

Demo 10: Digital Terrain Models

Humans are constrained by topography but also can alter it dramatically. Because of the significance of topography for resource distribution, cost of movement, and landscape perception, digital terrain modeling is an important component of any GIS database. In this demo, you will create and manipulate vector-based and raster-based terrain models for your study area. You will use these skills to create topographic models of your project area, using vector data derived from georeferenced topographic maps and raster data from NASA's [Shuttle Radar Topography Mission](#) (SRTM).

I. Guidelines for using GRIDs and TINs

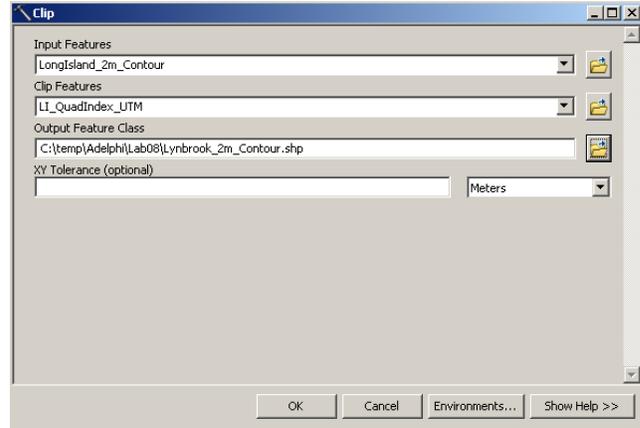
- a. GRIDs are the default ArcGIS file format. They are what happens if you forget to put the .tif on the end of an output. Throughout this demo I encourage you to use tifs, but you do not have to. But note that there are some extra restrictions to using the GRID file format.
- b. TINs are the vector terrain model we spoke about in class. They are also a proprietary ArcGIS format and thus have the same restrictions.
- c. Each GRID or TIN is stored as both files *and* folders. If some, but not all, of the associated files/folders are moved on the disk, it will corrupt the data. Decide ahead of time where you will store them on your disk space to avoid having to move them. If you must move a GRID or TIN (or a shapefile, for that matter), try to use ArcCatalog instead of Windows Explorer.
- d. Always keep a copy of the vector dataset (point or polyline) you used to generate GRIDs and TINs; if there is a problem with the output, you can regenerate it.
- e. Make sure that the path and filename are short and *without spaces or special characters*; for example, N:\lab08\gridname. ArcGIS insists that the names of GRIDs and TINs are ten characters or less long.
- f. This lab uses two new toolbars to perform functions with GRID and TIN files: the Spatial Analyst Toolbar and the 3D Analyst Toolbar. Activate them under View→Toolbars or right-click on the existing toolbars and check them. Although there is some redundancy, the 3D Analyst toolbar is primarily used with TINs while the Spatial Analyst toolbar is mainly used with GRID data.

II. Assemble the data sources

- a. Download **Demo10_Data.zip**
- b. Extract to your **Demo10** folder
- c. **Next, enable two new extensions: the Spatial Analyst and the 3d Analyst**
 1. Choose **Customize** → **Extensions** and enable the Spatial and 3d Analyst
 2. **If you are having problems, this is the most common thing that is omitted.**
- d. Often in GIS classes you vectorize contour lines and point elevations from a scanned quad sheet or topo map to build a Digital Terrain Model. The following section outlines this procedure, but do not do this right now.
 1. If you open your quad sheet from Lab 03 you can find these contour lines and elevation points.
 2. Alternatively, there are strictly topo maps available for each quad through the USGS
 3. You would then create a polyline shapefile for the contour lines and a point shapefile for the elevations
 4. Then you would add a field for the elevation outline each feature (like Week 05, but without Autocomplete)
 5. Here, I have given you the contours, heights and water already digitized as shapefiles, so we can proceed with the TIN creation.
- e. To start with these, add the following layers to a new, blank ArcMap Document
 1. **Michiana_Contours.shp**
 2. **Michiana_Water.shp**
 3. **Michiana_Spot_Elevations.shp**

III. Clipping shapefiles

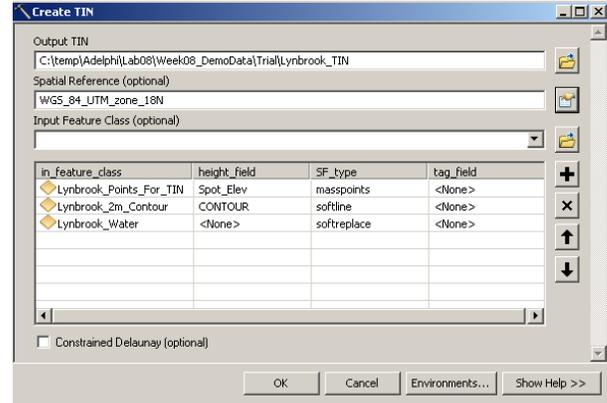
- a. The topographic data you have added are for all of Michiana. If we create a high quality Digital Terrain Model using all of these data then we will have an extremely large file.
- b. Thus, we should clip the data to the extent of the quad sheet and create the DTM using just the restricted data.
- c. First, you should add the **Parks.shp** layer.
- d. Next, open the attribute table and select your park. It should now be outlined in cyan.
- e. To clip go to **Geoprocessing** → **Clip** in the main menu.
- f. In the new window
 1. **Input Features** are each of the Michiana shapefiles
 - i. Start with **Michiana_Contours.shp**
 2. **Clip Features** is the **Parks.shp**.
 - i. Make sure that your quad sheet is selected
 3. **Output Feature Class** will be the new, smaller, shapefile
 - i. Put it in your permanent location
 - ii. Name it after your quad sheet with the relevant data type
 - iii. Here, **NotreDame_Contours.shp**
- g. Repeat this for **Michiana_ElevationPoints.shp** and **Michiana_Water.shp**
- h. You can now remove the three Michiana shapefiles and the Parks index
 1. Your ArcMap document should just contain
 - i. **NotreDame_Contours.shp**
 - ii. **NotreDame_Spot_Elevations.shp**
 - iii. **NotreDame_Water.shp**



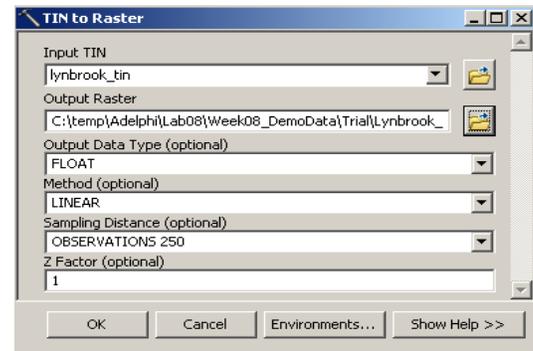
IV. Creating a TIN.

- a. First, we will create a Triangulated Irregular Network (TIN) surface model from these three layers
- b. You should be sure to use the three layers you clipped above (Section III.) and not the Michiana data
- c. In ArcGIS 10, creating a TIN can only be done in the ArcToolbox (in earlier version it was part of the 3d Analyst toolbar)
 1. Click on the toolbox icon (📁) or go to **Geoprocessing** → **ArcToolbox**
 2. Within the ArcToolbox window choose: **3d Analyst Tools** → **Data Management** → **TIN** → **Create TIN**
 3. This will bring up the Create TIN window
 - i. **Output TIN** is the name and location of the resulting TIN
 - a. Call it TIN_NotreDame
 - b. Note that TINs are folders, so you cannot move them
 - ii. Set the Coordinate System to WGS1984_UTM Zone 16N
 - iii. Next, drag over (or add) the three files we created for Notre Dame
 - iv. You will need to set the Height Field and SF_type for each
 - v. The Surface Feature Type (**SF_type**) is how the features are used in creating the TIN
 - a. Mass points are added as individual nodes in the TIN. This is the only option for point shapefiles.
 - b. **Hard** and **Soft Lines** place triangles along the polylines (or the edge of a polygon, between the vertices. With soft lines there is some interpolation, so in case of errors, the triangles can cross the lines.
 - c. **Hard** and **Soft** refer to the strength of the edge, particularly whether triangles can cross it.
 - d. **Erase** will either leave a blank area
 - e. **Replace** will give an area a systematic value.
 - f. **Clip** limits the extent of the TIN

- vi. For each of the layers set the variables as follows:
 - a. **NotreDame_Spot_Elevations.shp**
 1. The height_field is **Elev**
 2. These are individual points, so **masspoints** is our only option
 3. Leave **tag_field** as **<None>**
 - b. **NotreDame_Contours.shp**
 1. The height_Field is **Contour**
 2. These are lines, so we could set the SF_type as masspoints, hard or soft line. Because we want to use the linear data, but not to restrict the interpolation to just these points we will choose **Soft_Line**.
 3. Leave **tag_field** as **<None>**
 - c. **NotreDame_Water.shp**
 1. Make sure the height_field is **<None>**. This is because we want it to ignore areas of water, not interpolate a height for it.
 2. The **SF_type** here is **Soft_Replace**. We want the water areas to be shown as flat.
 3. Leave **tag_field** as **<None>**
 - d. Leave the **Constrained Delaunay** checkbox blank as the default.
 - e. Click **OK**
 - f. The TIN is added to the map. Zoom in on a topographically complex area to see how the TIN is structured. Note that the TIN is hillshaded by default; you can change the way the map is illuminated on the Illumination tab of the Data Frame properties.

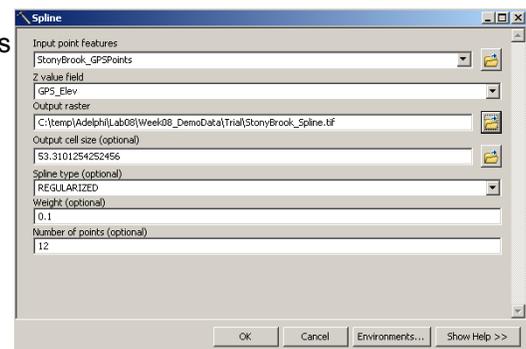


- d. You can now convert the TIN to a raster DEM using the **TIN to Raster** tool.
 1. This is useful if you want a more standard file format.
 2. Also, you can only interpolate a surface from polygon or polyline shapefiles with a TIN.
 3. In ArcToolbox choose **3D Analyst Tools** → **Conversion** → **From TIN** → **TIN to Raster**
 - i. Select the input TIN and the output rasters and leave the rest as the default.
 - ii. Here, put the output in your Lab07 folder and call it **NotreDame_DEM.tif**



V. Create a raster Digital Elevation Model (DEM) from a point layer

- a. In this section we will interpolate a new DEM from a series of simulated GPS points for Michiana
 1. Because the DEM created from the TIN is of a better quality I am not asking you do this for your study area individually, however, completing it for these sample data is part of the assignment.
- b. Add the **Interpolation_GPS_Points.shp** file
- c. Open the Attribute table and note that you have X, Y, and Elevation values for each point.
- d. Now we want to use these elevation points to interpolate, or estimate, the surface in between them.
 - i. Remember that you can interpolate any numeric data, not just elevations
- e. We are using the Spline technique here. Spline, or rubbersheeting, is one of the simpler interpolation techniques
 1. Kriging and IDW are other, more complicated, interpolation algorithms that are available in ArcGIS
- f. In the ArcToolbox window choose **Spatial Analyst Tools** → **Interpolation** → **Spline**
 1. The **Input Point Features** is



Interpolation_GPS_Points.shp

2. **Z value field** is **Elev**
3. Put the Output Raster in your Lab08 folder and call it **Michiana_Interpolation_Spline.tif**
4. The **Output Cell Size** is the resolution of the output DEM. The default is a little coarse, so you can change this down to **30** if you like.
5. The rest of the choices (Spline Type, Weight, and Number of points) are very specific options about the math used behind the scenes. Leave them all as the default.
6. Choose **OK** to run the interpolation
- g. The resulting image will come up classified into several non-intuitive colors. You should change its display to a stretched color ramp.
 1. Go to the **Layer Properties** for **Michiana_Interpolation_Spline.tif** by double-clicking on the name in the Table of Contents
 2. Go to the **Symbology** Tab and change it from **Classified** to **Stretched** under **Show**:
 - i. It will default to black-to-white. The traditional elevation ramps are more complex:



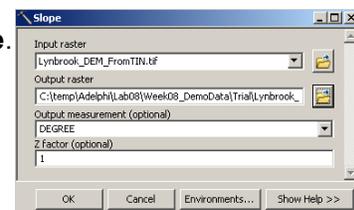
- c. You can find these by hand, but as a nice shortcut you can access their text names by right-clicking on the color ramp and unchecking **Graphic View**. These two are **Elevation #1** and **Elevation #2**

VI. Satellite and remotely sensed Elevation data

- a. Now we want to compare our TIN and interpolation to a known DEM, though a less precise one.
- b. Here we will use data from the Shuttle Radar Topography Mission (SRTM)
 1. I have provided the image for Michiana, but these data are freely available at 30 m resolution for the US and 90 m resolution for the world through the USGS Seamless Server or the Global Landcover Facility. Links are on Sakai.
- c. Add **SRTM_Michiana_UTM.tif** to your ArcMap document.
- d. Also make sure you have **Michiana_Interpolation_Spline.tif** and **Michiana_DEM.tif**
 1. You may want to change the color ramp on the SRTM image.
 2. Put it at the bottom of the Table of Contents (below the TIN and Spline)
- e. Now, just visually inspect the accuracy of the interpolated DEM (**Michiana_Interpolation_Spline.tif**) and the TIN.
 1. Right click on **Michiana_Interpolation_Spline.tif** and choose Zoom to Extent
 2. Now use the **Swipe** tool () in the **Image Analysis** Window to compare the two
 3. Repeat for **Michiana_DEM_FromTIN.tif**
- f. In this example, you should not have any major errors, but in real life you might.
 1. Usually, it is because of either erroneous or missing data.
 2. To fix problem, you should edit the original files and rebuild the TIN or interpolation.
 3. Sometimes you have to make points or polylines that trick the computer into making the right surface.

VII. Basic topographic analysis on DEMs and TINs

- a. Here we will calculate some of the standard topographic characters for your study area quad sheet.
- b. The only layers you need at this point are **TIN_NotreDame** and **NotreDame_DEM.tif**
 1. You can remove all of the interpolation data and the original shapefiles used to make the TIN.
- c. The process of each of these is different for a raster DEM or a TIN. We will start with the DEM
- d. **Topographic analysis on a raster DEM**
 1. Make **TIN_NotreDame** invisible. We will only work with **NotreDame_DEM.tif** for now
 2. **Slope**:
 - i. In ArcToolbox choose **Spatial Analyst** → **Surface** → **Slope**.
 - a. Indicate the **NotreDame_DEM.tif** as the **Input**.
 - b. Place the output in your Lab07 folder and call it

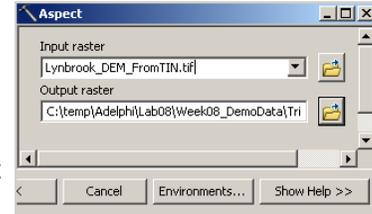


NotreDame_Slope.tif

- ii. The pixel values of the output image represent the slope of the surface, in degrees.

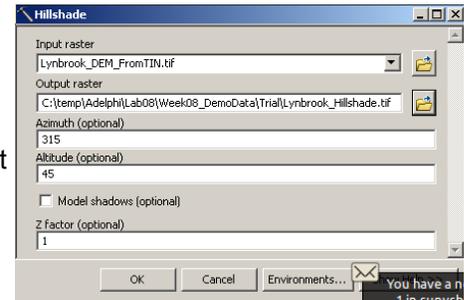
3. Aspect:

- i. In ArcToolbox choose **Spatial Analyst**→ **Surface**→**Aspect**.
 - a. Indicate the **NotreDame_DEM.tif** as the **Input**.
 - b. Place the output in your Lab08 folder and call it **NotreDame_Aspect.tif**
- ii. The pixel values of the output image represent the direction that the surface is facing, also in degrees.



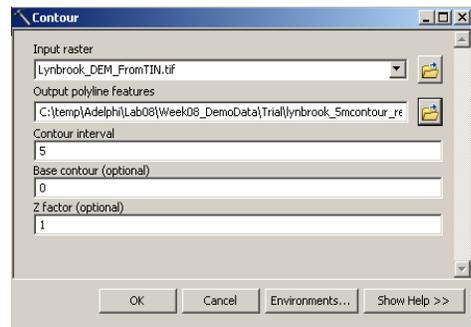
4. Hillshade:

- i. In ArcToolbox choose **Spatial Analyst**→ **Surface**→**Hillshade**.
 - a. Indicate the **NotreDame_DEM.tif** as the **Input**.
 - b. Place the output in your Lab08 folder and call it **NotreDame_Hillshade.tif**
 - c. The Azimuth is the direction of the sun
 - 1. For example, 180 indicates the sun is coming from the South. 0 indicates from the North
 - 2. Here leave it at **315**. This is from the West, so at sunset
 - d. The Altitude is how high the sun is
 - 1. This ranges from 0 (directly on the horizon) to 90 (directly overhead).
 - 2. Here leave it at **45**
 - e. Leave the rest at the default and choose **OK**
- ii. This will create another new layer for the Hillshade, scaled from 0 to 255 based on how heavily shaded each pixel is.
- iii. If you put the hillshade layer above the spline grid and set the display of the hillshade layer (Layer Properties → Display Tab → Transparency) to around 70% transparent, the terrain will appear partially shaded.



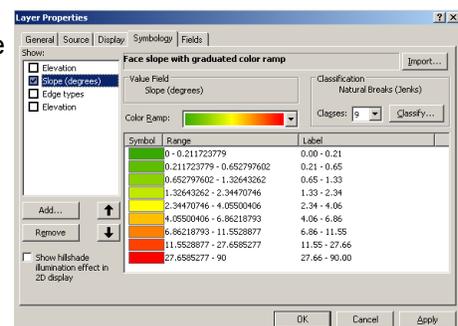
5. Contour

- i. This tool inputs a DEM and exports a polyline shapefile of contours at a specific interval
- ii. This is not particularly useful here because we built the original TIN from contour lines, but if you start with a SRTM or other DEM source, you can use this to make a standard contour map
- iii. In ArcToolbox choose **Spatial Analyst**→ **Surface**→**Contour**.
 - a. Indicate the **NotreDame_DEM.tif** as the **Input**.
 - b. Place the **Output Polyline Features** in your Lab08 folder and call it **NotreDame_5mContour_Rebuilt.shp**
 - c. Make the **Contour Interval** 5.
 - d. **Base contour** lets you exclude all data below a certain point. Here leave it at **0**, though if you have a lot of negative values (unlikely) you might want to make it -10
 - e. Z factor would convert the heights by some value. This is useful if you have a DEM in feet and want to work in meters. Leave it at 1 here.
 - f. Choose OK to run.
- iv. You should now have a new Polyline Shapefile with contours at every 5 meter.

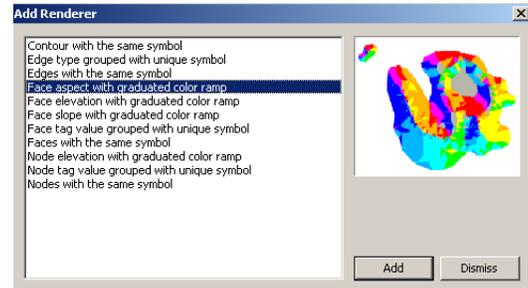


e. Topographic analysis on a TIN layer

- 1. TIN datasets, because they are in essence vector data, store slope and aspect without requiring the generation of additional files.
- 2. Make everything but **TIN_NotreDame** invisible.



3. Display the TIN layer's symbology by going to the **Layer Properties** → **Symbology** tab
4. The default data that are displayed are “**Elevation**” and “**Edge Types.**”
 - i. I find Edge Types, which are basically the topo lines, useless, so I almost always turn it off by unchecking it.
5. Click **Add** to display other data
 - i. In the new window you have a lot of choices, most of which are self-explanatory
 - ii. To display **Slope**:
 - a. Select “Face slope with graduated color ramp”
 - b. Click **Add**
 - iii. To display **Aspect**:
 - a. “Face aspect with graduated color ramp”
 - b. Click **Add**
 - iv. Click **Dismiss** to return to the TIN layer symbology.
 - a. Note that this does not remove a display. You do that in the main Symbology window
 - v. Uncheck all the other data but the Slope and click **Apply**.
 - a. Repeat for the Aspect
6. **Hillshade** for TINs is a bit different. It can be toggled on and off by checking or unchecking “**Show hillshade illumination effect in 2D display**” in the Symbology tab. It is under the Add and Remove buttons on the left side.

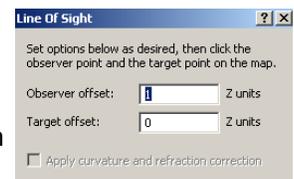


VIII. Interactive terrain analysis with terrain layers

- a. These tools all produce graphics, not features or new raster layers. Thus, they are mostly for quickly assessing a given feature or producing figures. Note this, because these can be used as graphics for your final projects / presentations.
- b. First, you want to enable the **3d Analyst Toolbar**
 1. Right click on a blank spot at the top of the ArcMap window and choose **3d Analyst**
 2. You can also go to **Customize** → **Toolbars** → **3d Analyst**
- c. The 3d Analyst Toolbar has a several integrated tools nearly all of which can be run on any terrain data: either raster DEM or TINs.



1. The dropdown menu under the name contains the options dialog. We are not going to change anything from the defaults
2. The **Layer:** box lists the active layer to be analyzed. Be careful that this is correctly set.
3. **Create Contours** (📏) will create a single contour line where you click on the image. It is not a shapefile, just a line graphic, but it will be saved until you delete it. This is useful for checking relative elevations around a certain point
4. **Create Steepest Path** (📍) will draw the steepest line downhill from a point you click on (e.g., the path water would flow if it originated in that spot).
5. **Create Line of Sight** (👁️) lets you drag a line across the terrain.
 - i. The color of the line indicates what would be visible (in green) or obstructed (in red) for a viewer standing at the initial position.
 - ii. In the popup, you can set the height of the observer, and the height of the target (for example a 1.6m tall person could be looking for a 5m high object).
 - iii. There is a more in-depth version of this called Viewshed analysis that we will work with in a future lab.
6. **Interpolate Point, Line or Polygon** (📍 📏 📐) will use the elevations from the active layer to generate a three-dimensional graphic.
 - i. Again, note that these are not shapefiles. They are only saved in your ArcMap document.
 - ii. You can copy and paste them into another ArcMap document, ArcScene or ArcGlobe.



- iii. The only really useful one of these is the **Interpolate Line** tool ()
7. **Create Profile Graph** () only becomes active when a 3d line feature is selected. This can be either a Line of Sight or a line from the Interpolate Line Tool. When you click **Create Profile Graph**. A popup of the elevation profile for that line is created.
- These can be edited and saved as graphics, but there are no spatial data (ie the location of the profile is only in the ArcMap Document)
 - A good workaround is to create a polyline shapefile and then trace an Interpolate Line over it.
8. The ArcScene and ArcGlobe ( ) buttons are shortcuts to launch these two programs for 3d analysis.
- We will work with these in a future lab,
- d. To delete the line created by any of the 3d Analyst tools: select them with the arrow tool () and press the Delete key.
- e. Now experiment with these tools using the **TIN_NotreDame** and **NotreDame_DEM.tif**
- You can also use the SRTM Data for all of Michiana, but it may be a bit slower.

