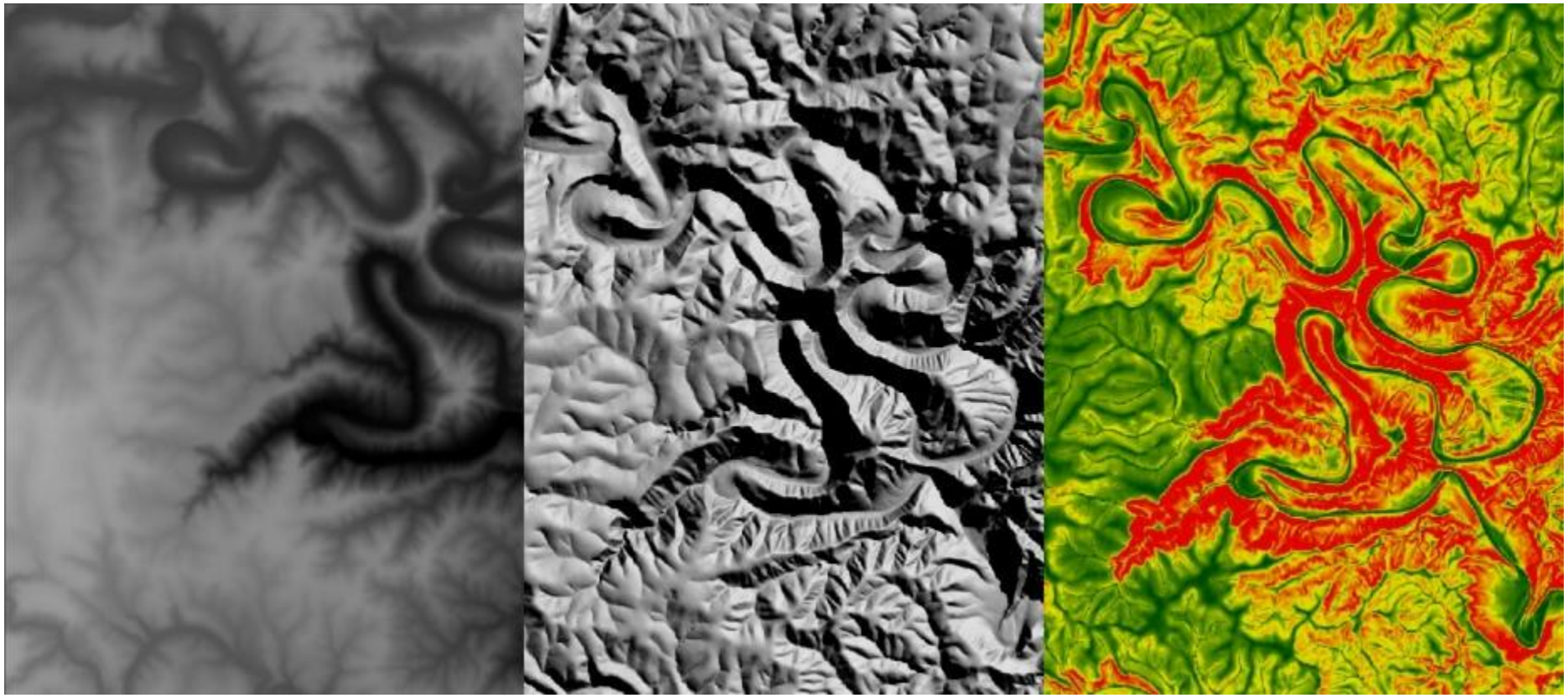

Terrain Analysis

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March 11, 2024

How to generate a DEM

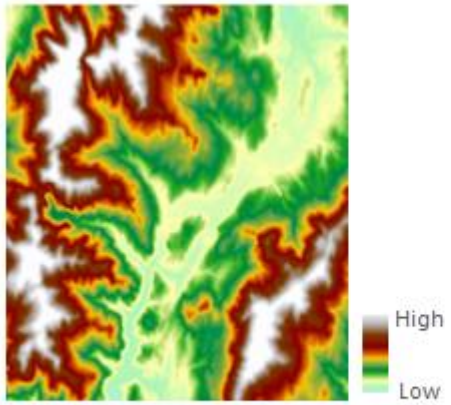
- **Photogrammetry**
- **Interferometric Synthetic Aperture Radar (InSAR)**
- **Lidar (Light Detection and Ranging)**

Available DEMs

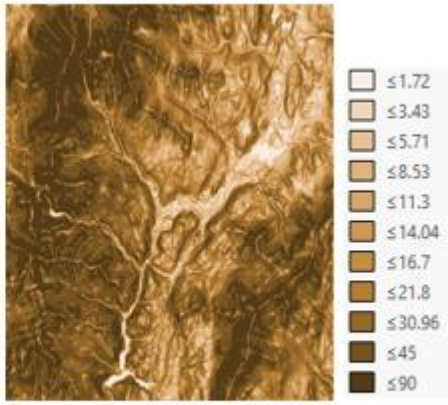
1. SRTM (Shuttle Radar Topography Mission)
2. ASTER Global Digital Elevation Model (GDEM)
3. ALOS World 3D (AW3D30)
4. TanDEM-X
5. Copernicus DEM (GLO30)
6. ArcticDEM
7. CDED

Primary Terrain Attributes

- **Slope**: Maximum elevation change between a pixel and its 8 neighbors, expressed in degrees or percentage.
  - Elevation change in X and in Y
  - 1 radian equals 180/π degrees
  - Atan converts the gradient to an angle



Input elevation raster



Output slope raster
(in degrees)

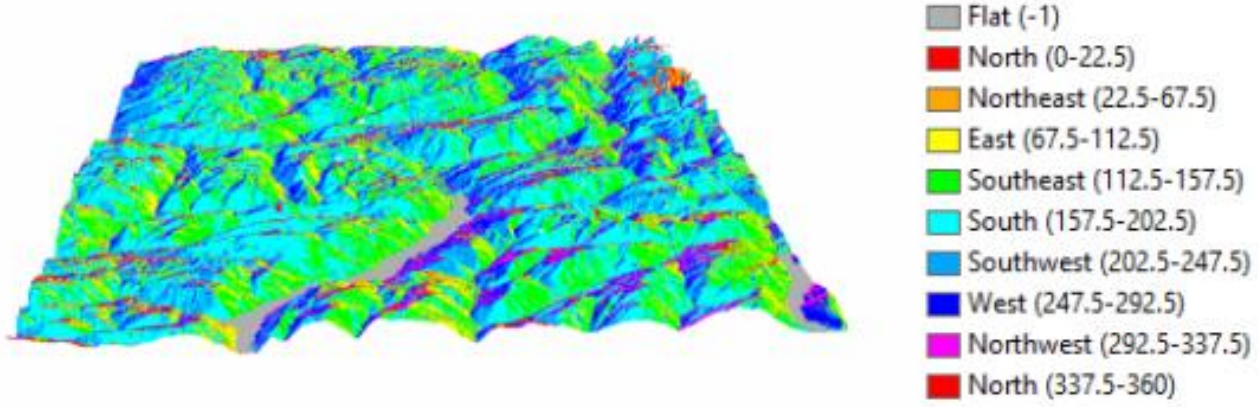
$$S_{\text{radians}} = \text{atan}\left(\sqrt{(\Delta z_x)^2 + (\Delta z_y)^2}\right)$$

$$S_{\text{degrees}} = \text{atan}\left(\sqrt{(\Delta z_x)^2 + (\Delta z_y)^2}\right) \times \frac{180}{\pi}$$

$$S_{\text{percentage}} = \sqrt{(\Delta z_x)^2 + (\Delta z_y)^2} \times 100$$

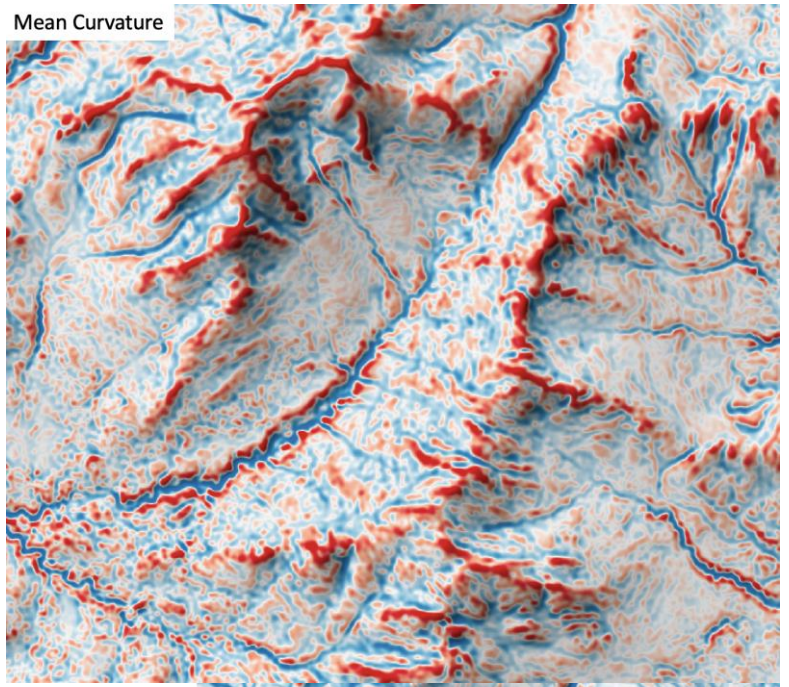
Primary Terrain Attributes

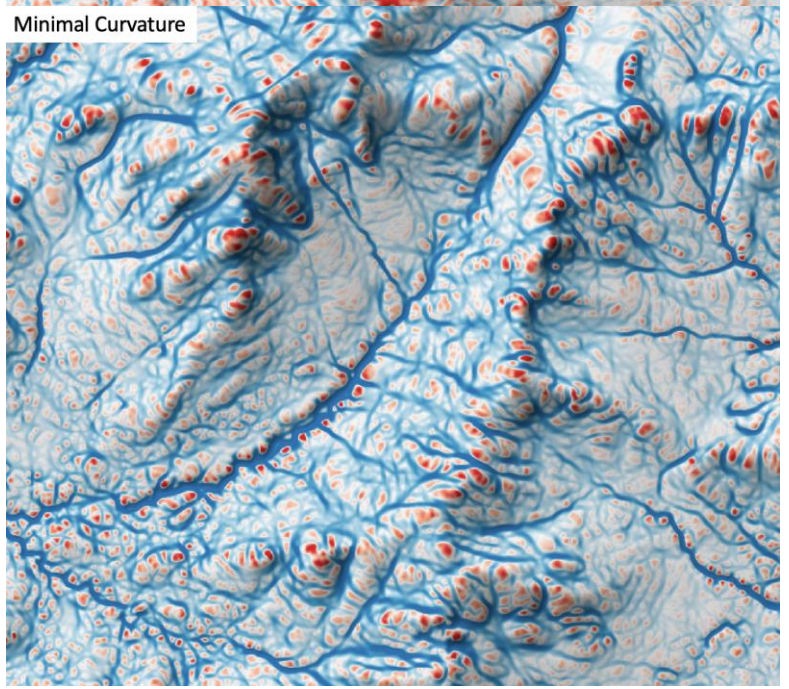
- **Aspect:** Compass direction in which the slope faces.
  - Flat (-1)
  - North (0°to 22.5°)
  - Northeast (22.5° to 67.5°)
  - East (67.5° to 112.5°)
  - Southeast (112.5° to 157.5°)
  - South (157.5° to 202.5°)
  - Southwest (202.5° to 247.5°)
  - West (247.5° to 292.5°)
  - Northwest (292.5° to 337.5°)
  - North (337.5° to 360°)



Primary Terrain Attributes

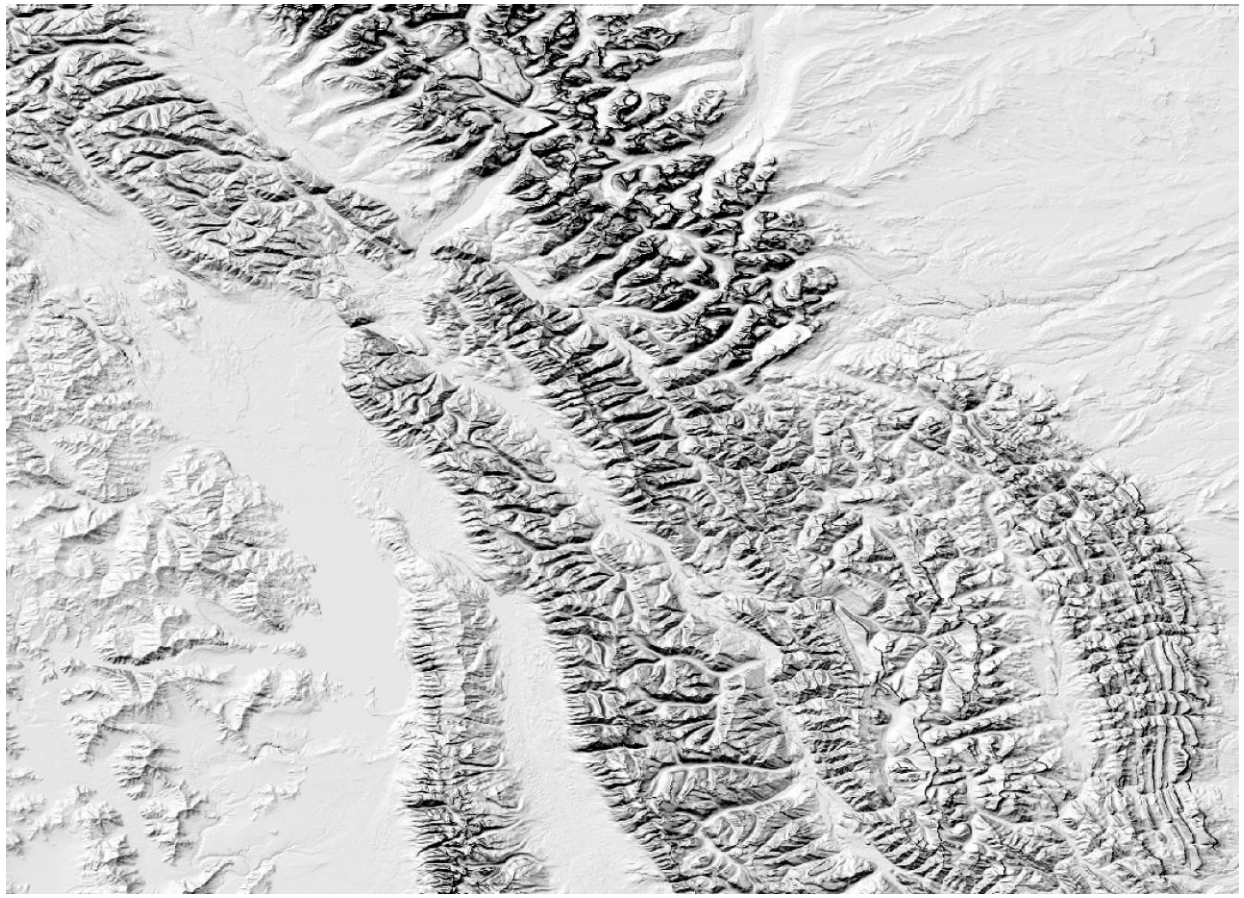
- **Curvature:** Describes the concavity or convexity of the surface, affecting runoff and erosion.





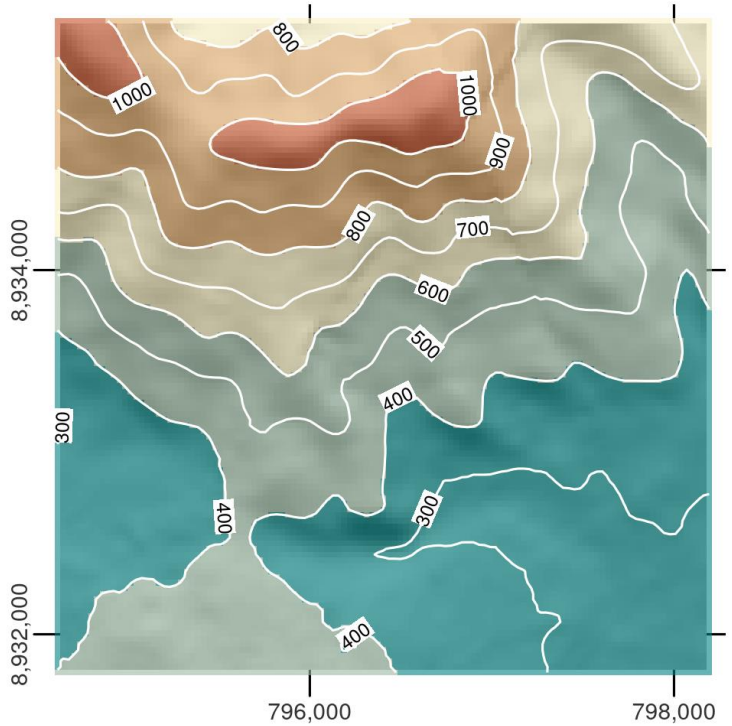
Visualization

- **Hillshade:** Simulating sunlight casting shadows across the terrain, based on sun elevation and azimuth.
- **Multidirectional hillshade:** multiple illumination sources.

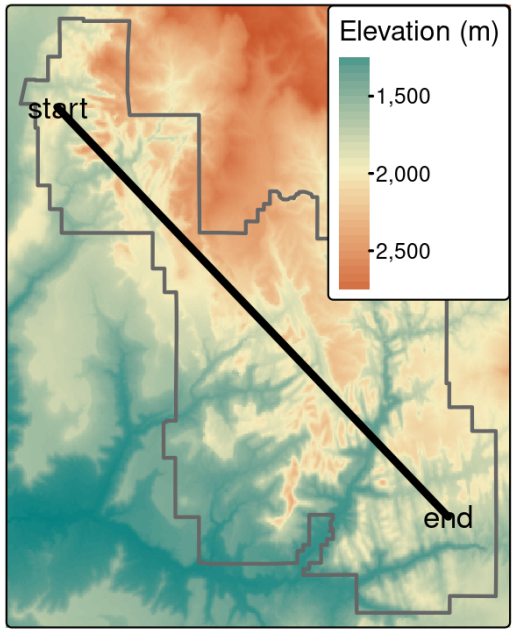


Visualization

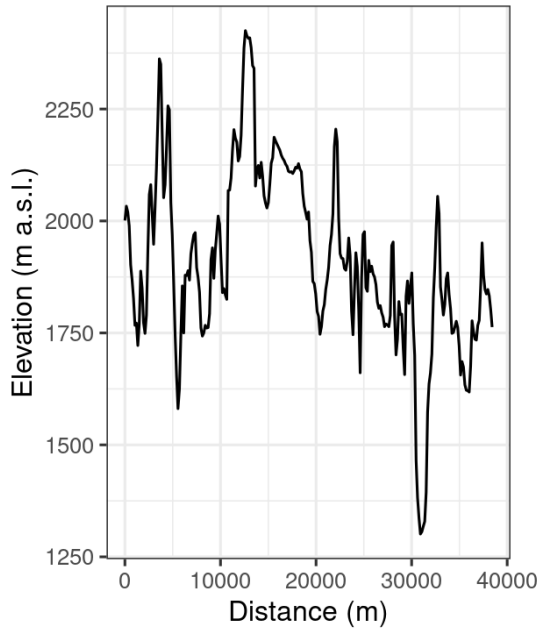
- **Contours:** from a DEM are lines of equal elevation derived by connecting points of the same height, creating a 2D representation of terrain relief.
- **Cross section:** Elevation values along a transect.



A. Line extraction

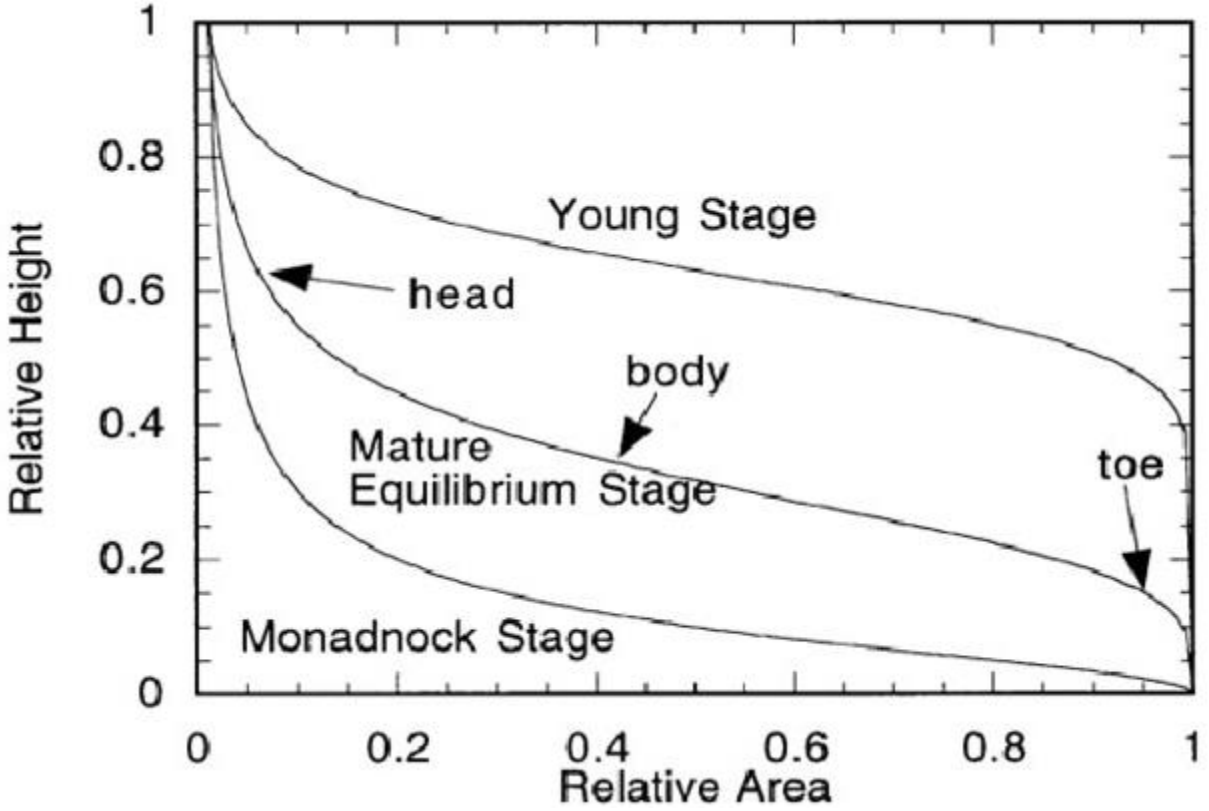


B. Elevation along the line



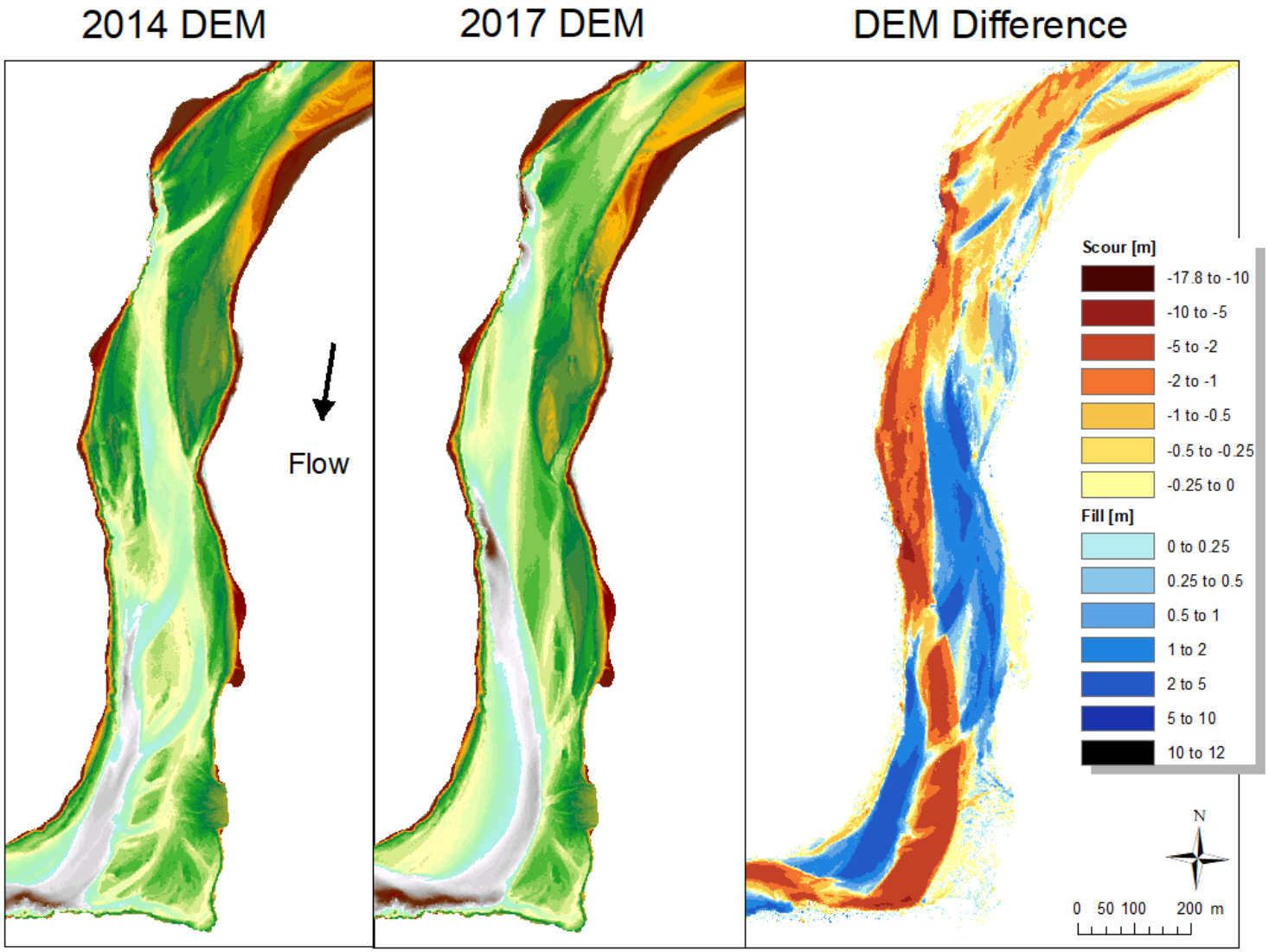
Hypsometry

- The hypsometric curve, which is a key tool in watershed hypsometry, plots the elevation of a land area against the area above a given elevation.



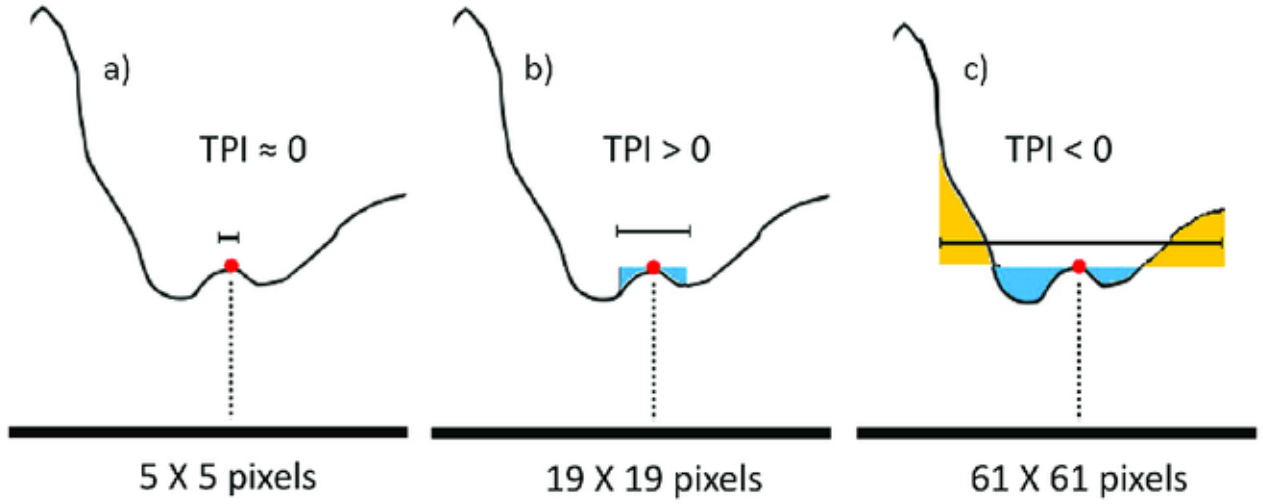
Change detection

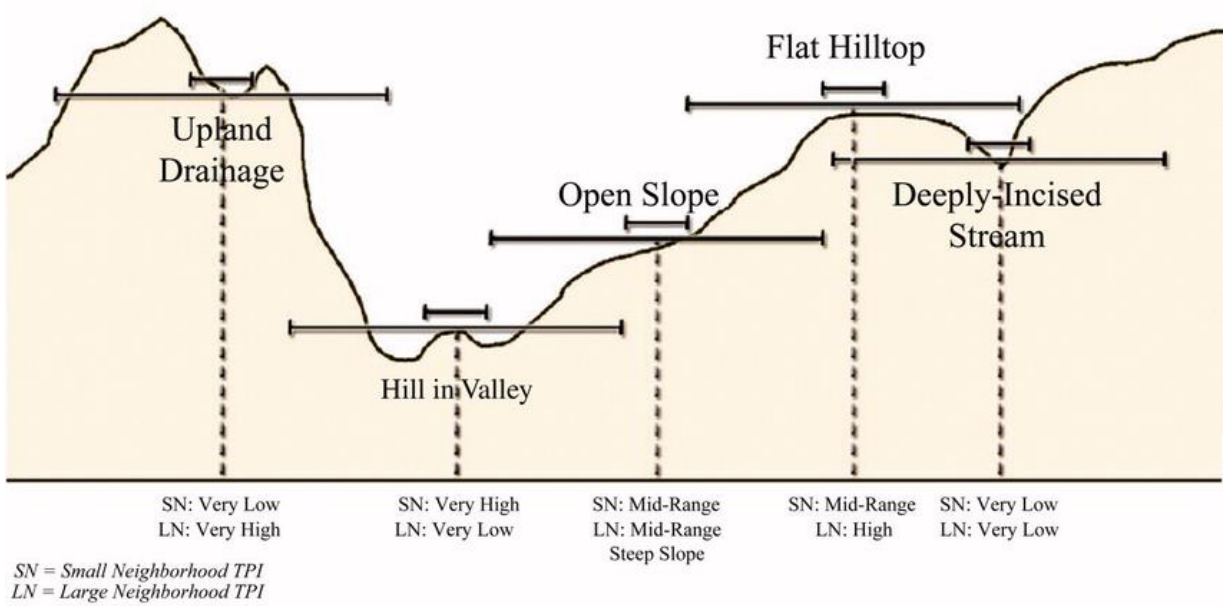
- Differencing
- Timeseries



Secondary Terrain Attributes

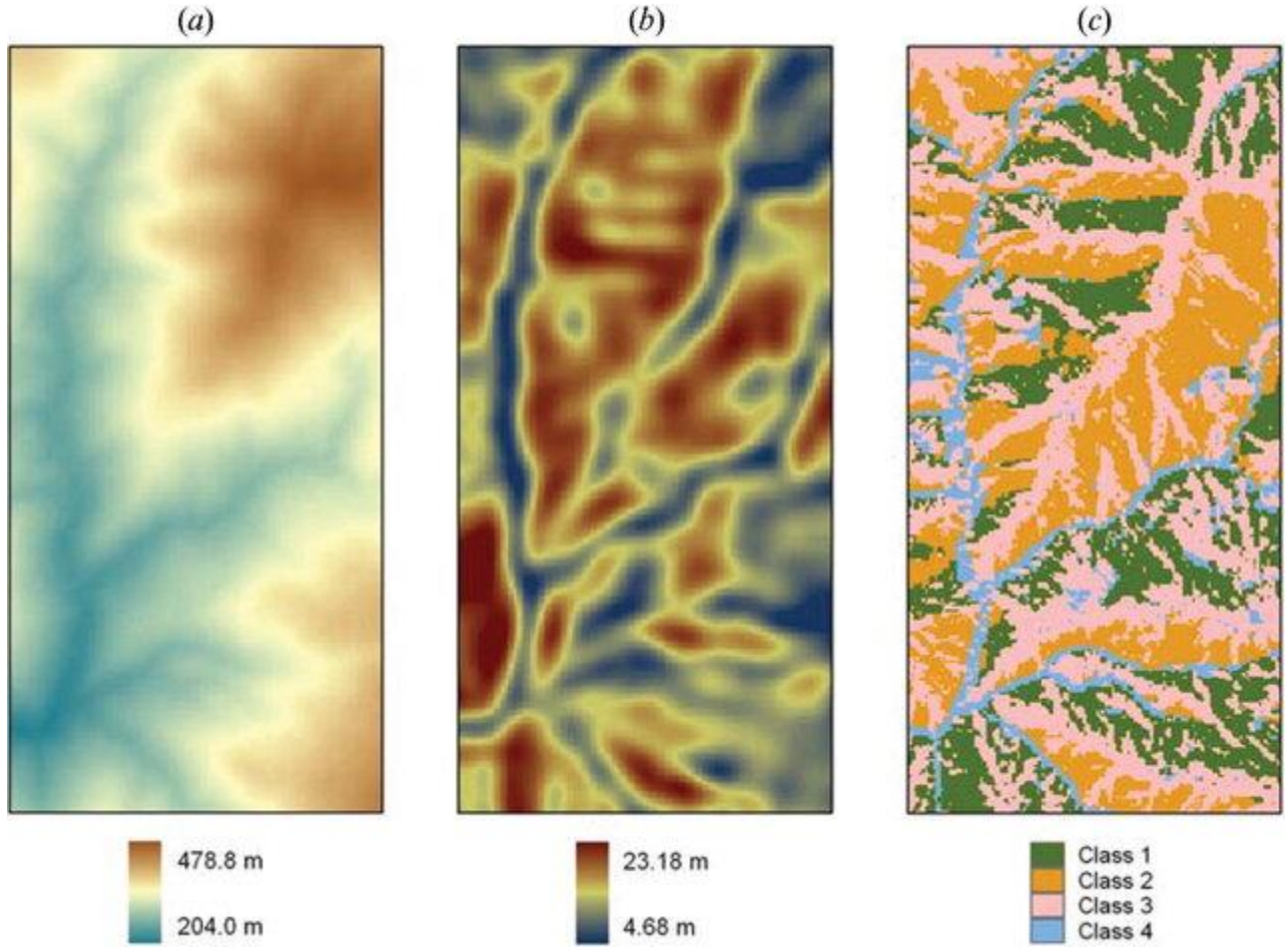
- **Topographic Position Index (TPI):** Relative position of a pixel to a neighborhood





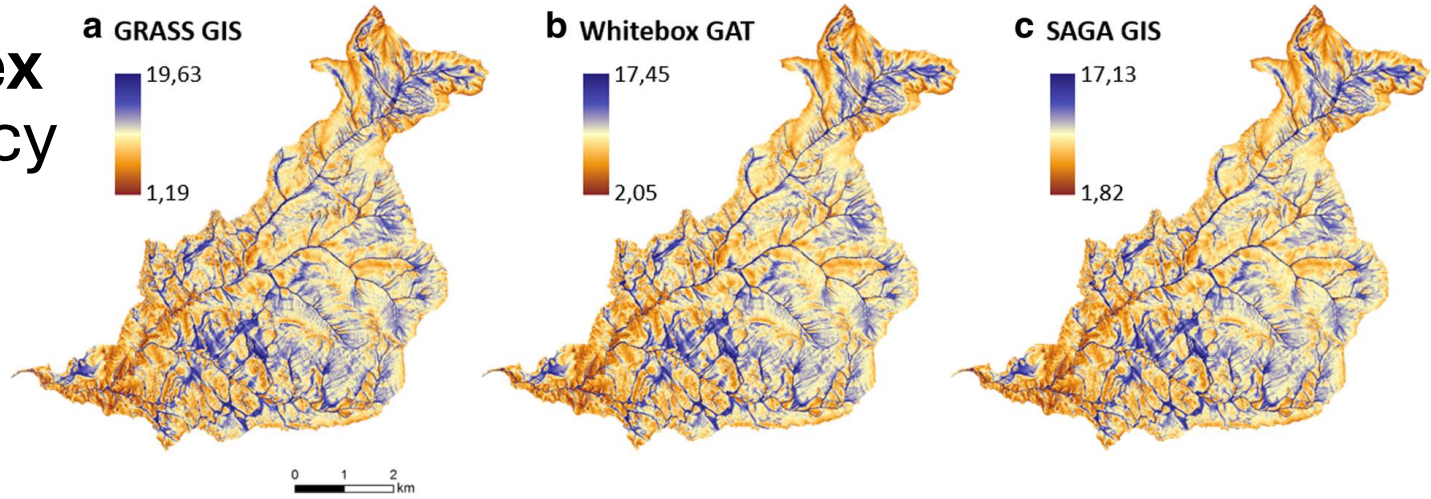
Secondary Terrain Attributes

- **Roughness:** Measures the variation in elevation within a specific neighborhood.



Secondary Terrain Attributes

- **Topographic Wetness Index (TWI):** Indicates the tendency of a location to accumulate water, considering both the slope and upstream area.
  - TWI = ln(a/tan(b))
    a = upslope contributing area (m^2)
    b = slope in radians
- **Stream Power Index (SPI):** Predicts the erosive power of flowing water on the terrain.
  - SI=ln(a·tan(b))
    a = upslope contributing area (m^2)
    b = slope in radians



https://opengeospatialdata.springeropen.com/articles/10.1186/s40965-019-0066-y

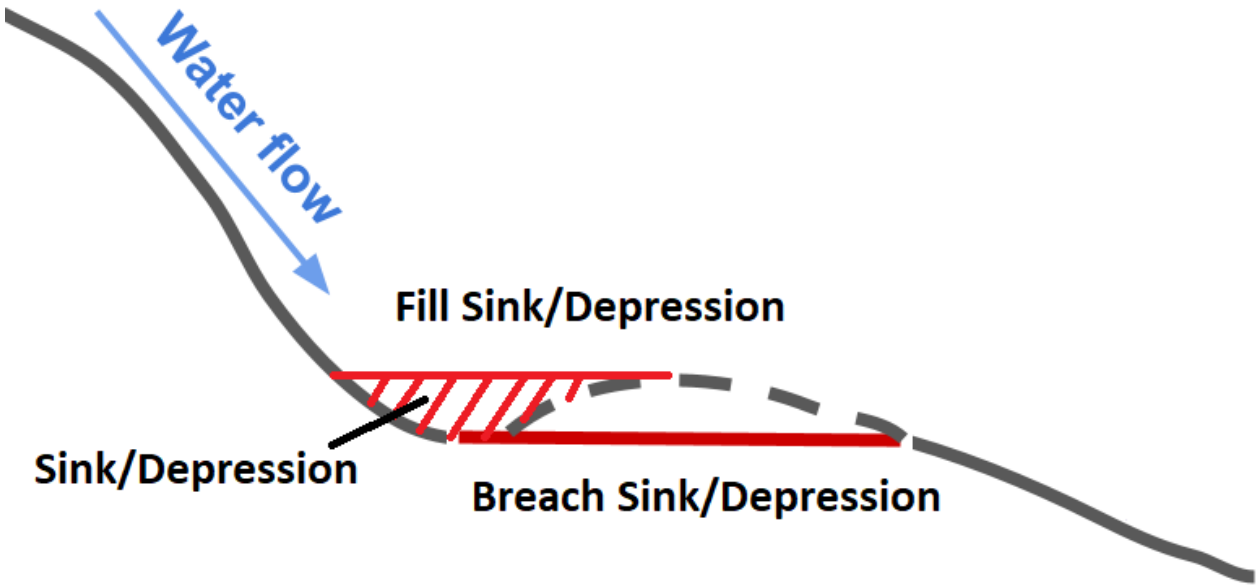
Secondary Terrain Attributes

- **Solar Radiation:** Estimates the amount of solar energy a surface receives, based on slope, aspect, and geographic location.

https://www.mdpi.com/2075-5309/4/2/195

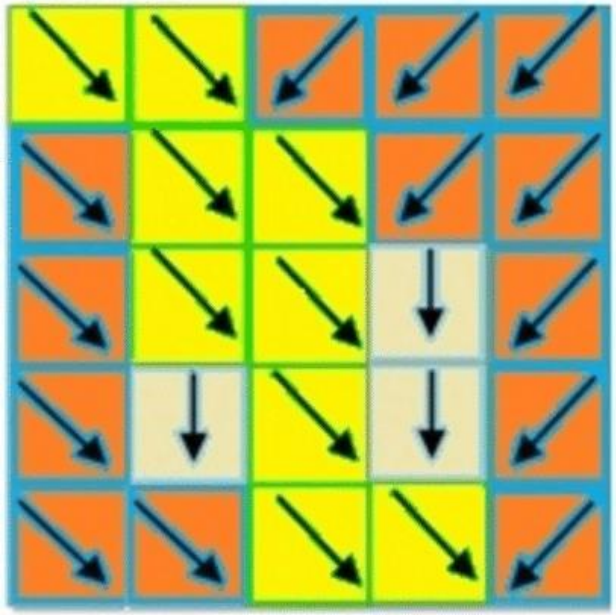
Hydrological Analysis

- **Fill depressions:** This tool can be used to fill all the depressions in a digital elevation model (DEM) and to remove the flat areas.



Secondary Terrain Attributes

- **Flow direction:** Determines the direction of water flow in a given cell. Based on the direction of the steepest descent in each cell.
- **Flow accumulation:** Represents the amount of water that would flow through each point, used in hydrology to predict streams and drainage patterns.



a- Flow Direction

0	0	0	0	0
0	1	2	2	1
2	4	5	2	1
1	7	8	4	0
1	2	10	12	1

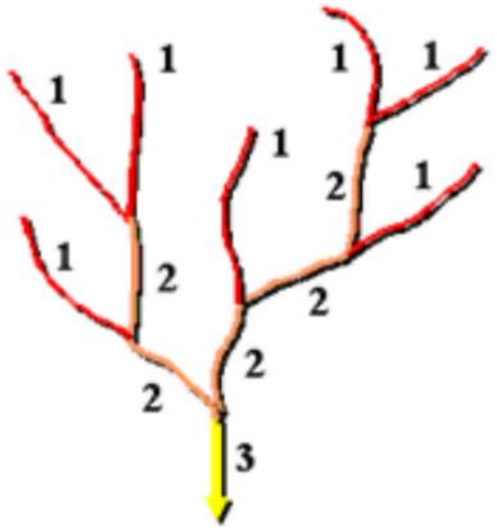
b- Flow Accumulation

Hydrological Analysis

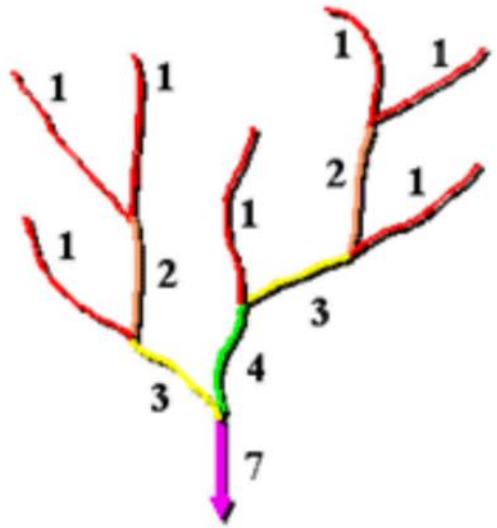
- **Extract stream network:** This tool can be used to extract, or map, the likely stream cells from an input flow-accumulation image.

Hydrological Analysis

- **Stream order:** Stream ordering is a method of assigning a numeric order to links in a stream network. This order is a method for identifying and classifying types of streams based on their numbers of tributaries.



Strahler stream ordering method



Shreve stream ordering method

Hydrological Analysis

- **Draw watershed:** With an outlet point defined and the flow direction raster, we can map the upstream catchment.