

HZDR

HELMHOLTZ ZENTRUM
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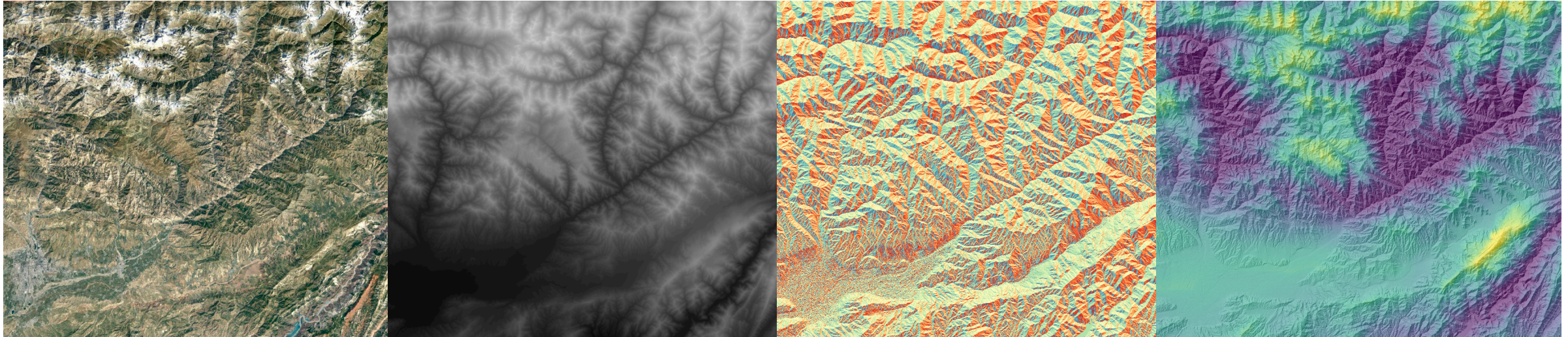
HiF

HELMHOLTZ INSTITUTE FREIBERG
FOR RESOURCE TECHNOLOGY



CLIENT II

International Partnerships
for Sustainable Innovations

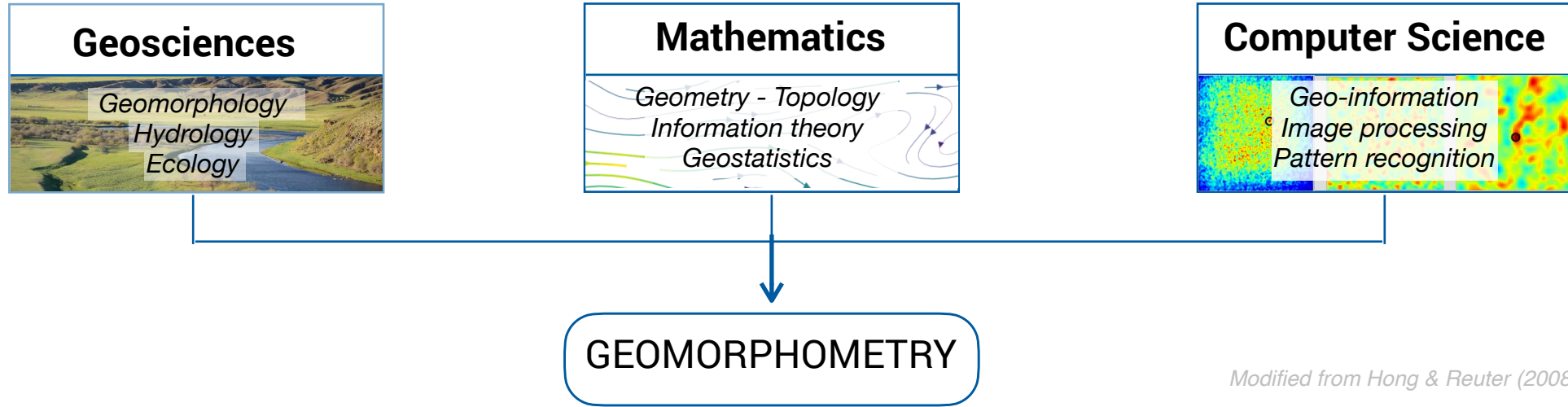


Morphometric analysis of landscapes using digital elevation models

Natalie Barbosa

www.hzdr.de/hif

GEOMORPHOMETRY

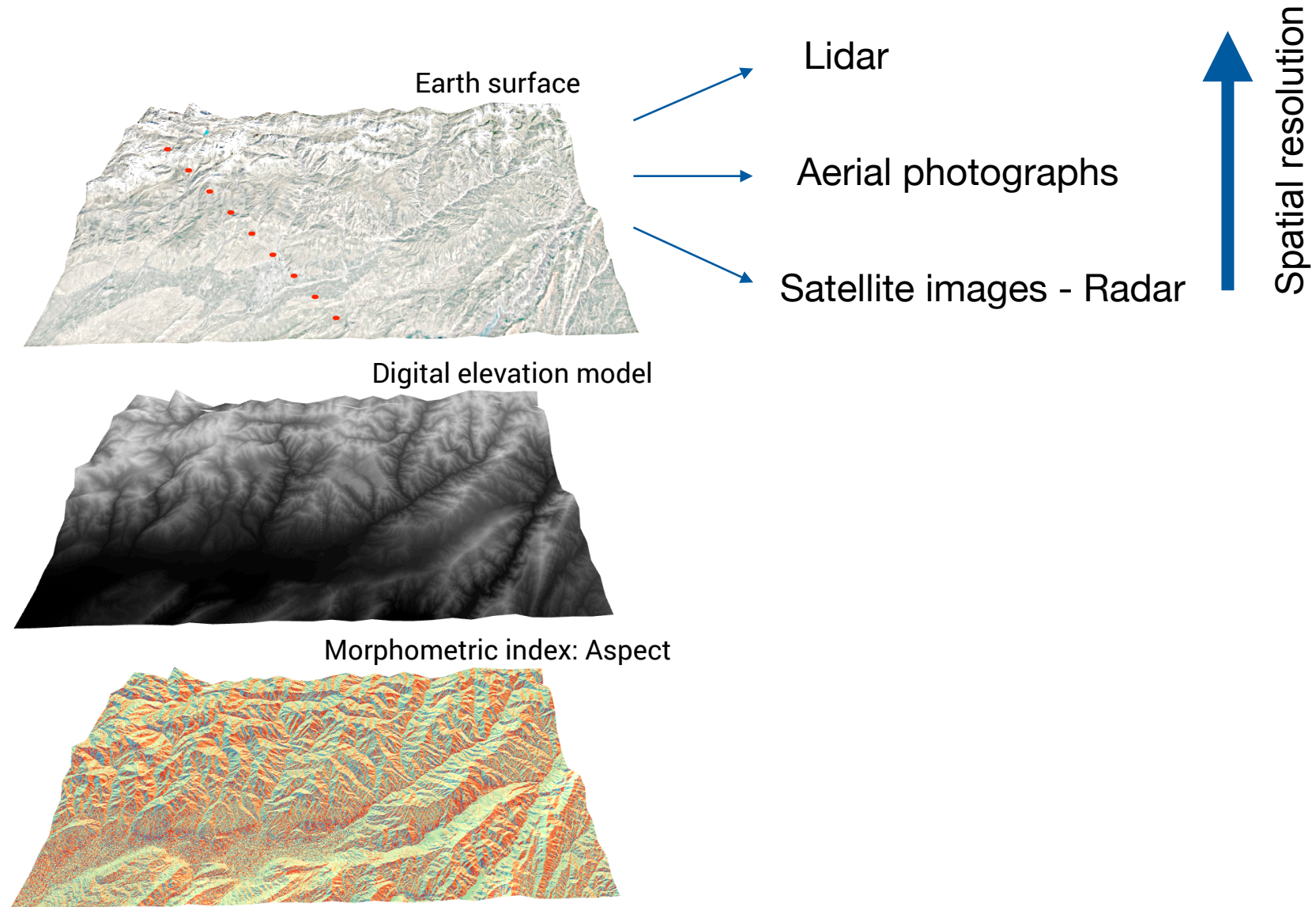
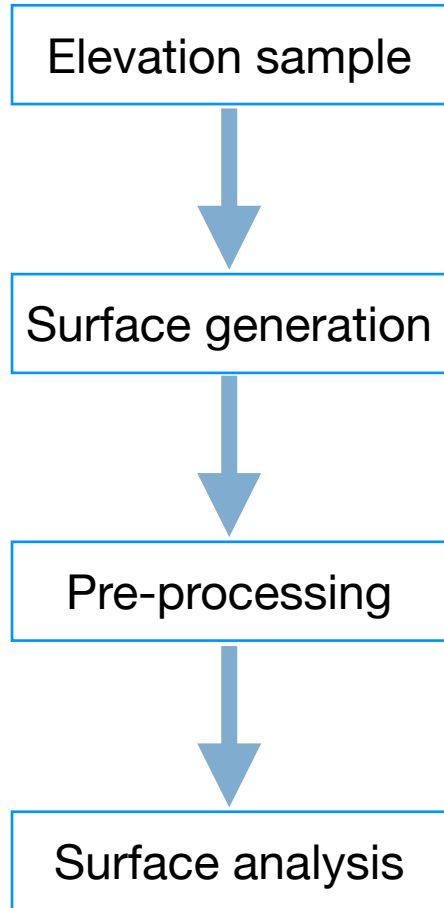


Modified from Hong & Reuter (2008)

Numerical representation of ground-surface and patterns.



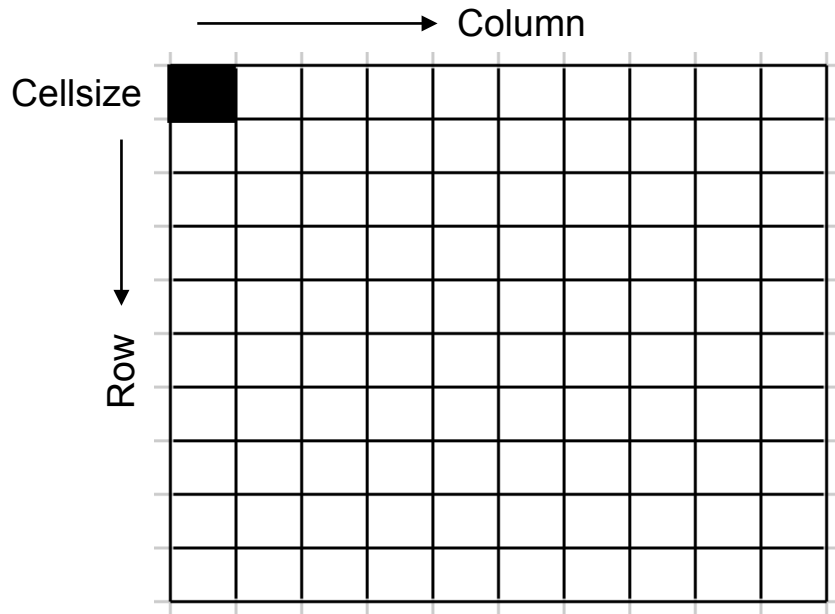
GEOMORPHOMETRY



DIGITAL ELEVATION MODEL (DEM)

Array of heights that can be manipulated mathematically

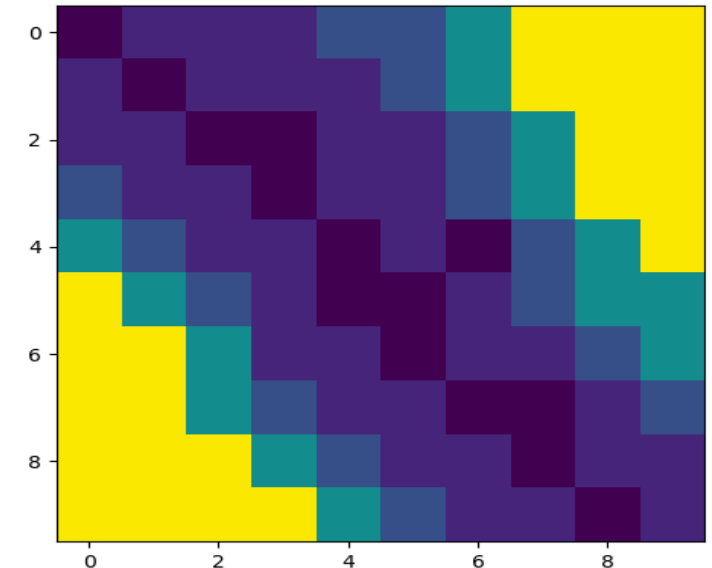
Raster structure



Raster with elevation information

3	4	4	4	5	5	7	11	11	11
4	3	4	4	4	5	7	11	11	11
4	4	3	3	4	4	5	7	11	11
5	4	4	3	4	4	5	7	11	11
7	5	4	4	3	4	3	5	7	11
11	7	5	4	3	3	4	5	7	7
11	11	7	4	4	3	4	4	5	7
11	11	7	5	4	4	3	3	4	5
11	11	11	7	5	4	4	3	4	4
11	11	11	11	7	5	4	4	3	4

Digital elevation model



DIGITAL ELEVATION MODEL (DEM)

DEM sources

USGS
science for a changing world

EarthExplorer Help Feedback Login

Search Criteria Data Sets Additional Criteria Results

4. Search Results
If you selected more than one data set to search, use the dropdown to see the search results for each specific data set.
Note: You must be logged in to download and order scenes

Show Result Controls

Data Set [Click here to export your results](#)

SRTM 1 Arc-Second Global

	Entity ID: SRTM1N38E067V3 Publication Date: 2014-09-23 00:00:00-05 Resolution: 1-ARC Coordinates: 38 , 67
	Entity ID: SRTM1N38E068V3 Publication Date: 2014-09-23 00:00:00-05 Resolution: 1-ARC Coordinates: 38 , 68
	Entity ID: SRTM1N38E069V3 Publication Date: 2014-09-23 00:00:00-05 Resolution: 1-ARC Coordinates: 38 , 69
	Entity ID: SRTM1N38E070V3 Publication Date: 2014-09-23 00:00:00-05 Resolution: 1-ARC

Search Criteria Summary (Show) Clear Search Criteria

(39° 30' 15" N, 071° 26' 40" E) Options + -

<https://earthexplorer.usgs.gov/>

<https://asterweb.jpl.nasa.gov/gdem.asp>

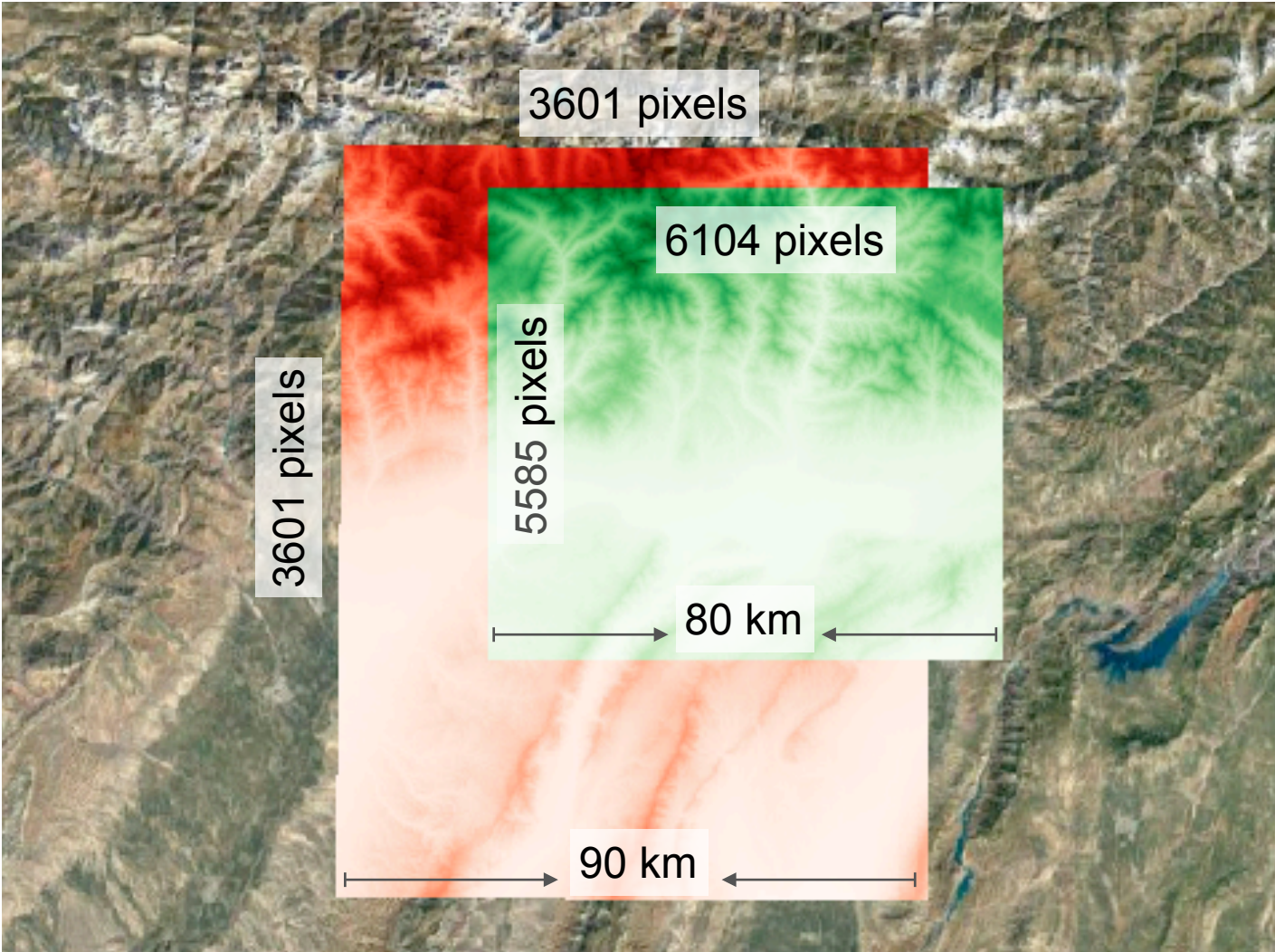
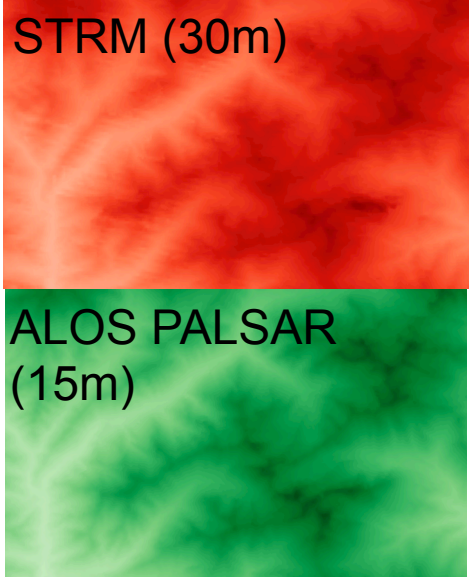
DIGITAL ELEVATION MODEL (DEM)

DEM sources

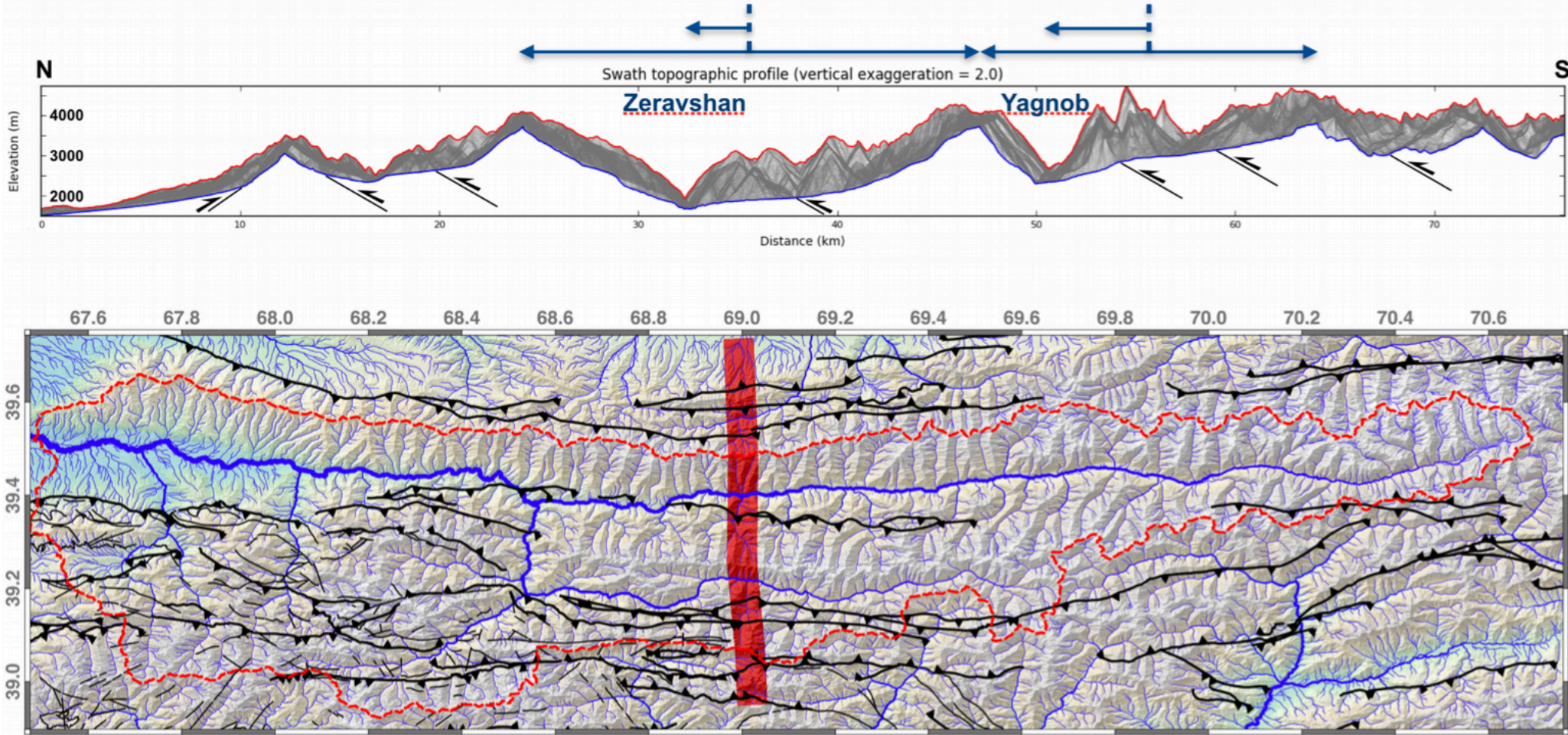
ALOS PALSAR (15 meter resolution)

The screenshot shows the ASF Data Search Vertex interface. At the top, there are search filters for 'Geographic' search type, 'ALOS PALSAR' dataset, and a polygon area of interest centered on Dushanbe, Tajikistan. The map displays various geographical features and labels in Tajik and Russian. Below the map, a list of 10 scenes is shown, with the selected scene 'ALPSRP074200760' highlighted. The scene details panel on the right shows a list of data products, with 'Hi-Res Terrain Corrected' (323.32 MB) highlighted by a red box and a red arrow pointing to it. Other products include 'Level 1.1 Complex' (1.14 GB), 'Level 1.0' (408.51 MB), 'Level 1.5 Image' (85.70 MB), and 'Low-Res Terrain Corrected' (69.90 MB). The interface also includes a 'Scene Detail' section with a thumbnail image of the terrain data.

DIGITAL ELEVATION MODEL (DEM)



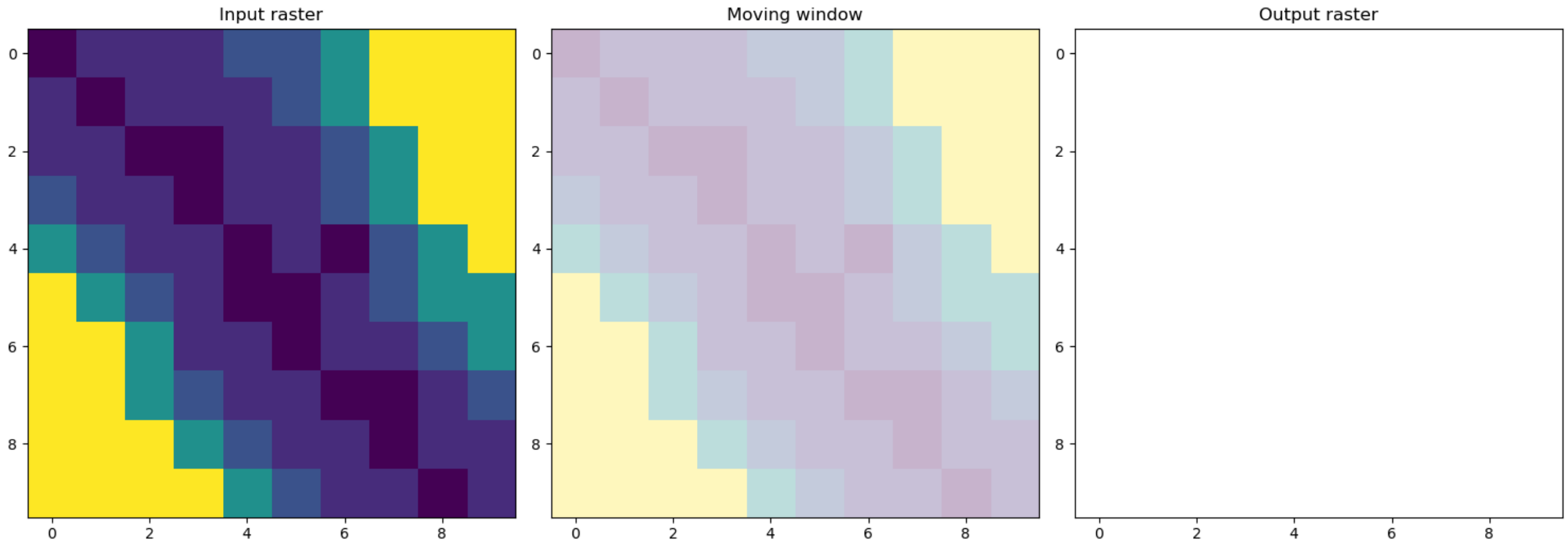
SWATH TOPOGRAPHIC PROFILE



MORPHOMETRIC INDICES

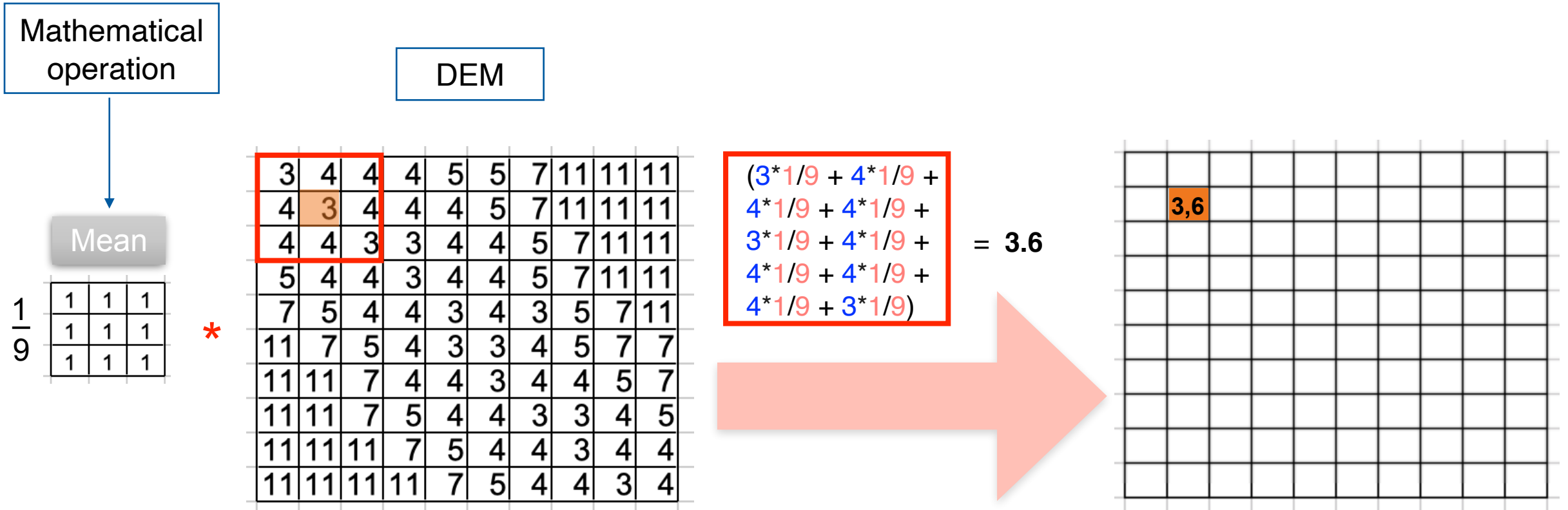
Moving window

Matrix used to applied a mathematical operation by slicing the moving window along the DEM



MORPHOMETRIC INDICES

Moving window



MORPHOMETRIC INDICES

Moving window

Mathematical operation

DEM

Mean

Mean elevation

$\frac{1}{9}$

1	1	1
1	1	1
1	1	1

3	4	4	4	5	5	7	11	11	11
4	3	4	4	4	5	7	11	11	11
4	4	3	3	4	4	5	7	11	11
5	4	4	3	4	4	5	7	11	11
7	5	4	4	3	4	3	5	7	11
11	7	5	4	3	3	4	5	7	7
11	11	7	4	4	3	4	4	5	7
11	11	7	5	4	4	3	3	4	5
11	11	11	7	5	4	4	3	4	4
11	11	11	11	7	5	4	4	3	4

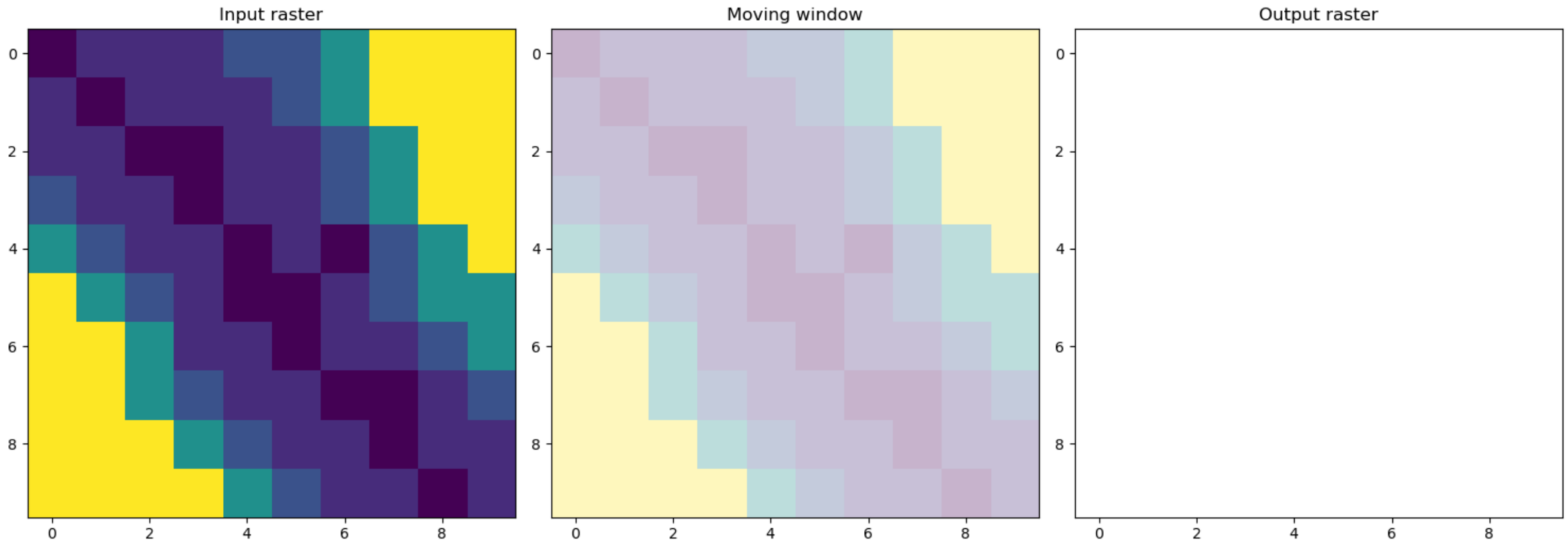
3,4	3,6	3,8	4,2	4,5	5,5	7,6	9,6	11	11
3,6	3,6	3,6	3,8	4,2	5,1	6,8	9	10,5	11
4,1	3,8	3,5	3,6	3,8	4,6	6,1	8,3	10	11
5	4,4	3,7	3,5	3,6	4	4,8	6,7	9	10,5
6,8	5,7	4,4	3,7	3,5	3,6	4,4	6	7,8	9,2
9	7,5	5,6	4,2	3,5	3,4	3,8	4,8	6,4	7,6
10,5	9	6,7	4,7	3,7	3,5	3,6	4,3	5,2	6
11	10,5	8,2	6	4,4	3,8	3,5	3,7	4,3	5
11	10,5	9,4	7,5	5,7	4,4	3,7	3,5	3,7	4,1
11	11	10,5	9	6,8	5	4,1	3,6	3,6	3,7

- Slope
- Min elevation
- Max elevation
- Local relief
- Surface roughness
- Others

MORPHOMETRIC INDICES

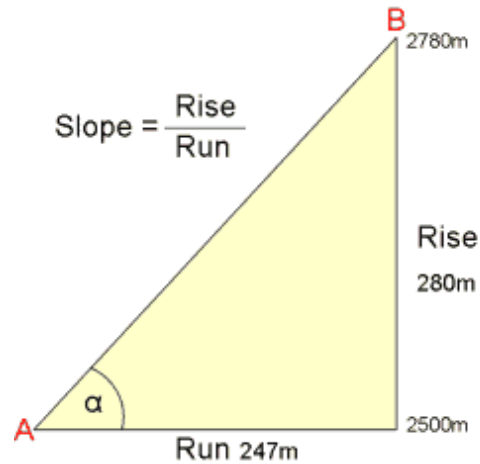
Moving window

Matrix used to applied a mathematical operation by slicing the moving window along the DEM



MORPHOMETRIC INDICES

Slope



Slope is measured as the **maximum rate of change** in value from a cell to its immediate neighbours.

First derivative

$$\nabla Z = \left(\frac{\partial z}{\partial x}, \frac{\partial z}{\partial y} \right)$$

a	b	c
d	e	f
g	h	i

Angle between the horizontal plane and the one tangential to the surface

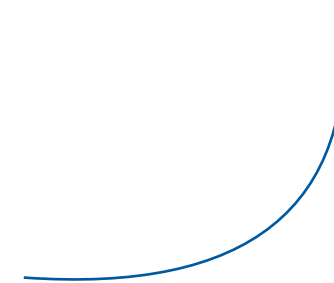
$$\text{slope_radians} = \text{ATAN} \left(\sqrt{ \left[\frac{dz}{dx} \right]^2 + \left[\frac{dz}{dy} \right]^2 } \right)$$

dz/dx

$\frac{1}{-6 \cdot \Delta s}$	0	$\frac{1}{6 \cdot \Delta s}$
$\frac{1}{-6 \cdot \Delta s}$	0	$\frac{1}{6 \cdot \Delta s}$
$\frac{1}{-6 \cdot \Delta s}$	0	$\frac{1}{6 \cdot \Delta s}$

dz/dy

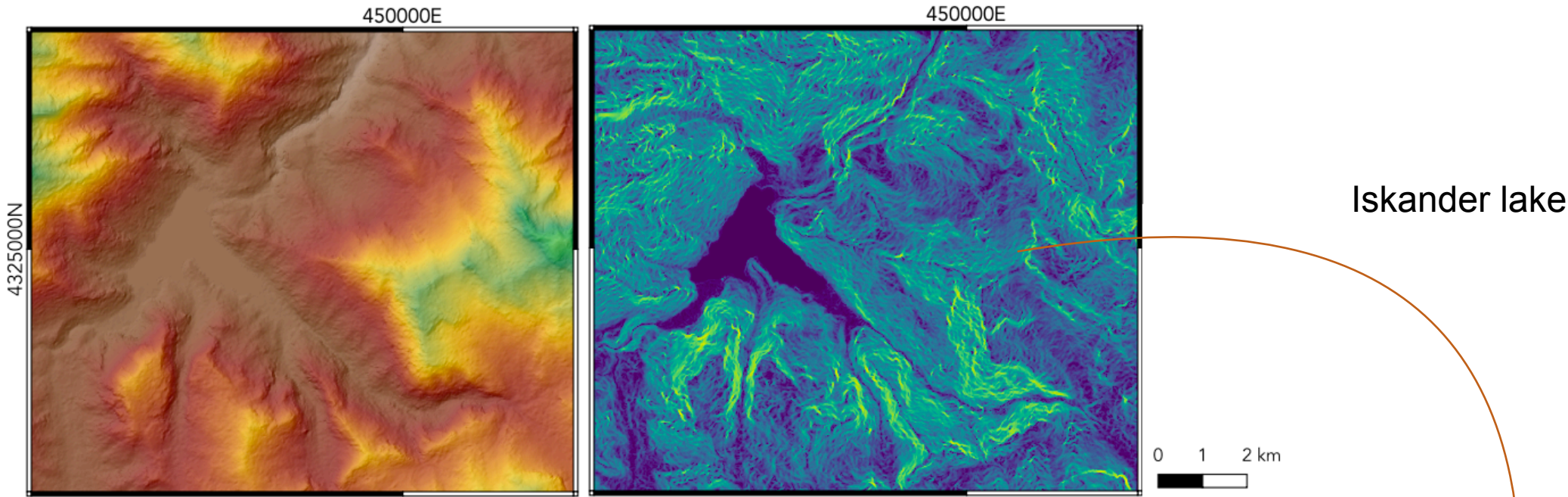
$\frac{1}{-6 \cdot \Delta s}$	$\frac{1}{-6 \cdot \Delta s}$	$\frac{1}{-6 \cdot \Delta s}$
0	0	0
$\frac{1}{6 \cdot \Delta s}$	$\frac{1}{6 \cdot \Delta s}$	$\frac{1}{6 \cdot \Delta s}$



Modified from <https://pro.arcgis.com/en/pro-app/tool-reference/3d-analyst/how-slope-works.htm>

MORPHOMETRIC INDICES

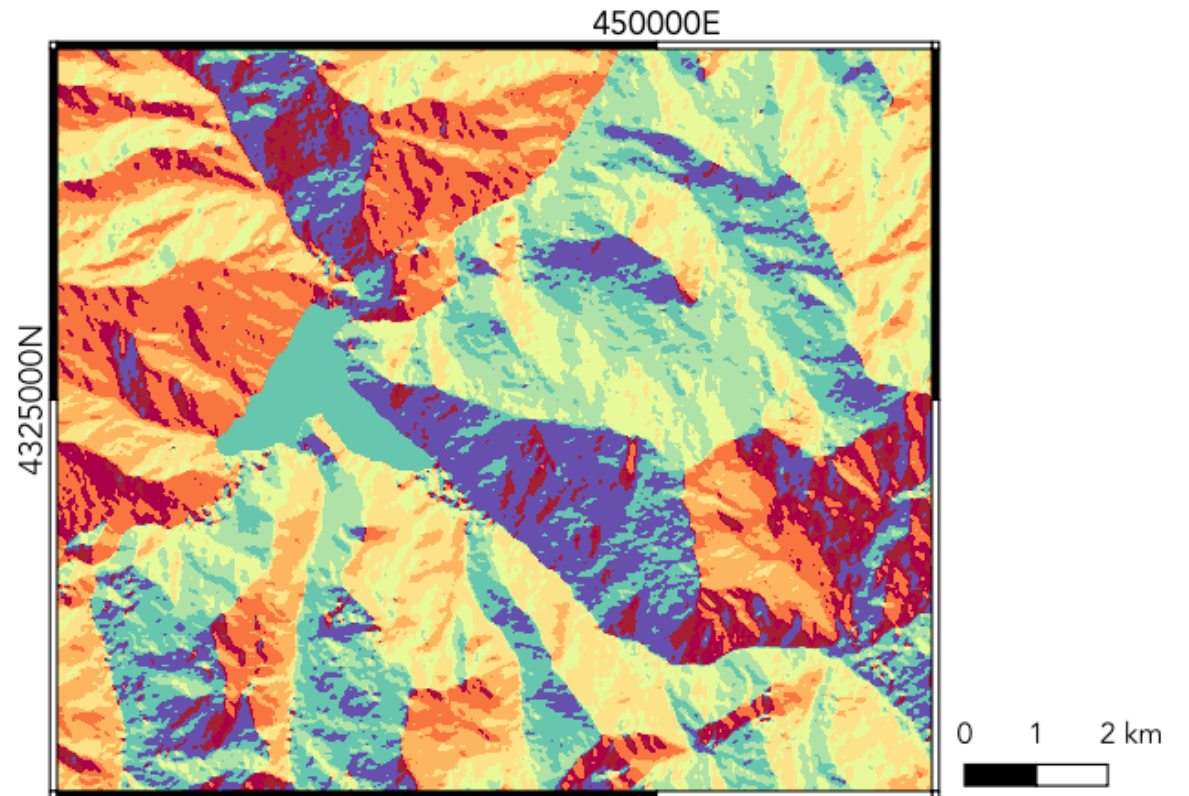
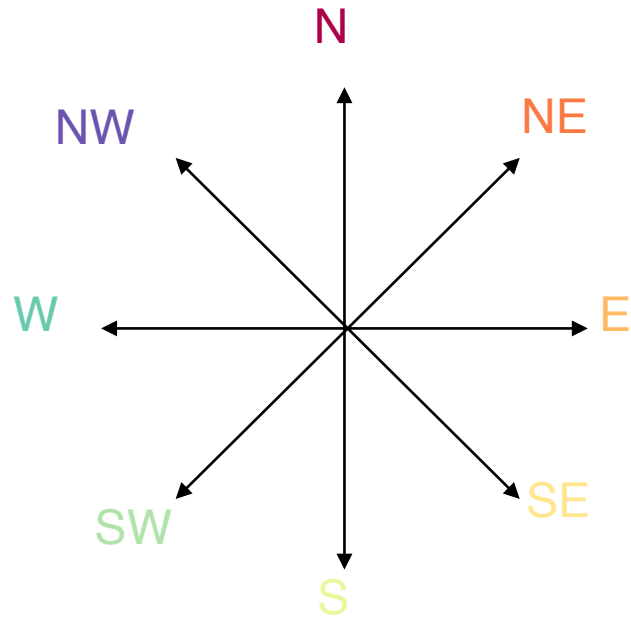
Slope



MORPHOMETRIC INDICES

Aspect

Aspect identifies the downslope direction of the maximum rate of change in value from each pixel to its neighbours

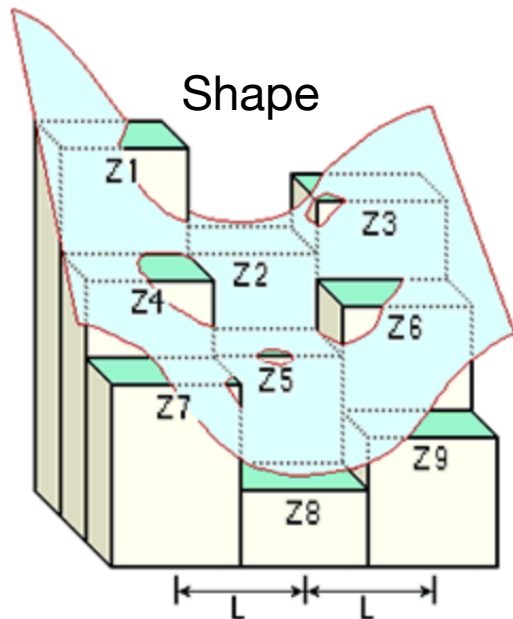


MORPHOMETRIC INDICES

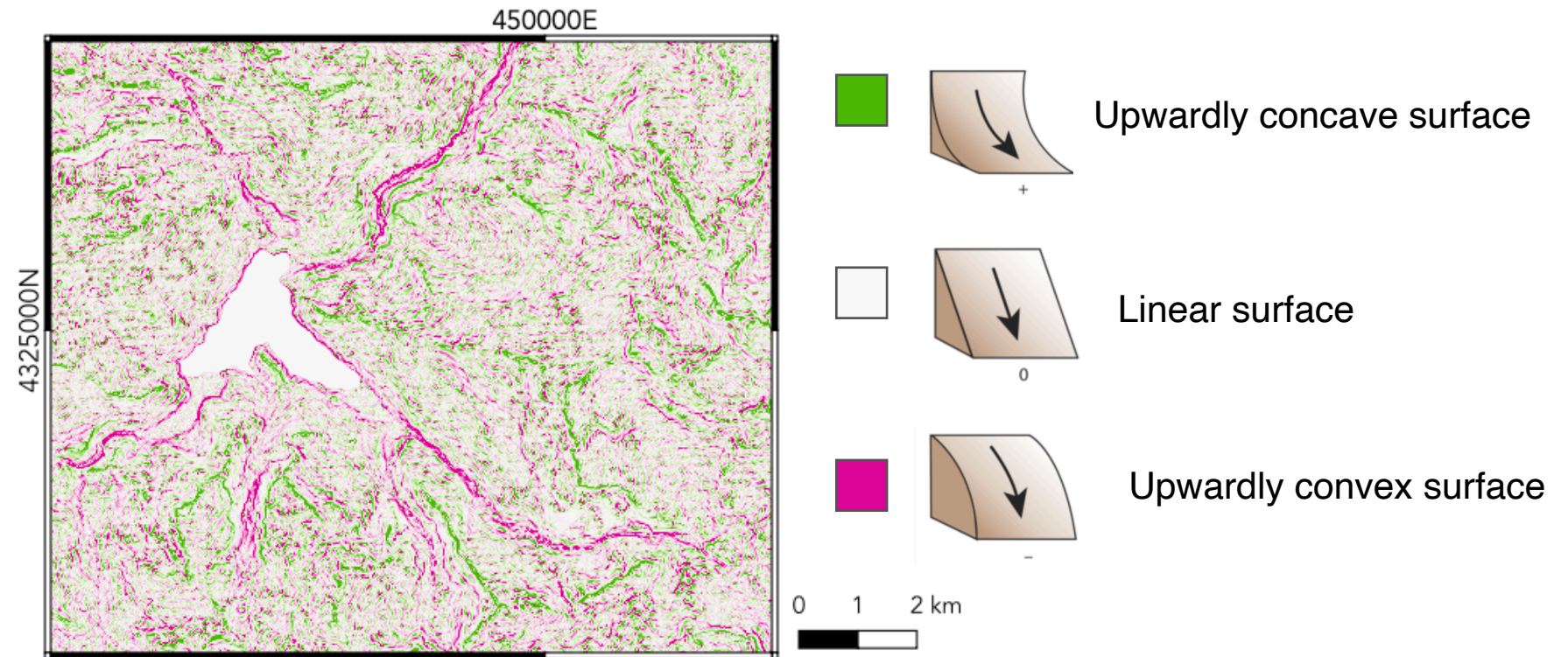
Curvature

Second derivative

$$\nabla^2 Z = \left(\frac{\partial^2 z}{\partial x^2}, \frac{\partial^2 z}{\partial y^2} \right)$$



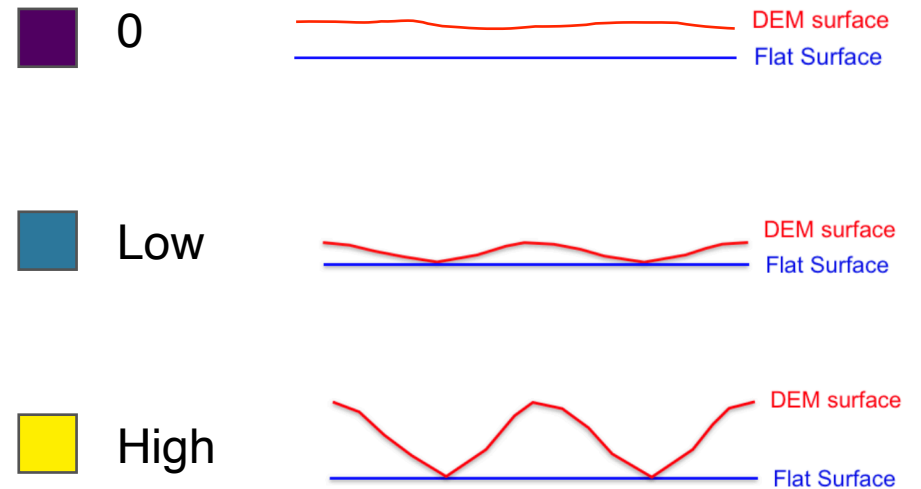
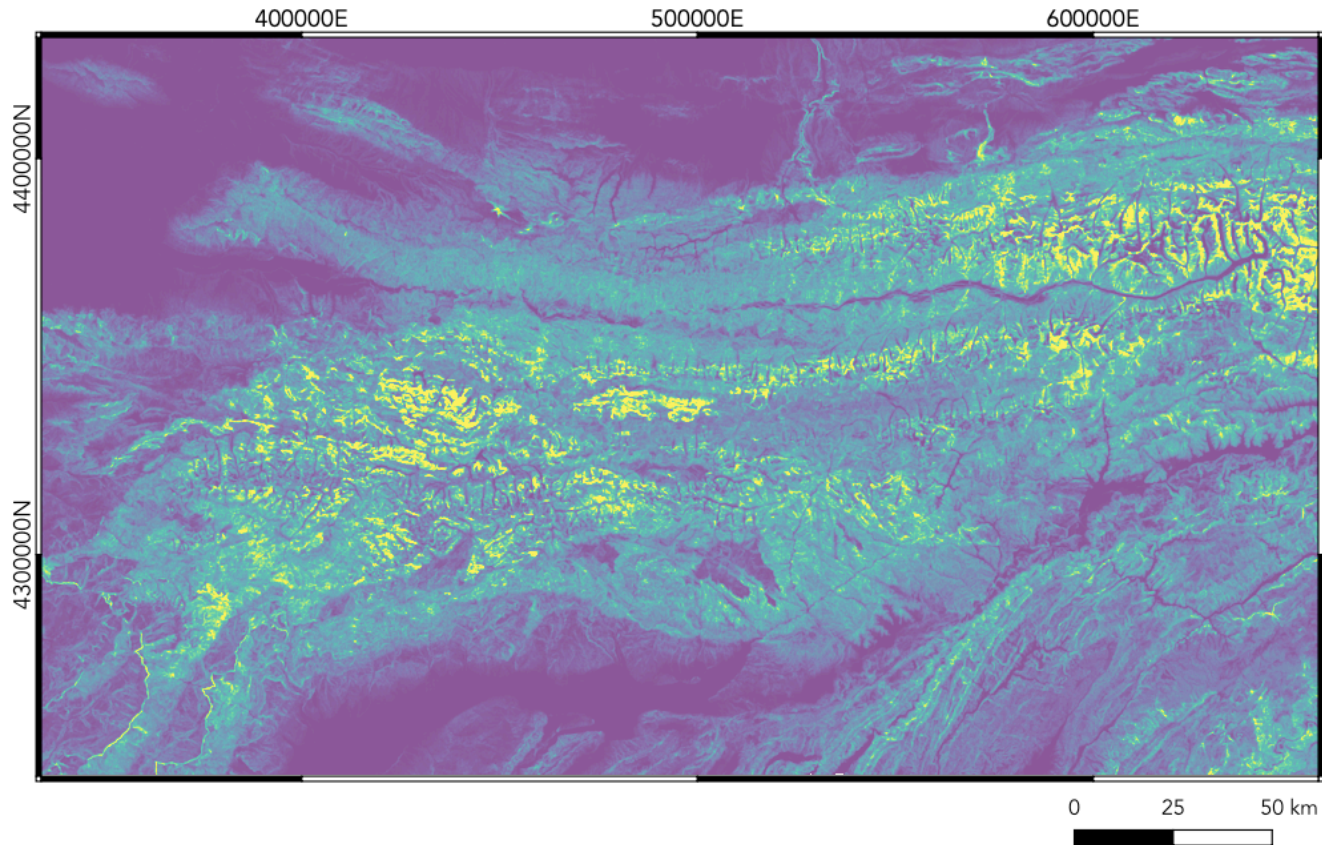
Profile curvature → Parallel to the slope. It affects the acceleration and deceleration of flow across the surface



MORPHOMETRIC INDICES

Surface roughness

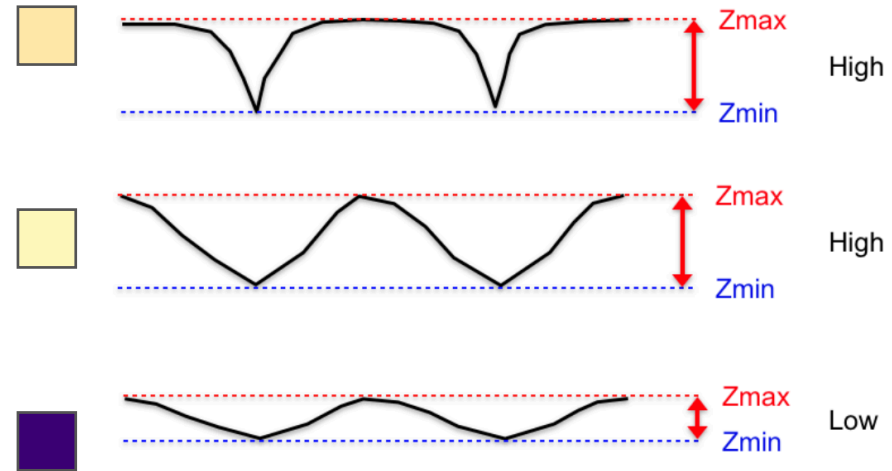
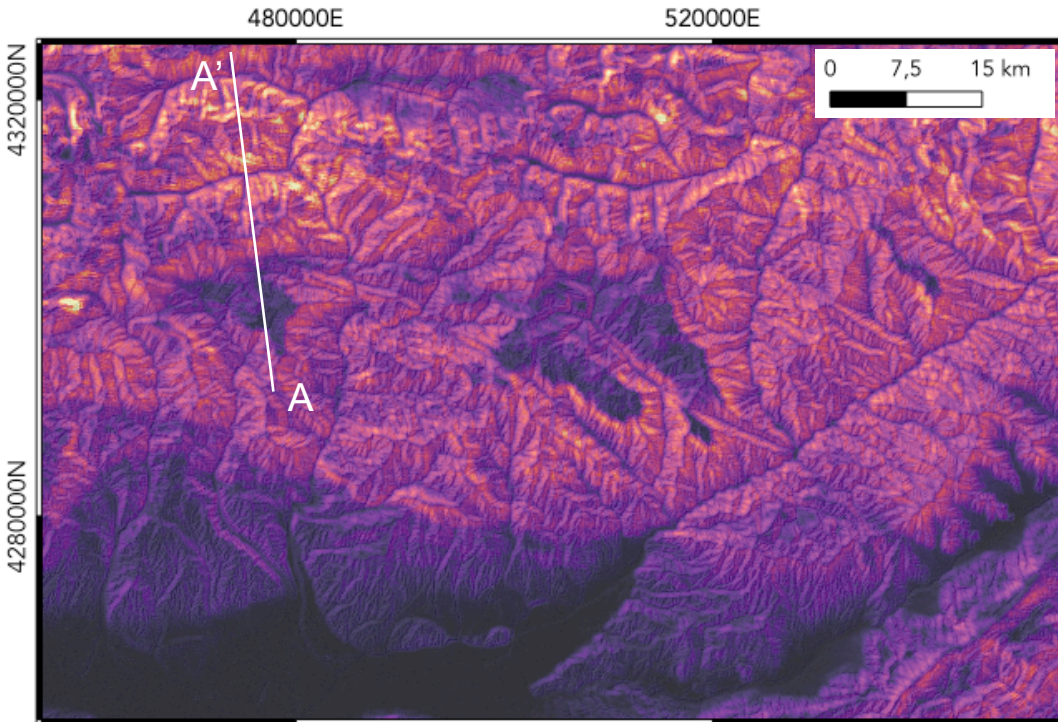
High surface roughness area may indicate the presence of erosional processes.



MORPHOMETRIC INDICES

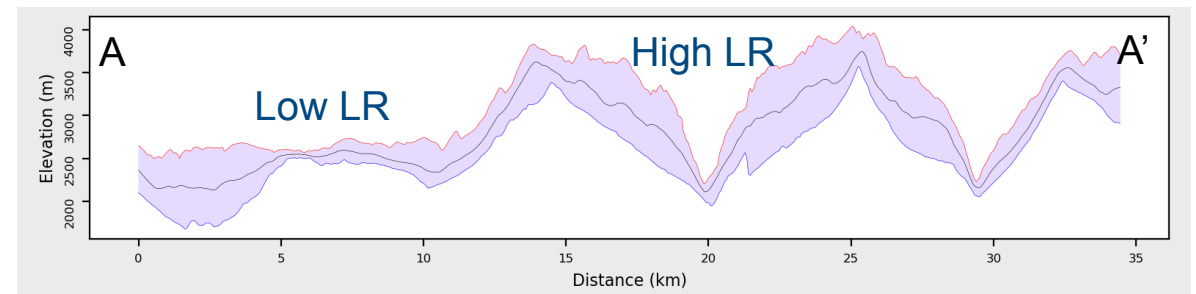
Local relief

Local relief gives us an idea of the river incision



Difference between the lower and the maximum elevation

$$LR = Z_{max} - Z_{min}$$

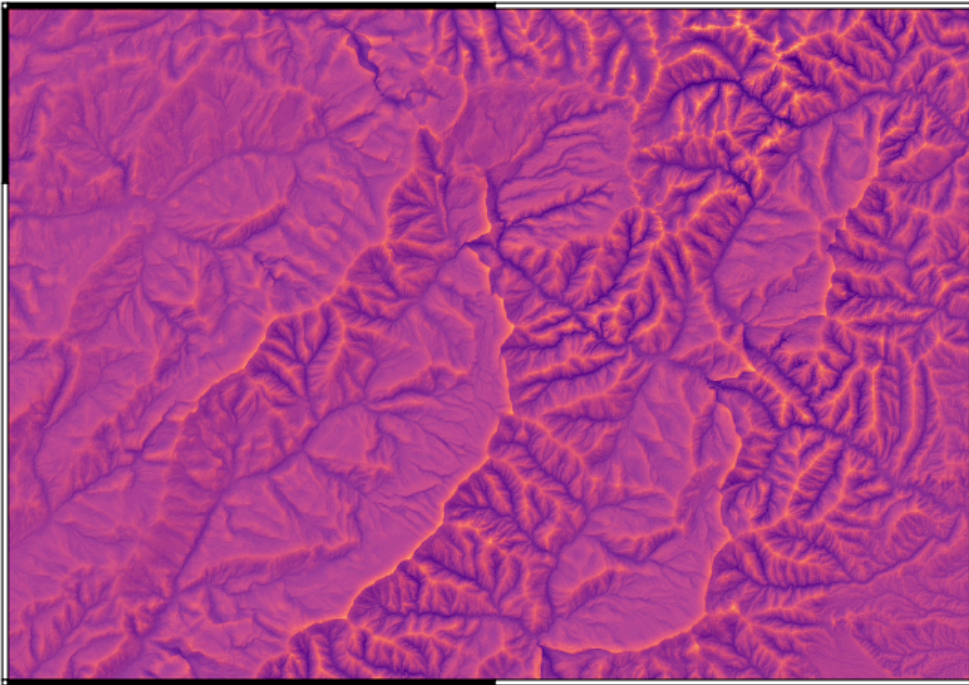


MORPHOMETRIC INDICES

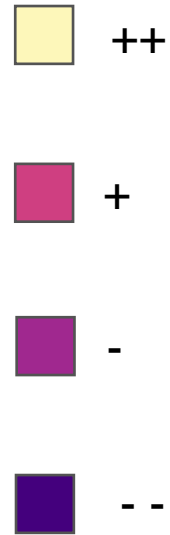
Topographic position index

Separation between ridges, valley bottoms and flat areas

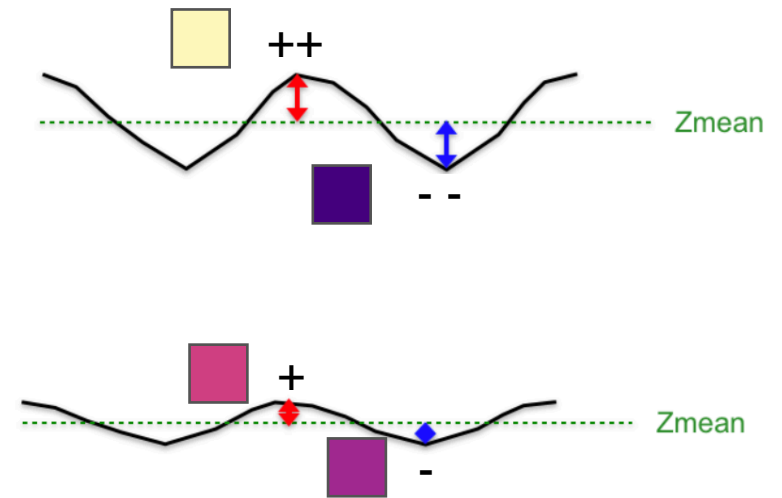
360000E



0 5 10 km



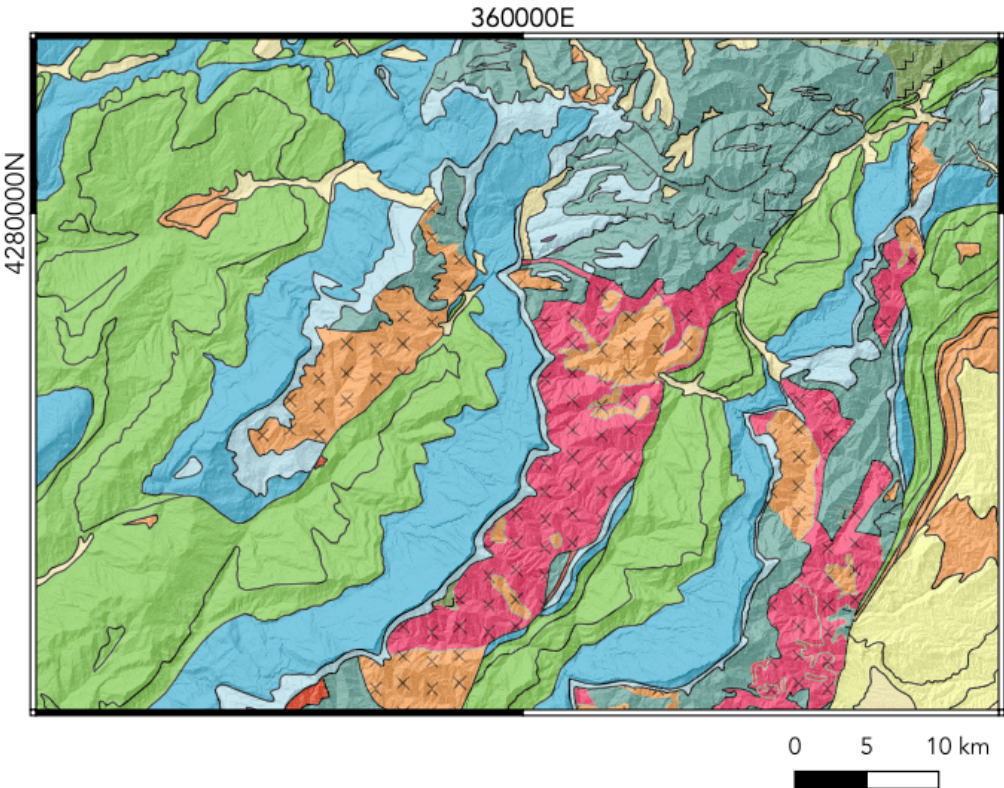
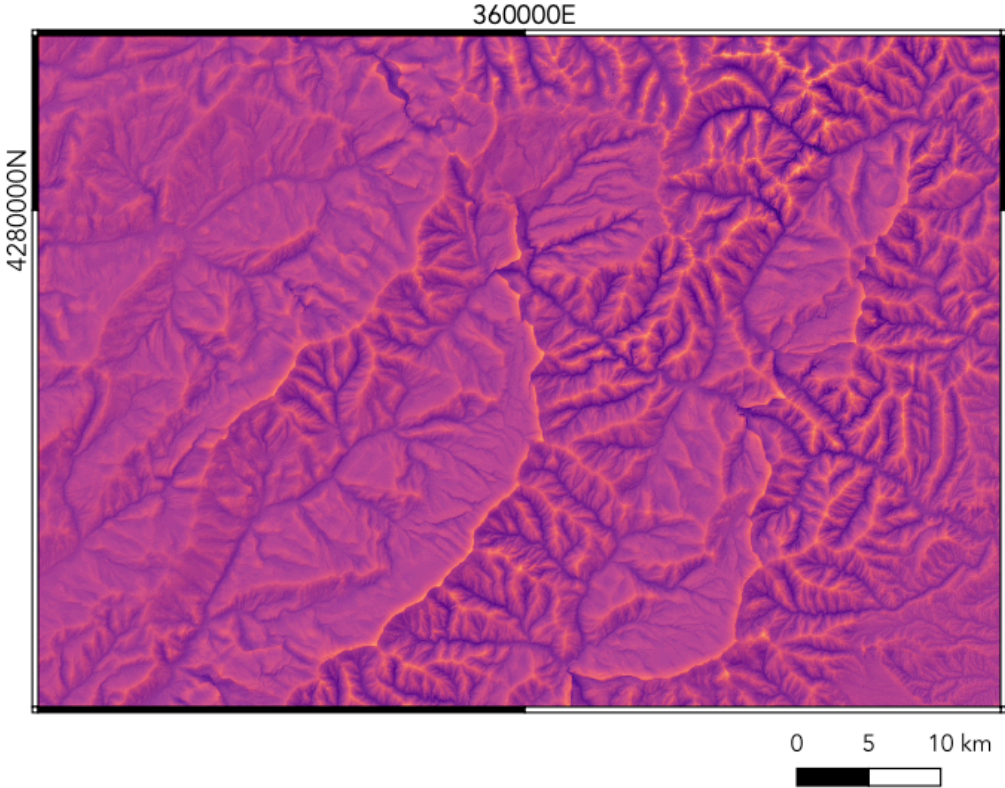
Difference between the pixel value and the mean elevation



MORPHOMETRIC INDICES

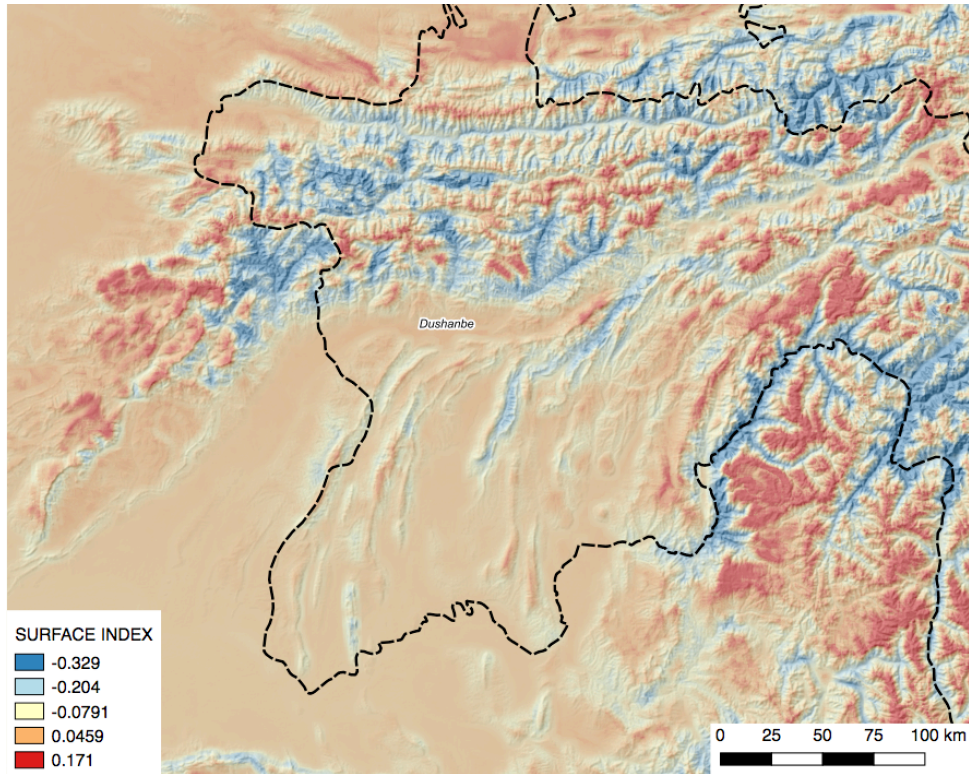
Topographic position index

Indication of differential erosion



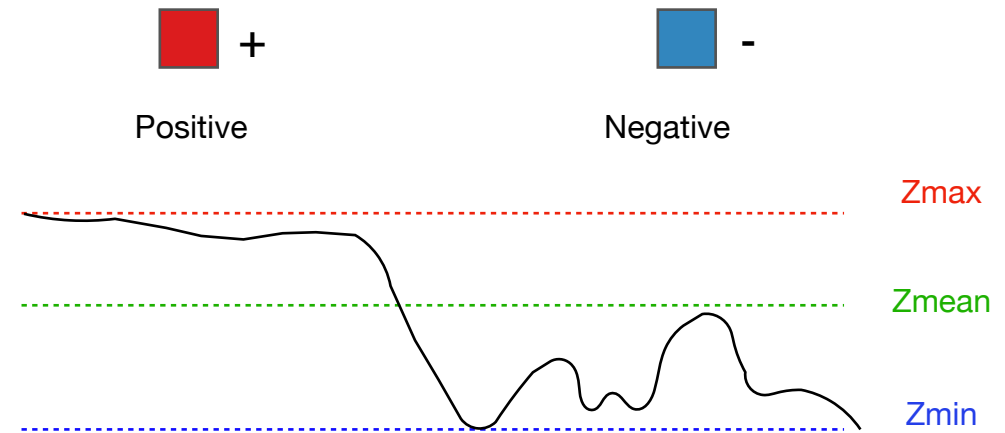
MORPHOMETRIC INDICES

Surface index



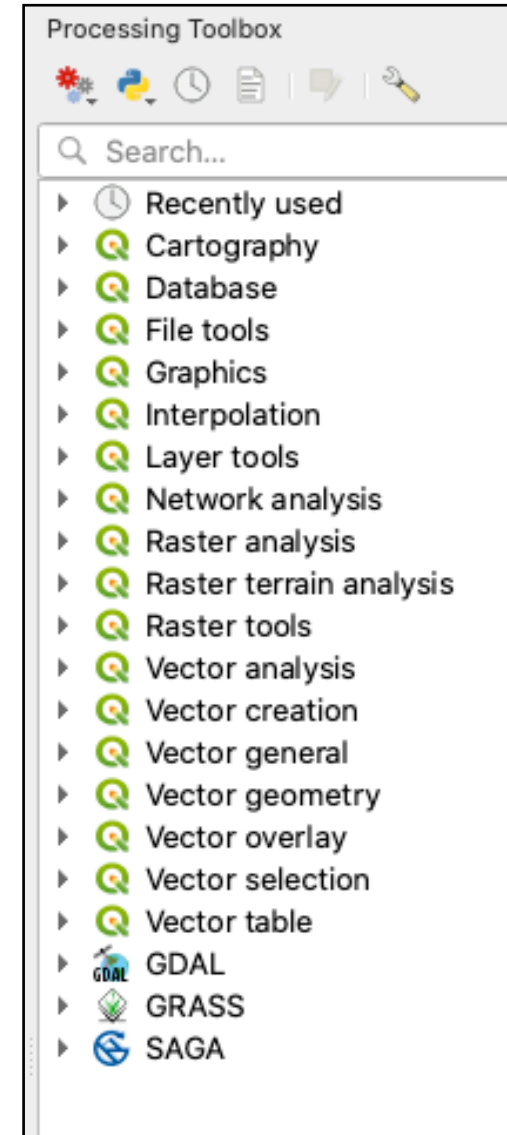
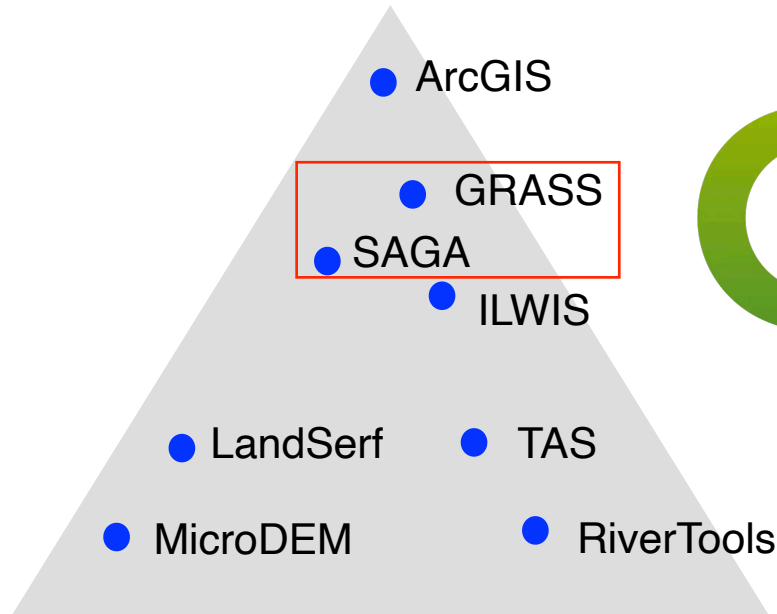
Identification of elevated relict landscapes

Combination of elevation, hypsometric integral and surface roughness



SOFTWARE PACKAGES

CARTOGRAPHY



HYDROLOGY

Modified from Hong & Reuter (2008)

TAKE AWAYS

Geomorphometry/ digital terrain modelling/ terrain analysis/ quantitative geomorphology is the numerical representation of ground-surface relief and associated patterns.

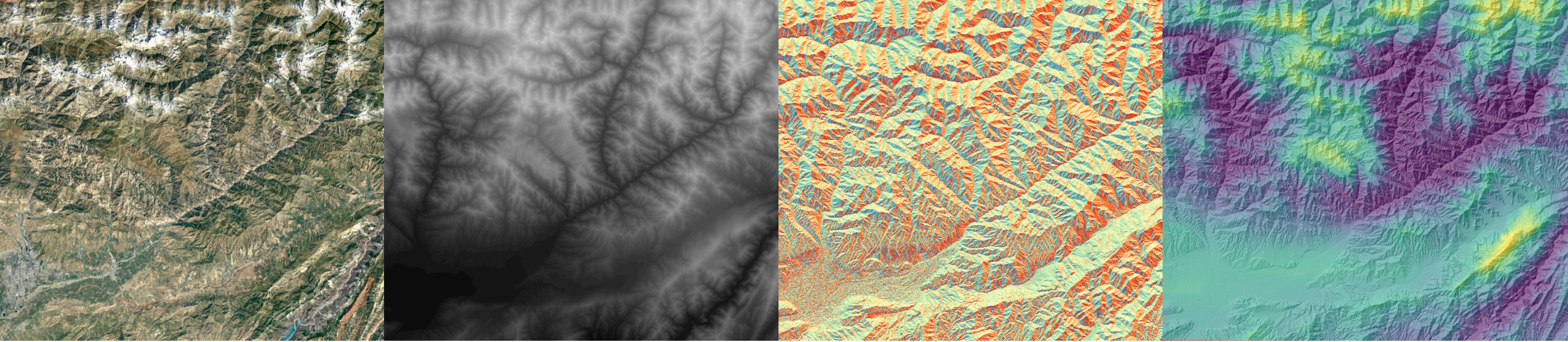
The increasing availability of more detailed digital elevation models with world coverage offers an extraordinary possibility to study landscape dynamics in remote areas and support a diversity of quantitative surface characterisation problems.

Geomorphometry has evolved into a source of reliable methods to address innumerable problems in the earth sciences and engineering fields as estimate soil erosion, map landslide susceptibility or predict the movement of groundwater.

Landscape can be studied by a combination of geomorphometric techniques as swatch profiles, morphometric indices and basin analysis.

Diverse morphometric indices are created by different disciplines. We have introduced morphometric indices used in landslide characterisation, geomorphological mapping and tectonic geomorphology.

QUESTIONS



CLIENT II

International Partnerships
for Sustainable Innovations



EBERHARD KARLS
UNIVERSITÄT
TÜBINGEN



DiG 



GEFÖRDERT VOM



Links

Free source Digital Elevation Models (DEM)

- STRM: <https://earthexplorer.usgs.gov/>
- ASTER: <https://asterweb.jpl.nasa.gov/gdem.asp>
- ALOS PAISAR: <https://search.asf.alaska.edu>

Free source softwares

- Qgis: <https://qgis.org/en/site/>
- SAGA GIS: <http://www.saga-gis.org/en/index.html>
- GRASS GIS: <https://grass.osgeo.org/>
- ILWIS: <https://www.itc.nl/ilwis/download/ilwis33/>

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Shahzad, Faisal, and Richard Gloaguen. "TecDEM: A MATLAB based toolbox for tectonic geomorphology, Part 2: Surface dynamics and basin analysis." *Computers & geosciences* 37.2 (2011): 261-271.

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APA

Strahler, Arthur N. "Hypsometric (area-altitude) analysis of erosional topography." *Geological Society of America Bulletin* 63.11 (1952): 1117-1142.