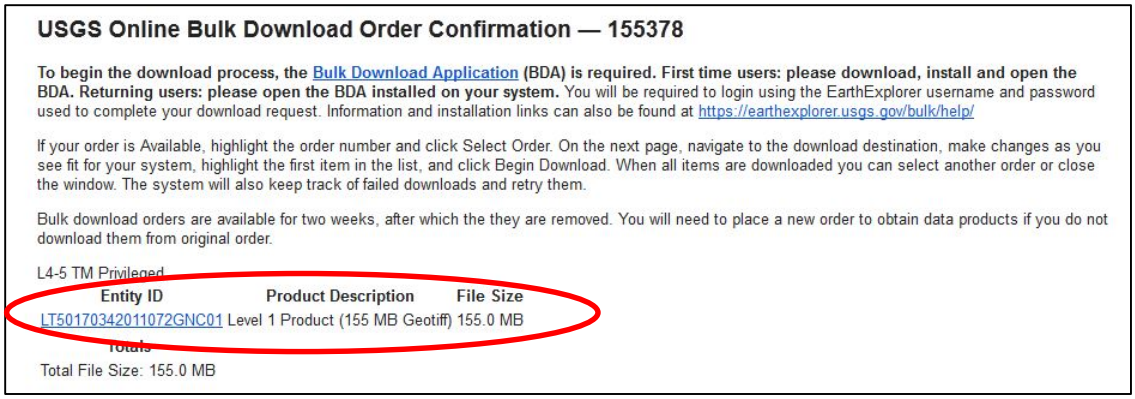
L4-5 TM Privileged

Entity ID	Product Description	File Size
LT50170342011072GNC01	Level 1 Product (155 MB GeoTiff)	155.0 MB

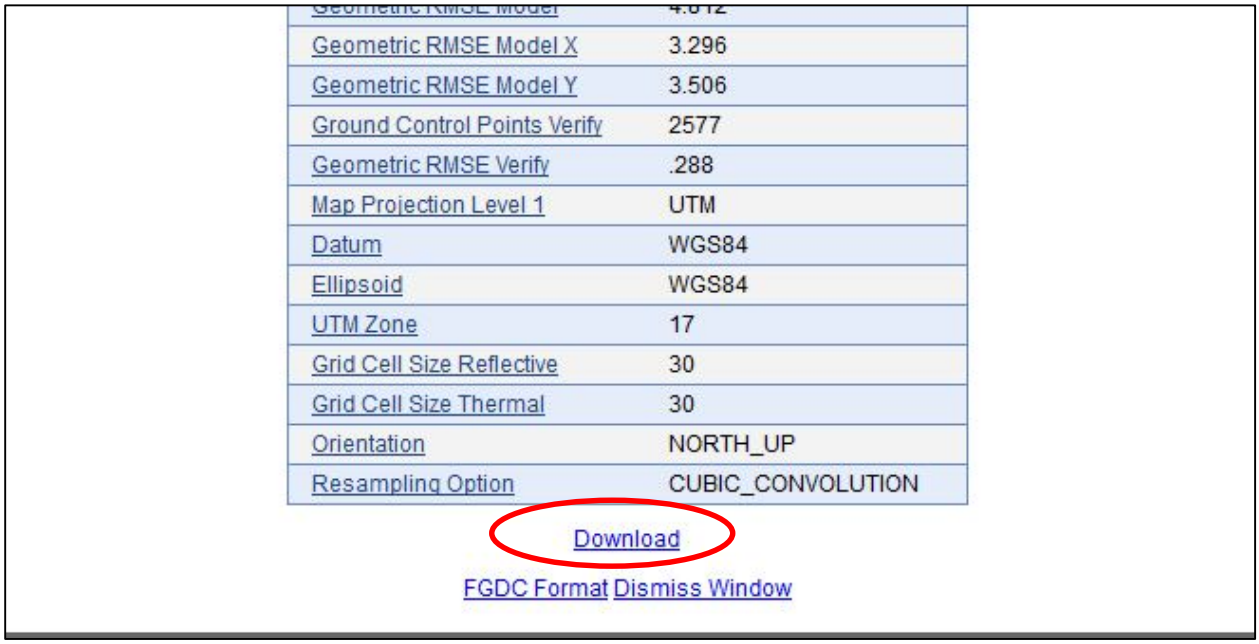
You will get the following screens (yes again) – click ***Bulk Download*** and ***Apply***.



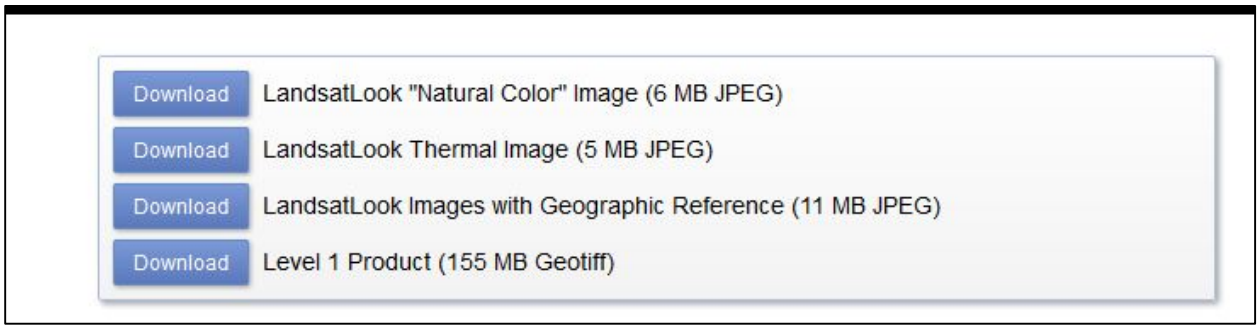
You will get another email with a link to the download, click on the ***Entity ID*** number within the email (red oval) – note the file type (***Geotiff***) and file size (***155.0 MB***).



You will get the screens as you did on pages 48 and 49. *(Note – we will discuss the metadata in another tutorial.)* Go to the bottom and click on ***Download*** (red oval).

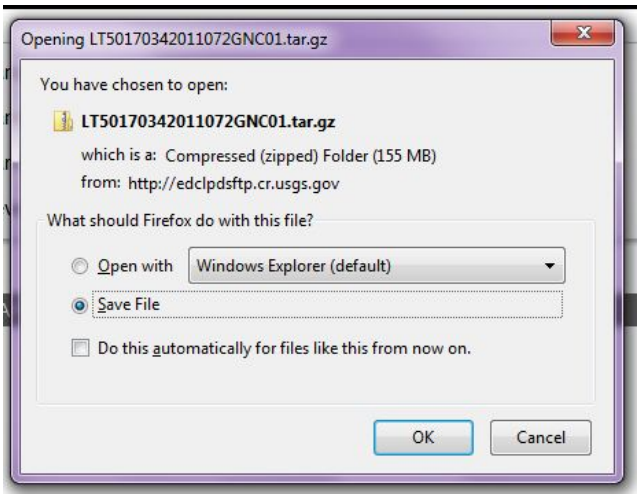


You will get the following screen. Again, you have access to the jpegs (as you did in the steps above), but now you have access to the ***Level 1 Product (155MB Geotiff)*** – geotiffs are images upon which you can perform analyses. Click on ***Download*** next to the ***Level 1 Product***.

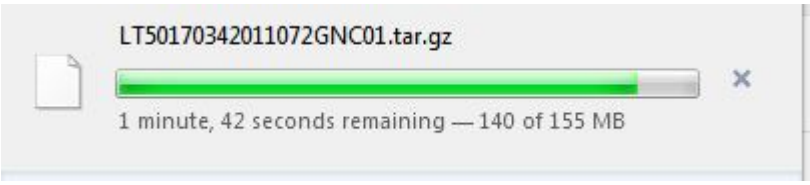


You get the download window.

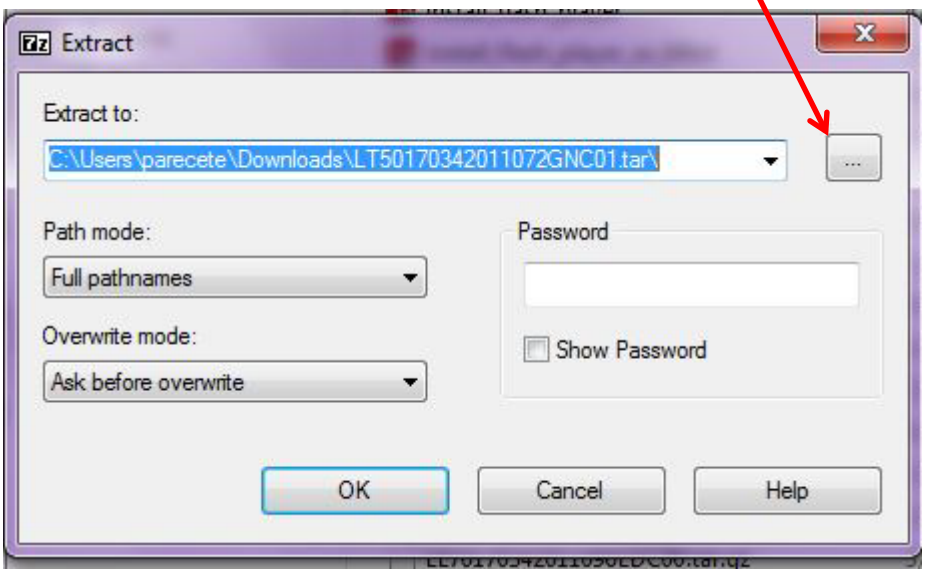
Save it and wait.



This is a very large file and will take a few minutes or more (depending on your WiFi speed) to save.

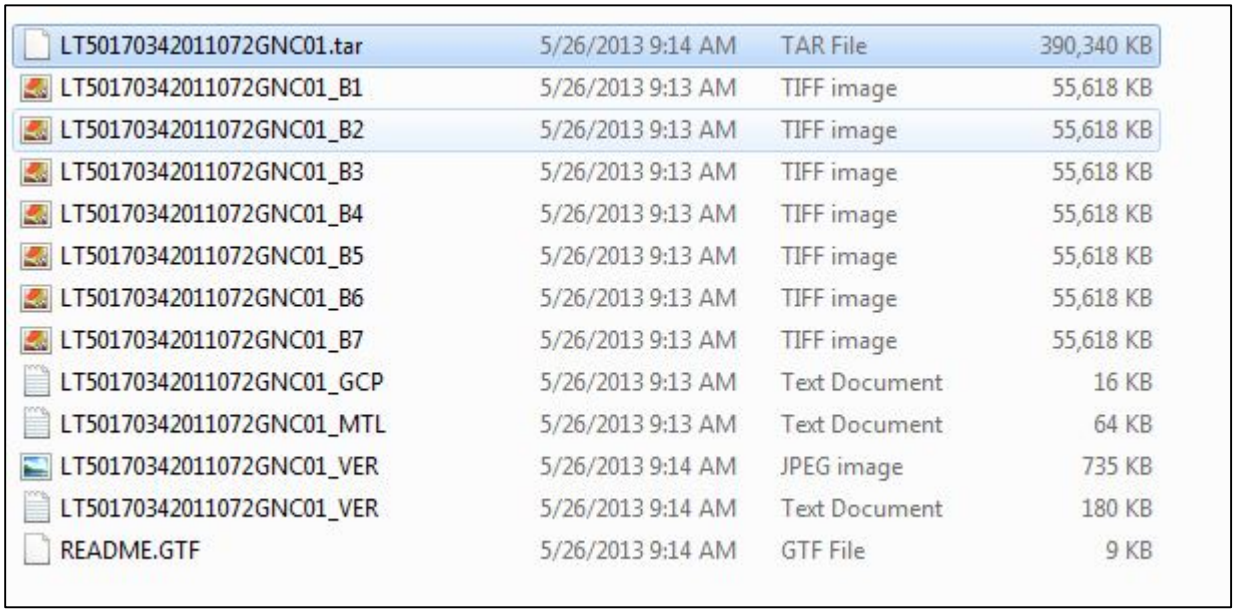


Once it has finished downloading, right click on the file and click on ***Open Containing Folder***. This will take you to the area on your computer where the file downloaded. Right click on the file name and extract it (unzipping it). Clicking on this button, you can navigate to the folder where you want to save the file.



Once it has unzipped, navigate to the folder where you unzipped it. You will find another zipped file (.tar). *(Note, because of the file size, these are double zipped, so you have to extract (unzip) them twice.)*

Right click and extract to here (unzip). Once it is finished, you will have the following files in your folder:



LT50170342011072GNC01.tar	5/26/2013 9:14 AM	TAR File	390,340 KB
LT50170342011072GNC01_B1	5/26/2013 9:13 AM	TIFF image	55,618 KB
LT50170342011072GNC01_B2	5/26/2013 9:13 AM	TIFF image	55,618 KB
LT50170342011072GNC01_B3	5/26/2013 9:13 AM	TIFF image	55,618 KB
LT50170342011072GNC01_B4	5/26/2013 9:13 AM	TIFF image	55,618 KB
LT50170342011072GNC01_B5	5/26/2013 9:13 AM	TIFF image	55,618 KB
LT50170342011072GNC01_B6	5/26/2013 9:13 AM	TIFF image	55,618 KB
LT50170342011072GNC01_B7	5/26/2013 9:13 AM	TIFF image	55,618 KB
LT50170342011072GNC01_GCP	5/26/2013 9:13 AM	Text Document	16 KB
LT50170342011072GNC01_MTL	5/26/2013 9:13 AM	Text Document	64 KB
LT50170342011072GNC01_VER	5/26/2013 9:14 AM	JPEG image	735 KB
LT50170342011072GNC01_VER	5/26/2013 9:14 AM	Text Document	180 KB
README.GTF	5/26/2013 9:14 AM	GTF File	9 KB

You have successfully downloaded the Landsat scene that includes Roanoke, Virginia dated March 13, 2011. We will discuss the files in the tutorial on Information about your Downloaded Landsat Imagery and Band Combinations.

You will need to determine if your downloaded imagery needs further processing beyond that completed by the USGS. For more information about the level and type of USGS processing of Landsat scenes, go to http://landsat.usgs.gov/Landsat_Processing_Details.php. See also Masek, J.G., et al., *A Landsat surface reflectance data set for North America, 1990-2000.* Geoscience and Remote Sensing Letters, 2006. **3**: p. 68-72.

This exercise, in combination with the companion EarthExplorer tutorial prepares you with the skills to download Landsat imagery. Subsequent tutorials will introduce techniques to analyze this imagery to extract information to support your research objectives.

Notes:

8. Downloading Landsat Imagery Using EarthExplorer

The instructional materials contained within these documents are copyrighted property of VirginiaView, its partners and other participating AmericaView consortium members. These materials may be reproduced and used by educators for instructional purposes. No permission is granted to use the materials for paid consulting or instruction where a fee is collected. Reproduction or translation of any part of this document beyond that permitted in Section 107 or 108 of the 1976 United States Copyright Act without the permission of the copyright owner(s) is unlawful.

This activity introduces you to procedures for using the EarthExplorer utility to select and download Landsat imagery to your computer as a preliminary step for analysis to extract information for specific application tasks. For this exercise, you will require a computer with an internet connection.

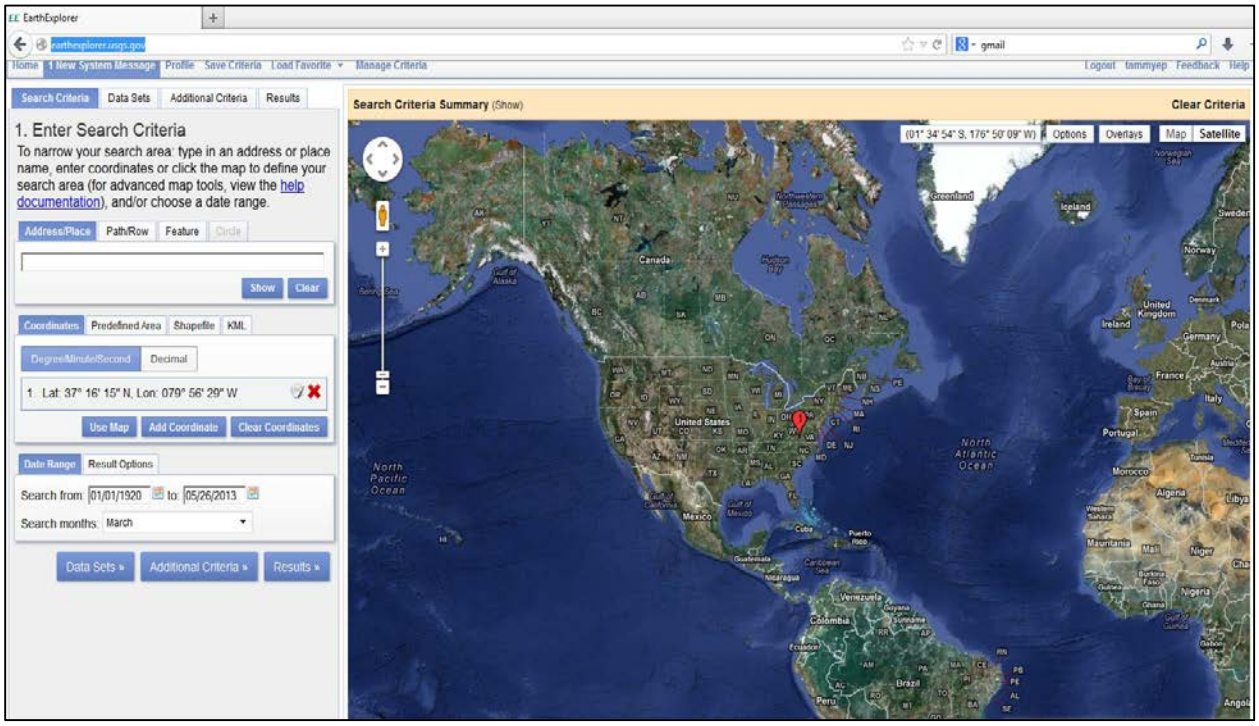
Introduction:

Landsat images are frequently used for land remote sensing analyses. The first Landsat Satellite was launched in 1972. The Landsat mission continues to this date with the most recent Landsat Data Continuity Mission satellite (now Landsat 8) launched in February, 2013. For more information and specific details on Landsat satellites, sensors, and potential analyses using Landsat images go to: http://landsat.usgs.gov/

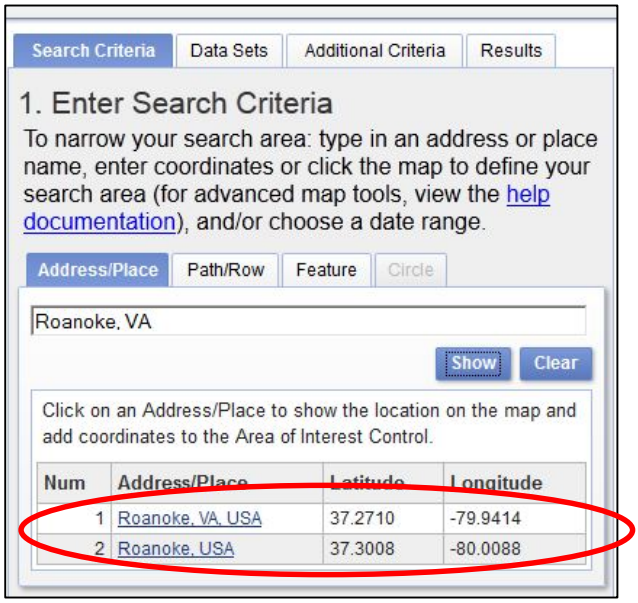
Landsat images are free and downloadable from the internet from http://earthexplorer.usgs.gov/. This tutorial provides step by step instructions to download images via the internet. Decisions on exactly which specific images you need for your specific analyses cannot be answered from this tutorial.

Navigating to your desired scene

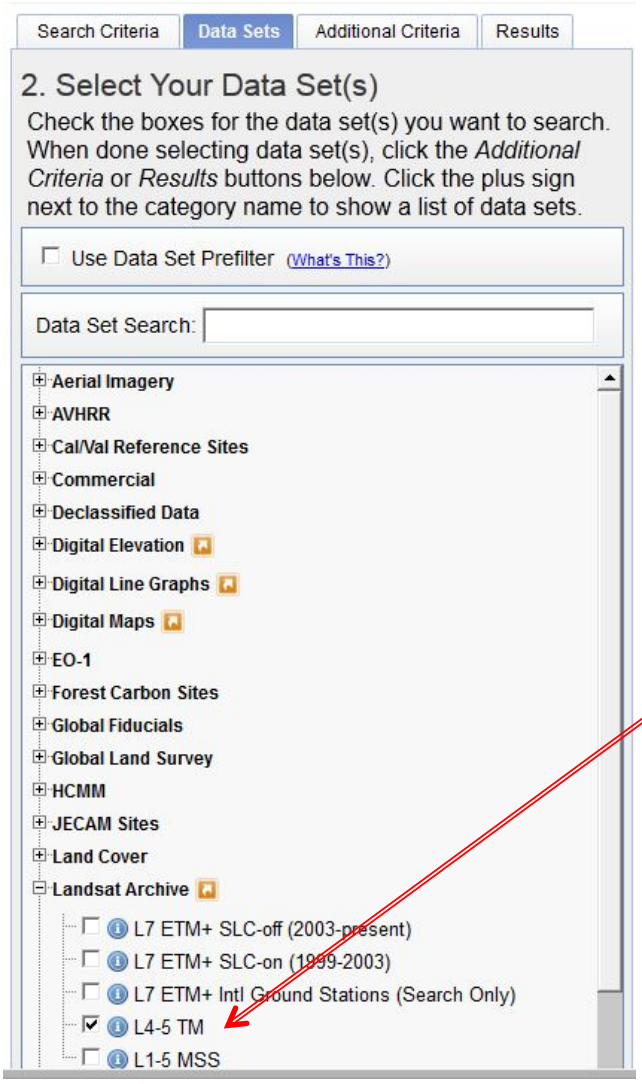
Go to http://earthexplorer.usgs.gov/. The screen looks like this:



You can actually put in an address, city, or country, etc. and the map will place a red balloon on the map for your selection. For this example, we are using Roanoke, Virginia. As you can see in the next screenshot, EarthExplorer identified a couple of options for my search parameters. We clicked on Roanoke, VA, USA.

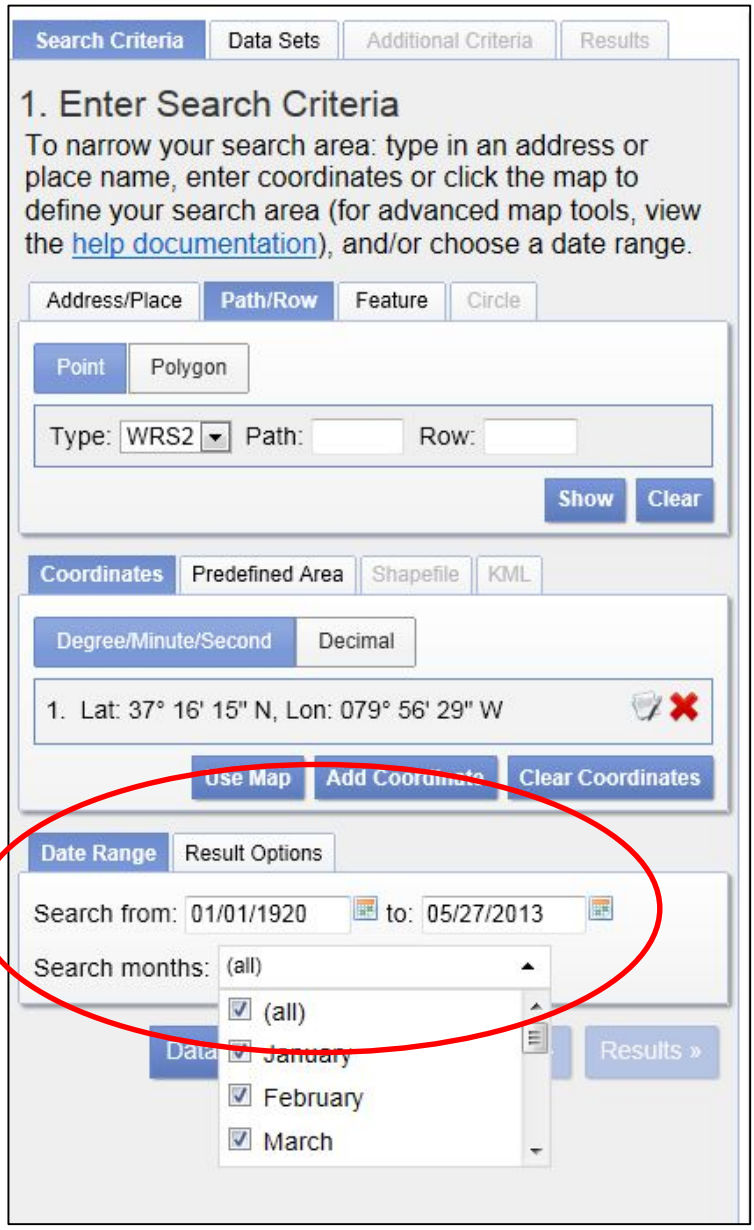


After choosing your area of interest, the next item to choose is the ***Data Sets***.



By clicking on the ***Data Sets*** tab, you will get a list of all sensors and satellites available for downloading from ***EarthExplorer***. We are interested in the ***Landsat Archive*** and ***L4-5 TM*** sensor, so have placed a check mark here.

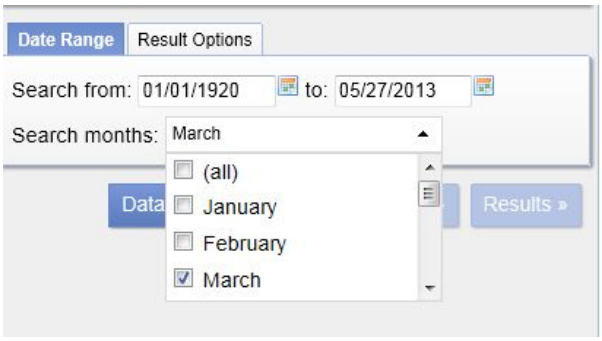
Selecting the image date & related criteria

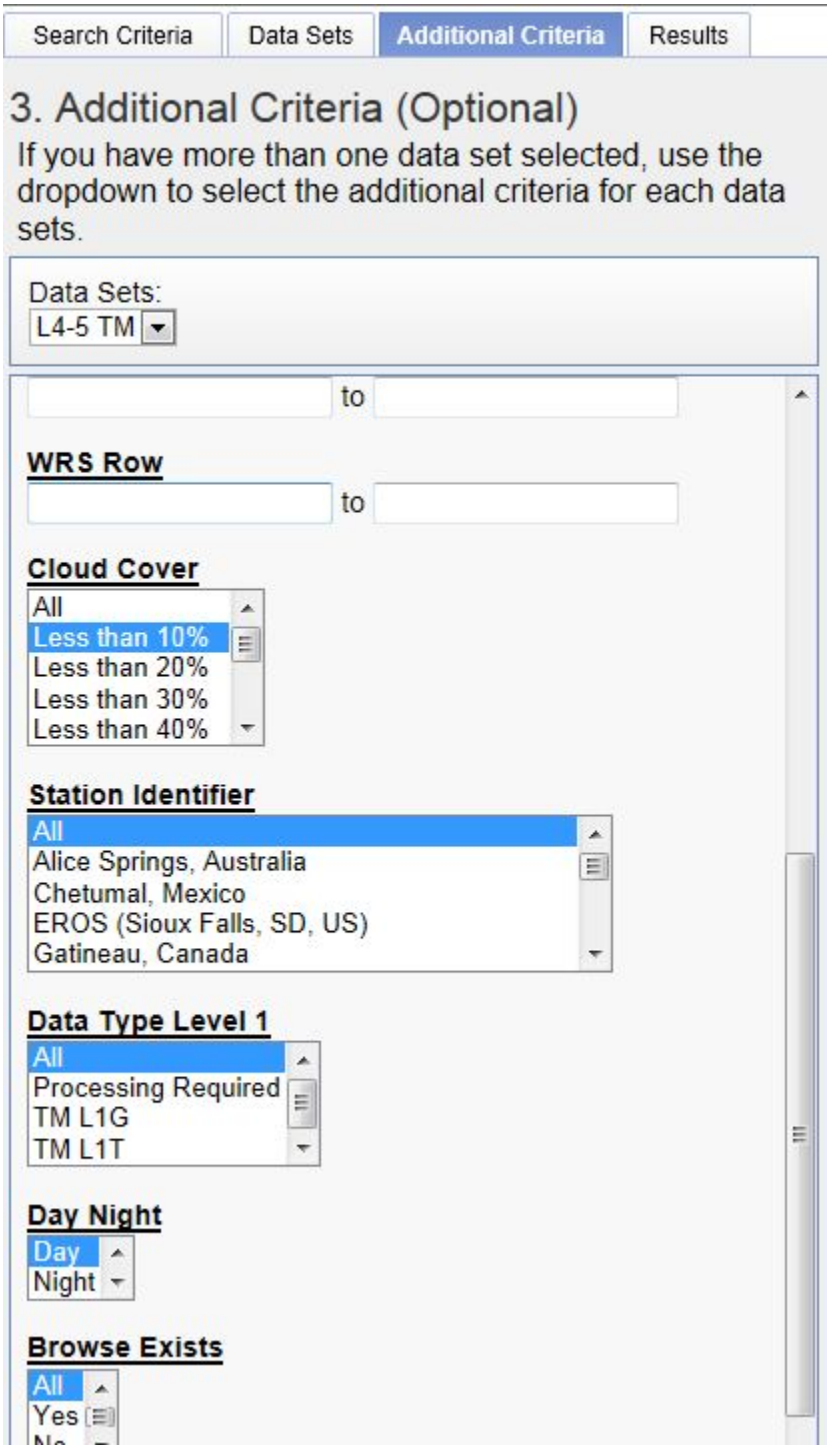


Go back to the ***Search Criteria*** tab**.**

Go to ***Date Range*** and enter the time period for which you wish to have Landsat scenes. *(Note: often, the date you choose may be determined by whether you want images collected "leaf-on" (when leaves are on the trees) or "leaf off" (after leaves have fallen in the autumn) to meet specific objectives of your project, or to match with other imagery. This is a decision that you must make depending upon the reasons for your analysis.)*

For this particular exercise, we want spring and leaf-off, so I have unclicked ***(all)*** on the ***Search months*** area and only clicked ***March***.





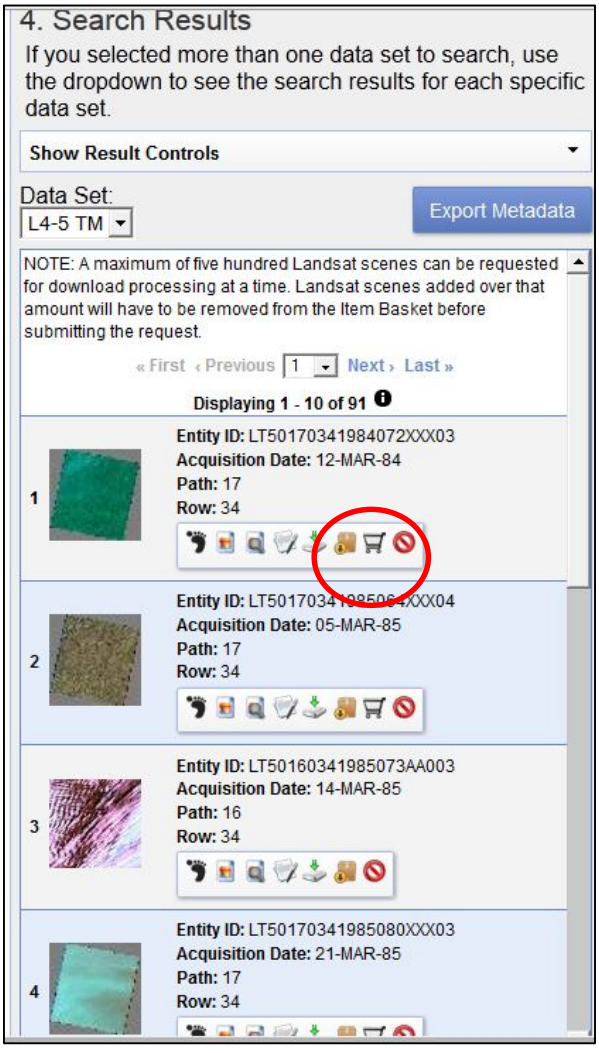
Next, click on the ***Additional Criteria*** tab at the top.

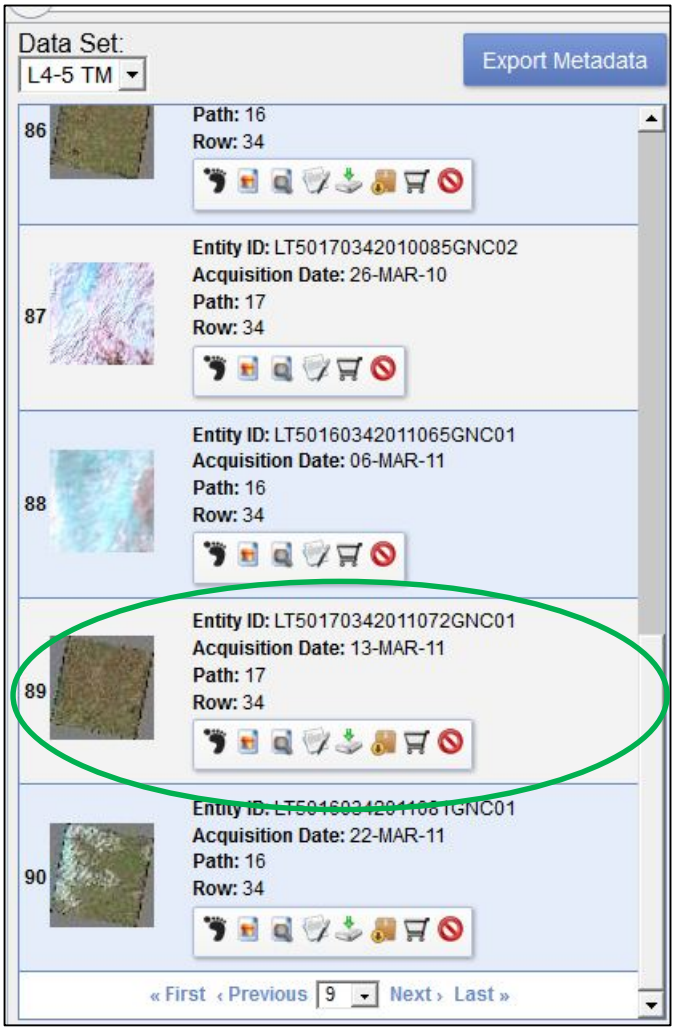
Note any additional parameters you wish. In this case, we want scenes with ***Less than 10% Cloud Cover.*** We want all ***Stations*** and all ***Data Types***. *(Note - Landsat scenes are only daytime scenes.)*

Finally, click on the ***Results*** button at the bottom

Interpreting the search results

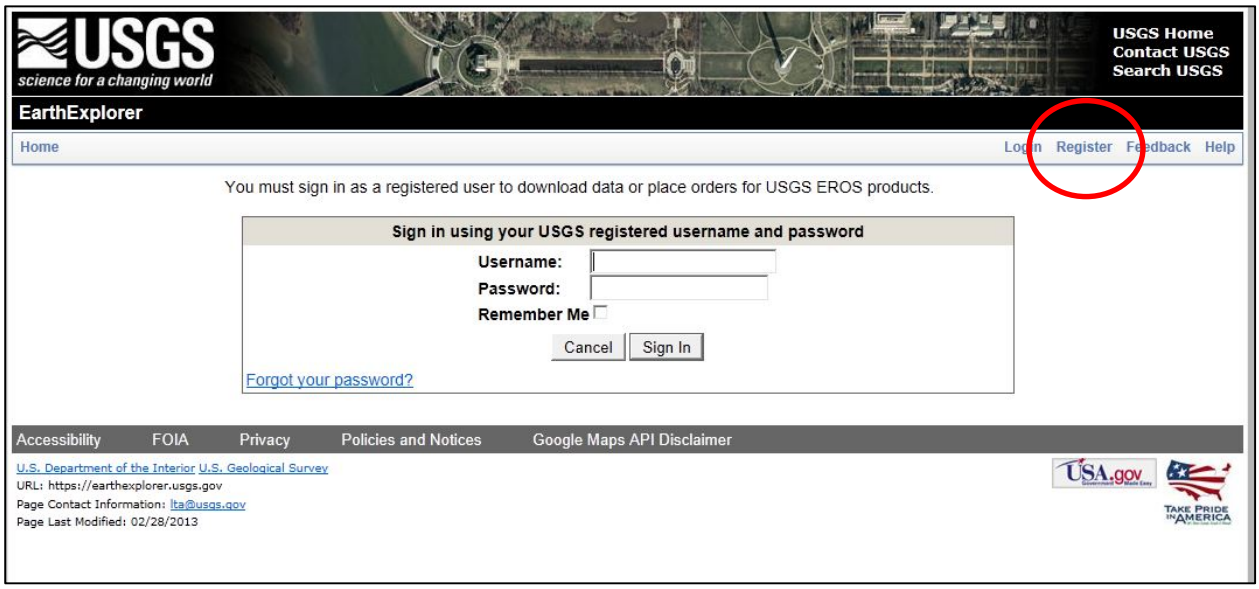
We get the following ***Results***. We have received a list of all Landsat scenes available for the month of March beginning in 1984 through 2012. For each scene that you want, click on the shopping cart icon (red oval). For this exercise, we are only going to order one scene – March 13, 2011 (green oval). We chose this date because Virginia Base Mapping Program aerial photos of Roanoke were taken during this same week in 2011.



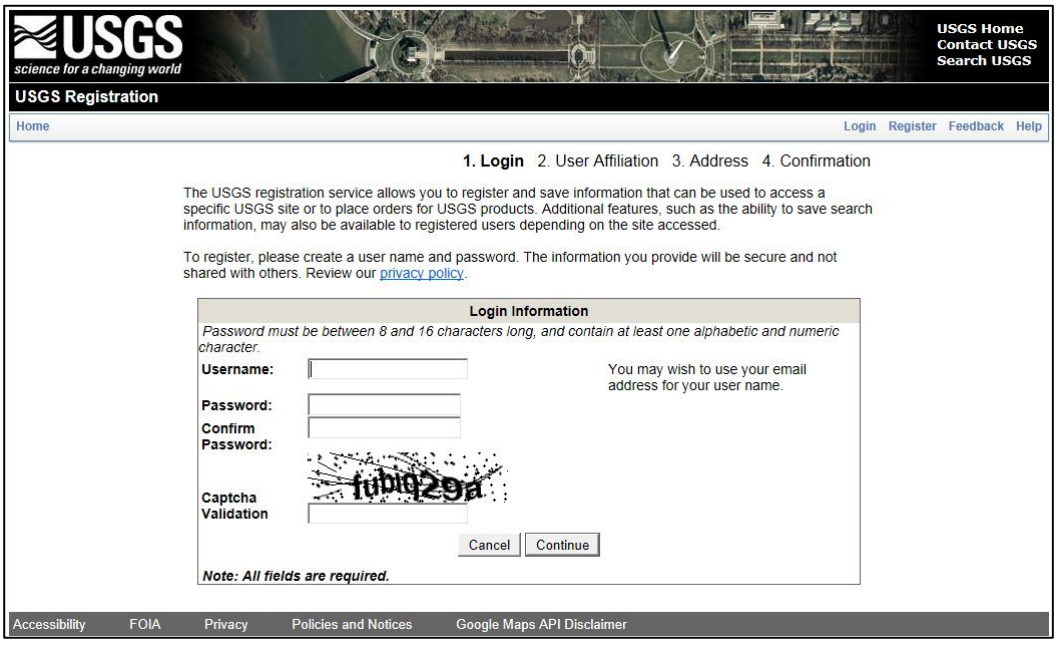


Logging in to your account and submitting your order

Once you have selected the scene, you will be taken to the ***Login*** page. If you already have a ***Login Username*** and ***Password***, enter them now. If not, then click on ***Register*** (red oval).

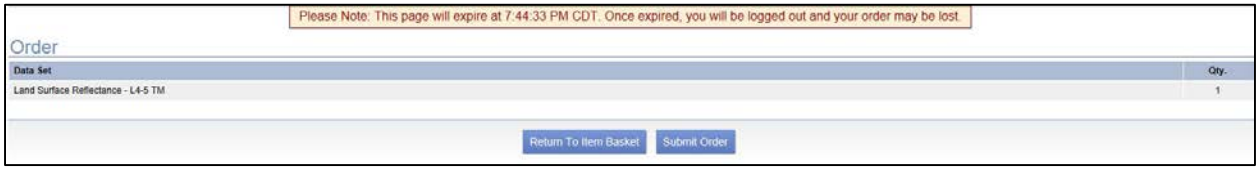


This takes you to the USGS Registration Page. Complete the registration.

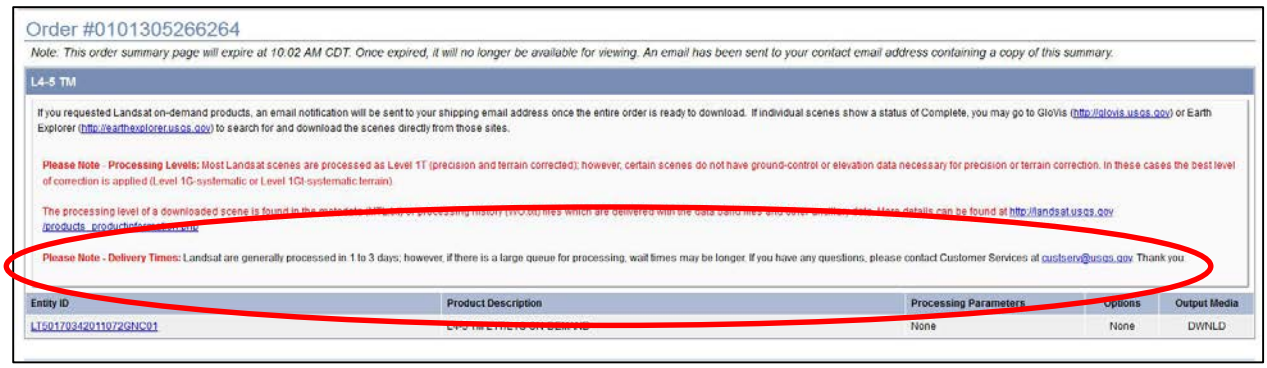


After you have registered, you will be taken to the next screen and it shows which image you have ordered. Click on ***Proceed to Checkout***.

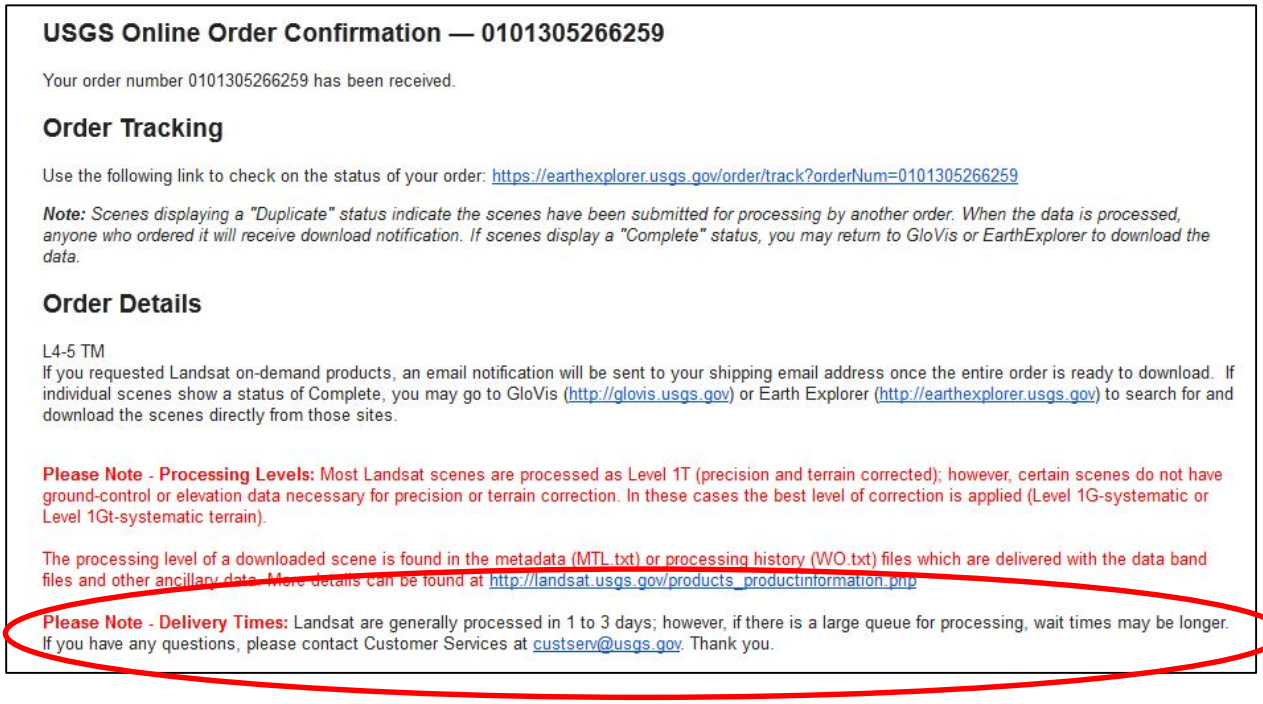
You will get the following screen. Click on ***Submit Order***.



You will then get the following message (please note the delivery time information – red oval).



You will get an ***Online Order Confirmation*** email with your order number, and, again, a notation on the ***Delivery Times***.



USGS Online Order Confirmation — 0101305266259

Your order number 0101305266259 has been received.

Order Tracking

Use the following link to check on the status of your order: https://earthexplorer.usgs.gov/order/track?orderNum=0101305266259

Note: *Scenes displaying a "Duplicate" status indicate the scenes have been submitted for processing by another order. When the data is processed, anyone who ordered it will receive download notification. If scenes display a "Complete" status, you may return to GloVis or EarthExplorer to download the data.*

Order Details

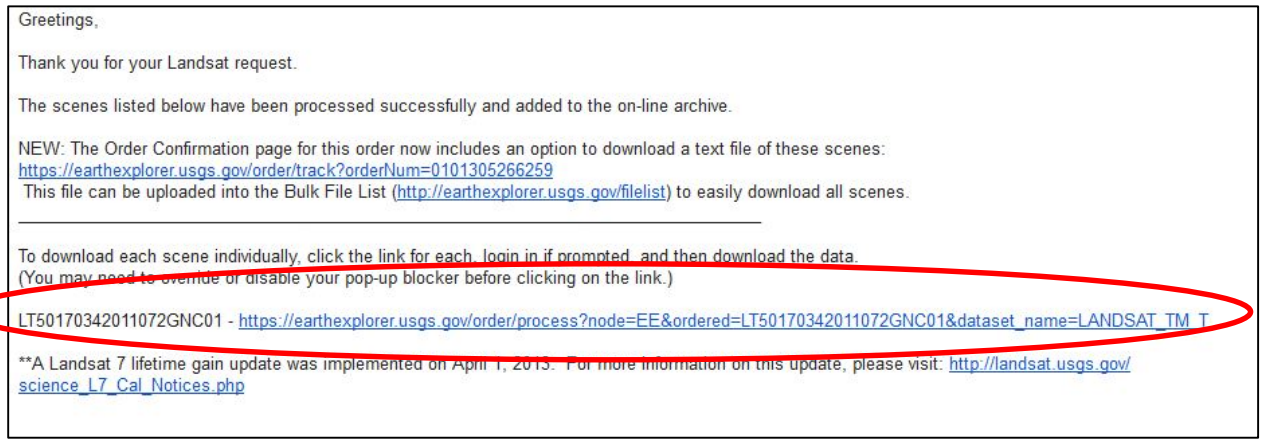
L4-5 TM
If you requested Landsat on-demand products, an email notification will be sent to your shipping email address once the entire order is ready to download. If individual scenes show a status of Complete, you may go to GloVis (http://glovis.usgs.gov) or Earth Explorer (http://earthexplorer.usgs.gov) to search for and download the scenes directly from those sites.

Please Note - Processing Levels: Most Landsat scenes are processed as Level 1T (precision and terrain corrected); however, certain scenes do not have ground-control or elevation data necessary for precision or terrain correction. In these cases the best level of correction is applied (Level 1G-systematic or Level 1Gt-systematic terrain).

The processing level of a downloaded scene is found in the metadata (MTL.txt) or processing history (WO.txt) files which are delivered with the data band files and other ancillary data. More details can be found at http://landsat.usgs.gov/products_productinformation.php

Please Note - Delivery Times: Landsat are generally processed in 1 to 3 days; however, if there is a large queue for processing, wait times may be longer. If you have any questions, please contact Customer Services at custserv@usgs.gov. Thank you.

You will get another email when your order is ready for downloading and you will need to click on the link (red oval):



Greetings,

Thank you for your Landsat request.

The scenes listed below have been processed successfully and added to the on-line archive.

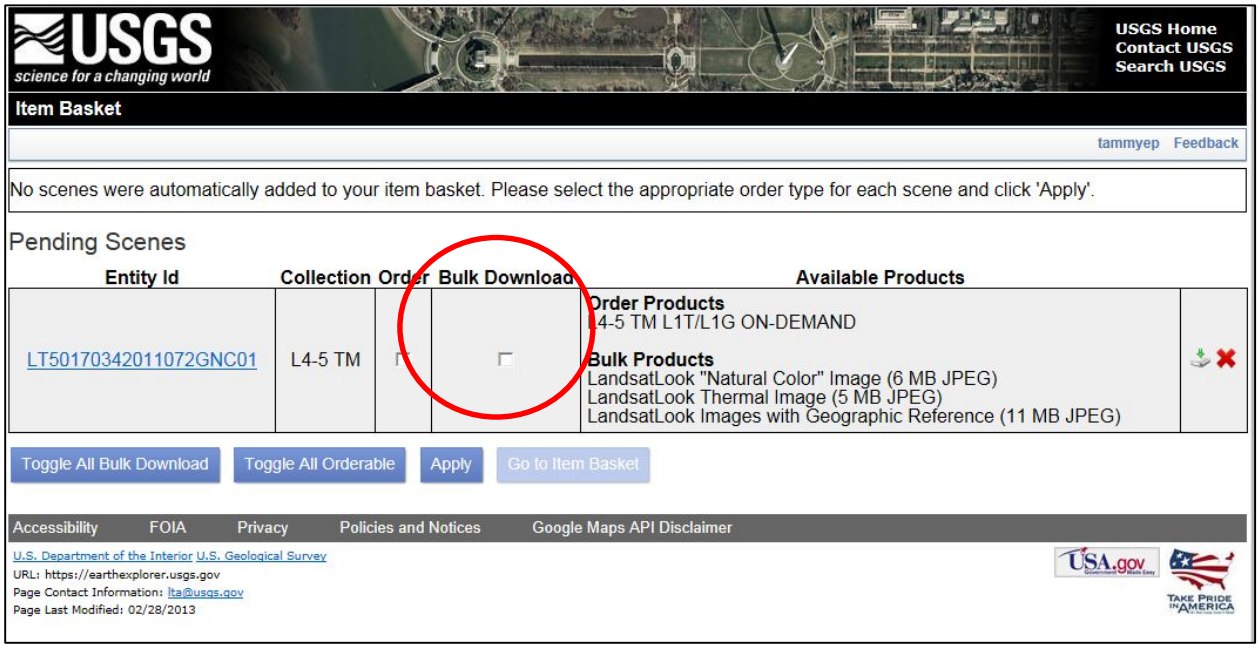
NEW: The Order Confirmation page for this order now includes an option to download a text file of these scenes:
https://earthexplorer.usgs.gov/order/track?orderNum=0101305266259
This file can be uploaded into the Bulk File List (http://earthexplorer.usgs.gov/filelist) to easily download all scenes.

To download each scene individually, click the link for each, login in if prompted, and then download the data.
(You may need to override or disable your pop-up blocker before clicking on the link.)

LT50170342011072GNC01 - https://earthexplorer.usgs.gov/order/process?node=EE&ordered=LT50170342011072GNC01&dataset_name=LANDSAT_TM_T

**A Landsat 7 lifetime gain update was implemented on April 1, 2013. For more information on this update, please visit: http://landsat.usgs.gov/science_L7_Cal_Notices.php

This will take you back to the EarthExplorer screens (where you will need to login). Following the steps on EarthExplorer to download the data – click in the ***Bulk Download*** area and then click apply.



You will get the following message:

You will also get the following email:

USGS Online Bulk Download Order Confirmation — 155382

To begin the download process, the Bulk Download Application (BDA) is required. First time users: please download, install and open the BDA. Returning users: please open the BDA installed on your system. You will be required to login using the EarthExplorer username and password used to complete your download request. Information and installation links can also be found at https://earthexplorer.usgs.gov/bulk/help/

If your order is Available, highlight the order number and click Select Order. On the next page, navigate to the download destination, make changes as you see fit for your system, highlight the first item in the list, and click Begin Download. When all items are downloaded you can select another order or close the window. The system will also keep track of failed downloads and retry them.

Bulk download orders are available for two weeks, after which the they are removed. You will need to place a new order to obtain data products if you do not download them from original order.

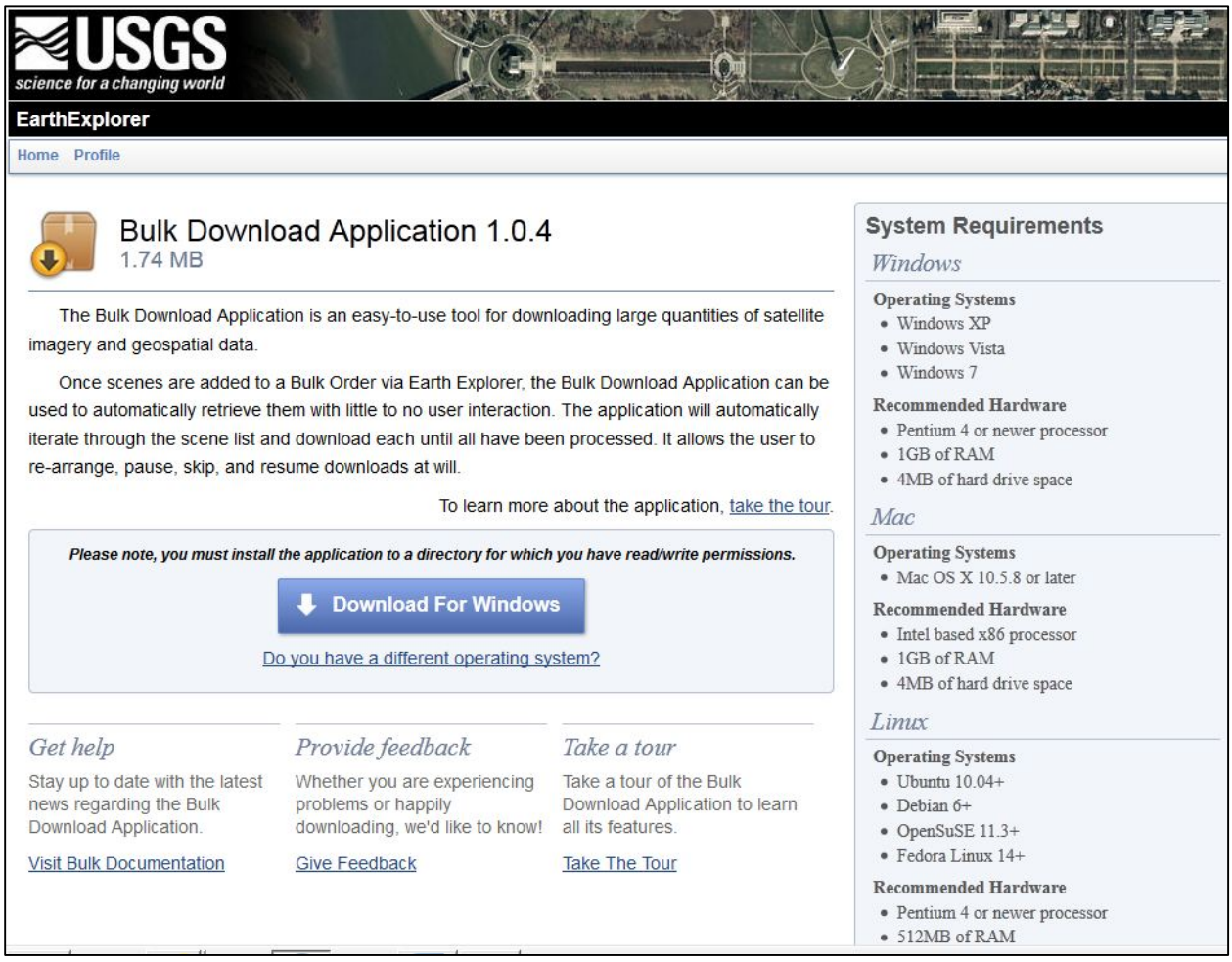
L4-5 TM Privileged

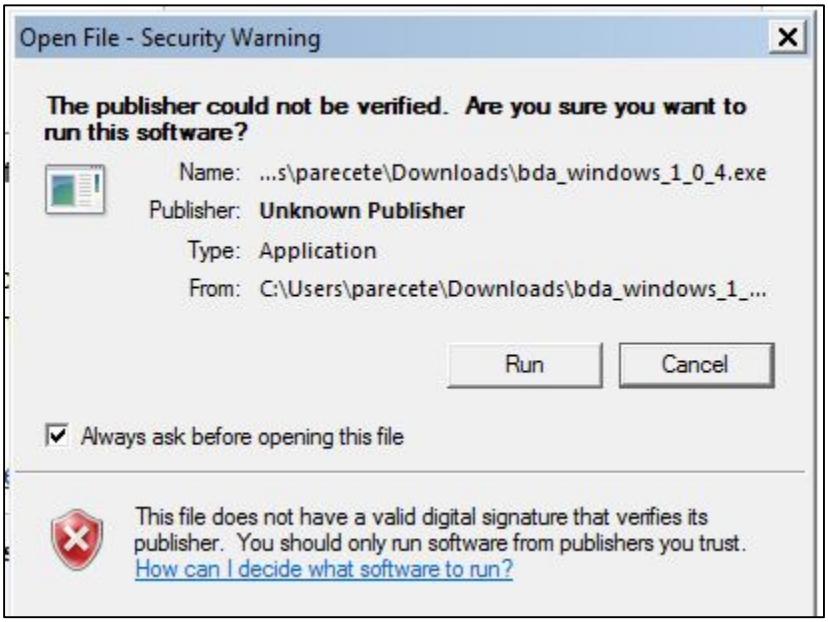
Entity ID	Product Description	File Size
LT50170342011072GNC01	Level 1 Product (155 MB Geotiff)	155.0 MB

Totals

Total File Size: 155.0 MB

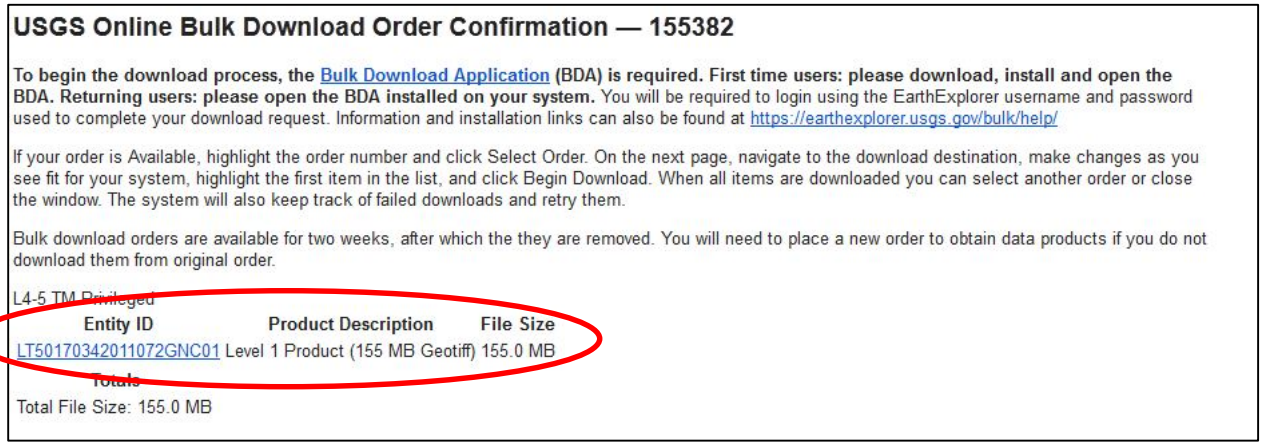
You MUST click the ***Bulk Download Application*** link to obtain the program you need to obtain bulk downloading capability. (*Note this is not downloading the information, just accessing the program you need to do the download*.) Clicking on ***Bulk Download Application*** will give you the following two screens. Click on the ***Download For Windows.***





Click on ***Run*** to download the program.

Once the application has been downloaded, you go back to your email and click on the ***Entity ID*** (red oval).



This will give you a screenshot of the scene and metadata about the scene. We will discuss the metadata in another tutorial.

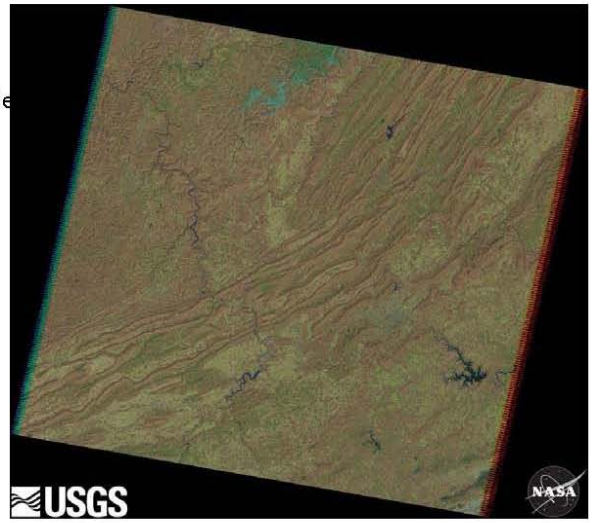
USGS
science for a changing world

EarthExplorer

USGS Home
Contact USGS
Search USGS

Full Display of LT50170342011072GNC01

LandsatLook "Natural Color" Previe

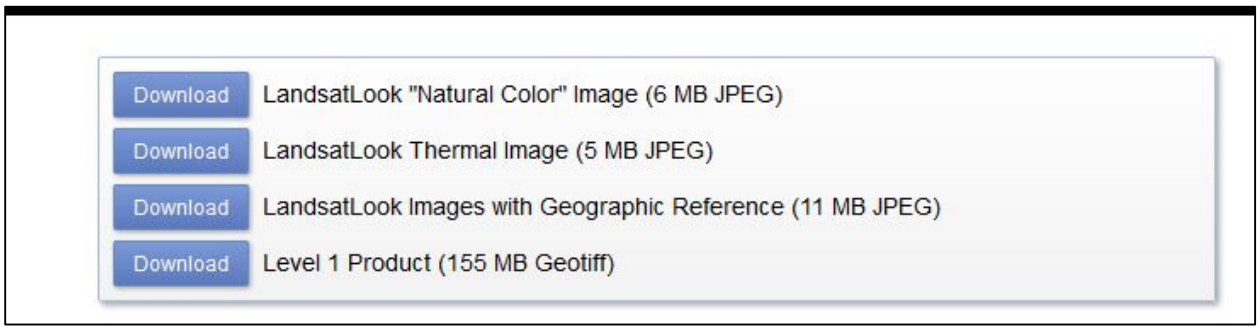


Data Set Attribute	Attribute Value
Landsat Scene Identifier	LT50170342011072GNC01
Spacecraft Identifier	LANDSAT_5
Sensor Mode	BUMPER
Station Identifier	GNC
Day/Night	DAY
WRS Path	017
WRS Row	034
WRS Type	2
Date Acquired	2011/03/13
Start Time	2011:072:15:48:53.19331
Stop Time	2011:072:15:49:19.80625
Sensor Anomalies	N
Acquisition Quality	9
Quality Band 1	9
Quality Band 2	9
Quality Band 3	9
Quality Band 4	9
Quality Band 5	9
Quality Band 6	9
Quality Band 7	9

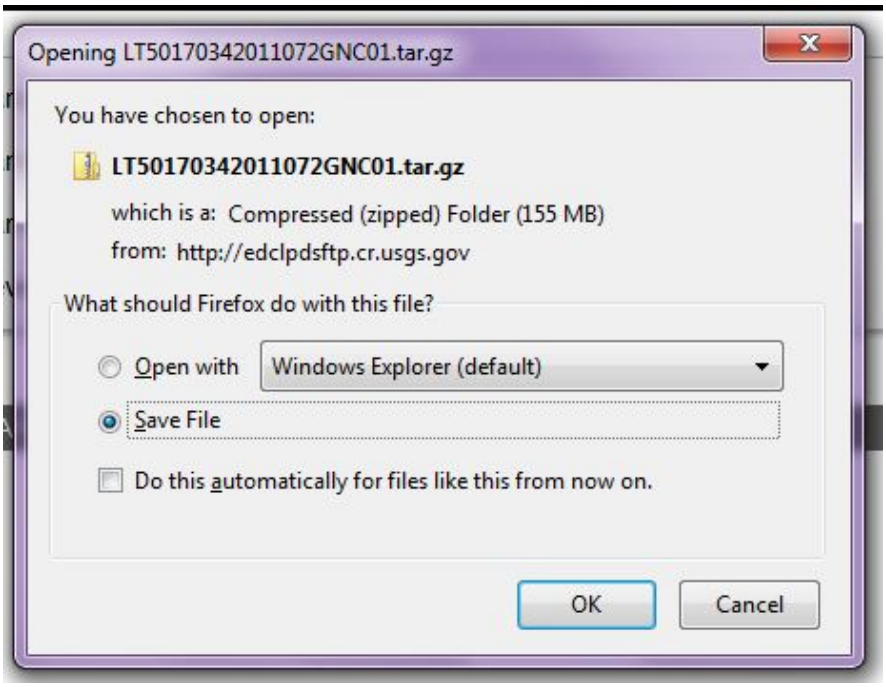
Data Set Attribute	Attribute Value
Cloud Cover	.06
Cloud Cover Quad Upper Left	.04
Cloud Cover Quad Upper Right	0
Cloud Cover Quad Lower Left	.01
Cloud Cover Quad Lower Right	.17
Sun Elevation	43.19207936
Sun Azimuth	143.81480711
Browse Exists	Yes
Data Category	NOMINAL
Map Projection LORa	
Data Type L0Rp	PR
Data Type Level 1	PROCESSING REQUIRED
Corner UL Latitude Product	38.44254 (38°26'33.14"N)
Corner UL Longitude Product	-81.77234 (81°46'20.42"S)
Corner UR Latitude Product	38.42840 (38°25'42.24"N)
Corner UR Longitude Product	-79.02264 (79°01'21.50"S)
Corner LR Longitude Product	-79.07263 (79°04'21.47"S)
Corner LL Latitude Product	36.52009 (36°31'12.32"N)
Corner LL Longitude Product	-81.75280 (81°45'10.08"W)
Corner LR Latitude Product	36.50689 (36°30'24.80"N)
Center Latitude	37°29'01.86"N
Center Longitude	80°24'21.60"W
NW Corner Lat	38°25'09.08"N
NW Corner Long	81°12'34.70"W
NE Corner Lat	38°06'59.36"N
NE Corner Long	79°07'51.13"W
SE Corner Lat	36°32'32.06"N
SE Corner Long	79°37'24.56"W
SW Corner Lat	36°50'19.61"N
SW Corner Long	81°39'38.23"W
Center Latitude dec	37.48385
Center Longitude dec	-80.406
NW Corner Lat dec	38.41919
NW Corner Long dec	-81.20964
NE Corner Lat dec	38.11649
NE Corner Long dec	-79.13087
SE Corner Lat dec	36.54224
SE Corner Long dec	-79.62349
SW Corner Lat dec	36.83878
SW Corner Long dec	-81.66062

Go to the bottom and click on ***Download*** (red oval).

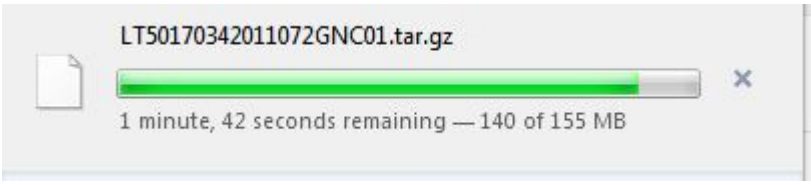
You will see the following screen. You can just access the jpegs (the first 3 items in the list), but if you want images upon which you can conduct analyses, you need the ***Level 1 Product (155MB Geotiff).*** Geotiffs are images upon which you can perform analyses. Click on ***Download*** next to the ***Level 1 Product***.



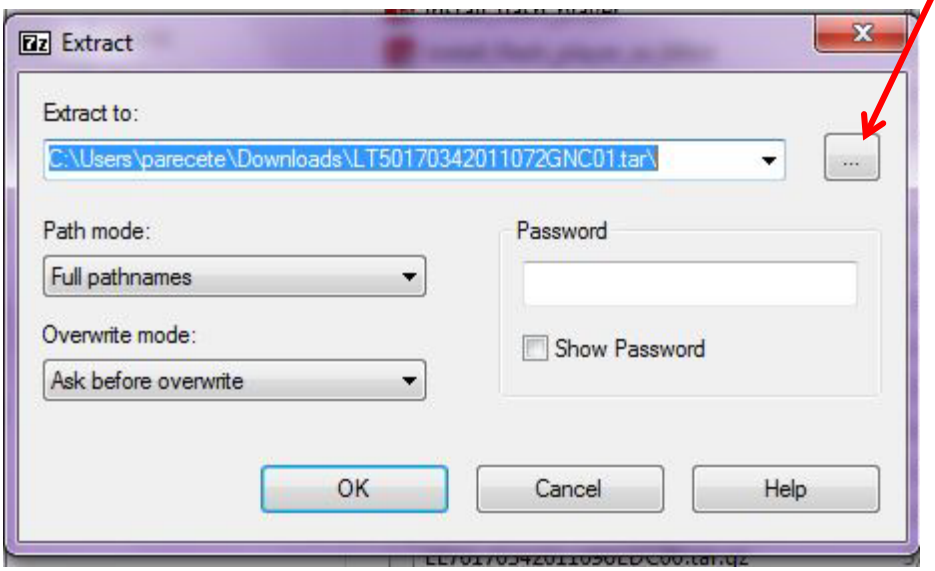
You get the download window. Save it and wait.



This is a very large file and will take a few minutes or more (depending on your WiFi speed) to save.

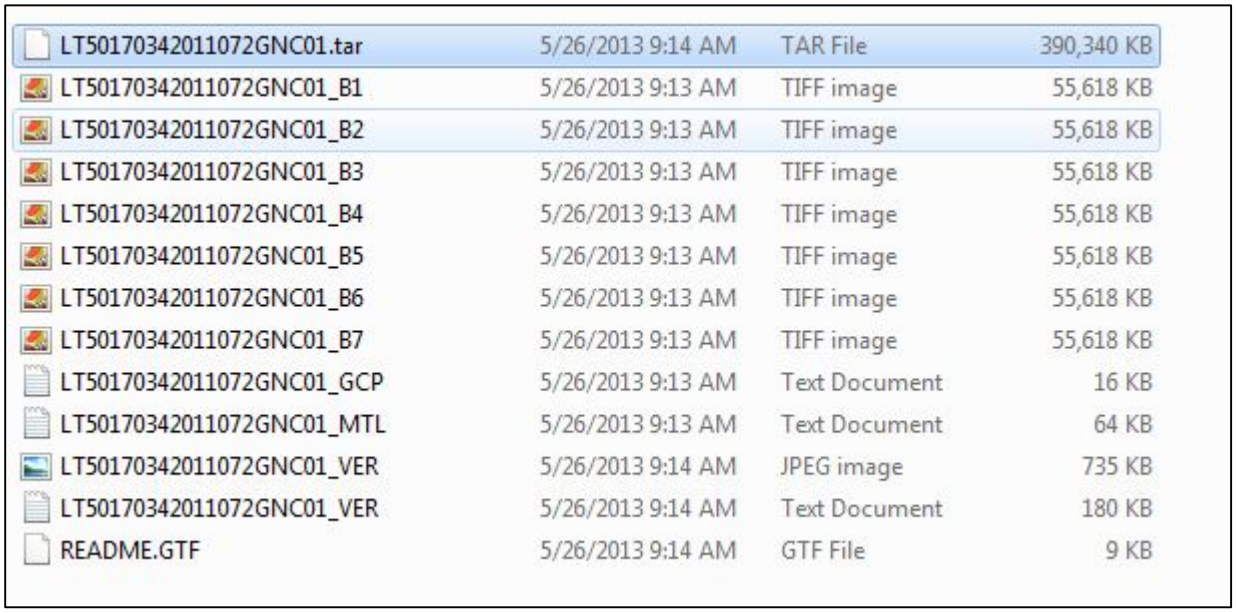


Once it has finished downloading, right click on the file and click on ***Open Containing Folder***. This will take you to the area on your computer where the file downloaded. Right click on the file name and click on ***Extract***, getting the following window. Clicking on this button will allow you to navigate to the folder where you want to save the file.



Once the file has been extracted (unzipped), navigate to the folder where you unzipped it. You will find a .tar file. This is another zipped file. (*Note - because of the file size, these are double zipped, so you have to unzip them twice*).

Right click and unzip (extract to here) again. Once it is finished, you will have the following files in your folder:



LT50170342011072GNC01.tar	5/26/2013 9:14 AM	TAR File	390,340 KB
LT50170342011072GNC01_B1	5/26/2013 9:13 AM	TIFF image	55,618 KB
LT50170342011072GNC01_B2	5/26/2013 9:13 AM	TIFF image	55,618 KB
LT50170342011072GNC01_B3	5/26/2013 9:13 AM	TIFF image	55,618 KB
LT50170342011072GNC01_B4	5/26/2013 9:13 AM	TIFF image	55,618 KB
LT50170342011072GNC01_B5	5/26/2013 9:13 AM	TIFF image	55,618 KB
LT50170342011072GNC01_B6	5/26/2013 9:13 AM	TIFF image	55,618 KB
LT50170342011072GNC01_B7	5/26/2013 9:13 AM	TIFF image	55,618 KB
LT50170342011072GNC01_GCP	5/26/2013 9:13 AM	Text Document	16 KB
LT50170342011072GNC01_MTL	5/26/2013 9:13 AM	Text Document	64 KB
LT50170342011072GNC01_VER	5/26/2013 9:14 AM	JPEG image	735 KB
LT50170342011072GNC01_VER	5/26/2013 9:14 AM	Text Document	180 KB
README.GTF	5/26/2013 9:14 AM	GTF File	9 KB

You have successfully downloaded the Landsat scene that includes Roanoke, Virginia dated March 13, 2011. We will discuss the files in the tutorials on Information about your Downloaded Landsat Imagery and Band Combinations.

You will need to determine if your downloaded imagery needs further processing beyond that completed by the USGS. For more information about the level and type of USGS processing of Landsat scenes, go to http://landsat.usgs.gov/Landsat_Processing_Details.php. See also Masek, J.G., et al., *A Landsat surface reflectance data set for North America, 1990-2000.* Geoscience and Remote Sensing Letters, 2006. **3**: p. 68-72.

This exercise, in combination with the companion GloVIS tutorial prepares you with the skills to download Landsat imagery. Subsequent tutorials will introduce techniques to analyze this imagery to extract information to support your research objectives.

Notes:

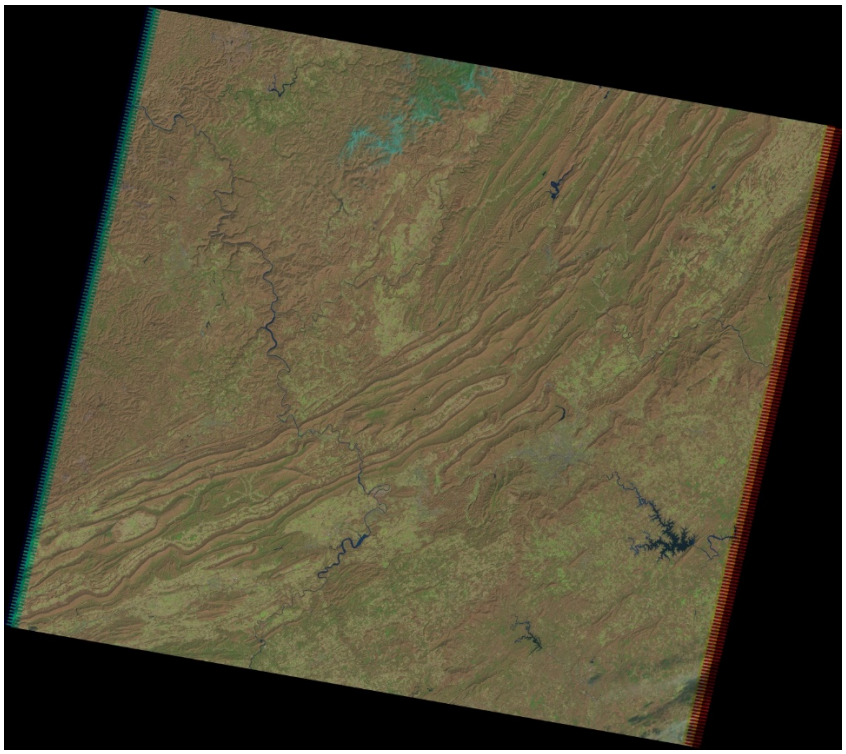
9. Information about your Downloaded Landsat Imagery

The instructional materials contained within these documents are copyrighted property of VirginiaView, its partners and other participating AmericaView consortium members. These materials may be reproduced and used by educators for instructional purposes. No permission is granted to use the materials for paid consulting or instruction where a fee is collected. Reproduction or translation of any part of this document beyond that permitted in Section 107 or 108 of the 1976 United States Copyright Act without the permission of the copyright owner(s) is unlawful.

Introduction:

Landsat images are frequently used for land remote sensing analyses. The first Landsat Satellite was launched in 1972. The Landsat mission continues to this date with the most recent Landsat Data Continuity Mission satellite (now Landsat 8) launched in February, 2013. For more information and specific details on Landsat satellites, sensors, and potential analyses using Landsat images go to: http://landsat.usgs.gov/

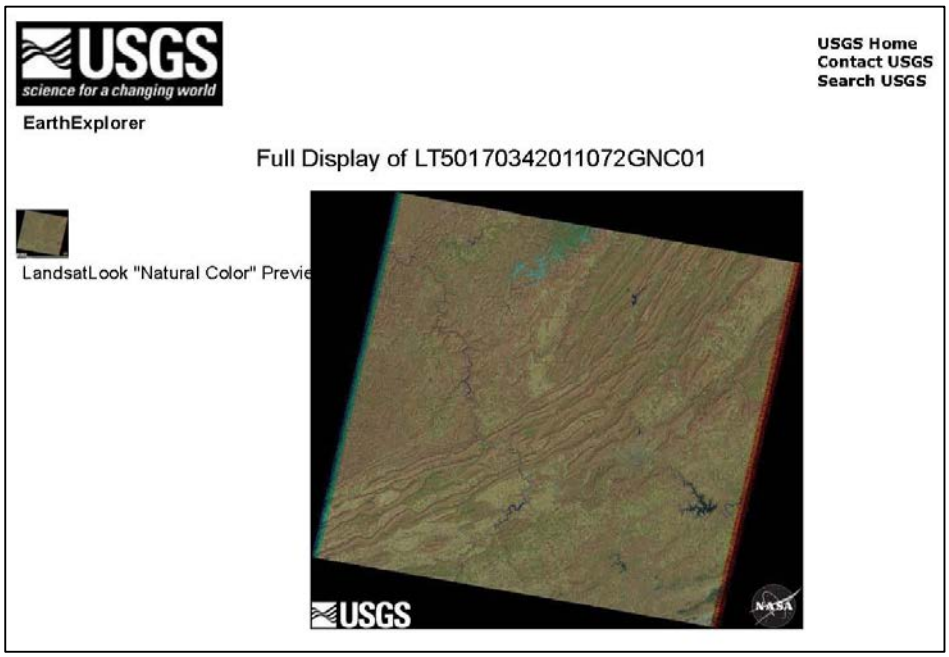
Landsat images are free and downloadable from the internet from http://glovis.usgs.gov/ or http://earthexplorer.usgs.gov/. You have already downloaded at least one scene from the USGS and this tutorial provides you with information to understand basics of your scene. Decisions on exactly which specific images you need for your specific analyses cannot be answered from this tutorial.



Jpeg of the Landsat scene you ordered from previous tutorials

9. Information about your Downloaded Landsat Imagery

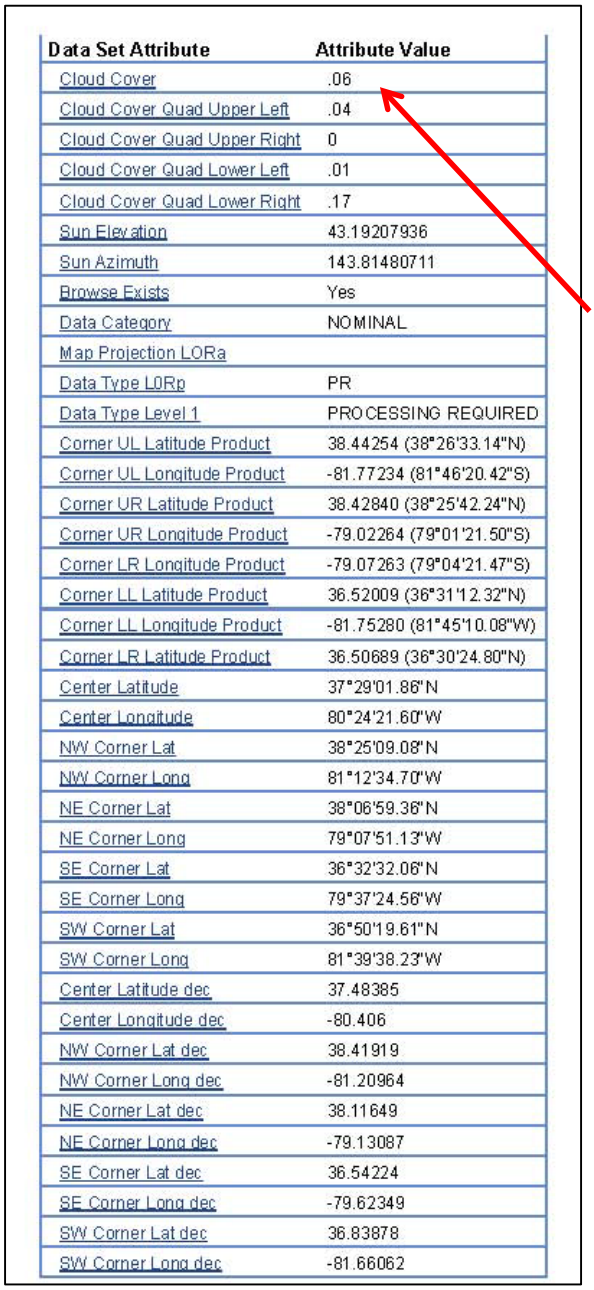
In the process of ordering and downloading your Landsat scene, you had access to the following information. This gave you a screen shot of a natural color preview and some of the metadata.



Data Set Attribute	Attribute Value
Landsat Scene Identifier	LT50170342011072GNC01
Spacecraft Identifier	LANDSAT_5
Sensor Mode	BUMPER
Station Identifier	GNC
Day/Night	DAY
WRS Path	017
WRS Row	034
WRS Type	2
Date Acquired	2011/03/13
Start Time	2011:072:15:48:53.19331
Stop Time	2011:072:15:49:19.80625
Sensor Anomalies	N
Acquisition Quality	9
Quality Band 1	9
Quality Band 2	9
Quality Band 3	9
Quality Band 4	9
Quality Band 5	9
Quality Band 6	9
Quality Band 7	9

The metadata gives you information about your Landsat Scene. We will not review each line as much of it is self-explanatory. The metadata provides the scene identification number. The scene identification number includes the Julian date the image was acquired. For this image, it was acquired in 2011, Julian day 072 – which in 2011 is March 13. You can use the Landsat Scene Identification Number if you need to re-order the exact same scene at a later date. This will also be the name of each one of the image files

that we downloaded. Remember, we ordered Landsat 4-5, this data tells us, the scene is actually from Landsat 5. The ground station was Gatineau, Canada. Landsat 5 imagery is always taken during the day. It provides the path and row numbers; this information will allow you to request the same scene but using different dates. The sensor had no anomalies while active for this particular scene.

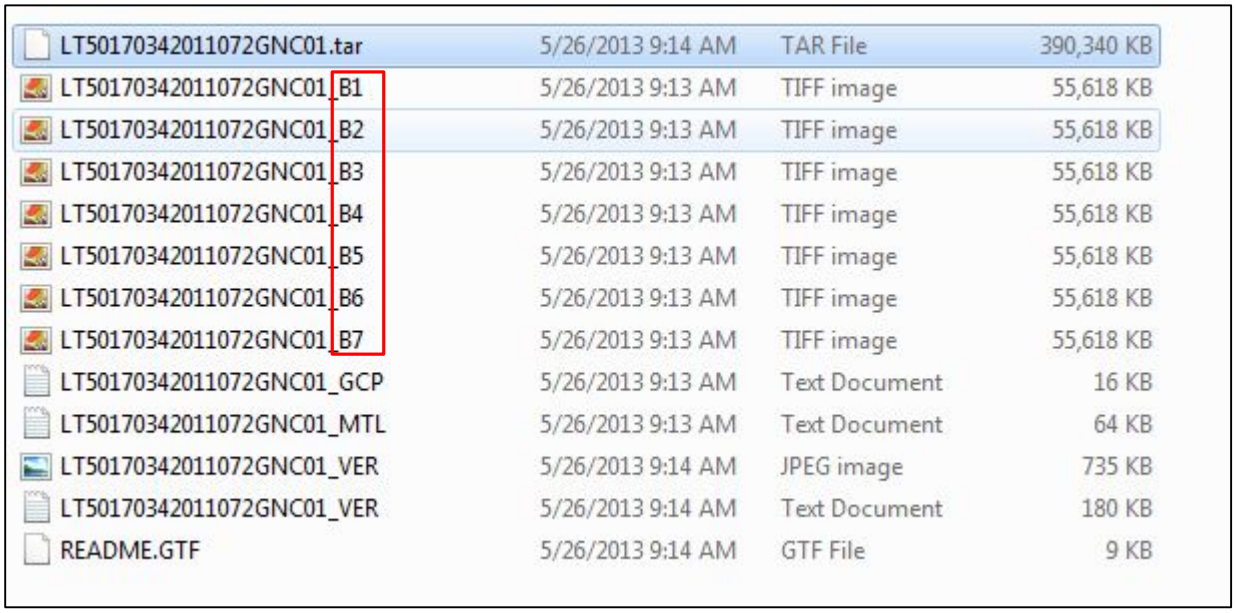


Data Set Attribute	Attribute Value
Cloud Cover	.06
Cloud Cover Quad Upper Left	.04
Cloud Cover Quad Upper Right	0
Cloud Cover Quad Lower Left	.01
Cloud Cover Quad Lower Right	.17
Sun Elevation	43.19207936
Sun Azimuth	143.81480711
Browse Exists	Yes
Data Category	NOMINAL
Map Projection L0Ra	
Data Type L0Rp	PR
Data Type Level 1	PROCESSING REQUIRED
Corner UL Latitude Product	38.44254 (38°26'33.14"N)
Corner UL Longitude Product	-81.77234 (81°46'20.42"S)
Corner UR Latitude Product	38.42840 (38°25'42.24"N)
Corner UR Longitude Product	-79.02264 (79°01'21.50"S)
Corner LR Longitude Product	-79.07263 (79°04'21.47"S)
Corner LL Latitude Product	36.52009 (36°31'12.32"N)
Corner LL Longitude Product	-81.75280 (81°45'10.08"W)
Corner LR Latitude Product	36.50689 (36°30'24.80"N)
Center Latitude	37°29'01.86"N
Center Longitude	80°24'21.60"W
NW Corner Lat	38°25'09.08"N
NW Corner Long	81°12'34.70"W
NE Corner Lat	38°06'59.36"N
NE Corner Long	79°07'51.13"W
SE Corner Lat	36°32'32.06"N
SE Corner Long	79°37'24.56"W
SW Corner Lat	36°50'19.61"N
SW Corner Long	81°39'38.23"W
Center Latitude dec	37.48385
Center Longitude dec	-80.406
NW Corner Lat dec	38.41919
NW Corner Long dec	-81.20964
NE Corner Lat dec	38.11649
NE Corner Long dec	-79.13087
SE Corner Lat dec	36.54224
SE Corner Long dec	-79.62349
SW Corner Lat dec	36.83878
SW Corner Long dec	-81.66062

The metadata continues here. Remember the scene we requested was for less than 10% cloud cover. This is the average cloud cover for the entire scene. For this particular one, the average was only 6% but as you can see over the next 4 lines, the cloud cover did vary across the scene. The metadata also provide us with the sun's elevation and azimuth, which will assist us if we want to include shadowing or solar insolation in our analyses.

Many of the rows on this portion of the metadata relate to latitudes and longitudes of different areas of the scene.

9. Information about your Downloaded Landsat Imagery



LT50170342011072GNC01.tar	5/26/2013 9:14 AM	TAR File	390,340 KB
LT50170342011072GNC01_B1	5/26/2013 9:13 AM	TIFF image	55,618 KB
LT50170342011072GNC01_B2	5/26/2013 9:13 AM	TIFF image	55,618 KB
LT50170342011072GNC01_B3	5/26/2013 9:13 AM	TIFF image	55,618 KB
LT50170342011072GNC01_B4	5/26/2013 9:13 AM	TIFF image	55,618 KB
LT50170342011072GNC01_B5	5/26/2013 9:13 AM	TIFF image	55,618 KB
LT50170342011072GNC01_B6	5/26/2013 9:13 AM	TIFF image	55,618 KB
LT50170342011072GNC01_B7	5/26/2013 9:13 AM	TIFF image	55,618 KB
LT50170342011072GNC01_GCP	5/26/2013 9:13 AM	Text Document	16 KB
LT50170342011072GNC01_MTL	5/26/2013 9:13 AM	Text Document	64 KB
LT50170342011072GNC01_VER	5/26/2013 9:14 AM	JPEG image	735 KB
LT50170342011072GNC01_VER	5/26/2013 9:14 AM	Text Document	180 KB
README.GTF	5/26/2013 9:14 AM	GTF File	9 KB

When we unzipped our bulk download, we ended up with the 12 files listed above. The first 7 have the scene identification number and also the band number. Landsat 5 had 7 bands, thus we have one image for each of the seven bands. Each band represents a different region of the electromagnetic spectrum. For Landsat 5 these are as follows:

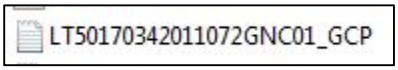
- Seven spectral bands, including a thermal band:
  - Band 1 Visible (0.45 - 0.52 µm) 30 m
  - Band 2 Visible (0.52 - 0.60 µm) 30 m
  - Band 3 Visible (0.63 - 0.69 µm) 30 m
  - Band 4 Near-Infrared (0.76 - 0.90 µm) 30 m
  - Band 5 Near-Infrared (1.55 - 1.75 µm) 30 m
  - Band 6 Thermal (10.40 - 12.50 µm) 120 m
  - Band 7 Mid-Infrared (2.08 - 2.35 µm) 30 m

Size of the pixel for the band

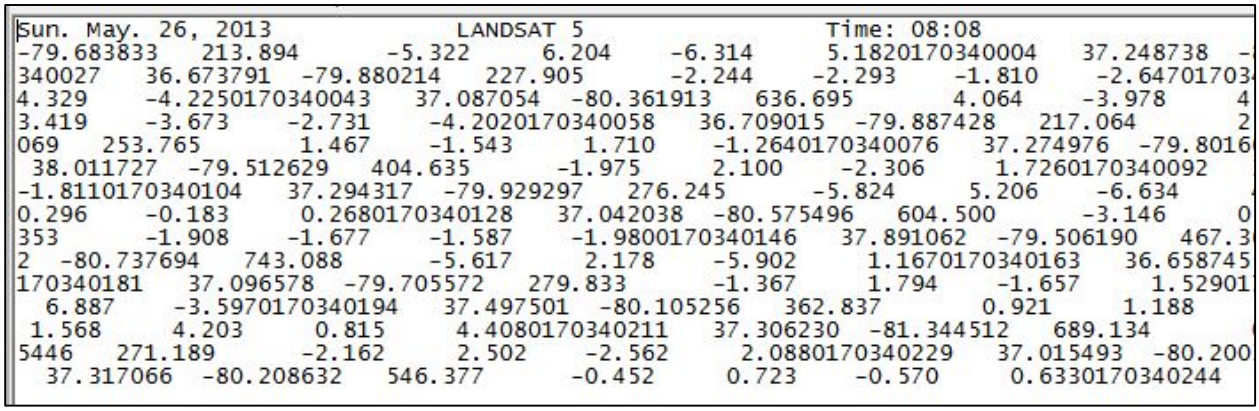
(http://landsat.usgs.gov/about_landsat5.php)

With the exception of the Thermal Channel (Band 6), the resolution (pixel size) is 30 meters by 30 meters. For Landsat 5, the Thermal Channel's pixel size is 120 meters by 120 meters.

9. Information about your Downloaded Landsat Imagery



This file is a text file that provides information on the resultant residual error from the ground control points (when the scene was geo-referenced to the ground). Yes, you do not have to geo-reference the scene as this step has already been completed by the USGS. Sometimes it is easier to read the .txt files if you import them into a spreadsheet. For instance for this specific file, opening .txt looks like:



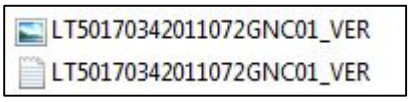
```
Sun. May. 26, 2013              LANDSAT 5                    Time: 08:08
-79.683833   213.894      -5.322      6.204     -6.314      5.1820170340004    37.248738  -
340027    36.673791  -79.880214    227.905       -2.244     -2.293     -1.810     -2.64701703
4.329     -4.2250170340043    37.087054   -80.361913    636.695       4.064     -3.978      4
3.419     -3.673     -2.731     -4.2020170340058    36.709015  -79.887428    217.064        2
069    253.765       1.467     -1.543      1.710     -1.2640170340076    37.274976  -79.8016
 38.011727  -79.512629    404.635       -1.975      2.100     -2.306      1.7260170340092
-1.8110170340104    37.294317  -79.929297    276.245       -5.824      5.206     -6.634
0.296     -0.183      0.2680170340128    37.042038  -80.575496    604.500       -3.146      0
353       -1.908     -1.677     -1.587     -1.9800170340146    37.891062  -79.506190    467.3
2  -80.737694    743.088       -5.617      2.178     -5.902      1.1670170340163    36.658745
170340181    37.096578  -79.705572    279.833       -1.367      1.794     -1.657      1.52901
  6.887     -3.5970170340194    37.497501  -80.105256    362.837        0.921      1.188
 1.568      4.203      0.815      4.4080170340211    37.306230  -81.344512    689.134
5446    271.189       -2.162      2.502     -2.562      2.0880170340229    37.015493  -80.200
  37.317066  -80.208632    546.377       -0.452      0.723     -0.570      0.6330170340244
```

Importing the data into a spreadsheet looks like:

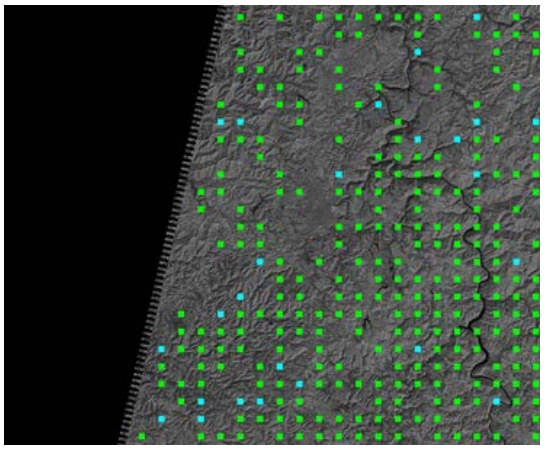
	A	B	C	D	E	F
1	Sun. May. 26, 2013	LANDSAT 5		Time: 08:08		
2		Image Assessment System				
3		GCP Residual Report				
4	----------	----------	---	---	---	
5	WOID: L7340718	Path/Row: 017 / 034				
6						
7	L0R Reference Image: L	51GNC1011072150100_HDF.131	461302			
8	Acquisition Date: Mar	13, 2011				
9						
10	Band Number: 5					
11						
12	GeoCover date for each	WRS-2 path/row used:				
13	Path Row Date					
14	017 034 2000-06-10					
15						
16						
17	Point_ID Latitude	Longitude Height	Across	Along	Residual	Residual
18			Scan	Scan	In y	in x
19			Residual	Residual	dir	dir
20	(deg)	(deg) (meters)	(meters)	(meters)	(meters)	(meters)
21						
22	0170340001 37.093855	-79.608401 211.144	-5.799	6.398	-6.817	5.291
23	0170340002 37.905230	-79.799023 411.786	-3.481	-0.707	-3.304	-1.297
24	0170340003 37.045772	-79.683833 213.894	-5.322	6.204	-6.314	5.182
25	0170340004 37.248738	-80.143385 314.374	4.904	2.41	4.408	3.222
26	0170340005 36.887506	-79.947798 410.883	-3.467	3.151	-3.958	2.499
27	0170340006 37.134858	-80.138591 779.854	-1.46	1.332	-1.666	1.057
28	0170340007 37.931282	-79.706092 414.710	5.221	-5.589	6.102	-4.598

Much easier to read and understand.

Here is another text file. It is metadata. Yes, again. But this file actually has additional data that was not listed when you explored the metadata from the email link. This metadata also provides: sensor name – thematic mapper (TM), radiance information, DATUM = "WGS84", ELLIPSOID = "WGS84", UTM_ZONE = 17, the number of ground control points and related RMSE, and other information. You should always review the metadata on any file prior to conducting analyses.



These two files refer to the ground control points (GCP). One is a jpeg of the GCPs and their visual location on the Landsat scene. If you open this file, note that the GCPs are different colors. The.txt file gives you the residuals for each GCP and also ranks them by the color coding.



Color mapping per rank

Rank 1 is Green: total residual <= 0.5
Rank 2 is Cyan: 0.5 < total residual <= 1
Rank 3 is Blue: 1 < total residual <= 2
Rank 4 is Yellow: 2 < total residual <= 3
Rank 5 is Red: 3 < total residual
Percentage of residuals by rank

Rank 1 -- 93.5%
Rank 2 -- 6.5%
Rank 3 -- 0.0%
Rank 4 -- 0.0%
Rank 5 -- 0.0%

9. Information about your Downloaded Landsat Imagery

The final file is

and is actually a file that has much of the information that we have just reiterated in this tutorial. To open this file, first open a notepad or another word processing program and then open the file within the program. Do not try to open the file by double clicking on it, as that will take you to an internet window asking which program you want to use to open it. If you have never worked with a Landsat image, we highly recommend that you read this document and the other .txt files.

Is any other pre-processing needed before you start using your Landsat Scene? Scenes downloaded from EarthExplorer and requesting the Landsat Surface Reflectance Data, the USGS has already preprocessed it for surface reflectance. If you are working with any other scene downloaded, you need to consider preprocessing for surface reflectance (see Masek, J.G., et al., *A Landsat surface reflectance data set for North America, 1990-2000.* Geoscience and Remote Sensing Letters, 2006. **3**: p. 68-72.)

For more information about the level and type of USGS processing of Landsat scenes, go to http://landsat.usgs.gov/Landsat_Processing_Details.php.

Now you are ready to proceed to the next tutorial which prepares you to analyze your Landsat data.

9. Information about your Downloaded Landsat Imagery

Notes:

The instructional materials contained within these documents are copyrighted property of VirginiaView, its partners and other participating AmericaView consortium members. These materials may be reproduced and used by educators for instructional purposes. No permission is granted to use the materials for paid consulting or instruction where a fee is collected. Reproduction or translation of any part of this document beyond that permitted in Section 107 or 108 of the 1976 United States Copyright Act without the permission of the copyright owner(s) is unlawful.

You have downloaded the Landsat 5 TM scene, which has given you 7 different images, one for each band. Now what? In this tutorial, you will load the files into ArcMap and examine the properties of each of these files. You will also be introduced to the Image Analysis Window.

Introduction

Landsat images are acquired in grayscale and when you add the different files each file is listed separately in the ***Table of Contents*** in ArcMap. Familiarity with your Landsat scene is important in order to do different types of analyses, such as unsupervised classifications, supervised classifications, and different indices (ex: NDVI). Different types of analyses will be covered in subsequent tutorials.

Remember, from prior tutorials, that the electromagnetic spectrum differs for each band. Each one of these bands is useful for distinguishing different features:

Table 3. TM and ETM+ band designations.

Spectral bands	Wavelength (micrometers)	Resolution (meters)	Use
Band 1–blue-green	0.45–0.52	30	Bathymetric mapping; distinguishes soil from vegetation; deciduous from coniferous vegetation.
Band 2–green	0.52–0.61	30	Emphasizes peak vegetation, which is useful for assessing plant vigor.
Band 3–red	0.63–0.69	30	Emphasizes vegetation slopes.
Band 4–reflected IR	0.76–0.90	30	Emphasizes biomass content and shorelines.
Band 5–reflected IR	1.55–1.75	30	Discriminates moisture content of soil and vegetation; penetrates thin clouds.
Band 6–thermal	10.40–12.50	120	Useful for thermal mapping and estimated soil moisture.
Band 7–reflected IR	2.08–2.35	30	Useful for mapping hydrothermally altered rocks associated with mineral deposits.
Band 8–panchromatic (Landsat 7)	0.52–0.90	15	Useful in 'sharpening' multispectral images.

Instrument-specific relative spectral response functions may be viewed and compared using the Spectral Viewer tool: *http://landsat.usgs.gov/tools_spectralViewer.php*.

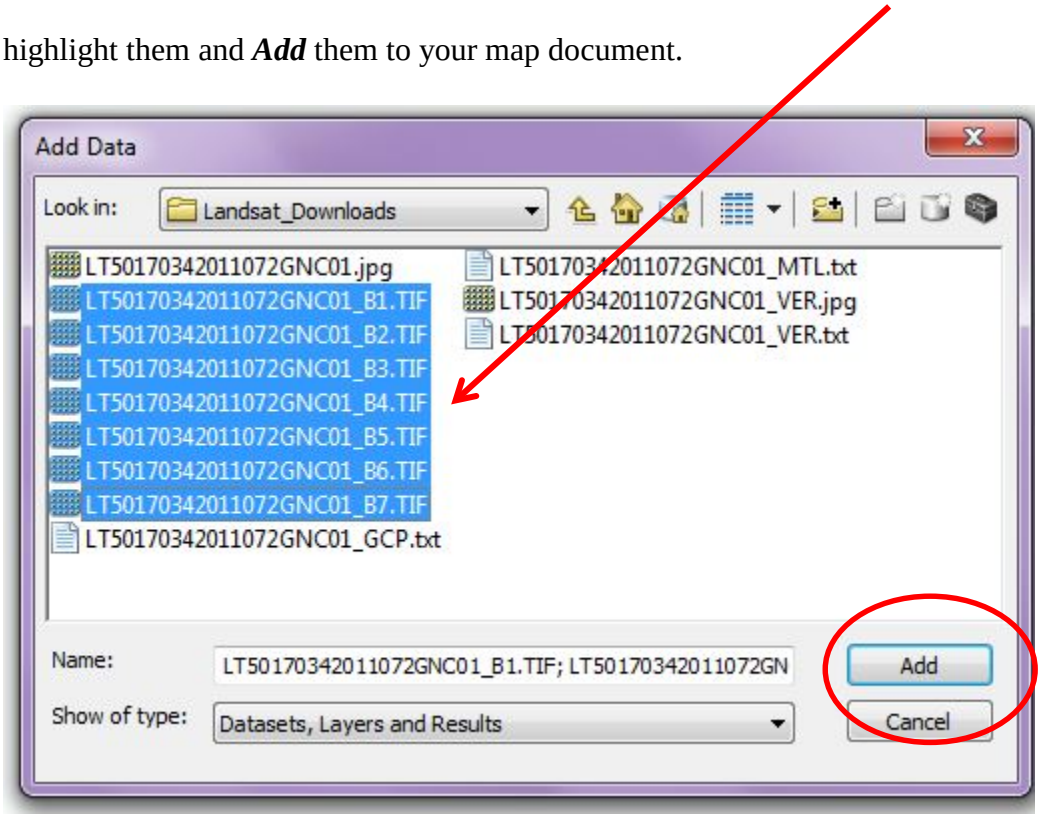
If you download a different scene from a different sensor, each band will likely convey different information. Please see: http://pubs.usgs.gov/fs/2012/3072/fs2012-3072.pdf for more information.

Adding your Landsat files to ArcMap

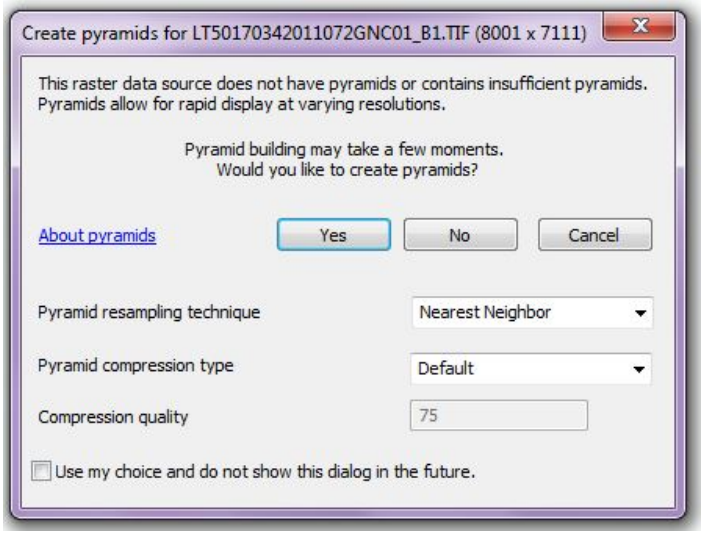
Remember, when you unzipped the files, you had 7 different images listed**:**

LT50170342011072GNC01_B1	5/26/2013 9:13 AM	TIFF image	55,618 KB
LT50170342011072GNC01_B2	5/26/2013 9:13 AM	TIFF image	55,618 KB
LT50170342011072GNC01_B3	5/26/2013 9:13 AM	TIFF image	55,618 KB
LT50170342011072GNC01_B4	5/26/2013 9:13 AM	TIFF image	55,618 KB
LT50170342011072GNC01_B5	5/26/2013 9:13 AM	TIFF image	55,618 KB
LT50170342011072GNC01_B6	5/26/2013 9:13 AM	TIFF image	55,618 KB
LT50170342011072GNC01_B7	5/26/2013 9:13 AM	TIFF image	55,618 KB

Now, open ArcMap and open a new map document. Click on the A***dd Data*** button, navigate to the folder where you unzipped your Landsat images. Click on all the images to highlight them and ***Add*** them to your map document.

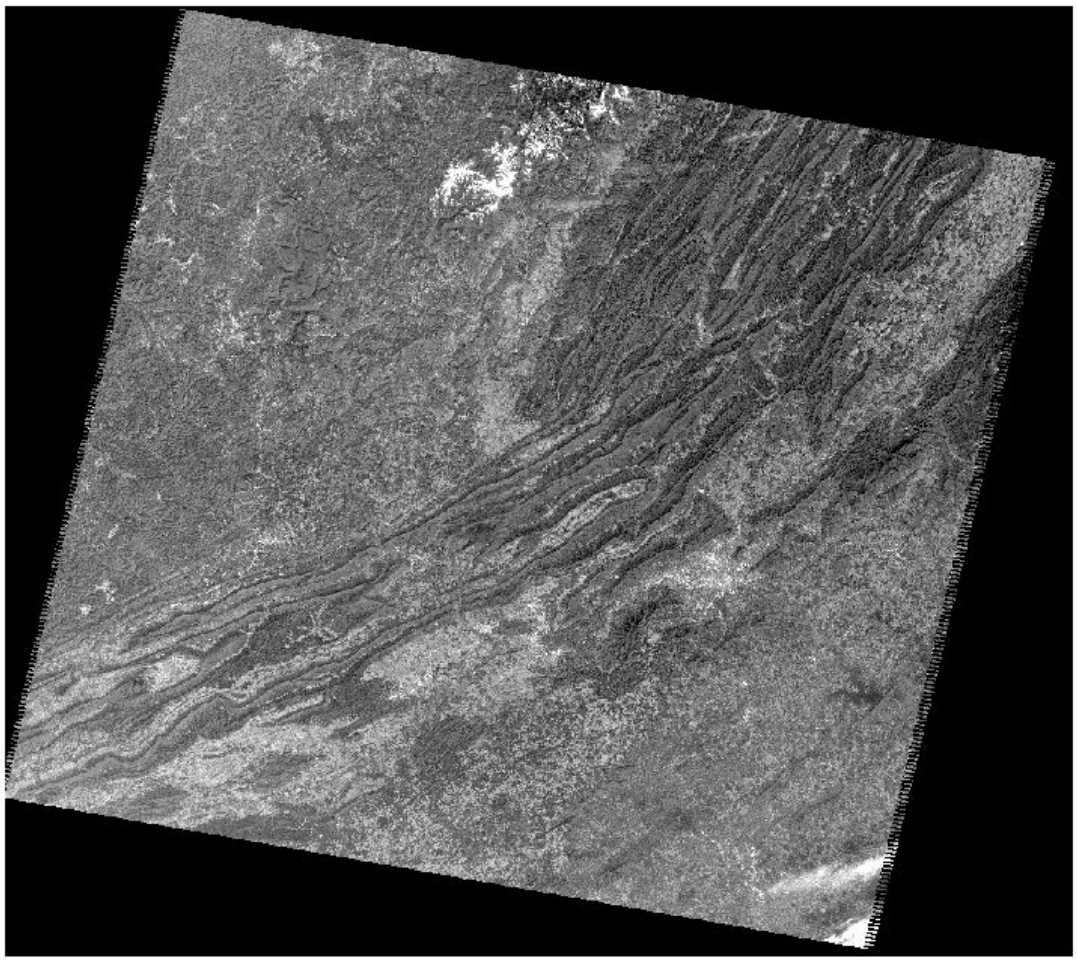


Once you click ***Add***, you will get the following message (7 times – once for each image).

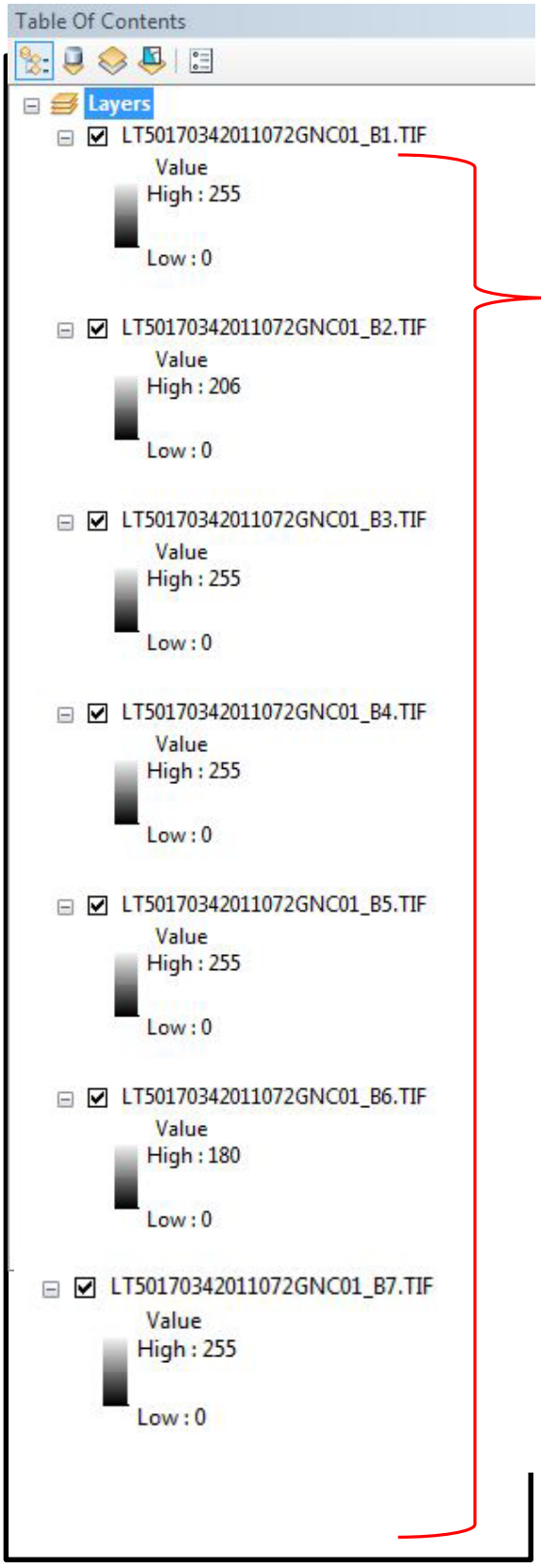


Click ***Yes*** and use all default parameters within the dialog box. (*For more information on **Creating pyramids** – see* the Adding Data to a Map Document tutorial for more information.

The following image will show in the display section of your ArcMap window:



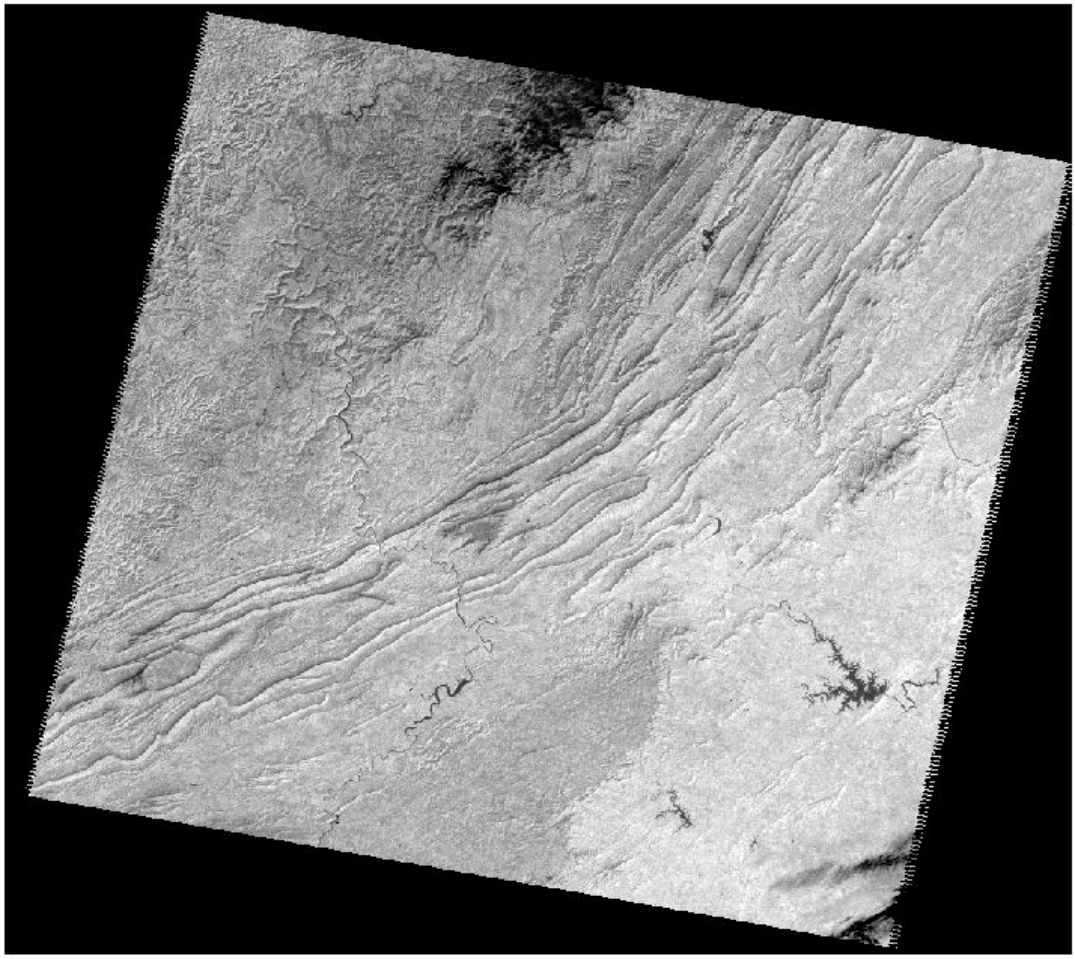
This is actually multiple images, one stacked on top of another.



Each images will be listed in the ***Table of Contents*** as separate layers, one for each band. You see only the image for Band 1 in the map document window because that is the layer that is on top in the ***Table of Contents***. You can uncheck a layer so it is no longer visible. You will then see the next layer in the sequence.

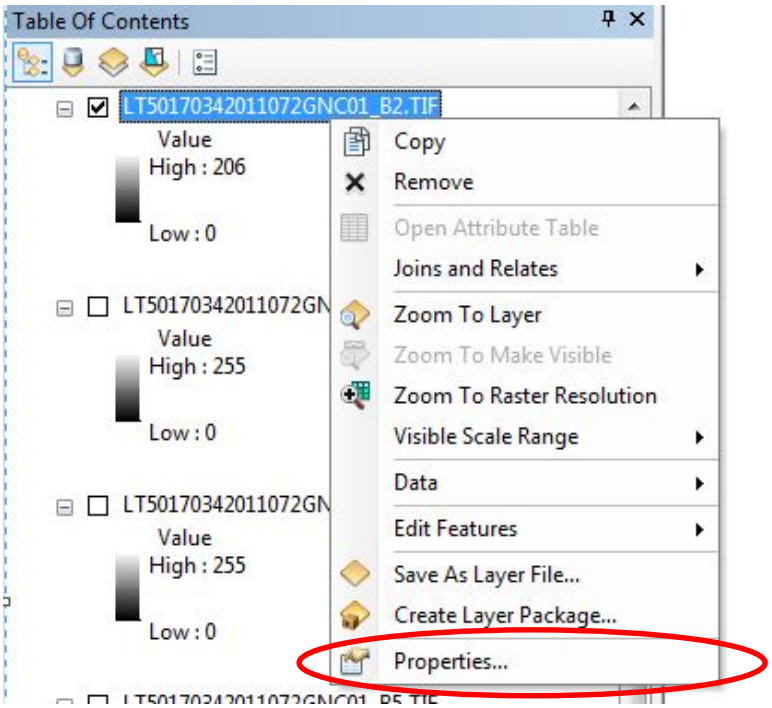
As you can see, each band is displayed in grayscale *(see **Displaying Data tutorial**, if you have questions.)* The digital number (DN) next to the grayscale tells you the brightness values within each band. Landsat 5 scenes are recorded in 8 bits, so you can have a total of 256 brightness values (numbers 0 – 255). For Band 1, you have 256 different brightness values (but, for Band 6, recording a portion of the thermal spectrum, only 180 different values). Brightness values refer to the reflectivity of the specific feature, the higher the number – the more reflective. *(For more information – see Introduction to Remote Sensing by Campbell and Wynne, 2011.)*

Uncheck each layer, starting with Band 1 and down to Band 6, so you can subsequently see each band displayed in the map document window. Do they look the same? No, each one has a slightly different look because remember each band records a different region of the electromagnetic spectrum, and each band serves a different purpose *(see Landsat table above and additional notes at the end of this tutorial)*. Which band looks most unlike the others?

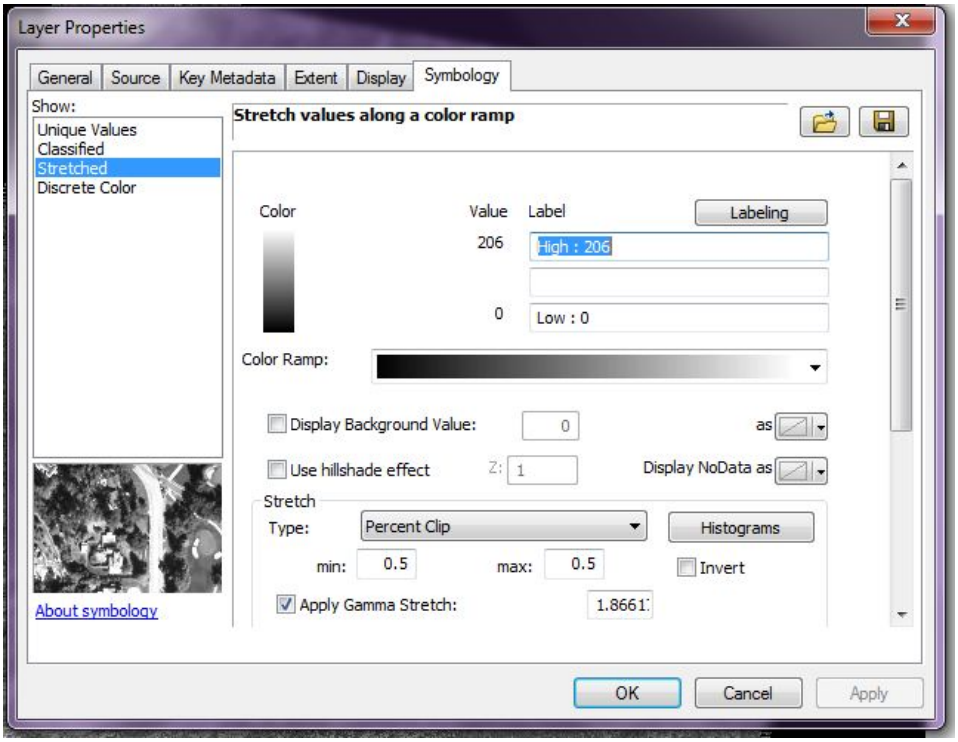


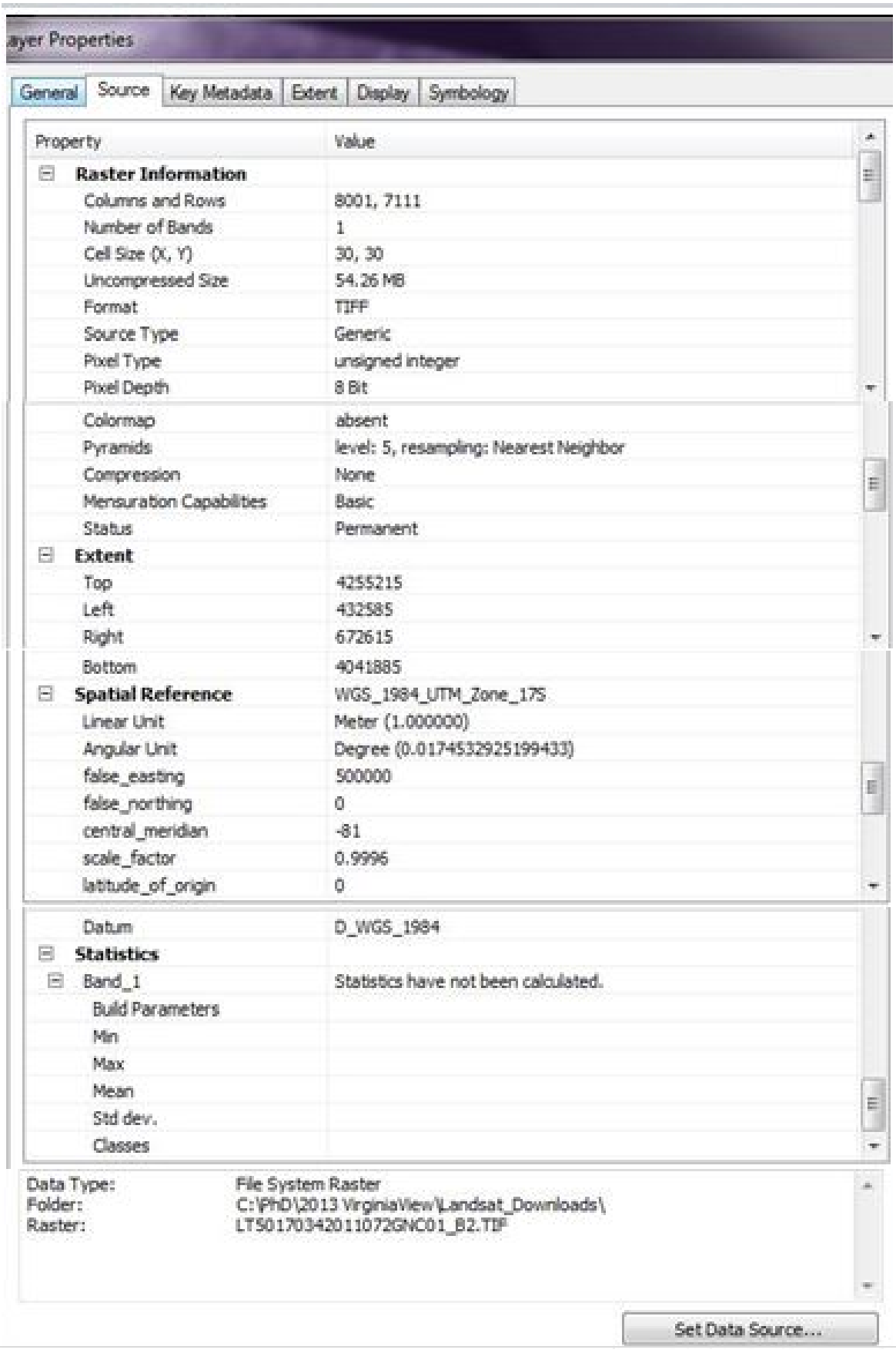
(Answer- Band 6, because Band 6 records thermal radiation, is distant on the spectrum from the other channels, and its pixel are larger in size than the other bands.)

What information can we get from the ArcMap display of a Landsat scene? Right click on any of the bands, and then click on ***Properties***.



This will give us the Layer Properties dialog box for that particular image. There are several different tabs – the ***Symbology*** tab was introduced in Tutorial 6. Here, we are interested in the ***Source*** tab. Click on it.

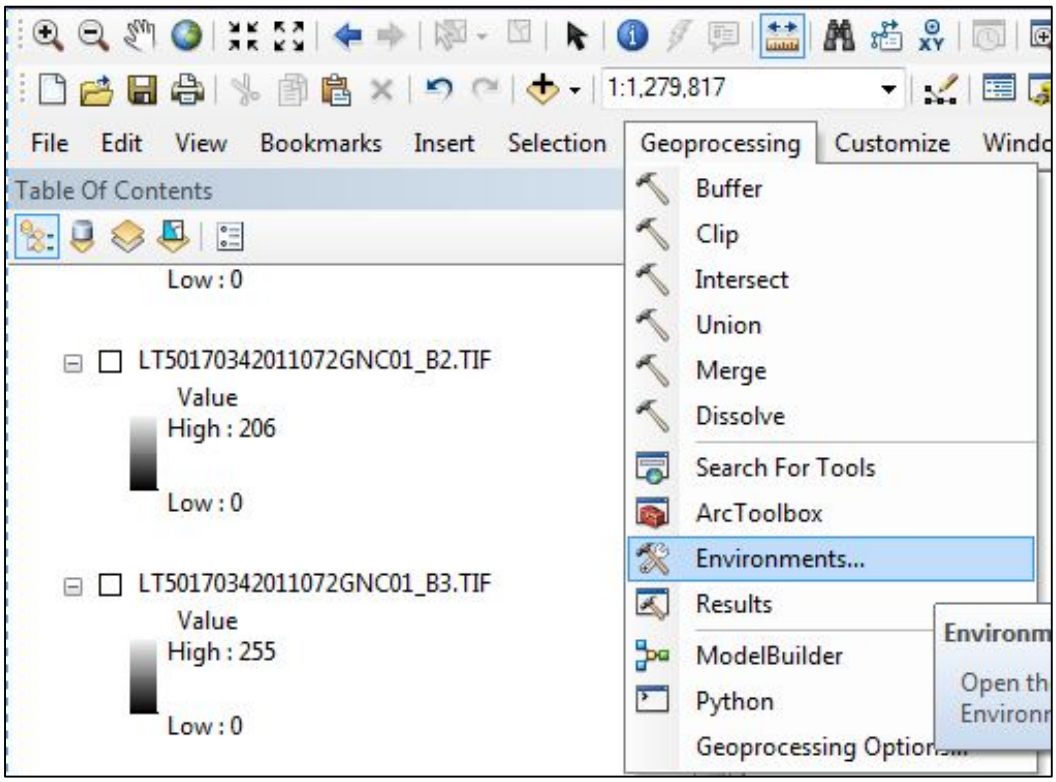



ayer Properties
General
Source
Key Metadata
Extent
Display
Symbology
Property
Value
Raster Information
Columns and Rows
8001, 7111
Number of Bands
1
Cell Size (X, Y)
30, 30
Uncompressed Size
54.26 MB
Format
TIFF
Source Type
Generic
Pixel Type
unsigned integer
Pixel Depth
8 Bit
Colormap
absent
Pyramids
level: 5, resampling: Nearest Neighbor
Compression
None
Mensuration Capabilities
Basic
Status
Permanent
Extent
Top
4255215
Left
432585
Right
672615
Bottom
4041885
Spatial Reference
WGS_1984_UTM_Zone_17S
Linear Unit
Meter (1.000000)
Angular Unit
Degree (0.0174532925199433)
false_easting
500000
false_northing
0
central_meridian
-81
scale_factor
0.9996
latitude_of_origin
0
Datum
D_WGS_1984
Statistics
Band_1
Statistics have not been calculated.
Build Parameters
Min
Max
Mean
Std dev.
Classes
Data Type:
File System Raster
Folder:
C:\PhD\2013 VirginiaView\Landsat_Downloads\
Raster:
LT50170342011072GNC01_B2.TIF
Set Data Source...

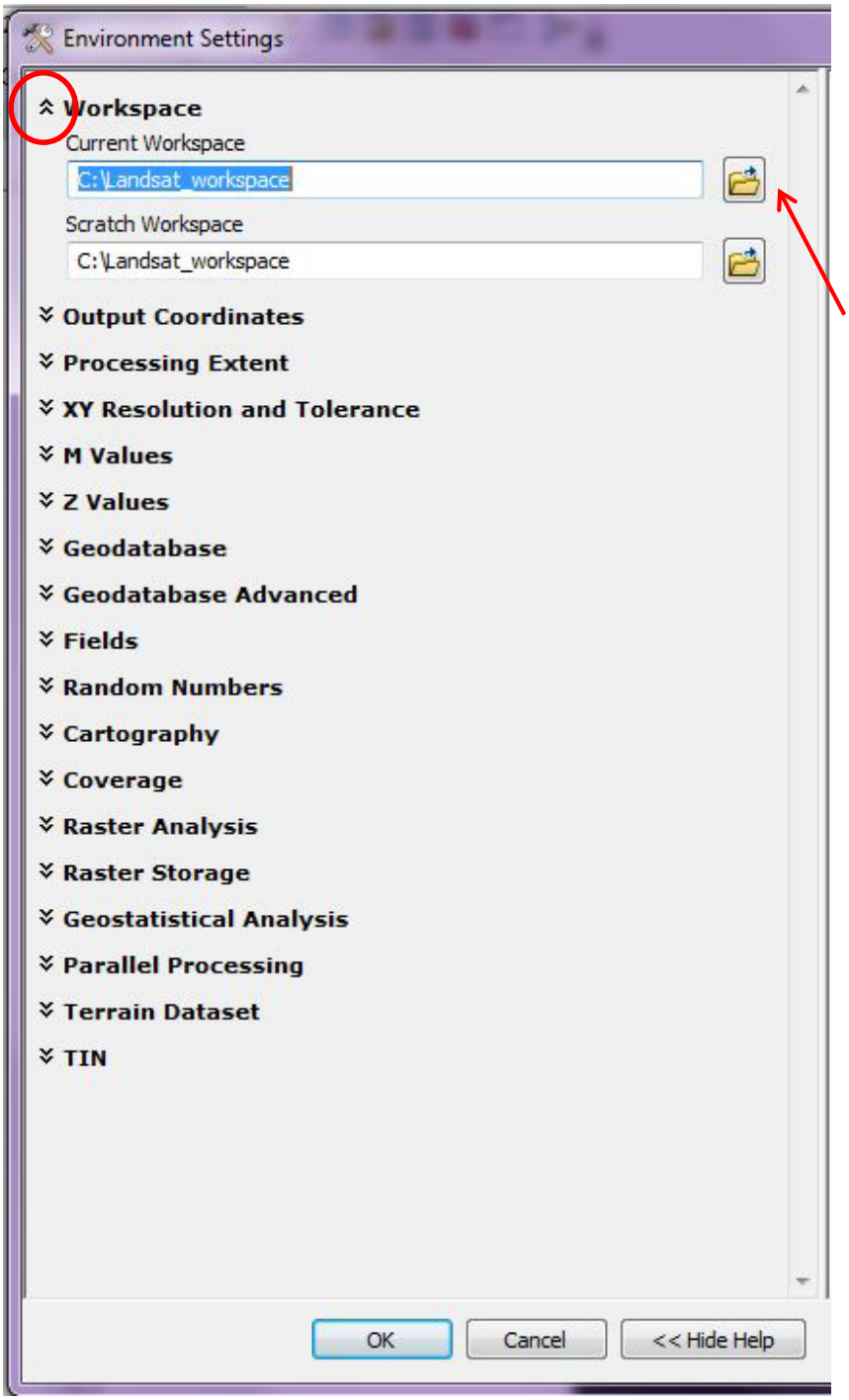
This tab gives you information that has been gleaned from the metadata (*note the prior image shows a series of screen shots to show you all the information available under the* ***Source*** *tab – your source tab will not display all this information at one time – you must use the scroll bar on the right to see the various items of information*). The number of ***columns and rows*** refers to how many cells in a column and in a row for this scene. The ***number of bands*** is 1, because this is only one of the 7 bands. The ***cell size*** is (30, 30) – what measurement unit? Look under ***Spatial Reference*** to find– *meter*. What other information do you see?

Setting up Image Analysis in ArcMap

First you need to set your workspace. Left-click on ***Geoprocessing.*** Within the ***Geoprocessing*** dialog box, left-click on ***Environments.***



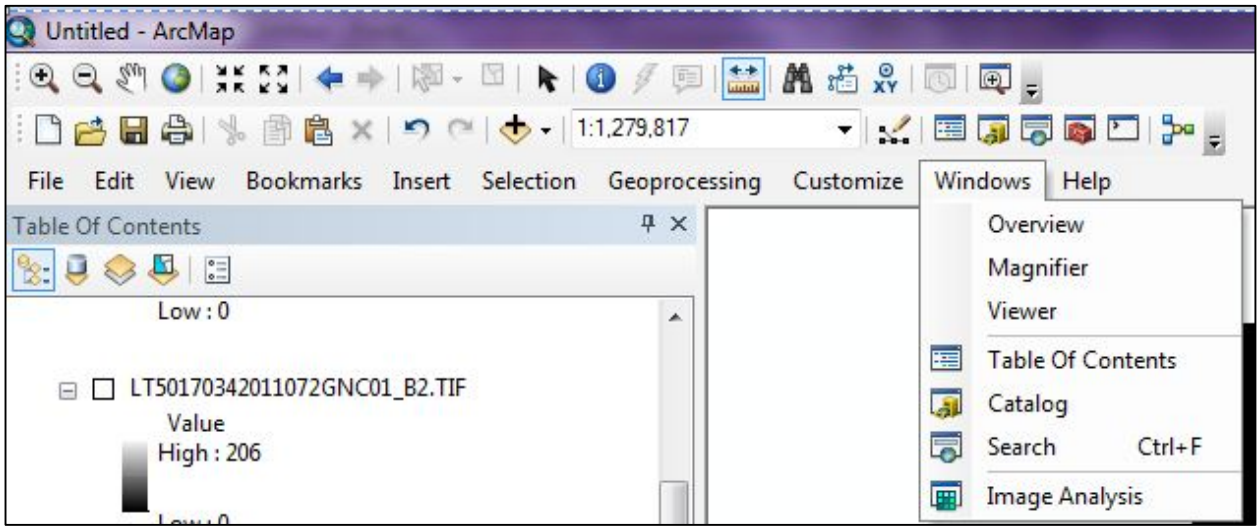
10a. Displaying your Landsat Imagery

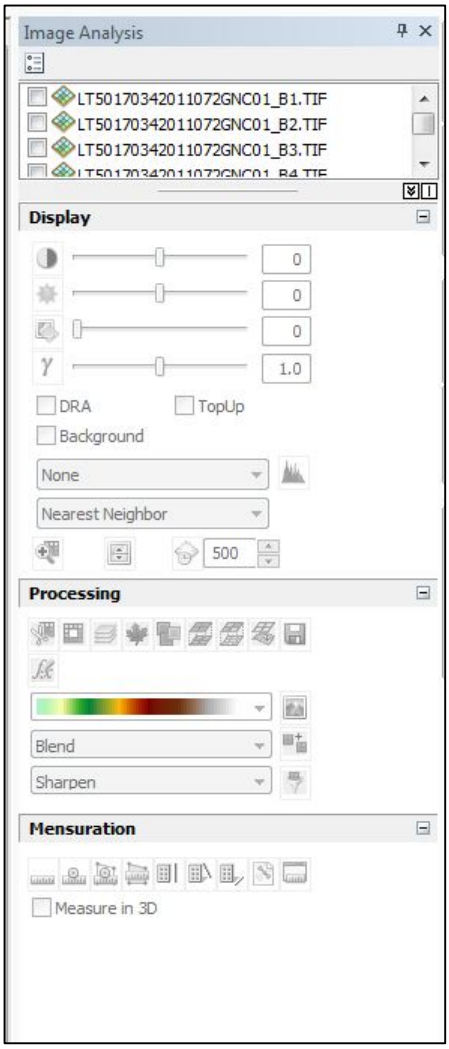


When the ***Environments Settings*** dialog box opens, click on the down arrows (red oval) next to ***Workspace.*** Click on the file folder next to ***Current Workspace*** and navigate to the folder where you want to save any work that you do within ArcMap. (*Note – it is recommended that you set up a file folder for your work, separate from the file folder where you have the original Landsat images*).

After you set this workspace, then click on the file folder next to ***Scratch Workspace*** and navigate to the same folder. Once your ***Workspaces*** have been set, click ***OK***.

Next, left-click on ***Windows*** and then left-click on ***Image Analysis.***





The ***Image Analysis*** window opens on the right side of the map document window. You will be using this window in most of the following tutorials. As you can see, it lists the layers at the top of this window as they are listed in the ***Table of Contents***. Please make sure that your layers are listed in order – band 1, band 2, band 3, etc. If you left-click on any one of the layers within the ***Image Analysis*** window, some of the buttons under ***Display*** and ***Processing*** will be enabled. If you click on more than one image (by holding down the shift key), additional buttons under ***Processing*** will be enabled.

We will not discuss these buttons in this tutorial (*see the tutorial on Radiometric Enhancement of Landsat Imagery or GIS help for more information on the Display buttons. Some Processing buttons will also be discussed in subsequent Tutorials*).

10a. Displaying your Landsat Imagery

You are now ready to start using the ***Image Analysis*** window in ArcMap. We recommend that you complete the tutorials on Creating a Composite Image, Band Combinations, and Sub-setting before you start performing different analyses.

10a. Displaying your Landsat Imagery

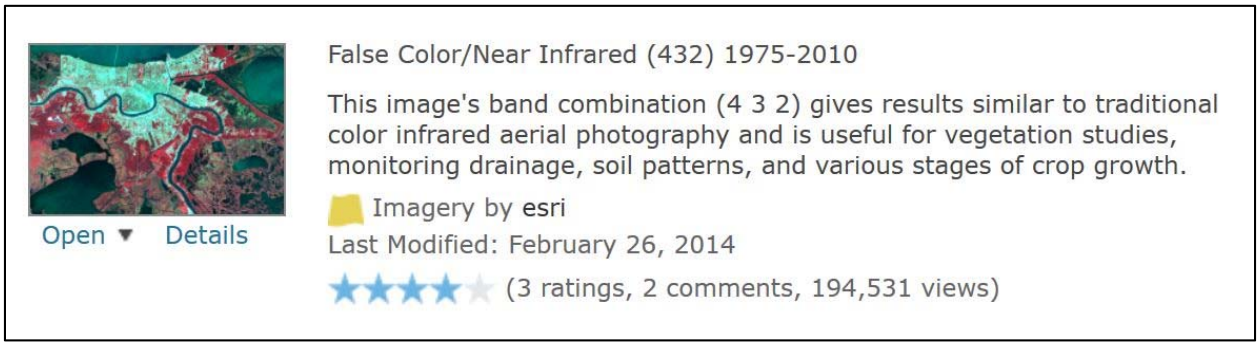
Notes:

The instructional materials contained within these documents are copyrighted property of VirginiaView, its partners and other participating AmericaView consortium members. These materials may be reproduced and used by educators for instructional purposes. No permission is granted to use the materials for paid consulting or instruction where a fee is collected. Reproduction or translation of any part of this document beyond that permitted in Section 107 or 108 of the 1976 United States Copyright Act without the permission of the copyright owner(s) is unlawful.

Introduction to ESRI's Landsat Community

The United States Geological Survey (USGS) has provided (and continues to provide) ESRI with the complete Landsat Archives. ESRI has processed many of the Landsat images for various purposes. You can find the complete list of proceesed images and descriptions at: http://www.arcgis.com/home/group.html?owner=esri&title=Landsat%20Community.

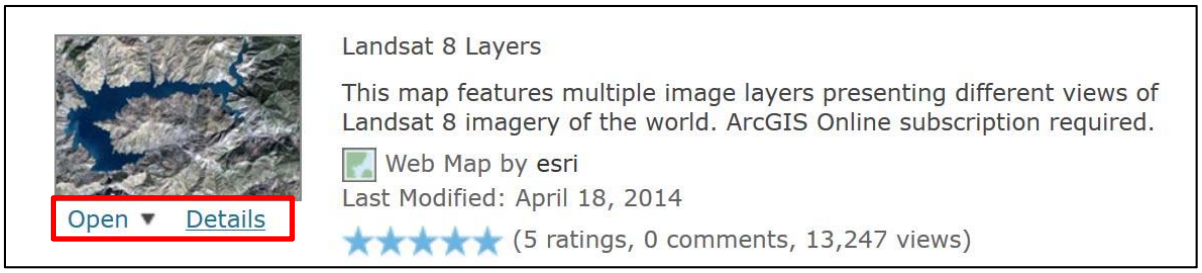
Examples of processed images are:



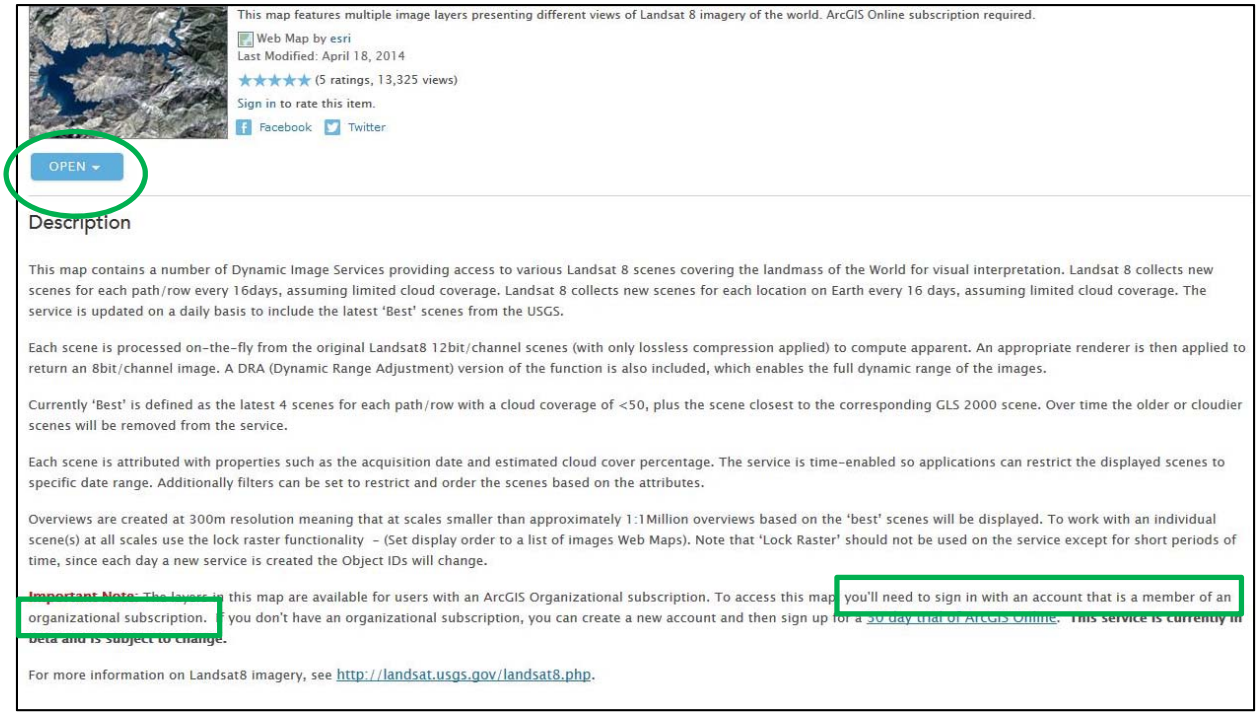
As you can see from the prior two figures, ESRI has provided brief descriptions of the processed images. ESRI updates these on a daily basis, as the USGS provides new Landsat data. In some instances, the existing image database is updated. In other instances a new image database may be generated. For instance, when the flooding in the Balkans occurred in late May 2014, ESRI processed a new database just for the purpose of showing the flooding and resultant changes.

Accessing the ESRI Landsat Data

Underneath the Figure within each description, you have two options – Open and Details.



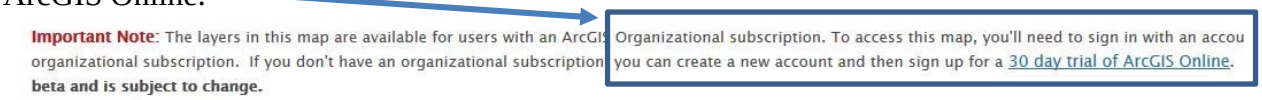
Clicking on Details provides a more comprehensive description of Landsat and processing.



These details also describe the level of ESRI access needed to use the data. There are two types of access, a *personal ArcGIS On-Line Subscription* and an *organizational subscription*. With either type of sign-on, you can view the data in ArcGIS On-Line or through the ESRI sign-in through ArcGIS desktop.

For example, (in the above figure and in the green box), an ESRI *organizational subscription* is required to access the *Landsat 8 Layers* images. Check with your organization to see if they have an account and to obtain a log in identification number and password. Please be sure to check with your organization on usage limitations[i] (K-12 educational institutions, please see Page 20 of this tutorial for more information).

If your organization does not have an organizational subscription, you can get a 30 day trial of ArcGIS Online.



Once you have decided which dataset you need, click Open (green circle) located underneath the image, it will take you to *ArcGIS On-Line* and ask that you sign-in. Once you sign-in, *ArcGIS On-Line* will be activated.

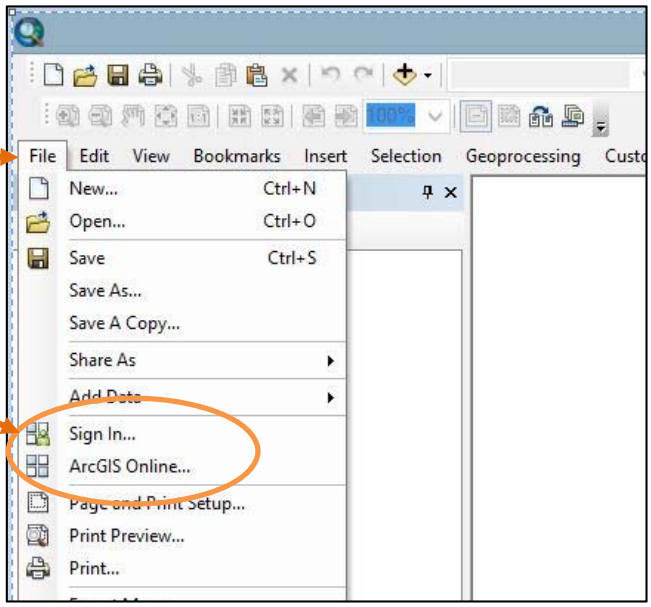
Accessing ESRI's Landsat Imagery Dataset through ArcGIS Desktop

Open *ArcMap*.

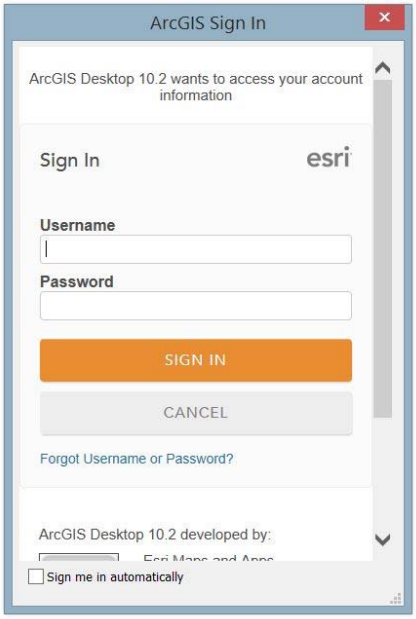
First, you need to sign into ESRI with your *organization account* sign-in.

Go to *File*

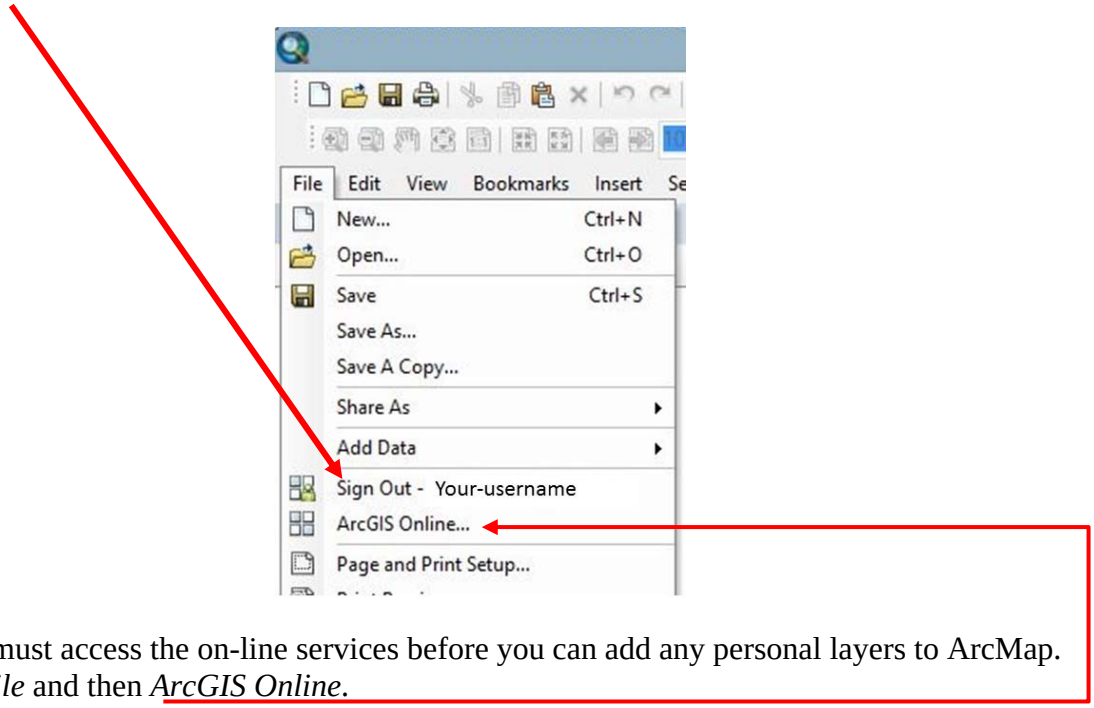
Sign In….



You get the *ArcGIS Sign In* window, enter both your Username and Password, then click **SIGN IN** (note: hitting enter won't work, you have to actually use your mouse and click on it).

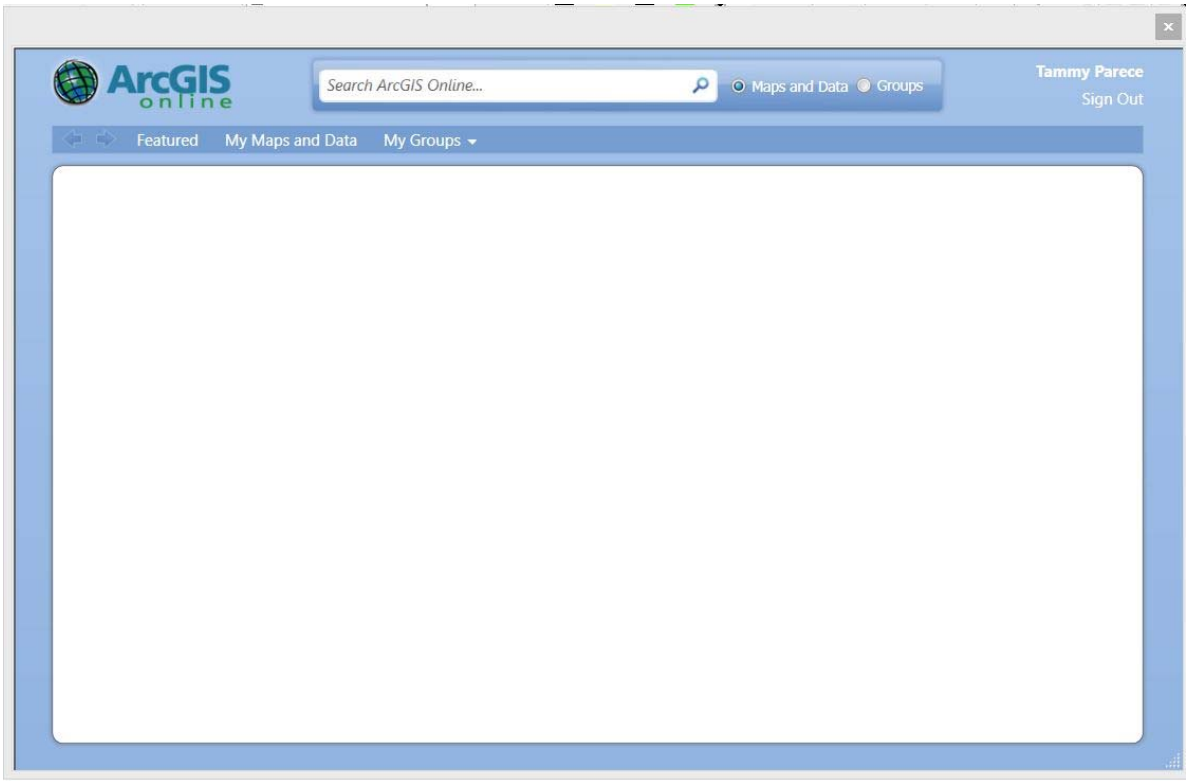


How do you know that you successfully signed in? Go back to *File*, you will now see it says *Sign Out – Your-username*

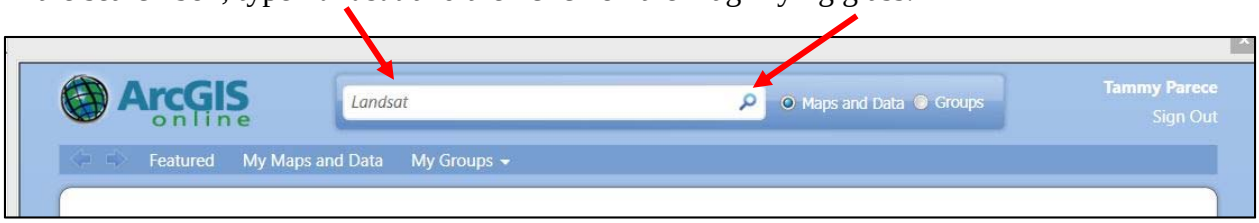


Next, you must access the on-line services before you can add any personal layers to ArcMap. Click on *File* and then *ArcGIS Online*.

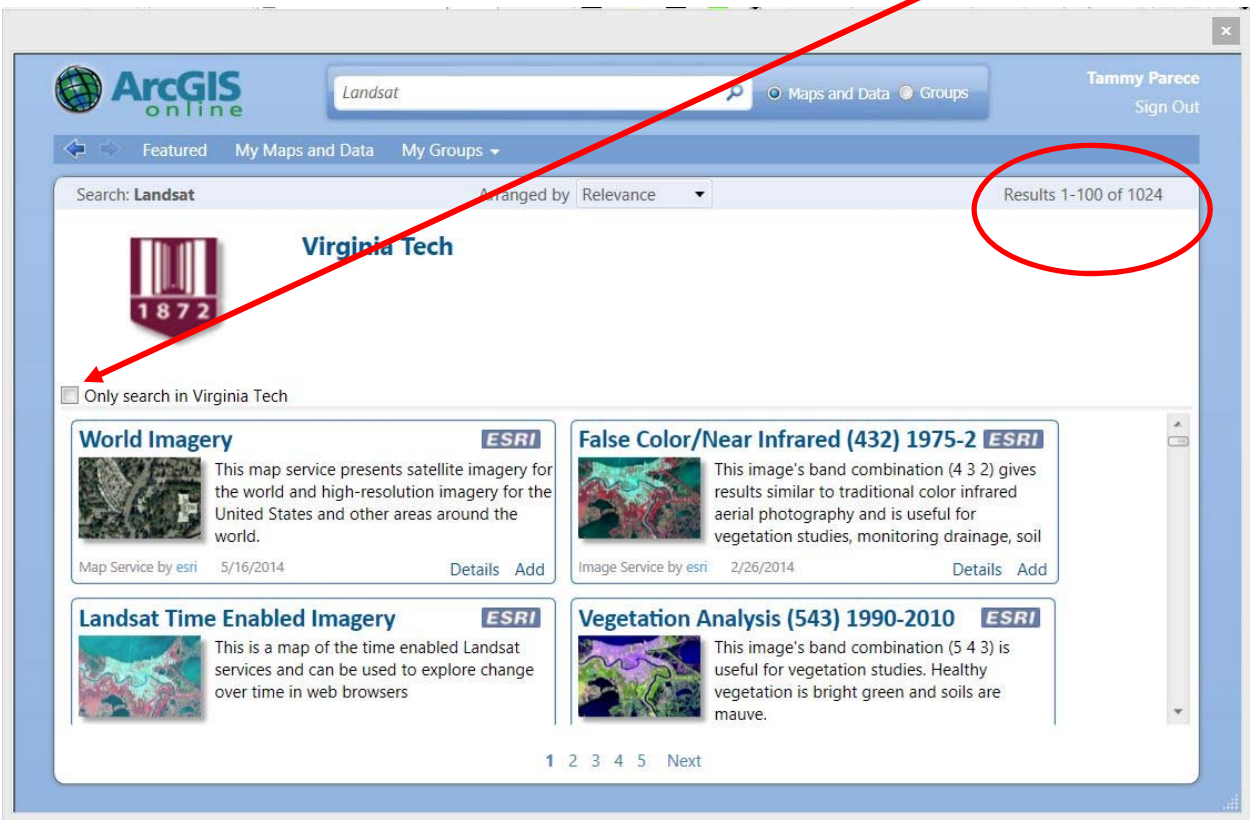
You get the following window:



In the search box, type *Landsat* and then click on the magnifying glass.



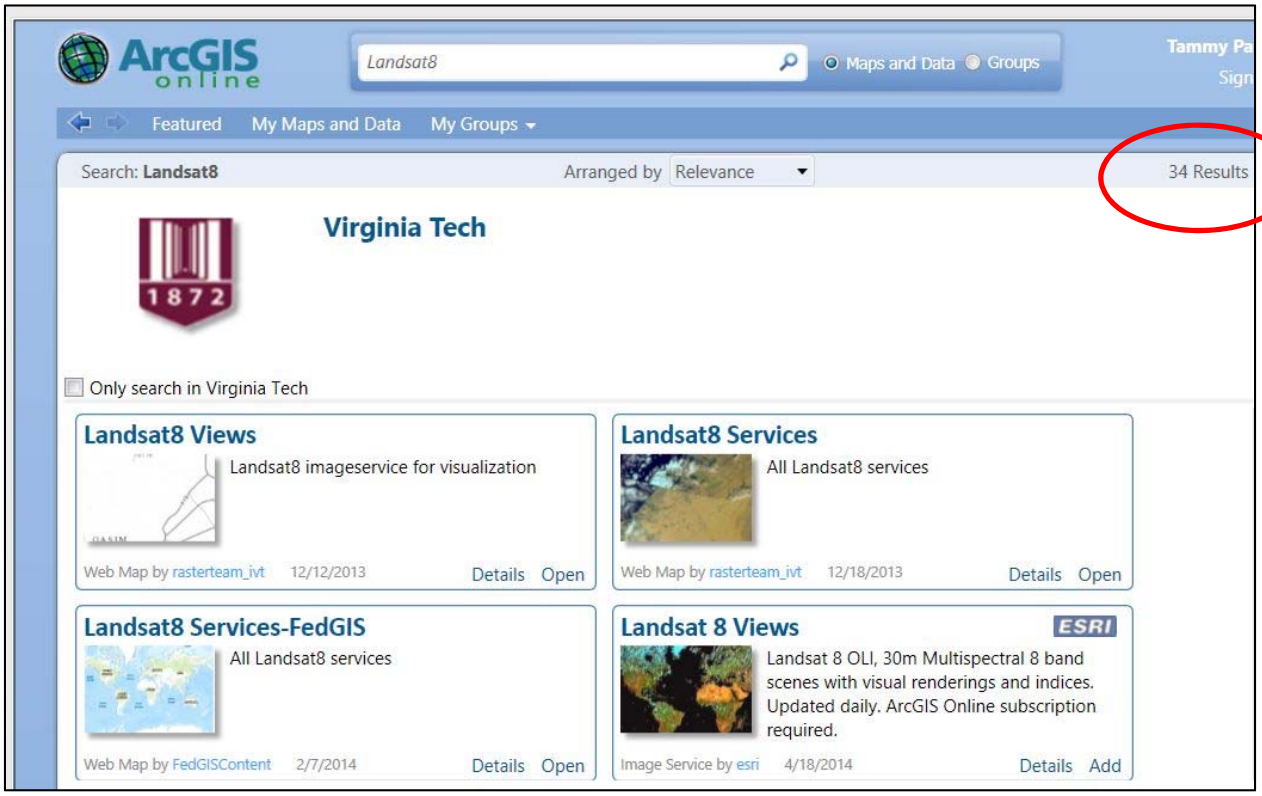
You may only see those maps that have been saved by your organization. To access maps that others outside of your organization have created, make sure that the box *Only search in…* is unchecked.



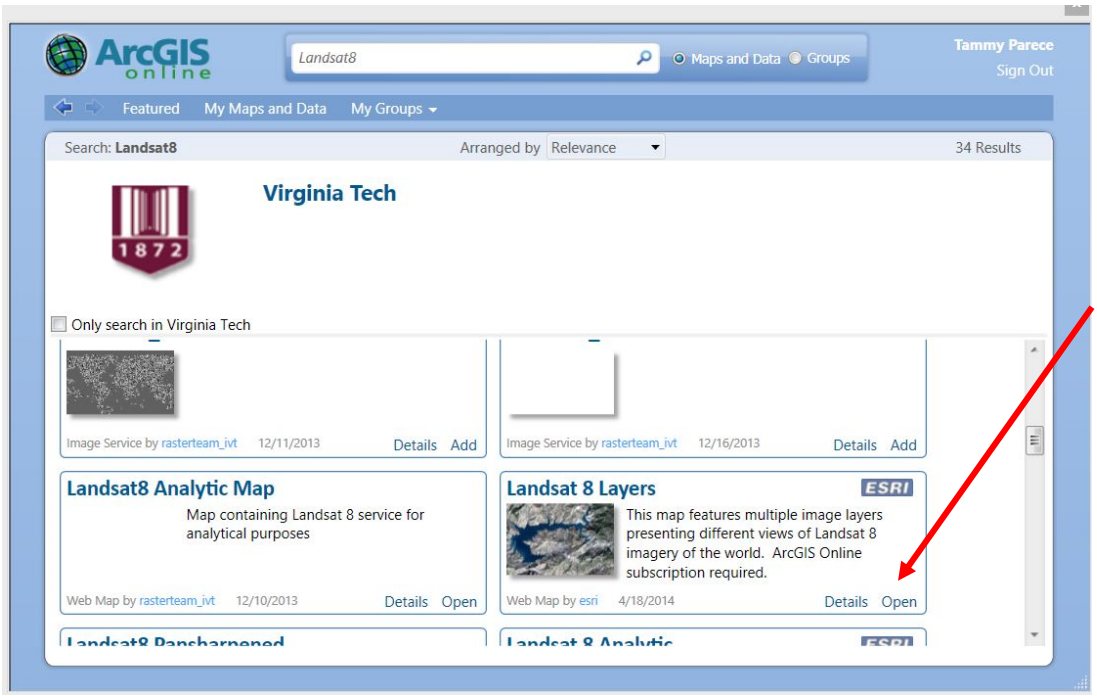
You will get all the results of map documents created by ESRI using Landsat imagery. There were over 1024 maps were available when this tutorial was completed (red circle).

That is a lot of maps to page through, so, let's refine the search and change the search type to *Landsat8*. (If you have already identified the exact map – as identified in pages 1 and 2 of this tutorial -- use the exact name of the map in the search window, including spaces if any).

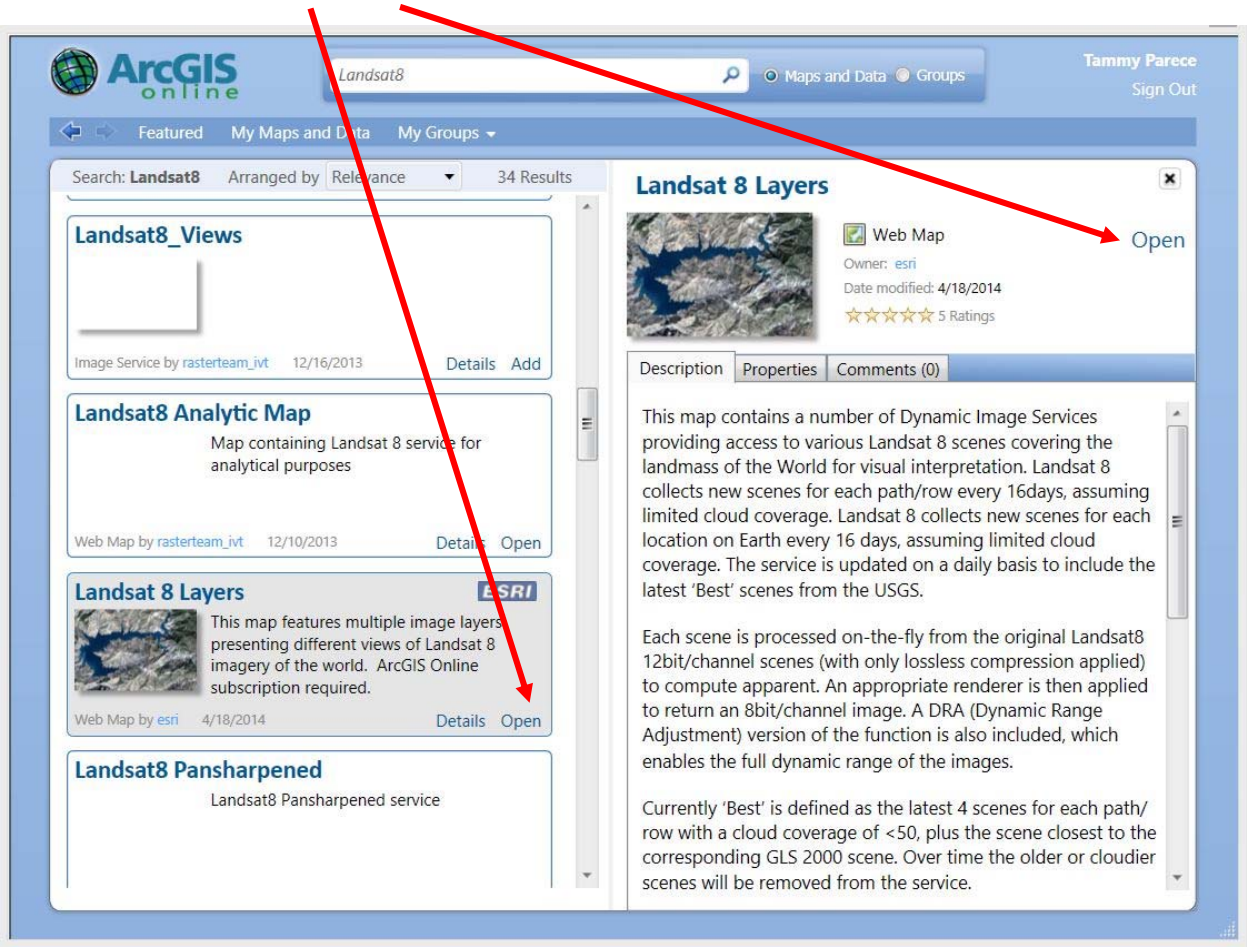
This time, we see only 34 results (red circle).



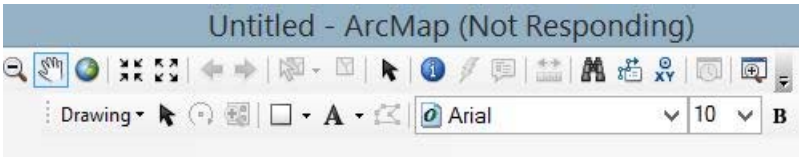
As seen in the above window, the window on page 5, and below, the same listing of maps are shown as we saw when we went straight to ESRI's website (page 1). We can also get the details from this window. Look for the map titled *Landsat 8 Layers*. As you can see we have both *Details* and *Open* as options. Click on *Details*. You will see the same details as you did before (page 2).



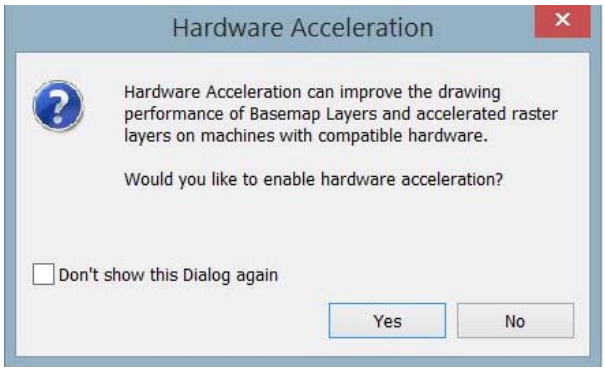
Now click on *Open,* here or here.



The on-line map document from ESRI will eventually open in your ArcMap window, just be patient. You may see the following in the upper status bar. Don't worry, be patient.

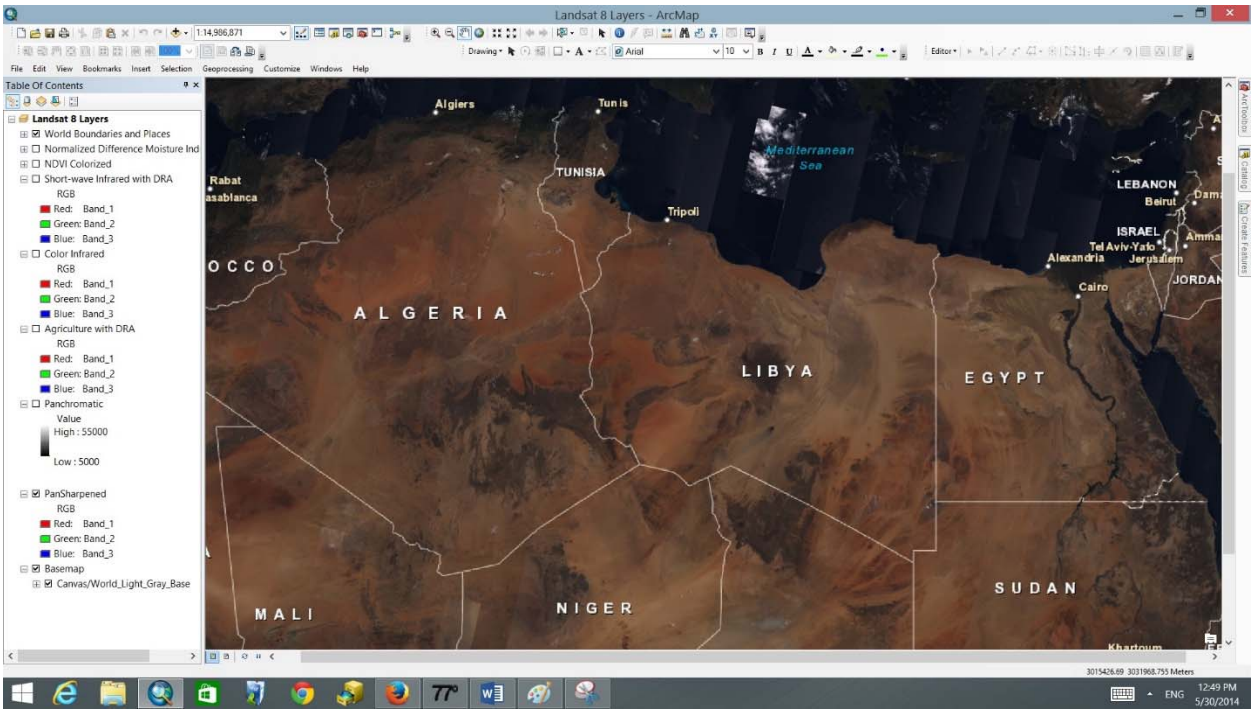


Once the map document is ready to open, you may see the window on the right. Be sure to check with your IT Department before clicking yes on this window. For now, just click *No*.



The document will then open in ArcMap.

Examing an ESRI Landsat 8 Map Document

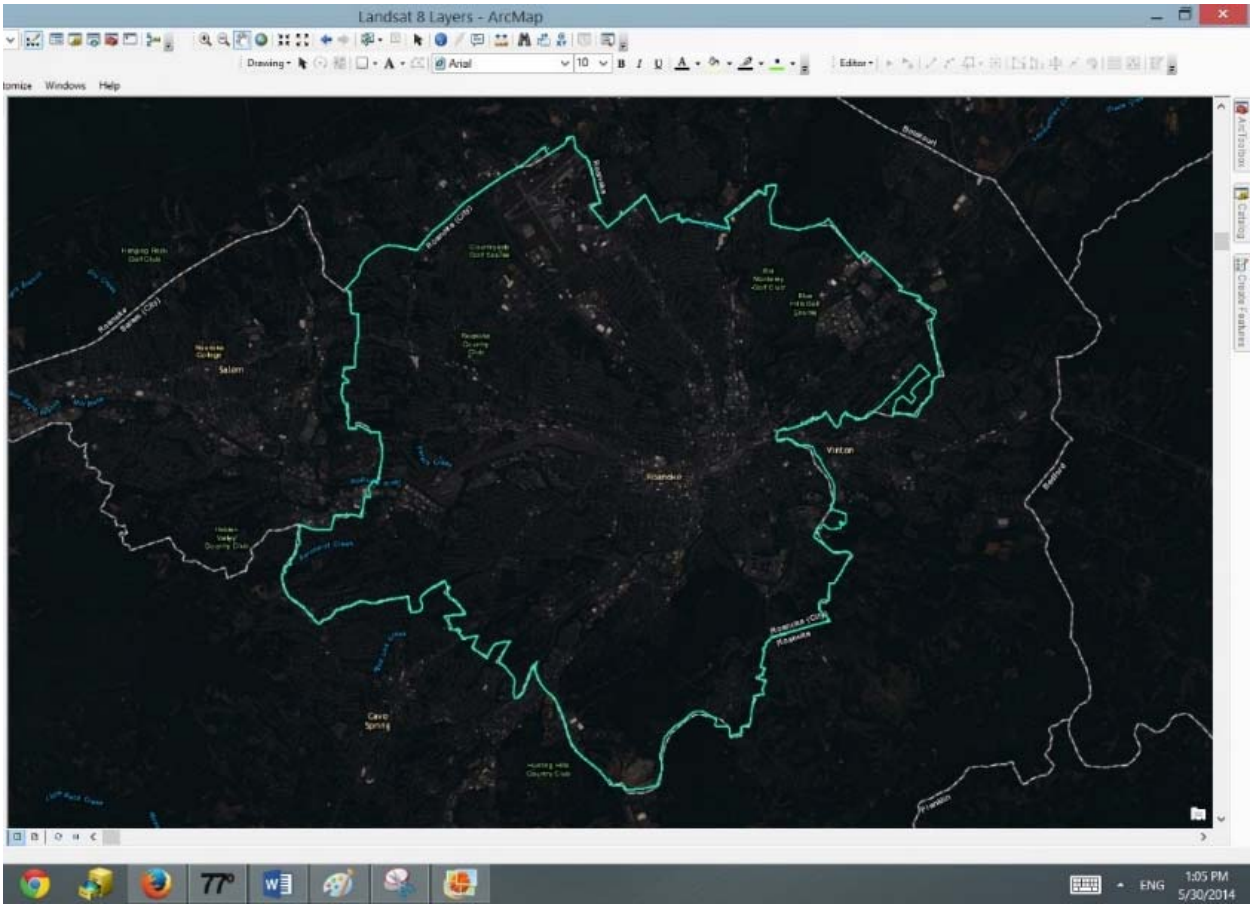


You have accessed Landsat 8 scenes for the entire world. It defaults to show Northern Africa, You can navigate to your own region of interest in one of two ways.

1 - You can navigate by using the pan tool to go to the region.

2 - Or, the better option is to add your personal shapefile for your region and then zoom in to the area. Yes, you can now add your personal shapefiles!

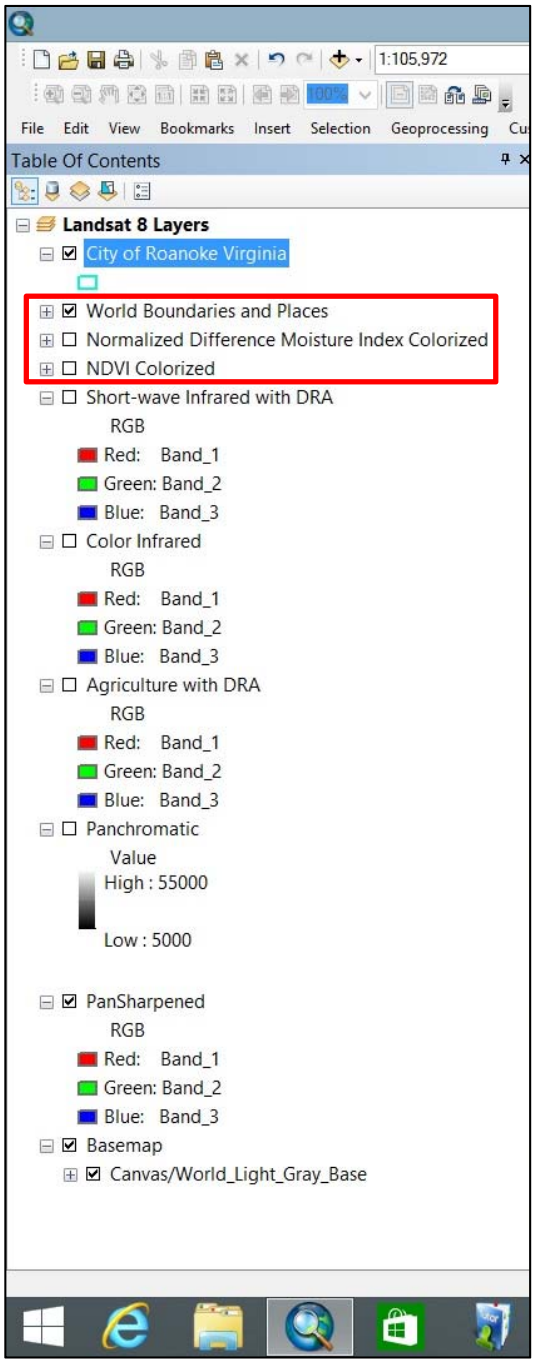
In the map document window, below, I have added the boundary file for the City of Roanoke, Virginia and then zoomed to the layer. I have altered the symbology for this polgyon file so it is hollow with a cyan-colored border.



Now let's take a closer look at the *Table of Contents* in the window on the left side of ArcMap.

You see the City of Roanoke, Virginia boundary layer on top since that is the last layer added.

For this particular ESRI Landsat 8 map document, it has several different layers. ESRI just did not create a map document with Landsat 8 images, they also have *World Boundaries and Places* (top of the *Table of Contents*) and an underlying *Basemap* (bottom of the T*able of Contents*).



Also included in the *Landsat 8 Layers* map document are several Landsat layers that have been processed by ESRI for certain properties. The first one is *Normalized Difference Moisture Index Colorized*, Then *NDVI Colorized*. (You can refer back to *Tutorial 16 - Spectral Enhancement of Landsat Imagery* – for specific uses on NDVI, Color Infrared, and other band ratios. Available from http://virginiaview.cnre.vt.edu/education.html#RSinArcGIS10

or from the Virginia Geospatial Technology YouTube channel.)

Remember the varying bands of Landsat do represent different regions of the electromagnetic spectrum, so please refer to earlier tutorials for more information. Landsat 8 has additional bands not present on prior Landsat satellites, and for specifics on the varying bands of Landsat 8, you should consult the USGS website on specific uses for the different Landsat bands.

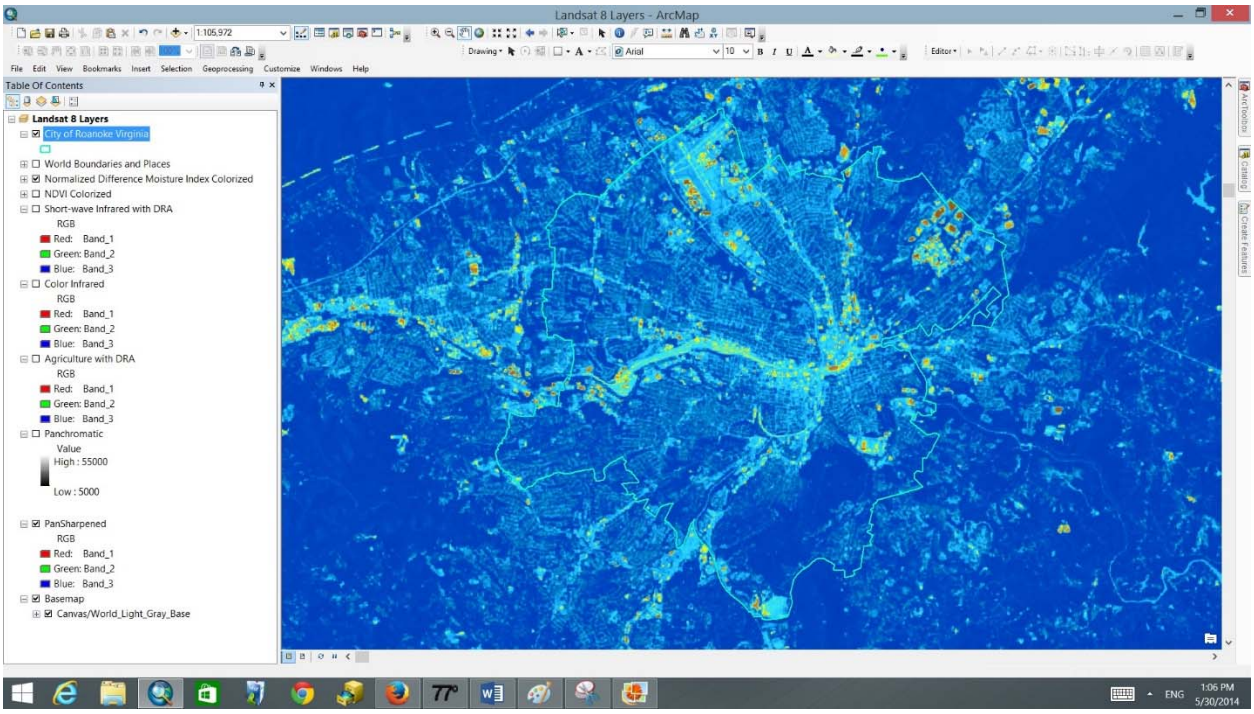
http://landsat.usgs.gov/band_designations_landsat_satellites.php

Not all of the layers in the *Table of Contents* are turned on. But you can turn on and off layers for display purposes. It is better not to have them all turned on at the same time. Remember you have a map document with images for the entire world, so it takes some time to load and unload.

Let's look at one of these layers as an example.

Uncheck *World Boundaries and Places* in the *Table of Contents*, and check *Normalized Difference Moisture Index Colorized* (red box).

Your map display will now look like this (note again, this is for the Roanoke, Virginia area):



ESRI has already processed the Landsat scene for this layer. It is a band ratio called Normalized Difference Moisture Index (NDMI). The formula for this ratio will vary, depending on the specific satellite system, so you should consult specific literature and the satellite system website to determine which bands should be used to calculate this or any other band ratio.

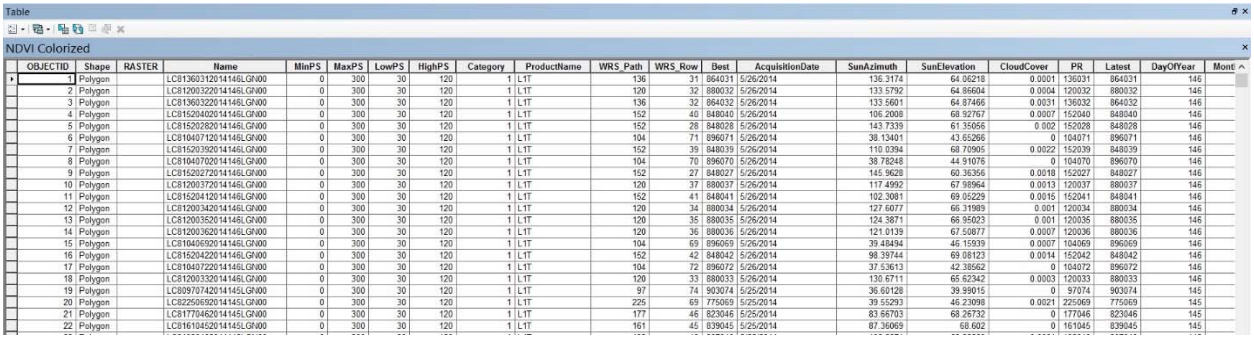
You could download Landsat Imagery yourself directly from EarthExplorer (*Tutorial 8 – Downloading Landsat Imagery from EarthExplorer*) and process it using ArcMap's *Image Analysis* or *Spatial Analyst* tools to develop the same index, but ESRI has saved you time and provided you with the results.

Colorized means that ESRI chose a default color scheme for this display. In the *Table of Contents*, it does show RGB, but since ESRI has already processed these particular images, these, again, are strictly colorization in the three basic visible colors – red, green and blue. You can change the symbology, if you wish, for different color combinations. This does not change the results.

ESRI has also already processed some of the images for display as specific band combinations (as discussed in *Tutorial 12 – Specific Band Combinations Using Landsat Imagery*). As an example, on the right – ESRI has processed these map documents with only three specific Landsat bands as noted in the map's title.

Please note that there is one ESRI Landsat Map document that allows us to create our own band combinations - we will discuss this in a subsequent section.

Each one of the layers in the *Table of Contents* also has an *attribute table* (example below).

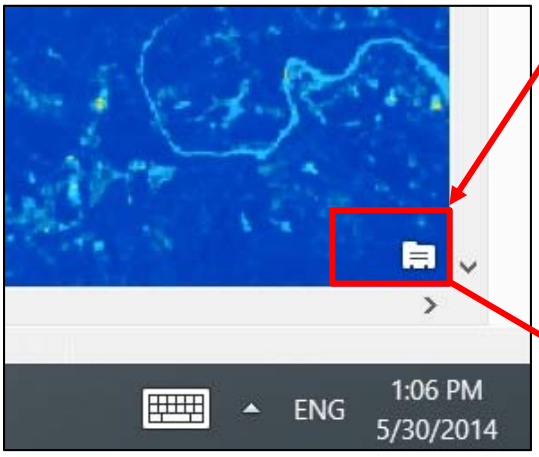


Table

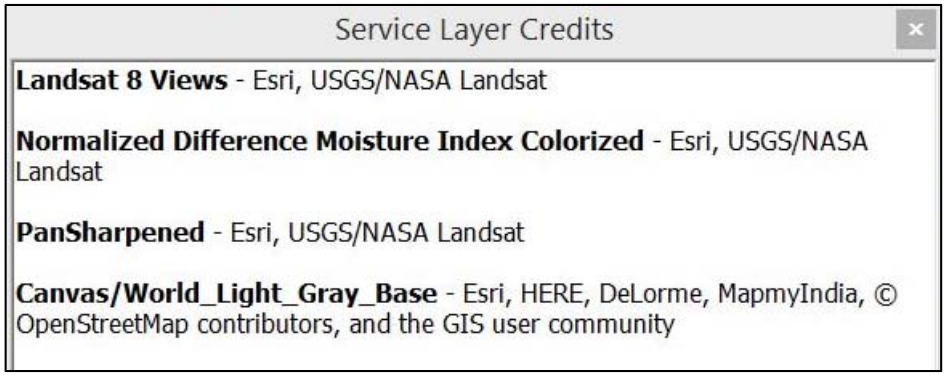
NDVI Colorized

OBJECTID	Shape	RASTER	Name	MinPS	MaxPS	LowPS	HighPS	Category	ProductName	WRS_Path	WRS_Row	Best	AcquisitionDate	SunAzimuth	SunElevation	CloudCover	PR	Latest	DayOfYear	Mont
1	Polygon		LC81360312014146LGN00	0	300	30	120	1	L1T	136	31	864031	5/26/2014	136.3174	64.06218	0.0001	136031	864031	146	
2	Polygon		LC81200322014146LGN00	0	300	30	120	1	L1T	120	32	880032	5/26/2014	133.5792	64.86604	0.0004	120032	880032	146	
3	Polygon		LC81360322014146LGN00	0	300	30	120	1	L1T	136	32	864032	5/26/2014	133.5601	64.87466	0.0031	136032	864032	146	
4	Polygon		LC81520402014146LGN00	0	300	30	120	1	L1T	152	40	848040	5/26/2014	106.2008	68.92767	0.0007	152040	848040	146	
5	Polygon		LC81520282014146LGN00	0	300	30	120	1	L1T	152	28	848028	5/26/2014	143.7339	61.35056	0.002	152028	848028	146	
6	Polygon		LC81040712014146LGN00	0	300	30	120	1	L1T	104	71	896071	5/26/2014	38.13401	43.65266	0	104071	896071	146	
7	Polygon		LC81520392014146LGN00	0	300	30	120	1	L1T	152	39	848039	5/26/2014	110.0394	68.70905	0.0022	152039	848039	146	
8	Polygon		LC81040702014146LGN00	0	300	30	120	1	L1T	104	70	896070	5/26/2014	38.78248	44.91076	0	104070	896070	146	
9	Polygon		LC81520272014146LGN00	0	300	30	120	1	L1T	152	27	848027	5/26/2014	145.9628	60.36356	0.0018	152027	848027	146	
10	Polygon		LC81200372014146LGN00	0	300	30	120	1	L1T	120	37	880037	5/26/2014	117.4992	67.98964	0.0013	120037	880037	146	
11	Polygon		LC81520412014146LGN00	0	300	30	120	1	L1T	152	41	848041	5/26/2014	102.3081	69.05229	0.0015	152041	848041	146	
12	Polygon		LC81200342014146LGN00	0	300	30	120	1	L1T	120	34	880034	5/26/2014	127.6077	66.31989	0.001	120034	880034	146	
13	Polygon		LC81200352014146LGN00	0	300	30	120	1	L1T	120	35	880035	5/26/2014	124.3871	66.95023	0.001	120035	880035	146	
14	Polygon		LC81200362014146LGN00	0	300	30	120	1	L1T	120	36	880036	5/26/2014	121.0139	67.50877	0.0007	120036	880036	146	
15	Polygon		LC81040692014146LGN00	0	300	30	120	1	L1T	104	69	896069	5/26/2014	39.48494	46.15939	0.0007	104069	896069	146	
16	Polygon		LC81520422014146LGN00	0	300	30	120	1	L1T	152	42	848042	5/26/2014	98.39744	69.08123	0.0014	152042	848042	146	
17	Polygon		LC81040722014146LGN00	0	300	30	120	1	L1T	104	72	896072	5/26/2014	37.53613	42.38562	0	104072	896072	146	
18	Polygon		LC81200332014146LGN00	0	300	30	120	1	L1T	120	33	880033	5/26/2014	130.6711	65.62342	0.0003	120033	880033	146	
19	Polygon		LC80970742014145LGN00	0	300	30	120	1	L1T	97	74	903074	5/25/2014	36.60128	39.99015	0	97074	903074	145	
20	Polygon		LC82250692014145LGN00	0	300	30	120	1	L1T	225	69	775069	5/25/2014	39.55293	46.23098	0.0021	225069	775069	145	
21	Polygon		LC81770462014145LGN00	0	300	30	120	1	L1T	177	46	823046	5/25/2014	83.66703	68.26732	0	177046	823046	145	
22	Polygon		LC81610452014145LGN00	0	300	30	120	1	L1T	161	45	839045	5/25/2014	87.36069	68.602	0	161045	839045	145	

The *attribute table* lists general Landsat metadata for each scene. Remember again, this map document has Landsat scenes for the entire world. (For more details on metadata, refer back to *Tutorial 9 - Information about your Downloaded Landsat Imagery*.)



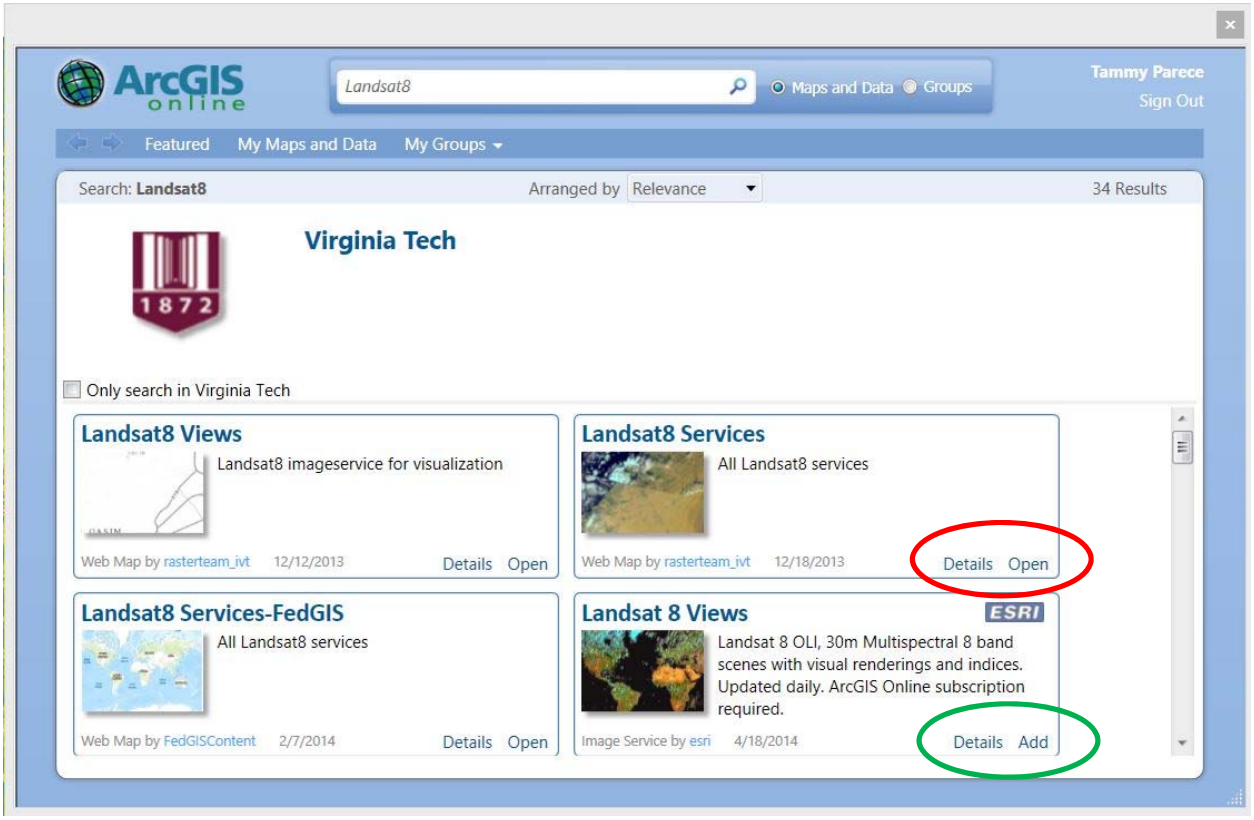
In the very bottom right corner of your map document window, you will see an index card (red square). If you click on this card you will get a *Service Layer Credits* window for each of the layers that are turned on in your *Table of Contents*. This window provides you with a quick reference for the images' source and processors.



Adding Multiple ESRI Landsat 8 Datasets to the Same Map Document

Sometimes, you can add multiple Landsat files to the same map document.

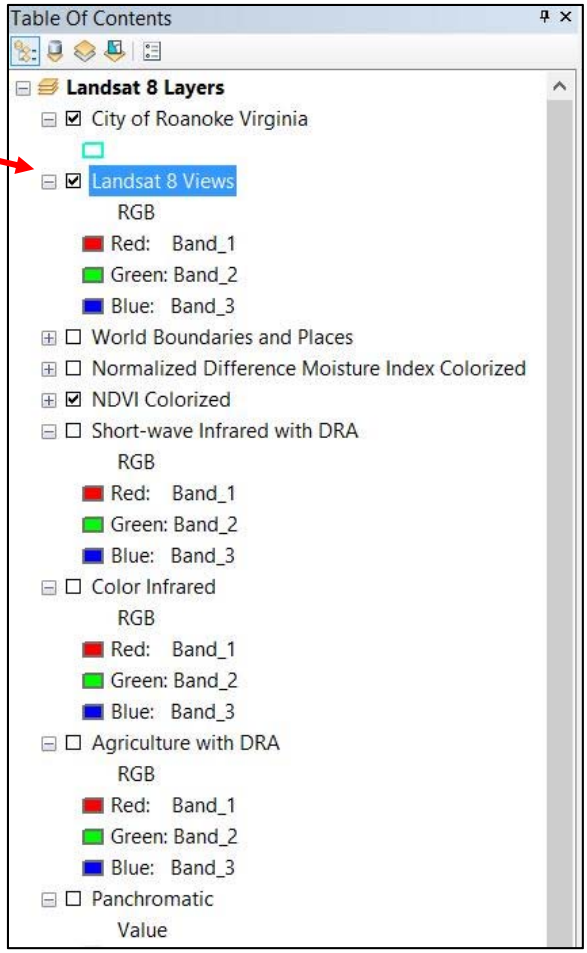
Go back to *File/ArcGIS Online* (page 4), pull up the search window and again search for Landsat 8. This time, look for *Landsat 8 Views*. When you have one Landsat file already open and active in ArcGIS Desktop (ArcMap), the search window returns results, but not all the results say *Details* and *Open* (red circle below for *Landsat8 Services*). Some of them will say *Details* and *Add* (green circle below for *Landsat 8 Views*).



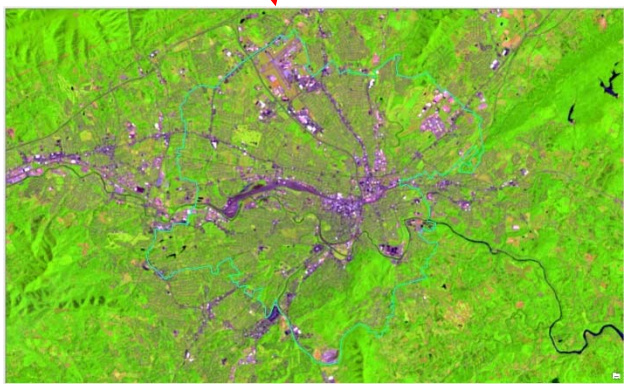
If the words are *Details* and *Open,* then ArcMap will only allow that map document to be opened as a new map document. If you click *Open*, ArcMap will close the current map document and load the new one. If the words are *Details* and *Add*, ArcMap will add this as an additional layer to the current map document.

Click on *Add* under *Landsat 8 Views*. Again, be patient while it loads!

Your results will show *that Landsat 8 Views* has been added as the top raster layer in your *Table of Contents*.



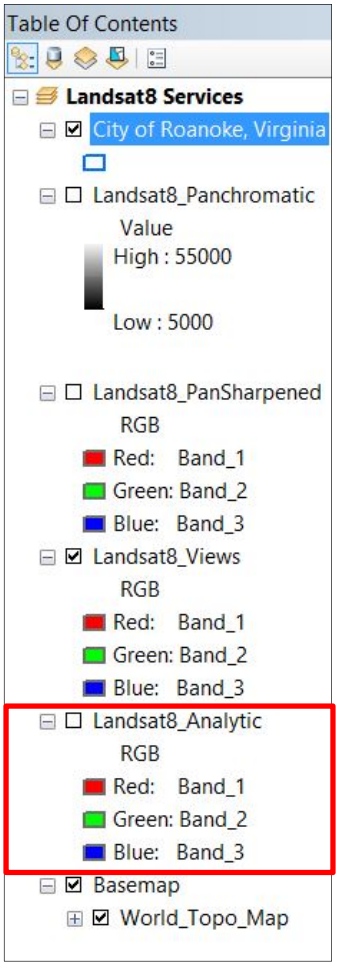
The layer is checked, so it is turned on and will be the layer that shows in the map display window.



ESRI Landsat 8 Services

ESRI's Map Document - *Landsat 8 Services* allows you to access Landsat 8 scenes with eight of the Landsat bands enabled to use in various displays and analysis. With this particular data set, you can display different band combinations of your choosing and even extract specific Landsat brightness values to vector point files.

As you can see from this data set, you cannot *Add* it to a current map document, you can only *Open* it as a new map document. Search for this in your *ArcGIS Online* search window and *Open* it. Remember, this will automatically open to show the region of Northern Africa, so you will again need to navigate to your area of interest. Next, add your boundary shapefile for your area of interest and zoom to this area. You will see the following in your map document window:



And the following Layers show in your Table of Contents. Again, the City of Roanoke, Virginia boundary file is displayed on top. The raster files related to the Landsat 8 images are listed in order by ESRI. For more information on the specifics of the *Landsat8_ Panchromatic*, *PanSharpened*, please visit the Landsat 8 website.

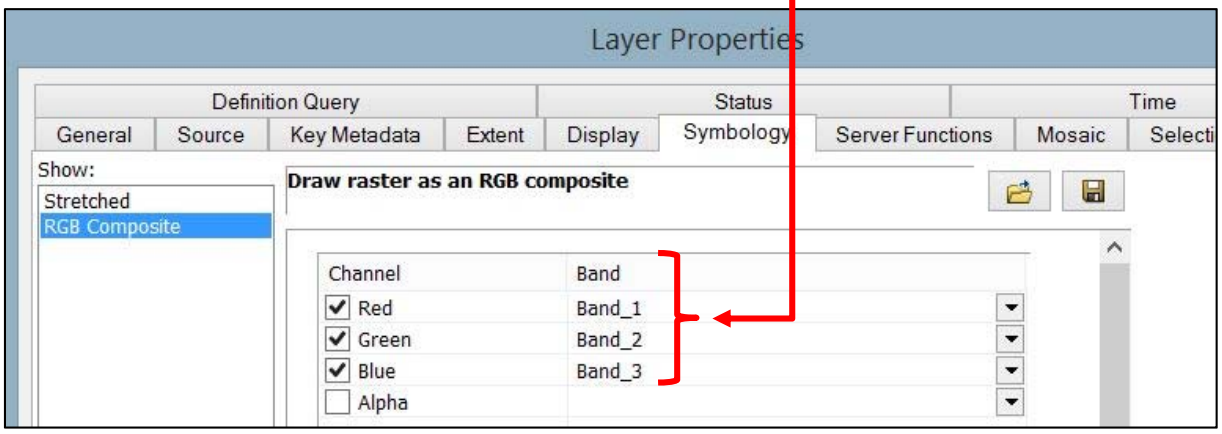
http://landsat.usgs.gov/band_designations_landsat_satellites.php

The layer that allows us to display different band combinations with eight of the Landsat 8 bands is *Landsat8_Analytic* (red box). This raster layer also shows it is displayed in red, green, and blue, but for this layer, you can choose which bands are actually displayed in the map document window.

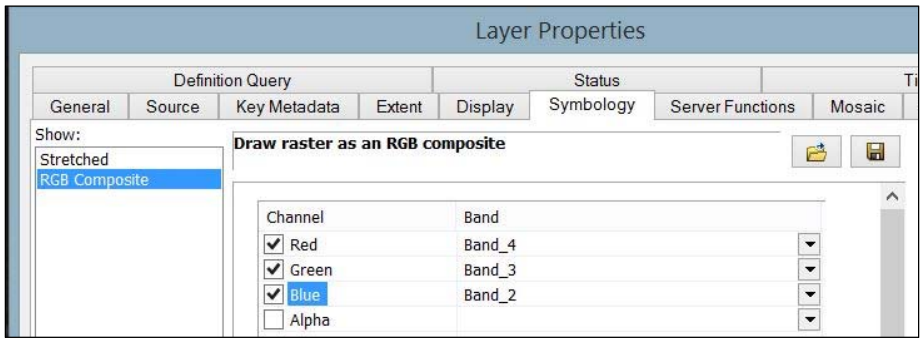
Uncheck all of the other layers (except your boundary layer) and check *Landsat8_Analytic*.

Your Map Document window will look like:

The above image is displaying Band 1 as red, Band 2 as green, and Band 3 as blue. The visual qualities of the image are easily enhanced!



Change this combination, red to 4, green to 3, and blue to 2.



Your map document window may look like this (a natural color image, for Landsat 8, Band 4 is red visible, Band 3 is green visible, and Band 2 is blue visible – see http://landsat.usgs.gov/band_designations_landsat_satellites.php):

If you don't remember how to create band combinations – see *Tutorial 12 – Creating Band Combinations from Landsat Imagery* (http://www.virginiaview.net/education.html).

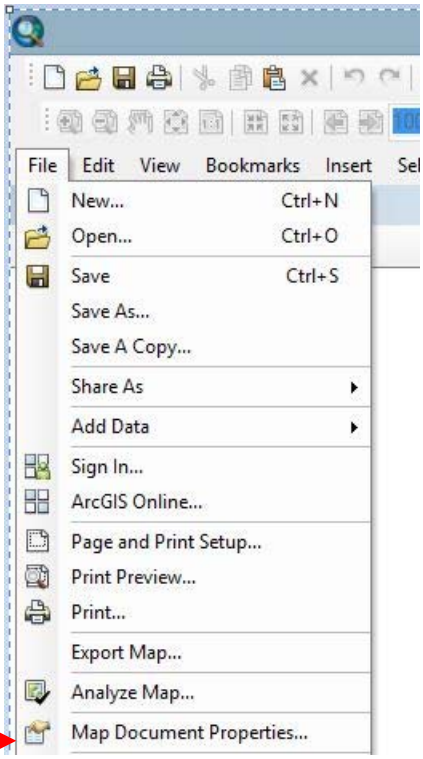
Does your image look different than the image above? You may need to change the resolution settings – radiometric, spatial and spectral. See *Tutorials 14, 15 and 16 on radiometric, spatial and spectral enhancement of Landsat Imagery.*

With the *Landsat8 Analytic* layer, you can work with the *Image Analysis* window in ArcMap, just as you would if you were working with Landsat images you downloaded directly from EarthExplorer. You can subset the image, you can make composite images, you can do land cover/land use classifications. You can also connect to the Virginia Geographic Information Network (VGIN) servers (or other GIS Servers) to access additional layers to add to your ESRI Landsat map document (*Tutorial 3 – Connecting to a Drive or Server in ArcMap*). For access to all the tutorials on using Landsat Imagery in an ArcGIS 10.X environment, go to:

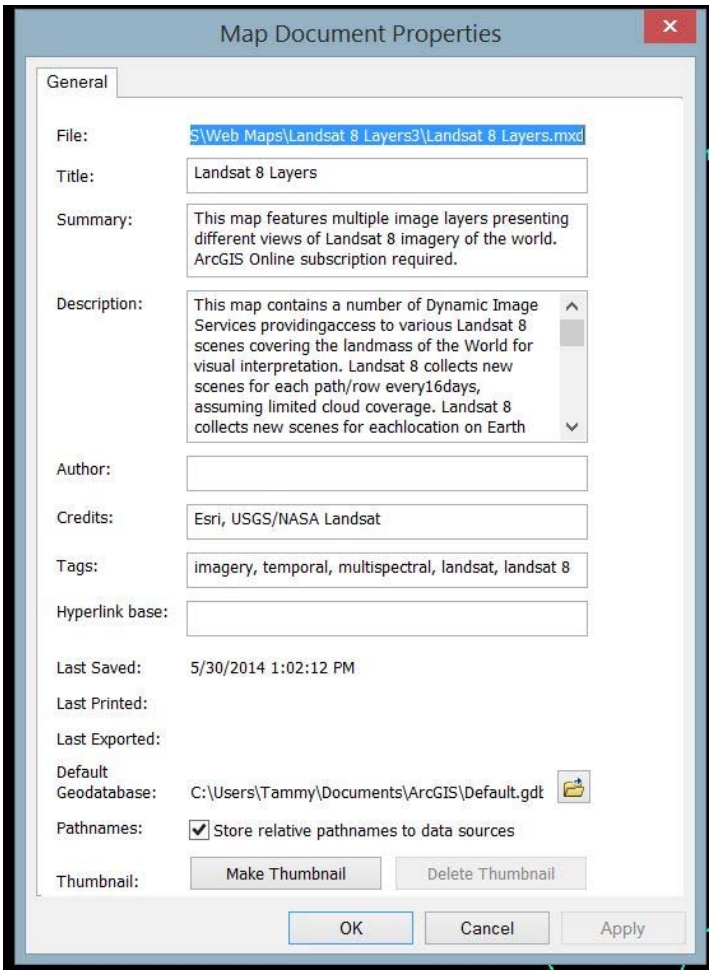
http://virginiaview.cnre.vt.edu/education.html#RSinArcGIS10

Additional Landsat Map Document Details

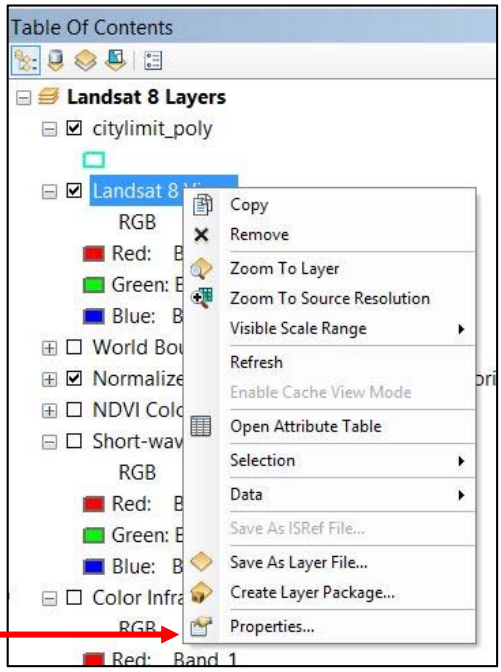
So now you have accessed multiple layers or map documents from ESRI's Landsat Database If you forget the details on any particular document that you have opened or added to your desktop application, you do not need to go back to *ArcGIS Online* or the ESRI website to get some details. These details are contained within your map document. Go to *File/Map Document Properties*.



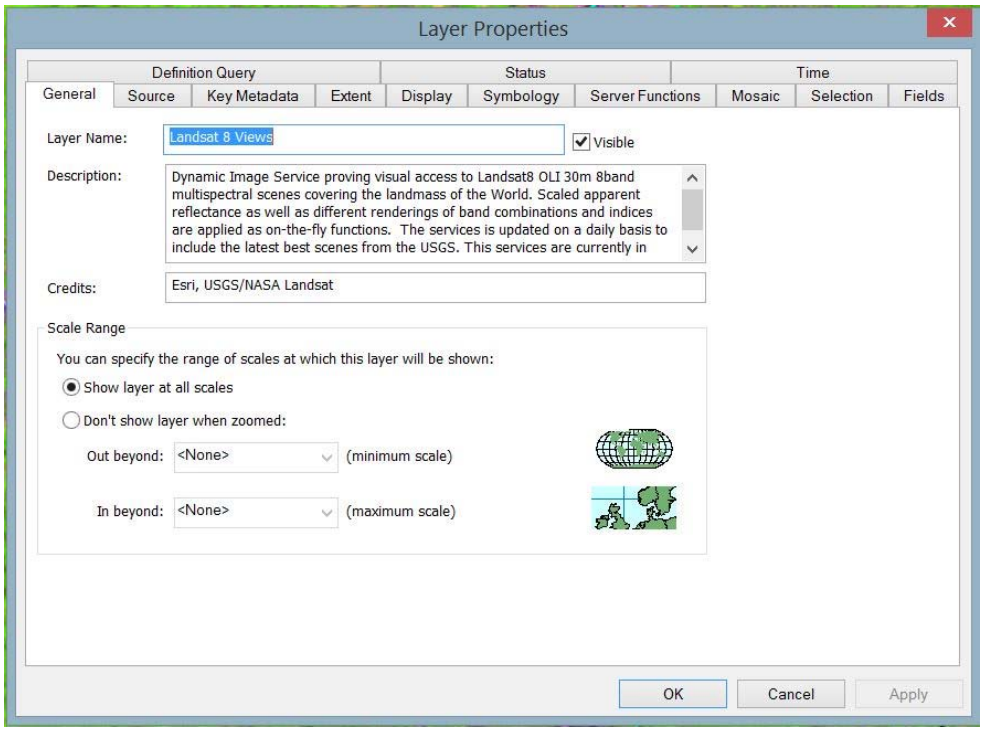
You will then see the window below, which gives you summary details you saw on pages 2 and 7.



Additional source information can be found in the individual layer properties window. Just right click on any layer name and click on the *Properties* tab.



You will get the *Layer Properties* window, below, which provides additional source credits.



Saving an ESRI Landsat 8 Map Document

Once you have finished with an ESRI map document, you can name it and save it to your organization's map files, but if you have not made any specific additions (i.e., added your own personal files), saving may not be necessary. Again, please be sure to check with your organization's usage details before saving any map documents to ESRI's online services.

Additional Help for using ArcMap or ArcGIS On-Line

ESRI has many tutorials on-line, written and video on using different services and tools within ArcGIS on-line and ArcGIS Desktop.

ArcGIS online Help can be accessed:

http://help.arcgis.com/en/arcgisexplorer/help/index.html#//01560000005p000000

The video tutorials can be accessed at this link:

http://training.esri.com/gateway/index.cfm?fa=seminars.recordedSeminars&WT.mc_id=EmailCampaigna34705

For written and video VirginiaView Tutorials on Image Analysis within an ArcGIS 10.X Environment:

http://virginiaview.cnre.vt.edu/education.html#RSinArcGIS10

[i] Any K-12 institution in the United States is eligible for a free ArcGIS Online for Organizations Account via Esri's ConnectEd initiative. For more information about this program, go here (http://connected.esri.com).

11. Creating a Composite Image from Landsat Imagery

The instructional materials contained within these documents are copyrighted property of VirginiaView, its partners and other participating AmericaView consortium members. These materials may be reproduced and used by educators for instructional purposes. No permission is granted to use the materials for paid consulting or instruction where a fee is collected. Reproduction or translation of any part of this document beyond that permitted in Section 107 or 108 of the 1976 United States Copyright Act without the permission of the copyright owner(s) is unlawful.

Landsat images are acquired in grayscale and a different image is downloaded for each one of the bands. By creating a composite image, you can display the images in color. Displaying bands in the RGB format allows you to see different features within a scene and become more familiar with the scene – to identify urban areas, forests, agriculture, and water bodies, for example. Familiarity with your Landsat scene is important in order to do different types of analyses, such as unsupervised classifications, supervised classifications, and different indices (ex: NDVI). Different types of analyses will be covered in subsequent tutorials.

Remember, from prior tutorials, that the electromagnetic spectrum differs for each band. Each one of these bands is useful for distinguishing different features.

Table 3. TM and ETM+ band designations.

Spectral bands	Wavelength (micrometers)	Resolution (meters)	Use
Band 1–blue-green	0.45–0.52	30	Bathymetric mapping; distinguishes soil from vegetation; deciduous from coniferous vegetation.
Band 2–green	0.52–0.61	30	Emphasizes peak vegetation, which is useful for assessing plant vigor.
Band 3–red	0.63–0.69	30	Emphasizes vegetation slopes.
Band 4–reflected IR	0.76–0.90	30	Emphasizes biomass content and shorelines.
Band 5–reflected IR	1.55–1.75	30	Discriminates moisture content of soil and vegetation; penetrates thin clouds.
Band 6–thermal	10.40–12.50	120	Useful for thermal mapping and estimated soil moisture.
Band 7–reflected IR	2.08–2.35	30	Useful for mapping hydrothermally altered rocks associated with mineral deposits.
Band 8–panchromatic (Landsat 7)	0.52–0.90	15	Useful in 'sharpening' multispectral images.

Instrument-specific relative spectral response functions may be viewed and compared using the Spectral Viewer tool: *http://landsat.usgs.gov/tools_spectralViewer.php*.

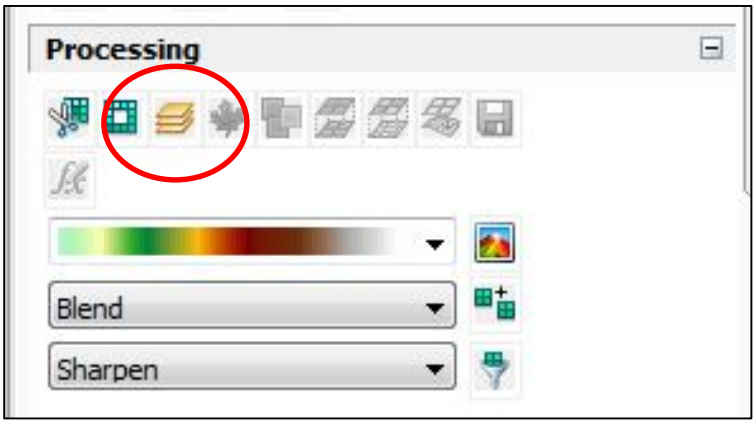
If you download a different scene from a different sensor, each band will likely convey different information. Please see: http://pubs.usgs.gov/fs/2012/3072/fs2012-3072.pdf for more information.

Please be sure you have completed the tutorial on Displaying Landsat Images in ArcMap before starting this tutorial.

Creating One Composite Image for 7 Bands

Open ArcMap, open a new map document, and add all 7 Landsat images to your map document. Remember, each image will be listed separately in your ***Table of Contents*** and displayed in the ArcMap document window on top of each other, so you will only see the image listed on top. Set your ***Workspace*** and open the ***Image Analysis*** window. Make sure your images are listed in band order 1 – 7.

In the top of the ***Image Analysis*** window, highlight all 7 images. (Left-click on the first image, then holding down the shift button on your keypad, left-click on the last image – all 7 images will be highlighted.) Notice that several additional buttons are now enabled. We are now most interested in the buttons under ***Processing***. The one we are going to use is ***Composite Bands***.

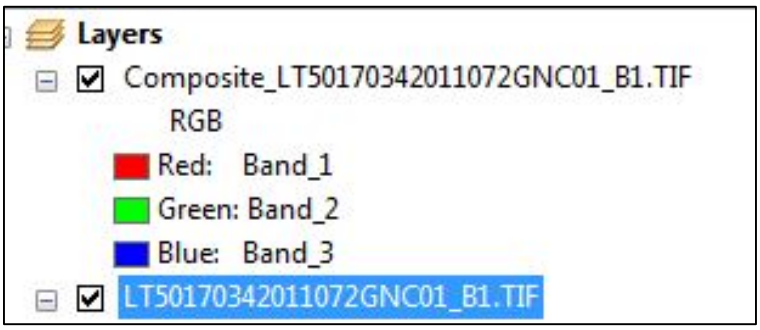


Left-click on this button (again be sure that all 7 images are highlighted in the top of the ***Image Analysis*** window before you click this button). This button creates a temporary composite image containing all seven bands. Why do we want to create a composite image? Compositing an image will allow us to display the image in color, most specifically in RGB style (Red, Green, Blue). The human eye can only see that portion of the electromagnetic spectrum

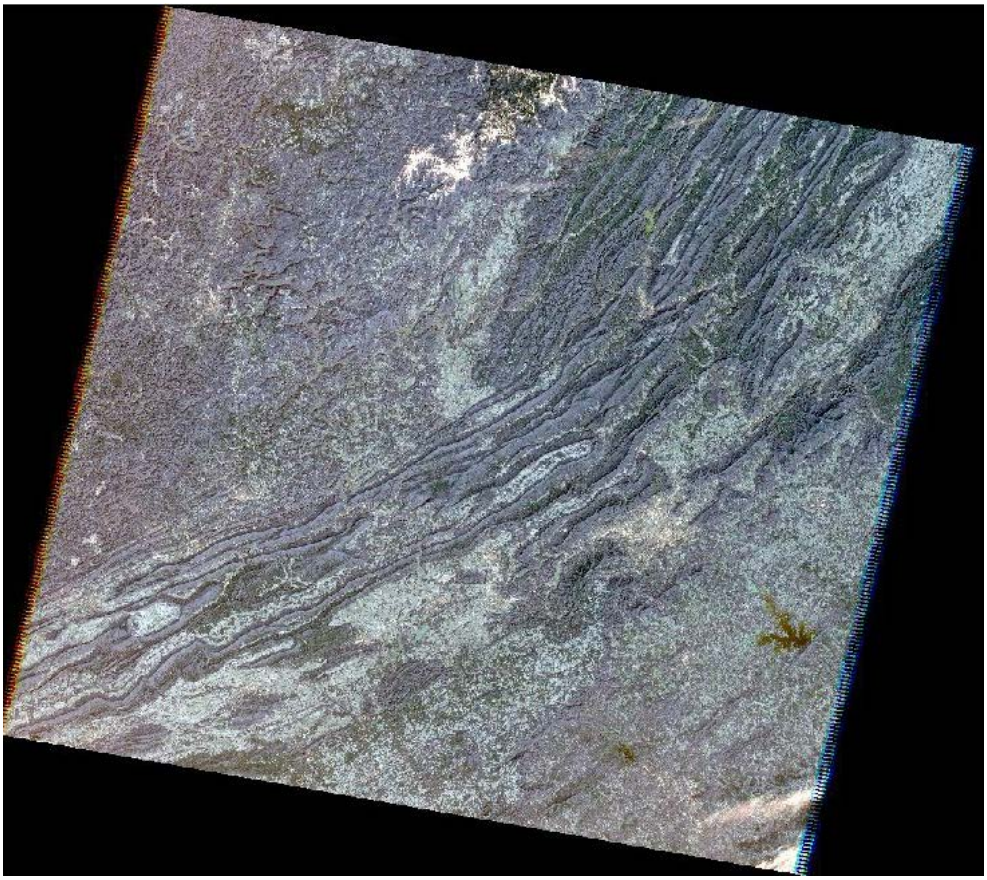
within the visual spectrum. By compositing the image, we can display different bands using the RGB color scheme, even those not visible to the naked eye.

You will see this new composite image in three different places:

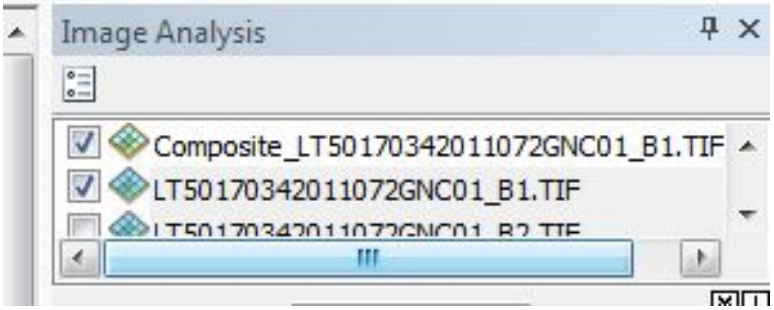
The ***Table of Contents***:



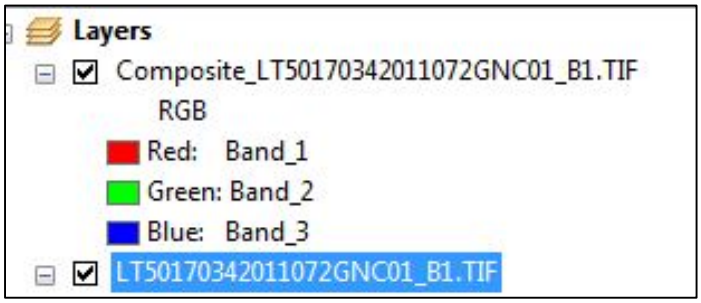
In the map document window:



And, listed as the top file in the list of files in the ***Image Analysis*** window:



Next, let's discuss what we see in the ***Table of Contents.***

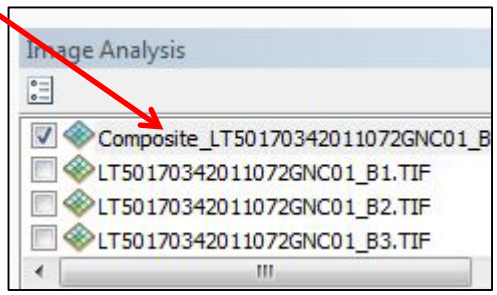


It shows Band 1 as Red, Band 2 as Green, and Band 3 as Blue. But remember from the Landsat Table above, Band 1 represents the blue range of the visible spectrum, Band 2 – the green, and Band 3 – the red. Why the difference? ArcMap has defaulted the order of the bands to the RGB order but the Landsat Bands are still displayed in order 1, 2, 3….. We can change the display and we will discuss in the tutorial on Creating Different Band Combinations.

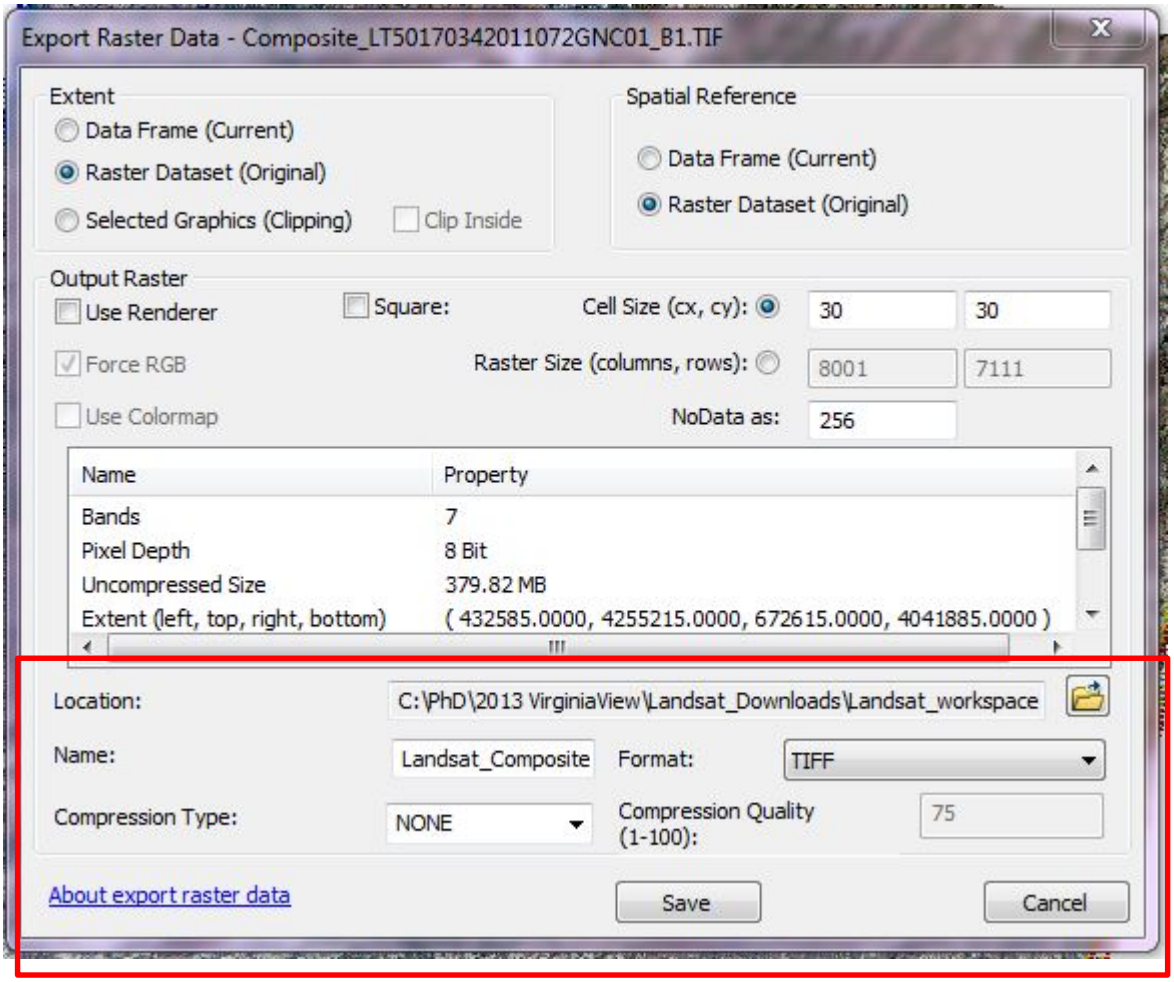
The composite file that you created is a temporary file. If you look in your workspace folder, you will not see this file listed. It cannot be added to any other map document and if you close this map document without saving the map document, it will disappear. You can use this temporary file if you immediately plan to proceed to the Creating Different Band Combinations tutorial. We recommend that you make this file permanent by saving it.

Saving Your New Composite Image

Within the ***Image Analysis*** window, left-click to highlight the composite image (or the image that you wish to save). Under the ***Processing*** section, the ***Save*** button will now be enabled. Left-click on this button.

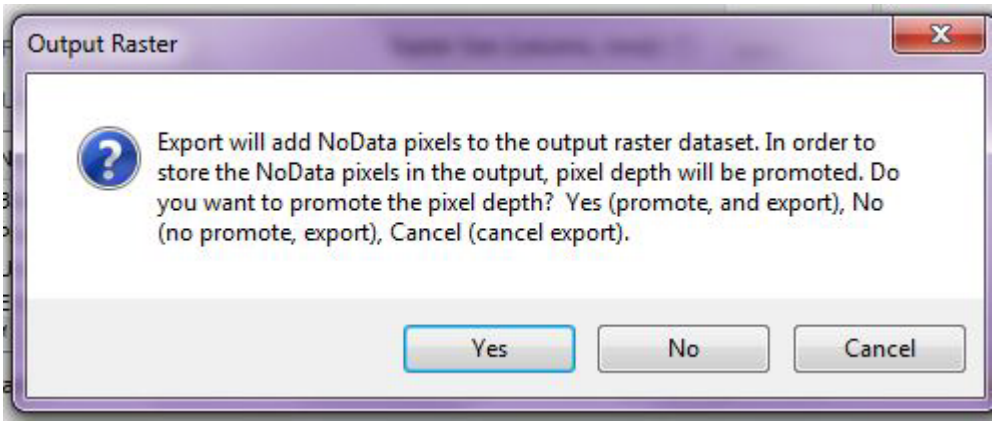


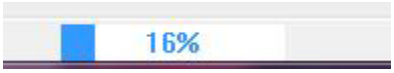
You will get the following dialog box. Accept the settings in the top of the window as shown.



At the bottom of the window, make sure your workspace is showing in ***Location***, name your file (it may have already filled in with a name but you can click in that window and name it what you want). Leave ***Compression Type*** as ***None*** and ***Format*** as ***TIFF***. *(Note- different Formats are available but please see ArcGIS help for more information as those different types are beyond the scope of this tutorial.)*

You will then receive the following dialog box. Left-click on ***No*** (*you do not want to promote the pixel depth by including the NoData pixels – this will change the image*)

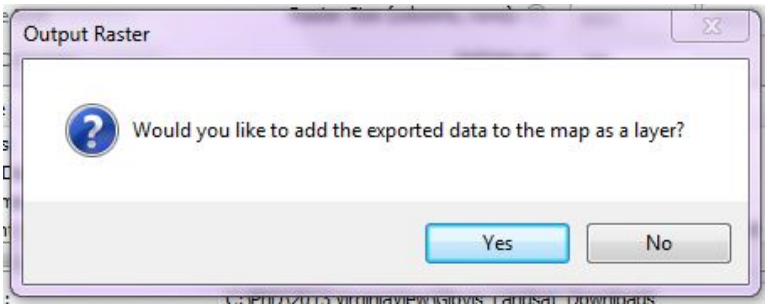


Once you have clicked on ***No***, you will see the following progress bar at the bottom of your ArcMap window: 

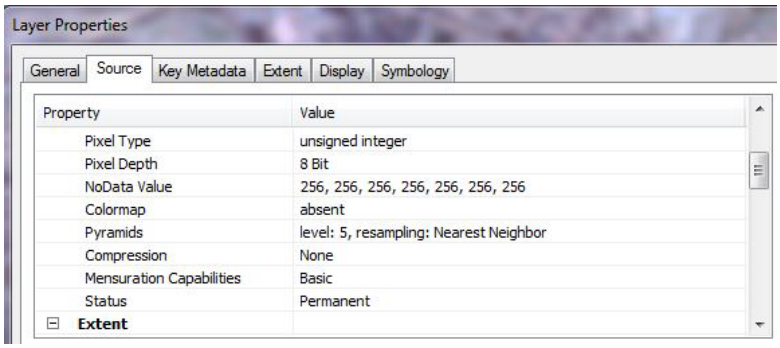
When it hits 100%, it will disappear and you will see the following in the lower left hand corner of your ArcMap window:

Be Patient!

Once that is complete, you will see the following dialog box:



Left-click on ***Yes***. Your file is now a permanent file. If you go to the ***Layer Properties/Source*** tab, you can see the ***Status*** as ***Permanent***.



You are now ready to proceed to the Band Combinations tutorial.

Notes:

12. Band Combinations Using Landsat Imagery

The instructional materials contained within these documents are copyrighted property of VirginiaView, its partners and other participating AmericaView consortium members. These materials may be reproduced and used by educators for instructional purposes. No permission is granted to use the materials for paid consulting or instruction where a fee is collected. Reproduction or translation of any part of this document beyond that permitted in Section 107 or 108 of the 1976 United States Copyright Act without the permission of the copyright owner(s) is unlawful.

In this tutorial, you will learn how to display color images in different band combinations using ArcGIS 10.X and how an analyst can use these different combinations.

Introduction

Landsat images are acquired in grayscale but by combining 3 or more bands, you can display the images in color. Using different band combinations to display your scene allows you to see different features within a scene and become more familiar with the scene – to identify urban areas, forests, agriculture, and water bodies, for example. Familiarity with your Landsat scene is important in order to do different types of analyses, such as unsupervised classifications, supervised classifications, and different indices (ex: NDVI). Different types of analyses will be covered in subsequent tutorials.

Remember, from prior tutorials, that the electromagnetic spectrum differs for each band. Each one of these bands is useful for distinguishing different features *(please also see additional notes at the end of this tutorial)*:

Table 3. TM and ETM+ band designations.

Spectral bands	Wavelength (micrometers)	Resolution (meters)	Use
Band 1–blue-green	0.45–0.52	30	Bathymetric mapping; distinguishes soil from vegetation; deciduous from coniferous vegetation.
Band 2–green	0.52–0.61	30	Emphasizes peak vegetation, which is useful for assessing plant vigor.
Band 3–red	0.63–0.69	30	Emphasizes vegetation slopes.
Band 4–reflected IR	0.76–0.90	30	Emphasizes biomass content and shorelines.
Band 5–reflected IR	1.55–1.75	30	Discriminates moisture content of soil and vegetation; penetrates thin clouds.
Band 6–thermal	10.40–12.50	120	Useful for thermal mapping and estimated soil moisture.
Band 7–reflected IR	2.08–2.35	30	Useful for mapping hydrothermally altered rocks associated with mineral deposits.
Band 8–panchromatic (Landsat 7)	0.52–0.90	15	Useful in 'sharpening' multispectral images.

Instrument-specific relative spectral response functions may be viewed and compared using the Spectral Viewer tool: *http://landsat.usgs.gov/tools_spectralViewer.php*.

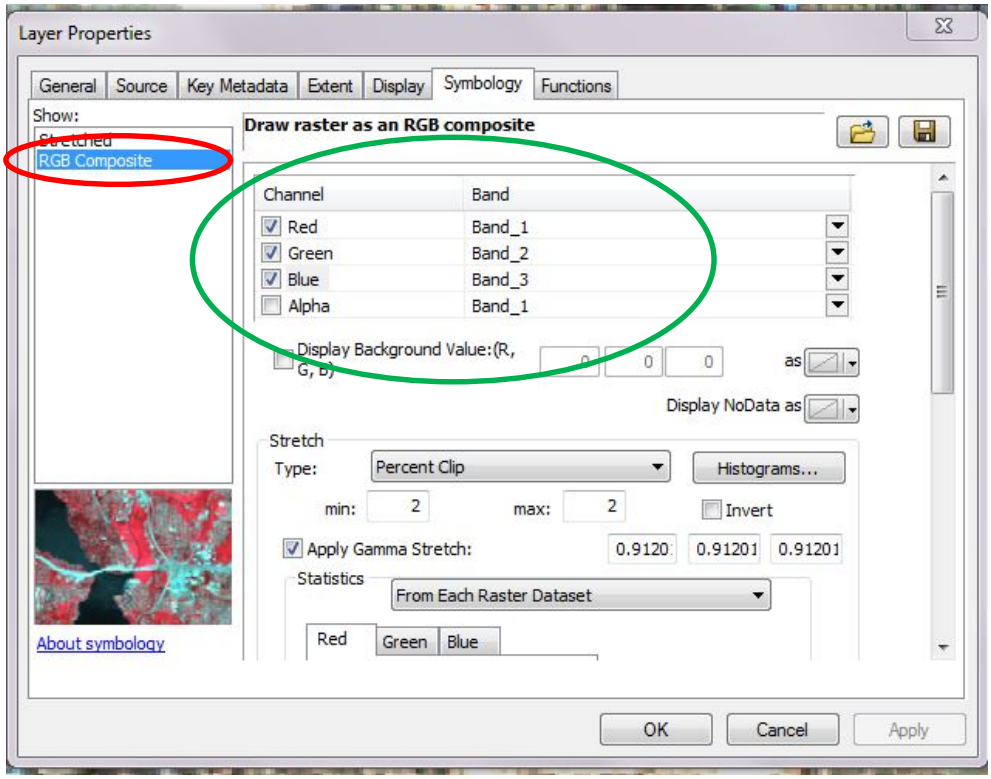
If you download a different scene from a different sensor, each band will likely convey different information. Please see: http://pubs.usgs.gov/fs/2012/3072/fs2012-3072.pdf for more information.

Creating Different Band Combinations

Open ArcMap, open a new map document, and add the composite image that was created in the tutorial on Creating a Composite Image from Landsat Imagery. Set your ***Workspace***. You will not need the ***Image Analysis*** Window to display different band combinations.

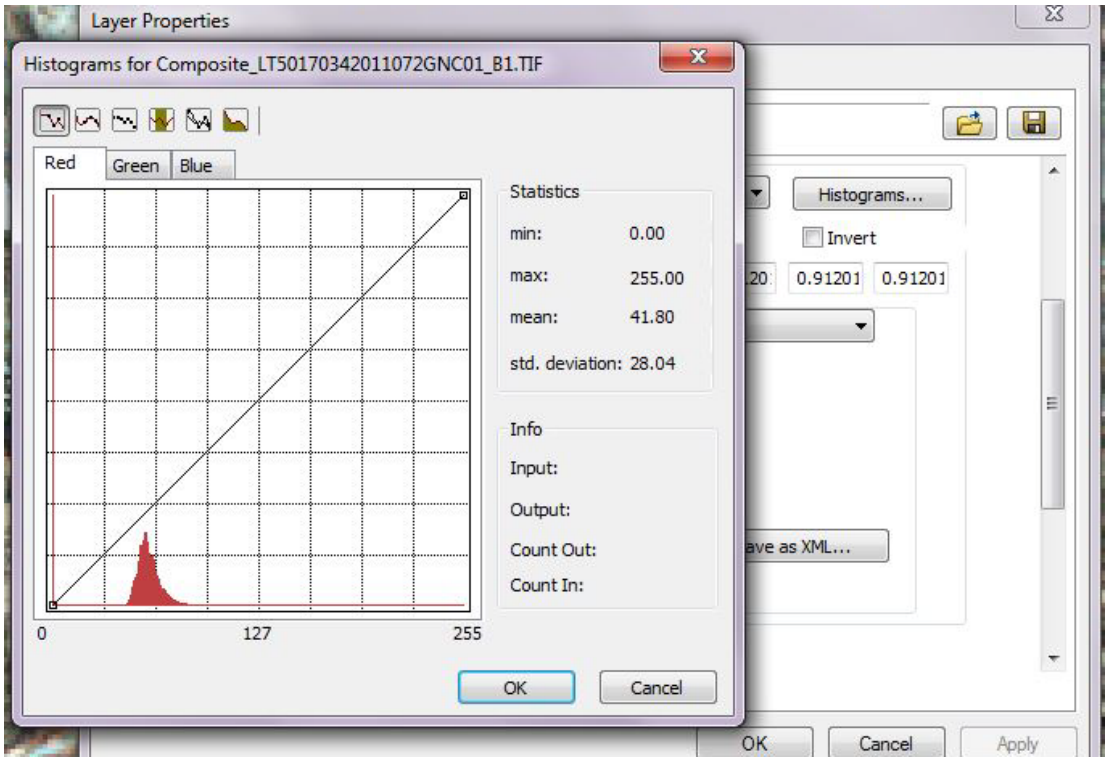
Right click on your composite image in the ***Table of Contents,*** go to ***Properties*** and click on the ***Symbology*** tab. This tab looks very different than it did when we were looking at the image of a single band. The ***RGB Composite*** is highlighted (red oval) and multiple ***Channels*** and ***Bands*** are listed (green oval).

Under ***Stretch,*** it lists the method that ArcMap used to stretch the colors over the range of brightness values (remember each band has a range of brightness values). (*Note – specific discussion of the different methods is beyond this tutorial – please see ArcGIS Help or other related sources for further information.)*

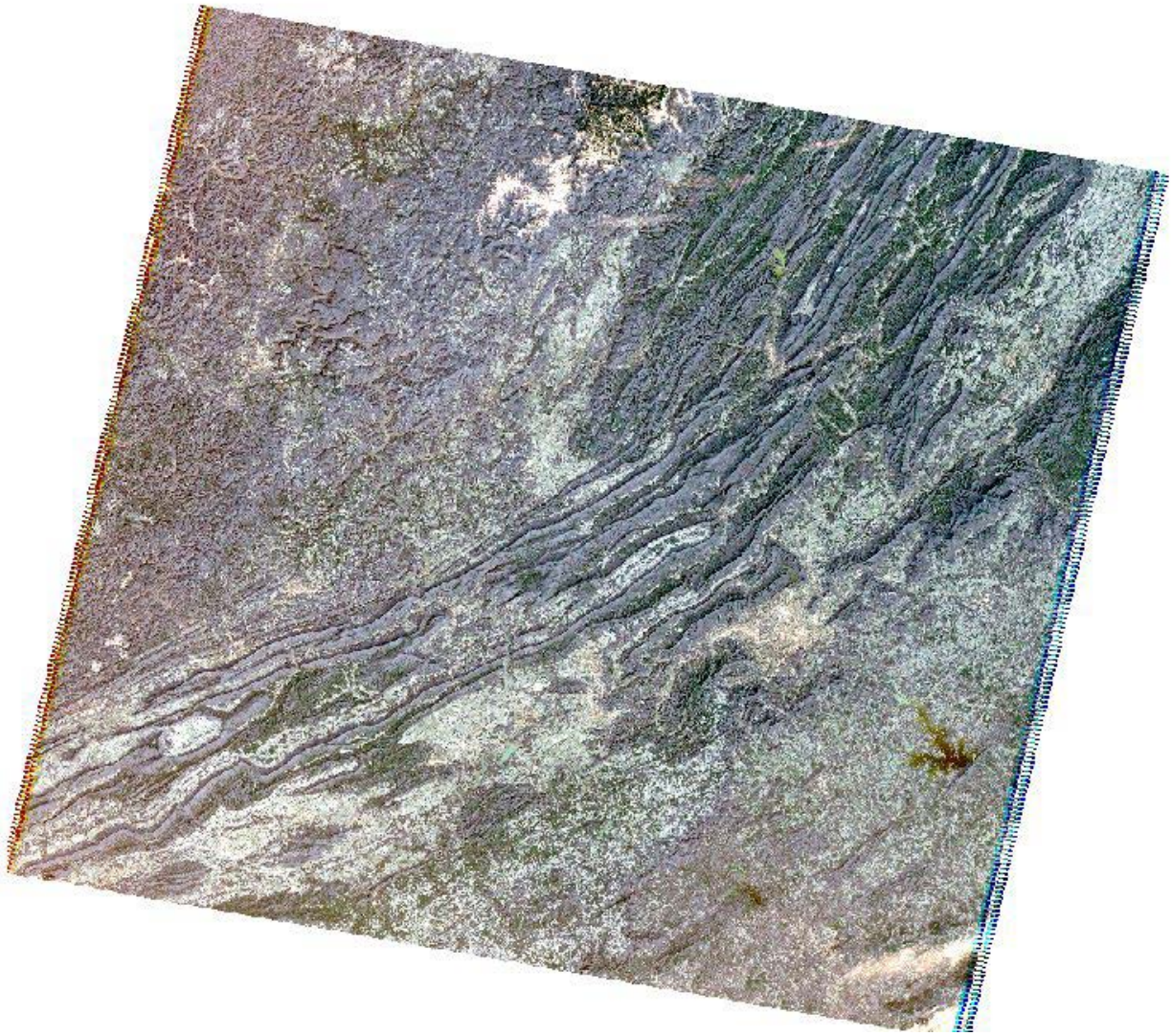


Click on the Histograms button. ArcMap displays the histograms for each band displayed in the red, green, or blue channels. These are frequency histograms which plot the values of the digital numbers (DNs) (x-axis) against the number of pixels with that value (y-axis). It shows the minimum DN value, and the maximum, mean, and standard deviation. Why would each histogram look different?

(Answer – because each band has a different range of DNs.) We will discuss Histograms more in the tutorial on **Radiometric Enhancement of Landsat Imagery**.



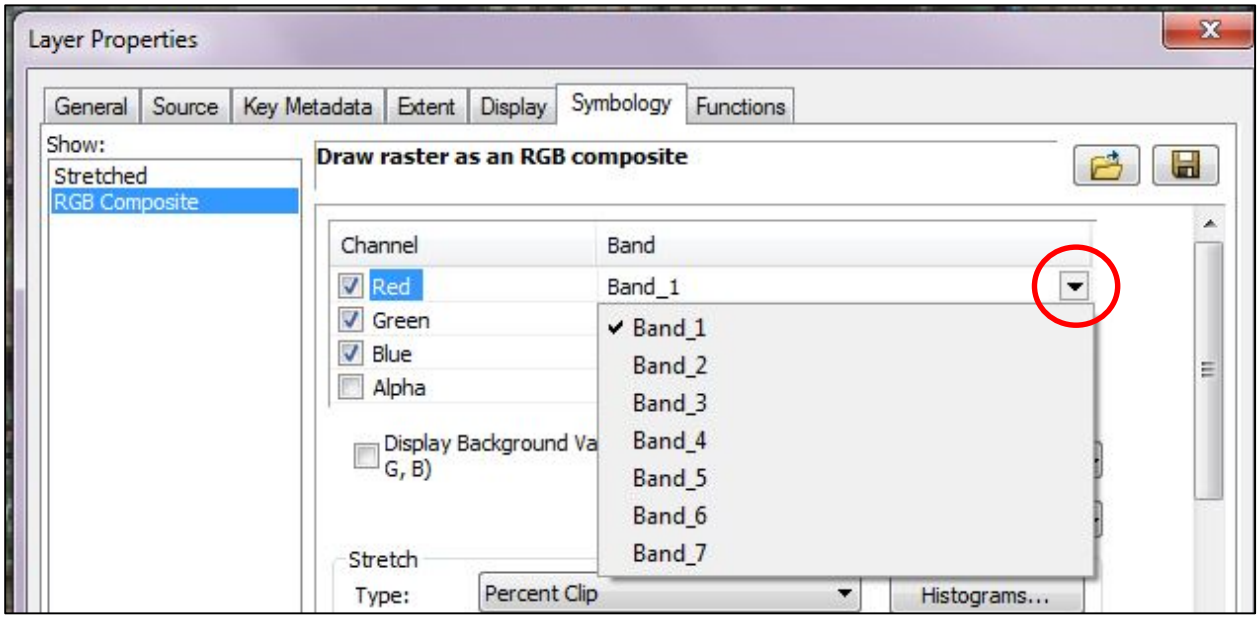
Close the dialog box and let's next look at the image in the map document. The image that is displayed in the map document window does not look very natural. Why?



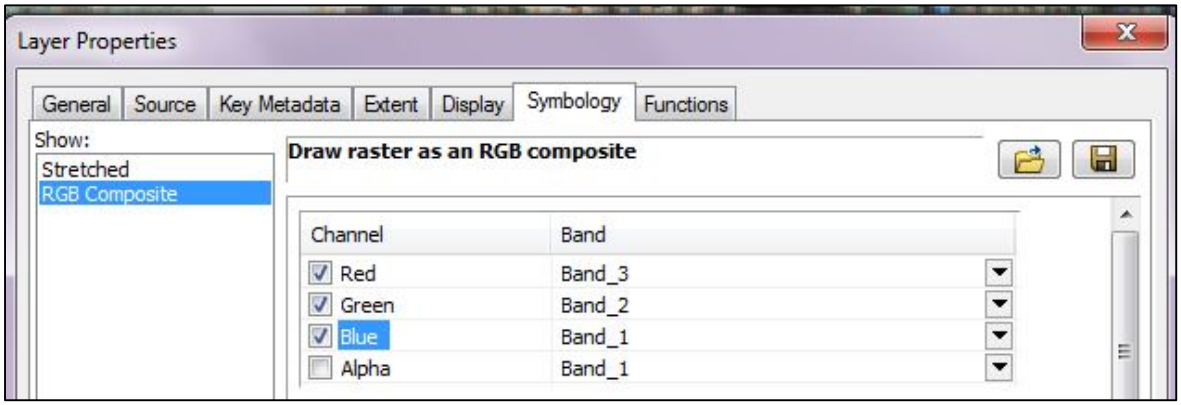
(Answer: because ArcMap is displaying the blue band as red and the red band as blue.)

Now, let's change this display strategy to make it look more natural.

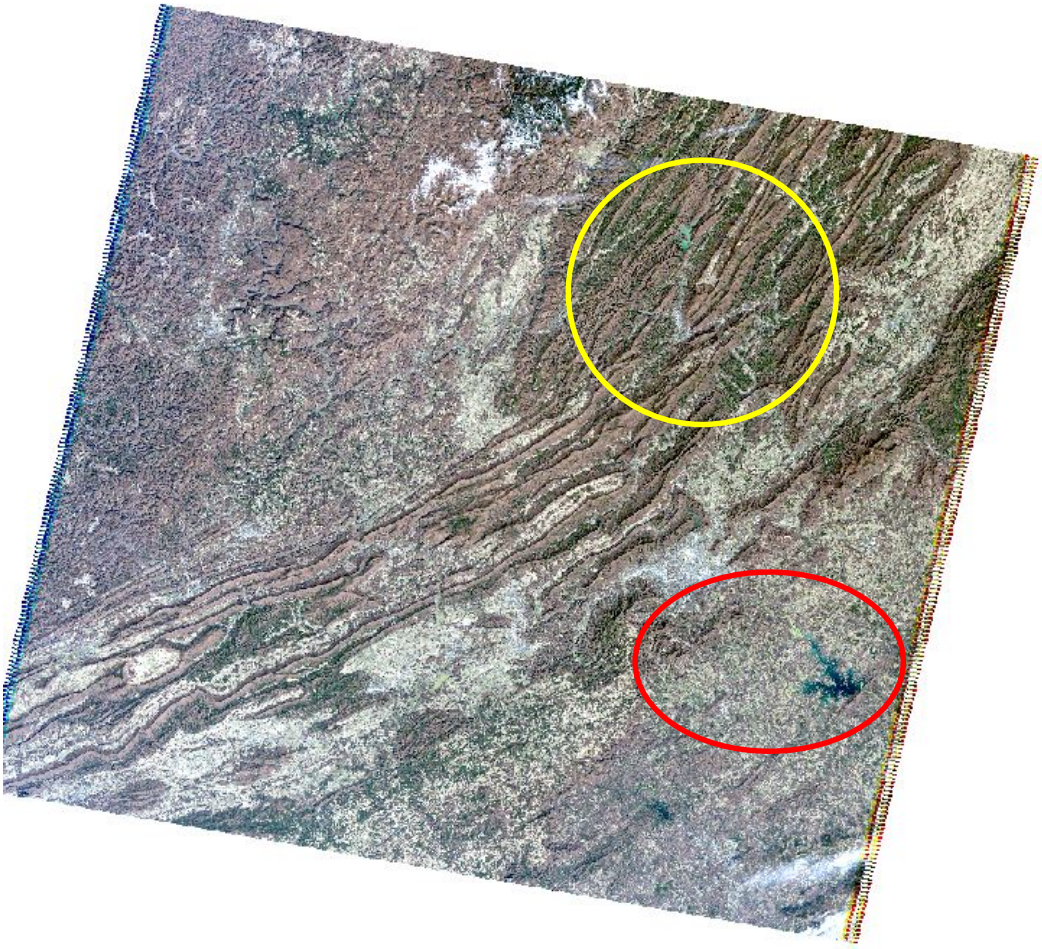
Go back to ***Layer Properties/ Symbology*** dialog box. Left-click on the down arrow at the end of the row of the ***Red Channel*** (red circle). It lists all bands from the Landsat image. Because all bands are included, you can display any of those bands in the red region of the visible spectrum. Click on ***Band_3*** to assign the red channel to band 3. Then, click on the down arrow at the end of the row for the ***Blue Channel*** and click on ***Band_1*** to assign band 1 to the blue channel



The dialog box should look like this. You are displaying the natural red colors as red, green as green and blue as blue. Click ***OK***.



The scene is now displayed in natural colors (a *true color image*). The lake (red oval) is now blue, whereas before, it was brown. You can see in the mountainous areas (yellow circle), some green. But, it certainly does not look very colorful, does it? Why is there not more color? Let's zoom in and examine closer.



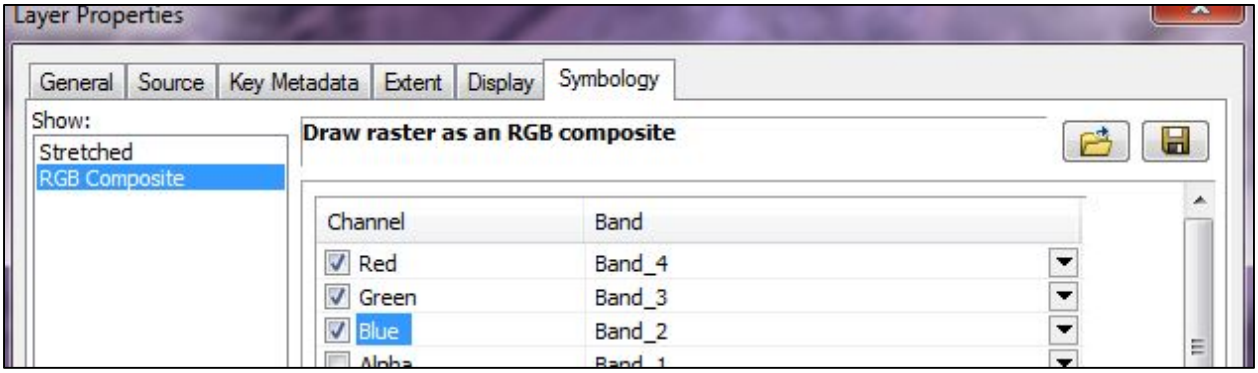
Zooming into the mountains, what do you see? You see some green, brown, some gray and white. What are these features? Think about when this image was acquired. Remember, we downloaded the March 13, 2011 image, so it is leaf-off. So if no leaves on the trees, why do we see some green? *(Answer - conifers.)* Brown areas would represent either the bare earth where no vegetation is currently growing, or the

deciduous trees. What about the white? What are long, linear features on the ground and could possibly be seen from an overhead image?

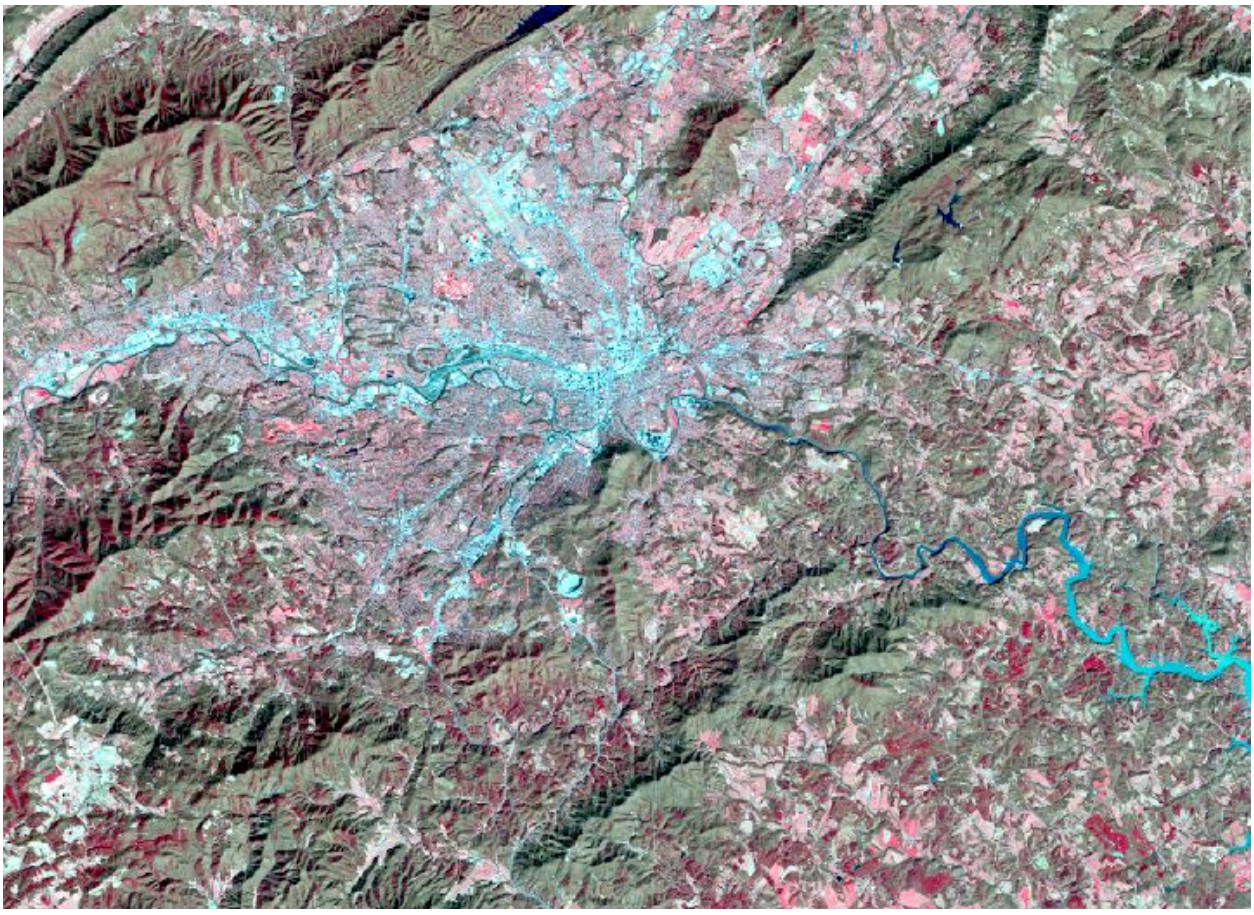
Let's look as another area of the scene, the city of Roanoke. Can you find it? Roanoke is the largest urban area in southwest Virginia and within this Landsat scene. Does this help? What do you find in urban areas *(hint – long linear features like roads, things with definite angles like buildings, perhaps an airport).* Did you find it? What do you see? When zoomed out?

Okay, now let's try a different combination. Try 4-3-2. What does this mean? The order of the combinations represents the RGB order. So, place ***Band_4*** in the ***Red Channel***, ***Band_3*** in the ***Green Channel*** and ***Band 2*** in the ***Blue_ Channel***. This combination is the traditional *false-color infrared* band combination in which healthy or mature vegetation is shown in red.

Your dialog box should appear as follows:



Don't forget to click ***OK*** before you close the window!

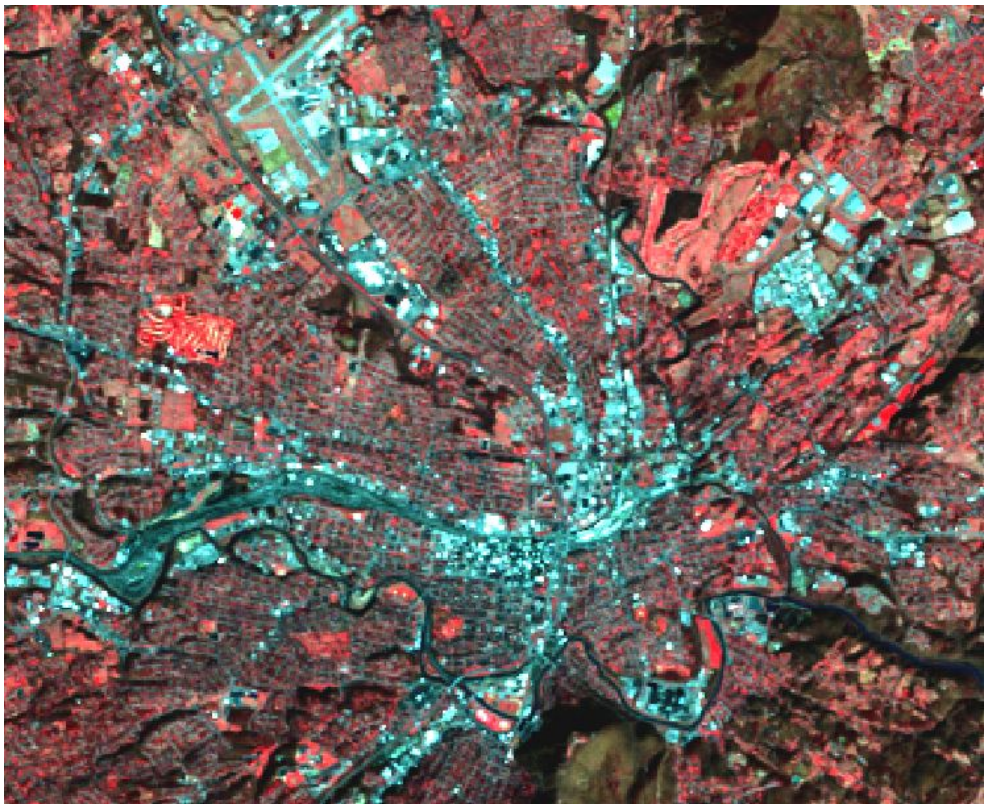


We were still zoomed into Roanoke. Looks a lot different doesn't it? Why? What do the different bands being placed within those specific channels mean? *(See Landsat Table above and additional notes at the end of this tutorial.)* Landsat ***Band_4*** is the near infrared and

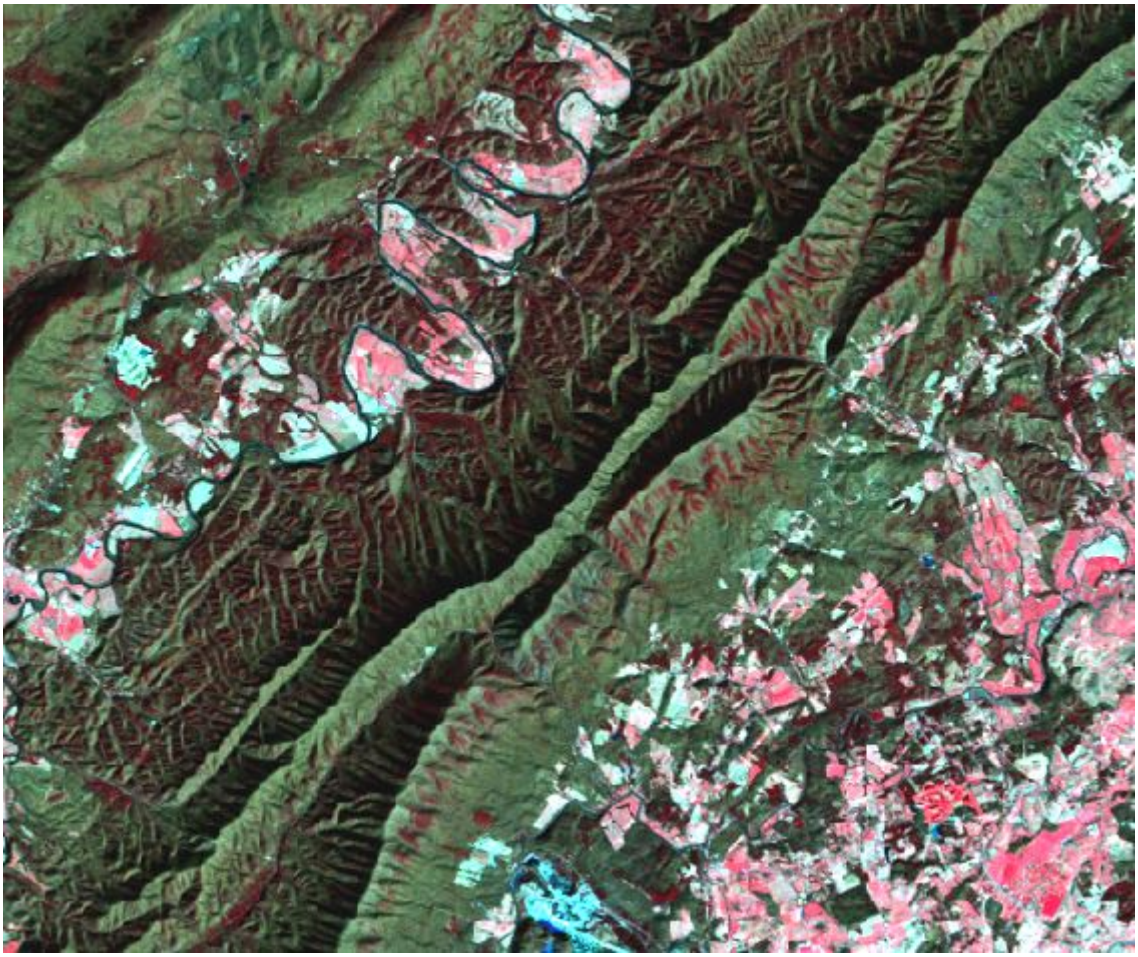
we have asked ArcMap to display the near infrared as red color. Vegetation shows bright in the near infrared, so the healthiest vegetation within this scene will show red. That does not mean that the pink is unhealthy vegetation – it could be vegetation just beginning to grow. Would any vegetation be growing in March? It will depend on the climate of the area. You can go to the National Weather Service website to determine the temperature of this area for this time frame.

What else can you now identify with this band combination that you could not discern from the natural color combination?

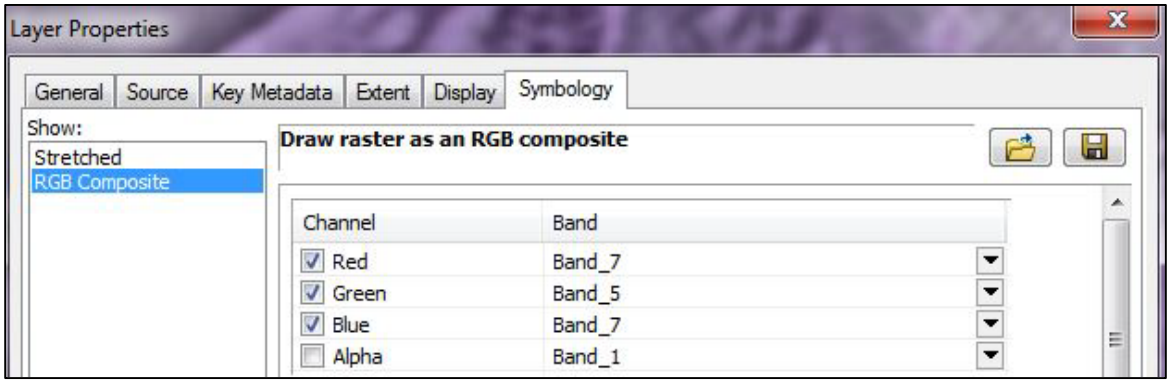
Zoom in closer on the city. This looks more defined. We can see some distinct features within the city. Do you see the airport? Major roads? What about neighborhoods? How can you tell the difference between major roads and neighborhoods? Can you find one of the golf courses? *(Hint – infrared is showing bright red for healthy vegetation – what do you find in a golf course year round?)* What else in a golf course – is it just lawn area? What about sand traps? Would they show as bright red? *(See Landsat Table above and additional notes at the end of this tutorial).* Can you find the river that flows through the city?



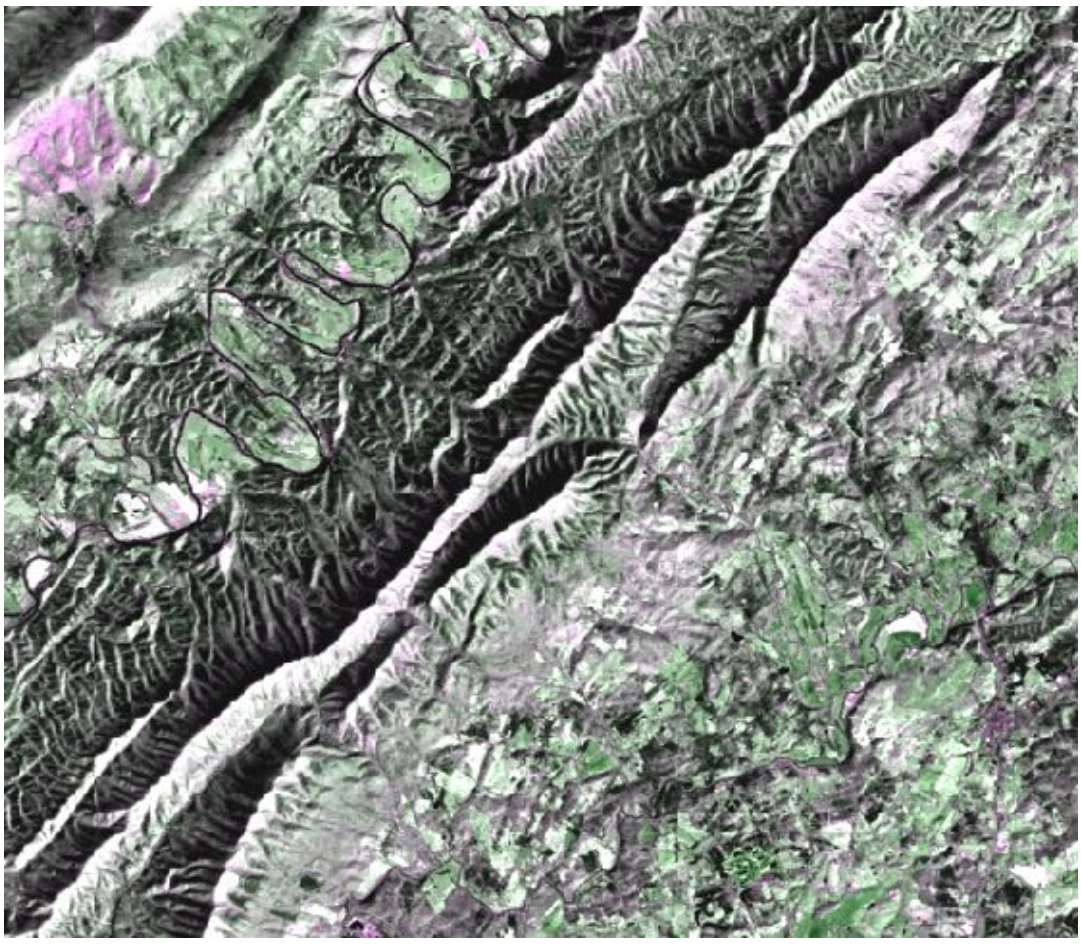
Now let's zoom in on the forest. What do you see? Can you see the difference between the conifers and the deciduous trees? What would be showing as red *(answer – conifers would have green leaves in March)* and what would show as green? What about the pink areas, what are those? Many of the pink areas have straight lines and sharp angles. (*Humans like to design things with straight lines and definitive angles.)* Can you see roads? Streams? Why is some of the forest darker? *(Answer – shadowing on sides of the mountains.)*



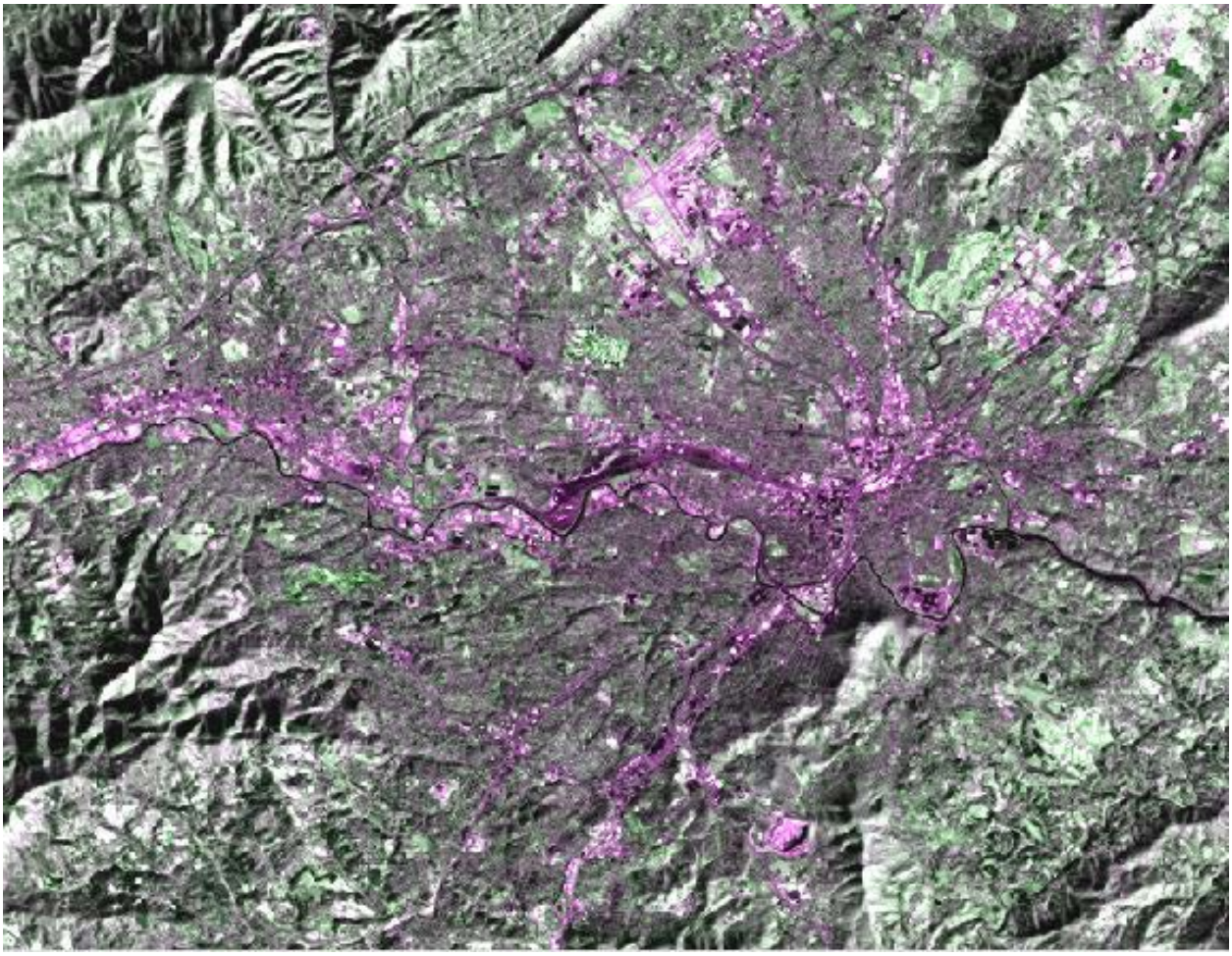
Let's do one more band combination. See window below and set your values as shown.



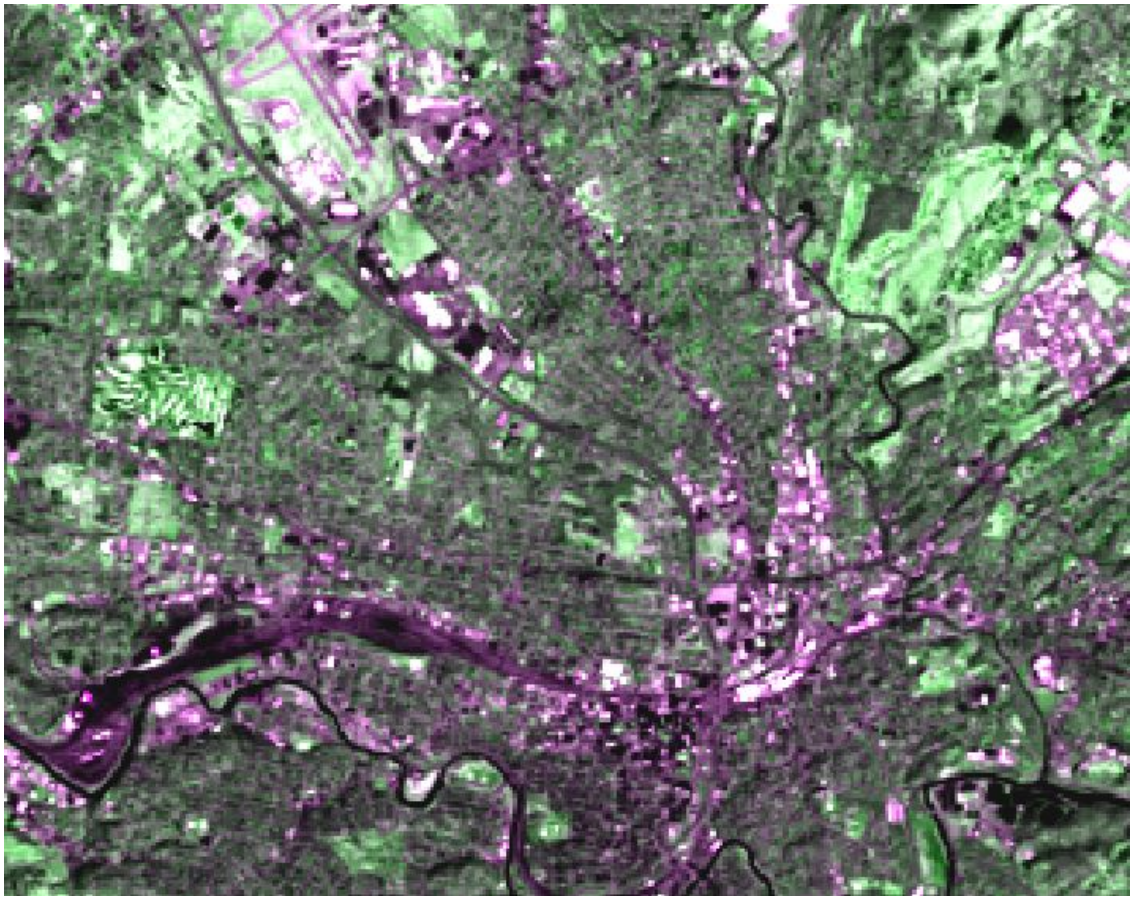
Yes, you can use the same band more than once. This again changes what you see in the map document window. Does this band combination help you see anything more distinctly in the forested mountains? *(Answer- no, Band_4 (near infrared) is the best for healthy vegetation and Band_4 is not used in this combination.)*



What about in the City of Roanoke? Why would the roads show more distinctly with this band combination? The river? The first golf course is even more distinguishable at this spatial resolution. Do you see a second one?



Zoom into the city, what happens? Do you see the remnants of a third golf course near the airport? Why is this band combination more helpful in urban areas?



Go ahead and try different band combinations for yourself.

Try different combinations for the whole scene, and then for different areas of the scene on a zoomed-in basis.

Note – some aerial photos are acquired in 4 bands – the three visible bands (RGB) and also the near-infrared. The U.S.D.A. NAIP imagery is acquired with 4 bands because their purpose to evaluate agricultural productivity and these photos are usually acquired during the growing season

(see http://www.fsa.usda.gov/FSA/apfoapp?area=home&subject=prog&topic=nai for further information). This imagery can be loaded into ArcMap and displayed using the different band combinations in similar fashion. The photos come as one image (not 7 separate images as with Landsat).

Additional Notes on LANDSAT TM – Single Band Sensitivities

0.45-0.52 µm BLUE (BAND 1)

- Shorter wavelengths most sensitive to atmospheric haze and so images may lack tonal contrast
- Shorter wavelengths have greatest water penetration (longer wavelengths more absorbed); optimal for detection of submerged aquatic vegetation (SAV), pollution plumes, water turbidity and sediment
- Detecting smoke plumes (shorter wavelengths more easily scattered by smaller particles
- Good for distinguishing clouds from snow and rock, and soil surfaces from vegetated surfaces

0.52-0.6 µm GREEN (BAND 2)

- Sensitive to water turbidity differences, sediment and pollution plumes
- Covers green reflectance peak from leaf surfaces, can be useful for discriminating broad vegetation classes
- Also useful for detection of SAV
- Also useful for penetration of water for detection of SAV, pollution plumes, turbidity and sediment

0.63-0.69 µm RED (BAND 3)

- Senses in strong chlorophyll absorption region, i.e. good for discriminating soil and vegetation
- Senses in strong reflectance region for most soils
- Delineating soil cover

0.76-0.9 µm NEAR IR (BAND 4)

- Distinguishes vegetation varieties and vegetation vigor
- Water is strong absorber of NIR, so this band is good for delineation of water bodies and distinguishing dry and moist soils

1.55-1.75 µm MID OR SWIR (BAND 5)

- Sensitive to changes in leaf-tissue water content (turgidity)
- Sensitive to moisture variation in vegetation and soils; reflectance decreases as water content increases
- Useful for determining plant vigor and for distinguishing succulents vs. woody vegetation
- Especially sensitive to presence/absence of ferric iron or hemitite rocks (reflectance increases as ferric iron increases)
- Discriminates between snow and ice (light toned) and clouds (dark toned)

2.08-2.35 µm MID OR SWIR (BAND 7)

- Coincides with absorption band caused by hydrous minerals (clay mica, some oxides, and sulfates) making them appear darker; e.g. clay alteration zones associated with mineral deposits such as copper
- Lithologic mapping
- Like band 5, sensitive to moisture variation in vegetation and soils

10.4-12.5 µm LWIR, THERMAL (BAND 6)

- Sensor designed to measure radiant surface temps -100 degrees C to +150 degrees C; day or nighttime use
- Heat mapping applications: soil moisture, rock types, thermal water plumes, household heat conservation, urban heat generation, active military targeting, wildlife inventory, geothermal detection

LANDSAT TM – Band Combination Sensititivies

3-2-1
This combination simulates a natural color image. It is sometimes used for coastal studies and for the detection of smoke plumes.

4-5-3
Used for the analysis of soil moisture and vegetation conditions. It is also good for the location of inland water bodies and land-water boundaries.

4-3-2
Known as false-color Infrared; this is the most conventional band combination used in remote sensing for vegetation, crops, land-use and wetlands analysis.

7-4-2
Analysis of soil and vegetation moisture content and the location of inland water. Vegetation appears green.

5-4-3
Separation of urban and rural land uses; identification of land/water boundaries.

4-5-7
Detection of clouds, snow, and ice (in high latitudes especially).

You are now ready to proceed to the next set of tutorials. We recommend that you complete the tutorial on sub-setting before you proceed to the tutorials on analyzing Landsat imagery.

Notes:

13. Sub-setting Landsat Imagery

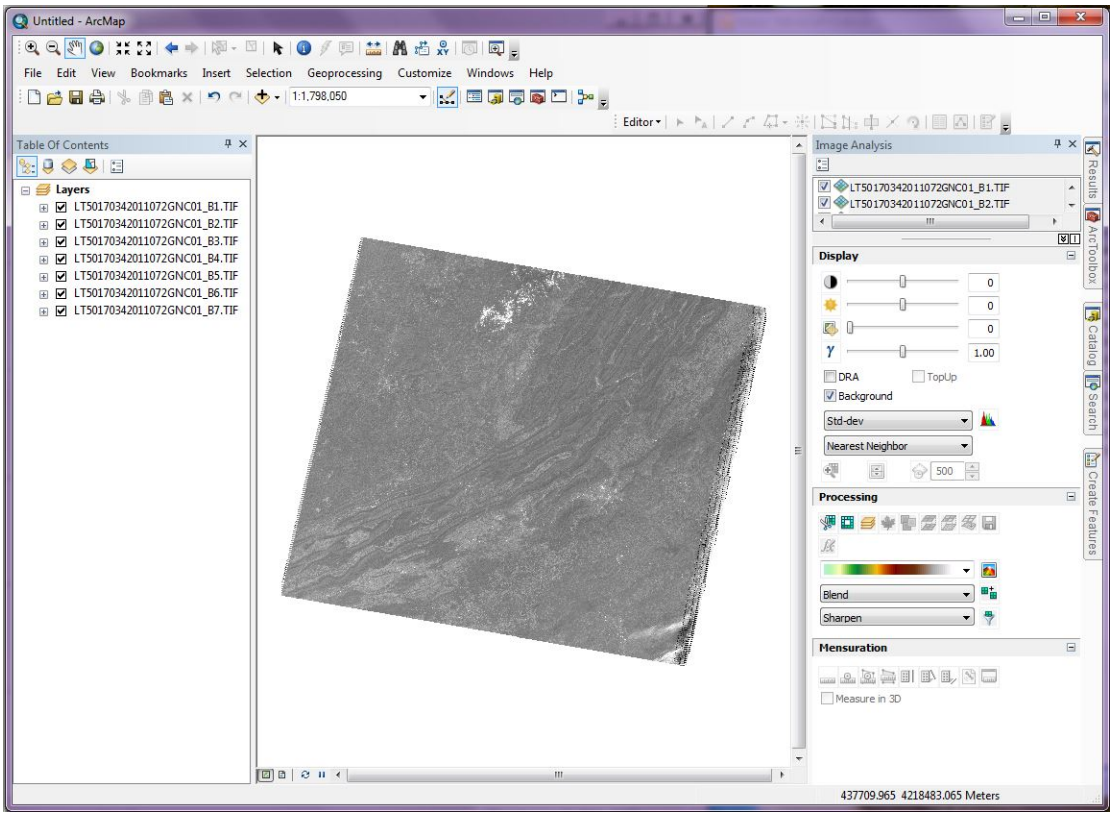
The instructional materials contained within these documents are copyrighted property of VirginiaView, its partners and other participating AmericaView consortium members. These materials may be reproduced and used by educators for instructional purposes. No permission is granted to use the materials for paid consulting or instruction where a fee is collected. Reproduction or translation of any part of this document beyond that permitted in Section 107 or 108 of the 1976 United States Copyright Act without the permission of the copyright owner(s) is unlawful.

There may be times where you are only interested in a portion of a Landsat scene. That portion could be only certain bands or only a small area.

This tutorial will provide instructions on how to limit the number of bands to specific bands or limit the spatial extent (sub-setting an image).

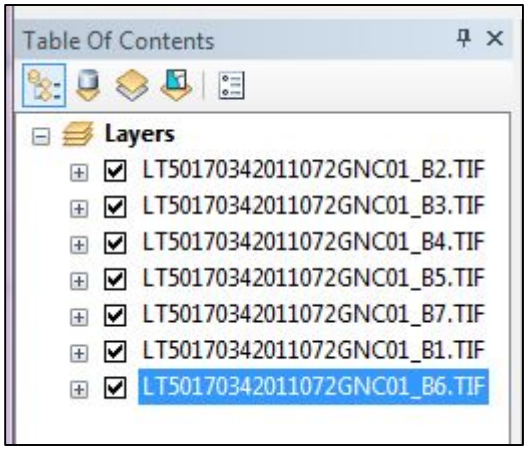
Limiting the number of bands

Open a new map document and add all seven individual bands from your downloaded Landsat scene. Open your **Image Analysis** window. To limit the number of bands to the image, you need to create a composite image using those specific bands.



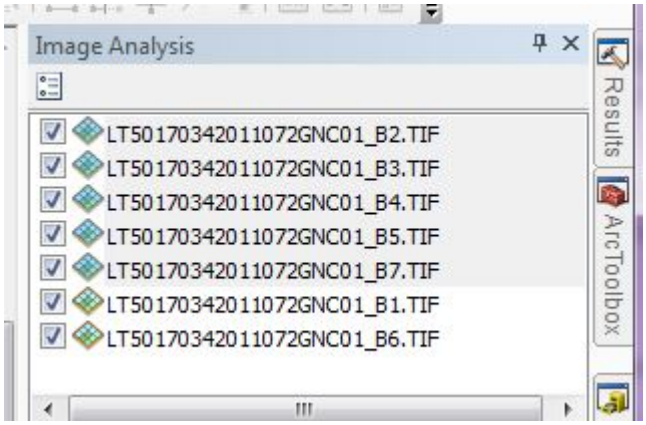
13. Sub-setting Landsat Imagery

Once you have decided which bands you wish to use in your sub-setted image, you need to list those bands in order in the ***Table of Contents***. *(Note – exactly which bands you may want to use will be dependent on your project and goals and is beyond the scope of this tutorial).*

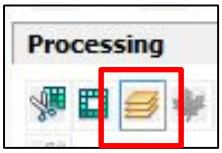


For this tutorial, we are going to use bands 2, 3, 4, 5 and 7 (strictly as an example), so order the bands that way. They will also show up in the Image Analysis window in the same order.

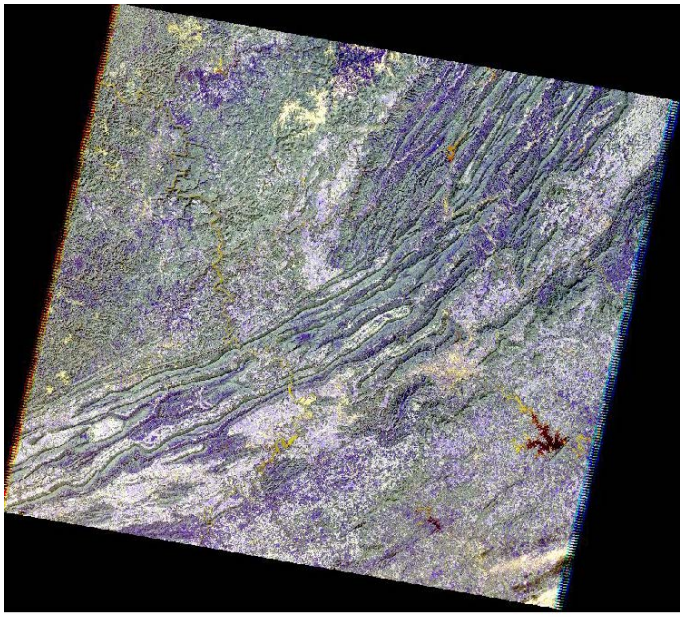
Next, within the Image Analysis window, highlight bands 2,3,4,5 and 7.

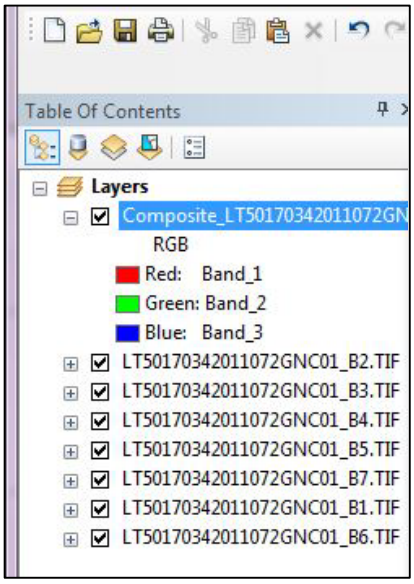


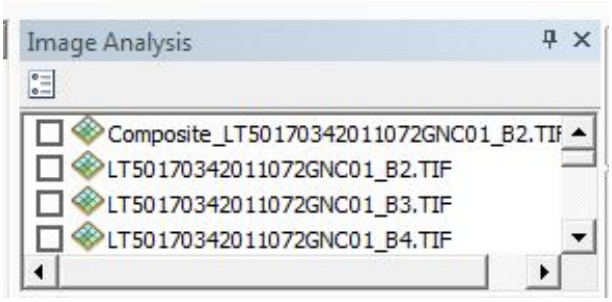
Then left-click the ***Composite*** button.

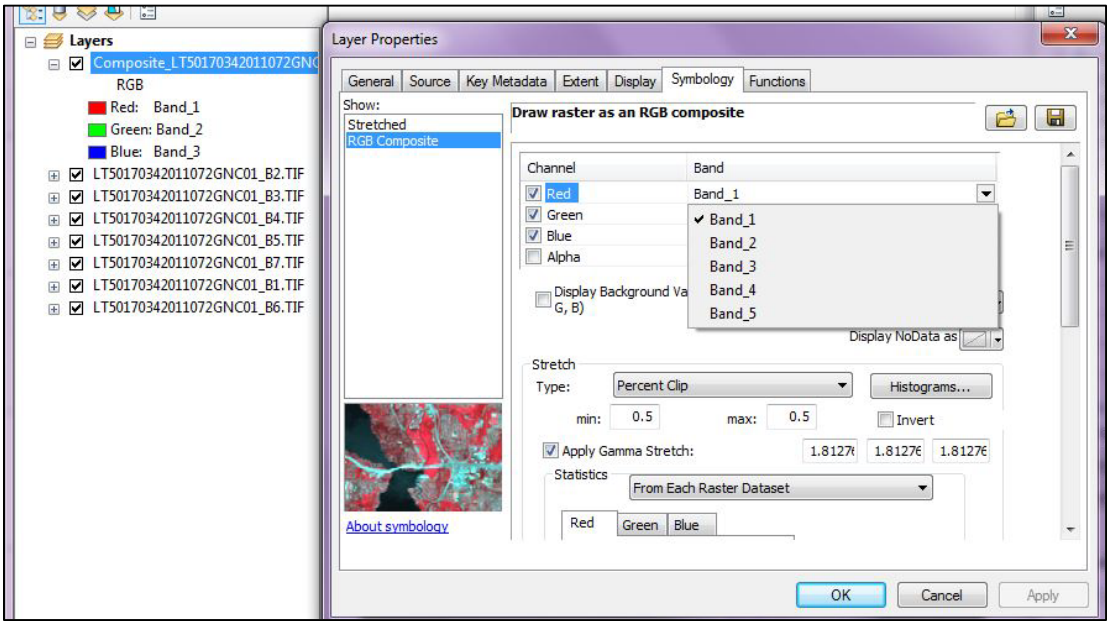


You will have a new TEMPORARY composite image. You see this in 3 places – ***Table of Contents***, map document window and the list of files in the ***Image Analysis*** window.

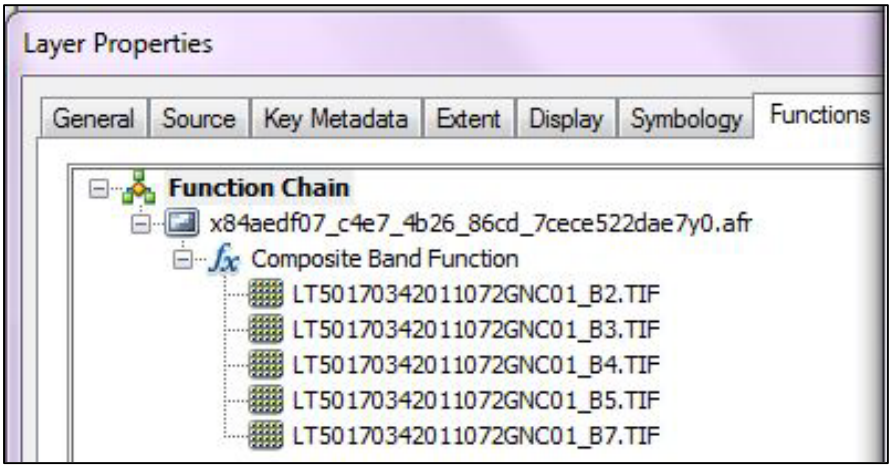








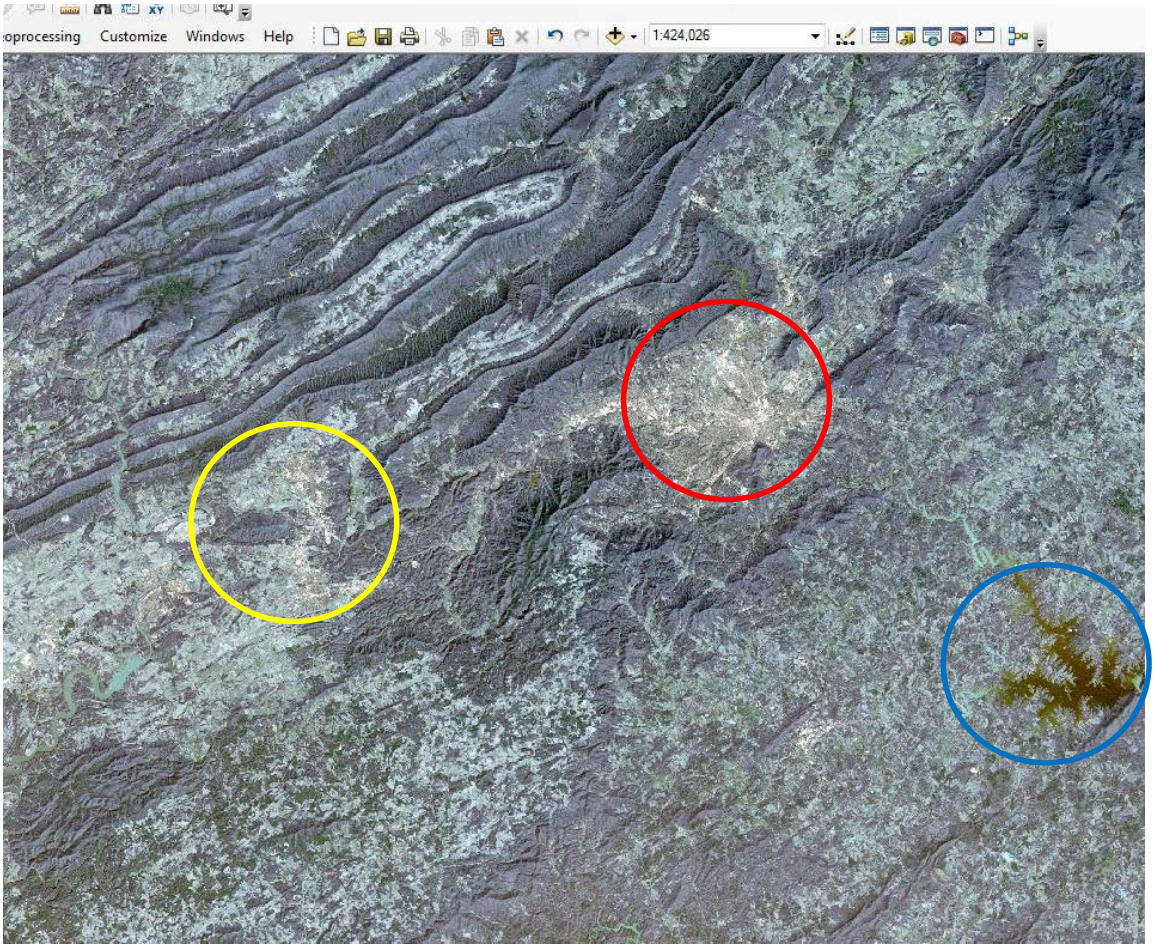
Please note that in ***Layer Properties/Symbology***, the bands are listed as ***Band_1, Band_2, Band_3, Band_4*** and ***Band_5***. The bands represent the Landsat bands in the order in which they appeared in the ***Table of Contents*** and ***Image Analysis*** windows at the time you hit the ***Composite*** button – i.e. the file at the top of the list is band 1, etc. You can see this relationship under ***Layer Properties/Functions***:



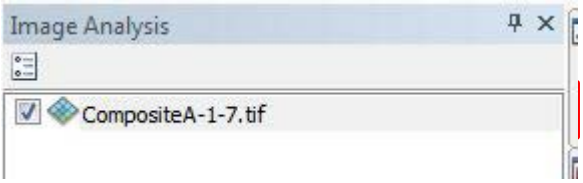
Remember, this file is a temporary file and you must save it as a permanent file to use it in subsequent analyses. (See on tutorial on **Band Combinations using Landsat Imagery**.*)*

Sub-setting by Spatial Extent

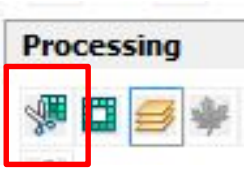
For this section of the tutorial, we are going to use the new image that was created in the previous section. You can clip the entire scene in two ways – by zooming in on the image in the map document window or by using a polygon vector file. First we are going to do it to the extent showing in the map document window. Zoom in on the image so that includes the City of Roanoke (red circle), the Blacksburg area (yellow circle) and Smith Mountain Lake (blue circle) (this will be the southeastern quadrant of the scene.). It should look like this:



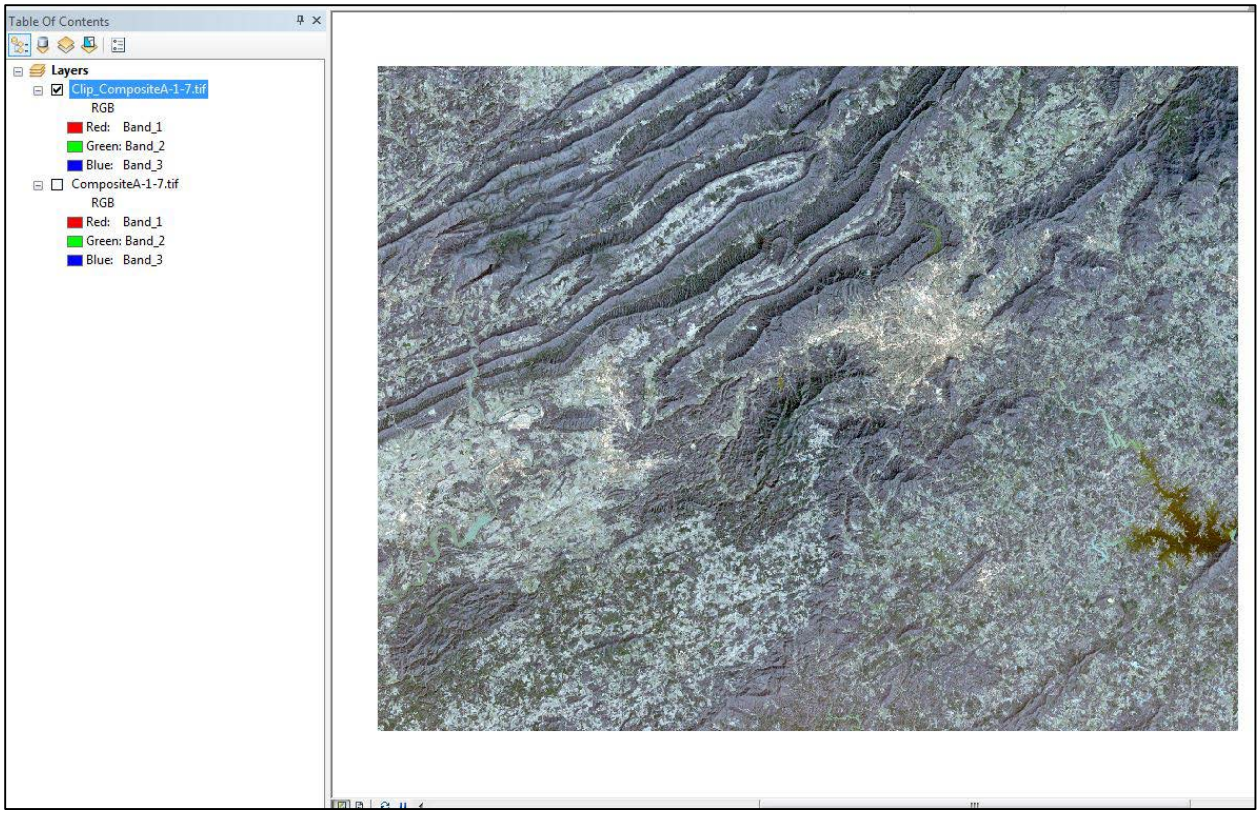
Highlight the image name in the ***Image Analysis*** window (make sure the only one highlighted is the image you wish to clip):



Click on the ***Clip*** button.

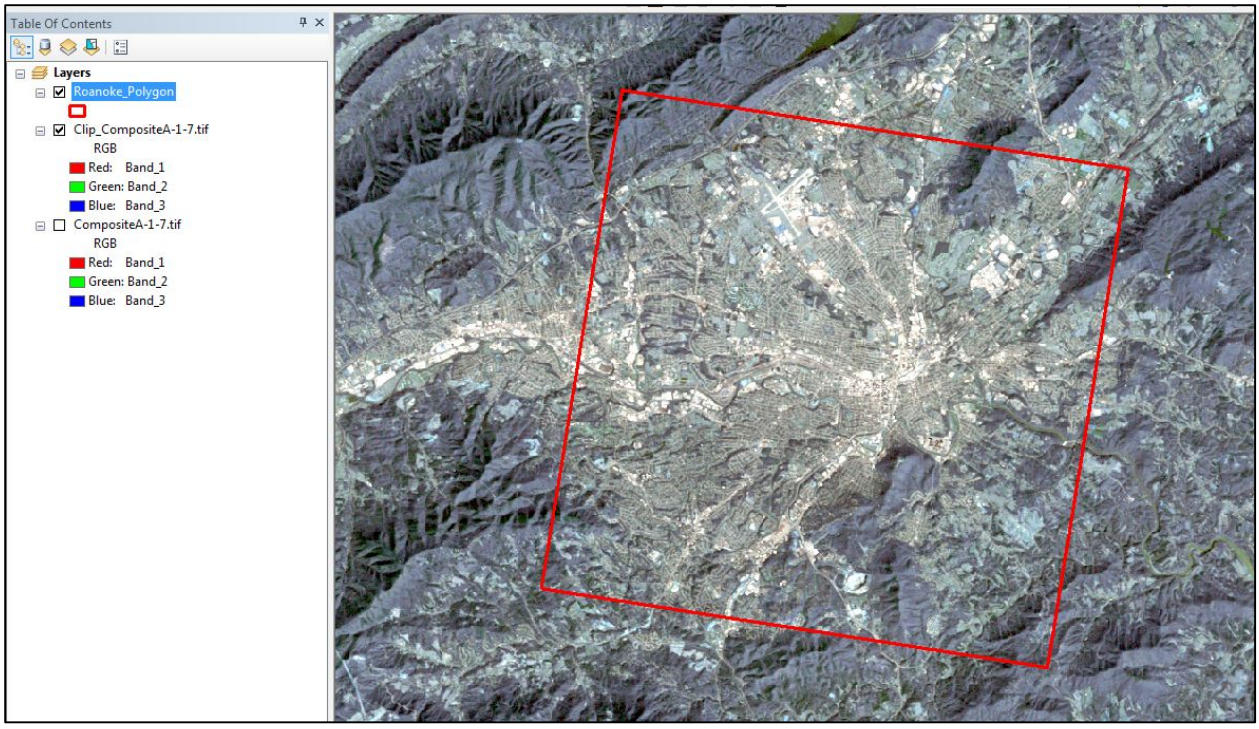


Result:

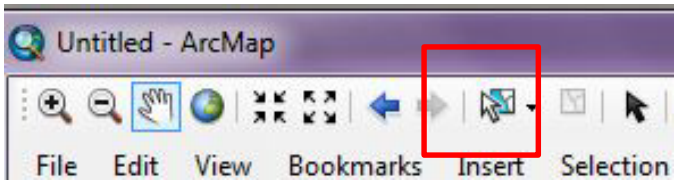


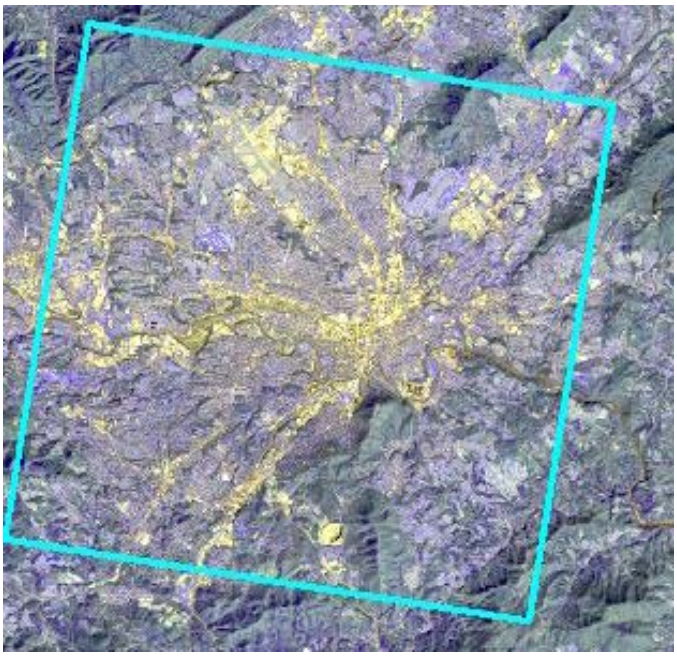
You have a new file listed in the ***Table of Contents*** and, the ***Image Analysis*** window, and a new display in the map document window. Again, in this instance, using the ***Clip*** button clips the image to the extent that was displayed in the map document window. Save this image as we are going to use this image in a subsequent tutorial. *(Note- if you don't remember how to save, go back to the tutorial on* **Band Combinations using Landsat Imagery***.)*

Now, we are going to clip using a polygon file. Go ahead and add the polygon vector file that represents the spatial extent of the area that you want to clip to. *(Note in the following screen shot, we are displaying the polygon as hollow so you can see the spatial extent that we want – the area which includes the City of Roanoke, Virginia.)*



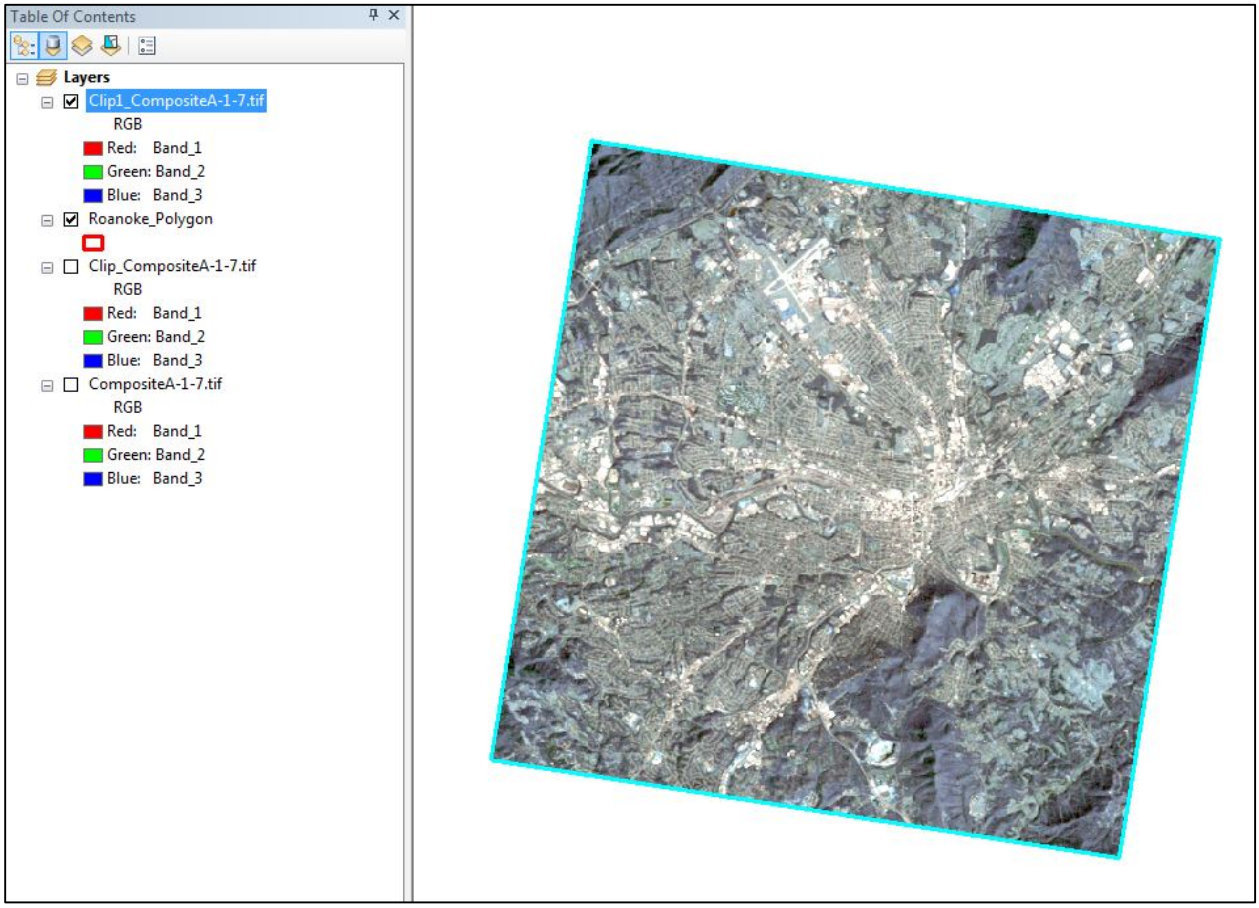
To clip the image to the extent of the polygon feature, you must first select the polygon. On the tool bar at the top of the ArcMap window, left-click on the ***Select Features*** button and then left-click on the polygon in the map document window to highlight it:





Once the polygon is highlighted, left-click on the ***Clip*** button.

You get the following results:



Your Landsat Composite Image is now clipped to the spatial extent of your polygon.

Your clipping polygon does not have to be a rectangle, it can be any shape – for example, you may want to clip it to the extent of a political boundary. You follow the same procedure -- add your polygon boundary file to the ***Table of Contents*** (for the following example, we added the boundary for the City of Roanoke). Select the polygon file with the ***Select Features*** button, make sure the image you want clipped is highlighted in the I***mage Analysis*** window, and left-click on the ***Clip*** button.

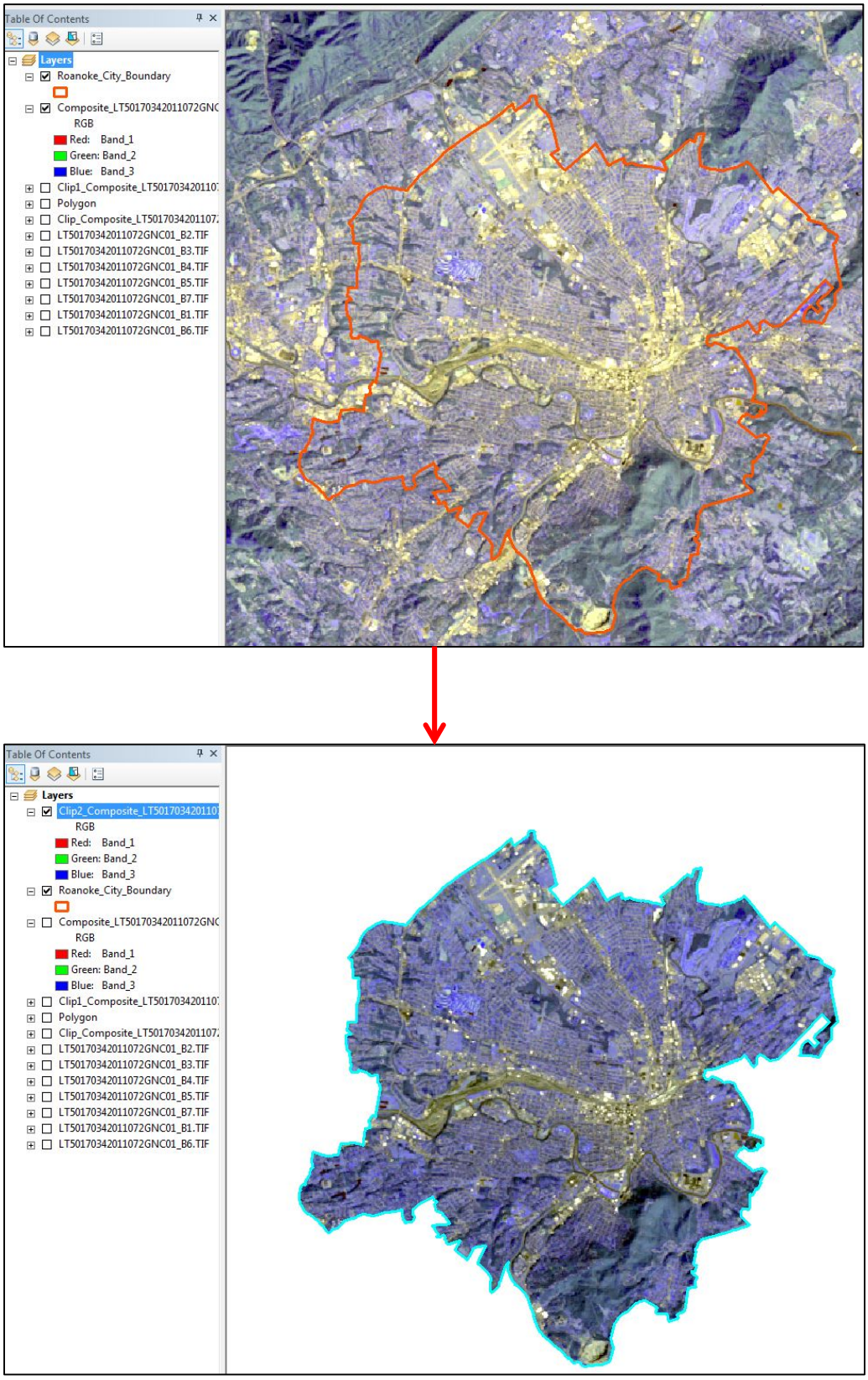
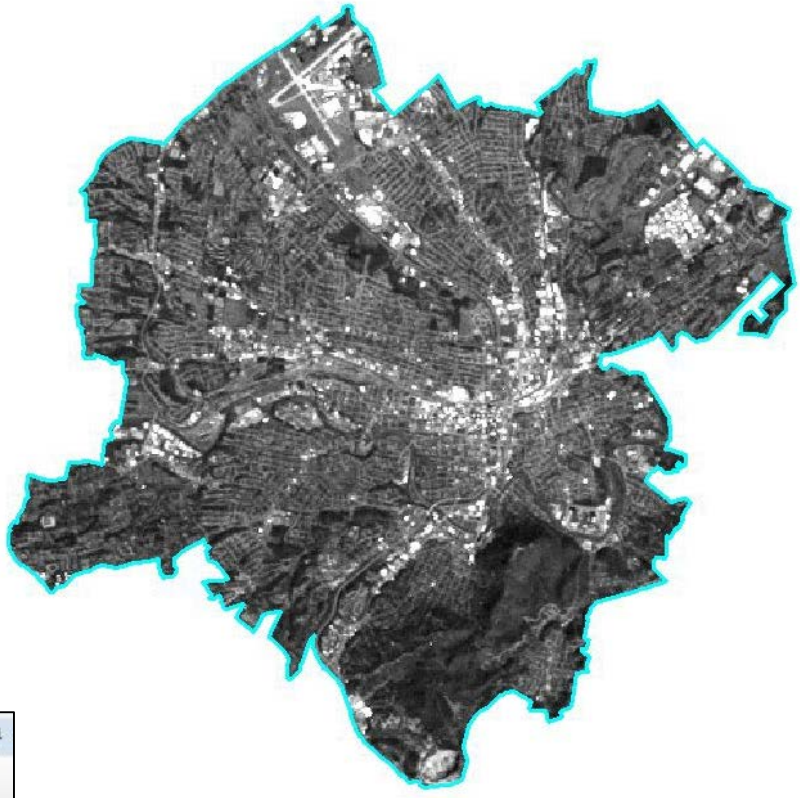
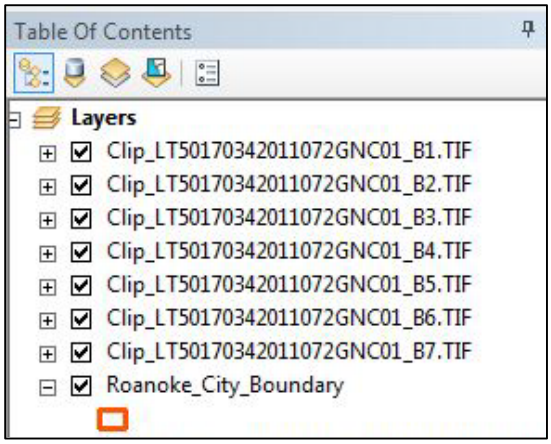


Table Of Contents
Layers
Roanoke_City_Boundary
Composite_LT50170342011072GNC
RGB
Red: Band_1
Green: Band_2
Blue: Band_3
Clip1_Composite_LT5017034201107
Polygon
Clip_Composite_LT5017034201107
LT50170342011072GNC01_B2.TIF
LT50170342011072GNC01_B3.TIF
LT50170342011072GNC01_B4.TIF
LT50170342011072GNC01_B5.TIF
LT50170342011072GNC01_B7.TIF
LT50170342011072GNC01_B1.TIF
LT50170342011072GNC01_B6.TIF
Table Of Contents
Layers
Clip2_Composite_LT5017034201107
RGB
Red: Band_1
Green: Band_2
Blue: Band_3
Roanoke_City_Boundary
Composite_LT50170342011072GNC
RGB
Red: Band_1
Green: Band_2
Blue: Band_3
Clip1_Composite_LT5017034201107
Polygon
Clip_Composite_LT5017034201107
LT50170342011072GNC01_B2.TIF
LT50170342011072GNC01_B3.TIF
LT50170342011072GNC01_B4.TIF
LT50170342011072GNC01_B5.TIF
LT50170342011072GNC01_B7.TIF
LT50170342011072GNC01_B1.TIF
LT50170342011072GNC01_B6.TIF

You can also clip multiple images at the same time. You follow the same procedure as the last two - add the polygon file and select it – but instead of highlighting one image in the ***Image Analysis*** window, you highlight all images that you want clipped. Left-click the ***Clip*** button and ArcMap clips all the highlighted images to the spatial extent of the polygon file. In this image, we clipped all of the original Landsat bands to the City of Roanoke boundary polygon file and ArcMap produced one new file for each band. The new files are listed separately in the ***Table of Contents*** but you only see one because they are stacked on top of each other in the map document window.





Don't Forget New Files Generated from Image Analysis Window are TEMPORARY! You must save them if you want to use them later.

You are ready to proceed to the next set of tutorials. You will be using one of your sub-setted images from this tutorial in some of the next few tutorials.

14. Radiometric Enhancement of Landsat Imagery

The instructional materials contained within these documents are copyrighted property of VirginiaView, its partners and other participating AmericaView consortium members. These materials may be reproduced and used by educators for instructional purposes. No permission is granted to use the materials for paid consulting or instruction where a fee is collected. Reproduction or translation of any part of this document beyond that permitted in Section 107 or 108 of the 1976 United States Copyright Act without the permission of the copyright owner(s) is unlawful.

In the next few tutorials, you will gain an understanding of the theory of image enhancement using ArcGIS 10.X. This specific tutorial involves radiometric enhancement.

Introduction to Image Enhancement

Image enhancement refers to procedures that remote sensing analysts use to adjust the values in a remotely sensed image to improve its visual qualities for a specific purpose. The brightness values at individual pixels are changed to achieve improved brightness, contrast, color balance, or other qualities.

The visual quality of an image is related to the range of brightness in the image, known as *contrast.* A high contrast image has a narrow range of brightness- mainly blacks and whites. A low contrast image has a wide range of brightness. Usually, excessive contrast is undesirable; as the analyst cannot see features depicted in the intermediate grey that usually form the most important part of an image. On the other hand, lack of contrast is usually undesirable as the analyst cannot the edges that form the see the

Image enhancement is a tool that permits the analyst to apply the level of contrast appropriate for a specific purpose. It is important to recognize that image enhancement is intended to improve the appearance of a specific image for a specific purpose. Because analysts have different objectives, and images have differing qualities, preferred enhancement techniques will vary from one application to the next. Image enhancement focuses entirely on manipulating the appearance of the image, so it is fundamentally cosmetic in nature, and should not be used as input for analytical purposes.

Most remotely sensed images require some form of enhancement because they use only a small range of the brightness available to a computer display, so many of the features depicted on the image are not visible to the analyst. As a result, in its original form, the image may not be suitable for its intended use. Image enhancement applies a strategy for expanding the range of brightness use to display the image, thereby revealing features that might not be visible in the original version.

> Enhancing image dynamically in a Viewer is much faster than writing permanent image file for every enhancement operation (and also saves disk space). Therefore, while experimenting to find the desired enhancement, use dynamic (temporary) enhancement in a Viewer. Once you achieve the enhancement that you want, it can be permanently saved.

14. Radiometric Enhancement of Landsat Imagery

Image enhancement can be best discussed in the contact of the frequency histogram of a digital image. A frequency histogram displays image brightness along the horizontal axis, and numbers of pixels at each brightness level along the vertical axis. The shape of a specific histogram is related to the features represented a scene, and conditions under which the image was acquired.

Linear Contrast Stretch extends the range of brightness through a systematic expansion of image brightness to occupy the full range of brightness available by creating new intermediate values to generate the necessary range of brightness.

Histogram Equalization expands the range of brightness by sliding the brightness along the brightness scale so that they occupy the full range of brightness available in the display. The histogram of the enhanced image shows gaps between the brightness values because they have been separated to create a wider range of brightness in the image.

There are a great variety of digital image enhancement techniques. The choice of particular technique(s) depends on the application, data available, experience and preferences of image analyst. In this and the next two tutorials, we will cover the three most important and widely used groups of enhancement techniques:

- **Radiometric Enhancement** - Enhancing images based on the values of individual pixels (this tutorial)
- **Spectral Enhancement** - Enhancing images by transforming the values of each pixel on a multiband basis (Band Ratios, Vegetation Indicies, & Tasseled Cap - see **Tutorial 15. Spectral Enhancement of Landsat Imagery**.)
- **Spatial Enhancement** - Enhancing images based on the values of individual and neighboring pixels (see **Tutorial 16. Spatial Enhancement of Landsat Imagery**)

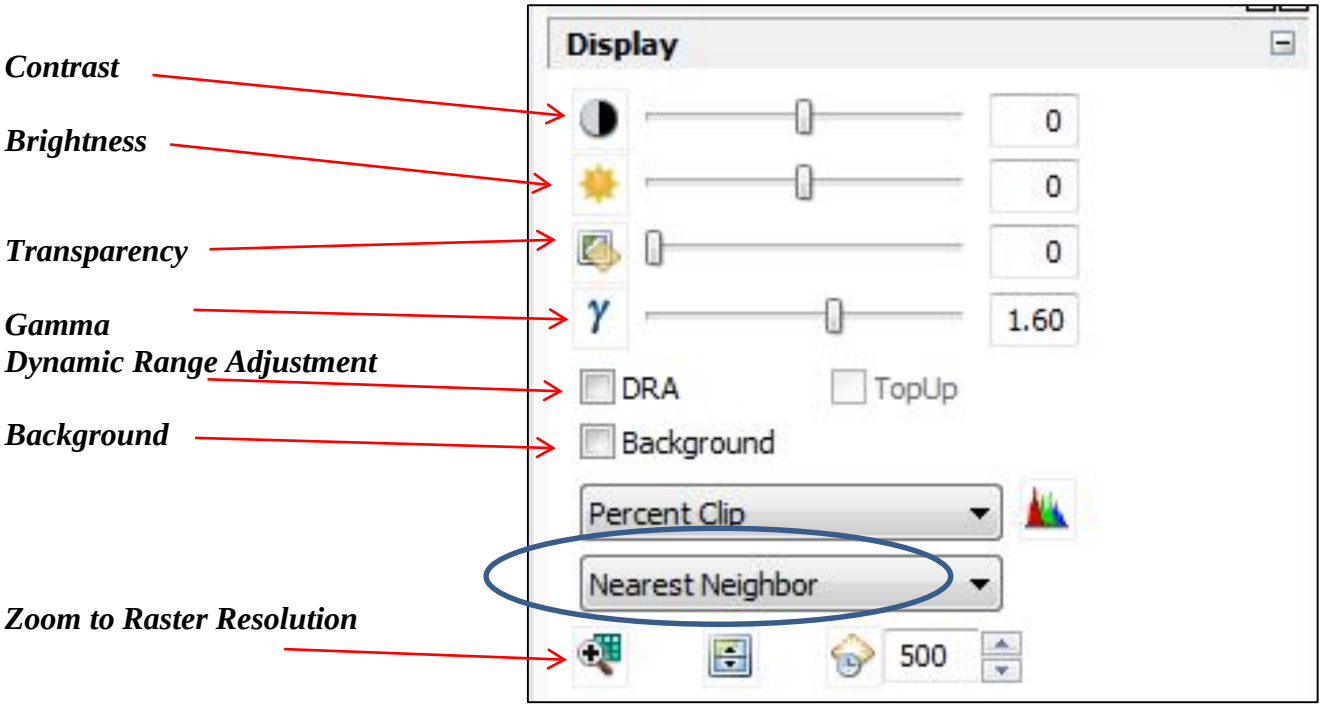
Using ArcGIS as a Viewer for Radiometric Enhancement

Open a map document and load the 7-band composite image that you created in the tutorial on Creating a Composite Images from Landsat Imagery. Be sure your ***Image Analysis*** window is open. Set your image with band combination 4-3-2. (*Note - you can also use these tools on each of the bands as separate images.)*

Left-click on the image name in the ***Image Analysis*** window. Once you click on it, it should activate most of the buttons in the ***Display*** window. First, we are going to examine each one of these buttons and their effects on the viewer. We will then examine histograms (next

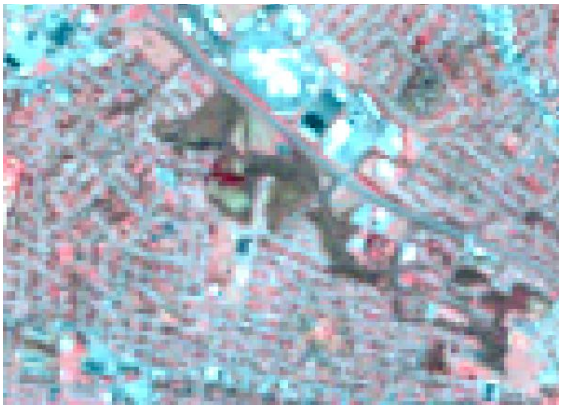
section) in two areas, within the ***Image Analysis/Display*** window and within the ***Layer Properties/Symbology*** dialog box.

Using the ***Display*** window, you can change the ***Contrast, Brightness***, ***Gamma***, and ***DRA*** (dynamic range adjustment) of the image in the map document window by either moving the sliding bar or placing a numeric value in the box next to the sliding bar. Go ahead and change the values, one at a time. Observe the changes in your display (note these are only changing the display, not the original image). Each one changes the display in different ways. **Brightness** will make the image appear lighter or darker. ***Contrast*** changes the range of differences between the darkest and lightest objects. ***Gamma*** controls relationships between the brightness of original scene and that on the display. (For example, at a gamma of 1.0, the two images will use the same scale of brightnesses, whereas at gammas of 0.5 or 1.5, the display shows, respectively, either compressed, or expanded, scales of brightness relative to the original.) These tools are useful when doing image classification to help you discern different features within the image.



We will discuss the list of options within the blue oval in the tutorial on **Spatial Enhancement of Landsat Imagery**.

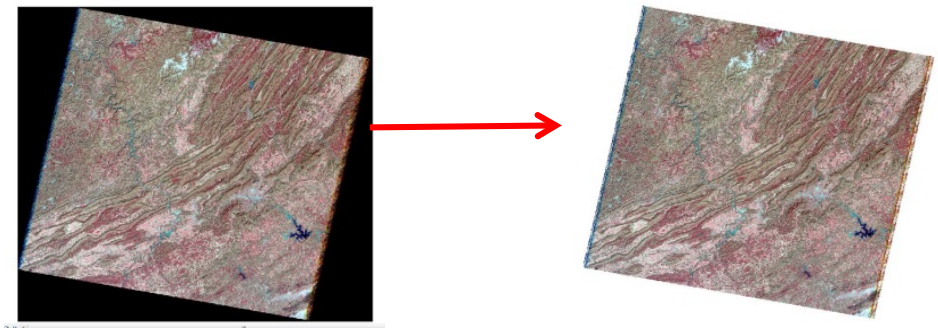
Transparency displays the image so you can see the image below it. If the image below is an aerial photo, you would be able to see and associate the various brightness values to specific objects. For example, by adjusting the transparency of the Landsat image (below left) from 0 (not transparent) to 50 (partially transparent) (below right) you can see that the very bright area at the top and center corresponds to a building within a parking lot.



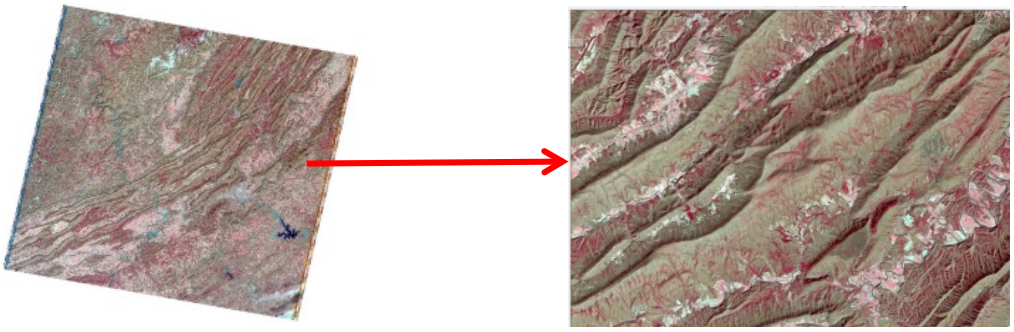
(right) Landsat image is opaque, masking view of the aerial photo. (left) Transparency allows a view of the detail of the aerial photo

To set these values back to the original values, just hit the reset button, which is the icon for each tool.

By placing a checkmark in the box next to ***Background*** you eliminate the *no data* value in the display (ArcMap makes Raster files square by adding no value boxes), so you will see the actual Landsat scene without ArcMap filling it in.



Finally if you hit ***Zoom to Raster Resolution***, the display will zoom in on the image.

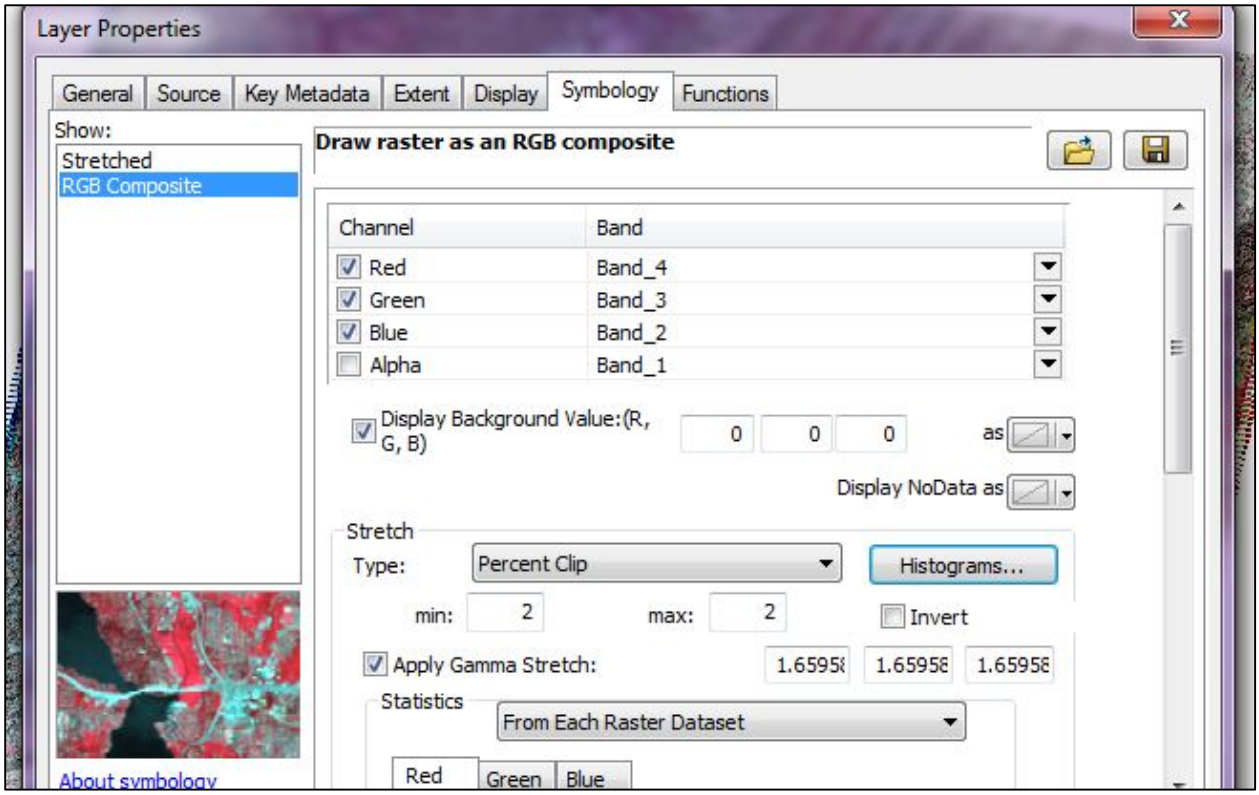


Before proceeding to the next steps, please hit the *reset* button on all the ***Display*** buttons, so we are back to the original images.

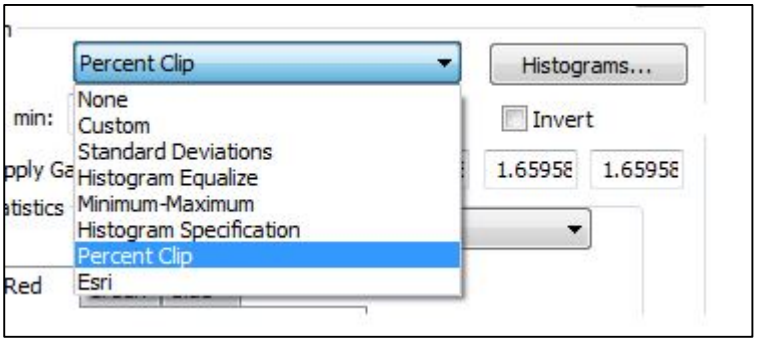
Histograms

As stated above, histograms plot the frequency values of the digital numbers (DNs) (x-axis) against the number of pixels with that value (y-axis). (Remember, the shape of the histogram is determined by the features represented in the image, and their brightnesses.) We will discuss histograms in two different areas within ArcMap.

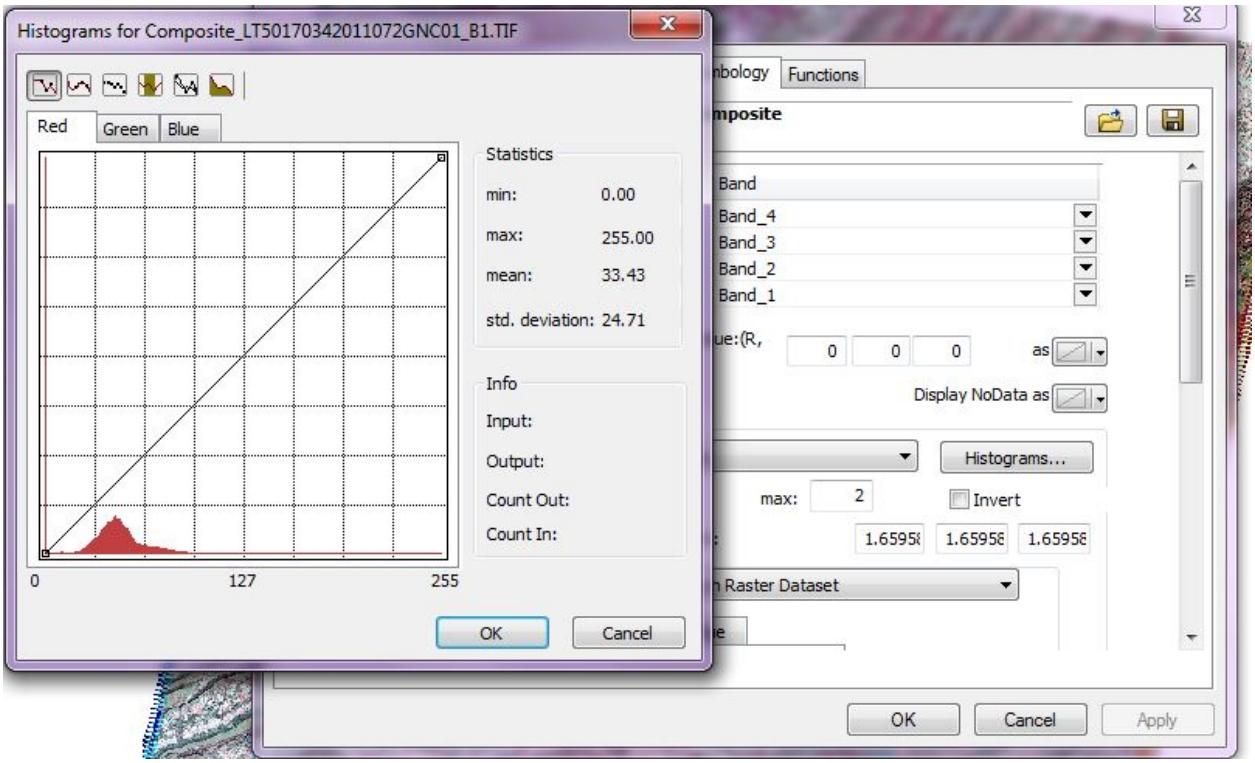
The first area where ArcMap displays histograms is in ***Layer Properties/Symbology*** tab. You will find the histogram button in the middle of the dialog box. Before clicking on this button, notice the ***Stretch Type – Percent Clip.***



Left-click on the down arrow and you find a list of different type of histogram stretches available in ArcMap. ***Percent Clip*** is the default; this method eliminates the minimum and maximum values ends of the histogram based on a percent (the default is 2.00). You can change these values by changing either the standard deviation or the percent of the clip. (For more information see ArcGIS on-line help.)

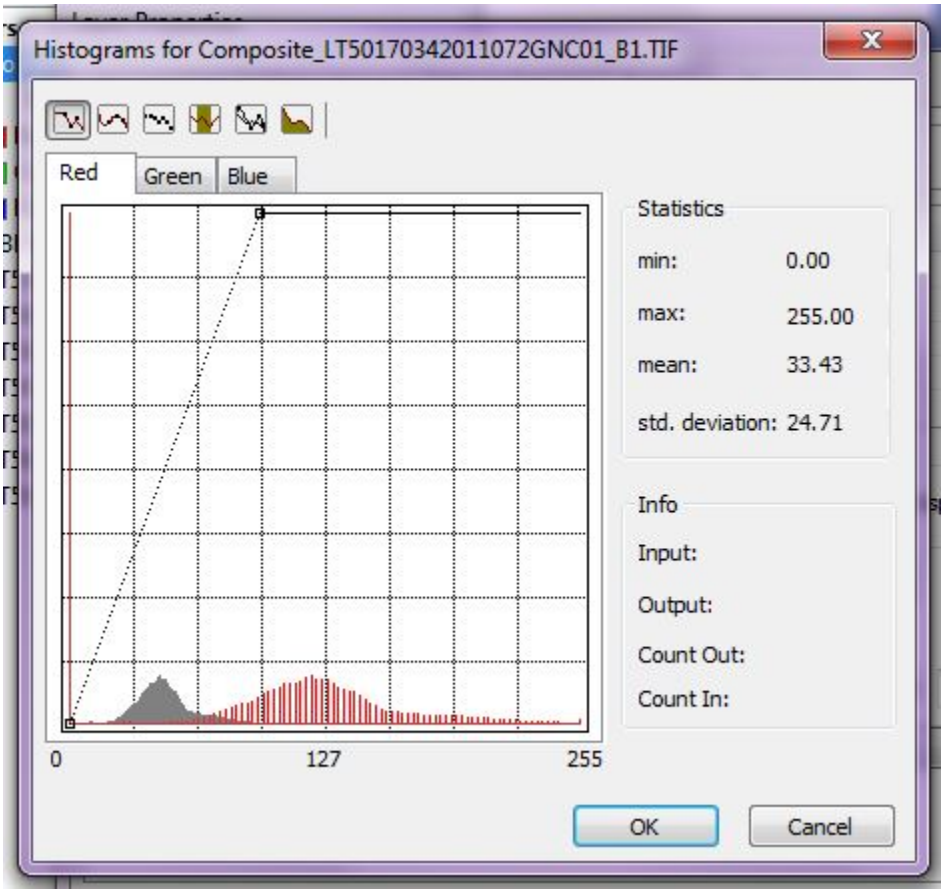


Now, left-click on this button. It displays one histogram – the red band. With a 4-3-2 band combination, which Landsat band is this? (*Answer – near infrared*). For this particular band, you see the minimum, maximum, mean and standard deviation values. By left-clicking on either the ***Green*** or ***Blue*** tabs, you can look at the histograms for the other two bands.



Why would each histogram look different? *(Answer – because each band has a different range of DNs.)*

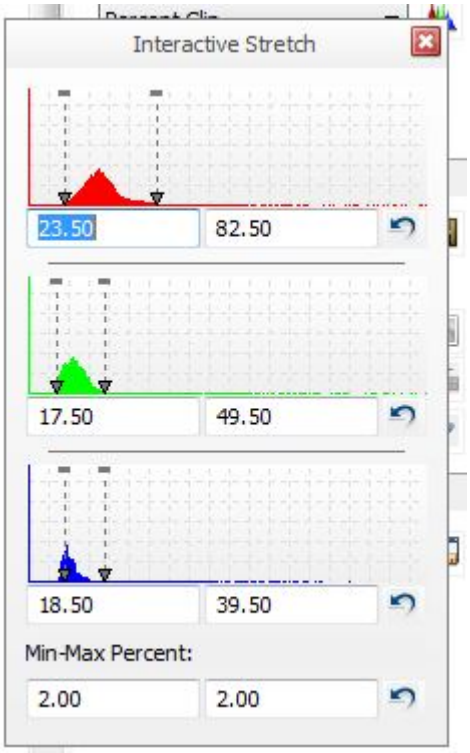
If you change the histogram stretch type, you must click on ***Apply*** in order for the change to take effect. Change the histogram stretch type to ***Standard Deviations***. What happened to the image? Now look at the histogram for the red band. ArcMap shows you the new histogram but also shows the original histogram from the ***Percent Clip*** method grayed-out so you can compare before/after views of frequency distributions as you make changes.



Now, let's explore the other area where you can look at histogram. Before closing out ***the Layer Properties/Symbology*** dialog box, reset the stretch method to ***Percent Clip*** and click on ***Apply***.

The second area where histograms are displayed are in the ***Image Analysis*** window. To use this tool, highlight the image that you wish to examine using icons visible at the top of the window in order to enable the display tools. Underneath ***Background***, you see the ***Percent Clip*** method and a button that looks like a histogram.

Make sure your image is zoomed out to the entire Landsat scene and left-click on the ***Histograms*** button. This gives you all three histograms for the three different bands that you are displaying (using the ***Percent Clip*** method). Remember, for 4-3-2, red is for the near-infrared band (Landsat Band_4), the green for the red (Landsat Band_3), and the blue for the green (Landsat Band_2). The numbers below each histogram correspond to the value of the arrows within the histogram and the values that correspond to the ***Min-Max Percent*** numbers.

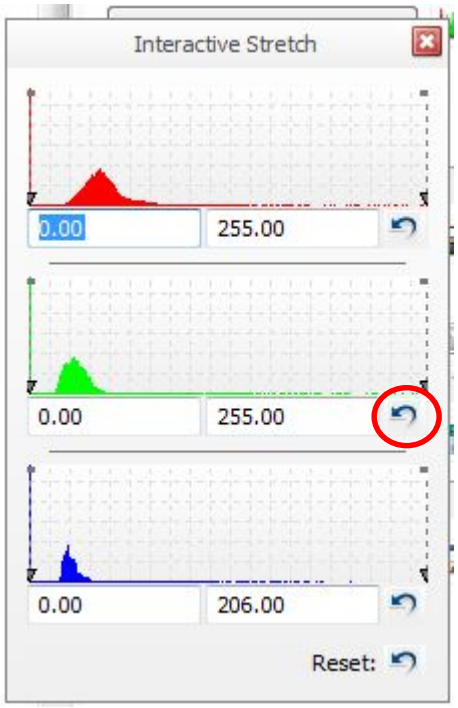


You move the arrows to identify different values within the histogram. When moving the arrows, you do this as a separate action on each band's histogram. To change the ***Min-Max Percent*** values, just enter the new value (hit enter after changing the values). As an example, enter 20 for the minimum and observe what happens to the image and the histograms—you can see that you have changed the red and green bands only slightly, but have lost most of the values in the blue band.

Is it reasonable to want to change the histograms using the exact same percent? Why or why not? (*Hint – each band is useful for different reason. Should you address each one independently?)* Would

you use the same method to assist in feature identification -- forest areas versus the city? Why or why not?

Additional question - What is the DN at the peak of the near-infrared band? What does this peak mean? (*Answer – this DN has the highest number of pixels.)* Don't worry about permanently changing the display - by clicking on the counter-clockwise arrow (red circle) for any of these, you will reset it to the original values.



Now let's do another one and see how it changes the image. Change the stretch method to ***Min-max***. How has the image and histogram window changed? *(The Min-Max Percent at the bottom is gone and it includes the entire range of values for each band).* You can now perform a contrast stretch separately to each band.

You can adjust the minimum value by either sliding the arrow or entering the value into the left box. To change the maximum value, enter the value into the right box.

Explore the various methods of histogram stretch with different band combinations. Which methods are best will depend on the purpose of your project.

You can also use ArcMap to perform **density slicing** to enhance your image. Density slicing differs from contrast stretch in that it assigns colors to specific brightness values. The colors do not add additional information, but simply permit the analyst to make sharper distinctions between brightness classes in the image. You cannot perform density slicing on a composite image within

ArcMap,--density slicing can only be accomplished on each individual band image that you received with your Landsat download. This procedure is beyond the scope of this tutorial.

We will discuss further Image Enhancement techniques in the next two tutorials on Spectral Enhancement of Landsat Imagery and Spatial Enhancement of Landsat Imagery.

As a review: Spectral Enhancement transforms the values of each pixel on a multiband basis (Band Ratios, Vegetation Indices, & Tasseled Cap) and Spatial Enhancement **e**nhances images based on the values of individual and neighboring pixels.

The instructional materials contained within these documents are copyrighted property of VirginiaView, its partners and other participating AmericaView consortium members. These materials may be reproduced and used by educators for instructional purposes. No permission is granted to use the materials for paid consulting or instruction where a fee is collected. Reproduction or translation of any part of this document beyond that permitted in Section 107 or 108 of the 1976 United States Copyright Act without the permission of the copyright owner(s) is unlawful.

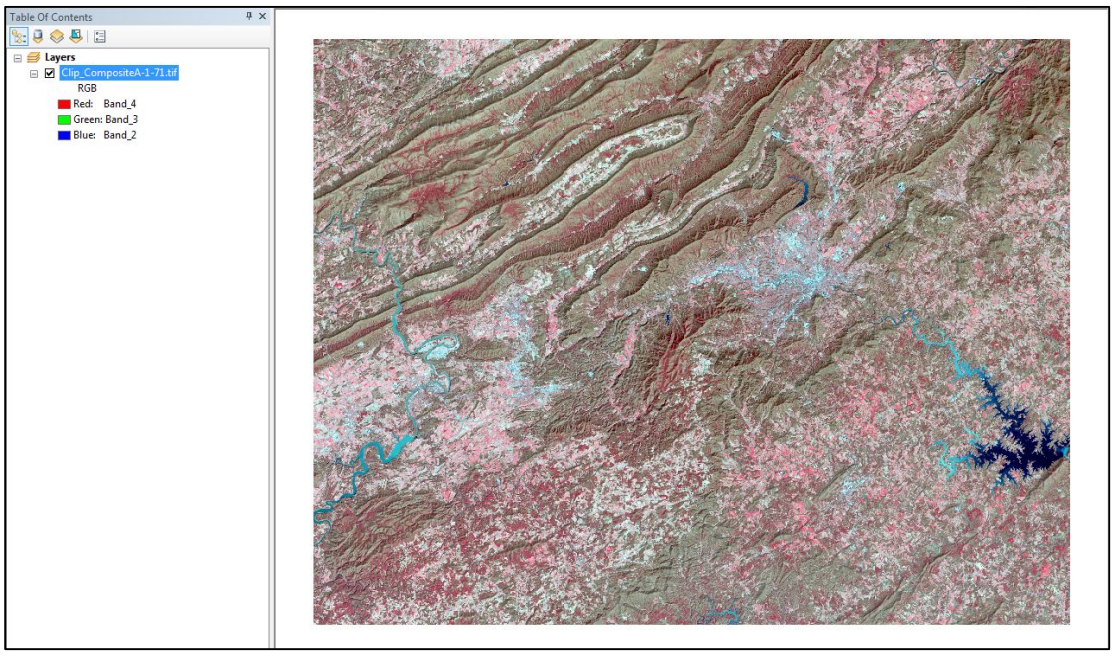
Introduction

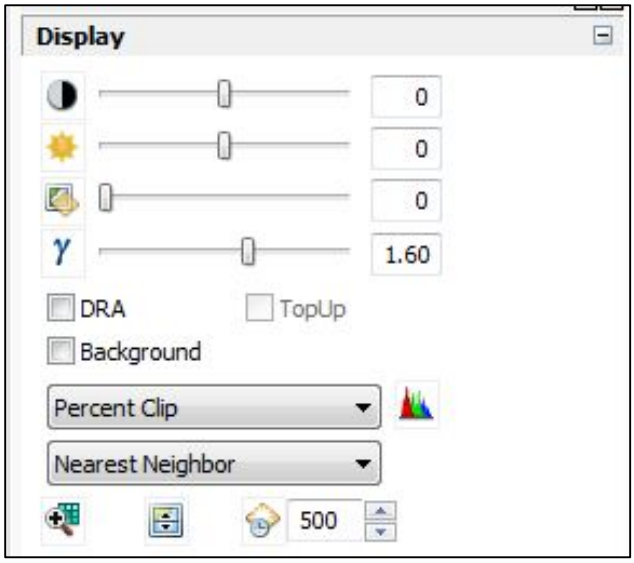
While radiometric and spectral enhancements operate on each pixel individually, spatial enhancement deals largely with spatial frequency and modifies pixel values based on the values of its neighbor pixels.

Spatial Enhancement within ArcGIS uses the Image Analysis window and the Spatial Analyst tools for different processes.

Spatial Enhancement Using Image Analysis Window

Open a new map document and add the image we created in the tutorial on sub-setting your Landsat Image. We want the image that we clipped to the spatial extent of the window – the image that contained Roanoke, Blacksburg, and Smith Mountain Lake. We will be working with that image in this tutorial. Make sure your Image Analysis window is open. Go ahead and set it to a false-color image.

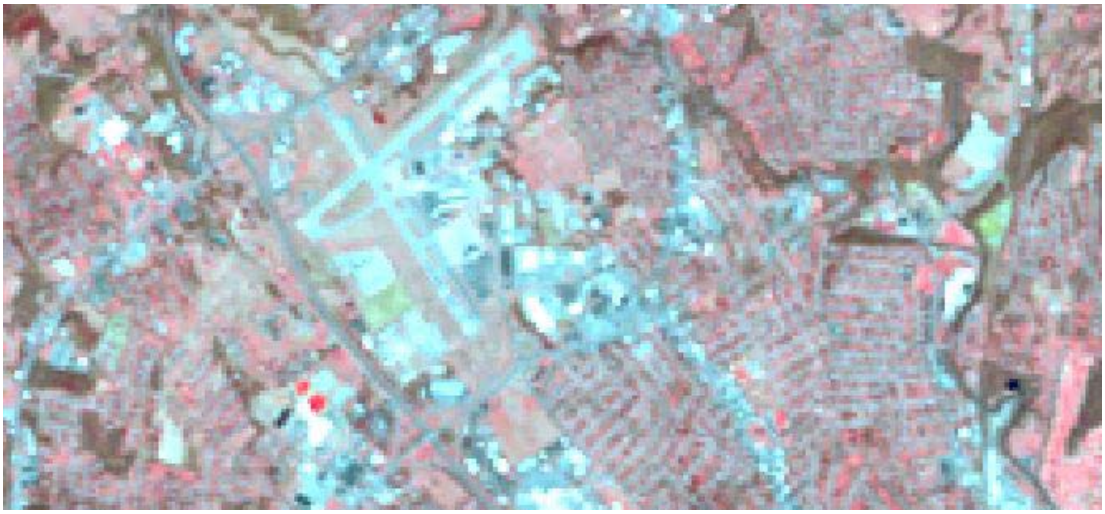




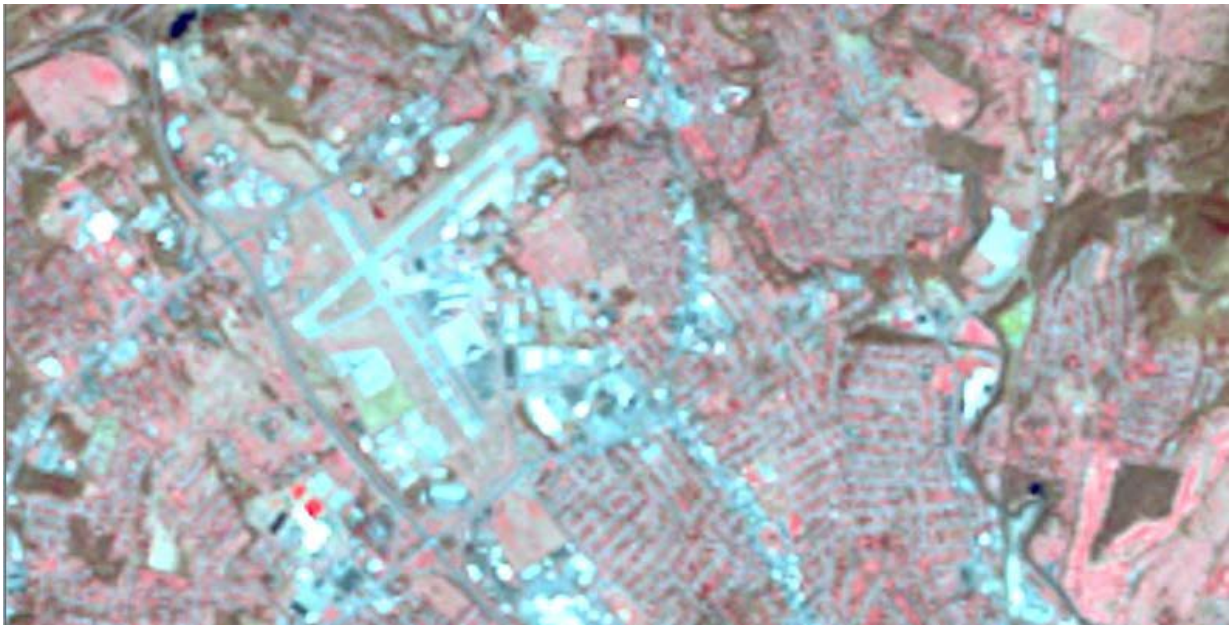
Remember from the prior tutorial, we deferred discussing one of the drop down lists on the ***Image Analysis/Display***. As a reminder, this window changes the image on display but does not change the file permanently. This particular list refers to a resampling method.

Click on the down arrow, you see a number of different options. Again, with spatial enhancement, we are changing the individual pixels based on its neighbors. How it is exactly done, depends on the method. When you change any of these methods you might not see much change if you are zoomed out, so zoom into the City of Roanoke and specifically on the airport area.

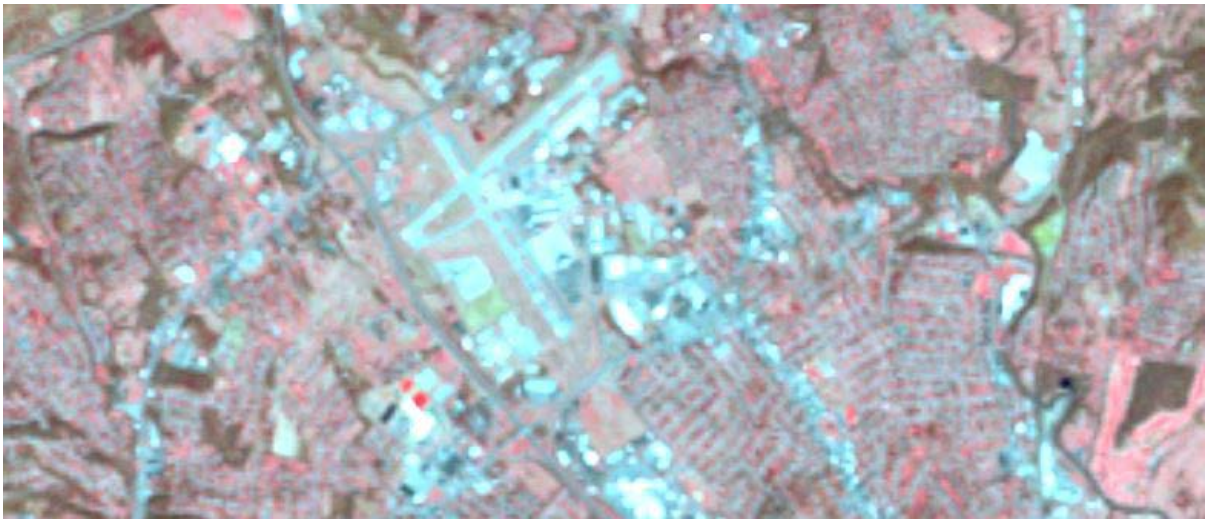
Nearest neighbor – the pixel is assigned the value of the cell closest to it.



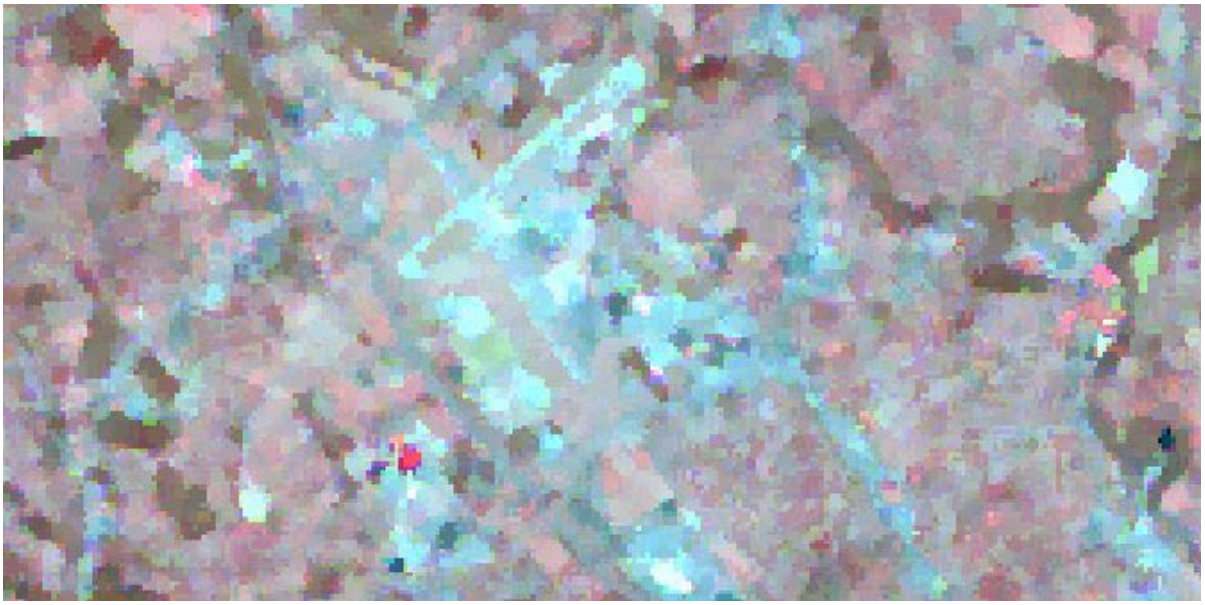
Cubic convolution creates a sharper-looking image.



Bilinear interpolation creates a smooth-looking result.

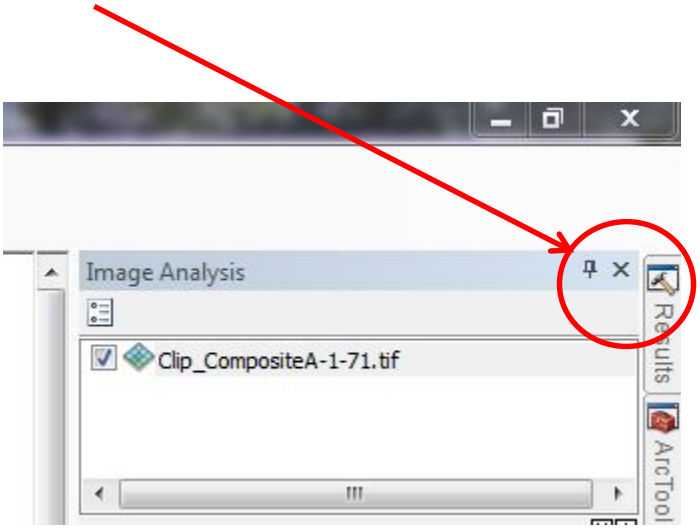


Majority - the pixel is assigned the most common value within a specific filter window, smoothing the image



For more specifics, see ArcGIS help. The method you choose to enhance your image will depend on the purpose of your project.

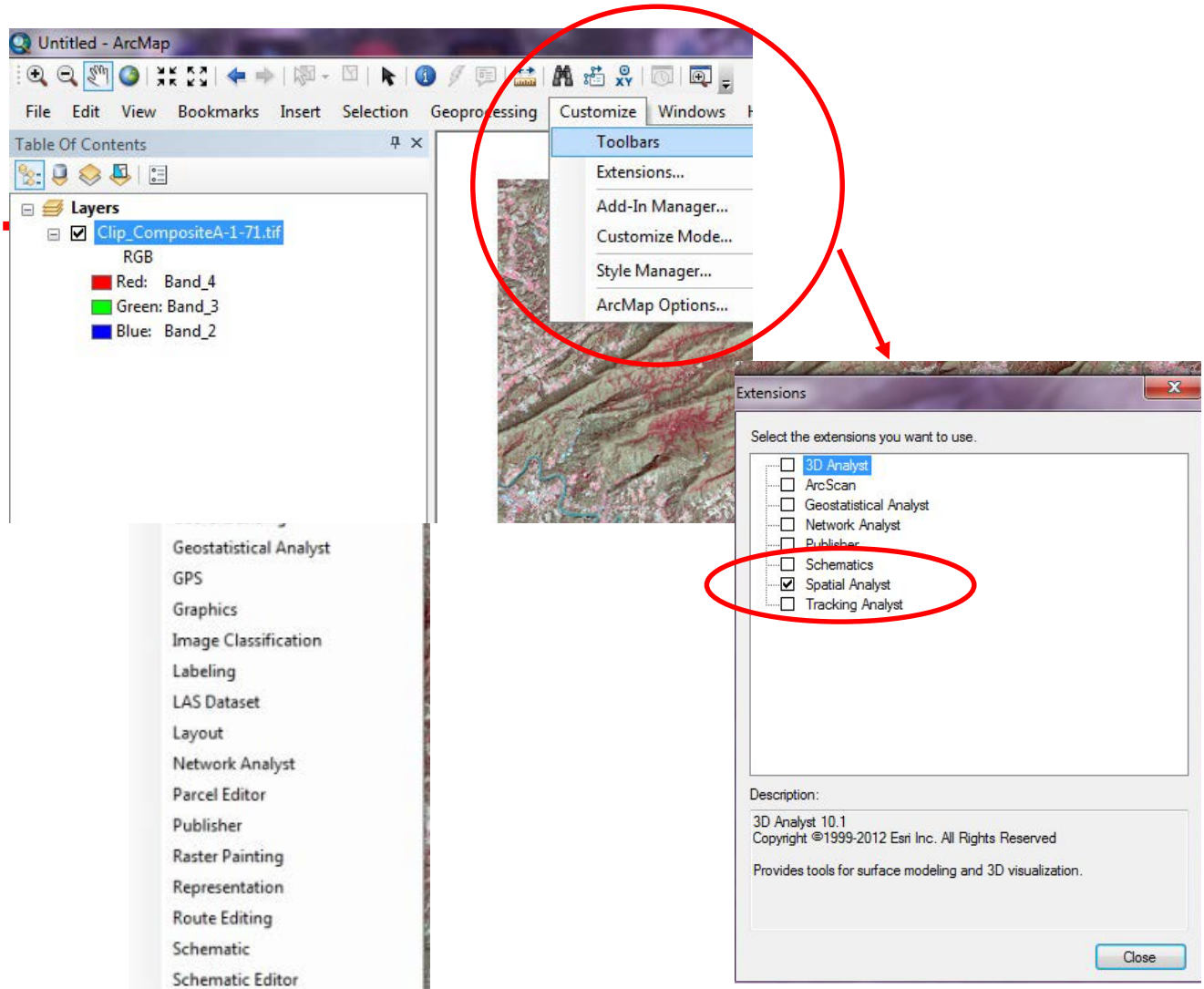
Reset your image to the default – nearest neighbor and close your ***Image Analysis*** window by clicking on the X in the top of the window (be sure you do the Image Analysis X and not the ArcMap X.

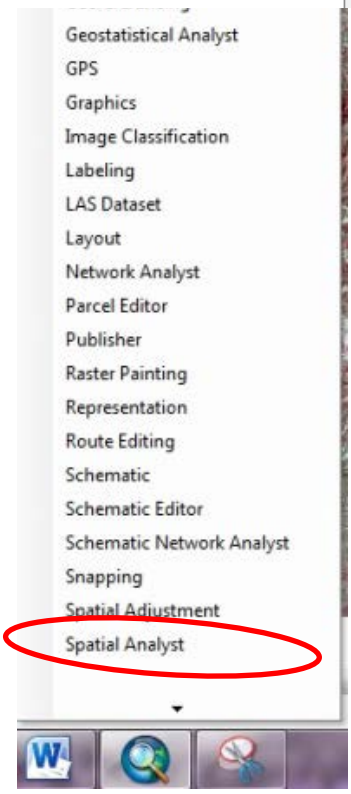


Spatial Enhancement Using Spatial Analyst Tools

First, we need to turn on the ***Spatial Analyst Extension*** and open the ***Toolbox***.

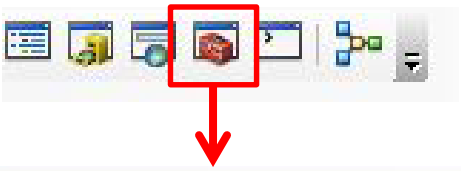
Left-click on ***Customize***, then ***Extensions***, and then click in the box next to ***Spatial Analyst***.

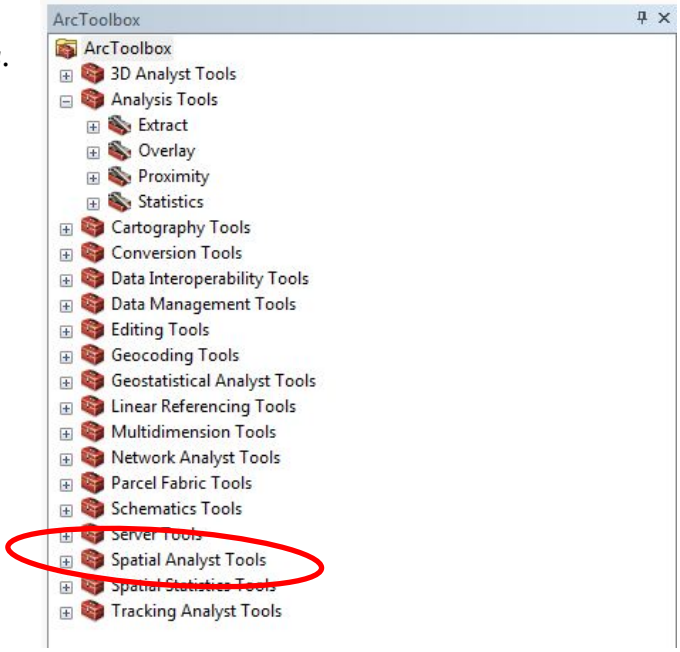




Then right-click anywhere in the upper toolbar of the ArcMap window, and click on Spatial Analyst.

Finally, left-click on the Toolbox icon in the upper toolbar and it opens the Toolbox. The tools we want are found under the ***Spatial Analyst Tools***.

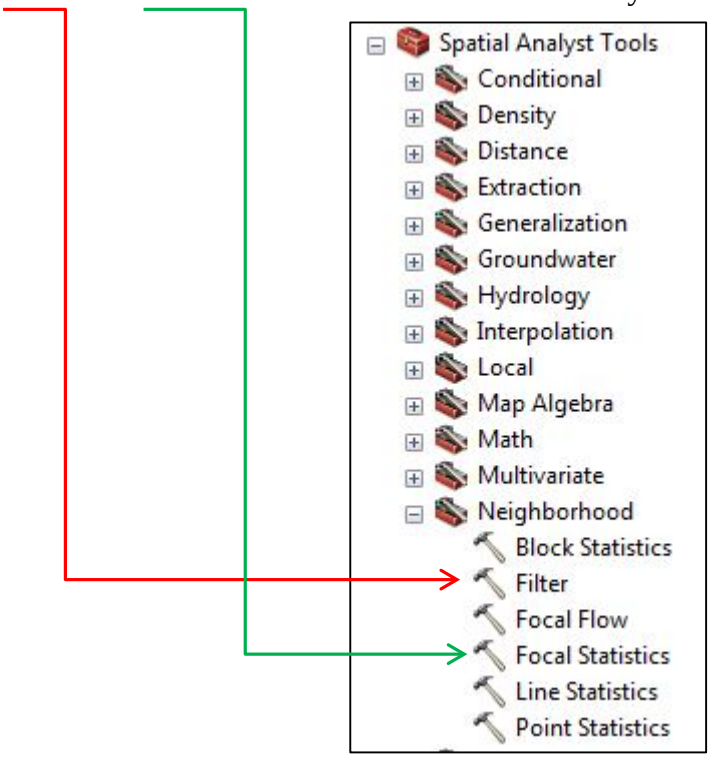




Convolution Filtering in ArcGIS

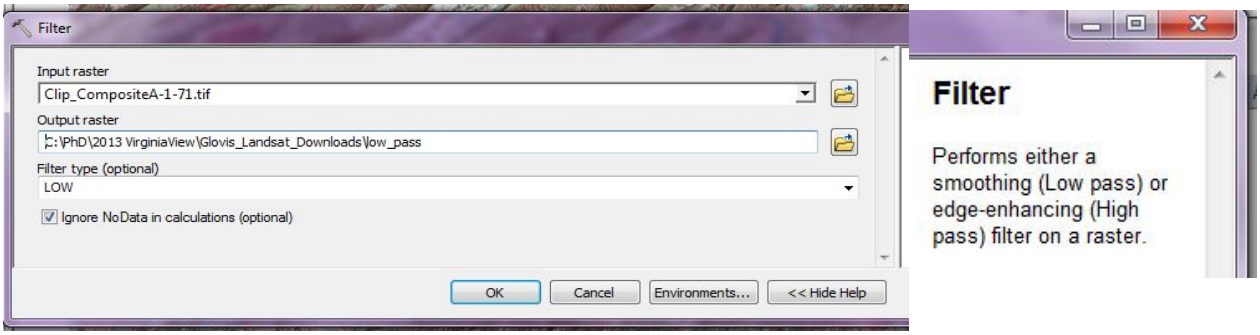
Convolution filtering is the process of averaging small sets of neighboring pixels across an image, and it is used to change the spatial frequency characteristics of an image. A *convolution kernel* is a matrix of numbers that assigns a weight to each cell (Choosing the kernel defines the neighborhood size.). As the kernel moves across the image, the values in each neighborhood are multiplied by the weights, and averaged. The resulting value is then assigned to the center pixel and the kernel moves on to the next neighborhood.

When using the Spatial Analyst Tools in ArcGIS, a new permanent file will result. Your original unaltered file will still be available and the new file added to ArcMap. We will be using two different tools – ***Filter*** and ***Focal*** Statistics. These are located in your Toolbox:



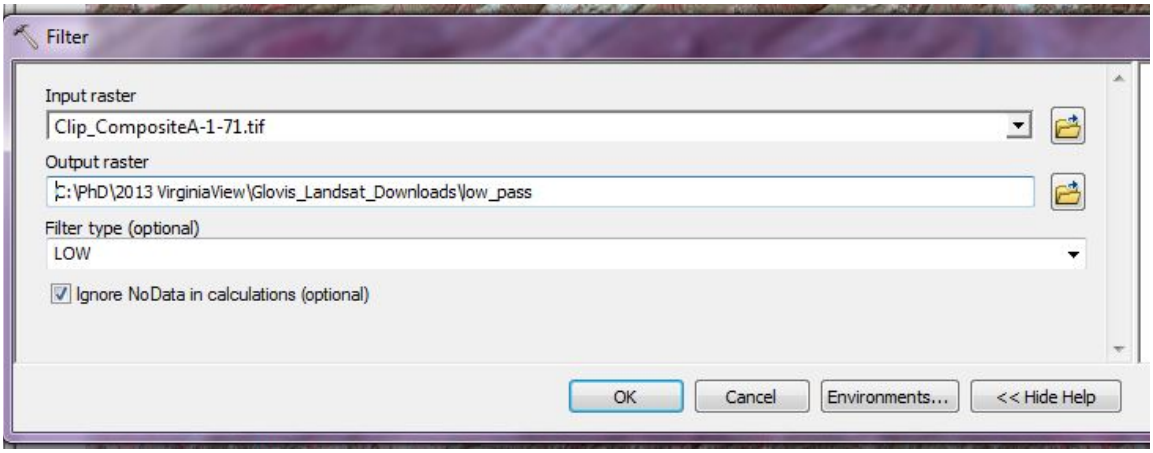
Using the ***Filter*** Tool

Double left-click on ***Filter*** and you open the following window:

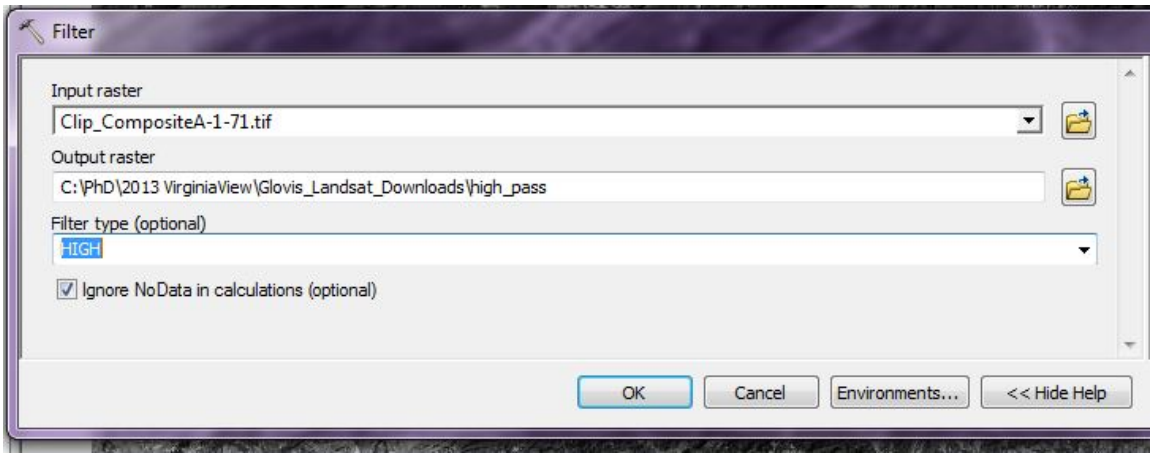


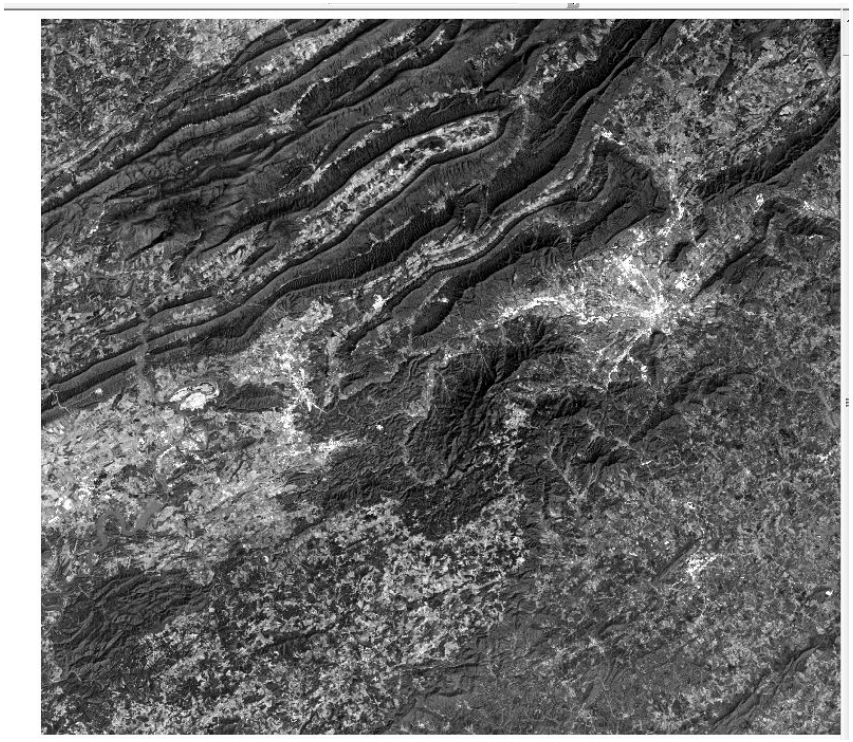
As you can see from the ***Filter Help*** information window on the right, ***Low pass*** smoothes and ***High pass*** enhances edges. *(Note – if your help window is not display, just click on the **Help** button at the bottom.)* Perform both methods and then let's compare them.

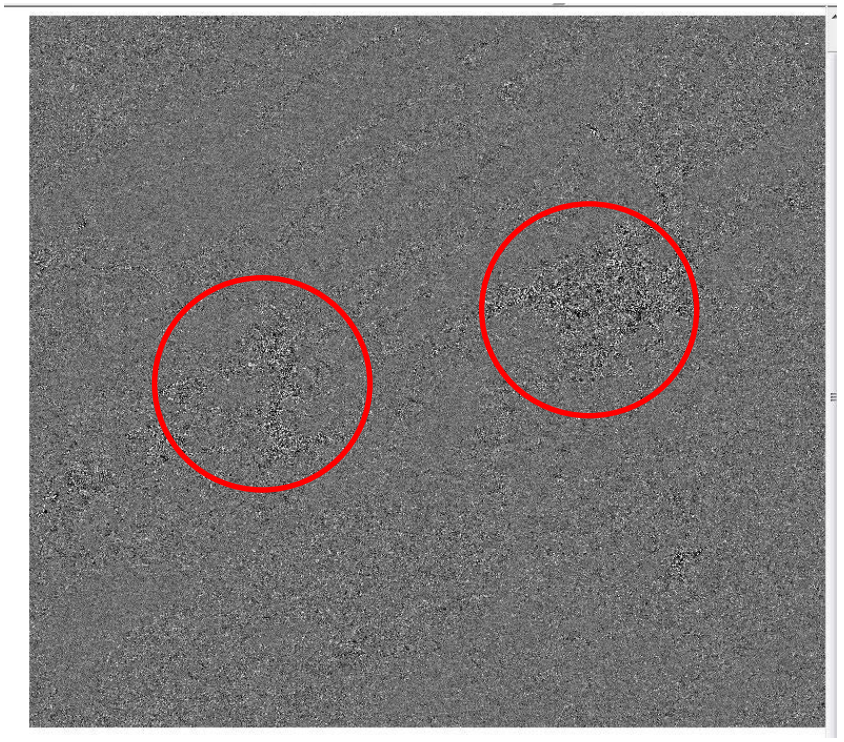
Your input raster is the clipped composite image, just clip on the down arrow at the end of the row and your image will be in a list, click on it and it populated the field. Name your output raster, but also make sure that your workspace is listed. If it is not, click on the file folder and navigate to the folder. (*Note – when saving raster images, you cannot put any spaces between words, use the underscore key in place of a space.*)



When doing the high pass, the only change is the name of your new file and the Filter type:



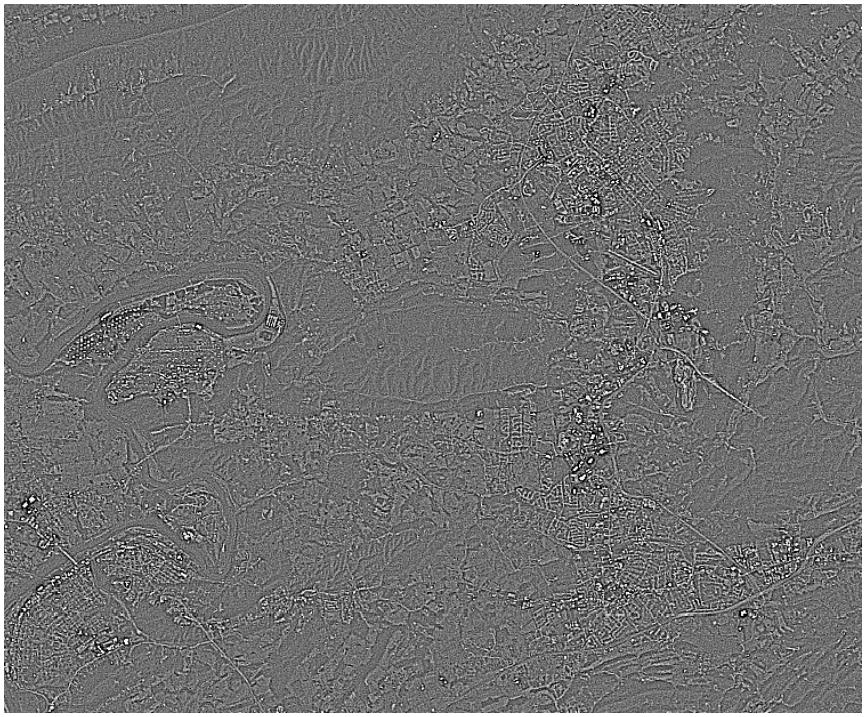




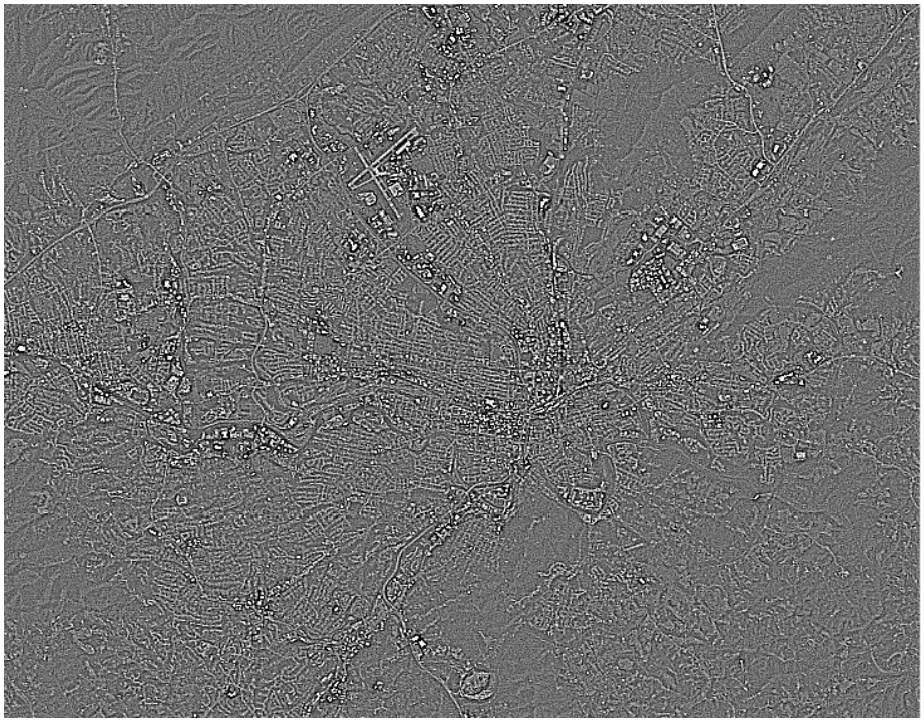
Results: Low Pass High Pass

The results of the low pass, smoothing of the image. Within the low pass image, what can you clearly see? On the high pass image, the tool seems not to have enhanced the image; you can see something has changed in a couple of areas (red circles). Let's zoom in to these areas.

Remember, high pass enhances edges. What edges do you see?



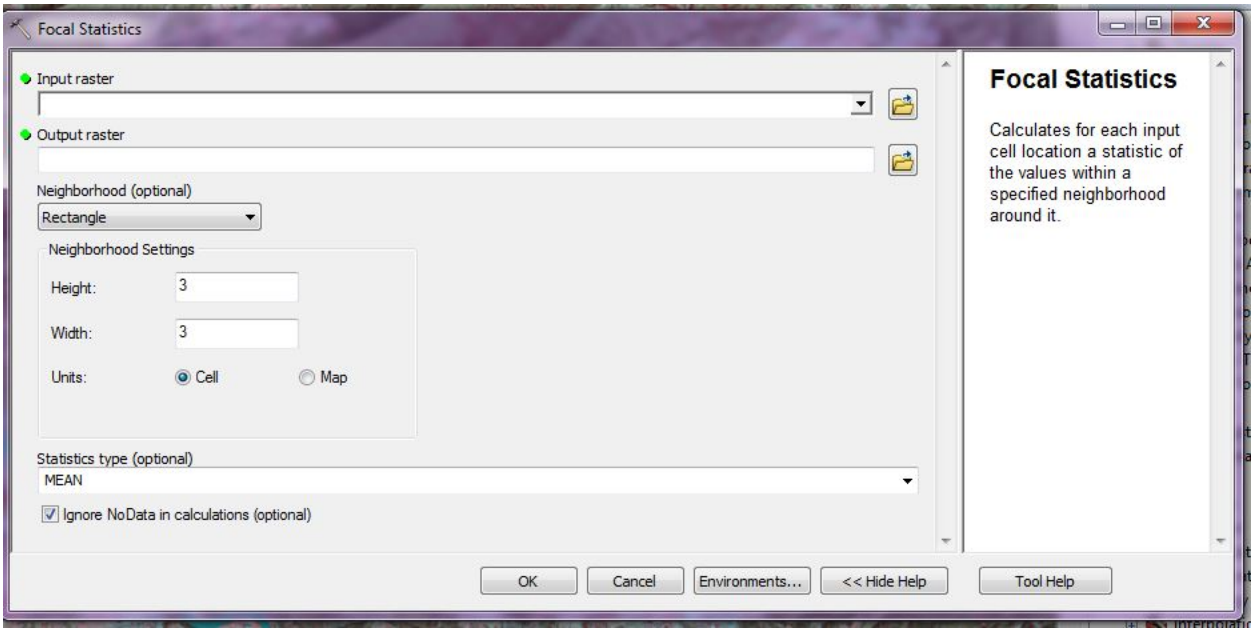
New River Valley (Town of Blacksburg in upper right, New River on the left side)



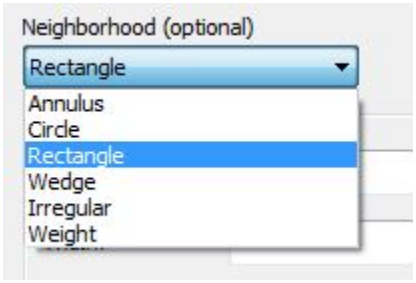
City of Roanoke

Using the ***Focal Statistics*** Tool

Using the ***Focal Statistics*** tool is similar to the ***Filter*** tool – the input raster and you have to name your new file -- except you have more decisions to make for the methodology.

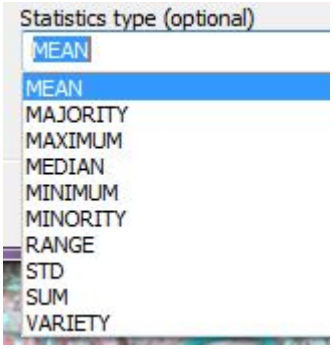


Your first decision is the shape of the neighborhood to use. You can leave the default – ***Rectangle*** – but don't have to. Once of the choices is ***Weight***, which gives you the *convolution kernel* option (page 6 above). You do need to have a .txt file with the weights assigned to use this function.

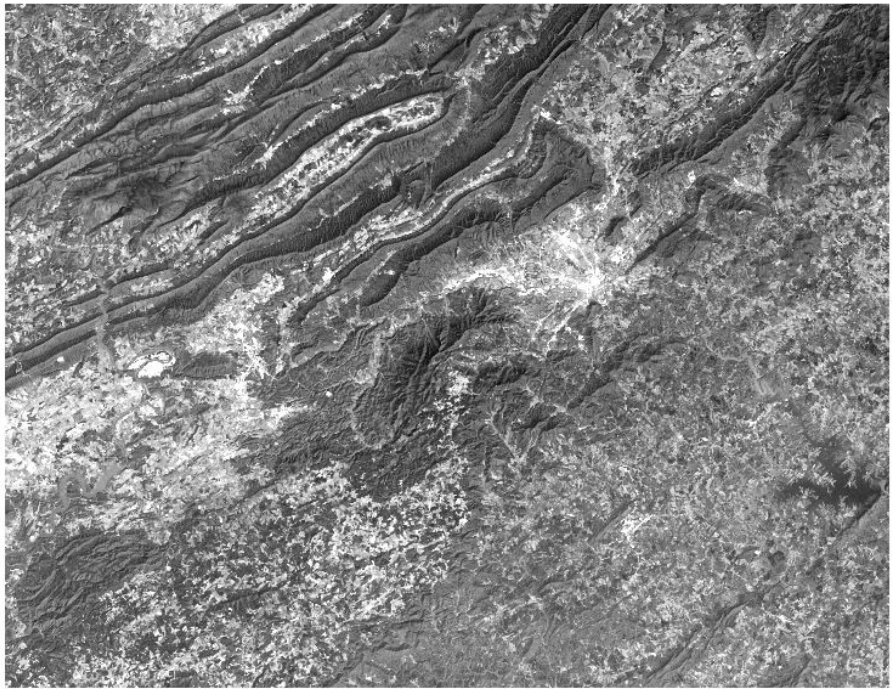


Your next decision is how big to make the neighborhood – this means the number of pixels. The default is 3 by 3.

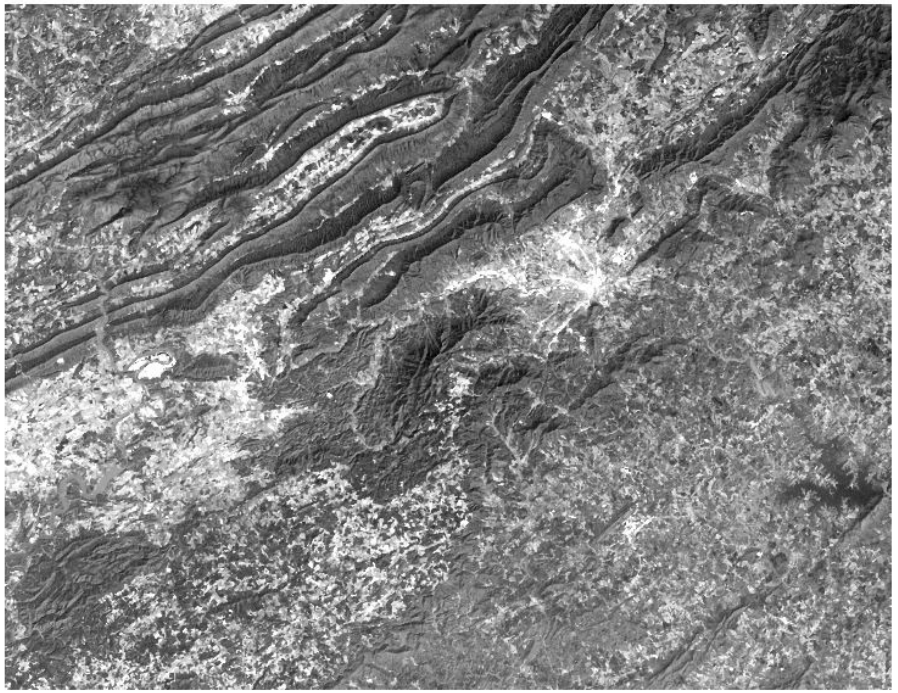
The final decision is what statistic to use. When clicking on the ***Statistic type*** line, the Help window will explain what each statistic in the list means.



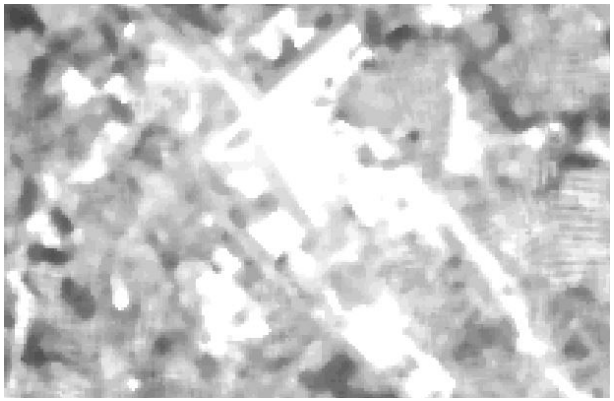
Okay, let's do a couple.

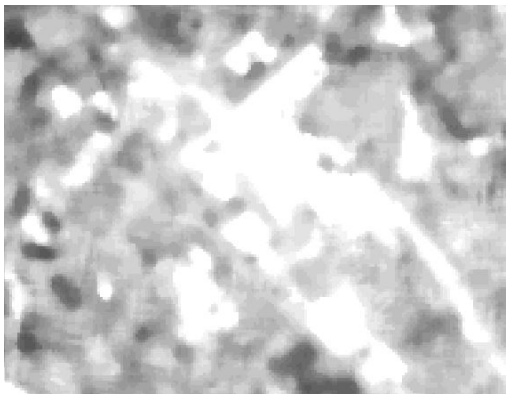


Settings – ***Rectangle***, ***5***x***5***, ***Median***

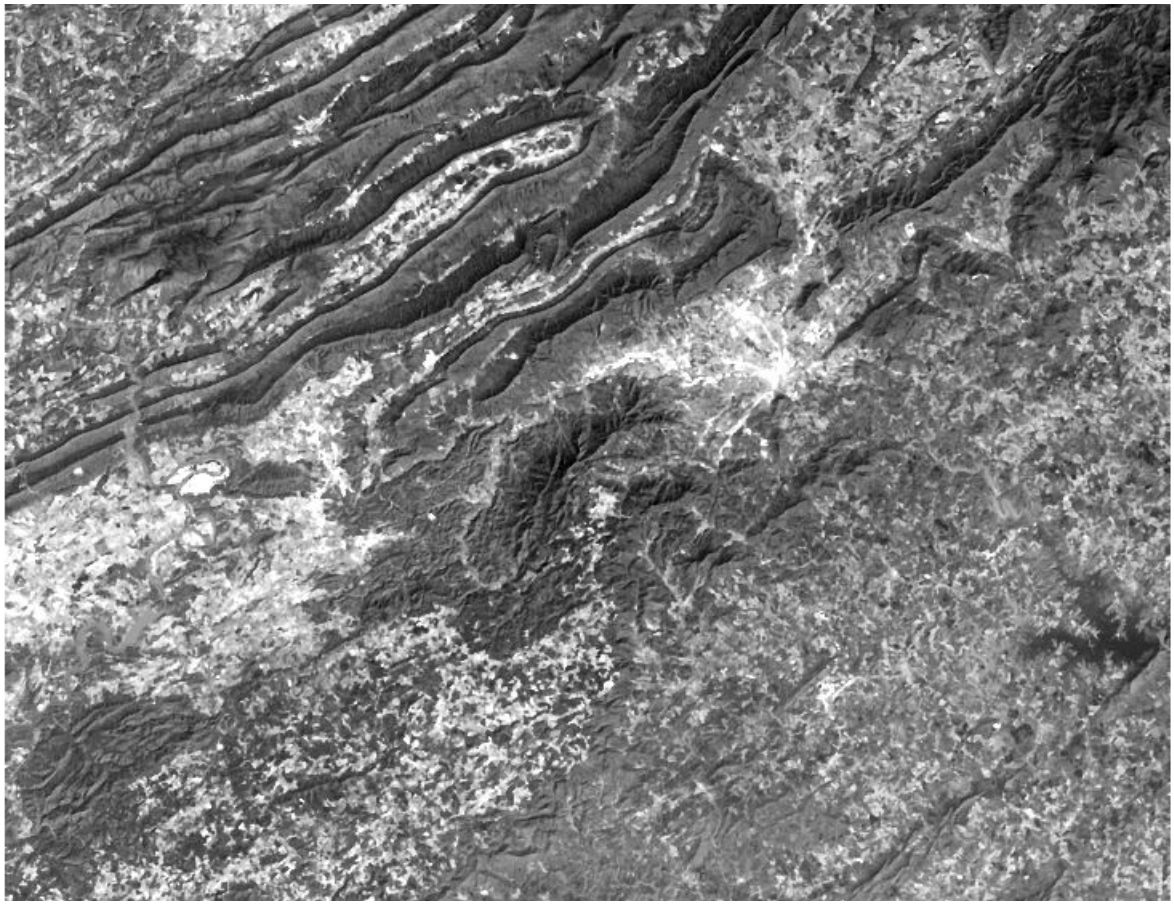


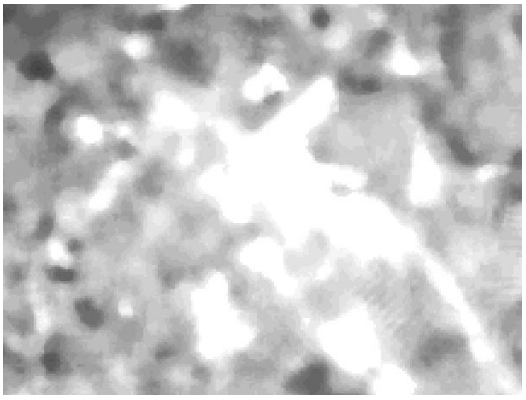
Rectangle, 7x7, Median





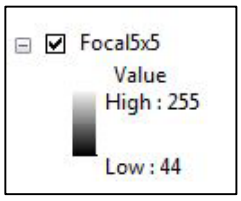
Settings: ***Circle, 5, Median***

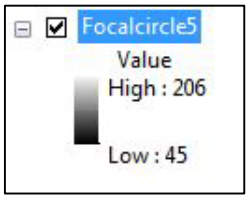


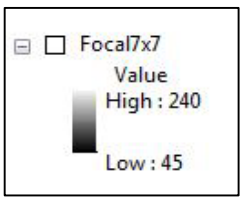


Do you see any differences? Why is the image sharper for the 5x5 rectangular neighborhood than the others? If you used a 3x3 neighborhood, would the image be sharper than the 5x5? Why? Why would the rectangular produce sharper images than using a circle neighborhood?

Also, look at your ***Table of Contents***:







The range of DNs is different for each result. Why?

Zoom in on the Blacksburg area and see what differences are between the three methods. Which is clearer? Why? Go ahead and continue to try different methods.

Ultimately the choice of methods to use is your decision and dependent upon which method or methods are best for your project.

Let's now proceed to the final enhancement tutorial - Spectral Enhancement of Landsat Imagery.

The instructional materials contained within these documents are copyrighted property of VirginiaView, its partners and other participating AmericaView consortium members. These materials may be reproduced and used by educators for instructional purposes. No permission is granted to use the materials for paid consulting or instruction where a fee is collected. Reproduction or translation of any part of this document beyond that permitted in Section 107 or 108 of the 1976 United States Copyright Act without the permission of the copyright owner(s) is unlawful.

Introduction

Spectral signatures refer to the range of reflected radiation wavelengths for different objects collected by the various Landsat bands. For example - spectral signatures can be used to distinguish between man-made objects and different types of vegetation. (For more information on different objects' spectral signatures – see Campbell and Wynne, 2011 or Keranen and Kolvoord, 2013).

Spectral enhancement is the process of creating new spectral data from available bands. New data are created on a pixel-by-pixel basis by applying an operation (e.g., subtraction, division) to corresponding pixels in existing bands. Spectral enhancement only applies to multi-band images. This technique is typically used to:

- Extract new bands of data that are more interpretable to the eye (in some cases to classifiers as well)
- Reduce redundancy in a multi-spectral dataset by compressing bands of data that are similar (principal component analysis)
- Display a wider variety of information in the three available colors of the visible spectrum (R,G,B)

The most widely used techniques of spectral enhancement are:

- ***Spectral Ratios and Indices*** - Performs band ratios that are commonly used in vegetation and mineral studies;
- ***Principal Components Analysis (PCA)*** - Compresses redundant data values into fewer bands which are often more interpretable than the source data (we will not perform a PCA in this tutorial);
- ***Tasseled Cap*** – Transforms and rotates the data structure axes to optimize data viewing for vegetation studies.

We will explore band ratios, vegetation indices, and tasseled cap. Remember the differences between the three types of enhancement techniques:

- **Radiometric Enhancement** - Enhancing images based on the values of individual pixels

- **Spatial Enhancement** - Enhancing images based on the values of individual and neighboring pixels.
- **Spectral Enhancement** - Enhancing images by transforming the values of each pixel on a multi-band basis (for multi-band images).

Band Ratios

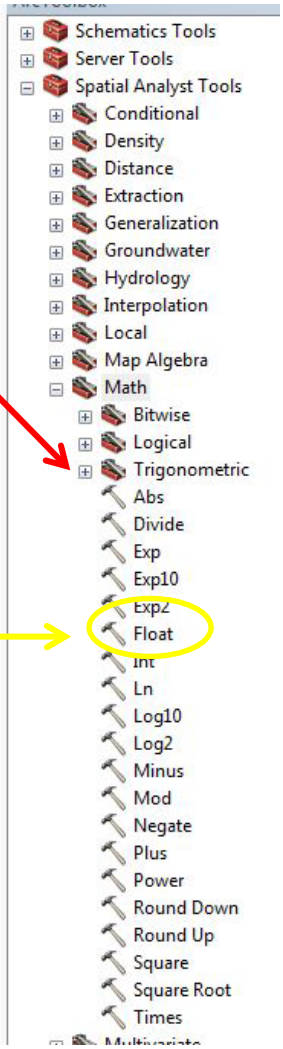
Avery, Thomas Eugene and Graydon Lennis Berlin, *Fundamentals of Remote Sensing and Aerial Interpretation.* 5th ed. New Jersey: Prentice-Hall Inc, 1992.

- **4 / 3 Ratio - (NIR/Red)** - enhances the presence of vegetation. The brighter the tones the denser the vegetation.
- **5 / 2 Ratio - (MIR/Green)** – To detect moisture levels.
- **2 / 5 Ration – (Green/MIR) –** To pull out water bodies.
- **3 / 7 Ratio - (Red/MIR)** – To see differences in water turbidity.
- **3 / 1 Ratio – (Red/Blue)** – To detect ferric iron rocks.
- **5 / 7 Ratio – (MIR / MIR)** – To detect clay rich rocks.

Aside from the 5 ratios listed here there are 25 other possible ratios to perform with Landsat TM imagery. The important thing to remember with ratios is the scanner system that produced the imagery. Landsat TM ratios will use different band numbers from those of Landsat MSS, SPOT, or IRS (India Remote Sensing).

Creating Band Ratios

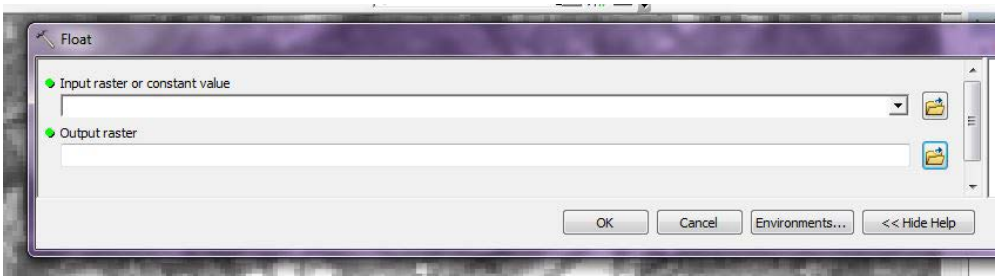
Open a new map document and add the seven separate images that you received when you unzipped the downloaded Landsat scene. To create a band ratio, you will be using the ***Spatial Analyst Toolset***, so be sure that the extension and toolbars are turned on, your ***Toolbox*** is open, and your workspaces are set. It does not matter what order the bands are listed in your ***Table of Contents***. For simple indices, you will be using ***Spatial Analyst/Math/Trigonometric*** tools. Within these tools is divide, plus, square, square root, etc.



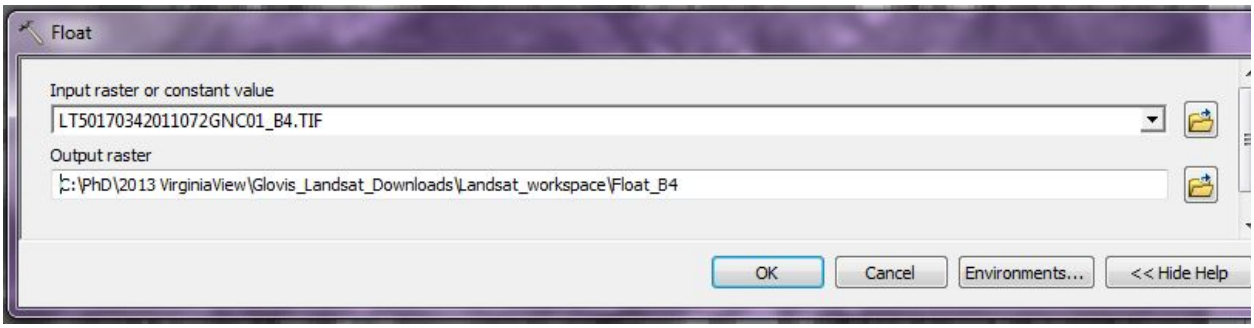
PLEASE NOTE – ArcGIS treats the pixel values for Landsat Imagery as integers. As such, when performing math operations, the results are integers, usually rounded down. We do not want our results to be integers but real numbers (numbers with decimal points). This means we need to change our images to floating point images. You do not need to accomplish this on all bands for this tutorial, only the bands you are going to use to create ratios.

Left-click on ***Float (yellow circle)***

You get the following window:

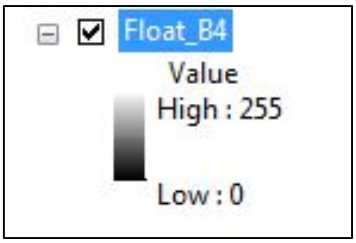


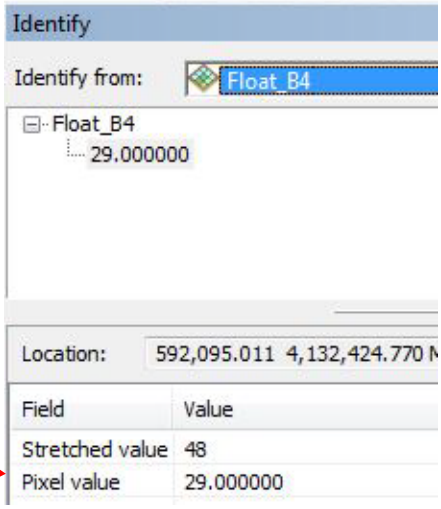
Left-click on the down arrow at the end of the ***Input Raster*** line, choose the band that you wish to convert. In this case, we chose band 4 (B4). For the ***Output raster***, it should fill with your workspace and after your workspace, name your file. In this case, we have named it Float_B4. The name cannot begin with a number and it cannot have any spaces or special characters. Left-click ***OK***.



Once you click OK, wait for ArcGIS to process it and it will automatically add your new file to your ***Table of Contents*** and map document window.

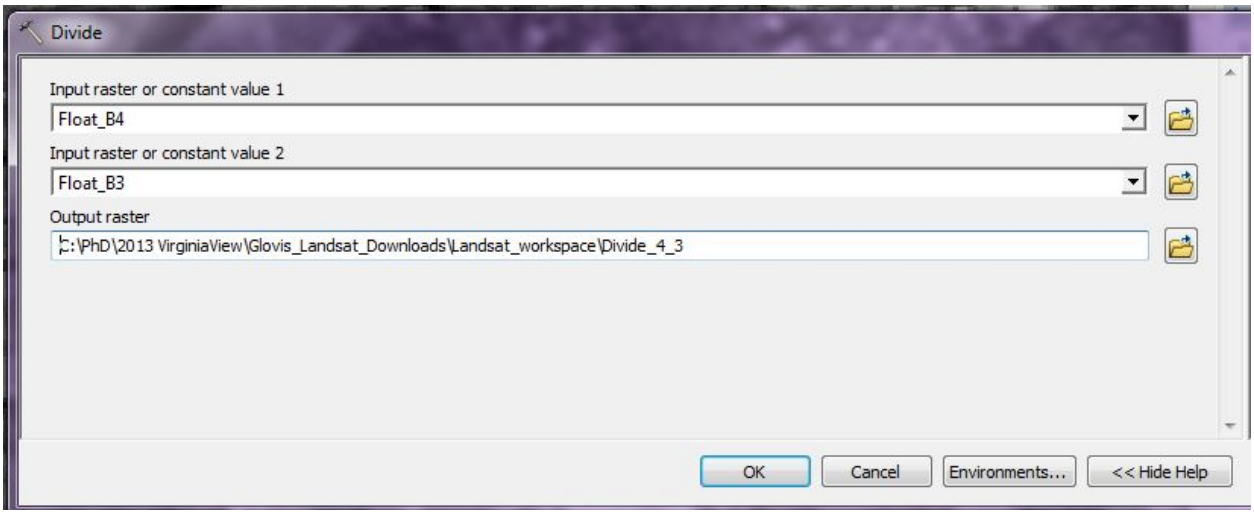
In the ***Table of Contents,*** this new file still looks like an integer, but if you use the ***Identify*** button and click anywhere on the image, you see that decimal points have now been added to the pixel value.



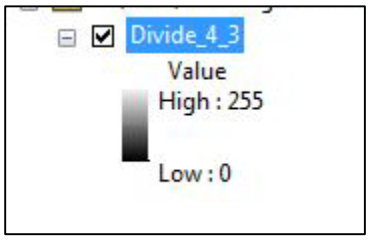


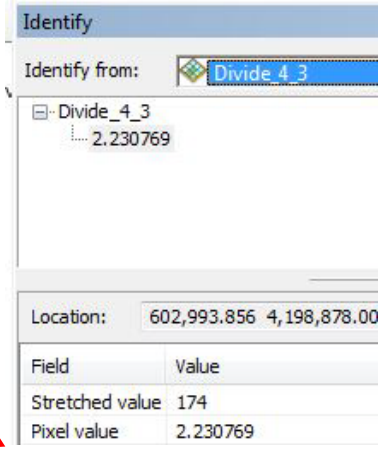
Now, let's do your first ratio – **4 / 3**. Make sure you have make floating point images for both bands before you proceed to the next step.

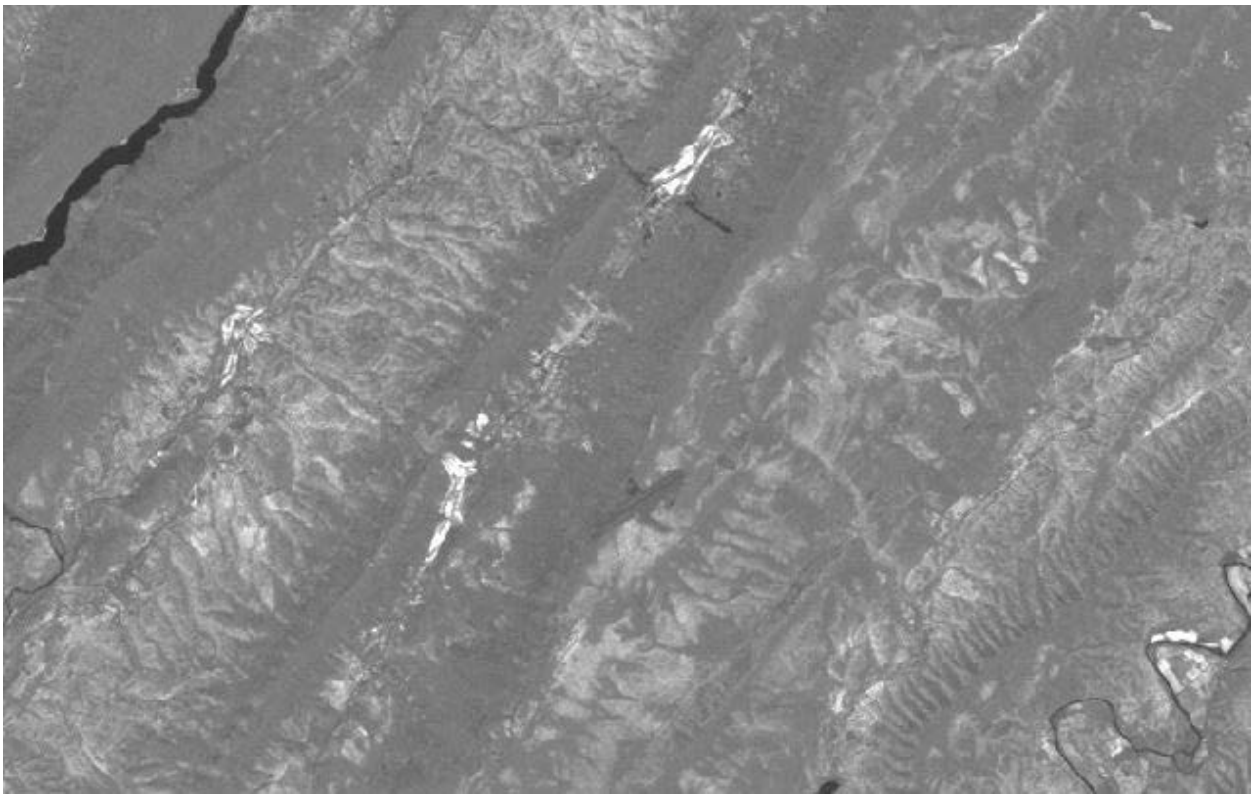
Once you have your two new images, you want to use ***Spatial Analyst/Math/Trigonometric/Divide.*** Double-left-click on that tool and the following dialog box opens. Enter the images as shown. Remember to name your new file appropriately.



Click ***OK***. ArcMap will automatically add the new image to your ***Table of Contents*** and map document window when the processing is complete. Again, it looks like we have integers but if you use ***Identify*** and click on any pixel, you will find a decimal number.



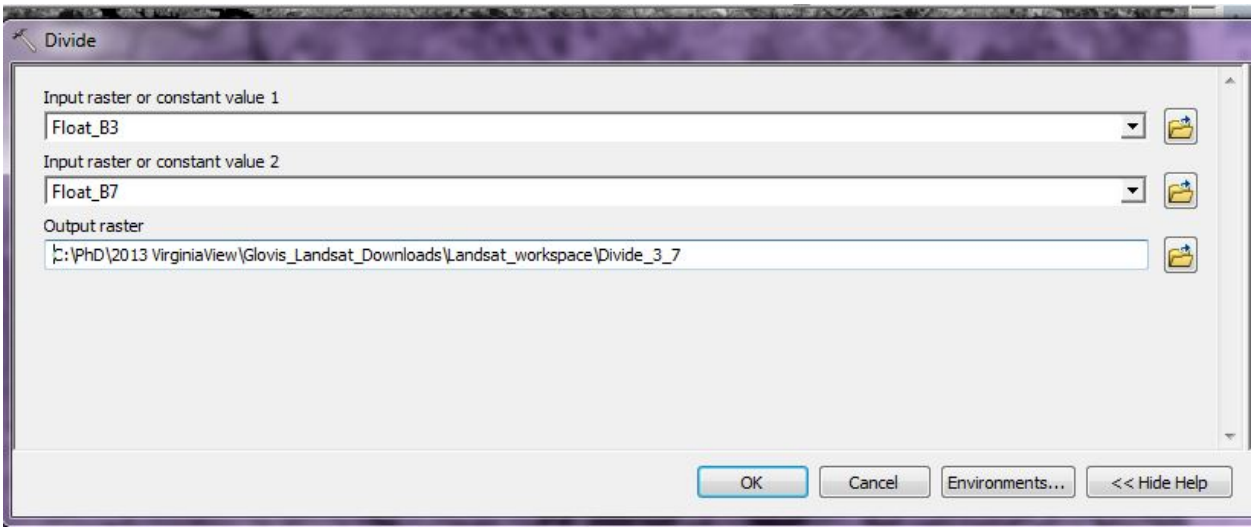




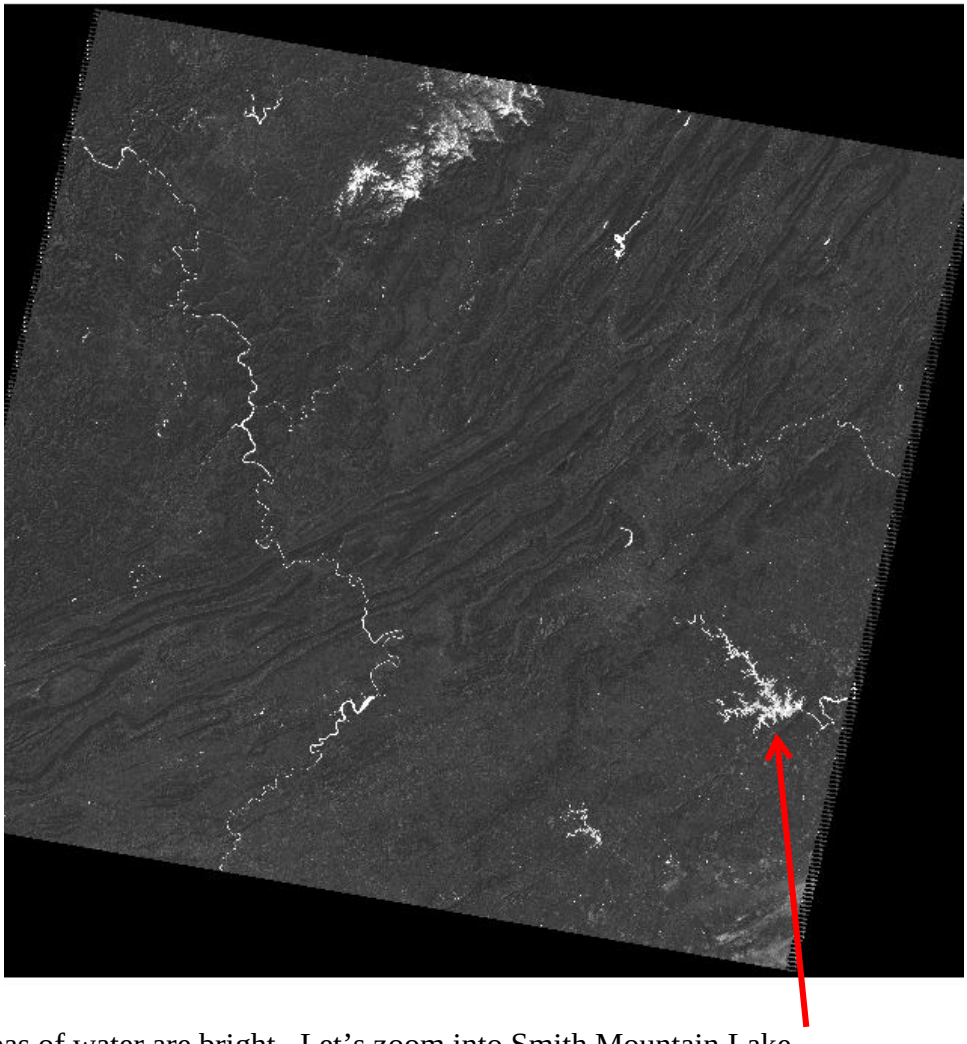
Let's look at the image. Remember from above, **4 / 3 Ratio - (NIR/Red)** - *enhances the presence of vegetation; the brighter the tones, the denser the vegetation.* Do you remember from prior Tutorials, what was present in the mountain areas? Our scene is from March, so leaf-off, except for conifers.

Let's do one more together - **3 / 7 Ratio - (Red/MIR)** – *To see differences in water turbidity*. (Don't forget, we need a floating point image for each band).

Using ***Spatial Analyst/Math/Trigonometric/Divide,*** your dialog box should looks as follows:



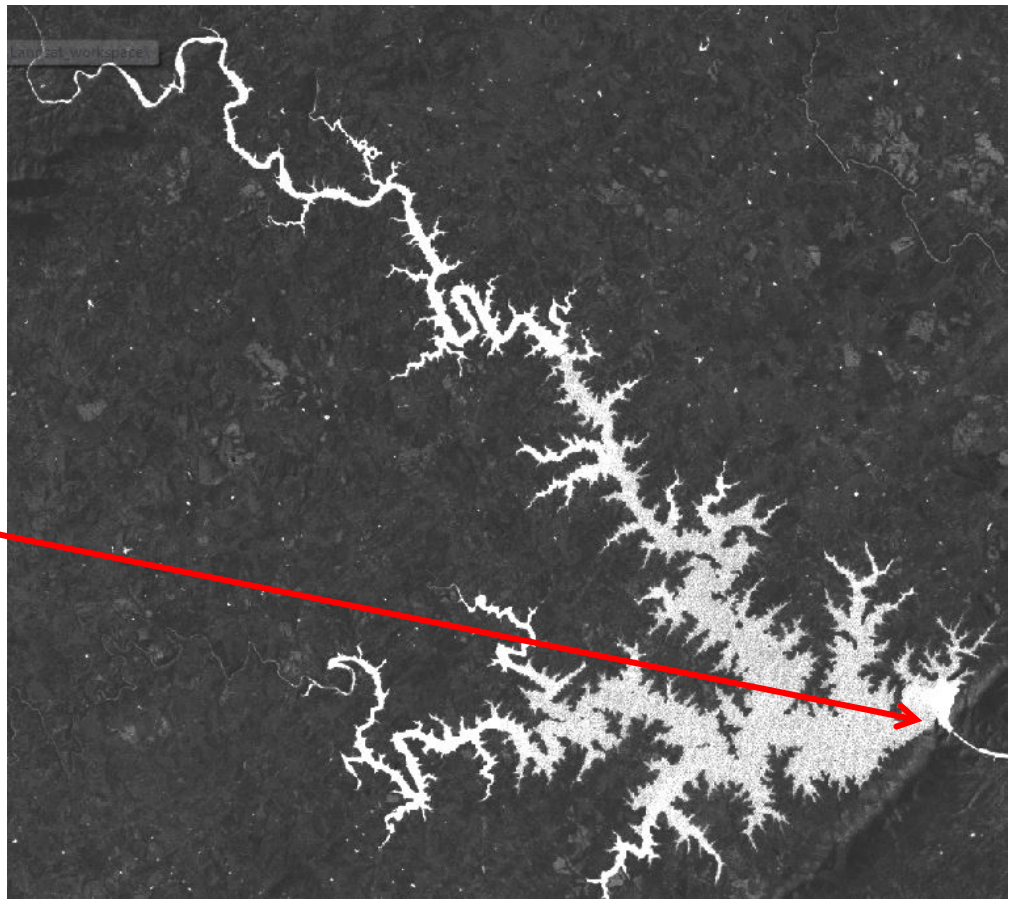
Click ***OK***.



Areas of water are bright. Let's zoom into Smith Mountain Lake.

What do you see? Why would areas leading into the lake be brighter? What about at the dam area?

Which areas are more turbid?



You can do any of the simple ratios using this tool set. (Simple ratios are those that require one function only.) You can do more complex ones using these tools, but you do it step by step and create images one at a time and then use that image in the next step. ***Raster calculator*** allows you to do a complex calculation in one step. We will see one of these indices in the next section.

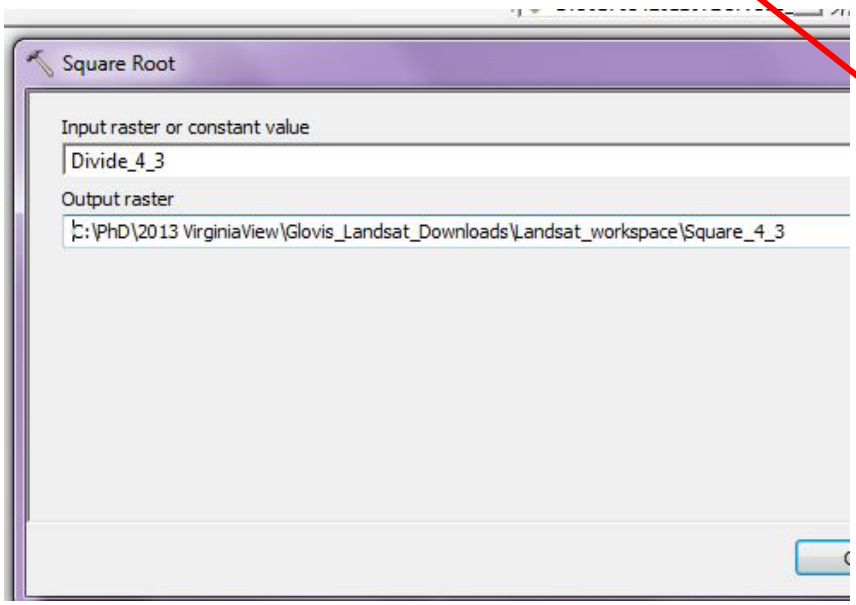
Vegetation Indices

Another spectral enhancement is a vegetation index. Although within ArcGIS, you can create many different many indices, we will only look at three of them: IR/R, square root (IR/R), & NDVI.

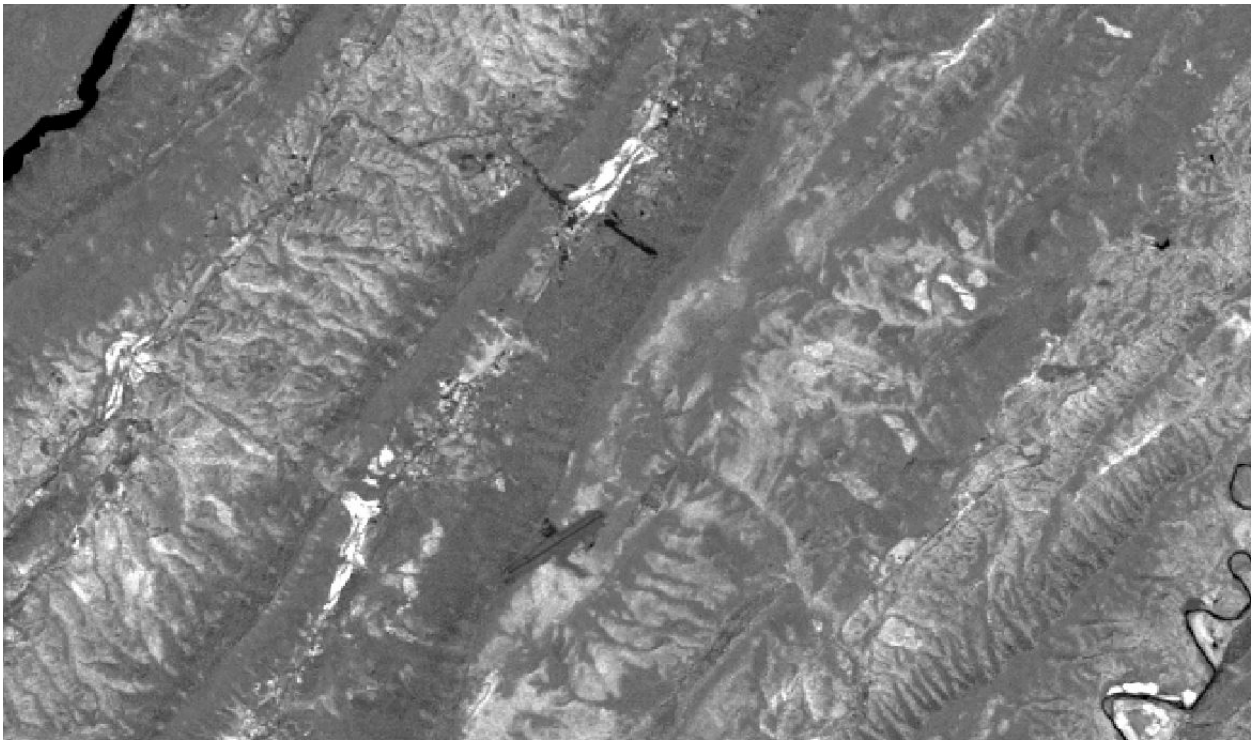
We have actually already calculated when we did the 4 / 3 ratio above. Which band is IR? Which band is R? (4 is IR and 3 is R). So when we calculated the ratio **4 / 3** above, we calculated this ratio. Remember - **4 / 3 Ratio - (NIR/Red)** defines the presence of vegetation; the brighter the tones, the denser the vegetation.

Let's look at the square root of IR/R next. We can do this two different ways, because we have already calculated the IR/R. The first way would be to take the square root of this result.

Double-left-click on this tool, your dialog box should look as follows and click ***OK***.

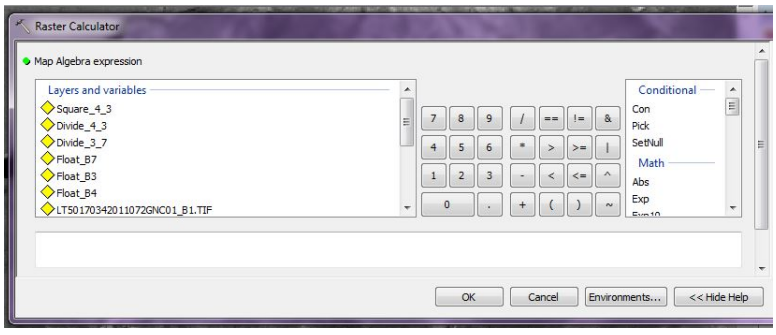


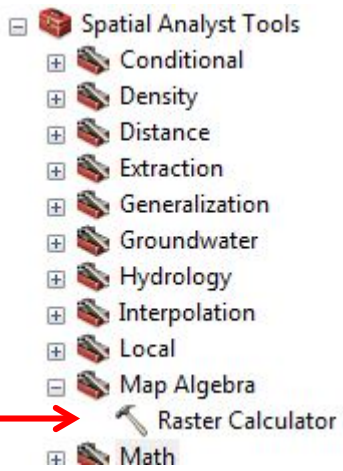
Zooming in on the same mountain area that we zoomed in above:



Adding the square root function makes the image a little brighter and has sharper distinction between features.

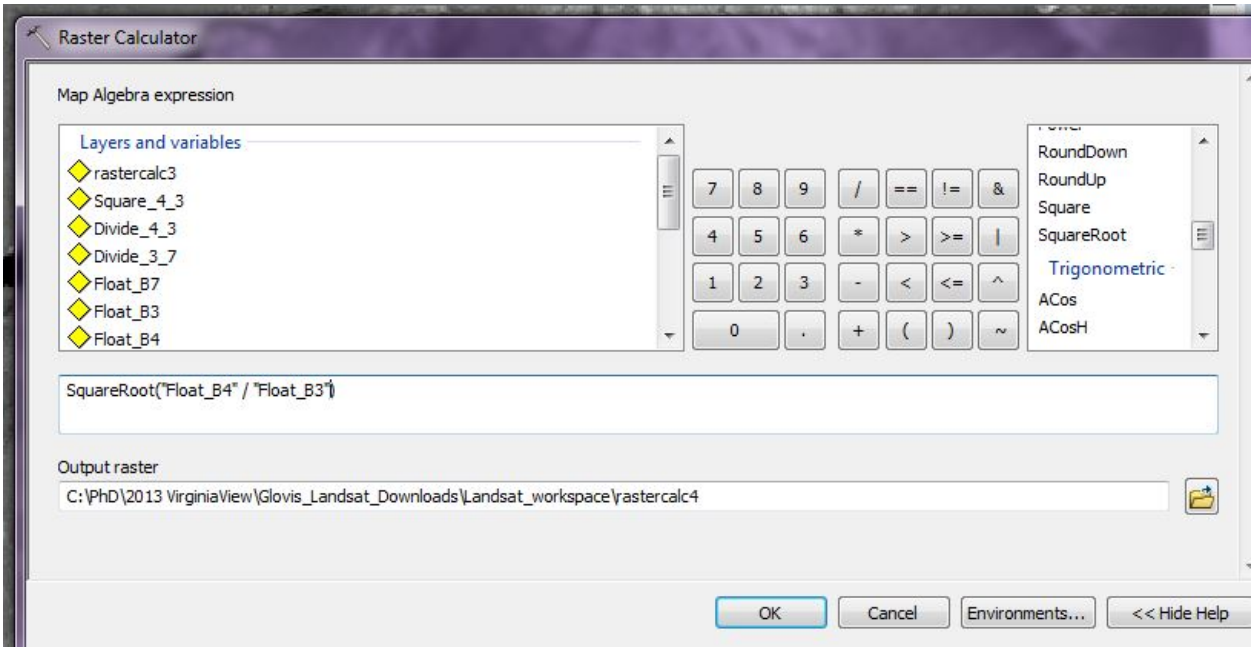
The second way to do this ratio is to use ***Raster Calculator***. This would be the step you would use if you had not already calculated the IR/R index.





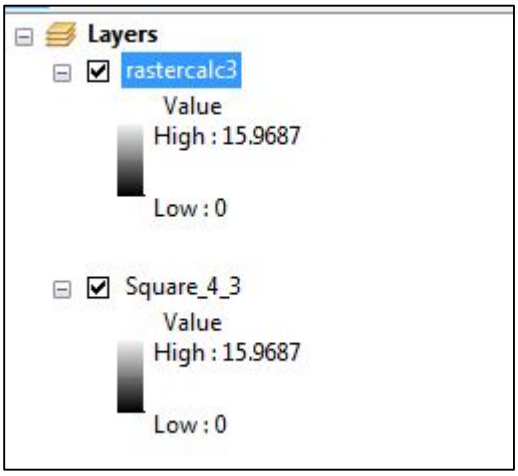
Use of this tool requires special attention to how you build your equation.

Your dialog box should appear as follows. Watch carefully where the parentheses are placed! With proper placement of parentheses, you can create much more complex equations.

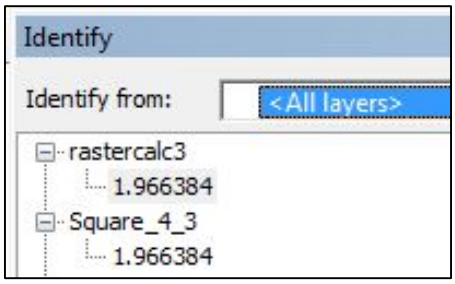


There is absolutely no difference between the two methods, except for the number of steps.

Layers in the **Table of Contents**



Value of a select pixel



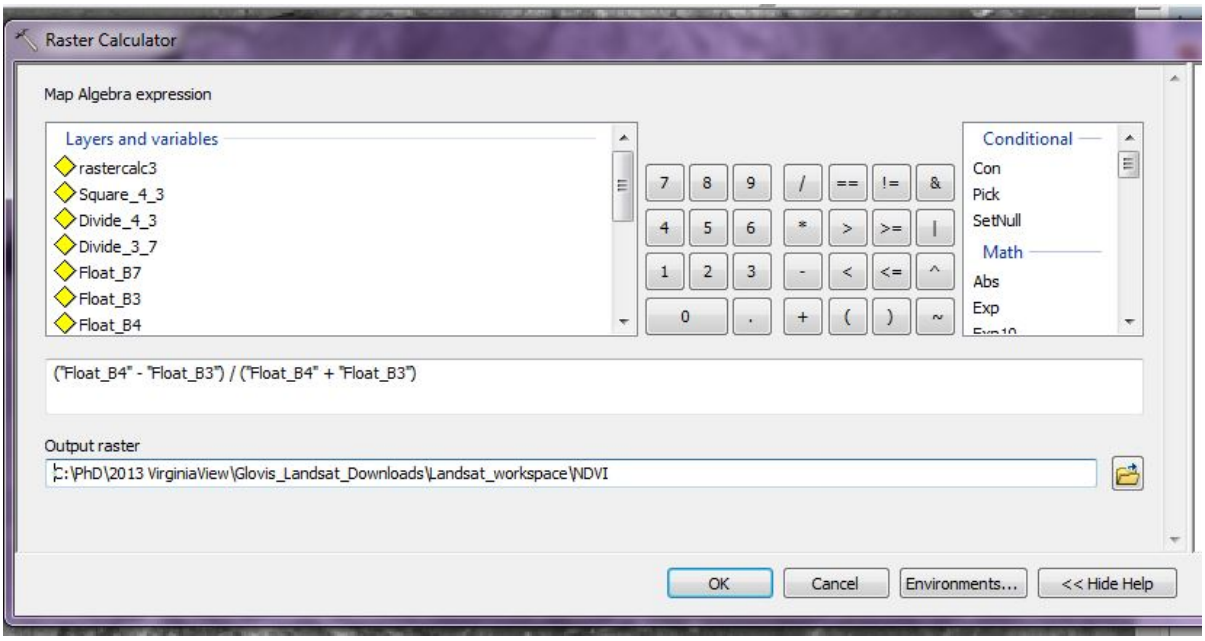
I did make an error when I used ***Raster Calculator***. Can you see what I did? I failed to rename my file before I clicked okay, so ***Raster Calculator*** created its own name for the new file. You must be careful to appropriately name your image, so you can identify it later.

Now let's do a more complex calculation – NDVI. The Normalized Difference Vegetation Index (NDVI) is a very important vegetative index. Healthy green leaves have a higher reflectivity in the near infrared band-- stressed, dry, or diseased vegetation much less reflectivity. So, NDVI can be useful an indicator of vegetation stress. What is the formula?

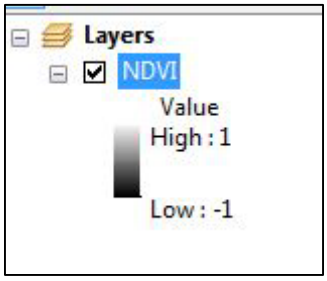
NIR-R/NIR+R or Landsat B4 - Landsat B3 / Landsat B4 + Landsat B3

Remember what we said about making sure we used parentheses?

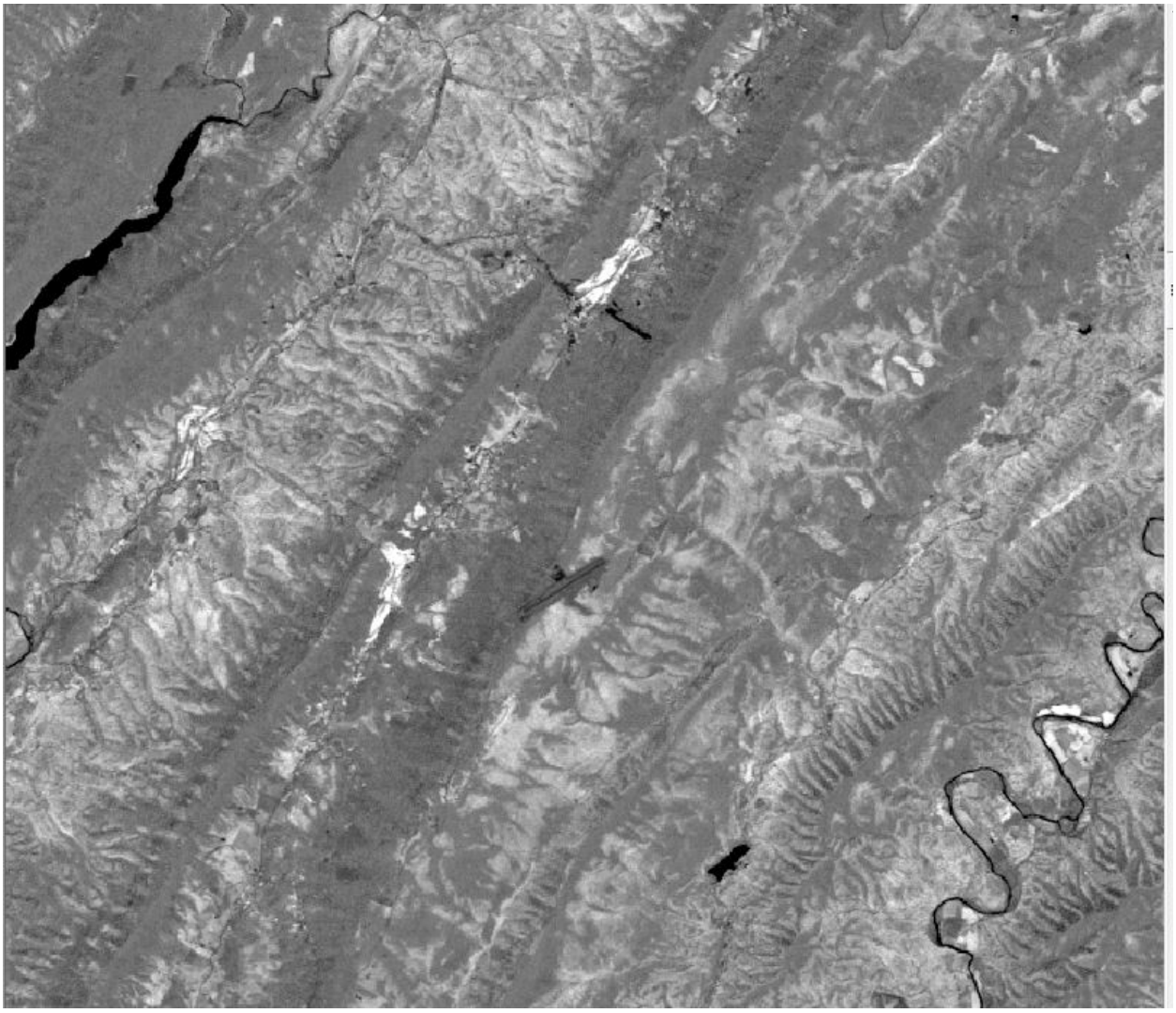
Open ***Raster Calculator***. You must put parenthesis around operations that must occur before other operations, otherwise ArcMap will perform the operation step by step from left to right. Don't forget to rename your file!! Click ***OK.***



The NDVI result gives you pixel values from -1 to +1. The closer to +1, the brighter the pixel and a brighter pixel means healthier vegetation. You can do NDVI step by step using the

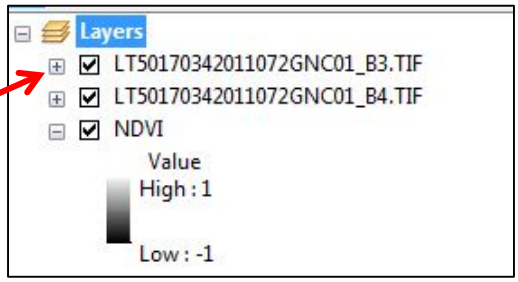


tools under ***Trigonometric***, but that would require 3 separate steps (not including creating the floating value images).



BUT-- guess what? There is an easier and much simpler way to do NDVI in ArcMap! ArcMap has a button in the ***Image Analysis*** window that you can use. You don't even need to create floating point images.

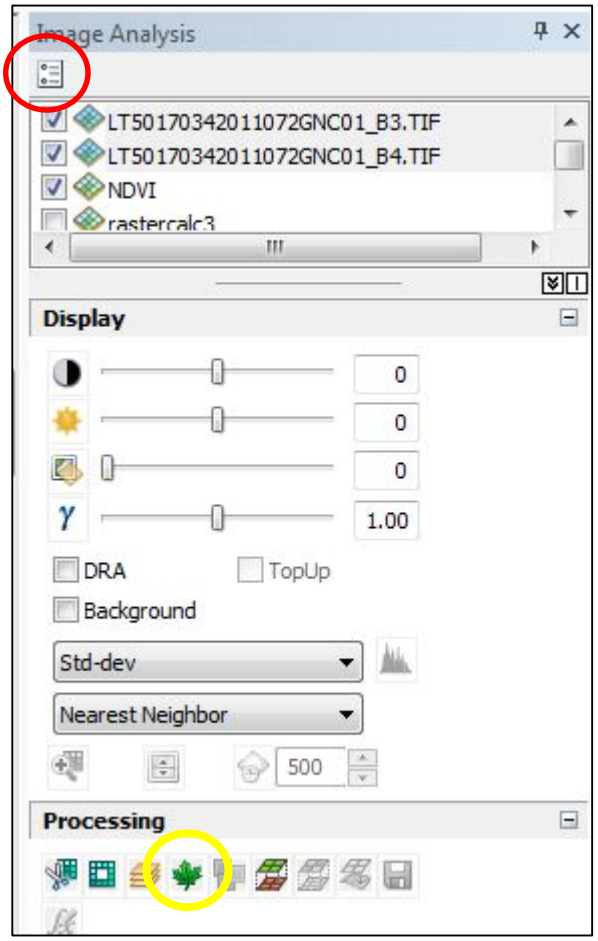
Move the Landsat Band 3 image on top in the ***Table of Contents*** and the Band 4 image in the second

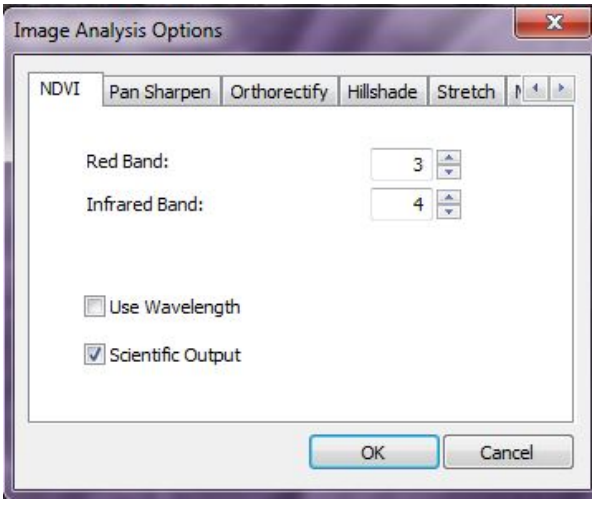


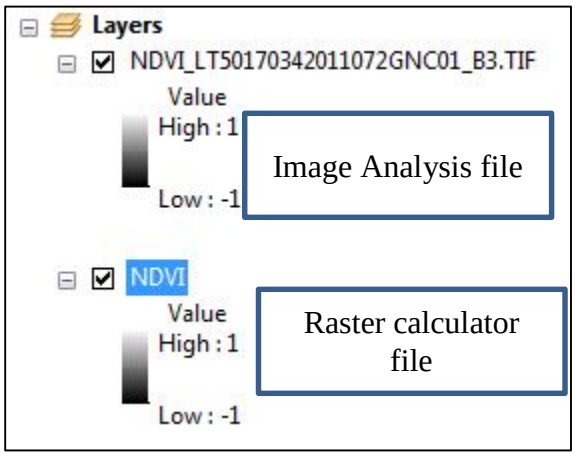
to top spot. Open your Image Analysis window. The images must be in the correct order to get the correct results!

This also puts the images on top in the ***Image Analysis*** window. Highlight the two images. Band 3 must be the first one! Now, look under ***Processing***, a button with a Leaf is now enabled! This is the ***NDVI*** button (yellow circle). Before you click, we need to check one thing. Go to ***Options*** (red circle). Look an NDVI Tab! Make sure that ***Use Wavelength*** is unchecked and ***Scientific Output*** is checked. Then click OK.

Then left-click on the Leaf button.

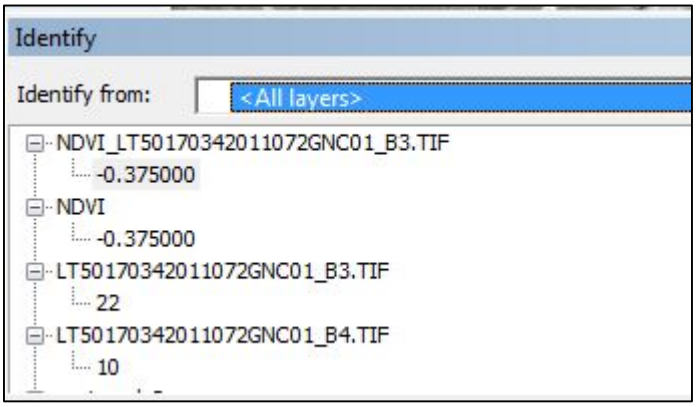






We got the exact same results from this method as with ***Raster Calculator,*** but that result is difficult to see just by looking at the ***Table of Contents***.

Let's look at individual pixels values using ***Identify***.

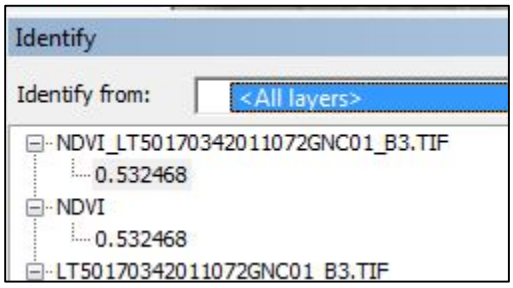


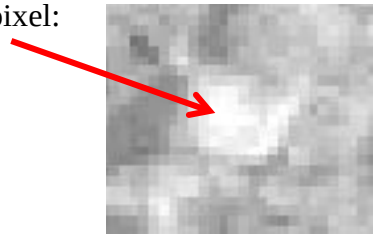
First, we look at a water pixel:

We have a negative value: - 0.375 for both. Why a negative for water?

Remember, this is a vegetation index and a low value for water is normal. What could be an exception? (*Answer – an extreme algae bloom or a prolific invasive water plant*)**)**

Let's look at an extremely bright pixel:





We have a positive value: 0.532468 for both.

You have now learned two ways to calculate NDVI. Both methods give you the same numeric and image results. But there is one major difference between the two resultant images.

Do you remember what they are? Hint – one was created from ***Raster Calculator*** and one from using the ***Image Analysis Processing*** button. So, which image is permanent and which is only temporary?

Tasseled Cap Transformation

The Tasseled Cap Transformation is a spectral enhancement aimed primarily at analyzing agricultural vegetation. The principle behind the Tasseled Cap calculation is the notion that the bands in a multispectral image are interrelated and can be viewed as planes in multidimensional space with pixel values placed in the respective planes. The clustering of values resulting from such scattering creates data structures shaped in a multidimensional hyperellipsoid, which is defined by the principal axes. By selecting pairs of principal axes and using them as the viewer's x and y axes, data structures representing different vegetation information content can be seen. Out of the 6 data structures created by the Tasseled Cap analysis, brightness, greenness and wetness are or the importance for this exercise. The output values for the data structures are calculated through a linear equation with the coefficients specific to the sensor that produced the image.

Tasseled Cap index is calculated from data of the six TM bands; however, three of the six bands are often used:

- band 1 (brightness, measure of soil)
- band 2 (greenness, measure of vegetation)
- band 3 (wetness, interrelationship of soil and canopy moisture)

Within ArcGIS 10.X the Tasseled Cap Transformation is accomplished using ***Functions***. Functions are more complex operations within ArcGIS and beyond the scope of this tutorial. You can refer to ArcGIS Help for more information.

Now that you have learned about the different types of enhancement and how to accomplish these in ArcGIS, you are ready to proceed with the tutorials on Change Detection and Image Classification.

17. Change Detection using Landsat Imagery

The instructional materials contained within these documents are copyrighted property of VirginiaView, its partners and other participating AmericaView consortium members. These materials may be reproduced and used by educators for instructional purposes. No permission is granted to use the materials for paid consulting or instruction where a fee is collected. Reproduction or translation of any part of this document beyond that permitted in Section 107 or 108 of the 1976 United States Copyright Act without the permission of the copyright owner(s) is unlawful.

Introduction

Change detection is the use of remotely sensed imagery of a single region, acquired on at least two dates, to identify changes that might have occurred in the interval between the two dates. Those two dates can be years apart, for example to track changes in urbanization, or days apart, for example to track changes from a volcanic eruption.

Change detection has been applied to examine effects such as land use changes caused by urban and suburban growth, effects of natural disasters (such as floods, forest and range fires), and impacts of insect infestations upon forest cover, for example. Change detection requires application of algorithms that are specifically designed to detect meaningful changes in the context of false alarms— ostensible changes that are, in reality, simply artifacts of the imaging process.

A critical prerequisite for application of change detection by remote sensing is the identification of suitable pairs of images representing the same region. The analyst must assure that (1) the two images register (that they match exactly when superimposed), (2) that they were acquired during the same season, especially if use to track changes in vegetation, and (3) that there are no significant atmospheric effects. In brief, the two images must be compatible in every respect-- scale, geometry, resolution – otherwise the change detection algorithm will interpret incidental differences in image characteristics as changes on the landscape.

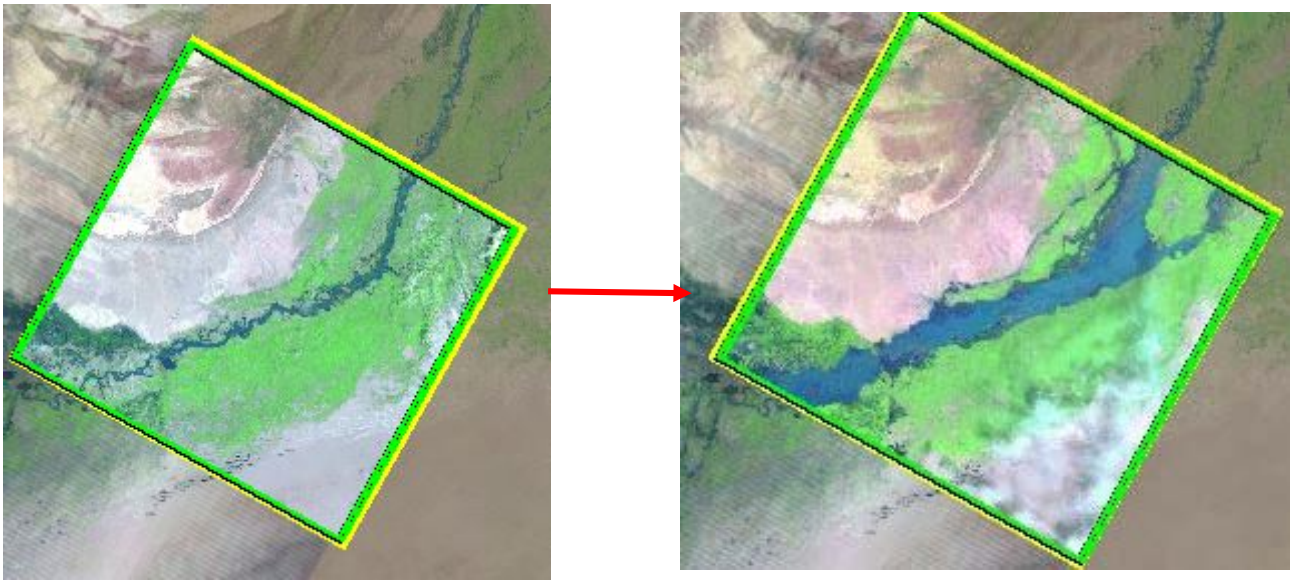
There has been much research devoted to evaluating alternative change detection algorithms. A basic distinction between pre-classification and post-classification comparisons captures a primary division in the natures of the approach. ***Post-classification change detection*** defines changes by comparing pixels in a pair of classified images (in which pixels have already been assigned to classes). Post-classification change detection typically reports changes as a summary of the "from-to" changes of categories between the two dates. ***Pre-classification change detection*** examines differences in two images prior to any classification process. Pre-classification algorithms typically permit the analyst to set thresholds for the magnitude of changes to be detected and highlighted.

This tutorial will introduce a simple procedure using ArcGIS Image Analysis for pre-classification change detection— other approaches are available for the more experienced student, and to examine other kinds of changes.

We will be using two images acquired over Pakistan to evaluate the changes due to river flooding. You will need to download these images prior to starting this tutorial.

Additional information about Pakistan images (path151/row40): The Pakistan floods began in July 2010. Two thousand people have died and over a million homes were destroyed by these severe floods. The study area is near KHAN City. The two Landsat 5 TM images were acquired on July 11 (before flooding) and Aug. 28 (after flooding).

When you are in GloVis, you can actually see the flooding within the Landsat Scene displayed in the GloVis window. Download both scenes.

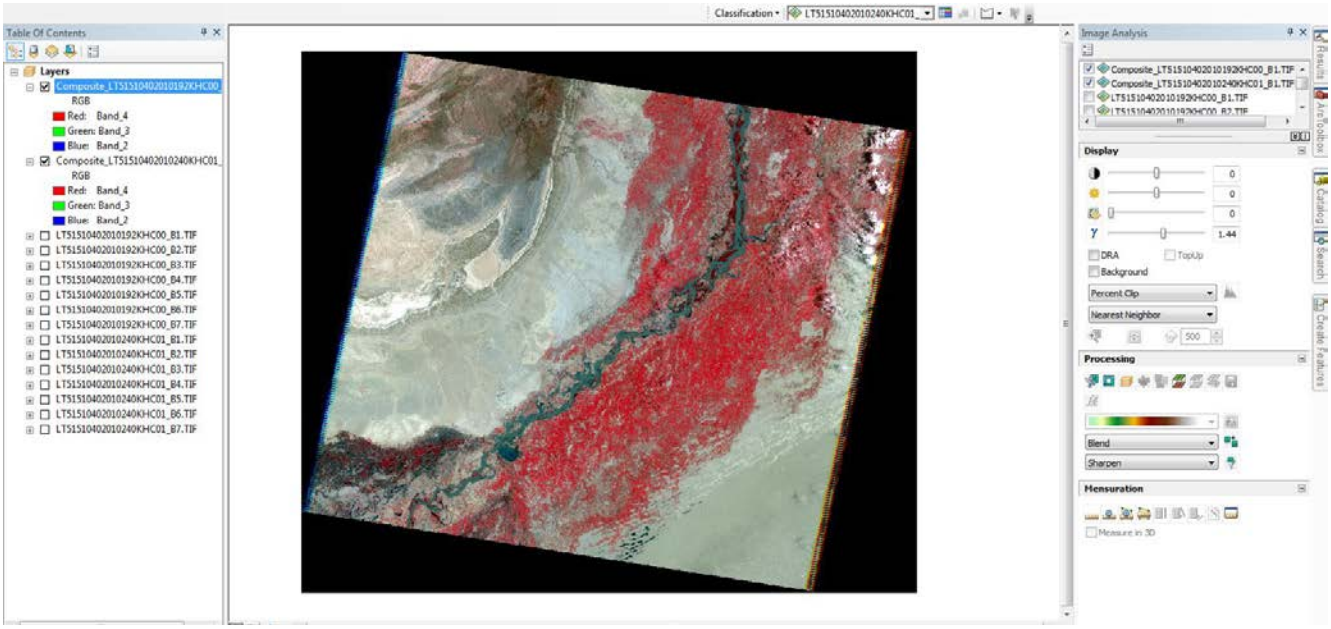


July 11 August 28

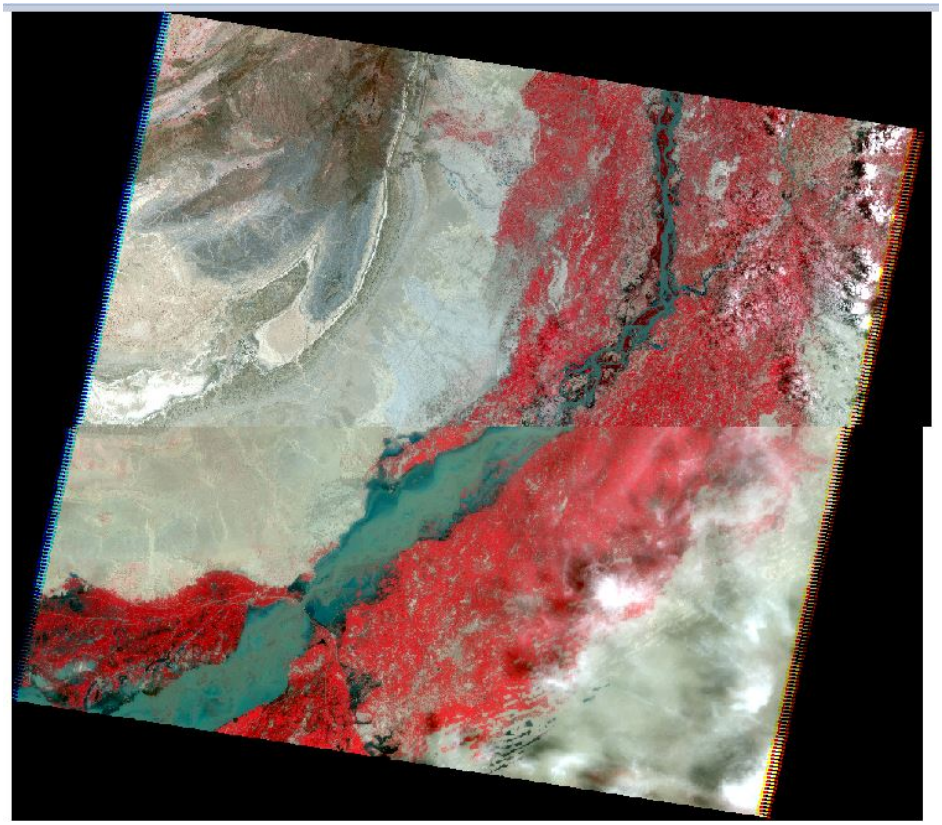
Change Detection using Image Analysis in ArcGIS

Once you have downloaded the scenes, open ArcMap with a new map document, the ***Image Analysis*** window, set your W***orkspaces,*** and add all bands for each image.

Composite the images for each scene. (Remember when you create images using the ***Image Analysis*** window, these are temporary, so if you cannot complete this Tutorial in one sitting, please save your composite images as permanent files). In ArcGIS, we don't use the composite images for the change detection but they are useful to see the differences that have occurred in the region after the flooding. Again when doing any remote sensing analysis, you need to be familiar with your data and your region.



Your composite images are displayed on top of each other -- the July should be on top. In this example, two images of the region in Pakistan show before and after the flood. By using the flicker button, you can visually see the differences between the two images.



July

Flicker Line

August

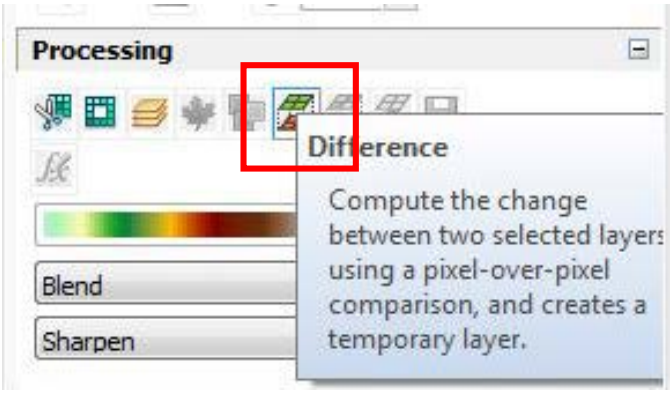
Applying image differencing (i.e. subtracting corresponding pixels values at each pixel, and then displaying the differences as colors) the areas that differ in brightness can be easily identified. The analyst must apply an understanding of both the region represented on the image, and the subject of the analysis, to generate useful results. Note that, when correctly applied, this approach will **not** identify the area of the river in the second image as flooded, as it identifies areas that have changed, not areas that were already covered by water. We do not use the composite image to calculate the differences, so it is important that you know which Landsat bands are best suited for distinguishing which features. When we calculate the differences, it just the differences between the same bands, not the composite images. Remember which bands are useful for which analysis:

Table 3. TM and ETM+ band designations.

Spectral bands	Wavelength (micrometers)	Resolution (meters)	Use
Band 1–blue-green	0.45–0.52	30	Bathymetric mapping; distinguishes soil from vegetation; deciduous from coniferous vegetation.
Band 2–green	0.52–0.61	30	Emphasizes peak vegetation, which is useful for assessing plant vigor.
Band 3–red	0.63–0.69	30	Emphasizes vegetation slopes.
Band 4–reflected IR	0.76–0.90	30	Emphasizes biomass content and shorelines.
Band 5–reflected IR	1.55–1.75	30	Discriminates moisture content of soil and vegetation; penetrates thin clouds.
Band 6–thermal	10.40–12.50	120	Useful for thermal mapping and estimated soil moisture.
Band 7–reflected IR	2.08–2.35	30	Useful for mapping hydrothermally altered rocks associated with mineral deposits.
Band 8–panchromatic (Landsat 7)	0.52–0.90	15	Useful in 'sharpening' multispectral images.

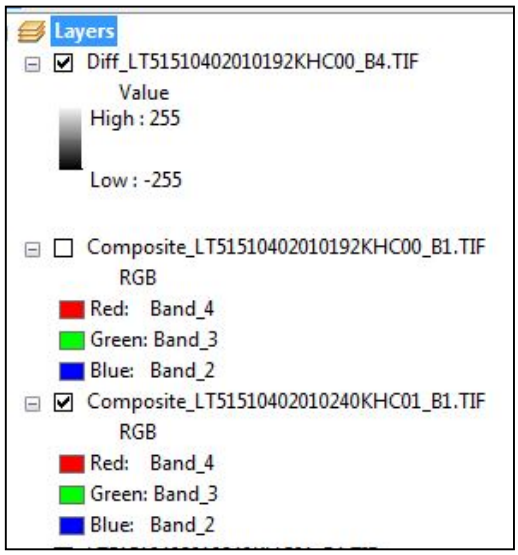
Instrument-specific relative spectral response functions may be viewed and compared using the Spectral Viewer tool: *http://landsat.usgs.gov/tools_spectralViewer.php*.

We are going to use Band 4 from each image and calculate the difference between the two. If you highlight the two B4 images in the top of the ***Image Analysis*** window, it will enable the ***Difference*** button in the ***Processing*** section of the window.



Click on the ***Difference*** button and a new temporary file is created, in grayscale. The image that was listed second in the ***Image Analysis*** window is subtracted from the image listed first.

Zooming in on the ***Table of Contents*** shows that we have a new file with values ranging from -255 to positive 255. Remember, these are differences between each of the pixel values in the two original images.

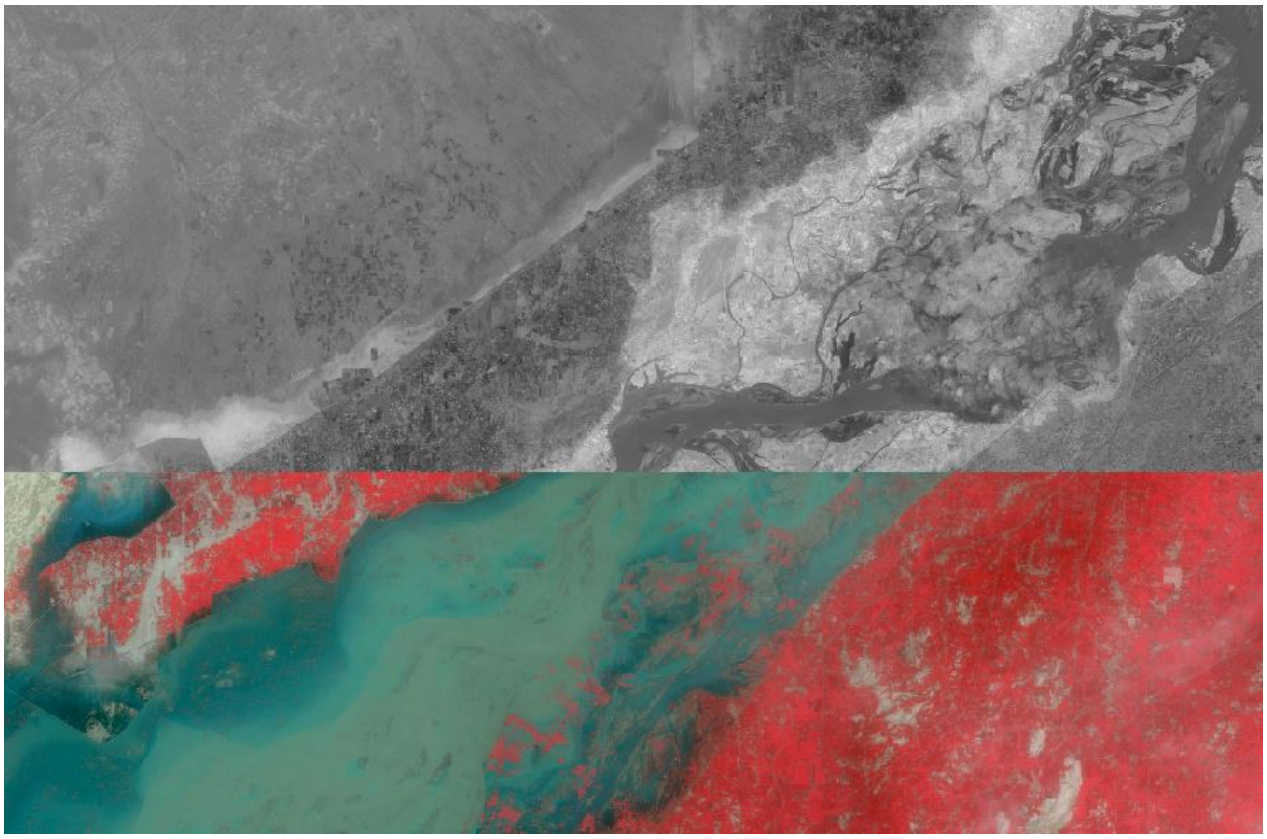


Turn off all the layers in the ***Table of Contents*** except for the August Composite Image and your new difference image. Do you remember how to distinguish between images taken on different dates? (Hint – the Julian date in contained within the scene identification number.)

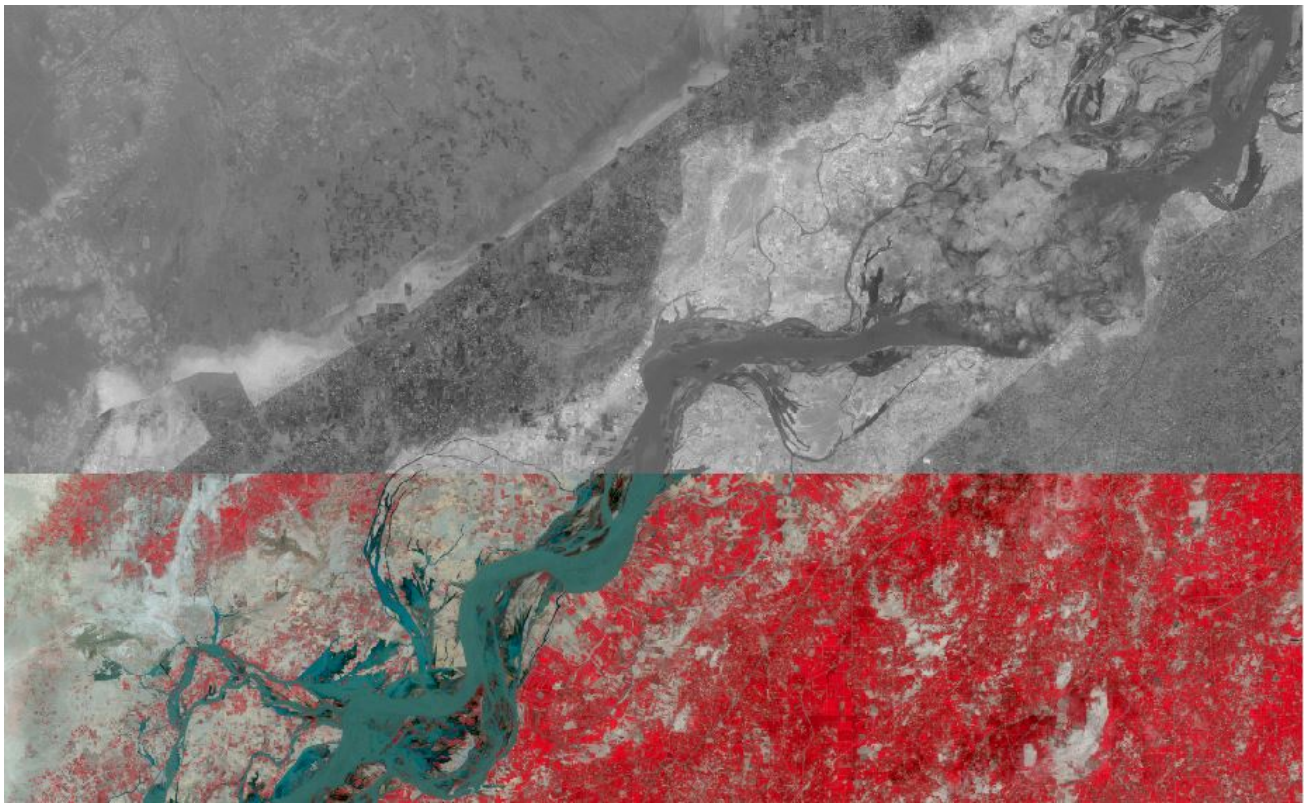
Highlight one of the Images in the top of the ***Image Analysis*** window and use the Flicker button to compare your

new image to the July and August composite images. In the August image, you could see the flooded area but it was difficult to see the original river within the image. With change detection, the original river is darker and the area of land that has been flooded is extremely bright. *(Remember from prior tutorials, you can change the symbology to different colors to see how if it highlights the changes more definitively.)*

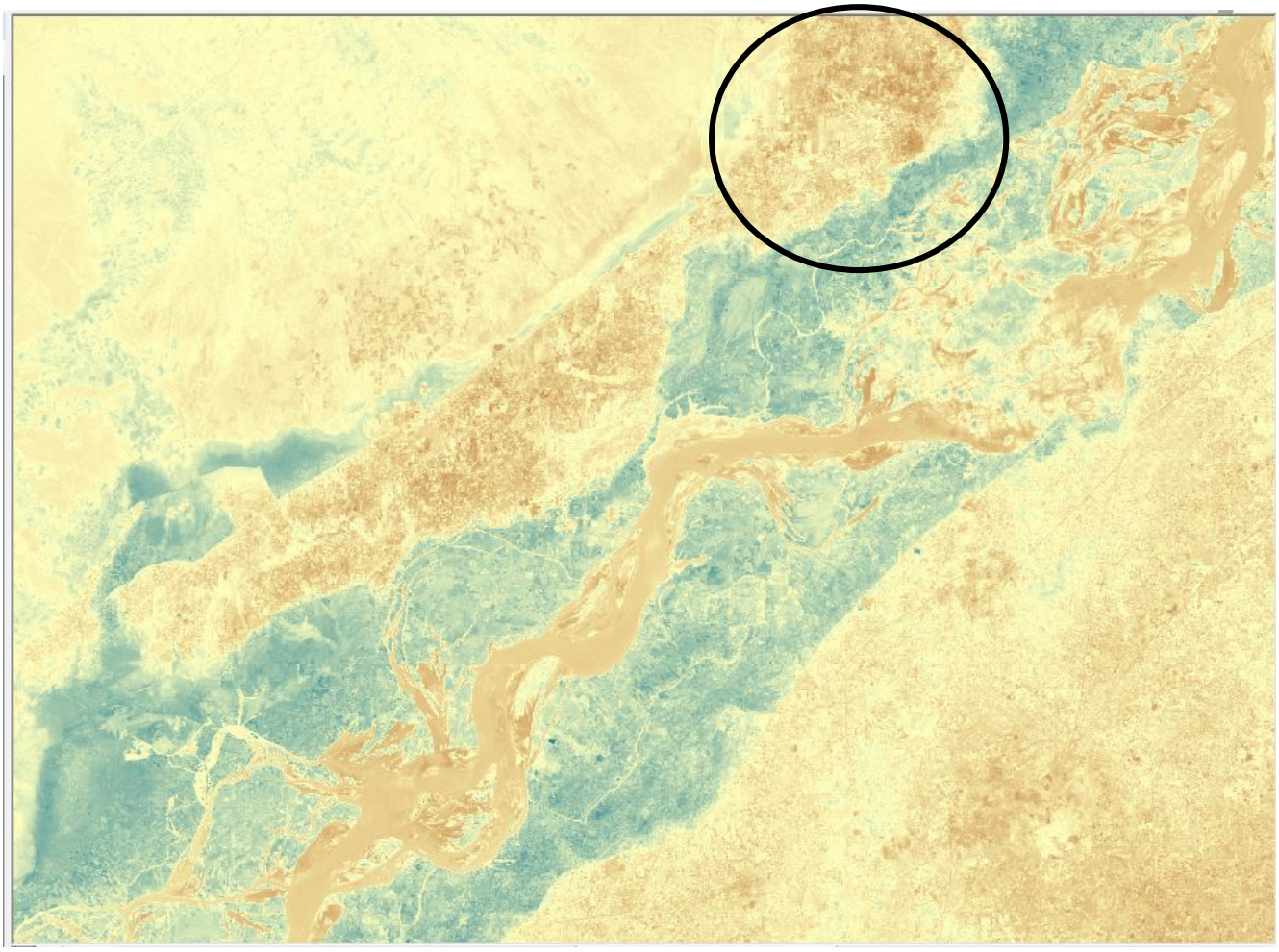
August image to change detection image is shown here.

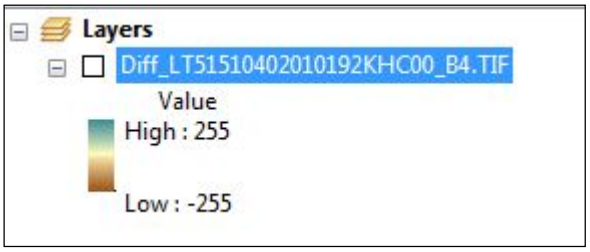


July image to change detection image is shown here



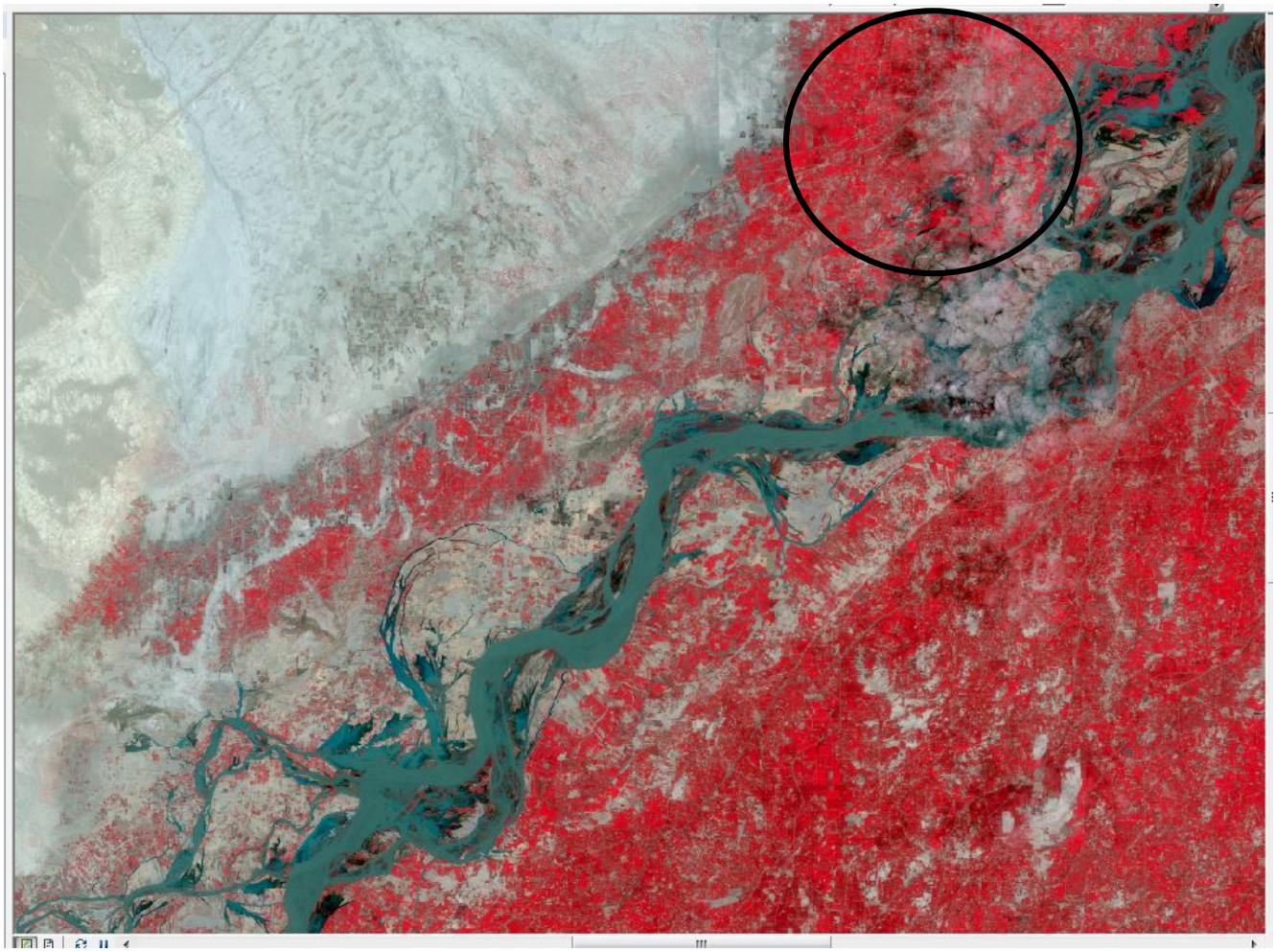
Let’s change the symbology on the change detection image and see what happens.



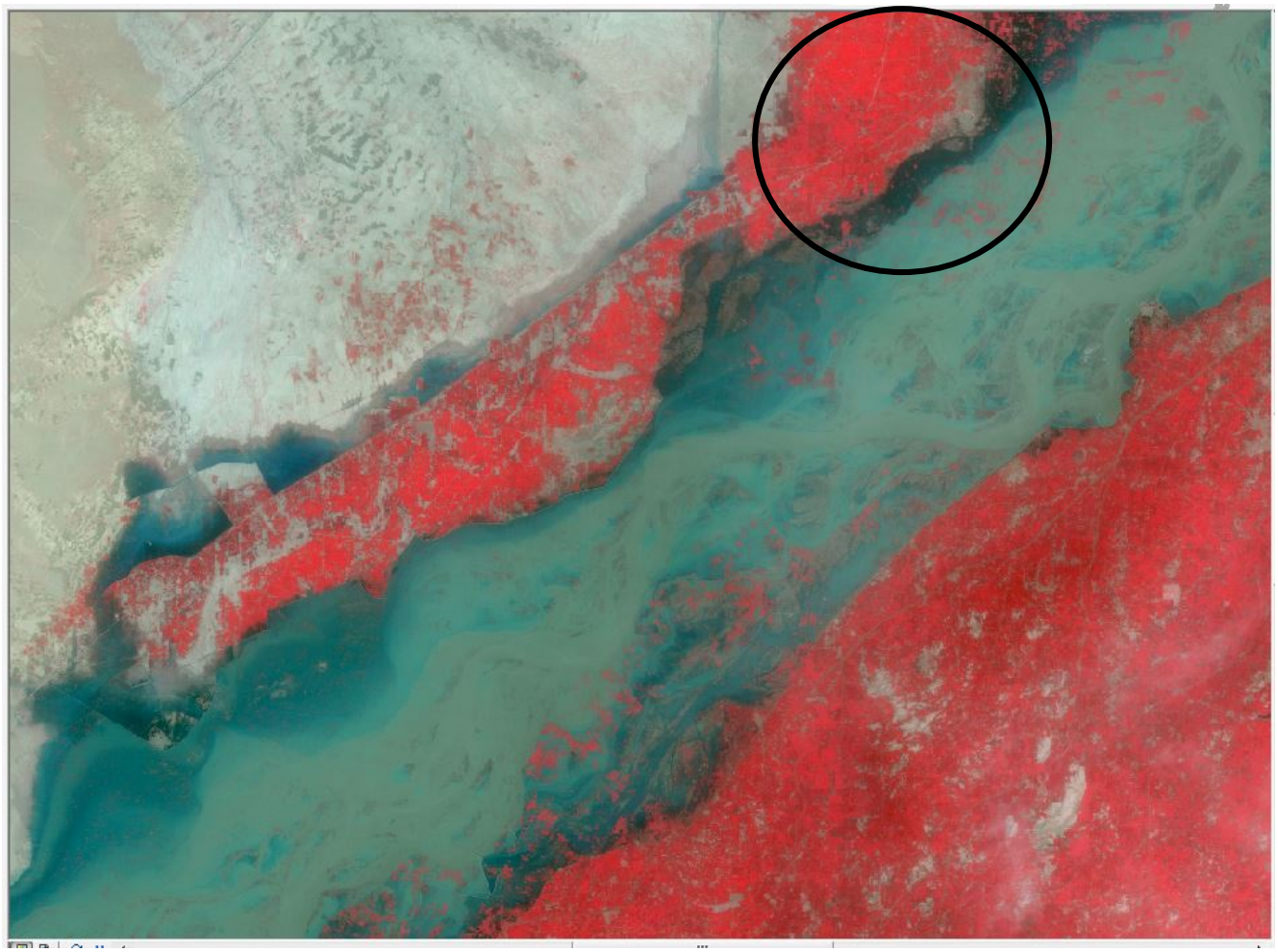


In this symbology, darker colors represent both extremes on the change in pixel value. The lighter color represents those areas with little or no change. Here, we chose blue to highlight where water is now located. Why is there a change in color within the river itself? (*Answer – flooding caused sediment to flow into the main river channel and thus changed the spectral quality of the river.)*

Now look at your original July and August images, and compare them to the change detection image. We also see other significant changes in the image, not due to the flooding. Why?



Hints – we are looking at an image in mid-July and comparing it to an image in late August. What do the red areas of this 4 - 3 - 2 band combination represent? Why would these areas show a change? Think about the latitude and longitude of Pakistan. Is this time period consistent with the growing season?



Again, the band that you chose to use in the change detection within ArcGIS will be dependent on the goal of your project and the exact features upon which you want to evaluate the change.

This tutorial covered change detection only. The images of Pakistan that you downloaded for this tutorial will not be used in any other tutorial.

18. Classification of a Landsat Image (Unsupervised)

The instructional materials contained within these documents are copyrighted property of VirginiaView, its partners and other participating AmericaView consortium members. These materials may be reproduced and used by educators for instructional purposes. No permission is granted to use the materials for paid consulting or instruction where a fee is collected. Reproduction or translation of any part of this document beyond that permitted in Section 107 or 108 of the 1976 United States Copyright Act without the permission of the copyright owner(s) is unlawful.

Introduction

Image classification is the process of sorting pixels into a finite number of individual classes, or categories, of data based on their pixel values. If a pixel satisfies a certain set of criteria, then the pixel is assigned to the class that corresponds to that criterion. There are two ways to classify pixels into different categories:

1. **Unsupervised Classification (this tutorial)**
2. **Supervised Classification – (Tutorial 19)**

Unsupervised classification is a method of identifying, grouping, and labeling features in an image according to their spectral values. In unsupervised classification, pixels are clustered together based on spectral homogeneity and spectral distance. An analyst may choose from a variety of techniques to measure distances.

It is important to emphasize that unsupervised classification produces classes of homogeneous spectral identities that may not always correspond to informational classes. While spectral classes denote pixels grouped by uniform brightness values, informational classes refer to groups that convey useful information (such as land use, soil classes, or agricultural productivity) to the user. When using unsupervised classification, the informational class may contain a variety of spectral identities. Therefore, a spectral class as identified by unsupervised classification seldom matches to an informational class.

Objectives:

- To perform an unsupervised classification on a Landsat image using ArcGIS 10.X.
- To determine what type of land use each spectral class represents and create color coded informational classes.
- We will use the following classes and color combinations. (The numbers assigned to the classification will become clearer later in the tutorial.)

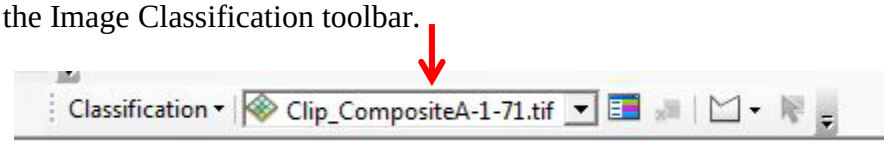
Open water = 4, blue
Mixed agriculture = 2, yellow
Urban/built up/transportation = 1, red
Forest & Wetland = 3, green

18. Classification of a Landsat Image (Unsupervised)

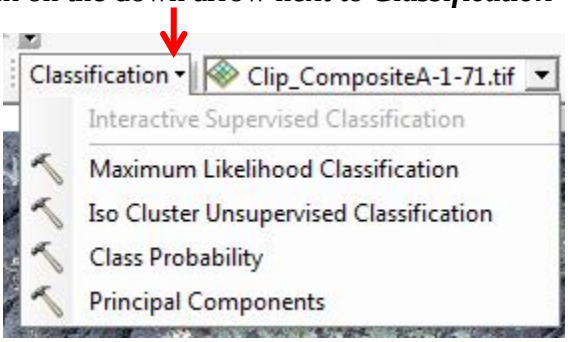
Conducting Unsupervised Classification

Open a new map document, enable the ***Spatial Analyst*** extension, the toolbars for ***Spatial Analyst*** and ***Image Classification***, and set your ***Workspaces***. Add the sub-set Landsat Image (created in the tutorial on Sub-setting Landsat Imagery) that includes Blacksburg, Roanoke, and Smith Mountain Lake.

Because you only have one raster dataset in your ***Table of Contents***, that is the dataset that shows in the Image Classification toolbar.

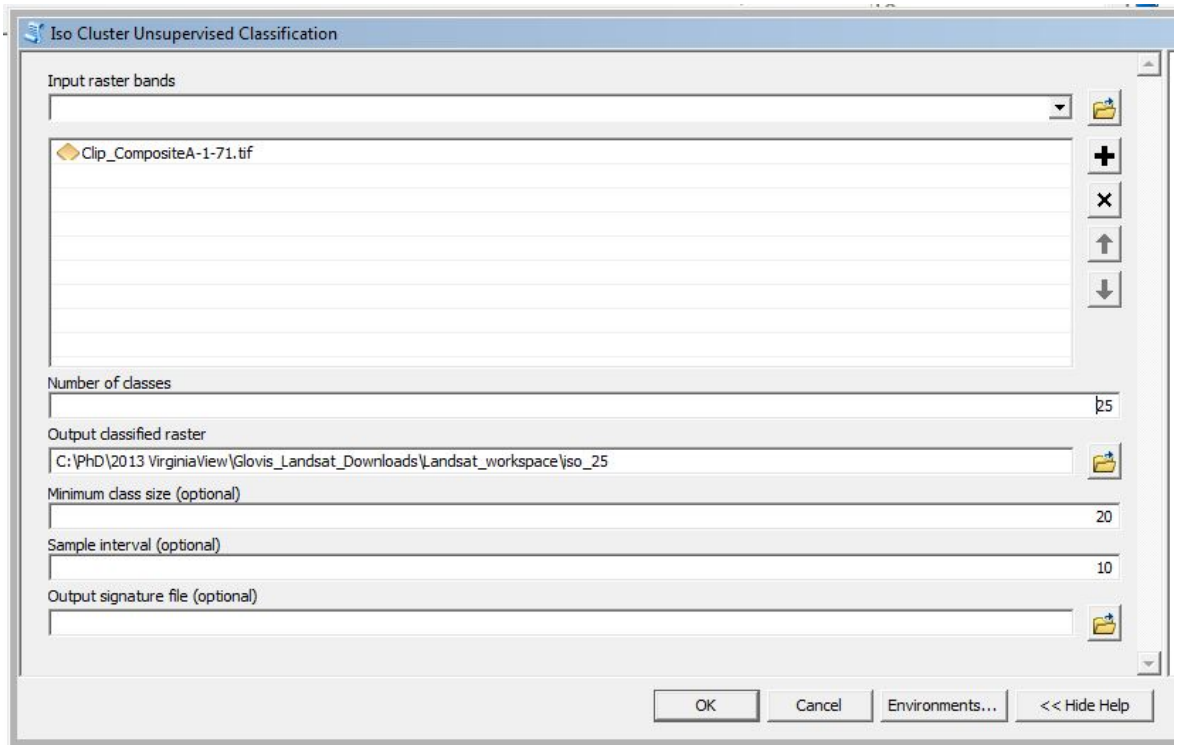


For an unsupervised classification, left-click on the down arrow next to ***Classification*** and it gives you a list of classification methods. For this tutorial, we will be using ***Iso Cluster Unsupervised Classification***. Left-click on that method.



The following dialog box opens. Again, because you only have one raster image in your ***Table of Contents***, it automatically prefills as the ***Input Raster***. We need to set the number of

classes and name your new file. Don't click ***OK*** yet -- we need to discuss the number of classes.



Determining the Number of Classes

Remember from above, for our final output, we want four different informational classes:

Open water = 4, blue
Mixed agriculture = 2, yellow
Urban/built up/transportation = 1, red
Forest & Wetland = 3, green

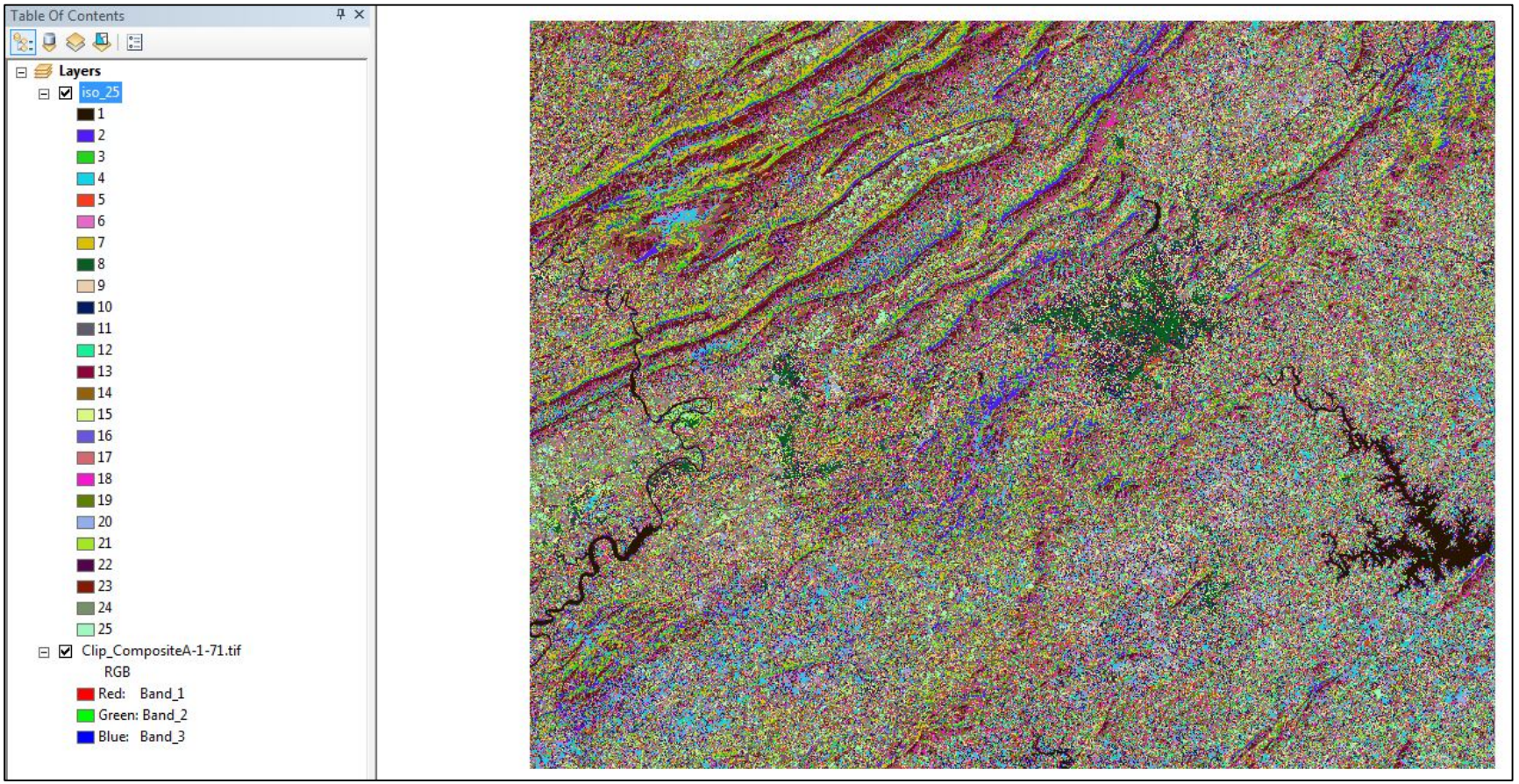
Yet, in the dialog box, we set the number of classes to 25. Why? Your image has 256 different pixel values. Each of your features or informational classes – water, agriculture, urban, forest – may contain a variety of spectral identities. Unsupervised classification produces groups of homogenous spectral identities. How many spectral classes we should set will be dependent on the number of informational classes, the complexity of your area of interest, and your final project. You may need to run the ***Iso Cluster Unsupervised Classification*** multiple times using

different numbers of spectral classes. Once you have run one set, you will need a reference image to compare your results to see if you need to set the number higher or lower.

Now, name your ***Output classified raster --*** we recommend that you include the number of spectral classes for future reference.

You can leave the next two items set at the default. ***Minimum class size*** (optional) is the minimum number of cells within a specific class. Leave ***Output signature file*** blank – we will not be using that for this tutorial. Now left-click on ***OK***.

ArcMap will automatically add your new file to the ***Tables of Contents*** and map document window. As you can see, it assigned 25 unique values and colors to your output. Again, these are homogenous spectral classes, not informational classes. We will need to determine which informational class contains each one of these spectral classes, and ultimately reclassify all 25 spectral classes into informational classes.

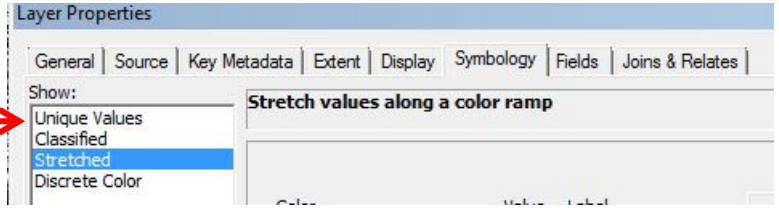


But before we do this, let's run the method one more time.

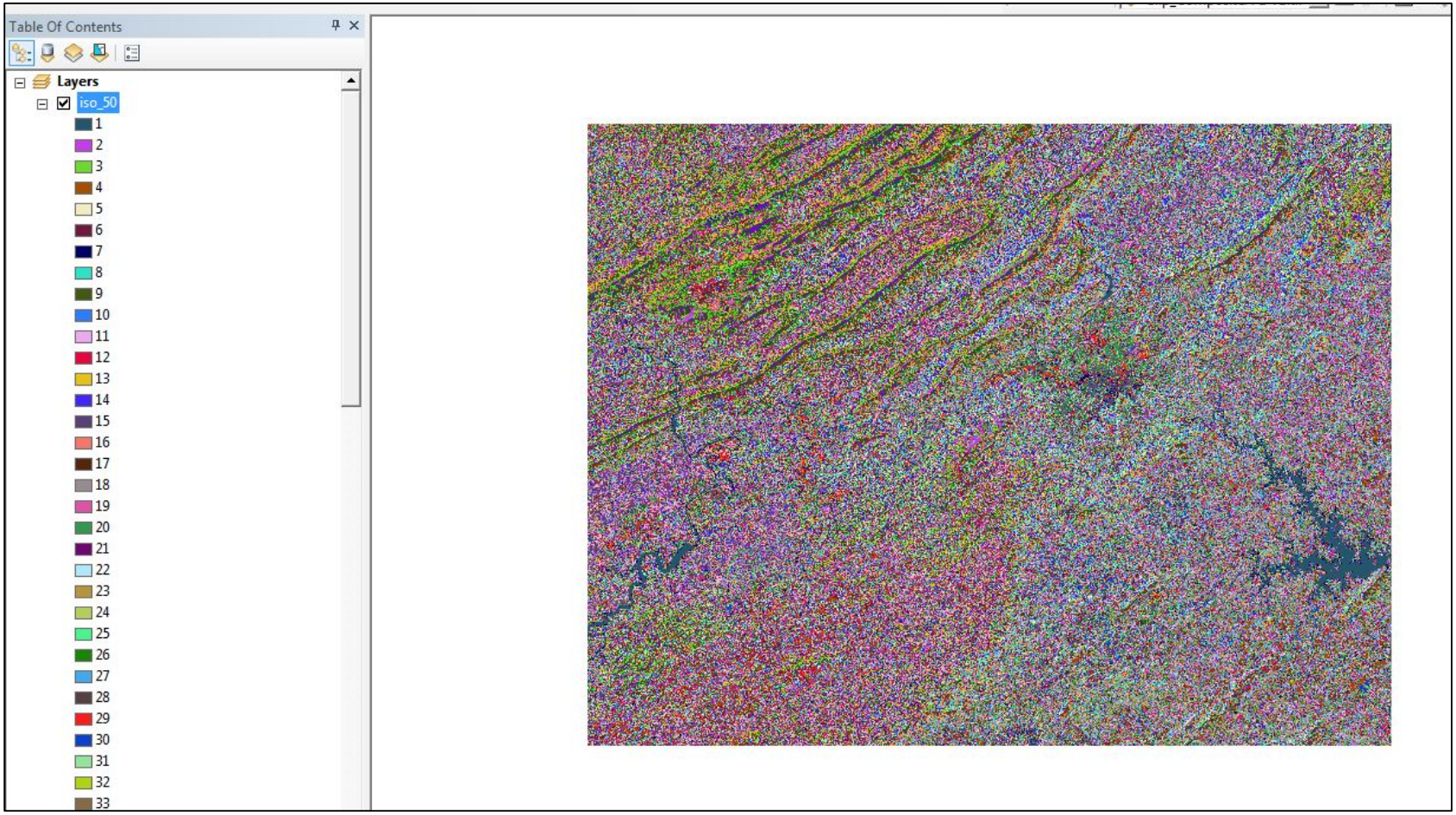
Set your classes to 50 and name your output raster accordingly and then left-click ***OK***.

This time ArcMap did not display ***Unique Values*** but ***Stretched***.

So, open ***Layer Properties/Symbology*** and left-click on ***Unique Values***.

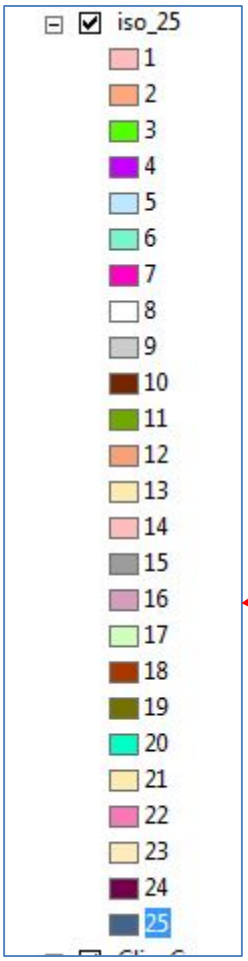


ArcMap now displays your unsupervised image with 50 spectral classes in 50 different colors.



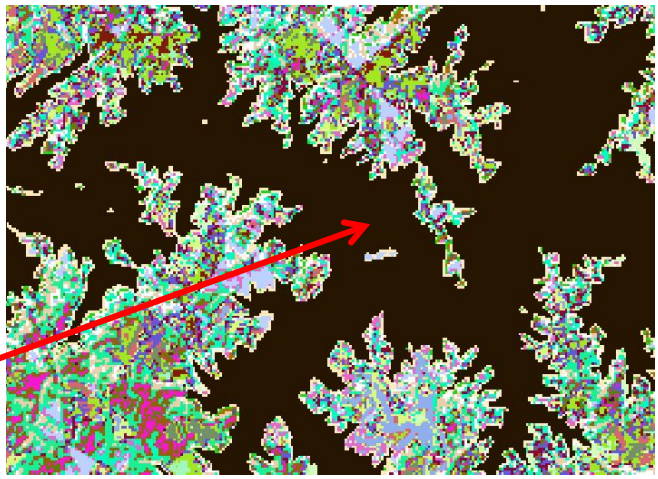
Now we need to decide which informational class contains each spectral class. Which new image will we use? We will use the ISO_25 image from here on, strictly for simplicity. Again, your choice will depend on many factors.

Remember our color scheme:

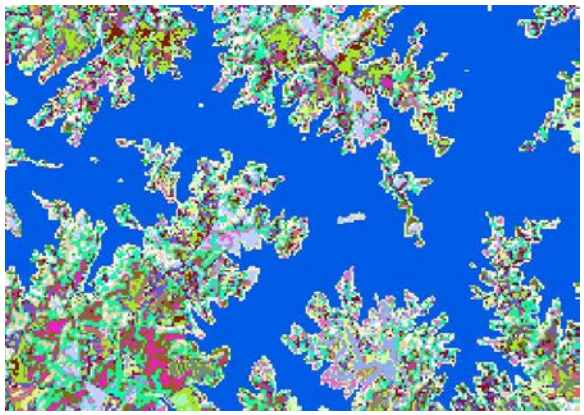


Open water = 4, blue
Mixed agriculture = 2, yellow
Urban/built up/transportation = 1, red
Forest & Wetland = 3, green

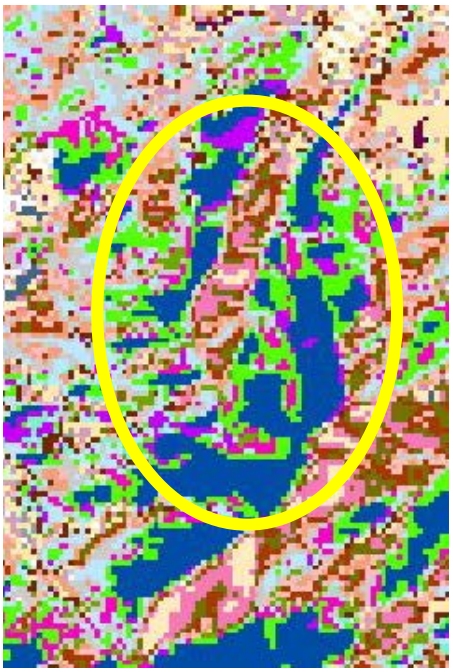
For your first step, you should change the color for any spectral class that has the above 4 colors. This will eliminate confusion if you have any spectral classes colored blue that belong to an informational class other than water. It is okay if you reuse any of the other colors. (You could set them to all the same color to begin and then proceed from there.) Your ***Table of Contents*** will look something like this (your colors may vary).



Now let's start with water. Water should be blue, so zoom into Smith Mountain Lake and see what color is there. Make it blue. If you can't tell which color it is or the corresponding spectral class number, use the ***Identify*** button.



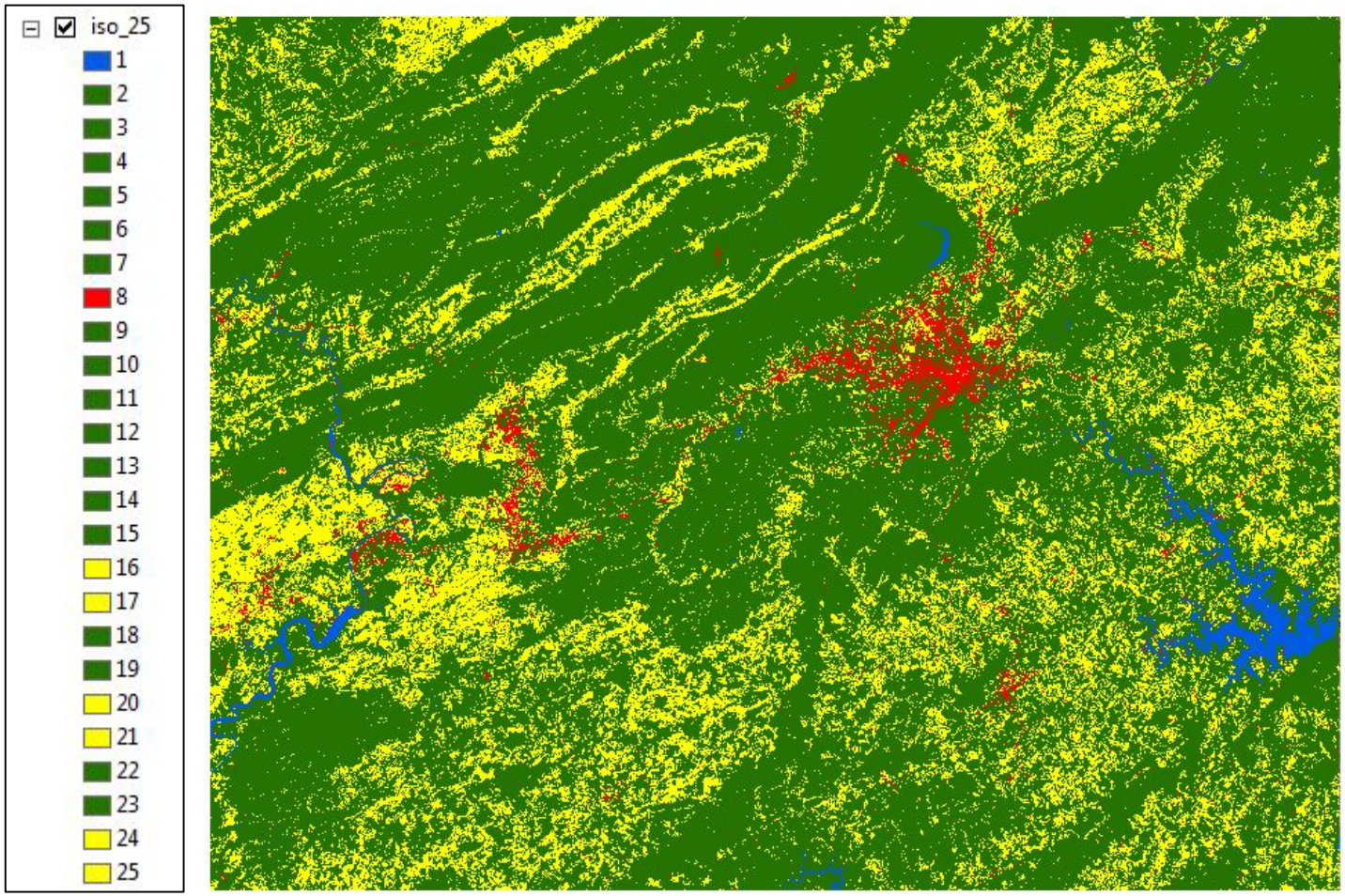
Next zoom to the rivers in the Roanoke and Blacksburg areas, and change their colors to blue. If you have difficulty finding the river in Roanoke, follow the blue water northwest out of Smith Mountain Lake. The river in Roanoke is a different color, so it will need to be changed. But be careful, we only have 25 spectral classes-- mountain shadows can mimic water, so if you change it, will it also change the mountain shadows to water? This is one of those situations in which you may need to decide you don't have enough spectral classes. Do you leave it blue? That depends on the purpose of your project.



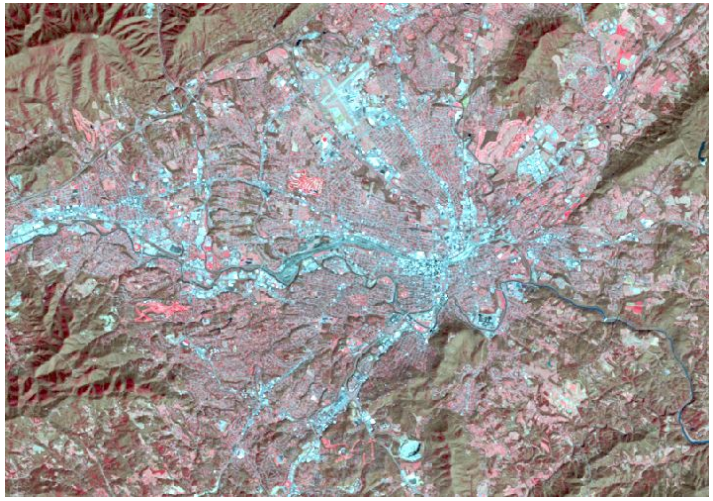
Remember -- to help you decide what features are present and belong to specific informational classes, check Google Earth, on-line server aerial images, your original sub-set image, different ***Display*** buttons in the Image ***Analysis*** window, or change the band combinations to help make different features more distinct. As you zoom in and out, ArcMap keeps the extent for all layers in the ***Table of Contents***, so you can turn off the ISO_25 image to see same region in the image underneath.

Zoom in and out to each area, changing the colors to our standards for our informational classes. After water, urban areas, are usually easy areas to identify. Forests versus agriculture is a little more complicated, so use of Google Earth or another on-line server imagery is suggested. If you have trouble identifying a color for a spectral value, use ***Identify***.

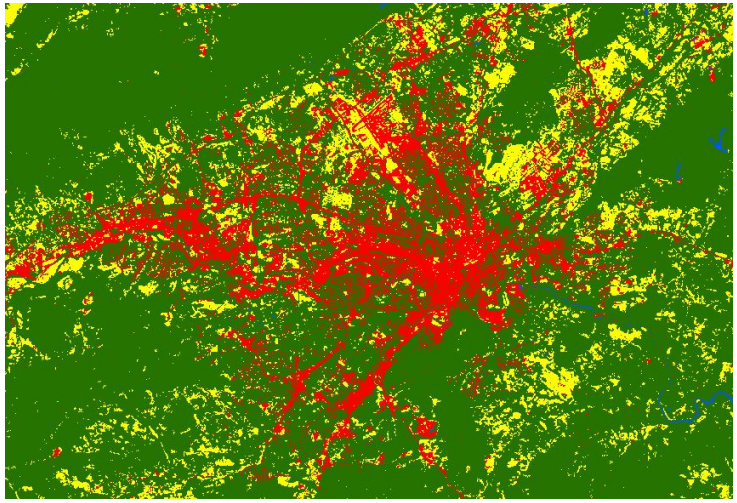
Ultimately, we want and image like this, with each one of the spectral classes assigned a color related to an informational class.



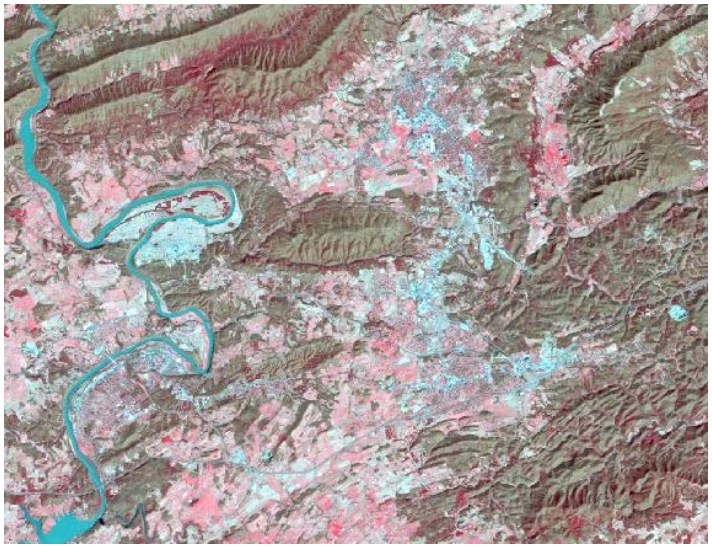
How well did we do with 25 classes? Let's look at a few areas of interest.



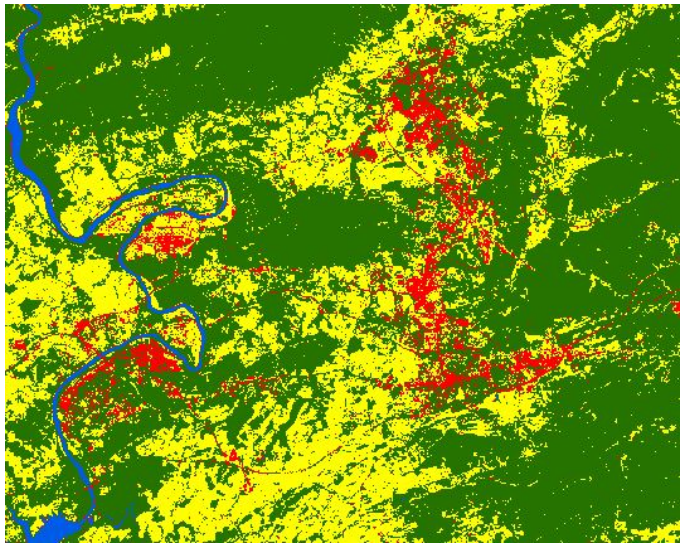
The City of Roanoke - Original Landsat Image



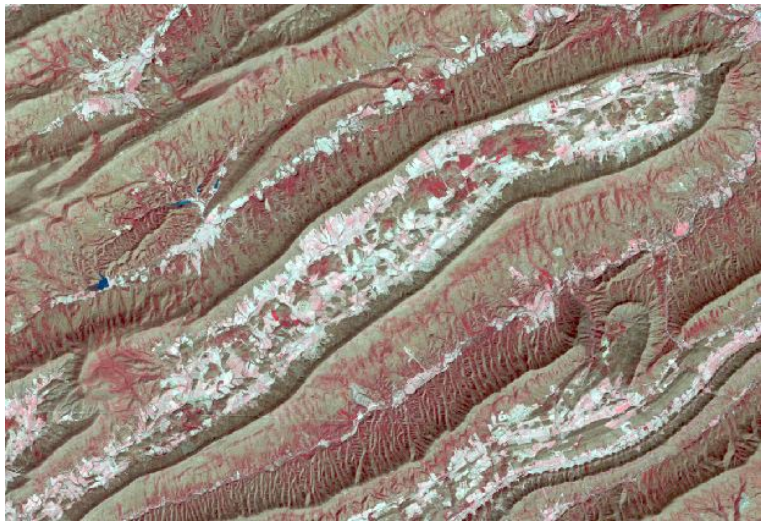
4 Spectral Classes



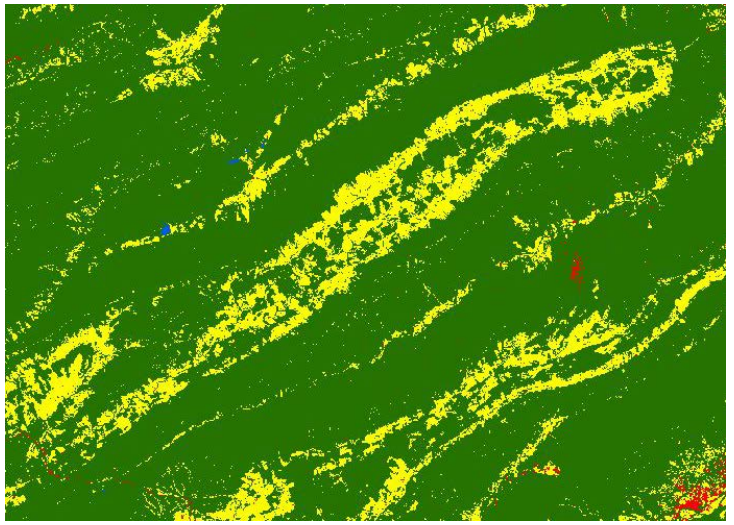
New River Valley Region - Original Landsat Image



4 Spectral Classes



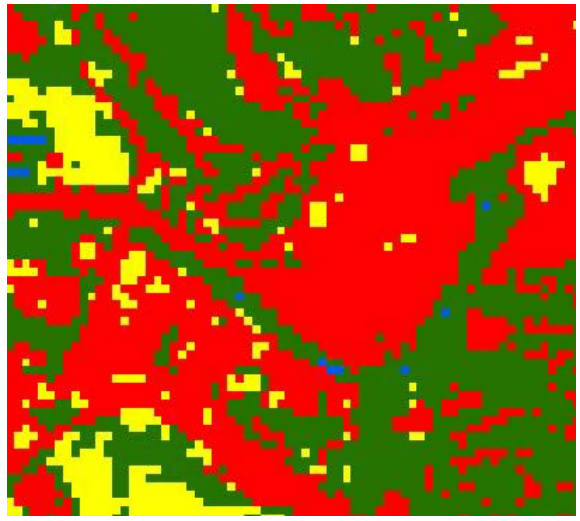
Mountain Area – Original Landsat Image



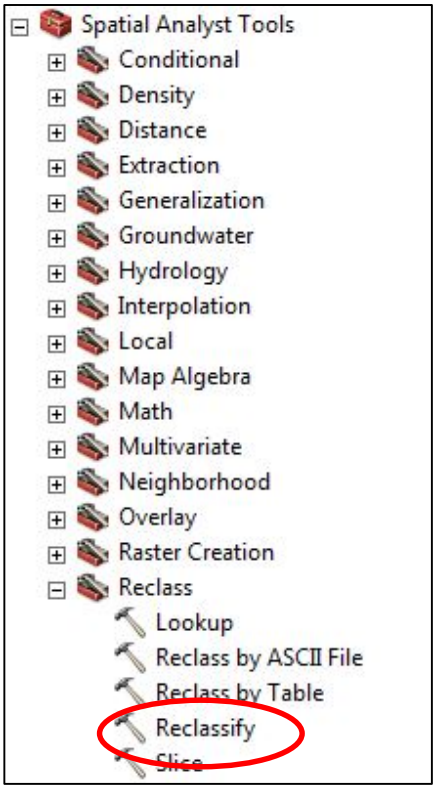
4 Spectral Classes

From that extent, it looks pretty good, although the river in the City of Roanoke appears to be missing (above).

Let's zoom in a little closer. Here, we actually did lose the river to forest. So if you are doing informational classes at this detail (for instance, breaking down urban into specific classes), more than 25 spectral classes would be appropriate.

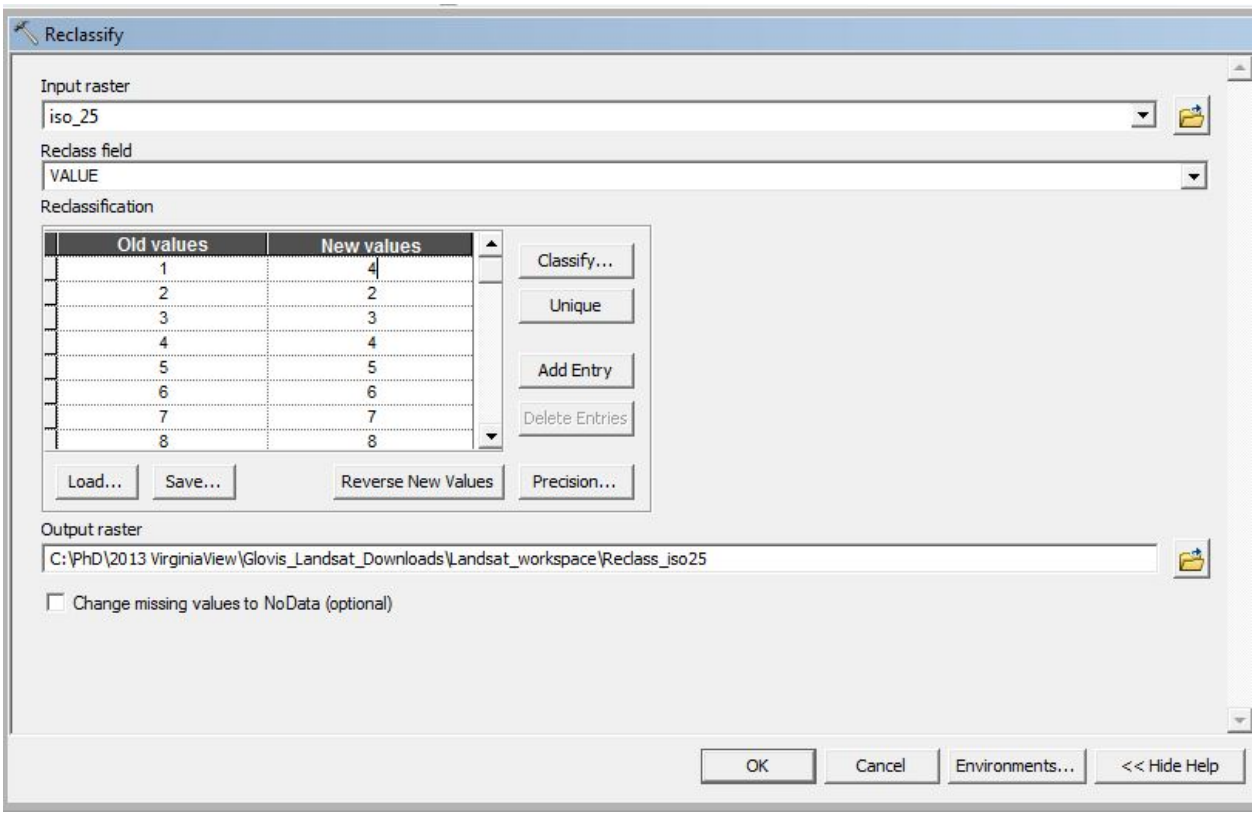


Reclassing Spectral Classes into Informational Classes



Okay, we now have 25 spectral classes colored to match our four informational classes. How do we change this to just 4 informational classes? We will use the ***Spatial Analyst Tools/Reclass/Reclassify*** (red oval).

Your ***Input Raster*** will be the raster you used above when you were identifying which spectral classes belonged to which informational class. The ***Reclass field*** is ***Value***. All ***Old values***, 1 – 25, are listed in a column,

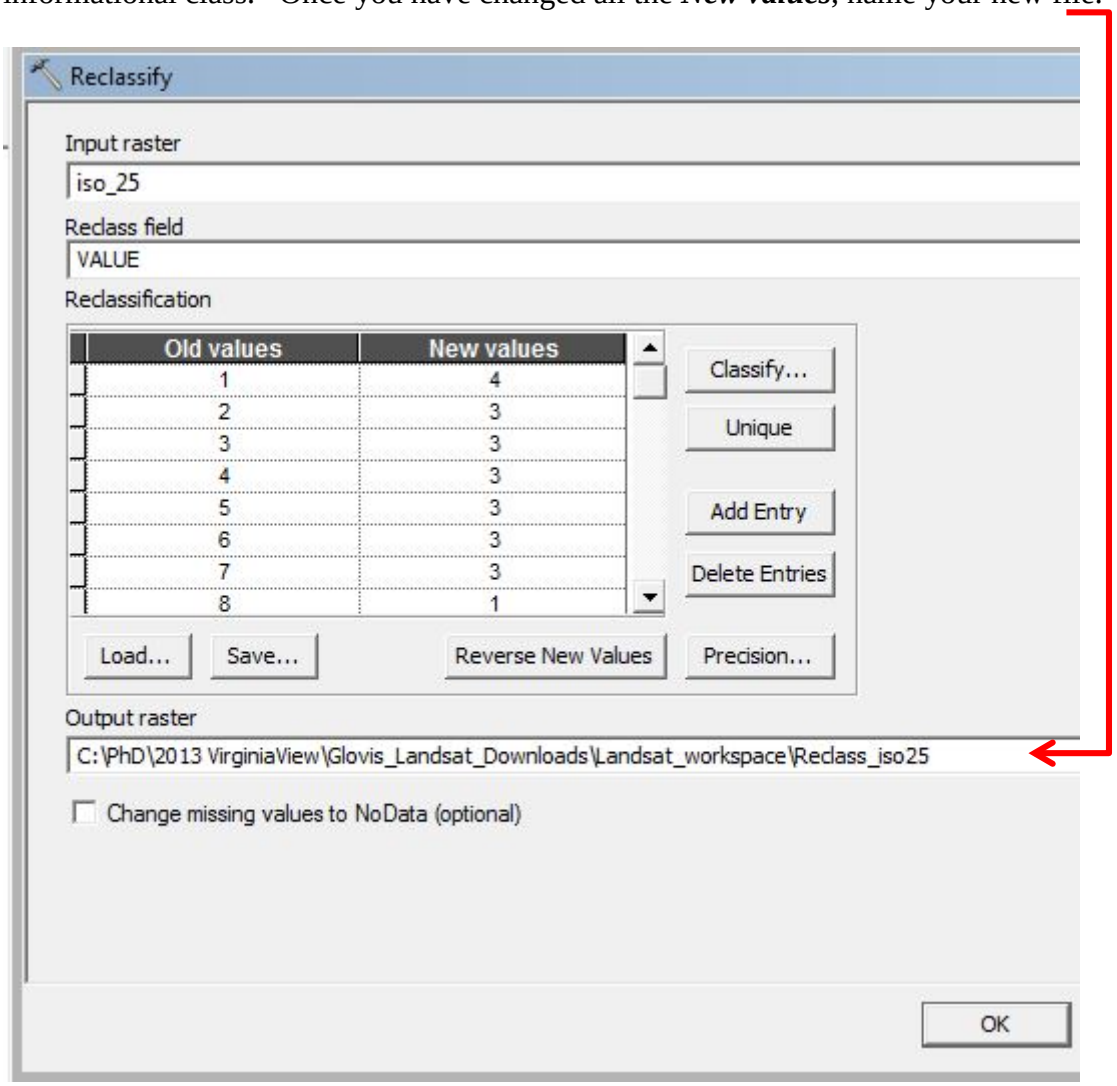


each on its separate line. The ***New values*** are currently the same -- you will change these to informational classes.

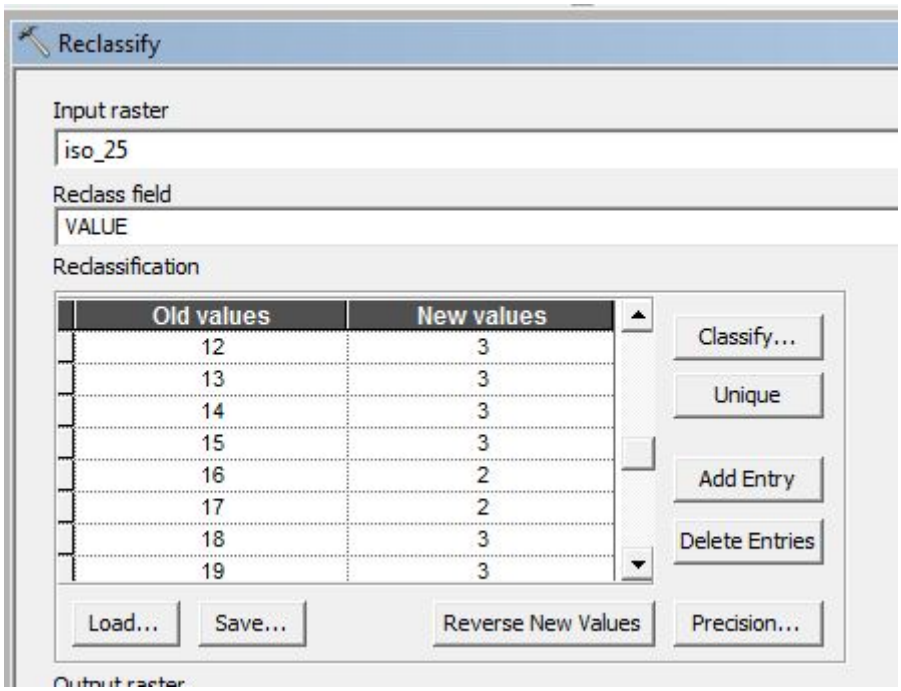
Recall:

Open water = 4, blue
Mixed agriculture = 2, yellow
Urban/built up/transportation = 1, red
Forest & Wetland = 3, green

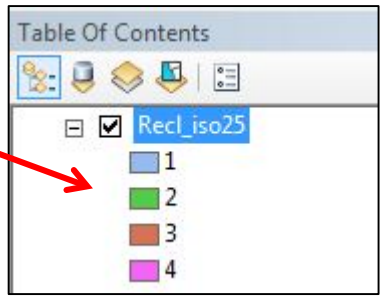
So line by line, you change the ***New values*** to the number corresponding to the correct informational class. Once you have changed all the ***New values***, name your new file.



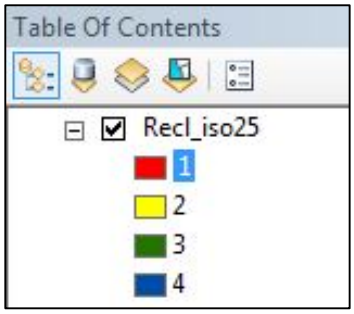
Don't forget, you need to do all 25 ***Old values***. You may need to use the scroll bar on the right side of the ***New values*** list. Click ***OK***.



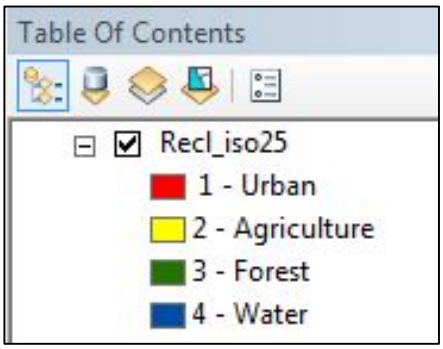
ArcMap will run the tool and automatically add the new file to your ***Table of Contents*** and map document window. The colors may not be the same as ArcMap assigns these at random.



So, re-do the color scheme:

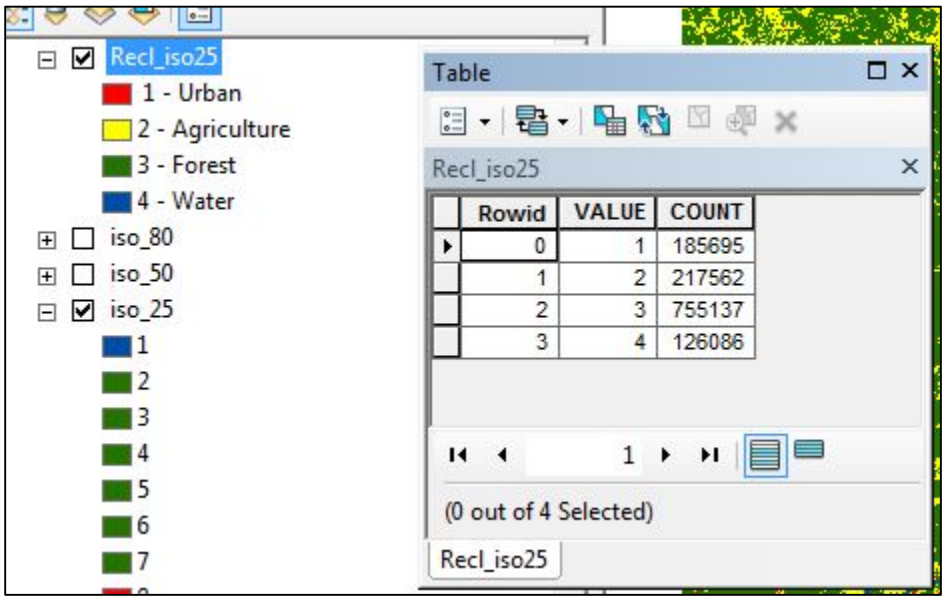


And add the informational class names to the menu.

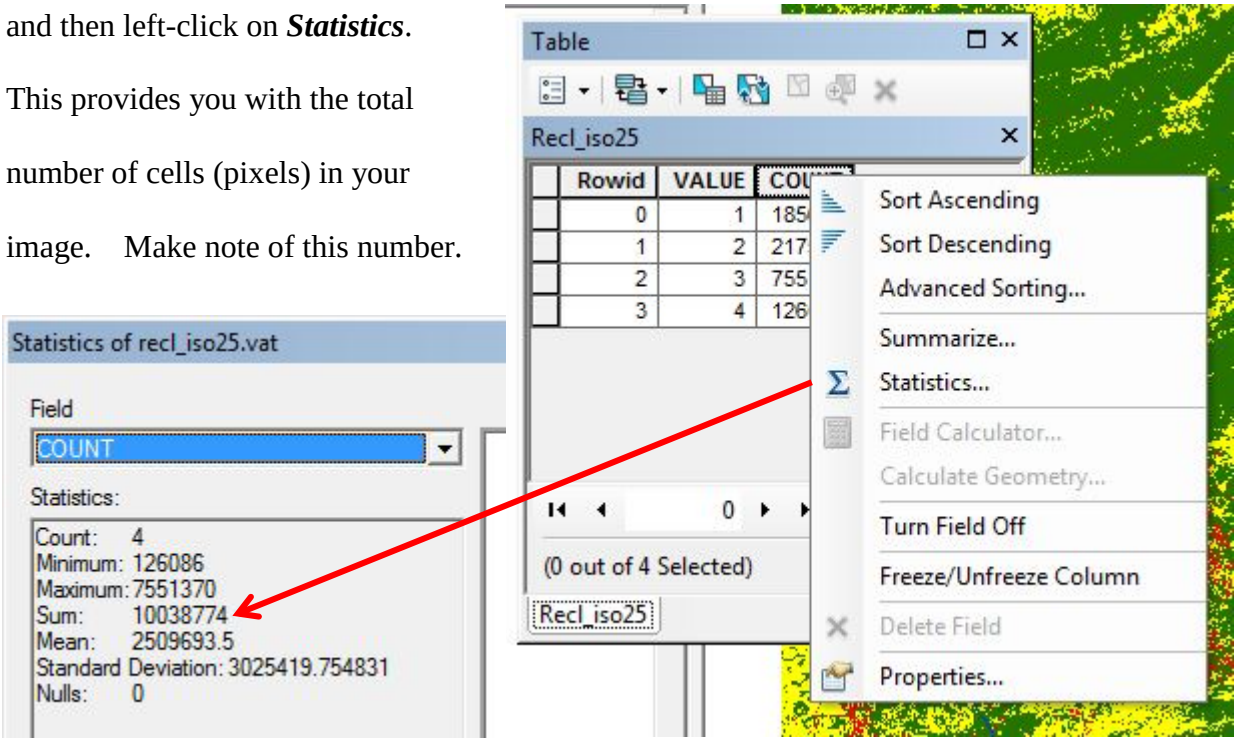


Calculating the Percent of Total Area for Each Informational Class

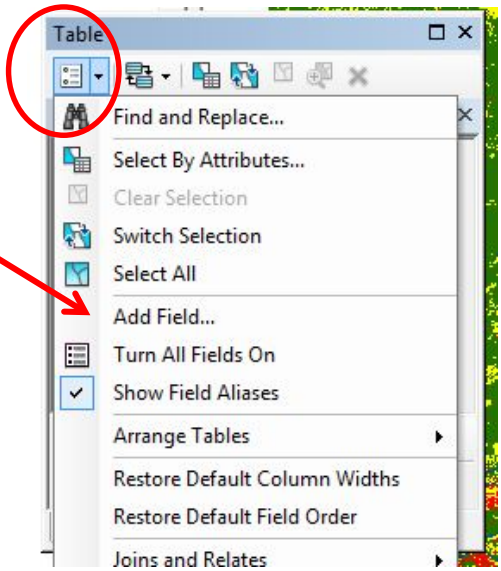
Right-click on the name of your new file and open the ***Attribute Table***. This table will provide you with the number of cells (***Count***) in each informational class.



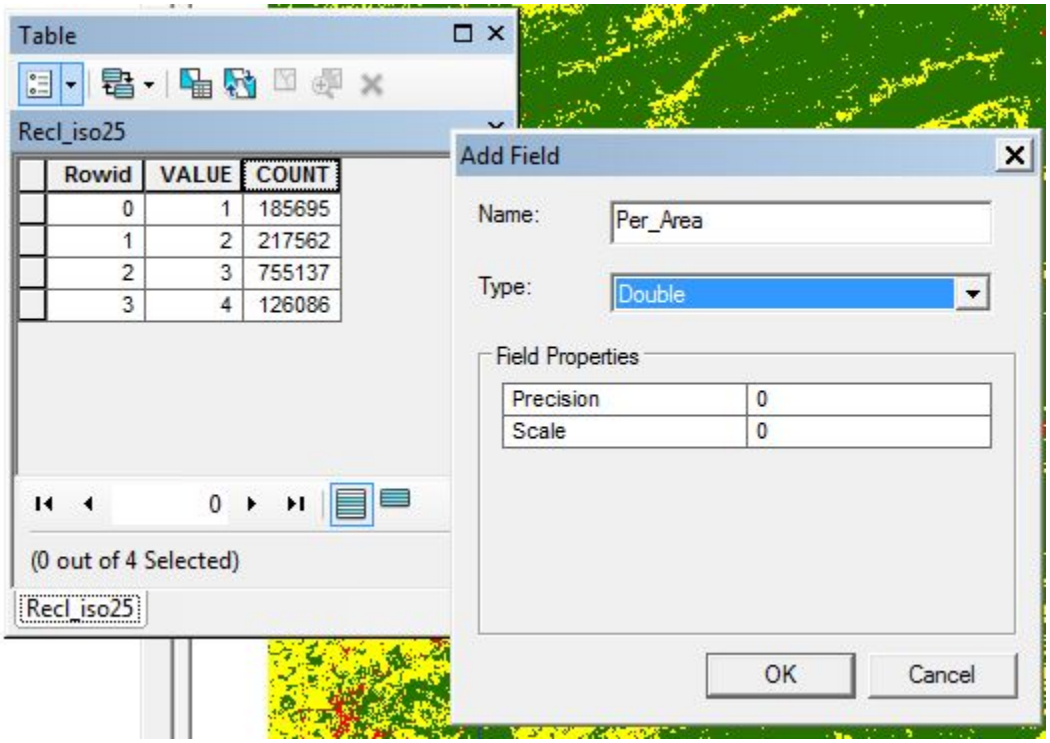
You can then calculate the percent for each informational class. Right-click on ***Count*** and then left-click on ***Statistics***. This provides you with the total number of cells (pixels) in your image. Make note of this number.



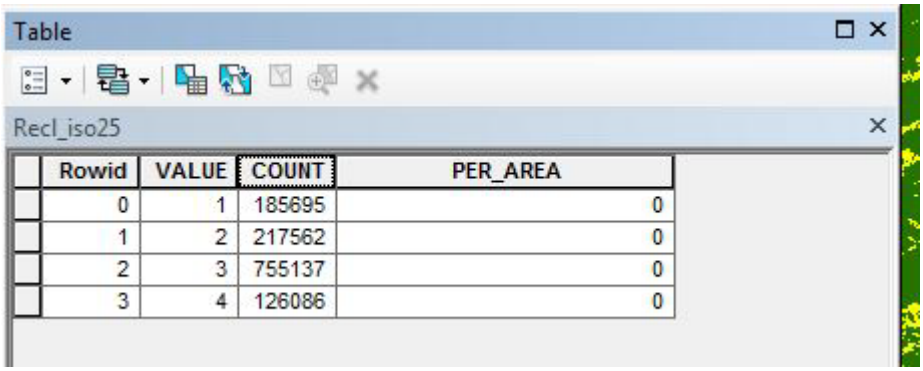
Next, left-click on down arrow underneath ***Table*** (red circle). Then left-click on ***Add Field.***



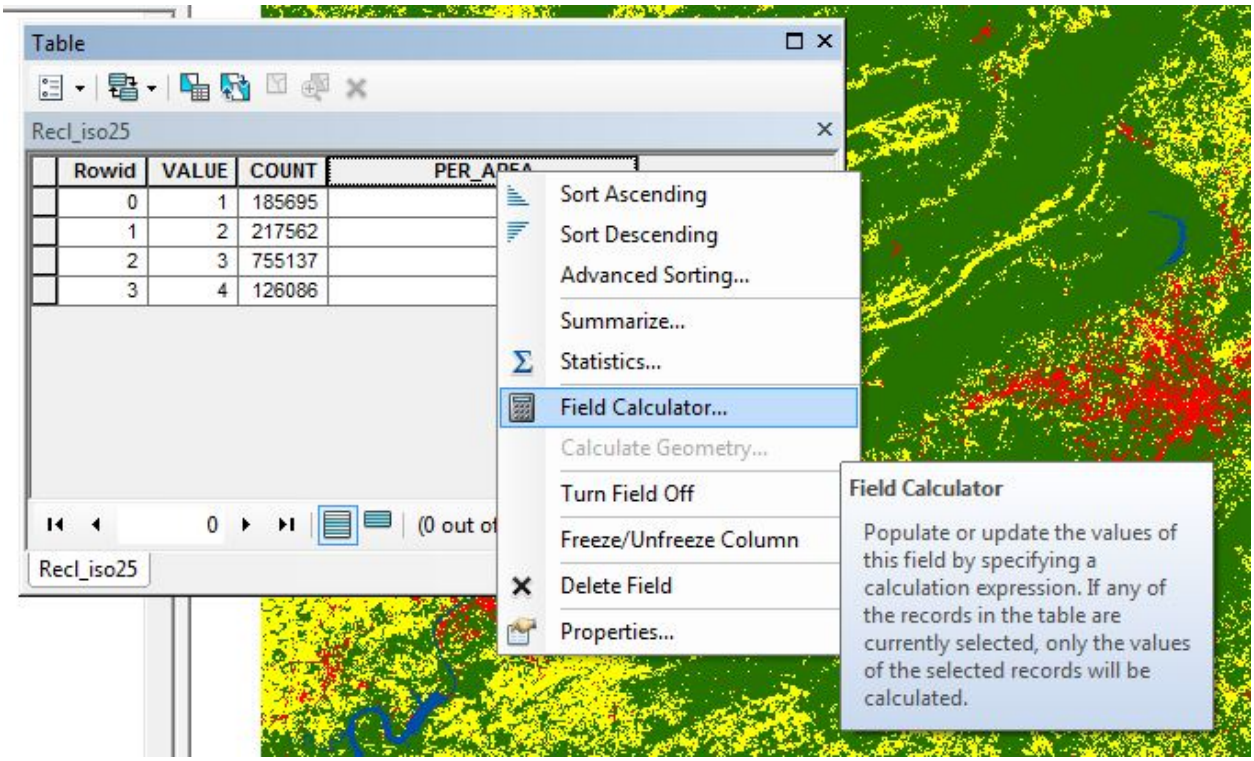
Name your new field something that you will later understand. You want ***Type* – Double**. Click ***OK.***



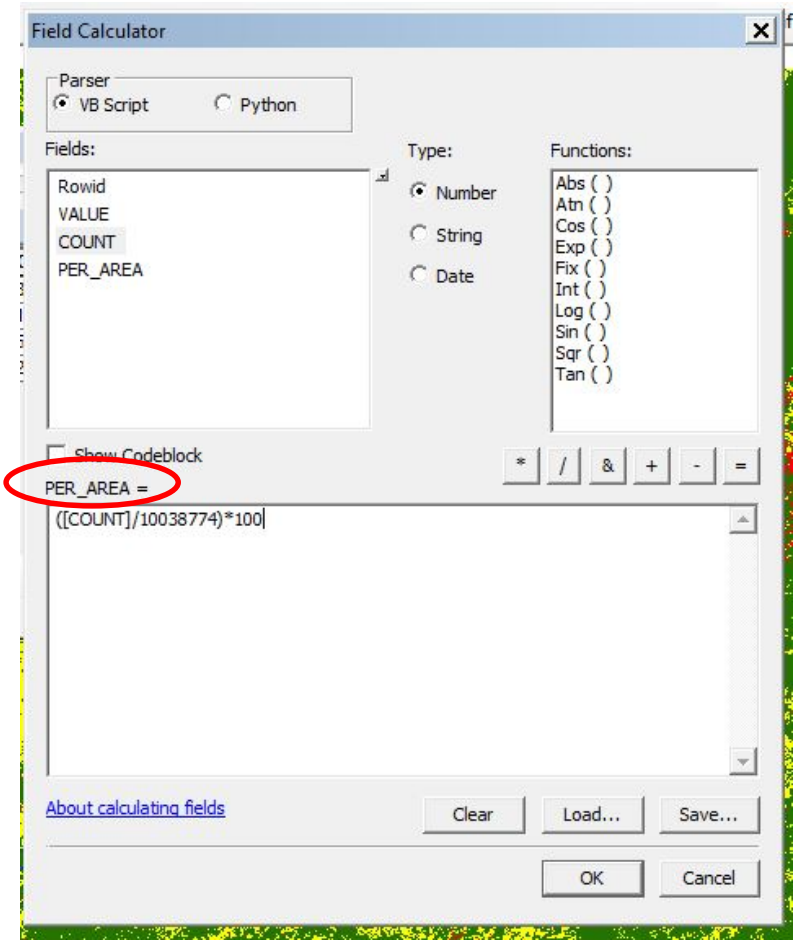
This adds a new field to your Attribute Table.



To calculate the value for the field: Right-click on the name of your new field, click on ***Field Calculator***.

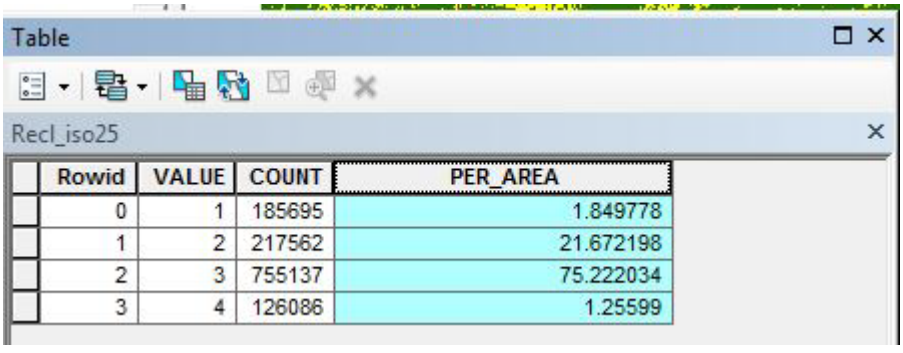


This dialog box opens. It shows you that you are calculating the value for your new field (red oval). Type the formula exactly as shown (remember from prior Tutorials, proper use of parentheses is essential).



Click ***OK***.

Open the ***Attribute Table.*** Now you have the percent for each informational class.



Rowid	VALUE	COUNT	PER_AREA
0	1	185695	1.849778
1	2	217562	21.672198
2	3	755137	75.222034
3	4	126086	1.25599

How accurate was your classification using the ***Iso Cluster Unsupervised Classification*** method and 25 classes? We will assess that in the tutorial on Accuracy Assessment. You may proceed directly to that tutorial or the next tutorial on Image Classification (Supervised).

19. Classification of a Landsat Image (Supervised)

The instructional materials contained within these documents are copyrighted property of VirginiaView, its partners and other participating AmericaView consortium members. These materials may be reproduced and used by educators for instructional purposes. No permission is granted to use the materials for paid consulting or instruction where a fee is collected. Reproduction or translation of any part of this document beyond that permitted in Section 107 or 108 of the 1976 United States Copyright Act without the permission of the copyright owner(s) is unlawful.

Introduction

In comparison to computer-controlled unsupervised classification, you have much closer control over the supervised classification process. In this process, you select pixels that represent patterns you recognize or can identify with help from other sources. Knowledge of the data, the classes desired, and the algorithm to be used is required before you begin selecting training samples. By identifying patterns in the imagery, you can "train" the computer system to identify pixels with similar characteristics. By setting priorities for these classes, you supervise the classification of pixels as they are assigned to class values. If the classification is accurate, then each resulting class corresponds to a pattern that you originally identified.

Supervised training requires *a priori* (already known) information about the data, such as:

- What information needs to be extracted? Soil type? Land use? Vegetation?
- What classes are most likely to be present in the data? That is, which types of land cover, soil, or vegetation (or whatever) are represented by the data?

In supervised classification, the user relies on her/his own pattern recognition skills and *a priori* knowledge of the data to help the system determine the statistical criteria (signatures) for data classification. To select reliable samples, the user should apply information (either spatial or spectral) about the pixels that they want to classify. The location of a specific characteristic, such as a land cover type, may be known through field observations that acquire knowledge about the study area from first-hand observation, analysis of aerial photography, personal experience, etc. Field data are considered to be the most accurate (correct) data available about the area of study. They should be collected at the same time as the remotely sensed data, so that the data correspond as much as possible. However, all field data may not be completely accurate because of observation errors, instrument inaccuracies, and human shortcomings. Global positioning system receivers are useful tools to conduct ground truth studies and collect training sets. Training samples are sets of pixels that represent what is recognized as a discernible pattern, or potential class. The system will calculate statistics from the sample pixels to create a parametric signature for the class.

You cannot assign every pixel value to a class. With your training data, you will identify many of the values and assign them to a specific class. But what happens with the unassigned pixels? In addition, some pixel values may fall into two classes – you've already encountered this situation in the unsupervised classification tutorial with respect to classification of water and the mountain shadows. In supervised classification, you will choose the method/algorithm that

decides how to assign these pixels. Different algorithms include (but are not limited to) minimum distance, maximum likelihood, Mahalanobis' Distance. Please see Campbell and Wynne (2011) for more information about supervised classification strategies.

Objectives:

- To perform a supervised classification on a Landsat image.
- To generate supervised signatures using training samples.
- To use histograms, scatterplots and statistics to evaluate normality, separability, and partitioning of training data

You have been working with a specific Landsat scene over several tutorials so should already be somewhat familiar with the area. If you feel you need more knowledge, take some time in Google Earth and explore the area covered by the Blacksburg, Roanoke and Smith Mountain Lake area. We will, again, be using that sub-set image in this Tutorial.

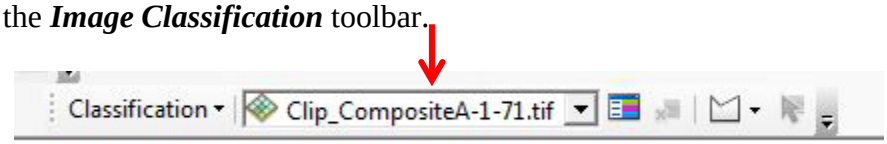
We will be using the same informational classes that we used in Tutorial 19, so as a reminder, the classes are:

Open water = 4, blue
Mixed agriculture = 2, yellow
Urban/built up/transportation = 1, red
Forest & Wetland = 3, green

Conducting Supervised Classification

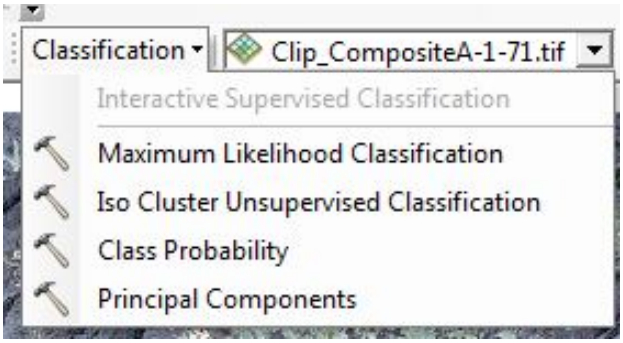
Open a new map document, enable the ***Spatial Analyst*** extension, the toolbars for ***Spatial Analyst*** and ***Image Classification***, and set your ***Workspaces***. Add the sub-set Landsat Image (created in the tutorial on Sub-setting Landsat Imagery) that includes Blacksburg, Roanoke, and Smith Mountain Lake.

Because you only have one raster dataset in your ***Table of Contents***, that is the dataset that shows in the ***Image Classification*** toolbar.



19. Classification of a Landsat Image (Supervised)

ArcGIS provides four supervised classification options:



Interactive

Maximum Likelihood

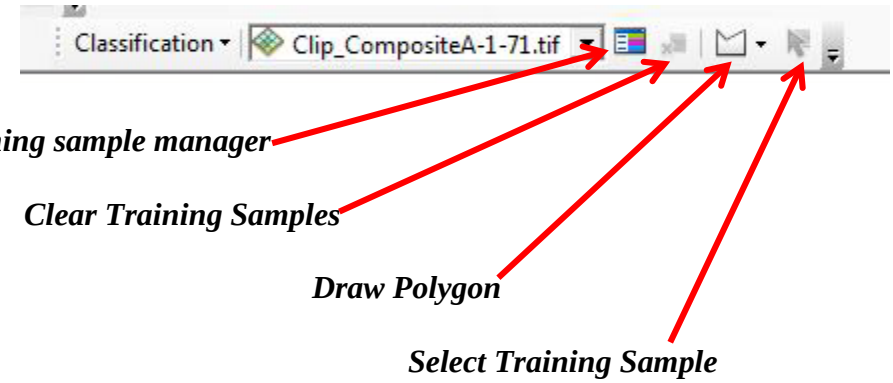
Class Probability

Principal Components

(Remember – ISO is unsupervised and was used in the prior tutorial).

Many other different methods are available for classifying Landsat Images in other programs. We are going to us Maximum Likelihood in this tutorial.

Let's explore some of the tools on the Image Classification toolbar that you will use:



Training sample manager allows you to see and change the properties of your training samples. We will go into more detail below.

Clear training samples deletes all training samples – be careful with this one, it does delete all of them if they have not been saved!

Draw Polygon – you use this tool to draw your areas of interest

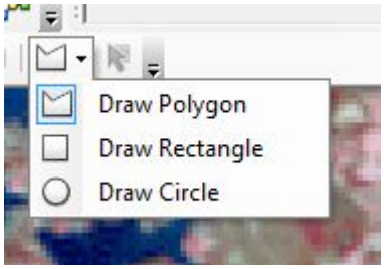
Select Training Sample – allows you to select one or more completed training samples

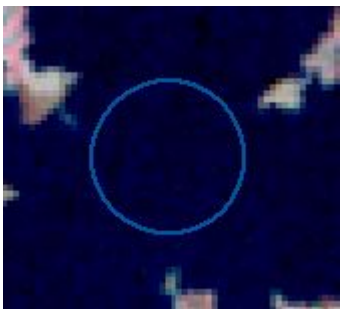
Some of these tools are not yet enabled but as soon as you create your first training sample, they will be.

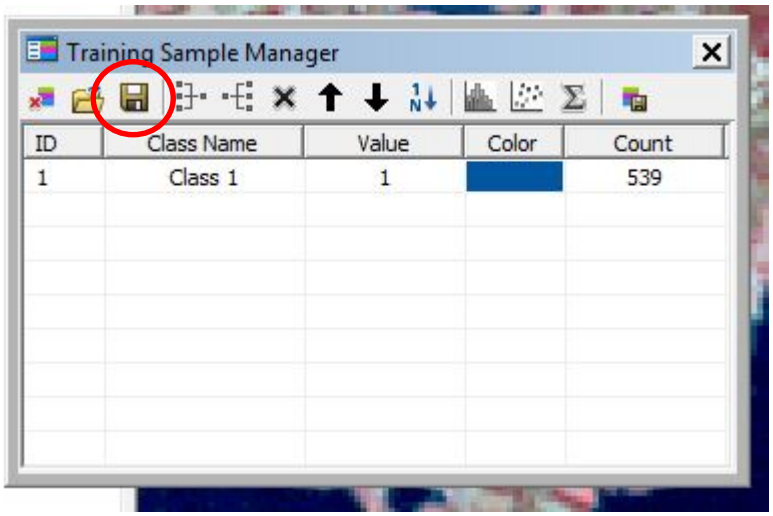
Creating Training Samples

We are going to start with identifying areas for the water class. (Remember, change your display with band combinations, contrast, Gamma, etc. as needed to help identify features in the scene.)

Zoom to Smith Mountain Lake region. Left-click on the down arrow next to ***Draw Polygon***. As you can see, this down arrow actually gives you three options to select regions on the image– ***Draw Polygon, Draw Rectangle, and Draw Circle***. Which one you choose is up to you, but experiment to find the one best-suited to your data. Left-click on ***Draw Circle*** --it gives you a + , which represents the center of a circle. Hold the left mouse button down and expand out creating a circle of the size you want. Be careful to stay away from shores of the lake. You can zoom in further, if necessary. This is your first training sample. All the buttons on the ***Image Classification*** tool bar are now enabled. Click on ***Training Sample Manager***.



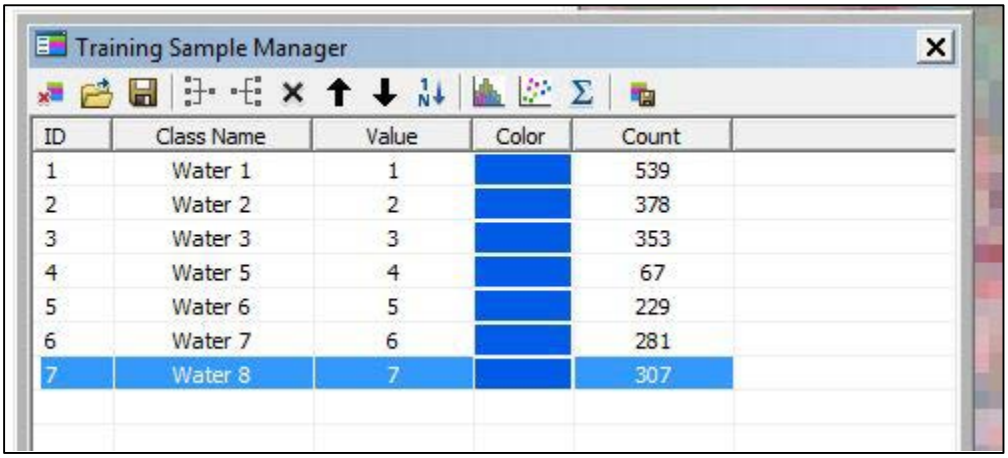




As you can see, you have one training sample, Class Name – Class 1, color blue and 539 pixels. Change the Class Name to water 1 (just click in the box and it highlights, type the word - Water). On your Training Sample Manager is a save button (red circle). You have to save your training samples separately from the map document. We recommend that each time you create a training sample, you save it. Saving your training samples allows you to stop at any time and finish your classification later. It also preserves your samples in case ArcMap closes.

Water is not characterized by just one spectral value. So use Smith Mountain Lake, your other water bodies – streams and ponds – to create multiple water training samples across the scene. Each time you create a sample, click on one of the ***Draw*** symbols, and rename it in your ***Training Sample Manager***, make sure all water is blue, and save it. (*Note – you do not need to do every single water body, but select a good sample of the different water spectral values*.)

Your Training Sample Manager may look something like this when you have finished with water.

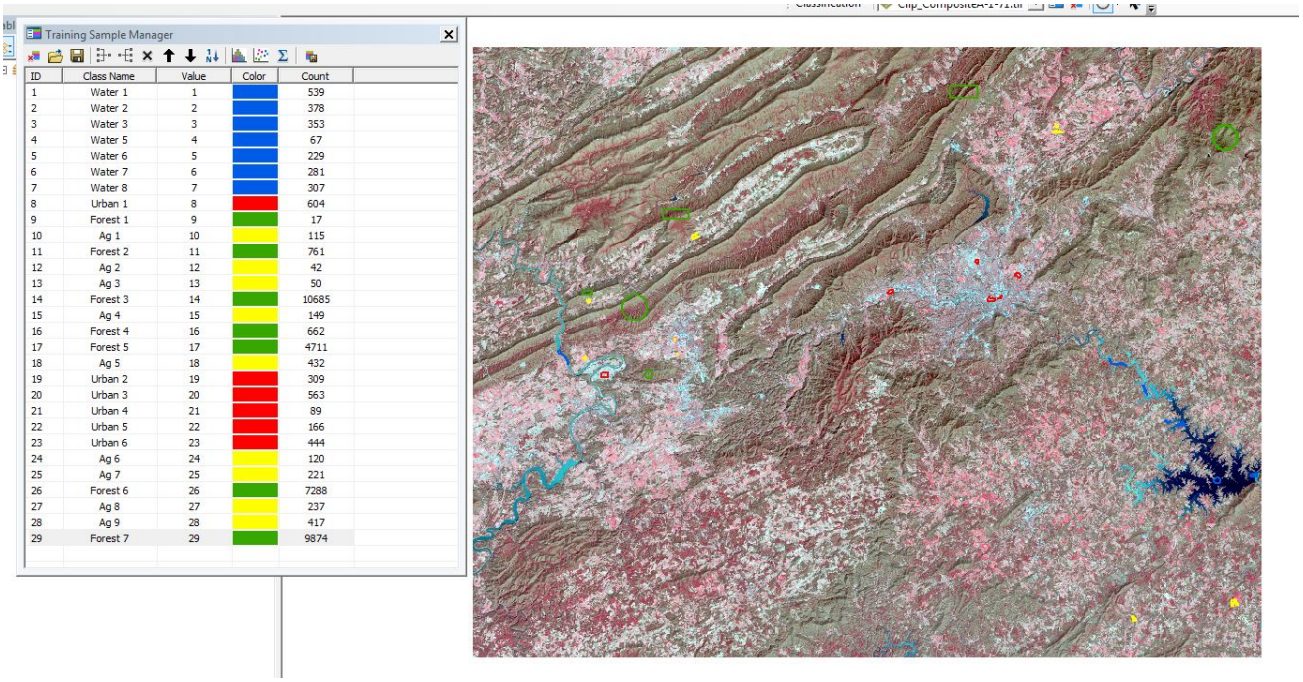


ID	Class Name	Value	Color	Count
1	Water 1	1		539
2	Water 2	2		378
3	Water 3	3		353
4	Water 5	4		67
5	Water 6	5		229
6	Water 7	6		281
7	Water 8	7		307

Now, do this for each one of the other three classes – agriculture, urban (developed) and forest. You do not need to do them one at a time, if you see pixels representative of all classes in one area, go ahead and do a training area for each one. Make sure you don't select all of your training data from one area, distribute them across the scene. If you don't like one of the training samples that you selected, just highlight it within the training sample manager, and click the delete button.

Don't worry if you have gathered classes with pixel values that may overlap spectrally. We will evaluate that situation before we do the actual classification.

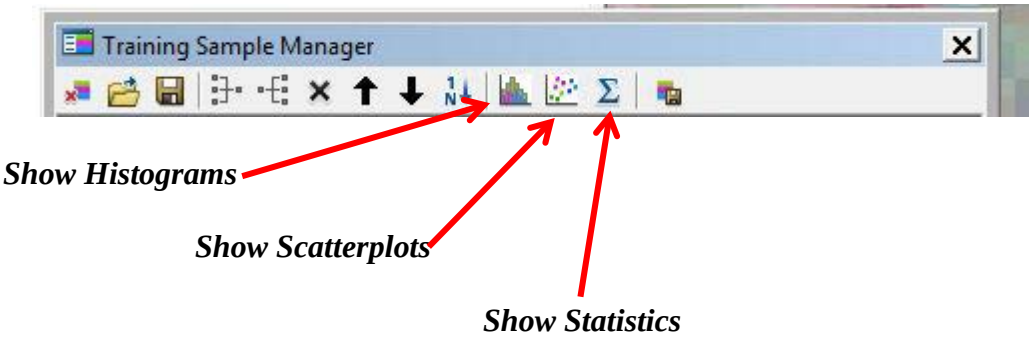
When you think you are finished, zoom to the full extent of the scene and take a look. Do you have training areas in different areas of the scene? Have you taken into account, the different forested areas – conifers, shadows, leaf-off, and deciduous? What about the different levels of plant growth in agriculture? As you can see from the ***Training Sample Manager***, we have a range of pixel counts in our different training areas. Again, don't worry about these yet.



Once you are satisfied with your training areas, proceed to the next section.

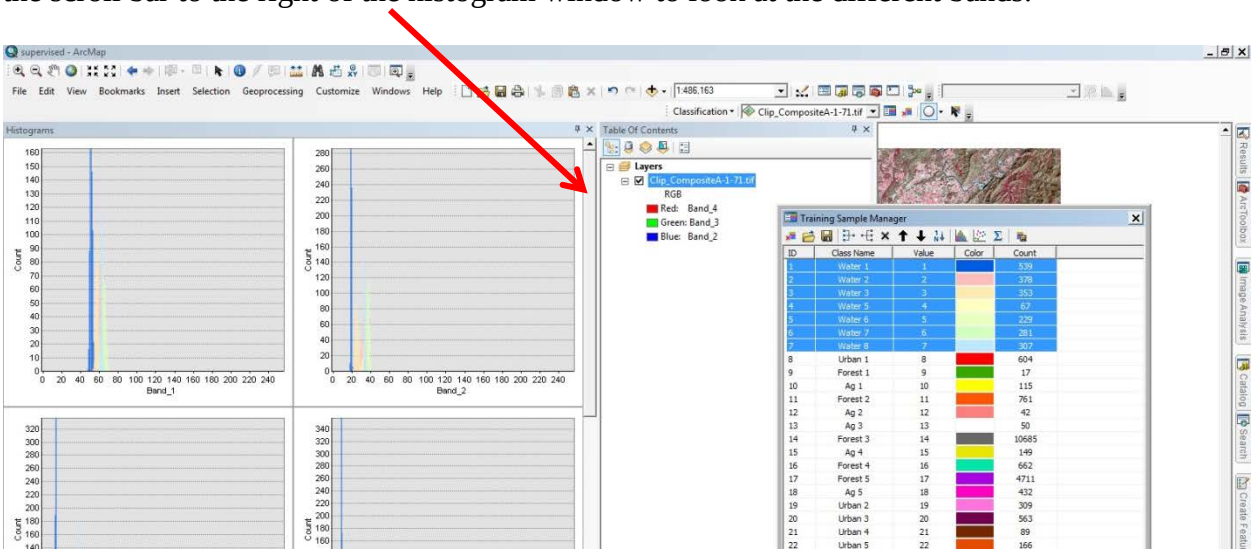
Evaluating Normality, Separability and Partitioning

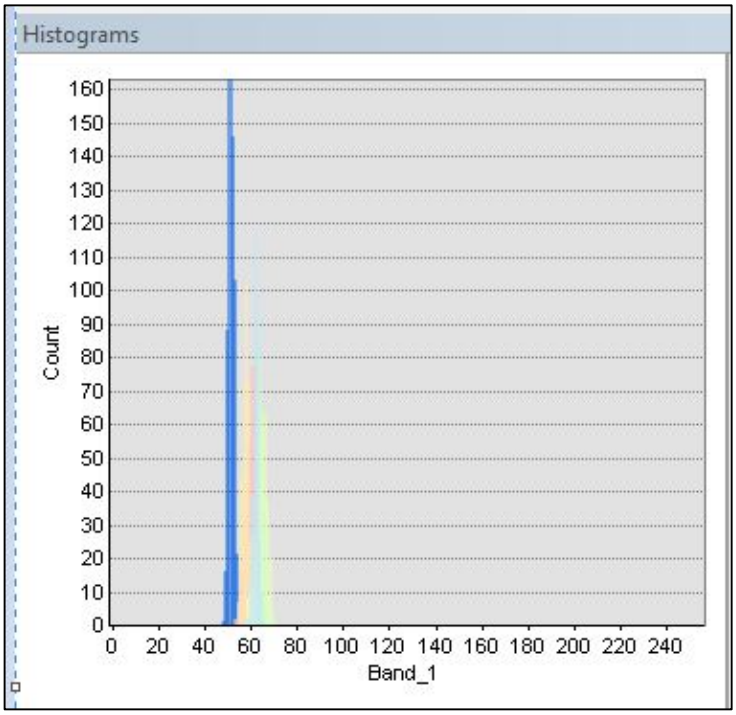
We are going to use three buttons at the top of the training Sample Manager window.



As you recall from other Tutorials, a histogram is the distribution of the number of pixels with respect to pixel values. You can look at one training sample at a time, or highlight many at one time, for instance -- all of water. Once you have highlighted the training sample row, click on the Histogram button. Give ArcMap a moment to build the histograms.

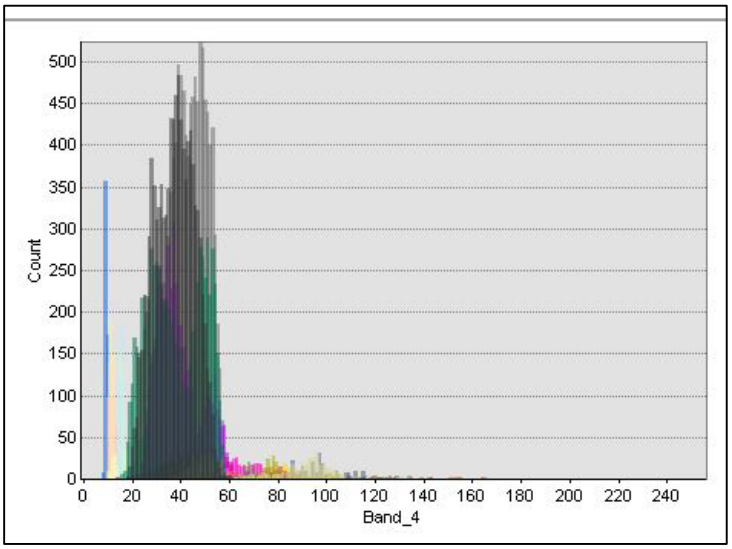
ArcMap opens the histogram window to the left of the ***Table of Contents***. You can use the scroll bar to the right of the histogram window to look at the different bands.





For this illustration, each of our water training samples is a different color. When examining each band (here, only Band 1 is illustrated), we do not see any overlap in the colors and the distributions appear to be normal.

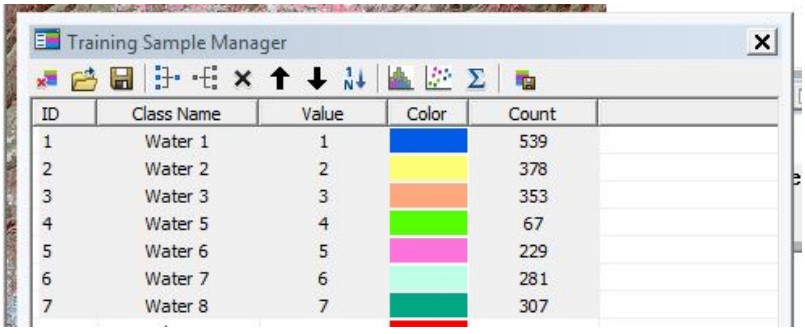
Examine each of your classes for normality. Do you need to add any training data to any of your classes? Your training data for each class may not cover the entire range of brightness values, so you don't need to be concerned that our water class appears only to range from about 50 – 70.



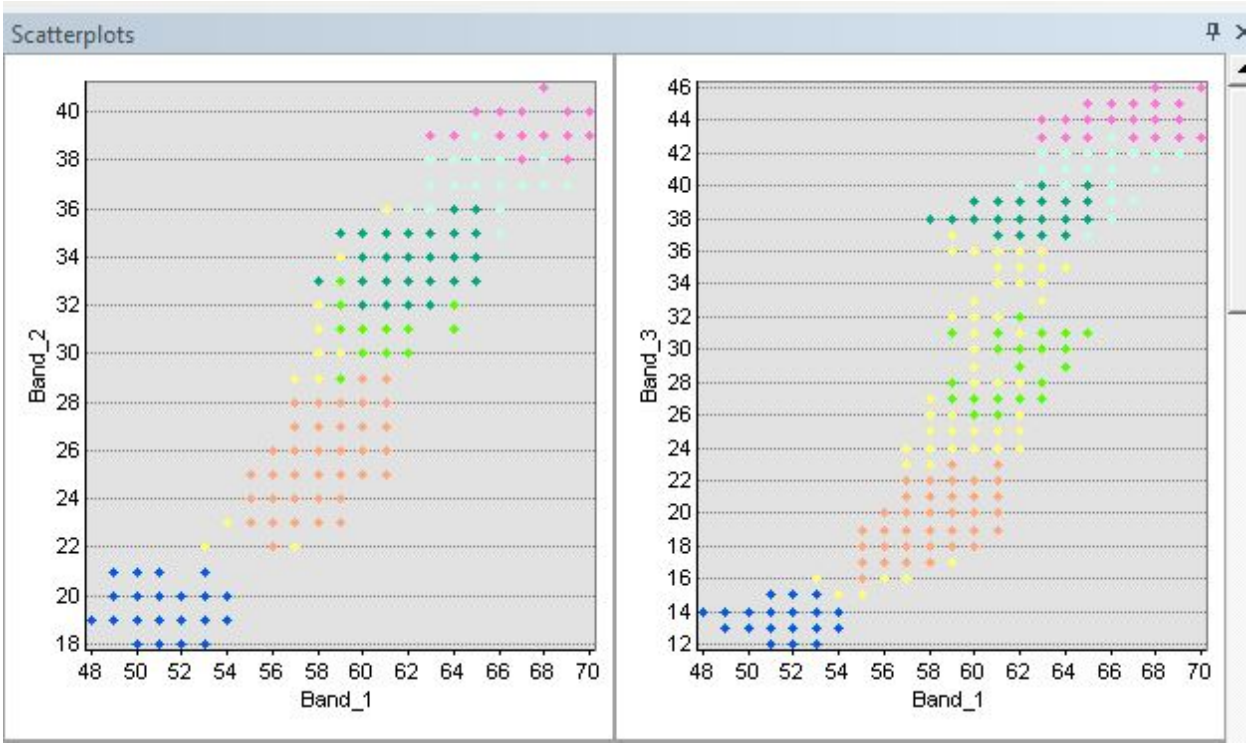
For illustration purposes only, we added all training samples to this histogram (again, each has a different color). What else might this histogram tell us? Some of our colors are overlapping, so we may have some training data that can be merged or deleted. We will evaluate those using the scatterplots.

Scatterplots plot the pixel values of your training data in one band against those of another. Viewed as scatterplots, the points should not overlap if the training samples represent different spectral classes. First, you should look at each individual class to see if there is any overlap and any opportunities to merge or delete training samples. (Note – when you merge training samples, you are changing the statistics, the mean, etc. If you merge training samples that are not overlapping or overlap just a little, you greatly alter the training sample and may lose some of the values within that class. As such, when you finish your evaluation, you very likely will have multiple rows of training data for each class.)

Highlight rows of water and the click on Scatterplots. Again, ArcMap opens a window on the left side of the ***Table of Contents***, this time for Scatterplots. There are many plots because is it comparing each band to another band. You

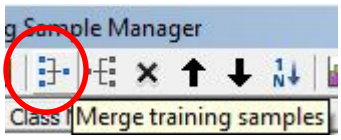


may need to change the colors within the ***Training Sample Manager*** to see the different samples.

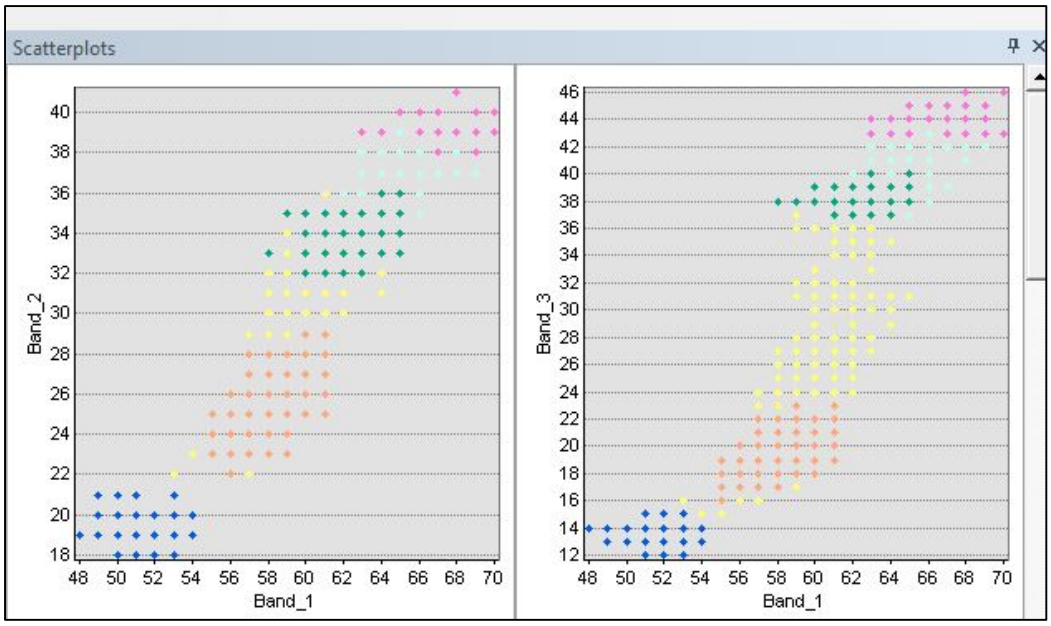


As you can see, it appears we may have some overlap in some of the training samples. (Note – here, we are only showing two of the scatterplots, but within others, we noticed the same effect.) This result indicates that we can possibly merge some of our training data. Let's start with the yellow and light green. Once we merge them, we will redo the scatterplots to see how they changed. Before you merge, save your training file – that way, if the merge was not positive, we can reload the training data as it was before the merge.

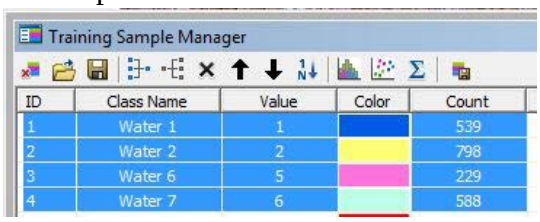
To merge, highlight the two rows. Notice as you did this, the scatterplots change and only show those two sets of data. Left-click on ***Merge training samples*** button. It merged the two waters into one, you know this because the scatterplot display changed and you have one less water training sample. Now redisplay all the waters. Just highlight them all and the scatterplots will automatically change.

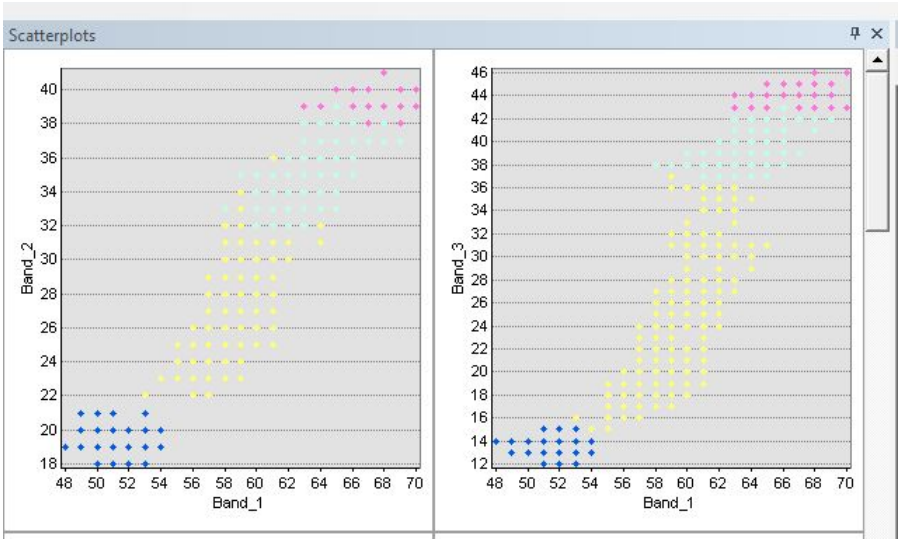


We are going to do at least one more. Let's try the yellow and the salmon together. Separately, do the cyan with the dark green. If you are merging multiples, do them one at a time. *(Note – your scatterplots may look different and may not need additional merging.)*



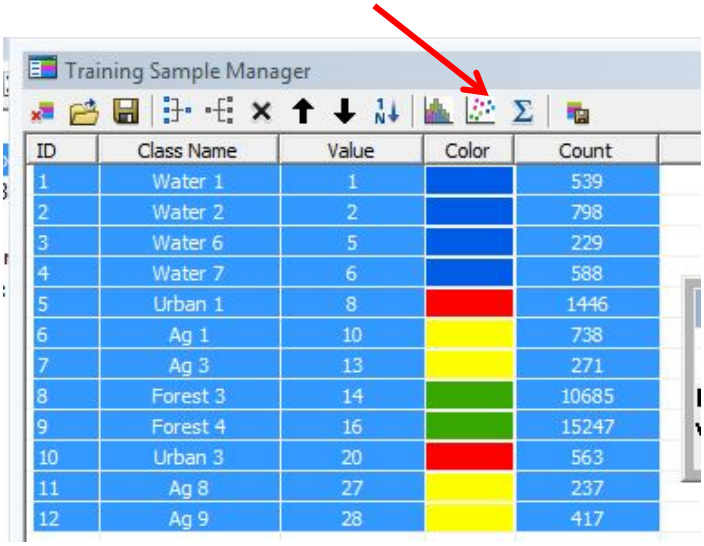
Water is looking pretty good, with very little to no overlap. We started with seven training areas for water -- after merging we have only 4. Change all the colors for water to blue. Save!





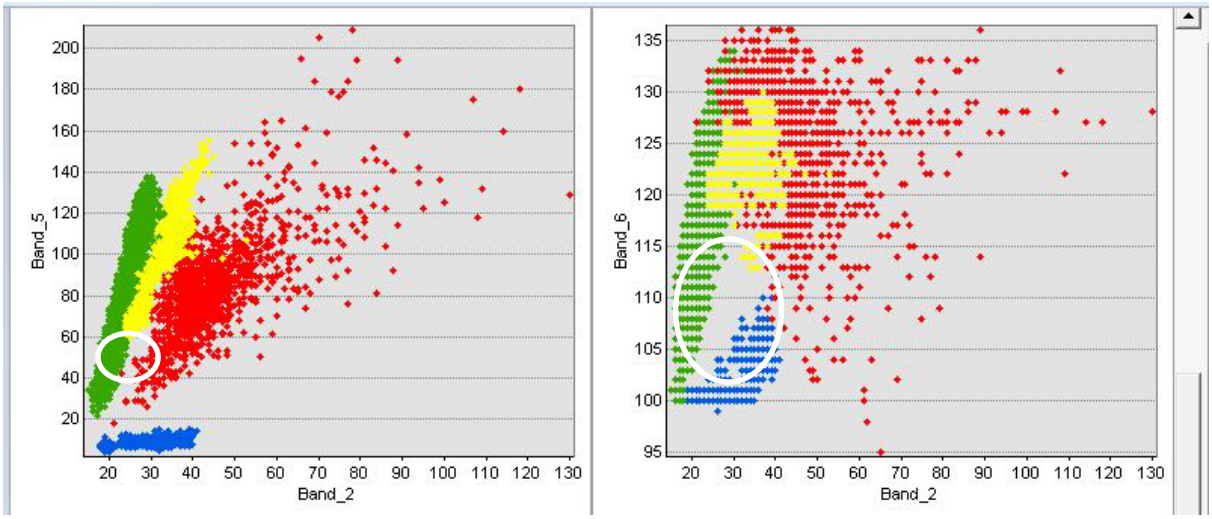
Now do this for your other three classes. Once you have finished evaluating all four classes, we will need to compare the classes to each other.

When we started, we had 29 training samples. Once we completed merging and deleting, we had 12 left (*Note - yours will likely differ*). Highlight all of your training samples so they all display on the scatterplots. Click on the ***Scatterplot*** button

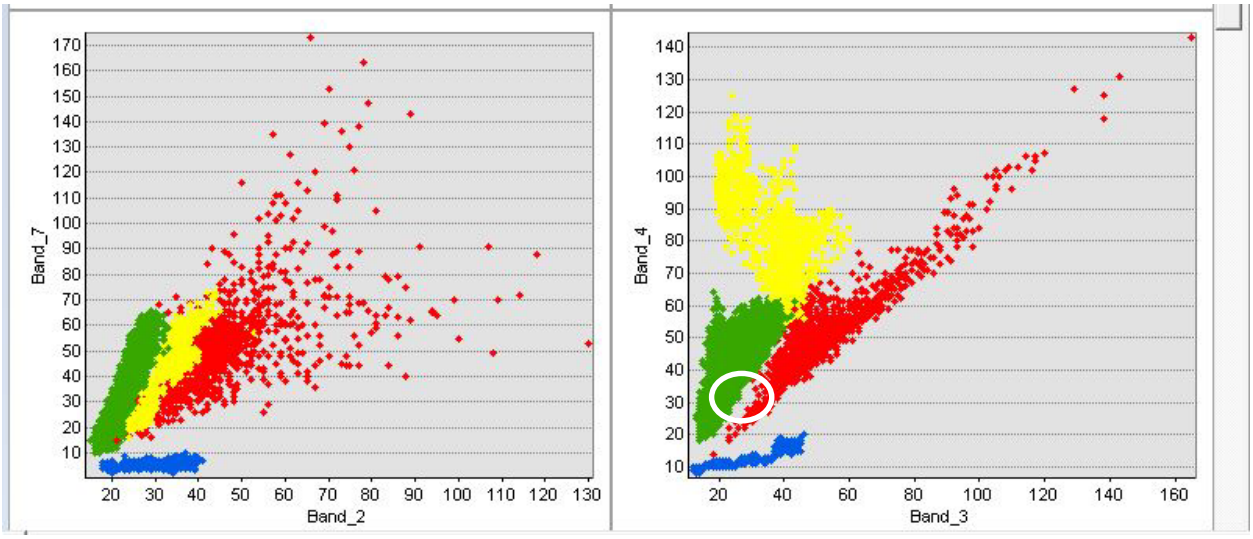


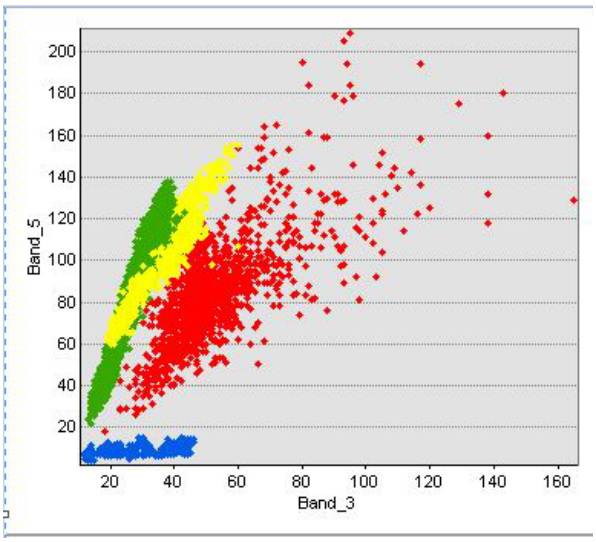
ID	Class Name	Value	Color	Count
1	Water 1	1		539
2	Water 2	2		798
3	Water 6	5		229
4	Water 7	6		588
5	Urban 1	8		1446
6	Ag 1	10		738
7	Ag 3	13		271
8	Forest 3	14		10685
9	Forest 4	16		15247
10	Urban 3	20		563
11	Ag 8	27		237
12	Ag 9	28		417

In the following screenshots, we are only showing you a sample of ours. But, again, you are looking for overlaps or training data for one class that is within another.



You may see results such as in Bands 2 and 5 (above right) or 2 and 7 (below left), or





even 3 and 5 (left) -- areas that look suspiciously like possible overlaps. You can effectively evaluate these by adding your rows of training data one at a time and watch the display as it changes. (*Note - water should be separate from the other classes, except for instances of flooding and high turbidity*).

You should also look for areas of missing data (white circles). We do have a couple of areas with missing training data that could cause us some problems when doing classification, but this is a small area (comparatively). If you fill in too much, you may create areas with significant overlap.

We have one more item to check before we perform our classification – Statistics. Statistics shows measures that characterize your training data (such as mean, mode, etc.) and covariance. Covariance evaluates the correlation of values in the different bands. Low values indicate that the values in a pair of bands tend to increase and decrease independently. High

values indicate that the values in the two bands tend to increase and decrease together— a high covariance. For effective classification, we prefer to see low covariances, indicating that the training data are providing independent information (i e., the data from the training fields are not replicating each other).

Close your scatterplot window, leave all rows in the ***Training Sample Manager*** highlighted and click on the ***Statistics***' button. ArcMap opens a window to the left of the ***Table of Contents.*** You get a statistics matrix for each of your training data rows. Check the covariance for each one. If you have evaluated your histograms and scatterplots effectively, you should not see any high numbers within these matrices. Numbers close to 2,000 mean that the bands are highly correlated to each other. If you see any high numbers, you should proceed back and re-evaluate your training data.

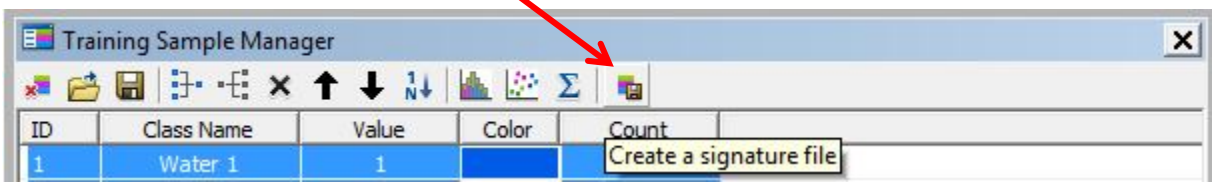
If you are satisfied with your results, save your training data one last time.

Statistics

Band_7	169.06	102.39	133.01	98.59	271.08	-25.30	228.63
Ag 1							
Statistics	**Band_1**	**Band_2**	**Band_3**	**Band_4**	**Band_5**	**Band_6**	**Band_7**
Minimum	61.00	26.00	31.00	52.00	94.00	113.00	36.00
Maximum	95.00	53.00	60.00	109.00	155.00	129.00	73.00
Mean	69.22	35.37	42.43	74.63	118.55	122.19	52.46
Std.dev	3.48	2.71	4.59	10.49	11.60	2.52	6.28
Covariance							
Band_1	12.12	8.19	13.31	8.79	28.74	1.89	14.55
Band_2	8.19	7.35	11.04	11.13	23.19	0.24	11.42
Band_3	13.31	11.04	21.08	3.43	44.03	0.45	24.31
Band_4	8.79	11.13	3.43	110.03	20.33	1.85	-7.07
Band_5	28.74	23.19	44.03	20.33	134.65	11.13	67.45
Band_6	1.89	0.24	0.45	1.85	11.13	6.36	4.08
Band_7	14.55	11.42	24.31	-7.07	67.45	4.08	39.43
Ag 3							
Statistics	**Band_1**	**Band_2**	**Band_3**	**Band_4**	**Band_5**	**Band_6**	**Band_7**
Minimum	55.00	24.00	22.00	68.00	70.00	117.00	26.00
Maximum	69.00	37.00	48.00	125.00	128.00	124.00	60.00
Mean	59.79	30.08	30.81	96.17	94.79	120.53	36.15
Std.dev	2.58	2.15	4.72	10.21	10.12	1.16	6.91
Covariance							
Band_1	6.66	4.20	10.00	-13.72	19.76	0.09	13.64
Band_2	4.20	4.62	9.33	-10.57	19.22	0.57	13.17
Band_3	10.00	9.33	22.31	-31.84	44.10	0.68	31.12
Band_4	-13.72	-10.57	-31.84	104.31	-59.70	0.59	-49.55
Band_5	19.76	19.22	44.10	-59.70	102.42	3.77	66.49
Band_6	0.09	0.57	0.68	0.59	3.77	1.36	1.79
Band_7	13.64	13.17	31.12	-49.55	66.49	1.79	47.70
Forest 3							
Statistics	**Band_1**	**Band_2**	**Band_3**	**Band_4**	**Band_5**	**Band_6**	**Band_7**
Minimum	45.00	17.00	14.00	22.00	28.00	107.00	11.00
Maximum	68.00	32.00	40.00	64.00	138.00	134.00	66.00
Mean	55.26	23.80	25.93	42.91	77.70	120.66	35.23
Std.dev	3.82	2.78	5.81	7.69	26.28	5.57	12.71
Covariance							
Band_1	14.60	9.83	20.84	21.38	93.56	16.42	45.12
Band_2	9.83	7.71	15.50	17.62	69.87	12.91	33.31

Preparing the Signature File

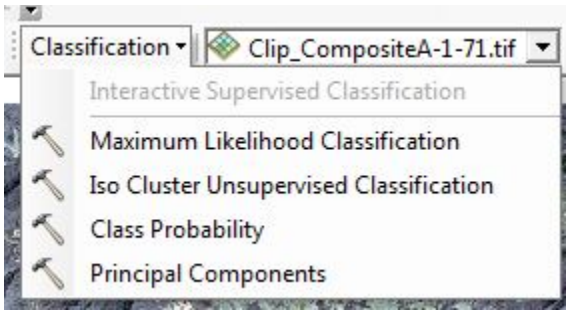
We have one last step before performing the classification. We need a signature file created from our training data. Highlight all the rows in your ***Training Sample Manager*** and left-click on the ***Create a signature file*** button.



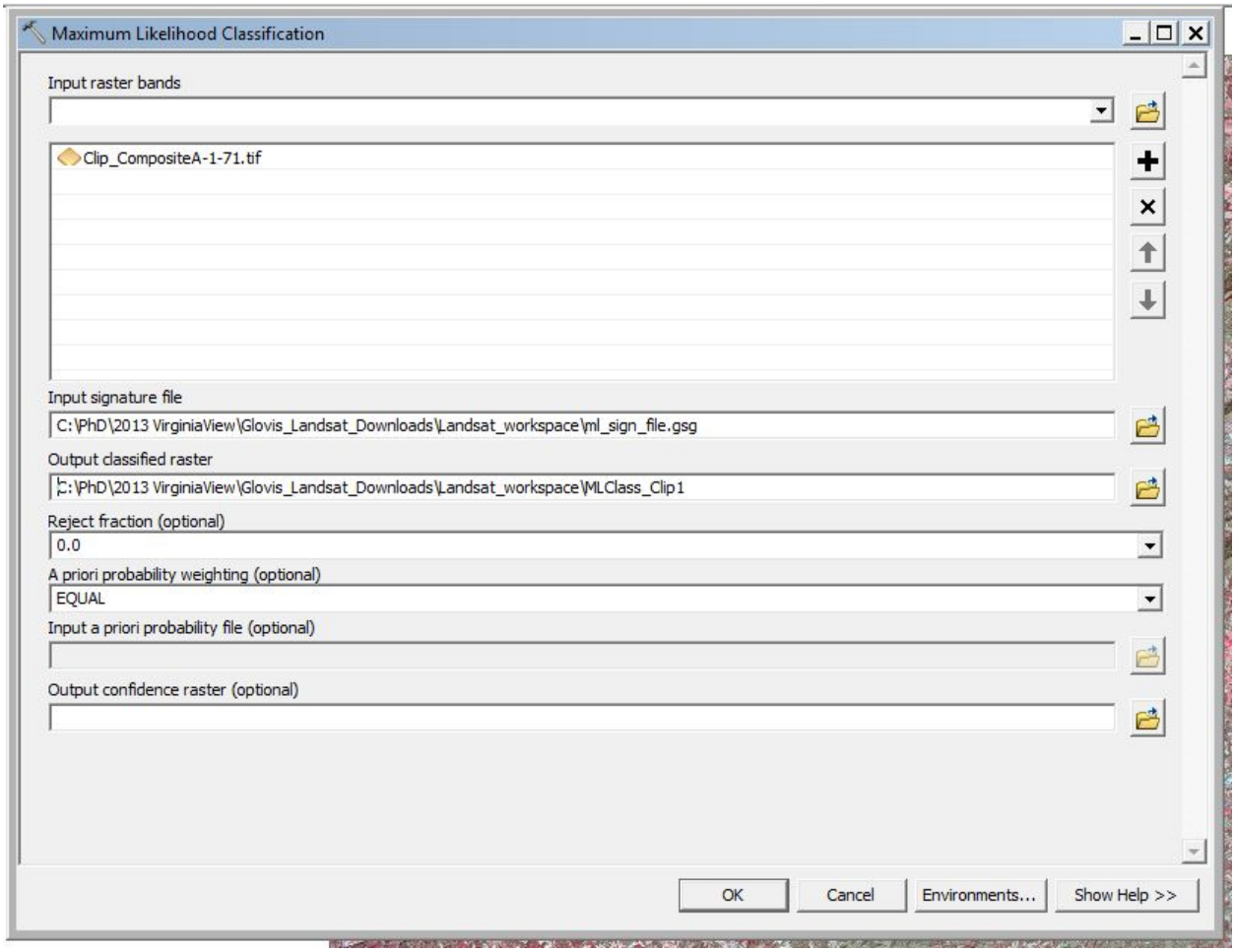
This will take you to a window to save and name your file. *(Note - even though you set your workspaces earlier, you may still need to navigate to your workspace to save and name your file.)* Once saved, go ahead and close the ***Training Sample Manager*** window. Click on the ***Clear Training Samples*** button and this will clear the training samples displayed in the map document.

Performing a Supervised Classification

Left-click on the down arrow next to classification and click on ***Maximum Likelihood Classification***.



You will get the dialog box at the top of the next page. Since your image is the only one in your map document, it defaults into the dialog box. Navigate to where you saved your signature file and add it to the dialog box, name your new output file, and leave the rest of the information as the default settings. (*Note - if you wish to change any of these, remember when you click on the line, the help window on the right explains the field.)* Click ***OK***.



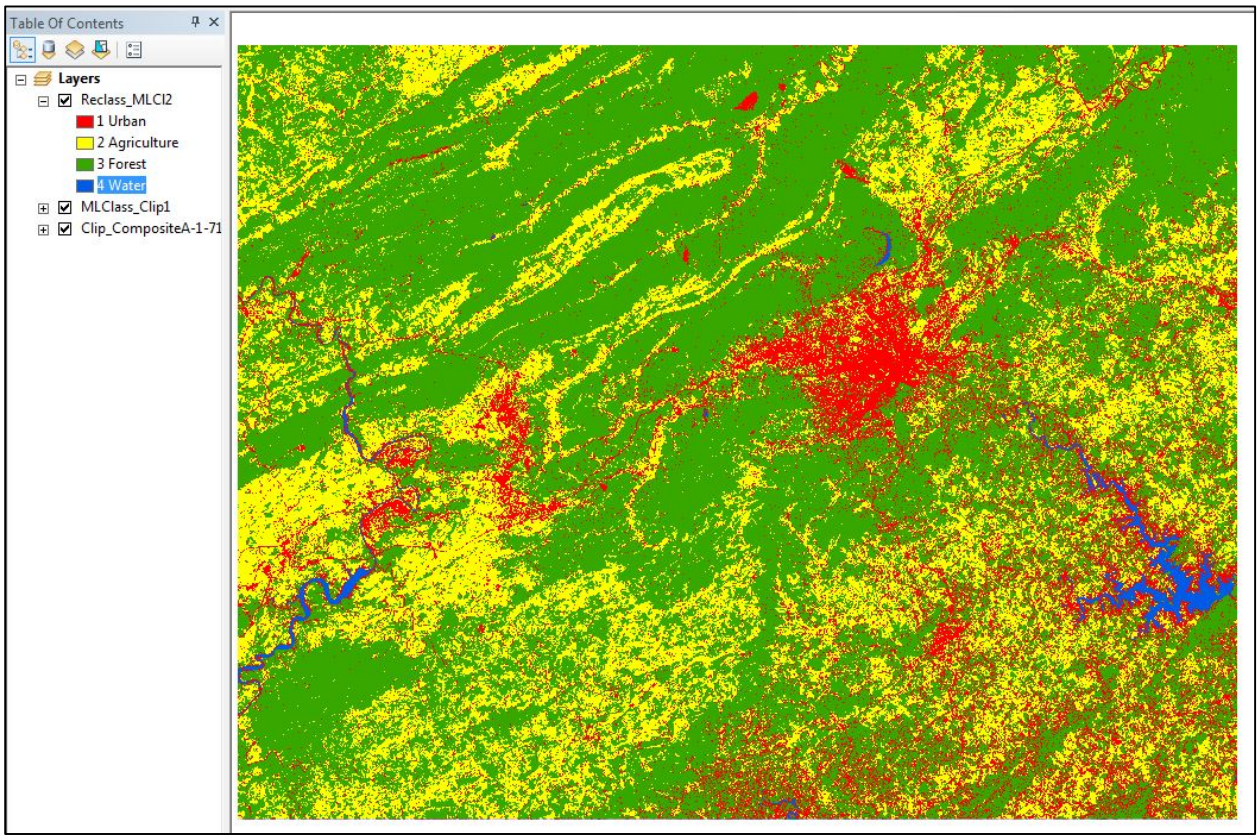
Your new file is automatically added to the ***Table of Contents*** and map document window. Because we had 12 training data sets, we have 12 categories. The colors are automatically set by ArcMap, so they don't correspond to our color set.

Reminder:

Open water = 4, blue
Mixed agriculture = 2, yellow
Urban/built up/transportation = 1, red
Forest & Wetland = 3, green

So, we will need to set the colors and do a ***Reclassify*** (as we did in the tutorial on Classification of a Landsat Image (Unsupervised). So, first set the colors to correspond to above

and then use the ***Spatial Analyst Tools/Reclass/Reclassify*** to classify into the 4 informational classes.



Calculating the Percent of Total Area for Each Informational Class

Now calculate the percent of total landcover for each informational class (just as you did in the last tutorial).

Table

Reclass_MLCI2

Rowid	VALUE	COUNT	PERCENT_TOTAL
0	1	132858	13.234534
1	2	260322	25.931663
2	3	601920	59.959543
3	4	87765	0.87426

How accurate was your classification using the ***Maximum Likelihood Classification*** method? We will assess that in the tutorial on Accuracy Assessment. You are now ready to proceed to that tutorial.

20. Accuracy Assessment

The instructional materials contained within these documents are copyrighted property of VirginiaView, its partners and other participating AmericaView consortium members. These materials may be reproduced and used by educators for instructional purposes. No permission is granted to use the materials for paid consulting or instruction where a fee is collected. Reproduction or translation of any part of this document beyond that permitted in Section 107 or 108 of the 1976 United States Copyright Act without the permission of the copyright owner(s) is unlawful.

Introduction

Accuracy Assessments are performed on classified images to determine how well the classification process accomplished the task. Accuracy Assessments are performed on unsupervised and supervised classification methods and should always be included in your project report. An accuracy assessment compares your classified image to an image which is assumed to be correct (such as an aerial photo).

This task is accomplished by compiling an error matrix. An error matrix is a table of values that compares the value assigned during the classification process to the actual value from an aerial photo. These are compared on a point-by-point basis. A random set of points is generated for the region covered by the area. Then using the aerial photos, the value for each point is identified. Then, these same random points are used to identify each point's known value in the classified image. The error matrix table is completed by comparing these two values. The accuracy assessment process will become clearer as we proceed step-by-step.

An important component of accuracy assessment, Cohen's kappa co-efficient is calculated from the error matrix. Kappa tells us how well the classification process performed as compared to just randomly assigning values, i.e. did we do better than random.

This tutorial provides a step-by-step process for performing an accuracy assessment by completing an error matrix, then calculating Kappa.

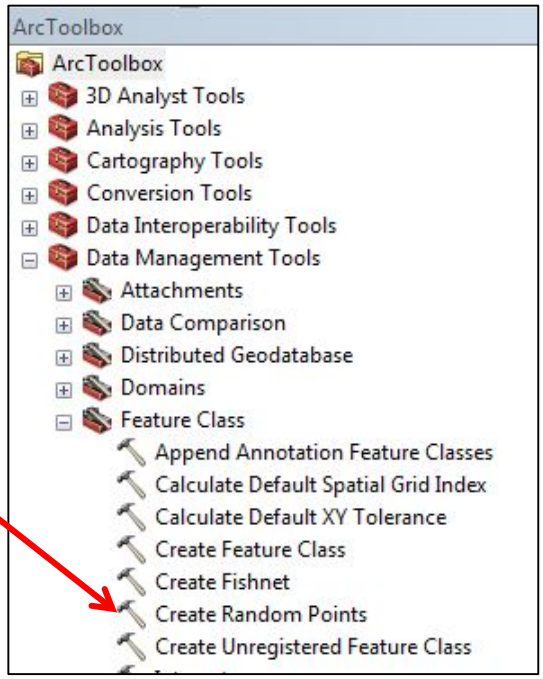
For more details on Accuracy Assessments and Kappa see Campbell and Wynne (2011).

Generating a Set of Random Points

Open a new ArcMap document and add the sub-set image of Blacksburg, Roanoke, and Smith Mountain Lake. Then add the two classified images that you created from the two tutorials on image classification. Don't forget to set your workspaces! (*Note- when loading*

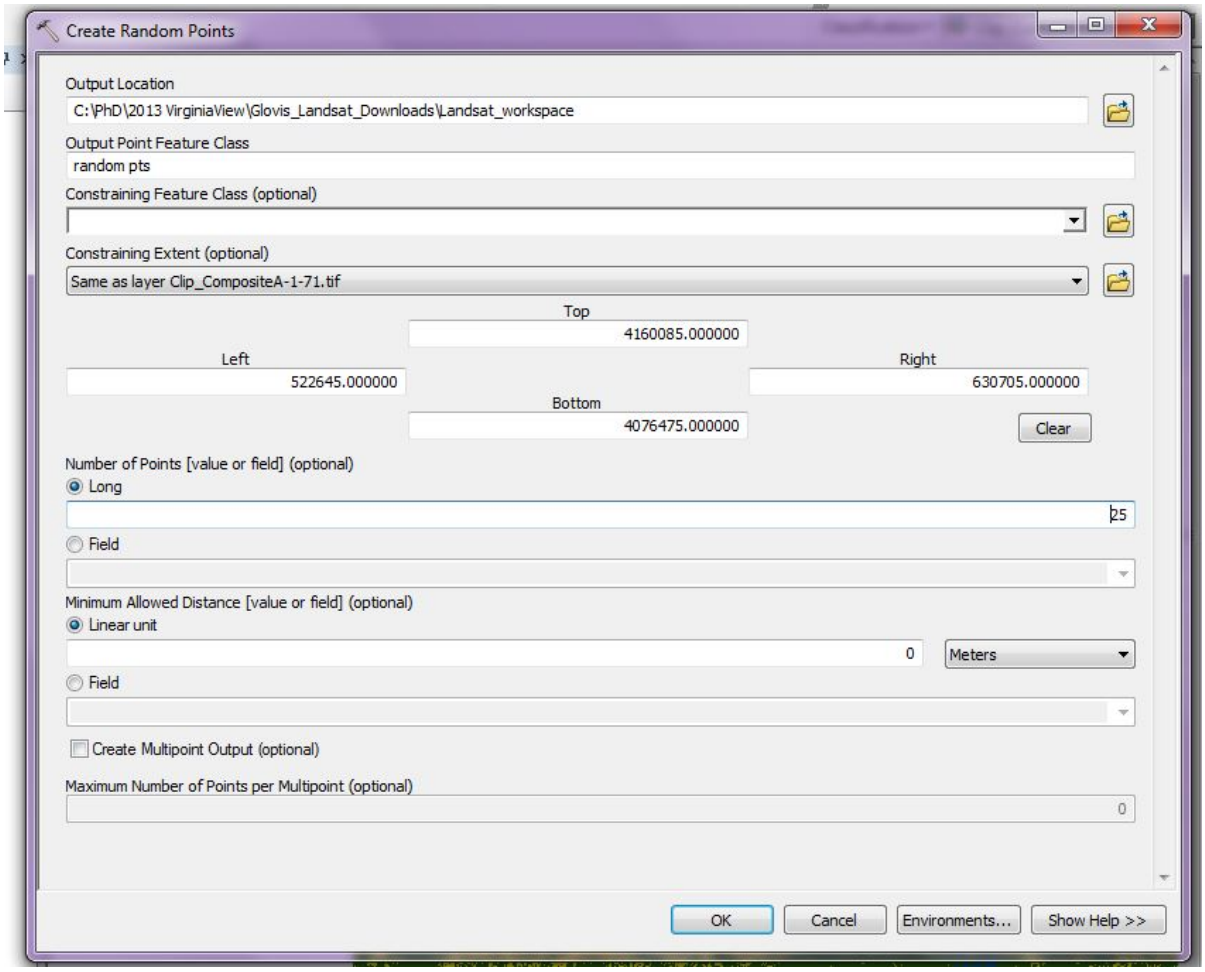
your classified images, your colors may change, don't get upset, ArcGIS randomly assigns colors. You can change the colors as needed.)

Next open your Toolbox and go to ***Data Management Tools/Feature Class/Create Random Points.***



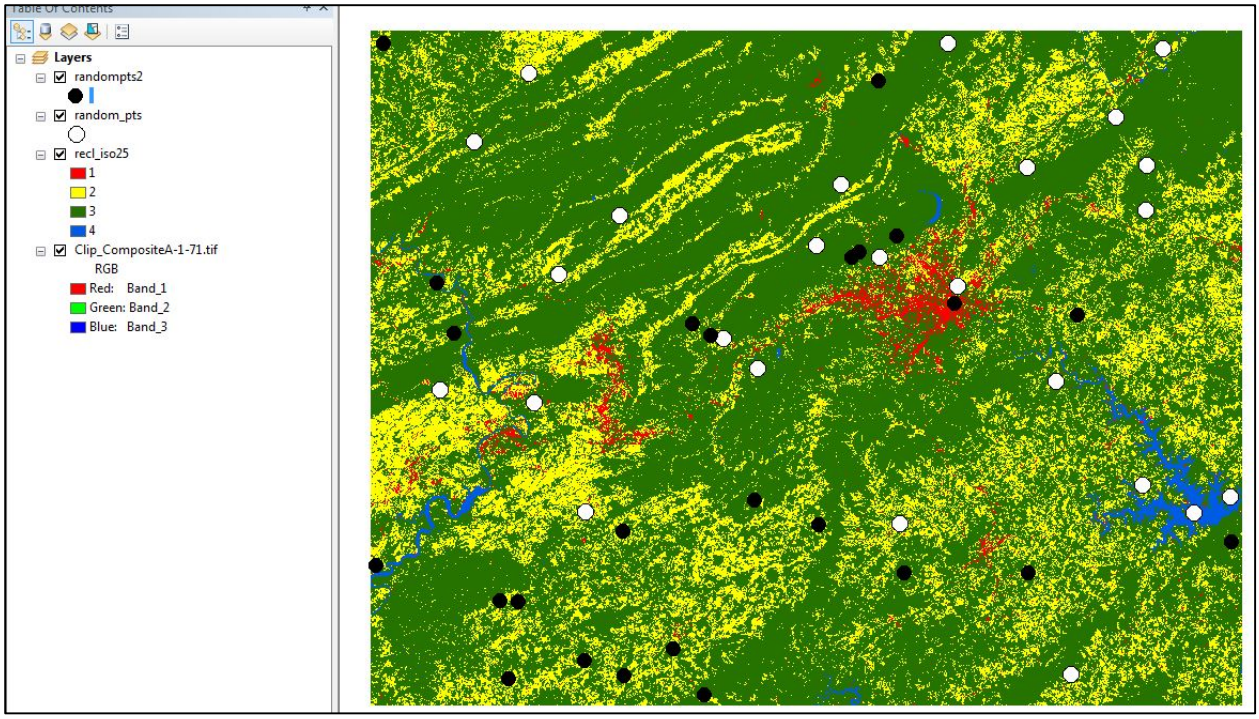
In the ***Create Random Points*** dialog box, name your ***Output Point Feature Class*** (this will be the file that has the random points), set your ***Constraining Extent*** to the sub-set image, and the number of random points to 25. If you have a vector shape file that you wish to use to limit the region of your random points (i.e. just to the City of Roanoke), you would use ***Constraining Feature Class*** instead of ***Constraining Extent***. These two inputs are used to keep your random points within a specific boundary.

We used 25 random points. (No, this number is not sufficient for an actual project). For an actual project, the number of points should be much higher. We are now using 25 just to illustrate how to complete the error matrix because identifying values for a larger set of random points value is too time-consuming for this exercise.



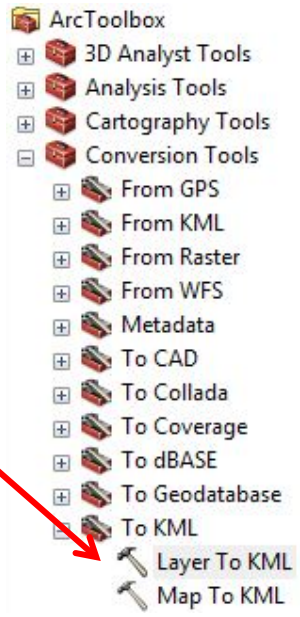
If your dialog box looks as above, click ***OK***.

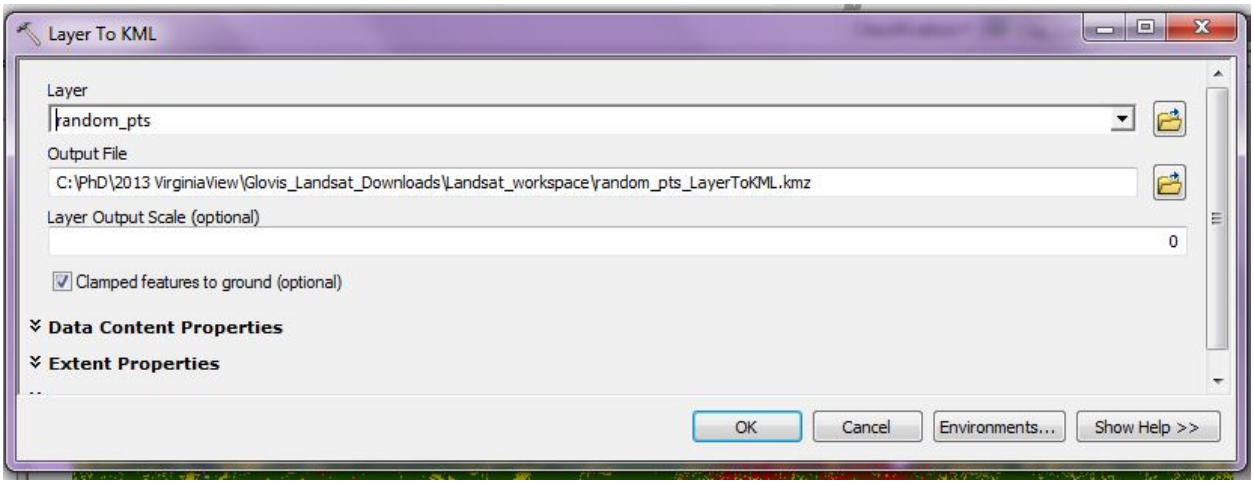
ArcMap adds the new vector point file to your ***Table of Contents*** and the random points to the map document. Just to show you that the random points generated using ArcGIS are indeed random, we completed a 2nd set – our first set is white points and the second black points. (*Note- your points will not be as large as those shown here- we have changed the symbology so they could be seen easier*.)



Identifying Each Random Point's Value from Aerial Imagery

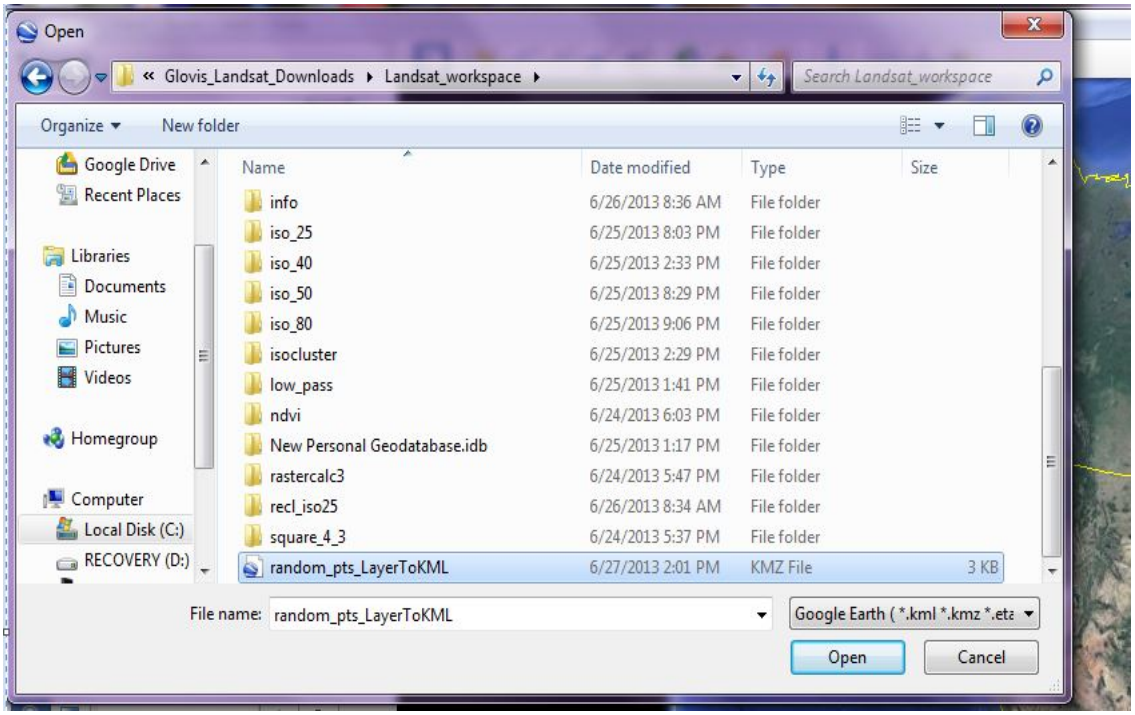
We are going to use Google Earth as the reference image with which to identify each random point's value. To do this, we need to export the file into .kml file so we can view it in Google Earth. Go to your Toolbox, ***Conversion Tools/To KML/Layer to KML.***



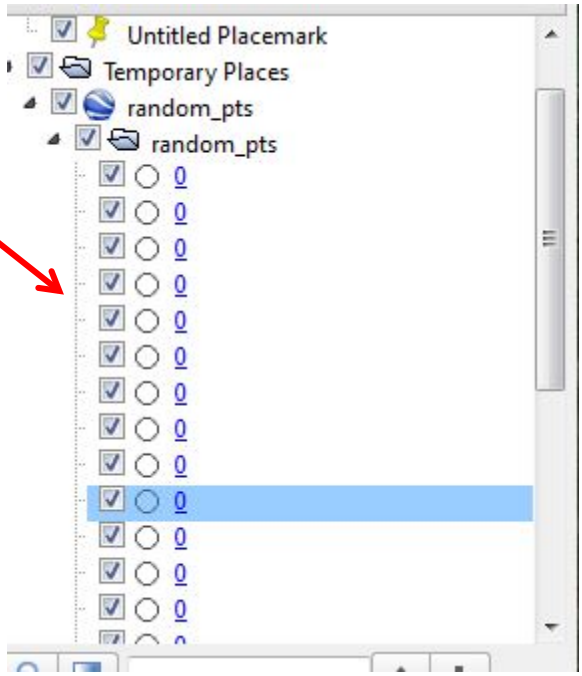


Enter your random points file as the ***Layer*** and then name your new .kml file. Note – ArcMap will not add it as a layer to your ***Table of Contents***. We don't need it there.

Open Google Earth. Once it is open, go to ***File/Open*** and navigate to your workspace. Double-click on your .kml file and then click open to add it to Google Earth. Use the Google Earth Image date that is closest to your Landsat date (March 2011).



Google Earth will add it to the map and also zoom to the area of your random points. You may need to change the symbology in Google Earth to see them.



If you left-double-click on any of the points in the list, Google Earth will zoom to the point. As you do so, Google Earth will display the FID number, so you know which point in your vector shapefile the point references. You can then add the value to the attribute table of your random points shapefile in ArcMap.

Adding the reference value to your Random Points shapefile

You will need to add a field in your ***Attribute Table*** in ArcMap so you can enter each point's value.

Remember our values from the image classification tutorials?

Open water = 4, blue
Mixed agriculture = 2, yellow
Urban/built up/transportation = 1, red
Forest & Wetland = 3, green

After identifying values for each point by examining the aerial photos, you will have a reference set against which to compare your classifications. The ***Attribute Table*** for your random points file and the reference image should look like this.

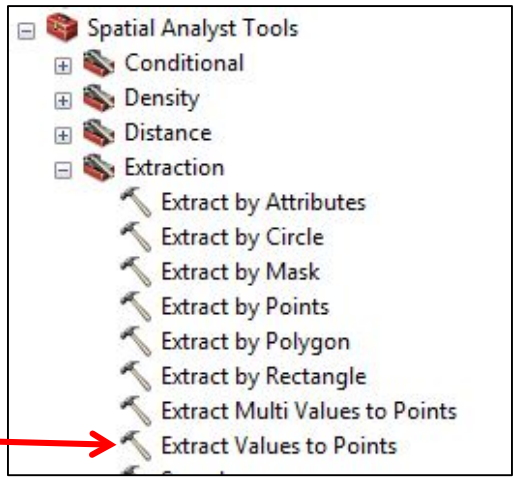
Table

random_pts

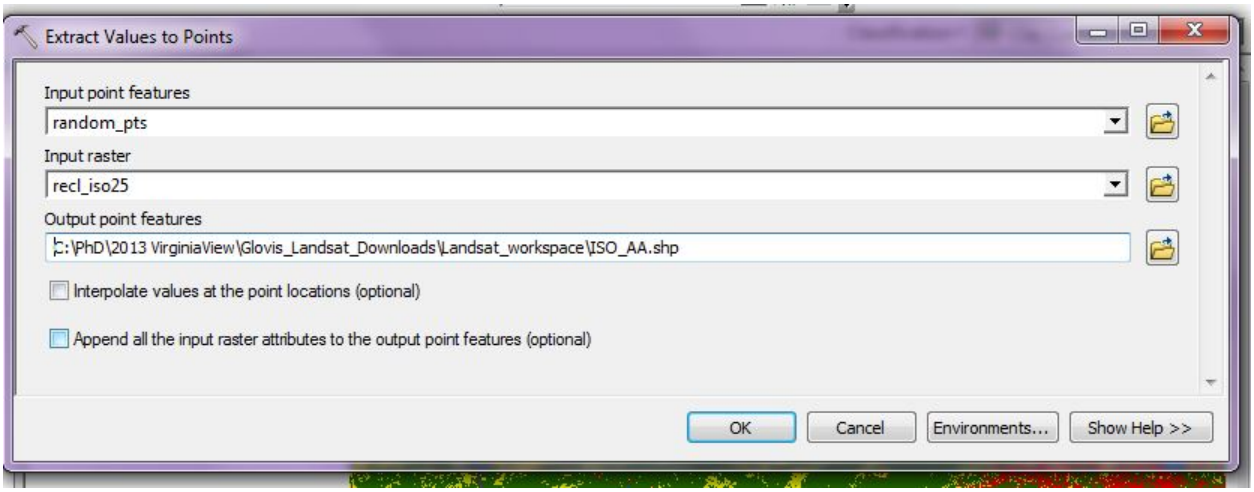
FID	Shape	Id	Aerial
0	Point	0	1
1	Point	0	3
2	Point	0	3
3	Point	0	3
4	Point	0	3
5	Point	0	3
6	Point	0	3
7	Point	0	3
8	Point	0	2
9	Point	0	3
10	Point	0	2
11	Point	0	3
12	Point	0	3
13	Point	0	2
14	Point	0	1
15	Point	0	3
16	Point	0	3
17	Point	0	2
18	Point	0	2
19	Point	0	3
20	Point	0	4
21	Point	0	1
22	Point	0	3
23	Point	0	3
24	Point	0	2

Now we need to add the values for the classified images. Let's first do the unsupervised image, and then we will immediately do the error matrix for the unsupervised classification. Make sure your ***Spatial Analyst Extension*** is enabled.

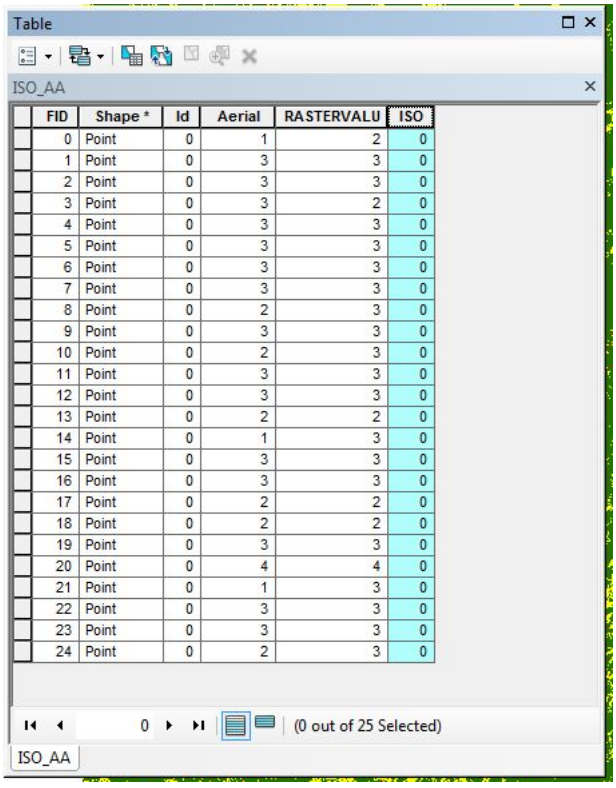
You want ***Spatial Analyst Tools/Extraction/Extract Values to Points.***



The dialog box opens: your ***Input Points Feature*** is your random points file. Your ***Input Raster*** is your Classified Image (remember we are using the unsupervised one for this example). This will create a new file, so name your new file appropriately. Then click ***OK***. ArcMap will add the new file to your ***Table of Contents*** and map document.



Open the ***Attribute Table*** of your new file. ArcGIS has added a new field and called it **RASTERVALU** – it pulled the values of the cells that match to each random point and added them to the ***Attribute Table***.



Table

ISO_AA

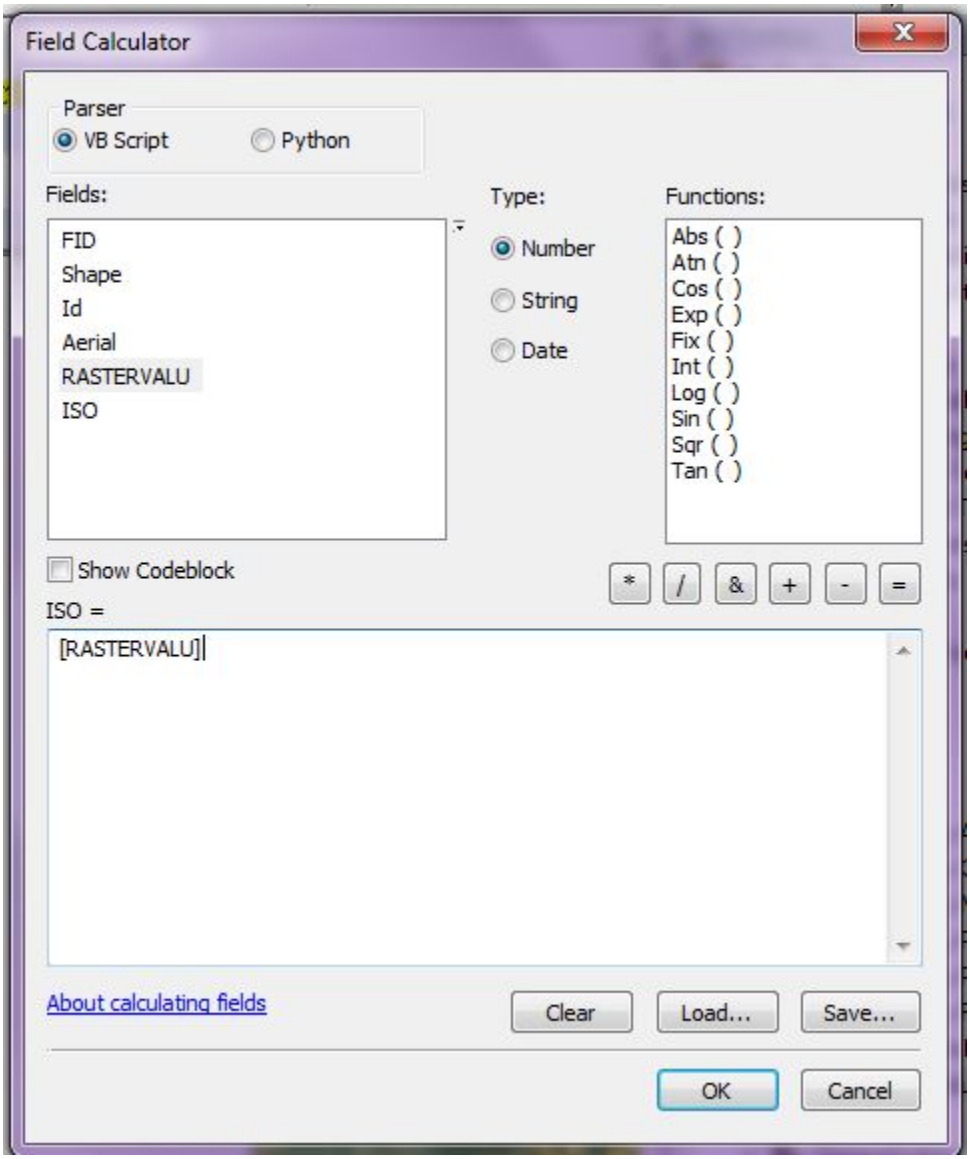
FID	Shape *	Id	Aerial	RASTERVALU	ISO
0	Point	0	1	2	0
1	Point	0	3	3	0
2	Point	0	3	3	0
3	Point	0	3	2	0
4	Point	0	3	3	0
5	Point	0	3	3	0
6	Point	0	3	3	0
7	Point	0	3	3	0
8	Point	0	2	3	0
9	Point	0	3	3	0
10	Point	0	2	3	0
11	Point	0	3	3	0
12	Point	0	3	3	0
13	Point	0	2	2	0
14	Point	0	1	3	0
15	Point	0	3	3	0
16	Point	0	3	3	0
17	Point	0	2	2	0
18	Point	0	2	2	0
19	Point	0	3	3	0
20	Point	0	4	4	0
21	Point	0	1	3	0
22	Point	0	3	3	0
23	Point	0	3	3	0
24	Point	0	2	3	0

0 (0 out of 25 Selected)

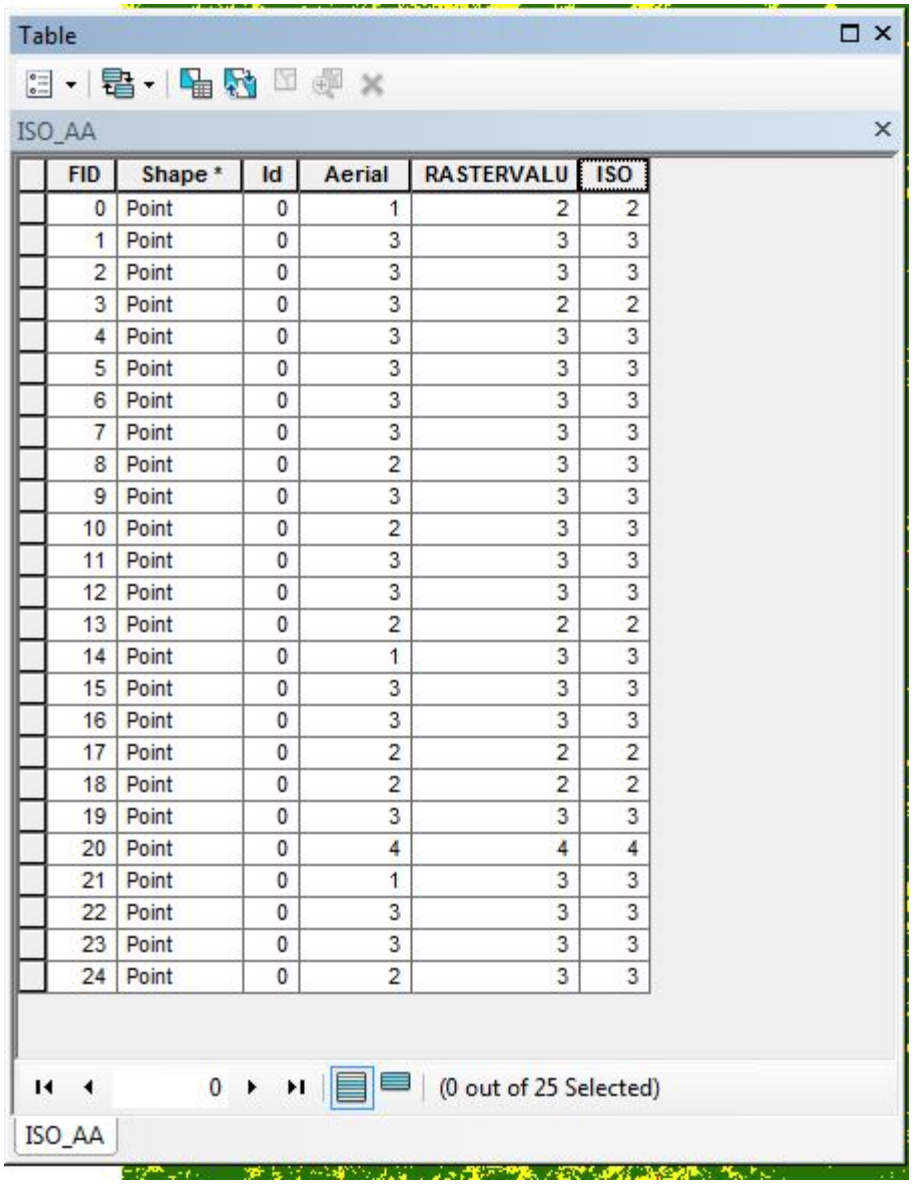
ISO_AA

If you were to close this Map document now, and open it two weeks from now, will you remember what this means? Maybe not, so we have added a new field and called it ISO so we can transfer the values from RASTERVALU field into this new field and retain a memory of what it represents.

Left-click on the ISO column and select ***Field Calculator***. To transfer the values from **RASTERVALU**, double-click on **RASTERVALU** in the ***Fields*** box of the screen, which populates it into the equation below. Click ***OK***.



Now you have a table that you will later be able to understand.



FID	Shape *	Id	Aerial	RASTERVALU	ISO
0	Point	0	1	2	2
1	Point	0	3	3	3
2	Point	0	3	3	3
3	Point	0	3	2	2
4	Point	0	3	3	3
5	Point	0	3	3	3
6	Point	0	3	3	3
7	Point	0	3	3	3
8	Point	0	2	3	3
9	Point	0	3	3	3
10	Point	0	2	3	3
11	Point	0	3	3	3
12	Point	0	3	3	3
13	Point	0	2	2	2
14	Point	0	1	3	3
15	Point	0	3	3	3
16	Point	0	3	3	3
17	Point	0	2	2	2
18	Point	0	2	2	2
19	Point	0	3	3	3
20	Point	0	4	4	4
21	Point	0	1	3	3
22	Point	0	3	3	3
23	Point	0	3	3	3
24	Point	0	2	3	3

From this table, we will compile the Error Matrix.

Remember: Open water = 4, blue
Mixed agriculture = 2, yellow
Urban/built up/transportation = 1, red
Forest & Wetland = 3, green

Error Matrix

	Water (4)	Urban (1)	Forest (3)	Agriculture (2)	
Water (4)	1 (a)	0 (b)	0 (c)	0 (d)	1 (e)
Urban (1)	0 (f)	0 (g)	2 (h)	1 (i)	3 (j)
Forest (3)	0 (k)	0 (l)	14 (m)	1 (n)	15 (o)
Agriculture (2)	0 (p)	0 (q)	3 (r)	3 (s)	6 (t)
	1 (u)	0 (v)	19 (w)	5 (x)	18 (y)

Your error matrix will not be the same as shown above, because your random points set will be different from ours. But we will explain each field, so you can compile your matrix. Each of the fields in the above error matrix contains a letter within parenthesis. We will use each of those letters to explain the number that belongs in that field.

a – How many random points that are water in the aerial photo and water in the ISO
b – How many random points that are water in the aerial photo but urban in the ISO
c – How many random points that are water in the aerial photo but forest in the ISO
d – How many random points that are water in the aerial photo but agriculture in the ISO
e – Total of the Row
f – How many random points that are urban in the aerial photo but water in the ISO
g – How many random points that are urban in the aerial photo and urban in the ISO
h – How many random points that are urban in the aerial photo but forest in the ISO
I – How many random points that are urban in the aerial photo but agriculture in the ISO
j – Total of the Row
k – How many random points that are forest in the aerial photo but water in the ISO
l – How many random points that are forest in the aerial photo but urban in the ISO
m – How many random points that are forest in the aerial photo and forest in the ISO
n – How many random points that are forest in the aerial photo but agriculture in the ISO
o – Total of the Row
p – How many random points that are agriculture in the aerial photo but water in the ISO
q – How many random points that are agriculture in the aerial photo but urban in the ISO
r – How many random points that are agriculture in the aerial photo but forest in the ISO
s – How many random points that are agriculture in the aerial photo and agriculture in the ISO
t – Total of the Row
u – Total of the Column
v – Total of the Column
w – Total of the Column
x – Total of the Column
y – Sum total of fields a, g, m and s

Calculating Overall Accuracy

Overall accuracy is the percentage of random points that are the same in both images. For our matrix above, that is 18 points (1 water, 0 urban, 14 forest and 3 agriculture). We have a total of 25 random points, so our overall accuracy is 18/25 or 72%.

User's accuracy, Producer's accuracy, errors of omission and errors of commission can also be calculated from the error matrix. We will not discuss these specific calculations or their use in this tutorial. Once you have compiled the error matrix, these can be easily calculated. Please see Campbell and Wynne, 2011 for more information.

Calculation of Cohen's Kappa

Kappa provides us with insight into our classification scheme and whether or not we achieved results better than we would have achieved strictly by chance. The formula for kappa is:

$$\frac{\text{Observed} - \text{expected}}{1 - \text{Expected}}$$

Observed is overall accuracy. Expected is calculated from the rows and column totals.

	Water (4)	Urban (1)	Forest (3)	Agriculture (2)	
Water (4)	1	0	0	0	1
Urban (1)	0	0	2	1	3
Forest (3)	0	0	14	1	15
Agriculture (2)	0	0	3	3	6
	1	0	19	5	18

First, you calculate the product of the rows and columns.

	Water Column	Urban Column	Forest Column	Agriculture Column
Water Row	1 x 1 = 1	1 x 0 = 0	1 x 19 = 19	1 x 5 = 5
Urban Row	3 x 1 = 3	3 x 0 = 0	3 x 19 = 57	3 x 5 = 15
Forest Row	15 x 1 = 15	15 x 0 = 0	15 x 19 = 285	15 x 5 = 75
Agriculture Row	6 x 1 = 6	6 x 0 = 0	6 x 19 = 114	6 x 5 = 30

Used to calculate product matrix

Then you calculate what would be expected based on chance:

$$\frac{\text{Product matrix}}{\text{Cumulative sum of product matrix}}$$

The product matrix is the sum of the diagonals: 1 + 0 + 285 + 30 = 316

The Cumulative Sum is: 1 + 0 + 19 + 5 + 3 + 0 + 57 + 15 + 15 + 0 + 285 + 75 + 6 + 0 + 114 + 30 = 625

So, expected is 316/625 = 50.6%

$$K = \frac{0.72 - 0.506}{1 - 0.506}$$

K = 43.3%

This figure is interpreted as that your classification is 43.3% better than would have occurred strictly by chance. Kappa can range from – 1 to + 1.

Remember, we only used 25 random points to do our accuracy assessment. This number is very low, and should be much higher when you perform an accuracy assessment for your research. We used this number only to illustrate the process using a practical example.

Now calculate your overall accuracy and Cohen's kappa for your supervised image.