Introduction to Geographic Information System

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What does a remote sensing image look like?



- Greyscale
- True Colour Composite
- False Colour Composite

ArcGIS

QGIS 3.4
Madeira

What software can handle geospatial data?

- ENVI
- ErDAS
- ArcGIS
- QGIS
- Google Earth Engine
- Other open source options through Python scripts and libraries

SAGA
System for Automated Geoscientific Analyses

Google Earth Engine

Why Spatial Analysis?

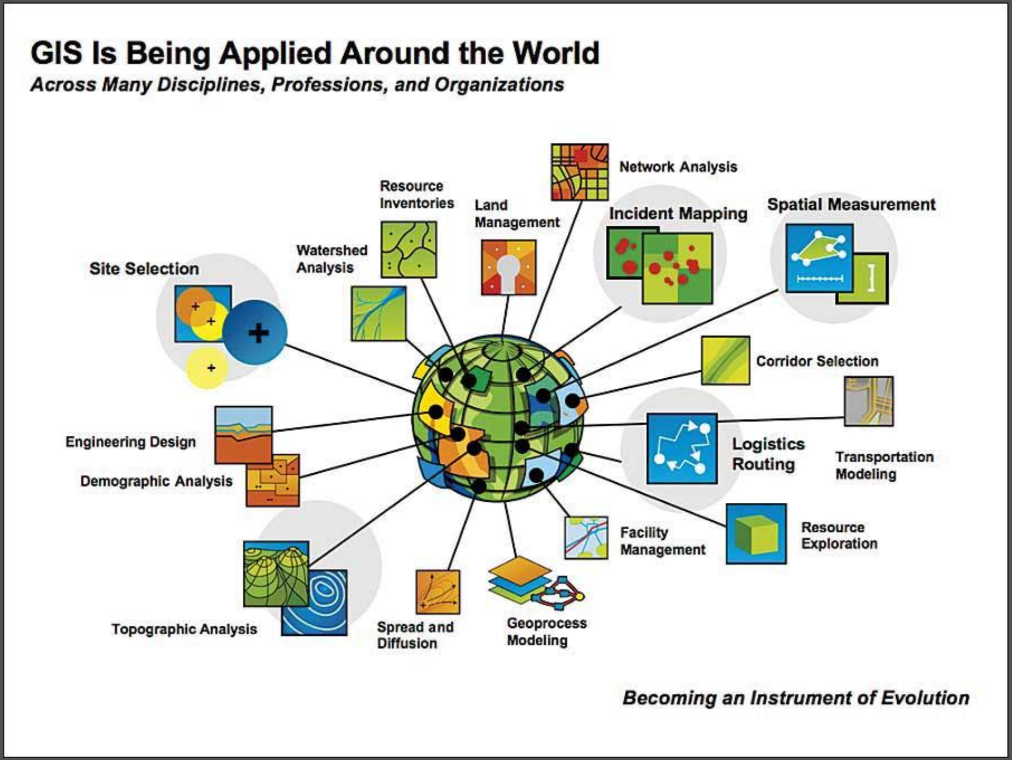
- To study and understand the real world processes by developing and applying manipulation and analysis criteria.
- To reveal new or previously unidentified information
- To visualize over the spatial domain via maps to aide planning and research.

GIS and it's Components: Hardware and Software

"GIS is a system comprising of computer hardware, software, geospatial data, and personnel designed to efficiently capture, store, update, manipulate, analyze and display all forms of geographically referenced information."

Some of the applications of GIS

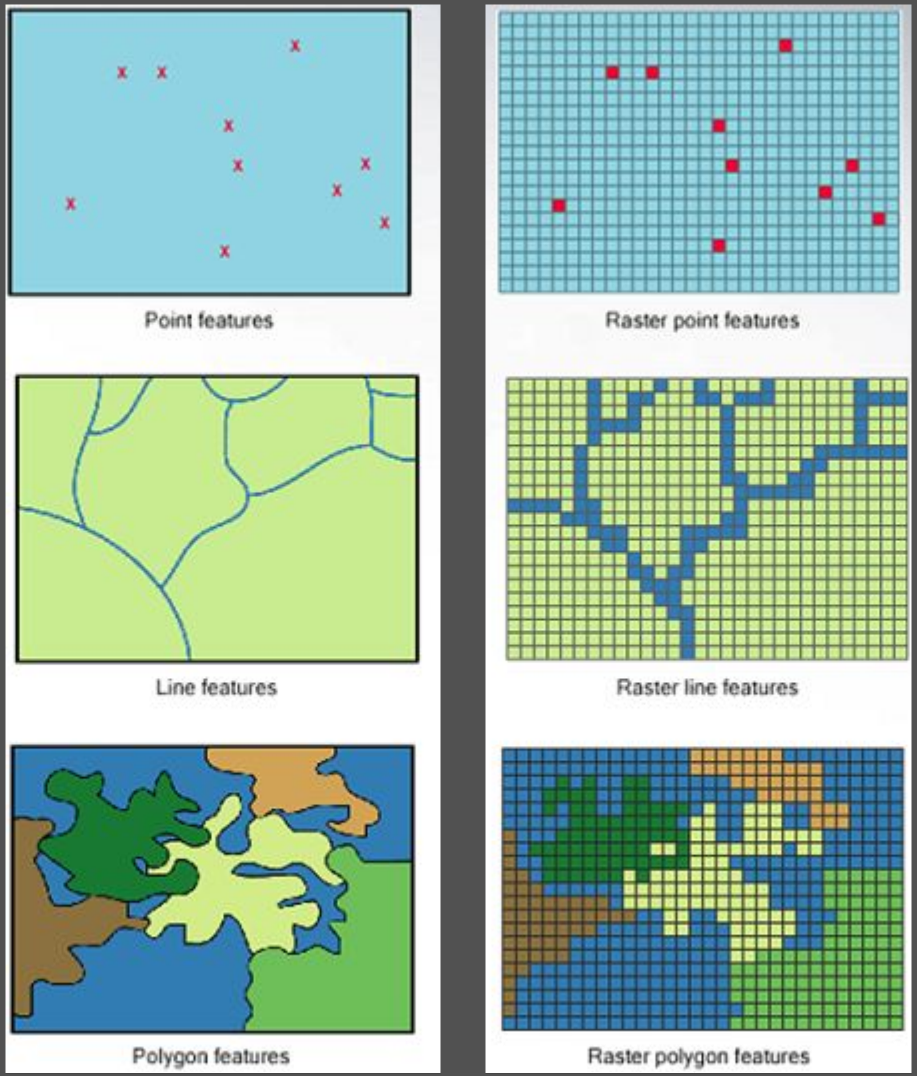
- Routing and traffic management
- Land-cover mapping
- Disaster risk reduction
- Site suitability analysis
- Medical: Checking the spread of diseases
- Site suitability analysis for urban and rural facilities



- Agricultural yield forecasting using agricultural and meteorological information

Vector and Raster Spatial Data model

Vector
In the form of discrete points, lines & polygons.

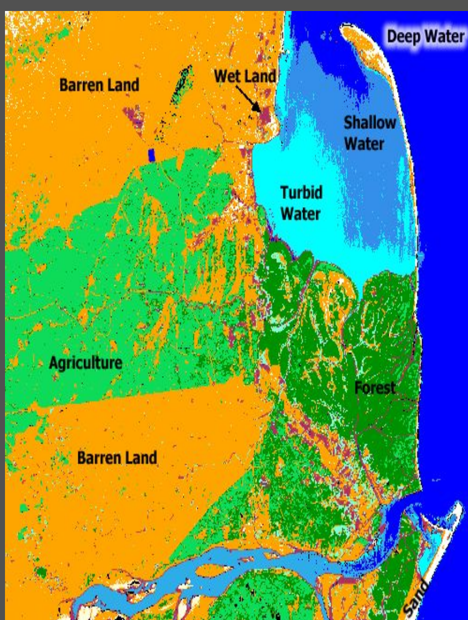


Vector Raster

Raster
Continuous data given by pixels.

Raster data structure

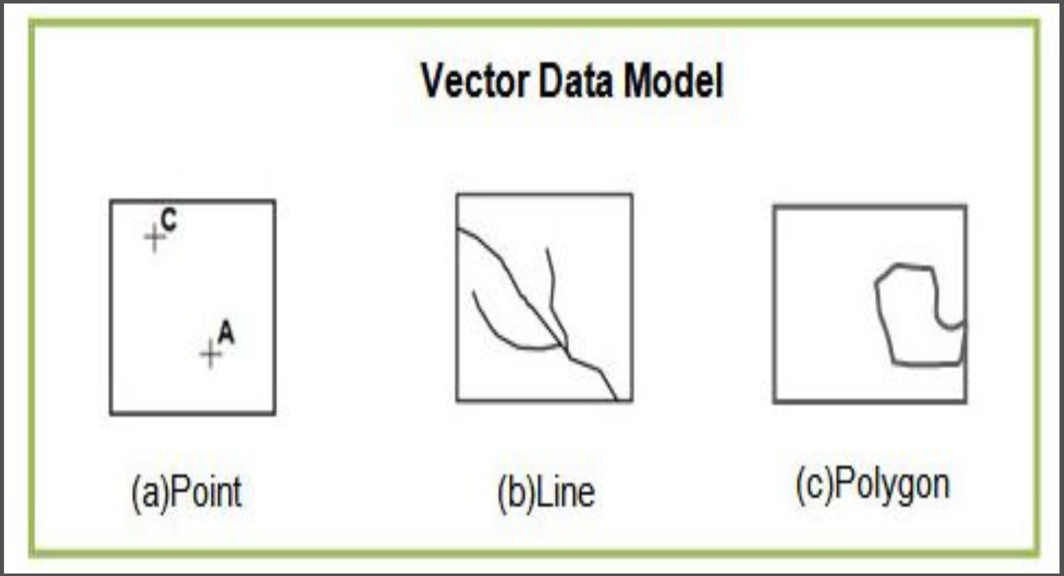
In a raster model of geospatial data, the basic unit is a pixel. The pixel values can be whole numbers or floating point integers. The geographic coordinates are known.



In this thematic layer, the pixel values are whole numbers. One value represents infomation about what class it is.

In this continuous layer, the pixel values denote the radiance or reflectance and will have a value for each band.

Vector data structure



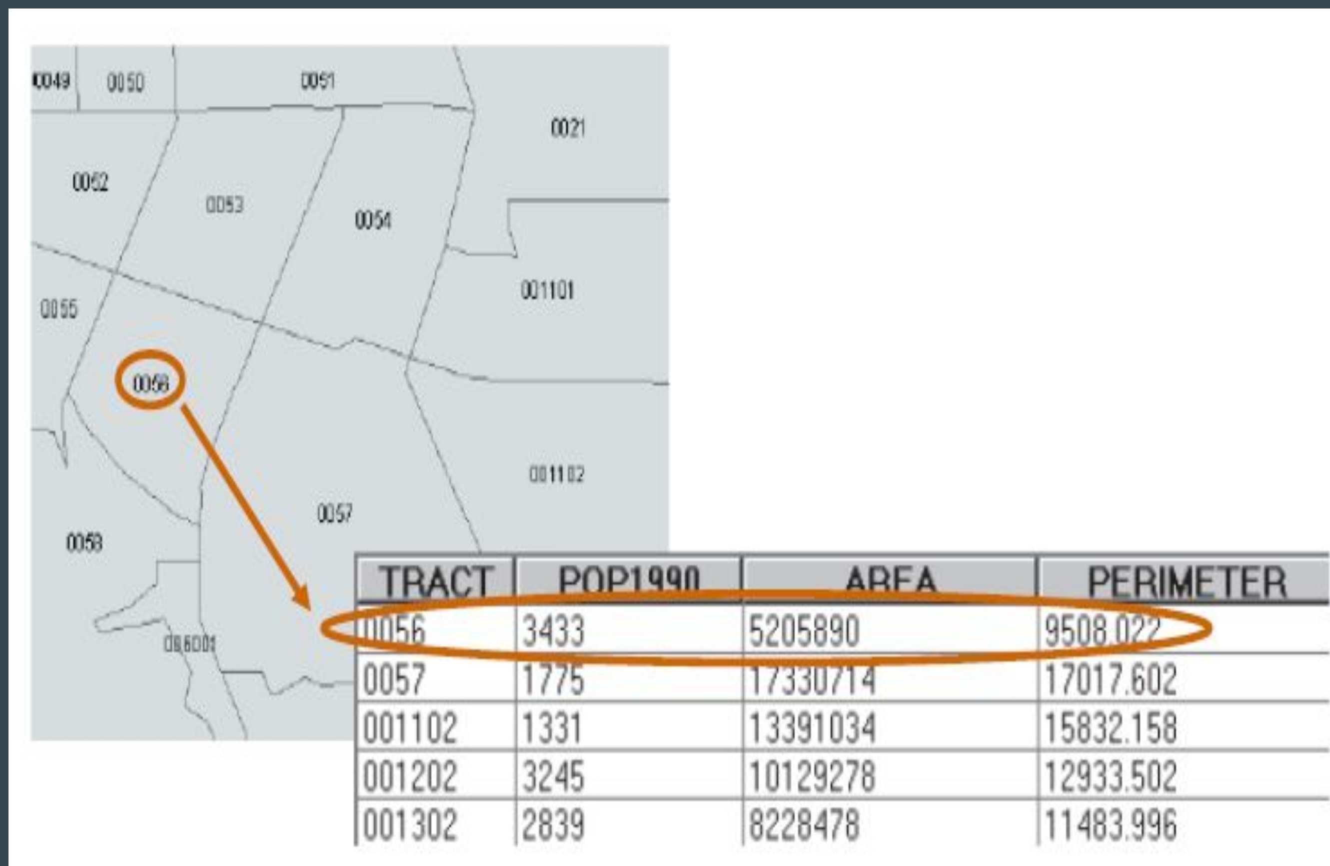
- Points are pairs of x, y coordinates
- Lines are sets of coordinates that define a shape
- Polygons are sets of coordinates defining boundaries that enclose areas

Raster and Vector Data model

Data Model	Advantages	Disadvantages
Raster	Simple data structure	Cell size determines the resolution at which the data is represented
	Compatible with remote sensing or scanned data	Requires a lot of storage space
	Spatial analysis is easier	Projection transformations are time consuming
	Simulation is easy because each unit has the same size and shape	Network linkages are difficult to establish
Vector	Data is represented at its original resolution and form without generalization	The location of each vertex is to be stored explicitly
	Require less storage space	Overlay based on criteria is difficult
	Editing is faster and convenient	Spatial analysis is cumbersome
	Network analysis is fast	Simulation is difficult because each unit has a different topological form
	Projection transformations are easier	

Vector data structure

- In vector data layers, the feature layer is linked to an attribute table.
- Every individual feature corresponds to one record (row) in the attribute table.



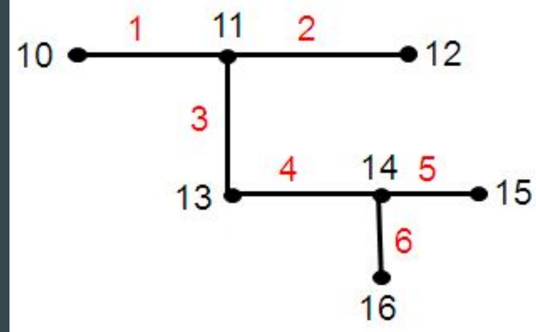
TRACT	POP1990	AREA	PERIMETER
0056	3433	5205890	9508.022
0057	1775	17330714	17017.602
001102	1331	13391034	15832.158
001202	3245	10129278	12933.502
001302	2839	8228478	11483.996

Type of Topology

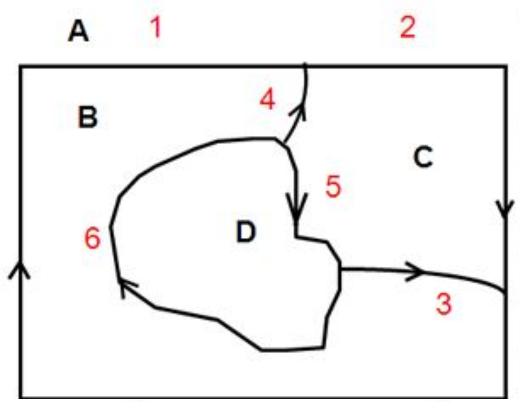
A topology is a mathematical procedure that describes how features are spatially related and ensures data quality of the spatial relationships.

Types of Topology

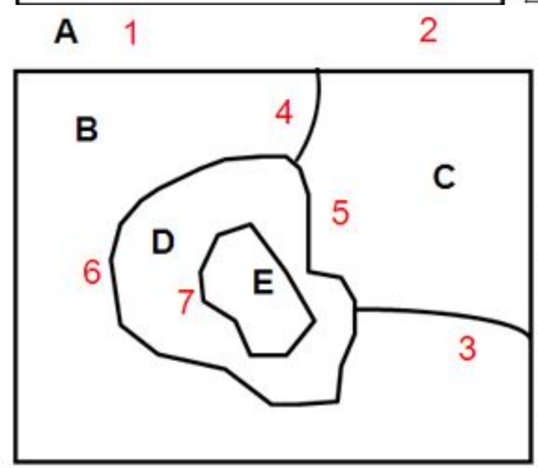
- Connectivity
- Adjacency
- Containment



Arc-Node List		
Arc	*From node*	*To node*
1	10	11
2	11	12
3	11	13
4	13	14
5	14	15
6	14	16



Left-Right Topology		
Arc	Left Polygon	Right Polygon
1	A	B
2	A	C
3	C	B
4	B	C
5	C	D
6	B	D



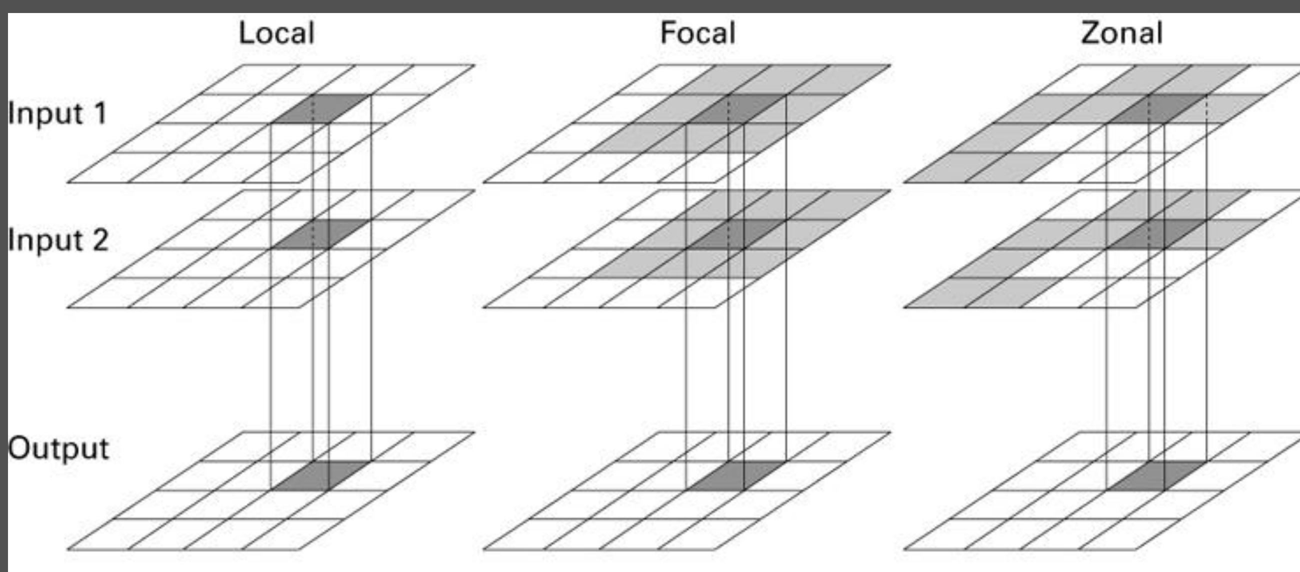
Polygon arc topology	
Polygon	Arc List
B	1, 4, 6, 3
C	2, 3, 5, 4
D	5, 6, 0, 7
E	7

GIS Operations

Raster Operations

Raster operations can be of four types depending upon the operand.

1. Local Operations or point operations
2. Focal Operations or neighbourhood operations
3. Zonal Operations or area operations
4. Global Operations or map operations



Raster Local Operations

- Independent of any other pixel.
- Element wise operations occur.
- New map is generated on a pixel by pixel basis.
- Eg: Arithmetic, relational and logical operations of raster.

2	0	1	1
2	3	0	4
4		2	3
1	1		2

X 3 =

6	0	3	3
6	9	0	12
12		6	9
3	3		6

Here, each element is multiplied by the scalar 3.

2	0	1	1
2	3	0	4
4		2	3
1	1		2

X

1	1	2	2
1	2	2	2
2	2	3	3
2	3	3	4

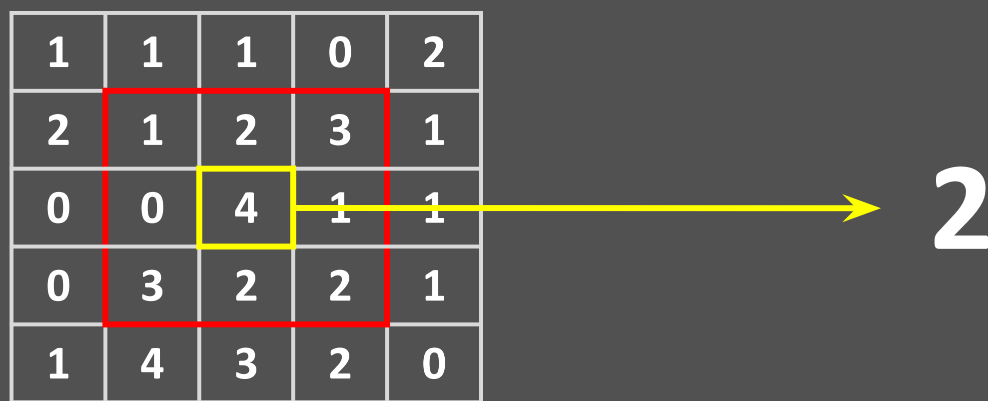
=

2	0	2	2
2	6	0	8
8		6	9
2	3		8

Here, each element of Raster 1 is multiplied by the corresponding element in Raster 2.

Raster Focal Operations

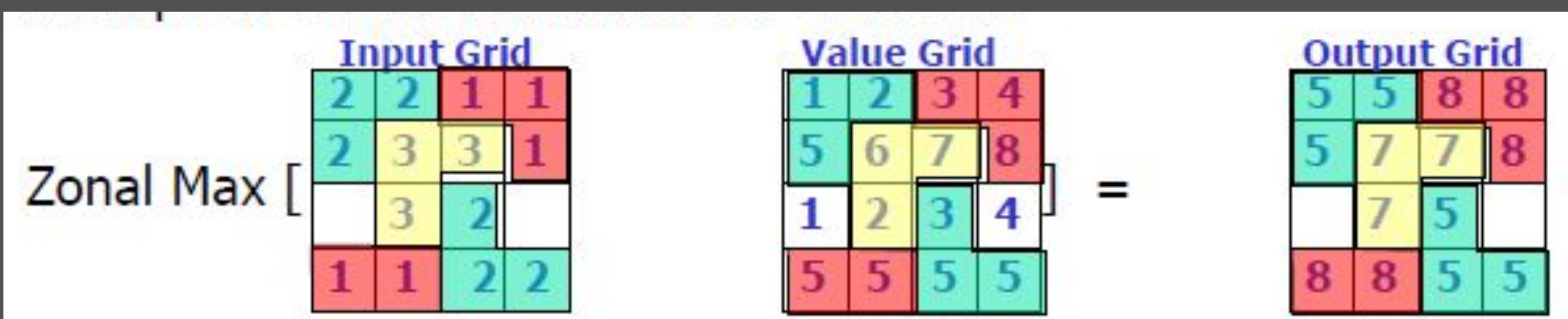
- The result is dependent on neighbouring pixels.
- For eg: mean operation where a kernel is applied on a raster.



Consider the above case where a raster is applied with a mean operation using a 3X3 kernel (red). The central value is substituted with the mean of neighbouring 9 pixels given by (1+2+3+1+4+2+2+3+0)/9=18/9=2. This is iterated for all the pixels in the raster.

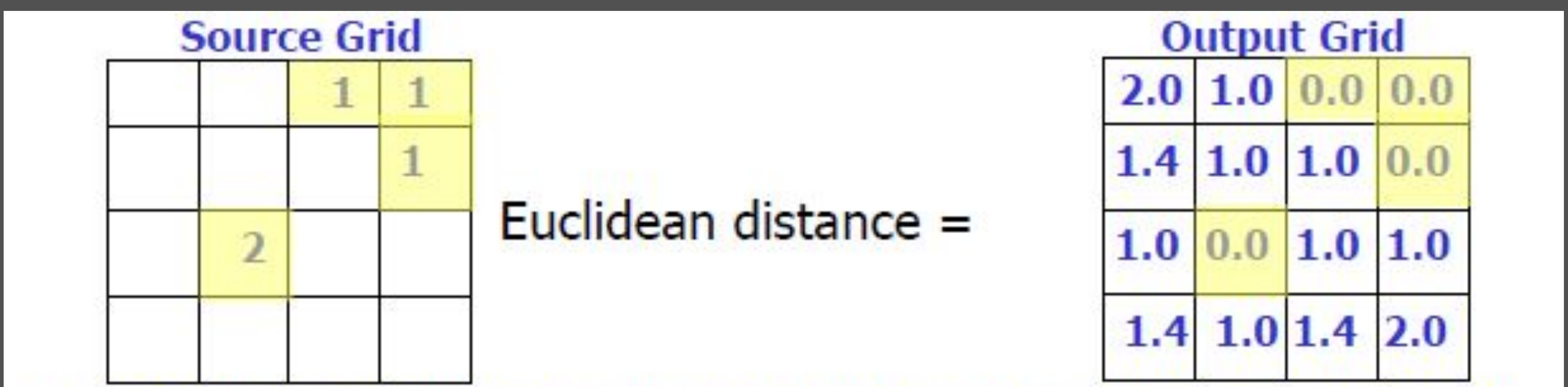
Zonal Functions

- We have two inputs for suchfunctions, the zone and the raster. Statistics of any operation performed on the raster is applied to all pixels falling within the zone.
- Consider the following example. The input grid is the zone. There are 3 zones: 1,2 and 3.
- We perform a zonal maximum which checks for the maximum pixel value in each zone and replaces the value of each pixel with that maximum value.
- This is useful in



Global Functions

- Output value of each cell is a function of the entire grid. For example, the total population is give by the population map total.
- Another standard example is the Euclidean distance
- Distance between non-adjacent cells can be computed according to their row and column addresses.
- For any other cell, the output value is the distance from its nearest source cell. Below, the source cells are given in yellow.



A Euclidean distance function computes the distance from the nearest source cell

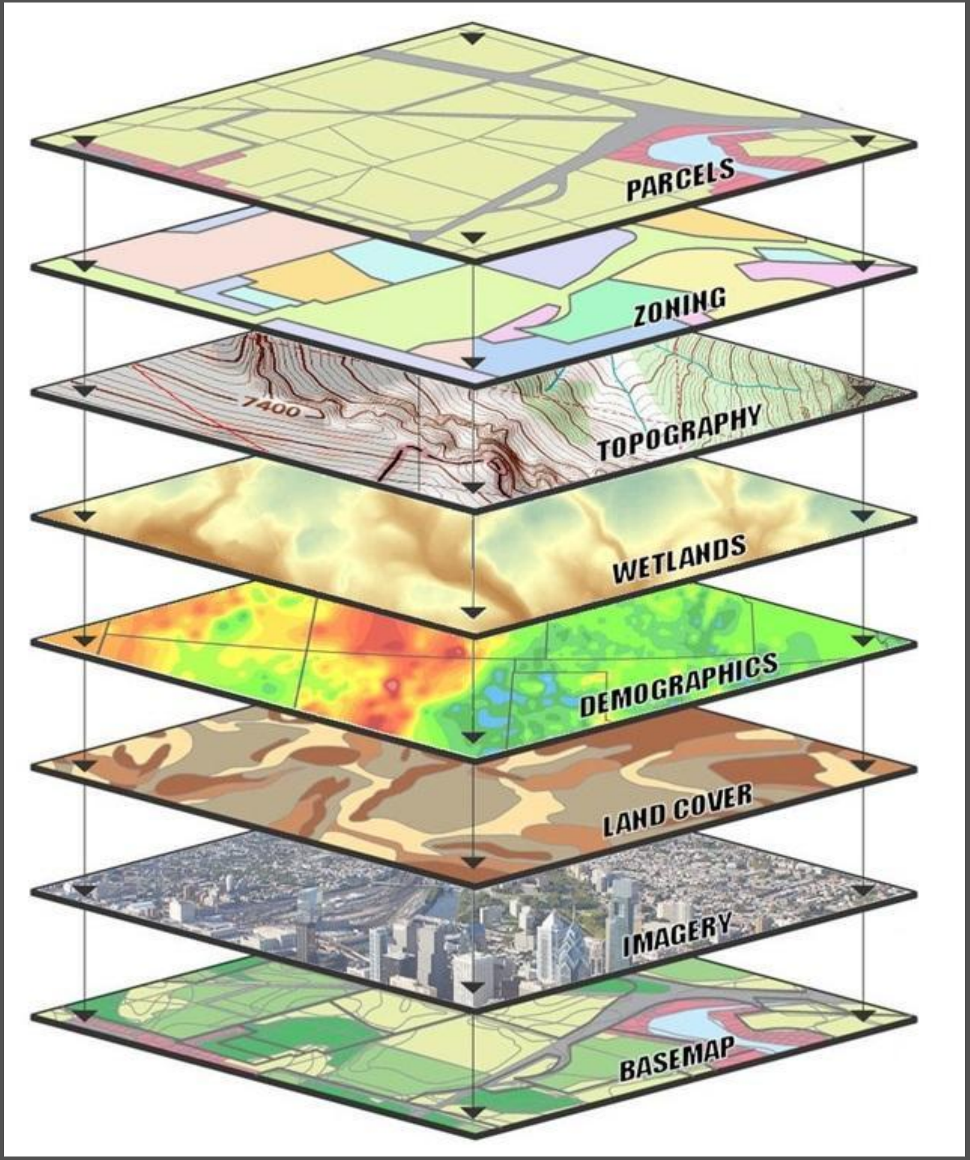
GIS Overlay Analysis

Raster Overlays

Raster overlay analysis allows us to perform an integrated analysis of multiple datasets and is particularly useful for site suitability studies, habitat analysis etc.

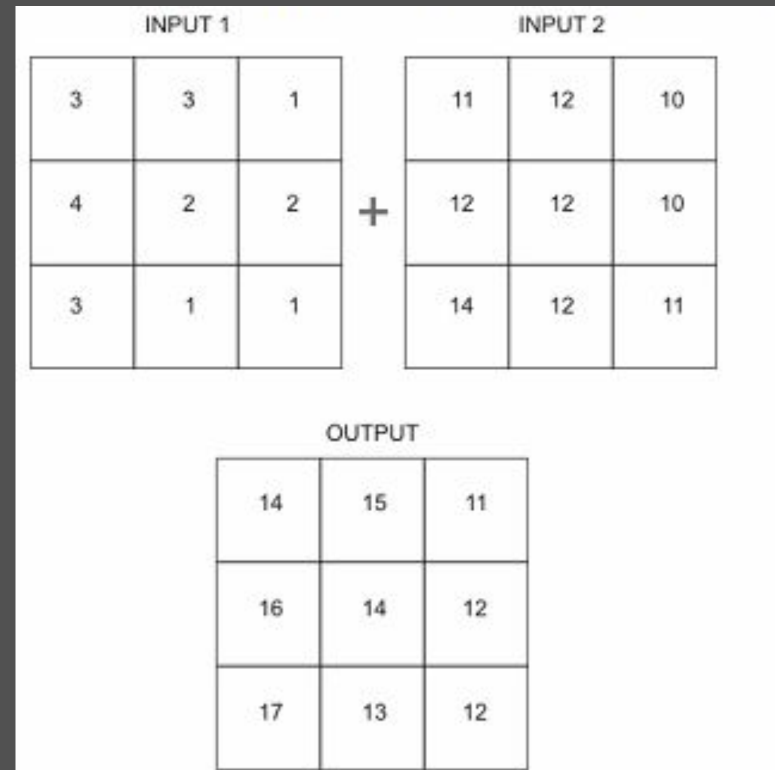
Types of raster overlays:

- Arithmetic
- Conditional
- Logical



Arithmetic Overlay

- Addition, subtraction, multiplication, division, modulo
- sin, cos, tan, asin, acos, atan.
- Eg Raster2 := Raster1 * 5
- Similar to elementwise matrix operations

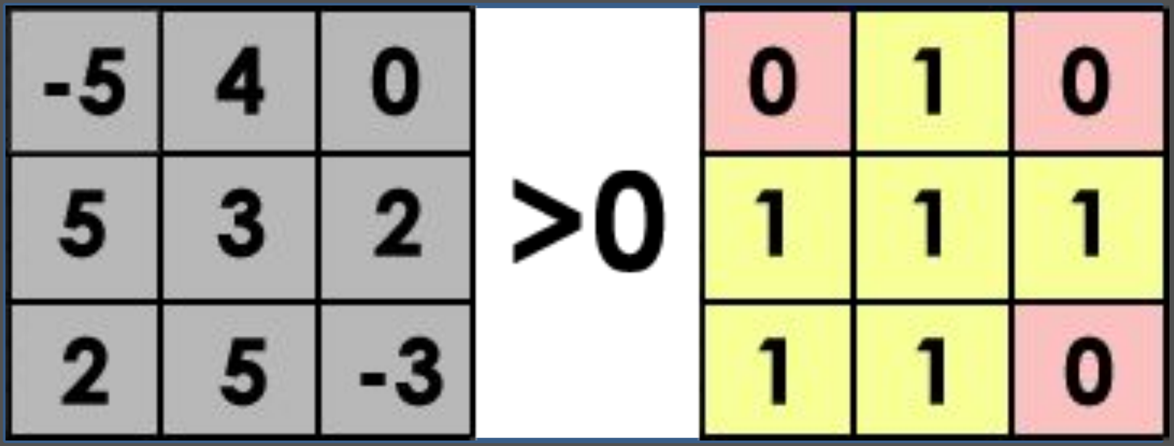


$$\mathbf{a} = \begin{pmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{pmatrix} \qquad \mathbf{5a} = \begin{pmatrix} 5 & 10 & 15 \\ 20 & 25 & 30 \\ 35 & 40 & 45 \end{pmatrix}$$

Relational Overlay

- These check for the condition.
- Equal to ==
- Greater than >
- Less than <
- Greater than or equal to >=
- Less than or equal to <=
- Not equal to !

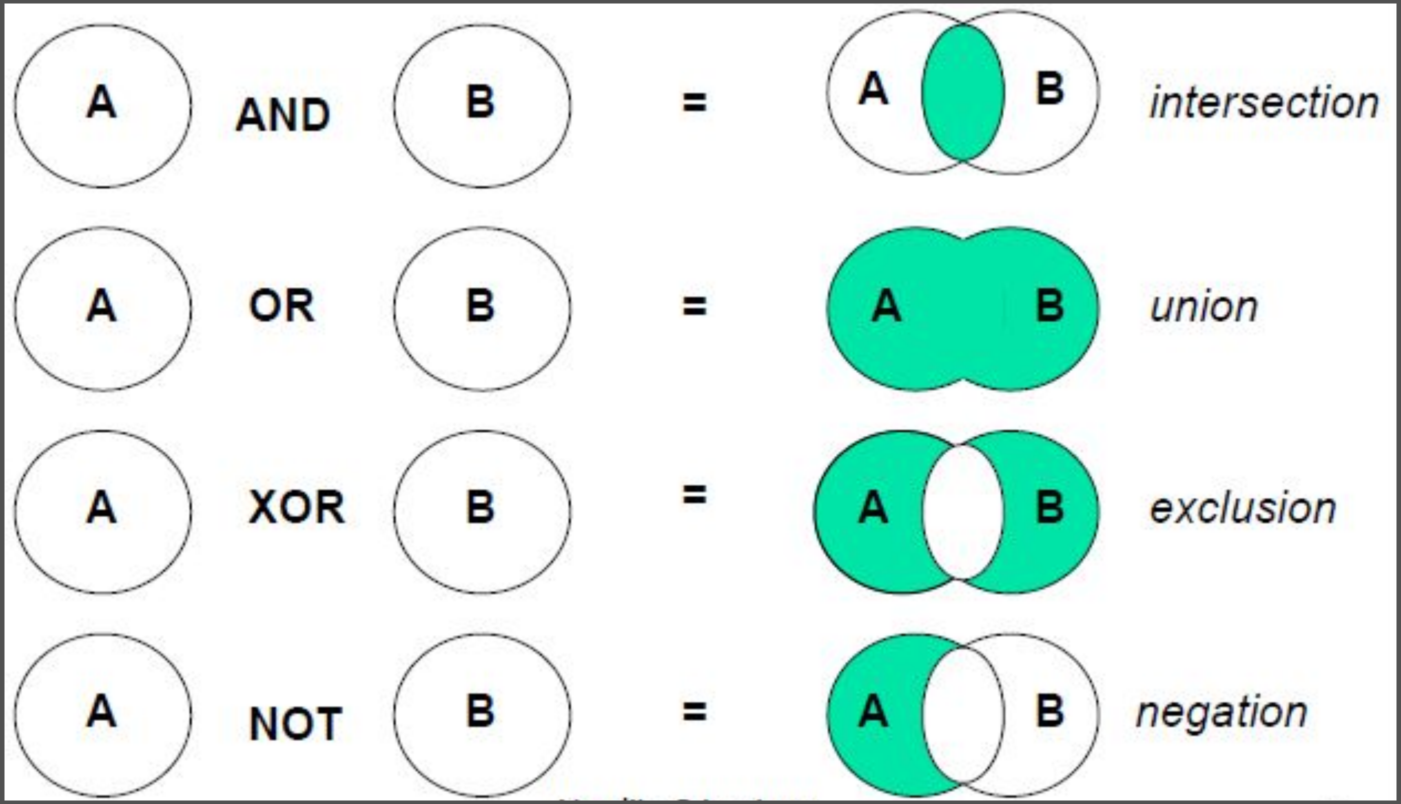
This provides Boolean Output of 1 for true and 0 for false.



Logical Overlays

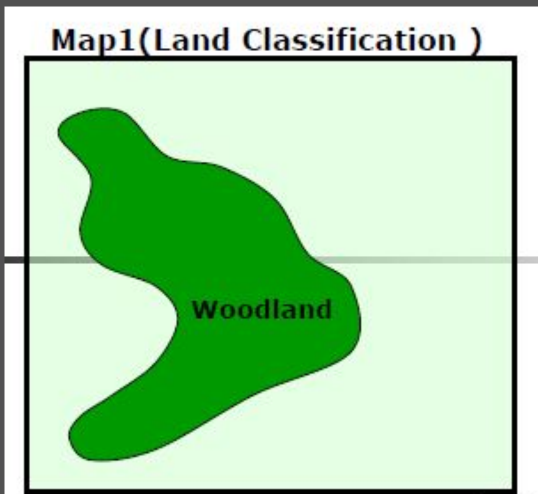
Logical conditions are specified with

- Operands(Data Elements)
- Operators (Relationships among data elements
- The cell values of output is either true or false

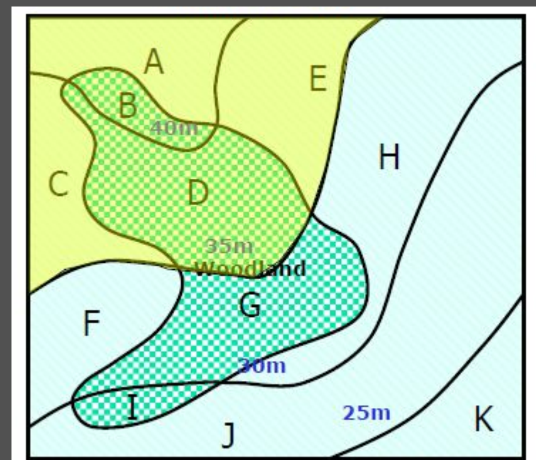


Types of Logical Operators

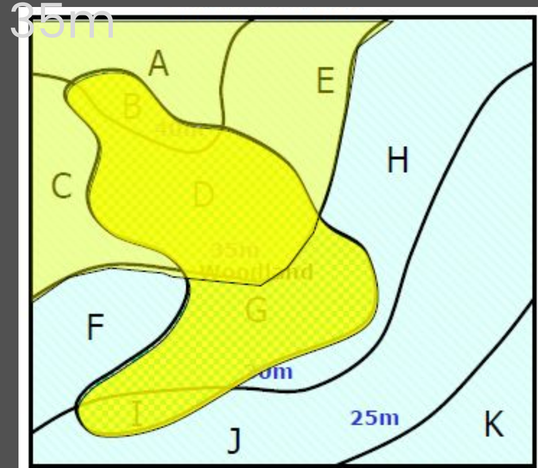
Examples of Logical Operation

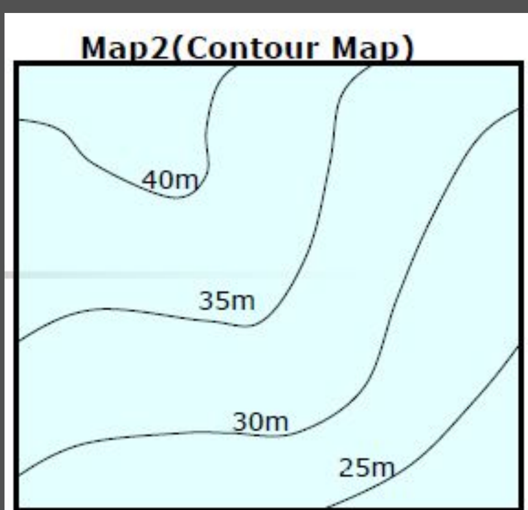


Land over 35 meters

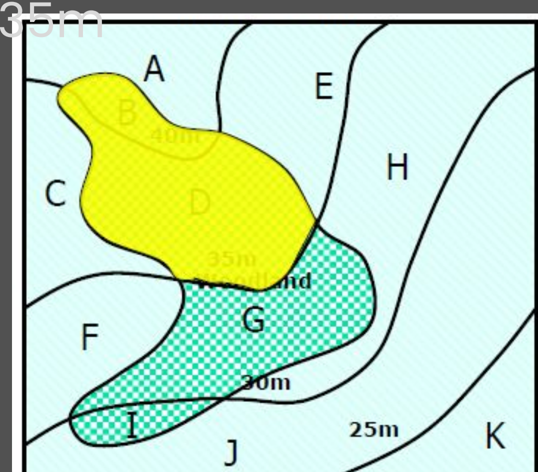


Woodland OR Over 35m

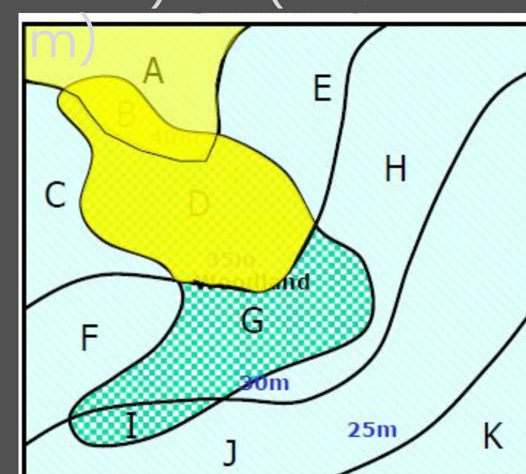




Woodland AND over 35m

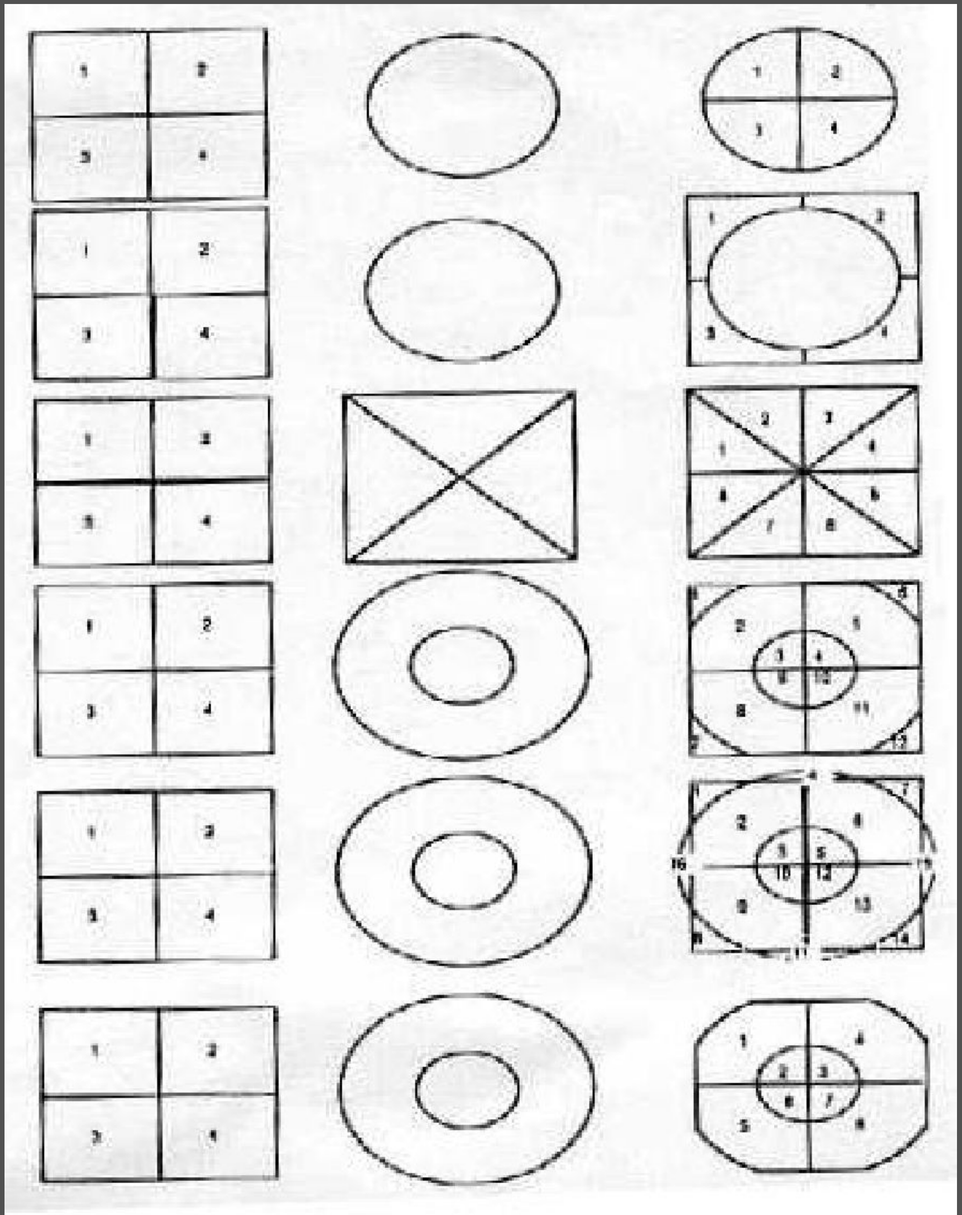


(Woodland AND Over 35 m) OR (Over 40 m)

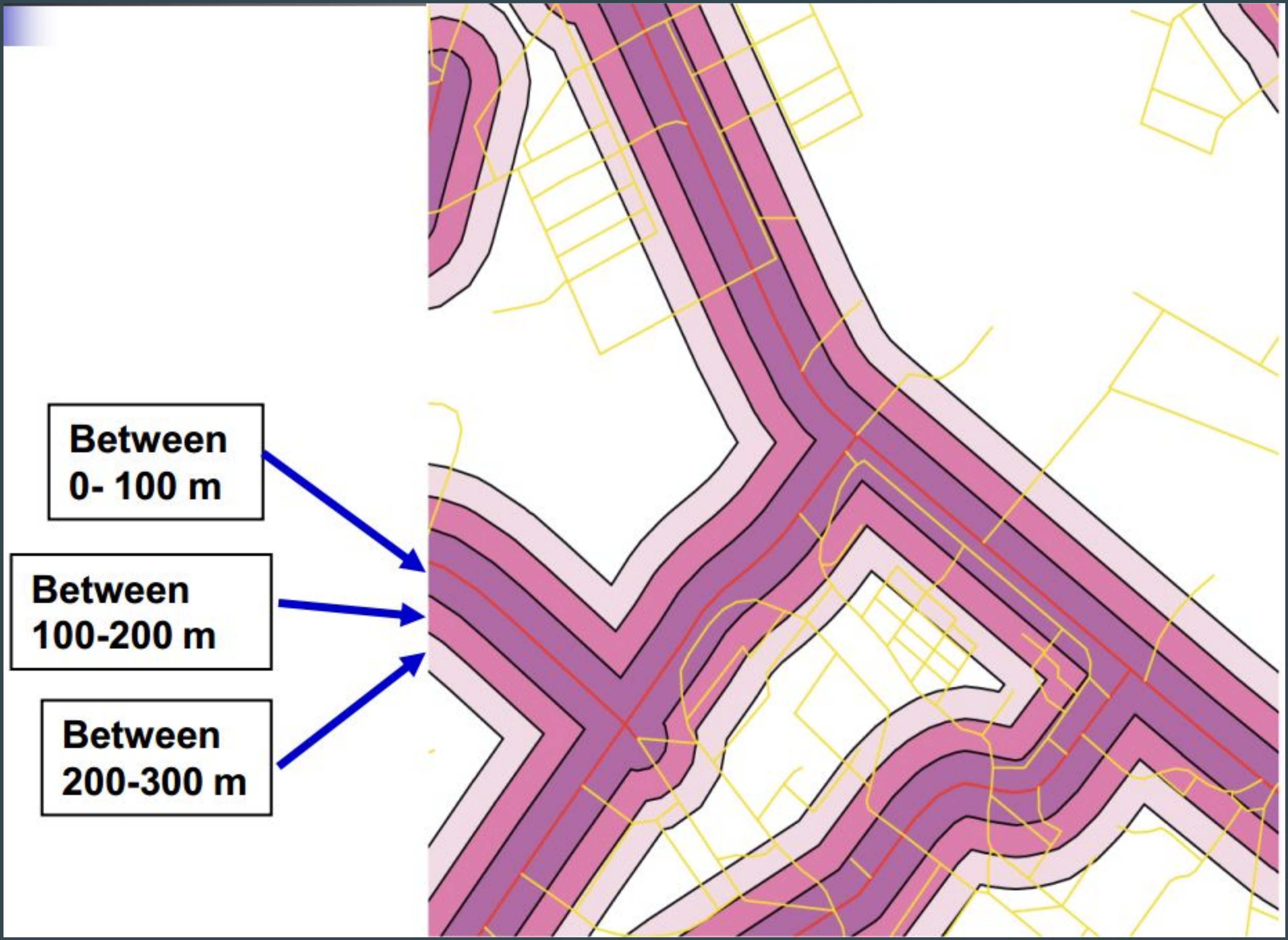


Topological Overlays for feature extraction

	PRIMARY	OPERATION	RESULT
CLIP			
ERASE			
SPLIT			
IDENTITY			
UNION`			
INTERSECT			

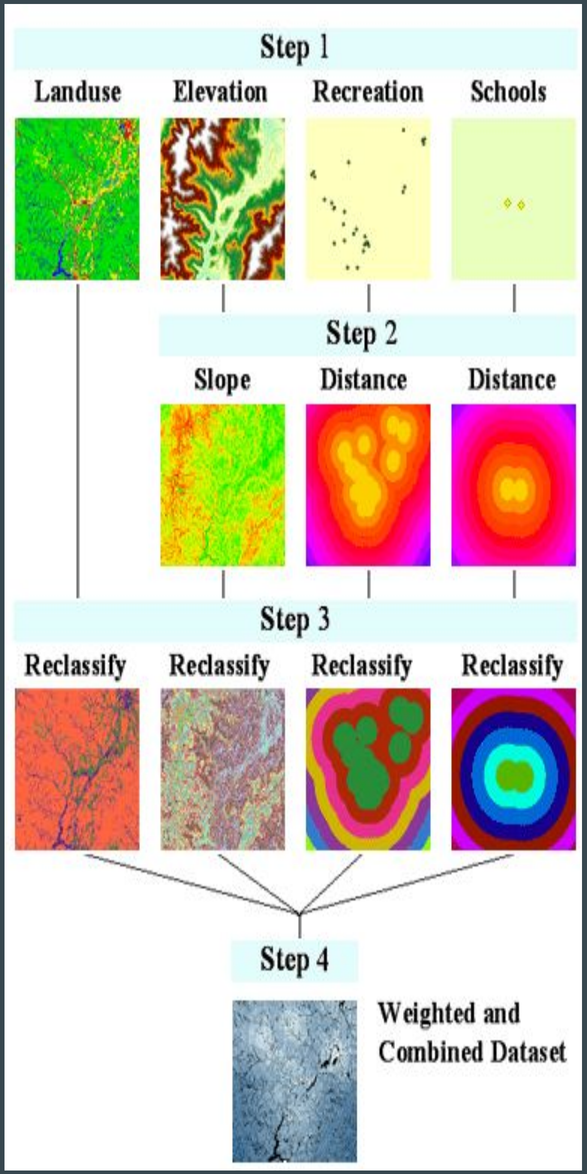


Neighborhood Operations: Multiple Ring Buffer

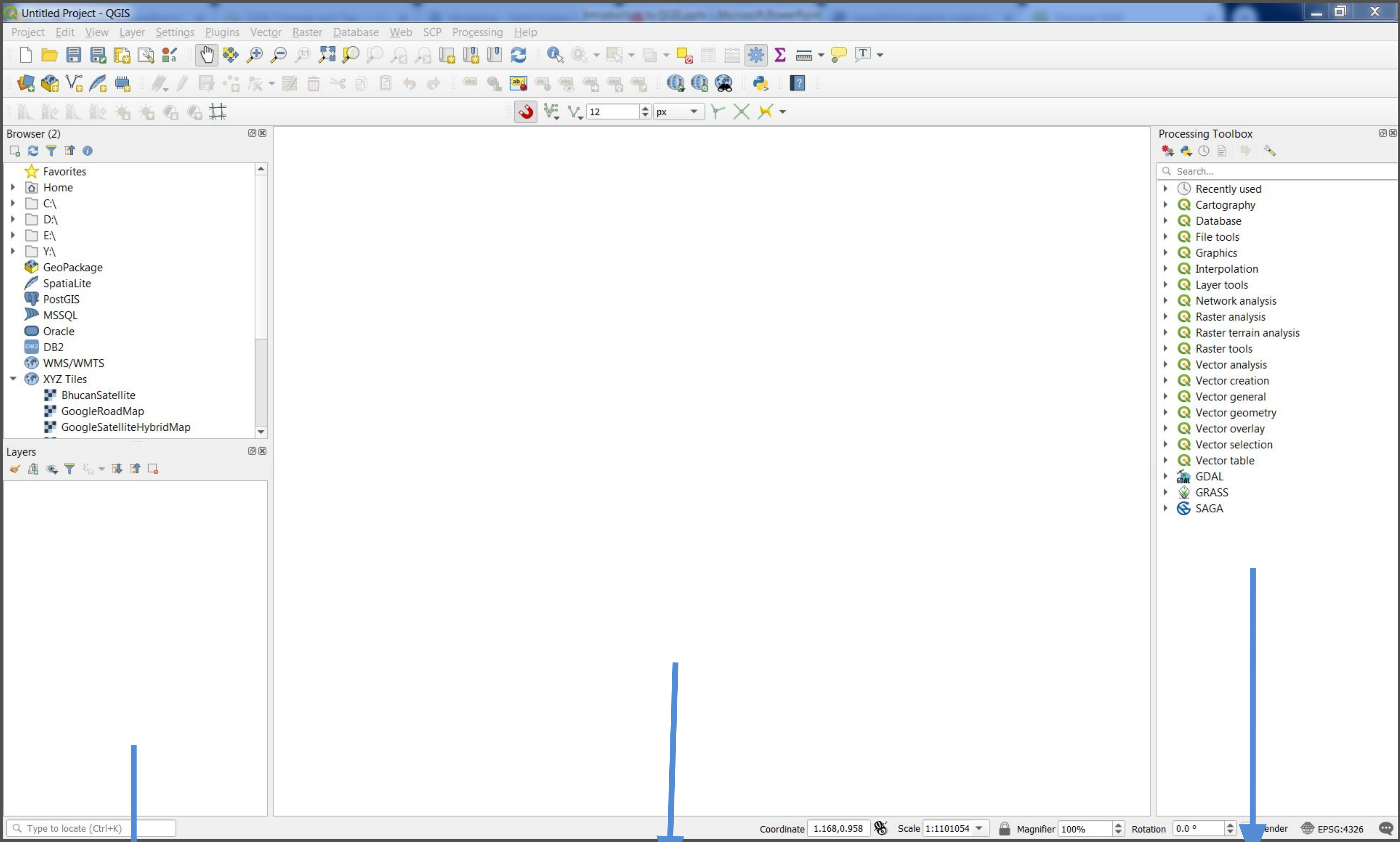


Understanding Reclassification

- Replacing values based on new information
- Grouping values together
- Reclassifying or rescaling values of a set of rasters to a common scale
- Setting specific values to NoData or setting NoData cells to a value
- Eg:
    - Classify an elevation map into classes with intervals of 50m



QGIS Window

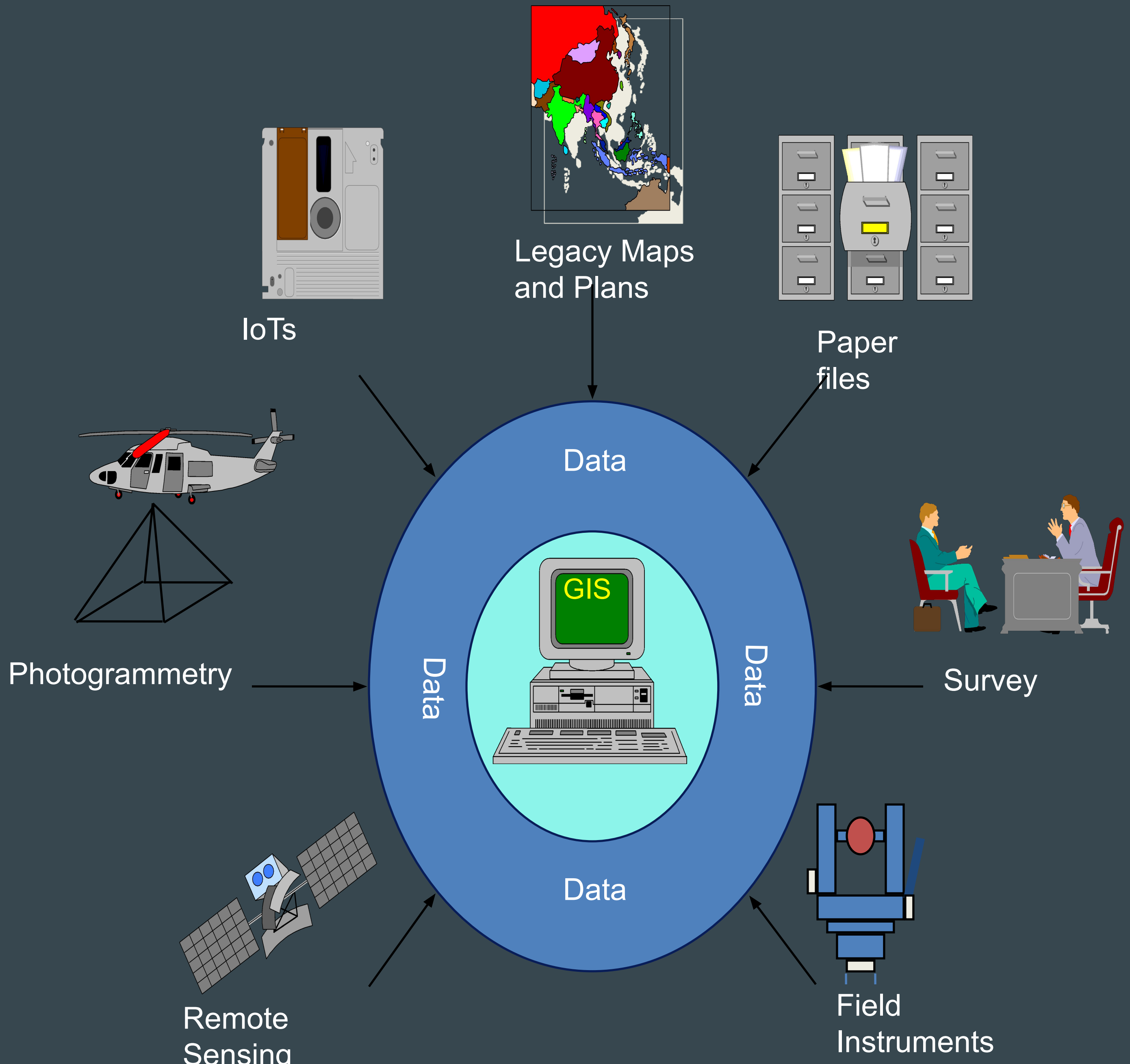


Layer Panel

Map Window

Processing Toolbox

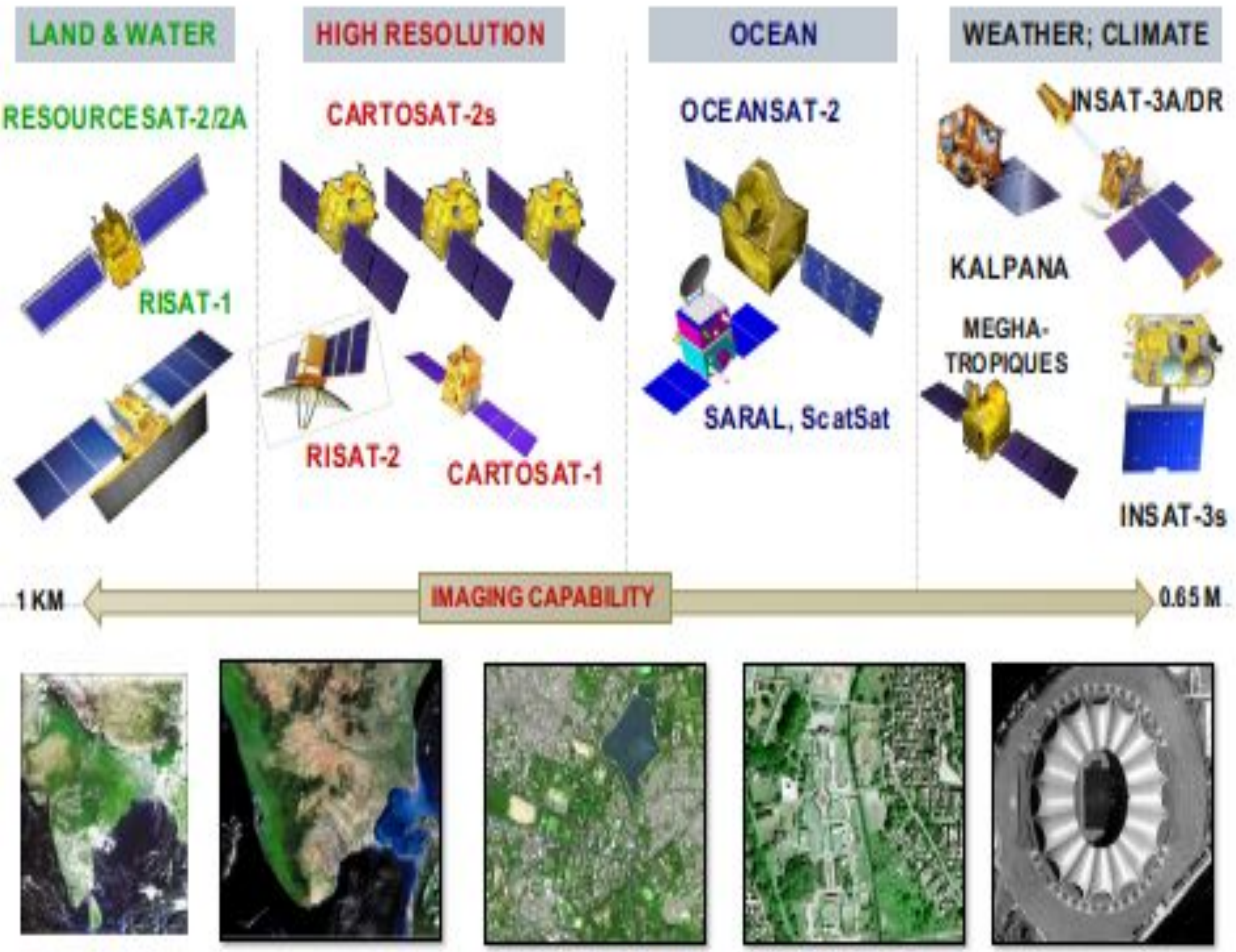
Final Notes on Geospatial Data



GIS Data Sources


01
VECTOR
Vertices and paths as points, lines and polygons.
RASTER
Raster data is made up of pixels or grid cells.
02
03
DATABASES
Geographic databases store vectors and rasters.
WEB
Data built to serve and display geographic features over the internet.
04
05
MULTITEMPORAL
Multitemporal geodata has a component of location and time.

Satellites To Choose from..



to be augmented with CARTOSAT 2/3 series; RESEOURCESAT 3series; GISAT, HRSAT, RISAT-1A/2A, OceanSat, NISAR......

Vector Data to Choose

1. Administrative Data

District Boundary
Cadastral
Sub-Division Boundary
Sub-Division Headquarters
Polling Area
Polling Stations
AC Boundary

2. Infrastructure

Hospitals
Police Station
Water Pipelines
Settlement Location
Tube Wells
Roads (1:10k)
Drainage
Sewerage Lines

3. Land Resources

Land Use/Cover (1:4k)
Land Use/Cover (1:50k)
Land Use/Cover II Cycle(1:50k)
Land Degradation Map
Waste Land 2003
Waste Land 2005-06
Waste Land 2008-09
Soil Ground Truth Points
Soil (1:250K)
Forest Area
Forest Cover
Forest Type
Geology

4. Water Resources

Surface Water bodies
Water bodies
Water bodies (River, Lakes)
River
Watershed
Aquatic Vegetation Post Monsoon 2008
Aquatic Vegetation Pre Monsoon 2008
Turbidity Pre Monsoon 2008
Wetland Boundary 2005
Wetland Points 2008
Wetland Post Monsoon 2008
Wetland Post Monsoon 2005

5. Bio Diversity

Biological Richness
Disturbance
Fragmentation

6. Terrain

Contour30m
Slope In % Rise

7. Action Plan

Aforestation
Horticulture

8. Disaster

Fire vulnerability zones
Flood Effected Area
Flood Prone River
Flood Prone Zone

Web Services to Choose from

www.nesdr.gov.in

www.nedrp.gov.in

www.nerdrr.gov.in

www.ndem.nrsc.gov.in

www.mosdac.gov.in

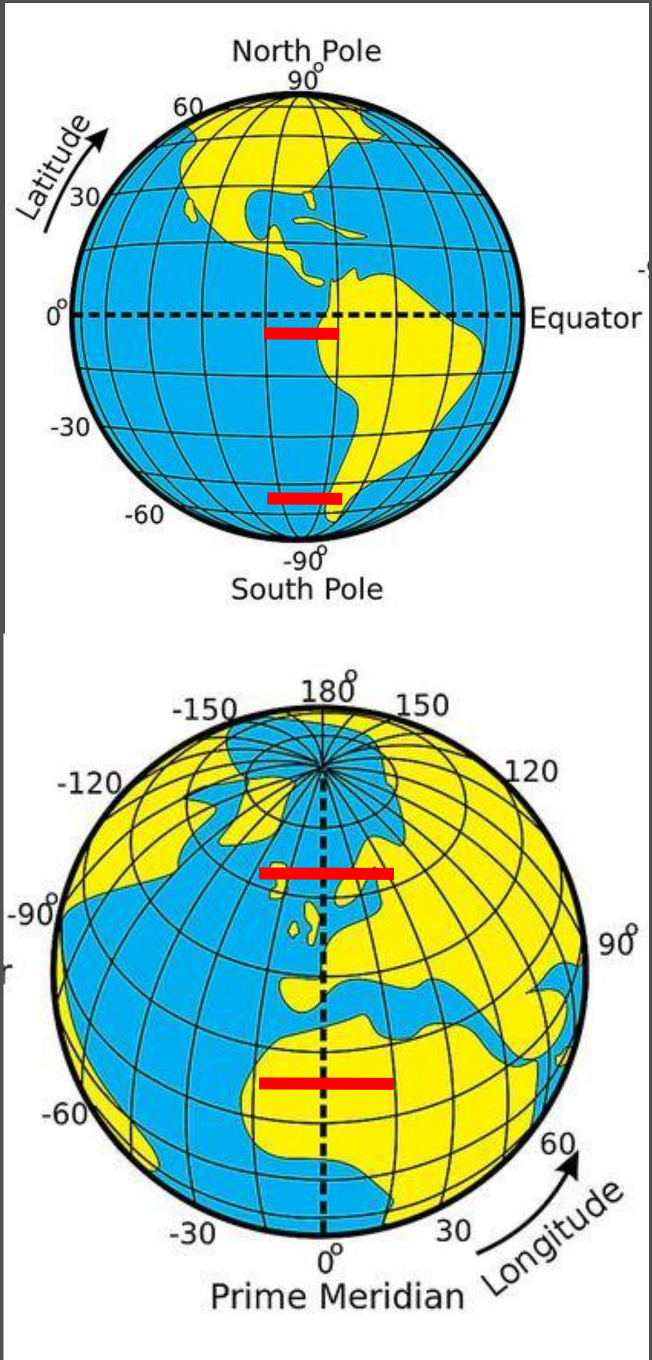
www.bhuvan.nrsc.gov.in

www.vedas.sac.isro.gov.in

Map Projections
(If Time Permits)

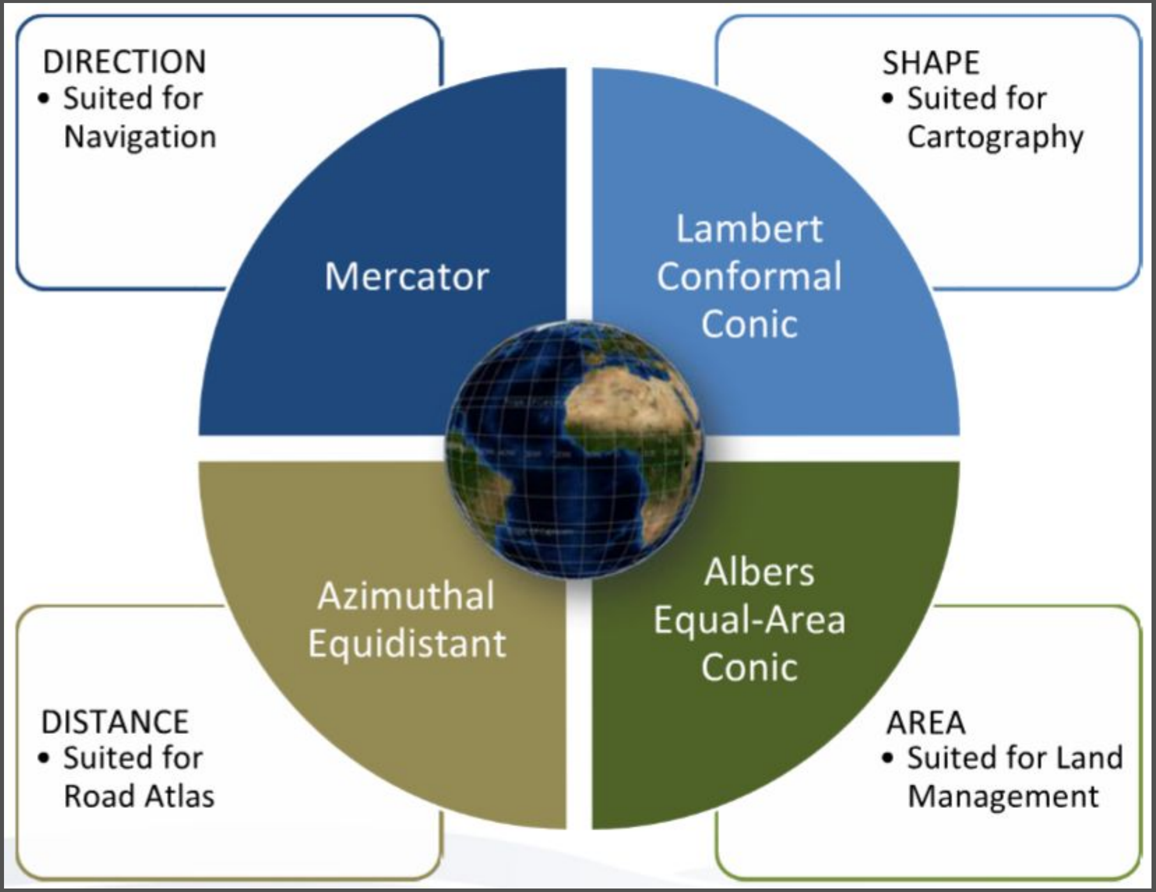
Coordinate Systems, Datums and Projections

- A datum typically defines the spherical surface.
- Geographic coordinate systems systems (lat/long) are the position of the surface relative to the centre of the earth based on the datum.
- A map projection is a way of representing the 3 dimensional real world information on 2 dimensional maps.
- This is accomplished by a series of transformations which convert the location of points on the spheroid to locations on flat plane.



Map Projections

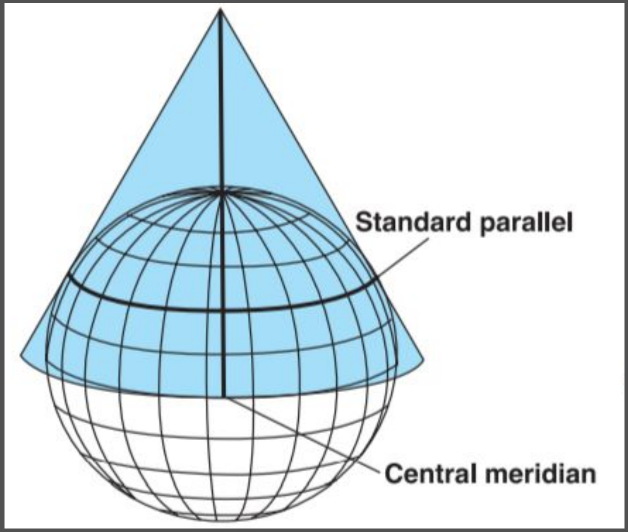
- Due to the reduction in dimension, some information in the form of shape, area, distance or direction will be lost. We need to choose our projections based on the application of interest.

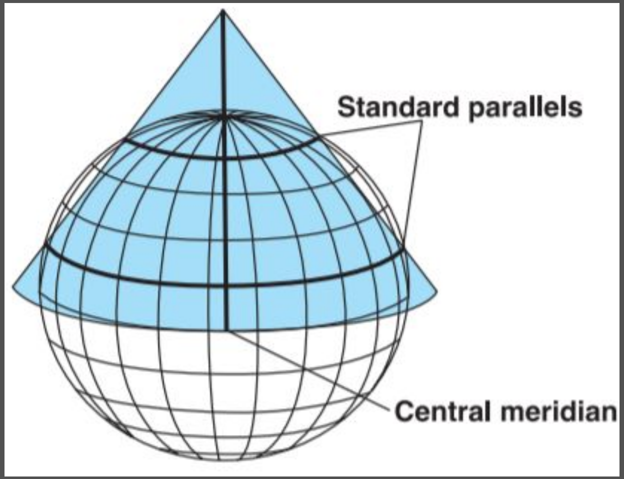


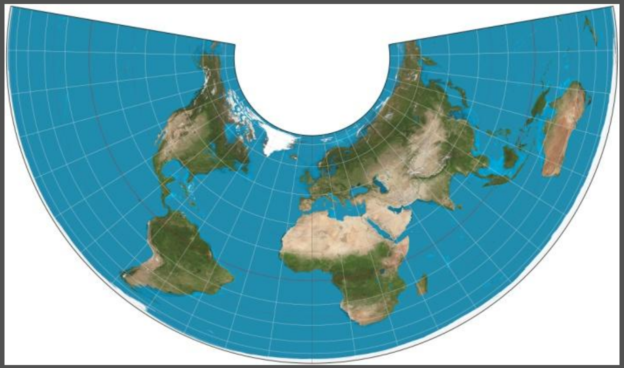
Typically, area and shape cannot be preserved simultaneously.

Conic Projections

- **Latitude:** rings **Longitudes:** radial lines.
- Standard parallel is the lat. at which the cone is tangential to the sphere. Distortions increase away from this parallel.
- Not ideal for polar surfaces or global maps. Suitable for mid-latitudes.
- Can have the cone as a secant rather than tangential which reduces distortion
- If the axis of the cone is not aligned with the polar axis: oblique conic projection.
- Polyconic possible (though outdated)
- Eg: Albers Equal Area Conic, Equidistant Conic, Lambert Conic (Conformal)

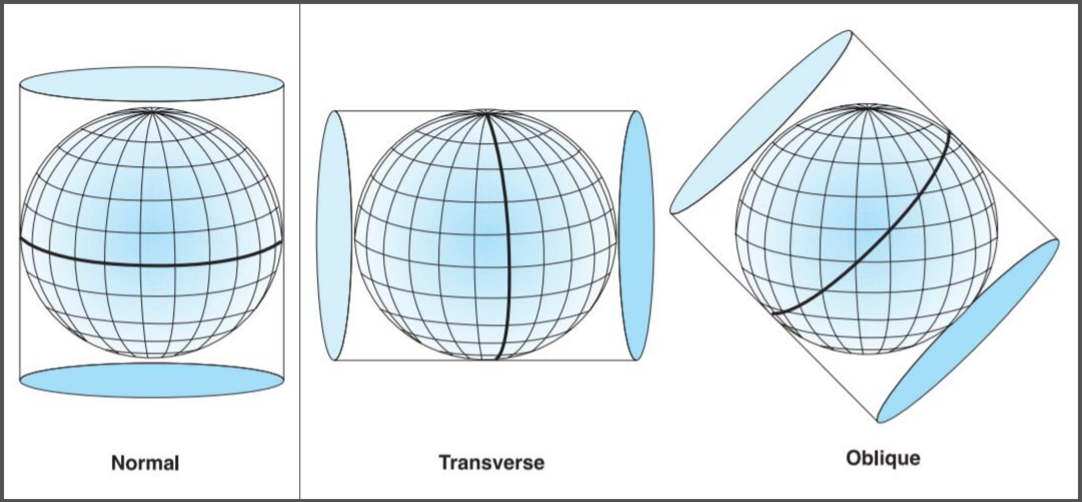






Cylindrical Projections

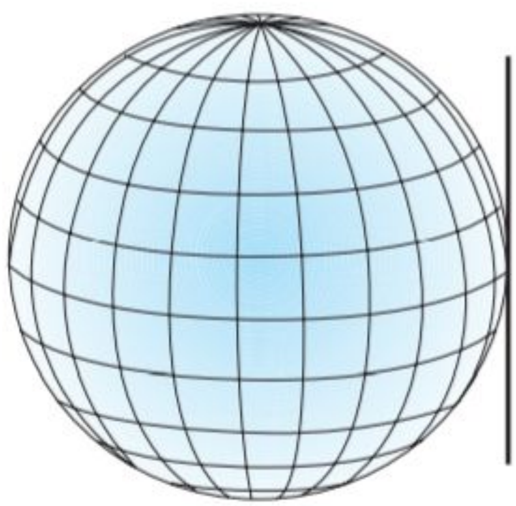
- Line of tangency or secancy displays equidistant behaviour
- If the axis of the cone is not aligned with the polar axis, it's an oblique conic projection. Called transverse if 90°
- The projection displays directions and shapes correctly.
- Areal distortion increases away from tangent/secant.
- Eg: Mercator



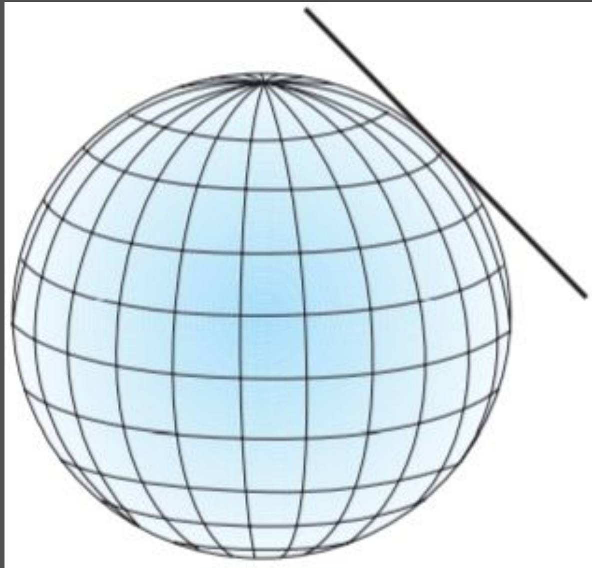
Planar Projections (Azimuthal/Zenithal Projection)

- Can be tangential or secantial
- If the axis of the plane is not aligned with the polar axis, it’s an oblique conic projection. Called equitorial if 90°
- Polar is the simplest with concentric circles of latitude and radial lines of longitude.
- Good for polar regions

Polar



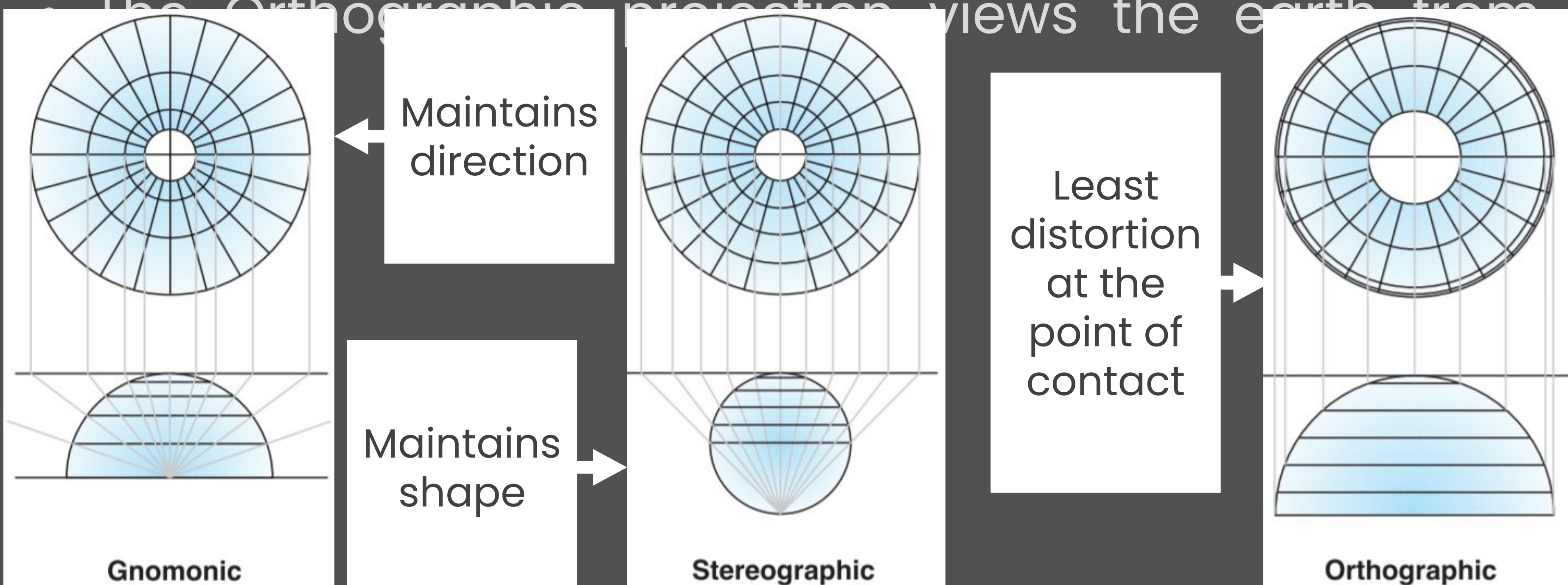
Equatorial



Oblique

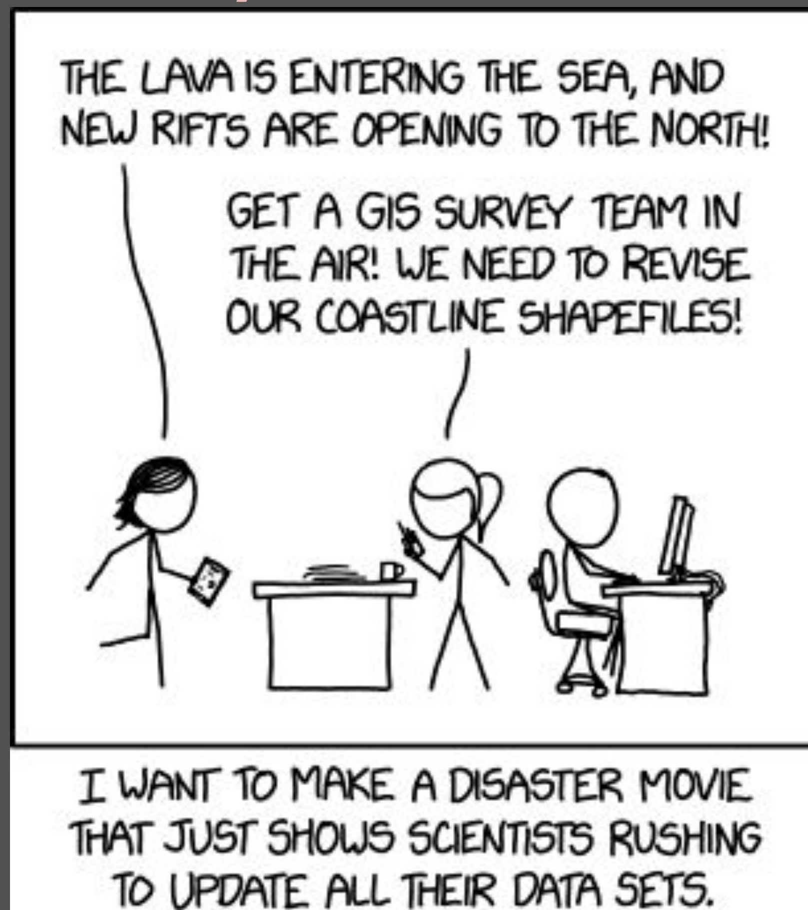
Planar Projections (Azimuthal/Zenithal Projection)

- Can also be segregated based on perspective point as described below.
- The Gnomonic projection views the surface data from the center of the earth
- The Stereographic projection views it from pole to pole.
- The Orthographic projection views the earth from



THANK YOU FOR YOUR PATIENCE

Any Doubts?



In case of any queries, drop me a line on

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