Integrate Remote Sensing Data and Methods with GIS

Workshop GeoAlberta 2011

Mei Mei Chong meimei@ualberta.ca Charlene Nielsen ccn@ualberta.ca
Abstract

This workshop introduces GIS and remote sensing concepts: the relationship between the two spatial technologies, different types of imagery, and some advanced GIS techniques for working with them. Western Canadian examples (primarily in natural resources) will be demonstrated.

Venue
SHAW Conference Centre, Edmonton, Alberta, Salon 3

Date
Monday May 30th, 2011
1:00 – 4:30 p.m.

Based on development of research solutions and educational support for remote sensing and GIS at the University of Alberta:

http://easweb.eas.ualberta.ca

http://ceos.ualberta.ca

http://www.biology.ualberta.ca/facilities/gis

http://www.biology.ualberta.ca/accru
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Introduction

This is a technical workshop showing how to combine the power of remote sensing imagery and analytical methods in Geographic Information Systems (GIS) as leveraged in research and education at the University of Alberta. It involves readily available GIS tools for visualization, characterization, and mapping of the earth’s surface.

Various Western Canadian datasets are used for the examples, but the methods can be adapted to a wide diversity of applications. Assorted remotely sensed image products are available, but the focus here is on 5 currently popular sensors:

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Geographic Area</th>
<th>Filename</th>
</tr>
</thead>
<tbody>
<tr>
<td>MODIS</td>
<td>central Alberta</td>
<td>mod_cab.img</td>
</tr>
<tr>
<td></td>
<td>Beaverhills</td>
<td>i5_bh.img</td>
</tr>
<tr>
<td></td>
<td>Birch Mountains</td>
<td>i5_bm1990.img</td>
</tr>
<tr>
<td></td>
<td></td>
<td>i5_bm1998.img</td>
</tr>
<tr>
<td></td>
<td></td>
<td>i5_bm2009.img</td>
</tr>
<tr>
<td></td>
<td>Columbia wetlands</td>
<td>i5_cw.img</td>
</tr>
<tr>
<td>Landsat 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPOT 5</td>
<td>Beaverhills</td>
<td>s5<em>m20</em>.tif</td>
</tr>
<tr>
<td></td>
<td></td>
<td>s5<em>p10</em>.tif</td>
</tr>
<tr>
<td>QuickBird</td>
<td>Elk Island National Park</td>
<td>n/a</td>
</tr>
<tr>
<td>LiDAR</td>
<td>Tofino</td>
<td>n/a</td>
</tr>
</tbody>
</table>

There are many image processing software applications that provide the specialized functionality for analyzing remotely sensed imagery. However, this workshop and manual outline the general steps for working with remotely sensed imagery directly in the industry standard GIS software:

**ESRI’s ArcGIS Desktop 9.3.1**

*Note: The only tool used here that is NOT version 10 compatible is the Single Output Map Algebra tool – it is replaced by the Raster Calculator tool in ArcToolbox – but all other methods demonstrated will work in ArcGIS 10.*
Set up the ArcMap document and the geoprocessing environments
The following instructions are the general tasks for getting started with the publicly available datasets needed to work through the topics. You may skip to the first topic on ‘Definitions.’

1. Click START >>> PROGRAMS >>> ARCGIS >>> ARCMAP
2. Start using ArcMap with a new empty map
3. Click the ADD DATA button
4. Navigate to your working directory and double click to open
5. Hold the CTRL key on the keyboard and select multiple files – most files will be in the \rsgis\work folder
6. Click ADD
7. Repeat the ADD DATA from any other workspace/folder
8. Take a few moments to understand what you have to work with (see the References section to view websites for metadata)
9. Click TOOLS >>> EXTENSIONS and make sure to check on SPATIAL ANALYST

IMPORTANT: Data Management Tools has a lot of raster image processing capability, but Spatial Analyst is required for many of the analytical tools!

10. If necessary, SHOW ArcToolbox
11. Right-click the name for ArcToolbox and click ADD TOOLBOX
12. Navigate to the \rsgis\ACCRU_Tools folder and select ACCRU Tools.tbx
13. Click OPEN

Note: ACCRU TOOLS is a custom toolbox with specialized tools that extend the built-in functionality of ArcGIS; of most interest here are the ‘2 Landscape Characterization’ tools.

14. Right-click the name for ArcToolbox and click ENVIRONMENTS
15. Specify the following General Settings:
   - Current Workspace = \rsgis\work
   - Scratch Workspace = \rsgis\work
16. Click OK
17. Click FILE >>> DOCUMENT PROPERTIES >>> DATA SOURCE OPTIONS
18. Click 'Store relative path names…'
19. Check beside 'Make relative paths the default…'
20. Click OK twice
21. Click FILE >>> SAVE as \rsgis\work\RS_GIS.mxd
22. Remember to regularly SAVE your map document
23. TIP: Insert new data frames to help organize data by topic and/or study area.

Extra: Add the World_Imagery.lyr file – this is a tiled global mosaic layer that streams over the internet, providing you with a handy low-resolution reference image for anywhere in the world, and high-resolution imagery for the U.S. and the more populated parts of Canada

http://www.arcgis.com/home/item.html?id=10df2279f9684e4a9f6a708fbeb2a9
1 Definitions

1.1 GIS
Geographic Information Systems (GIS) are a system/framework that allows for the management and analysis of digital geographic data for spatial relationships and processes. The topics below show how you can integrate remotely sensed data in a GIS.

1.2 Remote sensing
Remote sensing is the acquisition of information/data on a target without being in direct contact with it.

(A) Energy Source or Illumination
(B) Radiation and the Atmosphere
(C) Interaction with the Target
(D) Recording of Energy by the Sensor
(E) Transmission, Reception, and Processing
(F) Interpretation and Analysis
(G) Application

Remote sensing tools can be used to study objects on the Earth’s surface on all scales, including time scales, both in duration and frequency, which was previously impossible.
Measurements of key environmental indicators can be automated and made remotely at various time intervals to better characterize natural phenomena/processes.

Remote sensing allows the investigation of portions of the Earth that are otherwise unreachable.

1.3 EMR

Electromagnetic (EM) radiation is radiant energy emitted by matter at varying wavelengths. The EM spectrum gives the complete range of wavelengths that EM radiation extends. These radiations include electric currents, heat, radio waves, microwaves, infrared radiation, ultraviolet radiation, x rays, gamma rays, and cosmic rays.

Given how small the visible portion of the EM spectrum is, there is much radiant energy that cannot be detected with our eyes but can be detected by sensors.
Therefore, understanding the characteristics of EM radiation at various wavelengths and frequencies is essential to the understanding of the information acquired from remotely sensed data.

1.4 The three R’s

1.4.1 Spatial resolution
Spatial resolution is the smallest spatial element that can be sensed or resolved by a sensor. These elements are the pixels we see in imagery. The smaller the pixel, the higher the resolution!

- High: 0.6 – 4 meters
  (e.g. QuickBird, IKONOS, SPOT…)
- Medium: 4 – 30 meters
  (e.g. LANDSAT 7, ASTER)
- Low: 30 -> 1000 meters
  (e.g. MODIS)

1.4.2 Temporal resolution
Temporal resolution is the revisit frequency of the satellite sensor or imagery for a specific location.

- High: < 24 hours – 3 days
- Medium: 4 – 16 days
- Low: > 16 days
1.4.3 Spectral resolution
Spectral resolution is the range of wavelengths or width of spectral bands that can be detected and represented by an imaging system.

- High: 220 bands
- Medium: 2-15 bands
- Low: 3 bands

2 Selected sensors
The ‘References’ section indicates the source for acquiring your own raster data for each satellite or airborne sensor described below. The main idea to note is that most of these datasets are multiband rasters where each Layer represents the data from the original band or subdataset that was imaged or stored in the sensor file.

2.1 MODIS
The Moderate Resolution Imaging Spectroradiometer (MODIS) sensor is carried onboard the Terra and Aqua satellites, both which orbit the entire Earth’s surface every 1 to 2 days. There are various levels of processing.

http://modis.gsfc.nasa.gov

The example MODIS data is MOD13Q1: 250 meter, 16-day composites processed for vegetation indices, from 26 June 2008, for tile h11v03. Original data were downloaded in HDF format with a sinusoidal projection, projected to WGS84 UTM Zone 12, and clipped to the central Alberta extent.

IMG band ordering of MOD13Q1:
- Layer_1: subdataset 3 = red
- Layer_2: subdataset 4 = NIR
- Layer_3: subdataset 5 = blue
- Layer_4: subdataset 6 = MIR
- Layer_5: subdataset 0 = NDVI
- Layer_6: subdataset 1 = EVI
2.2 Landsat 5 TM

“For 37 years, the Landsat program has collected spectral information from Earth’s surface, creating a historical archive unmatched in quality, detail, coverage, and length.”

http://landsat.gsfc.nasa.gov

“Landsat sensors have a moderate spatial-resolution. You cannot see individual houses on a Landsat image, but you can see large man-made objects such as highways. This is an important spatial resolution because it is coarse enough for global coverage, yet detailed enough to characterize human-scale processes such as urban growth.”

The current fully operational sensor, Landsat 5, orbits the entire Earth’s surface every 16 days at a resolution of 30 meters, with each scene covering 185 km X 172 km.

The example Landsat 5 images are all 30 meter, with variable dates and path/row tiles. The Beaverhills (l5_bh.img), Path 42 Row 23, is from June 2008. The Birch Mountains (l5_bm*.img), Path 44 Row 20, is from the following dates: 24 September 1990, 29 August 1998, 12 September 2009. The Columbia River valley wetlands (l5_cw.img), Path 43 Row 25, is from 20 August 2009. All were downloaded as WGS84 UTM Zone 12 (or Zone 11 for the CW), and clipped to the respective study area extents (or extracted by study area mask for the CW).

IMG band ordering information for all Landsat 5 Thematic Mapper (TM):

- Layer_1: TM1 blue
- Layer_2: TM2 green
- Layer_3: TM3 red
- Layer_4: TM4 NIR
- Layer_5: TM5 MIR
- Layer_6: TM7 MIR
2.3 SPOT 5
The Système Probatoire d'Observation de la Terre (SPOT) has multiple sensors that orbit the entire Earth’s surface, typically every 2 to 3 days. A single image covers a footprint of 60 km X 60 km at resolutions of 20 m to 2.5 m.

http://www.spotimage.com

The example SPOT 5 data are 20 meter multispectral or 10 meter panchromatic, from 16 May 2008, and centred on longitude -112.59 and latitude 53.39.

IMG band ordering information for SPOT 5:
- Layer_1: Band1 green
- Layer_2: Band2 red
- Layer_3: Band3 NIR
- Layer_4: Band4 MIR

2.4 QuickBird
“DigitalGlobe’s QuickBird satellite offers sub-meter resolution imagery, high geolocational accuracy, and large on-board data storage.”


The entire Earth’s surface is orbited every 2.5 to 5.6 days, with a single scene covering 18 km X 18 km, at resolutions between 65 cm to 2.62 meters. It is excellent for near-airphoto detail.

2.5 LiDAR
Light Detection And Ranging (LiDAR) is an optical remote sensing technology that can measure the distance to, or other properties of a target by illuminating the target with light, often using pulses from a laser, and is typically onboard an aircraft (not satellites). There are several commercial companies that specialize in LiDAR data acquisition and processing for various products that can be used in research and operational applications.
LiDAR data is often supplied in a binary format with a .las extension. Depending on the software you are using to process your lidar data, this format may or may not be readable. When using ArcGIS, you will have to install a third-party add-on to read this format. las readers are available on the internet (both freely and otherwise), and allow you to open the data and export it to an ESRI format such as shapefiles or geodatabase feature classes.

3 Raster image visualization
Visualize and display single- and multi-band rasters: what the colours mean...


TIP: Use the EFFECTS toolbar to set the target layer and use the SWIPE LAYER tool to reveal the lower layer

3.1 Stretch enhancements
View each single band, applying various stretch methods (statistics and histograms)


1. Click ADD DATA
2. Navigate to the 'data' directory and double click an img file to open
3. Select a single layer and click ADD
4. Repeat for additional layers and one of the SPOT tif files
5. Right-click and layer name in the table of contents, to open the Layer Properties >> Symbology tab
6. Experiment with the Stretch methods and colour ramps
The figures below graphically depict linear and non-linear stretching of original values to new visually-enhanced values for display purposes.

### 3.2 Composites and RGB

Apply the Composite Bands tool to SPOT and then experiment with different RGB settings based on desired reflectance characteristics for the provided multispectral datasets.


Create a multiband raster from individual files:

1. In ArcToolbox, click DATA MANAGEMENT TOOLS >>> RASTER >>> RASTER PROCESSING >>> COMPOSITE BANDS
2. For the Input Rasters, click the BROWSE button (open folder icon) and navigate to the directory containing the unzipped SPOT imagery; hold the CTRL and click each of the *m20*.tif files to select and then click ADD

3. For the Output Raster, save to your working directory as s5m20.img – use a .img extension

4. Click OK

Note: Band or Layer? Depending on the file type, the multiband dataset will refer to each ‘subdataset’ as a Band (.tif, no extension: ESRI grid or gdb raster) or a Layer (.img).

Display each multiband raster using different RGB band combinations to learn how the earth’s surface is depicted:

- **MODIS (mod):** 2,1,3 (red vegetation); 4,2,1 (bright green vegetation and pink rock/soil)
- **Landsat (L5):** 3,2,1 (visible); 4,3,2 (bright red vegetation); 5,4,3 (bright green vegetation and pink rock/soil); 6,5,2 (aqua wet vegetation)
- **SPOT (s5):** 3,2,1 (red vegetation); 4,3,2 (bright green vegetation and pink rock/soil)
- **QuickBird:** 3,2,1 (visible); 4,3,2 (bright red vegetation)
The following table describes what each Landsat band helps represent:

<table>
<thead>
<tr>
<th>Band Number</th>
<th>Spectral Range (nm)</th>
<th>EM Region</th>
<th>Generalized Application Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>460 – 520</td>
<td>Visible Blue</td>
<td>Coastal water mapping, differentiation of vegetation from soils</td>
</tr>
<tr>
<td>2</td>
<td>520 – 590</td>
<td>Visible Green</td>
<td>Assessment of vegetation vigor</td>
</tr>
<tr>
<td>3</td>
<td>630 – 690</td>
<td>Visible Red</td>
<td>Chlorophyll absorption for vegetation differentiation</td>
</tr>
<tr>
<td>4</td>
<td>760 – 900</td>
<td>Near Infrared</td>
<td>Biomass surveys and delineation of water bodies</td>
</tr>
<tr>
<td>5</td>
<td>1550 – 1750</td>
<td>Middle infrared</td>
<td>Vegetation and soil moisture measurement; differentiation between snow and cloud</td>
</tr>
<tr>
<td>6</td>
<td>10400 – 12500</td>
<td>Thermal Infrared</td>
<td>Thermal mapping; soil moisture studies; plant heat stress measurement</td>
</tr>
<tr>
<td>7</td>
<td>2080 – 2350</td>
<td>Middle Infrared</td>
<td>Hydrothermal mapping</td>
</tr>
<tr>
<td>8</td>
<td>520 – 900</td>
<td>Green, Red, Near Infrared</td>
<td>Large area mapping; urban change studies</td>
</tr>
</tbody>
</table>

3.3 Pan-sharpen
The spatial detail of a panchromatic layer can be fused with the multispectral layers to provide an enhanced visualization of the study area.

Fuse the spatial detail of the higher resolution panchromatic band with the lower spatial resolution multi spectral information (this example is based on SPOT imagery):

1. In ArcToolbox, click DATA MANAGEMENT TOOLS >>> RASTER >>> RASTER PROCESSING >>> CREATE PAN-SHARPENED RASTER DATASET
2. The following provides the required parameters:
   - Input Raster: the multiband composite; e.g. s5m20.img
   - Output Raster Dataset: \work\s5_pansharp.img
   - Panchromatic Image: \data\s5*p10*.tif
3. Examine the help sidebar for info on the 'Pan-sharpening Type'
4. Leave all else at the defaults and click OK
5. Once the tool has completed and the new raster added to the map, notice that the RGB colour is automatically set to show
SPOT bands as a false colour (normally green vegetation is depicted as red)

4 LiDAR

View and interpret LiDAR data using a variety of GIS tools. This data not publicly available.

4.1 2D and 3D visualization

4.1.1 2D visualization

1. In ArcCatalog, navigate to the directory, right click on each file:
   - Tofino_LiDAR_subset_grd.txt (Ground return data)
   - Tofino_LiDAR_subset_Non_grd.txt (Non-ground data)

2. Select CREATE FEATURE CLASS >>> FROM XY TABLE >>> SELECT z in the z field >>> SET XY COORDINATE SYSTEM to Projected Coordinate System, UTM, WGS 1984, Zone 10n >>> SET Z COORDINATE SYSTEM to WGS 1984

3. In ArcMap, ADD DATA >>> Add the shapefiles that were generated

4. What is the density (points per square meter) of points for the various layers?
   - Open Attribute Table
   - Compare number of points in each shapefile to the size of the study area (250 m X 250 m)
   - Ground returns: 8775 / (250*250) = 0.140
   - Non Ground returns: 116729 / (250*250) = 1.868

4.1.2 3D visualization

1. Generate a DEM using a Natural Neighbours algorithm. Go to 3D ANALYST >>> INTERPOLATE TO RASTER >>> NATURAL NEIGHBOURS

2. Within the dialog box:
   - Select ground return data
   - Define height source (z)
   - Define cell size [Try 1, 5, &10 m]
• Specify an output file name and click OK

3. Look at the DEM characteristics using 3D ANALYST >>> SPATIAL ANALYSIS TOOLS
• Right click DEM to try to generate a Hill Shade and Slope surfaces

Note: There are other ways to generate DEMs – i.e. using a spline with tension algorithm (3D ANALYST >>> INTERPOLATE RASTER >>> SPLINE).

4.2 Canopy measures

4.2.1 Generate canopy height surfaces

1. Repeat same steps and generate DEMs for Non-ground data [Try cell size 0.5, 1, 5, & 10 m]

Notice the difference between 0.5 m and 5 m cell size. At 1 m we can start to see tree crowns.

2. Find the Height Above Ground (HAG) by subtracting the DEM from the Canopy Height Surface SPATIAL ANALYST >>> RASTER CALCULATOR and type the following expression:

\[
\text{Float([nongrd1] - Float([Grd1]))}
\]

3. Check statistics in Layer Properties: What are the maximum and minimum heights within this dataset?

Max: 34.794; Min: 0.056 (the negative values in the Canopy Height Surface are likely from “tree heights” lower than the DEM…since the DEM is interpolated).

4. What is the mean height within this dataset?

Mean height is 10.491.

5. Isolate tree crowns by applying a height threshold SPATIAL ANALYST >>> RASTER CALCULATOR >>> “CANOPY SURFACE LAYER > 5.0”
4.2.2 Calculate canopy densities

Calculate the ratio of vegetation returns greater than 5 m above the ground for each 10 m x 10 m cell, with the total number of returns within the same area.

- Add a column to our data containing a dummy value of 1
- Create a shapefile containing both ground and non-ground returns
- Create a shapefile containing only non-ground returns greater than five metres above the ground
- Use the “point statistics” tool and map algebra to create our ratio surface of relative canopy densities

Add a column to the ground and non-ground shapefiles containing a dummy value of 1 for each point:

1. OPEN ATTRIBUTE TABLE >>> OPTIONS >>> ADD FIELD Within the dialog box:
   - Name: Count
   - Type: Short Integer
   - Precision: 1

2. In the attribute table, right click on the new field Count and select FIELD CALCULATOR and set the new field to equal 1 for all points >>> Count = 1

Merge ground and non-ground hits into a single shapefile

3. ArcTOOLBOX >>> DATA MANAGEMENT >>> GENERAL >>> MERGE
   - Input file: Tofino_LiDAR_subset_grd.shp; Tofino_LiDAR_subset_Non_grd.shp
   - Output file: Tofino_LiDAR_merge.shp

Calculate the number of all LiDAR returns within each square of 10 m X 10 m cell found within the study area:

4. ArcToolbox >>> SPATIAL ANALYST TOOLS >>> NEIGHBOURHOOD >>> POINT STATISTICS
5. Within the dialog box:
Input: Tofino_LiDAR_merge  
Field: Count  
Output: all_pts  
Cell size: 10  
Neighbourhood: Rectangle  
Neighbourhood Settings: MAP  
Height: 10  
Width: 10  
Statistics type: SUM

The output will be a 10 m resolution grid with the number of returns per unit area.

Count the number of vegetation returns greater than 5m above ground per unit area. First calculate height above ground for each point:

6. ArcTOOLBOX >>> SPATIAL ANALYST>>> EXTRACTION>>>EXTRACT VALUES TO POINTS  
7. Within the dialog box:  
   - Input: Tofino_LiDAR_subset_Non_grd (feature)  
   - Input: Tofino_LiDAR_subset_nongrd1 (raster)  
   - Check box for “Append all the input raster attributes to the output point features”

Select the appropriate returns and count their numbers per unit area:

8. OPEN ATTRIBUTE TABLE OF Extract_Tofino_nongrd_1 >>> CREATE NEW FIELD “HAG (height above ground)”

9. Within the dialog box:  
   - Name: HAG  
   - Type: Float  
   - Precision: 0  
   - Scale: 0

Calculate height above ground for each point:

10. Type the following in the FIELD CALCULATOR

\[
HAG = [Z] - [RASTERVALU]
\]
Note that some of values in the “rastervalue” field equal -9999. These vegetation returns were not over the DEM surface and were therefore assigned a “no data” value of -9999.

Select all of the points greater than 5 m above ground containing a legitimate value:

11. OPEN ATTRIBUTES TABLE >>> OPTIONS >>> SELECT BY ATTRIBUTES

"RASTERVALU" <> -9999 AND "HAG" >=5

Note: <> represents not equal

12. Export selected features to a new shapefile by right clicking on the shapefile >>> DATA >>> EXPORT DATA

13. Using the POINT STATISTICS tool, count the number of LiDAR non-ground returns that are greater than 5 m above ground within the 10 m X 10 m area of the study area. Remember to sum the Count field:

14. ArcTOOLBOX >>> SPATIAL ANALYST TOOLS >>> NEIGHBOURHOOD >>> POINT STATISTICS

15. Within the dialog box:
   - Input: Nongrd_Grt_5m
   - Field: Count
   - Output: pts_grt_5m
   - Cell size: 10
   - Neighbourhood: Rectangle
   - Neighbourhood Settings: MAP
   - Height: 10
   - Width: 10
   - Statistics type: SUM

16. Finally, using Raster Calculator, divide the raster containing counts of the non-ground returns with the raster containing the counts of all returns. You may specify “float” option for both rasters.

   \[
   \text{Float}([\text{pts}\_\text{grt}\_5m]) / \text{Float}([\text{all}\_\text{pts}])
   \]
The output raster will contain floating point values between 0 and 1, where low values indicate relatively open canopies, and higher values indicate denser canopies.

4.2.3 Forest inventory analyses

Using the LiDAR vegetation returns greater than 5 m above ground, we will extract some basic forest inventory variables including Maximum Tree Height and Stem Volume Per Hectare.

1. Extract maximum heights within 5 cells in ArcToolbox >>> SPATIAL ANALYST TOOLS >>> NEIGHBOURHOOD >>> POINT STATISTICS

2. Within the dialog box:
   - Input: Nongrd_Grt_5m
   - Field: HAG
   - Output: max_5m_stat
   - Cell size: 5
   - Neighbourhood: Rectangle
   - Neighbourhood Settings: MAP
   - Height: 5
   - Width: 5
   - Statistics type: MAXIMUM

3. Repeat this operation, creating surfaces at spatial resolutions of 10 m and 30 m

4. Using RASTER CALCULATOR, apply a volume equation to the height data. This linear equation was developed for Douglas fir and had a $r^2$ value of 0.99:

   \[
   \text{Stand Volume (m}^3/\text{ha)} = 27.7 \times \text{Height (m)} - 345.4
   \]

5. Using the 10 m resolution height raster created, input the following:

   \[
   [\text{max}_{10\text{m_stat}}] \times 27.7 - 345.5
   \]

The output will be a map of estimated stand volume. Typical values may be between 70 and 850 m$^3$/ha.
5 Vegetation indices

Vegetation indices are standard practice measures for tracking phenology and the effect of landcover/landuse changes. The calculations of interest include:

- NDVI – calculated
- EVI – provided
- Greenness – from tasselled cap

Built-in GIS tools are employed to address vegetation characteristics in central Alberta’s Beaverhills region, which includes Elk Island National Park.


5.1 NDVI

Calculate the Normalized Difference Vegetation Index on the MODIS data (Note: this can also be applied to Landsat and SPOT – any data that has red and near-infrared bands).

\[
NDVI = \frac{NIR - Red}{NIR + Red}
\]

1. Examine the ACCRU Tools >>> 2.1 Vegetation Indices toolset: right-click 2.1.1 NDVI and click EDIT

This is a model tool that will quickly calculate the Normalized Difference Vegetation Index (NDVI) using the map algebra equation:

\[
\text{float(Near Infrared Band} - \text{Red Band) / float(Near Infrared Band} + \text{Red Band)}
\]

2. CLOSE the model and then double click the tool to OPEN it

3. Calculate NDVI and save the output as \work\*_ndvi (where * represents the input data sensor; e.g. l5, mod, s5)

4. Click SHOW HELP for parameter info and use the following as a guide:
5. Once the tool has completed, click ADD DATA, navigate to the data directory and double click the `mod_cab.img` raster to select as a single band for just Layer_5 (NDVI) and again for just Layer_6 (EVI).

6. Take a moment to view the new rasters and compare with the calculated

### 5.2 Tasselled cap transformation

Brightness, greenness, and wetness are the typical tasselled cap transformations calculated from multispectral imagery. The exact equation depends on the sensor and level of product processing. This example uses coefficients for Landsat TM 5 (Crist, Laurin, and Cicone 1986).

1. Examine the ACCRU Tools >>> 2.1 Vegetation Indices toolset: right-click 2.1.2 Tassel Cap and click EDIT

This is a Python script tool that will quickly calculate the brightness, greenness, and/or wetness indices from the Tassel Cap coefficients using the specified map algebra equation:

Coefficient1 * Band1 + Coefficient2 * Band2 + Coefficient3 * Band3 +
Coefficient4 * Band4 + Coefficient5 * Band5 + Coefficient7 * Band7 +
AdditiveTerm
2. CLOSE the script file and then double click the tool to OPEN it
3. Calculate only greenness on the available Landsat and save to the output folder \work

4. Click ADD DATA to view the completed calculation \work\tc_l5_bh.img\tcgre

6 Landcover classification
Two approaches to automatically classify multispectral data are:

- Unsupervised
- Supervised

The first approach will be applied to various years in Alberta’s boreal forest in the Birch Mountains, where forest fires have changed the landcover. The second approach will be applied to mapping aquatic versus terrestrial vegetation in B.C.’s Columbia River valley wetlands. Both require an initial signature file – in ASCII format with .GSG extension – for input to the maximum likelihood classifier tool.


6.1 Unsupervised classification

An isodata clustering algorithm is applied to the input raster bands to determine the statistical characteristics of natural cell groupings and results are stored in a signature file. This is called unsupervised because the class names of those groupings are not known up front.


TIP: A good RGB composite for highlighting burned areas in the forested study area is using Layer_5, Layer_4, Layer_3.

1. In ArcToolbox, click ACCRU TOOLS >>> 2.2.2 UNSUPERVISED CLASSIFICATION
2. The following provides the required parameters (browse to the full dataset so ALL bands are used!):
   - Input raster bands: L5_bm1990.img
   - Number of classes: 5
   - Output signature file: IsoClus_bm1990.GSG
   - Output classified raster: mlc_bm1990
3. Leave all else at the defaults and click OK
4. Repeat the 2.2.2 UNSUPERVISED CLASSIFICATION for L5_bm2009.img
5. TIP: In ArcToolbox, click the RESULTS tab, expand the Current Session and double-click to open the UnsupervisedClassification tool. The former process is shown with all input/output parameters. Highlight the Input raster bands L5_bm1990.img and click the delete button (X). Select a new input: L5_bm2009.img. Change the Output signature file and Output classified raster names to reflect the year 2009. Click OK.
6. Repeat (see TIP above) for L5_bm1998.img
7. While the custom tool runs, view the same tool in EDIT mode in ArcCatalog to examine how it was constructed. Right-click the tool name and click EDIT: the IsoCluster and Maximum Likelihood Classification tools have been connected in ModelBuilder with the necessary parameters exposed.
8. CLOSE the model and return to ArcMap
9. Once all classifications have completed, turn off all layers by holding the SHIFT key on the keyboard and clicking any checked box in the table of contents

IMPORTANT: The classification work is not even finished, because next you must assign actual landcover categories to class numbers. This may involve iteratively reclassifying. Also, classification accuracy should be assessed.

10. For each of the years, turn on only the paired set of `I5_*_.img` and `mLc*` layers to visualize how well the classification did in mapping out the wildfire burn areas
11. TIP: Use the EFFECTS toolbar to set the mlc_* as the target layer and use the SWIPE LAYER tool to reveal lower layer

12. Extra: Open the \work\*.GSG file in a text editor to examine the content

6.2 Supervised classification

A statistical description of the classes is derived from the samples identified on the input raster or feature sample data and stored in a signature file. This is called supervised because the classes must be known up front and the values must be mapped out as raster cells or features (points, lines, or polygons).


TIP: A good RGB composite for highlighting aquatic and terrestrial vegetation is using Layer_6, Layer_5, Layer_2 (the data correspond to original bands 7,5,2).

1. In ArcToolbox, click ACCRU TOOLs >>> 2.2.1 SUPERVISED CLASSIFICATION
2. The following provides the required parameters (browse to the full dataset so ALL bands are used!):
   - Input raster bands: l5_cw.img
   - Input raster or feature sample data: cw_ts
   - Sample field: CLASS
   - Output signature file: CreateS_l5_cw.GSG
   - Output classified raster: mlc_l5_cw
3. Leave all else at the defaults and click OK
4. While the custom tool runs, view the same tool in EDIT mode in ArcCatalog to examine how it was constructed. Right-click the tool name and click EDIT: the Create Signatures and Maximum Likelihood Classification tools have been connected in ModelBuilder with the necessary parameters exposed.
5. CLOSE the model and return to ArcMap
6. Once the classification has completed, turn off all layers except the new classification and original input bands to view

7. TIP: Use the EFFECTS toolbar to set the mlc_* as the target layer and use the SWIPE LAYER tool to reveal lower layer

8. Extra: Open the \work\*.GSG file in a text editor to examine the content

IMPORTANT: The classification work is not even close to being finished, because this is the time you would then evaluate the results and perform a classification accuracy assessment (not covered in this workshop).
7 Filtering

7.1 Majority smoothing
Filtering is typically applied post-classification to smooth out the salt-and-pepper effect by retaining the majority value within a 3x3 moving window. This yields a 'smoothed' raster and can only be applied to categorical inputs.


1. In ArcToolbox, click SPATIAL ANALYST TOOLS >>> GENERALIZATION >>> MAJORITY FILTER
2. The following provides the required parameters:
   - Input raster: pick any classification result from topic 6
   - Output raster: \work\m_filename
3. Examine the help sidebar for info on the ‘Number of neighbours to use’ and the ‘Replacement threshold’
4. Leave all else at the defaults and click OK (Note: ‘m’ indicates ‘majority’)
5. Once the tool has completed, use the SWIPE tool to inspect the before and after

Note: To use a window size larger than the built-in 3x3 of Majority Filter, apply the FOCAL STATISTICS tool, using the Majority statistic:

7.2 Low vs. high pass
Filtering for continuous data is also available and outputs new layers that soften or highlight edges. A 3x3 window is applied to average values in the low-pass filter or edge enhance in the high-pass filter.


1. In ArcToolbox, click SPATIAL ANALYST TOOLS >>> NEIGHBOURHOOD >>> FILTER
2. The following provides the required parameters:
   - Input raster: pick any single band
   - Output raster: \work\l_filename
   - Filter type: LOW
3. Leave all else at the defaults and click OK (Note: ‘l’ indicates ‘low’, ‘h’ indicates ‘high’)

4. REPEAT using HIGH so that you have output rasters for both filter types
5. Once the tool has completed, use the SWIPE tool to inspect the before and after rasters
8 Reduce dimensions: PCA

Principal Components Analysis (PCA) is applied to reduce data dimensionality for the 6 visible-infrared bands of the Landsat TM data. Data are compressed, eliminating redundancy, to uncorrelated multivariate attributes. The new components are useful as inputs to the multivariate classification methods you learned above, but also make interesting visualizations.


1. In ArcToolbox, click SPATIAL ANALYST TOOLS >>> MULTIVARIATE >>> PRINCIPAL COMPONENTS
2. The following provides the required parameters:
   - Input raster bands: `l5_bh.img`
   - Output multiband raster: `pca_bh.img`
   - Number of Principal components: 3
   - Output data file: `pca_bh.txt`
3. Click OK
4. Once the tool has completed, use all the visualization methods you have learned to inspect the before and after rasters
### Useful datasets

Selected web links for useful datasets, from raw imagery to classified global remotely sensed products.

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
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<tbody>
<tr>
<td>ArcGIS World Imagery</td>
<td>ArcGIS Online World Imagery layer file</td>
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<tr>
<td>CEC</td>
<td>Commission for Environmental Cooperation’s North American Environmental Atlas: Landcover</td>
</tr>
<tr>
<td>Earth Explorer</td>
<td>Satellite images, aerial photographs, and cartographic products from the U.S. Geological Survey</td>
</tr>
<tr>
<td>GeoBase</td>
<td>Access to a common, up-to-date and maintained base of quality geospatial data for all of Canada</td>
</tr>
<tr>
<td>GeoGratis</td>
<td>GeoGratis is a portal provided by the Earth Sciences Sector (ESS) of Natural Resources Canada (NRCan) which provides geospatial data at no cost and without restrictions via your Web browser.</td>
</tr>
<tr>
<td>GLCF</td>
<td>Largest free source of satellite data made available by the University of Maryland's Global Landcover Facility</td>
</tr>
<tr>
<td>Landsat WRS and Path/Row</td>
<td>Index grids for Landsat's Worldwide Reference System and Path/Row</td>
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<tr>
<td>LP DAAC</td>
<td>Land Processes Distributed Active Archive Center - processing, archiving, and distribution of satellite data</td>
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<tr>
<td>MODIS Tiles</td>
<td>Index grids for MODIS data in Sinusoidal projection</td>
</tr>
<tr>
<td>NLWIS</td>
<td>Agriculture Canada’s National Land and Water Information Service includes data for CLI, generalized landcover, climate, agricultural census, and watershed boundaries for the Canadian Prairies</td>
</tr>
<tr>
<td>NRCan CFS EOSD Landcover</td>
<td>Circa 2000-2003 satellite classification of the forested regions of Canada (click here for download access)</td>
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References


