Bharathidasan University

Tiruchirappalli – 620 023, Tamil Nadu

6 Yr. Int. M.Tech. Geological Technology and Geoinformatics

Course : MTIGT0501

GEOGRAPHIC INFORMATION SYSTEMS (GIS)

Unit-4 : Methods of Spatial Interpolation and Digital Elevation Model

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Course Objectives:

- To learn the basics and concepts of GIS
- To know the components and importance of GIS
- To study the capabilities of GIS in input, verification, analysis, modelling and outputgeneration
- To understand the importance of manipulation and their applications
- To learn the methods of spatial data analyses, simulation and modelling aspects.

<u>MTIGT0501: GEOGRAPHIC INFORMATION SYSTEMS</u> --- 3 credits

1. **Basics of GIS:** Definition - Usefulness of GIS - Components of GIS - Computer Hardware, Software Modules and Organizational Context of GIS. **6 Hrs.**

2. **Data Structure:** Data Structure in GIS - Types of Data (Points, Lines and Polygons)- Data Base Structures (Raster Data Structures and Vector data Structures) - Data Conversion, (Vector to Raster and Raster to Vector). **6 Hrs.**

3. **Data Input, Verification, Storage and Output:** Spatial Data Input Processes and Devices (Sources of data, - Different Types of Data Entry methods, viz., Manual input, Run length code, Digitization, Automated Scanning, etc. – Vector to Raster conversion – Raster to Vector conversion - Input devices) - Entry of non-spatial data – Linking of Spatial & Non-spatial data – Data Verification (Errors of different types) – Correction (Rubber Sheet Transformation, Bilinear interpolation, Cubic Convolution, etc.) – GIS capabilities for Data correction – Data output (Types of Output, GIS Capabilities for output, Output devices). **12 Hrs.**

4. **Methods of Spatial Interpolation and Digital Elevation Model:** <u>Spatial Interpolation:</u> Basic Principles of Interpolation – Methods of Interpolation (Interpolation by Joining Boundaries, viz., Simple vector maps, Theisson polygons) – Global Methods of Interpolation, Local Interpolation (Trend Surface Analysis) – Local Interpolation (Splines) - Optimal Interpolation (Kriging).

   <u>Digital Elevation Modeling:</u> Need for Three Dimensional Models - Methods of DEM - Products of DTM (Contour Maps, Shaded Relief Map, Maps Related To Slopes, Line of Sight Maps, Drainage Analysis, Volume Estimation, etc.) - Usefulness of DEM/DTM. **12 Hrs.**

5. **Data Analysis and Spatial Modeling:** Simple data retrieval – Data retrieval through Boolean Logic – Map Overlaying and Cartographic Modeling (Two layers, Multiple layers, Binary, Index, Regression, and Process Models) – Overlay analysis, Capabilities (Point Operations, Regional Operations, Neighbourhood Operations) – Buffering – Cartographic Modeling using Natural Language Commands – Advantages and disadvantages of Carto modeling – Net work analysis. **12 Hrs.**

6. **Current Contours: (Not for Final Exam, only for Discussion):** Recent advancements in GIS; Application of GIS in automation, decision making and query building processes in Geological Technology; Modules and capabilities of QUGIS, GRAM++, IDRISI GIS software.

1. Burrough, P.A 1986: Principles of Geographical information Systems for Land Resources Assessment, Clarandone Press, Oxford.
2. Kang - Tsung Chang, Introduction to Geographic Information System, MC Graw Hill, Boston. 2002.
3. Avery, T.V, Interpretation of Aerial Photography Burgass, Publishing Company.
4. Gautham, N.C 1970: Urban Landuse Study Through Aerial Photo interpretations Techniques, Pink Publishing House, Mathura.
5. American Society of Photogrammetry, 1983: Manual of Remote Sensing (2nd Edition), ASP Falls Church, Virginia.
6. Campbell, J 1984: introductory Cartography, Printers Hall Englewood Cliffs, N.J
7. Dent B.D 1985: Principles of Thematic Map Design, Addition - Wesley, Reading, Mass.
8. Freeman, H and GG.Pieroni 1980: Map Data Processing, Academic Press, New York.
9. Monmonier, M.A 1982: Computer Assisted Cartography - Principles and Prospects, Prentice Hall, Englewood Cliffs, NJ
10. Tomlinson, R.F Calkins, H.S and D.F.Marble 1976: Computer Handling of Geographic Data, UNESCO, Geneva.
11. Grame F. & Bonham – Carter; Geographic information Systems for Geoscientists; Modelling with GIS, Pergamon.

Course outcomes:

After the successful completion of this course, the students are able to:

1. Understand the basic concepts and virtues of this important tool providing various platforms to handle Geospatial data
2. Gain basic ideas to generate, group, store Geospatial data in effective data structures
3. Develop skills on manipulation, 3D visualization, Spatial Analysis and Spatial Modeling.
4. Handle Geologic problems Geospatially in GIS platform independently.

Unit-4

Methods of Spatial Interpolation and Digital Elevation Model: Spatial Interpolation: Basic Principles of Interpolation – Methods of Interpolation (Interpolation by Joining Boundaries, viz., Simple vector maps, Thiessen polygons) – Global Methods of Interpolation, Local Interpolation (Trend Surface Analysis) – Local Interpolation (Splines) - Optimal Interpolation (Kriging).

Digital Elevation Modeling: Need For Three Dimensional Models - Methods of DEM - Products of DTM (Contour Maps, Shaded Relief Map, Maps Related To Slopes, Line of Sight Maps, Drainage Analysis, Volume Estimation, etc.) - Usefulness of DEM/DTM. **12 Hrs.**

UNIT – 4 (A)

Spatial Interpolation: Basic Principles of Interpolation – Methods of Interpolation (Interpolation by Joining Boundaries, viz., Simple vector maps, Thiesson polygons) – Global Methods of Interpolation, Local Interpolation (Trend Surface Analysis) – Local Interpolation (Splines) - Optimal Interpolation (Kriging). **6** Hrs.

SPATIAL INTERPOLATION

- A process of using points with known values to estimate values at other points or in data gap areas.

- For e.g., the precipitation value at a location with no recorded data can be estimated through interpolation from known precipitation readings at nearby weather stations.

- In GIS, it is applied to a grid and estimates are made for all cells in the grid.

- A means of converting **point data to surface data / point-to-area conversions** – also known as **Spatial Manipulation**.

Necessity of spatial interpolation:

- To visualize an area by generating a map layer either in raster or vector mode.
- To analyse and make model as a semi-continuous or discontinuous piecewise surface, depending on the scale of the attribute.
- To generate a new set of data by re-sampling at a regular grid basis, and build point attribute table for multivariate analyses, and
- To improve the property of any unvisited sites.

Types of Spatial Manipulation:

- Methods of converting points to areas – i.e., Manipulation can be subdivided into two groups:
  - **Non-interpolative method** and
  - **Interpolative** method.

- **Non-interpolative methods** are particularly appropriate when the point attribute is measured on a categorical measurement scale, but can also be useful in some cases for an attribute measured on an ordinal, interval or ratio scale.

These are the four scales used mainly while collecting data:

- **Nominal/Categorical**: Used to categorize data into mutually exclusive categories or groups.
- **Ordinal**: Used to measure variables in a natural order, such as rating or ranking. They provide meaningful insights into attitudes, preferences, and behaviours by understanding the order of responses.
- **Interval**: Used to measure variables with equal intervals between values. This type of measurement is often used for temperature and time, allowing for precise comparisons and calculations.
- **Ratio**: Allows for comparisons and computations such as ratios, percentages, and averages. Great for research in fields like science, engineering, and finance, where ratios are used, percentages, and averages to understand the data.

NON-INTERPOLATIVE METHODS

1. Choropleth map:

- A map with line boundaries defining polygons enclosing areas that are assumed to be uniform throughout or to which a single description can be applied.
- In choropleth map, polygons cannot be finely divided into smaller entities
- we cannot say anything more precise about what is happening within their boundaries
- If we have point observations arranged either at random or on a regular lattice over the area of interest, then it is possible to make more precise statements about the value of properties of interest at unvisited sites.

Choropleth 2D & 3D maps

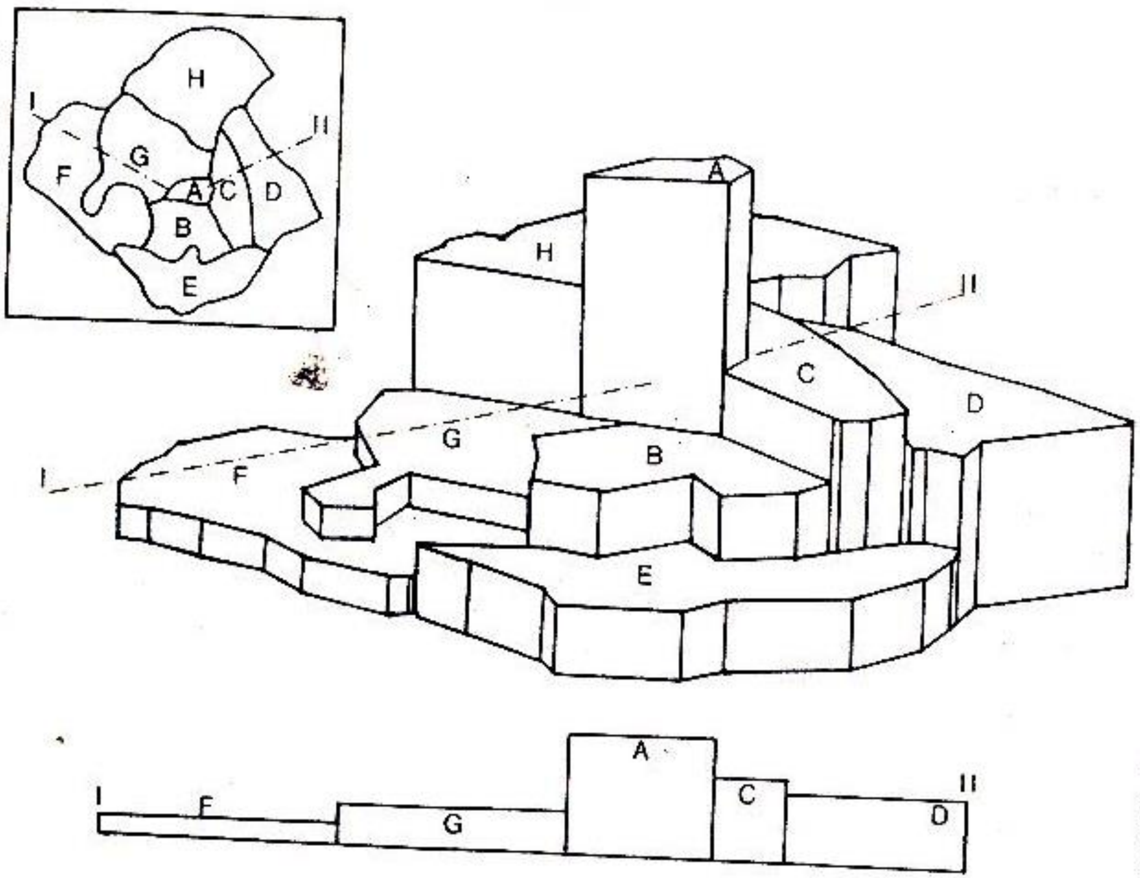
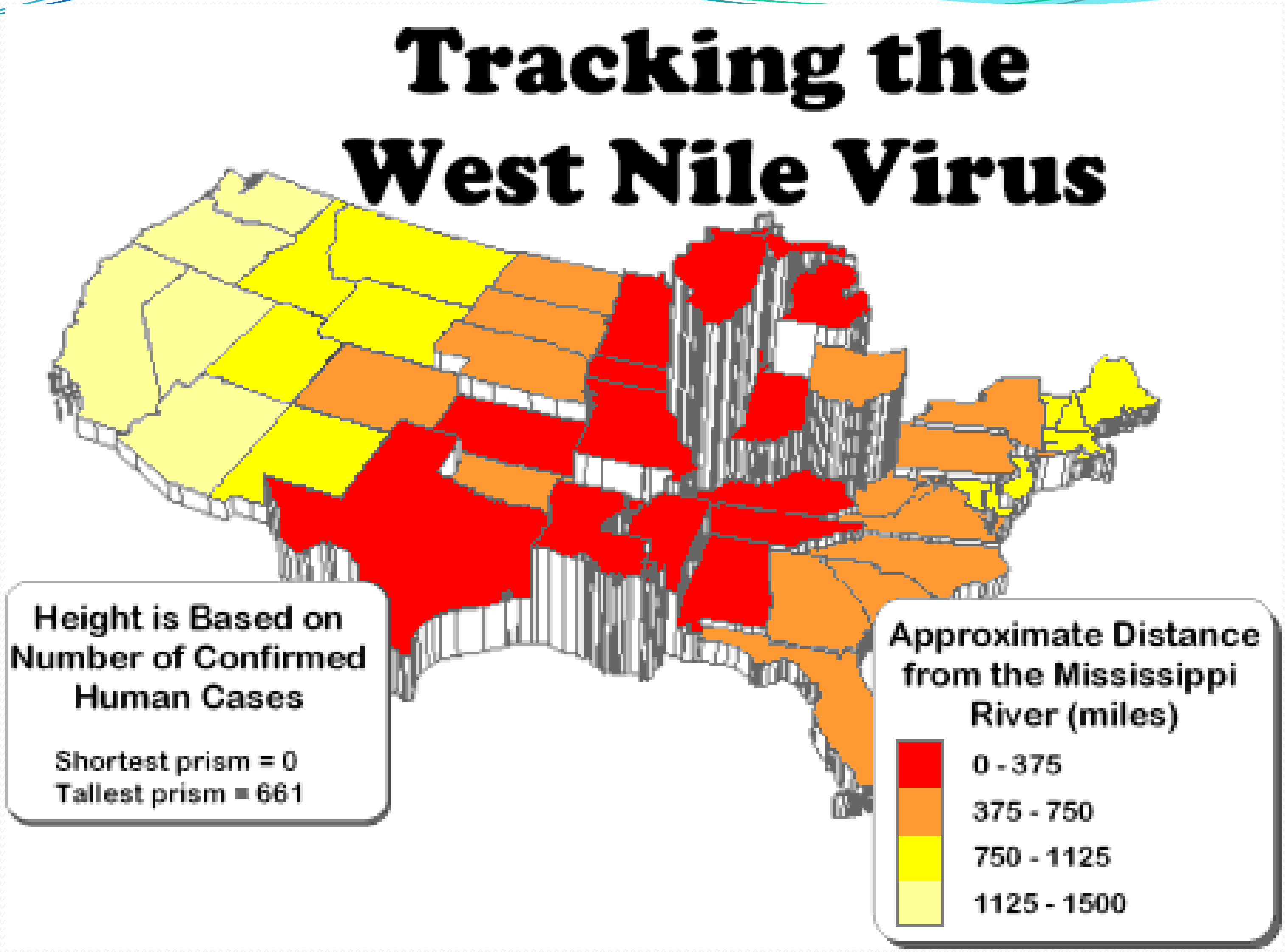


Fig. 8.1 The choropleth map is 'stepped' model of the landscape. (Based on a screen image, courtesy Computervision Corporation, The Netherlands.)


Tracking the
West Nile Virus
Height is Based on Number of Confirmed Human Cases
Shortest prism = 0
Tallest prism = 661
Approximate Distance from the Mississippi River (miles)
0 - 375
375 - 750
750 - 1125
1125 - 1500

NON-INTEROLATIVE METHODS

2. Thiessen Polygons

- Thiessen polygons are constructed around a sample of known points
- The predictions of attributes at unsampled locations are provided by the nearest single data point.
- Originally proposed to estimate effective area coverage of precipitation.
- Thiessen polygons require initial triangulation among known points, that is connecting known points to form triangles / polygons.
- This method divide a region up in a way that is totally determined by the configuration of the data points, with one observation per cell / a polygon.
- But, the value throughout such polygon is same and it is similar to Choropleth map.

- **Delaunay triangulation** – each known point is connected to its nearest neighbors, and that triangles are as equilateral as possible (shown as dashed lines in the following Figure-2 (b).
- After triangulation, Thiessen polygons can be easily constructed by connecting lines drawn perpendicular to the sides of each triangle at their midpoints – **Voronoi polygons / Dirichlet cells**.

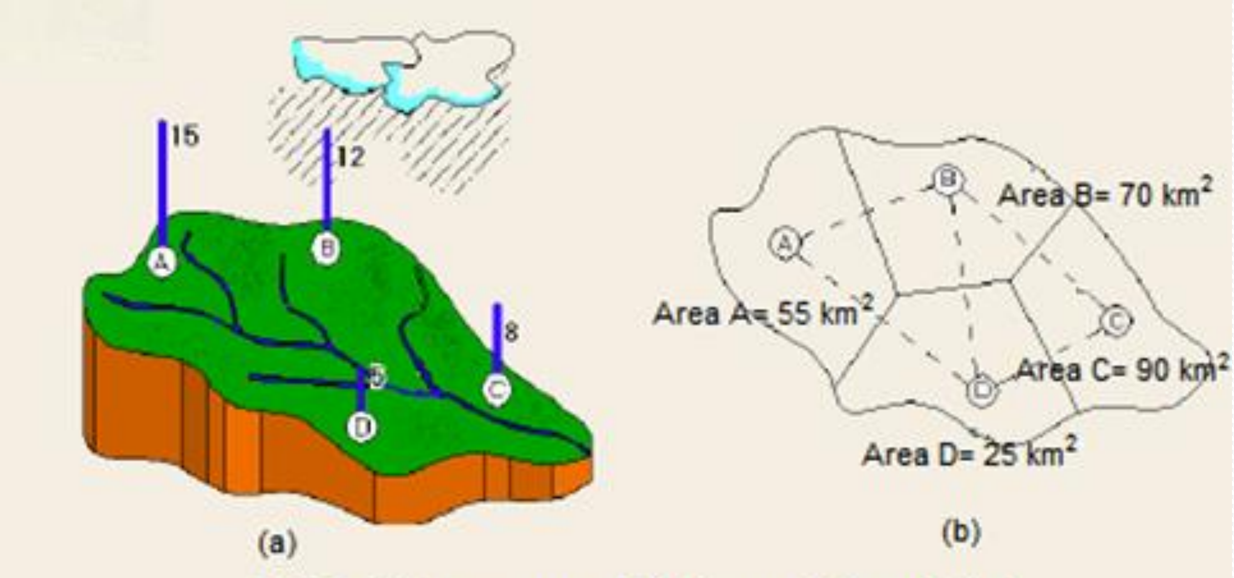


Fig-2: Rainfall measurement by Thiessen Polygon Method
(a) Rainfall Recorded, (b) Areas of Influence

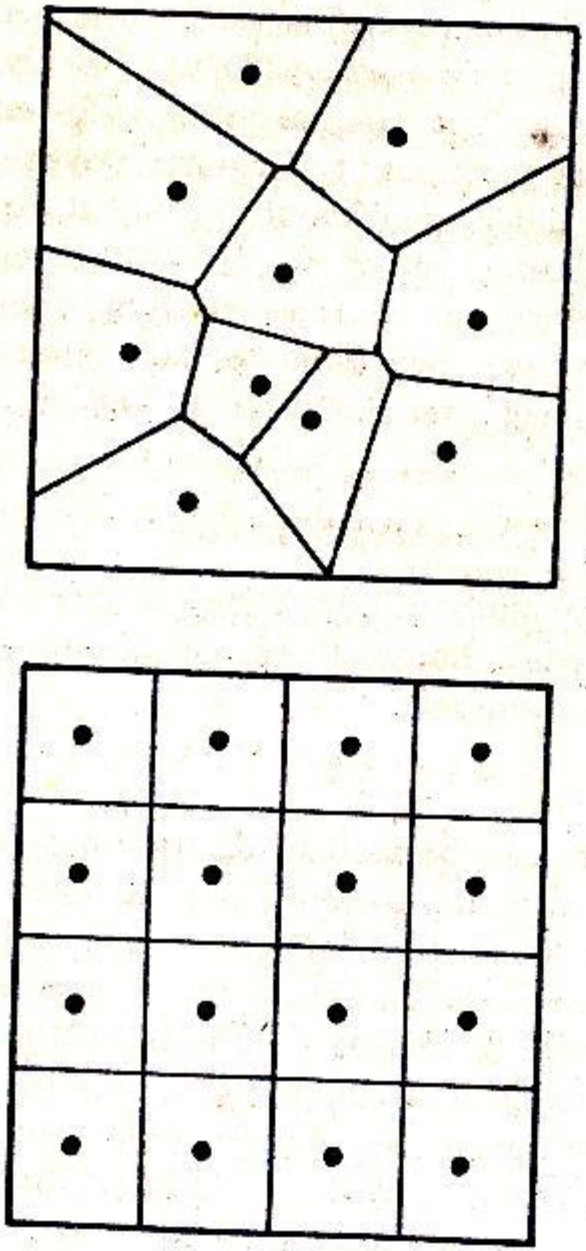


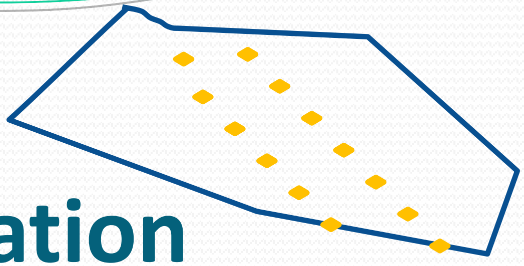
Fig. 8.2 Thiessen (or Dirichlet) polygons with irregular and regular sample point searching.

Unless there are many observations, this Thiessen polygon assumptions are not really appropriate for gradually varying phenomena like Rainfall, Air Temperature, Pressure ….
Because:

1) The form of the final map is determined by the distribution of the observations and
2) The method maintains the **choropleth map fiction of homogeneity within borders** and all changes only at borders.

As there is only one observation per tile available, there is no way to estimate **within-tile variability, short of taking replicate observations.**

Manipulation – Interpolative methods - 2 types:



1. Interpolation, & 2. Extrapolation

- This procedure of “Estimating the value of properties at unsampled sites **within** the area covered by existing point observations is called **interpolation**”.
- “Estimating the value of a property at sites **outside** the area covered by existing observations is called **extrapolation**.”
- The logic / basic idea behind Interpolation and Extrapolation is that,
- on average, points that are close together in space are more likely to have similar values than point further apart.

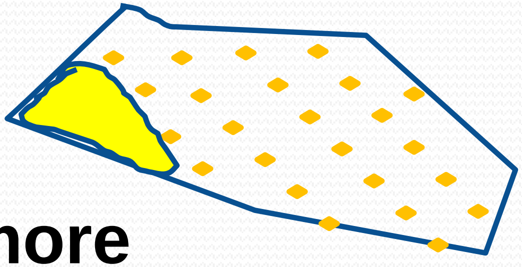
- For example,
- Two observation points a few metres apart on a single hill are more likely to have similar value for altitude,
- But, if the points on two hills some kilometers apart may not have similarity in height and we cannot say about in between point heights.
- Two different types of **spatial interpolation** methods are:
  - **Global** and
  - **Local** methods.
- The difference between these two groups lies in the use of control points, i.e., points with known values, in estimating unknown values.

Methods of Spatial Interpolation / Manipulation

- **Global method** - uses **every** control point available in estimating an unknown value – to derive an equation or a model.
- **Local method -** uses **a sample** of control points in estimating an unknown value.
- Control points - are the points with known values.

- Generally used terminology for manipulation as a whole, or representing either extrapolation or interpolation, it is holistically known as **Spatial Interpolation**. It becomes commonly used term now-a-days.

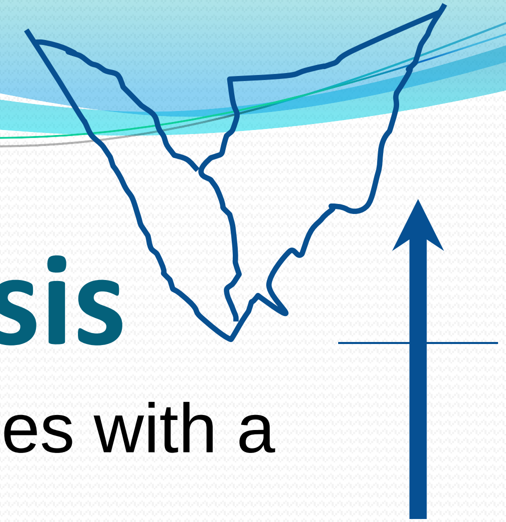
Basic assumption in spatial interpolation:



- The value to be estimated at a point is **more influenced** by **nearby control points** than those that are farther away.
- To be effective for estimation, **control points** should be **well distributed** within the study area - this ideal situation is rare in real-world applications.
- **Data-poor areas** – represent a major problem in estimation and cause problems in spatial interpolation.
- The <u>**number**</u> and <u>**distribution**</u> of control points can greatly influence the accuracy of spatial interpolation.

GLOBAL METHODS

1.Trend Surface Analysis



- Approximates points with known values with a polynomial equation.
- A linear or first-order trend surface uses the equation

$$\mathbf{Zxy = b_0 + b_1x + b_2y}$$

Where,

z = *attribute value, is a function of x and y*

b = *coefficients estimated from the control points*

- It is computed by the “least squares method”
- A method of approximation based on the minimization of the squared distance between two sets of variables.

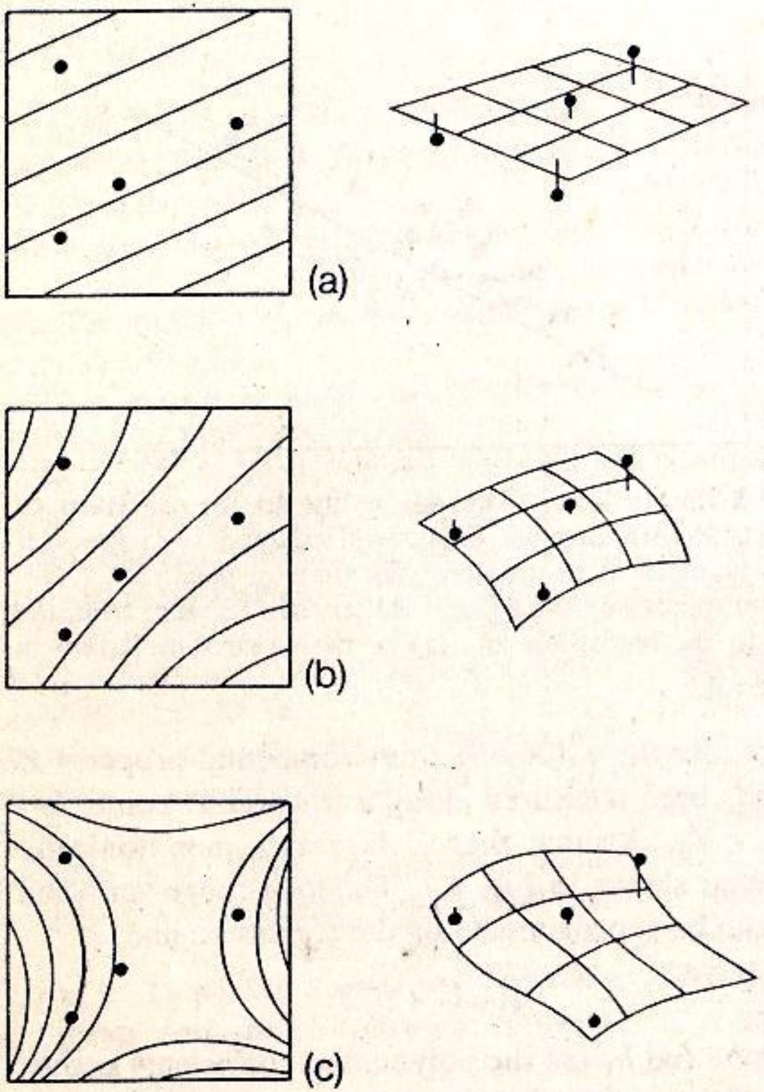
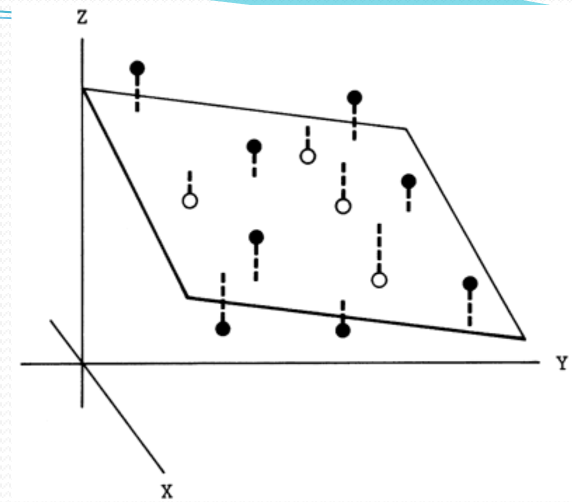
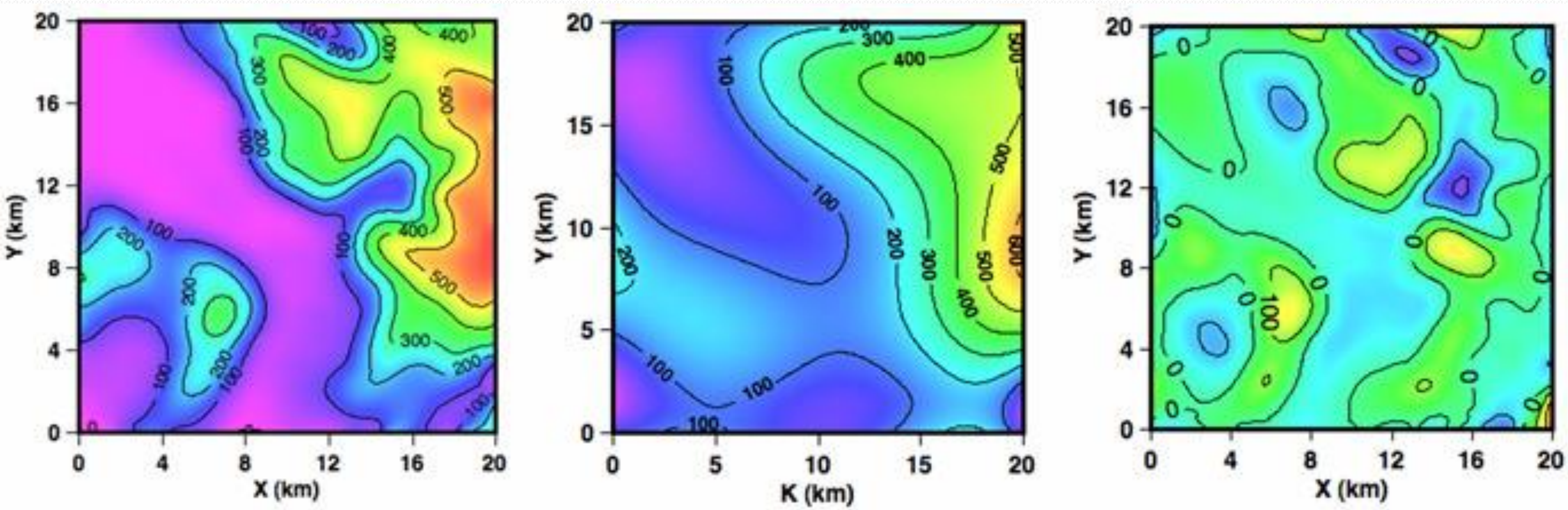


Fig. 8.5 Trend surfaces in two spatial dimensions. (a) Linear, (b) quadratic, (c) cubic.

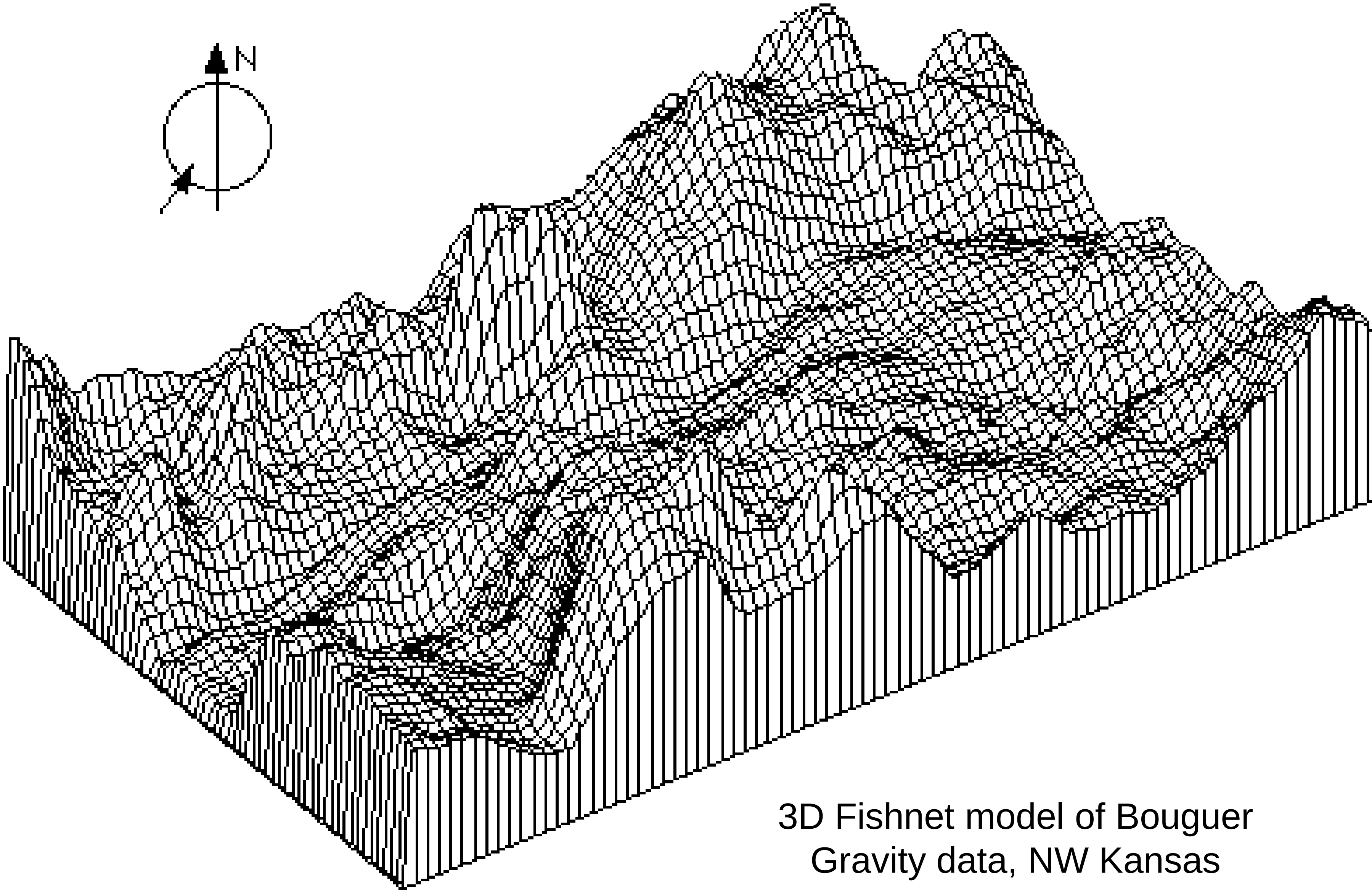




A Graphical Example of Applying Trend Surface Analysis to Matrix Data: (a) Original Surface, (b) the 6th-orderTrend Generated Surface, and (c) the Residual Matrix

Bouguer gravity, first-order residual, northwest Kansas

Azimuth -35° (0° is South), elevation 35°



3D Fishnet model of Bouguer Gravity data, NW Kansas

2.Regression Models

- A regression model relates a **dependent variable** to a number of **independent variables** in an equation, which can then be used for prediction or estimation.

- Many regression models use non-spatial attributes such as income, education etc., and are not considered as methods for spatial interpolation.

- Some exceptional models are available which uses the location and topographic variables as the independent variables and the terrain parameter or thematic data as dependent variable.

Regression Models…contd…

- **Simple Linear Regression** - By considering the values of the one Dependent and Independent parameters each in all the points of the study area, estimates the relationship of each location in numbers as well as sign (+ve / -ve).

- **Multiple Linear Regression** – Establishes the one-to-one relationships in numbers as well as their signs (+ve / -ve) by considering the values of the one Dependent and multiple Independent parameters in all the points / locations of the study area.

Global methods in ARC/INFO and ArcView

- TREND – command to run trend surface analysis from 1^{st} to 12^{th} order.

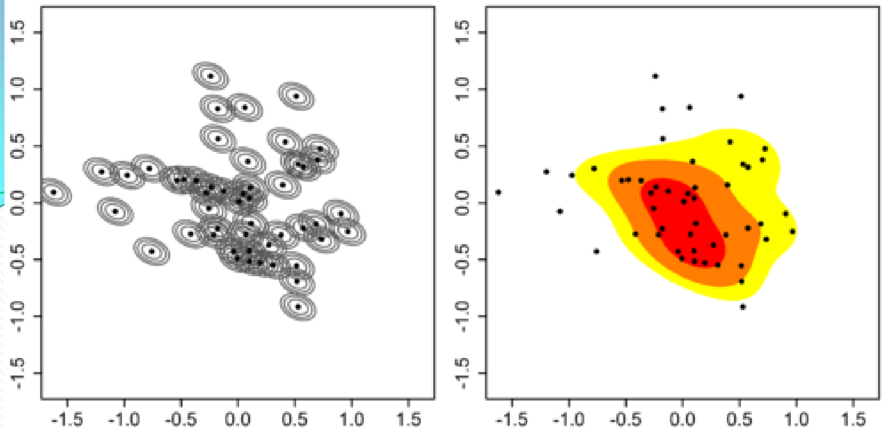
- REGRESSION – command for regression analysis, but without model-selection methods, maximum, R-square, etc.

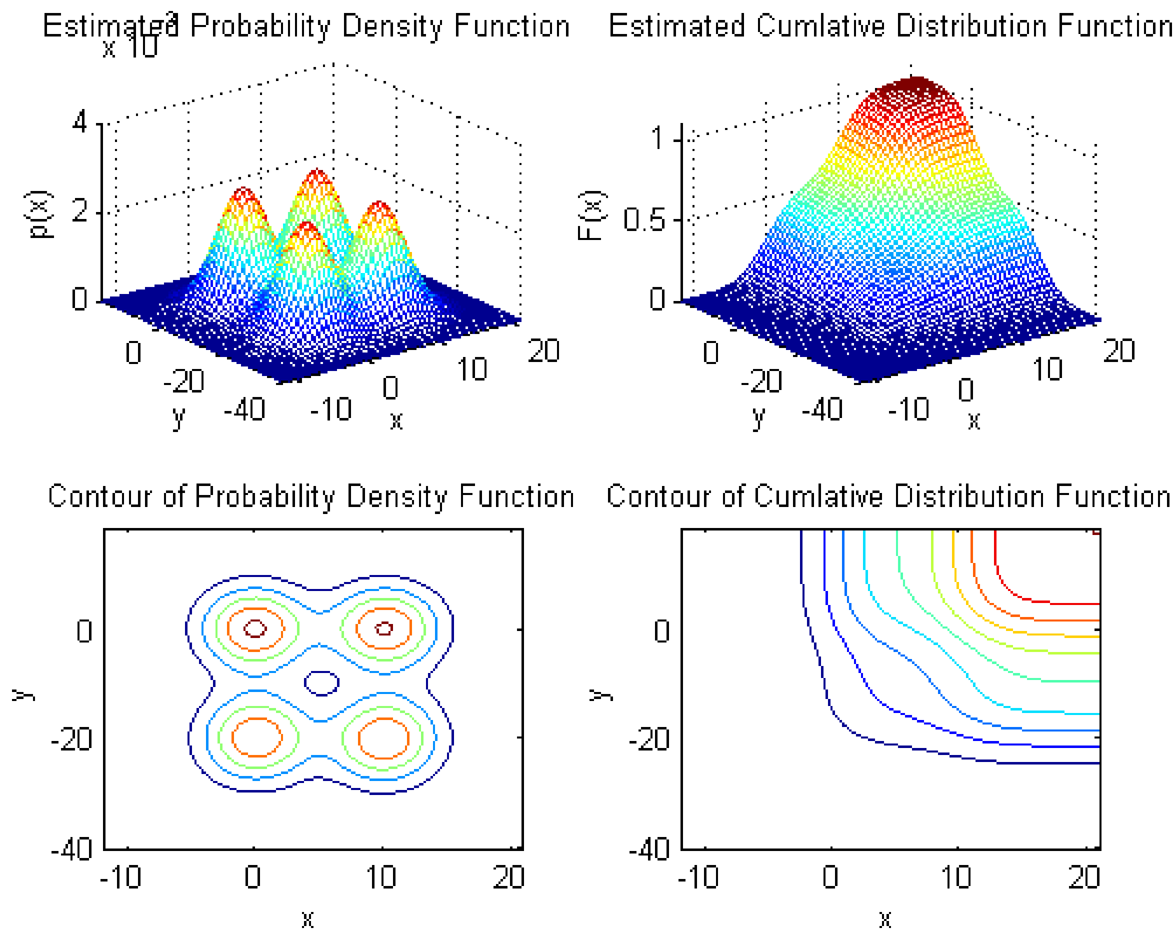
- AVENUE Script – to run trend surface analysis.

INTERPOLATIVE – LOCAL METHODS

1.Density estimation

- Density estimation measures densities in a grid based on a distribution of points and their known values.
- **Kernel estimation** is a different density estimation method, which associates each point or observation with a kernel function.
- Expressed as a bivariate probability density function, a kernel function looks like a “Bump”, centering at a point and tapering off to 0 over a defined bandwidth or window area.
- The kernel function and the bandwidth determine the shape of the bump, which in turn determines the amount of smoothing in estimation.

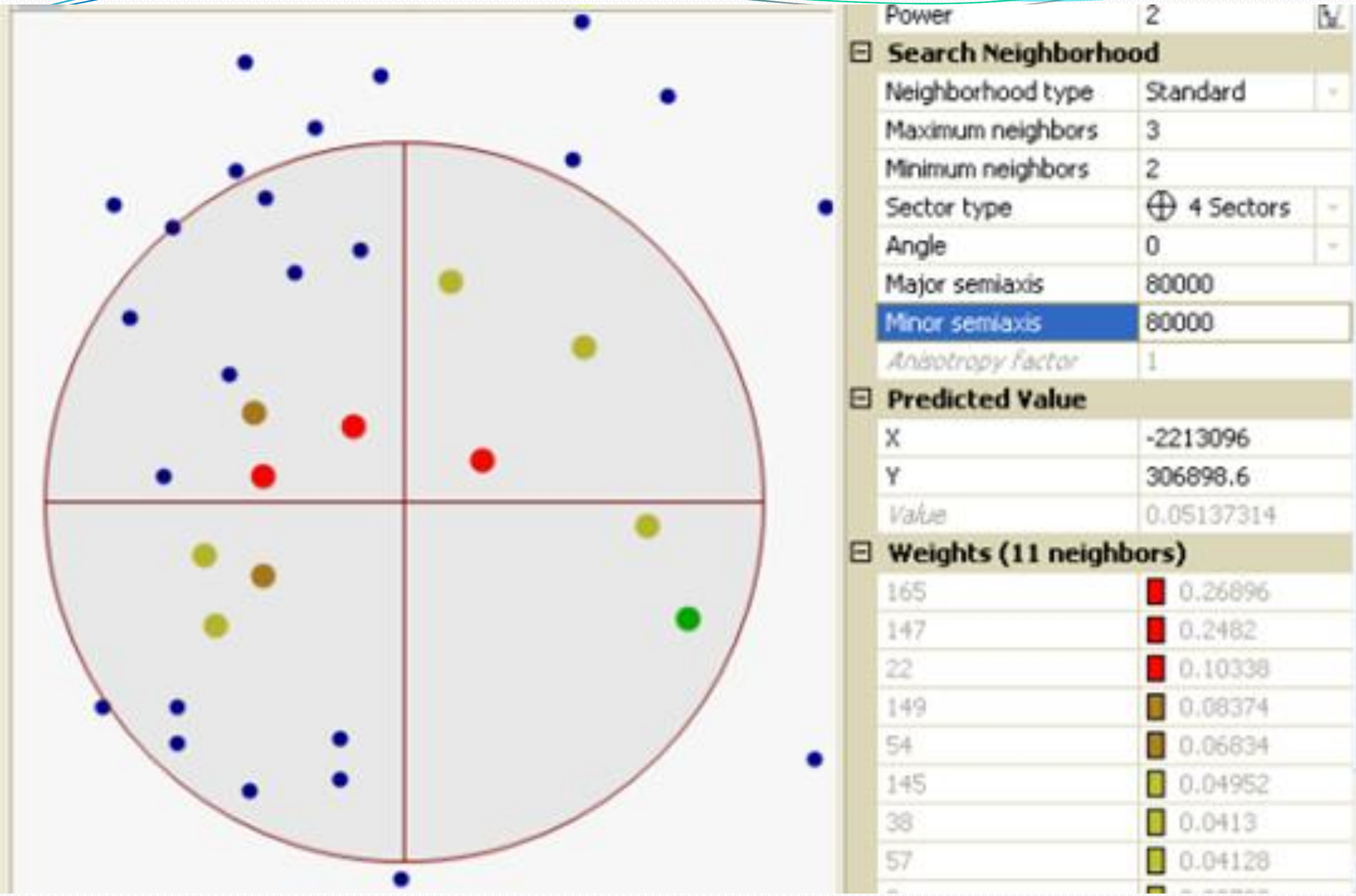

-1.5 -1.0 -0.5 0.0 0.5 1.0 1.5
-1.5 -1.0 -0.5 0.0 0.5 1.0 1.5


Estimated Probability Density Function
x 10
p(x)
y
x
Estimated Cumlative Distribution Function
F(x)
y
x
Contour of Probability Density Function
y
x
Contour of Cumlative Distribution Function
y
x

2. Inverse Distance Weighted Interpolation (IDW)

- It is a local method that assumes that the unknown value of a point is influenced more by nearby control points than those farther away.
- A type of deterministic method for multivariate interpolation with a known scattered set of points.
- The assigned values to unknown points are calculated with a weighted average of the values available at the surrounding known points.
- The weighted average applied since it resorts to the inverse of the distance to each known point ("amount of proximity") when assigning weights.

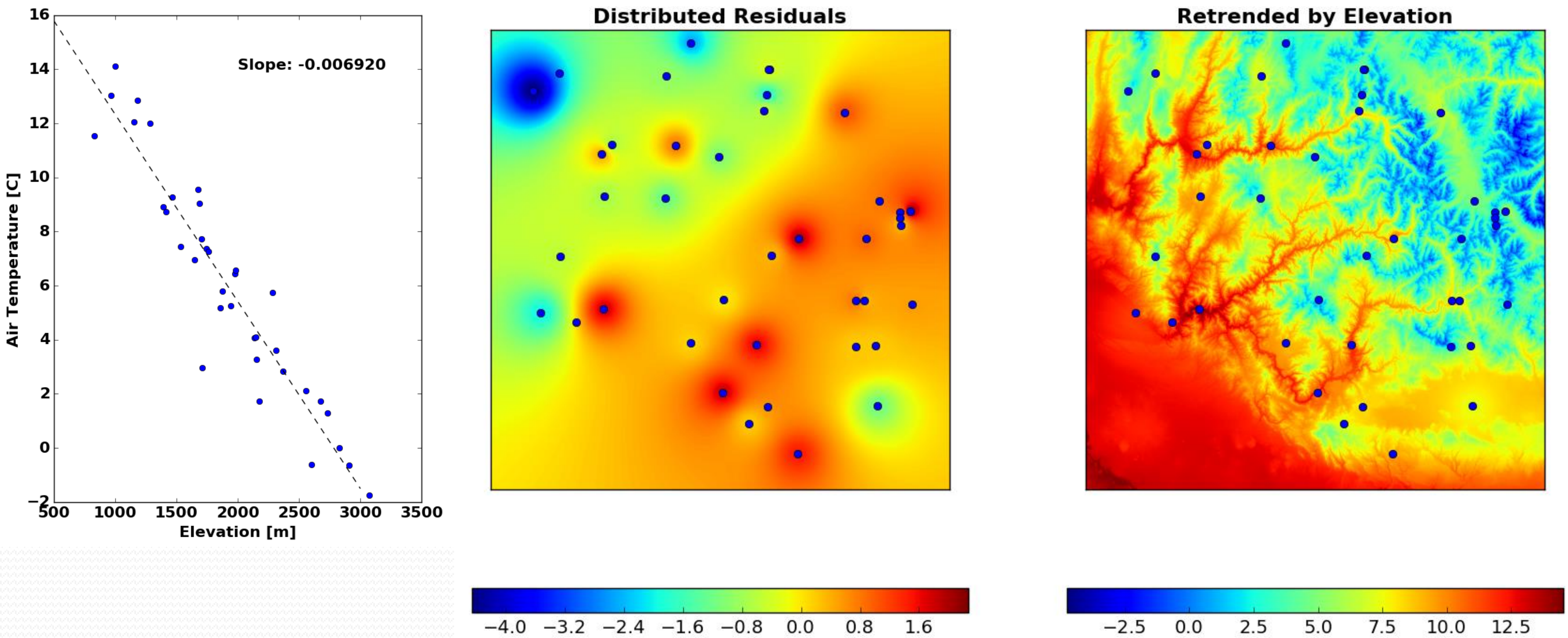
- To predict a value for any unmeasured location, IDW uses the measured values surrounding the prediction location.
- The **measured values closest to the prediction location** have **more influence** on the predicted value than those farther away.
- IDW assumes that each measured point has a local influence that diminishes with distance.
- It gives **greater weights** to **points closest** to the prediction location, and the weights diminish as a function of distance, hence the name **inverse distance weighted.**



Power
2
Search Neighborhood
Neighborhood type
Standard
Maximum neighbors
3
Minimum neighbors
2
Sector type
4 Sectors
Angle
0
Major semiaxis
80000
Minor semiaxis
80000
Anisotropy factor
1
Predicted Value
X
-2213096
Y
306898.6
Value
0.05137314
Weights (11 neighbors)
165
0.26896
147
0.2482
22
0.10338
149
0.08374
54
0.06834
145
0.04952
38
0.0413
57
0.04128

In order to get a meaningful map derived through spatial local interpolation is:

1. Prepare IDW image based on the sample location and their values
2. Identify the controlling parameters
3. Derive the relation between them and
4. Use the relationship to retrend the IDW map to get a near accurate one relevant to the Earth System Processes.



3. Thin-plate Splines

- Splines for spatial interpolation are conceptually similar to splines for line generalization, except that in spatial interpolation they apply to surfaces rather than lines.
- The name *thin plate spline* refers to a physical analogy involving the bending of a thin sheet of metal or flexible curves (made of metal wire coated with rubber) used in cartography to make smooth curved line.
- Thin-plate splines creates a surface that passes through control points and has the least possible change in slope at all points.
- In other words, thin-plate splines fit the control points with a minimum-curvature surface.

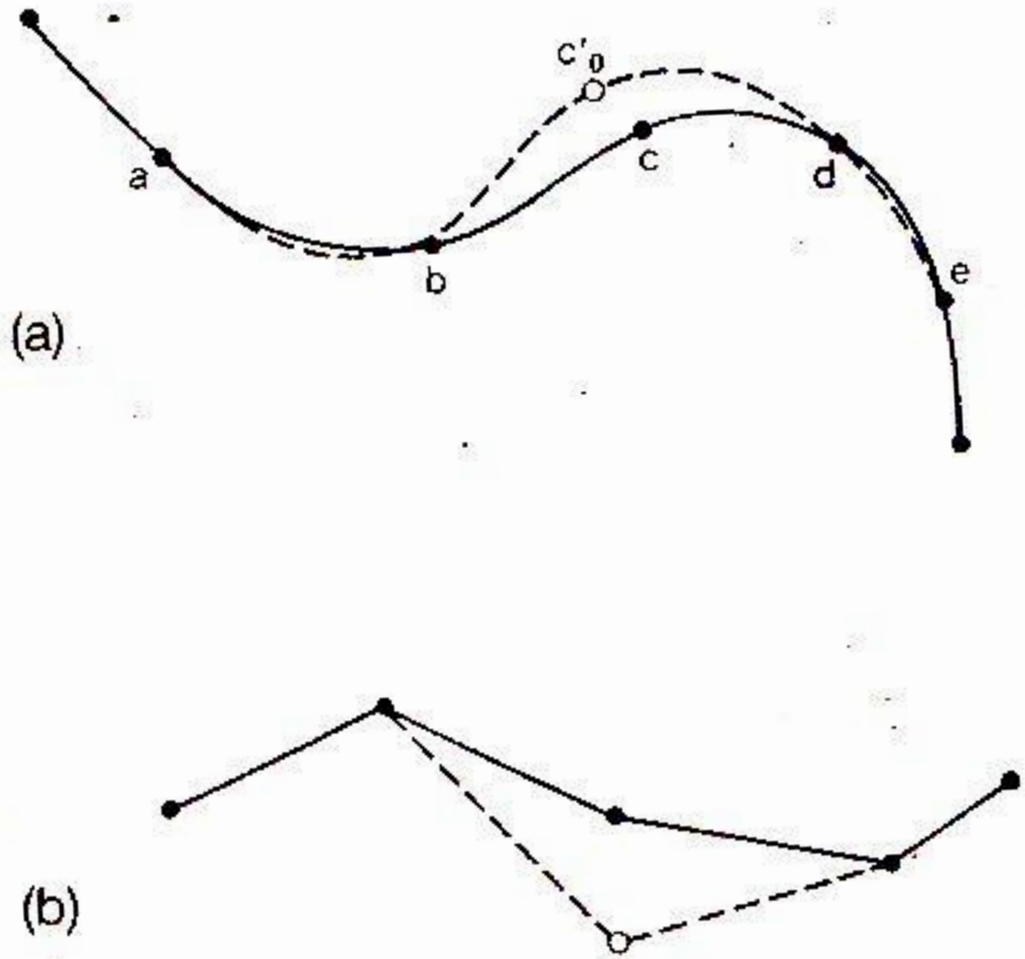


Fig. 8.6 The local nature of splines. When one point is displaced, four intervals must be recomputed for a quadratic spline (a) and two for a linear spline (b).

4. Kriging

- Kriging – the method named after the South African mining engineer D.G.Krige.
- Kriging is a geo-statistical method for spatial interpolation.
- The technique of Kriging assumes that the spatial variation of an attribute.
- For, e.g., changes in grade of ore within an ore body is neither totally random nor deterministic.

- Spatial variation – may consist of *three components*:
  - a spatially correlated component, representing the Variation of the regionalized variable
  - a drift or structure, representing a trend and
  - a random error term.
- The presence or absence of a drift and the interpretation of the regionalized variable have led to development of different Kriging methods for spatial interpolation.

They are:

- **Ordinary Kriging**
- **Universal Kriging**
- **Block Kriging and**
- **Co-kriging**.

Comparison of local methods

- **Cross validation analysis is possible in local methods**
- **For assessing the accuracy of estimates from different interpolation methods**

It involves,

- **Removal** of a **known point** from the data set and
- **estimating the value** at the point by **using** the **remaining known points** and **calculating the error** of the estimation by comparing the estimated with the known values.

Table 8.3 A comparison of methods of interpolation

Method	Deterministic/ stochastic	Local/ global	Transitions abrupt/ gradual	Exact interpolator	Limitations of the procedure	Best for	Output data structure	Computing load	Assumptions of interpolation model
'Eyeball'	Subjective/ deterministic	Global	Abrupt	No	Non-reproducible, subjective	Field data, aerial photo interpretation	Polygons	None	Intuitive understanding of spatial processes; homogeneity within boundaries
Edge-finding algorithm	Deterministic	Global	Abrupt	No	Often requires shapes to be defined and stored; better for man-made features than for natural landscapes	Raster images from remote sensors	Raster	Moderate	Homogeneity within boundaries
Proximal (Thiessen poly.)	Deterministic	Local	Abrupt	Yes	One data point per cell; no error estimates possible; tesselation pattern depends on data point distribution	Nominal data from point patterns	Polygons	Light/ moderate	'nearest neighbour' gives best information
Trend surface	Stochastic	Global	Gradual	No	Edge effects, outliers, complex polynomials do not necessarily have meaning; errors are rarely spatially independent.	Demonstrating broad features and removing them prior to other methods of interpolation	Points on a raster	Light/ moderate	Multiple regression—phenomenological explanation of trend surface; independent Gaussian errors
Fourier series	Stochastic	Global	Gradual	No	Not applicable to data; lacking periodicity	Periodic features such as sand dunes, ripple marks or gilgai, or man-made features	Points on a raster	Moderate	Strict periodicity in phenomenon of interest.
B-splines	Deterministic	Local	Gradual	Yes	No estimates of errors; masks all uncertainties in surface	Very smooth surfaces	Points on a raster	Light/ moderate	Absolute smoothness of variation
Moving average	Deterministic	Local	Gradual	No unless constrained	Results depend on configuration of data points and size of window; simple versions assume isotropy; no error estimates unless retrospectively calculated	Quick contour plots of moderately smooth data.	Points on a raster	Moderate	Continuous, differentiable surface is appropriate
Optimal interpolation (kriging)	Stochastic	Local	Gradual	Yes	Practical and theoretical problems of non-stationarity in data; large computing costs for mapping	Situations where the most detailed estimates and their errors are required	Points on a raster	Heavy (very heavy for universal kriging)	Intrinsic hypothesis (homogeneity of first differences); average local values can be represented by a continuous surface.

UNIT – 4 (B)

Digital Elevation Modeling: Need For Three Dimensional Models - Methods of DEM - Products of DTM (Contour Maps, Shaded Relief Map, Maps Related To Slopes, Line of Sight Maps, Drainage Analysis, Volume Estimation, etc.) - Usefulness of DEM/DTM. **6 Hrs.**

DIGITAL ELEVATION MODELS

DEFINITION

- **DEM -** Three dimensional representation **of relief (elevation/topographic) variations** over space using digital data is called as **Digital Elevation Model.**

- **DTM -** Three dimensional representation of **attributes of landscapes** over space using digital data is called as **Digital Terrain Model.**

Digital Terrain / Elevation Models (DTM / DEM)

- The **Digital** Terrain Models (DTM) are the 3D perspective visualization of topographic / terrain features.
- These are created either through DEM (Digital Elevation Model) or TIN (Triangulated irregular networks).
- In GIS, DEMs are generated by fragmenting the area or theme into regular network of grids / pixels which have well defined x (longitude), y (latitude) and z (elevation or theme).
- So according to the elevations (altitude matrixes), the GIS create the 3D perspective image.
- When the attributes of landscapes (other than altitude) are visualized, these are called as Digital Terrain Models (DTM).
- Over these DEM or DTM, any type of theme can be overlaid and seen.

Need for Three Dimensional Models

- For locating regional / local artificial, synclinal, domal and basinal structures for resource modelling
- for understanding regional landscape architecture
- for geomorphic mapping and geo environmental planning
- water reservoirs and dam / petroliferous reservoir planning
- Volume estimation, work efficiency and time need calculations, etc.

- Mine planning, site selection of mine dumps and

- Mine reclamation

- Geohazards and Disaster Management
- i) Isostatic and fault movements
- ii) Landslides, Earthquakes
- iii) Mine pollution
- iv) Flood hazard zone mapping
- v) Coastal erosion / quantum of soil eroded
- vi) Salt water intrusion

DATA SOURCES FOR DEM

- i) Toposheets
  - Contour lines-Closed or open contour lines, mid/broken contours(shown with broken lines in SOI toposheets)
  - Spot heights – Bench marks (BM), Triangulation Points (Δ), spot elevation in plains.
- ii) Aerial Photographs
  - heights are measured from stereo models
- iii) Satellite stereo images – SPOT, CARTOSAT, ...
- iv) RADAR DATA
- vi) LIDAR DATA
  - very high spatial resolution with a vertical accuracy of 15 cm
- vii) GPS DATA
- viii) Break lines
  - represents rapid changes in the land surface, e.g. Hill side Escarpments, Banks of Streams, -shorelines, -ridges, -roads ...
- ix) Area data – water spread area of lakes and reservoirs.

Other Data sources for DEM

- Stereoscopic aerial photographs
  - DEM prepared using photogrammetric instruments
- Ground surveys – DGPS survey for higher accuracy
- SONAR (Sound Navigation and Ranging)
  - to understand Sea bed configuration
- **ERS** (European Remote sensing Satellite – ENVISAT Interferometry),
- **SRTM** (Shuttle Radar Topographic Mission),
- TERRA **ASTER** GDEM(Advanced Spaceborne Thermal Emission and Reflection Radiometer Global DEM),
- **GTOPO** (Global Topographic 30 Arc-Second DEM),
- **GLOBE** (Global Land One-km Base Elevation data),
- **ALOS** (Advanced Land Observing Satellite) ,
- **ETOPO** (Earth topography five minute grid) … are available for free download by the common users.

Data Sampling methods

- Photogrammetric Sampling
- Using aerial photographs in stereo-plotters the sampling is done
- In order to have correct relief and slope different type of sampling is done

1. Selective Sampling
   - Sample points are selected prior to or during sampling process
2. Adaptive Sampling
   - When redundant samples (carrying little information) need to be rejected during sampling

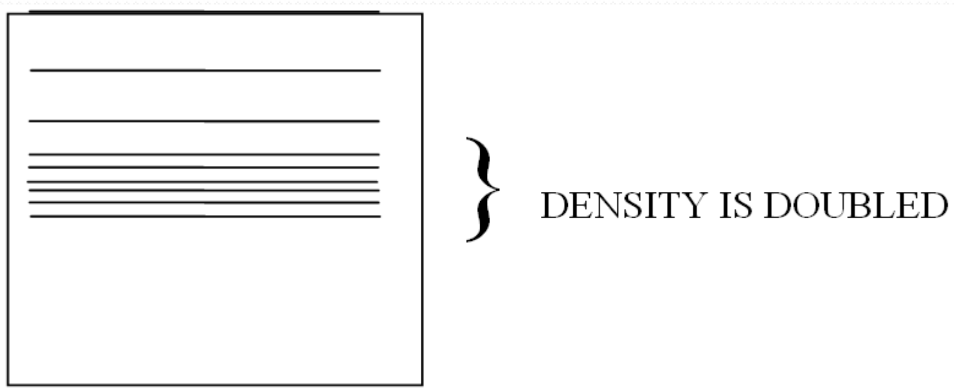
SAMPLING METHODS FOR   D E M

3. **PROGRESSIVE SAMPLING**

- When sampling and data analysis are carried out together, the results of the analysis can dictate how the sampling should proceed. Steps involved are:

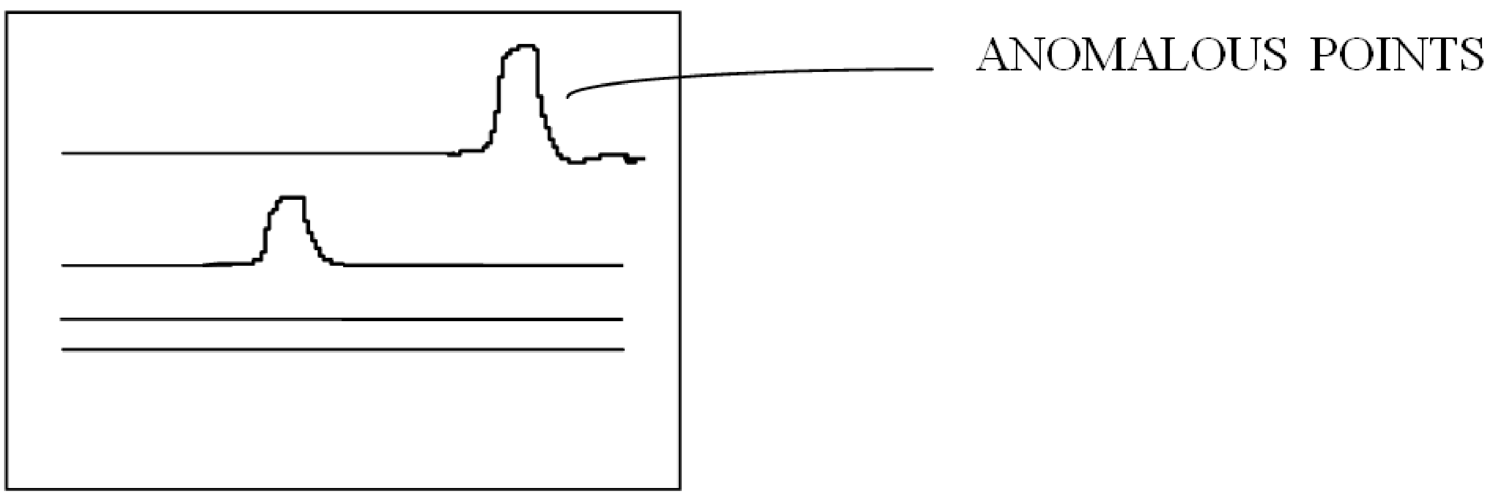
i) Series of successive runs are made first with coarser grid and then with successive finer grids

ii) This   will be done automatically when the profiling proceeds



4. COMPOSITE SAMPLING

- Progressive sampling with removal of anomalous points – check for gaps and data dense areas-which is unnecessary there



Concepts of Monoscopic methods of Depth Perception

Distances to objects, or depth can be perceived monoscopically on the basis of

- **Relative sizes of objects**
- **Hidden objects**
- **Shadows and**
- **Differences in focusing of the eye for viewing objects at varying distances.**

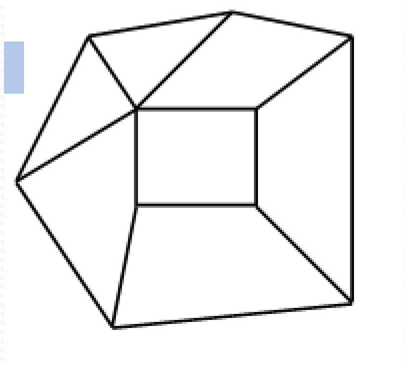
Concepts of Stereoscopic methods of Depth Perception

In combination of monoscopic parameters, the distances to objects, or depths can be perceived stereoscopically using **parallax differences** between same points / locations of objects seen in two or more images.

METHODS OF DTM GENERATION

- **MATHEMATICAL PATCH METHODS**

- Split the complete surface into square cells or irregularly shaped patches of equal area and fit to a point of observation
- Mathematical functions are used to weld them.



Methodology - Mathematical patches

Prepared on the basis of local method of spatial interpolation. The steps involved are:

- The surface area is split into square cells or irregularly shaped patches of roughly equal areas
- The surfaces are fitted to the point observations within the patch
- Weighting functions are used to ensure matching along the edges of surface patches, though not always seem to be continuous in slope along borders / break lines
- Mathematical functions using piecewise approximations for interpolating surfaces – useful in modeling complex surfaces in CAD systems - are adopted.

IMAGE METHODS

1. LINE METHODS

i) digitise the contours and add the attributes

ii) Identify the areas of equal inclination / increase/ decrease in values and make them as polygons and

iii) develop DTM

- ➔ output is too general

2. POINT METHODS

a) altitude matrices

i) develop grids

ii) identify the elevation of the grids from air photo using stereo plotters and develop altitude matrices and

iii) develop DTM

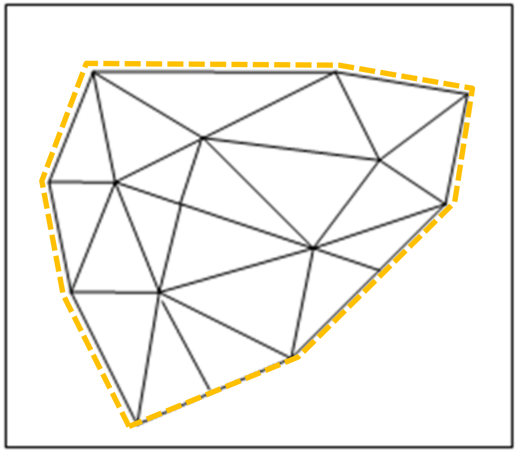
- ➔ grid size may vary for areas of complex relief and slope
- ➔ data redundancy in areas of uniform slope

3. Triangulated Irregular Network (TIN)

➔ Aerial triangulation - the process for determining the correct position and orientation of each surface in an area so they can be compiled into a triangles of equal slope / value

➔ develop network

➔ Develop altitude matrices



➔ Treat each and every Δ as polygon in vector

➔ Develop DTM

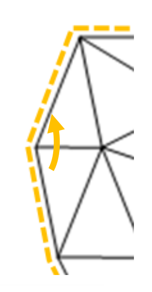
- Triangulation is done
- Elevations are identified
- DTM is prepared
- In tin each and every triangle is treated as "**vector polygon**"

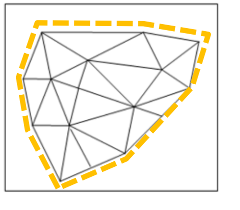
TIN ...Contd...

- Designed by Peuker and his co-workers – this avoids the redundancies of the altitude matrix
- More efficient for different types of computation (such as slope) than systems that are based only on digitized contours.
- This terrain model uses a sheet of continuous, connected triangular facets based on a Delaunay triangulation of irregularly spaced nodes or observation points.
- Unlike the Altitude Matrices, the TIN allows extra information to be gathered in areas of complex relief without the need for huge amounts of redundant data
- That is, a TIN is typically based on a Delaunay triangulation but its utility will be limited by the selection of input data points: well-chosen points will be located so as to capture significant changes in surface form, such as **topographical summits, breaks of slope, ridges, stream lines / valley floors, pits and cols.**
- These linearities can also be digitized as lines where topography is changing rapidly, called **"Break lines"**.
- After data capture along the above said important topological features – can be digitized with required accuracy.

TIN ….CONTD…….

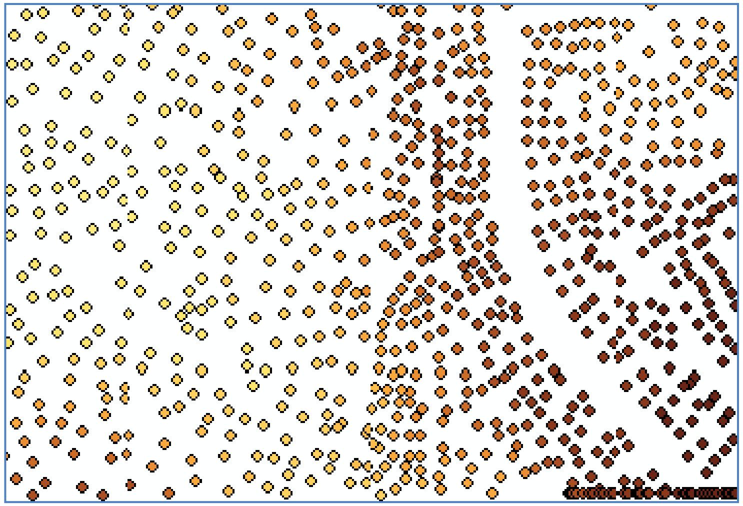
- TIN – vector topological structure similar to the **fully topologically defined structure** for representing polygon networks
- With exception that it does not have to make provision for islands or holes
- Records the **nodes of the network** as primary database
- Topological relations are built into the database by **constructing pointers** from each node to each of its neighbouring nodes.
- The **neighbour list** is sorted clockwise around each node starting at north
- The world outside the area modeled by the TIN is represented by a **dummy node** on the reverse side of the topological sphere
- This dummy node assists with describing the topology of the border points and simplifies their processing
- The database consists of 3 sets of records: **Node list**, **Pointer list**, & **Trilist**
- In Node list – records identifying each node, coordinates, number of neighbouring nodes and the start location of the identifiers of these neighbouring nodes in the Pointer list
- Nodes on the edge of the area have a **dummy pointer** set to **-32000** to indicate that they border the outside the world / study area – known as **Universal polygon -** enveloping imaginary polygon useful to cross-check the total area with the inner polygons.





CREATING TIN SURFACES FROM VECTOR DATA

TINs are usually created from a combination of vector data sources. You can use point, line, and polygon features as input data for a TIN.

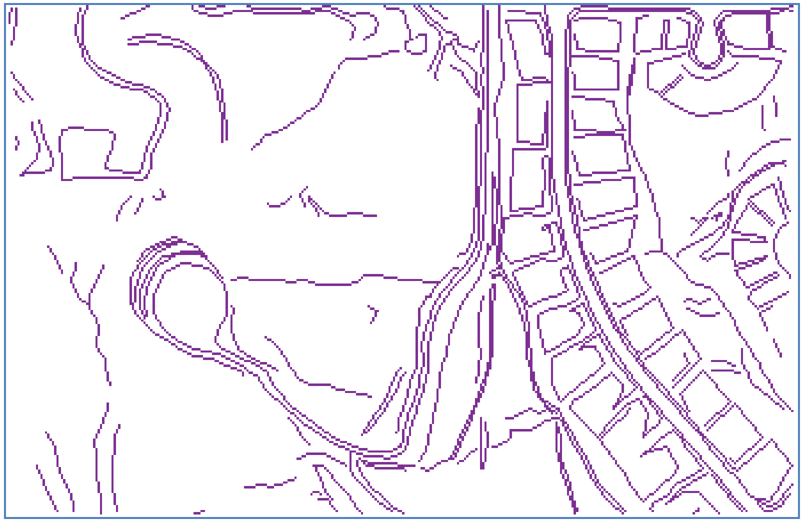


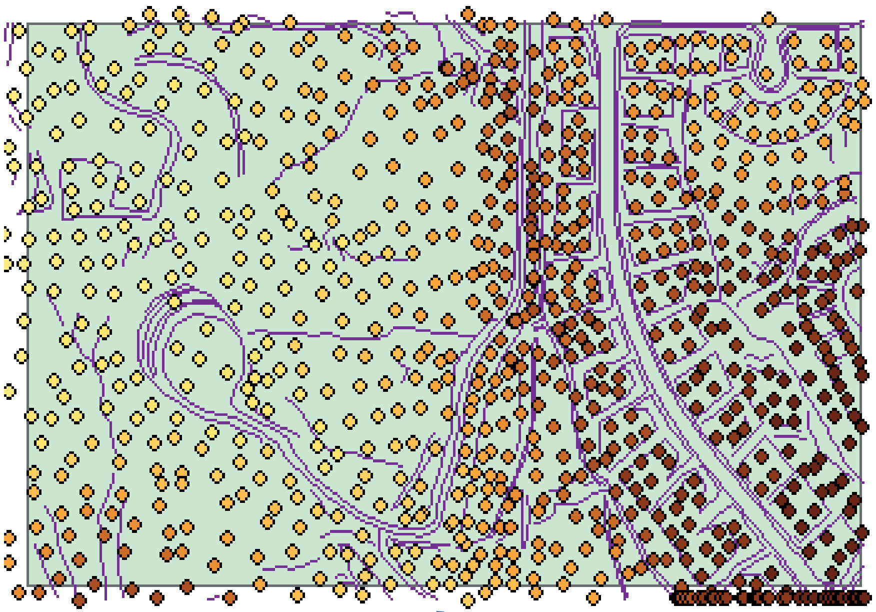
Mass points, are categorized by height attribute values.

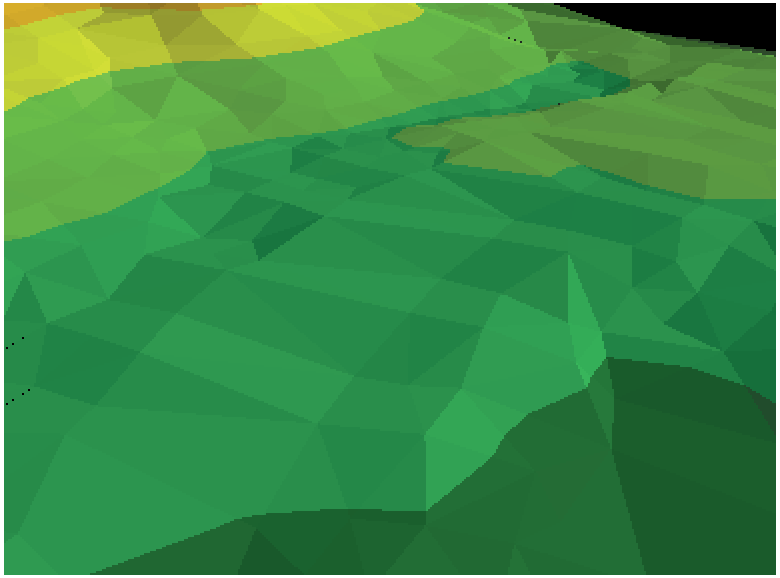
Breaklines

are lines with or without height measurements.

Breaklines typically represent either natural features such as ridgelines or streams or built features such as roadways.

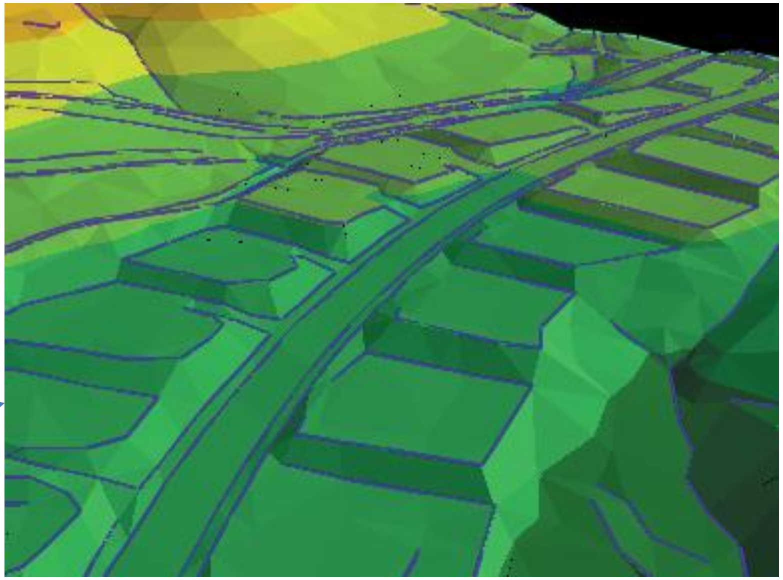




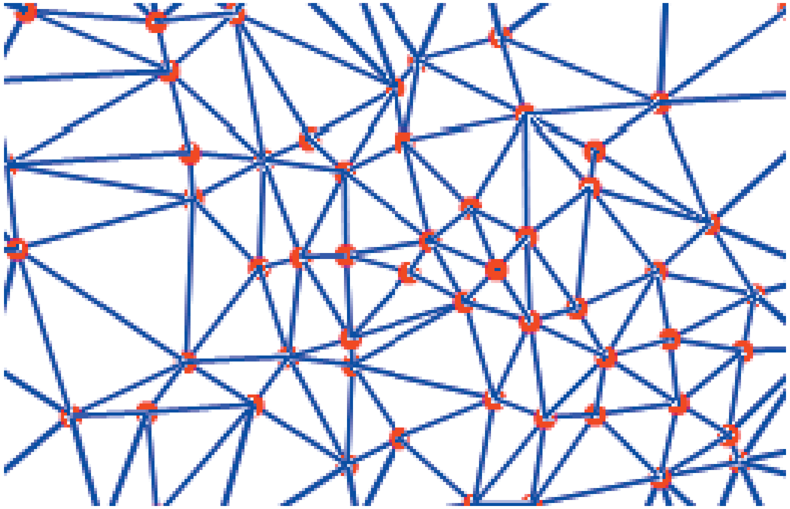


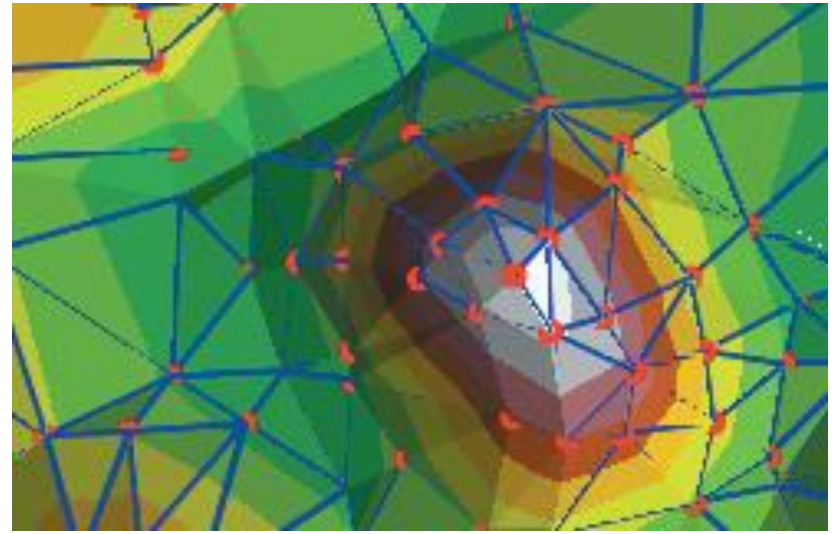
TIN created from mass points alone

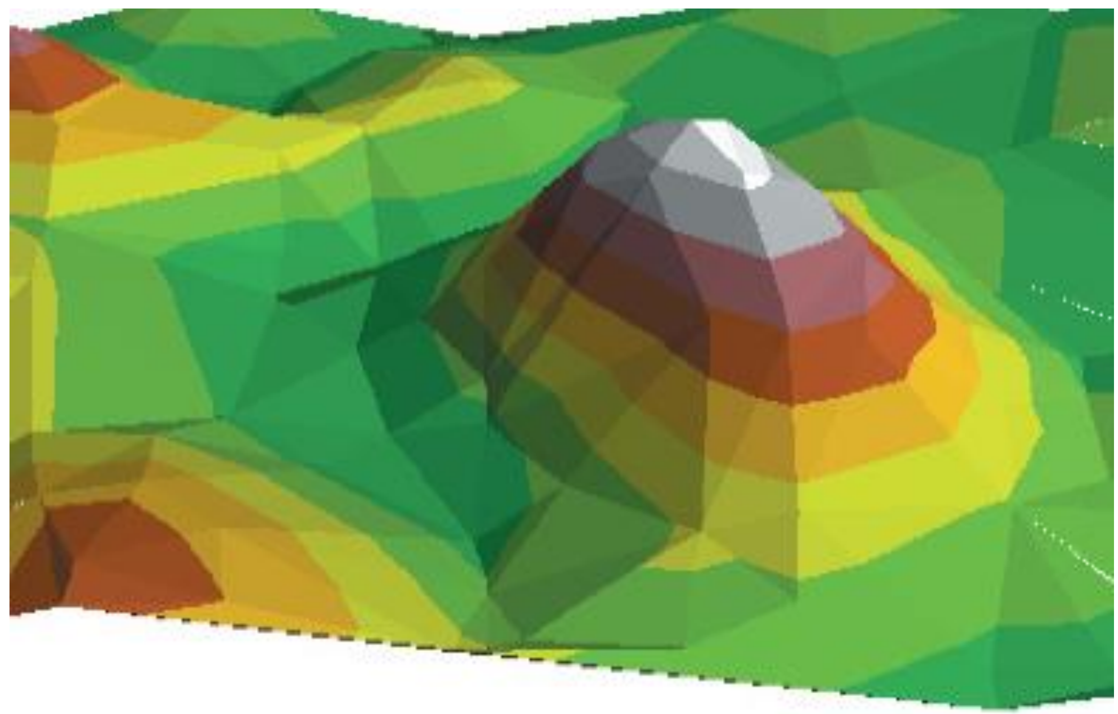
TIN of the same area created with more accuracy from the combination of both mass points and breaklines.



Nodes and edges of a TIN







TIN in perspective view

Vertical Exaggeration

Need for Vertical Exaggeration in 3D Visualization:

1. In spatial data, the z units are not always the x, y units of the coordinate system.

- For example, the **well** (dug / bore) features might be stored in UTM **meters** but have a **well depth** attribute in **feet**.
- To represent the wells correctly in 3D, the z-values must be converted to UTM meters.
- Otherwise, when the wells are seen in a 3D view, they will appear to be three times as deep as they really are.

2. In order to represent the flat topography / surface with enhanced elevation changes so as to highlight the subtle physical features that are there, vertical exaggeration is required.

Z-factor or Vertical Exaggeration Factor

The z-factor is a conversion factor that adjusts the units of measure for the vertical (or elevation) units when they are different from the horizontal coordinate (x,y) units of the input surface.

- It is the number of ground x,y units in one surface z unit. If the vertical units are not corrected to the horizontal units, the results of surface tools will not be correct.

- The z-values of the input surface are multiplied by the z-factor when calculating the output surface. If the x,y, and z units are all the same (in feet, for example), the z-factor is 1.

- This is the default value for the z-factor.

Z-factor … contd…

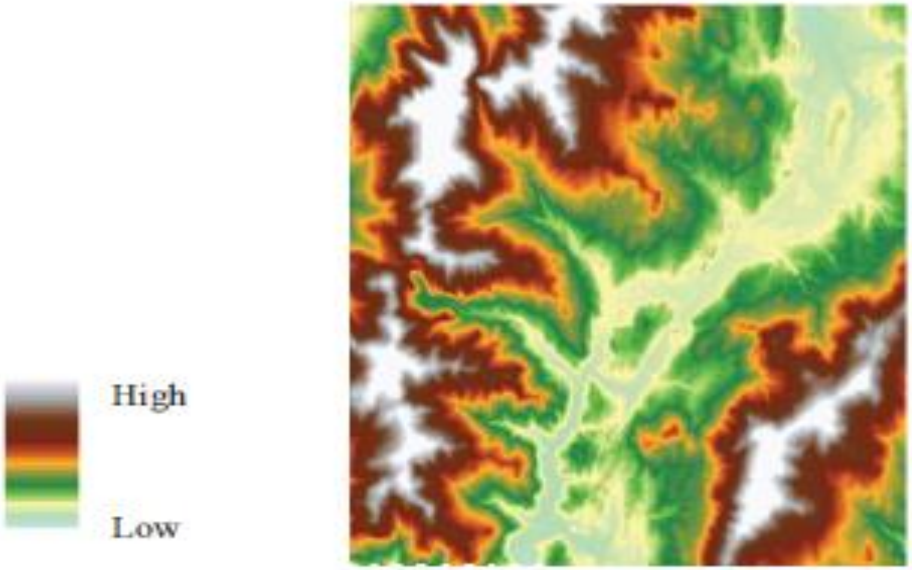
- For another example, if your vertical z units are feet and your horizontal x,y units are meters, you would use a z-factor of 0.3048 to convert your z units from feet to meters (1 foot = 0.3048 meter).
- The correct use of the z-factor is particularly important when the input raster is in a spherical coordinate system, such as decimal degrees.
- It is not uncommon to perceive the output from Hillshade to look peculiar if the input surface raster is not in a projected coordinate system.
- This is due to the difference in measure between the horizontal ground units and the elevation z-units. Since the length of a degree of longitude changes with latitude, you will need to specify an appropriate z-factor for that latitude.

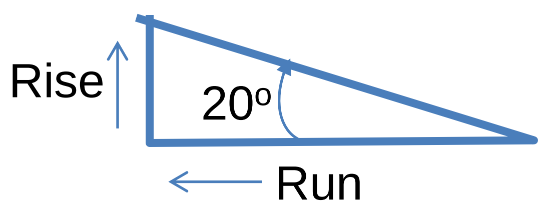
Products of DEM

1. Block diagrams, Profiles and Horizons
2. Anaglyphs
3. Volume estimation by numerical integration
4. Contour maps
5. Line of sight maps – Inter-visibility,
6. Maps of slope-radiance/degree, convexity, concavity and aspect
7. Shaded Relief Maps
8. Drainage Network and Drainage Basin / Watershed delineation
9. Drainage / Stream Orders, Flow length, Flow direction and Accumulation, etc.

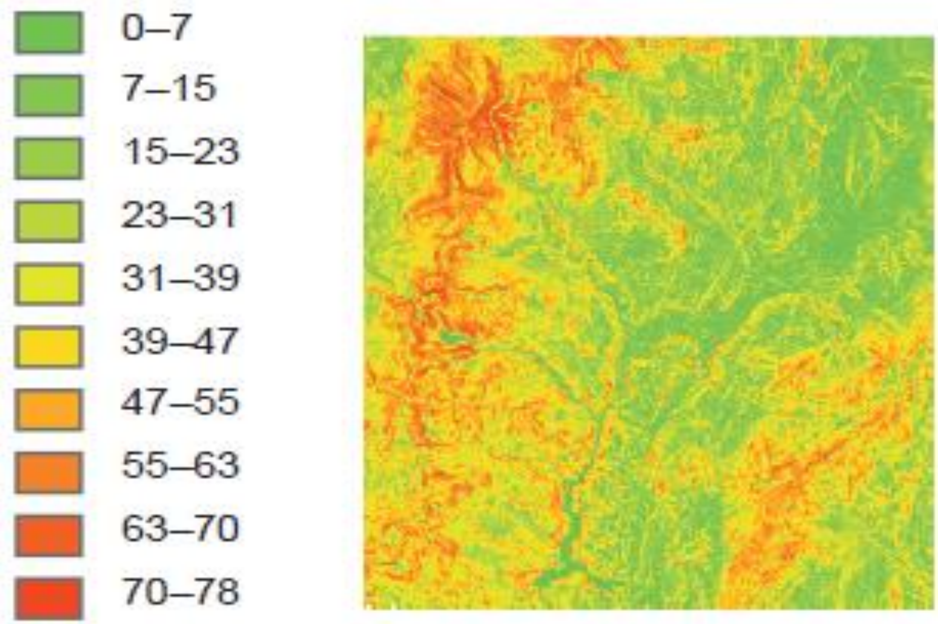
CALCULATING SLOPE

Elevation grid





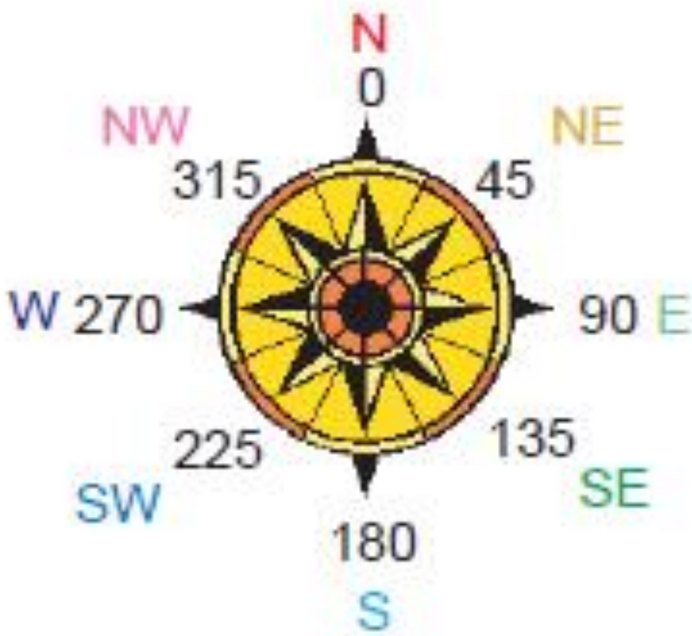
Slope in percent = 100 x (rise/run)

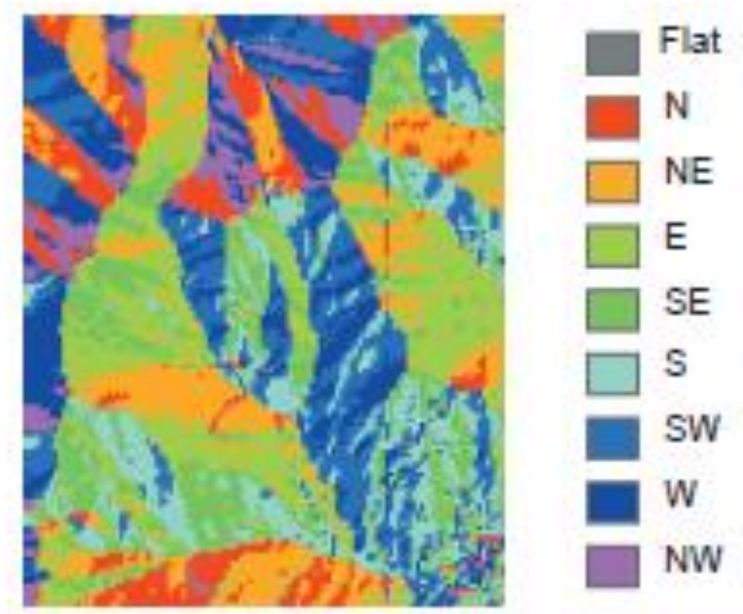


Slope map (in degrees)

CALCULATING ASPECT

Aspect is the direction that a slope faces





APPLICATION

Find all southerly slopes in a mountainous region to identify locations where the snow is likely to melt first, as part of a study to identify those residential locations that are likely to be hit by meltwater first.

Identify areas of flat land to find an area for a plane to land in case of emergency.

How to derive Slope, Aspect, geometry of slope?.....

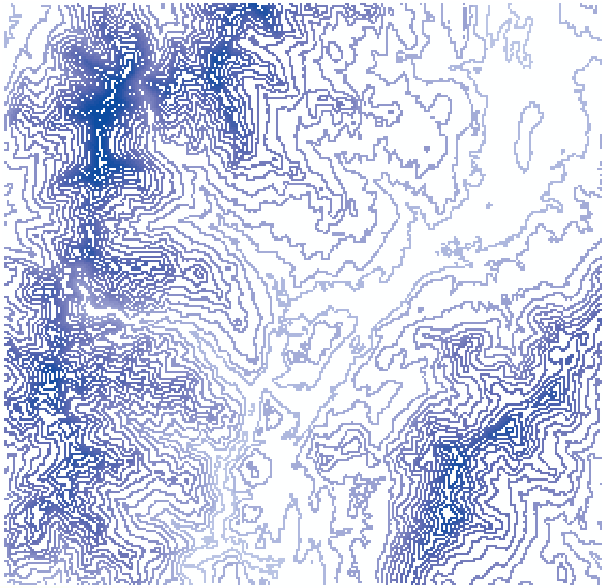
- All of the terrain / surface parameters (such as **slope** -the percentage or degree change in elevation over distance(degrees or percent), **aspect**-the direction (azimuth) that a surface faces, typically in degrees clockwise from North (0 degrees) and various slope geometries like **convexities** and **curvatures / plain / concavities**) are calculated by fitting a quadratic surface to the digital elevation data for the entered **kernel** size and taking the appropriate derivatives.
- The kernel size can be changed to extract multi-scale topographic information.
- **The slope degree is the convention of 0 degrees for a horizontal plane.**
- **The s/w measures the aspect angle with the convention of 0 degrees to the north (up) and angles increasing clockwise.**
- **The slope percent is the traditional percent grade and is calculated with the formula 100*rise/run.**
- **For example, a road that climbs 264 feet in a mile is a 5% grade (100*264/5280). To translate between slope in degrees and the percent just form 100*tan(<slope in degrees>).**

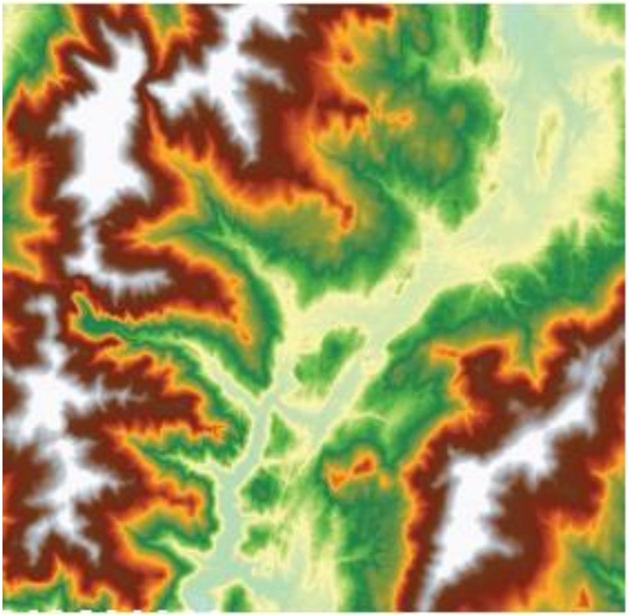
- For the convexity and curvature measures, convex surfaces are given positive values and concave surfaces are given negative values.
- The profile convexity (intersecting with the plane of the z-axis and aspect direction) measures the rate of change of the slope along the profile.
- The plan convexity (intersecting with the x,y plane) measures the rate of change of the aspect along the plan.
- These two surface curvature measures are in orthogonal directions with the profile convexity in the direction of maximum gravity effects and the plan convexity in the direction of minimum gravity effects.
- The longitudinal curvature (intersecting with the plane of the slope normal and aspect direction) and cross-sectional curvature (intersecting with the plane of the slope normal and perpendicular aspect direction) are also measures of the surface curvature orthogonally in the down slope and across slope directions, respectfully.
- The minimum and maximum overall surface curvatures can also be calculated.
- The programme also generates a root mean square (RMS) error image, which indicates how well the quadratic surface fits the actual digital elevation data.

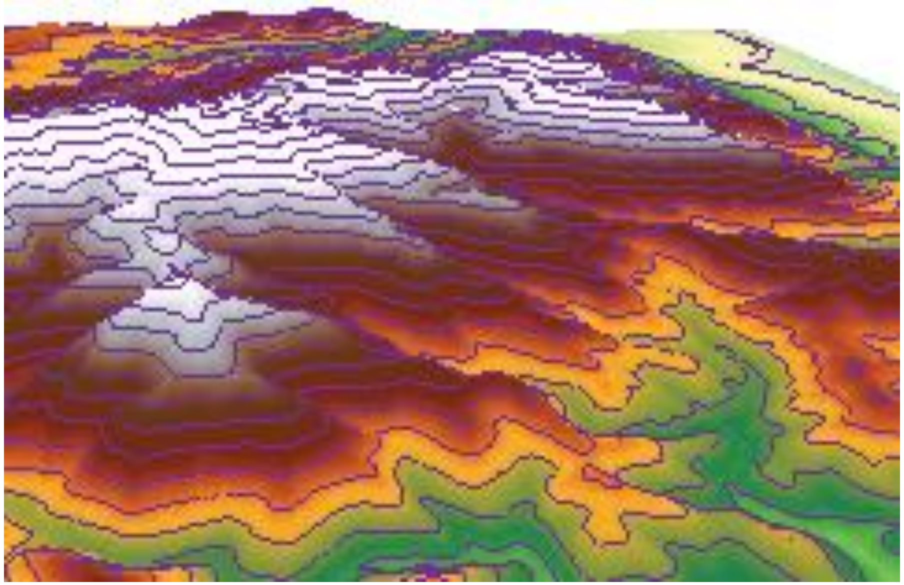
Mapping contours and isolines

Contours are lines that connect points of equal elevation valuee

Isolines are the lines that connect points of equal values such as, temperature (isotherm), precipitation (isohyet), pollution (isopol), or atmospheric pressure (isobar)….





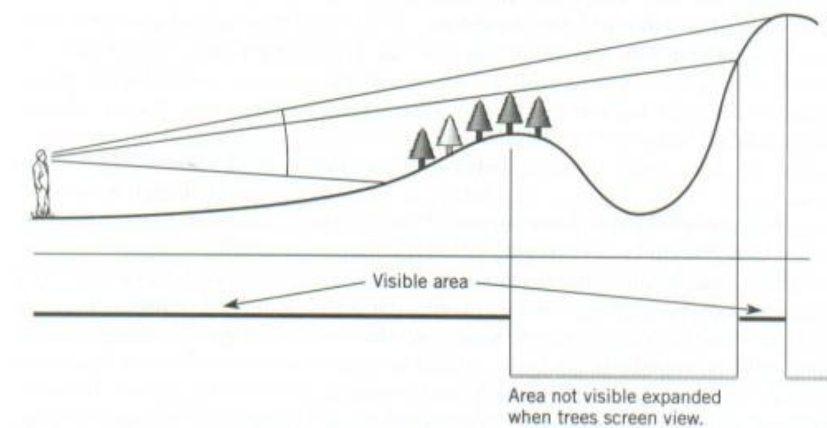


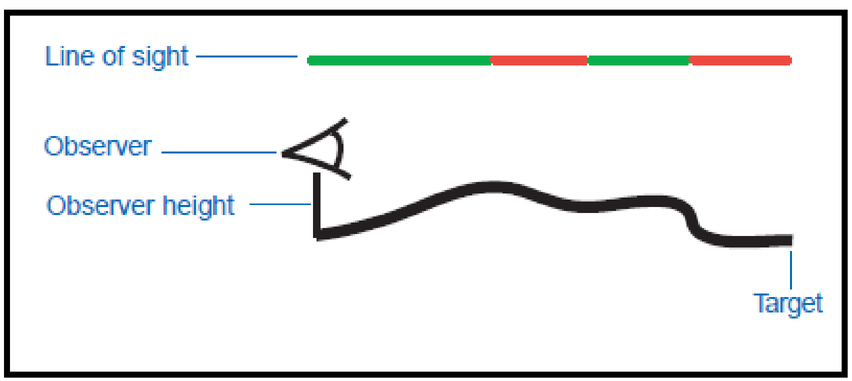
Analyzing visibility (line of sight)

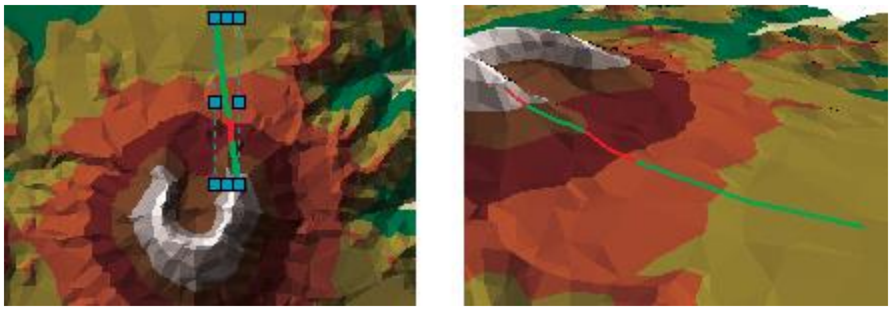
The shape of a terrain surface dramatically affects what parts of the surface someone standing at a given point can see.

A *line of sight* is a line between two points that shows the parts of the surface along the line that are visible to or hidden from an observer

Application: real estate, the location of telecommunications towers, or the placement of military forces.







The visible segments are shown in green, and the hidden segments are shown in red.

What is the viewshed?

The viewshed identifies the cells in an input raster that can be seen from one or more observation points or lines

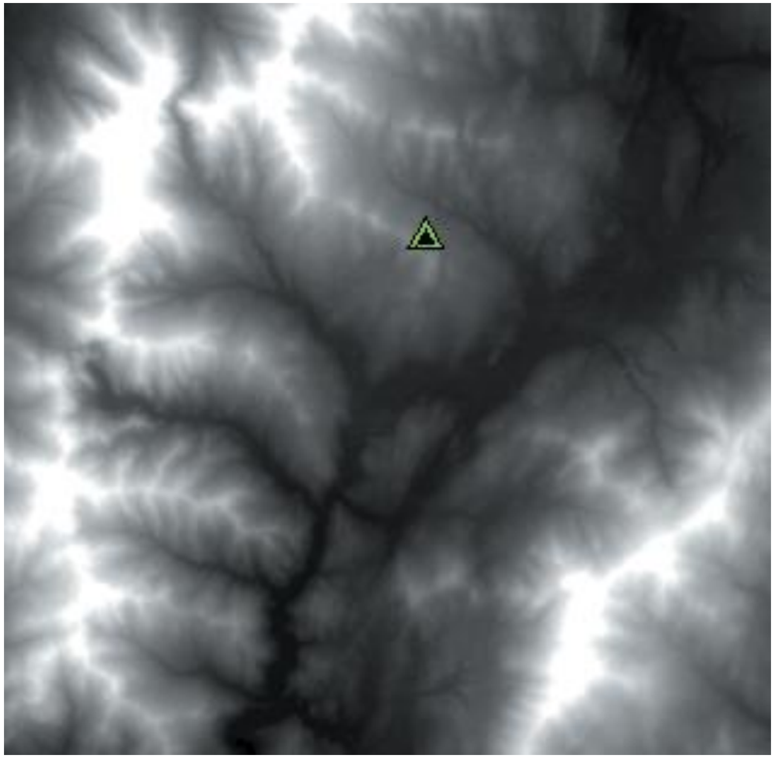
The viewshed is useful when you want to know how visible objects might be

For example, you may need to know "from which will be the best location to hold my advertisement board so that it can be visible from maximum places

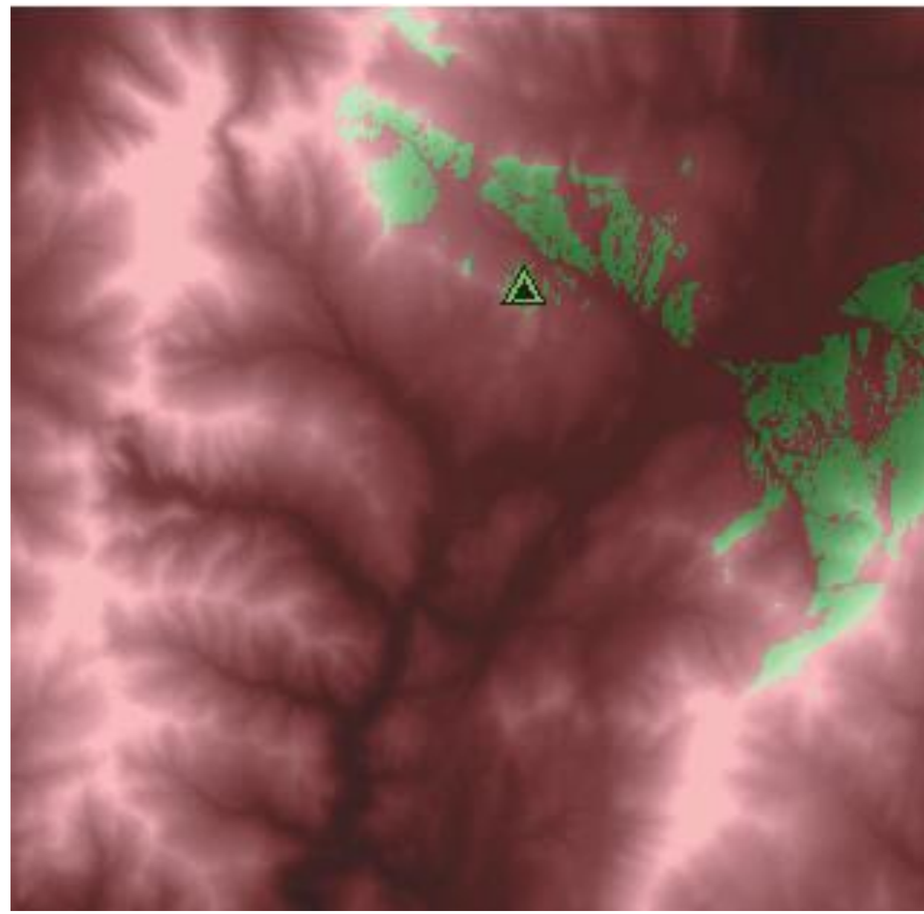
"What will the view from this road?

"Would this be a good place for a communications tower?"

the observation point is marked as a green triangle.

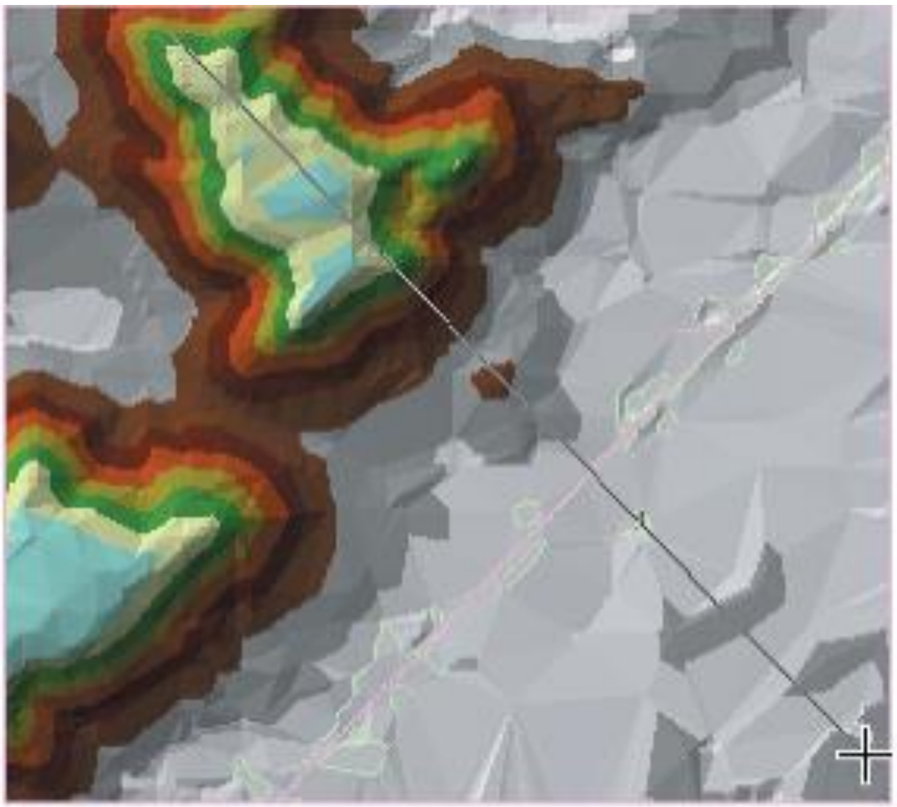


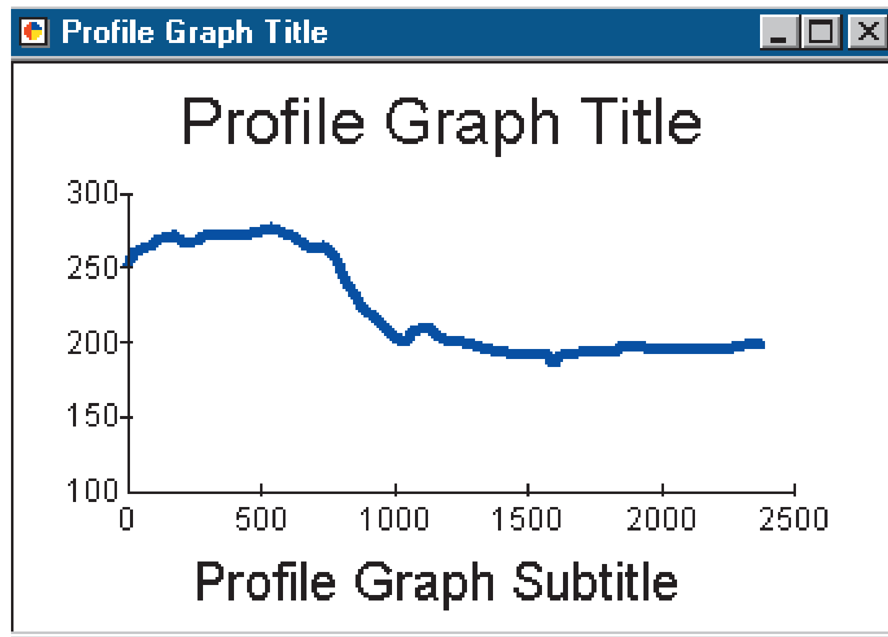
grid displays the height of the land (darker locations represent lower elevations), and the observation point is marked as a green triangle.



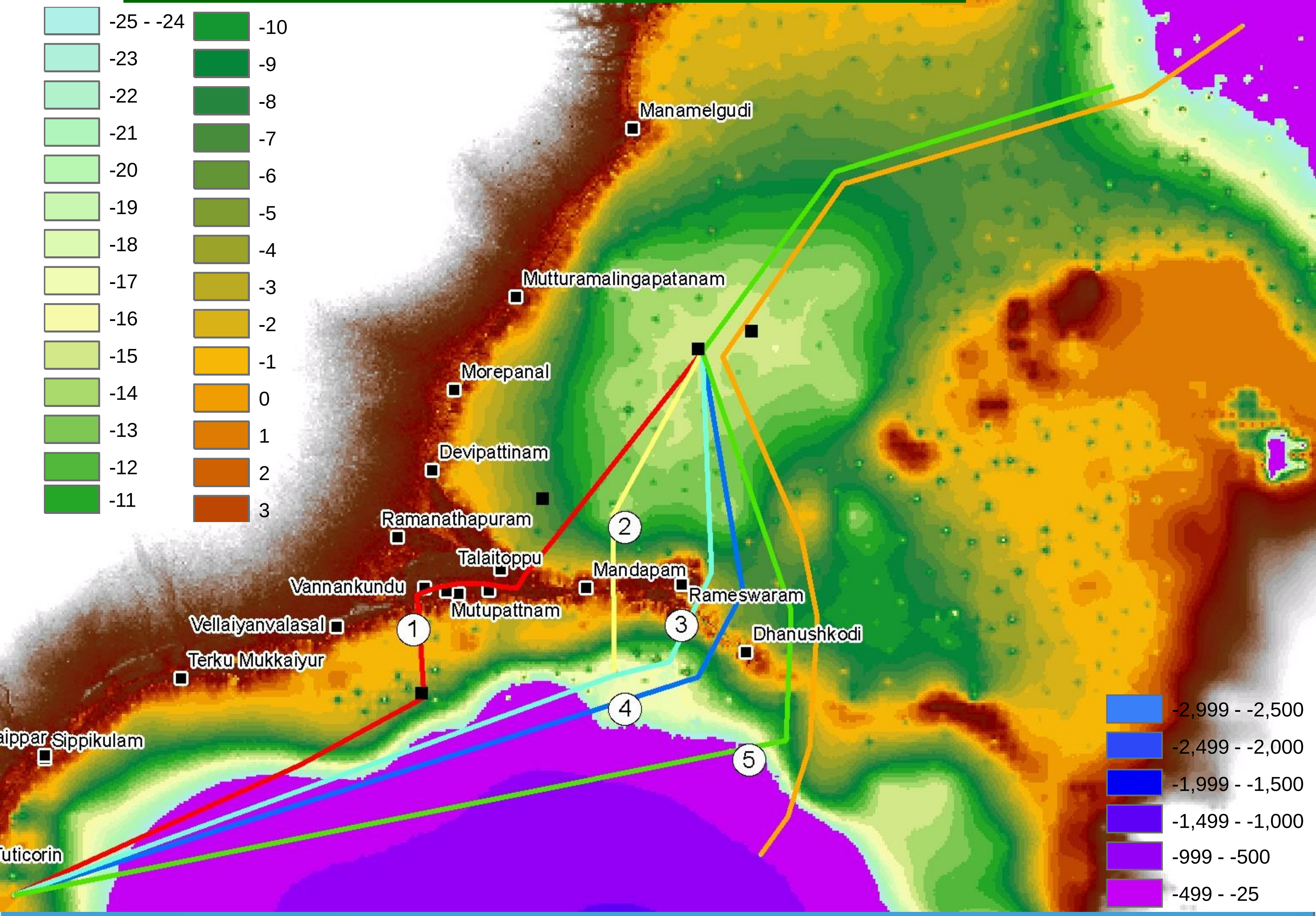
Determining height along a profile

Profiles show the change in elevation of a surface along a line. They can help you assess the difficulty of a trail or evaluate the feasibility of placing a rail line along a given route.

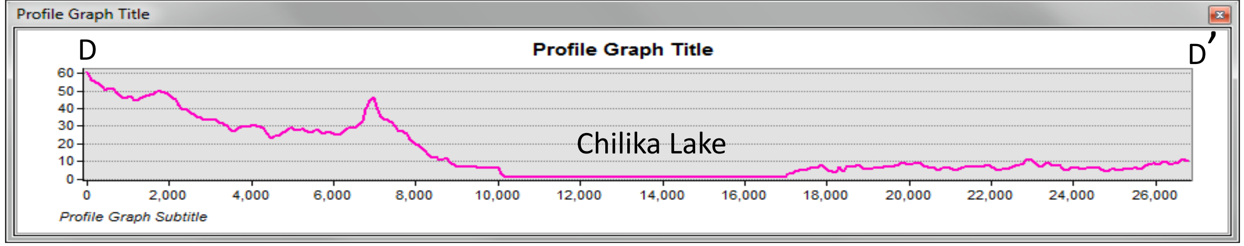


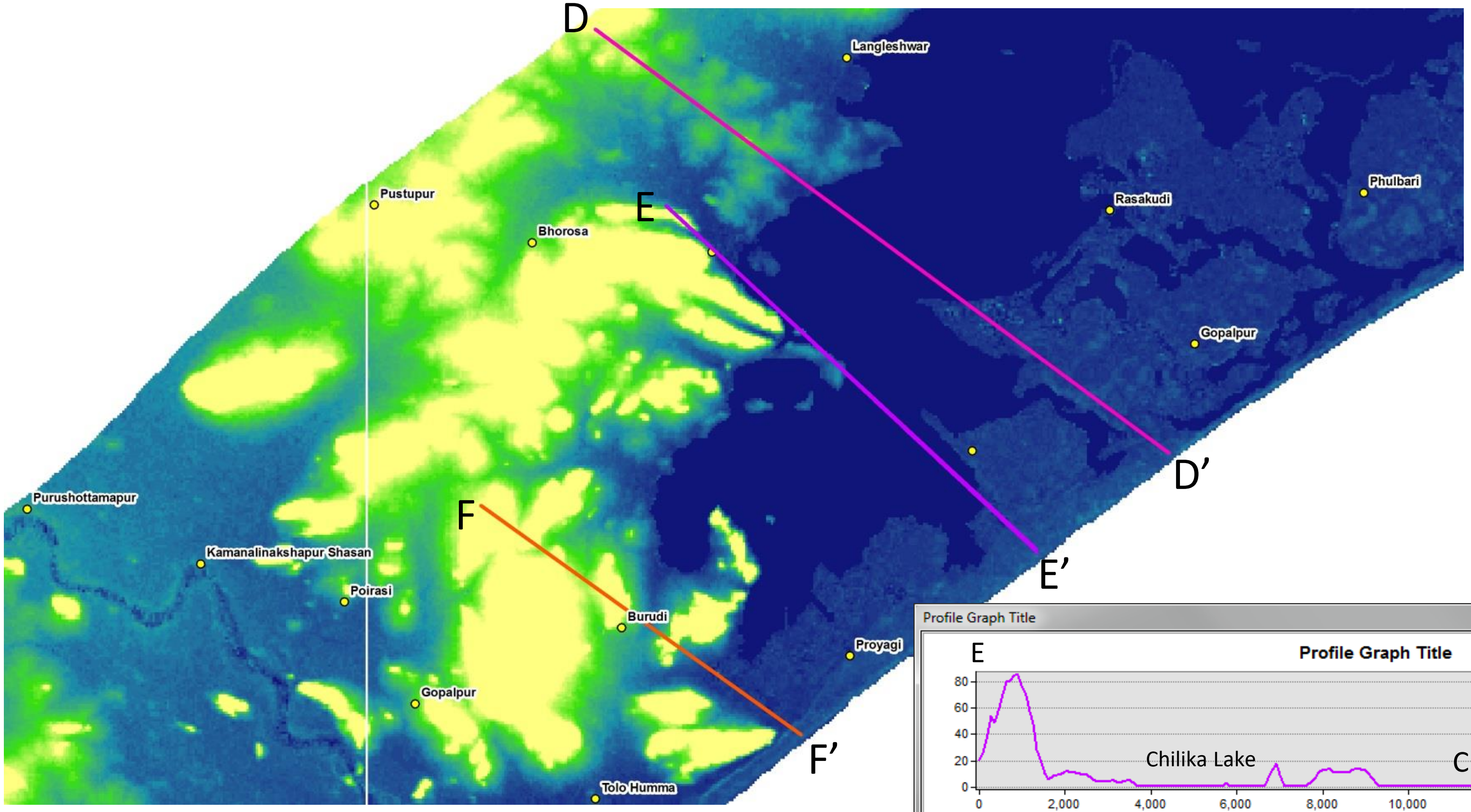


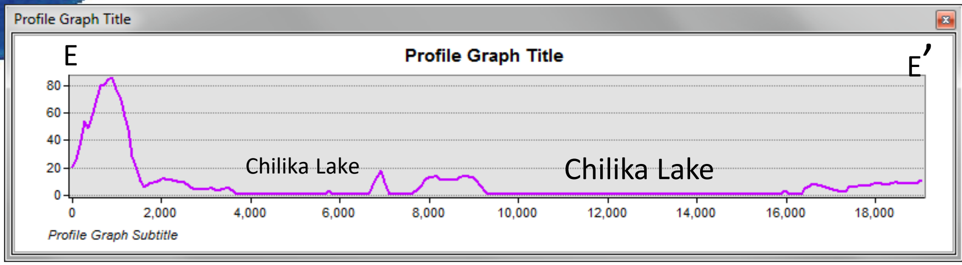
NAVIGATION - SRTM and Bathymetry DEM of the area

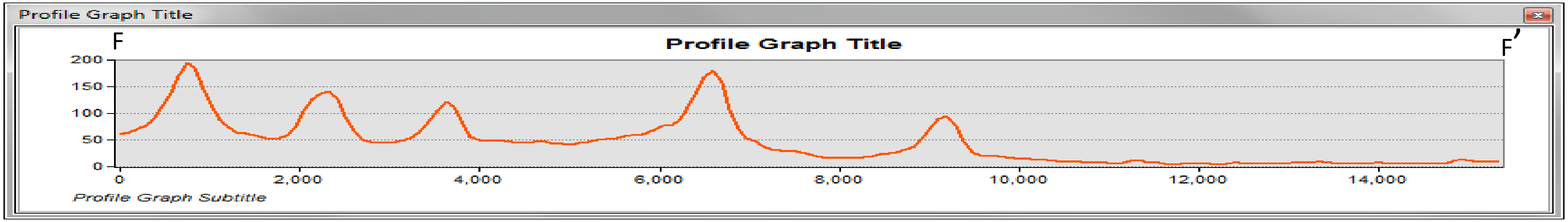


Vertical Profiles

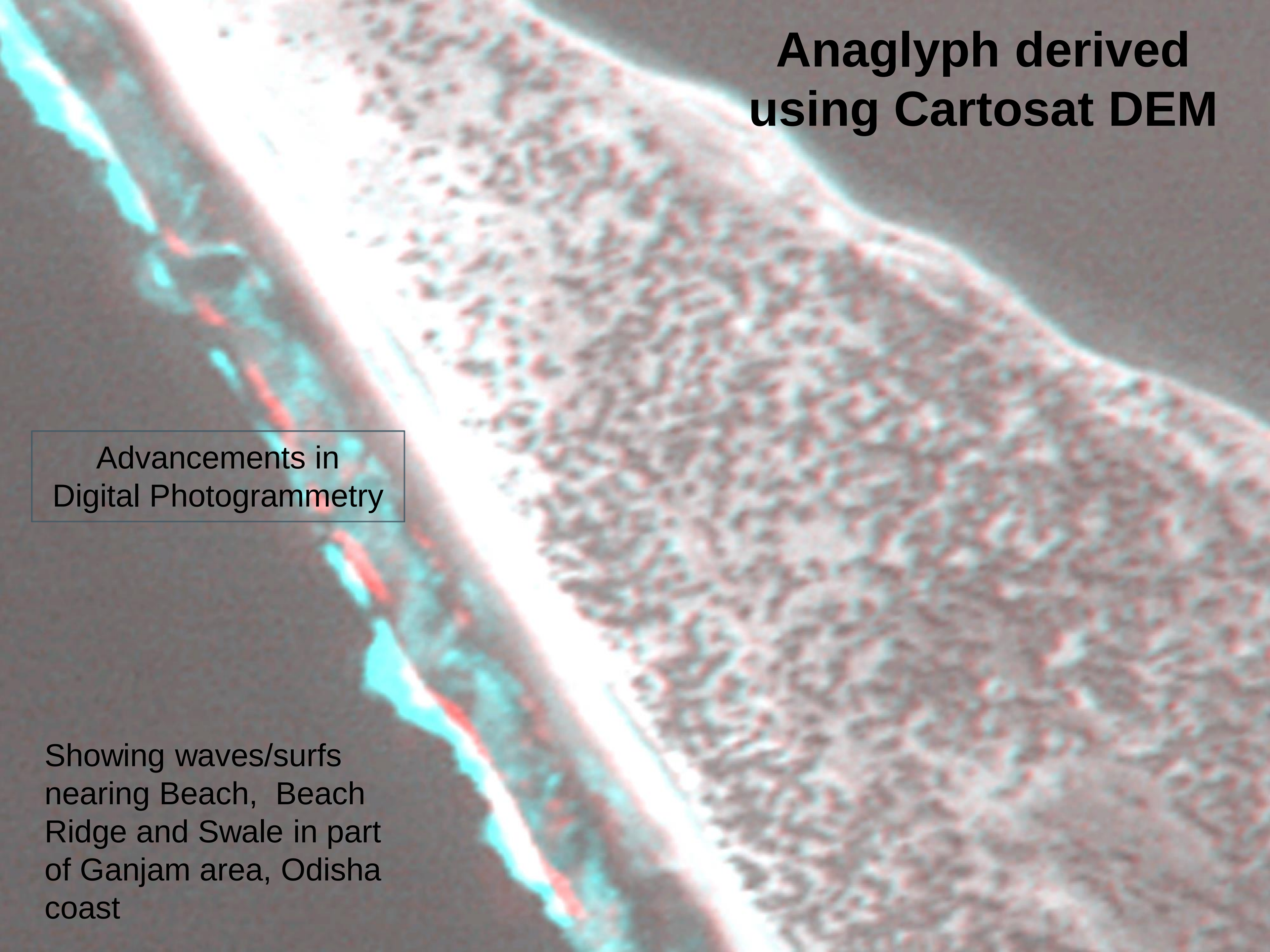








Anaglyph derived using Cartosat DEM

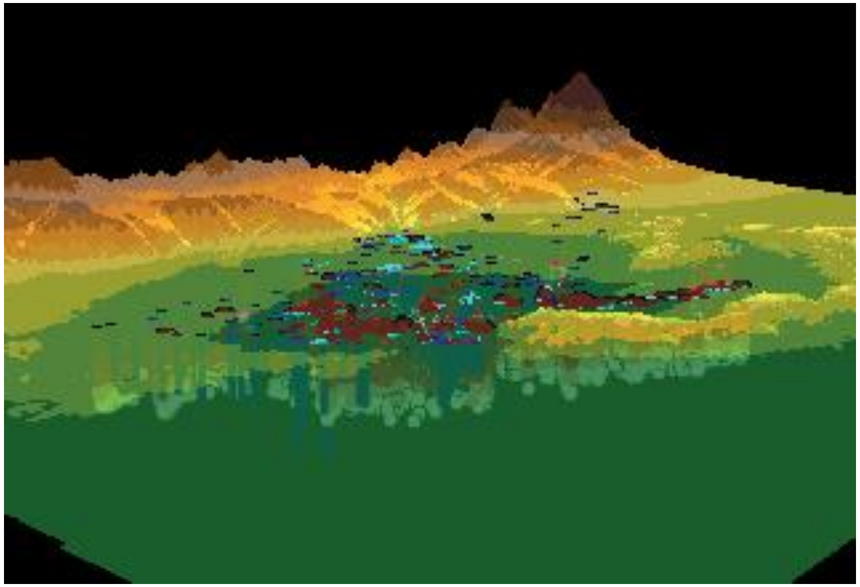


Advancements in Digital Photogrammetry

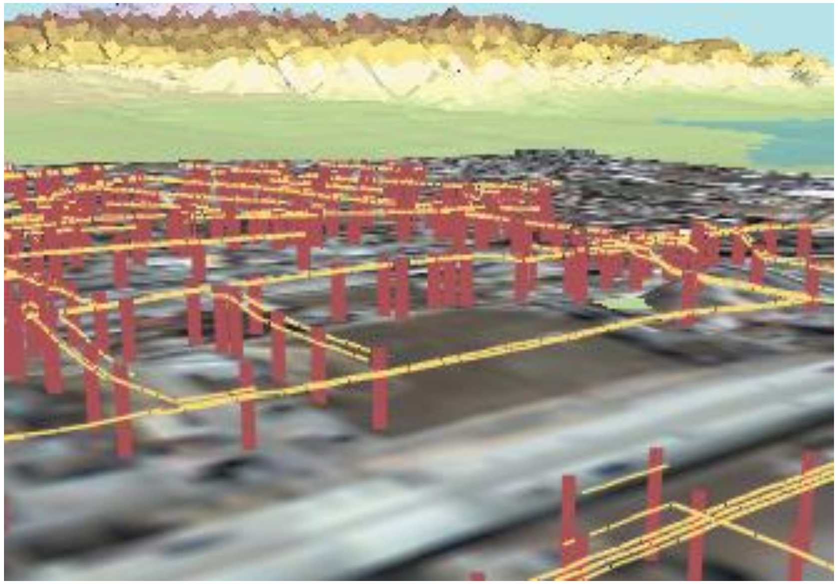
Showing waves/surfs nearing Beach, Beach Ridge and Swale in part of Ganjam area, Odisha coast

DEM BASED VISUALIZATION OF TERRAINS / SURFCES

3D view of raster and vector data

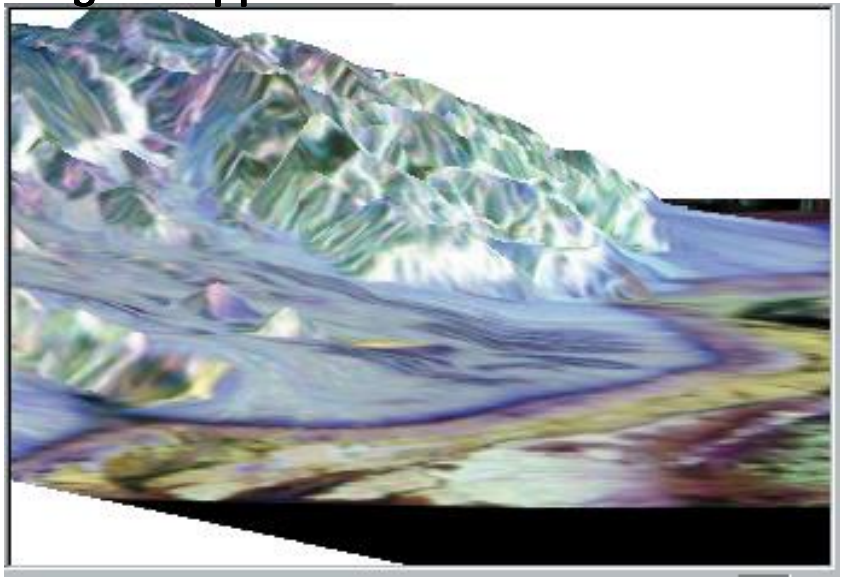


3D view of utility poles and power lines

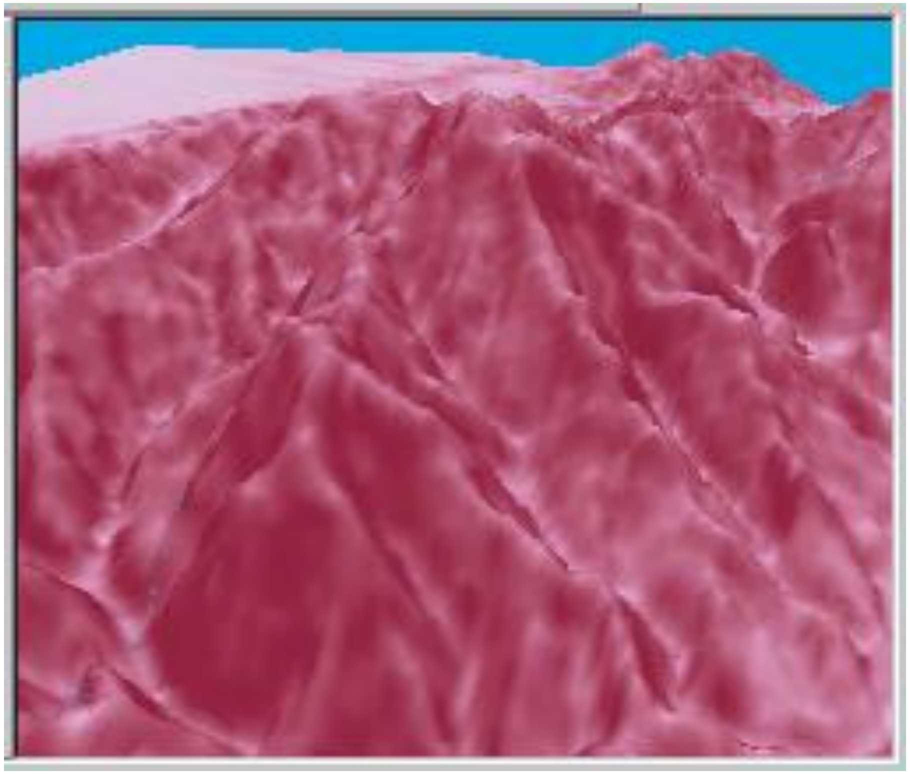


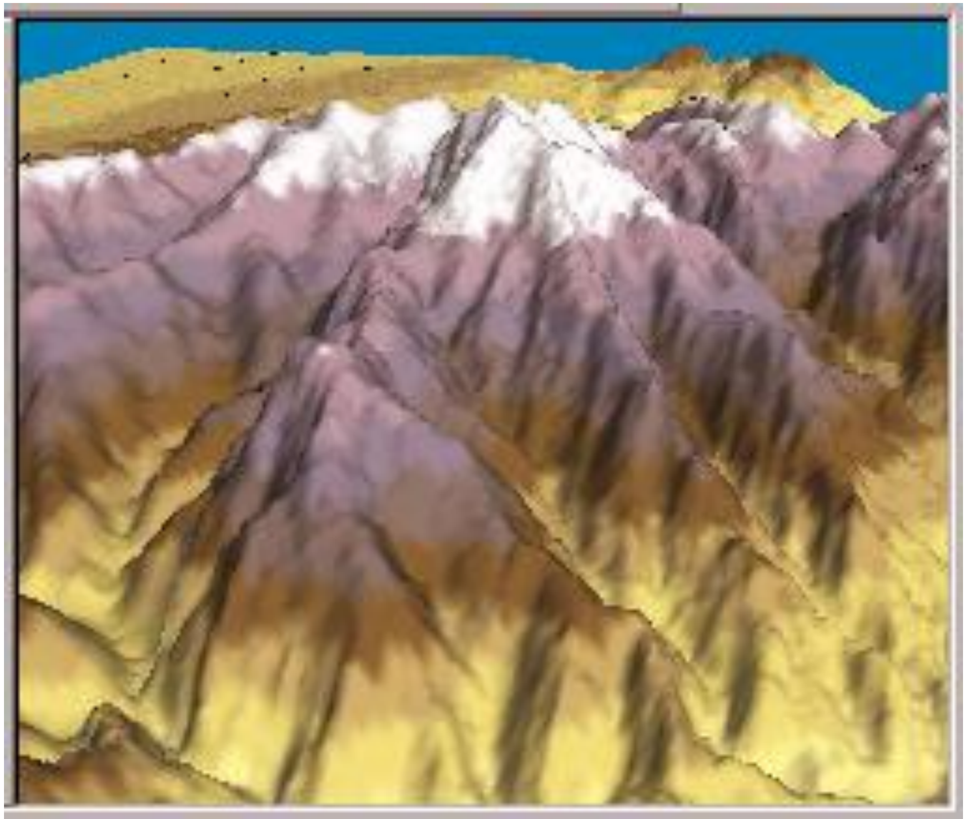
3Dimensional choropleth map -vector data

Image Wrapped DEM

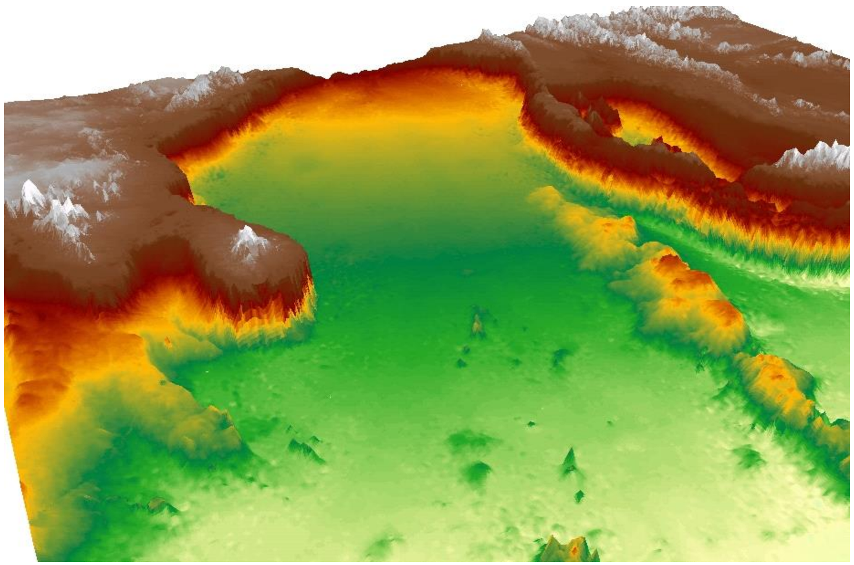


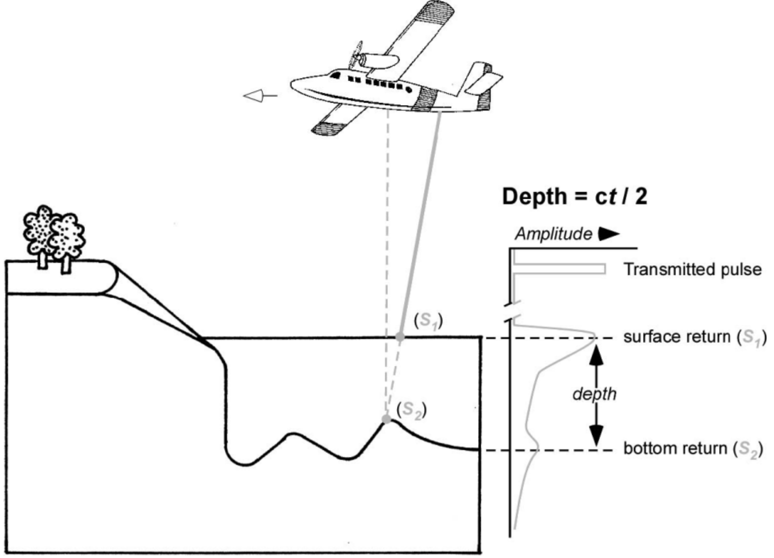
Understanding the shape of a surface

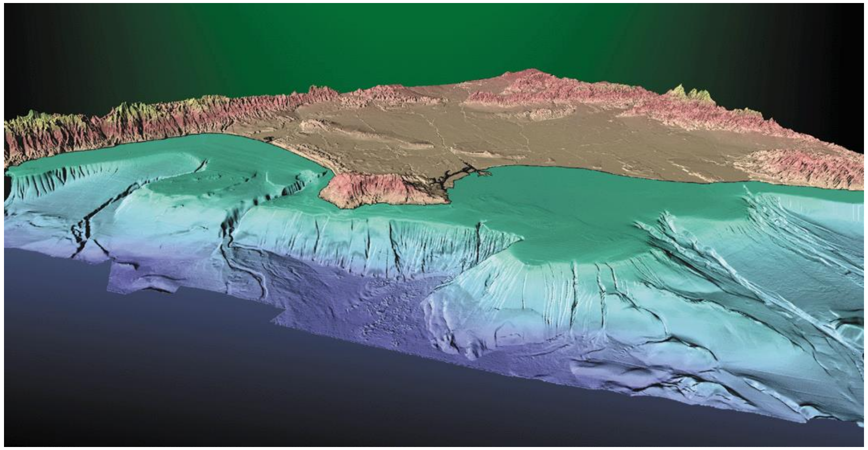




BATHYMETRY:

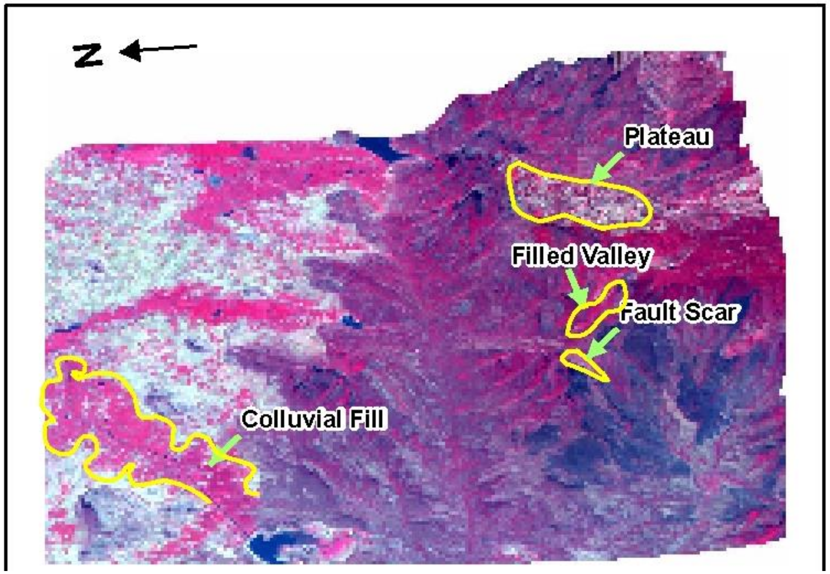


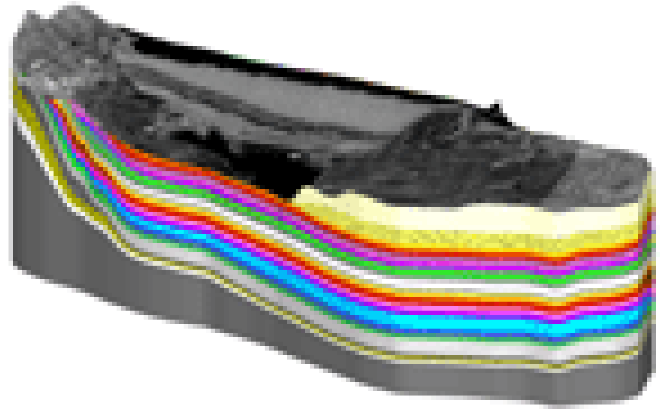


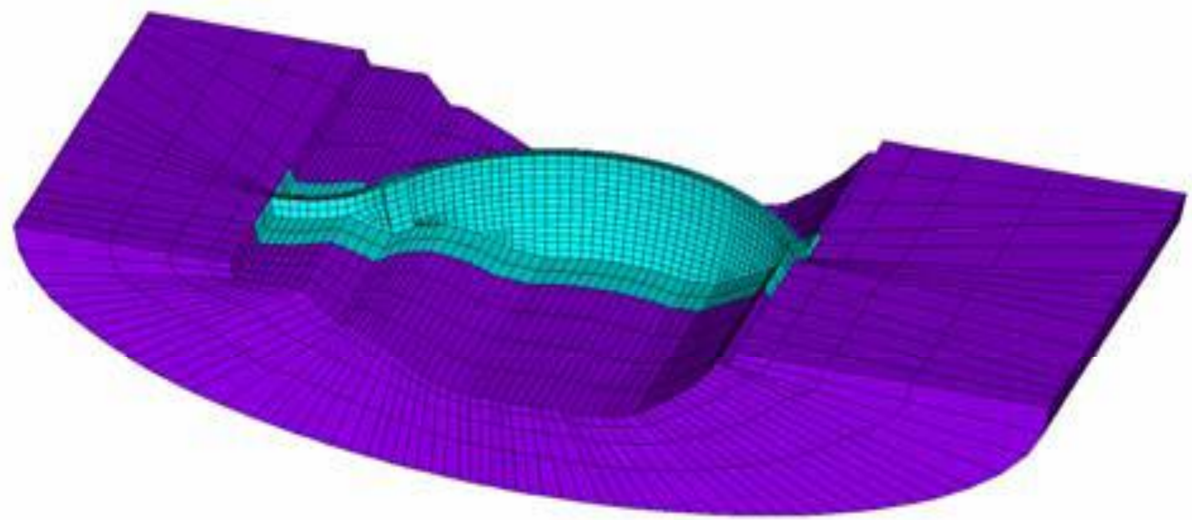


For any offshore structures including harbor development

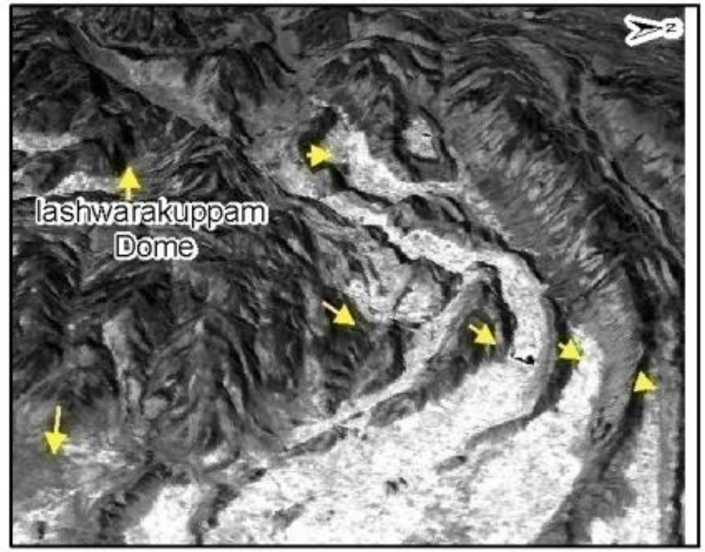
Pipeline etc.,


N
Plateau
Filled Valley
Fault Scar
Colluvial Fill

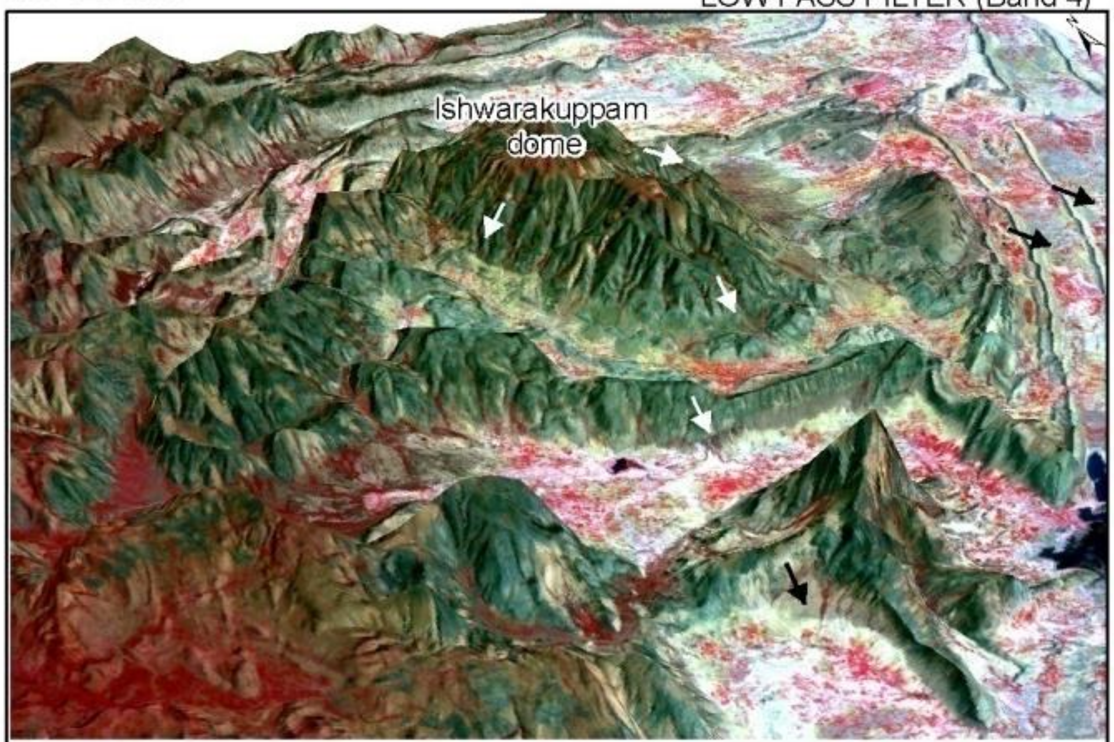




TM FCC data

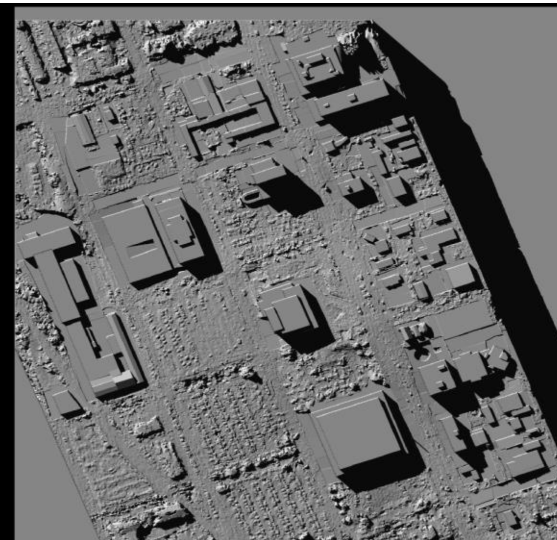


LOW PASS FILTER (Band 4)



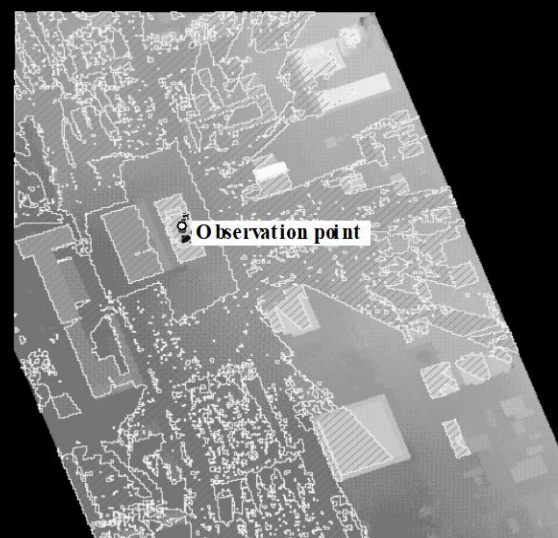
Digital Surface Model Creation

Original Panchromatic Aerial Photograph



Digital Elevation Model (DEM)

Orthophoto Draped Over DEM



Cellular Transceiver Location Model

Concepts of Shaded Relief mapping

Initially, to create shaded Relief map, slope and aspect are to be calculated based on the plane defined for each triangle.

Slope can be written in degrees by specifying degree and Aspect is always reported in degrees. Zero is north, and values increase clockwise like a compass. Flat triangles will be assigned an aspect value of -1.

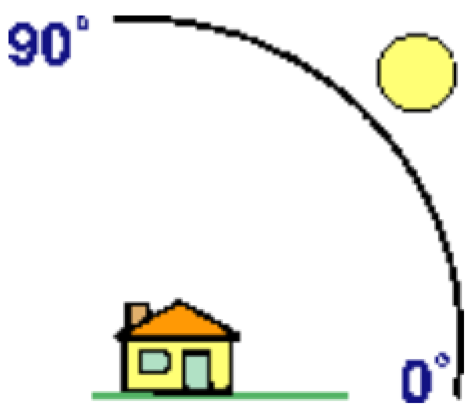
Optionally, a hillshade field can be written containing a brightness value for each triangle. Values range from zero to 255.

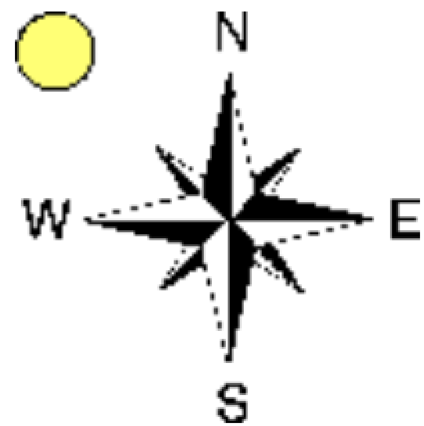
The brightness value is based on the relation between the plane defined by each triangle and a **light source**. The position of the light source defaults to the northwest, with an azimuth of 315 degrees (compass-based with 0 north, positive clockwise) and an altitude of 45.

For Hill shade, it is necessary to obtain the hypothetical illumination of a surface by determining illumination values for each cell in a raster.

It should be done by setting a position for a hypothetical light source **(Sun Elevation Angle)** and calculating the illumination values of each cell in relation to neighboring cells.

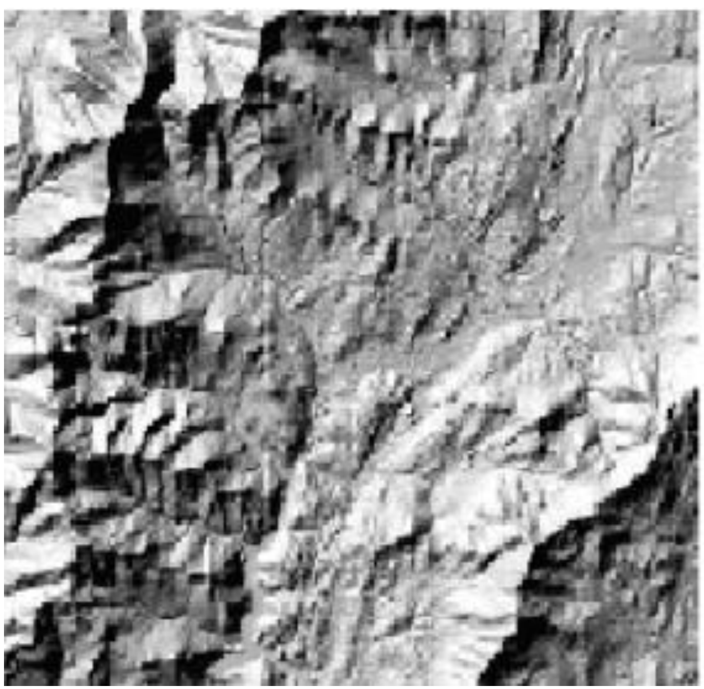
It can greatly enhance the visualization of a surface for analysis or graphical display, especially when using transparency.





By default, shadow and light are shades of gray associated with integers from 0 to 255 (increasing from black to white).
The **Sun azimuth Angle** is the angular direction of the sun, measured from north in clockwise degrees from 0 to 360. An azimuth of 90 is east. The default is 315 (NW).

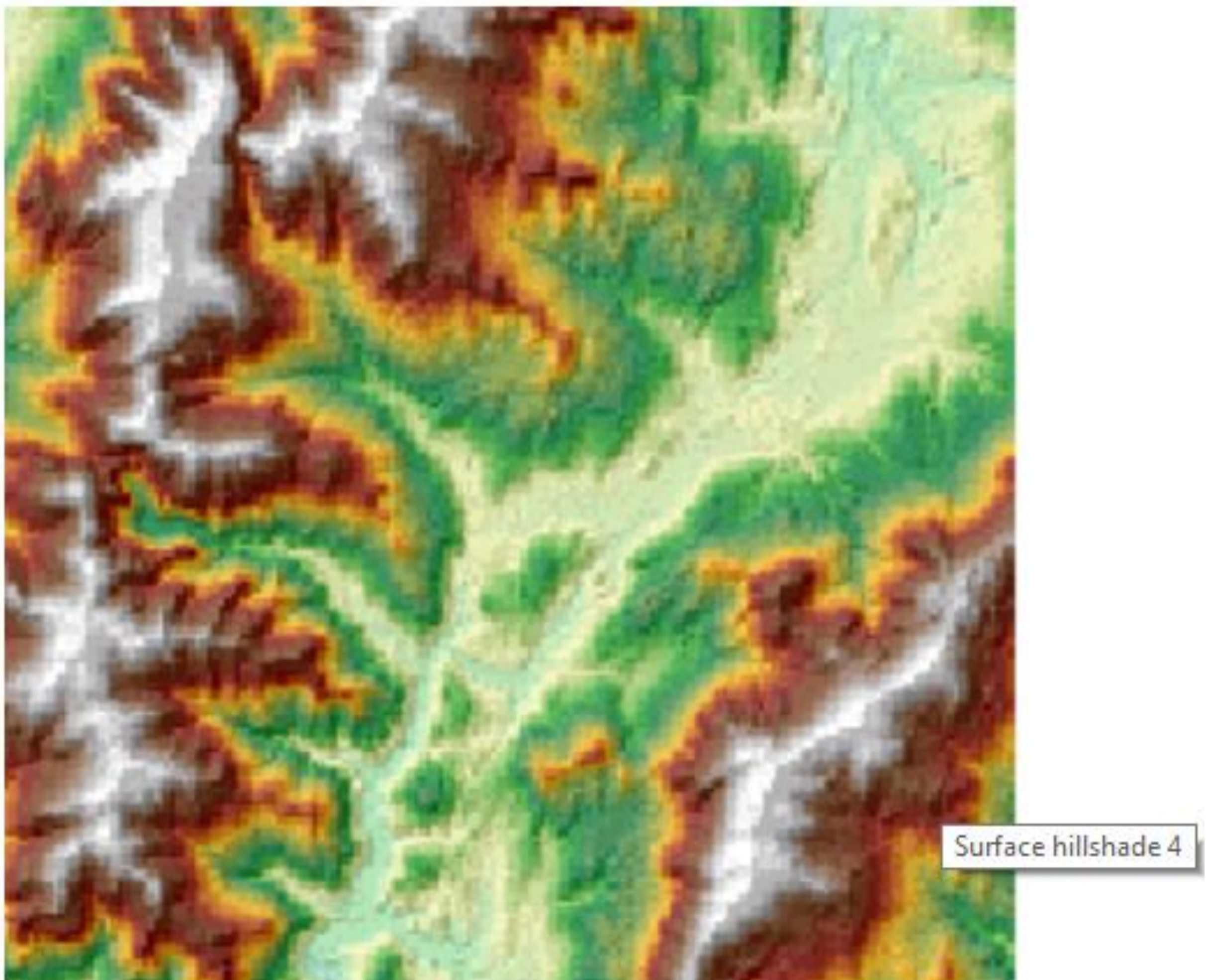
The altitude is the slope or angle of the illumination source above the horizon. The units are in degrees, from 0 (on the horizon) to 90 (overhead). The default is 45 degrees.



Shaded Relief Map with an azimuth of 315 and an altitude of 45 degrees

Use of Shaded Relief Map in Visualization/Display

By placing an elevation raster on top of a created hillshade and making the elevation raster transparent, it is possible to create realistic images of the landscape.



Other layers can also be added, such as roads, streams, or vegetation, to further increase the informational content in the display.

Use of Shaded Relief Map in Analysis

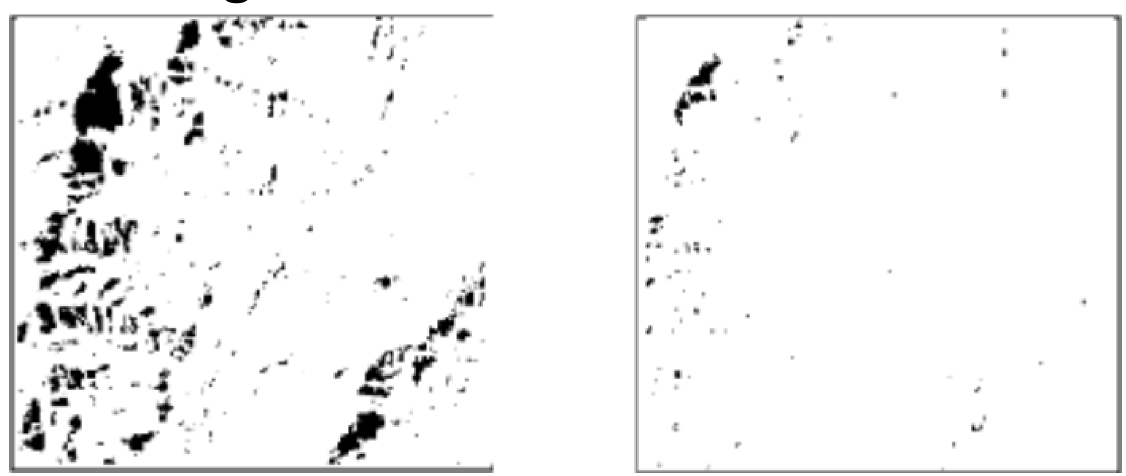
- By modeling shade (shadow), we can calculate the local illumination and whether the cell falls in a shadow or not at a particular time of day.

- Cells that are in the shadow of another cell are coded 0; all other cells are coded with integers from 1 to 255.

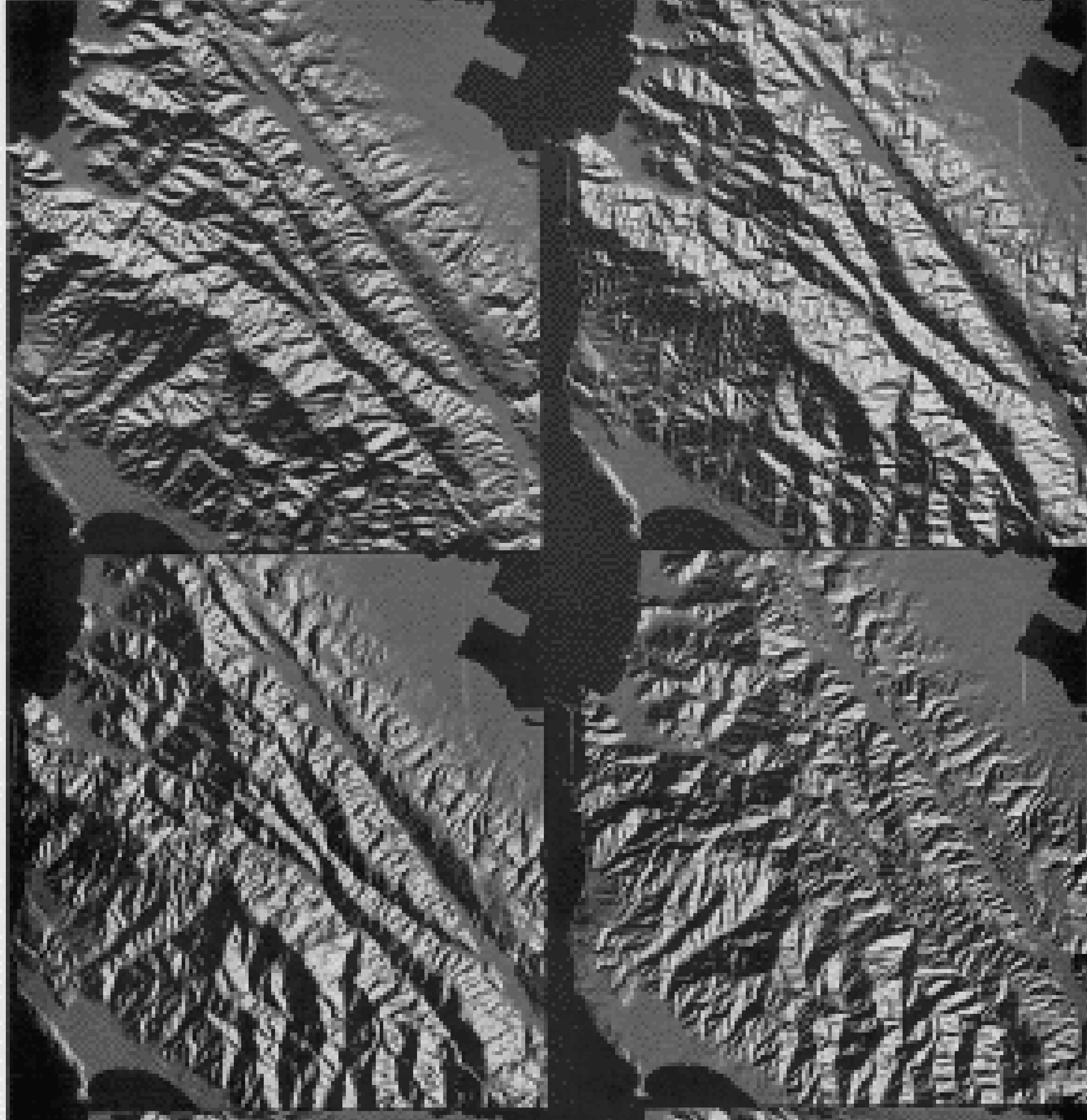
- All values greater than 1 to 1, can be reclassified producing a binary output raster.

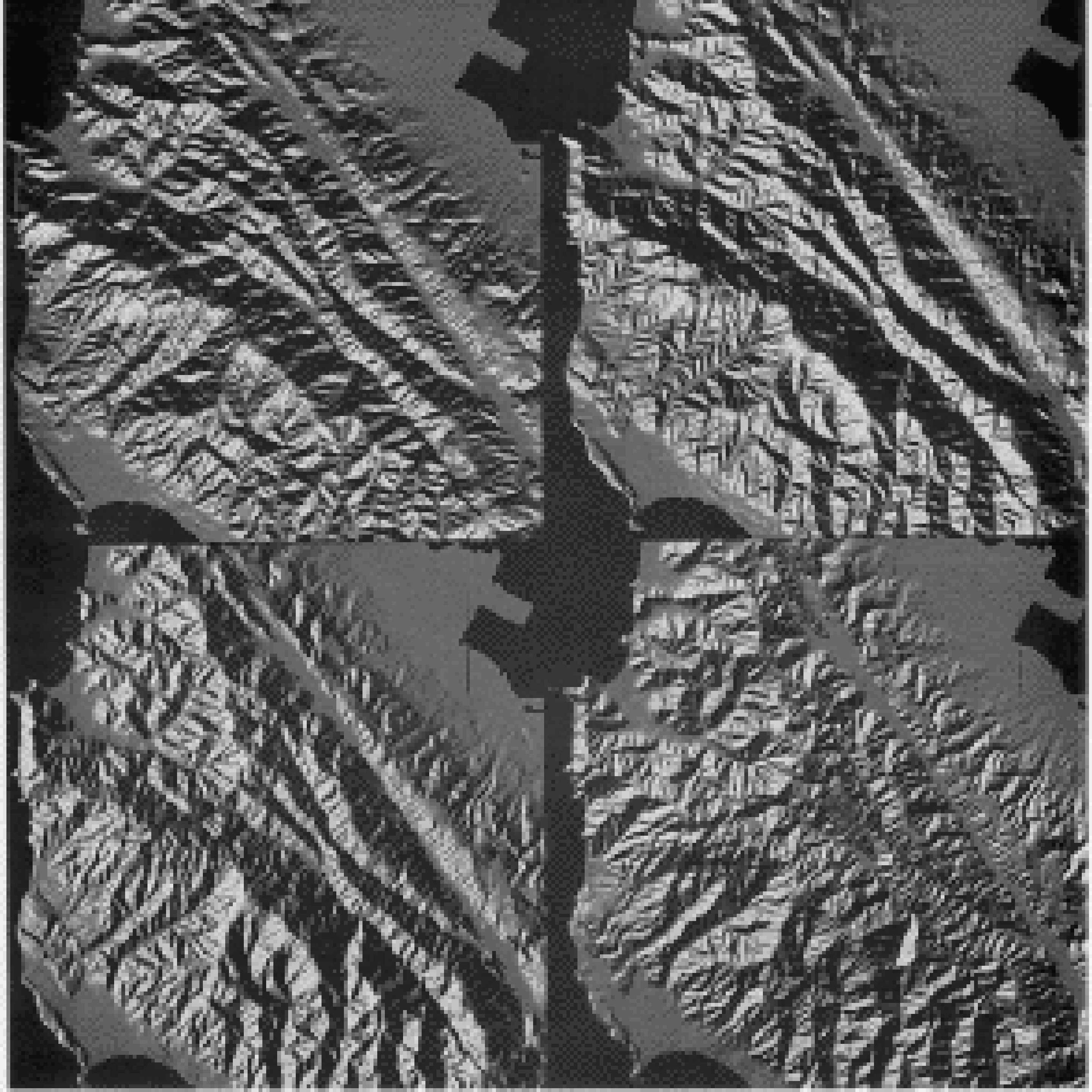
Fig. Black areas are in shadow

Azimuth is same in each image, but the sun angle (altitude) has been modified.

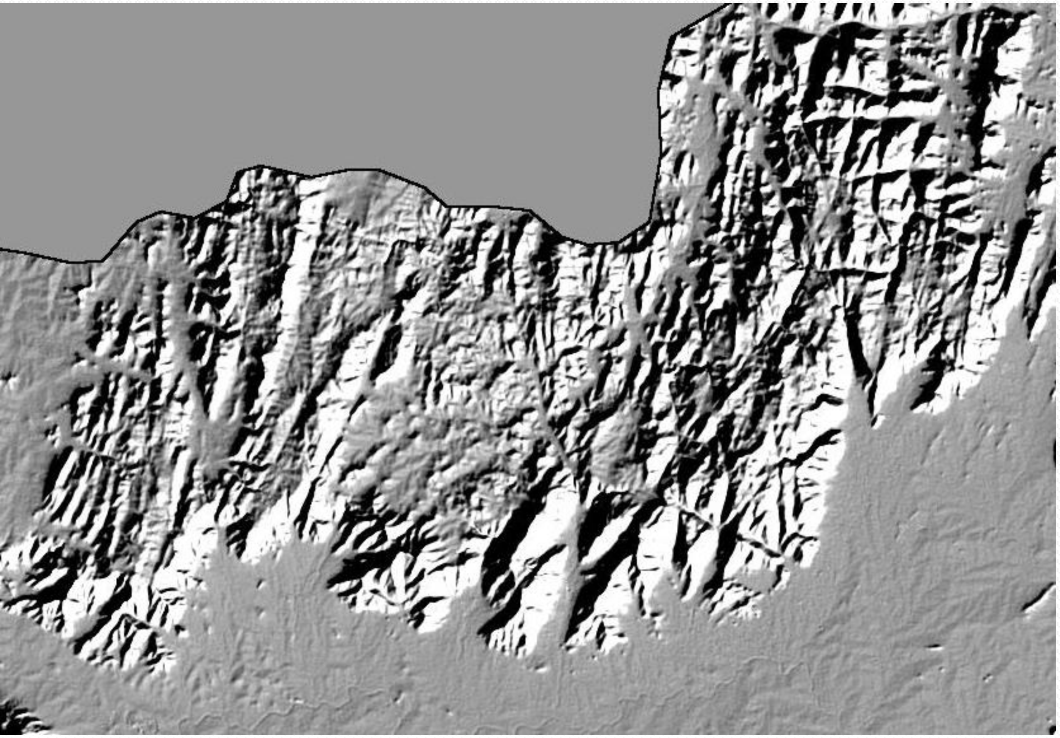


SRMs of San Andreas Fault zone in northern San Mateo County, California. With a Constant Sun Elevation Angle = 30^{o} and Sun Azimuth Angles with an interval of 45^{o} ; = $0^{o;}$ 45^{o} 90^{o} ;135^{o}; 180^{o}; 225^{o}; 270^{o}

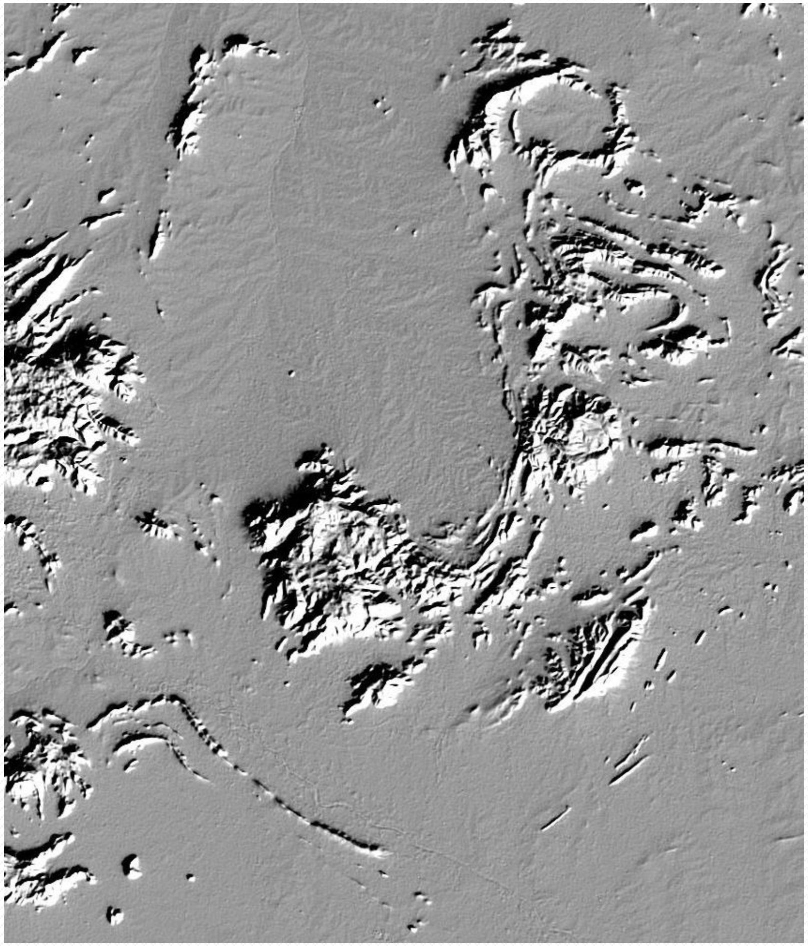


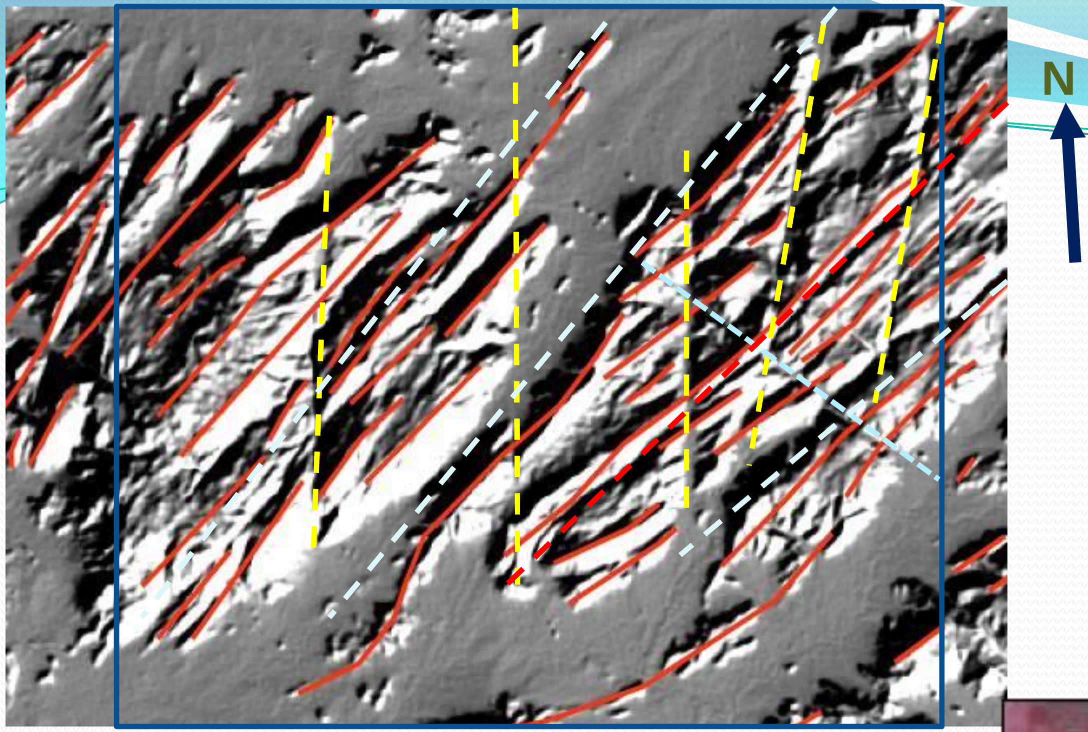


Shaded relief image showing Fractures in parts of Tamil Nadu



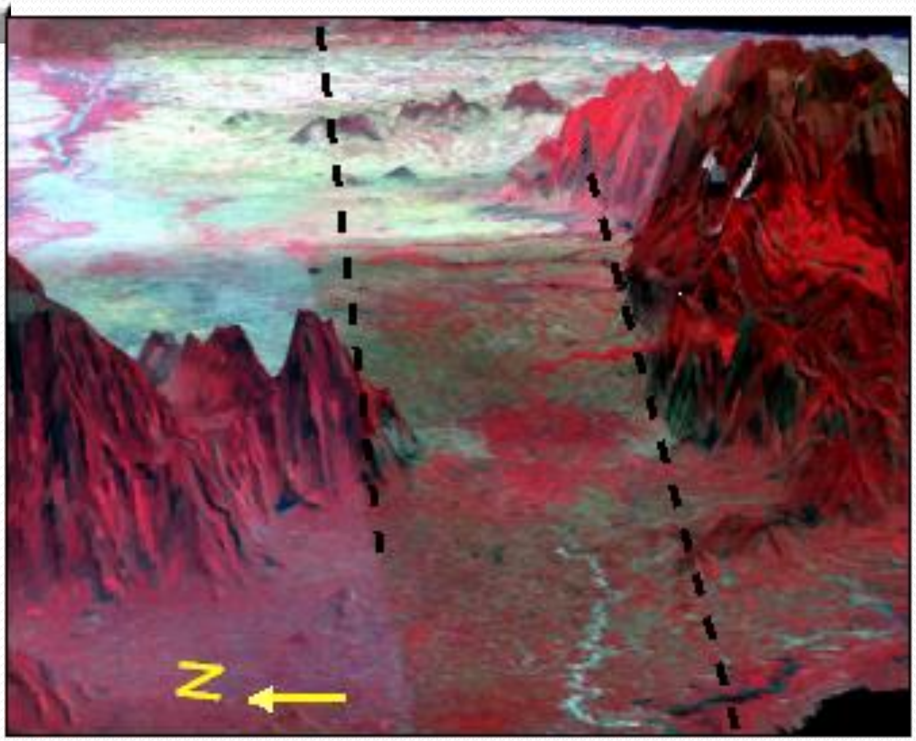
Shaded relief image showing Folds in parts of Tamil Nadu





Mapping of Terrain Parameters

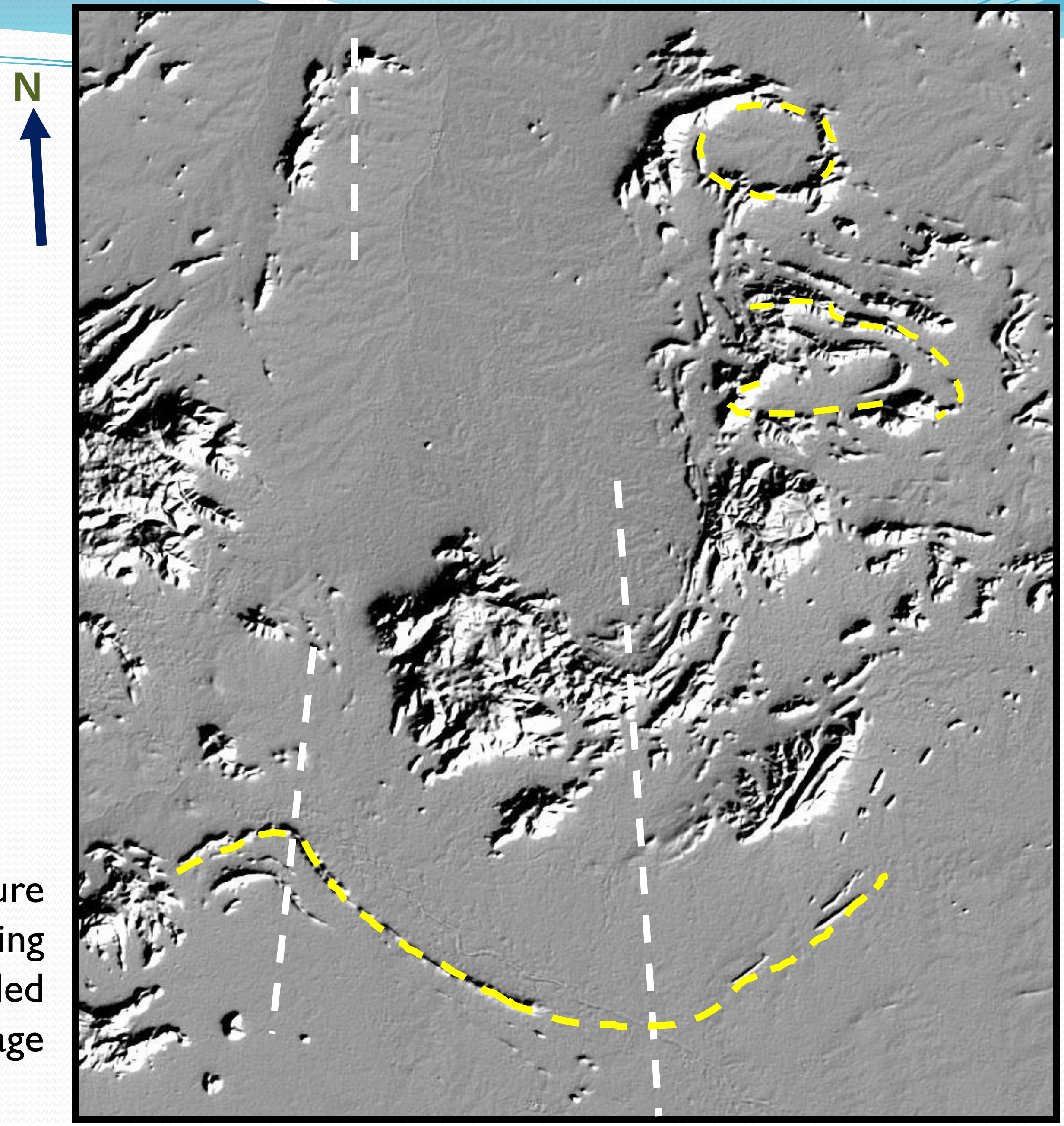
FCC wrapped over SRTM DEM shows the Palaghat Graben



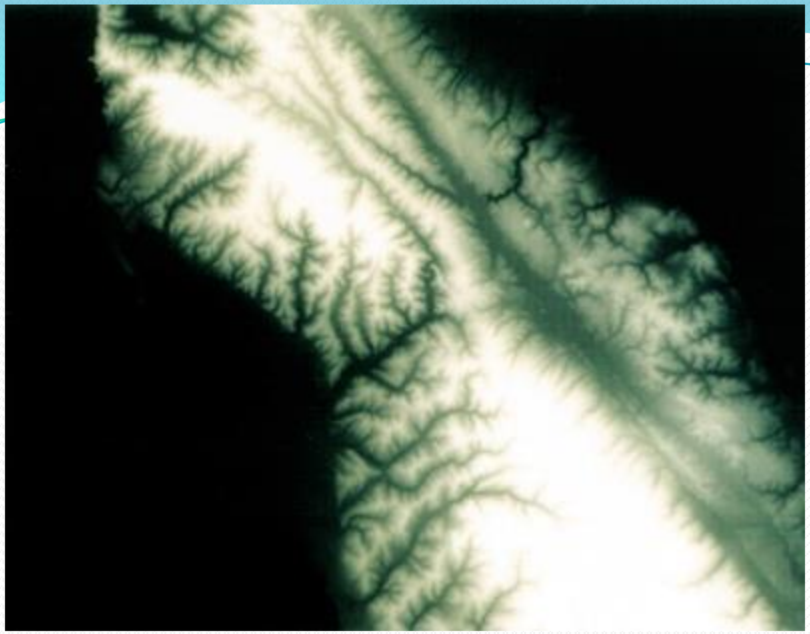
SRTM based shaded relief image shows the faults / fractures in Chitteri and Kalrayan hills

Lineaments / Faults

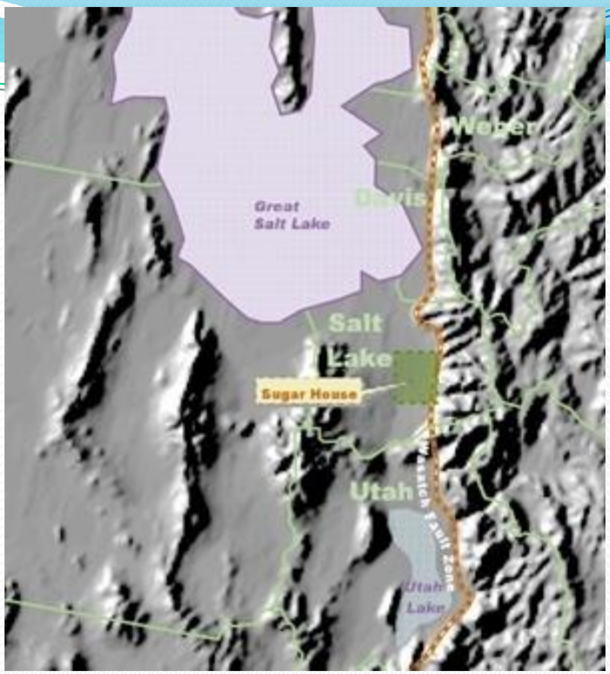
Mapping of Folded structures – Fold Axes, Structural Trends



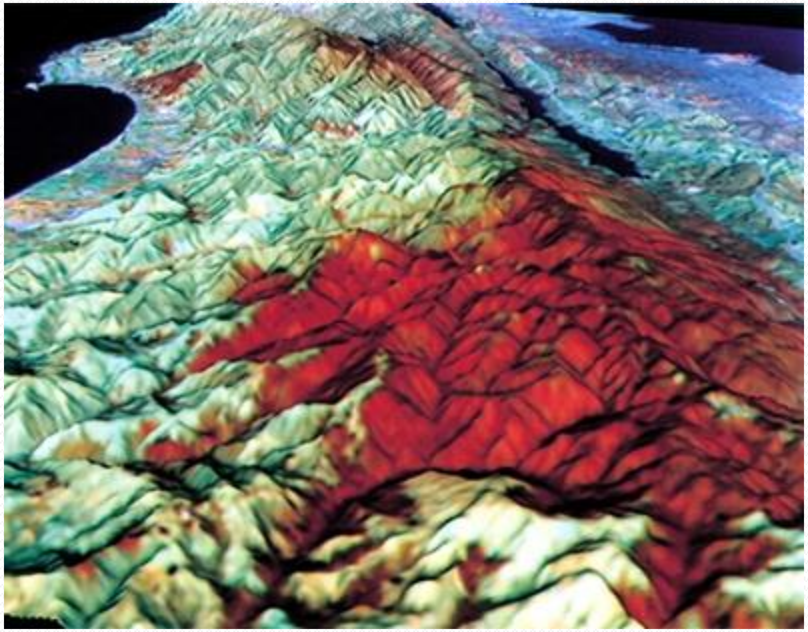
Mapping of Kadavur structure using SRTM based shaded relief image



DEM – 2D display using Black and White colour ramp



SHADED RELIEF MAP



SATELLITE FCC IMAGE WRAPPED OVER DEM

Analysis of Gravity data

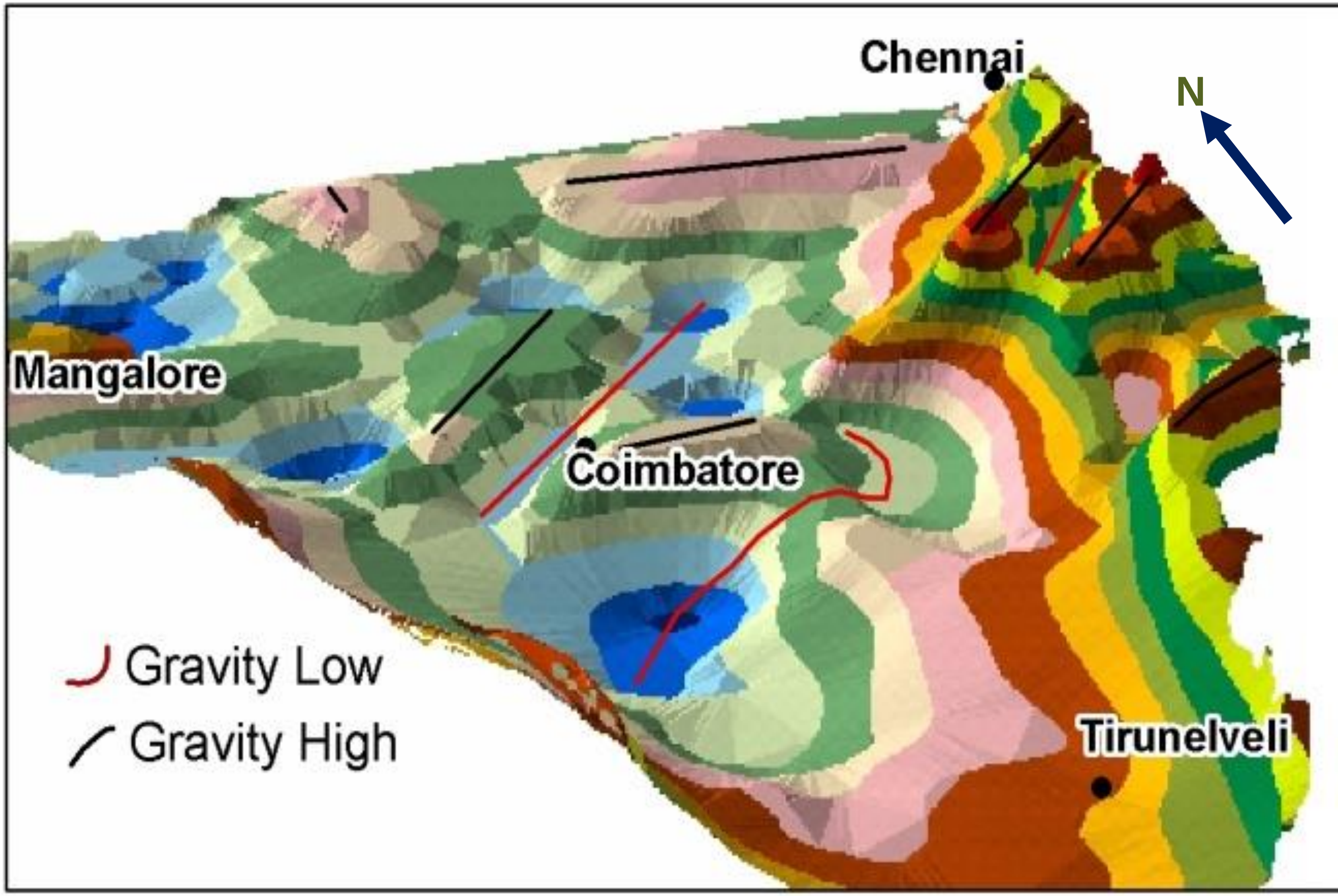


Fig. 5 3D GIS Image of Gravity Variation in South India

Analysis of Resistivity data

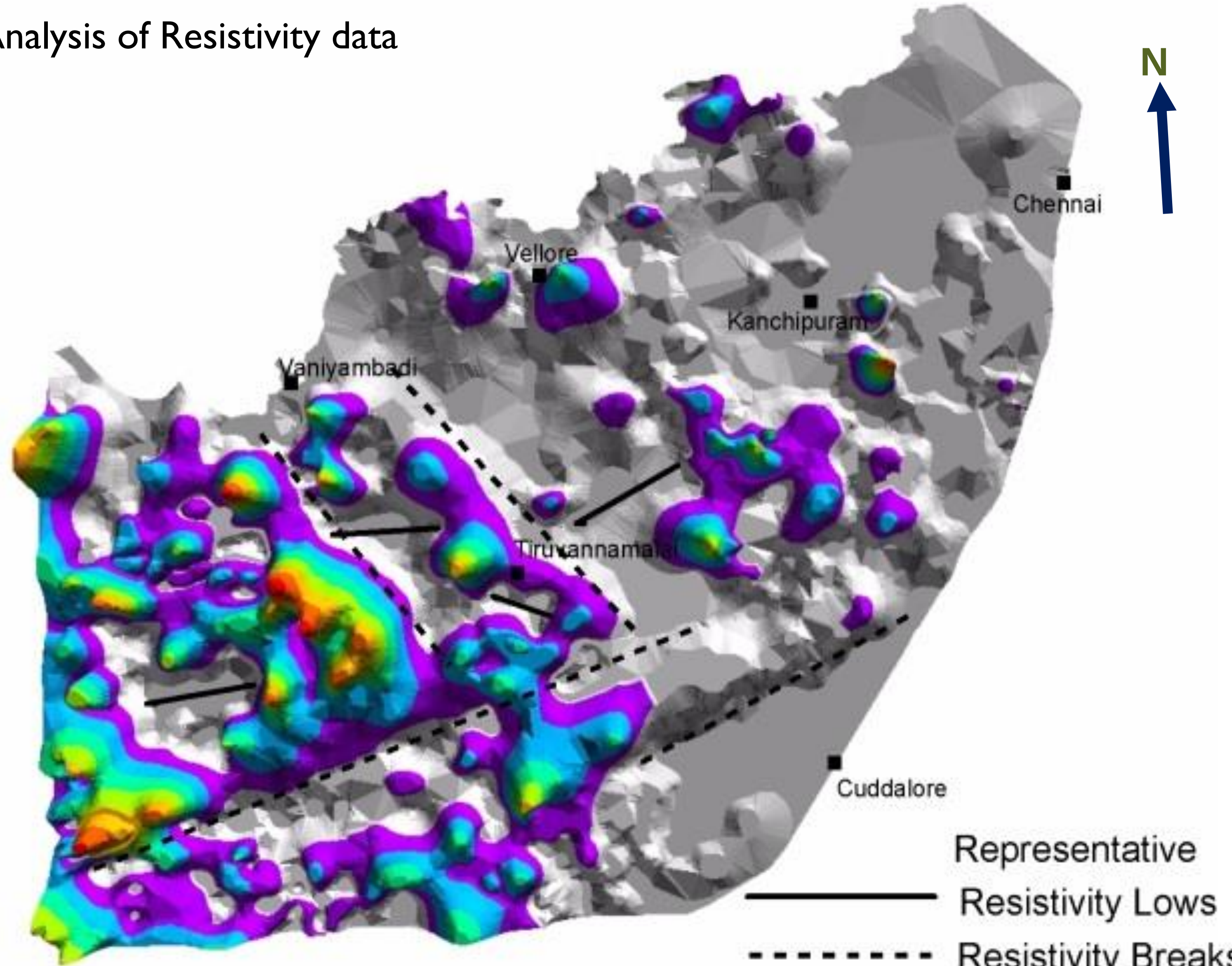


Fig. 6 Visualization of subsurface structures using resistivity data under 3D GIS environment

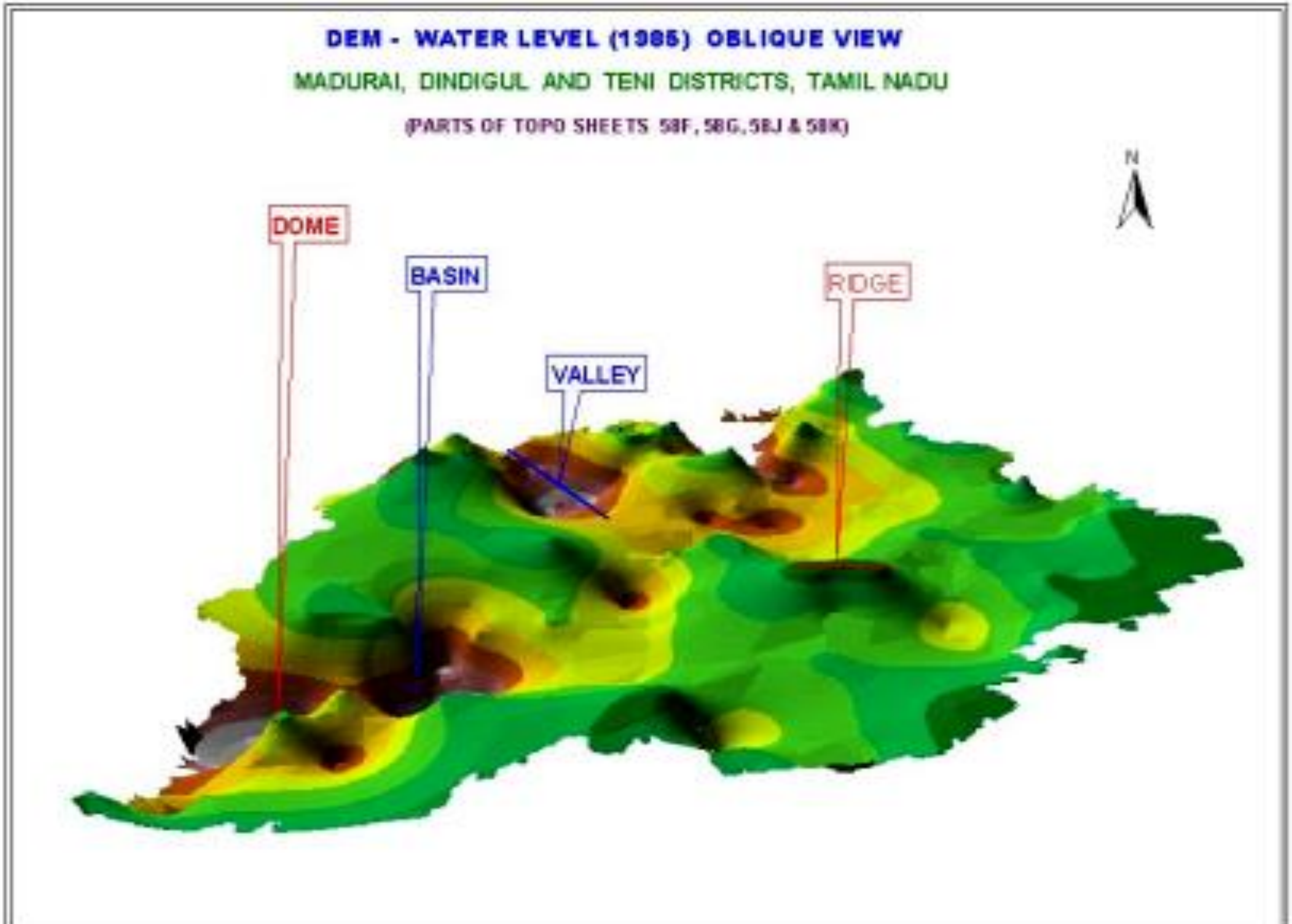
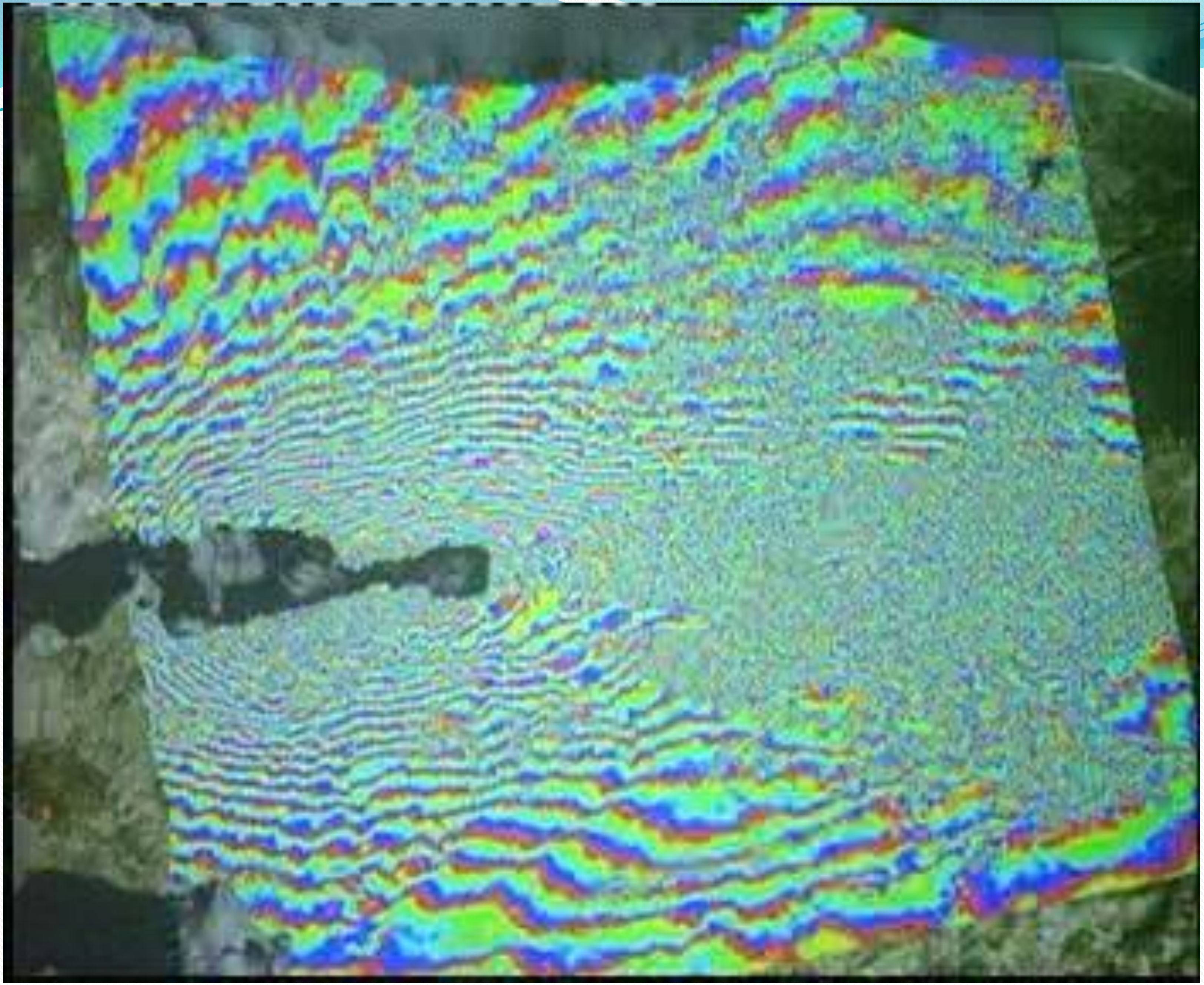


Fig. 7 3D Visualized GIS Image of Groundwater Levels for parts of Western Ghats, Tamil Nadu



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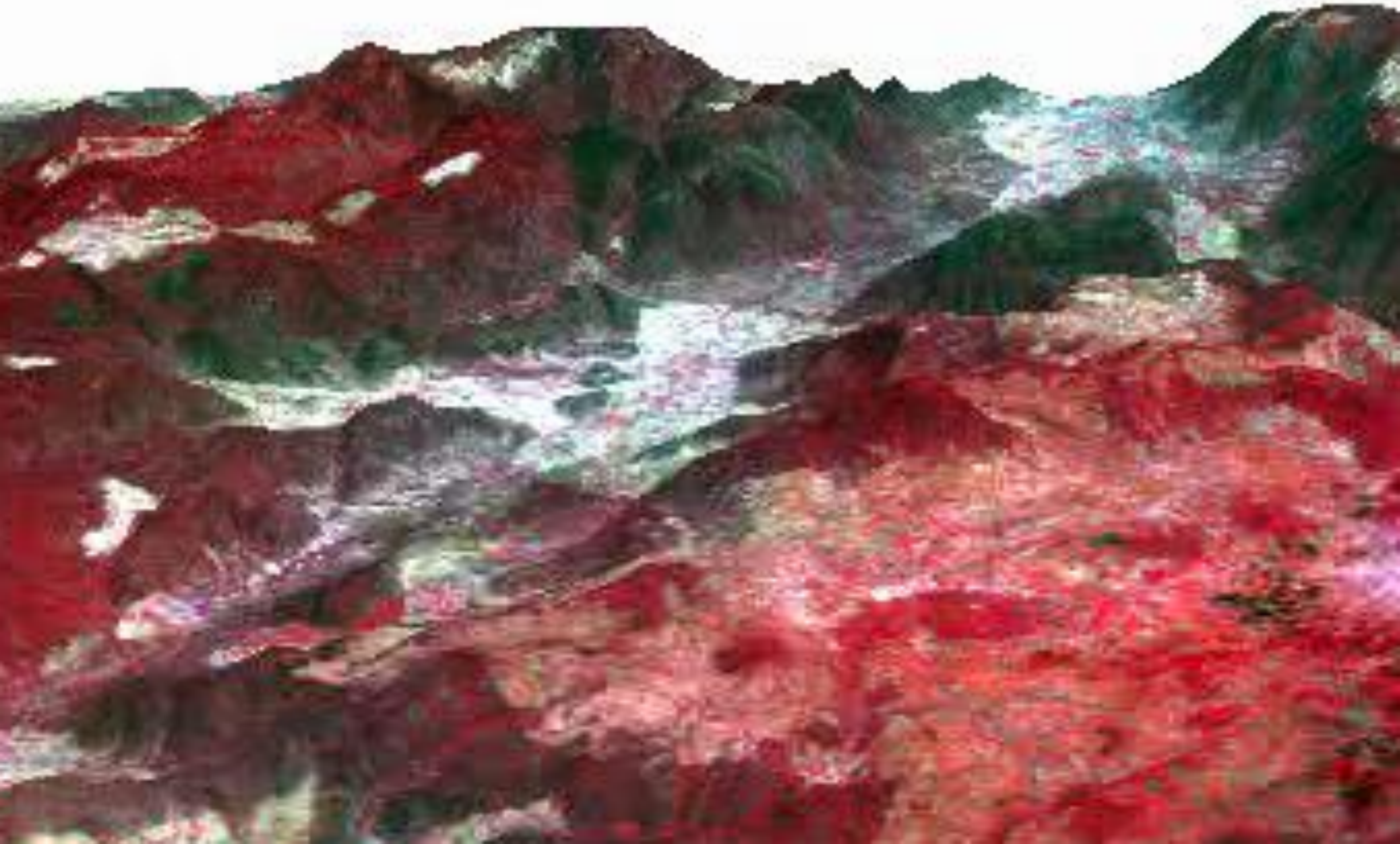

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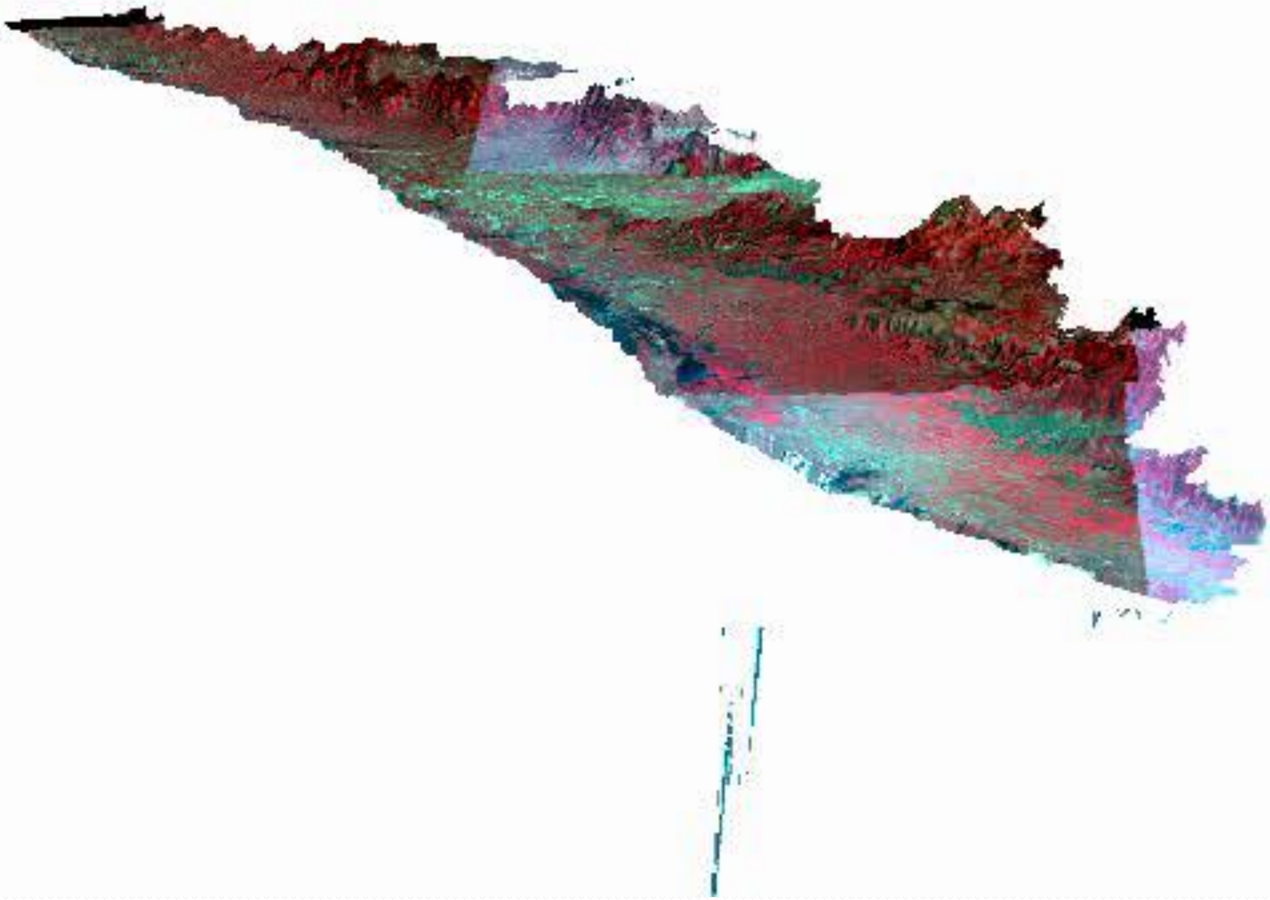

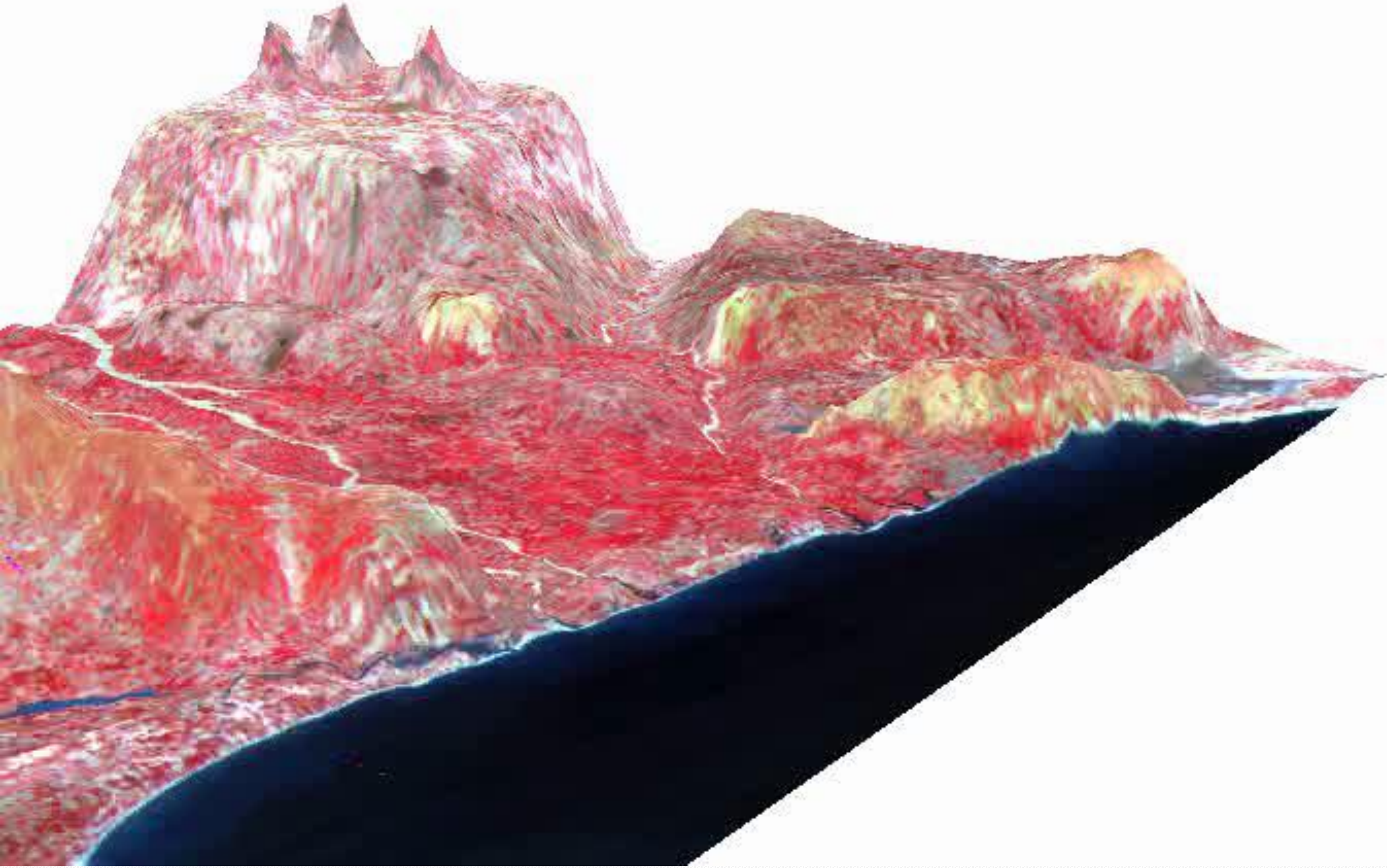

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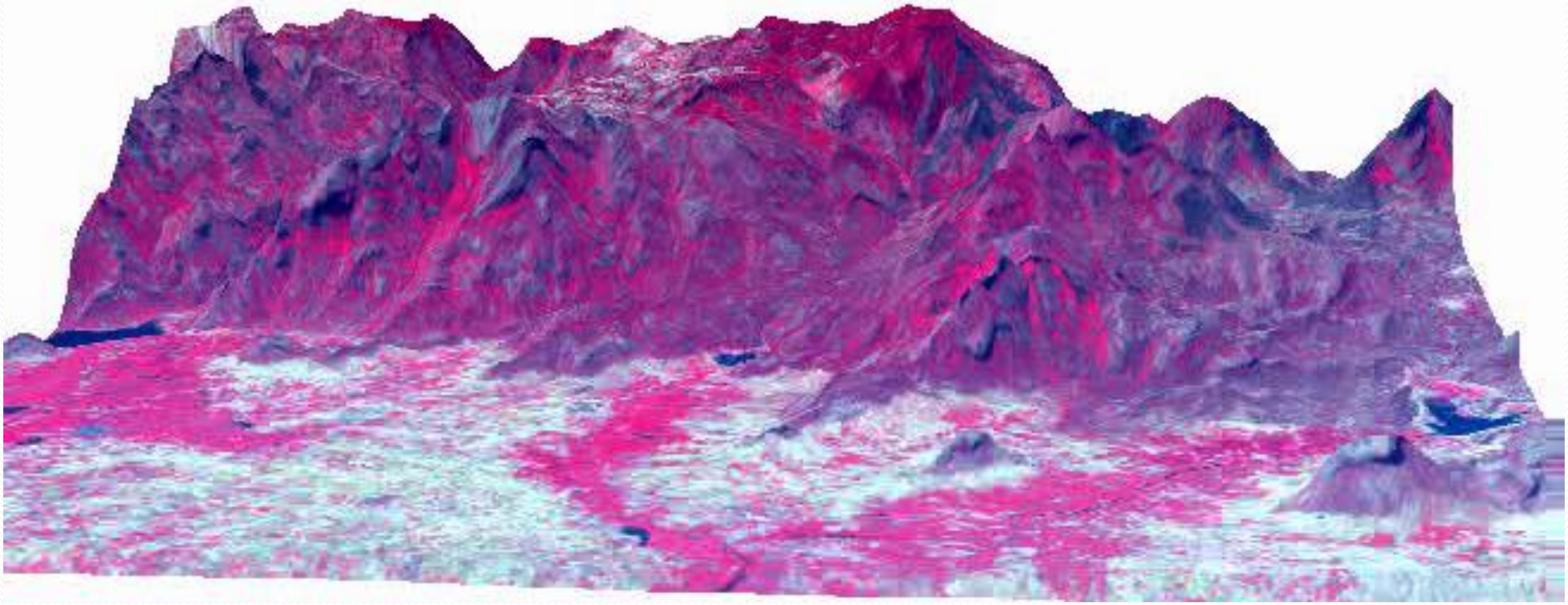
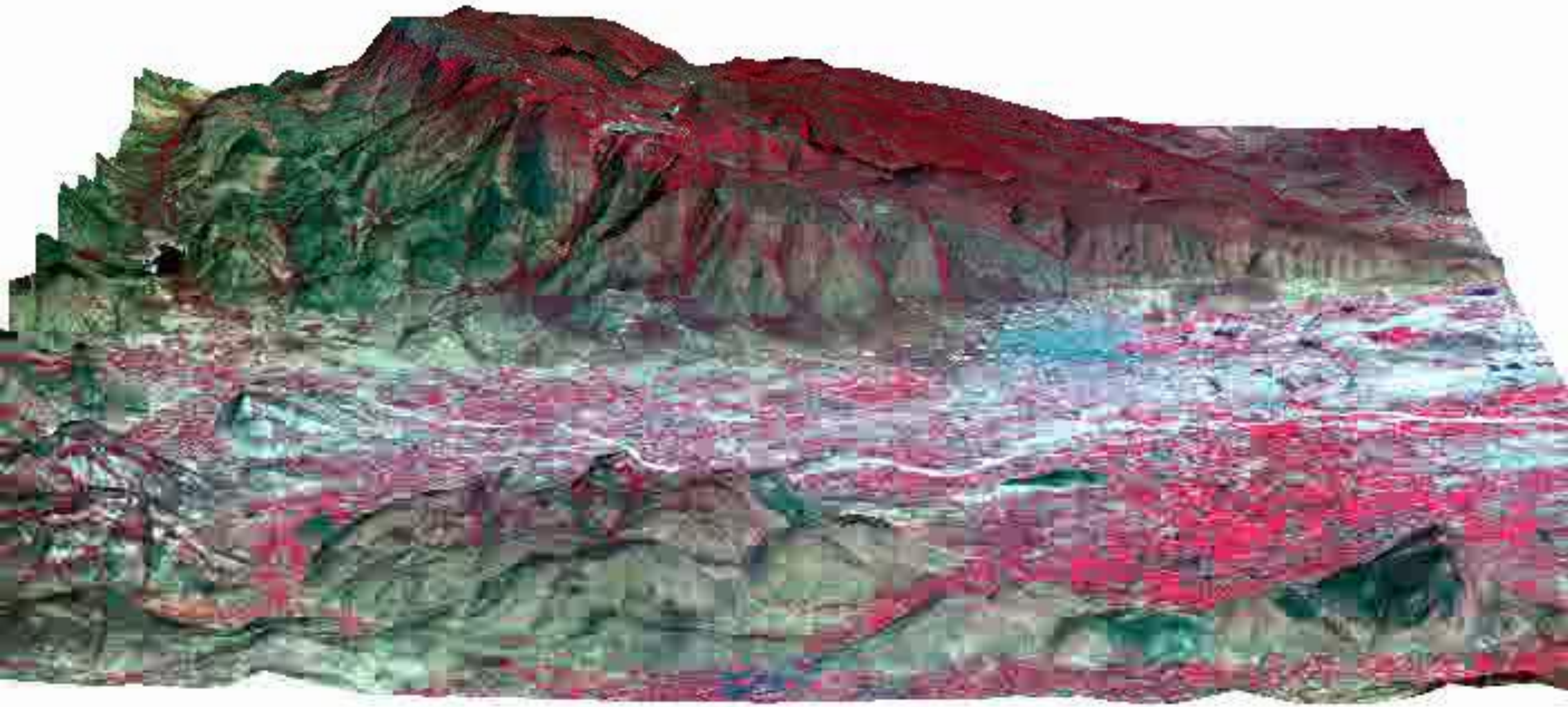


BACK

3D Flythru model of Tirumala Tirupathi region – Cuesta with Epiarchaen Unconformity and Swarnamuki river in front



UNIT – V
GIS Data Analyses & Modelling