Cartography and Geovisualization

CSCI 5715 – Nov. 25, 2014
Cartography and Geovisualization

1. Coordinate systems
   a. Analytical implications of coord. systems
2. Reference Maps
3. Thematic Maps
Refresher Questions from Part #1

What’s the shape of the Earth?
Shape of the Earth
How can we model most map projections in our heads?
Cylindrical

Conic

Azimuthal
How large is 1.0 deg\(^2\) lat/lon?
Meridians of Longitude

To North Pole

240 mi

460 miles

690 miles

To South Pole

120° W

110° W

Equator
Refresher Questions from Part #1

What is preserved with a Web Mercator projection like Google Maps? What is not preserved?
Refresher Questions from Part #1

Describe the transition that has occurred in cartography in the past 10 years or so.
Cartography and Geovisualization

1. Coordinate systems
   a. Analytical implications of coord. systems

2. Reference Maps

3. Thematic Maps
I need volunteers!
Reference Maps

Intended to (geo)communicate the location of specific entities (and how to get to them)

Used primarily for navigation and orientation

Thematic Maps

Thematic maps are “used to emphasize the spatial distribution of one or more geographic attributes”.
Reference Maps

Google Maps app

Apple Maps app

Waze

Nokia HERE Maps
Publicly-displayed local maps:

Reference Maps
Reference Maps

Road Atlases

World Atlases
World's oldest map: Spanish cave has landscape from 14,000 years ago

Archaeologists have discovered what they believe is man's earliest map, dating from almost 14,000 years ago.

Image 1 of 2
Archaeologists have discovered what they believe is man's earliest map, dating from almost 14,000 years ago. Photo: EPA

By Fiona Govan in Madrid
7:30AM BST 06 Aug 2009

A stone tablet found in a cave in Abauntz in the Navarra region of northern Spain is believed to contain the earliest known representation of a landscape.

Reference Maps
Knowing how to make reference maps isn’t nearly as useful as it used to be...
Limitations of popular online and mobile reference maps:

1. Inaccurate representations (e.g. Mercator projection)
Winkel Tripel

By Strebe (Own work) [CC-BY-SA-3.0], via Wikimedia Commons
Refresher Questions from Part #1

How large is 1.0 deg² lat/lon? km² on a Web Mercator map?
Limitations of popular online and mobile reference maps:

1. Inaccurate representations (e.g. Mercator projection)
2. Paper maps are still better in a few ways
Paper Map

(1) larger display sizes
(2) zero power requirement

Smartphone Map
World's oldest map: Spanish cave has landscape from 14,000 years ago

Archaeologists have discovered what they believe is man’s earliest map, dating from almost 14,000 years ago.

By Fiona Govan in Madrid
7:30AM BST 06 Aug 2009

A stone tablet found in a cave in Abautz in the Navarra region of northern Spain is believed to contain the earliest known representation of a landscape in the world. The tablet was discovered in a cave in the Bardenas Reales Natural Park in the Navarra region of northern Spain.

The tablet, which is about 2,000 years younger than the most recent example of human-made maps, was found in a cave in the Bardenas Reales Natural Park. It is 1.4 metres long and 1 metre wide and is decorated with symbols that represent a landscape.

The symbols include images of mountains, rivers, and valleys, as well as other objects such as a bird, a fish, and a bird’s head.

The discovery is significant because it suggests that people were using maps more than 14,000 years ago, much earlier than previously thought.

The map is thought to have been made by a hunter-gatherer who lived in the area and who used it to navigate the landscape.

The map is now on display at the Museo de Arqueología de Navarra in Pamplona, Spain.

Related Partners

The best way to transfer money overseas

In Spain
Local Maps

Made for a purpose, adapted to a certain location, highly used, …
Collection of over 380 local maps
<table>
<thead>
<tr>
<th>Map Category</th>
<th>Count</th>
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<td>orientation</td>
<td>north-up</td>
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<td>you-are-here dot type</td>
<td>allocentric</td>
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<td>TRUE</td>
</tr>
<tr>
<td>north arrow</td>
<td>TRUE</td>
</tr>
<tr>
<td>map layers used</td>
<td>paths, ba…</td>
</tr>
<tr>
<td>info in paramap/meta-info</td>
<td>rules…</td>
</tr>
<tr>
<td>base map type</td>
<td>standard</td>
</tr>
</tbody>
</table>
Emphasis on area of interest
Space usage rules
Allocentric “You are Here” Dots
Location-aware Map Perspectives
Location-aware Map Orientations
Significant differences across map categories were detected in...

map perspective selection*
map orientation selection***
north arrow inclusion**
map scale inclusion*
emphasis of area of interest***
type of basemap***
...and more

* p < 0.05, ** p < 0.01, *** p < 0.001
Location-aware Cartography
Limitations of popular online and mobile reference maps:

1. Inaccurate representations (e.g. Mercator projection)
2. Paper maps are still better in a few ways
3. Terms of use limitations
Using maps in print

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http://www.google.com/permissions/geoguidelines.html#maps-print
Google My Maps demo

https://www.google.com/maps/d/u/0/
25,000 map loads

90 consecutive days

$€¥
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For a browsable electronic map, the credit should appear in the corner of the map. For example:
Limitations of popular online and mobile reference maps:

1. Inaccurate representations (e.g. Mercator projection)
2. Paper maps are still better in a few ways
3. Terms of use limitations
4. Cartographic hegemony
Google maps error sparks invasion of Costa Rica by Nicaragua

Nicaragua has used an error on Google's internet maps system to justify an invasion of Costa Rica.
Apple Maps demo
Limitations of popular online and mobile reference maps:

1. Inaccurate representations (e.g. Mercator projection)
2. Paper maps are still better in a few ways
3. Terms of use limitations
4. Cartographic hegemony
5. Base map is not editable
asphalt

dirt
(and grass)
Google My Maps: “Terrain” Base Map
Google My Maps: “Whitewater” Base Map
Cartography and Geovisualization

1. Coordinate systems
   a. Analytical implications of coord. systems

2. Reference Maps

3. Thematic Maps
   a. What they are and why we make them
   b. The basics of how to make them
Limitations of popular online and mobile reference maps:

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Intended to (geo)communicate the location of specific entities (and how to get to them)

Used primarily for navigation and orientation

Thematic maps are “used to emphasize the spatial distribution of one or more geographic attributes”.

Reference Maps

Thematic Maps

Remember the volunteer exercise?
Thematic maps are “used to emphasize the spatial distribution of one or more geographic attributes”.

(Slocum et al. 2009)
In Climbing Income Ladder, Location Matters

A study finds the odds of rising to another income level are notably low in certain cities, like Atlanta and Charlotte, and much higher in New York and Boston.

The chance a child raised in the bottom fifth rose to the top fifth

Atlanta: 4.0%
New York: 9.7%
Boston: 9.8%
Charlotte: 4.3%

Top income level is equal to family income of more than $70,000 for the child by age 30, or more than $100,000 by age 45.

ATLANTA — Stacey Calvin spends almost as much time commuting to her job — on a bus, two trains and another bus — as she does working part-time at a day job. She has the best chance of getting to work on time in Atlanta, her home town.

What’s the attribute being visualized?
What’s the attribute being visualized?
What’s the attribute being visualized?
What's the attribute being visualized?
What’s the attribute being visualized?
Foreign fighters flow to Syria

An estimated 15,000 militants from at least 80 nations are believed to have entered Syria to help overthrow the regime of President Bashar al-Assad according to the CIA and studies by ISCR and The Soufan Group. Many of these fighters are believed to have joined units that are now part of the Islamic State. Western officials are concerned about what these individuals may do upon returning to their native countries.

Countries from which citizens or residents have reportedly gone to fight.

http://www.washingtonpost.com/world/foreign-fighters-flow-to-syria/2014/10/11/3d2549fa-5195-11e4-8c24-487e92bc997b_graphic.html
Why Thematic Cartography is Useful

[MacEachren 1983; Slocum et al. 2009]

Median Family Income
by U.S. state

1 Specific information
2 Regional information
3 Compare between maps

Data source: Department of Housing and Urban Development

$47.3K - $56.2K
$56.2K - $61.4K
$61.4K - $65.6K
$65.6K - $71.0K
$71.0K - $86.3K
Why Thematic Cartography is Useful

[MacEachren 1983; Slocum et al. 2009]

1. Specific information
2. Regional information
3. Compare between maps
4. Compare between map and mental model

Data source: Centers for Disease Control and Prevention

Obesity Rates by U.S. state

- 21.0% - 23.9%
- 24.0% - 26.0%
- 26.1% - 27.8%
- 27.9% - 30.4%
- 30.5% - 34.0%
Cartography and Geovisualization

1. Coordinate systems
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   a. What they are and why we make them
   b. The basics of how to make them
Using a visual variable to visually encode the values of one or more attributes ($z$) (one is better) into the spatial footprint ($x$).
Visual variables for quantitative attributes

Slocum et al. 2009
Visual variables for qualitative attributes

Slocum et al. 2009
Qualitative or Quantitative?
Visual Variable?
What’s the attribute being visualized?

Qualitative or Quantitative?
Visual Variable?
What’s the attribute being visualized?

Qualitative or Quantitative?

Visual Variable?
What’s the attribute being visualized?

Qualitative or Quantitative?
Visual Variable?
Qualitative or Quantitative?
Visual Variable?
Visual variables for quantitative attributes

Use with caution

Slocum et al. 2009
### Visual Variables for Qualitative Attributes

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<thead>
<tr>
<th></th>
<th>Point</th>
<th>Linear</th>
<th>Areal</th>
<th>2½-D</th>
<th>True 3-D</th>
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<td>![Areal Orientation (Non-Recommended)]</td>
<td>![2½-D Orientation (Non-Recommended)]</td>
<td>![True 3-D Orientation (Non-Recommended)]</td>
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<td>![Areal Shape (Non-Recommended)]</td>
<td>![2½-D Shape (Non-Recommended)]</td>
<td>![True 3-D Shape (Non-Recommended)]</td>
</tr>
<tr>
<td><strong>Arrangement</strong></td>
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<td>![Linear Arrangement]</td>
<td>![Areal Arrangement (Non-Recommended)]</td>
<td>![2½-D Arrangement (Non-Recommended)]</td>
<td>![True 3-D Arrangement (Non-Recommended)]</td>
</tr>
</tbody>
</table>

#### Figure 5.4
Visual variables for qualitative phenomena. For visual variables for color maps, also see Color Plate 5.3.
Thematic cartography in a **nutshell**:  

Using a **visual variable** to visually encode the values of one or more attributes ($z$) (one is better) *into the spatial footprint* ($x$).

<table>
<thead>
<tr>
<th>Spatial Footprint ($x$)</th>
<th>Attributes ($z$)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>footprint</th>
<th>name</th>
<th>median income</th>
<th>obesity rate</th>
<th>region</th>
<th>favorite team</th>
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<tbody>
<tr>
<td>Montana</td>
<td>Montana</td>
<td>$56200</td>
<td>23.0%</td>
<td>Mountain West</td>
<td>Montana Grizzlies</td>
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<tr>
<td>Nebraska</td>
<td>Nebraska</td>
<td>$62600</td>
<td>26.9%</td>
<td>Midwest</td>
<td>Nebraska Cornhuskers</td>
</tr>
</tbody>
</table>

**Quantitative attributes**  
**Qualitative attributes**
Types of thematic maps we’re going to cover:

- Choropleth
- Graduated / Proportional Symbol
- Cartograms
Poverty in the United States
Percent of the Population Below the Poverty Line

Data sources: U.S. Census American Community Survey 2006-2010, ESRI

Classification: Natural Breaks
COLOR-related challenges when making choropleth maps:

1. Deciding on the set of colors you will use

2. Deciding how to assign colors to specific data values (data classification)
COLOR-related challenges when making choropleth maps:

1. Deciding on the set of colors you will use

   - QUANTITATIVE attributes
   - QUALITATIVE attributes
With **quantitative** attributes, you want color schemes like:

[Color Brewer website](colorbrewer.org)
### Visual Variables for Quantitative Attributes

<table>
<thead>
<tr>
<th>Visual Variable</th>
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<th>Linear</th>
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<th>2½-D</th>
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<tr>
<td>Size</td>
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</tr>
<tr>
<td>Perspective Height</td>
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<td></td>
<td></td>
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<td>None Possible</td>
</tr>
<tr>
<td>Color (Hue)</td>
<td>Yellow</td>
<td>Orange</td>
<td>Red</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Color (Lightness)</td>
<td>Light Green</td>
<td>Green</td>
<td>Dark Green</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Color (Saturation)</td>
<td>Muted Red</td>
<td>Red</td>
<td>Void Red</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 5.3** Visual variables for quantitative phenomena. For visual variables for color maps, also see Color Plate 5.2.

Slocum et al. 2009
Poverty in the United States

Percent of the Population Below the Poverty Line

Higher Values

Pct. Below Poverty Line

- 0.00 - 11.3%
- 11.4 - 16.2%
- 16.3 - 21.7%
- 21.8 - 29.6%
- 29.7 - 49.5%

Data sources: U.S. Census American Community Survey 2006-2010, ESRI Classification: Natural Breaks
Population Density in the U.S.
People per Square Mile by County

Data sources: U.S. Census, ESRI

People per Square Mile
0 - 822
833 - 3270
3721 - 9675
9676 - 20418
20419 - 69568

Classification: Natural Breaks
85+ Population in the United States

Pct of the Population that is 85 Years Old or Older

Data sources: U.S. Census, ESRI
Classification: Natural Breaks
Poverty in the United States
Percent of the Population Below the Poverty Line

Data sources: U.S. Census American Community Survey 2006-2010, ESRI

Classification: Natural Breaks

Pct. Below Poverty Line
- 0.00 - 11.3%
- 11.4 - 16.2%
- 16.3 - 21.7%
- 21.8 - 29.6%
- 29.7 - 49.5%

Higher Values
Poverty in the United States

Percent of the Population Below the Poverty Line

Classification: Natural Breaks

Data sources: U.S. Census American Community Survey 2006-2010, ESRI
Divergent color schemes:
Diverging Color Scheme
COLOR-related challenges when making choropleth maps:

1. Deciding on the set of colors you will use

- QUANTITATIVE attributes
- QUALITATIVE attributes
Examples of **qualitative** spatial attributes:

1. Land cover type (e.g. urban, forest, water)
2. The primary religion in an area
3. The primary language spoken in an area
4. The region of an area like East Coast, West Coast, Midwest, etc.
Implies increasing values
http://506sports.com/nfl.php?yr=2014&wk=1
COLOR-related challenges when making choropleth maps:

1. Deciding on the set of colors you will use
   ✔

2. Deciding how to assign colors to specific data values (data classification)
Example Unclassed Choropleth Map

In the map below, notice how you can easily see a large geographic pattern of unemployment rates, but it is very hard to compare or rank counties: try to accurately arrange the counties in California from lowest to highest...it's nearly impossible.

Limitations

There are at least three major drawbacks with unclassed choropleth maps. First, while the idea of letting our data speak for itself is appealing we often find it has too much to say. Cartographers have long relied on classification to suppress random noise or insignificant variations to highlight large, major differences. For example, a very simple 2-class map of unemployment (using only 2 colors) would quickly show whether a place is above or below the national average: More detail is that are easily confused with each other. This makes it very hard to estimate values or get specific numbers from the map (e.g.,
Choropleth Maps

Unclassed Maps
- Natural Breaks
  - Pretty Breaks

Classed Maps
- Quantile
  - Defined Interval
- Equal Interval
  - Manual
- Std. Deviation
  - Geom. Interval
Natural Breaks Classification

Pct. Below Poverty Line Attribute Value Distribution

- 0.00 - 11.3%
- 11.4 - 16.2%
- 16.3 - 21.7%
- 21.8 - 29.6%
- 29.7 - 49.5%
Natural Breaks Classification

Population Density (People per Square Mile)
Population Density in the U.S.

People per Square Mile by County

Data sources: U.S. Census, ESRI

People per Square Mile

- 0 - 822
- 833 - 3270
- 3721 - 9675
- 9676 - 20418
- 20419 - 69568

Classification: Natural Breaks
Choropleth Maps

Unclassed Maps
- Natural Breaks
  - Pretty Breaks
  - Manual

Classed Maps
- Quantile
  - Defined Interval
- Equal Interval
- Std. Deviation
- Geom. Interval
<table>
<thead>
<tr>
<th>State Name</th>
<th>Attribute Value</th>
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<tbody>
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<td>1 Wyoming</td>
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<td>2 Wisconsin</td>
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<td>7 Utah</td>
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</tr>
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<td>13 Pennsylvania</td>
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<td>19 New York</td>
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<td>Minnesota</td>
<td>0.7410474042</td>
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<td>Alaska</td>
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<td>Louisiana</td>
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<td>Wyoming</td>
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<td>Florida</td>
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<tr>
<td>Kentucky</td>
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<td>Colorado</td>
<td>0.398861222</td>
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<tr>
<td>Connecticut</td>
<td>0.3847875695</td>
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</tbody>
</table>
Population Density in the U.S.

People per Square Mile by County

Data sources: U.S. Census, ESRI

- People per Square Mile
- Classification: Natural Breaks

0 - 12.1
12.2 - 31.7
31.8 - 61.2
61.3 - 154.2
154.3 - 69586.4

Data sources: U.S. Census, ESRI
Classification: Natural Breaks
Highest Attribute Value (e.g. Manhattan’s population density) - Lowest Attribute Value (e.g. Loving County, TX population density) = Class Width

Number of classes (we’ve been using ‘5’)

Number of classes (we’ve been using ‘5’)

No, really! This is what the data says!

Lying with maps!
85+ Population in the United States
Pct of the Population that is 85 Years Old or Older

Pct. Pop 85+
Years Old

- 0.0 - 1.4%
- 1.4 - 2.0%
- 2.0 - 2.8%
- 2.8 - 3.9%
- 3.9 - 8.3%

Data sources: U.S. Census, ESRI
Classification: Natural Breaks
Data sources: U.S. Census, ESRI
Classification: EQUAL INTERVAL
COLOR-related challenges when making choropleth maps:

1. Deciding on the set of colors you will use

2. Deciding how to assign colors to specific data values (data classification)
http://www.wired.com/2014/10/cindy-brewer-map-design/
http://www.colorbrewer.org
Types of thematic maps we’re going to cover:

- Choropleth
- Graduated / Proportional Symbol
- Cartograms
Population in the United States

Number of People per County

People per County

- 82 - 220000
- 220001 - 744344
- 744345 - 2035210
- 2035211 - 5194675
- 5194676 - 9818605

Data sources: U.S. Census, ESRI
Classification: Natural Breaks
Choropleth Maps

Unclassed Maps
- Natural Breaks
- Pretty Breaks

Classed Maps
- Quantile
- Defined Interval
- Manual

Graduated Symbol Maps
- Equal Interval
- Std. Deviation
- Geom. Interval

Proportional Symbol Maps
Population in the United States

Number of People per County

Data sources: U.S. Census, ESRI

People per County

- 47,420
- 80,064
- 195,126
- 981,860
Pros and cons of graduated/proportional maps relative to choropleth maps:

Pro: Differences in size may be better than differences in color for some purposes

Con: Symbols overlap

Con: Confusing to use size for percentages, densities, etc.
**Fig. 3.** Response time values in seconds

Garlandini and Fabrikant 2009
Data sources: U.S. Census, ESRI
Classification: Natural Breaks
Types of thematic maps we’re going to cover:

- Choropleth
- Graduated / Proportional Symbol
- Cartograms
Indegree Sum
Japanese Wikipedia

- 10 - 629,319
- 629,320 - 1,258,628
- 1,258,629 - 1,887,936
- 1,887,937 - 2,517,245
- 2,517,246 - 3,146,554
Indegree Sum
Japanese Wikipedia

- 10 - 629,319
- 629,320 - 1,258,628
- 1,258,629 - 1,887,936
- 1,887,937 - 2,517,245
- 2,517,246 - 3,146,554
The Electoral Map: Building a Path to Victory

A New York Times assessment of how states may vote, based on polling, previous election results and the political geography in each state.

Obama 243
Electoral Votes
Needs 27 to win

Romney 206
Electoral Votes
Needs 64 to win

States sized by number of electoral votes

Leaning Democratic (6)
Maine
Maine has largely slipped from the ranks of top battleground states, with Democrats winning here in the last five presidential elections. The new political map shows Maine holding on to its status as a must-win state for Democrats. In 2012, it is likely to flip back to the Republican column.

Leaning Republican (2)
Arizona
The politics of Arizona are gradually shifting with its demographics. For now, Republicans believe their party has an advantage in presidential elections and may win back this state. It is the number one battleground state for Republicans in 2012.
Types of thematic maps we’re going to cover:

- Choropleth
- Graduated / Proportional Symbol
- Cartograms
Dot Maps

http://demographics.coopercenter.org/DotMap/
Flow Maps

Foreign fighters flow to Syria

An estimated 15,000 militiamen from at least 80 nations are believed to have entered Syria to help overthrow the regime of President Bashar al-Assad according to the CIA and studies by ISCR and The Soufan Group. Many of these fighters are believed to have joined units that are now part of the Islamic State. Western officials are concerned about what these individuals may do upon returning to their native countries.

Countries from which citizens or residents have reportedly gone to fight.

http://www.washingtonpost.com/world/foreign-fighters-flow-to-syria/2014/10/11/3d2549fa-5195-11e4-8c24-487e92bc997b_graphic.html
Cartography and Geovisualization

1. Coordinate systems
   a. Analytical implications of coord. systems
2. Reference Maps
3. Thematic Maps
   a. What they are and why we make them
   b. The basics of how to make them