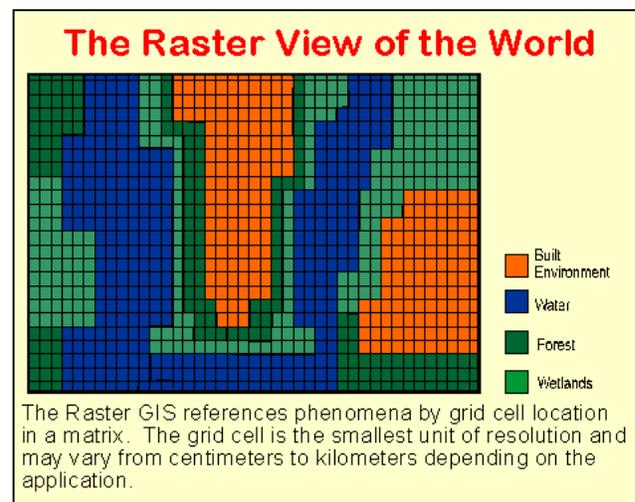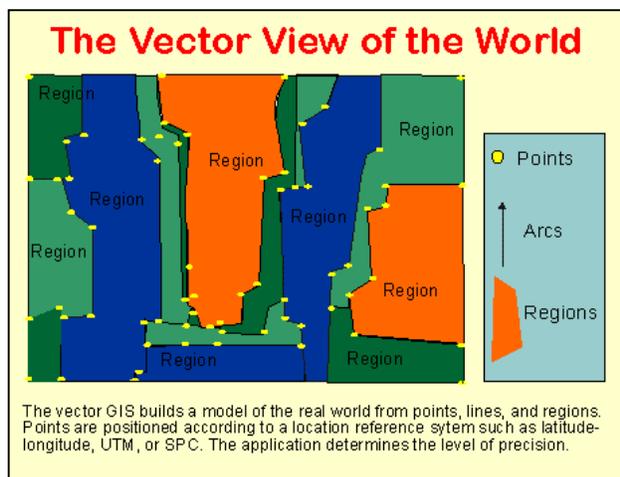# Cookbook 15 October 2013
Raster Data and Spatial Analyst (Part 1)

Overview

1. What are Raster Data?
2. Types of Raster Data
3. Raster Software
4. Digital Elevation Models
5. ArcGIS Extensions, Tools, and Programs
6. Your Turn: Explore the Massachusetts DEM
7. Homework for tomorrow
8. Tutorials

Reality is made virtual as vector or raster data – your choice!

The Vector View of the World

The vector GIS builds a model of the real world from points, lines, and regions. Points are positioned according to a location reference sytem such as latitude-longitude, UTM, or SPC. The application determines the level of precision.

The Raster View of the World

The Raster GIS references phenomena by grid cell location in a matrix. The grid cell is the smallest unit of resolution and may vary from centimeters to kilometers depending on the application.

1) What are Raster Data?

Raster Data uses a grid and grid cells to represent the spatial variations of a parameter.

- The information about the parameter is the grid cell value.
- Raster data are suitable for representing continuous parameters (e.g. elevation, temperature, wind speed, etc.).
- The most commonly used raster data are air photos, satellite images, and digital elevation models.
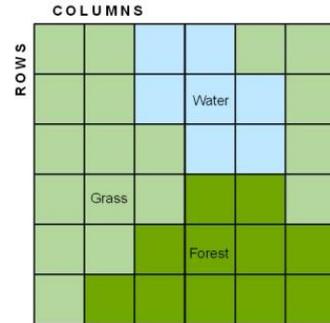
Of course, the real-world consists of both…vector and raster data. In other words, we can show the real world in vector or raster format.
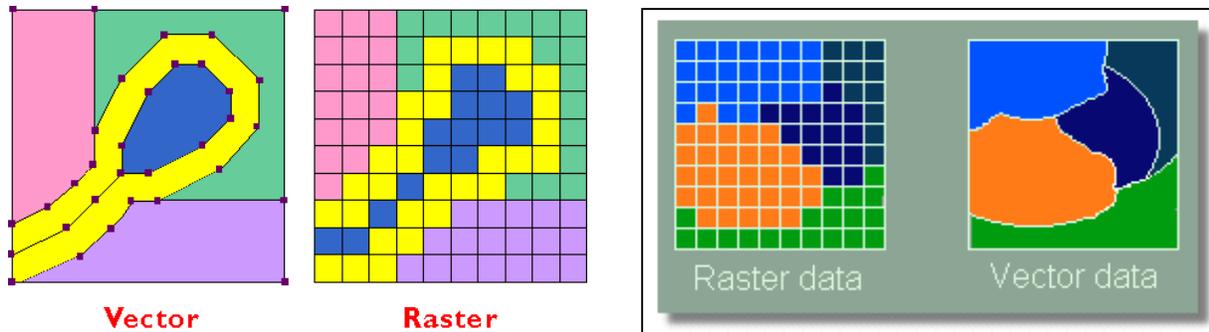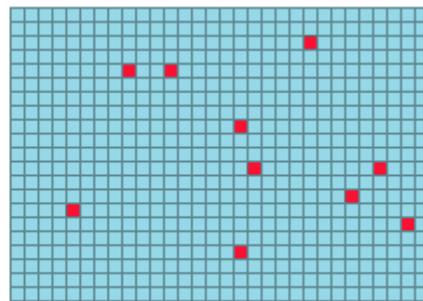
Point Features as Raster

A point is represented by an explicit x,y coordinate in vector format, but as a raster, it is represented as a single cell—the smallest unit of a raster. By definition, a point has no area but is converted to a cell representing area.
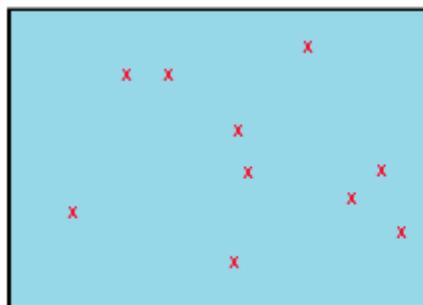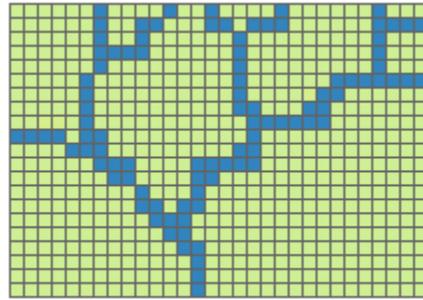
Line Features as Raster

In vector format, a line is an ordered list of x,y coordinates, but in raster format, it is represented as a chain of spatially connected cells with the same value.


Line features

Raster line features

Polygon Features as Raster

A vector polygon is an enclosed area defined by an ordered list of x,y coordinates in which the first and last coordinates are the same, thereby representing area. By contrast, a raster polygon is a group of contiguous cells with the same value that most accurately portray the shape of the area. Examples of polygonal features include buildings, ponds, soils, forests, swamps, and fields.
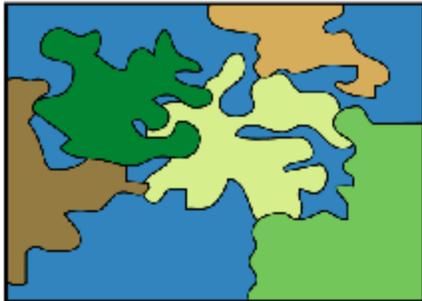

Polygon features
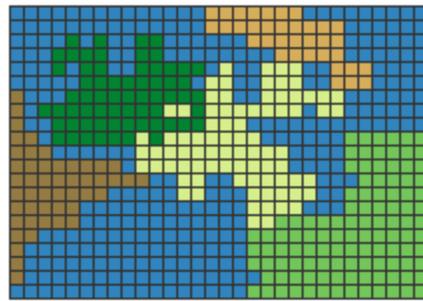
Raster polygon features

For example: A Lake

You can show a lake as vector data = as a polygon. You can show the lake shore very detailed by adding many vertices and sides to your polygon. Or, you can simplify things because you are not interested in the details of the lake shore. You can even show the lake as a point if the actual shape of the lake is not relevant for your map or analysis.

But, you can also show a lake as raster data.
Here you break the lake apart into squares. If you use really small squares (e.g. 1 foot) you can show the lake in great detail. If you use larger squares (e.g. 100 yards) your lake shore will be much simplified.
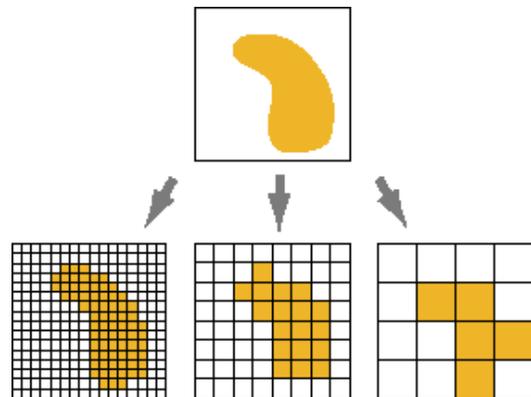
Real map making, for example the topographic maps produced by the United States Geological Survey, always uses both vector and raster data. Why? Makes sense! You use whatever data is best suited for your specific map!
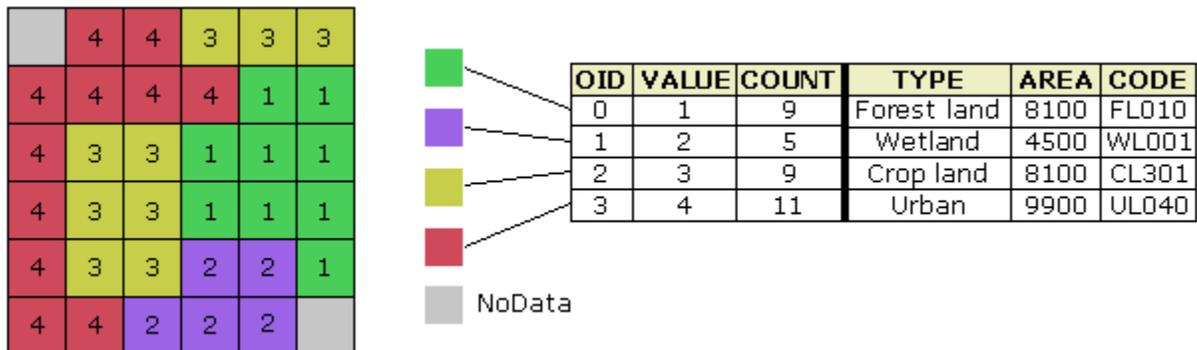

Vector representation of lake polygon features. Note the detail maintained in the shoreline that defines the boundary between water and upland.

Raster representation of the same lake. With a raster data format, cells are used to encode geographic data. The entire area of each cell is assigned to a single category and boundary details are lost.
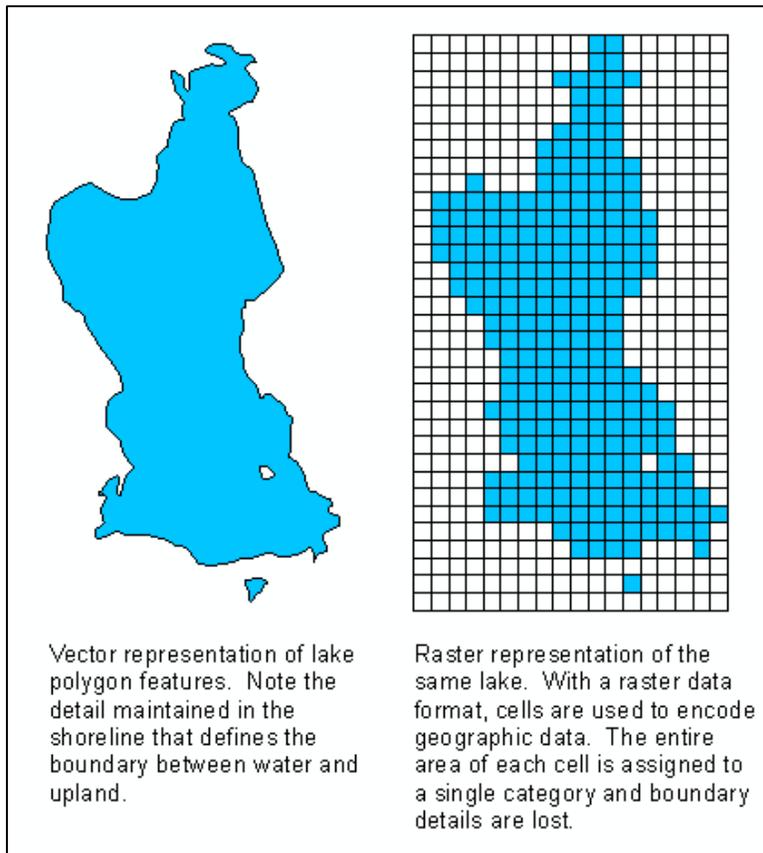
1.1) Attribute Data in Rasters

The attribute information is the grid cell value – that's all!

| OID	VALUE	COUNT	TYPE	AREA	CODE
0	1	9	Forest land	8100	FL010
1	2	5	Wetland	4500	WL001
2	3	9	Crop land	8100	CL301
3	4	11	Urban	9900	UL040

NoData

A Few Characteristics

Cell values can be either positive or negative, integer, or floating point. Integer values are best used to represent categorical (discrete) data and floating-point values to represent continuous surfaces. Cells can also have a NoData value to represent the absence of data.

- Raster attribute tables typically have cell values that represent or define a class, group, category, or membership. For example, a satellite image may have undergone a classification analysis to create a raster dataset that defines land uses such as forestland, wetland, cropland, and urban. The numbers below could represent which cell value in the raster dataset would define the land use:

- The ObjectID (OID) is a unique, system-defined, object identifier number for each row in the table. VALUE is a list of each unique cell value in the raster datasets (in a grid, this is an integer). COUNT represents the number of cells in the raster dataset with the cell value in the VALUE column. Cell values represented by NoData are not calculated in the raster attribute table.

- You cannot edit a raster attribute table!

Value applies to the center point of the cell

For certain types of data, the cell value represents a measured value at the center point of the cell. An example is a raster of elevation

+315	+319	+321	+323
+317	+323	+328	+326
+313	+318	+325	+323
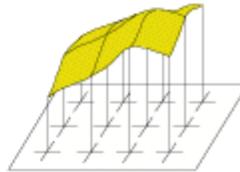
Value applies to the whole area of the cell

For most data, the cell value represents a sampling of a phenomenon, and the value is presumed to represent the whole cell square.

50	45	40	35
35	40	35	25
20	25	30	20

More Information

- NoData in raster datasets
  http://resources.arcgis.com/en/help/main/10.1/index.html#//009t0000002v000000

2) Types of Raster Data

There are four main types of raster data in GIS:

1. Digital Elevation Models (DEMs). Here the value of each grid cell corresponds to the mean elevation of the grid cell.
2. Remote Sensing Imagery = aerial photographs or satellite images. These are, in essence, the same what your digital camera produces, except they (should be) georeferenced and (can be) multi-spectral.
3. Other gridded quantitative data, for example wind speed, air temperature, etc.
4. Other gridded classified data, for example land use, soil types, zoning, etc.

What's a line or border anyways?

With polygons we show the demarcation between two different polygons as a sharp, crisp, and discrete line. That may be appropriate for parcel or zoning data where there is a definite change (e.g. in ownership) when you cross the line.

Natural characteristics, in reality, have fuzzy boundaries and transitions. For example, land use polygons, soil type polygons, etc. make it appear as though there is a single transition whereas in reality the situation is more fuzzy and complex.

This generalization is implicit in most spatial data. For example, we may show a 200 acre polygon as agricultural land use whereas in reality there are 'islands' of forest and water inside that polygon.

Additional Information

*   Understanding Raster Data
    http://www.fire.org/niftt/released/RasterPrimer.pdf
*   Raster Data
    http://linfiniti.com/dla/worksheets/5_RasterData.pdf

3) Raster Software

Within ArcGIS Desktop
1. ArcScene
2. Spatial Analyst, 3D Analyst, Image Analysis Window
3. (Image Analyst) – not available to us.

Other Programs (free)
*   MultiSpec: A Freeware Multispectral Image Data Analysis System from Purdue University.
    https://engineering.purdue.edu/~biehl/MultiSpec/
*   ImageJ: free image processing and analysis. http://rsbweb.nih.gov/ij/

4) Digital Elevation Models

= gridded elevation data! Issues to consider:

- Spatial resolution vs. spatial coverage.
- Computer resources!
- Accuracy/Uncertainty: systematic errors.
- Accuracy/Uncertainty: random errors/noise.
- Accuracy/Uncertainty: gaps and artifacts.

All DEMS become 'grainy' when you zoom-in too much = reach the detail that's available. The same is true for vector data.
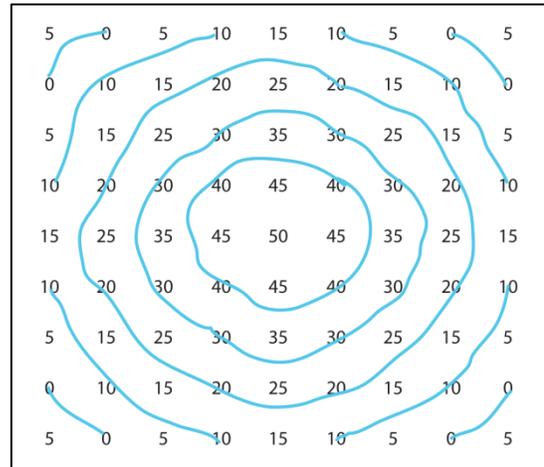
4.1) DEM Creation

1. Ground-based from individual survey points, interpolation to contours, and gridding/interpolation to a grid.

That's the classic DEM available for many parts of the country and the world based on original survey data and topographic maps.

2. Airborne or space-based using radar inferometry.

The classic example here is the Shuttle Radar Topographic Mission (SRTM) that created the first consistent 'global' DEM at 90 m resolution. 30 m resolution is available for the United States.

3. LIDAR (Light Detection And Ranging, also LADAR) 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.

LIDAR DEMs are becoming increasingly available and popular because of their high spatial resolution (grid size 1 m or less) and high vertical accuracy (10 cm or less). There are a lot of private companies involved in the LIDAR market.
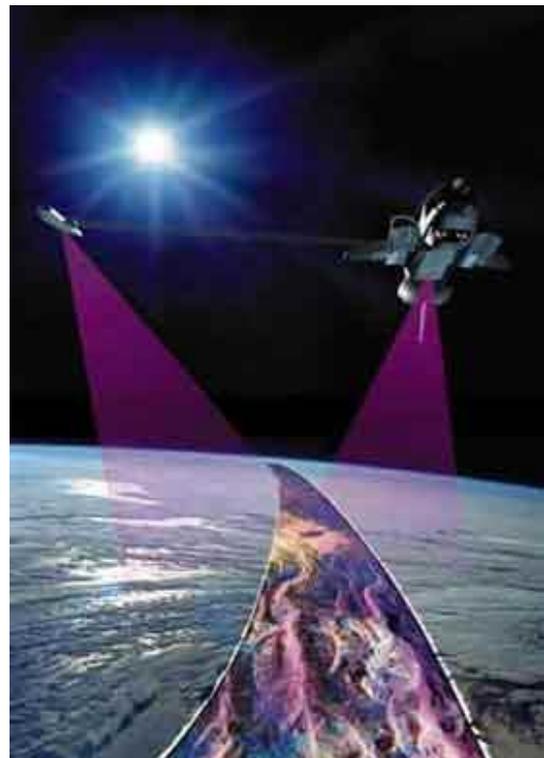
4. Stereoscopic image analysis. This is the traditional way DEMs where creates using stereo-paired aerial photographs and survey elevations.

A new application of this old technology is the ASTER GDEM because the ASTER instrument on the Terra satellite can collect the stereo pairs necessary to generate high resolution DEMS = a 30 m resolution global DEM.
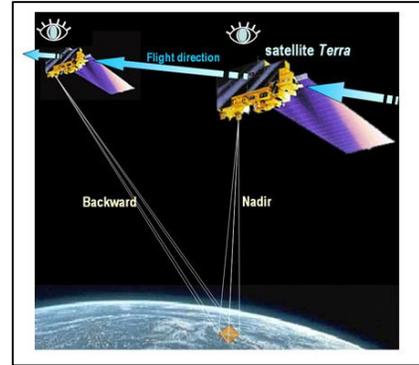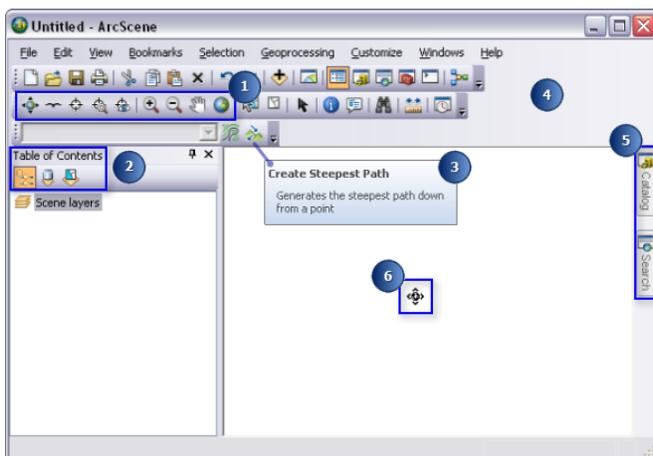
More Information and Data

Visit http://www.westfield.ma.edu/cbraun/resources/gis-resources/ and loo for the Raster Data / Remote Sensing Section.

5) ArcGIS Extensions, Tools, and Programs

ArcScene

ArcScene is a 3D visualization application that allows you to view your GIS data in three dimensions. Features are placed in 3D by providing height information from feature geometry, feature attributes, layer properties, or a defined 3D surface, and every layer in the 3D view can be handled differently. Data with different spatial references will be projected to a common projection, or data can be displayed using relative coordinates only. ArcScene is also fully integrated with the geoprocessing environment, providing access to many analysis tools and functions.

- ArcScene is essentially the same as ArcMap, but in 3D, using grids or TINs.
- ArcScene is fun to use on the computer…but the cool 3D overlays do not print well.
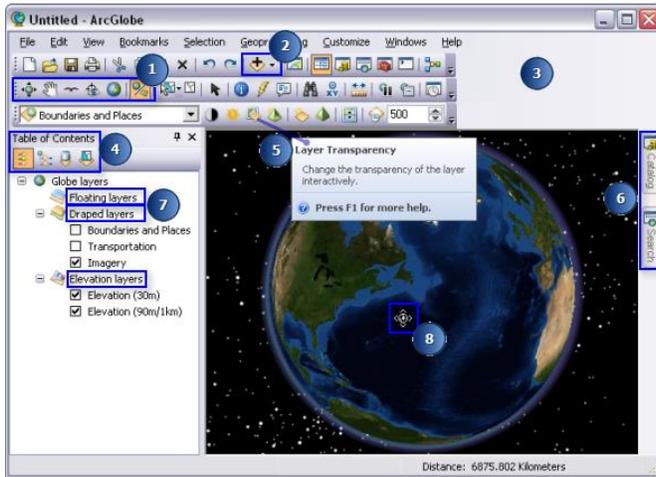- ArcScene works well with the 3D Analyst extension

More information at
http://resources.arcgis.com/en/help/main/10.1/index.html#/Introducing_the_ArcScene_user_interface/00q8000000ws000000/

ArcGlobe

ArcGlobe is part of the ArcGIS 3D Analyst extension. This application is generally designed to be used with very large datasets and allows for seamless visualization of both raster and feature data. It is based on a global view, with all data projected into a global Cube projection and displayed at varying levels of detail (LODs), organized into tiles.
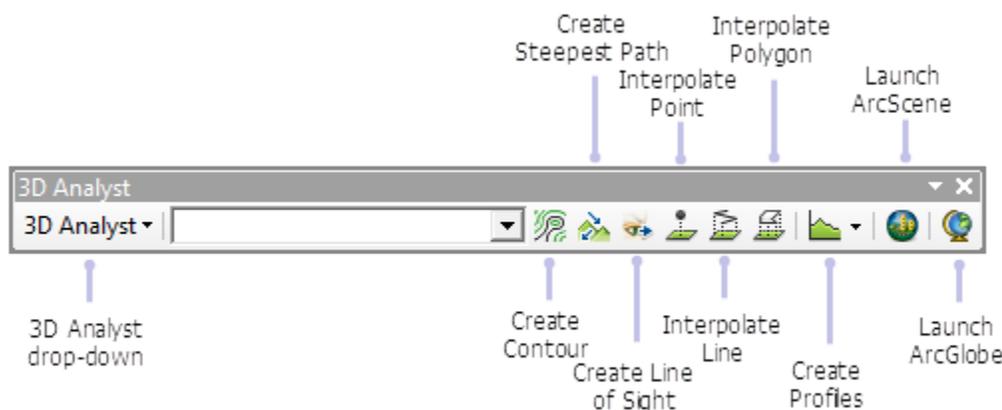

More information at
http://resources.arcgis.com/en/help/main/10.1/index.html#/The_ArcGlobe_user_interface/00q8 00000091000000/

ArcGIS 3D Analyst Extension

The ArcGIS 3D Analyst extension provides tools for creating, visualizing, and analyzing GIS data in a three-dimensional (3D) context.
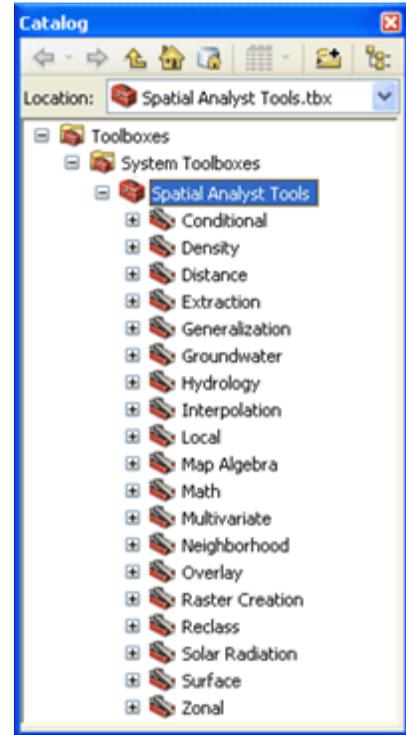

More information at
http://resources.arcgis.com/en/help/main/10.1/index.html#/What_is_the_ArcGIS_3D_Analyst_ extension/00q8000000wv000000/
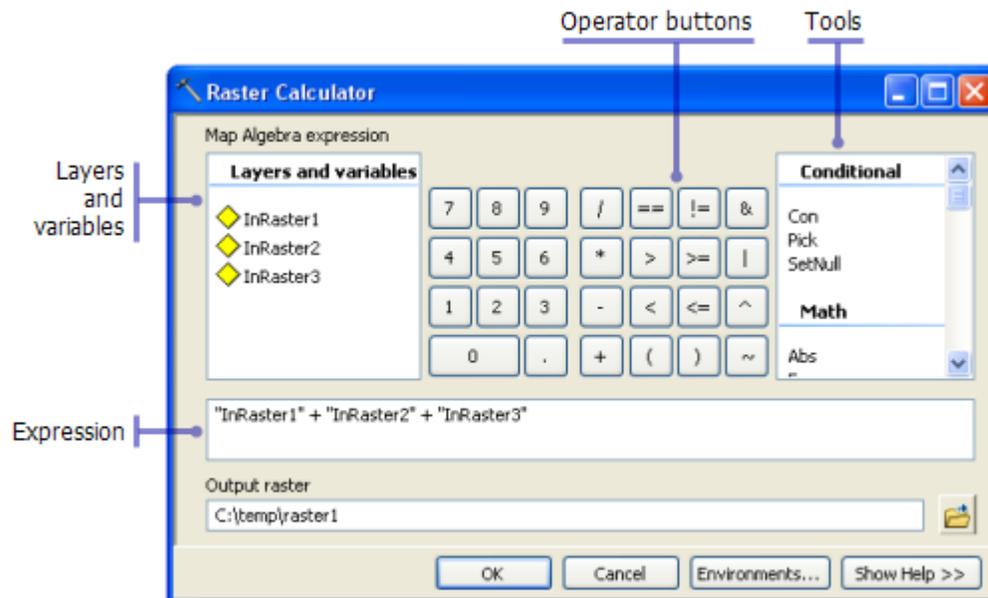
ArcGIS Spatial Analyst Extension

The ArcGIS Spatial Analyst extension provides a broad range of powerful spatial modeling and analysis capabilities. You can create, query, map, and analyze cell-based raster data; perform integrated raster/vector analysis; derive new information from existing data; query information across multiple data layers; and fully integrate cell-based raster data with traditional vector data sources.

- Visualize data in 3D (e.g. hill shades).
- Create 3D surfaces form different data sources.
- Create rasters from a variety of input data
- Slope/Aspect calculations; Area/Volume calculations.
- Visibility and Viewshed determinations.
- Cross-Sections through the raster data.
- Reclassify and recalculate the raster.
- Convert raster into vector and vice-versa.

Some of the tools and functions of Spatial Analyst can be accessed via the Spatial Analyst toolbar. However, most of the 170 geoprocessing tools are organized as 19 toolsets via the Spatial Analyst toolbox.

Probably the most useful tool is the Raster Calculator where you can perform mathematical calculations on raster data sets.

More Information

- What is the ArcGIS Spatial Analyst extension?
  http://resources.arcgis.com/en/help/main/10.1/index.html#/What_is_the_ArcGIS_Spatial_Analyst_extension/005900000001000000/

- Raster Calculator
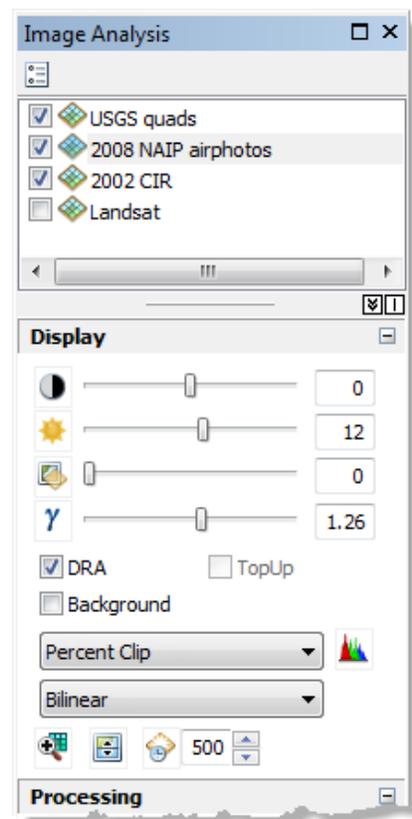 http://resources.arcgis.com/en/help/main/10.1/index.html#/Raster_Calculator/009z000000z7000000/

Note

ArcGIS 3D Analyst and Spatial Analyst are so-called extensions that need to be activated first! (Customize – Extensions…) Then you can activate the associated toolbars (Customize – Toolbars) and use the associated tools.

Image Analysis Window

The Image Analysis window supports the analysis and exploitation of image and raster data in ArcMap with a collection of commonly used display capabilities, processes, and measurement tools. This is a window that can be docked, for example, to the side of the application's window and either pinned open or allowed to retract to a tab along the side of the application window.

Select Windows – Image Analysis to open the Image Analysis window in ArcMap.

More information at
http://resources.arcgis.com/en/help/main/10.1/index.html#/What_is_the_Image_Analysis_window/009t000001tm000000/

6) Your Turn: Explore the Massachusetts DEM

1. Copy the Massachusetts DEM from the server to your own USB flash drive into a dedicated sub-folder of your \data folder (~700 MB).

2. If needed: activate the Spatial Analyst extension and add the toolbar.

3. Add the DEM to your map – both the raw DEM and the associated layer file. What's the difference between the raw data and the layer file?

Now: remove the layer file and work only with the raw DEM.

4. Explore the Properties, especially the Source tab. What is the pixel size? What is the spatial refercence?

5. Explore the Symbology options: Unique Values, Classified, Stretched, and Discrete Color – make sure you understand the differences! Explore the Help as needed! Experiment with Hillshade and choose a suitable symbology for the DEM.

6. Zoom-in until the DEM becomes pixelated (= grainy) and use the Identify tool to find the elevation of the grid cells. Use the ruler tool and measure a pixel – is it indeed 5 m?

7. Create a cookie-cutter or mask for Adams = a polygon file for the town of Adams. See the 2 October 2013 cookbook.

8. Use the Extract by Mask tool to extract the raster cell for Adams. Save your Adams DEM to your USB flash drive into your generic file geodatabase.

9. Open the attribute table for the Adams DEM. Do you understand what you are looking at? Explore the Help as needed!

10. Open the Image Analysis window and explore some of its options for display and analysis. Explore the Help as needed!

11. Start ArcScene add the Adams DEM, and select a suitable symbology.

12. Goto Layer Properties, select the Base Heights tab, and select Floating on a custom surface. The custom surface, by default, is the actual DEM. Now you DEM is displayed in 3D!

13. Double-click on Scene Layers to display the Scene Properties and experiment with the Vertical Exaggeration.

14. Save your ArcMap map and ArcScene scene to your USDB flash drive, into the\garp0344sfall2013\week7 folder. Make sure that you check 'Store relative pathnames to data sources under Map/Scene properties before you save!

7) Homework for tomorrow

Finish…
Finish the 14 steps listed in Section 6.
We will need those tomorrow!

Watch…Analyzing Data in 3D in ArcGIS Desktop
Here is a great demonstration of how to analyze data in 3D as part of thematically analyzing spatial data in ArcGIS Desktop. Very cool: the extrusion capabilities in ArcScene!
http://edcommunity.esri.com/Resources/ArcLessons/Lessons/A/Analyzing_Data_in_3D_in_ArcGIS

Watch…Raster Calculator Demonstration: Site Location
This is a great demonstration of Raster Calculator!
http://edcommunity.esri.com/Resources/ArcLessons/Lessons/R/Raster_Calculator_Demonstratio

Explore…the Slope and Aspect Tools
How Slope works
http://resources.arcgis.com/en/help/main/10.1/index.html#/How_Slope_works/009z000000vz000000/
How Aspect works
http://resources.arcgis.com/en/help/main/10.1/index.html#/How_Aspect_works/009z000000vp000000/

Explore
See what data are available for our area at http://www.opentopography.org/

8) Tutorials

ArcGIS Tutorials for 10.0
http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#/ArcGIS_tutorials/00v20000000t000000/
- 3D Analyst, Spatial Analyst, Network Analyst, and more!
- Tutorials available as PDF, data from ArcGIS for Desktop DVD.

ArcGIS Tutorials for 10.1
http://resources.arcgis.com/en/help/main/10.1/index.html#/ArcGIS_tutorials/00qn0000013t000000/
- Spatial Analyst, Network Analyst, and more!
- Tutorials available online *only*, data from ArcGIS for Desktop DVD.