SAINT LOUIS UNIVERSITY

Conceptual Frameworks of Geospatial Analysis

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GIS4120/5120 Geospatial Analytics
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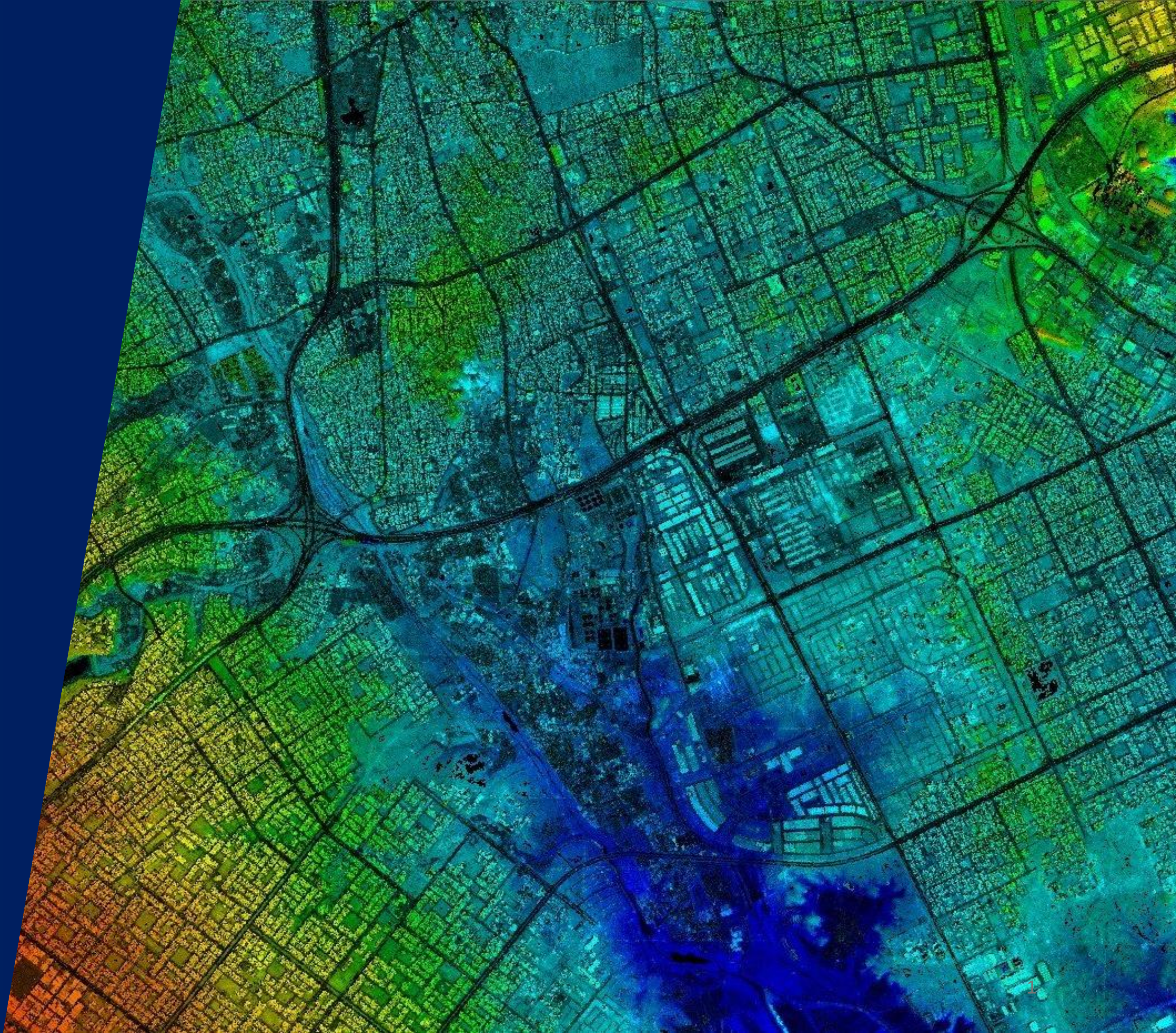
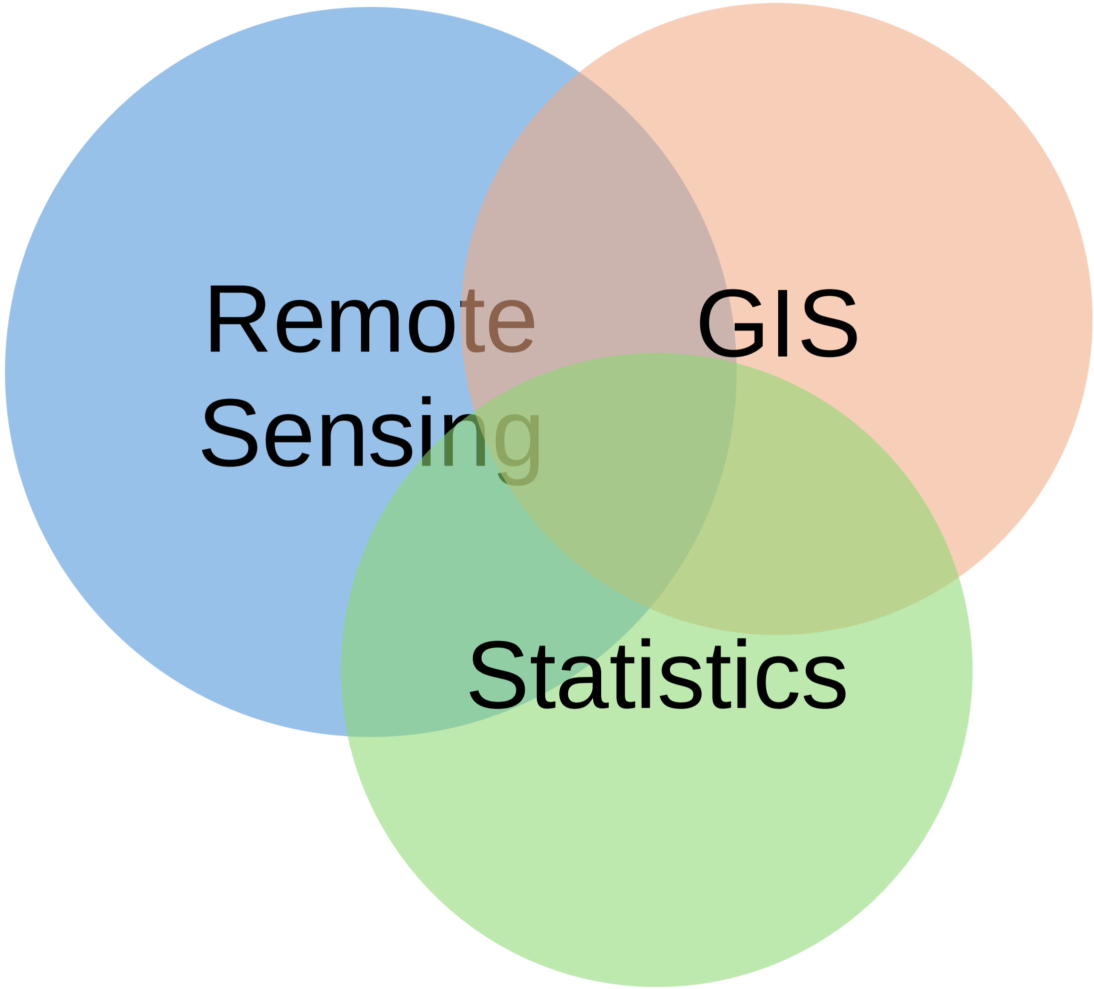


So, what is Geospatial Analytics?

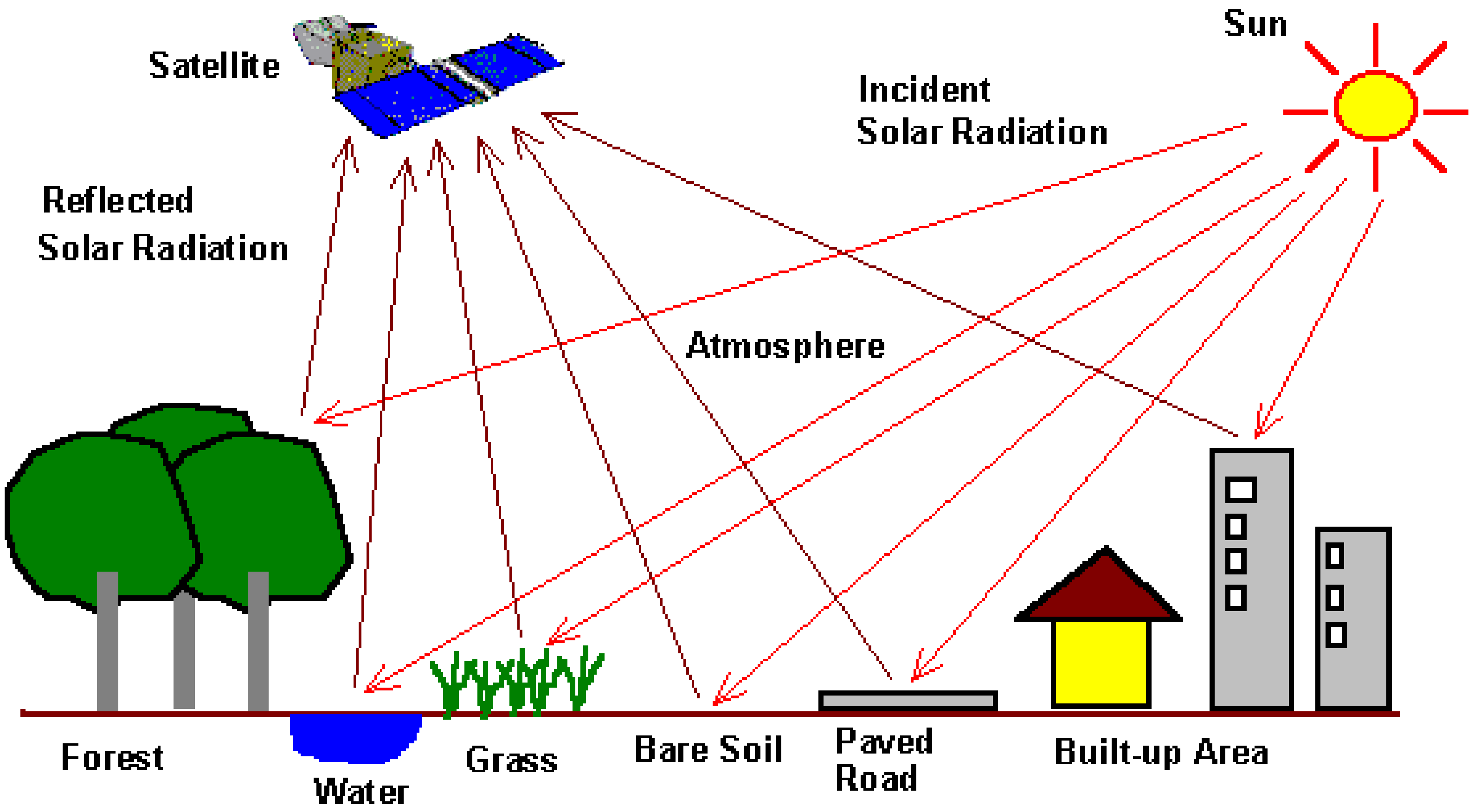


- Spatial Modeling
- Geocomputation
- Data Visualization
- Big Data
- Geographic Patterns
- Spatial Relationship
- Environmental Modeling
- Machine Learning

GIS is integral part of Geospatial Analytics

Source

Remote Sensing is another component



Source

Spatial Statistics is the backbone of the analysis

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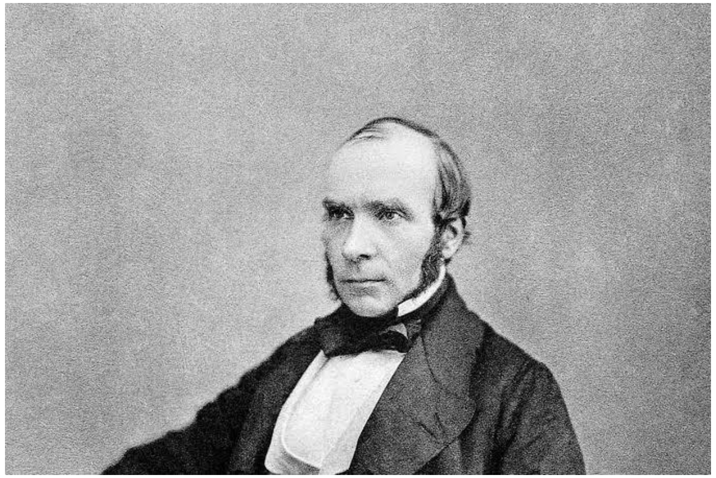
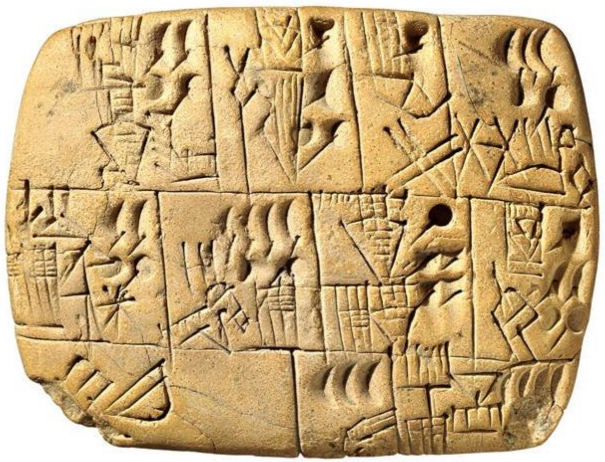


Dr. John Snow (1813 – 1858)

John Snow's cholera map was the first spatial analysis to reveal the correlation between cholera outbreaks and contaminated water sources by mapping the locations of deaths relative to water pumps in London.

What makes a “data” geospatial?

Abstraction of real-world relationship has been the backbone of mathematical representation



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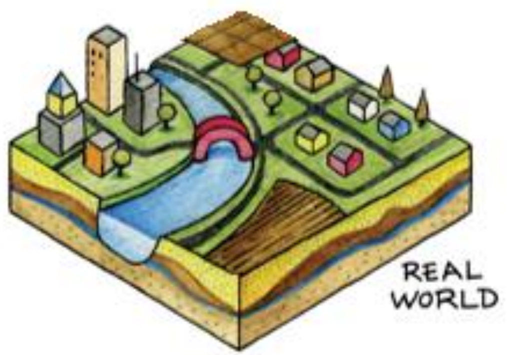
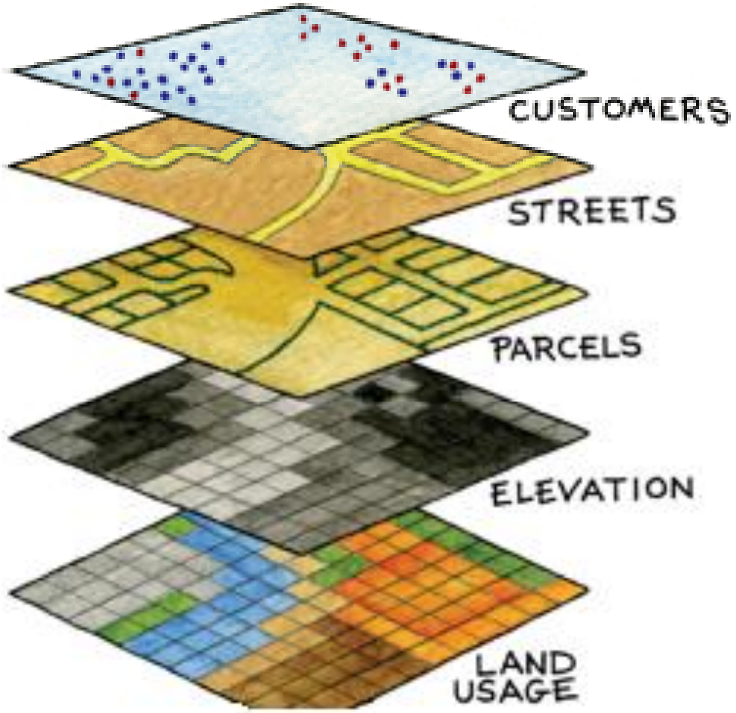
Count the number of Bisons	12, 14, 15
Differentiate between # Bison and weight of Meat	x = Bisons, y = Meat
Understand relationship between Bison and Meat	$y = mx + C$
More complex relationship at multiple dimensions	$ax^2 + bx + c = y$
Efficient solution to represent multiple equations	$\begin{bmatrix} 2 & -5 \\ 3 & 7 \end{bmatrix} = \begin{bmatrix} 3 \\ 7 \end{bmatrix}$

GIS recreates real world spatial data

Complex real data without any inherent meanings

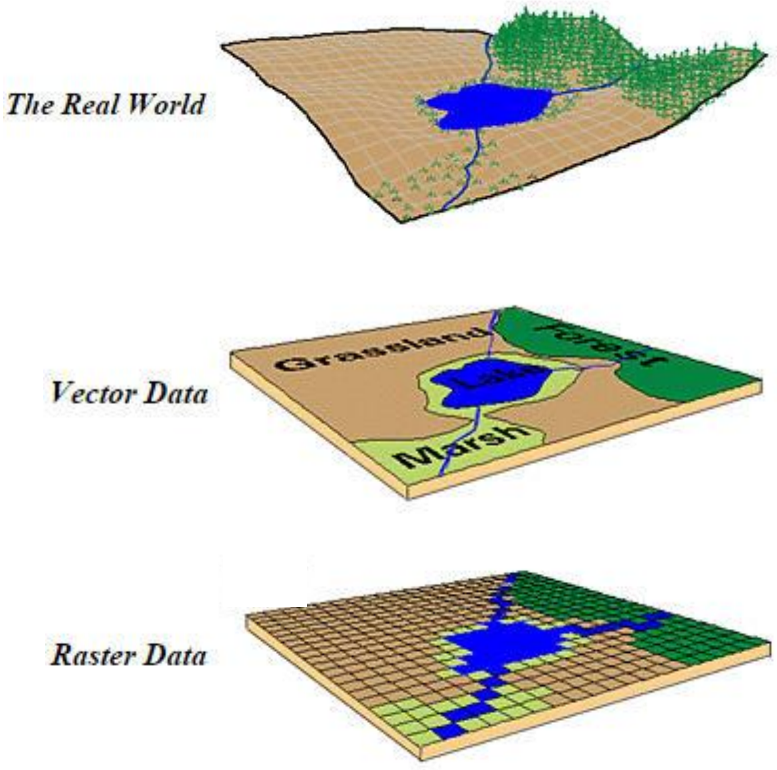


Structured data representing different themes



Specific information generated from analyzing the data

Two types of geospatial data

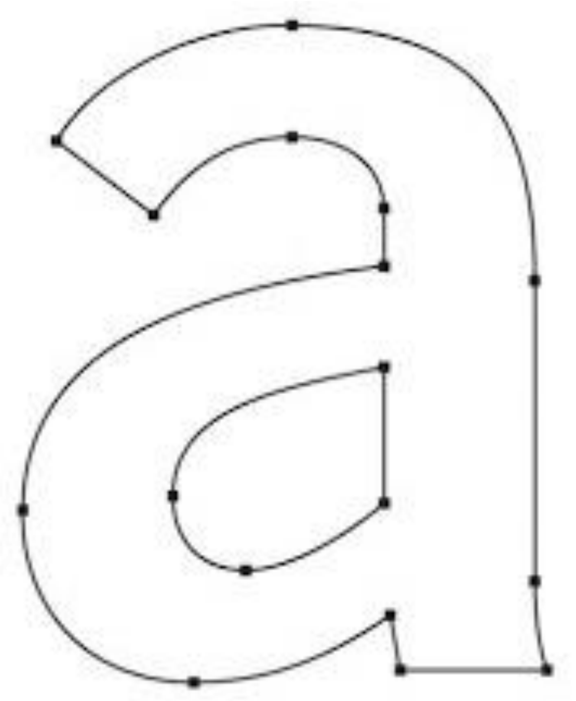


Images © University of Washington

Geospatial or coordinate data can be represented in two different data formats	Examples
Vector: e.g., points, lines, and polygons	School locations, road networks
Raster: e.g., row and column matrix	Land use land cover, Digital Elevation Model

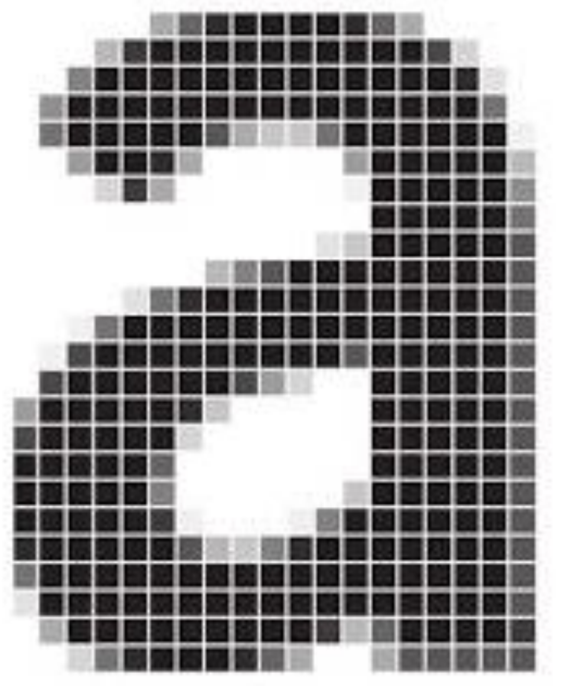
Vector vs Raster

Vector Model



Composed of coordinates

Raster Model



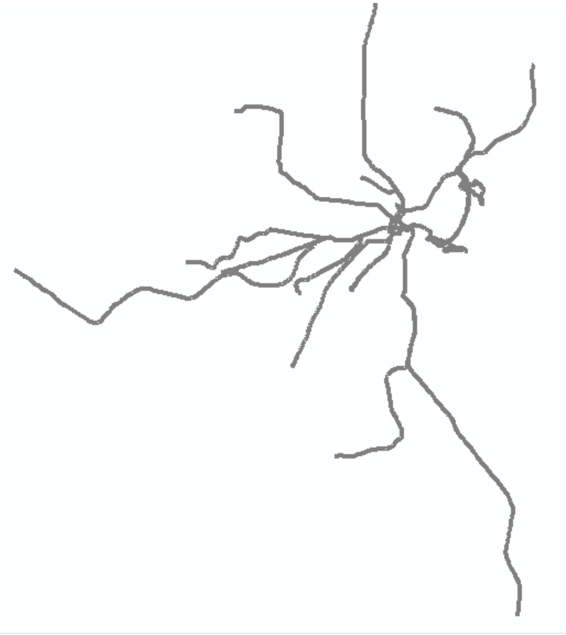
Composed of pixels

Image courtesy of [Zina Yonten]

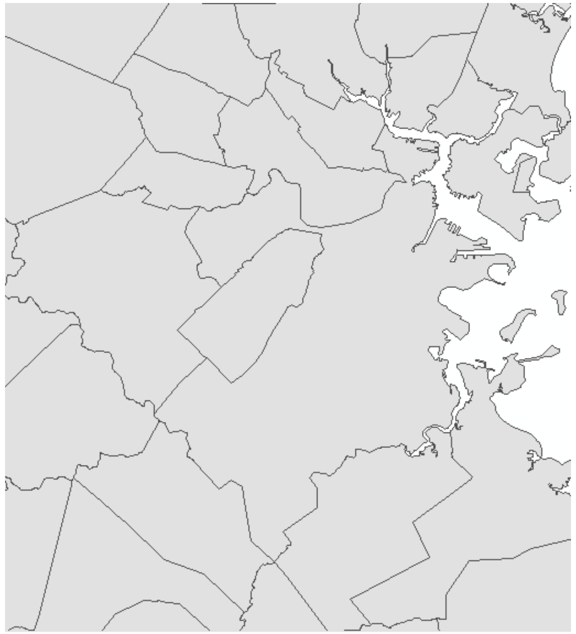
Points, lines and polygons as vector

Points

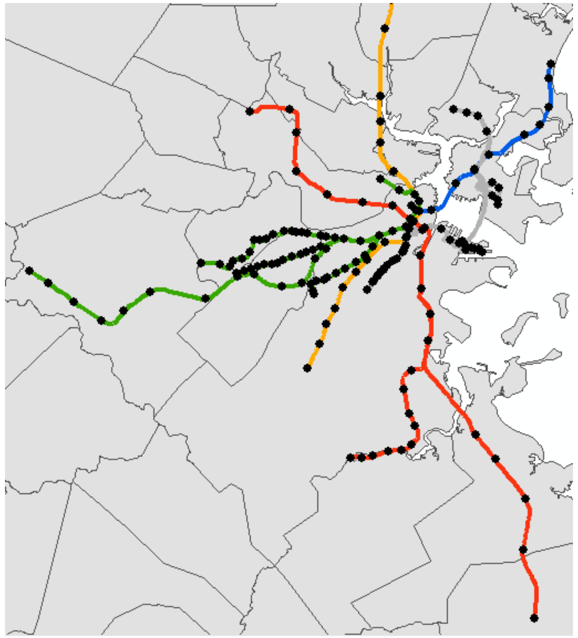
Lines



Polygons



Combined

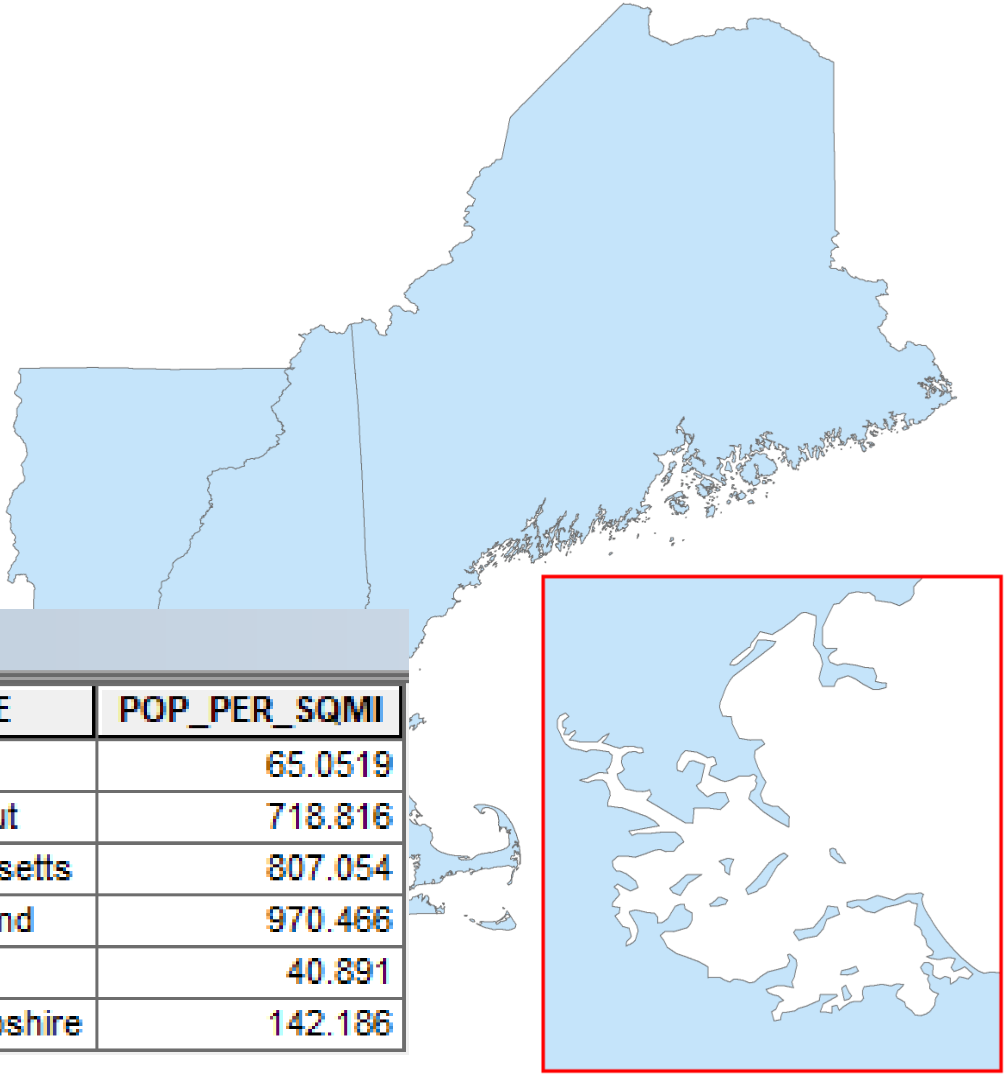


Vector data is represented in two fronts

Vectors have a **frontend geometry**
In this example the geometry represents state polygons

Vectors have a **backend database**,
normally called an ‘attribute table’

- **rows** represent unique geometries (e.g. state polygons)
- **columns** represent a number of variables (theoretically infinite)
- Here each row (state) is symbolized by ‘NAME’ (categorical variable)

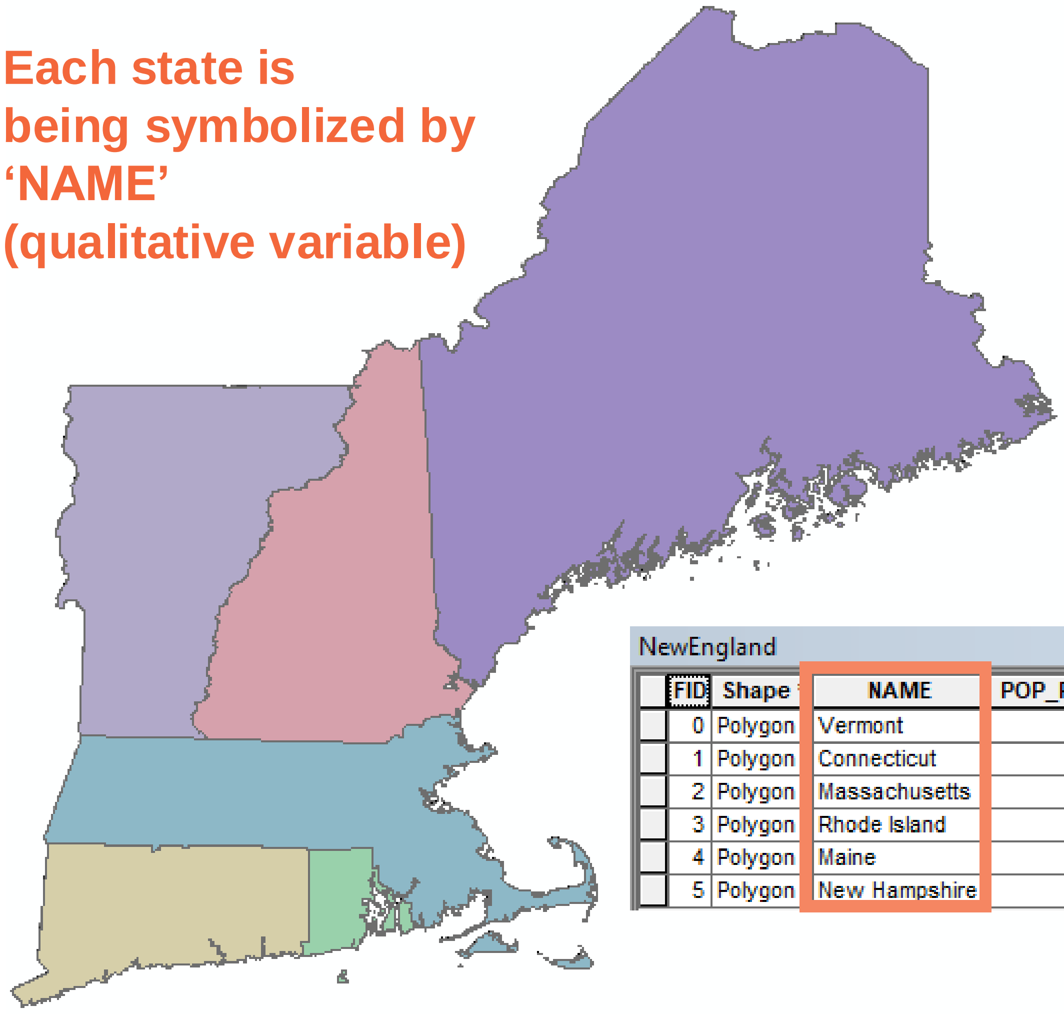


NewEngland

FID	Shape *	NAME	POP_PER_SQMI
0	Polygon	Vermont	65.0519
1	Polygon	Connecticut	718.816
2	Polygon	Massachusetts	807.054
3	Polygon	Rhode Island	970.466
4	Polygon	Maine	40.891
5	Polygon	New Hampshire	142.186

Vector data can be symbolized by different data

Each state is being symbolized by 'NAME' (qualitative variable)



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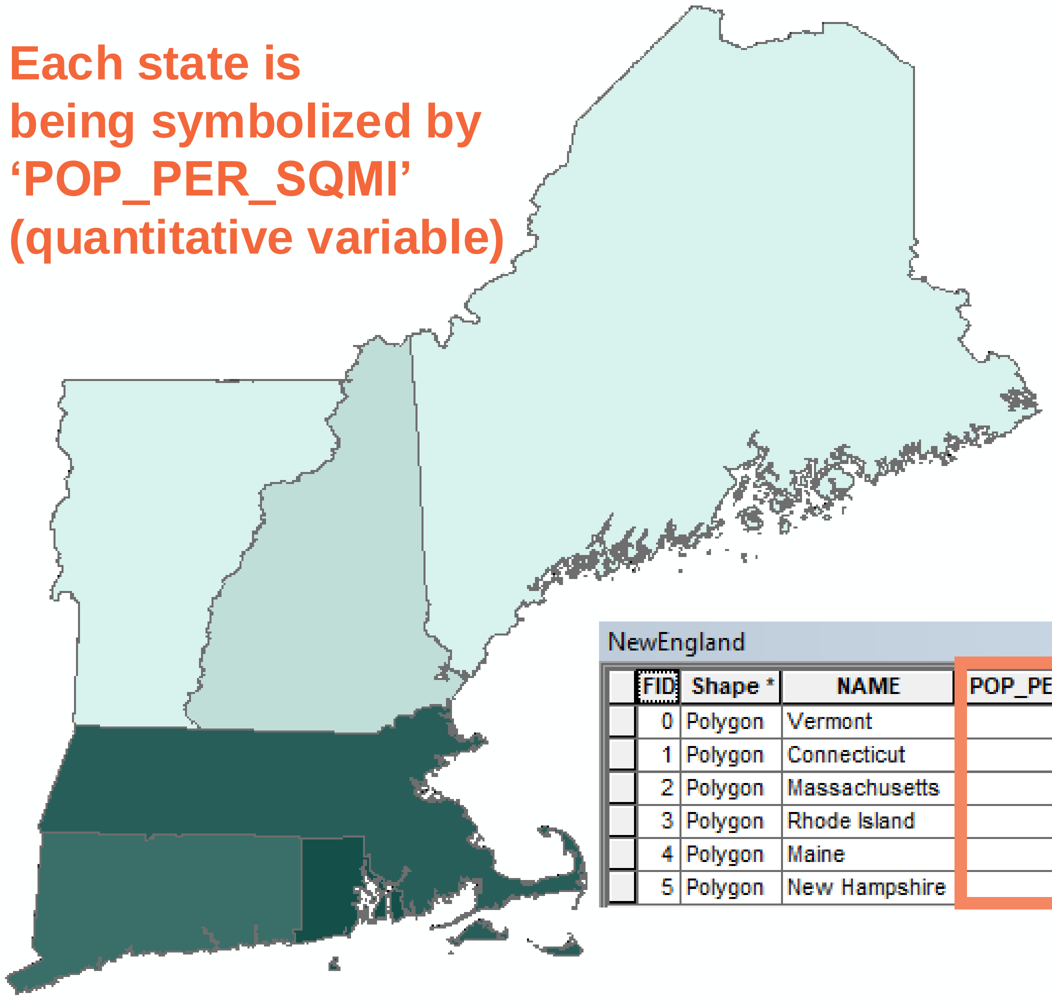
Each state is being symbolized by 'POP_PER_SQMI' (quantitative variable)



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Different levels of measurement for attribute data

Categorical

Nominal

- Gender, ethnicity, eye color, blood type
- Land use, land cover

Ordinal

- Income level
- Customer ratings
- Political orientation

Numerical

Interval

No true zero.

- Temperature in Fahrenheit or Celsius
- Test scores

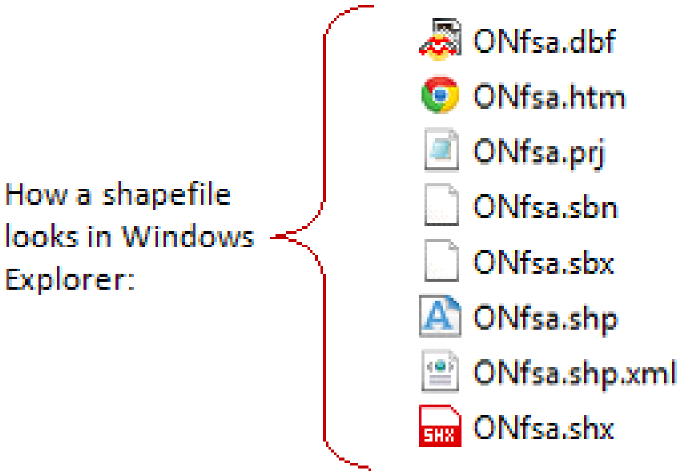
Ratio

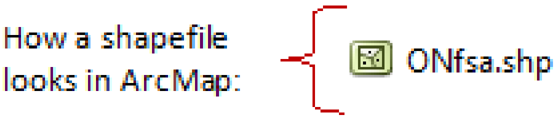
Has true zero.

- Age
- Height
- Weight
- Temperature in Kelvin

The most common vector data format is ‘.shp’

- “A” shapefile is a collection of several different files with different extensions
- Each file serves different purposes which in combine represent a vector data model
- The three required files are:
  –**SHP** is the feature geometry.
  –**SHX** is the shape index position.
  –**DBF** is the attribute data.
- –**PRJ** is the projection system metadata.
  –**XML** is the associated metadata.
  –**SBN** is the spatial index for optimizing queries.
  –**SBX** optimizes loading times.



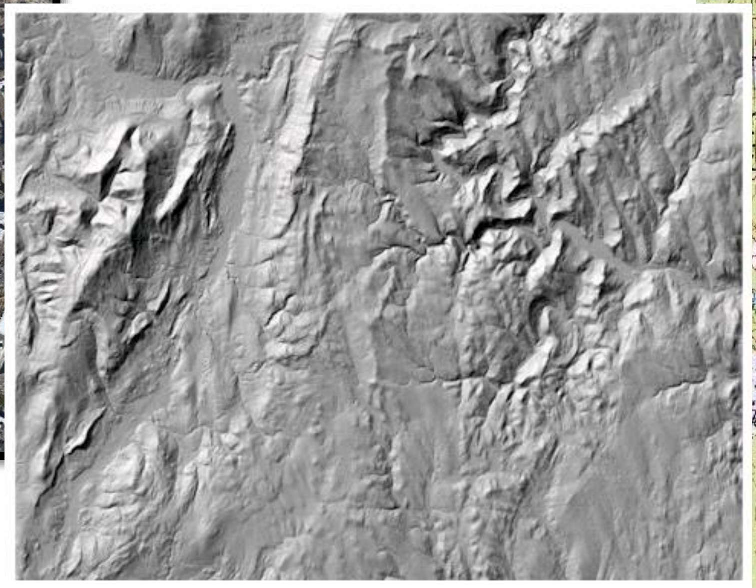


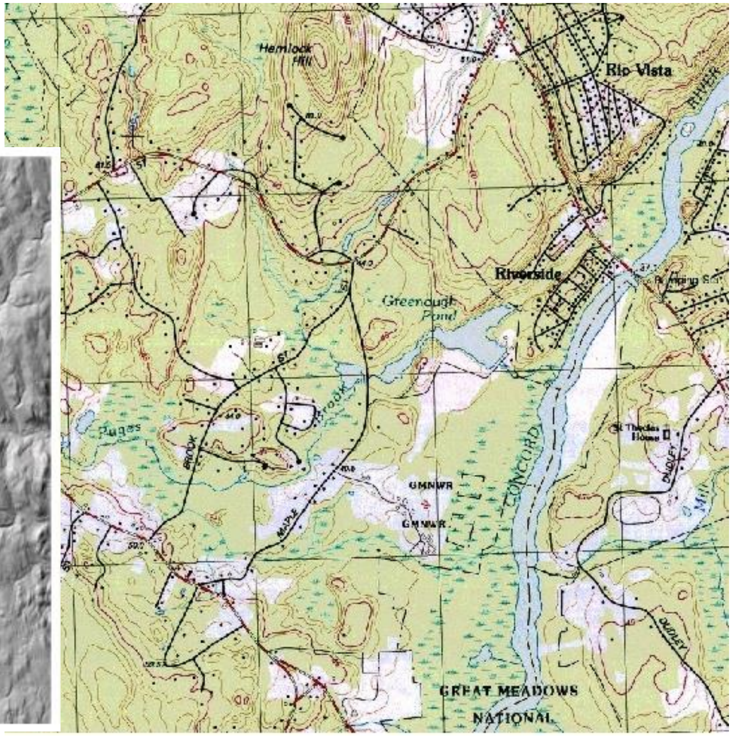
There are other popular vector data formats

- .GEOJSON: GeoJSON is a format for encoding geographic data structures, such as points, lines, and polygons, using JavaScript Object Notation (JSON)
- .GML: GML allows for the use of geographic coordinates extension of XML.
- .KML: KML stands for Keyhole Markup Language. This GIS format is XML-based and is primarily used for Google Earth.
- Learn more at: https://gisgeography.com/gis-formats/

Raster data model

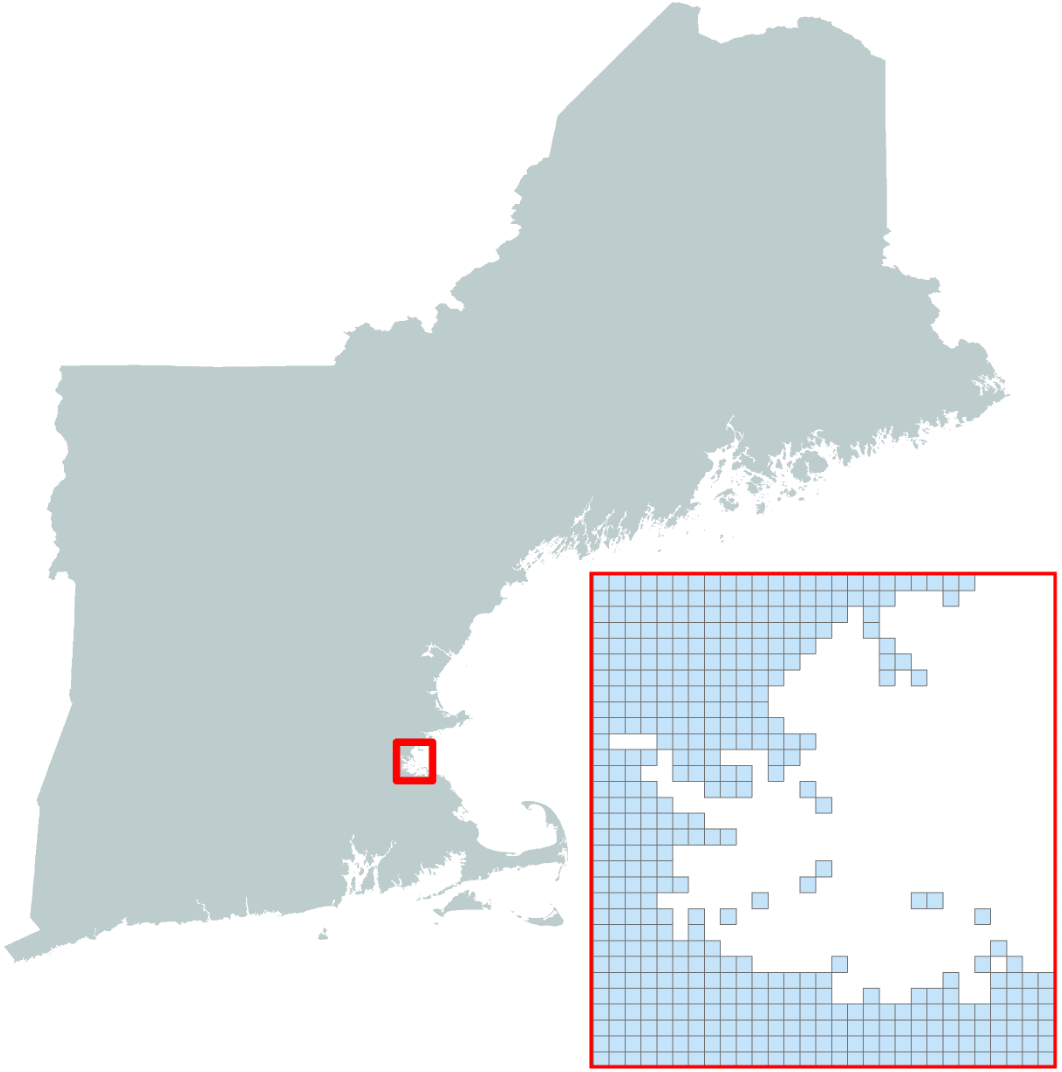
Raster data includes aerial photographs, digital elevation models, and scanned maps.





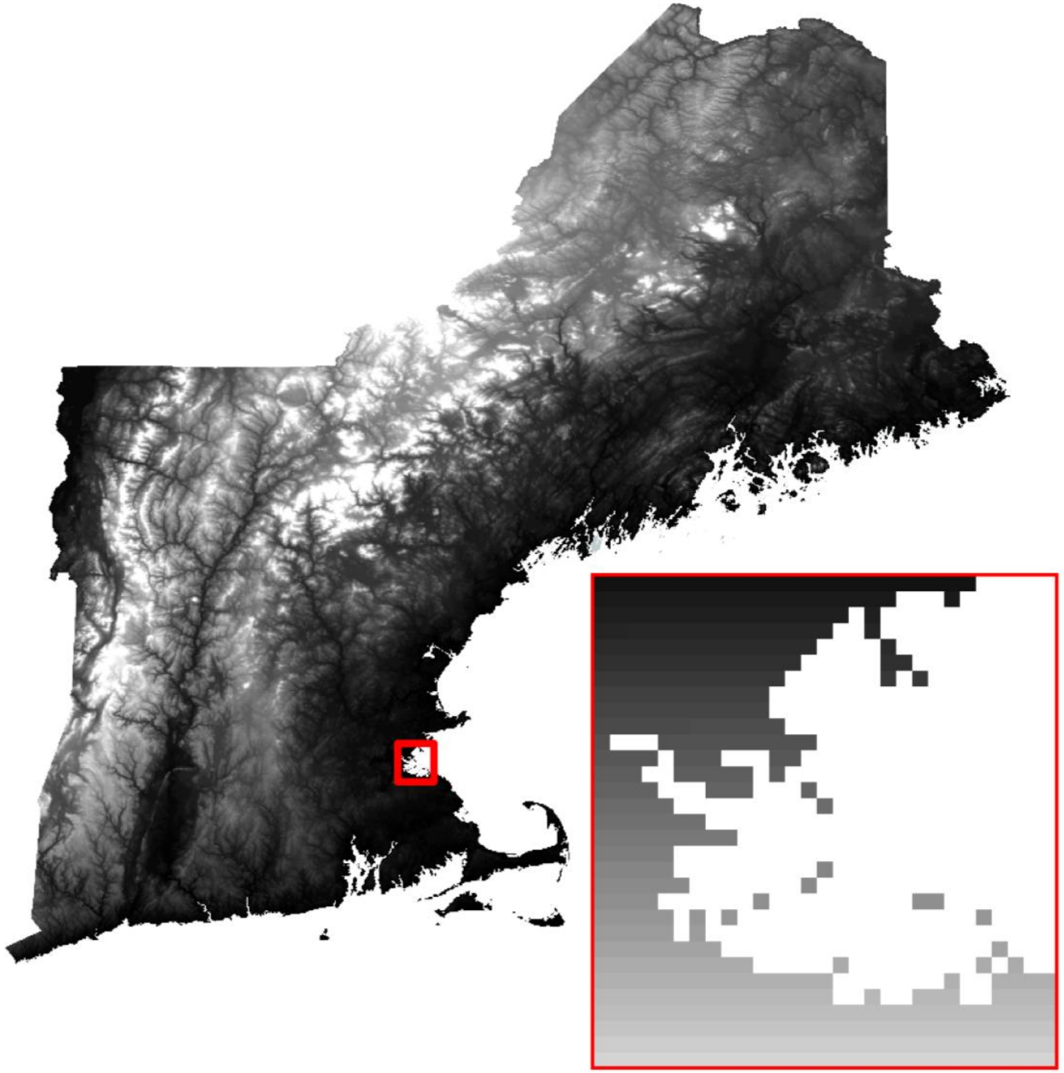
Raster data has a frontend cell matrix

- Where each cell has its own value
- A raster can only symbolize one variable at a time
- Multiple bands can be stacked together to represent multiple variables



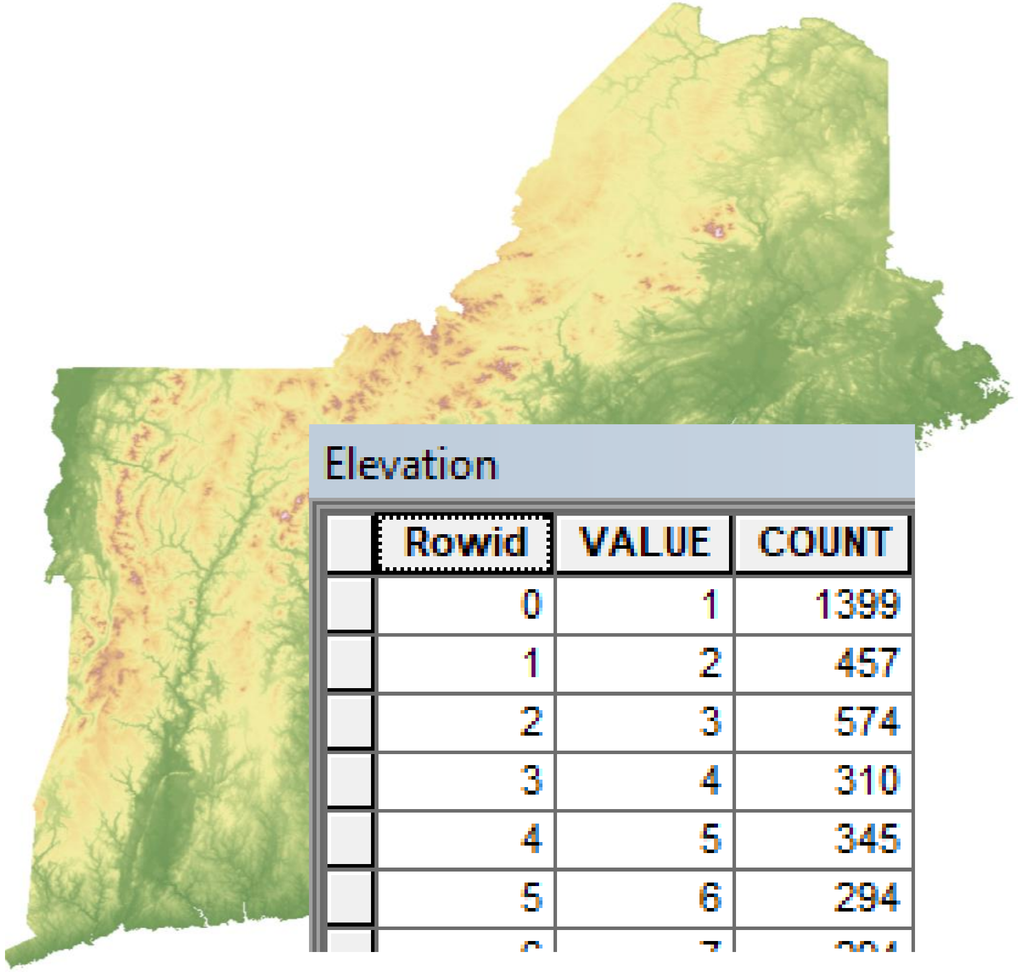
Raster data has a frontend cell matrix

- Where each cell has its own value
- A raster can only symbolize one variable at a time
- Multiple bands can be stacked together to represent multiple variables
- **Here each cell/pixel is being symbolized by elevation value**



Raster data can have a **backend database** too

- Raster data have a **backend database**, normally called an ‘attribute table’
- **rows** represent unique values (1m, 2m, 3m, etc.)
- **columns** have specific variables
  1) unique ‘ROW ID’
  2) unique ‘VALUE’
  3) ‘COUNT’ of pixels with that ‘VALUE’

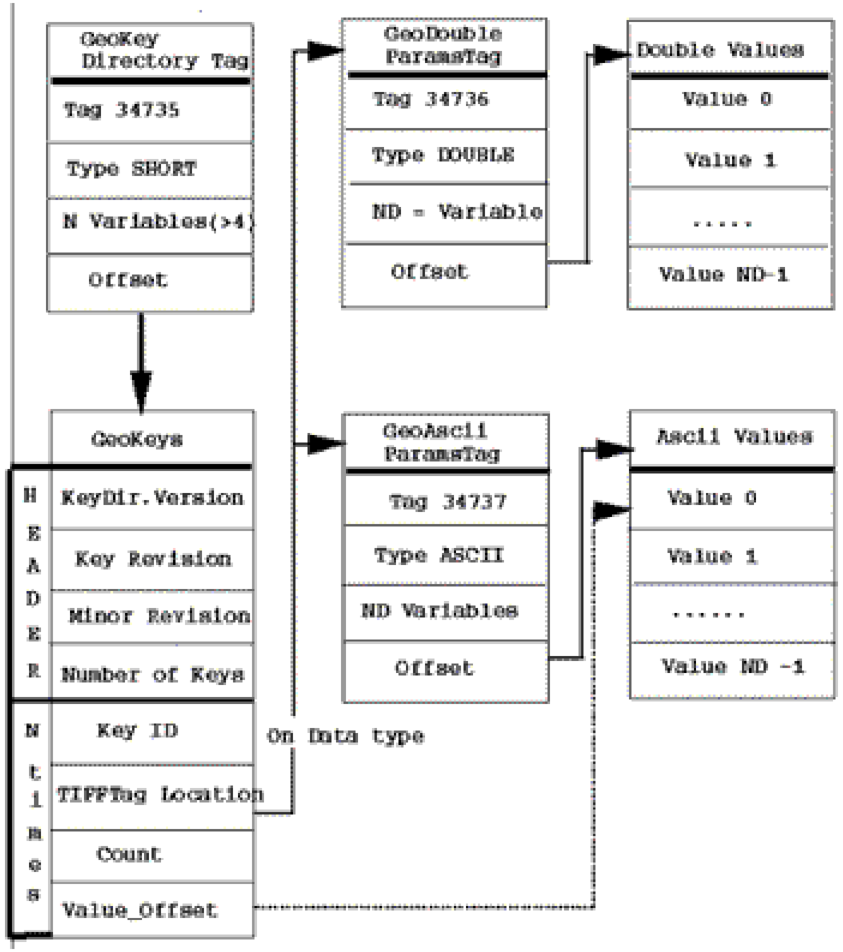


Elevation

Rowid	VALUE	COUNT
0	1	1399
1	2	457
2	3	574
3	4	310
4	5	345
5	6	294

My go to choice as raster data format is GeoTIFF

- A .tif file stores metadata or attributes about the file as embedded tif tags.
- A GeoTIFF is a standard .tif image format with additional spatial (georeferencing) information embedded in the file as tags.
- Some example of tags:
  - Extent
  - Resolution
  - Coordinate Reference System (CRS) - we will introduce this concept in a later episode
  - Values that represent missing data (NoDataValue)



Source

Tabular data is also a common data format needed in geospatial analytics

Tabular data can be transformed into spatial data in two ways:

1. Joining
   - **Use a shared unique identifier** (GEOID, name, etc.) to match up tabular data to the spatial data's attribute table.
2. Geocoding
   - **Use lat/lon** coordinates in table to plot as points on map
   - **Use addresses** to plot locations based on a street network

QGIS cannot read Excel file formats.

.csv

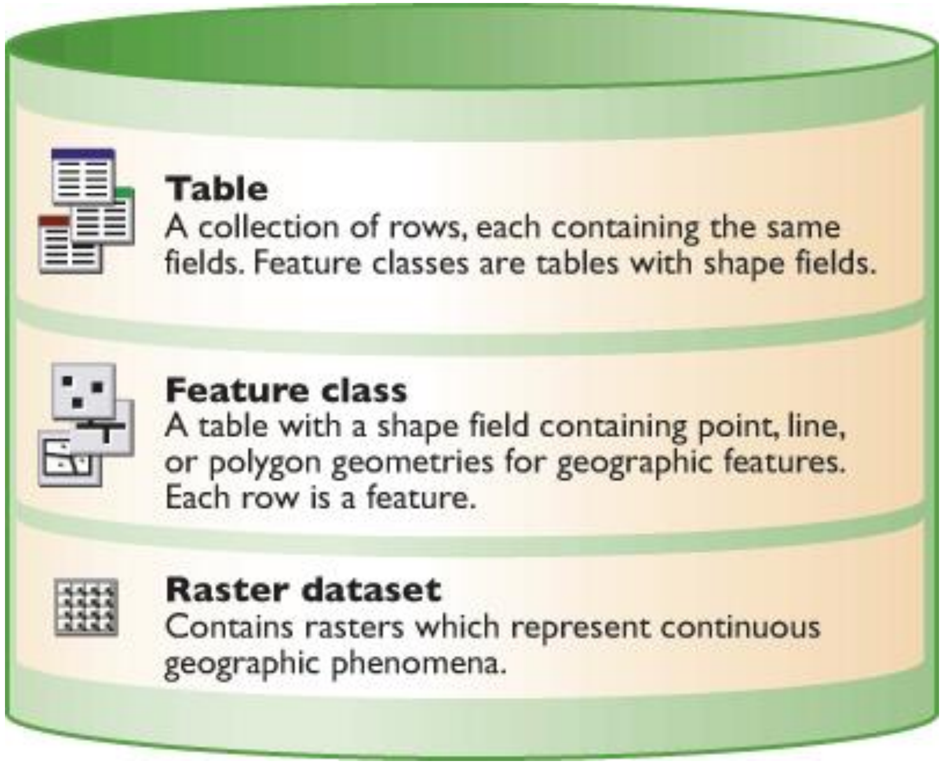
.xlsx

.dbf

Shapefiles include a .dbf, which is a tabular format that can be opened in other software, like Excel.

Geodatabase is a more complex and efficient data structure to represent multiple geospatial data

- ESRI/ArcGIS storage system
- A collection of geographic datasets of various types held in a common file system folder
- **Advantages:** larger files size limits, faster processing time when using analysis tools
- **Disadvantages:** can only be opened in ESRI software
- Learn more about using geodatabases in Pro.

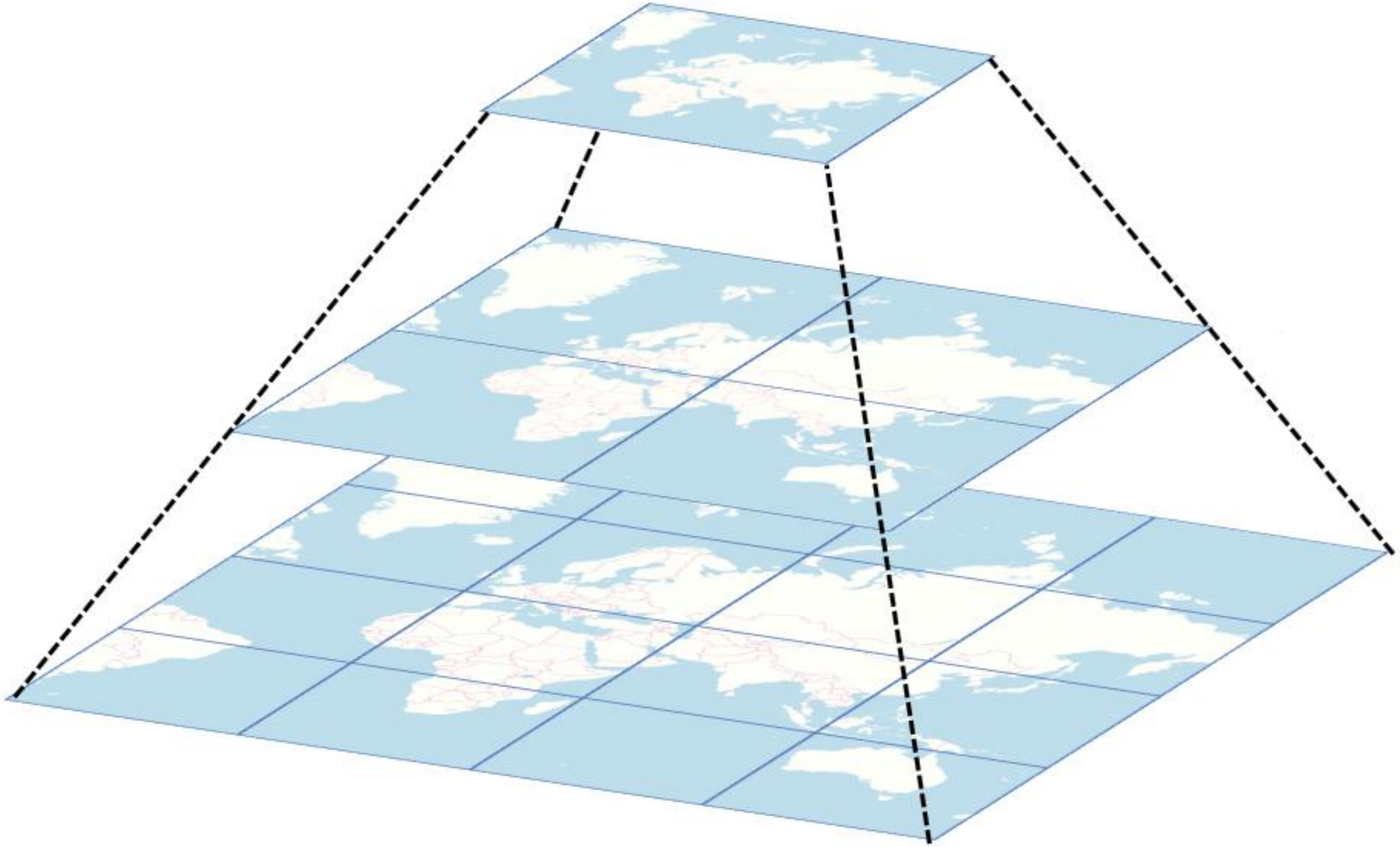


Source

Raster and vector tiles are now the face of online mapping

[Source](#)

Vector tiles are replacing the use of raster tiles



- Vector tiles are a way of storing and serving geographic data in a compact and efficient format.
- Unlike traditional raster tiles, which are pre-rendered images, vector tiles contain vector data that can be rendered dynamically on the client side.

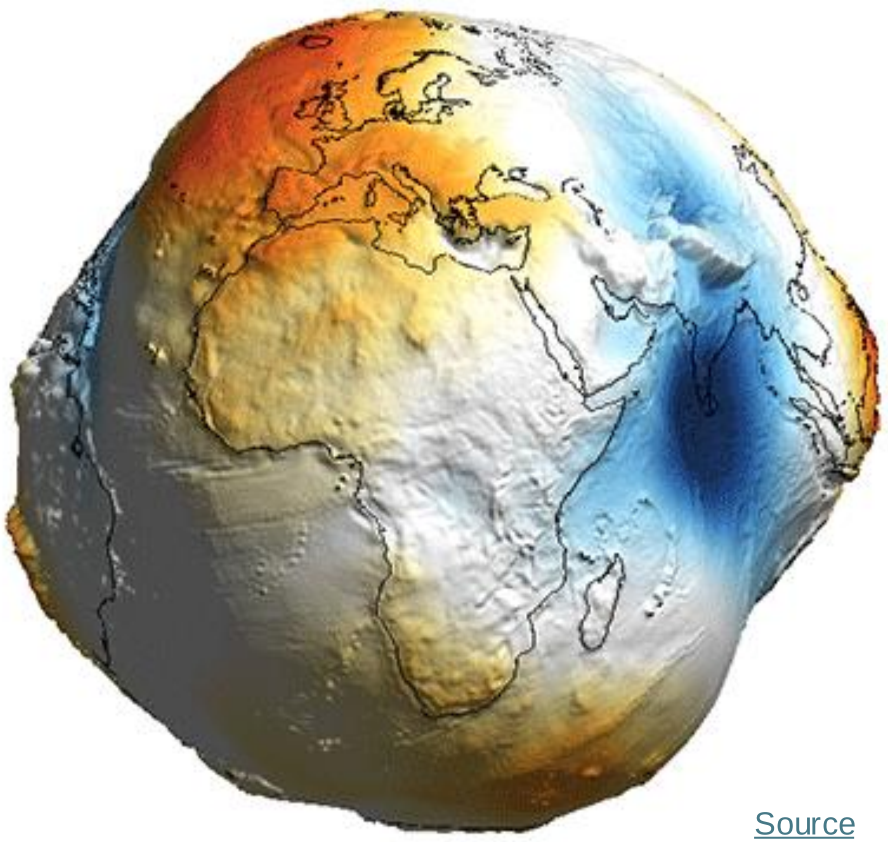
Why should we care about projections or CRS?

If a coordinate system is wrong or missing, data will not display in the correct location

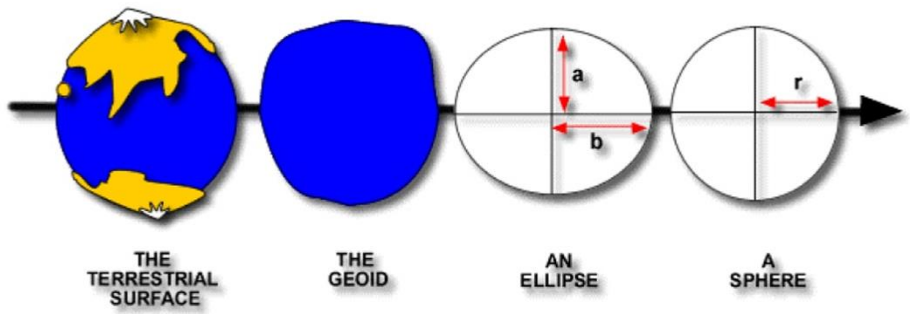
Source: Dan Mahr. https://ihatecoordinatesystems.com/

Earth’s geoid is a complex shape to map

The geoid is an irregular-shaped model of the Earth's gravity field

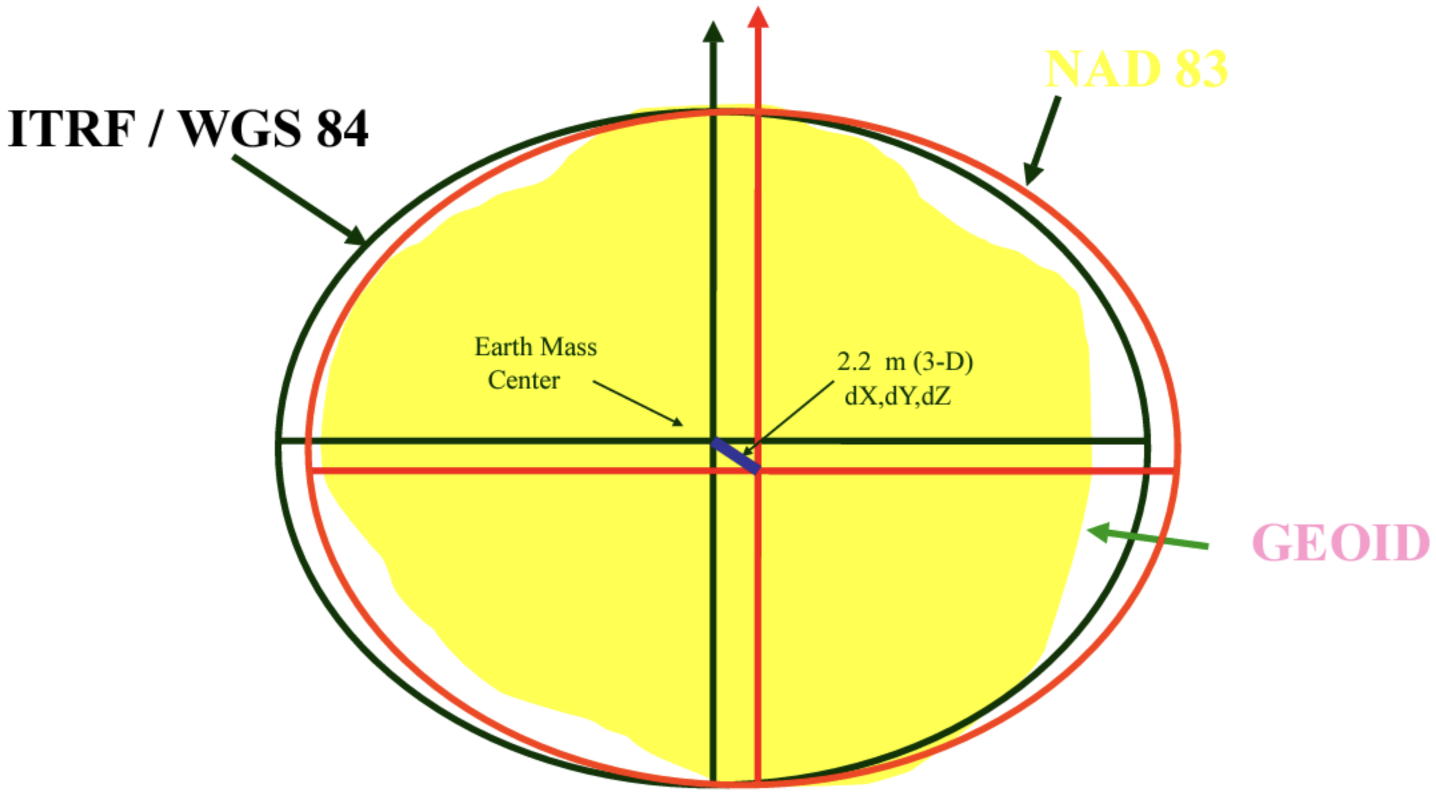


Source



- Sphere can be used as a first approximation to the geoid.
- Fits well locally
- Globally it is a poor approximation.
- Difference between equatorial and polar radius: 21km
- Rotational or biaxial ellipsoid is a good approximation both locally and globally.

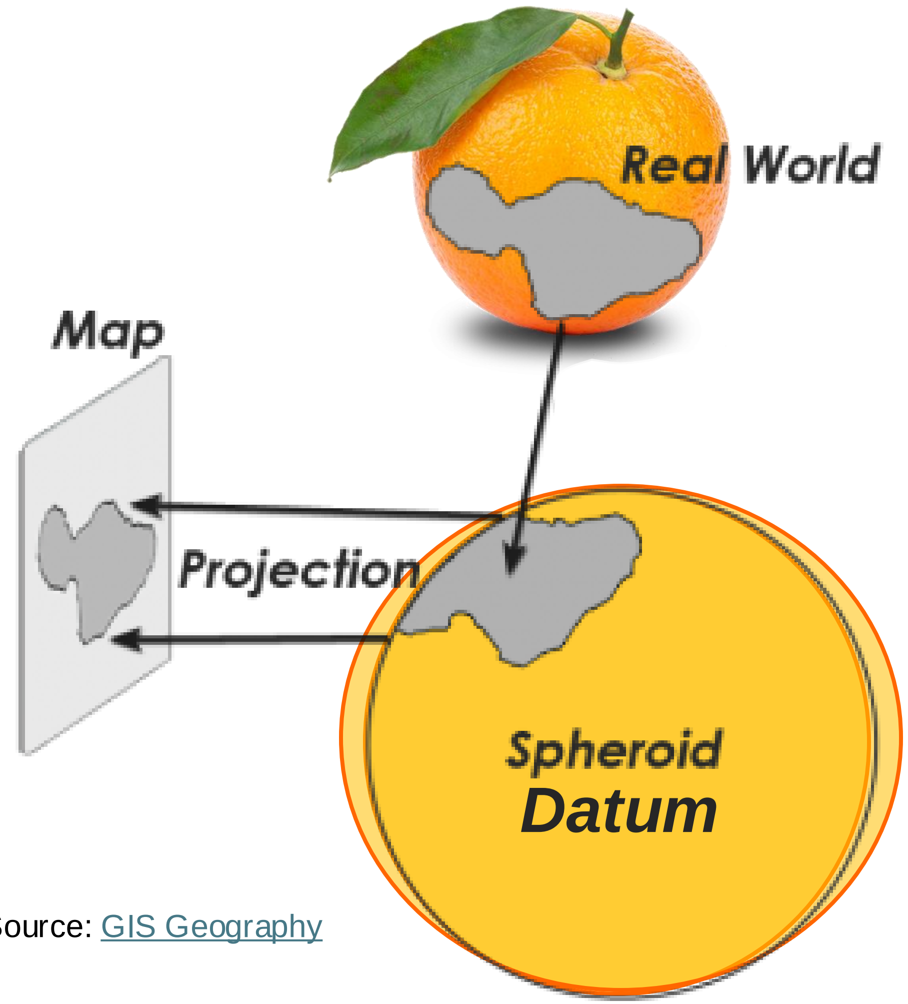
Datum is an idealized mathematical representation of the Earth's 3D model



- Geographic Coordinate System (GCS) is the 3D representation of the Earth's coordinates.
- WGS84 (EPSG:4326), NAD83 (EPSG:4269)

Projection algorithm is applied to GCS to create a Projected Coordinate System (PCS)

- Imagine an orange as the Earth, and you want to be able to peel it in such a way as to lay the peel flat.
- Similarly, **projection is a method by which cartographers translate a 3D globe (spheroid or ellipsoid) to a 2D map surface.**

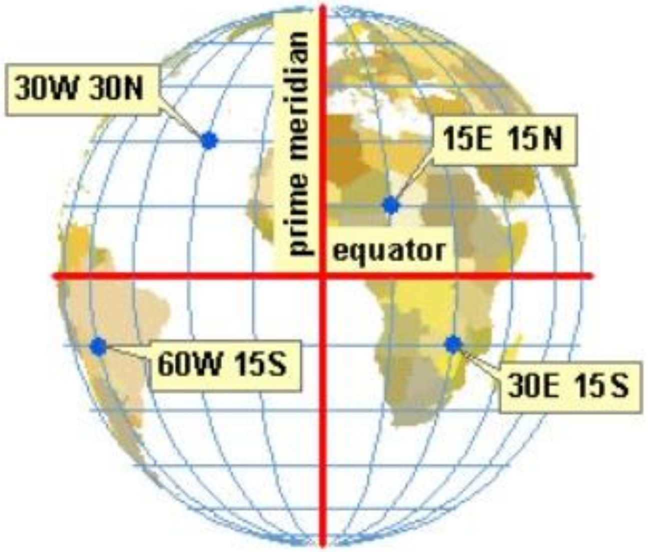


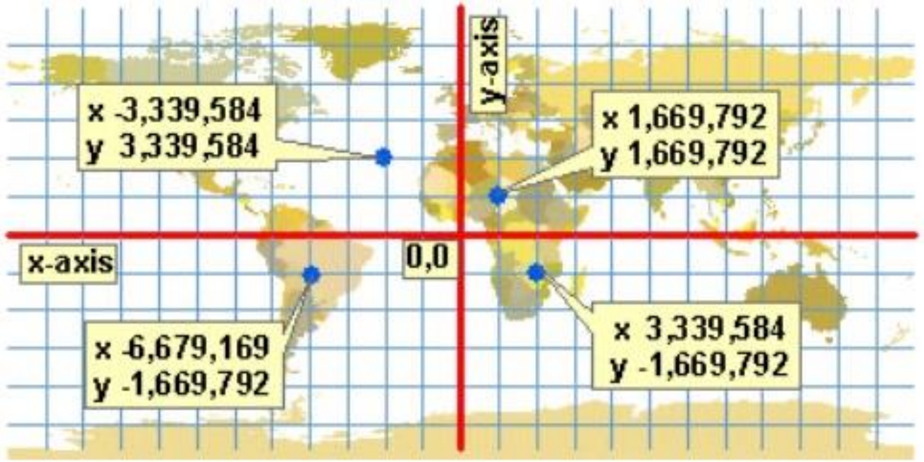
Source: [GIS Geography]

PCS is consisted of several items

- Geographic Coordinate System
- Projection Algorithm
- Linear Unit
- Parameters that center the system on a certain location

https://www.youtube.com/watch?v=kIID5FDi2JQ

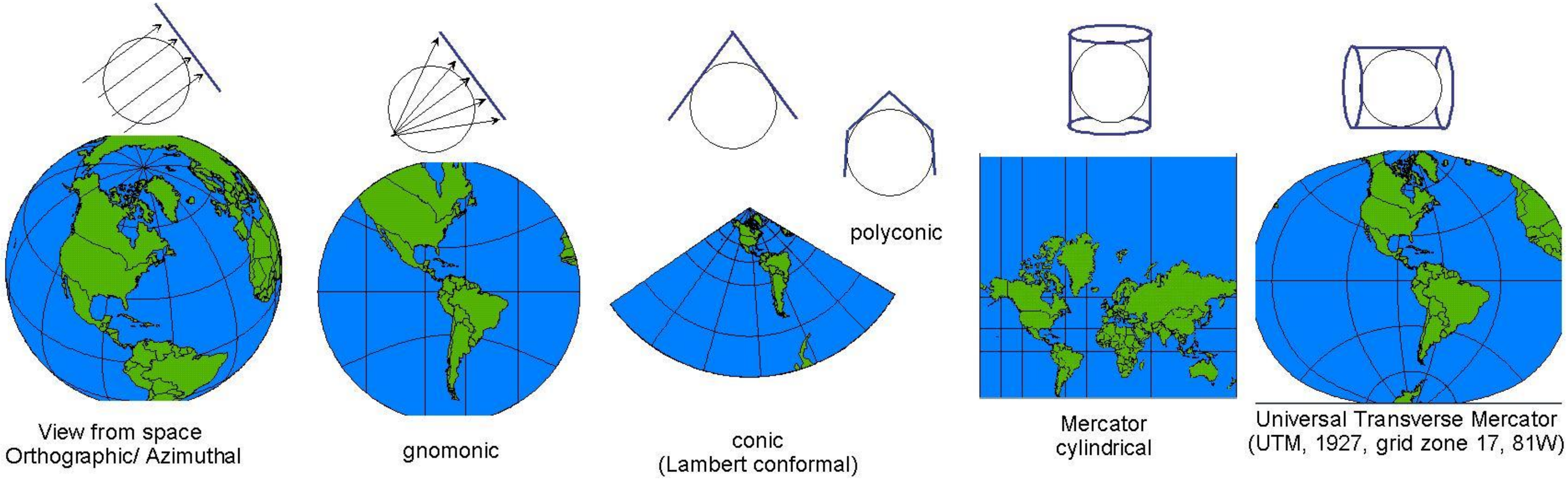




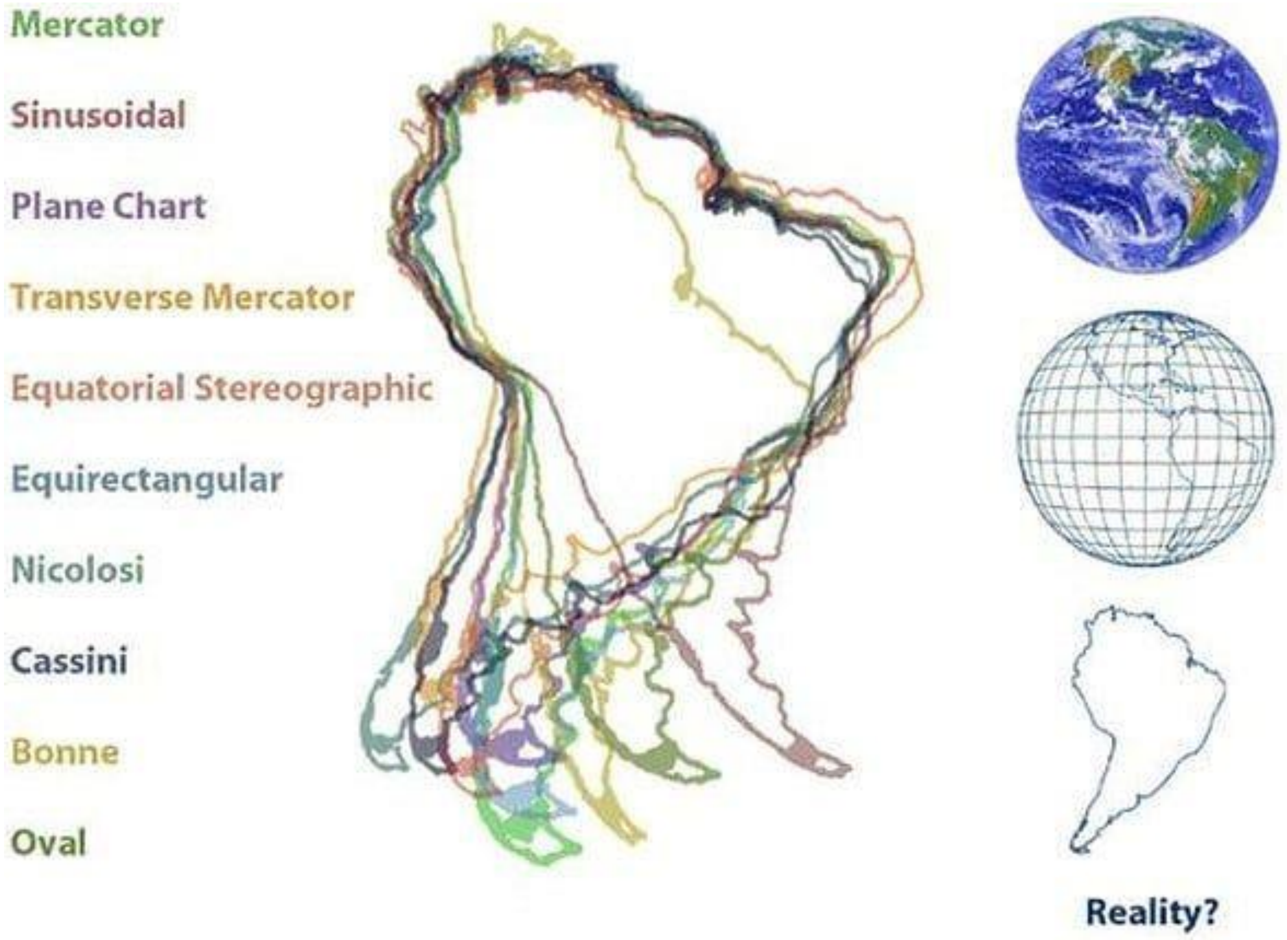
Source: Jochen Albrecht

Lots of option for projection systems

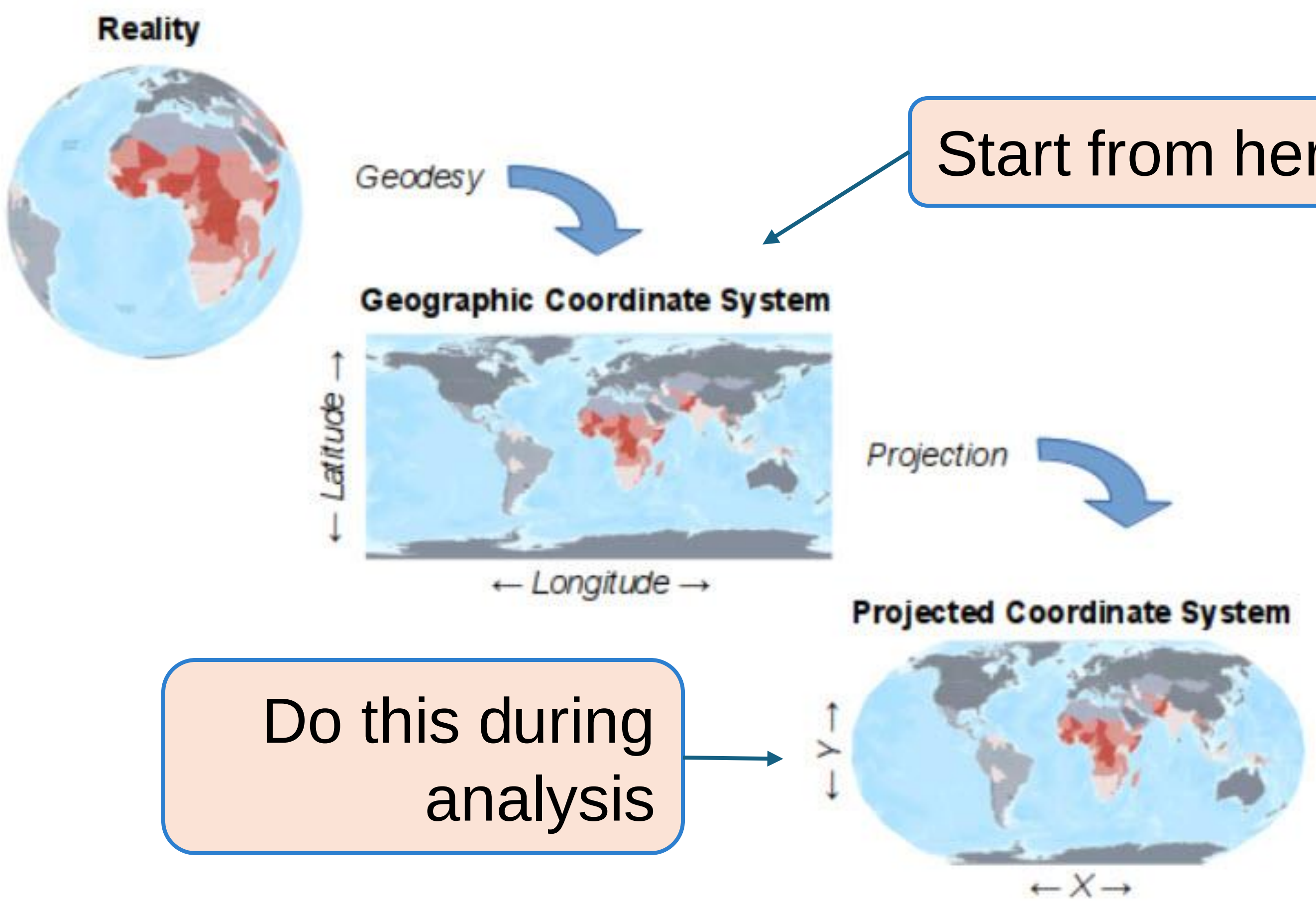
- There are many different types of projections.
- Each have certain strengths and limitations in the following types of distortions: shape, area, distance, direction



Analysis tools with shape, area or distance calculations require data to be in a projection



So, what to do?

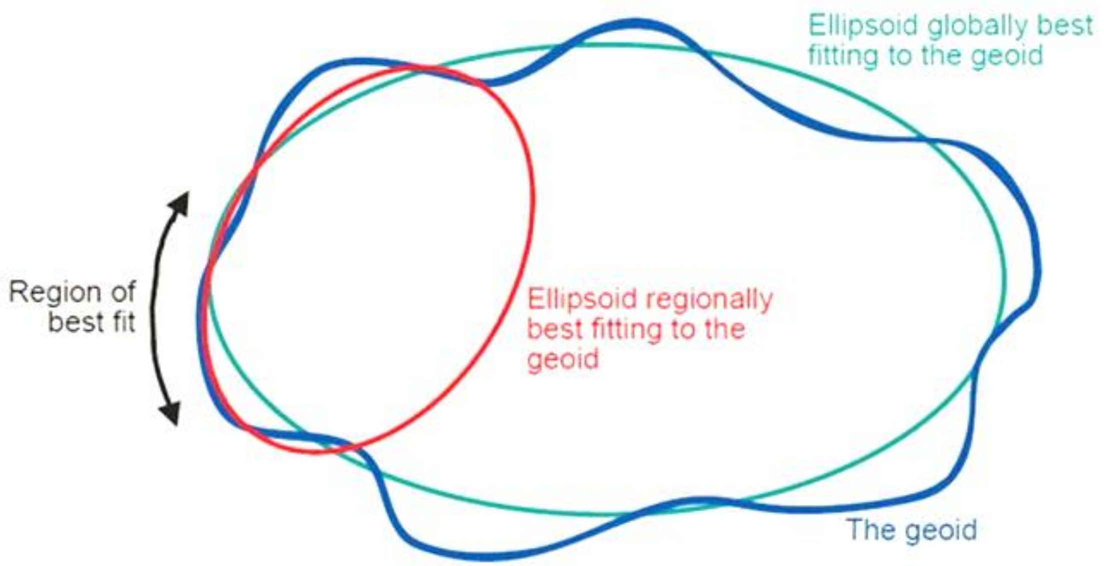


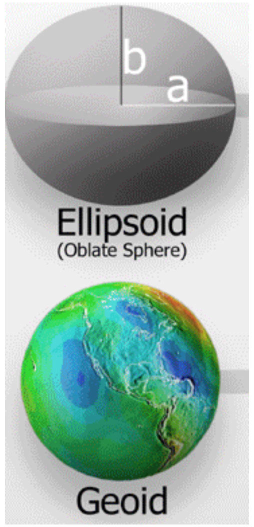
Reality
Geodesy
Geographic Coordinate System
← Latitude →
← Longitude →
Projection
Projected Coordinate System
← Y →
← X →
Start from here
Do this during analysis

Commonly encountered systems

- Geographic Coordinate System

- NAD83 (North American Datum) – best fitting ellipsoid for North America
- WGS1984 (World Geodetic System) – best fitting ellipsoid for the globe/world



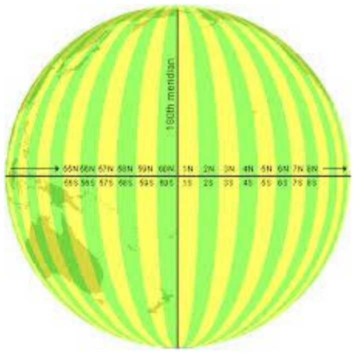


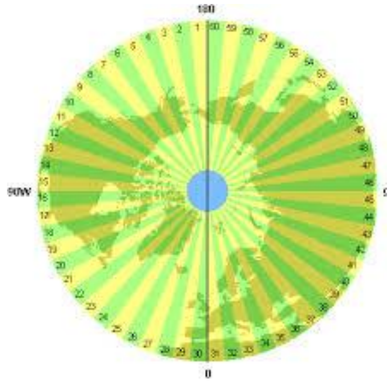
Courtesy of NOAA

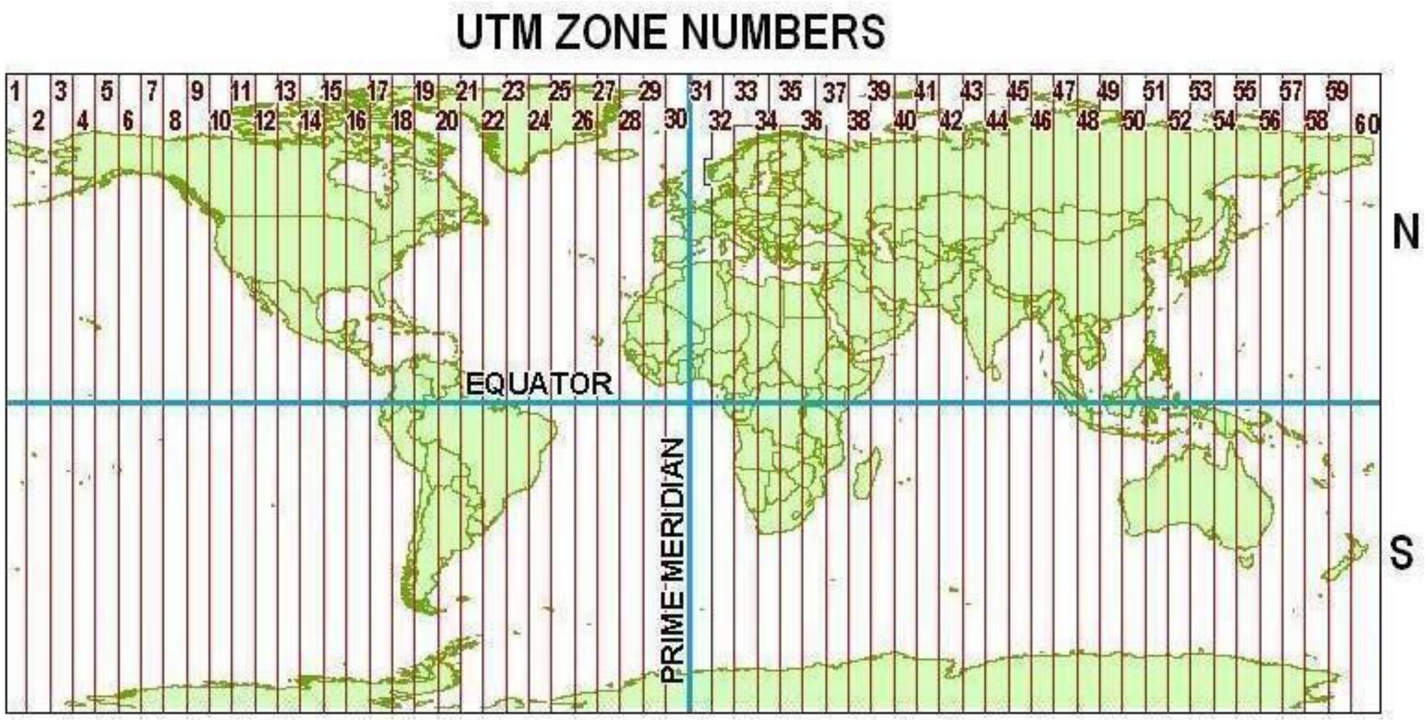
Commonly encountered systems

- Projected Coordinate System

- UTM (Universal Transverse Mercator) – often best for large regions



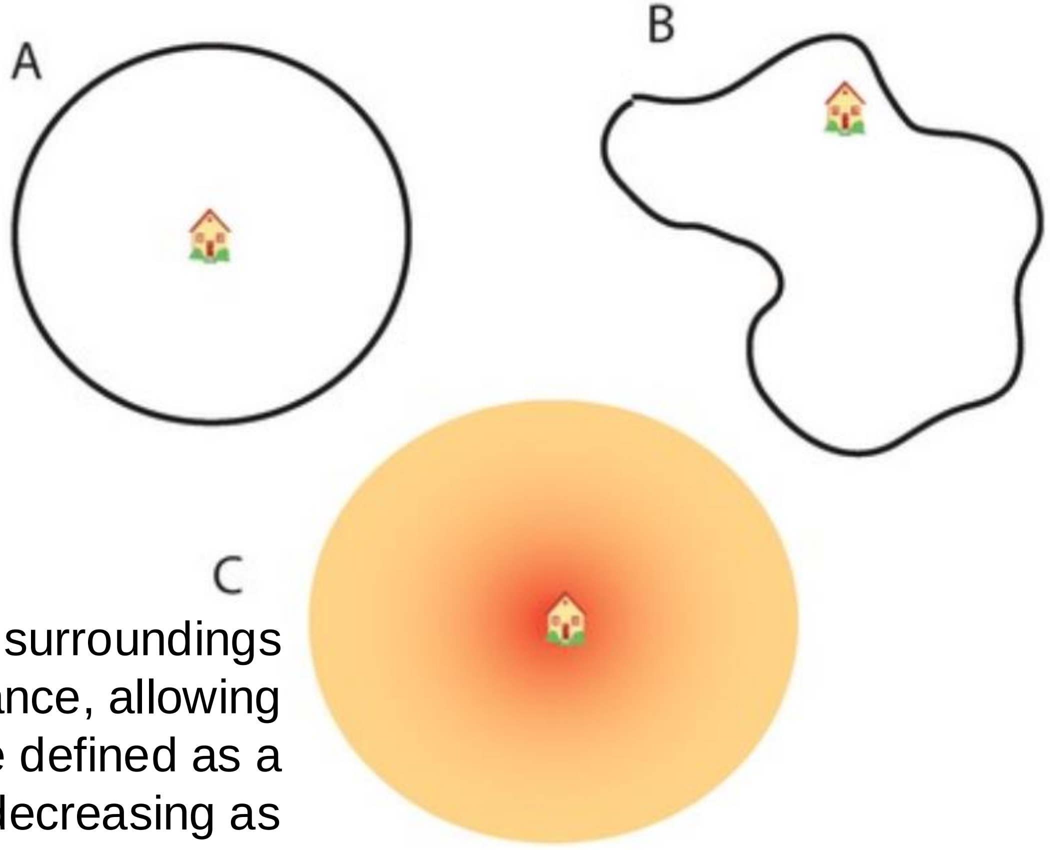




Source: Jochen Albrecht

Neighborhood is a contextual concept

Neighborhood is defined as a circle centered on the house, extending equally in all directions.



Neighborhood is equated with an existing zone, i.e., census tract or precinct, reflecting the common strategy of using existing aggregated data to characterize a household's surroundings.

Weights are applied to surroundings based on distance, allowing neighborhood to be defined as a convolution with weight decreasing as a simple function of distance.

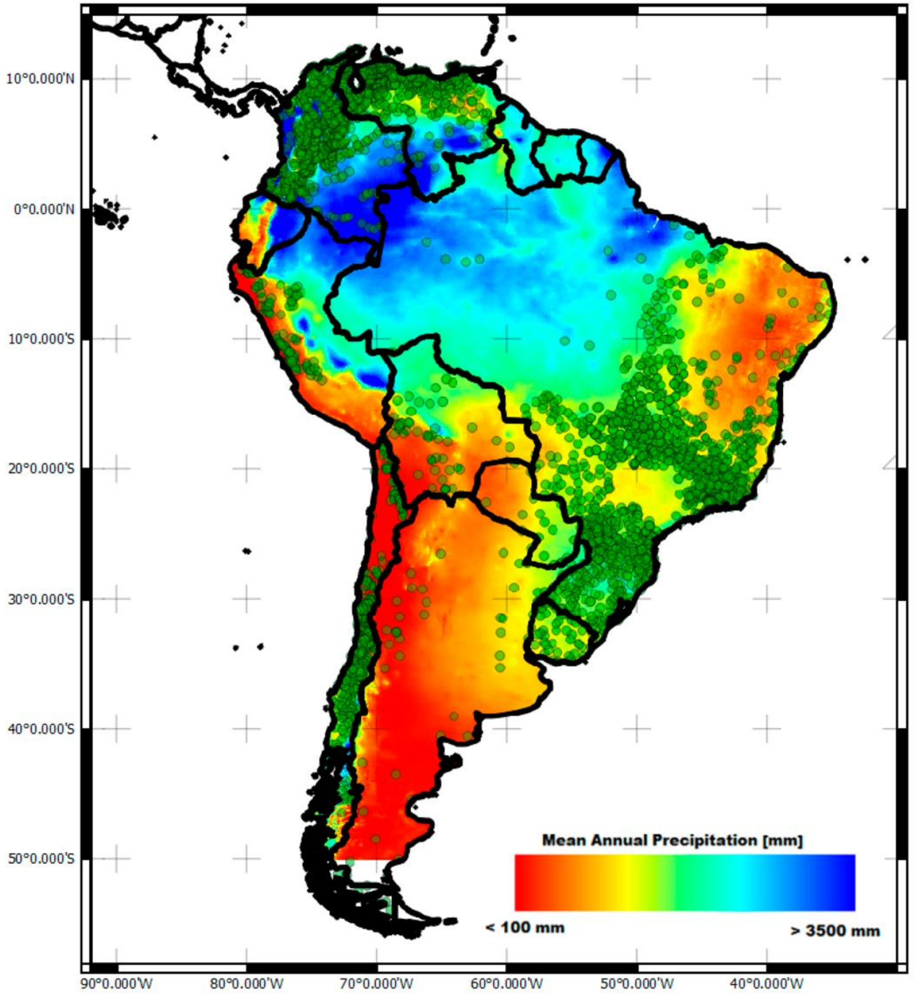
Spatial heterogeneity is common in many contexts

[Source]

- The Earth's surface displays incredible spatial heterogeneity
- Analysis performed in one area cannot be simply transferred to another area without considering its heterogeneity
- Local relationship should be given priority in specific analysis

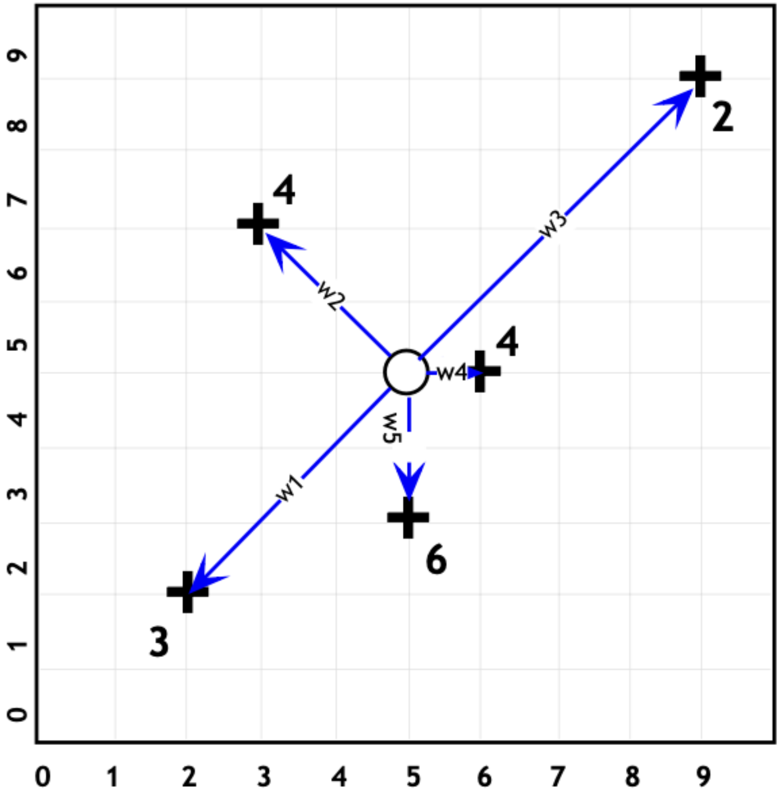
Spatial dependence – the first rule of geography

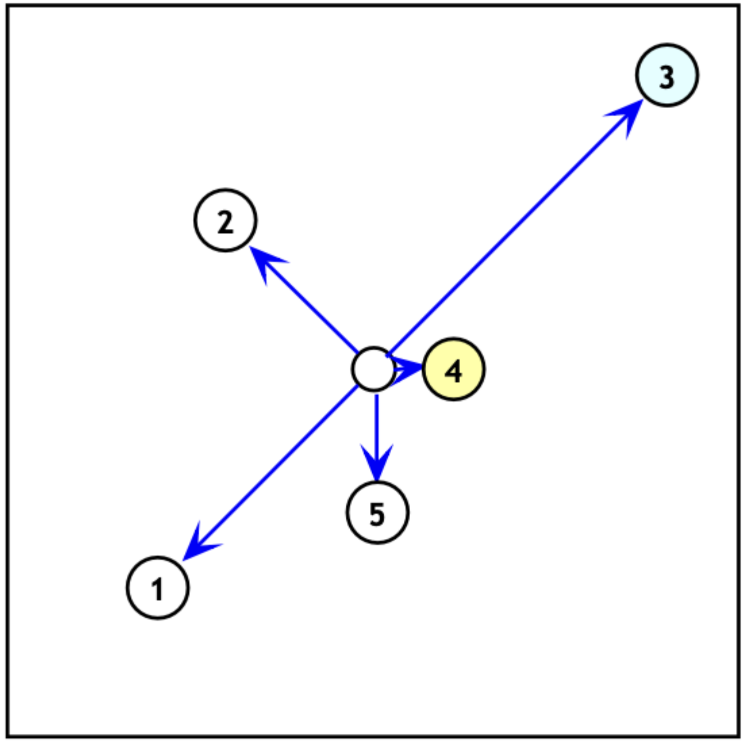
- Tobler's rule: *"All things are related, but nearby things are more related than distant things."*
- Spatial dependence underlines the field of **Geostatistics**
- If we know the information of certain location, we can "interpolate/predict" similar information based on location



Source

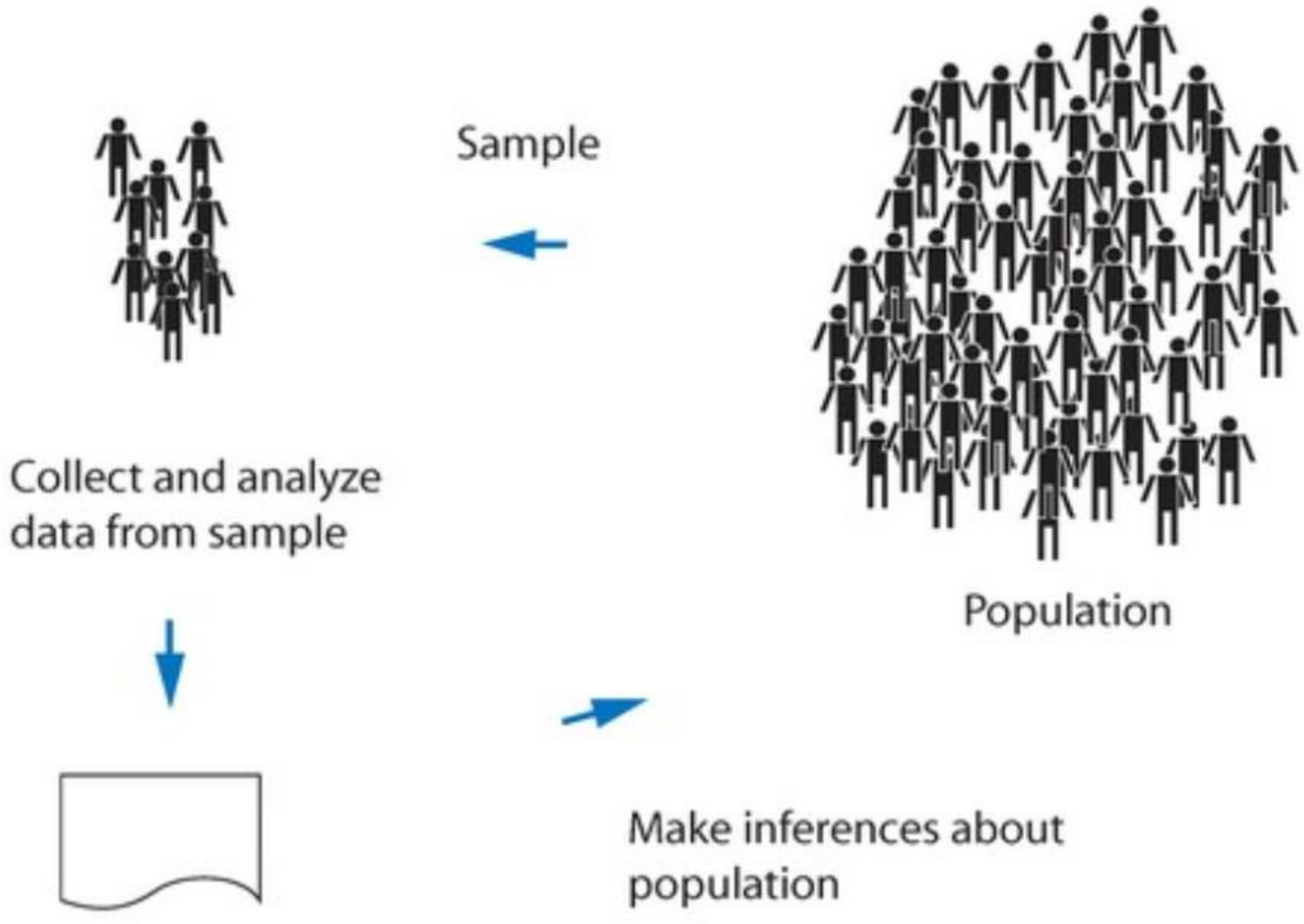
Spatial interpolation uses geostatistics principles to interpolate unknown values at given location



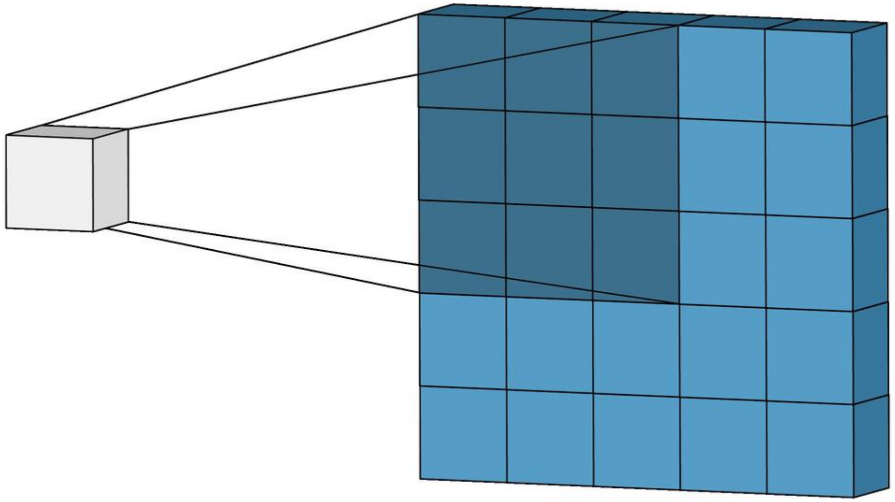


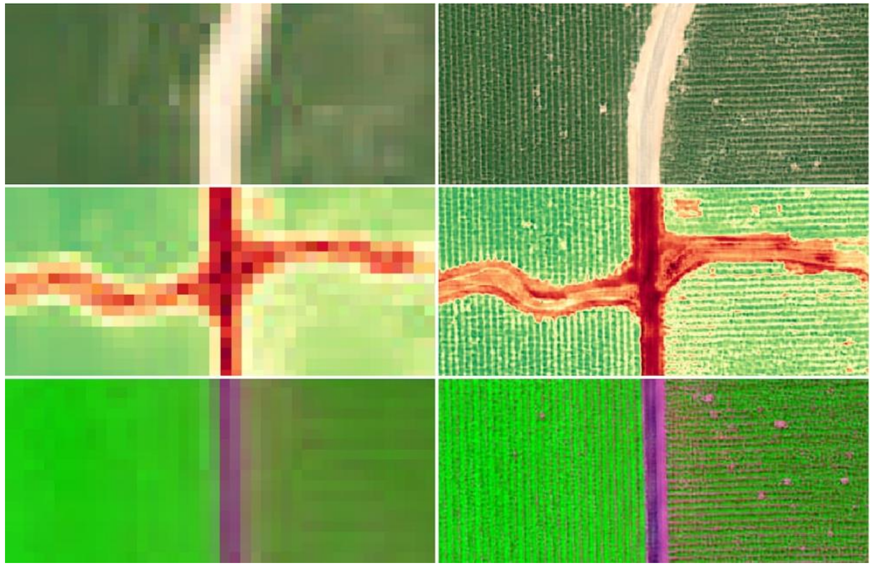
- We can only interpolate ***continuous*** variable, NOT discrete variables
- Deterministic interpolation and geostatistical interpolation

Spatial sampling is very important in geospatial analysis projects



Smoothing often generalizes a complex spatial process and helps with the inference





Source

Thank You