GEOG 531 Quantitative Methods In Geographic Research

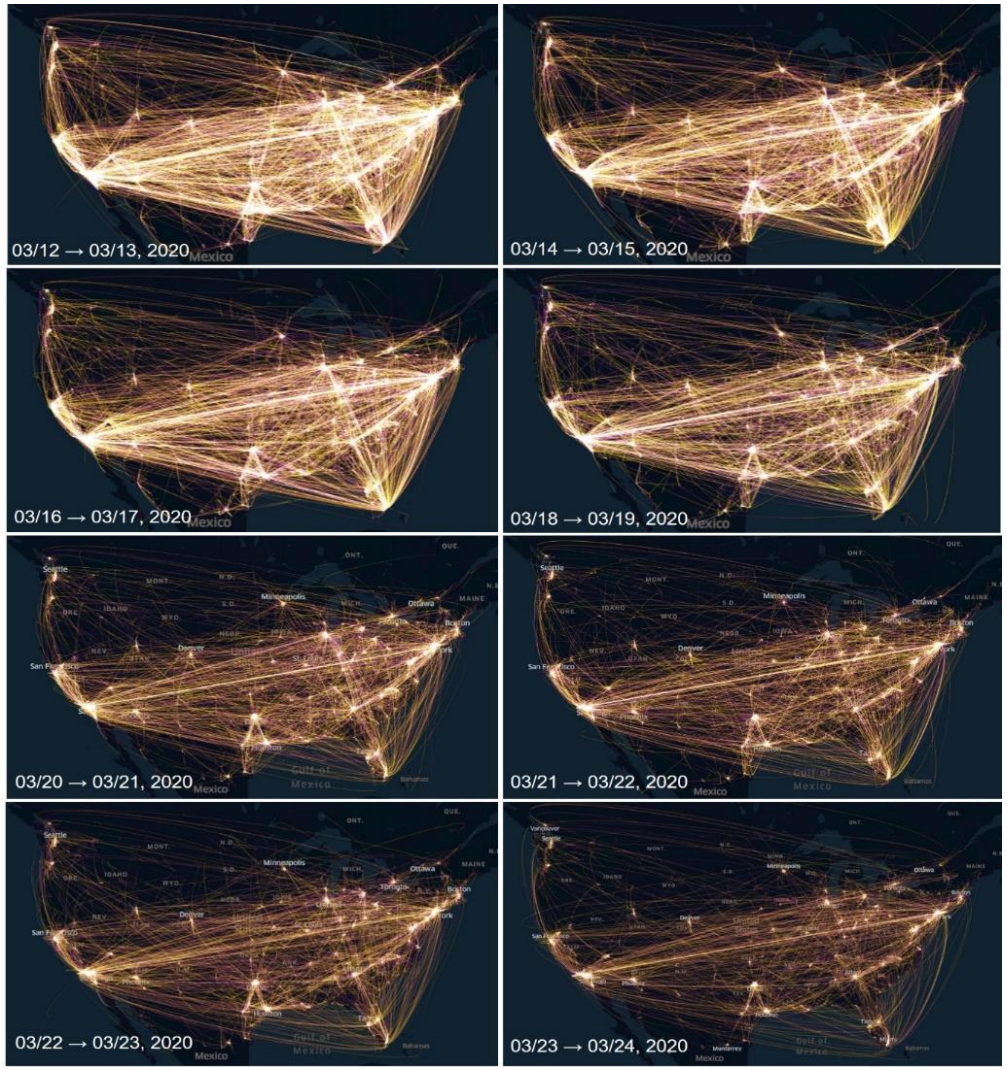
Statistical Data Types and Nature of Spatial Data

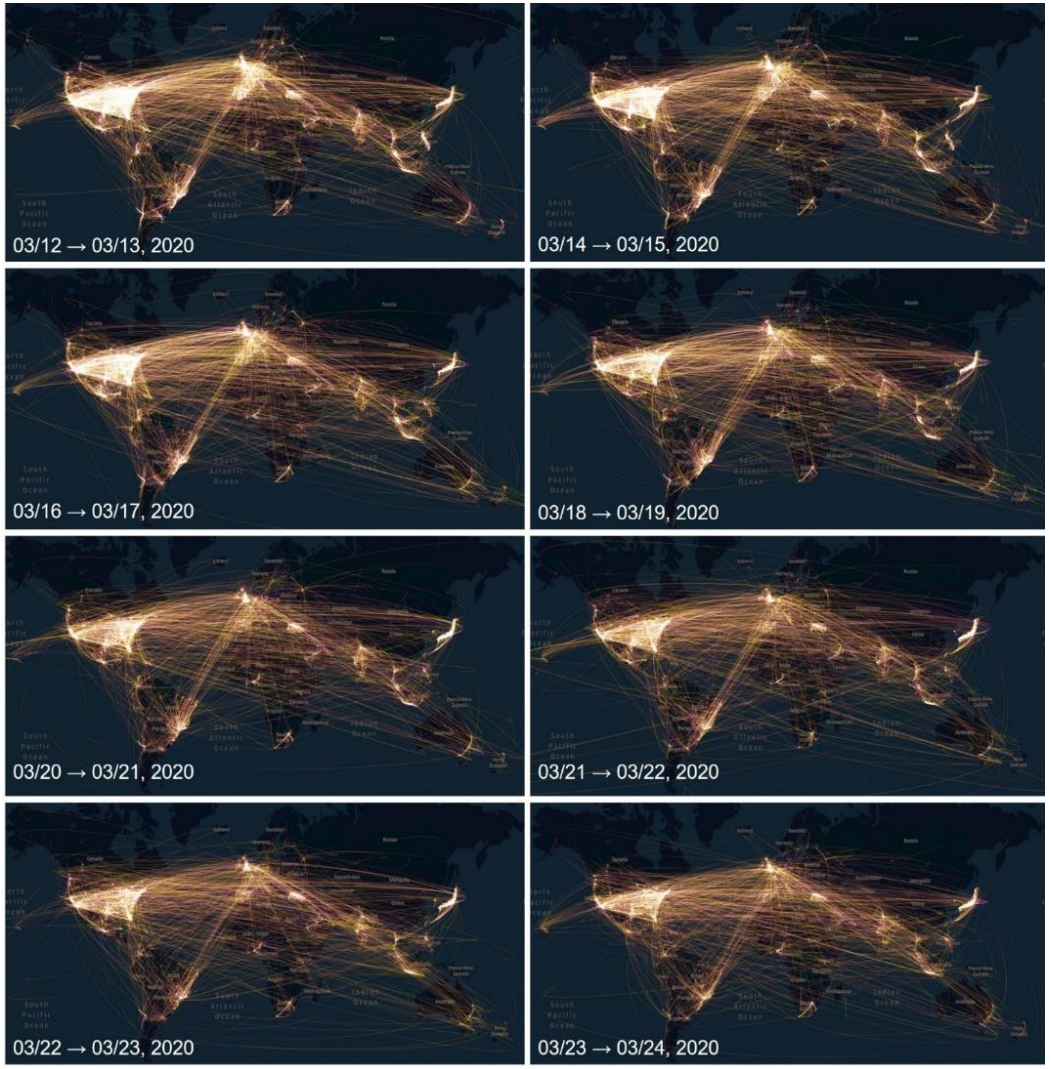
Lecture Outline

- Descriptive vs Inferential Statistics
- Statistical Data Types and Spatial Data
- Hands-on Exercise 1: Thematic mapping with ArcGIS

- Nature of Spatial Data
  - First law of geography
  - MAUP (Modifiable Areal Unit Problem)
  - Boundary problem
  - Projection problem

Population daily movement changes in March 2020





Any patterns? What causes the pattern? How to quantify the movement changes?

Types of Statistics

- Based on domains:
  - **Classical statistics** (basic and fundamental)
  - Biostatistics
  - Econometrics
  - ……
  - **Spatial statistics (deal with spatial/geographic data)**
- Based on functions:
  - **Descriptive statistics** (summary)
  - **Inferential statistics** (forecasting, decision making)

Descriptive Statistics

- Concerned with summarization and presentation of data
  - Numerical
    - mean/average, median, range
  - Tabular
    - tables
  - Graphical
    - histograms, scatter plot
  - Cartographical
    - Thematic maps

Descriptive Statistics Example

Home sales of Milwaukee, Wisconsin, 2014 (subset)

Address	Sqft	Sale $
129 W BOLIVAR AV	1,246	130,000
1336 W VAN NORMAN	1,143	87,000
137 W UNCAS AV	1,521	150,000
1409 W WANDA AV	1,059	168,000
1416 W HOWARD AV	1,958	122,500
1420 W FOSTER AV	1,208	136,000
1421 W KLEIN AV	1,135	157,000
1430 W RAMSEY AV	1,053	115,000
1444 W FOSTER AV	1,070	134,900
1510 W CLAYTON CREST	1,282	159,880
1521 W HOLMES AV	936	123,000
1526 W VOGEL AV	942	108,500
154 W WILBUR AV	1,346	180,000
1564 W DENIS AV	1,427	156,500
1566 W GRANGE AV	1,326	100,000
1573 W BOLIVAR AV	1,208	116,000
158 W TRIPOLI AV	1,341	200,000
1647 W BOTTSFORD AV	1,364	156,000
165 W VAN NORMAN A	1,096	111,500
1700 W HOWARD AV	2,988	170,000
1801 W BOLIVAR AV	2,354	179,960
181 W SAVELAND AV	1,373	148,000
1815 W GRANGE AV	1,949	203,500
1816 W WHITAKER AV	1,[illegible]	
1819 W HOLMES CT	2,[illegible]	

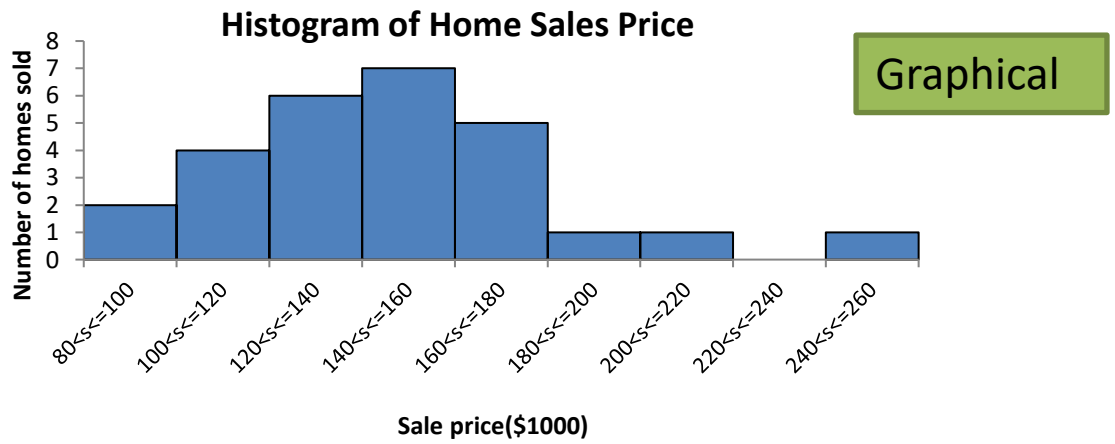
Tabular

Can we use fewer numbers to describe the sale price?

Mean	147489.6
Median	148000
Standard Deviation	36391.91949
Minimum	87000
Maximum	245000

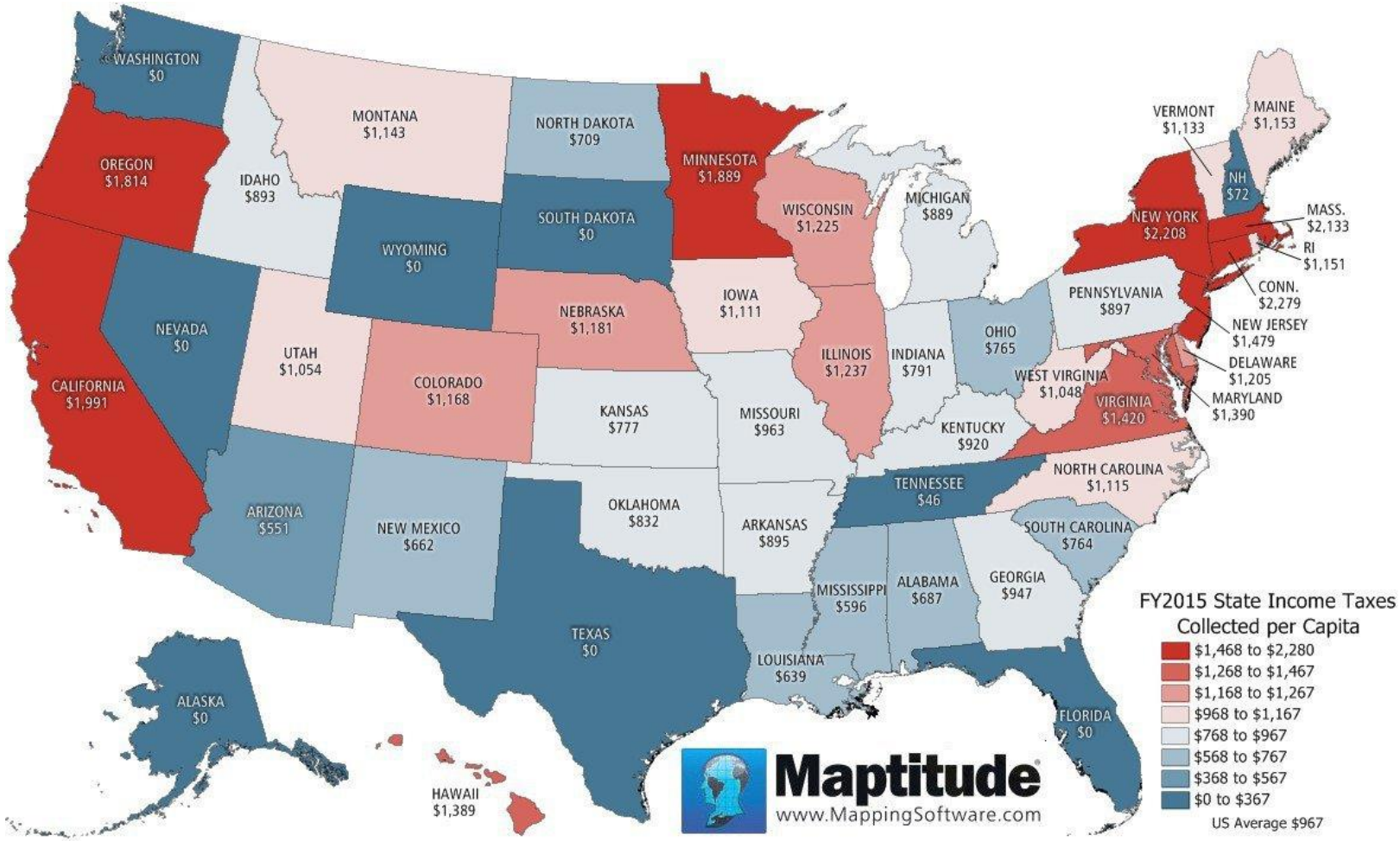
Numerical

Using a diagram?



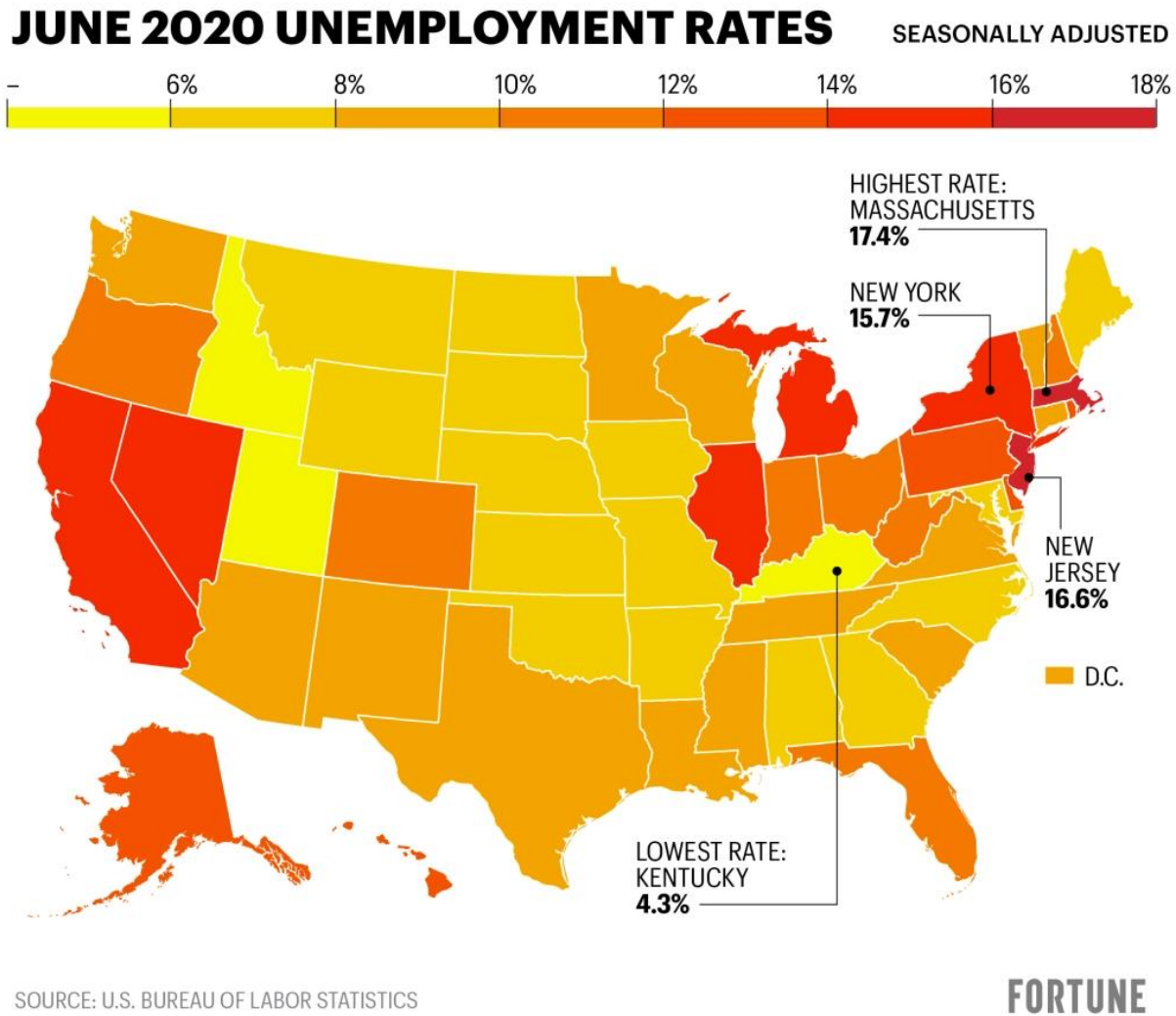
Graphical

Descriptive Statistics Example: Per Capita State Income Taxes



https://www.caliper.com/featured-maps/maptitude-state-income-taxes-per-capita.html

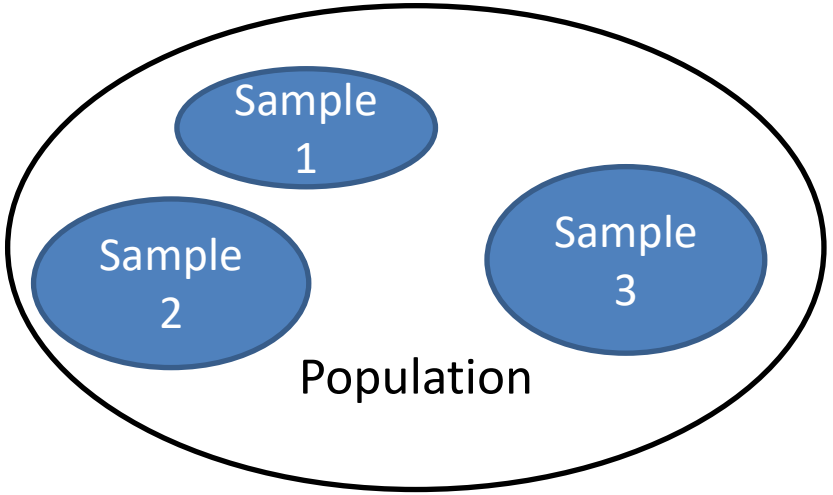
Descriptive Statistics Example: Thematic map of unemployment rates



https://fortune.com/2020/08/06/us-unemployment-rate-states-recovery-economy-benefits-jobless-claims-new-york-kentucky-massachusetts/

Population and Sample

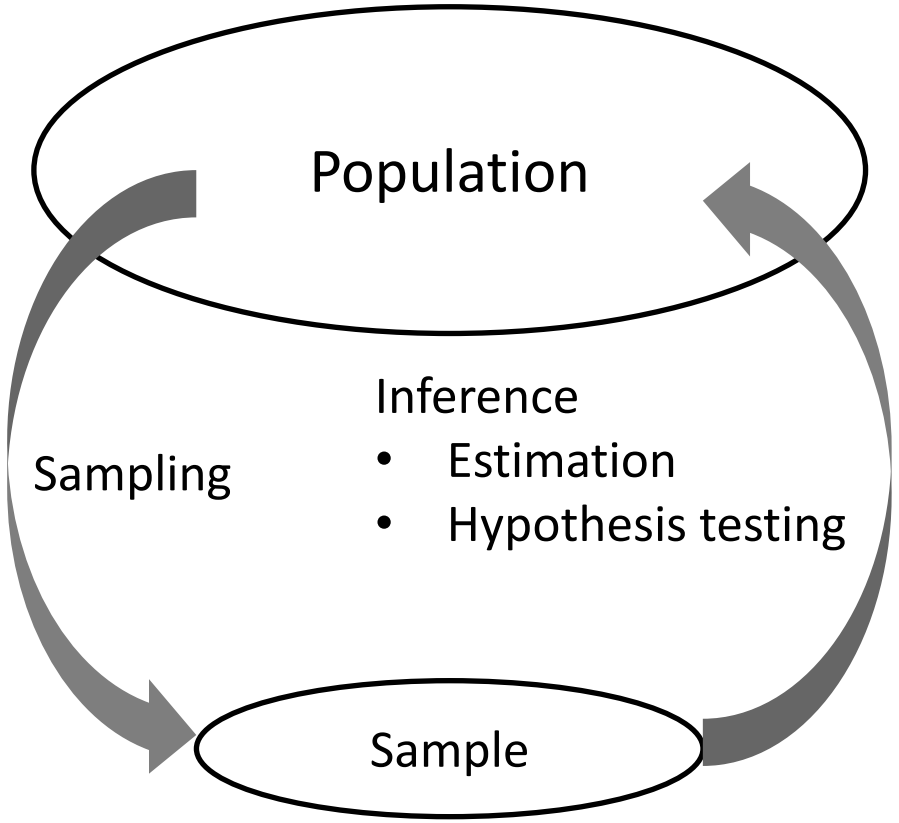
- Population: all data
  - Sometimes impossible to get (e.g., bodyweight of human population)
  - Test could be destructive (e.g., Joke on matches)
- Sample: a subset of population
  - Usually what we have
  - Cost effective, timely/fast



Population	Sample
All trees in a forest	50 trees from the forest
All students at USC	Students majored in Geography
All home sales in SC	100 home sales in Columbia

Inferential Statistics

- Make statements about population based on a sample



Estimation: estimate population properties based on a sample

Hypothesis Testing: determine if an observed pattern in the sample is likely to be true in the population

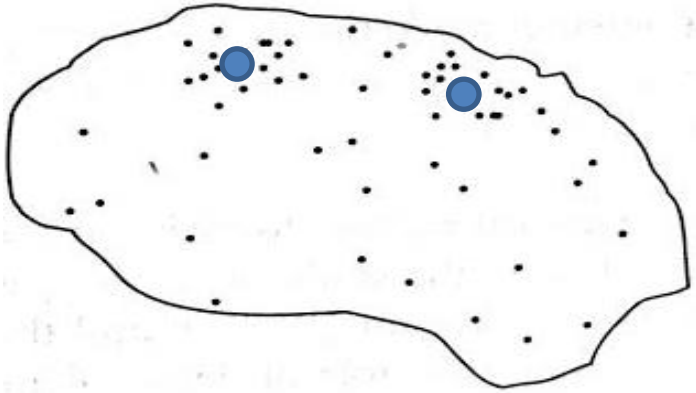
Descriptive vs Inferential Statistics

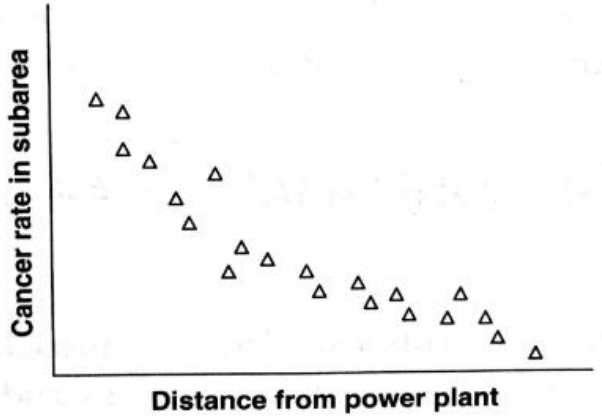
- Descriptive Statistics: exploratory methods
  - Explore patterns and trends in the data
  - Suggest hypotheses
- Inferential Statistics: confirmatory methods
  - Confirm hypotheses
  - Either accept or reject a hypothesis
- Often used together

Typical Steps of using Quantitative Methods

Study the spatial patterns of cancer cases in an area

- 1. Collect data
- 2. Display data
- 3. Discover patterns
- 4. Form hypothesis
  - Cancer cases are related to the distance from local power plant
- 5. Test hypothesis
  - Modeling
  - Statistical inference
- 6. Draw conclusions





The whole process is the core of the Scientific Method

Application Example

PNAS PNAS PNAS

Temporal and spatial changes in social vulnerability to natural hazards

Susan L. Cutter* and Christina Finch

Hazards and Vulnerability Research Institute, Department of Geography, University of South Carolina, Columbia, SC 29208

Edited by B. L. Turner II, Clark University, Worcester, MA, and approved December 21, 2007 (received for review November 2, 2007)

During the past four decades (1960–2000), the United States experienced major transformations in population size, development patterns, economic conditions, and social characteristics. These social, economic, and built-environment changes altered the American hazardscape in profound ways, with more people living in high-hazard areas than ever before. To improve emergency management, it is important to recognize the variability in the vulnerable populations exposed to hazards and to develop place-based emergency plans accordingly. The concept of social vulnerability identifies sensitive populations that may be less likely to respond to, cope with, and recover from a natural disaster. Social vulnerability is complex and dynamic, changing over space and through time. This paper presents empirical evidence on the spatial and temporal patterns in social vulnerability in the United States from 1960 to the present. Using counties as our study unit, we found that those components that consistently increased social vulnerability for all time periods were density (urban), race/ethnicity, and socioeconomic status. The spatial patterning of social vulnerability, although initially concentrated in certain geographic regions, has become more dispersed over time. The national trend shows a steady reduction in social vulnerability, but

(elderly and children), migration, and housing tenure (renter or owner). For example, the literature has cited many reasons why the elderly are more vulnerable in the event of a disaster: physical limitations that influence their inability or unwillingness to comply with mandatory evacuation orders; postdisaster psychological stress that impairs recovery and increases the need for additional social services; declining cognitive abilities to process hazard information necessitating specially targeted risk communication or warning messages; and fewer economic resources to repair damaged homes, especially by elderly residents on fixed incomes (15–18). Thus, the greater the proportion of elderly in a community, the more vulnerable it is and the longer it will take for the community to fully recover from the disaster's aftermath.

There have been some notable attempts to measure vulnerability. There are many national-level hazards and disasters indicator studies that incorporate social characteristics such as population numbers and distributions as a method for defining population exposures to a variety of hazard agents (19–25). Other studies incorporating vulnerability metrics focused on human-environmental systems at different subnational spatial scales: within India (26), U.S. watersheds (27), U.S. Great Plains

Cutter, S. L., & Finch, C. (2008). Temporal and spatial changes in social vulnerability to natural hazards. *Proceedings of the national academy of sciences*, *105*(7), 2301-2306.

Quantitative methods used in this paper

- Descriptive statistics
- Global spatial statistics
- Local indicator of spatial autocorrelation (LISA or the Local Moran's *I*)
- Correlation(*r*)
- Simple linear regression
- Hypothesis test (F-test)
- Principal components analysis (PCA)

Cutter, S. L., & Finch, C. (2008). Temporal and spatial changes in social vulnerability to natural hazards. *Proceedings of the national academy of sciences*, *105*(7), 2301-2306.

Lecture Outline

- Descriptive vs. Inferential Statistics
- **Statistical Data Types and Spatial Data**
- Hands-on Exercise: Thematic map with ArcGIS
- Nature of Spatial Data
  - First law of geography
  - MAUP
  - Boundary problem
  - Projection problem

Data and Dataset

- Data: Measurable information
  -- e.g., population of a city
- Dataset: A collection of data consisting of observations, variables and data values

Home sales of Milwaukee, Wisconsin, 2014 (subset)

Address	Sqft	Sale $
129 W BOLIVAR AV	1,246	130,000
1336 W VAN NORMAN	1,143	87,000
137 W UNCAS AV	1,521	150,000
1409 W WANDA AV	1,059	168,000
1416 W HOWARD AV	1,958	122,500
1420 W FOSTER AV	1,208	136,000

- **Observations**: the elements under the study
- **Variables**: the properties of observation that measured
- **Data values**: the measurement of the properties of the observations

based on Steven Farber, Geographical Analysis , University of Utah

Statistical Data Types

- Nominal, Ordinal, Interval, and Ratio
  - Indicate different levels of measurement/information
- Discrete and Continuous
  - Discrete data: can only take certain values(finite number of values), e.g., zip codes, number of sunny days in a year, COVID cases
  - Continuous data: can take any value(within a range, infinite number of values) e.g., height, temperature
- Quantitative and Qualitative
  - Quantitative: deals with numbers
  - Qualitative: deals with descriptions, e.g., color of eyes

Nominal Data

- Also known as Categorical Data
- Observations are placed into a set of unordered categories
  - mutually exclusive
  - e.g., gender: {male, female},

    geographic location: {North, South, West, East}
  - Qualitative or quantitative? →Qualitative
- Binary Data: when only two categories:, e.g., yes/no, success/failure

Ordinal Data

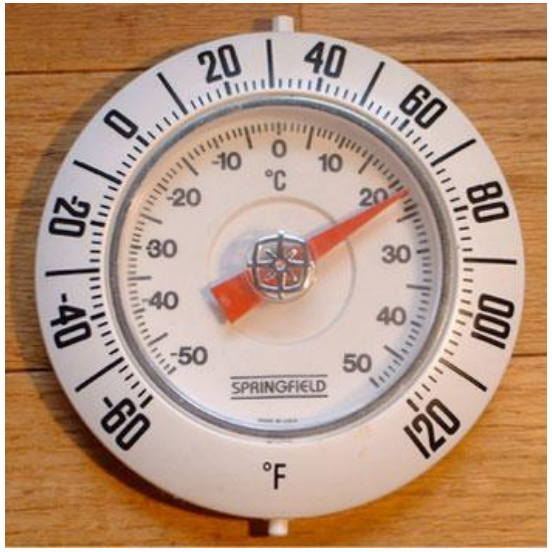
- Observations are ordered or ranked
  - ordered by groups: weak order (e.g., low, average, high)
  - ordered by individual ranks: strong order (e.g., 1st, 2nd,3rd, … last)
  - Comparable: e.g. A is larger than B. But cannot tell how by how much.
  - Qualitative or quantitative? →Qualitative

Country ranked by Area:

Rank	Country	Area(sq km)
1	Russia	17,075,200
2	Canada	9,984,670
3	United States	9,826,630
4	China	9,596,960
5	Brazil	8,511,965

Interval Data

- Not only indicates order, but also the difference between observations
- No natural zero point
- Can add/subtract, **cannot** multiply/divide



Example: temperature in Celsius or Fahrenheit

0 °C doesn't mean "no temperature"

30 °C is 15 °C warmer than 15 °C , but is not twice as warm as 15 °C (15 °C vs -15 °C)

Quantitative or Qualitative? →Quantitative

Ratio Data

- Interval data with a natural zero point
- +,-, x, ÷ is meaningful
- Most numerical data is ratio data
  - population in an area
  - height, weight …
  - temperature in Kelvin: absolute zero(no energy)

Quantitative or Qualitative? →Quantitative

Data Types Summary

Low — Level of information — High

Properties	**Nominal**	**Ordinal**	**Interval**	**Ratio**
Distinctness (= ≠)	√	√	√	√
Order (< >)		√	√	√
Addition (+ -)			√	√
Multiplication (x ÷)				√

qualitative
discrete

quantitative
continuous/discrete

Data Type Exercise

For the following measurements, identify their data types:
– nominal, ordinal, interval or ratio?
– discrete or continuous?
– qualitative or quantitative?

- **Zip code**

–nominal, discrete, qualitative

- **Bronze, Silver, and Gold medals as awarded at the Olympics**

–ordinal, discrete, qualitative

- **Temperature in Fahrenheit**

– interval, continuous, quantitative

- **Number of patients in a hospital**

–ratio, discrete, quantitative

- **Angles as measured in degrees between 0◦ and 360◦**

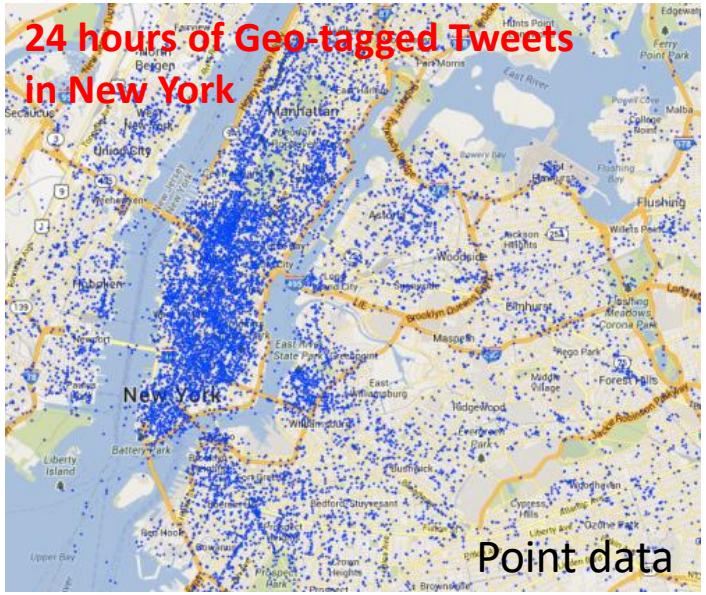
–ratio, continuous, quantitative

What is spatial data?

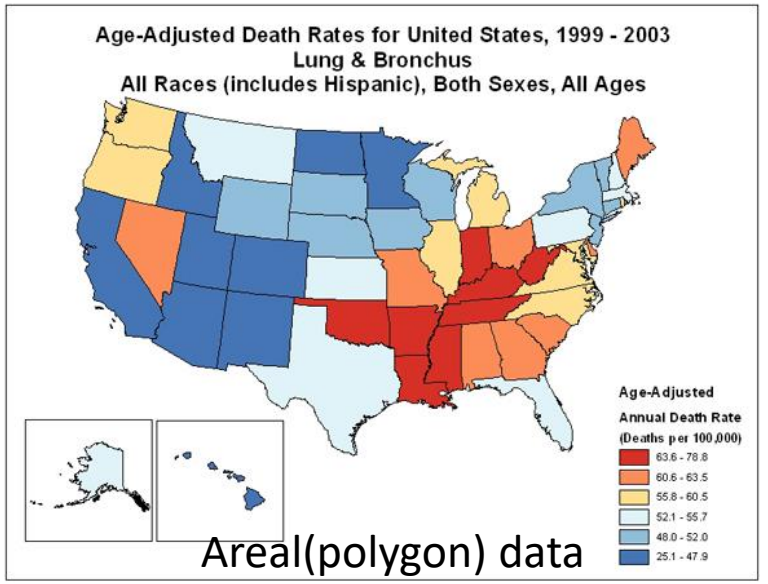
- Data with location
  - Absolute location: latitude, longitude on the Earth surface
  - Relative location: e.g., distance to a highway

- Spatial data types
  - Point data: e.g., cities in a world map; event: flu cases, geo-tagged tweets
  - Areal/polygon data: e.g., US states, lakes
  - Line data : rivers, roads
  - Continuous/surface data: raster data, e.g., DEM(Digital Elevation Model, terrain)

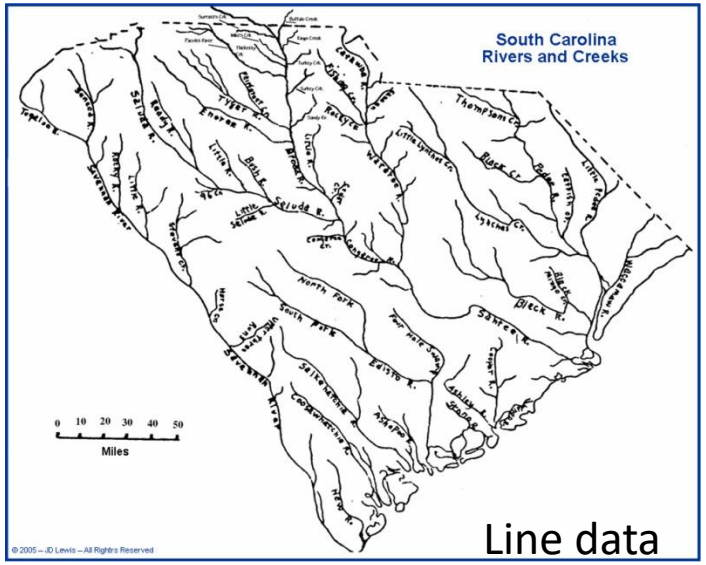
Spatial Data Examples



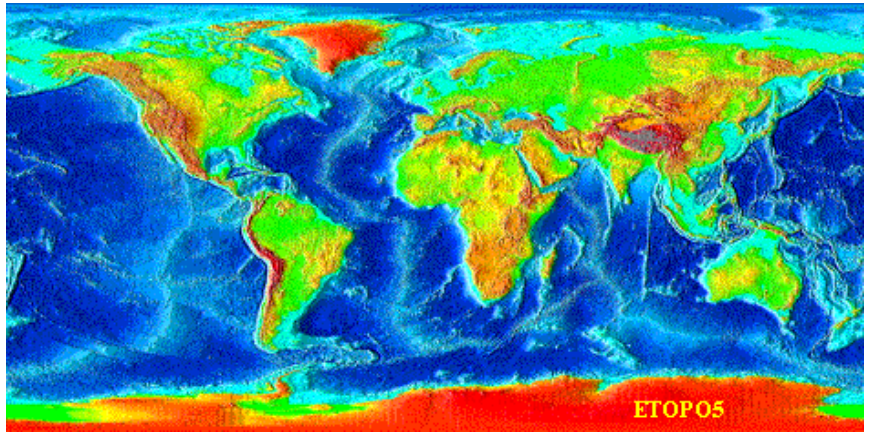
Point data



Areal(polygon) data



Line data



Continuous/Surface data

Spatial Scales

- Point data vs. Areal data
- e.g., Cities

http://www.mapsofworld.com/usa/usa-capital-and-major-cities-map.html

Google Maps

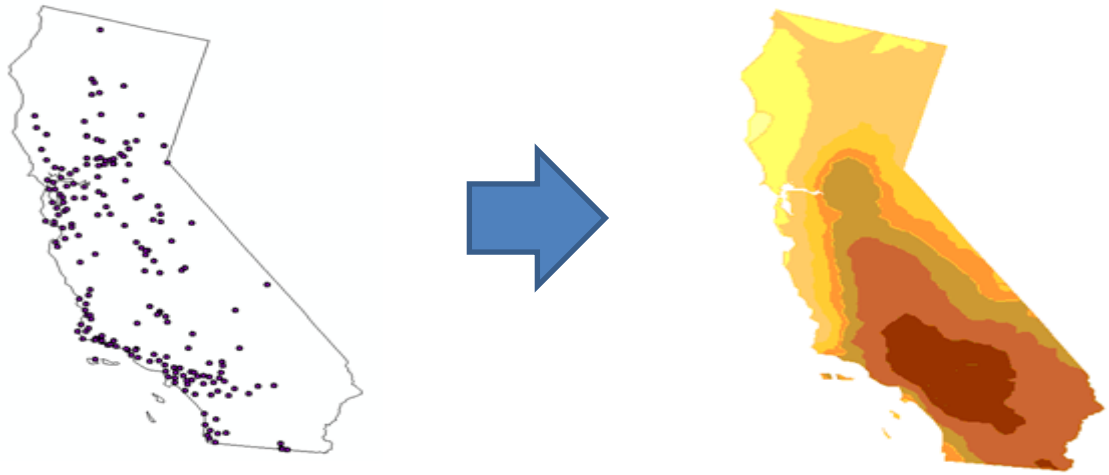
Columbia as a point

Columbia as polygons

http://resources.arcgis.com/

Data Conversion

- From point to area: using interpolation



- From area to point: using polygons' centroids

Generating points from state polygons

http://resources.arcgis.com/

http://giscommons.org/earth-and-map-preprocessing/