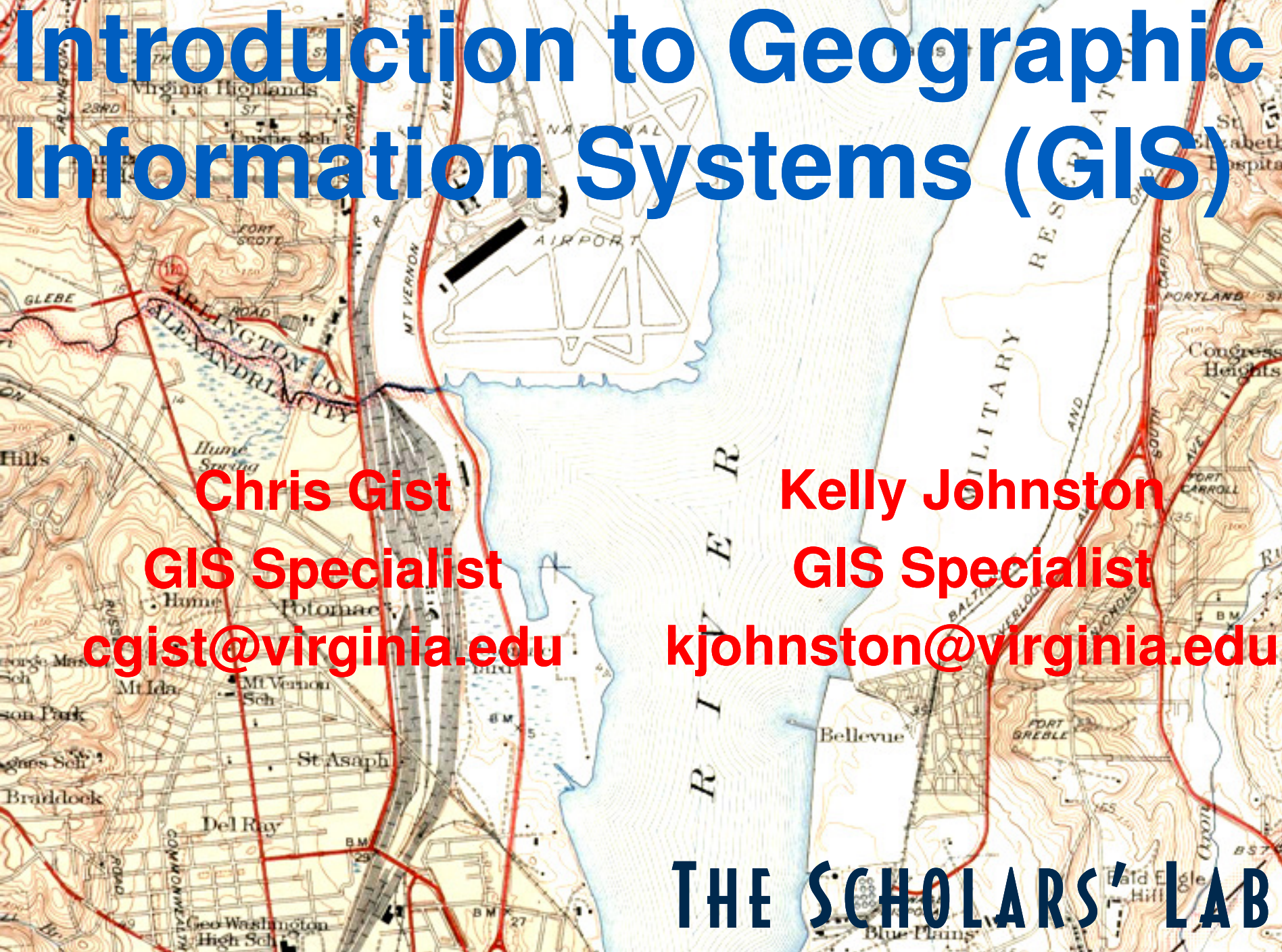


# Introduction to Geographic Information Systems (GIS)



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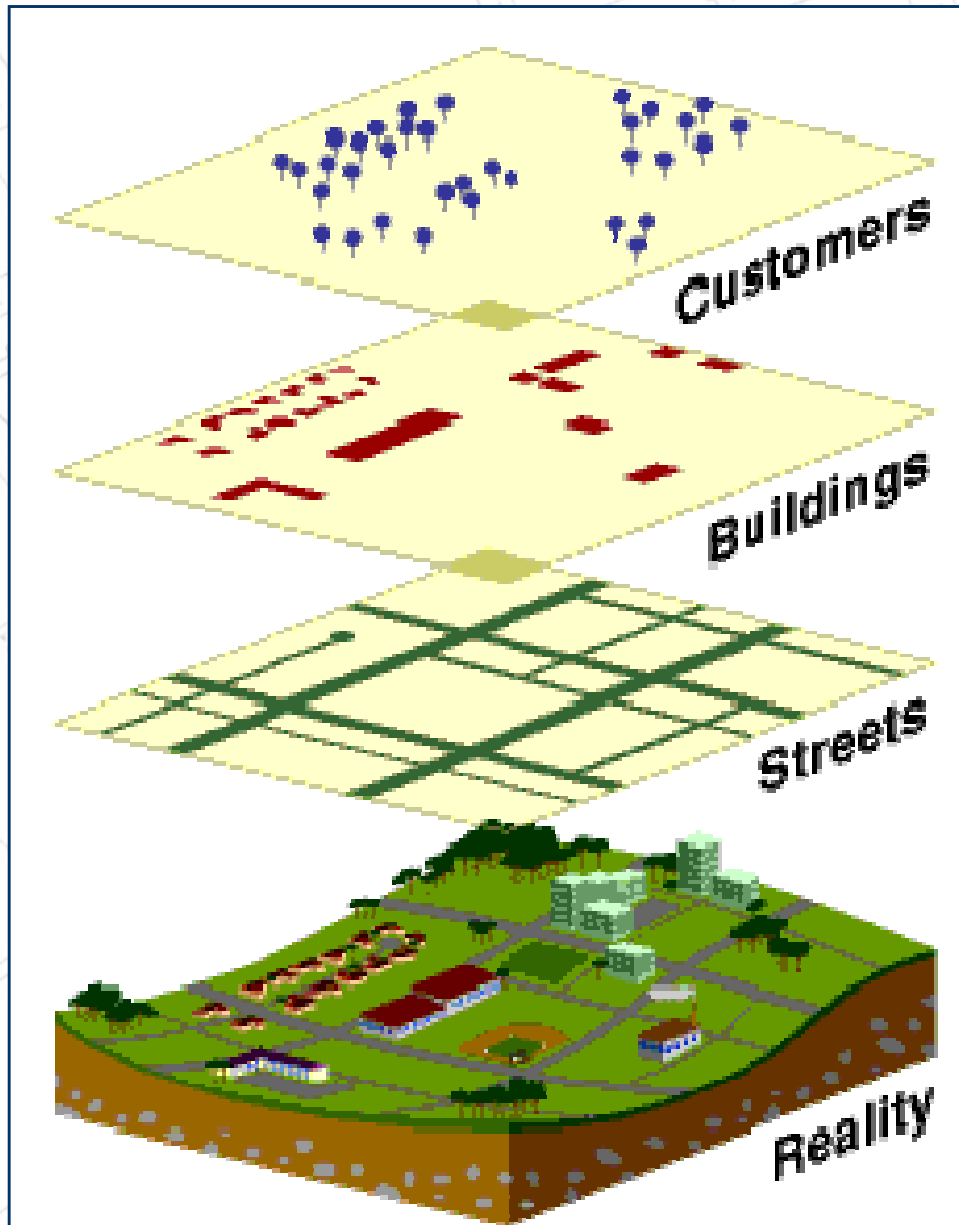
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**THE SCHOLARS' LAB**



# What is GIS?

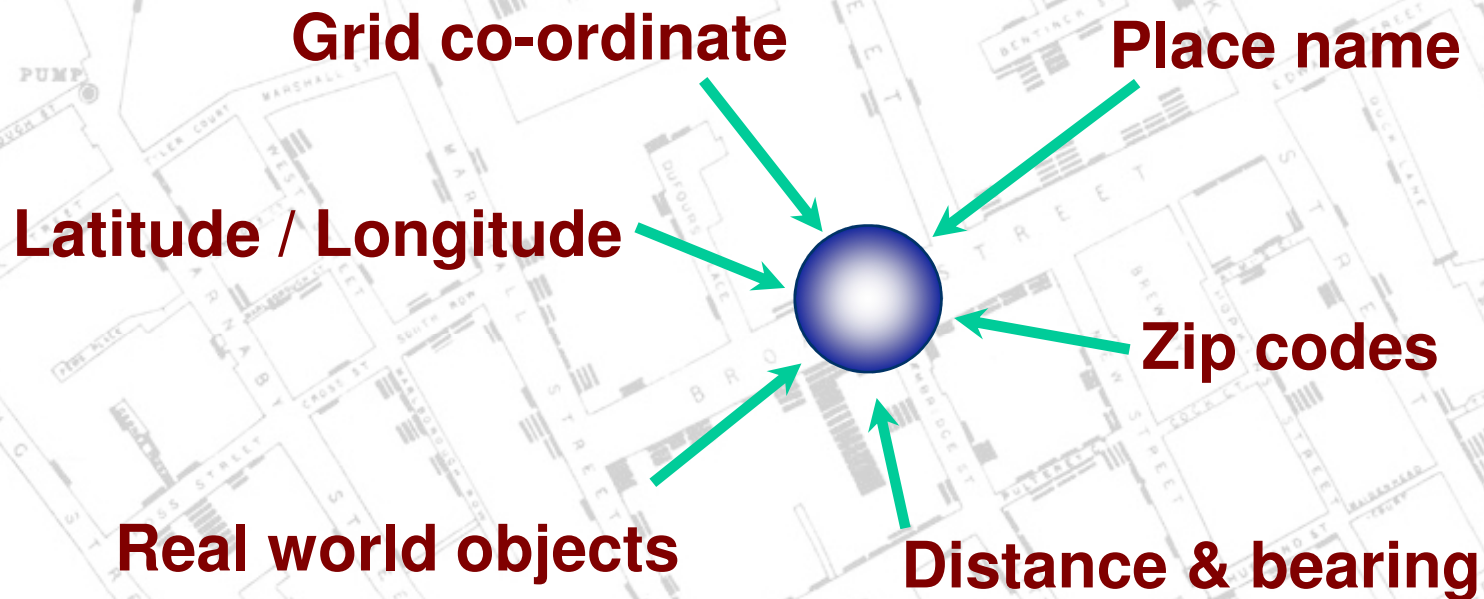


- A technology
  - hardware & software tools
- An information handling strategy
- The objective: to improve overall decision making by visualizing data and seeing new patterns.

# What is a GIS?

“An organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced data.”  
(Understanding GIS, 1997)

# What makes data spatial?





# Why GIS?

## First (and only) Law of Geography

“Everything is related to everything else, but near things are more related than distant things.”

Waldo Tobler, 1970

# Why GIS?

Many of the issues in our world have a critical spatial component

- Land management
- Emergency Response
- Hazard Mitigation
- Property lines, easements, right of ways
- Data on land values, taxation, assessment
- Business site selection, advertising
- Proximity of 'our' land to other facilities (pollution, hunting, municipal, federal, state)

“I don't know what's over that hill” is a common problem.  
What is adjacent to the land we are using?



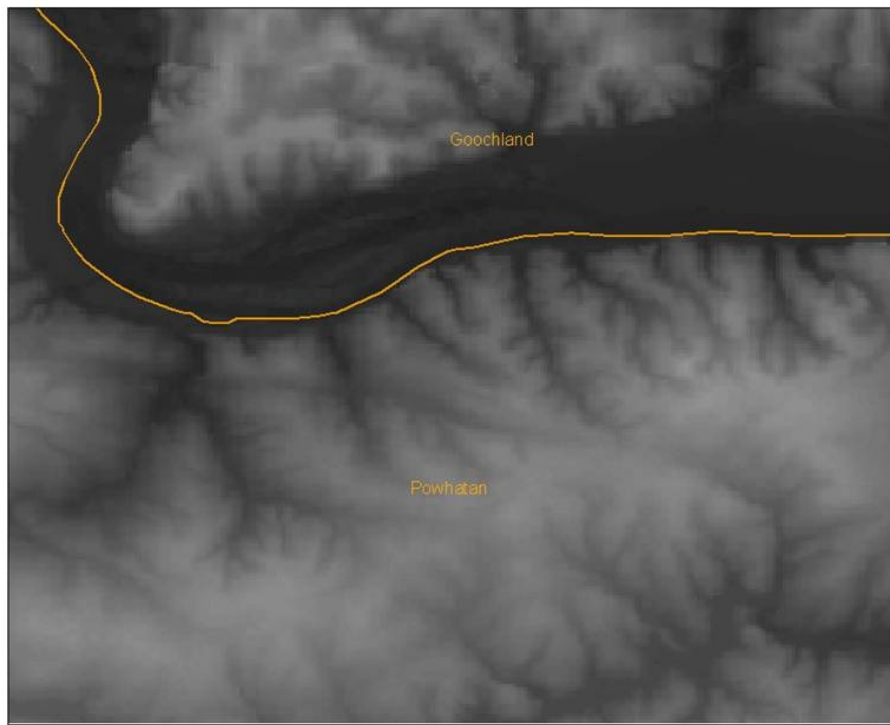
# Why is GIS unique?

- GIS handles SPATIAL information
  - Information referenced by its location in space
- GIS makes connections between activities based on spatial proximity
- Creates relationships between otherwise unrelatable data

# Types of Geographic Data

Raster

Vector





# Types of Geographic Data

## Vector

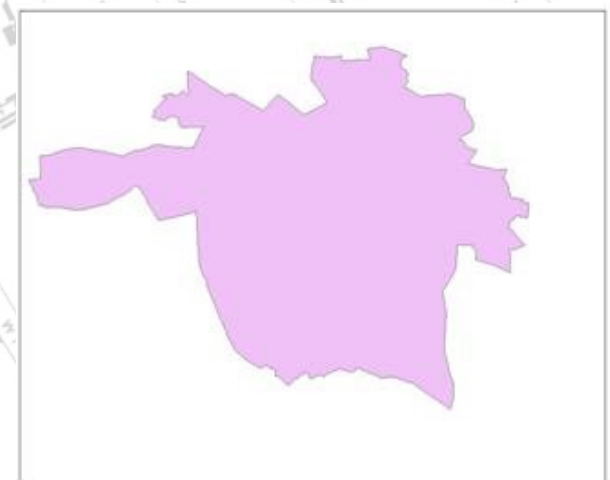
Point



Arc(Polyline)



Polygon



# Vector Data Formats

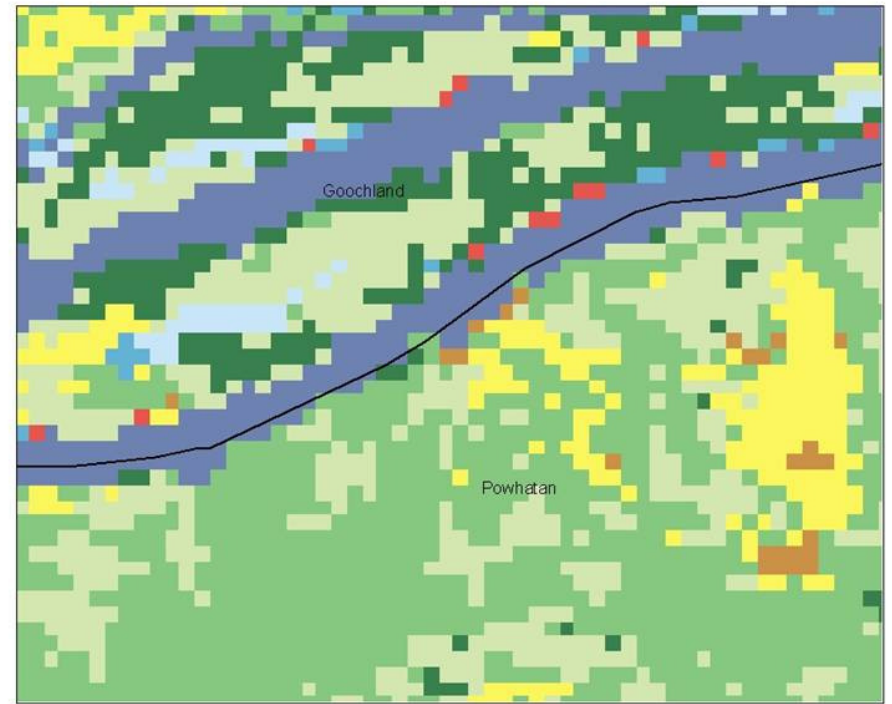
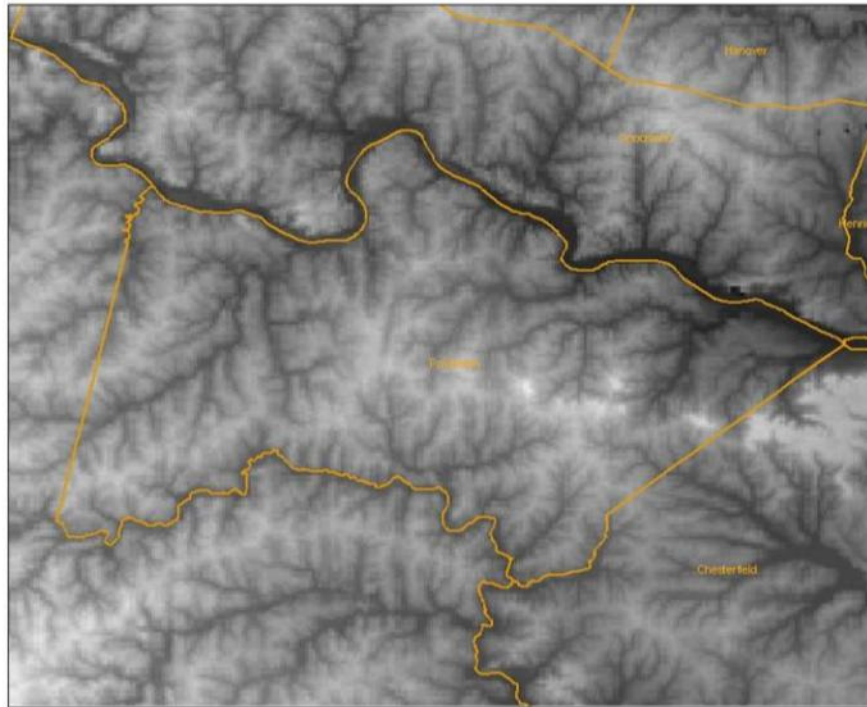
- CAD – subclasses (.dxf)
- Coverage – supports subclasses (folders)
- E00 – coverage exchange format (.e00)
- Shapefile – industry standard (.shp)
- Geodatabase – (.mdb)
- Smart Data Compression – new proprietary ESRI file format (.sdc)



# Types of Geographic Data

## Raster

Collection of cells or pixels, each with a specific value



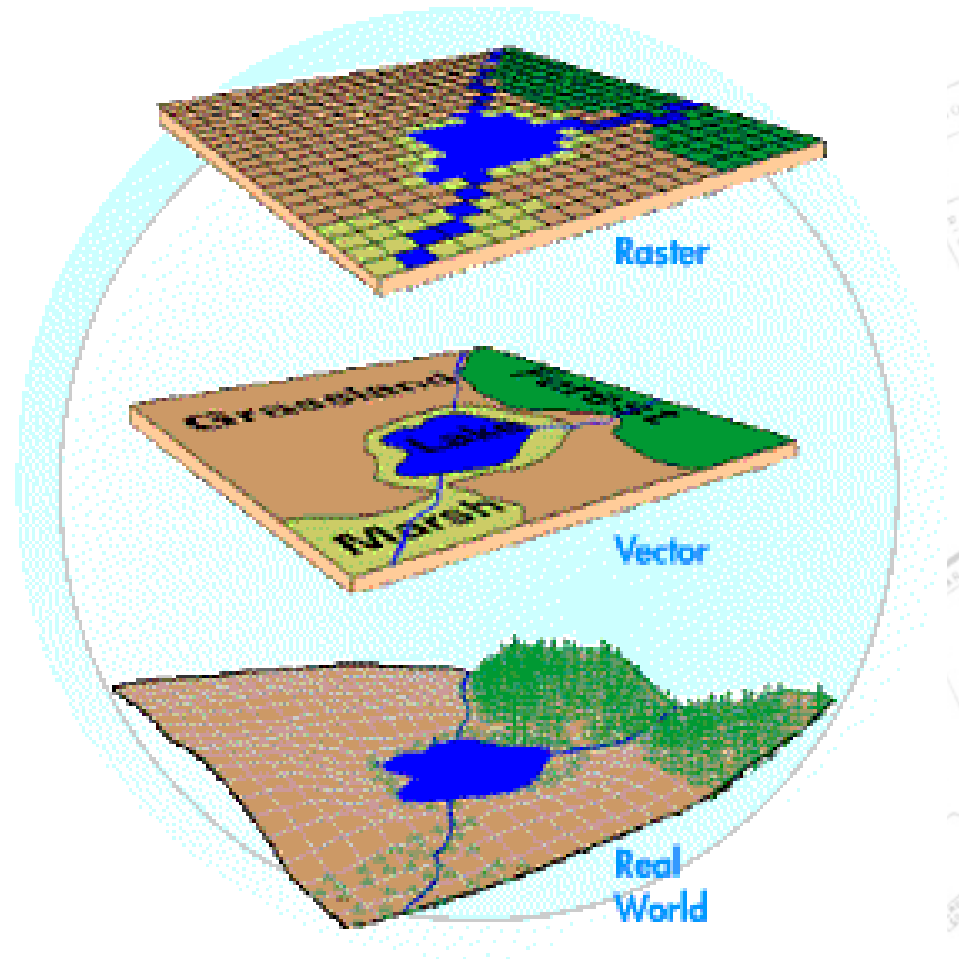
# Raster Data Formats

- Images (.tif, .jpg, .img, .sid, .jp2)
- Grids – ESRI proprietary (folders)
- E00 – Grid exchange (.e00)
- SDTS
- DEMs (.dem, folders)
- ASCII (.txt, .asc)

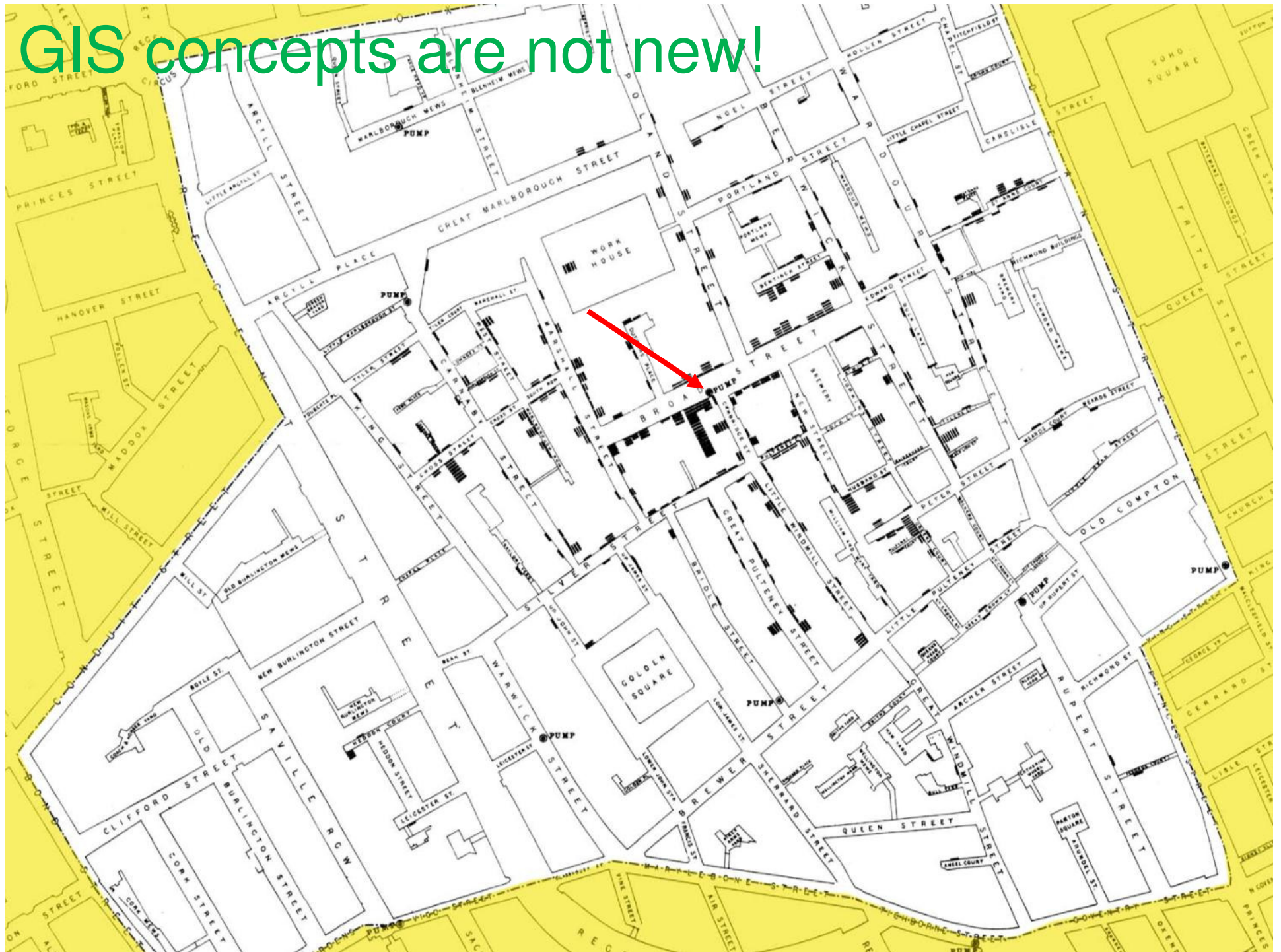


# Raster vs. Vector: types of GIS map representation



- Two basic ways that spatial data can be represented
- Raster:
  - Data represented by pixels with values, creating a grid
  - Allows certain types of operations not possible with vector data
  - Map algebra is possible with multiple data layers – creating index maps
- Vector:
  - Data stored as points, lines, and polygons
  - Uses less memory than raster format
  - Does not lose positional accuracy



GIS concepts are not new!



This figure shows a map of a city street network, represented by orange lines. The network is overlaid with several types of markers: red crosses, white circles, and blue dots. The red crosses are densely clustered in the central area of the map, indicating a high concentration of data points or events. White circles are placed at various intersections, possibly highlighting specific locations of interest. Blue dots are located at a few specific points on the network. The map also includes labels for 'TON STREET' and 'UPDON ST'.

 Cholera death  
 Water pump

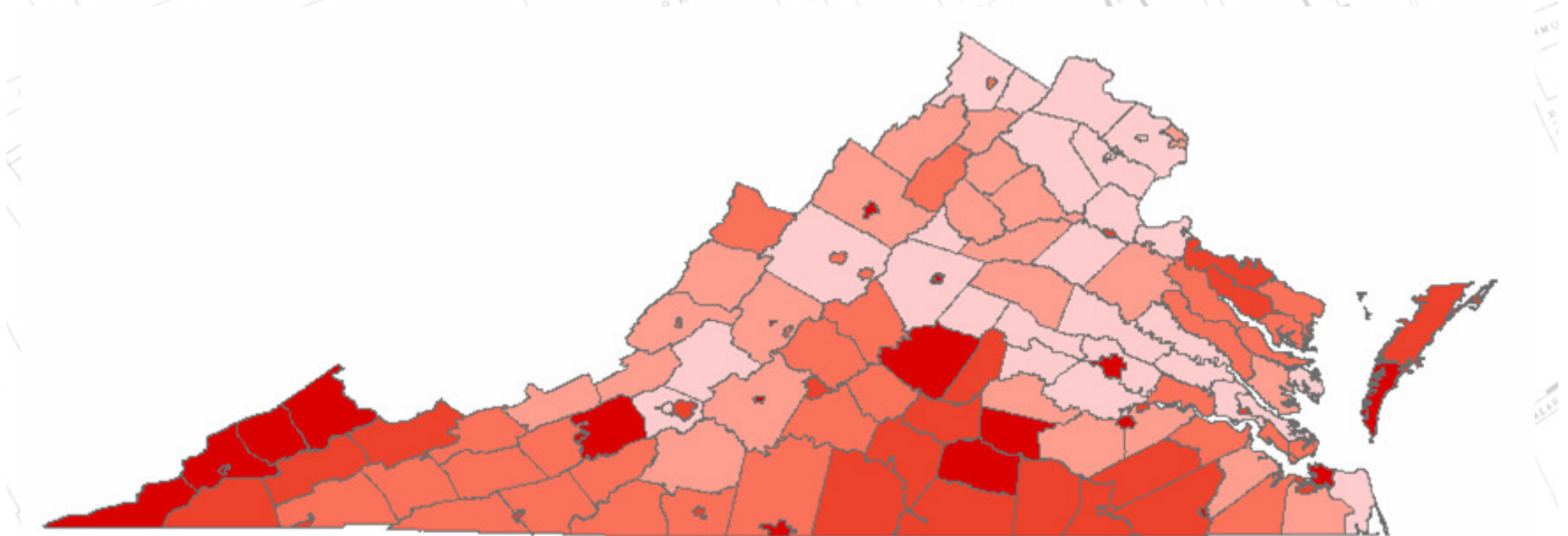
# THE SCHOLARS' LAB



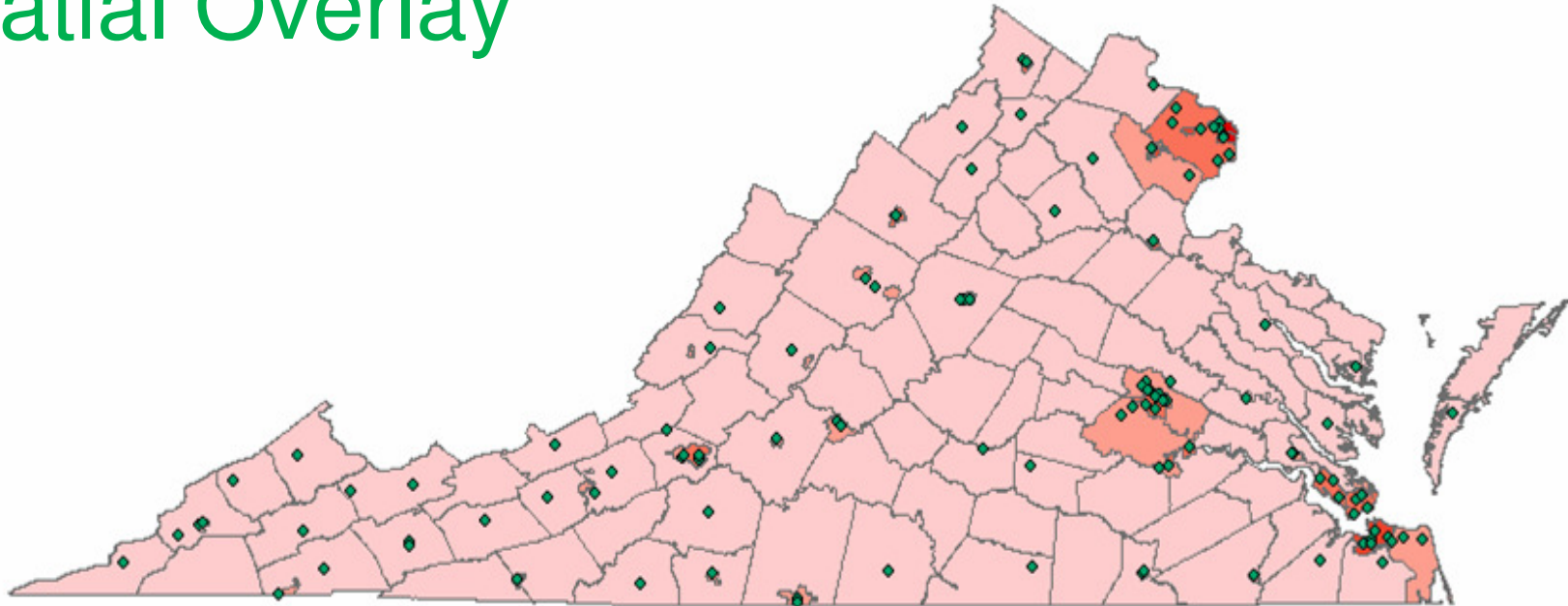
# Visualizing Data

FIPS_1	NAME_1	TOTPOP	PERAA	PERNATIVE	PERASIAN	PEROTHER	PERMALE	PERFEMALE	PERLT5	PERGT65	PERPOV
51163	Rockbridge County, Virginia	20808	2.72	0.06	0.59	1.24	50.34	49.66	5.27	15.61	9.59
51143	Pittsylvania County, Virgini	61745	23.66	0.17	0.12	1.03	48.65	51.35	5.68	14.26	11.75
51105	Lee County, Virginia	23589	0.43	0.44	0.35	0.82	48.75	51.25	5.8	15.49	23.92
51019	Bedford County, Virginia	60371	5.94	0.23	0.96	1.19	49.8	50.2	5.78	12.86	7.11
51027	Buchanan County, Virginia	26978	2.34	0	0.2	0.4	50.87	49.13	4.87	11.39	23.17
51185	Tazewell County, Virginia	44598	2.17	0.07	0.5	0.87	47.51	52.49	5.36	15.37	15.30
51051	Dickenson County, Virginia	16395	0.3	0.09	0.16	0.53	49	51	5.42	14.49	21.31
51021	Bland County, Virginia	6871	4.58	0.22	0.23	0	54.37	45.63	4.48	14.76	12.36
51155	Pulaski County, Virginia	35127	5.65	0.29	0.07	1.51	49.41	50.59	5.74	15.35	13.09
51067	Franklin County, Virginia	47286	9.55	0.11	0.19	1.22	49.28	50.72	5.37	14.27	9.70
51195	Wise County, Virginia	40123	1.57	0.17	0.26	1.04	48.91	51.09	5.67	14	19.99
51121	Montgomery County, Virginia	83629	3.89	0.19	3.75	1.95	52.21	47.79	4.83	8.64	23.24
51197	Wythe County, Virginia	27599	2.64	0.12	0.43	1.37	47.52	52.48	5.49	15.79	11.05
51077	Grayson County, Virginia	17917	6.89	0.09	0.02	1.93	51.81	48.19	4.71	17	13.62
51167	Russell County, Virginia	30308	2.97	0.16	0.09	1.01	50.54	49.46	5.23	13.35	16.35
51173	Smyth County, Virginia	33081	2	0.24	0.1	0.93	48.24	51.76	5.34	16.31	13.33
51720	Norton city, Virginia	3904	5.97	0.15	1.08	2.64	43.78	56.22	5.48	15.7	22.76
51191	Washington County, Virginia	51103	1.54	0.12	0.43	0.7	48.45	51.55	5.06	15.33	10.93
51169	Scott County, Virginia	23403	0.87	0.27	0.06	0.54	48.16	51.84	5.06	17.75	16.76
51520	Bristol city, Virginia	17367	5.2	0.13	0.41	1.61	45.17	54.83	5.11	20.45	16.24
51023	Botetourt County, Virginia	30496	3.67	0.15	0.39	0.97	49.8	50.2	5.7	13.23	5.19
51045	Craig County, Virginia	5091	0.26	0.12	0.33	0.2	50.95	49.05	5.17	13.67	10.26
51071	Giles County, Virginia	16657	1.56	0.01	0.16	1.09	48.83	51.17	5.58	16.65	9.55
51750	Radford city, Virginia	15859	7.49	0.06	1.26	2.3	45.15	54.85	3.73	9.79	31.35
51005	Alleghany County, Virginia	12926	2.54	0	0.56	0.39	50.31	49.69	5.6	15.7	7.14
51580	Covington city, Virginia	6303	13.1	0	0.4	1.6	47.18	52.82	6.38	20.45	12.89
51678	Lexington city, Virginia	6867	10.27	0.19	1.09	1.78	56.53	43.47	3.07	16.37	21.57
51161	Roanoke County, Virginia	85778	3.15	0.15	1.16	1.42	47.31	52.69	5.25	15.82	4.46
51515	Bedford city, Virginia	6299	22.84	0.13	0.51	1.51	47.28	52.72	5.64	21.84	19.68
51770	Roanoke city, Virginia	94911	26.75	0.28	1.06	2.85	46.76	53.24	6.52	16.4	15.95
51775	Salem city, Virginia	24747	5.72	0.15	1.03	1.26	47.38	52.62	4.87	16.92	6.71
51063	Floyd County, Virginia	13874	1.33	0	0.15	1.74	49.06	50.94	5.72	15.79	11.72
51035	Carroll County, Virginia	29245	0.71	0.1	0.22	1.85	49.96	50.04	5.59	17.18	12.46
51141	Patrick County, Virginia	19407	6.81	0.1	0.45	1.59	48.96	51.04	5.82	16.46	13.41
51089	Henry County, Virginia	57930	22.88	0.37	0.27	2	48.68	51.32	5.3	14.89	11.65
51640	Galax city, Virginia	6837	7.3	0.12	0.23	6.1	47.68	52.32	5.47	18.62	18.61
51690	Martinsville city, Virginia	15416	41.84	0.06	0.45	1.58	44.81	55.19	5.76	20.87	19.19
51590	Danville city, Virginia	48411	44.19	0.3	0.5	1.26	45.4	54.6	5.9	19.68	19.96
51017	Bath County, Virginia	5048	5.74	0	0.32	0.69	49.76	50.24	4.46	17.12	7.79
51091	Highland County, Virginia	2536	0.08	0.24	0	0.35	49.92	50.08	3.67	20.19	12.56
51003	Albemarle County, Virginia	79236	9.72	0.2	3.1	1.75	48.15	51.85	6.29	12.5	6.74
51033	Caroline County, Virginia	22121	34.61	0.8	0.48	1.43	50.13	49.87	6.09	13.07	9.35

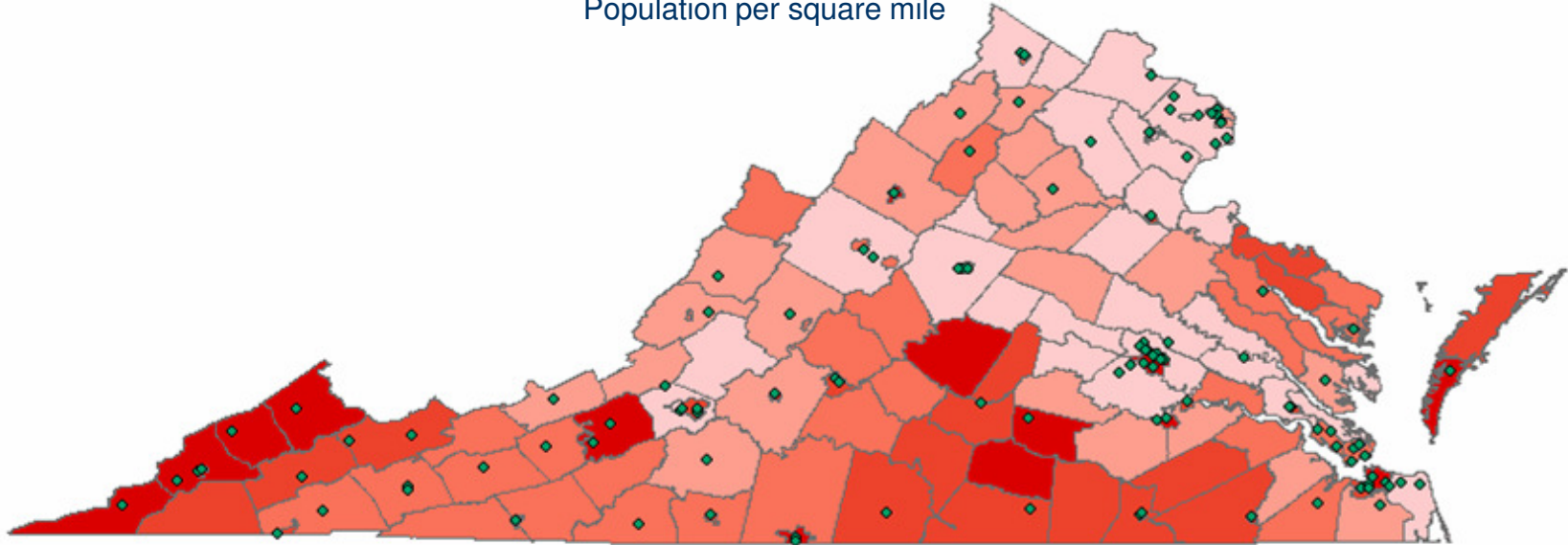
# Visualizing Data



# Spatial Overlay



Population per square mile



Percent Poverty



# Things Anyone Using GIS Should Know

- Time
- Projections, projections, projections
- Accuracy
- Scale and resolution
- Aggregation - Modifiable Areal Unit Problem
- Every map is a lie
  - Unavoidable
  - Usually unintentional
  - Sometimes malicious

# Date

- Lags between survey and production
- Cost of constant updates are still prohibitive
- Most GIS data has been produced within the last 10 years
- Historical data is not being created in significant amounts

# Projection System

- Also known as “coordinate system”
- Dependent upon:
  - Local standards
  - Uses and needs
- Multiple data sources mean multiple projections

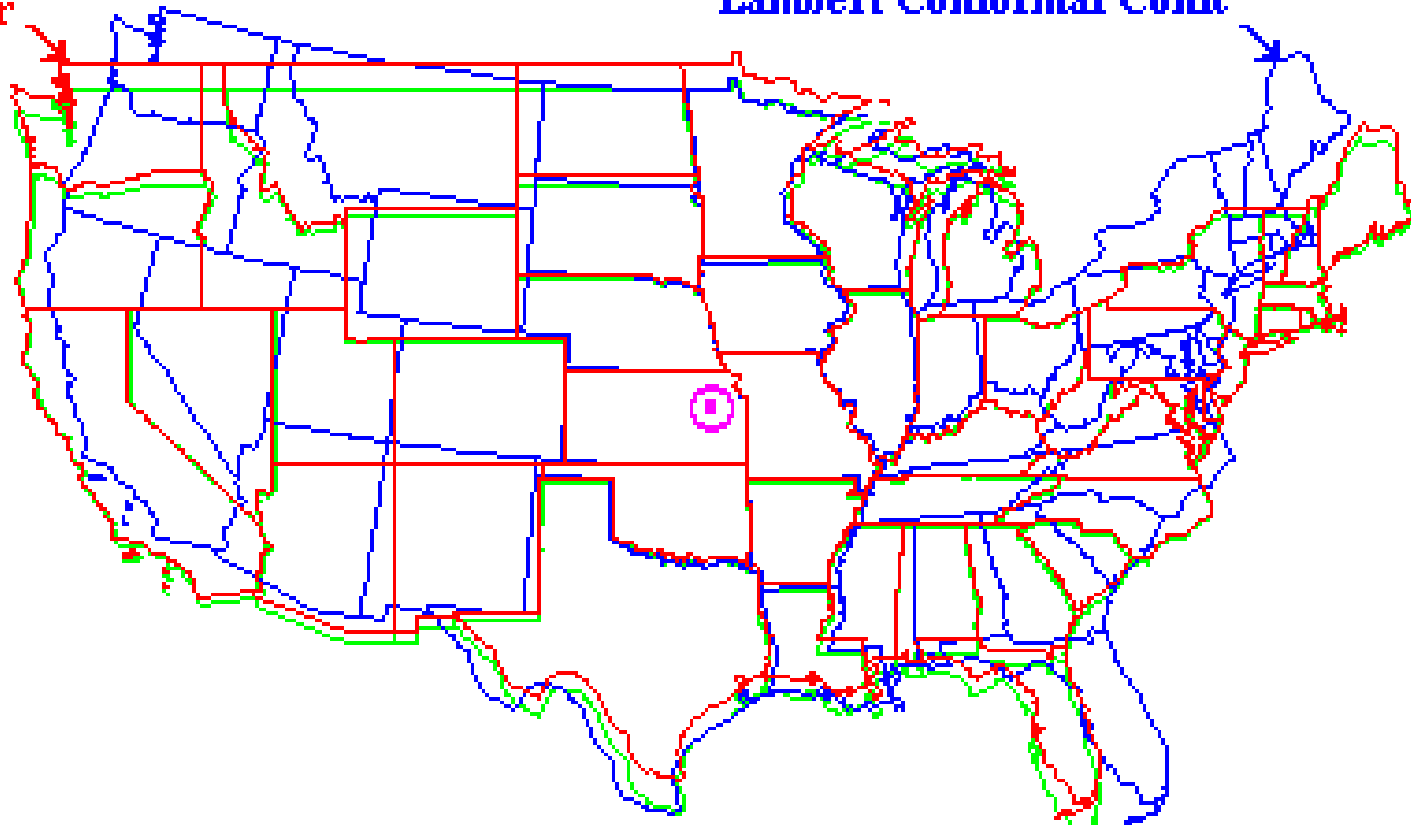


# Projections

## Three Map Projections Centered at 39 N and 96 W

**Mercator**

**Lambert Conformal Conic**



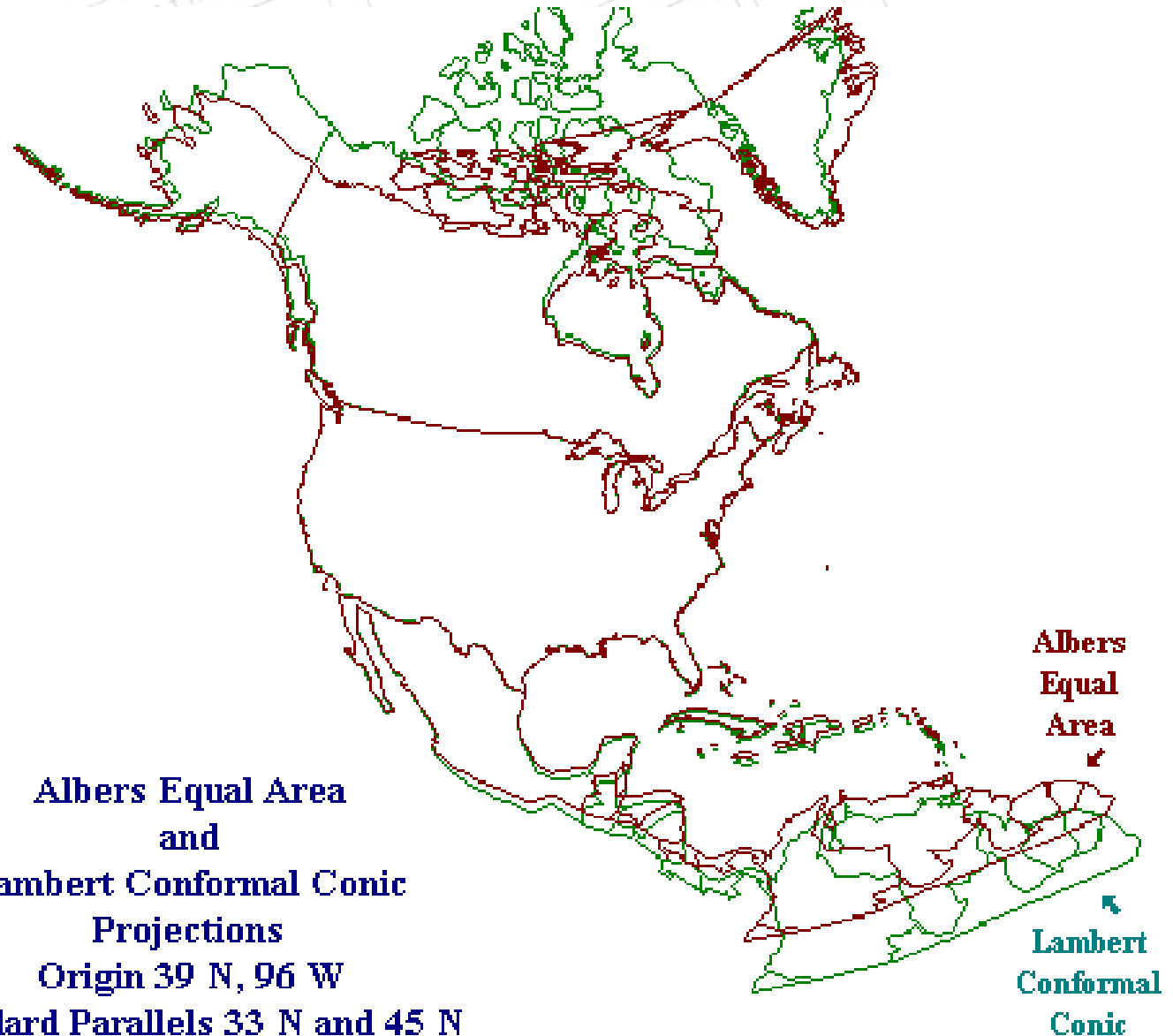
**Un-Projected Latitude and Longitude**

Peter H. Dana 6/23/97

# Projections

- Notice the boundary lines do not line up
- Points that are placed on the wrong projection will be misaligned as well

**Albers Equal Area  
and  
Lambert Conformal Conic  
Projections**  
Origin 39 N, 96 W  
Standard Parallels 33 N and 45 N



# Projections

## Summary

- = Yes
- = Partly

Summary		Properties						Suitable for Mapping						General Use							
Projection	Type	Conformal						World						Topographic Maps							
		Equal area			Equidistant			Hemisphere			Continent/Ocean			Geological Maps							
											Region/Sea			Thematic Maps							
					True direction						Medium Scale			Presentations							
					Perspective						Large Scale			Navigation							
					Compromise									USGS Maps							
		Straight rhumbs																			
Globe	Sphere	●	●	●	●					●							●	●			
Mercator	Cylindrical	●			○		●			○		●					●	●		●	●
Transverse Mercator	Cylindrical	●									●	●	●	●			●	●		●	
Oblique Mercator	Cylindrical	●									●	●	●	●			●			●	
Space Oblique Mercator	Cylindrical	●											●				●			●	
Miller Cylindrical	Cylindrical					●				●							●			●	
Robinson	Pseudocylindrical					●				●							●	●			
Sinusoidal Equal Area	Pseudocylindrical		●	○						●		●					●			●	
Orthographic	Azimuthal				○	●					○									●	
Stereographic	Azimuthal	●			○	●					●	●	●	●	●		●	●		●	●
Gnomonic	Azimuthal				○	●							○						●	●	
Azimuthal Equidistant	Azimuthal			○	○					○	●	●	●		○		●			●	
Lambert Azimuthal Equal Area	Azimuthal		●		○						●	●	●					●	●		●
Albers Equal Area Conic	Conic		●									●	●	●				●	●		●
Lambert Conformal Conic	Conic	●			○							●	●	●	●		●	●		●	●
Equidistant Conic (Simple Conic)	Conic			○								●	●						●	●	
Polyconic	Conic			○		●								○	○		●				●
Bipolar Oblique Conic Conformal	Conic	●										●					●				●

All above projections (except Robinson) are explained in detail in *Map Projections—A Working Manual*, John P. Snyder, Geological Survey Professional Paper 1395 (Washington: USGPO, 1987, 383 pp.)



# Accuracy: Census Streets Data





# Accuracy: City Planning Data

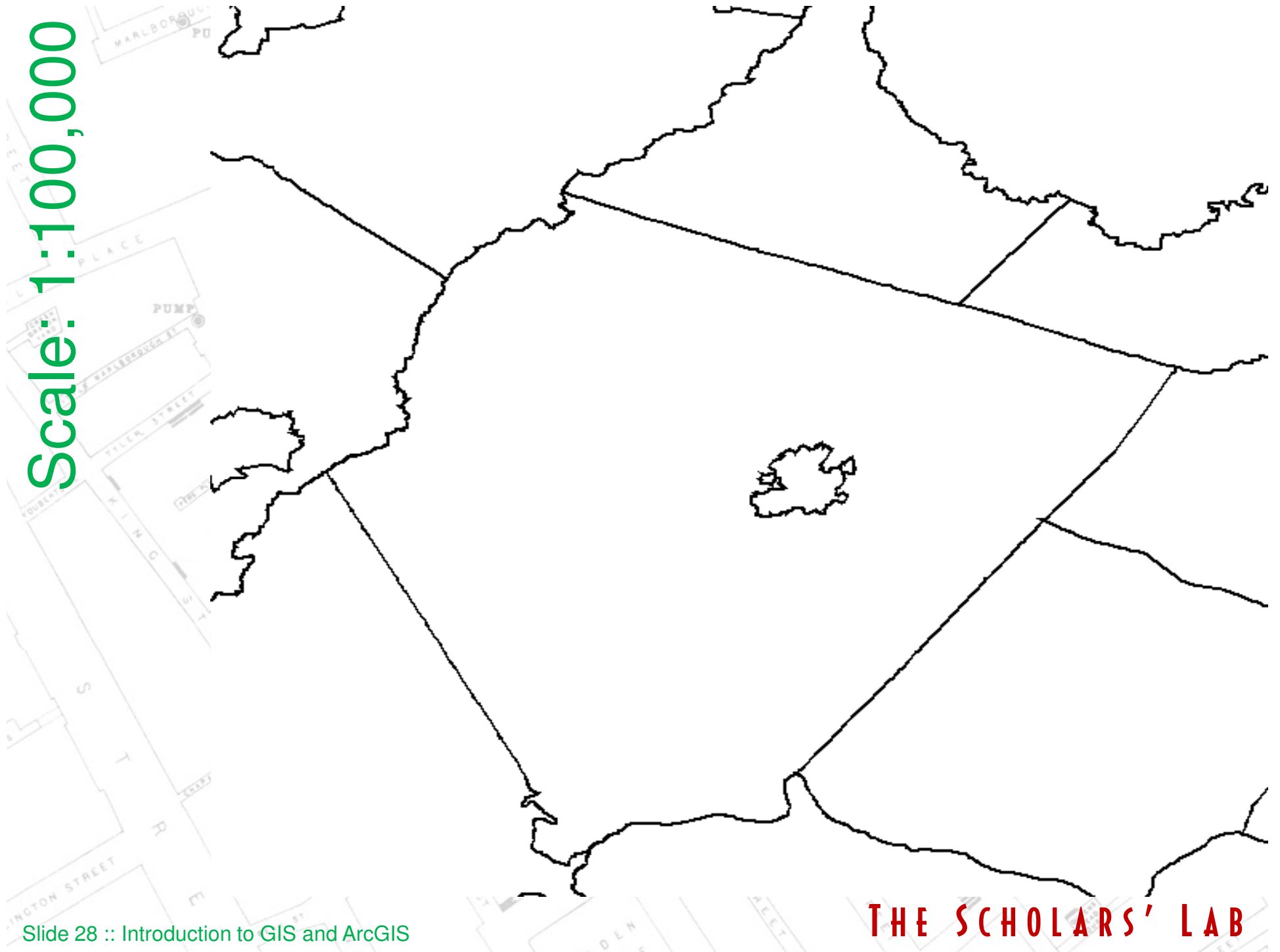


# Scale & Resolution

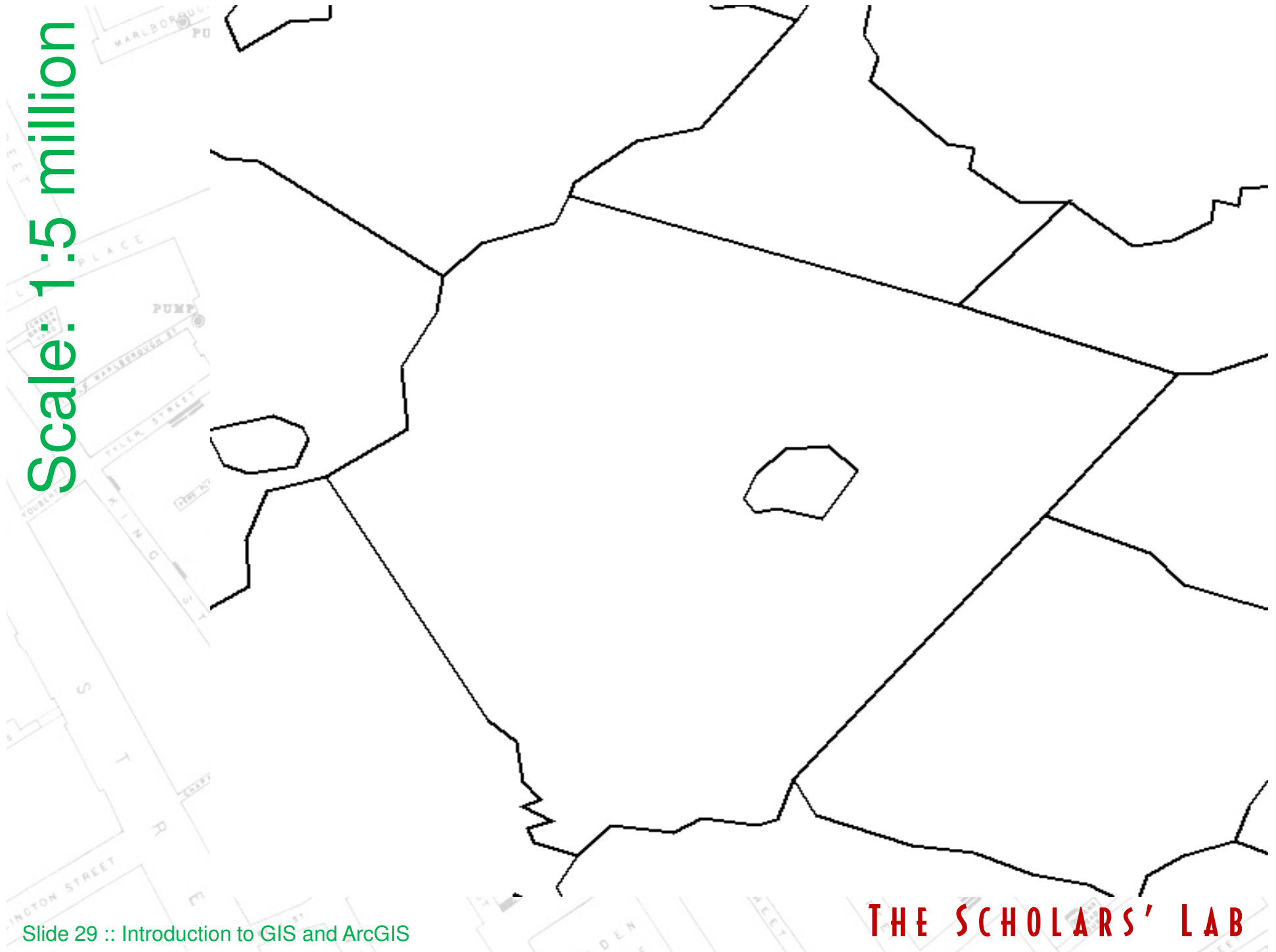
- Ratio between map dimensions and real world
- Large scale: “big picture of small space”
- Small scale: “little picture of big space”
- 1:63,360 translates into 1 inch to the mile  
(5280 feet = 63,360 inches)
- points, lines, polygons – objects
  - cities as points or polygons?
  - rivers as lines or polygons?
- For GIS data, scale and resolution refer to the *source*

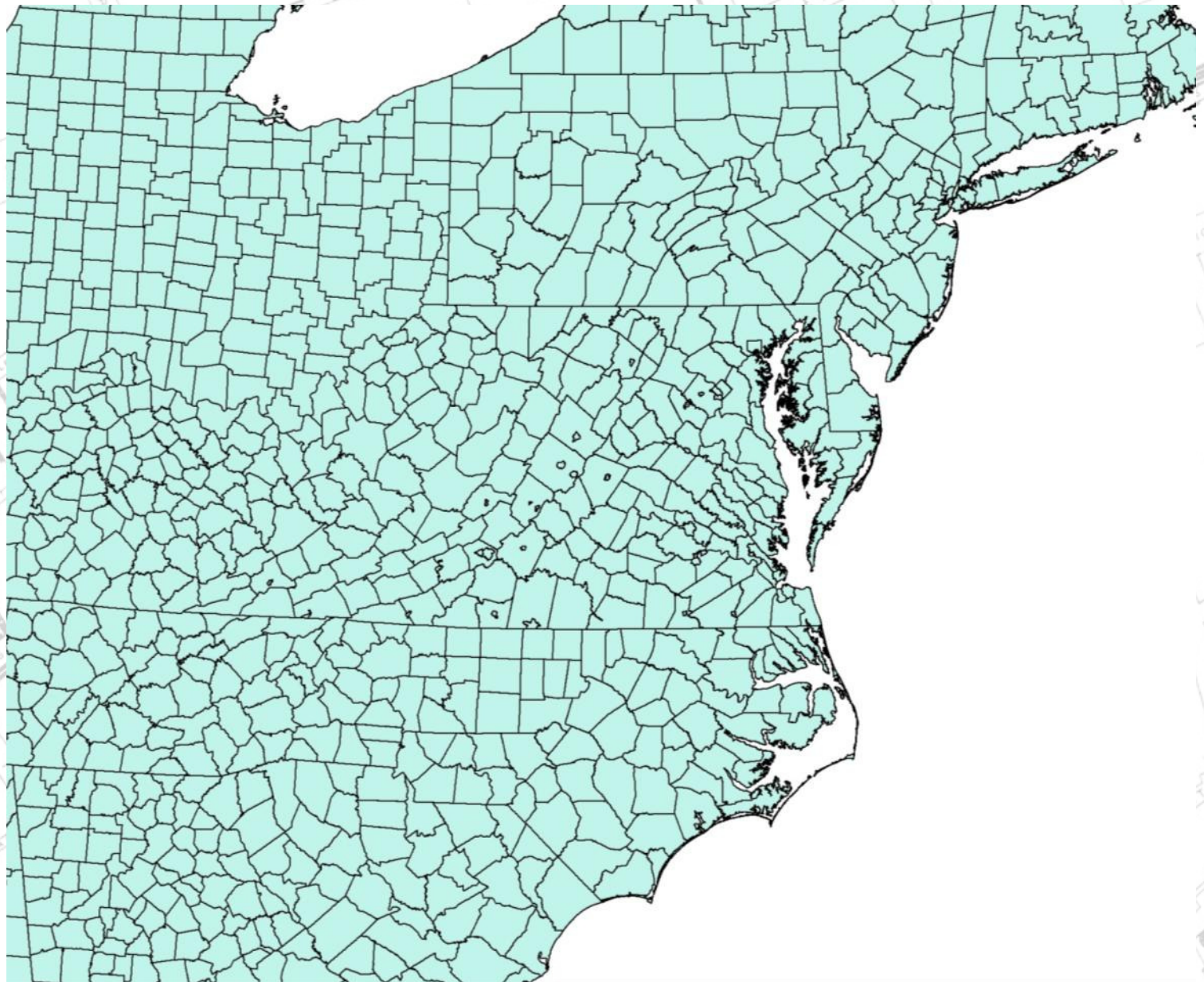


Scale: 1:100,000

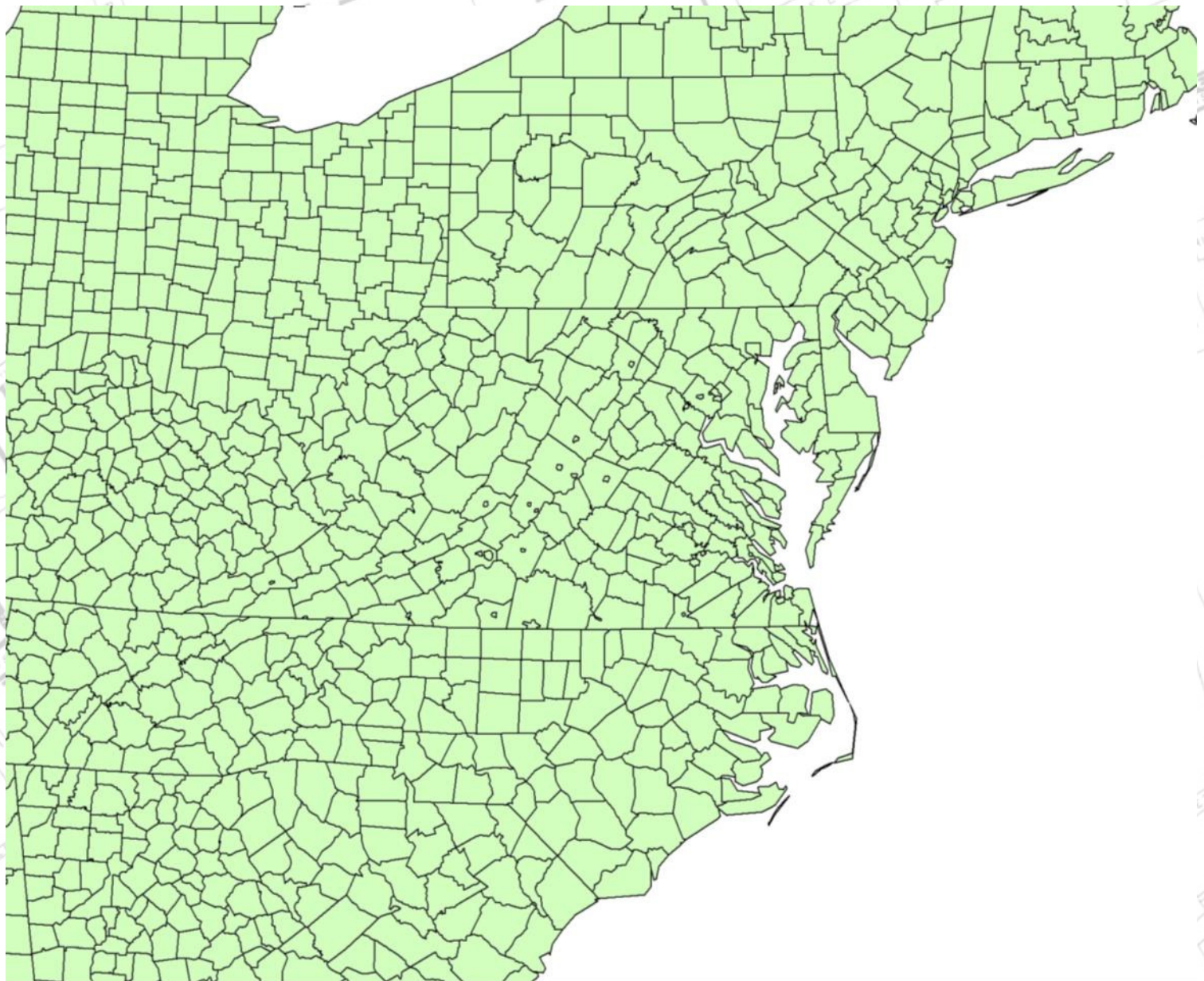


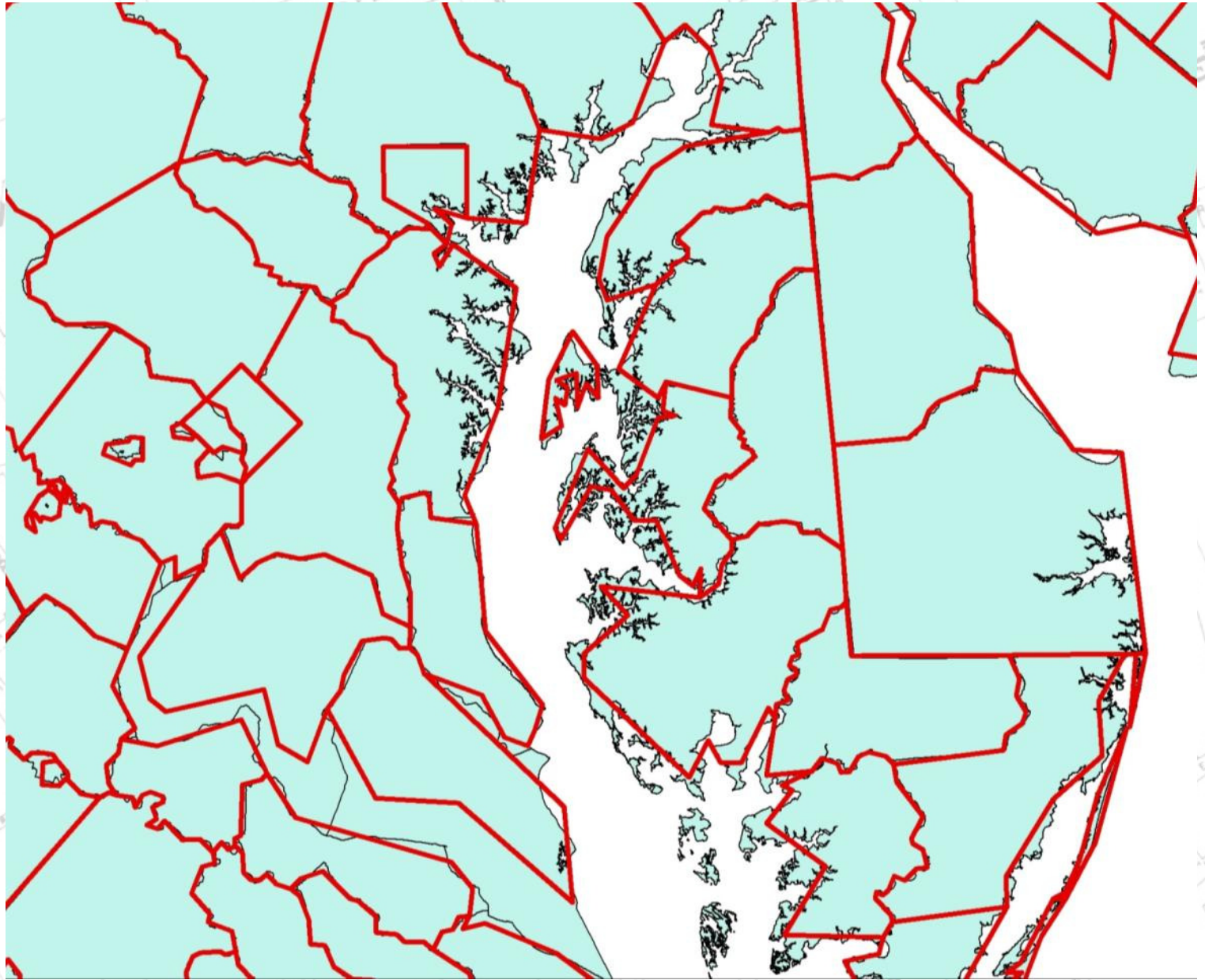
Scale: 1:5 million













Resolution: 1-foot/pixel





Resolution: 1-meter/pixel



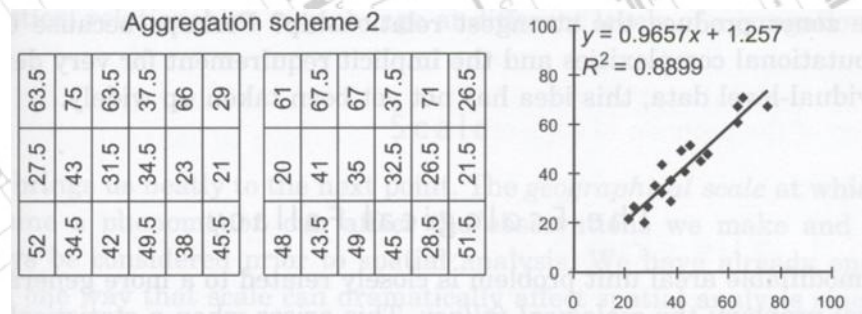
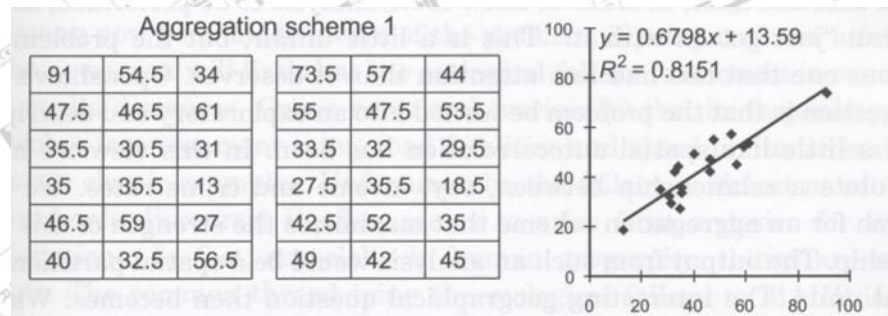
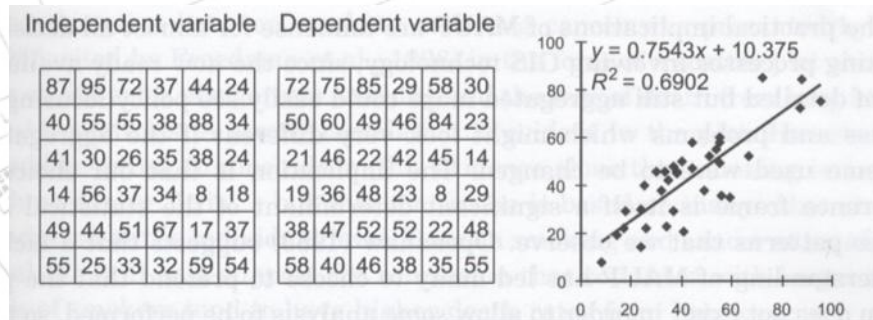






# Modifiable Areal Unit Problem (MAUP)

Aggregation units are arbitrary with respect to the underlying data, yet the units used will affect statistics determined by those aggregations.



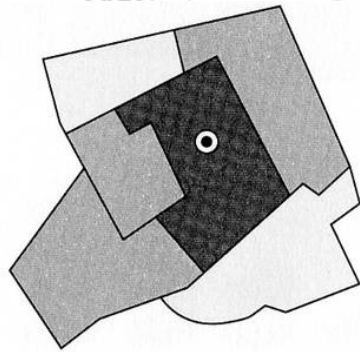


# Snow's Map

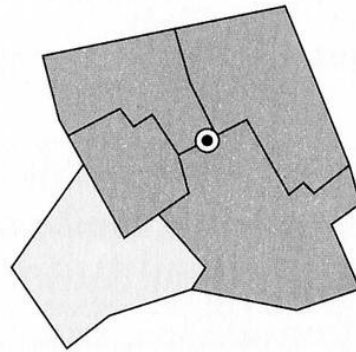
Slide 37 :: Introduction to GIS and ArcGIS

THE SCHOLARS' LAB

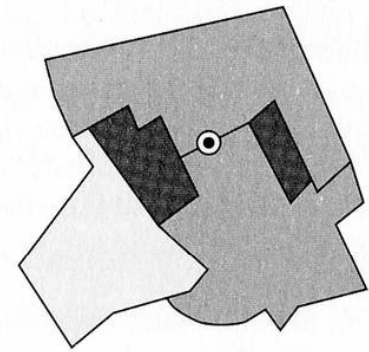
# Modifiable Areal Unit Problem (MAUP)



In this aggregation of individual deaths into six areas, the greatest number is concentrated at the Broad Street pump.



Using different geographic subdivisions, the cholera numbers are nearly the same in four of the five areas.



In this aggregation of the deaths, the two areas with the most deaths do not even include the infected pump!

Tufte's example using Snow's cholera area of London

# Every Map is a Lie

*By seducing viewers into believing that the data are reliable, relevant, and essentially complete, a geographic information system can become a dangerous instrument of self-deception.*

*Mark Monmonier, HTLWM, p. 180*



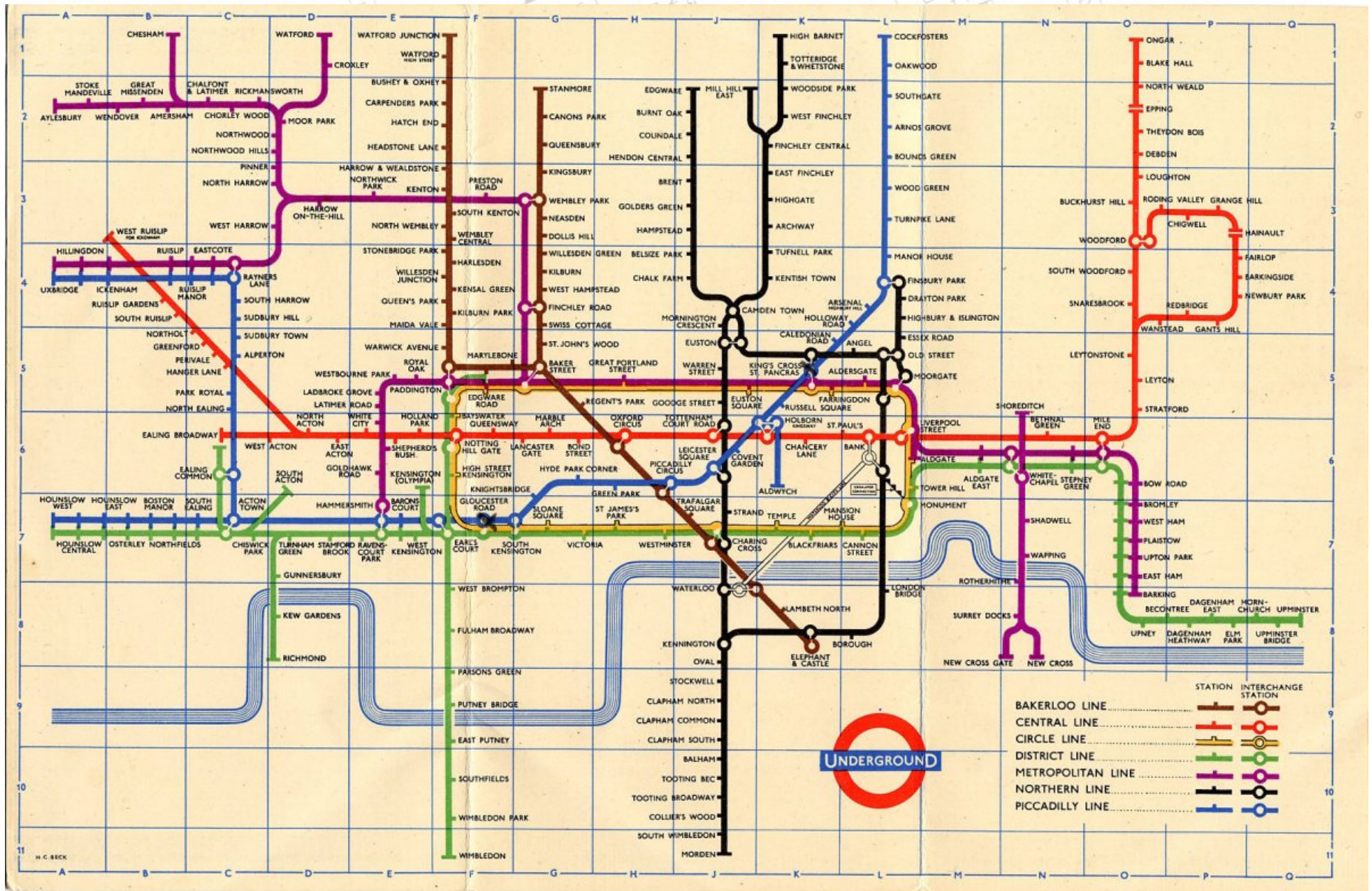
# Every Map is a Lie

## *Map*

*“It tells the truth by lying, like a poem  
With bold hyperbole of shape and line,  
A masterpiece of false simplicity...”*

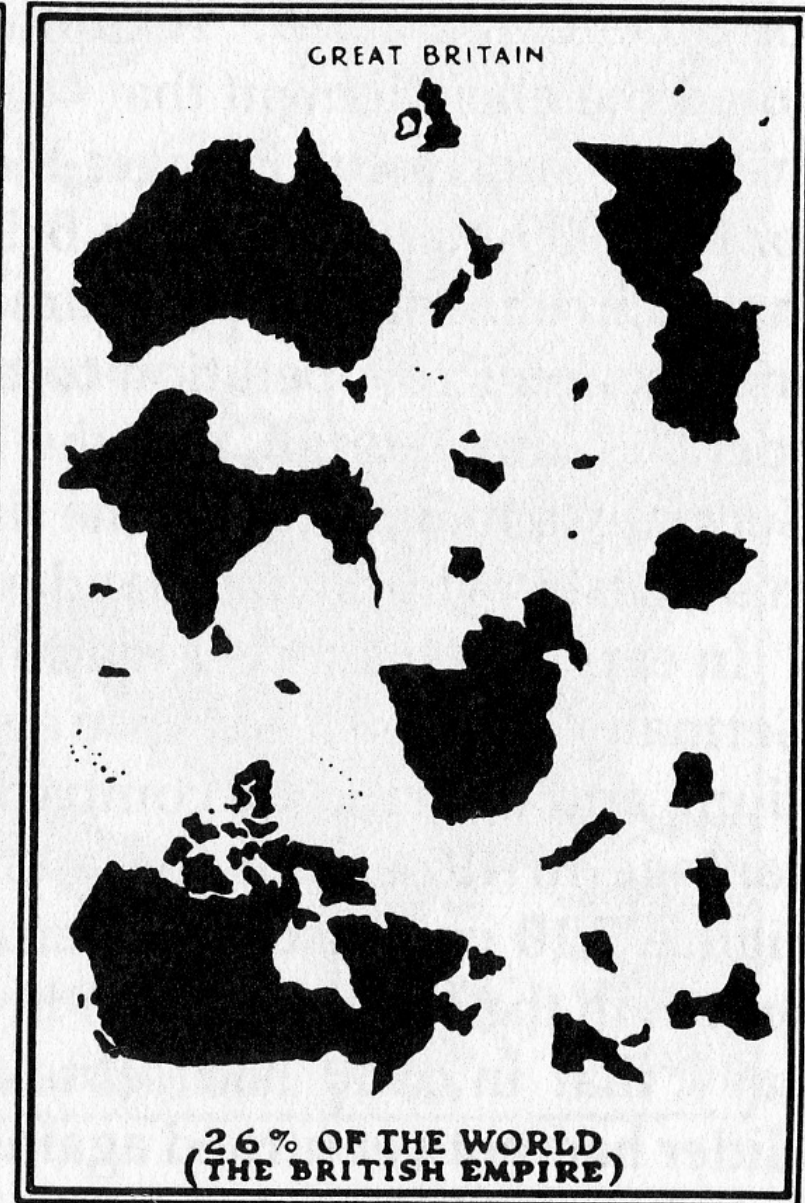
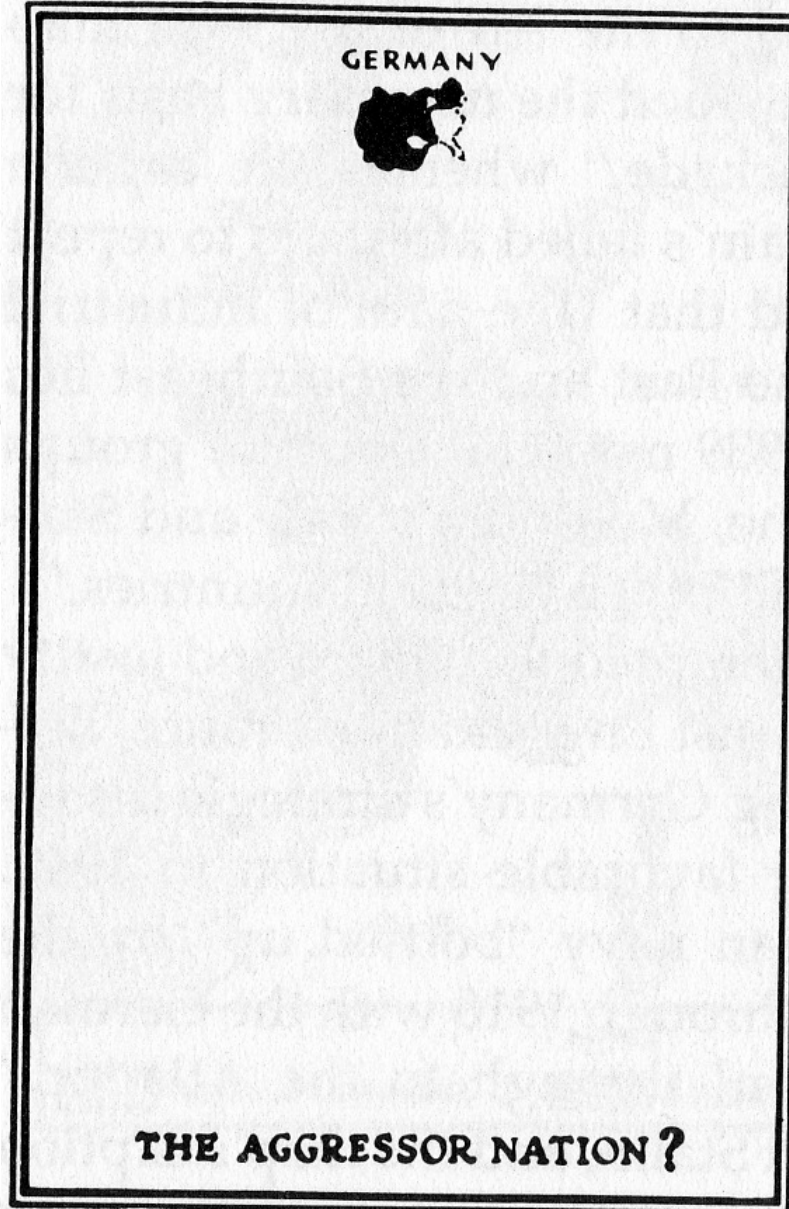
Juliana O. Muehrcke  
in *Map Use* by Phillip C. Muehrcke

# Deliberate choice of design over geographical accuracy...



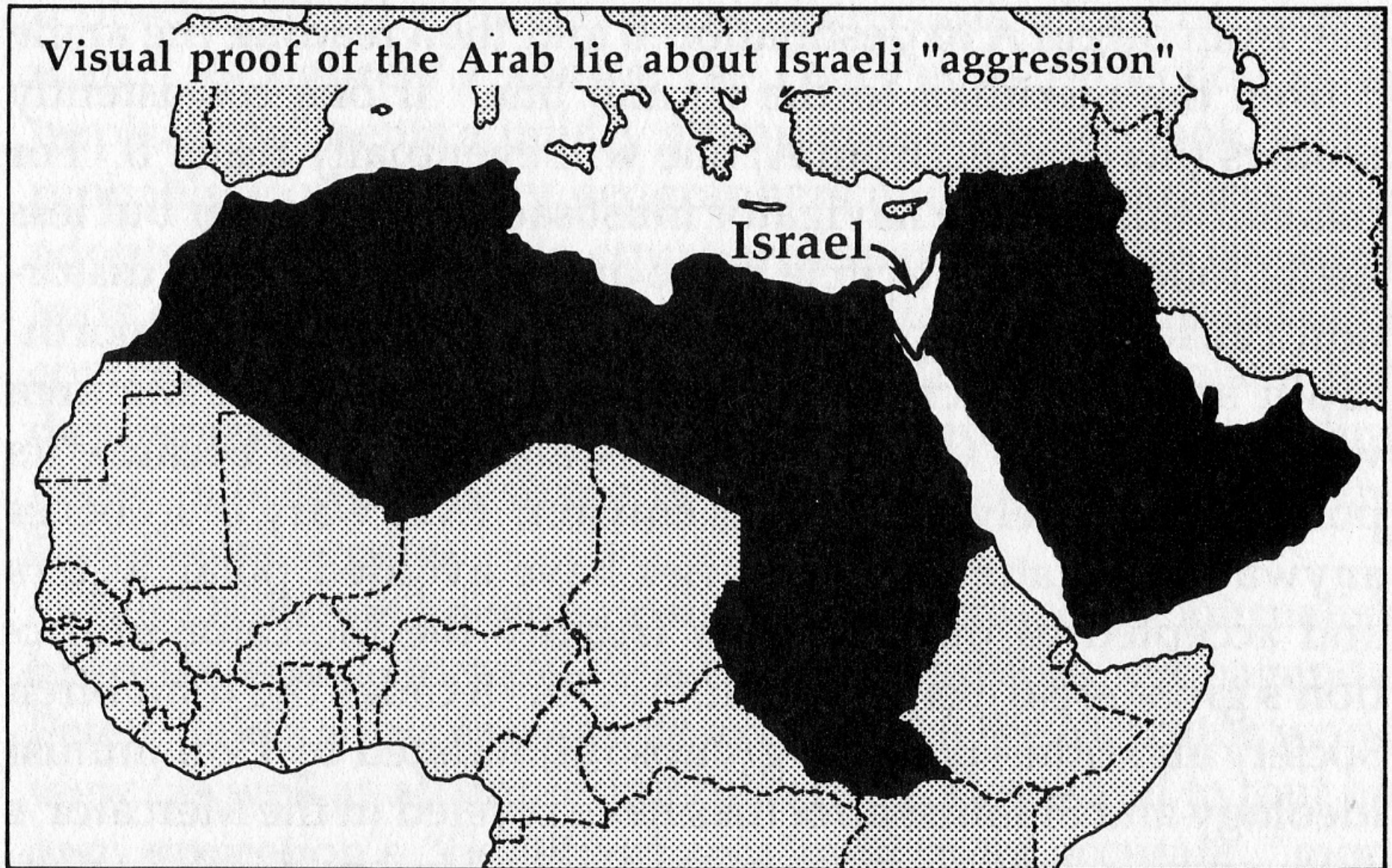


# A STUDY IN EMPIRES





# Political Propaganda



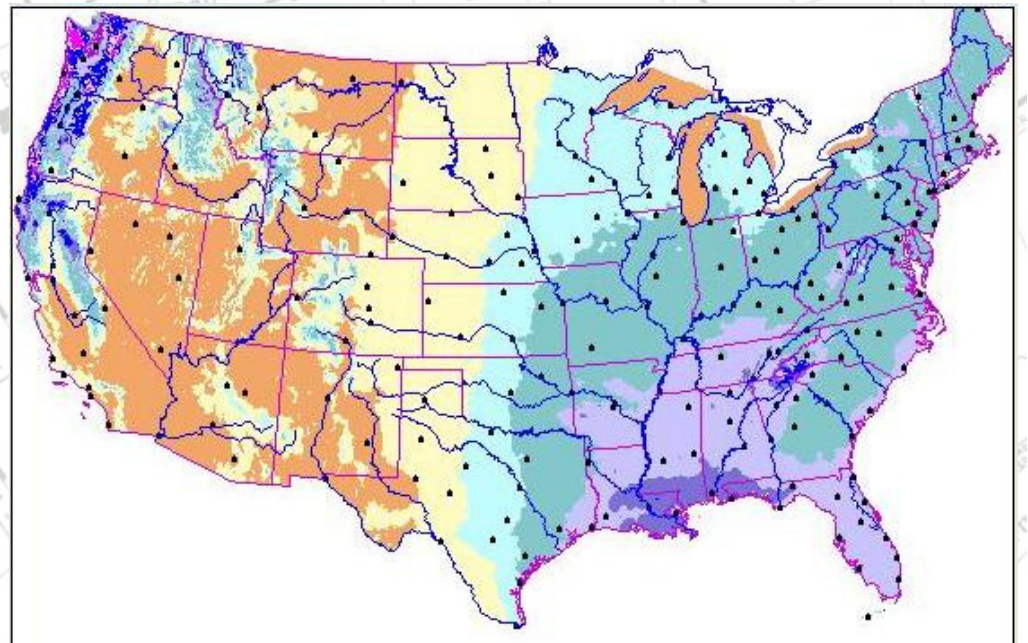
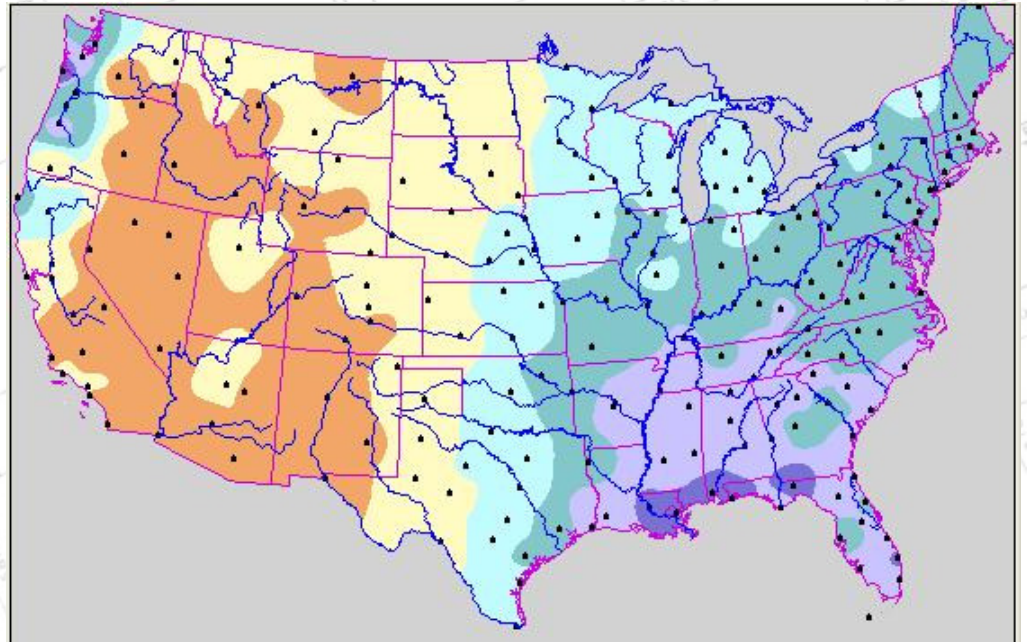


# Making surfaces from points....

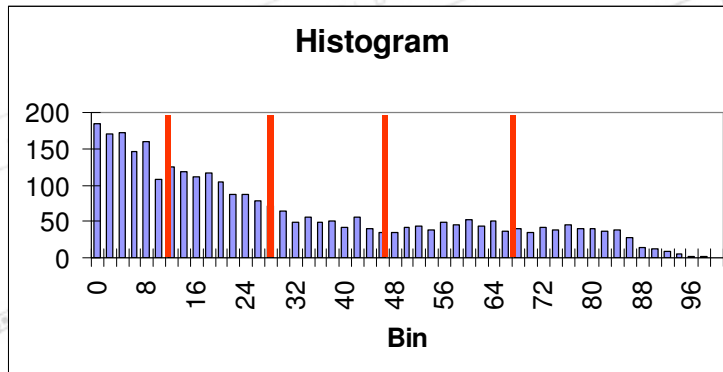
**200 weather  
stations**

**vs.**

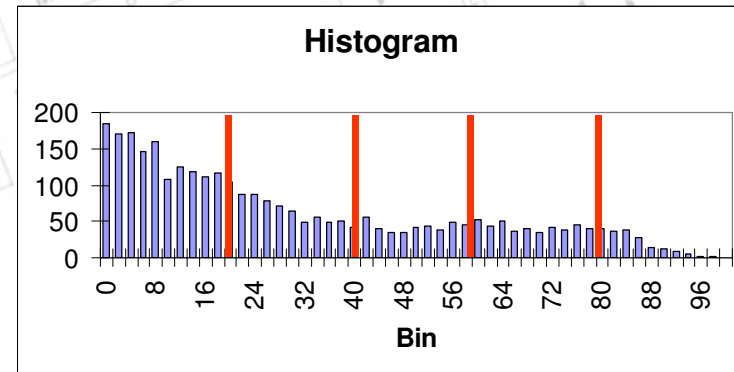
**9000 weather  
stations**



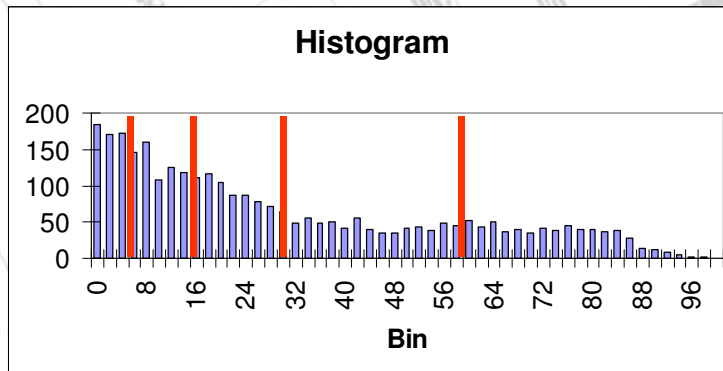
# Playing with the numbers...



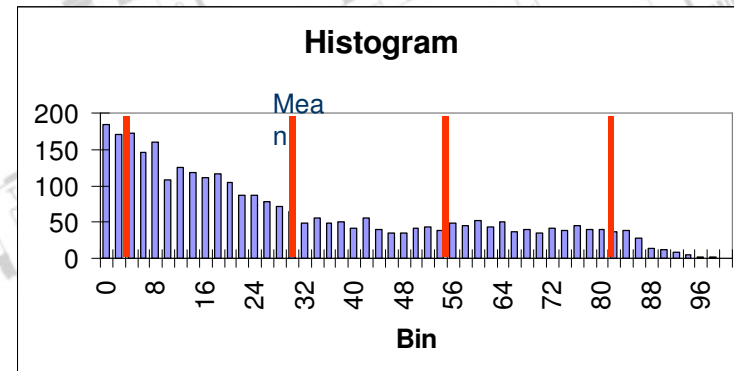
**Natural breaks**



**Equal interval**



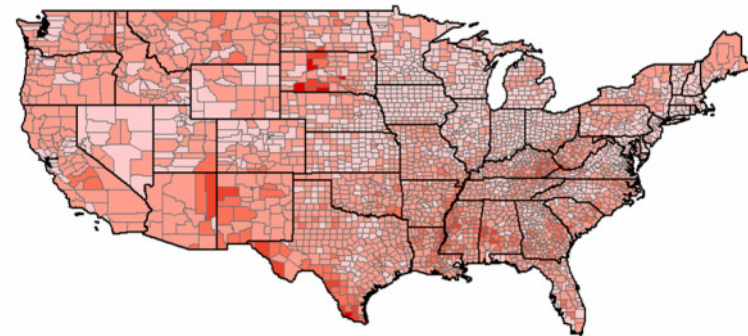
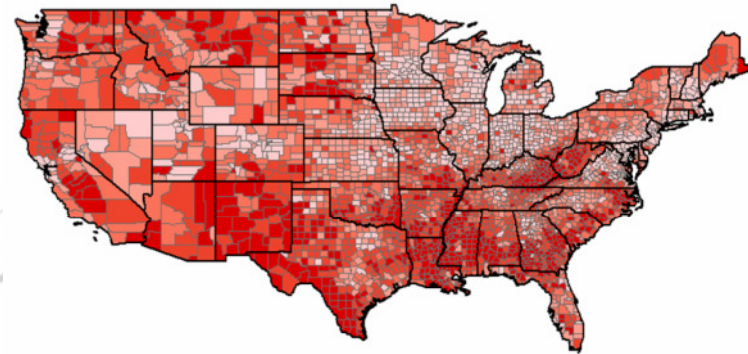
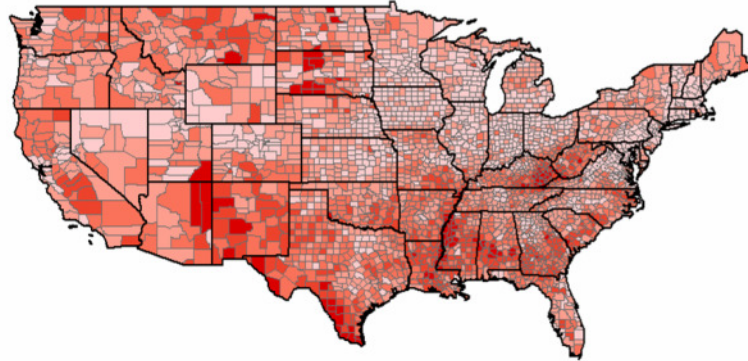
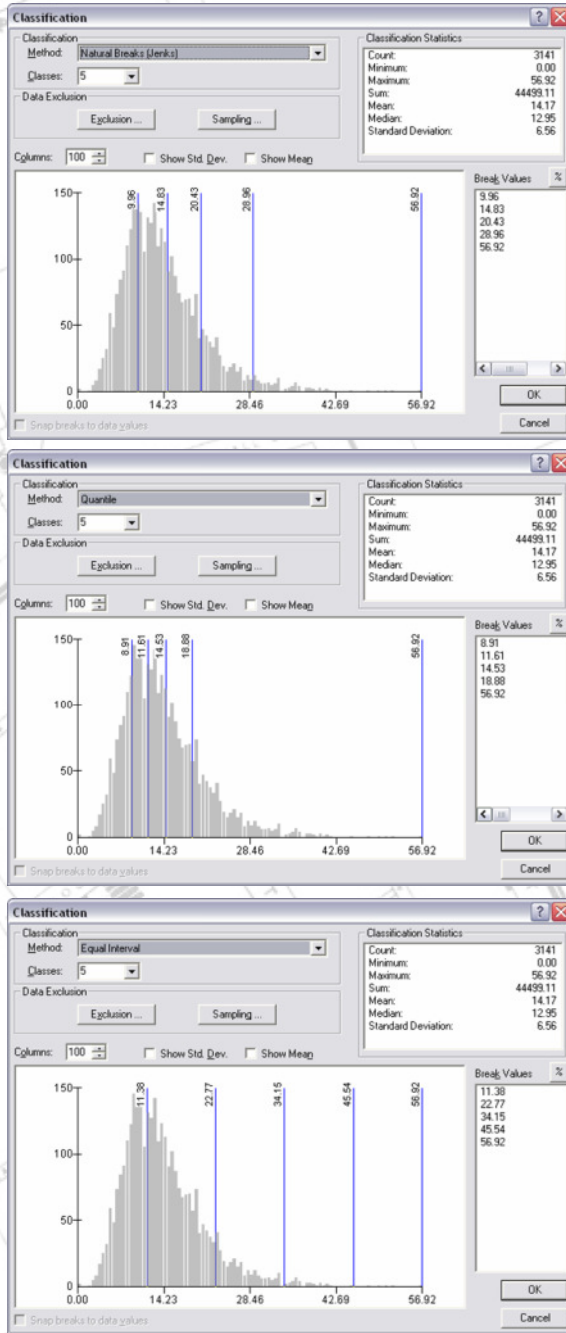
**Quantile**



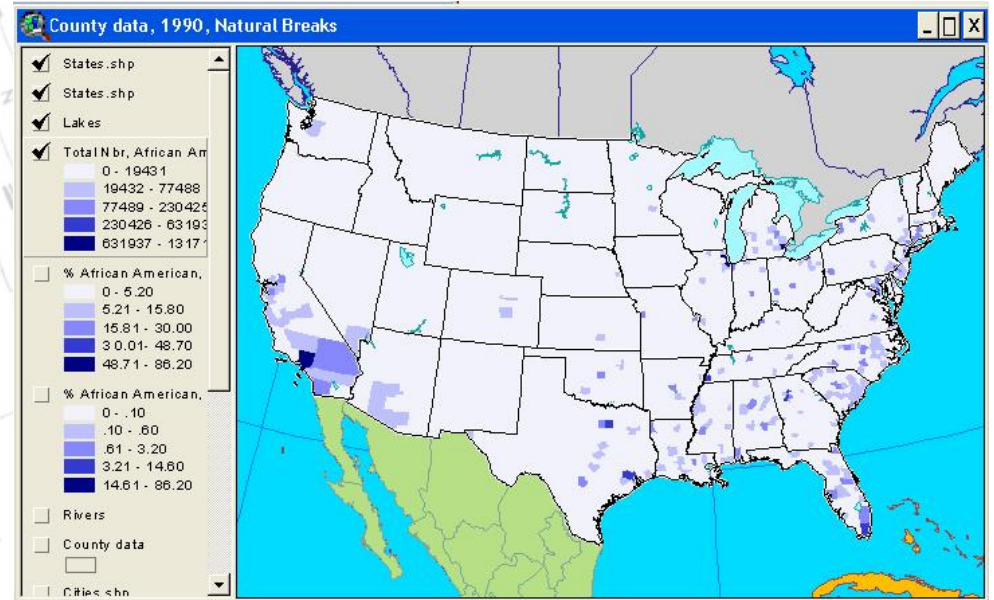
**Standard  
Deviation**



# Playing with the numbers...

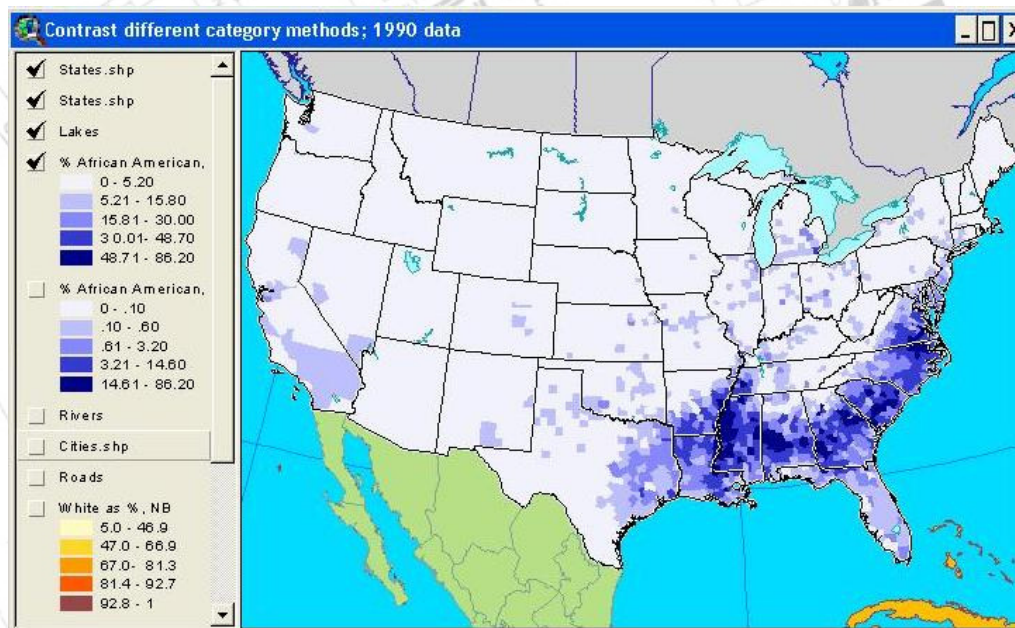


# Playing with the numbers...



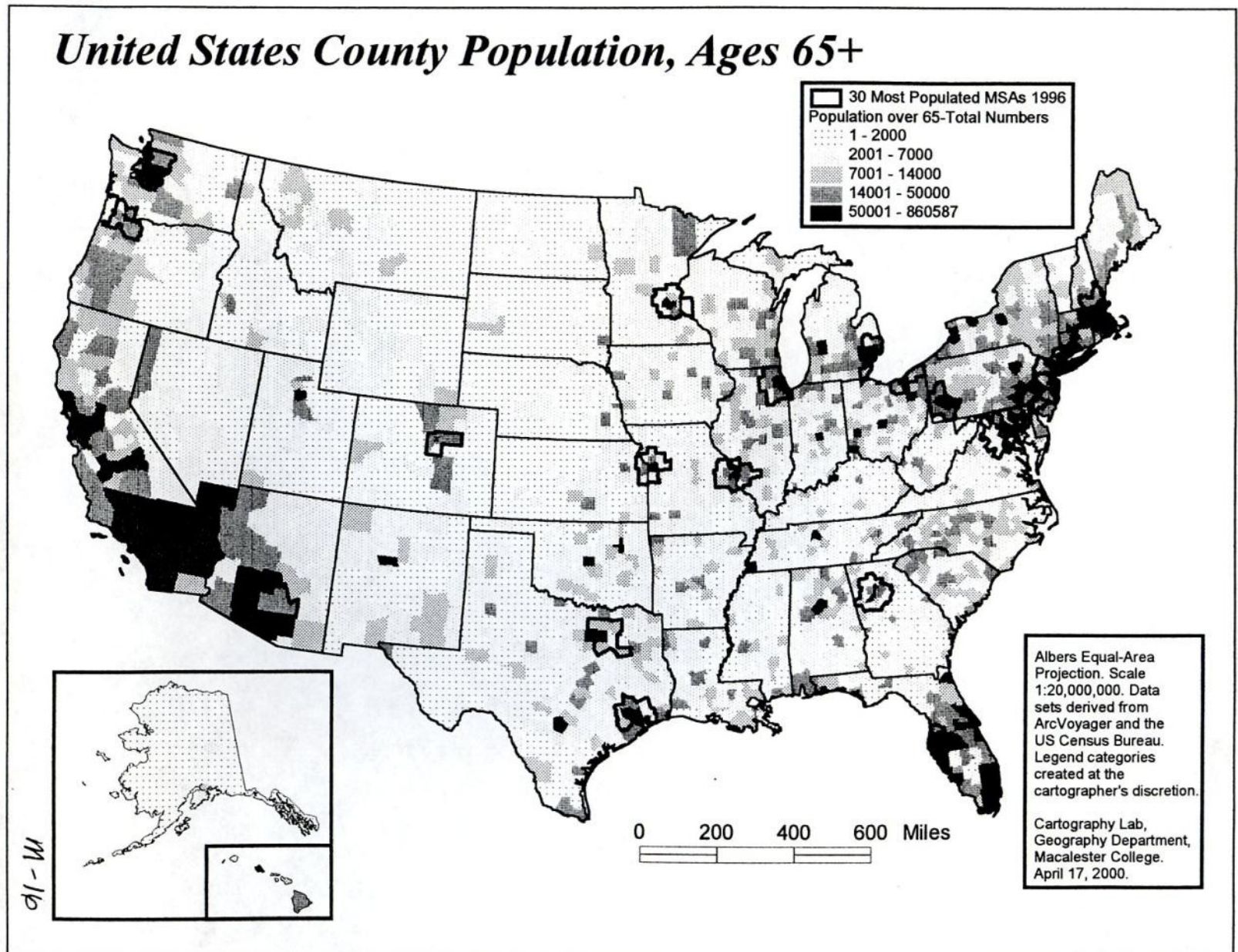
Normalized data

Total Number data



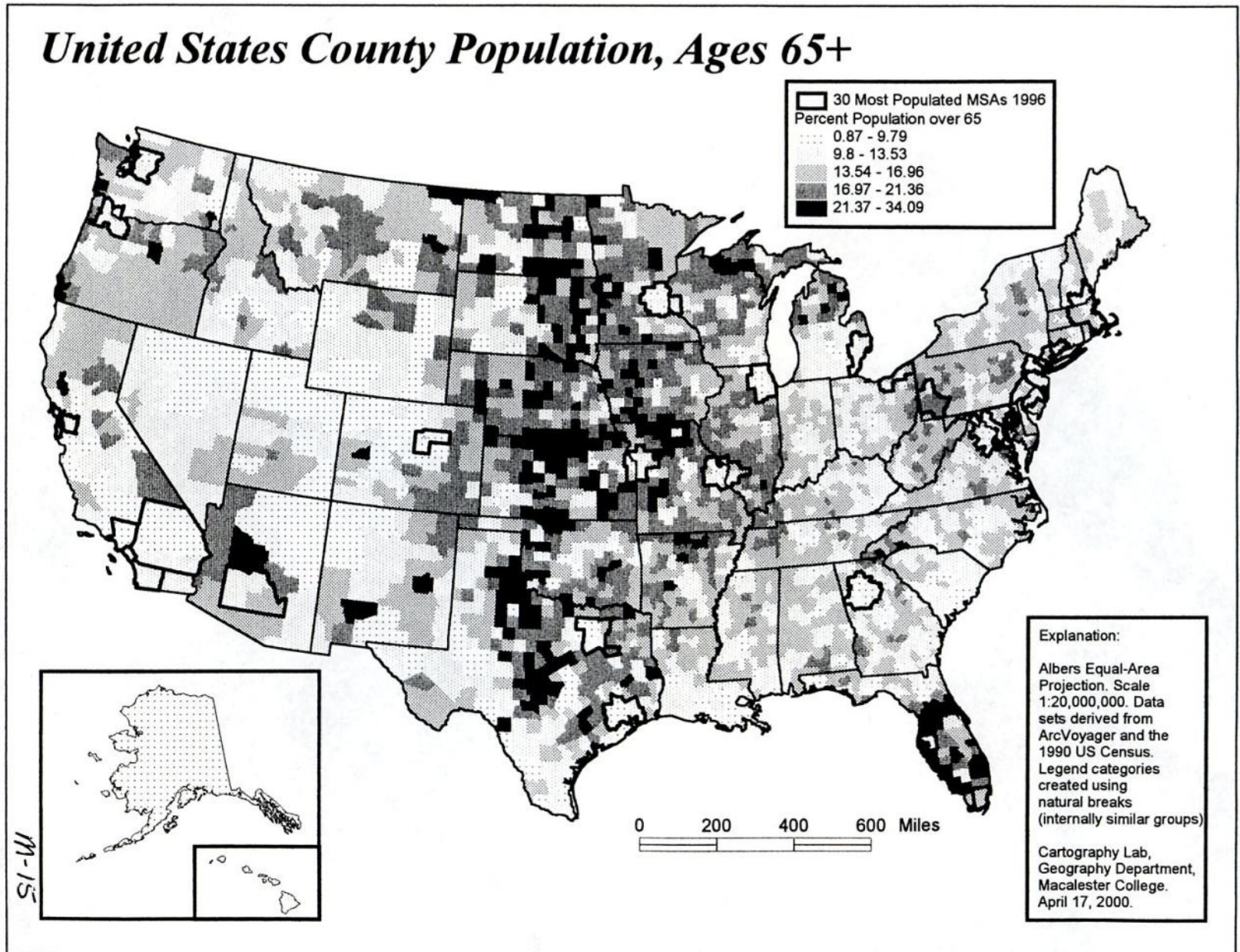


# Normalization



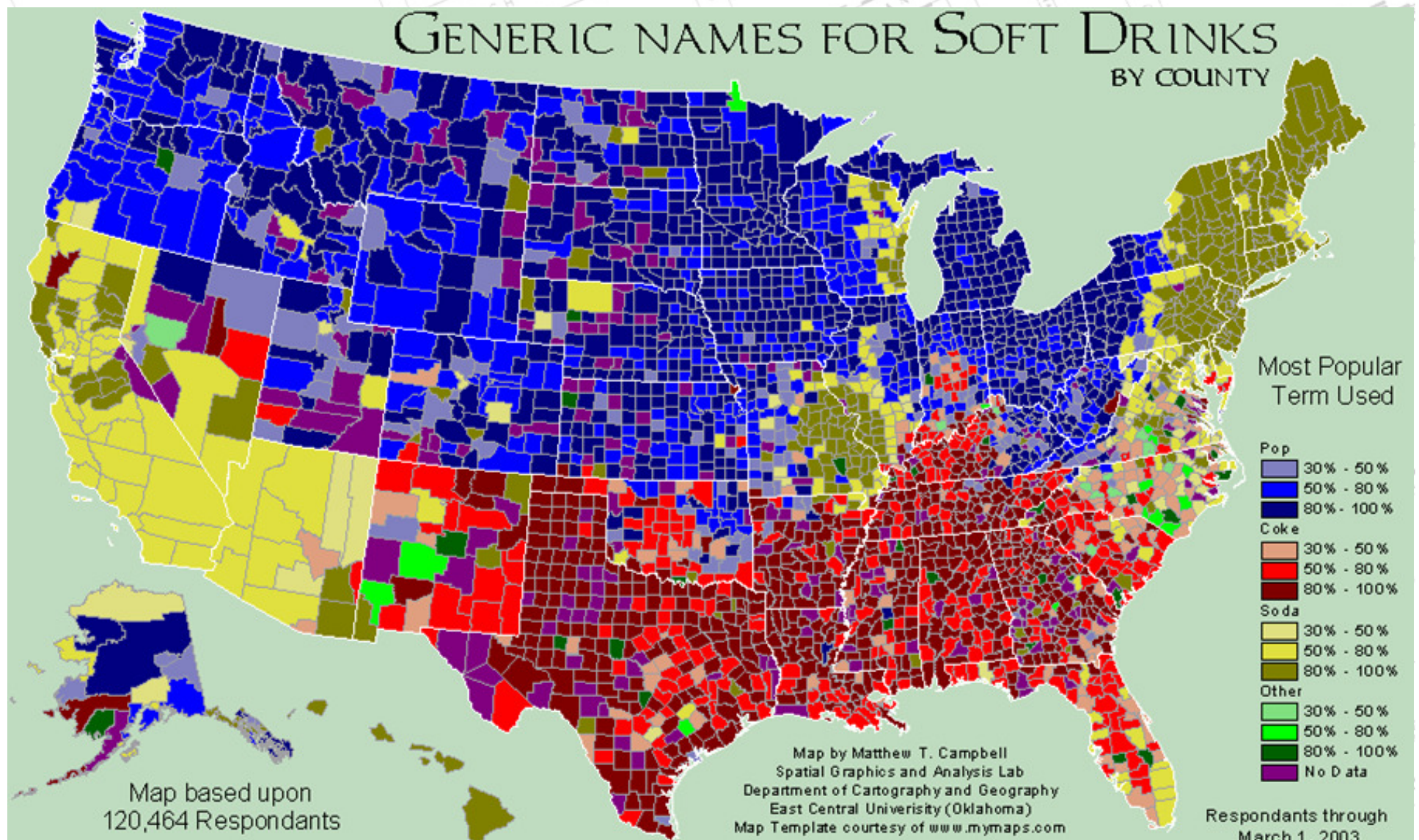
Is this map telling the whole truth about elderly population in the U.S.?



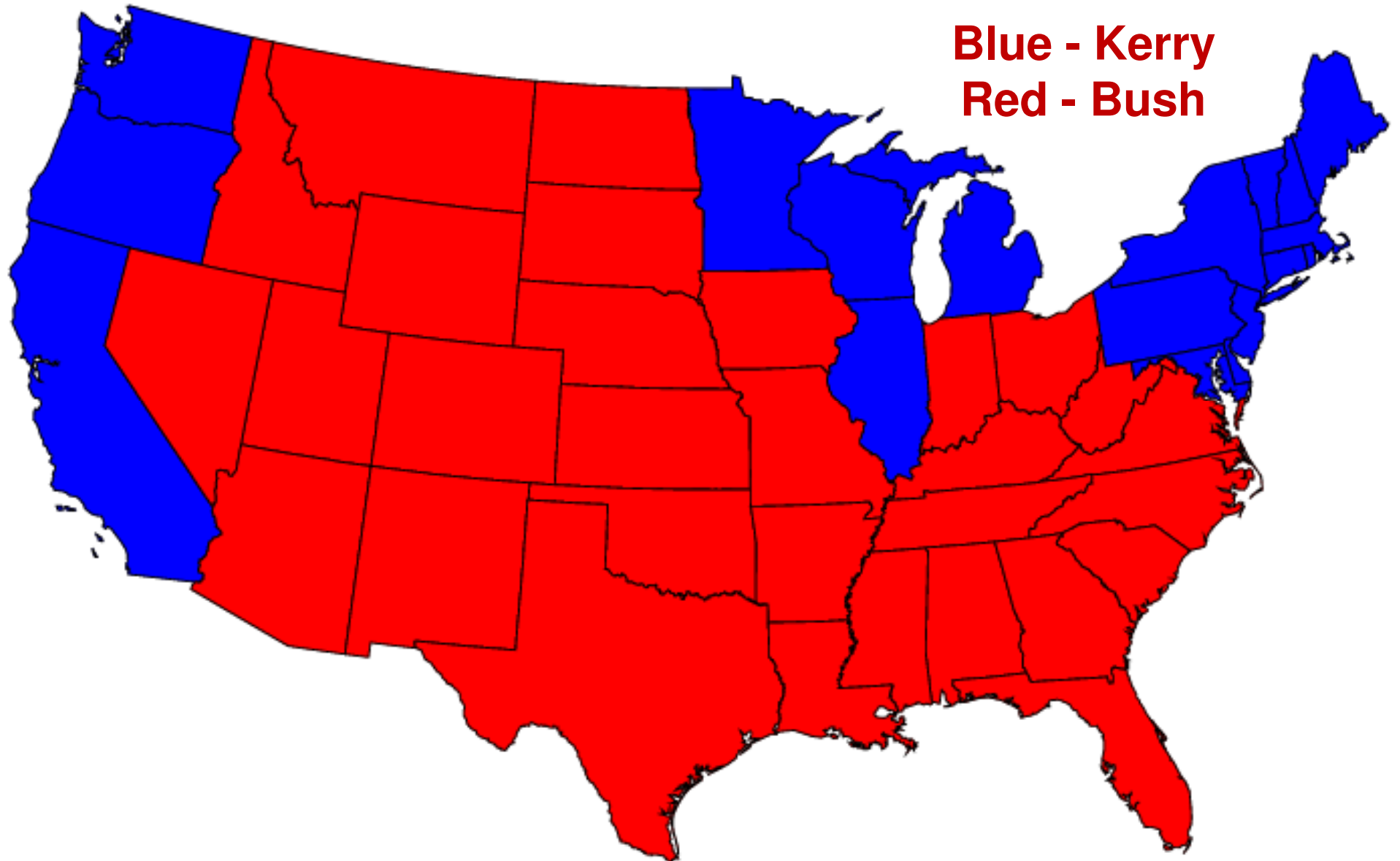




# What's Wrong with This?



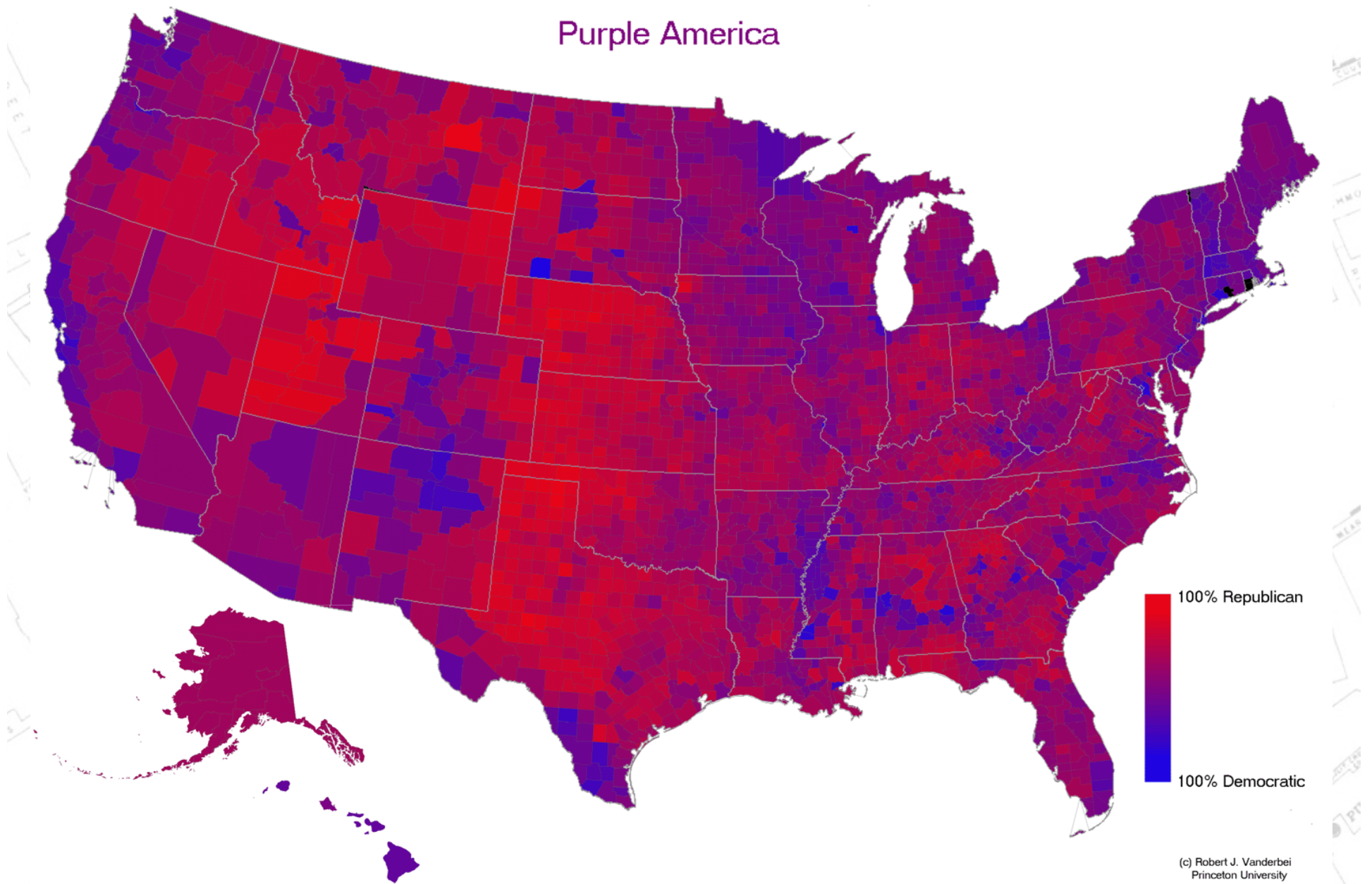
# 2004 Election Results



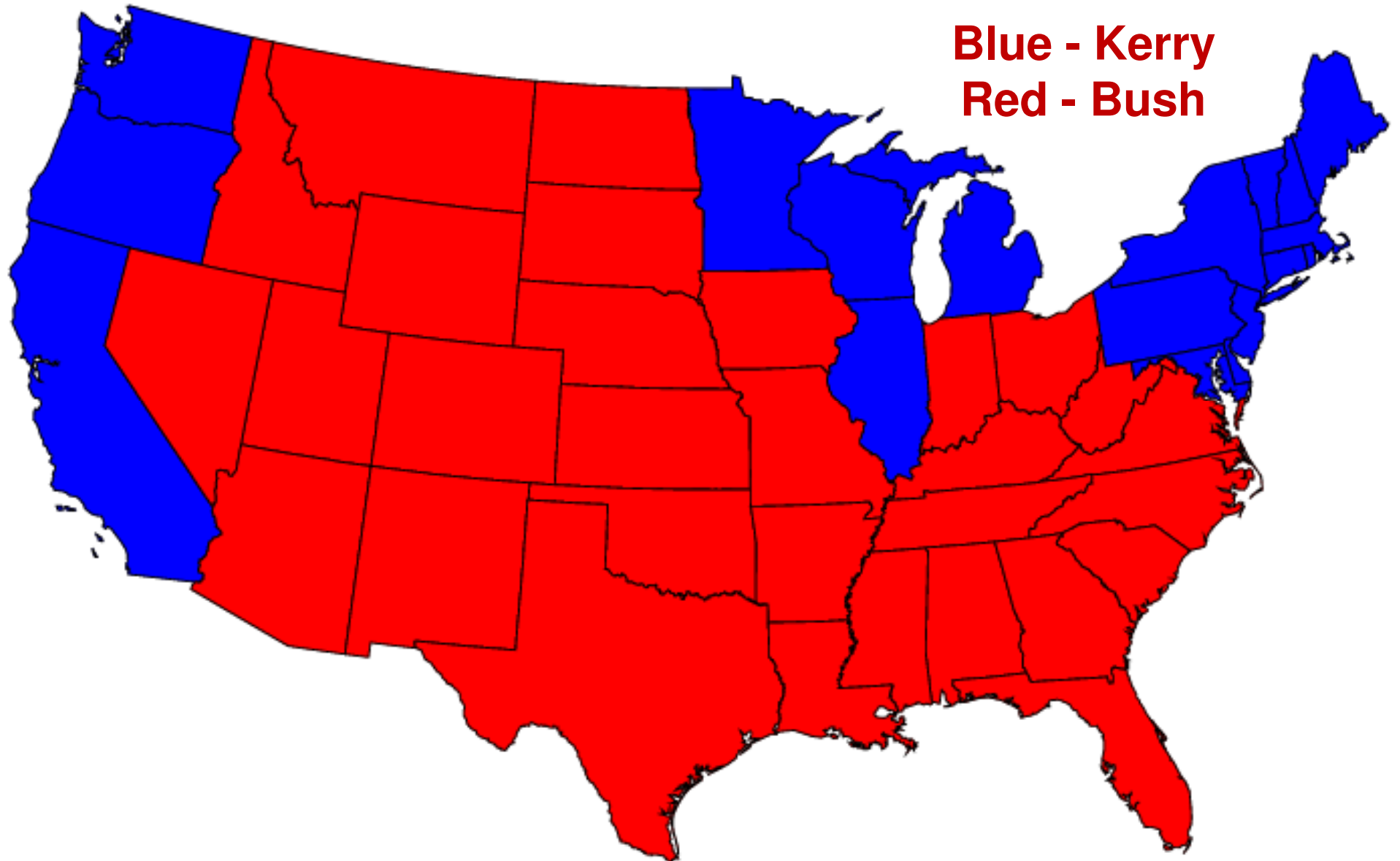


# 2004 Presidential Election

Purple America

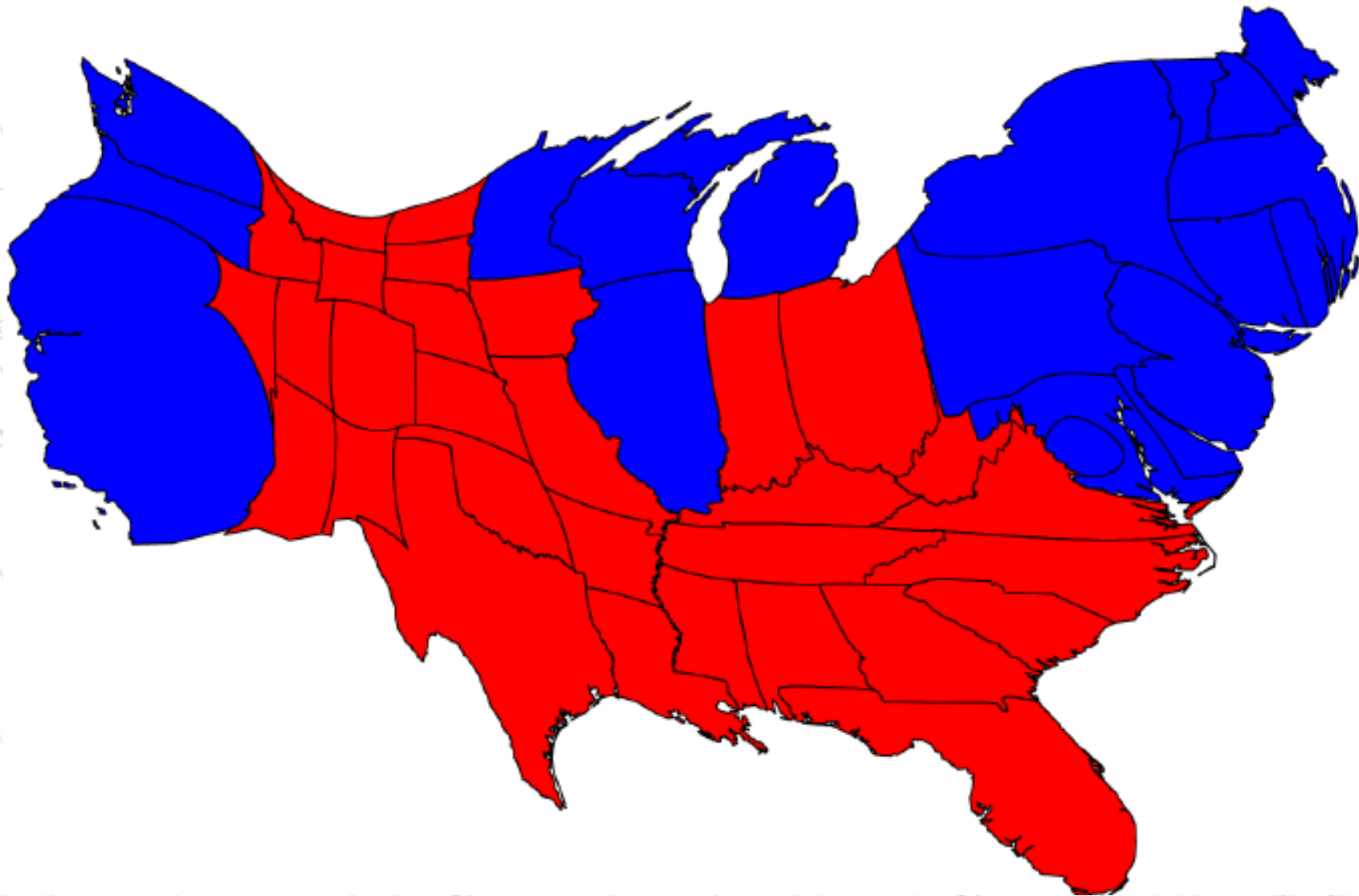


# 2004 Election Results





# 2004 Election Results: As Cartogram



# 2004 Election Results: The Purple Map As Cartogram





# GIS Software

## ESRI Products

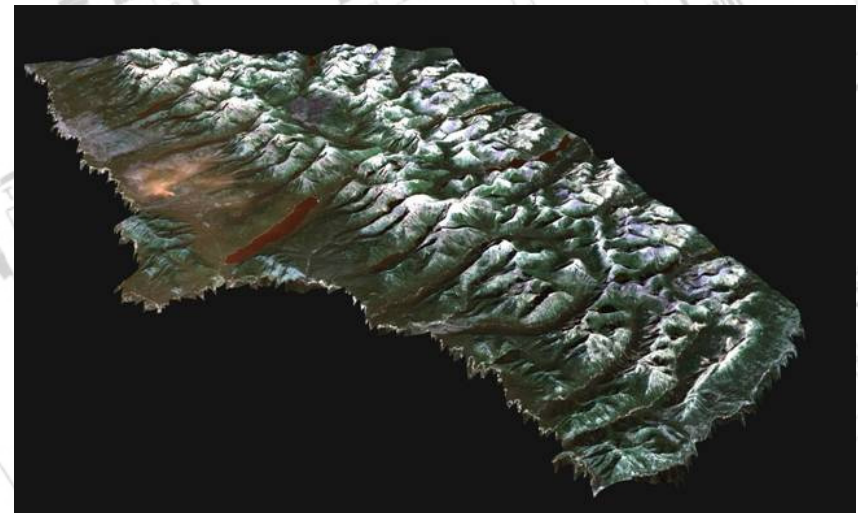
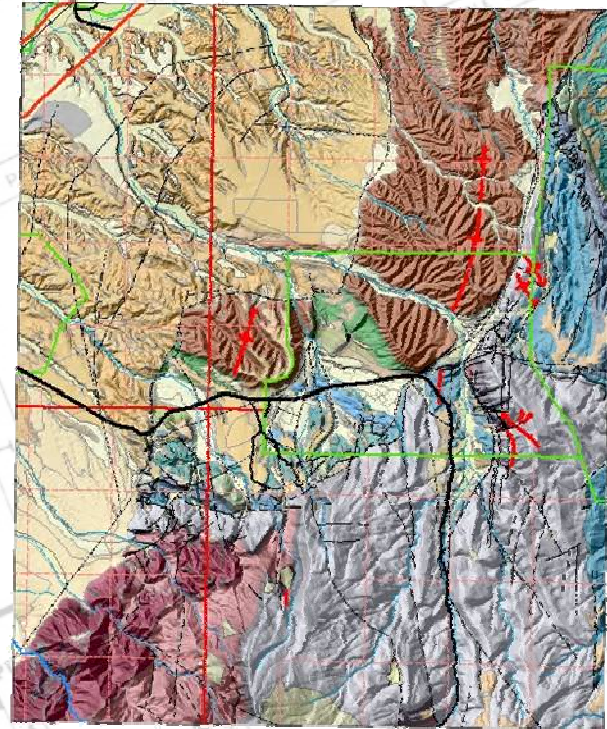
- ArcView 3.x
- ArcGIS 9.x
- ArcIMS, ArcGIS Server
- Many other extensions

## Other

- Desktop
  - Quantum GIS
  - UDig
  - GRASS
  - Manifold GIS
- Web
  - MapServer
  - MapGuide
  - Manifold
  - OS Geo (<http://www.osgeo.org/>)

# ArcGIS

- ESRI's Premiere GIS software
- A scalable suite of GIS tools
- Provides a wide range of GIS tools for needs which range from Desktop mapping to Geostatistical Analysis





# ArcGIS Desktop has four levels of usability:

**ArcReader**

**Free**

**No Spatial Tools**

**ArcView**

**ArcEditor**

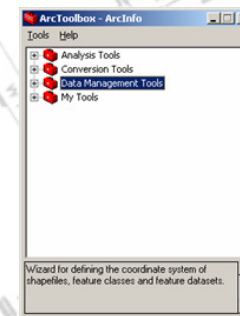
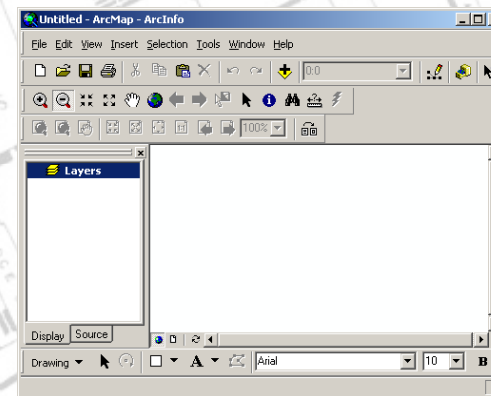
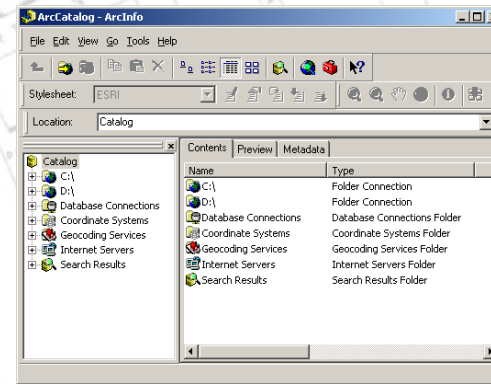
**ArcInfo**

**Very Expensive**

**Spatial Tool Rich**

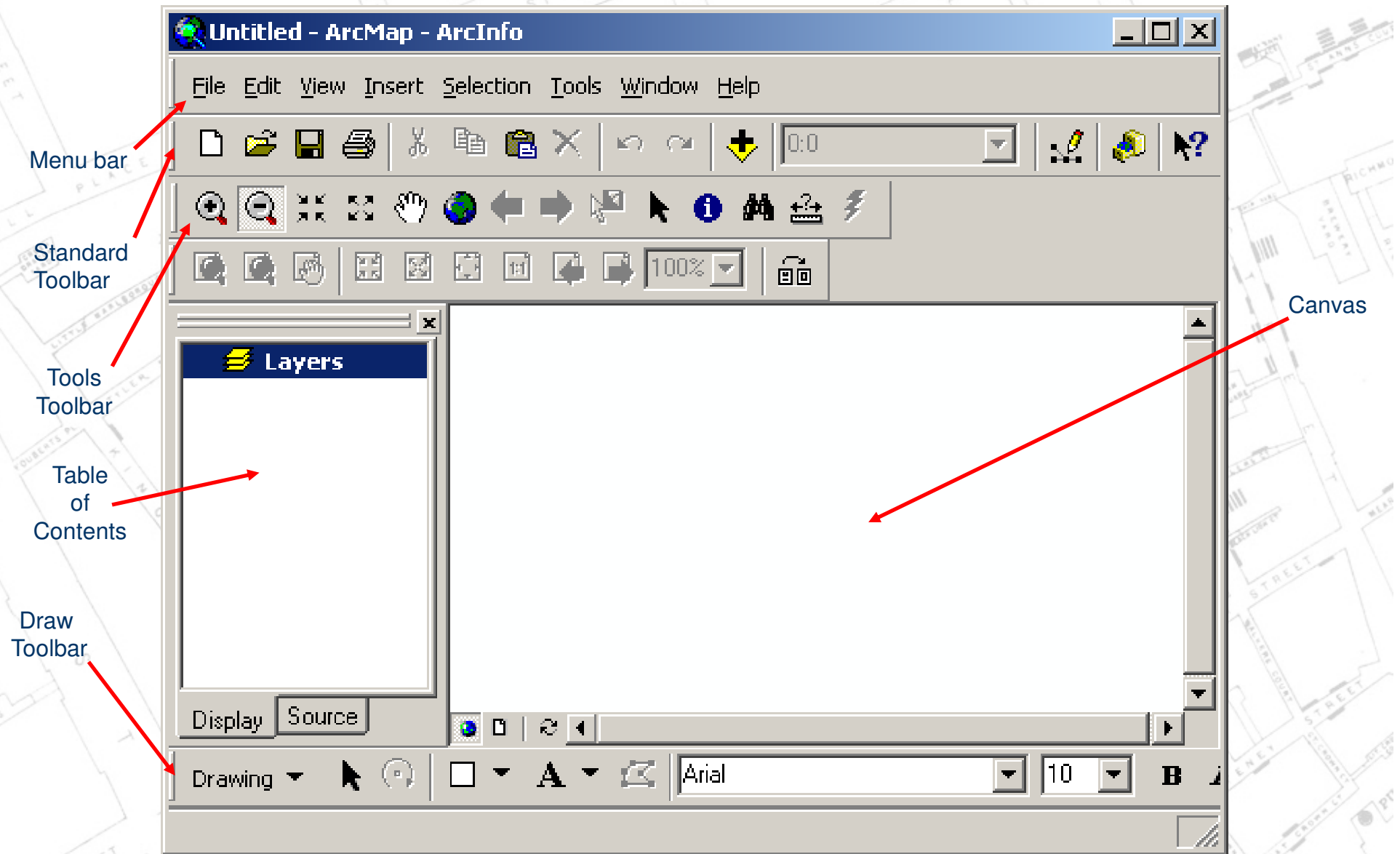
# ArcGIS Desktop has a three part interface:

- **ArcCatalog** – for navigating spatial data
- **ArcMap** – for creating presentation graphics
- **ArcToolbox** – powerful geoprocessing tools (embedded into ArcMap and ArcCatalog)



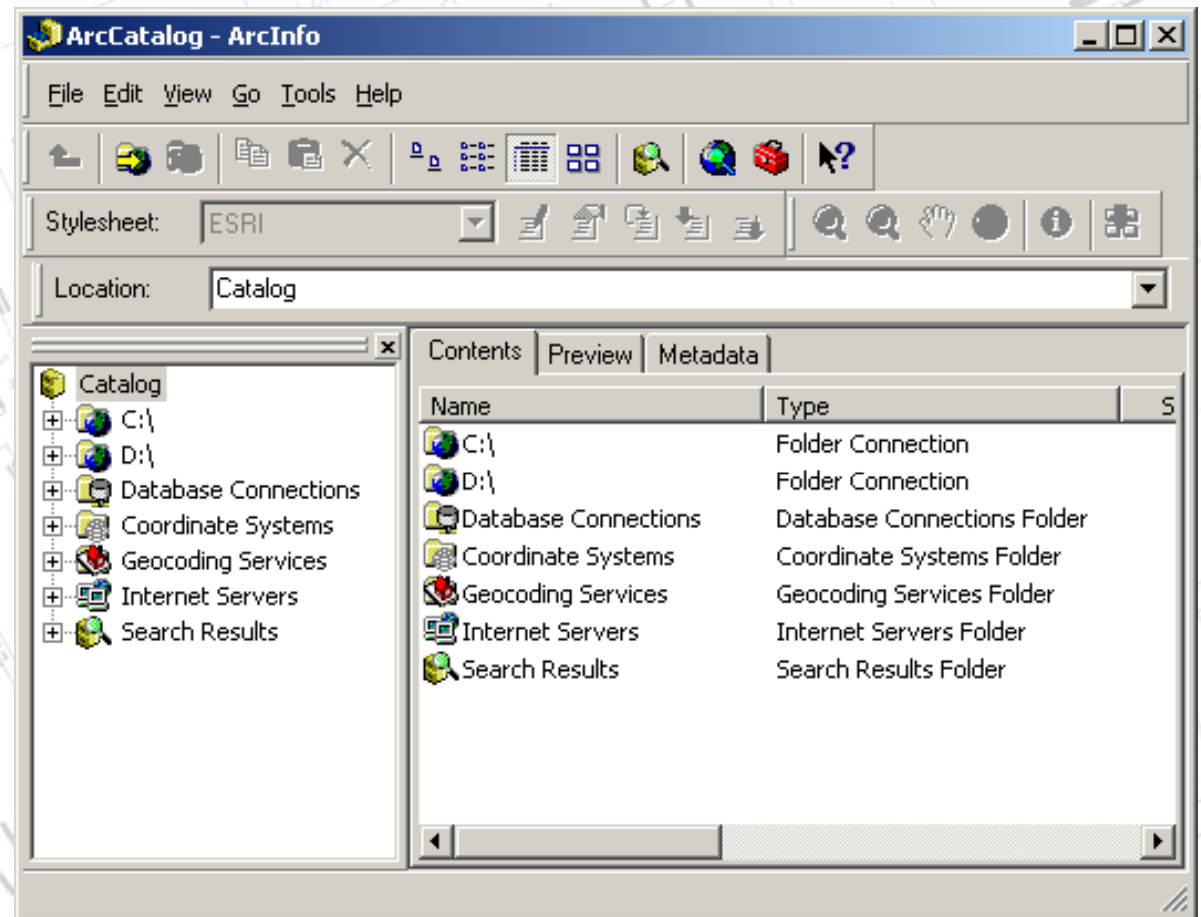


# ArcMap: Map View



# ArcCatalog

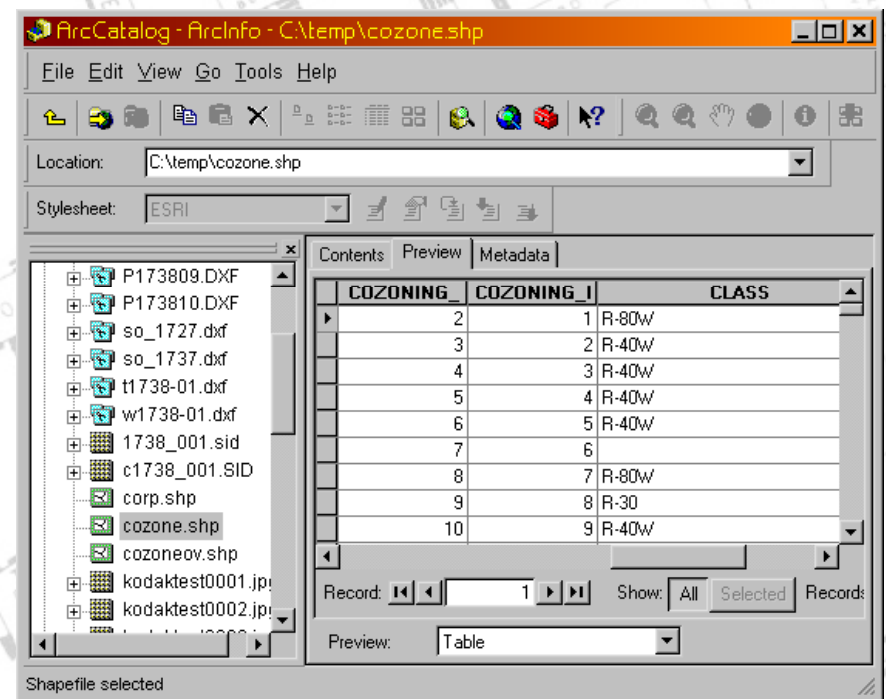
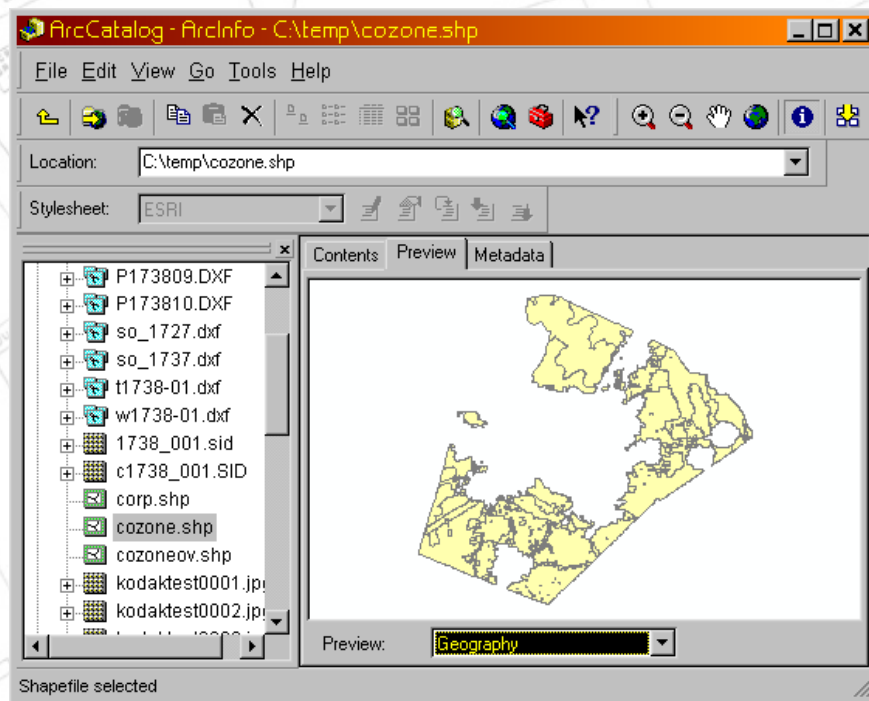
ArcCatalog is similar to the Windows “explorer”, or the “My Computer” icon on your windows desktop. It is a tool for navigating through your GIS datasets. The benefit of using ArcCatalog is that it has been specially designed for use with spatial data.





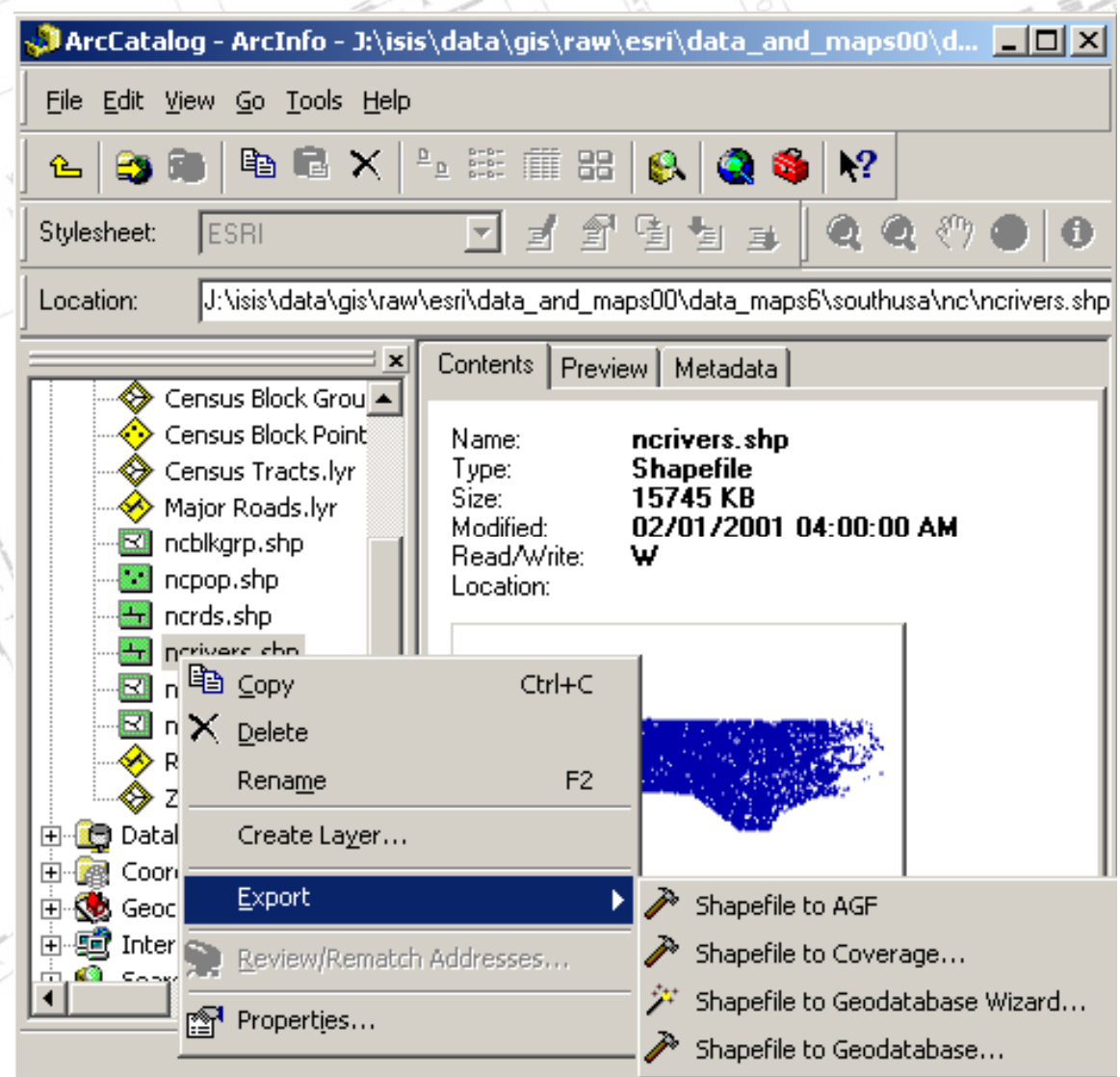
# ArcCatalog: Previews

Using ArcCatalog you can easily preview both your spatial datasets, and the attribute data associated with them



# ArcCatalog: Data Management

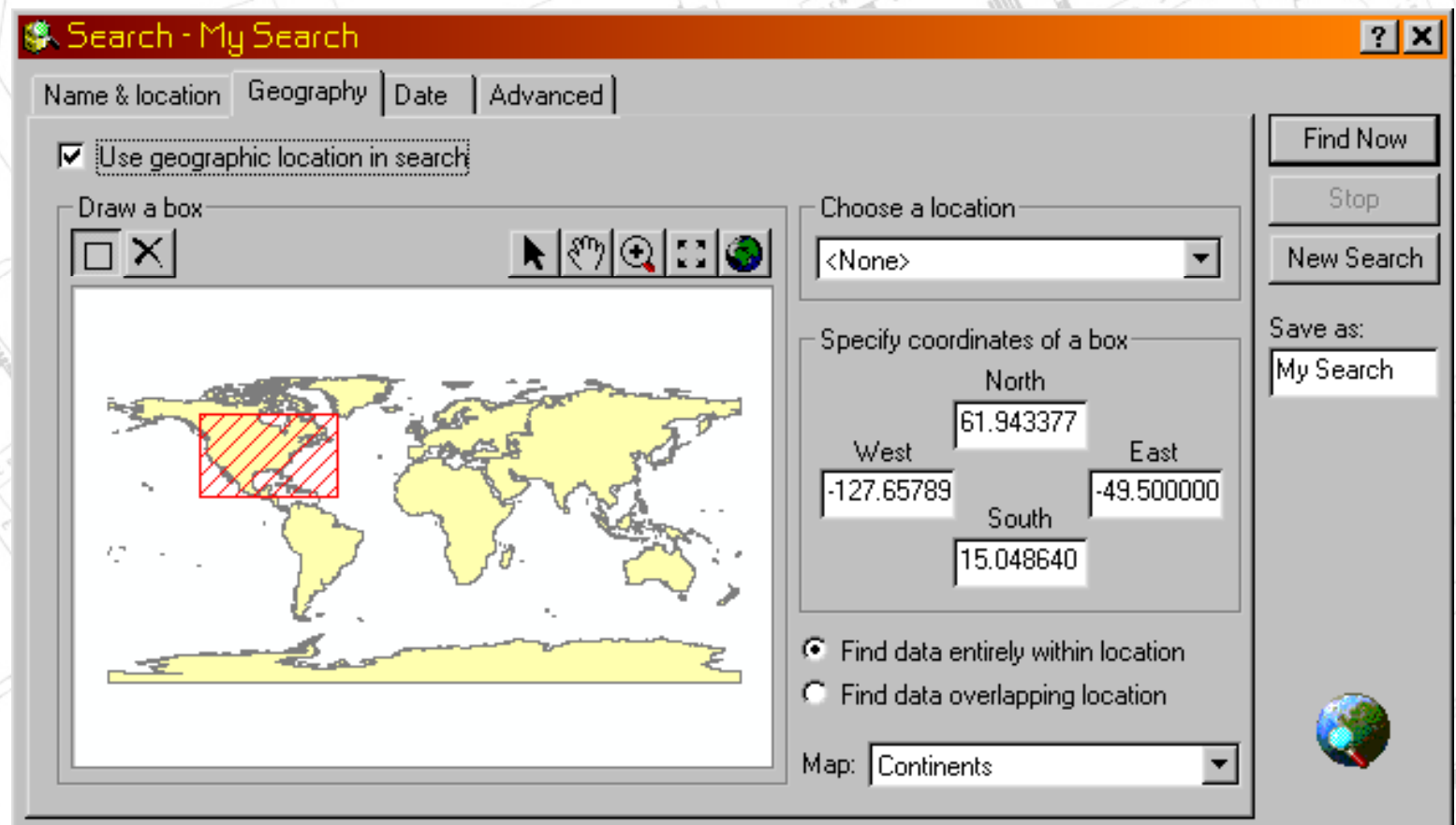
ArcCatalog provides an environment where it is safe to cut and paste spatial data into new directories, and even into geodatabases.





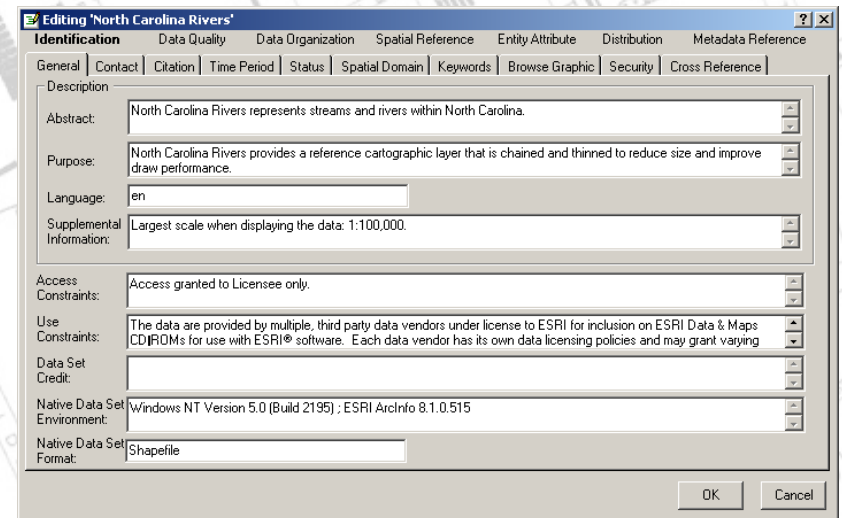
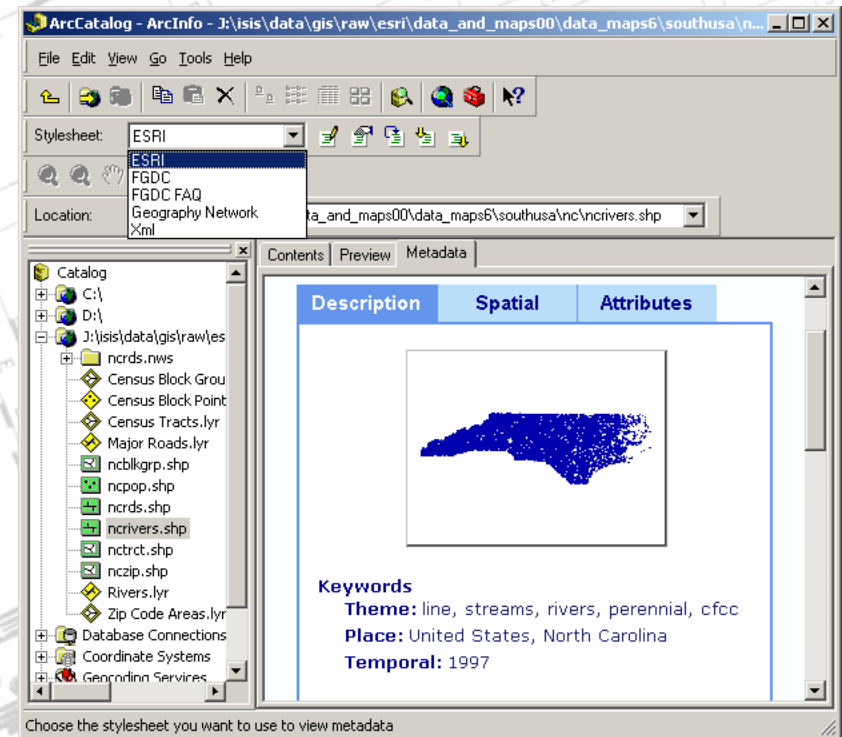
# ArcCatalog: Spatial Search

Within ArcCatalog you can easily search for data based on location and attributes stored in its metadata



# ArcCatalog: Metadata

ArcCatalog includes tools for viewing and editing Metadata. It even has an option to automatically update some items in the metadata whenever a dataset is edited





# ArcToolbox

For heavy duty processing, ArcToolbox contains analysis, conversion, and data management tools. Additionally, there is an option to construct your own custom tools. You may set up most tools using wizards which help take the guess work out of some of the otherwise complicated options

