DEM & TIN

- Two common types of input data for terrain mapping and analysis are

  Raster based DEM

  Vector based TIN

- We cannot use both together
- DEM and TIN are inter-convertible
- DEM → Maxm. Z- tolerance algorithm OR VIP algorithm → TIN
- TIN → Local first order polynomial interpolation → DEM

DEM- Characteristics

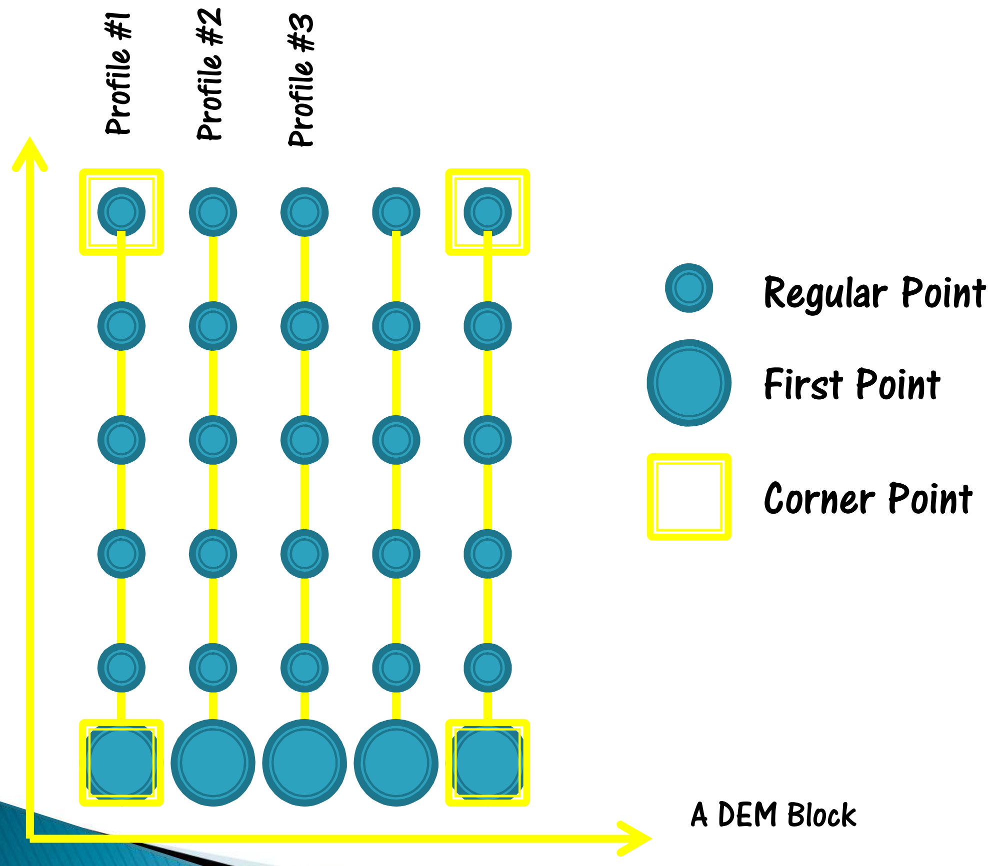
- A regular array of elevation points
- Sources of DEM – Satellite images, radar or LIDAR data
- Point based DEM is to be converted to elevation raster before being input to terrain mapping and analysis
- Conversion is done by placing each elevation point at the center of the cell
- Quality of DEM influences the accuracy of terrain measures such as slope and aspect.

DEM- Characteristics

- Described by three elements: Block, Profile and Elevation Point
- Block: Describes the physical extent of DEM..also c/a a tile
- May be tied to a particular topographic map series but may not always necessarily cover the same geographical extent
- Profile is a linear array of sampled elevation points. Spacing between the profiles represents one dimension of the spatial resolution of the DEM

Elevation points: Three types

Corner points, First points along a profile and Regular points



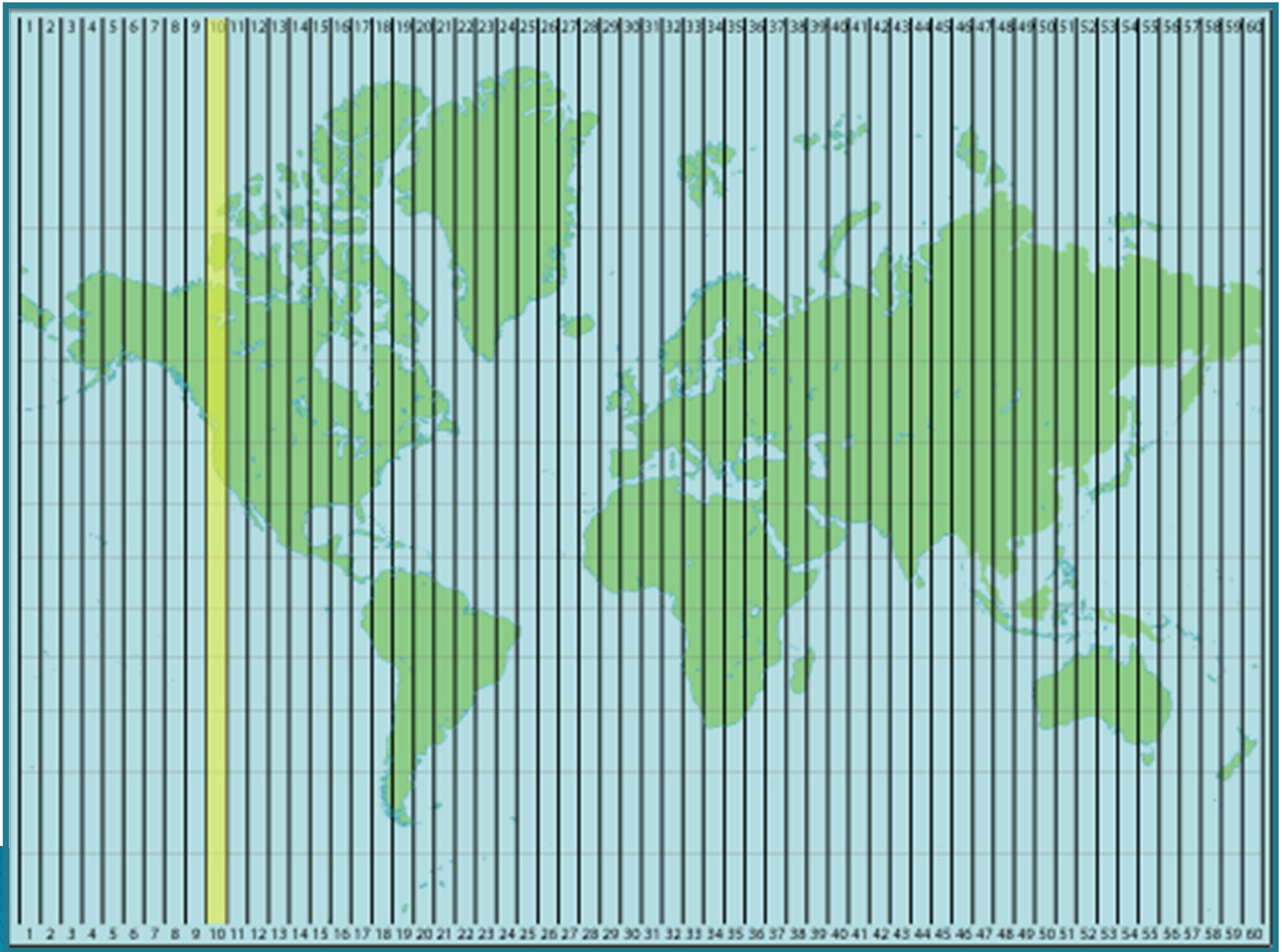
Coordinates are stored only for First points and corner points. These coordinates are used to tie DEM Block to an accepted geo-referencing system. They are also used to calculate the spacing of profiles and coordinates of regular elevation points

- A DEM is usually referenced to either Geographic coordinate system (lat./ long) or the UTM (easting/ northing) Coordinate system
- When georeferenced to Geog. Lat/long, spacing of profiles is expressed in terms of arc seconds or arc minutes
- One arc second is equal to approx. 30 m of linear measurement
- When geo-referenced to UTM coordinate system, spacing of profiles is expressed in meters

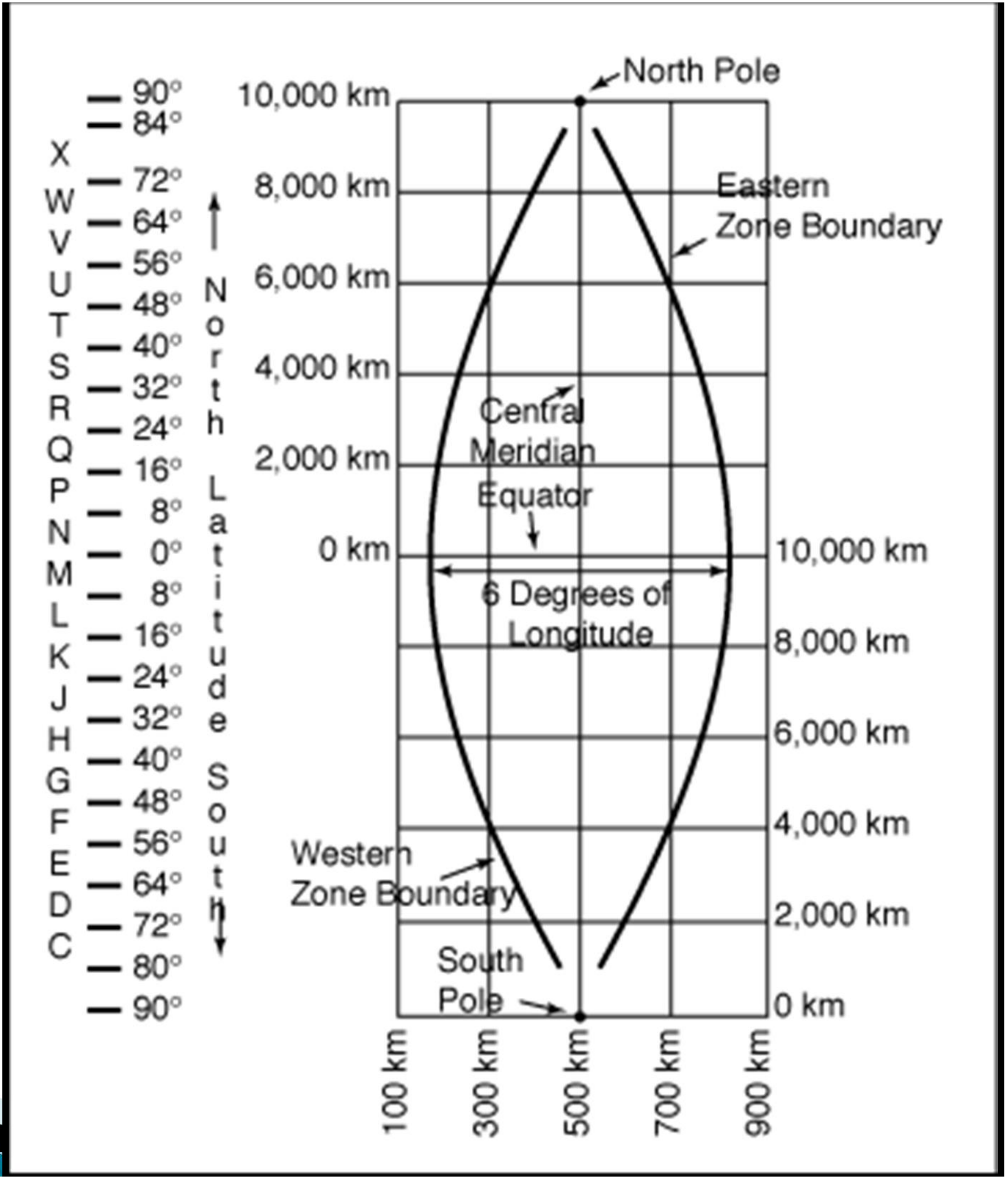
UTM Zones

- World is divided into 60 zones.
- Each zone is 6° of longitude wide.
- Zones are numbered 1 to 60, starting at 180° and progressing to the east.

UTM Zones


1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60

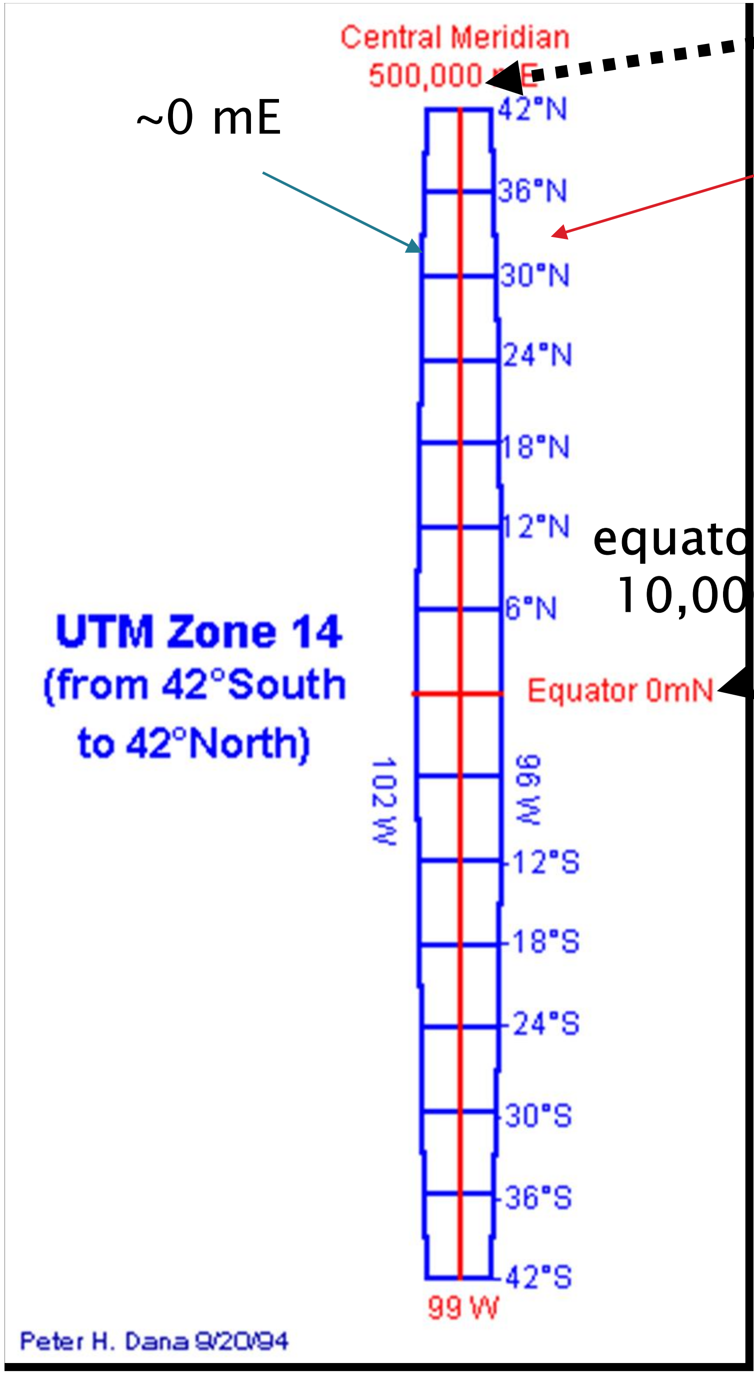
UTM Zone Details



false easting

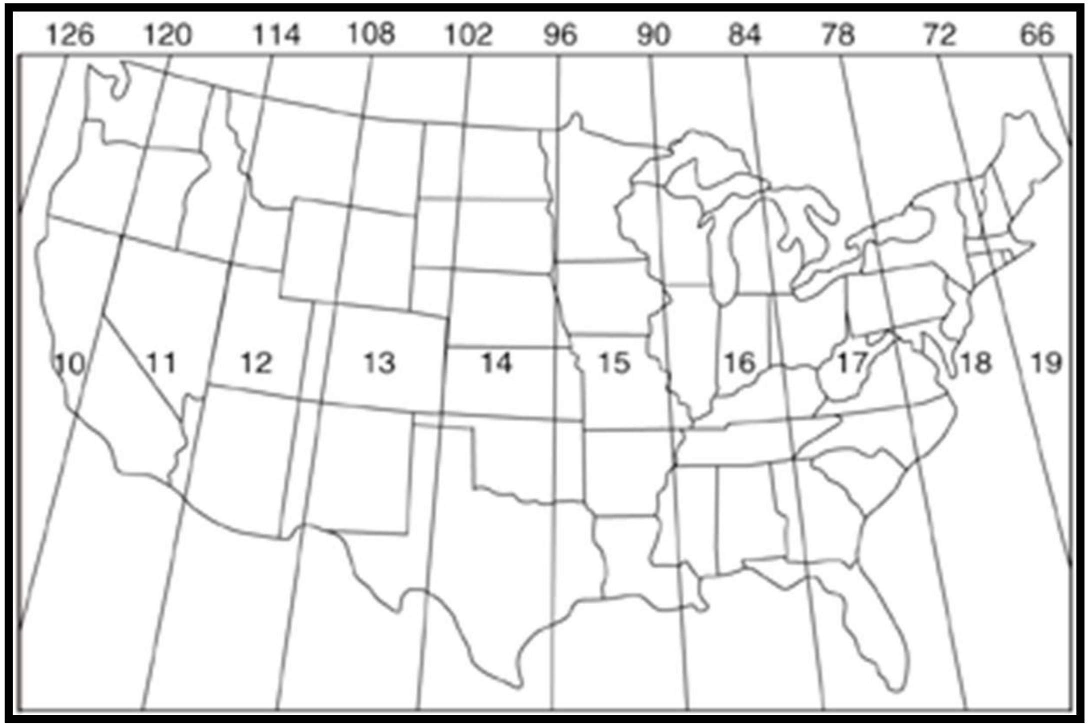
~0 mE

~1,000,000 mE



equator 0 m N or
10,000,000 m S

false northing



Some freely available DEM data

In United States

Nodal Agency – USGS (United States Geological Survey)

Products

DEM	Spatial Res.	Coverage	Available at
ETOPO5	5 x 5 arc minutes	Whole world	www.ngdc.noaa.gov
GTOPO30	30 x 30 arc seconds	Whole world	USGS EROS data center
SRTM	3 x 3 arc second	Whole world (60° n to 56 ° S)	edc.usgs.gov

In India

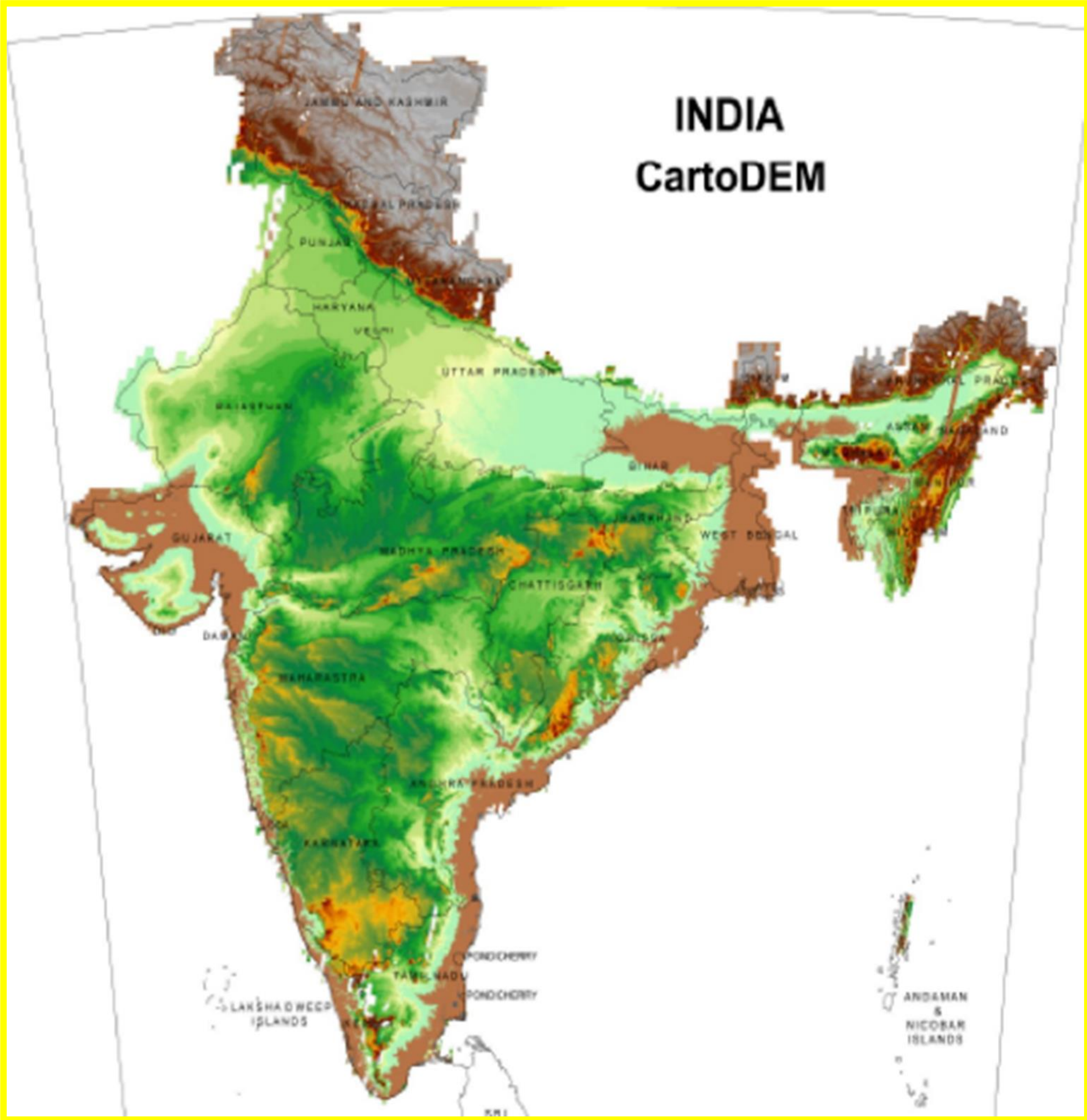
Nodal Agency – NRSC, ISRO

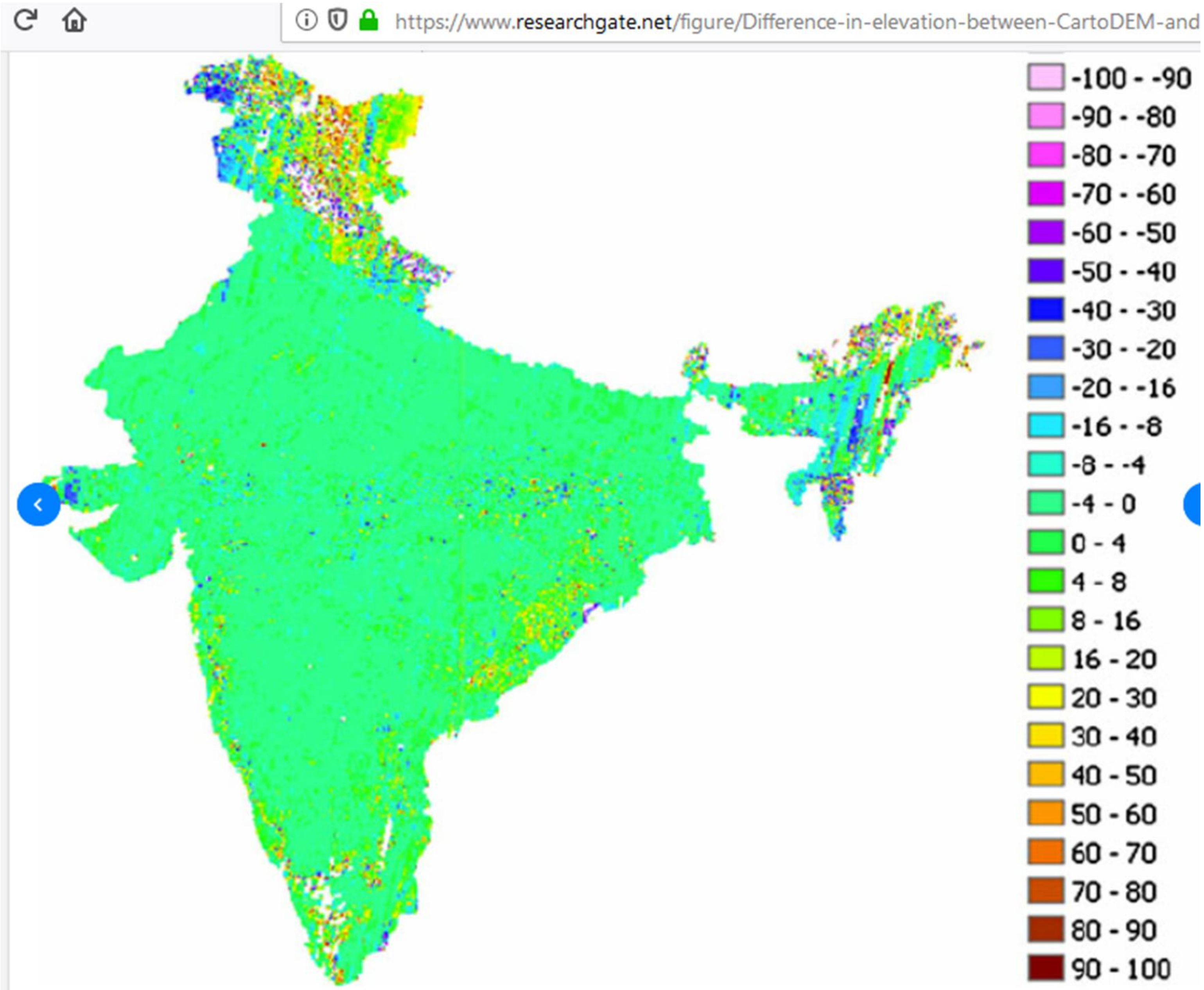
Freely available at www.bhuvan.nrsc.gov.in

Spatial resolution 30 m, Coverage- India

Coordinate System – GCS, Height units - meters

Tile extent – 7.5' x 7.5 '


INDIA
CartoDEM
JAMMU AND KASHMIR
PUNJAB
HARYANA
UTTAR PRADESH
BIHAR
WEST BENGAL
GUJARAT
MADHYA PRADESH
CHATTISGARH
MAHARASTRA
ANDHRA PRADESH
KARNATAKA
TAMIL NADU
PONDICHERRY
PONDICHERRY
LAKSHADWEEP
ISLANDS
ANDAMAN
&
NICOBAR
ISLANDS

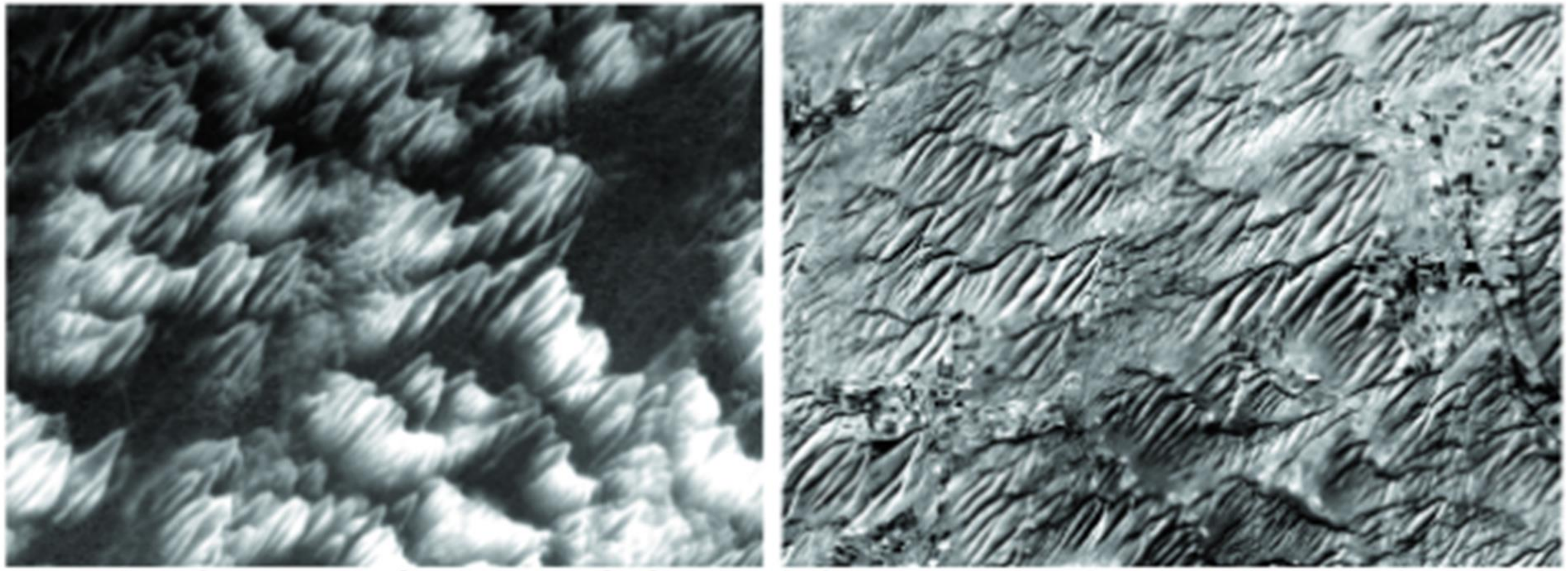


Difference in elevation between CartoDEM and SRTM

Some snapshots of CartoDEM

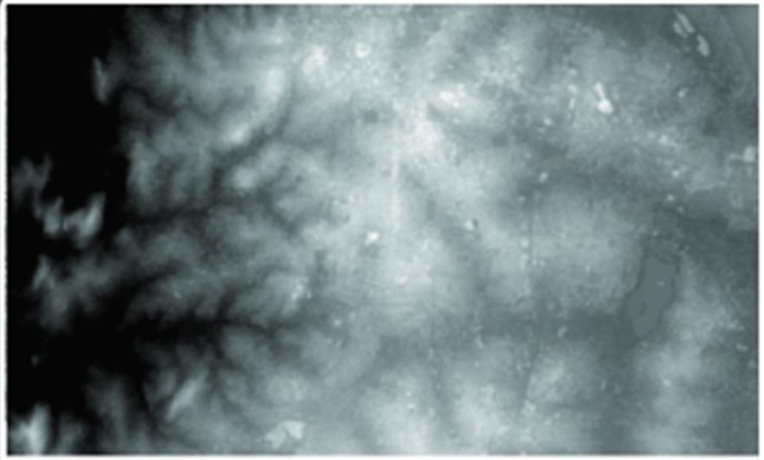
Source: CartoDEM Brochure, https://bhuvan-app3.nrsc.gov.in/data/download/tools/document/cartodem_bro_final.pdf

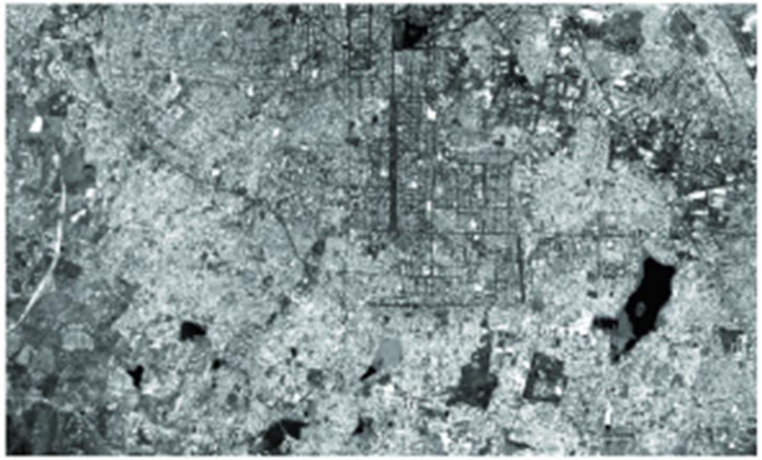
Kurkuti village, Dhauliganga, Uttarakhand



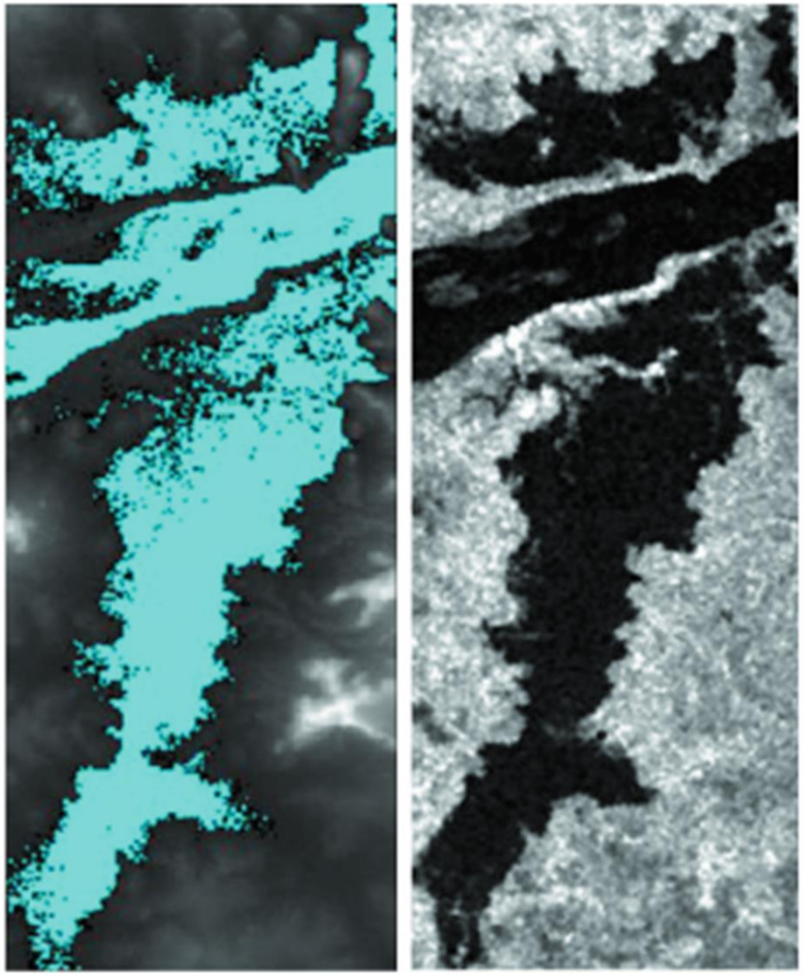
DEM and ortho-image depict parabolic sand dune complex in Thar desert of Rajasthan.
Minute variations in height of sand dunes is captured by CartoDEM in desertic terrain.

CARTODEM Applications





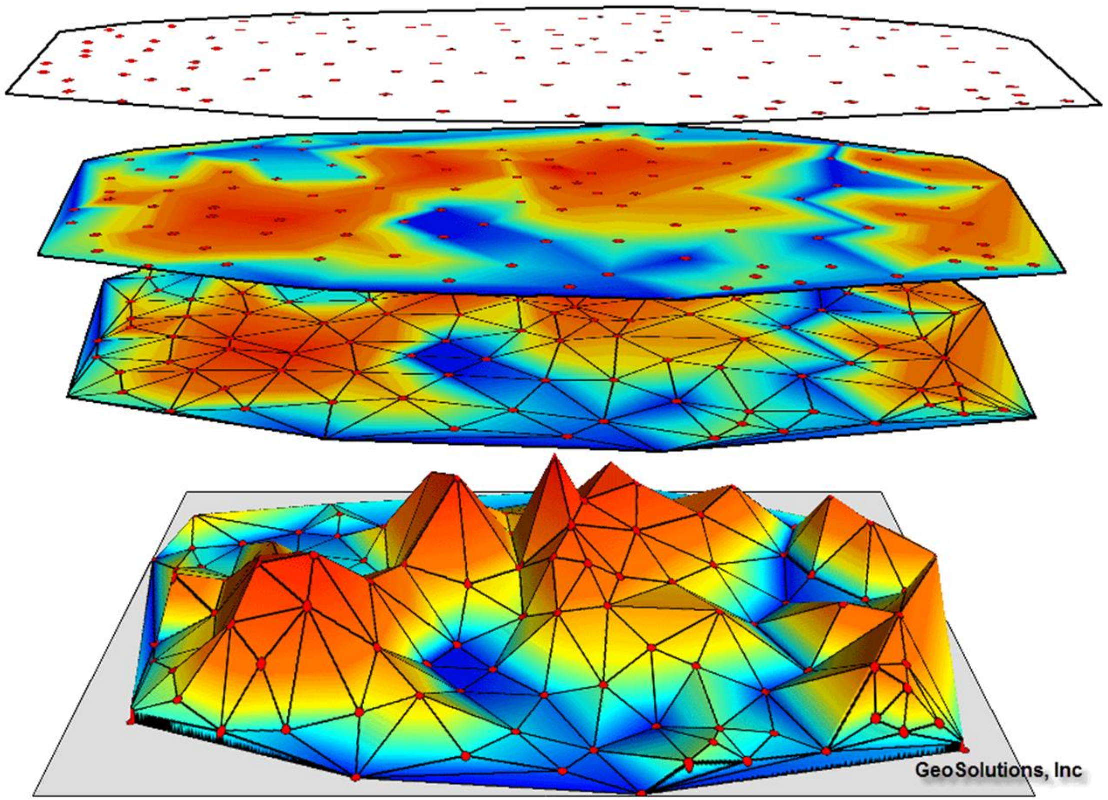
The DEM and ortho-image corresponds to part of Banaglore city, Karnataka. The drainage pattern and overland flow dirctions are clearly depicted in CartoDEM and highly useful for planning storm drainage in dense urban areas.



The simulated flooded area using CartoDEM (left) and corresponding actural flood inundated area, in dark tone, in a micro-wave image (right) of Mahanadi river basin demonstrates the potential of CartoDEM for identifying flood depth.

TRIANGULAR IRREGULAR NETWORK - TIN

- A TIN is a vector based representation of the surface
- Terrain is recorded as a continuous surface made up of mosaic of non-overlapping triangular facets.
- Triangles are formed by connecting selectively sampled elevation points using a consistent method of triangle construction.



TRIANGULAR IRREGULAR NETWORK - TIN

- The triangular facets are planar defined by three edges. Each edge is bounded by two vertices (also c/a nodes)
- The edges depict linear terrain features (e.g. breaks, ridges, stream channels) while vertices describe nodal topographic features (e.g. peaks, pits etc.)
- Elevation values (z-values) along with x-, y- coordinates are stored at nodes that make up the triangles.

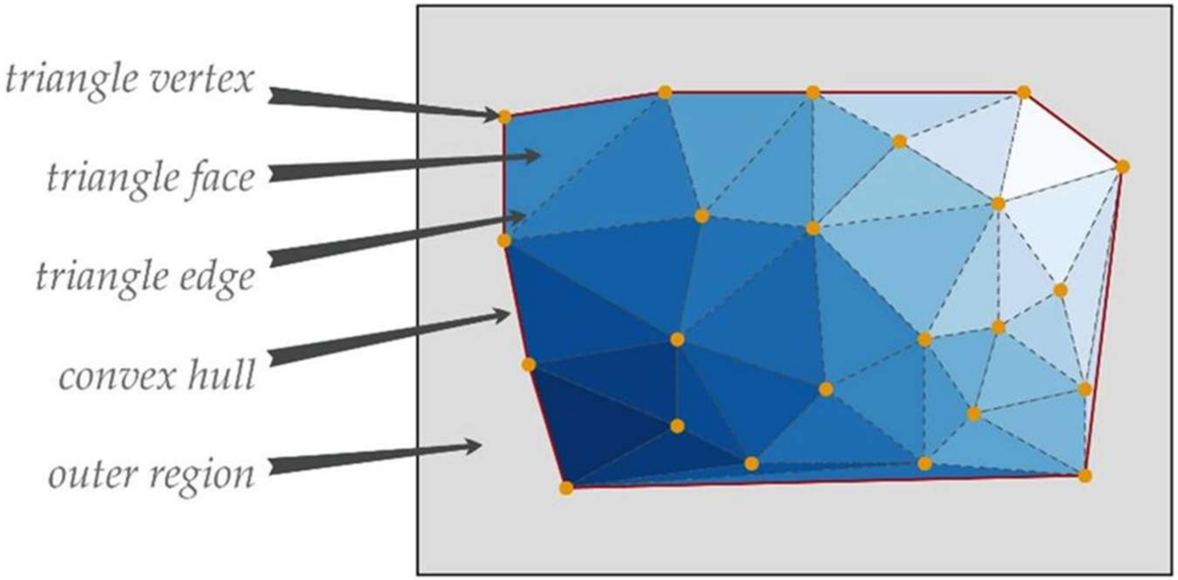


Image credit: google images

TIN Vs DEM (Structure)

- Contrary to DEM, TIN is based on irregular distribution of elevation points. Sampling density can be varied as a function of nature of topography – more samples in areas with more variable elevations and fewer samples in relatively flatter areas
- Each sample point in TIN has x,y coordinate and elevation (z) value . Location of regular points is implicit in DEM

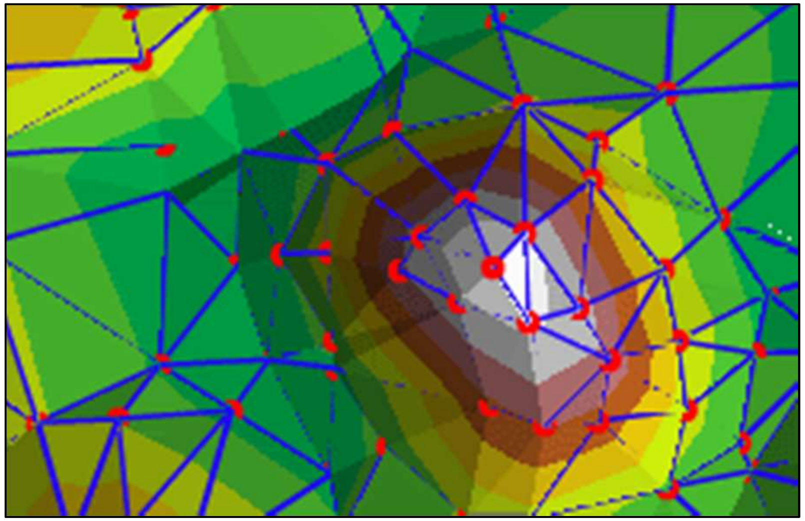


Image credit: arcgis resources

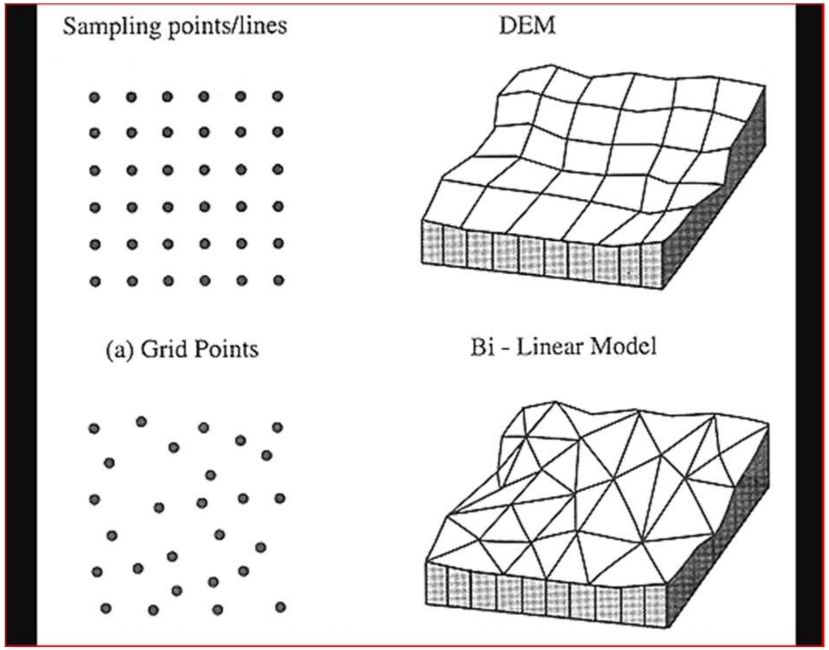
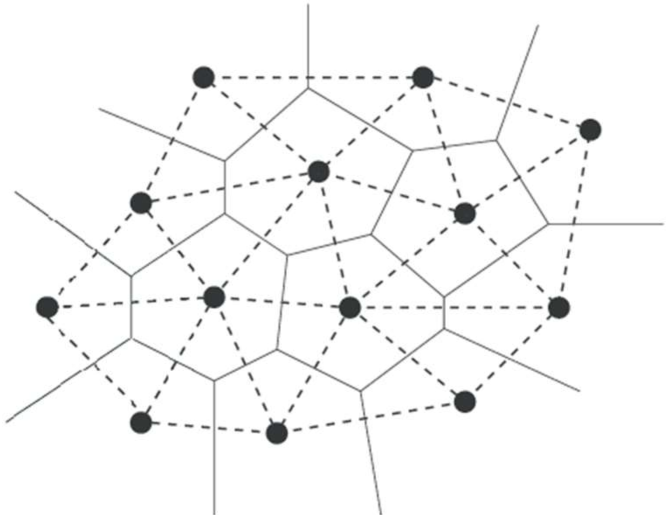


Image credit : http://wtlab.iis.u-tokyo.ac.jp/wataru/lecture/rsgis/giswb/vol1/cp2/2-11.gif

TIN- Construction

- Most commonly used method of creating network of triangles from sampled elevation points for a TIN is Delaunay triangulation
- The geographic space is divided into Thiessen polygons (also c/a Voronoi polygons/ proximal regions/ nearest neighbourhood regions)
- Two vertices are connected if their Theissen Polygons share an edge.
- Empty circle criterion is used as a mechanism to automatically construct TIN from the sample points
- Delaunay triangulation may be extended to include breaklines – c/a constrained Delaunay Triangulation



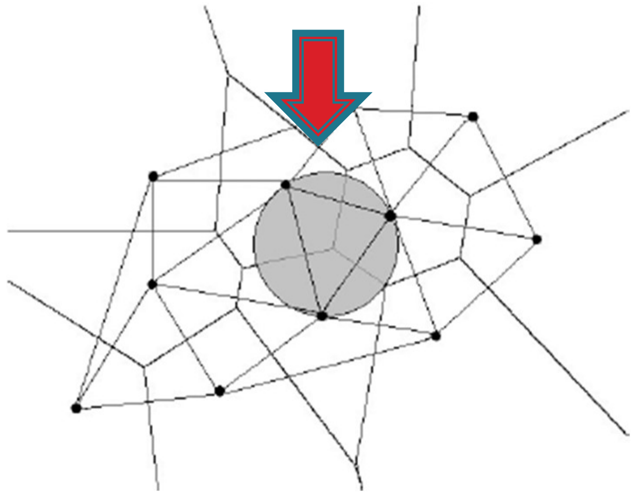


Image credit: researchgate.net

SOURCES OF ELEVATION DATA FOR TIN

Point data

- DEM – Usually primary data source trough conversion process
- Surveyed elevation points
- GPS data
- LIDAR data

Line data - Contour lines and Break lines (Break lines are line features that represent changes of the land surface such as streams, shorelines, ridges, roads etc.)

Area data – Lakes and reservoirs

Creating TIN from DEM

- Selected Elevation points plus additional elevation points from contour lines, survey data, GPS/LIDAR data are connected to form a series of non-overlapping trainagles – the initial TIN
- Common algorithm used is DELAUNAY TRIANGULATION
- Triangles formed by Delaunay Triangulation have

  All nodes connected to nearest neighbours to form triangles

  Triangles are equi-angular or compact as possible

DEM → TIN

- MESH SIMPLIFICATION- Process by which TIN model is constructed from DEM data
- Every point in DEM is not used to create a TIN
- Points which are more important in representing the terrain are selected
- Objective is to form a TIN with minimum number of points while at the same time preserving the maximum amount of information about the terrain structure
- Algorithms used for selecting significant points are

  VIP (Very Important Points)

  Maximum z- tolerance

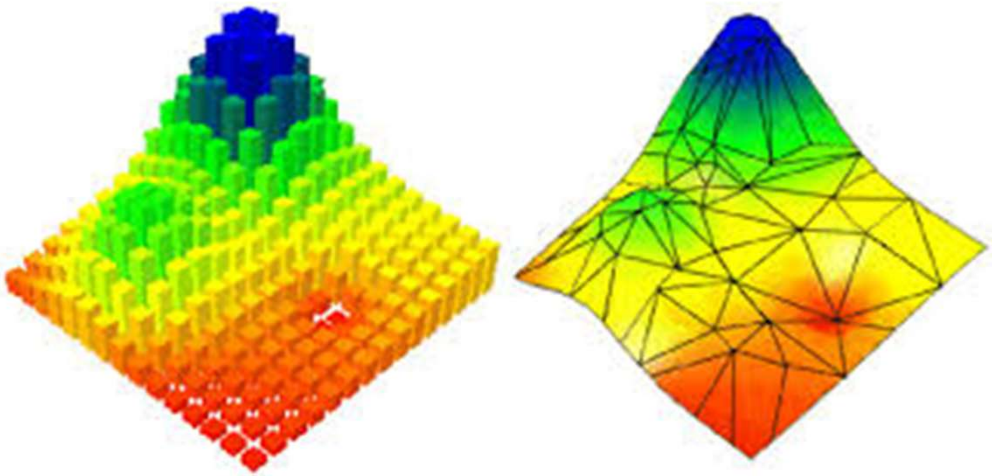


Image credit:
researchgate.net

MESH SIMPLIFICATION

Different algorithms may be quite different

The following iterative process comprising two phases is common to all

1. Determine the surface significance of elevation points in the DEM data by using the spatial relationships between an individual point and its neighbors. An elevation point is considered 'important' or 'surface specific' when its elevation cannot be closely interpolated using values of its neighbors

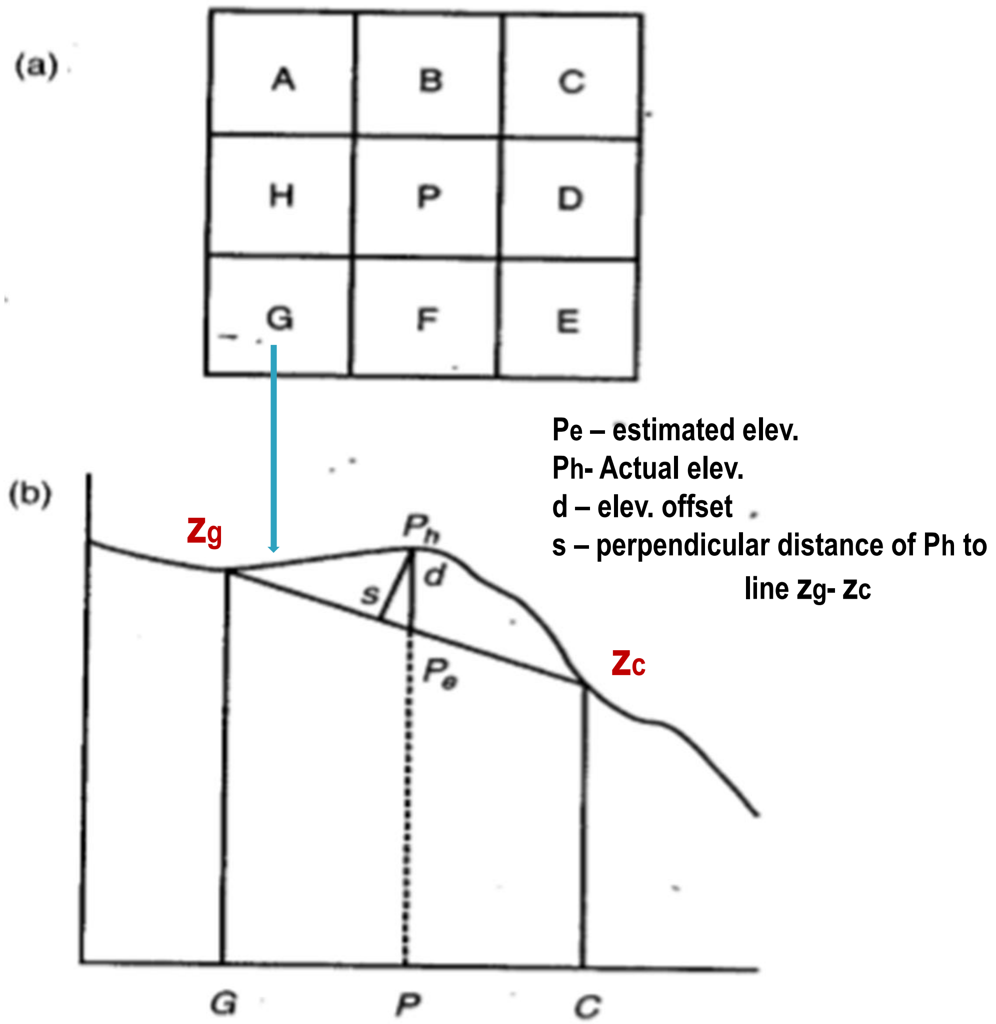
2. Establish the rules and tolerances to terminate the point selection process.

These rules may be quantitative criterion (when no. of points reaches a pre-determined number)

Or qualitative criterion (when there is no point whose computed importance exceeds a predefined level, such as median or maximum errors)

VERY IMPORTANT POINTS ALGORITHM (VIP)

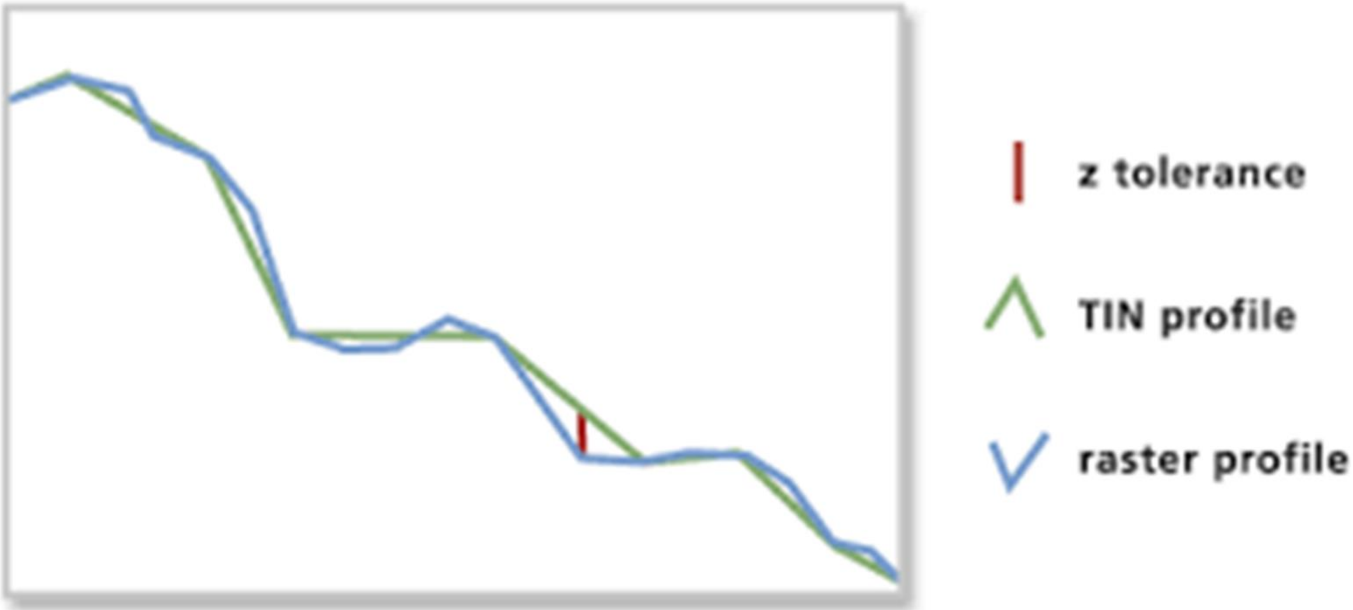
1. Used by ArcGIS
2. First converts DEM into a raster
3. Then evaluates the importance of each point (cell) by measuring how well its value can be estimated from neighboring values (P) in a 3 by 3 moving window
4. Calculates *s* for each of four pairs
5. Averages the four *s* values – the average is considered the significance of P
6. *s* for each cell is computed
7. Desired number or points with specified significance are selected – VIP



Maximum *z*- tolerance Algorithm

1. An iterative process
2. Begins by constructing a candidate TIN
3. For each triangle in the TIN, computes elevation difference from each point in the raster to the enclosing triangular facet
4. Determines the point with the largest difference
5. If difference is greater than a specified *z*- tolerence, the algorithm flags the point for addition to the TIN
6. After very triangle in the initial TIN is checked, a new triangulation is computed with the additional flagged points
7. Process continues until all points in the raster are within the specified maximum tolerance

Maximum *z*- tolerance Algorithm

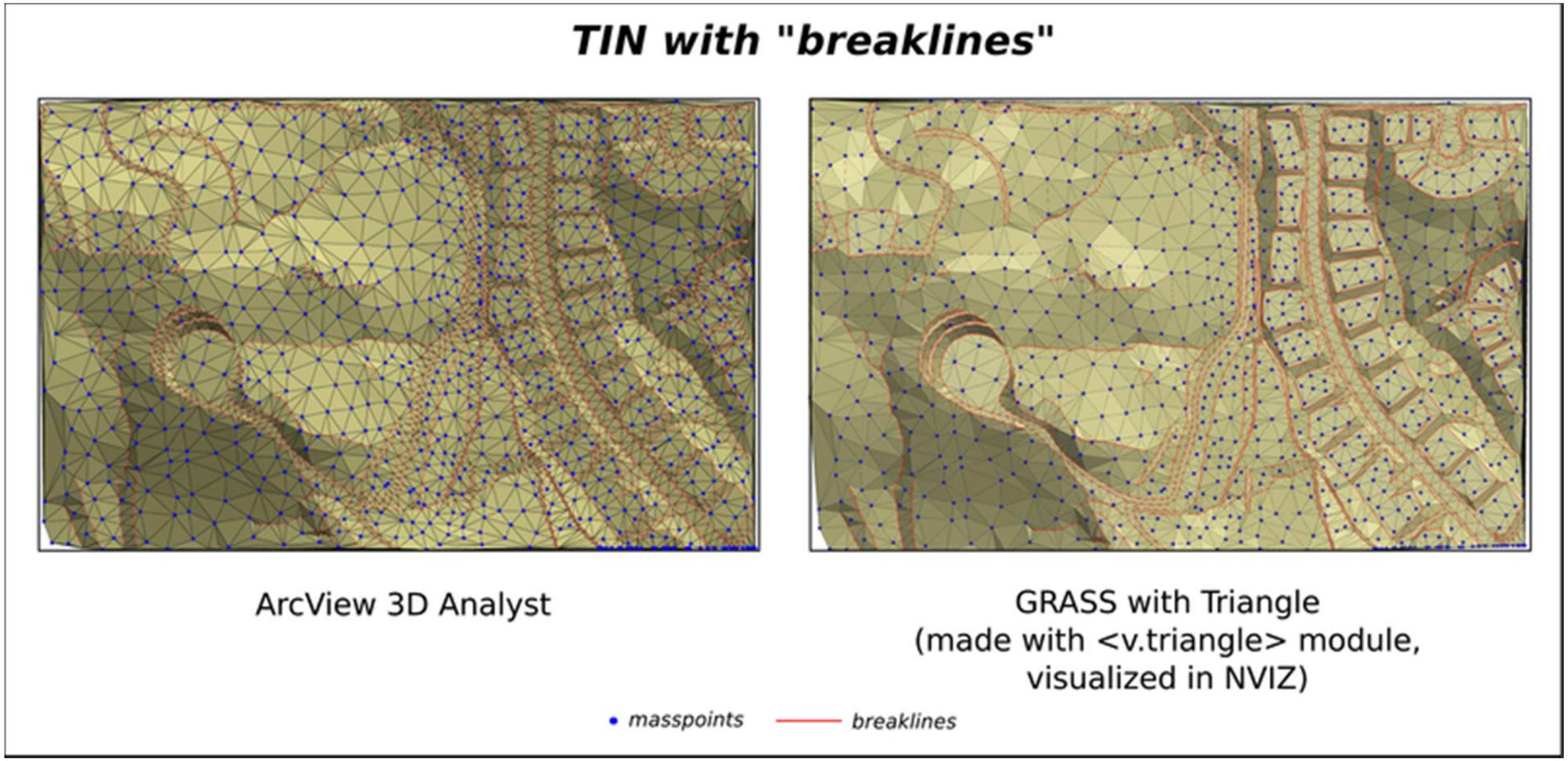


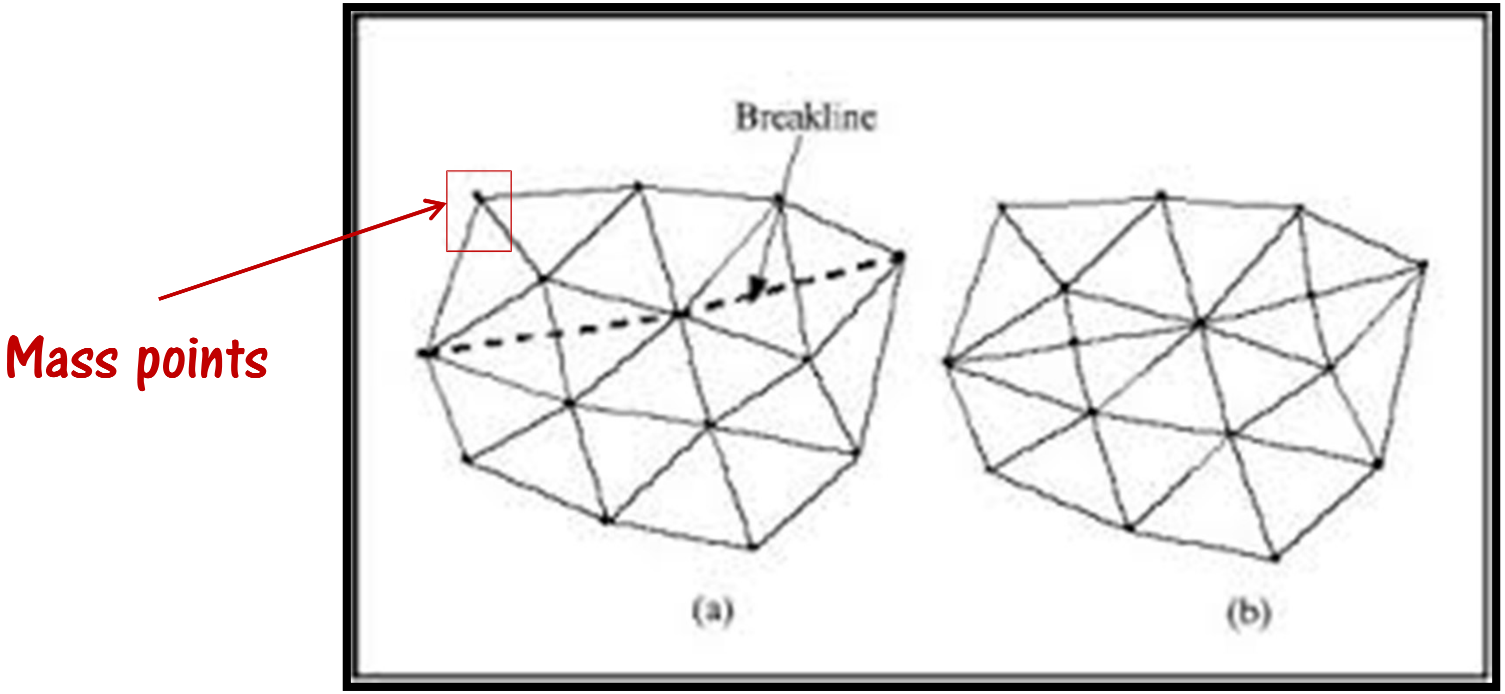
TIN is constructed such that for every point in the elevation raster, the difference between the original elevation and the estimated elevation from the TIN is within the maximum z-tolerance

BREAK LINES

Breaklines are line features that represent changes of the land surface such as streams, shorelines, ridges and roads

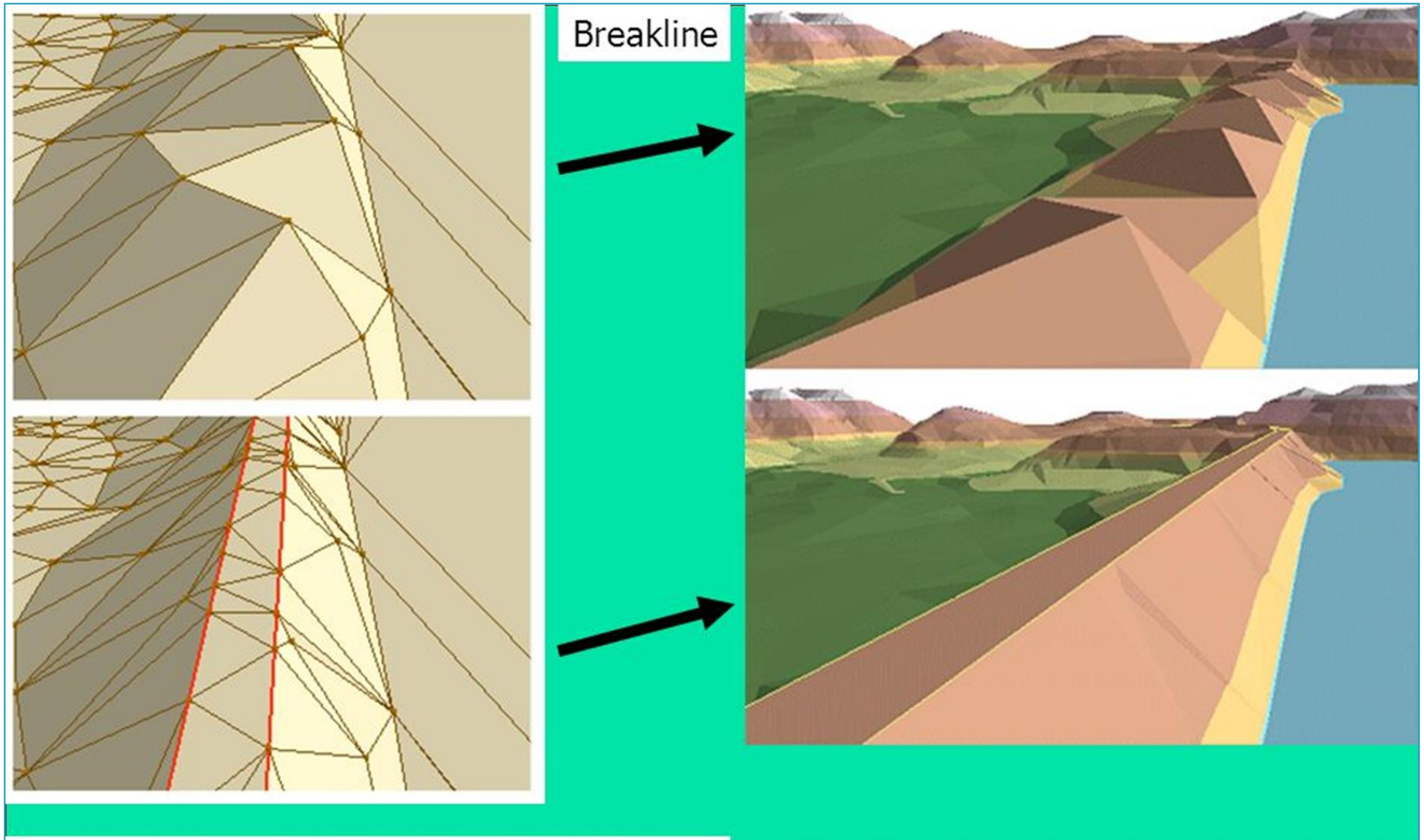
Breaklines may be included in the initial TIN or used to modify the initial TIN





The dashed line in (a) represents a breakline, which subdivides the triangles in (a) into series of smaller triangles in (b)

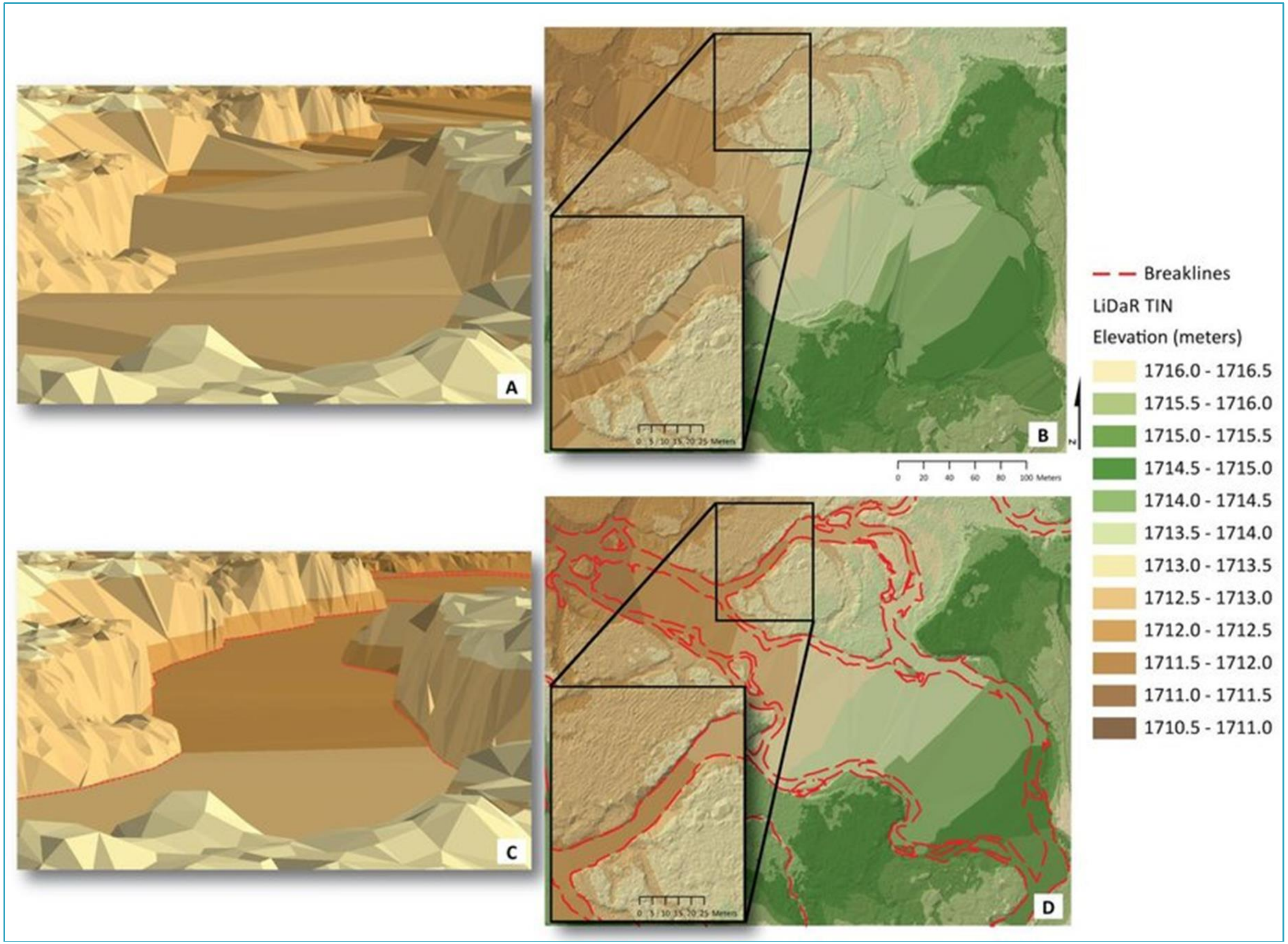
- Breaklines provide the physical structure in form of triangle edges to show change of land surface
- If the z-values for each point of a break line are known, they can be stored in a field
- If not, they can be estimated from the underlying DEM or TIN surface

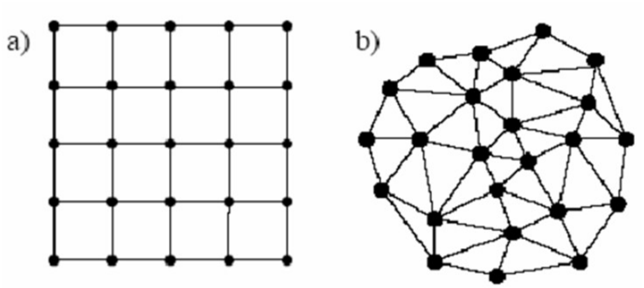


Top: Without breaklines, the triangles cross the ridge of the dam.
Bottom: With breaklines (red) along both sides of the ridge, the TIN is retriangulated. No triangles cross a breakline

Top: Simple mass point triangulation does not adequately model the dam.
Bottom: The dam is successfully modeled with breaklines.

Example of influence of breakline on TIN data quality





DEM Vs TIN

Advantages of TIN

1. Flexibility with input data sources – can use inputs from DEM, contour lines, LIDAR, GPS survey data….
2. Elevation points and break lines can be added at precise locations to define surface discontinuities
3. Excellent data model for terrain mapping and 3-D display
4. Triangular facets better define the land surface and create a sharper image

DEM

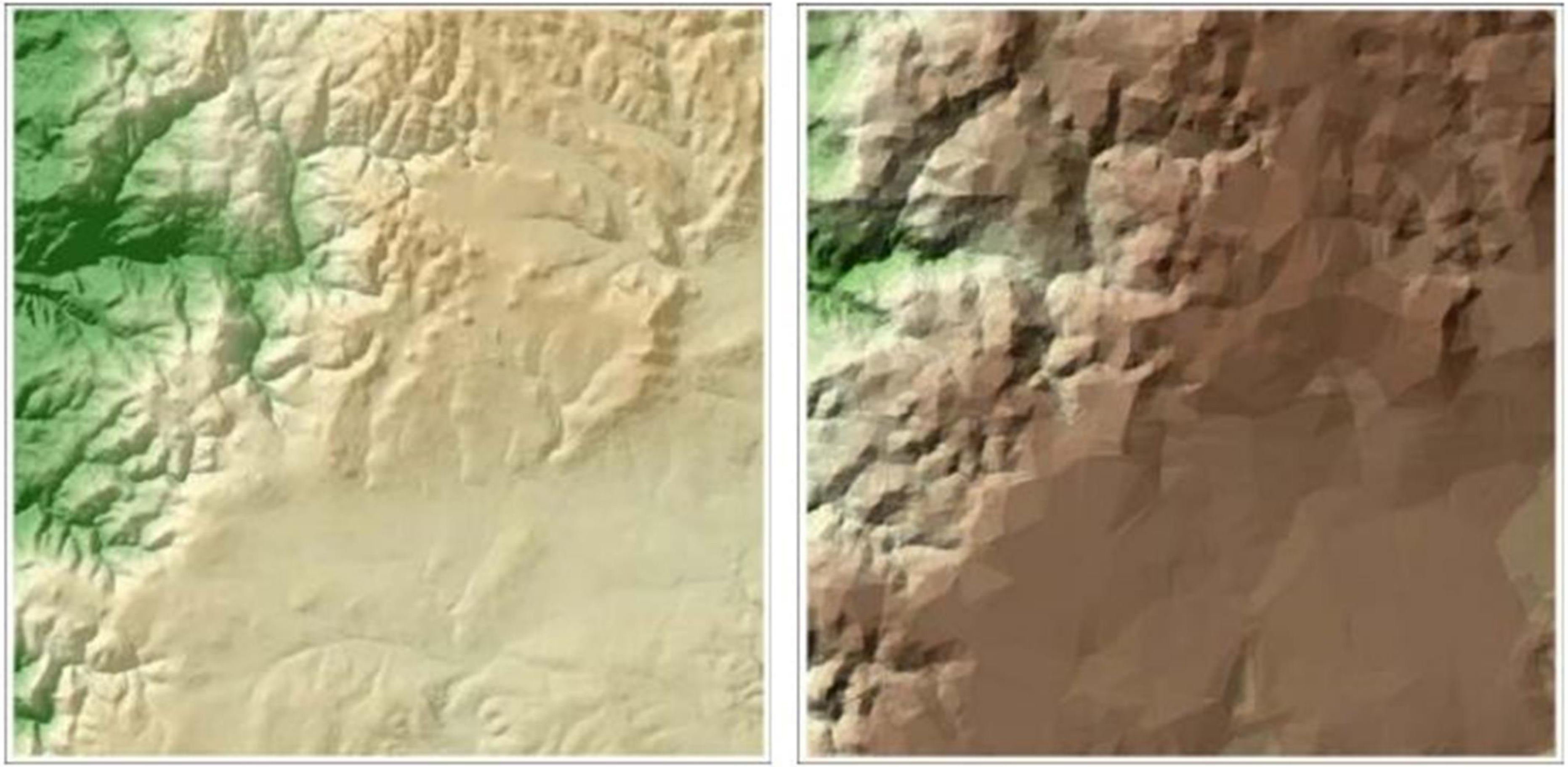
1. Modelling accuracy of DEM is constrained by its resolution – fixed cell size
2. Increasing resolution is a costly affair
3. DEM cannot indicate a stream in hilly area and the accompanying topographic characteristics if the stream width is smaller than its resolution
4. New sample points cannot be added to increase surface accuracy

DEM Vs TIN

Advantages of TIN

1. Less data storage requirements
2. No redundancy in data storage- all vertices and edges stored only once in georelational data model.
3. Since TIN data are based on the topological arc-node structure of the geo-relational data model, they may be applied relatively easily to vector based geo-processing such as automated contouring, 3D landscape visualization, site visibility studies, volumetric and cut and fill computations in engineering design ....

DEM Vs TIN



TIN can accurately describe complex terrain surfaces with far smaller number of elevation points

DEM Vs TIN

Advantages of DEM

1. Computational efficiency
2. Simple data structure
3. Easy, fast and efficient neighbourhood operations - computation of derivatives viz. slope, aspect, curvature, relative radiance etc.

TIN

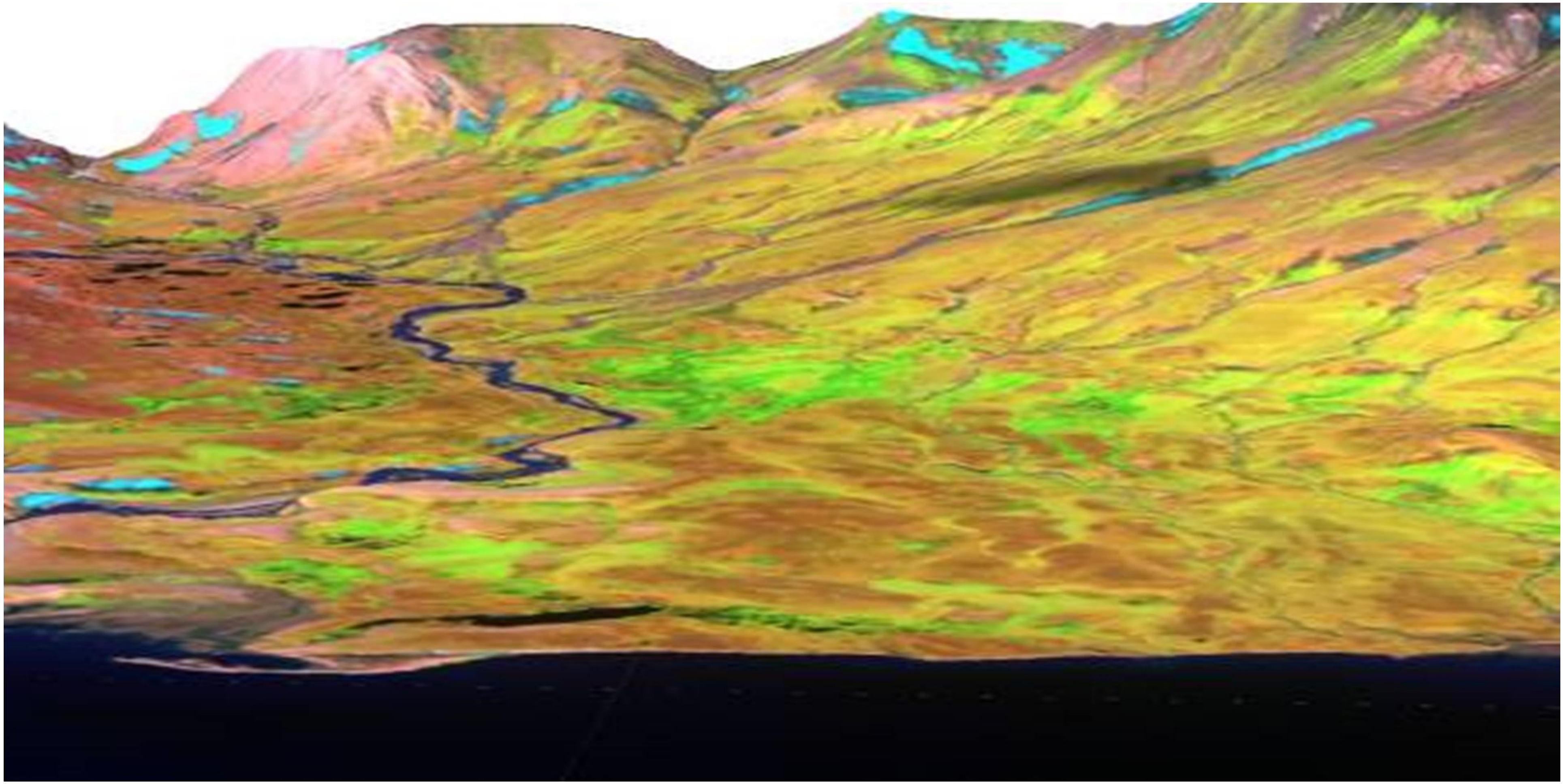
1. Computational load of a TIN increases significantly as number of triangles increases
2. For some terrain analysis operations GIS packages convert TIN to DEM prior to analysis

DEM or TIN ????

Which data model is more accurate??? Answer depends on how it has been created.

1. If a TIN has been made by sampling a DEM, it will be less accurate than the full DEM
2. If DEM has been interpolated from TIN, it is less accurate than TIN
3. Studies have suggested TINs inferior to DEM for terrain modelling
4. DEM is more suitable for overlay operations
5. TIN are more efficient for 3D Perspective viewing

TERRAIN MAPPING AND ANALYSIS



Prof. Seema Jalan

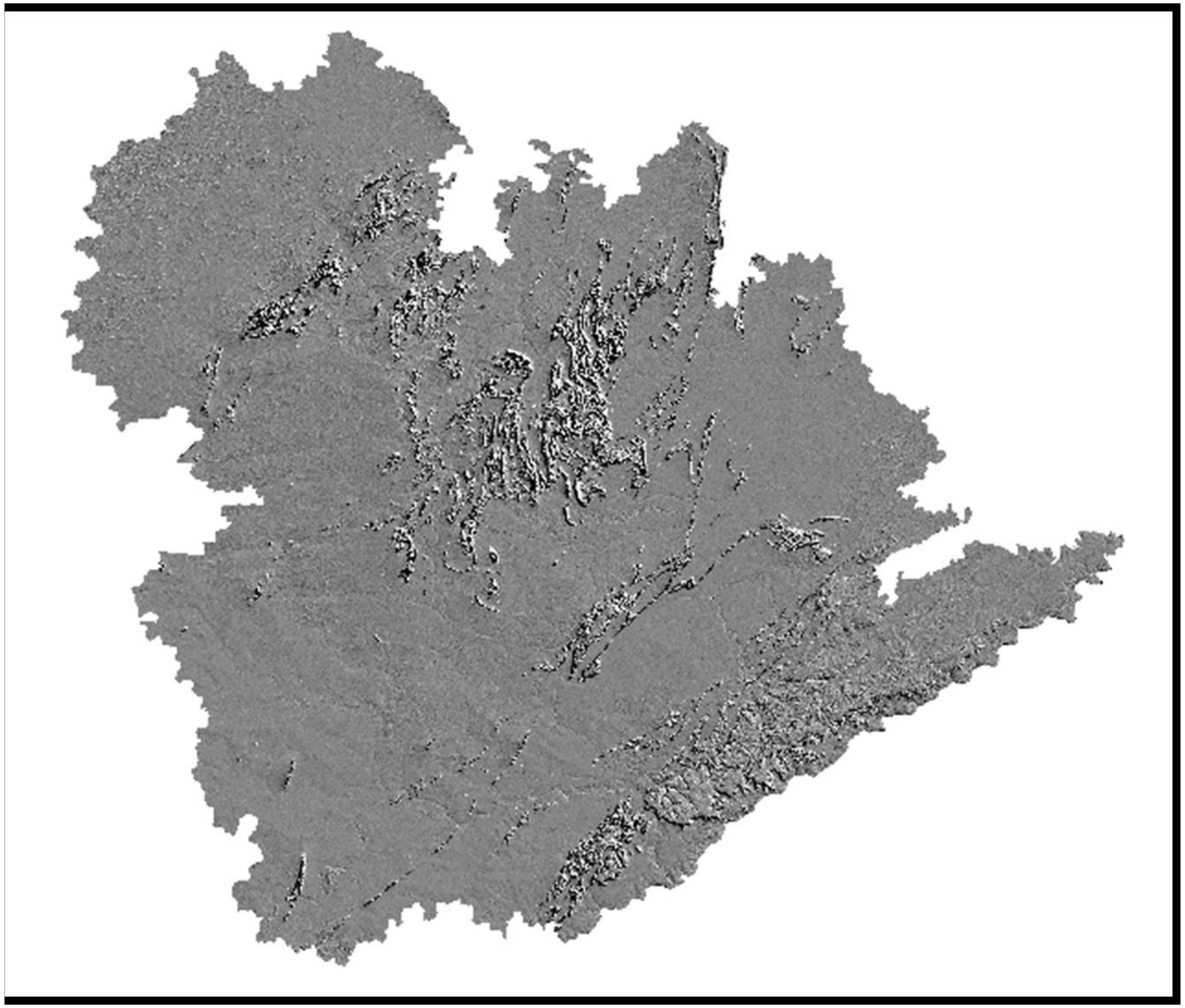
Lecture outline

- Terrain Visualization
- Terrain mapping methods - Derivatives of DEM/TIN
- Water Shed Analysis
- Viewshed Analysis

Terrain Visualization

- Ultimate aim of a DTM is to present relevant terrain information about a given geographic space that results from an analysis of its topography and related spatial phenomenon
- Visualization serves two primary purposes:
  1. To communicate geographic information
  2. To provide a means for data exploration and hypothesis refinement
- Various methods (on basis of dimension of graphical display)
  1. Two D
  2. Two- and-a-half D
  3. 3D
  4. Multidimensional- fly through, animations to visualize change over time

2D- Shaded relief



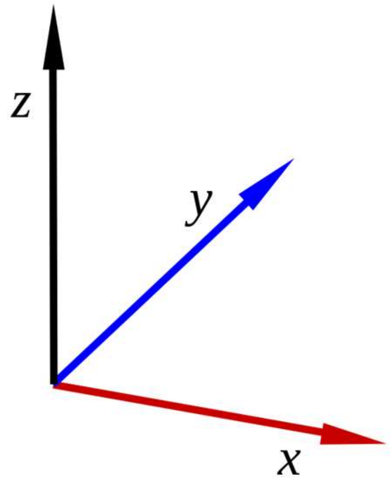
Contour lines are the conventional quantitative method of 2D visualization

However they are difficult to comprehend by inexperienced map users

Hill shading is a qualitative method but creates a good impression of the topographic form

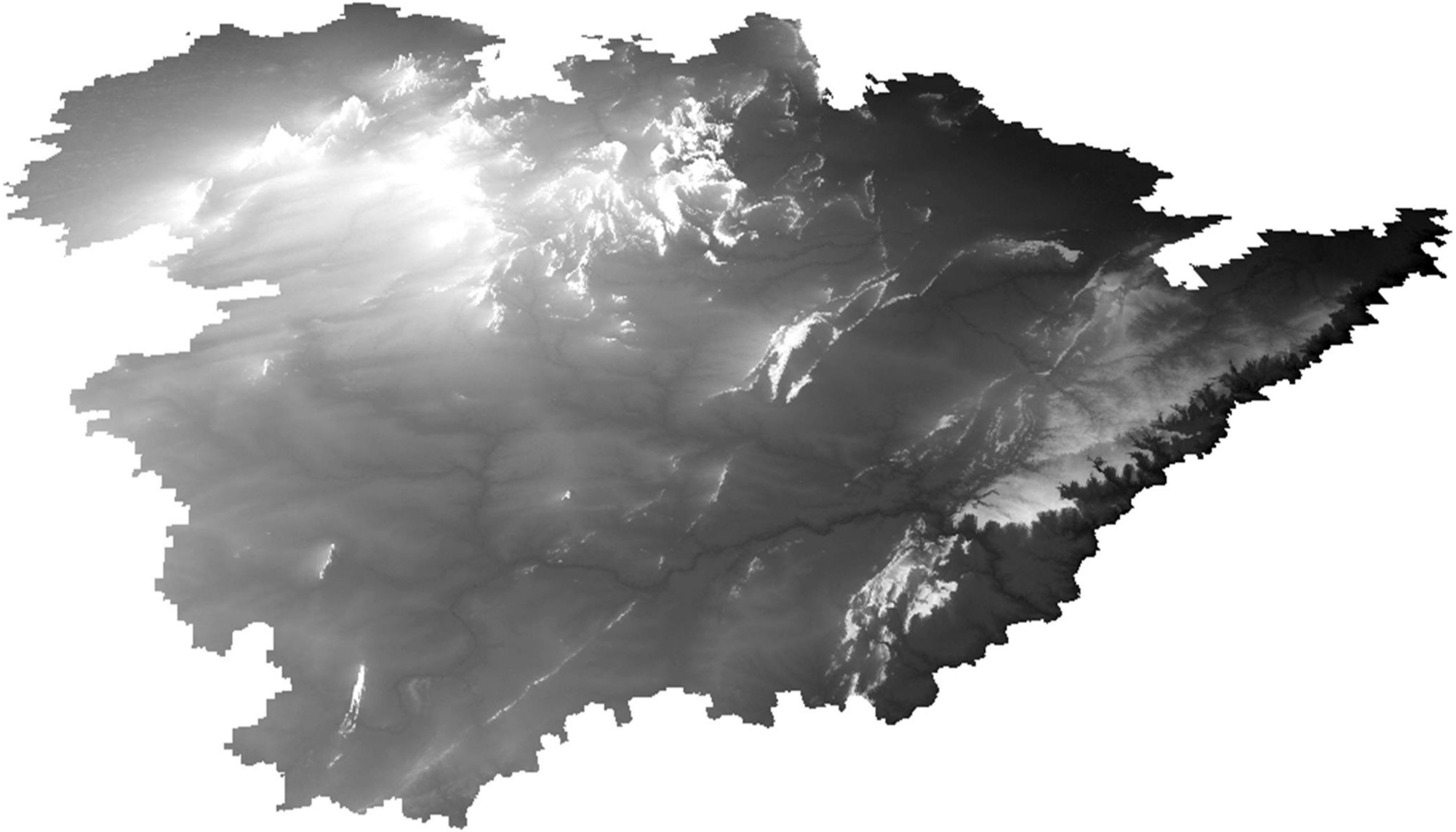
Numerical elevation values cannot be measured from the display

Two-and-a half D Visualization

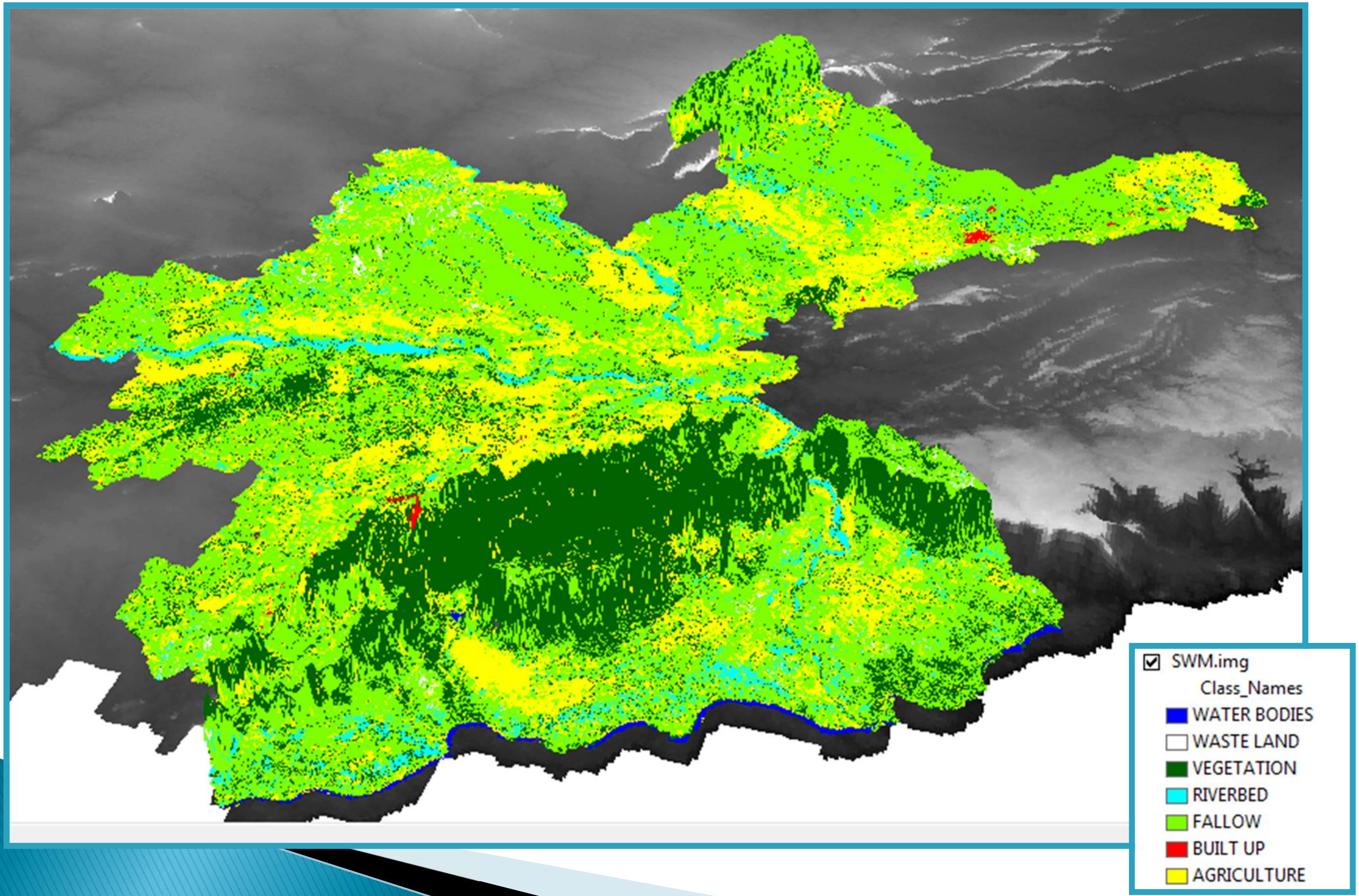


- Z attribute associated with an x,y location is projected onto an x,y,z coordinate reference system
- Creates a map of Z attribute for an x,y position such that each z- attribute defines a position on the z-axis, creating a surface that is perceived as 3 dimensional
- C/a 2.5 D because does not create the impression of visual depth (i.e. distant objects are smaller than closer ones)
- May be used with other kinds of images that are draped on them to create a more realistic perspective view of the terrain

2.5 D Terrain visualization



2.5 D Visualization: Sawai Madhopur District



Perspective view

- 3-D views of the terrain
- The terrain has same appearance as it would have if viewed at an angle from airplane
- **Four parameters** control appearance of 3D View
  1. **Viewing azimuth** – Direction of observer to the surface (0 to 360 degree in clockwise direction)
  2. **Viewing angle** – angle from horizon to altitute of observer (0 to 90 degree) 3D effect reaches its maximum as angle approaches 0 degree i.e. horizon
  3. **Viewing distance** – distance between viewer and surface
  4. **Z-scale** – vertical exaggeration factor (ratio between vertical scale and horizontal scale-useful for highlighting minor landform features)

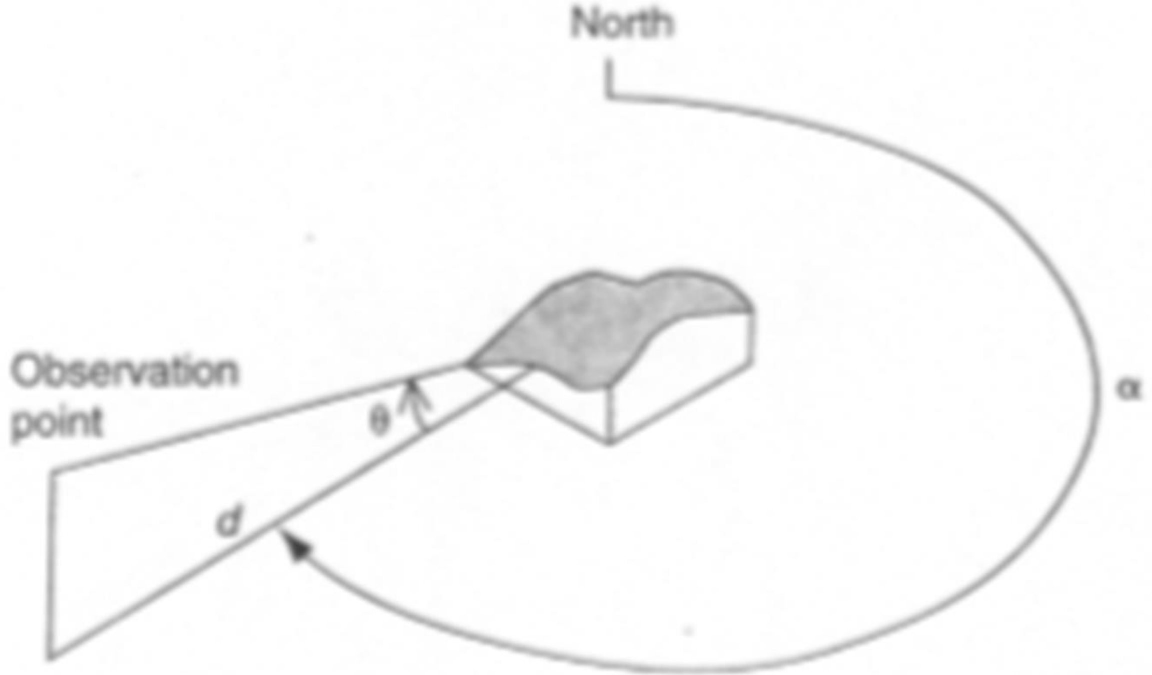


Figure 12.8
The diagram shows three parameters controlling the appearance of a 3-D view. α is the viewing azimuth, measured clockwise from the north. θ is the viewing angle, measured from the horizon. d is the viewing distance, measured between the observation point and the 3-D surface.

3-D Draping

- Perspective view can be made more realistic by superimposing the view by layers such as hydrographic features, land cover, vegetation, roads etc.
- GIS users can rotate the surface, navigate the surface, or take a close-up view of the surface.

3 D Visualization

- An analog for the physical space in nature as perceived by the observer

Extraction Of Topographic Attributes And Landscape Features

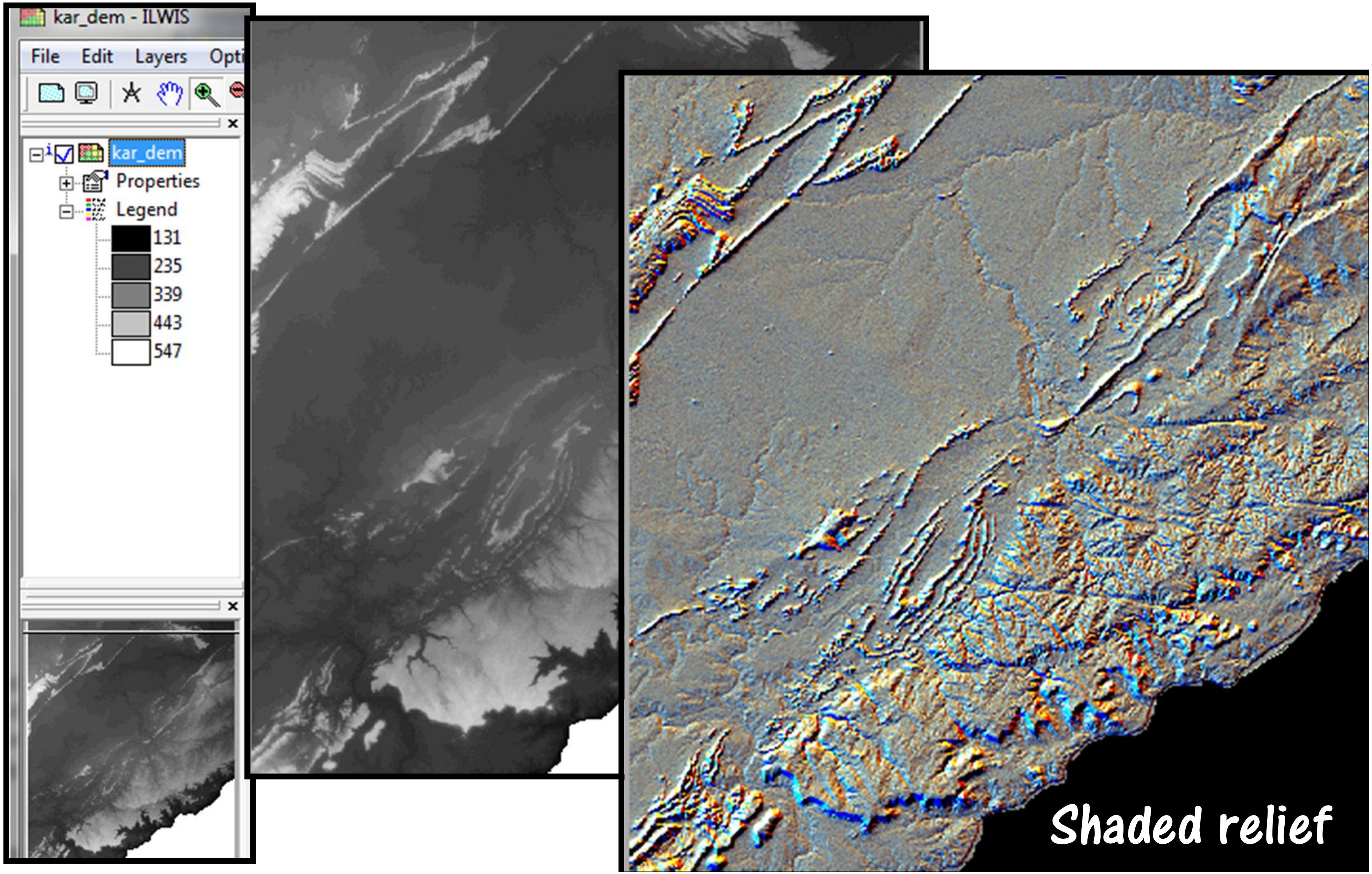
- Topographic attributes are numerical descriptions of the terrain
- May be classified as Primary and Secondary attributes
- Primary topographic attributes are those geomorphic parameters that may be directly calculated from digital terrain such as elevation and slope.
- Secondary attributes also c/a Compound attributes are those which are formed by combining the primary attributes with other environmental indices that characterize the spatial variability of specific processes occurring in the landscape (e.g. soil water content distribution)

Primary Topographic Attributes

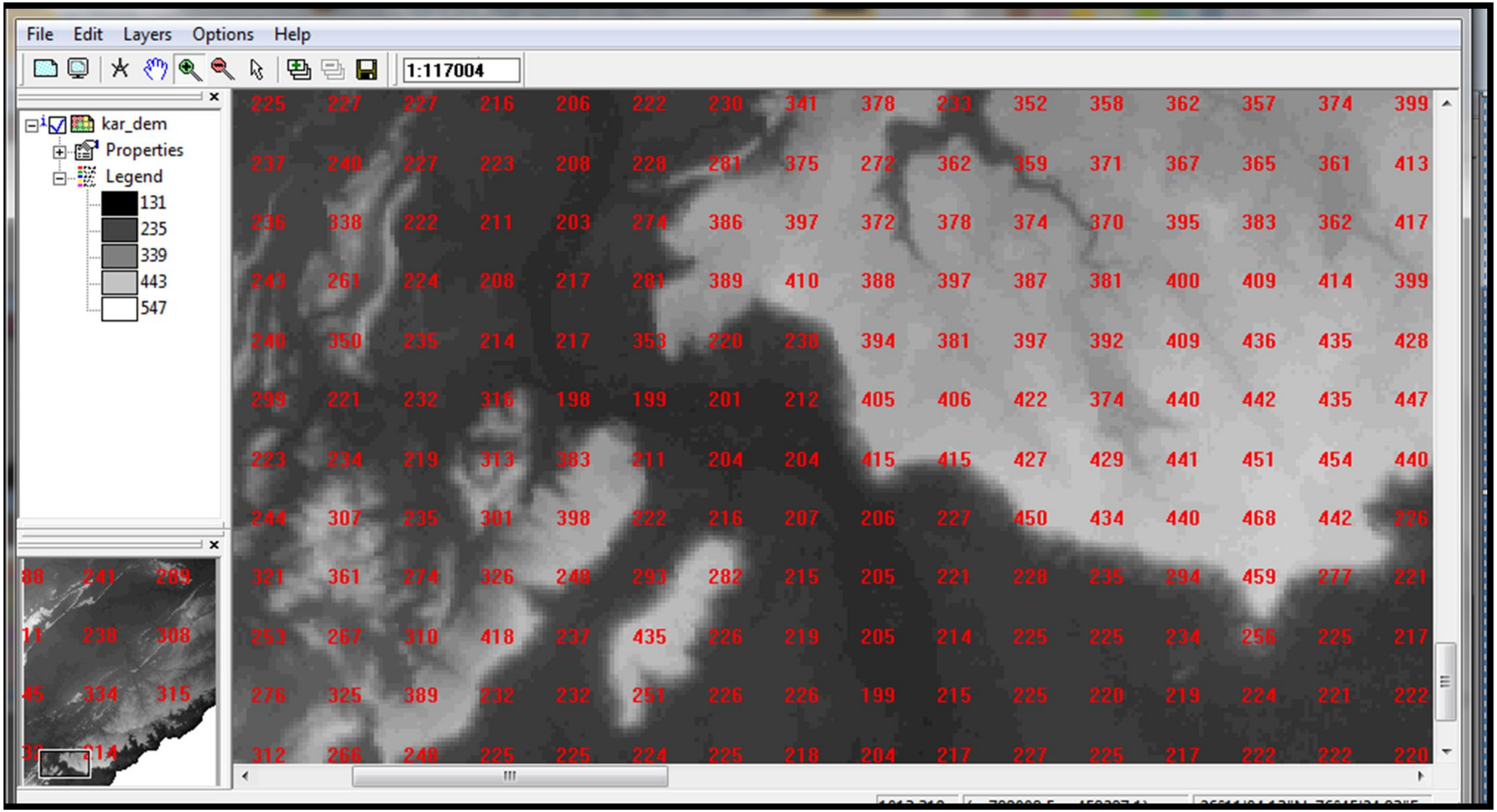
The following PA s can be easily estimated from DEM data using automated methods

- **Elevation**
- **Slope**
- **Aspect**
- **Profile Curvature**
- **Plan curvature**
- **Flow path length**
- **Local relief**
- **Drainage density….**

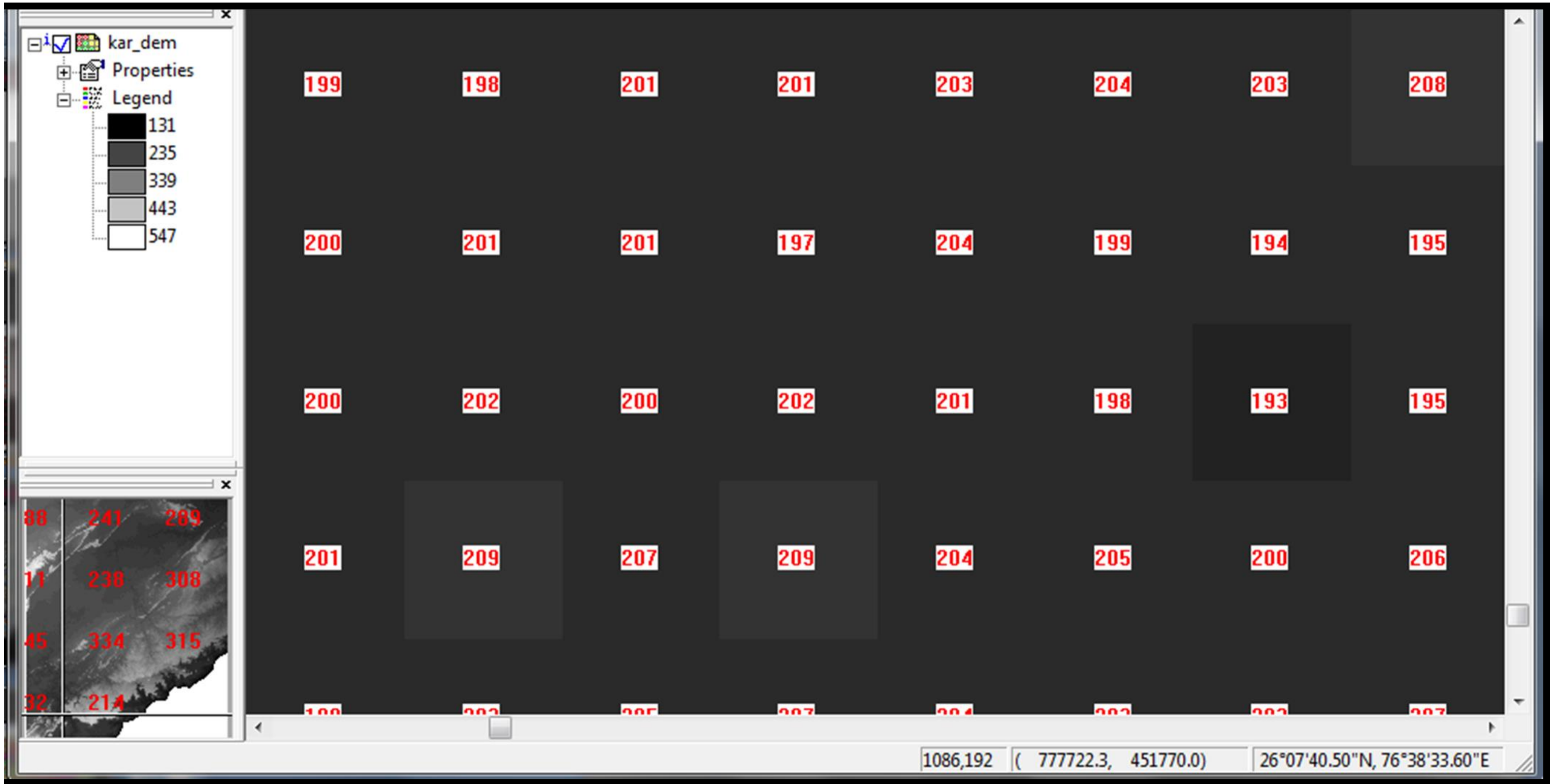
SRTM DEM of Karauli Distt - ILLWIS



Elevation Values



Elevation Values....



Landscape features

- The extraction of topographic attributes and geo-morphometric parameters is usually an intermediate process in digital terrain modelling.
- Data obtained are used more as input for further terrain modelling rather than an end product
- Most of the terrain features extracted are associated with drainage and hydrological applications
- Three primary types of landscape features are extracted:
  - Surface specific points
  - Linear or network features
  - Areal features

Landscape Feature Extraction for drainage and hydrological applications

Surface specific Point Features

- Peaks
- Pits
- Passes
- Saddles

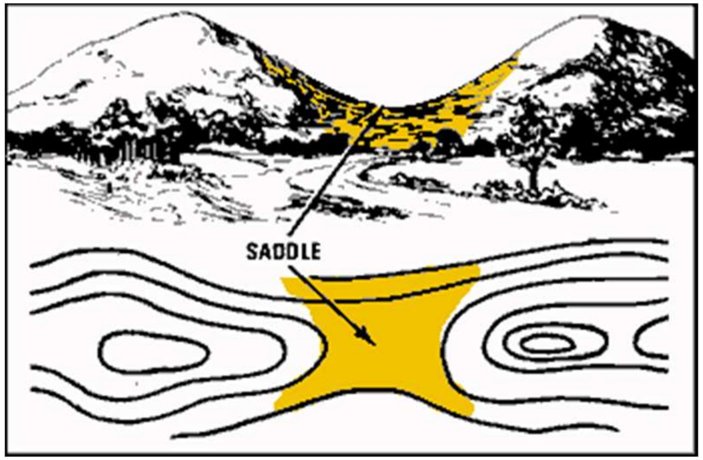
Algorithms are based on comparison of elevation differences in local neighbourhood (local relief)

In DEM peaks are represented by local elevation maxima

Pits, passes and saddles are represented by local elevation minima

Linear or Network Features/ Area features

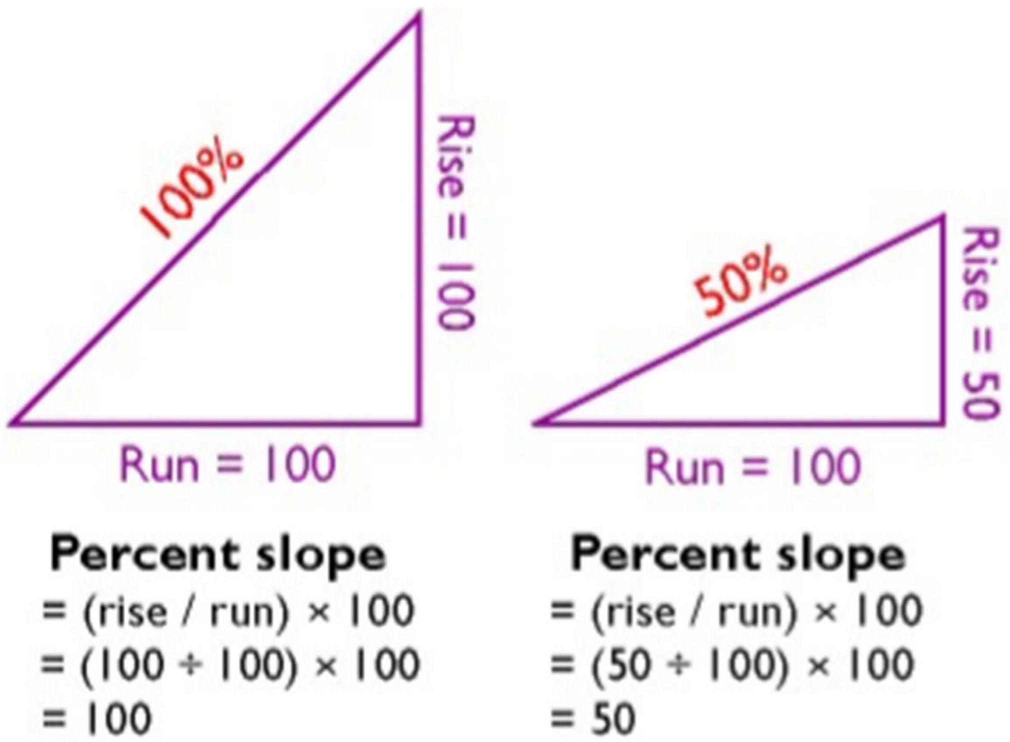
- Flow direction map
- Flow accumulation map
- Drainage network
- Drainage network ordering
- Catchment area delineation



Slope

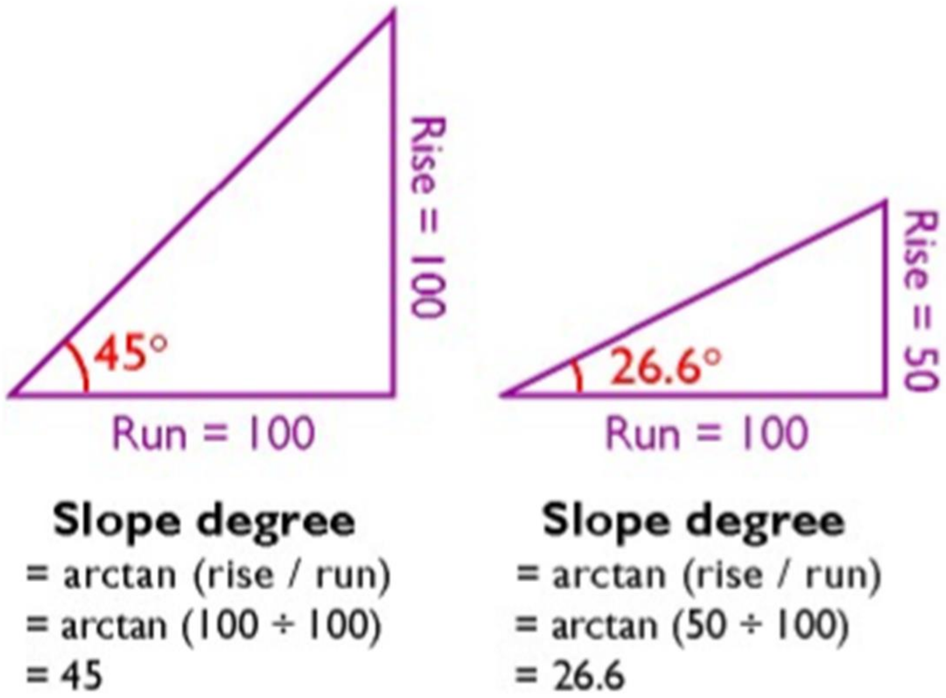
- Measure of rate of change in elevation – Steepness, Gradient of a unit of terrain
- Measures maximum rate of change across the surface, from cell to cell in a gridded surface
- Every cell in an output grid has a slope value
- The lower the slope value, the flatter the terrain; the higher the slope value, the steeper the terrain
- Slope is often calculated as either percent slope or degree of slope
- Slope along with Aspect used in applications such as site selection models to find areas suitable for development, forest inventory estimates, hydrological modeling, soil loss modeling, habitat suitability, landform classification, morphometric characterization..

Percent slope

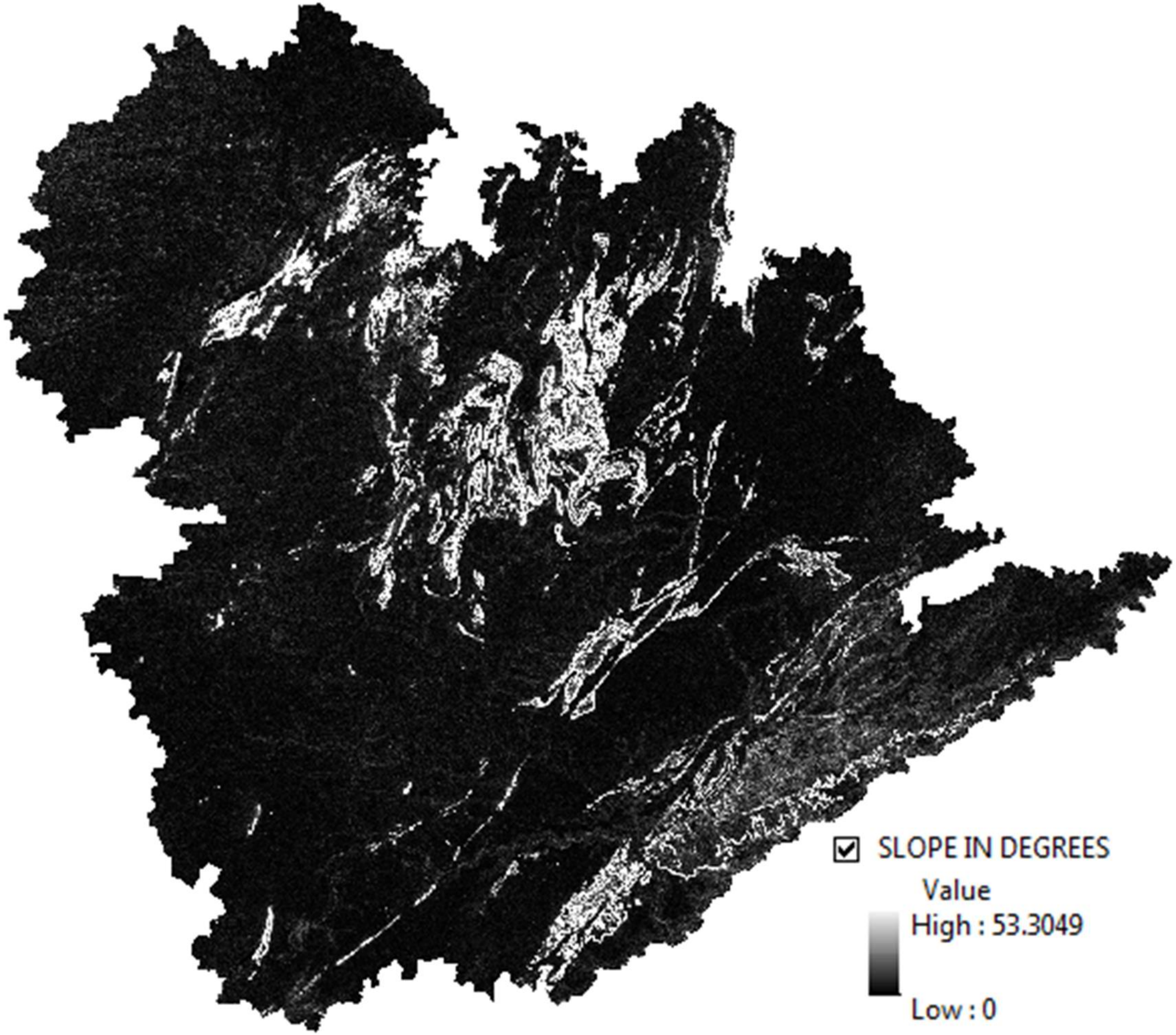


- Divide the difference between the elevations of two points (RISE) by the distance between them (RUN)
- Multiply the quotient by 100.
- Thus, percent slope equals (rise / run) x 100.

Slope in Degrees/ Slope angle



- If you visualize rise and run as sides of a right triangle, then the degree of slope is the angle opposite the rise.
- Since degree of slope is equal to the tangent of the fraction rise/run, it can be calculated as the arctangent of rise/run.


SLOPE IN DEGREES
Value
High : 53.3049
Low : 0

Aspect

- Aspect is the directional measure of slope
- identifies the steepest down slope across a surface
- It is measured clockwise in degrees from 0 (due north) to 360 (again due north, coming full circle).
- The value of each location in an aspect dataset indicates the direction the surface slope faces.
- The aspect of a hillside says a lot about what can grow or live somewhere because it determines how much solar energy it receives. This is useful information when planning of development or recreation sites, and also agriculture and forestry depending on the latitude and climate.

Aspect

- Being circular measure an aspect of 10^0 is closer to 360^0 than 30^0
- Users often have to transform aspect measures for use in data analysis.
- Common method is to classify aspects in four principal or eight principal directions and to treat like categorical data

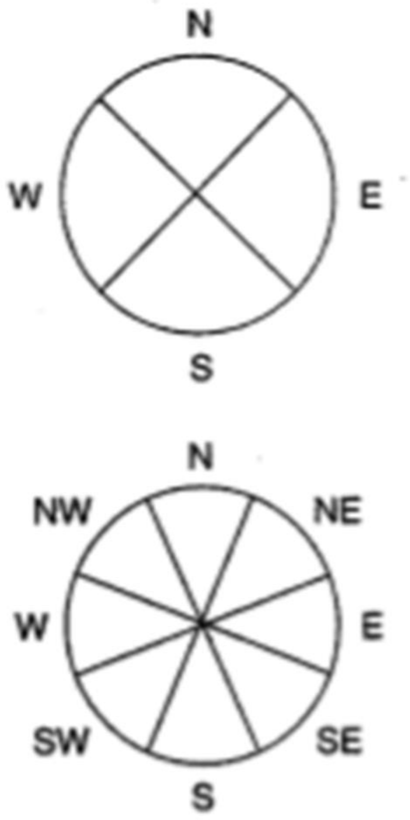


Figure 12.11
Aspect is a directional measure in degrees. Aspect measures are often grouped into 4 principal directions (top) or 8 principal directions (bottom).

Aspect

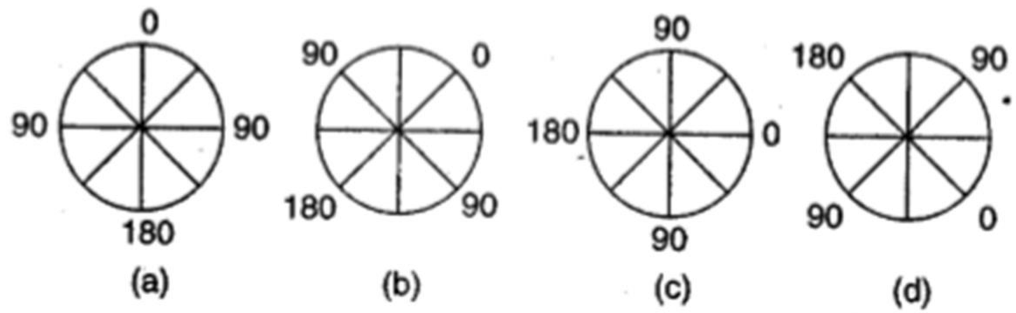
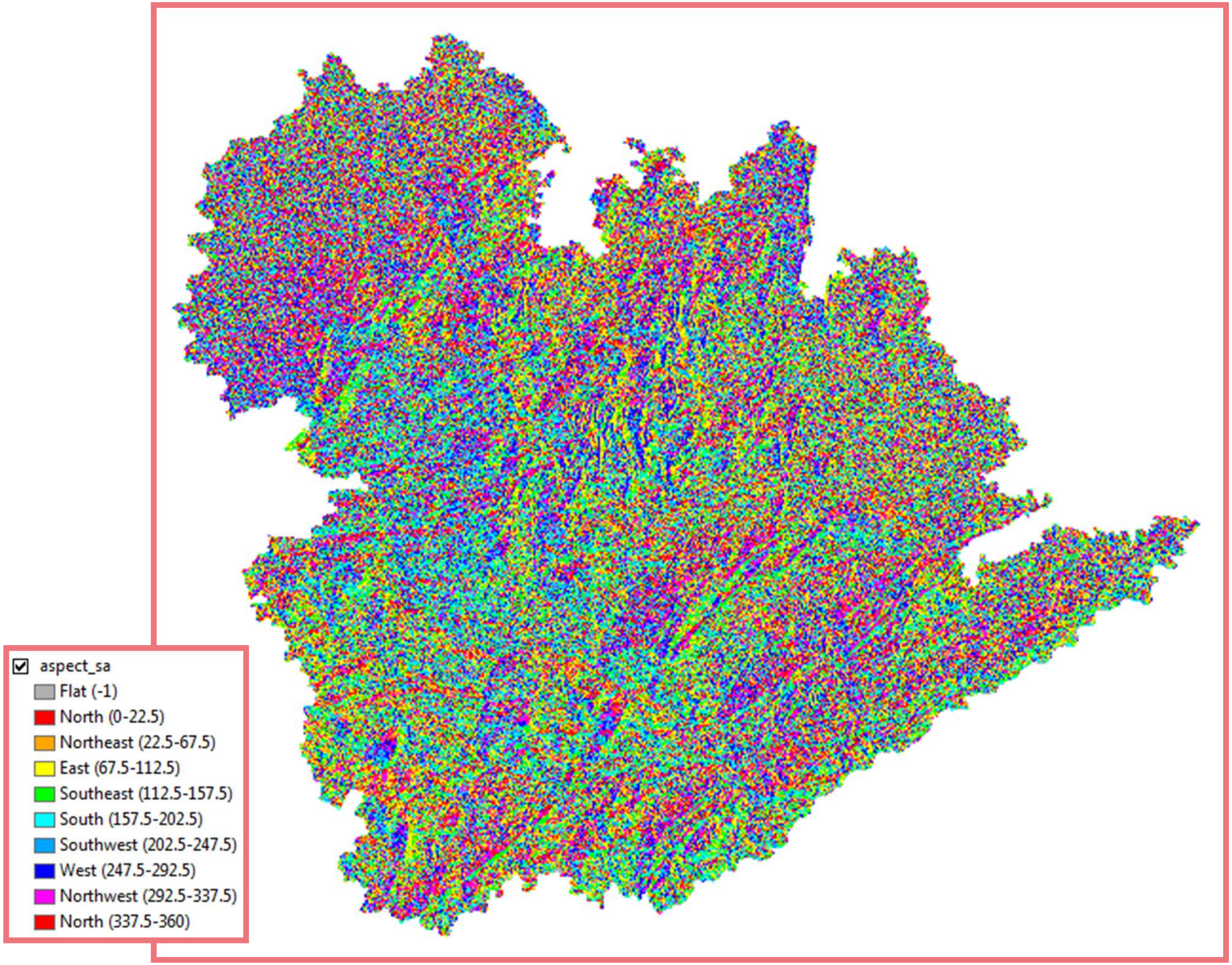


Figure 12.12
Transformation methods to capture the N-S direction (a), the NE-SW direction (b), the E-W direction (c), and the NW-SE direction (d).

- Chang & Li have proposed a method of capturing the principal direction while retaining the numeric measure. For eg. To capture N-S principal direction, 0^0 is set at north, 180^0 at south, 90^0 at both east and west.

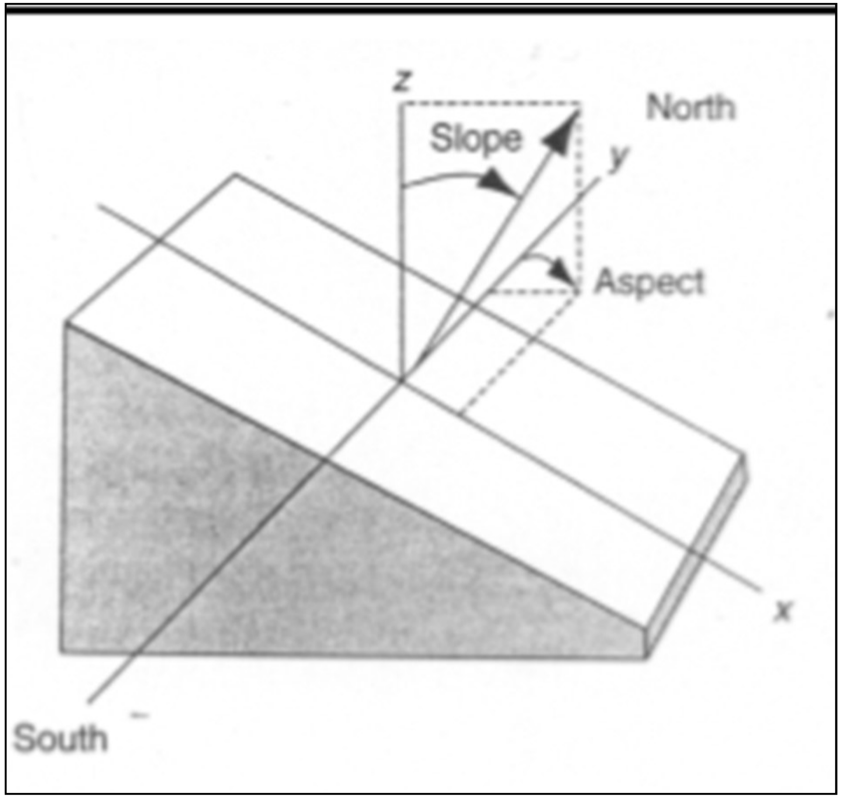

aspect_sa
Flat (-1)
North (0-22.5)
Northeast (22.5-67.5)
East (67.5-112.5)
Southeast (112.5-157.5)
South (157.5-202.5)
Southwest (202.5-247.5)
West (247.5-292.5)
Northwest (292.5-337.5)
North (337.5-360)

How does GIS do it ????

- GIS does not compute slope and aspect for each point. But for discrete units such as cells of elevation raster or triangles of a TIN.

- For the areal unit (cell or triangle) slope and aspect are measured by the quantity and direction of tilt of the units normal vector – a directed line perpendicular to the unit

- Given a normal vector (n_x, n_y, n_z), the formula for computing the unit's slope (s) and aspect (A) is



$$s = (n_x^2 + n_y^2)^{0.5} / n_z$$

$$A = \arctan(n_y / n_x)$$

Approximation methods – DEM

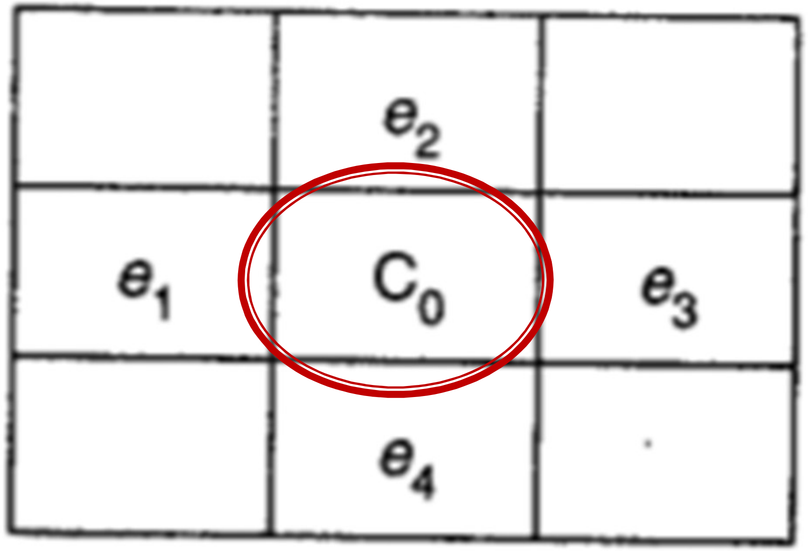
Several algorithms have been developed to calculate slope (percent slope and degree of slope) from ELEVATION RASTER

Ritter's Algorithm

- Use 3x3 moving windows
- The slope of the center cell can be estimated by the four immediate members. See Figure 12.14

$$S = \left((e_1 - e_3)^2 + (e_4 - e_2)^2\right)^{0.5} / 2d$$

$$D = \arctan\left((e_4 - e_2)/(e_1 - e_3)\right)$$



- S is slope gradient if multiply S by 100, the unit is in percent slope.
- D is measured in radian with respect to x-axis, can be converted into degree from a north base of 0^0 using algorithm (see text in Chang'

HORN'S ALGORITHM

- Simplest and most common is neighbourhood method (Horn's algorithm). The method is used in ArcGIS
- Neighbourhood method calculates the slope at one grid point by comparing the elevations of eight grid points surrounding it

Z_1	Z_2	Z_3
Z_4	Z_5	Z_6
Z_7	Z_8	Z_9

Figure 7.10.3 The neighborhood algorithm estimates percent slope in cell 5 by comparing the elevations of neighboring grid cells.

Source: https://www.e-education.psu.edu/natureofgeoinfo/book

Steps

Z_1	Z_2	Z_3
Z_4	Z_5	Z_6
Z_7	Z_8	Z_9

Figure 7.10.3 The neighborhood algorithm estimates percent slope in cell 5 by comparing the elevations of neighboring grid cells.

Percent slope at grid cell 5 is the sum of absolute values of E-W slope (S e-w) and N-S slope(S n-s) multiplying the sum by 100

$$S_5 = \left(\sqrt{S^2_{e\text{-}w} + S^2_{n\text{-}s}}\right) \times 100$$

$$S_5 = \left(\sqrt{S^2_{e\text{-}w} + S^2_{n\text{-}s}}\right) \times 100$$

$$S_{e\text{-}w} = \frac{\begin{bmatrix} z_1 & & z_3 \\ 2z_4 & - & 2z_6 \\ z_7 & & z_9 \end{bmatrix}}{8 \times \text{Grid Spacing}}$$

$$S_{n\text{-}s} = \frac{\begin{bmatrix} z_1 & 2z_2 & z_3 \\ & - & \\ z_7 & 2z_8 & z_9 \end{bmatrix}}{8 \times \text{Grid Spacing}}$$

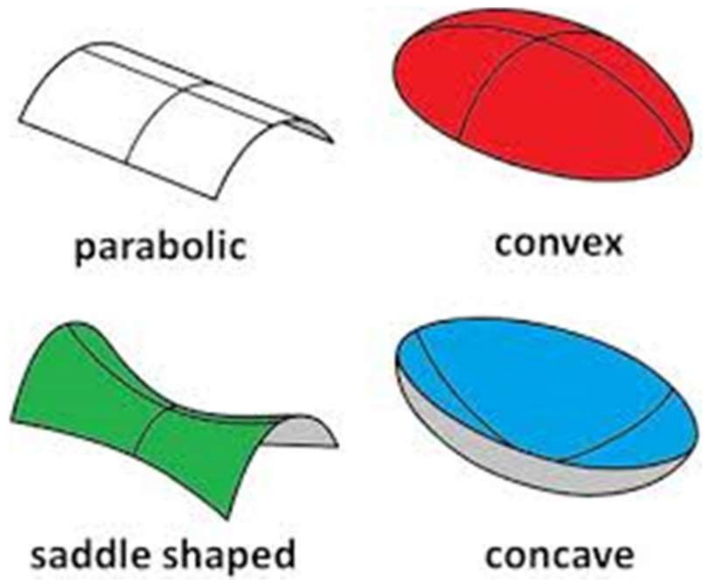
1. 3x 3 grid is identified around each cell
2. E-W slope is the difference between the sums of elevations of the first and third columns of the 3x3 matrix
3. N-S slope is the difference between the sums of the elevations in the first and the third rows
4. In both cases, middle value is weighted by a factor of 2
5. Percent slope is calculated for every cell in the elevation grid
6. Percent slope can be converted into degrees

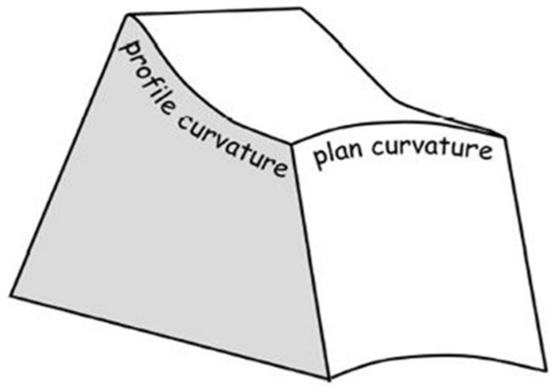
Factors influencing accuracy of slope and aspect

- **Resolution of DEM:** Accuracy of slope and aspect estimates decreases with decreasing DEM resolution.
- **Quality of DEM** – Quality of DEM depends on software package, quality of input data including GCPs
- **Computing algorithm** – Accuracy of output of algorithms varies with topography
- **Local topography** - Errors in slope estimates tend to be higher in areas of higher slopes. Errors in aspect estimates tend to be greater in areas of lower relief

SURFACE CURVATURE

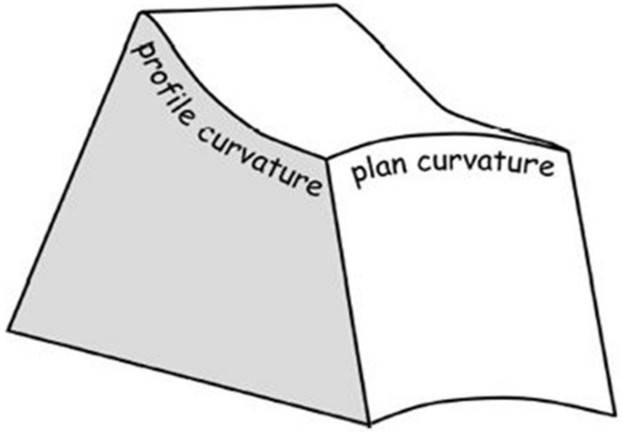
- Rate of change of Slope and/or Aspect
- Is the surface at a cell location upwardly concave or convex?
- Very significant input in hydrological applications, erosion modelling…
- Curvature values can be used to find distribution of water on land





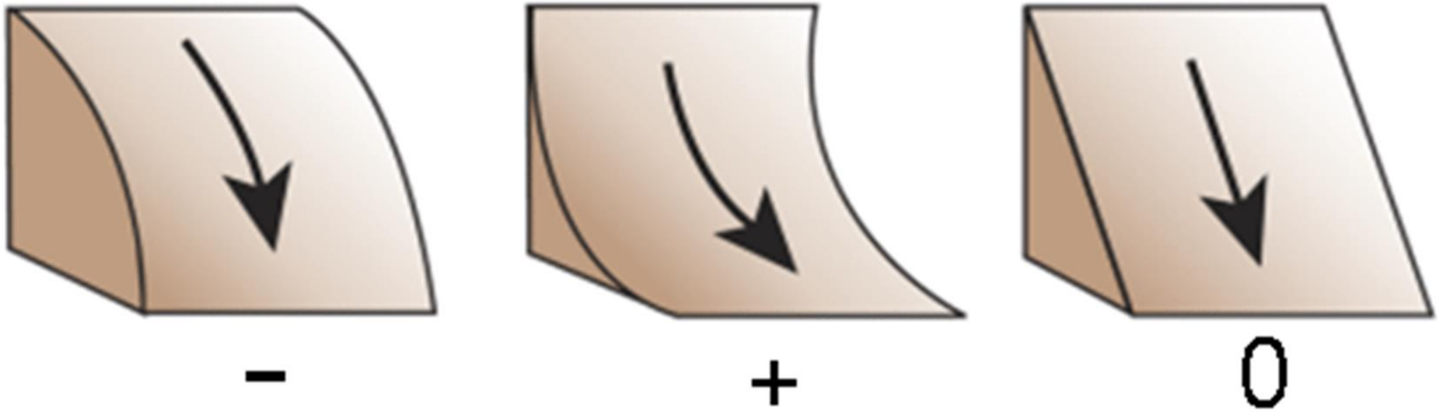
SURFACE CURVATURE

- Three measures
  - Profile curvature : Estimated along direction of maximum slope. Affects acceleration or deceleration of flow hence influences erosion or deposition
  - Plan curvature : Estimated across the direction of maxm. Slope. Influences convergence or divergence of flow
  - Curvature : Difference between the two (profile curvature - plan curvature)

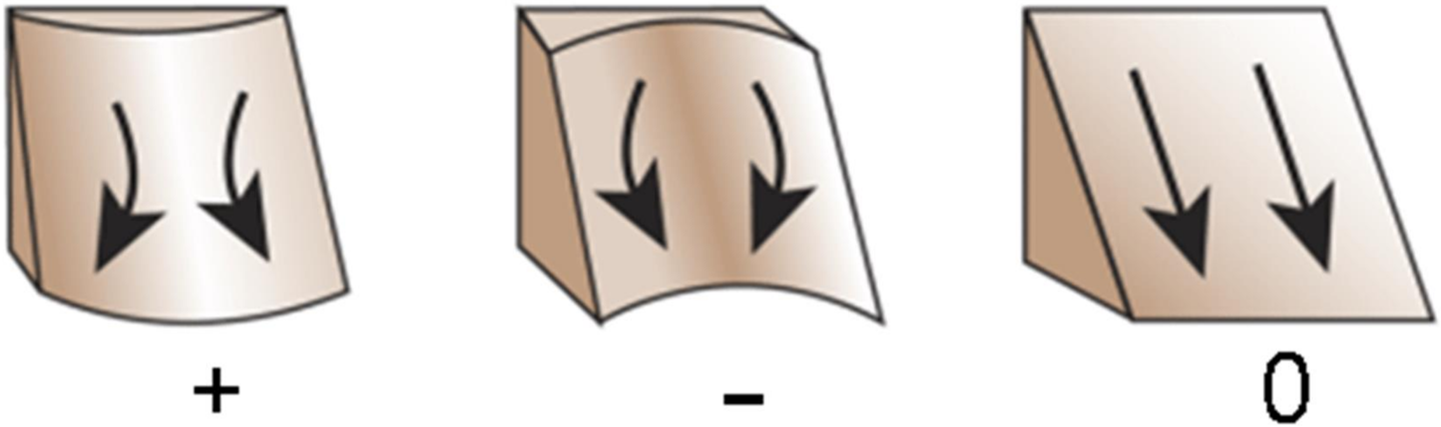


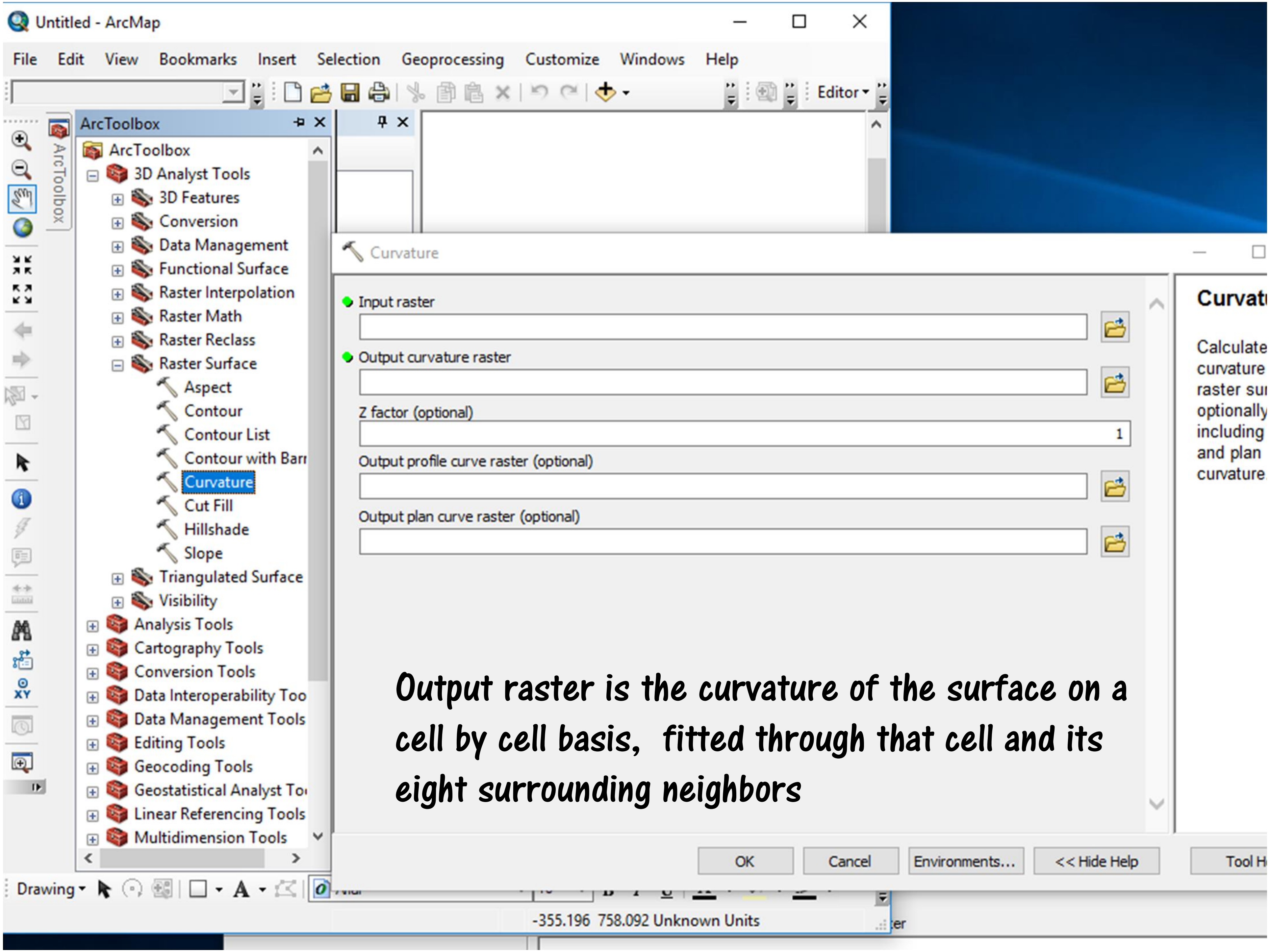
Choose the curvature type which best suits the application and visualization you desire

Profile curvature



Plan curvature





Output raster is the curvature of the surface on a cell by cell basis, fitted through that cell and its eight surrounding neighbors

Common algorithm to estimate curvature from an elevation raster is to fit a 3x3 window with a quadratic polynomial equation

Z_1	Z_2	Z_3
Z_4	Z_0	Z_5
Z_6	Z_7	Z_8

$\leftarrow C \rightarrow$

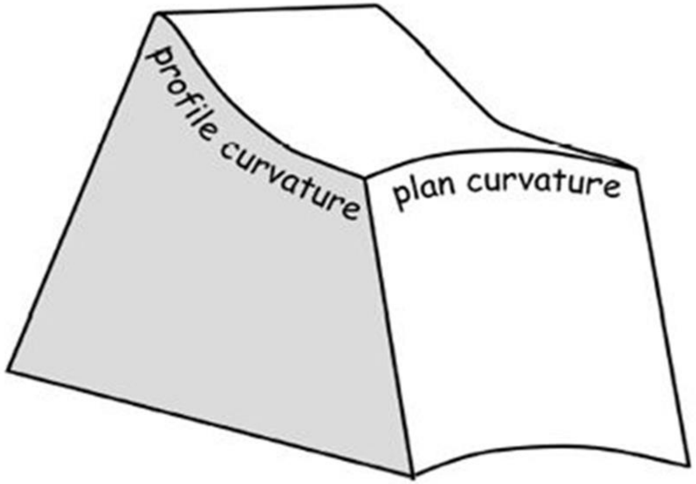
$$D = [\,(Z_4 + Z_5)/2 - Z_0\,] / C^2$$

$$E = [\,(Z_2 + Z_7)/2 - Z_0\,] / C^2$$

$$F = (Z_3 - Z_1 + Z_6 - Z_8) / 4C^2$$

$$G = (Z_5 - Z_4) / 2C$$

$$H = (Z_2 - Z_7) / 2C$$



plan curvature

$$\frac{2\,(DH^2 + EG^2 - FGH)}{G^2 + H^2}$$

profile curvature

$$\frac{-2\,(DG^2 + EH^2 + FGH)}{G^2 + H^2}$$

Curvature = -2 (D+E)

PROFILE CURVATURE

Rate of change of slope relative to a linear or flat profile

- Negative curvature indicates the surface is upwardly convex at that cell and flow will be decelerated
- Positive curvature indicates the surface is upwardly concave at that cell and flow will be accelerated
- A value of 0 indicates the surface is flat (linear)

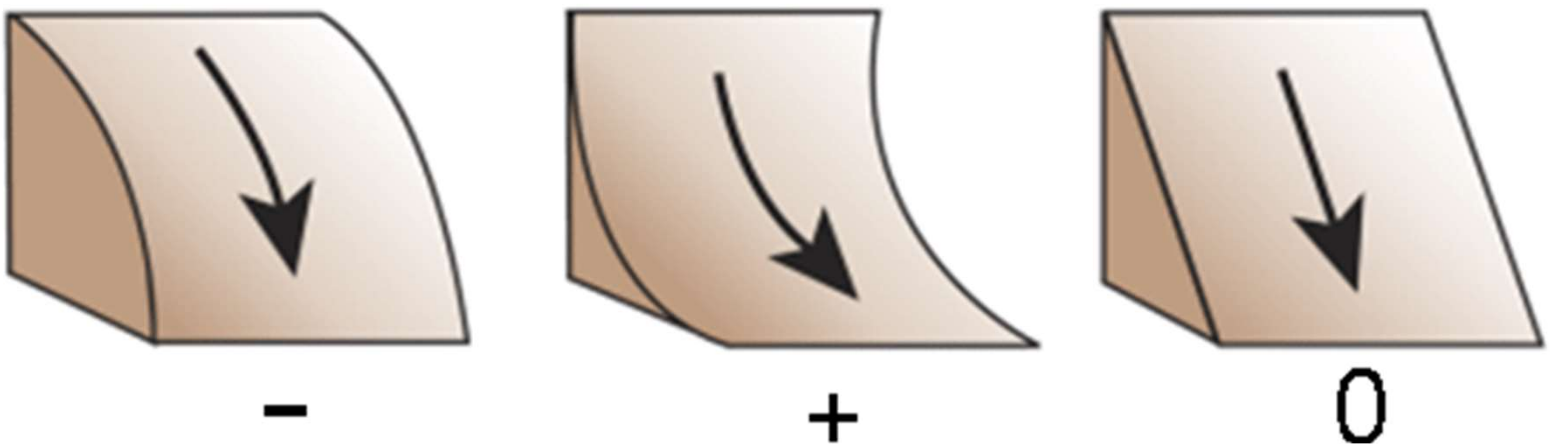


Image source: https://desktop.arcgis.com/

PLAN (PLANFORM) CURVATURE

Rate of change of aspect relative to a given datum

Perpendicular to the direction of maximum slope

- Positive curvature indicates the surface is upwardly convex at that cell ... convex planform such as spurs and ridges
- Negative curvature indicates the surface is upwardly concave at that cell ... concave planform such as troughs and valleys
- A value of 0 indicates the surface is flat

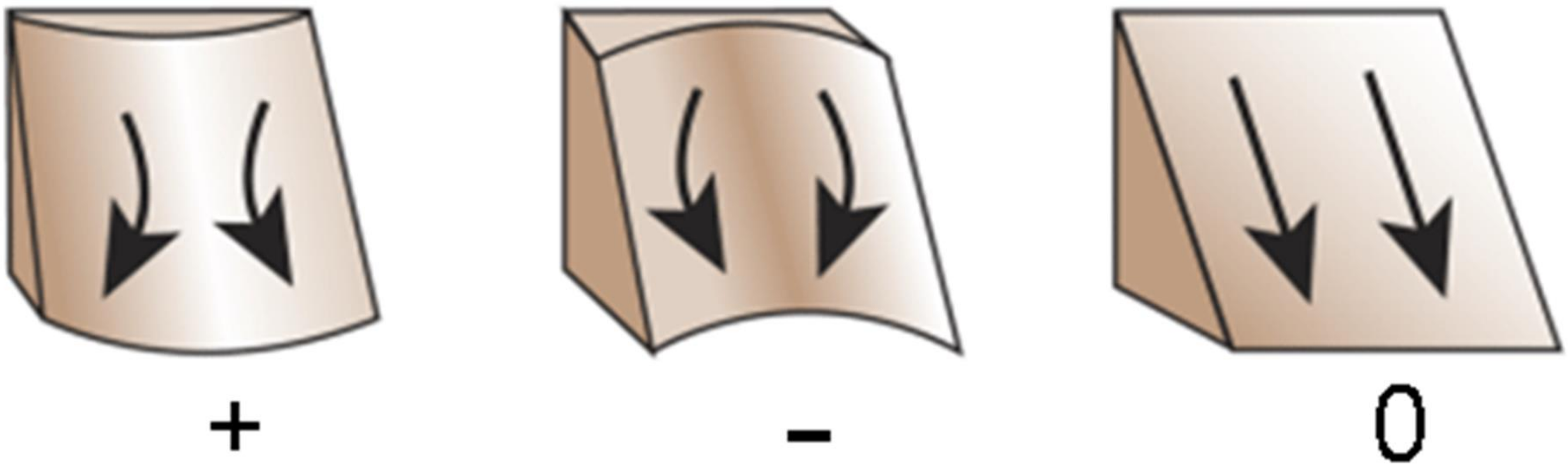


Image source: https://desktop.arcgis.com/

STANDARD CURVATURE

Combines both profile and plan curvatures

- Positive curvature indicates the surface is upwardly convex at that cell
- Negative curvature indicates the surface is upwardly concave at that cell
- A value of 0 indicates the surface is flat

Image source: https://desktop.arcgis.com/

STANDARD CURVATURE

The columns show the planform curves and the rows show the profile curve. The planform columns are positive, negative, and 0—going from left to right. The profiles curves are negative, positive, and 0—going from top to bottom.

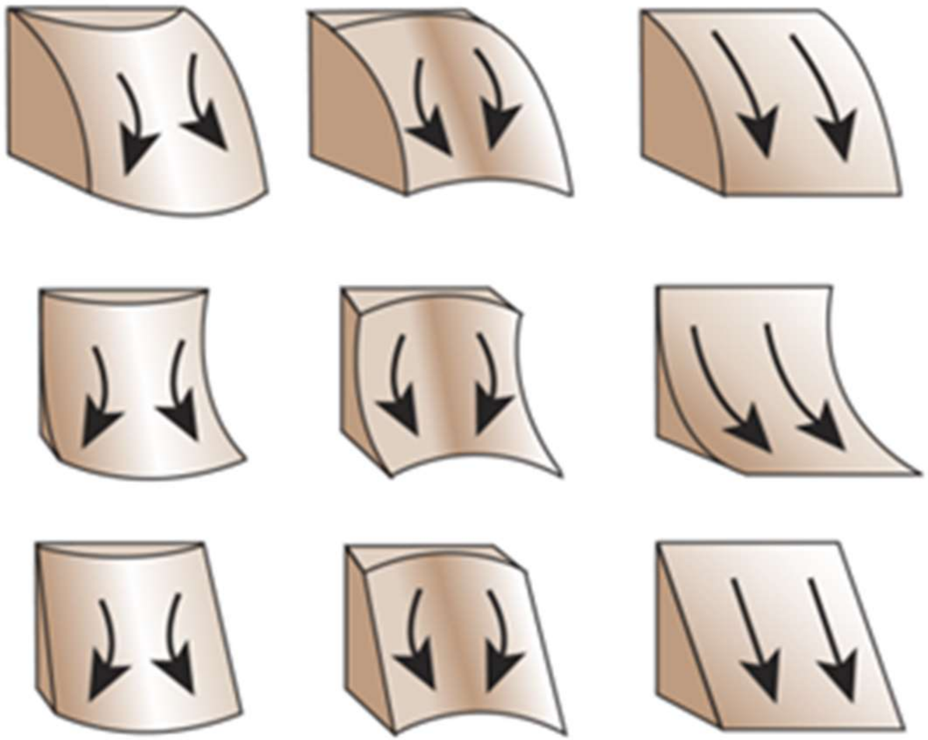
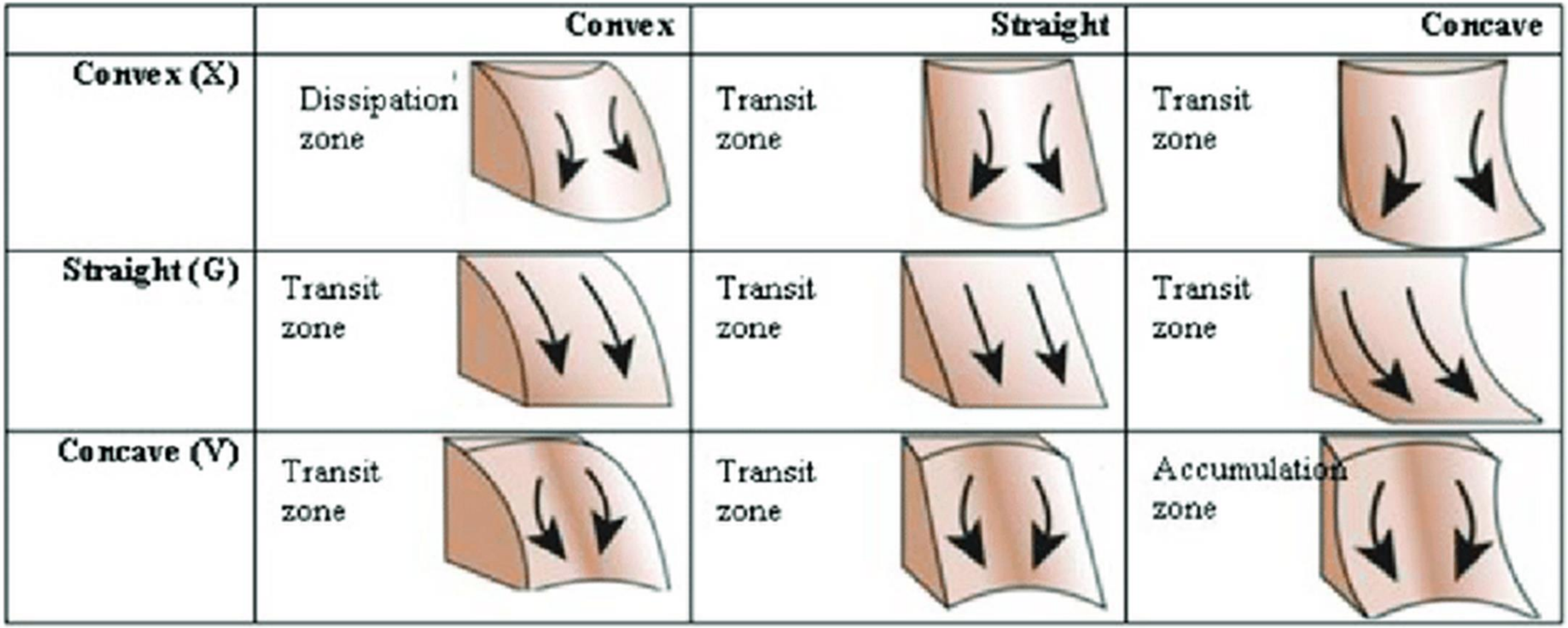


Image source: https://desktop.arcgis.com/

STANDARD CURVATURE

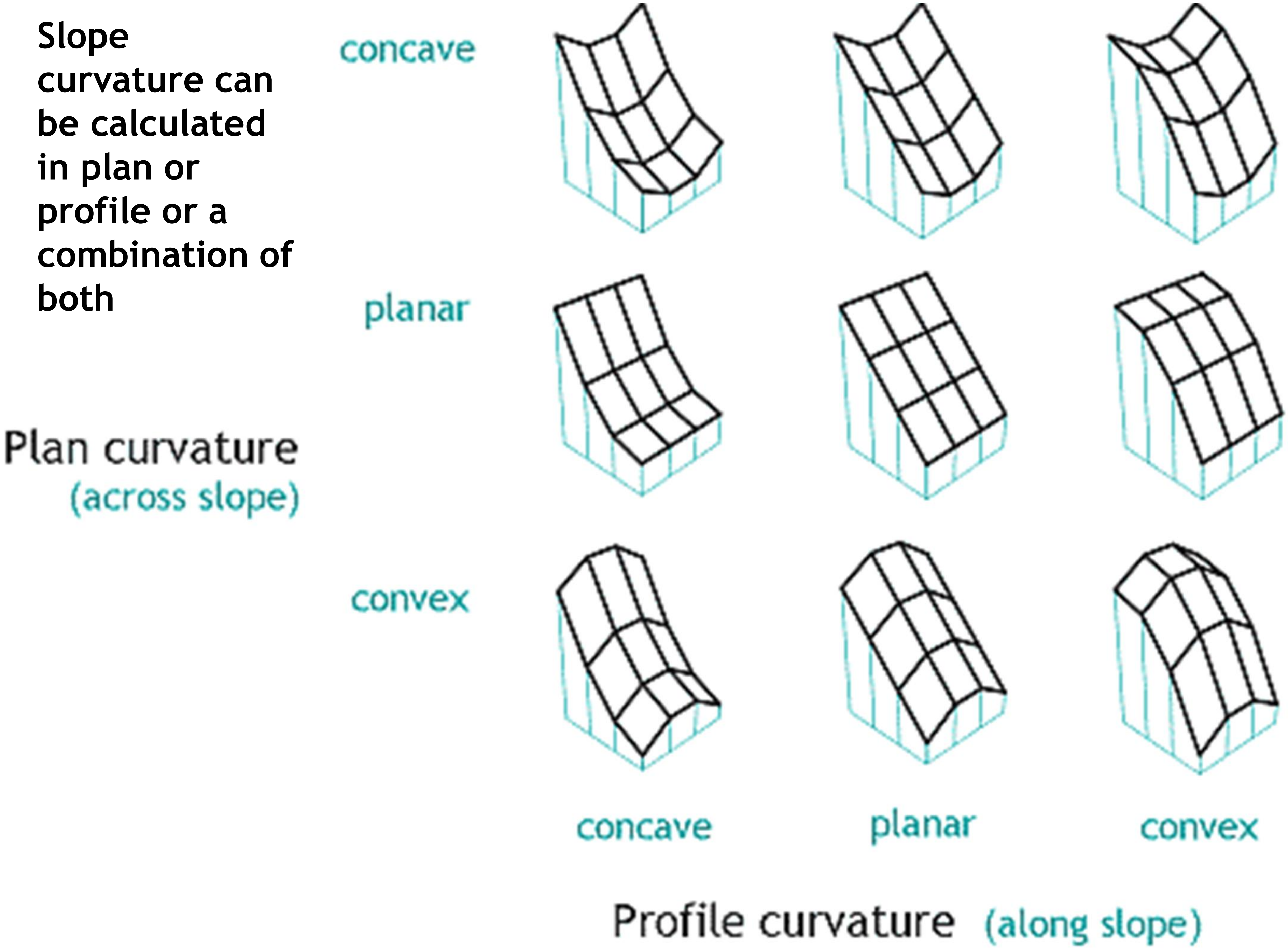
Considering both together allows you to understand the flow across a surface more accurately



Hydroforms classified on the basis of profile and plan curvature (after Florinsky 2000).

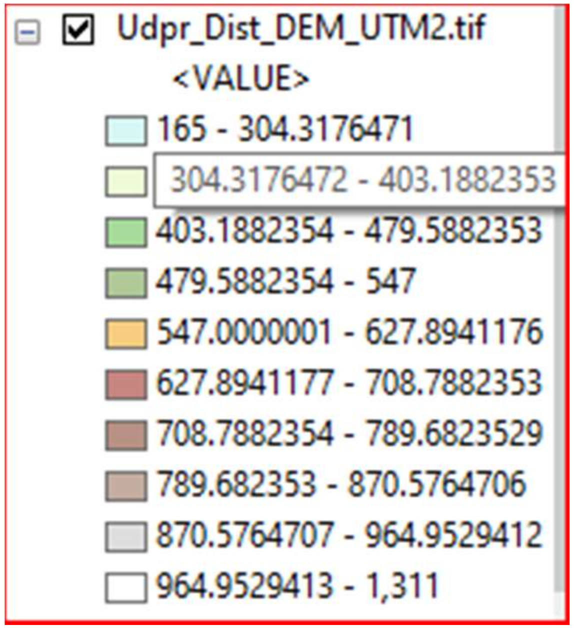
Image source: https://www.researchgate.net/publication/273481152 (Elmahdy et. al (2015)

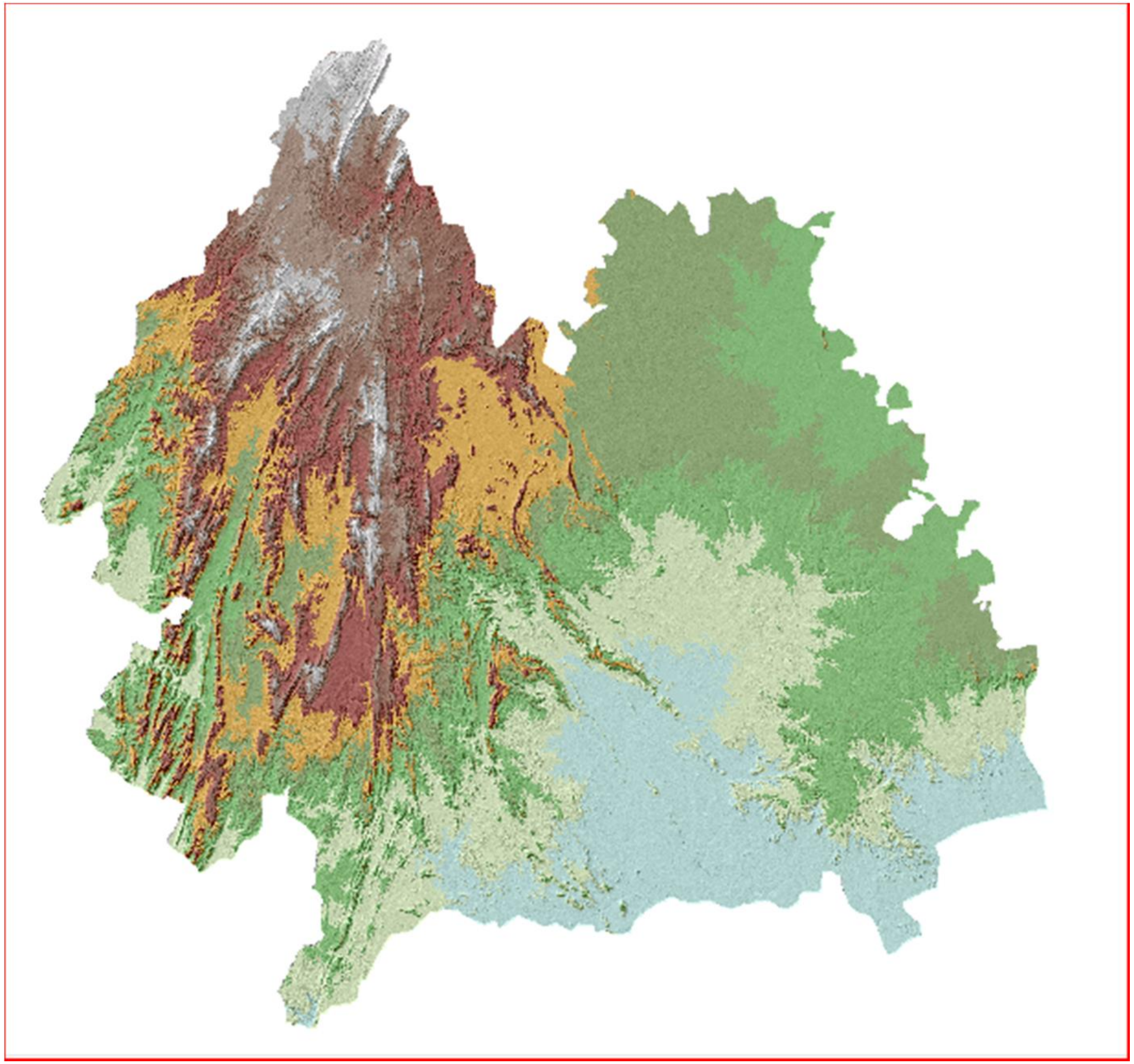
Slope curvature can be calculated in plan or profile or a combination of both



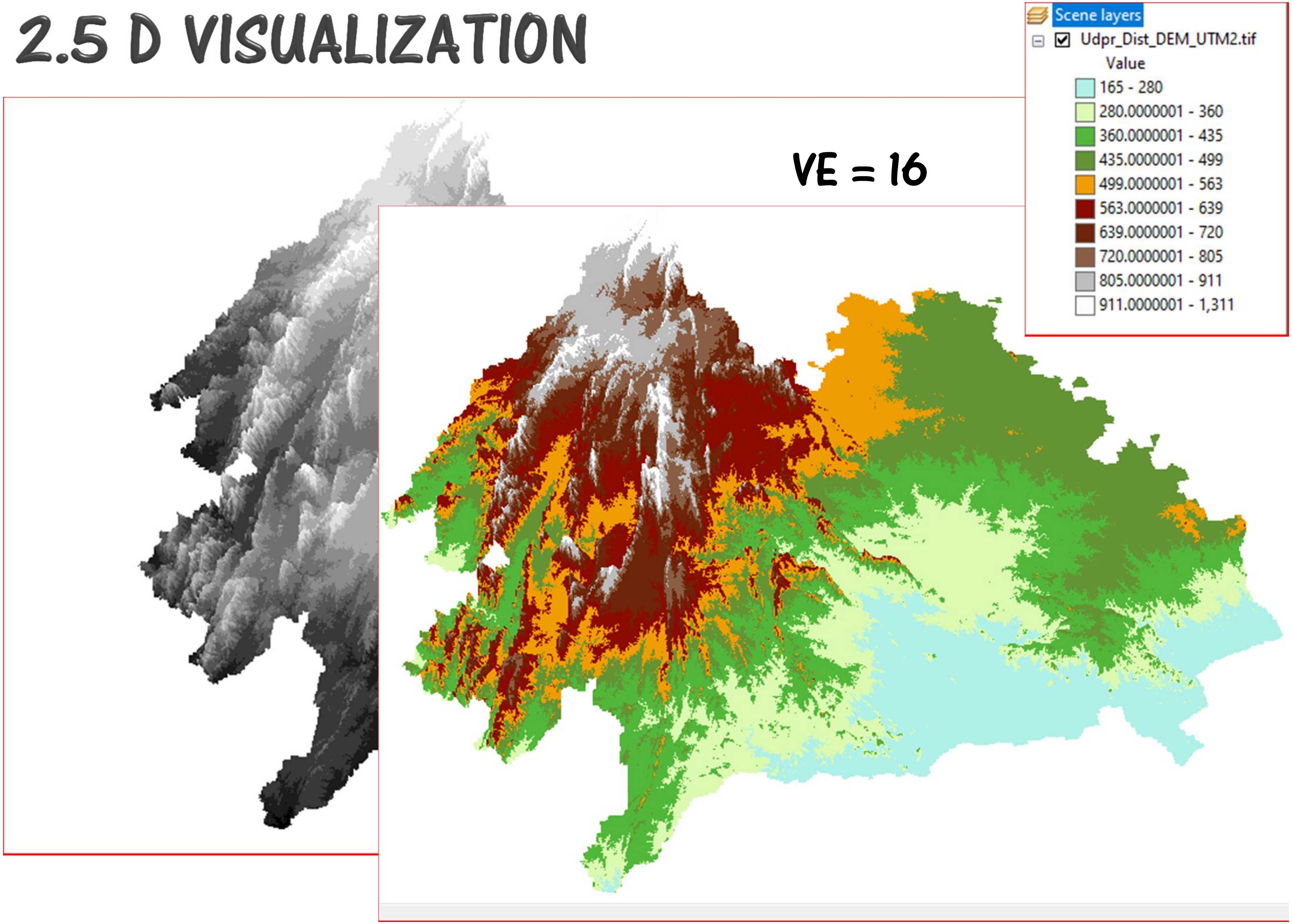
LETS MAP UDAIPUR DISTRICT

SRTM DEM 30 meters overlain on hill shade map

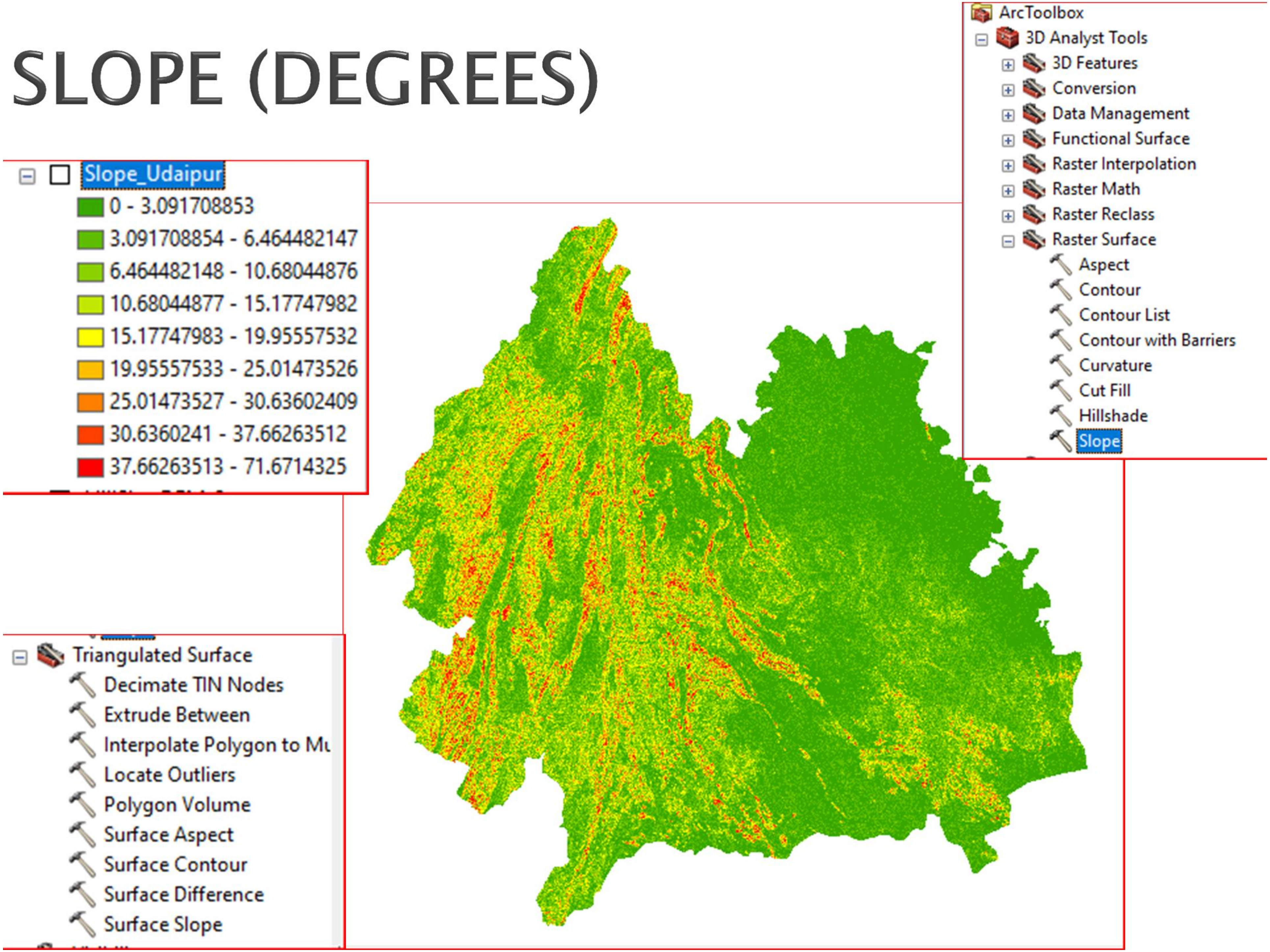




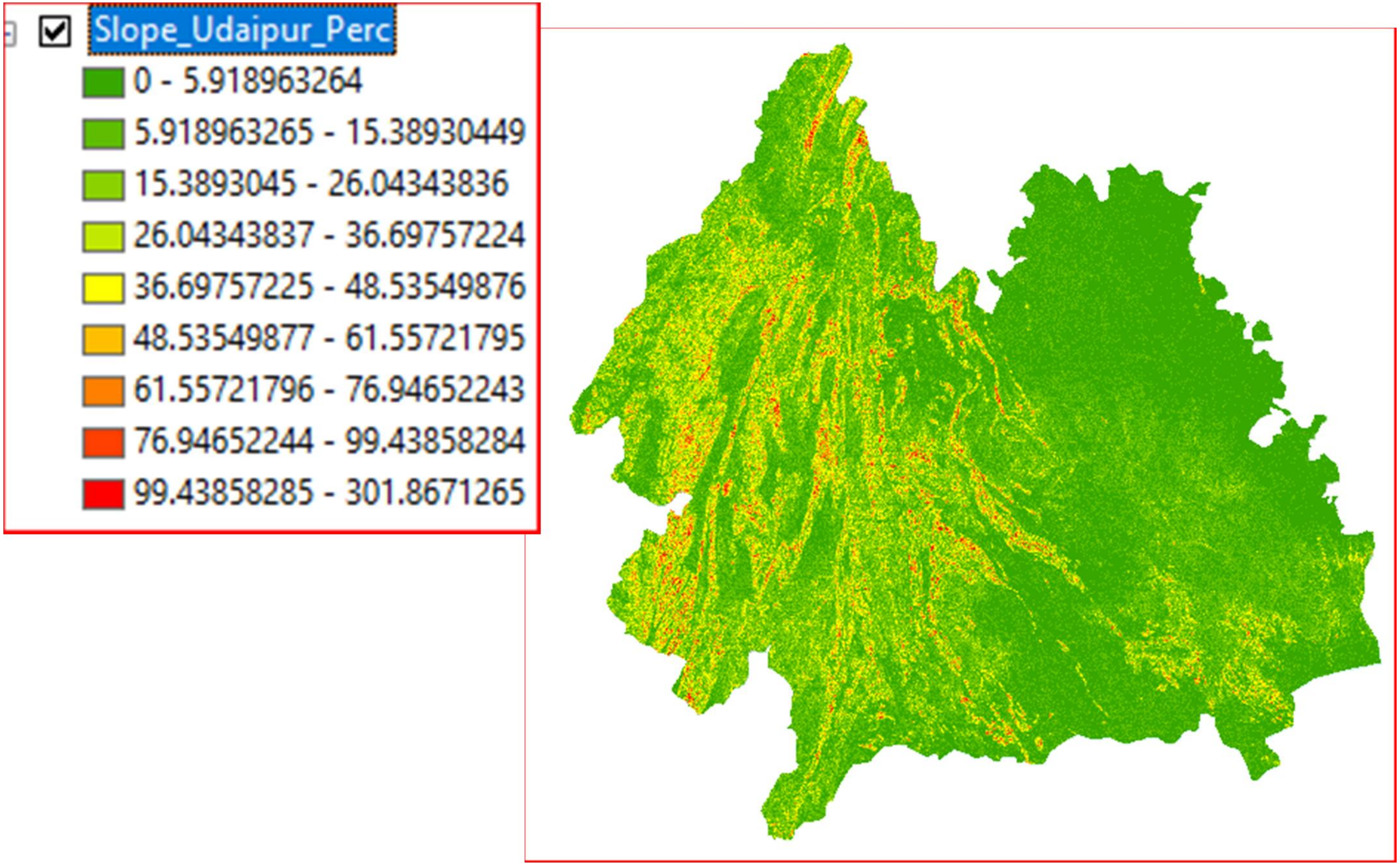
2.5 D VISUALIZATION



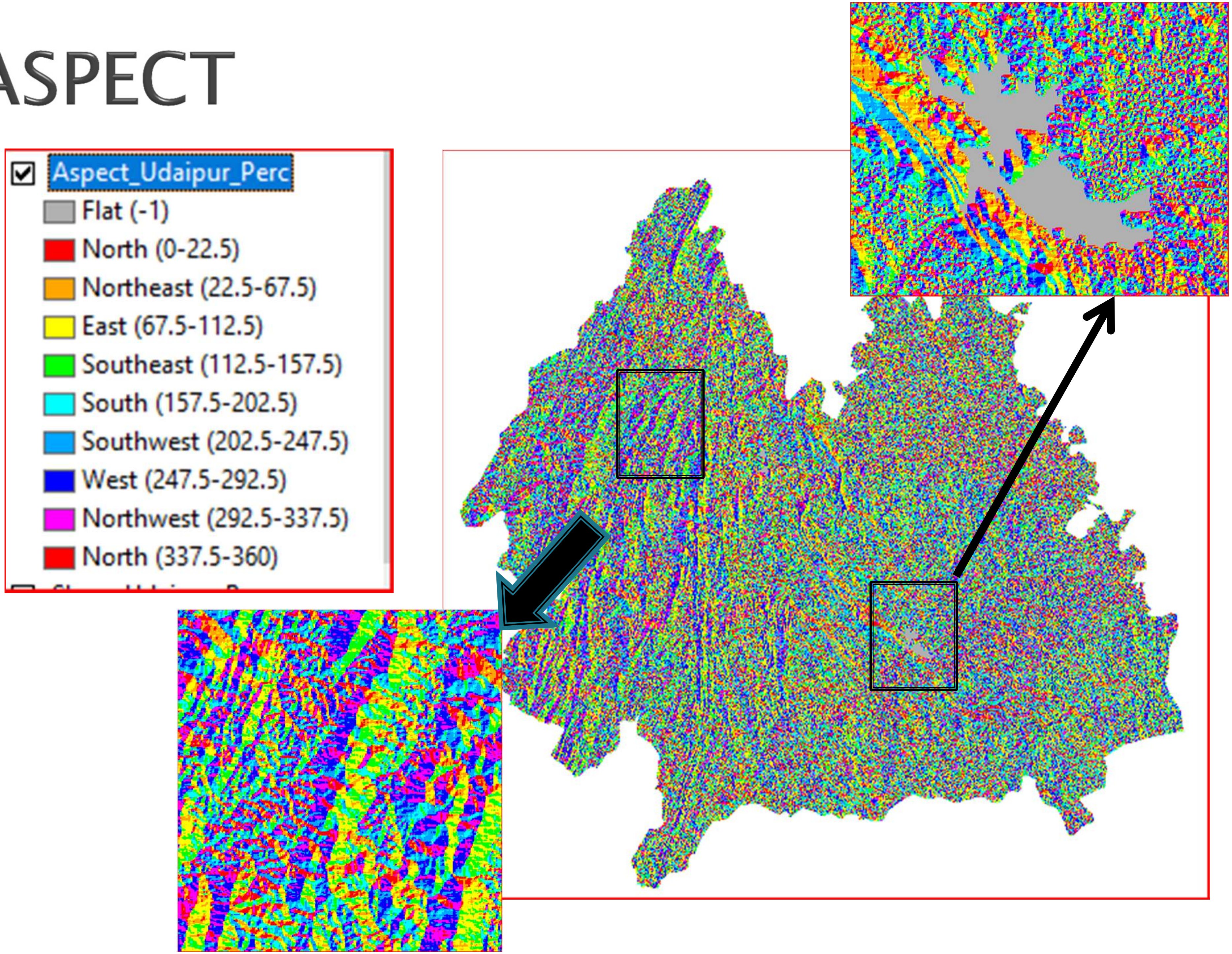
SLOPE (DEGREES)



SLOPE (PERCENT



ASPECT


Aspect_Udaipur_Perc
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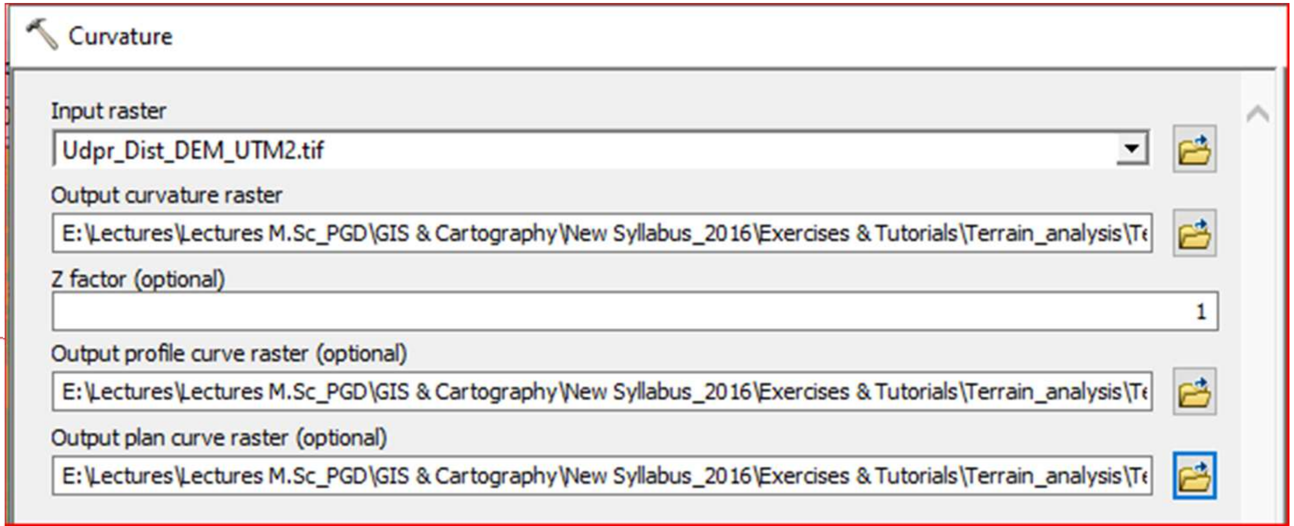
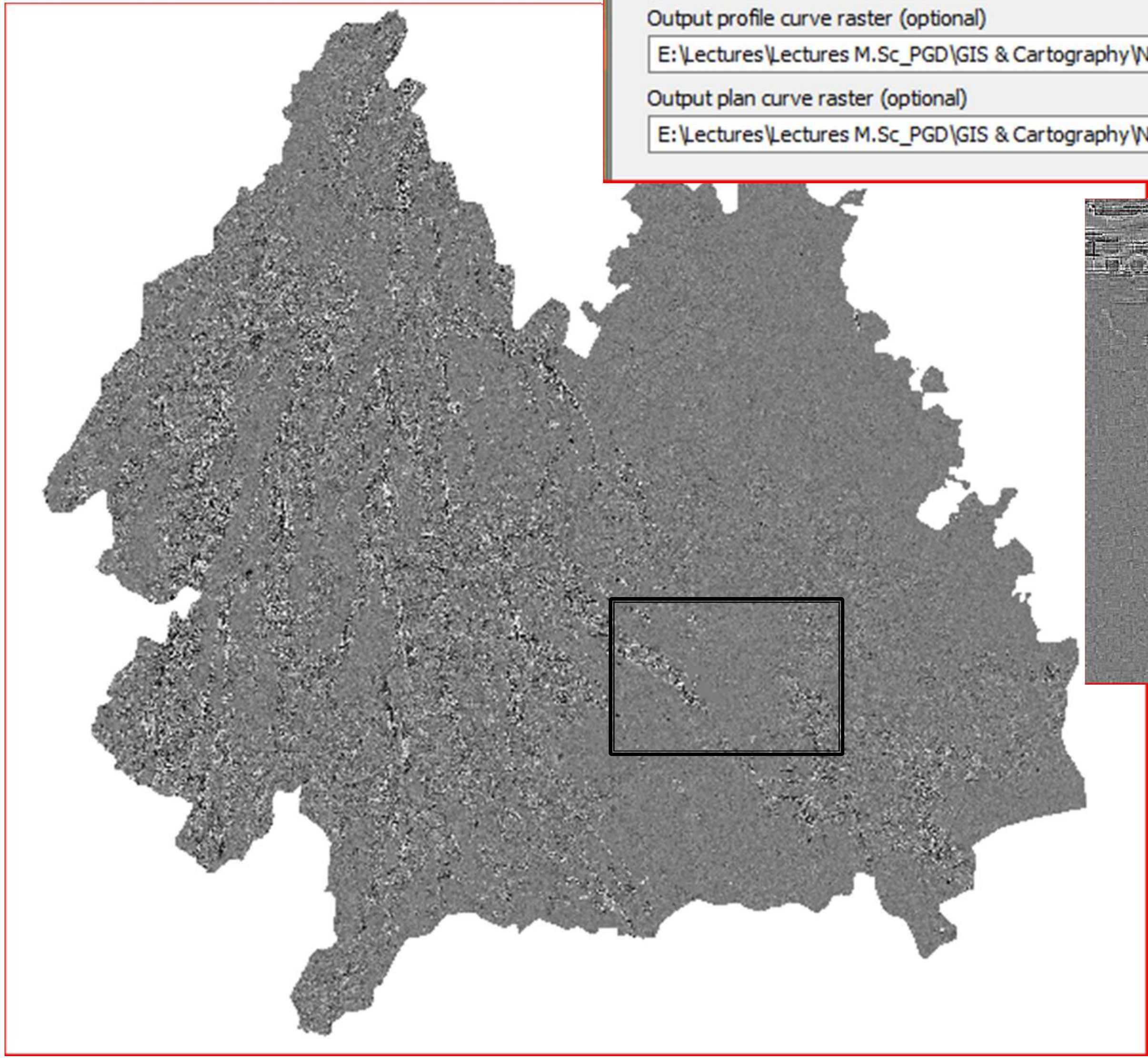
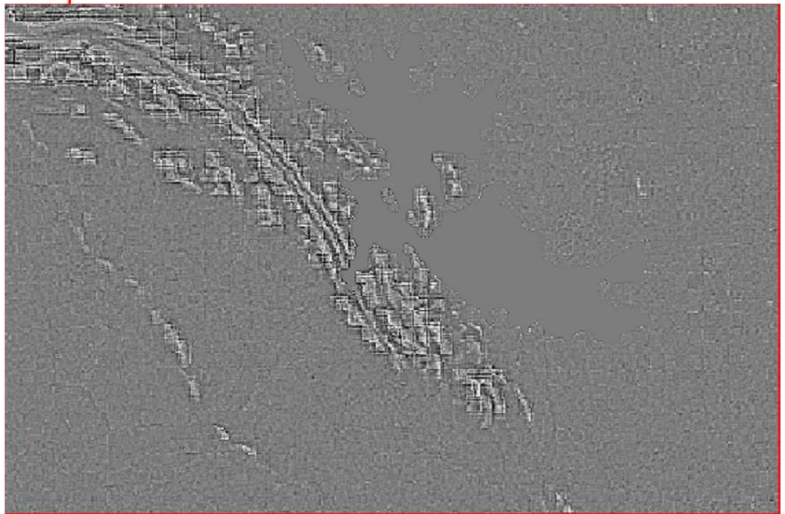
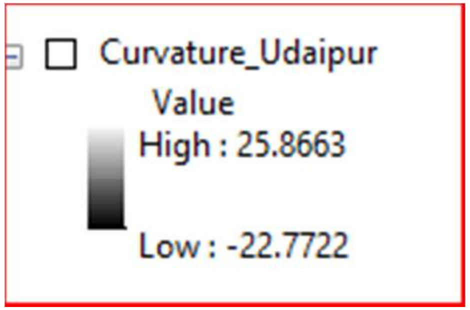
North (0-22.5)
Northeast (22.5-67.5)
East (67.5-112.5)
Southeast (112.5-157.5)
South (157.5-202.5)
Southwest (202.5-247.5)
West (247.5-292.5)
Northwest (292.5-337.5)
North (337.5-360)

CURVATURE

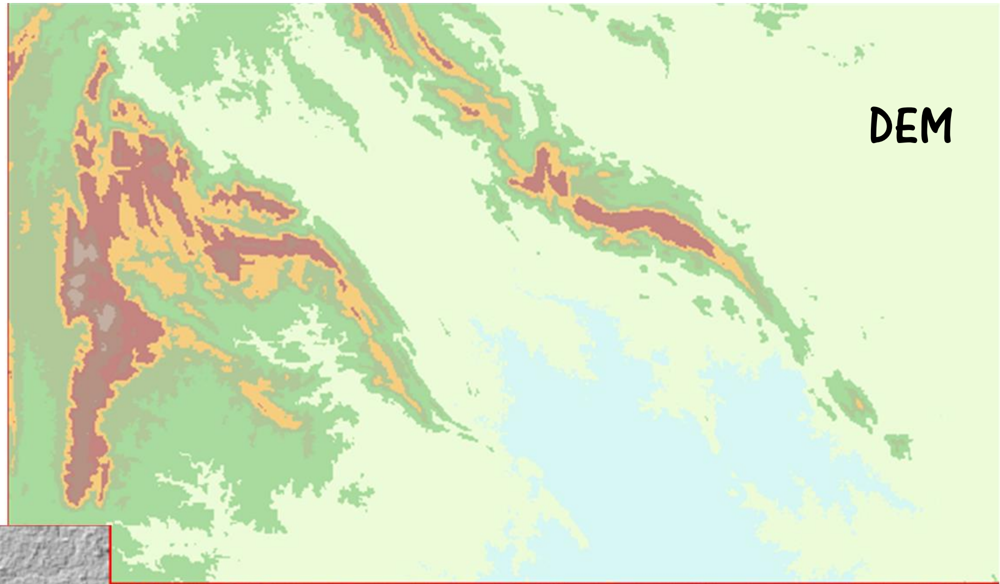

Curvature
Input raster
Udpr_Dist_DEM_UTM2.tif
Output curvature raster
E:\Lectures\Lectures M.Sc_PGD\GIS & Cartography\New Syllabus_2016\Exercises & Tutorials\Terrain_analysis\Te
Z factor (optional)
1
Output profile curve raster (optional)
E:\Lectures\Lectures M.Sc_PGD\GIS & Cartography\New Syllabus_2016\Exercises & Tutorials\Terrain_analysis\Te
Output plan curve raster (optional)
E:\Lectures\Lectures M.Sc_PGD\GIS & Cartography\New Syllabus_2016\Exercises & Tutorials\Terrain_analysis\Te






Curvature_Udaipur
Value
High : 25.8663
Low : -22.7722


Gudel
Jawad
Adwas
Loda
Dhulji Ka Gurha
Mahuri
Jamboora
Saradi
Kaduni
Gatonr
Jaisamand Lake
Shyampura
Veerpura
Jhadol
Image Landsat / Copernicus
©2020 Google
Image © 2020 Maxar Technologies
Image © 2020 CNES / Airbus
Goo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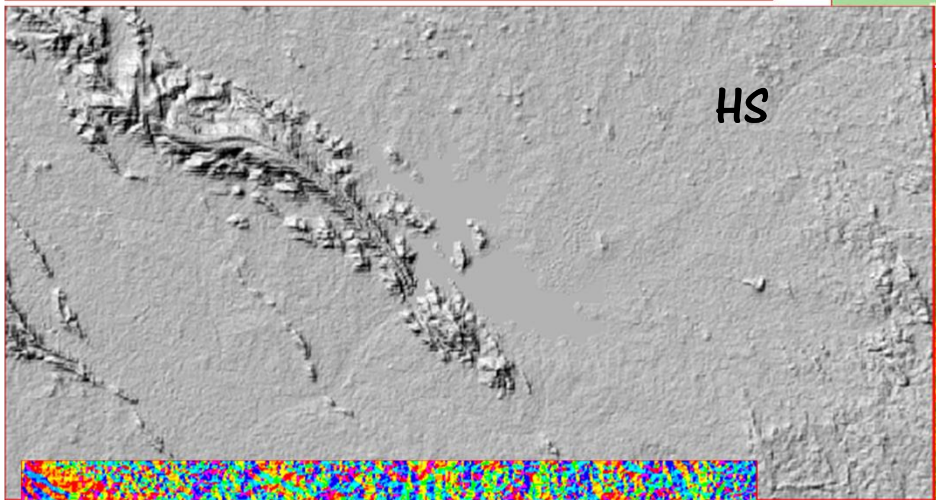
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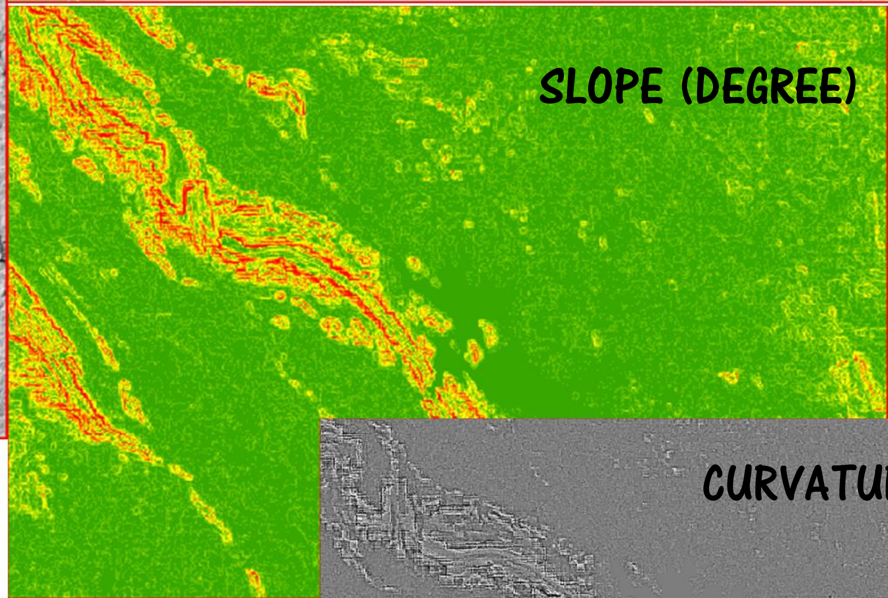
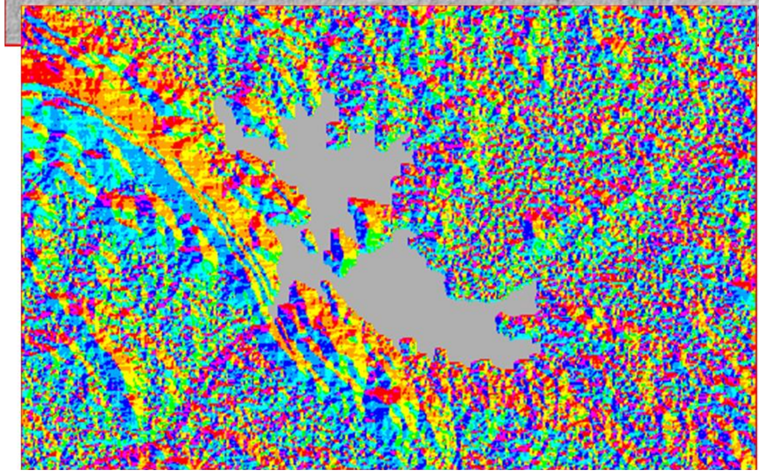
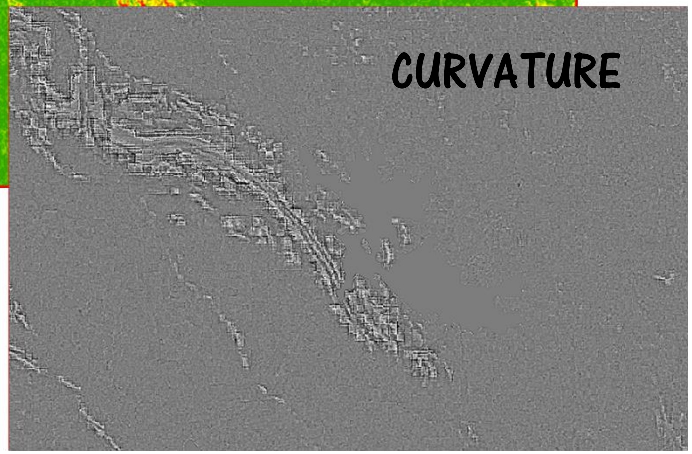
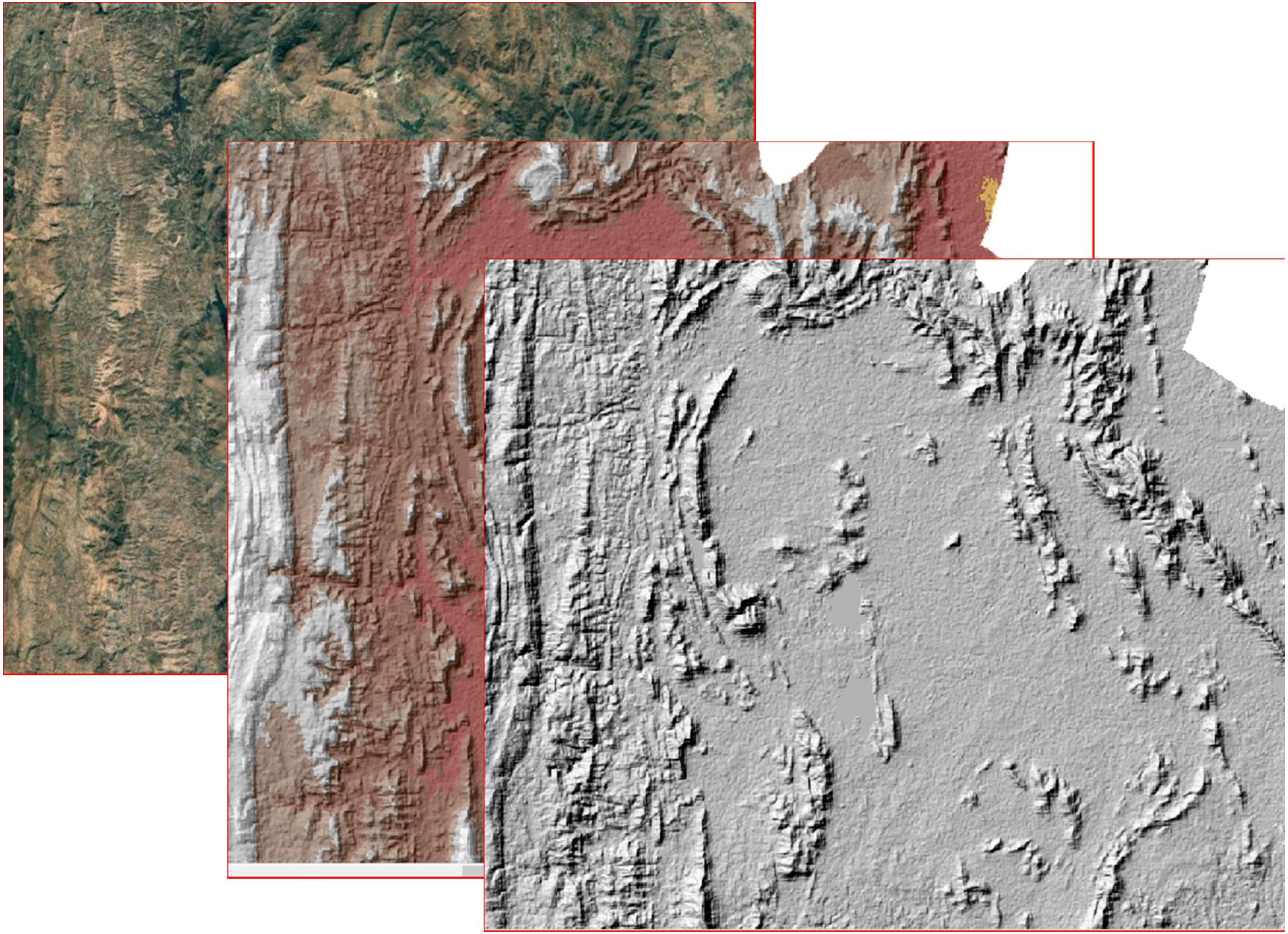

SLOPE (DEGREE)

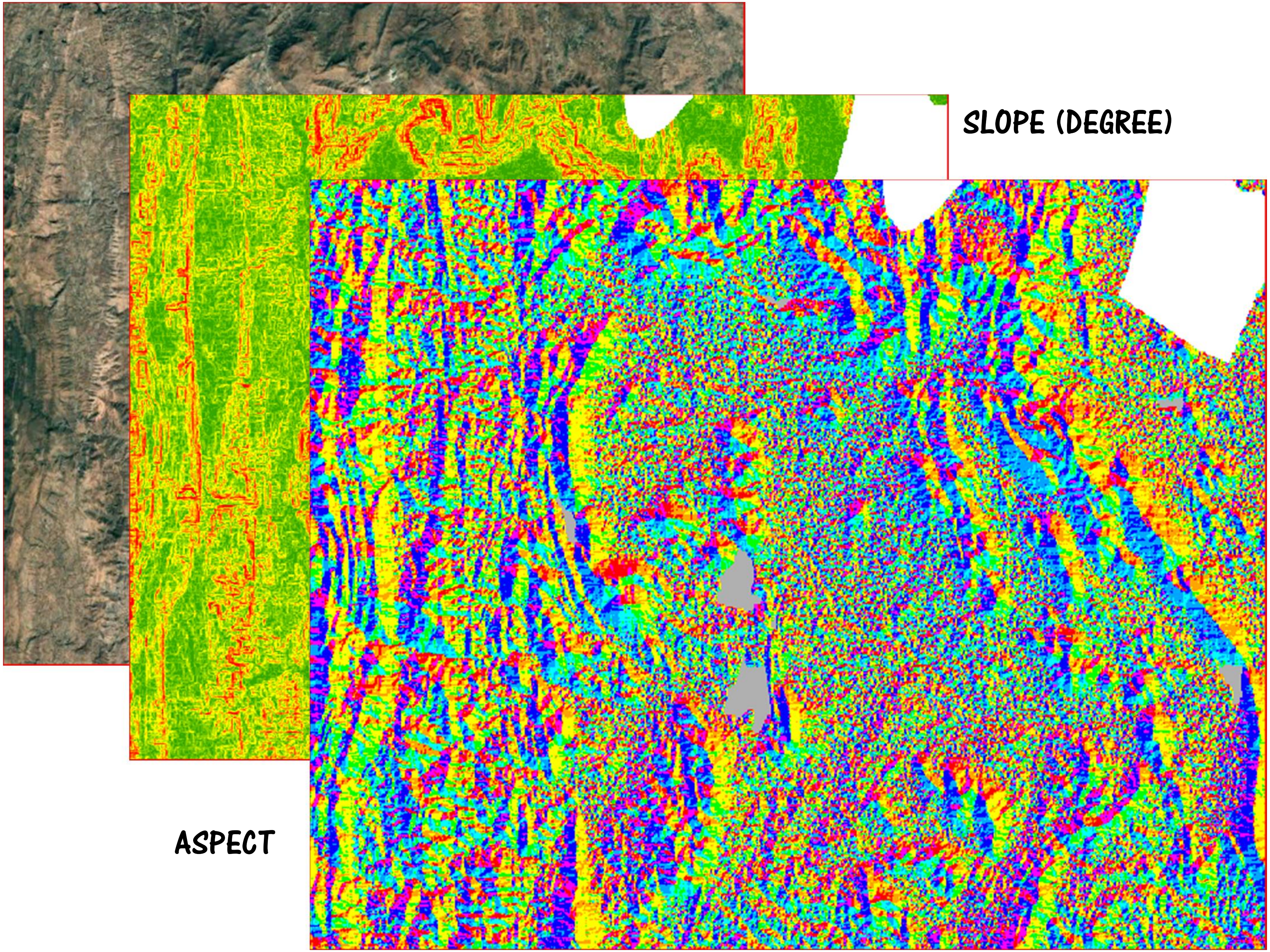


ASPECT


CURVATURE

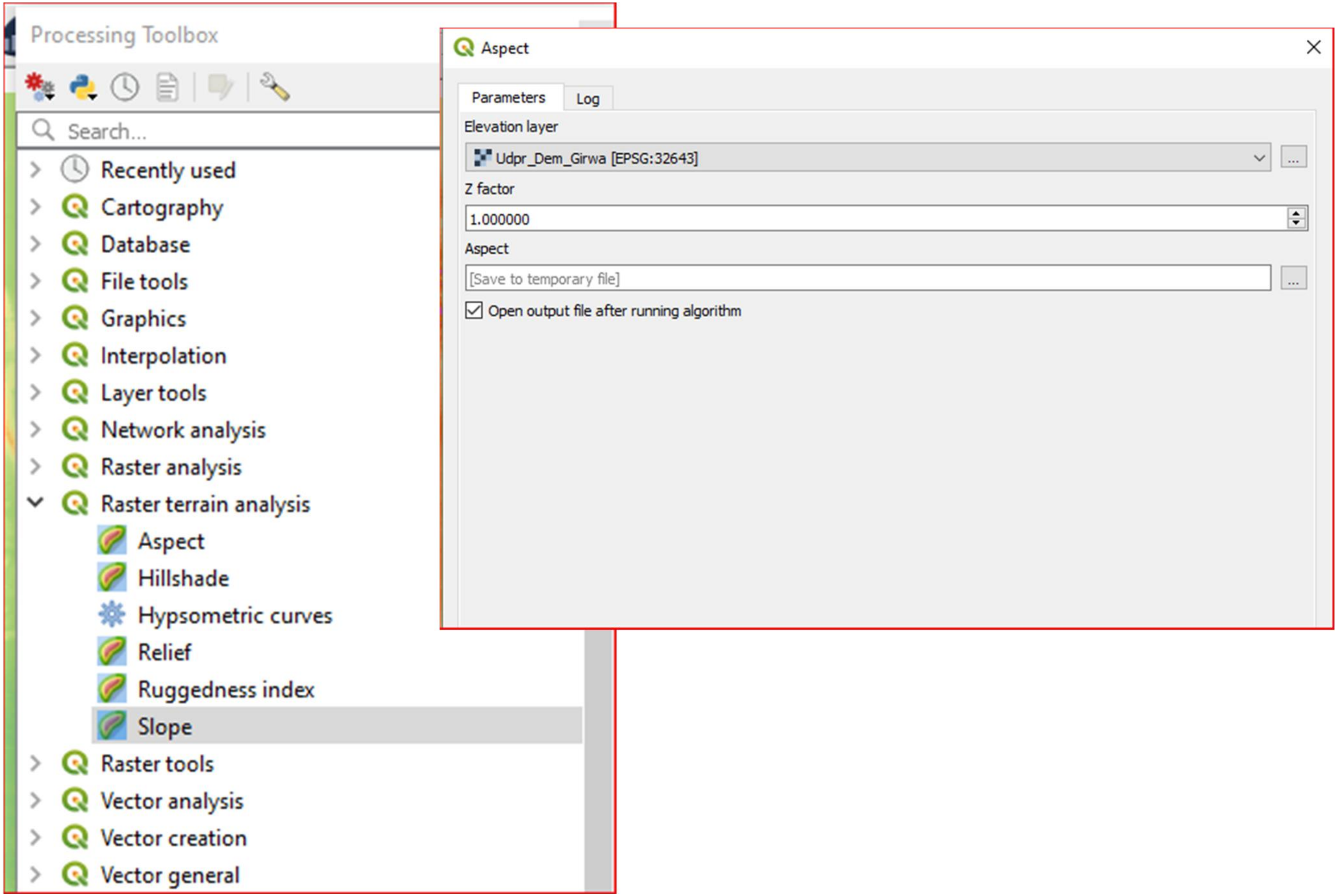


Prof. Seema Jalan


SLOPE (DEGREE)
ASPECT


GENERAL CURVATURE
PROFILE CURVATURE
PLAN CURVATURE

THE QGIS INTERFACE – Version 3.6.0



APPLICATION

- Knowledge of slope curvature is important for studies of slope forming processes and hydrology as it controls mass movement and run off, and flow rates
- Combination of plan and profile curvature can be used to identify and extract features from a DTM such as peaks, passes, ridges and troughs
- It is an important tool for geomorphologists to understand landscape form and processes