Clustering river networks to classify landscape domains

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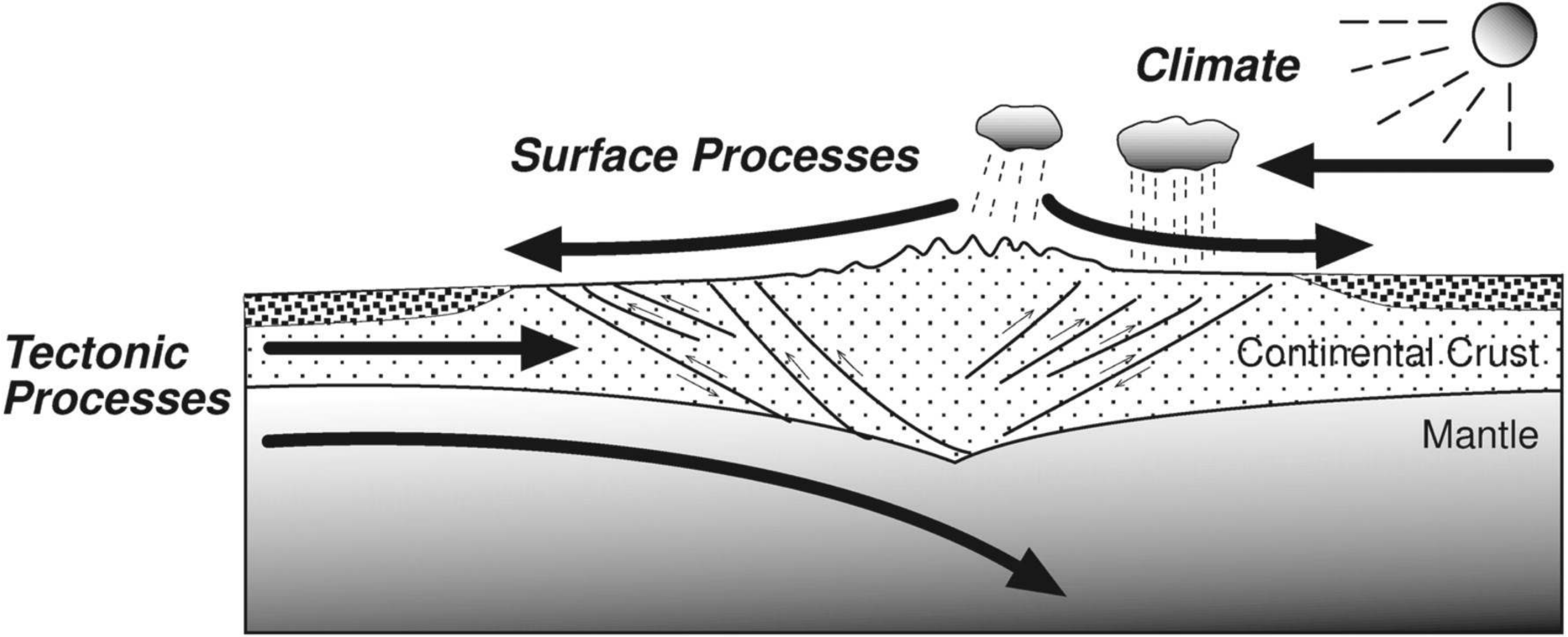
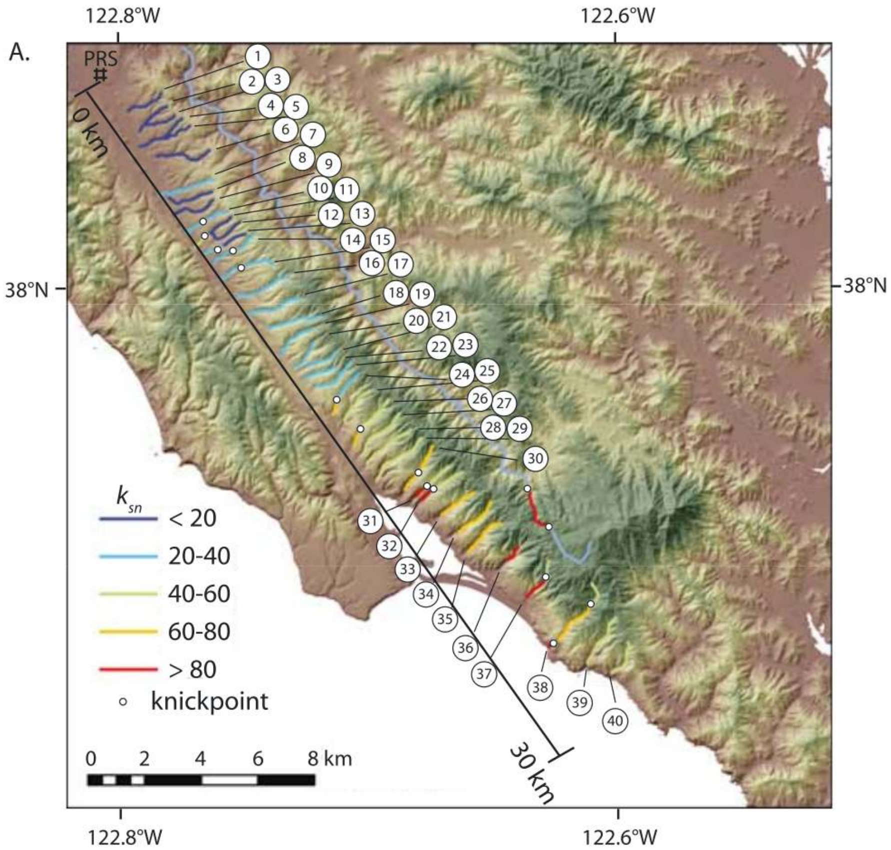
Why should we care about river network morphology?



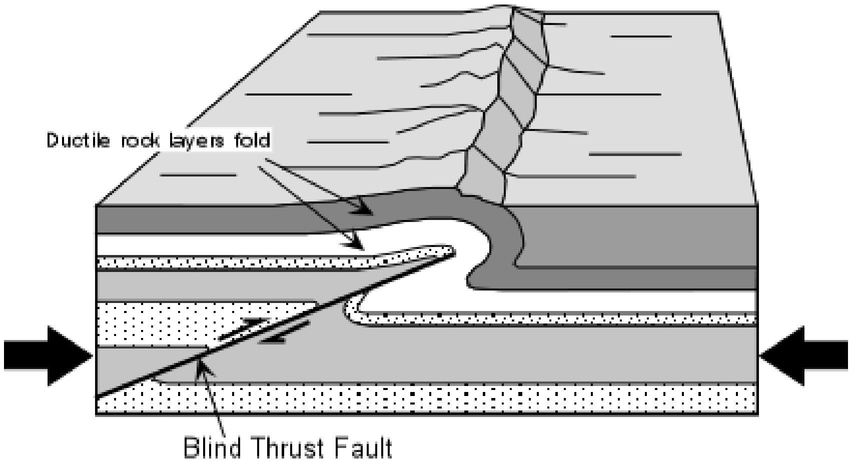
Roe et al. (2008)

We can use rivers to quantify Earth’s topography

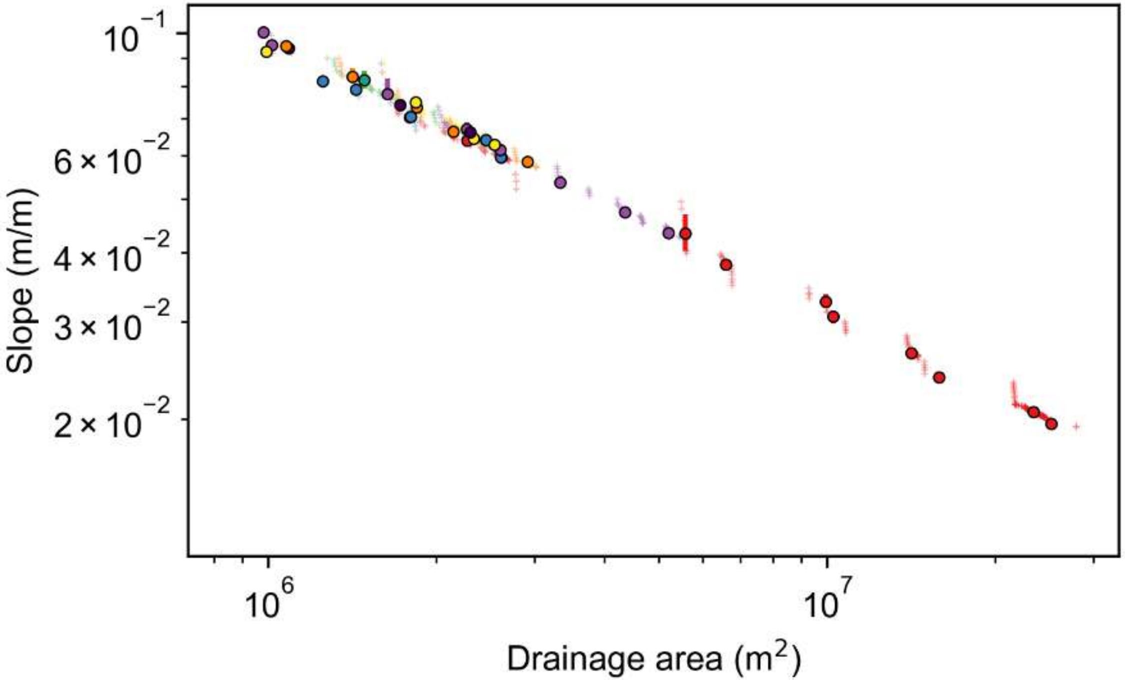


Kirby et al. (2007)

We might be able to identify faults remotely, e.g. blind thrust faults



Slope vs. drainage area

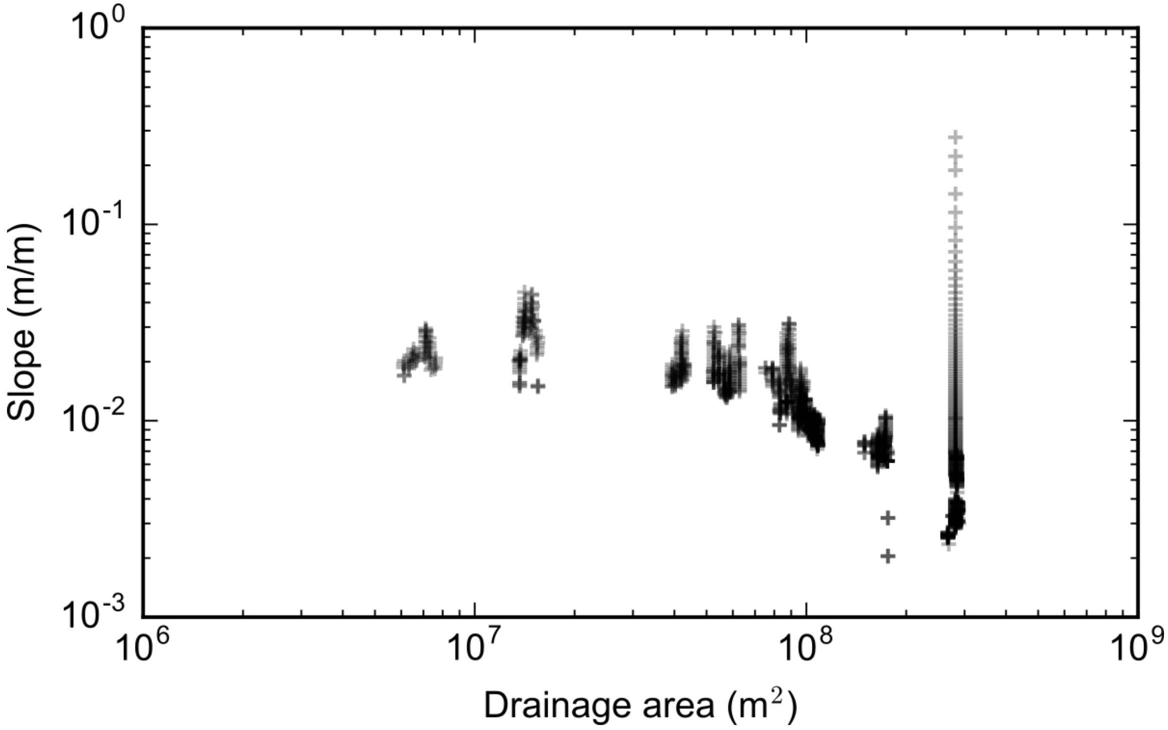


Power law relationship between slope and drainage area:

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

k_s = channel steepness
θ = concavity index

Problem: Data gaps and noise



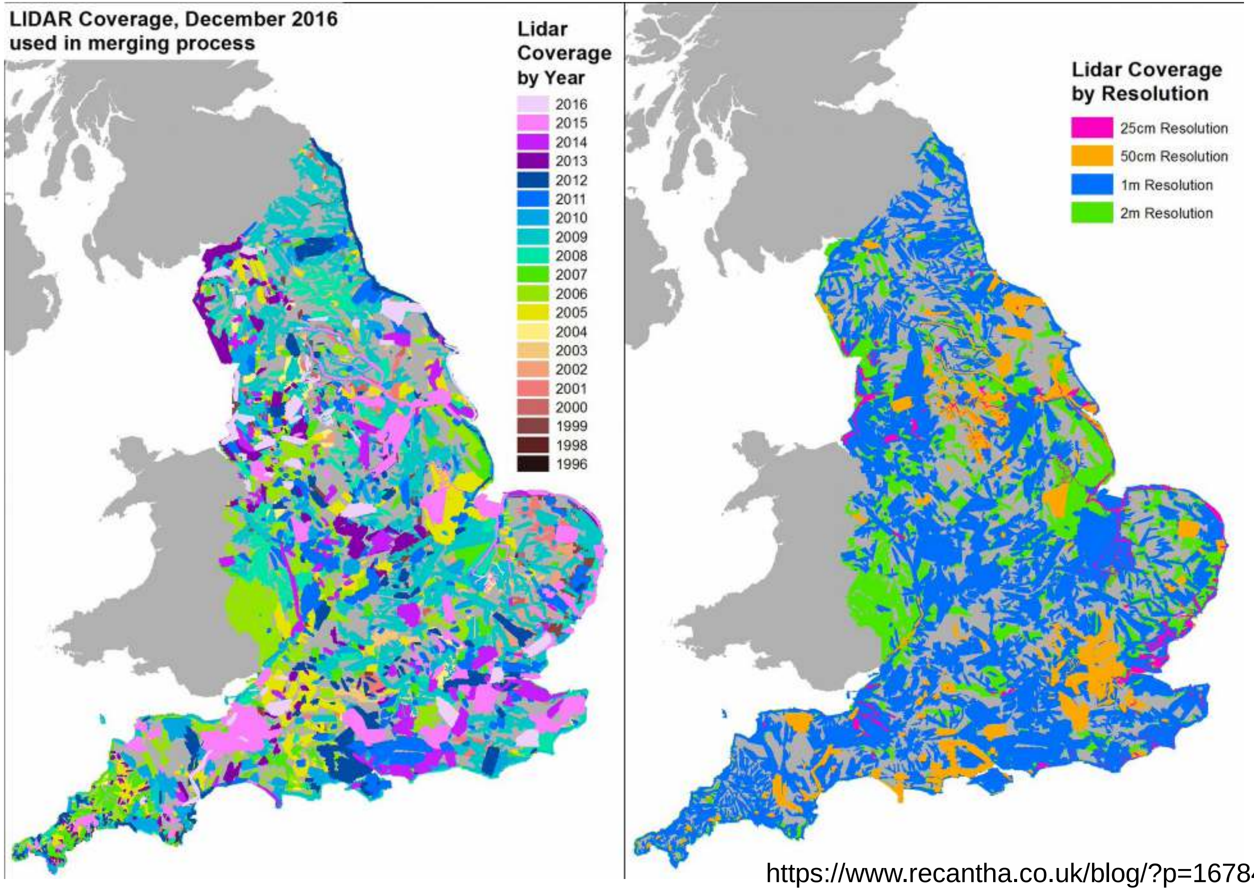
Typical slope-area plot from river basin near Xi’an, China (SRTM 30 m)

Mudd et al. (2018)

Problem: We now have large volumes of data to analyse...

Many countries now have freely available national lidar data (e.g. Scotland, England, Netherlands, Belgium, Spain, Finland, Denmark, Slovenia, etc…)

We need new techniques that can deal with global topographic data at high resolutions



https://www.recantha.co.uk/blog/?p=16784

Potential solution: clustering of river profiles

- Separate channels with different morphology

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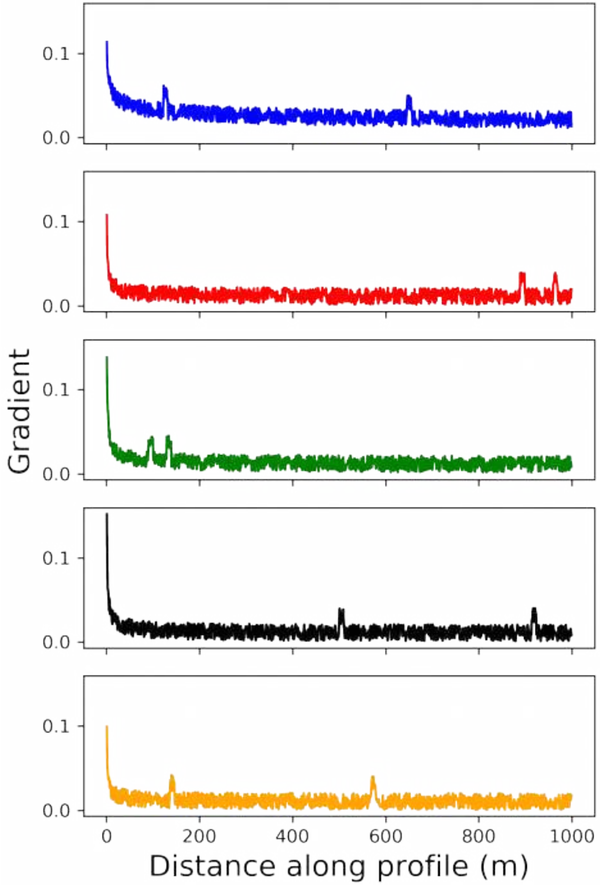
- Separate channels with different morphology
- Allow more robust extraction of channel metrics, such as normalised channel steepness
- Data driven technique that can help to distinguish signal from noise

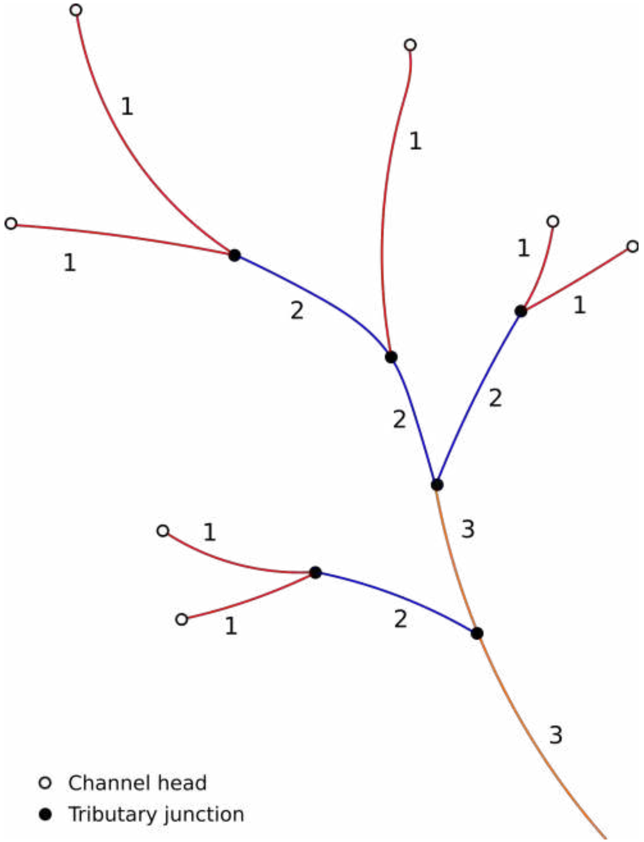
Clustering of 1D data

- Algorithms developed mostly for time series data

- Used in diverse fields: climate science, meteorology, evolutionary biology, geophysics, quantitative finance, economics, epidemiology, etc...



Applying to river networks



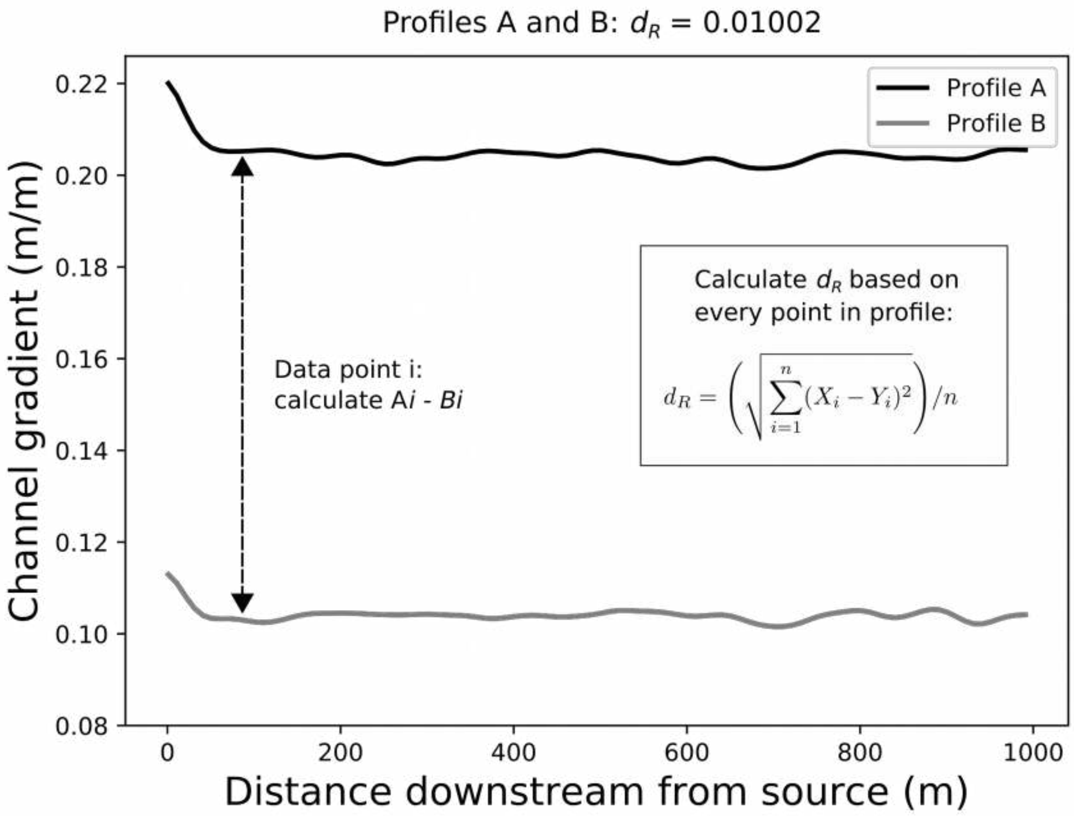
Separate channels by stream order to ensure we are comparing channels with similar discharge/drainage area

Profile dissimilarity

STEP 1

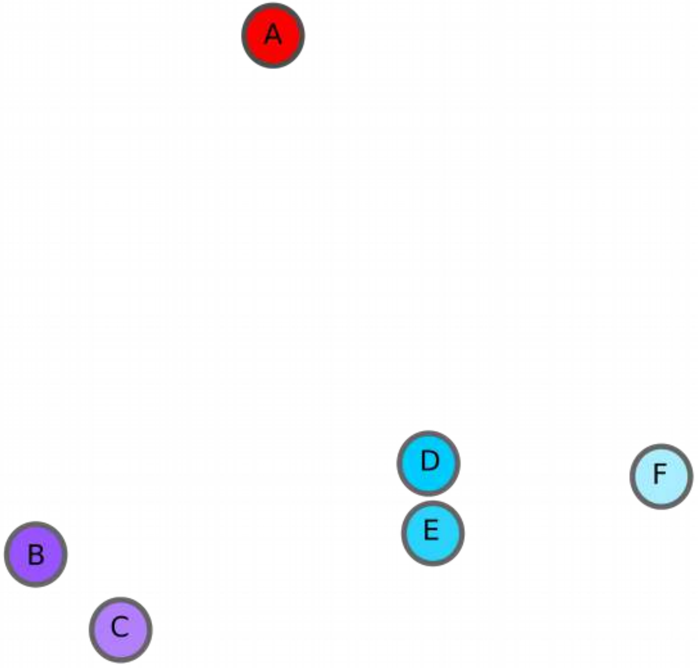
Compare the similarity of each pair of profiles

d_R = dissimilarity metric



Agglomerative hierarchical clustering

STEP 2: Use matrix of pairwise d_R values for clustering



	A	B	C	D	E	F
A		1.0	1.2	0.79	0.8	0.7
B	1.0		0.2	0.22	0.21	0.3
C	1.2	0.2		0.42	0.4	0.5
D	0.79	0.22	0.42		0.01	0.08
E	0.8	0.21	0.4	0.01		0.1
F	0.7	0.3	0.5	0.08	0.1	

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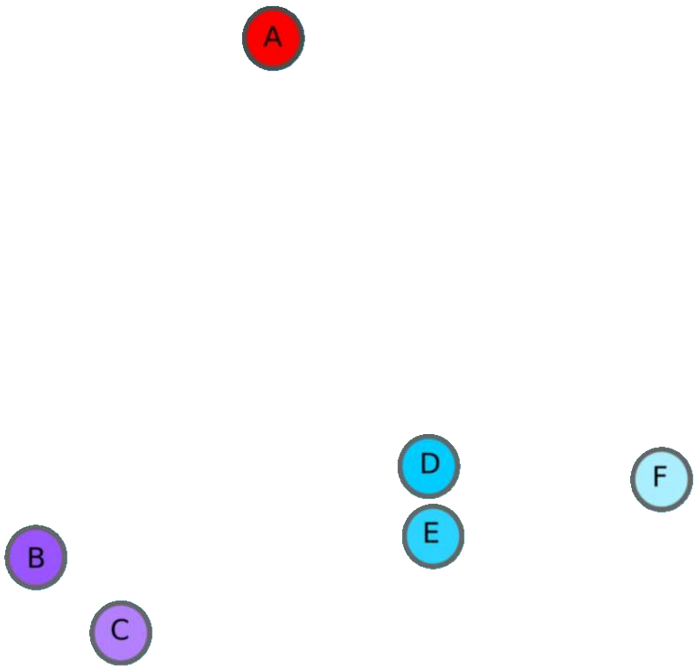
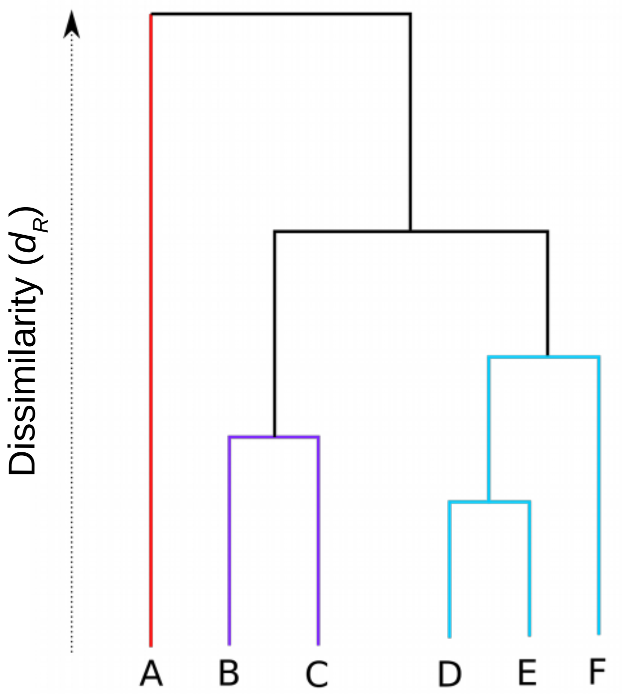
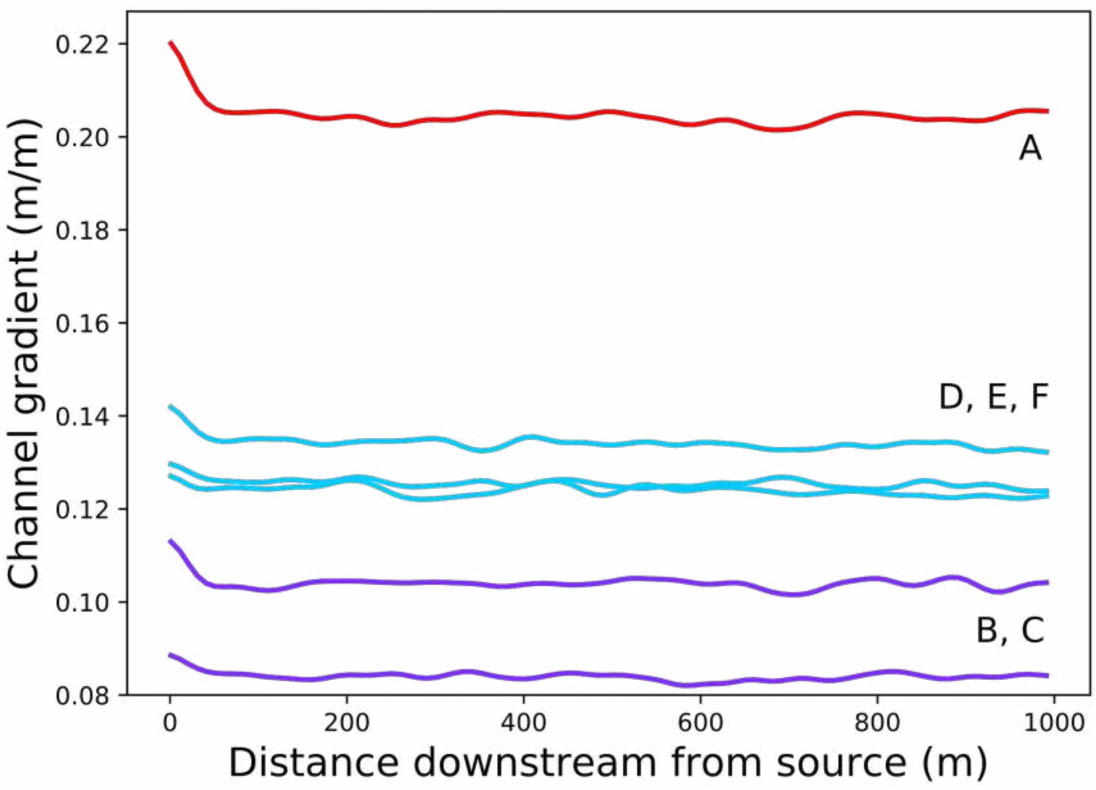




Applying to river networks

STEP 3

Assign clusters back to the original profiles



Applying the method

Applying the method

- Bitterroot National Forest, Idaho

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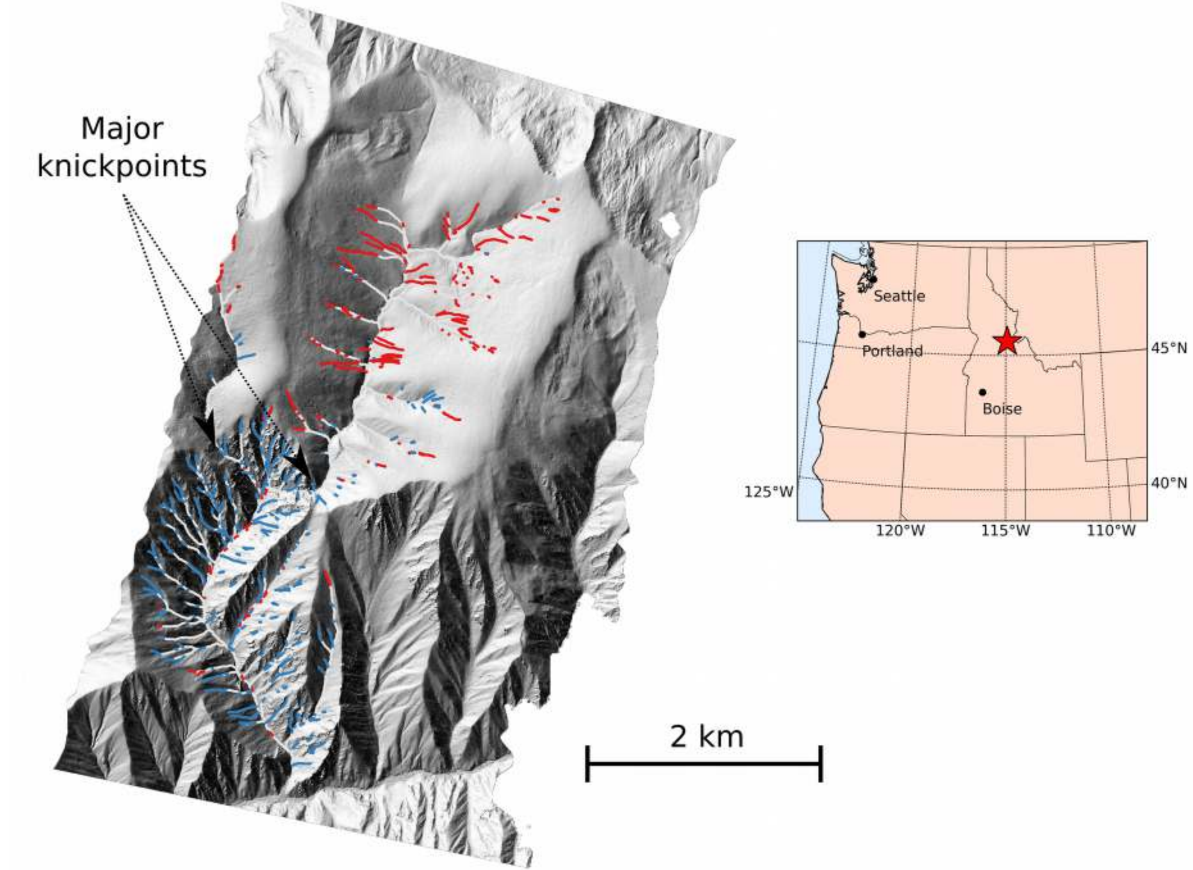
- Santa Cruz Island, California

Transient incision: Bitterroot National Forest, Idaho



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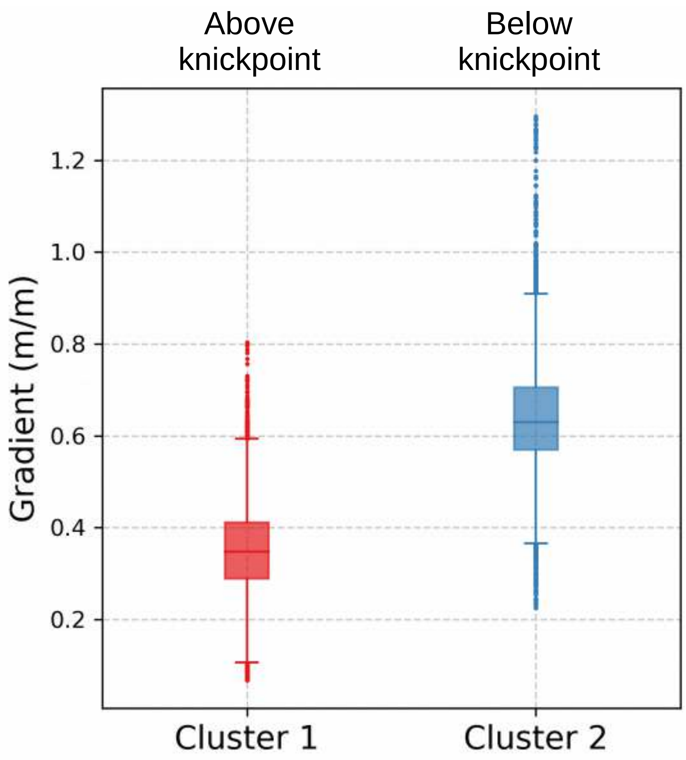
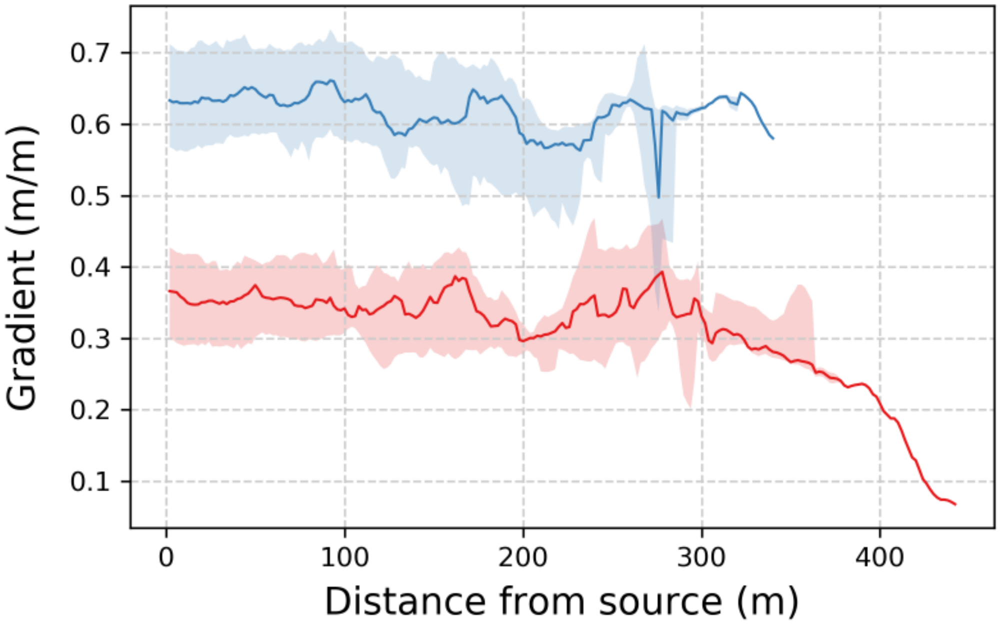


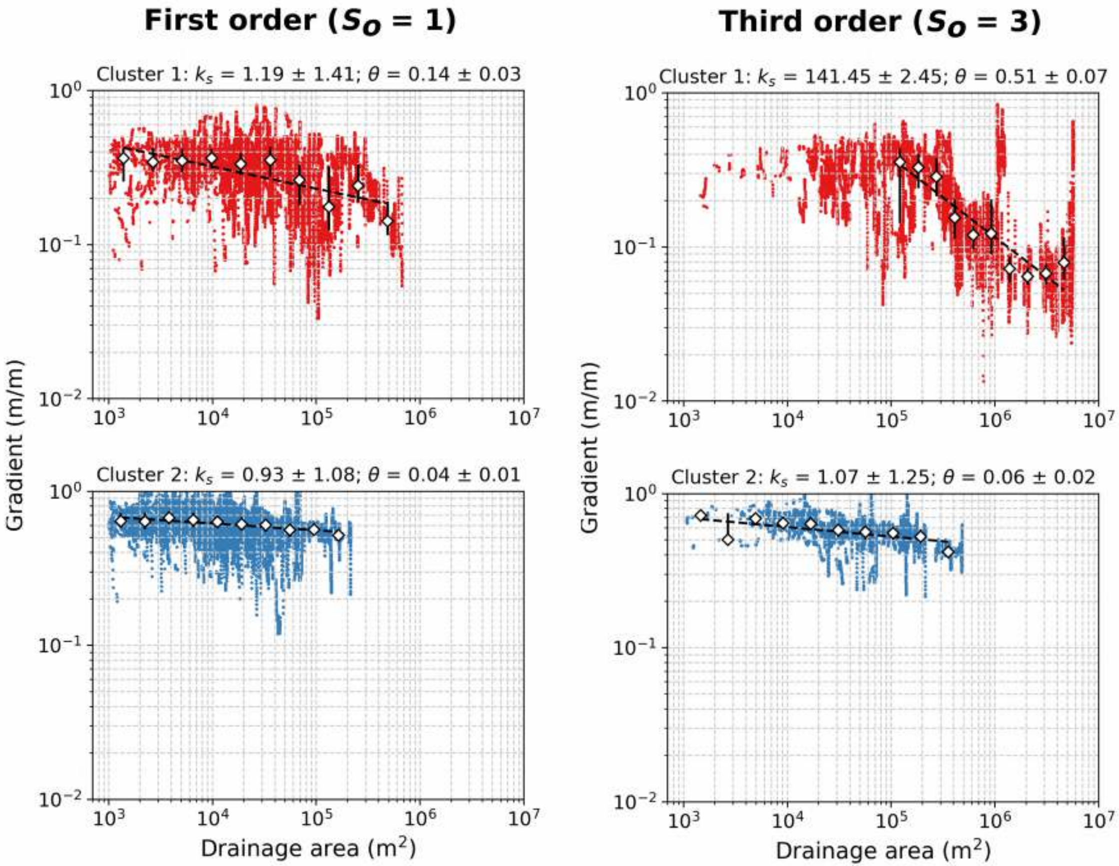


Distinguishing fluvial and debris flow process domains

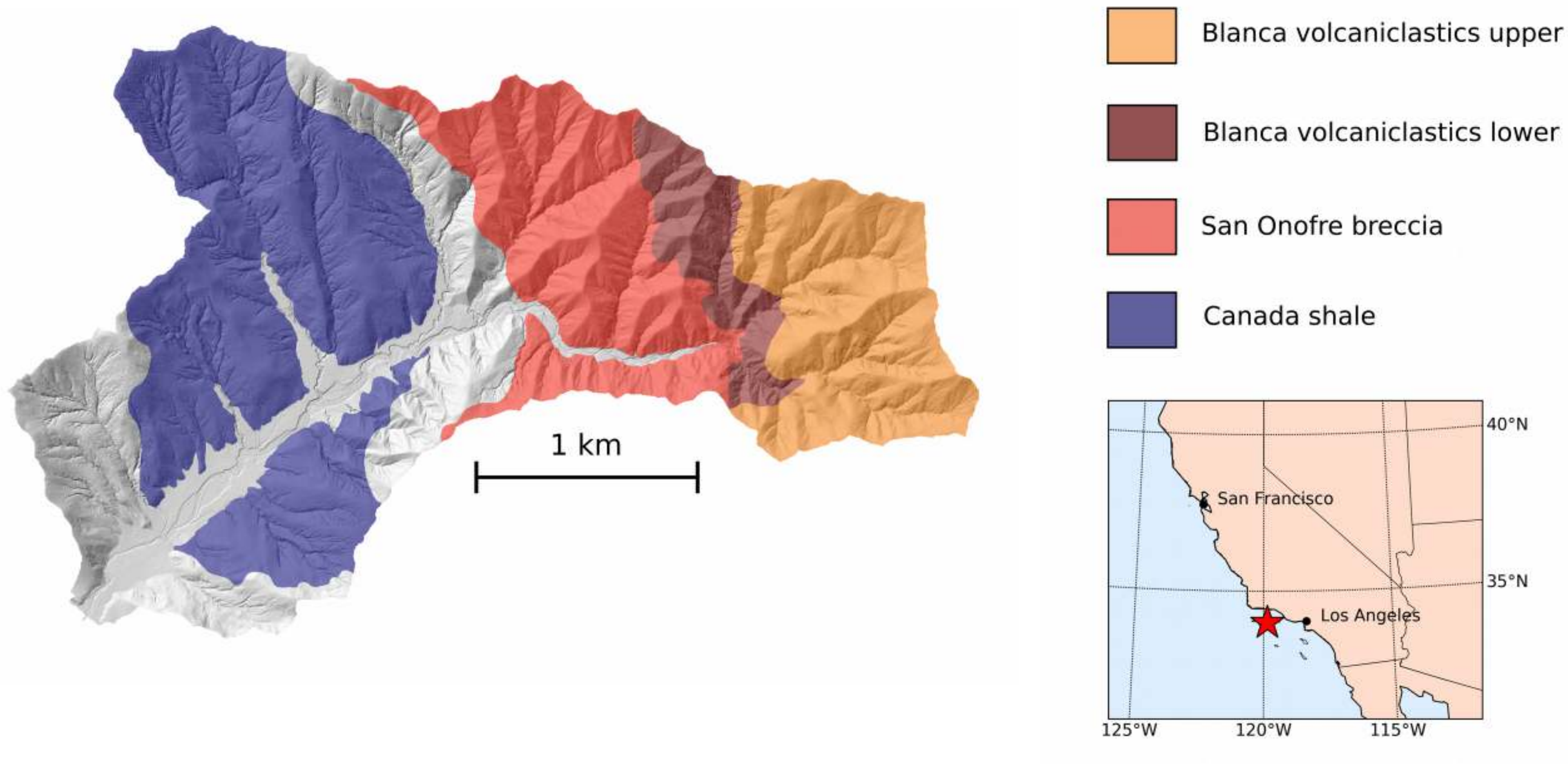
First order channels: both clusters have **low concavity**

Third order channels:

- **Low concavity cluster (debris flow dominated)**
- **High concavity cluster (fluvial dominated)**



Impact of lithology: Pozo catchment, Santa Cruz Island



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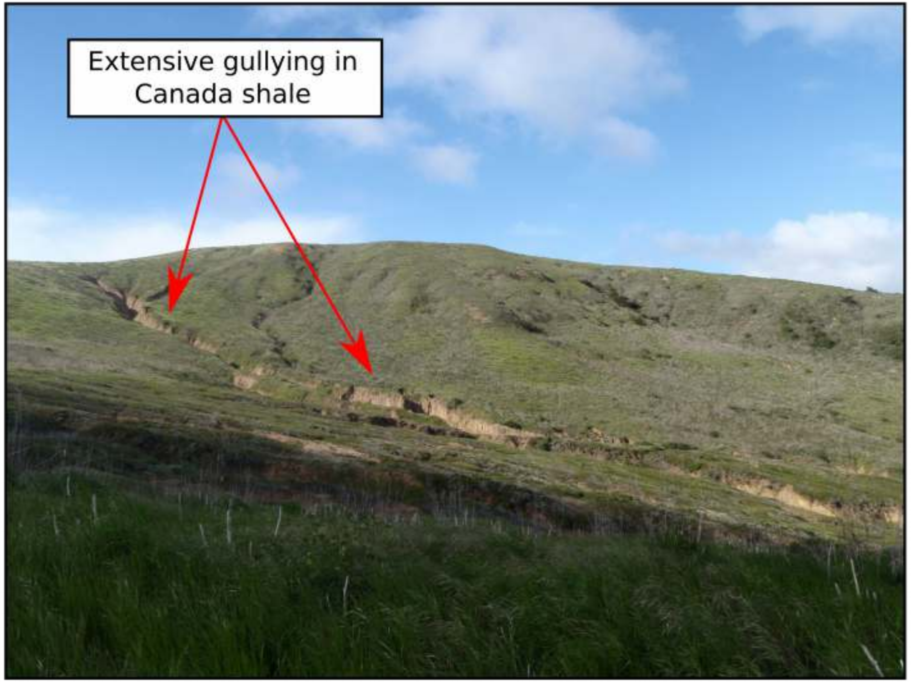

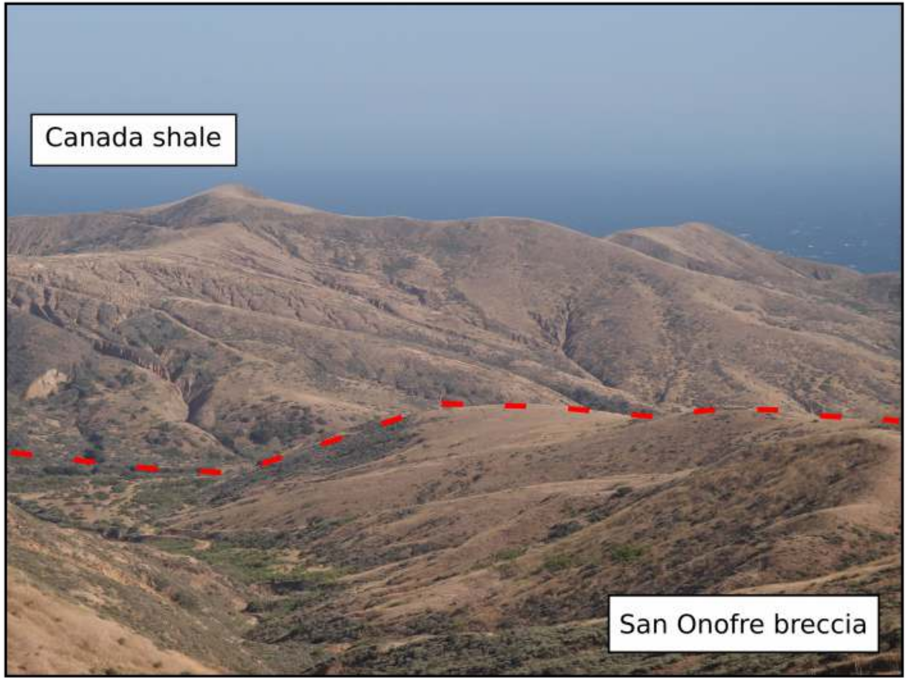

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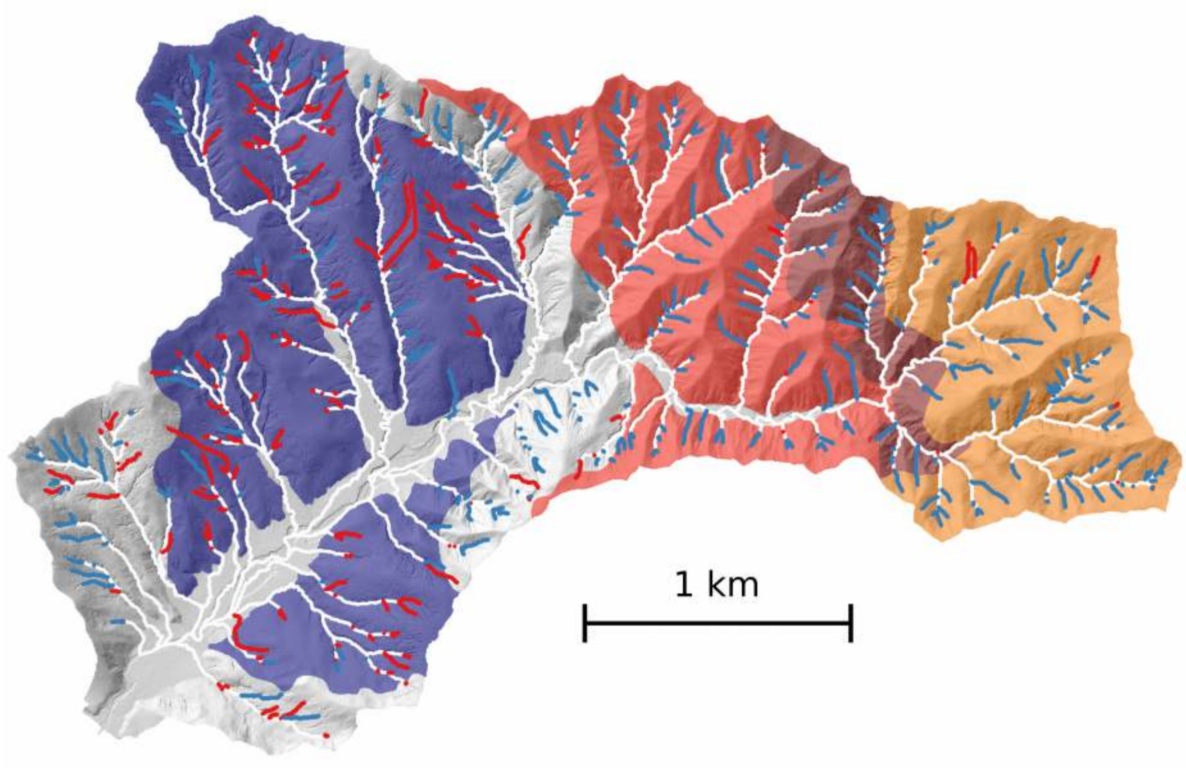
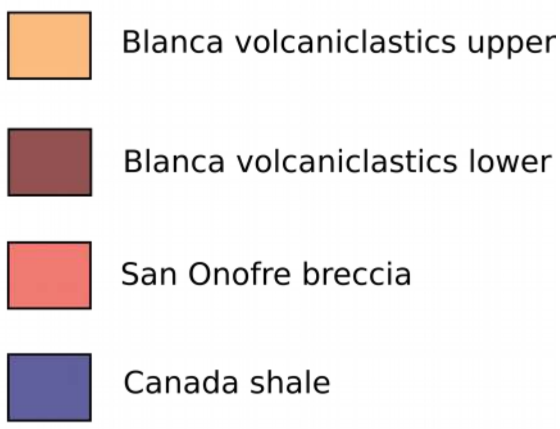
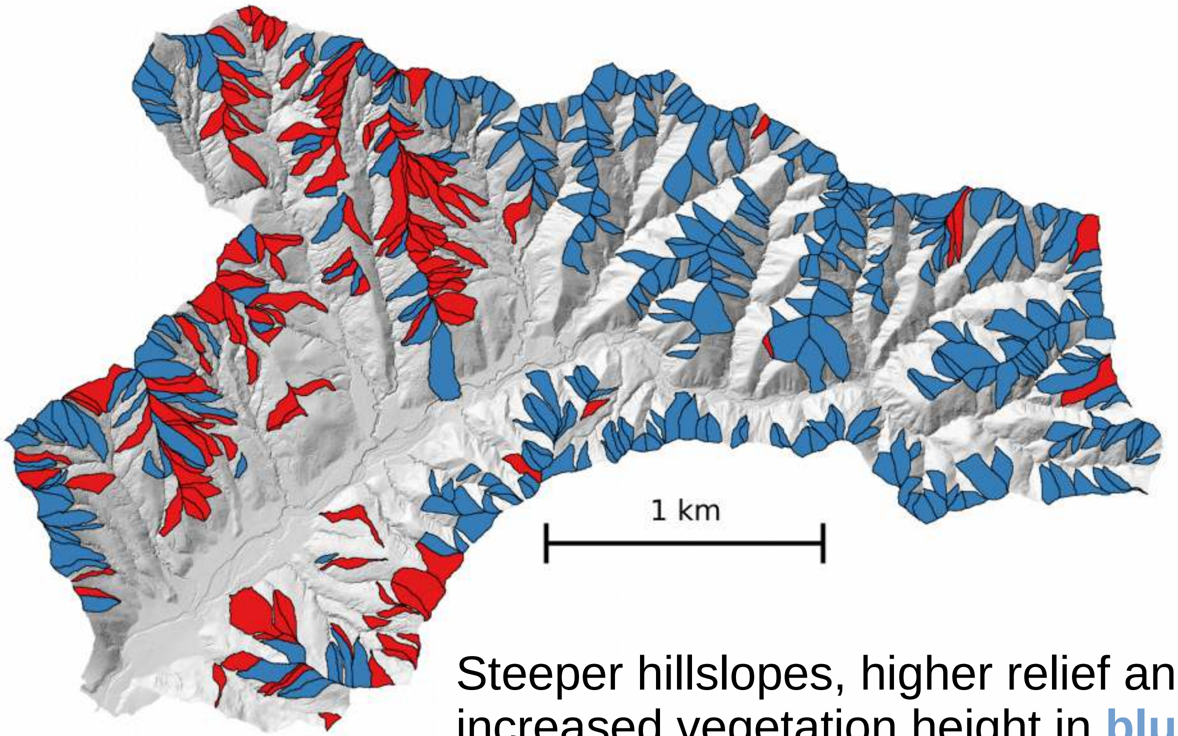


Red cluster: 95% Canada shale

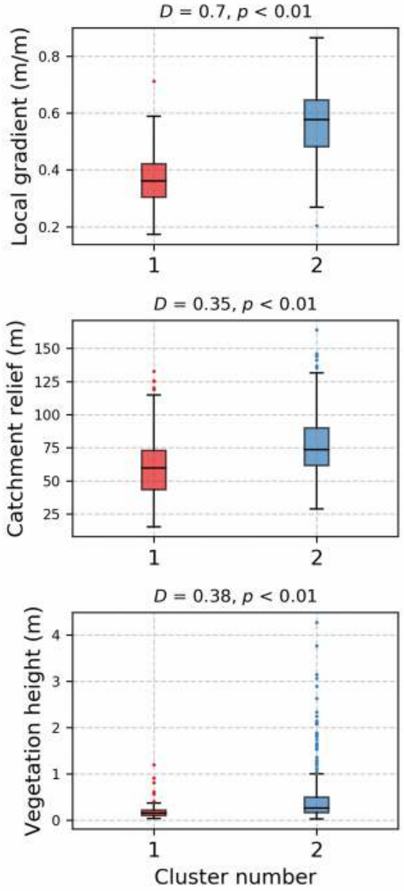
Blue cluster: 78% breccia/volc.



First order catchment metrics

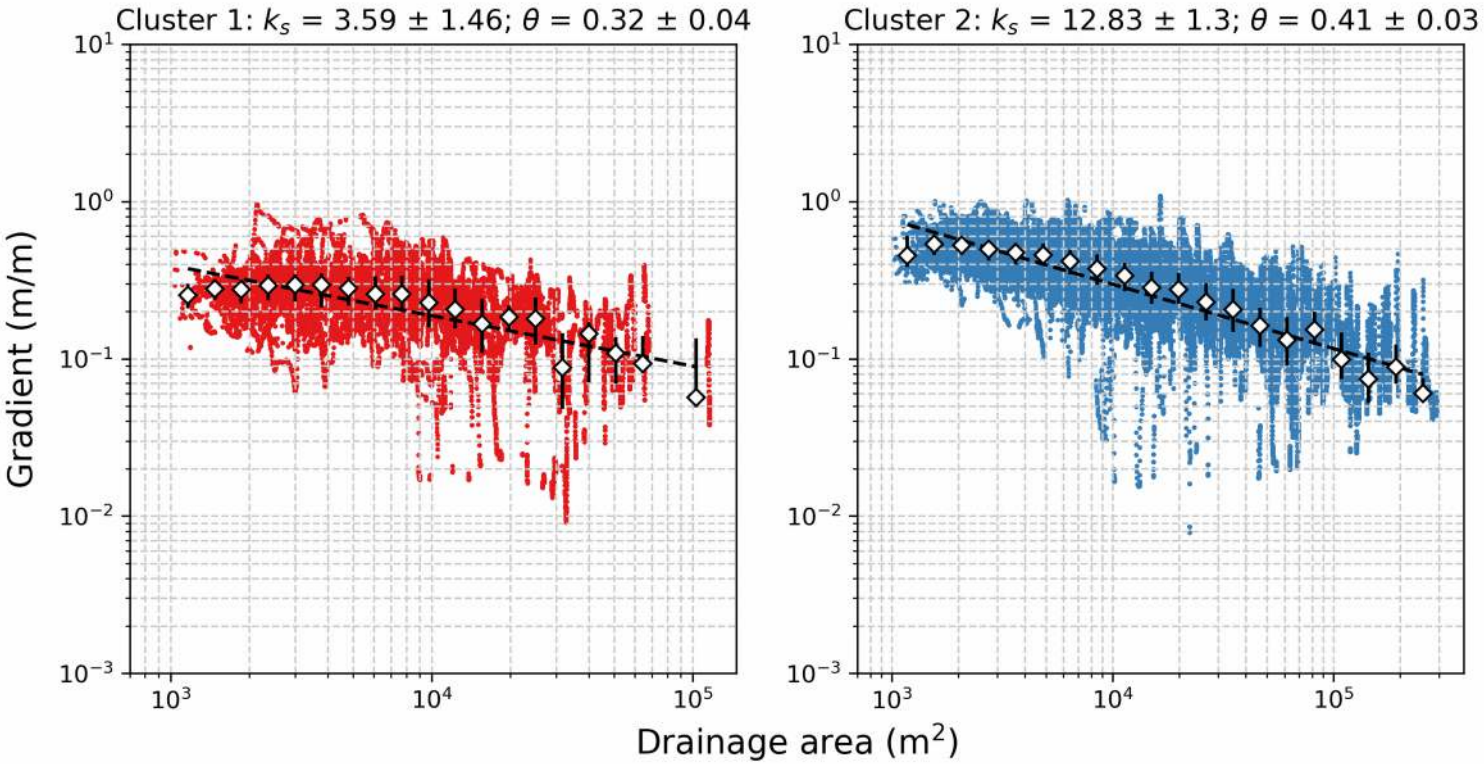


Steeper hillslopes, higher relief and increased vegetation height in **blue cluster** (more resistant lithology)

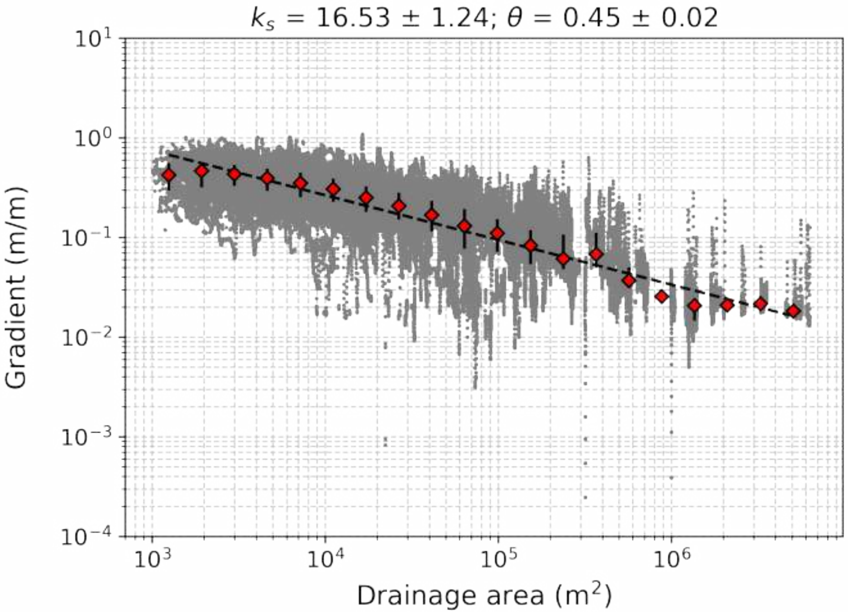


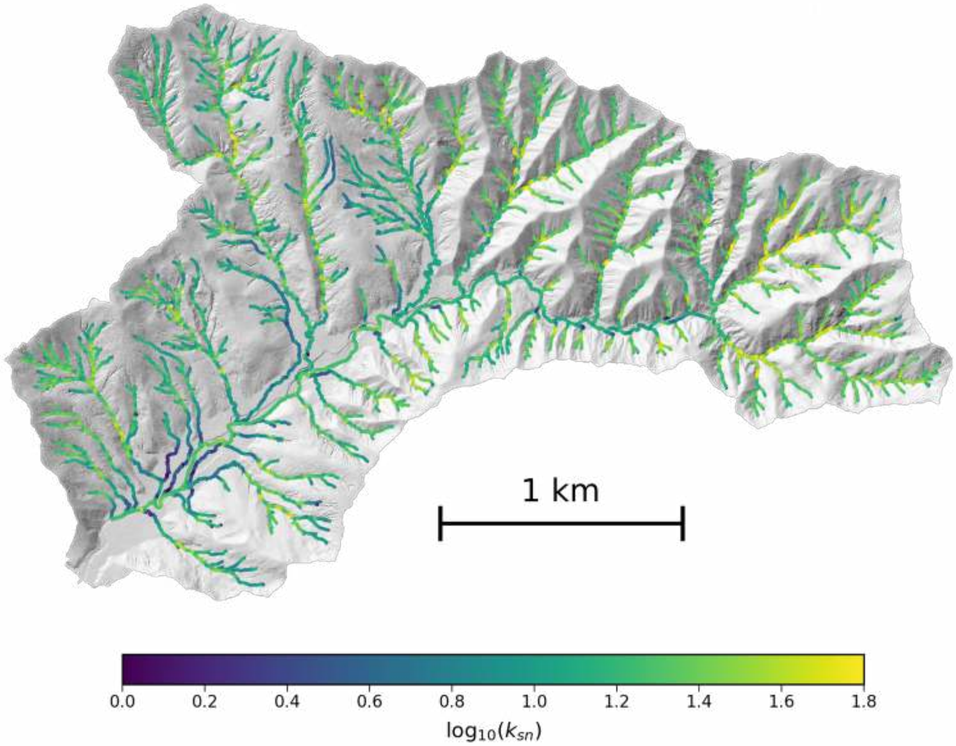
Slope-area plots by cluster

Higher concavity and channel steepness in **blue cluster** (more resistant lithology)



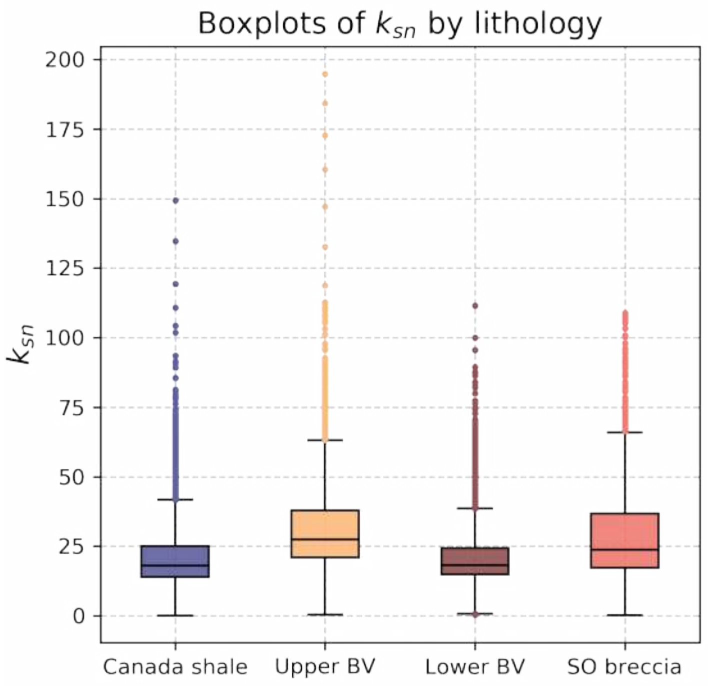
Comparison with normalized channel steepness

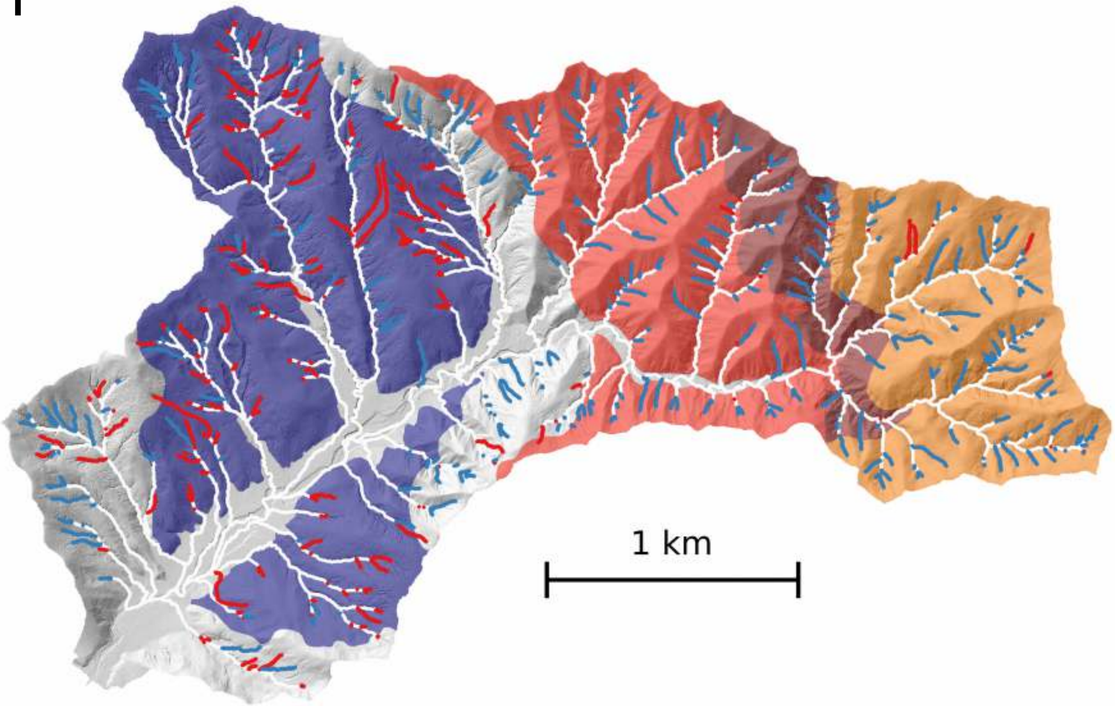




Comparison with normalized channel steepness

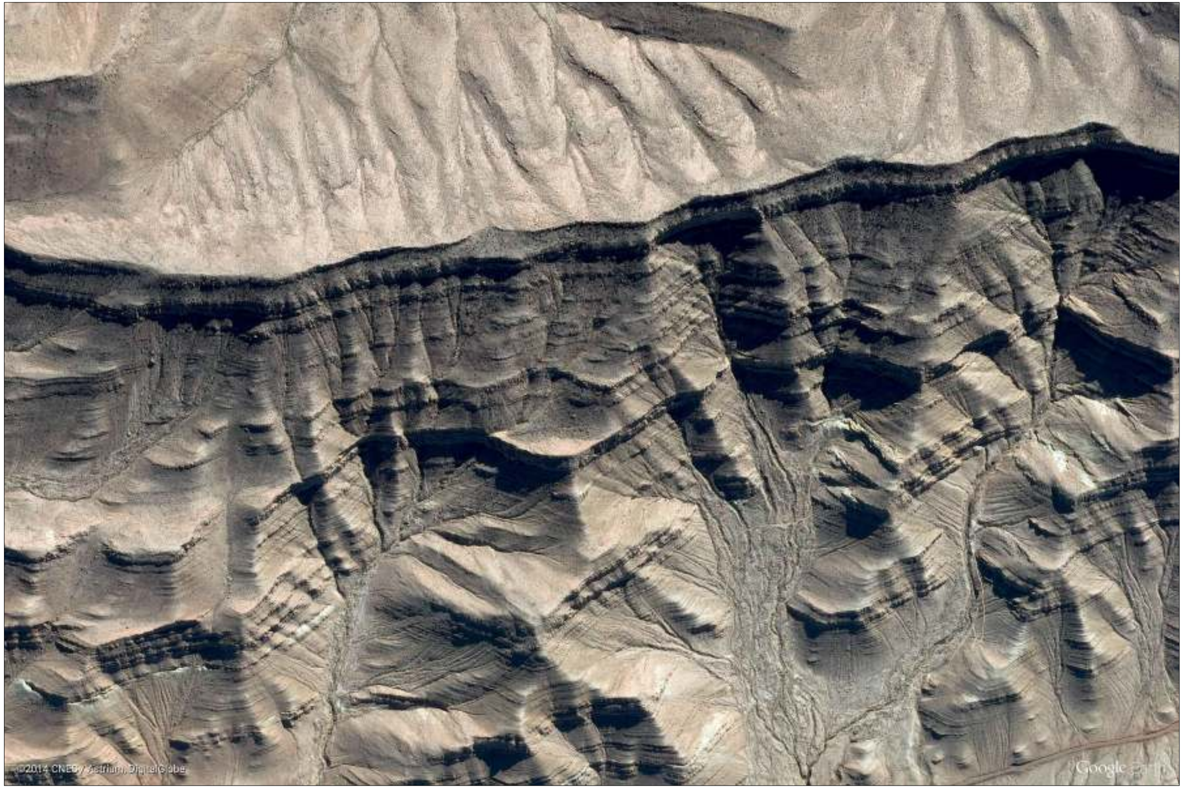
No significant variation in k_{sn} with lithology





Conclusions and potential applications

- Clustering can be used to tackle the problem of landscape heterogeneity



Arequipa, Peru, Google Earth View

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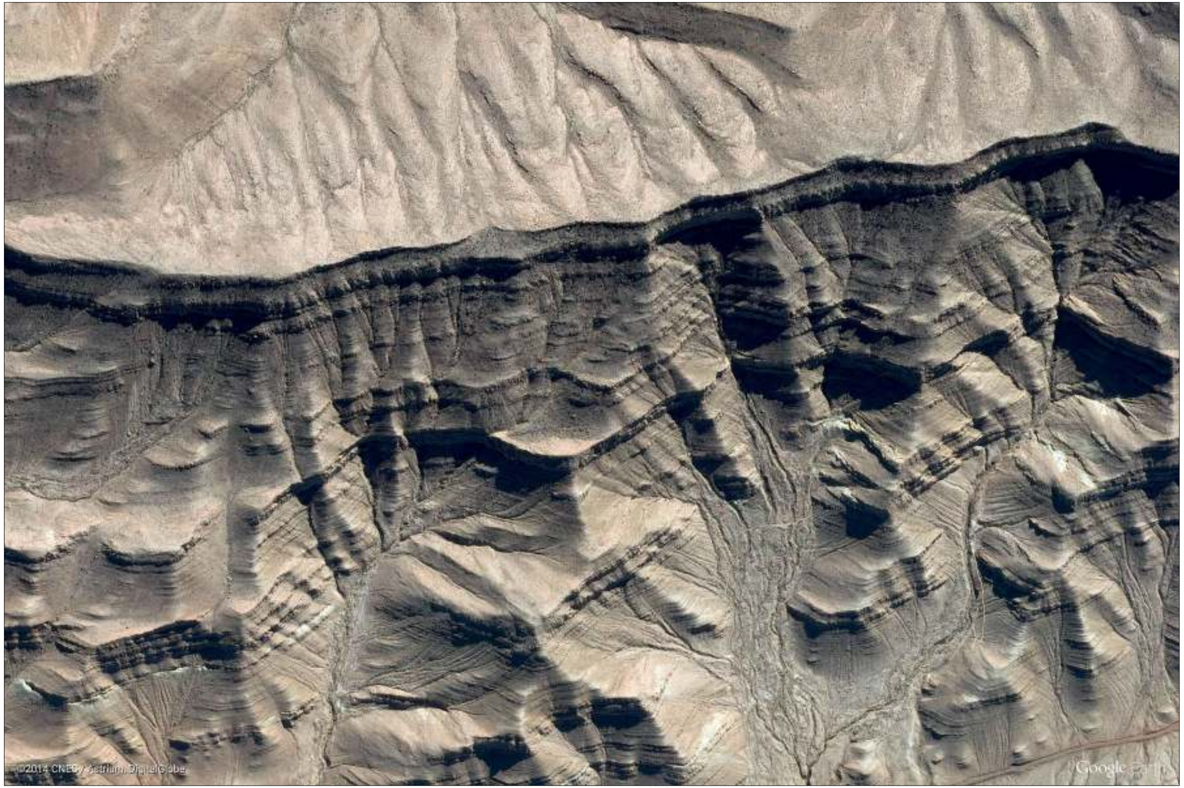
- Clustering can be used to tackle the problem of landscape heterogeneity

- Data-driven approach with few assumptions



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Conclusions and potential applications

- Clustering can be used to tackle the problem of landscape heterogeneity

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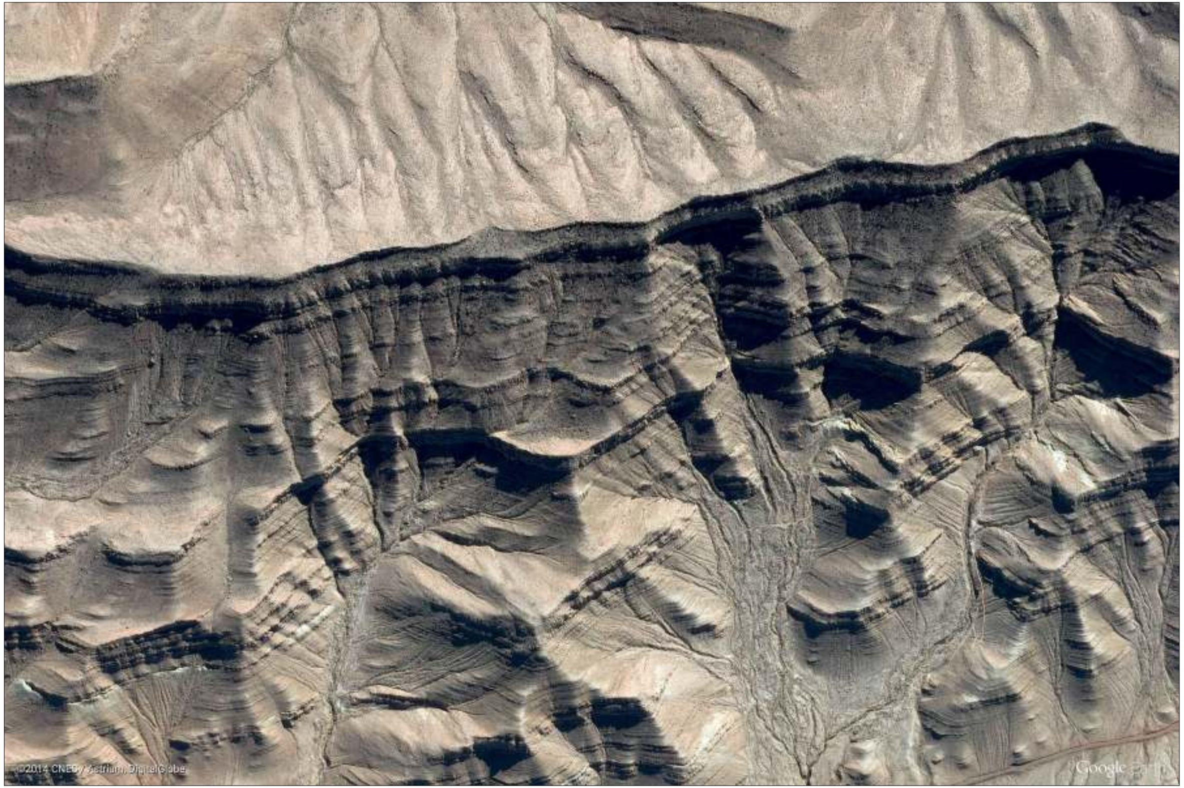
- Potential applications: channel steepness analysis, identification of debris flow domains, hillslope-valley transitions, extraction of alluvial reaches, etc.



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