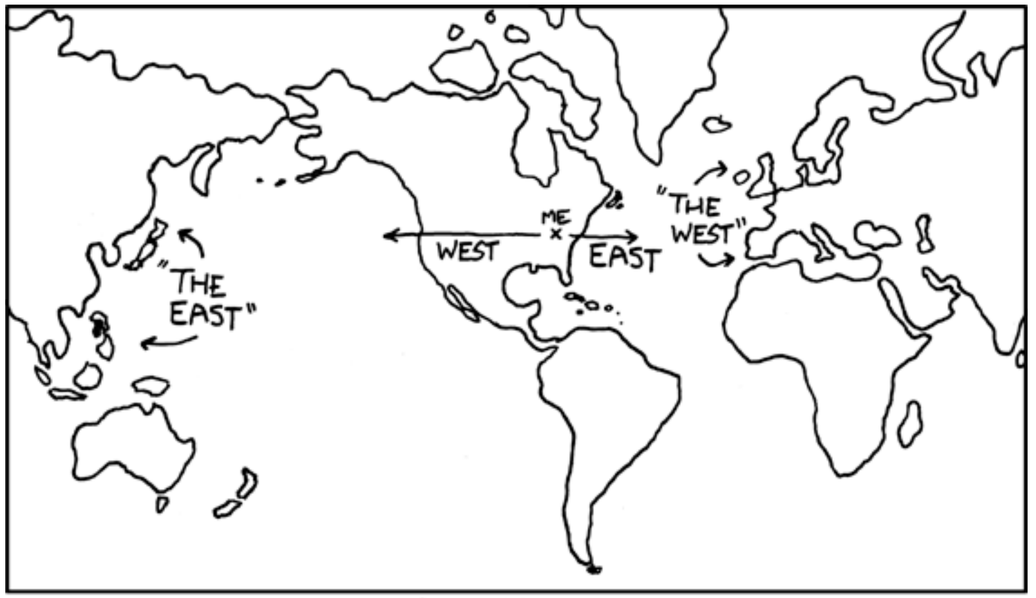
CS-5630 / CS-6630 Visualization
Maps

Alexander Lex
alex@sci.utah.edu

THE UNIVERSITY OF UTAH

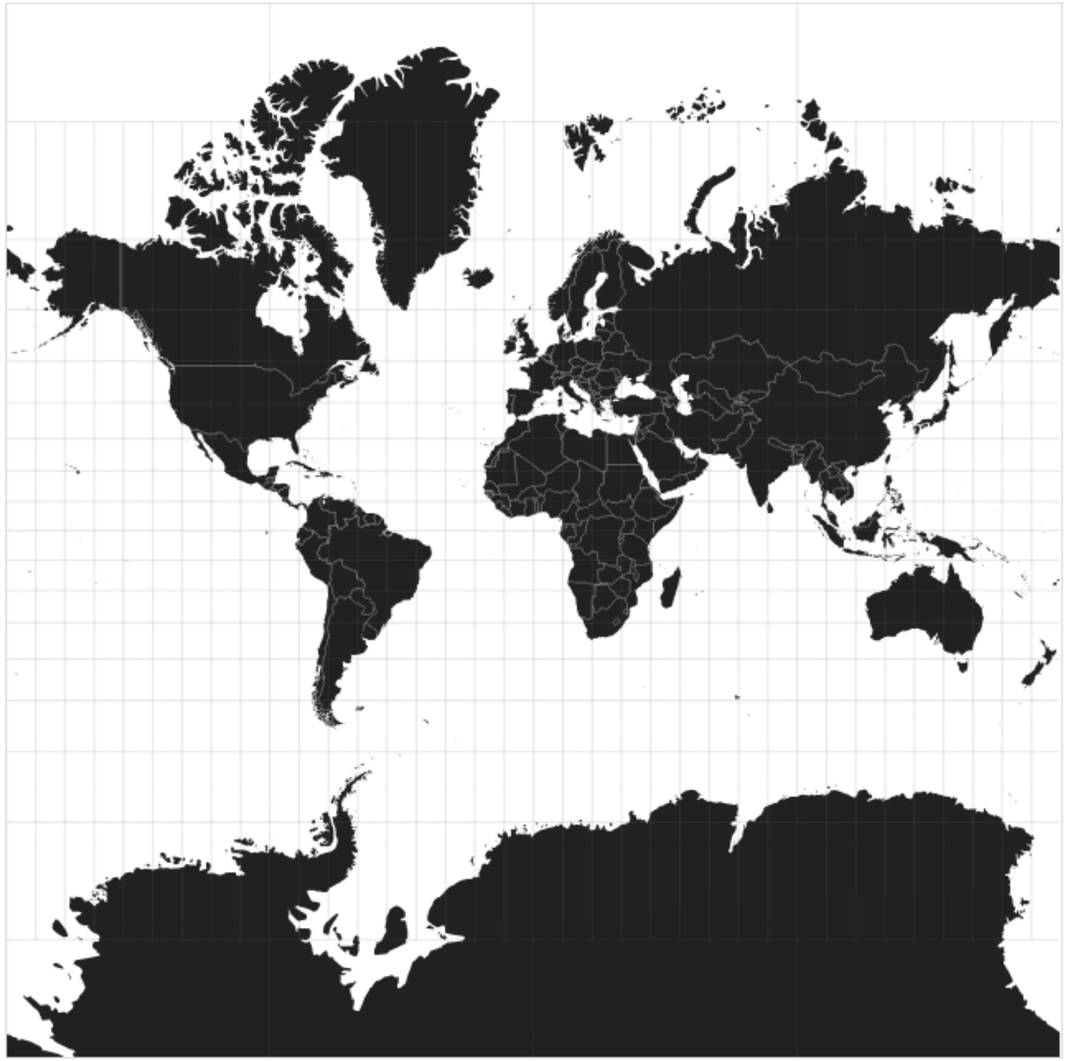


THIS ALWAYS BUGGED ME.

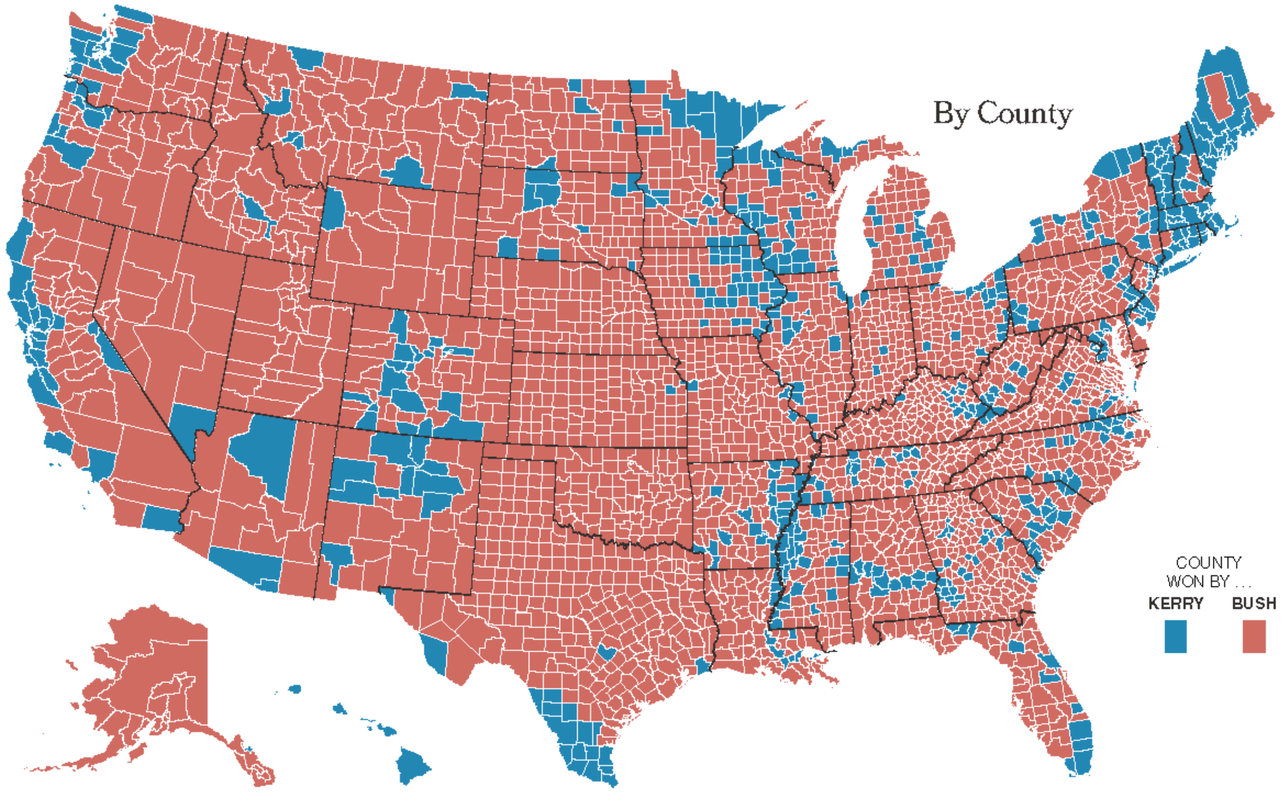
[xkcd]

Two Problematic Maps

https://twitter.com/realDonaldTrump/status/1178989254309011456

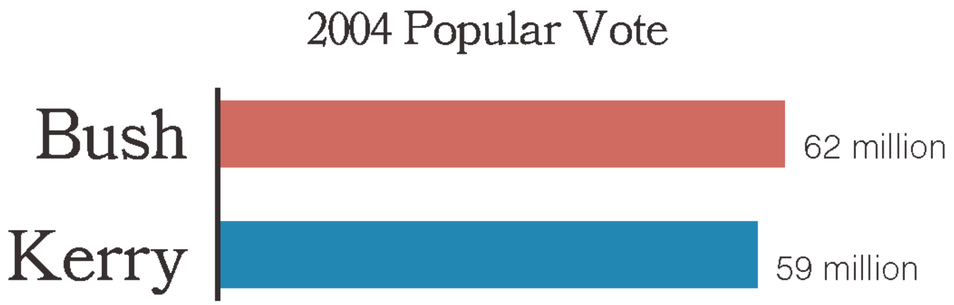


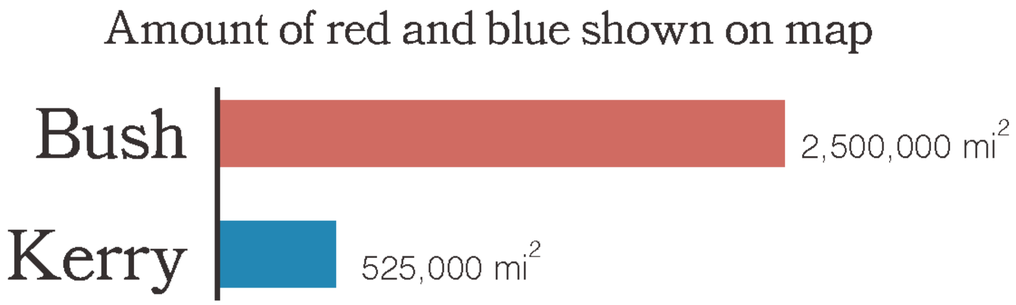
Kerry vs. Bush, 2004



Matthew Ericson, NY Times

Challenge: Magnitude of Effect vs Perceived Effect





Matthew Ericson, NY Times

Principles

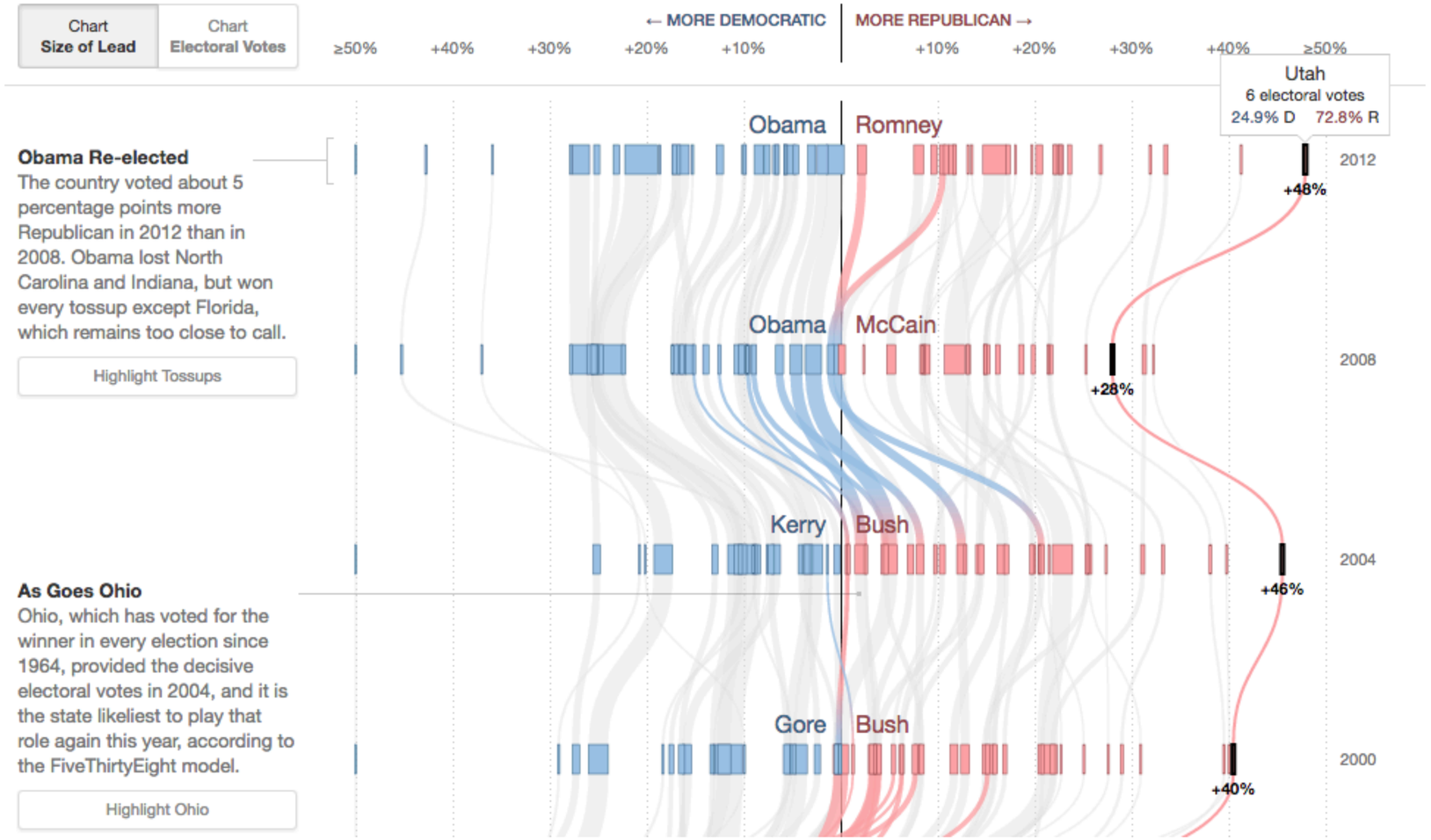
Special type of Spatial Data

Use maps when spatial relationships are paramount

Map Tasks:

- Find location / feature (county, country, city, street)
- Find route
- Identify attribute associated with location (elevation, land/water, GDP)
- Compare attributes between locations/features

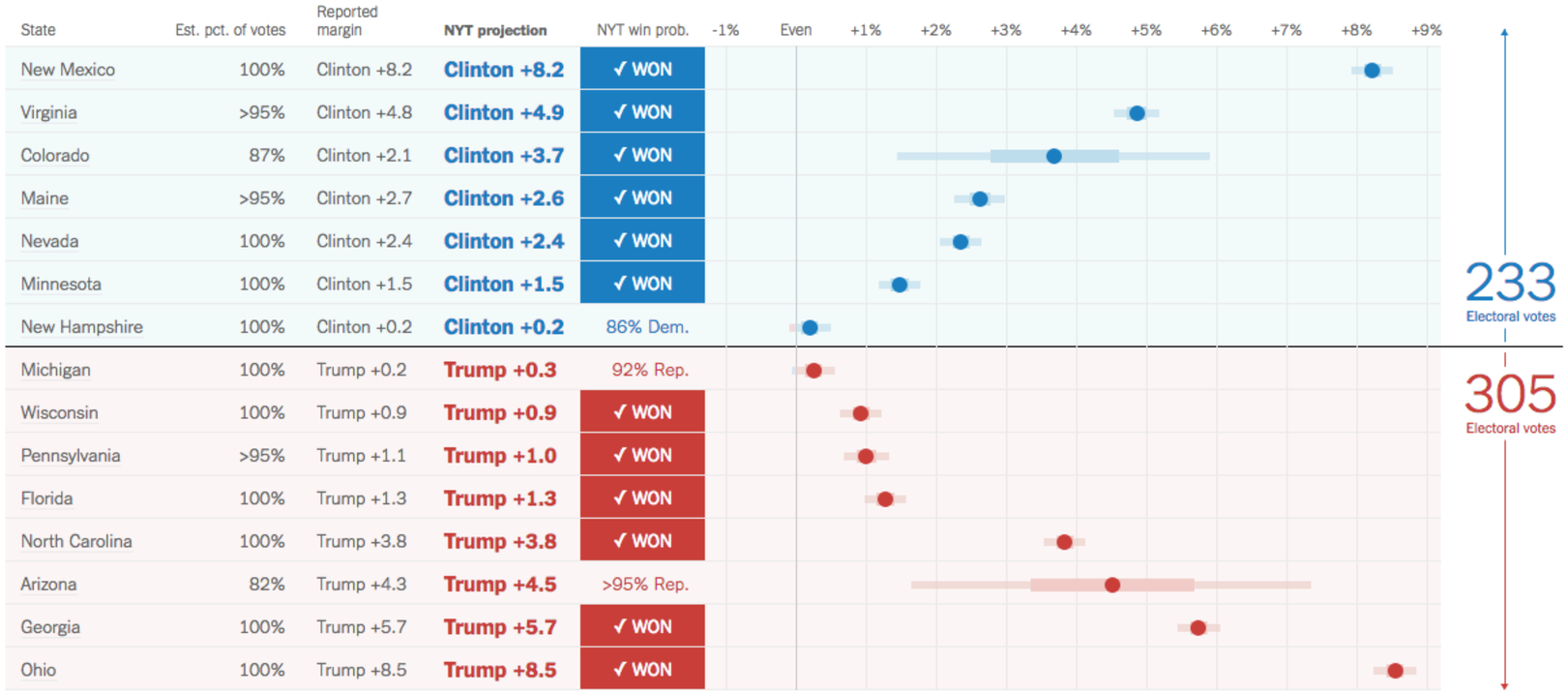
Do we really need a map?



Do we really need a map?

It’s hard to do more complex things with maps

Is the spatial context paramount?



Map Projections

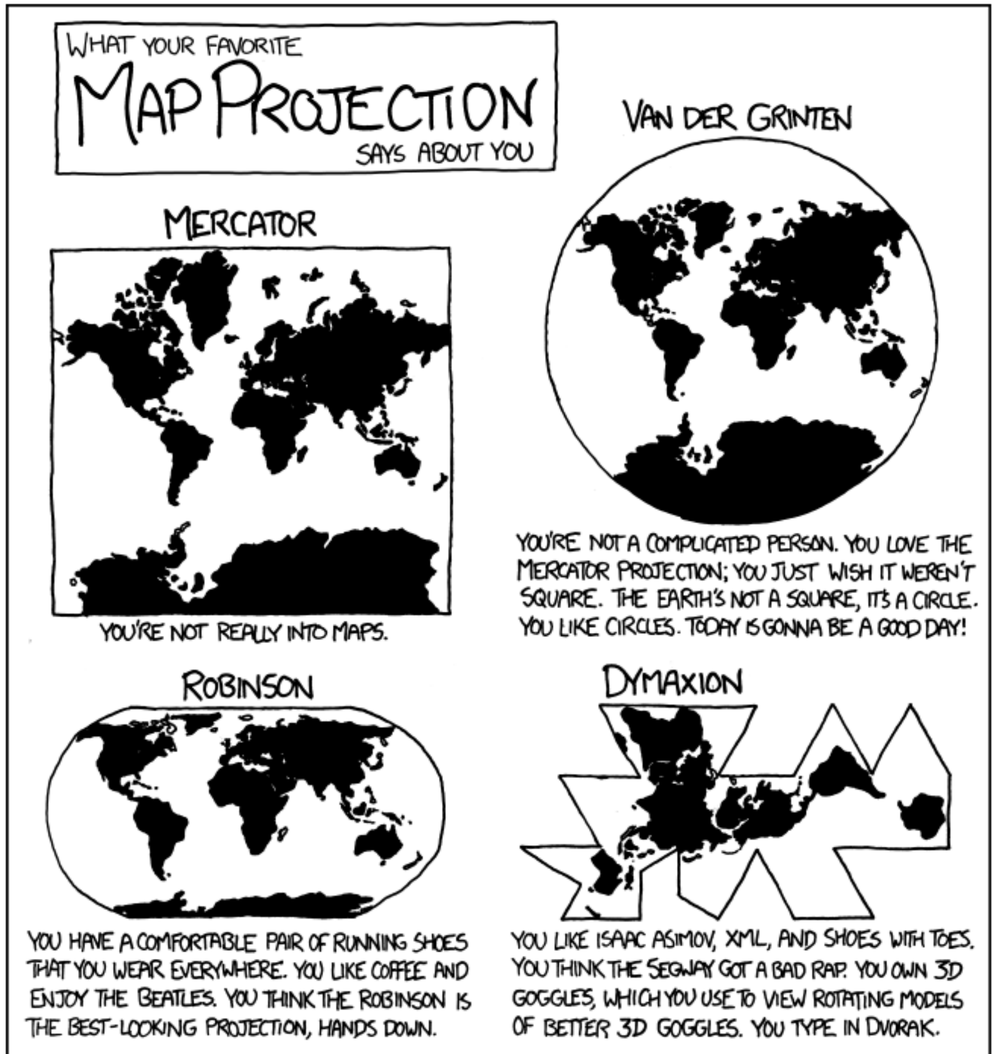
Why projections?

Earth is a (flattened) Sphere

Need to project or “unfold” the hull of the sphere to fit onto paper/ screens

Relevant attributes:

Area, Shape, Direction, Bearing, Distance, Scale



Simple Solution: Use Globe

Mercartor Projection

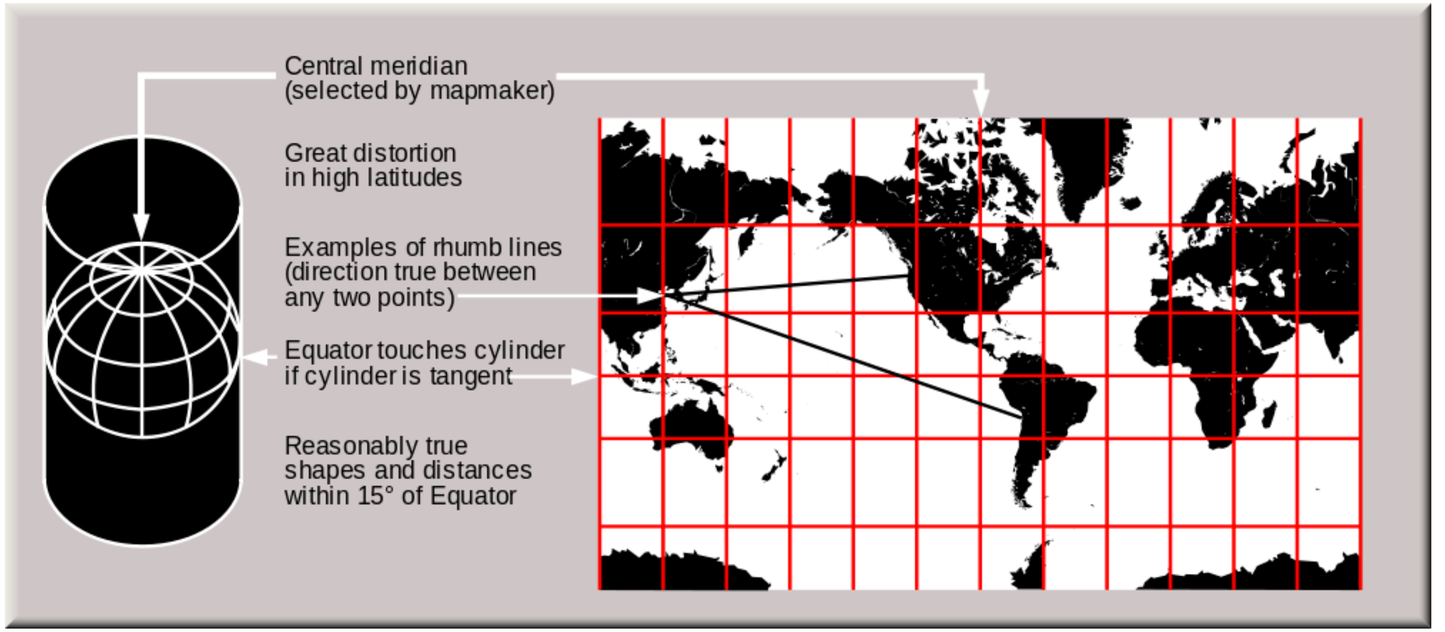
Gerardus Mercator, 1569

Projection onto a cylinder wrapped around the globe

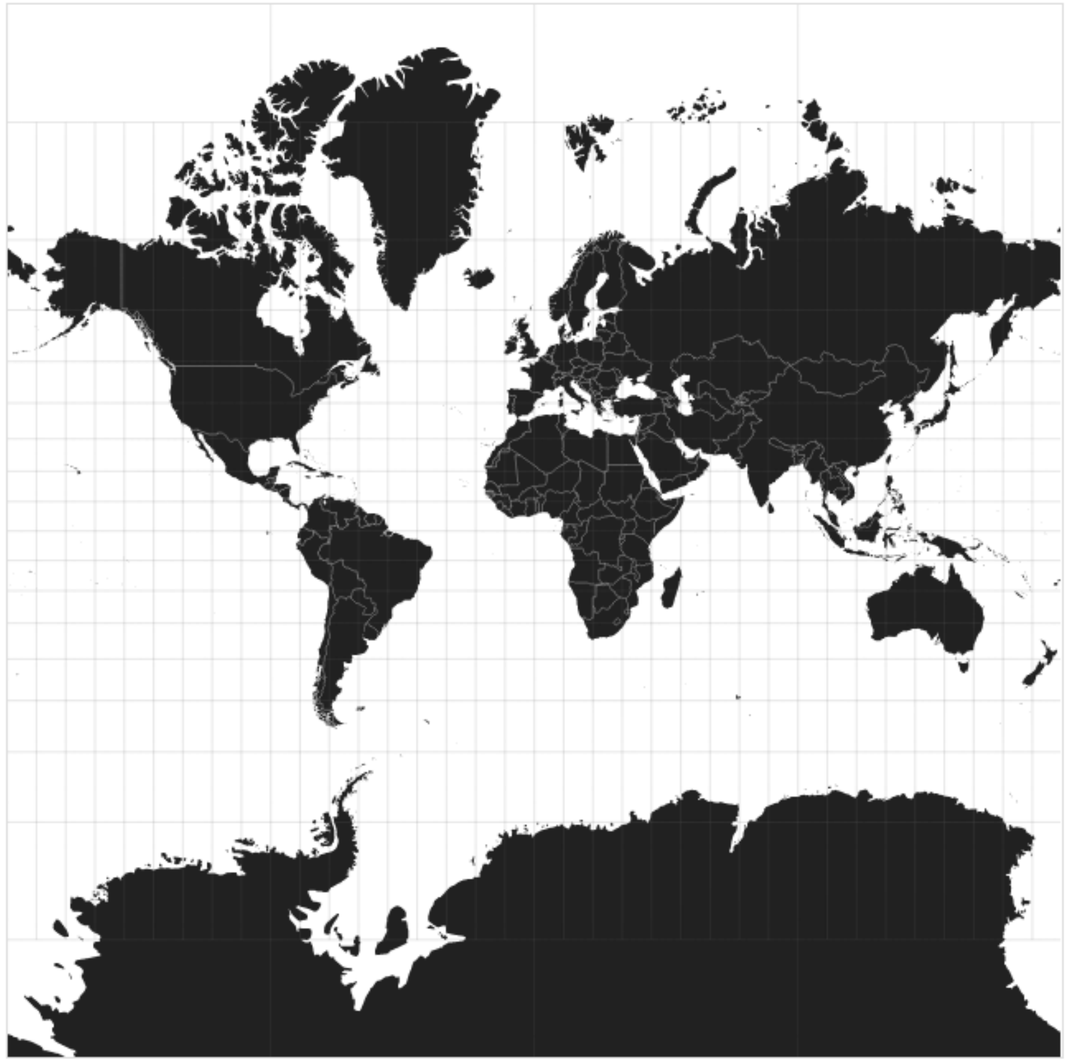
Angles are preserved.

Lines of constant bearing are straight lines.

Constant bearing means constant compass heading – developed for sailors

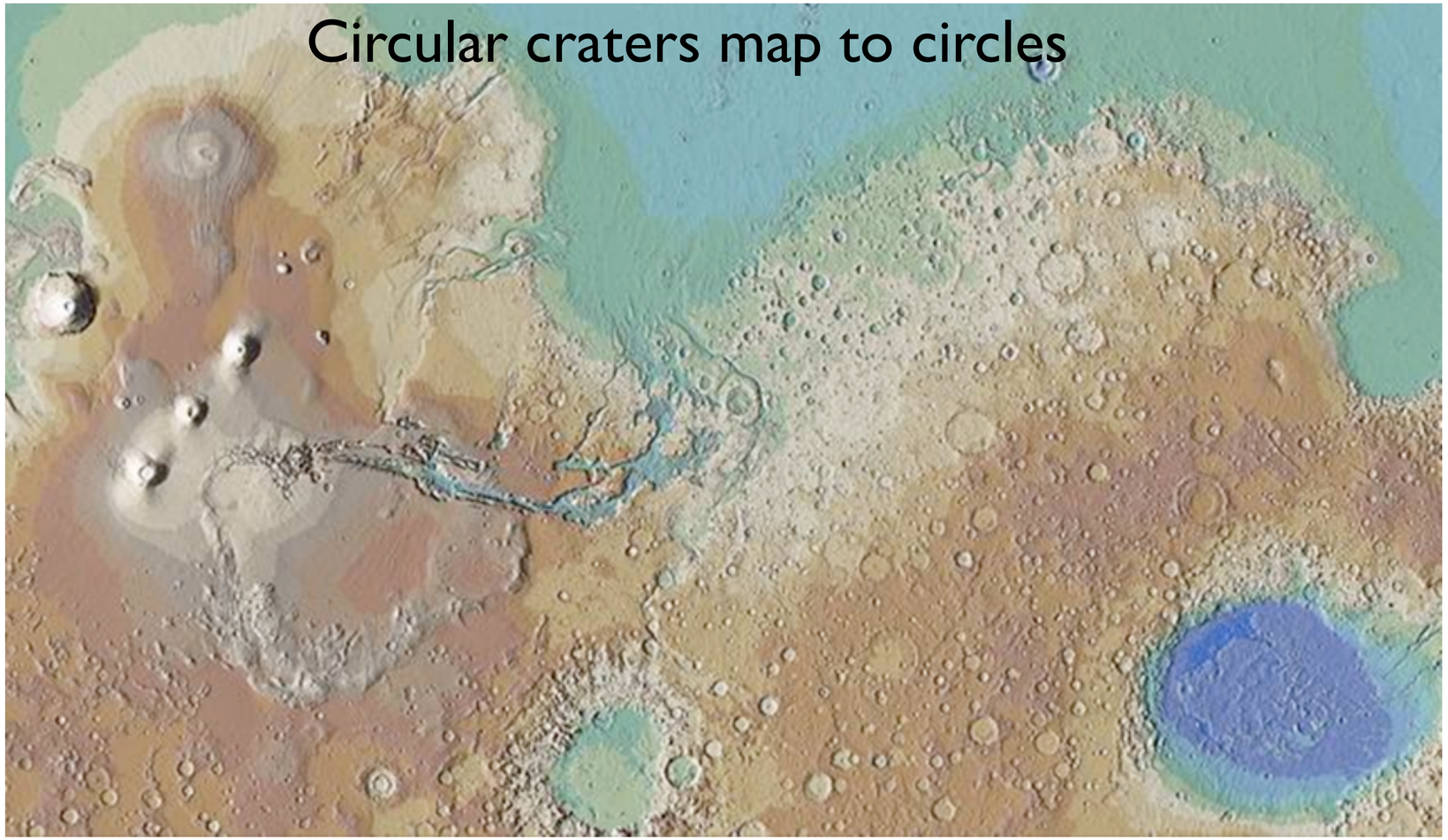


Mercator Projection



D3 / M. Bostock

Mercator Projection of Mars



Based on slide from Hanrahan

Why Mercator is Problematic

Traditional map, was used to teach geography

Massive distortion of area distant from equator

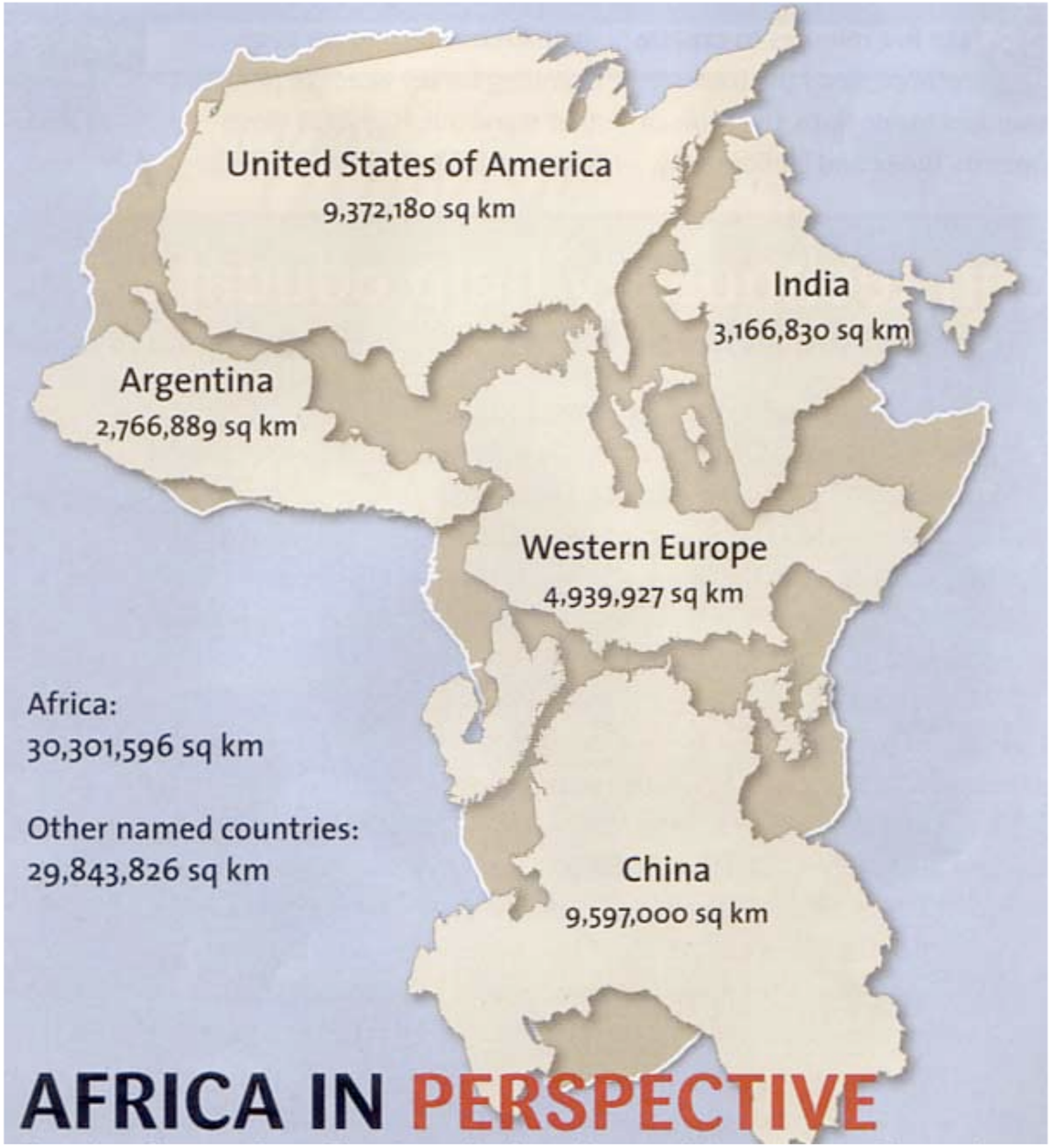
“unfair to the global South, making places that are mostly trees, snow, and better-off white people look huge, and the places where most of the world’s population lives look puny"

http://giscollective.org/slippy-map-projections-explained/

Mercator Projection

Mercator works really great if you're, say, Ferdinand Magellan looking for a compass bearing that will take you around Cape Horn, because all of the latitude and longitude lines and angles in between lay out nice and straight on the map like we experience them in real life. It also works well if you're Google and you want a map image that you can neatly slice up into little squares that your server sends to a customer's browser. North is always up, your hometown doesn't look squished or slanted when you zoom in to it, and everybody's happy.

http://giscollective.org/slippy-map-projections-explained/

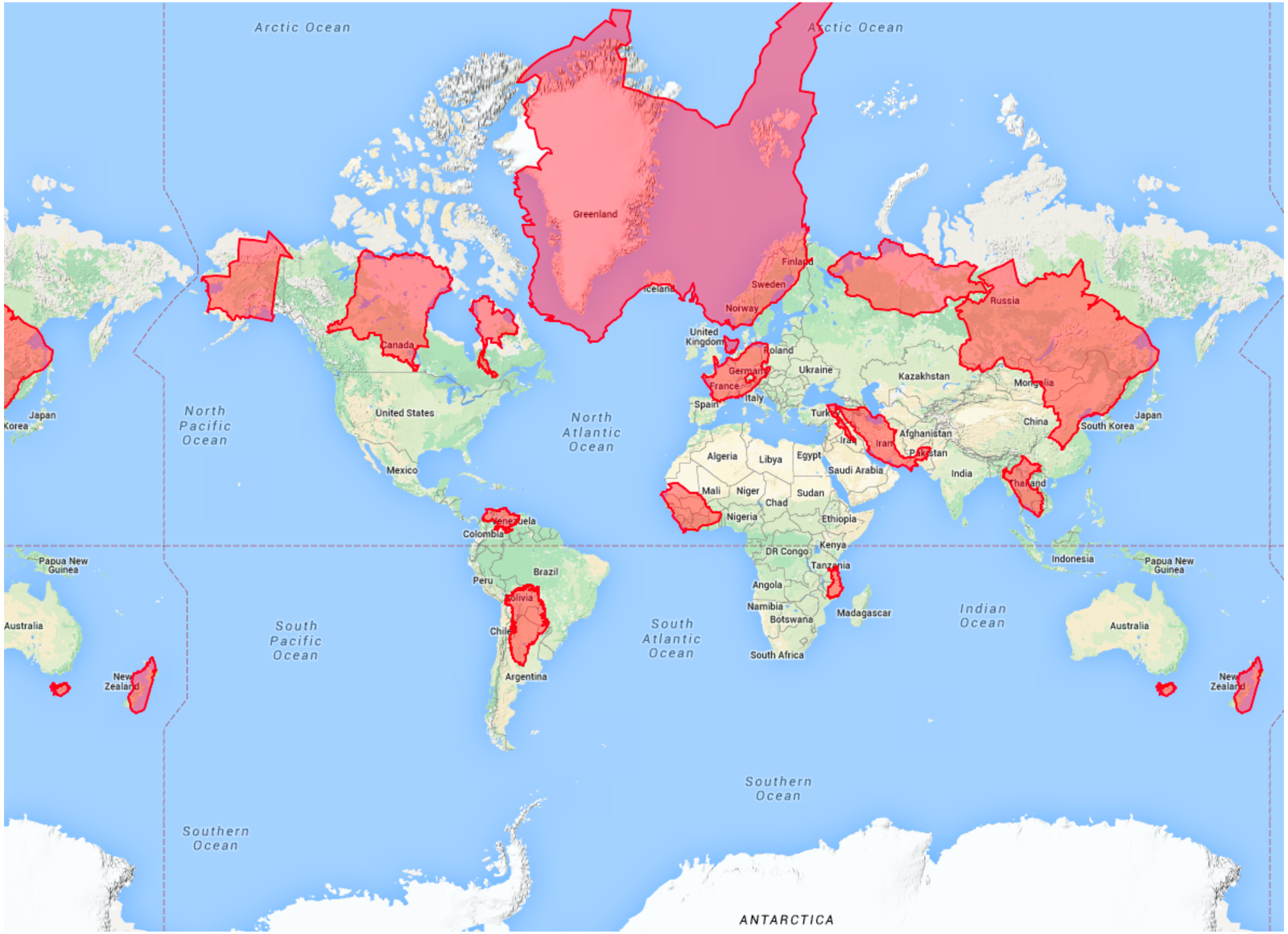


http://strangemaps.wordpress.com/2006/11/20/35-the-size-of-africa/

World Mercator projection with true country size added

@neilrkaye

Mercator Puzzle



Caveat

Only a problem for large areas

- Continents
- World

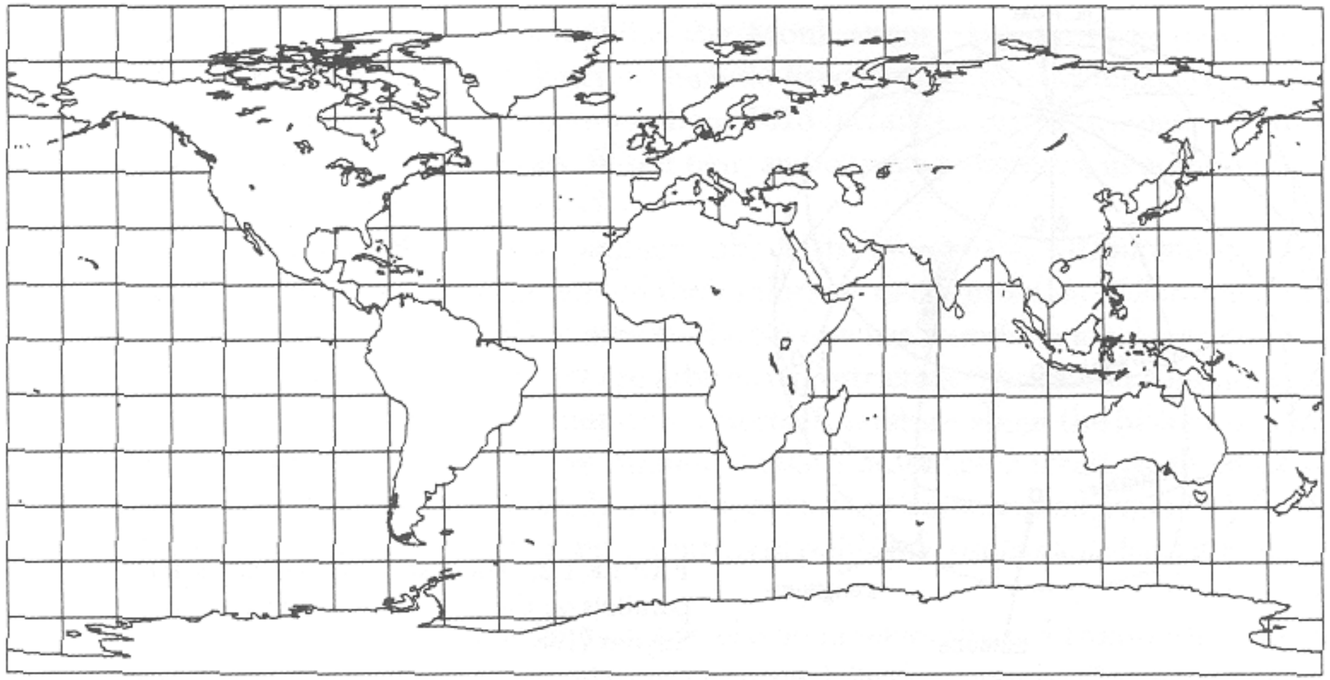
Distortion is not a problem on a state/city level!

Latitude-Longitude

Does not preserve angles

Does not preserve areas

Things are squashed
at the top and bottom



Snyder, "Flattening the Earth"
Based on slide from Hanrahan

Azimuthal Projections

Radical Cartography

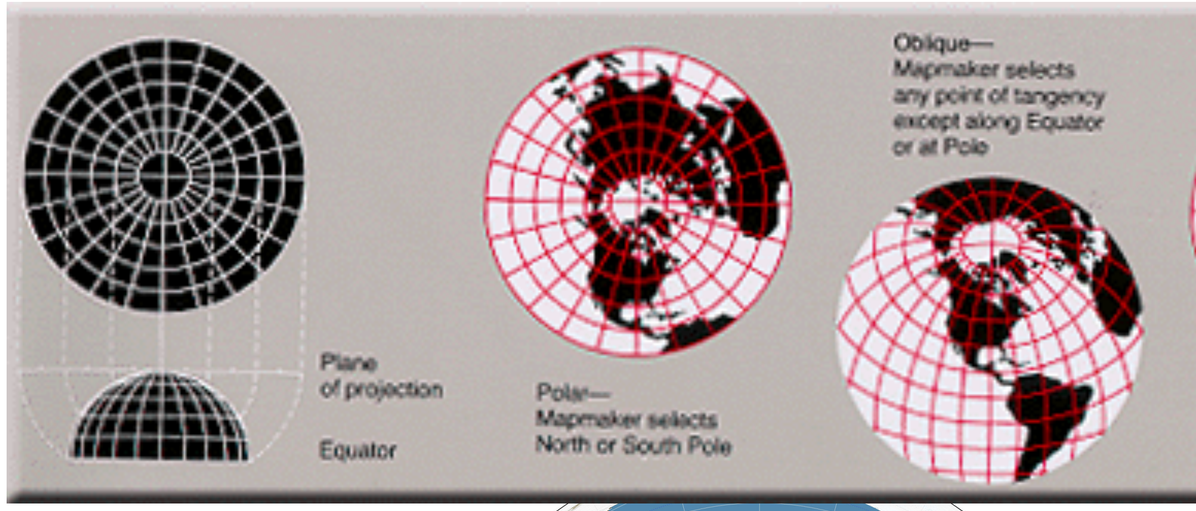
Projection onto a plane tangent to the Earth

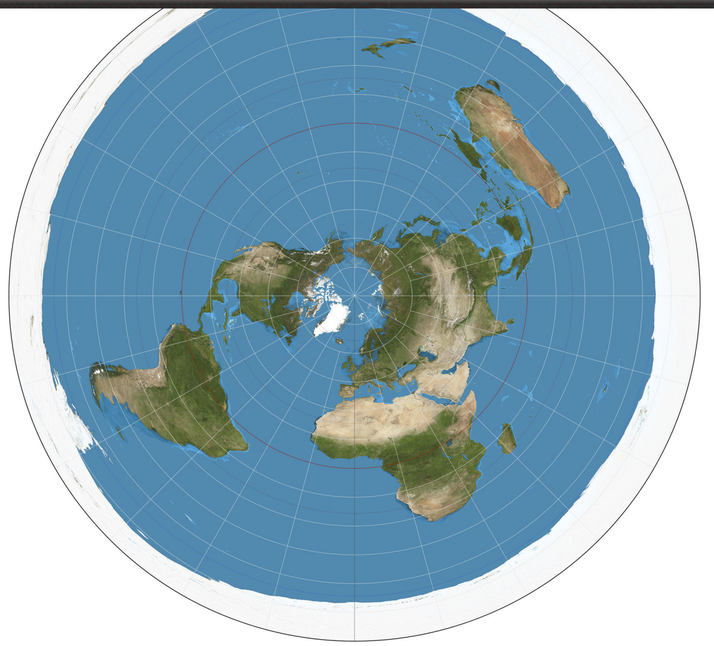
angles are correct around the center point

Great circles through the center are straight lines

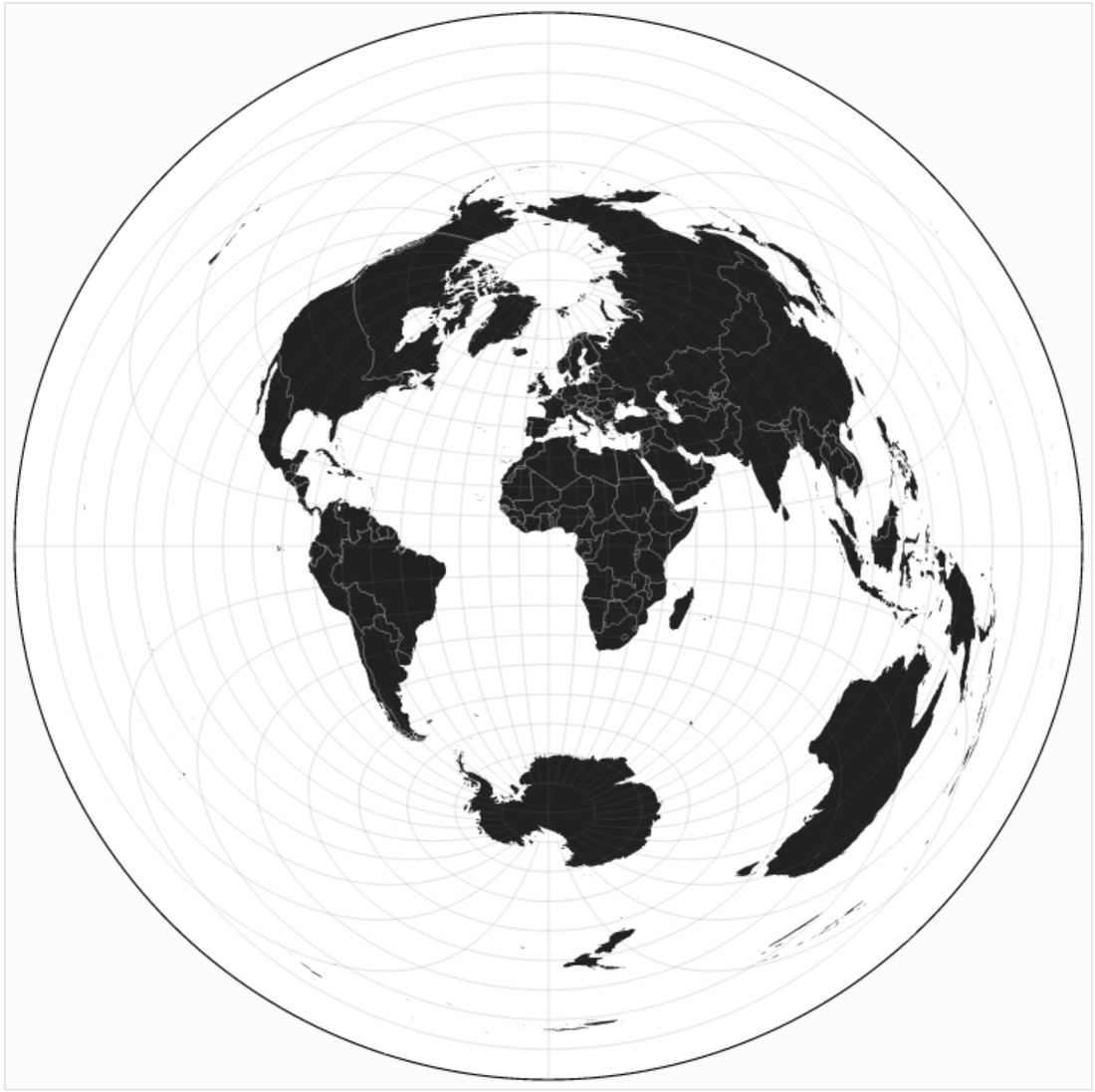
Radii correspond to true distances

Sometimes see this in airline magazine centered around the hub





Azimuthal Equidistant



D3 / M. Bostock

ON ASSIGNMENT

In Reykjavik and Rio, New Delhi and Khartoum, Calcutta, Capetown, Sydney and Suva, as you read this—in every troubled news-corner of the globe—are one or more of the 300 special correspondents who work for TIME, LIFE and FORTUNE. In the past twelve months alone, their assignments carried them the 1,505,000 miles you see plotted on this map.

Some of these people are reporters, some photographers, some researchers. Two were on an American cruiser off Hawaii when the Japs blasted Pearl Harbor. Two more were in Manila on December 7, now are interned by the Japanese in ancient Santo Tomas University. Still another managed to make Corregidor from the mainland, filed almost daily dispatches all through January and February, last reported that he had finally reached Australia in safety, joined three other TIME — LIFE — FORTUNE correspondents there. Two of these men had made the trip to Australia in a troop ship with an AEF convoy; the third had arrived on a grimy freighter, he its only passenger, high explosives its only cargo.

But this is not a map of adventure. Rather it is an attempt to visualize a hard-working, world-wide research organization—the News and Picture Bureaus of TIME, LIFE and FORTUNE.

The real significance of the map grows out of the hundreds of fact-finding assignments it represents—the millions of words filed—the stories documented with photos, the weeks and months of observation and analysis it plots.

Eighty thousand of the 1,505,000 miles of travel plotted on the map, for example, were covered by Correspondent Allan Michie. The dispatches he filed from Cairo, Tehran, Simla, Singapore, Batavia and Manila were the basis of news stories in the columns of TIME. Documented with pictures taken by a Picture Bureau photographer in the Middle East, several of his pieces ran in LIFE. Back in New York, he assembled the threads of his experiences and first-hand knowledge on the broad pattern of world strategy into the story of *The Coming Battle for Asia* that appeared in FORTUNE for March.

This same mechanism functions similarly as Walter Graebner, head of the London office, returns to New York to report on the European situation for TIME and LIFE and write the story of *British Politics and the War* for the April FORTUNE—as Sherry Mangan heads back from Buenos Aires via Santiago, Lima and Panama — as correspondents file their dispatches from Ireland, Alaska, India and Bataan . . .

These and three hundred other men like them are a part of the world-wide news and picture organization which is constantly serving your editors, with spot news, with background information, with well-documented research.

TIME—LIFE—FORTUNE

Winkel Tripel Projection

Modified azimuthal map projection

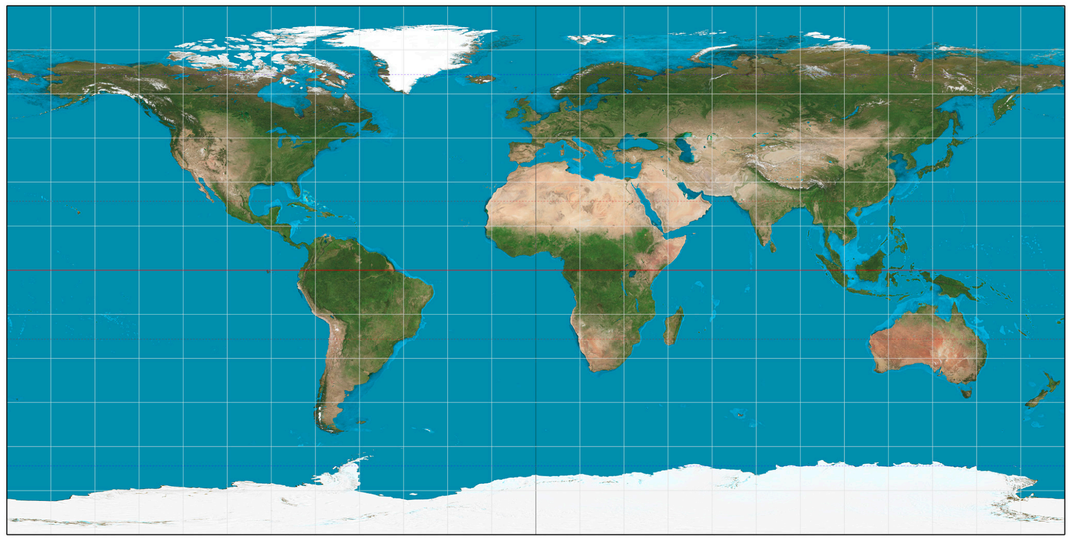
averaged to cylindrical projection

Minimizing three kinds of distortion:

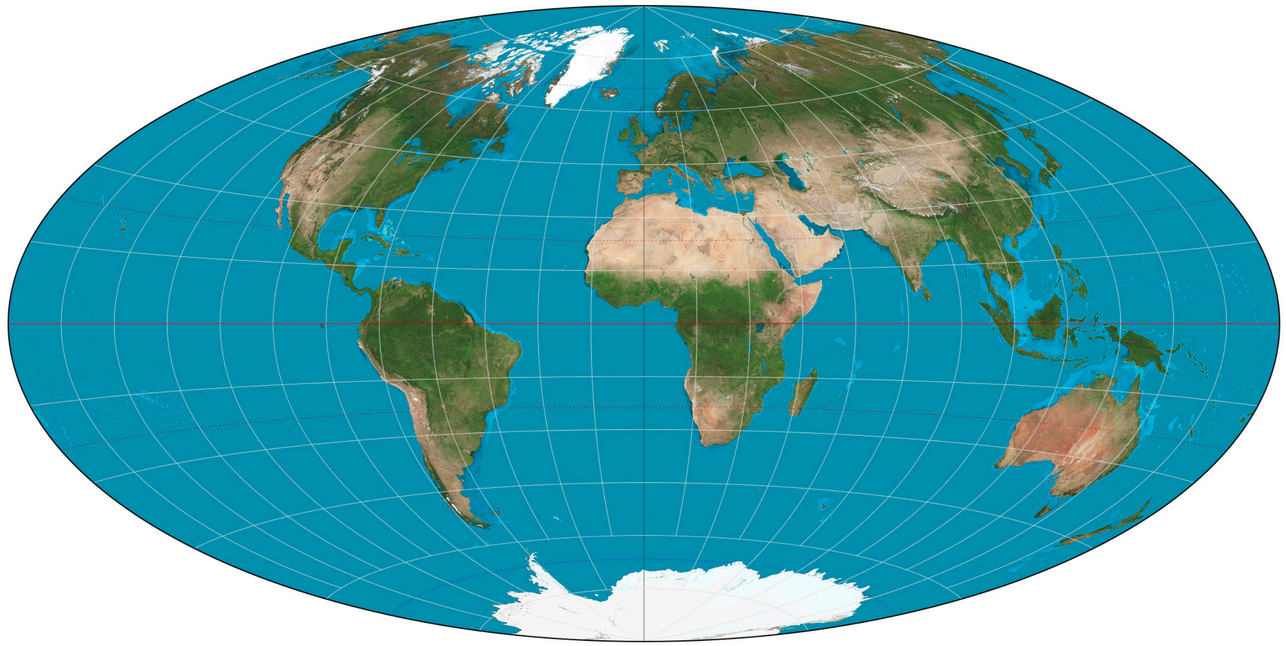
- area
- direction
- distance

Considered good projection for world maps, endorsed by National Geographic Society, used in Textbooks

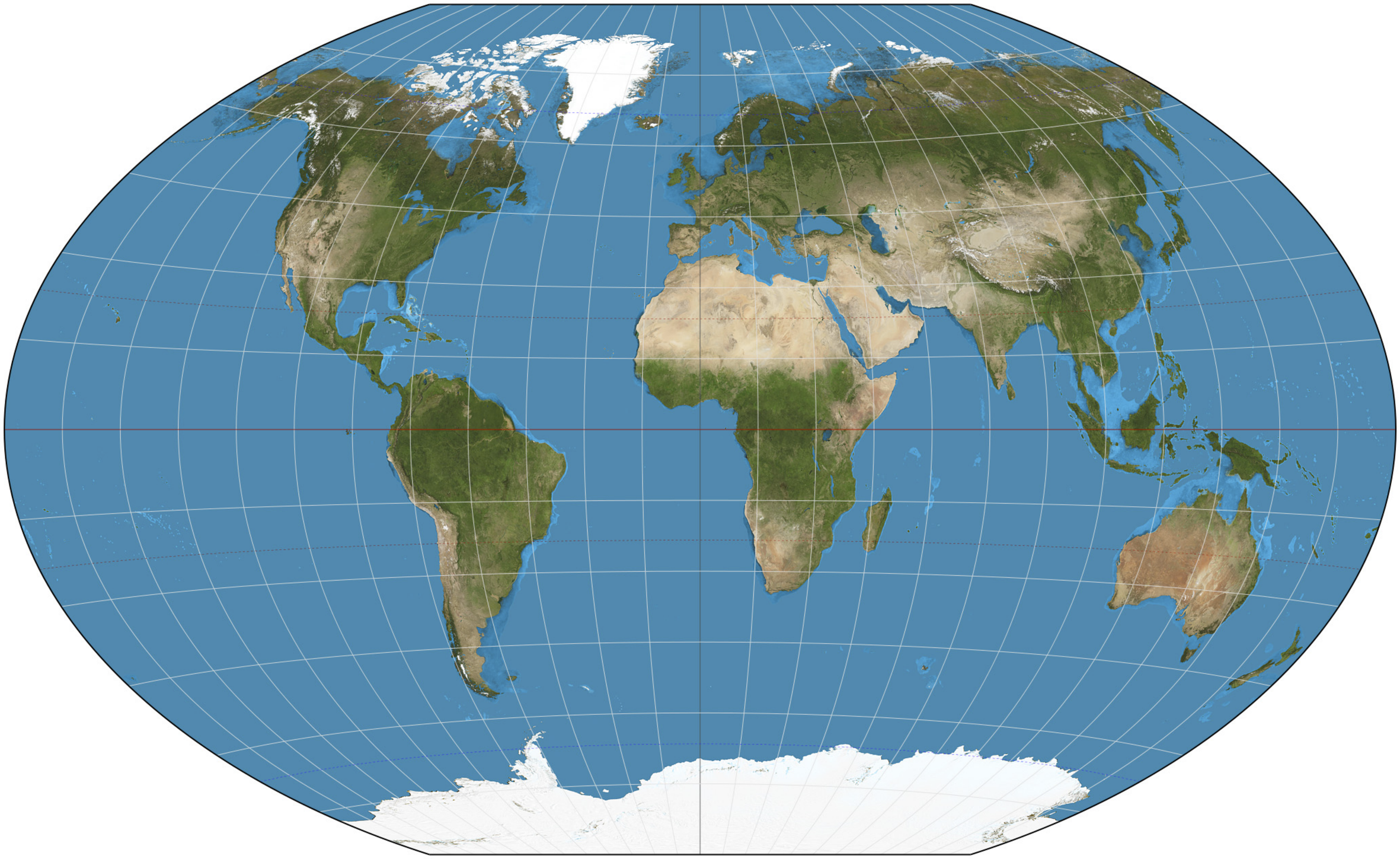
Mean of Azimuthal and Equirectangular

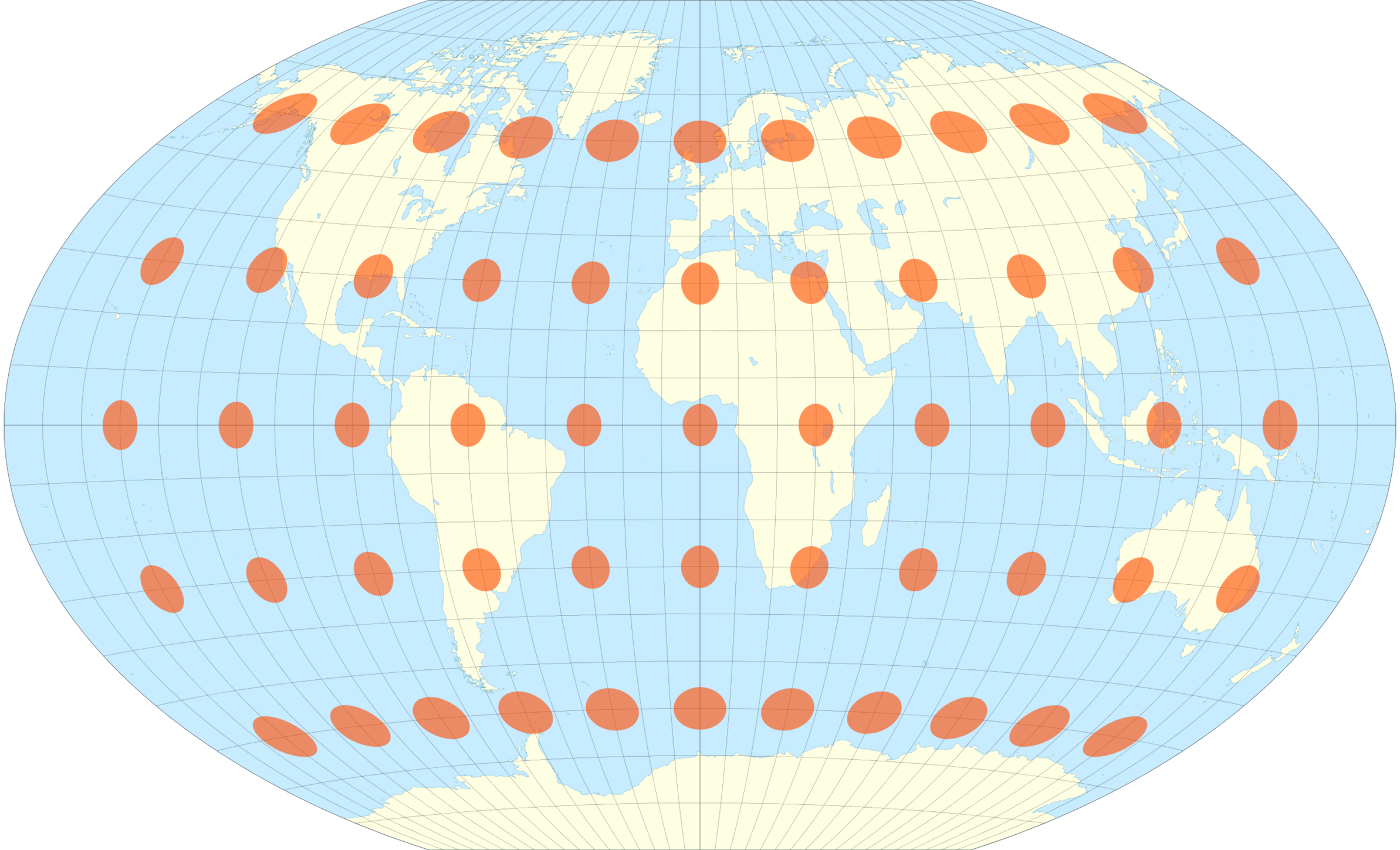


https://en.wikipedia.org/wiki/Equirectangular_projection



https://en.wikipedia.org/wiki/Aitoff_projection

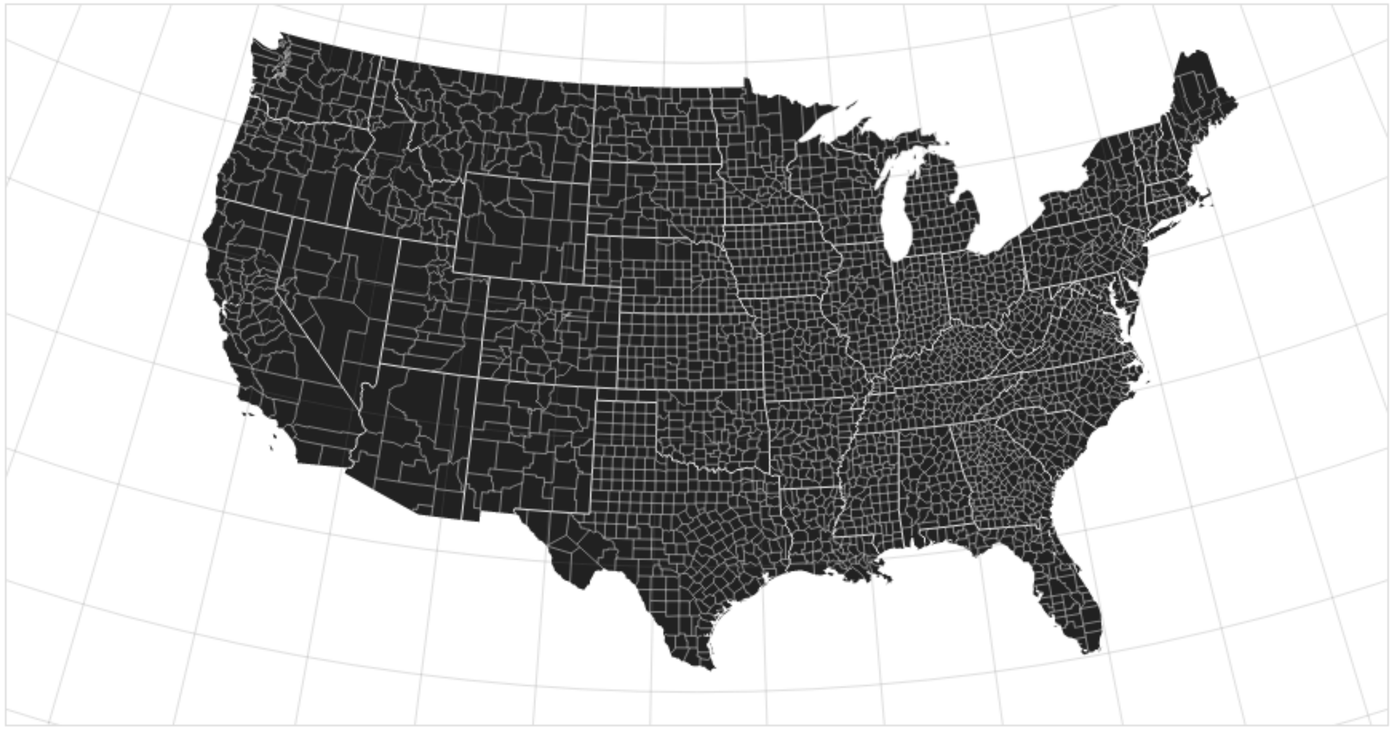




Albers Equal-Area

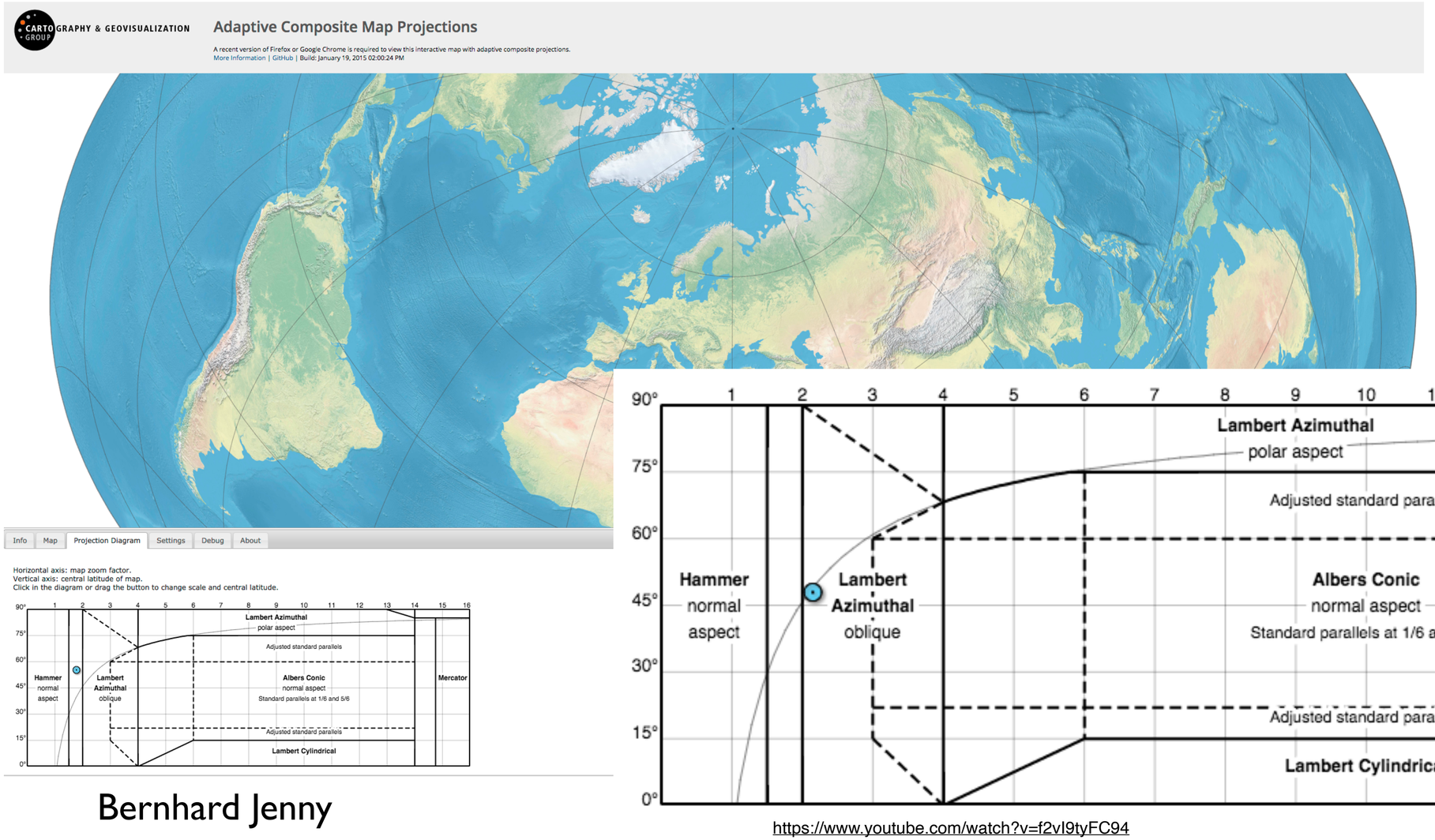
Shows areas correctly

Distorts distances and shapes

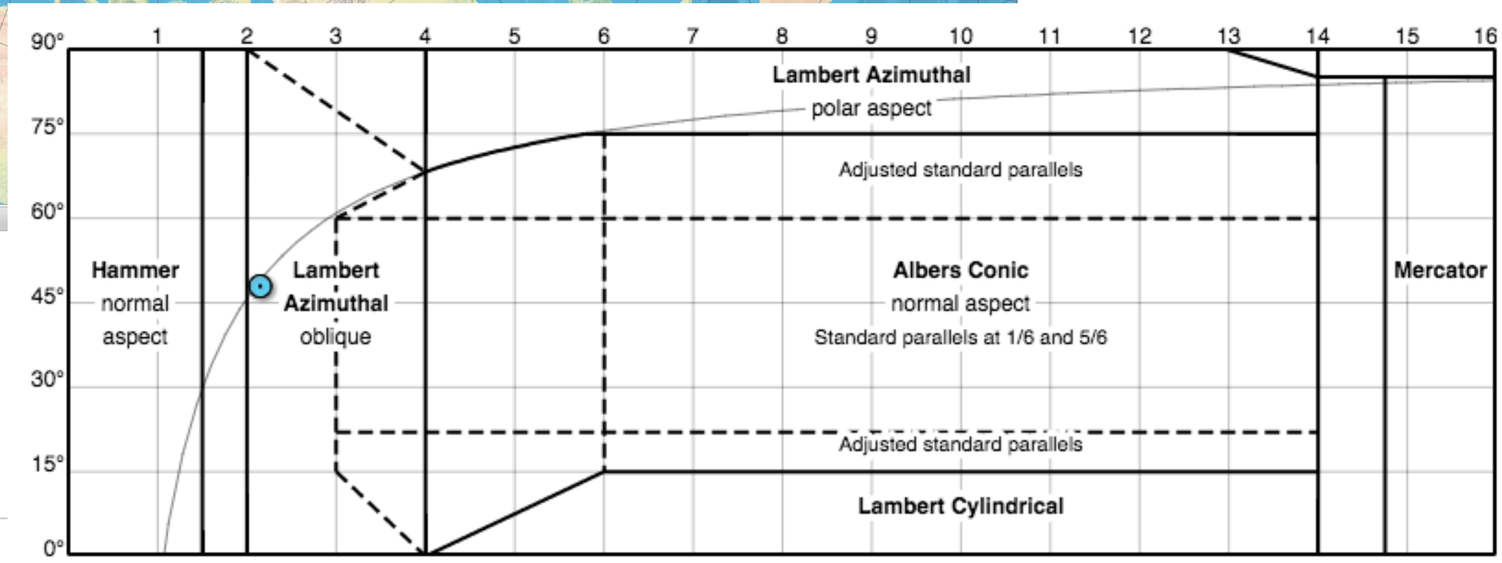


D3 / M. Bostock

Composite Projections



Bernhard Jenny



https://www.youtube.com/watch?v=f2vI9tyFC94

Projections in D3

Many projections included:

https://github.com/d3/d3-geo/blob/master/README.md#projections

https://github.com/d3/d3-geo-projection/

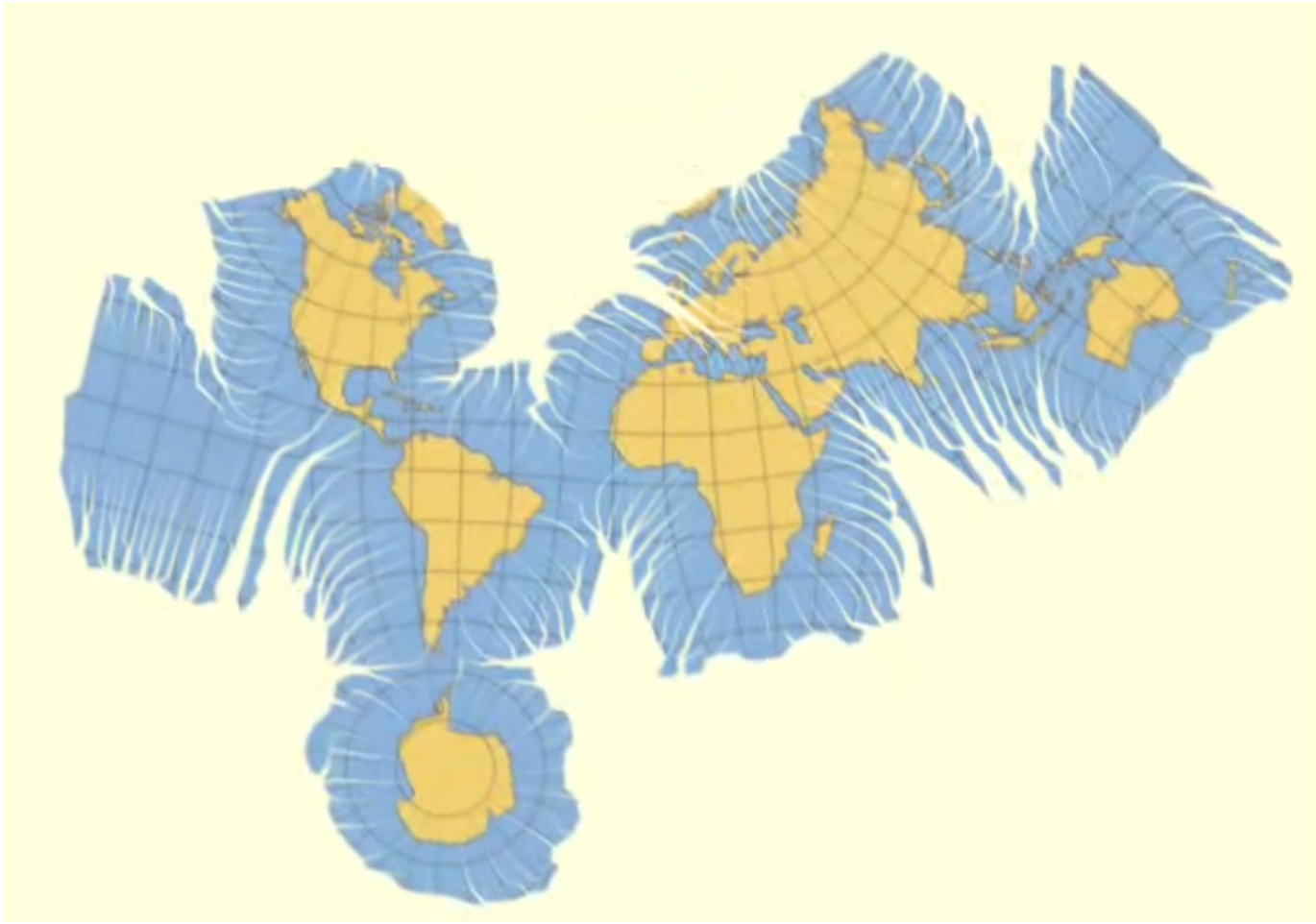
Unfolding The Earth

Idea: use small patches

flatten them out

Jarke van Wijk

http://www.win.tue.nl/~vanwijk/myriahedral/

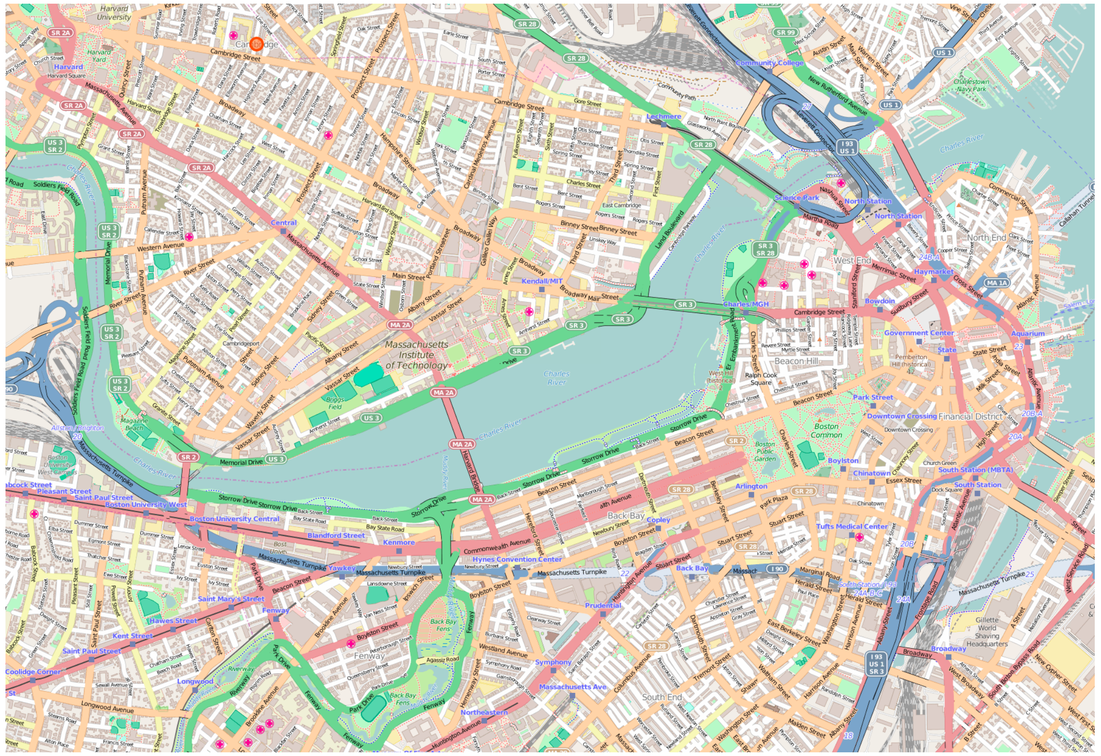


More Info:

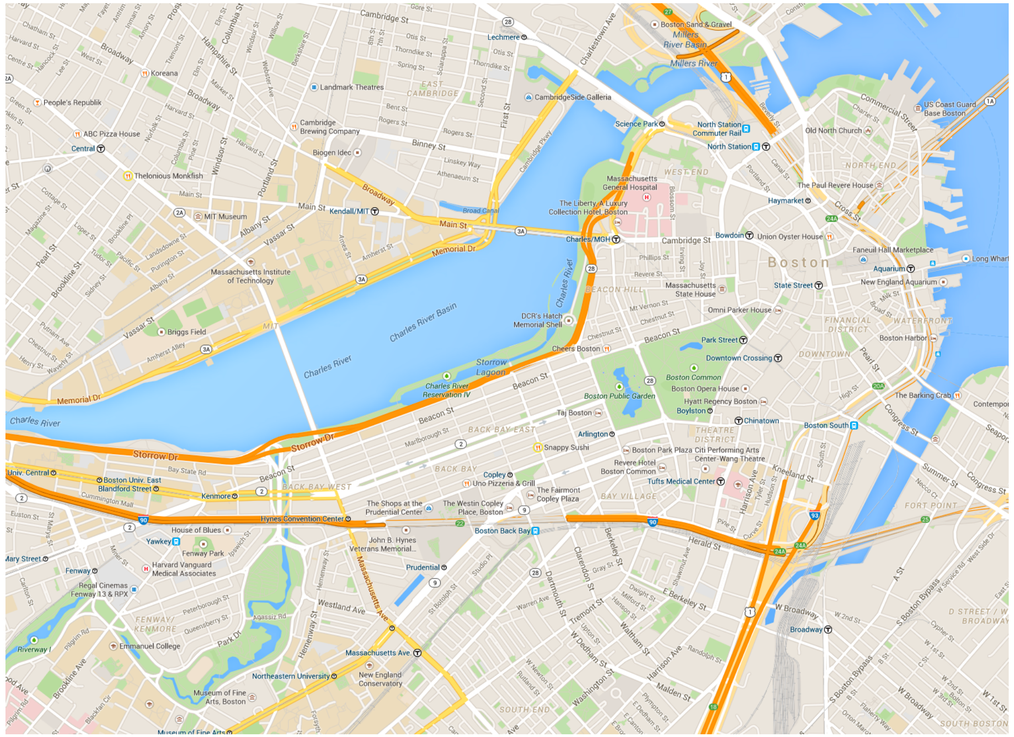
http://mjfoster83.github.io/projections/

Map Software / Navigation

Mapping Software



Open StreetMap

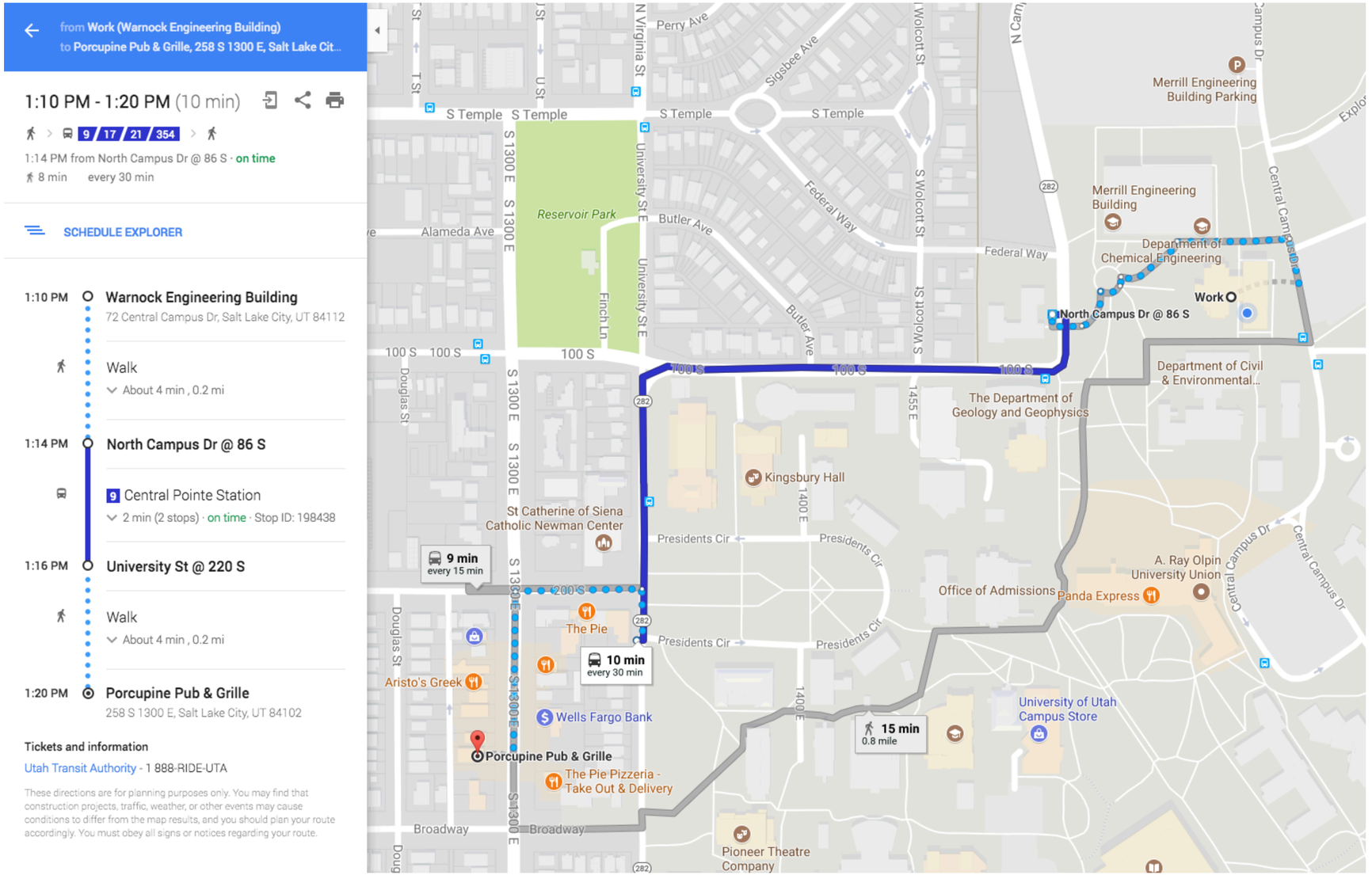


Google Maps

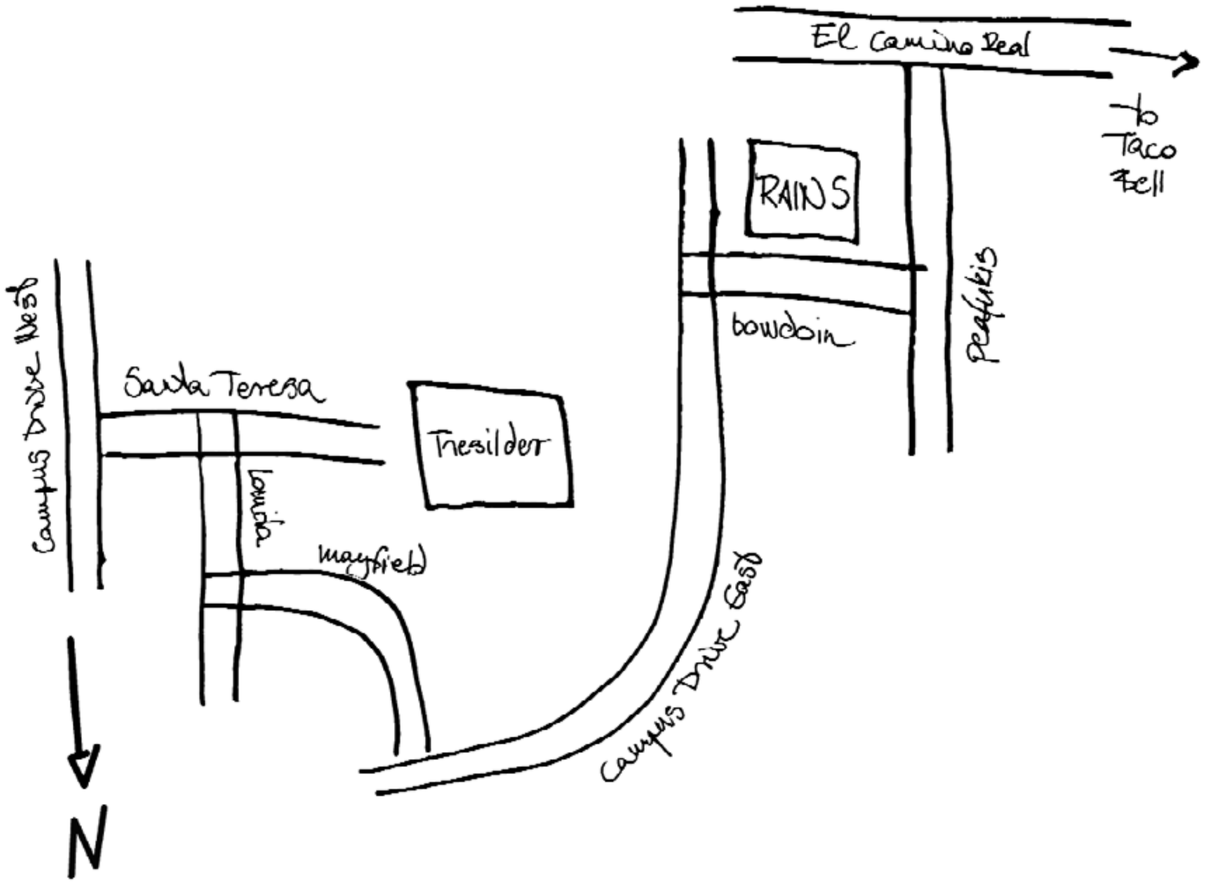
Navigation

Specific

Abstract



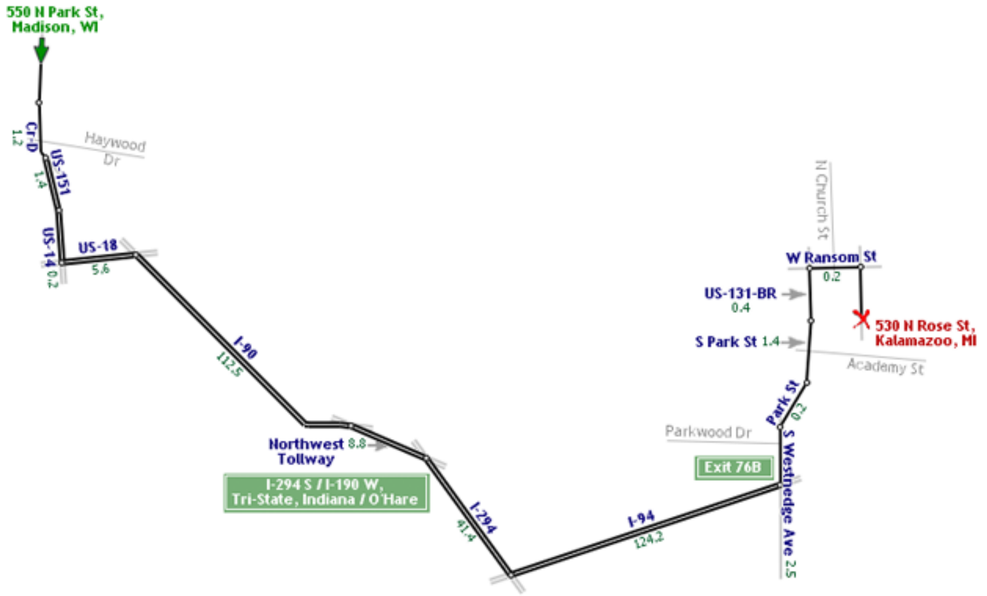
Landmarks & Paths

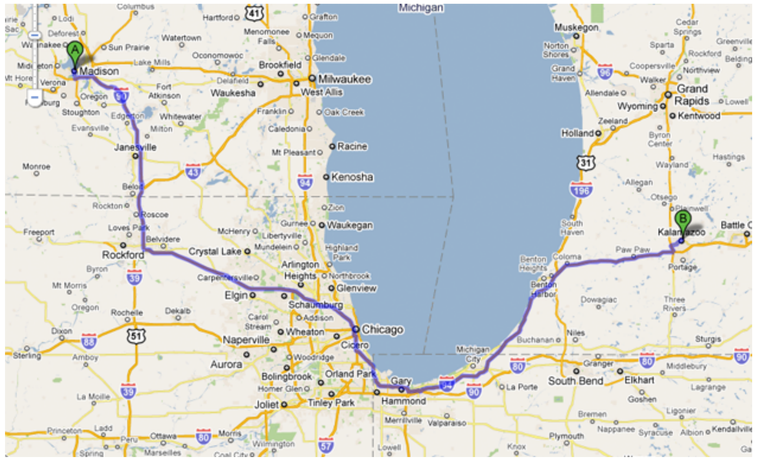


Based on slide from B.Tversky

LineDrive, 2001

Straighten wiggly lines
Turn directions to right angles
Expand regions with turns
Contract long straight roads
Label carefully to avoid clutter
Maintain overall orientation





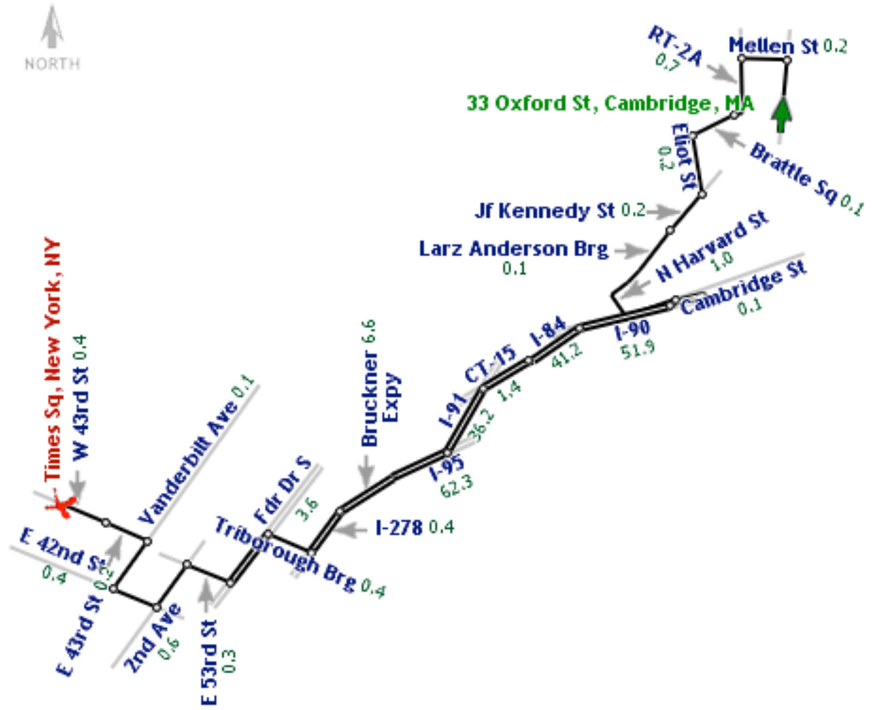
[Agrawala & Stolte, 2001]
Based on slide from Hanrahan

Microsoft

msn Maps & Directions

Home | Maps | Directions | Help

Map Size | Print | E-mail



Start: 33 Oxford St, Cambridge, MA 02138
End: Times Sq, New York, NY 10036
Total Distance: 211.2 Miles
Estimated Total Time: 3 hours, 29 minutes

Directions	Miles

Route
- Turn-by-Turn Directions
- Reverse Directions
- Change Start
- Change End
- Get New Directions

Local Resources
- Traffic Maps
- City Guide
- Yellow Pages
- Weather

advertisement

Microsoft

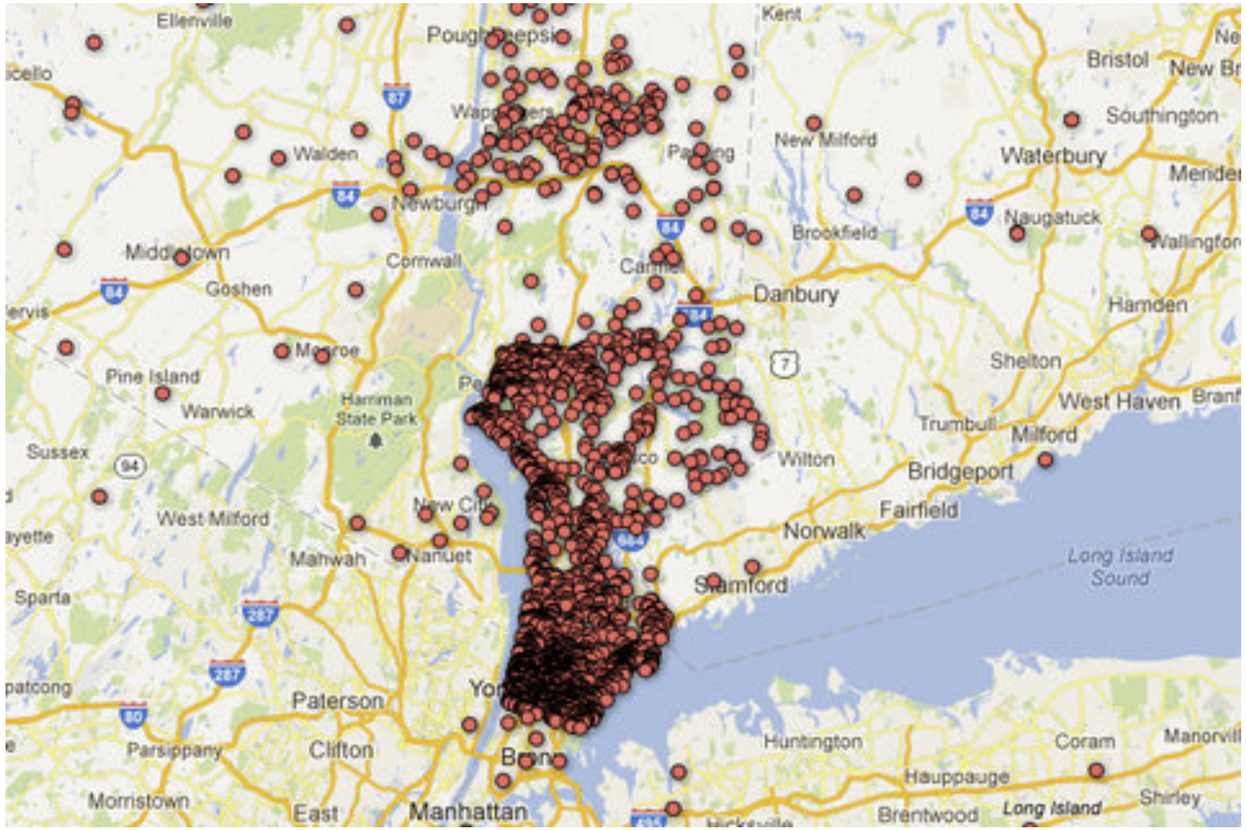
Direct Mapping

One data point one pixel

Mashup: Visualizing Addresses of Gun Owners

Mashup map: augmenting a detailed street map with symbols.

Can resolve individual addresses.



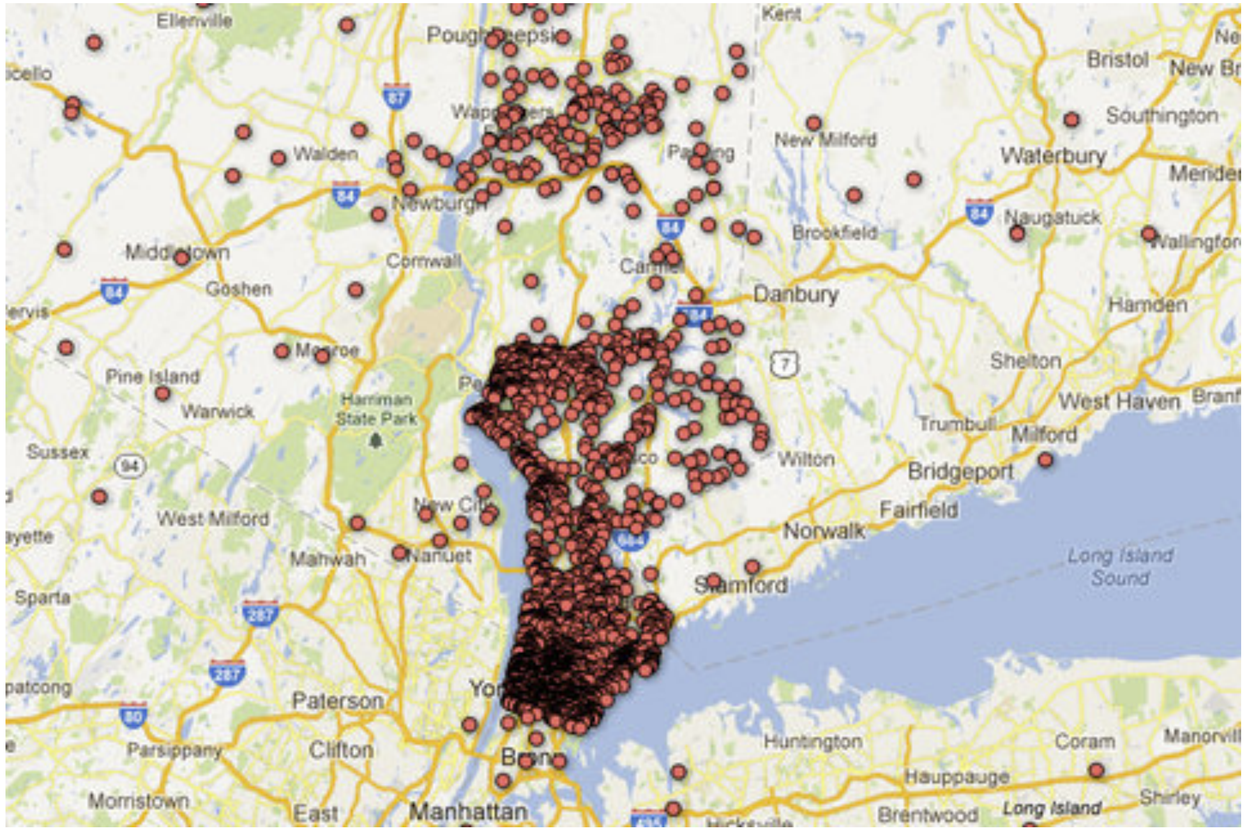
http://learning.blogs.nytimes.com/2013/01/08/did-a-newspaper-act-irresponsibly-by-publishing-the-addresses-of-gun-owners/

Ethical Questions

Published after Connecticut school killings

What are the ethics of visualization?

Data is public: is making it accessible problematic?



http://learning.blogs.nytimes.com/2013/01/08/did-a-newspaper-act-irresponsibly-by-publishing-the-addresses-of-gun-owners/

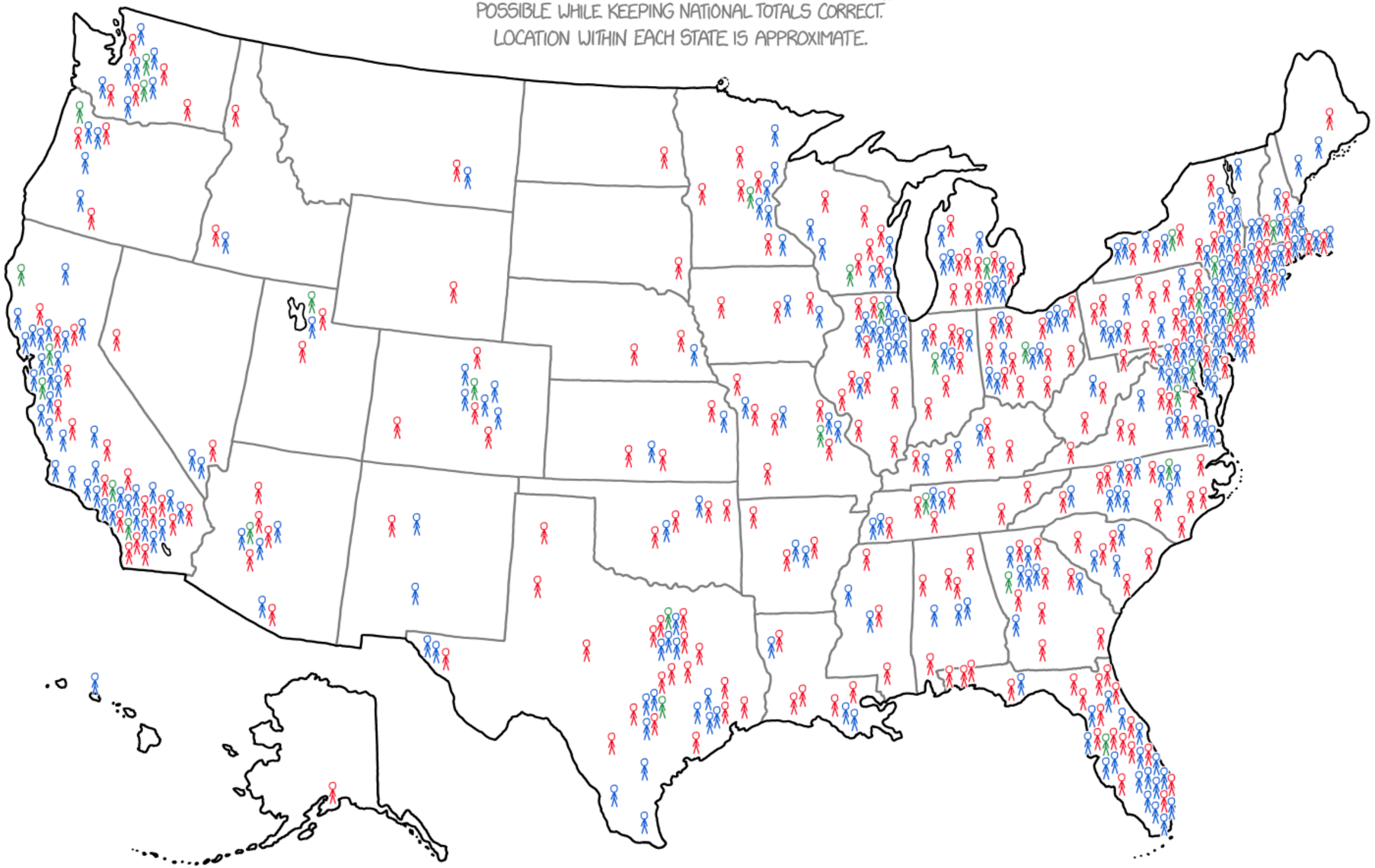
2016 ELECTION MAP

EACH FIGURE REPRESENTS 250,000 VOTES

TRUMP CLINTON OTHER

VOTES ARE DISTRIBUTED BY STATE AS ACCURATELY AS POSSIBLE WHILE KEEPING NATIONAL TOTALS CORRECT.

LOCATION WITHIN EACH STATE IS APPROXIMATE.



Choropleth Maps

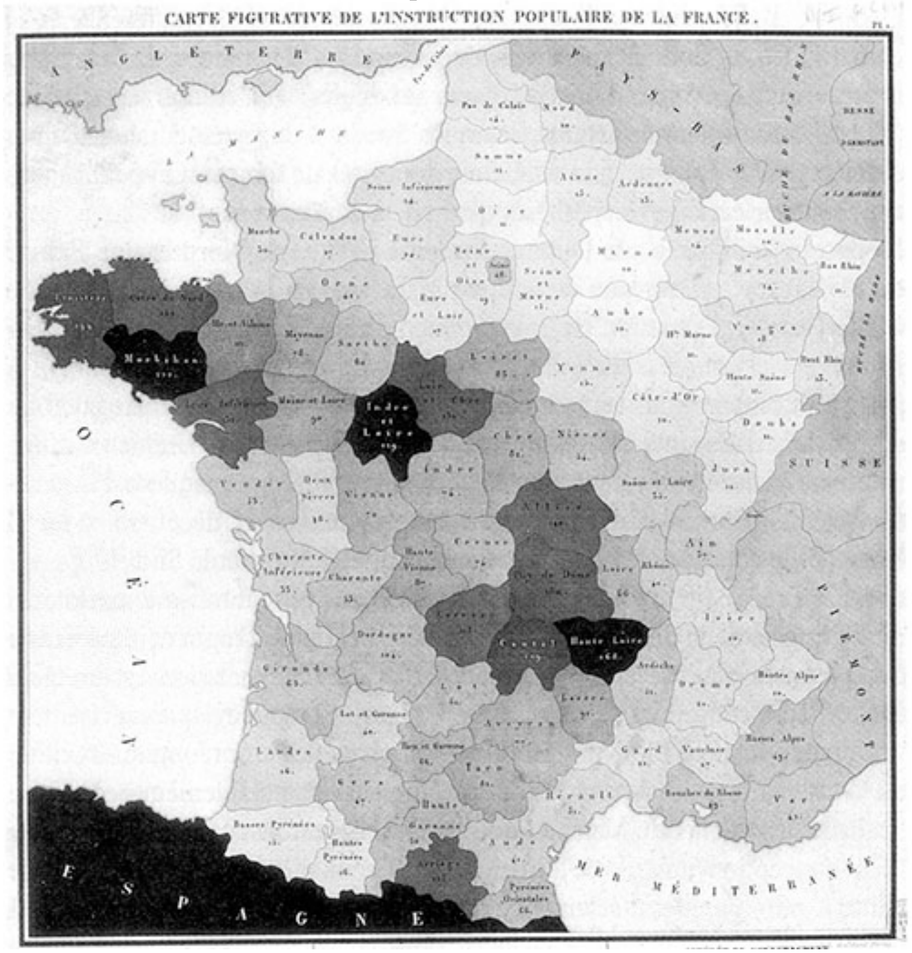
Principle

Areas are shaded or patterned in proportion to measurement

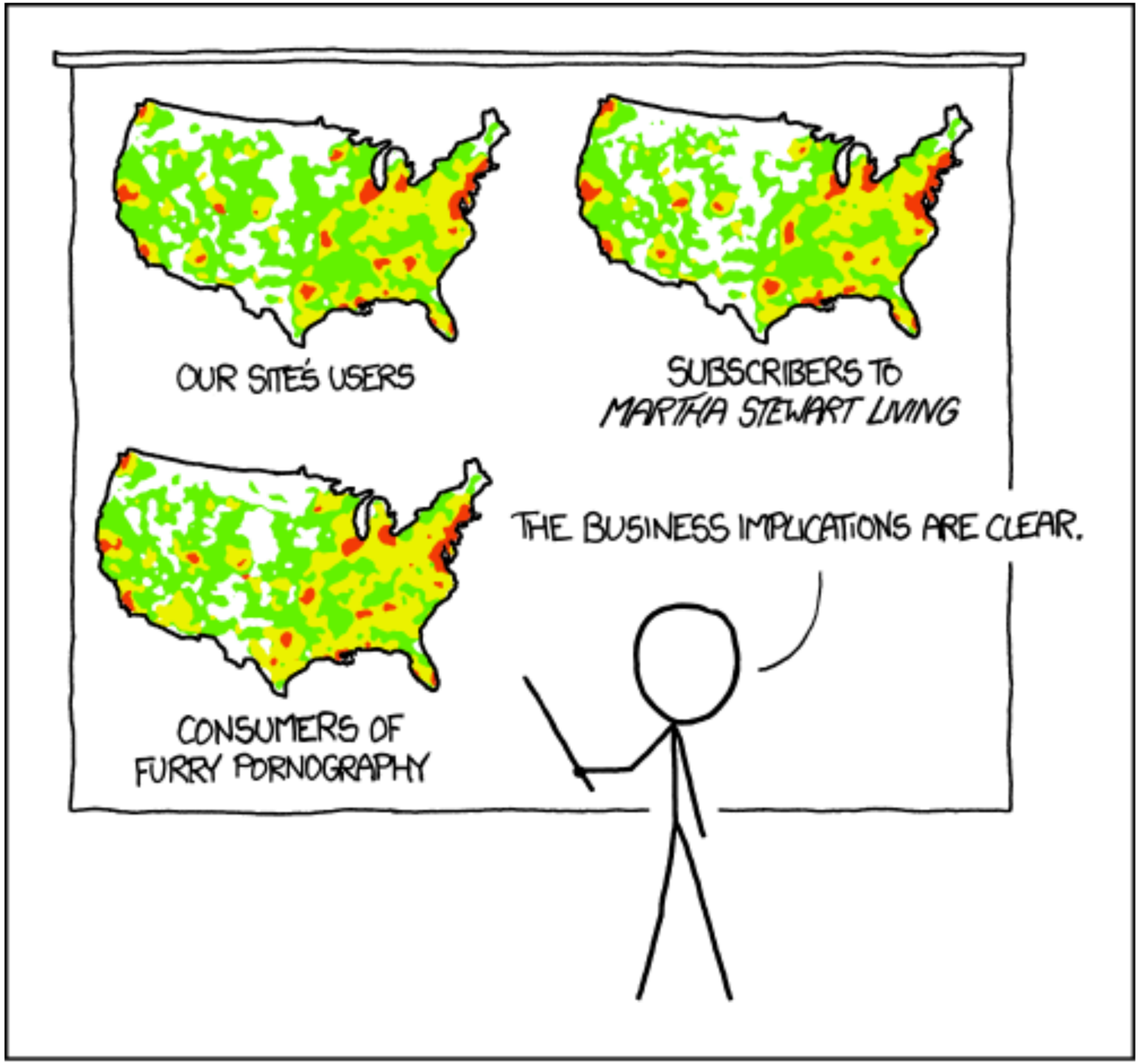
Each spatial unit is filled with a uniform color or pattern

Early Choropleth Map

Illiteracy in France



Charles Dupin, 1826



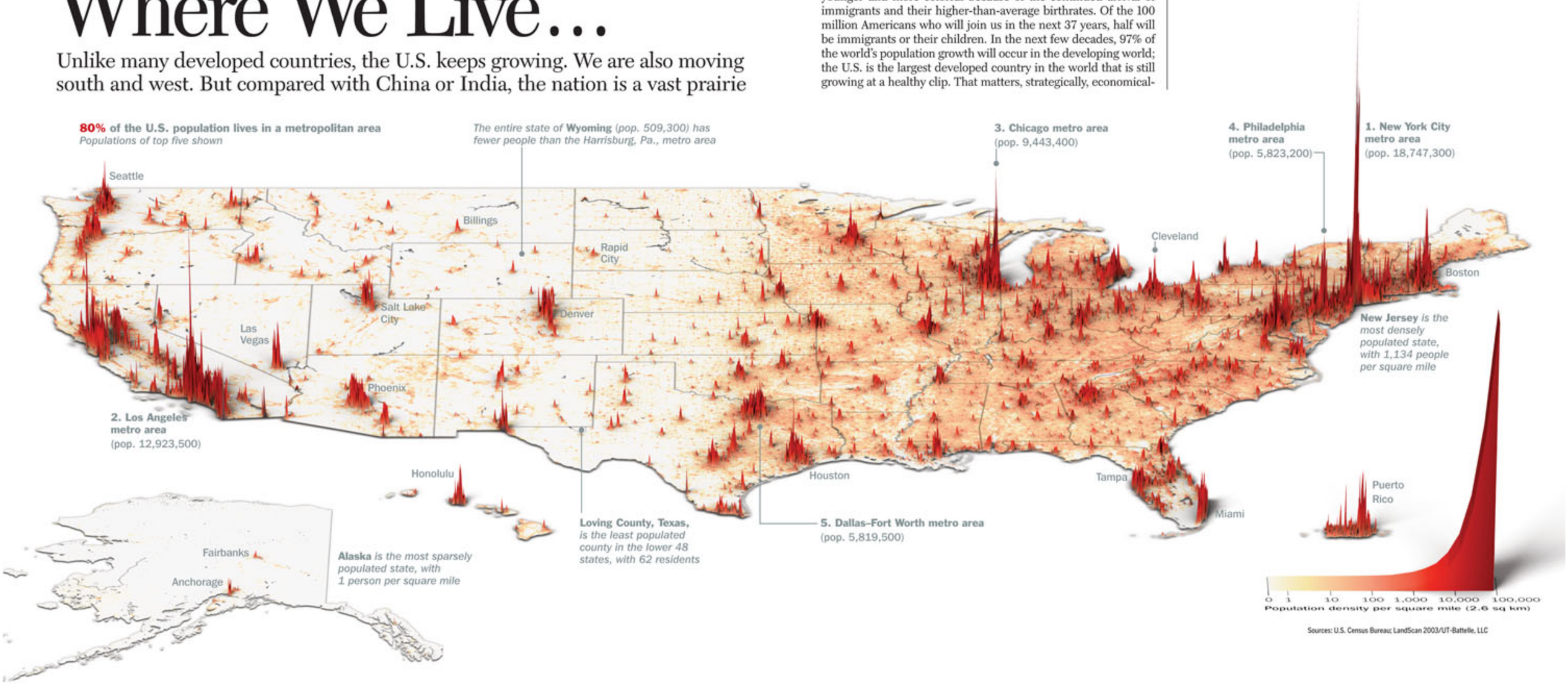
PET PEEVE #208:

GEOGRAPHIC PROFILE MAPS WHICH ARE BASICALLY JUST POPULATION MAPS

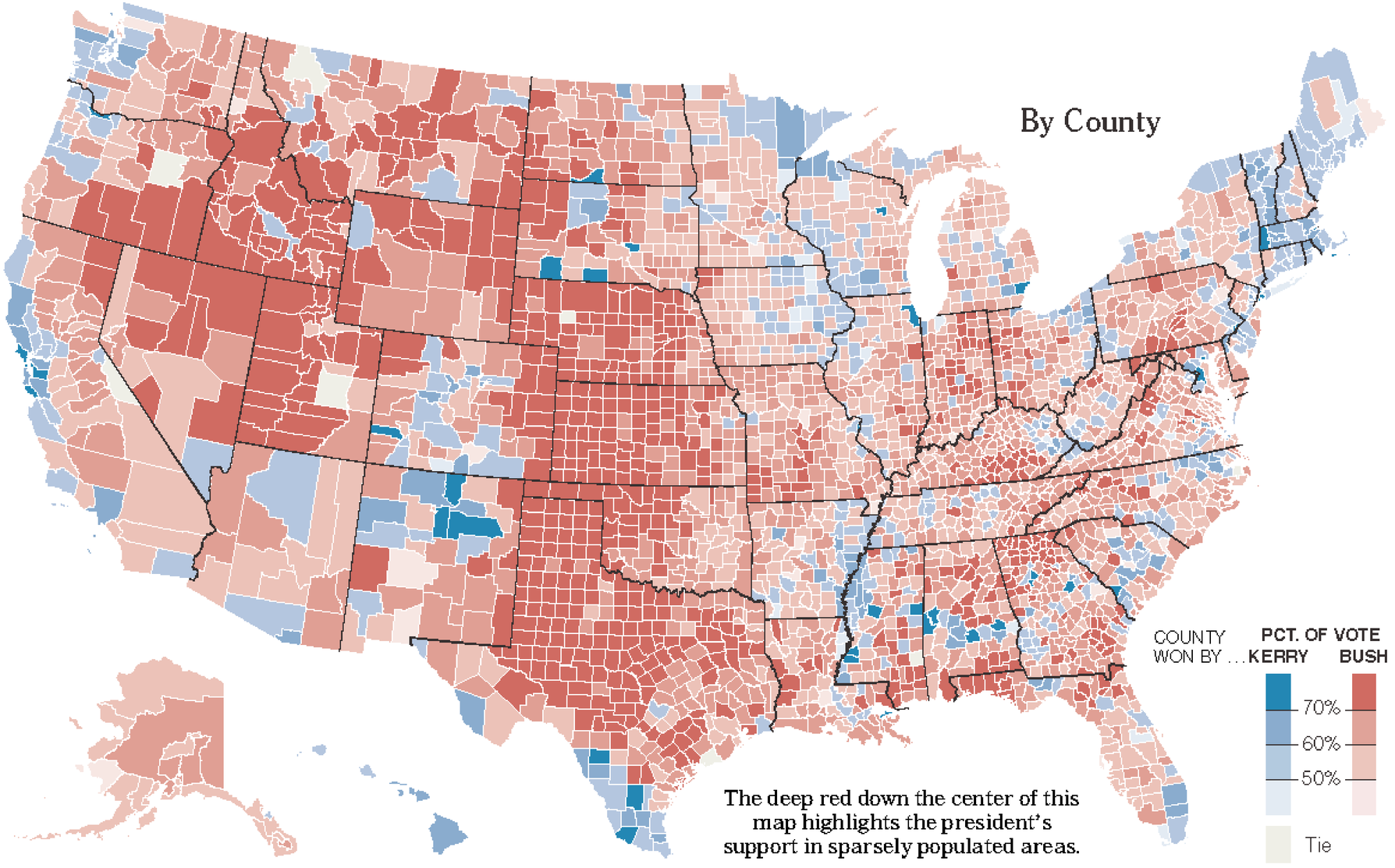
Where We Live…

Unlike many developed countries, the U.S. keeps growing. We are also moving south and west. But compared with China or India, the nation is a vast prairie

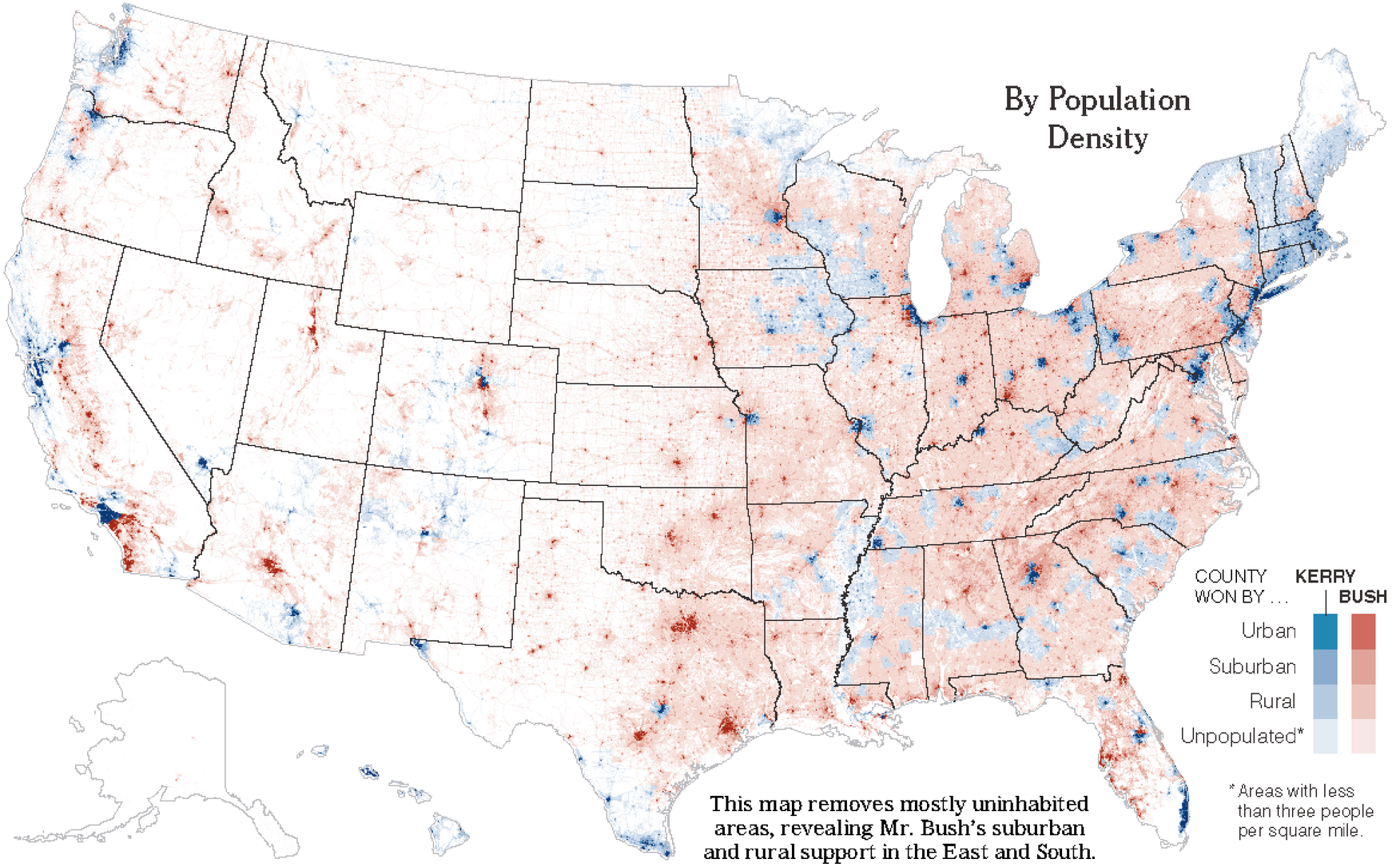
Our families are getting smaller—with one vital exception. Compared with those of Europe and Japan, the U.S. population is younger and more colorful because of the continued arrival of immigrants and their higher-than-average birthrates. Of the 100 million Americans who will join us in the next 37 years, half will be immigrants or their children. In the next few decades, 97% of the world's population growth will occur in the developing world; the U.S. is the largest developed country in the world that is still growing at a healthy clip. That matters, strategically, economically—Ala.; Possum Trot, Ky.; or Lonelyville, N.Y. But they are all probably close to someone's idea of paradise. *—By Nancy Gibbs*



Sources: U.S. Census Bureau; LandScan 2003/UT-Battelle, LLC

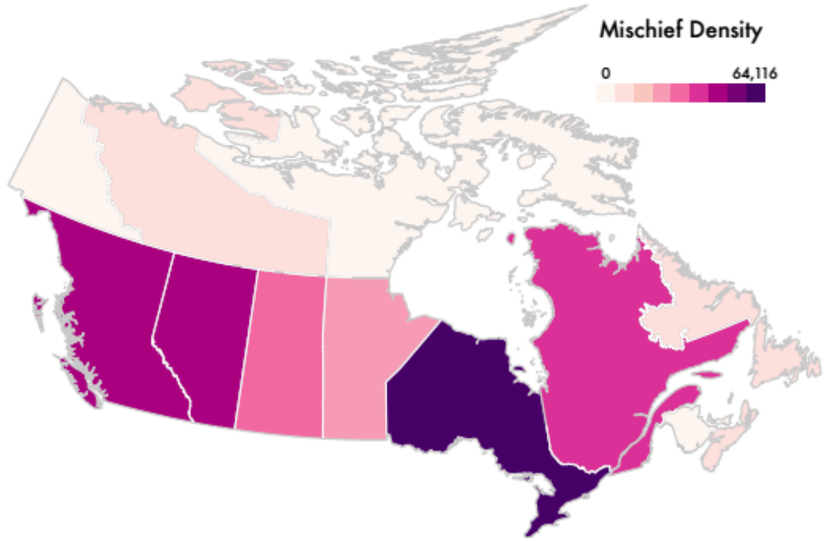


Matthew Ericson, NY Times

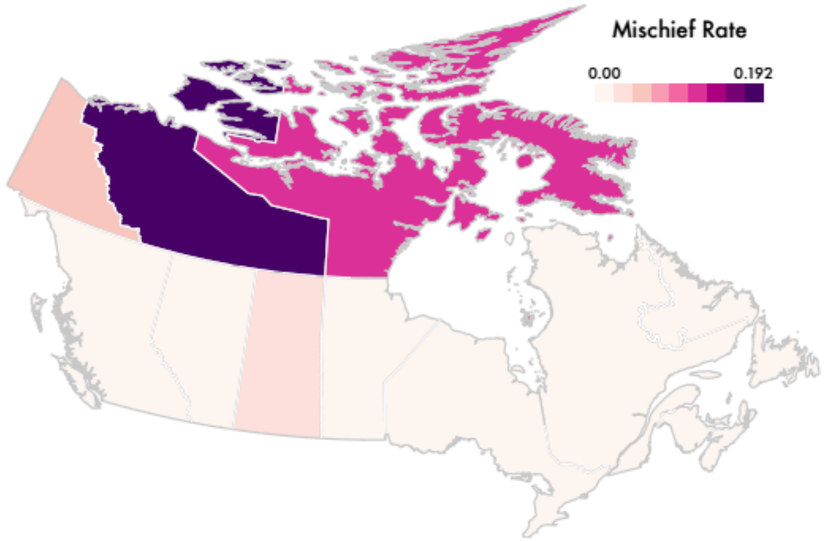


Matthew Ericson, NY Times

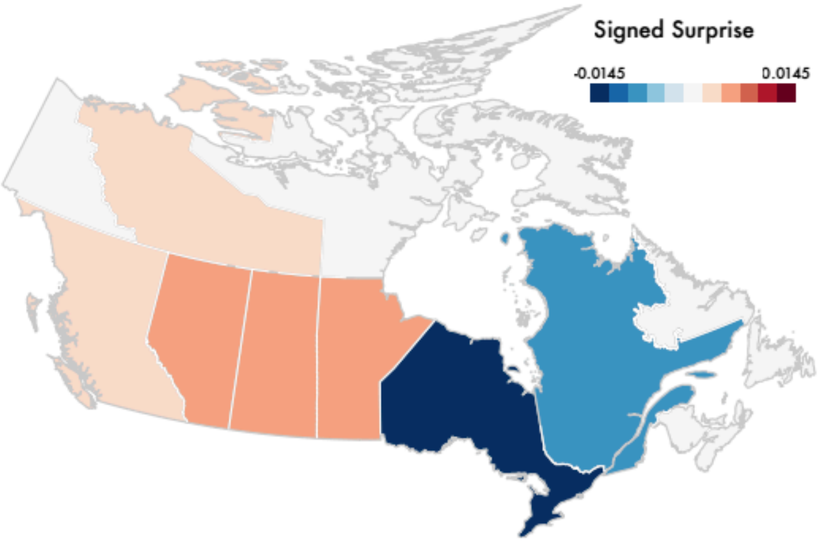
Approach: Use a Prior, show difference. Which province is safest?



(a) The **Event Density** of "mischief" in Canada.



(b) The per-capita **Event Rate** of mischief.



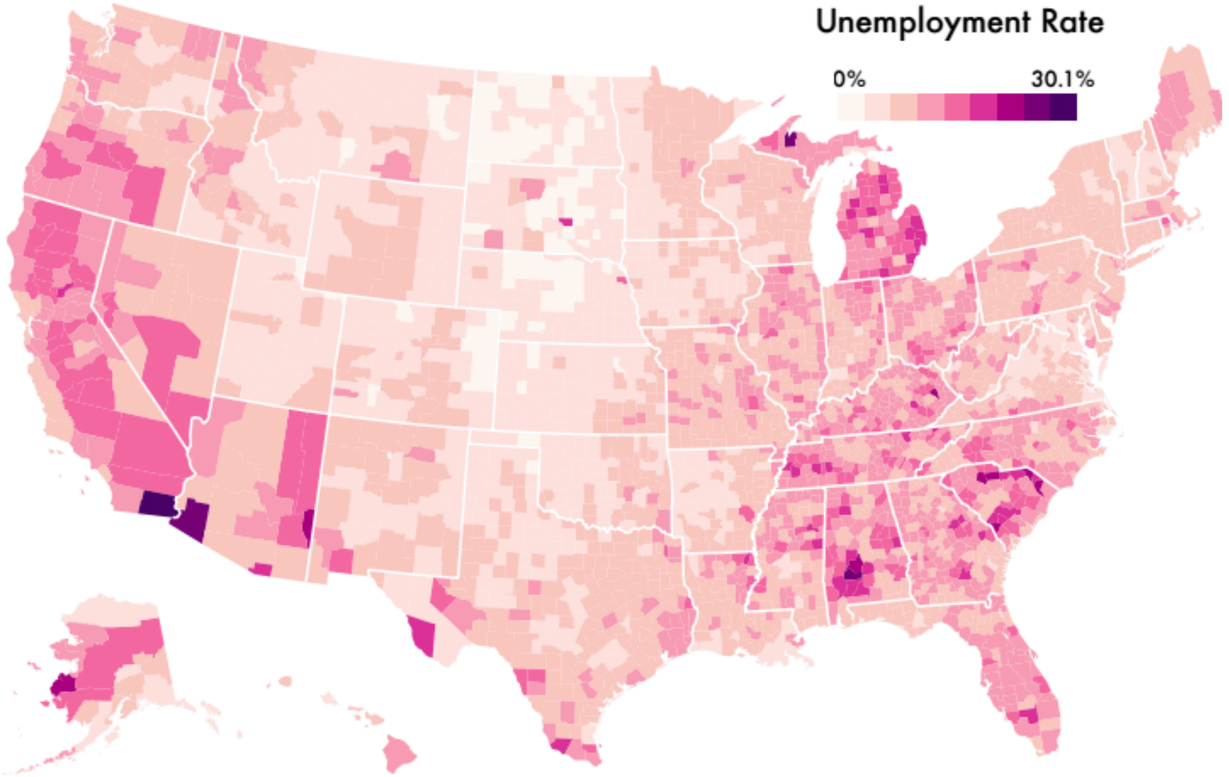
(c) The **Surprise Map** of mischief.

mischief = property damage such as vandalism in Canada

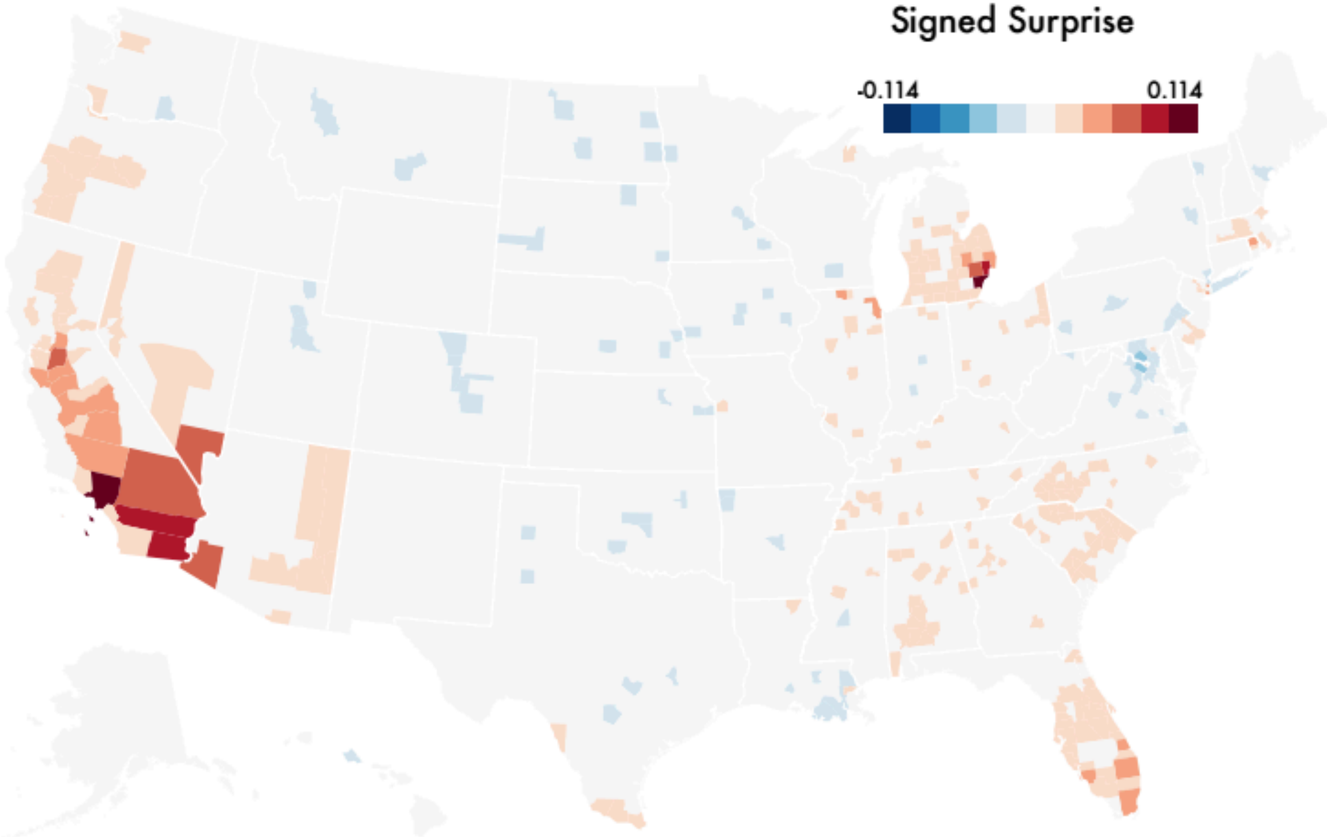
model of population density + accounting for variability when analyzing small numbers

[Corell 2016]

Surprise Map: Unemployment



(a) Per capita event rate map.



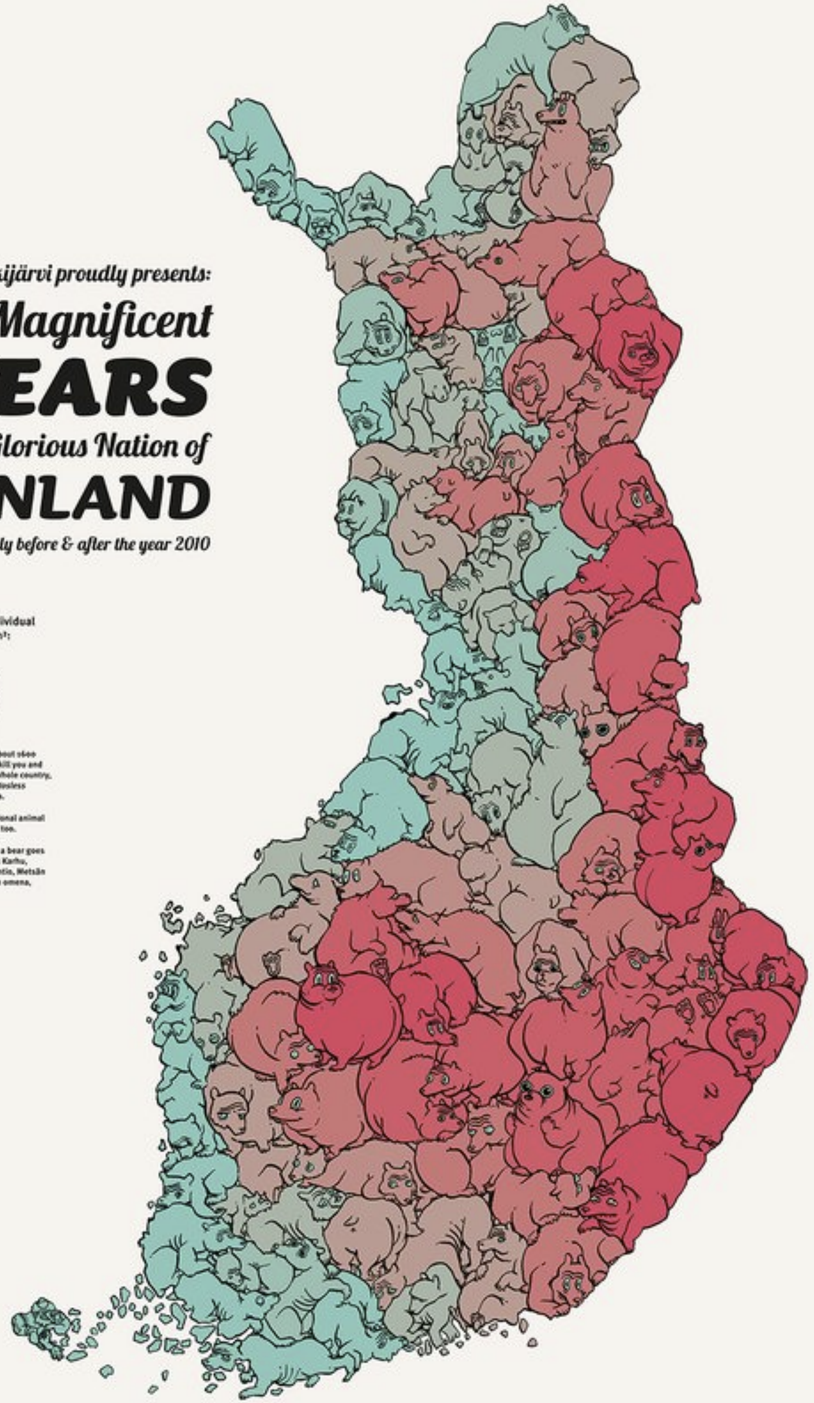
[Corell 2016]

(b) Signed Surprise Map.

A.A. Mäkijärvi proudly presents:

The Magnificent BEARS of the Glorious Nation of FINLAND

Approximately before & after the year 2010



The amount of individual bears per 1000 km²:

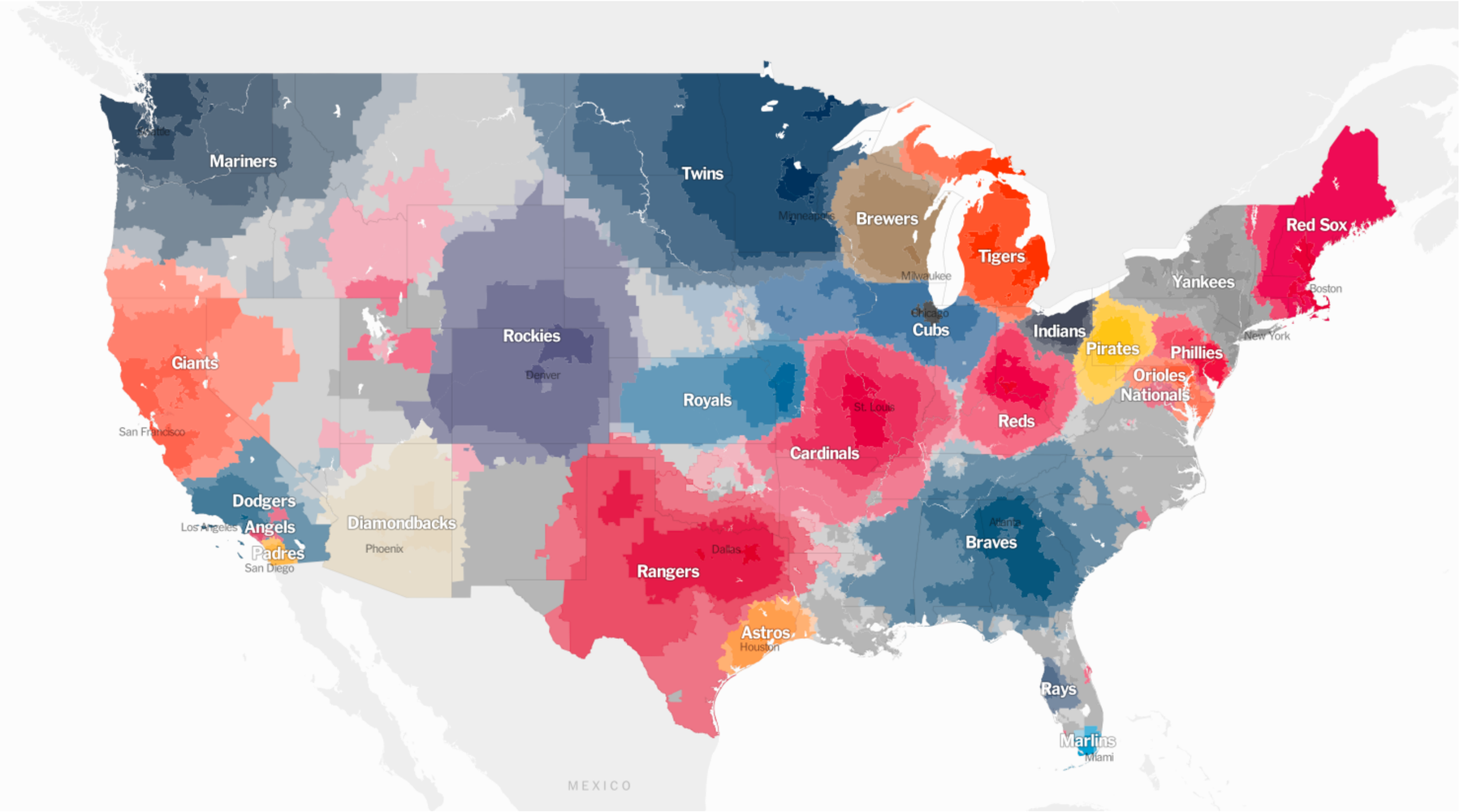
- 0 - 2,0
- 2,1 - 4,0
- 4,1 - 6,0
- 6,1 - ∞

Which means there is about 1600 graceful bears ready to kill you and your loved ones in the whole country, excluding the Ursus arctoidea province of Ahvenanmaa.

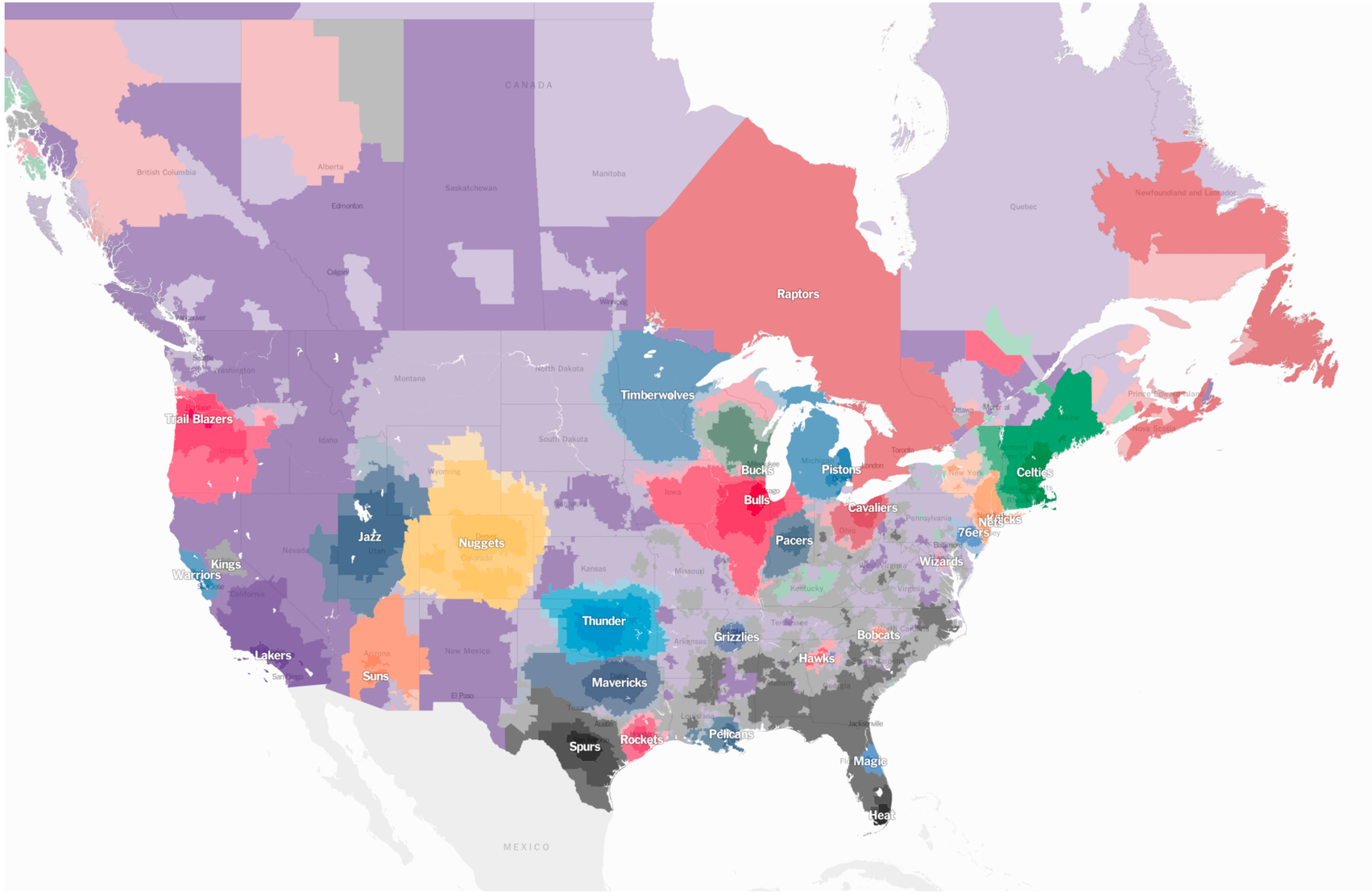
Fun fact! Bear is the national animal of Finland. And Russia's too.

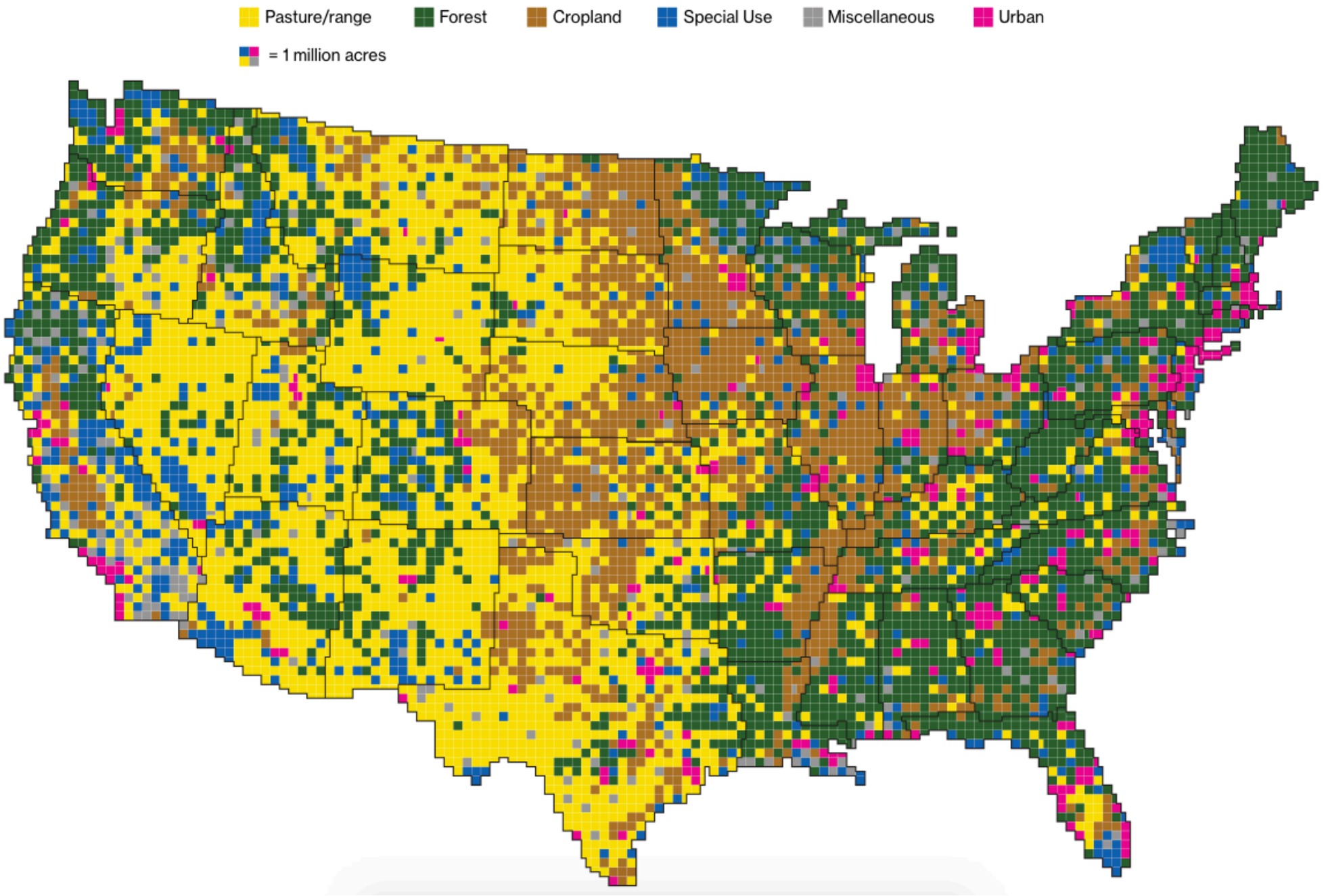
In the Finnish language a bear goes by the following names: Karhu, Mesikämmen, Otso, Kontio, Metsän kuningas, Nalle, Metsän omena, Ohto and Nallukka.

Baseball Territories



Lakers Dominate Baskeball (2014)



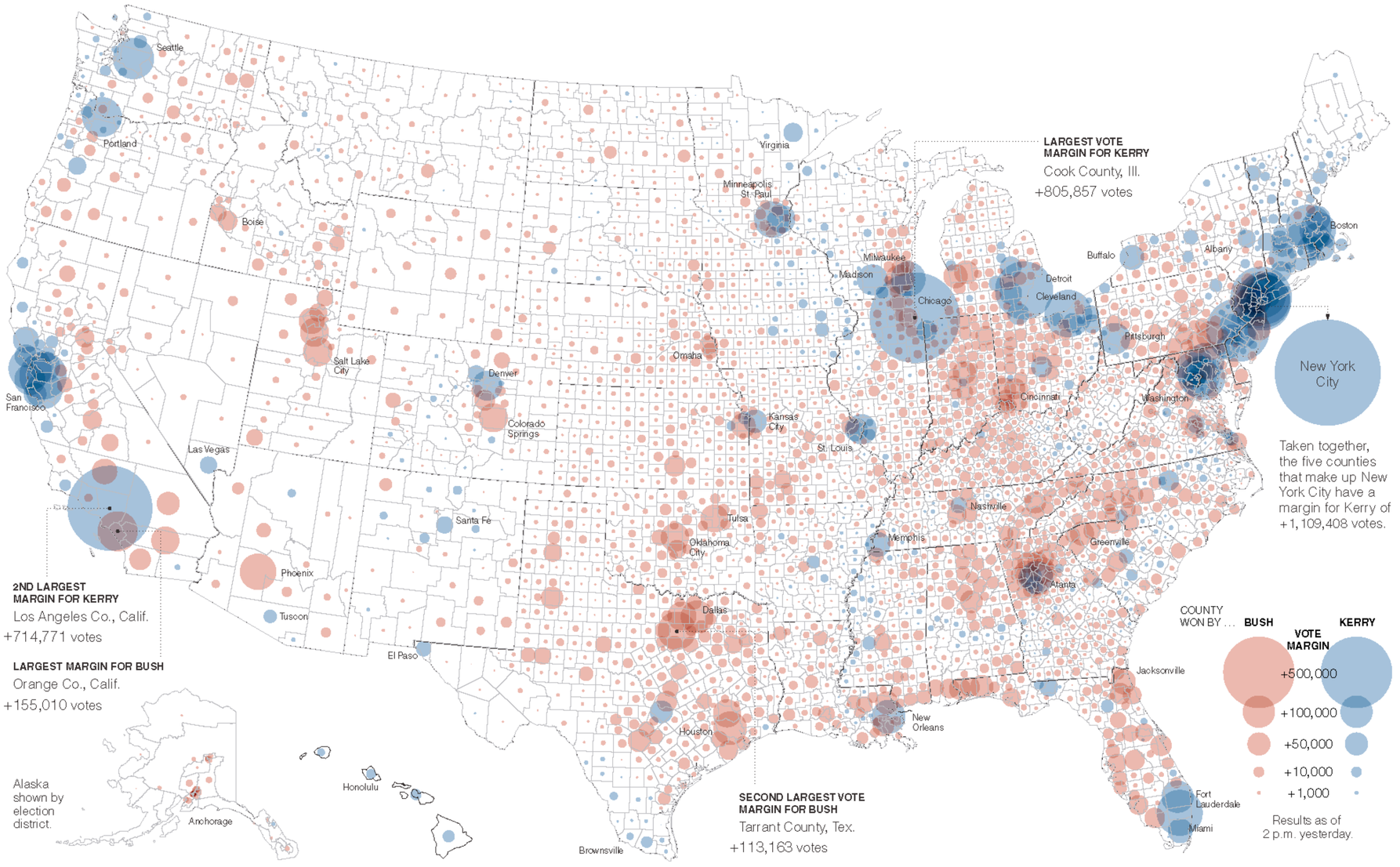

Pasture/range
Forest
Cropland
Special Use
Miscellaneous
Urban
= 1 million acres

Proportional Symbol Maps

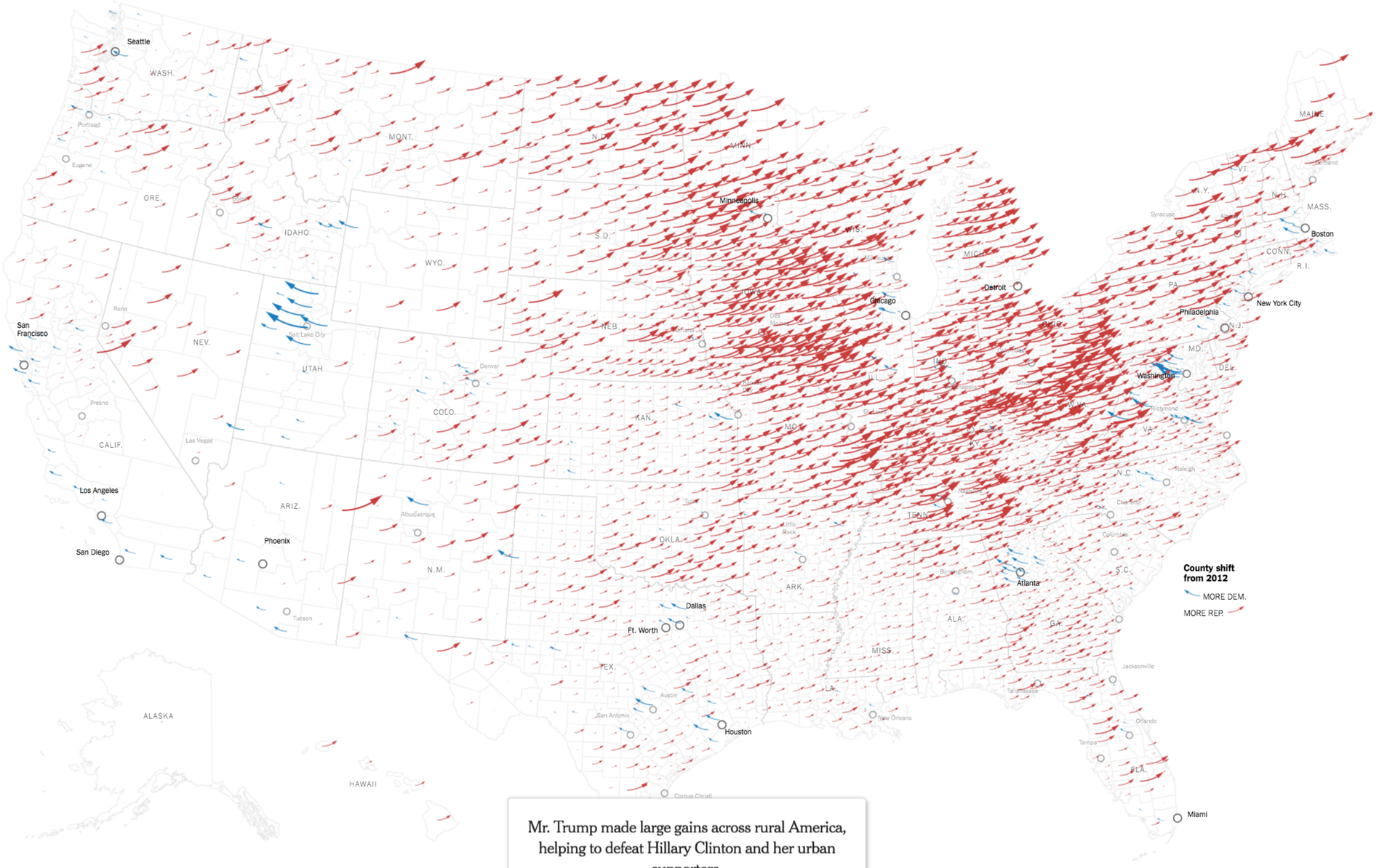
Alternative to Choropleth

Use a Symbol instead of color

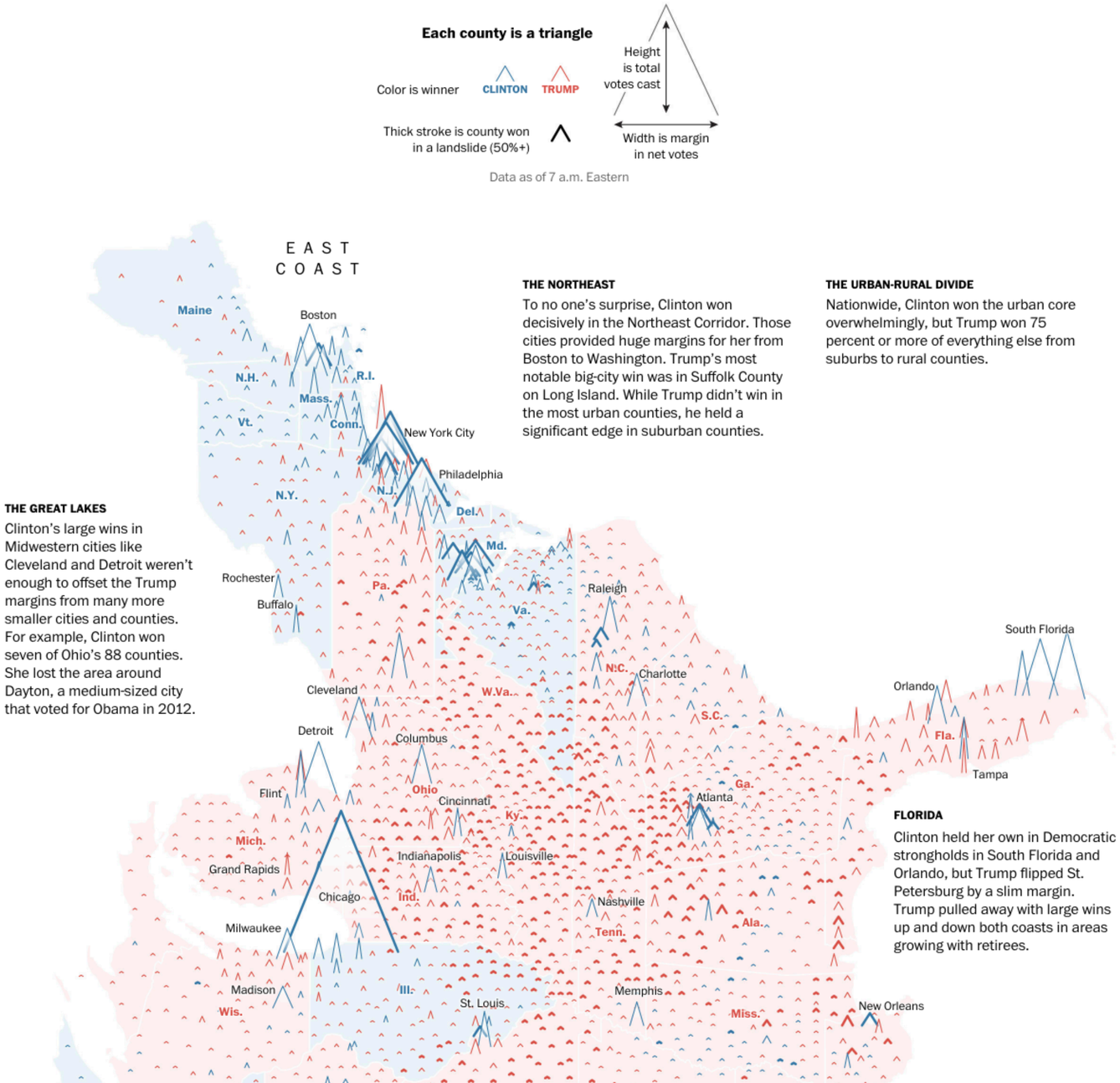
Scale symbol according to data



Matthew Ericson, NY Times

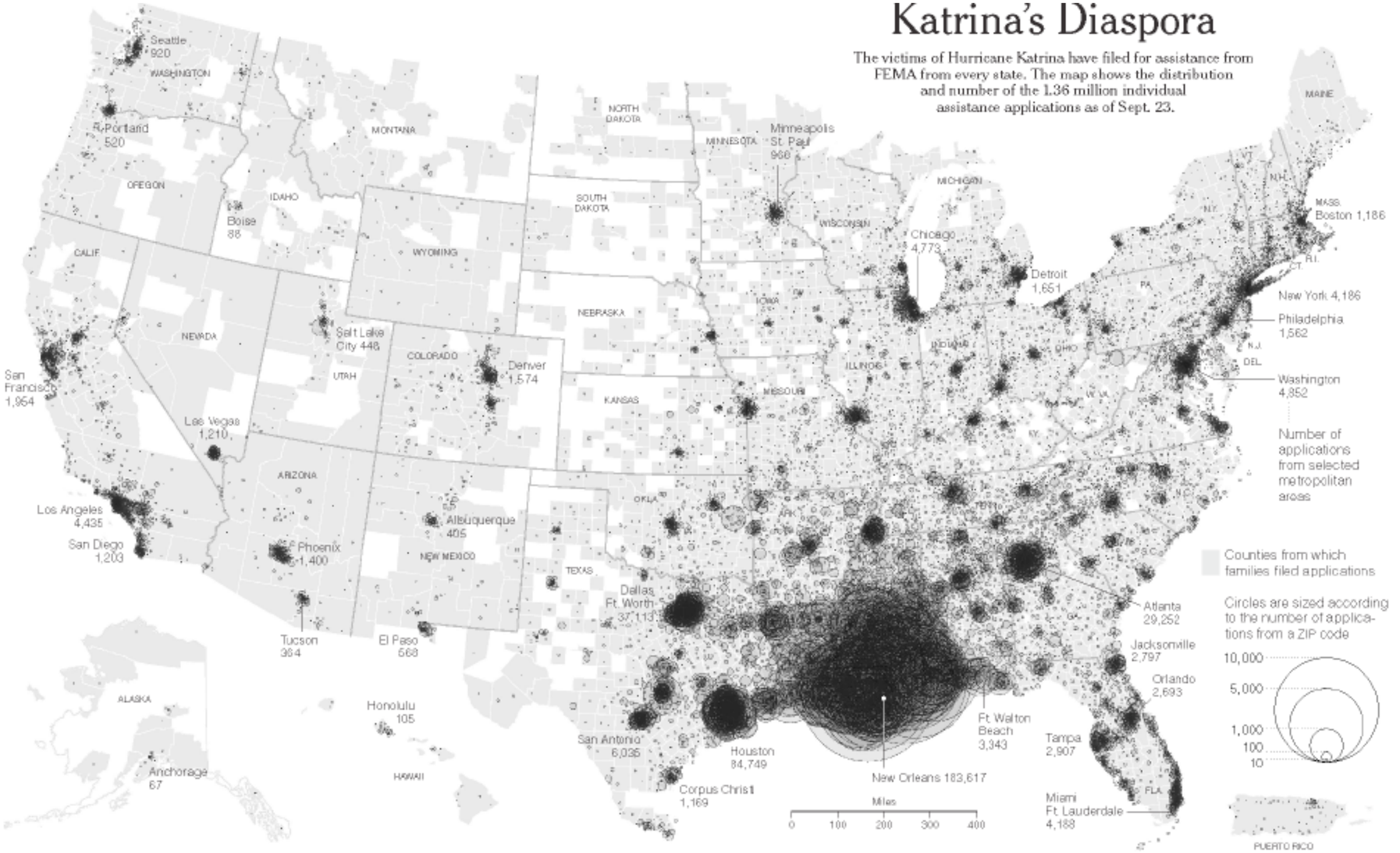


Mr. Trump made large gains across rural America, helping to defeat Hillary Clinton and her urban supporters.


Each county is a triangle
Color is winner
CLINTON
TRUMP
Height is total votes cast
Thick stroke is county won in a landslide (50%+)
Width is margin in net votes
Data as of 7 a.m. Eastern
EAST COAST
Maine
Boston
N.H.
R.I.
Mass.
Vt.
Conn.
New York City
Philadelphia
N.J.
N.Y.
Del.
Md.
Rochester
Buffalo
Pa.
Raleigh
Va.
N.C.
Charlotte
Cleveland
W.Va.
S.C.
Detroit
Columbus
Orlando
South Florida
Fla.
Tampa
Flint
Ohio
Cincinnati
Ga.
Atlanta
Ky.
Mich.
Indianapolis
Louisville
Grand Rapids
Chicago
Ind.
Nashville
Ala.
Tenn.
Milwaukee
Madison
Ill.
Memphis
St. Louis
Wis.
Miss.
New Orleans
THE NORTHEAST
To no one's surprise, Clinton won decisively in the Northeast Corridor. Those cities provided huge margins for her from Boston to Washington. Trump's most notable big-city win was in Suffolk County on Long Island. While Trump didn't win in the most urban counties, he held a significant edge in suburban counties.
THE URBAN-RURAL DIVIDE
Nationwide, Clinton won the urban core overwhelmingly, but Trump won 75 percent or more of everything else from suburbs to rural counties.
THE GREAT LAKES
Clinton's large wins in Midwestern cities like Cleveland and Detroit weren't enough to offset the Trump margins from many more smaller cities and counties. For example, Clinton won seven of Ohio's 88 counties. She lost the area around Dayton, a medium-sized city that voted for Obama in 2012.
FLORIDA
Clinton held her own in Democratic strongholds in South Florida and Orlando, but Trump flipped St. Petersburg by a slim margin. Trump pulled away with large wins up and down both coasts in areas growing with retirees.

Katrina's Diaspora

The victims of Hurricane Katrina have filed for assistance from FEMA from every state. The map shows the distribution and number of the 1.36 million individual assistance applications as of Sept. 23.



They are scattered through all 50 states, the District of Columbia and Puerto Rico — 623 in Utah, 1,114 in Kansas, 101 way out in Alaska. They are clustered by the thousands in large Southern cities like Dallas, Atlanta and Memphis, and huddled in handfuls in unlikely hamlets like Shell Knob, Mo. (pop. 1,393) and Fountain Run, Ky. (pop. 236).

Evacuees fled Hurricane Katrina and the floods that followed in caravans of cars and fleets of buses, on helicopters and

emerges of where they landed, based on ZIP codes from which applications for aid were submitted to the Federal Emergency Management Agency as of Sept. 23.

Of 1,356,704 applications, 86 percent came from Louisiana, Mississippi, Texas and Alabama. But 35,539 families were more than 1,000 miles from the Gulf — among the farthest: one in Nome, Alaska, 3,931 miles from the French Quarter and another in Lihue, Hawaii, 4,279 miles away.

Residents of New Orleans, a city that

centers. On average, the applicants came from counties where blacks were 28 percent of the population, more than twice the national average.

Baton Rouge, La., appears to be temporary home to 10 percent of evacuees, Houston 6.25 percent. But after the top 18 hubs, applicants are spread like the wind that whipped through their old neighborhoods: none of the other 900-plus metropolitan areas has even 1 percent of the total.

Some 4,000 ZIP codes — among them

Applications by state

Louisiana	523,149	38.6%
Mississippi	383,840	28.3%
Texas	156,895	11.6%
Alabama	109,469	8.1%
Georgia	35,342	2.6%
Florida	31,005	2.3%
Tennessee	15,529	1.1%
Arkansas	11,027	0.8%
California	10,959	0.8%
Illinois	6,430	0.5%

Applications by distance from New Orleans

MILES	APPLICANTS	PCT.
0-100	626,232	46.2%
100-200	338,080	24.9%
200-400	184,169	13.6%
400-800	143,497	10.6%
800-1,600	45,371	3.3%
1,600-3,200	13,403	1.0%
3,200+	232	0.0%

Distances could not be calculated for 0.4 percent of applications.

M. Ericson, NY Times

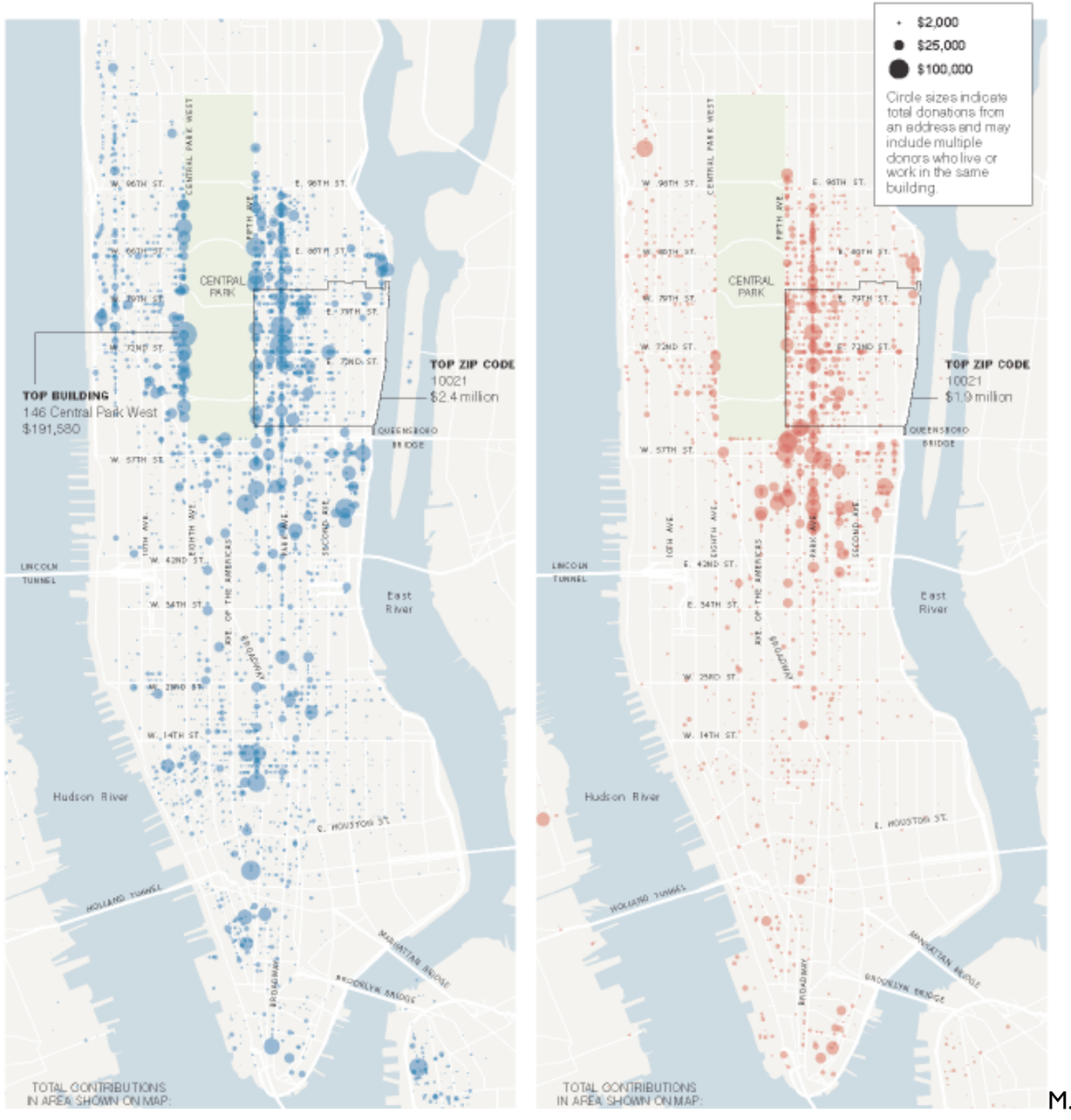
JOHN KERRY ← and the Democratic National Committee

Contributions to each candidate and his party's national committee

→ **GEORGE W. BUSH** and the Republican National Committee

Manhattan

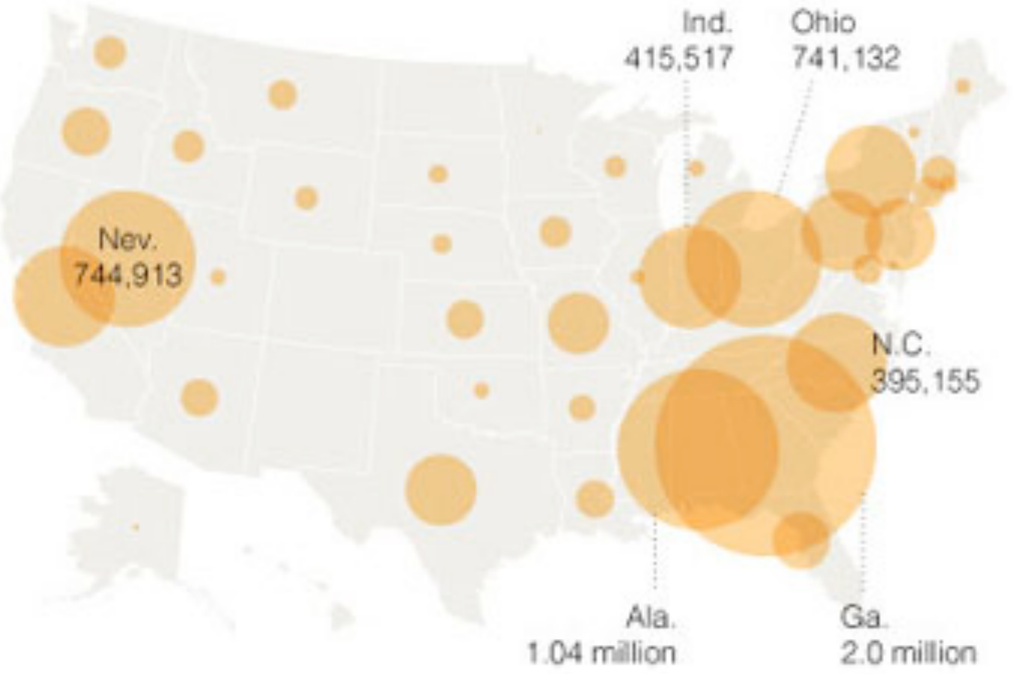
For both sides, the top ZIP code in the nation for contributions was 10021 on the Upper East Side. Mr. Kerry's appeal, however, was greater throughout much of the rest of Manhattan, bringing in more money than Mr. Bush and the R.N.C. in areas like the Upper West Side, Greenwich Village and SoHo.

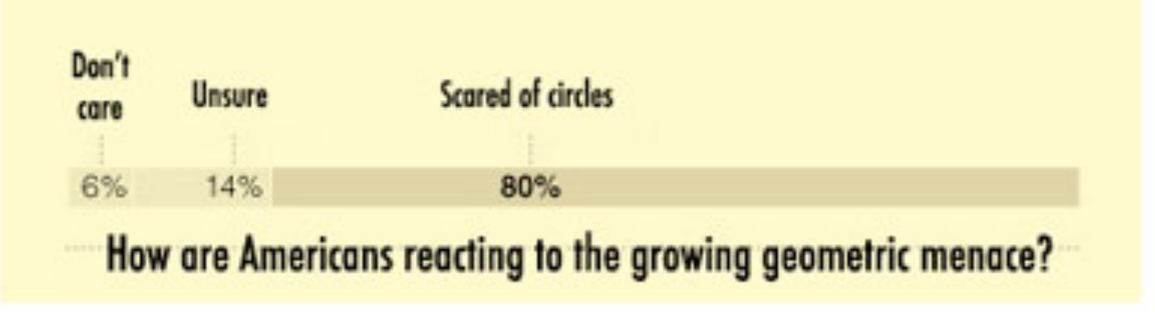


M. Ericson, NY Times

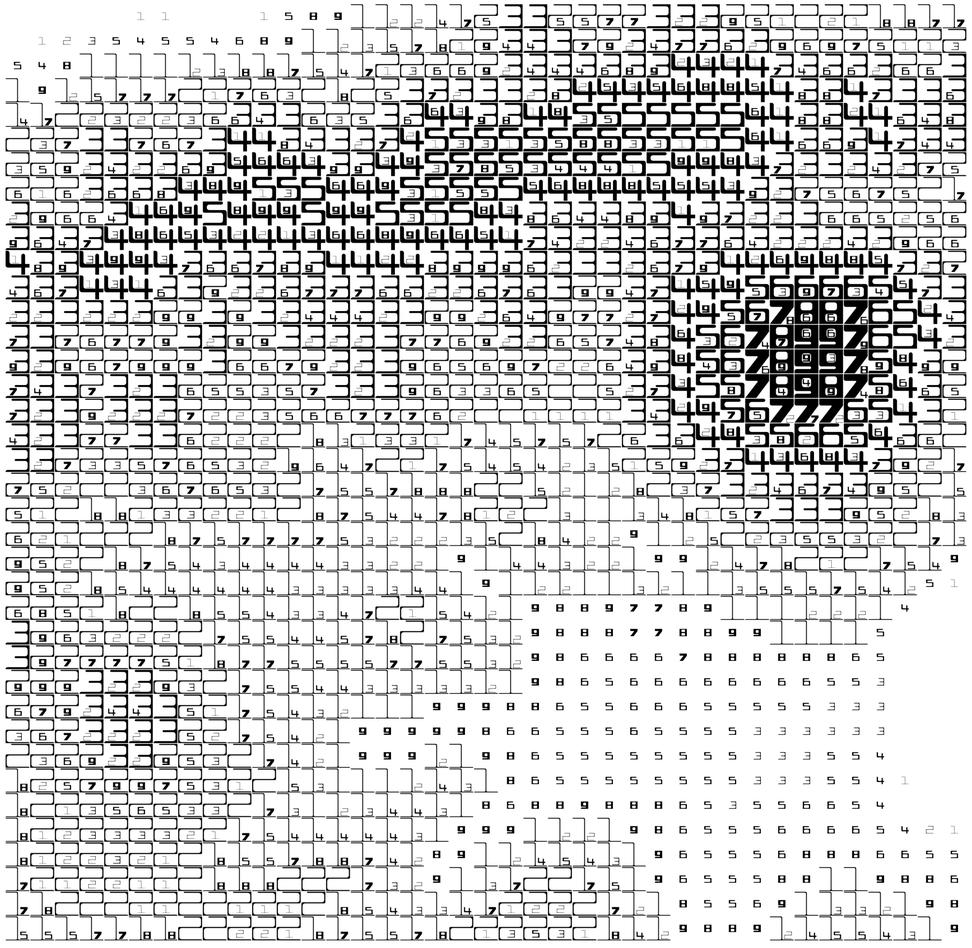
Killer circles threaten America

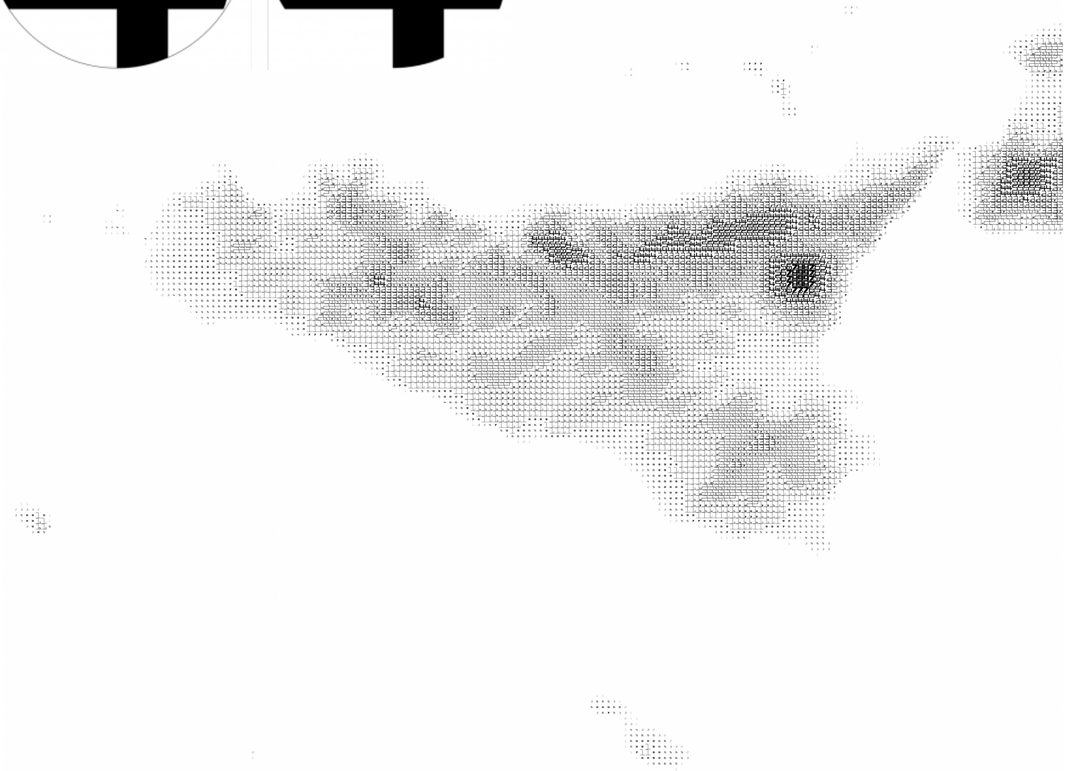
- No sides
- Area equal to πr^2
- Extremely round
- Often fatal
- North Dakota, New Mexico, Colorado remain circle-free



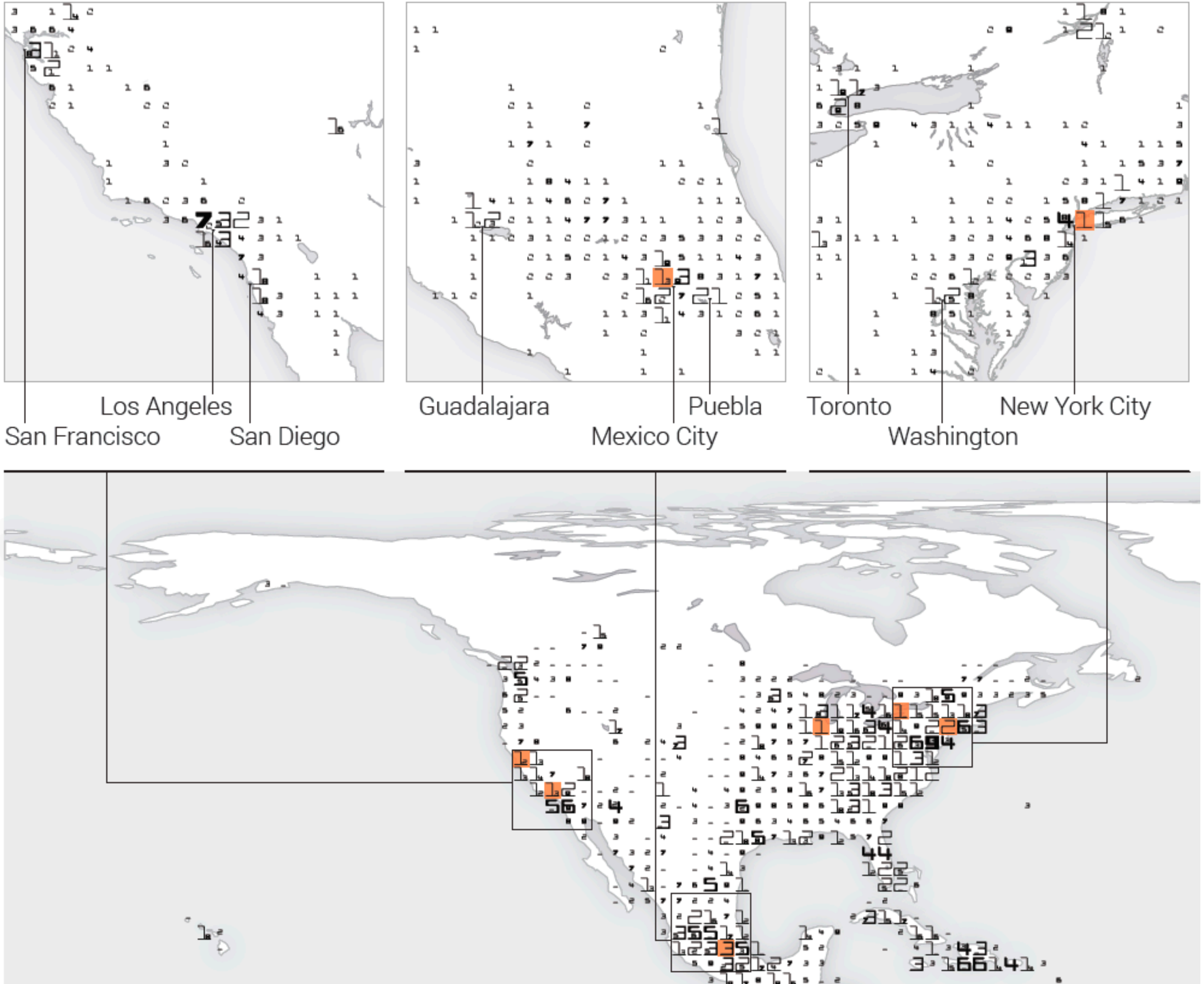


FatFonts





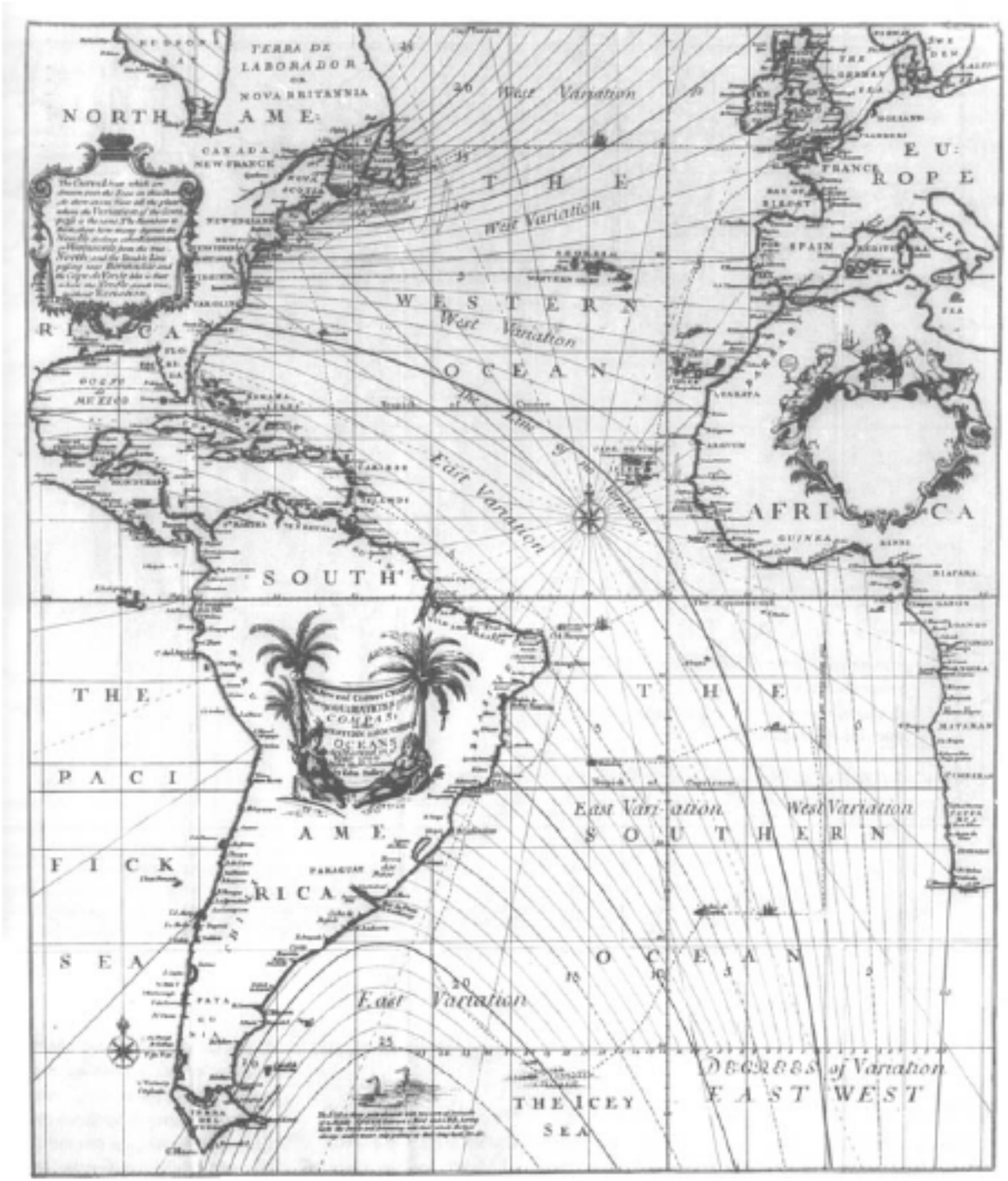
http://fatfonts.org/

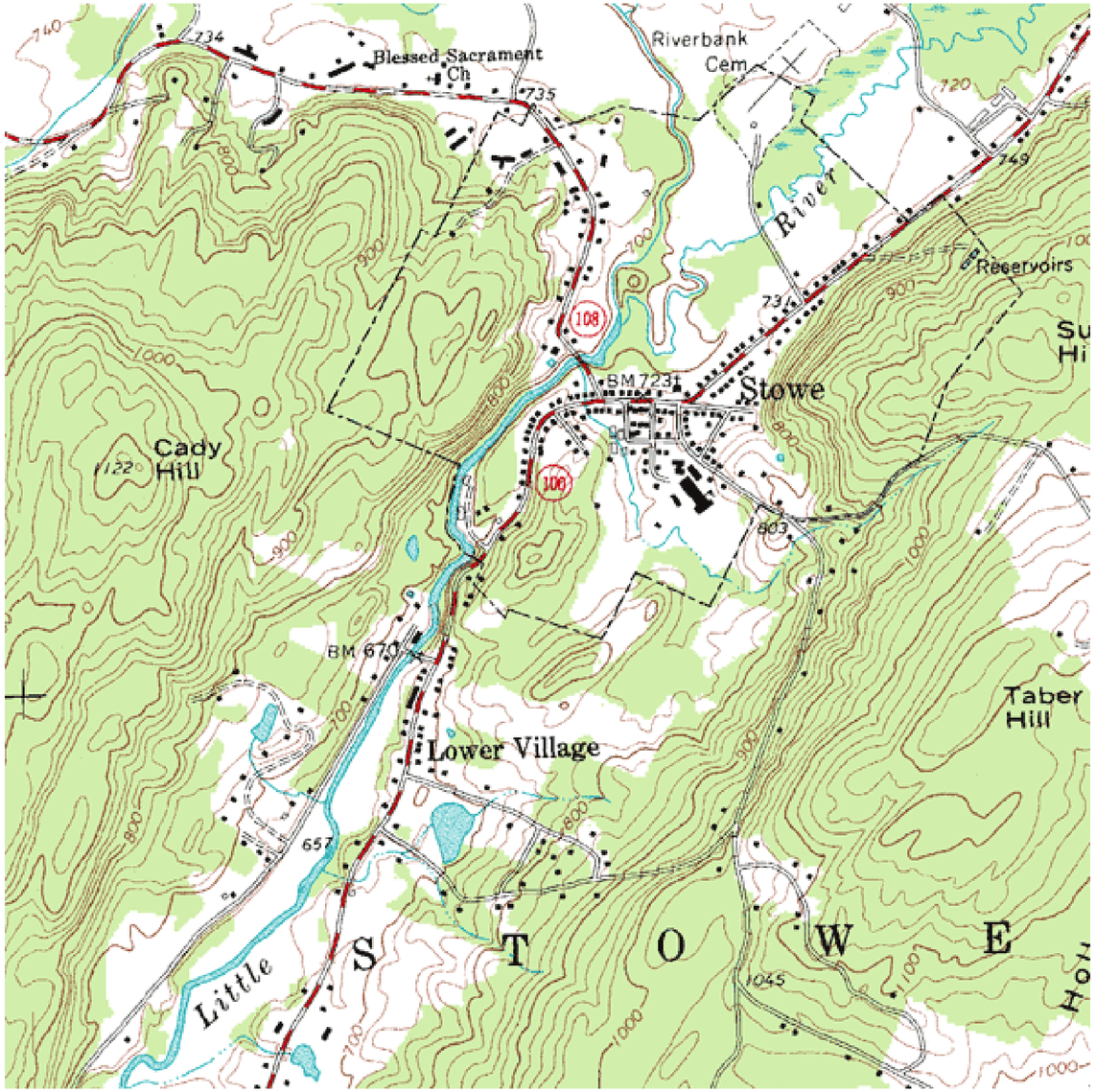

San Francisco
Los Angeles
San Diego
Guadalajara
Mexico City
Puebla
Toronto
Washington
New York City

Contour (Isopleth) Maps

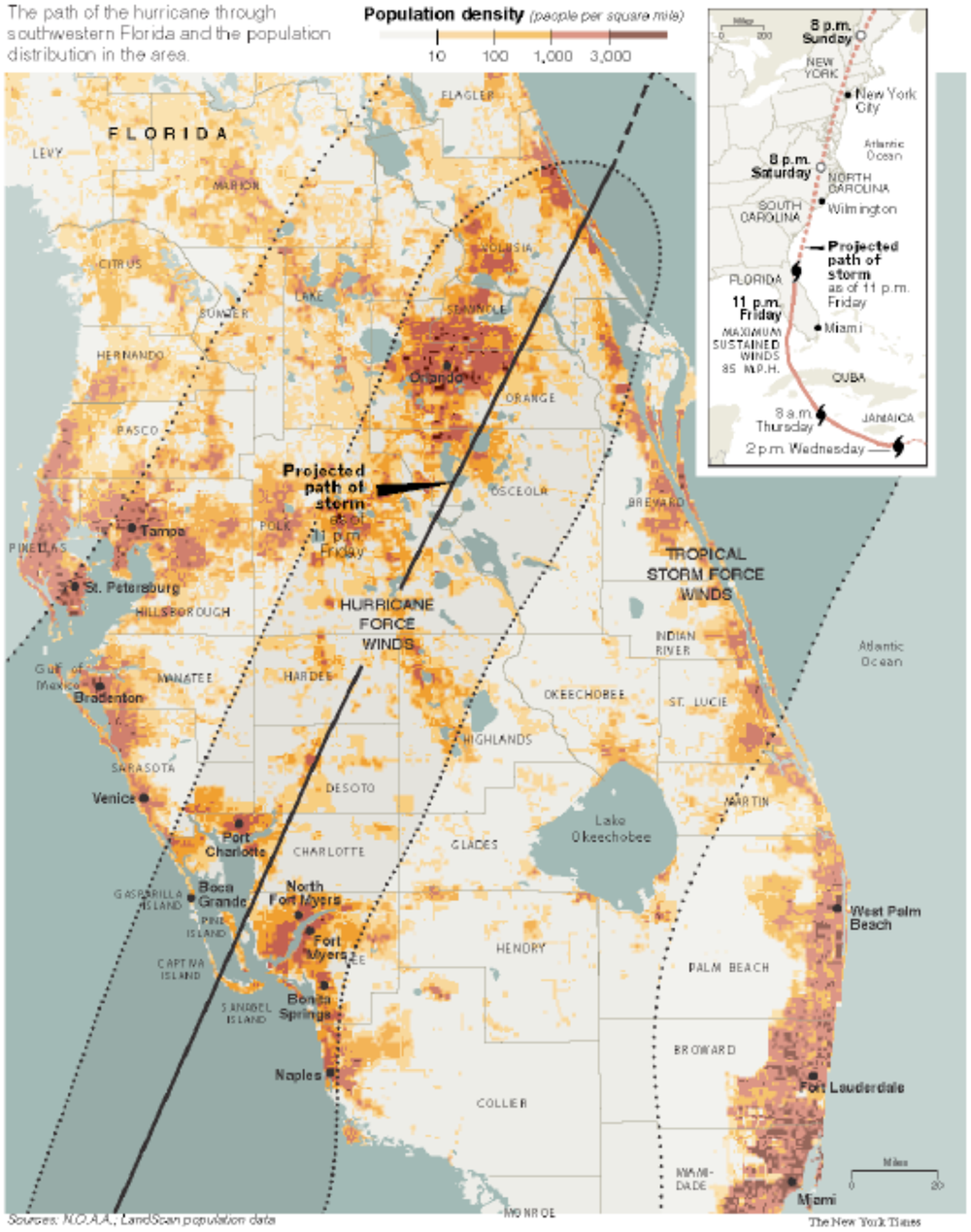
Early Contour Map

Halley’s lines of equal magnetic declination, 1701





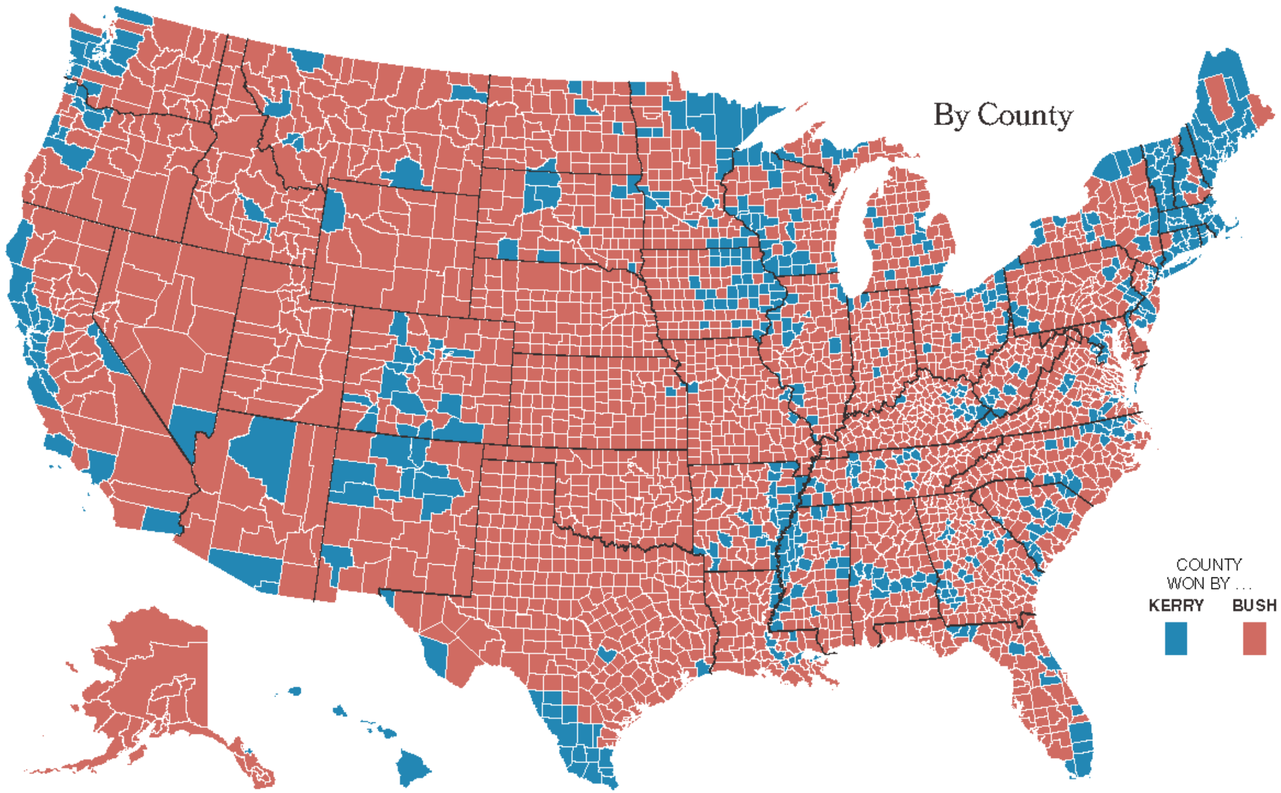
wikipedia.org

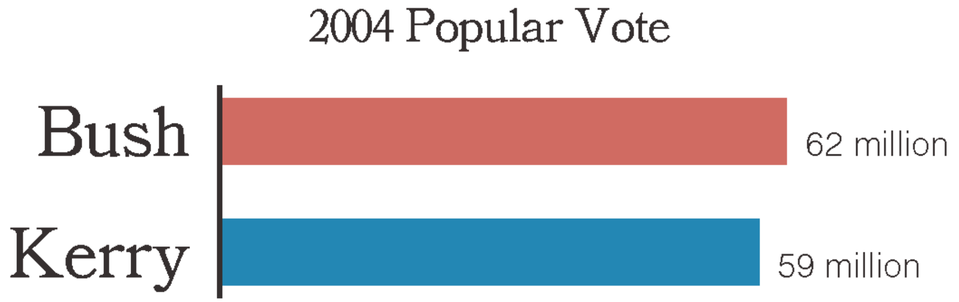


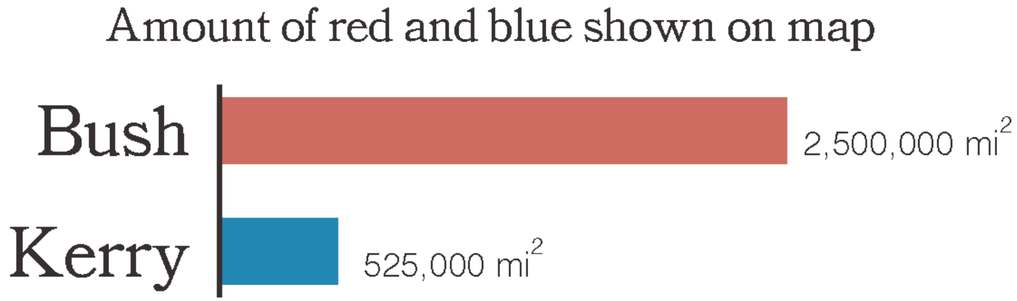
M. Ericson, NY Times

Cartograms

Again: Size vs Data effect





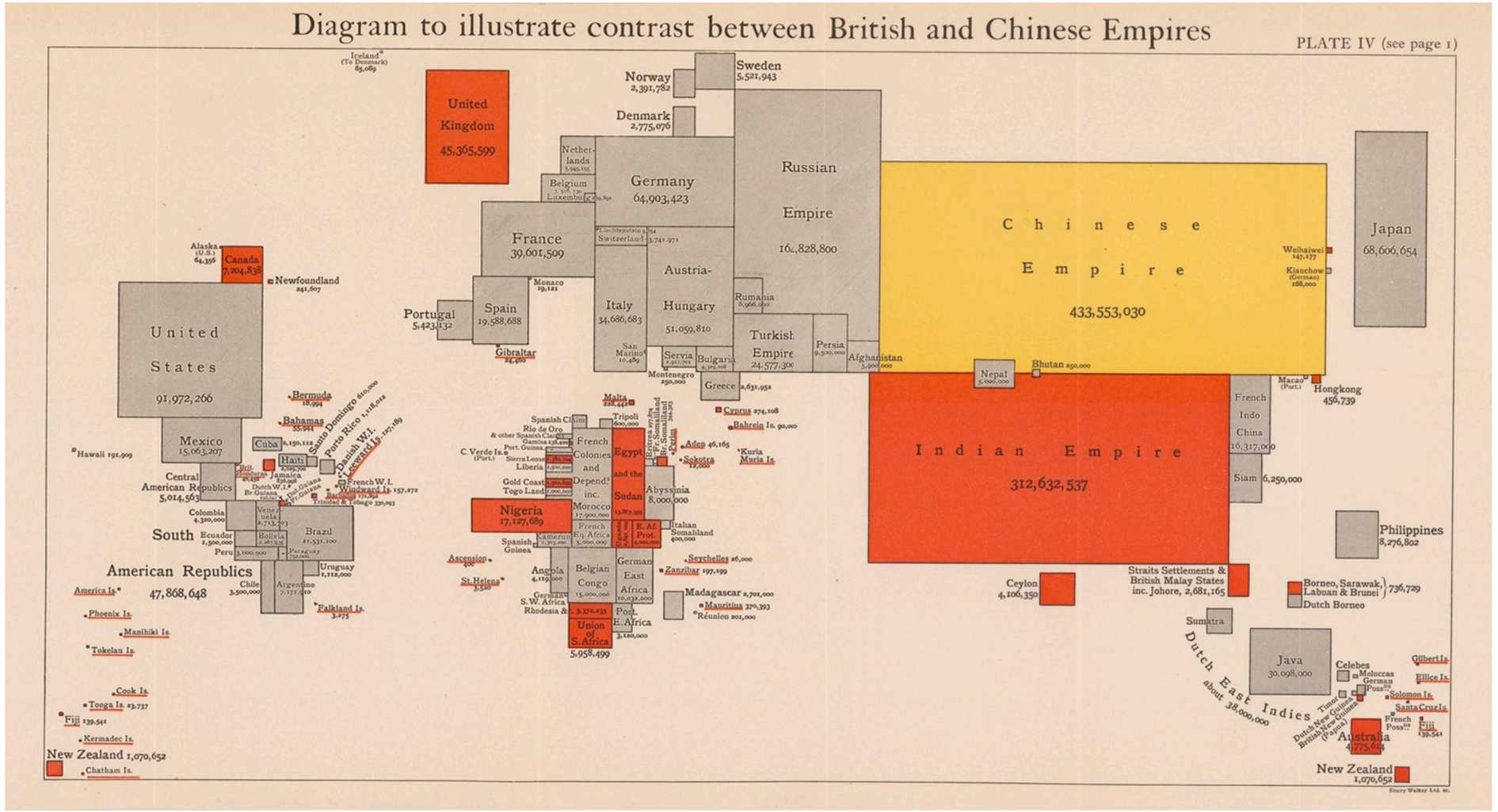


Matthew Ericson, NY Times

What if we just change the size on the map?

Compromise between geospatial accuracy and quality of data encoding.

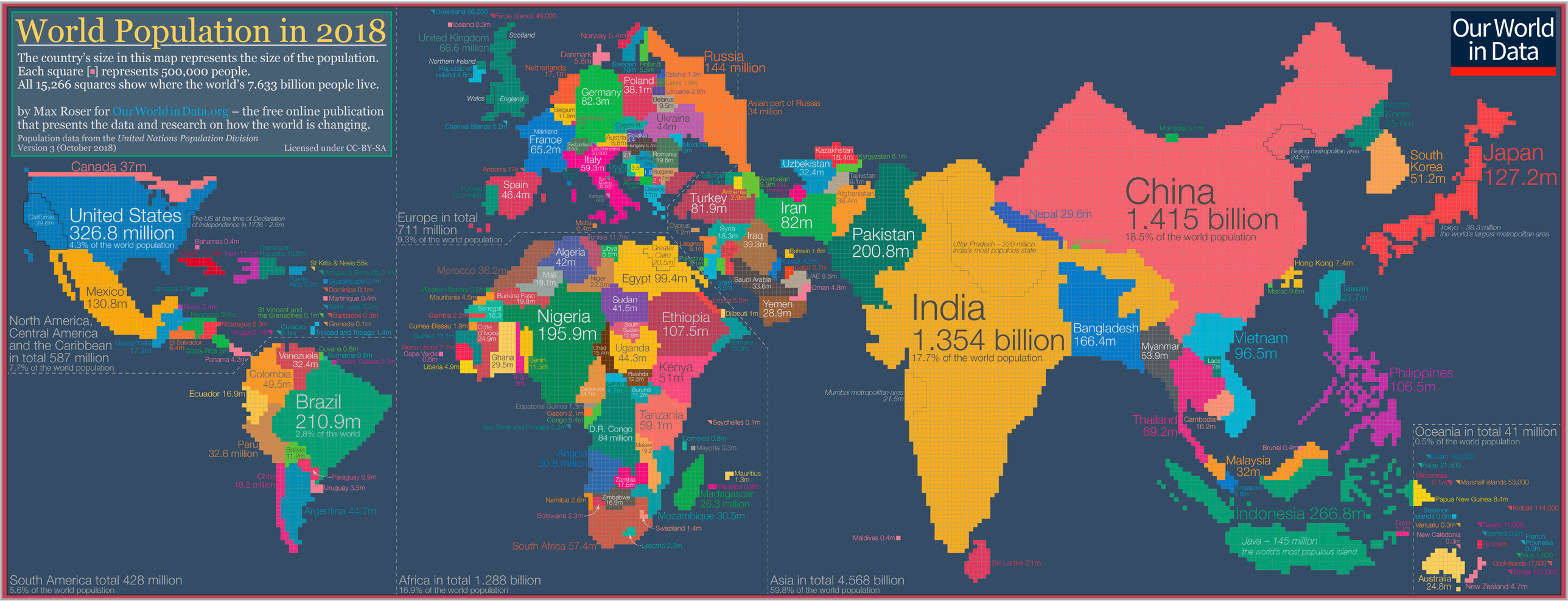
World Population in 1916



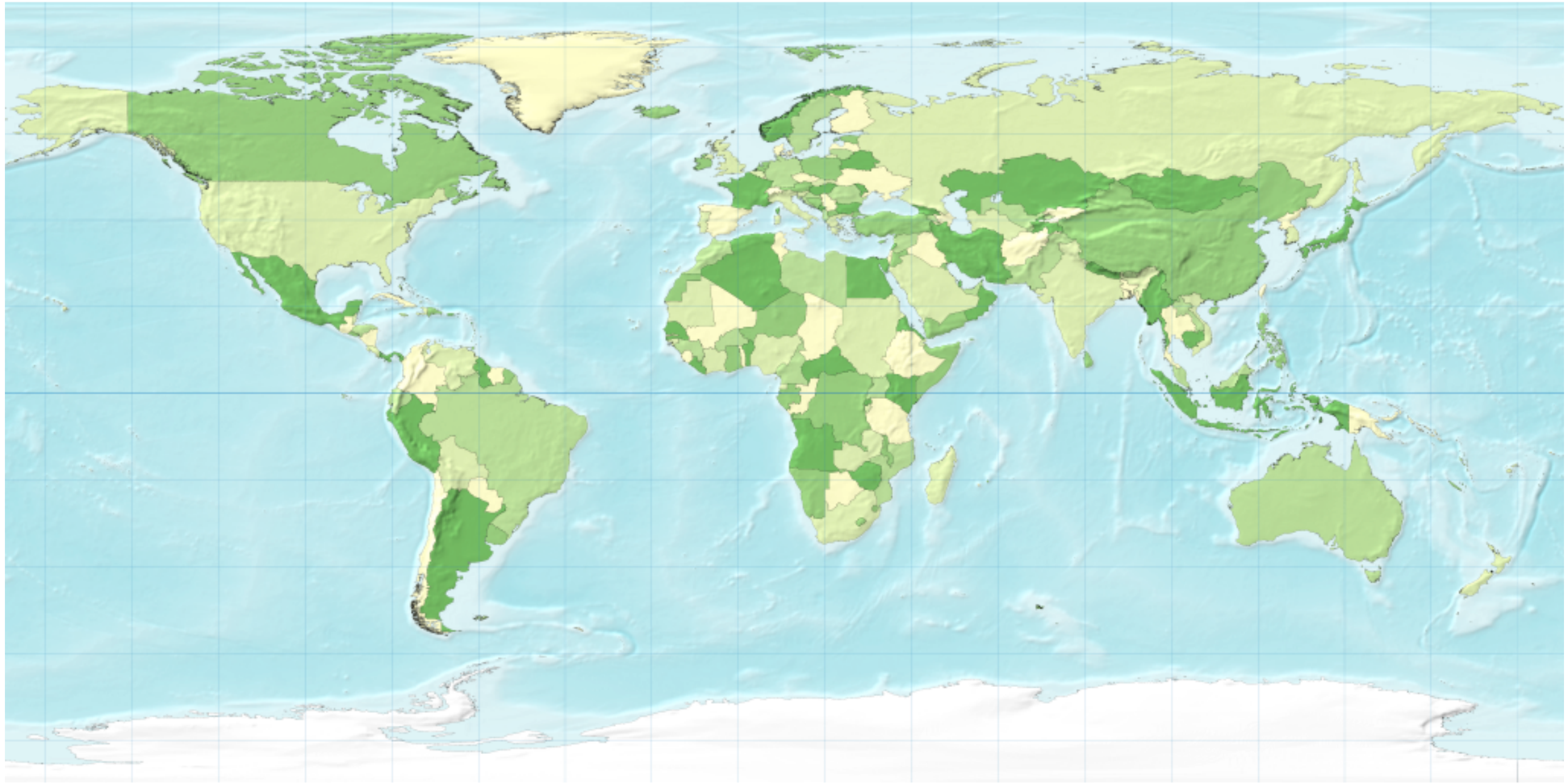
https://twitter.com/lisacrost/status/860507536797163522/photo/1

https://digital.library.cornell.edu/catalog/ss:3293861

World Population in 2018



The World

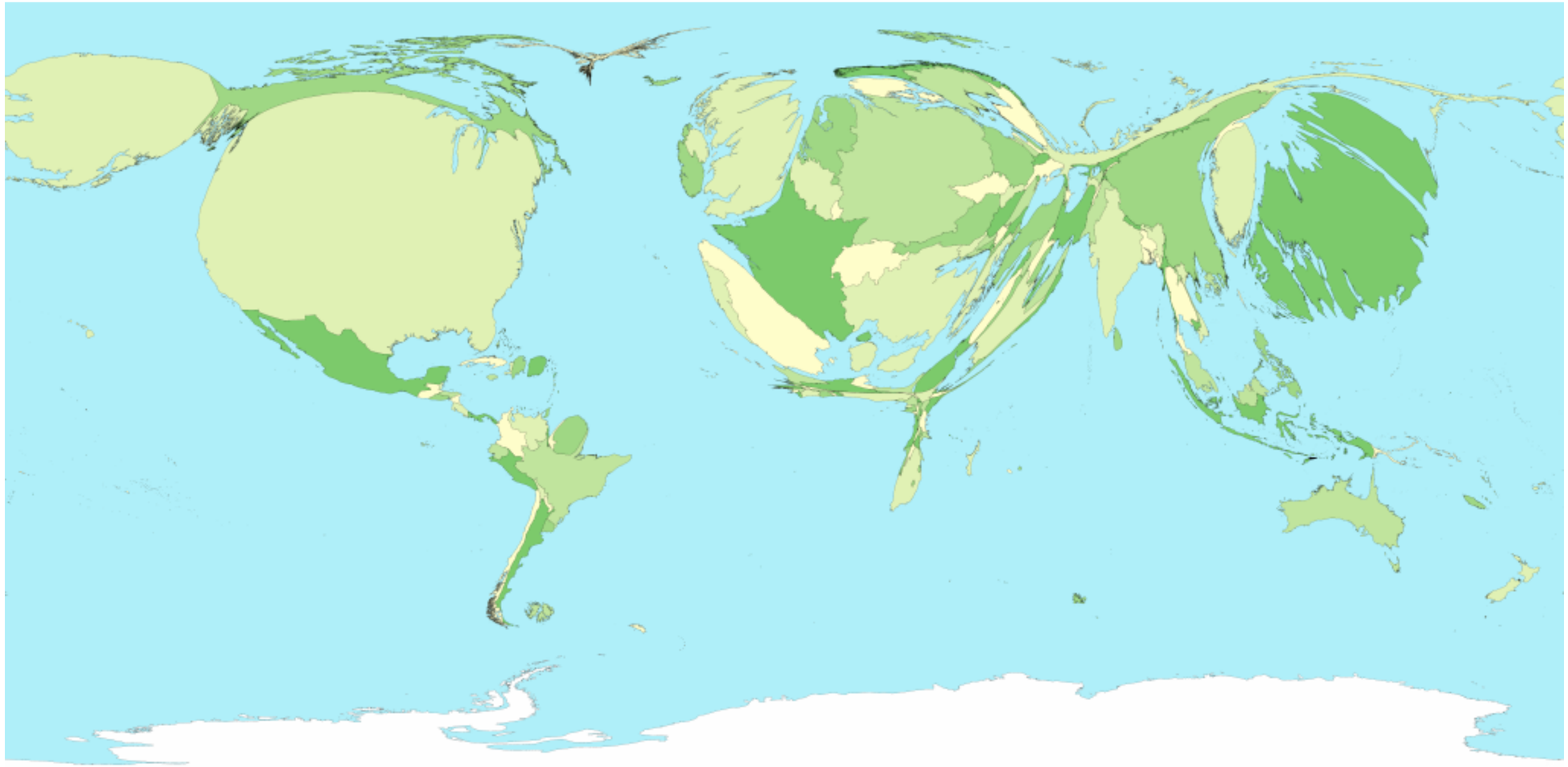


Mark Newman, Univ. Michigan

Population

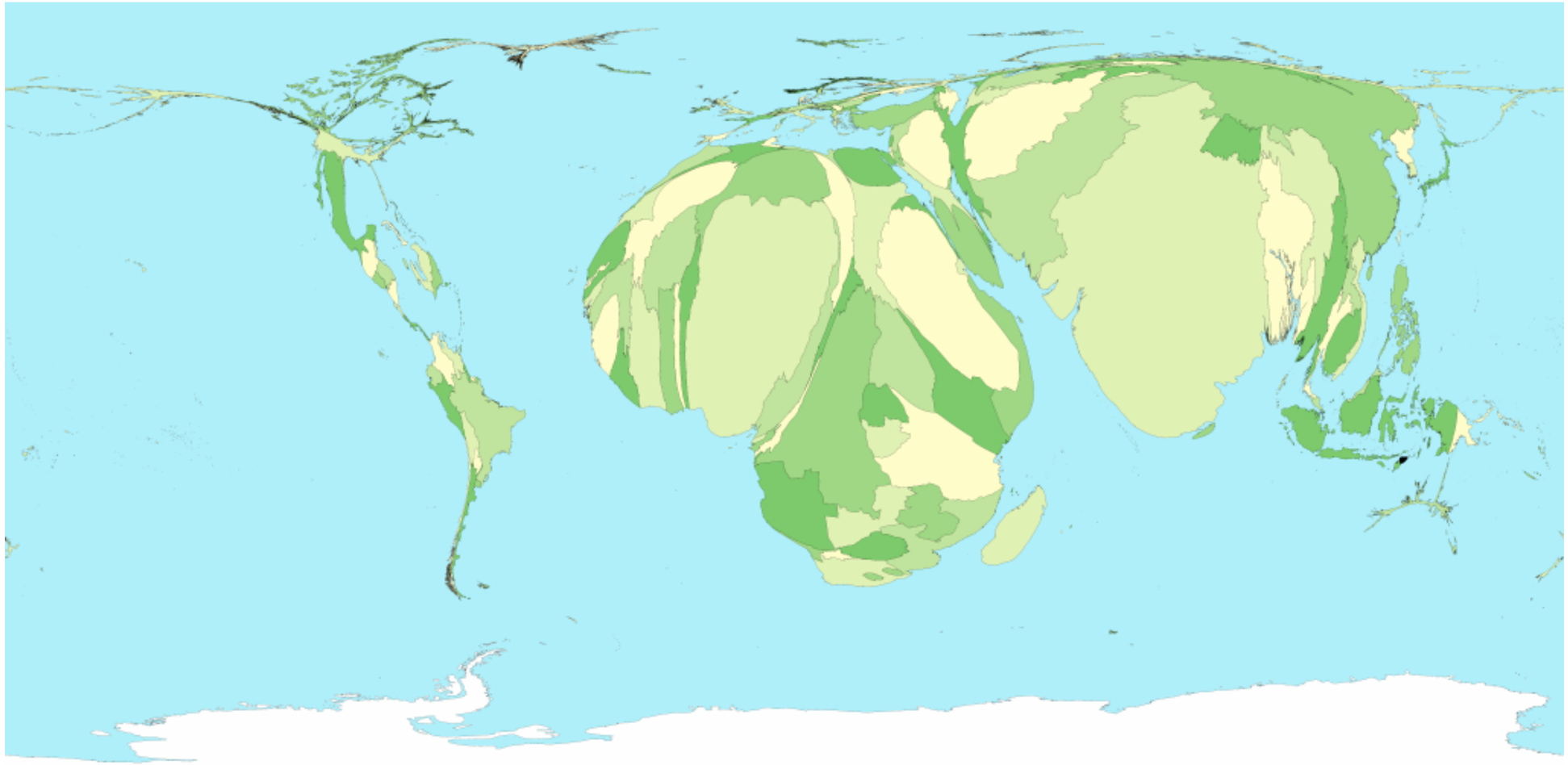
Mark Newman, Univ. Michigan

GDP



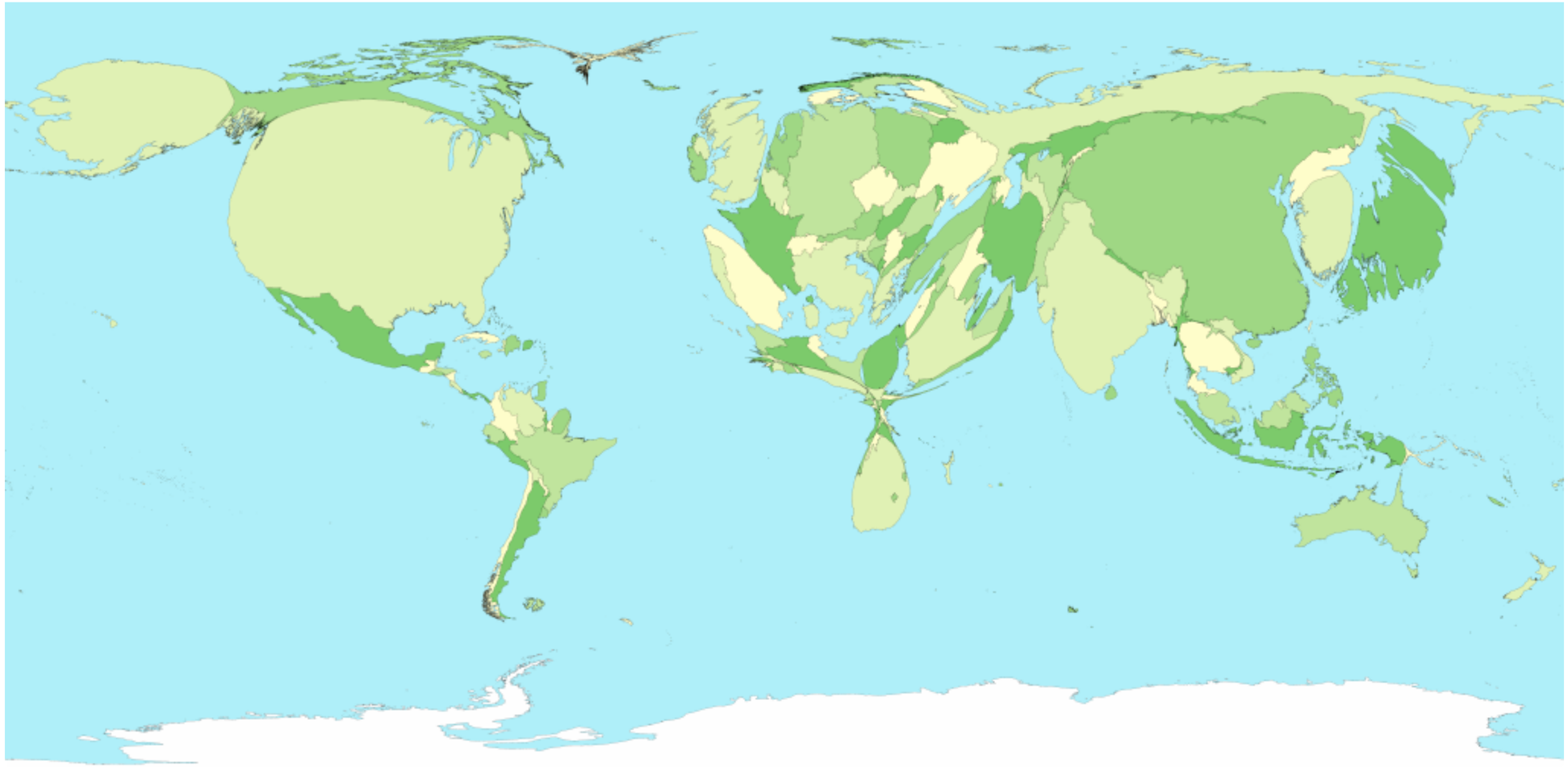
Mark Newman, Univ. Michigan

Child Mortality



Mark Newman, Univ. Michigan

Greenhouse Emissions



Mark Newman, Univ. Michigan

Kerry vs. Bush 2004

Michael Gastner,
Cosma Shalizi, and
Mark Newman

University of Michigan

Matthew Ericson, NY Times

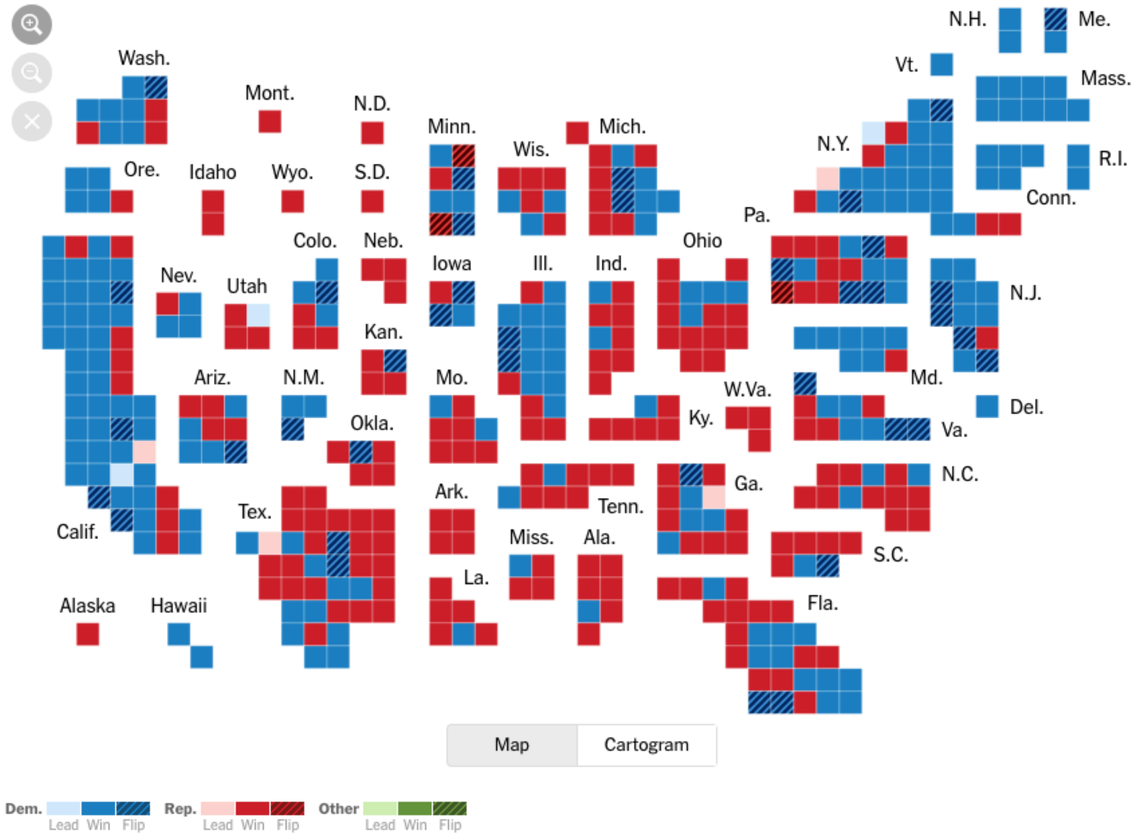
House Election Results: Democrats Take Control

230 Democrats — Gained 35 seats — 54,505,369 votes (51.8%)

7 undecided

198 Republicans — Lost 35 seats — 48,955,236 votes (46.5%)

218 FOR CONTROL



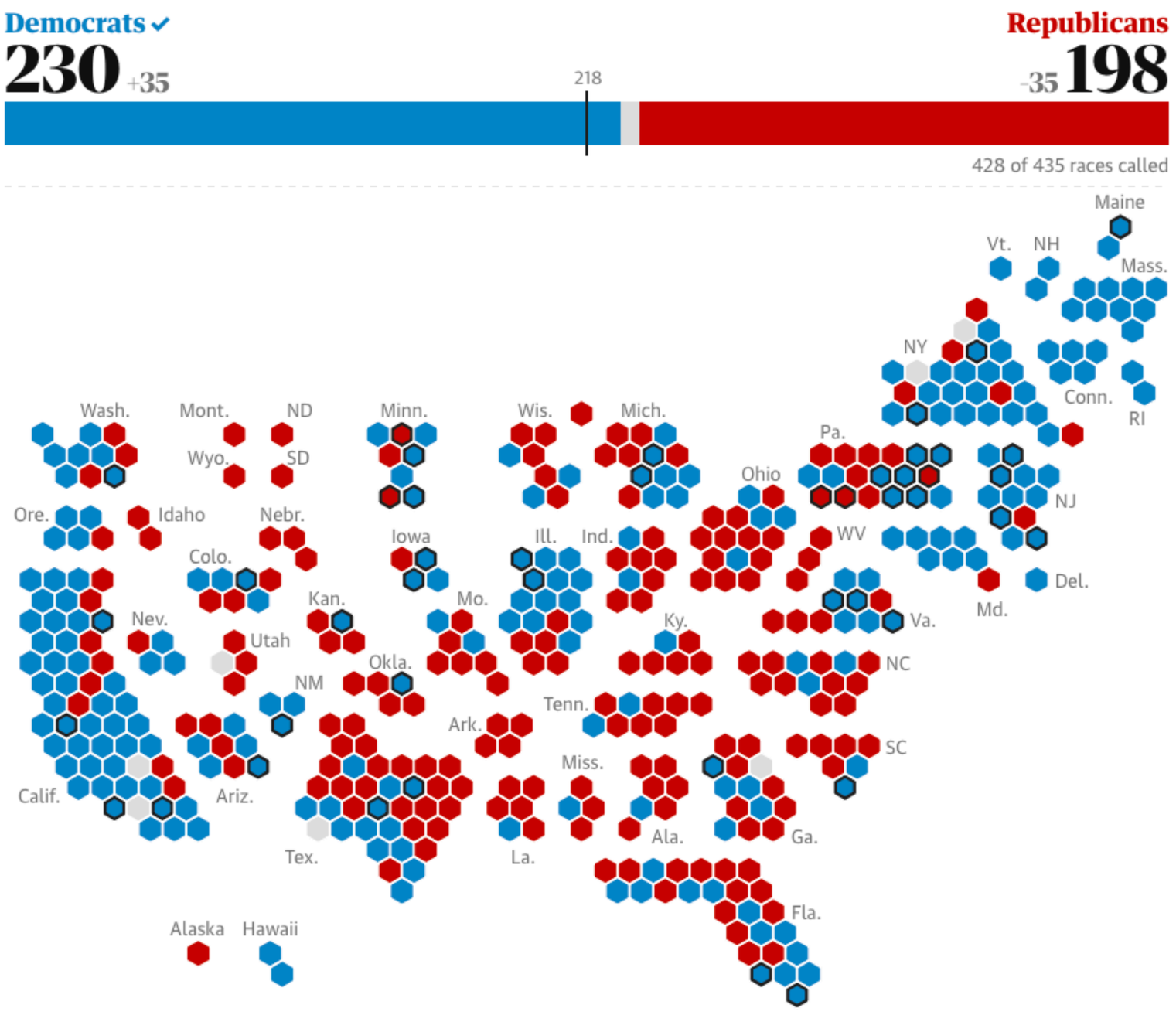
One-party rule in Washington is over, at least for the next two years. Democrats won the seats needed to take the House after capturing districts where President Trump is unpopular.

Key States to Watch Florida › New Jersey › New York › Pennsylvania › California ›

Key Races 80 Total

Dem. favored		Tossup		Rep. favored	
DISTRICT	MARGIN	DISTRICT	MARGIN	DISTRICT	MARGIN
Ariz. 2	✓	Calif. 10	✓	N.Y. 11	✓
Calif. 49	✓	Calif. 25	✓	S.C. 1	✓
Colo. 6	✓	Calif. 48	✓	Minn. 8	✓
Fla. 27	✓	Fla. 26	✓	Pa. 14	✓
Iowa 1	✓	Ga. 6	✓	Alaska	✓
Ill. 6	✓	Iowa 3	✓	Calif. 50	✓
Kan. 3	✓	Ill. 14	✓	Fla. 6	✓
Mich. 11	✓	Me. 2	✓	Fla. 16	✓
Minn. 2	✓	Mich. 8	✓	Fla. 18	✓
Minn. 3	✓	N.J. 3	✓	Fla. 25	✓
N.J. 2	✓	N.J. 7	✓	Iowa 4	✓
N.J. 11	✓	N.M. 2	✓	Ill. 12	✓
Pa. 6	✓	N.Y. 19	✓	Ill. 13	✓
Pa. 7	✓	Tex. 7	✓	Mich. 6	✓
Pa. 17	✓	Tex. 32	✓	Mo. 2	✓
Va. 10	✓	Va. 2	✓	Mont.	✓
Wash. 8	✓	Va. 7	✓	N.C. 2	✓
Ariz. 1	✓	Calif. 45	D+1.6	Neb. 2	✓
Nev. 3	✓	N.Y. 22	D+0.6	N.Y. 24	✓
Nev. 4	✓	Utah 4	D+0.4	Ohio 1	✓
		Minn. 1	✓	Pa. 16	✓
		Fla. 15	✓	Tex. 22	✓
		Kan. 2	✓	Va. 5	✓
		Ky. 6	✓	Wash. 3	✓
		N.C. 9	✓	Wash. 5	✓
		N.C. 13	✓	Wis. 1	✓
		Ohio 12	✓	W.Va. 3	✓
		Pa. 1	✓	Ga. 7	R+0.4
		Pa. 10	✓	N.Y. 27	R+1.1
		Calif. 39	R+0.0	Tex. 23	R+0.5

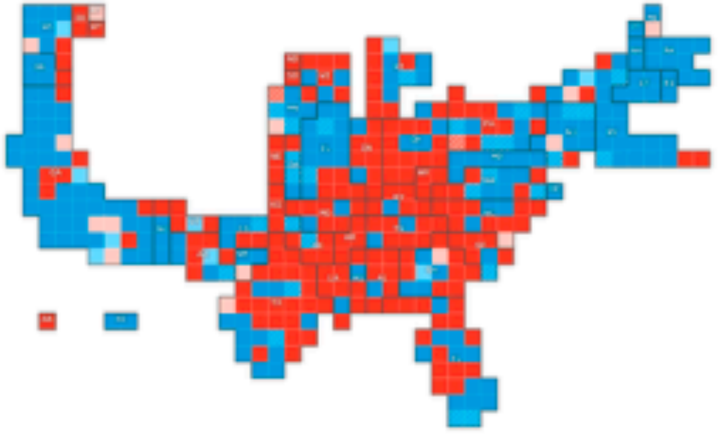
NYTimes


Democrats ✓
230 +35
218
Republicans
-35 198
428 of 435 races called
Maine
Vt.
NH
Mass.
NY
Conn.
RI
Wash.
Mont.
ND
Minn.
Wis.
Mich.
Pa.
Ohio
Wyo.
SD
NJ
Ore.
Idaho
Nebr.
Iowa
Ill.
Ind.
WV
Colo.
Del.
Kan.
Mo.
Md.
Nev.
Utah
Ky.
Va.
Okla.
NC
NM
Tenn.
Ark.
SC
Miss.
Calif.
Ariz.
Ala.
Ga.
Tex.
La.
Fla.
Alaska
Hawaii

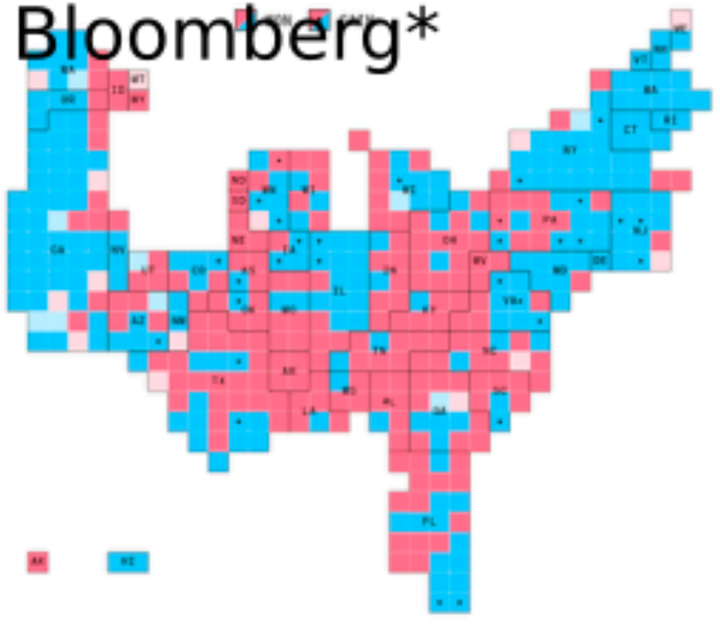
Guardian

The Guardian

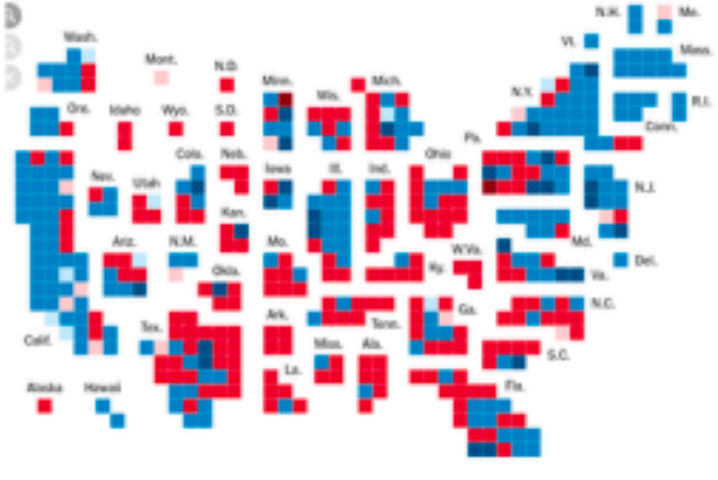
Axios*



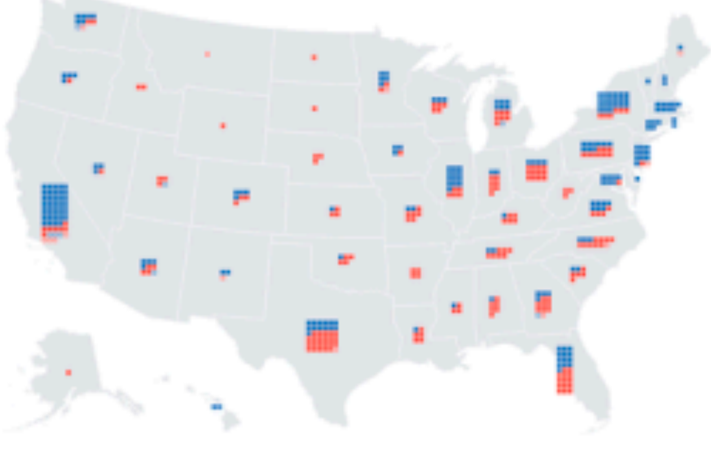
Bloomberg*



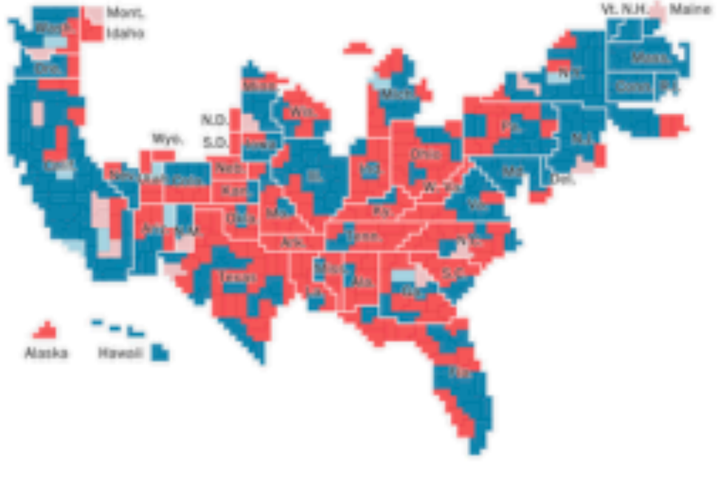
New York Times*



Politico



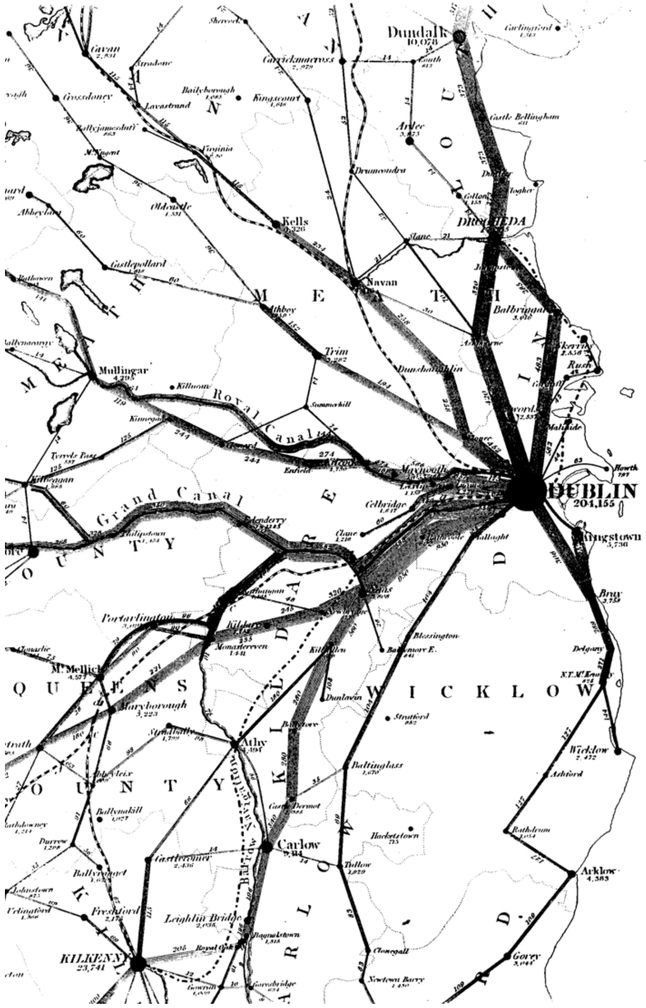
Washington Post*



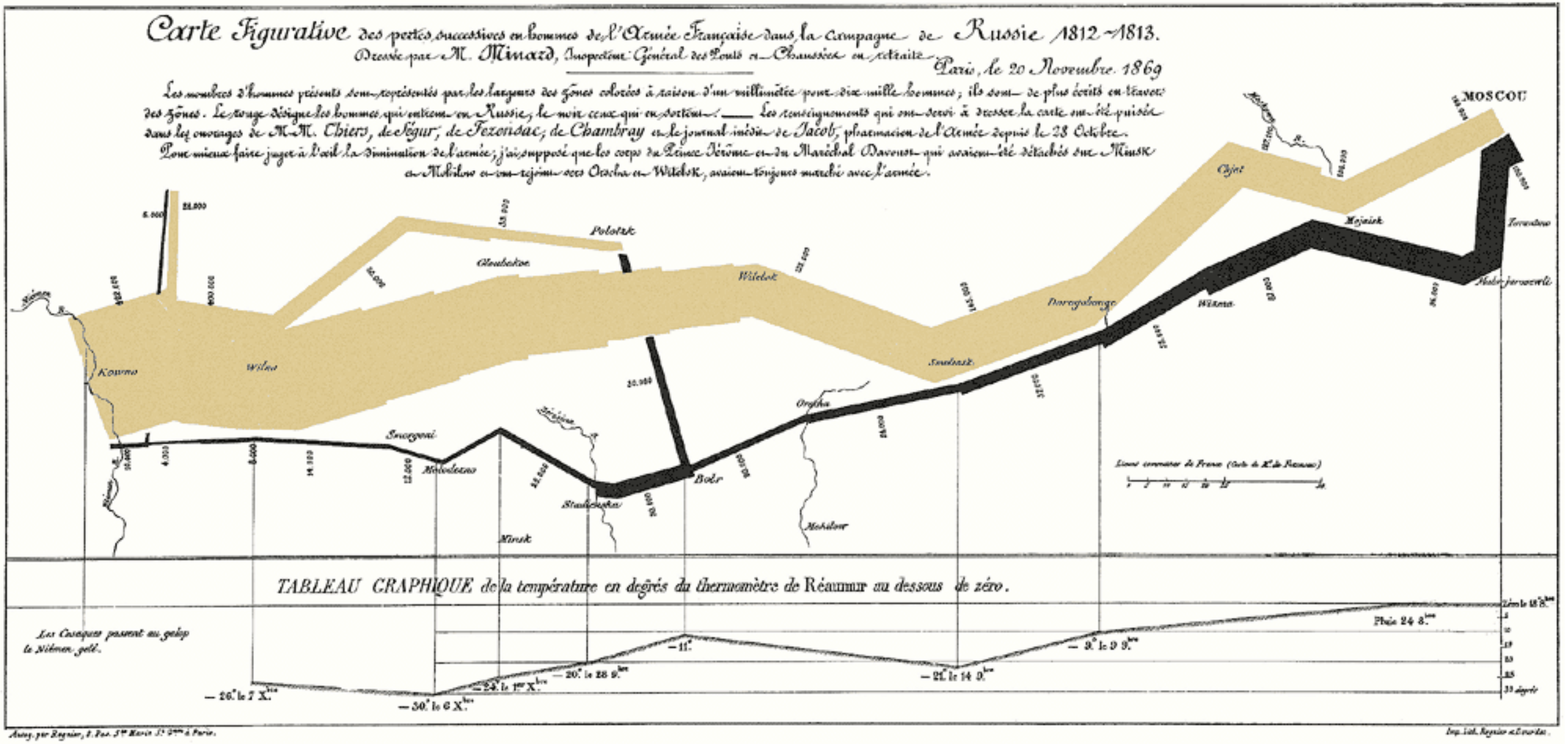
https://twitter.com/niko_tinius/status/1060185135918866433

Flow Maps

Early Flow Map



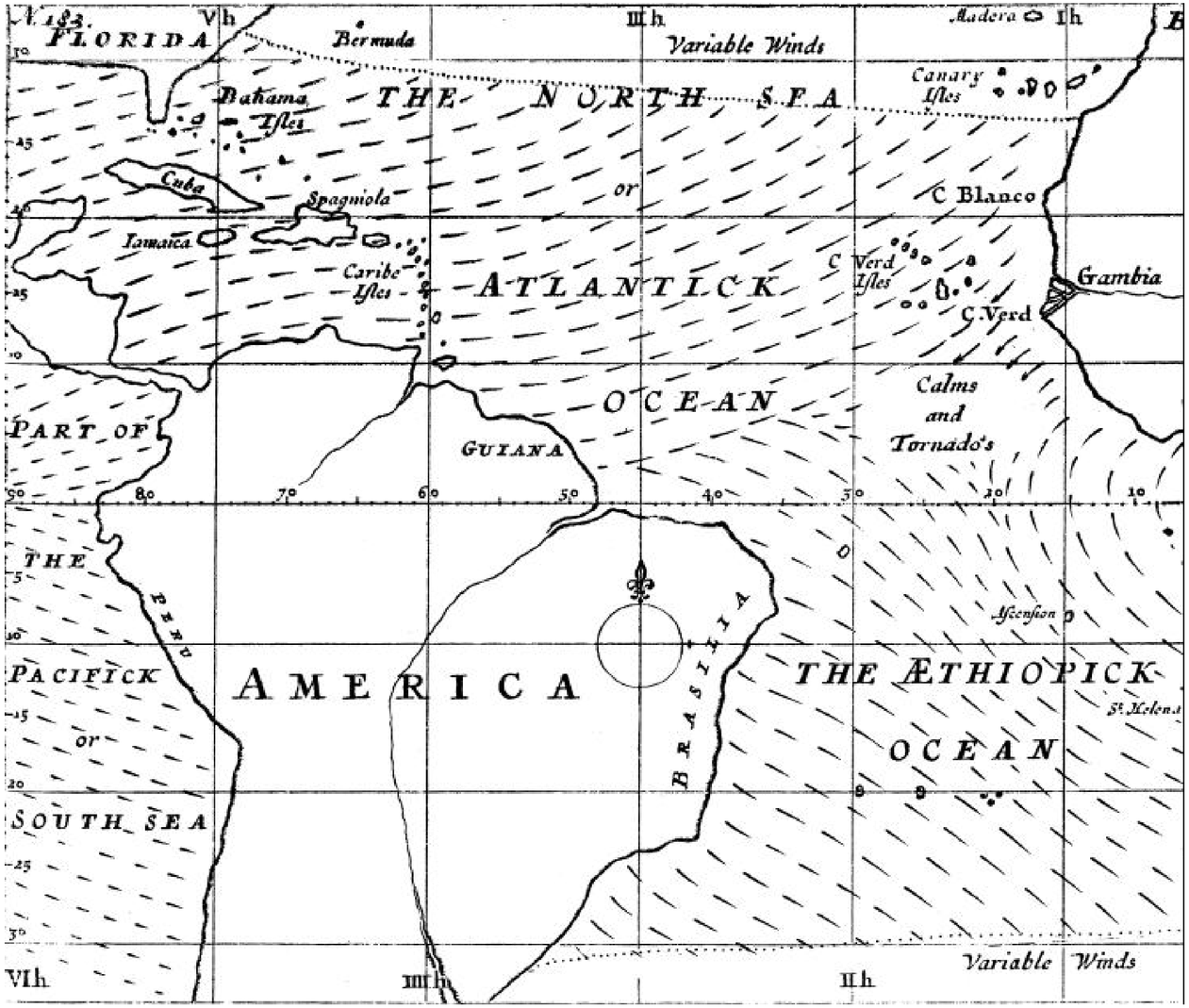
Transportation of Passengers
in Ireland
Henry Drury Harness, 1837



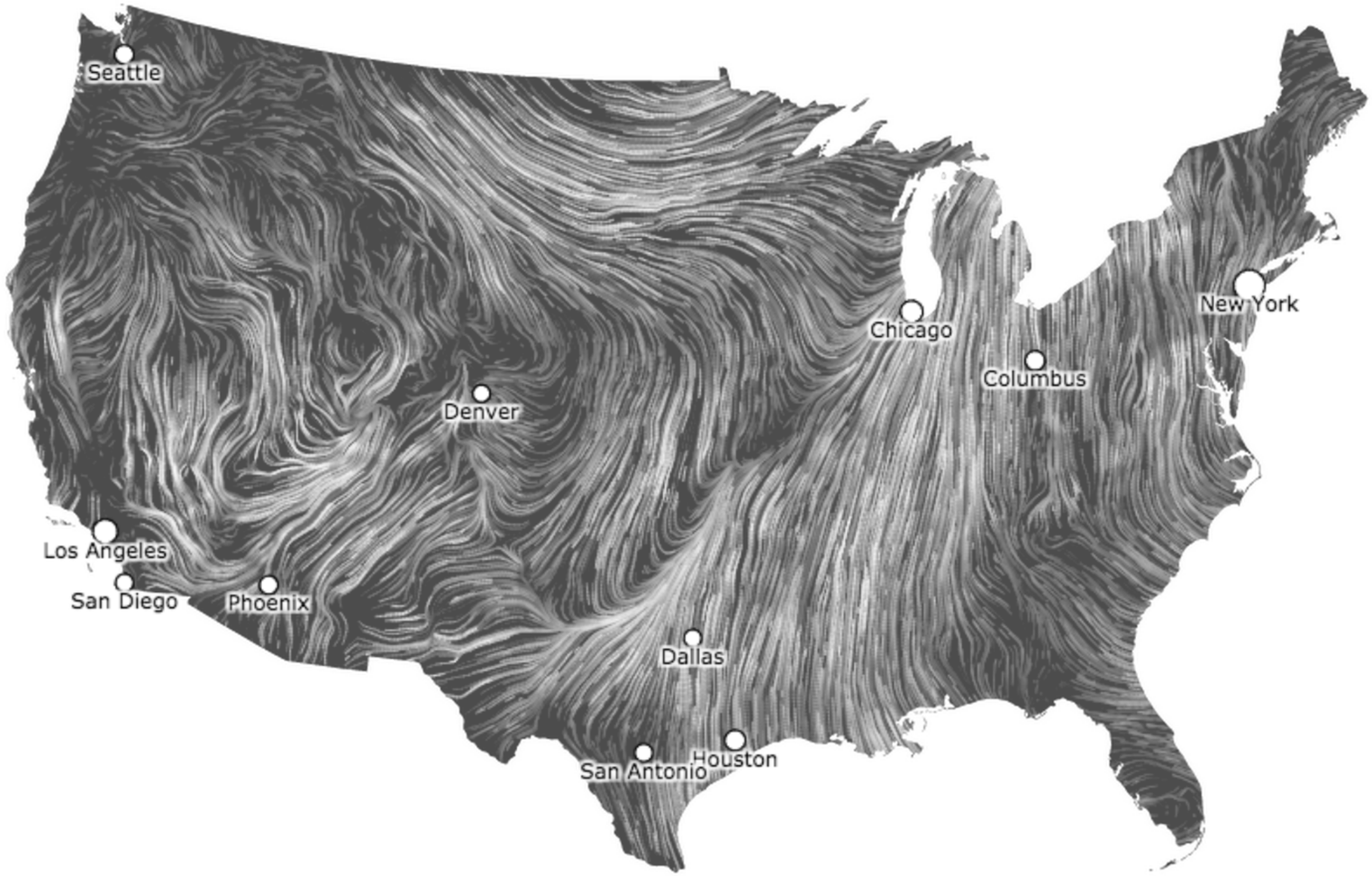
C. Minard, 1869

Early Weather Map

Halley's wind map, 1686

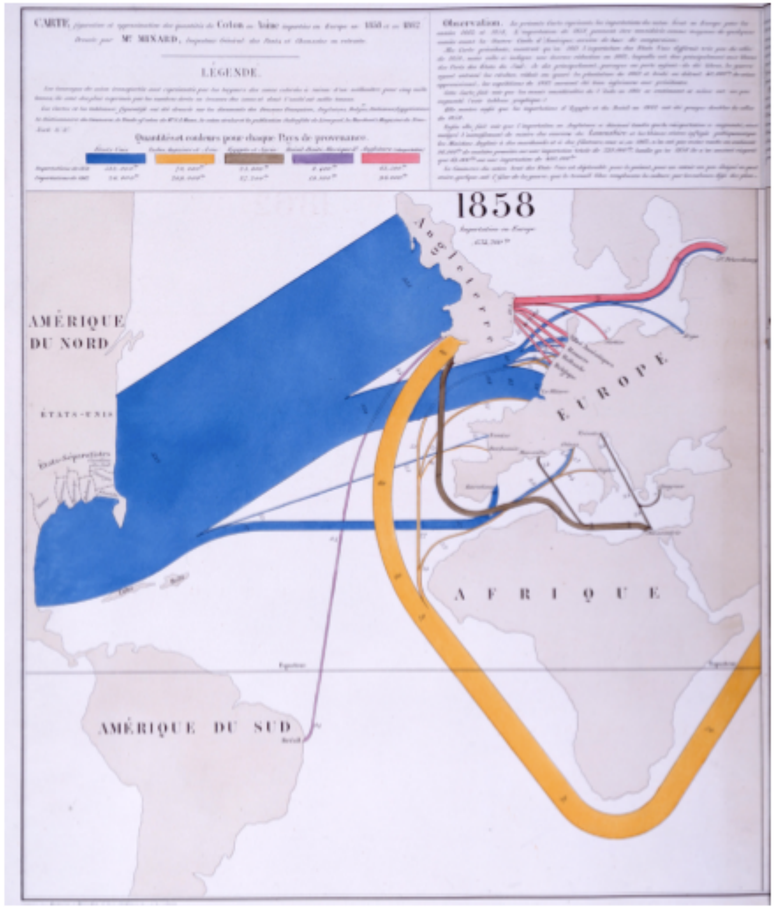


Wind Map

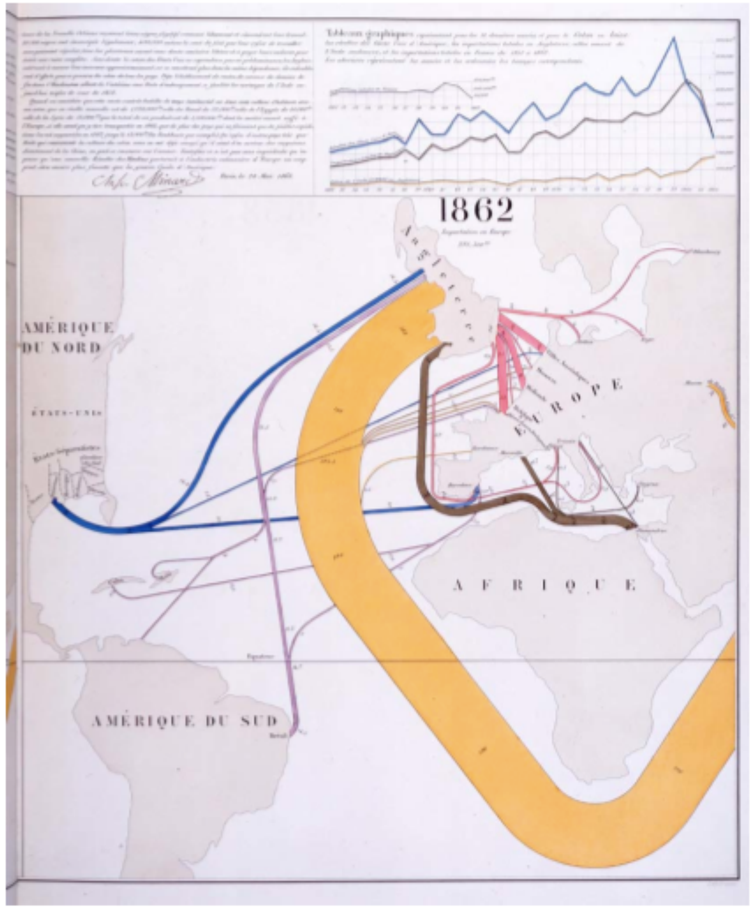

Seattle
Chicago
New York
Columbus
Denver
Los Angeles
San Diego
Phoenix
Dallas
San Antonio
Houston

Effect of US Civil War on Cotton Trade

Before



After

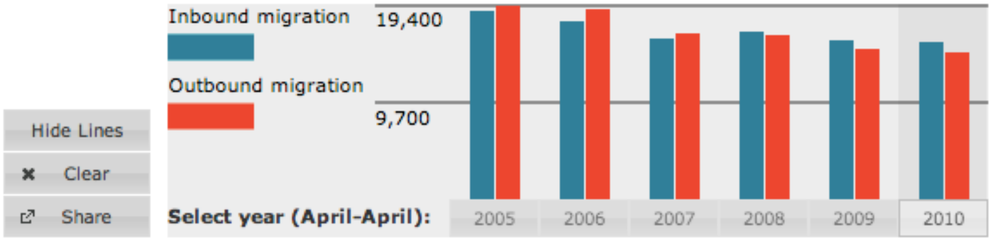


Milestones Project

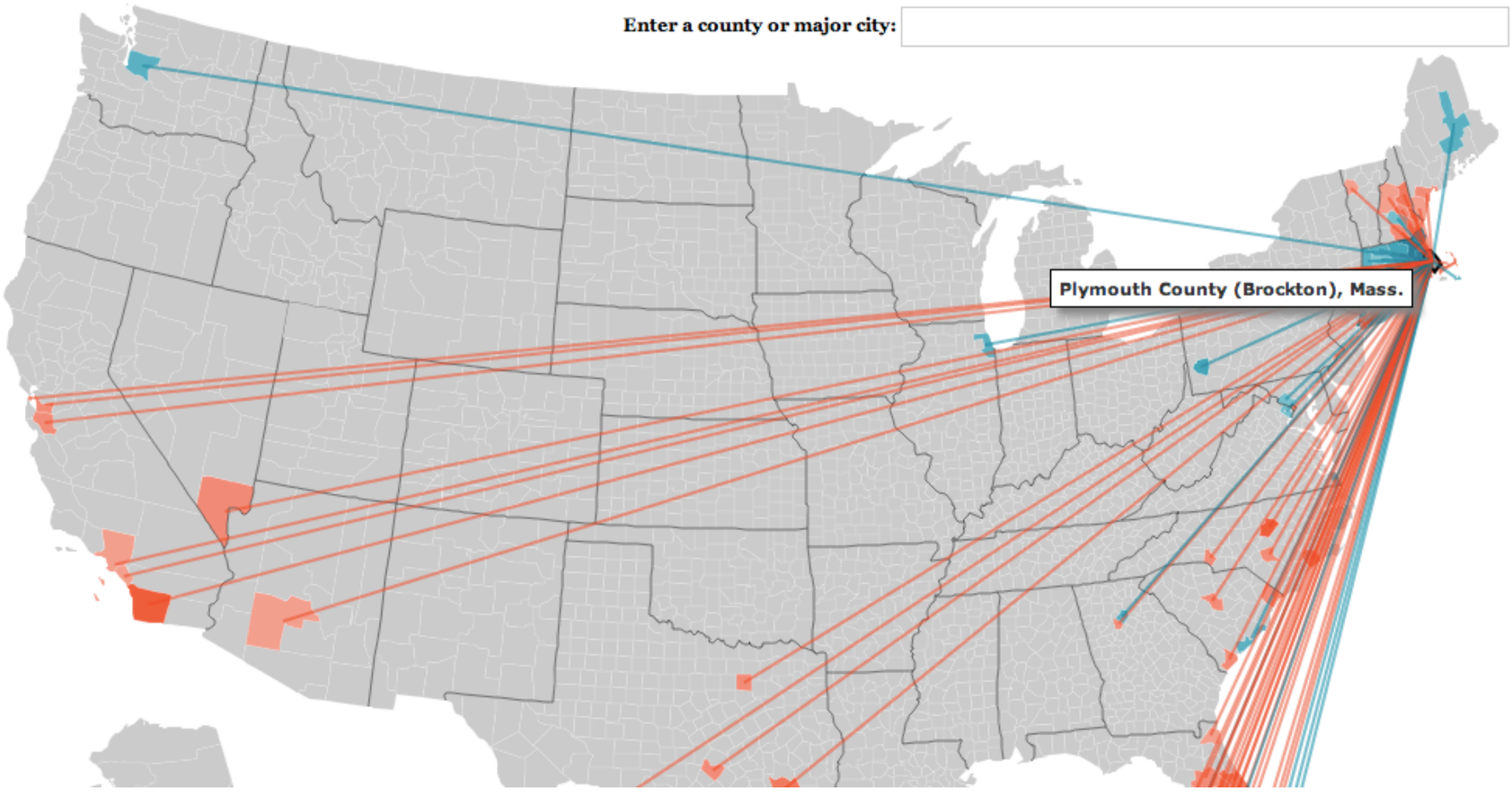
11.5k Share
1.7k Tweet
440 Share
4.8k Submit
385 +1
791 reddit

Plymouth County (Brockton), Mass.

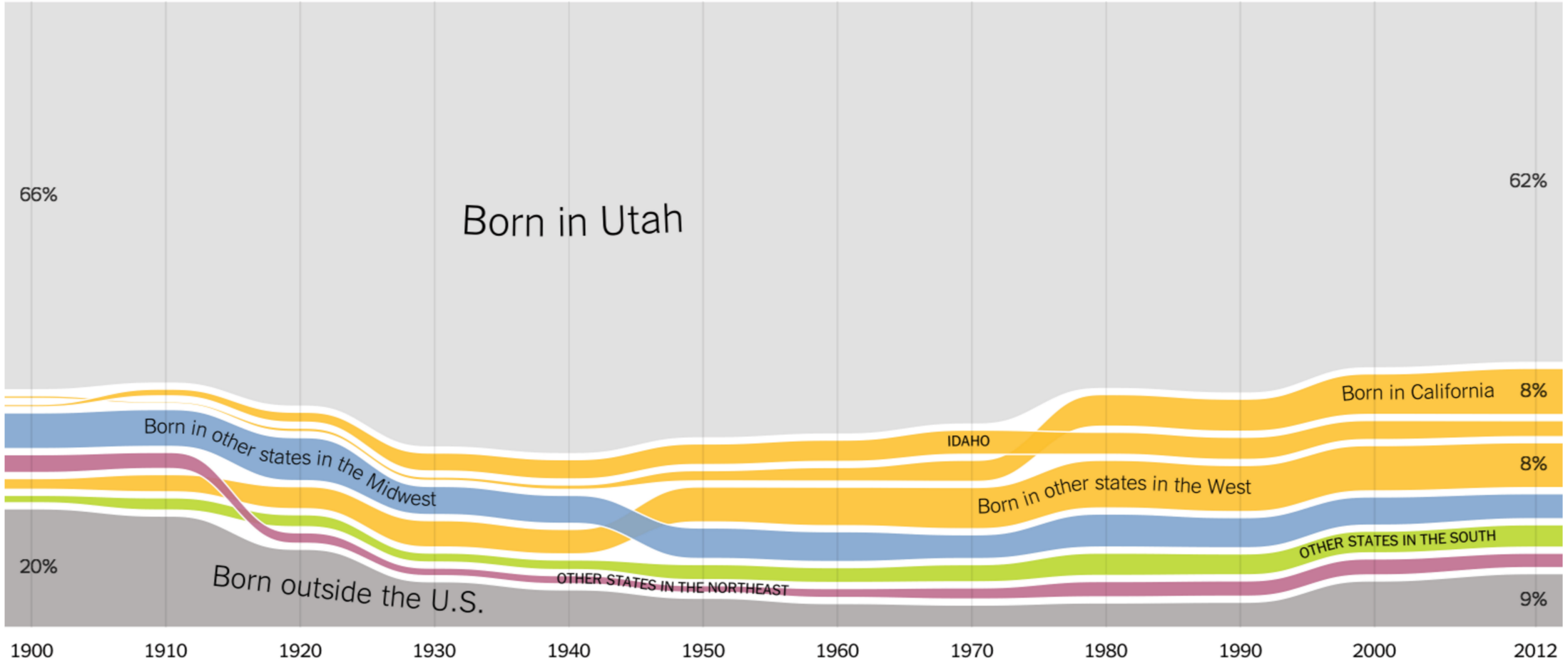
Population (2010): 494,919
Population (2005): 486,292
Inbound income per cap. (2010): $32,500
Outbound income per cap. (2010): $29,300
Non-migrant income per cap. (2010): $33,000



Enter a county or major city:

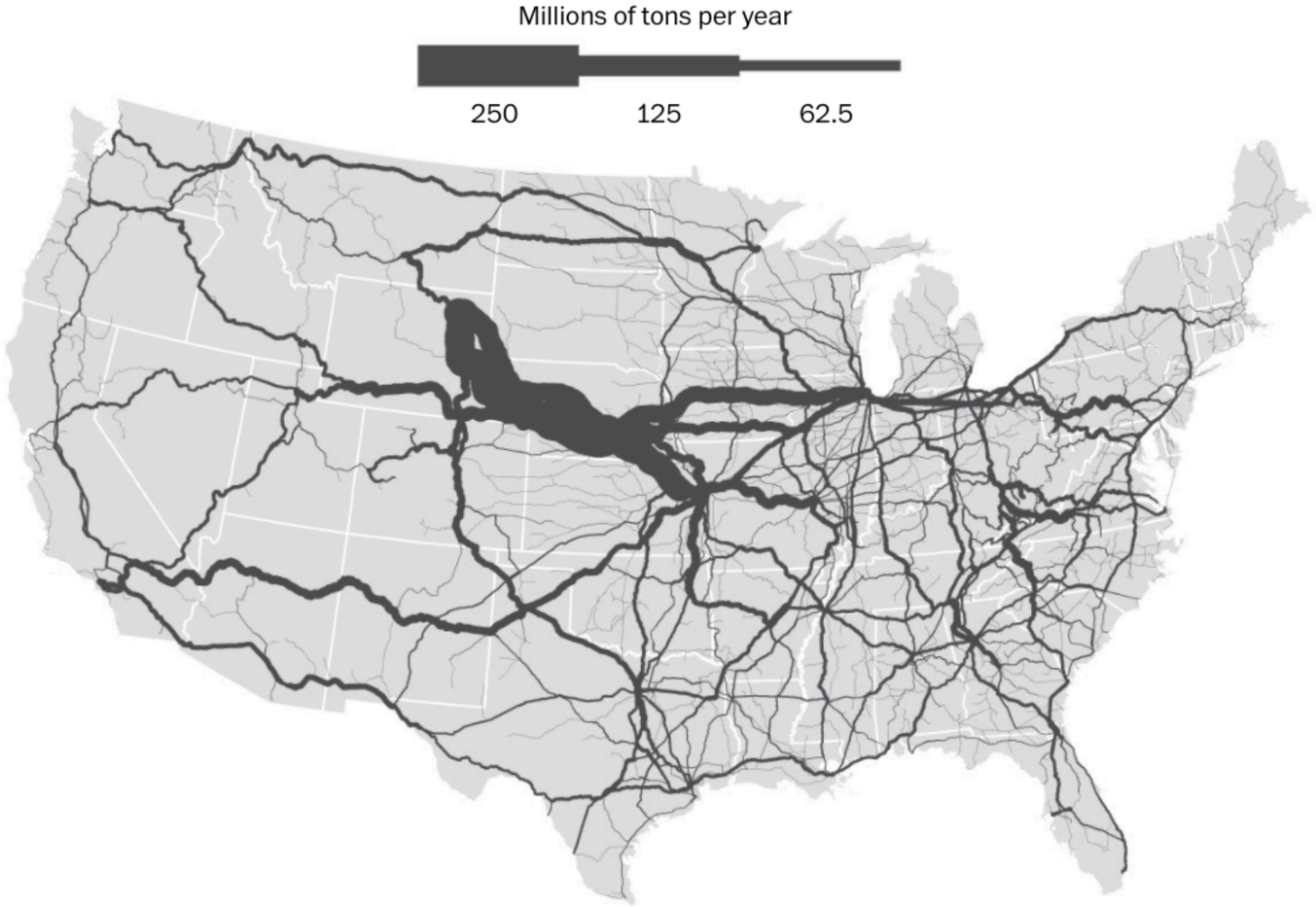


Compare to Non-spatial Representation



Which is better?

Rail Freight Tonnage



https://www.washingtonpost.com/graphics/national/maps-of-american-infrastrucure

Latitude
Longitude

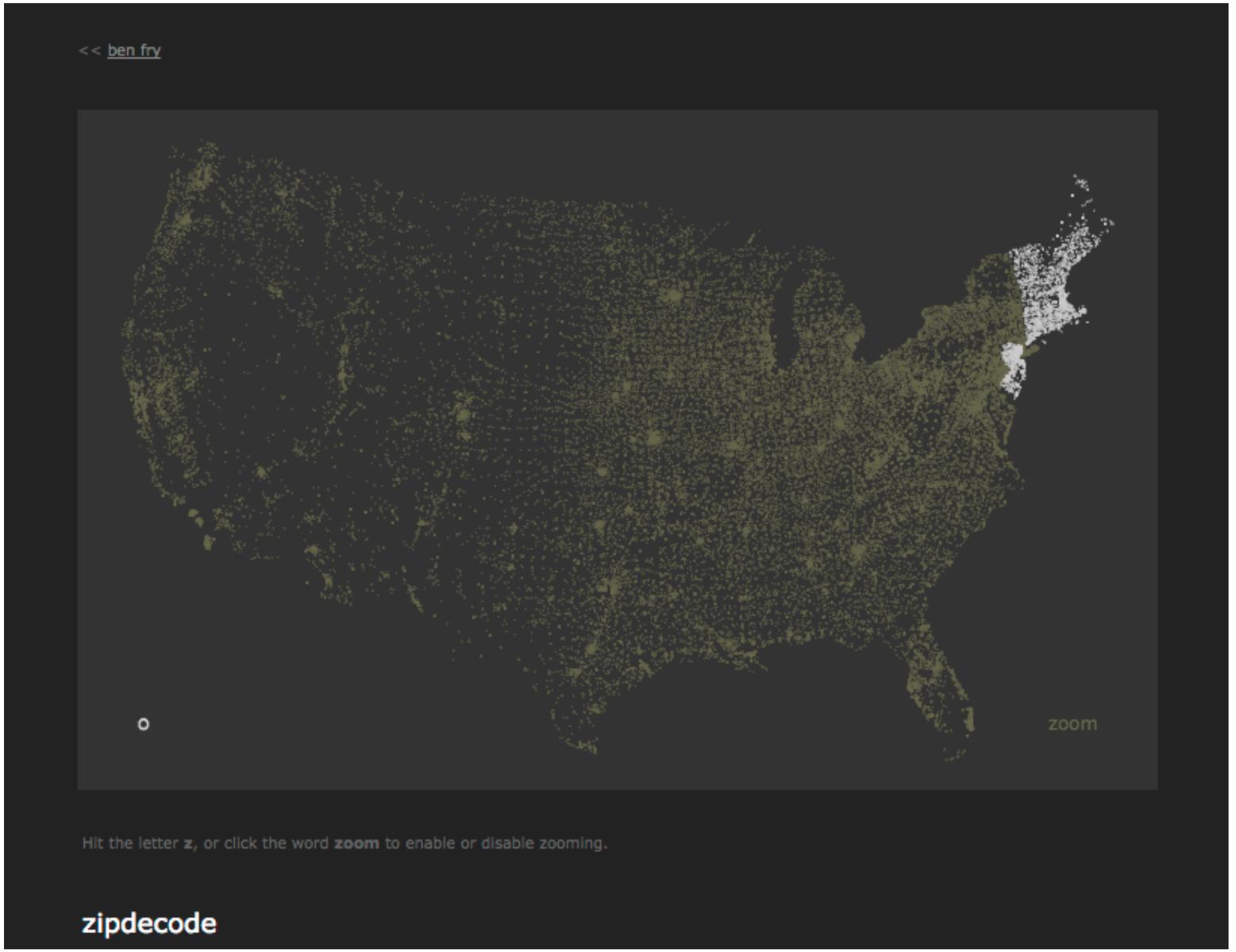
Data Driven Maps

Data Driven Maps

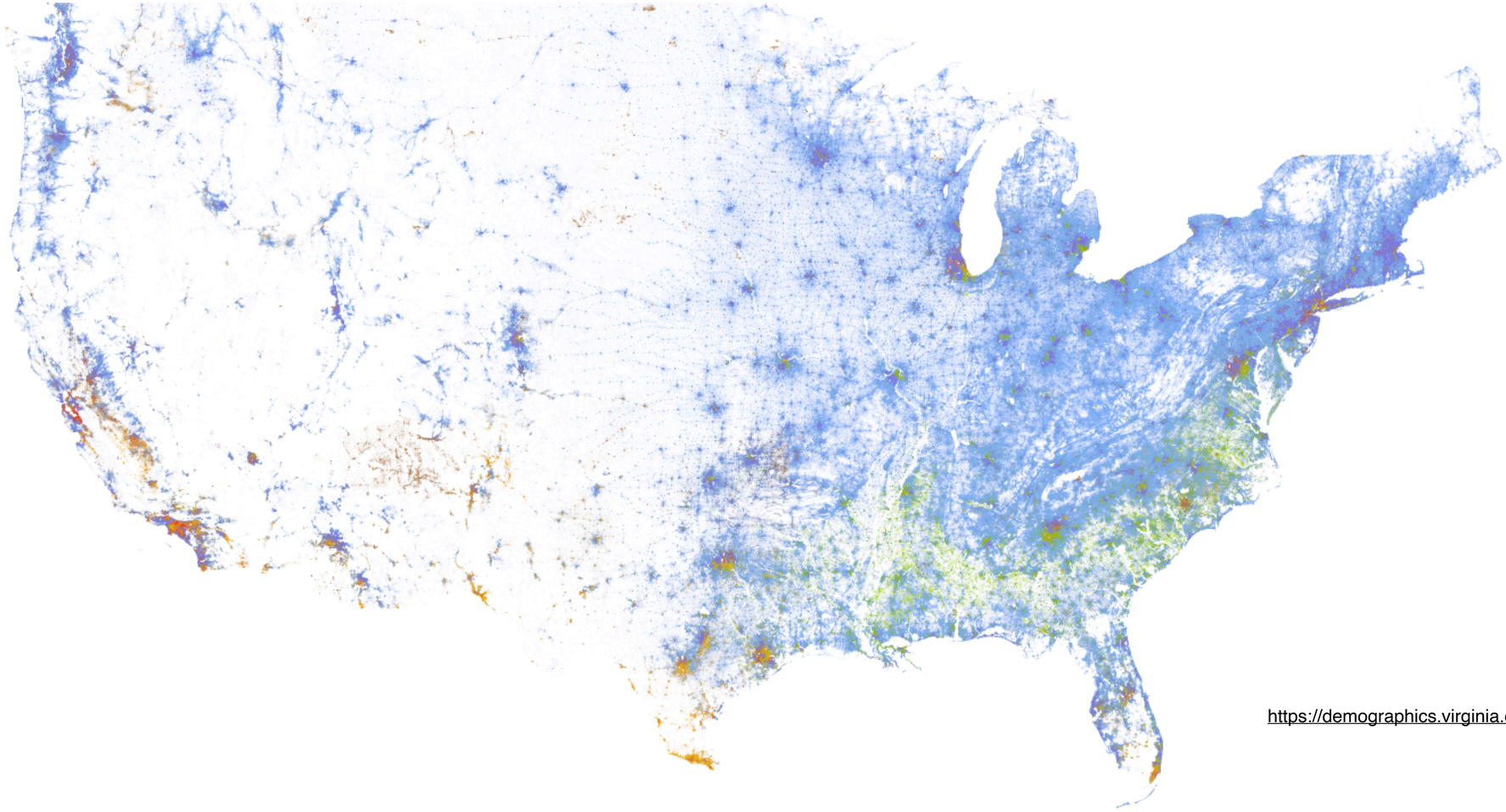
Idea: don’t use a map to render on top

Let the data make up the map

ZipDecode


<< ben fry
zoom
Hit the letter z, or click the word zoom to enable or disable zooming.
zipdecode

Racial Dot Map



https://demographics.virginia.edu/DotMap/

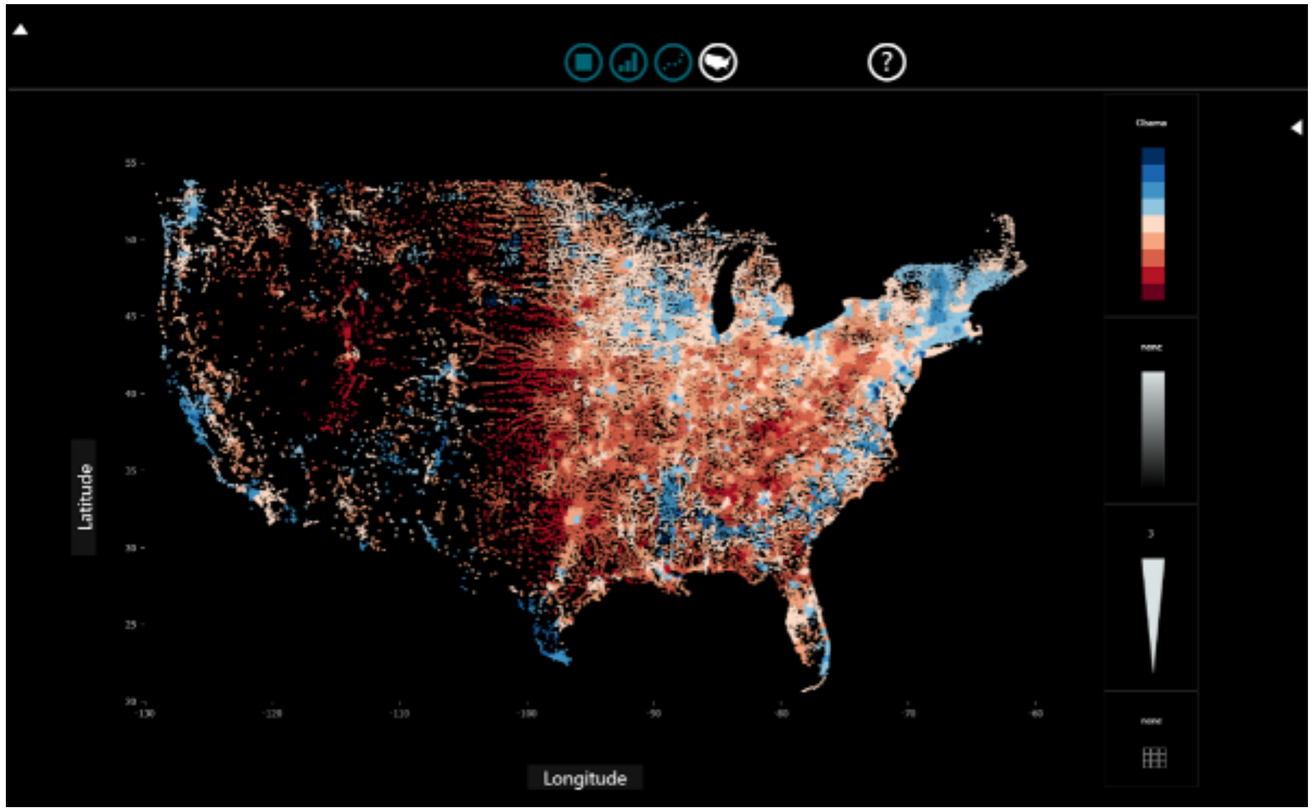
ZipScribble

Taxi Drop-Offs

http://toddwschneider.com/posts/analyzing-1-1-billion-nyc-taxi-and-uber-trips-with-a-vengeance/

SandDance

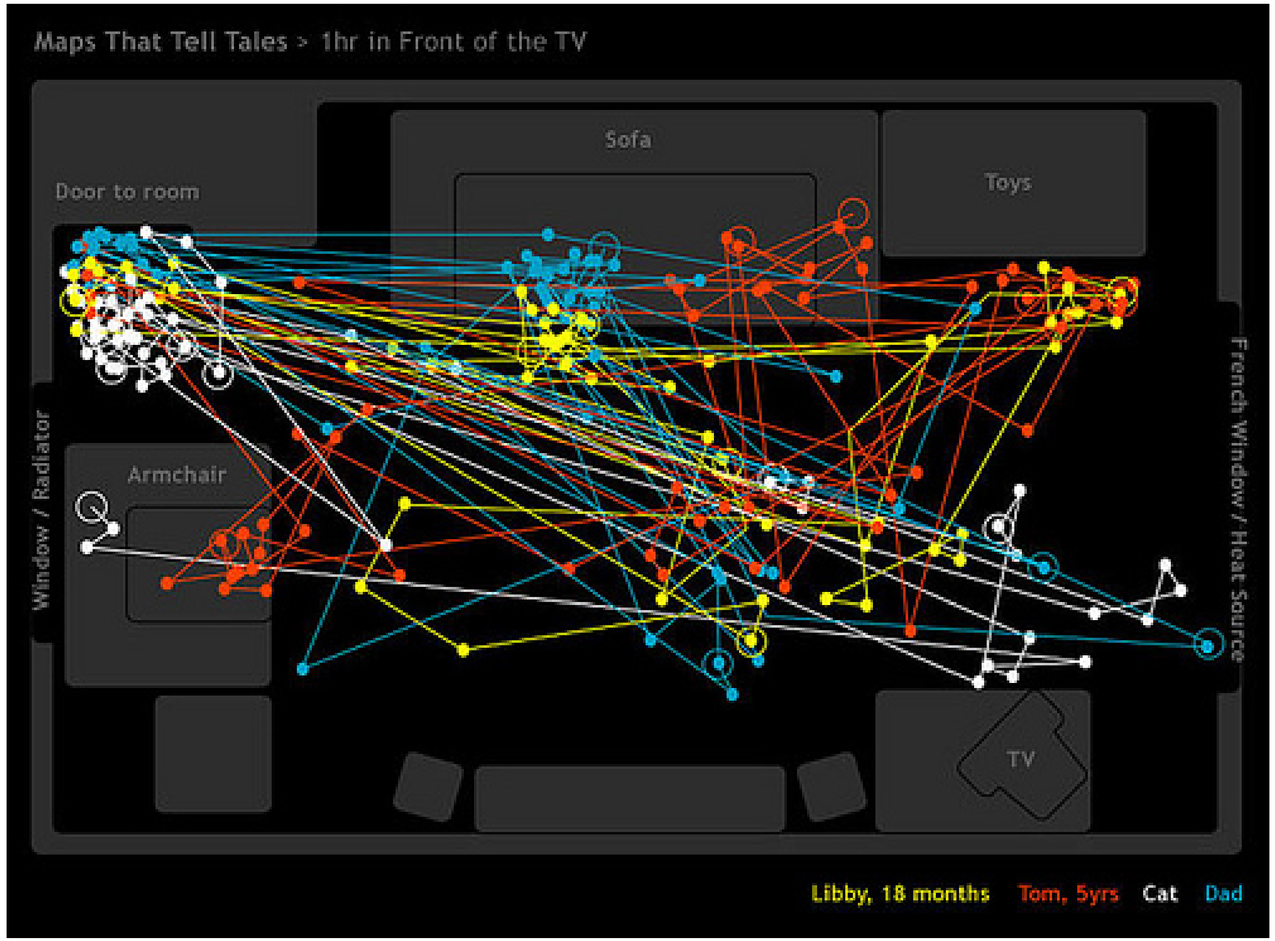
Arrange Particles
to create visualizations



http://research.microsoft.com/en-us/projects/sanddance/

Small Scale Maps

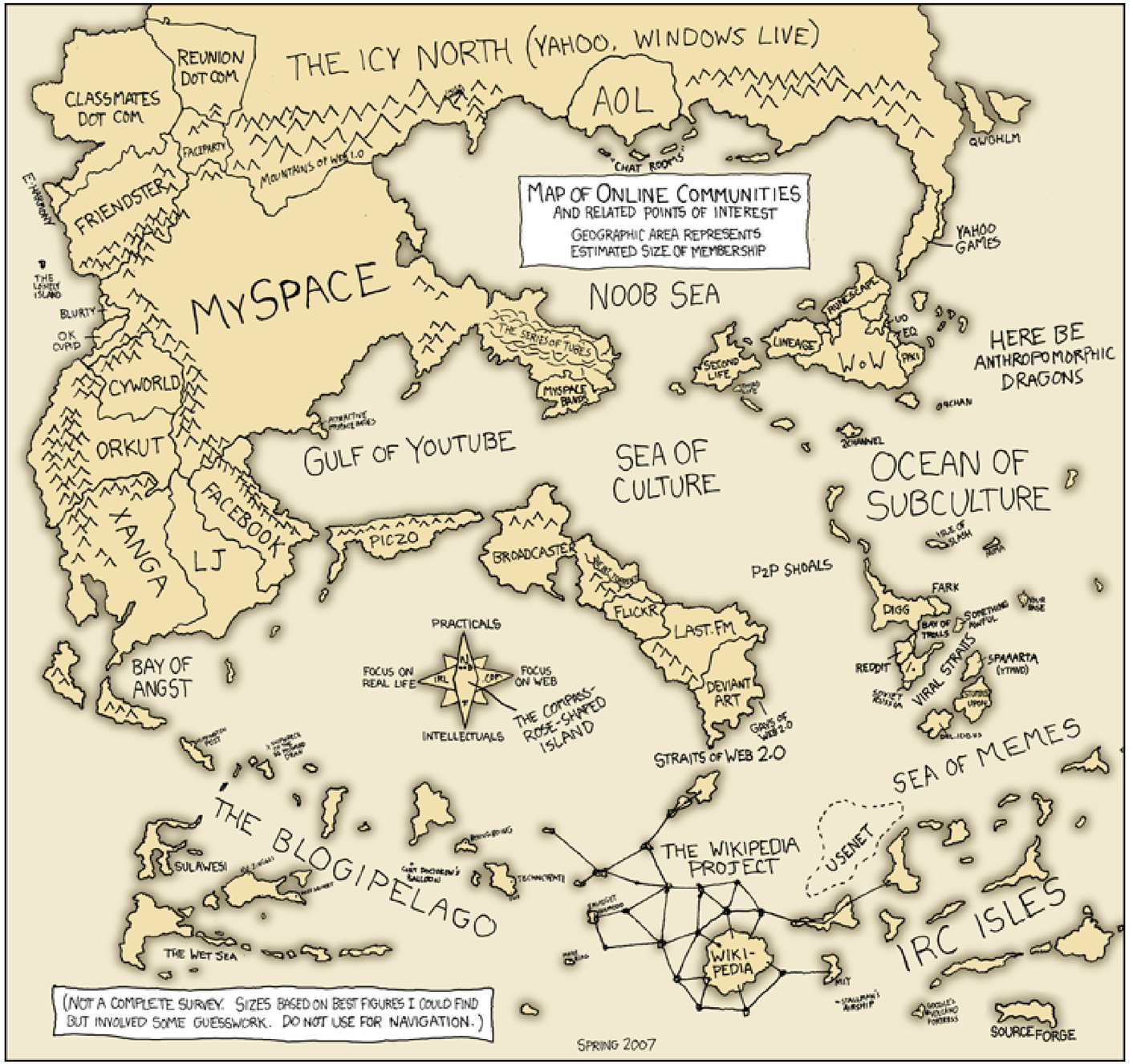
One hour in front of the TV



Map by The Bumblebee
http://www.flickr.com/photos/the_bumblebee/2229041742

Thematic Maps

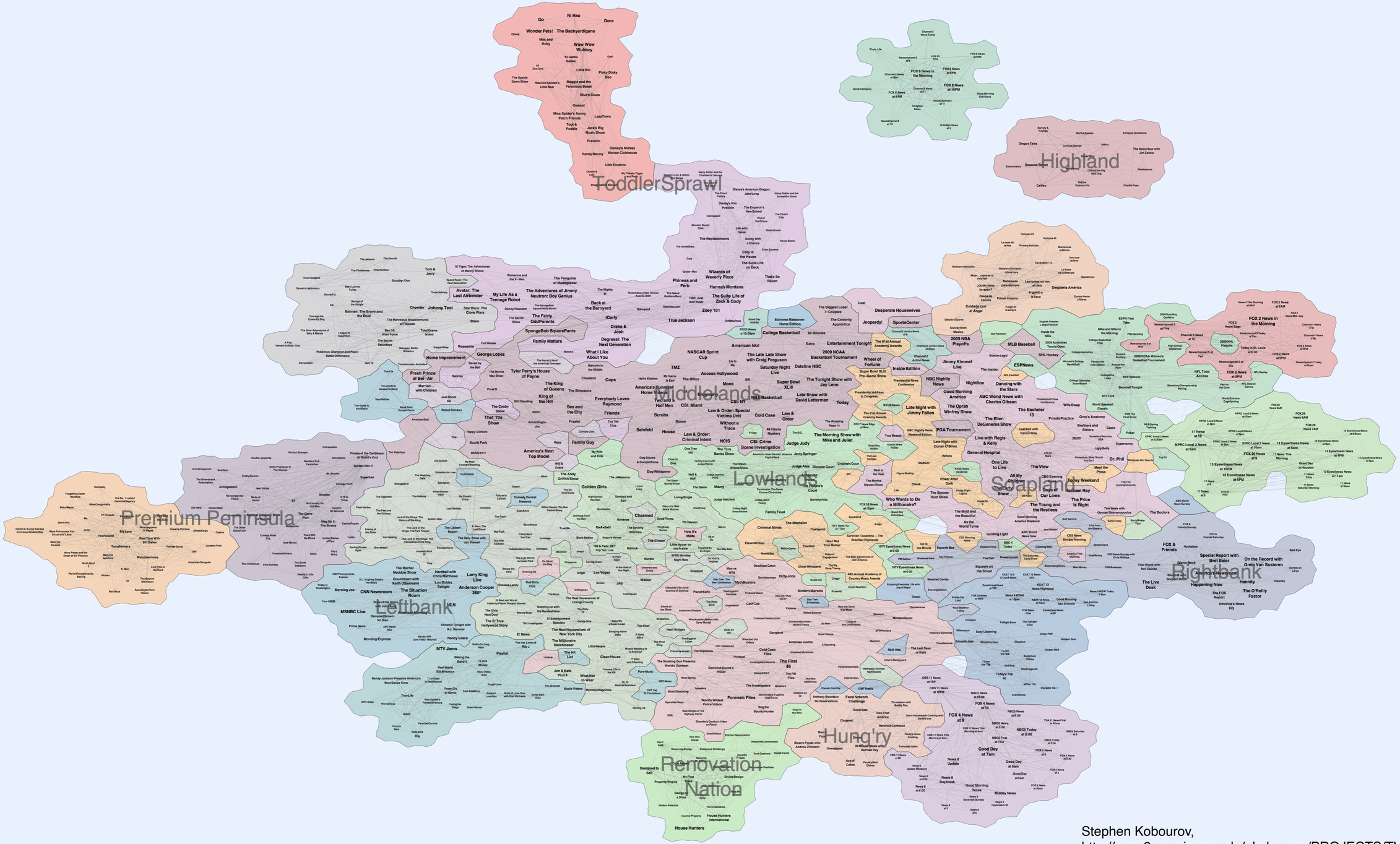
Non-geography, map as an analogy



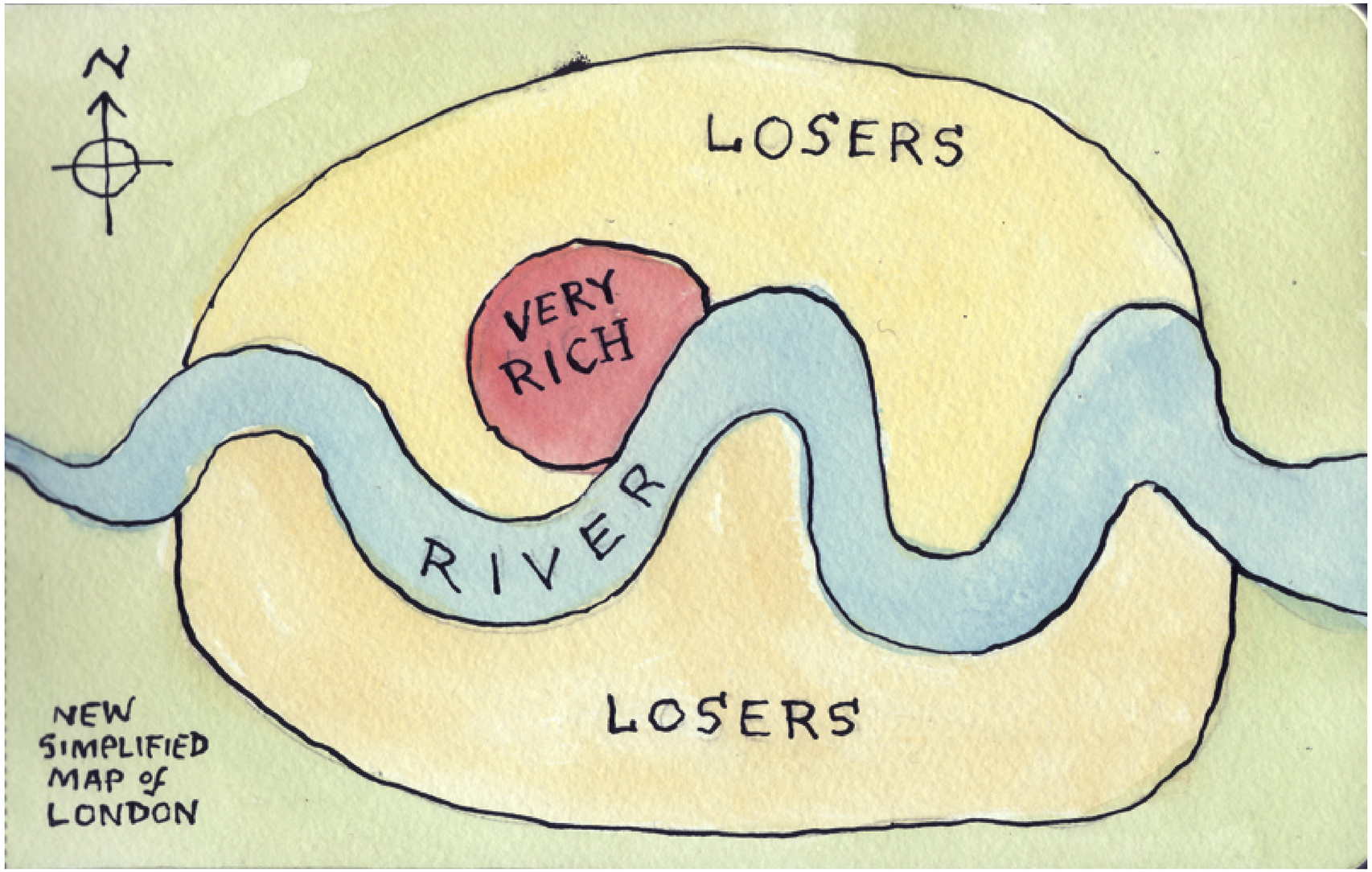
2007

http://xkcd.com/256/

http://xkcd.com/802/



Stephen Kobourov,
http://www2.cs.arizona.edu/~kobourov/PROJECTS/TVLand.png



From Memory (was: Maps from Memory)
http://www.flickr.com/groups/46079190@N00/