Open-source topographic analysis with LSDTopoTools

Boris Gailleton – GFZ Potsdam
ESP Summer Institute 2020

THE UNIVERSITY of EDINBURGH
School of Geosciences

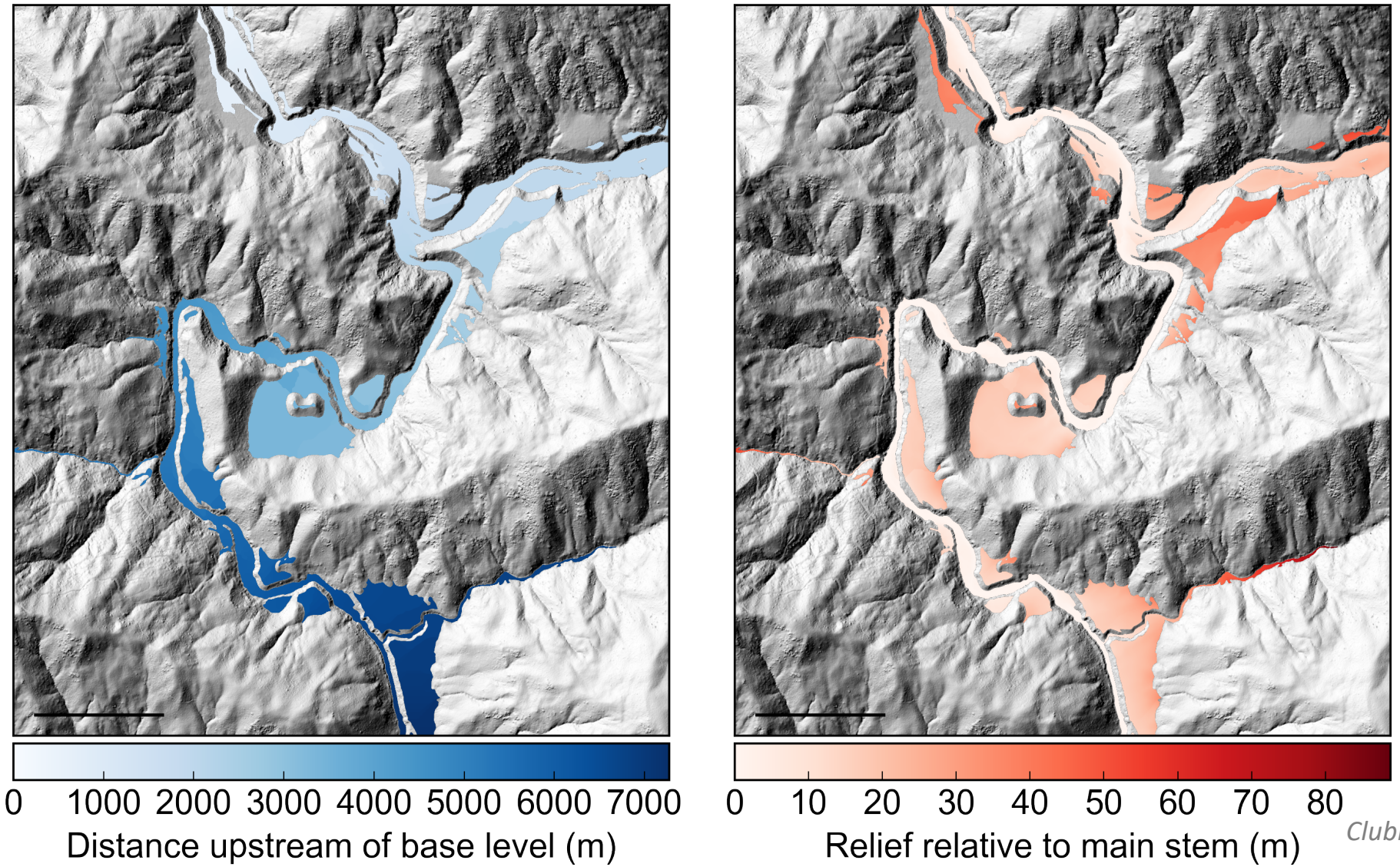
The LSDTopoTools team

Universities of Edinburgh, Glasgow, Queen Mary London, Durham, GFZ Potsdam

NERC SCIENCE OF THE ENVIRONMENT

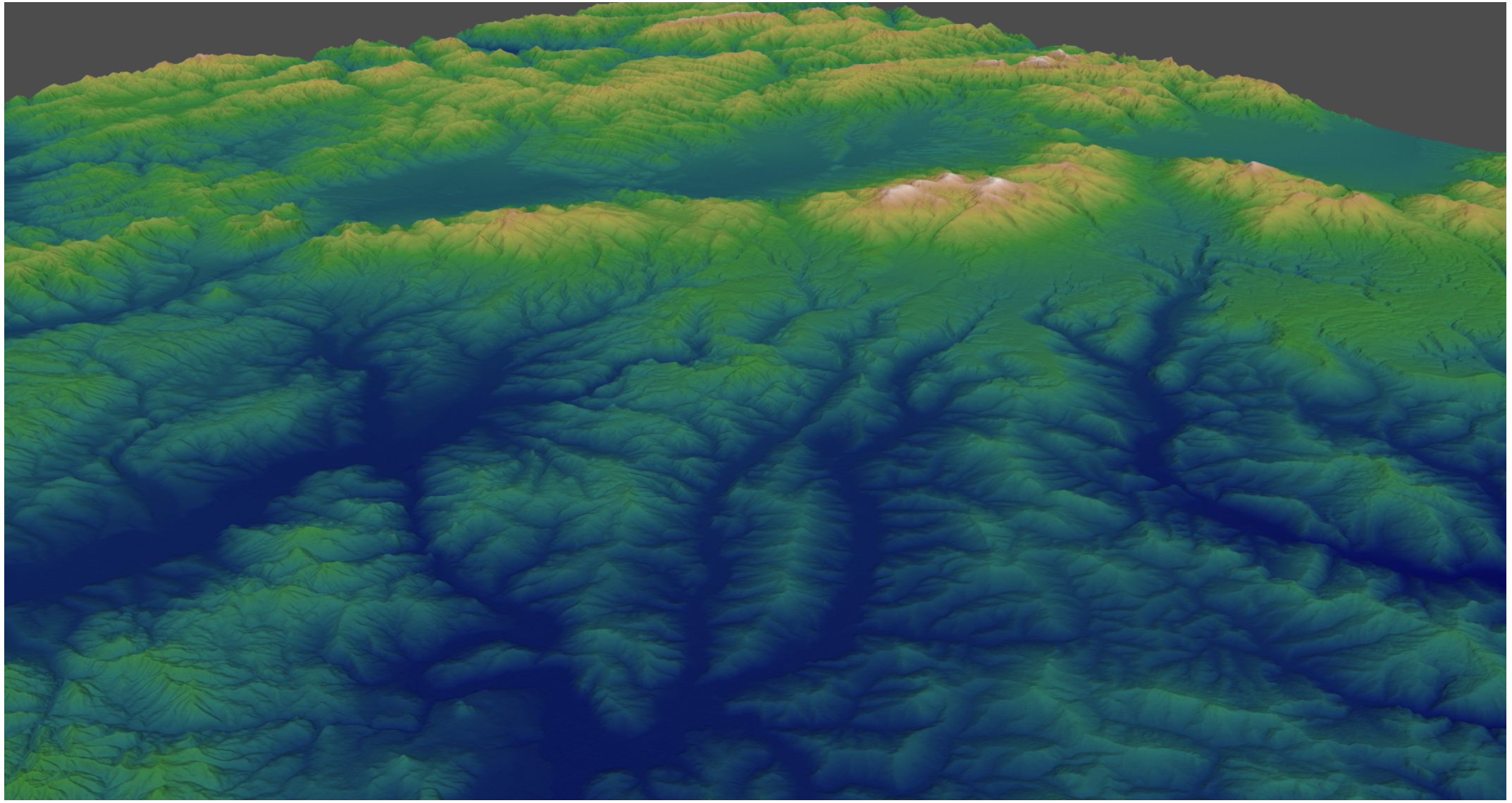
Topographic analysis, what is it?

(Beside good looking figures)



Clubb et al., 2017

DEM available in the whole world:

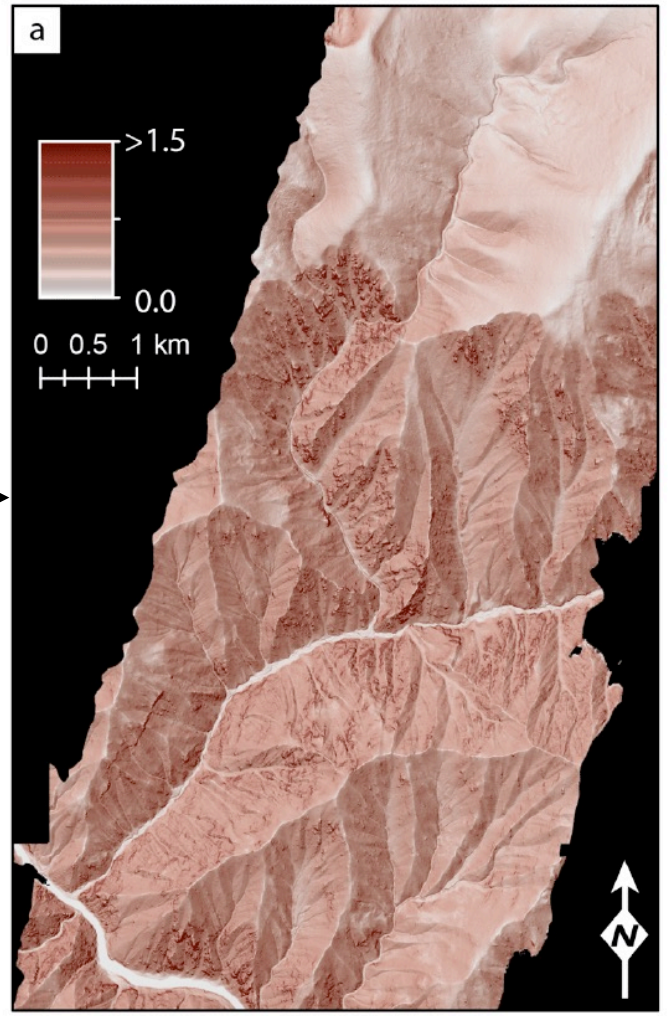


SRTM 30m downloaded from opentopography website and plotted with pyvista – Transylvanian Alps - Romania

Topographic Analysis

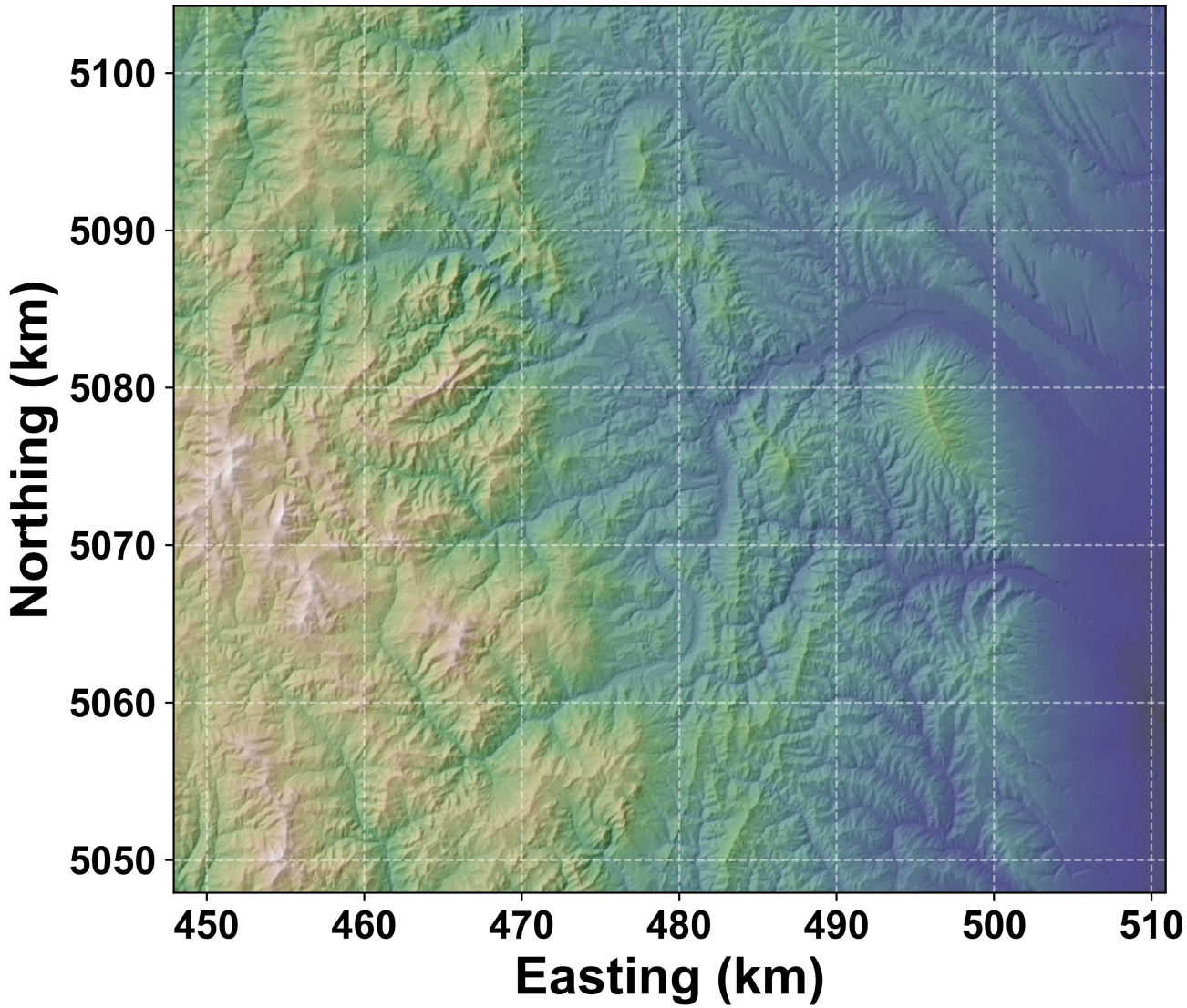
=

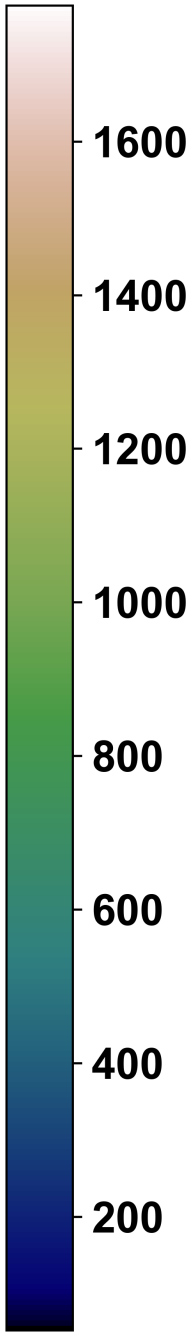
Any process that will aim to quantify or visualise aspects of the earth surface



Topographic gradient
Milodowski et al. (2015) Earth Surf. Dynam.

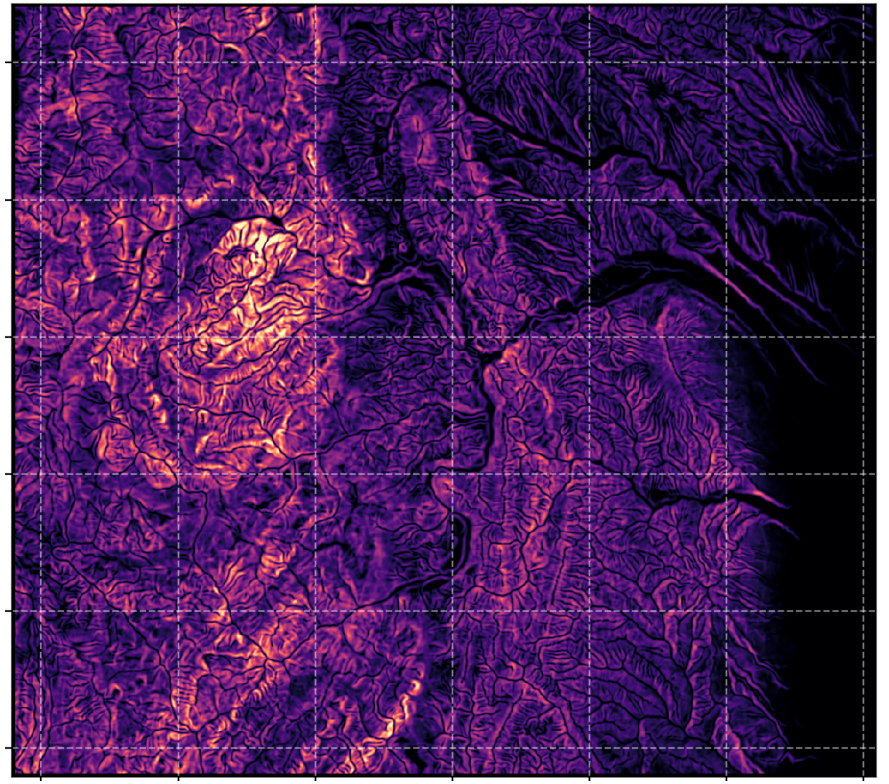
Examples of Topographic Analysis



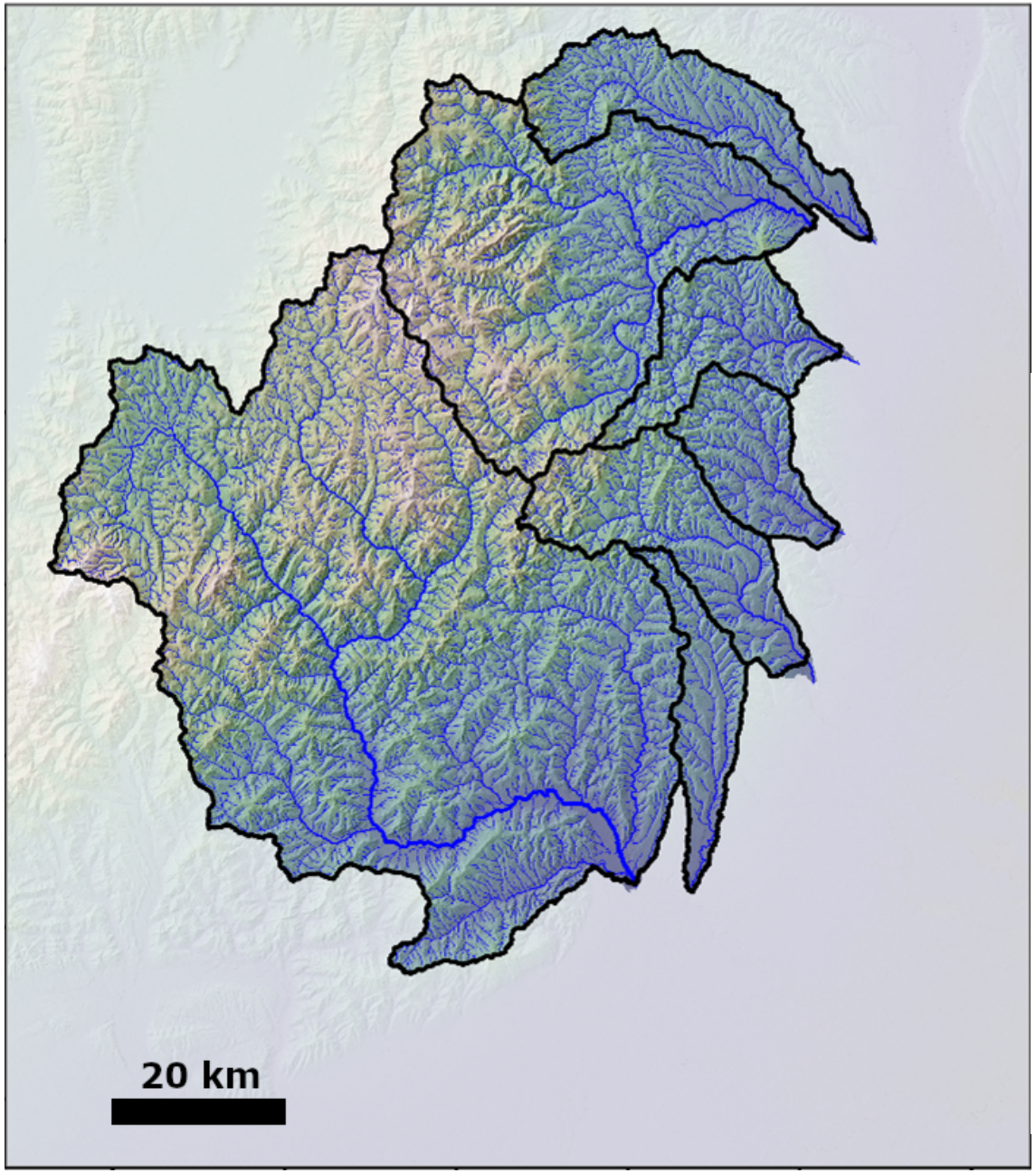


Topographic metrics

- *Location map*
- *Qualitative mapping of geomorphic objects*
- *Slope map, curvature map, …*

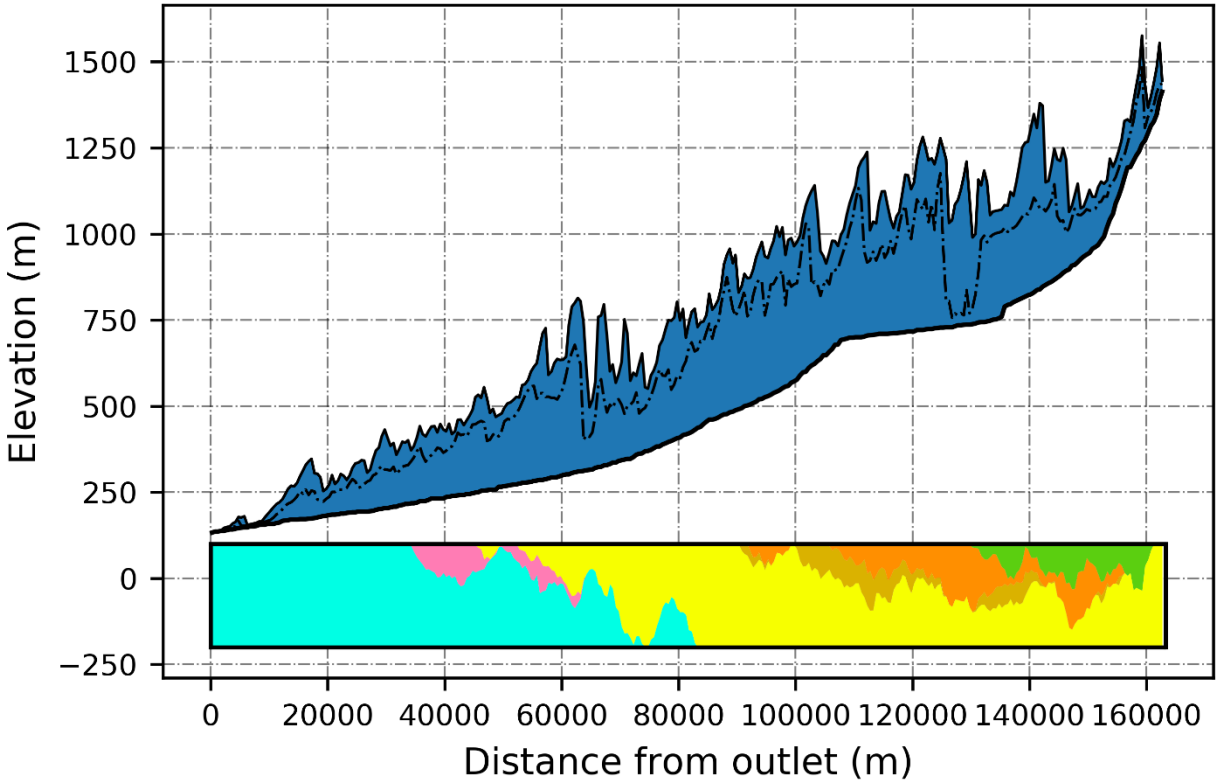


Examples of Topographic Analysis

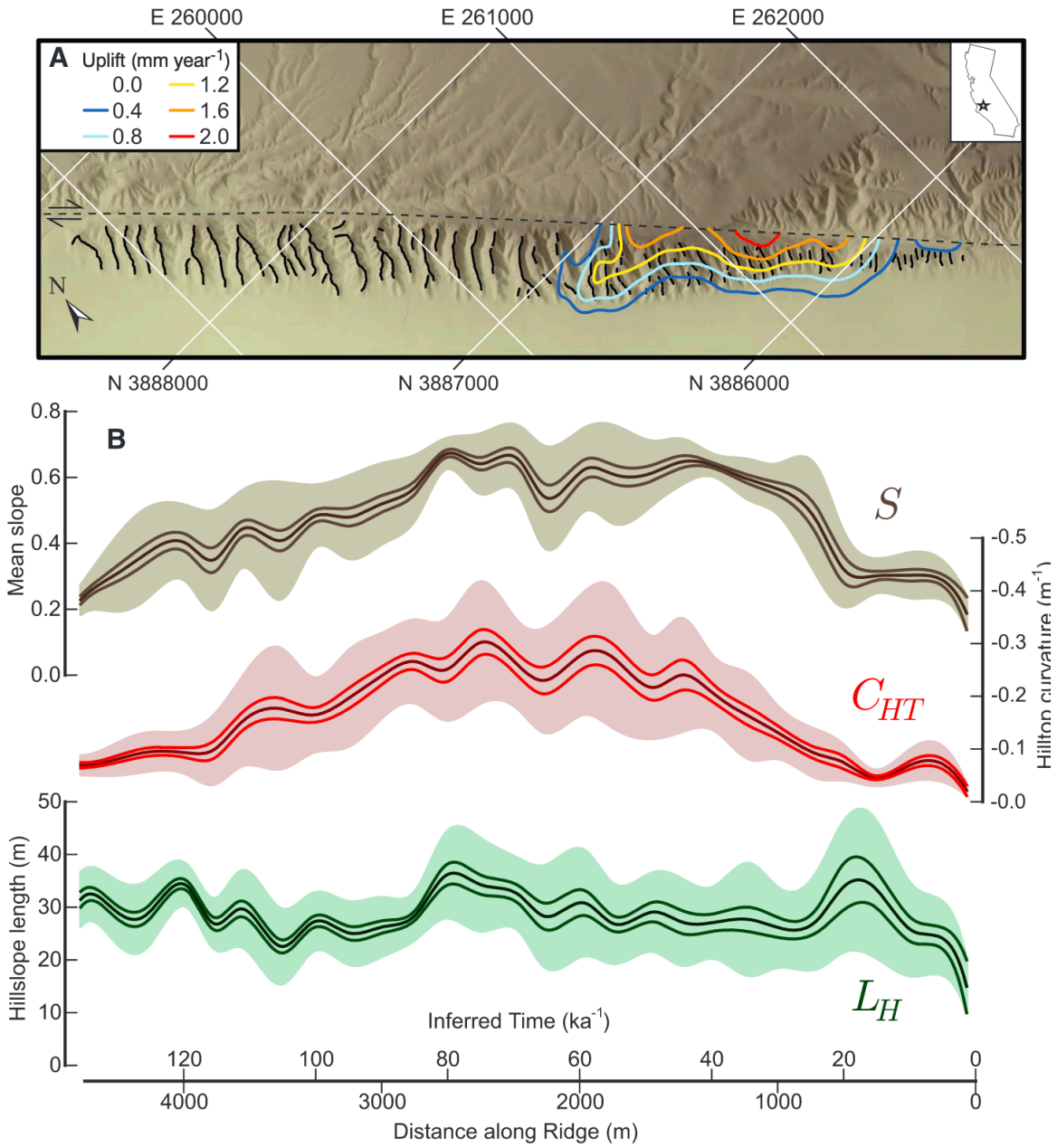


Fluvial metrics

- *River network extraction*
- *River long profile*
- *Terrace mapping*
- *…*

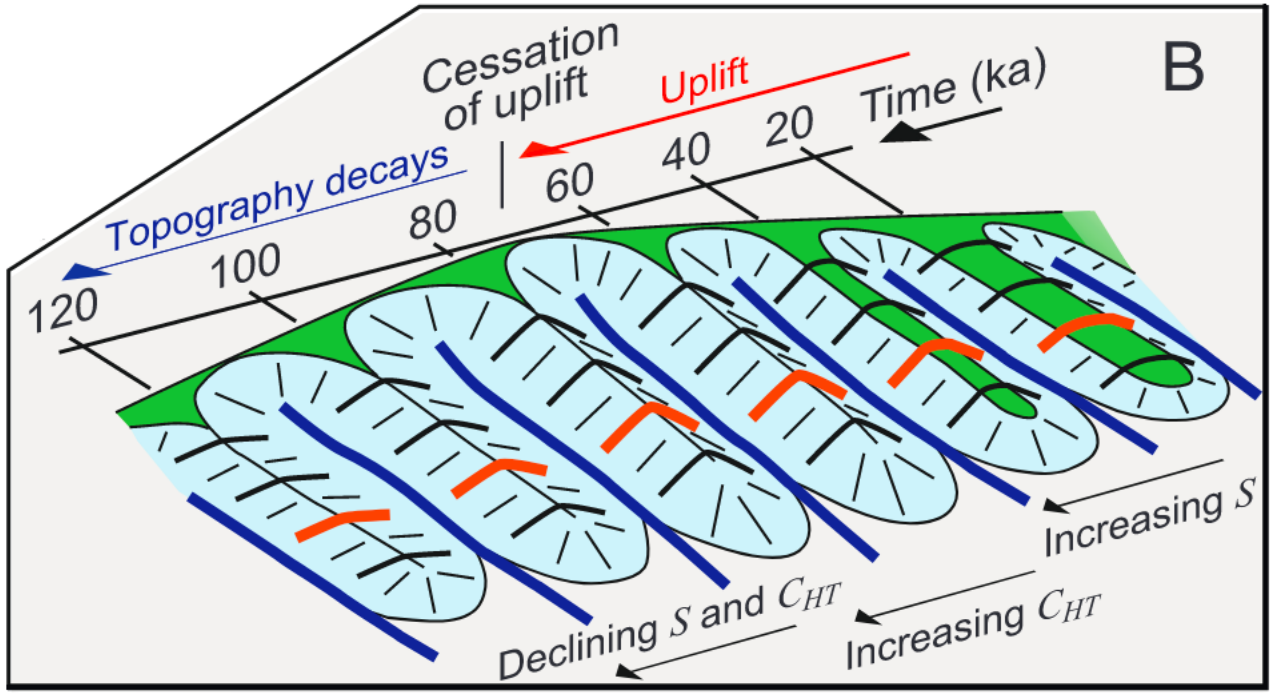


Examples of Topographic Analysis



Hillslope metrics

- *Roughness*
- *Length, curvature, …*
- *Relate to erosion rates and tectonics*



Hurst et al. (2013) Sciences

Tools for topographic analysis

Scripting Research software

- Dedicated to specific analysis
- Reproducible
- Easier to expand
- Lead by researchers

e.g.:

LSD Topo Tools

GDAL

RichDEM

LANDLAB

TopoToolbox *

GIS software

- User-friendly
- GUI based and for general use
- Customizable via toolboxes
- Slower and contain “black boxes”

e.g.:

ArcGIS *

MapInfo *

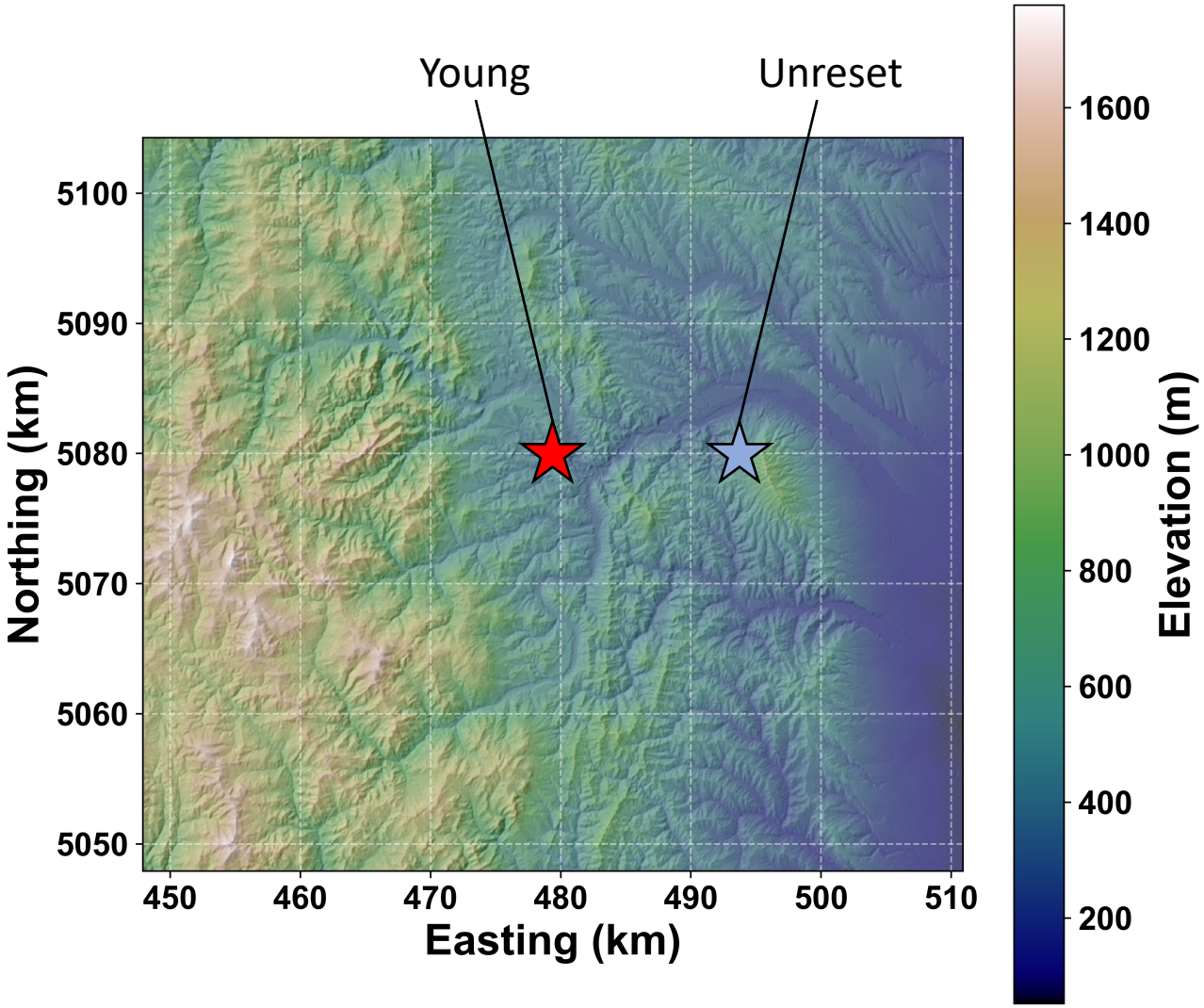
* = relies at least partially on proprietary codes (licence cost + hidden code)

LSDTopoTools

- Started in 2012 by Simon Mudd
- Core written in C++, focus on performances
- Python bindings
- Specialised in hillslope and fluvial geomorphology
- Encompasses many research algorithm to:

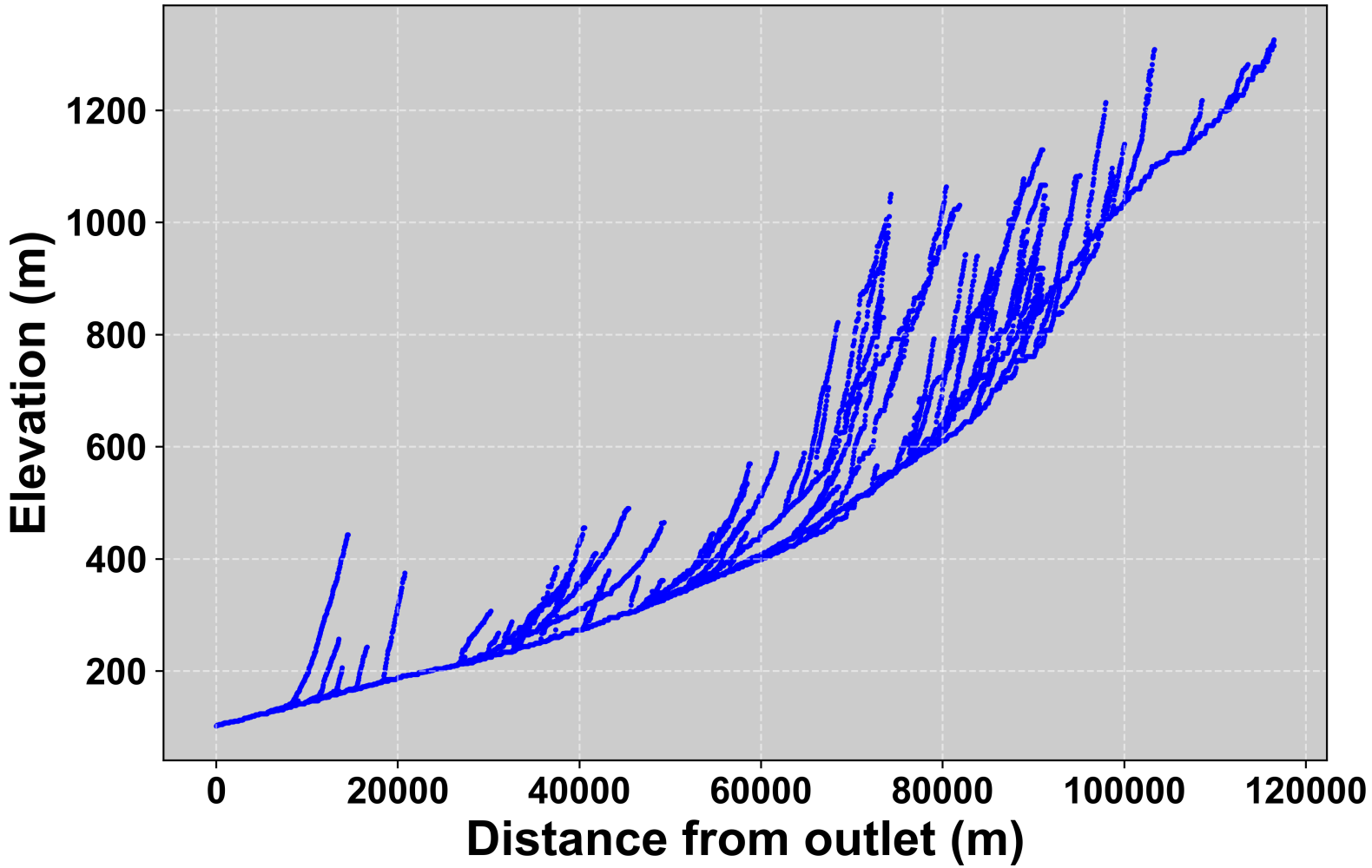
Extract channel head geometrically	Extract long profiles metrics
Extract channel head process-oriented	Stream order
Flow routing (D8, Dinf)	Slope-Area metrics (k_s, theta)
Polynomial window (slope, curvature, …)	Integral approach (chi)
Topographic roughness and local relief	Drainage Density
Topological ordering	Knickpoint location
Terrace extraction	Dimensionless erosion
Hillslopes length and distance to channels	Hillshading
Swath templates	General functions

LSDTopoTools example: theoretical background



- Romanian Carpathians (Eastern Europe)
- Young and unreset thermochronometers in the area (see Matenco et al., 2017) suggesting recent exhumation
- Complex terrace system (see Necea et al., 2014) and GPS data suggesting ongoing vertical movements
- Can the river network help us understand the pattern of recent tectonics?

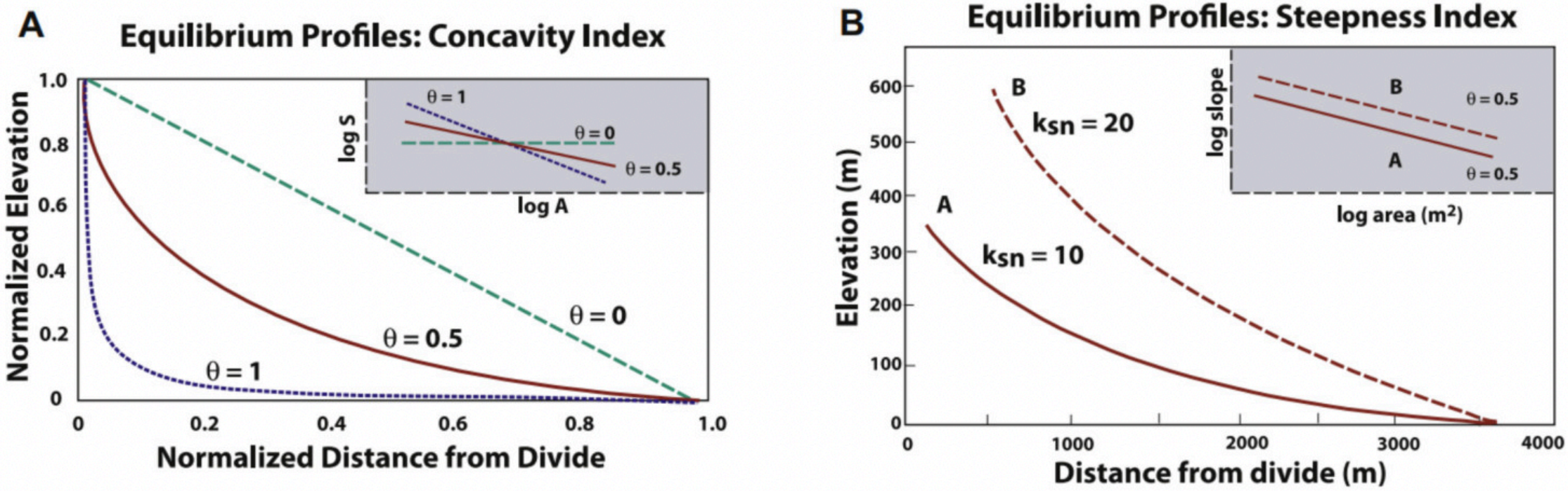
LSDTopoTools example: theoretical background



LSDTopoTools example: theoretical background

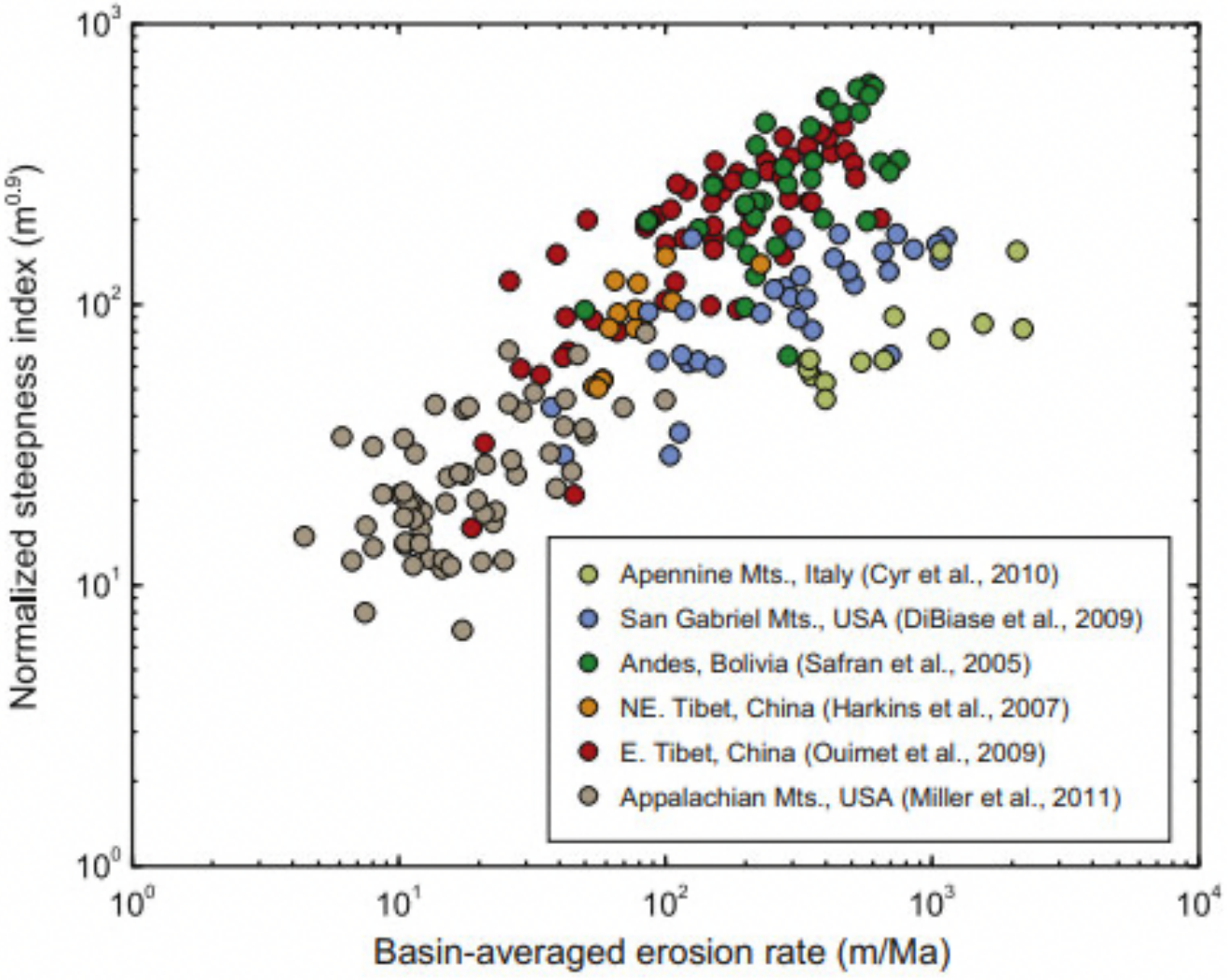
$$S = k_{sn} A^{-\theta}$$

Morisawa (1960), Leopold and Maddock (1953), Flint (1976)



From Kirby and Whipple, 2012

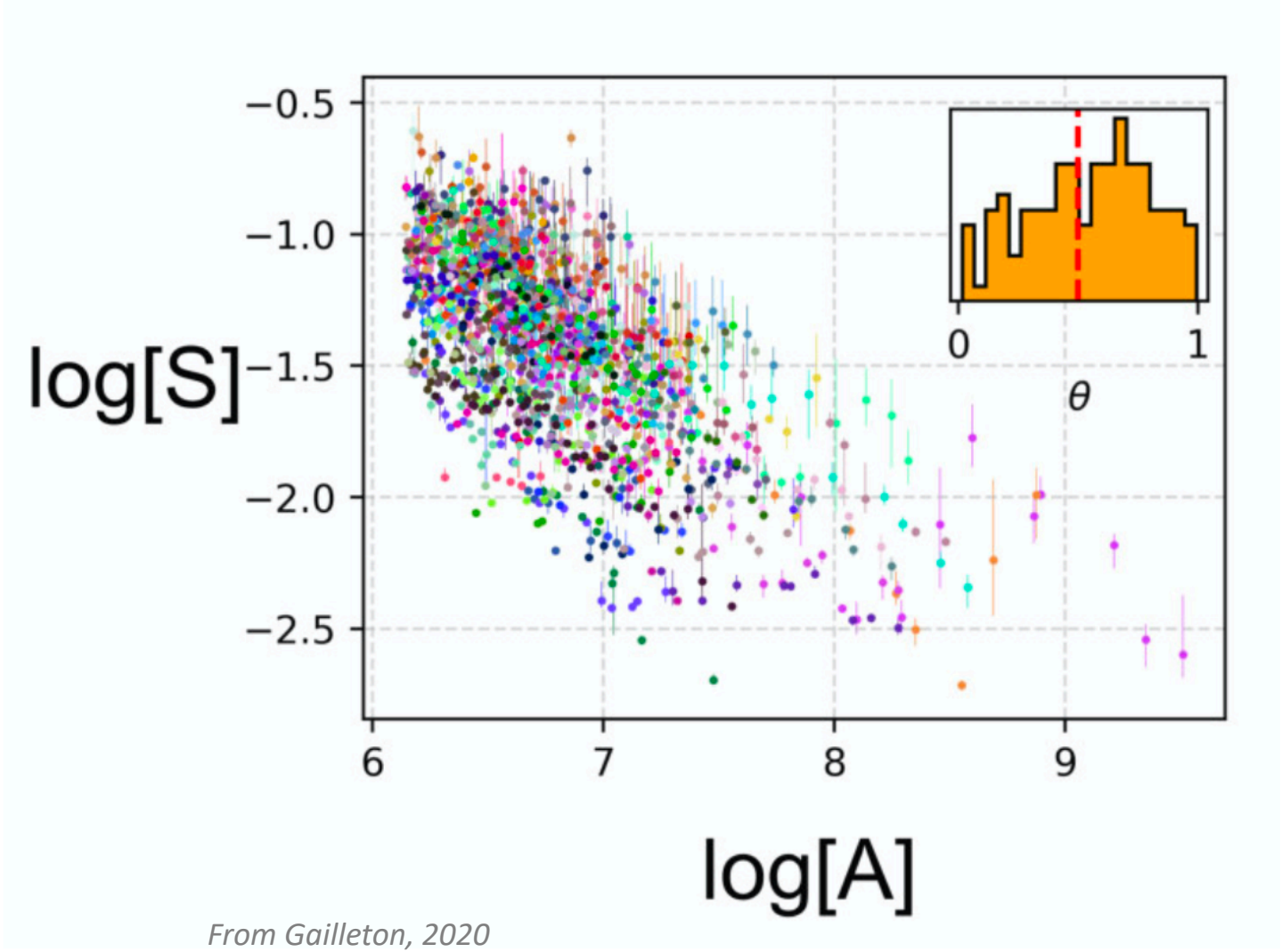
LSDTopoTools example: theoretical background



From Kirby and Whipple, 2012

- Normalised Channel Steepness directly linked to a change of process efficiency
- It can be a change of erosion, lithology, fracturation, climate, …
- Change in *ksn* <=> change in external or internal forcings affecting the river

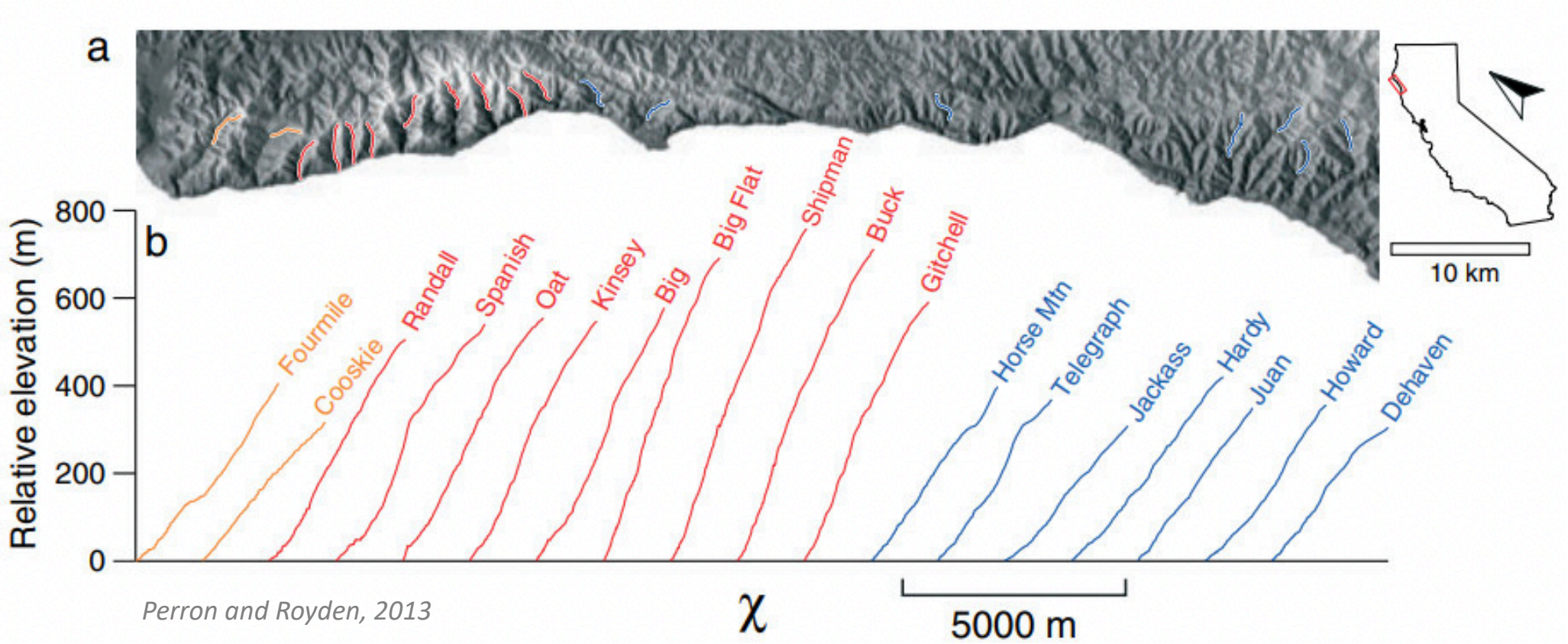
LSDTopoTools example: theoretical background



From Gailleton, 2020

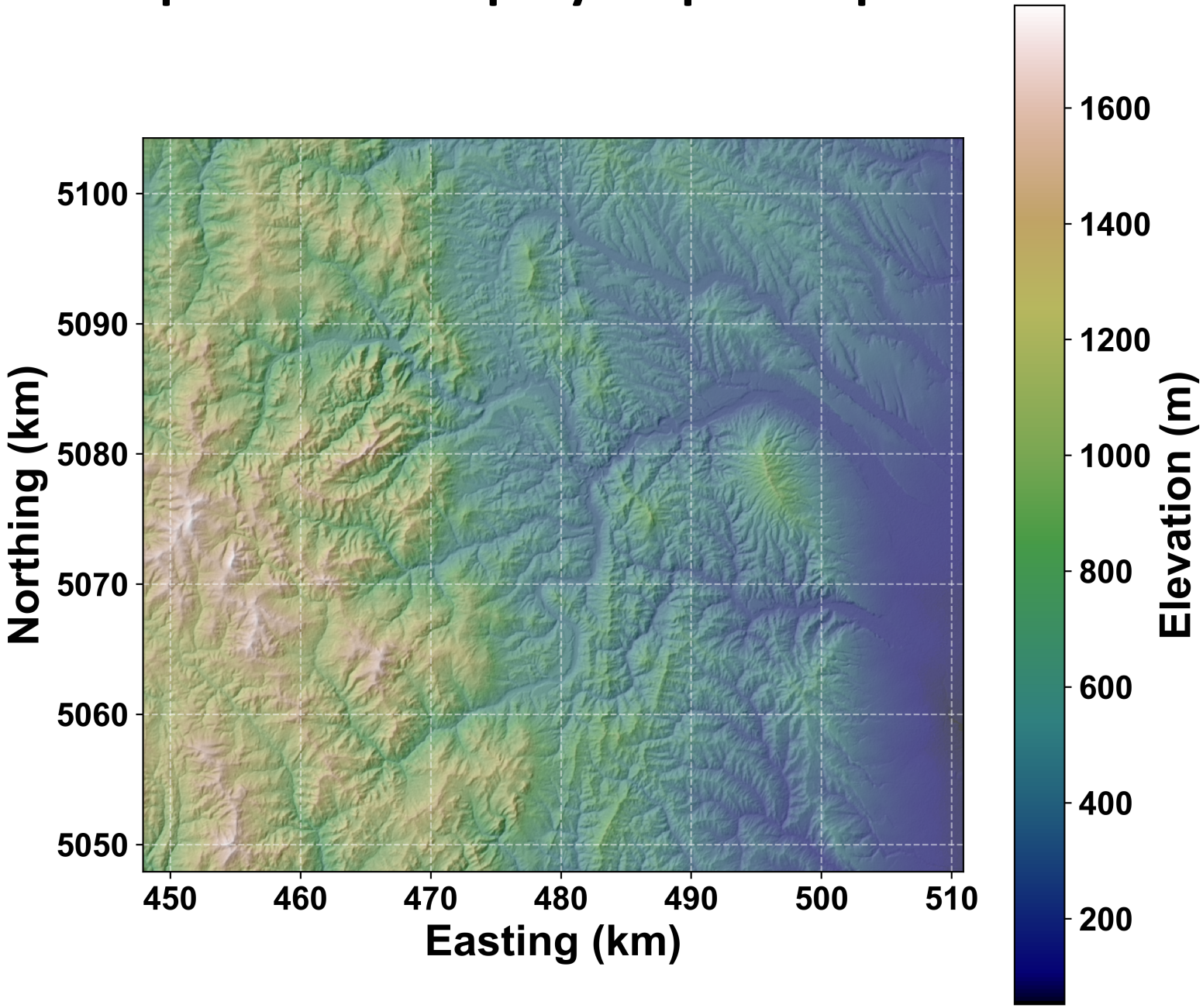
- However relatively difficult to calculate with S—A data …

LSDTopoTools example: theoretical background



- New approach: finding the optimal normalisation θ and directly integrate A into it
- Result: Slope of transformed profile = k_sn and is much a cleaner way to calculate/represent it

LSDTopoTools: a step-by-step example in the Romanian Carpathians



- Preprocess the DEM
- Extract channel network
- Normalise it
- Calculate Channel Steepness
- Visualise the metrics

Step #0: Getting a DEM

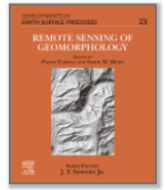
OpenTopography
High-Resolution Topography Data and Tools

- Many possible sources
- Here just an example using opentopography
- Opentopography is an online platform distributing open topographic data
- Here we will use SRTM30

Review on available topographic data:

ELSEVIER

Developments in Earth Surface Processes
Volume 23, 2020, Pages 91-128



Chapter 4 - Topographic data from satellites

Simon M. Mudd

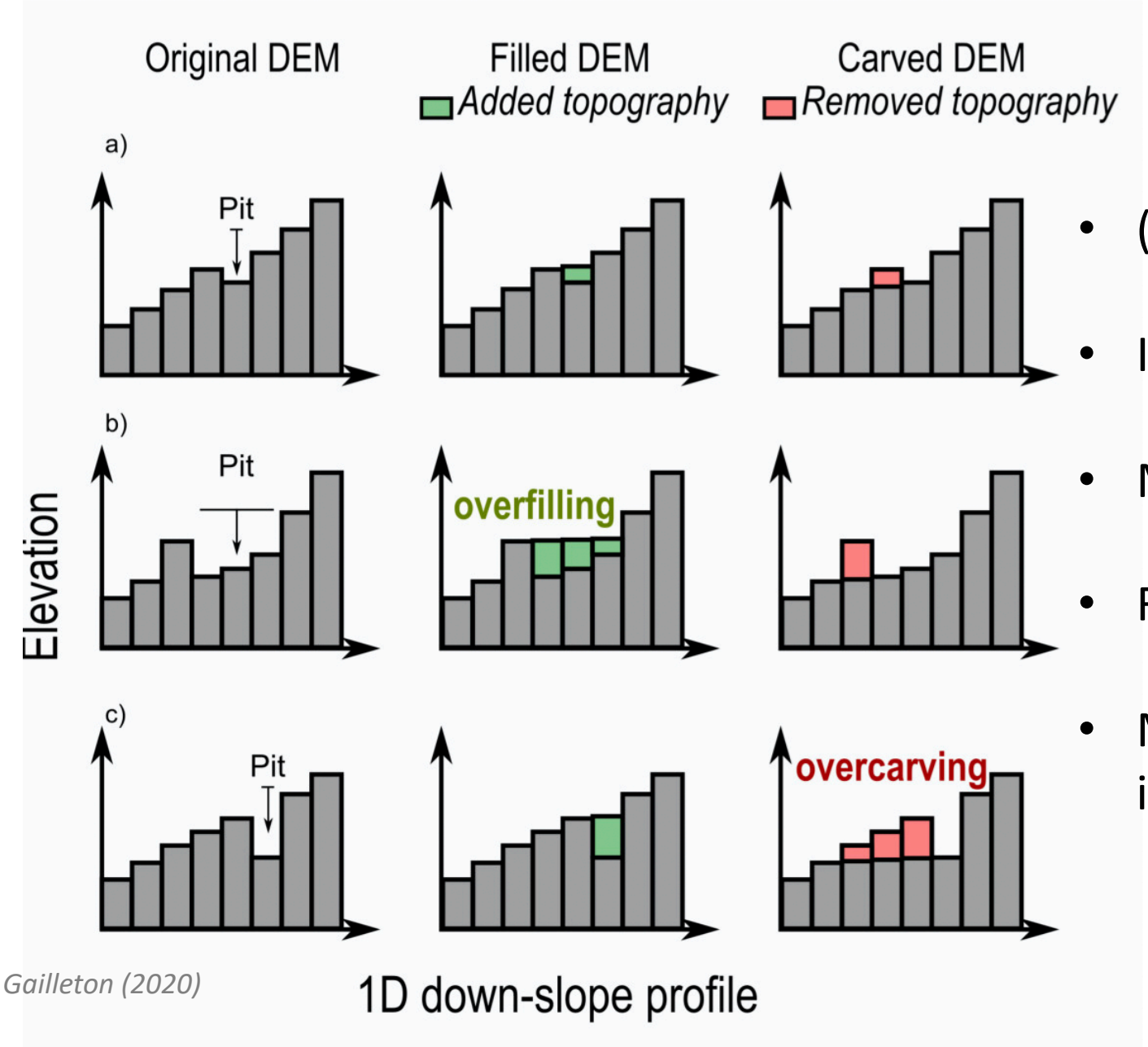
University of Edinburgh, School of GeoSciences, Edinburgh, United Kingdom

Available online 16 April 2020.

Step #0.5: Reprojection

- Reprojecting a DEM into UTM is important to get meaningful units

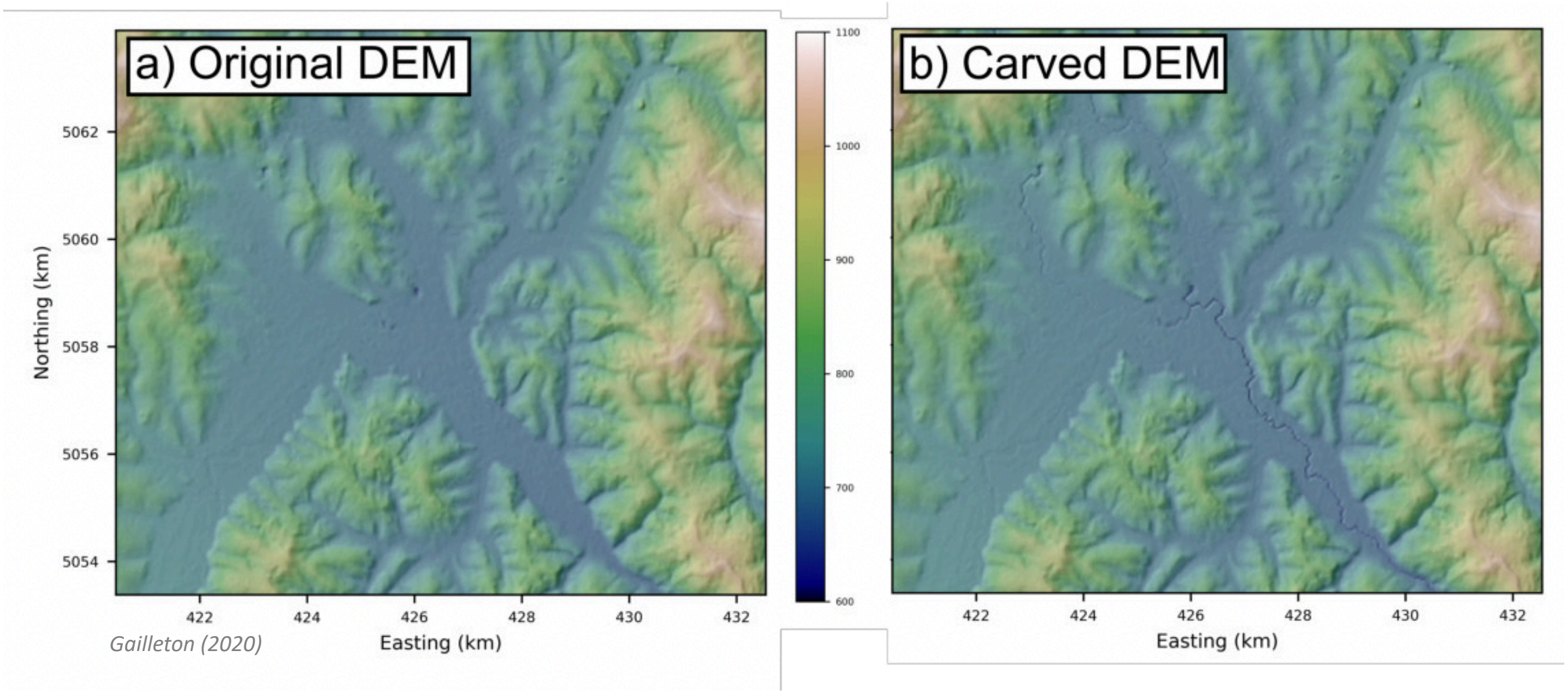
Step #1: Preprocessing DEM for flow routing



Gailleton (2020)

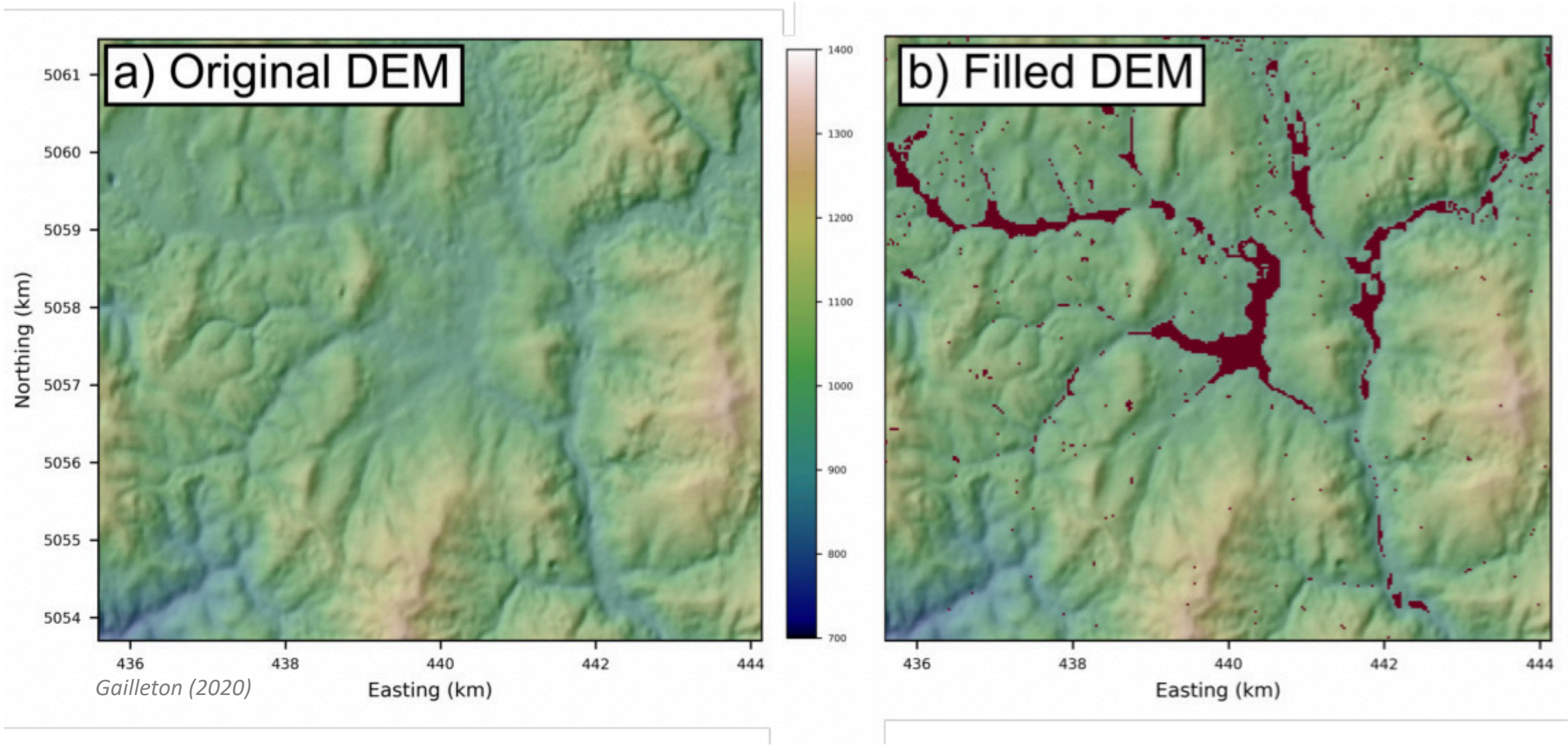
- (real) DEMs are noisy
- It can stop numerical flow
- Many solutions depending on the problem
- Filling and carving are common and fast
- More sophisticated solutions are possible if lake hydrology is important

Step #1: Preprocessing DEM for flow routing



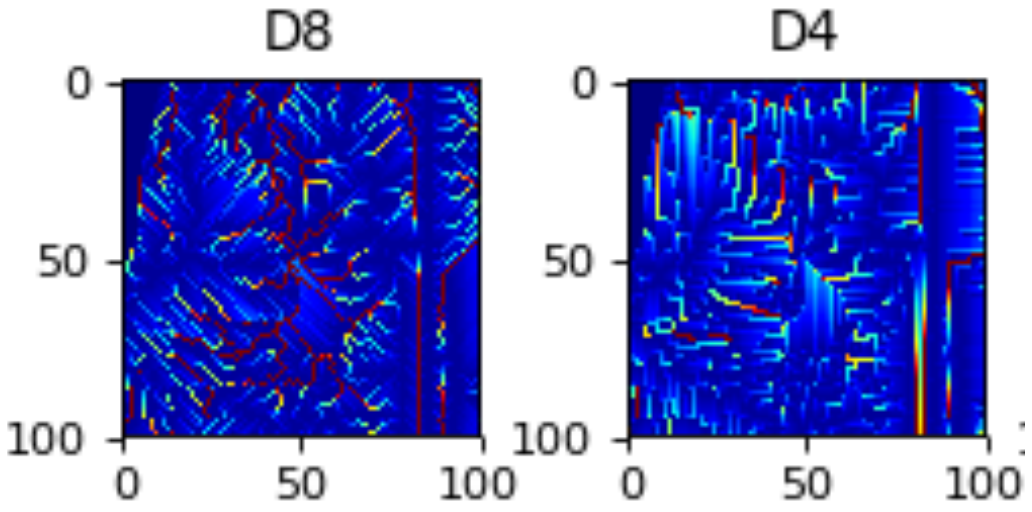
Gailleton (2020)

Step #1: Preprocessing DEM for flow routing

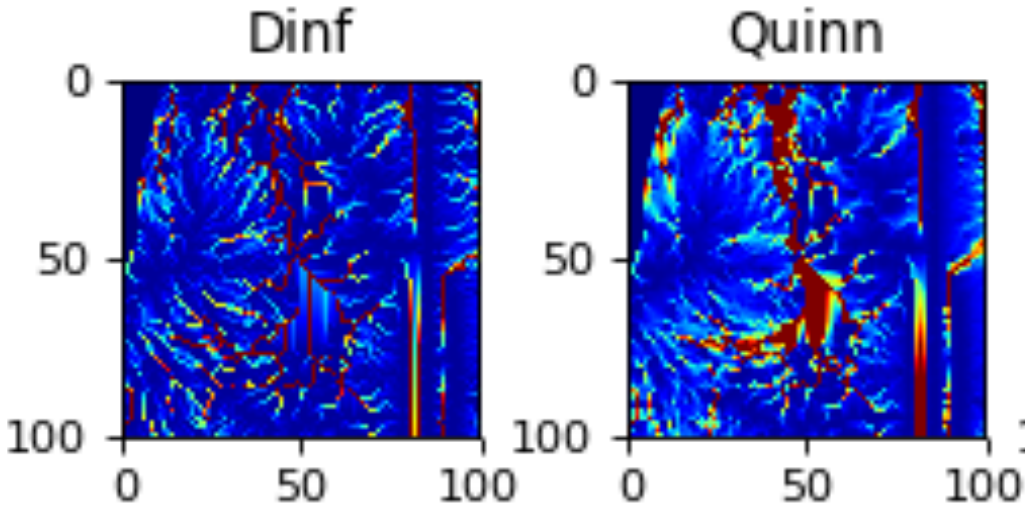


Gailleton (2020)

Step #2: Flow routing

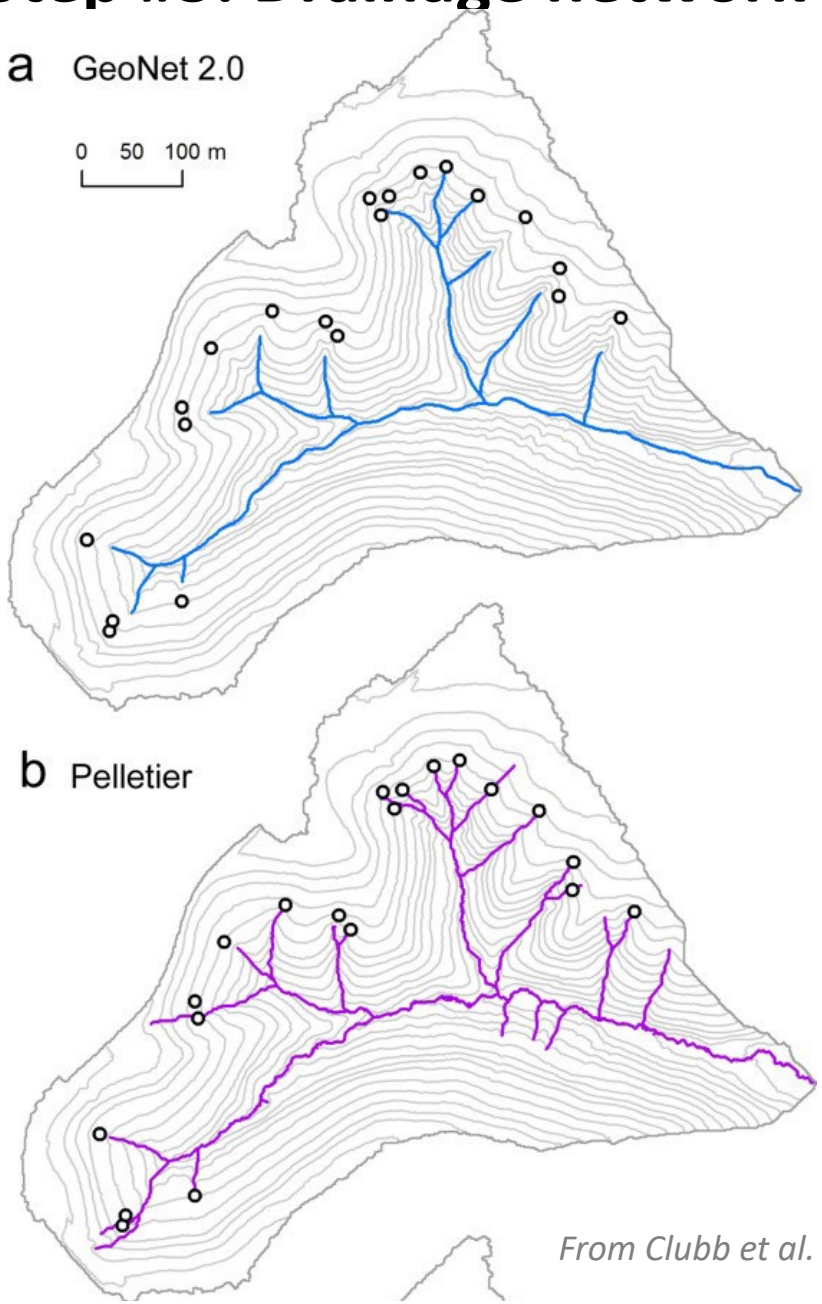


From RichDEM documentation



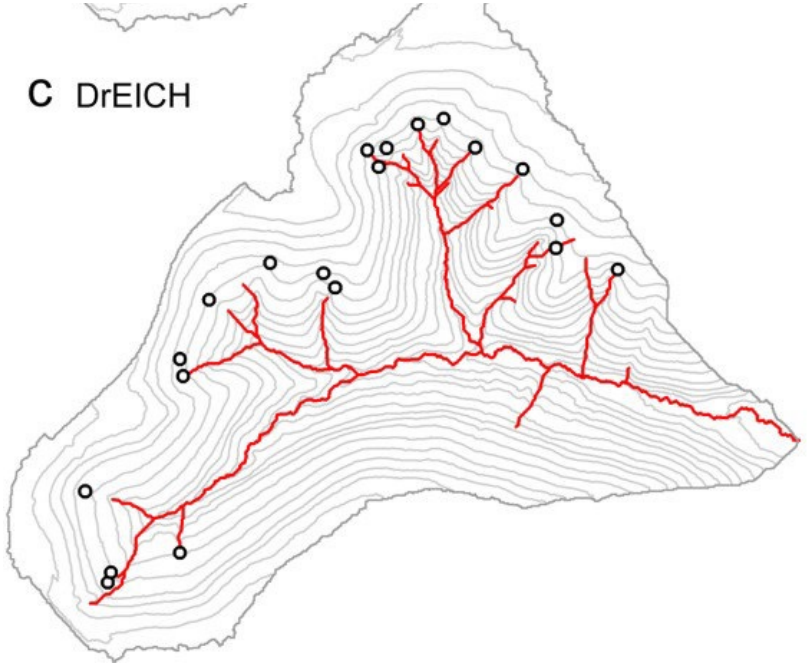
- Calculates behind the scene flow direction, flow accumulation, drainage area (eventually Discharge) and topological ordering (Braun and Willett, 2012)
- Depends on available data or what is needed
- Simple, straightforward and fast go-to method is D8 (i.e. except if you have a good reason not to)
- D8 assume water follows the steepest descent

Step #3: Drainage network extraction

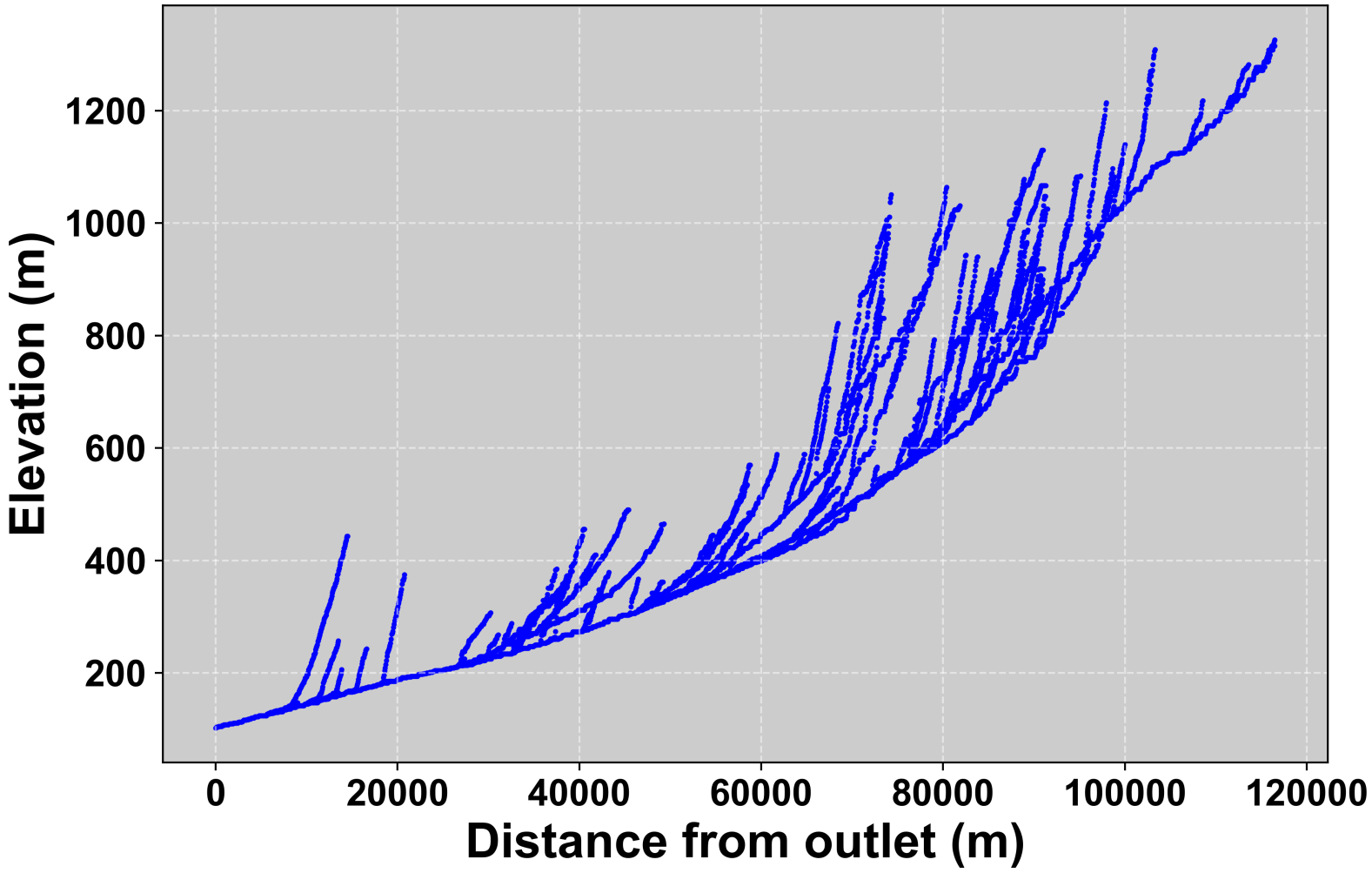


From Clubb et al. 2014

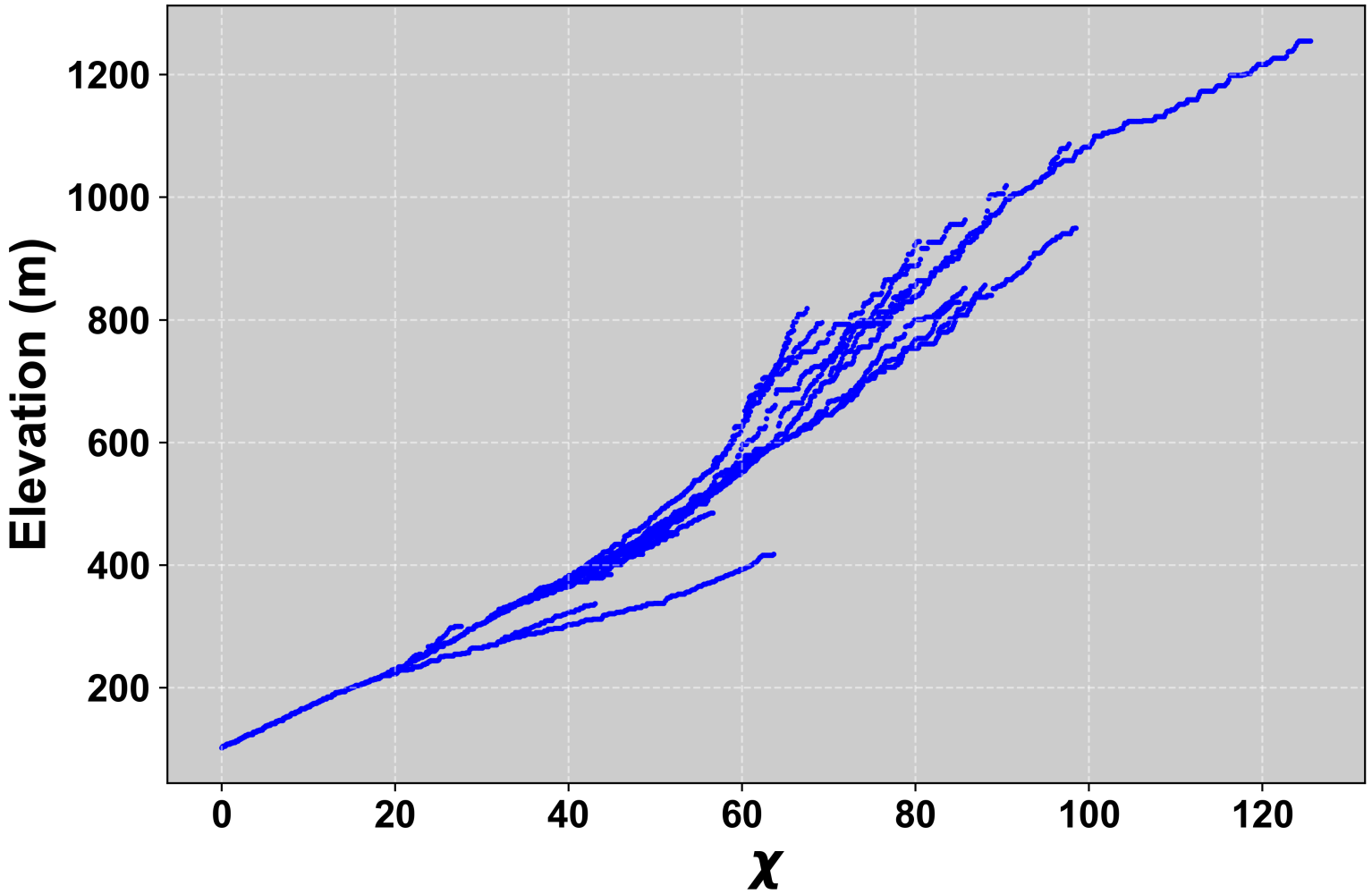
- Determine the channel head to build a network
- Again, it depends on the data and the study
- Straightforward solution if the exact location is not crucial: A or Q threshold



Step #4: Transforming long profile

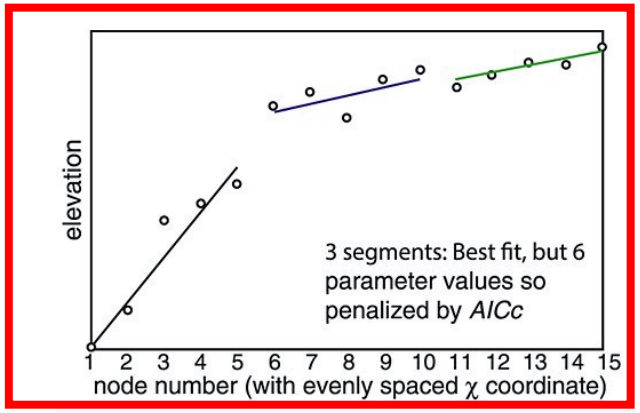


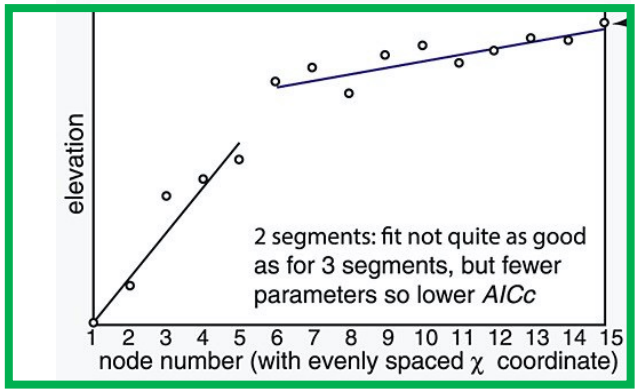
Step #4: Transformed long profile



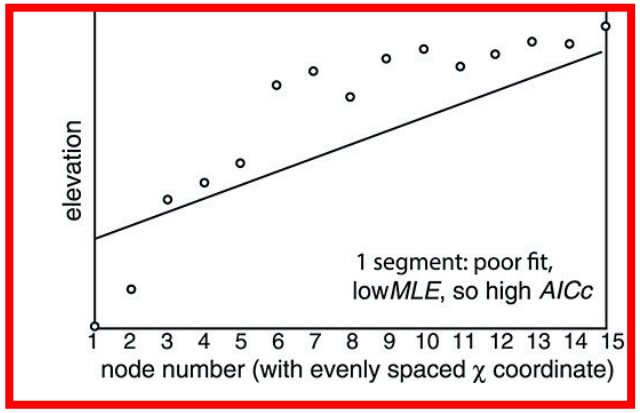
Step #4: Calculating segmented ksn

Too many segments = High penalty





Poor fit = High penalty



Mudd et al., (2014)

- Segment chi-profiles to find best combinations of ksn-segments
- Algorithm from Mudd et al.,2014 tests all combinations of segments and keeps the largest ones which fit the profile the best

References:

Website (to be updated): https://lsdtopotools.github.io/

Documentation (to be updated, no python tools) :
https://lsdtopotools.github.io/LSDTT_documentation/

lsdtopytools now available on conda-forge (the workshop gave me motivations):
https://anaconda.org/conda-forge/lsdtopytools

Complete version (C++ and command line):
https://github.com/LSDtopotools/LSDTopoTools2

Notebook examples (python tools and others):
https://github.com/LSDtopotools/lsdtt_notebooks

Contact: boris.gailleton@gfz-Potsdam.de - simon.m.mudd@ed.ac.uk

Also: https://www.youtube.com/channel/UCB4-XOd0afIW_RDhfuV2WFw

Software development

Simon Mudd, Edinburgh

Stuart Grieve, QMUL

David Milodowski, Edinburgh

Boris Gailleton, Edinburgh

Fiona Clubb, Durham

Martin Hurst, Glasgow

Declan Valters, Edinburgh