Tutorial 2: Introduction to ArcGIS and the geomorphology of Maui

Objectives
In this lab you will: 1) Learn the basics of the software package we will be using for the remainder of the semester, and 2) Discover the role that climate and geologic history play in controlling the morphology of volcanic islands.

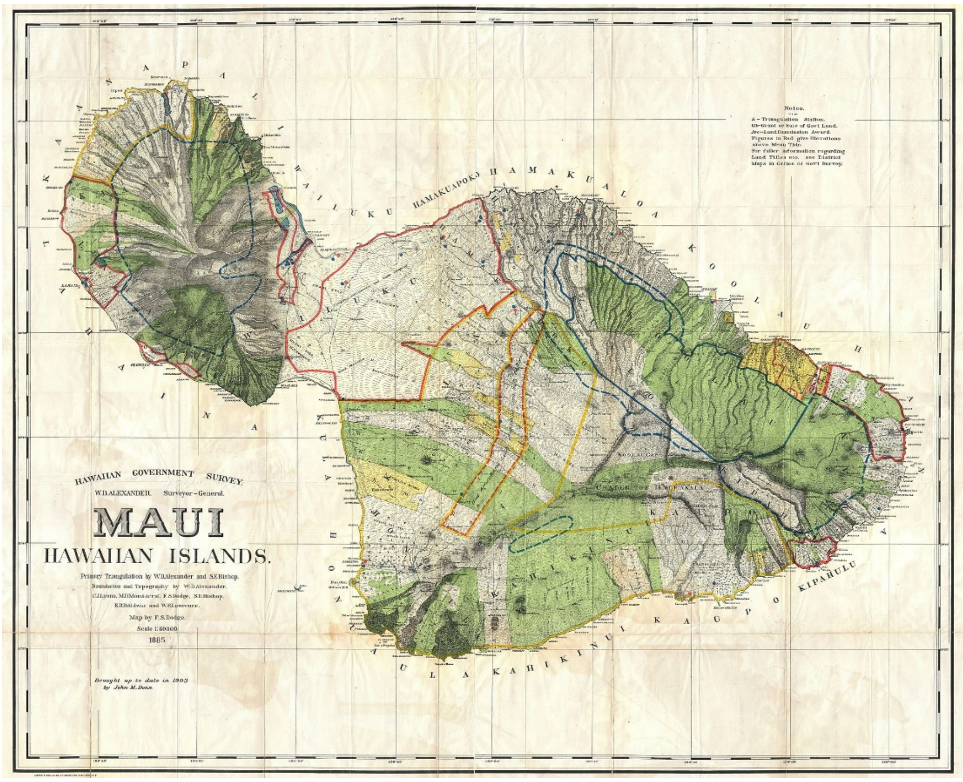

Figure 1: Hawaiian Government Map of Maui, 1885

Background
For much of the 20th century, quantitative analysis of landscapes involved paper maps constructed from painstaking field surveys (like in Fig. 1 above), and later supplemented with aerial photographs. With the explosion of personal computers and satellite-based remote sensing, a new very powerful tool, the geographic information system (GIS), has emerged. The power of GIS comes from the integration of visualization, analysis, and database management of geospatial datasets, with applications ranging from geologic mapping to municipal planning to epidemiology. In this lab you will learn the basics of ArcGIS, a popular commercial software package that we will be using in a more rigorous manner for later labs.

2.0 Opening a file geodatabase and adding data sets

For this tutorial, make a folder called "Tutorial_2" or something similar, and download/extract the zipped lab data from Angel here. Next, right click on "tutorial_2_data.gdb" and select **Make Default Geodatabase**.

The four datasets given to you are summarized below:

File name	Data type	Grid size	Description	Source
maui30_dem	Raster	30 m	Digital elevation model (m)	USGS National Elevation Dataset http://viewer.nationalmap.gov/viewer/
maui_annual_rainfall_grid	Raster	250 m	1978-2007 Interpolated mean annual rainfall (mm)	UH Rainfall Atlas of Hawai'i 2011 http://rainfall.geography.hawaii.edu/downloads.html
maui_rainfall_data.shp	Point shapefile	-	Rainfall station data	UH Rainfall Atlas of Hawai'i 2011 http://rainfall.geography.hawaii.edu/downloads.html
maui_geology.shp	Polygon shapefile	-	Geological units	USGS Geologic Map of Hawai'i 2007 http://pubs.usgs.gov/of/2007/1089/

To load these into your current project, simply drag and drop the four icons into the main window. Alternatively, you can click on the **Add Data** icon on the **Standard** toolbar and add datasets individually.

If you are having trouble at this point, see **Tutorial 1**, Section **1.2** and **1.3** for help.

2.1 Visualizing data

You should now see the four datasets in the table of contents under the **Data Frame** "Layers". A **Data Frame** is a map element that defines the geographic context and display properties for one or more **layers** or datasets in ArcMap. Right click on the **Data Frame** "Layers" and select **Properties** (Fig. 2). Here you can rename the **Data Frame**, change the coordinate system and display units, and control how the **Data Frame** is displayed in **Layout View** (see section 1.6).

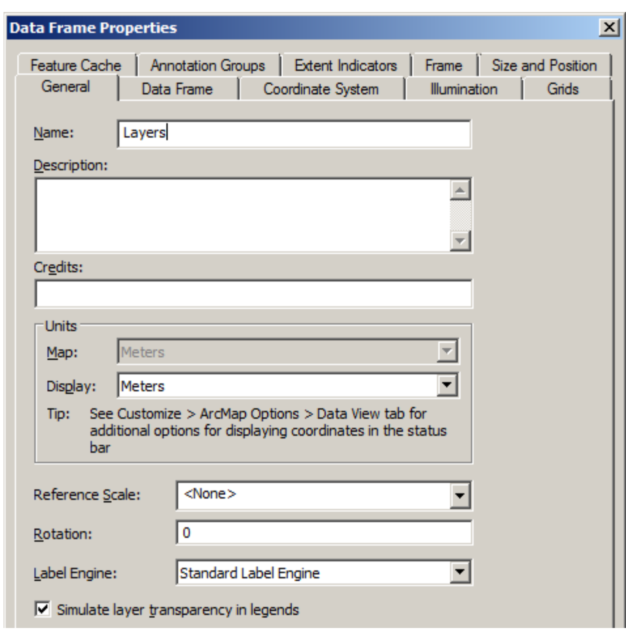

Figure 2. Data Frame Properties dialog box.

Now double-click the layer "maui30_dem" to bring up the **Layer Properties** window (Fig. 3). Here you can control the **Symbology** for each layer – that is, how the data are displayed in the main window. You can color code using different color ramps, and choose how you map the data to the color ramp by adjusting the **Stretch**. You can also assign specific colors to ranges of values by using a **Classified** symbology. You can also control the transparency of each layer in the **Display** tab of the "Properties" window. Experiment a bit here!

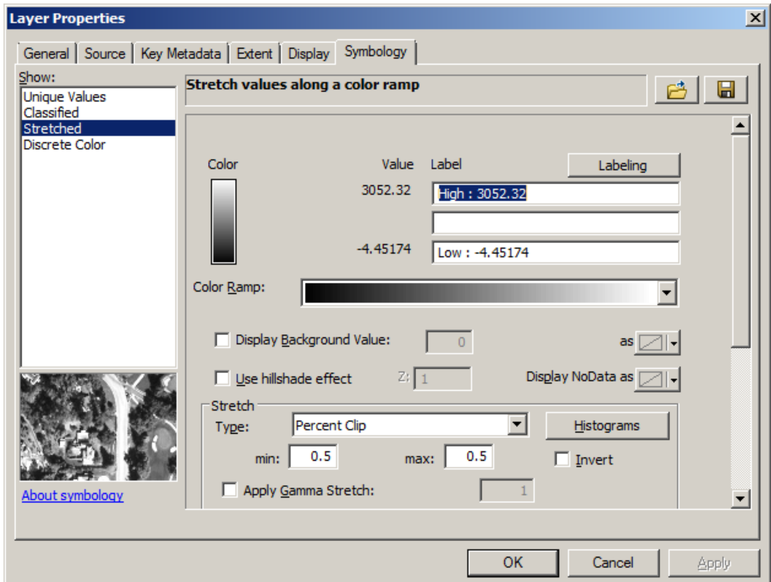

Figure 3. Layer properties window (raster dataset)

Next, open the properties window of the layer "maui_rainfall_data", and go to the **Symbology** tab (Fig. 4). Here you can choose which symbol to use, and vary the color and/or size of the symbols according to various attributes in the **Attribute Table**. For example, you can color-code the rainfall stations by mean annual rainfall in millimeters (the field "AnnAvgMM"). To aid in legend readability, it is a good idea to simplify the labels (Fig. 4).

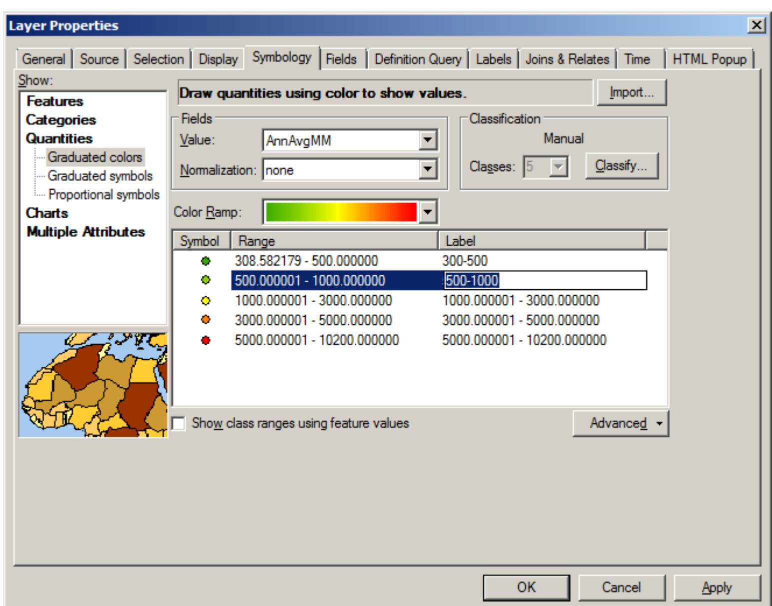

Figure 4. Layer properties window for Maui rainfall data, showing the Labels being edited for clarity.

You can change the symbol and size by clicking **Symbol** and then **Properties for all symbols…**, and you can change the numerical classification scheme by clicking on **Classify**, which also presents some basic summary statistics for the dataset (Fig. 5).

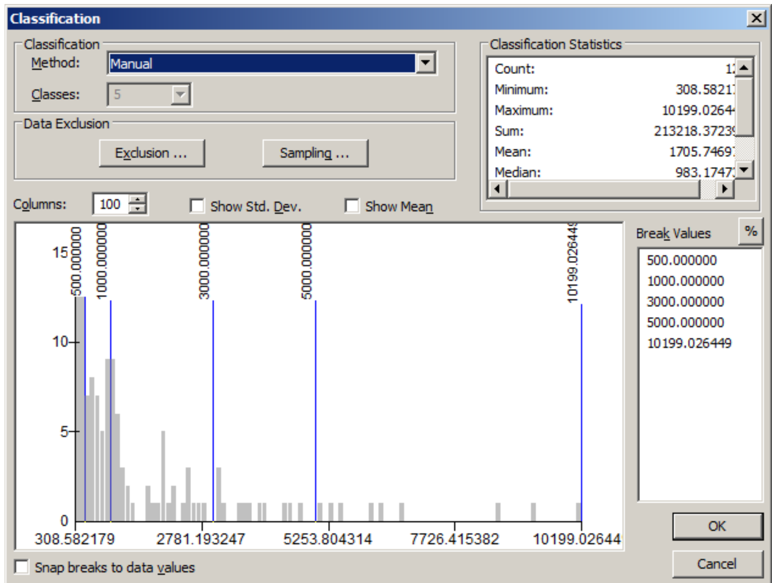

Figure 5. Classification window for Maui rainfall data feature class symbology

Experiment a bit to get the feel of displaying different attributes of the shapefiles. If you want to see the actual database behind the shapefile, right click on the layer and select **Open Attribute Table**. You can think of this as an Excel data table where each row corresponds to a specific geometric shape and location on the map. In the case of the “maui_rainfall_data” layer, this geometry is simply a point with x,y coordinates. For the “maui_geology” layer, each row corresponds to a polygon outline of a geologic unit on the map. This connection between databases and geographical information is at the core of why Geographic Information Systems (GIS) are so powerful!

2.2 Exploring data:

Take some time to explore your data a bit. You can zoom in and pan around with your mouse, and if you get lost, click the little blue globe on the **Tools** toolbar to get you back to the maximum extent (Fig. 6). The **Ruler** icon allows you measure distances, perimeters, and areas, which are displayed using the units defined in the **Data Frame** properties. Also on the **Tools** toolbar is the **Info** icon that will give you layer information where clicked. You can spot-check an elevation, get the info from a geologic map, etc. Experiment!

Figure 6. “Tools” toolbar.

One incredibly helpful tool is the **Profile Graph** tool on the 3D Analyst toolbar (Fig. 7). This allows you to extract the information of a raster dataset along a linear or segmented profile.

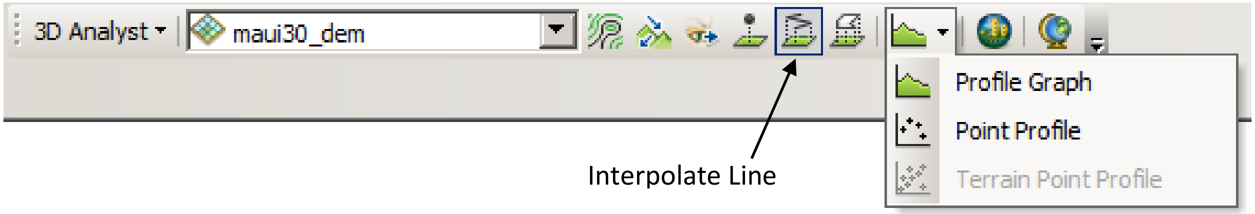

Figure 7. 3D Analyst Toolbar and the interpolate line tool.

First, select the raster dataset you wish to draw a profile of (here we'll use the DEM). To draw your line, use the **Interpolate Line** button and start clicking out a path. Double click the last point to finish, and then select **Profile Graph** to plot your profile. It will look something like Fig. 8 below:

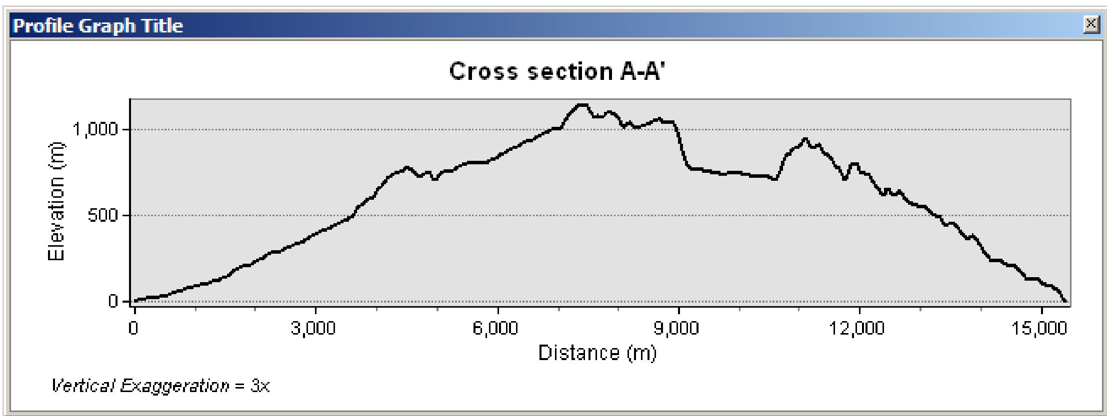

Figure 8. Profile graph of elevation, showing vertical exaggeration and location of cross section.

Note that the y-axis here shows elevation in meters, and the x-axis shows distance in meters. Be sure to note the **vertical exaggeration** on your plot, which is simply the ratio of the horizontal scale to the vertical scale. Using Fig. 8 as an example, 1" corresponds to 3,000 m on the horizontal axis, but only 1,000 m on the vertical axis, thus the vertical exaggeration is 3x. Unfortunately, there is no clean way to set the vertical exaggeration of your chart, so you will have to determine this manually or eyeball it.

A common pitfall is to accidentally plot a profile of a different raster, such as the mean rainfall, slope, or hillshade. Use common sense, and if something looks weird (like elevations ranging from 0-70), you probably made a mistake somewhere!

You can edit the axes, labels, etc. by right clicking anywhere on the chart and choosing **Properties** (Fig. 9). At a minimum, you must label all of your axes (including units) and indicate vertical exaggeration. For aesthetics, I would also remove the grey background and any unnecessary outlines or distracting grids. Neat and tidy graphic design is an underrated component of scientific communication!

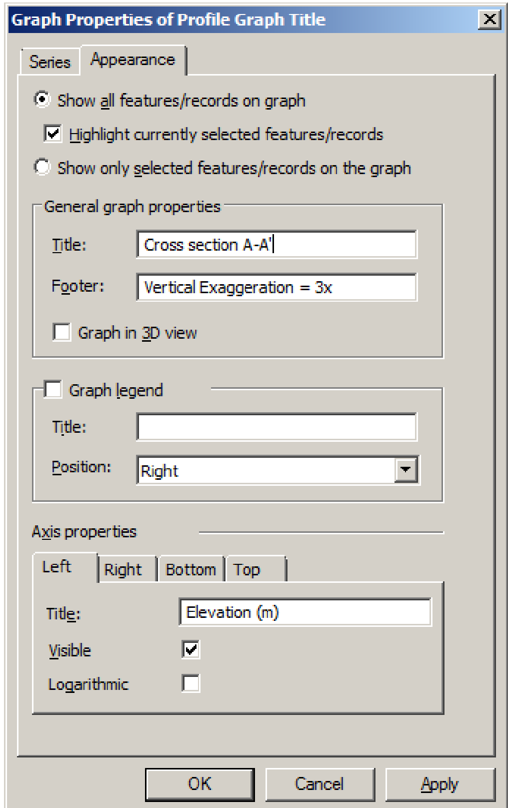

Figure 9. Profile graph appearance properties

You can export the finished plot by right clicking and choosing **Export…** and then saving as a PDF (Fig. 10). It is also possible to right click the graph, select **Copy as Graphic**, and then paste the graph into your map in **Layout View** (see section 1.6). There are some minor annoyances that may arise with automatic resizing, so be aware and find a method that works to your liking.

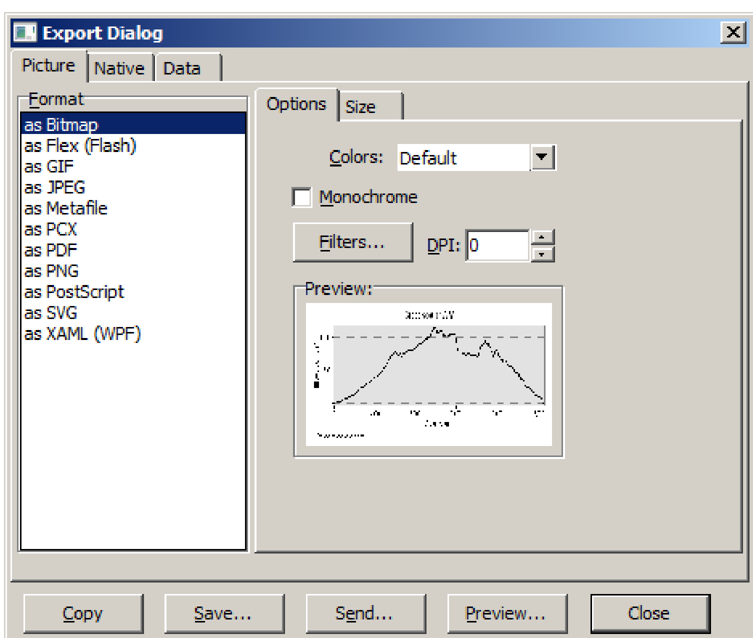

Figure 10. Export dialog for profile graph.

In the **Export** dialog box you can also export the raw x-y data by clicking on the **Data** tab. This is helpful if you would like to use another program like Excel to plot and manage your profile data. If you want to redo the profile, you can delete the line on the map after selecting it with the black selection arrow on the **Tools** toolbar (Fig. 6).

If you would like to save your profile line as a feature class, first select the line graphic, then go to the drop-down menu on the **Drawing** toolbar and run the tool **Convert Graphics To Features…** This is not necessary for this lab assignment, but may come in handy later in the semester.

2.3 Using GIS tools to perform calculations and generate new data sets

To visualize our digital elevation model, it is helpful to make a hillshade of the topography. A hillshade is a simulation of incident sunlight intensity on the surface defined by the digital elevation model.

Go to the ArcToobox window and double click on **\\Spatial Analyst Tools\Surface\Hillshade** (Fig. 11). We want to make a hillshade of the layer **maui30_dem**, so select this from the pull down menu **Input Raster**. For the **Output Raster**, we'll save to the same folder, and give it the name **maui30_hillshade**.

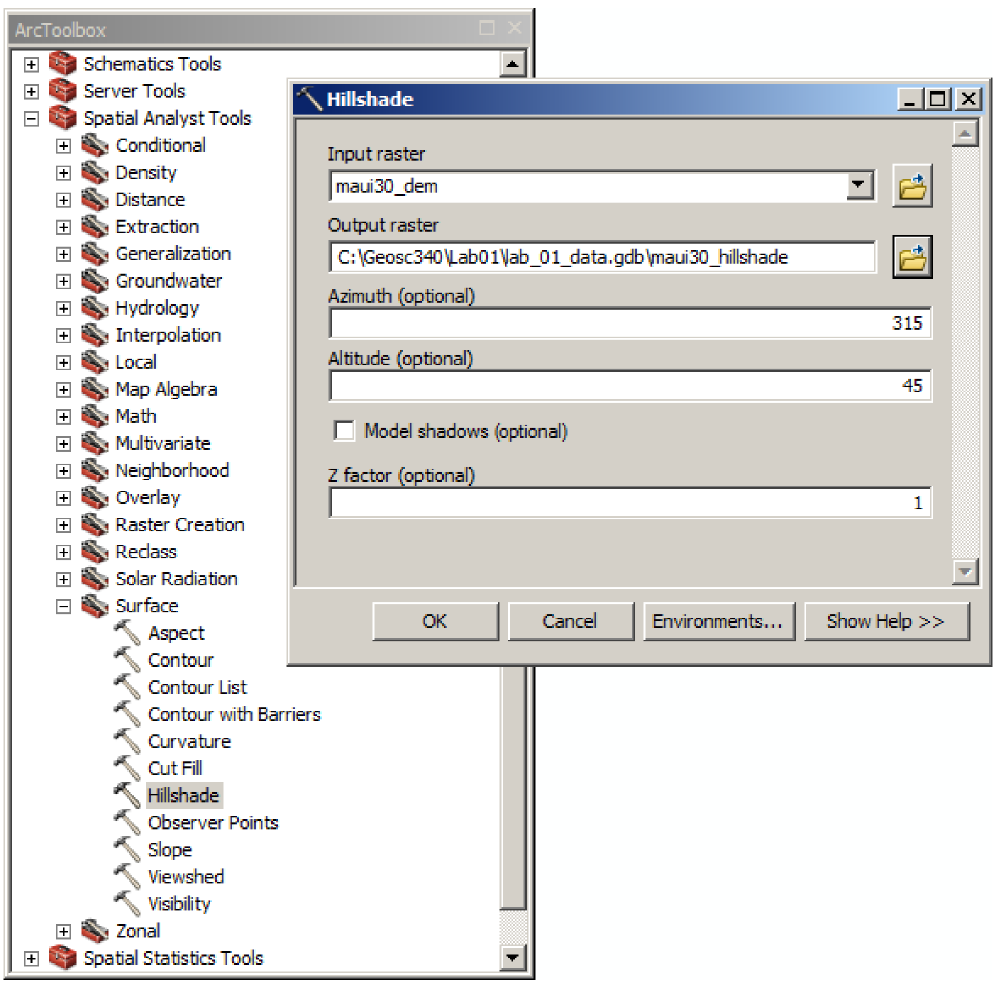

Figure 11. ArcToolbox window and the Hillshade tool graphical user interface

Another common task for geomorphologists is the make a slope map. Double click on **Spatial Analyst Tools\Surface\Slope** (Fig. 12). We'll stick with units of Degrees rather than Percent_Rise for now.

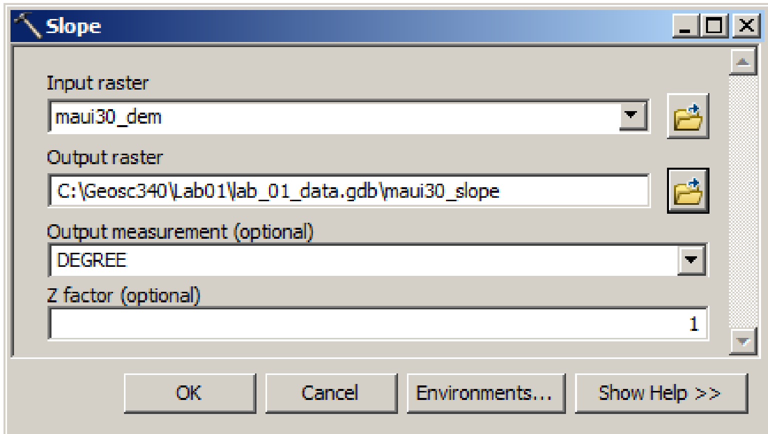

Figure 12. Slope tool dialog box.

The final calculation we will perform is to generate a contour map of mean annual rainfall from the dataset "maui_annual_rainfall_grid". Navigate to and double click on **Spatial Analyst Tools\Surface\Contour** (Fig. 13). We can start with a contour interval of 1000 mm, but you can experiment to find the most appropriate interval.

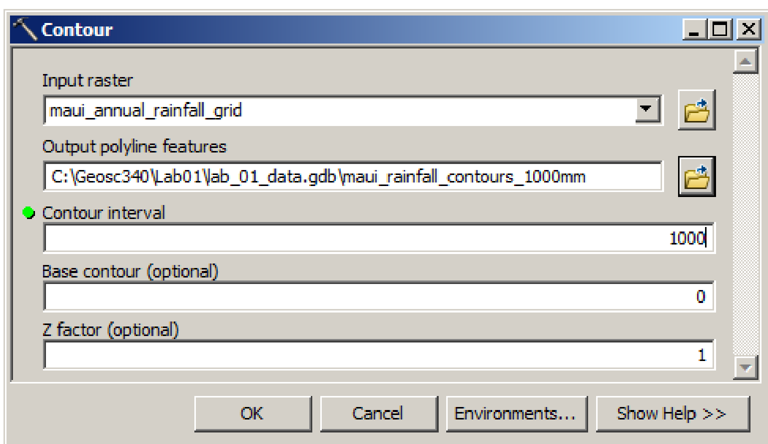

Figure 13. Contour tool dialog box.

Note that if you screw up and make a layer you don't want, you can remove it from the **Table of Contents by right clicking and selecting **Remove**, and then delete the actual file in the **Catalog**. DO NOT try to delete individual files in Windows explorer.

2.4 Making a map

Now that we have loaded and generated some layers, we want to present them in both an informative and visually appealing manner. Take some time first to experiment with **symbology**, the layer order, which layers are visible, and the transparency levels. Decide on what you want to show/emphasize, and then cut the fluff. Once you have a nice looking map, switch to layout view by choosing **Layout View** from the drop down menu **View**. This is essentially a print preview, and what you see is what you get.

To pan around in layout view, use the zoom and pan tools in the **Layout Toolbar** (Fig. 14).

Figure 14. Layout Toolbar

If you want to move the map around within the data frame, you can use the pan/zoom tools in the Tools Toolbar (Fig. 6). If you want to save an extent so you can zoom quickly back to it, you can bookmark it by selecting **Create Bookmark…** from the Bookmark pull down menu.

You can insert various graphics elements such as scale bars, north arrows, legends, and text annotations. Some of these are accessible from the **Insert** menu, and others are found on the **Draw** toolbar. When you print your maps to turn in, make sure to **always include a title, scale bar, north arrow, and an appropriate legend, including units**.

I expect these to be publication quality, and will show you a few examples in class of what I mean by this. In general, it is good practice to ask yourself whether someone unfamiliar with this week's tutorial would be able to understand everything on your map.

Some tips:

- Make sure to label everything and indicate the units of measurement for each layer.
- Eliminate unnecessary "chart junk", such as incomprehensible layer names and generic titles like "Legend".
- To change the color or thickness of your cross section lines, double click on the map in **Layout View** to **Focus** the **Data Frame**. This enables you to select and edit graphics items that were created in **Data View**.
- Annotate all of your cross section lines with A-A' or similar.
- Be sure that your map scale bar shows analogous units to your cross sections.
- Make sure to scale the size of your text and labels appropriately, so that they are readable when the map is displayed in full.

For this week's lab, the map of Maui is going to fit better in Landscape orientation than in Portrait. To change this, select **Page and Print Setup** from the **File** menu, and select Landscape orientation (Fig. 15).

This semester, you will be handing in digital copies of your labs as .pdf's rather than printing them out. To export your map from layout view, select **Export** from the **File** menu (Fig. 16). Set the resolution to 300 dpi, and give it a helpful file name like "Tutorial_2_Figure_1_lastname.pdf"

For now, exit out of layout view by selecting **Data View** from the drop down menu **View**.

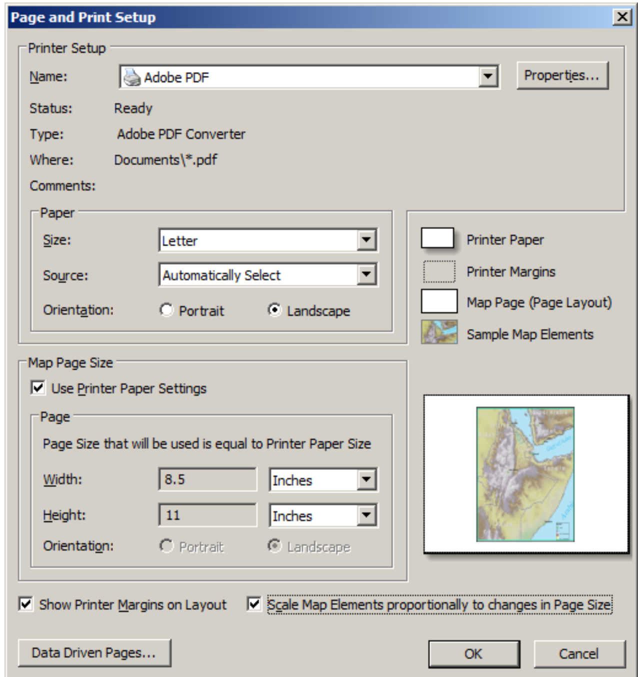

Figure 15. Page and Print Setup

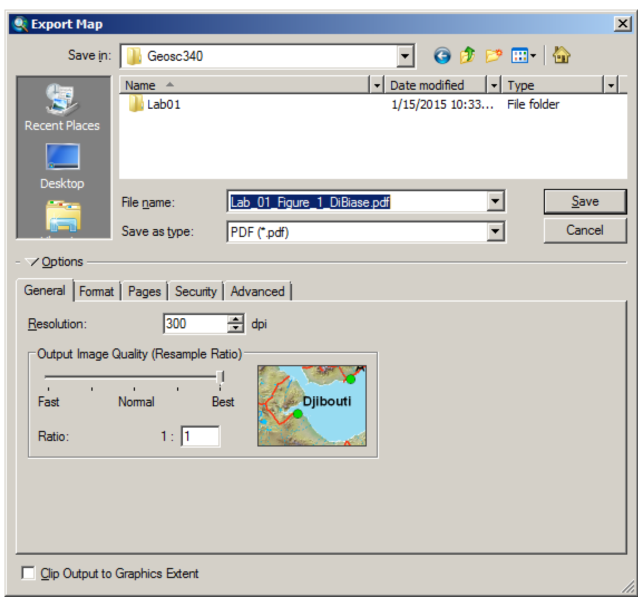

Figure 16. Export dialog

2.5 Saving your workspace

To save your mapping workspace, select **Save as…** from the **File** pull down menu. These workspaces are saved as .mxd files. It is important to note that .mxd files simply point to the original datasets, and are used to save the layer orders, transparencies, symbology, and layout. Thus, I highly suggest keeping a different .mxd file for each map you turn in.

If you want to open your .mxd file on a different computer, or if you move your folders around, it is important to first go to **File/Map Document Properties**, and check the box next to **Store relative pathnames to data sources**.

2.6 3D Visualization of data in ArcScene (OPTIONAL)

Often times, it is helpful to view a 3D rendering of the landscape, as when you use Google Earth. The program ArcScene enables you to directly load custom image and elevation datasets that you have generated in ArcMap in a much more flexible manner than Google Earth.

First, open up the program ArcScene using the shortcut on the 3D Analyst toolbar: . The layout looks quite similar to ArcMap, and you have access to the same tools and catalog. Open the catalog window, navigate to the raster dataset "maui30_dem", and load it into your map window. Right now it is a flat plane that you can rotate and move around using various mouse buttons.

To make this layer 3D, we need to assign **base heights**. Double click on the layer and go to the **Base Heights** tab (Fig. 17).

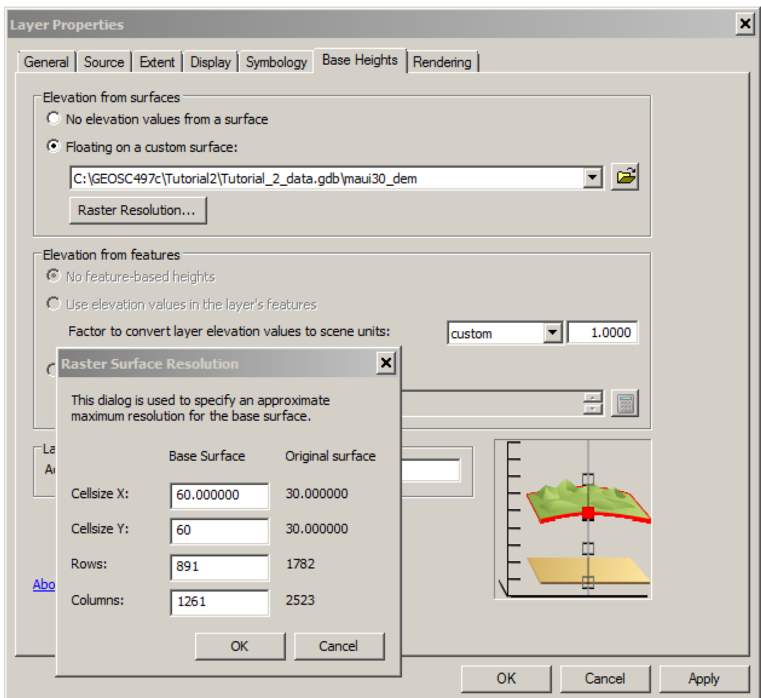

Figure 17. Assigning base heights in ArcScene.

We want to assign the elevation values from "maui30_dem", so select **Floating on a custom surface** and then navigate to the raster "maui30_dem" if it is not already selected. We can also control the resolution of the base height assignment. Our data set has a Cell size of 30 m, but to make visualization smoother on slow machines, set the values for **Cellsize X** and **Cellsize Y** to 60. You can increase or decrease this number to enable faster 3D rendering or see more detail. You can also adjust vertical exaggeration and offset in this window. Try setting the conversion factor to 2.0 and see what happens.

After you adjust the base heights, reset the scene extent by clicking the large globe button on the right hand side of the navigation toolbar (Fig. 18)

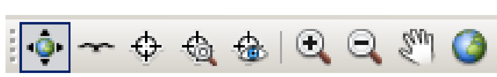

Figure 18. Navigation toolbar in ArcScene.

We can add illumination to scene by going to the **Rendering** tab in the **Layer Properties** dialog and selecting **Shade areal features relative to the scene's light position** (Fig. 19). While you are here, crank up the slider bar on **Quality enhancement for raster images**. Similar to choosing the base height resolution, this adjusts the image resolution of your raster datasets. If your computer is getting bogged down, you can slide this back to the left.

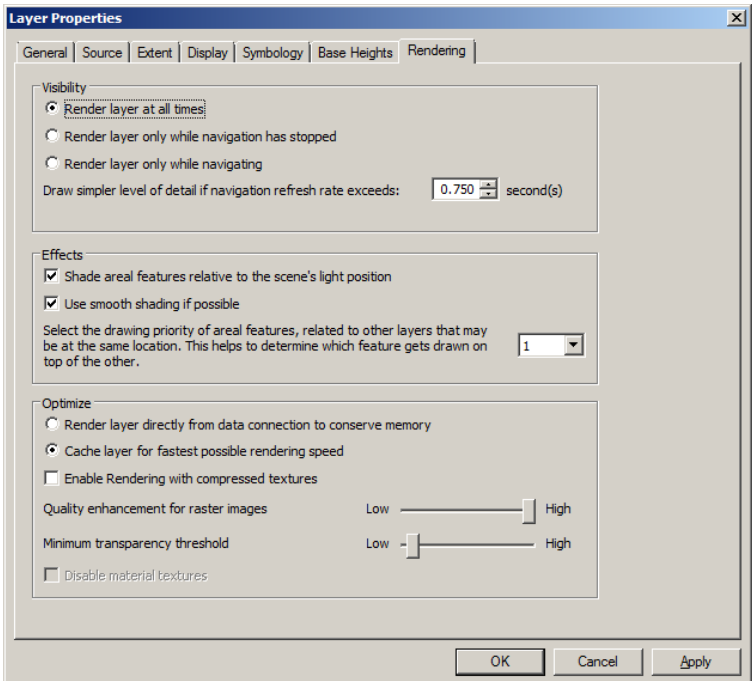

Figure 19. Rendering properties for layer in ArcScene.

You should end up with something that looks like Fig. 20.

Figure 20. 3d perspective of Maui, shaded by elevation, with 2x vertical exaggeration, viewfield angle = 55°.

You can change the perspective and lighting of the scene by opening the **View Settings** and **Scene Properties** dialog boxes from the **View** menu (Fig. 21). In **View Settings**, it is often helpful to adjust the **Viewfield** angle to its lowest value, 1 degree, so as to minimize foreshortening (Fig. 22).

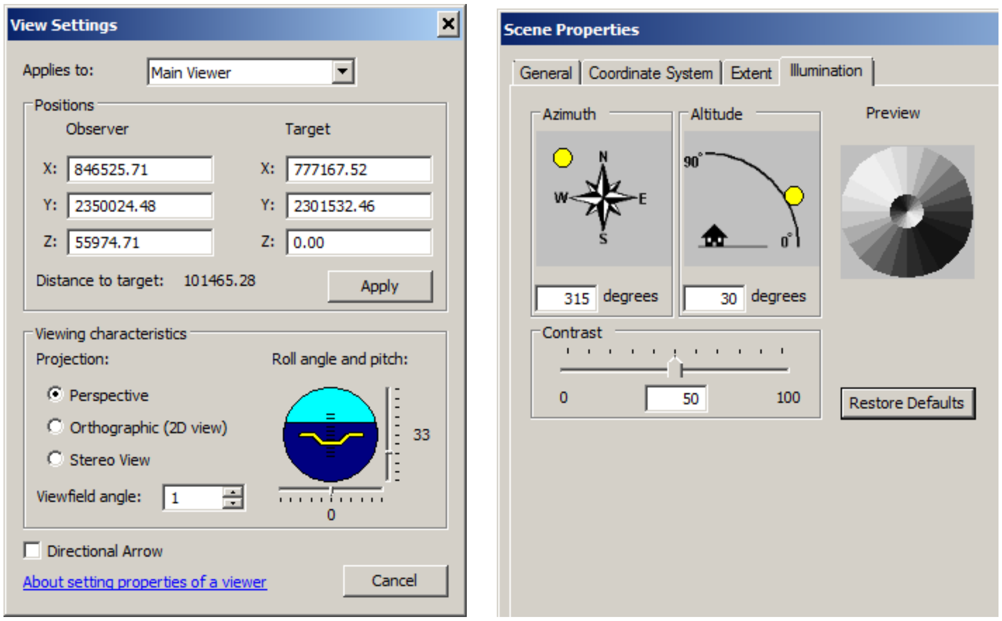

Figure 21. View Settings and Scene Properties dialog boxes.

Figure 22. Same as Fig. 21, but with viewfield angle = 1°.

Often times, it is more useful to visualize a separate dataset, such as a slope map or geologic map for this tutorial. Navigate to and load up the dataset "maui30_slope" that you made in **Section 2.3** above, and adjust the symbology to match what you used in ArcMap. Repeat the steps shown above to assign base heights using the DEM (Fig. 17), shade the features using the scene's light position, and crank up the quality enhancement for the raster image (Fig. 19). Now you should have a nicely-rendered slope map to explore! To save this image, take a screenshot or go to File/Export Scene/2D. You can make a high-resolution output by increasing the **View size** and **resolution**.

Tutorial 2 deliverables, due 5:00 pm Friday, February 12 (10 pts total)

Please submit as single PDF file to the Tutorial 2 drop box on Angel

(6 pts) Four maps made in ArcGIS, all of which must have a title, scale bar, north arrow, and appropriate legend, including units.

- A map of Maui showing the **elevation** partially transparent over the hillshade, and including labeled cross section lines for the topographic cross sections below. For this map, the elevation (DEM) layer should have a “stretched” symbology.
- A map or Maui showing slope partially transparent over the hillshade. For this map, the slope layer should have a “classified” symbology with appropriately chosen intervals.
- A map of Maui showing contours of mean annual rainfall, including the station locations – you may overlay this on the elevation, hillshade, slope map, or some combination.
- A map showing the geology of Maui. Again, it may be helpful to overlay this on a hillshade. Be sure to choose an appropriate symbology that highlights the most informative contrasts in geology across the island.

(2 pts) Two topographic cross sections extracted from the DEM, both of which must have titles, labeled axes, and the approximate vertical exaggeration noted.

- A representative cross section of the east summit that begins and ends at sea level.
- A representative cross section of the west summit that begins and ends at sea level.

(2 pts) A written report no more than 2 pages long (12 pt font, 1.5 line spacing, 1” margins), which should include the following:

- A brief introduction and description of the datasets used (1 paragraph)
- A description of the morphology and climate of Maui – be as quantitative as you can (1-2 paragraphs focused on *observations and measurements*)
- A discussion of how climate and the timing of volcanism influence the patterns of erosion on Maui (~2 paragraphs focused on *interpretations*)

You will not need any outside resources for this report. Trust your observations! Below are some questions to help motivate the written report:

What is the elevation of the western summit? What is the elevation of the eastern summit?
How does rainfall vary with elevation on the western part of the island? On the eastern part?
How does the depth of river incision vary across the island?
Where are the oldest basalt flows found on the eastern part of the island?