GIS 4 Geomorphology

Geomorphometry of Mountain Landscapes & Upland Watersheds…a little Wildlife, too

Swath Profiles

Swath profiles condense elevation data to a single profile. The profile is similar to the ridgeline your eye would tra if you were standing in the valley looking up at a mountain range (think: the Tetons from the visitor center). **SWA**

PROFILE EXAMPLE: Goshute Mountains, NV

Another option is to stack several individual topographic profiles together on one figure. Below is a worked example. Older notes are below that.

1.) Go to EarthExplorer website (www.earthexplorer.usgs.gov).

2.) Login or create a new login. There's no risk in doing this. USGS doesn't spam you.

3.) Select the Search Criteria tab and click to add points to the map and define your study area.

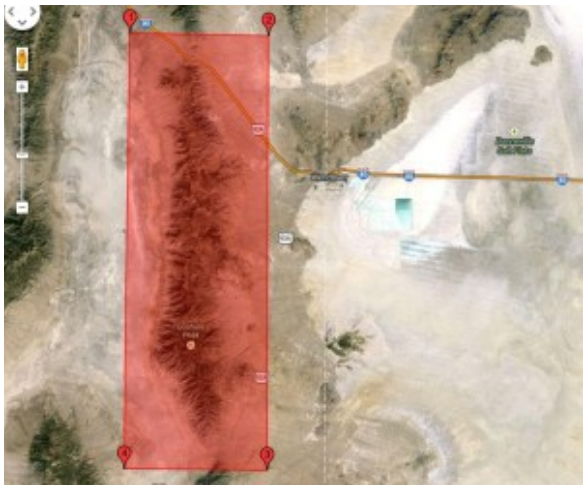
Selected study area is the Goshute Mountains of northeastern Nevada. It is an isolated, compact, linear range oriented north-south.

4.) With study area defined, select the Data Sets tab > Digital Elevation > ASTER Global DEM. OK any warnings along the way.

5.) Select Results tab. All ASTER DEM tiles that intersect with your search polygon will appear.

6.) Click on Footprint icon next to each tiled DEM file to determine which tiles you need.

7.) Click the Download icon to download zipped folder containing each file.



Zoomed in view of Earth Explorer showing search box drawn over the Goshute Mountains of Nevada. The Goshutes are an isolated, compact, linear range that is oriented north-south, which makes it easier to work with.

8.) Unzip (uncompress) each folder. In Windows, Right-click > Extract all (see HERE). Use the unzipped files. Discard the zipped folder(s).
Ex: ASTFTM2_N40W115_dem.tif

9.) Open ArcGIS 10.x.

10.) Turn on Spatial Analyst extension (Customize > Extensions). Turn off Enable Background processing (Geoprocessing > Geoprocessing Options). Set up a project folder.

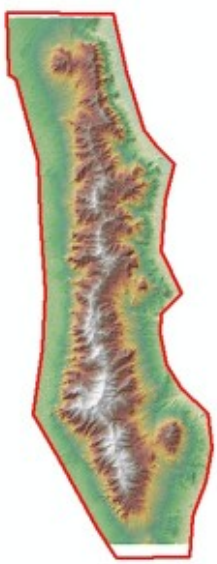
11.) Add DEM(s) to view. By default, they come in WGS84 (unprojected). Set Data Frame Coordinate System (Example: PCS: UTM NAD83 Zone 11, Display units = Meters). If you have multiple DEMs covering your study a you should Mosaic them. See instructions HERE.

12.) Create a Hillshade raster from the DEM (Spatial Analyst > Surface > Hillshade tool). Adjust the Z-factor usin this table of values:

Approx Latitude	**Z-factor**
0	0.00000898
10	0.00000912
20	0.00000956
30	0.00001036
40	0.00001171
50	0.00001395
60	0.00001792
70	0.00002619
80	0.00005156

– The Goshutes are at about 40 degrees N, so I'll choose a Z-factor of 0.00001171.
– Set the Display to BILINEAR (Properties > Display > Resample during display…).
– Adjust Transparency to about 50%.
– Move Hillshade above DEM layer.
– Change DEM color ramp to Elevation #1 (Properties > Symbology > Right-click color ramp bar > uncheck Graphic view > names of color ramps appear).

13.) Clip the DEM down to size. Draw a polygon graphic encircling the mountain range. Draw it relatively close to your range front boundary (Draw toolbar). Your goal is to reduce the overall number of pixels and just work with those representing the mountain range itself. Alternatively, you could create some contours or use Identify tool to determine the approximate elevation of the range front – where a prominent slope break occurs an alluvial fans begin). Click on both sides of the range along the range front (Example: 1800m works well for the Goshutes).



Clipped DEM with clipped hillshade. There is still some noise in the DEM data (a few hills separated from the ma body of the range itself), but it's not that big of a deal. You could be more meticulous in your work than me.

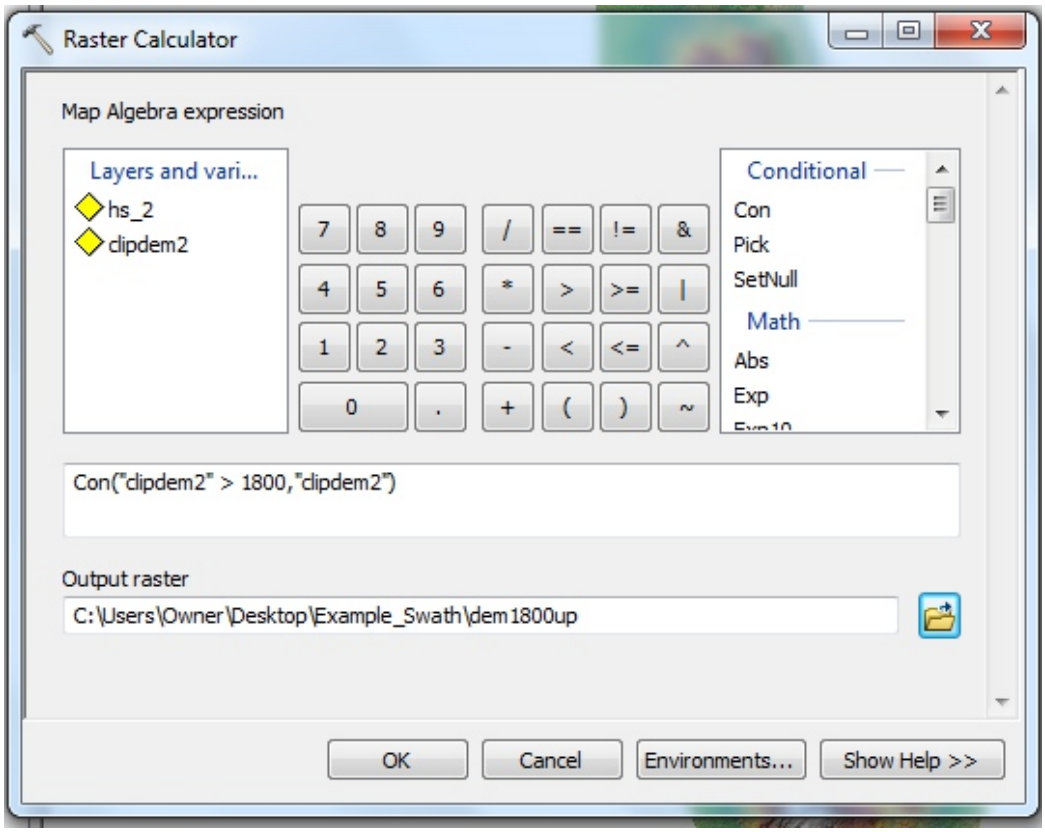
14.) Convert the graphic to a feature* (shapefile), add it to the map, use the shapefile as the cookie cutter to clip DEM. Use the the appropriate shapefile-raster Clip tool (Data Management > Raster > Raster Processing > Clip) *Ex: ClipDEM*

** Converting graphics to features: Draw a graphic using Draw tools (Customize > Toolbars > Draw). There are several tools available if you click-hold the rectangle tool. Draw the shape you want. With it selected (see the blu grips), right-click on the data frame name in the Table of Contents frame (default is called Layers) > Convert graphics to features. Save as a shapefile.*

15.) Saved your map lately?

16.) Use Raster Calculator to remove the extra "basin" pixels, keeping only those pixels at or above the range fro slope break elevation (Ex: 1800m). Raster Calculator is located in Spatial Analyst > Map Algebra.

Construct an equation like this: **Con("clipdem2" > 1800, "clipdem2")**



Use a Conditional statement in Raster Calculator to further clean up the DEM prior to running your swath elevation profile. The output file created by RC is a raster named "dem1800up". Always use the buttons in RC; type as little as possible. In this example, I only typed 1800.

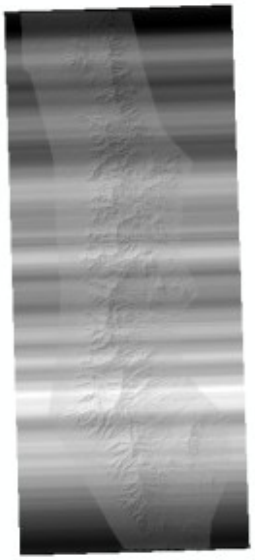
This equation is a Conditional statement (an if-then statement), which reads:
"If the value in any cell of the input raster, called "clipdem2″, is greater than 1800m, then keep the value in the output raster. If not, then change the value to NoData, or Null, which will omit all pixels below 1800m from the output raster."

Ex: dem1800up

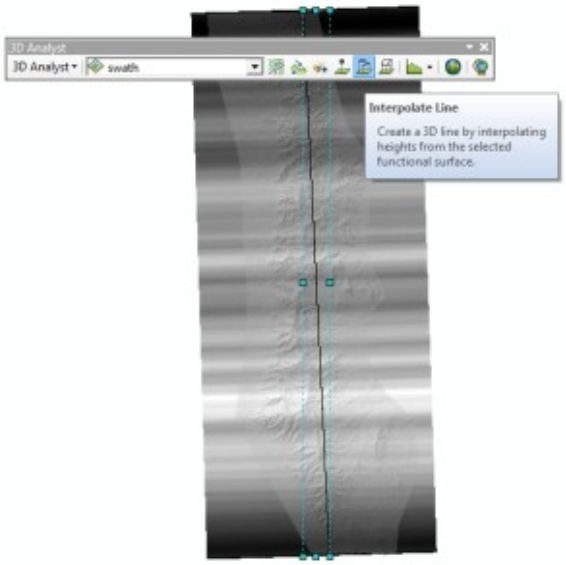
17.) Now we'll create the MEAN ELEVATION swath profile. Since the Goshute Mountains run north-south, we'll s
up the Focal Statistics tool as below (Spatial Analyst > Neighborhood > Focal Statistics).

Height = 1 cell
Width = 2 x Long Dimension
Units = Cells
Statistics Type = Mean

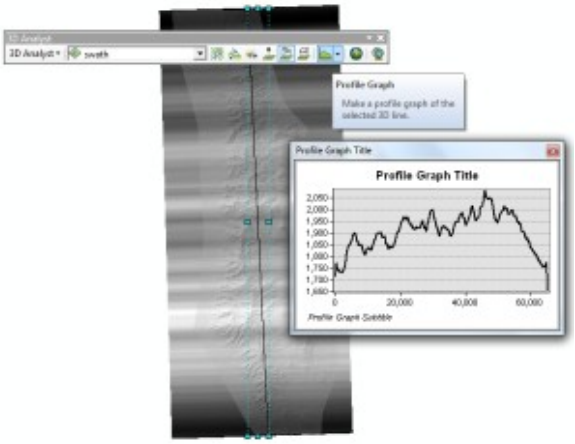
Goshute Example Data Inputs:
H = 1 cell or 28m
W = 2 x 64,000m = 128,000m or 4571 cells



Swath profile raster created with Focal Statistics. For a north-south oriented mountain range, the stripes should run east-west. The hillshade is shown for reference here; you won't see it.



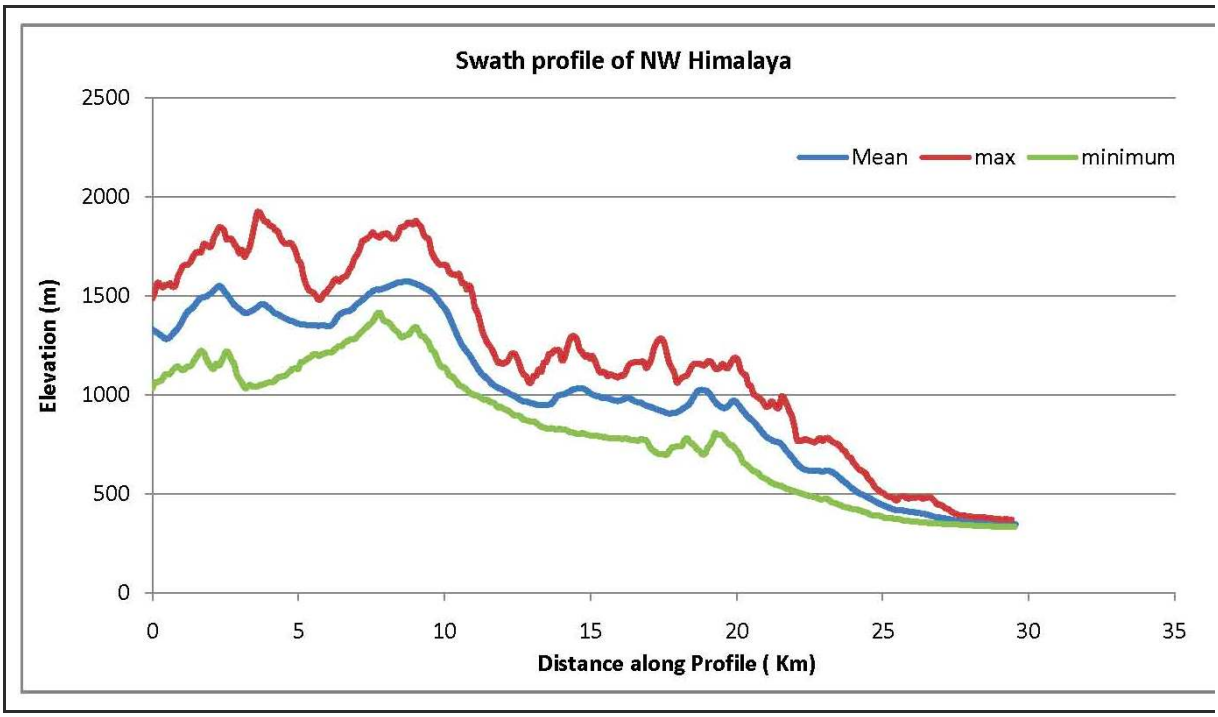
Use the Interpolate Line tool on the 3D Analyst toolbar to create a profile across the stripes. Its not crucial how its drawn, since each stripe has only one value all the value, the mean elevation. If you have multiple rasters, make sure you draw a new line each time you extract a profile (a quirk of Arc).



With the Profile Line selected, click the Profile Graph tool. A plot of the MEAN ELEVATION swath profile will appear. Right-click on Graph > Export > Data tab > Excel format.

18.) Repeat the steps to create the MAXIMUM ELEVATION swath profile, taking care to change the Statistics Ty in Focal Statistics tool to Max.

19.) Plot both profiles as separate Series in an Excel chart.



— Example swath profile for a Himalayan study area submitted by our man in India, Rahul Kumar Kaushal of IIT-GN Earth Sciences. Thanks, Amit!

……..

Older Notes Below:

Method A: Classic Swath Profile

Swath profiles are commonly displayed in graph-like figures where distance along the range front is on the x-axis and elevation is on the y-axis. It is common to show minimum and maximum lines (or +/-1 S.D. envelope) togetl with the mean profile line (primary profile line). Minimum profiles can be problematic if you don't crop the DEM tig to the mountain front. Depending on what's available, other data such as low temperature thermochronometry points (rock uplift rate), precipitation data, or geology can be added to the same figure. See figures in referencec papers for ideas on how to construct your swath profile figure.

OPTIONAL: ROTATE DEM

It is best if your mountain range trends either N-S or E-W. You can rotate the raster if need be: Data Managemer Tools > Projects and Transformations > Raster > Rotate. Angles are clockwise. Turn off the original DEM when complete and use the rotated one from then on. For segmented ranges (Ex. Bighorn Mountains), use two or mo rotated swaths.

PREPARE DEM

Option A: Mask DEM at 2100m Contour

– Download 30m DEM of Tetons, output = "ned_96010610"
– RC: DEM > 2100, output = "over2100m"
– Reclass: Old Values = 0,1, New Values = NoData,0, output = "over2100re"
– RC: "over2100re" + ned_96010610″, output = "newDEM"
– Remove and delete "over2100re" and "over2100m" (use ArcCatalog)

Option B: Define Rectangular Clipping Polygon

– Use Draw tools to draw the "swath", a rectangular graphic (Customize > Toolbars > Draw).
– Rotate and position the graphic carefully over the DEM to capture the topographic ridgeline.
– Convert graphic to a shapefile (Right-click Layers > Convert Graphics to Features). Fill the checkbox for automatically deleting the graphic.
– Use the resulting shapefile as a clipping mask to extract elevation data contained inside it (Data Management : Raster > Raster Processing > Clip). Make sure to fill the little checkbox.
– Delete the graphic.

Workflow for Method B: ArcGIS-Excel-Illustrator

1.) You will need the 3D Analyst extension, the Interpolate shape tool, and the Profile Graph tool. Turn on the extension (Customize > Extensions > 3D Analyst). Open 3D Analyst toolbar (Customize > Toolbars).

2.) Check to see that the name of your DEM layer is shown in the toolbar. Whatever layer is shown is the layer 3l Analyst will profile.

3.) Draw profile using tools on 3D Analyst toolbar. Click the Interpolate Line tool button and draw a line. With line selected, choose the Profile Graph tool. A graph will appear in its own window.

4.) Export values to Excel by right-clicking on graph to open the Export Dialogue window > Data tab > Excel opt Set other parameters as you wish.

5.) Open file in Excel.

6.) Bin the data (see Binned Elevation Histogram lesson). Bin size is up to you.

7.) Create a chart (histogram) in Excel. X-axis is the horizontal distance along profile line (i.e., Easting), Y-axis is elevation.

8.) Repeat the process for additional profiles. Stack multiple profiles (separate data series) in Excel, then bring th whole chart into Illustrator (optional).

9.) Copy/paste your completed chart from Excel to AI. Delete the clipping mask(s), remove any compound path and ungroup elements as necessary. Edit chart elements in AI as you see fit. See Rowberry paper for an exampl

10.) Analyze: identify paleosurfaces, anomalous steep zones, etc. Modify figure in AI.

CREATE SWATH

– Use the Measure tool to determine the length of the swath's long axis.
– Write this distance down in meters and convert value to cells. Cell dimension for DEM is found in Properties > Source or are available from the DEM source website.
– Create a mean elevation raster from the clipped/rotated swath DEM, Spatial Analyst Tools > Neighborhood > Focal Statistics. The inputs to the tool vary depending on the orientation of the range.

For a N-S oriented swath, set the inputs in the Focal Statistics too this way:
Height = 1 cell
Width = 2 x Long Dimension
Units = Cells
Statistics Type = Mean

Tetons Example:
Clip DEM to 2100m contour (Option A)
Height = 1 cell
Width = 5042 cells (70,000m = 2521 cells at 27.77m pixel size = 5042 cells = 2x long dimension)
Neighborhood = Rectangle
Unit = Cells
The output should appear as a striped grayscale raster, where the stripes are oriented across the long dimensio the swath (horizontal).

EXTRACT PROFILE

– Turn on 3D Analyst Extension (Customize > Extensions > 3D Analyst) and open the 3D Analyst toolbar (Customize > Toolbars > 3D Analyst).
– Set the target layer on the toolbar to your striped swath raster.
– Choose the Interpolate Line button and click-drag a line across stripes. Double-click to end line.
– Click the Create Profile Graph button. A plot of your profile should appear in a small window.

EXPORT & CHART DATA

– Right-click on the graph to export the values to a spreadsheet for charting (Export > Data tab) or to generate a image of the chart created by 3D Analyst (Export > Picture tab).

– You may need to draw a new profile line each time you construct a profile for export. Since the total distance v vary with the angle of your profile line, try to keep profile line orientations identical (perpendicular to swath stripes

SUMMARY STATISTICS

– Min, Max, and STD elevation swath profiles can be made from the same input DEM using Focal Statistics. Typically, you should choose one of three ways to display the data:

a.) Max and mean

b.) Mean and 1 SD envelope

c.) Max, Mean, Min

Note: Minimum elevation profiles are usually least helpful; the data usually are heavily influenced by adjacent vall

Method B: Stacked Profiles

This is the 'superimposed profiles' method used by Rowberry et al. (2007, Figs 4,5 and 6). Here's how it works. set of parallel, regularly-spaced section lines is drawn across the mountain range (study area landscape). Every cell along the line is sampled, thus the sampling interval is the width of 1 cell. For a 30m DEM, the sample interv 30m. Unlike Method A, the section line is only one-cell tall. With a section line drawn, you extract the elevations export them via table (or text file) out of ArcGIS and into Excel. Altitude-frequency histograms can be constructe a spreadsheet and displayed on a figure. The look of the figure can be improved in Illustrator.

Refs:

Mitchell & Montgomery (2006a)

Mitchell & Montgomery (2006b)

Reiners et al. (2003)

Burbank (1992)

Fielding et al. (1994)

Bishop et al. (2002)

Grohmann (2004)

Grohmann (2005)

Montgomery (2001)

Rehak et al. (2008)

Rowberry et al. (2007) Norwegian Journal of Geology 87

Musumeci et al. (2003)

Foster et al. (2008)

Adlakha et al. (2013) Tectonophysics 582