THE UNIVERSITY OF MEMPHIS

CENTER FOR EARTHQUAKE RESEARCH AND INFORMATION

Homework 2

"Analyzing Spatial Data - Fault Roughness"
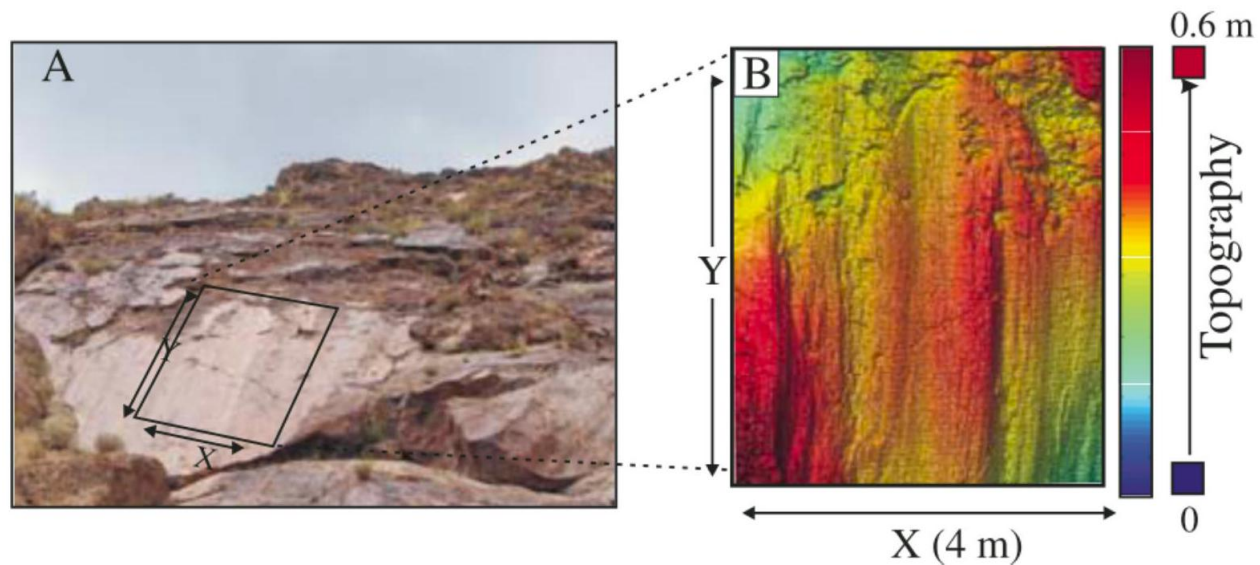
DATA ANALYSIS IN GEOPHYSICS

CERI 8104

FALL SEMESTER - 2025

Presented by:

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September 30, 2025

Figure 1 – *A: Section of partly eroded slip surface at Mirrors locality on Dixie Valley fault, Nevada B: Light detection and ranging (Lidar) fault surface topography as color-scale map, rotated so that X-Y plane is best-fi t plane to surface and mean striae are parallel to Y. From: Sagy, A., Brodsky, E. E., & Axen, G. J. (2007). Evolution of fault-surface roughness with slip. Geology, 35, 283-286.*

INSTRUCTIONS:

1. Load and inspect the data file (fault_roughness.txt).

2. Remove all nan values by using the following line:

   a. $XYZ = XYZ(\sim isnan(XYZ(:,3)),:)$

   b. the $\sim$ symbol reverses the boolean array from isnan to anything that is not nan.

3. Find the unique elements in X and Y and create a regular spaced grid. Use this grid to interpolate the Z coordinates of the roughness data using `griddata`.

4. Create a first plot of the gridded data. Describe your observations and submit the plot together with your report!

5. Now detrend the data by using the function `detrend_2d(ZZ)`. Again describe your observation and submit the figure!

6. You will now compute the power spectral density for each along-slip roughness profile and determine the roughness exponent based on the stacked densities. For this purpose, set up a `for loop` over all x-coordinates and get the roughness profiles along the y-direction, that is vertical profiles going from left to right.

   a. Demean and detrend each profile

   b. Compute the Fourier transform using $fft(z)$, normalize by the length of the spectrum, `nfft` and multiply by a factor of 2 . You can ignore the frequency range of the fft for now. We will later only plot the data for a specific range of wavelength.

c. The power spectral density can be determined using:

$$PSD = |fft(z)|^2 \Delta x$$

d. Plot the average power spectral density over wave length, λ. Instead of limiting the data range for the plot, you can simply limit the x-axis range using $x \lim([10, 2000])$.

e. Determine an approximate range over which the plot is linear and compute the roughness exponent by performing a liner regression on the log-transformed data.

f. What is the resulting roughness exponent? What is the range over which the roughness profiles are linear in log-log space and when and why does this linear scaling break down?

g. Save a colormap of the detrended initial roughness scan and a figure of the fitted power spectral density profiles. Add labels to all plots and include the figures in your report for this assignment.

h. Lastly, compute the rms roughness and compare it to the corner wavelength of the power-spectral density. Discuss your observations!

RESULTS:

After loaded the data file (`fault_roughness.txt`), the columns that represent x, y, and z coordinates represent the X and Y coordinates, also the third column that is the roughness values of the fault surface.
The range of topography is from 16.0 to 494.6 microns and 1 microns was used as the grid spacing. The figures below show the raw data and the detrended data. The raw data shows a clear, large-scale planar trend. The color gradient indicates a smooth change in elevation across the entire sample. This large-scale trend represents the overall orientation of the fault block itself, but it is not part of the roughness, so in the next figure the detrended data is shown, which no longer exhibits the large-scale trend. The surface is now centered around a zero mean, and the color map highlights the local positive and negative deviations. This figure now shows the true roughness of the fault surface.
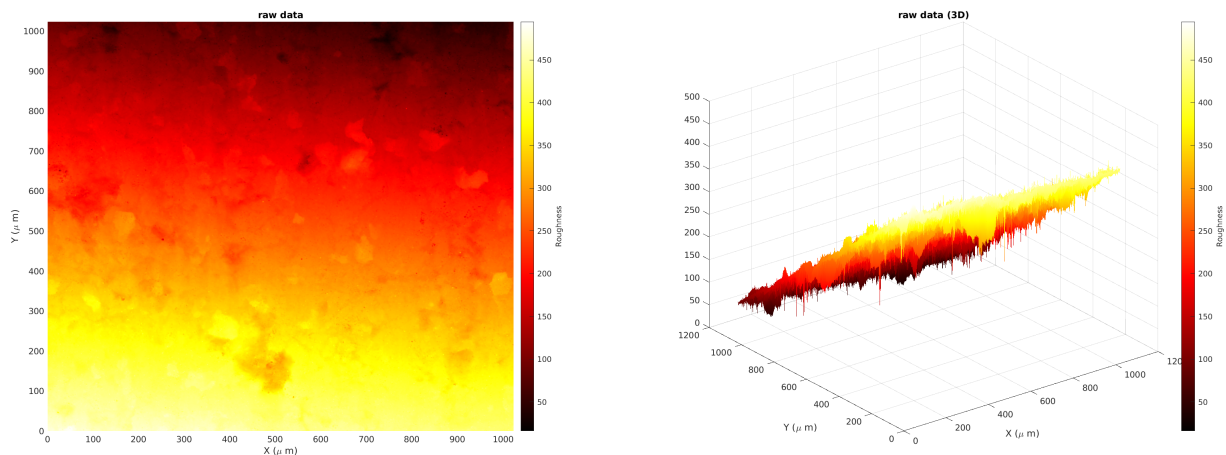

Figure 2 – *Raw surface data as as color-scale map (left) and 3D surface (right).*
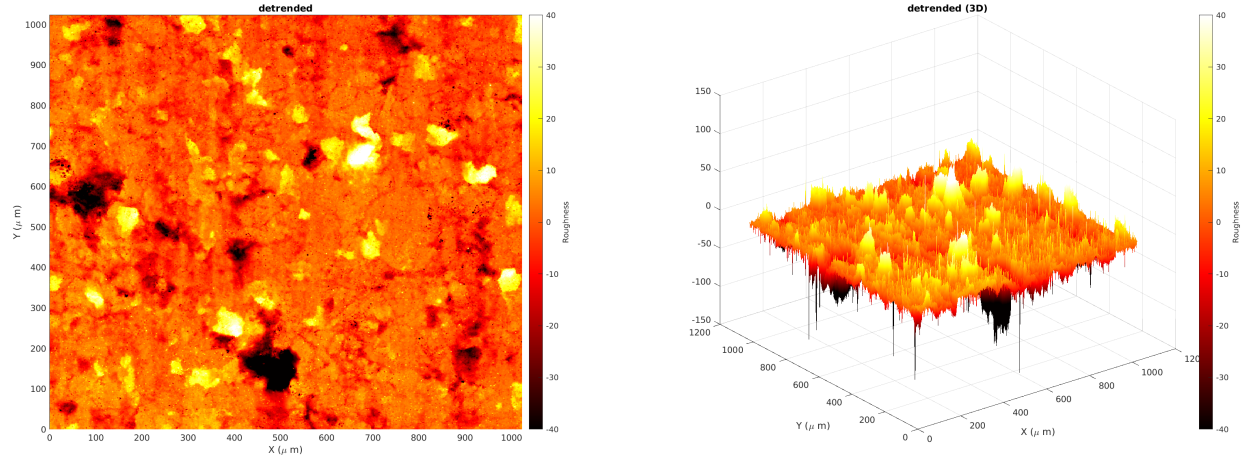
Figure 3 – *Detrended surface data as as color-scale map (left) and 3D surface (right).*

After, inspecting and preprocessing the data, the power spectral density (PSD) was calculated for 1D profiles across the surface in both slip-perpendicular (x-direction) and slip-parallel (y-direction) orientations. This profiles were stacked and the average PSD was computed for both direction in order to have a plot of the average power spectral density over wave length, λ. These plots in log-log scale are shown below.
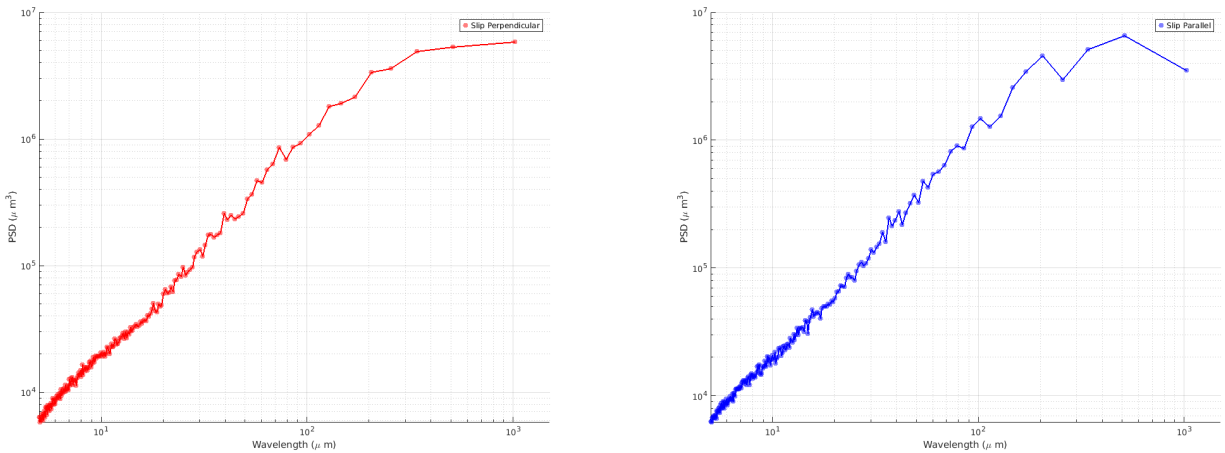
Figure 4 – *Power spectral density (PSD) for slip-perpendicular (left) and slip-parallel (right) profiles. The dashed lines indicate the linear fit to the data in the selected wavelength range. The green dashed lines indicate the selected wavelength range.*

On the log-log plots, where selected interactive the wavelength range from 5.0 to 205.1 microns this as a visual selection of the range of wavelengths over which the PSD is linear. Then, I performed the linear fit to the log-transformed data in this range. The fitted lines are shown as dashed lines in the figure 5 below. The linear fits within this range are excellent for both profiles, but a breakdown of the linear scaling is observed outside this range, especially at larger wavelengths where the PSD flattens out.
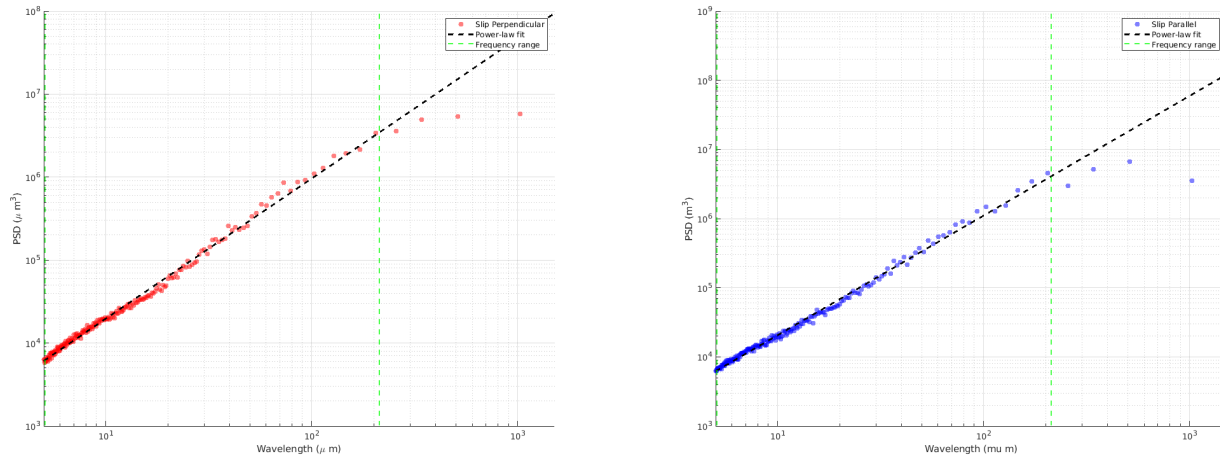
Figure 5 – *Power spectral density (PSD) for slip-perpendicular (left) and slip-parallel (right) profiles with linear fits (dashed lines) in the selected wavelength range (green dashed lines).*

For the roughness exponent, a value of approximately 1.7 was obtained and the corresponding Hurst exponent is in average 0.36, between the slip-perpendicular and slip-parallel directions. Lastly, the rms roughness was computed to be 10.05 microns and the corner wavelength of the power-spectral density is 204.8 microns.