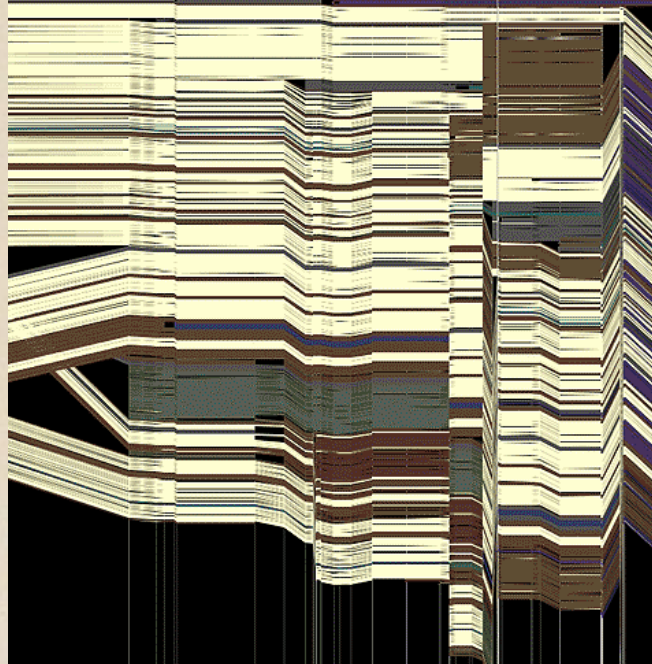
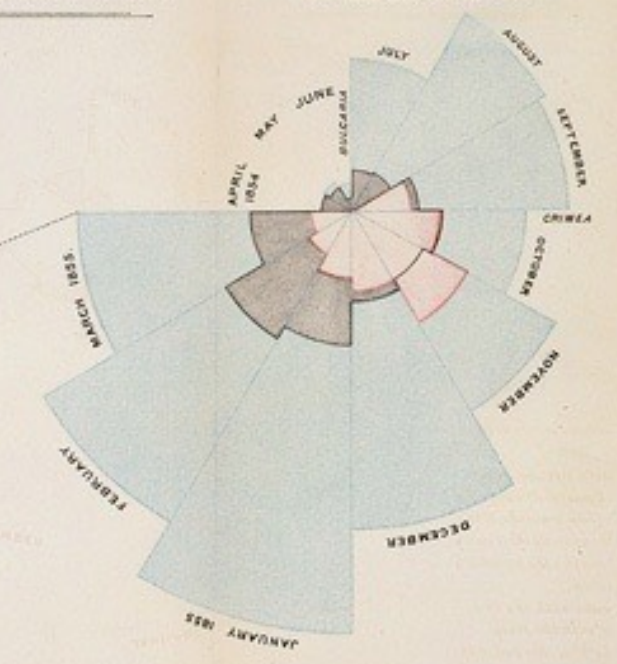


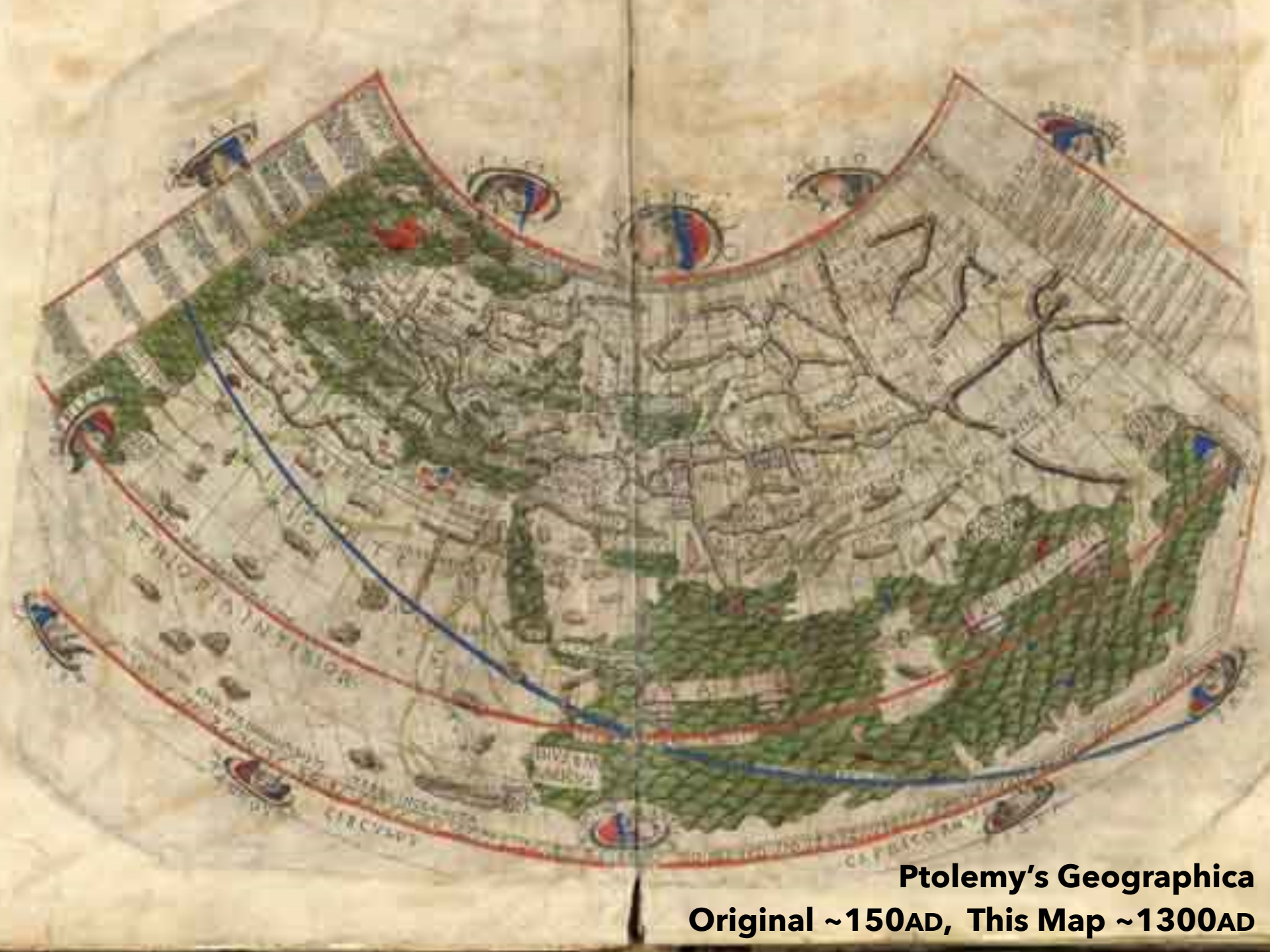
CSE 442 - Data Visualization

Mapping & Cartography

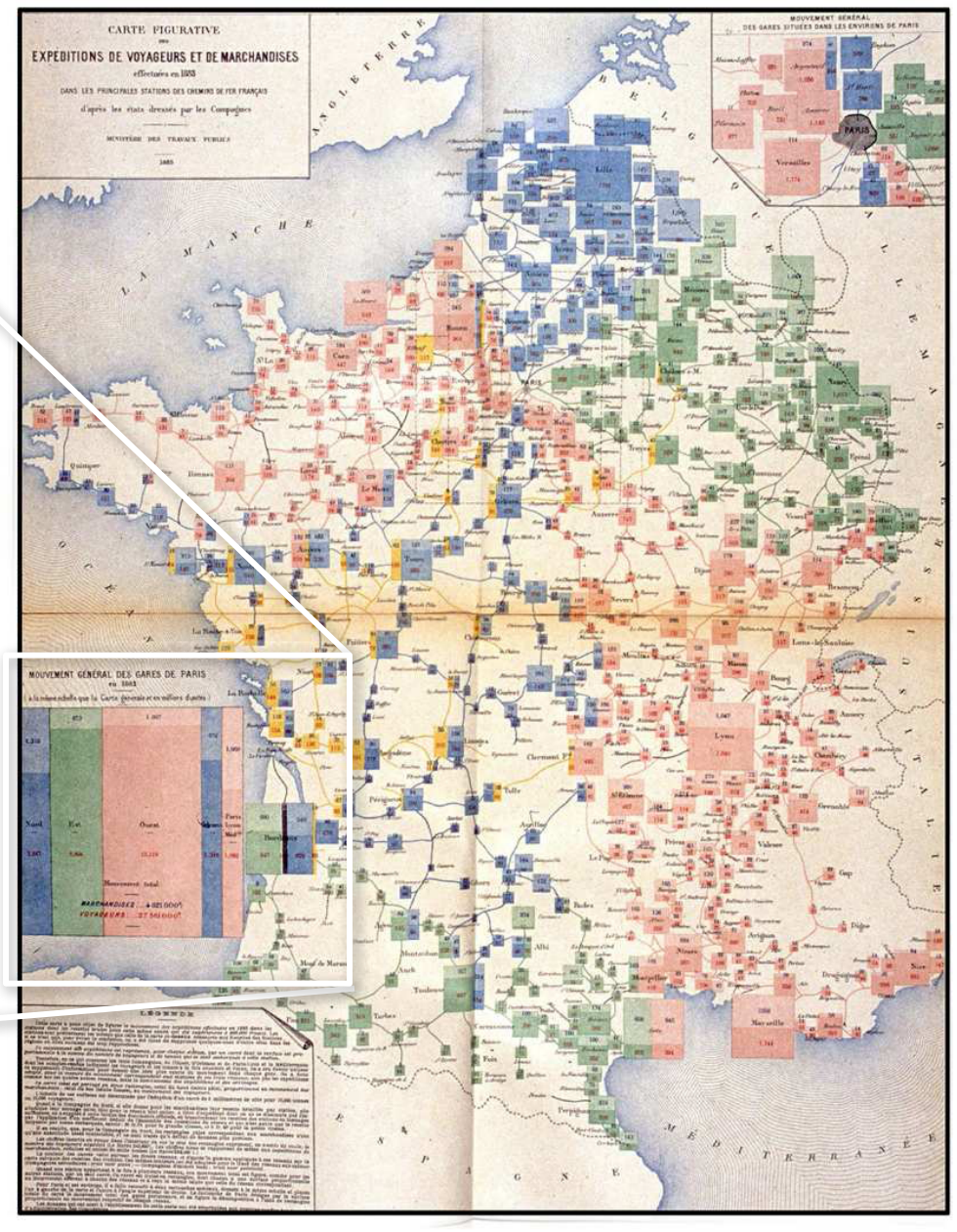
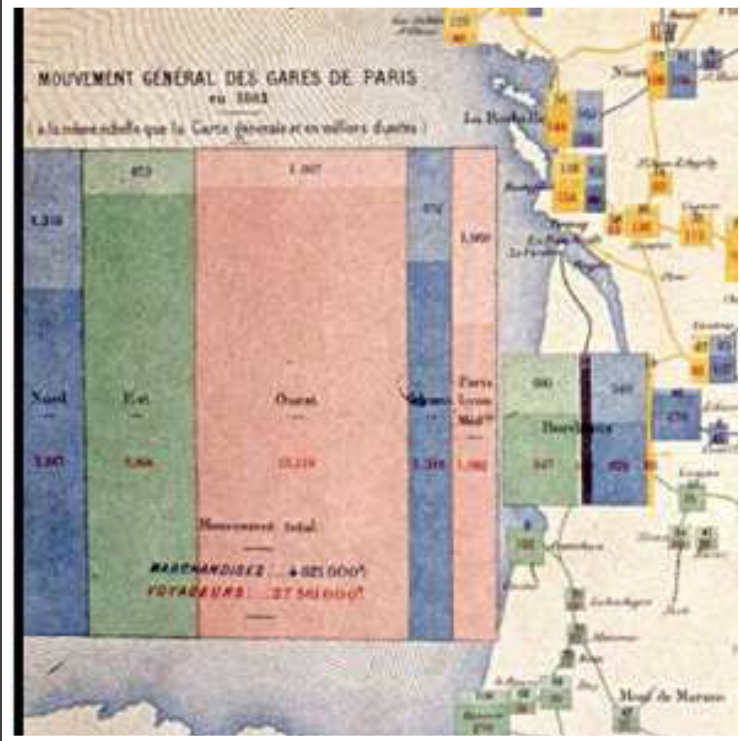


Jeffrey Heer University of Washington

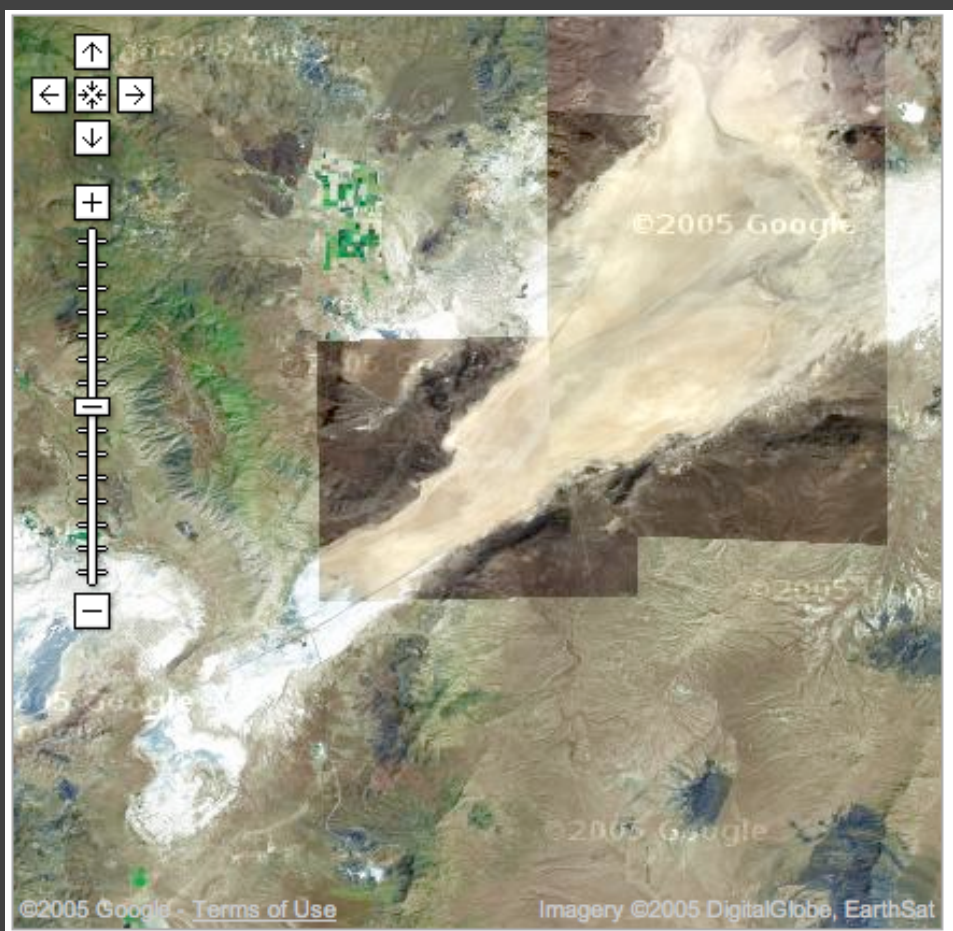
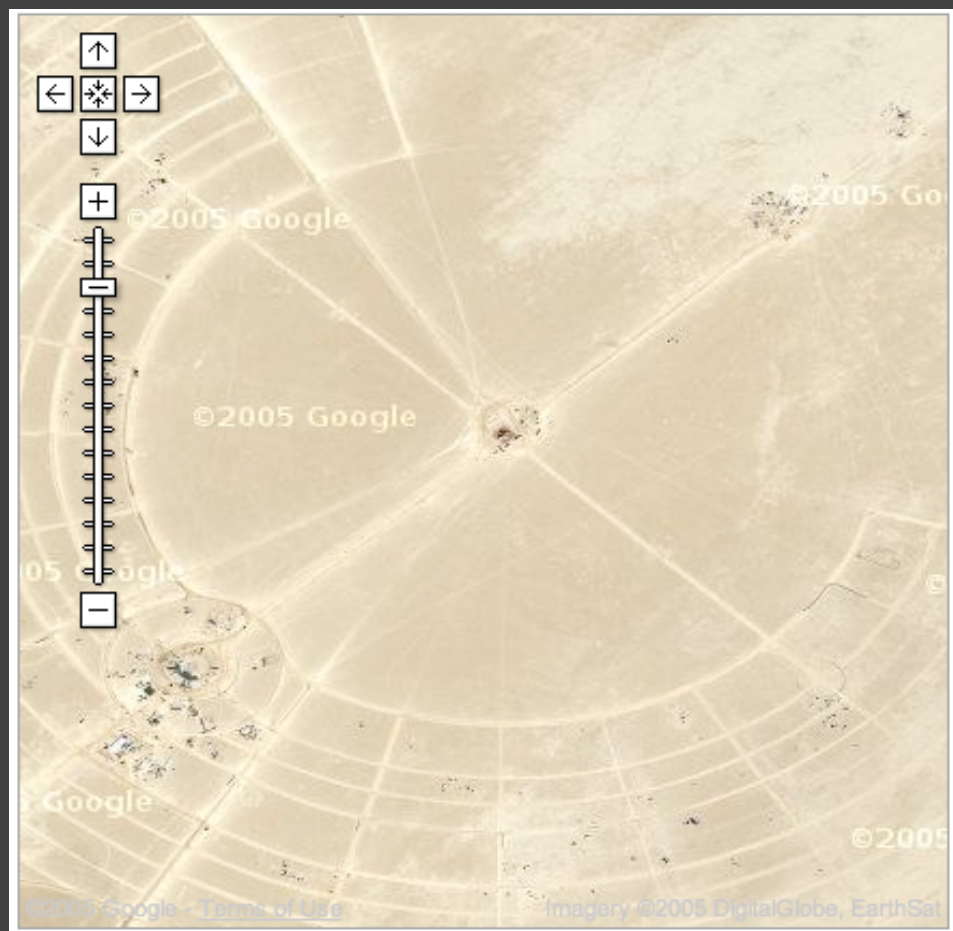
(with significant material from Michal Migurski)



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



Rail Passengers and Freight from Paris 1884



Google Maps 2005

Casualties of War

FACES | ANALYSIS | THEIR STORIES

E-MAIL | FEEDBACK

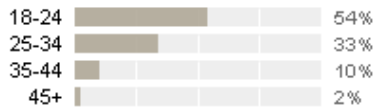
Use the slider below to investigate the demographics and military status of U.S. service members who died during the war in Iraq.

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

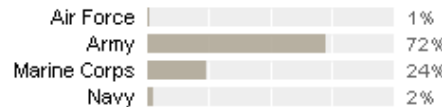
Show all | Initial invasion | First invasion of Falluja | Second invasion of Falluja | Since troop buildup began

4,097 deaths

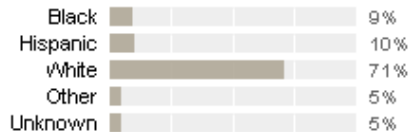
Age



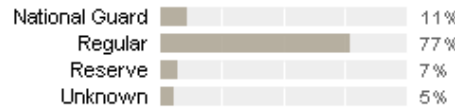
Branch of Military



Race



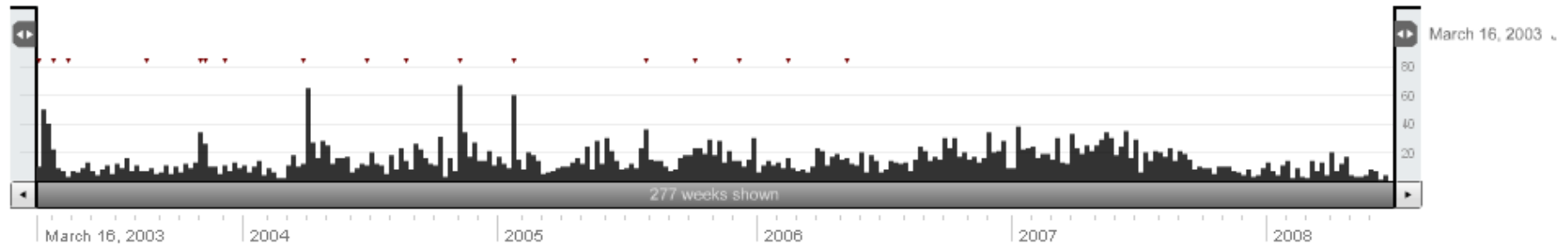
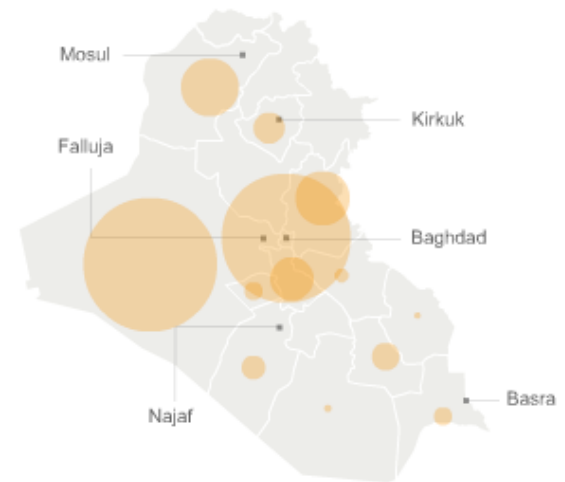
Type of Duty



Location of death

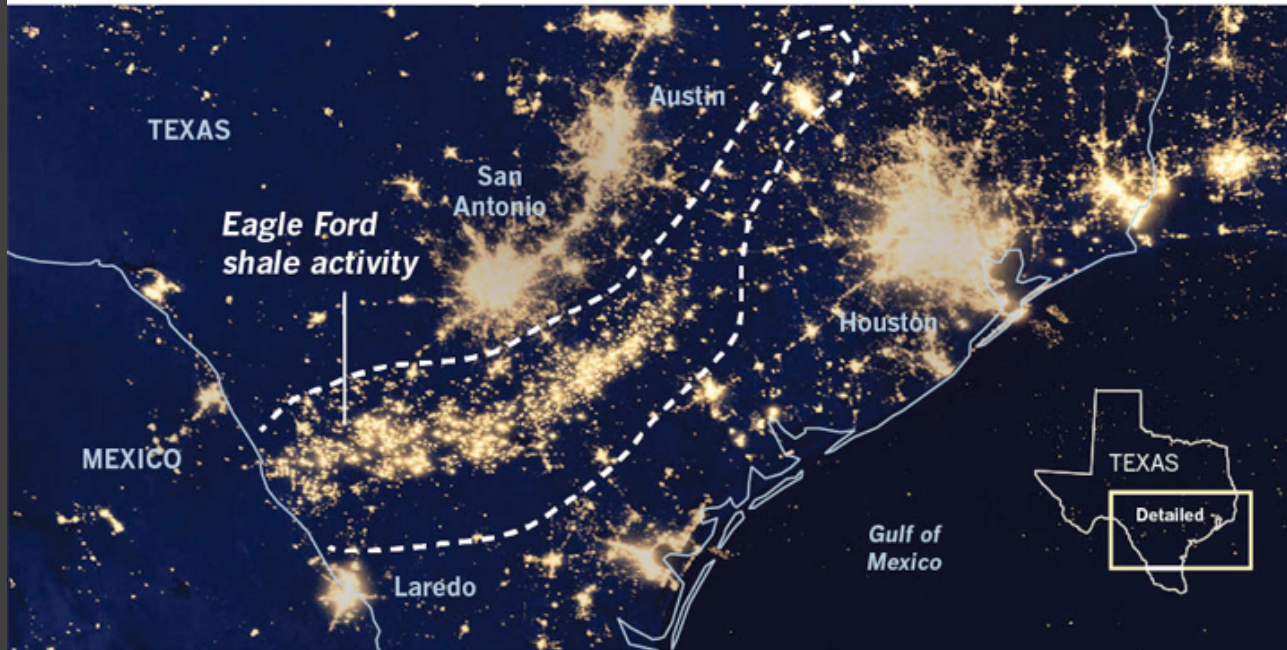
Circles sized according to percentage of deaths in each Iraqi province.

Show home



Texas oil boom is visible from space

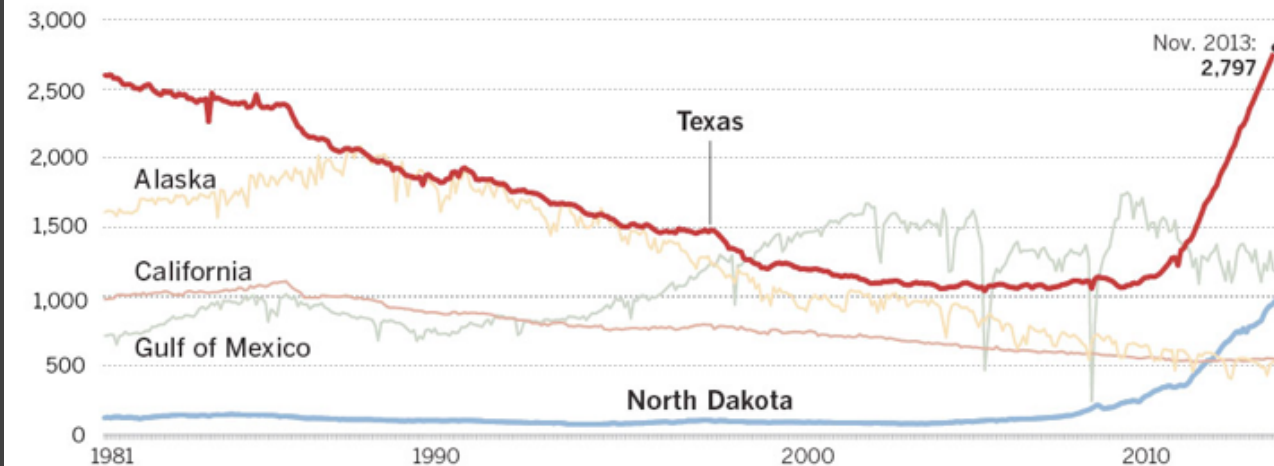
Lighting and natural gas flares from drilling on the 400-mile-long Eagle Ford shale formation can be seen from space in this image.



NASA

The new formation has helped make Texas the No. 1 oil-producing state in the nation.

Oil production from different U.S. regions (in thousands of barrels per day)



Source: Energy Information Administration

MATT MOODY Los Angeles Times

LA Times
2014

Ramadi: The Government Provides an Opening for ISIS ISIS Control

Tensions between this city's residents, who are mostly Sunni, and the central government had been brewing here for at least a year. Then in December, Iraq's prime minister, Nuri Kamal al-Maliki, ordered security forces to dismantle a protest camp — an outlet for disenchanting Sunnis angered at their treatment by the Shiite-dominated government. The action ignited days of violence and created the opening ISIS needed to seize parts of the city, the provincial capital.

Falluja: A Symbolic Fall ISIS Control

Just days after the raid on the camp in Ramadi, ISIS fighters destroyed the Police Headquarters and mayor's office here, planted their flag on government buildings and decreed the city to be theirs. Ten years earlier, American forces had captured this city from Qaeda-style insurgents at a considerable cost of American lives.



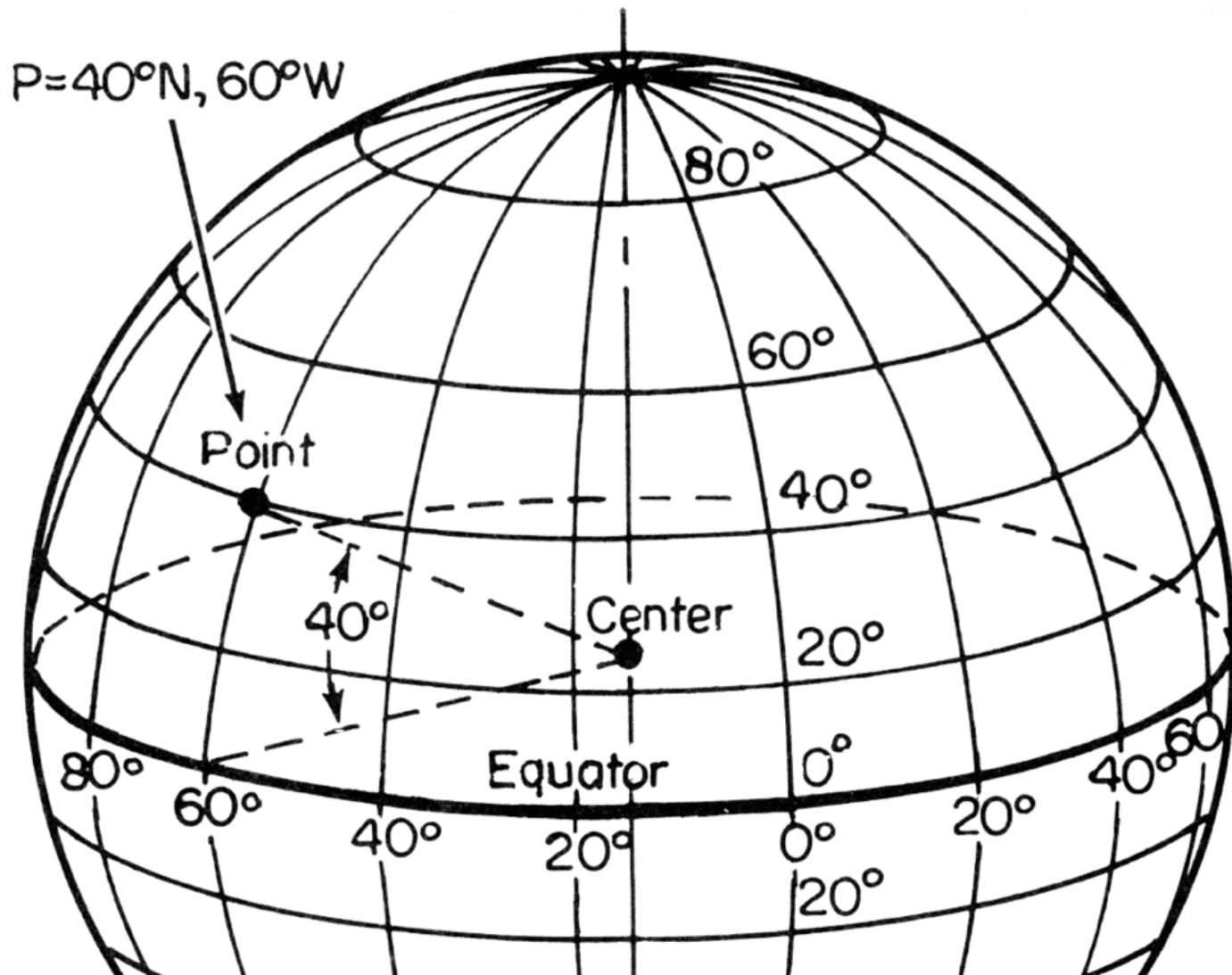
17 MILES TO BAGHDAD

Cartography

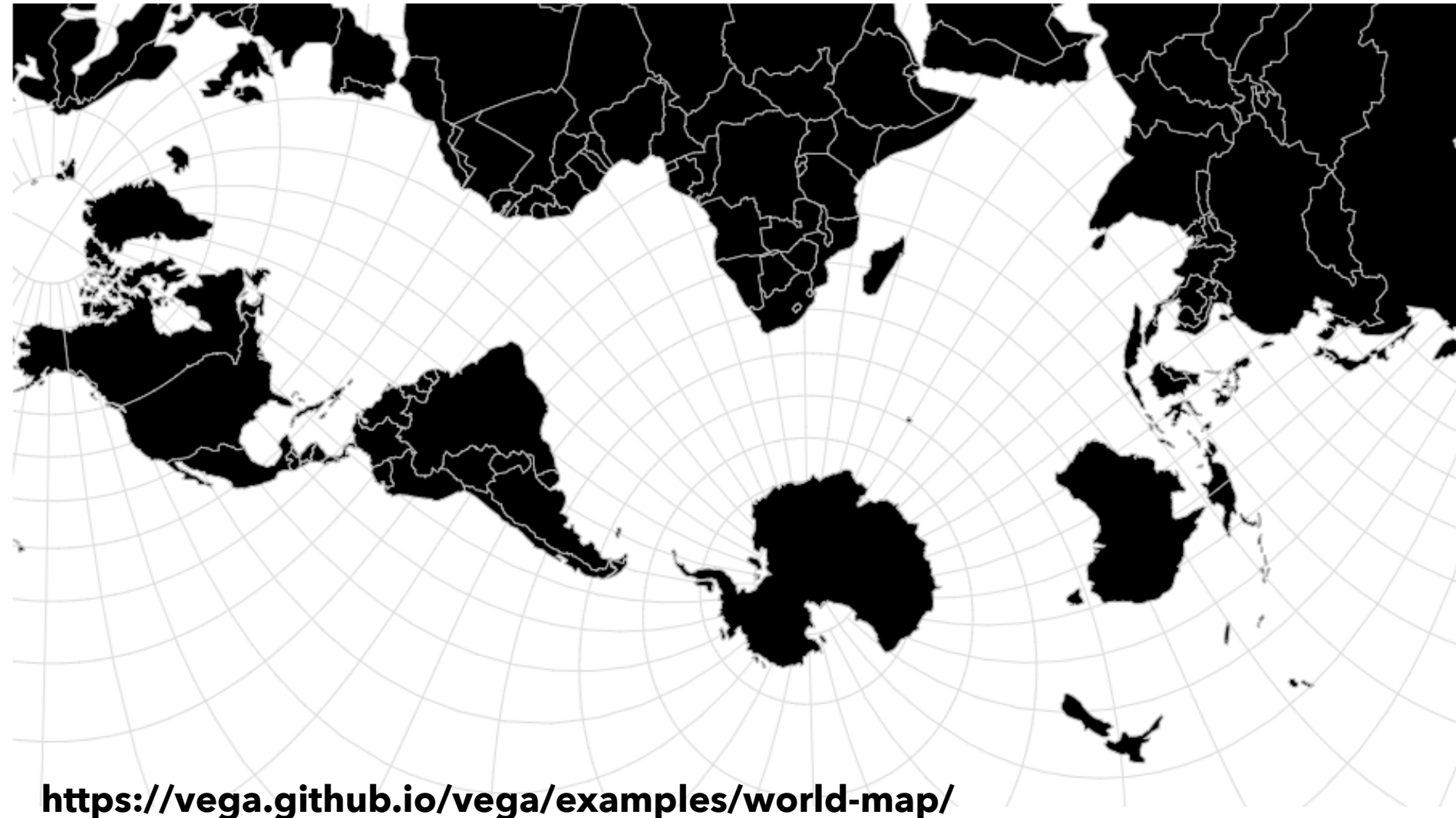
The Making of Maps

Projections

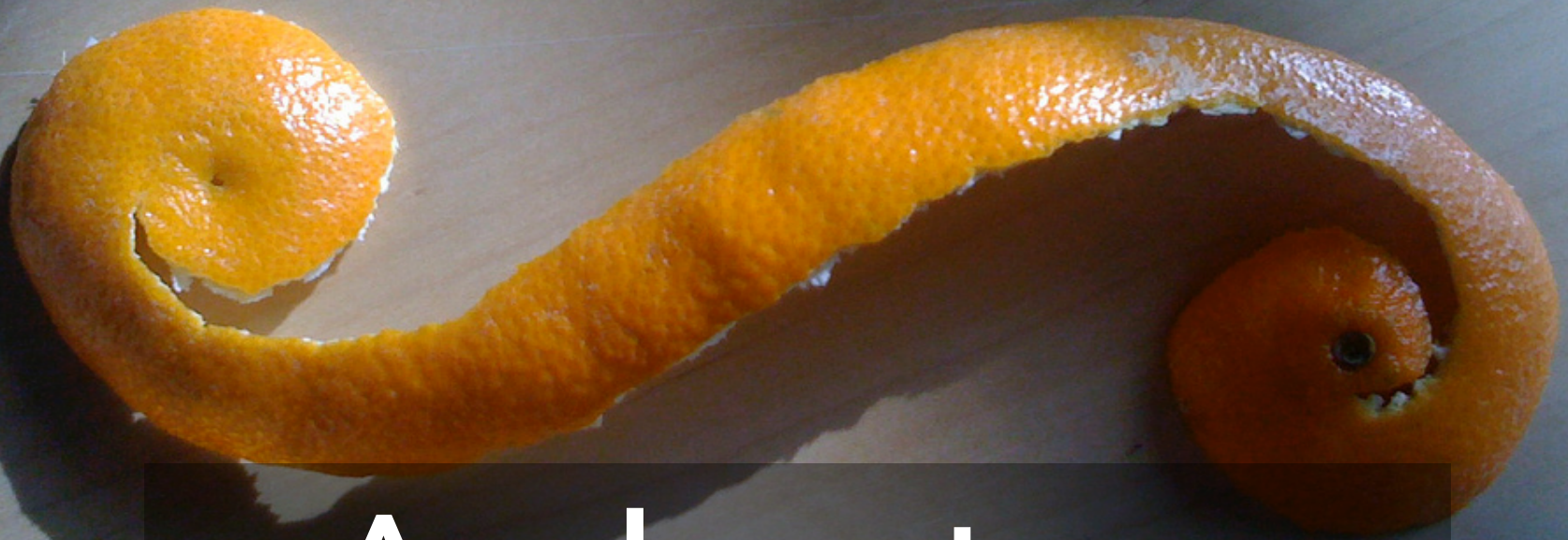
Latitude, Longitude



Exploring Projections...



<https://vega.github.io/vega/examples/world-map/>



**A sphere tears
when you flatten it**

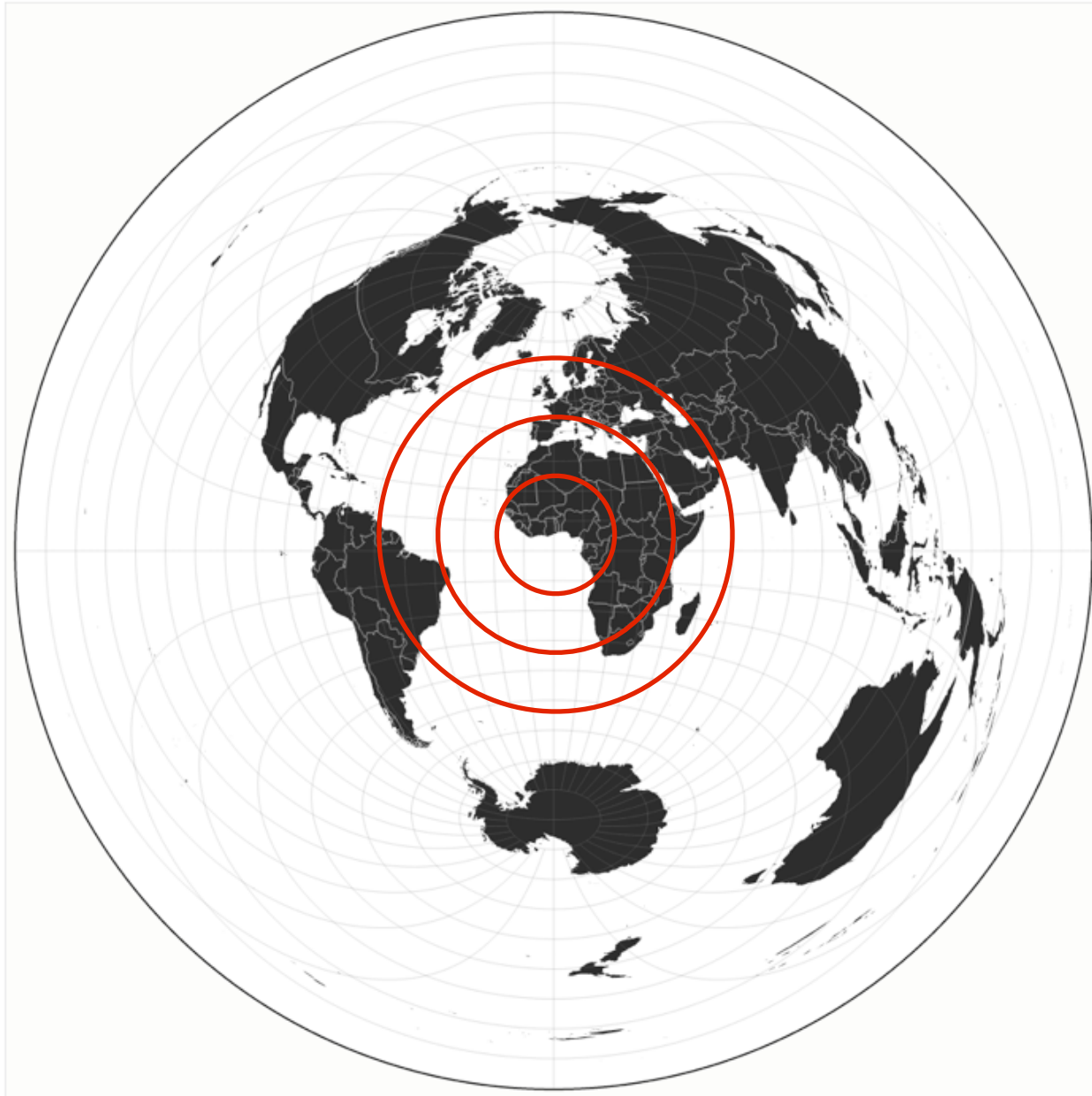
**Three example
ways to categorize
projections...**



Azimuthal

Preserve direction / distance from center

Azimuthal Equidistant

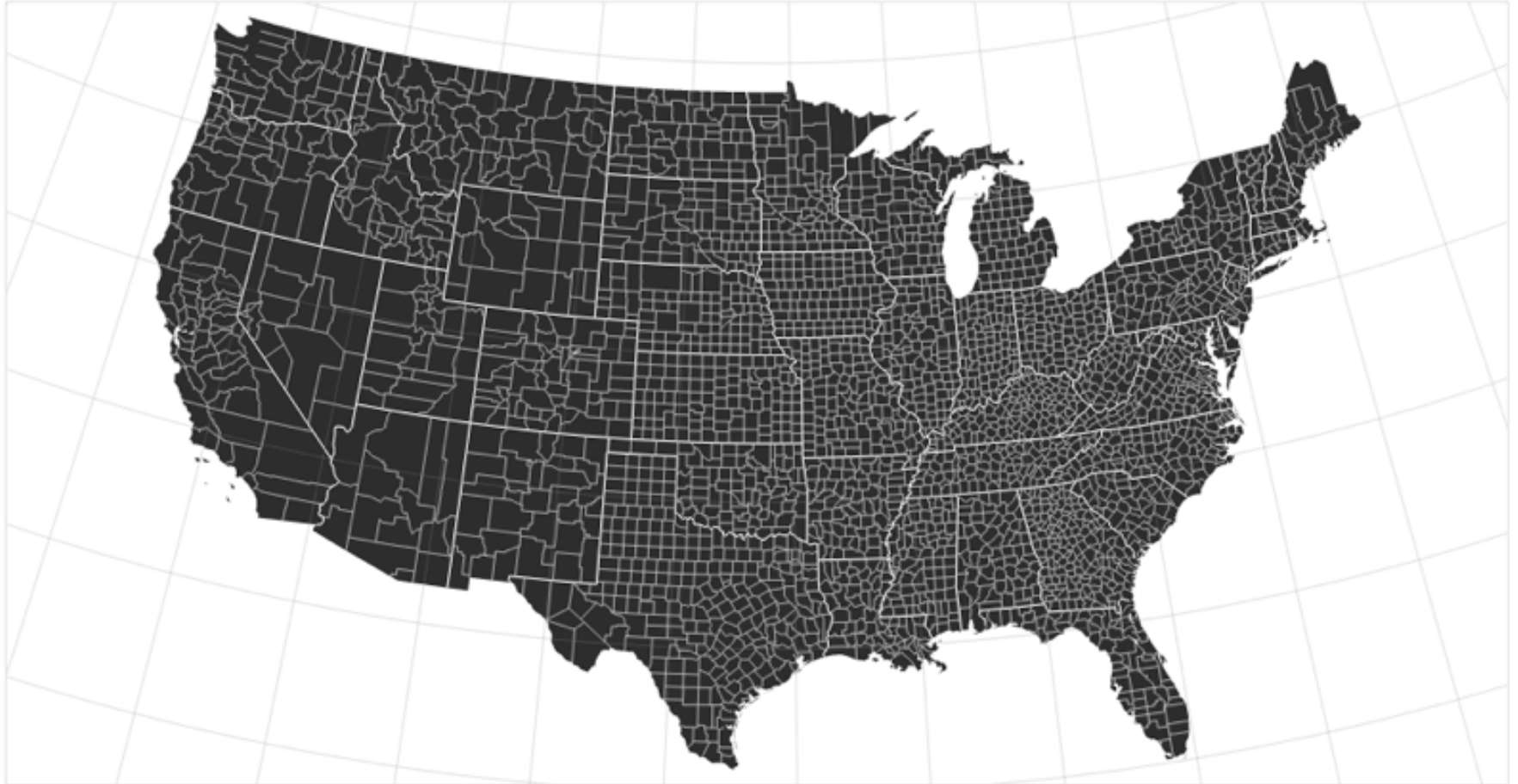


A world map with a dark gray background. Landmasses are outlined in black. A large area in the North Pacific, including Alaska, the Yukon, and parts of Canada, is highlighted in a light yellow color. A semi-transparent dark gray rectangular box is overlaid on the map, containing the text 'Equal-Area' and 'Preserve area'.

Equal-Area

Preserve area

Albers Equal-Area Conic



The [Albers equal-area conic projection](#) is available as [d3.geo.albers](#). See also the [interactive version](#).

[Open in a new window.](#)

A world map with a yellow background and black outlines for continents and country borders. A semi-transparent grey rectangular box is centered over the map, containing text. The text is white and reads "Conformal" in a large font, and "Preserve local angles ('shape')" in a smaller font below it.

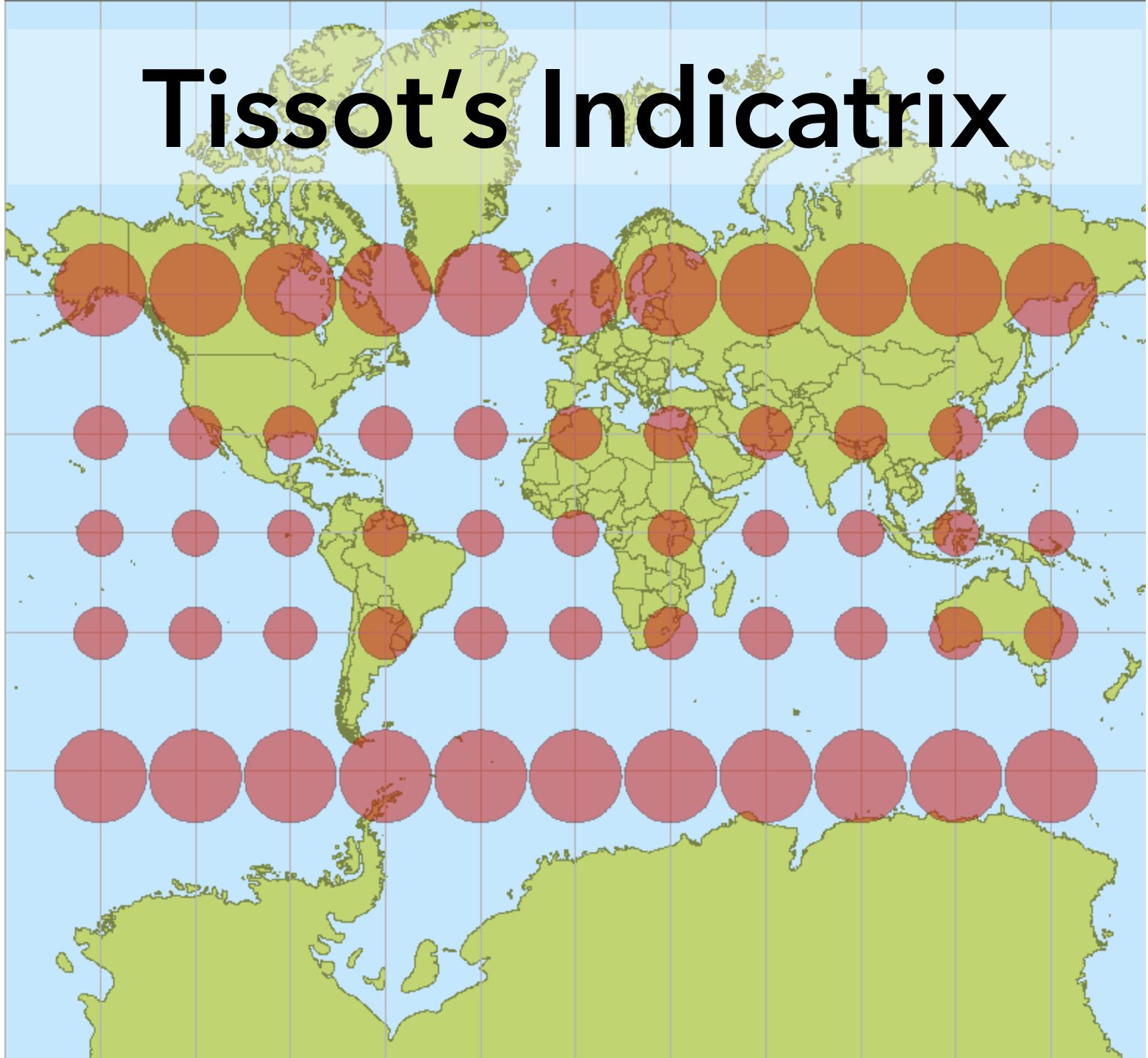
Conformal

Preserve local angles ("shape")

Spherical Mercator



Tissot's Indicatrix





**Spherical Mercator
is ubiquitous on
the web—why?**

Web Mercator

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

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

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.

The Earth as a Square



Peirce Quincuncial



The [Peirce quincuncial projection](#) is implemented as `d3.geo.peirceQuincuncial` in the [geo.projection D3 plugin](#). It is derived from the [Guyou projection](#).

[Open in a new window.](#)

A map of the Americas, including North and South America, is shown in yellow. A vertical orange rectangular box highlights the western coast of North America, from the Canadian border down to the Mexican border. The text "Projections usually have a home" is overlaid in white on a semi-transparent grey background at the bottom of the map.

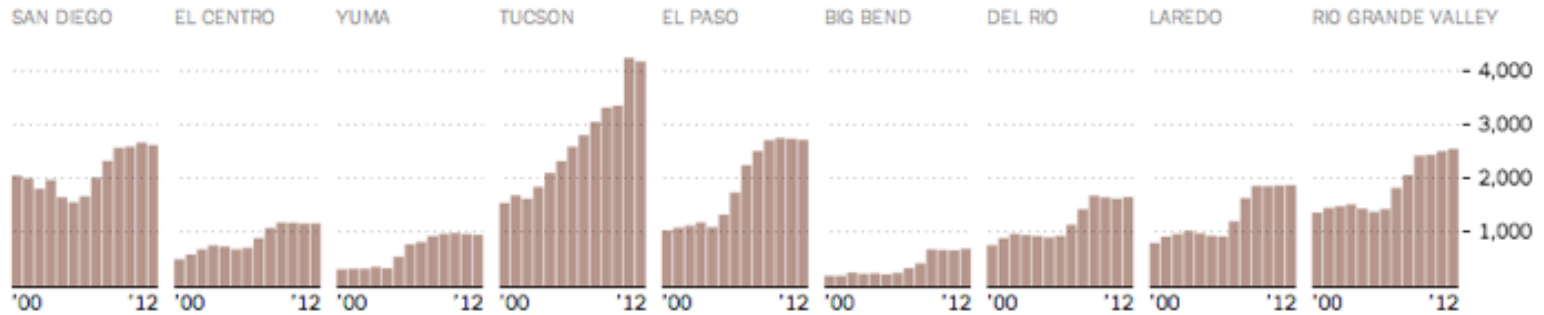
Projections usually
have a home

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

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



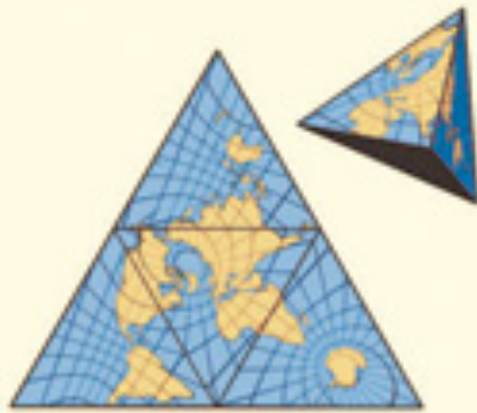
YOU THINK THAT WHEN WE LOOK AT A MAP, WHAT WE REALLY SEE IS OURSELVES. AFTER YOU FIRST SAW *INCEPTION*, YOU SAT SILENT IN THE THEATER FOR SIX HOURS. IT FREAKS YOU OUT TO REALIZE THAT EVERYONE AROUND YOU HAS A SKELETON INSIDE THEM. YOU *HAVE* REALLY LOOKED AT YOUR HANDS.

A world map with a grid of latitude and longitude lines. The landmasses are colored in a light tan or yellowish-brown, while the oceans are light blue. A series of white, jagged lines represent a path where the sphere is being torn, starting from the top left and moving towards the bottom right, passing through the Atlantic and Indian Oceans. The map is presented in a slightly distorted, non-rectangular shape.

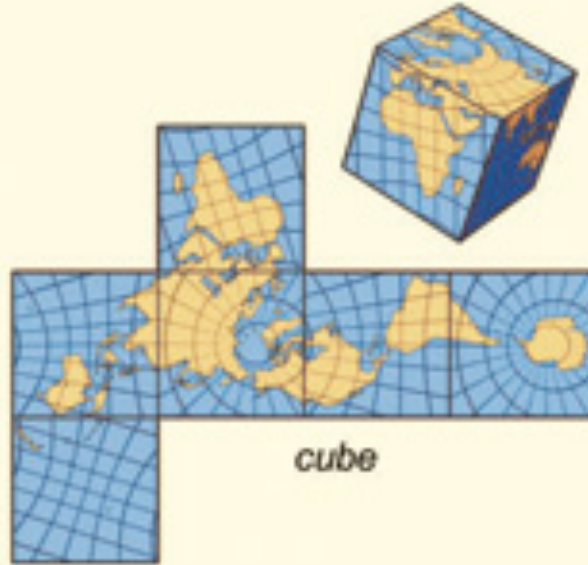
**There are interesting
ways to tear spheres**

One notable interesting
way to tear a sphere

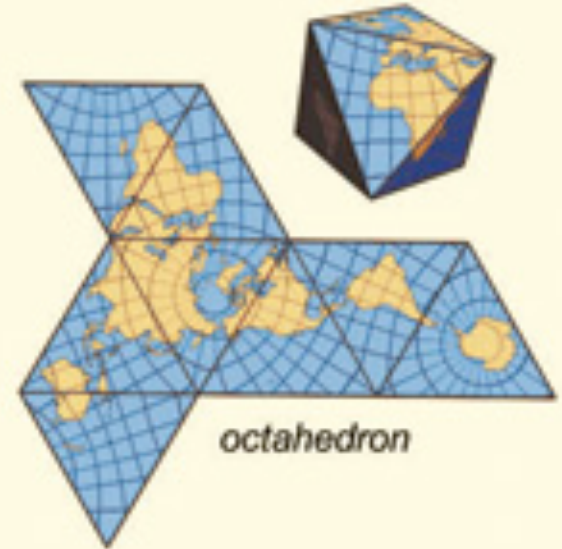




tetrahedron



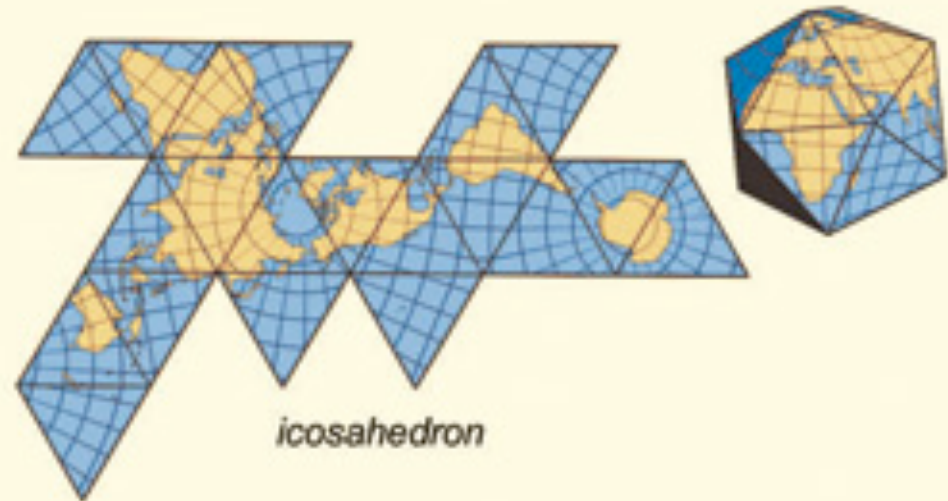
cube



octahedron



dodecahedron



icosahedron



ADAPTIVE COMPOSITE MAP PROJECTIONS

Scale

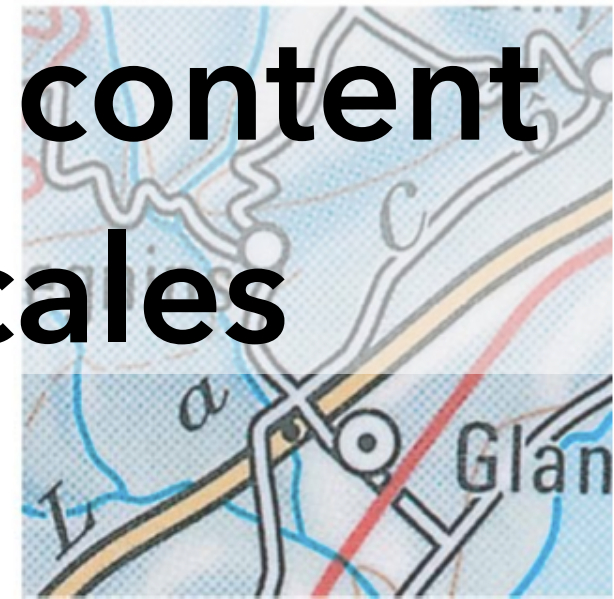
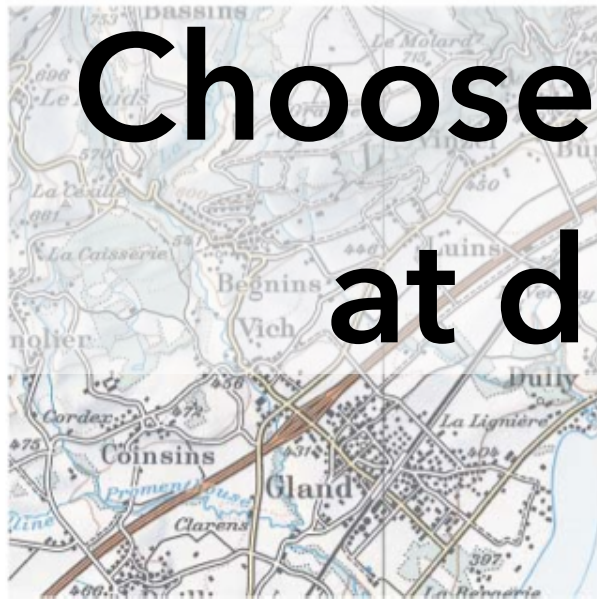
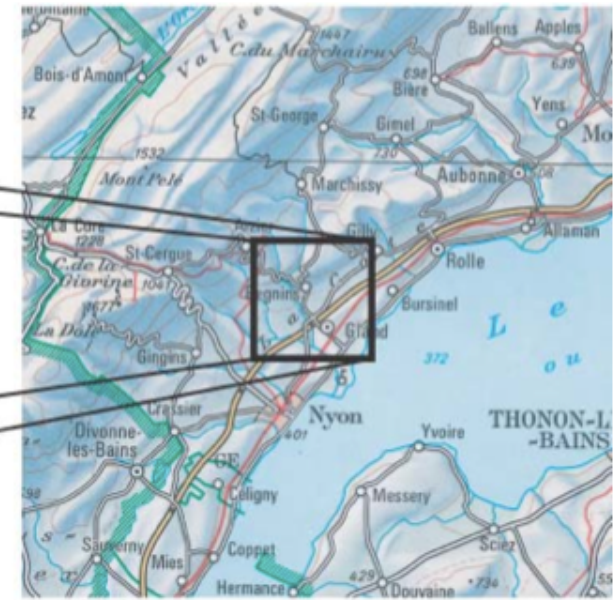
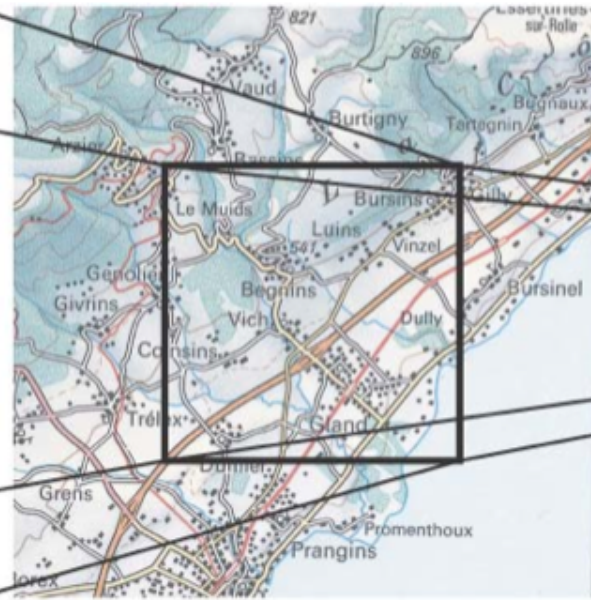


This is not "scale"

Texas-Europe Size Comparison

Scale is an idea imported from print





**Choose the right content
at different scales**

Four maps, same area



What shows at different scales?





Pittsburgh

Harrisburg

Reading

NEW JERSEY

Camden

Cumberland

MARYLAND

Millville

Washington

DELAWARE

Harrisonburg

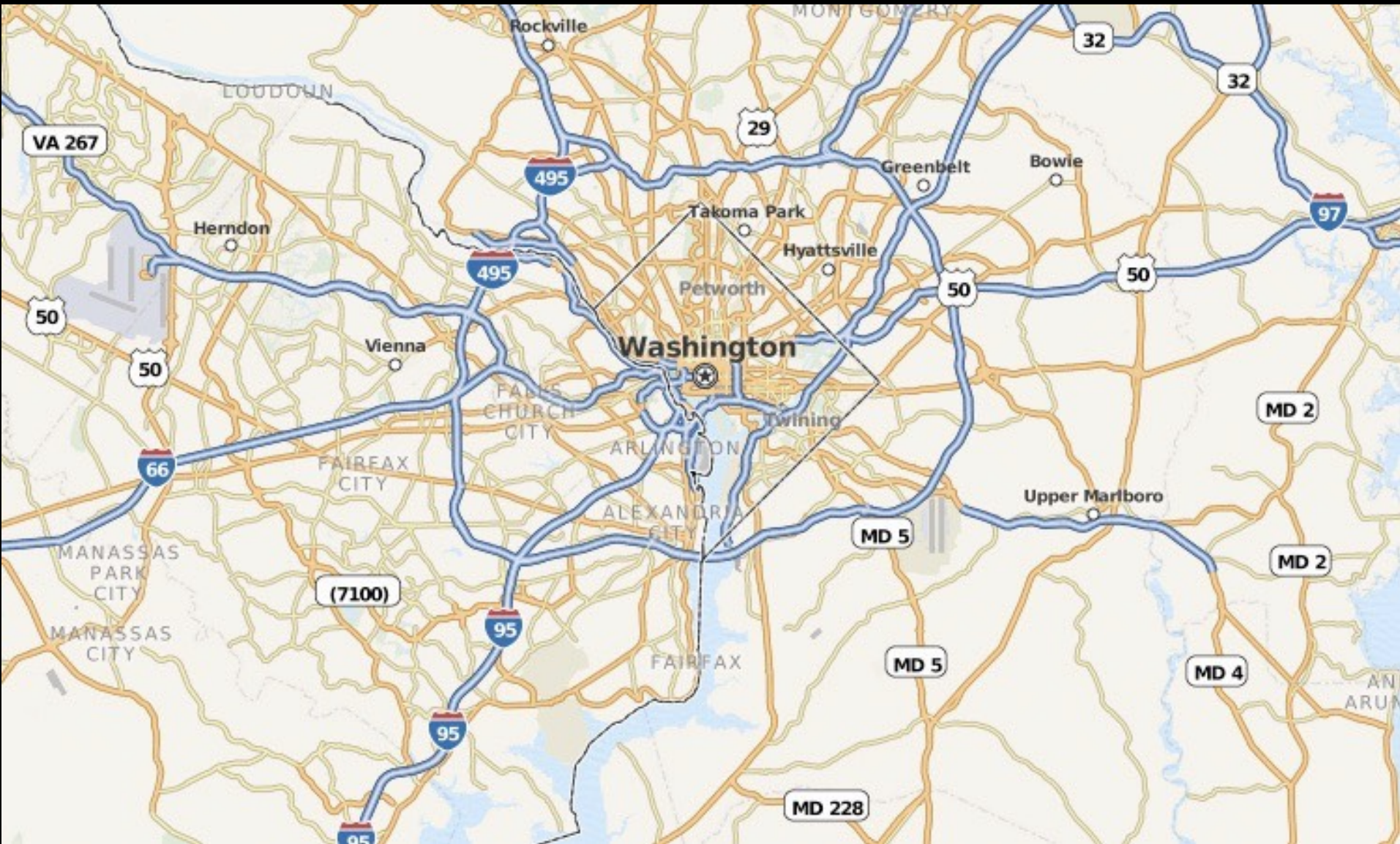
WEST VIRGINIA

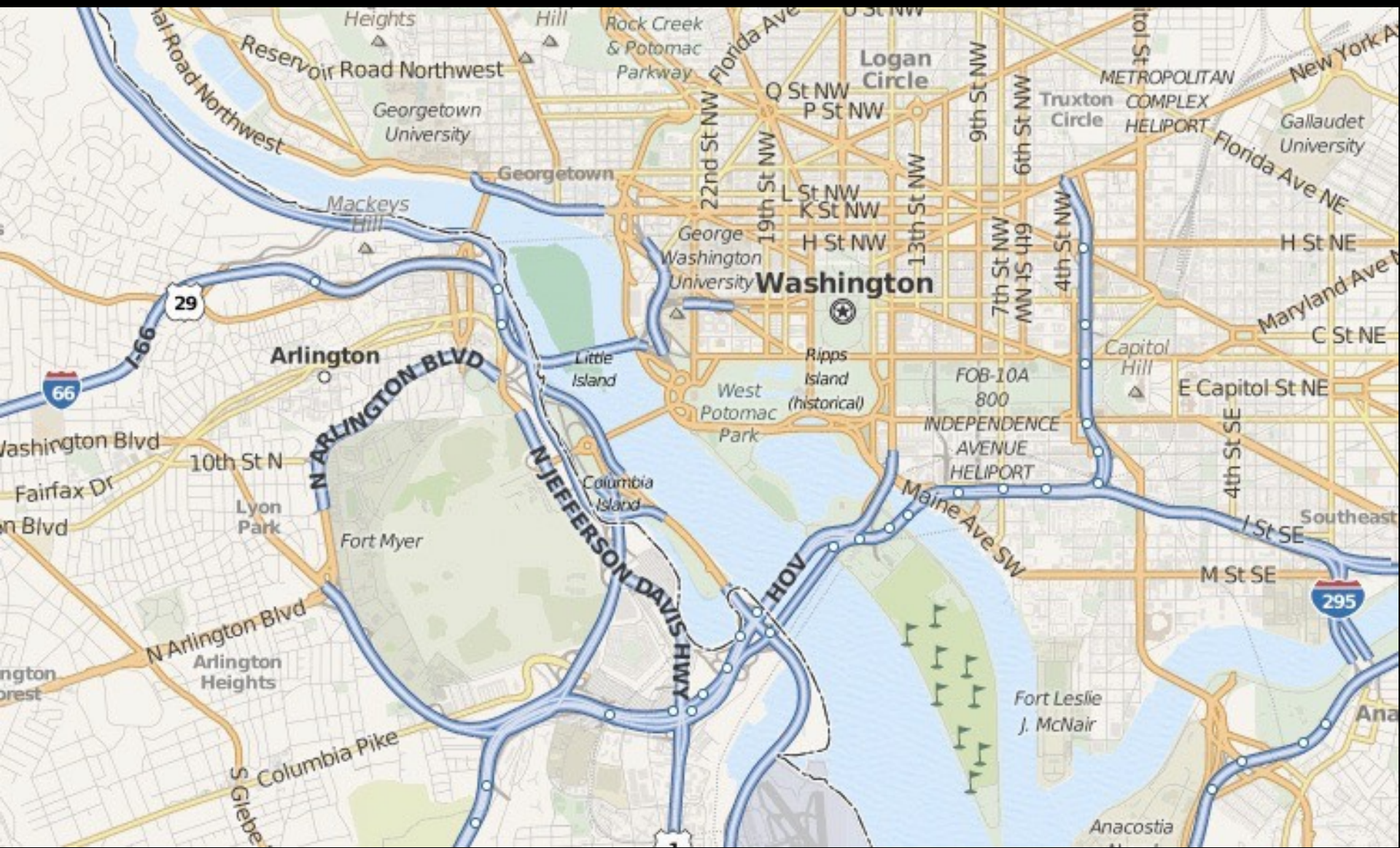
Richmond

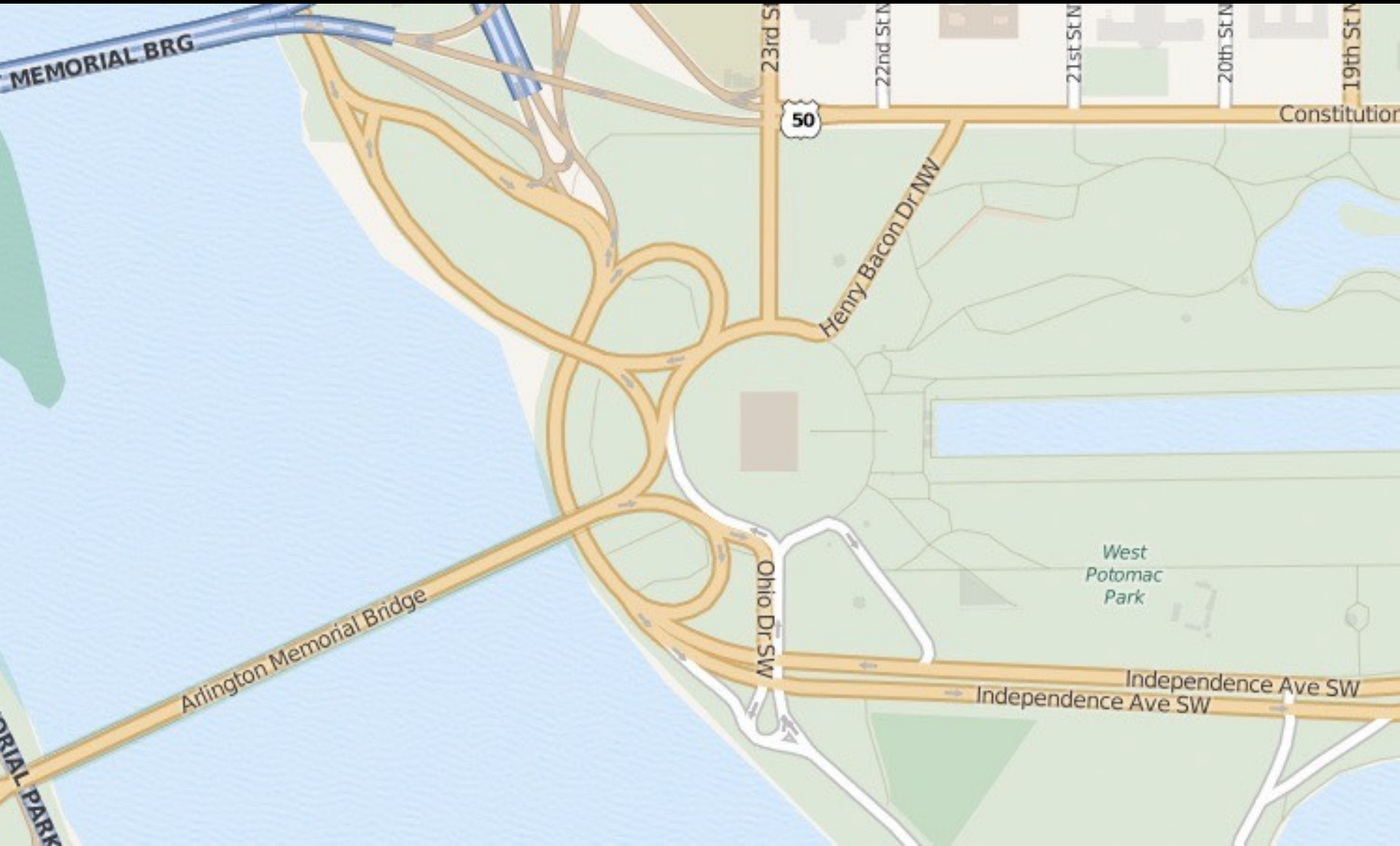
Roanoke

VIRGINIA

Suffolk







MEMORIAL BRG

50

Constitution

Henry Bacon Dr NW

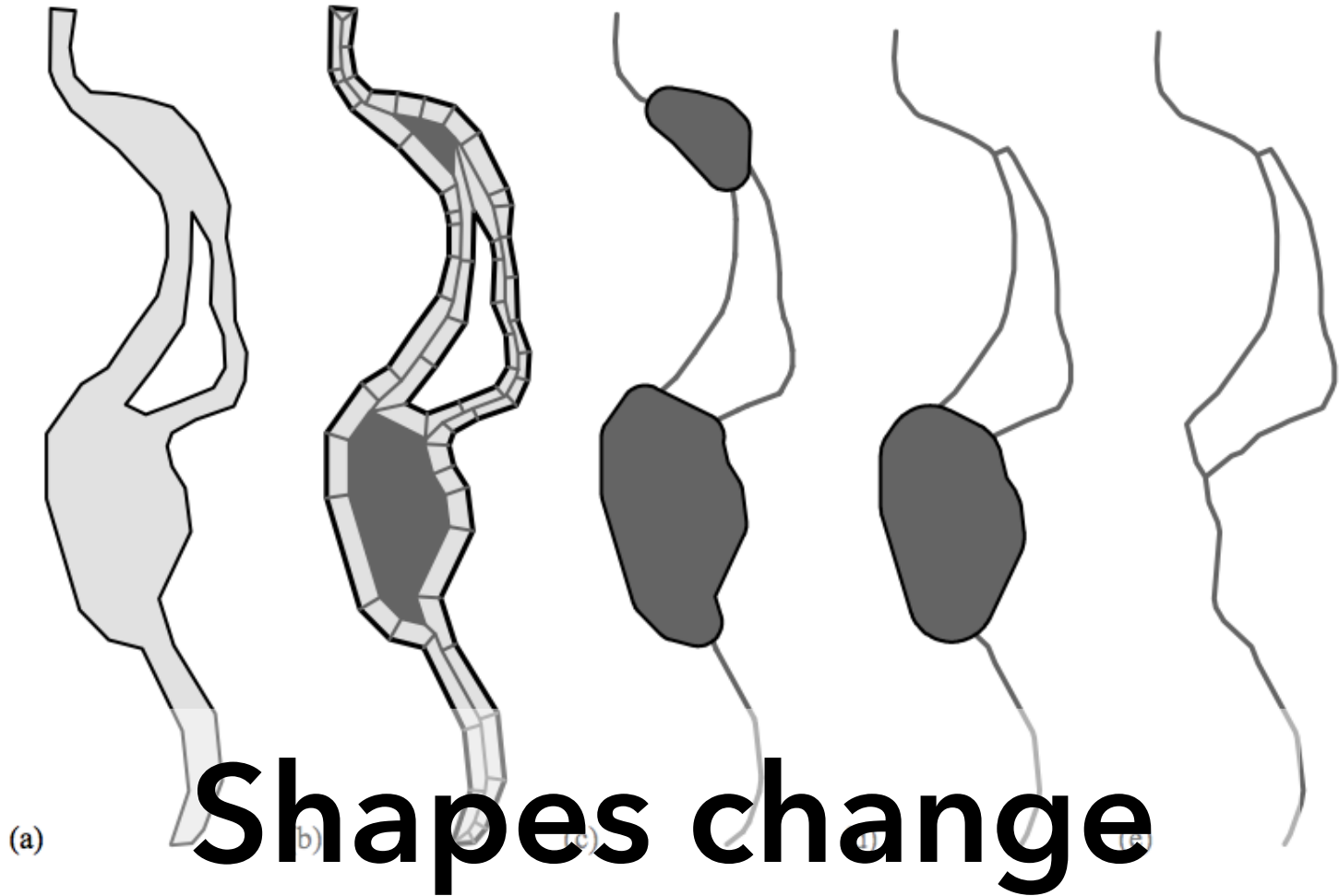
West Potomac Park

Arlington Memorial Bridge

Ohio Dr SW

Independence Ave SW

RIAL PARK



Shapes change

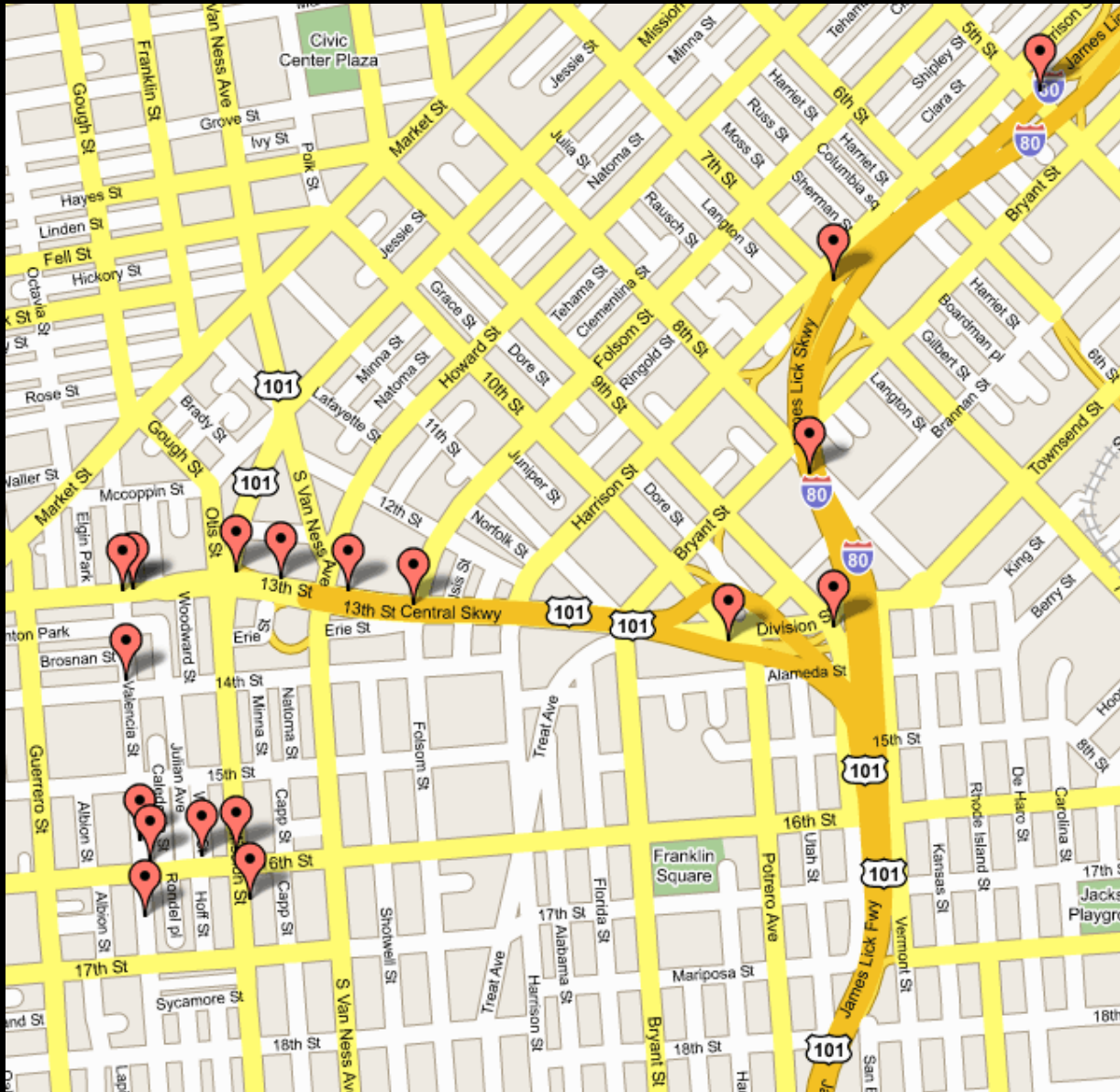
Figure 11. Fragmentation of a river into polygons and lines with different thresholds leading to different results (c, d, e).

at different scales

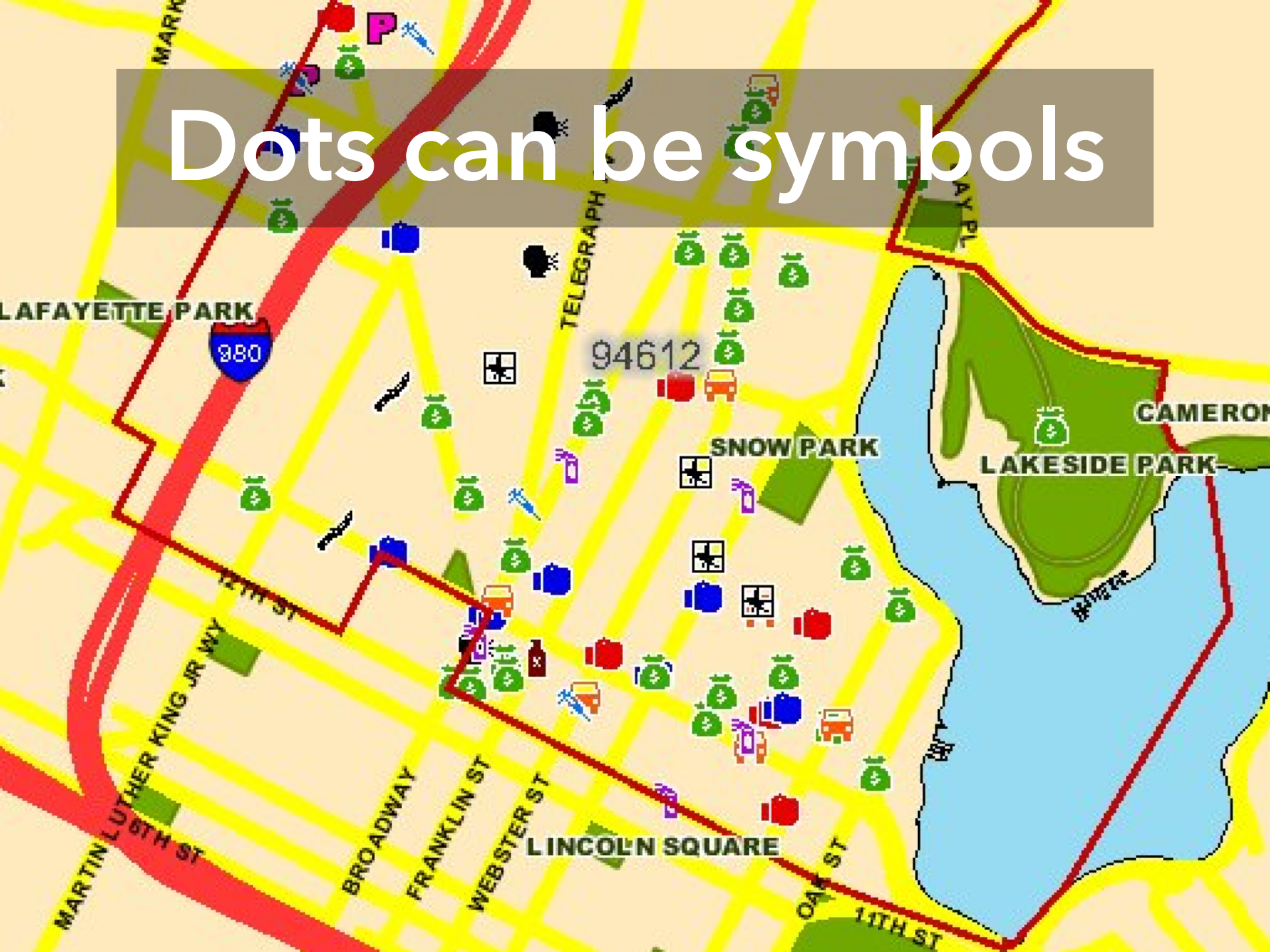
Mapping

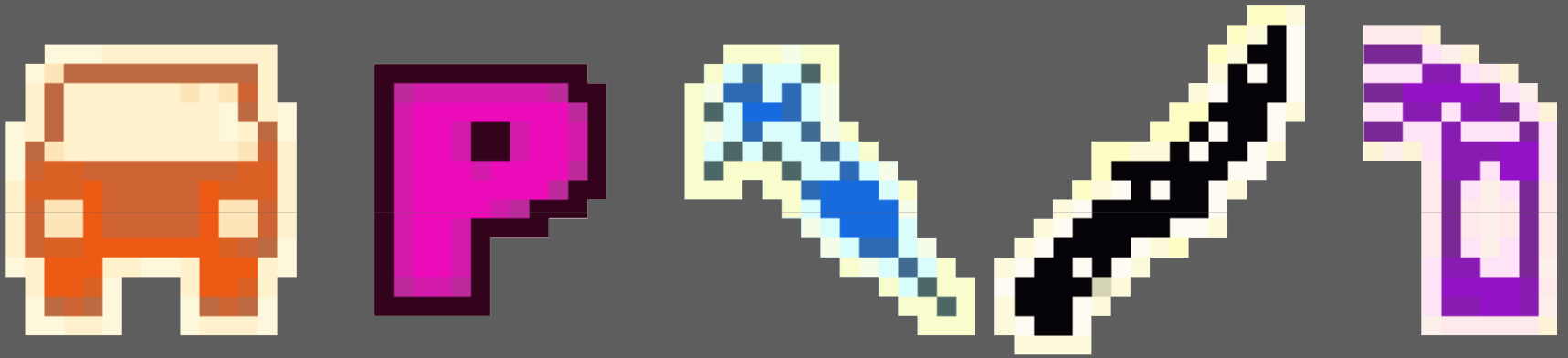
Visualizing Geospatial Data

Symbol Maps



Dots can be symbols





Guess the crime

Dots can can be good symbols



TIME OF DAY
Show All | Hide All
Light | Dark [nearest hour]
Commute | Nightlife
Day | Night | Swing Shift

NOON
12 3 6 9
AM 6 12 PM
MIDNIGHT

CRIME TYPE Show All | Hide All

| | |
|----|----------------------|
| AA | Aggravated Assault |
| Mu | Murder |
| Ro | Robbery |
| SA | Simple Assault |
| DP | Disturbing the Peace |
| Na | Narcotics |
| Al | Alcohol |
| Pr | Prostitution |
| Th | Theft |
| VT | Vehicle Theft |
| Va | Vandalism |
| Bu | Burglary |
| Ar | Arson |

DATE Past Week
Sep 2009
AUG 17 2009 AUG 24 2009 AUG 31 2009 SEP 7 2009

T W Th F S S M T W Th F S S M T W Th F S S M



Dots can include data

Dots are ubiquitous



"Red Dot Fever"



Mapping America: Every City, Every Block

Find something interesting? Share this view on [Twitter](#) or [Facebook](#)

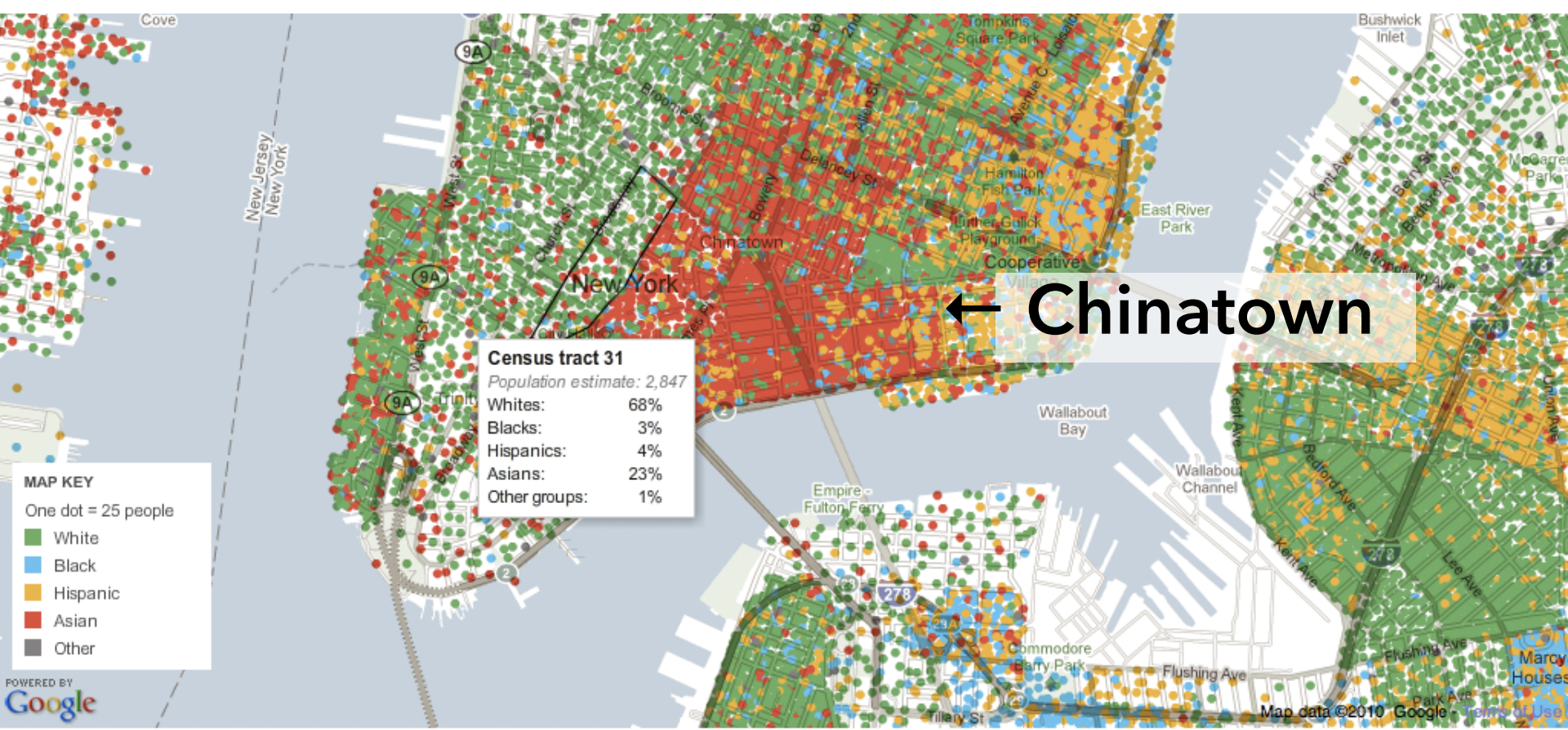
Browse local data from the Census Bureau's American Community Survey, based on samples from 2005 to 2009. Because these figures are based on [View Readers Maps \(49\)](#) samples, they are subject to a margin of error, particularly in places with a low population, and are best regarded as estimates.

Distribution of racial and ethnic groups

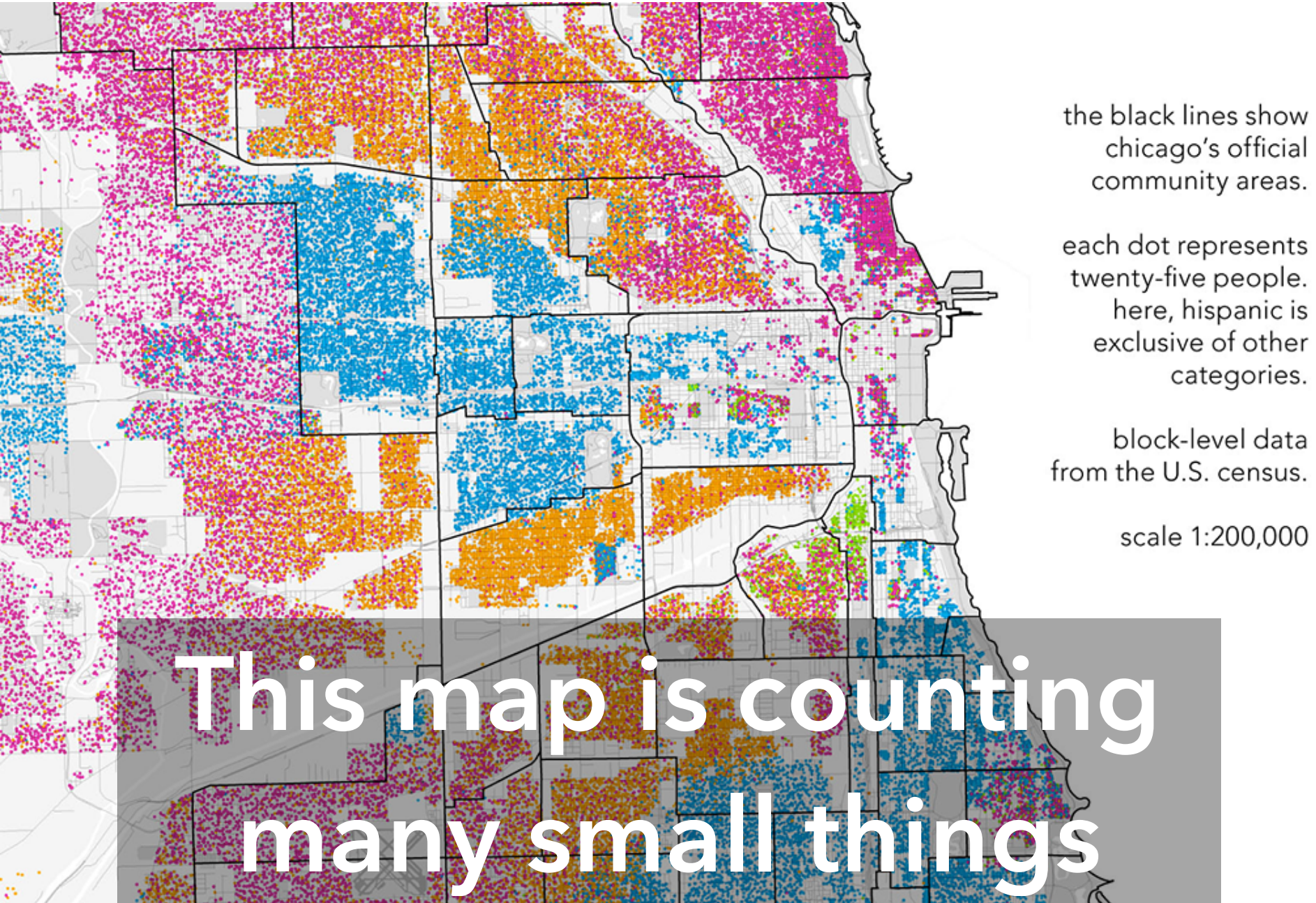
[View More Maps](#)

Address, ZIP code or city

Go

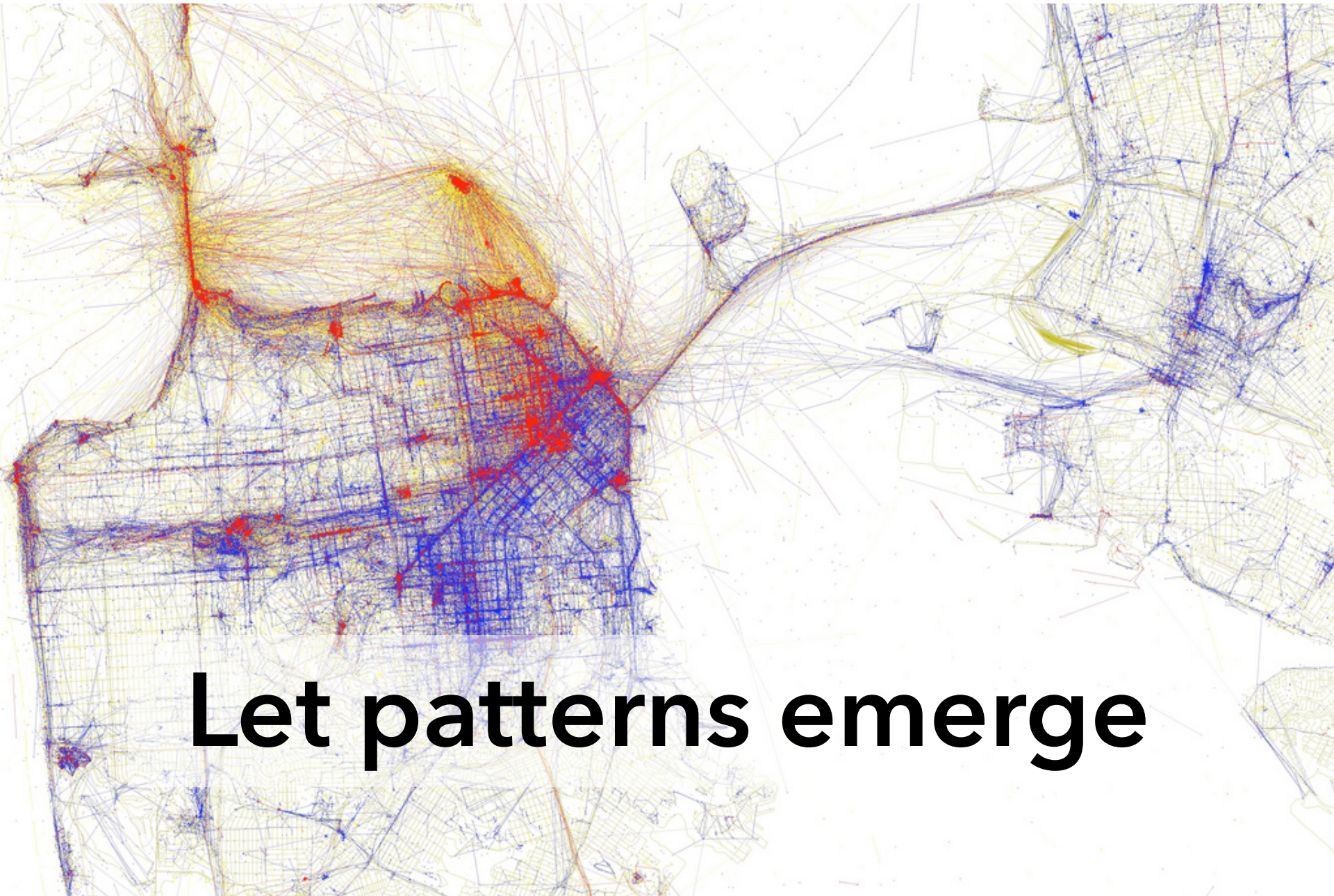


← Chinatown



Clustering, grouping

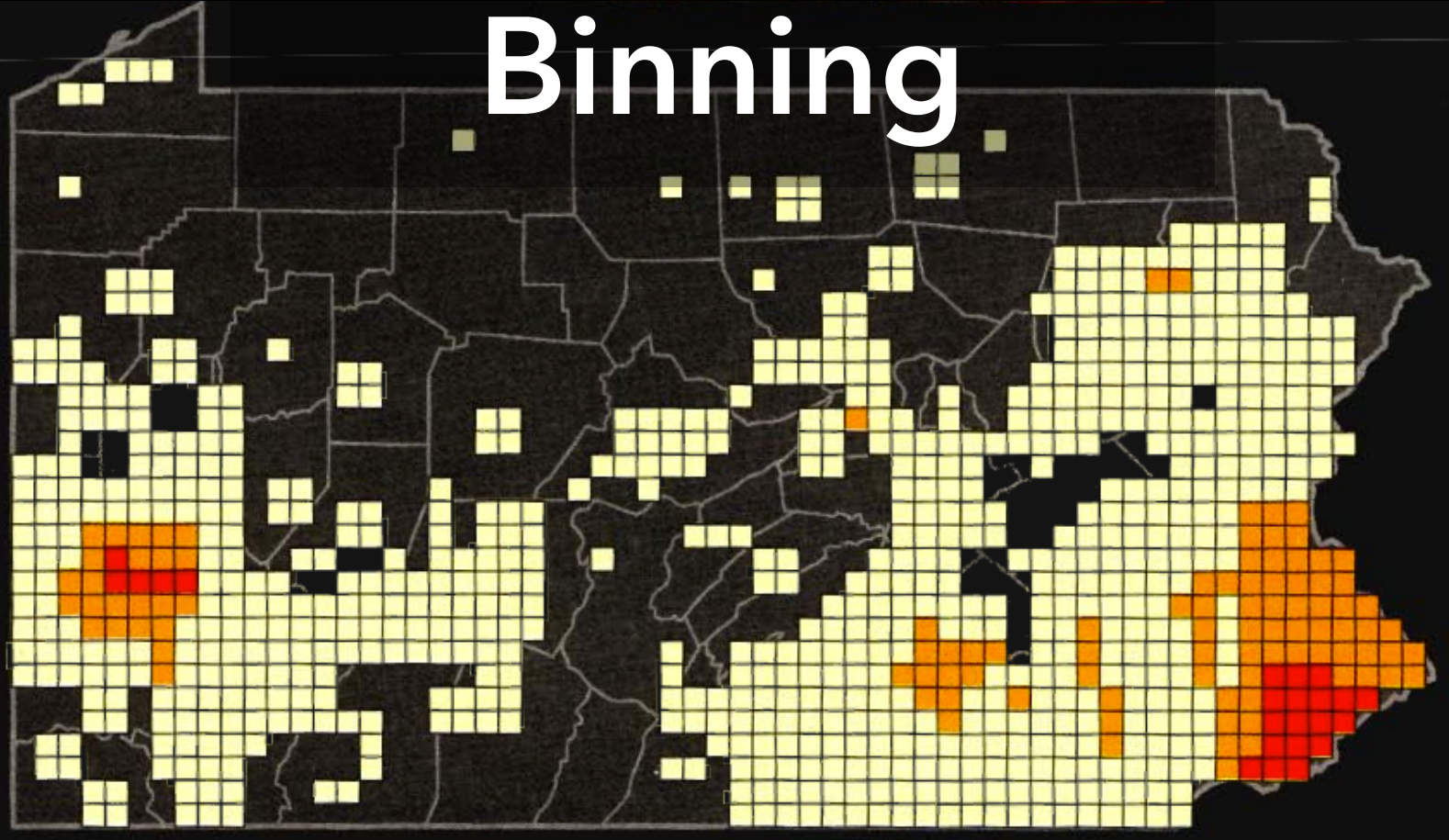


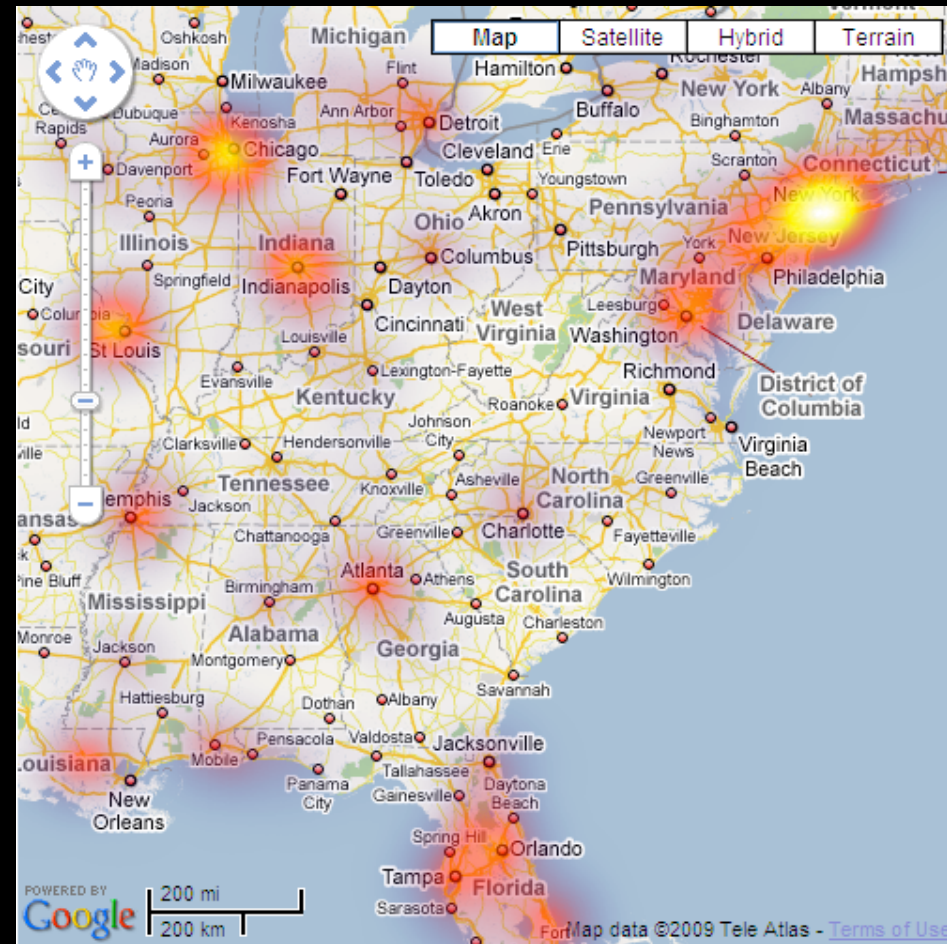
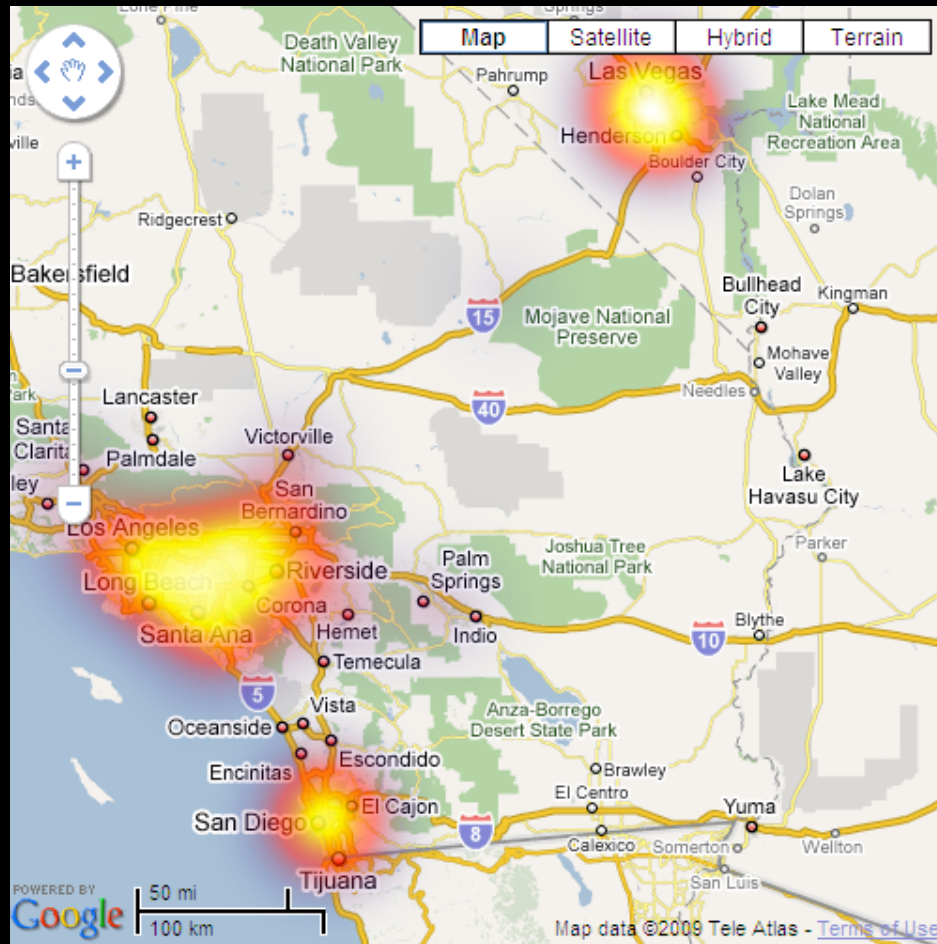


Let patterns emerge

Continuous Data

Binning

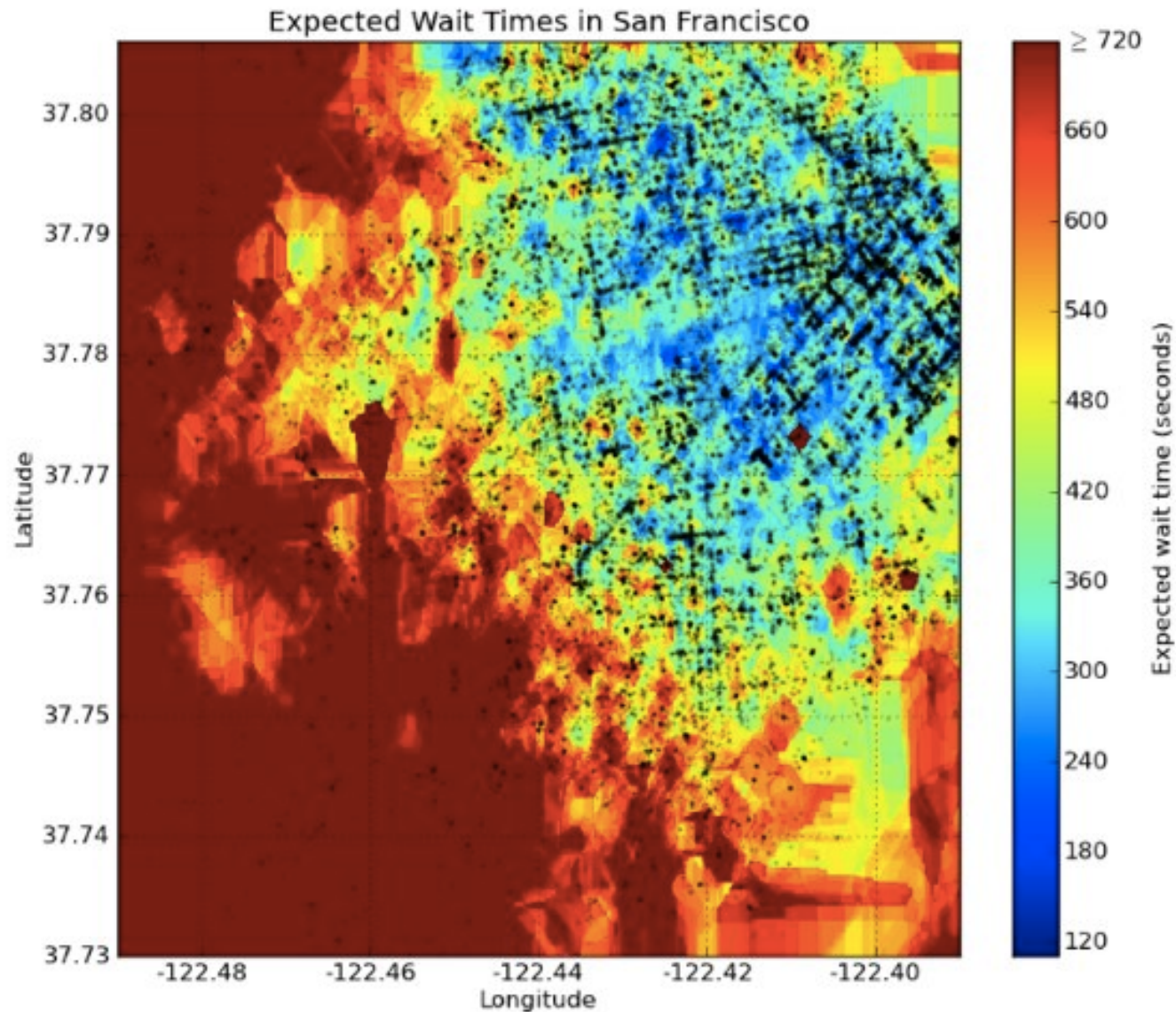




Don't hide the context

Uber Wait Times, 2011

<http://sta.mn/6x27>



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

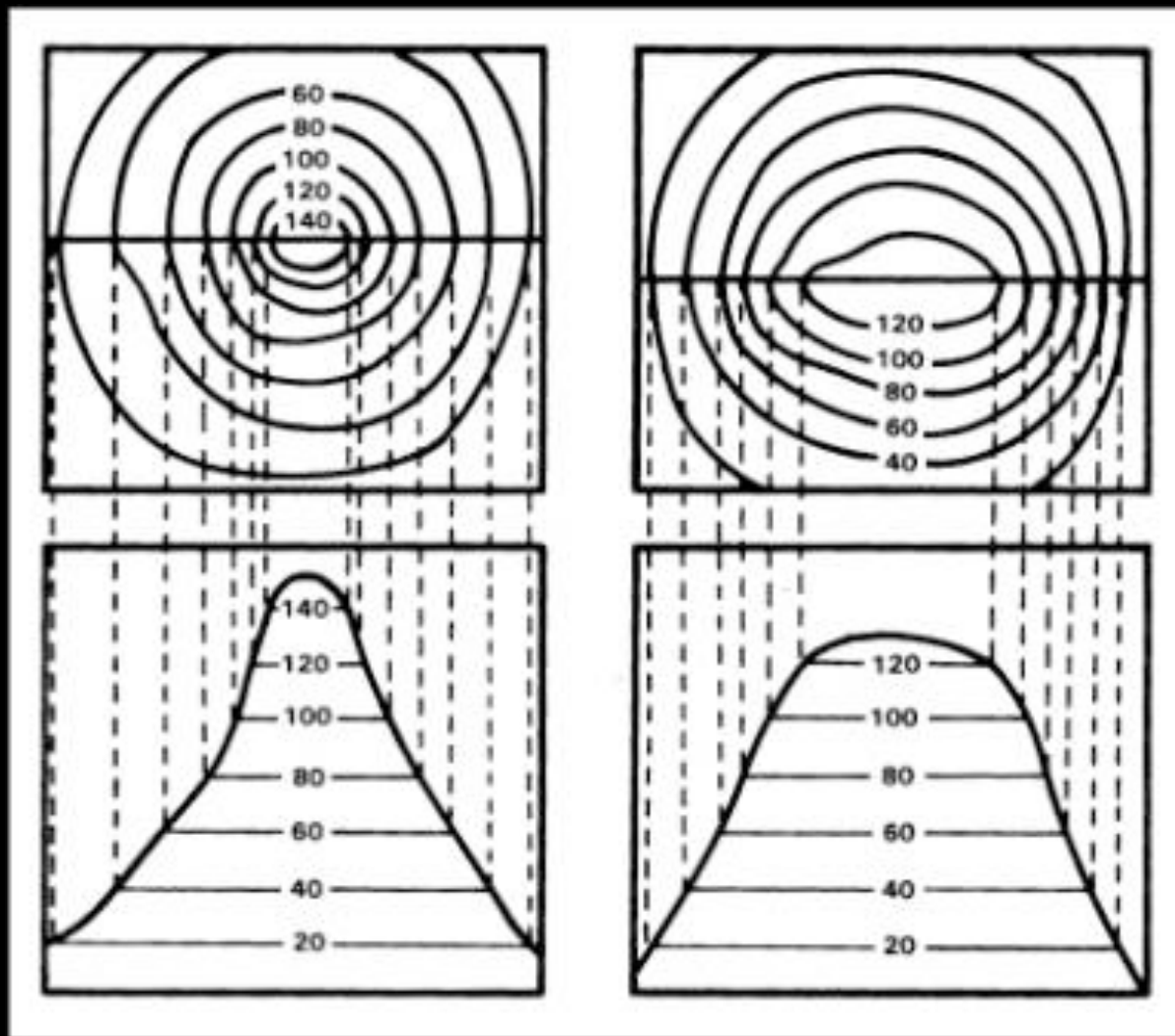
KEY

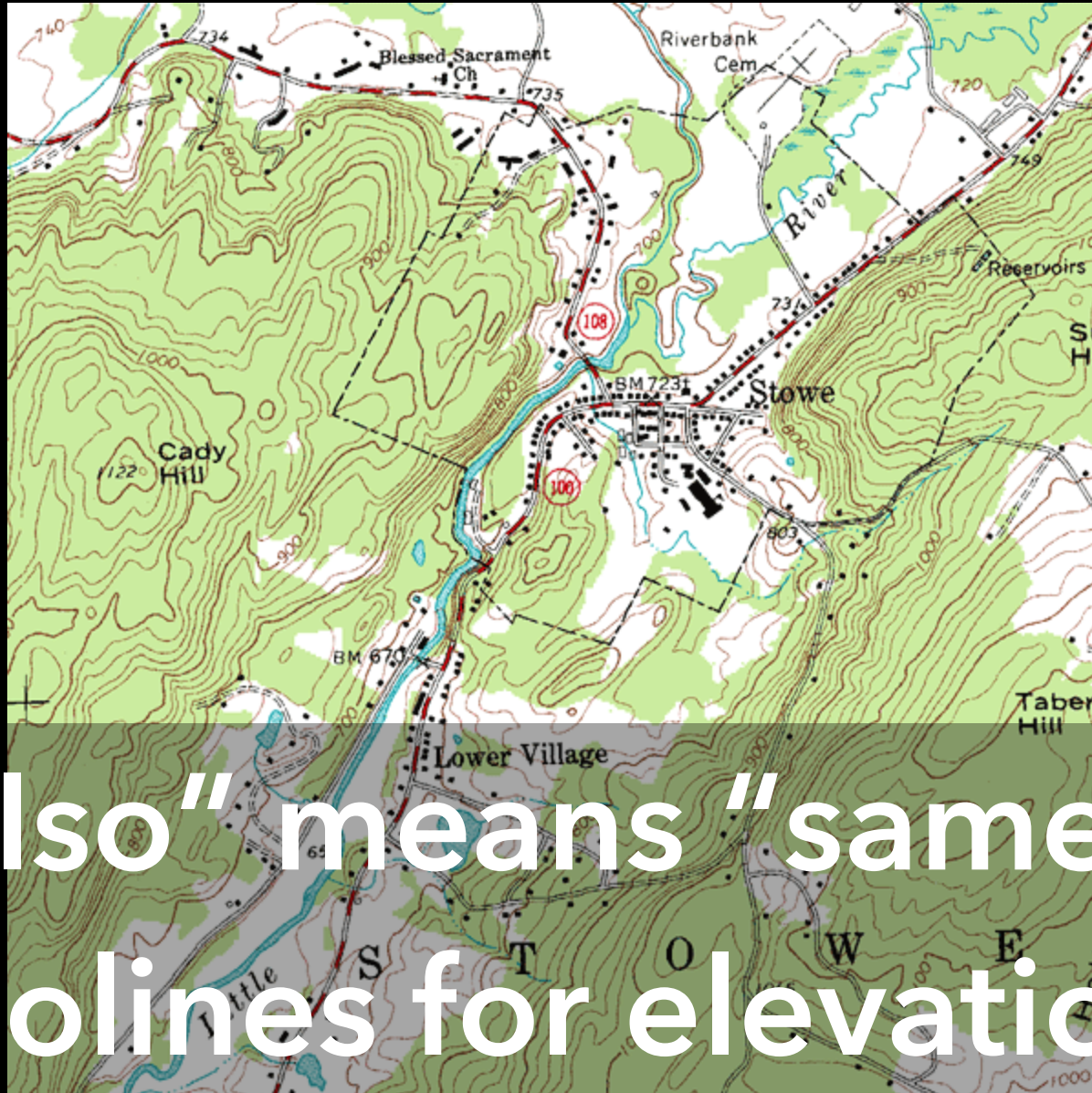
Colours show how recently a crime was reported in a given part of Oakland

- A week ago
- Two weeks ago
- A month ago
- Two months ago
- Three months ago
- Four months ago
- Five months ago

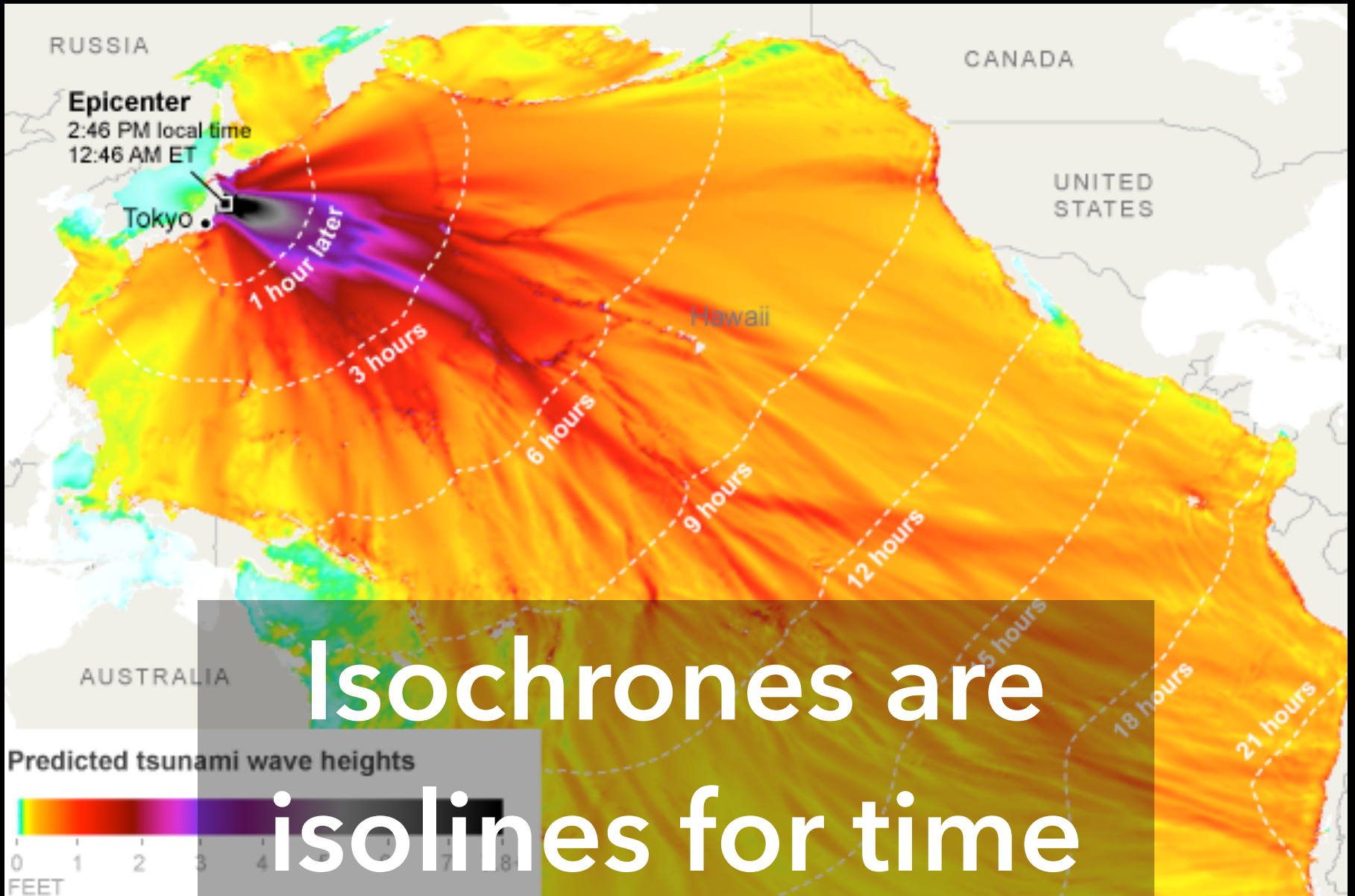
Meaningful buckets

<http://sta.mn/b6>



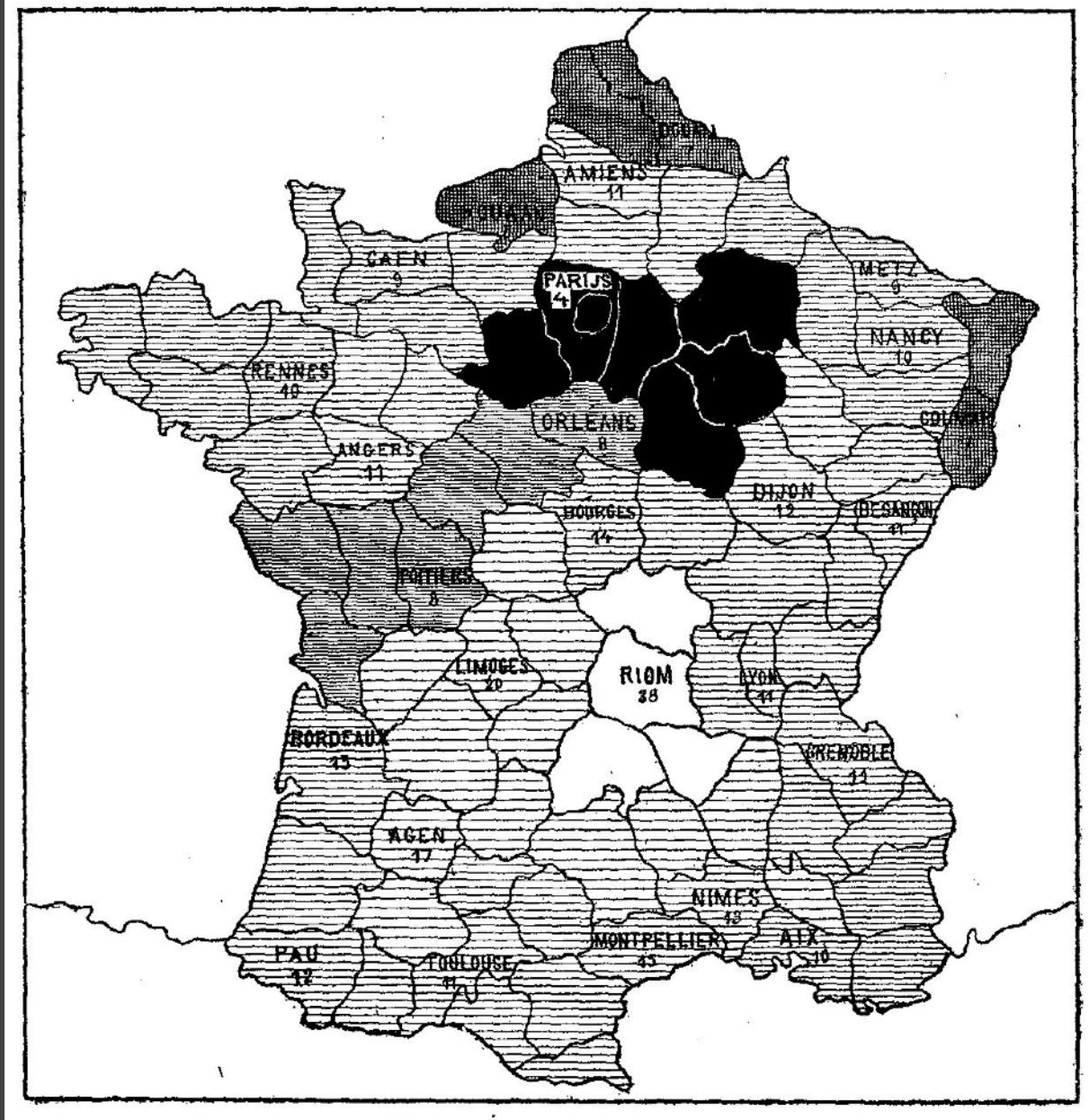


“Iso” means “same”
Isolines for elevation



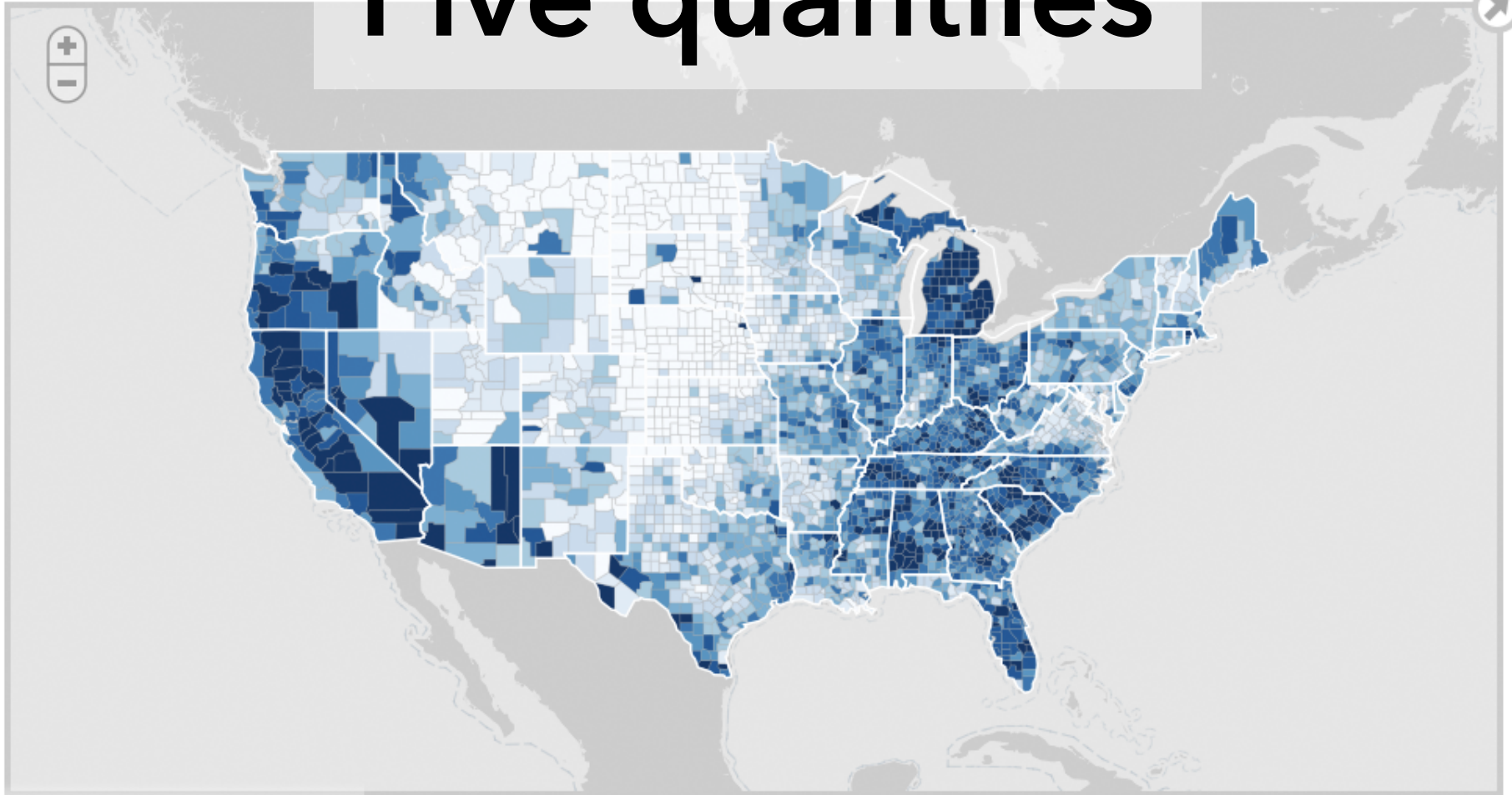
**Isochrones are
isolines for time**

Choropleth Maps

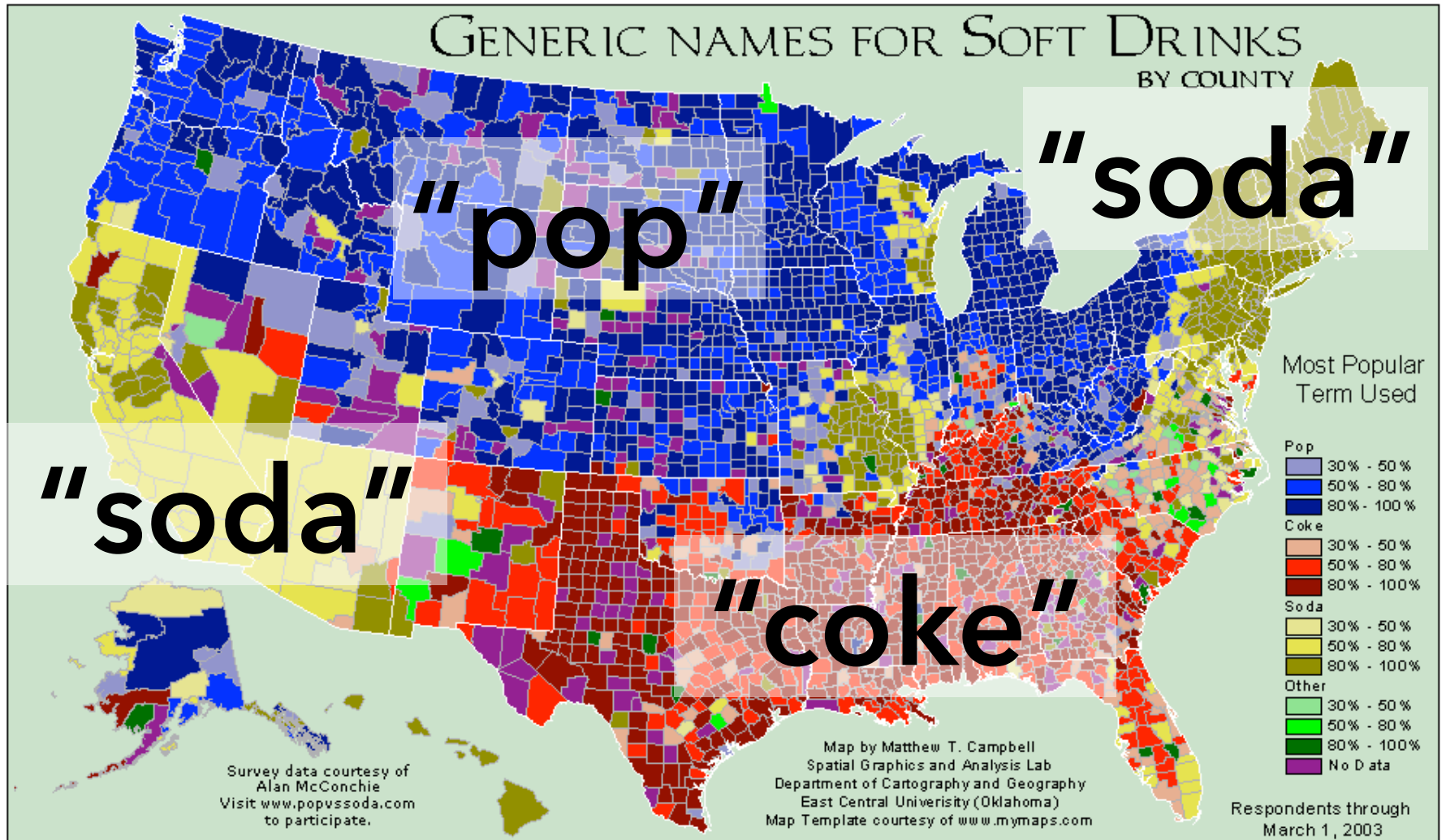


1826(?) Illiteracy in France, Pierre Charles Dupin

Five quantiles

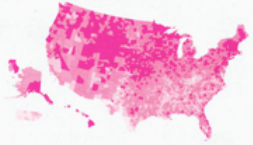


GENERIC NAMES FOR SOFT DRINKS BY COUNTY



READING, WRITING, AND EARNING MONEY

The latest data from the U.S. Census's American Community Survey paints a fascinating picture of the United States at the county level. We've looked at the educational achievement and the median income of the entire nation, to see where people are going to school, where they're earning money, and if there is any correlation.



A HIGH SCHOOL GRADUATES 65% 75% 82% 85%



B COLLEGE GRADUATES 15% 22% 30% 40%

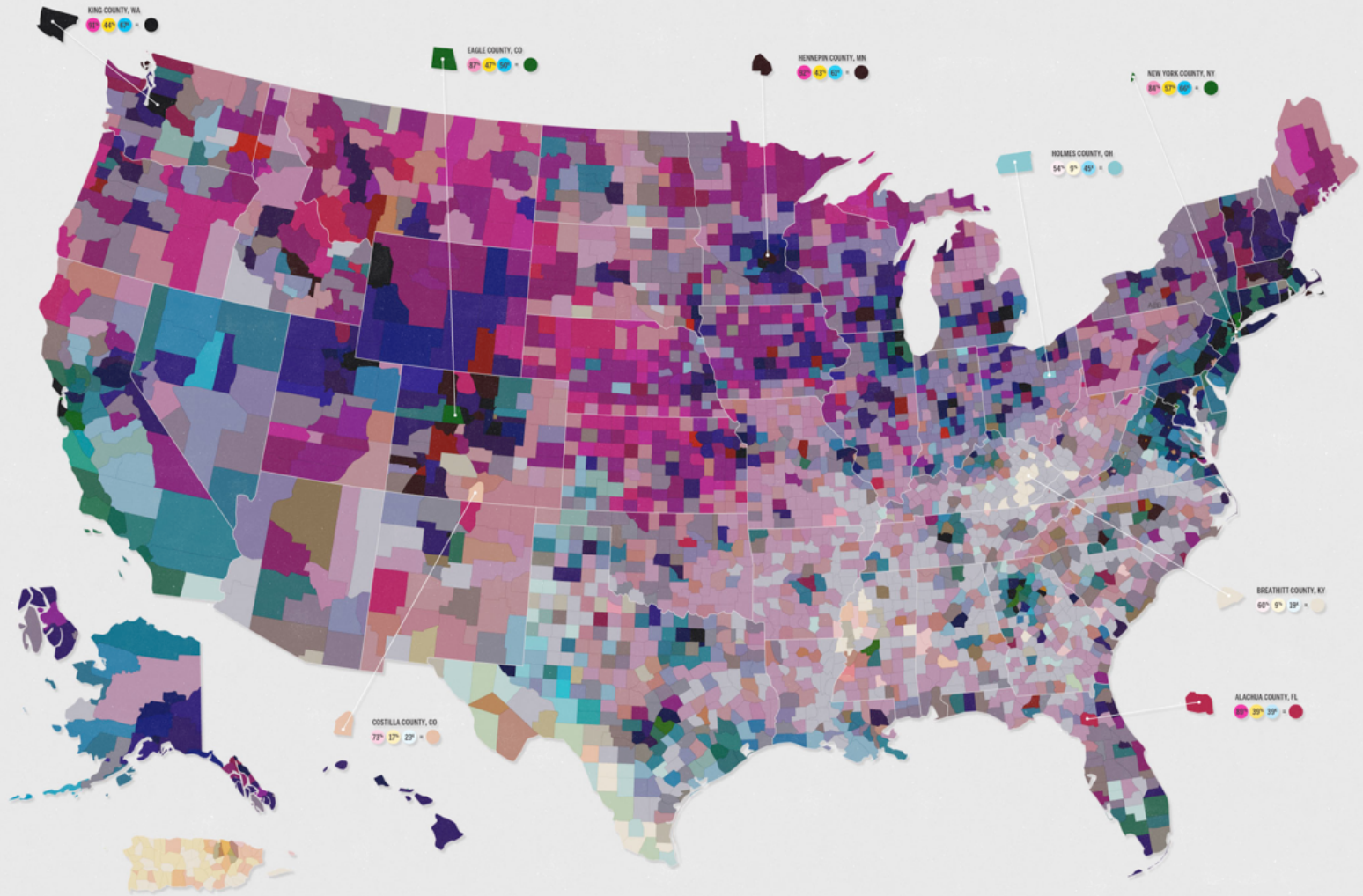


C MEDIAN HOUSEHOLD INCOME 25K 40K 50K 60K

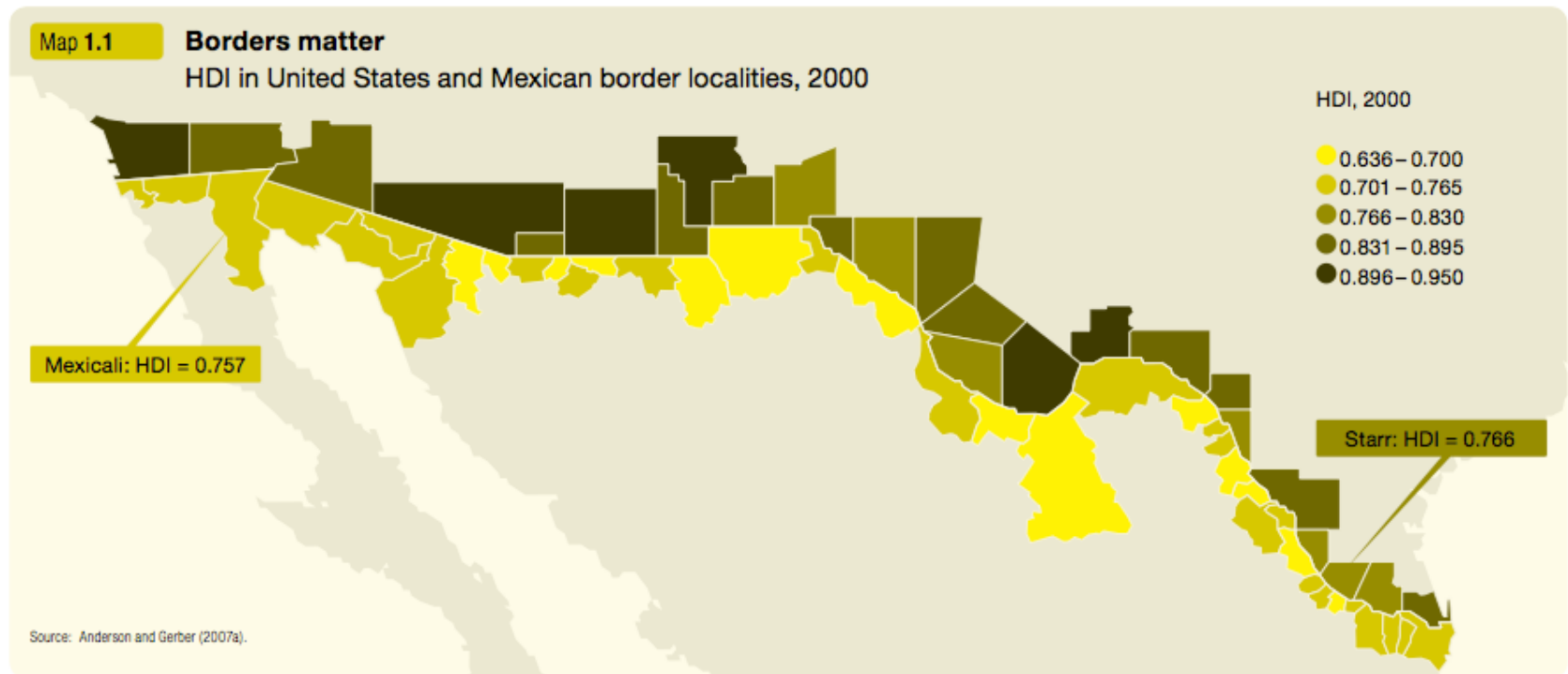
The map at right is a product of overlaying the three sets of data. The variation in hue and value has been produced from the data shown above. In general, darker counties represent a more educated, better paid population while lighter areas represent communities with fewer graduates and lower incomes.



A collaboration between GOOD and Gregory Huback
SOURCE: US Census



Choose colors well



Focus on the foreground

Sort: Default Edit

State



ABC City

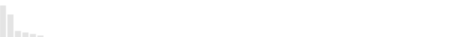


WASHINGTON 40 2.60%

File_Number



ABC CommitteeID



ABC Occupation



ABC Memo_Text



ABC Report_Type



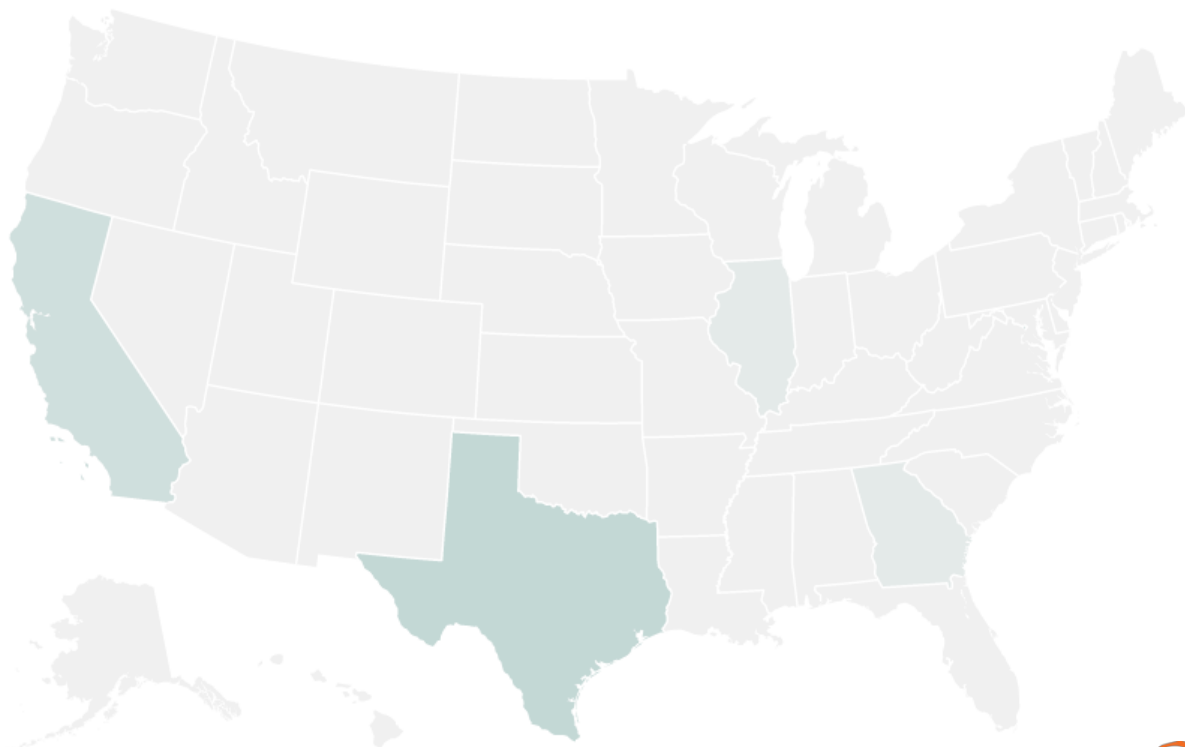
Trans_Date



Trans_Amount



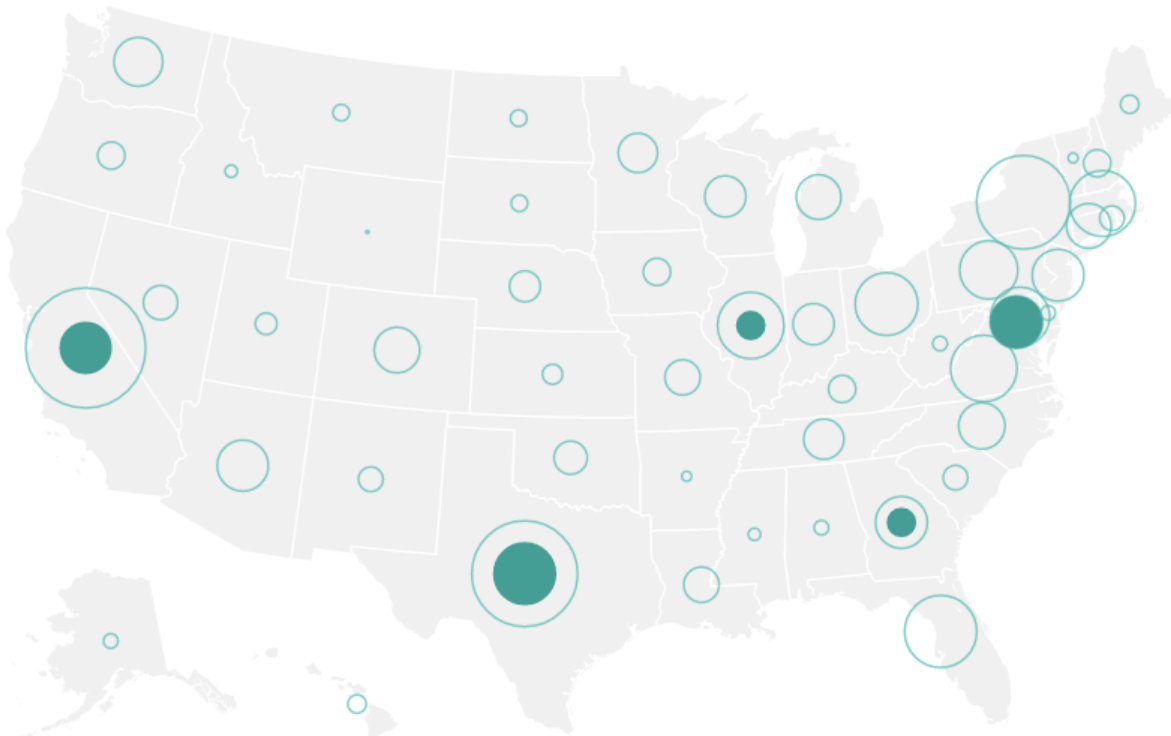
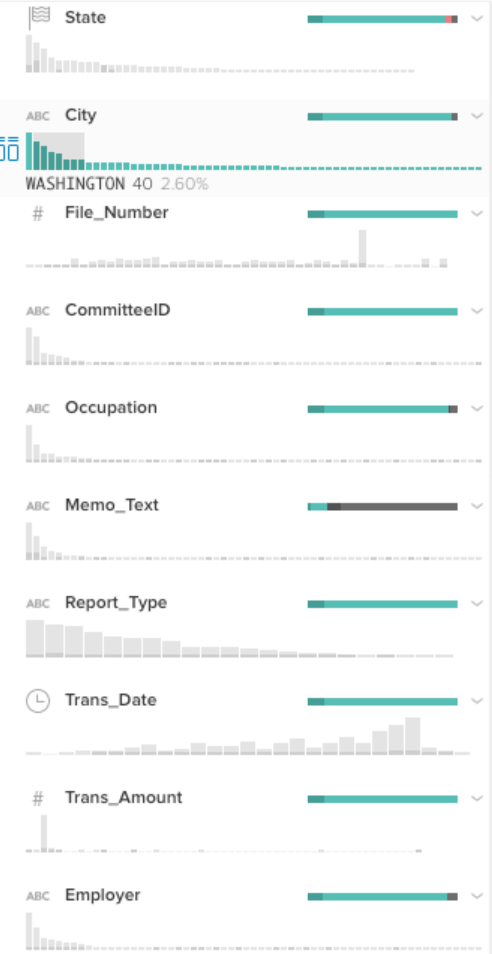
ABC Employer



What is obscured?

Sort: Default Edit

State



Regions -> Symbols

Cartograms

New York Times ratings

198
Safe Dem.

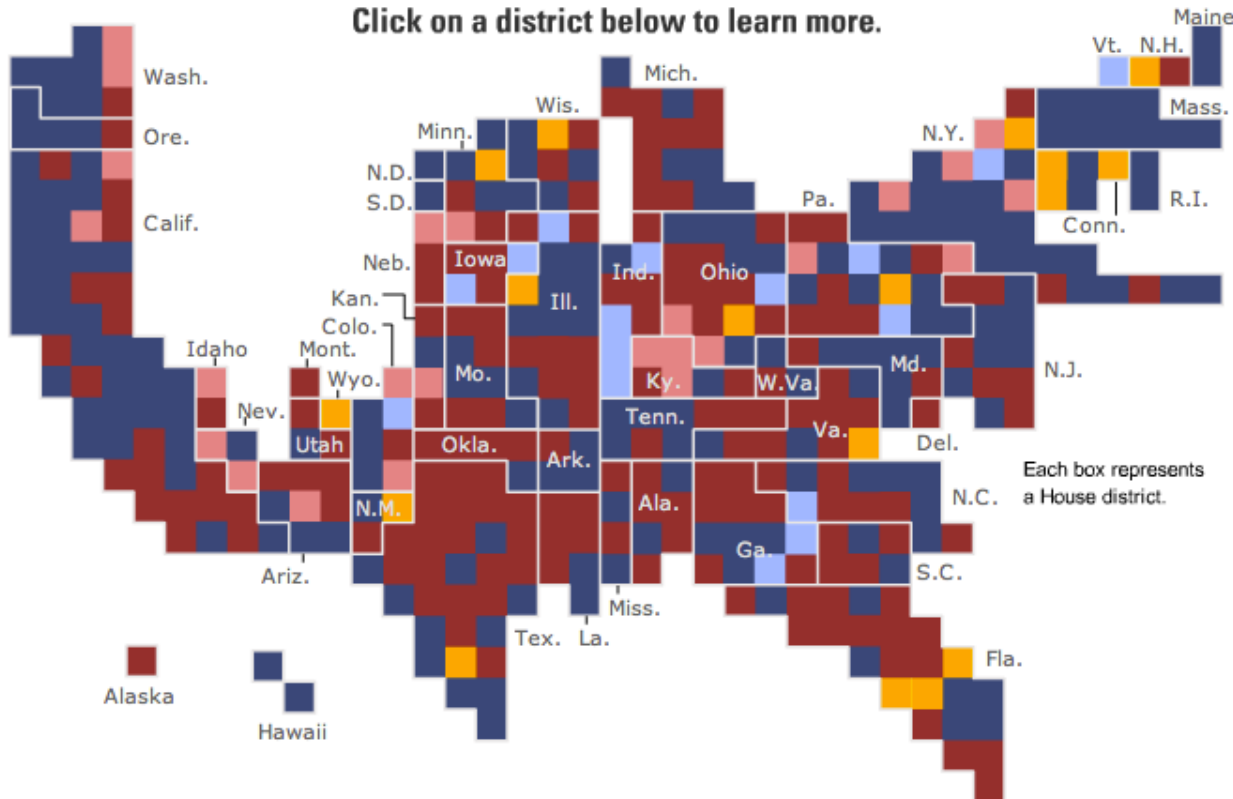
16
Leaning Dem.

17
Toss up

24
Leaning Rep.

180
Safe Rep.

Click on a district below to learn more.



Each box represents a House district.

ANALYZE RACES

CREATE OUTCOMES

Shade the map using the pulldown...

New York Times ratings [dropdown menu]

...then show only certain states

New York Times ratings ?

Democrat: Safe Leaning Toss Up

Republican: Safe Leaning

Current Rep. Dem. Rep.

Margin in 2004 House race

Democrat: >50% 25-50% <25%

Republican: >50% 25-50% <25%

Votes for president Kerry Gore Bush Bush

Appearances by big fundraisers ?

George W. Bush Bill Clinton

Races to watch ?

Open races

Switch districts ?

Urbanization

Urban Suburban Rural Mixed

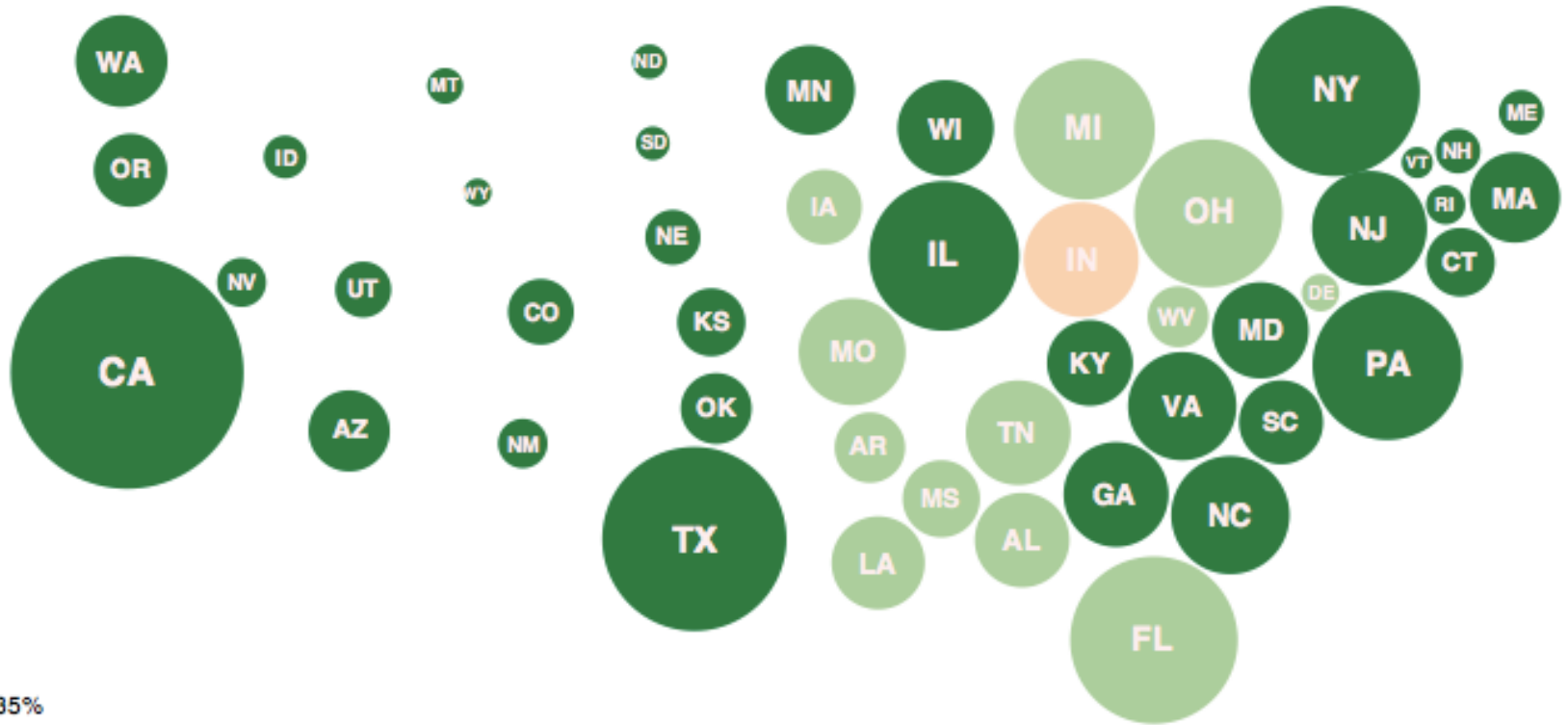
Race/Ethnicity

White Black Hispanic

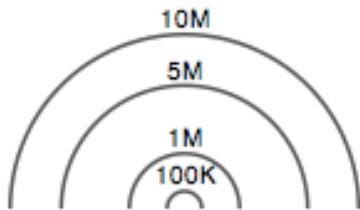
Median income

<\$30K \$30-50K >\$50K

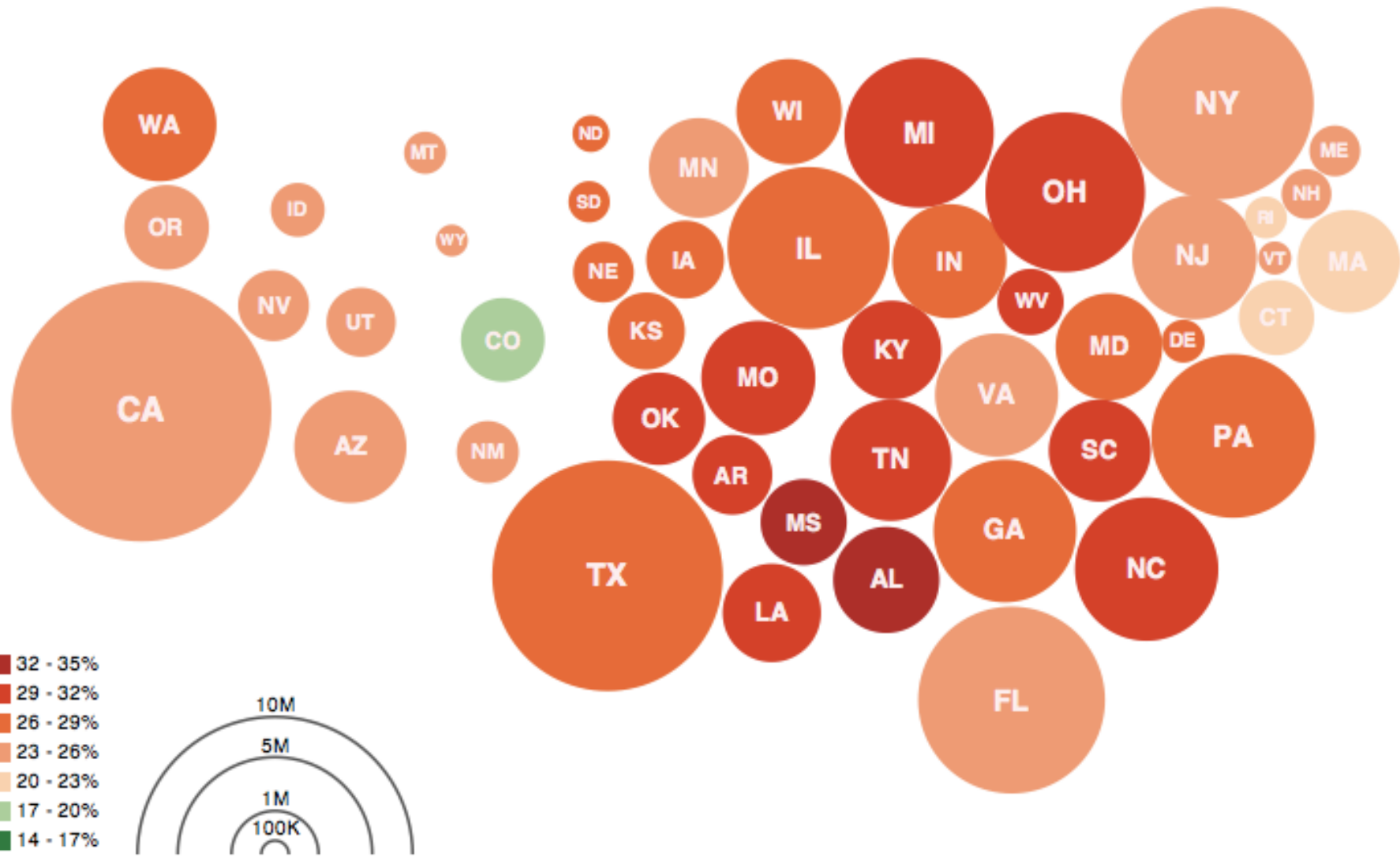
RESET



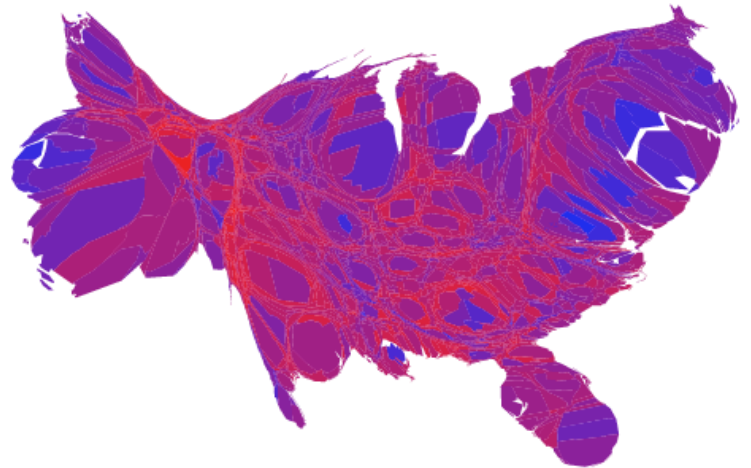
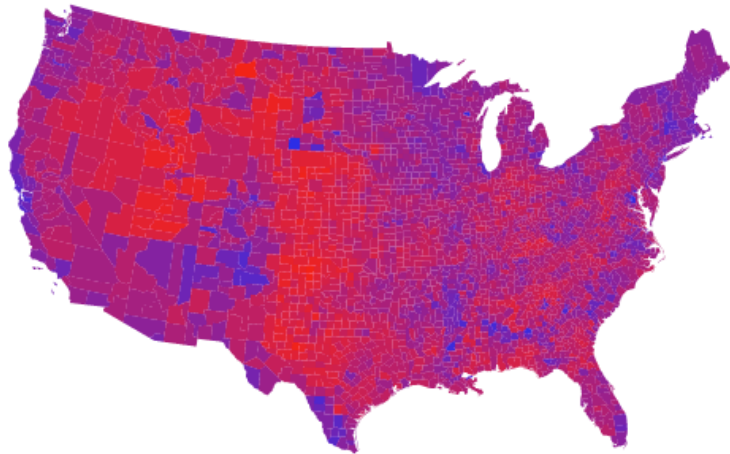
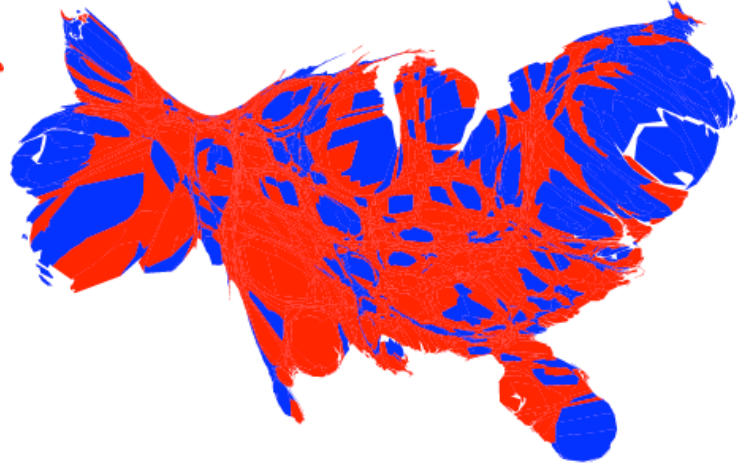
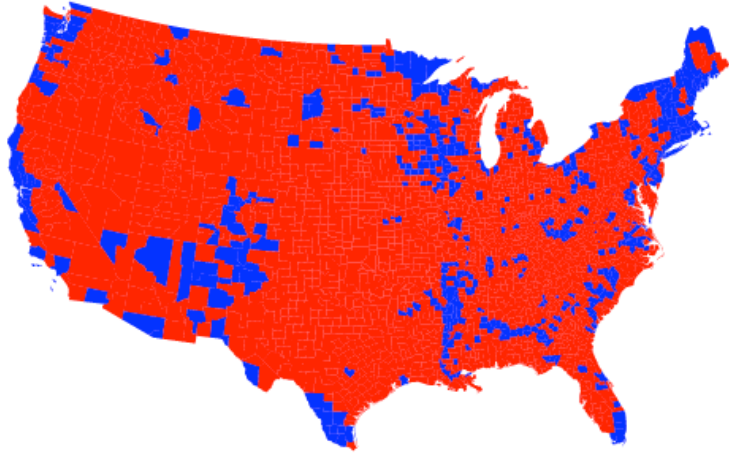
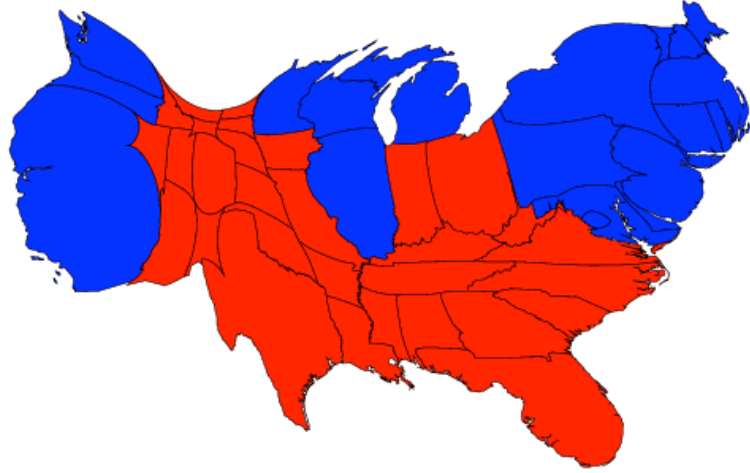
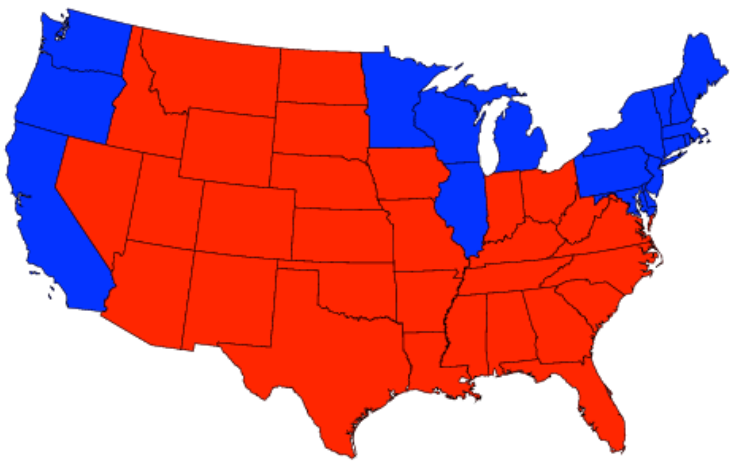
- 32 - 35%
- 29 - 32%
- 26 - 29%
- 23 - 26%
- 20 - 23%
- 17 - 20%
- 14 - 17%



Obesity Map (Dorling Cartogram) Vadim Ogievetsky



Obesity Map (Dorling Cartogram) Vadim Ogievetsky



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 »](#)

Economic Output

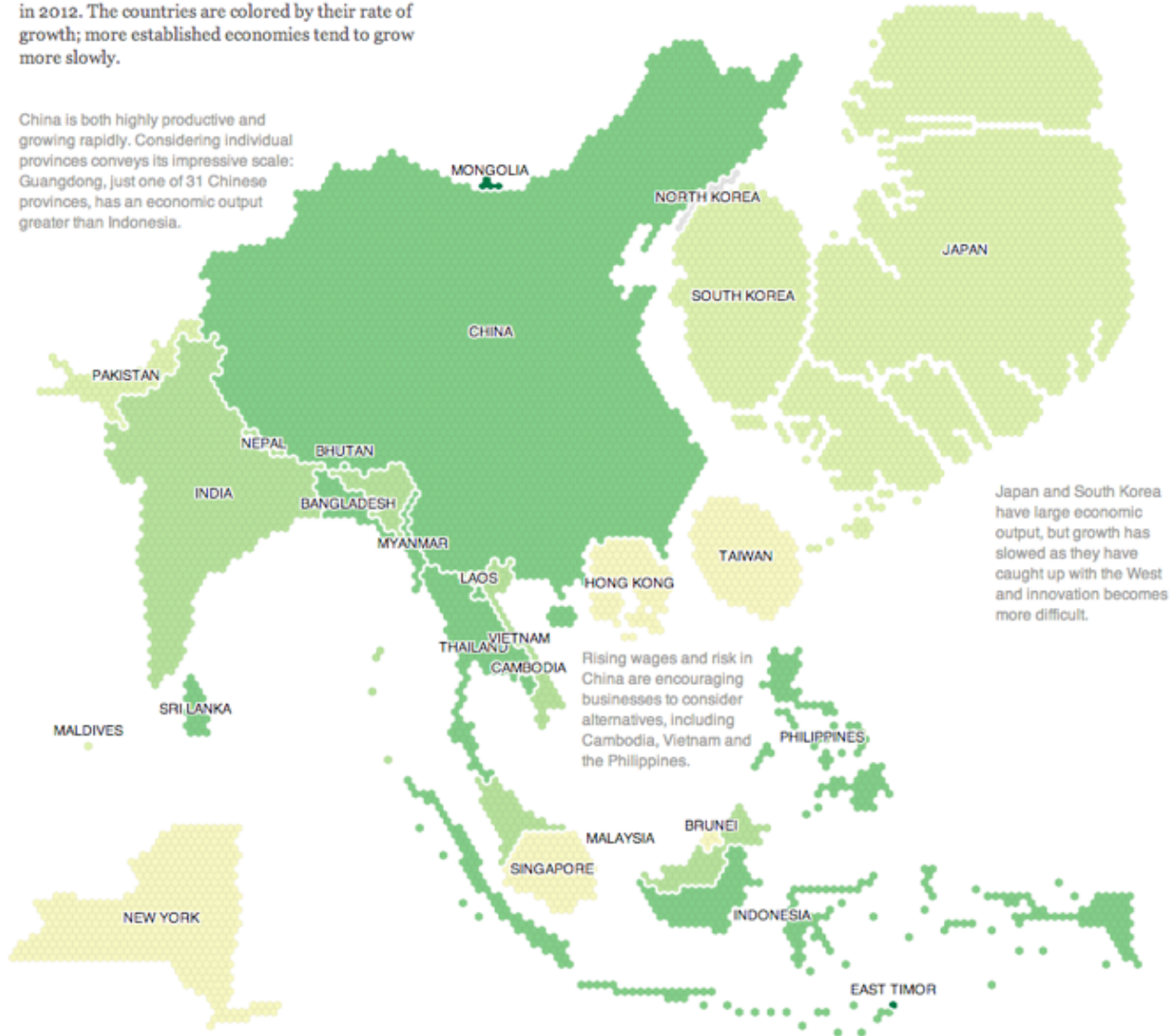
In this map, geography is distorted so that each country is **sized according to its economic output in 2012**. The countries are colored by their rate of growth; more established economies tend to grow more slowly.

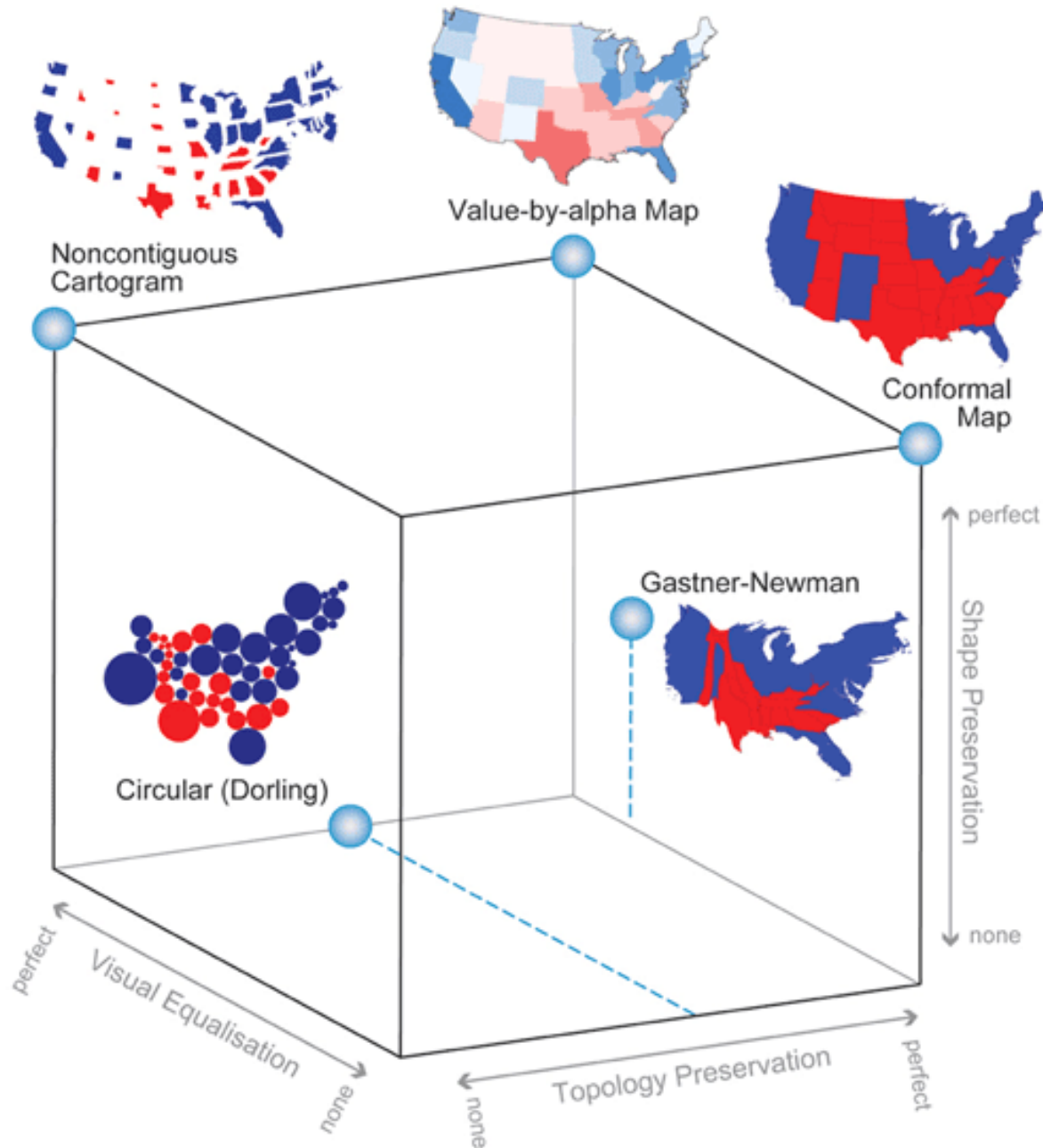
China is both highly productive and growing rapidly. Considering individual provinces conveys its impressive scale: Guangdong, just one of 31 Chinese provinces, has an economic output greater than Indonesia.

Each hexagon represents \$2.7 billion in G.D.P.

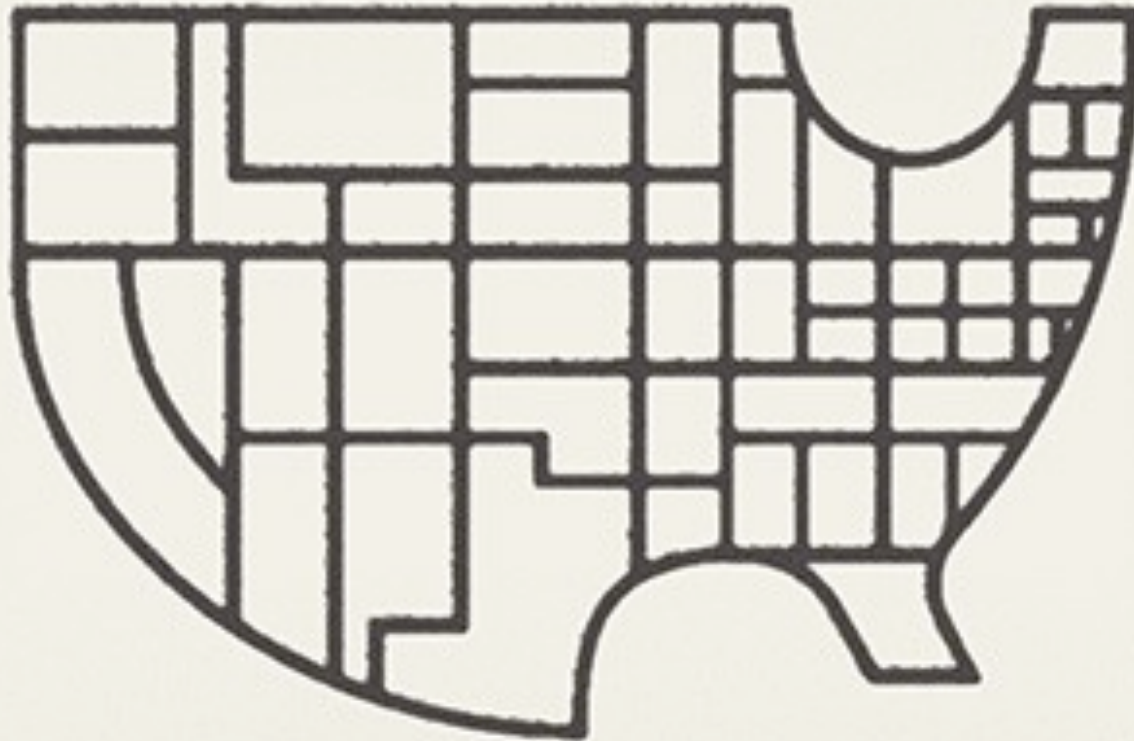
G.D.P. growth, 2011 to 2012

2 4 6 8 +10%





**Major distortions
can stay recognizable**



Flow Maps

Minard 1869: Napoleon's march

Carte Figurative des pertes successives en hommes de l'Armée Française dans la campagne de Russie 1812-1813.
Dressée par M. Minard, Inspecteur Général des Ponts et Chaussées en retraite Paris, le 20 Novembre 1869.

Les nombres d'hommes présents sont représentés par les largeurs des zones colorées à raison d'un millimètre pour dix mille hommes; ils sont plus écrits en travers des zones. Le rouge désigne les hommes qui entrent en Russie, le noir ceux qui en sortent. Les renseignements qui ont servi à dresser la carte ont été puisés dans les ouvrages de M. M. Chier, de Fozensac, de Chambray et le journal inédit de Jacob, pharmacien de l'Armée depuis le 28 Octobre. Pour mieux faire juger à l'œil la diminution de l'armée, j'ai supposé que les corps du Prince Jérôme et du Maréchal Davout qui avoient été détachés sur Minsk et Mohilow et qui rejoindrent Orscha et Witebsk, avoient toujours marché avec l'armée.

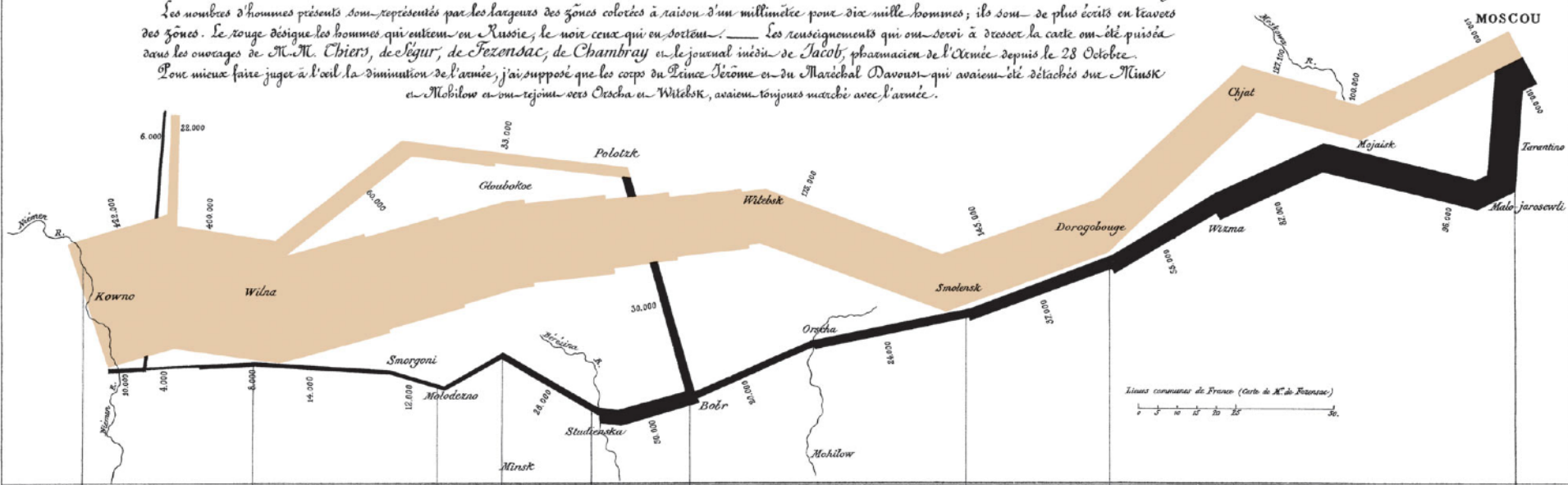
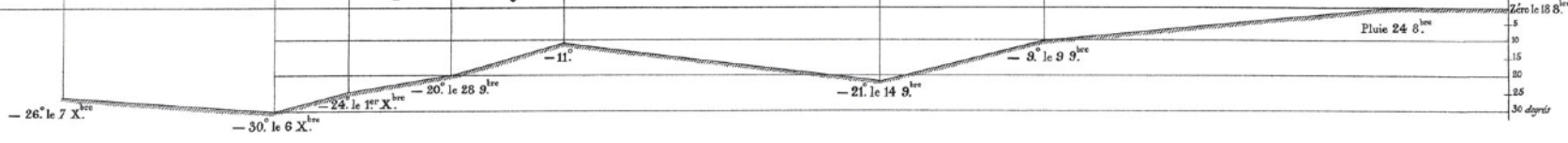


TABLEAU GRAPHIQUE de la température en degrés du thermomètre de Réaumur au dessous de zéro.

Les Cosaques passent au galop le Niémen gelé.



Autog. par Regnier, 8, Rue St-Marc St-Germain à Paris.

Imp. Lit. Regnier et Dourdet.

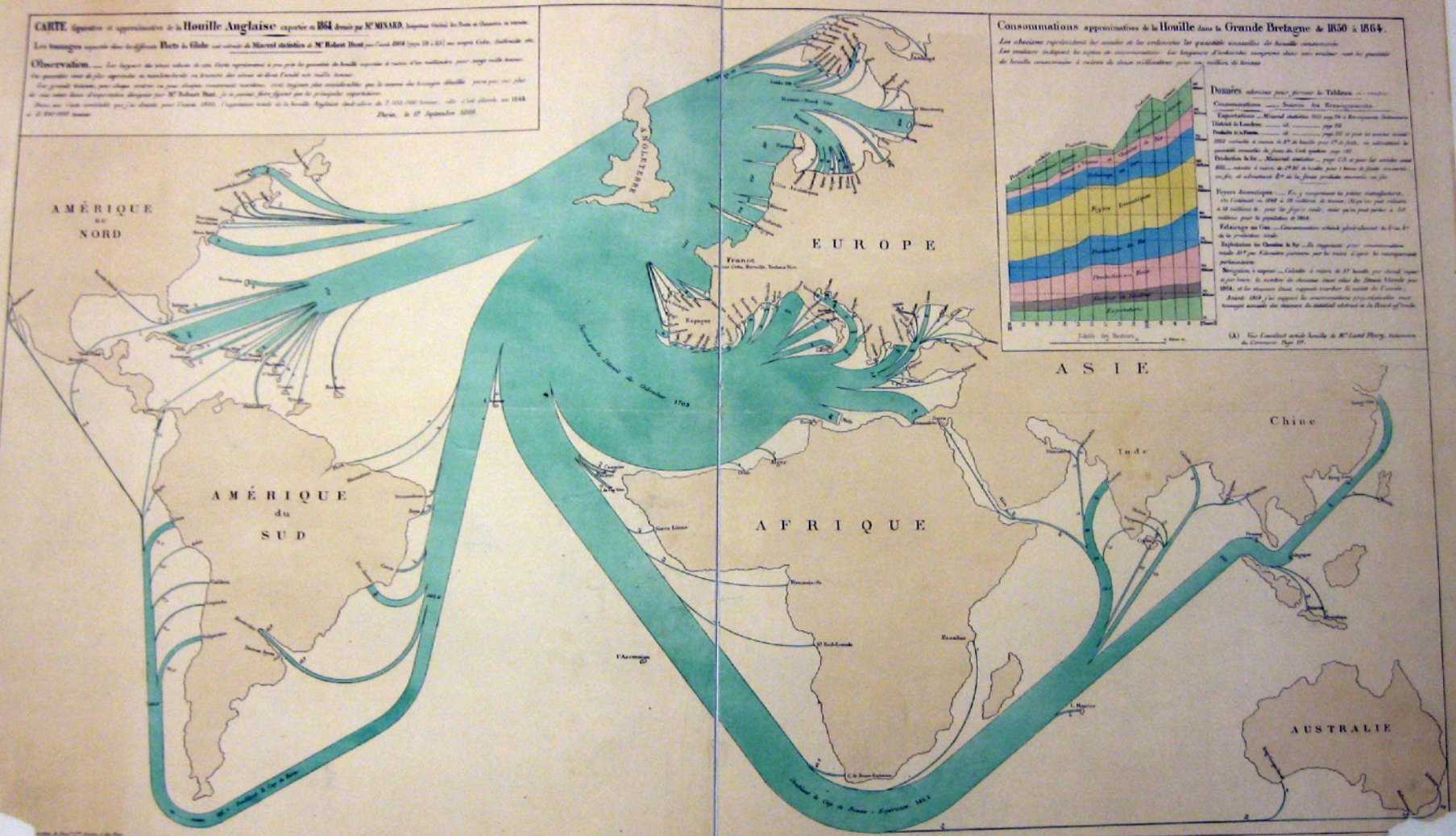
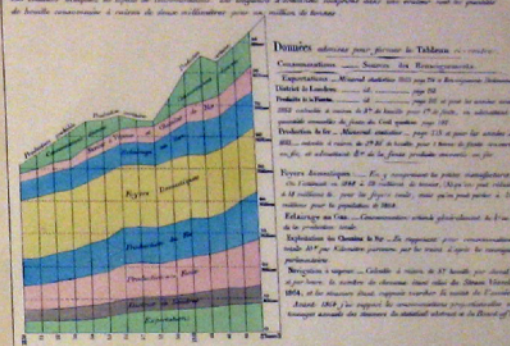
CARTE figurative et approximative de la **Houille Anglaise** exportée en 1864 dessinée par M^r MINARD, Ingénieur Civil des Ponts et Chaussées en France.

Les données sont tirées des statistiques de M^r Robert Bast, Ingénieur Civil des Ponts et Chaussées en France, publiées en 1864.

Observation. — Les données de cette carte sont purement approximatives et ne peuvent être considérées que comme des données générales. Les données exactes sont contenues dans le rapport de M^r Robert Bast, Ingénieur Civil des Ponts et Chaussées en France, publié en 1864.

Consommations approximatives de la Houille dans la Grande Bretagne & 1850 à 1864.

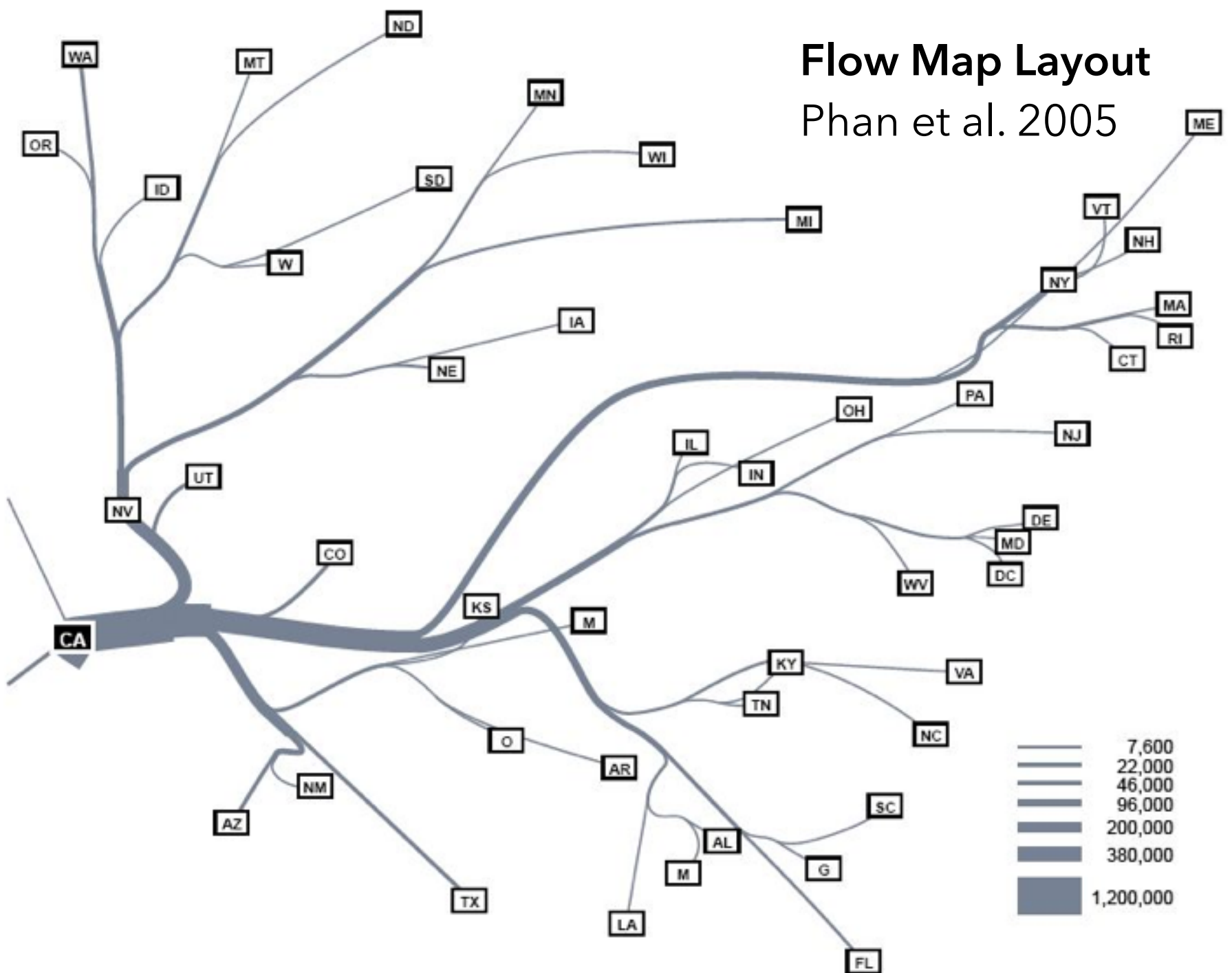
Les données sont tirées des statistiques de M^r Robert Bast, Ingénieur Civil des Ponts et Chaussées en France, publiées en 1864.



1864 British Coal Exports, Charles Minard

Flow Map Layout

Phan et al. 2005

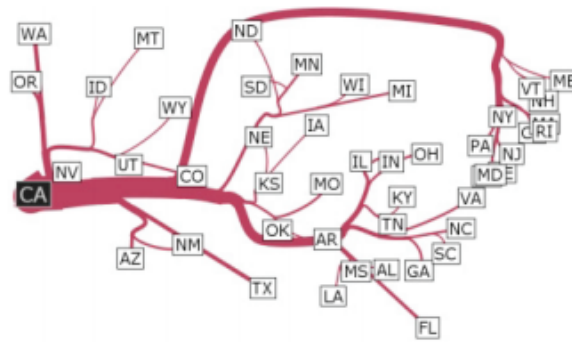


Migration from California, 95-00

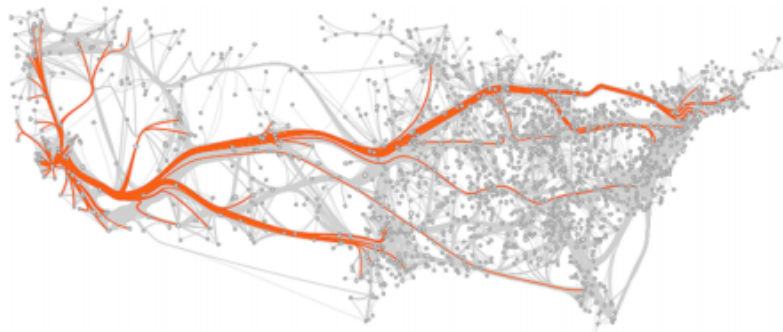
Tobler 1987



Phan et al. 2005



Verbeek et al. 2011



Cui et al. 2008



Holten & van Wijk 2009

wind map

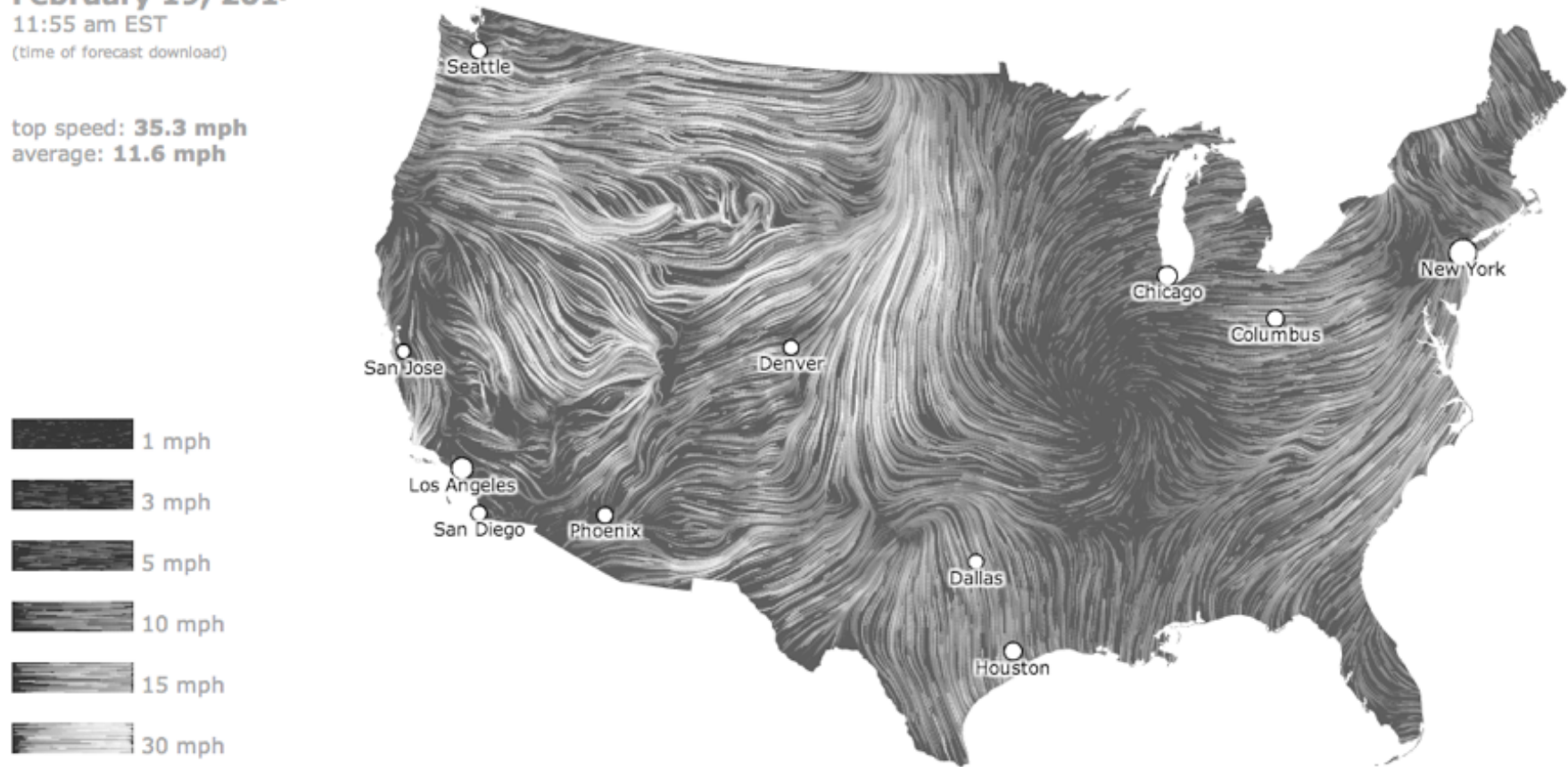
February 19, 2014

11:55 am EST

(time of forecast download)

top speed: **35.3 mph**

average: **11.6 mph**



How Obama Won Re-election

Whites Were Outvoted

Women

Hispanics

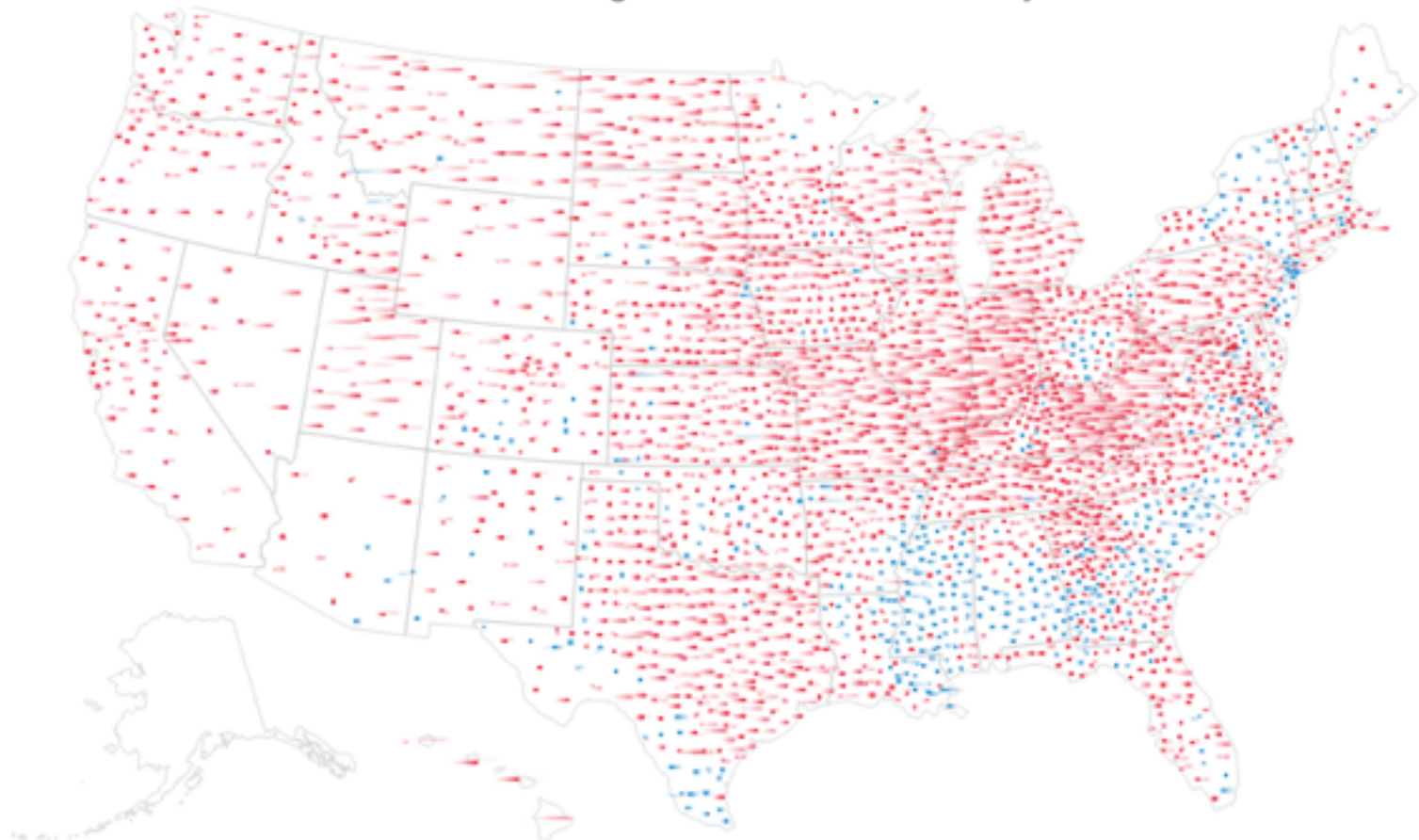
Youth

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.



Generalization

CARTE figurative et approximative de la Houille Anglaise exportée en 1864 dessinée par M. MINARD. Imprimée chez les Bureaux de Commerce et de Navigation.

Les branches indiquées dans les différents Ports et Golfs ont été dessinées de M. Robert Duret, par l'année 1864 (pages 18 & 19) sur un rapport Gênes, daté du 10 Mars 1864.

Observation. Les lignes de même couleur de cette Carte représentent à peu près la quantité de Houille exportée à raison d'un millimètre pour vingt mille tonnes.

Une grande ligne, pour chaque continent, se trouve dans les mêmes couleurs, mais toujours plus considérable que la somme des branches dessignées, parce que ces plus de six cent mille tonnes de Houille exportées par M. Robert Duret, se trouvent dans les principales exportations.

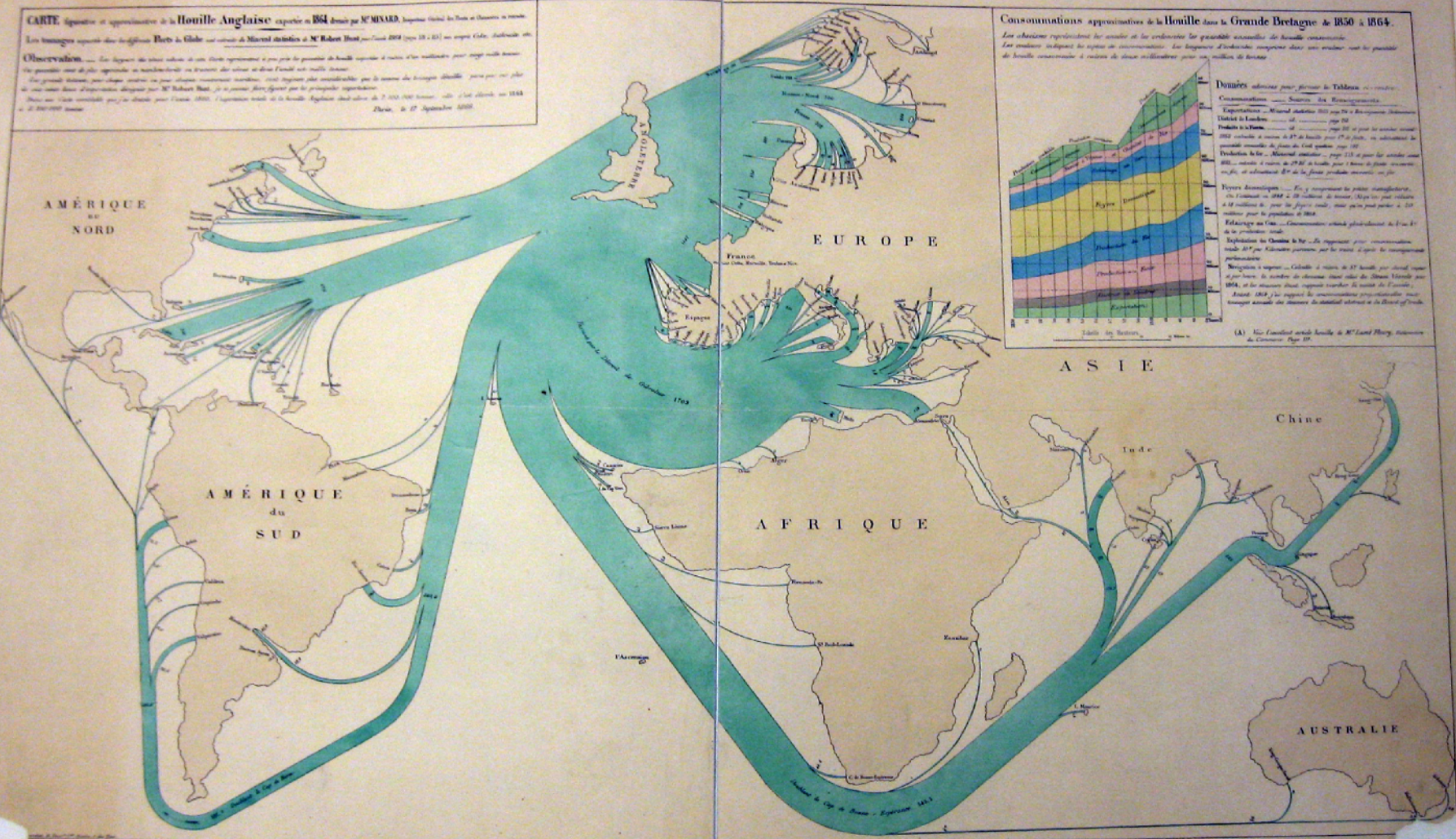
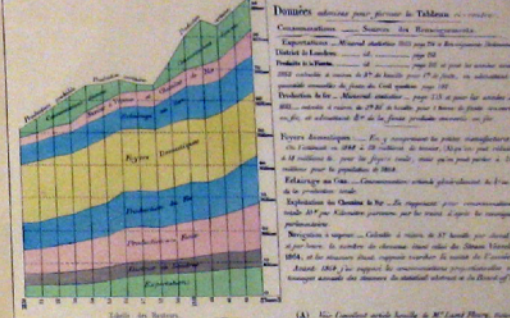
Il y a une grande quantité de Houille exportée par l'année 1864, à raison de 7,000,000 tonnes, celle d'été de 1864 et de 1865-1866.

Paris, le 27 Septembre 1864.

Consommations approximatives de la Houille dans la Grande Bretagne & 1850 à 1864.

Les branches indiquées dans les différents Ports et Golfs ont été dessinées de M. Robert Duret, par l'année 1864 (pages 18 & 19) sur un rapport Gênes, daté du 10 Mars 1864.

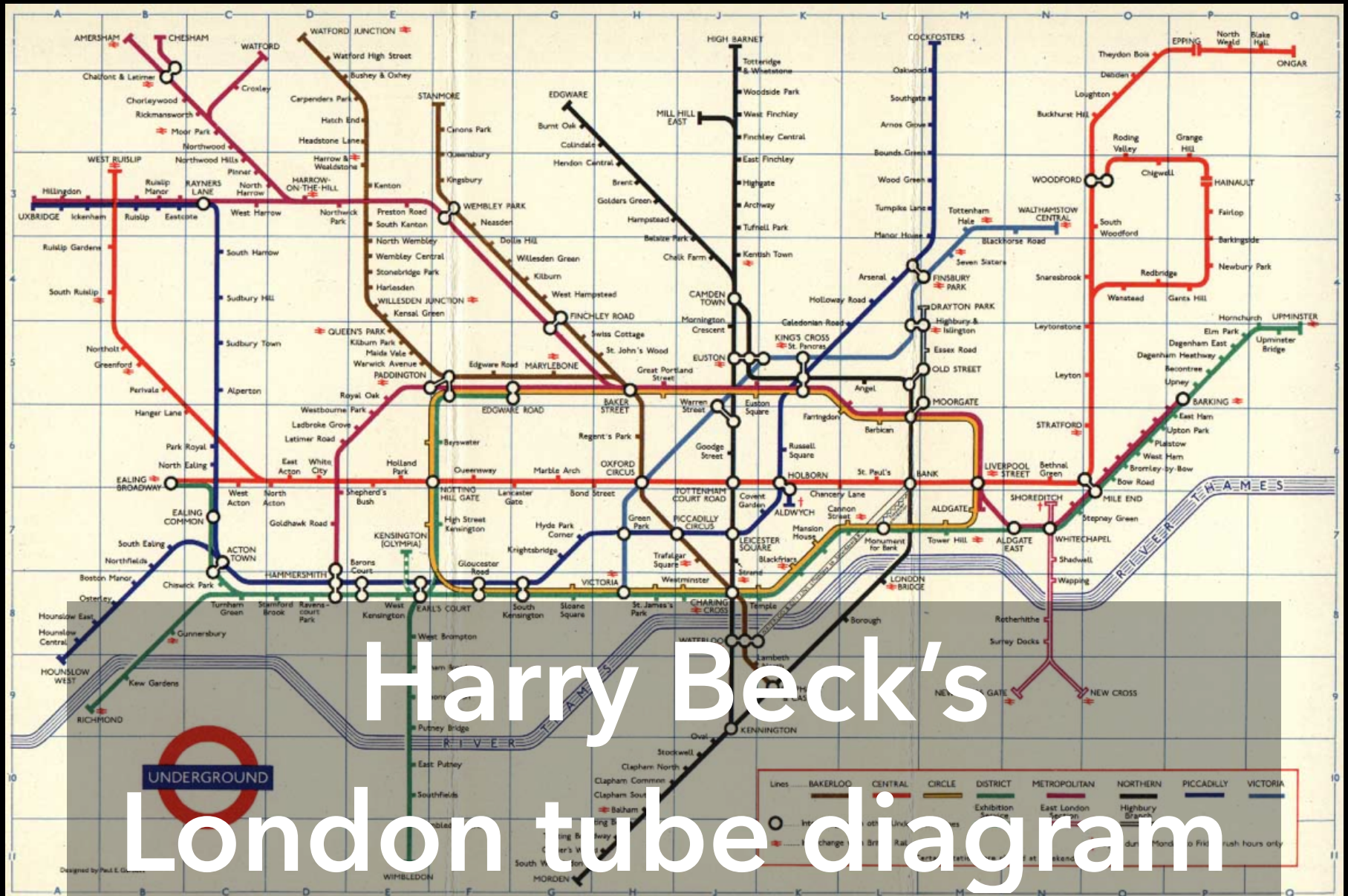
Les branches indiquées dans les différents Ports et Golfs ont été dessinées de M. Robert Duret, par l'année 1864 (pages 18 & 19) sur un rapport Gênes, daté du 10 Mars 1864.

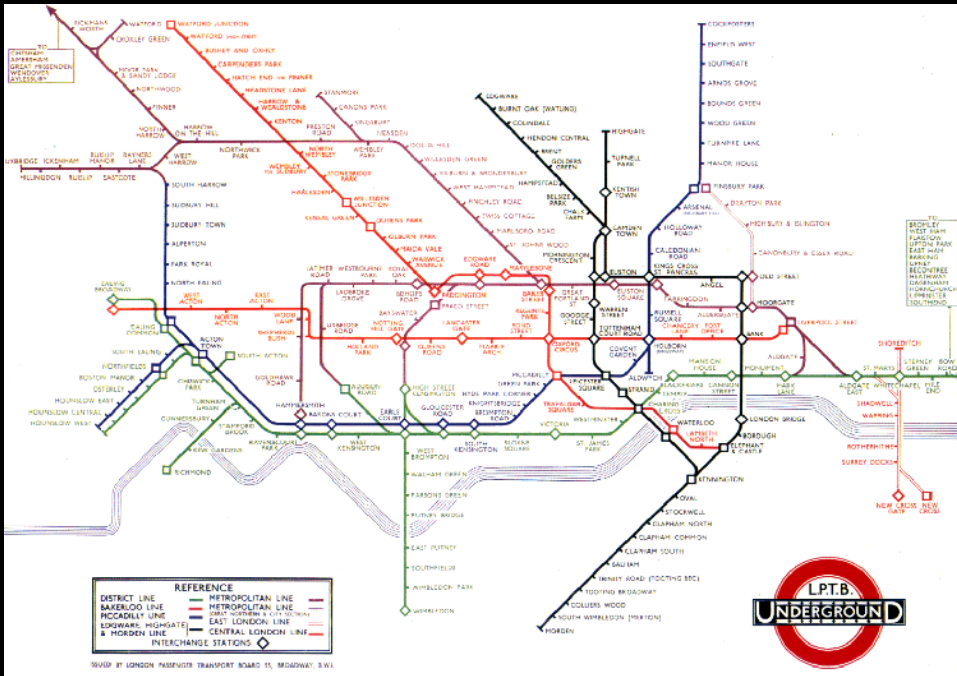


2094-626258

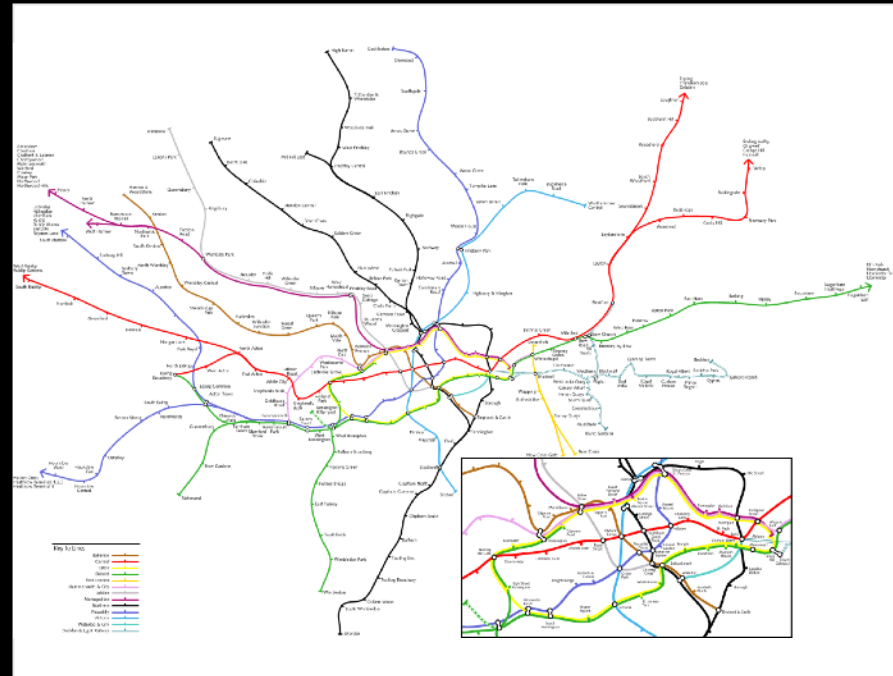
C2201-14-1864-M3

1864 British Coal Exports, Charles Minard





London Underground [Beck 33]



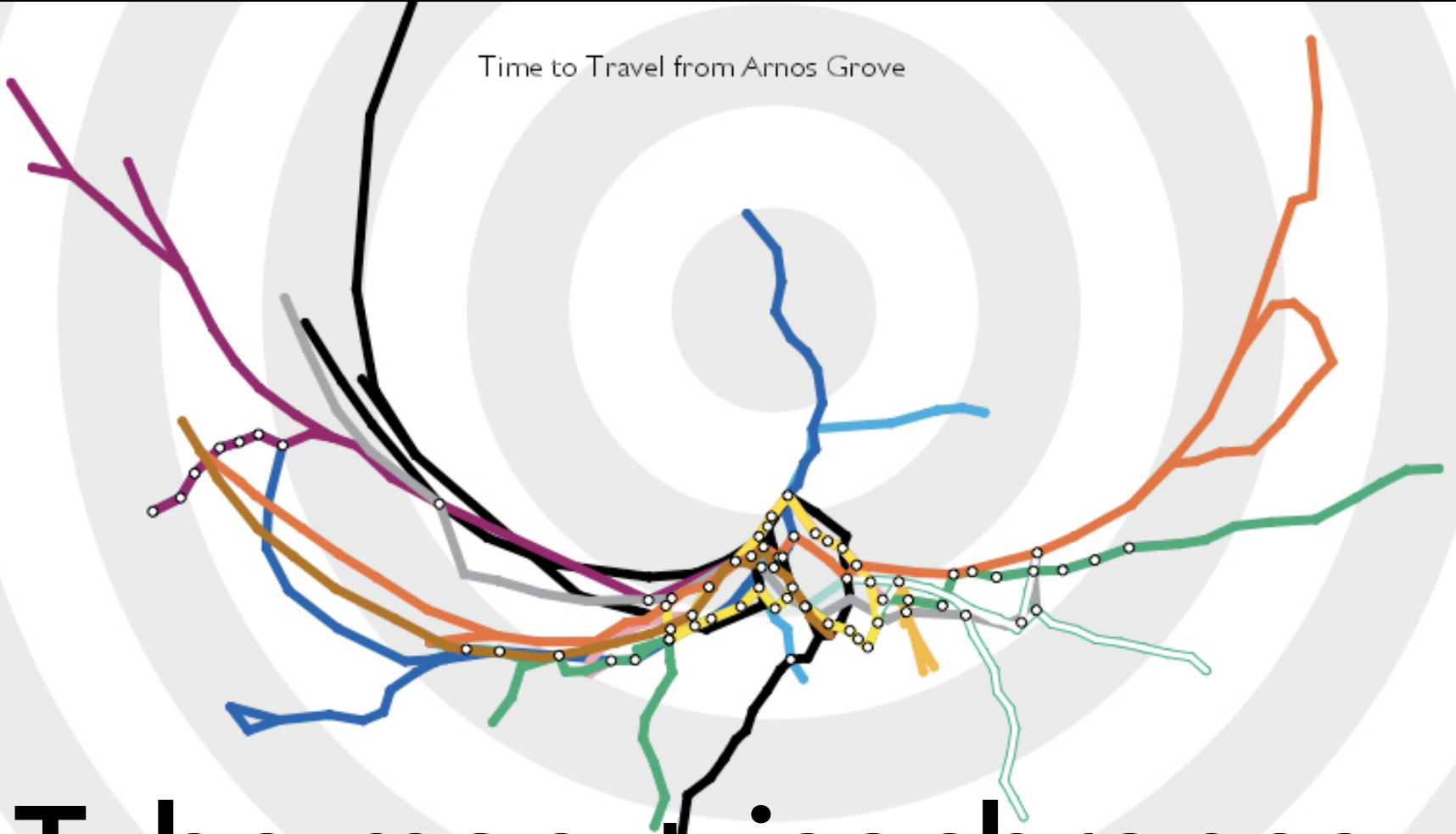
Geographic version of map

Principle: Straighten lines to emphasize stop sequence
Technique used to emphasize/de-emphasize information



People *love*
the tube map

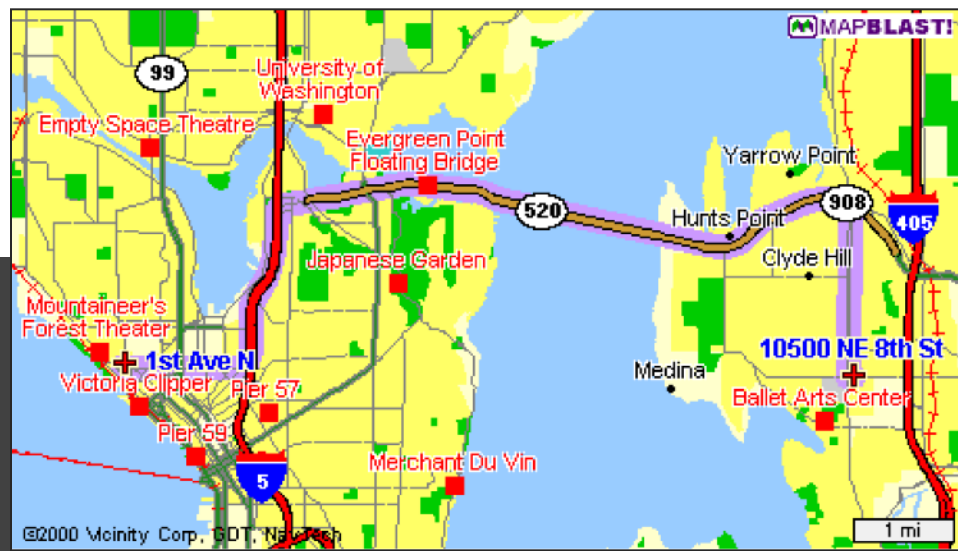
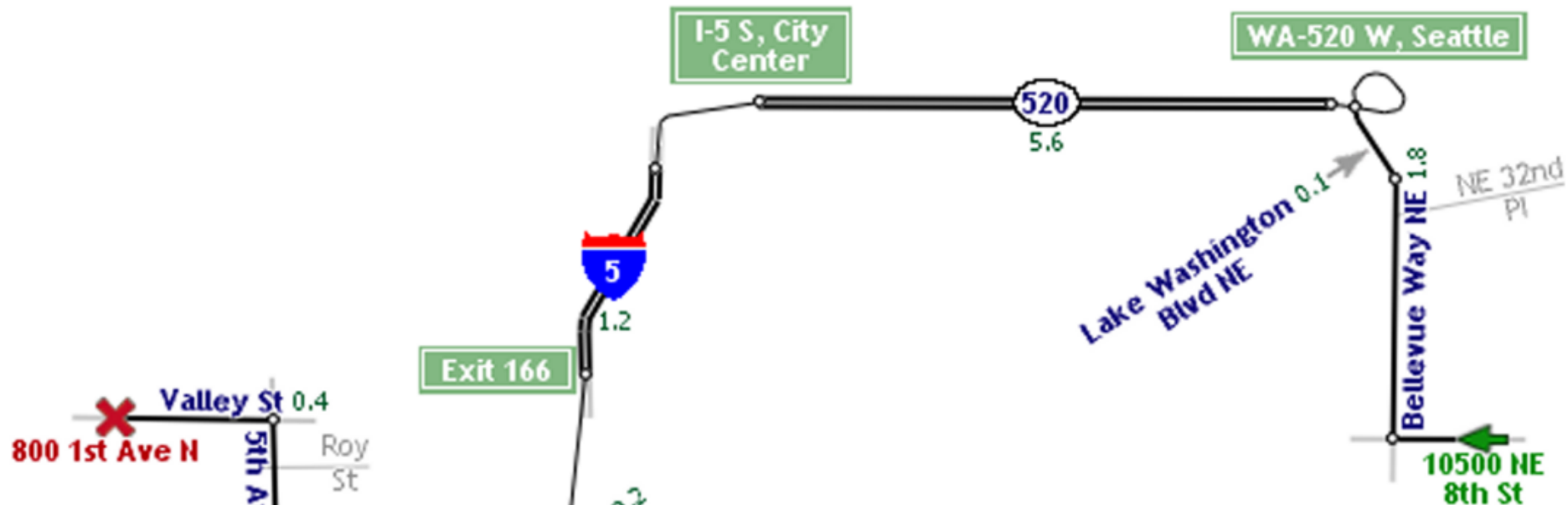
Time to Travel from Arnos Grove



Tube map + isochrones

0 5 10
minutes

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

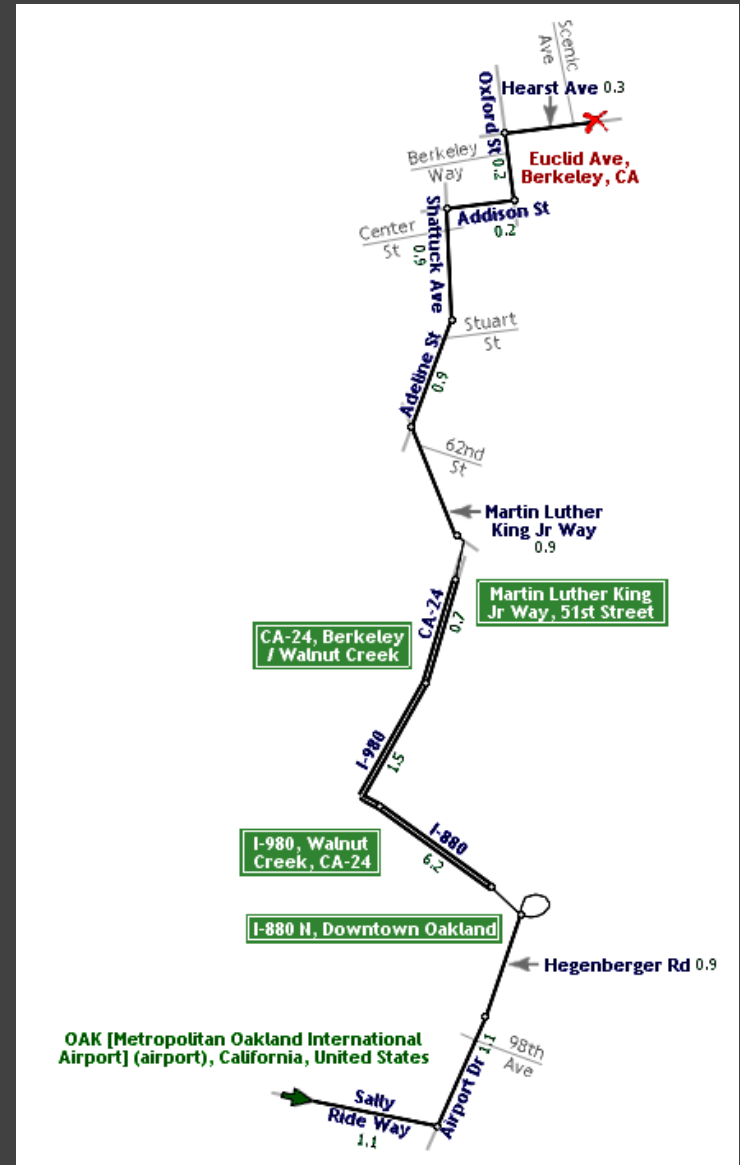
Develop constraints based on design principles

Simulated annealing

Perturb: Form a layout

Score: Evaluate quality

Minimize score



Road Layout Constraints [Agrawala '01]

Length

Ensure all roads visible

$$((L_{\min} - l(r_i)) / L_{\min})^2 * W_{\text{small}}$$

Maintain ordering by length

$$W_{\text{shuffle}}$$

Orientation

Maintain original orientation

$$|\alpha_{\text{curr}}(r_i) - \alpha_{\text{orig}}(r_i)| * W_{\text{orient}}$$

Topological errors

Prevent false

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

Prevent missing

$$d * W_{\text{missing}}$$

Ensure separation

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

Overall route shape

Maintain endpoint direction

$$|\alpha_{\text{curr}}(v) - \alpha_{\text{orig}}(v)| * W_{\text{enddir}}$$

Maintain endpoint distance

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

Tools

Software Tools

Web Tools

d3.geo: projections, paths and more

GeoJSON: JSON format for geo data

TopoJSON: topology -> compressed GeoJSON

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

Let's Make a Map!

<http://bost.ocks.org/mike/map/>

How to Infer Topology

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