

Lab 5: DEM Analysis: San Gabriel Mountains, CA

In this lab you will work with digital topographic and geologic maps with a set of DEM analysis tools (ArcGIS and Matlab scripts) to study the topography of the San Gabriel Range in southern California. The challenge is to attempt to deconvolve the many possible controls on landscape morphology (lithology, tectonics, climate, etc). You will also have a paper on this topic by Blythe et al (2000) – this work can help guide your analysis, but you should aim for an evaluation/critique of the paper. Read it first, ask questions in class if you have any about it. They looked at topographic data, but not at stream profiles which ought to contain the most tectonic information in mountainous landscapes. Do your analyses validate their interpretation? Are there some problems? Can you upgrade/refine their interpretation?

You are working on an unresolved research problem: no one knows fully the answers to the questions posed below for the San Gabriel mountains. Moreover, keep in mind that it is unlikely that analyses of topography alone can resolve all of the issues – your assignment is to explore both what you can and cannot decipher from the topography. This type of analysis can provide a useful guide to subsequent field work. Where the topography allows multiple interpretations, strive to (a) recognize this fact; (b) identify alternate hypotheses; and (c) suggest what additional data would be required to resolve the question under consideration.

Motivating Questions (to be addressed in your analysis and report)

- Is the San Gabriel Range subject to spatially variable uplift? If so, can you define the pattern?
- If spatial patterns in channel steepness (k_s) are apparent, do they correlate with mapped structures? Do they correlate with long-term exhumation rates determined from low-temperature thermochronology? (i.e., Are the “blocks” defined by Blythe et al (2000) supported? Would you draw different boundaries?)
- Is the landscape in steady-state? Can you tell?
- Is there evidence for a temporal change in rock uplift rate? Can you distinguish a temporal change in uplift (migrating knickpoints) from a spatial pattern (fixed knickpoints)? How?
- Do lithologic variations importantly influence stream profiles and hillslope gradients in the San Gabriel Mountains?
- Can topographic analyses alone discriminate the relative importance of tectonics, lithology, and climate factors? If not, what additional data is needed and how could it be obtained?

For Graduate Students:

- Are there spatial patterns in fluvial drainage density (that is, differences in x_c as measured by the break in slope-area scaling that might indicate a transition from debris-flow to fluvial erosion processes) and do they correlate with channel steepness patterns? (i.e., are debris-flows more important in areas with steeper slopes?).
- Are the channels of the upper San Gabriel River (north of the San Gabriel fault) detachment-limited? Can you tell, and if so how?
- Is there evidence that a downstream transition from detachment-limited to transport-limited conditions occurs?

Data Available

- Paper by Blythe et al (2000) with discussion of interpretation of low-temperature thermochronologic data (generally young ages = faster long-term erosion).
- 1:24,000 USGS Topographic Contour Maps (paper copies in map library; scanned versions in Langtang/public – ask TA if you want to see these)
- Digital Geologic map, Faults map, and Thermochronologic data (ArcGIS project)
- Digital Elevation map (10m), Shaded Relief map, Slope map, 50m Contours (ArcGIS project)
- Stream_profiler analysis codes (ArcGIS dll and Matlab scripts) (ArcGIS project)
- Matlab code for bedrock channel evolution (from bedrock channel lab)

Your Assignment

Deliverables: 6 page (1.5 line spacing, 12 pt font), thoughtful analysis and discussion of the San Gabriel Mountains in terms of the motivating questions above. Reports should be supported by whatever figures and tables are necessary to illustrate what you have learned and what key problems remain unconstrained. Digital figure submissions are fine (pdf or ArcGIS project) if you'd rather not bother with printing color figures (please provide black and white print). You may find that some simulations with your bedrock channel code help with your analysis/interpretation. Focus on the south-draining drainage basins within the DEM, aim for an analysis of about 20 profiles (start with larger tributaries that cover the regional pattern – you might want to look at channels representative of each of the blocks defined by Blythe). As always you are encouraged to work together and discuss your approach with your fellow students, TA, and instructor. The main point is to learn both the strengths and limitations of DEM analysis. However, I expect each of you to do your own stream profile analysis and to prepare your final reports independently.

Setting up Digital Data for your Analysis

Each of the lab computers has all the required data in a directory called **user_data\labuser\sg_class**. You will want to pick one lab computer and do all your work there (you need Matlab and ArcGIS 8.x or 9.0 (sp1) on any alternate machine you'd like to work on in your home or office – talk to your TA about what is required to set this up). Within **sg_class** you will find directories **data**, **profile_codes**, and **my_project**. Do not edit, move or rename the **data** or **profile_codes** directories – these will be used by all. You will start by copying and renaming the directory **my_project** as **name_project** or similar. Do not alter the source **my_project** directory in any way.

Inside your new **name_project** directory you will find a pre-loaded ArcGIS project (**san_gabes1.mxd**) and two directories **arcgis** and **matlab**. The **arcgis** directory will store all files generated by ArcGIS stream profiler (including temporary files). The **matlab** directory contains the dem and drainage area arrays and will be used to store all matlab stream profiler output, including postscript files of your plots for printing. Save the **san_gabes1.mxd** ArcGIS project with a personalized name. Now you should be ready to go.

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Stream Profile Analysis Procedure

First a quick overview of the basic steps, that **must** be followed in order – each and every time you restart the ArcGIS project (detailed instructions for working with both the ArcGIS and Matlab profiler codes are given in another section below, or are attached).

1. Open your ArcGIS project.
2. Set the stream profile run parameters – click the first profiler button (**I**). Set: both save and temp directories to ...\`sg_class\name_project\arcgis` (... \`sg_class\my_project\arcgis` is the default – make sure to change this!). Click the button below to save your location as the default. Set `m/n` to 0.45. Set cellsize to 10. Set dem to `sg_dem` (default). Stream number does not matter. Finally Click “send parameters to matlab”. Note: if the unchecked “turn off messages” button you will get helpful, but quickly annoying, tips on what to do next.
3. Select the second profiler button (cross-hairs) – this is the stream selection tool. Use it to click somewhere near the head of the stream you wish to look at (make sure you are within the right drainage basin and near the stream line you are interested in – exact placement is not necessary). Enter a name for this stream (numbering works fine) and click “submit name and close file”. You are now ready to go to Matlab to analyze the stream.
4. Start Matlab. Set the working directory to ...\`sg_class\profile_codes` (this should be an option in the pull-down menu). Start the `profile3.m` code:

```
>> profile3('sg1_', '...\sg_class\name_project\arcgis', '...\sg_class\name_project\arcgis', 5, 10);
```
5. Immediately after completing the analysis in Matlab (details below) and **before** answering “yes, I want to do another”, go back to ArcGIS and import the stream profile (click third profiler button that looks like a squiggly line) and any knickpoints (fourth profiler button – looks like stair steps). Once loaded (takes a minute), save your project. Later you will set a color map to show stream steepness index (k_s) values in color-code in map view.
6. Repeat step 3 **before** going back to Matlab. If you skip step 5, that data will be lost to ArcGIS. If you go back to Matlab without repeating step 3, Matlab will re-run the same stream profile.

Recommended Options in Matlab Profile Analysis (in order of appearance)

1. Say yes to remove spikes (enter **y**) (but makes little difference)
2. Say no to remove steps (enter **n**)
3. Say yes to smooth profile (**y**)
4. Set smoothing window (meters) to **250**
5. Set contour interval (meters) to **12.192**
6. Arrange the 2 figure windows side-by-side for convenience
7. Choose logS – logA plot for picking regression limits (enter **a**) (in some cases you may wish to try different options here, but this is the standard method)
8. For regression limits only the x position matters, not the vertical, so long as the cursor is in the right panel. Make sure you click the minimum (left side) first.

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9. Set ks window(km) to **1** (this affects only the lower plot in “figure 3”, it does not influence any calculation)
10. If you are happy with your choice of regression limits and wish to save this data, answer yes to “remember this fit?” (**y**).
11. If you wish to fit regressions to another stream segment, answer yes (**y**); if you are done with this stream profile, answer no (**n**). (**important advice**: do not typically fit regressions to the hillslope/colluvial segment, look for sub-parallel segments on the profiles downstream of x_c – expect more than one segment, but breaking into 2-4 segments will be more effective than finely dicing into 5-10 mini segments; avoid including dams and other spikes in the data within the bounds of any regression – these spikes create a huge bias in slope data).
12. If you have noted interesting features (do not have to be knickpoints – just places you want to see where they plot in plan-view or to mark in a data file) and wish to mark them, enter **y**; else enter **n**
13. Choose which ever plot has distinct breaks or knicks you wish to mark, the standard is “**b**” – the elevation profile, but some features show up most clearly on other plots. The marked points appear on all plots, so this can be a convenient way to just see where breaks on one plot fall on another
14. Say no to classifying knickpoints (not yet functional) (enter **n**)
15. Say yes to change axis limits (enter **y**). It is convenient to save all plots at the same scale for comparison, so setting limits based on the tallest and longest profiles is a good idea. I suggest: **z min = 0**, **z max = 3000** (meters), **distance = 90** (km). This should be sufficient for all. It is possible all would fit with distance = 80 (km) as well. (next time you do this just answer yes (enter **y**) to “use previous bounds?” after you say yes to “change axis limits”. Every time you restart Matlab you will have to re-enter these limits.
16. Unless you have decided to scrap this analysis and start over, answer yes to all prompts whether to save data and print files. All matlab files will be saved to `...\sg_class\name_project\matlab`, and ArcGIS files will be saved to `...\sg_class\name_project\arcgis`.
17. Make sure to import data into ArcGIS before answering yes to doing another analysis in Matlab (or it will repeat on the same stream profile).

Viewing Profile Composites for Comparison in Illustrator

This is not by any means required, but it can be useful to load your output matlab plots into different layers in Illustrator for direct comparison and for plotting composites. For this to work you need to have set all plots to the same axis limits (see item 15 above). Steps:

1. Open the first *.ps file with Illustrator
2. Make a new layer and name the layer with a stream_name
3. Use PLACE command to insert the stream_name.ps file
4. Repeat 2-3 for ALL plots, including the one you opened in step 1.
5. save file occasionally
6. Remove the first, unnamed layer – this one will not be in exactly the same place.
7. save your file

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8. For each layer you need to remove the background (opaque white) on each figure panel to be able to “see through” to layers below. Click on the plot to highlight. Leave all selected and execute: Ungroup (ctrl-shift-g). Release Clipping Mask (ctrl-alt-7). 2nd time Release Clipping Mask (ctrl-alt-7). Now every item in the layer can be edited individually.
9. click near the border to highlight surrounding frame (not visible) – delete
10. click in each figure panel to highlight background frame (not visible) – delete
11. now you should see through to the layer below. Lock this layer. Turn off this layer to avoid confusing clutter.
12. repeat for each layer, saving occasionally
13. leave all layers locked to avoid accidentally moving something. Turn on and off various layers to create the composites you want to see. You can print any composite sets and/or save as pdf files.

How to use ArcGIS: a primer for students of Surface Processes

1. Finding and opening the application

- a. Locate the document with the extension XXX.mxd in your folder. This is an ArcMAP document. It is the map where you will be displaying and characterizing all of the stream profile data you will be collecting in MATLAB.
- b. The application may also be found at:
 - i. Start/Programs/ArcGIS/ArcMAP
 - ii. C:\arcgis\arcexe83(or82)\bin

2. The Legend

- a. Once you open the .mxd file, you should see a legend to the left and a map to the right.
 - i. In the legend, layers of the map can be turned on and off (with the checkmark)
 - ii. classification of the data in a layer can be visible or hidden (click the + of - sign).
 - iii. you can change the order of the layers (what’s on top of what) by click-and-dragging any layer up or down in the legend. (layers are all set to be opaque)
 1. you can change the transparency of any layer (in the legend, right click on the layer-name, select ‘properties,’ select the ‘display’ tab)
 - iv. Setting Classification Schemes for the data layers that you collect in MATLAB:
 1. Once you have imported all your stream profiles into ArcMAP, you will want to combine them all into a single file (see the How-To further down this list). After they have been grouped into a single layer, then you will want to create a Classification Scheme to best visualize the result. To do this: right click on the name of the layer you are working with and select ‘Properties.’ Under the “Symbology” tab, you will select from the left column

“Quantities.” You will need to choose the particular attribute of the layer that you want to plot (for example for a stream segment you can color the stream according to one of 16 attributes). For example, to plot the steepness (k_s) according to the forced concavity (θ), you need to select from the pull-down menu next to ‘Value:’ ‘KsRefCon1.’ Leave ‘Normalization’ as <none>. Under classification, you can choose the number of categories you want to group the data into and the method by which you choose breaks between groups. Using the ‘Classify...’ button, groups can be set according to equal intervals or natural Jenks or standard deviation. Natural Jenks with ~5 classes works well for me.

3. Tools

- a. The Information Tool
 - i. This is a fundamental tool for finding what data lies within each map layer. For example, for each knickpoint that you collect in Matlab, you can find the elevation and drainage area by clicking on the knickpoint point in ArcMAP.
 - ii. To create a table of all the attributes of all the points or lines in a particular layer, you can right-click on the name of the layer in the legend and select ‘Show attribute table.’ In this table you can sort the data or make plots of one attribute against another.
- b. Self-Explanatory Tools
 - i. Zoom (the mag. glass), Pan (the hand), Zoom to full extent (the globe)...
 - ii. (if you put the mouse over any of the tools, it will tell you what it is/does)

4. Grouping a set of data files together

- a. before beginning, all data files must be visible in the legend (not necessarily in the map)
- b. also, I strongly suggest that the mainstem channels are at the top of the legend so that they over-ly the tributary streams.
- c. next, under the pull-down menu ‘Tools,’ select the ‘Geoprocessing Wizard’
- d. you want to merge individual files into one
- e. check-off all the stream profiles you want to combine and designate an location and name for the resulting layer (which will be a polyline shapefile)
- f. once you have created this grouped layer and loaded it into ArcGIS (which should happen automatically) you will want to apply a classification scheme to this file (see 2.a.iv above)