



Introducing ArcGIS 3D Analyst: Mount St. Helens - Before and After



US Geological Survey – Mount St. Helens from north looking over Mount Margaret

In this lesson you will be introduced to some of the functionality of the **3D Analyst** extension for **ArcGIS**.

Scenario: On May 18th, 1980, the long dormant Mount St. Helens volcano erupted and over the course of several weeks the blast transformed the surrounding landscape from forested slopes into lava, ash, and mud covered desolation. Using the **3D Analyst** extension, you will perform cut and fill calculations on the mountain, look at lines of sight, create contour lines, and generate slope, aspect, and *hillshade* maps.

This lesson requires special datasets that are included in the archive with this document:

1. hbefore (grid)
2. hafter (grid)
3. observation (shapefile)



How is **3D Analyst** used?

With the ArcGIS 3D Analyst extension, you can perform a variety of tasks such as:

- Visualize your data in three dimensions
- Creating surface models from different data sources (elevation, temperature...)
- Determining height at any location on a surface
- Finding out what is visible from an observation point
- Calculating the volumetric difference between two surfaces (cut and fill)
- Working with 3D vector features to make realistic models of the 3D world





Types of data used in 3D Analyst

1. Grids (raster data)

Raster data is different from vector data in that raster data is a *cell-based representation of map features called a grid*. A grid is comprised of cells organized into rows and columns. Each cell in the structure has a value. A group of cells with the same value represents a feature.

- Grids represent entities
- Grids are made of cells
- There is a value applied to each cell

2. TINs (Triangulated irregular networks)

TINs represent surfaces using contiguous, non-overlapping triangle facets. One can estimate a surface value anywhere in the triangulation by averaging node values of nearby triangles, giving more weight and influence to those that are closer.

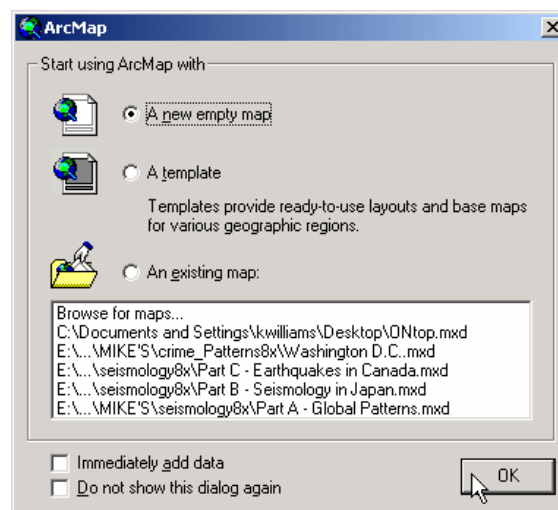
While the cell size of a grid is consistent throughout the entire grid, the size of the triangles in the **TINs** can vary. They are usually more detailed in areas where the surface is more complex and less detailed in areas where the surface is simpler.

A TIN dataset contains points with x, y, and z values and a series of edges joining these points to form triangles. The triangular mosaic forms a continuous faceted surface, which can be used to analyze and display terrain and other types of surfaces. TINs offer an alternative to the raster data model for representing surfaces.

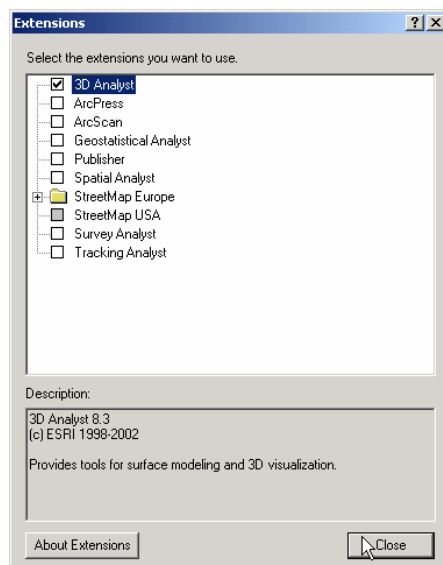
In general, Grids tend to be used for smaller, regional applications while **TINs** are used for more detailed, larger scale applications.

Let's Get Started

1. Start ArcMap and from the ArcMap window, choose "A new empty map."



2. From the **Tools** menu, choose **Extensions** and check off **3D Analyst**. Click **Close**.

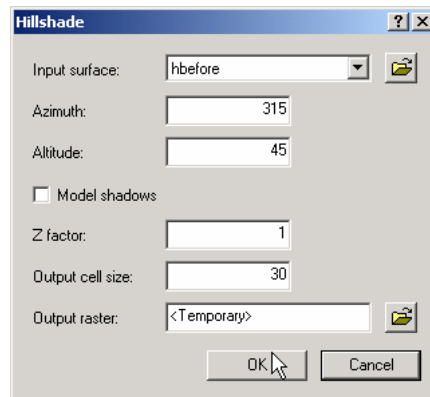


3. Click on the **Add Data** button  and navigate to **mtsthelens** folder for this lesson (ask your teacher if you are unsure where this is).
4. Add the **hafter** and **hbefore** grids to your table of contents.
5. Turn on ☒ both the grids and examine the information. Change the order that they appear in the table of contents by dragging one above or below the other.
6. This would be a good time to **save your project**. To do this, go to the **File menu** and choose **Save As**. Give your project a name and save it to the project folder.

Creating a Hillshade

You can see from looking at the elevation grids the elevation on the north side of the mountain decreases drastically. Let's take a quick look at what Mount St. Helens looks like when you apply an illumination to the surface. This will help you get a better idea of what the terrain looks like there.

1. **Turn off** ☐ the visibility for the grids. Make the **hbefore** grid the **active layer** (appears highlighted in blue compared to the other layer).
2. Add the **3D Analyst** toolbar by going to the **View** menu, **Toolbars**, and finally clicking beside **3D Analyst**.
3. From the **3D Analyst** toolbar, click the **3D Analyst** drop down menu and select **Surface Analysis** then **Hillshade**. In the dialog box that appears, leave the settings as they are and click **OK**. A new grid will be added to the table of contents.

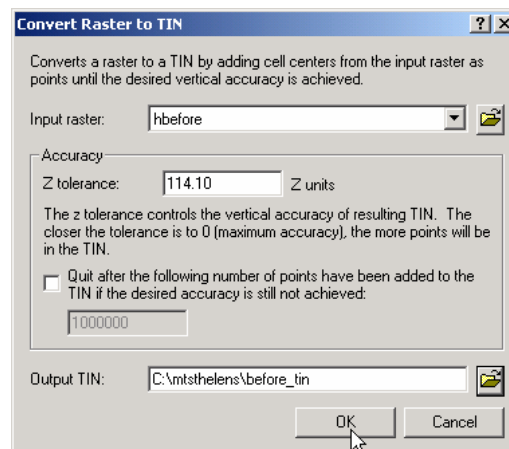


4. Turn on ☒ the visibility for the **new grid**. *What are you looking at?* This is a **hillshade** of Mount St Helens before the eruption. The sun (illumination) angle is at 315 degrees (from the north west) and is at an altitude of 45 degrees.
5. Repeat the same steps as above and create a **hillshade** for the **hafter** grid. Try playing around with different sun angles and altitudes.
6. When you are done, **remove** all the layers from the view **except** for the *hbefore* and *hafter* grids (the original layers that you added in).

Converting to TIN

In order to work with the data in 3 dimensions, you are going to have to convert it to a **TIN**.

1. Make the *hbefore* **layer active**. From the **3D Analyst** menu, choose **Convert, Raster to TIN**.
2. In the dialog box that appears, change the name of the new **TIN** to *before_tin*. Make sure that the *hbefore* grid is listed beside Input raster and that your **TIN** is **being saved** in the *c:\mtsthelens* folder!
3. Leave the z tolerance as it appears. Click **OK**.

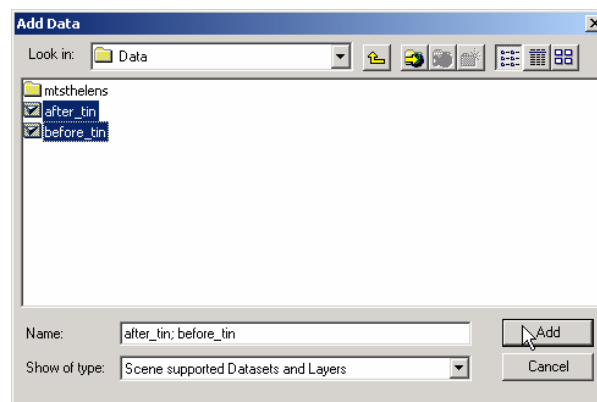




4. Convert the *hafter* grid to a **TIN** as well. Call it *after_tin*.
5. **Turn on** ☒ the visibility for both the **TIN layers**.
6. **Zoom in**  to each of them and notice that they are now made up of a series of *different sized triangles*, not a regular grid of values.

Working in a 3D Scene

1. Click the **ArcScene** button  to open the 3D application.
2. Click on the **Add Data** button . Select both the before and after TINs using the **Ctrl** key and add them to the 3D scene.



3. **Turn on** ☒ and **off** ☐ the layers to see what they look like in 3 dimensions.
4. Using the **Navigate tool** , rotate, turn, and zoom in on the **TINs** in your **3D Scene**.
 - a. To *rotate and flip* the **TIN**, make sure the **Navigate tool** is *active*. Click and hold inside the 3D scene and move your cursor around.
 - b. To **zoom in** and **out**, make sure the **Navigate tool** is *active*, hold down the right mouse button and drag the cursor down to zoom in or drag it up to zoom out.

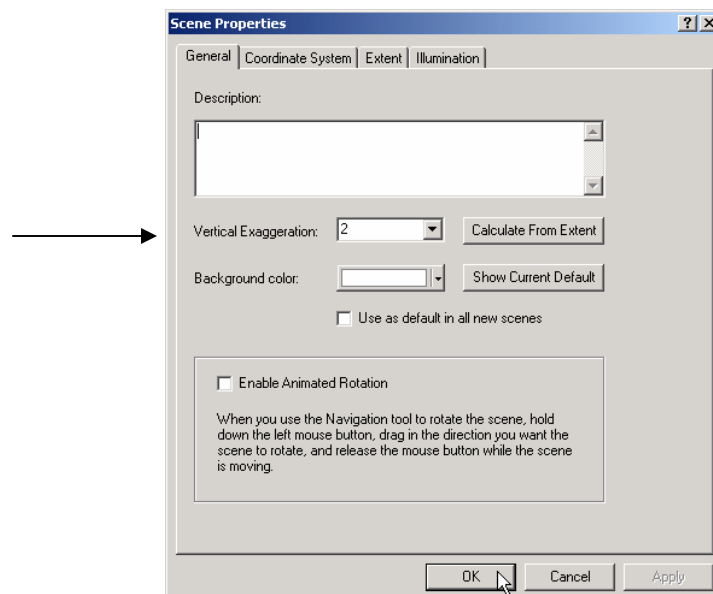
Now that you are familiar with how to **navigate** within a **3D Scene**,
Let's try working with some of the functionality of **3D Analyst**.



Extruding features

Sometimes, seeing features from a **3D** perspective is difficult if there isn't a great deal of difference in elevation between each of the features. In order to make this difference more apparent, **3D Analyst** allows you to do what is called **Vertical Exaggeration** on all the **layers** in the **3D Scene**. This **vertical exaggeration factor is consistent for all the layers and their features inside the scene**.

1. In the ArcScene **View** menu, select **Scene Properties**.
2. Click the **General** tab.
3. Click the **Vertical Exaggeration** dropdown arrow and change the Vertical exaggeration factor to **2**.
4. Click **OK**.



3. **Turn your layers on and off** – *what happened to your view of Mount St Helens?* Experiment with the Vertical exaggeration factor and see what happens in ArcScene.



Area and volume calculations

3D Analyst allows you to **calculate the area** and **volume** of **TIN data sources**.

1. Return to **ArcMap**.
2. Make the *Before_tin* the **active layer**. From the **3D Analyst menu**, choose **Surface Analysis** then **Area and Volume**.
3. Leave the height of plane value as it appears (the height is in meters).
4. You want to **choose** to **calculate statistics ABOVE the plane**.
5. Click on **Calculate Statistics**.

Write the values here:

2D area:

Surface area:

Volume:

****Surface area** is measured along the slope of a surface, taking height into consideration. The area calculated will always be greater than simply using the 2D planimetric extent of the model. To envision this, think of a pyramid. Looked at from directly above, it appears to be a square, the area of which is less than the surface area of the pyramid. When compared to planimetric area, surface area gives you an idea about surface roughness. The larger the difference between the two values, the rougher the surface.

6. Now make the *After_tin* **layer active** and follow the steps to calculate the area and volume statistics for this layer.

Write the values here:

2D area:

Surface area:

Volume:

What differences are there? What can you say about the change in area/volume after the explosion?



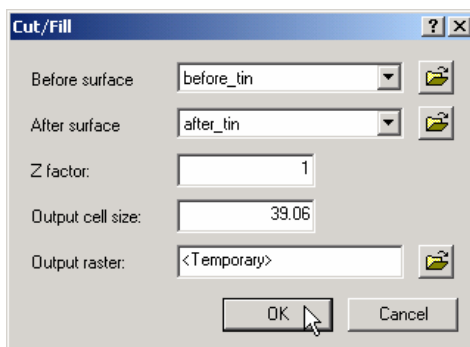
Cut and fill analysis and assigning base heights

Cut-fill analysis determines how much material is lost or gained in an area by comparing two surface models of it; one before a change and one after.

Cut-fill is useful in construction projects for estimating how much material needs to be moved. By comparing the present surface with a proposed surface, you can determine how much dirt needs to be hauled out.

Cut-fill is also useful in environmental applications. Investigating deposition of silt in front of a dam or a river delta can help determine when and where to dredge. Two different water table surfaces can be used to estimate changes in groundwater volume over time.

1. Return to **ArcScene**, hold down your **Ctrl** key and make both the *Before* and *After* TINs **active**.
2. From the **3D Analyst** menu, choose **Surface Analysis** then **Cut /Fill**.
3. From the drop down list, choose *Before_tin* as the “before surface” and the *After_tin* as the “after surface”. Click **OK**.



ArcScene will do some calculations (this might take a minute or two, depending on the speed of your computer). You will then have a new layer added to your Table of Contents.

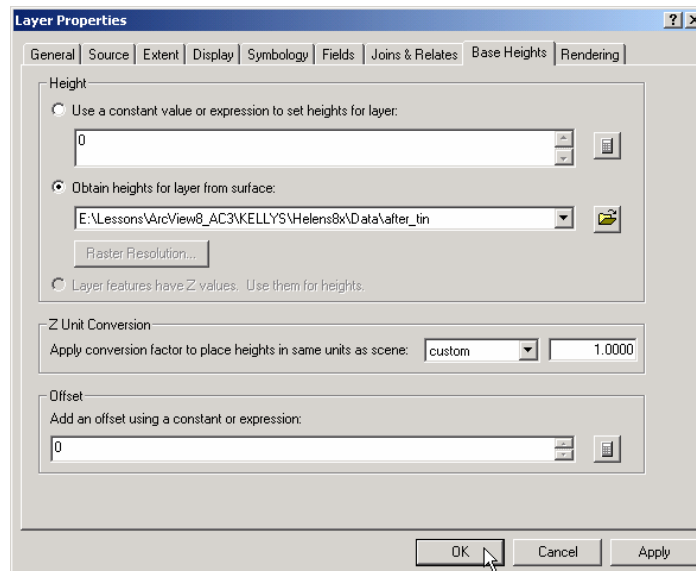
4. **Turn on** the visibility for this new layer and **turn off** the visibility for the other TINs. You will notice that the new TIN is just a flat surface. The reason is that it doesn't know from which surface it should take its base heights.

This is not the same as extruding features! **Base heights** are a set of reference heights for a layer. They are defined by an expression (mathematical equation), a surface, or in the case of 3D feature layers, the 3D shapes themselves. **All layer types require that base heights be defined.**

5. Make the new **cut-fill layer** the **active layer**. Right click on the layer and select **Properties**.



6. Click the **Base Heights** tab. Use the **drop-down menu** for *obtain heights for layer from surface* and choose the *After_tin* layer. Click **OK**.



7. Use the **Navigate tool**  to **zoom in** and **out** of the **cut fill layer** and to **move it around**.

What are you looking at here? What do the blue areas represent? What do the red areas represent? Why are there areas of Net Loss along the base of the mountain? What features could have been "lost" here?



8. Try this...go back to the **Properties** for the **cut fill layer** and change the Surface to the *Before_tin*. Click on **OK**.

How does this change the way you view the cut fill layer? Is this way of viewing the layer more representative of the data that you are trying to show?

Analyzing visibility

Determining what is visible on a surface from a set of one or more locations is useful for a wide range of applications, from estimating real estate value to locating new cellular phone towers.

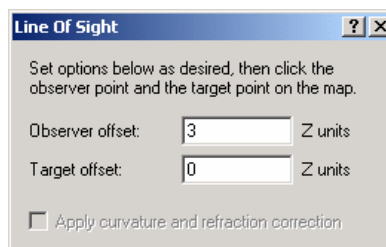
Line of sight

The **line of sight** tool tells you whether a given target is *visible from a point of observation*. If the *target is obscured*, you're given the coordinates of the first obstruction. You also find out what is visible along the line of sight.

1. Return to **ArcMap**, go to the **Insert** menu and select **Data Frame**.
2. Add the following layers to your **New Data Frame**:
After_tin (from the c:\mtsthelens directory)
Observation.shp (from ArcCanada 3.0 disk4/3d/mtsthelens)
3. **Turn on** the visibility for both layers and make the *After_tin* the **active layer**.

4. Choose the **Line of Sight** tool .

5. In the dialog box, change the observer offset to 3 and leave the target offset at zero. Close the box.





You need to specify how many units the observer and target positions will be offset above the surface. You typically don't want to position the observer at ground level, which is where it will be if you give a 0.0 offset. Chances are not much will be visible. Put it this way, if you set the offset height to zero, you are basically telling ArcView that you will be laying flat on the ground to observe your target. The target might not have a height but if you are looking at cell phone towers, then you will have to adjust that height accordingly! Therefore 3 meters is a good estimation of a person's height, combined with accounting for uneven terrain.

6. Now, your cursor will turn into crosshairs. **Click and hold** the crosshairs on the observation point (observation.shp) drag a line to the location of the target that you wish to observe, let's say, the peak of the mountain, then release your mouse button. A new line will appear.

The red portion(s) of the line indicates that you will not be able to see those areas from the observation, the green lines means that you will.

Play around with the **Line of Sight tool**. List some real world applications where you think this technology would be useful.

Viewshed:

The last type of Visibility Analysis that you are going to look at is Viewshed. Viewshed refers to the areas on a surface visible from one or more observation points. For any visible position, you also discover how many observers can see that position. With the viewshed function you cannot only control the height of an observer but also can provide constraints on how far, how high, and which direction it can look.

1. Still in ArcMap, with **both layers still visible**, hold down your **Ctrl** key and make both **layers** (after_tin and observation) **active**. From the **3D Analyst menu**, choose **Surface Analysis** then **Viewshed...**
2. Change the **Input surface** to **After_tin** and the **Observer Points** to **observation**. Leave all the other values as they are and click on **OK**. A new grid layer will be created where the red areas are not visible from the observation point and the green areas are.
3. Convert the new **raster grid to features** (from the 3D Analyst menu) and save it in the project folder. The new layer will be added to your map.
4. Bring up the **Layer Properties** and make a **unique value** legend, showing colours that best represent the areas that can and cannot be seen from the observation point. This can all be done under the **Symbology** tab.



5. Make this layer see through. To do this, click on the Display tab and set the transparency. Experiment with this until you find the right level of transparency for your map.

Note: Transparency is measured as a percentage where 0 indicates NO transparency and 100 indicates that the layer is COMPLETELY see through.

How does the viewshed match up with the line of sight results? What kind of applications would make good use of a viewshed analysis?

Let's Print!

1. OK, let's make a really nice layout...While you are still in the data view in ArcMap, **turn off** the visibility for the **viewshed layer** and **turn on** the **after TIN**. With the **observation layer active**, use your **Pointer tool** to select the line of sight (light blue handles will appear around it). Right click on it and change it's properties (i.e., colour or thickness) if you find it necessary.
2. Make sure to change all your layer names to meaningful titles by making each layer active and double clicking on it to bring up the Layer Properties dialog box (use terms that a beginner map reader would understand).
3. Select the **Layout** view by clicking the Layout button  located to the bottom left of the map view. Right click on a blank portion of the layout and select **Page Setup**. Change the layout from **Portrait** to **Landscape**.
4. As usual, insert the title and scale bar... from the **Insert** menu.
5. You are also going to add your line of sight as a profile view of **Mount St Helens**. First, select the **Interpolate Line**  button and trace the line of sight (single click to start and double click to finish the line).
6. Make sure that when you click on the **Profile Graph tool**  that it is visible, if not than go **back** to your **Data View** and make sure that your **After_tin layer is active**. (The **Profile Graph Tool** will take selected 3D lines from either the graphics of the active layer and create a graph that shows the height measured along the lines.).
7. Right click on the graph and select **Show on Layout**. Resize and move the graph to a good place on your map.
8. In the **Profile Graph Properties dialog box** (right click on it and select properties), change the title of the profile graph to something like "Profile of Mt. St. Helens - After". Leave all the other values as they appear. Click on **OK**.
9. Go back to your original Data Frame. Turn on the visibility for the before TIN.



10. Follow the same procedure to create a profile of the **before_tin**.
11. Move your title, maps, profile graphs and legend components around and resize them to make a nice layout. Go ahead and **PRINT!**

