GIS IN ECOLOGY:
VISUALIZING IN 3D

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ACCRU

UNIVERSITY OF ALBERTA

Contents

This is an applied course on how to use ESRI's ArcGIS ***3D Analyst*** extension to work with and visualize three-dimensional data. Please see the references for more 3D theory and concepts in GIS.

References:

Booth, Bob. 2000. "Using ArcGIS 3D Analyst." Environmental Systems Research Institute, Inc. Redlands, CA. 218 pp.

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

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Introduction

> *"If a picture is worth a thousand words, then a three-dimensional surface that you can navigate and fly through must be worth a million" (ESRI, 2002).*

The earth is not flat and standard GIS is not capable of satisfying our visual sense of depth. With ESRI's ArcGIS 3D Analyst, you can add zest to your GIS data by displaying it in three dimensions. Not only does a 3D representation of your data wow an audience, but the extension also gives you access to a powerful set of analytical tools.

3D Analyst and ArcScene

3D Analyst adds functionality to ArcMap and ArcCatalog, but you also have access to a new desktop application called ArcScene, which lets you visualize and interact with your GIS data in a 3D environment. See the appended "Quick Reference" for available tools. See ArcGIS Help for info on the more sophisticated ArcGlobe (not covered here).

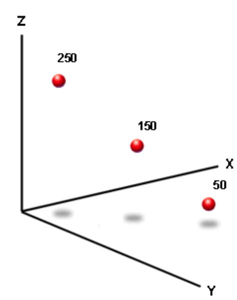
ArcGIS's 3D Analyst provides three-dimensional visualization, topographical analysis, and surface creation capabilities:

- Build surface models from standard geographically enabled data
- Perform interactive perspective viewing, including pan and zoom, rotate, tilt, and animated fly-throughs for presentation and analysis
- Model ground-level surfaces such as forest or urban landscapes
- Model subsurfaces such as groundwater and caves
- Exaggerate 3D data for presentation emphasis
- Drape two-dimensional data onto three-dimensional surfaces
- Calculate surface area, volume, slope, aspect, and hillshade
- Create contours in either 2D or 3D space
- Calculate viewsheds, lines of site, and steepest paths
- Query 3D data based on attributes or location
- Export data and views for presentation and the Web

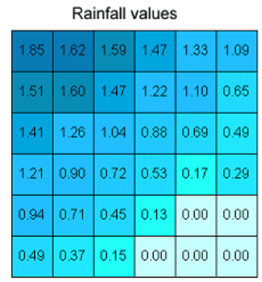
3D Data

3D Analyst lets you work with three broad categories of 3D data:

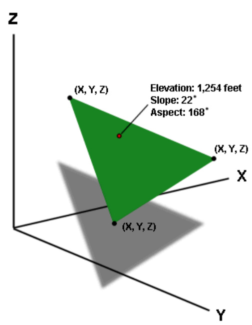
- Rasters
- TINs
- 3D features



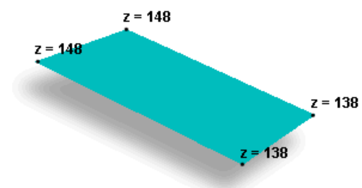
Each data model represents geographic features differently, but the Z-value is the important similarity and defining attribute. A ***Z-value*** stored for a given location represents an attribute other than that location's horizontal position. For example, the longitude and latitude of a point can be stored respectively as an X and Y coordinate. The density or quantity (e.g. elevation) of that same point is stored as its Z-value.



A ***raster*** is an array of equally-spaced cells, or pixels, which taken as a whole represent a thematic map or an image. Each raster cell contains a value representing the measurement of some phenomena, for example, elevation or precipitation.



A Triangulated Irregular Network (***TIN***) represents space using a set of non-overlapping triangles that border one another and vary in size and proportion. They are created from a set of input points with X, Y, and Z values that become the triangle vertices (nodes). Lines connect the nodes to form the triangle boundaries (edges). Once the TIN is built, the elevation of any location on a TIN surface can be mathematically estimated or interpolated using the X, Y, and Z values of the bounding triangle's nodes. Slope and aspect for each face is also calculated.



A ***3D feature*** is a point, line, or polygon that, in addition to its X,Y coordinates, stores a Z-value as part of its geometry. The "Shape" field of the attribute tables indicates this with either PointZM, PolylineZM, or PolygonZM. A point has one Z-value; lines and polygons have a single Z-value for each vertex in the shape.

Data Model	TINs	Rasters
Advantages	• variable resolution • preserves X,Y location of input points, allowing for more detail where there's lots of surface variation and less detail where there's not • can refine surface topography with features representing roads, rivers, lakes, ridgelines, etc. • display well at all zoom levels	• same amount of information for each part of the surface • demand fewer system resources • created/displayed more quickly • take up less disk space. • more familiar and readily-available • more mathematical and statistical functions are available
Disadvantages	• demand more system resources • take up more space	• display degrades when you zoom in too close • same amount of information for each part of the surface
Suggested Choice	• for large-scale applications (those covering a small area in detail) • display quality is very important	• for small-scale applications (those covering a large area) • require statistical analysis of data

Course Data Sources

The data layers used in this short course have a projection/datum of ***NAD 1983 UTM Zone 11*** (map units in meters) and are available from: http://geogratis.cgdi.gc.ca. The following provides metadata for each geographic layer in \\bio_print\Courses\GIS-100\6_VI3:

Name	Description	Scale	Feature
Access	Roads and linear features in SW Alberta (082G)	1:250,000	Line
Contours	Elevation contours for 082G08 and 082G09	1:50,000	Line
Rivers	Rivers in SW Alberta (082G)	1:250,000	Line
Den	Location of animal den	1:50,000	Point
Observation	Location for observing den	1:50,000	Point
Lakes	Waterbodies for 082G08 and 082G09	1:50,000	Polygon
Range1, Range2	Animal kernel home ranges	1:50,000	Polygon
SWAlberta543	Landsat 7 Bands 5,4,3 subset of path 41 row 26 (19990920)	30m	Image

Instructions for Copying the Course Dataset

1. Double click on the COURSES shared directory icon on the Desktop
2. Open the “GIS-100” folder and right-click to COPY the “**6_VI3**” folder
3. Click on the FOLDERS icon along the top menu bar
4. On the left side of the exploring window, click and drag the scroll bar until you can see “My Computer”
5. Expand by clicking on the “**+**”’s from My Computer >>> **C:\Workspace**
6. PASTE the “**6_VI3**” folder in to the **C:\WorkSpace** directory
7. Once all the files have copied over, close the exploring window
8. Notice that there is a **\Work** folder available in which you will save all your working files

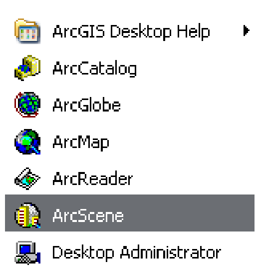
Tasks

The course exercises apply 3D Analyst to address the following ecological questions:

- How can we visualize the spatial distribution and density of fish observations?
- What is the actual surface area of an animal’s range?
- Where should we locate an optimal den observation point?
- What does the terrain look like for a bird flying across the landscape?

Visualizing and Measuring in Terrain

What better way to get familiar with 3D data and visualization than to jump right in and explore the ArcScene application and 3DAnalyst extension. Using several examples in ecological research and data from the southwestern corner of Alberta, you will create a TIN from contour features, visualize data by draping and extruding, create a profile and line of sight for use in habitat monitoring, and determine home range surface areas.

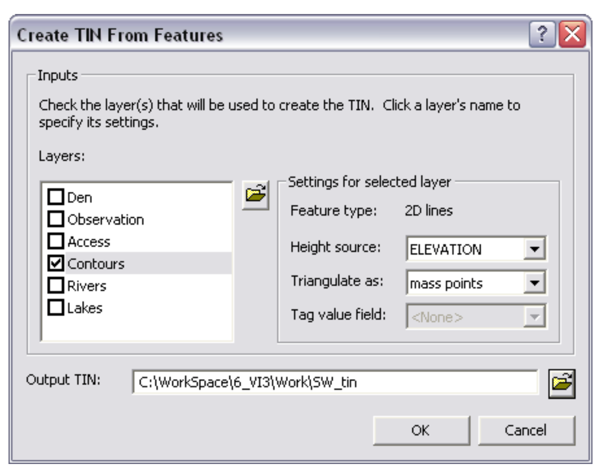


1. Click START >>> PROGRAMS >>> ARCGIS >>> ARCSCENE
2. Check that the 3D Analyst extension is enabled (TOOLS >>> EXTENSIONS) the toolbar is showing (VIEW >>> TOOLBARS)

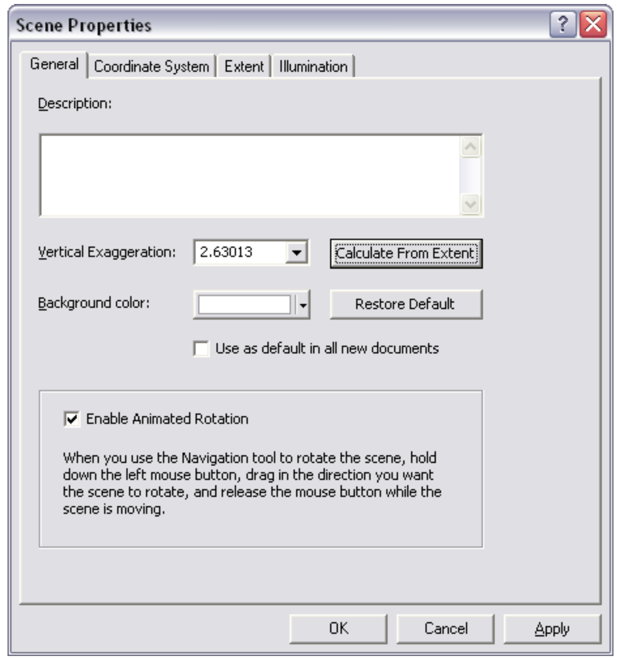
Creating a TIN from elevation contours

Creating a TIN from contours is a very useful skill to know, especially if you can get your hands on georeferenced, small-scale contour lines.

3. Click the ADD DATA button
4. Add all LAYER files from the **\SWAlberta** folder
5. Turn all layers OFF except for **Contours**
6. Choose 3D ANALYST >>> CREATE/MODIFY TIN >>> CREATE TIN FROM FEATURES
7. Click on **Contours**
8. Triangulate ***ELEVATION*** as ***mass points*** (this uses the nodes of the contour lines)
9. Output to **C:\WorkSpace\6_VI3\Work\SW_tin**
10. Click OK
11. Turn off the **Contours** layer



12. Explore the various tools in the Tools toolbar to navigate through the TIN, keeping in mind that the elevation Z-values are in ***feet***

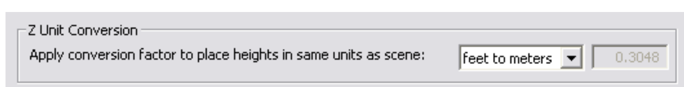


Scene and layer properties

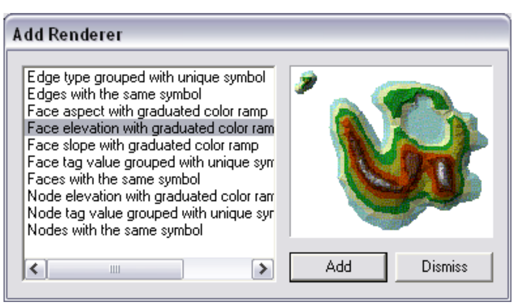
13. Double click on the “Scene Layers” data frame
14. Examine each of the tabs
15. On the GENERAL tab, click the CALCULATE FROM EXTENT for the Vertical Exaggeration and check “Enable Animated Rotation”

Vertical exaggeration is purely a visual effect, which results from multiplying the z-values in a scene by some factor, and does not influence analysis. You can turn molehills into mountains by multiplying z-values by a number greater than 1 or turn mountains into molehills by multiplying by a decimal fraction. Vertical exaggeration can be used to emphasize elevation on a relatively flat surface or it can bring z-values into proportion with x,y values when these units measure different things (e.g. x,y in meters and z in feet, population density, precipitation).

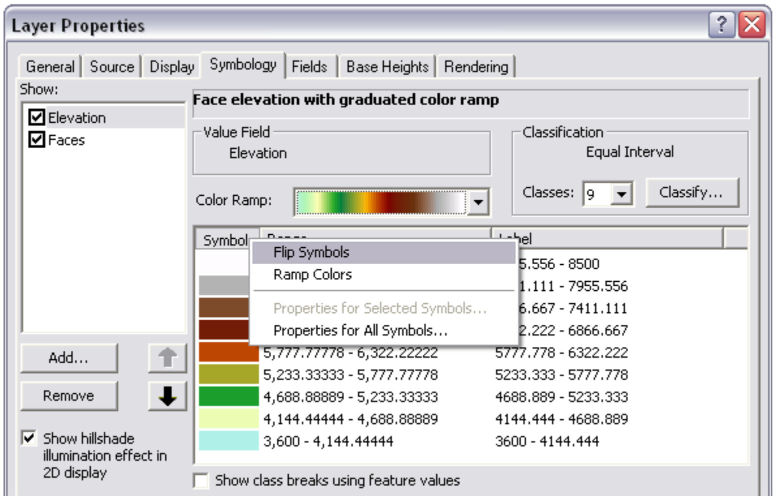
16. Click OK
17. Double-click on the TIN name to access the layer properties
18. Examine each of the tabs
19. Double click on **SW_tin** to view the BASE HEIGHTS tab
20. Select **feet to meters** as the Z UNIT CONVERSION (this brings the Z units equal to the XY measurement)
21. Click OK



22. CHALLENGE: Symbolize **Contours** using the ELEVATION field and an appropriate Z Unit Conversion

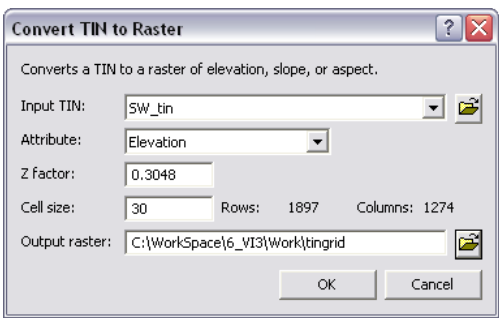


23. Back in the SYMBOLOGY tab for SW_tin, click on the ADD button and select the following renderer : “Face elevation with graduated color symbol”
24. Click ADD and then DISMISS
25. Optionally, modify the classification
26. Click on the SYMBOL button (heading) and click FLIP SYMBOLS
27. In the SHOW box, **UN**check Faces
28. Click OK
29. ADD a couple other renderers



Converting a TIN to a raster grid

You will convert the TIN to a grid… especially useful when incorporating elevation into a raster calculation. You can also convert to features to enable you to perform selection queries and geoprocessing operations.



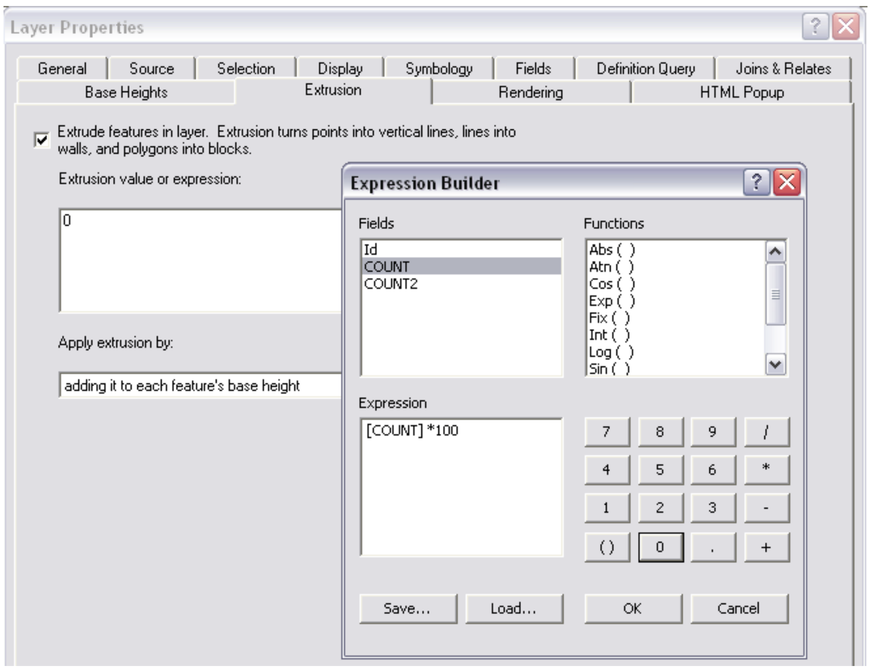
30. Choose 3D ANALYST >>> CONVERT >>> TIN TO RASTER
31. Select **sw_tin** as the input
32. Select ***ELEVATION*** as the attribute
33. Type **30** for the cell size
34. Z factor: **0.3048**
35. Type **C:\WorkSpace\6_VI3\Work\tingrid** as the output
36. Click OK
37. Double click on the **tingrid** layer name
38. Click on the BASE HEIGHTS tabs and specify to obtain base heights from itself
39. Click on the SYMBOLOGY tab
40. Symbolize as STRETCHED, using HISTOGRAM EQUALIZE with the ELEVATION #2 color ramp
41. Click on the RENDERING tab
42. Click "*Shade areal features relative to the scene's light position*"
43. Click OK
44. Reset the vertical exaggeration for the Scene Properties (*you may also want to uncheck "Enable Animated Rotation"*)

Visualizing trout inventory in 3D

You can use the TIN or elevation grid to display your regular 2D data in 3D. You will drape a satellite image and the linear features over the elevation heights, and use attribute values to extrude the sample fish data to help you visualize it in 3D.

1. Click ADD DATA to add in **Samples** and **SWAlberta543** in the **\SWAlberta.gdb**
2. Turn OFF all layers (*so ArcScene isn't always drawing – to speed things up*)
3. Set the BASE HEIGHTS by obtaining heights from **tingrid** for the following layers: **Rivers**, **Lakes**, **Access**, and **Samples**
4. Click OK

5. Symbolize the **SWAlberta543** image using the following:
    - DISPLAY tab: *Resample during display using: CUBIC CONVOLUTION*
    - SYMBOLOGY tab: 2 STANDARD DEVIATIONS
    - BASE HEIGHTS tab: Obtain heights from **tingrid** (*remember that you already applied the 0.3048 z-factor conversion when converting to raster!*)
6. Click OK
7. Turn ON **Rivers**, **Access**, **Lakes**, **Samples**, and **SWAlberta543**
8. Right click on **Samples**
9. Select ZOOM TO LAYER
10. Double click on **Samples**
11. Click on the SYMBOLOGY tab and show **SPECIES** as CATEGORIES using bright colors
12. Click on the EXTRUSION tab
13. Click on the CALCULATOR button
14. Select **[COUNT] * 100** and click OK
15. Click OK again
16. Apply vertical exaggeration and navigate around the scene



Extrusion is three-dimensional extension for features. As you can see an extruded point becomes a line (likewise, an extruded line becomes a wall and an extruded polygon becomes a block). By symbolizing and displaying the data in this way, you can quickly see which locations had a greater number of fish by species.

17. SAVE and CLOSE ArcScene

Creating a transect profile and line of site for monitoring a marmot den

*Perhaps you study marmots and you want to locate the best place for you and your telescope/binoculars for observing the small alpine mammals. By looking at the topographic map, you have come up with three possible locations that you want to take a closer look at using **line of sight** – an operation in 3D Analyst that allows you to see whether one point location (called the target) can be seen from another point location (called the observer).*

1. OPEN ***ArcMap***
2. ADD the **tingrid**, **Access.lyr**, **Observation.lyr** and **Den.lyr** layers
3. SYMBOLIZE **tingrid** using STRETCHED, HISTOGRAM EQUALIZE, and the ELEVATION #2 color ramp

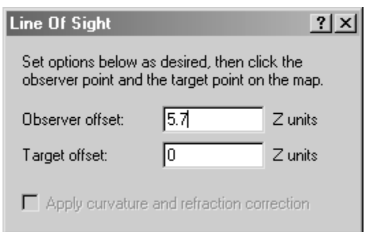
4. Create a HILLSHADE surface of **tingrid** and then display it as *transparent* over the shaded relief *(Refer to ArcGIS Desktop Help or previous short course manuals if you need help with this.)*

*First, you want to determine how easy it would be to hike to each of the observation locations, so you will create a **profile graph**. (You must use the 3D Analyst toolbar in ArcMap – not ArcScene – and have either a TIN or raster surface loaded.)*

5. Set **tingrid** as the target layer in the 3D ANALYST toolbar
6. ZOOM in to the area surrounding the marmot den
7. Click on the INTERPOLATE LINE button

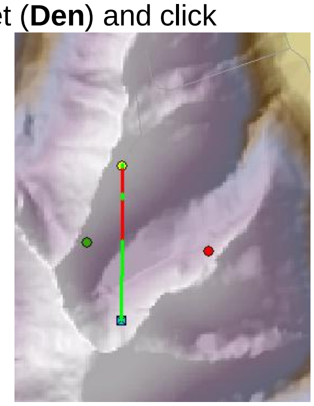
8. Click on the *confluence of the trails* down the valley from the observation points
9. Double click on one of the observation points
10. Click on the CREATE PROFILE GRAPH tool

11. You may wish to name the graph – choose TOOLS >>> GRAPHS >>> MANAGE
12. DELETE the line graphic
13. REPEAT the previous six steps for the other observation points



14. Click the CREATE LINE OF SIGHT tool
15. In the dialog that opens, change the observer's offset to **1.7** (or your height in meters)
16. Move the dialog box out of the way
17. Center the cursor's crosshairs over one of the observer points and click
18. Then center the cursor on the target (**Den**) and click

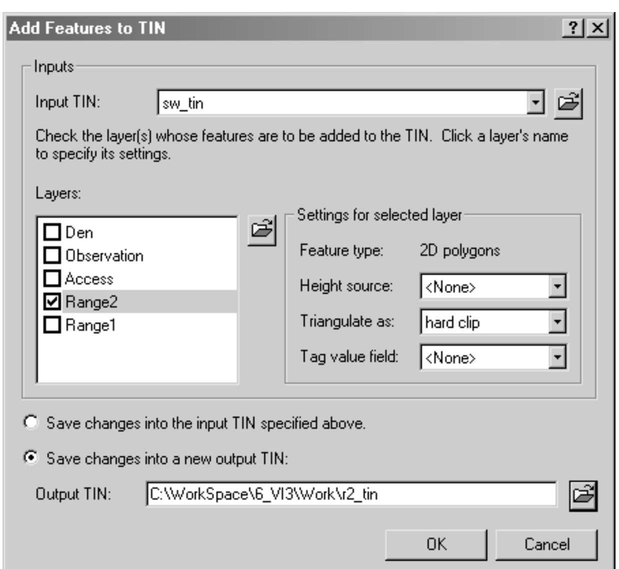
*The __**status bar**__ (located at the lower left hand corner of ArcMap's interface) __reports whether the target is visible or not__. The line of sight is drawn as a 3D graphic in the display. Visible portions along the line are colored green. Non-visible portions of the ground (maybe due to a steep down-slope, an intervening ridge, or something else) are colored red.*



19. REPEAT the previous five steps on the other points

After careful analysis of the profile graphs and the line of site graphics, you can decide where the best observation point would be (or how great of magnification your binoculars should be).

20. SAVE the map document

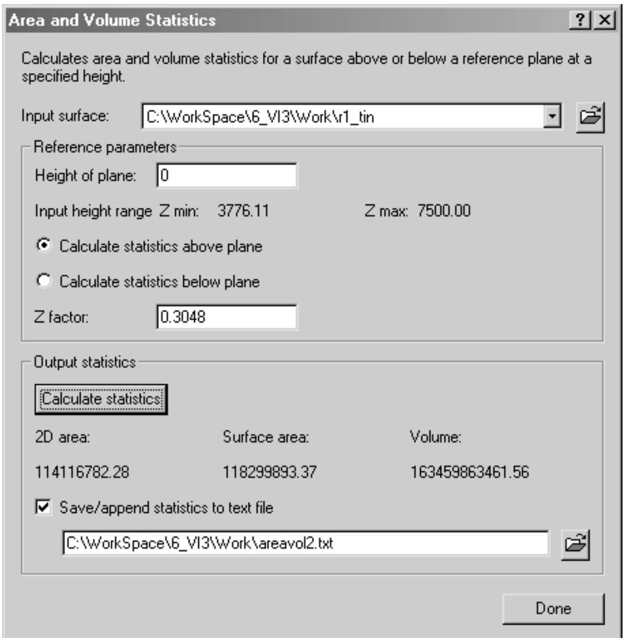


Determining which home range has greater surface area

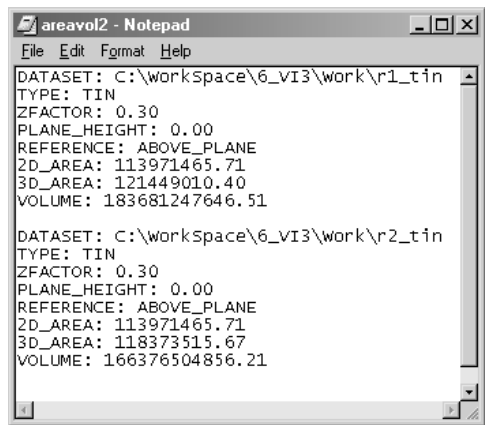
In mountainous terrain, 2D area can be quite different from 3D surface area. When measuring from above, two areas can have identical 2D areas, but when you factor in slopes and elevation influences, one animal's territory may actually be larger than the other.

21. Start a NEW empty map document
22. ZOOM TO FULL EXTENT
23. Add the **sw_tin**, **Range1** and **Range2** layers to the scene
24. OPEN ATTRIBUTE TABLE for each home range to compare the 2D areas

25. Choose 3D ANALYST >>> CREATE/MODIFY TIN >>> ADD FEATURES TO TIN
26. Select **sw_tin** as the input
27. Check on **Range1**
28. Select **<None>** as the height source
29. Triangulate as **hard clip**
30. Choose to save changes in a new output TIN; e.g. **C:\WorkSpace\6_VI3\Work\r1_tin**
31. Click OK
32. REPEAT for **Range2** and name the new output TIN as **r2_tin**
33. Choose 3D ANALYST >>> SURFACE ANALYSIS >>> AREA AND VOLUME



34. Check to *Save/append statistics to text file* (accept default name to the **\Work** folder)
35. Select **r1_tin** as the input surface
36. Type **0** for height of plane
37. Choose to *Calculate statistics for above plane*
38. Type **0.3048** as the Z factor (remember those pesky feet units)
39. Click CALCULATE STATISTICS



40. REPEAT for **r2_tin**
41. Click DONE when finished
42. View the text file from Windows Exploring or Notepad
43. SAVE the map document
44. CLOSE ArcMap

Flying through the Landscape

Wouldn't it be wonderful to view your landscape from an eagle's eye? ArcScene allows you to fly above and over the terrain and other layers displayed in 3D. Open your last ArcScene document and skip to ***Animated rotation***, or start from scratch, then see what it is like to fly.

1. Start a new scene document in ***ArcScene***
2. ADD the **SWAlberta543.tif**, **Rivers.lyr**, and **Lakes.lyr** (accessible from the **\SWAlberta** folder)
3. Set the BASE HEIGHTS for **SWAlberta543**, **Rivers**, and **Lakes** using **tingrid** (browse for the raster in the **\Work** folder)
4. SYMBOLIZE each layer appropriately
5. Apply vertical exaggeration and a background color to the SCENE PROPERTIES

Adjusting the View Settings

6. Choose VIEW >>> VIEW SETTINGS
7. In the *Viewing characteristics* frame, select **Orthographic (2D view)**
8. Experiment with the NAVIGATE and ZOOM tools
9. Switch back to **Perspective**
10. Modify the *Viewfield Angle*, *Roll Angle*, and *Pitch* values
11. Note that there are several other functions of the View Settings dialog box
12. CLOSE the window

Animated rotation

13. Go to the GENERAL TAB for Scene Properties
14. Select ENABLE ANIMATED ROTATION
15. Click OK to dismiss the window
16. Click on ZOOM TO FULL EXTENT
17. Click on the NAVIGATE button (notice the different appearance)
18. Place your cursor at the right side of the display
19. While holding down the left mouse button, drag the cursor to the left, and release the mouse button while dragging from right to the left
20. Take your hand off the mouse
    *If the display does not continue to rotate after you let go of the mouse, try again and make sure you are releasing the mouse button **while** dragging the cursor across the display.*
21. Experiment with other tools interactively while in animated rotation mode
    As soon as you click another tool, ArcScene temporarily suspends the rotation. To restart the rotation, click the NAVIGATE button.
22. Stop rotation by placing your mouse cursor is over the display and then press the **Esc** key on the keyboard

Flying

Before you practice using the FLY tool, take a moment to get familiar with the commands:

Fly Tool Instructions

Action	Command
Activate Fly tool	Click Fly Tool then left-click on the scene
Start flight	Left-click
Increase speed	Additional left-clicks
Decrease speed	Right-click
Stop flight	Press the **Esc** key, or click the middle mouse button
Fine tune speed	Press the **up** or **down** arrow keys
Create downward or upward perspective	Hold down the left **Shift** key and drag the cursor straight up or down while in motion with the Fly tool
Movement	Once in motion, flight through the scene will follow the movements of your mouse.
Note: you can also fly backward by starting flight with a right-click. Increasing and decreasing speed while flying backward is the same as flying forward but the commands are reversed (right click to increase speed, left click to decrease speed).	

When you activate the FLY tool, your starting fly speed defaults at zero, a.k.a. the stopped state. While in the stopped state, you can change your direction of view before starting the fly through. The direction you're facing when you start the flight will be the initial direction of travel. Your flight speed is reported in the status bar.

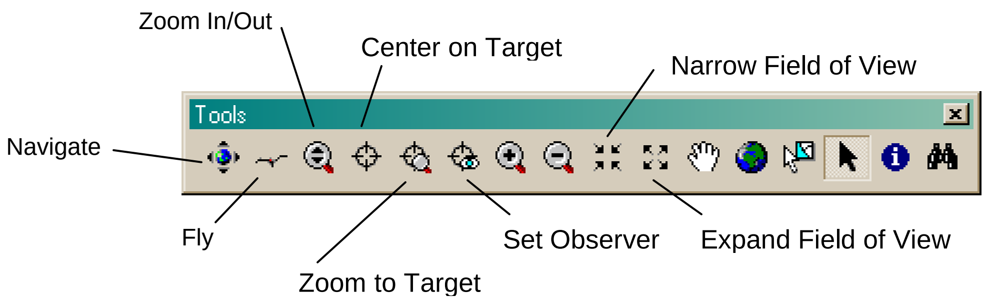
- Using the commands listed on the **Fly Tool Instructions** table, practice flying over the surface in different directions and speeds
- Do this until you feel comfortable controlling your flight
- If you lose track of your position within the surface or fly outside the extent of the data, press the **Esc** key to stop the flight, reorient yourself within the scene, and restart your flight
- Fine-tune your travel speed by pressing the **up or down arrow keys** on the keyboard after setting your flight speed (e.g. Pressing the up arrow will increase your rate of forward motion without changing the flight speed value. The more times you press the up or down arrow, the greater the increase or decrease of speed.)
- To create a downward or upward perspective and still maintain a constant altitude and direction (similar to being in a plane at cruising altitude and looking out the window at the ground), hold down the left **Shift** key on the keyboard and drag the cursor straight up or down while in motion with the Fly tool
- Keep playing until you feel comfortable controlling your flight's direction, speed, and altitude

Exporting a 3D scene:

You can export a 2D image of a scene to a graphics file in several common file formats and placed in other documents; e.g. in maps or reports.

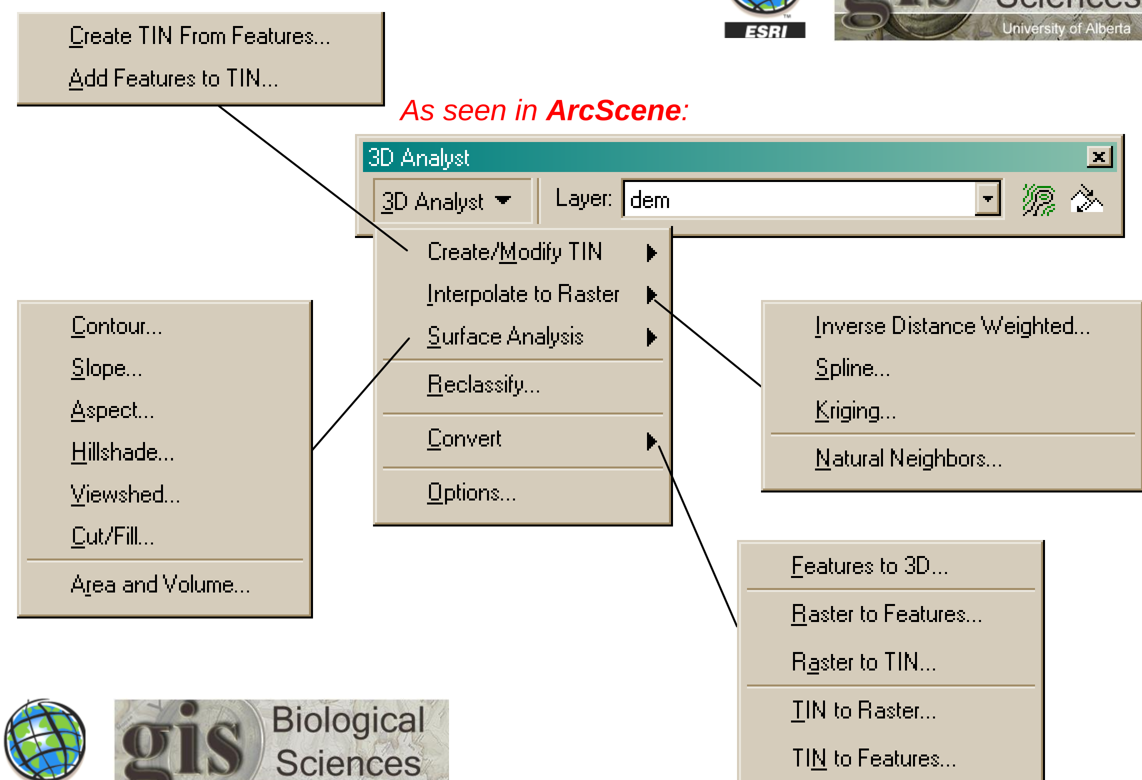
23. Choose FILE >>> EXPORT SCENE >>> 2D
24. Navigate to the location where you want to save the image of the scene
25. Click the dropdown arrow to choose the graphics file format to export
26. Type a name and click EXPORT

ArcScene and 3D Analyst Quick Reference



Note: the rest of the tools operate just like in ArcMap

*As seen in **ArcScene**:*



*As seen in **ArcMap**:*