SC4024/CZ4124
Data Visualization

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Chapter 10
Geospatial Data Visualization

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Outline

- What is geospatial data
- What is map
- Map projection
- Visualization of geospatial data
  - Point data visualization
  - Line data visualization
  - Region data visualization
- Geospatial datasets

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Geospatial Data

- Geospatial data (a.k.a, location-based data or geographic data) refers to data and information that has explicit or implicit association with a location relative to Earth.

XCOORD	YCOORD	NAME
103.8589	1.2840	Livewire (Marina Bay Sands)
103.8574	1.2947	Singapore Pools Suntec City
103.8469	1.2835	Kis Store
103.8493	1.2829	Singapore Turf Club China Square
103.8521	1.2836	Tay Sui Lan Agency
103.8492	1.2861	7-Eleven Circular Rd
103.8440	1.2858	Singapore Pools People's Park Centre
103.8464	1.2850	Feng Yuen Agency Enterprise

SUBZONE_C	TOTAL_POP	YOUNG
AMSZ01	4990	850
AMSZ02	30390	3950
AMSZ03	28650	3410
AMSZ04	24160	3260
AMSZ05	19190	2620
AMSZ06	24550	3050
AMSZ07	6860	1030
AMSZ08	8370	1200

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Geospatial Data

- Geospatial data (a.k.a, location-based data or geographic data) refers to data and information that has _explicit or implicit association with a location_ relative to Earth.

- Geospatial data can be sourced from telematics devices, Global Positioning System (GPS) data, geospatial satellite imagery, Internet of Things, geotagging, etc.
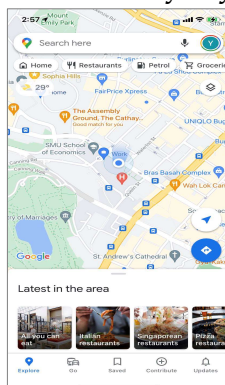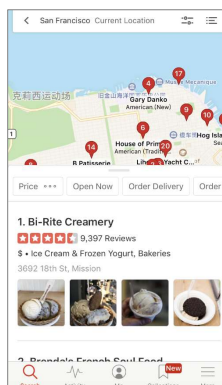
5

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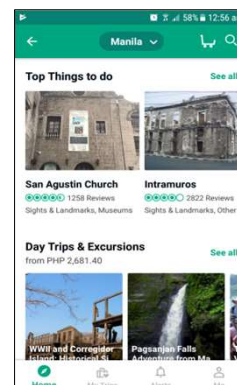# Geospatial Data Example: Location-based Services

- Geospatial data is highly relevant to our everyday life
- Geospatial data is also generated by mobile devices and sensors everyday

| Google Maps | Yelp | Tripadvisor |

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Outline

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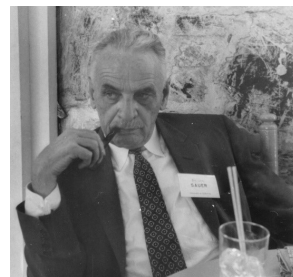 - Region data visualization
- Geospatial datasets

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What is Map?

- "The map speaks across the barriers of language; it is sometimes claimed as the language of geography."

-- Carl Ortwin Sauer, 1956

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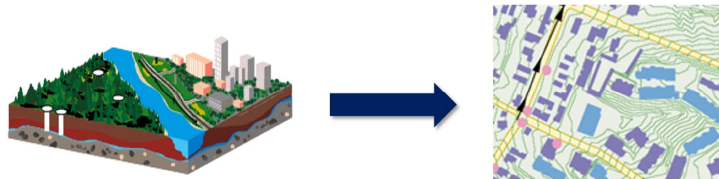## What is Map?

- A map is a model of real world depicted by a collection of cartographic symbols or/and visual abstraction.
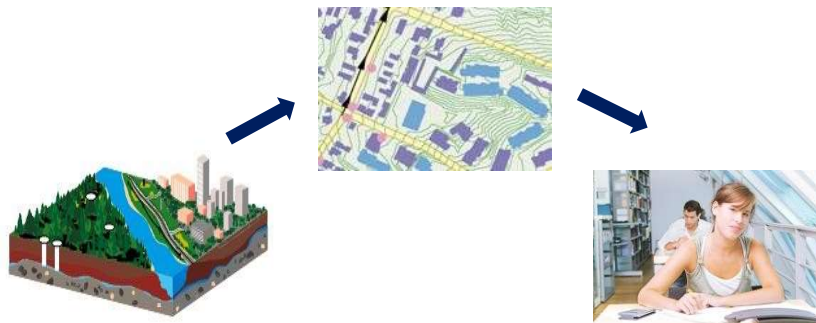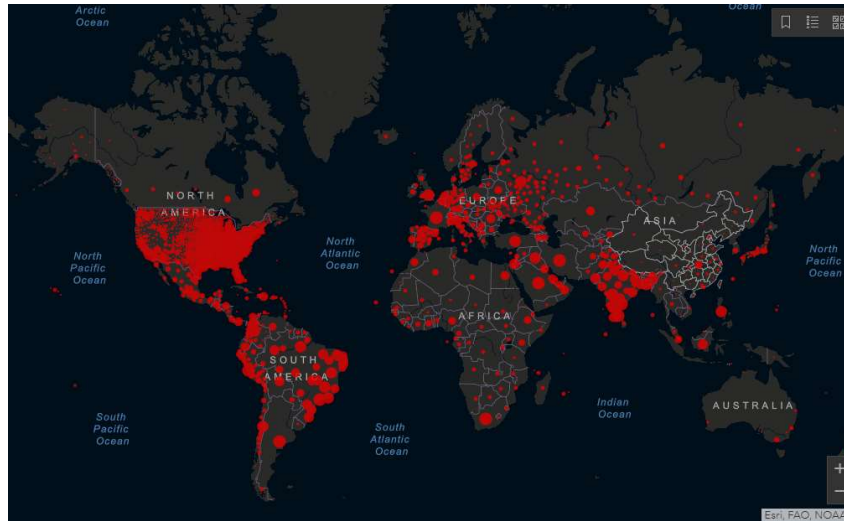

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What is Map?

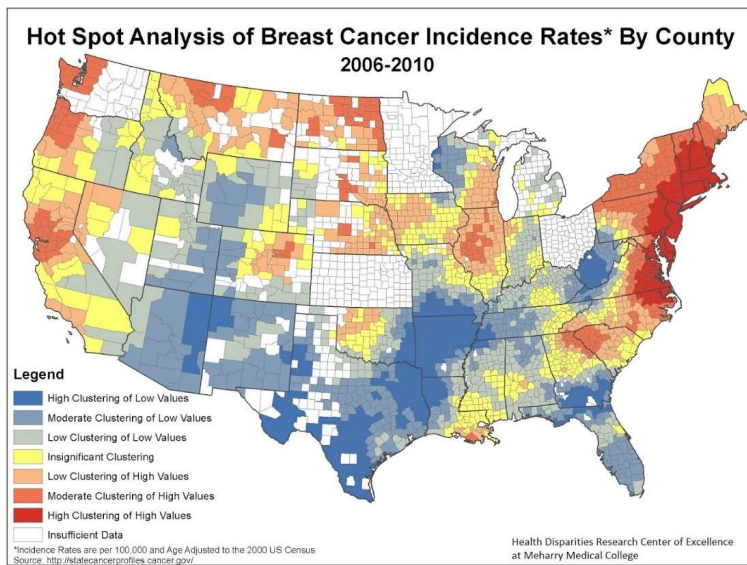- An interface between geospatial data and map users.

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Map

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Map

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Map

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Map

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Taxonomy of Maps

Real World

Reference Maps

Thematic Maps

Discrete
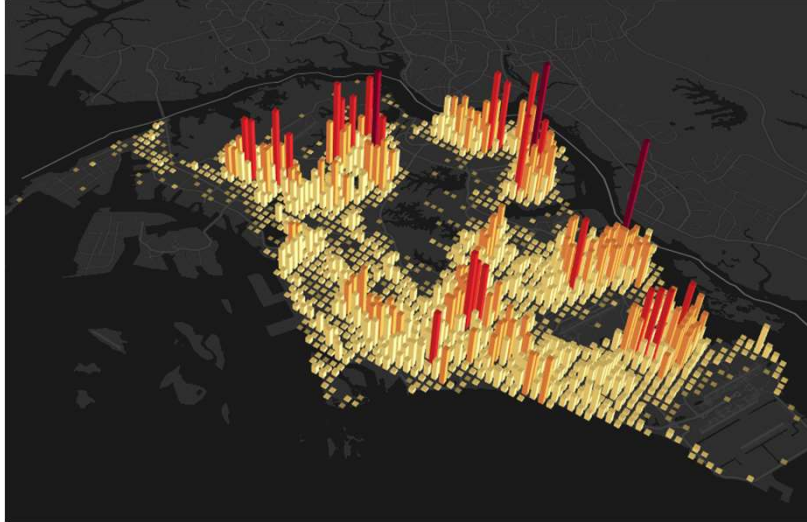
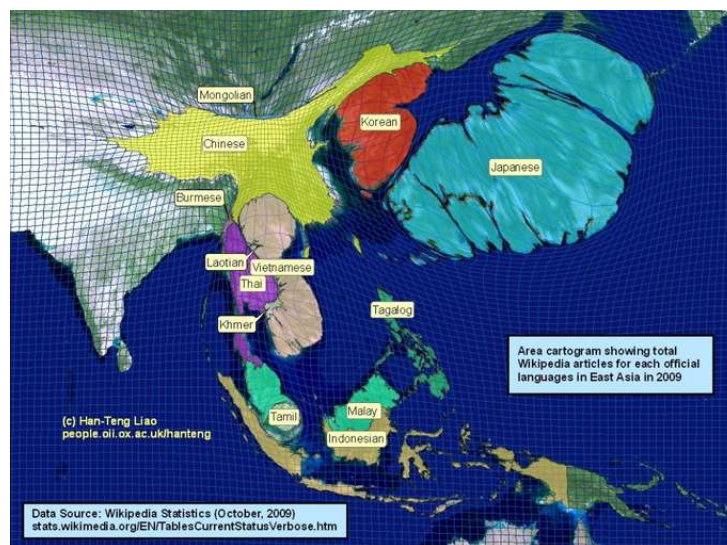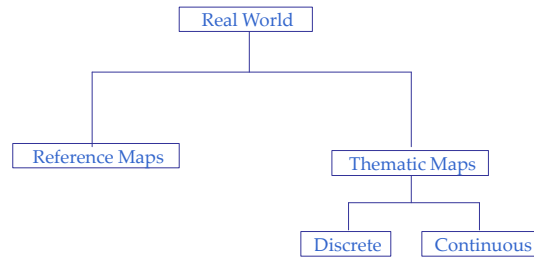Continuous

Slocum, T. A., McMaster, R. B., Kessler, F. C., and Howard, H. H. (2008) *Thematic Cartography and Geovisualization, 3rd Edition.*
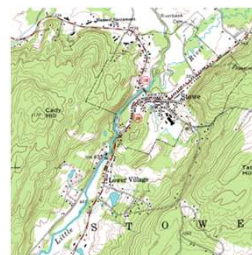
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Reference Maps

- A.k.a., General-Purpose Map
- Emphasize the location of spatial phenomena, such buildings, roads, vegetation, rivers, etc.
- Some of popular reference maps: topographical map and internet map such as Google map
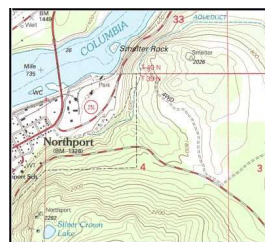
(Source: US Geological Survey)

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Thematic Maps

- A.k.a., Statistical Map
- A thematic map is used to display the spatial pattern of **a theme or attribute**
- Starting from 19th century
- Some popular thematic maps: Choropleth map, Cartogram map, etc.

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Thematic Map: Land Use Map

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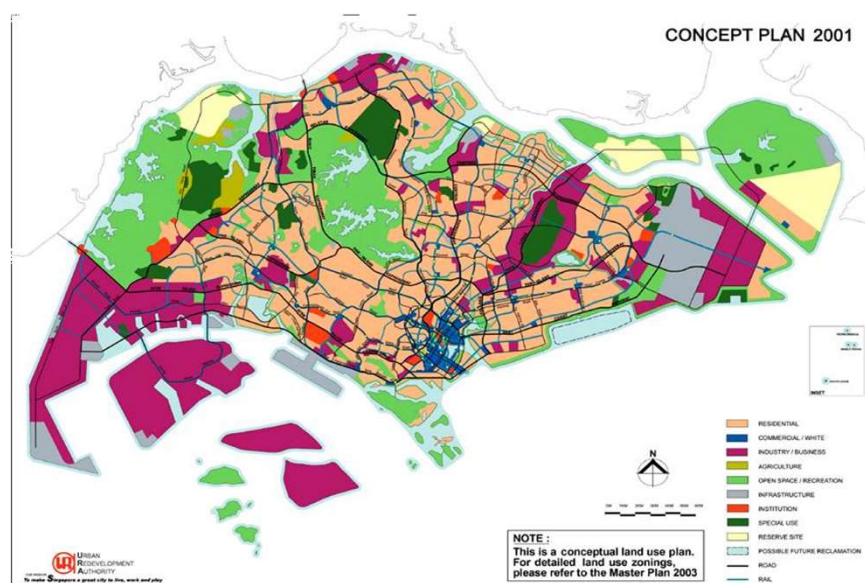 - Point data visualization
  - Line data visualization
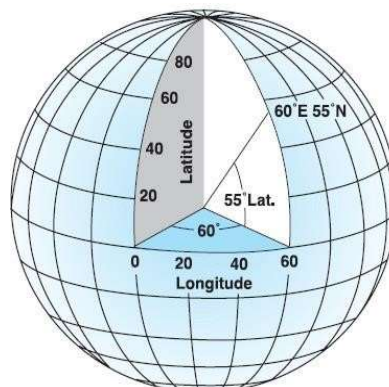 - Region data visualization
- Geospatial datasets

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Geographic Coordinate Systems

- Define the locations on the earth using a 3D spherical surface

Latitude-Longitude

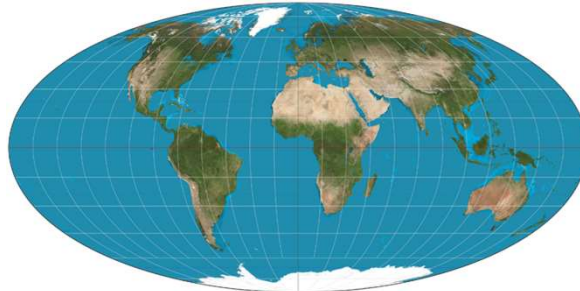https://desktop.arcgis.com/en/arcmap/10.3/guide-books/map-projections/about-geospatial-coordinate-systems.htm
https://www.youtube.com/watch?v=2PllX2YOAHo

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Map Projection

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- Represent the **surface** of a sphere or other 3D body on a plane
- Necessary for creating maps

Wikipedia, Map projection.
https://en.wikipedia.org/wiki/Map_projection

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Map Projection

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From a Sphere to a Plane

- Hundreds of different map projections have been devised since the early Babylonian stone-inscribed world map[1] which was created in early 600 BC.

- It is generally acknowledged that most maps fall into **three** broad families of **map projection**[2].

- These map projections are based on the **developable surfaces** of the **cylinder**, **cone** and **plane**.

- Which surface is best will depend on the **region** to be mapped, its geographical **extent** and the desired **geometric properties** of the map[2].
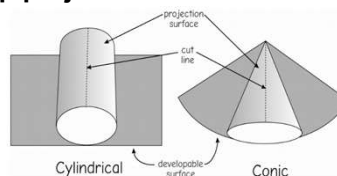
An ancient Babylonian map of the Mesopotamian world (700-500 BC)
Image from [2]

[1] World History Encyclopedia, Babylonian Map of the World - https://www.worldhistory.org/image/526/babylonian-map-of-the-world/
[2] Mathworks, The Three Main Families of Map Projections - https://www.mathworks.com/help/map/the-three-main-families-of-map-projections.html

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Map Projection

Cylindrical Projection

- Cylindrical projection is produced by wrapping a cylinder around a globe (Earth). The map projection is the image of the globe projected onto the cylindrical surface, which is then unwrapped into a flat surface.

- Cylindrical projections can be either **equal-area** (preserves area but distorts shape), **conformal** (preserves angle/shape but distorts area and distance), or equidistant (preserve distance).
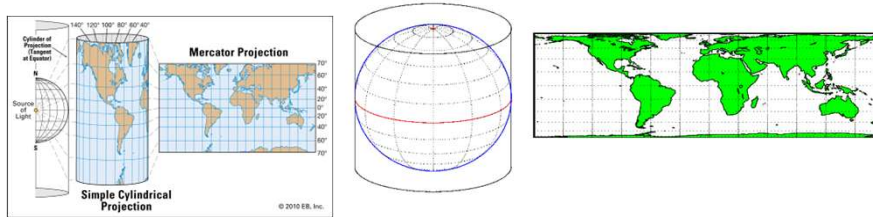
Mercator conformal cylindrical projection
Image from [1]

Equal-area cylindrical projection
Image from [2]

[1]   Mathworks, The Three Main Families of Map Projections - https://www.mathworks.com/help/map/the-three-main-families-of-map-projections.html
[2]   Britannica, Mercator Projections - https://www.britannica.com/science/Mercator-projection

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Example: Mercator Projection
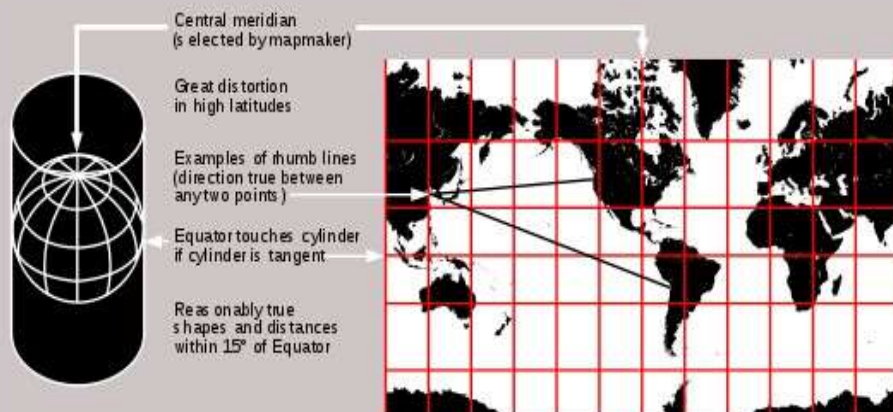
A cylindrical map projection

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Example: Mercator Projection

Distorted Area Size
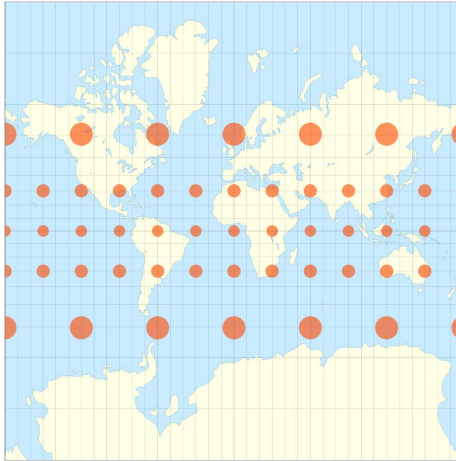
Wikipedia, Mercator projection.
https://en.wikipedia.org/wiki/Mercator_projection

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Example: Mercator Projection

Distorted Area Size

Snyder, "Flattening the Earth"
Based on slide from Hanrahan

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Example: Mercator Projection

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MERCATOR PROJECTION

https://www.youtube.com/watch?v=8I_VpC6IuJs
https://www.youtube.com/watch?v=kIID5FDi2JQ

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Map Projection

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Conic Projection

- A conic projection is derived from the projection of the globe onto a **cone** placed over it. In the normal aspect, the apex of the cone lies on the polar axis of the Earth.
- Conic projections often achieve less distortion at mid and high latitudes than cylindrical projections[1].

Albers Equal Area Conic   Equidistant Conic   Lambers Conformal

Albers Equal-Area projection, polar aspect

3 conical projections examples: **Albers equal area** (preserves area), **equidistant** (preserves distance) and **conformal** (preserves shape) [2]

Image from [1]

[1] Mathworks, The Three Main Families of Map Projections - https://www.mathworks.com/help/map/the-three-main-families-of-map-projections.html
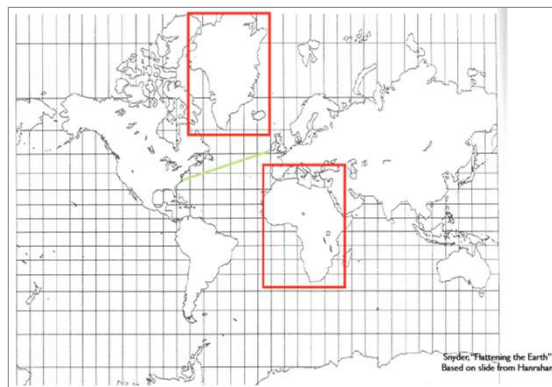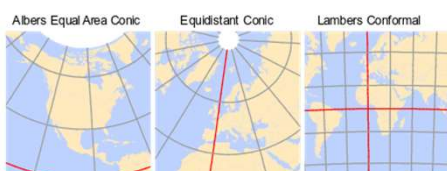[2] Conical Projections - https://mgimond.github.io/Spatial/chp09-0.html

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Map Projection

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Azimuthal Projection

- An azimuthal projection is a projection of the globe onto a plane.

- Most azimuthal projections are not suitable for displaying the entire Earth in one view, but give a sense of the spherical globe[1].

Orthographic   Gnomonic   Equidistant
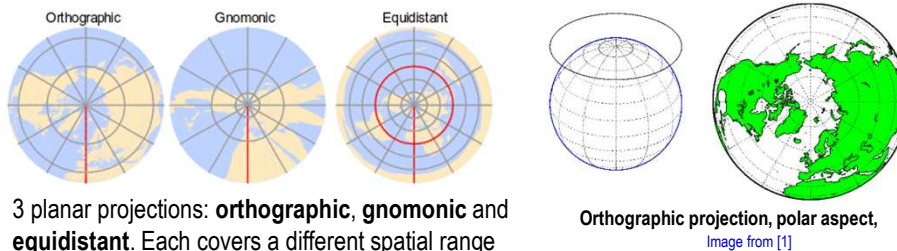
3 planar projections: **orthographic**, **gnomonic** and **equidistant**. Each covers a different spatial range (with the latter covering both northern and southern hemispheres) and each preserves a unique set of spatial properties.) [2]
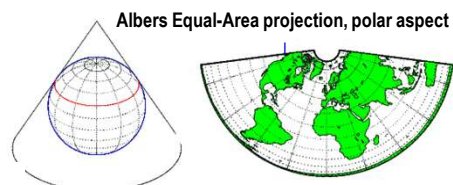
Orthographic projection, polar aspect,
Image from [1]

[1] Mathworks, The Three Main Families of Map Projections - https://www.mathworks.com/help/map/the-three-main-families-of-map-projections.html
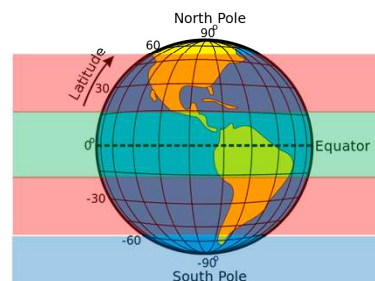[2] Planar Projections - https://mgimond.github.io/Spatial/chp09-0.html

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Map Projection

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Which Projection Should I Choose for a Region?

- The **latitude rule**[1] is a good rule of thumb in making a decision on which map projection to use for a given geographical region.

- To map **tropical** regions (e.g. Singapore, India), use **cylindrical** projection (e.g. Mercator).

- To map **middle latitude** (e.g. USA, China, New Zealand), use **conic** projection (e.g. Albers Equal-Area, Equidistant Conic).

- To map **polar regions** (e.g. North Pole), use **azimuthal** projection (e.g. Azimuthal Equidistant).

[1] Jochen Albrecht (Hunter College, City University of New York, CUNY), Choosing a projection -
http://www.geo.hunter.cuny.edu/~jochen/gtech201/lectures/lec6concepts/map%20coordinate%20systems/how%20to%20choose%20a%20projection.htm

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Map Projection

What is the Purpose of the Map?

- The **purpose** of your geospatial analysis also influences the map projection choice. Map projections are not 100% accurate. Each projection distorts the surface of the Earth in some ways, while retaining some useful properties.

- The **equal-area** projections (e.g. "Lambert Cylindrical Equal Area", "Albers Equal Area Conic") **preserve area**[1]. This is a good choice, if you want to **calculate the area** of a country or city or plot a **dot density map** for each region.

- The **equidistant** projections (e.g. "Azimuthal Equidistant projection") **preserve distance**[2] and would be suitable if you want to analyse flight distances or shipping routes.

- The **conformal** projection is useful when the map's main purpose involves **measuring angles**, showing accurate **local directions**, or representing the **shapes** of features or **contour lines** (e.g. in weather maps, civil engineering & military maps)[1].

[1]   Jochen Albrecht (Hunter College, City University of New York, CUNY), Choosing a projection - http://www.geo.hunter.cuny.edu/~jochen/gtech201/lectures/lec6concepts/map%20coordinate%20systems/how%20to%20choose%20a%20projection.htm
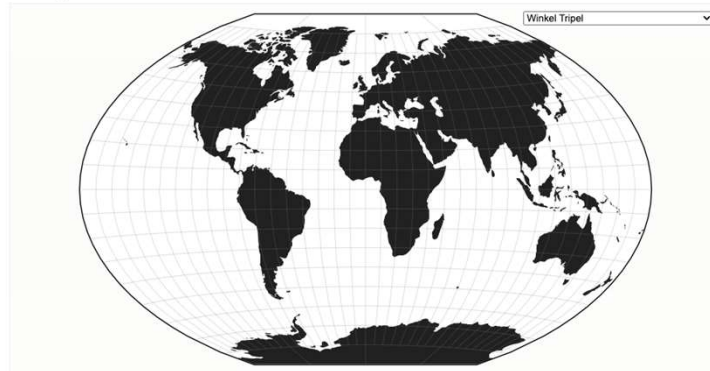[2]   Alexis Cook, Coordinate Reference Systems- https://www.kaggle.com/alexisbcook/coordinate-reference-systems

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Demo of More Map Projections

- https://observablehq.com/@d3/projection-transitions

Projection Transitions

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Outline

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- What is map
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- Visualization of geospatial data
  - Point data visualization
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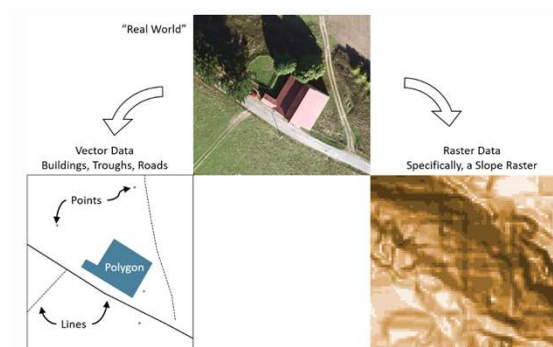 - Region data visualization
- Geospatial datasets

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Basic Geospatial Data Models

- Vector data model represent features as discrete **points, lines and polygons**, and is widely used in cartography, and network analysis
- Raster data model represent the continuous data as rectangular matrix of square cells (i.e., pixels), and is useful as background maps and for spatial analysis

Data model definitions: https://gsp.humboldt.edu/olm/Lessons/GIS/04%20CreatingSpatialData/VectorDataModels1.html

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Vector Data Model

- Used to represent **points, lines, and areas**

- All are represented using coordinates
  - One per **point**
  - Lines as **polylines**
    - Straight lines between points
  - Areas as **polygons**
    - Straight lines between points, connecting back to the start
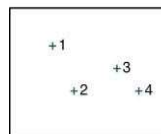   - Point locations recorded as coordinates
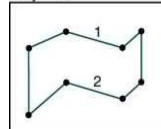
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Vector Data Model
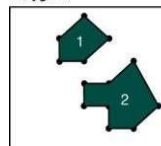

Points	Point number	(x,y) coordinates
	1	(2,4)
	2	(3,2)
	3	(5,3)
	4	(6,2)

Polylines	Polyline number	(x,y) coordinates
	1	(1,5) (3,6) (6,5) (7,6)
	2	(1,1) (3,3) (6,2) (7,3)

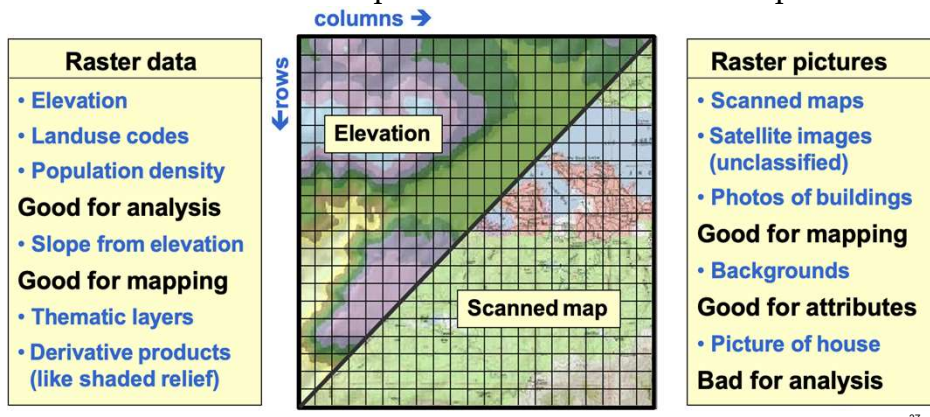| Polygons	Polygon number	(x,y) coordinates
	1	(2,4) (2,5) (3,6) (4,5) (3,4) (2,4)
	2	(3,2) (3,3) (4,3) (5,4) (6,2) (5,1) (4,1) (4,2) (3,2)

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Raster Data Model

- All raster formats are basically the same
    - Cells organized in a matrix of rows and columns
   - Content is more important than format: data or picture?

columns →

←rows

Raster data		Raster pictures
• Elevation	Elevation	• Scanned maps
• Landuse codes		• Satellite images (unclassified)
• Population density		• Photos of buildings
Good for analysis		**Good for mapping**
• Slope from elevation		• Backgrounds
Good for mapping		**Good for attributes**
• Thematic layers	Scanned map	• Picture of house
• Derivative products (like shaded relief)		**Bad for analysis**

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Geospatial Data File Formats

Basic types

- There are a variety of geospatial data file formats that are widely used by existing Geographical Information Systems (GIS). The two basic types are:

- **Raster GIS file** – These files contain raster data that are made up of **pixels** (i.e. grid cells of data values). They are usually regularly spaced and square but need not always be so[1].

- **Vector GIS file** – These files contain **vector graphics** that comprise of data that describes individual points (e.g. landmarks), vertices of polygons (e.g. boundaries), lines (e.g. roads or paths) and other geometric entities[2].

Adapted from [1], [2]
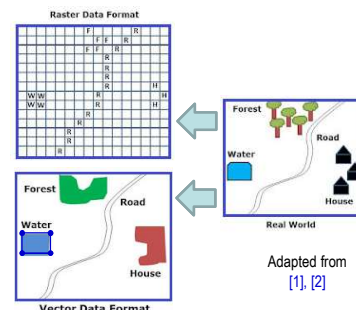
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[1] What are the Raster Data Formats in GIS and Remote Sensing (2020) - https://www.gisoutlook.com/2020/04/raster-data-formats-in-gis.html
[2] What is Vector Data Model of GIS (2020) - https://www.gisoutlook.com/2020/04/vector-data-model-of-gis.html

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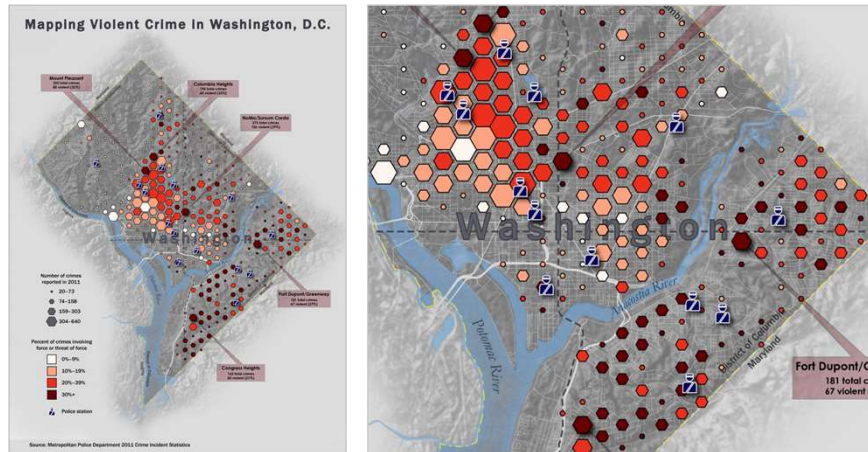- Geospatial datasets

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Point Data

- Points scattered in the geographic space, with longitude and latitude information, optionally with weights
  - Landmarks on the map
  - Restaurants of your neighborhood

- Marking the data on the map would be the most direct and simplest way to visualize point data

- Point-based visualizations are widely used
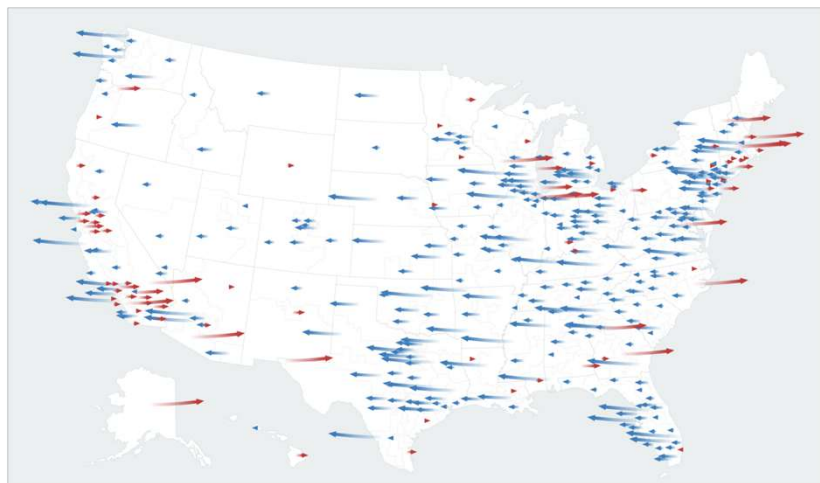
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Symbol Map

Cooper Thomas, Violent Crime in Washington, D.C.
https://visual.ly/community/infographic/geography/violent-crime-washington-dc
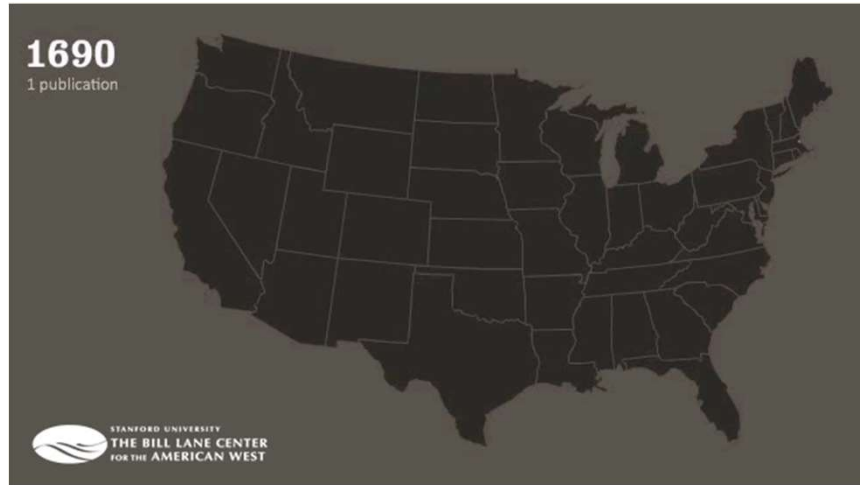
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Symbol Map

The New York Times, How Democrats Took the House.
https://www.nytimes.com/interactive/2018/11/07/us/politics/how-democrats-took-the-house.html

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Symbol Map

Rural West Initiative, Mapping Journalism's Voyage West.
https://web.stanford.edu/group/ruralwest/cgi-bin/drupal/visualizations/us_newspapers

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Point Distribution Map

BBC, Every death on every road in Great Britain 1999-2010.
https://www.bbc.co.uk/news/uk-15975724

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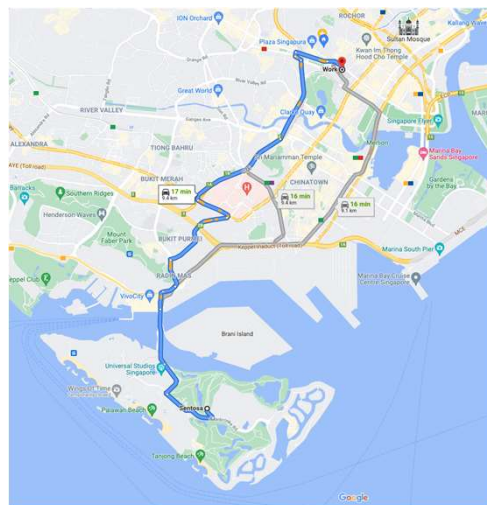 - Region data visualization
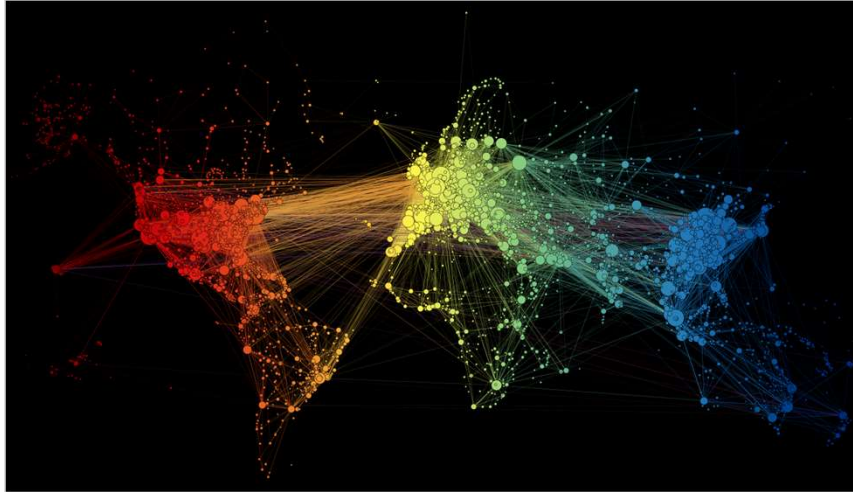- Geospatial datasets

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Line Data

- Line data comprise locations and the paths between them
- Each line has a length property, namely the distance between two locations

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Air Traffic Network

Martin Grandjean, Connected World: Untangling the Air Traffic Network.
http://www.martingrandjean.ch/connected-world-air-traffic-network/

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Facebook Friend Relationship

Facebook, 2013.
https://bit.ly/2P7WZep
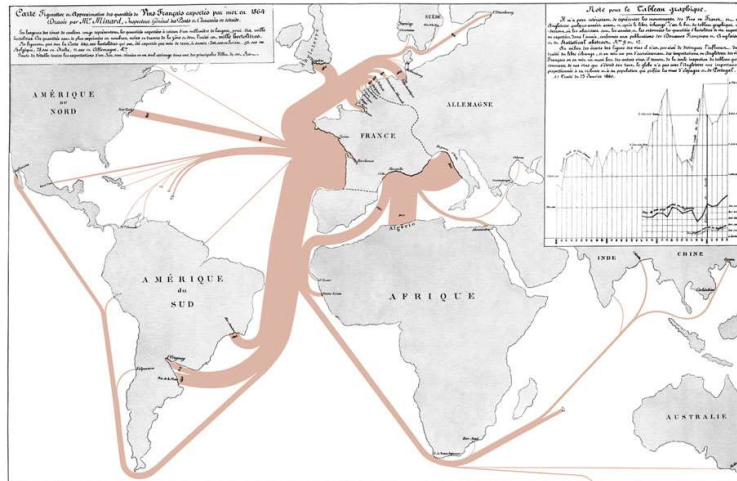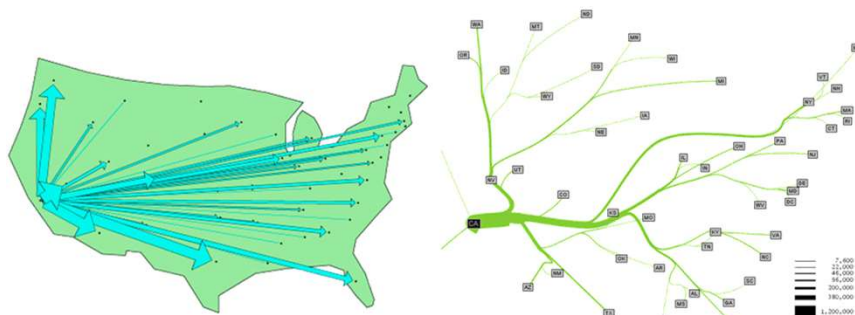
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Bundling Lines

Charles Joseph Minard, French wine exports,1864.
https://en.wikipedia.org/wiki/Flow_map

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Flow Map

Linking the immigrations from California
to other states with arrows

Visualized with Flow Map

Buchin, Kevin, Bettina Speckmann, and Kevin Verbeek. "Flow map layout via spiral trees."
IEEE transactions on visualization and computer graphics 17.12 (2011): 2536-2544.
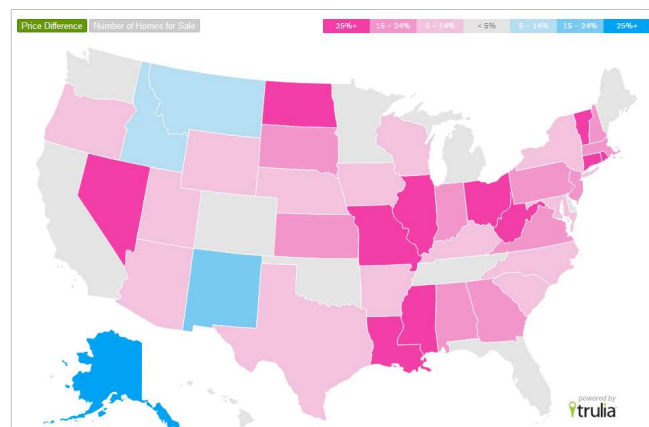
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  - Line data visualization
  - Region data visualization
- Geospatial datasets

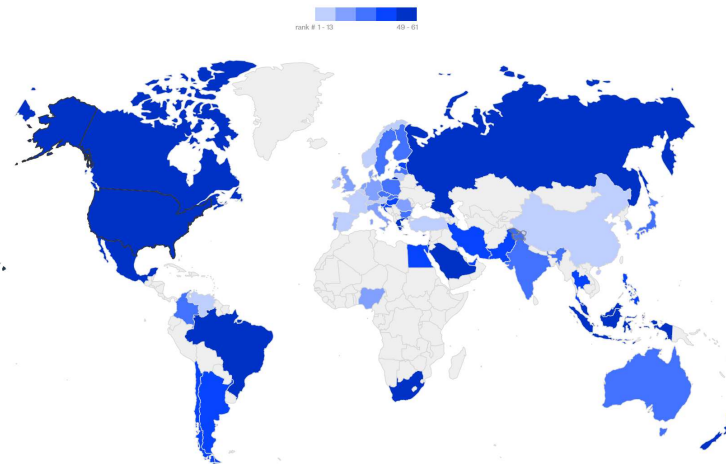51

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Selling Real Estate: Men vs. Women

Trulia, Is real estate a man's or woman's world.
https://bit.ly/2KIh9LE

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The World Gas Prices

Gasoline Prices Around the World
https://www.bloomberg.com/graphics/gas-prices/#20183:United-States:USD:g

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Choropleth Map

- A thematic map in which a set of pre-defined areas (e.g., states or countries) are shaded or patterned in proportion to the measurement of the statistical variable within different regions

- Also known as, filled map

- Assume that the data is evenly distributed in the area

- Often represent the scales of data with **<u>colors</u>**

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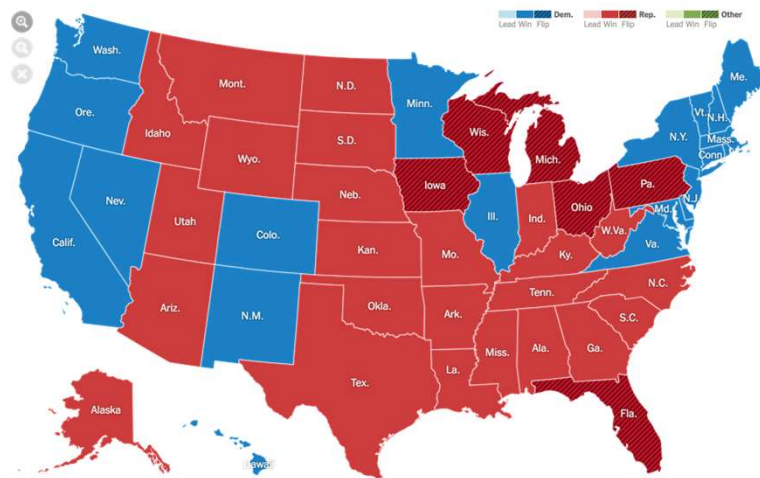# Choropleth Map

- Colour scheme tool: ColorBrewer

http://colorbrewer2.org
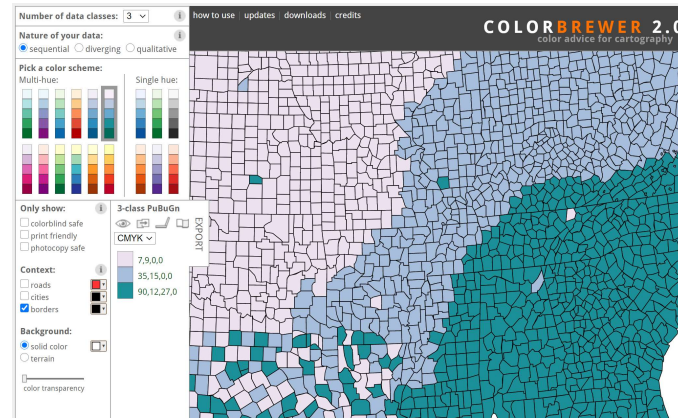
55

Choropleth Map

The New York Times, 2016 Presidential Election Results.
https://www.nytimes.com/elections/2016/results/president

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Choropleth Map Can Be Misleading

- The map fails to take account of **the population distribution**
  - It fails to allow for the fact that the population of the red states is on average significantly lower than that of the blue ones. The blue may be small in area, but they represent a large number of voters, which is what matters in an election

- When data is accumulated at the place where display space is less, there comes a mismatch, and vice versa

- This mismatch would very possibly **mislead** the audience

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Choropleth Map Can Be Misleading

Mark Newman, 2016 Maps of the 2016 US presidential election results.
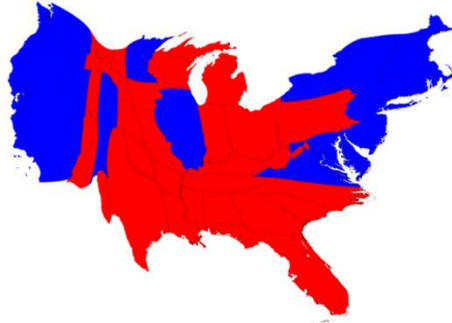http://www-personal.umich.edu/~mejn/election/2016/
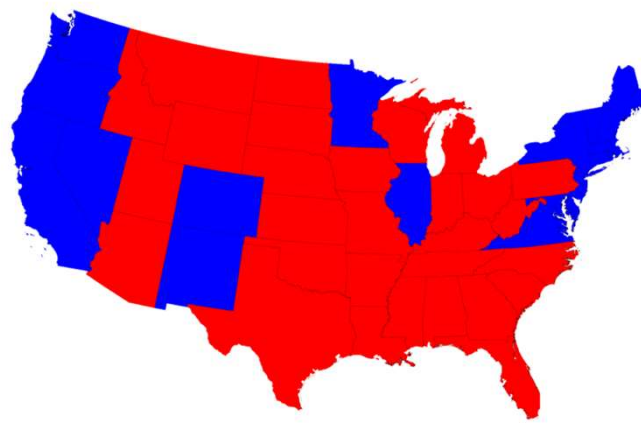
58

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Cartogram Map

- A map in which some thematic mapping variable – **such as travel time, population, or Gross National Product** – is substituted for land area or distance.

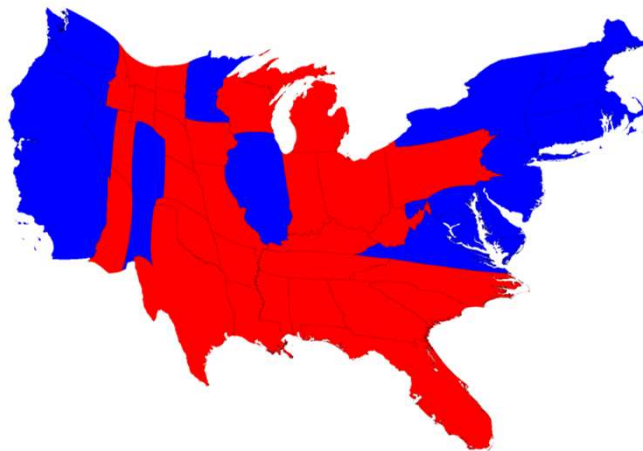Mark Newman, 2016 Maps of the 2016 US presidential election results.
http://www-personal.umich.edu/~mejn/election/2016/

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Cartogram Map

Mark Newman, 2016 Maps of the 2016 US presidential election results.
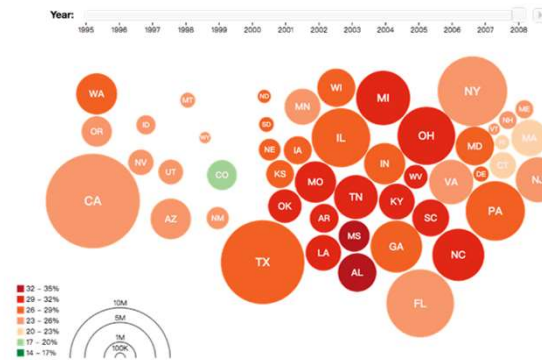http://www-personal.umich.edu/~mejn/election/2016/

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Other Maps: Dorling Cartogram

- Cartograms distort the shape of geographic regions so that the area directly encodes a data variable. A common example is to resize countries proportional to population or GDP.
- **Dorling cartogram** represents each geographic region as non-overlapping circles.

Mike Bostock , Obese People Per State.
http://mbostock.github.io/protovis/ex/cartogram.html

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Outline

- What is geospatial data
- What is map?
- Map projection
- Visualization of geospatial data
  - Point data visualization
  - Line data visualization
  - Region data visualization
- Geospatial datasets

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Geospatial Datasets

OpenStreetMap
https://www.openstreetmap.org/

HK Government Datasets
https://data.gov.hk

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Geospatial Datasets

- Google/Baidu API
- OpenStreetMap (http://www.openstreetmap.org)
- HK government dataset (http://data.gov.hk)
- NYC Open Data (https://opendata.cityofnewyork.us)
- Data.gov (https://www.data.gov)

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Common Geospatial Data Visualization Packages

- JavaScript
  - D3: d3.geo (https://d3js.org/d3-geo)
  - Leaflet (https://leafletjs.com/)
  - …

- Python
  - Geoplot (https://residentmario.github.io/geoplot)
  - GeoPandas (https://geopandas.org/en/stable/)
  - …

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Summary

- What is geospatial data
- What is map
- Map projection
- Visualization of geospatial data
  - Point data visualization
  - Line data visualization
  - Region data visualization
- Geospatial datasets

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Summary

- Geospatial data refers to data and information that has explicit or implicit association with a location, and has been widely seen in various applications

- Map projection converts the **surface** of a sphere or other 3D body on a 2D plane. Each map projection method is a trade-off of different criteria and there is no optimal map projection for all situations

- Geospatial data models include vector and raster data models

- Geospatial data visualization techniques mainly cover three types: Point data visualization, line data visualization and region data visualization

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Questions?

Thank You!

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Interesting examples of cartogram

- Cartogram of the world's languages
  http://th-mayer.de/cartogram/

- China Still Dominates, but Some Manufacturers Look Elsewhere
  https://archive.nytimes.com/www.nytimes.com/interactive/2013/04/08/business/global/asia-map.html

- Dorling Cartogram of Obesity in the United States (1995 to 2008)

https://homes.cs.washington.edu/~jheer/files/zoo/ex/maps/cartogram.html

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Example: HTML5 + JavaScript based GeoVisual Analytics

Drought Extends, Crops Wither

This summer's heat and rainlessness, which rivals the devastating 1988 drought, has left crops withering in the fields and farmers trying to calculate their losses. An analysis by The New York Times looks at the widely varying effects of this summer's heat and drought on crops critical to the nation's farm economy. Related Article »
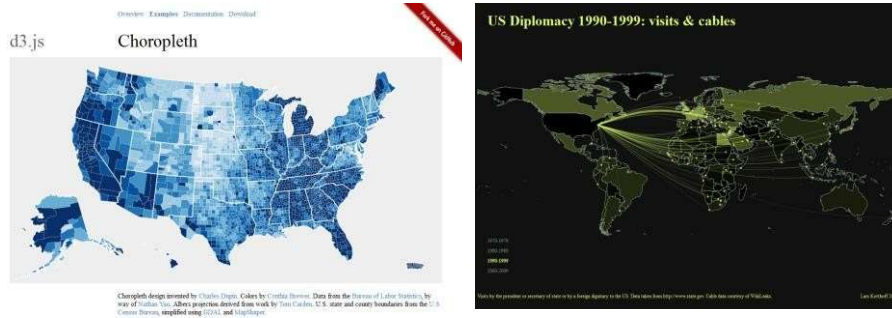

http://www.nytimes.com/interactive/2012/08/24/us/drought-crops.html
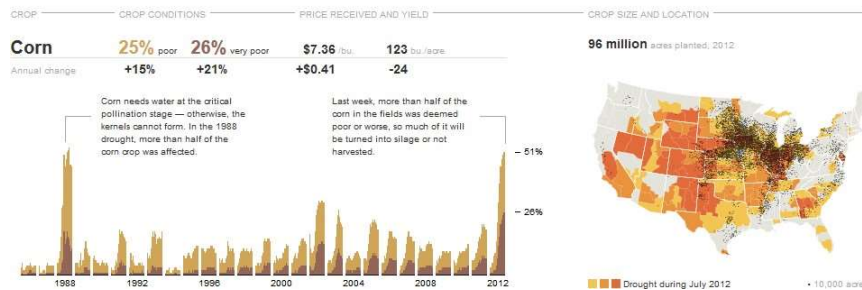
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d3.js for Visualizing Geographical Data

- d3.geo (Geography)
  (https://github.com/mbostock/d3/wiki/Geo)

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D3 Tutorial

- Let's Make a Map
  https://bost.ocks.org/mike/map/

- How to Make Choropleth Maps in D3
  https://rockcontent.com/blog/how-to-make-choropleth-maps-in-d3/

- A Map to Perfection: Using D3.js to Make Beautiful Web Maps
  https://www.toptal.com/javascript/a-map-to-perfection-using-d3-js-to-make-beautiful-web-maps

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