Earth and Planetary Surface Processes
Winter 2017 - Lab 4. River channel long profiles.
Wieboldt 310C, 10:30a-11:20a
Grades are not assigned for lab, but attendance is required.
If you are unable to make a lab, email kite@uchicago.edu to set up an alternate time.

Download TopoToolbox
https://topotoolbox.wordpress.com/download/
Unzip it, launch Matlab, and at the command prompt enter the following (recall that the 'up' arrow brings back the previous command). Substitute the actual location of the TopoToolbox-2 directories for "C:\path\to\wherever\you\installed\this\"

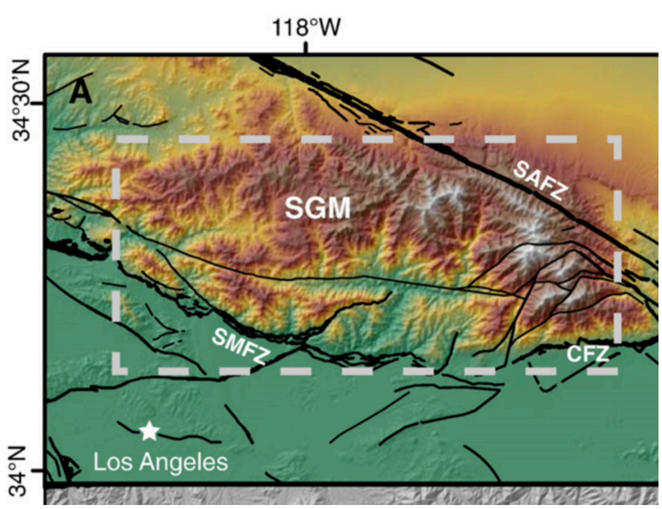
addpath C:\path\to\wherever\you\installed\this\TopoToolbox-2
addpath C:\path\to\wherever\you\installed\this\TopoToolbox-2\utilities
addpath C:\path\to\wherever\you\installed\this\TopoToolbox-2\topoapp
addpath C:\path\to\wherever\you\installed\this\TopoToolbox-2\DEMdata

1. From raw topographic data to a river long-profile analysis.

At the Matlab prompt, type

DEM = GRIDobj('srtm_bigtujunga30m_utm11.tif');

(Explanation of the filename: Space Shuttle Radar Topography Mission, Big Tujunga Creek – Southern California in the San Gabriel mountains, 30m resolution, Universal Transverse Mercator projection). You are looking at a small portion of a transpressional mountain belt, undergoing rapid (~mm/yr) tectonic uplift. Uplift is localized between the San Andreas Fault Zone (SAFZ) to the north, and the Sierra Madre Fault Zone (SMFZ) to the south. The area of the DTM is in the W of the gray box shown below (from DiBiase et al. Earth and Planetary Science Letters 2010).



View the DEM:

imagesc(DEM)

and the DEM slope:

imageschs(DEM,min(gradient8(DEM),1))

Use 'colorbar' to look at the scale for Matlab images.

We will now carry out a standard hydrography workflow for this DEM. The steps are not specific to TopoToolbox, although the command names are. Before each command, type "help <commandname>" and read the description. For example, before entering the fillsinks command, type "help fillsinks."

DEMf = fillsinks(DEM);
FD = FLOWobj(DEMf); A = flowacc(FD);

View a map of the stream network:

imageschs(DEM,dilate(sqrt(A),ones(5)),'colormap',flipud(copper));

DB = drainagebasins(FD); DB = shufflelabel(DB);
A = flowacc(FD);

Ignore parts of the DEM with a drainage area of <=10000 pixels, i.e. 0.9 km^2; assume these are hillslopes.

W = A>10000;
Map view of the major streams:

S = STREAMobj(FD,W);
plot(S)
S = klargestconncomps(S,1);
hold on; plot(S, 'r')

plotdz(S,DEM)
Note that there is a small dam 21km upstream (not important for this lab).

What is the overall slope of the main stem?

What is the overall slope of the tributaries?

2. Average concavity, and deviations from the mean concavity.

What is the elevation of the knickpoints? How tall are the knickpoints? Where are the knickpoints located?

C1 = slopearea(S,DEM,flowacc(FD))

What is the concavity index for these data?

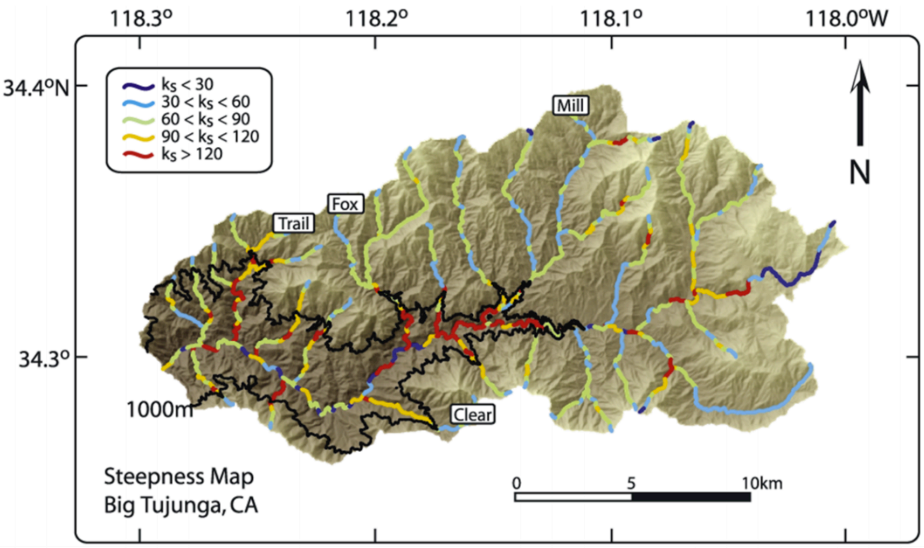


Figure 2. Map view of normalized steepness indices (θ_{ref} = 0.45) in the Big Tujunga basin. The boundary between high and low steepness values lies close to the 1000 m contour, and the highest steepness indices are generally confined to the lowermost portions of the drainage basin, consistent with a model of basin-wide knickpoint retreat. High k_{sn} reaches upstream of 1000 m contour line represent minor perturbations to smooth, low-gradient channel profiles and may be related to localized lithologic heterogeneities, landsliding, or boulder rapids over short channel reaches.

(From Wobus et al. JGR 2006).

Recall:

$$S = k_s A^{-\theta}$$

is equivalent to

$$\left|\frac{dz}{dx}\right| = \left(\frac{U}{K}\right)^{\frac{1}{n}} A(x)^{-\frac{m}{n}}$$

from lecture.

Here, theta is the concavity index, and k_s is the steepness index. Notice how k_s is related to uplift rate (i.e. tectonics), whereas the concavity index is related to *m* and *n* in the streampower law which can be independent of tectonics.

$$\frac{\partial z}{\partial t} = U(x,t) - K(x,t)A(x,t)^m \left|\frac{\partial z}{\partial x}\right|^n$$

(note *k* in the streampower law is **not** the same as k_s).
Now use the interactive 'slopeareatool'

slopeareatool(FD,DEM)

"Change color" to red, and select some streams topographically below the knickpoints until you have built up many red dots on the slope-area plot. Change color to black, and do the same for some streams above the knickpoints (you may find it helpful to refer to Fig. 2 from the Wobus paper). Select "Curve fitting" and fit to both the red and the black data. What is the ratio of steepness indices between the two? Which is steeper for a given drainage area?

3. Chi-profile analysis.
Chi-profiles (also known as the "integral approach") were developed to reduce noise in slope-area analysis, and to collapse multiple tributaries onto a single river profile. With elevation on the y axis, instead of distance along profile on the x axis, we plot instead

$$\chi = \int_{x_b}^{x} \left(\frac{A_0}{A(x)} \right)^{\frac{m}{n}} dx$$

where x_b is the beginning (downstream) of the profile and A0 is a reference drainage area (we will use 1 km^2, which is the program default). In general we do not know m/n in advance. Enter

C2 = chiplot(S,DEM,flowacc(FD))

How does the program-reported best-fit (m/n) compare to your measurements and fits from slopeareatool?

You should see most of the tributaries collapse onto a single line with scatter that is much-reduced compared to 'slopeareatool'. The non-linearity of this profile corresponds to changes in uplift rate with time. The signal of changes in uplift starts at the base of the river profile and propagates uphill (as a retreating knickpoint, for example as a back-eroding waterfall).

Based on the chi plot, what (qualitatively) is the history of uplift of the San Gabriel mountains? You can assume that uplift is spatially uniform between the San Andreas and the Sierra Madre fault zones, and varies only with time.

You should be looking at results that are qualitatively similar to those from Perron & Royden, Earth Surface Processes and Landforms, 2013 (copied below).

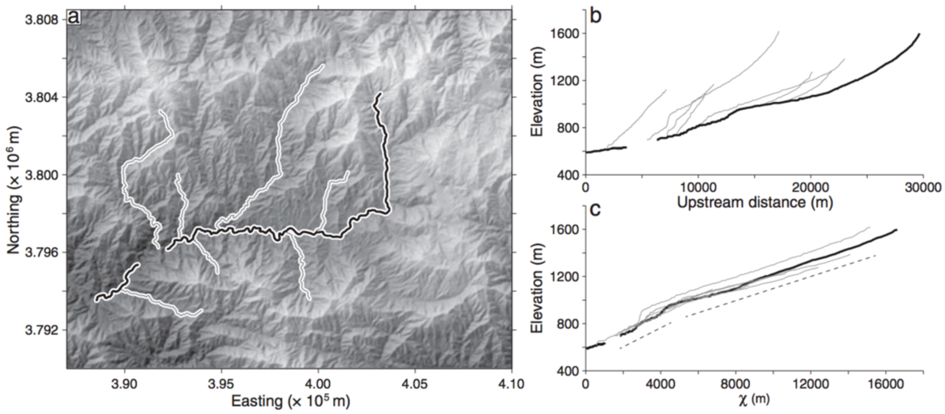


Figure 4. Big Tujunga drainage basin in the San Gabriel Mountains of California, USA. (a) Shaded relief map with black line tracing the main stem and gray lines tracing seven tributaries. Digital elevation data are from the 1/3 arcsecond (approximately 10 m) US National Elevation Dataset. UTM zone 11 N. (b) Longitudinal profiles of the main stem (black line) and tributaries (gray lines). The gap in the main stem is the location of Big Tujunga Dam and Reservoir. (c) Chi plot of longitudinal profiles, transformed according to Equation 6, using $A_0 = 10$ km^2 and $m/n = 0{\cdot}4$, illustrating the approximate co-linearity of the tributaries and main stem despite the fact that the profiles do not appear to be in steady state with respect to uniform erodibility and uplift. Two straight dashed segments with different slopes are shown for comparison