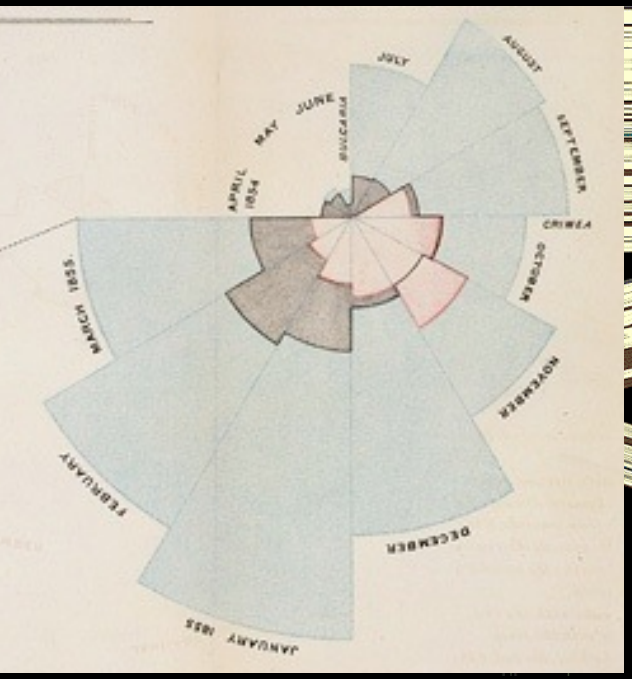
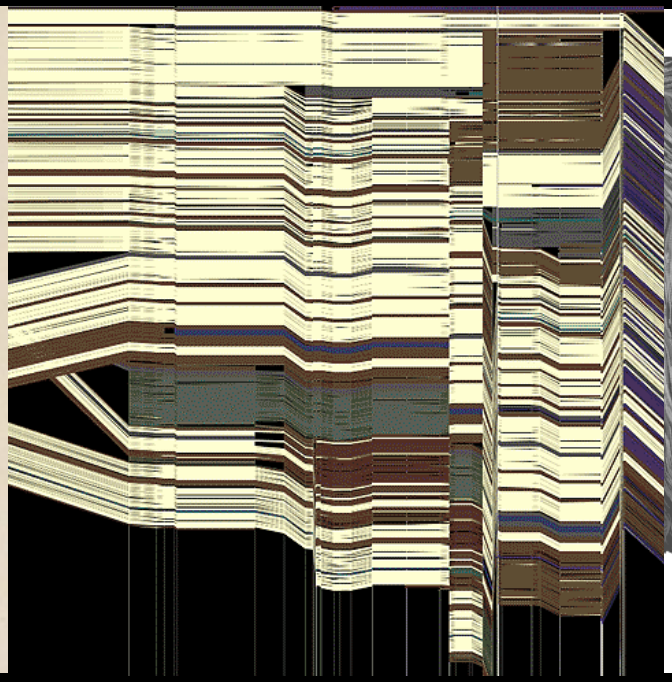
CSE 442 - Data Visualization

Mapping & Cartography





Leilani Battle University of Washington
(with significant material from Michal Migurski)

Why is Geographic Information hard to Visualize?

Earth is Complicated

- It's 3D!
- Many land features
  - e.g., deserts, forests, rivers, oceans, clouds, cities, etc.
- Constantly changing
  - Orbit/rotation
  - Weather/climate
  - Human development
- Accuracy is always a challenge

Learning goals

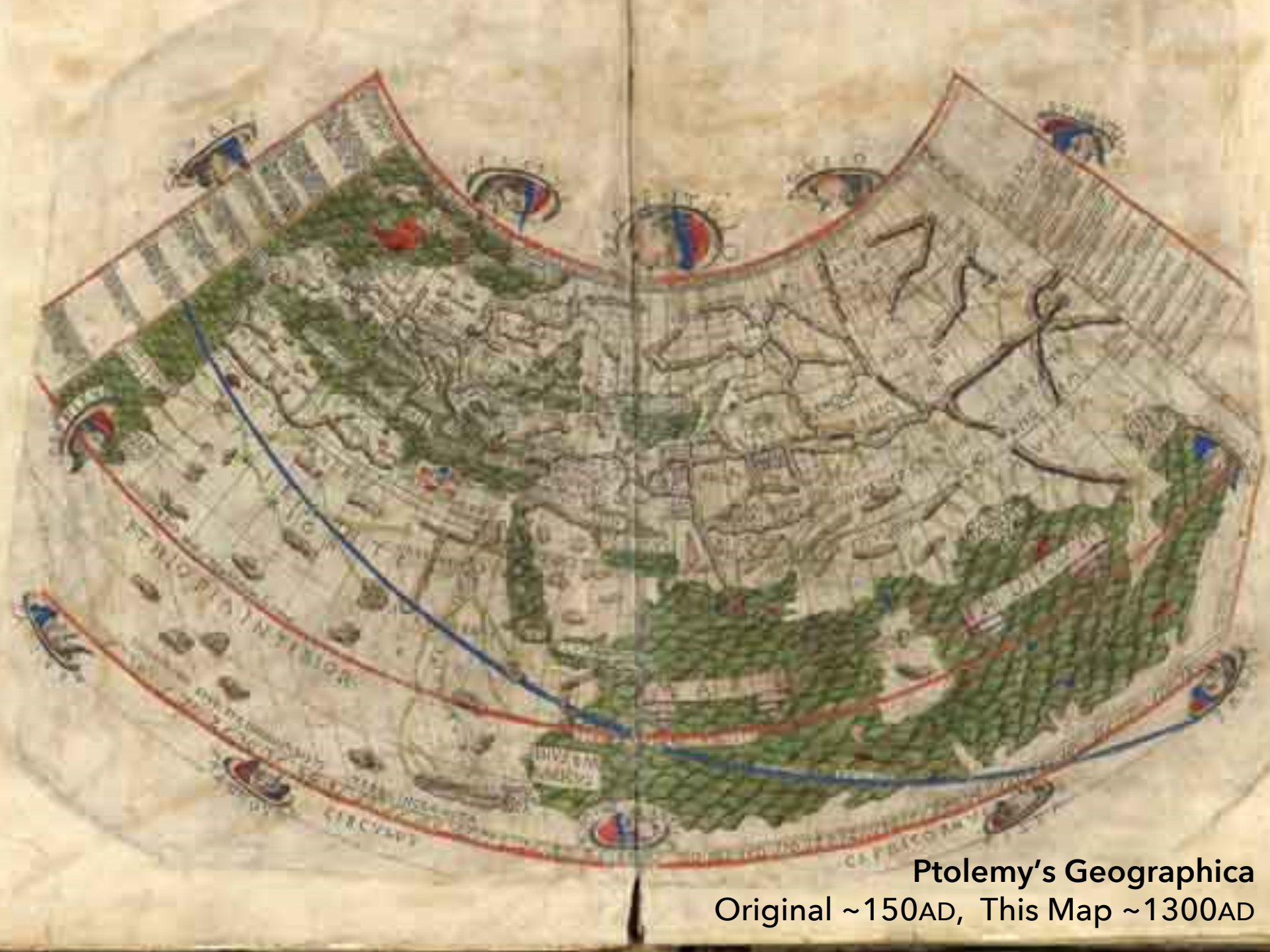
What layout and encoding strategies should we consider when rendering map visualizations?

What are critical factors and tradeoffs to consider when applying these strategies?

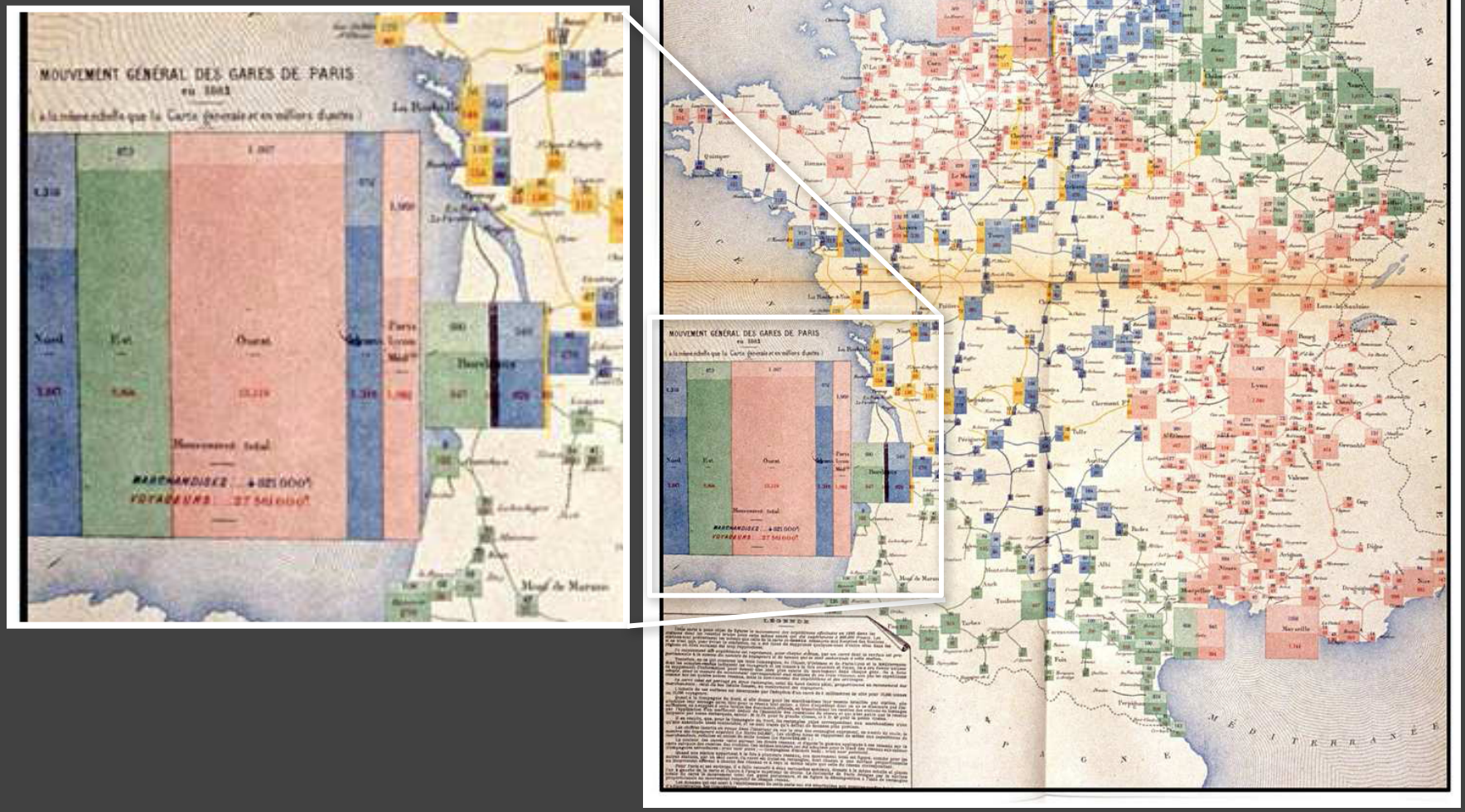
What tools and resources are available for map-based visualization?

Topics

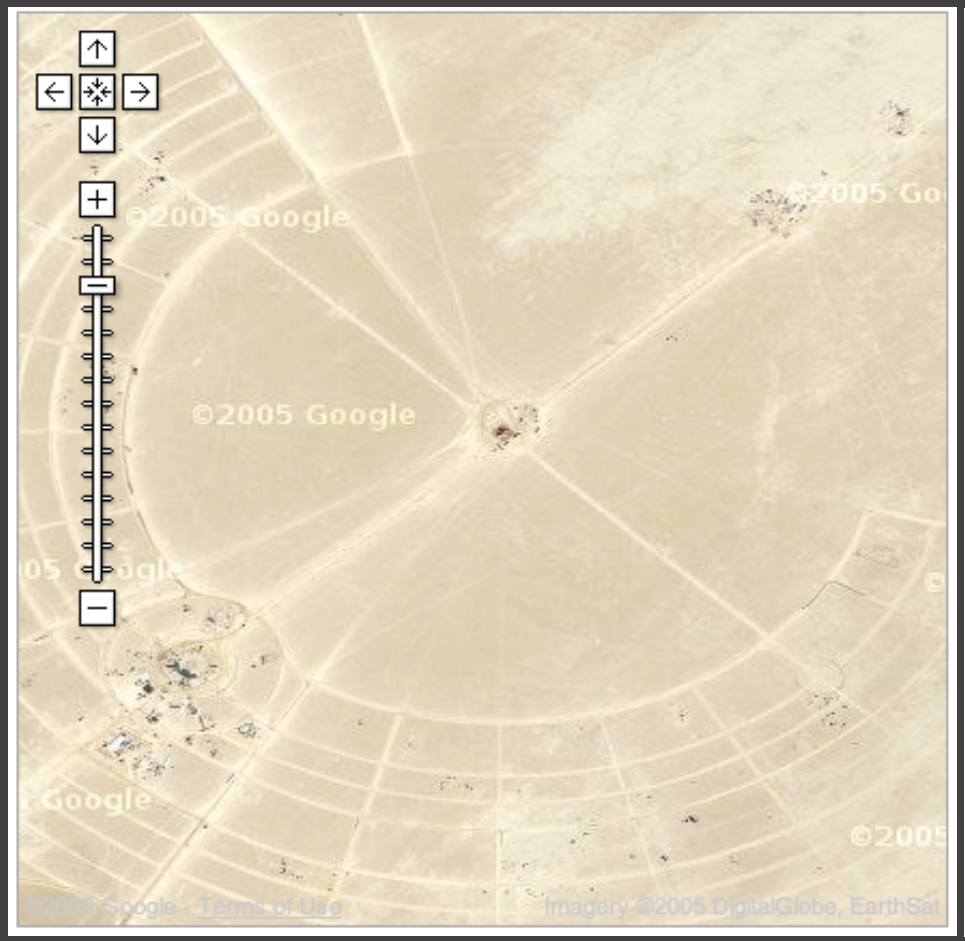
- Cartography
  - Projections
  - Scale
- Mapping
  - Symbol Maps
  - Choropleth Maps
  - Heatmaps / Contour Maps
  - Cartograms
  - Flow Maps
- Generalization
- Tools



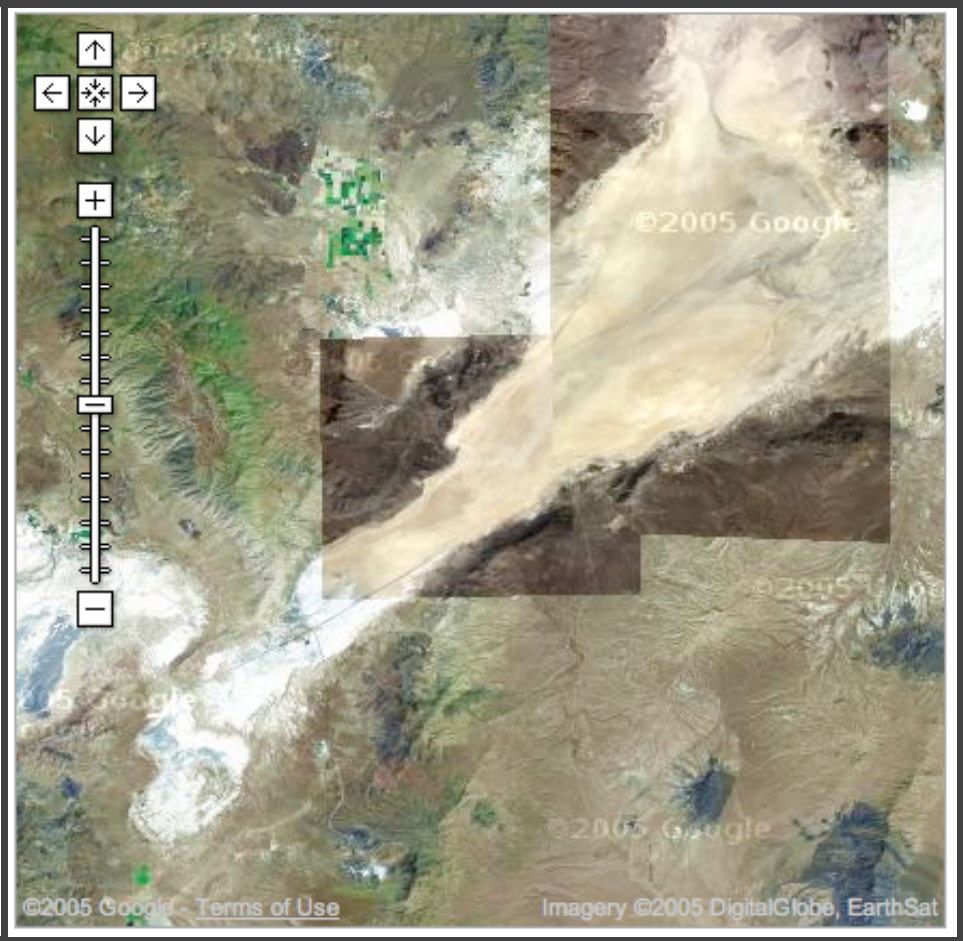
Ptolemy's Geographica
Original ~150AD, This Map ~1300AD



Rail Passengers and Freight from Paris 1884



Black Rock City, Nevada
(Burning Man)



Google Maps 2005

Casualties of War

FACES | ANALYSIS | THEIR STORIES

E-MAIL | FEEDBACK

Use the slider below to investigate the demographics and military status of U.S. service members who died during the war in Iraq.

MARCH 16, 2003 JULY 5, 2008 (277 WEEKS)

Show all | Initial invasion | First invasion of Falluja | Second invasion of Falluja | Since troop buildup began

4,097 deaths

Age

18-24	54%
25-34	33%
35-44	10%
45+	2%

Branch of Military

Air Force	1%
Army	72%
Marine Corps	24%
Navy	2%

Race

Black	9%
Hispanic	10%
White	71%
Other	5%
Unknown	5%

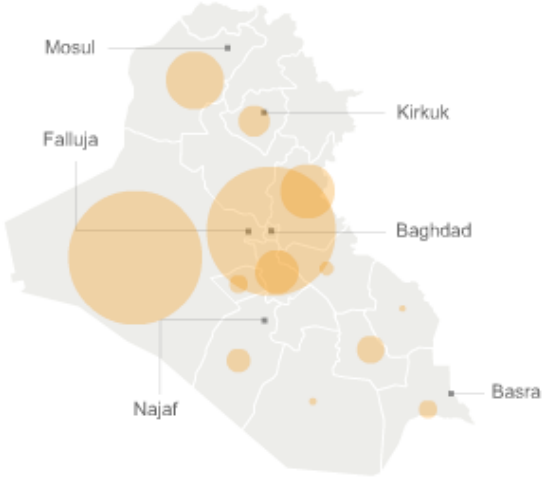
Type of Duty

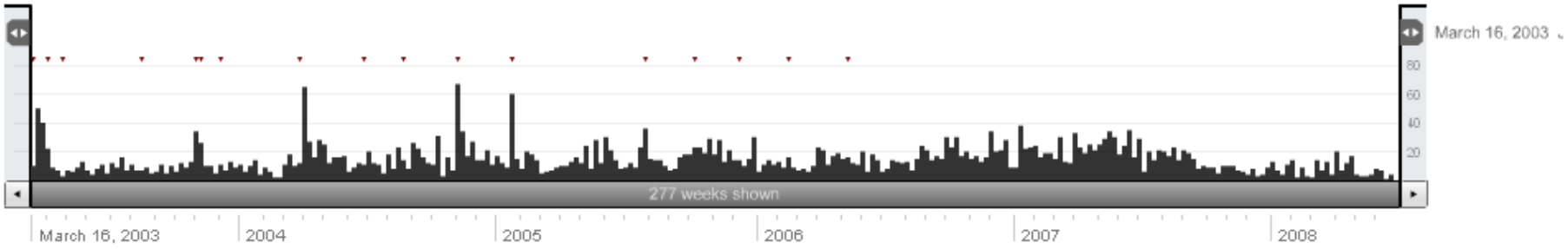
National Guard	11%
Regular	77%
Reserve	7%
Unknown	5%

Location of death

Circles sized according to percentage of deaths in each Iraqi province.

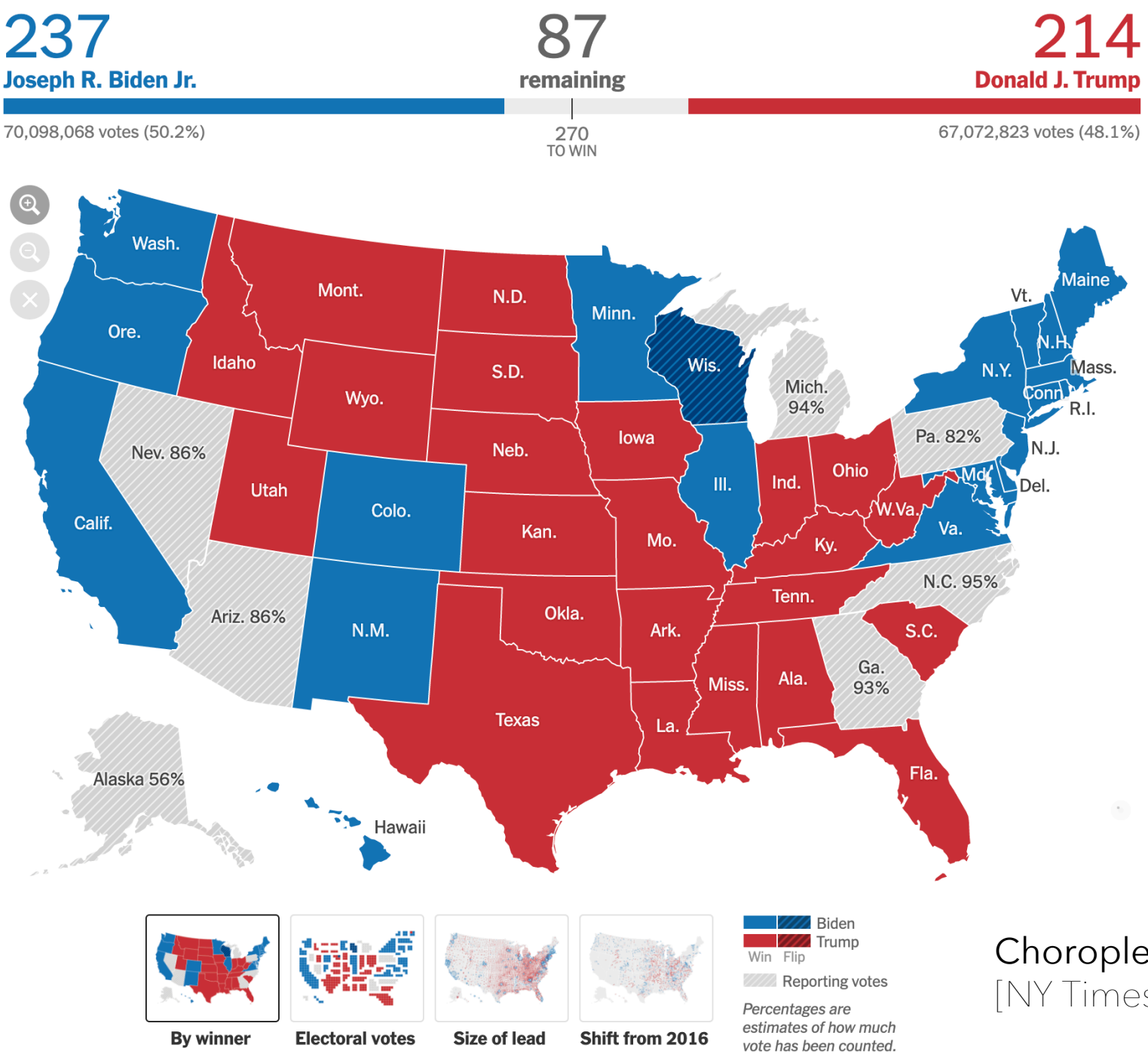
Show home



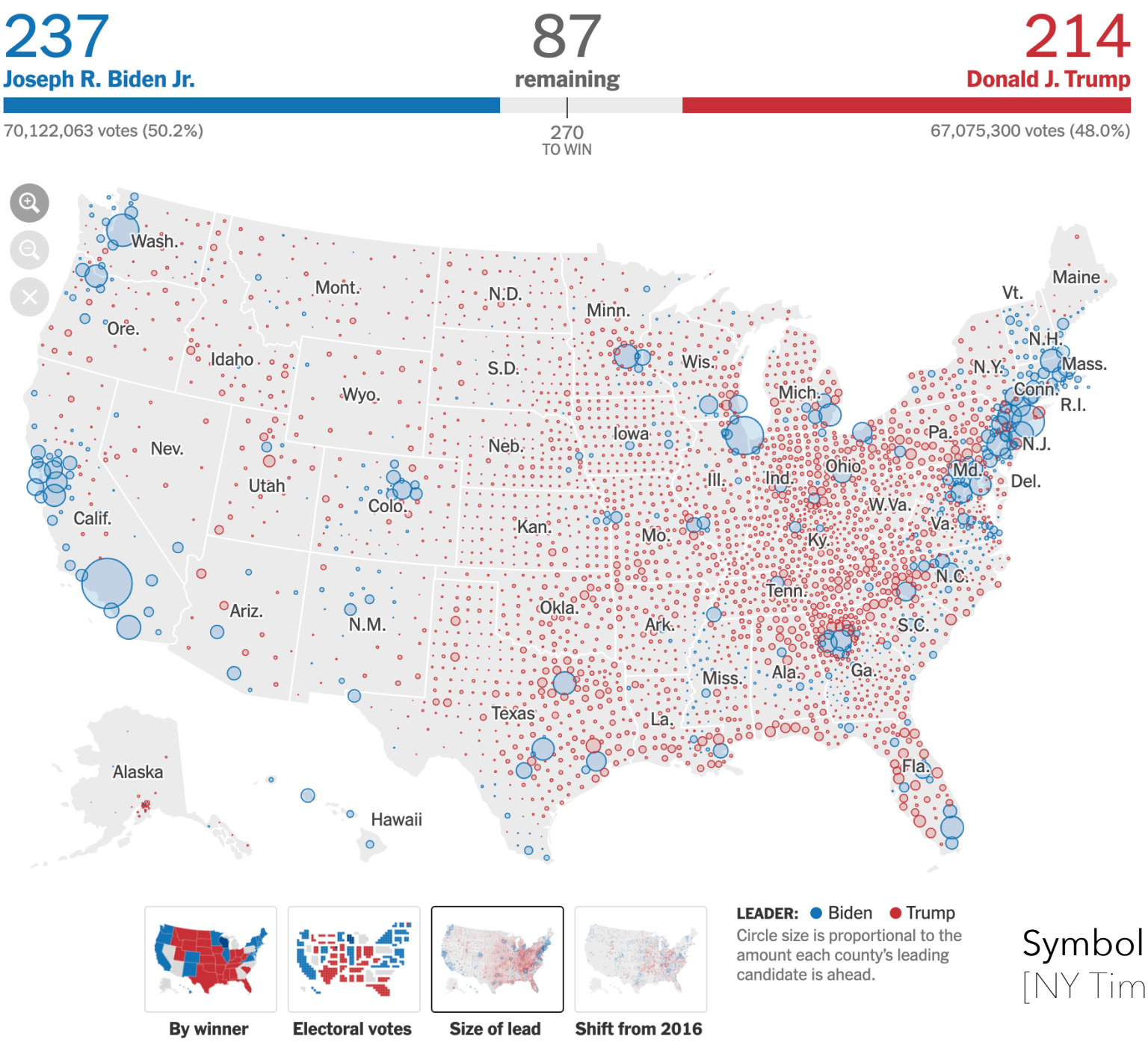


Casualties of War, New York Times 2006

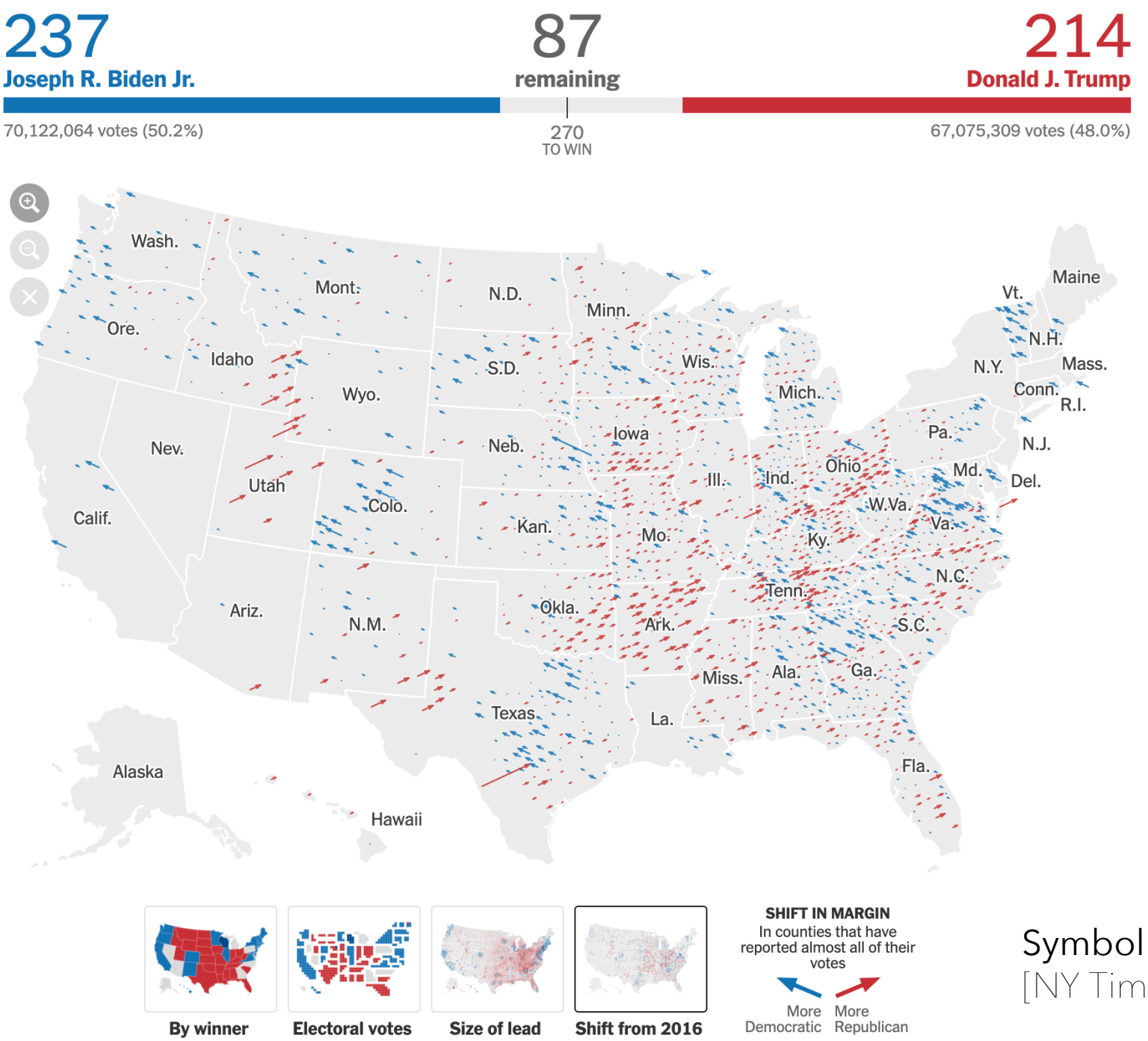
NY Times
2014



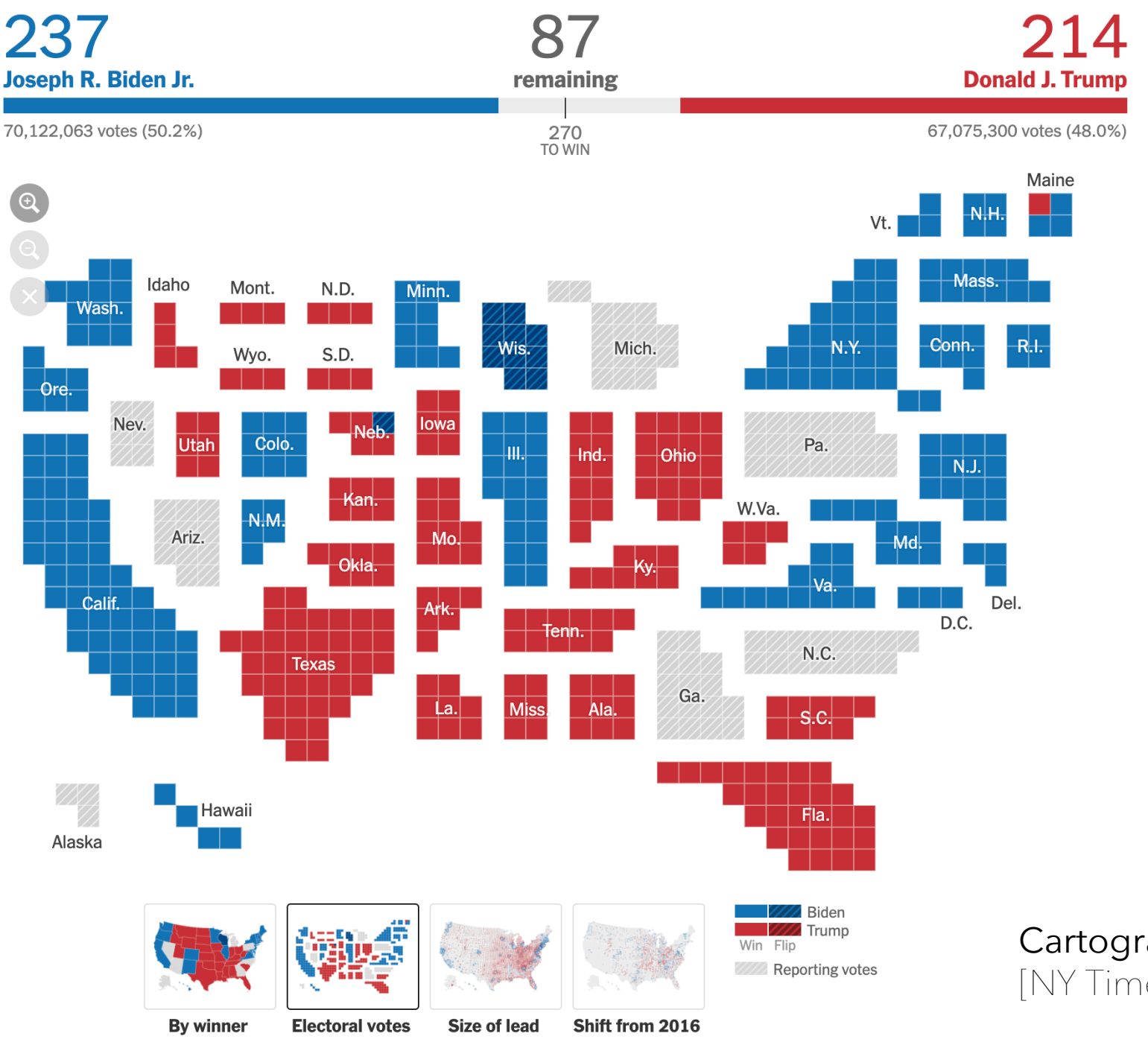
Choropleth Map
[NY Times]



Symbol Map
[NY Times]



Symbol Map
[NY Times]



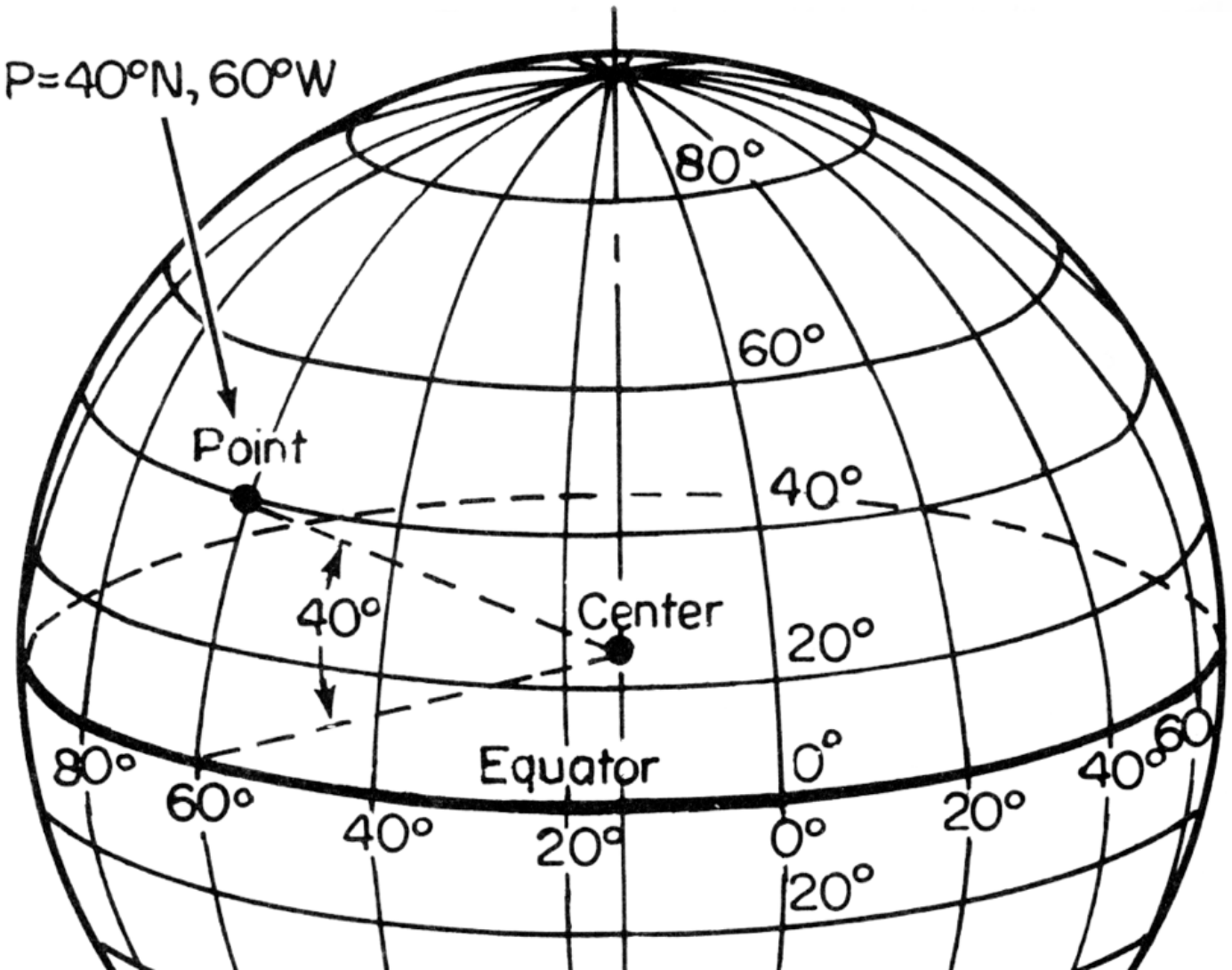
Cartogram
[NY Times]

Cartography

The Making of Maps

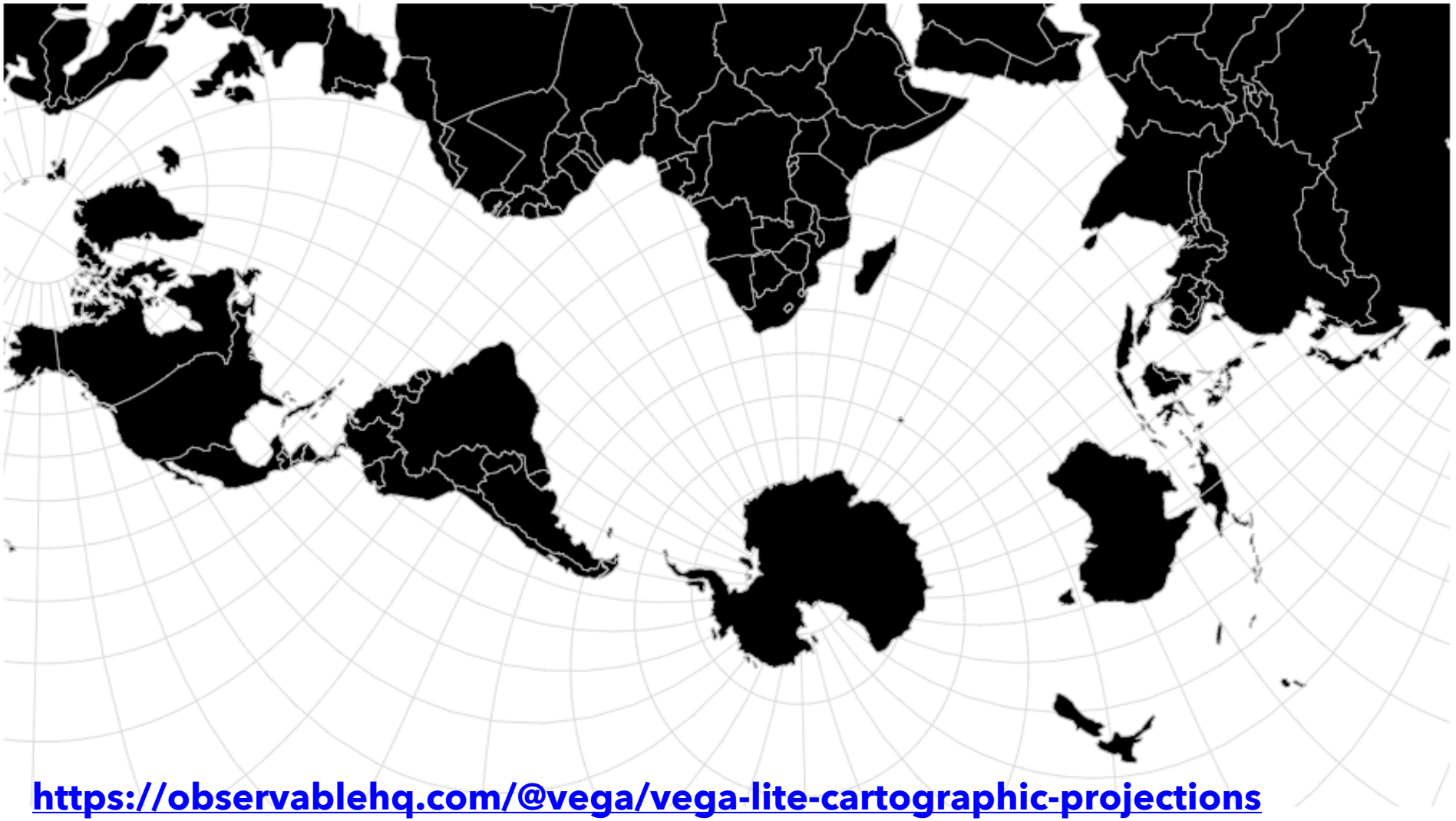
Projections

Latitude, Longitude




A sphere tears
when you flatten it

Exploring Projections…

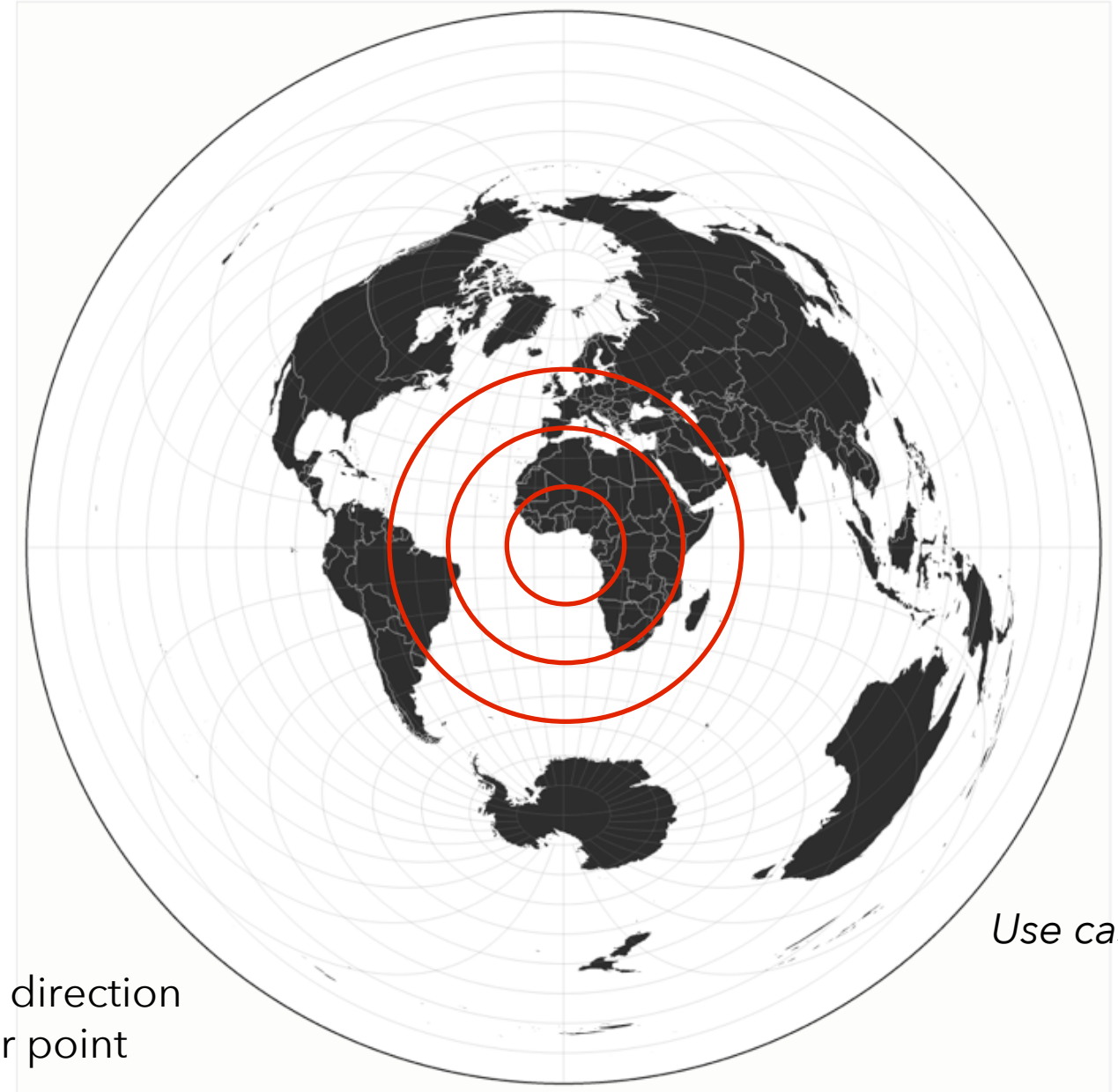


https://observablehq.com/@vega/vega-lite-cartographic-projections

We can categorize projections by what they preserve…


Distance
Preserve distance / direction from center

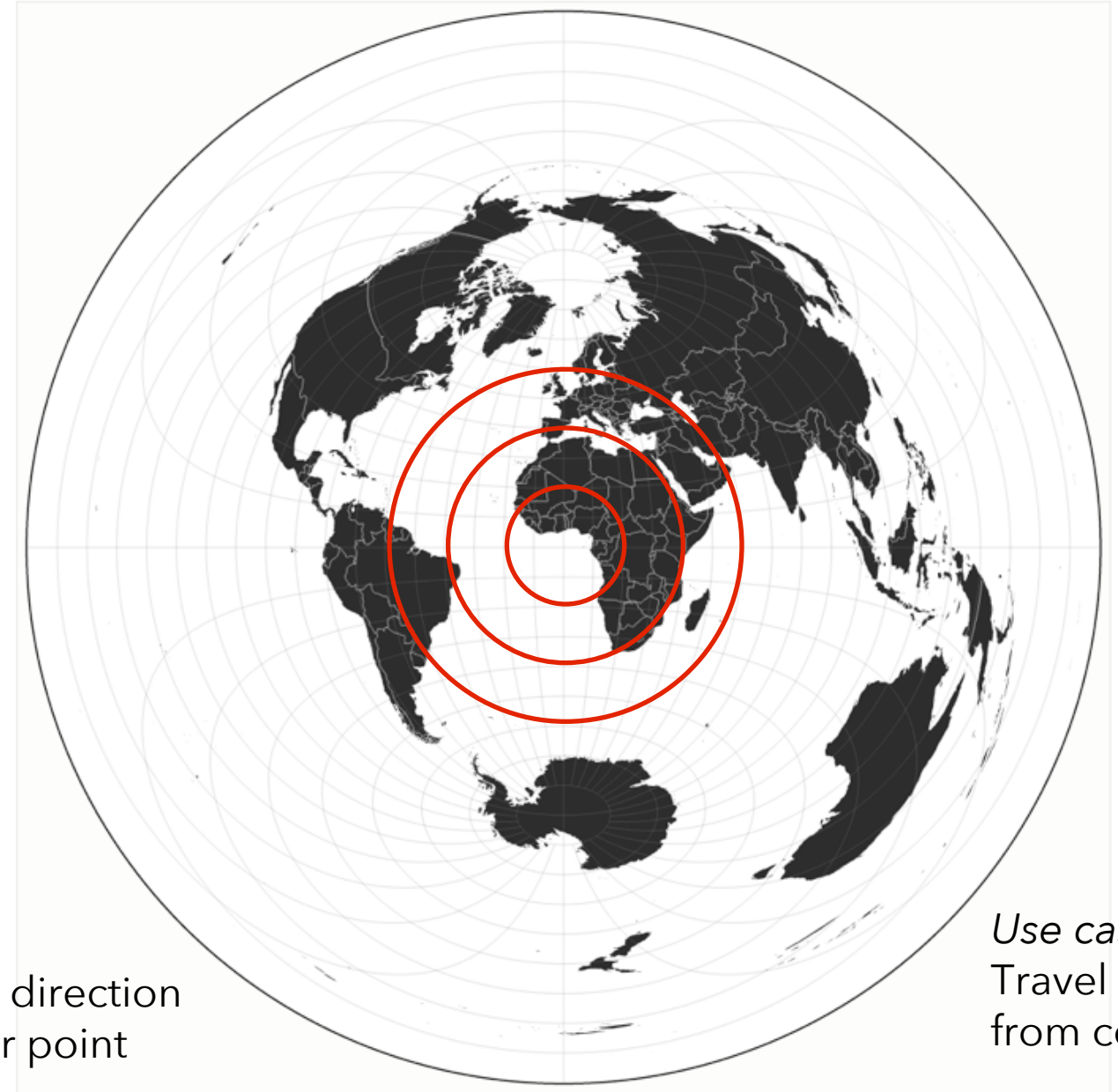
Azimuthal Equidistant



Preserves:
Distance & direction
from center point

Use cases?

Azimuthal Equidistant

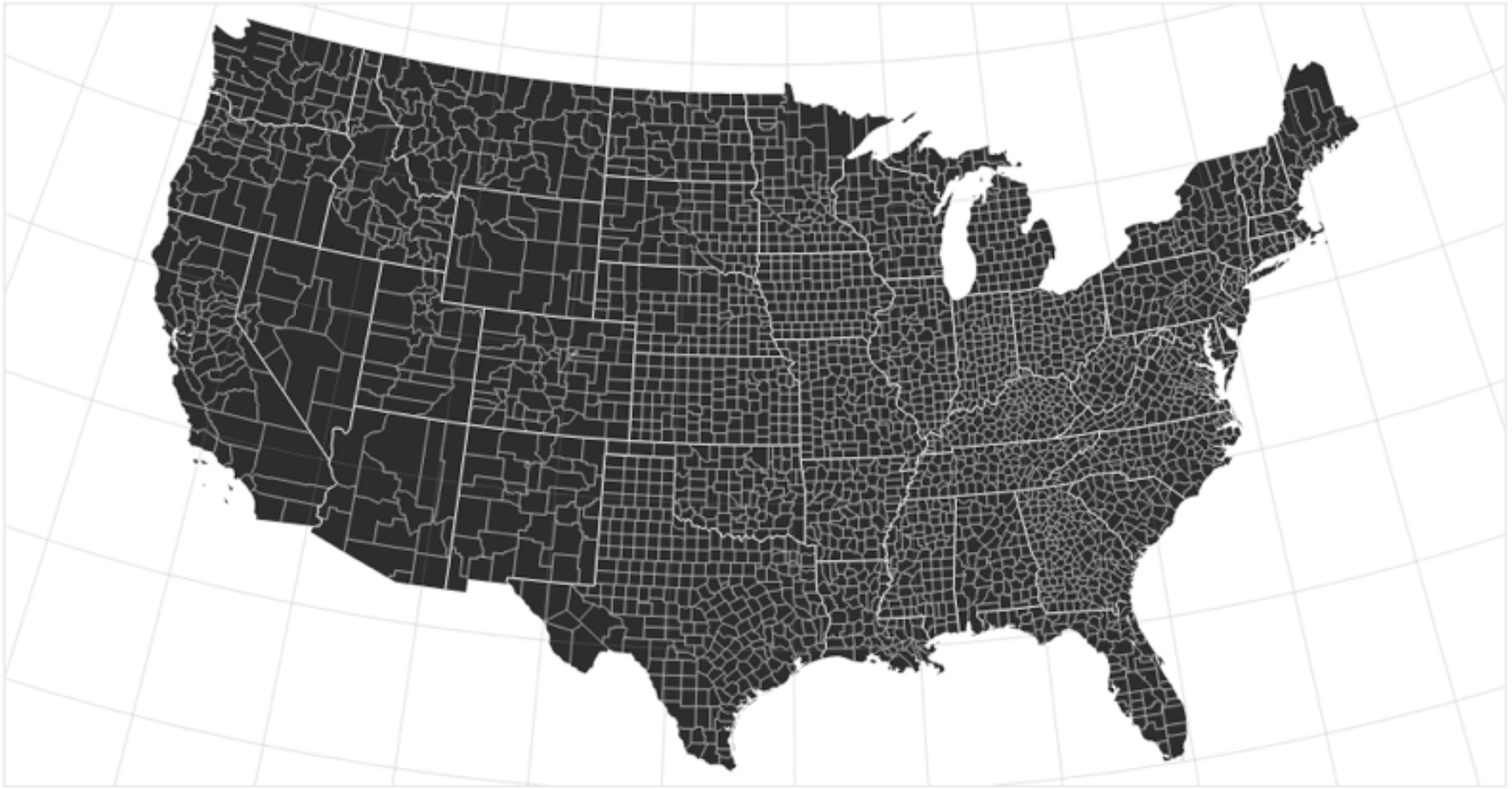


Preserves:
Distance & direction
from center point

Use cases:
Travel / propagation
from center point


Equal-Area
Preserve proportional areas

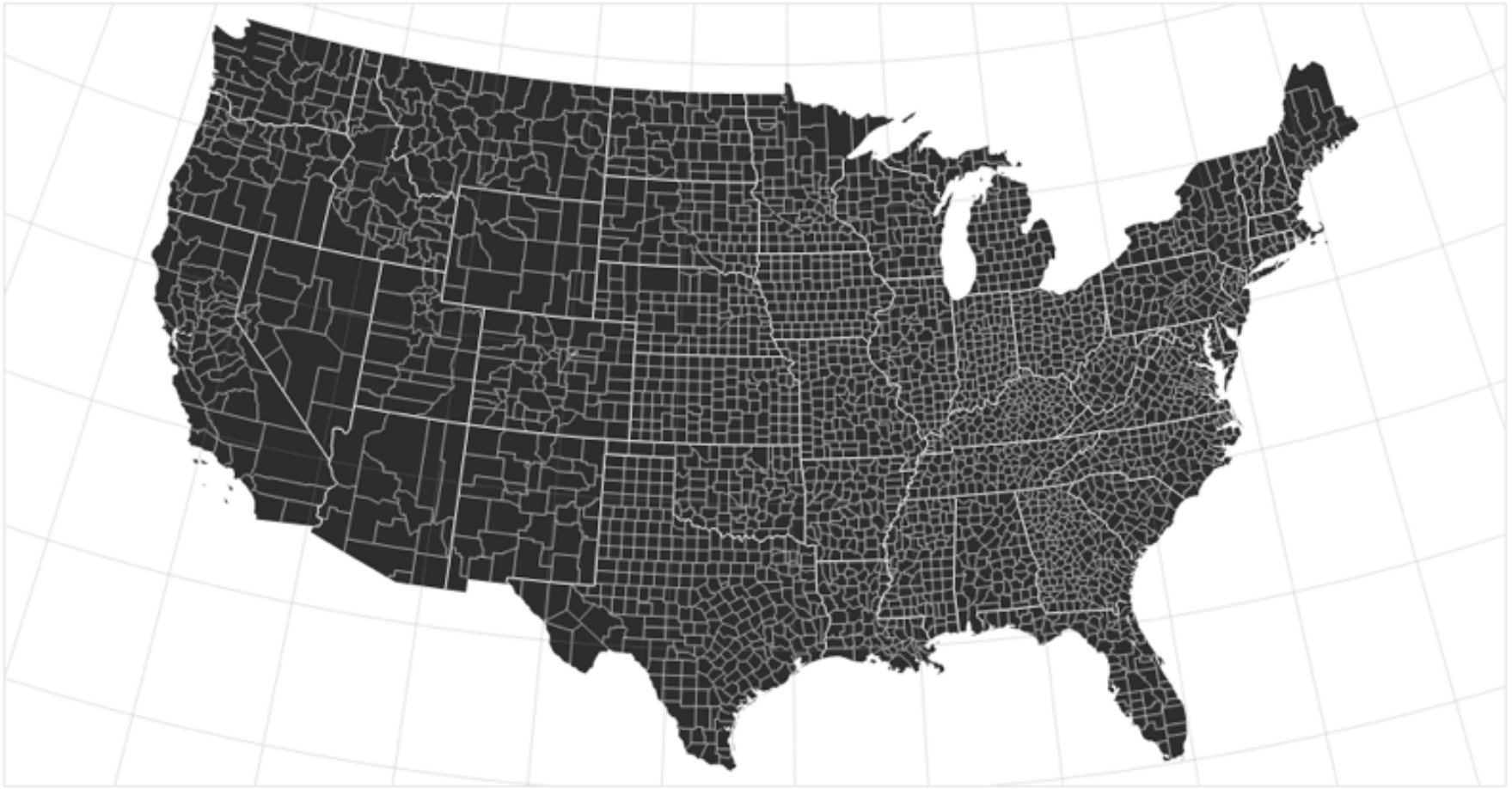
Albers Equal-Area Conic



Preserves: Proportional area of geographic regions

Use cases?

Albers Equal-Area Conic



Preserves: Proportional area of geographic regions

Use cases: Land surveys, choropleth (shaded) maps


Conformal
Preserve local angles (“shape”)

Spherical Mercator

Preserves:
Compass bearing
as a straight line

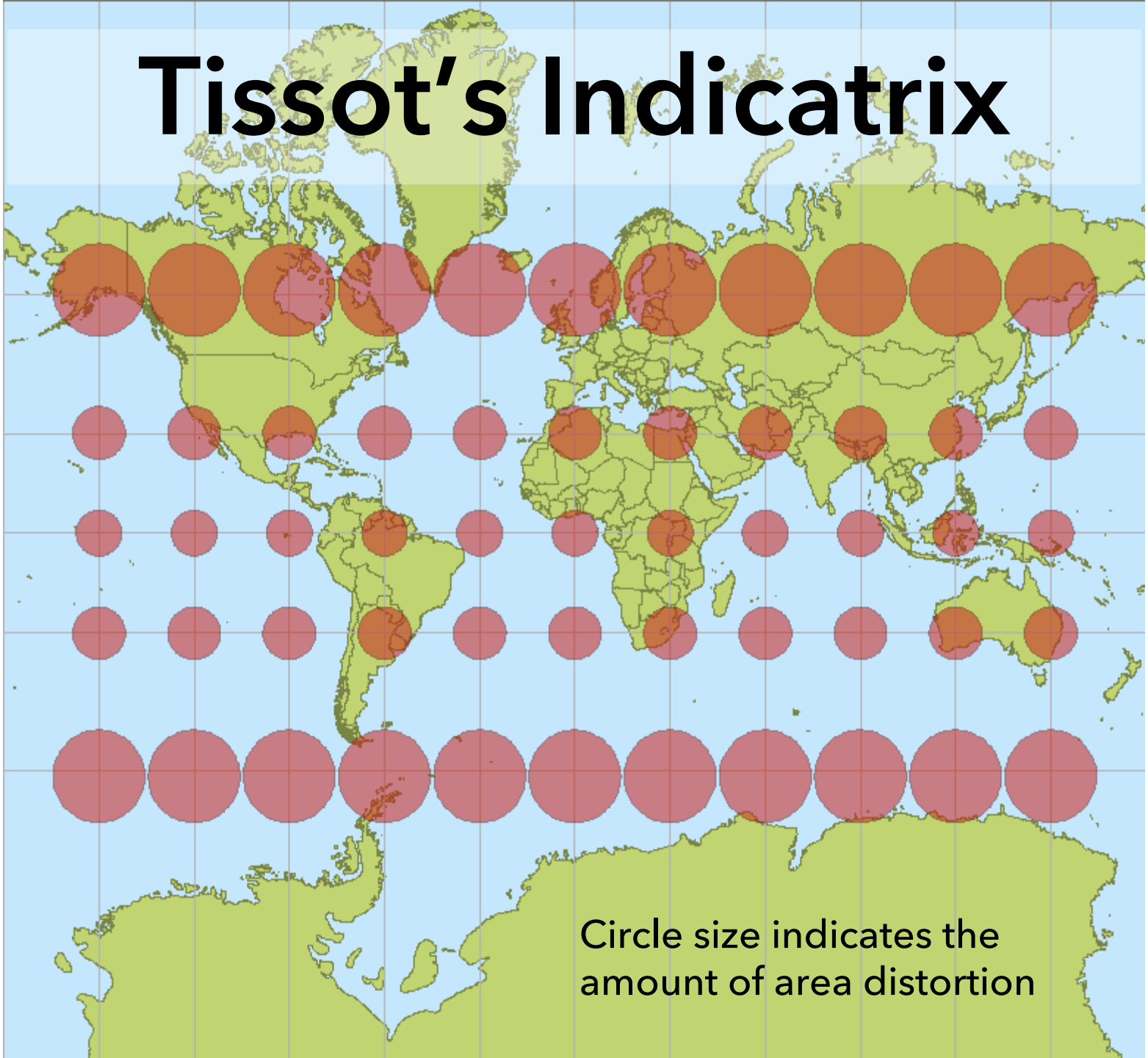
Use cases?

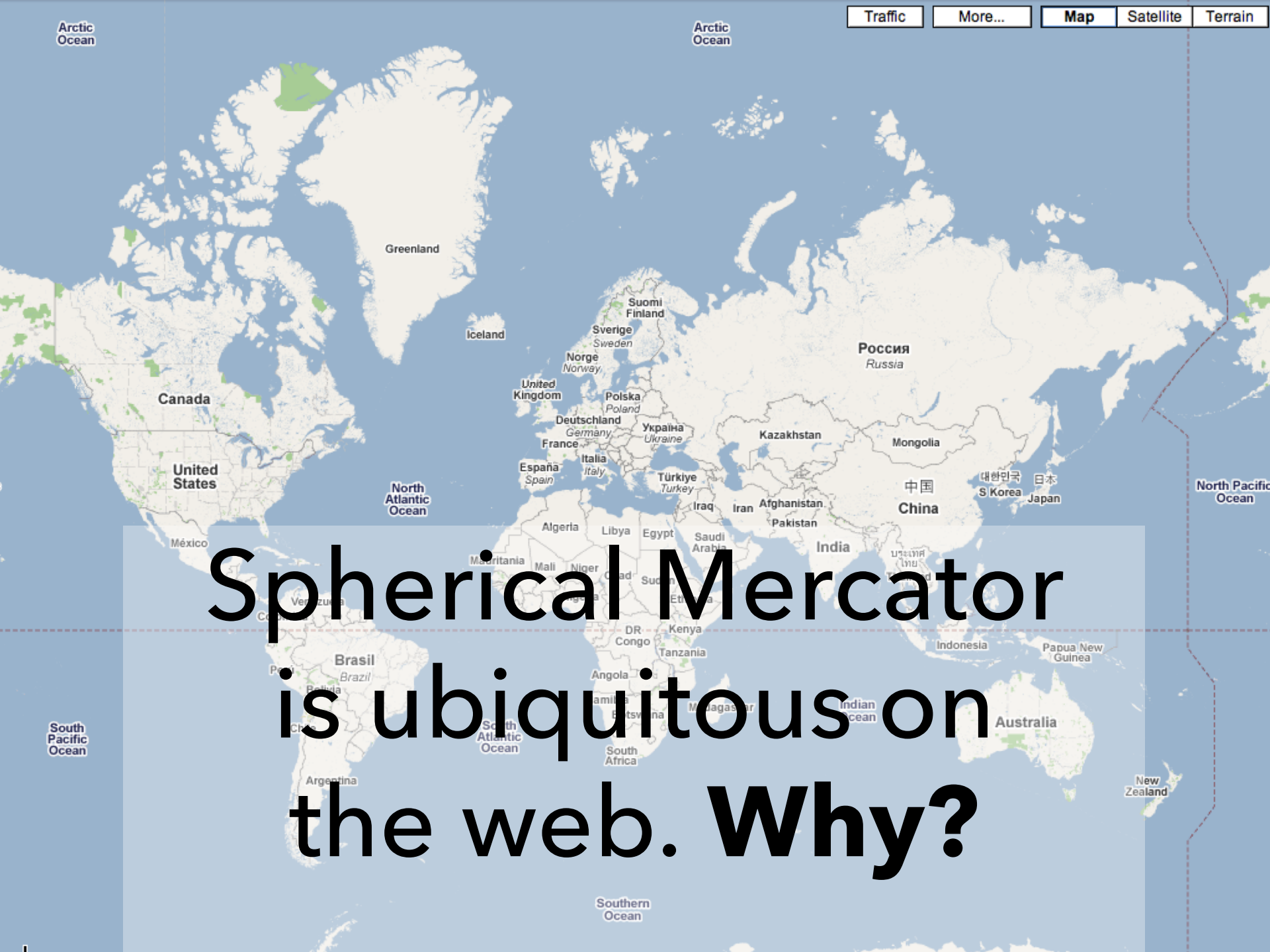
Spherical Mercator

Preserves:
Compass bearing
as a straight line

Use cases:
Navigation

Tissot's Indicatrix





Spherical Mercator is ubiquitous on the web. **Why?**

The Earth as a Square

Web Mercator

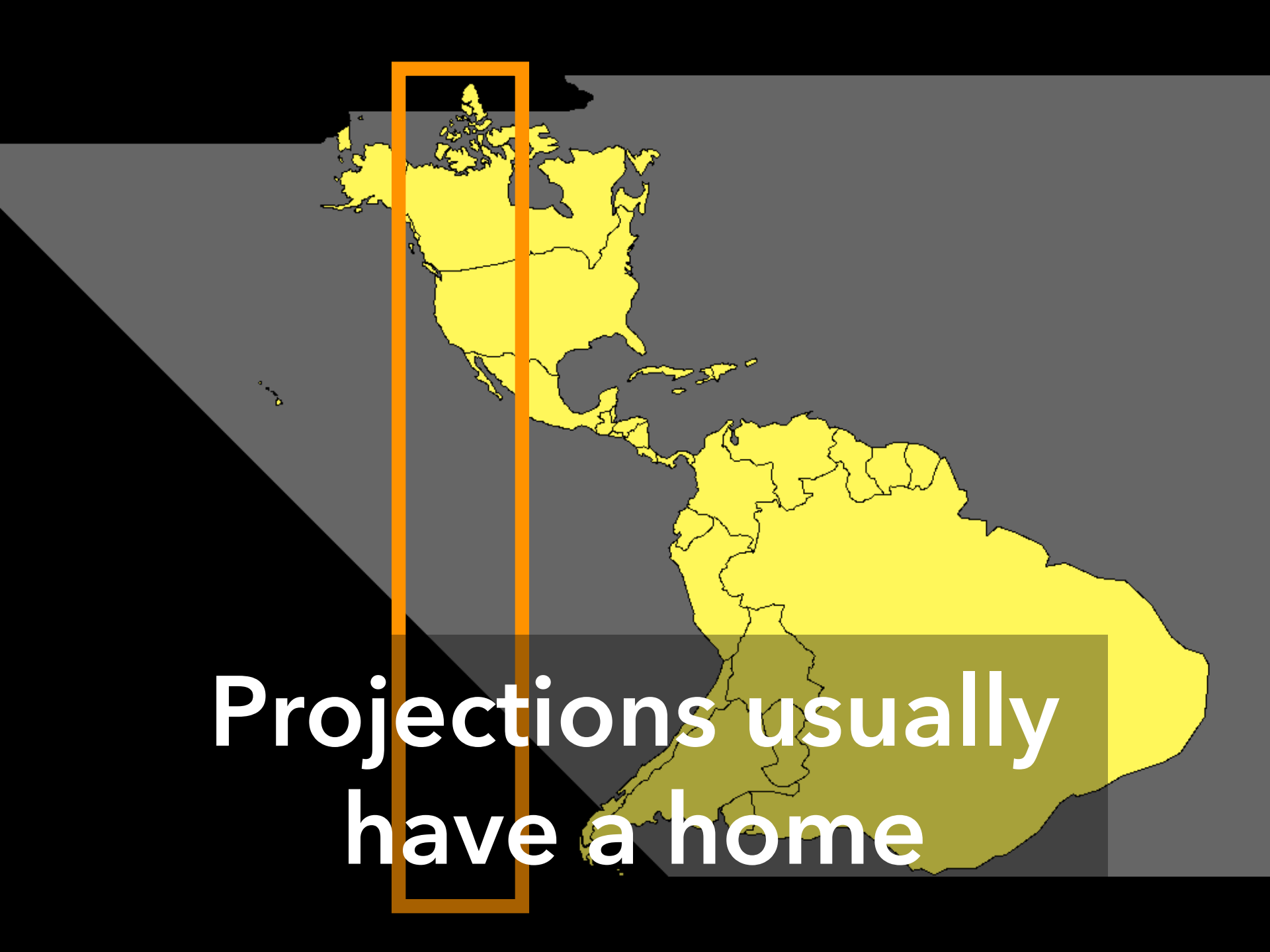
$$x = \frac{128}{\pi} 2^{\text{zoom level}} (\lambda + \pi) \text{ pixels}$$

$$y = \frac{128}{\pi} 2^{\text{zoom level}} (\pi - \ln \left[\tan \left(\frac{\pi}{4} + \frac{\varphi}{2} \right) \right]) \text{ pixels}$$

World coordinates adjusted to map to 256 x 256 pixels.
Latitude cut-offs at 85.051129 degrees: the exact point at which the projection frames the world in a square.

Peirce Quincuncial

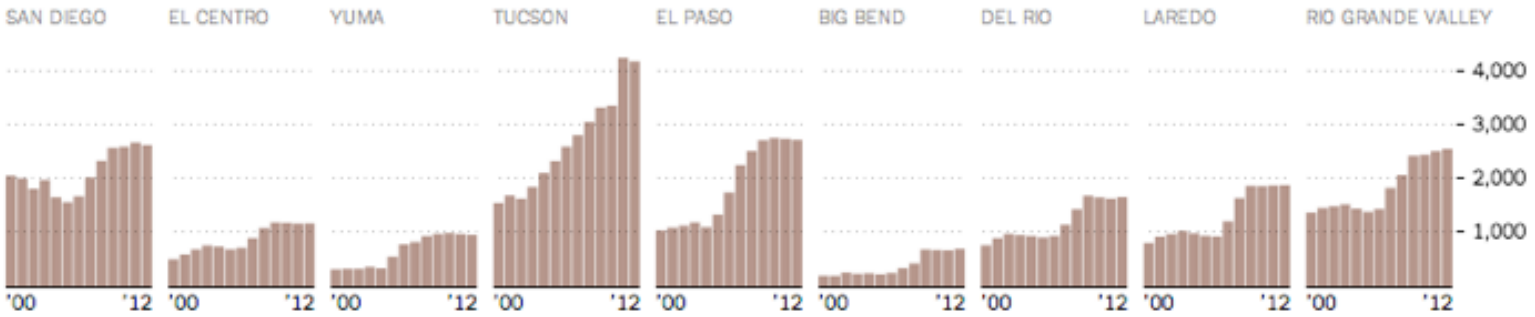
But there are other ways to fit the Earth into a square…


Projections usually
have a home

Increased Border Enforcement, With Varying Results

There are now more agents along the 1,954 mile-long border than ever before...

Border agents per sector.



Satellite Projection, NY Times

Not appropriate for the whole Earth, but fits the chosen focus region!

http://xkcd.com/977

WHAT YOUR FAVORITE MAP PROJECTION SAYS ABOUT YOU

MERCATOR

YOU'RE NOT REALLY INTO MAPS.

VAN DER GRINTEN

YOU'RE NOT A COMPLICATED PERSON. YOU LOVE THE MERCATOR PROJECTION; YOU JUST WISH IT WEREN'T SQUARE. THE EARTH'S NOT A SQUARE, IT'S A CIRCLE. YOU LIKE CIRCLES. TODAY IS GONNA BE A GOOD DAY!

PEIRCE QUINCUNCIAL

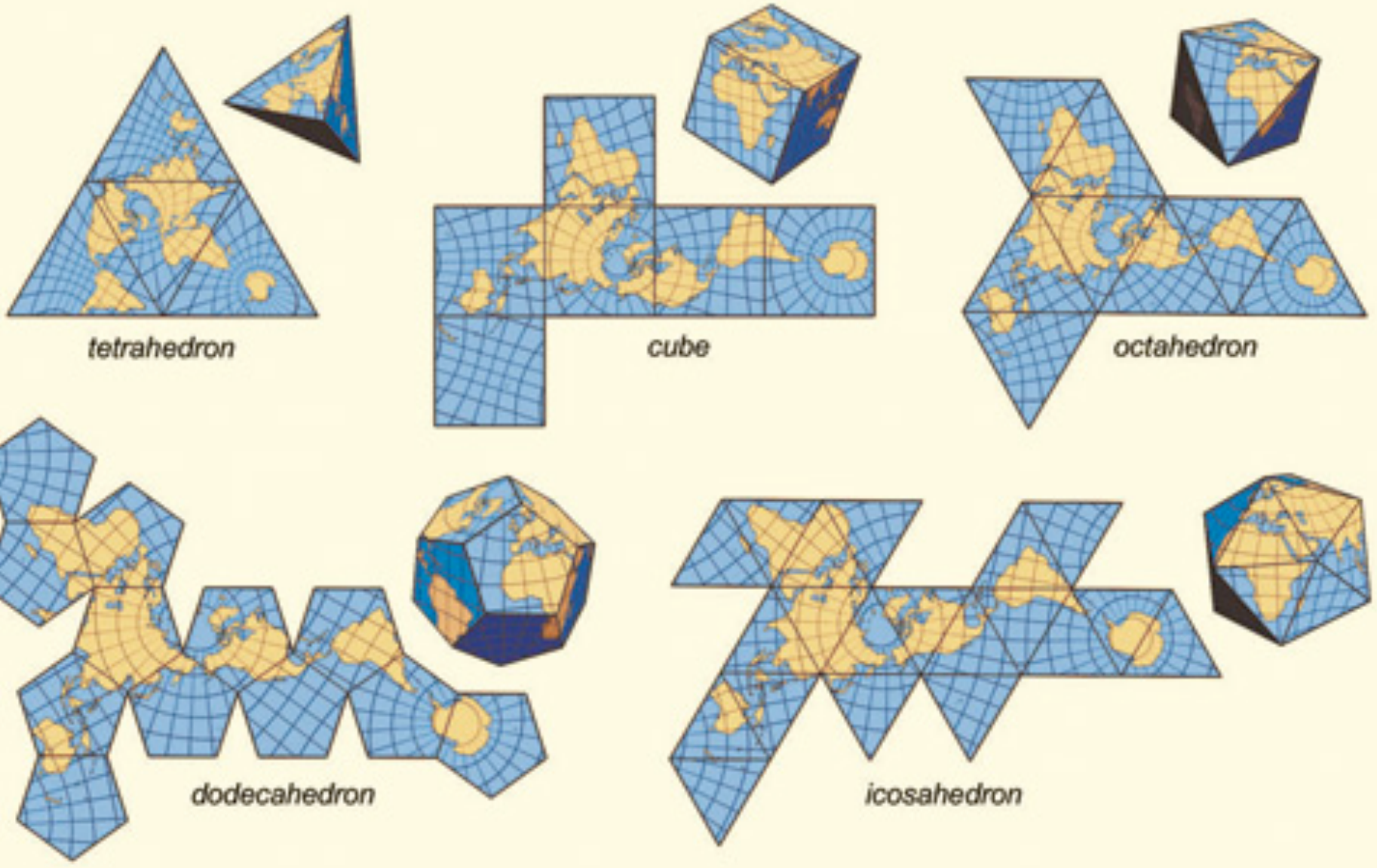
YOU THINK THAT WHEN WE LOOK AT A MAP, WHAT WE REALLY SEE IS OURSELVES. AFTER YOU FIRST SAW *INCEPTION*, YOU SAT SILENT IN THE THEATER FOR SIX HOURS. IT FREAKS YOU OUT TO REALIZE THAT EVERYONE AROUND YOU HAS A SKELETON INSIDE THEM. YOU *HAVE* REALLY LOOKED AT YOUR HANDS.

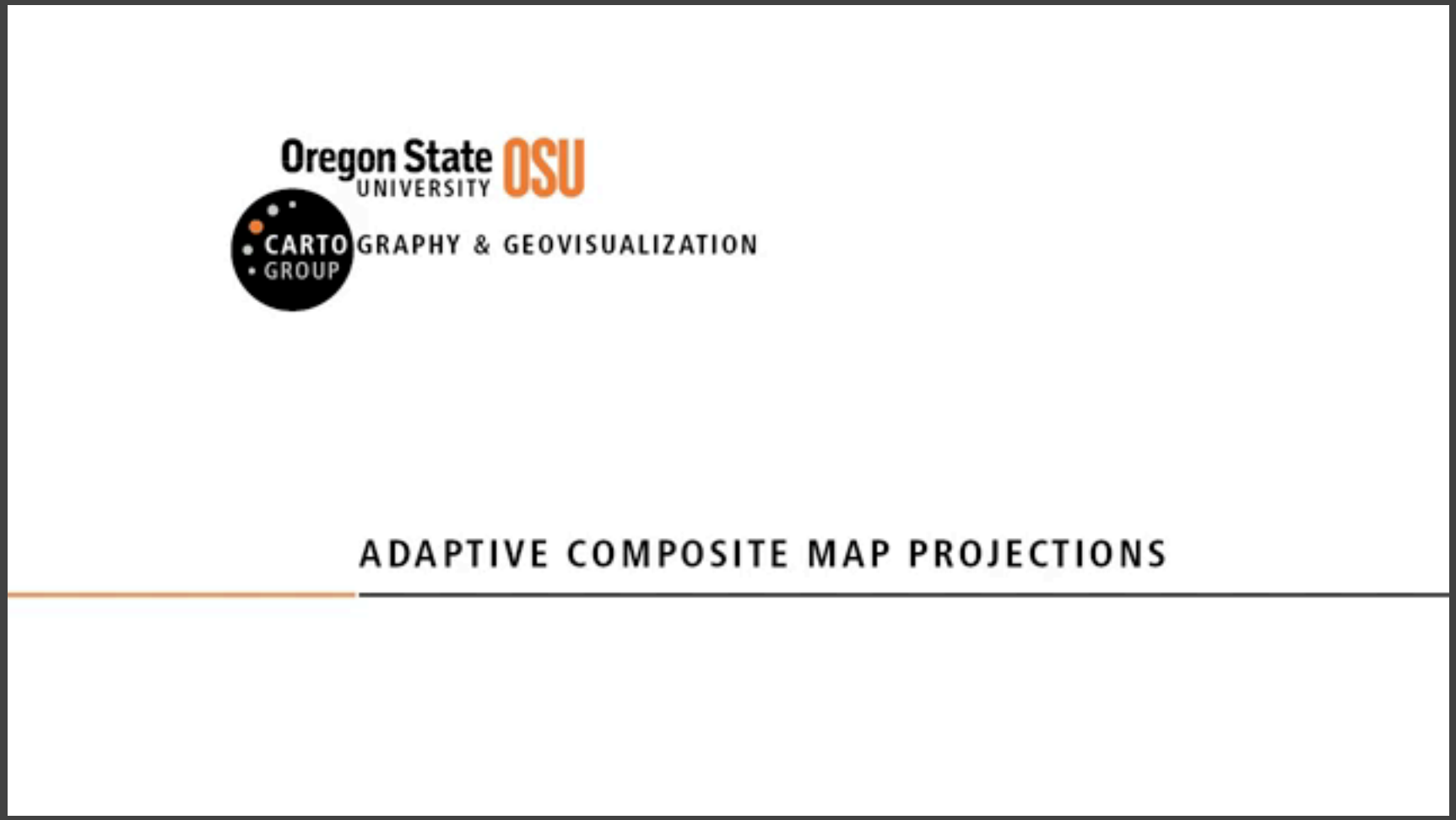
There are interesting ways to tear spheres

One notable interesting way to tear a sphere

Balances preservation of area and shape.

Provides different ways of thinking about the world!


tetrahedron
cube
octahedron
dodecahedron
icosahedron



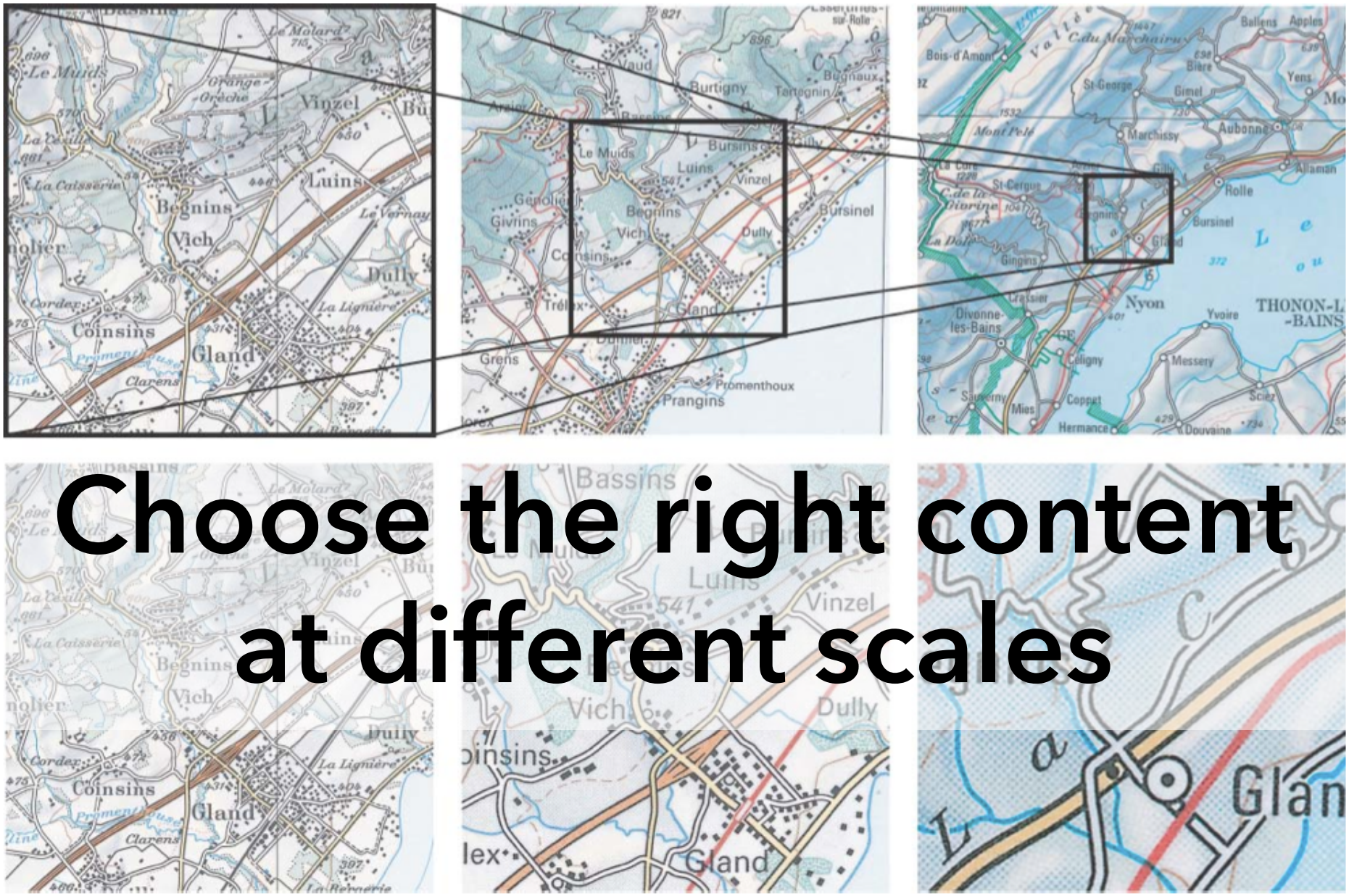
Idea: switch *between* projections by location and zoom level

Scale


This is not "scale"
Texas-Europe Size Comparison
Copenhagen
Kaliningrad
RUSSIA
Bornholm
Gdańsk
Hamburg
Bremen
Berlin
Poznań
POLAND
Łódź
Warsaw
Amsterdam
NETH.
Rotterdam
London
Cardiff
Birmingham
Liverpool
Manchester
Leeds
KINGDOM
Isle of Man (U.K.)
Essen
Leipzig
Cologne
Wroclaw
Luxembourg
Paris
Stuttgart
Strasbourg
Munich
Nantes
Vienna
Bratislava
SLOVAKIA
HUNGARY
LIECH.
Zurich
Bern
Vaduz
SWITZ.
FRANCE
Ljubljana
Zagreb
SLOVENIA
Lyon
Milan
Bordeaux
CROATIA
BOSNIA AND HERZEGOVINA
Sarajevo
Genoa
MONACO
Bilbao
Toulouse
ITALY
Adriatic Sea
Jersey (U.K.)
Guernsey (U.K.)
0
300 Kilometers
0
300 Miles

Scale is an idea imported from print

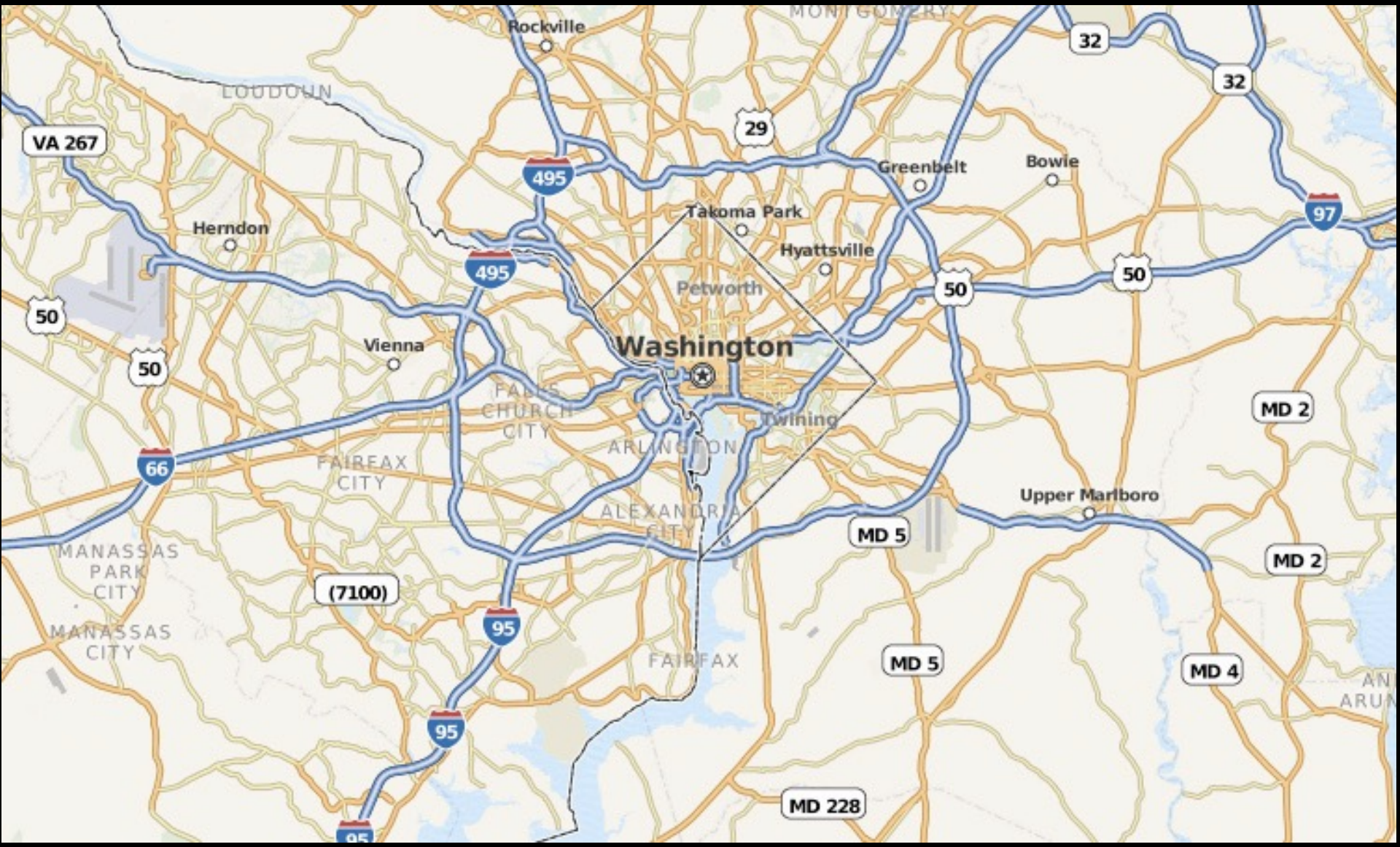
1:1,000,000 scale mapping | 1:625,000 scale mapping | 1:250,000 scale mapping | 1:50,000 scale mapping | 1:25,000 scale mapping | 1:10,000 scale mapping

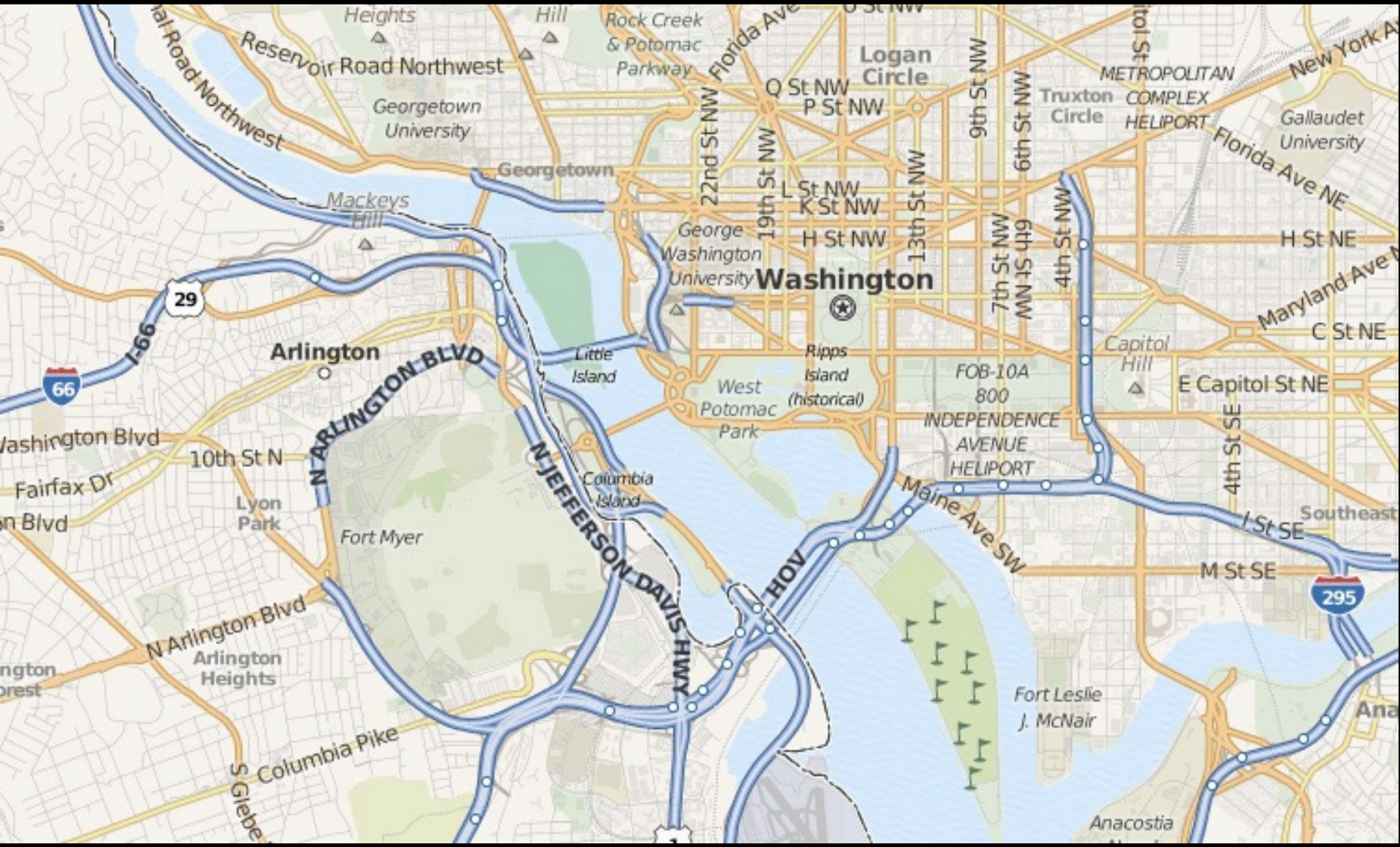

Choose the right content
at different scales

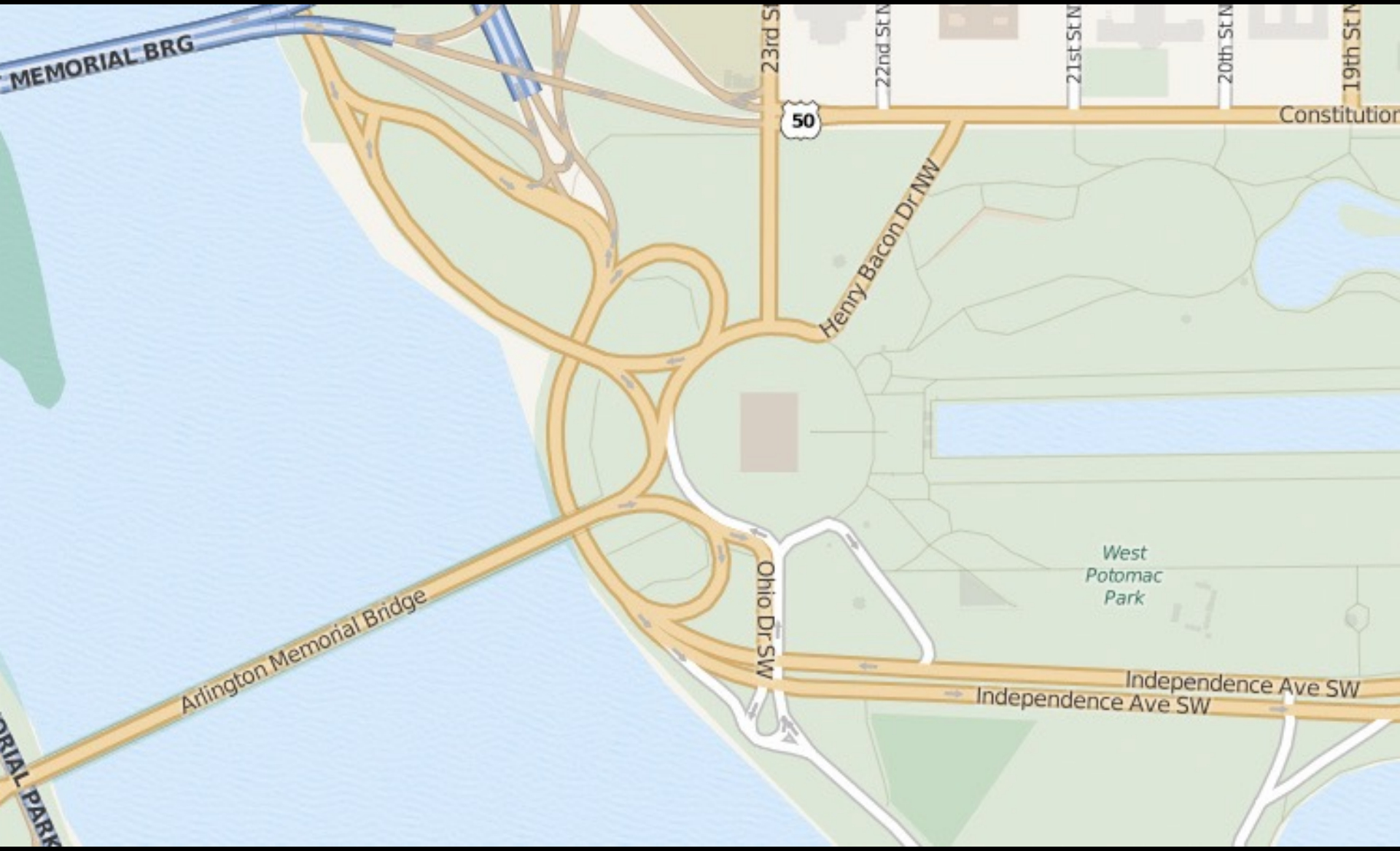
Four maps, same area

What shows at different scales?


Pittsburgh
Harrisburg
Reading
Camden
NEW JERSEY
Cumberland
MARYLAND
Millville
Washington
DELAWARE
Harrisonburg
WEST VIRGINIA
Richmond
Roanoke
VIRGINIA
Suffolk
70
79
76
83
68
81
95
64
85


Rockville
MONTGOMERY
LOUDOUN
VA 267
29
32
32
495
Greenbelt
Bowie
97
Takoma Park
Herndon
Hyattsville
495
50
50
Petworth
50
Vienna
Washington
50
FALLS CHURCH CITY
Twining
MD 2
66
FAIRFAX CITY
ARLINGTON
Upper Marlboro
ALEXANDRIA CITY
MD 5
MD 2
MANASSAS PARK CITY
(7100)
95
MANASSAS CITY
FAIRFAX
MD 5
MD 4
95
MD 228


Heights
Hill
Rock Creek & Potomac Parkway
Florida Ave
Reservoir Road Northwest
Logan Circle
Q St NW
P St NW
9th St NW
6th St NW
Truxton Circle
METROPOLITAN COMPLEX HELIPORT
New York A
Georgetown University
22nd St NW
19th St NW
13th St NW
7th St NW
6th St NW
4th St NW
Gallaudet University
Florida Ave NE
Georgetown
Mackeys Hill
L St NW
K St NW
H St NW
George Washington University
Washington
H St NE
Maryland Ave
C St NE
29
I-66
66
Arlington
N ARLINGTON BLVD
Little Island
Ripps Island (historical)
West Potomac Park
Capitol Hill
FOB-10A
800 INDEPENDENCE AVENUE HELIPORT
E Capitol St NE
4th St SE
Washington Blvd
10th St N
Fairfax Dr
N JEFFERSON DAVIS HWY
Columbia Island
Lyon Park
Fort Myer
Maine Ave SW
I St SE
Southeast
M St SE
295
HOV
N Arlington Blvd
Arlington Heights
Fort Leslie J. McNair
Columbia Pike
Anacostia


MEMORIAL BRG
23rd St
22nd St N
21st St N
20th St N
19th St N
50
Constitution
Henry Bacon Dr NW
West
Potomac
Park
Ohio Dr SW
Arlington Memorial Bridge
Independence Ave SW
Independence Ave SW

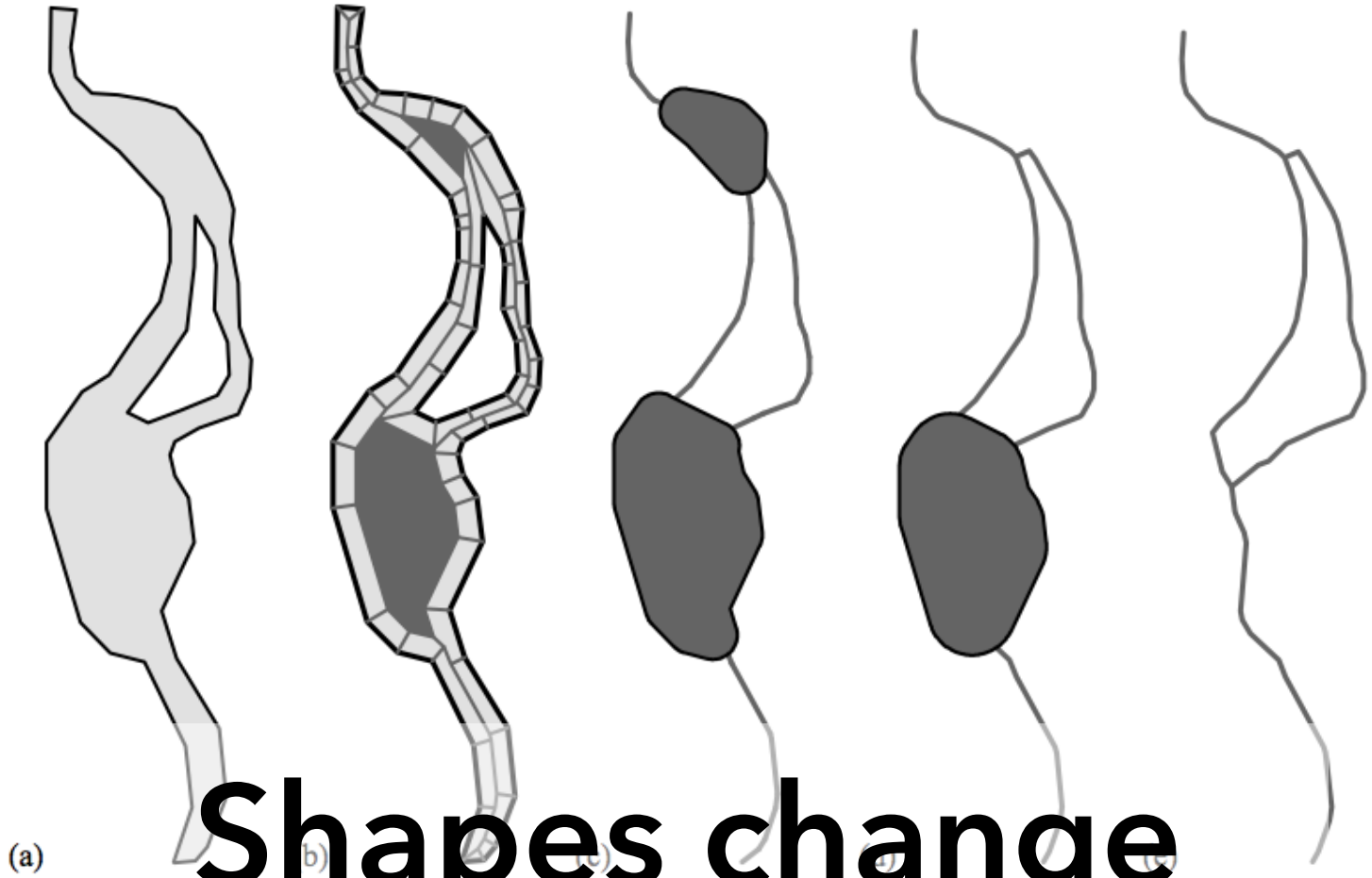


Figure 11. Fragmentation of a river into polygons and lines with different thresholds leading to different results (c, d, e).

Shapes change at different scales

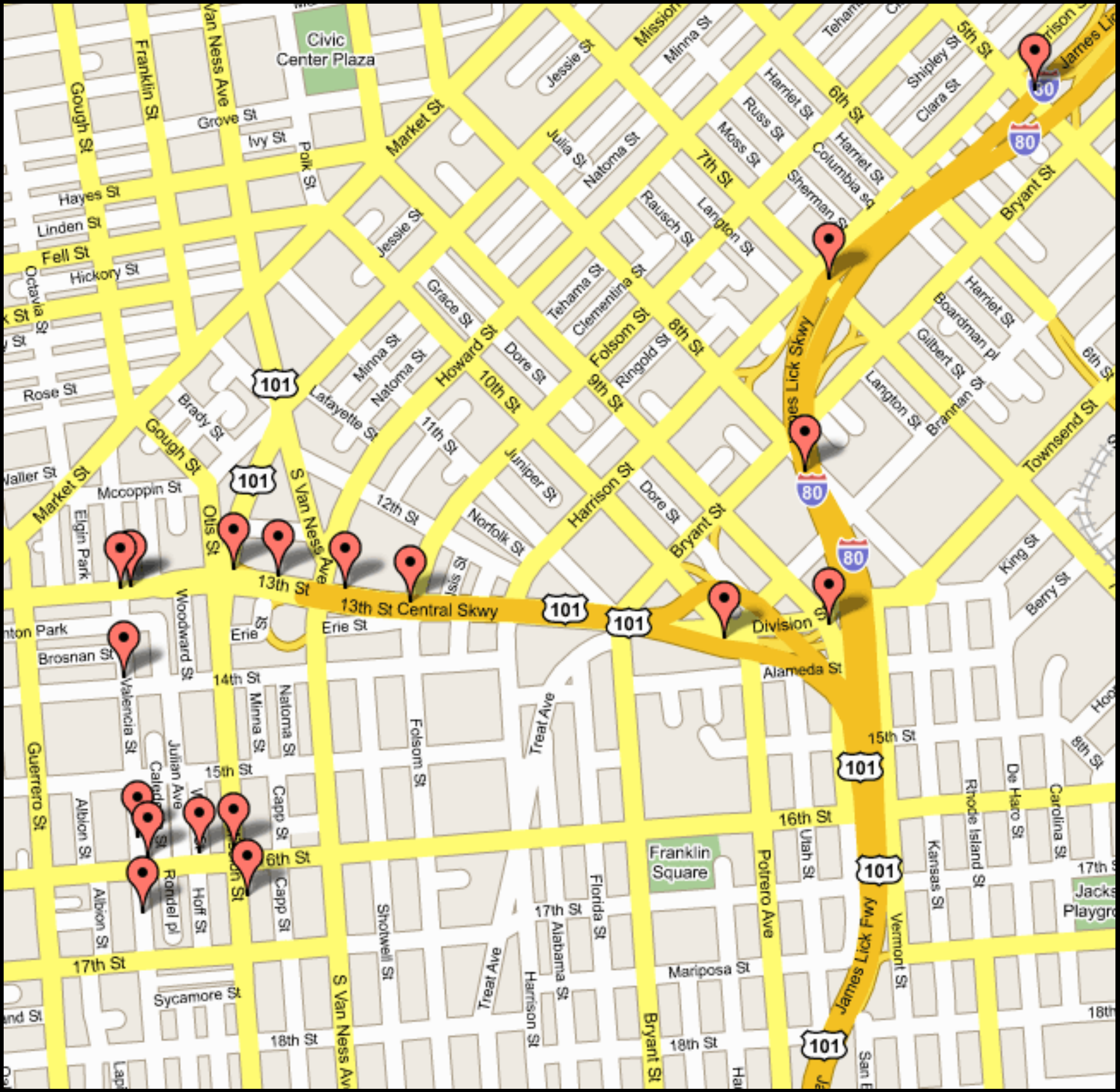
Questions?

Mapping

Visualizing Geospatial Data

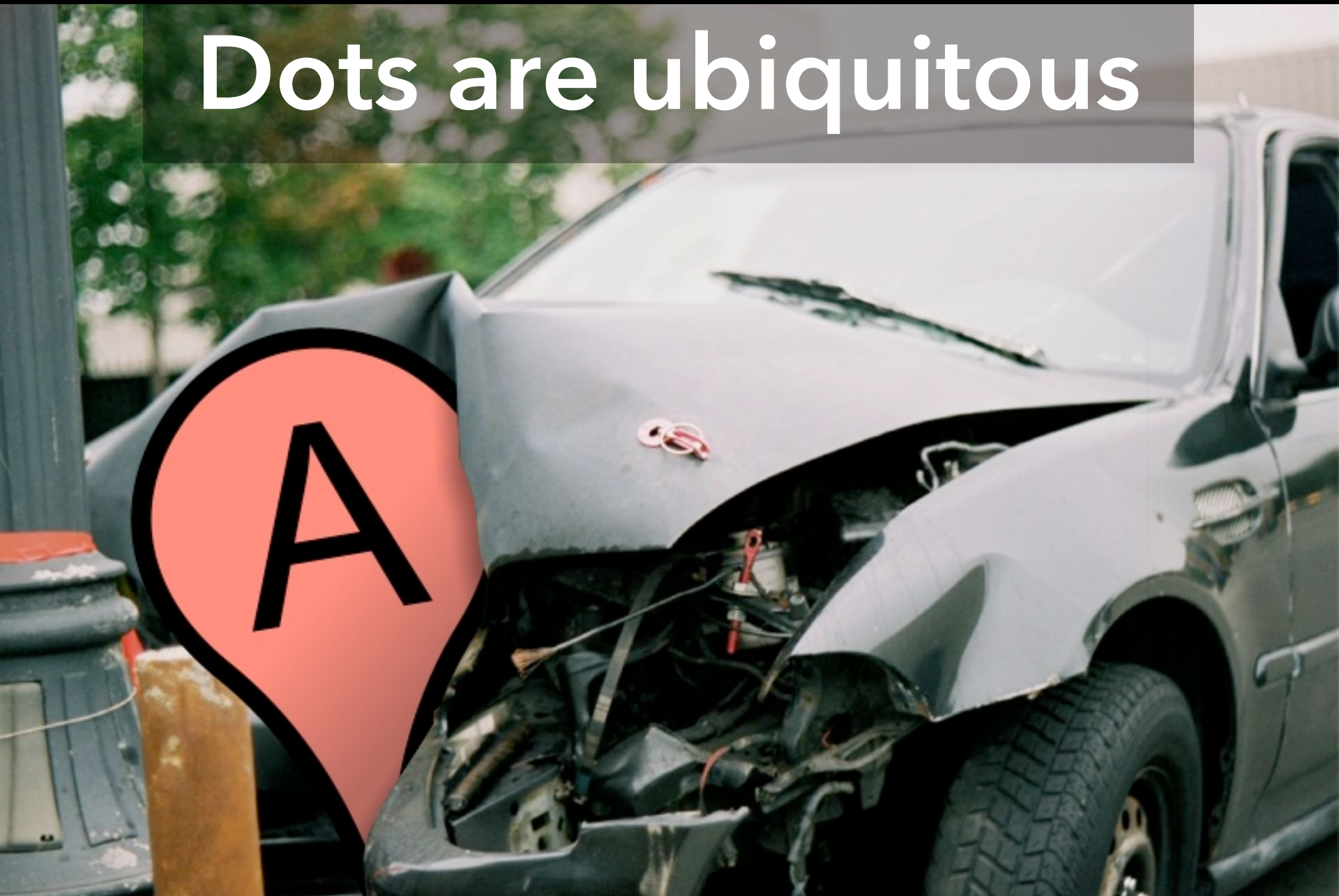
Symbol Maps

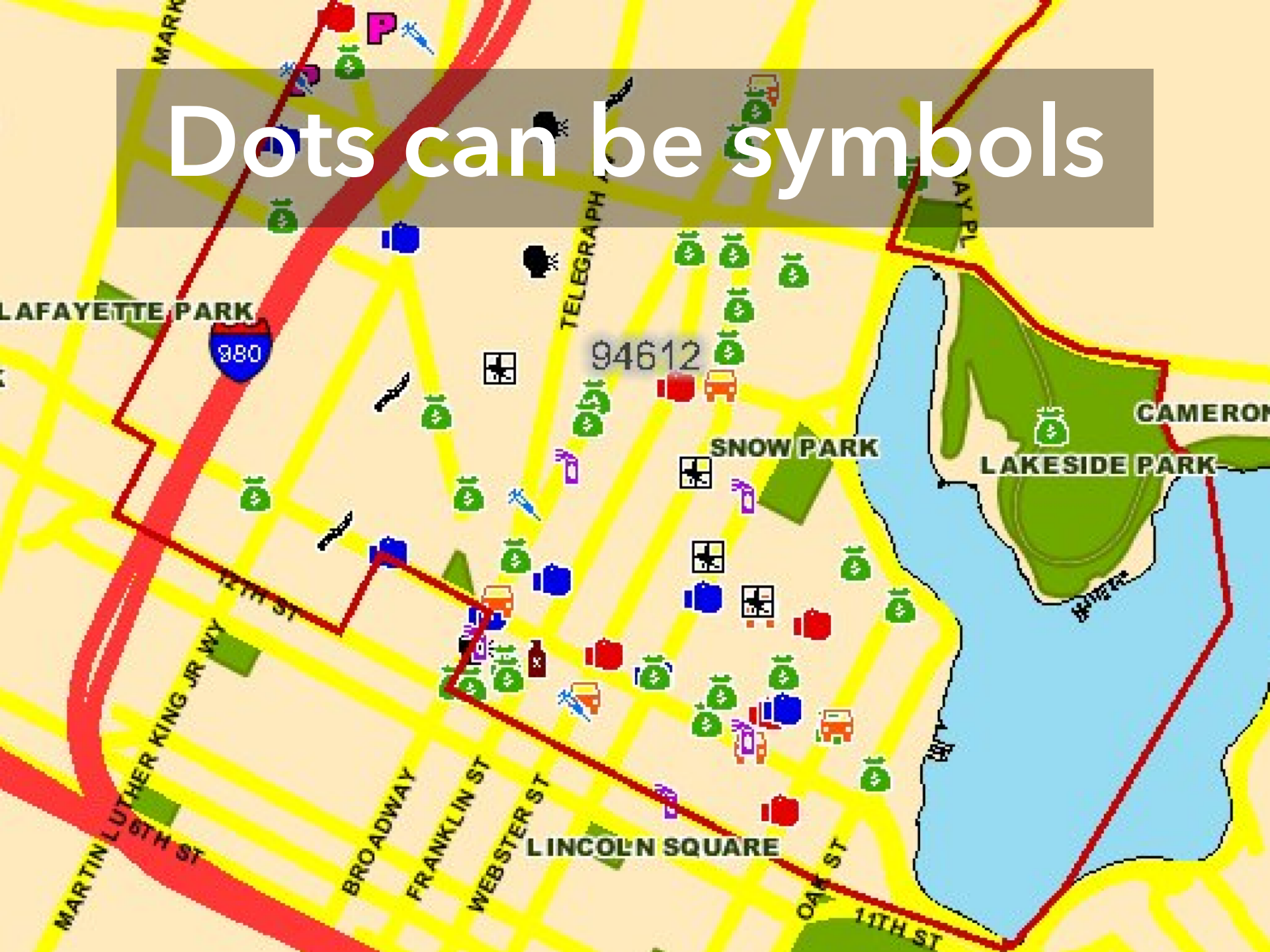
Convey Locations & Magnitudes

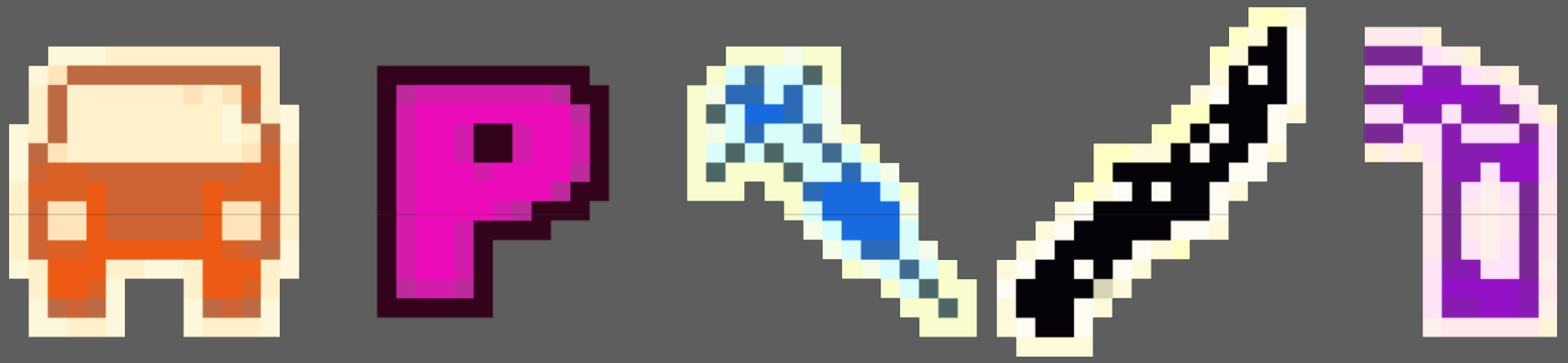


Civic
Center Plaza
Van Ness Ave
Franklin St
Gough St
Grove St
Ivy St
Polk St
Market St
Hayes St
Linden St
Fell St
Hickory St
Octavia St
Rose St
Brady St
Gough St
Waller St
Market St
Mccoppin St
Elgin Park
Otis St
S Van Ness Ave
13th St
13th St Central Skwy
Erie St
Erie St
Brosnan St
Woodward St
14th St
Valencia St
Minna St
Natoma St
Guerrero St
Albion St
Julian Ave
15th St
Capp St
16th St
Rondel pl
Hoff St
Albion St
17th St
Sycamore St
18th St
S Van Ness Ave
Shotwell St
Folsom St
Treat Ave
Harrison St
17th St
Alabama St
Florida St
Bryant St
18th St
Mariposa St
Franklin
Square
Potrero Ave
Utah St
16th St
15th St
James Lick Fwy
Vermont St
Kansas St
Rhode Island St
De Haro St
Carolina St
17th St
Alameda St
Division St
Jessie St
Mission St
Minna St
Julia St
Natoma St
7th St
Russ St
Moss St
Harriet St
6th St
5th St
Tehama St
Shipley St
Clara St
Columbia sq
Sherman St
Rausch St
Langton St
Bryant St
Jessie St
Grace St
Tehama St
Clementina St
Folsom St
8th St
Ringold St
9th St
Dore St
10th St
Howard St
Minna St
Natoma St
Lafayette St
11th St
Juniper St
12th St
Norfolk St
Harrison St
Dore St
Bryant St
Harriet St
Boardman pl
Gilbert St
Langton St
Brannan St
Townsend St
King St
Berry St
6th St
8th St
101
80

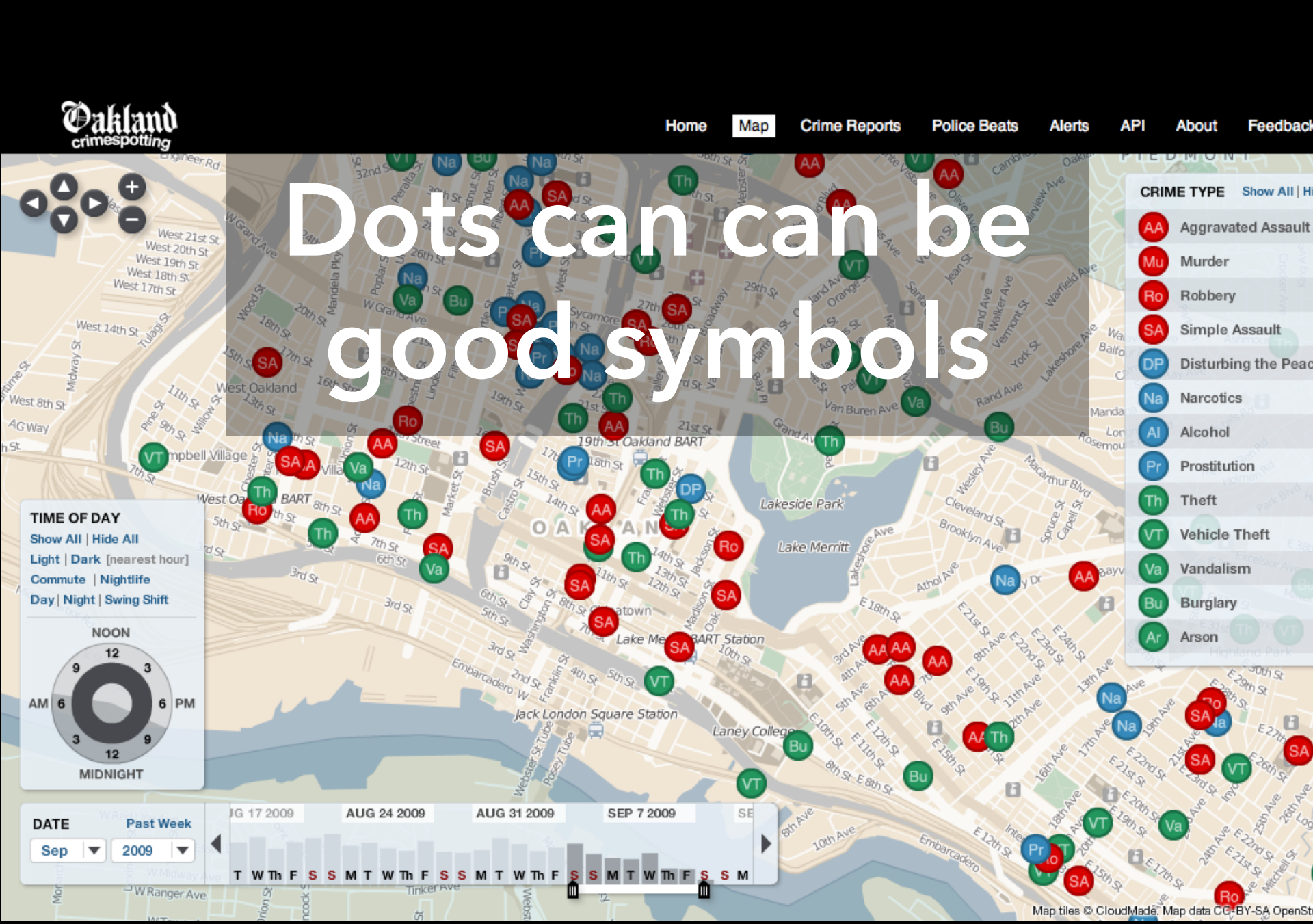
Dots are ubiquitous

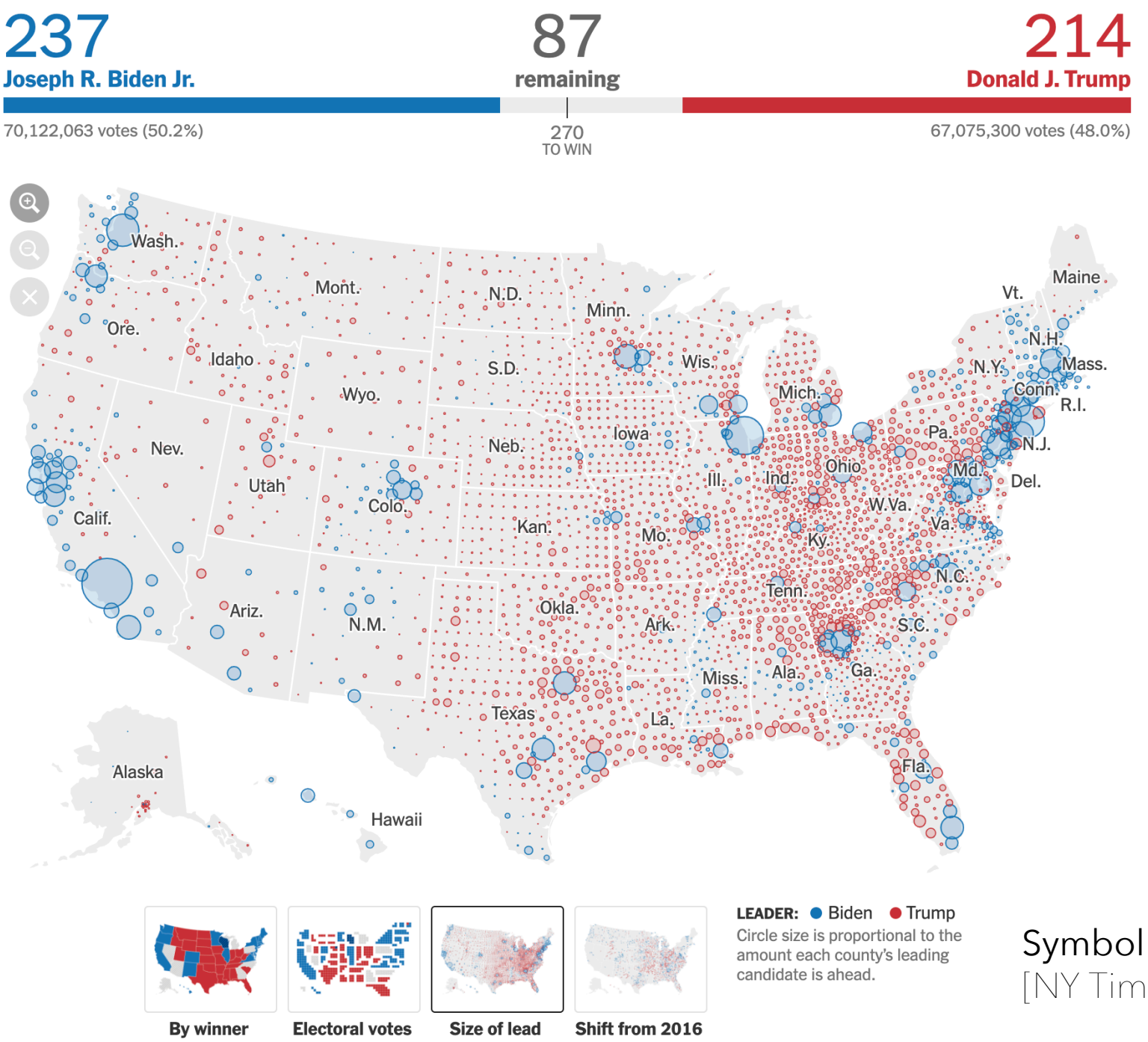



Dots can be symbols
LAFAYETTE PARK
980
TELEGRAPH
94612
SNOW PARK
LAKESIDE PARK
CAMERON
12TH ST
MARTIN LUTHER KING JR WY
BROADWAY
FRANKLIN ST
WEBSTER ST
LINCOLN SQUARE
OAK ST
11TH ST



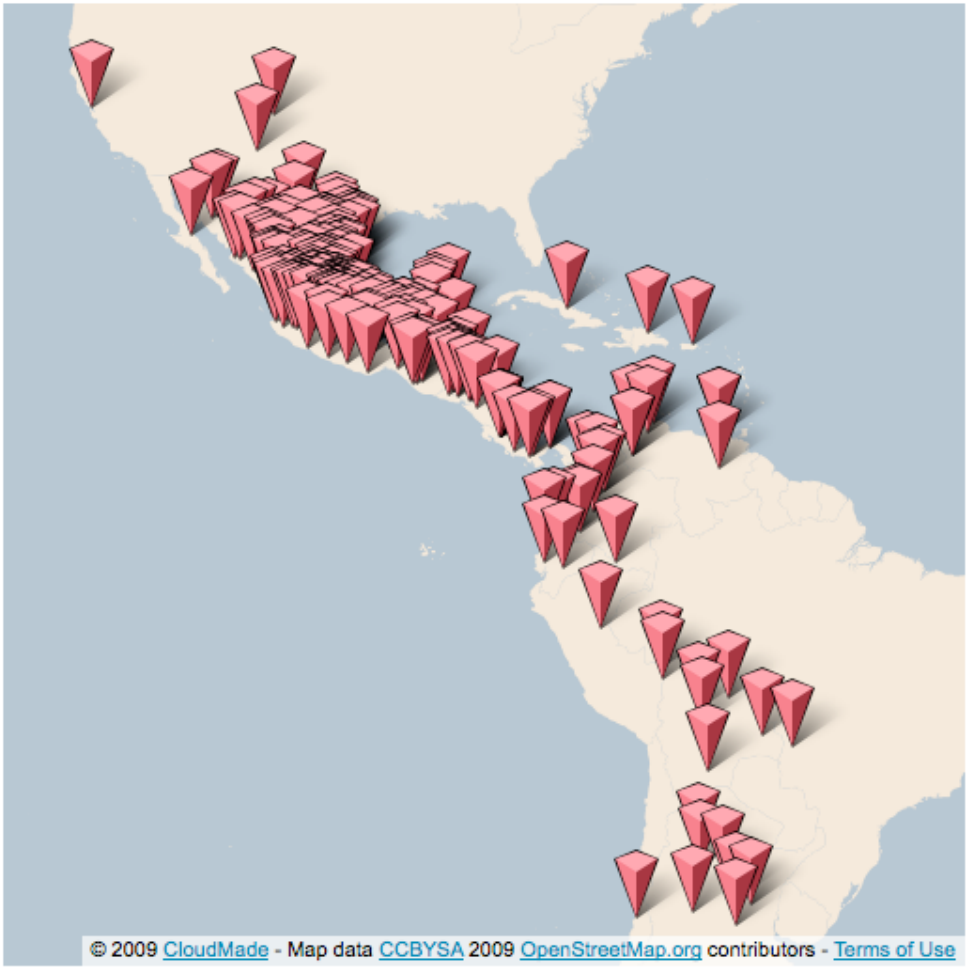
Guess the crime


Oakland crimespotting
Home
Map
Crime Reports
Police Beats
Alerts
API
About
Feedback
Dots can can be good symbols
CRIME TYPE
Show All | Hi
AA Aggravated Assault
Mu Murder
Ro Robbery
SA Simple Assault
DP Disturbing the Peac
Na Narcotics
Al Alcohol
Pr Prostitution
Th Theft
VT Vehicle Theft
Va Vandalism
Bu Burglary
Ar Arson
TIME OF DAY
Show All | Hide All
Light | Dark [nearest hour]
Commute | Nightlife
Day | Night | Swing Shift
NOON
MIDNIGHT
AM
PM
DATE
Past Week
Sep
2009
AUG 17 2009
AUG 24 2009
AUG 31 2009
SEP 7 2009
Lakeside Park
Lake Merritt
Jack London Square Station
Laney College
19th St Oakland BART
Map tiles © CloudMade. Map data CC-BY-SA OpenSt



Symbol Map
[NY Times]

“Red Dot Fever”



The New York Times

Mapping America: Every City, Every Block

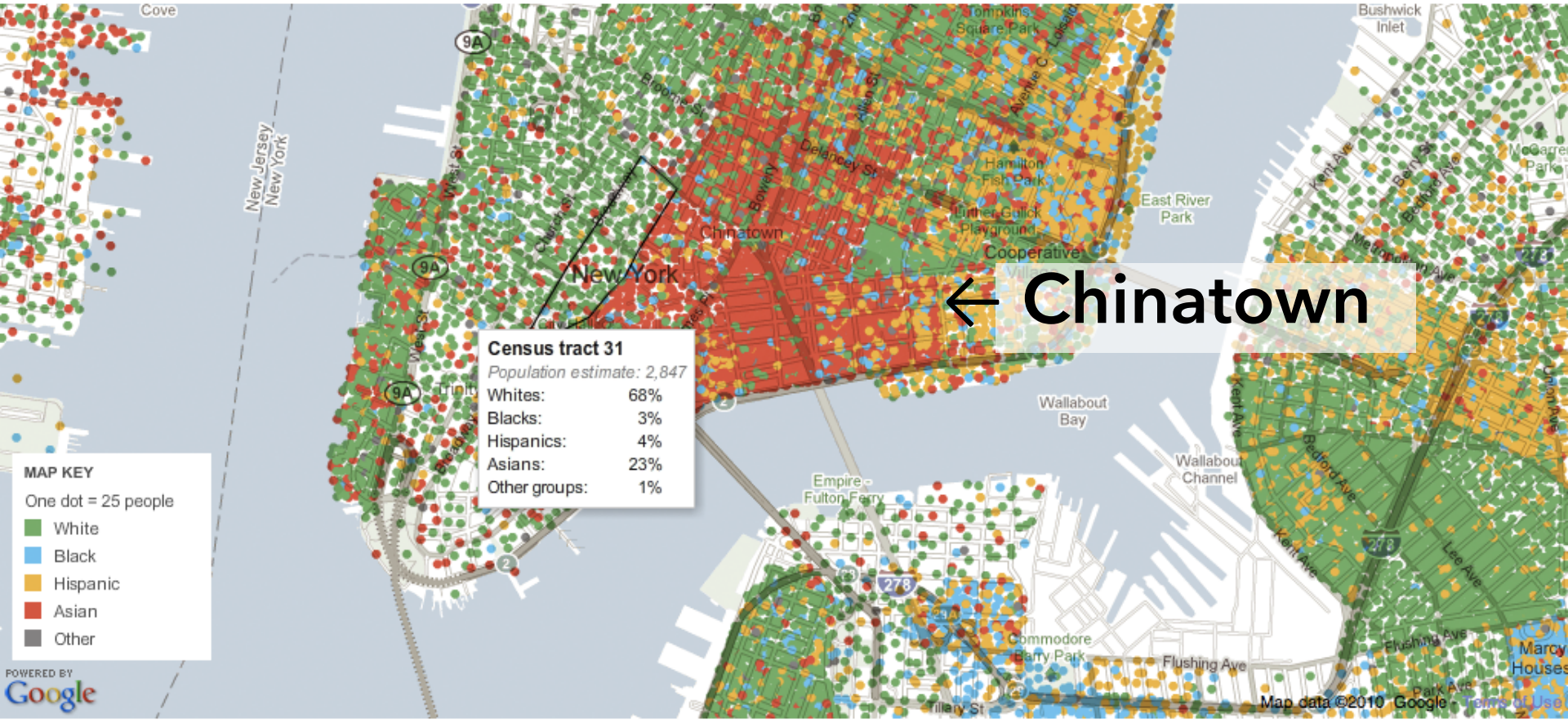
Find something interesting? Share this view on Twitter or Facebook

Browse local data from the Census Bureau's American Community Survey, based on samples from 2005 to 2009. Because these figures are based on samples, they are subject to a margin of error, particularly in places with a low population, and are best regarded as estimates.

View Readers Maps (49)

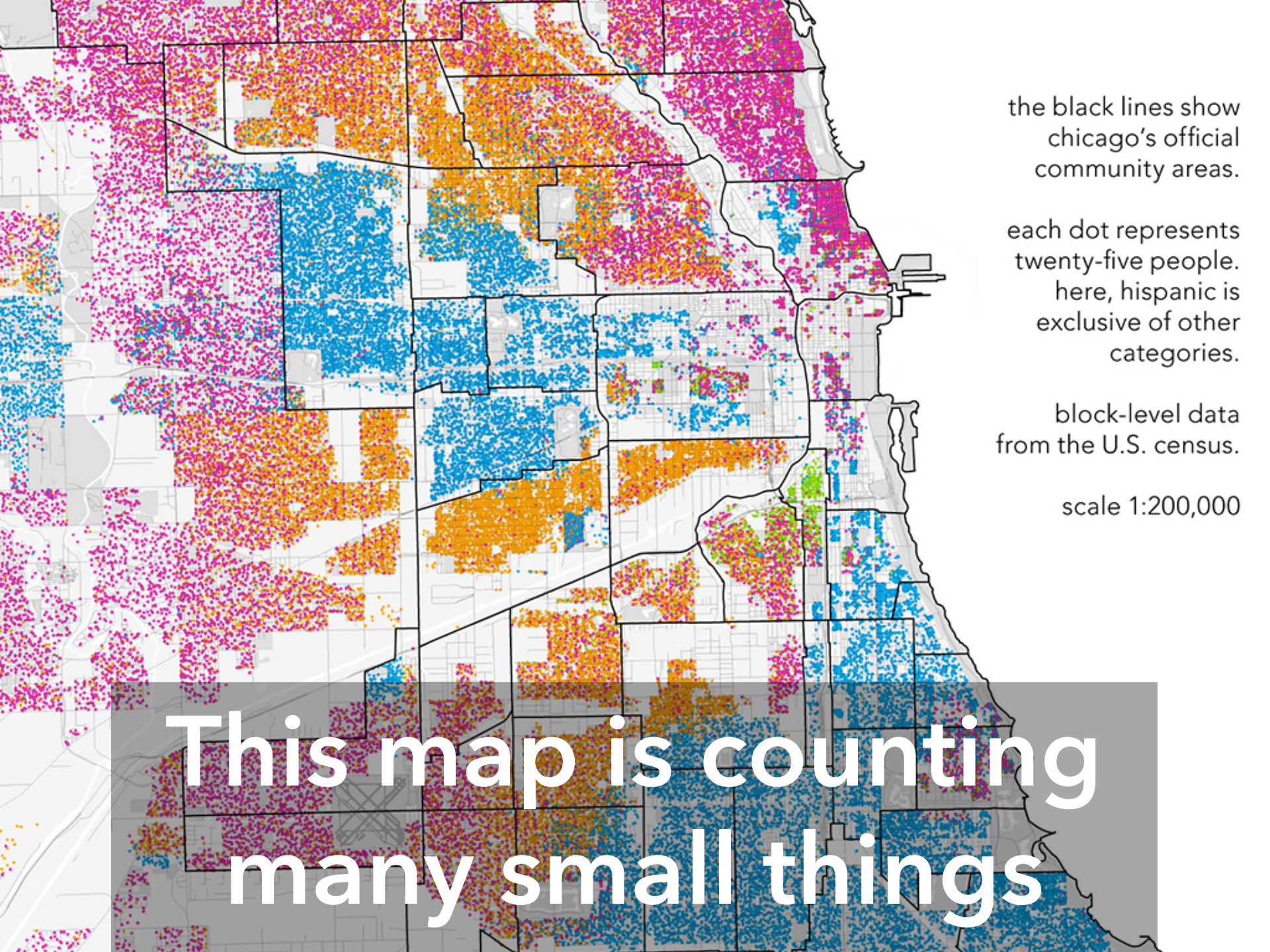
Distribution of racial and ethnic groups

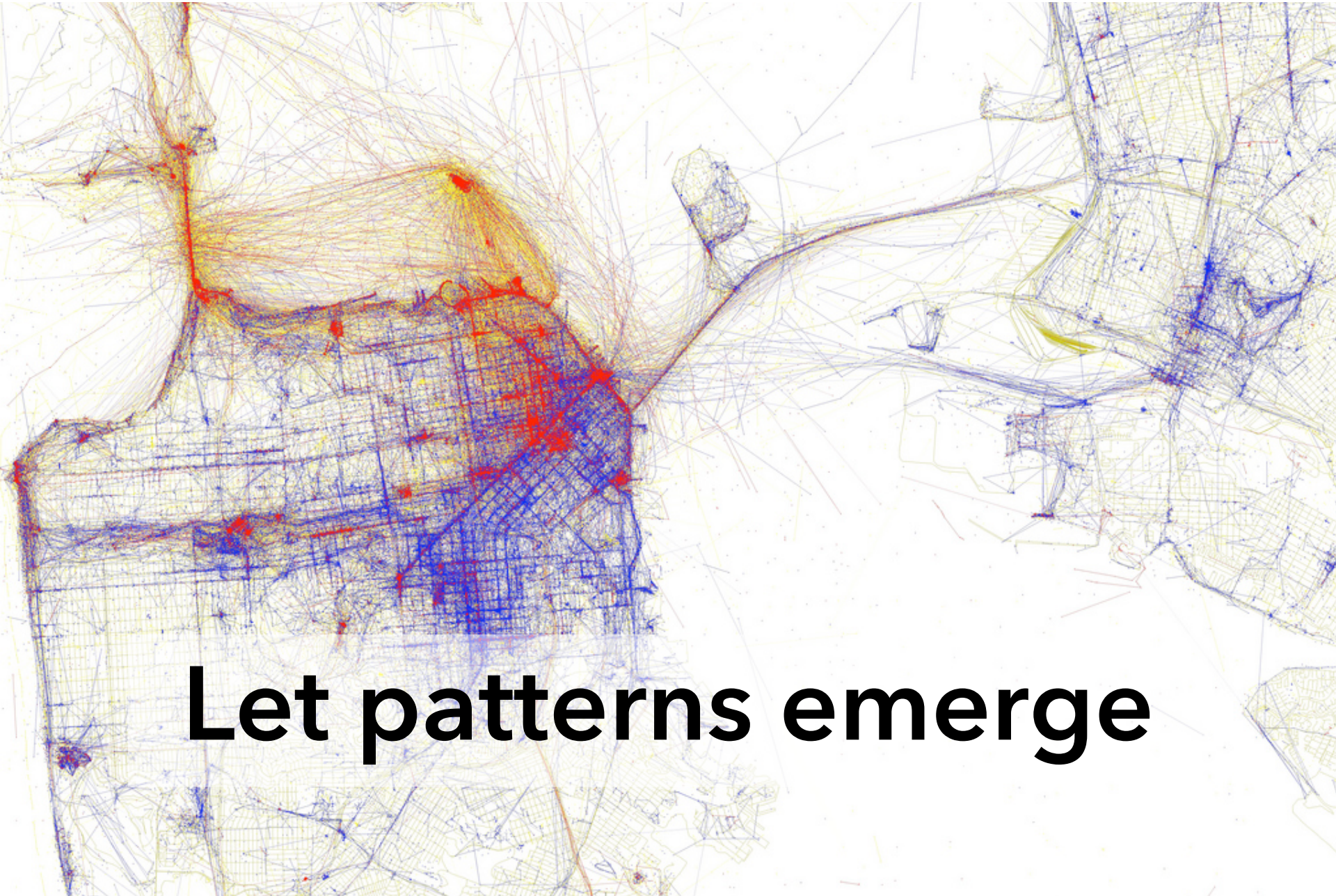
View More Maps | Address, ZIP code or city Go



By MATTHEW BLOCH, SHAN CARTER and ALAN McLEAN | Source: 2005-9 American Community Survey, Census Bureau; socialexplorer.com

Note: Dots are evenly distributed across each Census tract or county. Dollar amounts are adjusted for inflation.

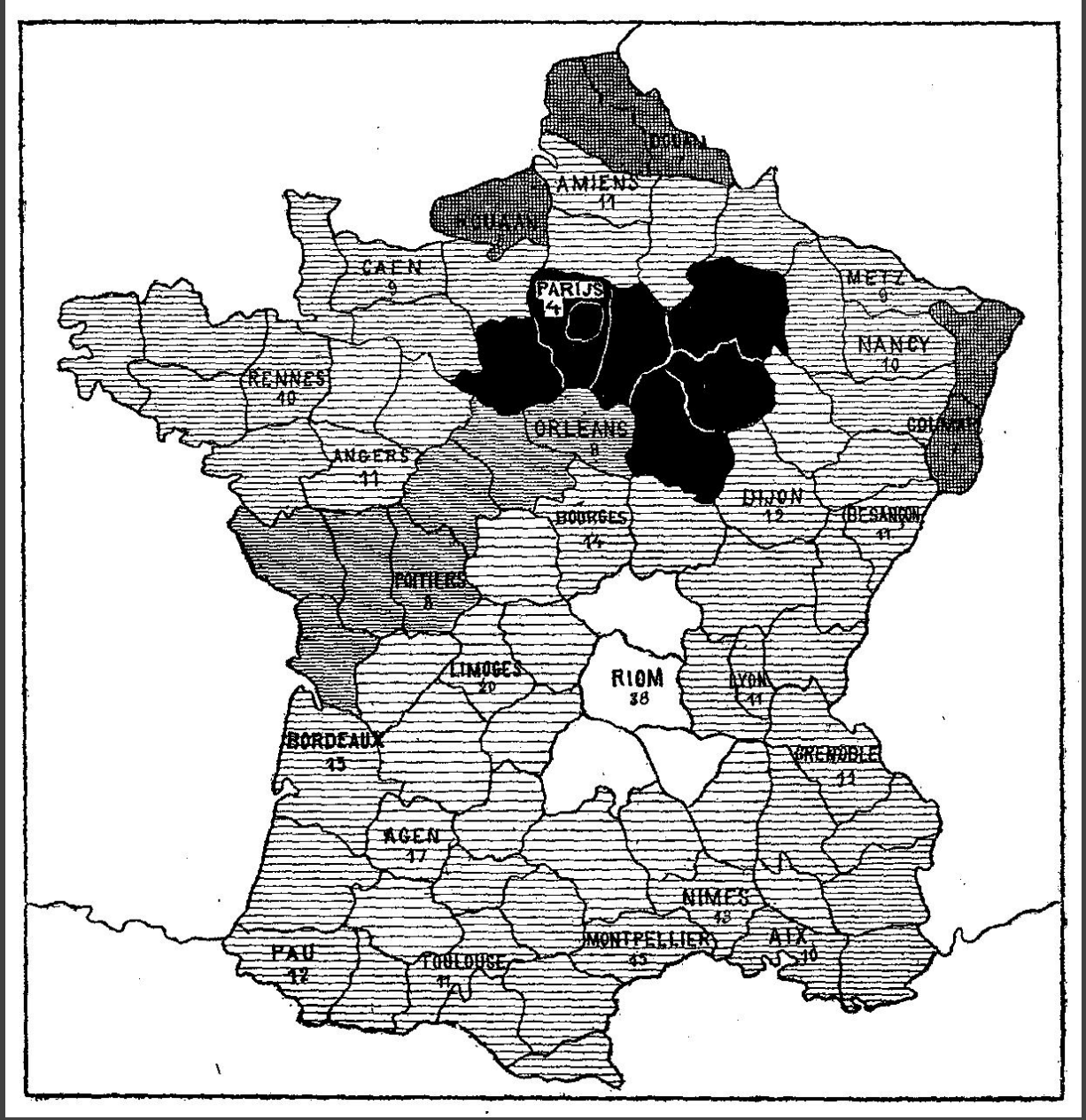

the black lines show chicago's official community areas.
each dot represents twenty-five people. here, hispanic is exclusive of other categories.
block-level data from the U.S. census.
scale 1:200,000
This map is counting many small things



Let patterns emerge

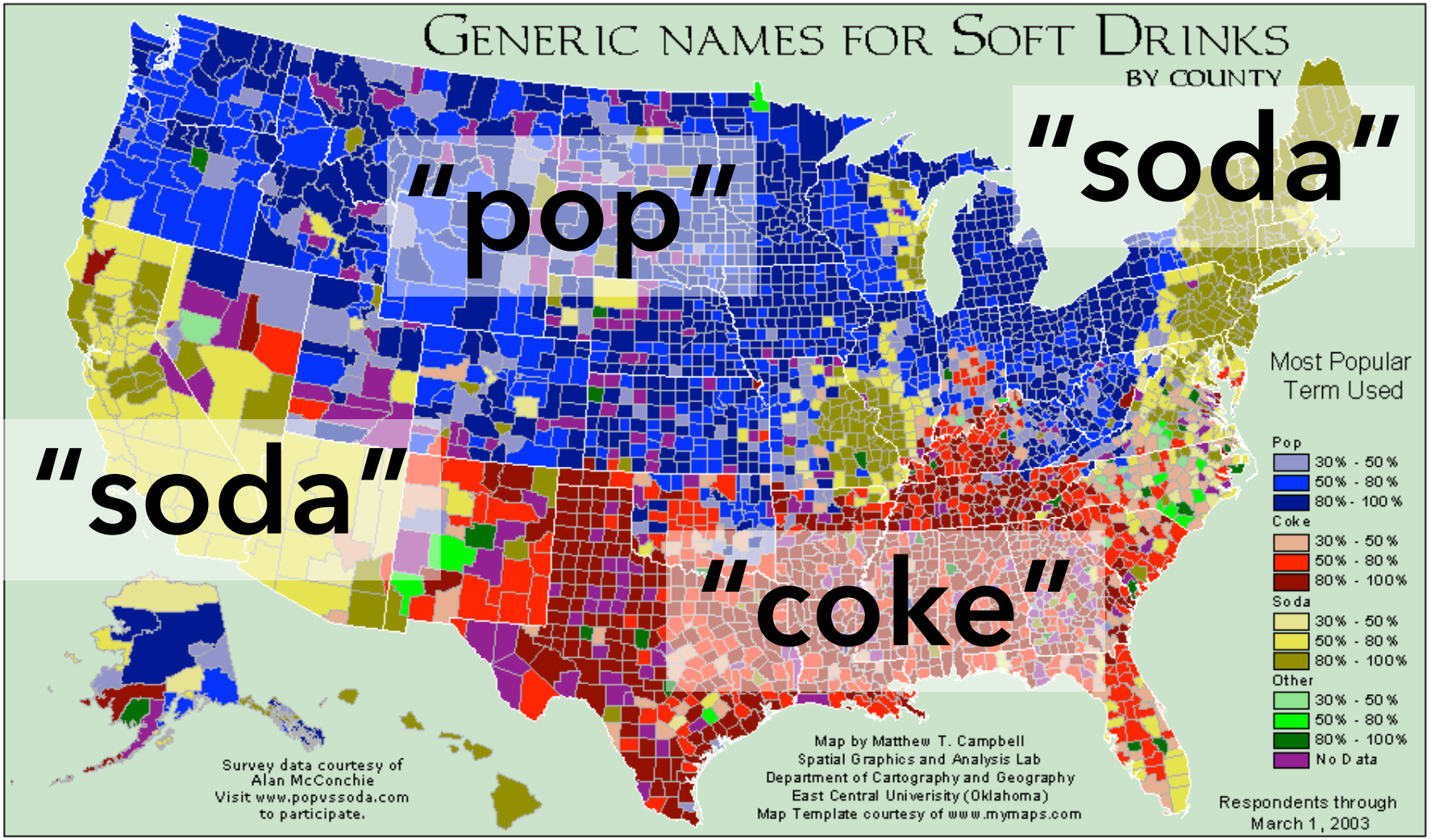
Choropleth Maps

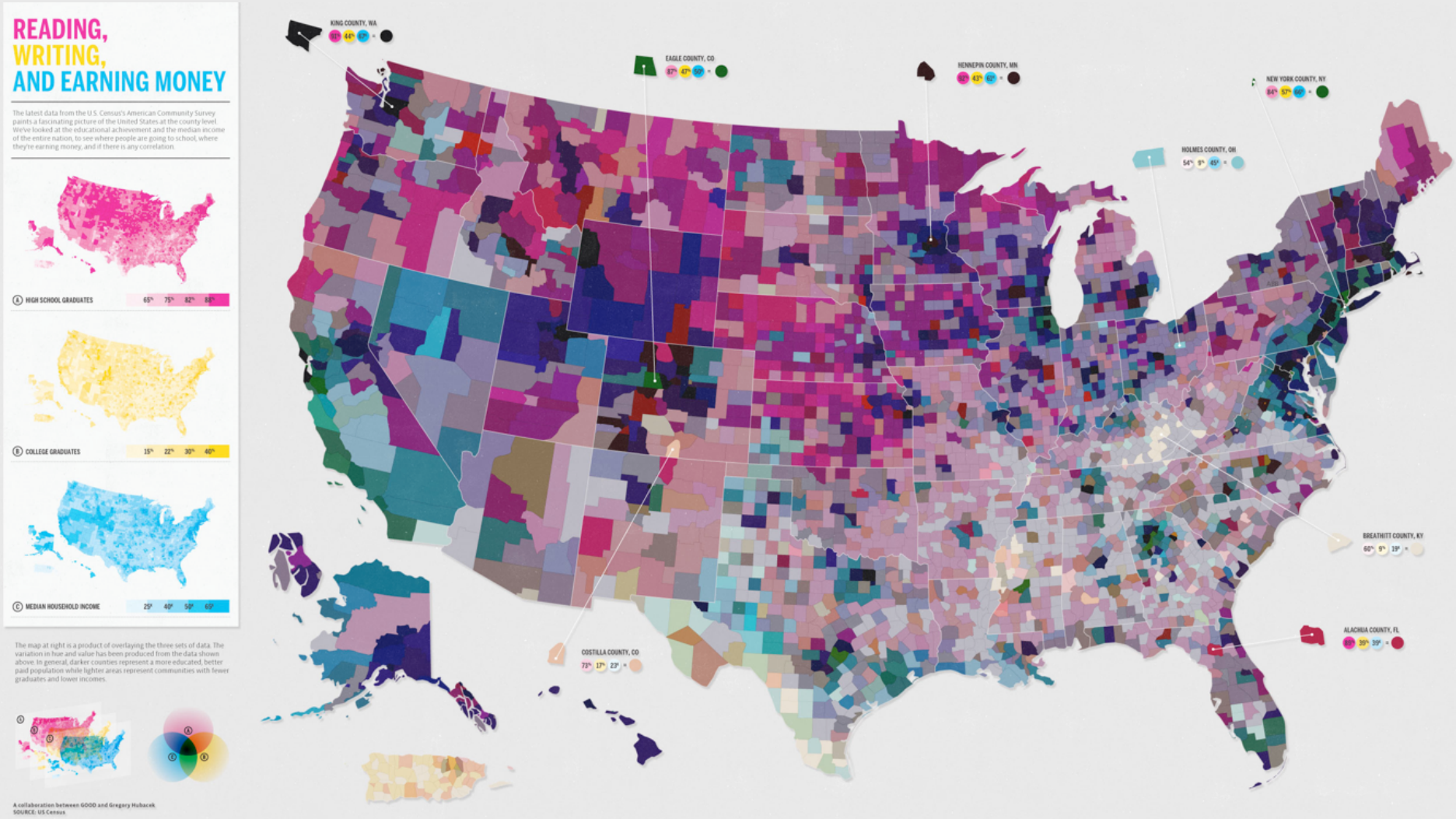
Convey Rates Across Regions



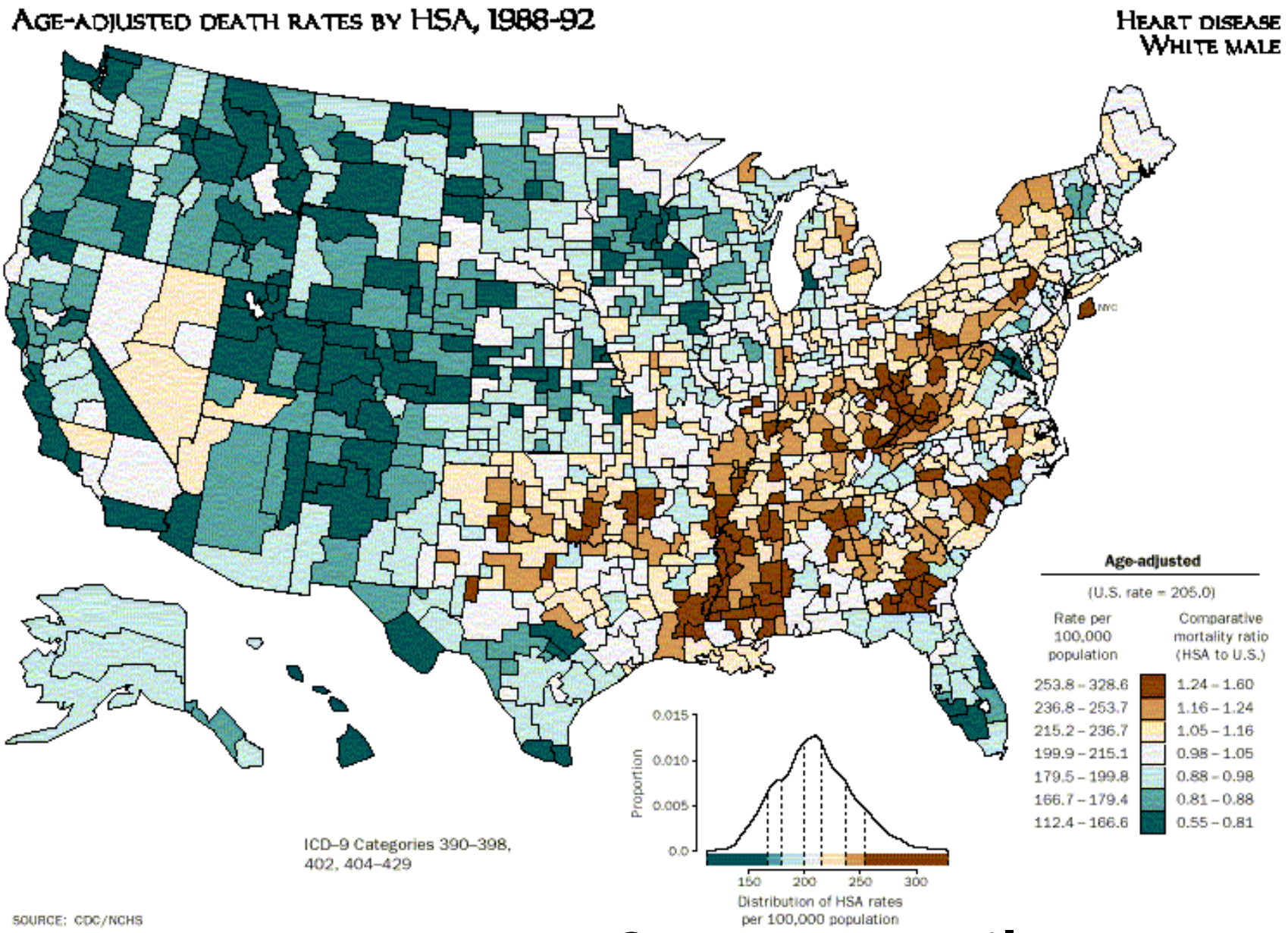
1826(?) Illiteracy in France, Pierre Charles Dupin

http://popvssoda.com

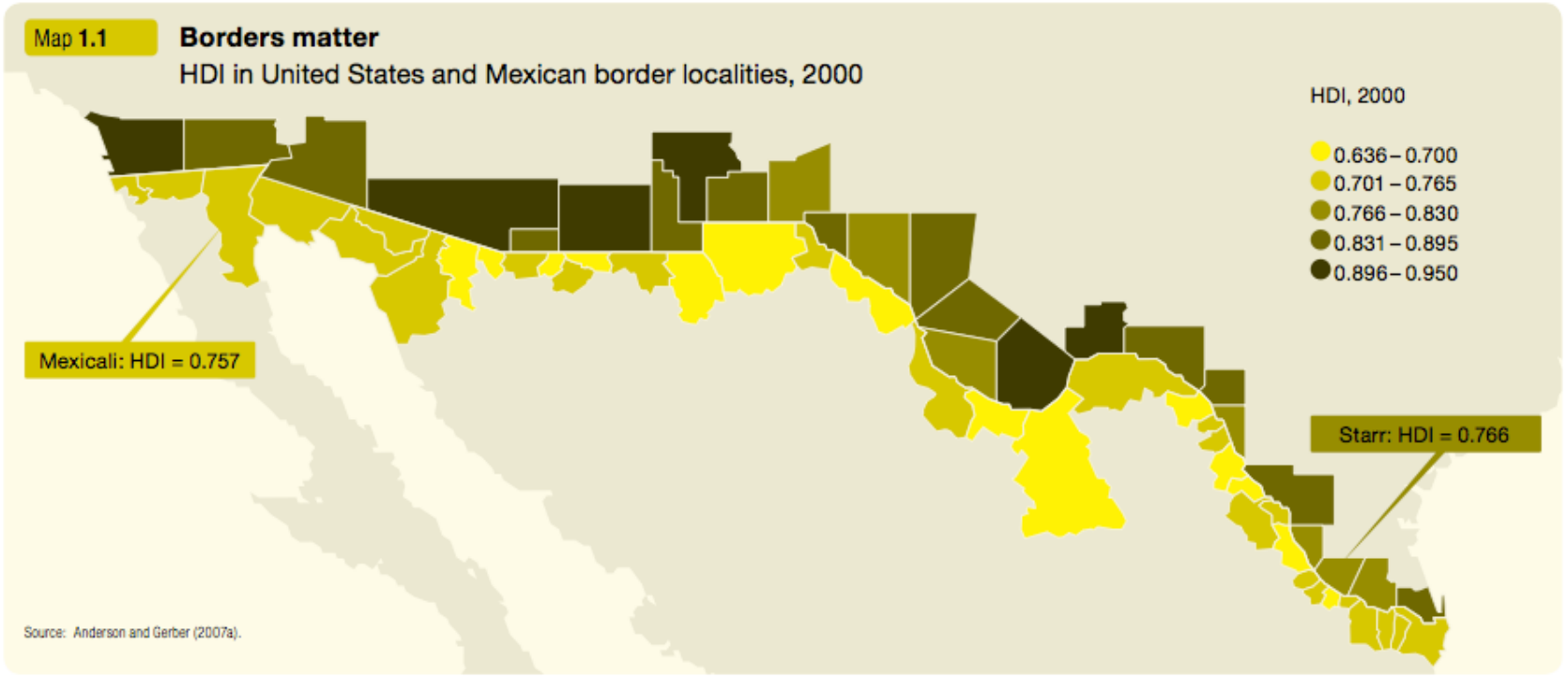




Choose colors with care



Seven quantiles

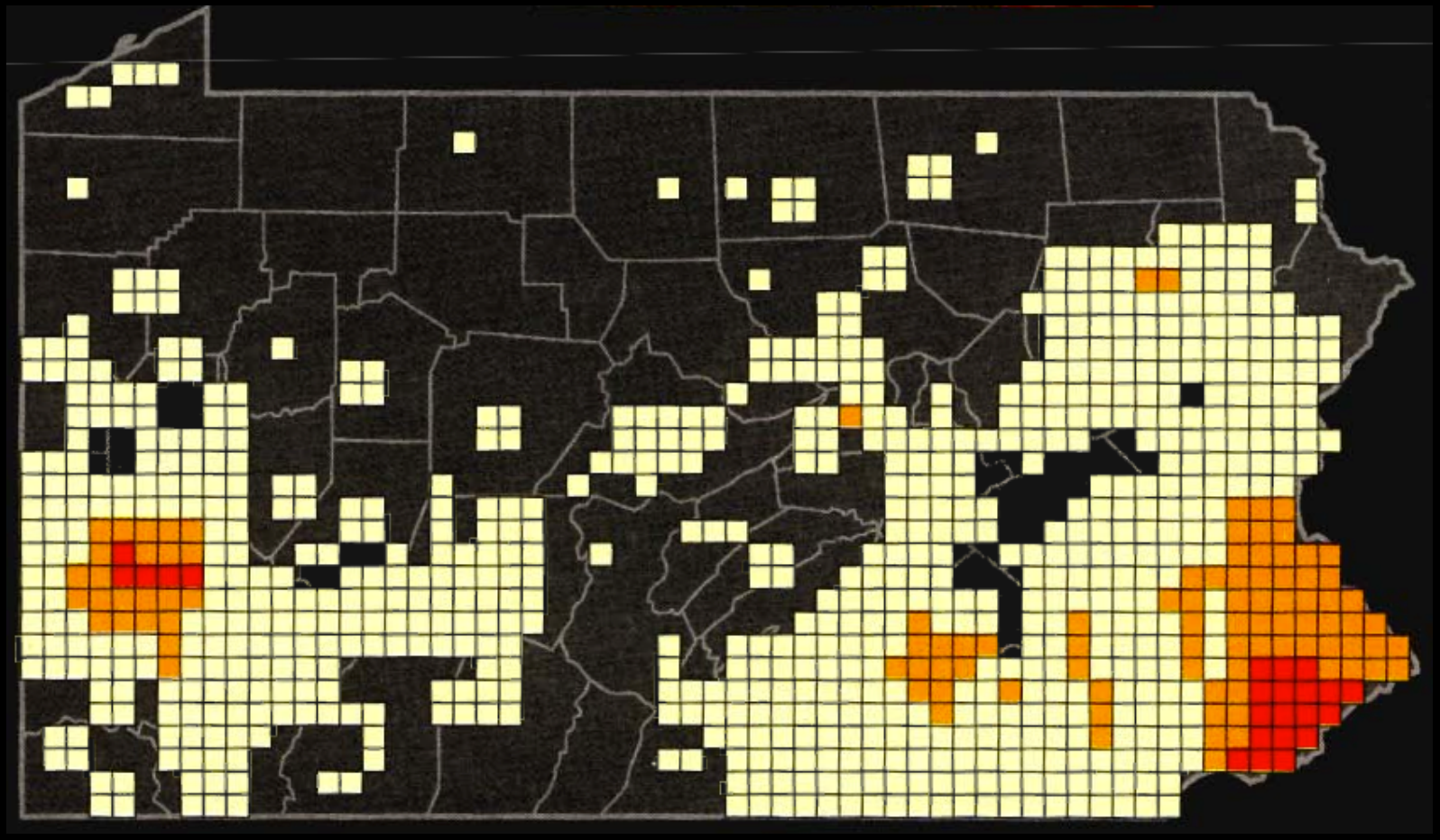


Focus on the foreground

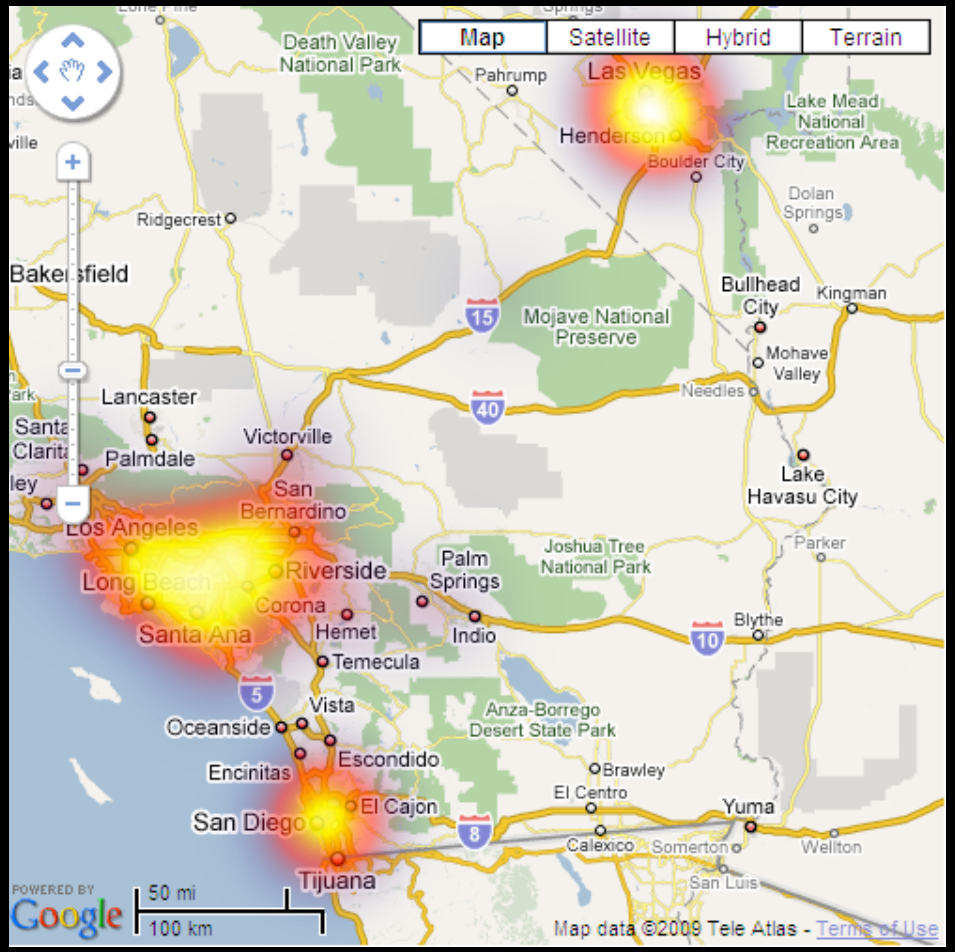
Heatmaps / Contour Maps

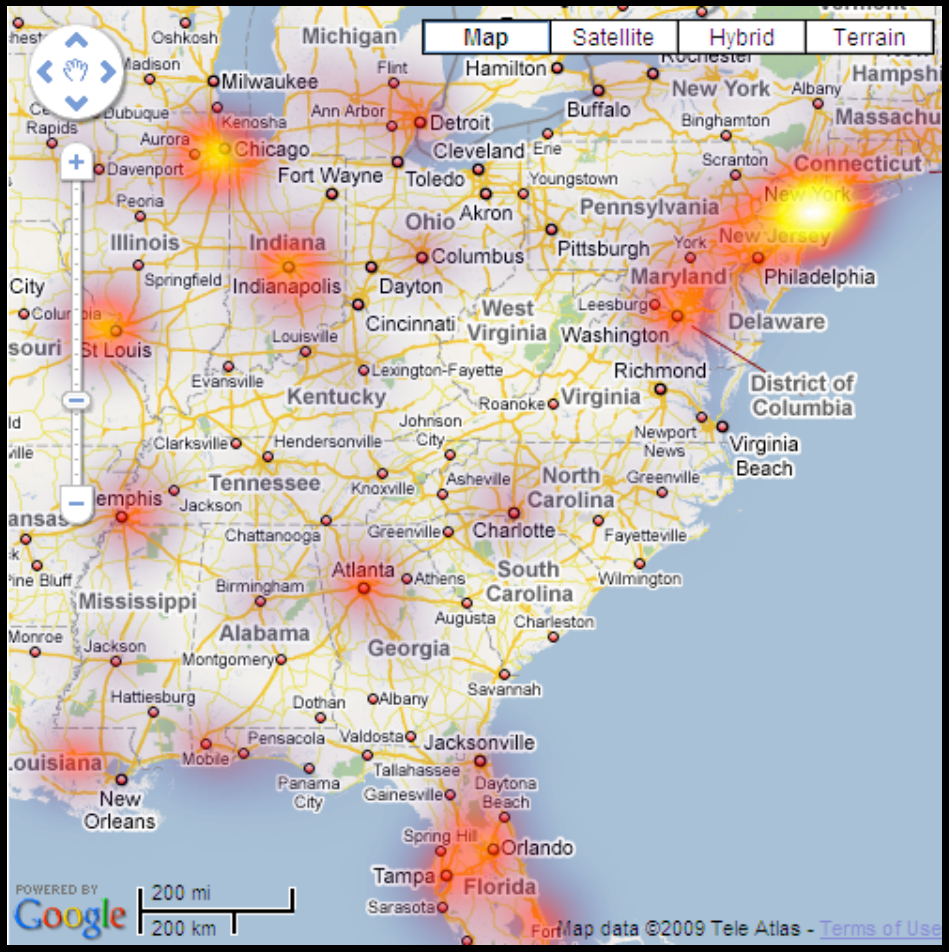
Convey Continuous Data

Binning



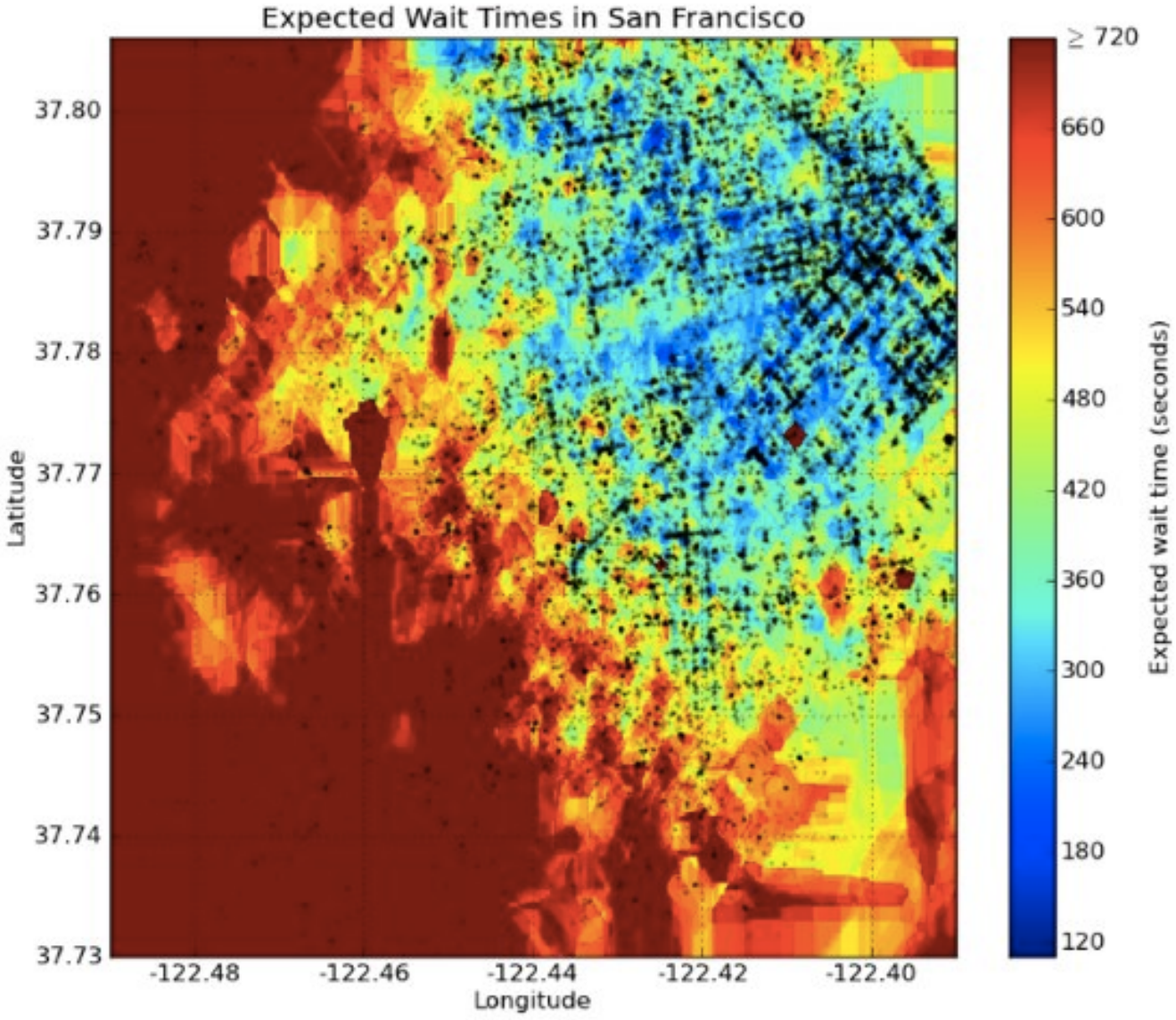
Chorodot Maps: Alan MacEachren and David DiBiase, 1991



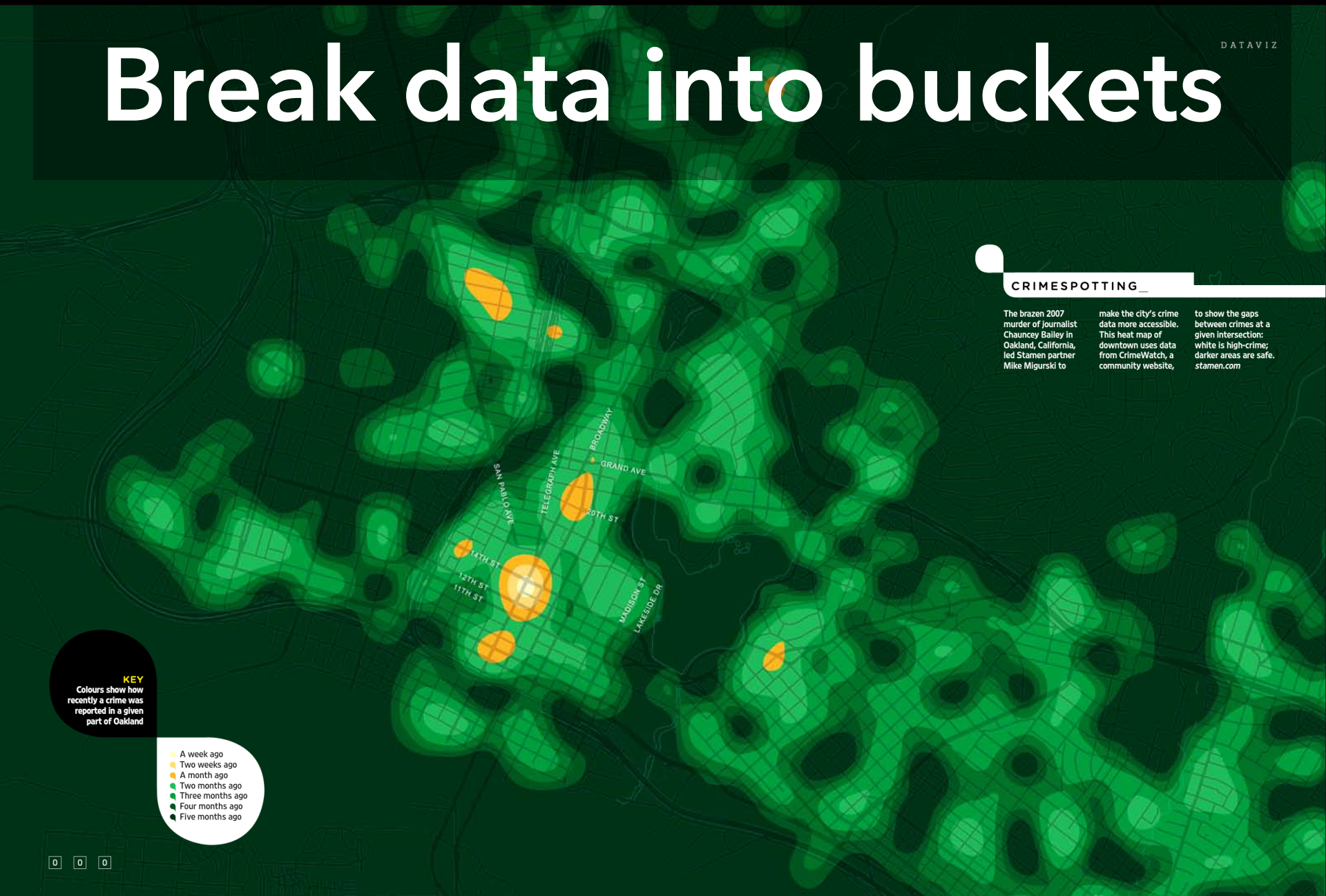


Don’t hide the context

Uber Wait Times, 2011



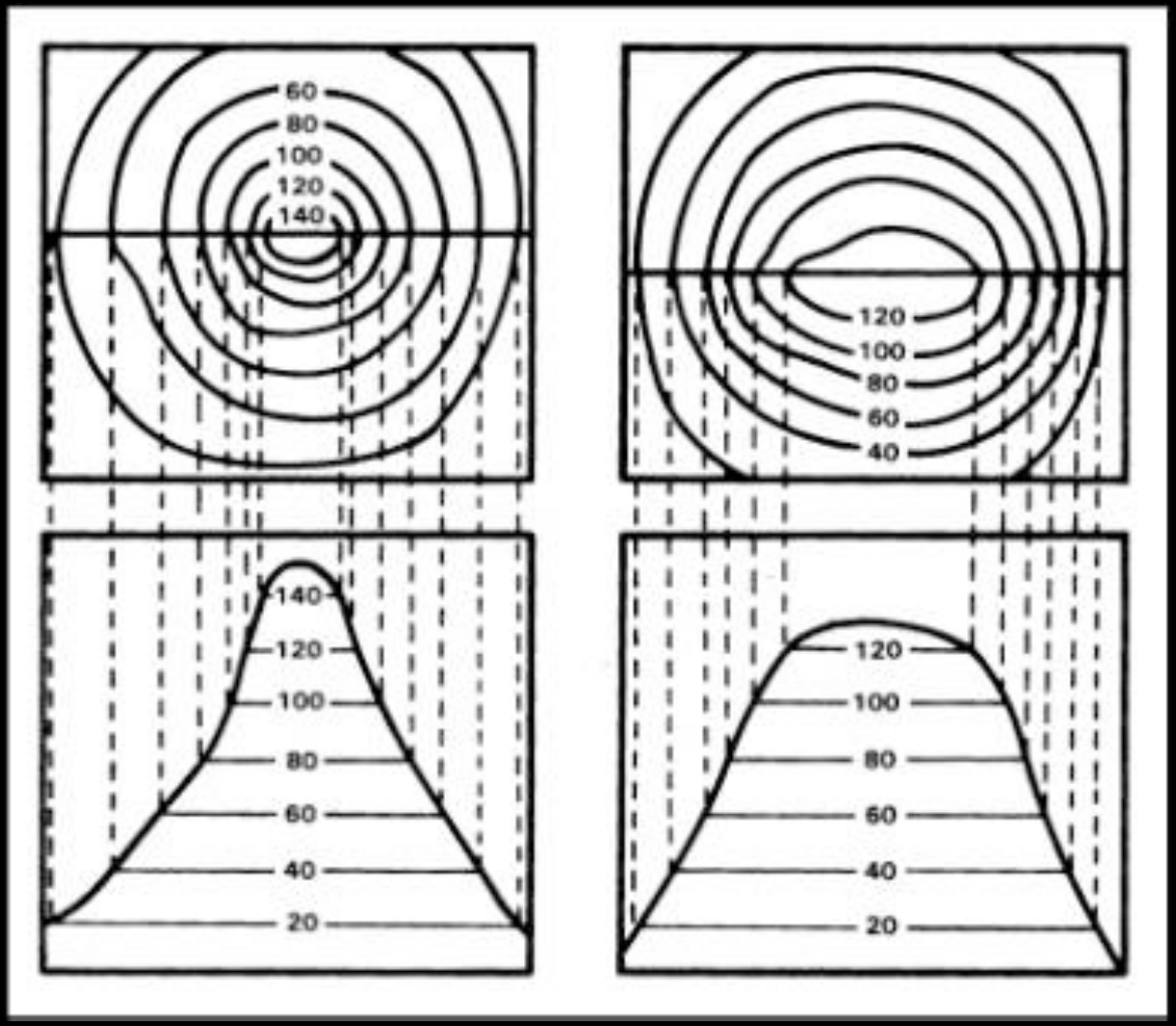
Break data into buckets

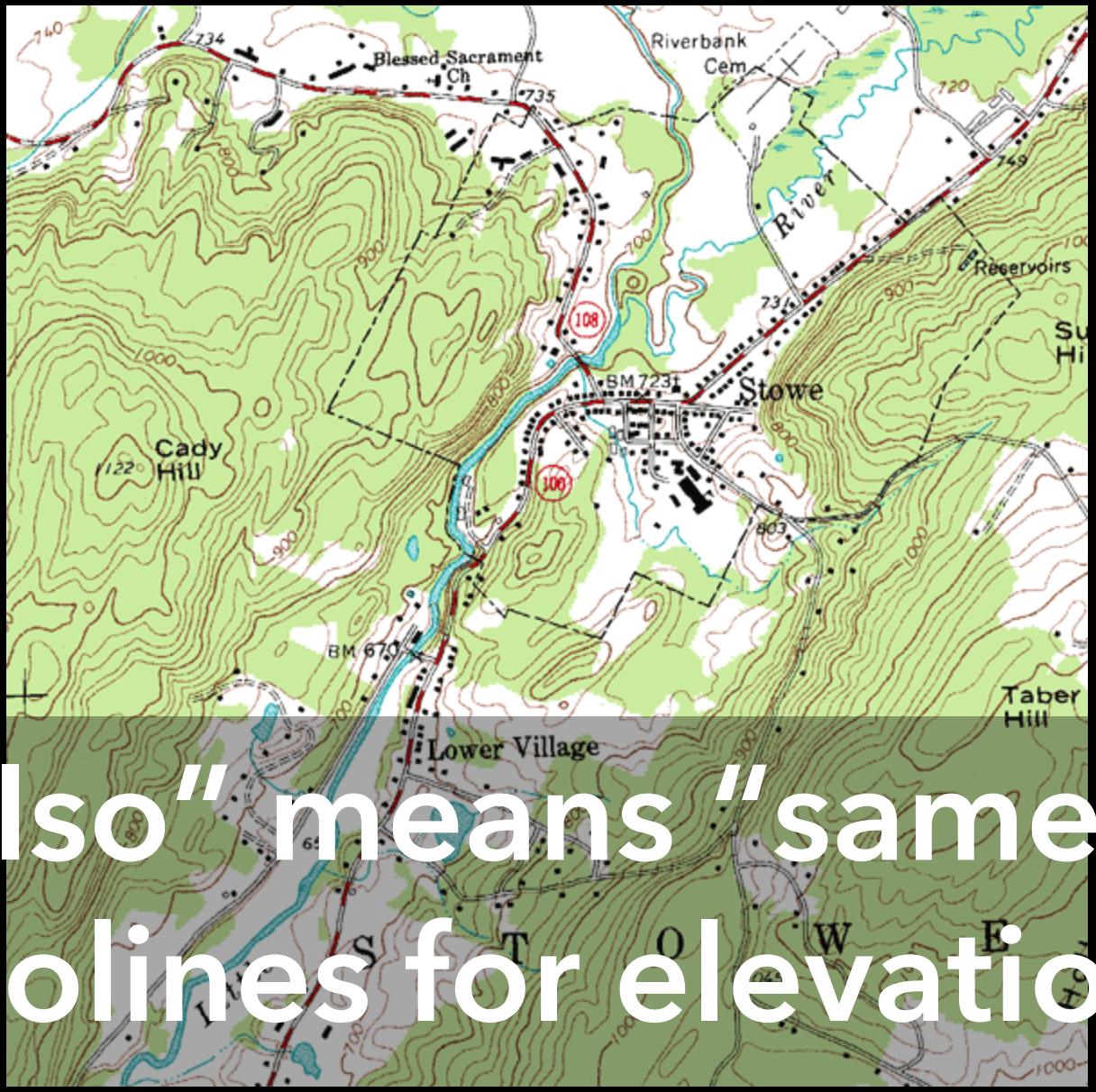


CRIMESPOTTING_

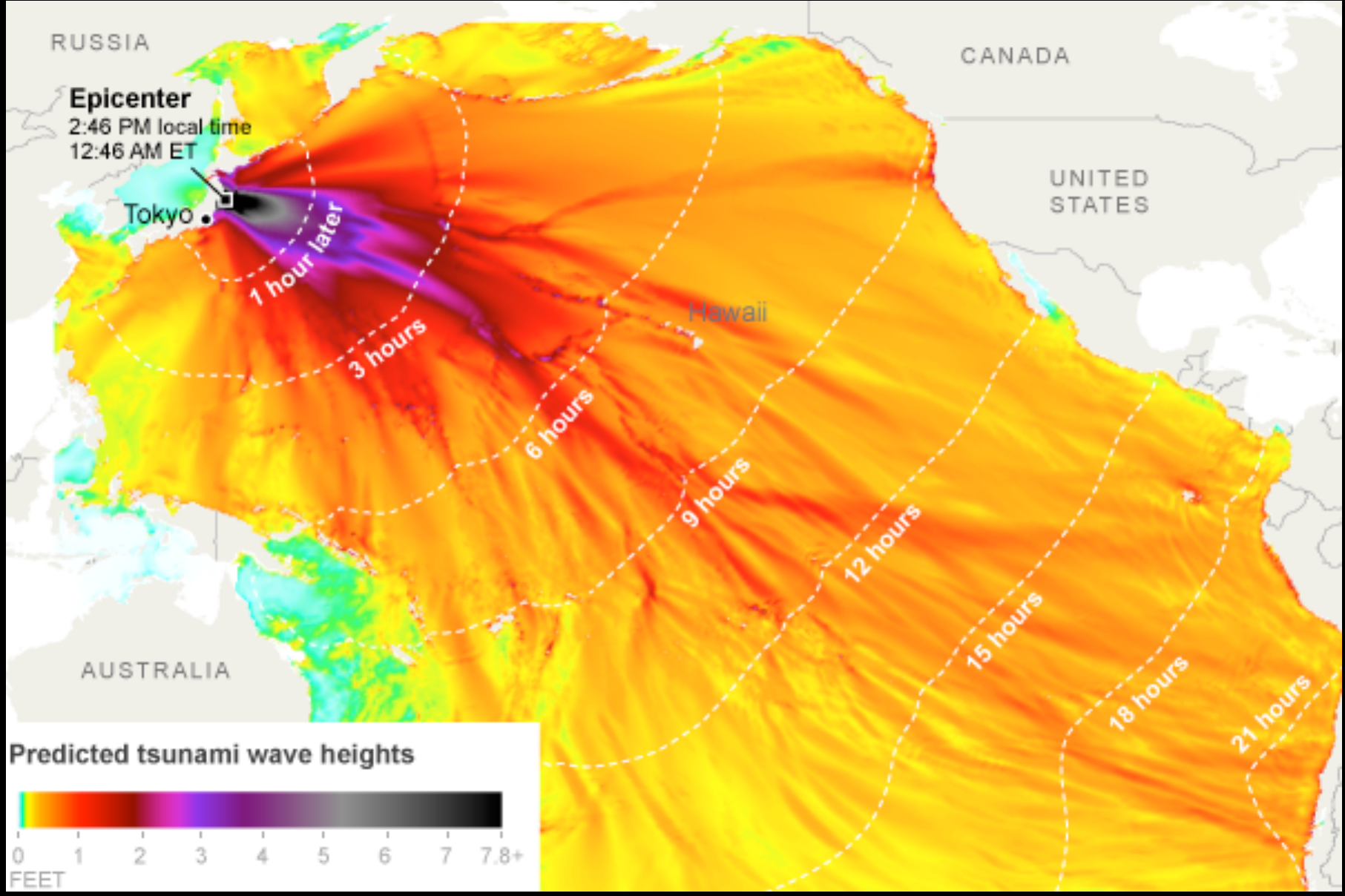
The brazen 2007 murder of journalist Chauncey Bailey in Oakland, California, led Stamen partner Mike Migurski to make the city's crime data more accessible. This heat map of downtown uses data from CrimeWatch, a community website, to show the gaps between crimes at a given intersection: white is high-crime; darker areas are safe. *stamen.com*

Meaningful buckets, isolines





"Iso" means "same"
Isolines for elevation

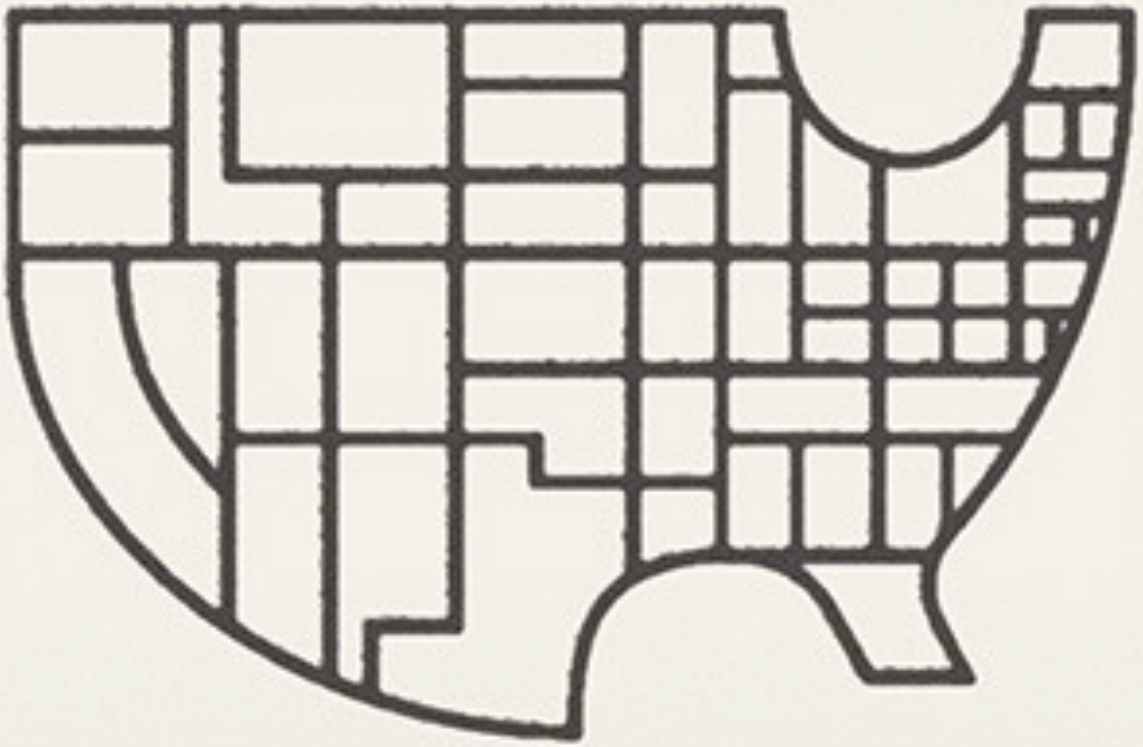


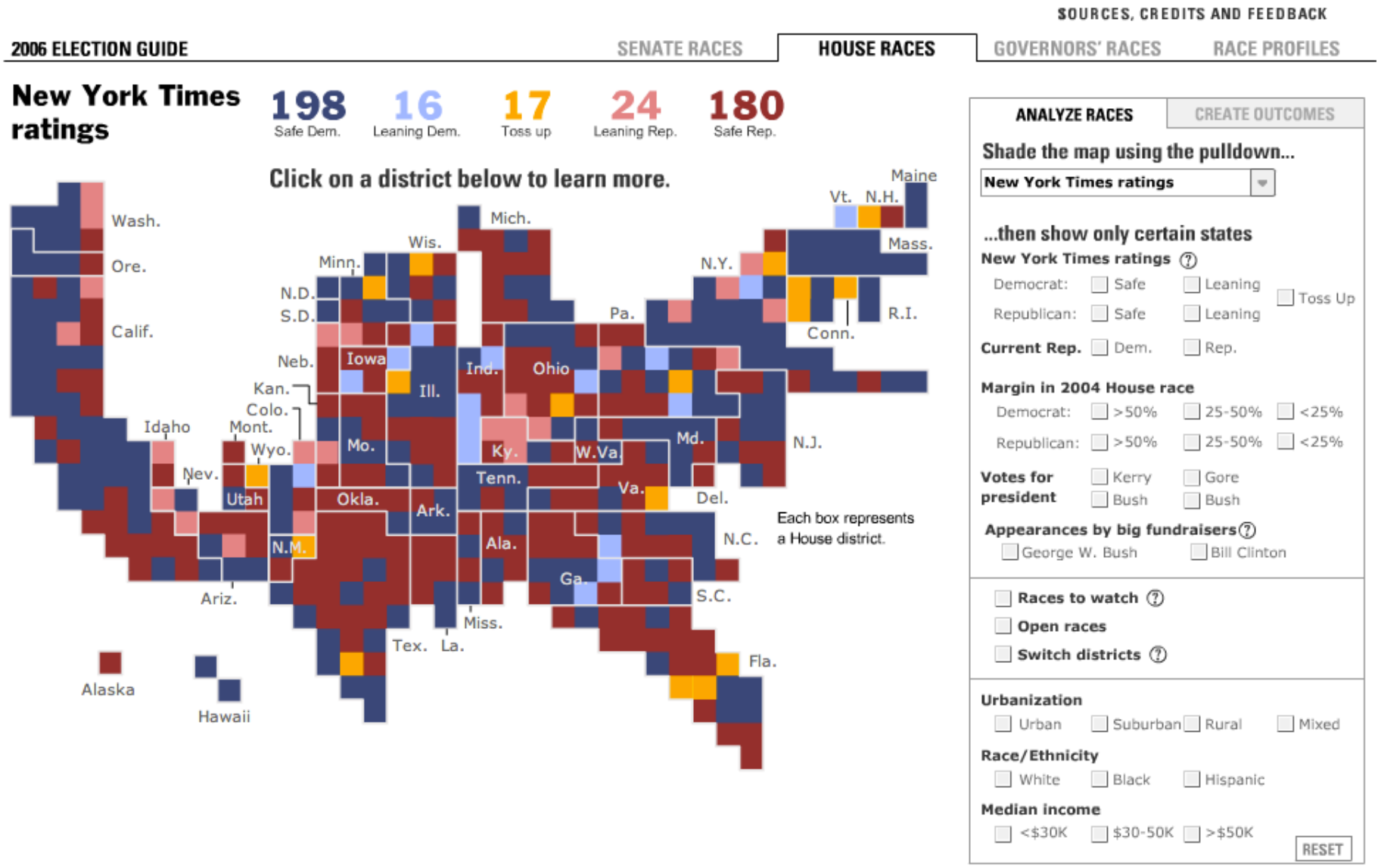
Isochrones are isolines for time

Cartograms

Distort Shape to Convey Quantities

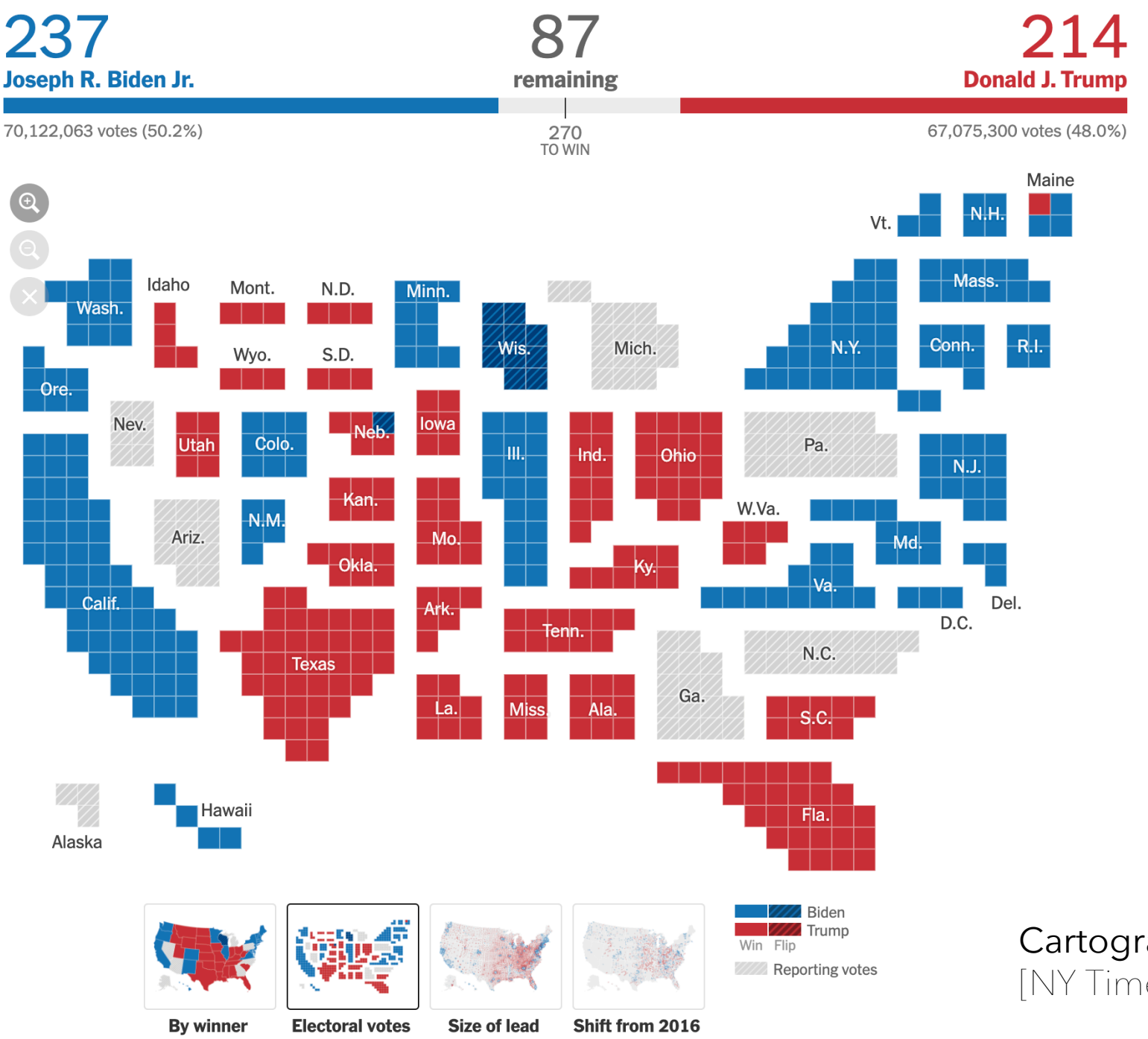
Major distortions can stay recognizable





Block Cartogram: Discrete Units

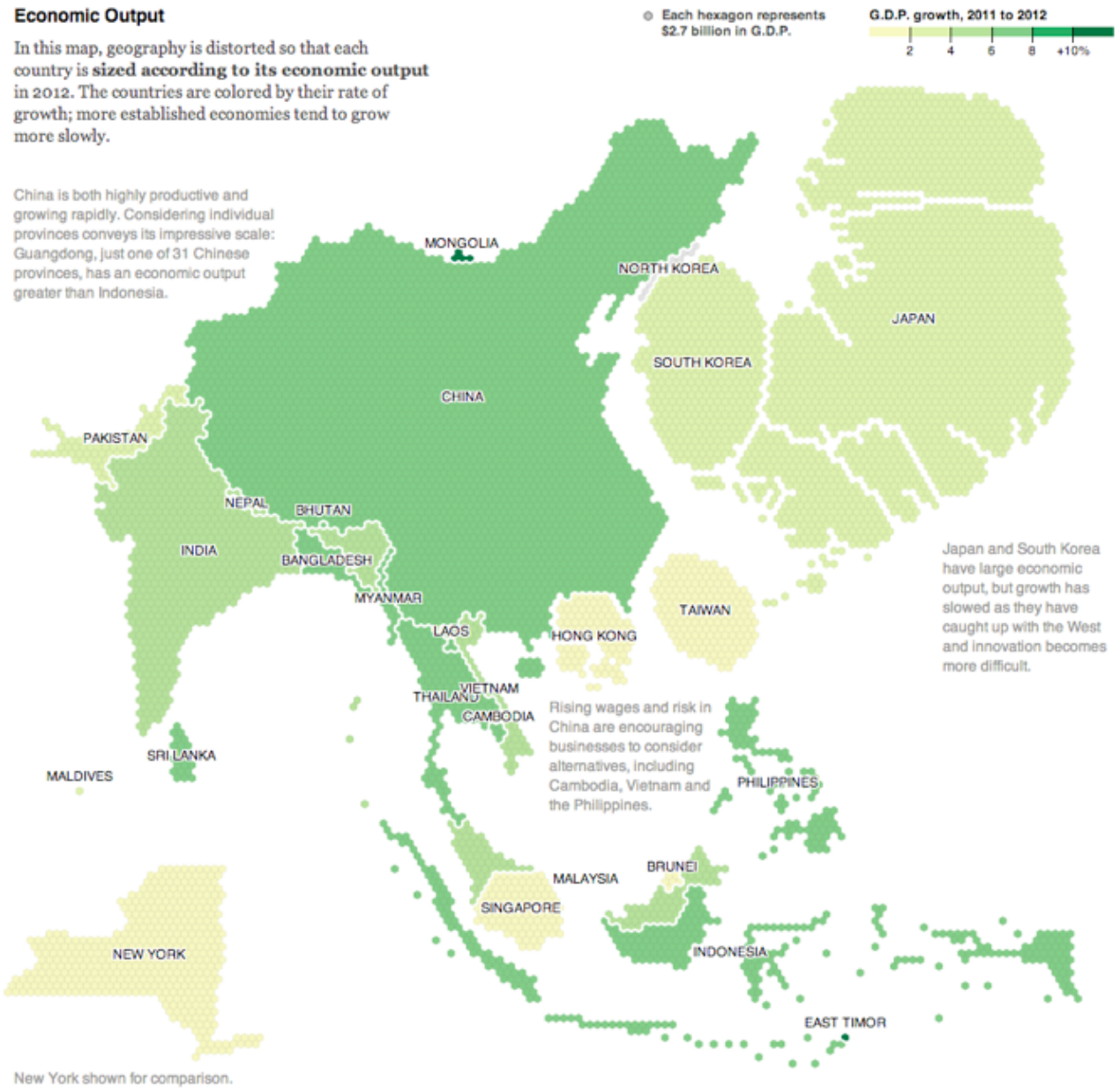
NY Times



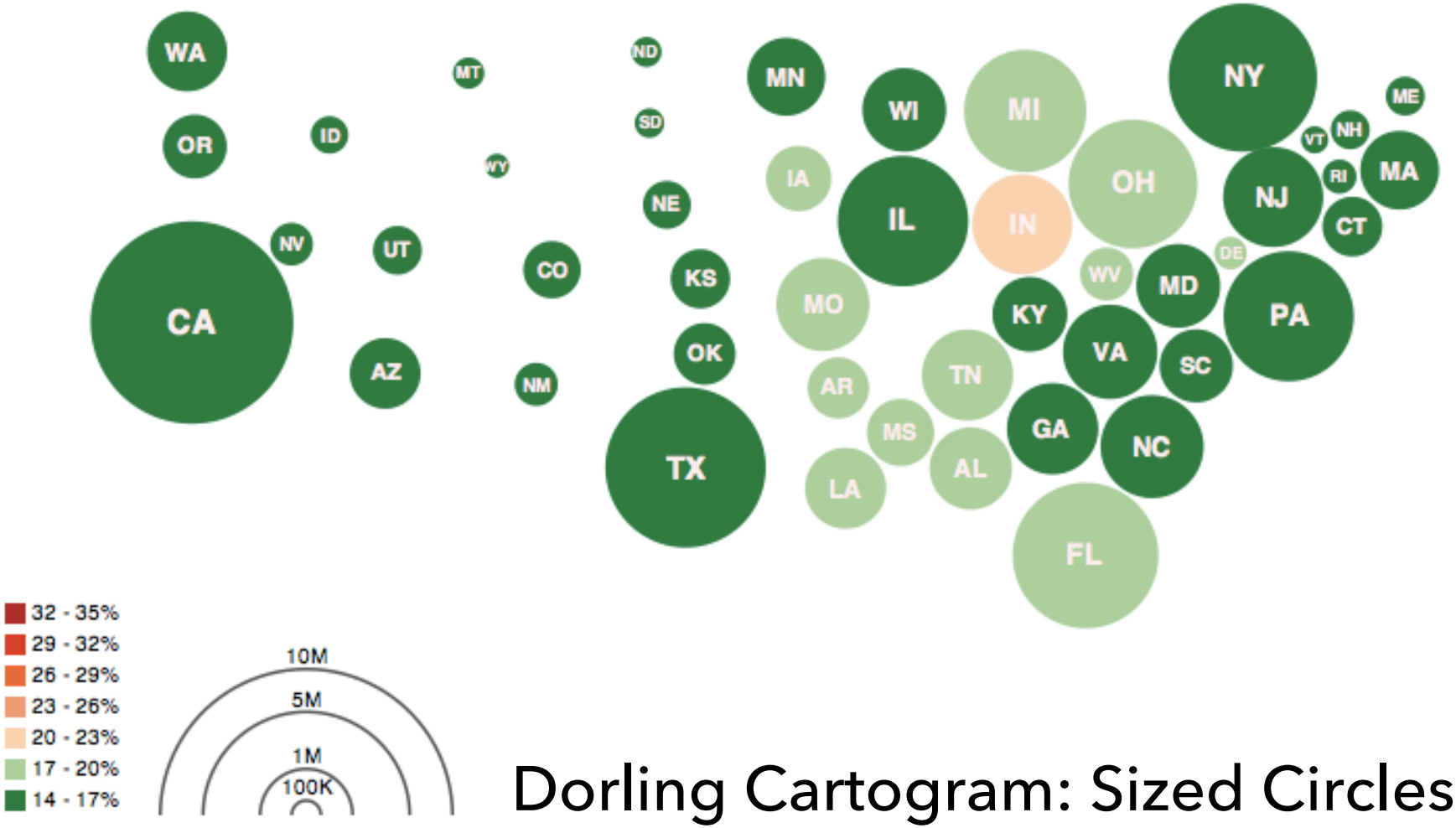
Cartogram
[NY Times]

China Still Dominates, but Some Manufacturers Look Elsewhere

While China maintains its overwhelming dominance in manufacturing, multinational companies are looking for ways to limit their reliance on factories there. Related Article »

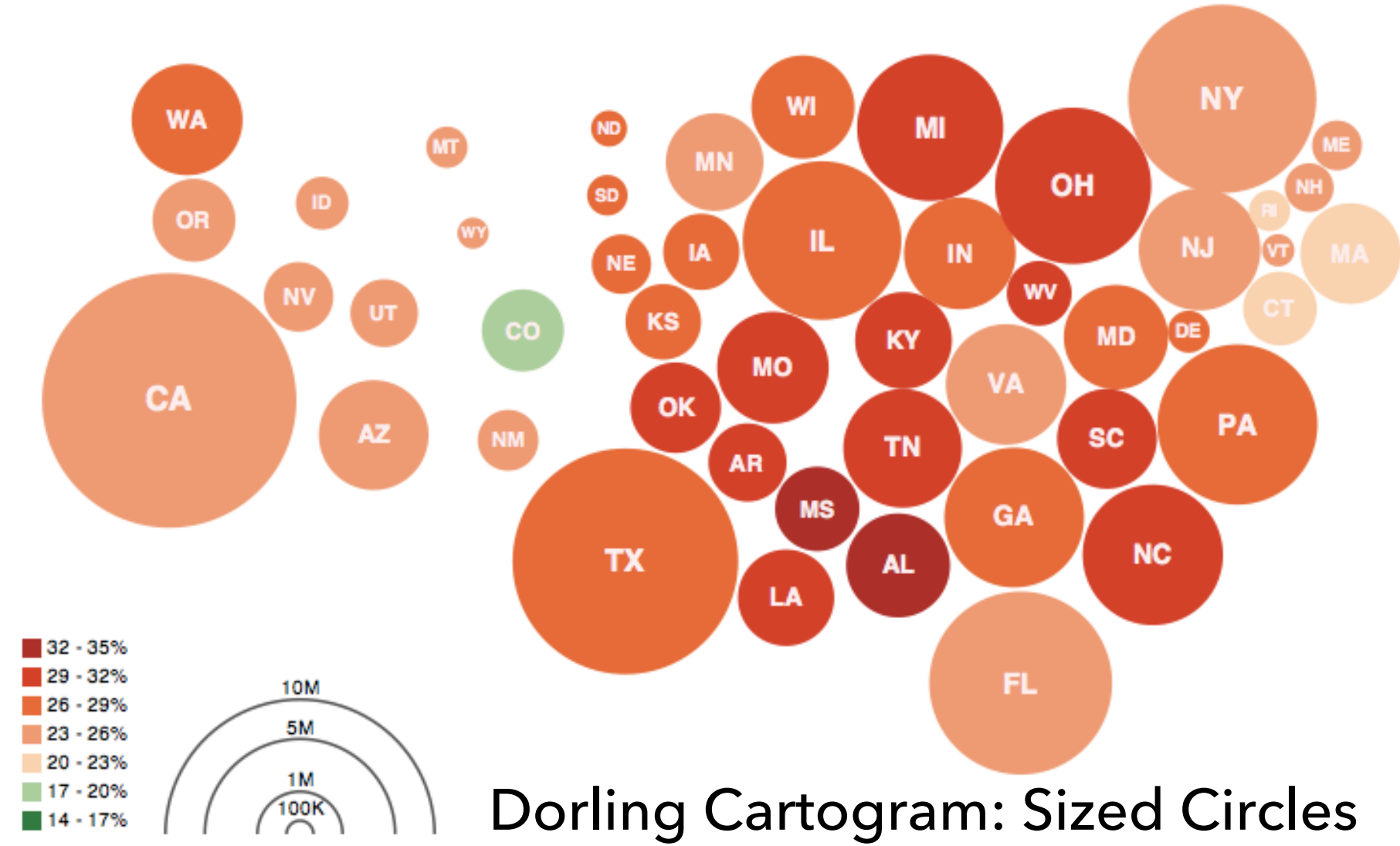


NY Times



Dorling Cartogram: Sized Circles

Obesity Map Vadim Ogievetsky



Dorling Cartogram: Sized Circles

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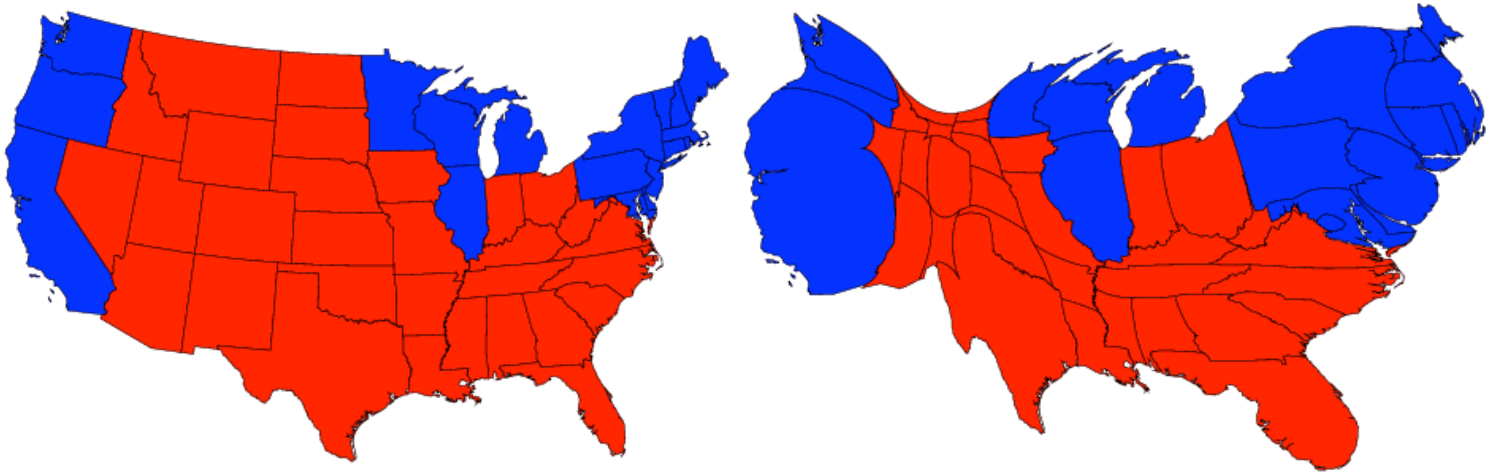
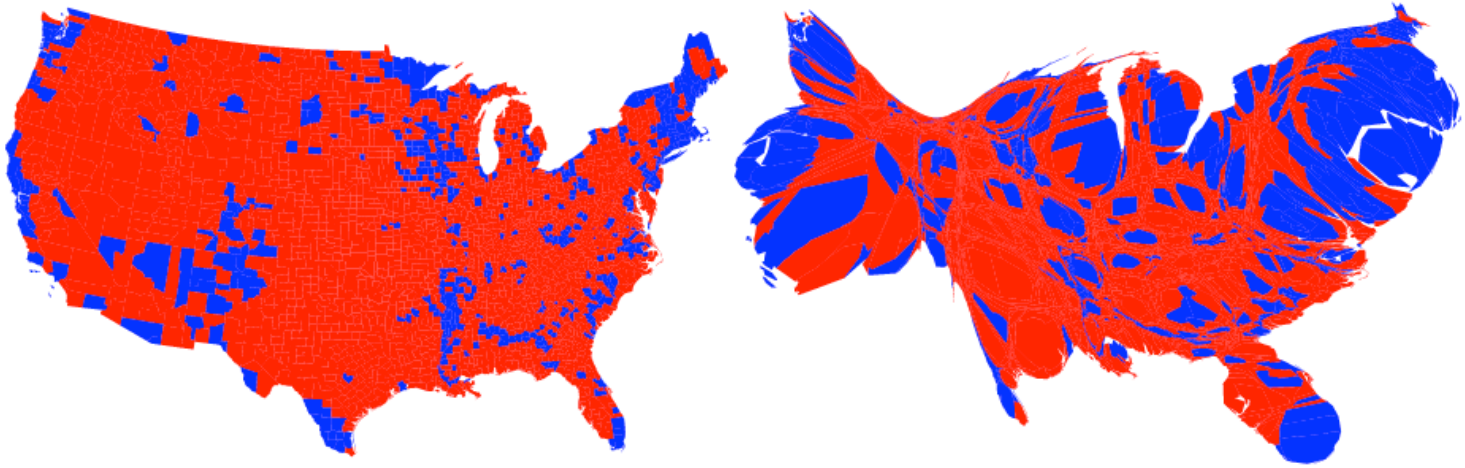
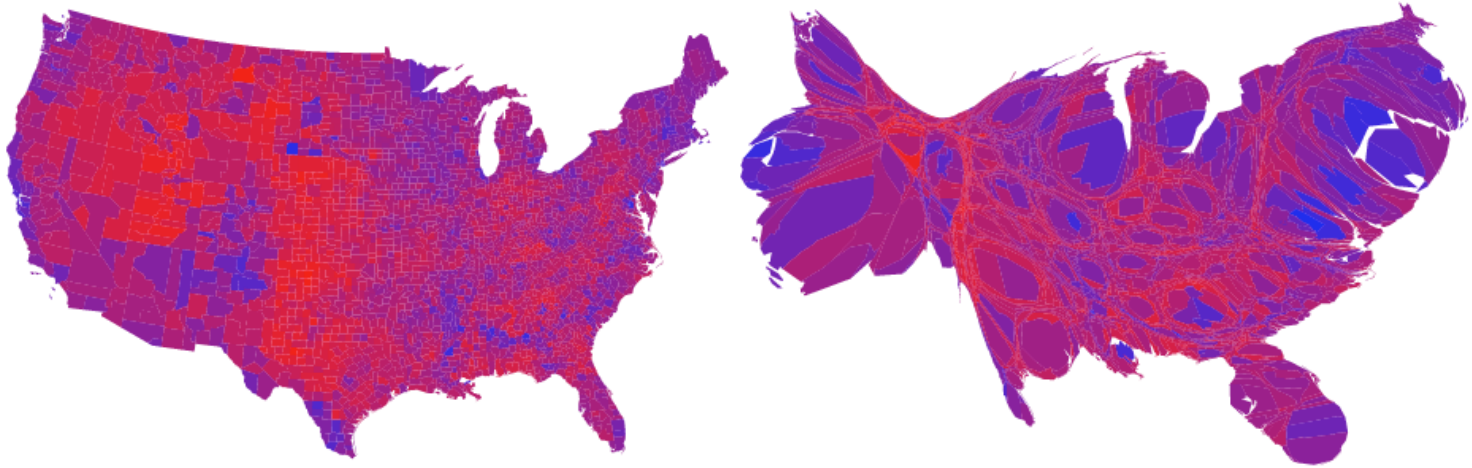


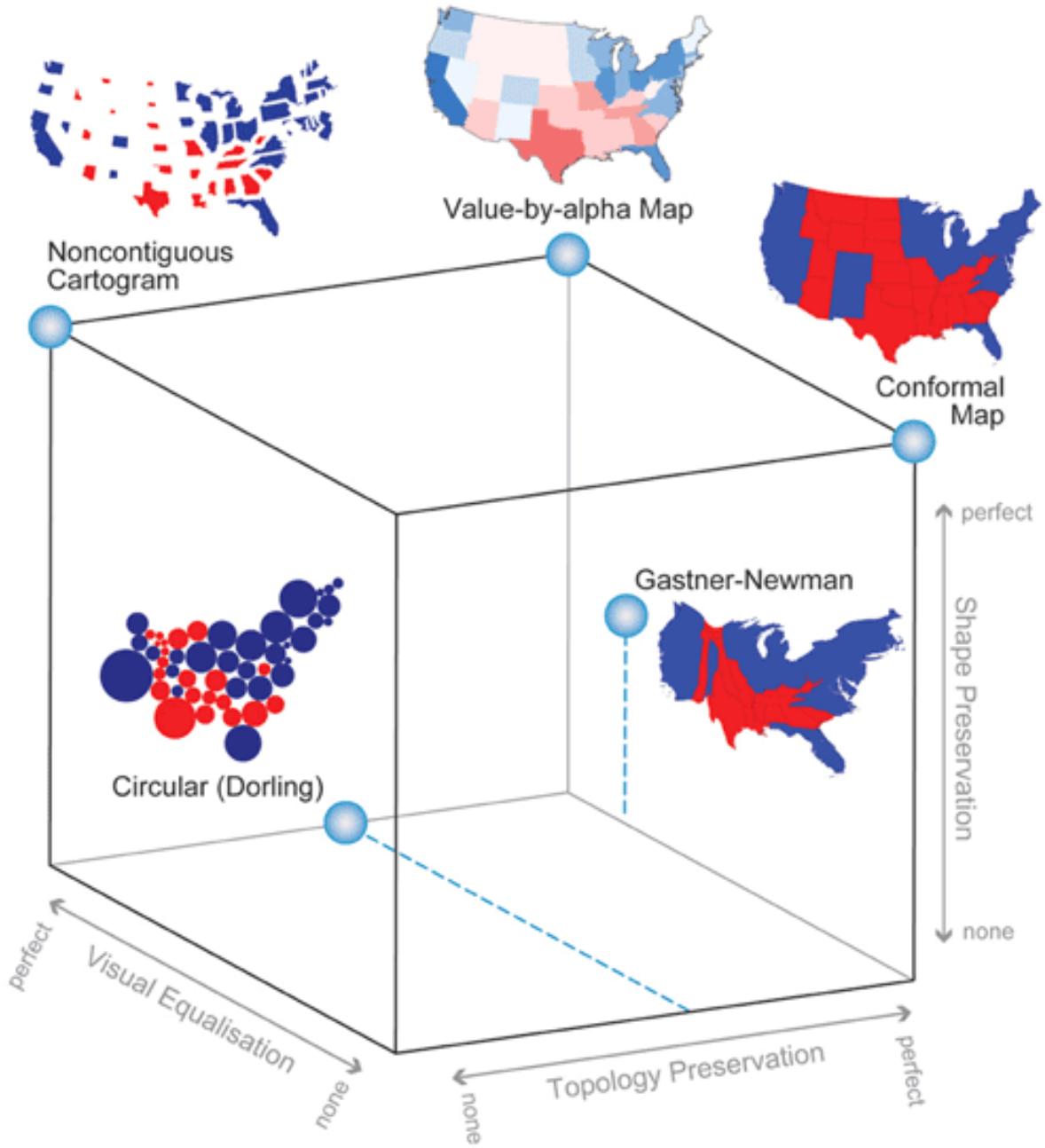




Physical Diffusion Model

[Newman 2004]

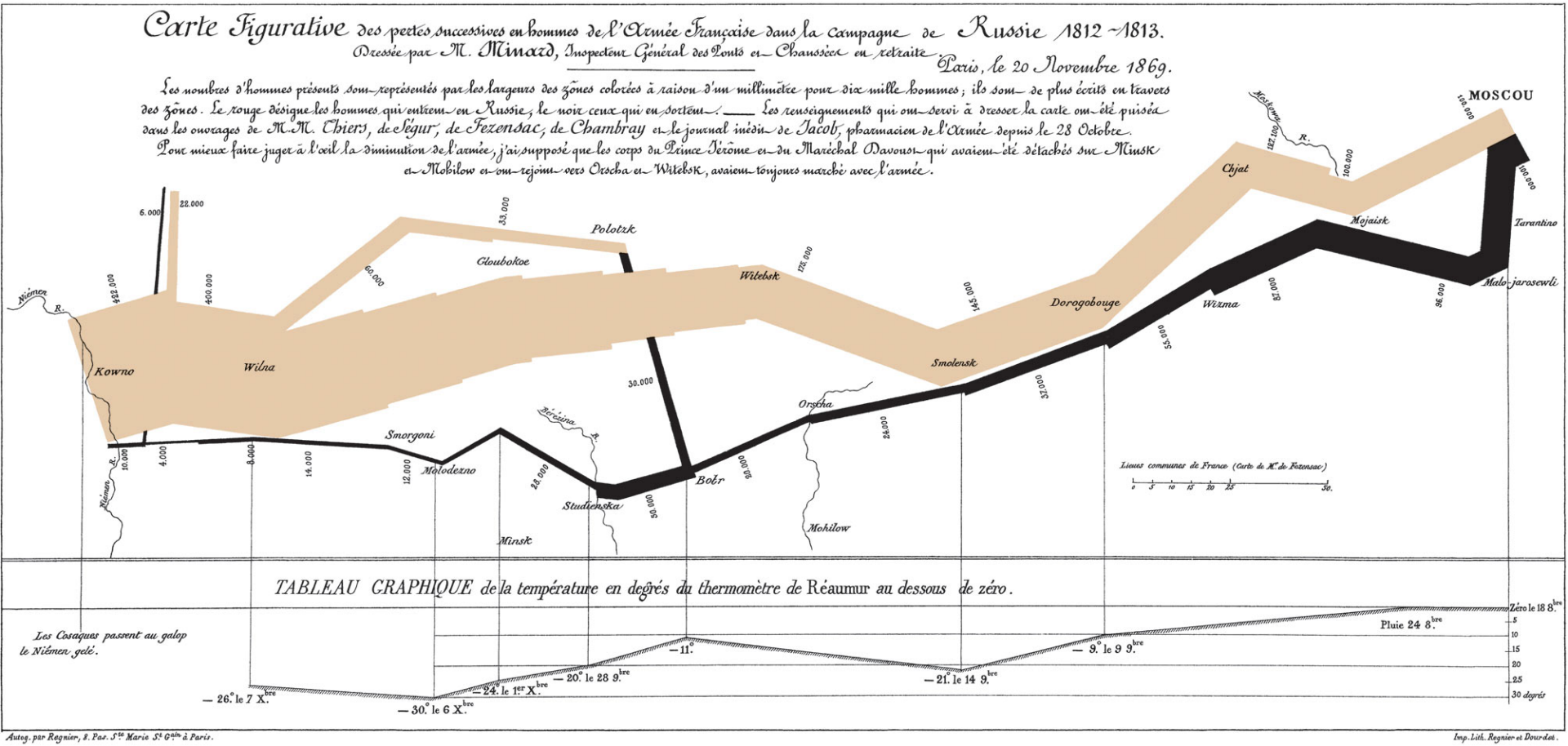
http://sta.mn/wz

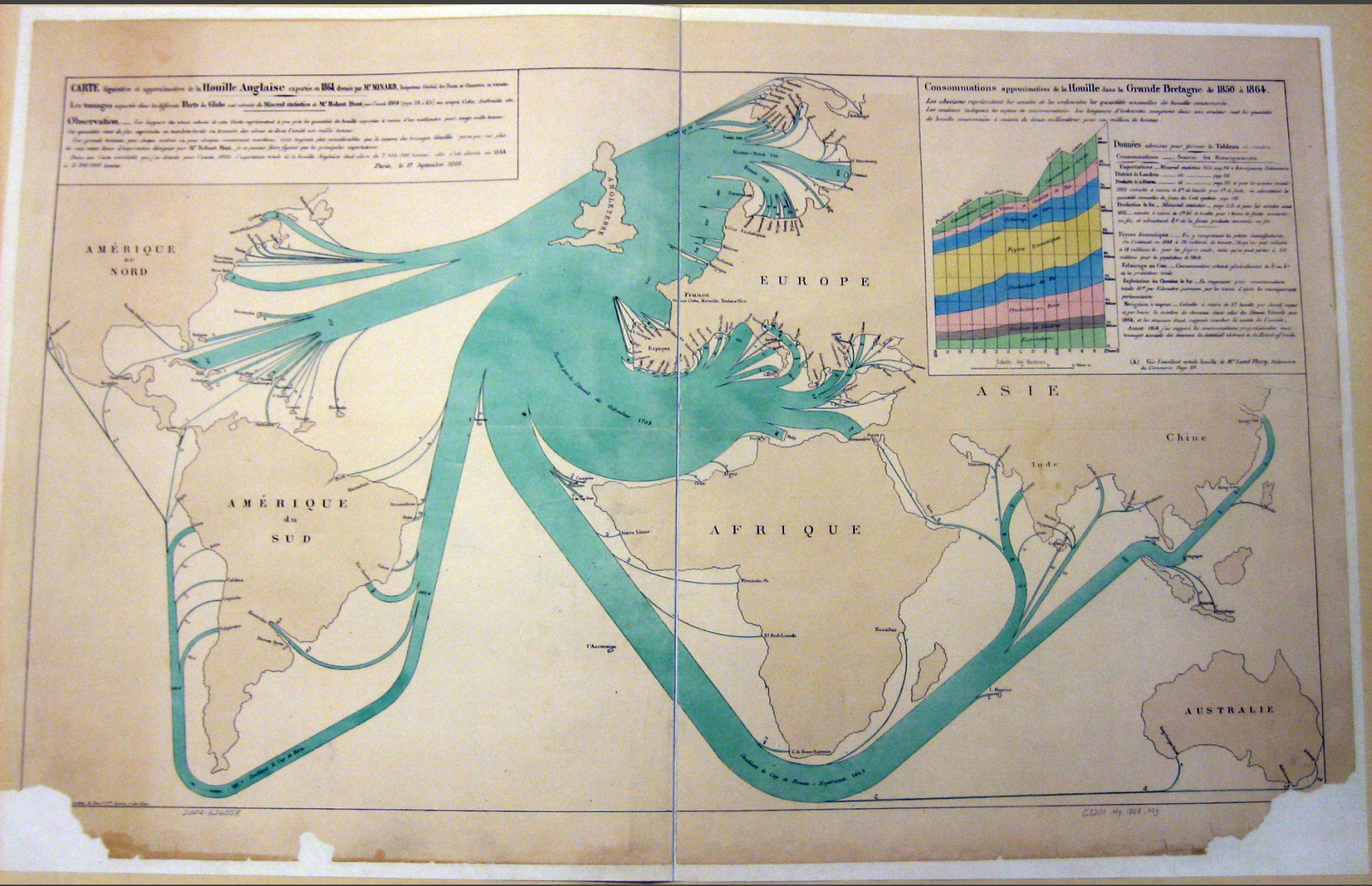


Flow Maps

Convey Flux Between Locations

Minard 1869: Napoleon's march

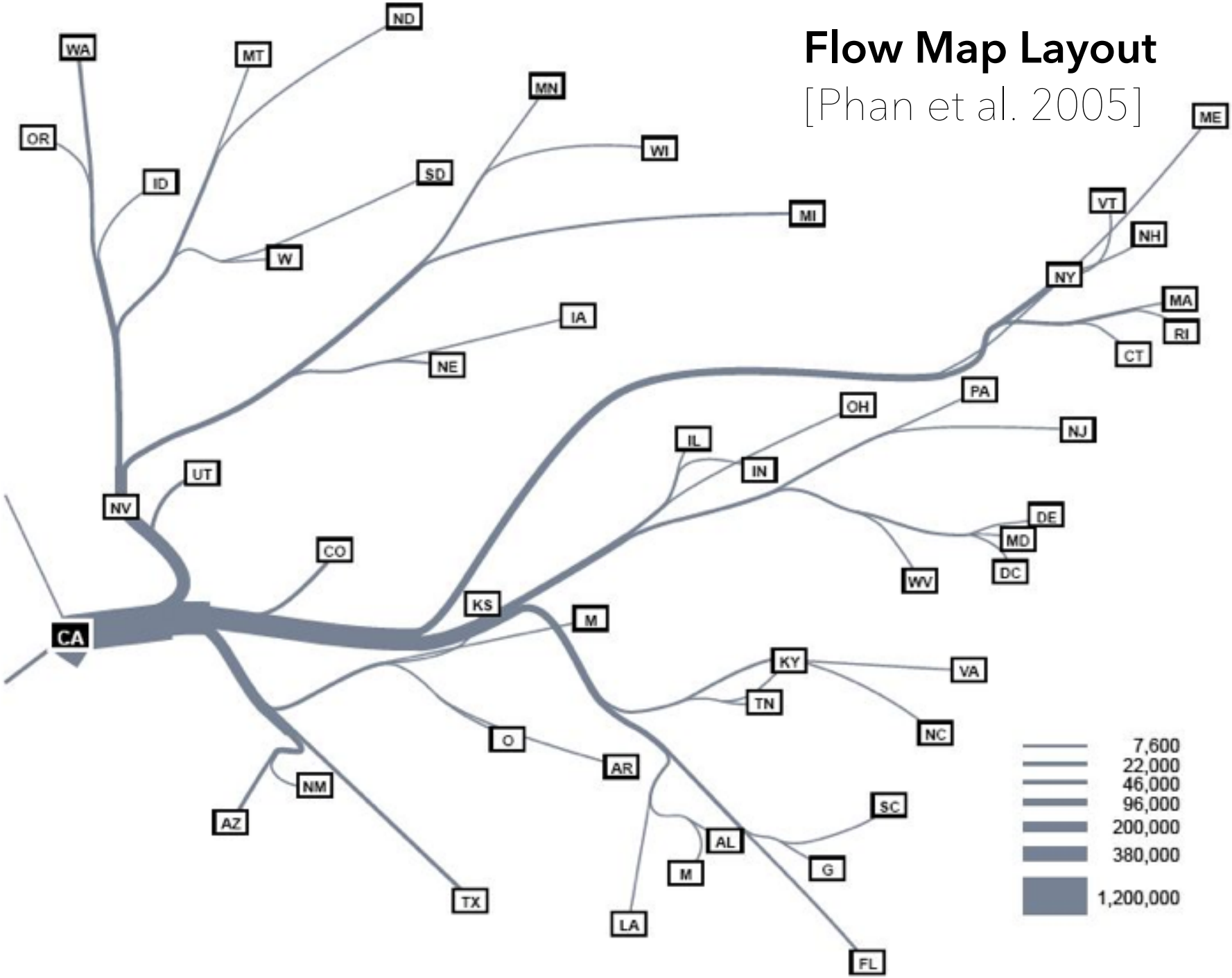




1864 British Coal Exports, Charles Minard

Flow Map Layout

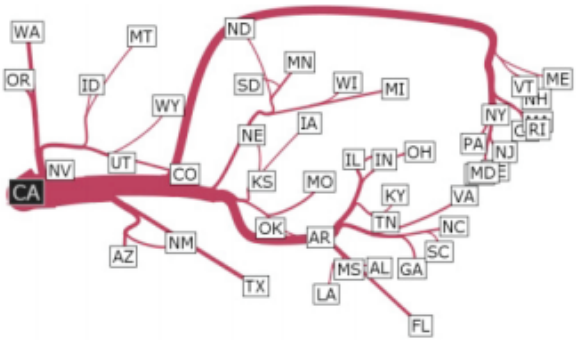
[Phan et al. 2005]



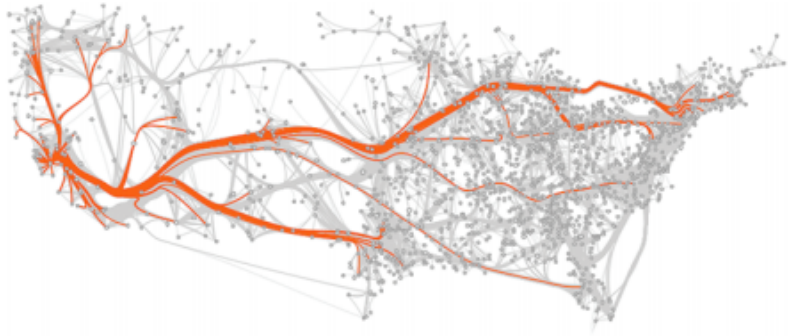
Migration from California, ’95-’00

Tobler 1987

Phan et al. 2005



Verbeek et al. 2011



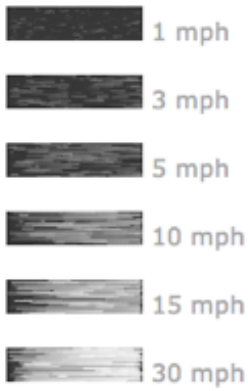
Cui et al. 2008

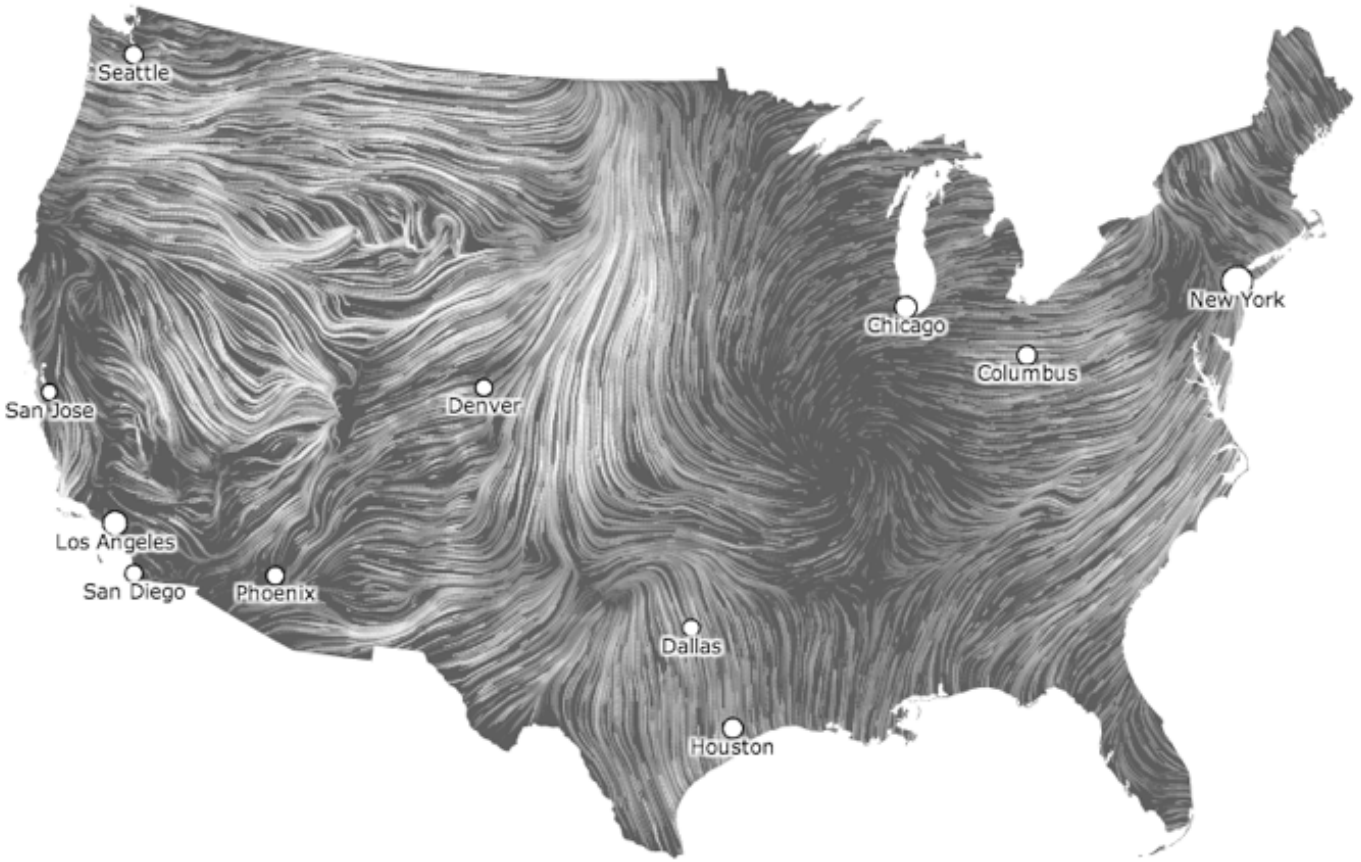
Holten & van Wijk 2009

wind map

February 19, 201
11:55 am EST
(time of forecast download)

top speed: **35.3 mph**
average: **11.6 mph**





Wattenberg & Viegas

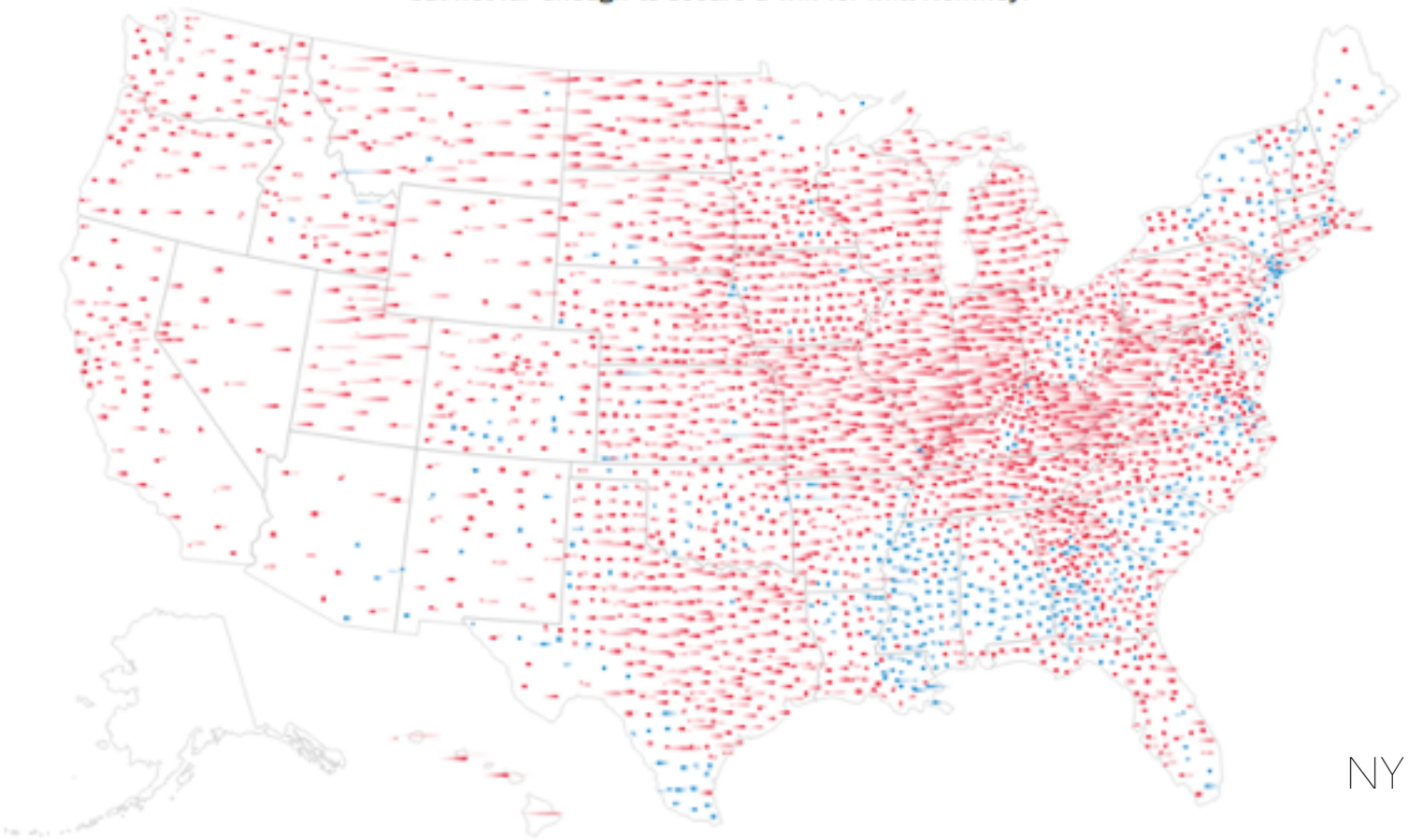
How Obama Won Re-election

Whites Were Outvoted | Women | Hispanics | Youth

Romney's Shift Wasn't Enough

2008 | 2012

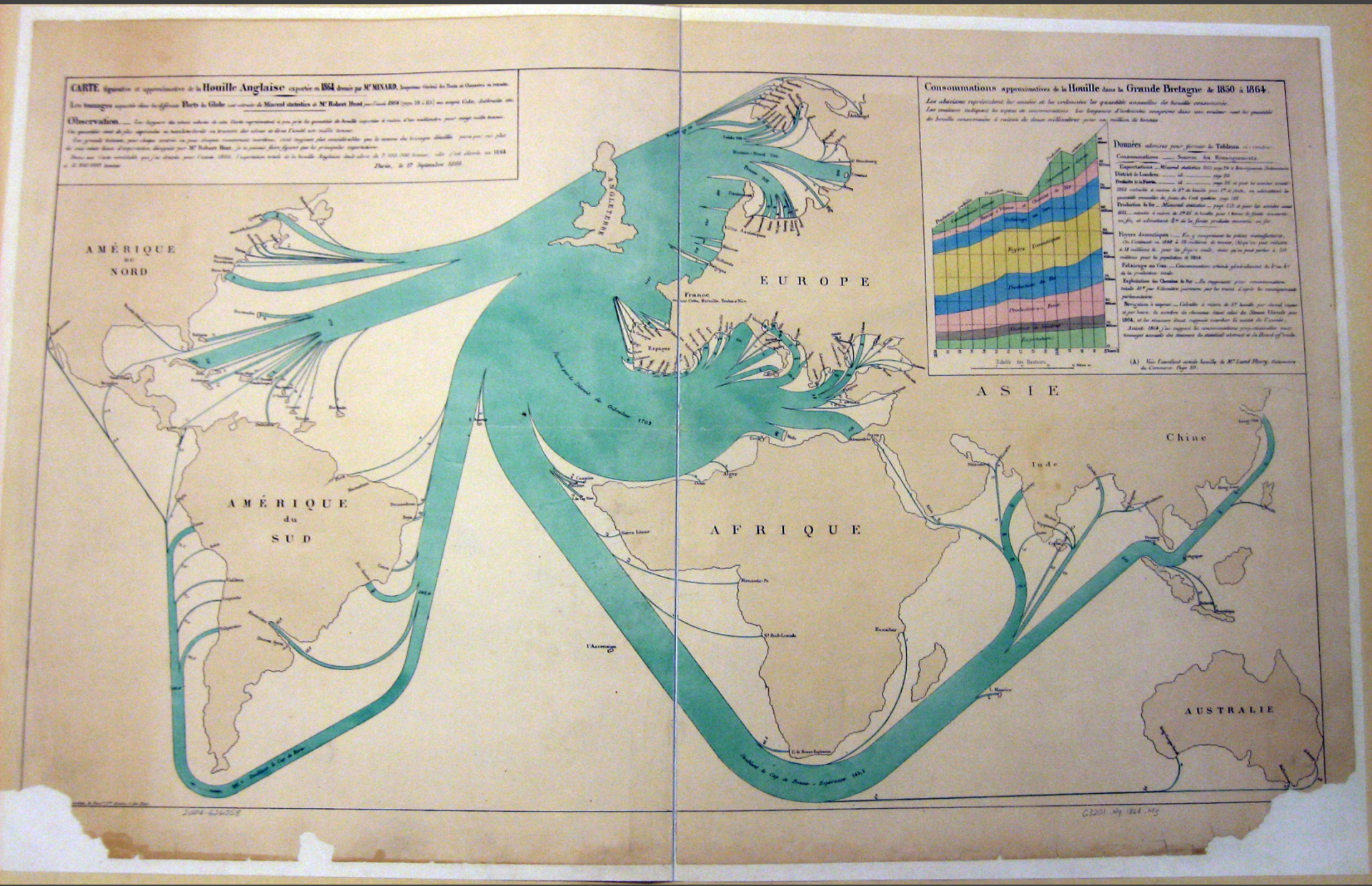
Most of the nation shifted to the right in Tuesday's vote, but not far enough to secure a win for Mitt Romney.



NY Times

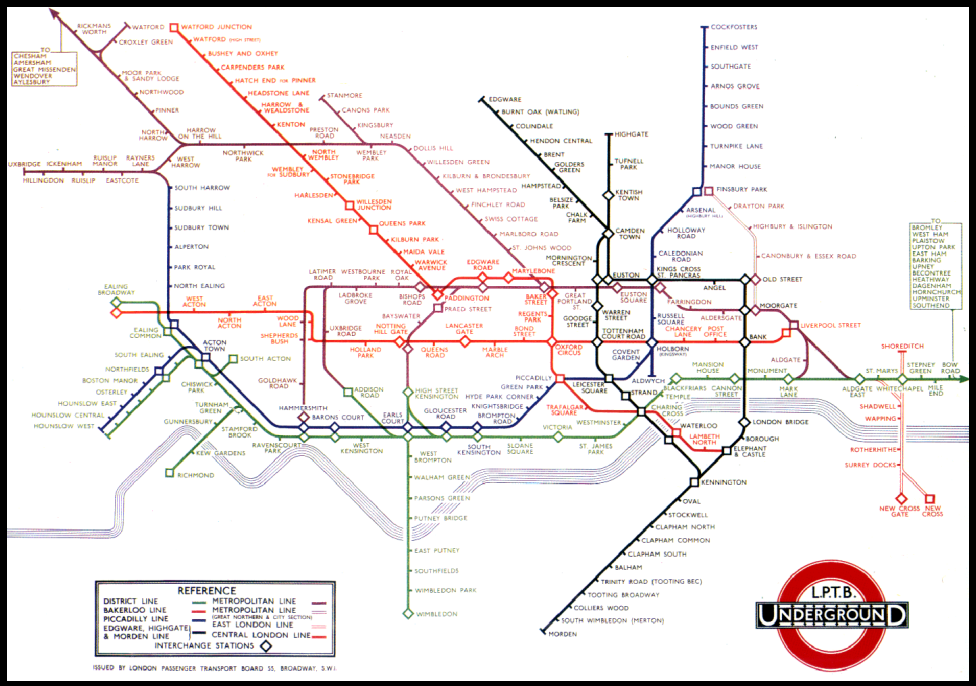
Generalization

Abstraction to Convey Topology

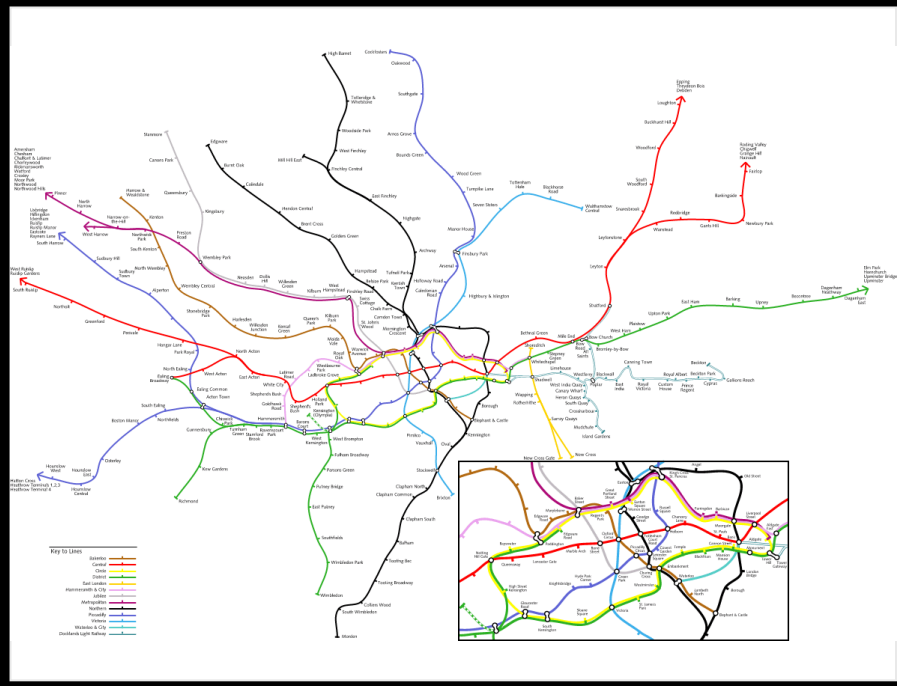


1864 British Coal Exports, Charles Minard

Beck's London tube diagram



London Underground [Beck 33]



Geographic version of map

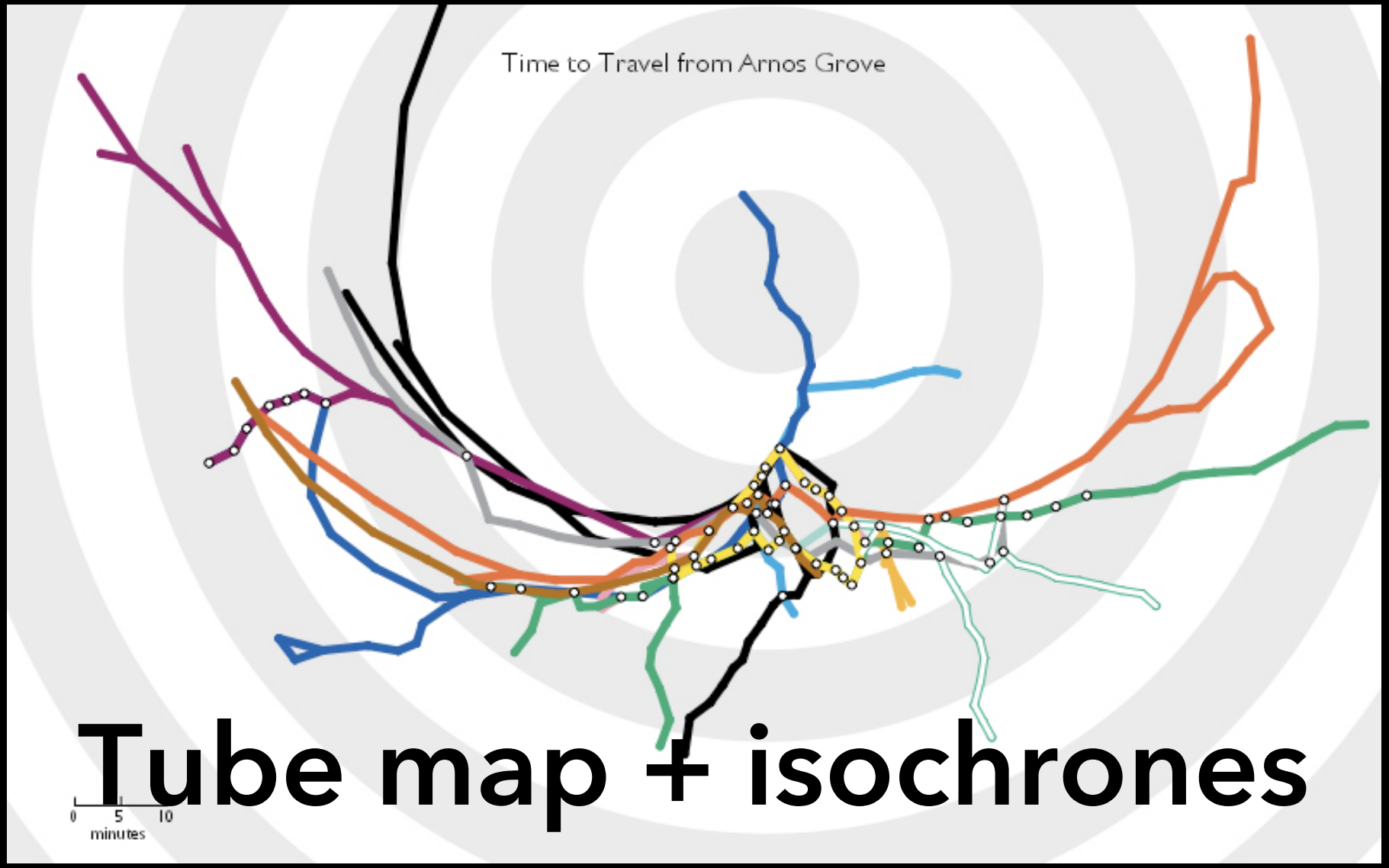
Principle: Straighten lines to emphasize stop sequence

Technique used to emphasize/de-emphasize information

People ***love*** tube maps…

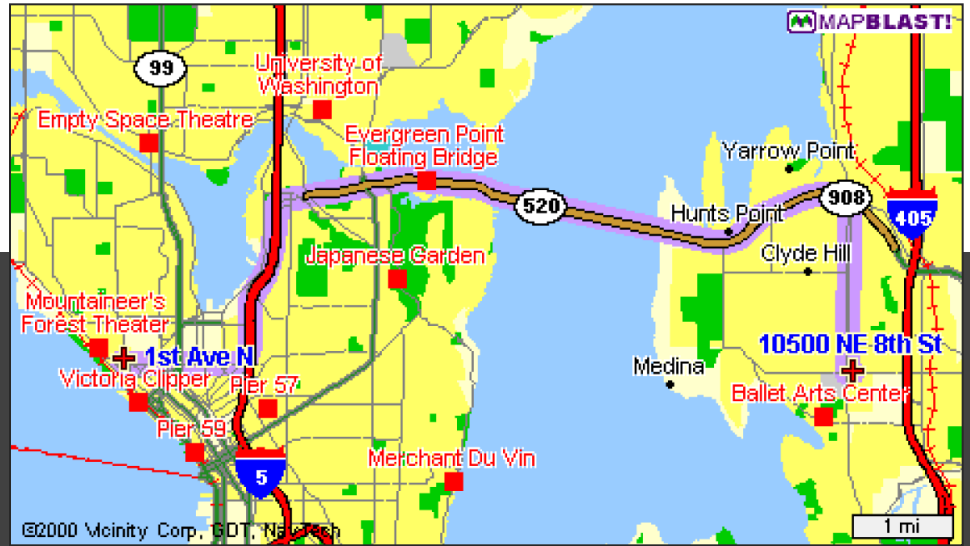
[Huffman]

http://sta.mn/nb



Tube map + isochrones

Route Maps: Bellevue to Seattle



Map Design via Optimization [Agrawala '01]

Set of graphic elements

Roads, labels, cross-streets, …

Choose visual attributes

Position, orientation, size, …

Distortions increase flexibility

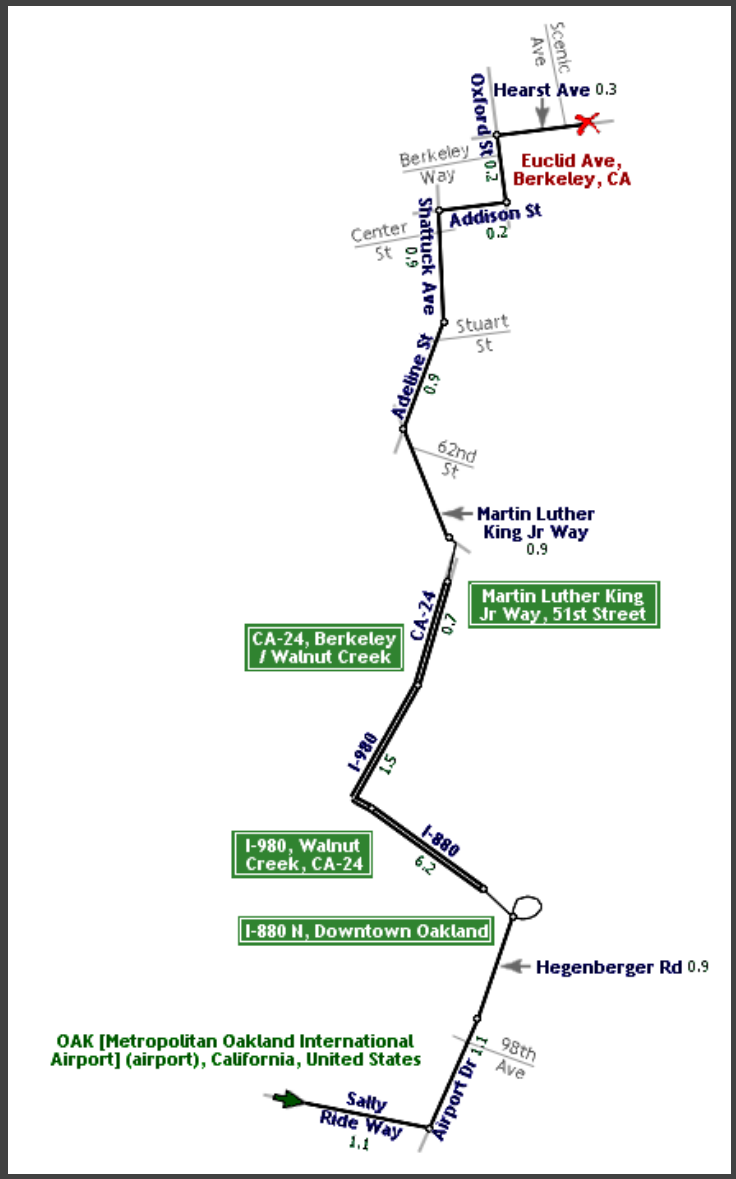
Develop constraints based on design principles

Simulated annealing

Perturb: Form a layout

Score: Evaluate quality

Minimize score



Road Layout Constraints [Agrawala '01]

Length

Ensure all roads visible $((L_{min} - l(r_i)) / L_{min})^2 * W_{small}$

Maintain ordering by length $W_{shuffle}$

Orientation

Maintain original orientation $|a_{curr}(r_i) - a_{orig}(r_i)| * W_{orient}$

Topological errors

Prevent false $\min(d_{origin}, d_{dest}) * W_{false}$

Prevent missing $d * W_{missing}$

Ensure separation $\min(d_{ext}, E) * Ext$

Overall route shape

Maintain endpoint direction $|a_{curr}(v) - a_{orig}(v)| * W_{enddir}$

Maintain endpoint distance $|d_{curr}(v) - d_{orig}(v)| * W_{enddist}$

Summary

Map visualizations reconcile competing goals

- Rendering geographic information (e.g., latitude, longitude, elevation)
- Rendering abstract information (e.g., population, political orientation, exports)

Map visualization types emphasize different encoding channels in response

- Size and color encodings are common

There are always tradeoffs in accuracy vs. clarity

- Projections sacrifice accuracy along some geographic properties to preserve others
- Sacrificing some geographic accuracy can improve clarity of abstract information (e.g. metro maps, cartograms)

Tools

Software Tools

Web Tools

d3-geo: projections, paths and more
GeoJSON: JSON format for geo data
TopoJSON: topology -> compressed GeoJSON
MapShaper: online editor for map data
Leaflet: open-source, customizable map tile system

Other

PostGIS: Postgres DB extensions for geo data
Mapnik: Render your own map tiles!

Data Resources

Natural Earth Data
naturalearthdata.com

OpenStreetMap
openstreetmap.org

U.S. Government
nationalatlas.gov, census.gov, usgs.gov

Tutorials

Cartographic Visualization in Vega-Lite

https://observablehq.com/@uwdata/cartographic-visualization

Command-Line Cartography

https://medium.com/@mbostock/command-line-cartography-part-1-897aa8f8ca2c

How to Infer Topology

http://bost.ocks.org/mike/topology/

Administrivia

A2 Peer Reviews

On Friday 10/21 you will be assigned two peer A2 submissions to review. For each:

- Try to determine which is earnest and which is deceptive
- Share a rationale for how you made this determination
- Share feedback using the “I Like / I Wish / What If” rubric

Assigned reviews will be posted on the A2 Peer Review page on Canvas, along with a link to a Google Form. You should submit two forms: one for each A2 peer review.

Due by **Mon 10/24 11:59pm**.

I Like… / I Wish… / What If?

I LIKE…
Praise for design ideas and/or well-executed implementation details. *Example: "I like the navigation through time via the slider; the patterns observed as one moves forward are compelling!"*

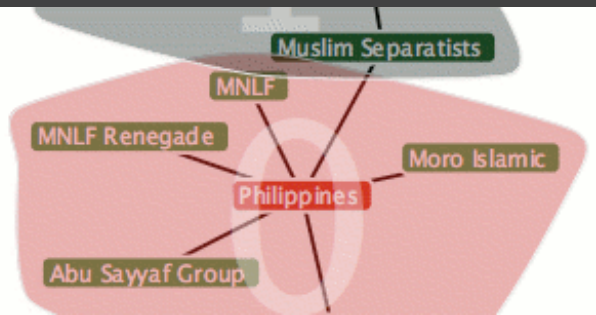
I WISH…
Constructive statements on how the design might be improved or further refined. *Example: "I wish moving the slider caused the visualization to update immediately, rather than the current lag."*

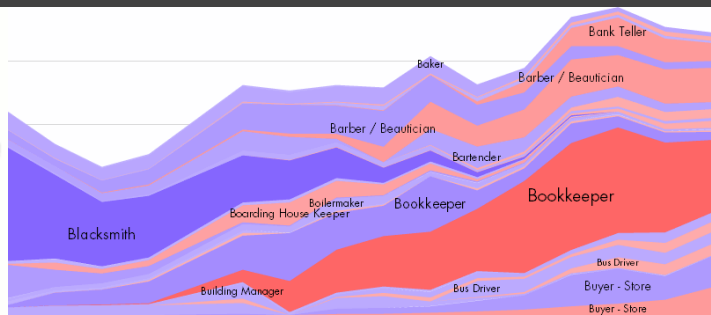
WHAT IF?
Suggest alternative design directions, or even wacky half-baked ideas. *Example: "What if we got rid of the slider and enabled direct manipulation navigation by dragging data points directly?"*

A3: Interactive Prototype

Create an interactive visualization. Choose a driving question for a dataset and develop an appropriate visualization + interaction techniques, then deploy your visualization on the web.

Due by *11:59pm* on **Monday, November 7**.
Work in project teams of 3-4 people.





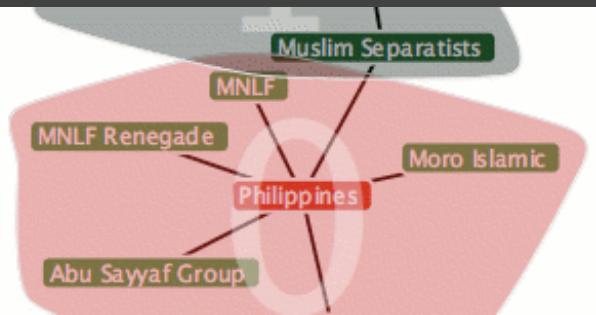
Form A3 + Final Project Team

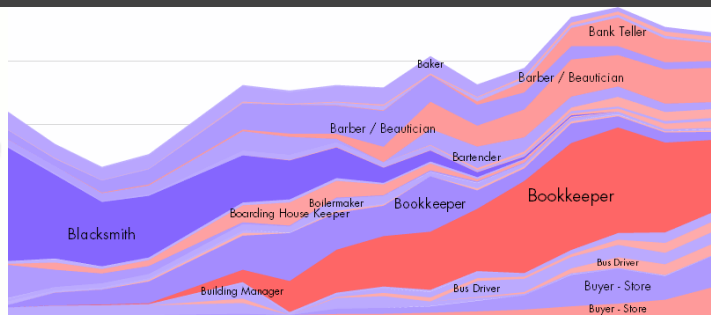
Form a **team of 3-4** for A3 and the Final Project.

Submit signup form by **Friday 10/28, 11:59pm**.

If you do not have team mates, post on Ed about your interests/skills/project ideas!

We will send out a reminder early next week.





Team Member Roles

We encourage you to structure team responsibilities!

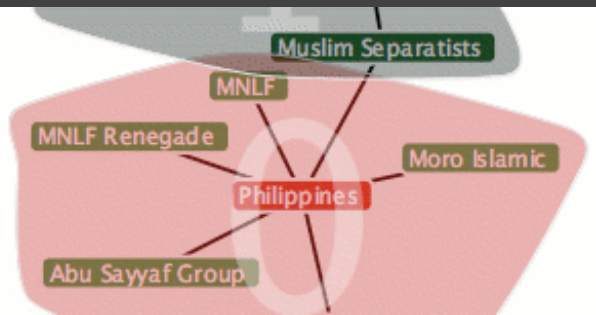
Coordinator: Organize meetings, track deadlines, *etc.*

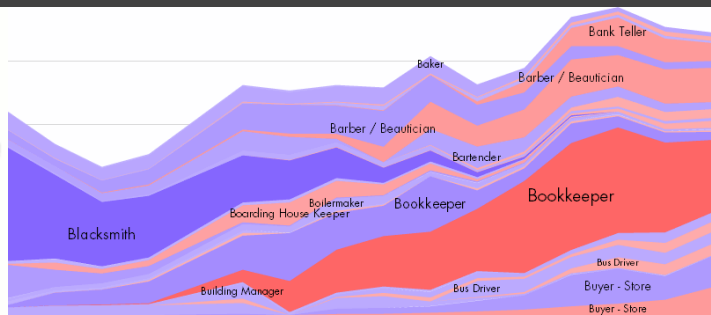
Data Lead: Data wrangling, management, distillation

Tech Lead: Manage code integration, GitHub repo

UX Lead: Visualization/interaction design & evaluation

One may have multiple roles, share work across roles…



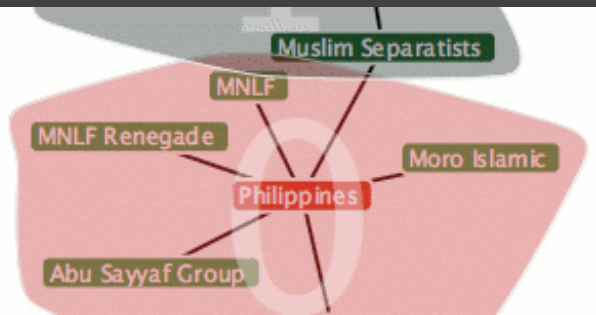


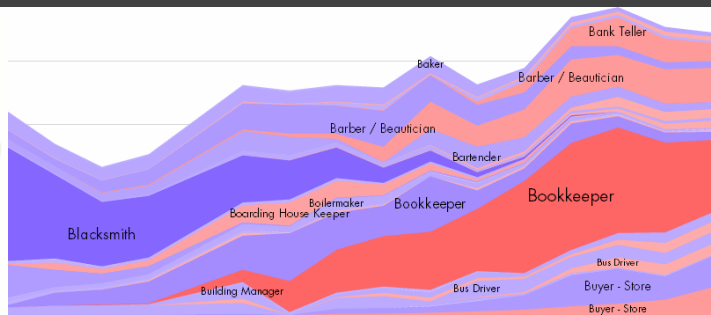
Requirements

Interactive. You must implement interaction methods! However, this is not only selection / filtering / tooltips. Also consider annotations or other narrative features to draw attention and provide additional context

Web-based. D3/Vega-Lite are encouraged, but not required. Deploy to web using GitHub pages.

Write-up. Provide design rationale.



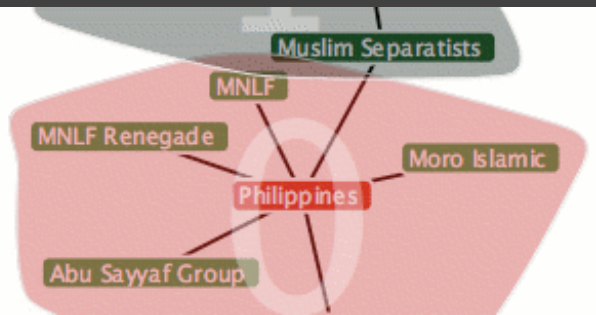


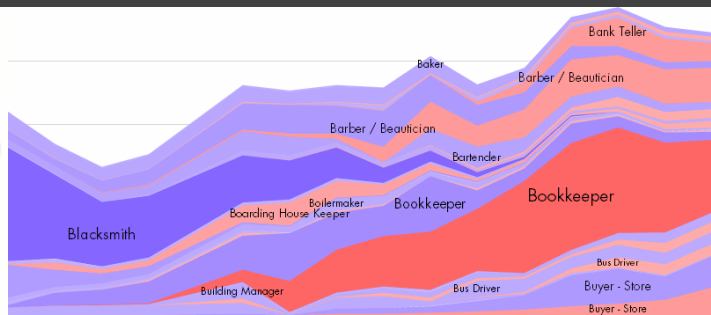
Interactive Prototype Tips

Start now. It will take longer than you think.

Keep it simple. Choose a *minimal* set of interactions that enables users to explore and generate interesting insights. Do not feel obligated to convey *everything* about the data: focus on a compelling subset.

Promote engagement. How do your chosen interactions reveal interesting observations?





Two Tutorials Coming Up

D3.js Deep Dive: Thursday 10/27
During lecture
Led by Vishal and Tukey

Web Publishing: Friday 10/28
4:30-6pm, Gates G20
Led by Aakash and Wei Jun

Break Time!