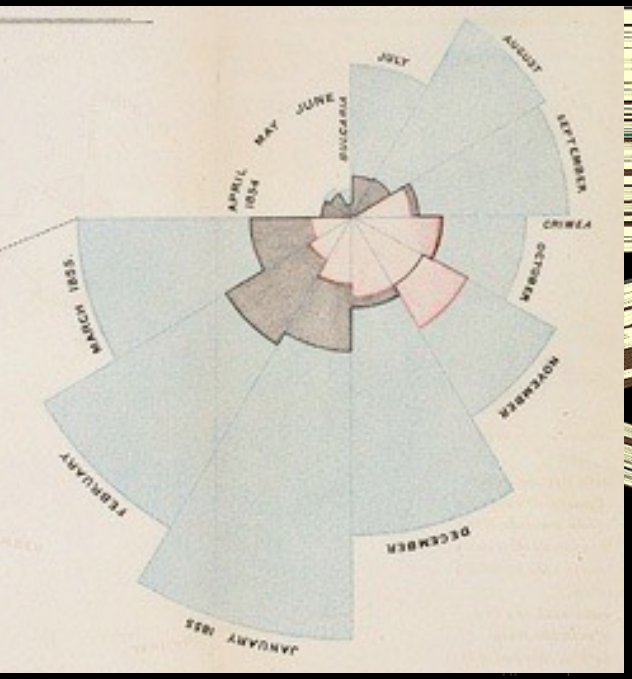
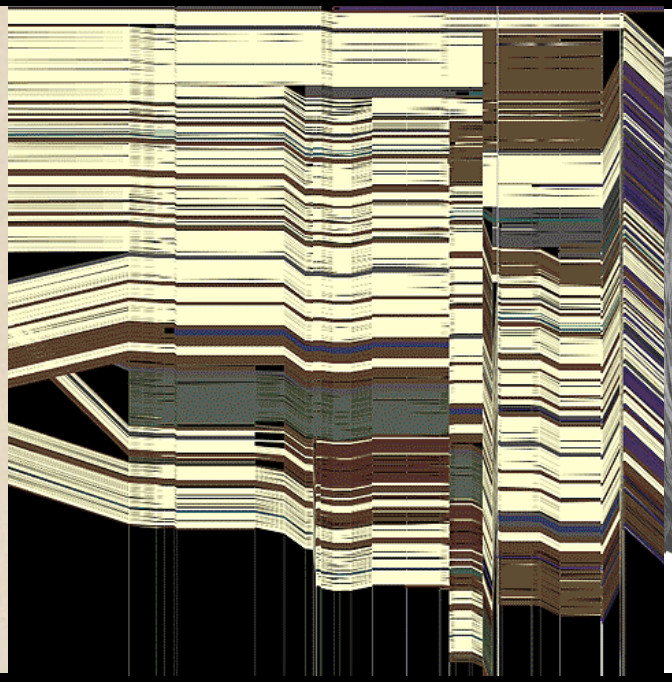
CSE 442 - Data Visualization

Mapping & Cartography

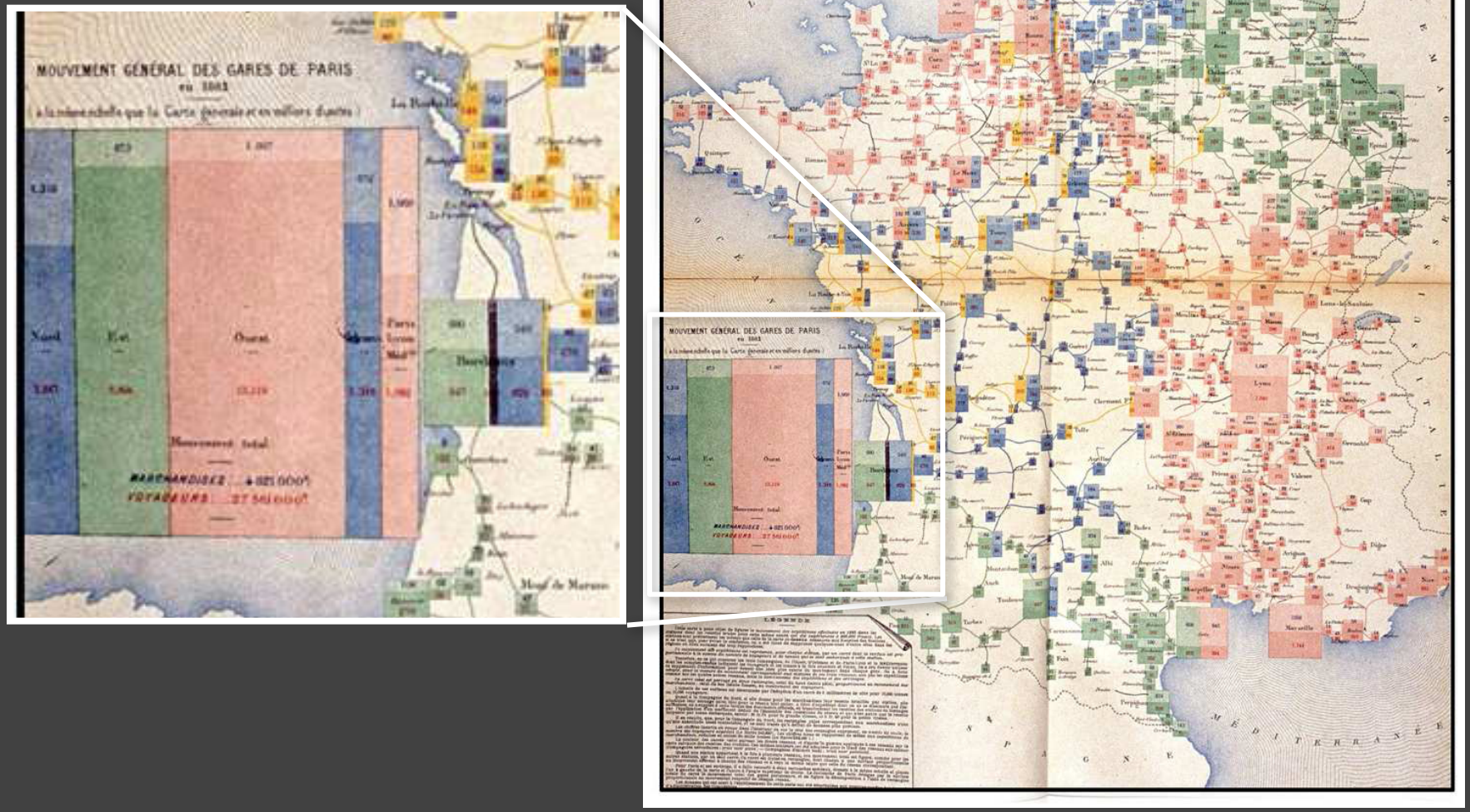




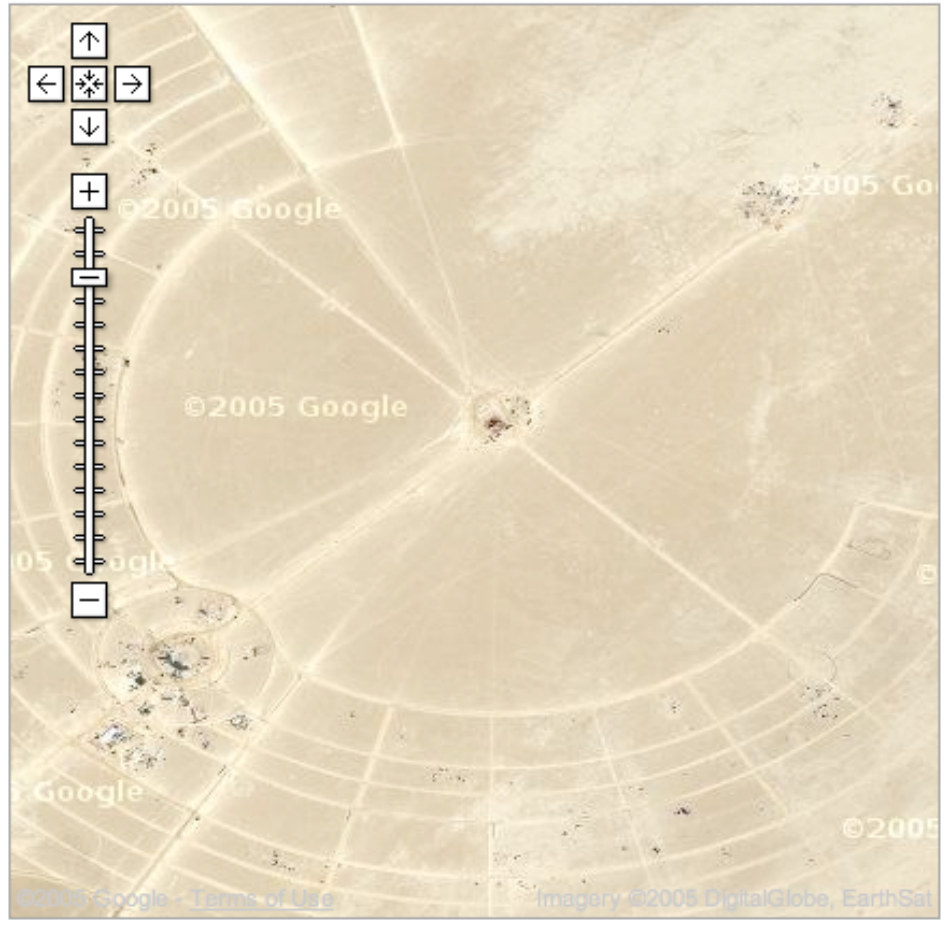
Jeffrey Heer University of Washington
(with significant material from Michal Migurski)

Ptolemy's Geographica

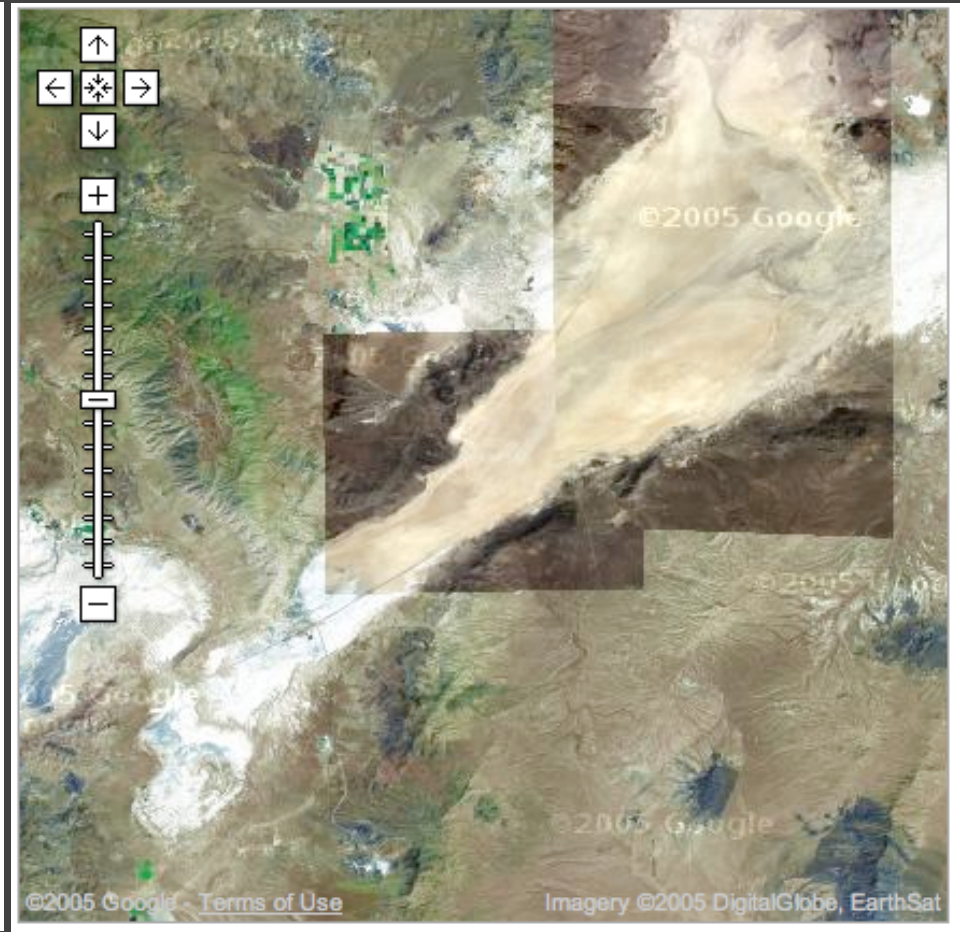
Original ~150AD, This Map ~1300AD



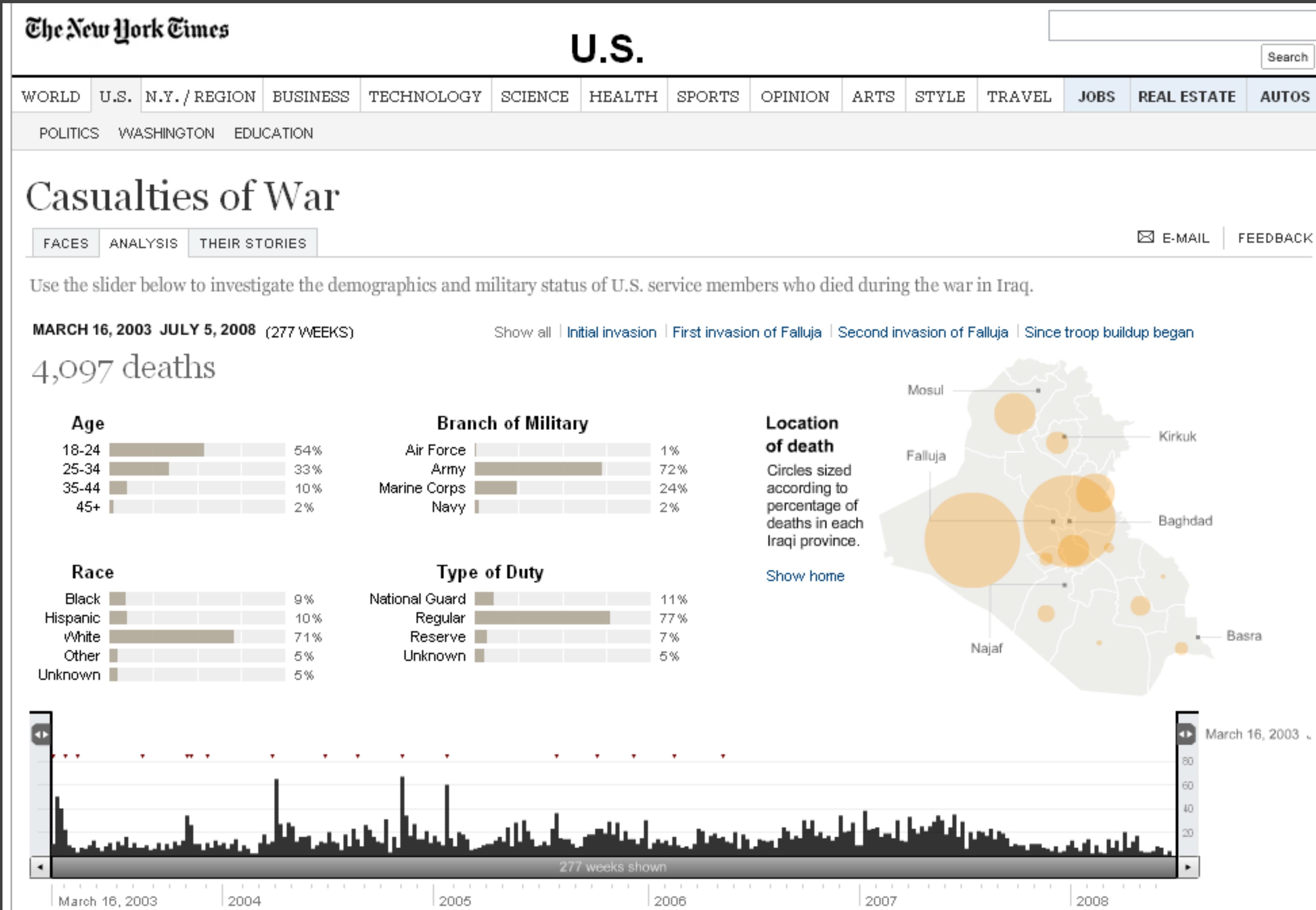
Rail Passengers and Freight from Paris 1884



Black Rock City, Nevada
(Burning Man)



Google Maps 2005



Casualties of War, New York Times 2006

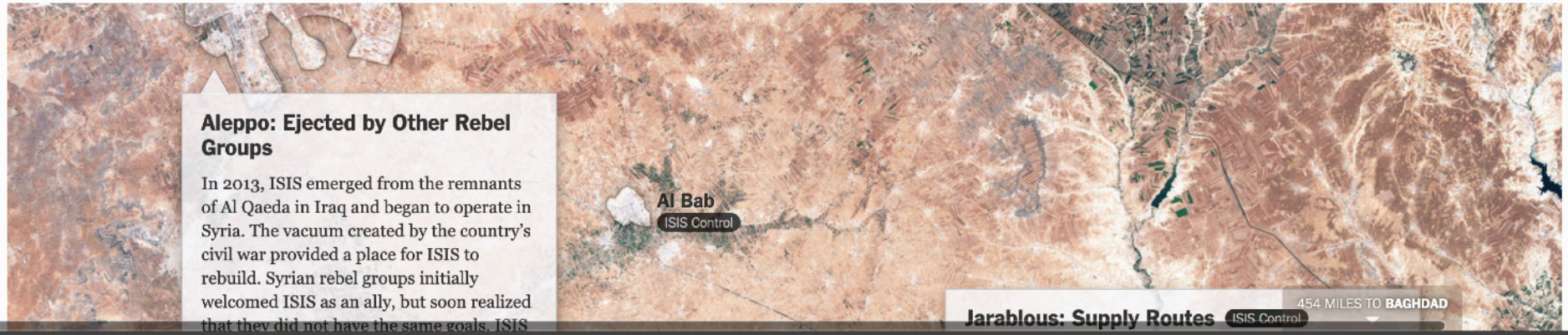
A Rogue State Along Two Rivers

How ISIS Came to Control Large Portions of Syria and Iraq

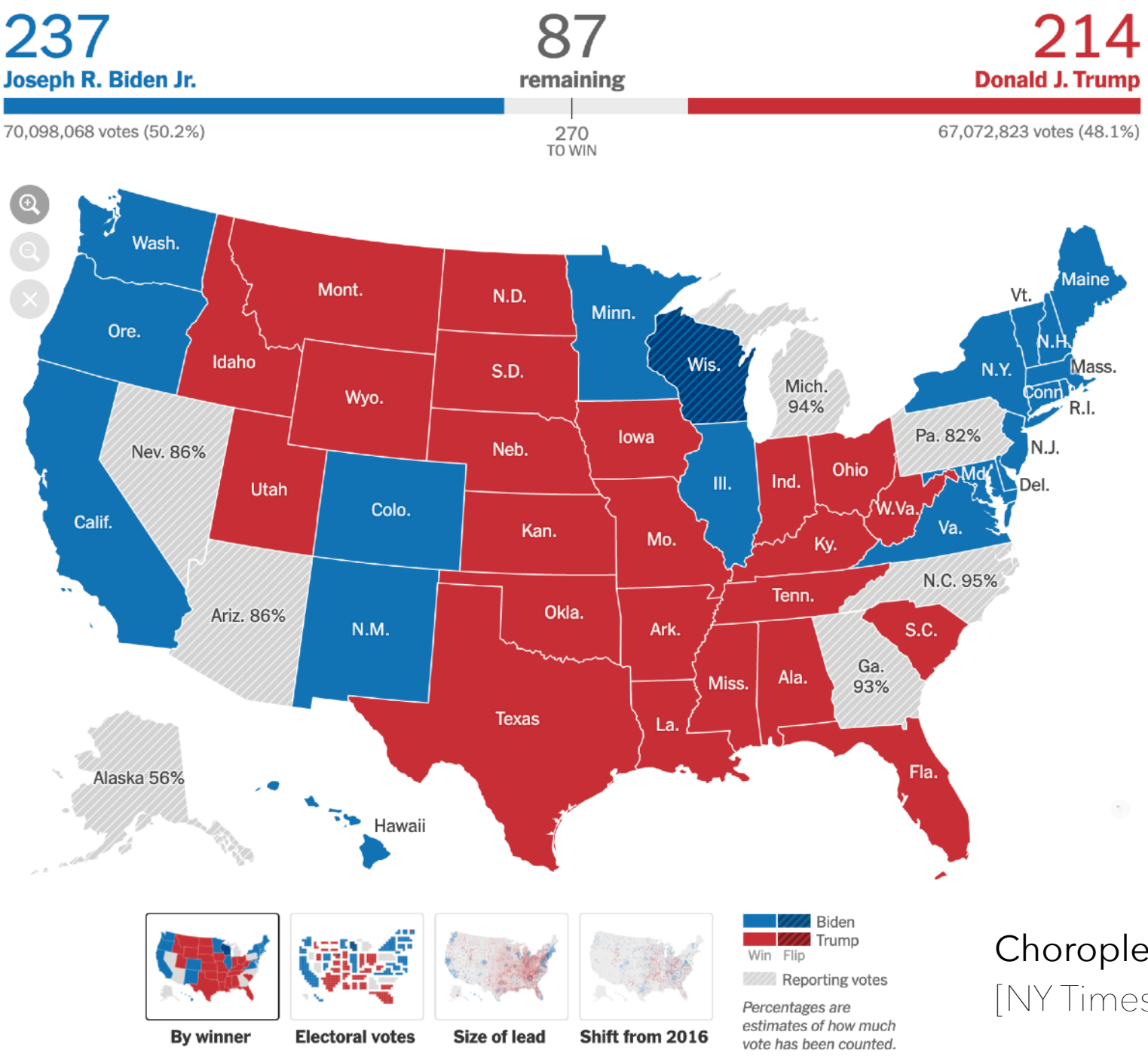
By JEREMY ASHKENAS, ARCHIE TSE, DEREK WATKINS and KAREN YOURISH July 3, 2014

The militant group called the Islamic State in Iraq and Syria, or ISIS, seemed to surprise many American and Iraqi officials with the recent gains it made in its violent campaign to create a new religious state. But the rapid-fire victories achieved over a few weeks in June were built on months of maneuvering along the Tigris and Euphrates Rivers.

The Euphrates

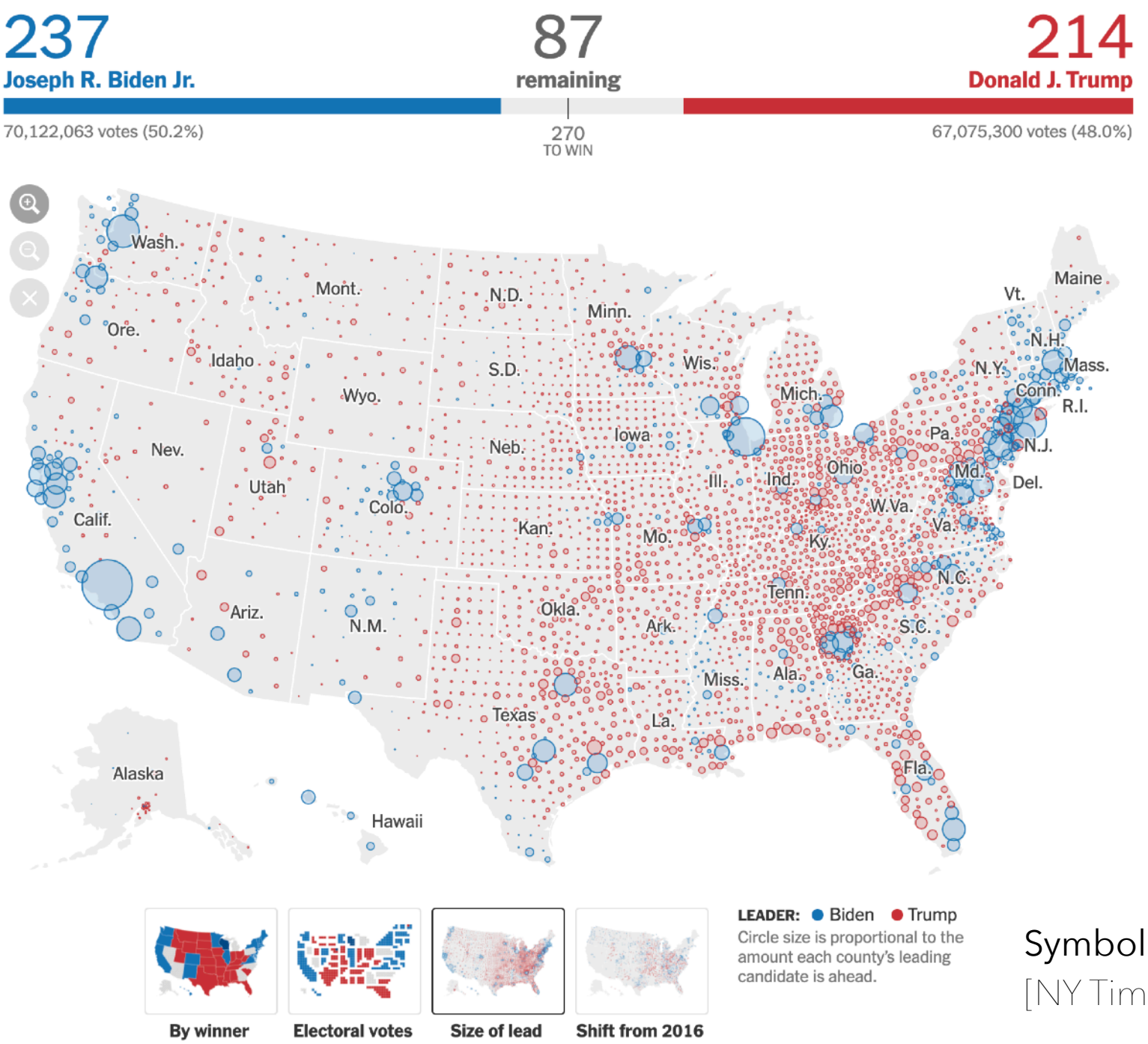


NY Times 2014

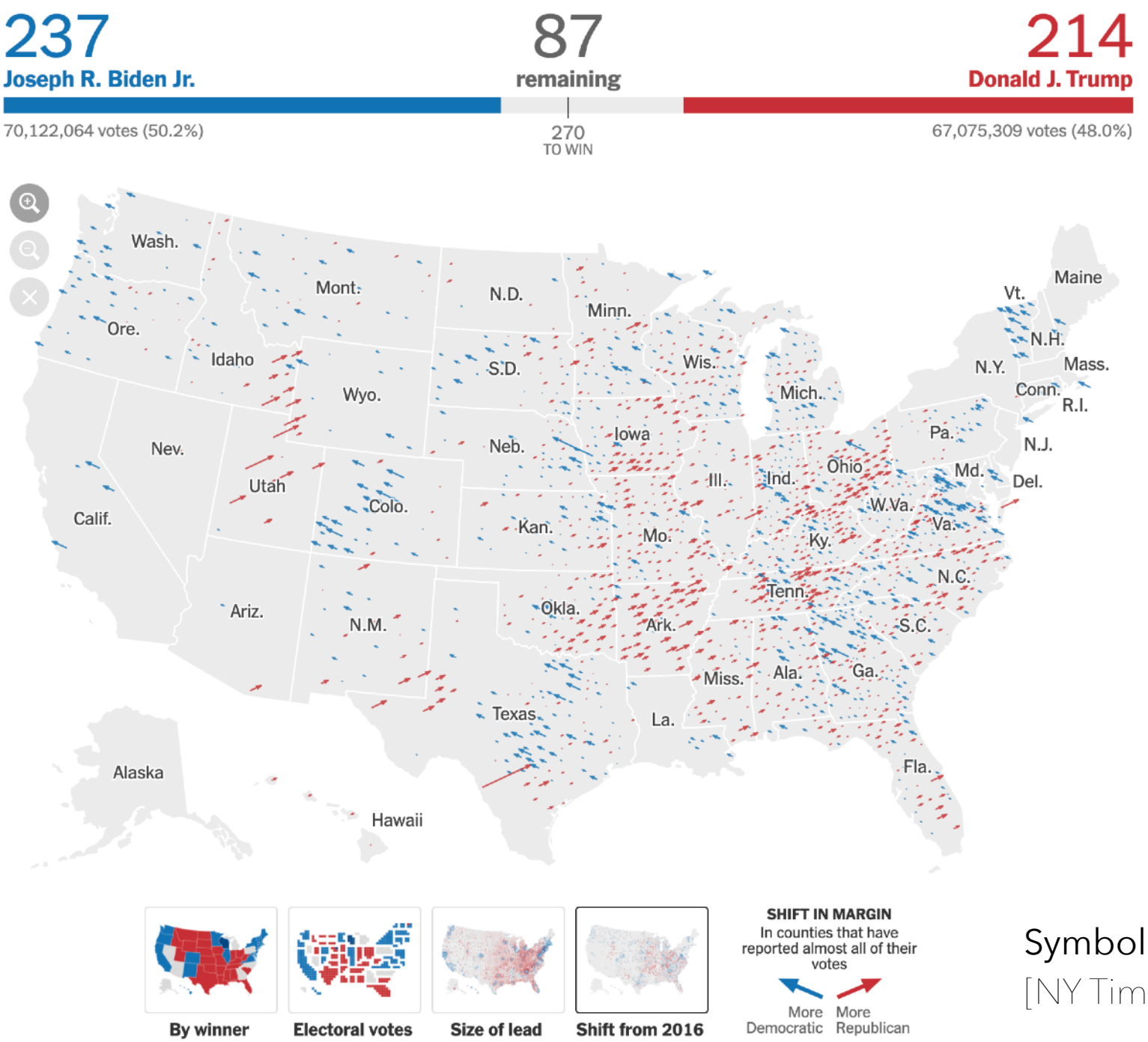


Choropleth Map

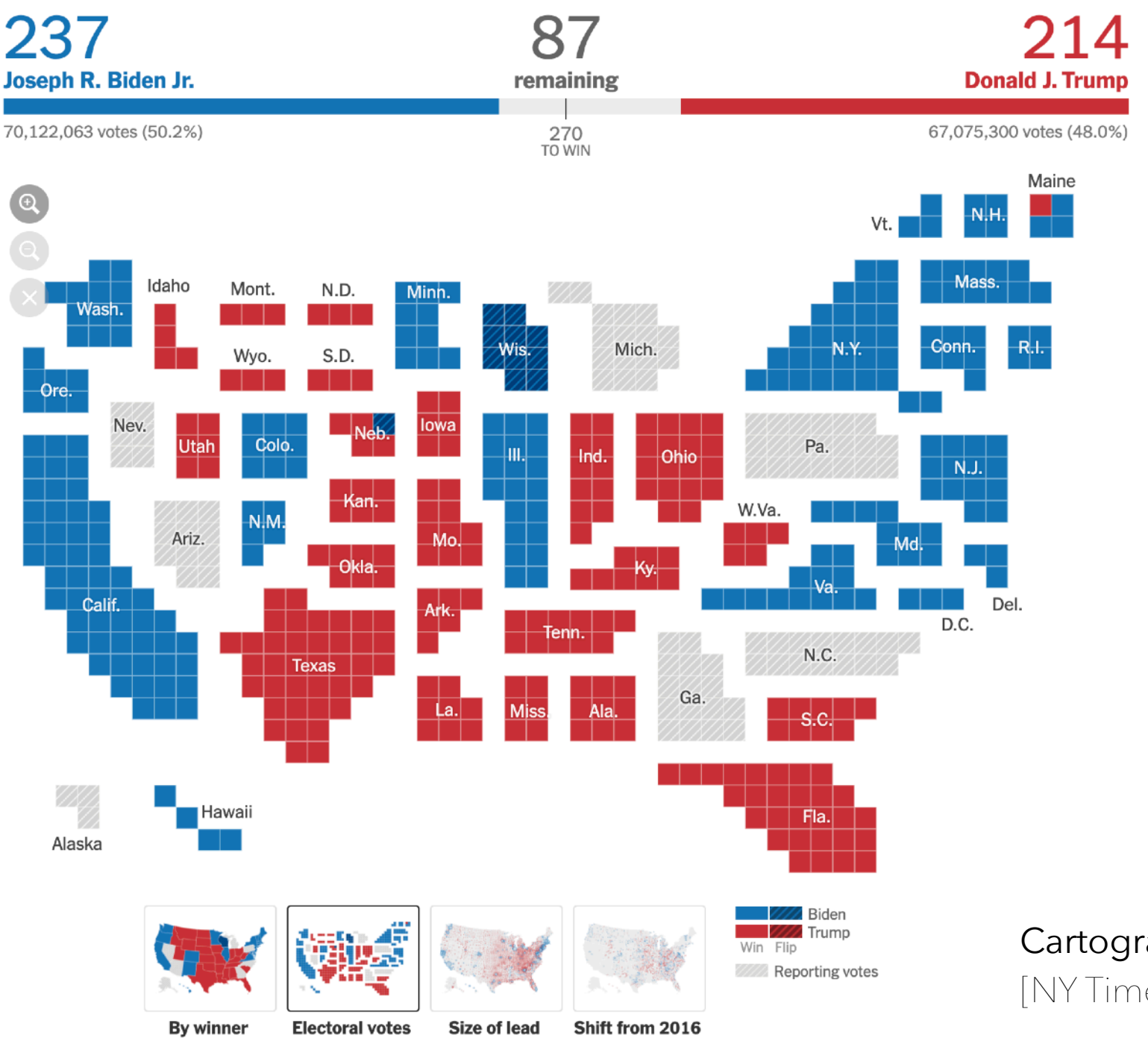
[NY Times]



Symbol Map
[NY Times]



Symbol Map
[NY Times]



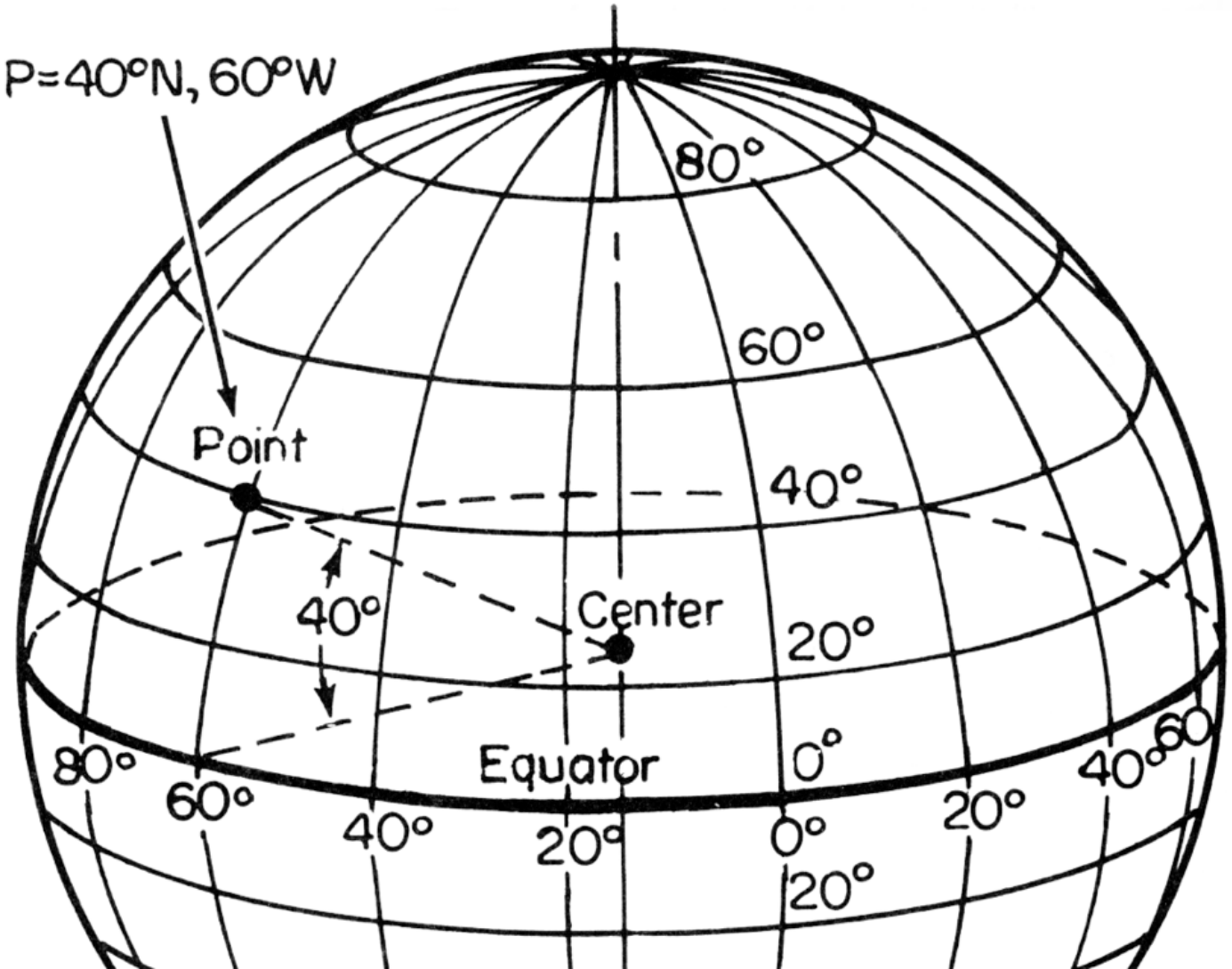
Cartogram
[NY Times]

Cartography

The Making of Maps

Projections

Latitude, Longitude




A sphere tears
when you flatten it

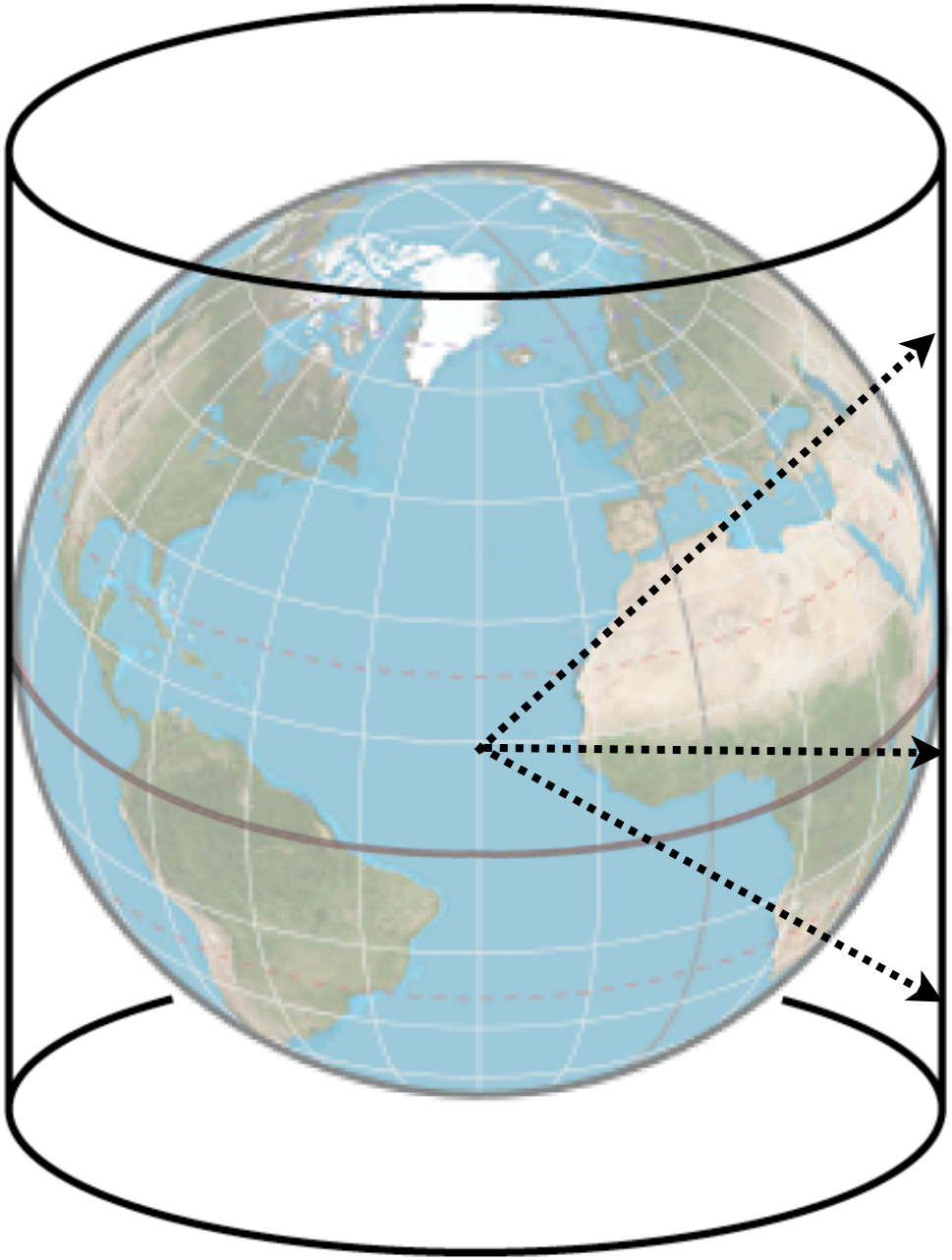
Projections

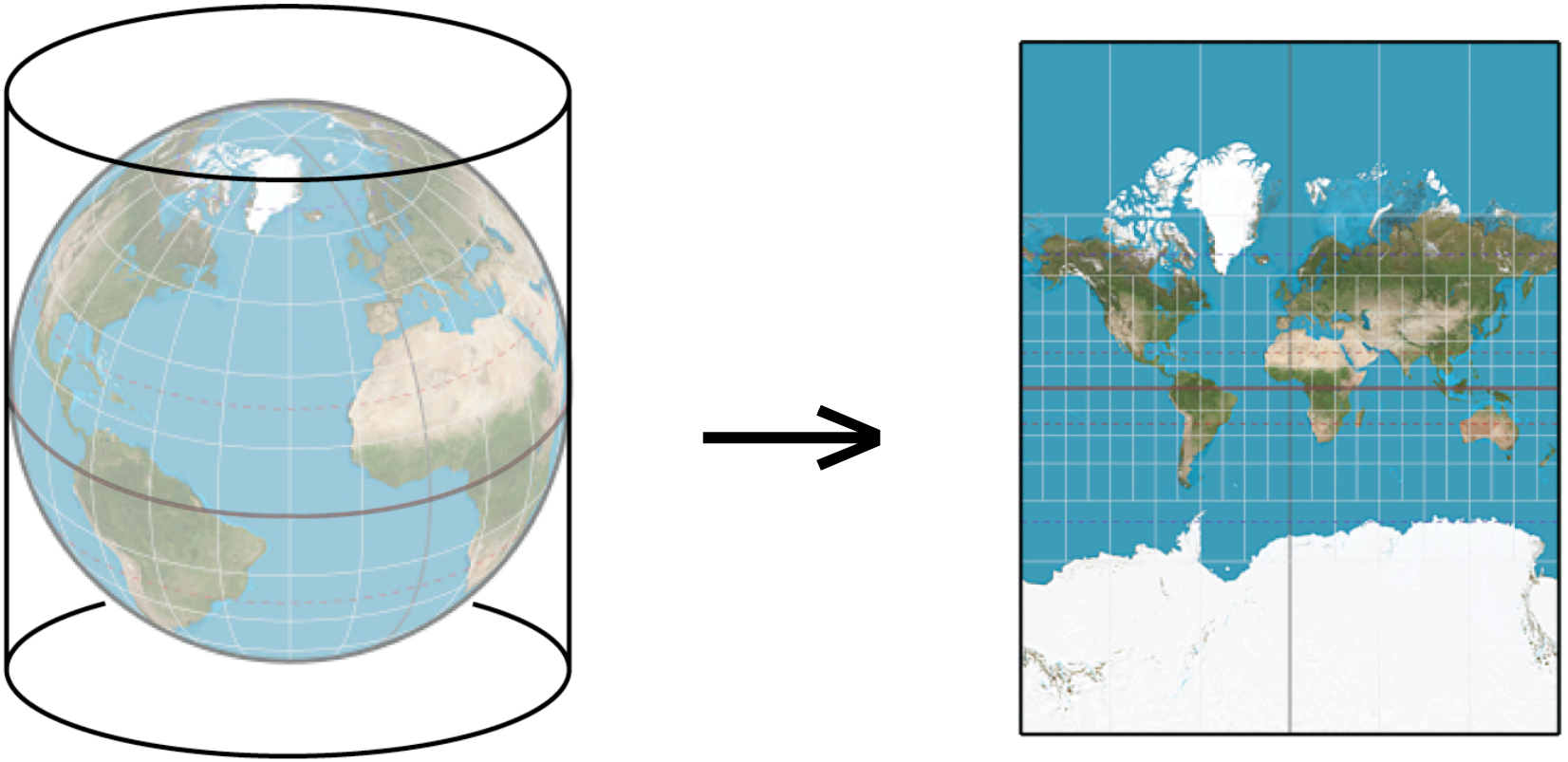
$$f(\varphi, \lambda) \rightarrow (x, y)$$

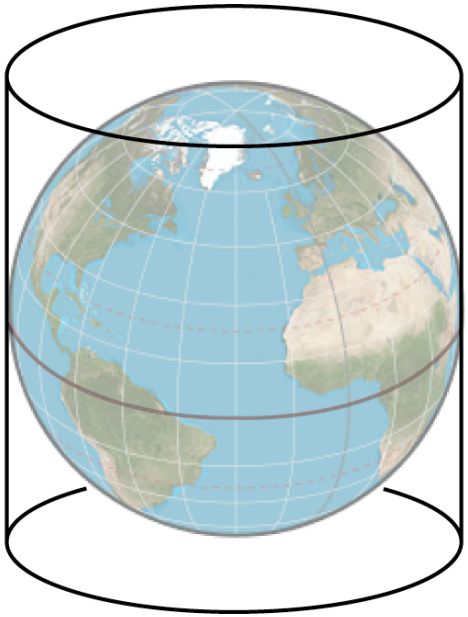
Projections

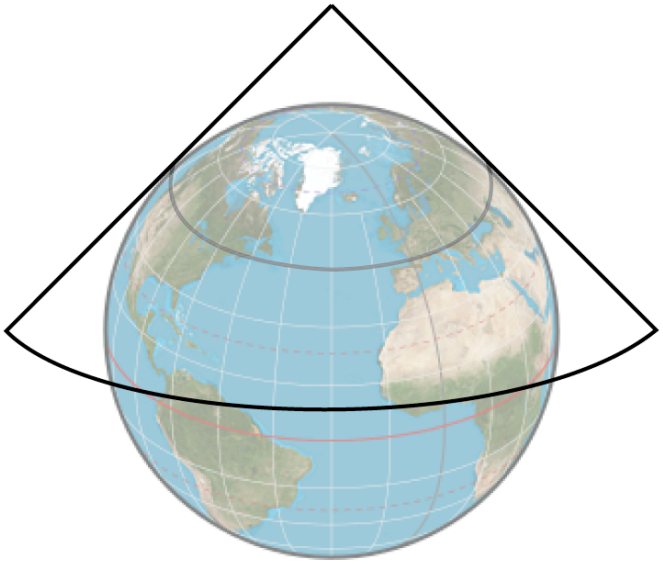
$$f(\varphi, \lambda) \leftrightarrow (x, y)$$

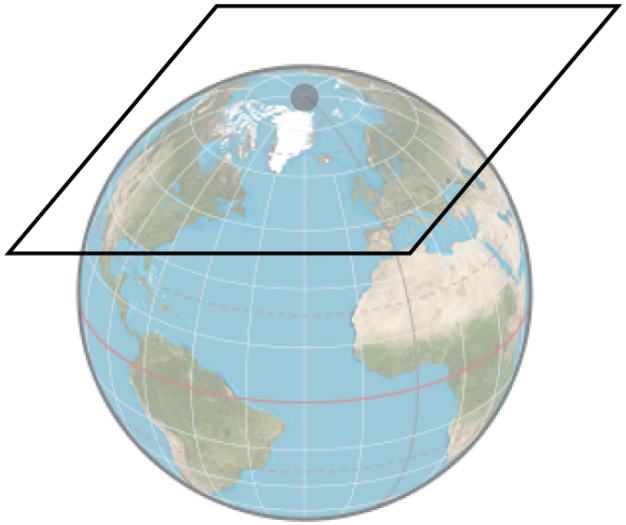
??

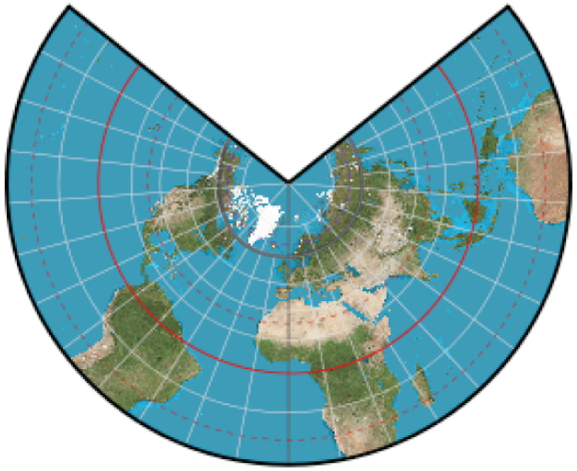


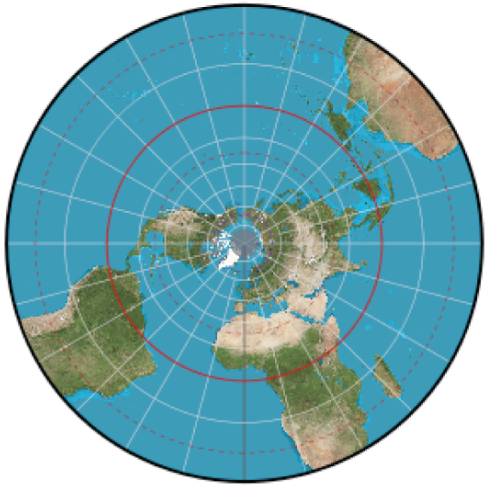










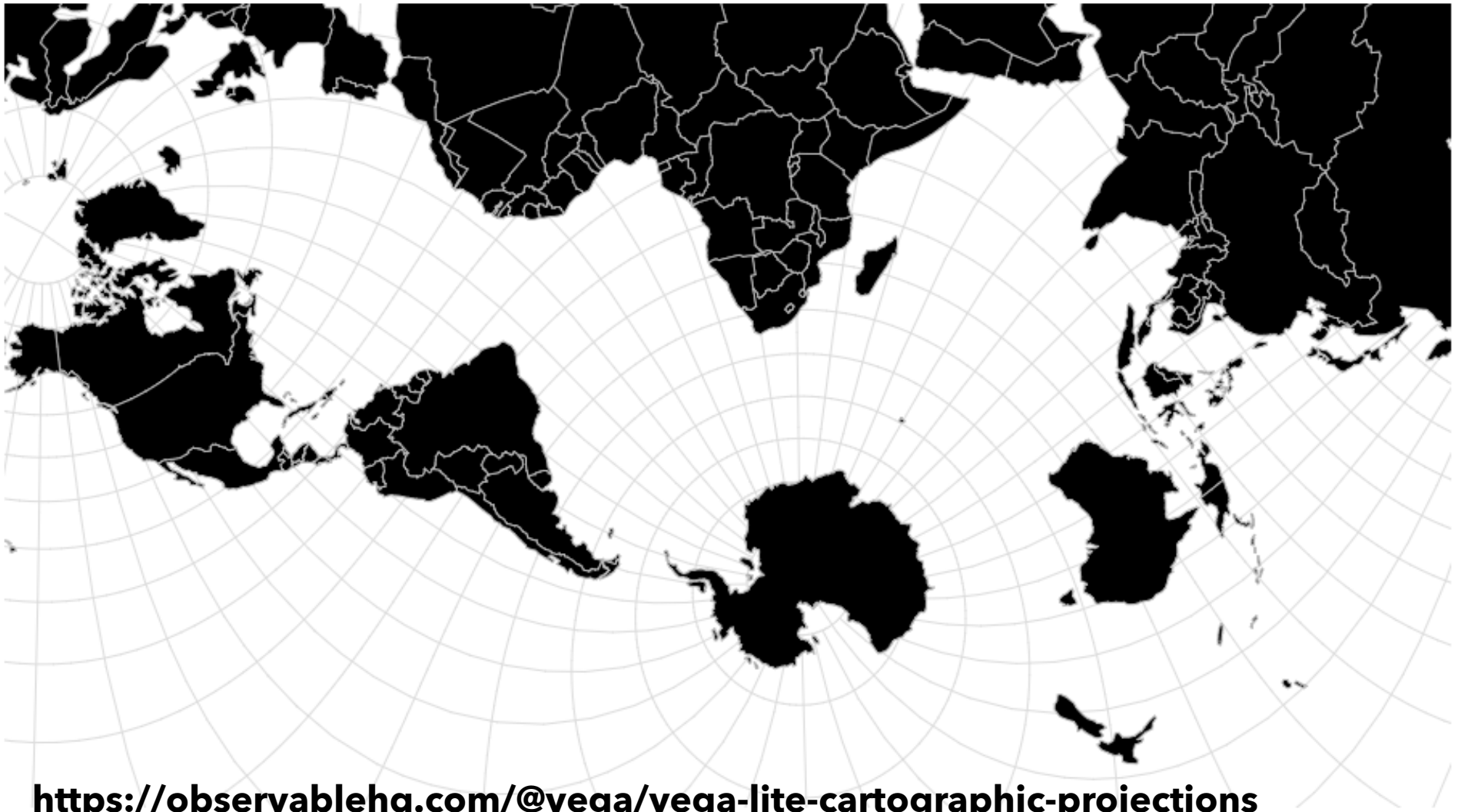


Cylindrical

Conical

Azimuthal

Exploring Projections…



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

Type mercator

Scale 140

Yaw 0

Pitch 0

Roll 0

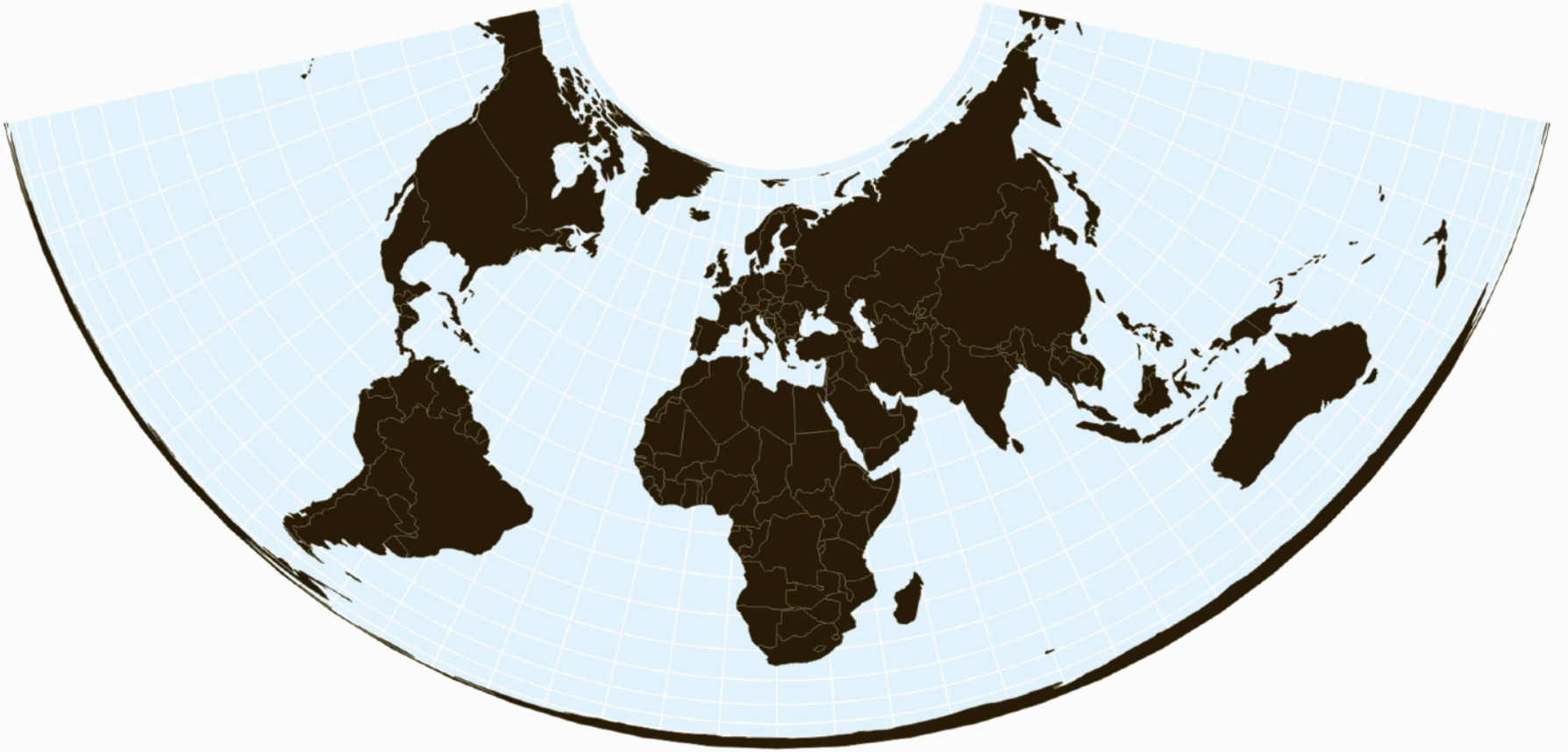
Type mercator

Scale 140

Yaw 0

Pitch 0

Roll 0



Type conicEqualArea

Scale 140

Yaw -20

Pitch 0

Roll 0

Type orthographic

Scale 140

Yaw 0

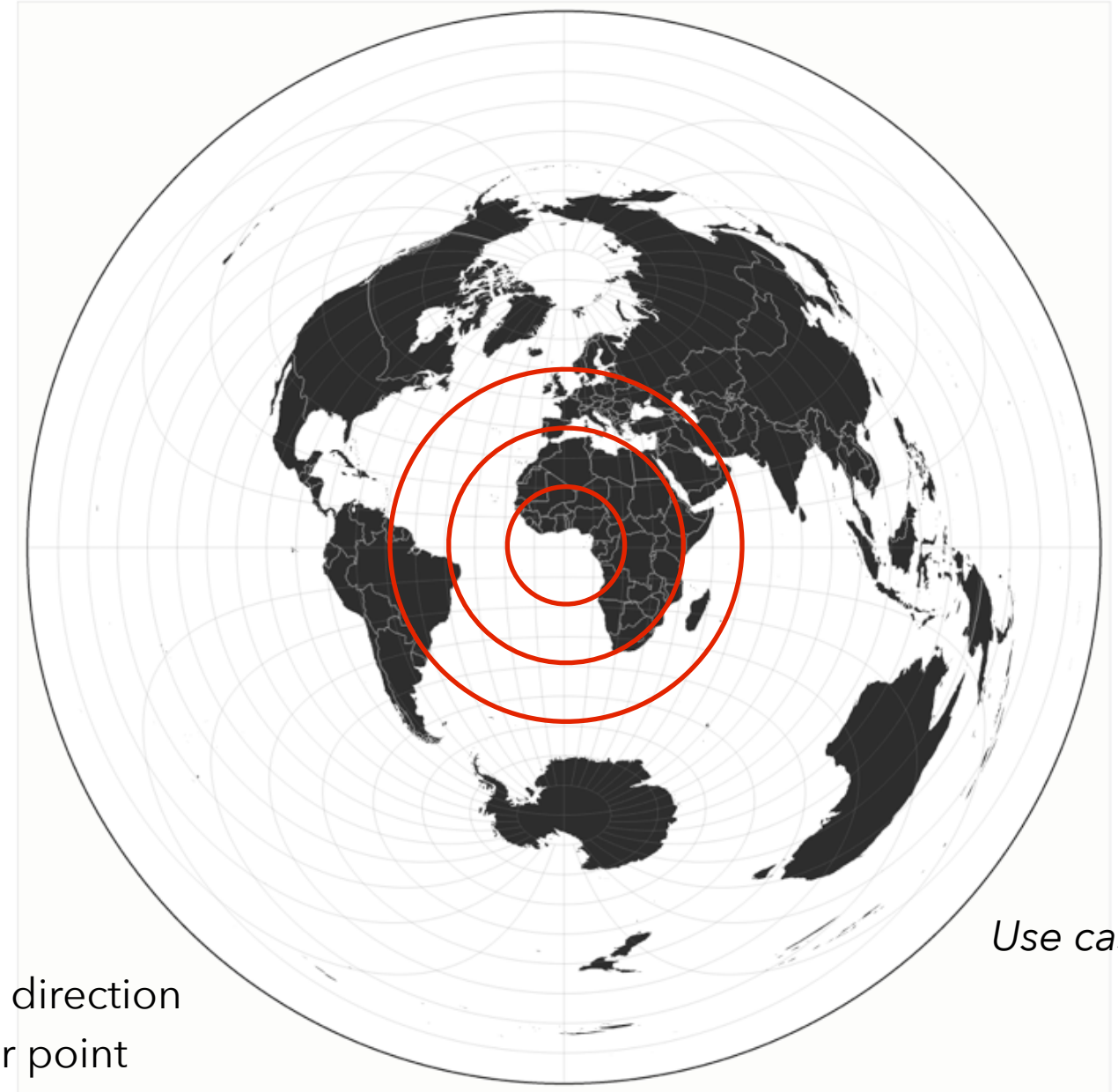
Pitch 0

Roll 0

We can categorize projections by what they preserve…


Distance
Preserve distance / direction from center

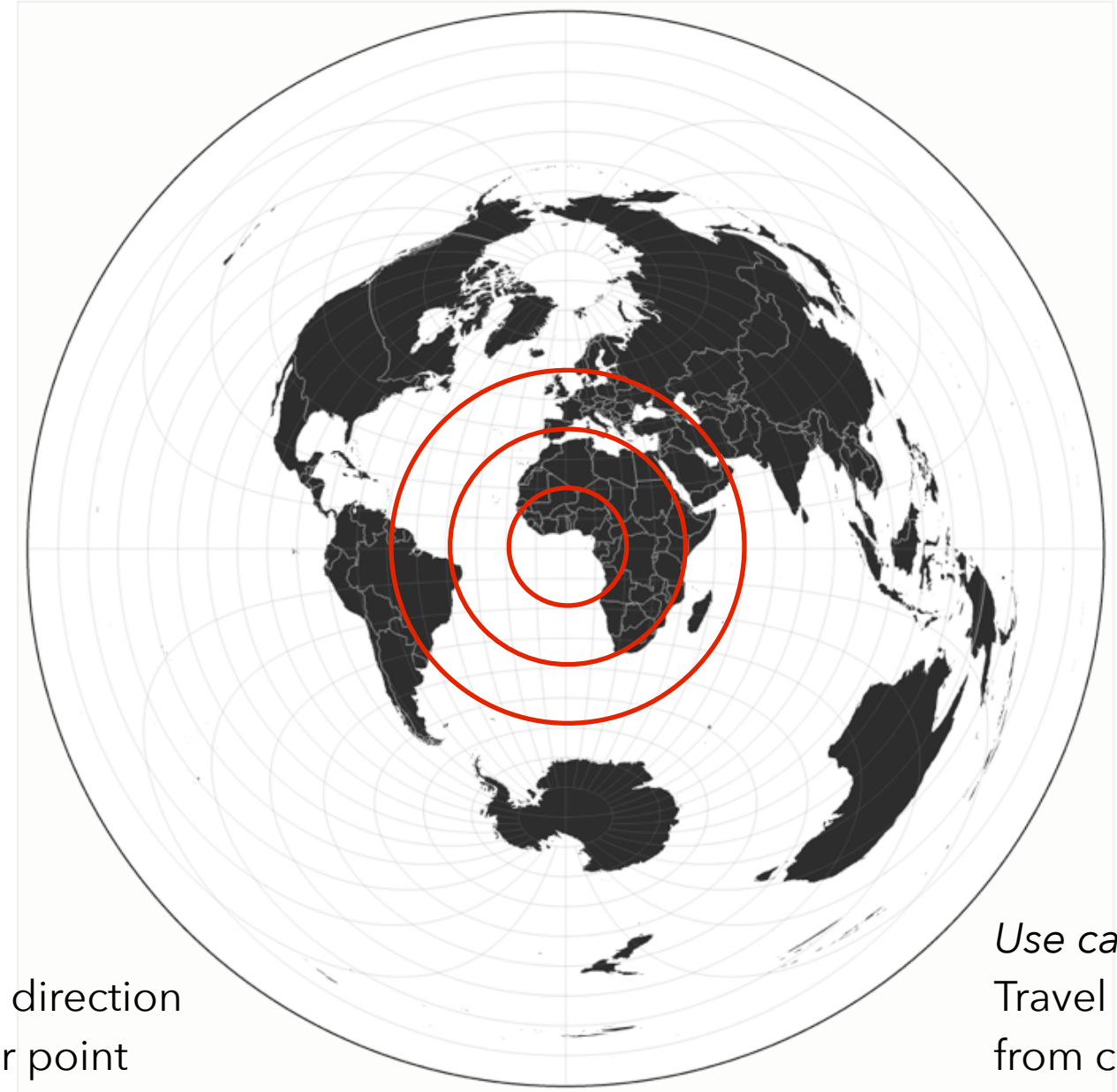
Azimuthal Equidistant



Preserves:
Distance & direction
from center point

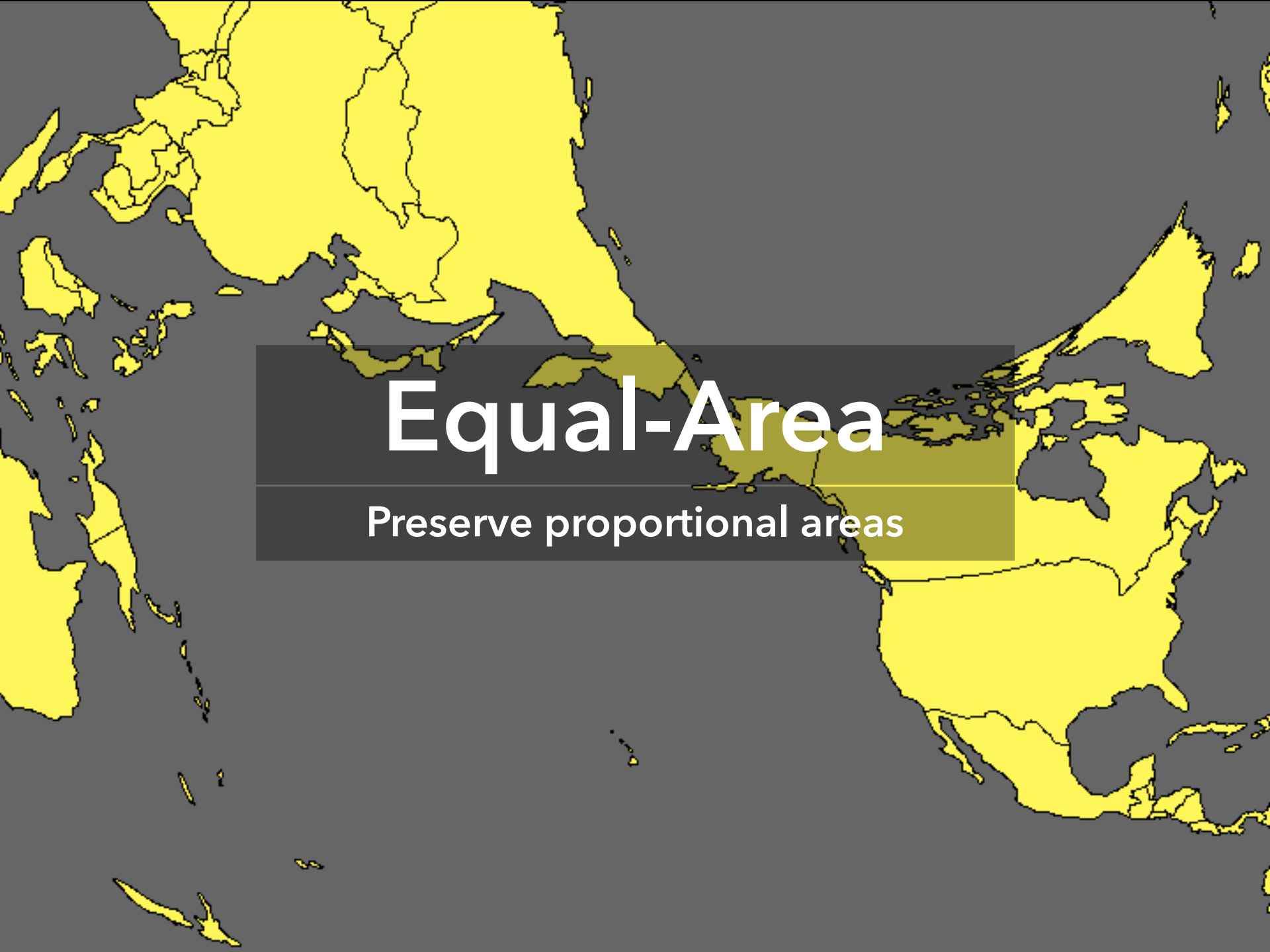
Use cases?

Azimuthal Equidistant

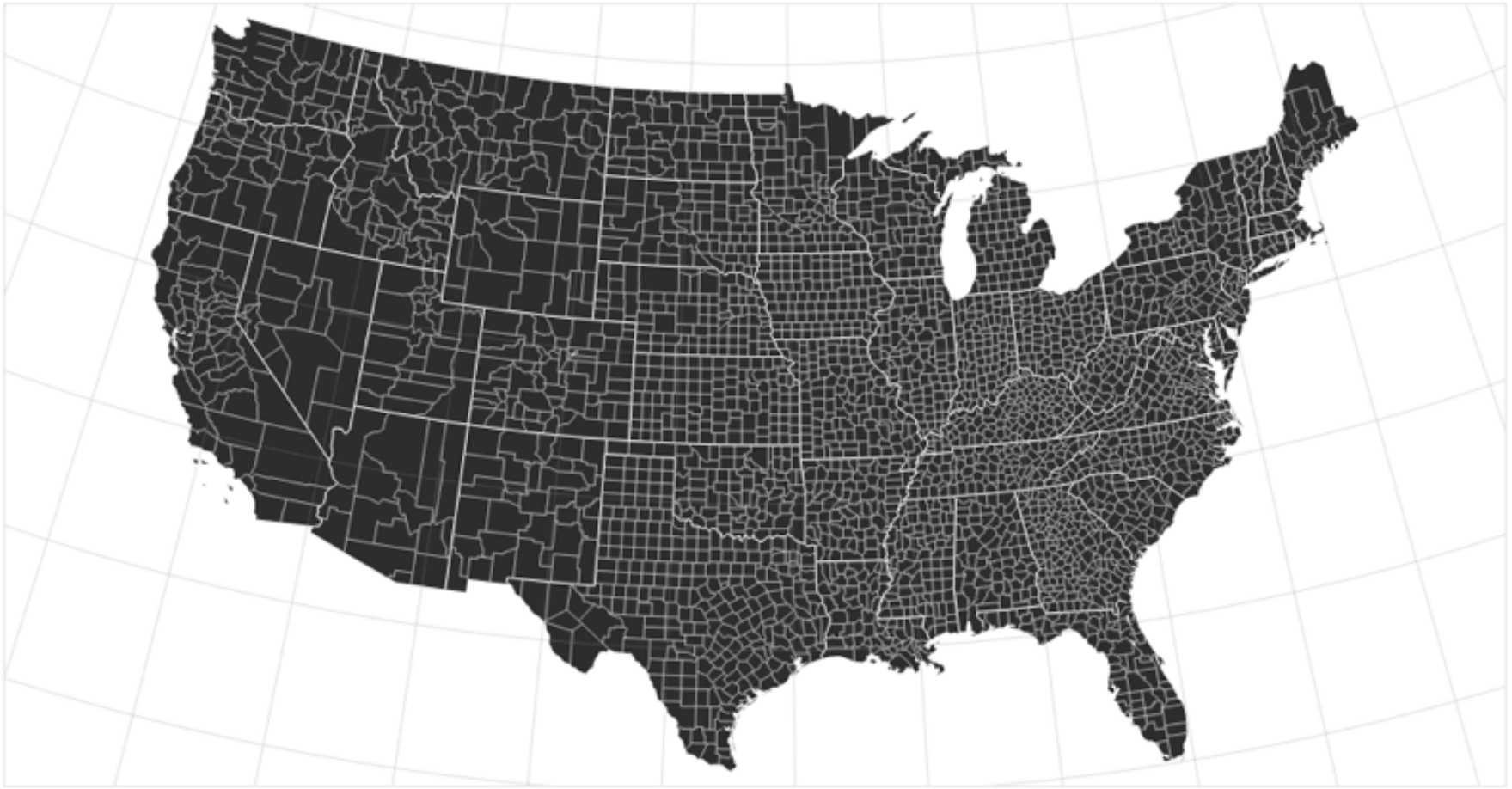


Preserves:
Distance & direction
from center point

Use cases:
Travel / propagation
from center point


Equal-Area
Preserve proportional areas

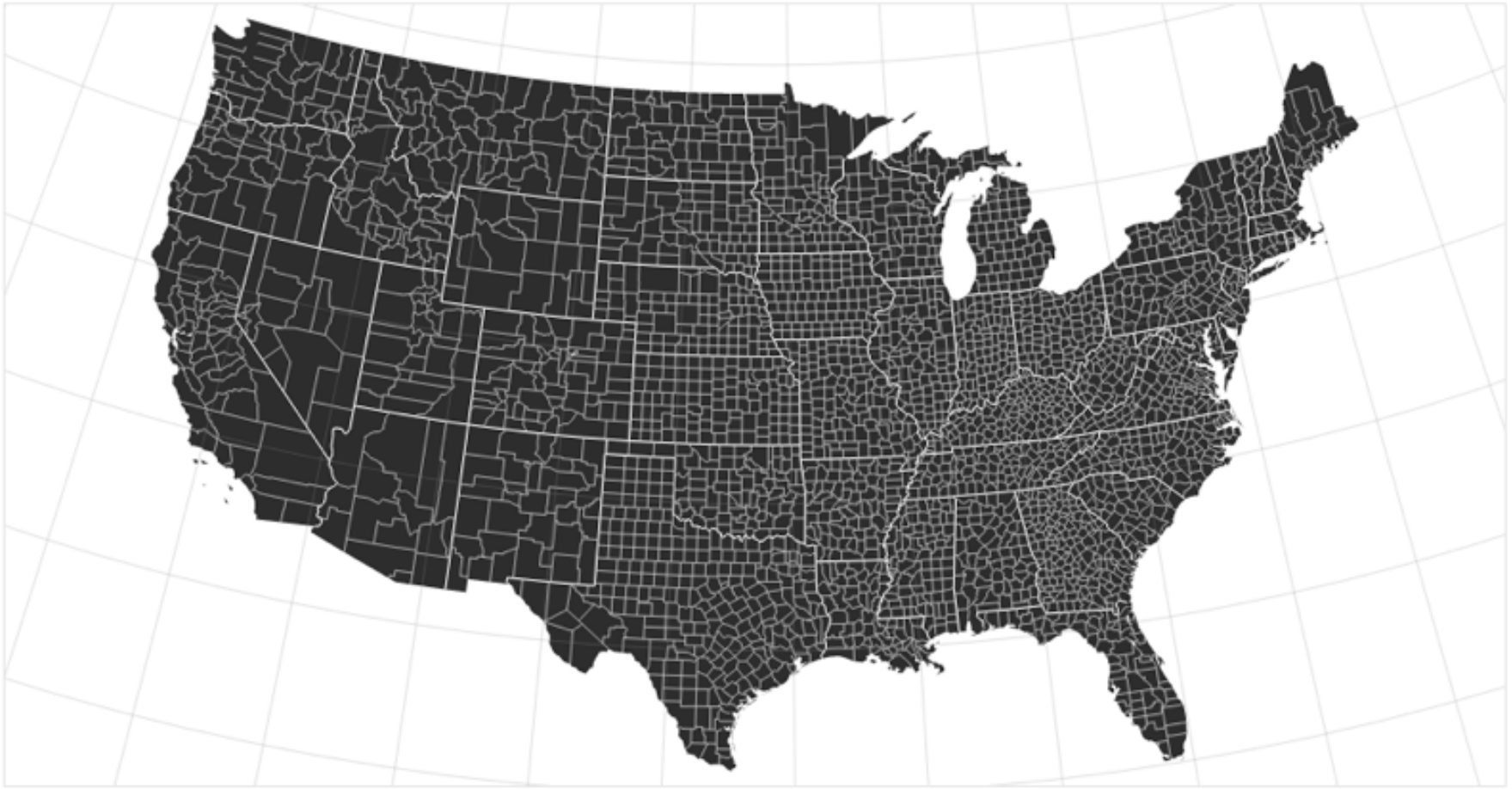
Albers Equal-Area Conic



Preserves: Proportional area of geographic regions

Use cases?

Albers Equal-Area Conic

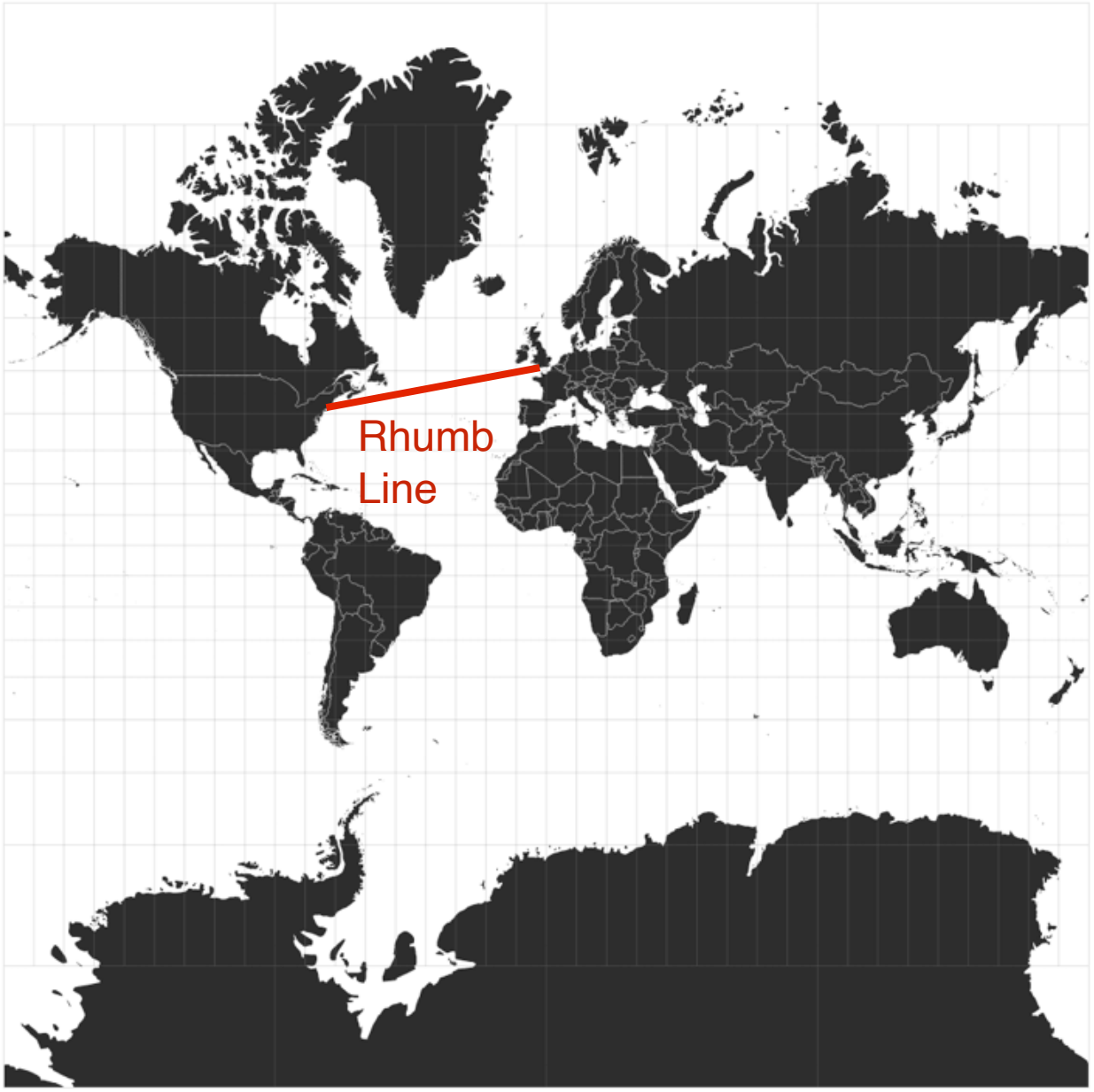


Preserves: Proportional area of geographic regions

Use cases: Land surveys, choropleth (shaded) maps


Conformal
Preserve local angles (“shape”)

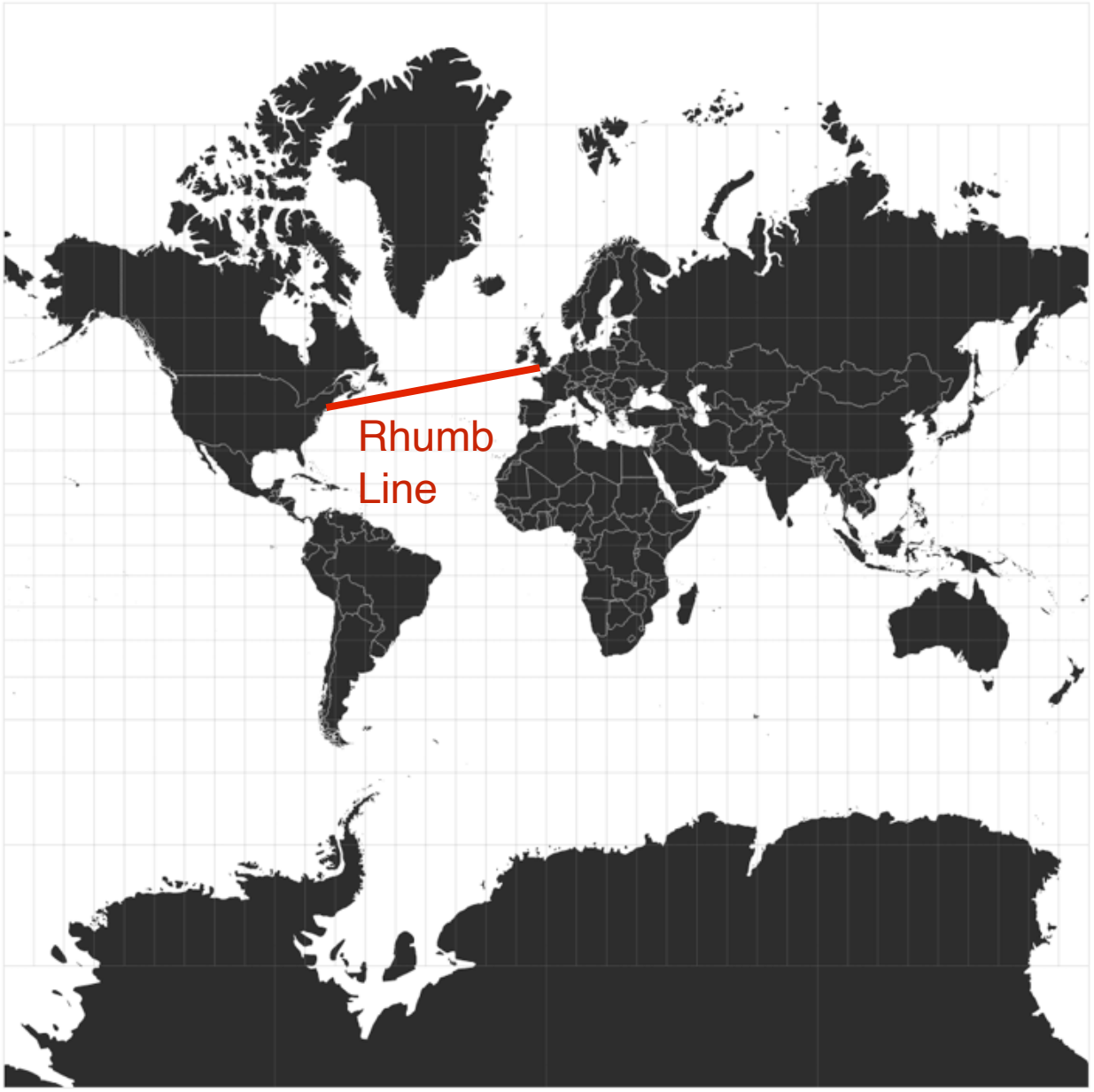
Spherical Mercator



Preserves:
Compass bearing
as a straight line

Use cases?

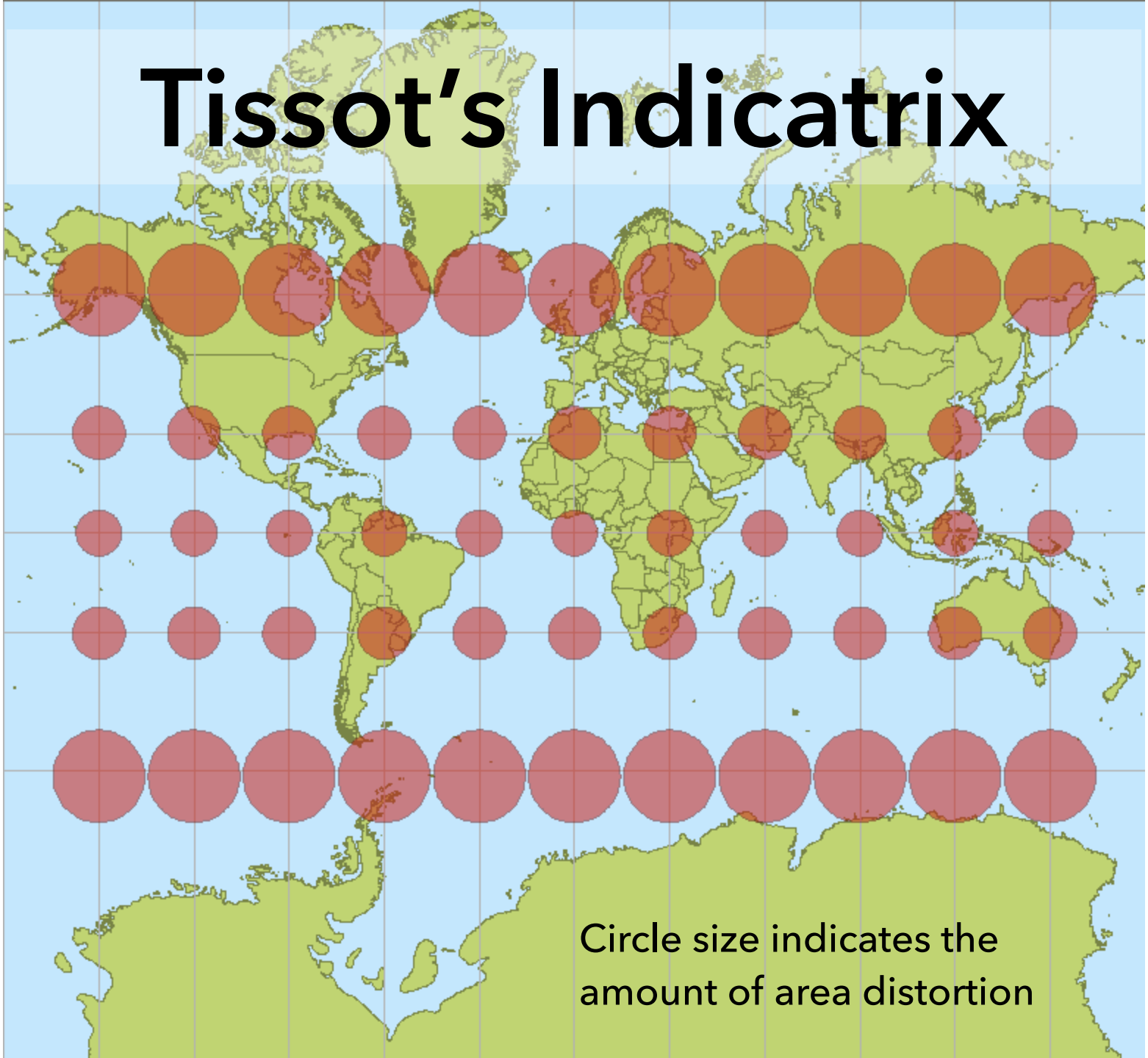
Spherical Mercator

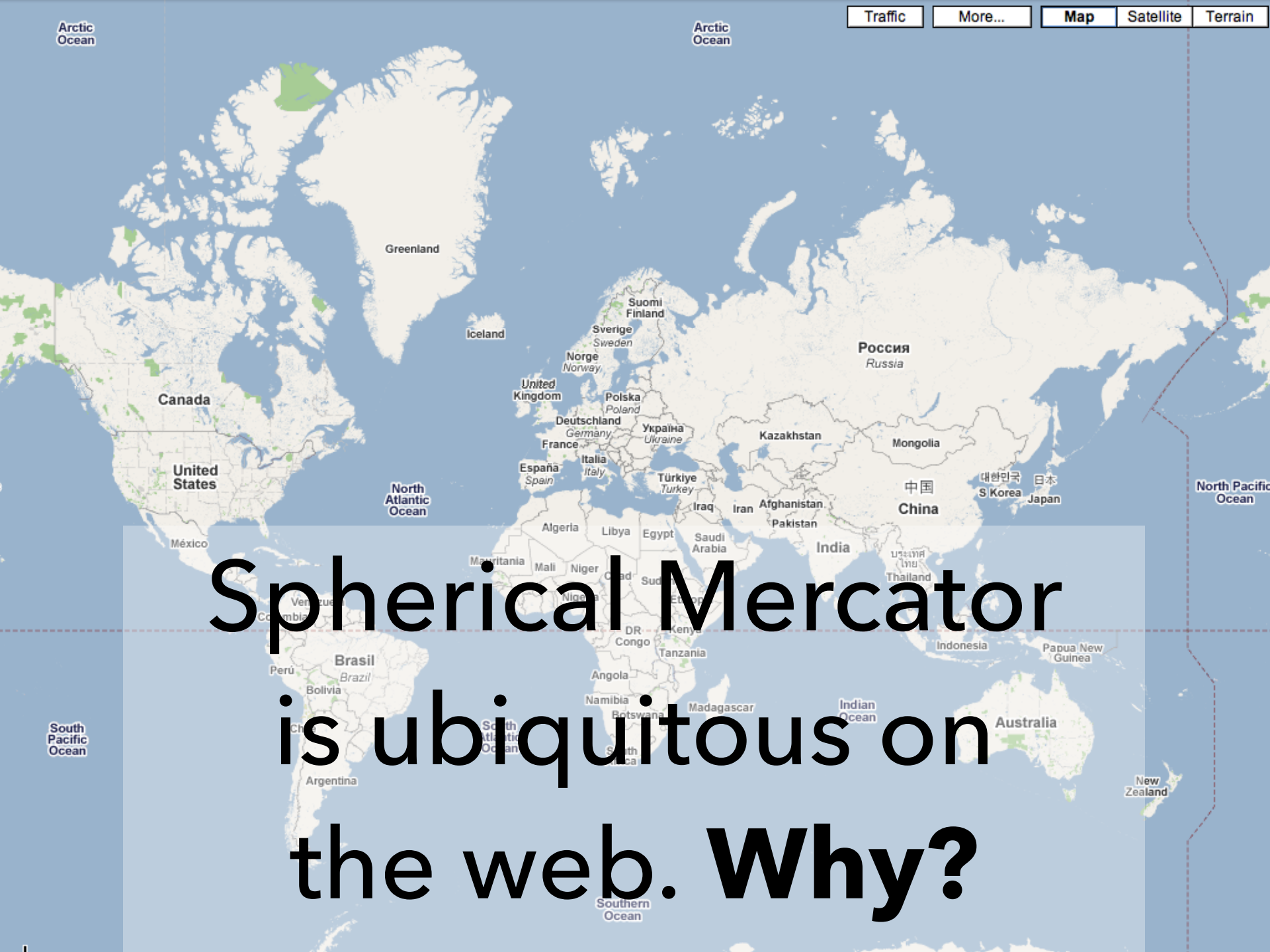


Preserves:
Compass bearing
as a straight line

Use cases:
Navigation

Tissot's Indicatrix





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

The Earth as a Square

Web Mercator

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

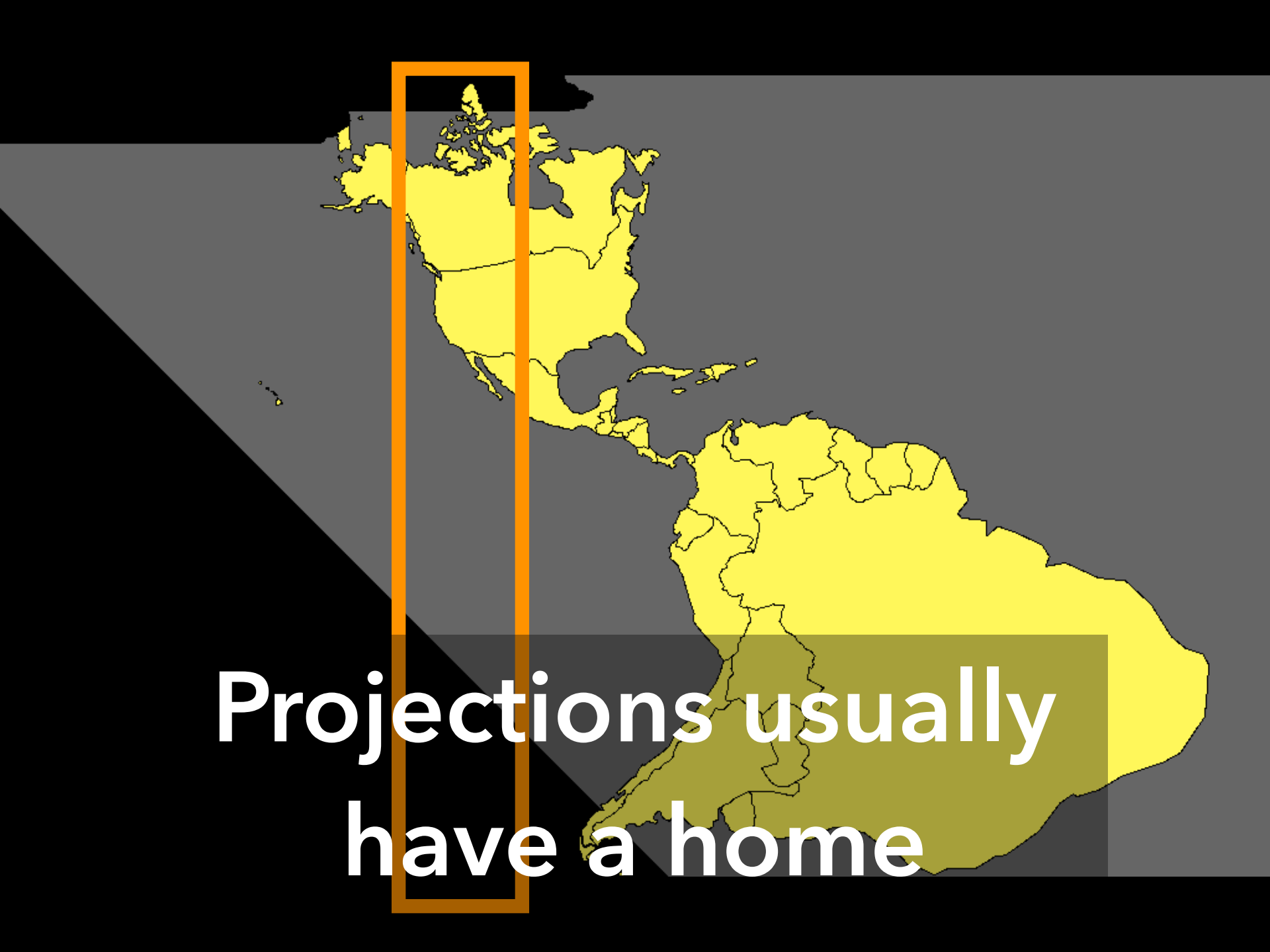
$$y = \frac{128}{\pi} 2^{\text{zoom level}} (\pi - \ln \left[\tan \left(\frac{\pi}{4} + \frac{\varphi}{2} \right) \right]) \text{ pixels}$$

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

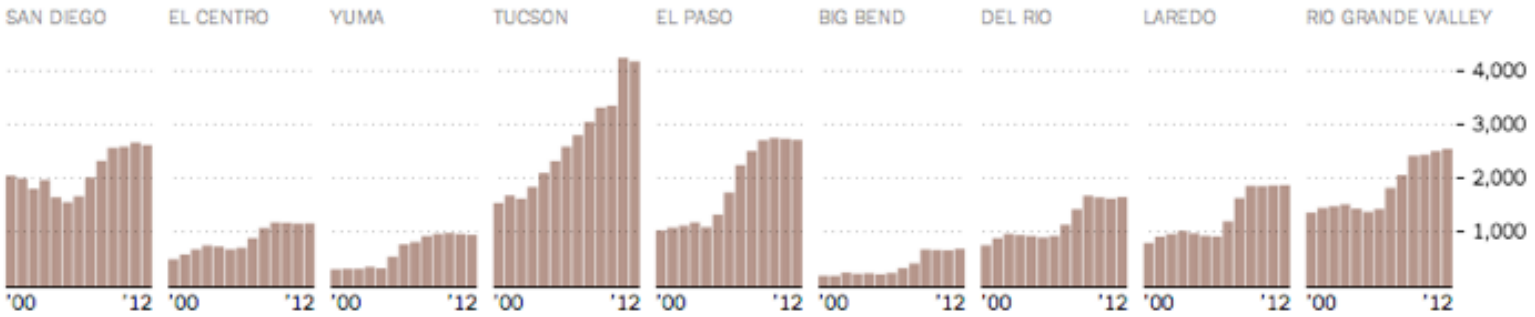
But there are other ways to fit the Earth into a square…


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

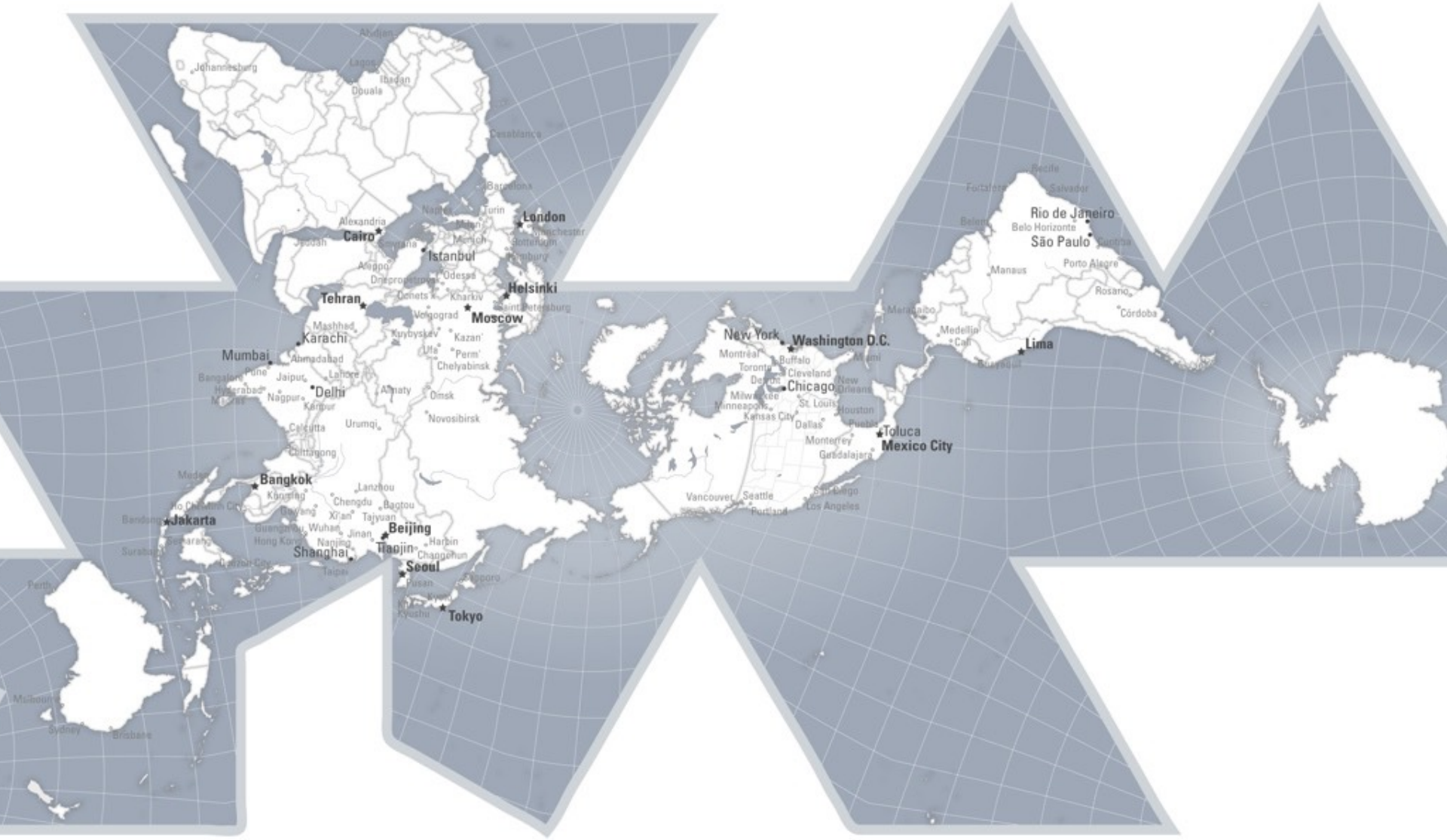
YOU'RE NOT A COMPLICATED PERSON. YOU LOVE THE MERCATOR PROJECTION; YOU JUST WISH IT WEREN'T SQUARE. THE EARTH'S NOT A SQUARE, IT'S A CIRCLE. YOU LIKE CIRCLES. TODAY IS GONNA BE A GOOD DAY!

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.

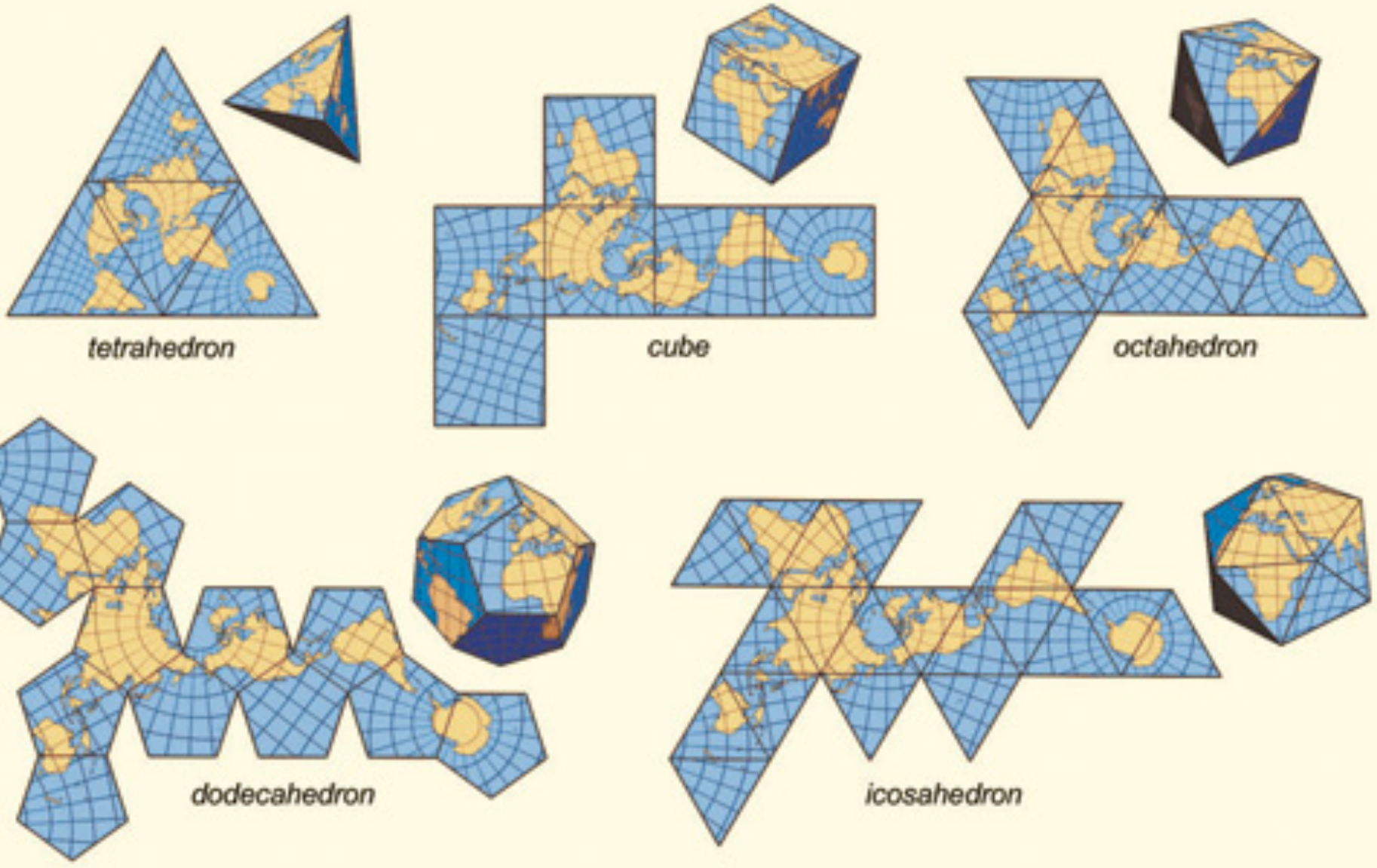
There are interesting ways to tear spheres

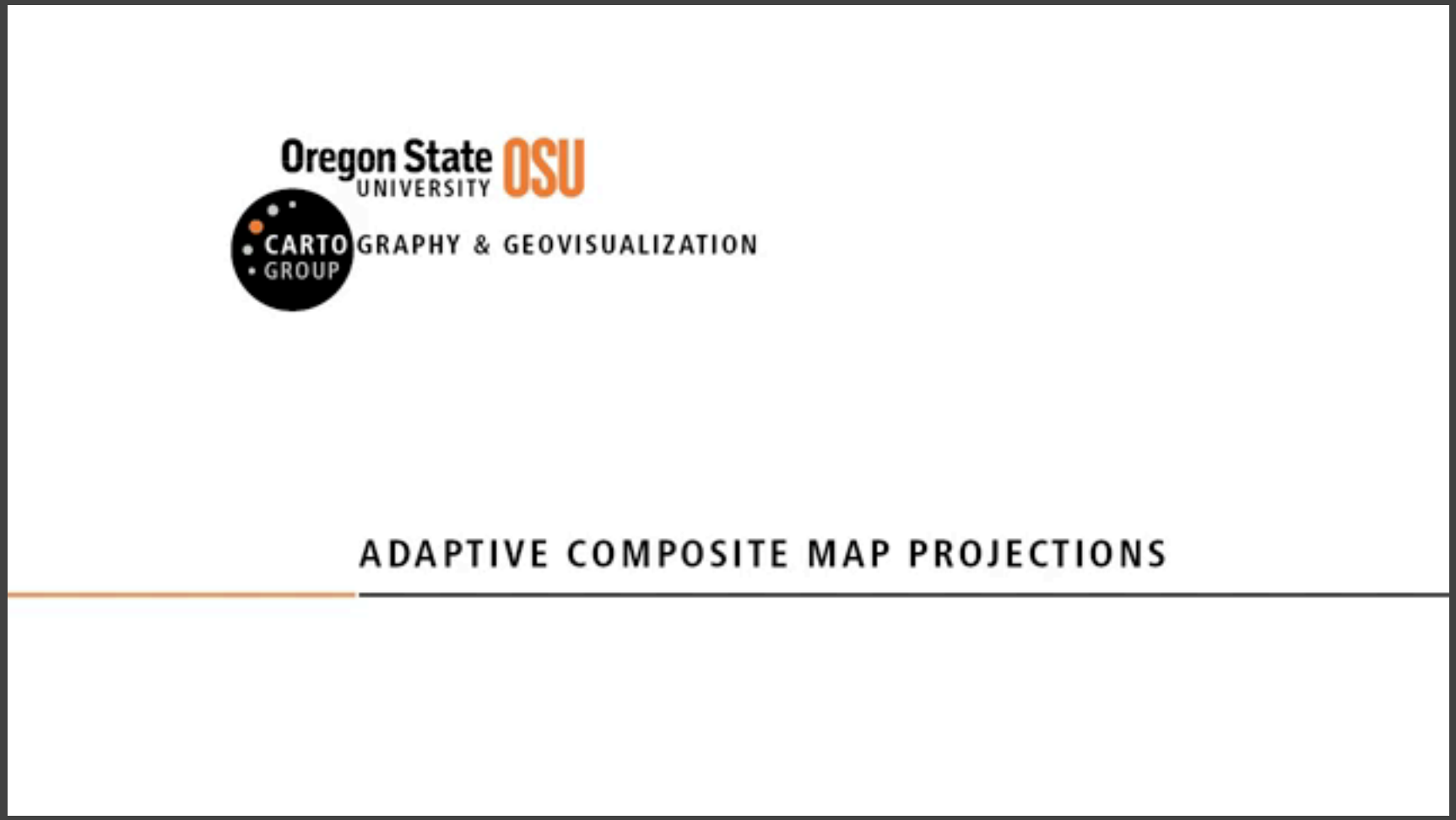
One notable interesting way to tear a sphere



Balances preservation of area and shape.

Provides different ways of thinking about the world!


tetrahedron
cube
octahedron
dodecahedron
icosahedron



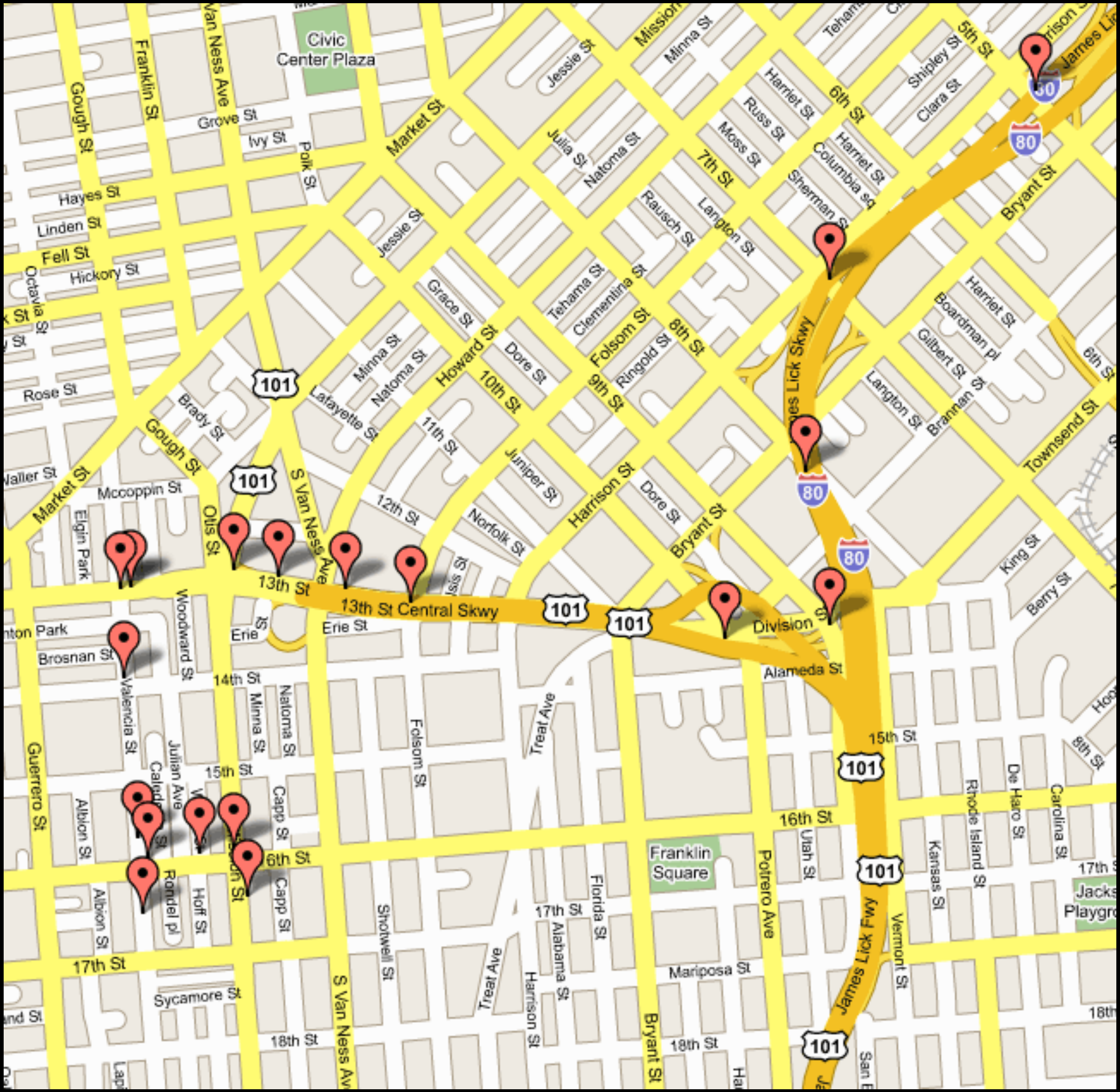
Idea: switch *between* projections by location and zoom level

Mapping

Visualizing Geospatial Data

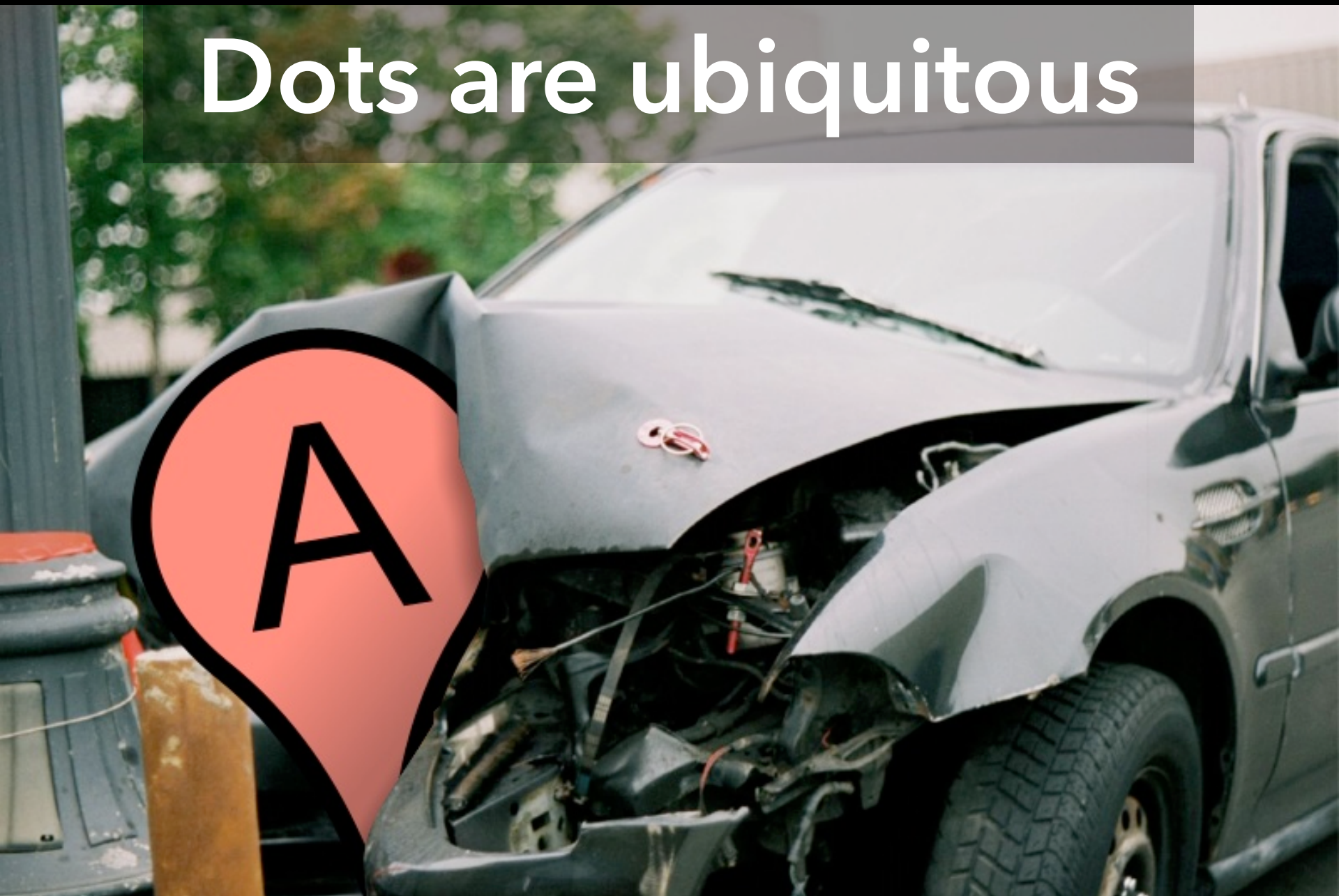
Symbol Maps

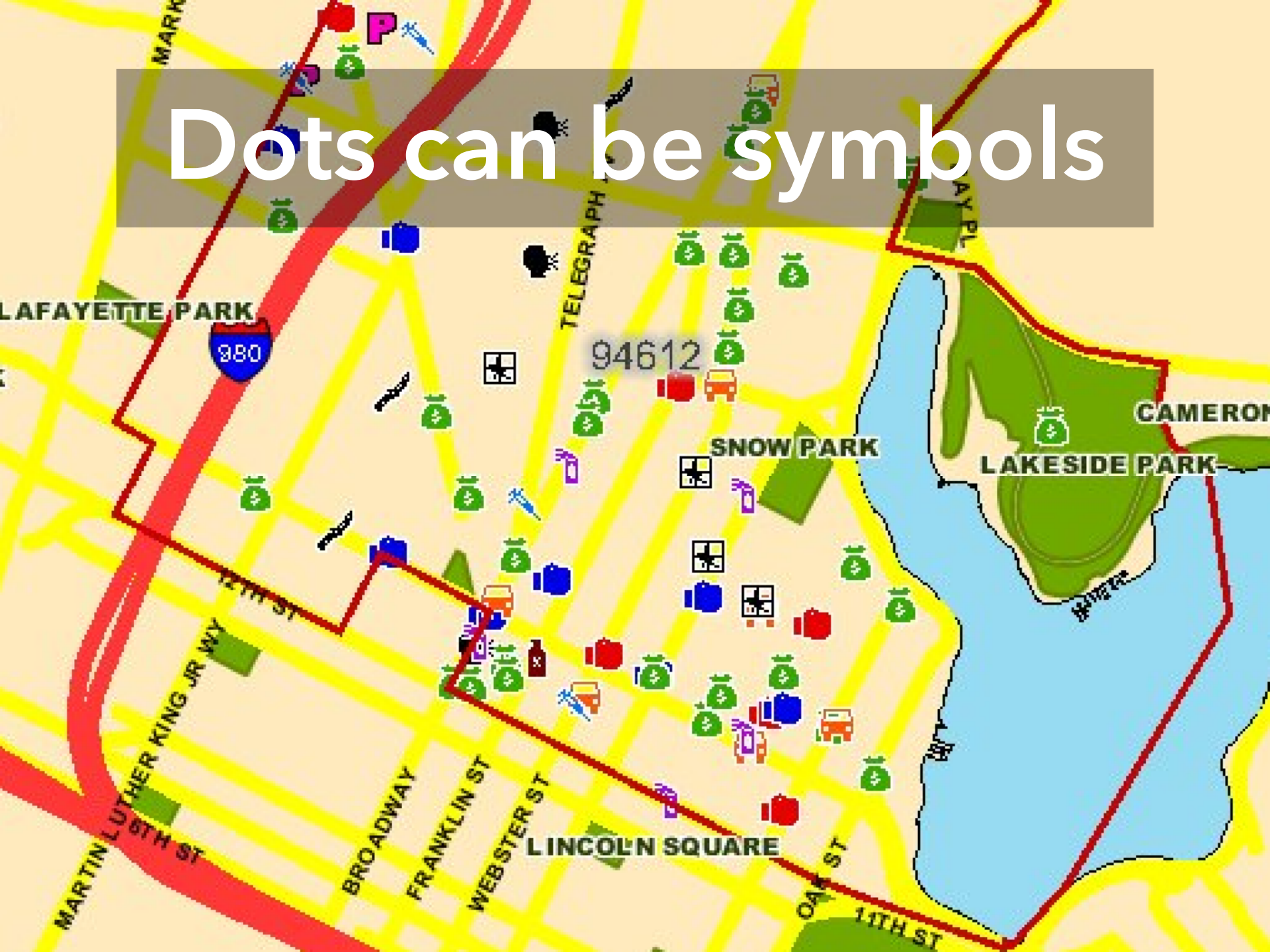
Convey Locations & Magnitudes

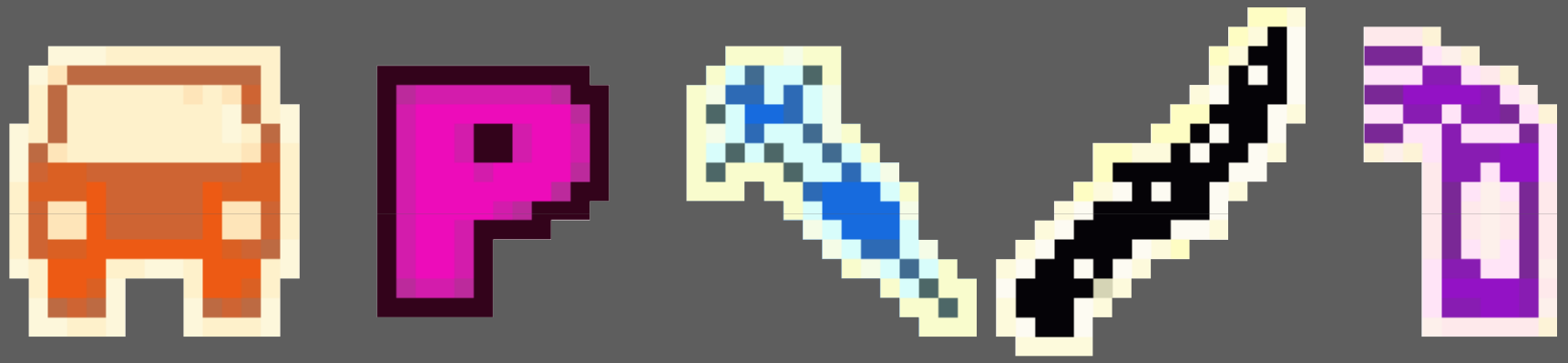


Civic Center Plaza
Gough St
Franklin St
Van Ness Ave
Grove St
Ivy St
Polk St
Market St
Hayes St
Linden St
Fell St
Hickory St
Octavia St
Rose St
Brady St
Gough St
101
Lafayette St
Minna St
Natoma St
Jessie St
Howard St
Grace St
10th St
Dore St
11th St
Juniper St
12th St
Norfolk St
Harrison St
Bryant St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

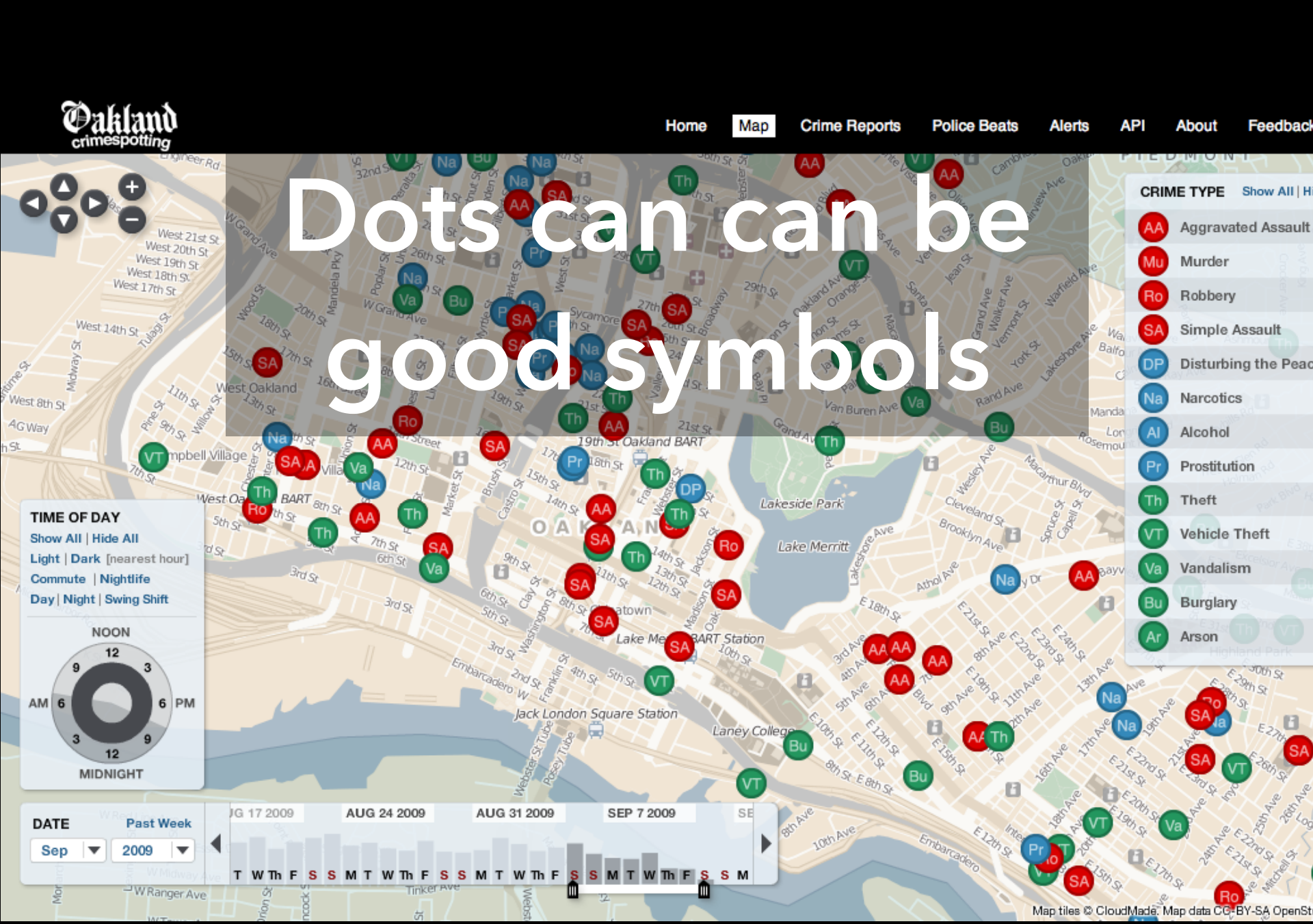
Dots are ubiquitous

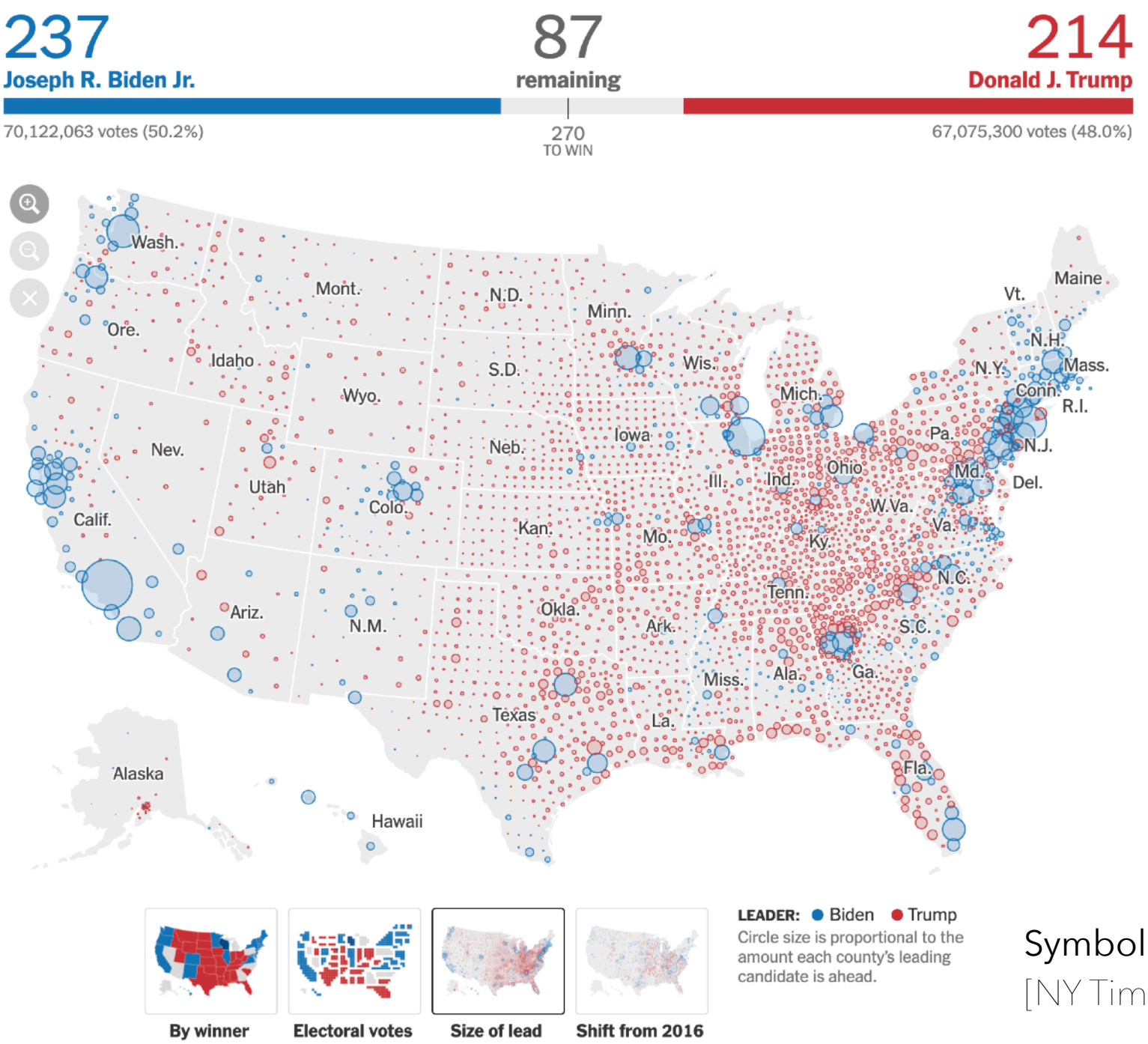



Dots can be symbols
LAFAYETTE PARK
980
TELEGRAPH
94612
SNOW PARK
LAKESIDE PARK
CAMERON
12TH ST
MARTIN LUTHER KING JR WY
BROADWAY
FRANKLIN ST
WEBSTER ST
LINCOLN SQUARE
OAK ST
11TH ST



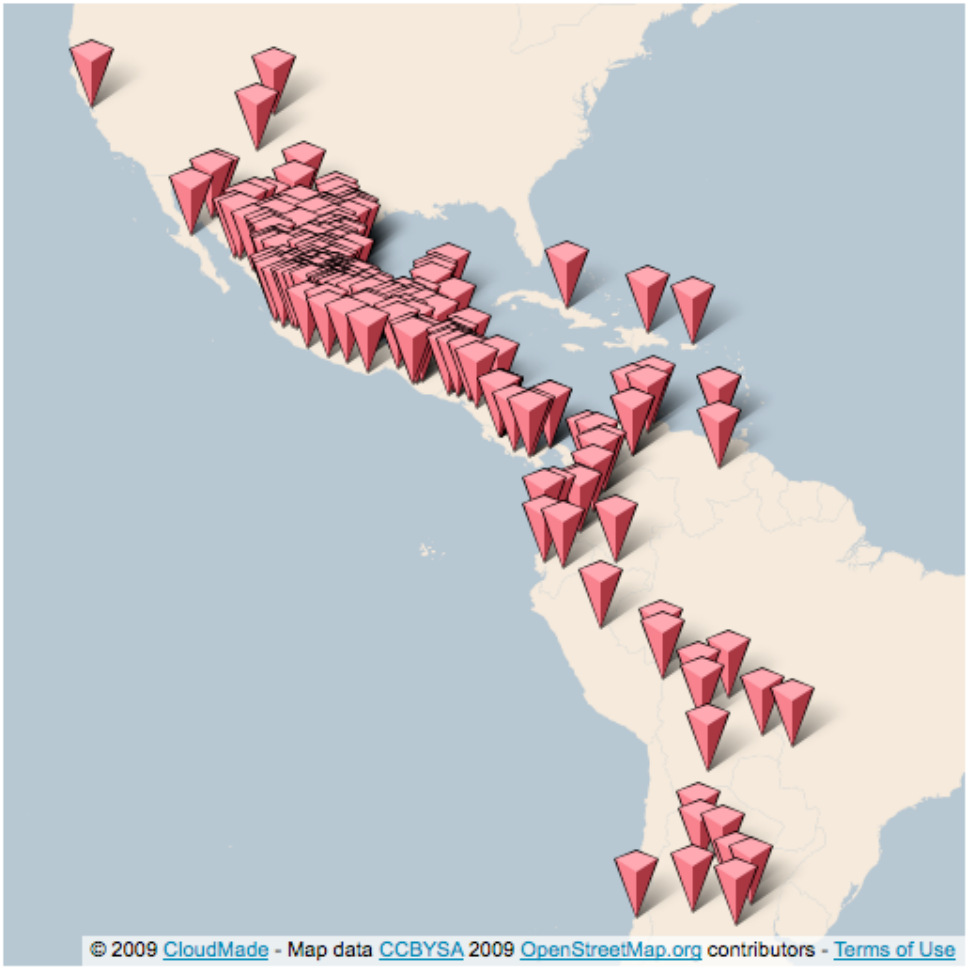
Guess the crime


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 24 2009
AUG 31 2009
SEP 7 2009
Lake Merritt
Lakeside Park
Jack London Square Station
19th St Oakland BART
Laney College
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

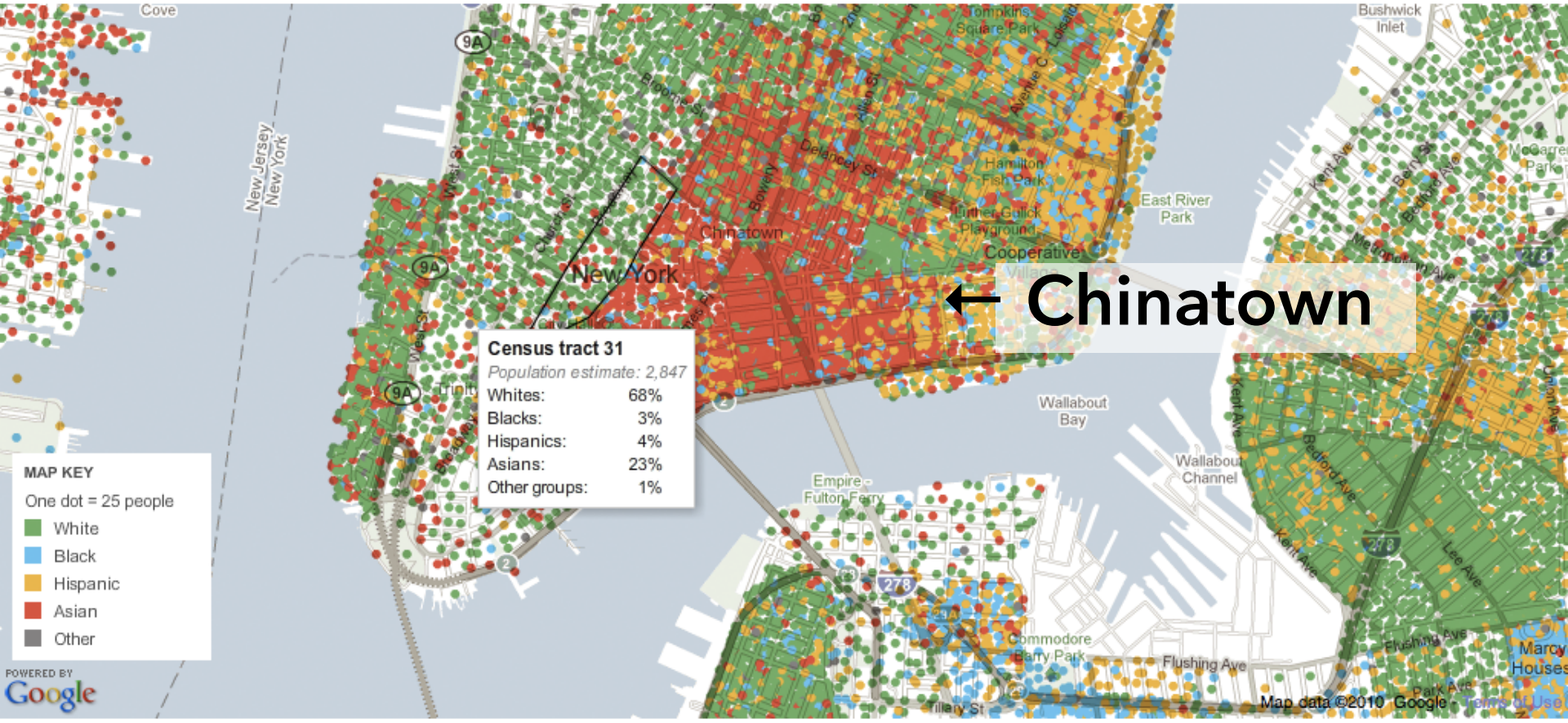
Find something interesting? Share this view on Twitter or Facebook

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)

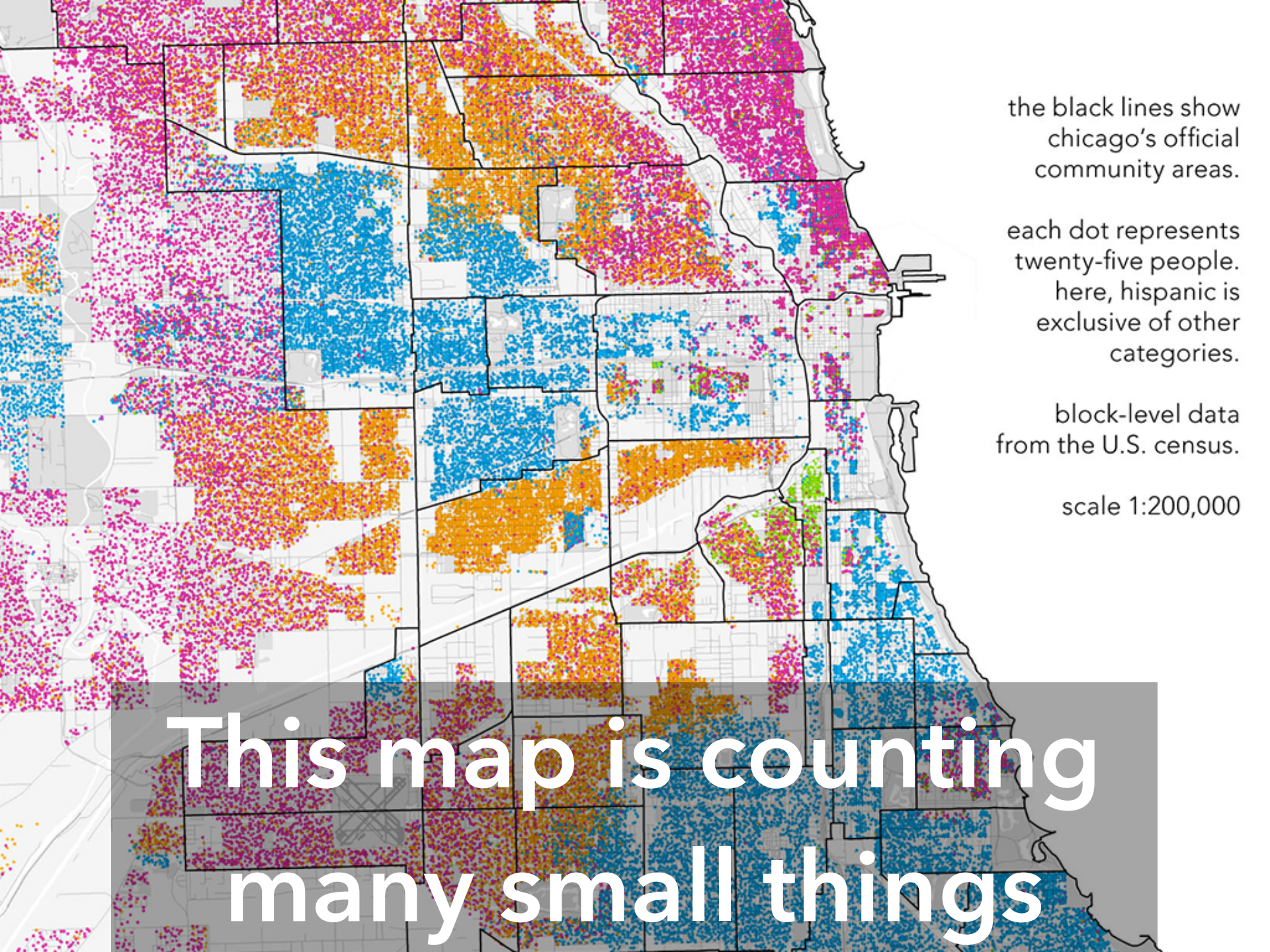
Distribution of racial and ethnic groups

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

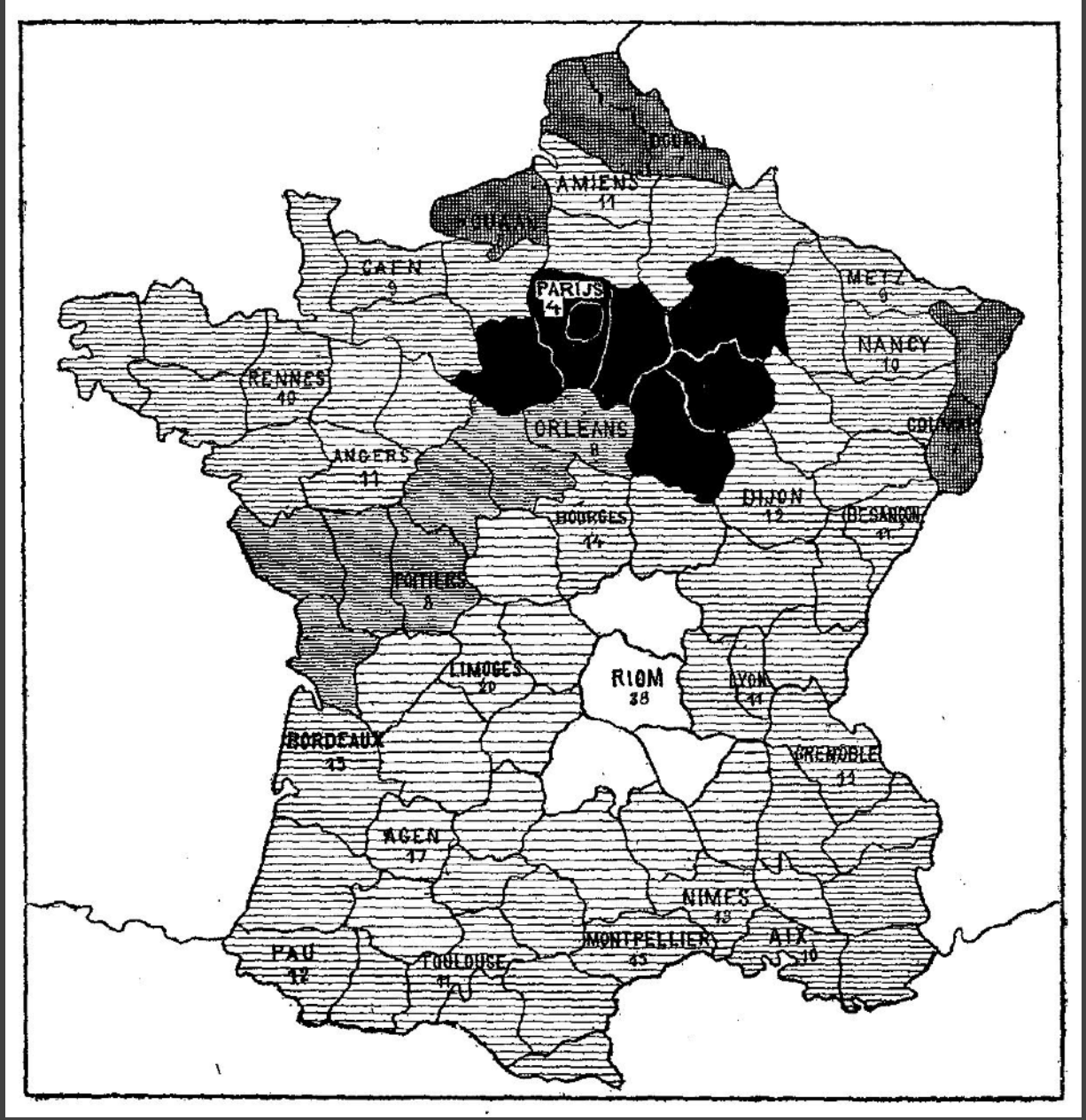
Note: Dots are evenly distributed across each Census tract or county. Dollar amounts are adjusted for inflation.



This map is counting many small things

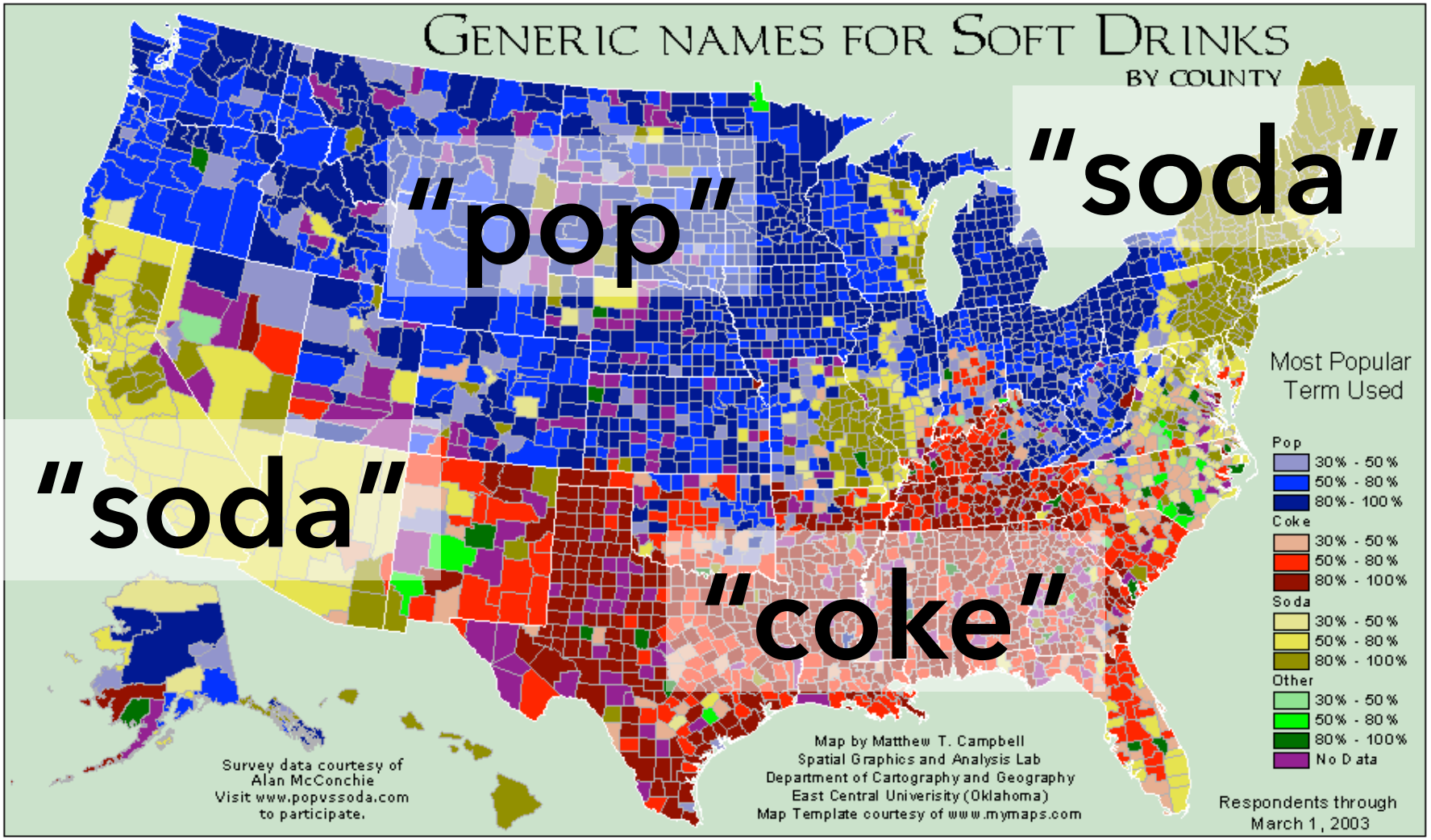
Choropleth Maps

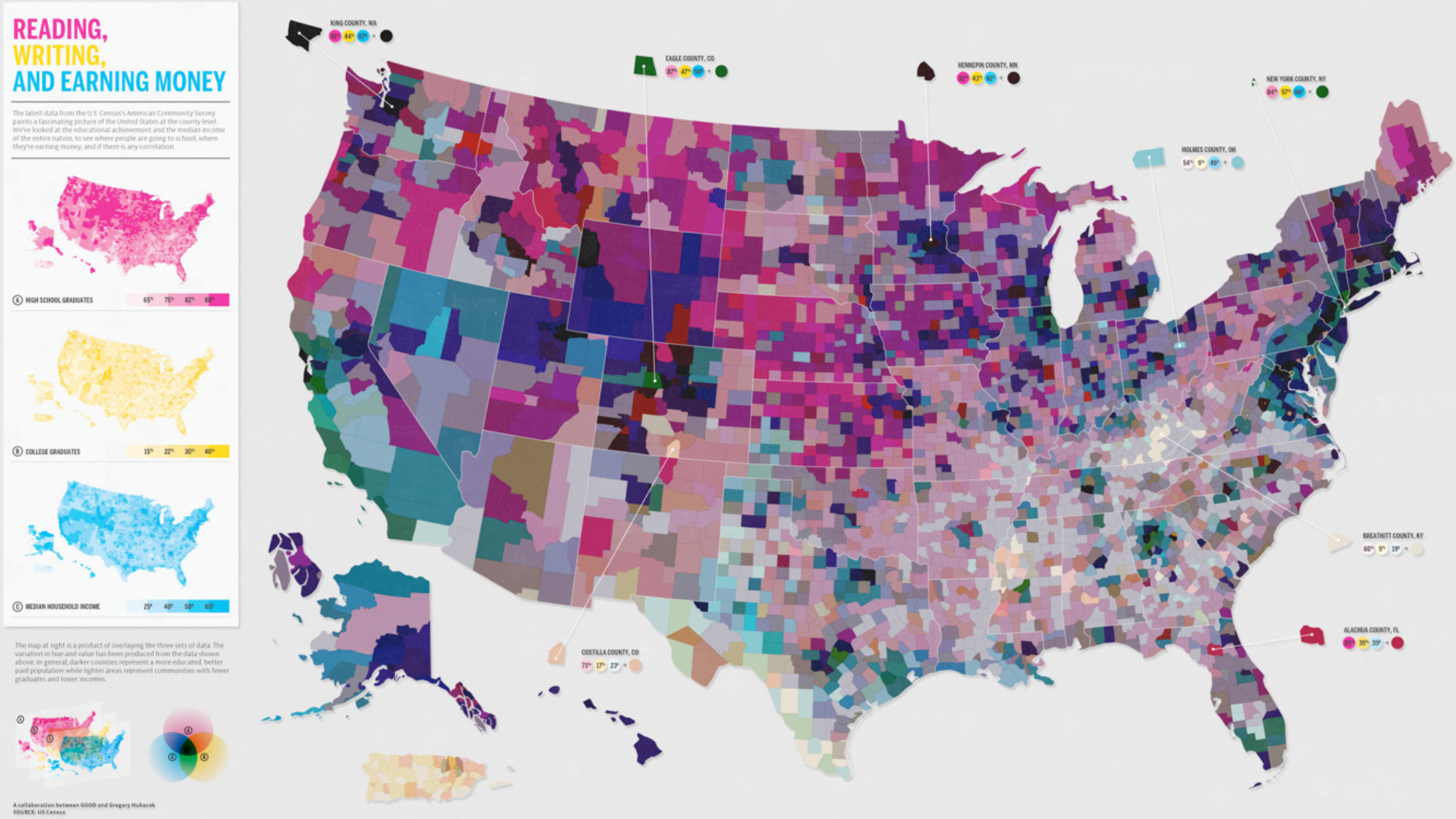
Convey Rates Across Regions



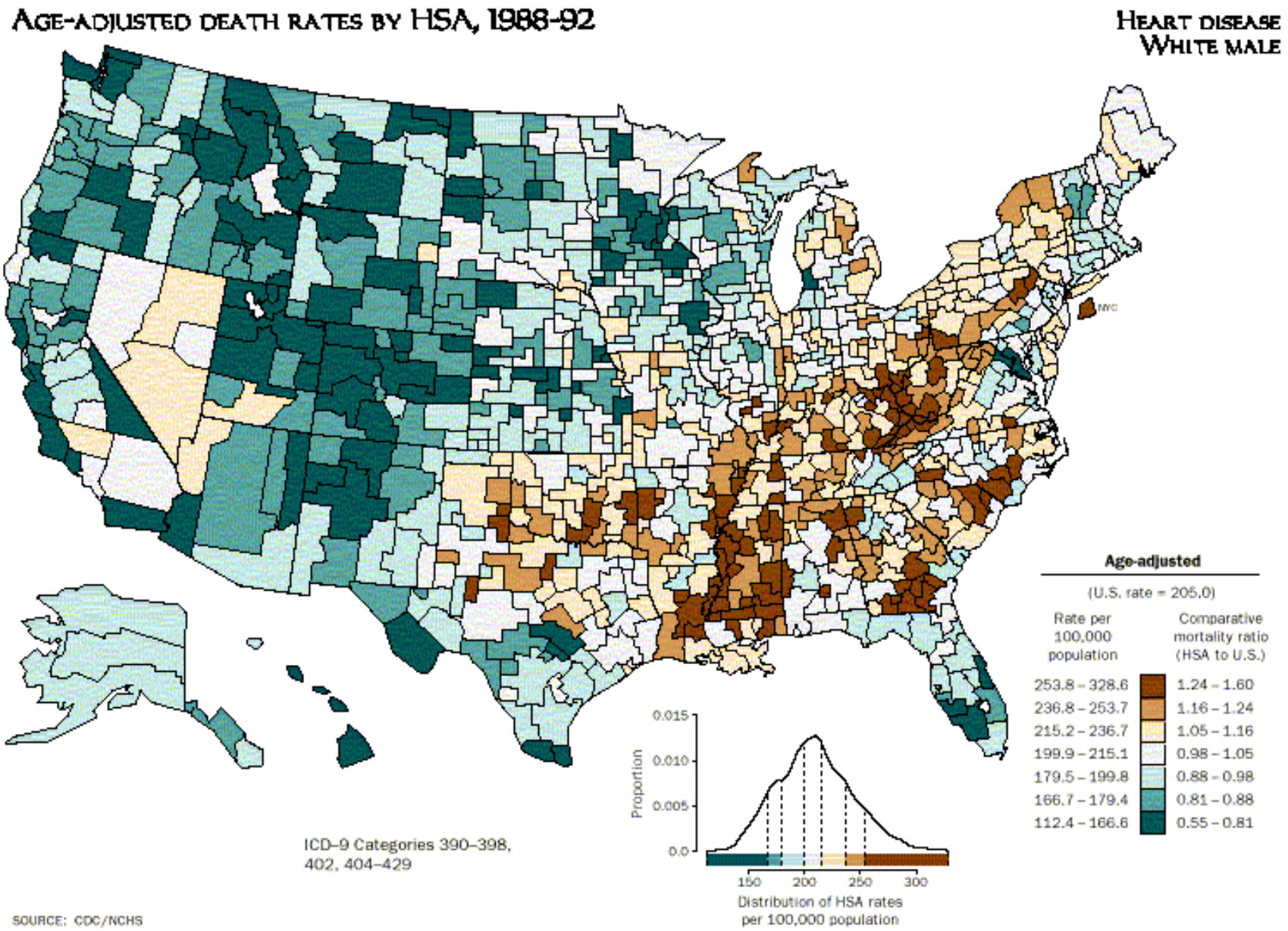
1826(?) Illiteracy in France, Pierre Charles Dupin

http://popvssoda.com

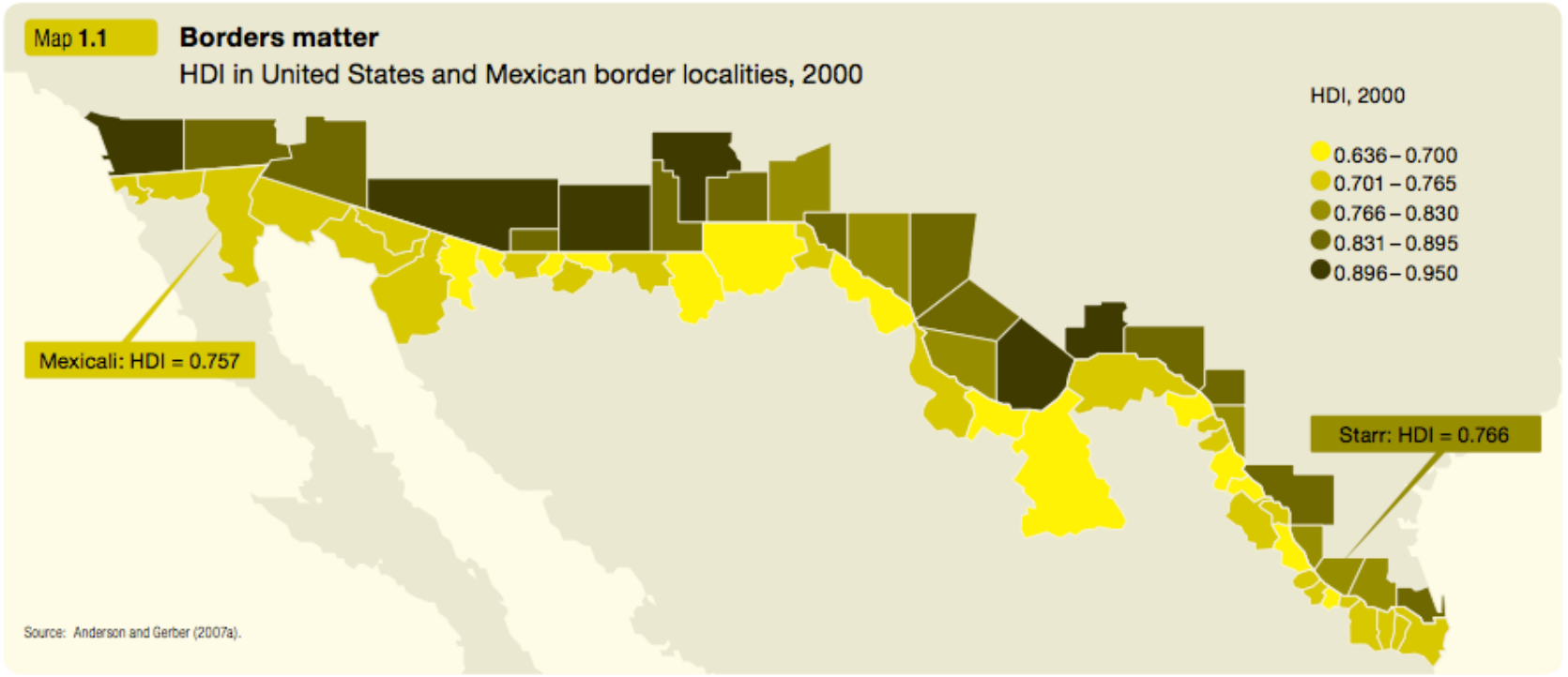




Choose colors with care



Seven quantiles

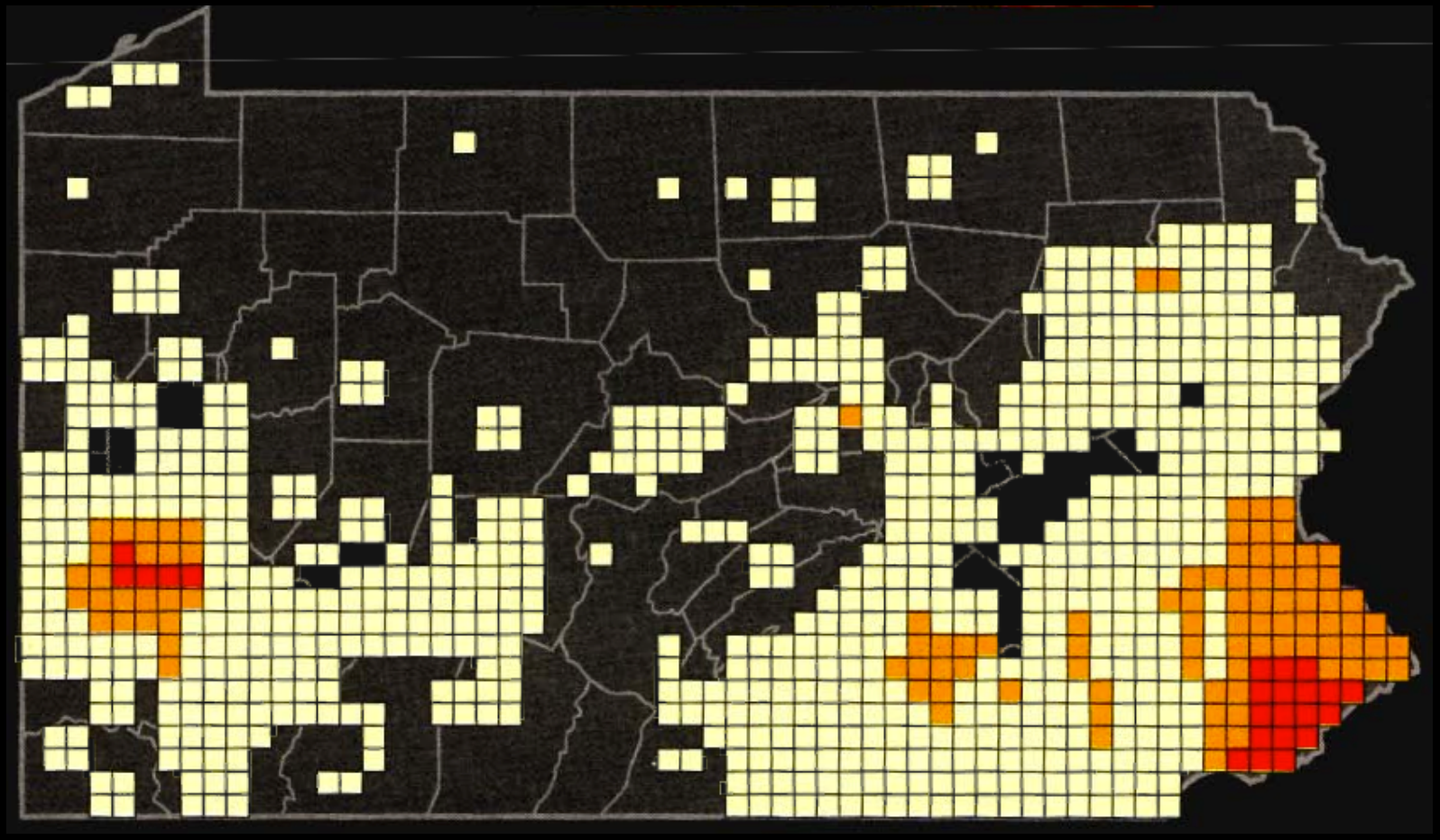


Focus on the foreground

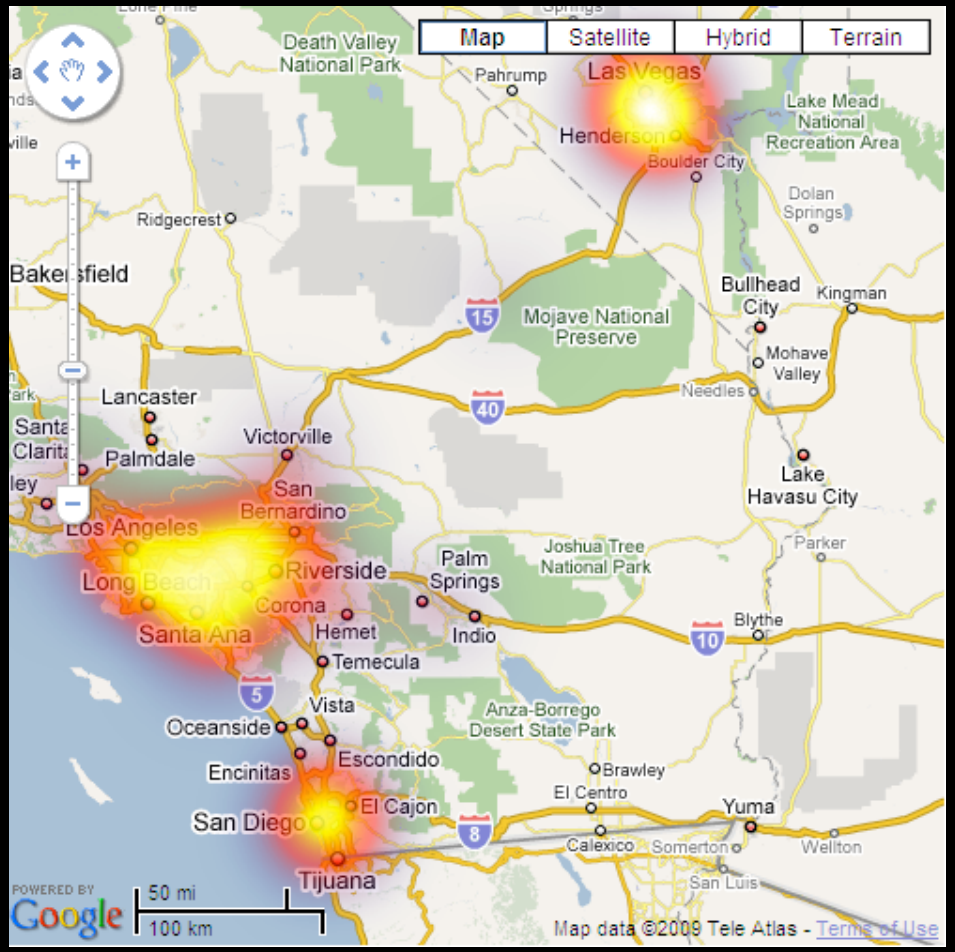
Heatmaps / Contour Maps

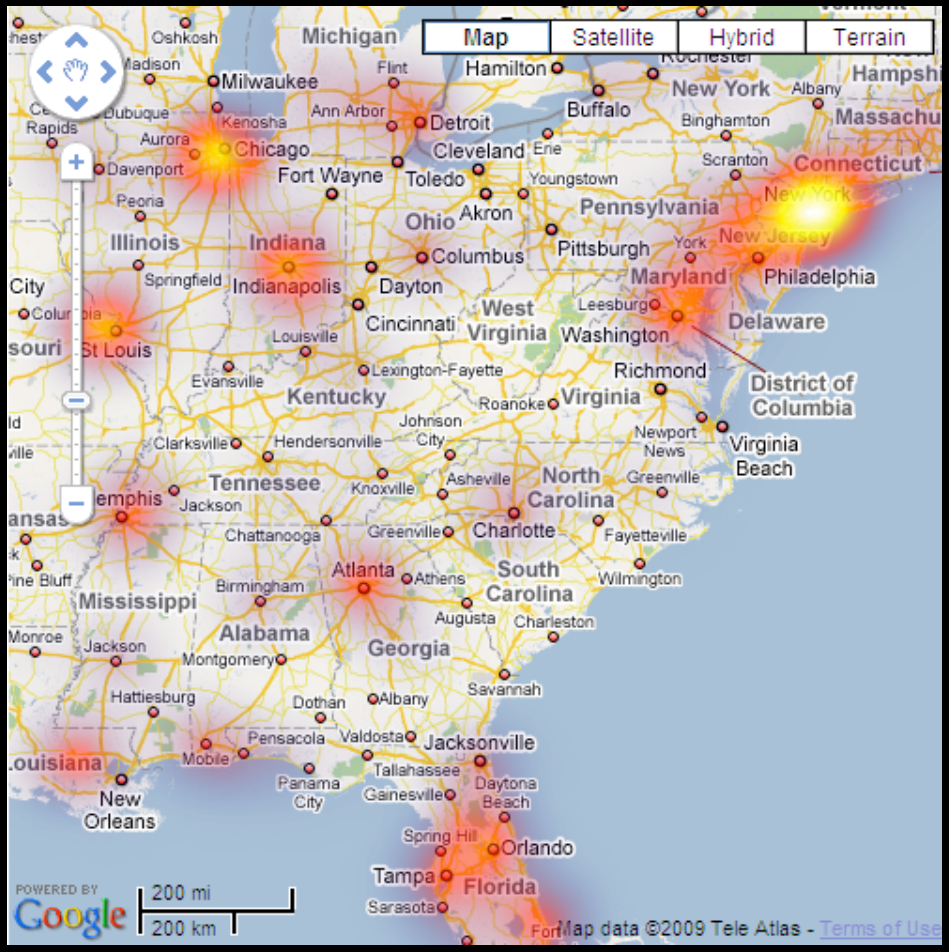
Convey Continuous Data

Binning



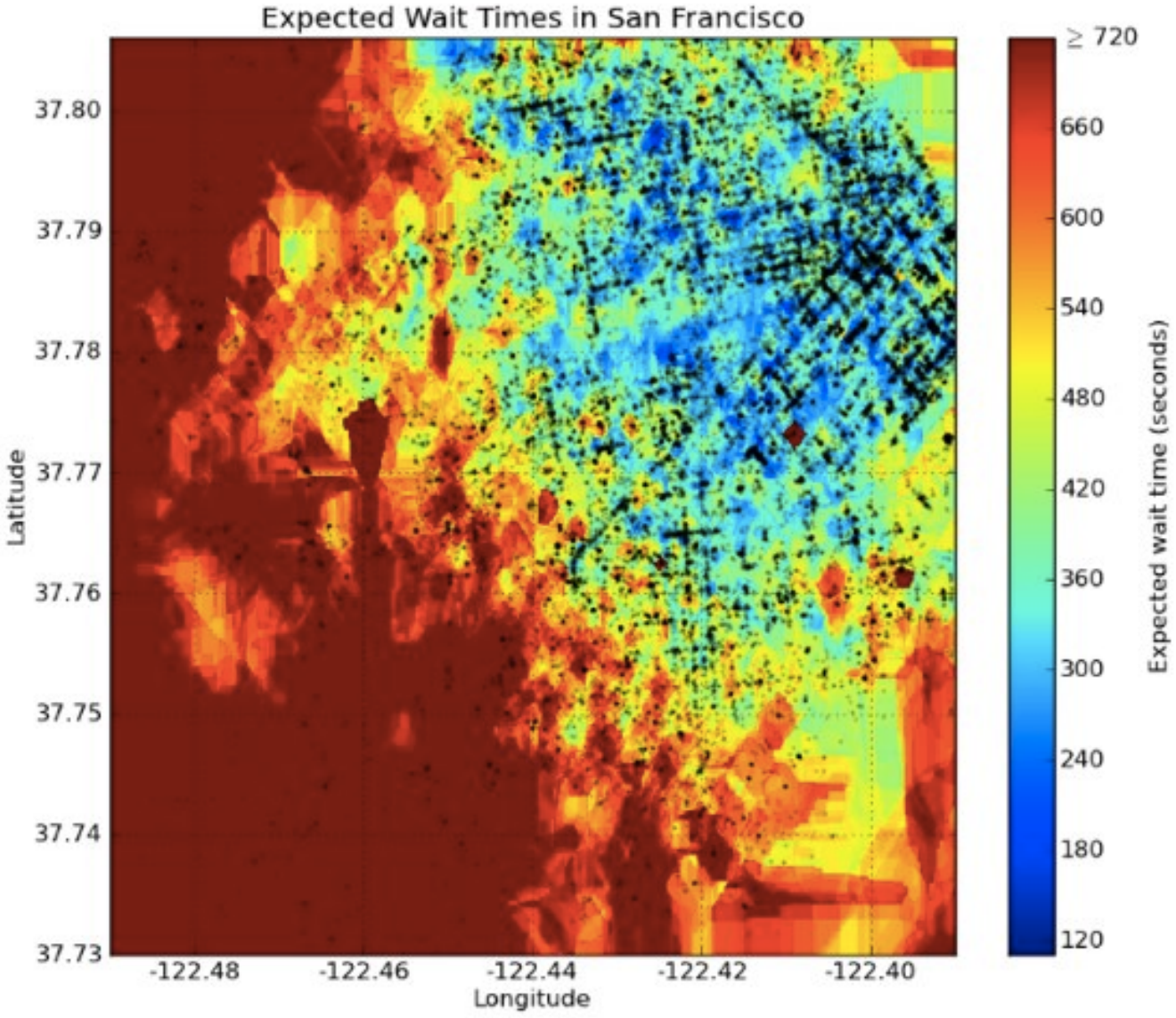
Chorodot Maps: Alan MacEachren and David DiBiase, 1991



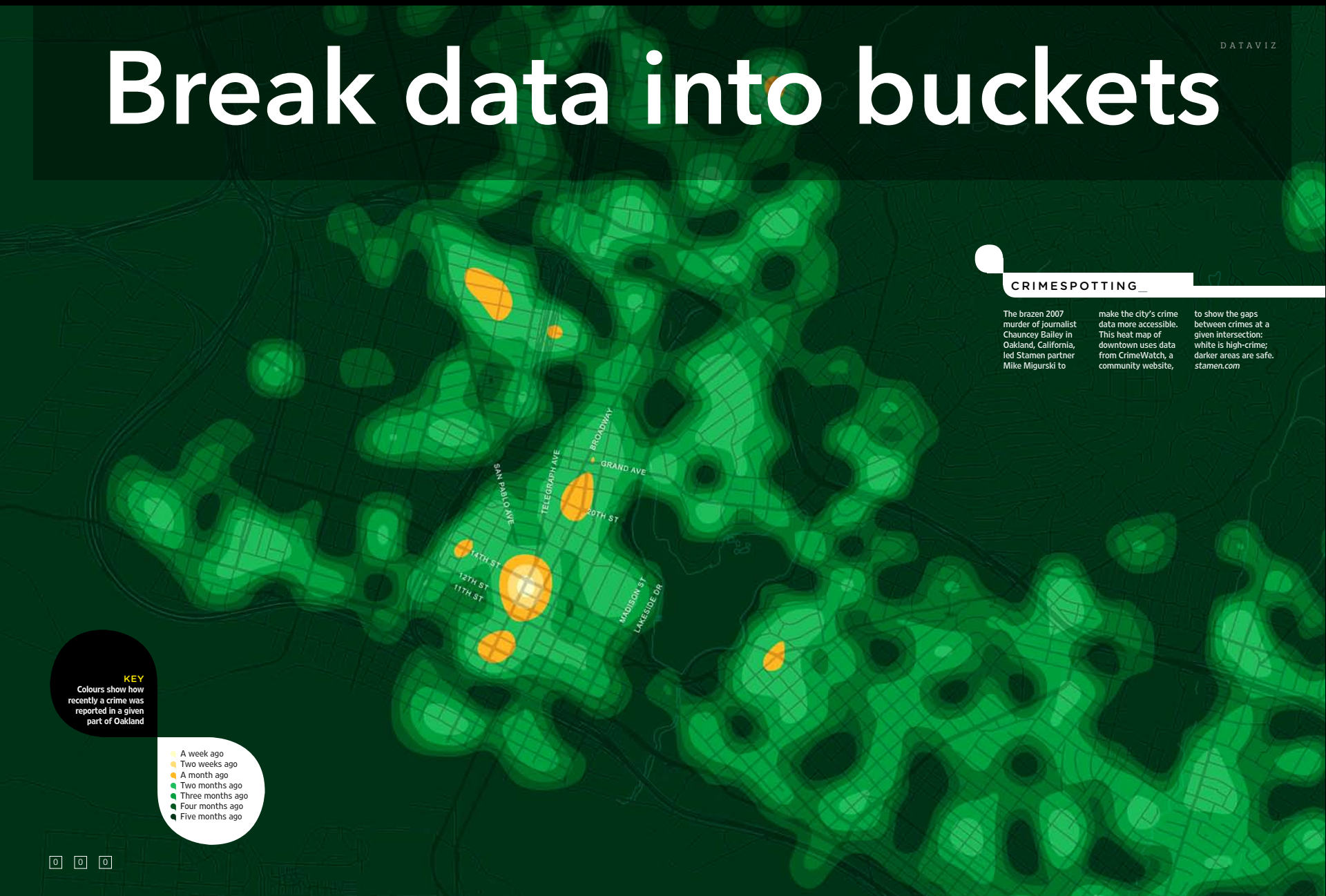


Don’t hide the context

Uber Wait Times, 2011



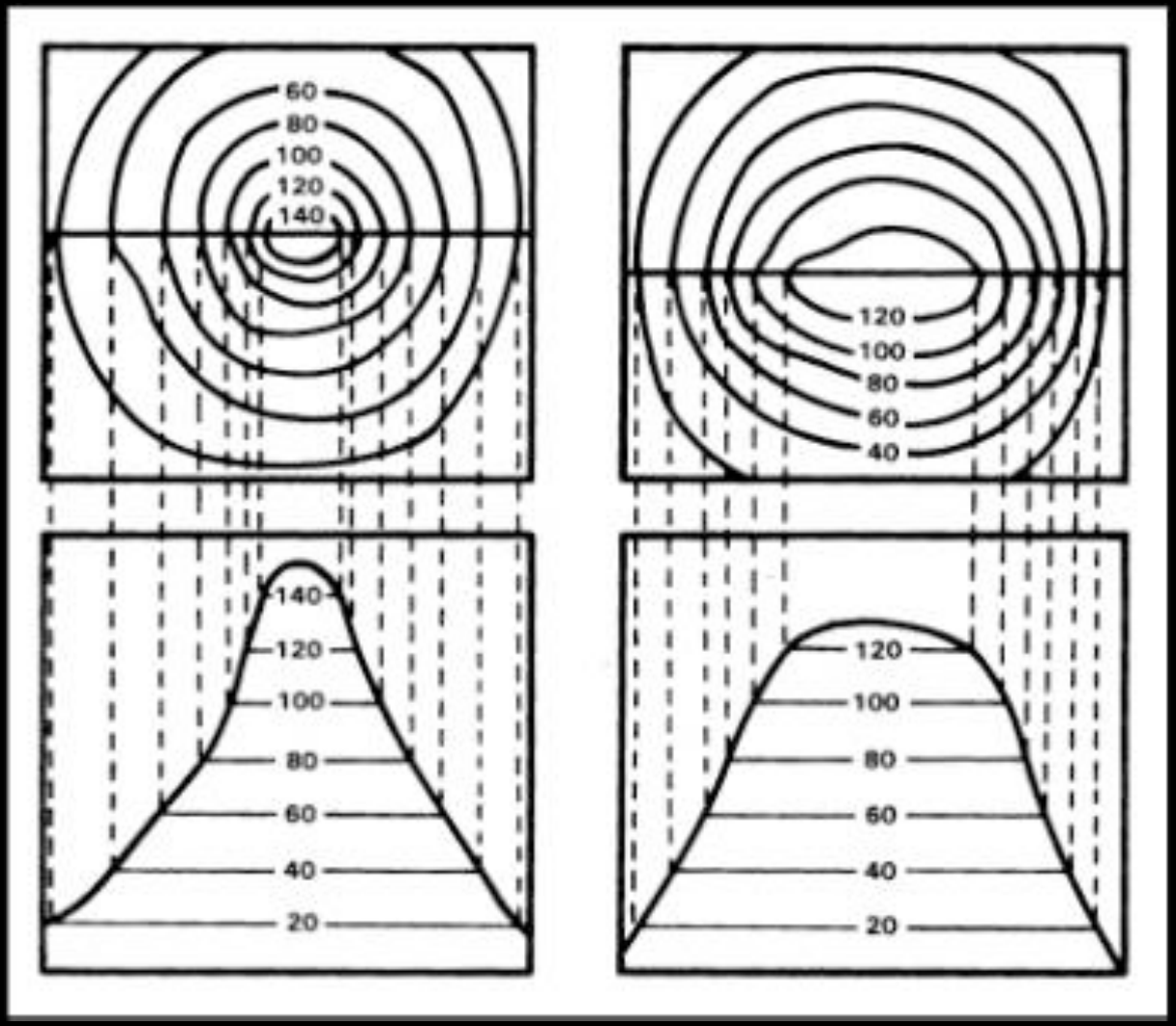
Break data into buckets

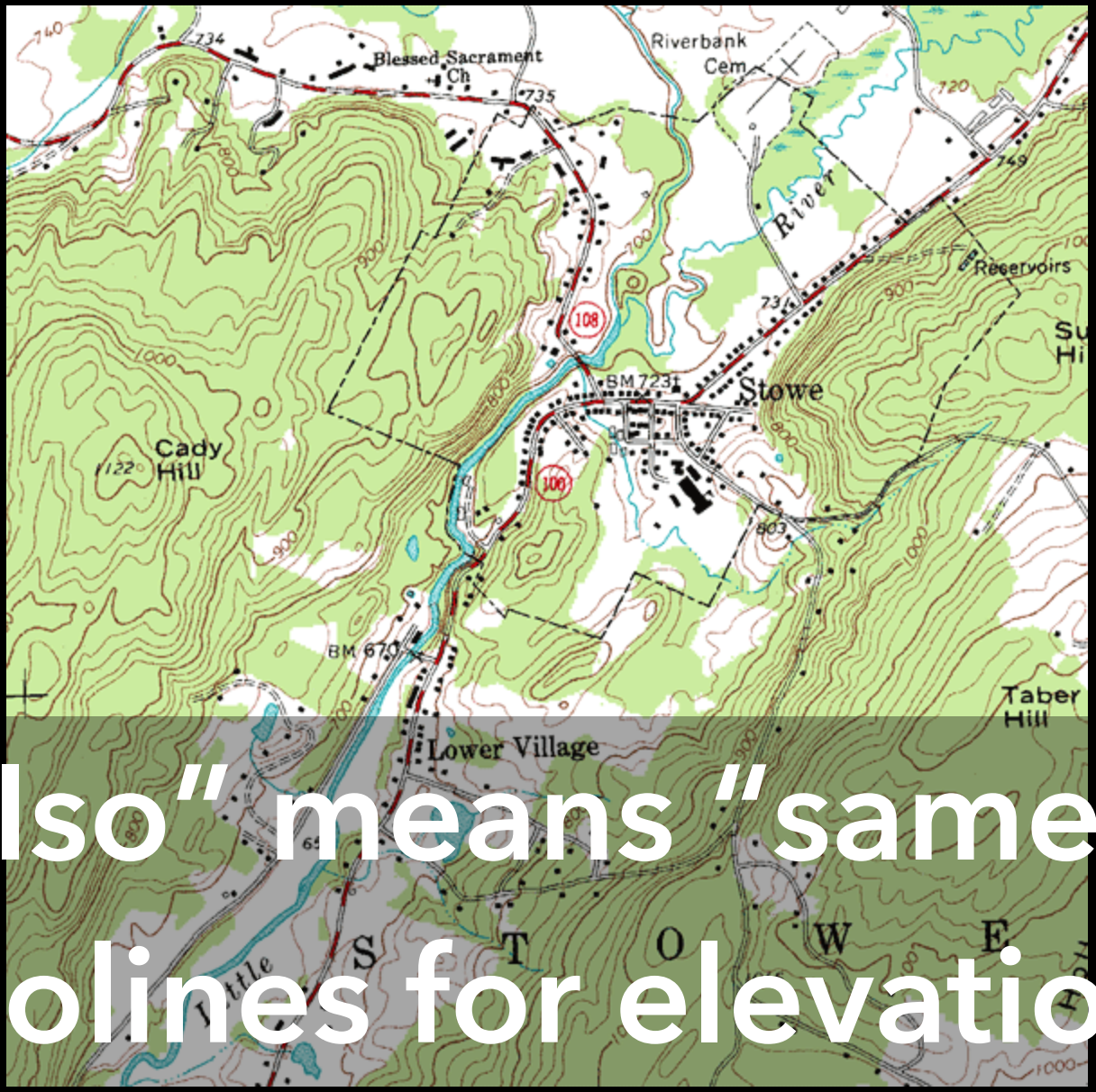


CRIMESPOTTING_

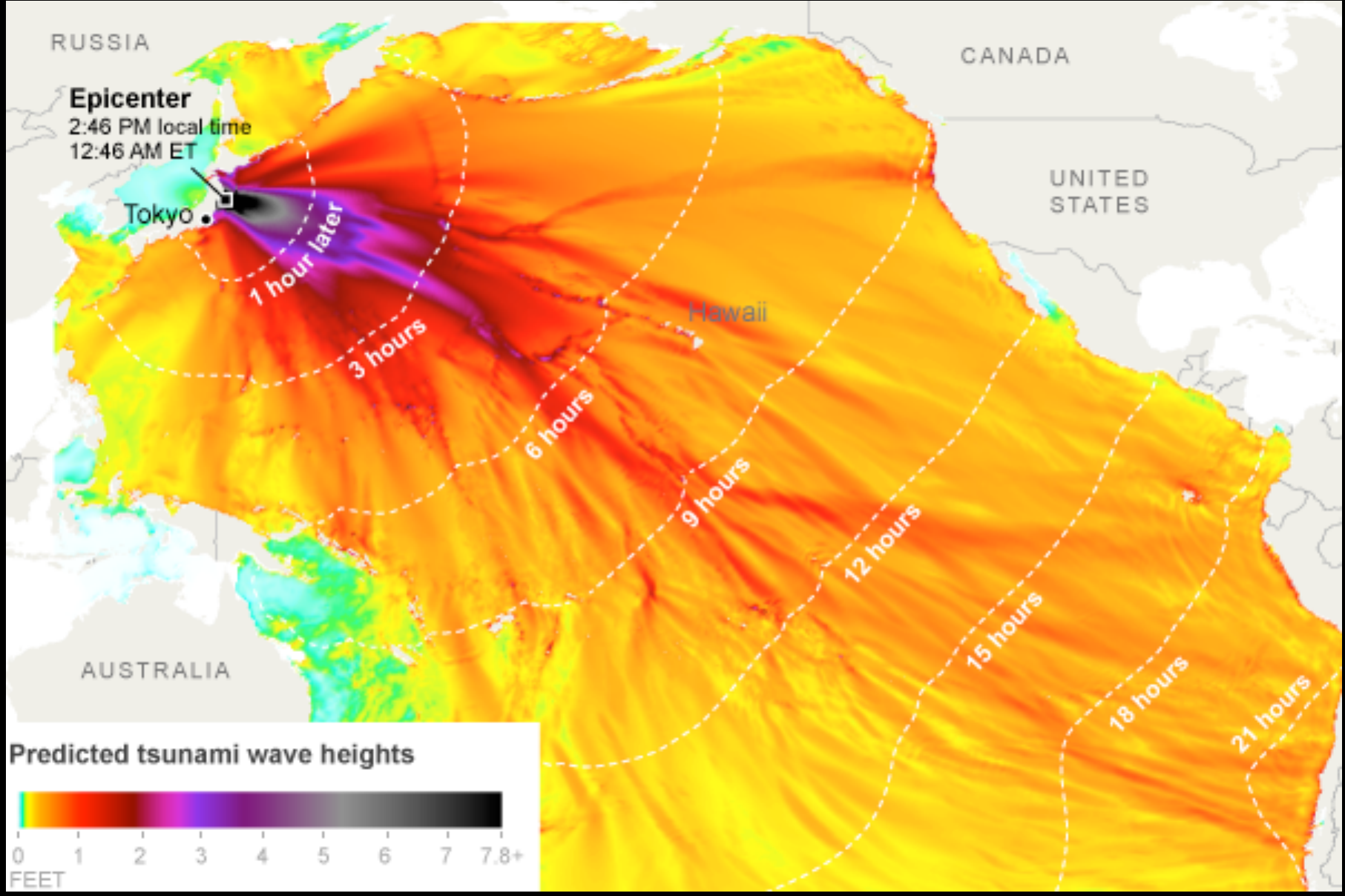
The brazen 2007 murder of journalist Chauncey Bailey in Oakland, California, led Stamen partner Mike Migurski to make the city's crime data more accessible. This heat map of downtown uses data from CrimeWatch, a community website, to show the gaps between crimes at a given intersection: white is high-crime;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

Meaningful buckets, isolines





"Iso" means "same"
Isolines for elevation

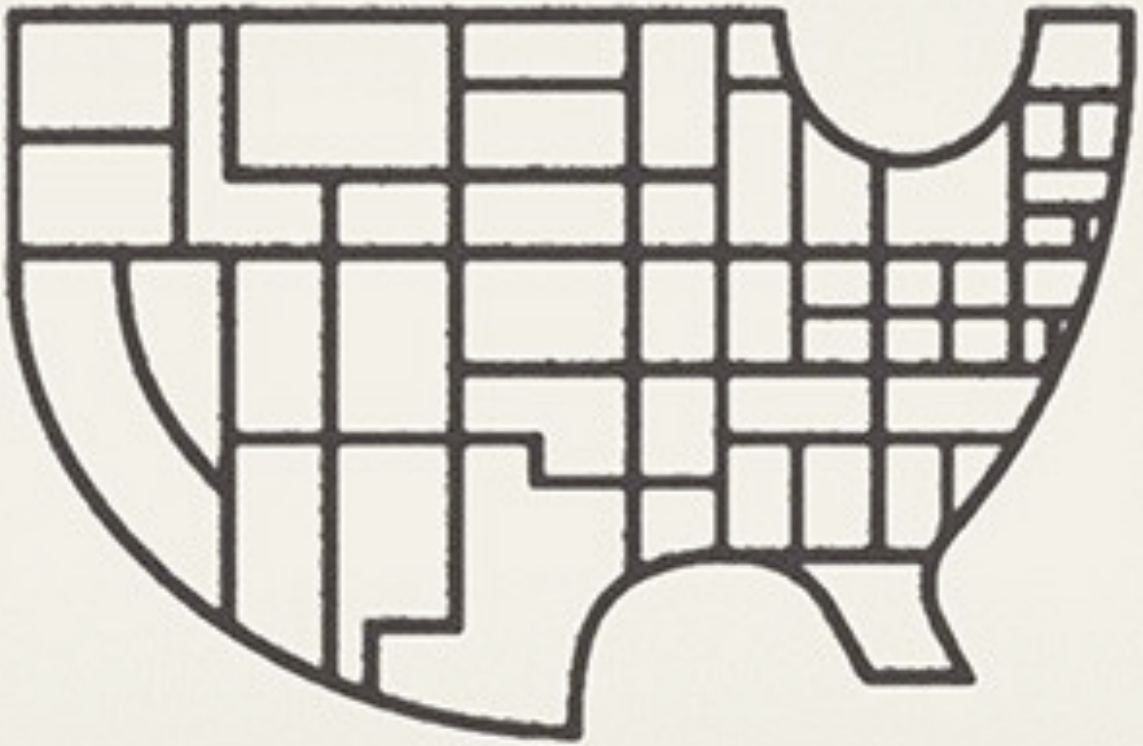


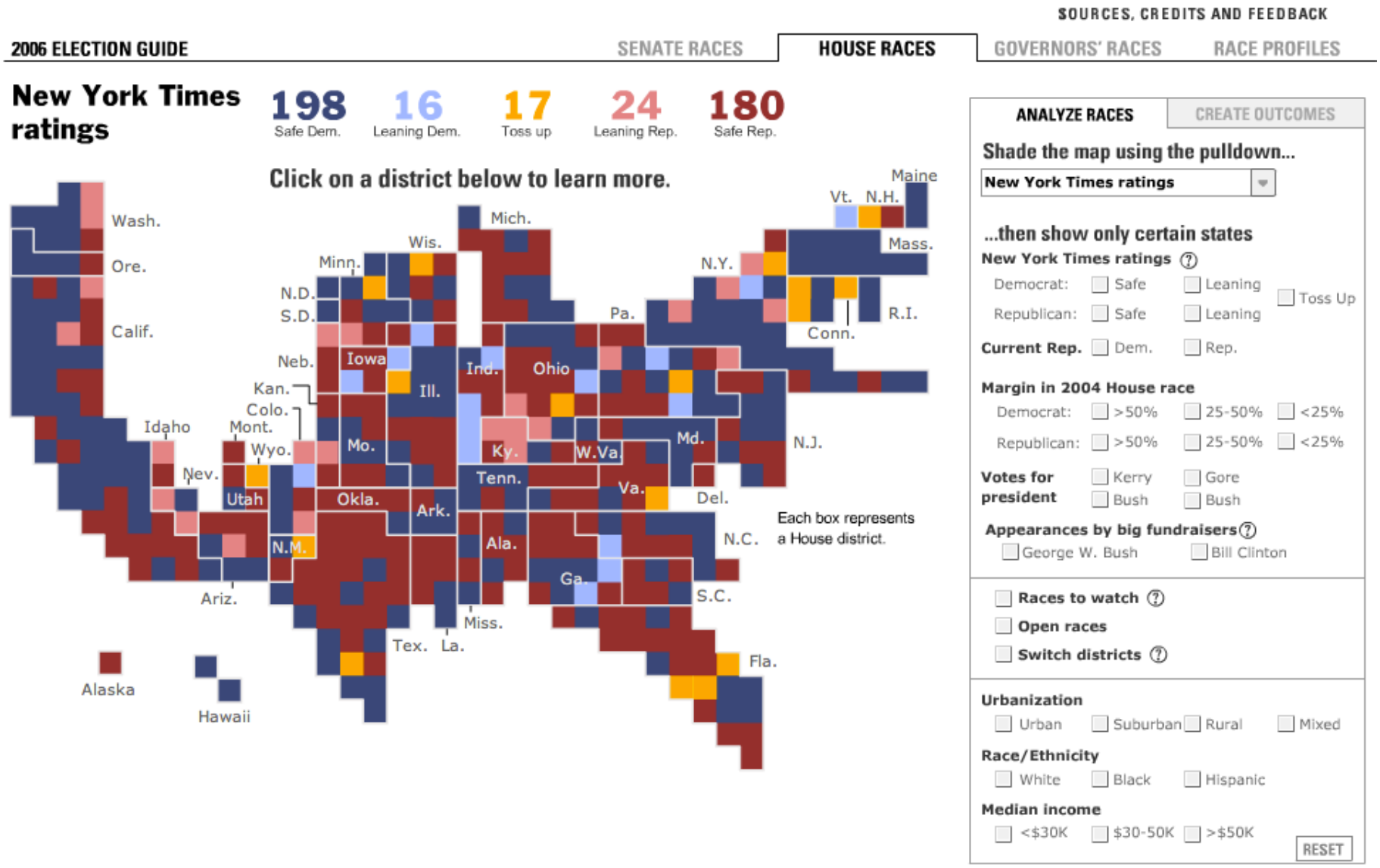
Isochrones are isolines for time

Cartograms

Distort Shape to Convey Quantities

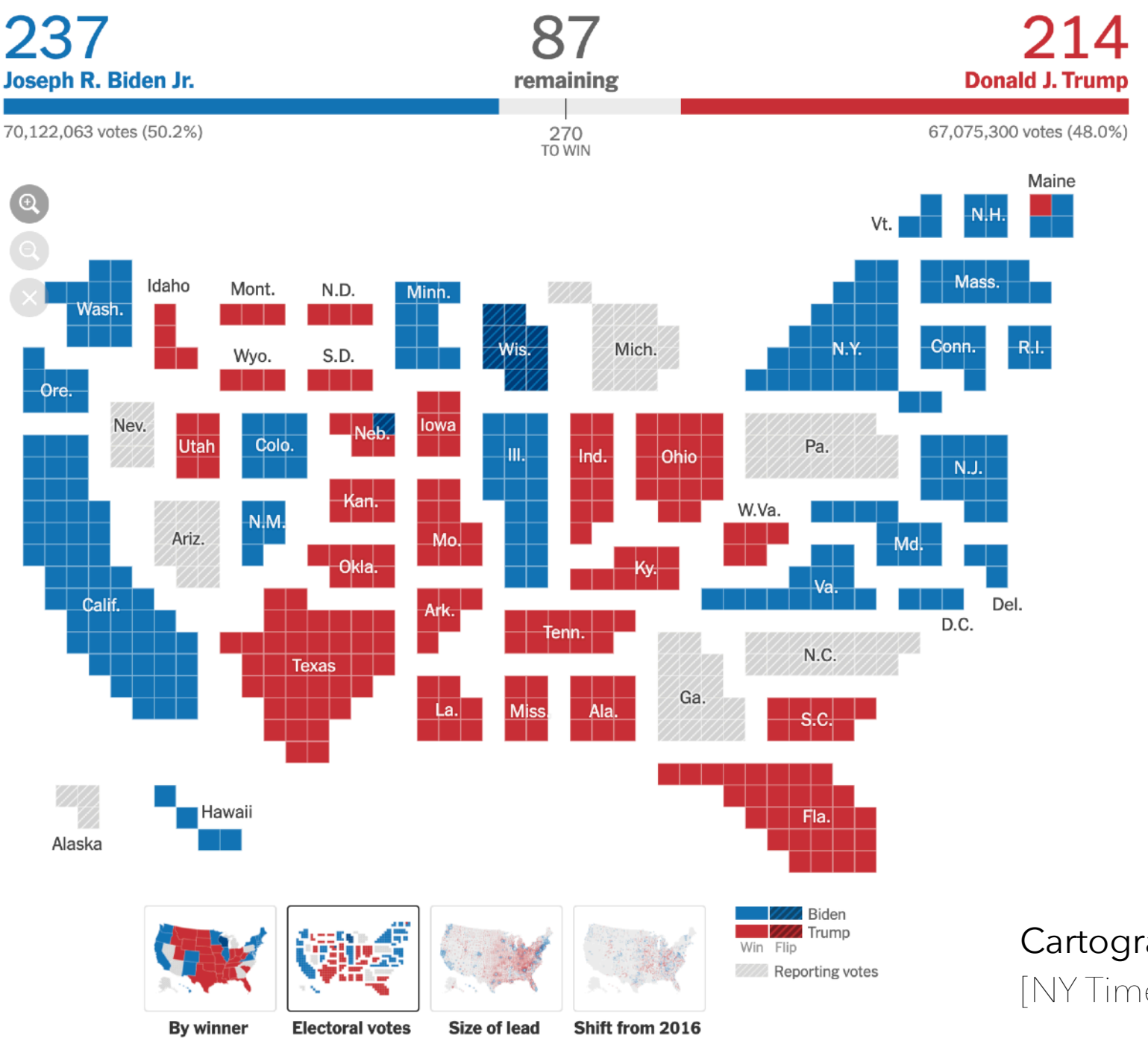
Major distortions can stay recognizable





Block Cartogram: Discrete Units

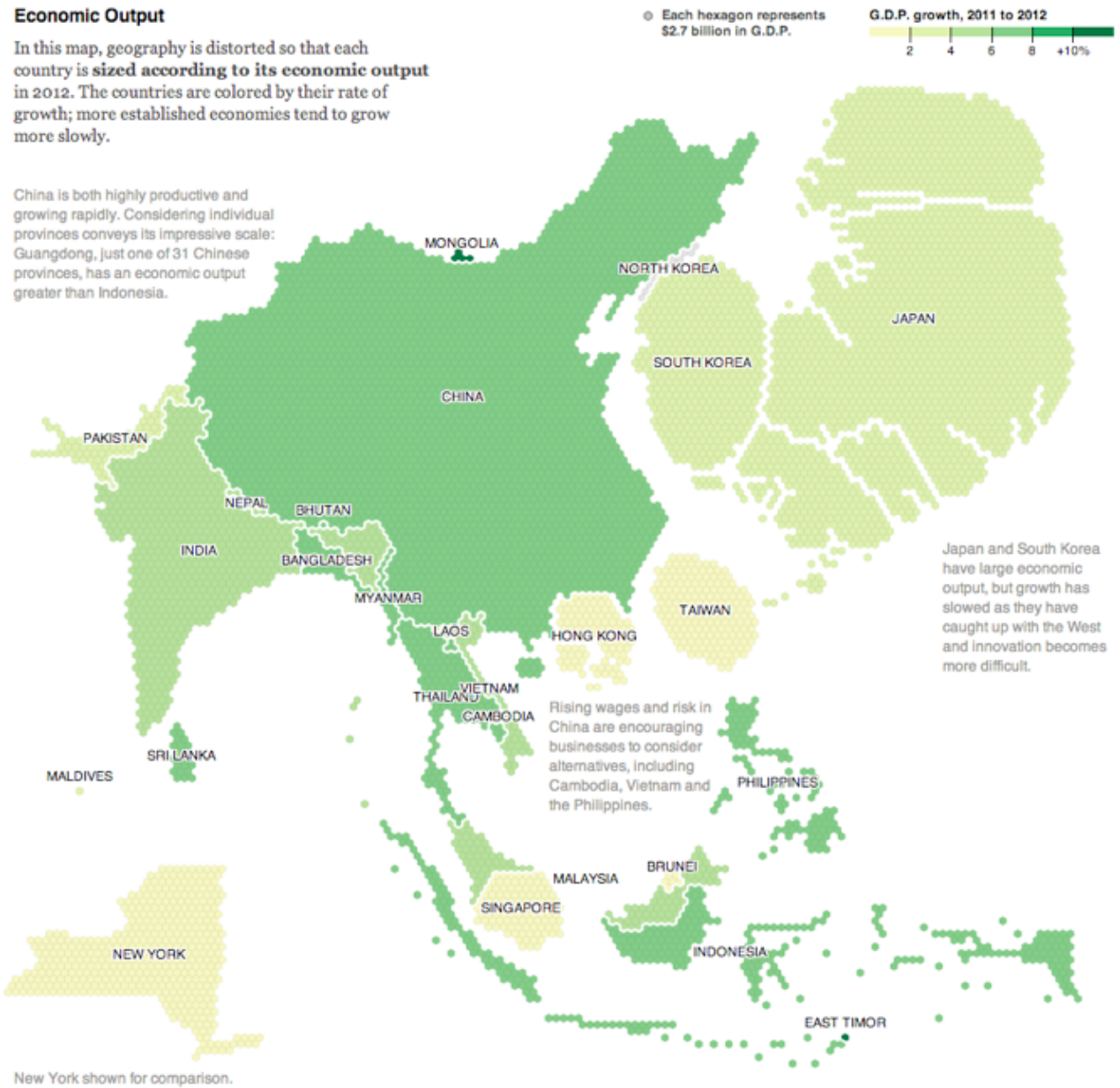
NY Times



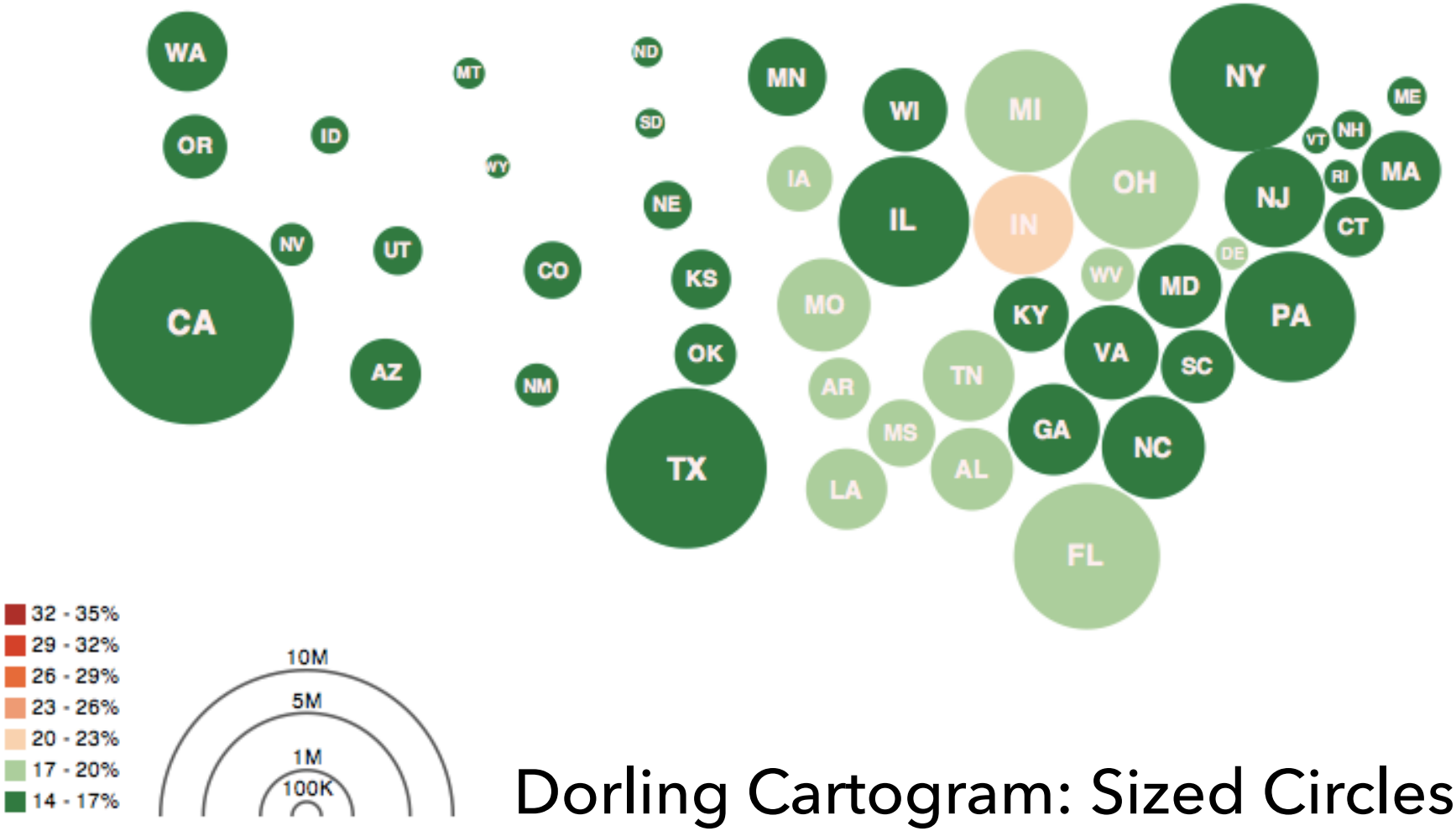
Cartogram
[NY Times]

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 »

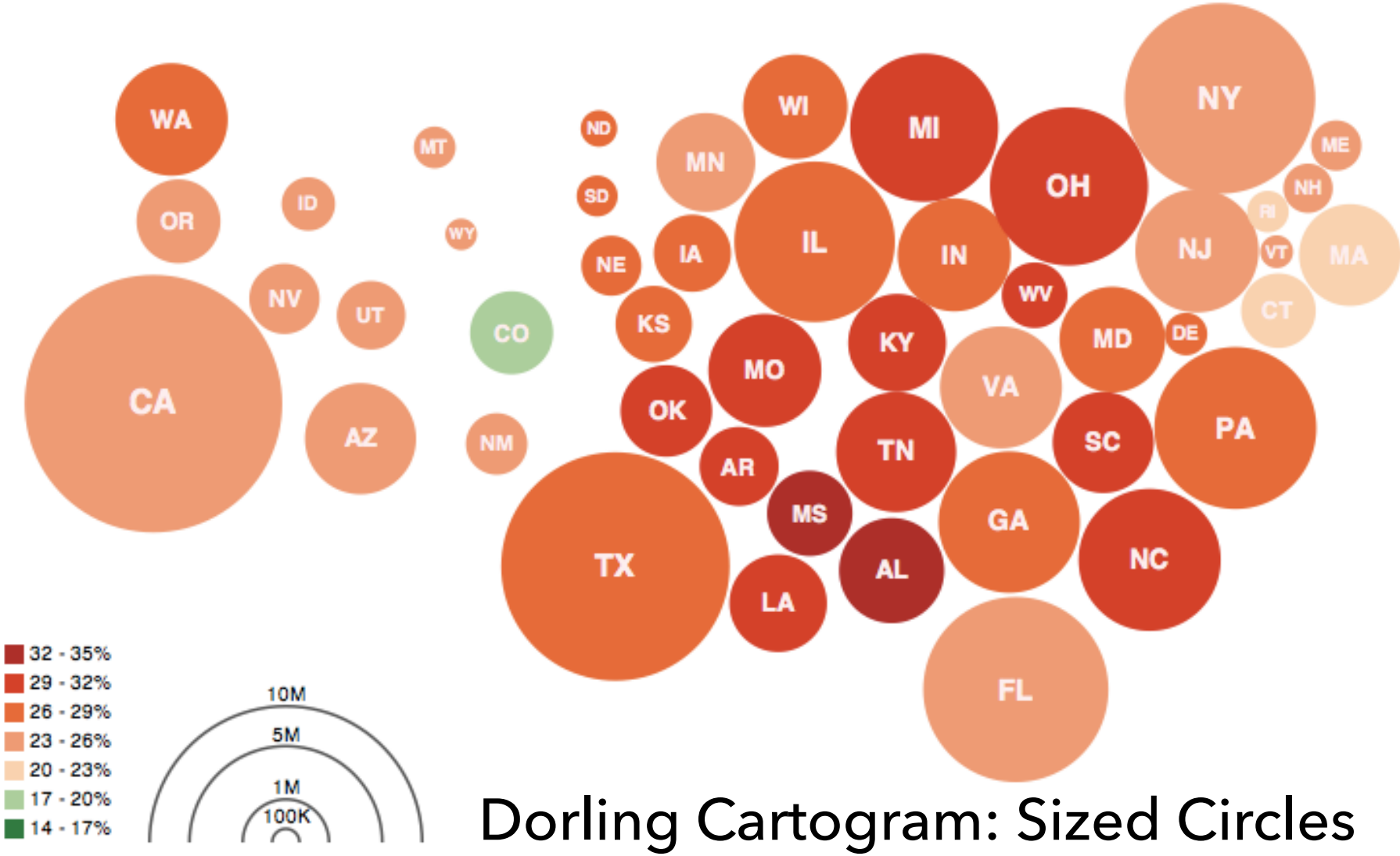


NY Times



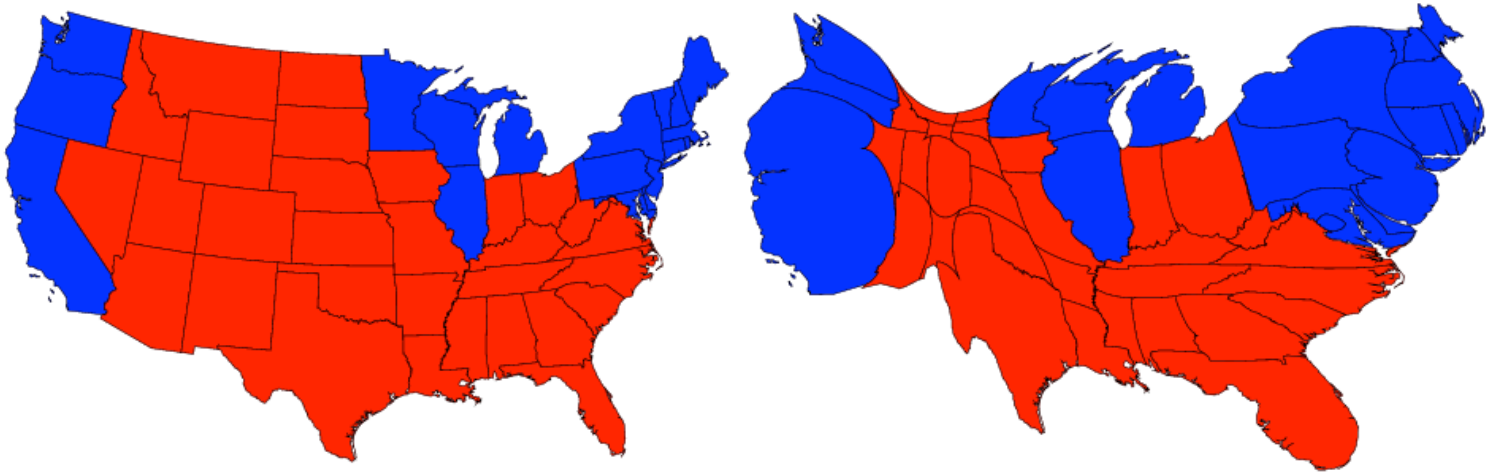
Dorling Cartogram: Sized Circles

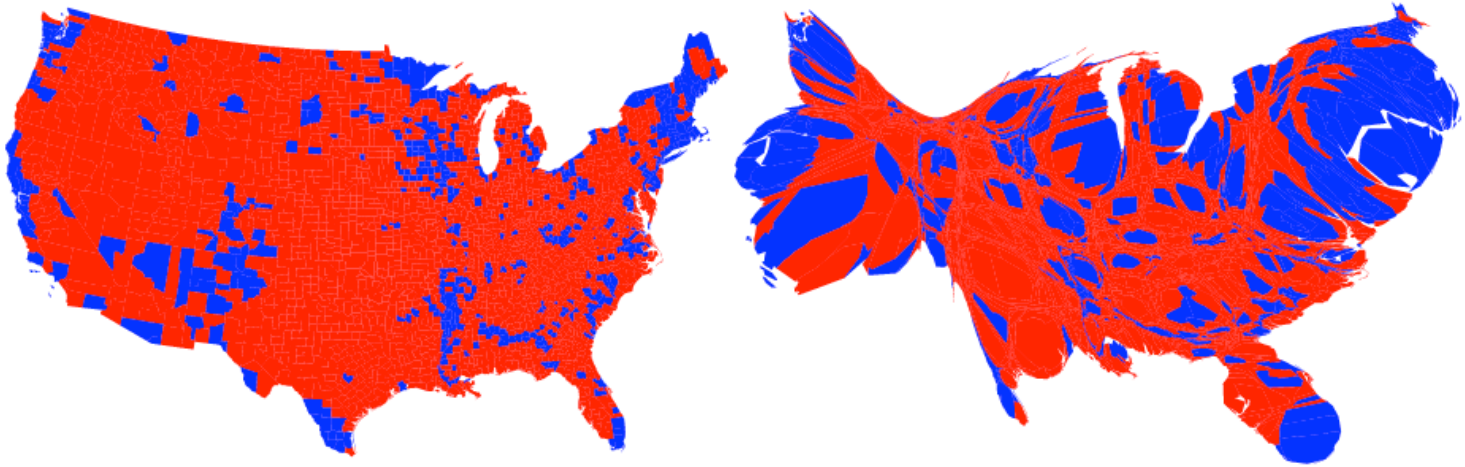
Obesity Map Vadim Ogievetsky

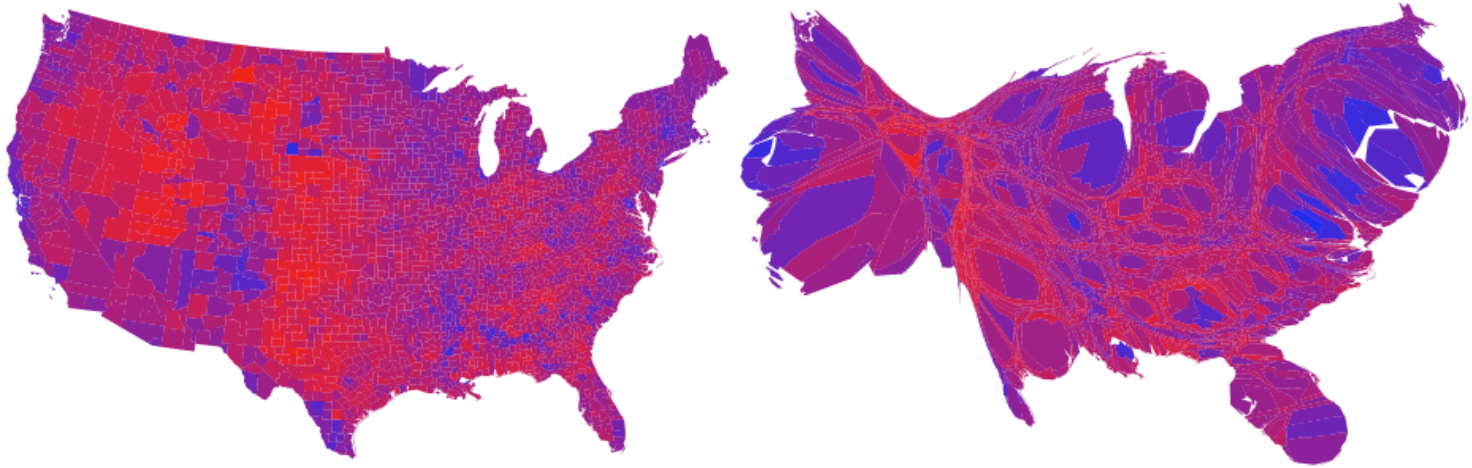


Dorling Cartogram: Sized Circles

Obesity Map Vadim Ogievetsky







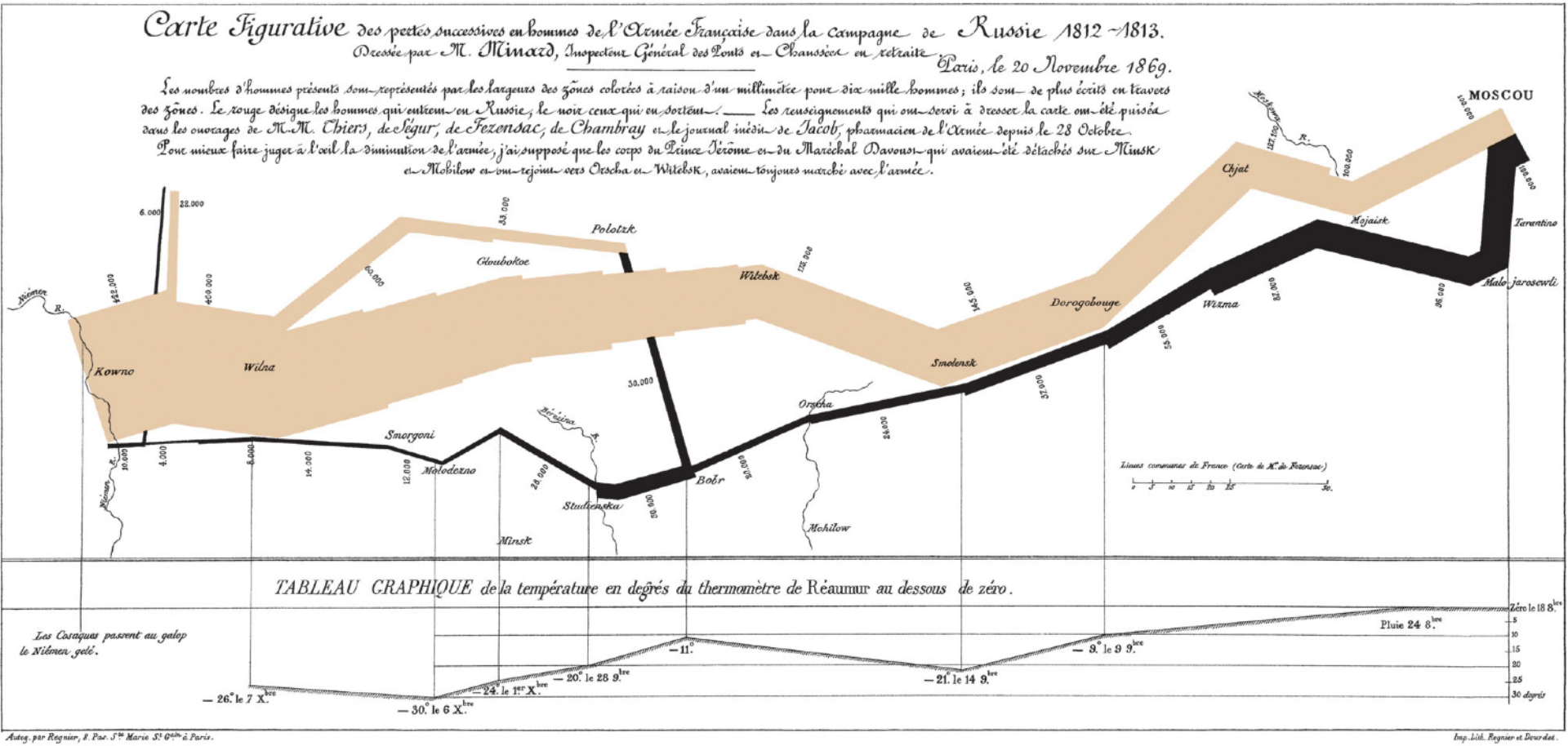
Physical Diffusion Model

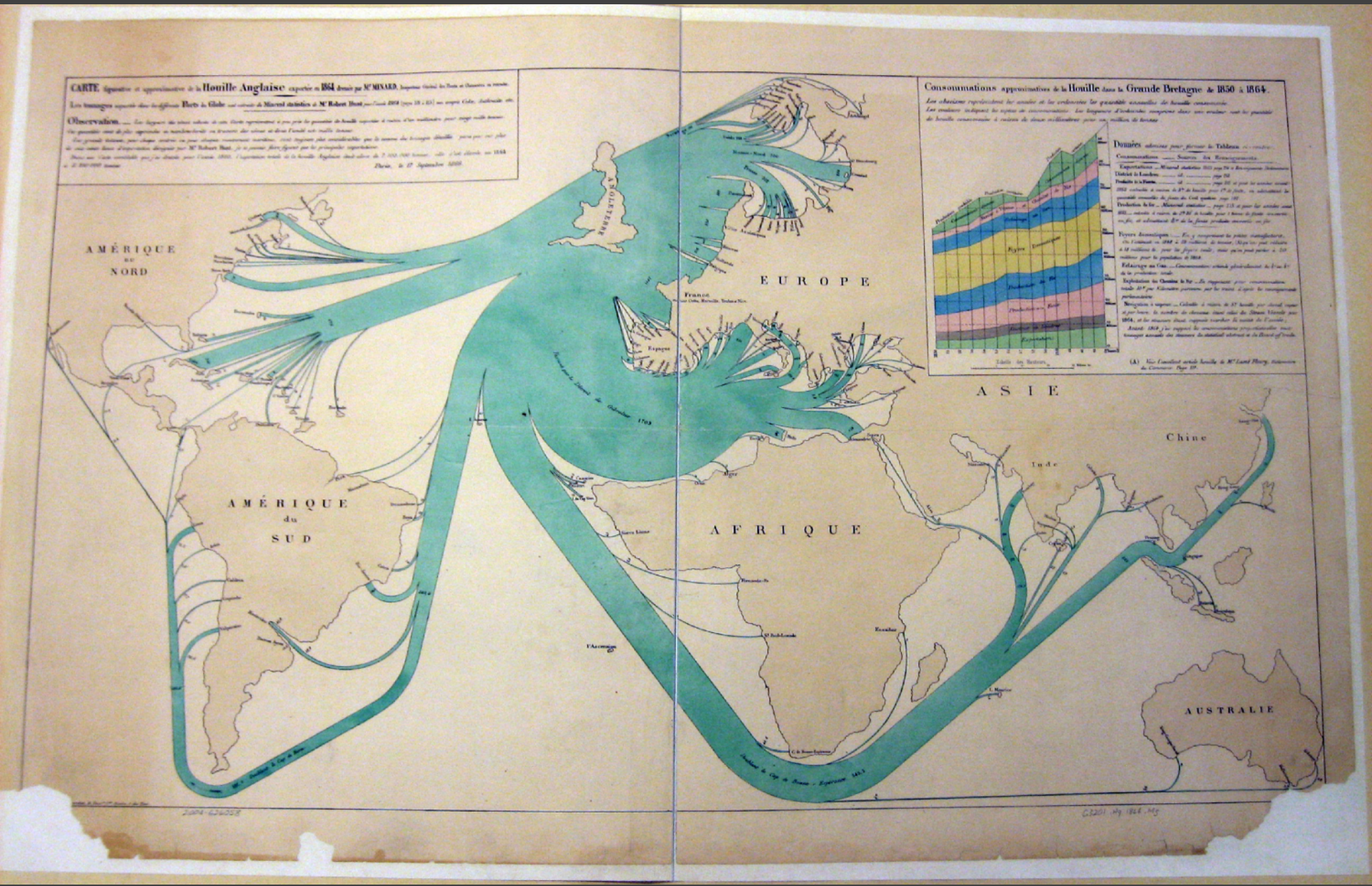
[Newman 2004]

Flow Maps

Convey Flux Between Locations

Minard 1869: Napoleon's march

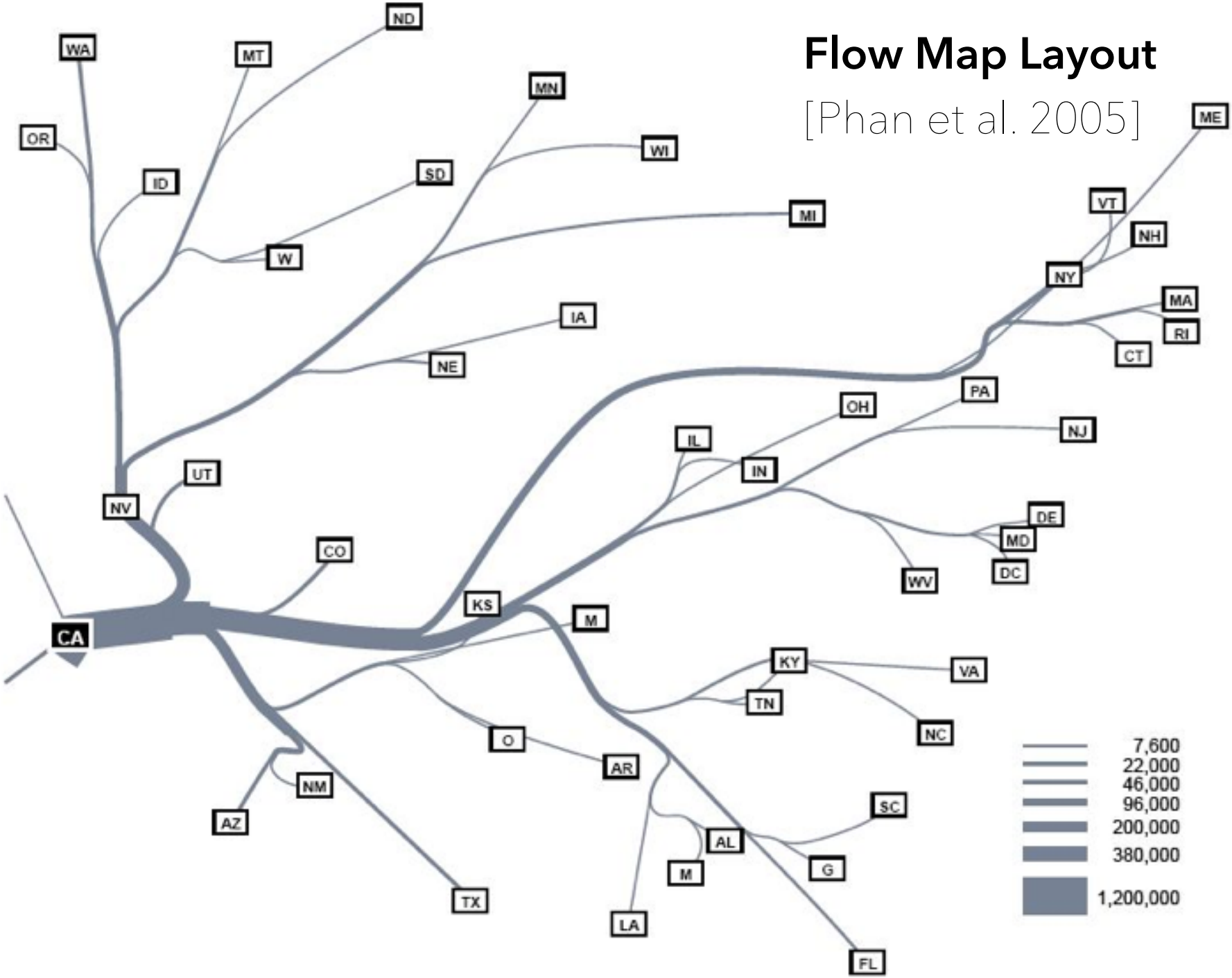




1864 British Coal Exports, Charles Minard

Flow Map Layout

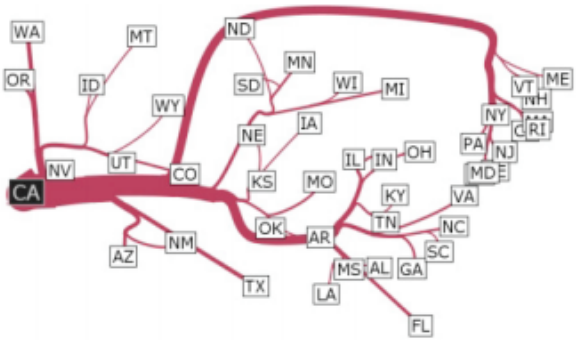
[Phan et al. 2005]



Migration from California, ’95-’00

Tobler 1987

Phan et al. 2005



Verbeek et al. 2011

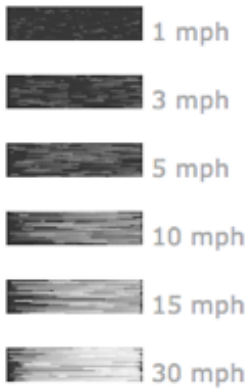
Cui et al. 2008

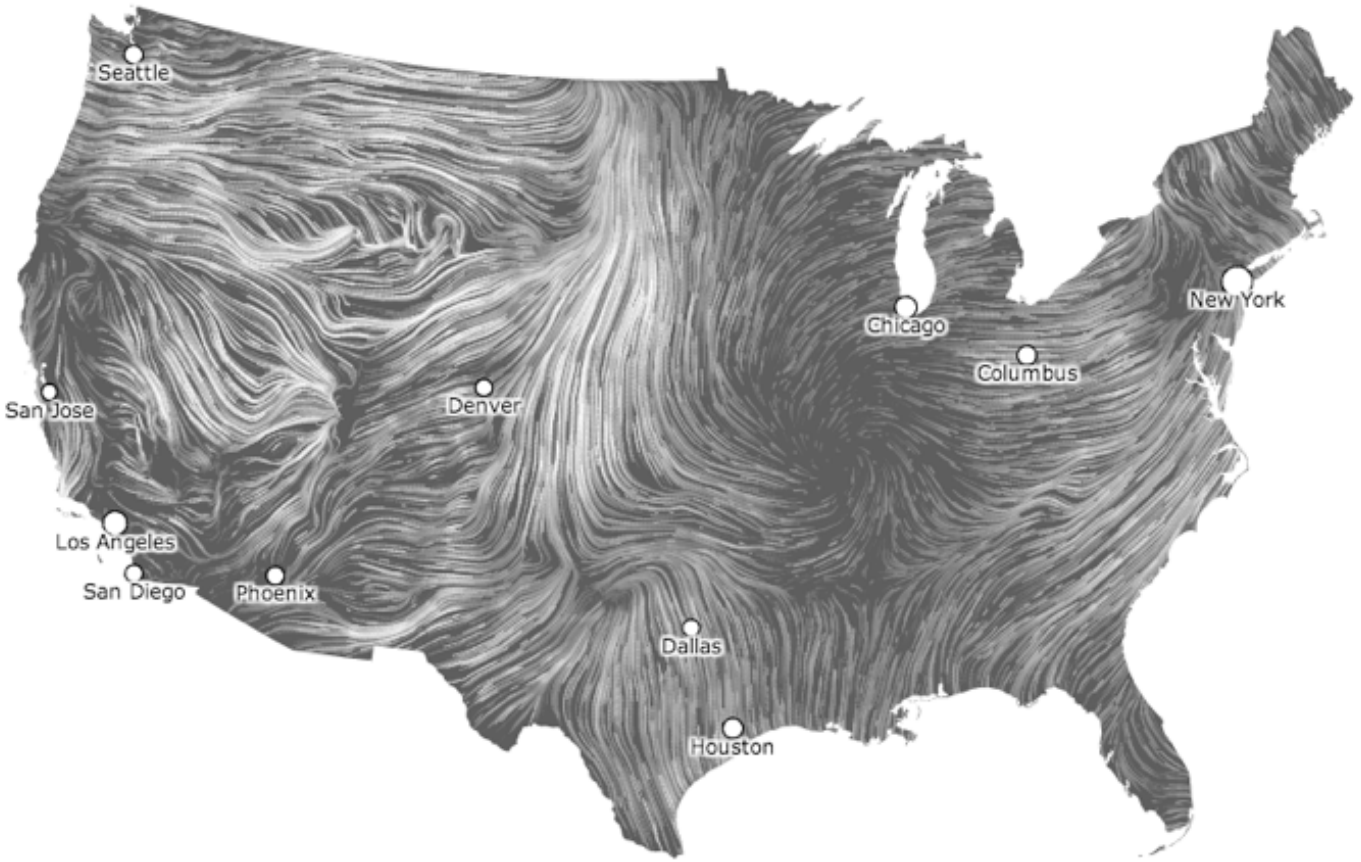
Holten & van Wijk 2009

wind map

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

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

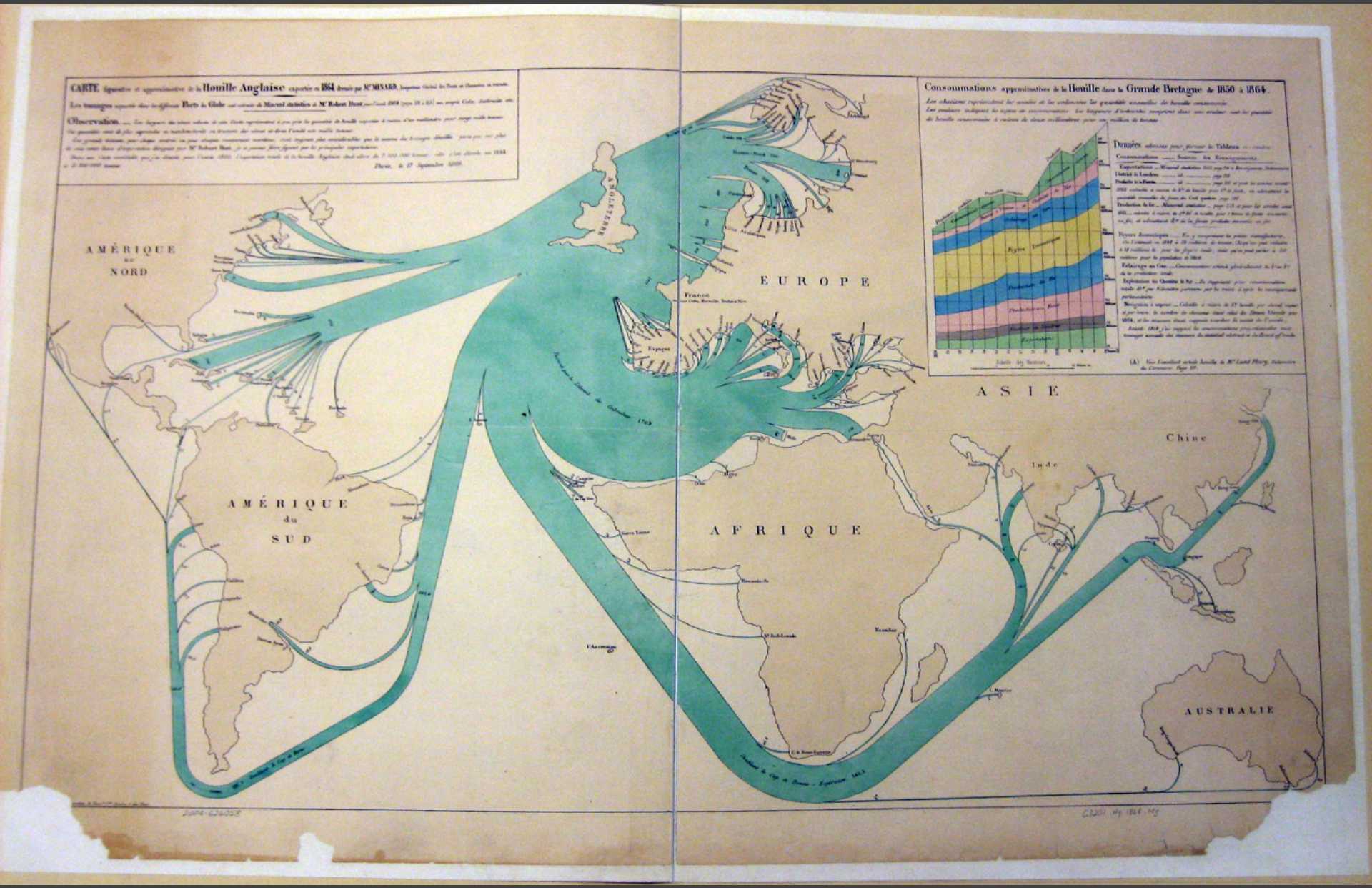




Wattenberg & Viegas

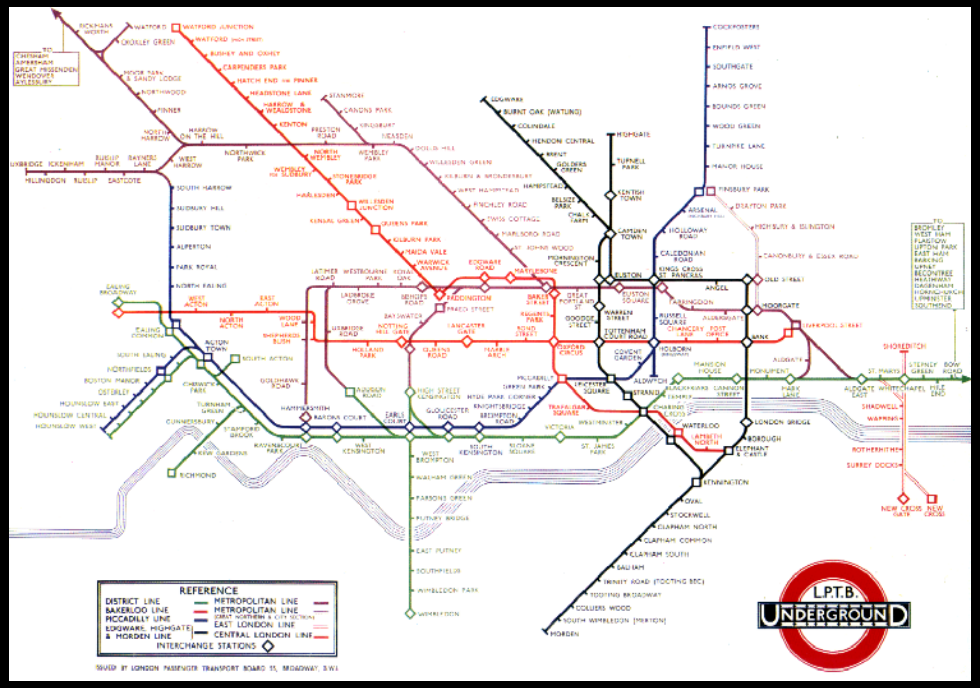
Generalization

Abstraction to Convey Topology

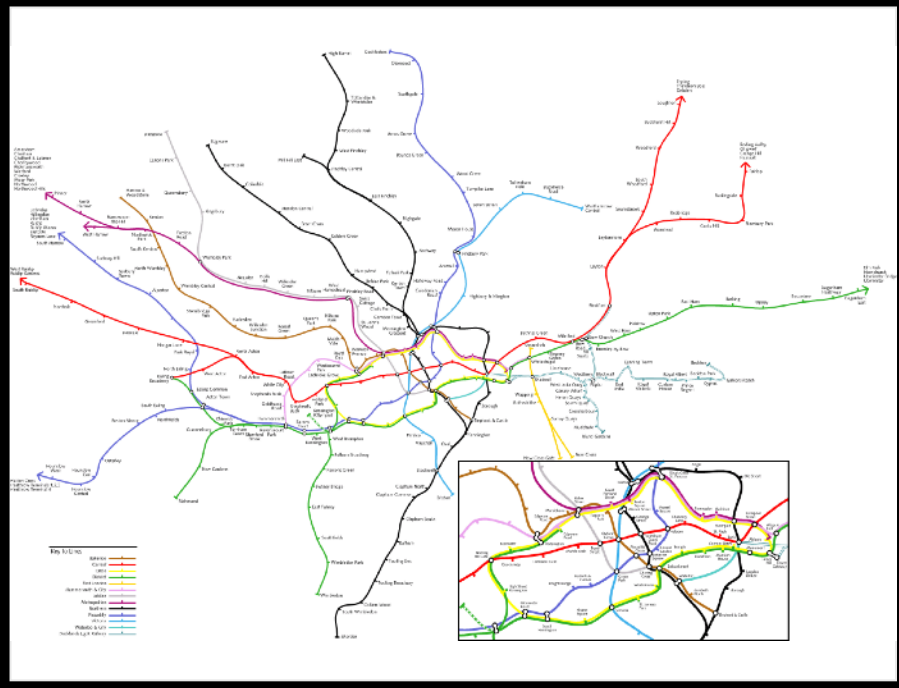


1864 British Coal Exports, Charles Minard

Beck's London tube diagram



London Underground [Beck 33]

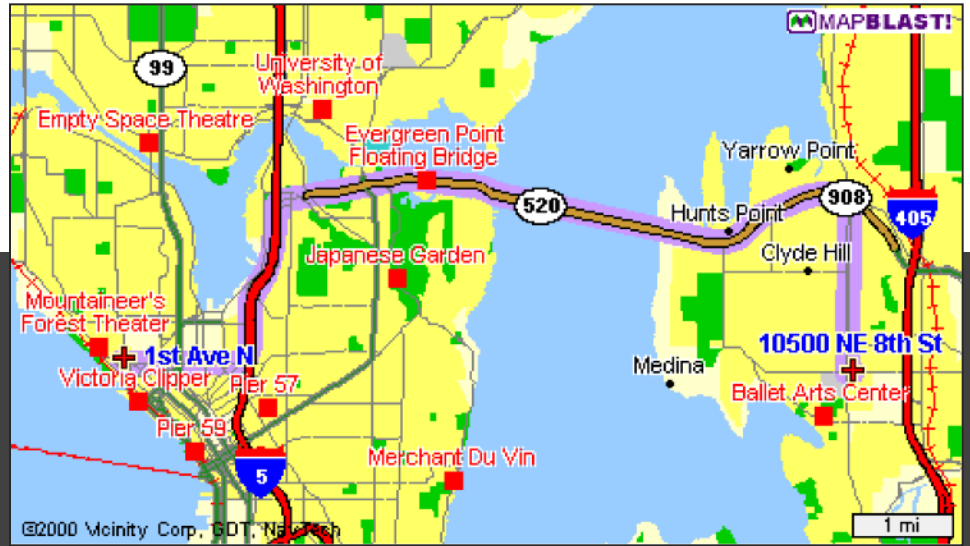


Geographic version of map

Principle: Straighten lines to emphasize stop sequence

Technique used to emphasize/de-emphasize information

Route Maps: Bellevue to Seattle



Map Design via Optimization [Agrawala '01]

Set of graphic elements

- Roads, labels, cross-streets, …

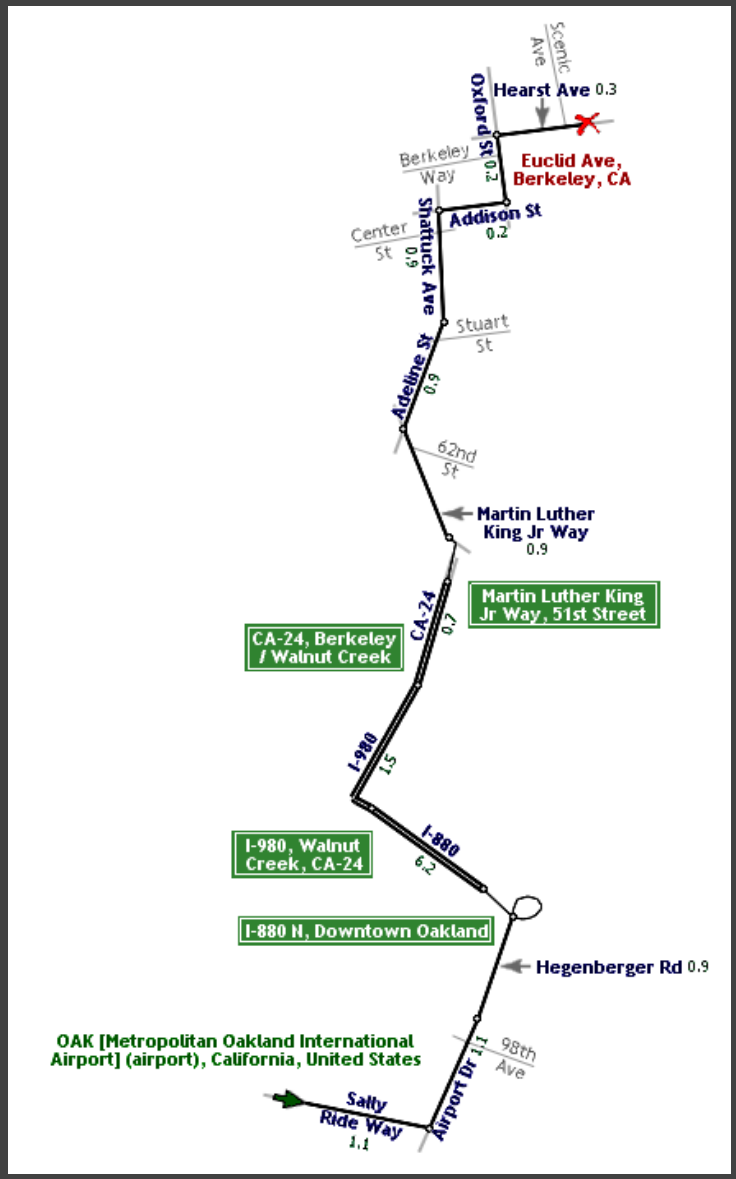
Choose visual attributes

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

Approaches to Mapping Data

Symbol Maps → plot data over a map

Choropleth Maps → colored regions

Heatmaps & Contours → show densities

Cartograms → distort to show quantities

Flow Maps → flux across regions

Generalization → distort/abstract to aid tasks

Resources

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/