Map projections

- Elements in map projections
  - Datum (e.g., WGS84 \sim NAD 83, NAD 27)
  - Developable surfaces
  - Projection

- Distortions
  - shape (conformal), distance, area (equivalent), direction
  - distortions magnitude varies across a map
  - be careful of what you want to preserve

- A handy guide to a varieties of projections and their use: http://www.radicalcartography.net/index.html?projectionref, made by Bill Rankin
Mercator Projection

- One of the most commonly used map projections in wall maps
- Which of the following operations is/are suitable in Mercator projection?
  1. navigation
  2. distance measuring
  3. nearest neighbors
- Why the air flight traces are not straight lines on a map?
- What would it really look like if drawing a line on a map with Mercator projection?
Distortions of Mercator Projection

- It usually leads to distortions in terms of shape and area
- Online map websites (e.g., Google Maps, ArcGIS online) use Web Mercator, a variant of Mercator projection
- Mercator puzzle:
  http://hive.sewanee.edu/pridepj0/286/mercatorMap.html
• Africa in Mercator projection
• In fact, area of Africa is about **14** times of Greenland
Mercator Projection

- In fact, Africa is as big as the United States, China, India, Japan and all of Europe combined.

Figure: Image courtesy: Kai Krause

- Scene in TV show West Wing: https://www.youtube.com/watch?v=n8zBC2dvERM
Gall-Peters Projection

- Peters projection mentioned in the video
- Equal-area
Other Commonly Used Projections

- UTM (Universal Traverse Mercator)

- Gnomonic (great circles as straight lines)

- Equal-area (e.g., Lambert, Albers)
Cartogram

• County map of 2004 US presidential election result
Cartogram

- Equal-density cartogram of 2004 US presidential election result

*Figure:* Image courtesy: Gastner, Shalizi, and Newman
Cartogram

- **Equal-density**: cartogram of world population in the year of 2000

*Figure*: Image courtesy: ESRI
Measures and Map Projections

- Comparing results of volume measures (e.g., length and area) in different map projections [http://servicesbeta.esri.com/demos/compareMeasurements.html](http://servicesbeta.esri.com/demos/compareMeasurements.html)
Maps could lie, be critical when reading them!!
Introduction to Spatial Analysis and Modeling
Components of Spatial Analysis and Modeling

- Data do not equal information
- Components of spatial analysis (geospatial data in particular)
  - Visualization: **Showing** interesting patterns (mapping, geovisualization)
  - Exploratory spatial data analysis: **Finding** interesting patterns
  - Spatial modeling, regression: **Explaining** interesting patterns
Scope of Spatial Analysis and Modeling

- Type of spatial data analysis
  - Spatial data manipulation (in GIS)
    - Spatial query, measurements, transformation, network analysis, location analysis (spatial optimization) ...
  - Spatial data analysis
    - Exploratory spatial analysis
    - Visual analytics
    - Data-driven, let data speak themselves
  - Spatial statistics
    - An extension of traditional statistics into a spatial settings to determine whether or not data are typical or unexpected
    - Geostatistics: Quantify the spatial relationships between observations of different locations for estimation of unknown locations
  - Spatial modeling
    - Involves constructing models to predict spatial outcomes
    - Only focus on spatial statistical modeling
Topics

- Spatial data representation and manipulation
  - Buffer, spatial query, overlay analysis (lab 2-3)
  - Surface analysis and map algebra (lab 4)
  - Model builder (lab 5)
  - Geocoding (lab 6)

- Point pattern analysis (lab 7)

- Spatial statistics
  - Spatial autocorrelation (lab 8)
  - Spatial regression (lab 9)

- Spatial interpolation
  - Deterministic interpolation (lab 10)
  - Kriging (lab 10)

- Spatial uncertainty
Characteristics of (Geographic) Spatial Data

1. Spatial (and temporal) Context: “Everything is related to everything else, but near things are more related than distant things”
   - Waldo Tobler’s First Law (TFL) of geography
   - nearby things are more similar than distant things
   - phenomena vary slowly over the Earth’s surface
   - Compare time series
Characteristics of (Geographic) Spatial Data

• Implication of Tobler’s First Law (TFL)
  • We can do samplings and fill the gap using estimation procedures (e.g. weather stations)
  • Spatial patterns
• Image a world without TFL:
  • White noise
  • No lines, polygons or geometry (how to draw a polygon on a white noise map?)
Characteristics of (Geographic) Spatial Data

2. Spatial heterogeneity

- “Second law of geography” (Goodchild, UCGIS 2003)
- Earth’s surface is non-stationary
- Laws of physical sciences remain constant, virtually everything else changes
  - Elevation,
  - Climate, temperatures
  - Social conditions
- Implications
  - Global model might be inconsistent with regional models
  - Spatial Simpsons Paradox (a special case of modifiable areal unit problem, which we will discuss more in the later of this class)
Side note: example of Simpson’s paradox

- Simpson’s paradox usually fools us on tests of performance in real life
- The following is a real life example. Comparison of recovery rates between a new treatment and a traditional treatment for kidney stones.

<table>
<thead>
<tr>
<th></th>
<th>New Treatment</th>
<th>Traditional Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Stones</td>
<td>93%(81/87)</td>
<td>87%(234/270)</td>
</tr>
<tr>
<td>Large Stones</td>
<td>73%(192/263)</td>
<td>69%(55/80)</td>
</tr>
<tr>
<td>All</td>
<td>78%(273/350)</td>
<td>83%(289/350)</td>
</tr>
</tbody>
</table>

- Comparison of batting average of two baseball players:

<table>
<thead>
<tr>
<th></th>
<th>1996</th>
<th>1997</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Derek Jeter</td>
<td>25.0%(12/48)</td>
<td>31.4%(183/582)</td>
<td>31.0%(195/630)</td>
</tr>
<tr>
<td>David Justice</td>
<td>25.3%(104/411)</td>
<td>32.1%(45/140)</td>
<td>27.0%(149/551)</td>
</tr>
</tbody>
</table>
Characteristics of (Geographic) Spatial Data

- In a spatial settings, it is related to modifiable areal unit problem (MAUP) or omitted variable problem, which will discuss more in the later of this class.

*Figure: Image Courtesy of OpenShaw*
Characteristics of (Geographic) Spatial Data

3. Fractal behavior
   • What happens as scale of map changes?
   • Coast of Maine

   • Implications
     • Scale is critical for the problem of study
     • Volume of geographic features tends to be underestimated
       • length of lines
       • area of polygons
     • Think of the difference of distances that an ant and elephant needed to travel from where I stand to the center of memorial circle

Figure 4.18 The coastline of Maine, at three levels of recursion: (A) the base curve of the coastline; (B) approximation using 100 km steps; (C) 50 km step approximation; and (D) 25 km step approximation
Please try to tell whether the following maps are micro- or macro-scale:

- https://weather.com/science/news/macro-or-micro-can-you-tell-these-images-apart-20131107
Summary: three interrelated characteristics of spatial data

- Spatial context/spatial pattern/spatial structure/spatial dependence/spatial texture..
- Spatial heterogeneity/locality
- Fractal behaviors/scaling effects