# Introduction to GIS and Spatial Analysis

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# About RCC-GIS

- **Support for Geospatial Information Science Research**
- Assistance for all UChicago students, faculty, and staff
    - Training
    - Consultation
    - Events

- https://gis.rcc.uchicago.edu

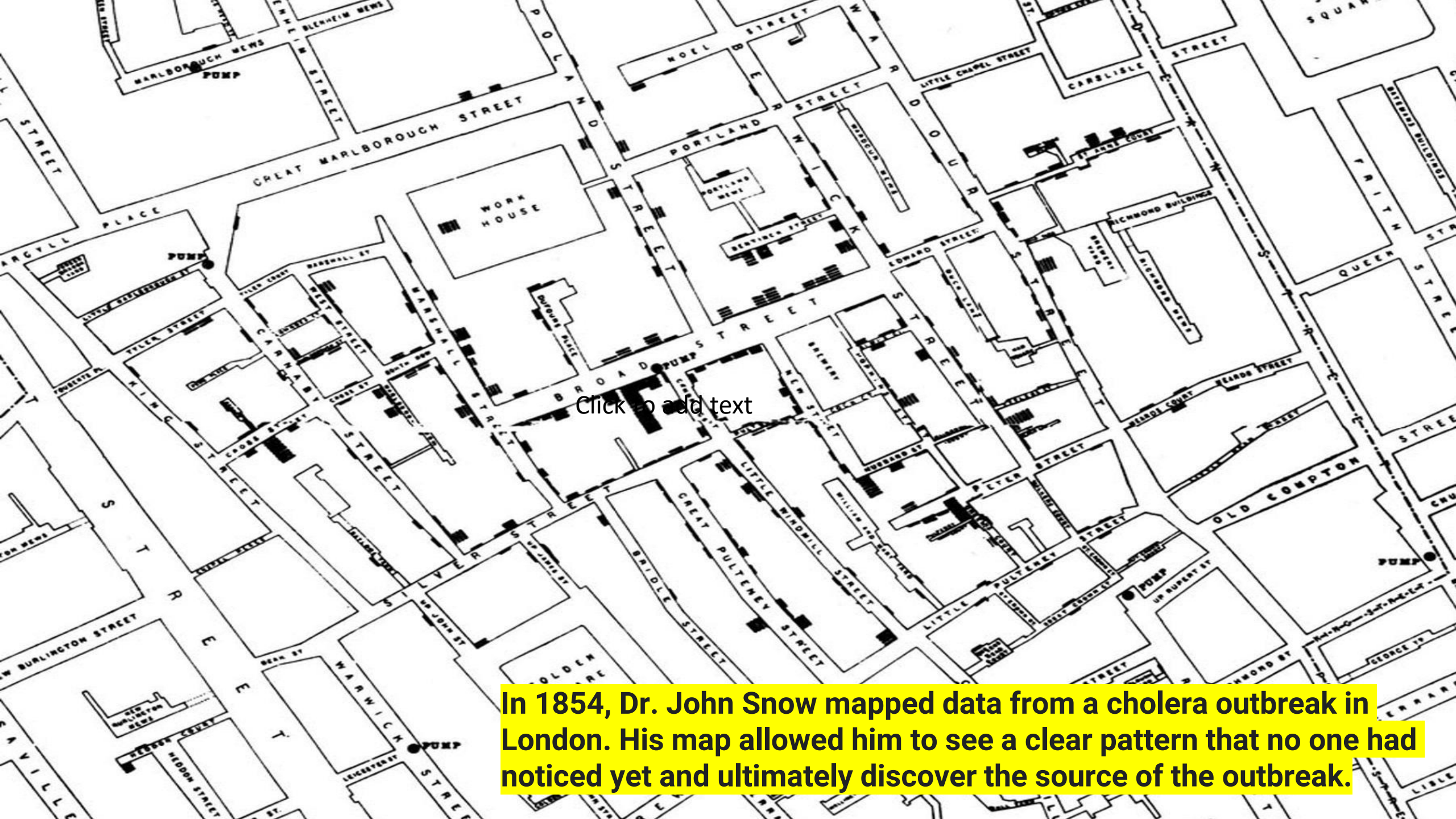
# Topics

- Software and packages for GIS analysis
- Basic GIS operations.
- Understanding the Census
- Spatial Analysis with Vector data
- Geocoding and Geo-referencing
- Basic web mapping techniques

# GIS

- A geographic information system (GIS) lets us visualize, question, analyze, interpret, and **understand data to reveal relationships,  patterns, and trends**.

- - esri


Click to add text
In 1854, Dr. John Snow mapped data from a cholera outbreak in London. His map allowed him to see a clear pattern that no one had noticed yet and ultimately discover the source of the outbreak.


# What can GIS do?

As an integrated  system for geographic data

- Capturing data
- Storing data
- Querying data
- Analyzing data
- Displaying data

# What can GIS do?

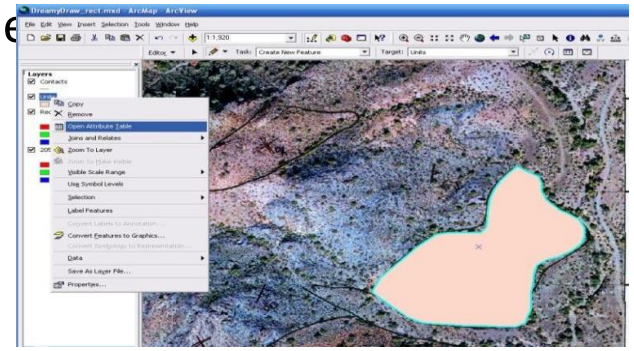
- Geographic Information System (GIS):

  An integrated system for geographic data

  - Capturing data
  - Storing data
  - Querying data
  - Analyzing data
  - Displaying data

# Capturing data

- Digitizing
  - Creating a digital copy of existing data
  - Paper maps, Aerial imagery, Topographic maps
  - Output is a GIS friendly vector format



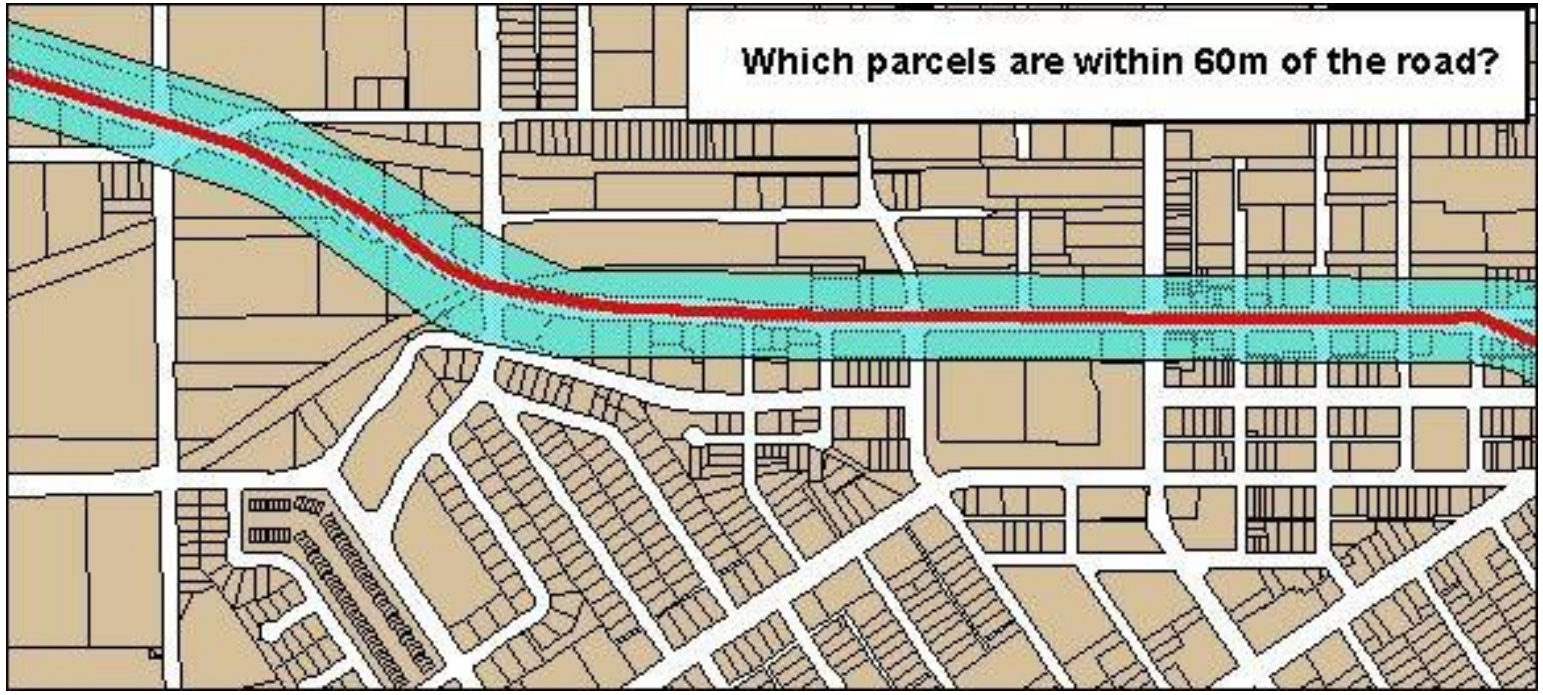
- GPS
  - Global Positioning System
  - Coverage of entire planet
  - Data Formats:
    - Temporal – accurate to about 14 nanoseconds
    - Spatial – sub-meter accuracy

# Storing data

- Files
  - Shapefile
  - KML (Google)
  - Spreadsheet
  - Esri Geodatabase
- Spatial Database
  - PostGIS, Oracle, SQL Server
  - Traditional database management system that also stores vector feature geometry and location data

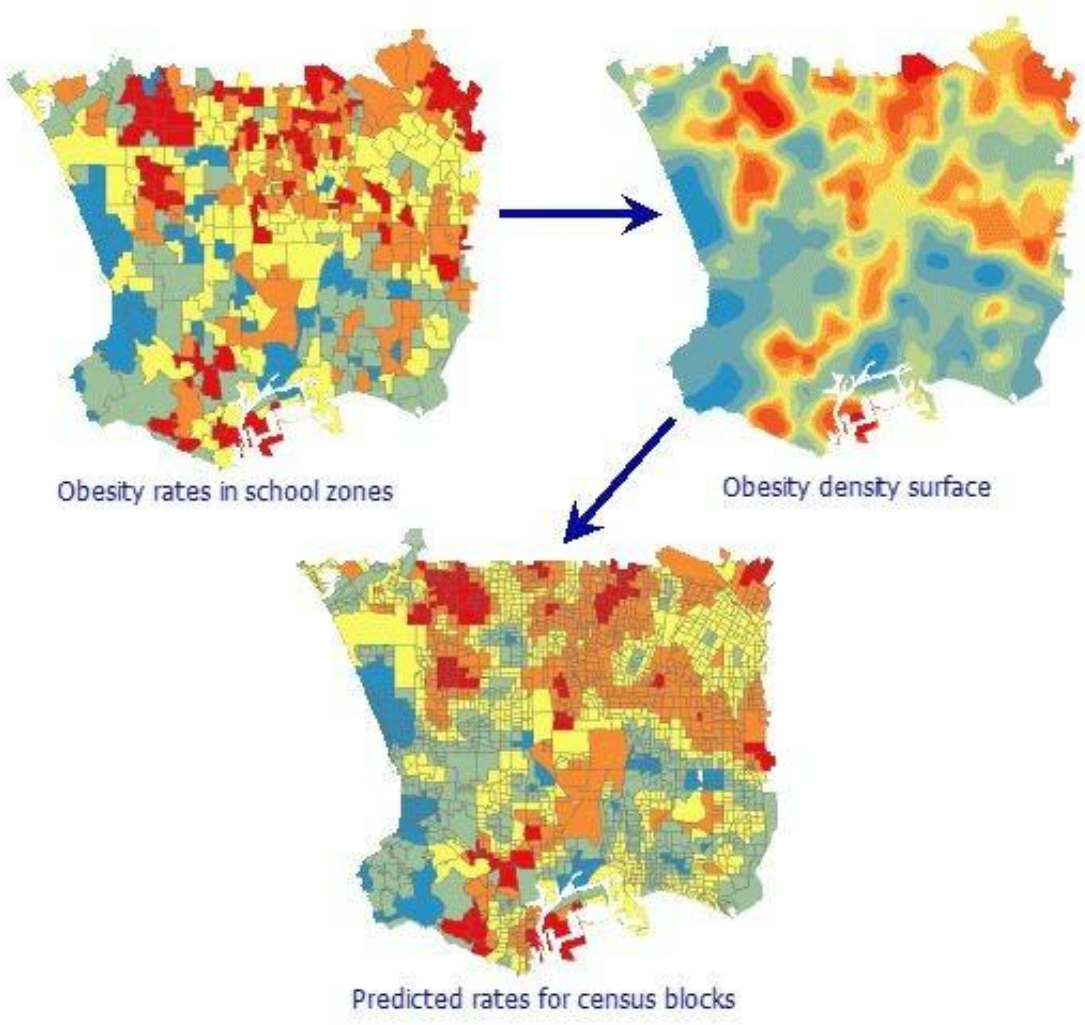
# Querying data

Ask a question of the data based on location or other attribute



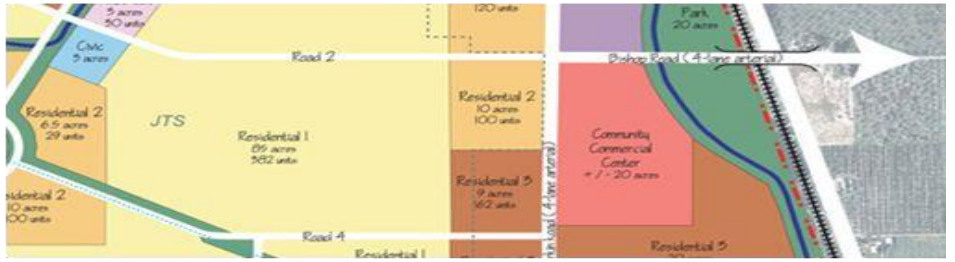
# Analyzing data

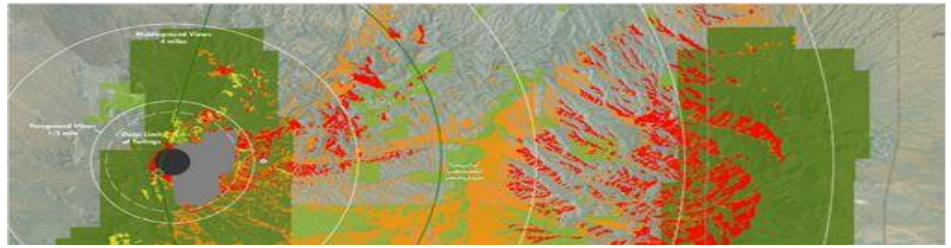
- Performing operations on the spatial data
  - “How far am I from the nearest park?”
  - Overlays
  - Extracts
  - Proximity
  - Spatial Statistics



# Displaying data

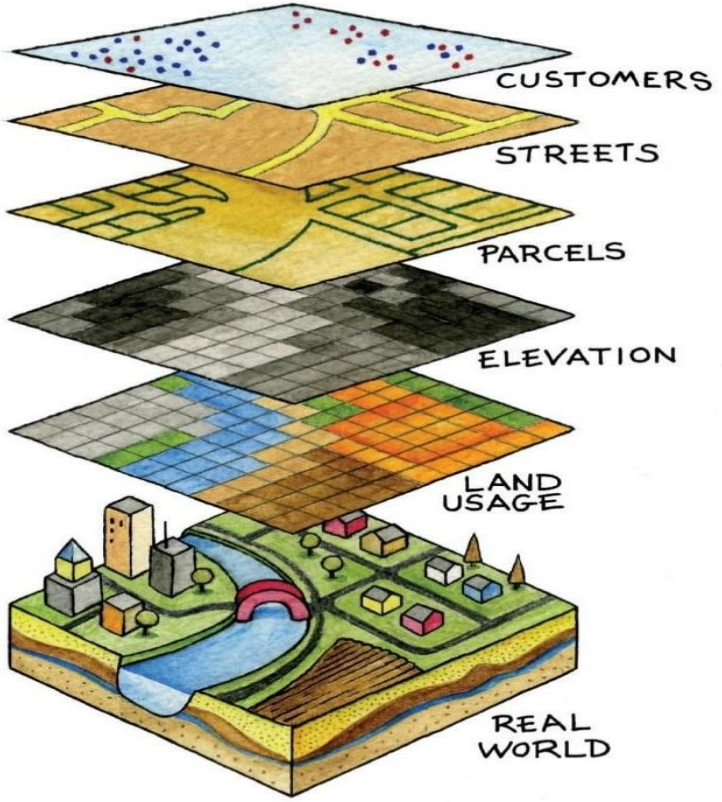
- Mapping
  - The display of spatial data for a specific purpose
  - Visualization
    - Re-emerging as a popular means to artistically portray traditional data
    - Not necessarily spatial data
- Output Format
  - Print or Web

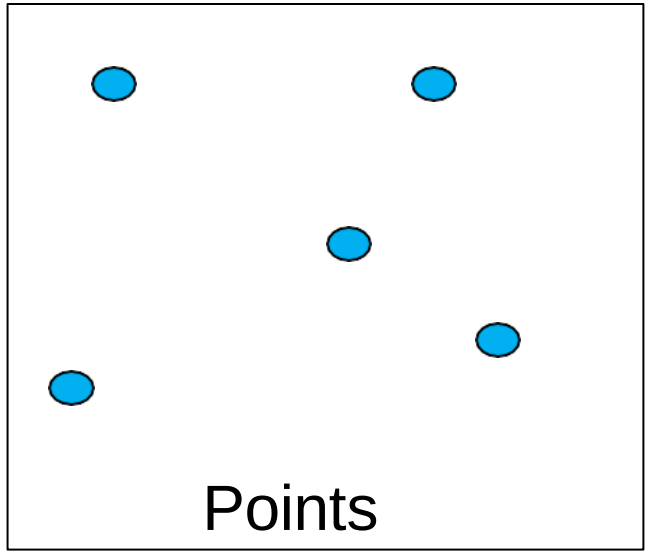



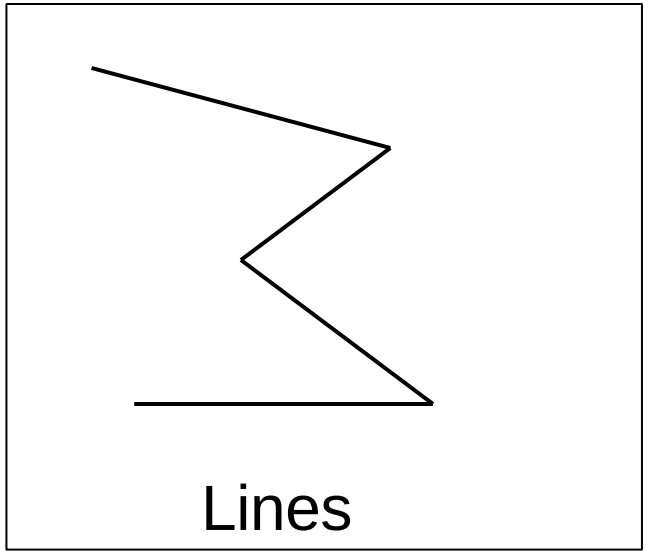
# Spatial Data Models

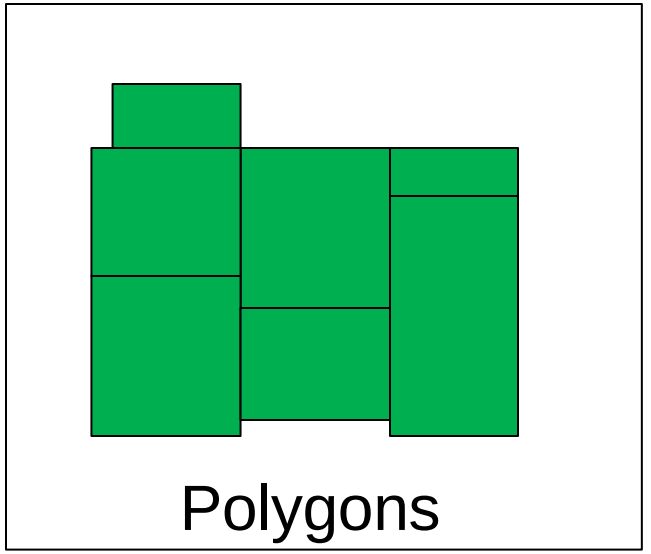
- Vector
- Raster



# Vector Data Model



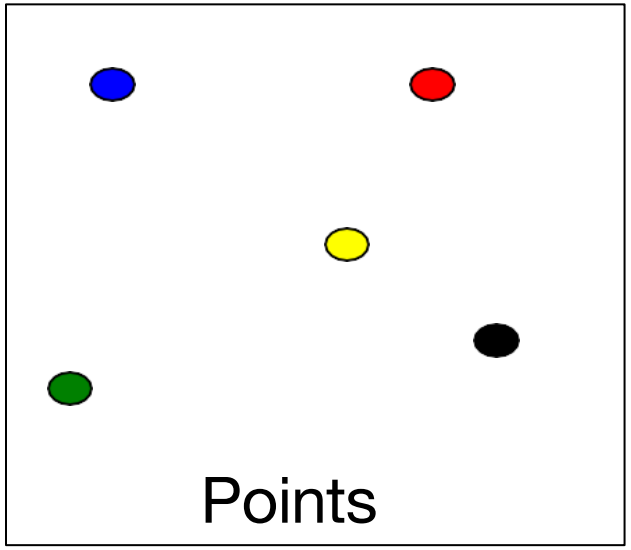



# Spatial and Tabular Data

- Adds geometry to traditional data
  - Geometry: location and geometric characteristics of geographic (real-world) features
  - Attributes: data describing the characteristics of geographic features

# Spatial and Tabular Data

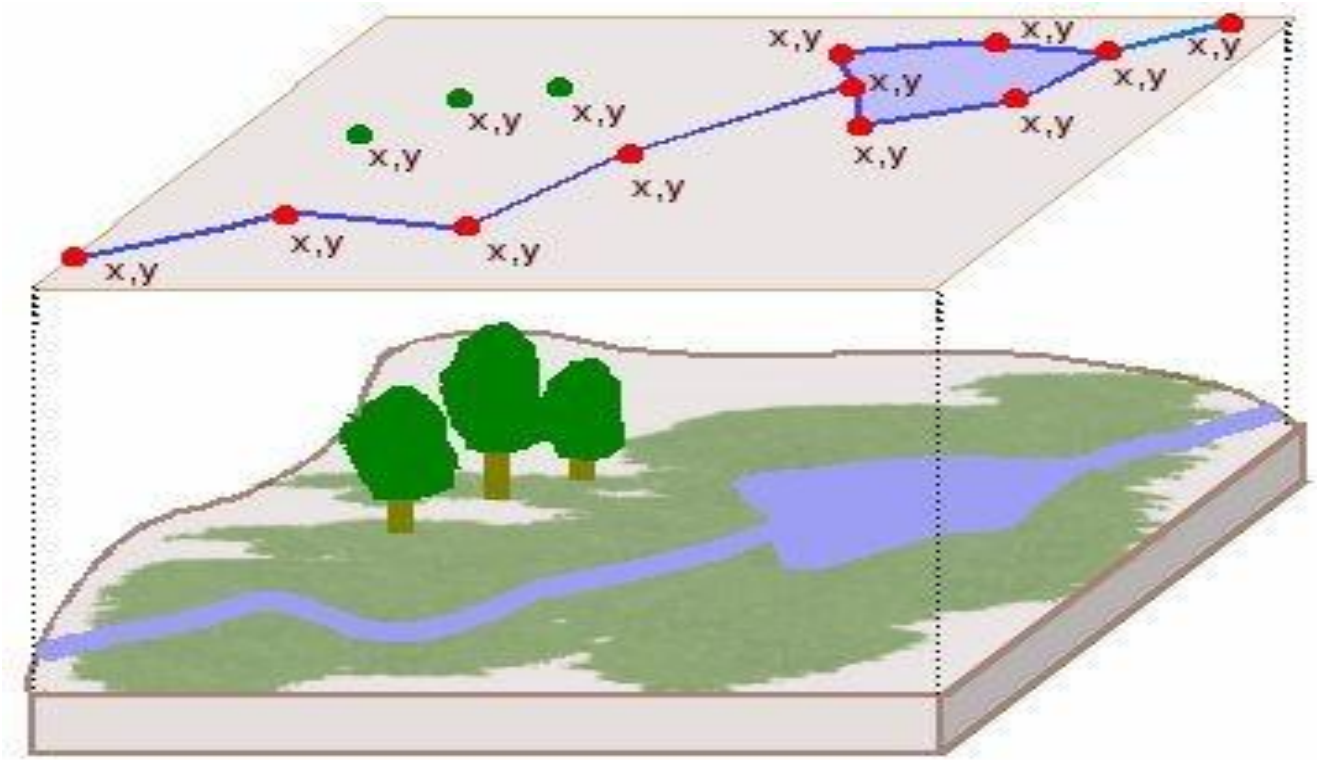
## **Geometry + Attributes**




| **ID** | **Color** | **Use** |
|---|---|---|
| 1 | Blue | Hospital |
| 2 | Red | Fire Dept. |
| 3 | Green | Office |
| 4 | Yellow | University |
| 5 | Black | Retail |

# Vector Model

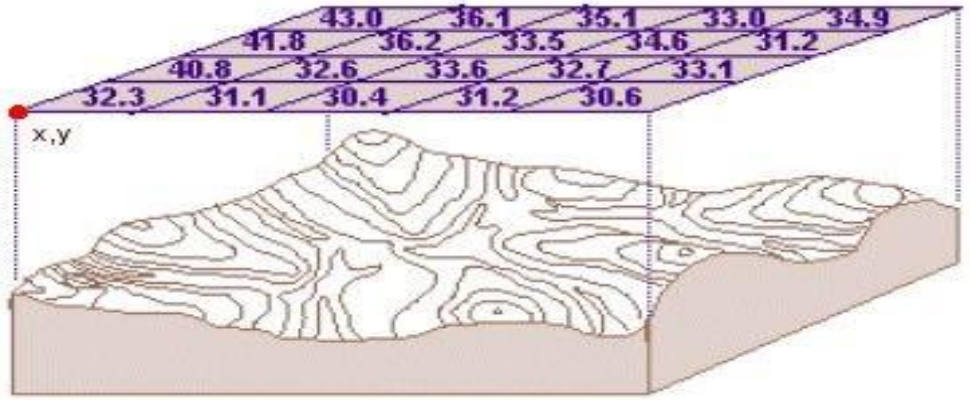
- Vector
  - Discrete entities defined by coordinate points
  - Three types of vector data
    - Point
    - Line
    - Polygon




Source: ESRI Virtual Campus

# Raster Model

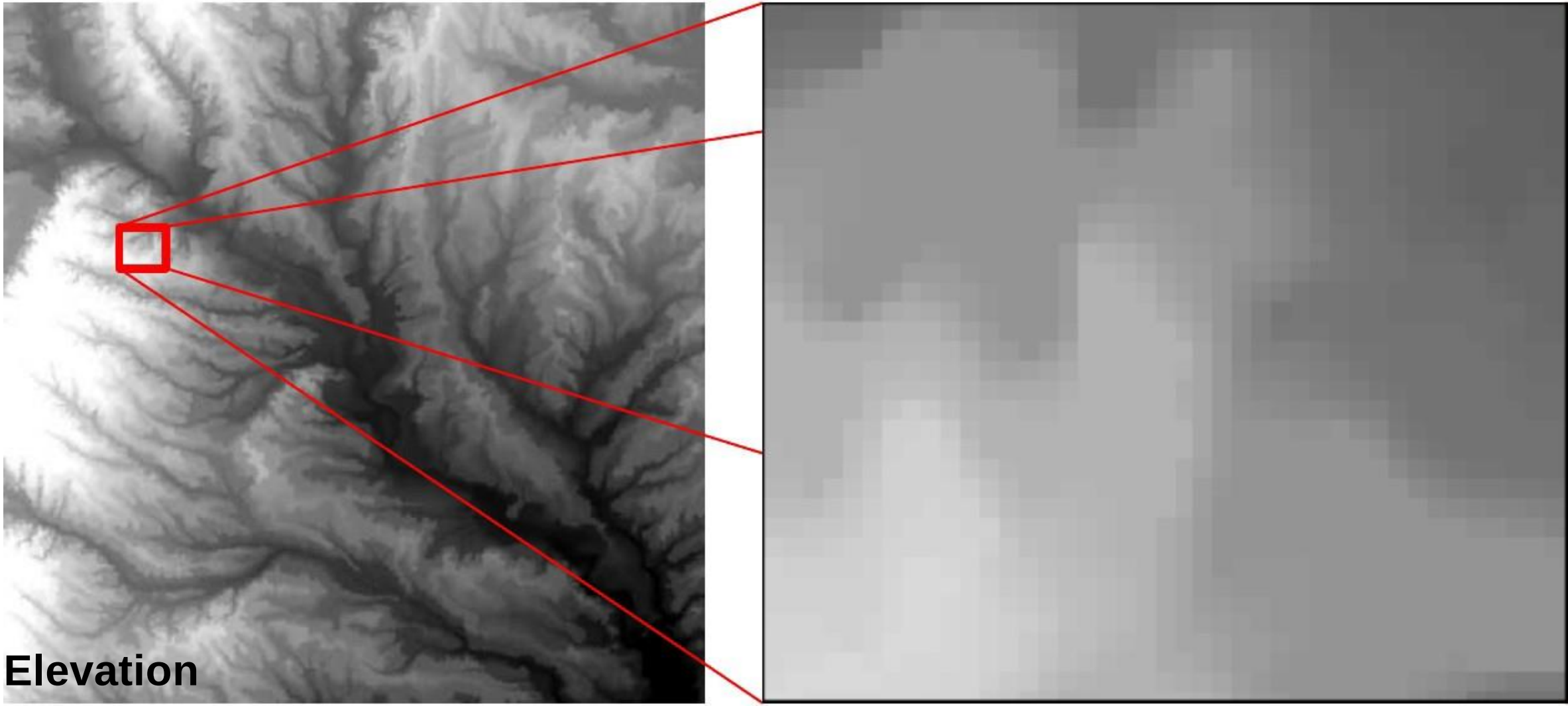
- Composed of a regular grid of cells
- Every grid cell has a value
- Every point on ground belongs to a grid cell
- Examples
  - Elevation
  - Crime hotspot
  - Temperature
  - Rainfall




AVERAGE ELEVATION

# Raster Data Model

- Conventionally, stored row by row from the top left corner
- Attributes are recorded by assigning each cell a single value: e.g., landuse type
- Simple data structure
  - Directly store each layer as a single table
  - each layer is analogous to a ''spreadsheet''  or ''matrix''



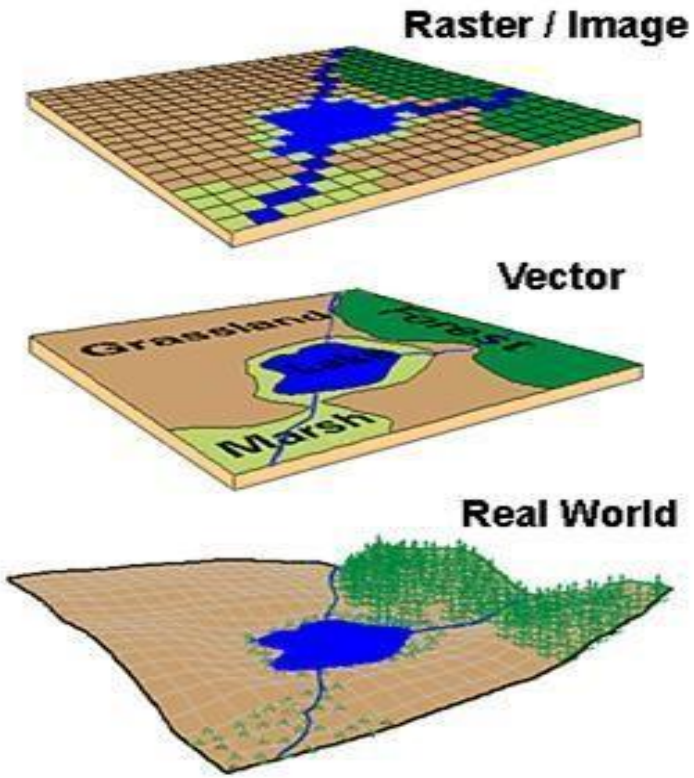

- High : 262
- Low: 73

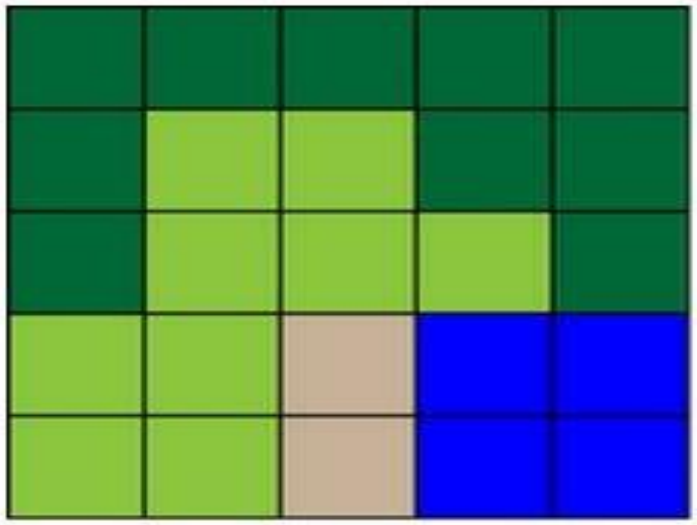
## Elevation in Dallas county

The whole county and a small area in thecounty
(Data Source: USGS)

# Raster vs. Vector

- Different ways of displaying the “real world”



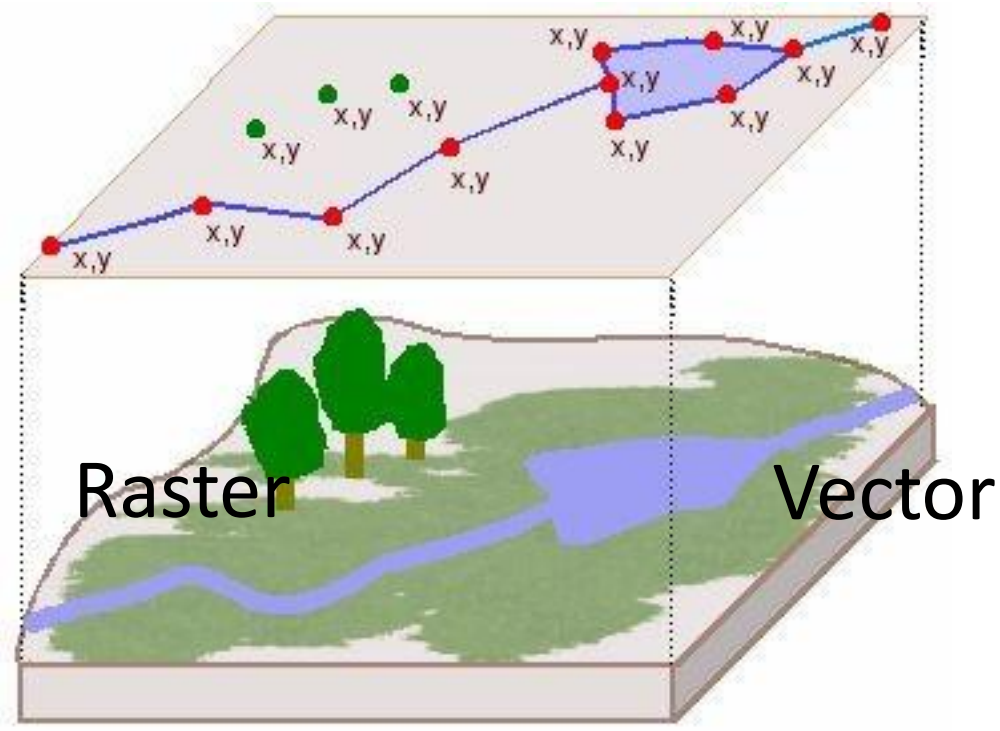
Raster

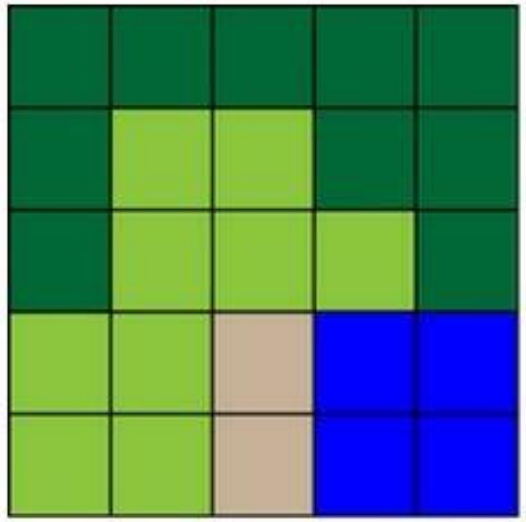
Vector

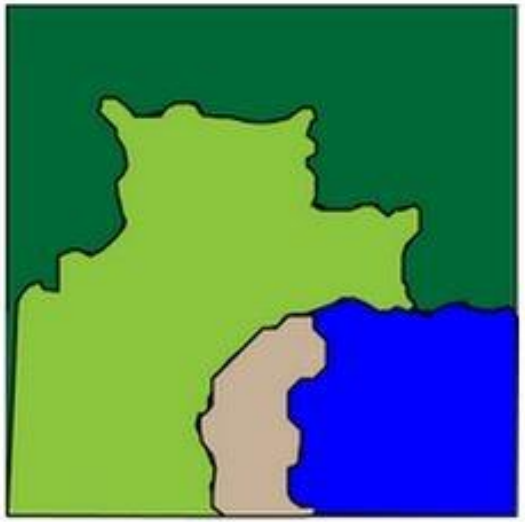
Source: University of Connecticut

# Generalization

- The amount of detail given to an object





# Data formats

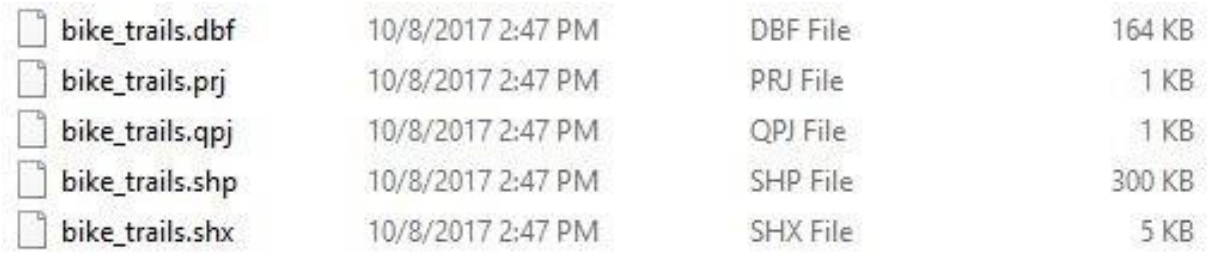
Individual files vs. databases

# Spatial Data: Shapefile

- Most common spatial data format in GIS
- Has been around for 40 years!
- Made up of points, lines, or polygons (**vector**)
- All GIS software will read shapefiles
- Used across all disciplines

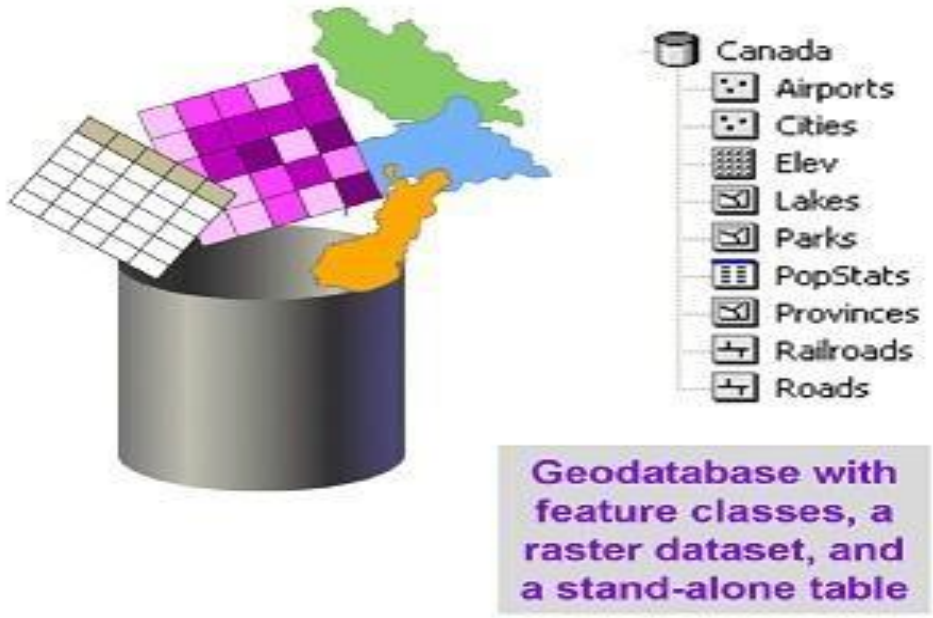
# Spatial Data: Shapefile

- Single shapefile actually consists of multiple files
  - .shp – stores geometry
  - .dbf – stores attributes
  - .shx – index file
  - .prj – projection file
  - .xml – metadata file



# Geodatabase

- Stores a set of files
- Also allows for data query, data management



# Feature Class

- Layer
- Grouping of one type of feature

  (i.e. points, lines, polygons)
- With spatial and attribute information for each feature
- A “shapefile” stored within a Geodatabase

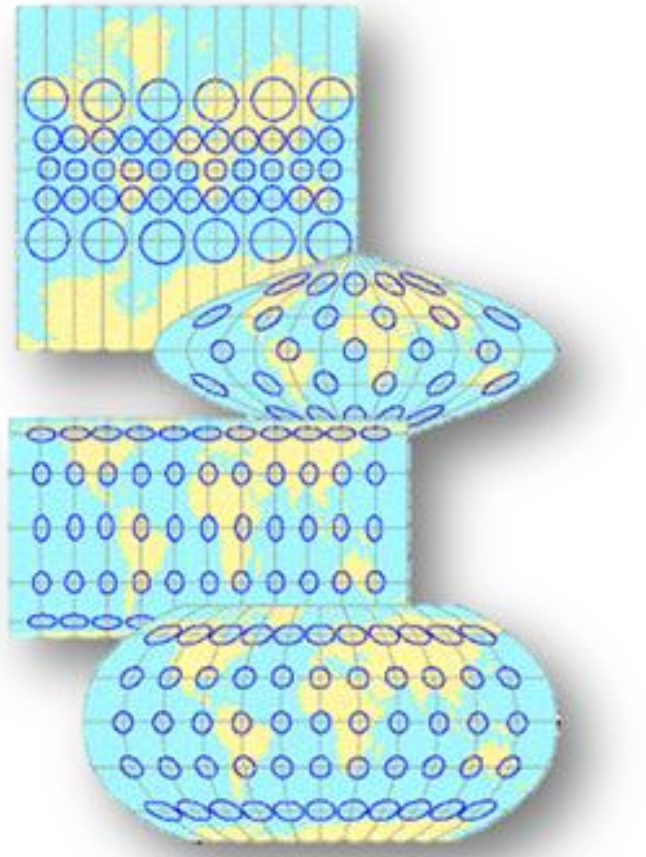
# Metadata

- Data about data
- Describes the content, lineage, creator, distributor, processing steps, and spatial reference of the spatial data
- Helps users determine the availability and access requirements for data
- Helps users judge the quality and “fitness-for-use” of the data for their particular application
- Results only as good as input data!
- “**View Metadata**” in ArcGIS Pro

# Projection

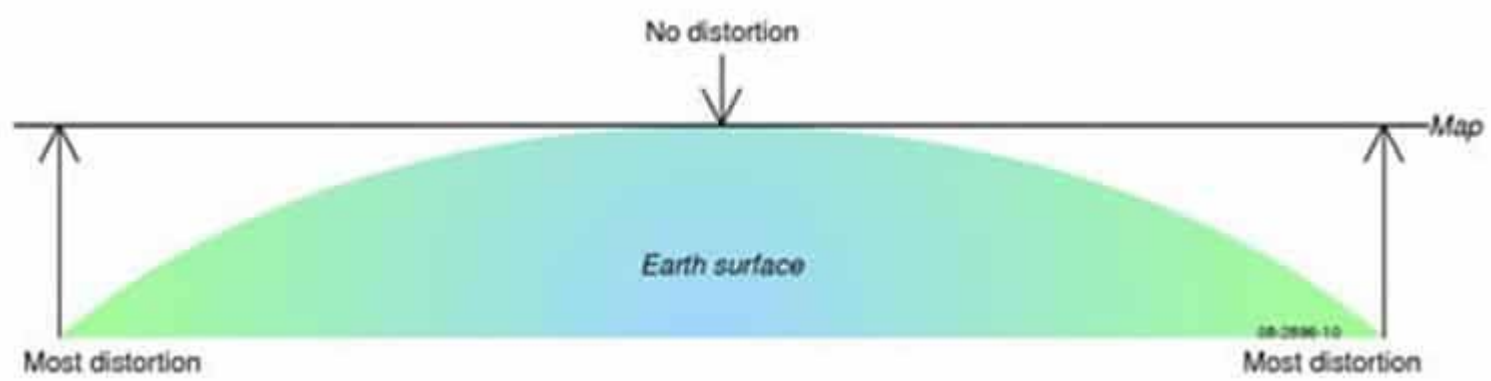
- Earth is spherical, maps are not
- Projections allow for “best” views of specific areas
- Will not be covered in detail but
  - Different Scales use different projections
  - States have their own projections
  - Counties have their own projections

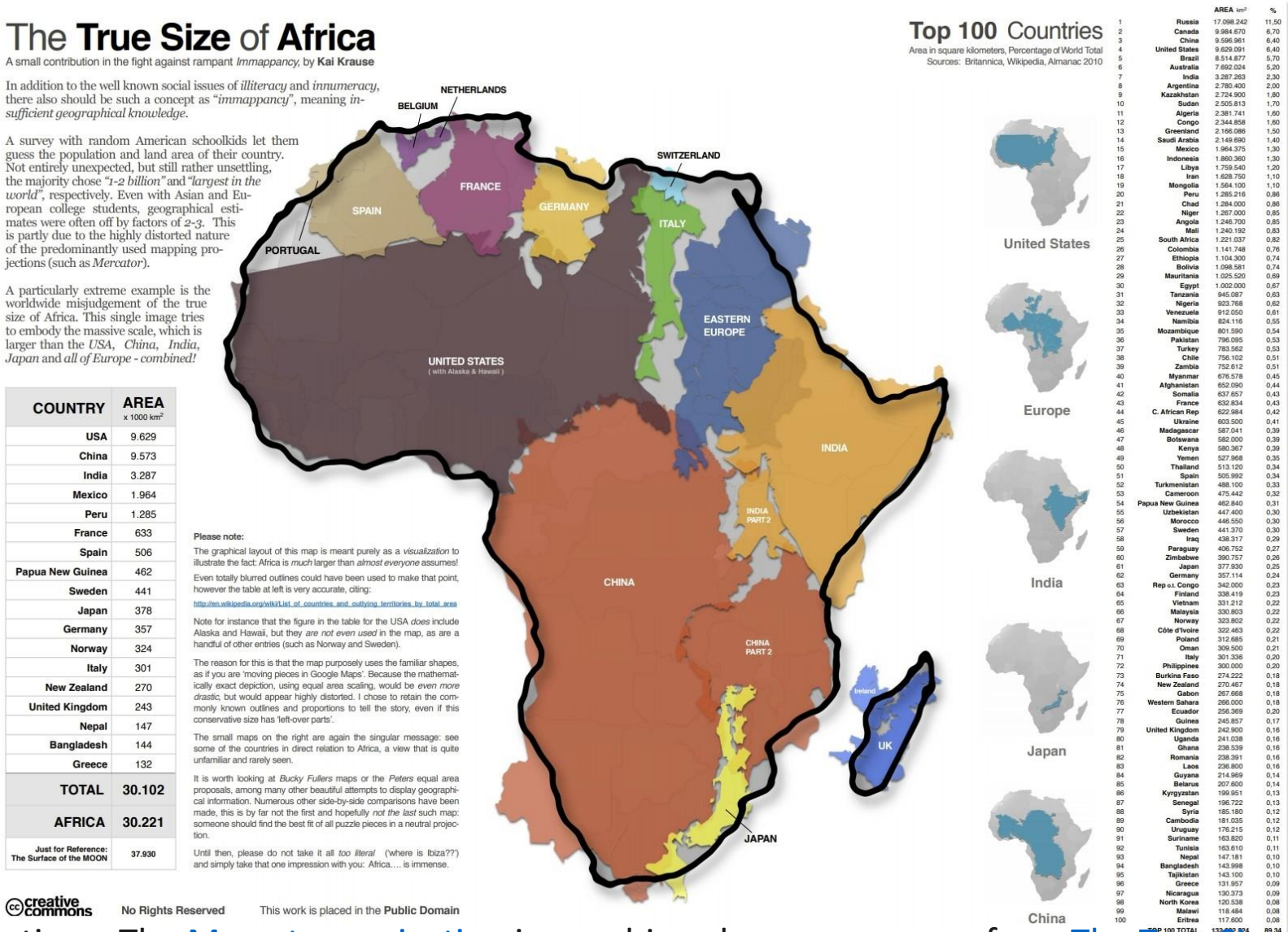
# Projections



projection distortion

- The Earth is an ellipsoid whose larger radius is located at the Equator. If the jurisdiction of the owner is small enough, the planar assumption is valid.






| COUNTRY | AREA x 1000 km² |
|---|---|
| USA | 9.629 |
| China | 9.573 |
| India | 3.287 |
| Mexico | 1.964 |
| Peru | 1.285 |
| France | 633 |
| Spain | 506 |
| Papua New Guinea | 462 |
| Sweden | 441 |
| Japan | 378 |
| Germany | 357 |
| Norway | 324 |
| Italy | 301 |
| New Zealand | 270 |
| United Kingdom | 243 |
| Nepal | 147 |
| Bangladesh | 144 |
| Greece | 132 |
| TOTAL | 30.102 |
| AFRICA | 30.221 |
| Just for Reference: The Surface of the MOON | 37.930 |

**Top 100 Countries**

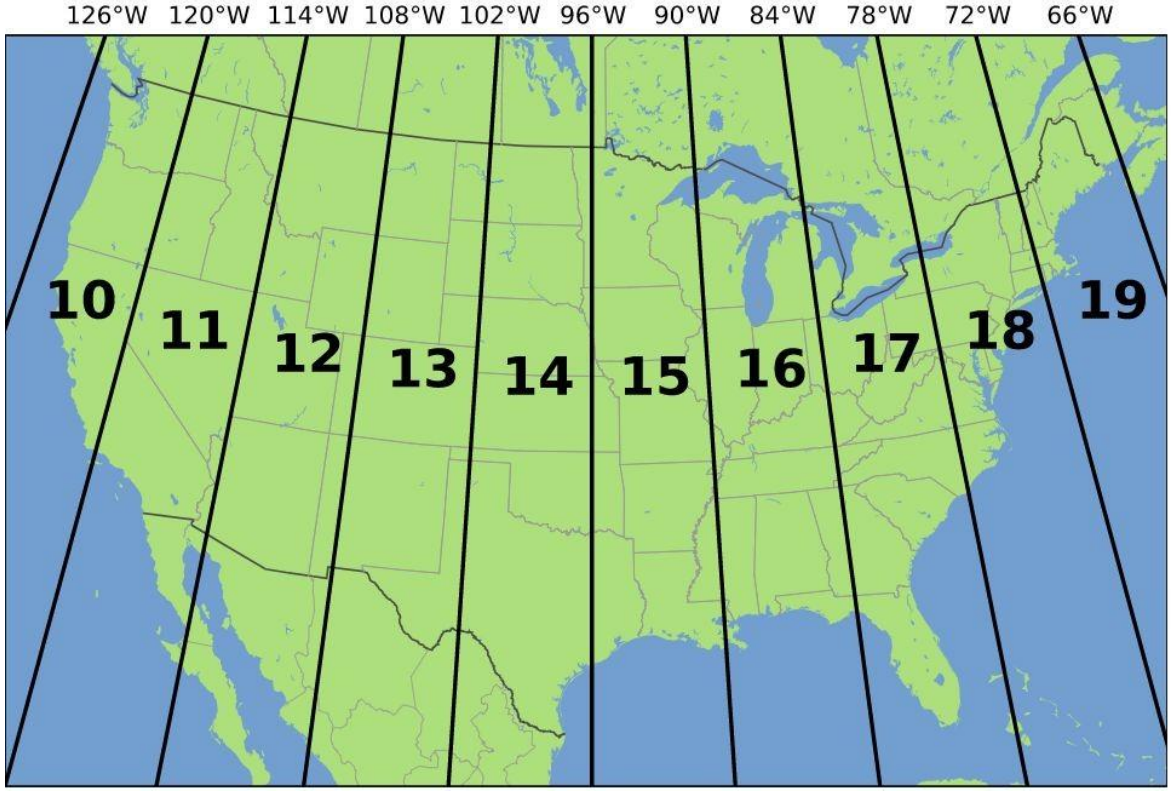
Area in square kilometers, Percentage of World Total
Sources: Britannica, Wikipedia, Almanac 2010

| | | AREA km² | % |
|---|---|---|---|
| 1 | Russia | 17.098.242 | 11,50 |
| 2 | Canada | 9.984.670 | 6,70 |
| 3 | China | 9.596.961 | 6,40 |
| 4 | United States | 9.629.091 | 6,40 |
| 5 | Brazil | 8.514.877 | 5,70 |
| 6 | Australia | 7.692.024 | 5,20 |
| 7 | India | 3.287.263 | 2,30 |
| 8 | Argentina | 2.780.400 | 2,00 |
| 9 | Kazakhstan | 2.724.900 | 1,80 |
| 10 | Sudan | 2.505.813 | 1,70 |
| 11 | Algeria | 2.381.741 | 1,60 |
| 12 | Congo | 2.344.858 | 1,60 |
| 13 | Greenland | 2.166.086 | 1,50 |
| 14 | Saudi Arabia | 2.149.690 | 1,40 |
| 15 | Mexico | 1.964.375 | 1,30 |
| 16 | Indonesia | 1.860.360 | 1,30 |
| 17 | Libya | 1.759.540 | 1,20 |
| 18 | Iran | 1.628.750 | 1,10 |
| 19 | Mongolia | 1.564.100 | 1,10 |
| 20 | Peru | 1.285.216 | 0,86 |
| 21 | Chad | 1.284.000 | 0,86 |
| 22 | Niger | 1.267.000 | 0,85 |
| 23 | Angola | 1.246.700 | 0,85 |
| 24 | Mali | 1.240.192 | 0,83 |
| 25 | South Africa | 1.221.037 | 0,82 |
| 26 | Colombia | 1.141.748 | 0,76 |
| 27 | Ethiopia | 1.104.300 | 0,74 |
| 28 | Bolivia | 1.098.581 | 0,74 |
| 29 | Mauritania | 1.025.520 | 0,69 |
| 30 | Egypt | 1.002.000 | 0,67 |
| 31 | Tanzania | 945.087 | 0,63 |
| 32 | Nigeria | 923.768 | 0,62 |
| 33 | Venezuela | 912.050 | 0,61 |
| 34 | Namibia | 824.116 | 0,55 |
| 35 | Mozambique | 801.590 | 0,54 |
| 36 | Pakistan | 796.095 | 0,53 |
| 37 | Turkey | 783.562 | 0,53 |
| 38 | Chile | 756.102 | 0,51 |
| 39 | Zambia | 752.612 | 0,51 |
| 40 | Myanmar | 676.578 | 0,45 |
| 41 | Afghanistan | 652.090 | 0,44 |
| 42 | Somalia | 637.657 | 0,43 |
| 43 | France | 632.834 | 0,43 |
| 44 | C. African Rep | 622.984 | 0,42 |
| 45 | Ukraine | 603.500 | 0,41 |
| 46 | Madagascar | 587.041 | 0,39 |
| 47 | Botswana | 582.000 | 0,39 |
| 48 | Kenya | 580.367 | 0,39 |
| 49 | Yemen | 527.968 | 0,35 |
| 50 | Thailand | 513.120 | 0,34 |
| 51 | Spain | 505.992 | 0,34 |
| 52 | Turkmenistan | 488.100 | 0,33 |
| 53 | Cameroon | 475.442 | 0,32 |
| 54 | Papua New Guinea | 462.840 | 0,31 |
| 55 | Uzbekistan | 447.400 | 0,30 |
| 56 | Morocco | 446.550 | 0,30 |
| 57 | Sweden | 441.370 | 0,30 |
| 58 | Iraq | 438.317 | 0,29 |
| 59 | Paraguay | 406.752 | 0,27 |
| 60 | Zimbabwe | 390.757 | 0,26 |
| 61 | Japan | 377.930 | 0,25 |
| 62 | Germany | 357.114 | 0,24 |
| 63 | Rep o.t. Congo | 342.000 | 0,23 |
| 64 | Finland | 338.419 | 0,23 |
| 65 | Vietnam | 331.212 | 0,22 |
| 66 | Malaysia | 330.803 | 0,22 |
| 67 | Norway | 323.802 | 0,22 |
| 68 | Côte d'Ivoire | 322.463 | 0,22 |
| 69 | Poland | 312.685 | 0,21 |
| 70 | Oman | 309.500 | 0,21 |
| 71 | Italy | 301.336 | 0,20 |
| 72 | Philippines | 300.000 | 0,20 |
| 73 | Burkina Faso | 274.222 | 0,18 |
| 74 | New Zealand | 270.467 | 0,18 |
| 75 | Gabon | 267.668 | 0,18 |
| 76 | Western Sahara | 266.000 | 0,18 |
| 77 | Ecuador | 256.369 | 0,20 |
| 78 | Guinea | 245.857 | 0,17 |
| 79 | United Kingdom | 242.900 | 0,16 |
| 80 | Uganda | 241.038 | 0,16 |
| 81 | Ghana | 238.539 | 0,16 |
| 82 | Romania | 238.391 | 0,16 |
| 83 | Laos | 236.800 | 0,16 |
| 84 | Guyana | 214.969 | 0,14 |
| 85 | Belarus | 207.600 | 0,14 |
| 86 | Kyrgyzstan | 199.951 | 0,13 |
| 87 | Senegal | 196.722 | 0,13 |
| 88 | Syria | 185.180 | 0,12 |
| 89 | Cambodia | 181.035 | 0,12 |
| 90 | Uruguay | 176.215 | 0,12 |
| 91 | Suriname | 163.820 | 0,11 |
| 92 | Tunisia | 163.610 | 0,11 |
| 93 | Nepal | 147.181 | 0,10 |
| 94 | Bangladesh | 143.998 | 0,10 |
| 95 | Tajikistan | 143.100 | 0,10 |
| 96 | Greece | 131.957 | 0,09 |
| 97 | Nicaragua | 130.373 | 0,09 |
| 98 | North Korea | 120.538 | 0,08 |
| 99 | Malawi | 118.484 | 0,08 |
| 100 | Eritrea | 117.600 | 0,08 |
| | TOP 100 TOTAL | 132.082.824 | 89,34 |

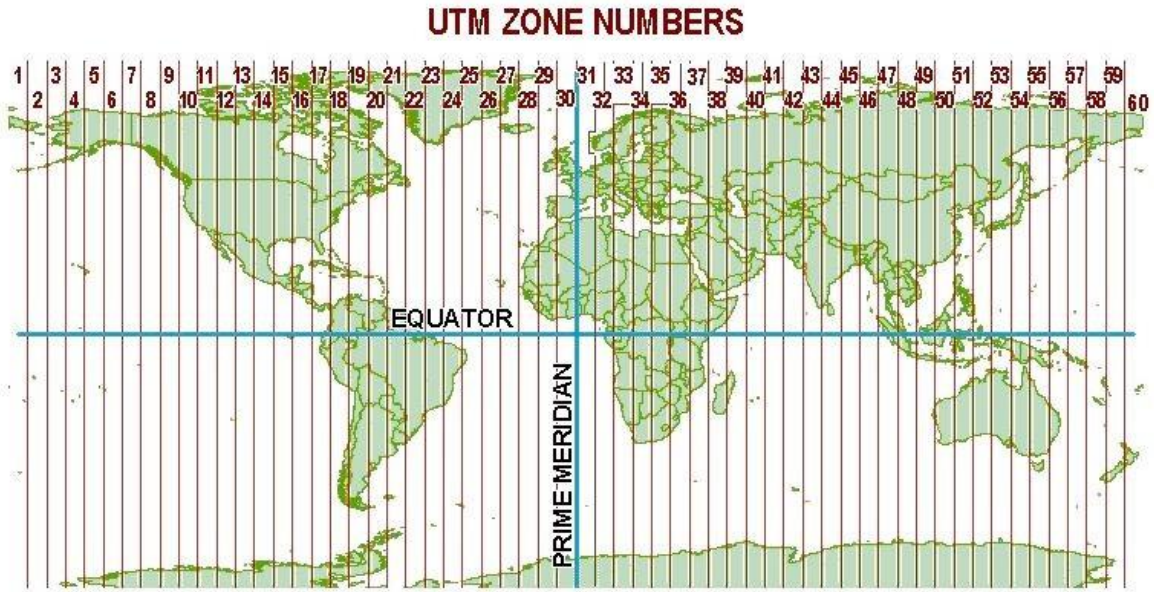
Different projections: The [Mercator projection](#) is very biased, as you can see from [The True Size of Africa](#).

# UTM Projections

## UTM Zones for the United States




## UTM Zones for the World

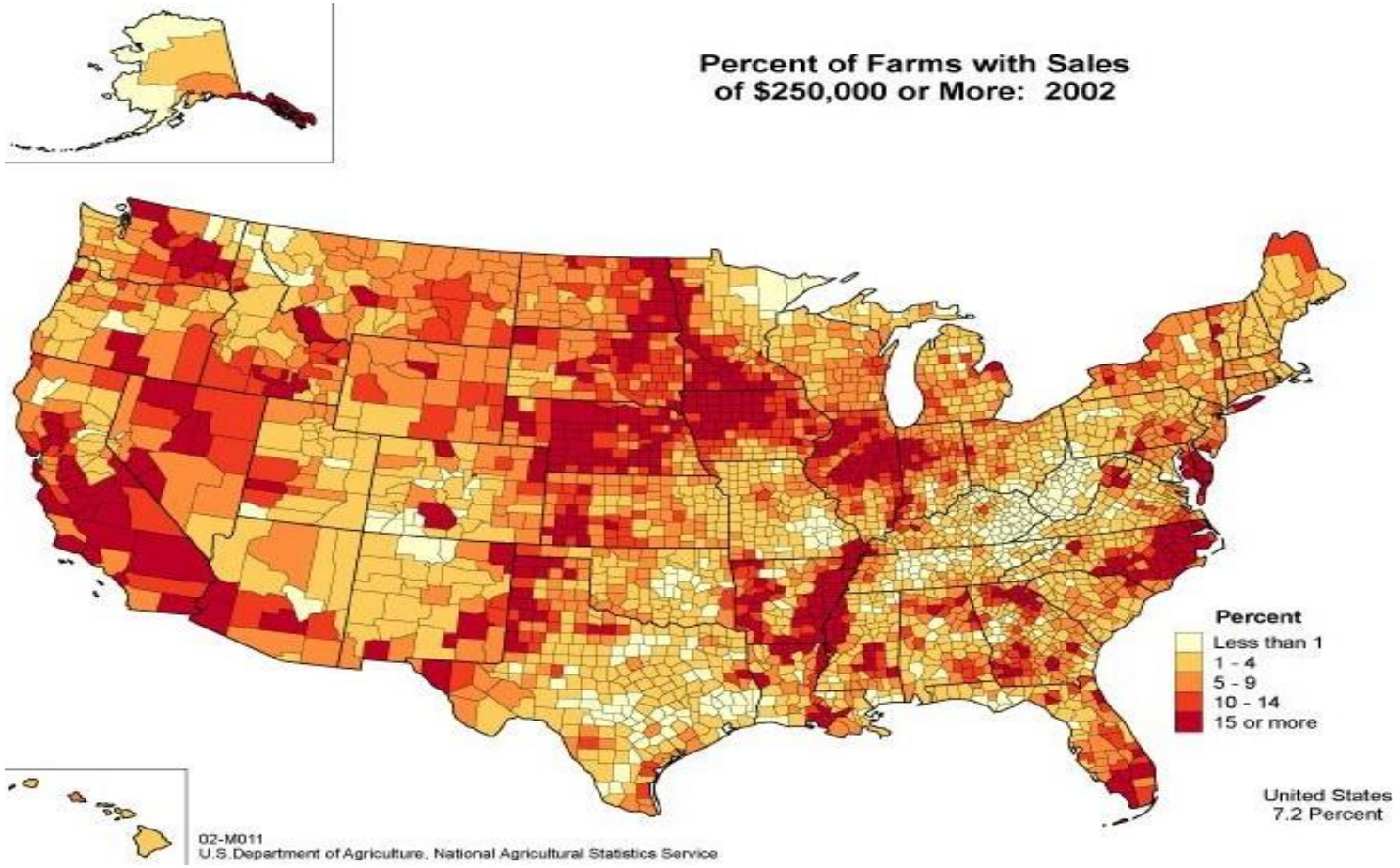


# Mapping

# Types of Thematic Maps

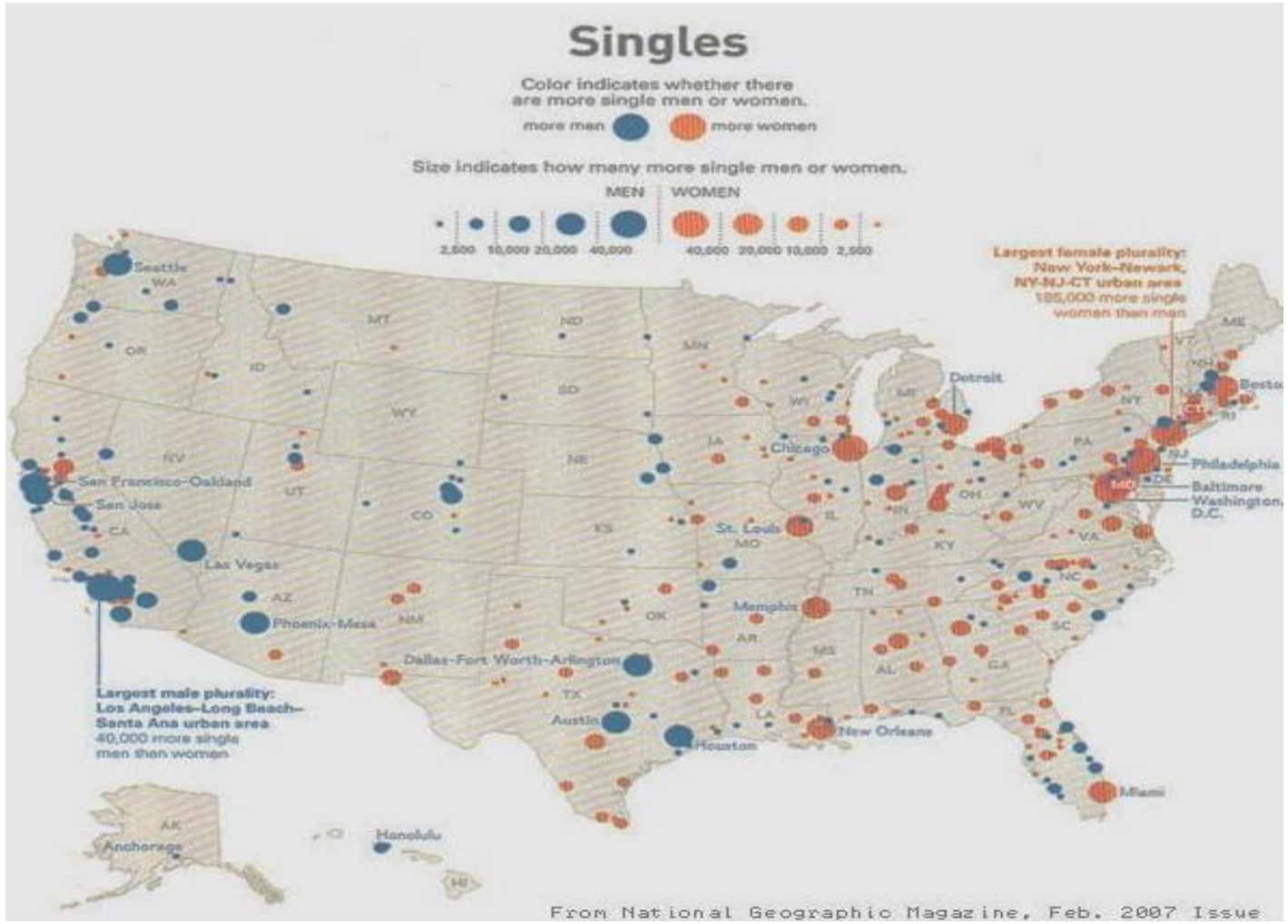
- Choropleth
- Graduated Symbol
- Hot Spot
- Isarithmic

# Choropleth Map




Shows value per unit using colors. Use these for comparing relative numbers across space.

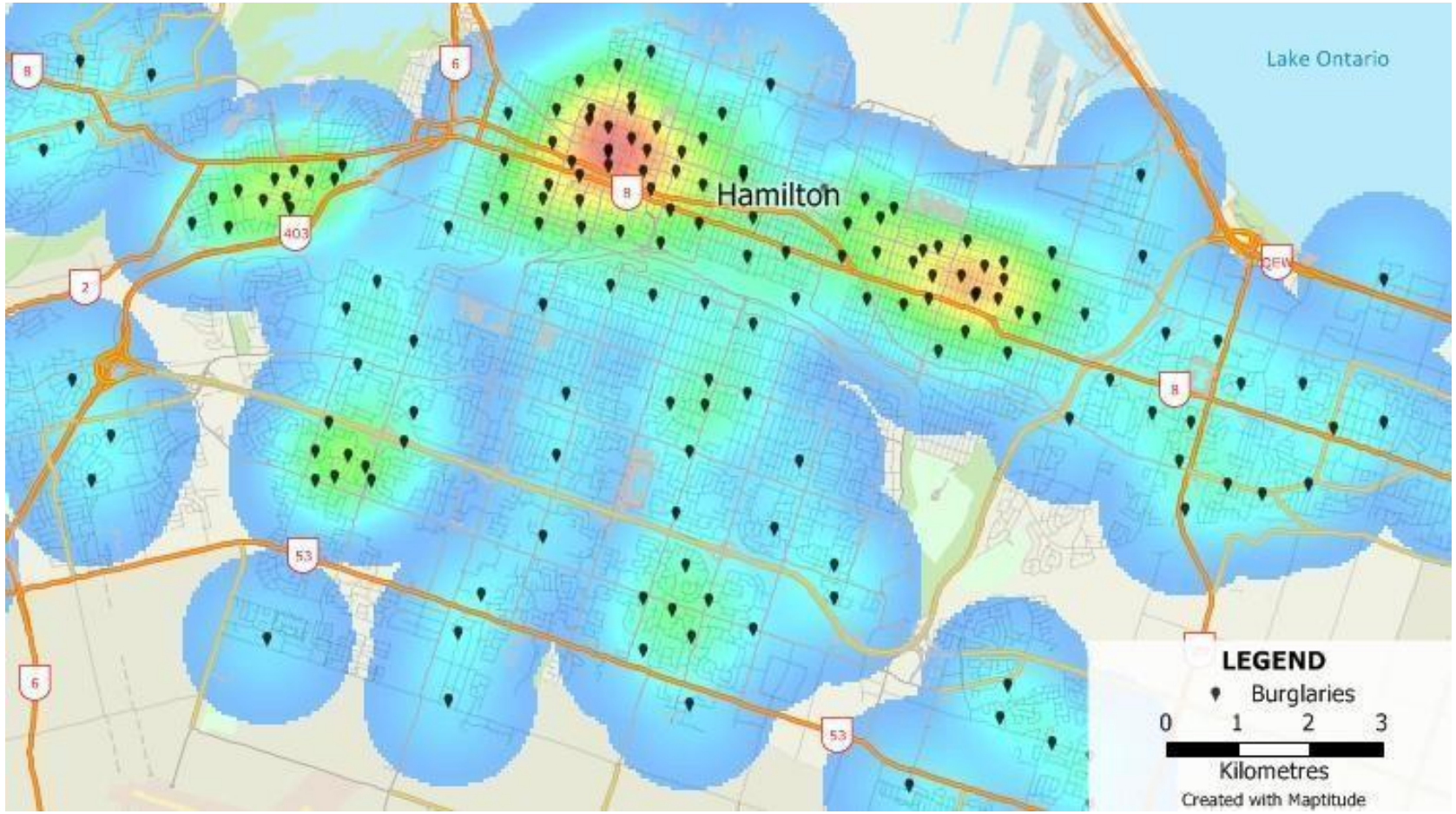
# Proportional Symbol Map




The size of the symbol is representative of the value of the variable.

Difficult use well.

# Hot Spot Map

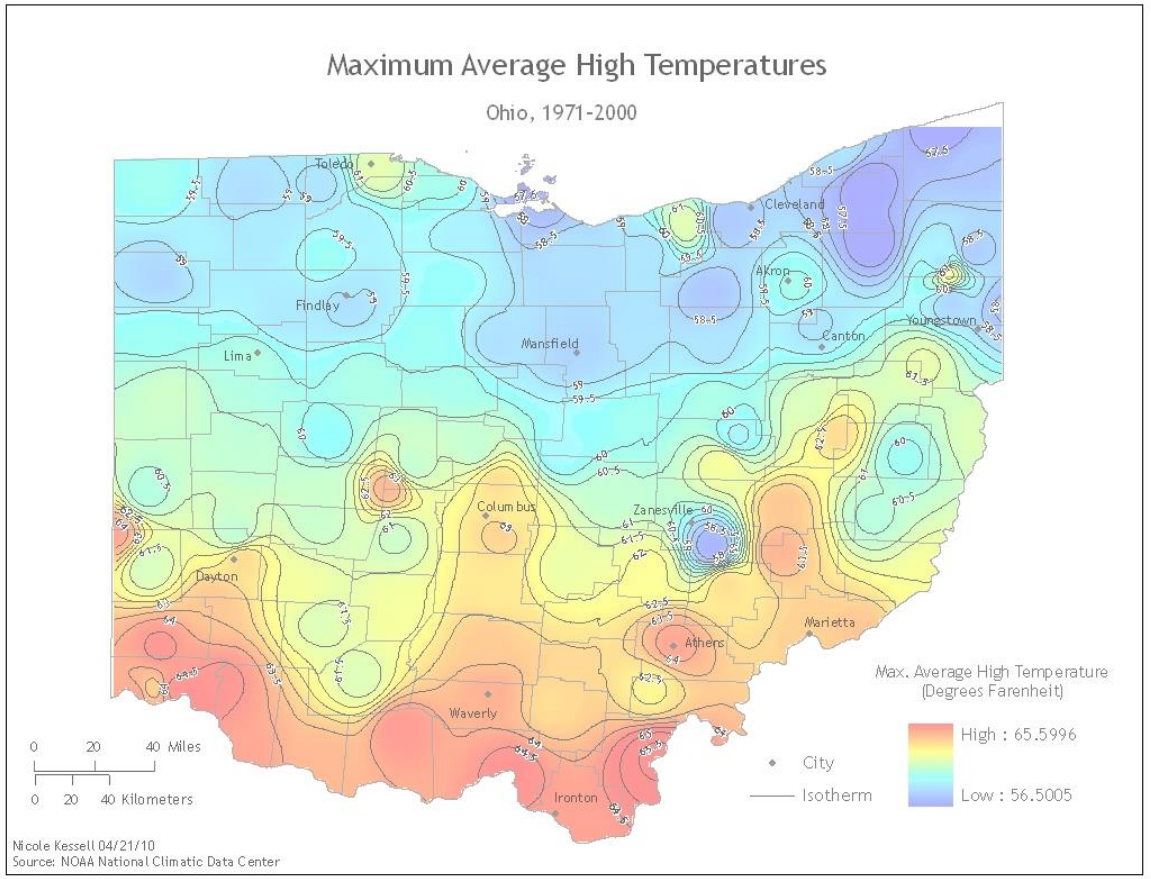



Shows density or clustering of phenomenon using color.

Statistically significant areas are displayed, excluding areas with no data.

# Isarithmic Map

- Change in value is shown through intervals across map.

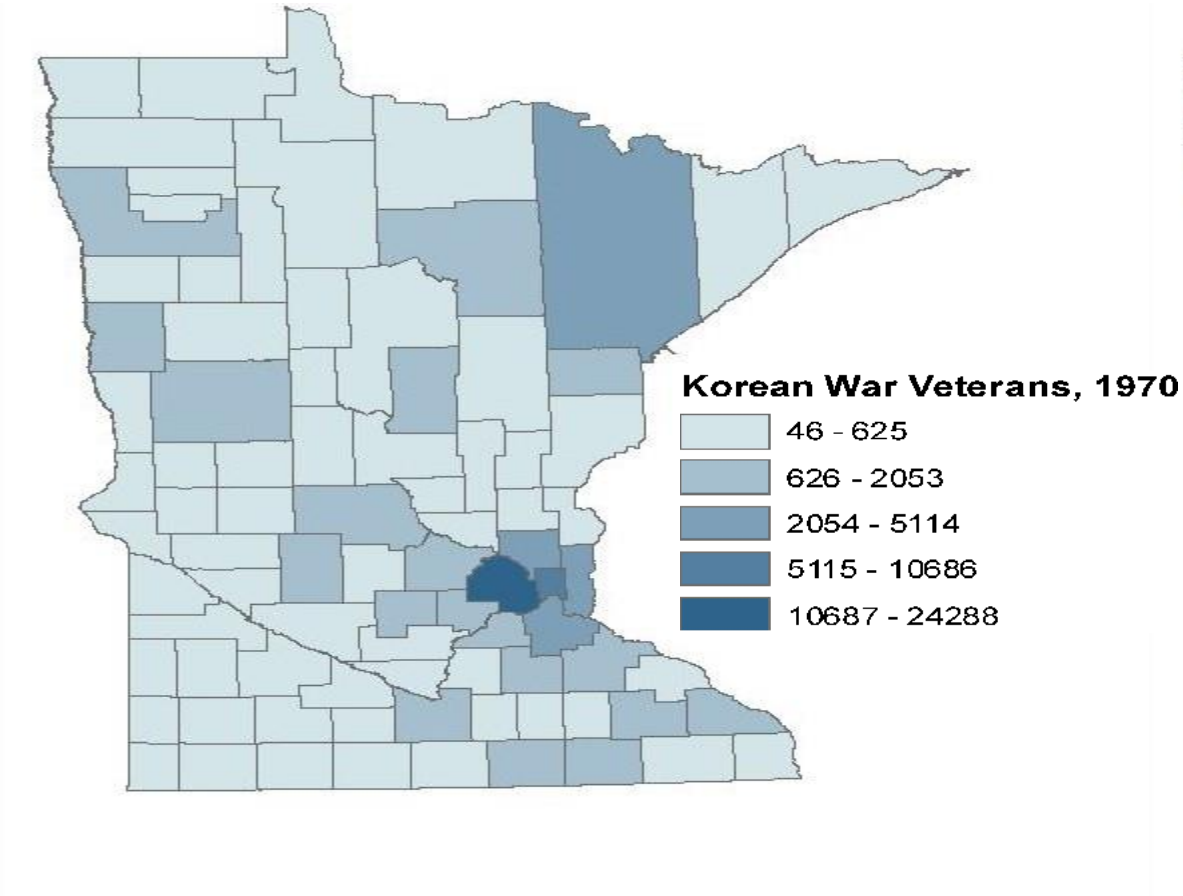


# Data Standardization

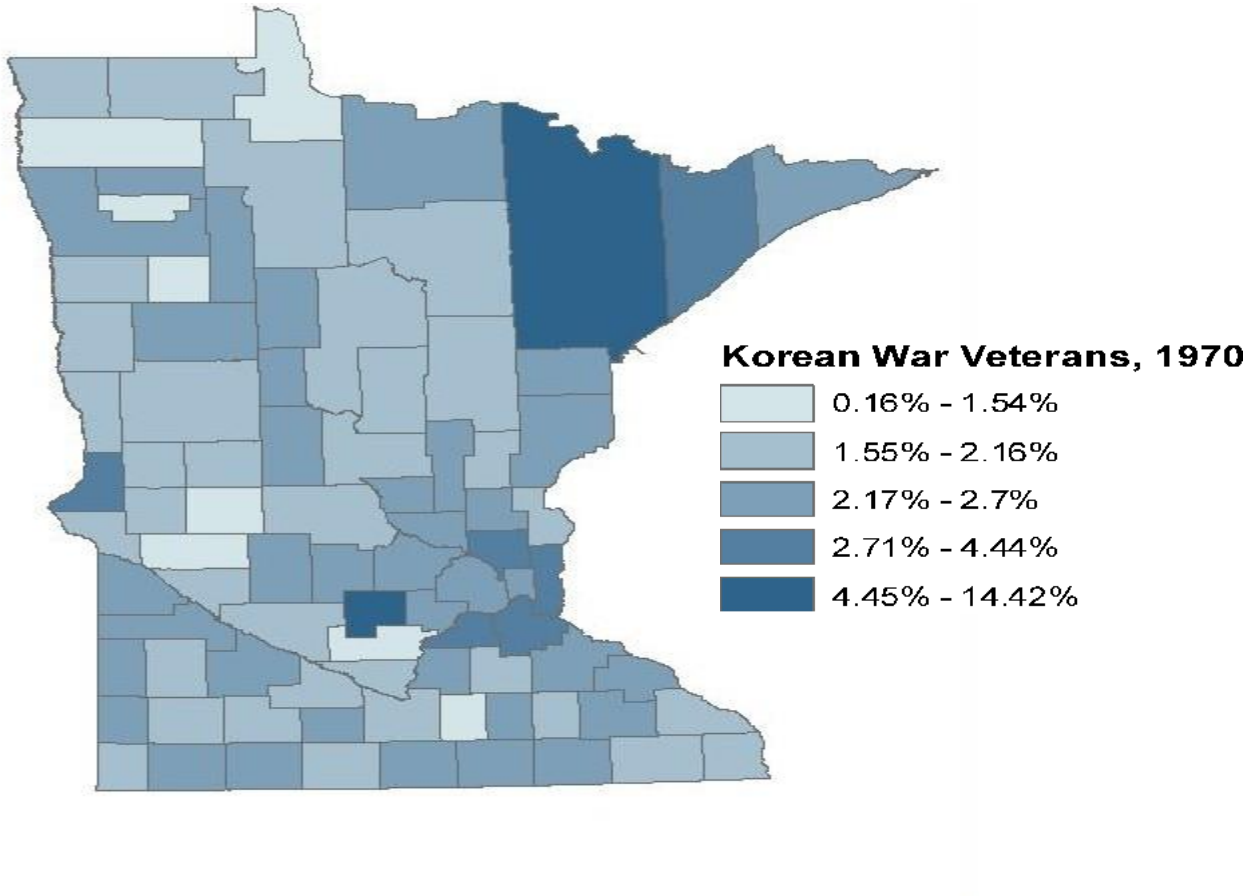
- Data should usually be standardized
    - Ability to compare areas
- By Population
    - Per person, Percentages
- By Area
    - Density

# Data Standardization by Pop

## Unstandardized

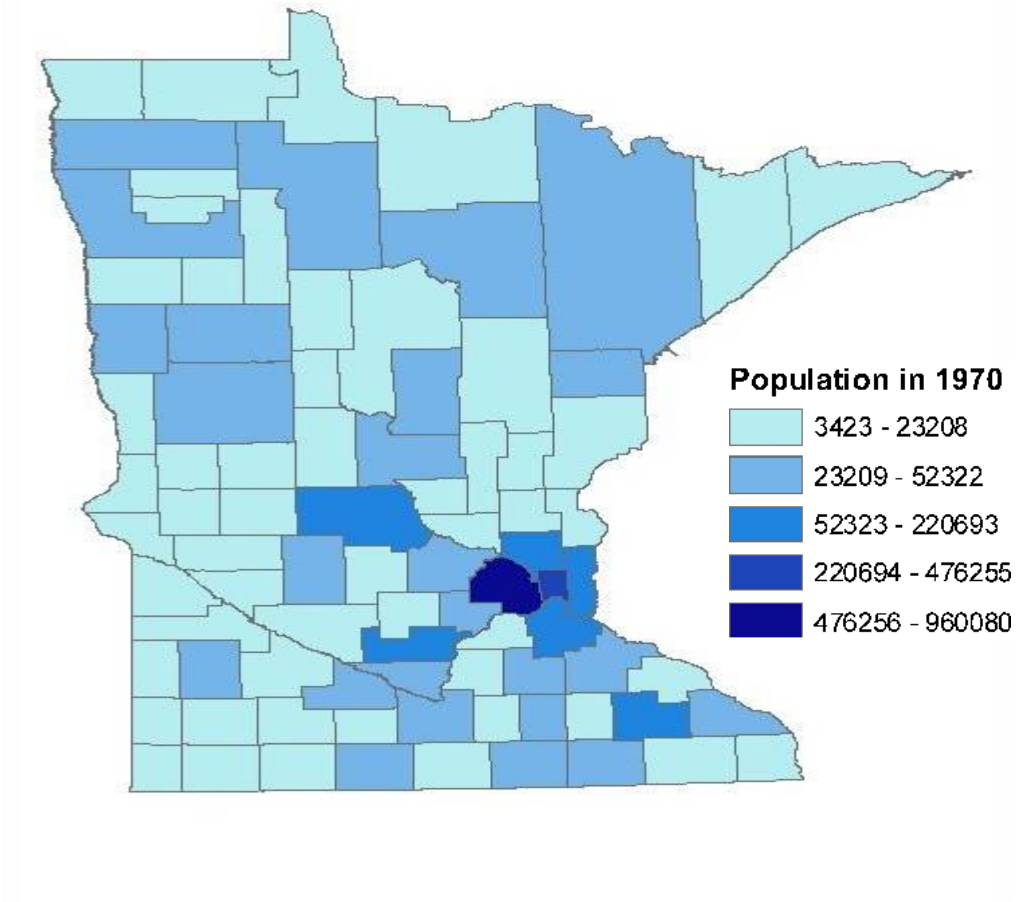



## Standardized/Normalized

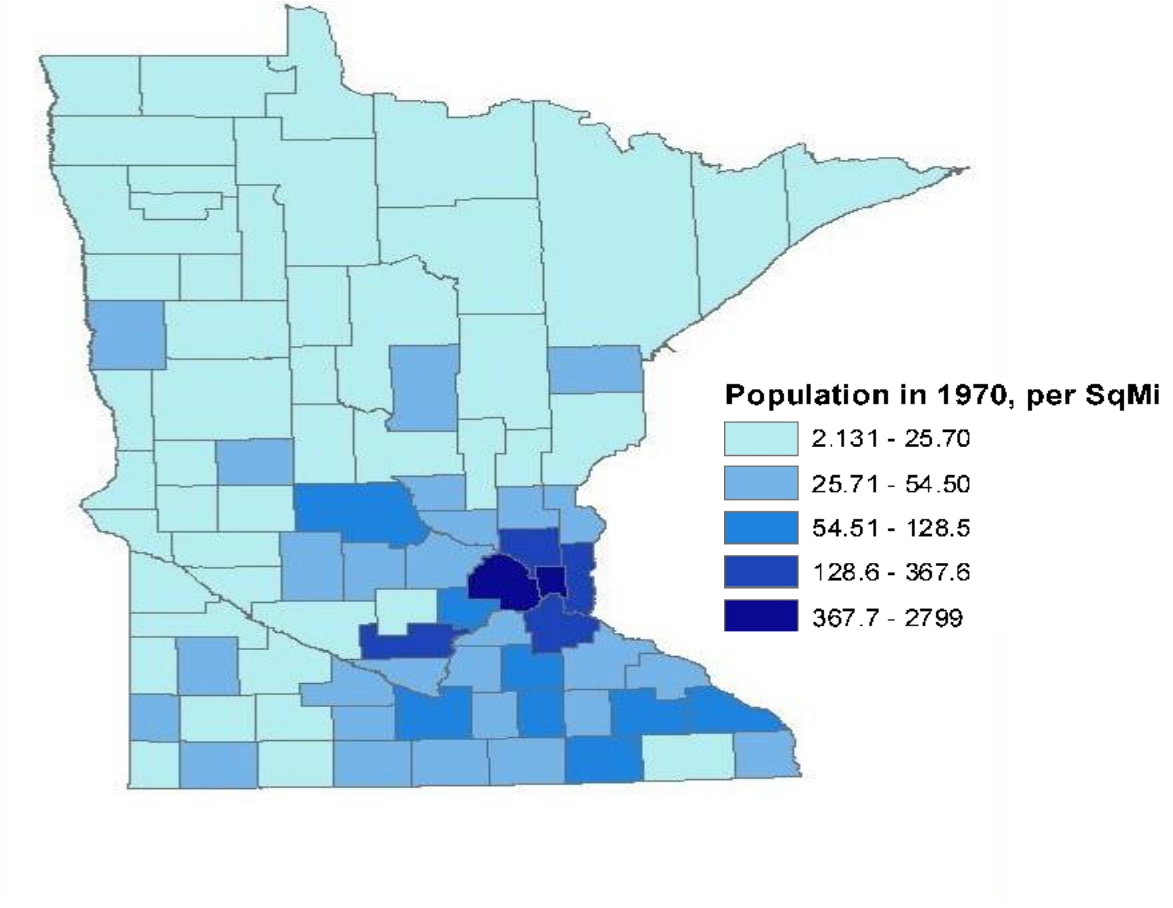


# Data Standardization by Area

## Unstandardized




## Standardized/Normalized

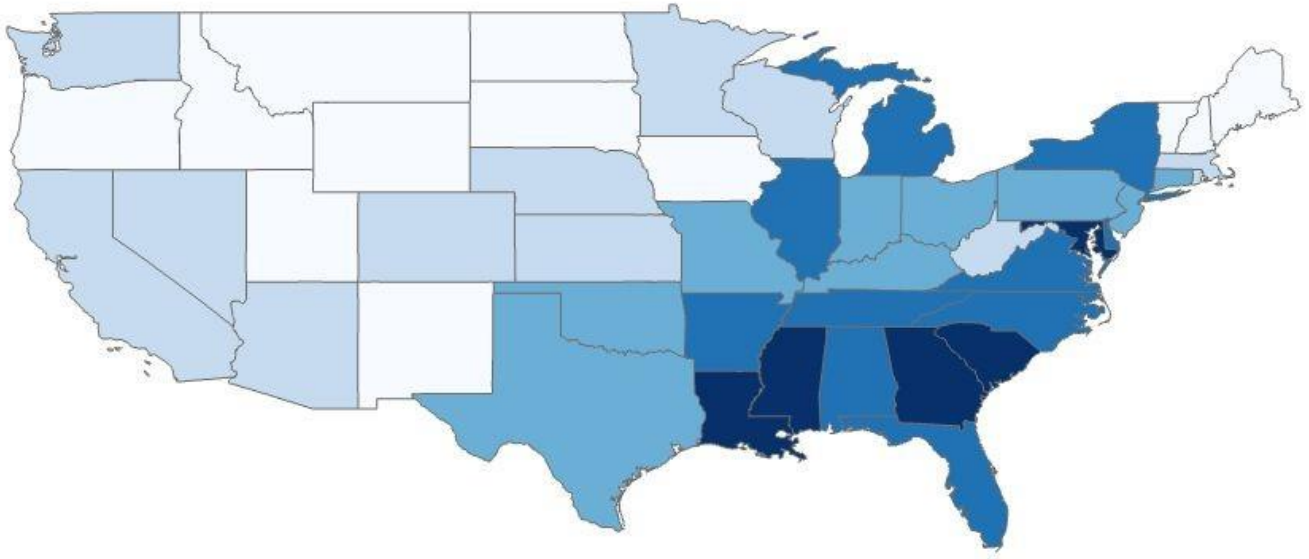


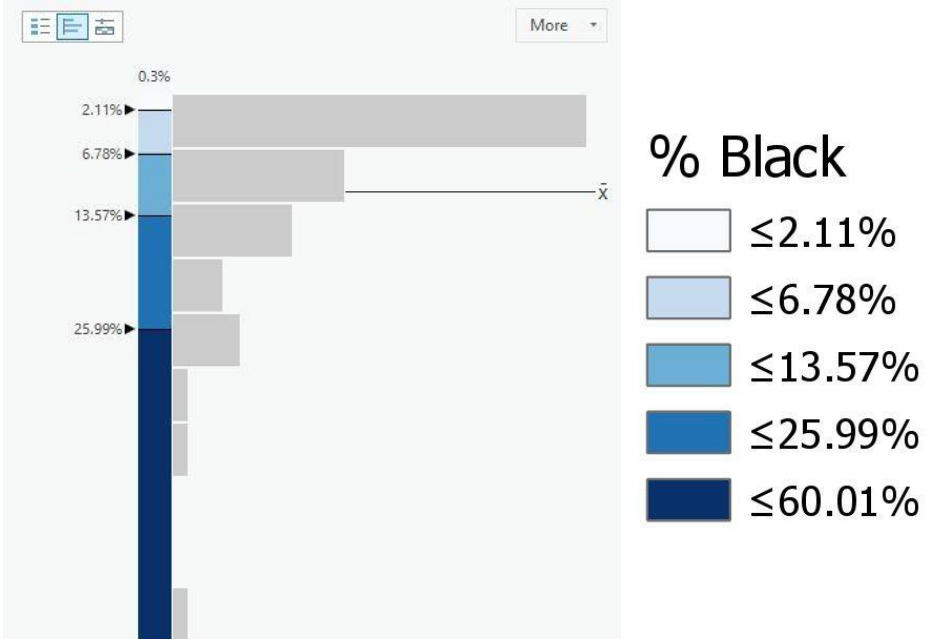
# Classification

- Natural Breaks/Jenks
- Quantile
- Equal Interval Based on Range
- Equal Interval not Based on Range/Defined Interval

# Natural Breaks (Jenks)

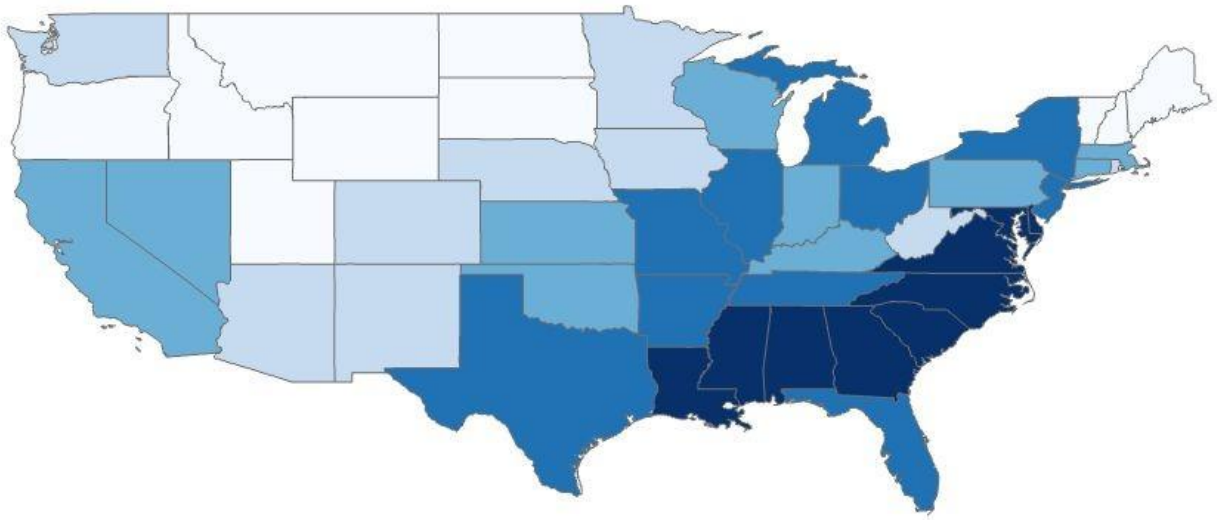
Natural Breaks has intervals that are created using natural clustering of the data. It maximizes variance between groups and minimizes variation within groups.

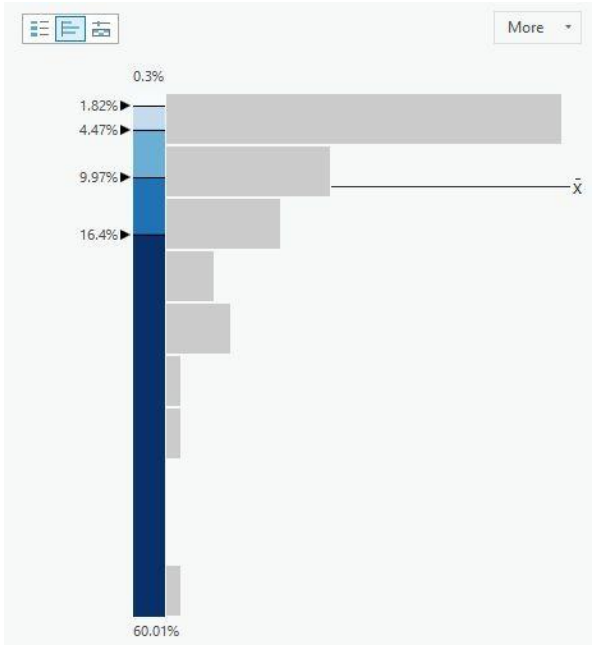


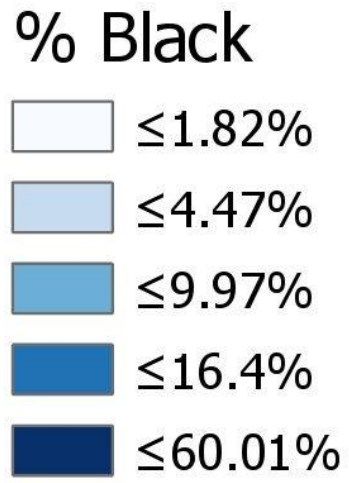


# Quantile

Quantile has equal numbers of data in each class– sometimes called Quintile for 5 classes



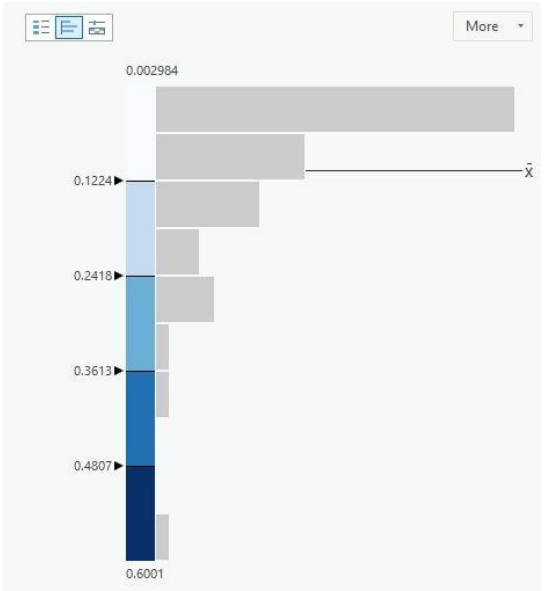


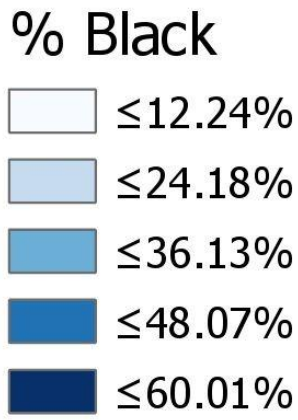



# Equal Interval (Based on Range)

Equal-sized subranges

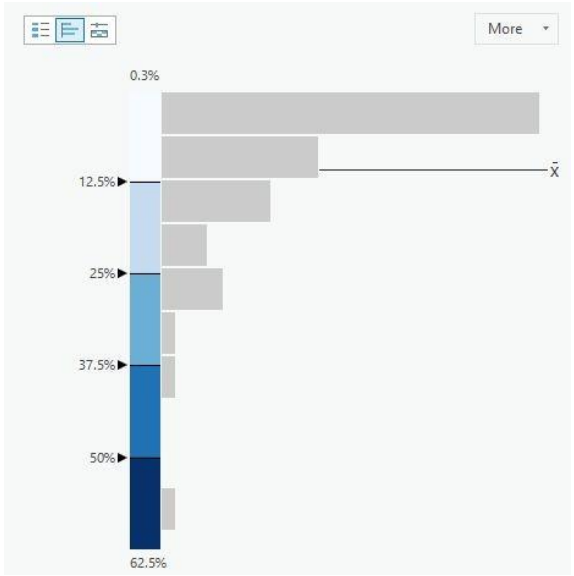
$$\frac{\text{Value of Highest Observation - Value of Lowest Observation}}{\text{Number of Classes}}$$



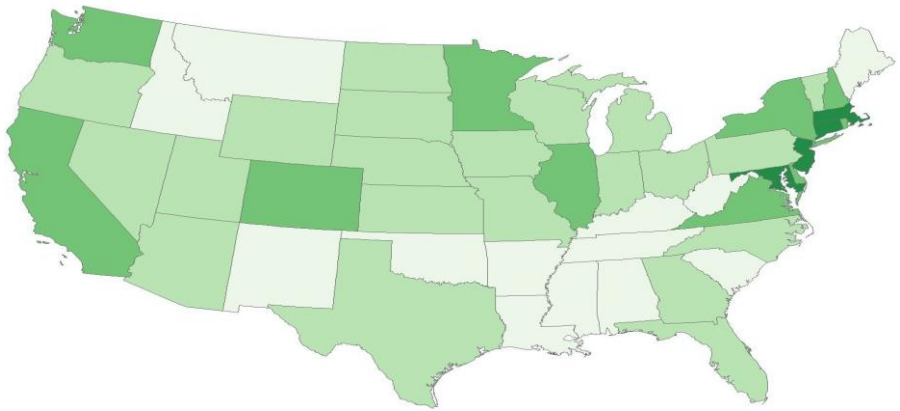



# Defined Interval

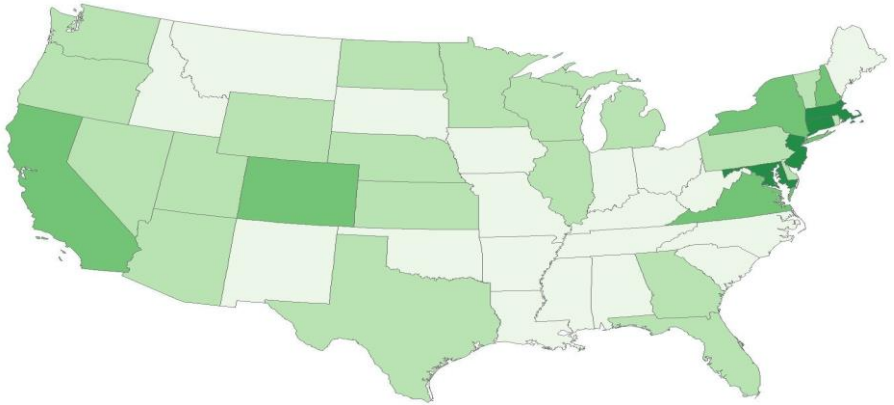
- Equal Interval not based on Range
- Good for comparing values across time
- Legends may be easier for audience to read



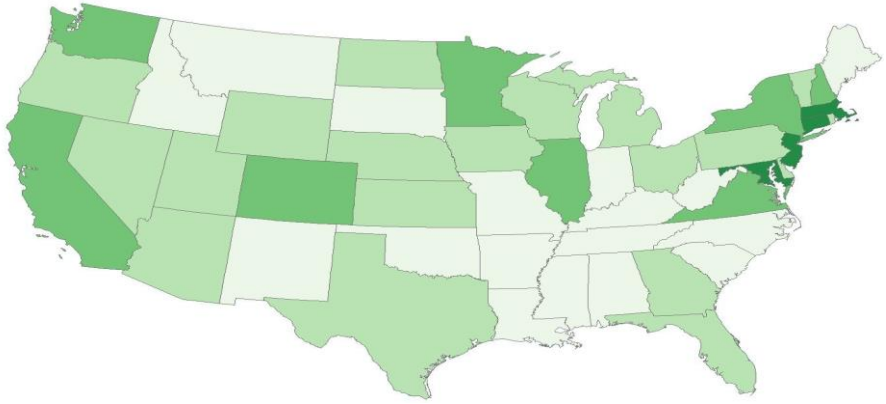

# Classification: Method Comparison



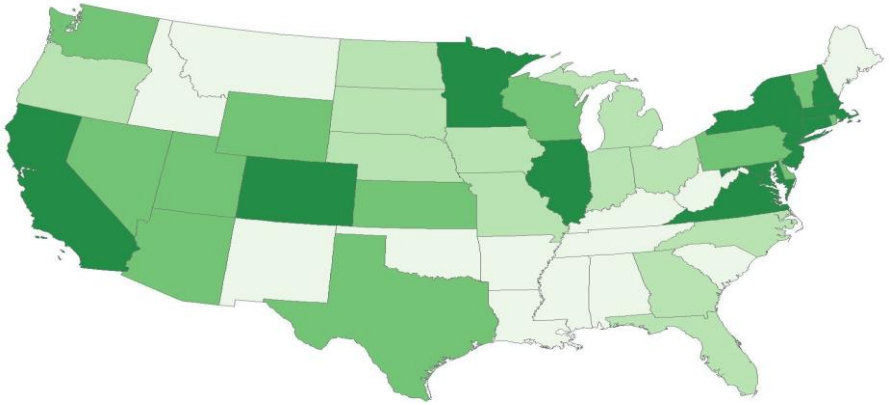
Natural Breaks



Equal Interval



Standard Deviation

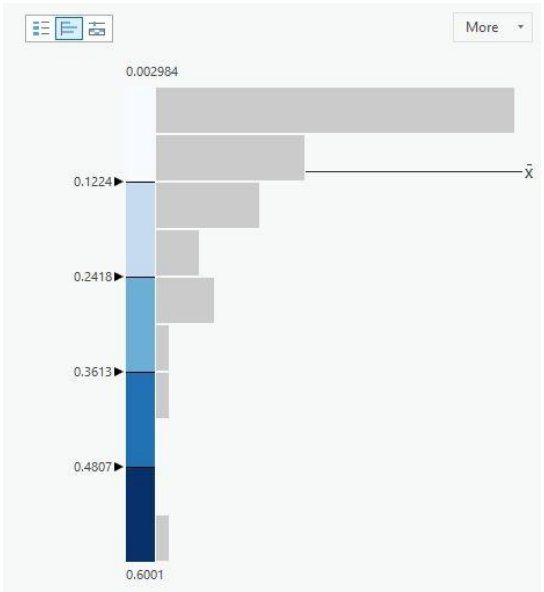


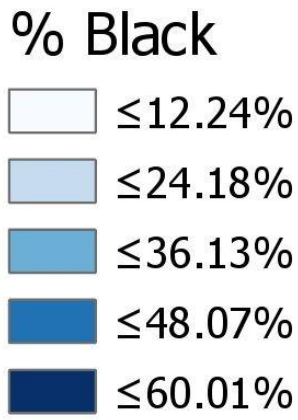
Quantile

# Equal Interval (Based on Range)

Equal-sized subranges

$$\frac{\text{Value of Highest Observation - Value of Lowest Observation}}{\text{Number of Classes}}$$

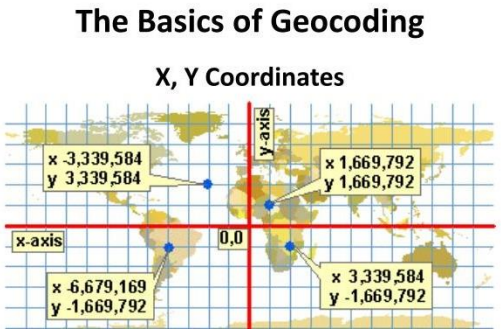


# Software

# Geocoding

- The process of finding the location of an address on a map.
- The location can be a pair of (X, Y) coordinate or a street address, postal delivery location, or building.
  - X – longitude (+ for E hemisphere; - for W hemisphere)
  - Y – latitude  (+ for N hemisphere; - for S hemisphere)
- In GIS, geocoding requires a reference dataset that contains address attributes for the geographic features in the area of interest.




# Address Matching

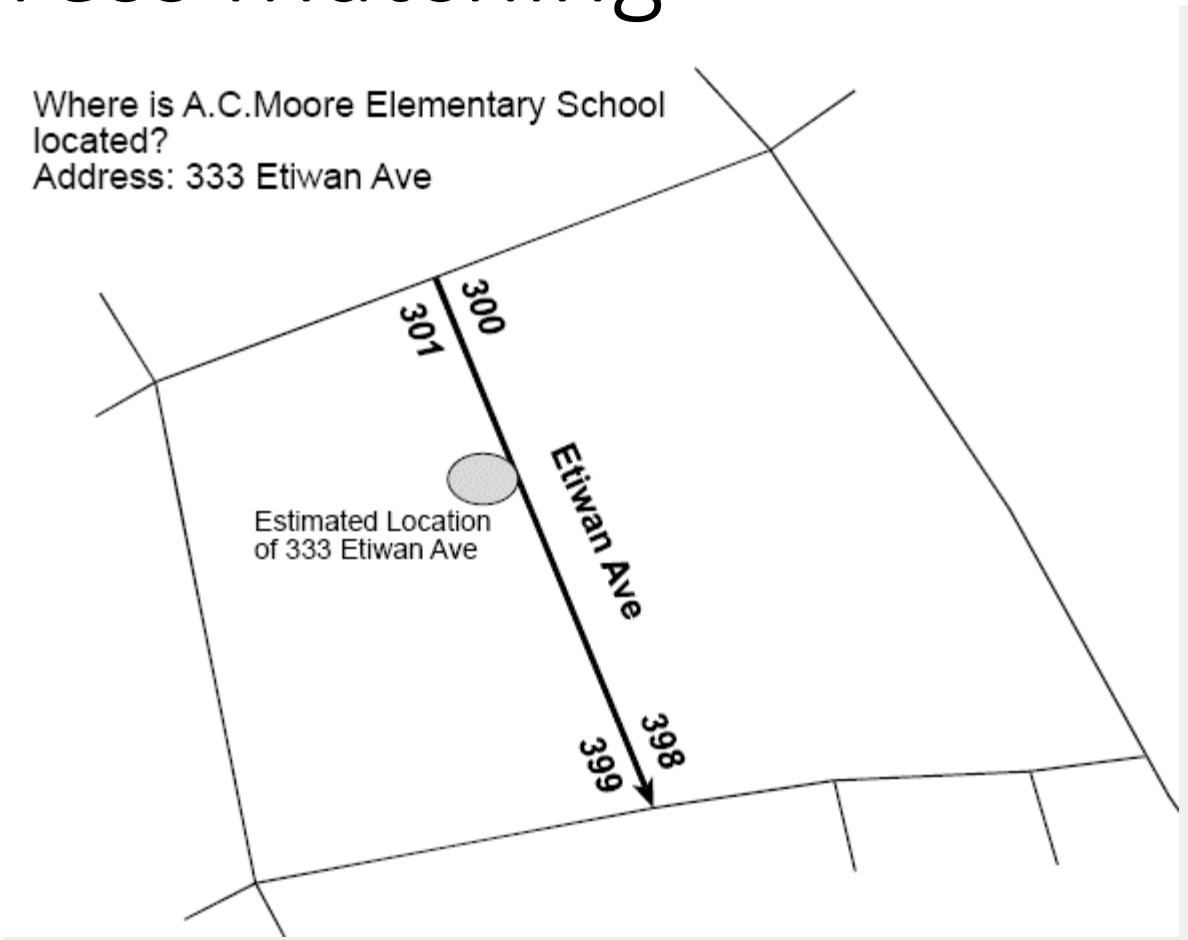
Address matching is the process of assigning an actual address to a geographic location on some reference files.

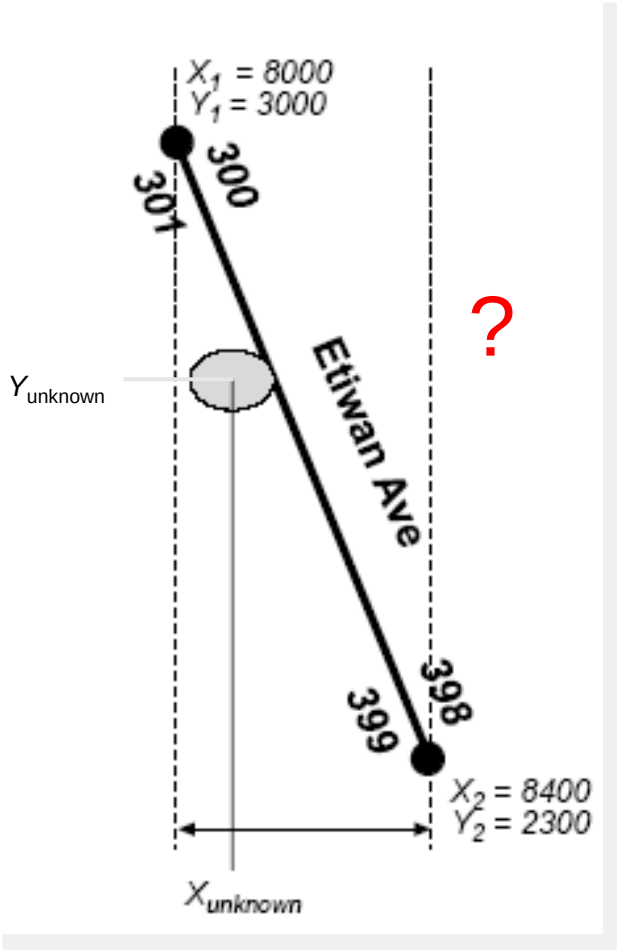
If an address falls within a feature's address range, it is considered a match and a location can be returned.

Address database


Reference map

# Address Matching




- --- Both X and Y need to be interpolated allocate the address.

# RCC-GIS Geocoding Service: Formatting Data for Processing

https://gis.rcc.uchicago.edu/content/rcc-gis-geocoding-service

**Based on ESRI world Geocoder**

**Acceptable headers:**

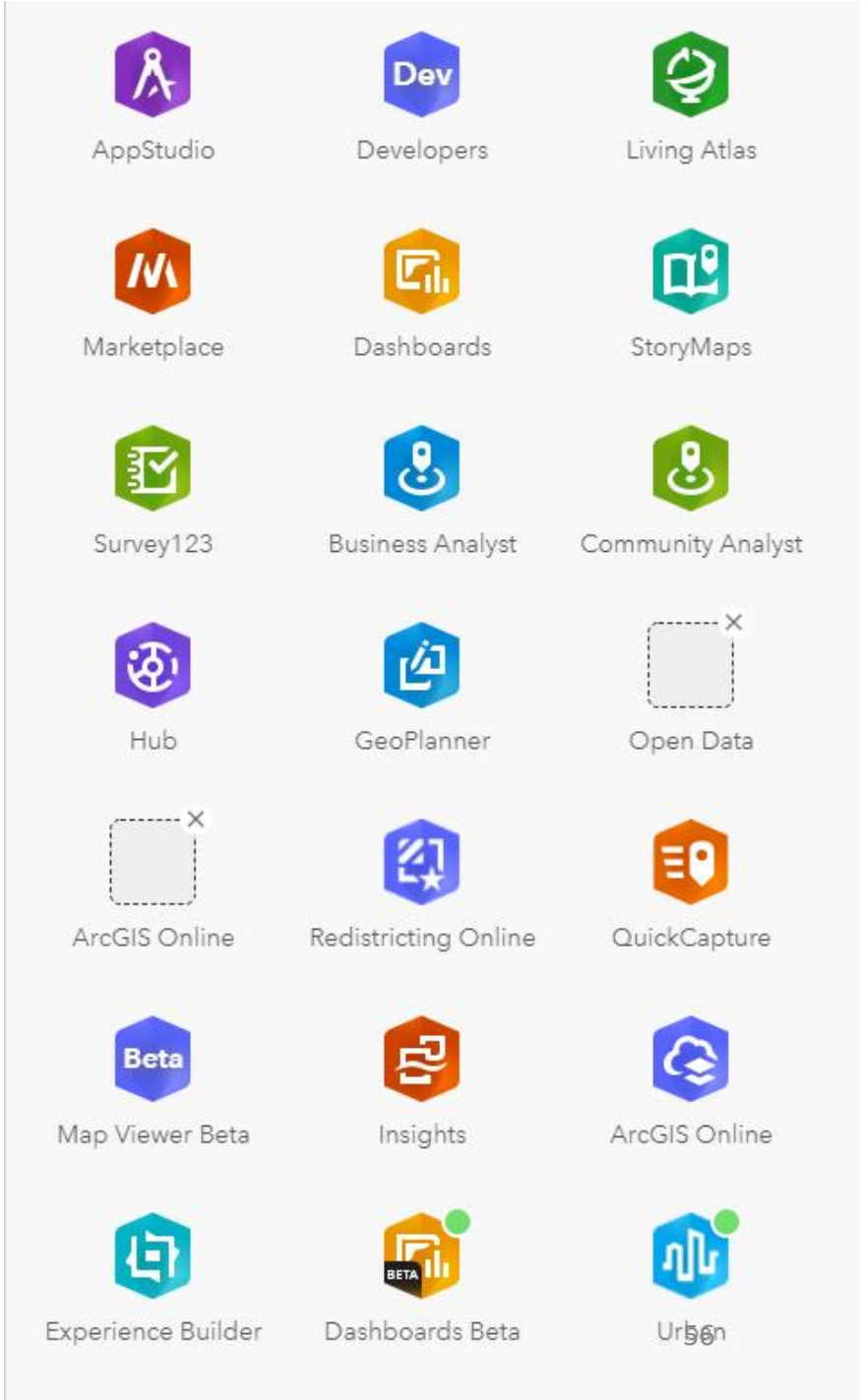
ID
ADDRESS
NEIGHBORHOOD
CITY
SUBREGION
REGION or STATE or ST
POSTAL or ZIP or ZIP CODE
COUNTRYCODE

# Geocoding Review

- Be careful which locator service you use, online geocoders are not HIPAA compliant
- Geocode to the appropriate geographic scale, can take care of confidentiality issues
- A high match score does not mean the point is accurate, best practice is to choose a small percentage of results to review
- Valid address does not necessarily mean correct location!

# ArcGIS Online

- https://uchicago.maps.arcgis.com



# Using ArcGIS Online

- Wayback App
- https://livingatlas.arcgis.com/wayback

- Navigate to https://livingatlas.arcgis.com
- Sign in using CNETid
- Search “Global Imagery Browse Services”

Global Imagery Browse Services

Search examples

All Trending Basemaps Imagery Boundaries People Infrastructure Environment

Filters: All content types All time All regions Esri-only content

Sort by: Relevance

21 Results

## MODIS True Color - Terra Surface Reflectance

Imagery Layer By: esri

This layer provides access to NASA Global Imagery Browse Services, which delivers global, full-resolution satellite imagery. This band composition (Bands 1 4 3) most accurately represents how we see the earth's surface with our own eyes.

Authoritative

## MODIS True Color - Aqua Corrected Reflectance

Imagery Layer By: esri

This layer provides access to NASA Global Imagery Browse Services, which delivers global, full-resolution satellite imagery. This band composition (Bands 1 4 3) most accurately represents how we see the earth's surface with our own eyes.

Authoritative

## MODIS True Color - Terra Corrected Reflectance

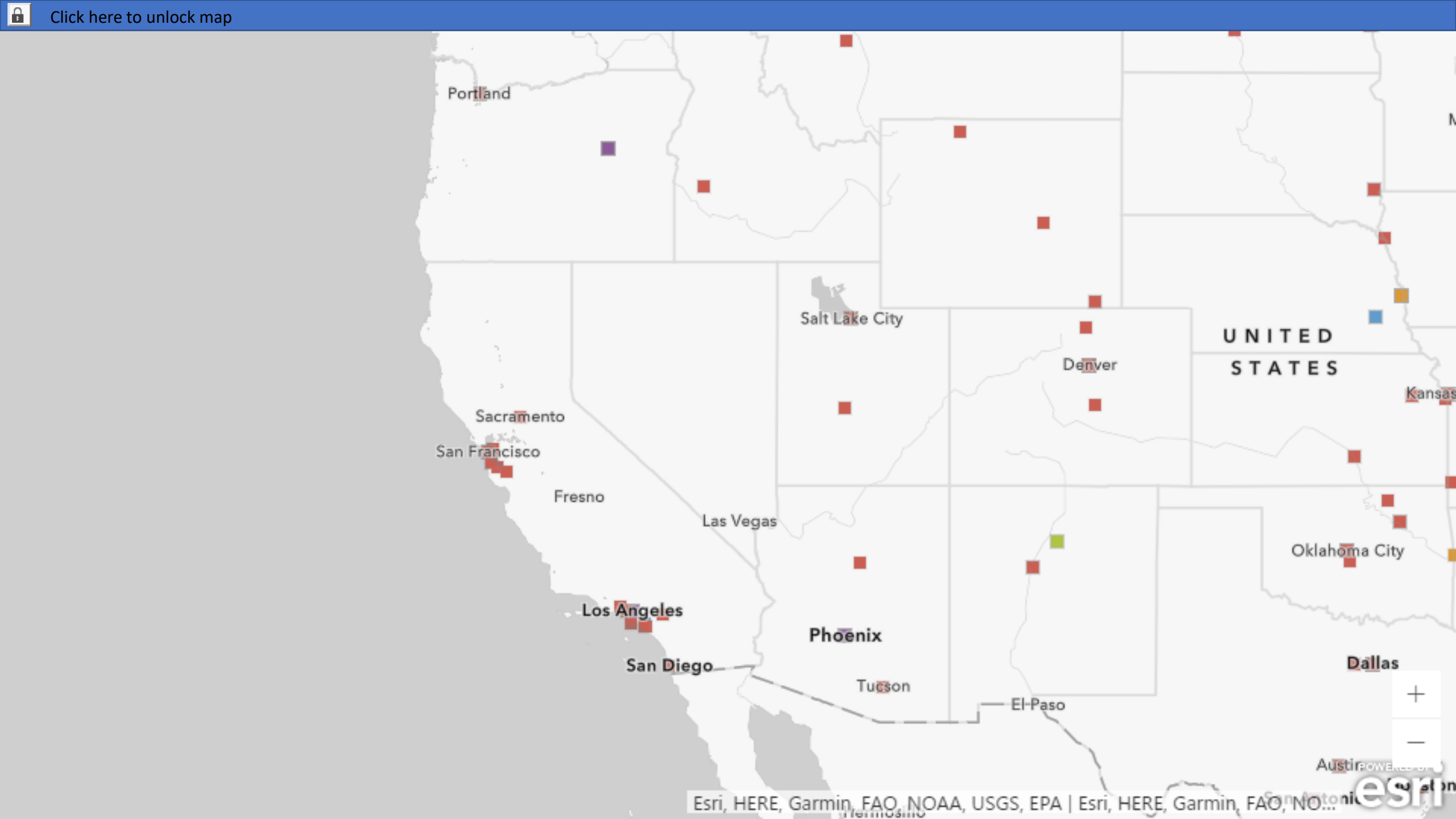
Imagery Layer By: esri

This layer provides access to NASA Global Imagery Browse Services, which delivers global, full-resolution satellite imagery. This band composition (Bands 1 4 3) most accurately represents how we see the earth's surface with our own eyes.

## Daily Planet Imagery


Web Map By: esri

This map shows imagery for the planet that is updated on a daily basis. It features the NASA MODIS imagery True Color band composition (Bands 1 4 3 | Red, Green, Blue) which most accurately shows how we see the earth's surface with our own eyes.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