CATENA
CLIMATIC AND TECTONIC NATURAL HAZARDS IN CENTRAL ASIA

Tectonic and lithologic controls over knickpoints

Federal Ministry of Education and Research

CLIENT II
International Partnerships for Sustainable Innovations

Kokcha river basin, northern Afghanistan

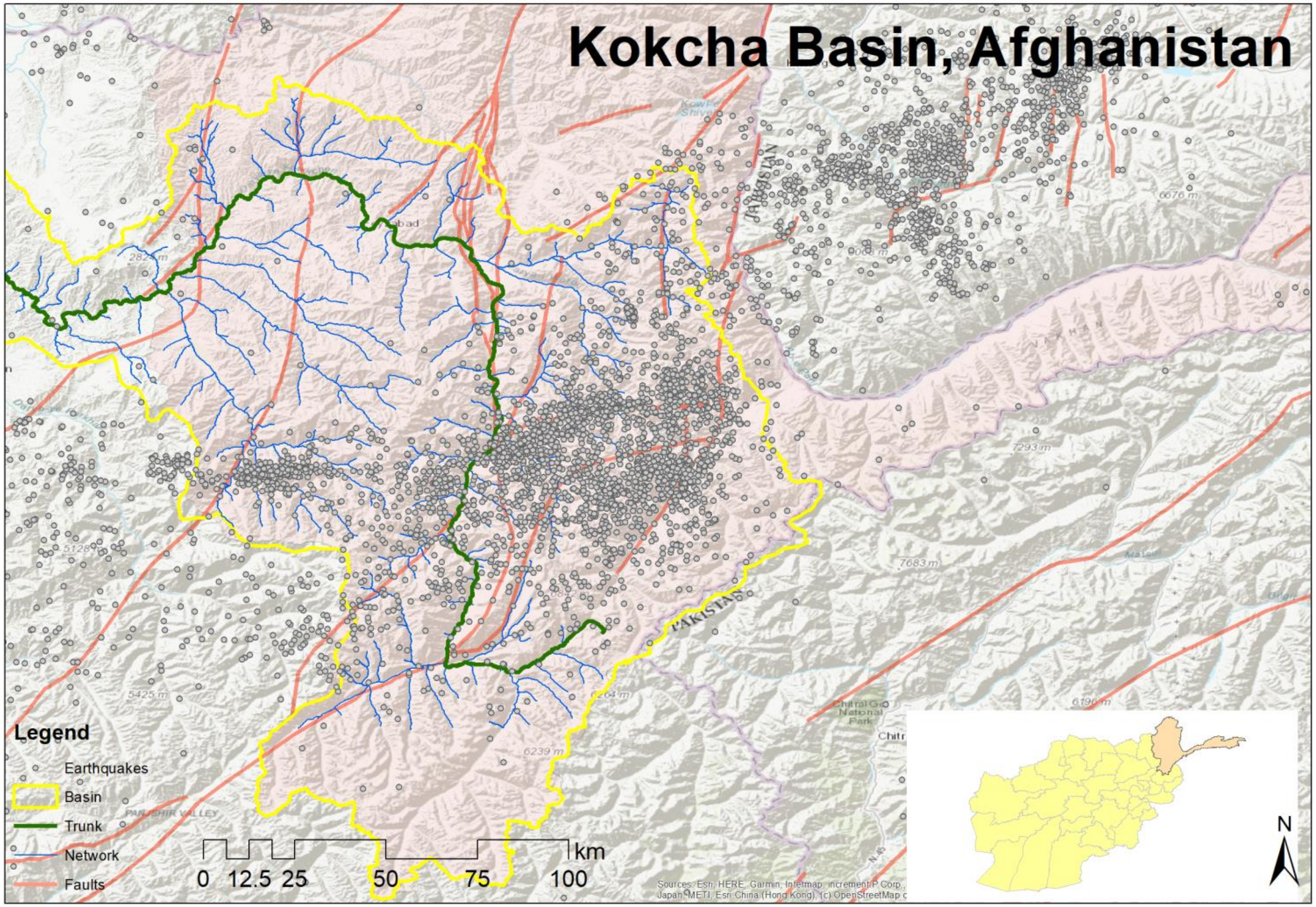
GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

Kakar.N

GFZ Helmholtz-Zentrum Potsdam · TU berlin · TU Bergakademie Freiberg · Universität Potsdam · Eberhard Karls Universität Tübingen · DiGeoS · DELPHI IMM · HZDR Helmholtz Zentrum Dresden Rossendorf

Motivation

- Tectonically most **active** regions
- High-magnitude **earthquakes**
- **Loss** of life and livelihoods
- High **erosion** rates

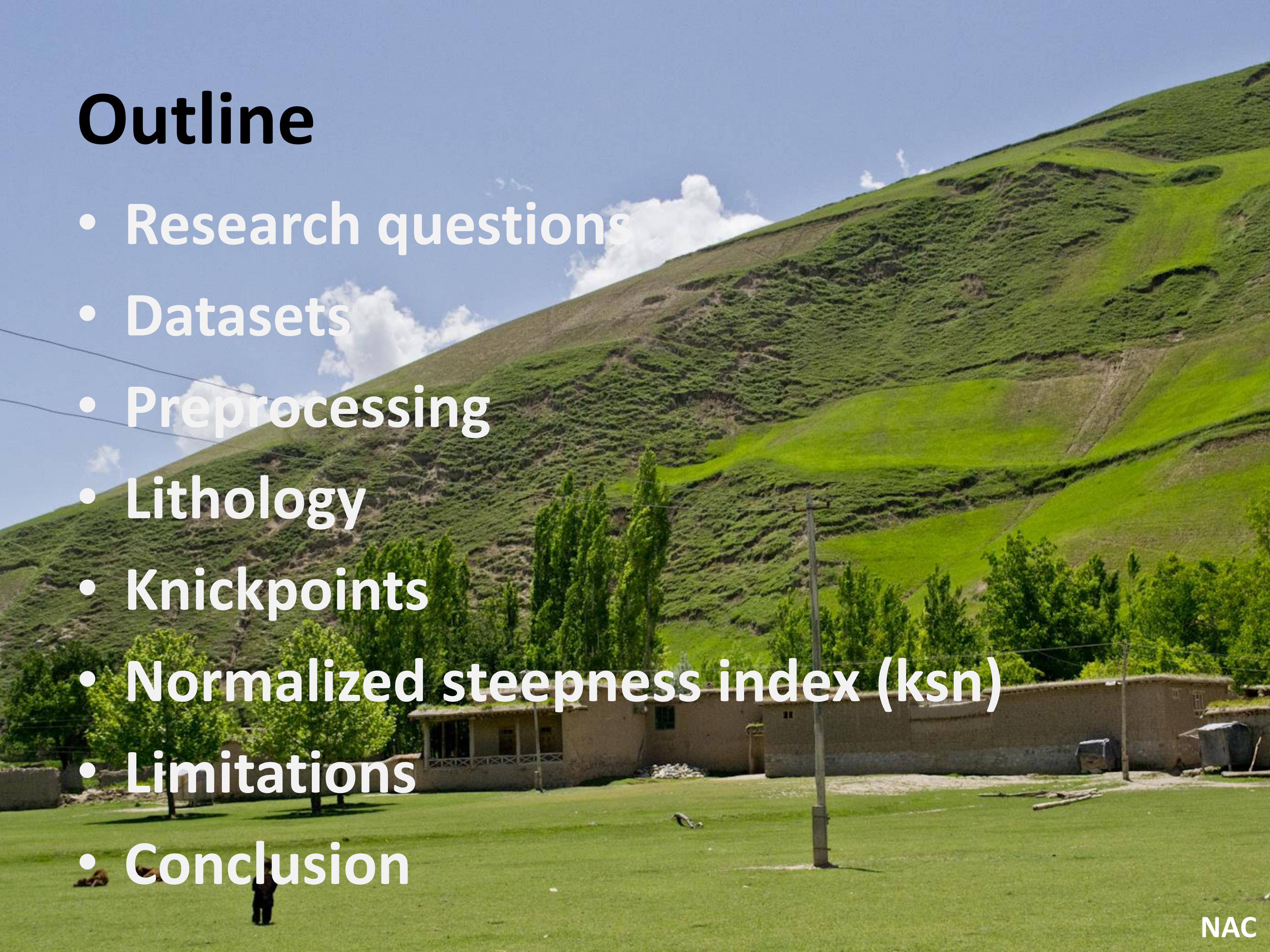


lithologically diverse **numerous faultlines**

Motivation

High levels of **erosion** downstream lead to **knickpoints,** landslides **etc.**

(Turmel, Locat, Parker, 2012)



Outline

- Research questions
- Datasets
- Preprocessing
- Lithology
- Knickpoints
- Normalized steepness index (ksn)
- Limitations
- Conclusion

NAC

Research Questions

- Which of the major **knickpoints** along the Kokcha River are **transient** and **stable?**
- Which of the **stable** knickpoints are due to **lithological** and **faultline** changes?
- How does normalized steepness index (ksn) respond after **knickpoints**

Datasets and Tools

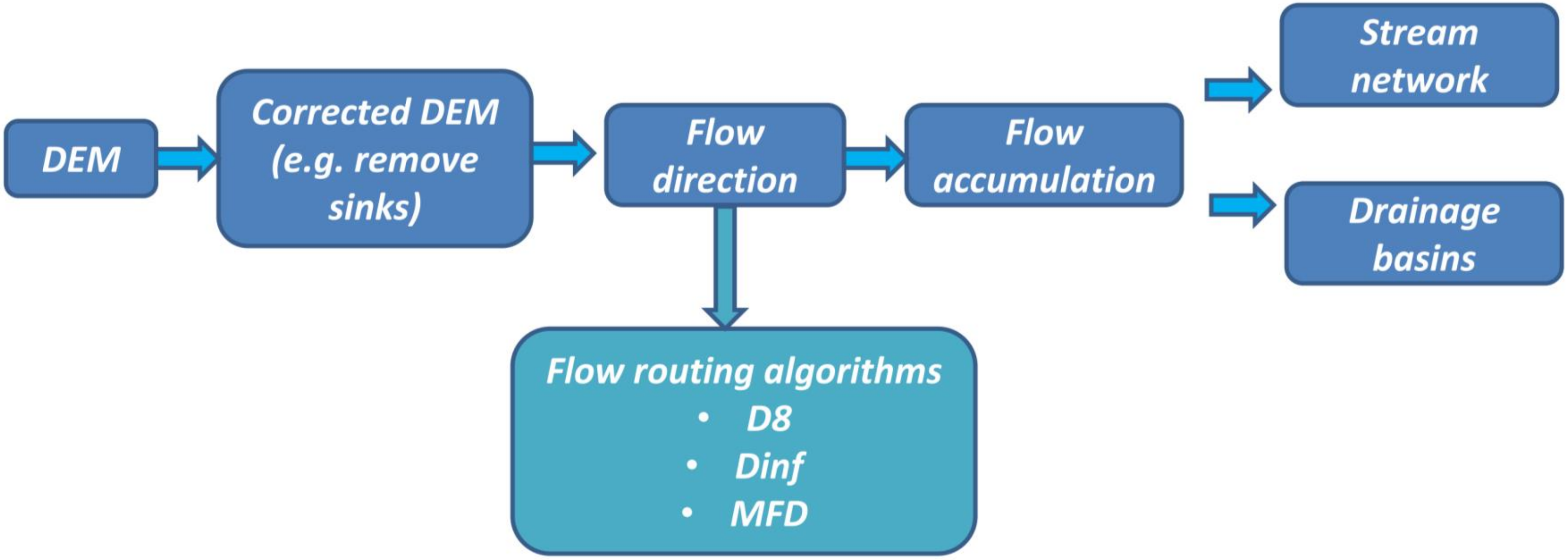
- Digital elevation model
- Lithological map
- Fault maps including Quaternary fault database

- TopoToolbox
- Matlab
- ArcGIS
- Google earth

NAC

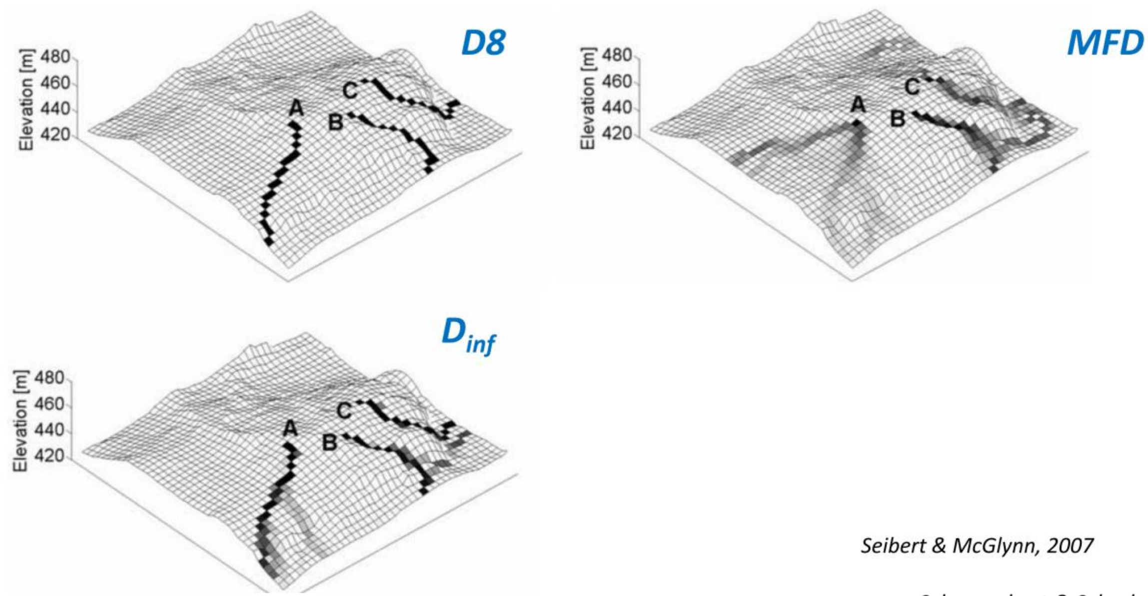
Preprocessing

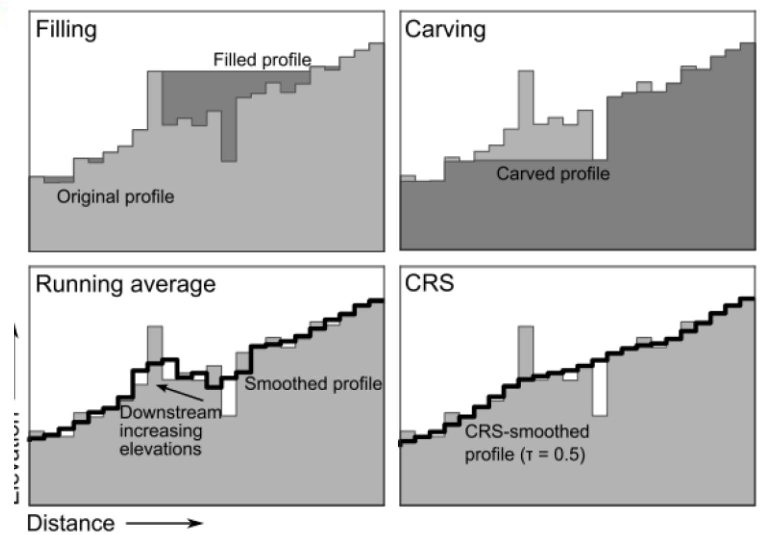
General assumption: **Water** always flows **downstream.** Therefore, all derived channel networks are based on **slope.**



Schwanghardt (2010)

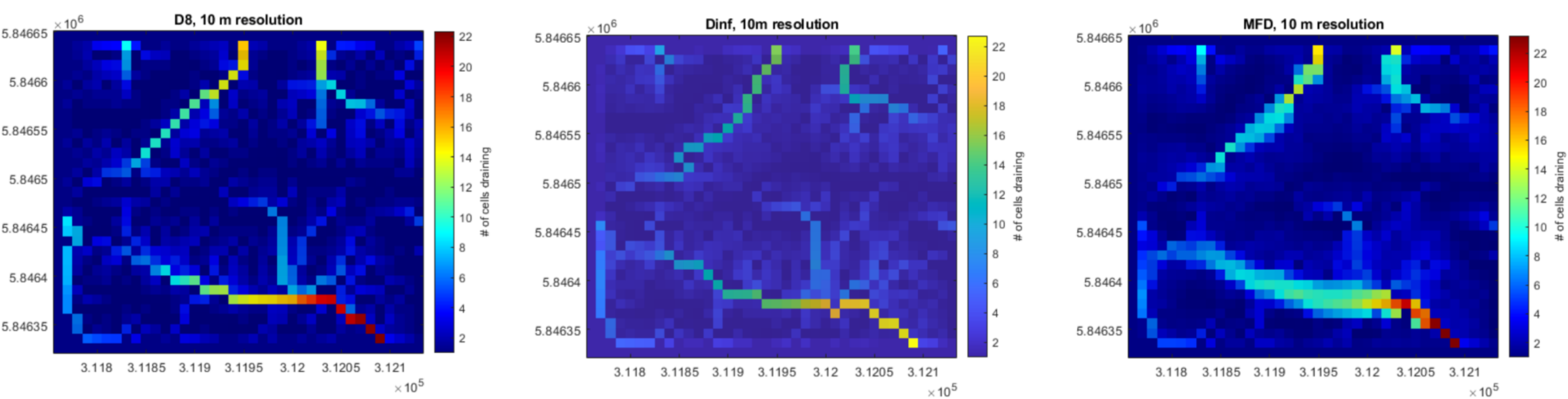
Preprocessing





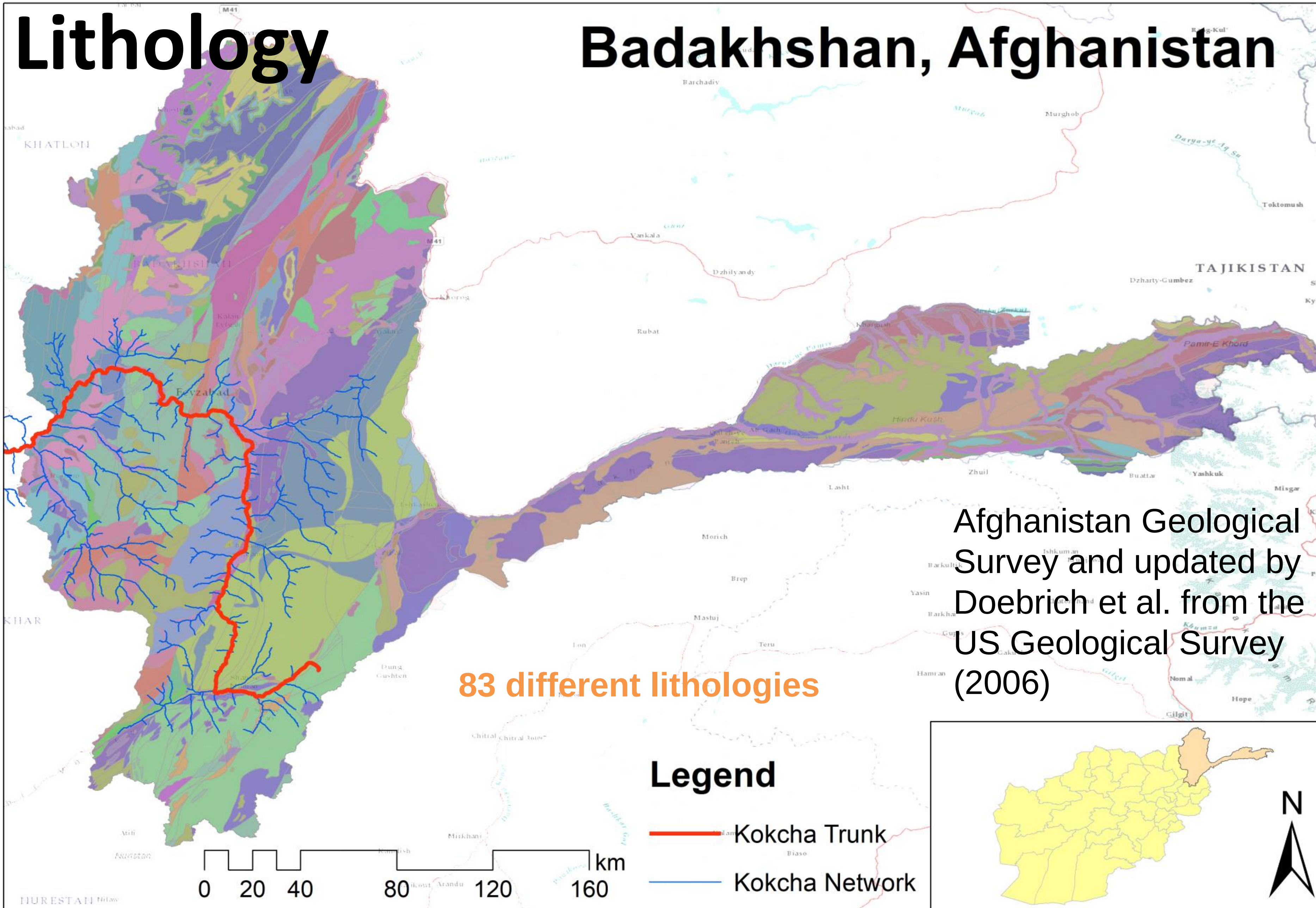
Seibert & McGlynn, 2007

Schwanghart & Scherler (2017)



Lithology

Badakhshan, Afghanistan

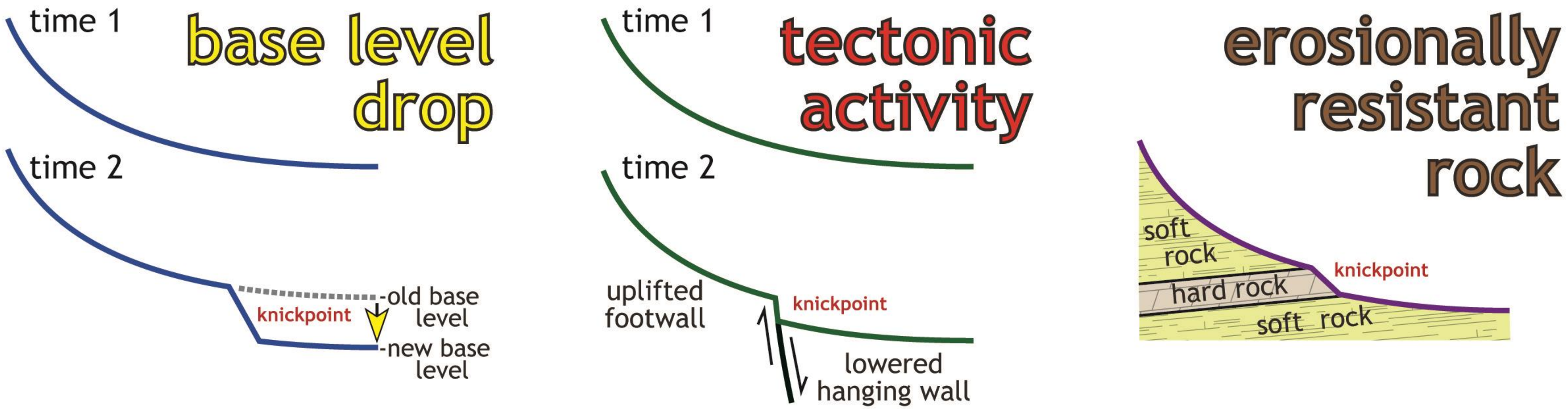


Afghanistan Geological Survey and updated by Doebrich et al. from the US Geological Survey (2006)

Knickpoints

knickpoints are part of a river or channel where there is a sharp change in channel slope.

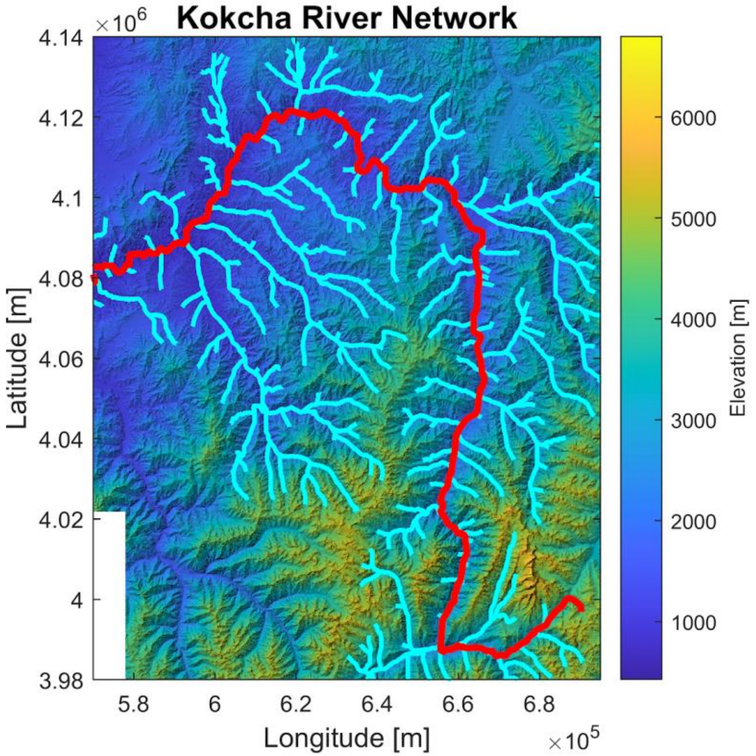
They reflect conditions and processes caused by erosion, glaciation, fault movements or variance in lithology.

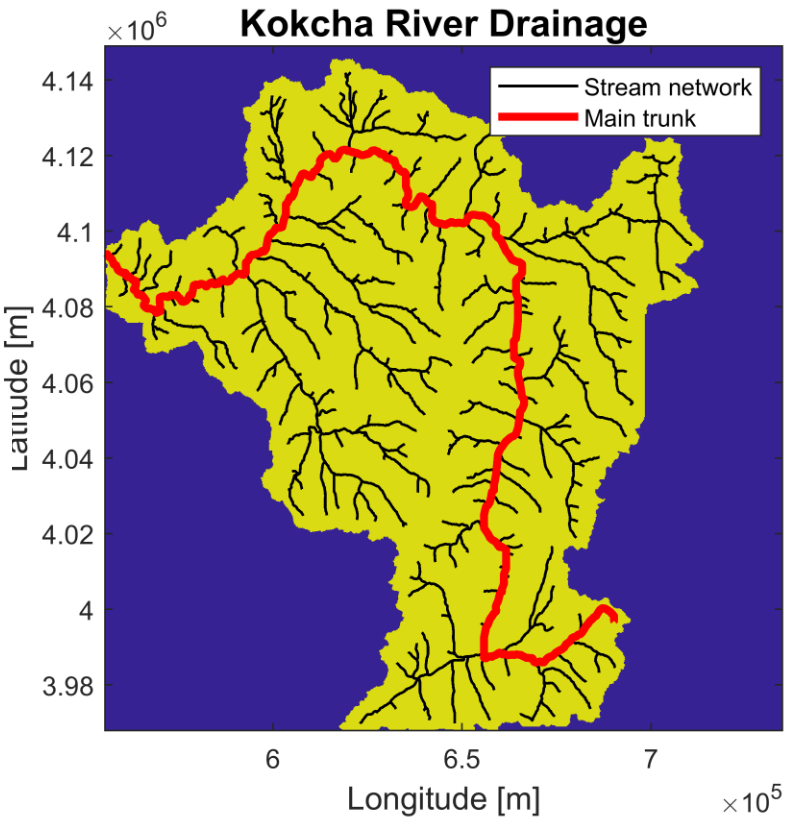


wmblogs.wm.edu

Kokcha - Network

- Highest peaks over **6500**m
- Kokcha River shows a **dendritic drainage** pattern

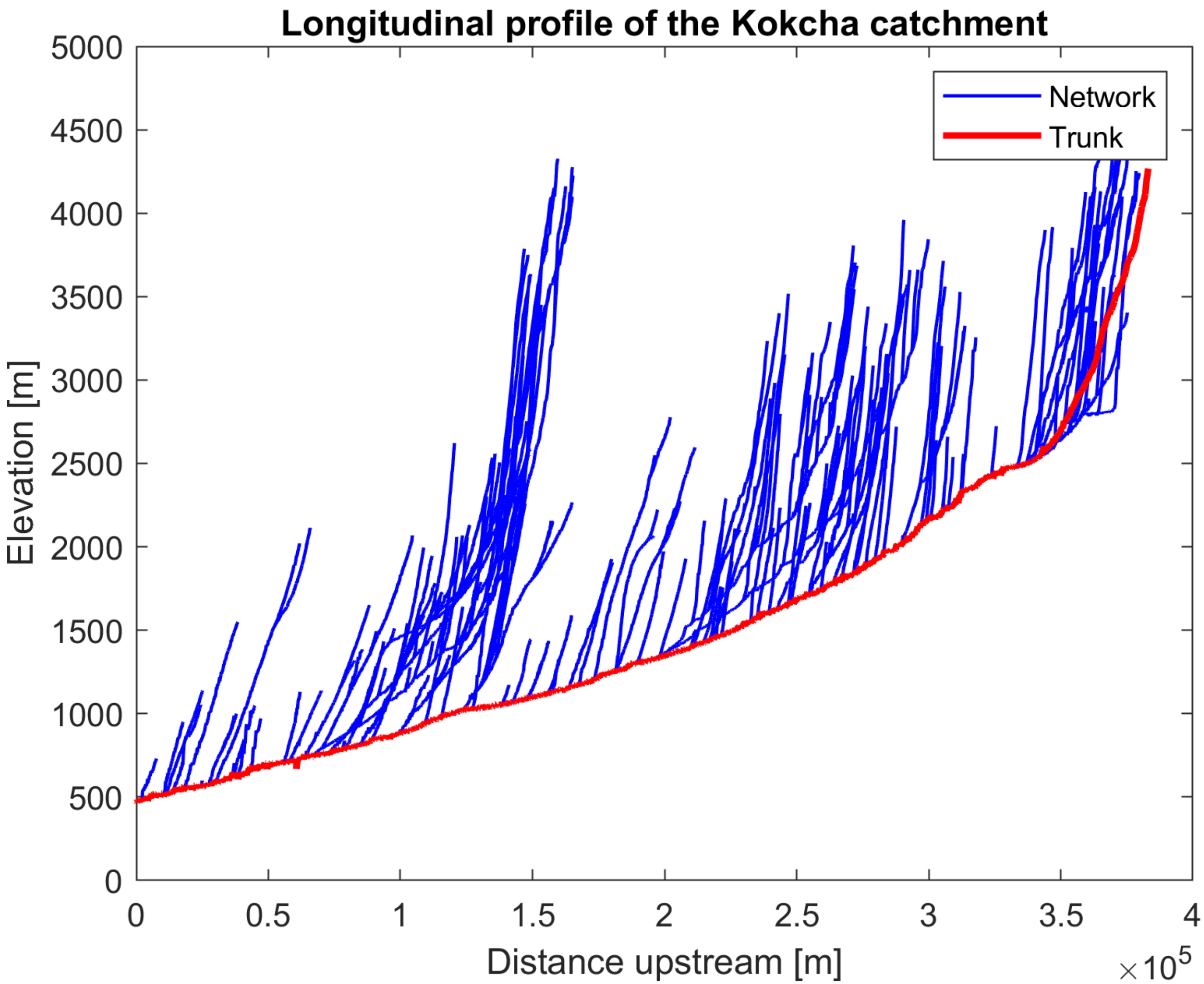




Drainage area ~22367.692 km2

Longitudinal Profile

- **Longitudinal** river profile was extracted
- The minimum drainage area was considered: **100,000** pixels

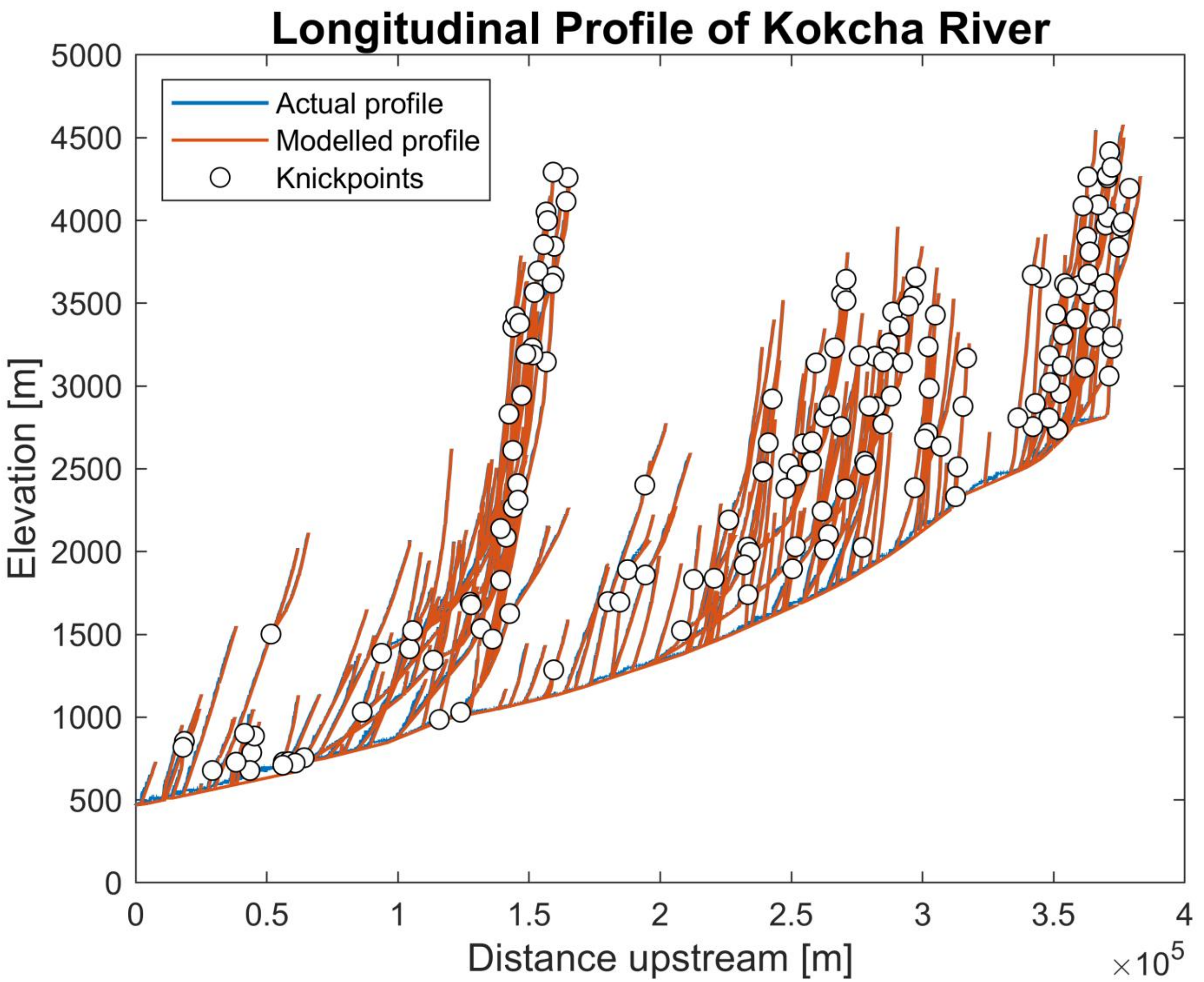


Longitudinal Profile

- **Knickpointfinder**

- Adjusts a strictly **concave** upward profile to the actual profile and **repeats**

- Highest = **318m**
- Lowest = **50m**

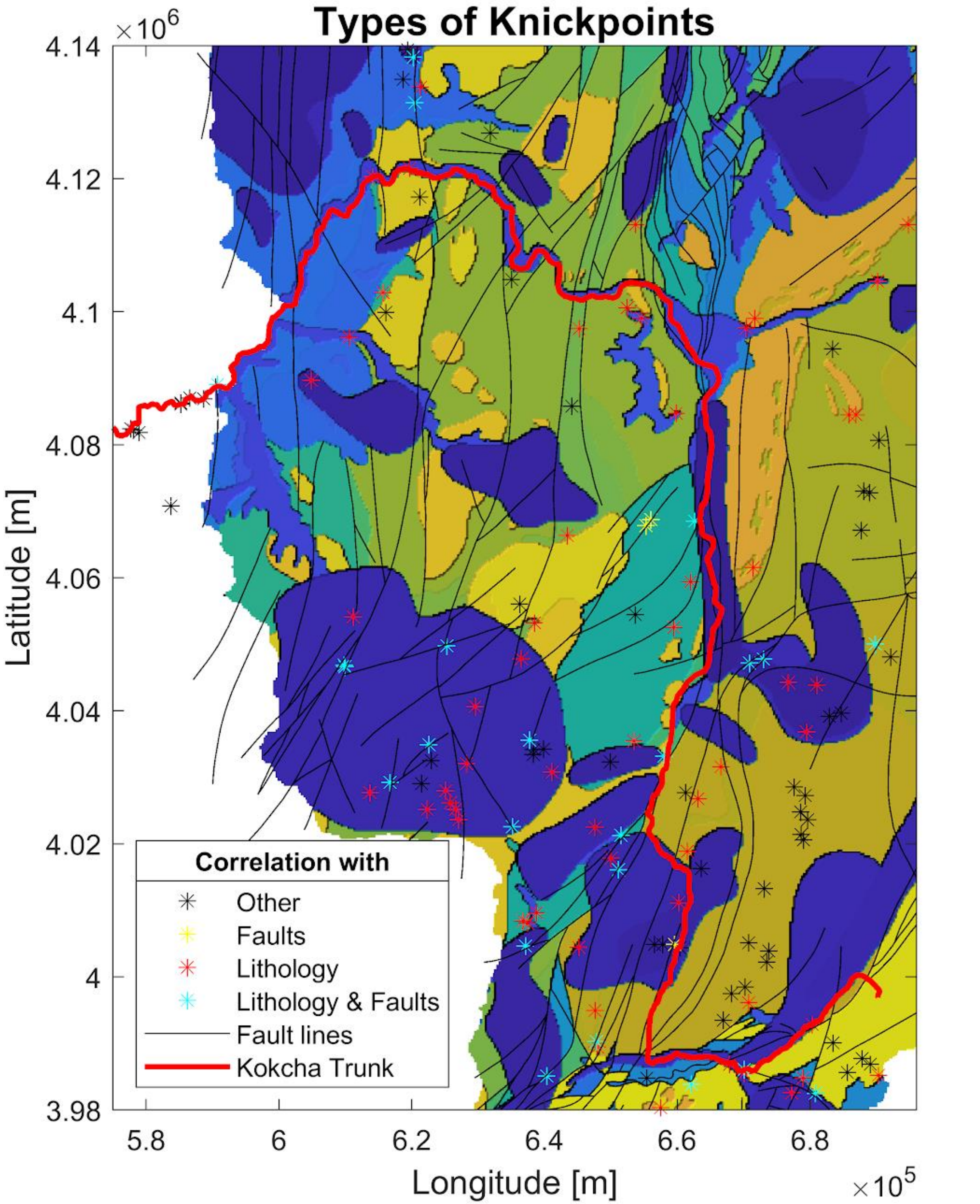


(Schwanghardt, 2019)

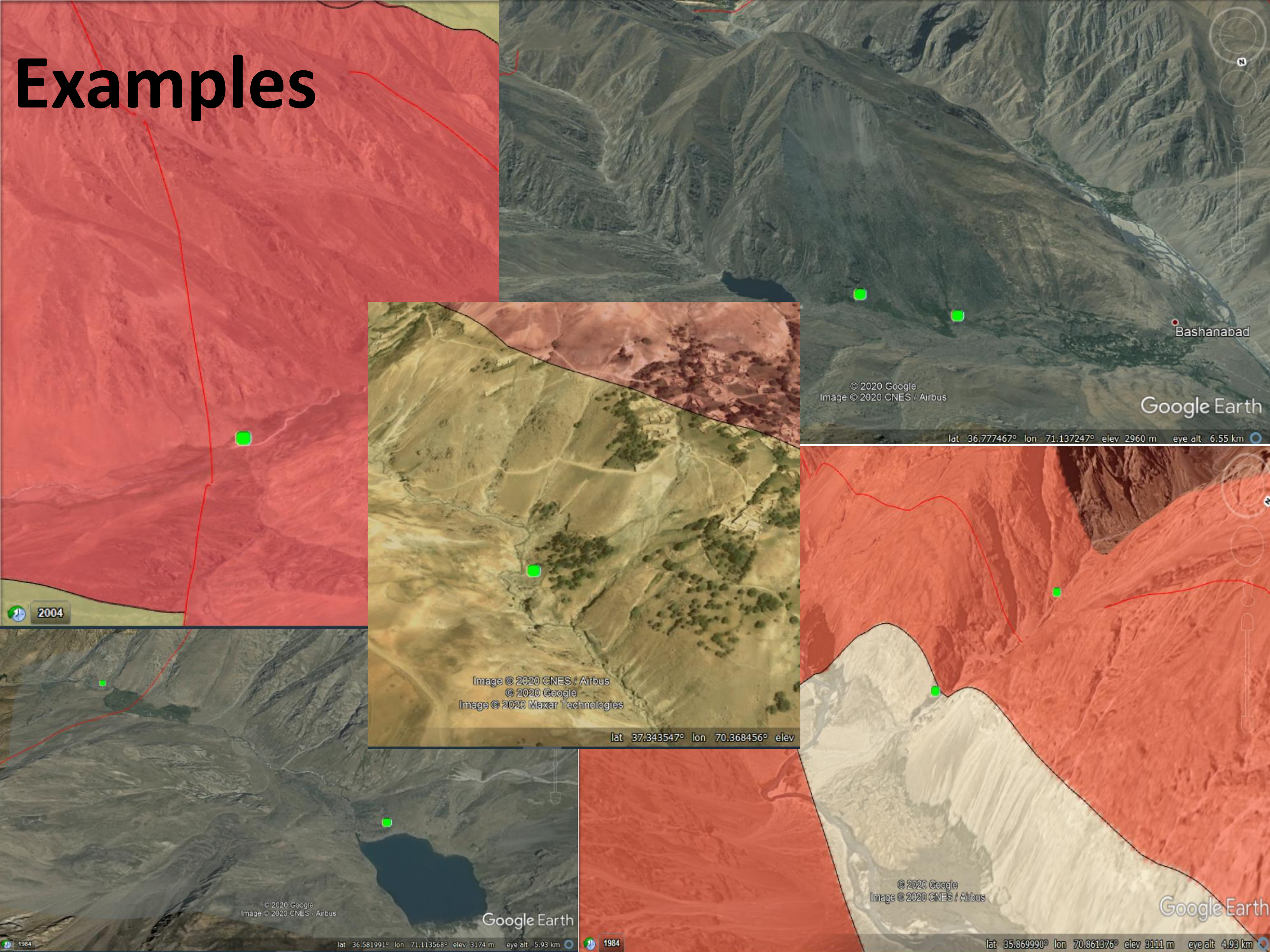
Knickpoints vs Lithology

- **Transient** = 37
- **Stable** = 125

- **94** within **1000m** of lithology
- **31** within **500m** of faults
- **28** stable both



Examples


2004
© 2020 Google
Image © 2020 CNES / Airbus
Bashanabad
Google Earth
lat 36.777467° lon 71.137247° elev 2960 m eye alt 6.55 km
Image © 2020 CNES / Airbus
© 2020 Google
Image © 2020 Maxar Technologies
lat 37.343547° lon 70.368456° elev
© 2020 Google
Image © 2020 CNES / Airbus
Google Earth
lat 36.581991° lon 71.113568° elev 3174 m eye alt 5.93 km
1984
© 2020 Google
Image © 2020 CNES / Airbus
Google Earth
1984
lat 35.869990° lon 70.861376° elev 3111 m eye alt 4.93 km

Steepness Index (ks)

Steepness index (ks) describes the normalized slope over drainage area (θ) = **concavity index**

$$\frac{dz}{dt} = Uplift - Incision \qquad \frac{dz}{dt} = U - KA^m S^n$$

Simple stream power law

The equilibrium river length profile

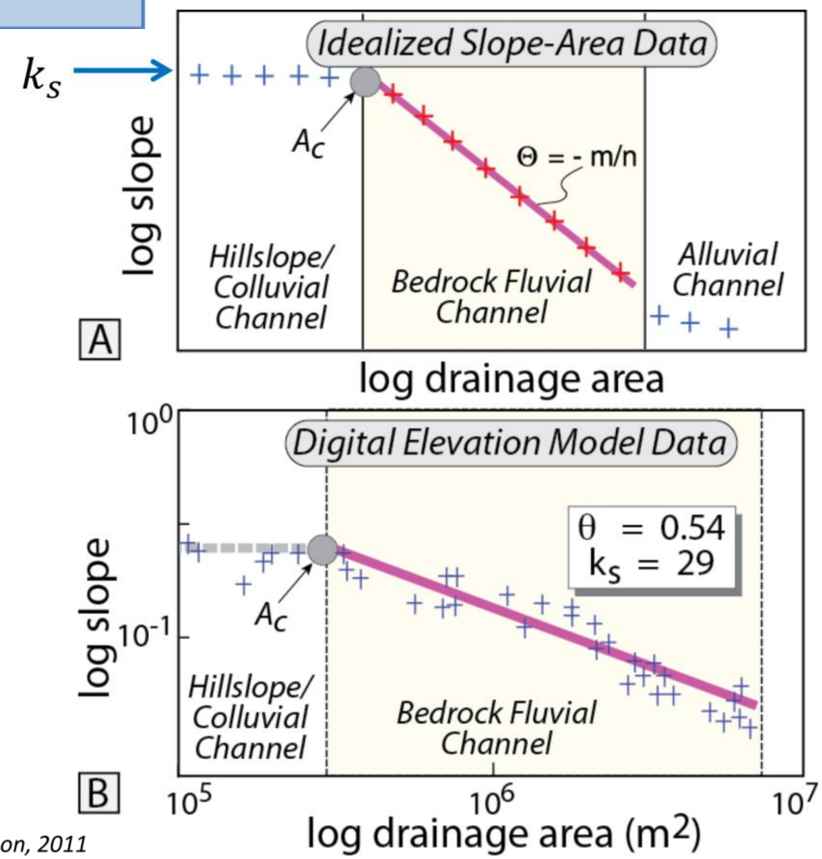
$S = k_s A^{-\theta}$

$k_s = (\frac{U}{K})^{\frac{1}{n}}$

- k_e (lithology, jointing, bedding, climate, vegetation, etc.)
- ρ_w g
- Sediment flux function $f(q_s)$
- n: erosional processes on channel bed
- **Uplift !** (or erosion if non steady-state)

$\theta = \frac{m}{n}$

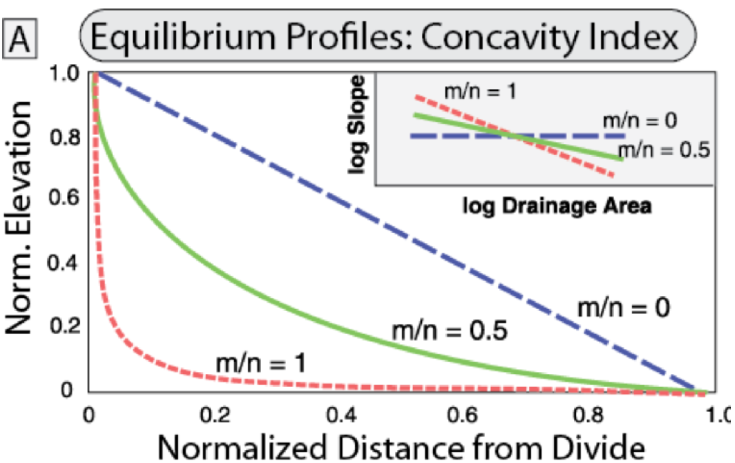
- m: basin hydrology
- n: erosion processes on channel bed



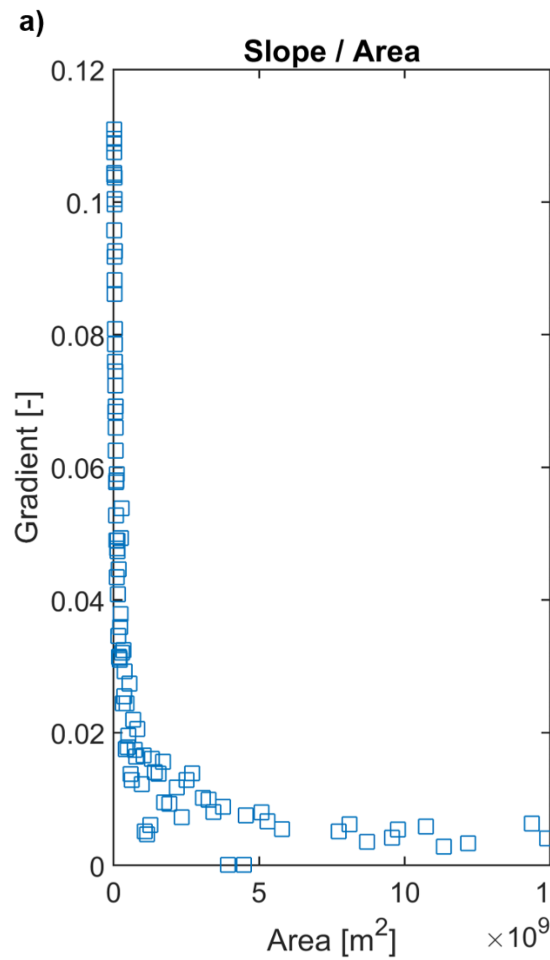
Burbank & Anderson, 2011

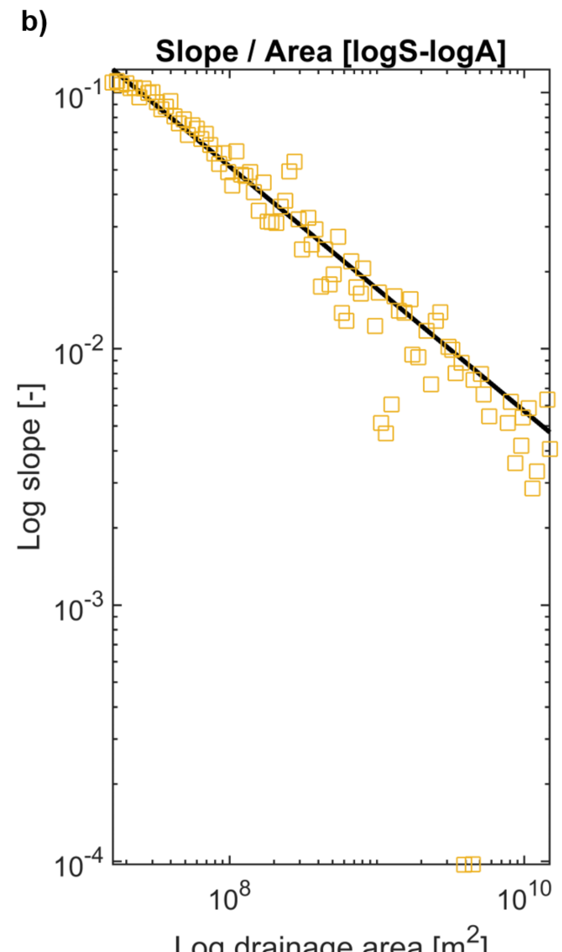
Steepness Index (ks)

Assuming ks is constant, the relation between slope and area is described by θ.



Burbank & Anderson, 2011

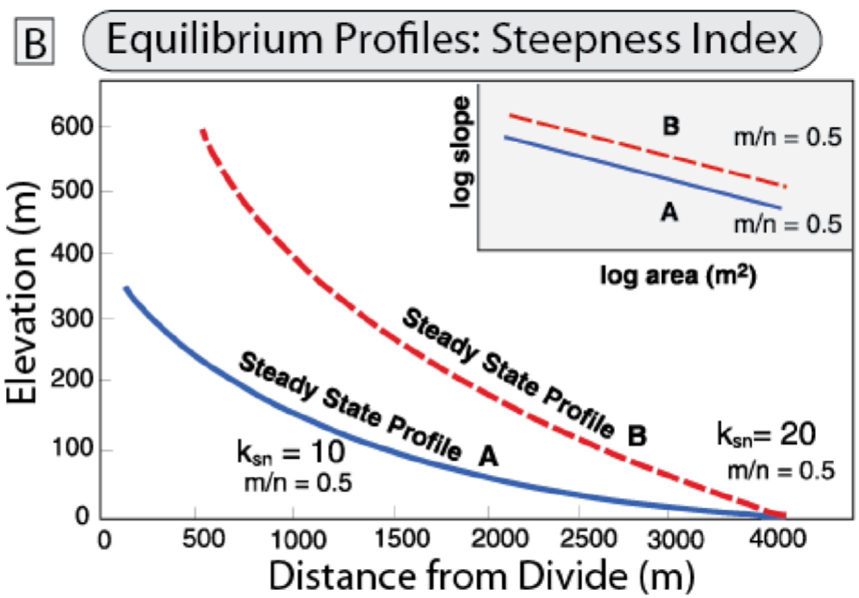




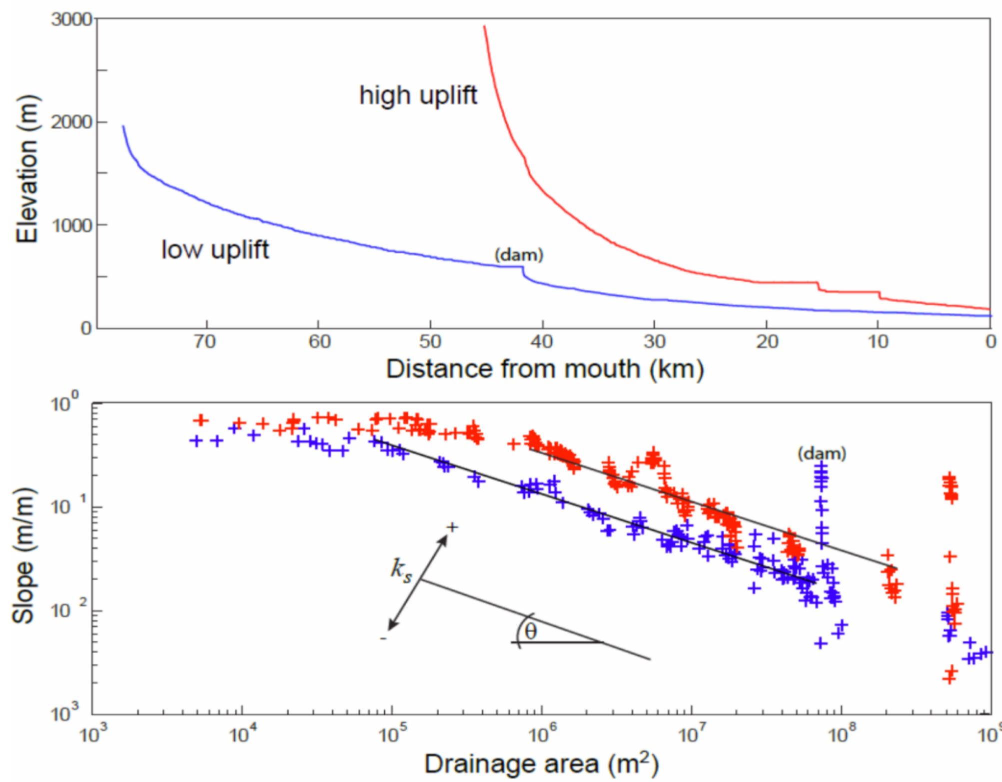
Kokcha basin indicates a very extreme pattern

Normalized Steepness Index (ksn)

Ksn correlates with **uplift** rates



Example from the San Gabriel Mountains, CA



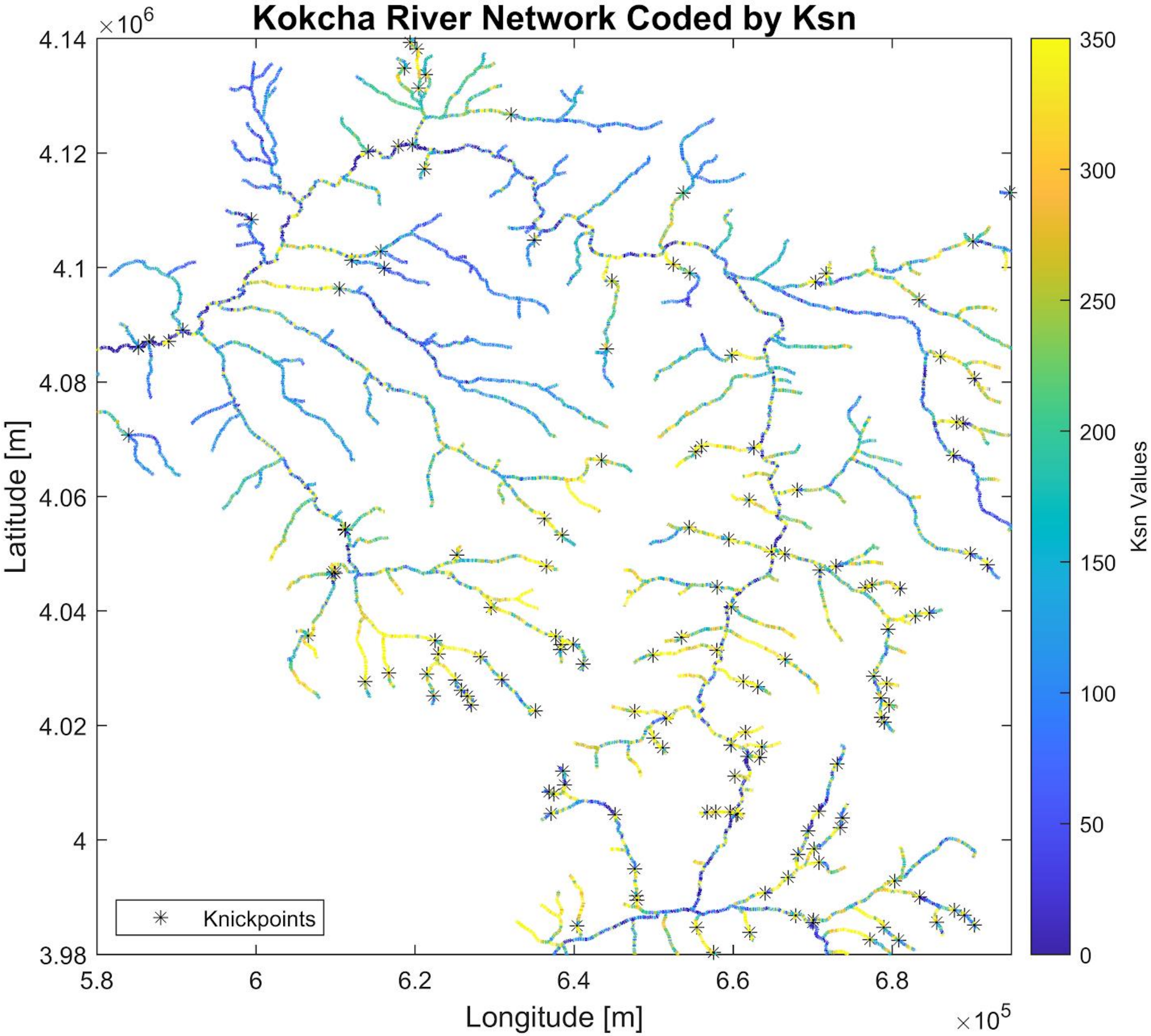
Wobus et al., 2006 (figure from R. DiBiase)

Normalized Steepness Index (ksn)

Therefore,

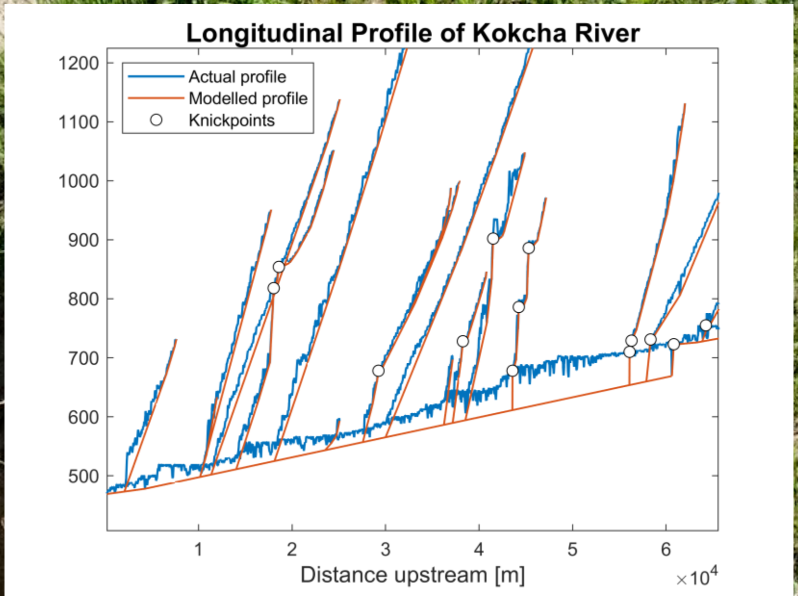
We can use ksn to **estimate** erosion/rock uplift rate

(Kirby and Whipple, 2012)



Limitations

- The ALOS DEM, 12.5 m resolution, was **upsampled** from 30m
- Lithological map is more than 50 years old and available only at a **1:250,000** scale (Doebrich et al., 2006)
- Flow routing algorithms – **memory limitations**
- **Filling** the DEM



NAC

Conclusion and outlook

- The **majority** of **knickpoints** in the Kokcha's drainage system are **stable.**
- They are **correlated** with changes in **lithology**, **faults**, or **both.**
- **ksn** extracted from DEM is a good **proxy** for uplift or erosion.
- **Could detect landslides?**
- **Adding precipitation data to extract stream power?**


Thank you!
NAC