06. Geo Visualization

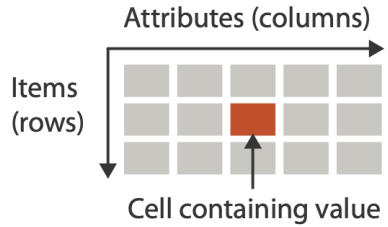
ID 413: Information Graphics and Data Visualization
Spring 2025

Venkatesh Rajamanickam (@venkatrajam)
venkatra@iitb.ac.in
http://info-design-lab.github.io/ID413-DataViz/

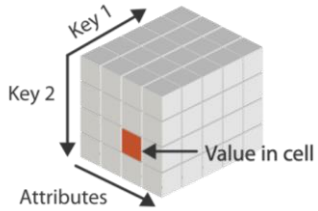
Spatial Datasets

Dataset Types

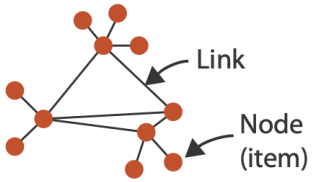
Tables



Multidimensional Table



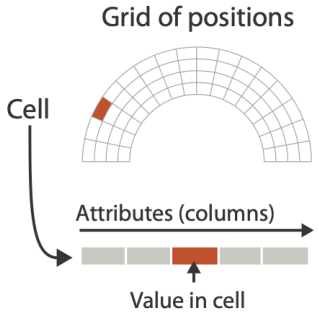
Networks



Trees

Spatial

Fields (Continuous)



Geometry (Spatial)

Spatial Datasets

- use given spatial position
- when?
  - dataset contains spatial attributes and they have primary importance
  - central tasks revolve around understanding spatial relationships

- examples
  - geographical/cartographic data
  - sensor/simulation data

Geographic Maps

Cartography - Münster's Geographia (1552)

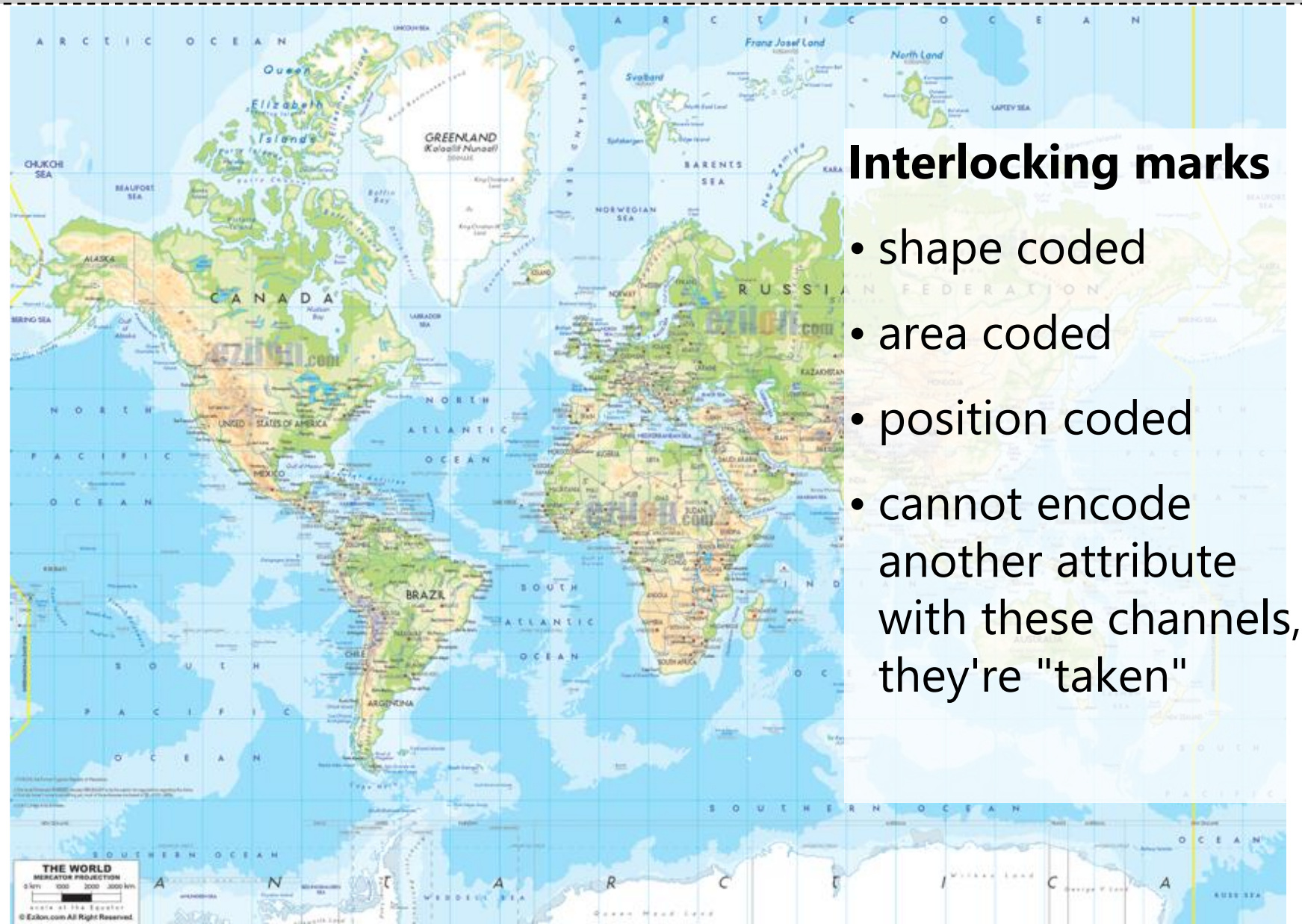
Cartography - Johannes van Keulen (1679)

Cartography - Daniël Stoopendaal (1702)

Cartography - S. Augustus Mitchell (1867)

Cartography – 20th Century physical

Cartography – 20th Century physical



Interlocking marks

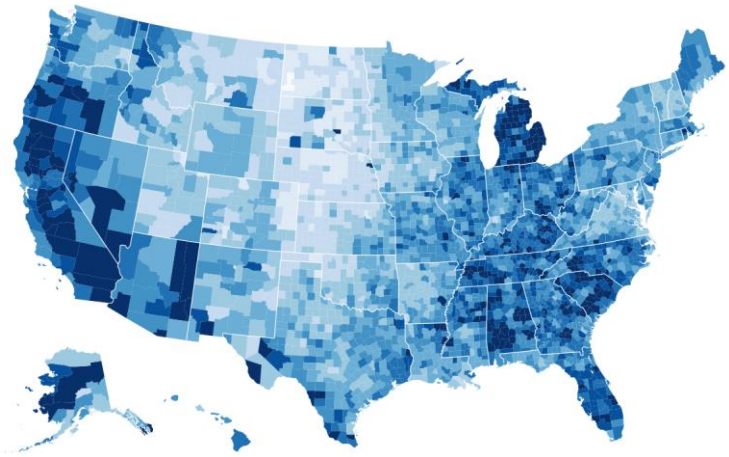
- shape coded
- area coded
- position coded
- cannot encode another attribute with these channels, they're "taken"

Thematic maps

- show spatial variability of attribute ("theme")
  - combine geographic / reference map with (simple, flat) tabular data
  - join together
    - region: interlocking area marks (provinces, countries with outline shapes)
      - also could have point marks (cities, locations with 2D lat/lon coords)
    - region: categorical key attribute in table
      - use to look up value attributes
- major idioms
  - choropleth
  - symbol maps
  - cartograms
  - dot density maps

Idiom: Choropleth maps

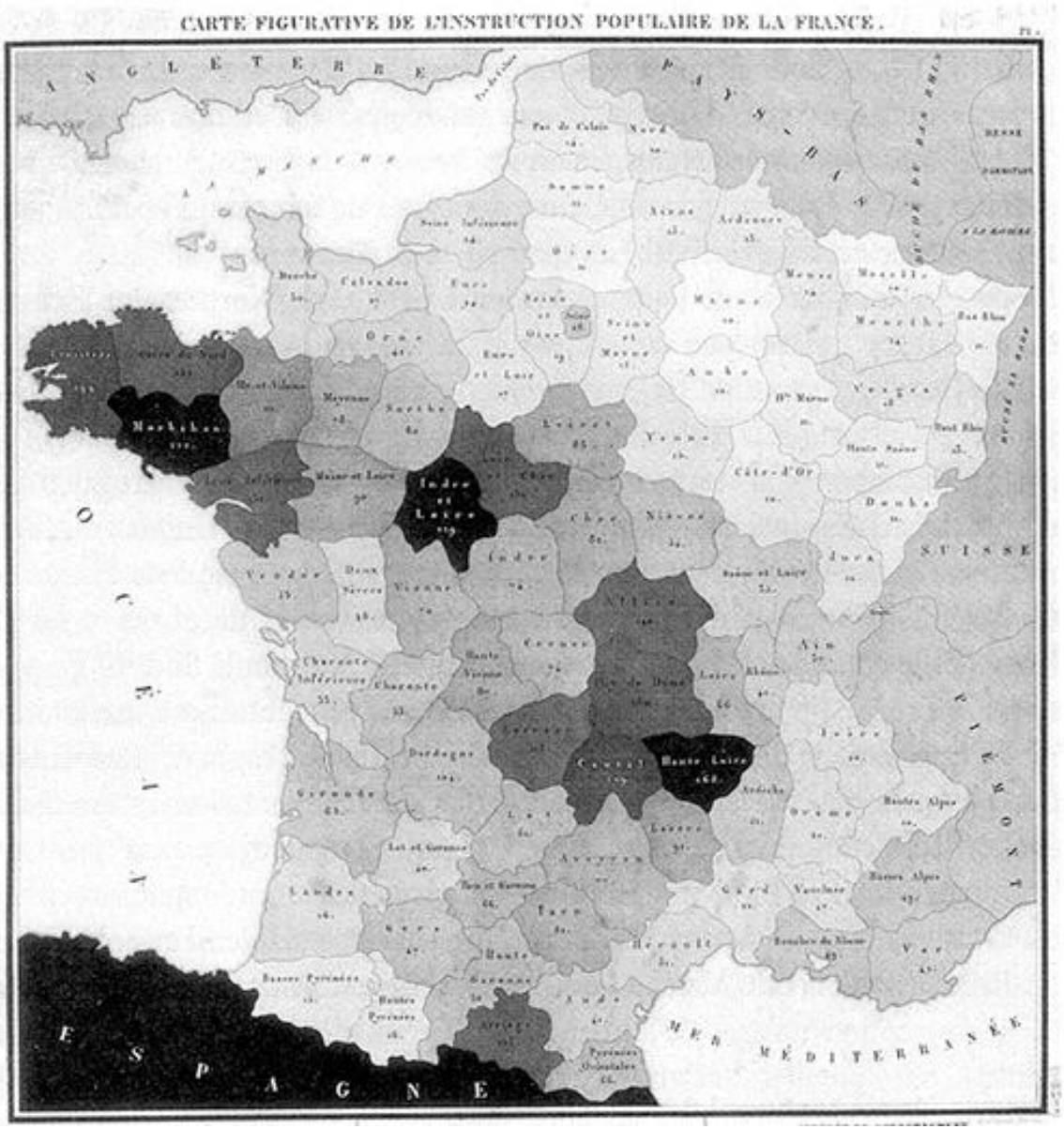
- use given spatial data
  - when central task is understanding spatial relationships
- data
  - geographic geometry
  - table with 1 quant attribute per region
- encoding
  - position:
    use given geometry for area mark boundaries
  - color:
    sequential segmented colormap



http://bl.ocks.org/mbostock/4060606

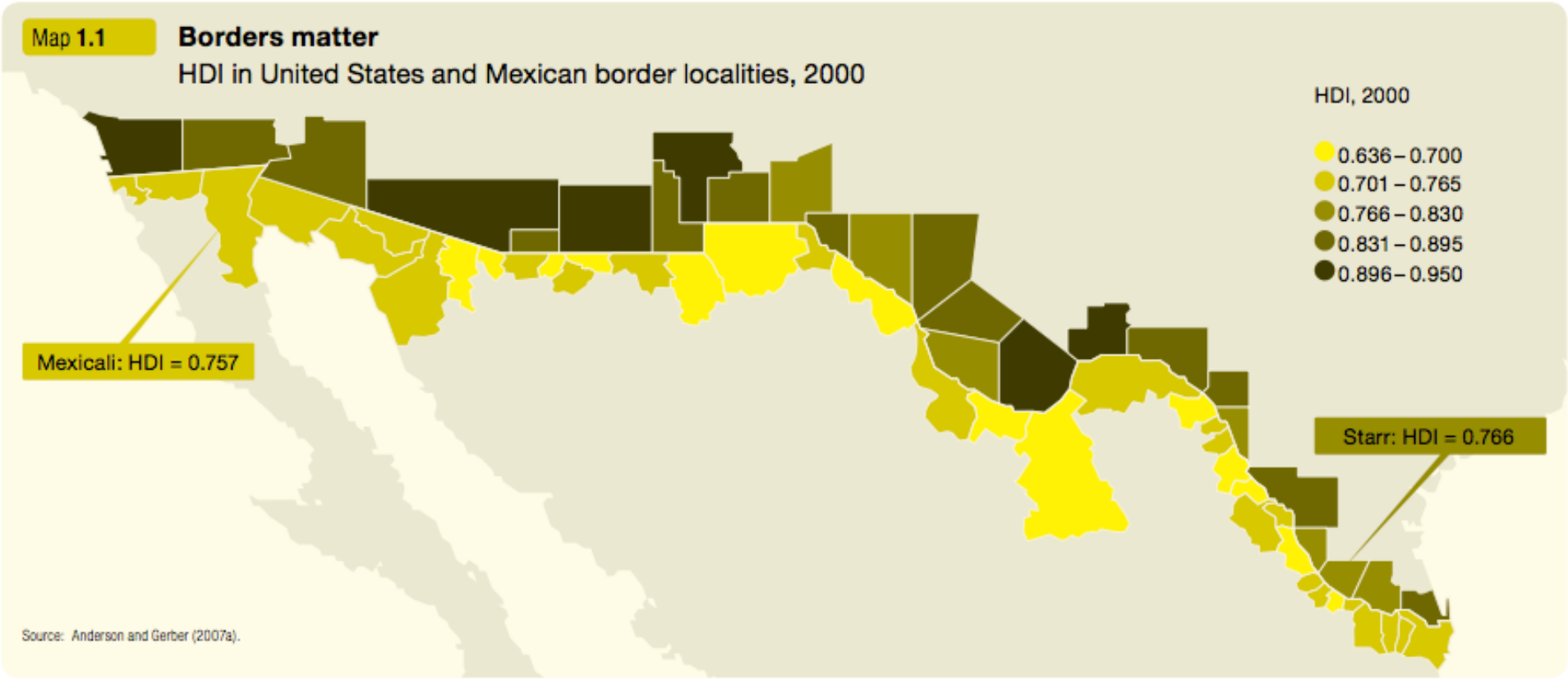
Idiom: Choropleth maps

- Map in which areas are shaded, coloured, or patterned relative to a data attribute value
- e.g. Illiteracy in France (first choropleth map, Charles Dupin, 1826)



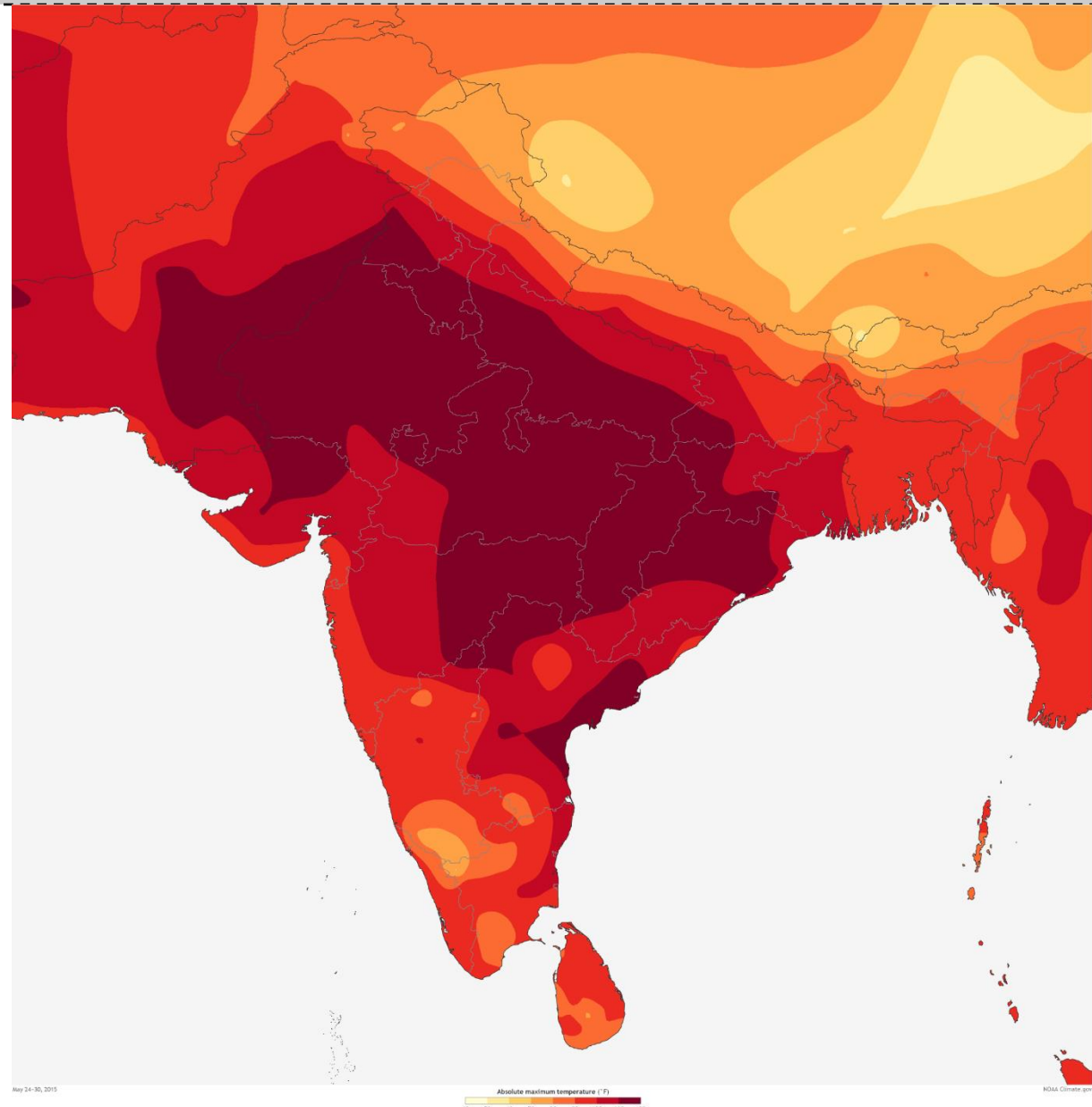
Idiom: Choropleth maps

Show contrast



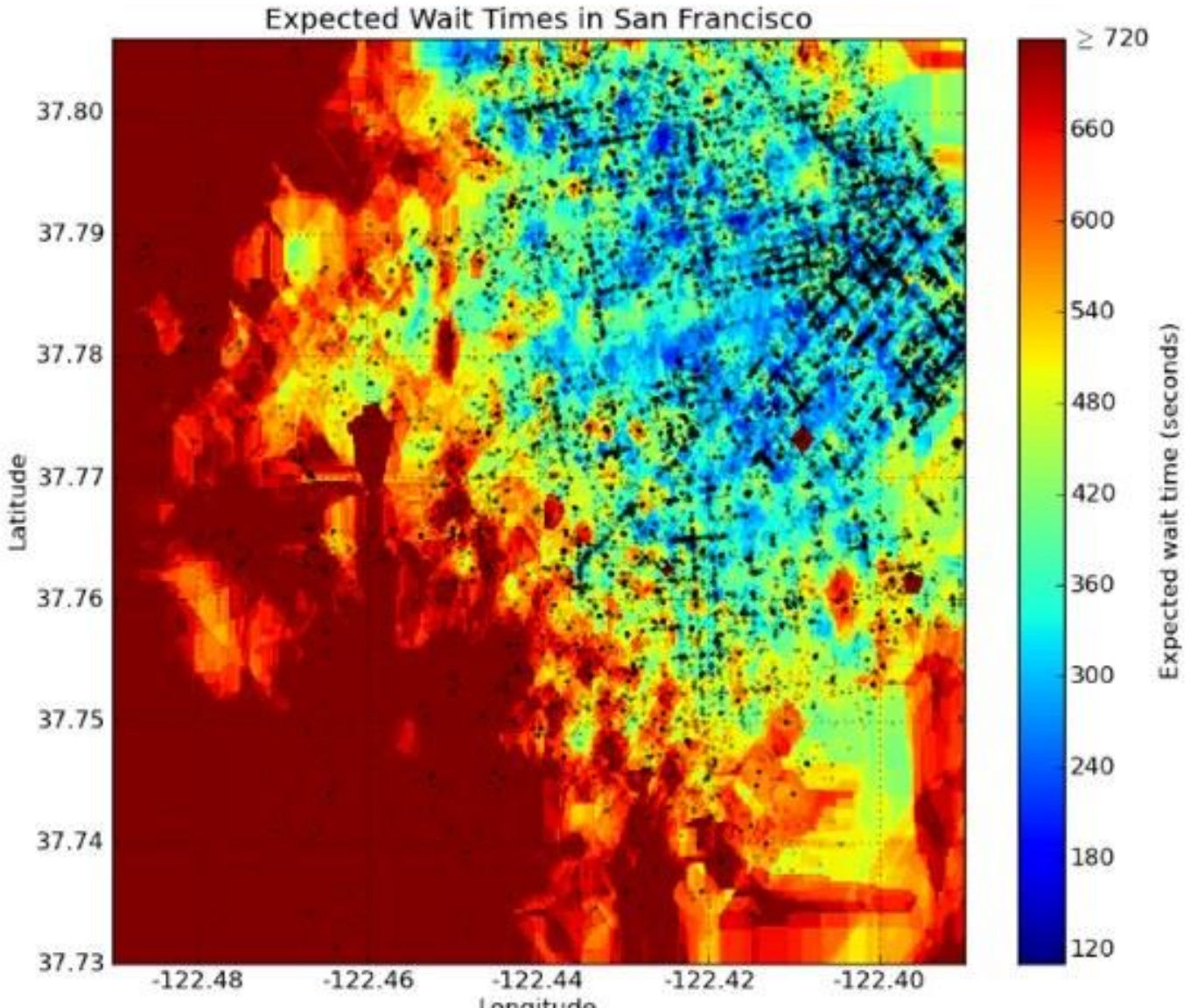
Idiom: Choropleth maps

India Heat Wave:
week of May 24-30,
2015

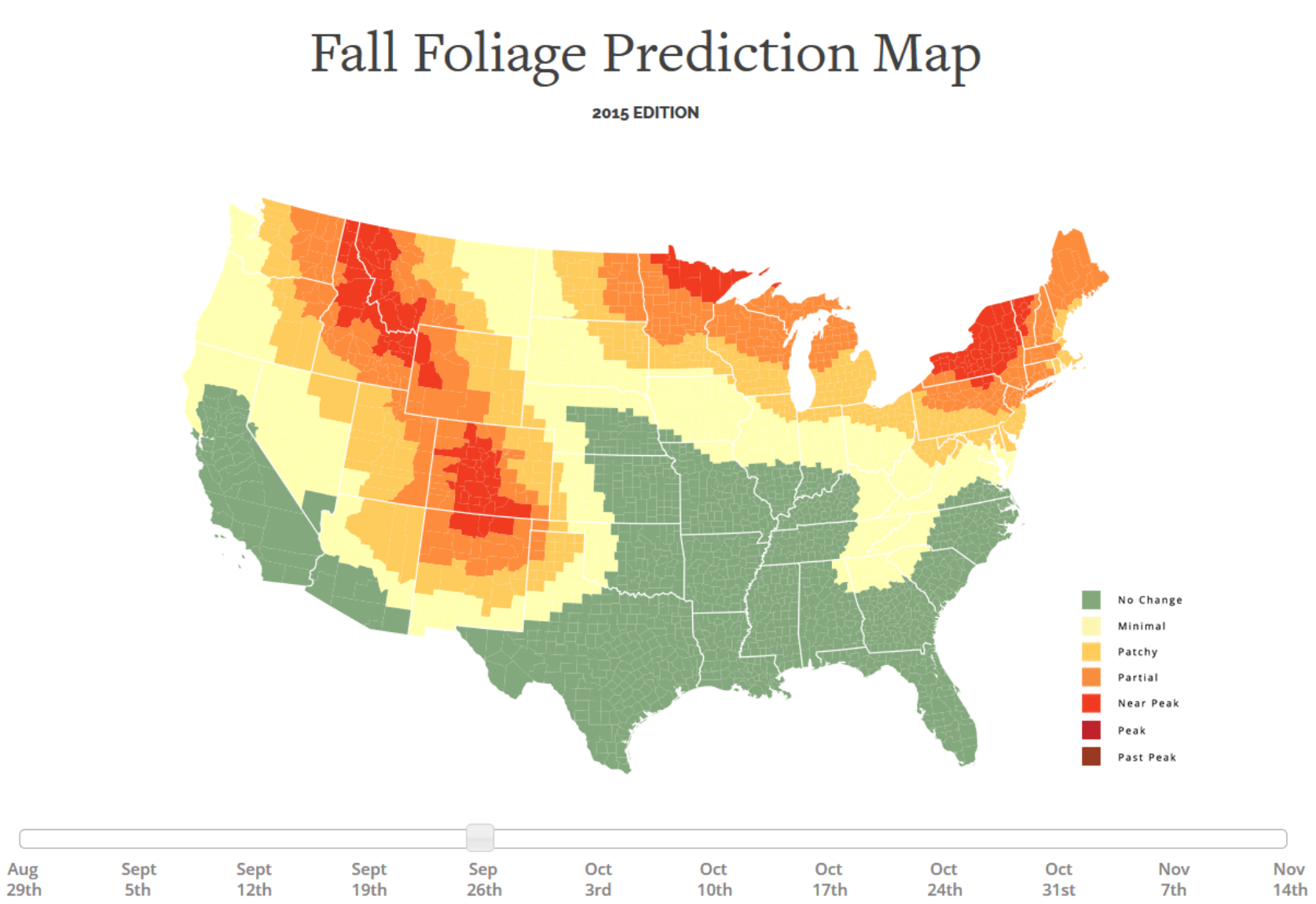


Idiom: Choropleth maps

Uber wait times, SF



Idiom: Choropleth maps



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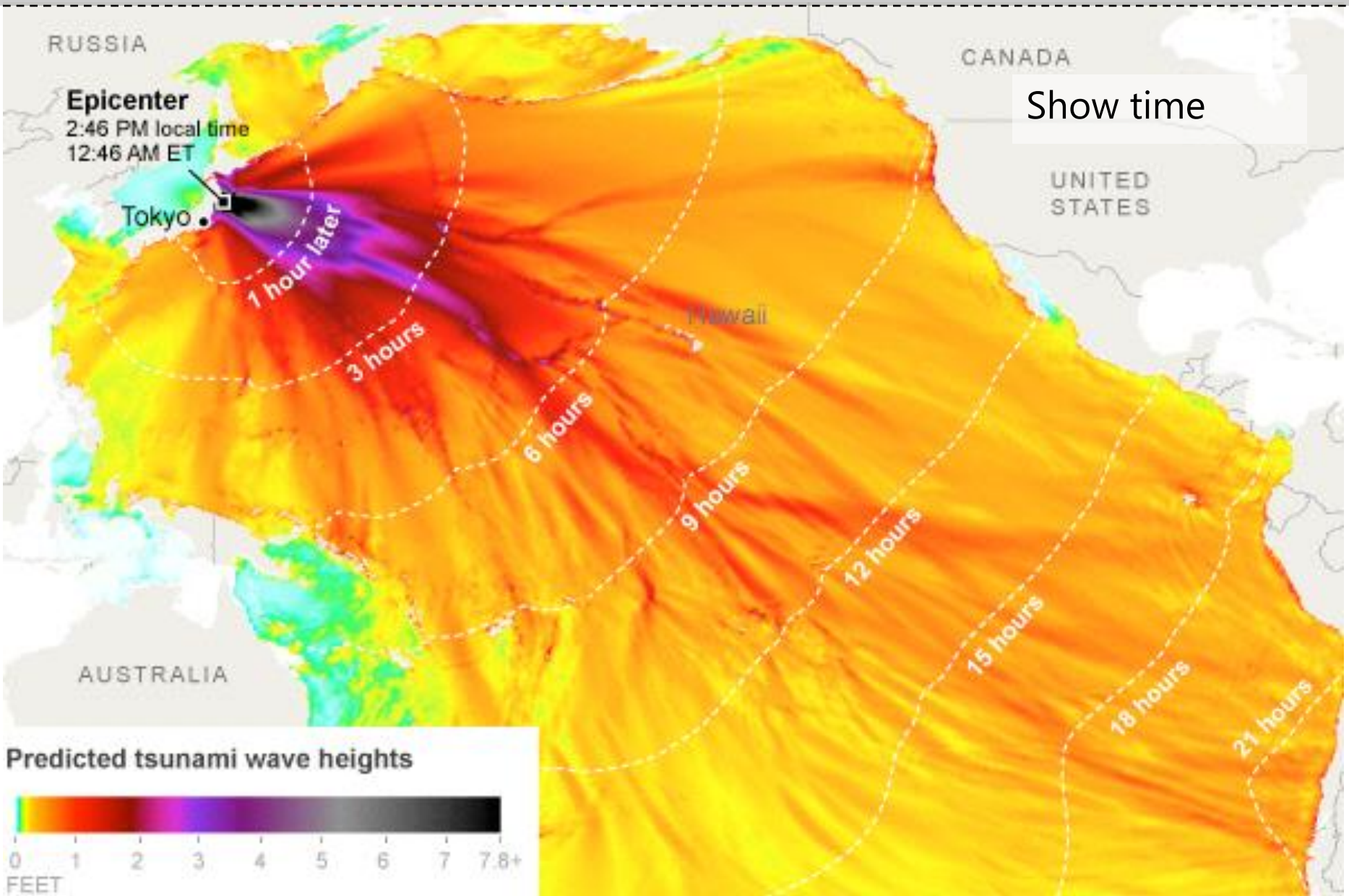
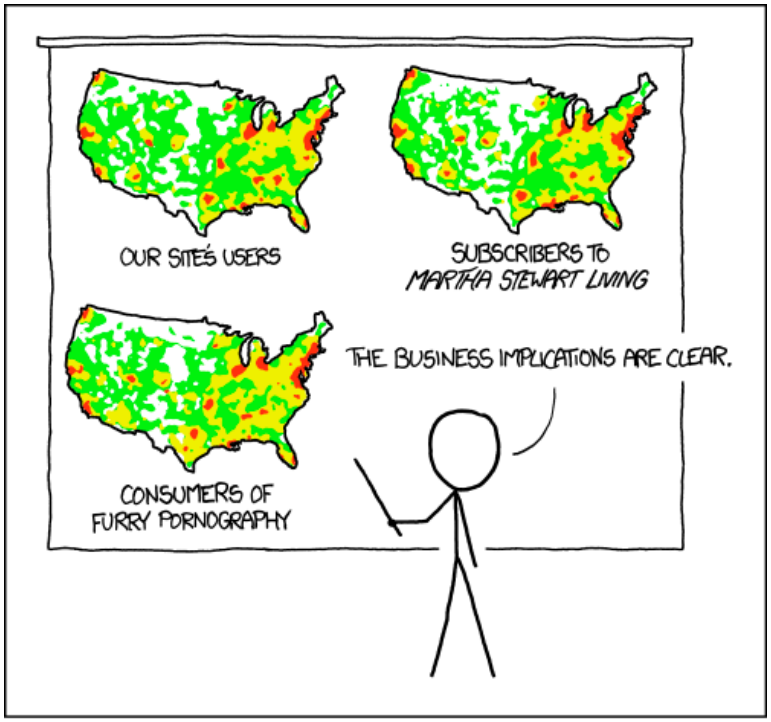


Idiom: Choropleth maps

Beware: Population maps trickiness!

- spurious correlations: most attributes just show where people live

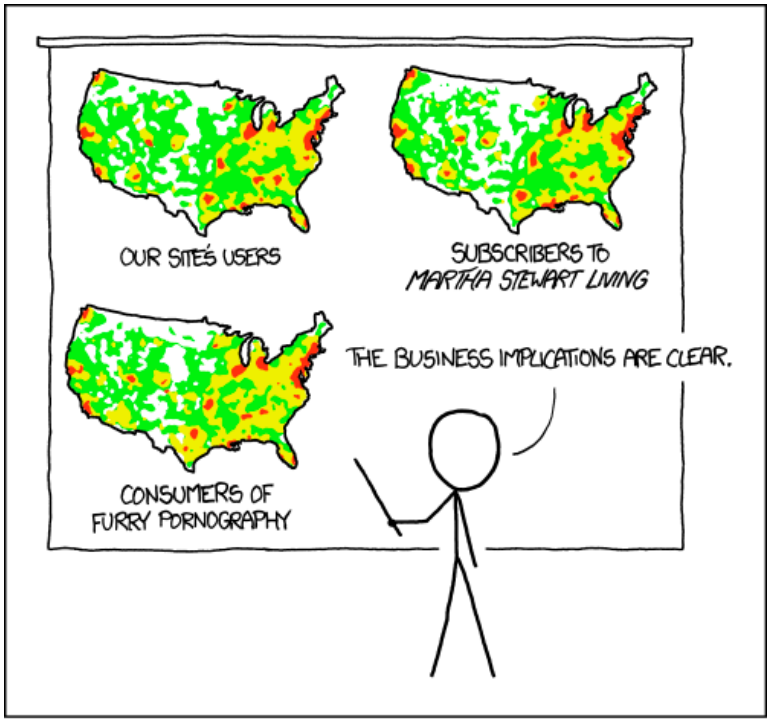


PET PEEVE #208:
GEOGRAPHIC PROFILE MAPS WHICH ARE BASICALLY JUST POPULATION MAPS

Idiom: Choropleth maps

Beware: Population maps trickiness!

- spurious correlations: most attributes just show where people live
- consider when to normalize by population density
  - encode raw data values
    - tied to underlying population
  - but should use normalized values
    - unemployed people per 100 citizens, mean family income



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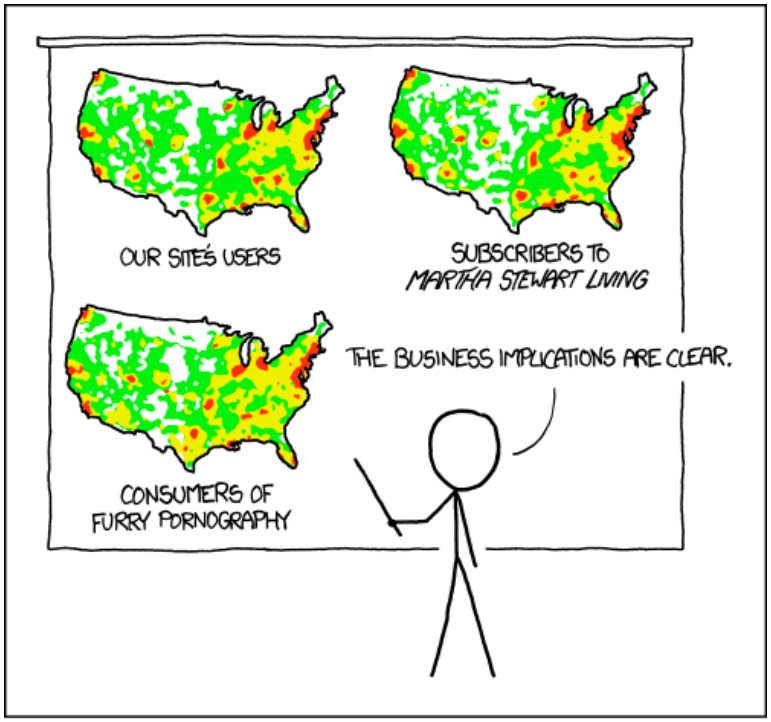
- spurious correlations: most attributes just show where people live
- consider when to normalize by population density
  - encode raw data values
    - tied to underlying population
  - but should use normalized values
    - unemployed people per 100 citizens, mean family income
- general issue
  - absolute counts vs relative/normalized data
  - failure to normalize is common error



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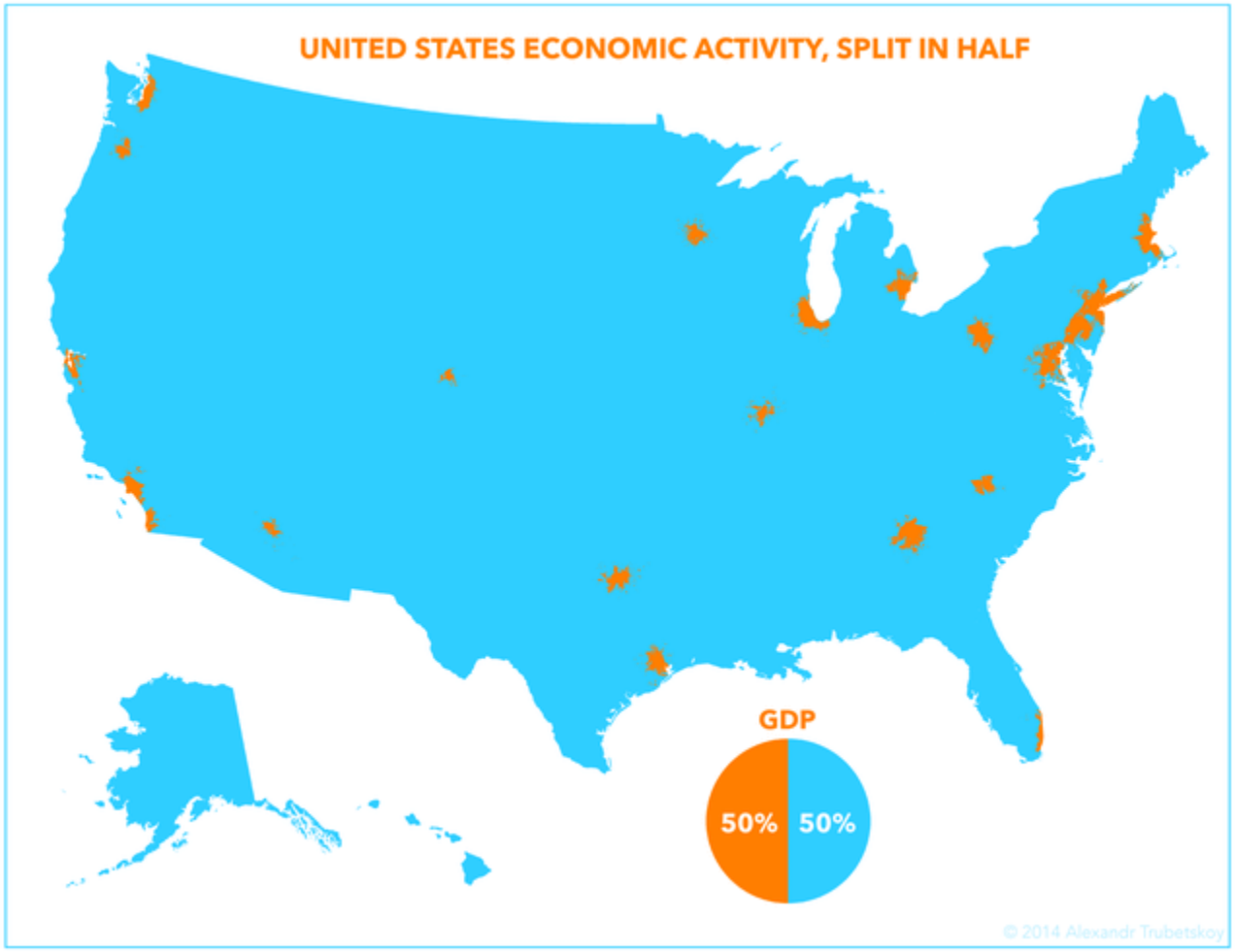
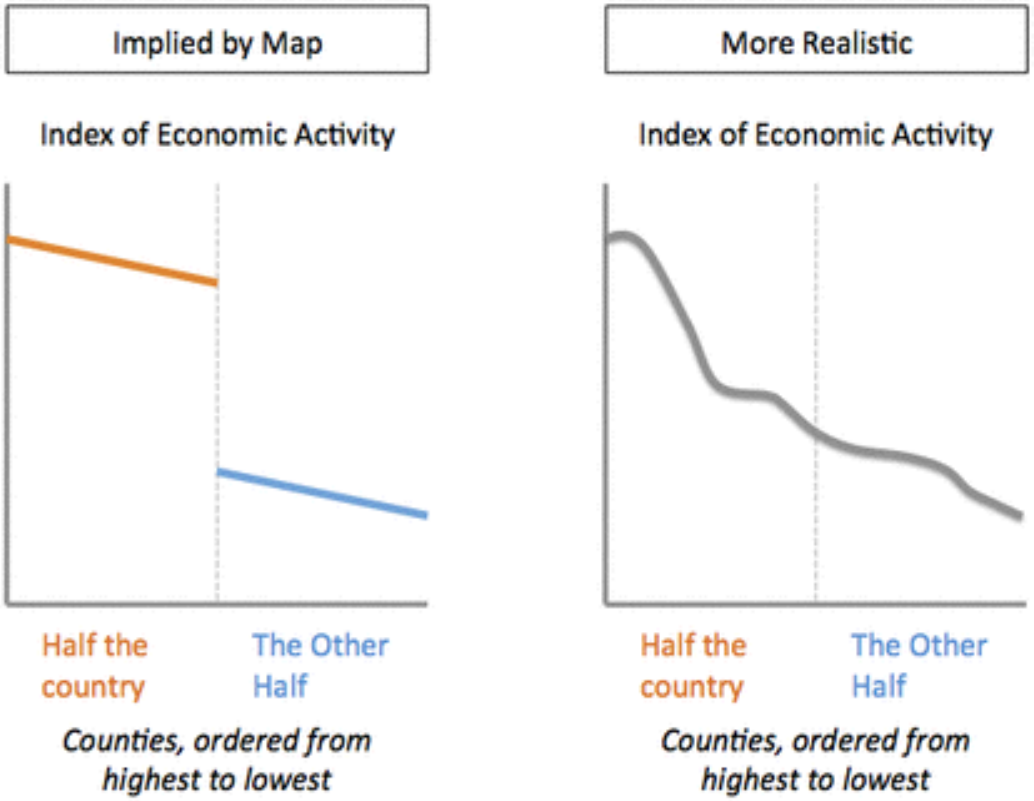


https://vividmaps.com/us-economic-activity-split-in-half/

The map does not make false claims but it leads readers to the conclusion that the orange areas are much more important than the blue region (equal economic activity but much smaller area). The first problem is that the types of economic activities are vastly different between those regions, and this significant factor is ignored.

The second problem is that the designer over-aggregated the data. All counties (or zip codes) are classified into two groups ("split in half") when in fact, the level of economic activity at the level of counties (or zip codes) is a gradient. Imagine plotting the economic activity index by county, ordered from the highest to the lowest. Do we see a dramatic drop-off after counting out half the counties (i.e., the pattern shown on the left chart below)? Or are we more likely to see the pattern shown on the right? If you see a distribution like the one shown on the right, would you summarize that with just two segments?



Choropleth maps: Recommendations

- only use when central task is understanding spatial relationships
- show only one variable at a time
- normalize when appropriate
- be careful when choosing colors & bins
- best case: regions are roughly equal sized

Choropleth maps: Pros & cons

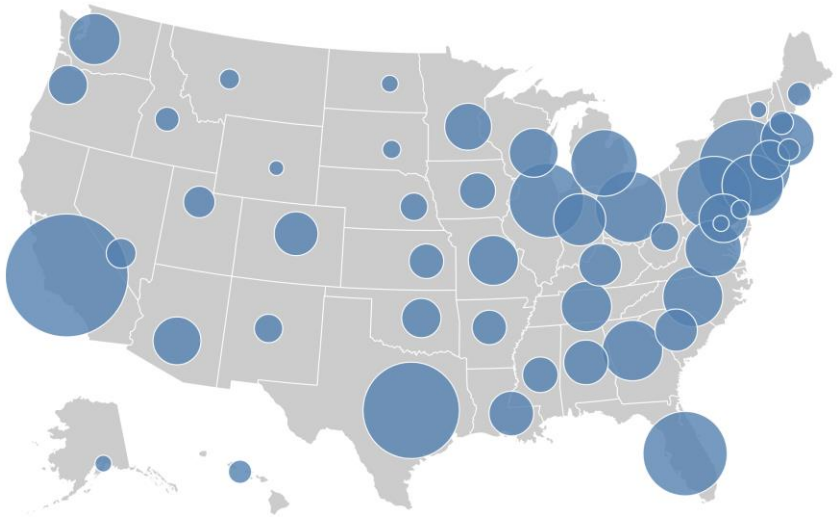
- pros
  - easy to read and understand
  - well established visualization (no learning curve)
  - data is often collected and aggregated by geographical regions

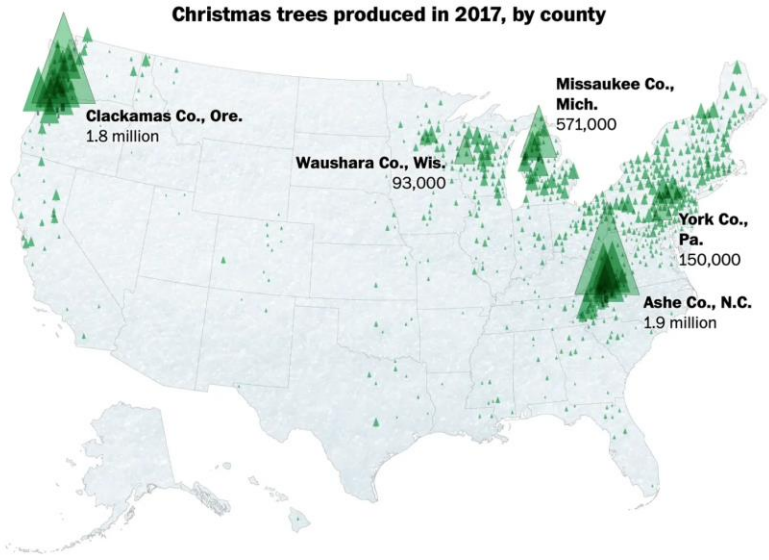
- cons
  - most effective visual variable used for geographic location
  - visual salience depends on region size, not true importance wrt attribute value
    - large regions appear more important than small ones
  - color palette choice has a huge influence on the result

Idiom: Symbol maps

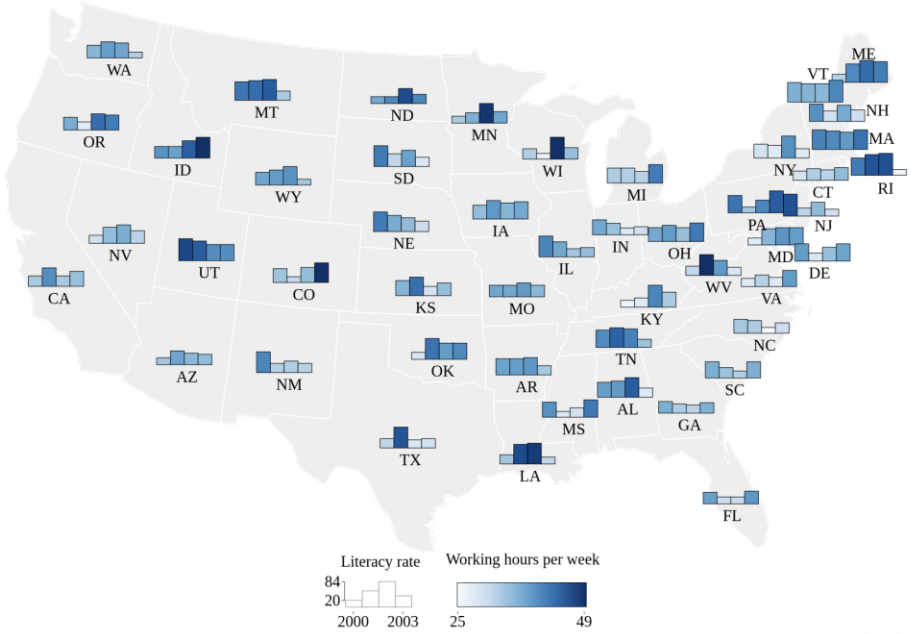
- symbol is used to represent aggregated data (mark or glyph)
  - allows use of size and shape and color channels
    - aka proportional symbol maps, graduated symbol maps
- keep original spatial geometry in the background
- often a good alternative to choropleth maps

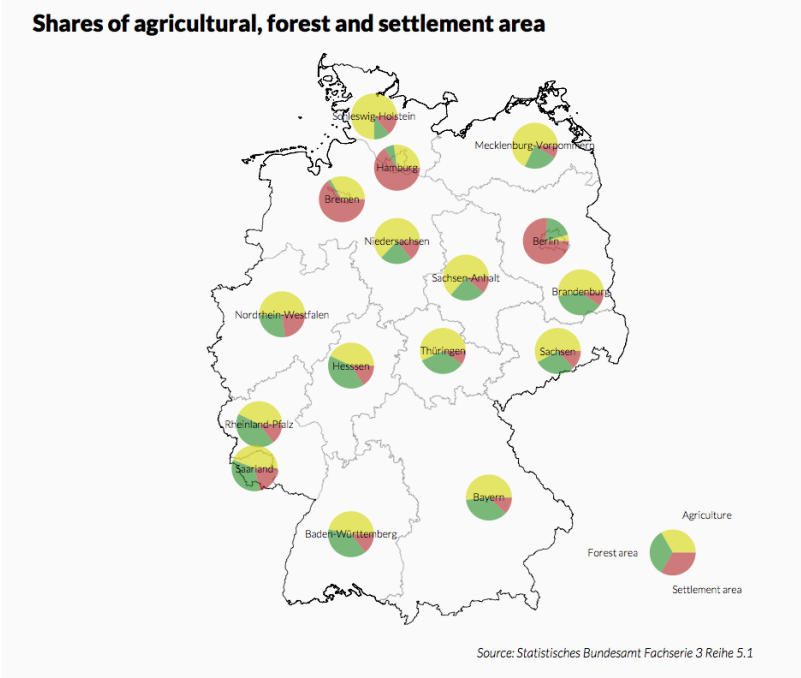
State population





Idiom: Symbol maps with Glyphs





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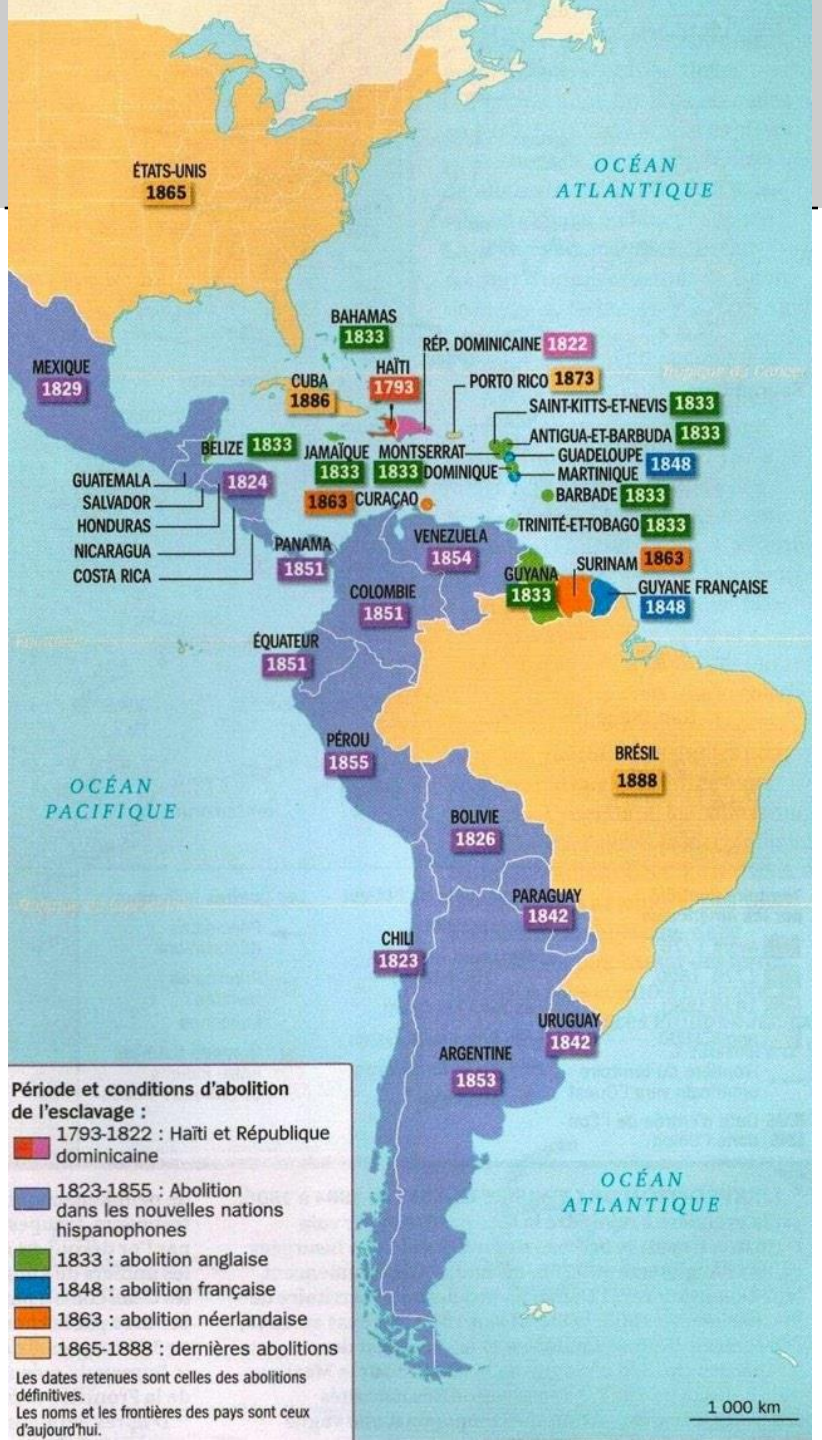
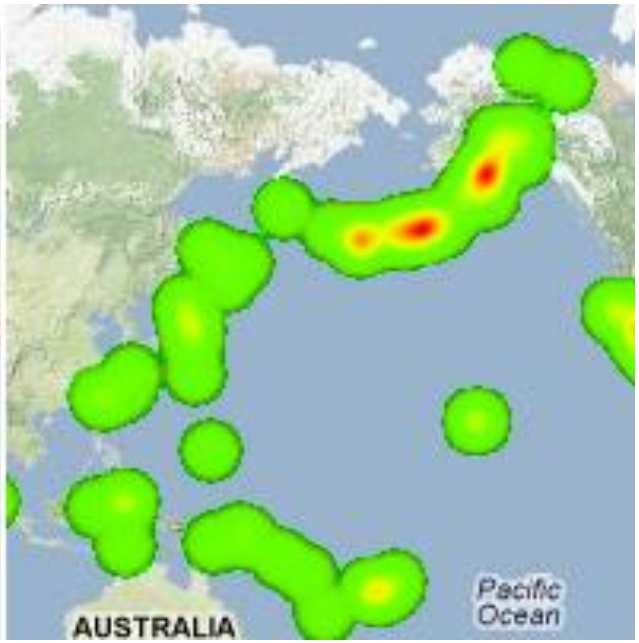


Data as Time

Idiom: Glyphs

Mapping Earthquake

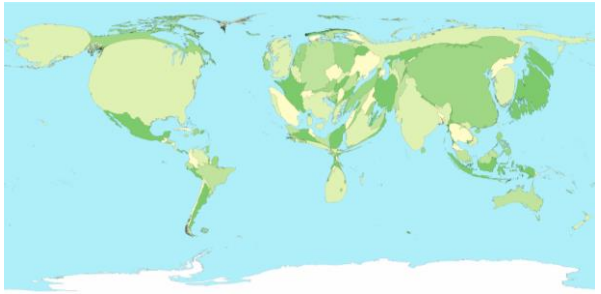


Idiom: Symbol maps Pros & Cons

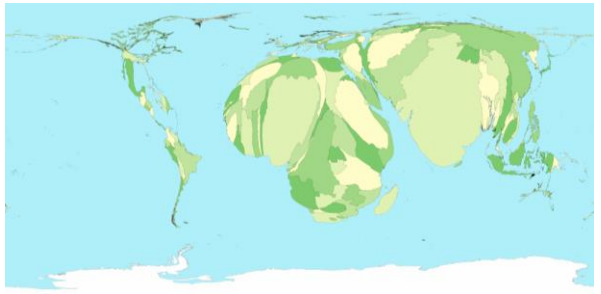
- pros
  - somewhat intuitive to read and understand
  - mitigate problems with region size vs data salience
    - marks: symbol size follows attribute value
    - glyphs: symbol size can be uniform
- cons
  - possible occlusion / overlap
    - symbols could overlap each other
    - symbols could occlude region boundaries
  - complex glyphs may require explanation / training

Idiom: Contiguous cartogram

- interlocking marks:
  shape, area, and position coded
- derive new interlocking marks
  - based on combination of original interlocking marks and new quantitative attribute
- algorithm to create new marks
  - input: target size
  - goal: shape as close to the original as possible
  - requirement: maintain constraints
    - relative position
    - contiguous boundaries with their neighbours



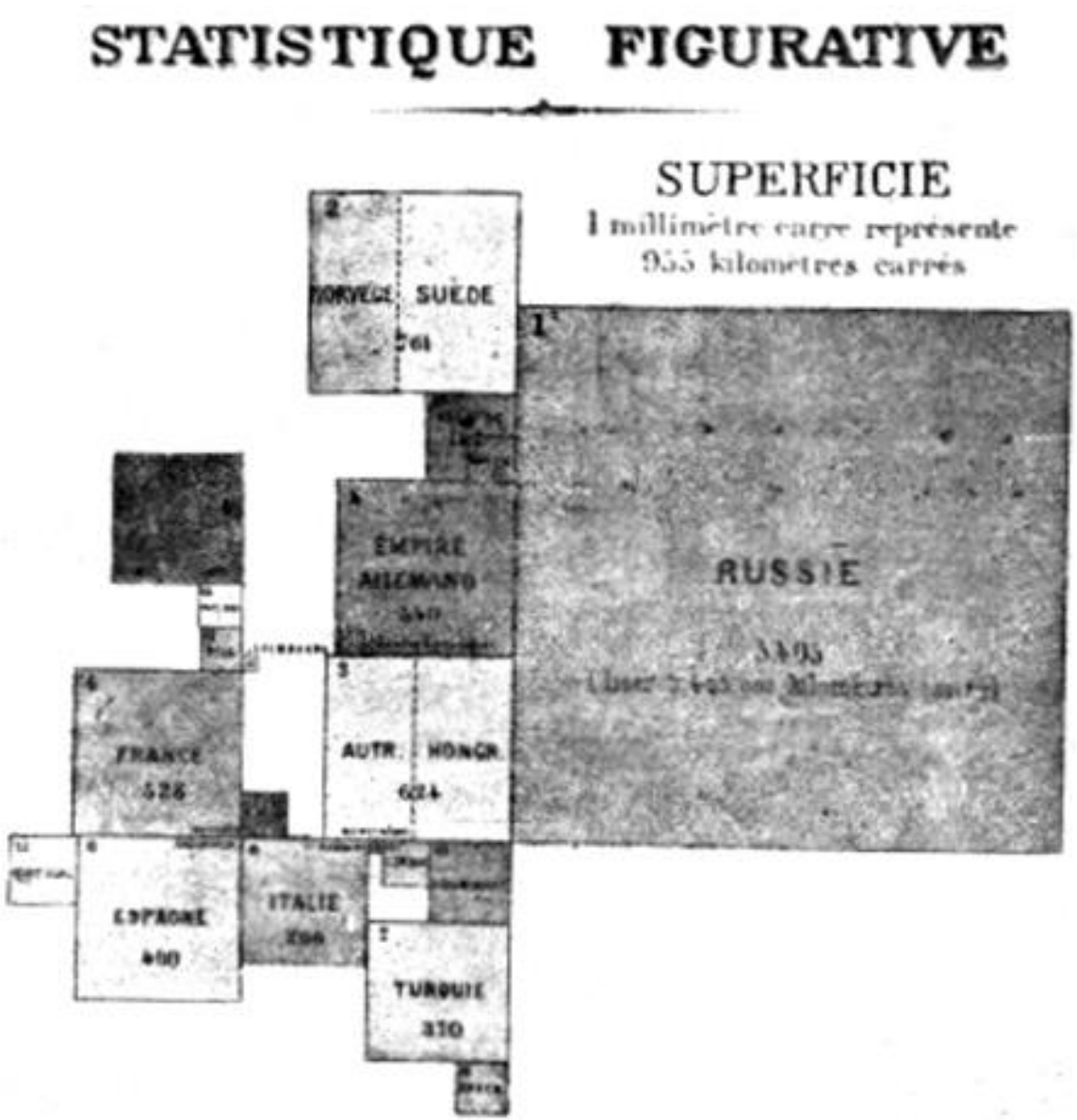
Greenhouse Emissions



Child Mortality

Idiom: cartogram

- Map in which areas are scaled and distorted relative to a data attribute value
- e.g. Land Area
  (first cartogram, Emile Levasseur, 1868)



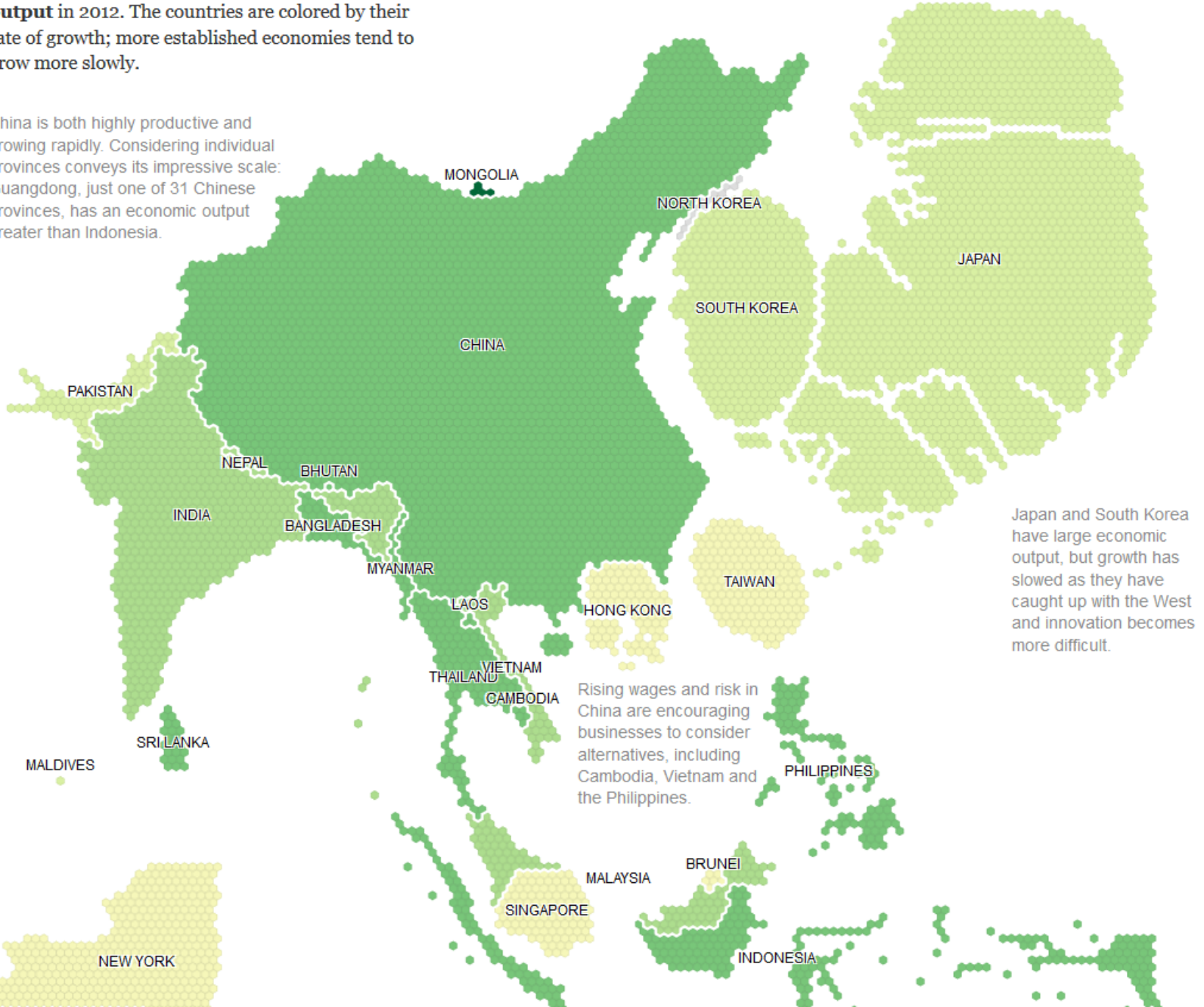
Economic Output

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.

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

G.D.P. growth, 2011 to 2012

2 4 6 8 +10%



Population

Sizing by population instead gives an estimate of a country's economic potential, at least for labor-based manufacturing. The color here shows the economic output per capita: a measure of how effectively that potential has been realized, and a proxy for labor cost.

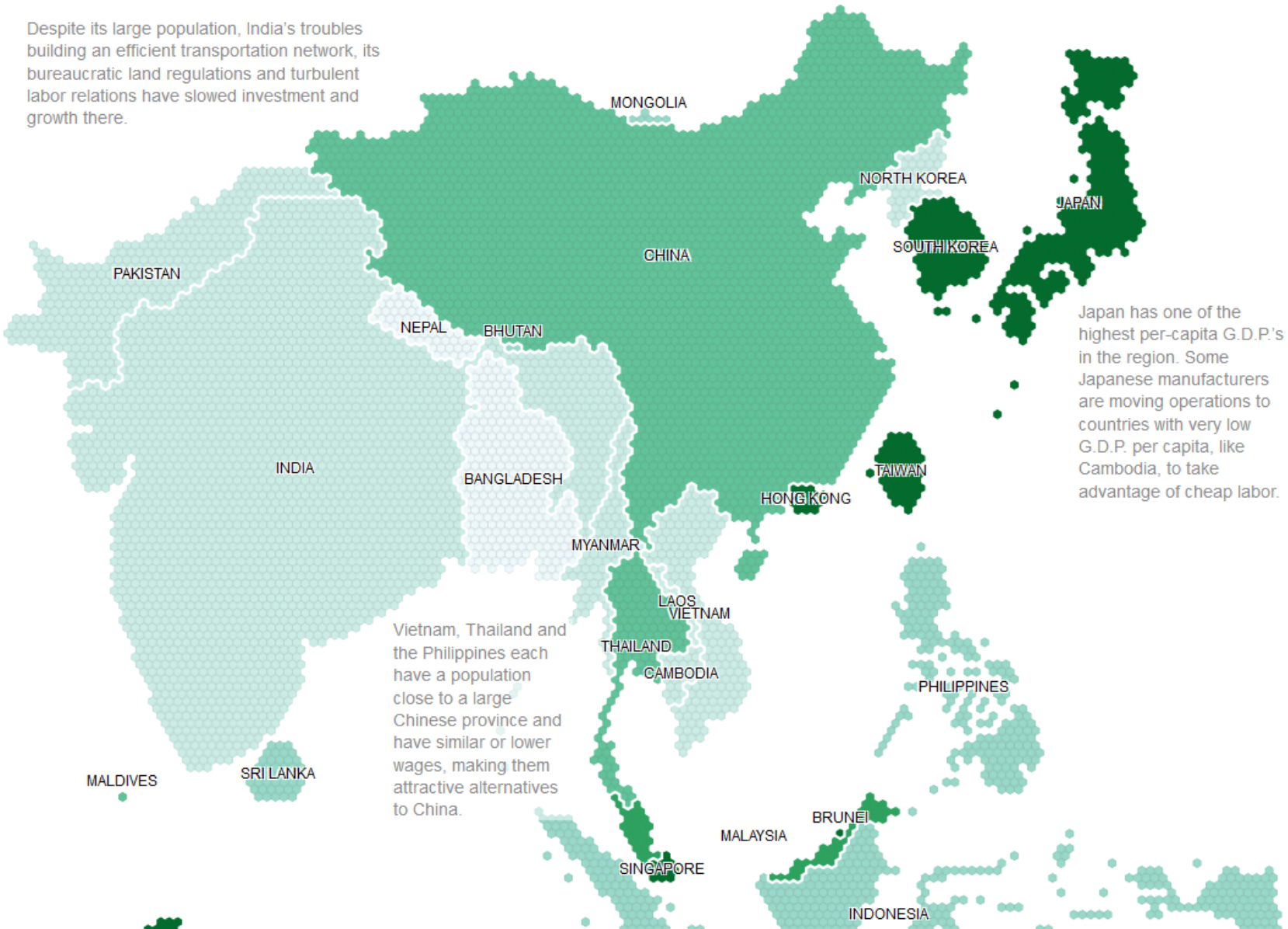
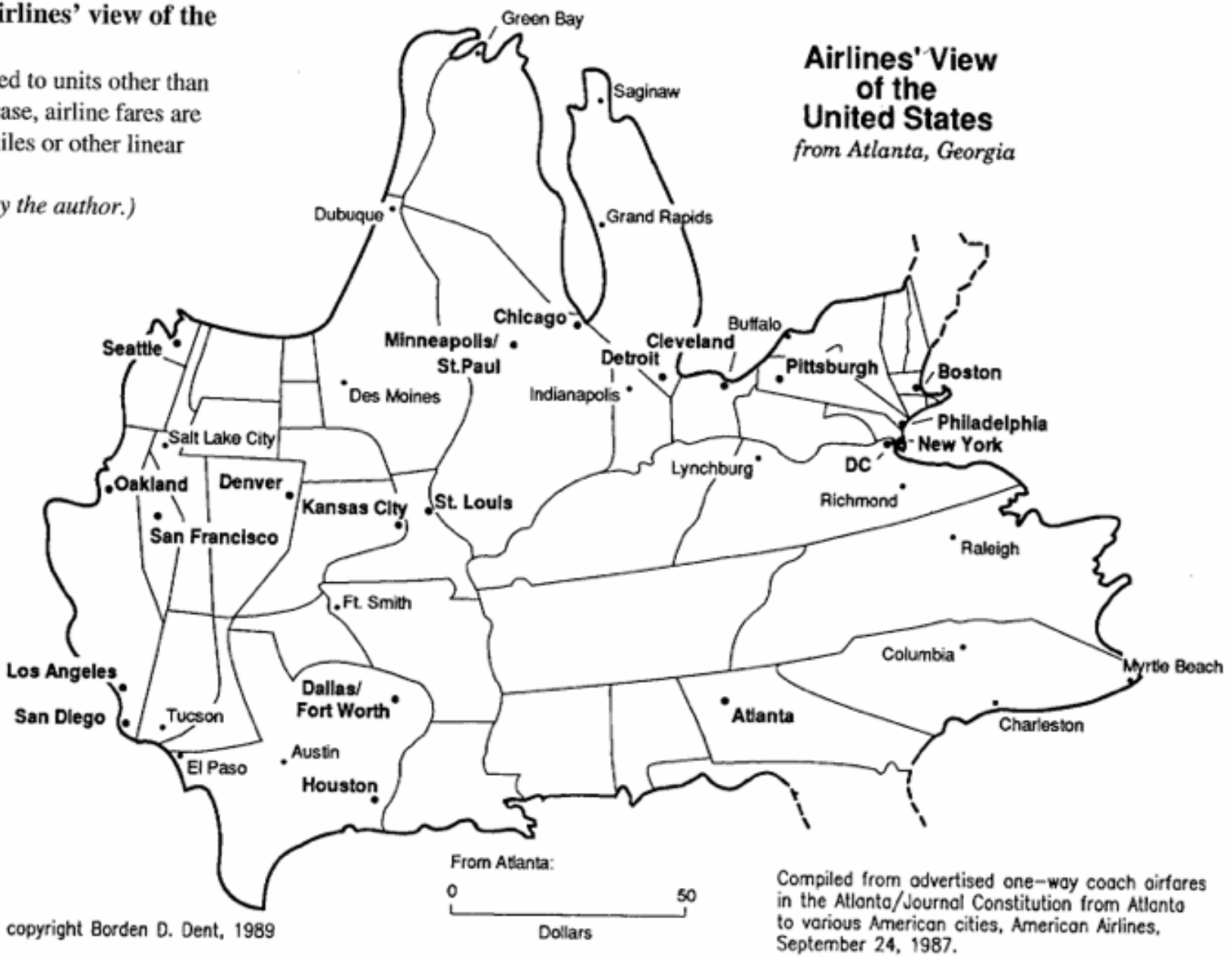
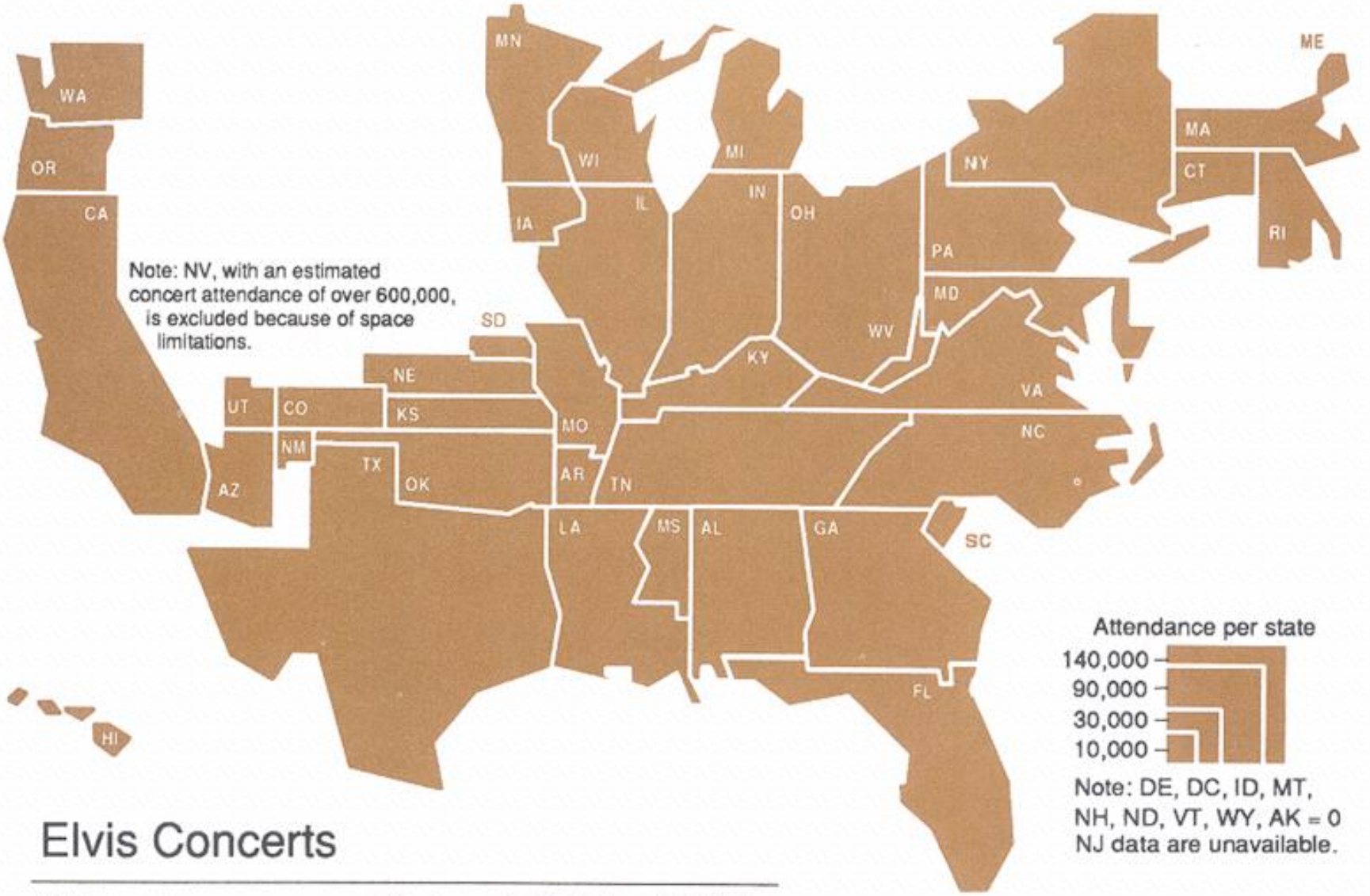


Figure 1.8 Airlines' view of the United States.
Maps can be scaled to units other than distance. In this case, airline fares are used instead of miles or other linear units.
(Map copyright by the author.)



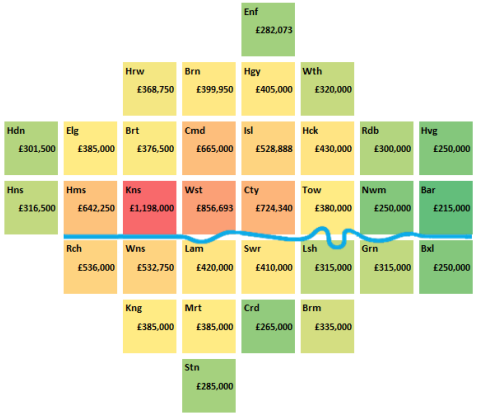


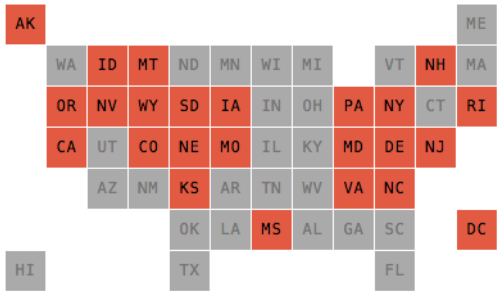
Elvis Concerts

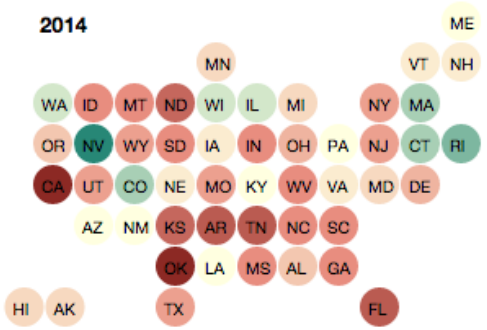
Attendance per State, 1970 - 1977

Source: Stanley, David E., with Frank Coffey. The Elvis Encyclopedia. Santa Monica, CA.: General Publishing Group, Inc , 1994.

Idiom: Grid cartogram





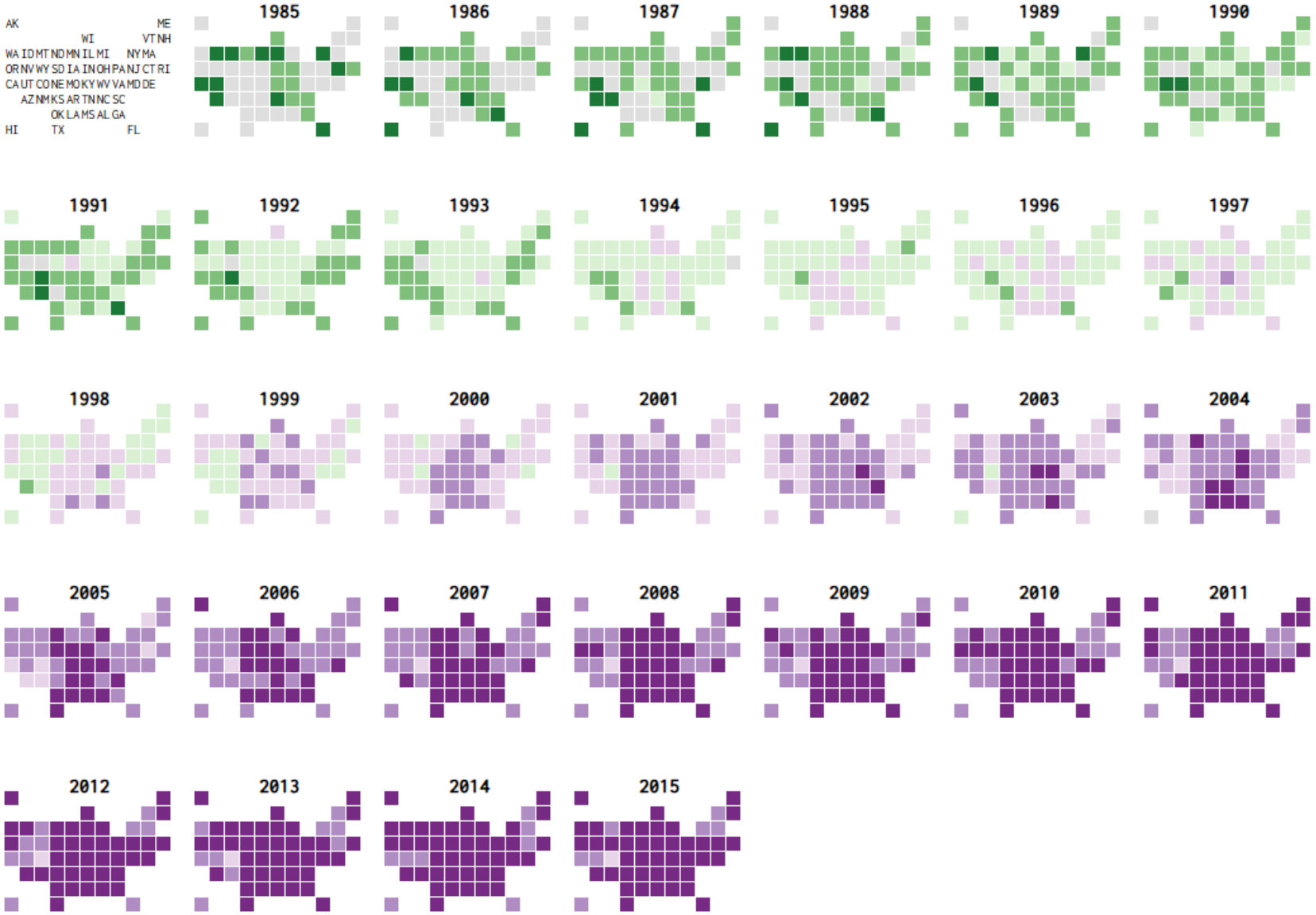


- uniform-sized shapes arranged in rectilinear grid
- maintain approximate spatial position and arrangement

OBESITY RATES OVER THE YEARS

SEX Female **Male**

10% 15% 20% 25% 30%



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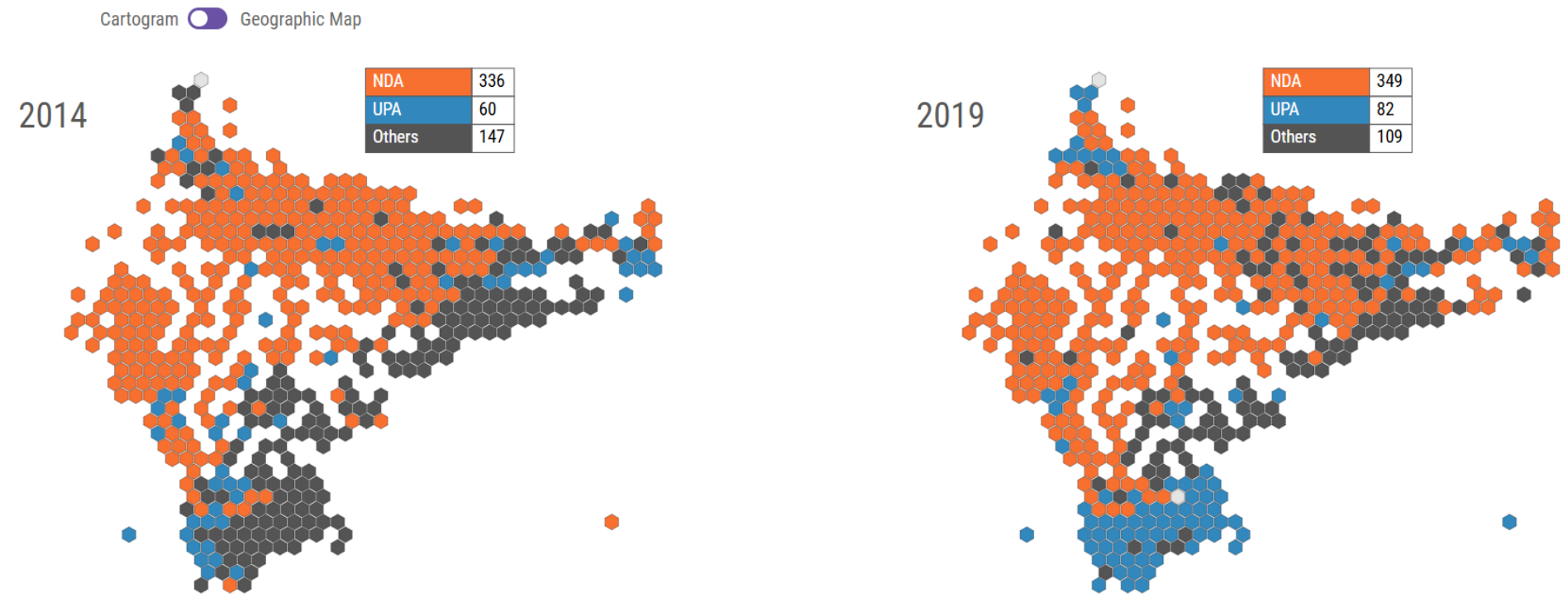
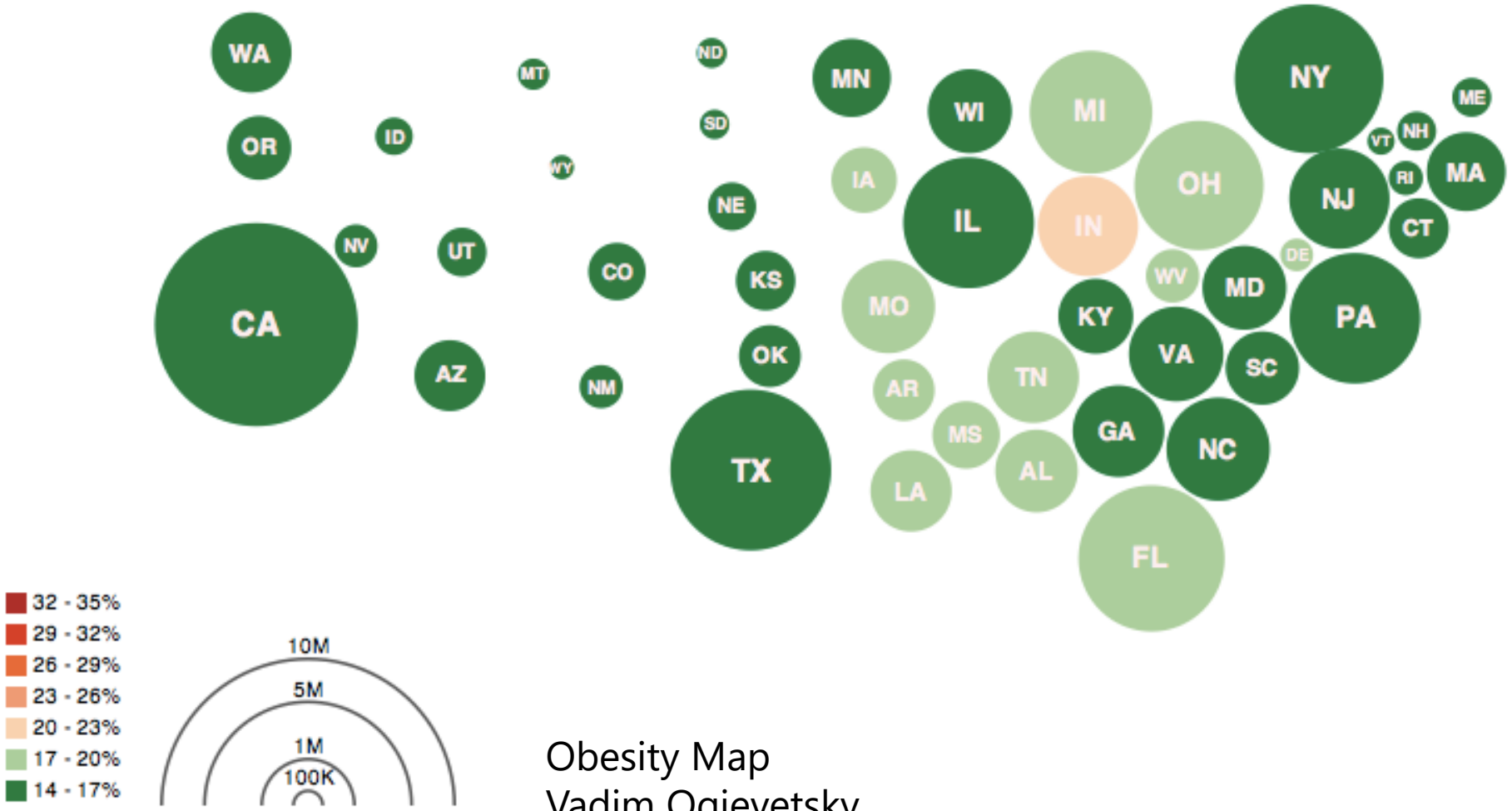
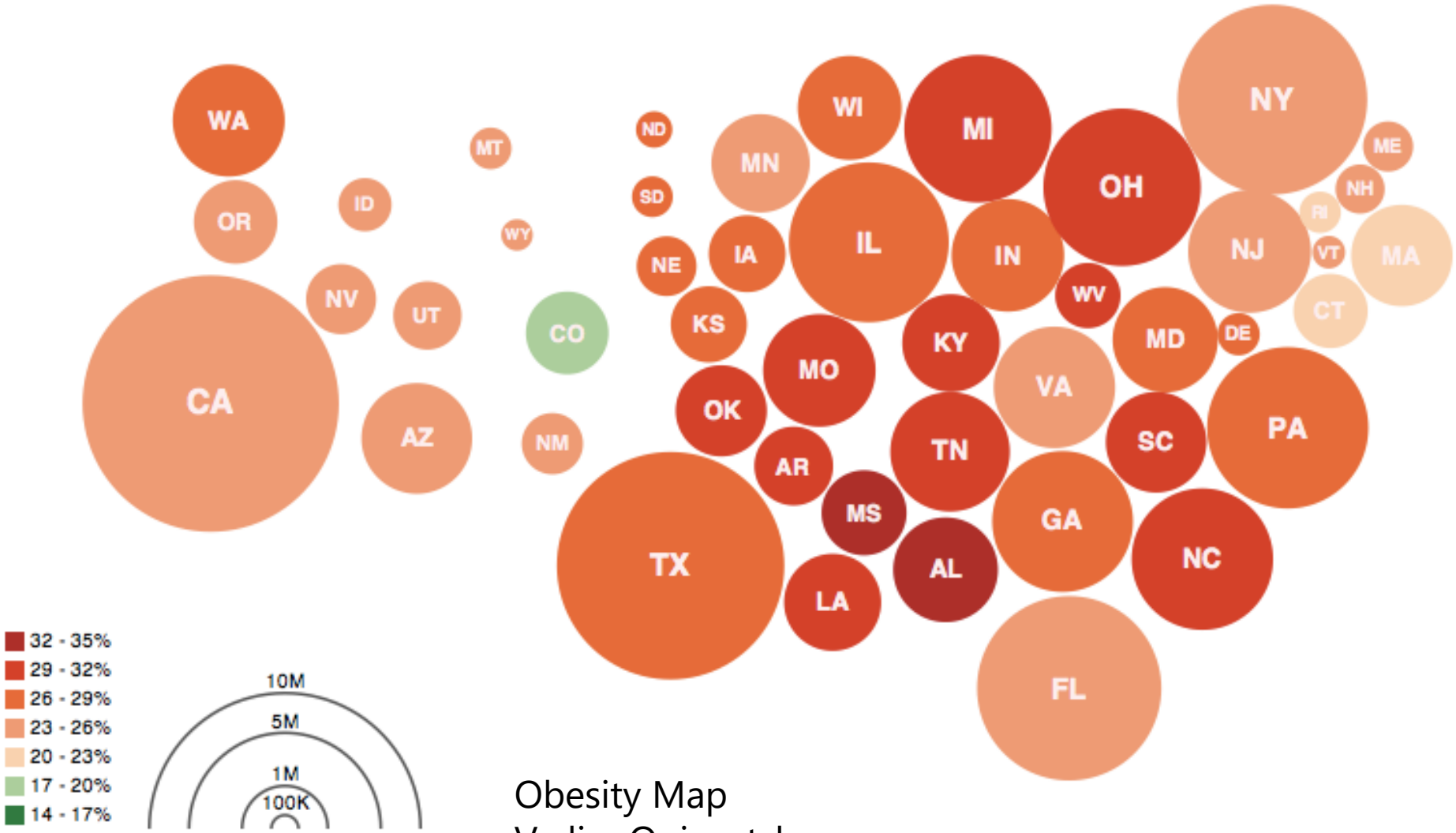


Idiom: Dorling cartogram



Obesity Map
Vadim Ogievetsky

Idiom: Dorling cartogram



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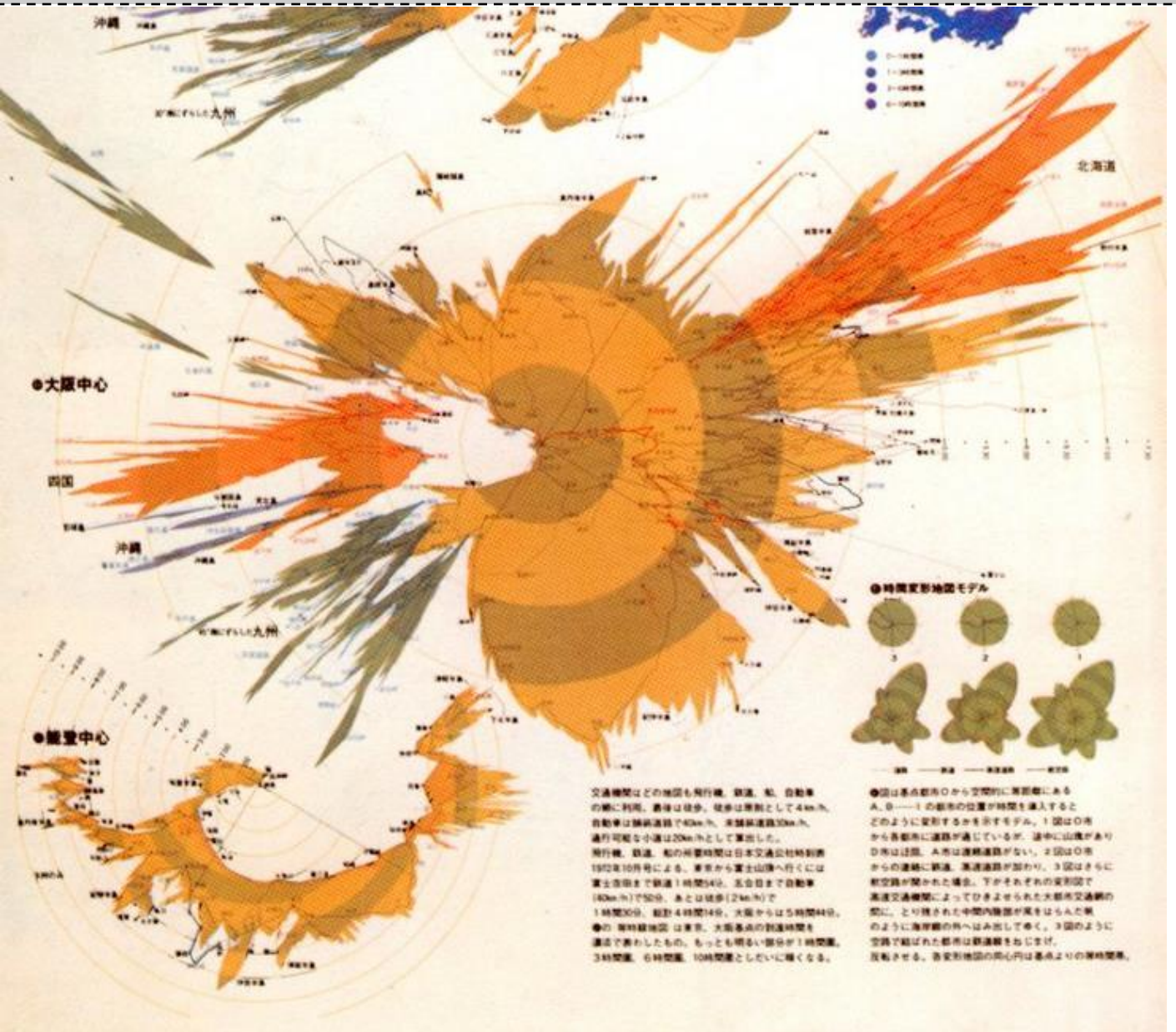


Kohei Sugiura's
time map of Tokyo

US Presidential Election 2024

Results mapped at county level showing the candidate with the largest vote share in each area

Results

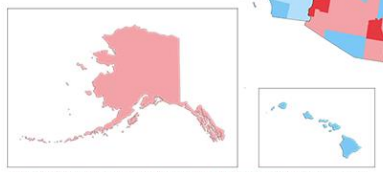
Harris
75,012,178 votes (51.1%)
226 electoral votes

Trump
77,302,416 votes (49.8%)
312 electoral votes

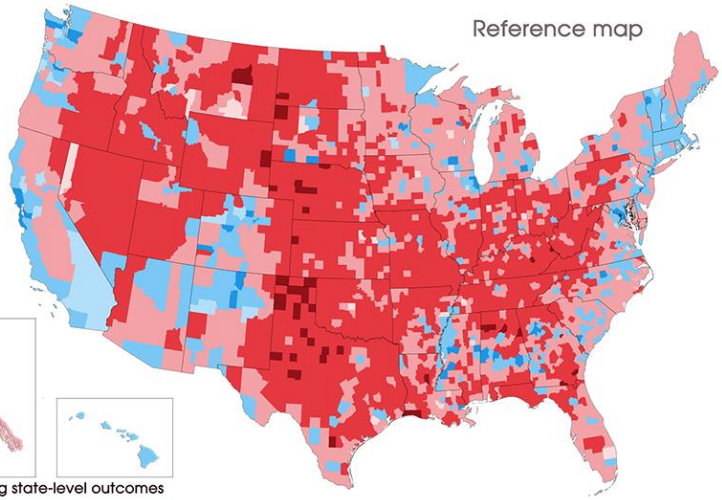
Vote share
of candidate with most votes

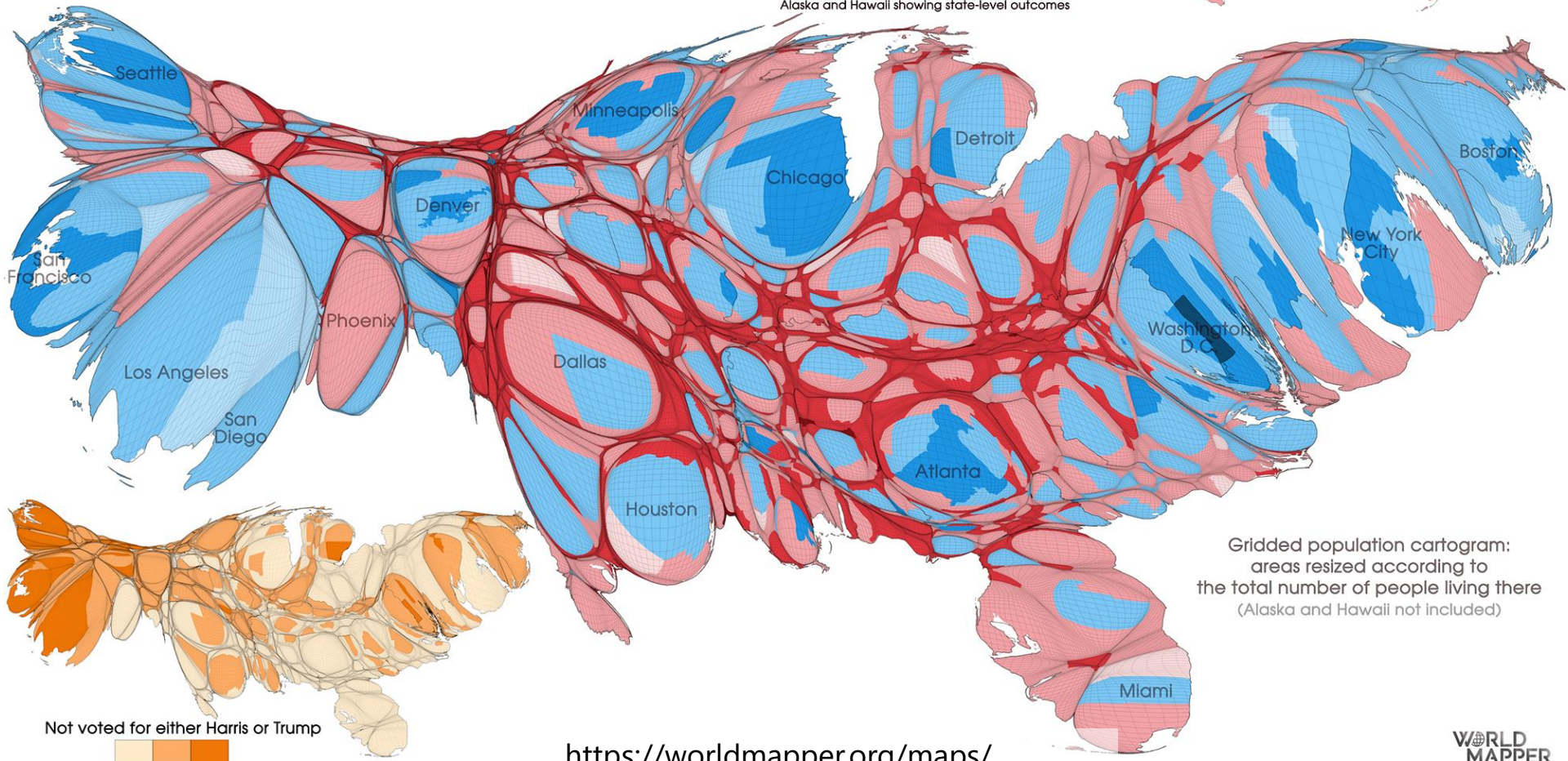
Harris
0 50 70 90%
Trump

Data Sources: BBC, Tony McGovern (tonmcg / github), Oak Ridge National Laboratory



Alaska and Hawaii showing state-level outcomes





Gridded population cartogram:
areas resized according to
the total number of people living there
(Alaska and Hawaii not included)

https://worldmapper.org/maps/

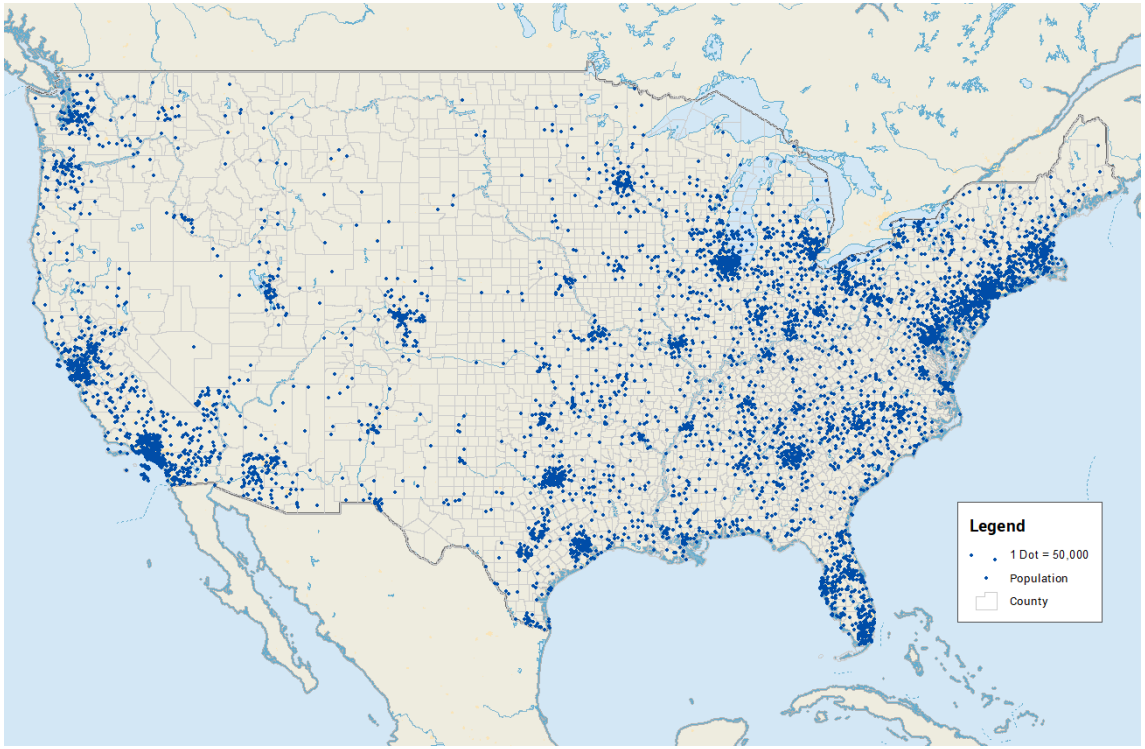
WORLD MAPPER
www.worldmapper.org

Cartogram: Pros & cons

- pros
  - can be intriguing and engaging
  - best case: strong and surprising size disparities
  - non-contiguous cartograms often easier to understand
- cons
  - require substantial familiarity with original dataset & use of memory
    - compare distorted marks to memory of original marks
    - mitigation strategies: transitions or side by side views
  - major distortion is problematic
    - may be aesthetically displeasing
    - may result in unrecognizable marks
  - difficult to extract exact quantities

Idiom: Dot density maps

- visualize distribution of a phenomenon by placing dots
- one symbol represents a constant number of items
  - dots have uniform size & shape
  - allows use of color channel
- task:
  show spatial patterns, clusters



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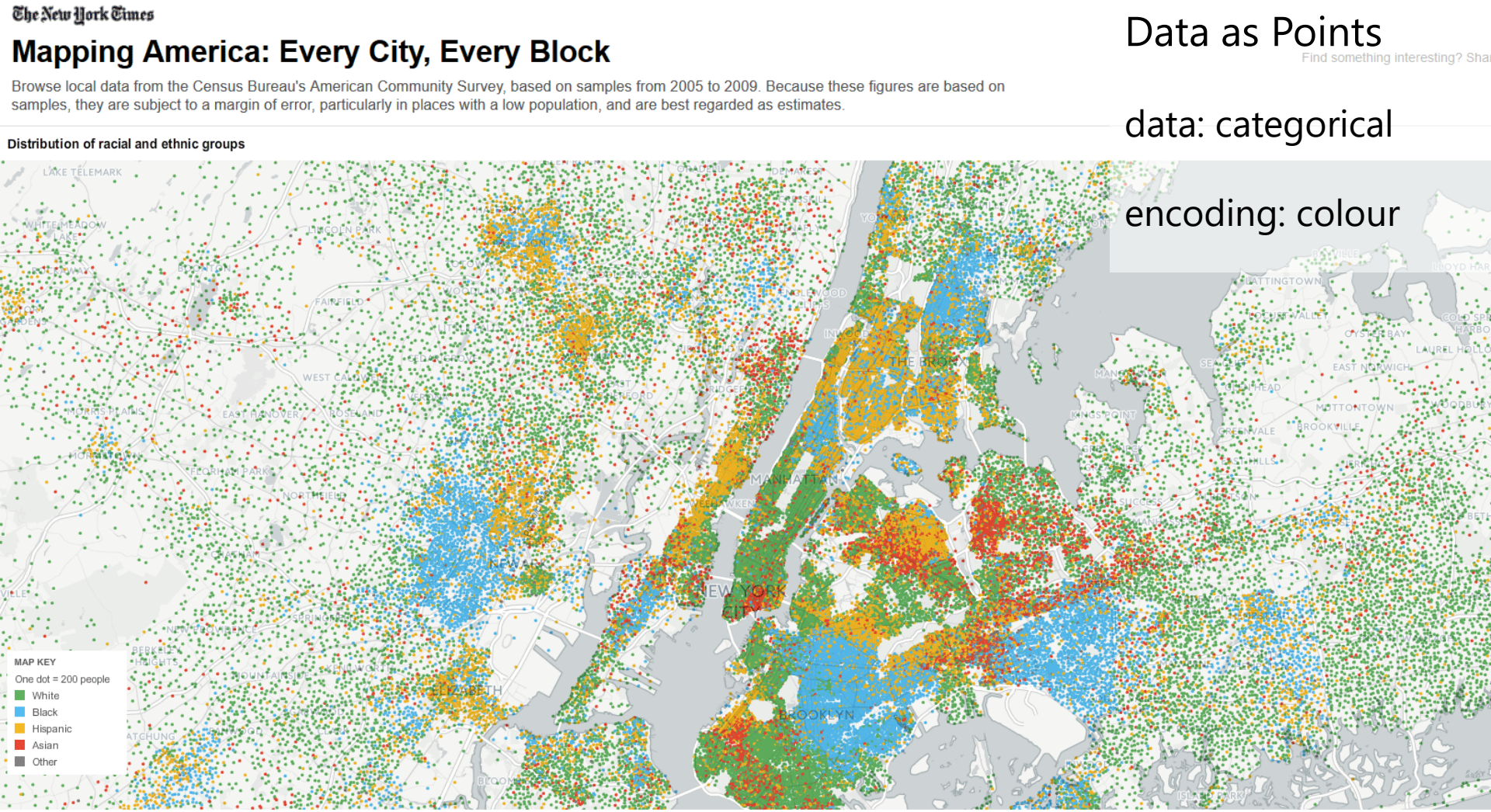
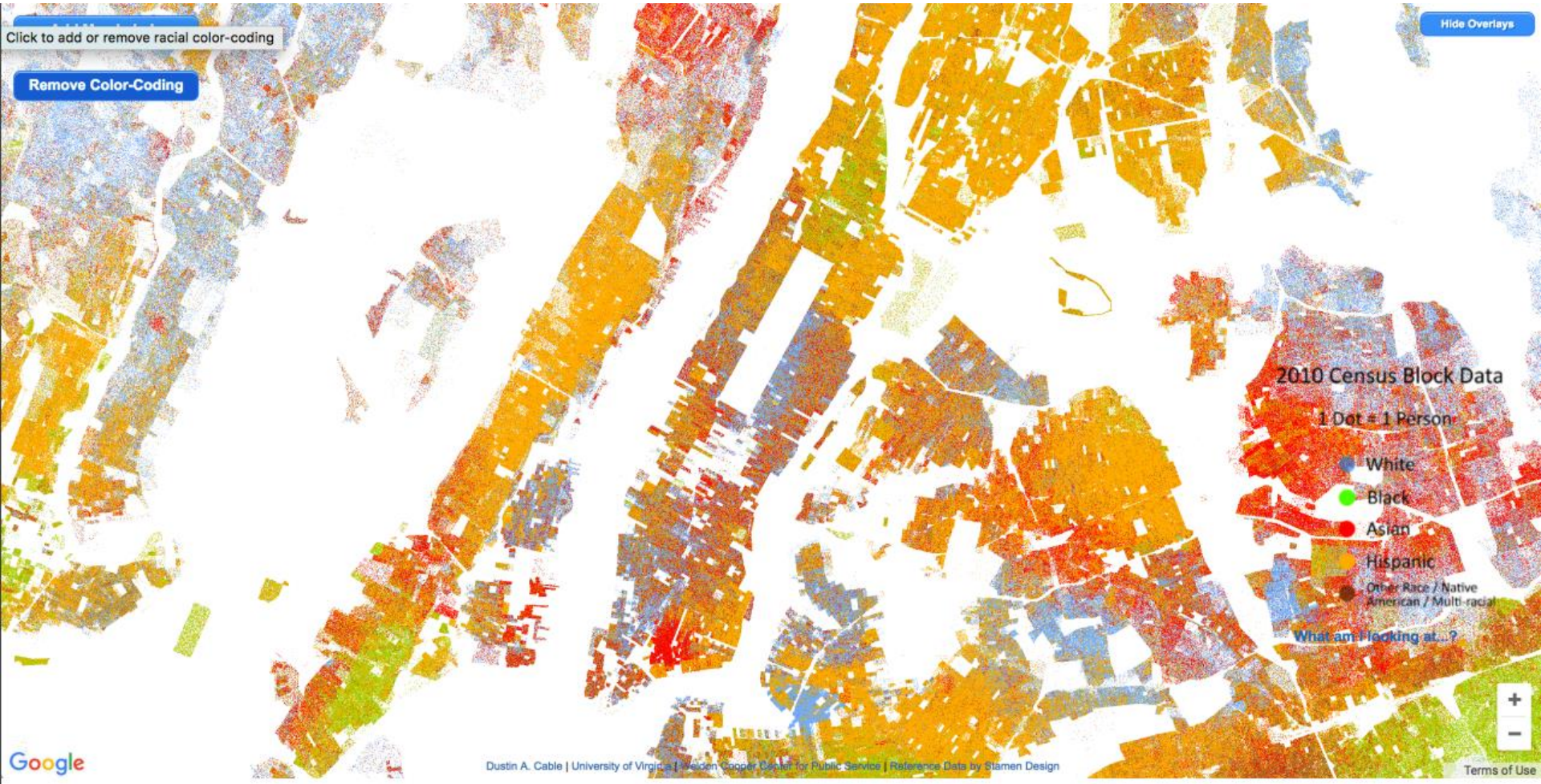


Data as Points

data: categorical

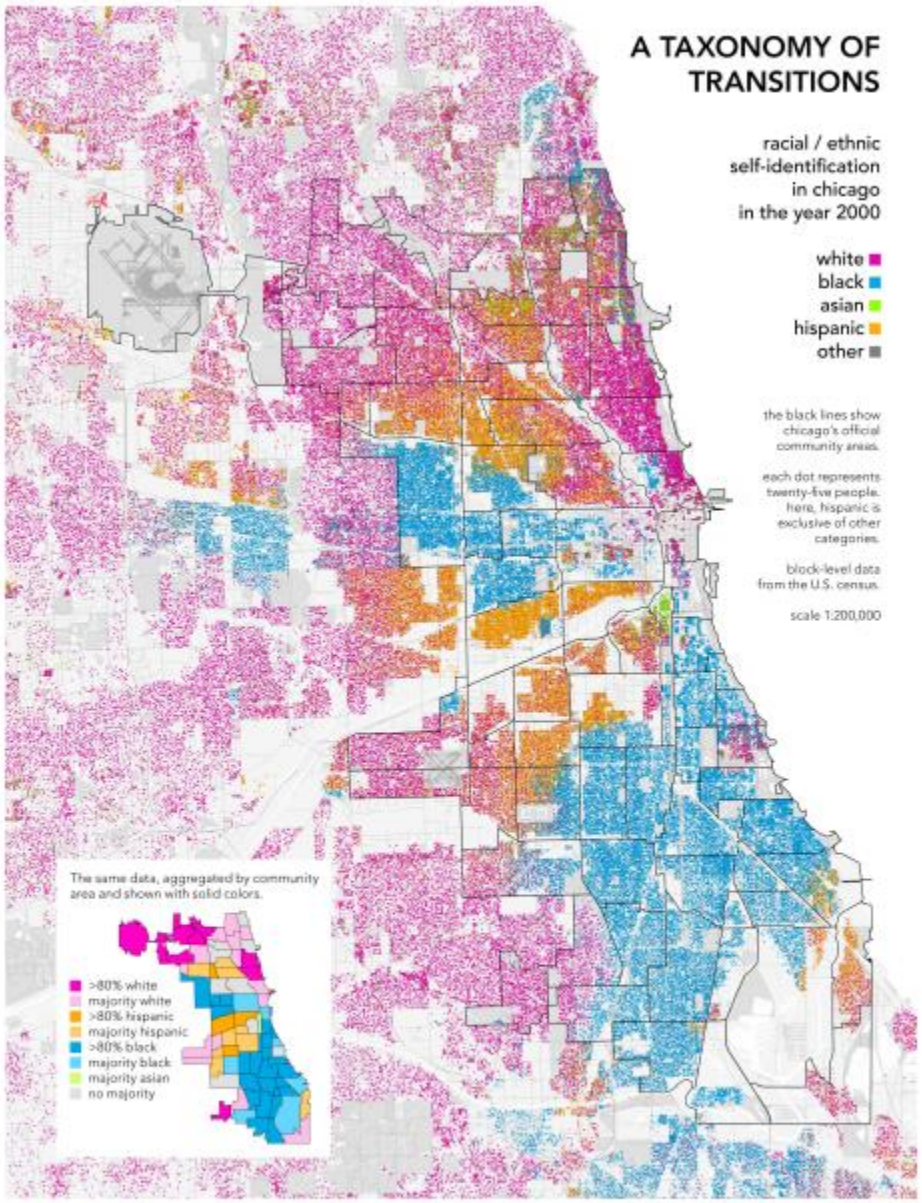
encoding: colour

Idiom: Dot density maps



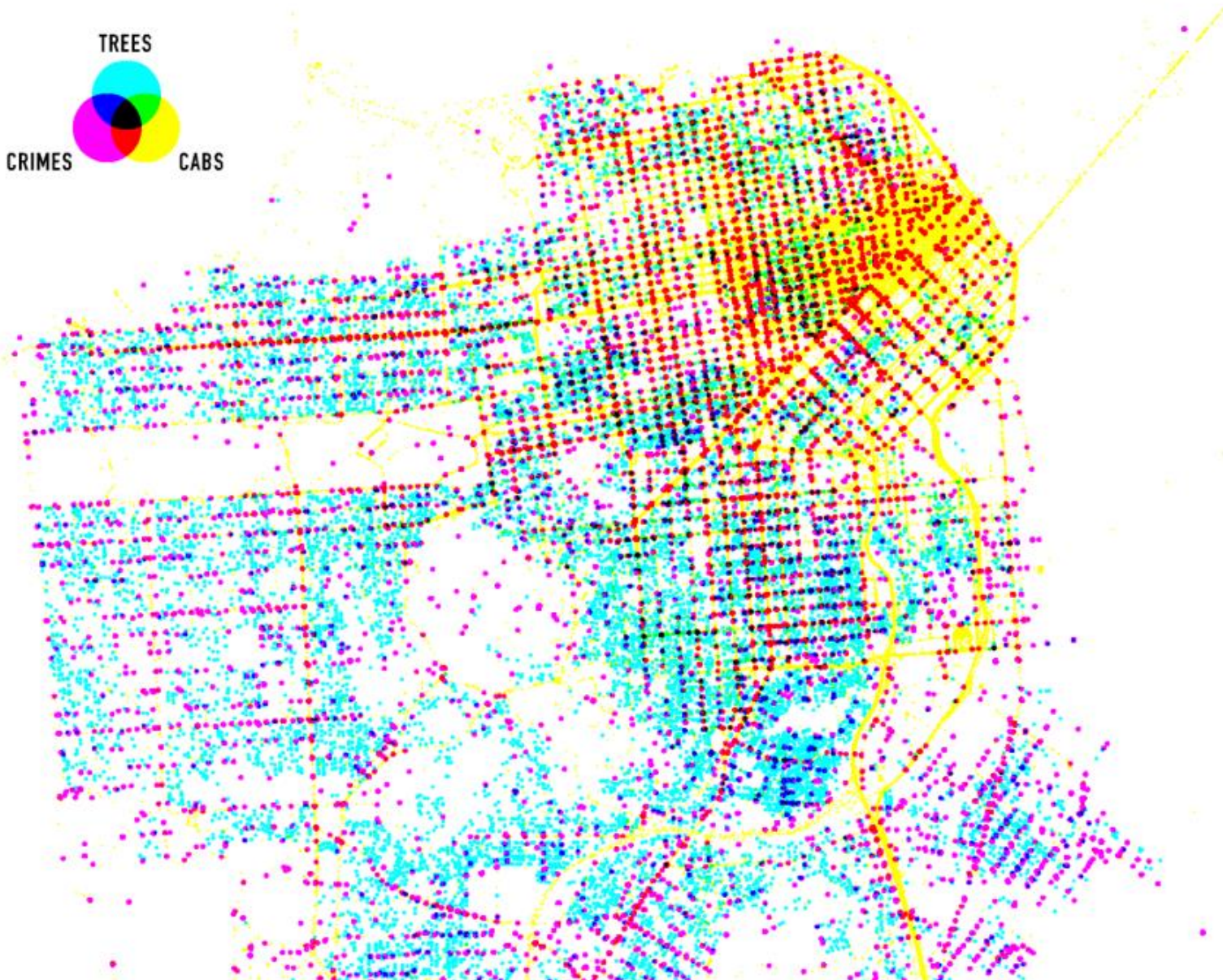
Racial segregation: *dots + color*

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



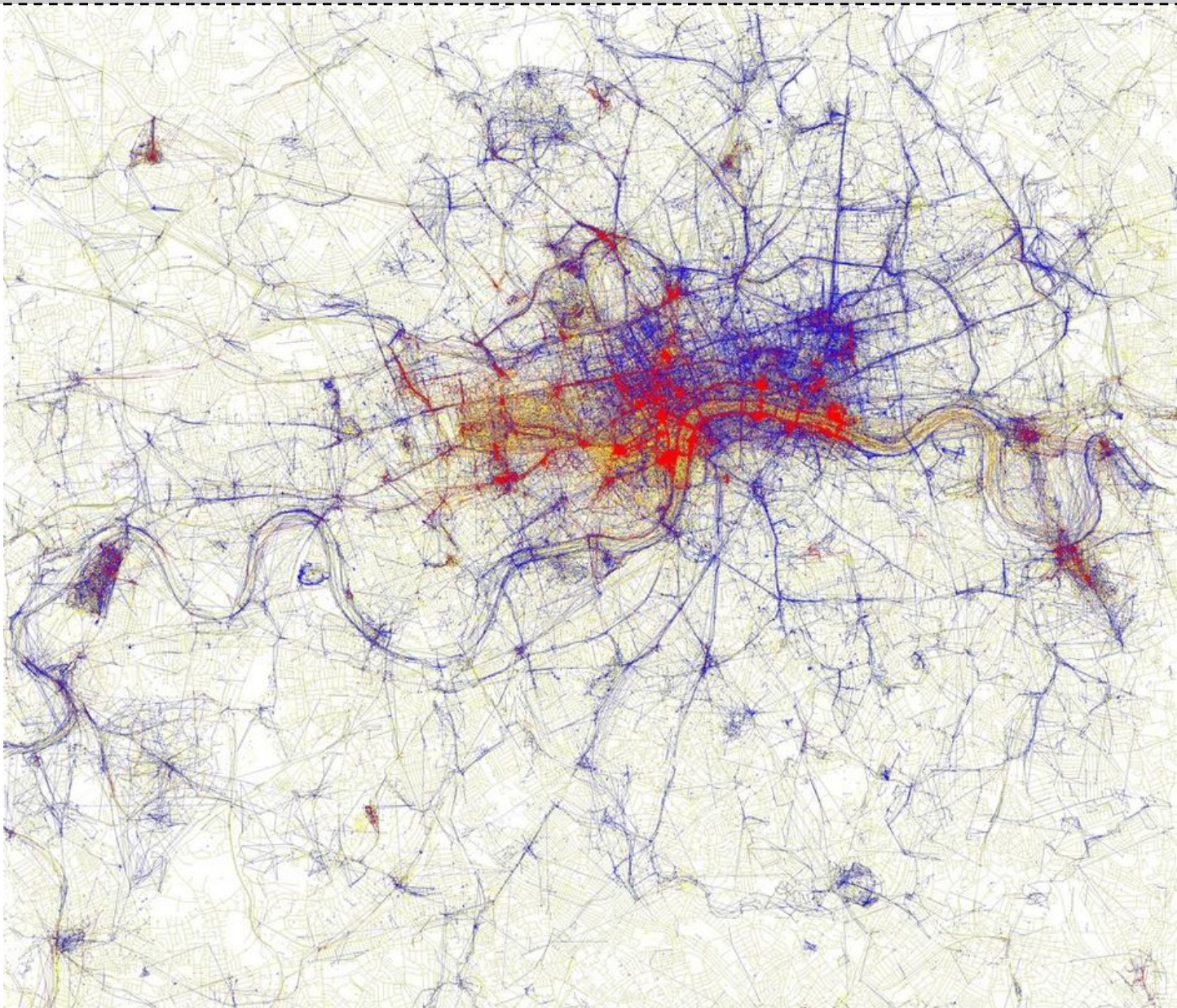
Racial segregation in Chicago: *dots vs choropleth*

Idiom: Dot density maps



Idiom: Dot density maps

Data as Points

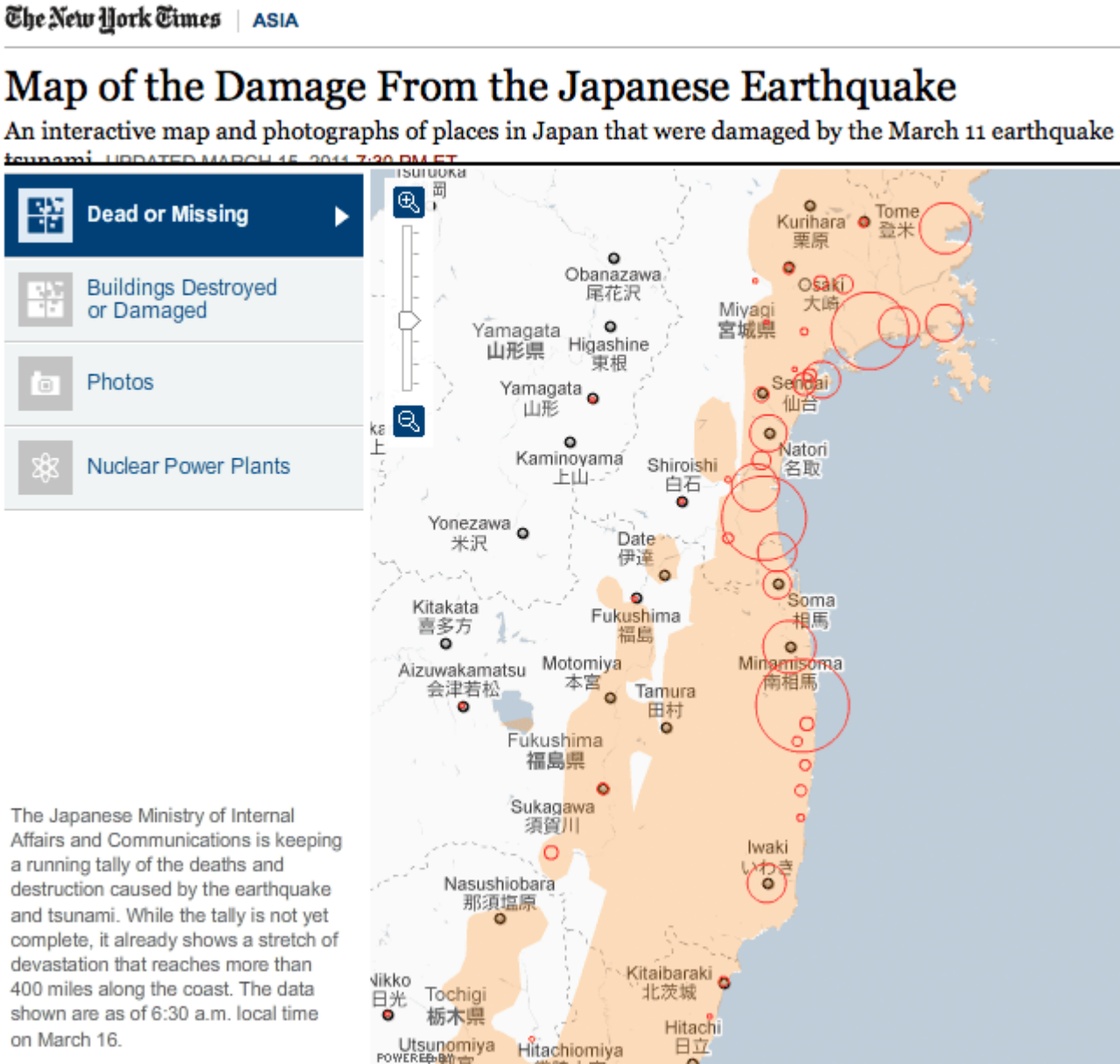


Idiom: Dot density maps

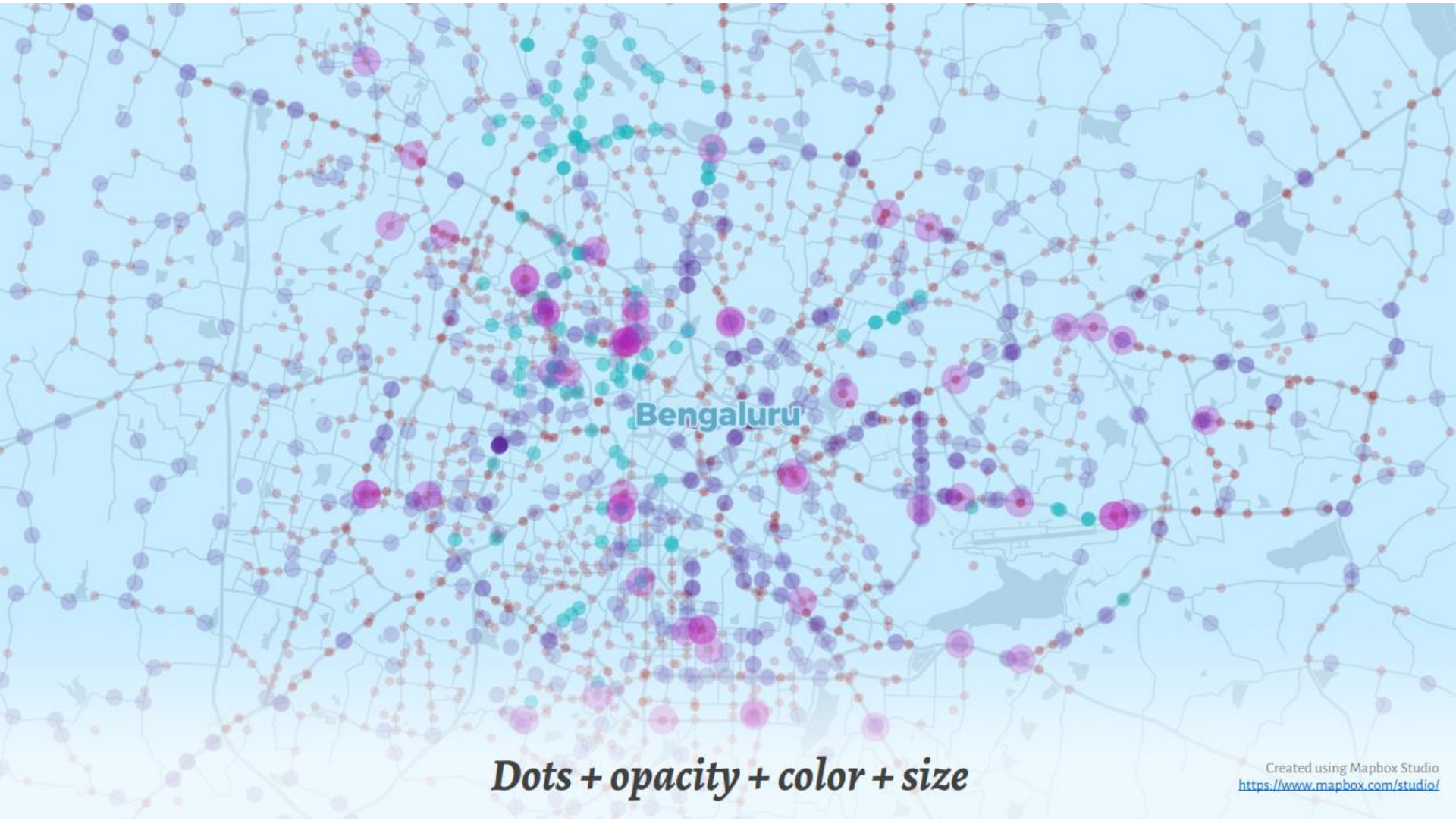
Data as Points

data: ordered/ quantitative

encoding: position, size



Idiom: Dot density maps

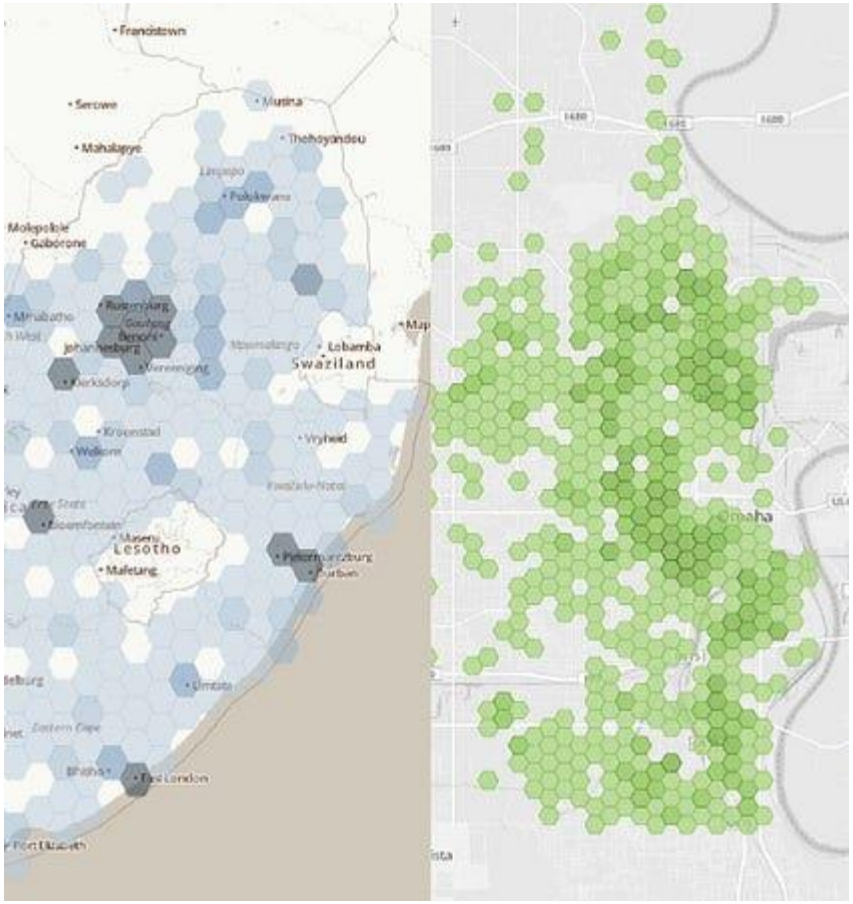


Dot density maps: Pros & Cons

- pros
  - straightforward to understand
  - avoids choropleth non-uniform region size problems
- cons
  - challenge: normalization, just like choropleths
    - show population density (correlated with attribute), not effect of interest
  - perceptual disadvantage:
    difficult to extract quantities
  - performance disadvantage:
    rendering many dots can be slow

Idiom: Binning as an alternative to dot density maps

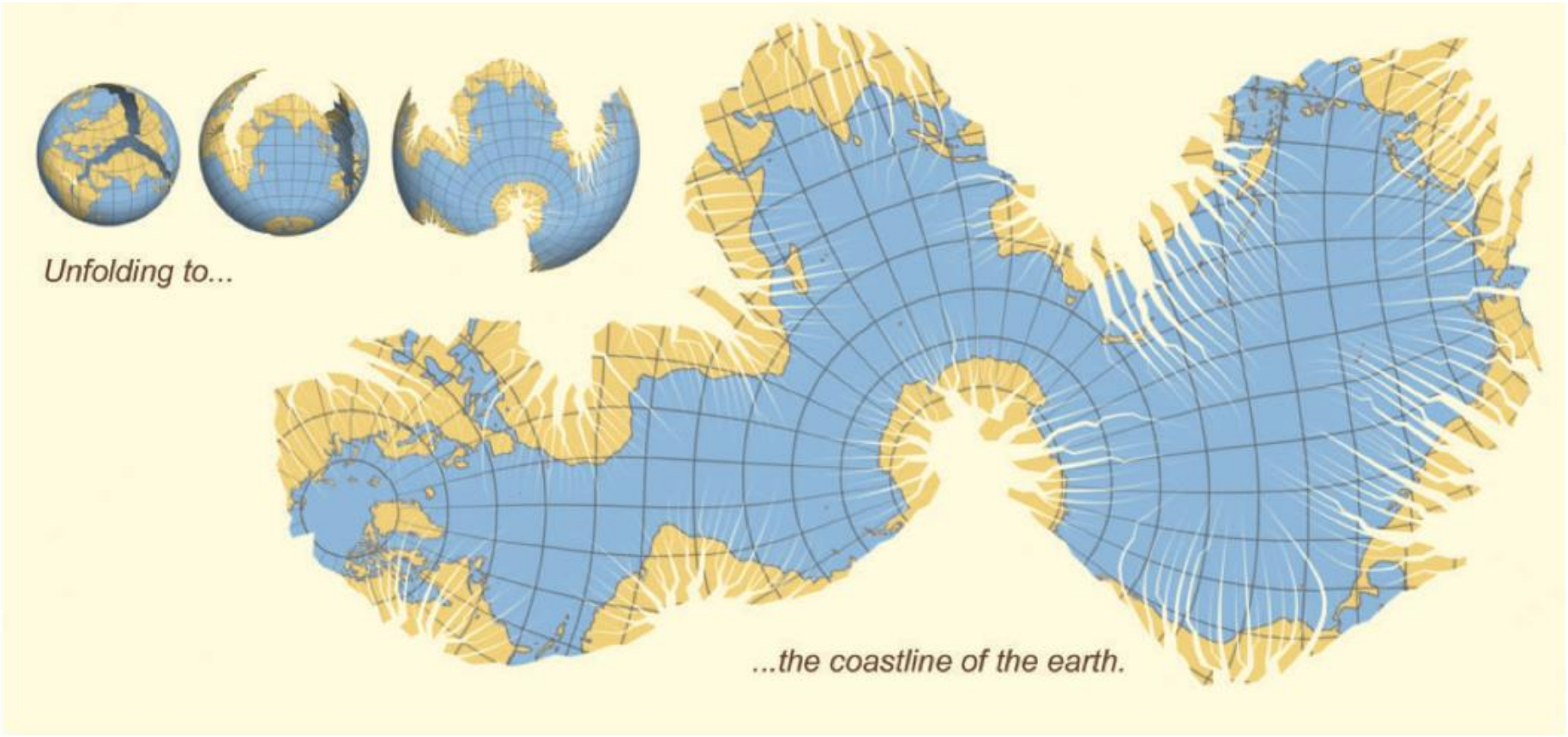
- Binning is a great alternative technique for visualizing density when working with large data sets
- Sometimes aggregating the data tells a better story or uncovers new findings
- One method is hexagonal binning, which uses hexagon shapes to create a grid and develop a spatial histogram
- Binning is simple — it's the number of points that fall within a rectangle or hexagon in a gridded surface



https://blog.mapbox.com/binning-an-alternative-to-point-maps-2cfc7b01d2ed

Map Projections

A sphere tears when you flatten it

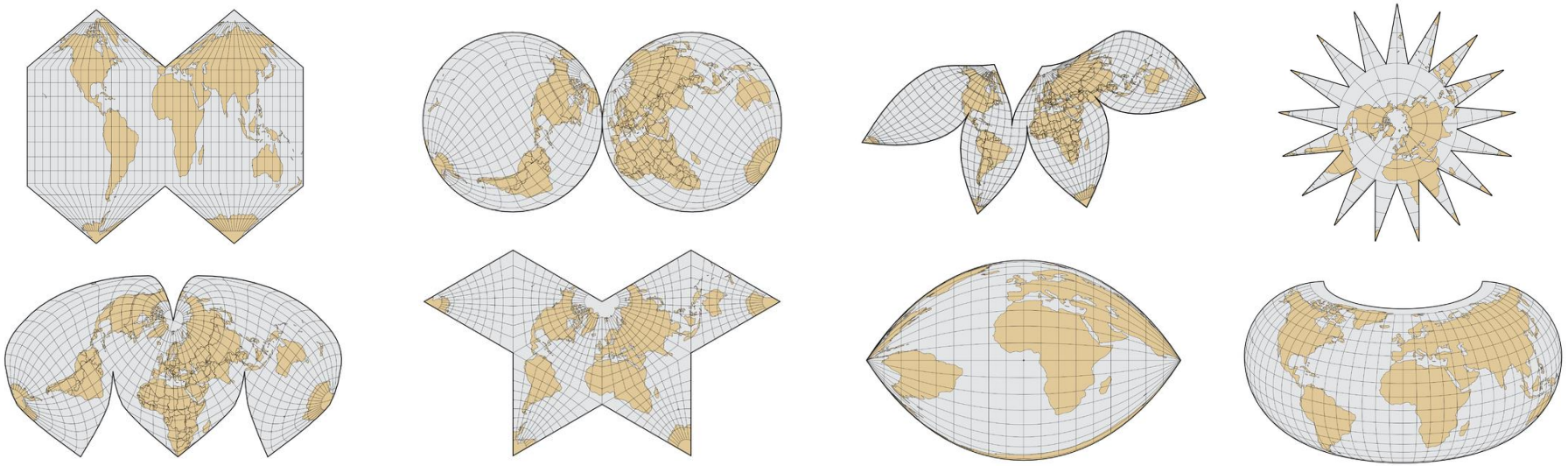


Many ways to tear it

van Wijk 2008

Map Projections

- mathematical functions that map 3D surface geometry of the Earth to 2D maps
- all projections of sphere on plane necessarily distort surface in some way
- interactive: philogb.github.io/page/myriahedral/ and jasondavies.com/maps/



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!

ROBINSON

YOU HAVE A COMFORTABLE PAIR OF RUNNING SHOES THAT YOU WEAR EVERYWHERE. YOU LIKE COFFEE AND ENJOY THE BEATLES. YOU THINK THE ROBINSON IS THE BEST-LOOKING PROJECTION, HANDS DOWN.

DYMAXION

YOU LIKE ISAAC ASIMOV, XML, AND SHOES WITH TOES. YOU THINK THE SEGWAY GOT A BAD RAP. YOU OWN 3D GOGGLES, WHICH YOU USE TO VIEW ROTATING MODELS OF BETTER 3D GOGGLES. YOU TYPE IN DVORAK.

WINKEL-TRIPEL

NATIONAL GEOGRAPHIC ADOPTED THE WINKEL-TRIPEL IN 1998, BUT YOU'VE BEEN A W-T FAN SINCE *LONG* BEFORE "NAT GEO" SHOWED UP. YOU'RE WORRIED IT'S GETTING PLAYED OUT, AND ARE THINKING OF SWITCHING TO THE KAVRAYSKIY. YOU ONCE LEFT A PARTY IN DISGUST WHEN A GUEST SHOWED UP WEARING SHOES WITH TOES. YOUR FAVORITE MUSICAL GENRE IS "POST-".

GOODE HOMOLOSINE

THEY SAY MAPPING THE EARTH ON A 2D SURFACE IS LIKE FLATTENING AN ORANGE PEEL, WHICH SEEMS EASY ENOUGH TO YOU. YOU LIKE EASY SOLUTIONS. YOU THINK WE WOULDN'T HAVE SO MANY PROBLEMS IF WE'D JUST ELECT *NORMAL* PEOPLE TO CONGRESS INSTEAD OF POLITICIANS. YOU THINK AIRLINES SHOULD JUST BUY FOOD FROM THE RESTAURANTS NEAR THE GATES AND SERVE *THAT* ON BOARD. YOU CHANGE YOUR CAR'S OIL, BUT SECRETLY WONDER IF YOU REALLY *NEED* TO.

HOBO-DYER

YOU WANT TO AVOID CULTURAL IMPERIALISM, BUT YOU'VE HEARD BAD THINGS ABOUT GALL-PETERS. YOU'RE CONFLICT-AVERSE AND BUY ORGANIC. YOU USE A RECENTLY-INVENTED SET OF GENDER-NEUTRAL PRONOUNS AND THINK THAT WHAT THE WORLD NEEDS IS A REVOLUTION IN CONSCIOUSNESS.

PLATE CARRÉE
(EQUIRECTANGULAR)

YOU THINK THIS ONE IS FINE. YOU LIKE HOW X AND Y MAP TO LATITUDE AND LONGITUDE. THE OTHER PROJECTIONS OVERCOMPLICATE THINGS. YOU WANT ME TO STOP ASKING ABOUT MAPS SO YOU CAN ENJOY DINNER.

WATERMAN BUTTERFLY

NEEDS IS A REVOLUTION IN CONSCIOUSNESS.

A GLOBE!

YES, YOU'RE VERY CLEVER.

WATERMAN BUTTERFLY

REALLY? YOU KNOW THE WATERMAN? HAVE YOU SEEN THE 1909 CAHILL MAP IT'S BASED— ...YOU HAVE A FRAMED REPRODUCTION AT HOME?! WHOA. ...LISTEN, FORGET THESE QUESTIONS. ARE YOU DOING ANYTHING TONIGHT?

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.

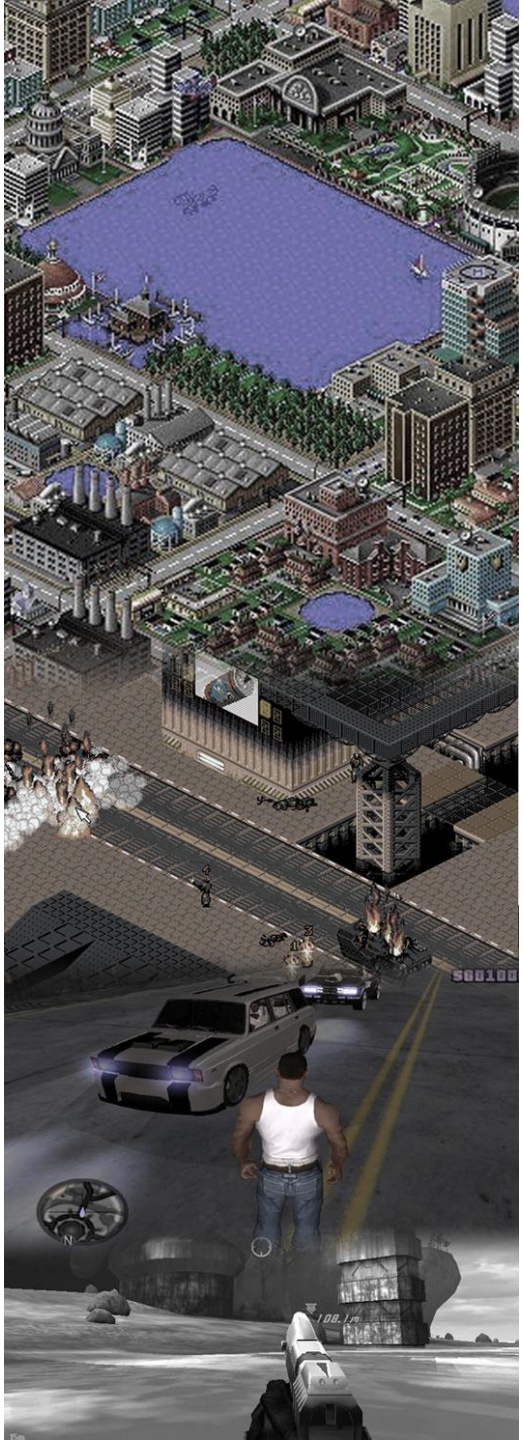
GALL-PETERS

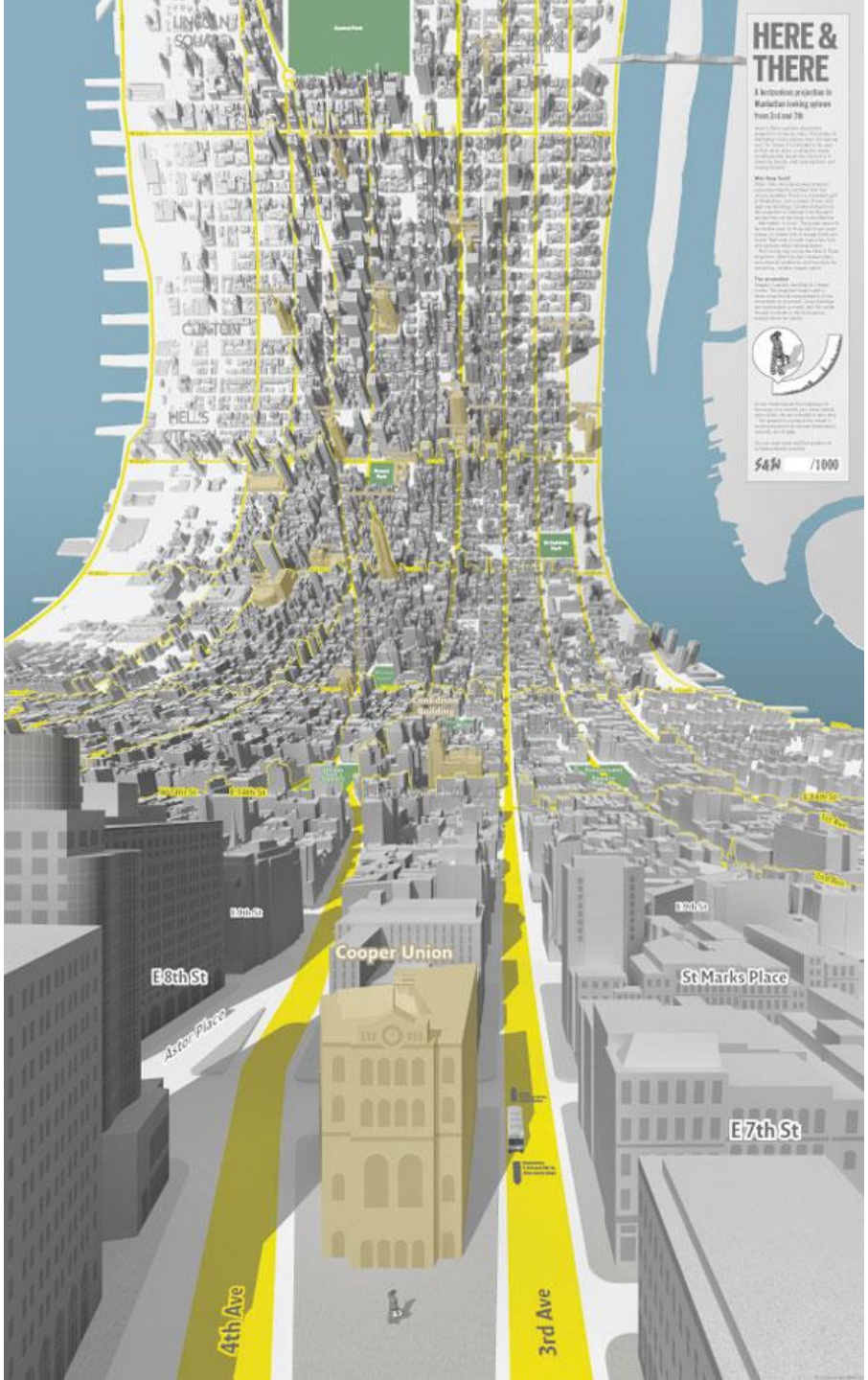
I *HATE* YOU.

http://xkcd.com/977/

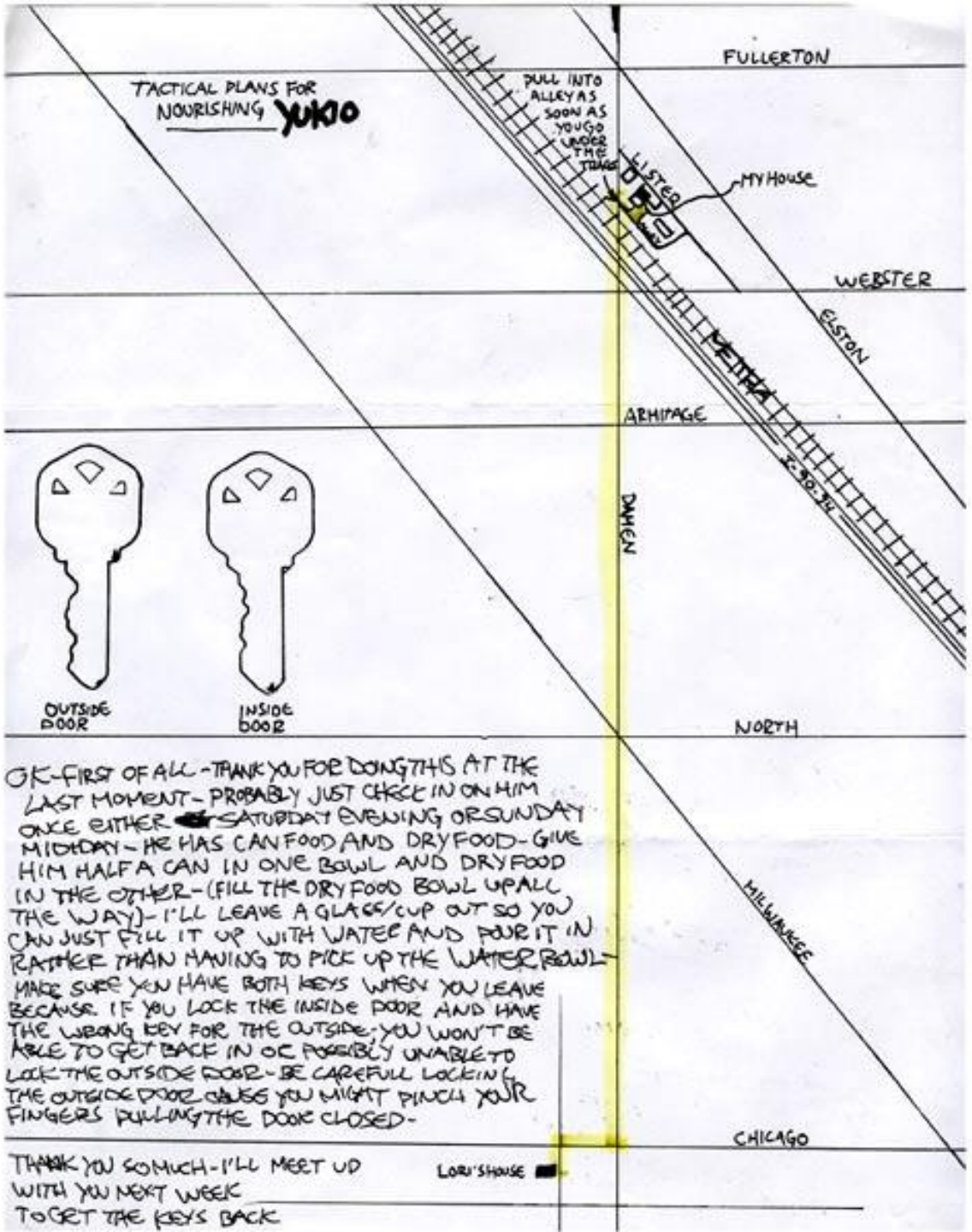
Projections Types

- Azimuthal: Preserves direction from a central point
- Authalic: Preserves area
- Conformal: Preserves angles / local shapes
- Others? Combinations?




HERE &
THERE
Cooper Union
E 8th St
St Marks Place
E 7th St
4th Ave
3rd Ave
Astor Place

Mental Maps


TACTICAL PLANS FOR NOURISHING YUKO
PULL INTO ALLEY AS SOON AS YOU GO UNDER THE TRACKS
LISTER
MY HOUSE
FULLERTON
WEBSTER
ELSTON
METRA
ARMITAGE
DAMEN
NORTH
MILWAUKEE
CHICAGO
OUTSIDE DOOR
INSIDE DOOR
OK-FIRST OF ALL-THANK YOU FOR DOING THIS AT THE LAST MOMENT- PROBABLY JUST CHECK IN ON HIM ONCE EITHER SATURDAY EVENING OR SUNDAY MIDDAY- HE HAS CAN FOOD AND DRY FOOD- GIVE HIM HALF A CAN IN ONE BOWL AND DRY FOOD IN THE OTHER- (FILL THE DRY FOOD BOWL UP ALL THE WAY)- I'LL LEAVE A GLASS/CUP OUT SO YOU CAN JUST FILL IT UP WITH WATER AND POUR IT IN RATHER THAN HAVING TO PICK UP THE WATER BOWL- MAKE SURE YOU HAVE BOTH KEYS WHEN YOU LEAVE BECAUSE IF YOU LOCK THE INSIDE DOOR AND HAVE THE WRONG KEY FOR THE OUTSIDE; YOU WON'T BE ABLE TO GET BACK IN OR POSSIBLY UNABLE TO LOCK THE OUTSIDE DOOR- BE CAREFULL LOCKING THE OUTSIDE DOOR UNLESS YOU MIGHT PINCH YOUR FINGERS PULLING THE DOOR CLOSED-
THANK YOU SO MUCH- I'LL MEET UP WITH YOU NEXT WEEK TO GET THE KEYS BACK
LORI'S HOUSE

Mental map exercises

- Where am I in the city?
- From here to there
- What's around here?
- Where I went and what I did

Mental Maps

What's so interesting about these maps?

Taking note of people's intuitive strategies – as landscape architects might use shortcuts taken by users or as park planners might in some cities after the snow.

Mental Maps

- Individually tailored “Made for an audience of one”
- In a moment, ephemeral

Directions

- Steps
- Intermediate goals
- Progressive disclosure

Efficient

- Edited, only necessary information
- Shorthand notation to accompany verbal description

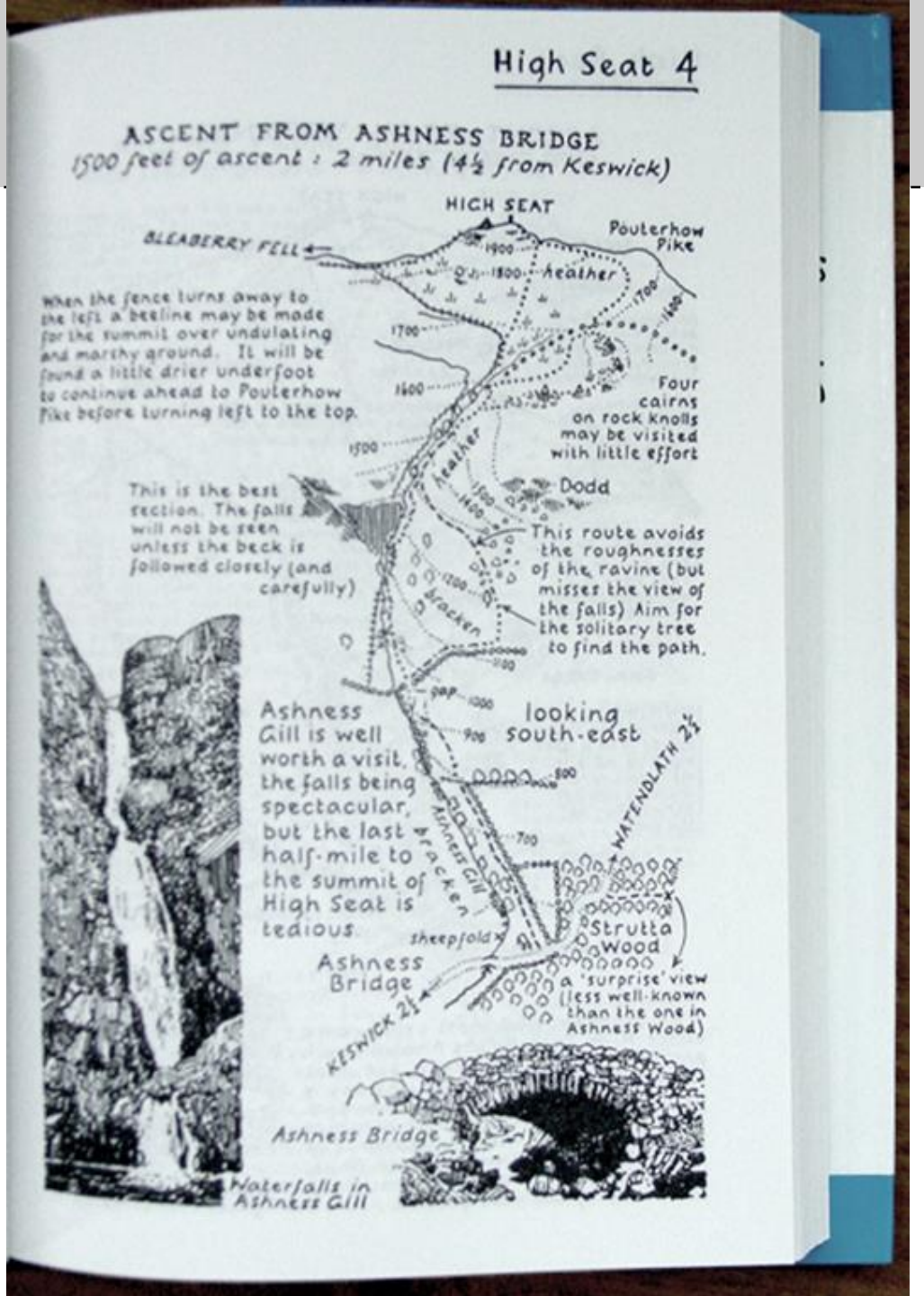
Rotate and distort

- Orientation eg. seaside maps
- Geography
- Geometry eg. ‘rectilinear correction’
- Scale
- Detail, ‘granularity’

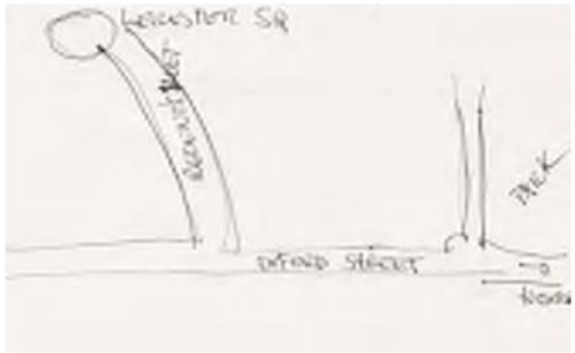
Supportive

- Annotated
- Error detection, “If you reach the toll road, you’ve gone too far”

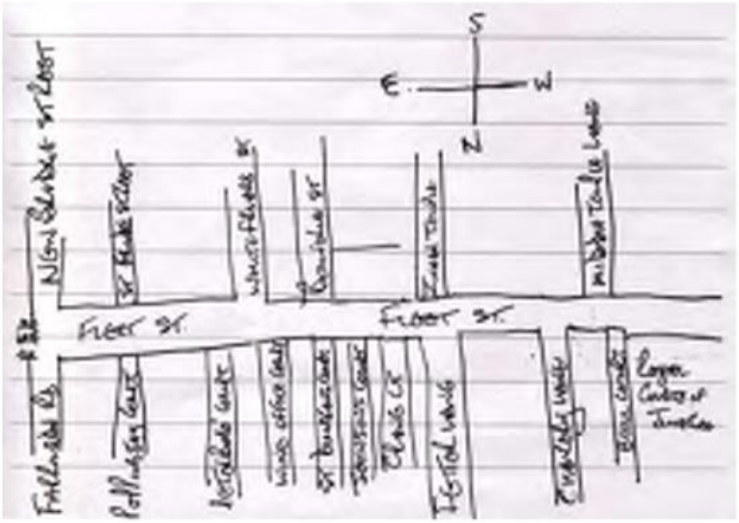
Mental Maps

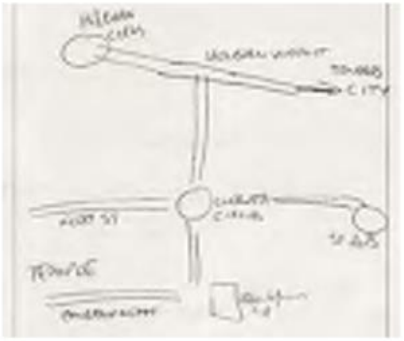

High Seat 4
ASCENT FROM ASHNESS BRIDGE
1500 feet of ascent : 2 miles (4½ from Keswick)
HIGH SEAT
BLEABERRY FELL
Pouterhow Pike
Heather
When the fence turns away to the left a beeline may be made for the summit over undulating and marshy ground. It will be found a little drier underfoot to continue ahead to Pouterhow Pike before turning left to the top.
Four cairns on rock knolls may be visited with little effort
Dodd
This is the best section. The falls will not be seen unless the beck is followed closely (and carefully)
This route avoids the roughnesses of the ravine (but misses the view of the falls) Aim for the solitary tree to find the path.
Bracken
looking south-east
Ashness Gill is well worth a visit, the falls being spectacular, but the last half-mile to the summit of High Seat is tedious.
WATENDLATH 2¾
Ashness Gill
sheepfold
Strutta Wood
Ashness Bridge
a 'surprise' view (less well-known than the one in Ashness Wood)
KESWICK 2¼
Ashness Bridge
Waterfalls in Ashness Gill

Mental Maps



Linear
This mental map demonstrates the importance of backbone walking routes. Broad and reasonably straight, Fleet Street provides the perfect spine from which roads jut off to the north and south. Names are in the right order, but not geographically. The level of detail and familiarity with the street names suggests that the person responsible has worked in this area for some years.

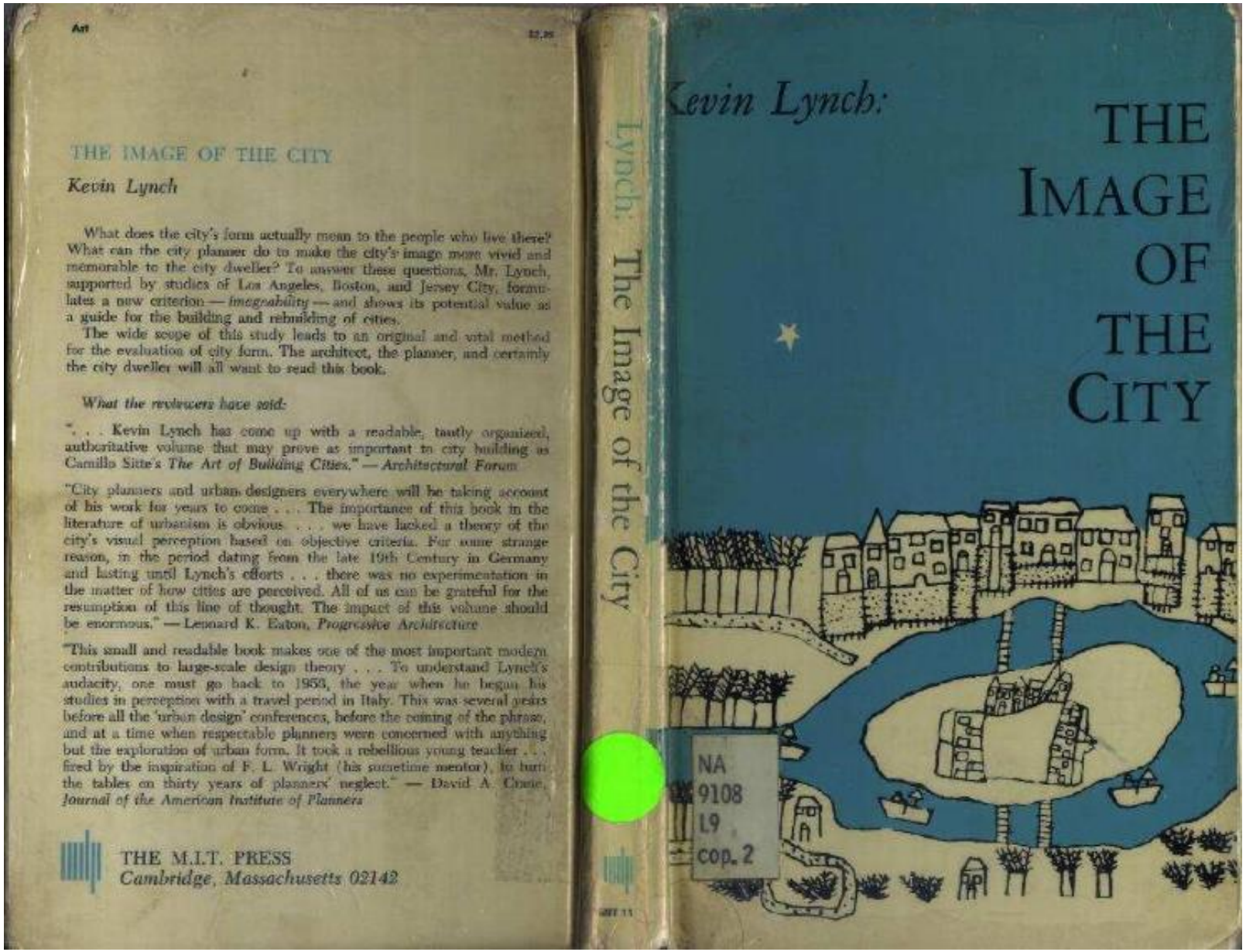




Stick and ball
This map is defined by destinations (drawn as circles and named) rather than the routes (drawn as parallel lines and left unnamed). It is probably influenced by the Tube map, and emphasises the arrival rather than the journey.

Human A-Z
Possibly the work of a professional. The level of detail is exceptional, with accomplished draftsmanship and a thorough understanding of geographical relationships. Note the number of important landmarks (to the author!)

The Image of the City – Kevin Lynch



Art

$2.25

THE IMAGE OF THE CITY

Kevin Lynch

What does the city's form actually mean to the people who live there? What can the city planner do to make the city's image more vivid and memorable to the city dweller? To answer these questions, Mr. Lynch, supported by studies of Los Angeles, Boston, and Jersey City, formulates a new criterion — *imageability* — and shows its potential value as a guide for the building and rebuilding of cities.

The wide scope of this study leads to an original and vital method for the evaluation of city form. The architect, the planner, and certainly the city dweller will all want to read this book.

What the reviewers have said:

". . . Kevin Lynch has come up with a readable, tautly organized, authoritative volume that may prove as important to city building as Camillo Sitte's *The Art of Building Cities.*" — *Architectural Forum*

"City planners and urban designers everywhere will be taking account of his work for years to come . . . The importance of this book in the literature of urbanism is obvious . . . we have lacked a theory of the city's visual perception based on objective criteria. For some strange reason, in the period dating from the late 19th Century in Germany and lasting until Lynch's efforts . . . there was no experimentation in the matter of how cities are perceived. All of us can be grateful for the resumption of this line of thought. The impact of this volume should be enormous." — Leonard K. Eaton, *Progressive Architecture*

"This small and readable book makes one of the most important modern contributions to large-scale design theory . . . To understand Lynch's audacity, one must go back to 1953, the year when he began his studies in perception with a travel period in Italy. This was several years before all the 'urban design' conferences, before the coining of the phrase, and at a time when respectable planners were concerned with anything but the exploration of urban form. It took a rebellious young teacher . . . fired by the inspiration of F. L. Wright (his sometime mentor), to turn the tables on thirty years of planners' neglect." — David A. Crane, *Journal of the American Institute of Planners*

THE M.I.T. PRESS
Cambridge, Massachusetts 02142

Lynch: The Image of the City

Kevin Lynch:

THE IMAGE OF THE CITY

The Image of the City – Kevin Lynch

Mental maps used by Lynch to isolate distinct features of a city and deduce their impact on public experience

The Image of the City – Kevin Lynch

Imageability, or legibility, of a place

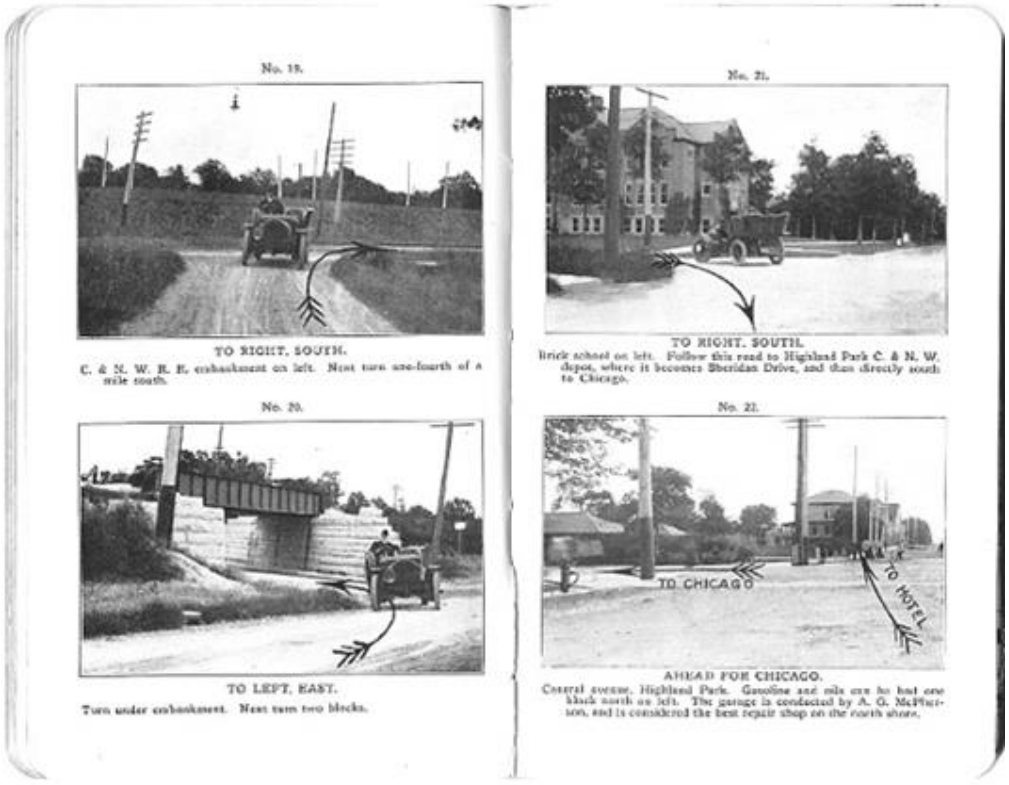
Five elements

1. Paths – routes
2. Edges – other lines eg. shoreline
3. Districts – realms
4. Nodes – foci, centres
5. Landmarks – architectural, natural

Locate / Describe

Mapping – systematically locating things
A map – representation of this

J.W.Jones
Jones-Live Map (1909)



No. 19.

TO RIGHT, SOUTH.
C. & N. W. R. R. embankment on left. Next turn one-fourth of a mile south.

No. 20.

TO LEFT, EAST.
Turn under embankment. Next turn two blocks.

No. 21.

TO RIGHT, SOUTH.
Brick school on left. Follow this road to Highland Park C. & N. W. depot, where it becomes Sheridan Drive, and then directly south to Chicago.

No. 22.

TO CHICAGO
TO HOTEL

AHEAD FOR CHICAGO.
Central avenue, Highland Park. Gasoline and oils are to be had one block north on left. The garage is conducted by A. G. McPherson, and is considered the best repair shop on the north shore.

Andrew McNally II
Photo-Auto Guide (c. 1907)

Locate / Describe

"A shift in perception is reflected in changing methods of mapping. Our knowledge of the world allows us to see it in different ways, and this manifests itself in new [graphic] representations."

Emmet Connolly
Web developer, Google
blog.thoughtwax.com

LineDrive

Rendering Effective Route Maps: Improving Usability Through Generalization

Maneesh Agrawala Chris Stolte
Stanford University*

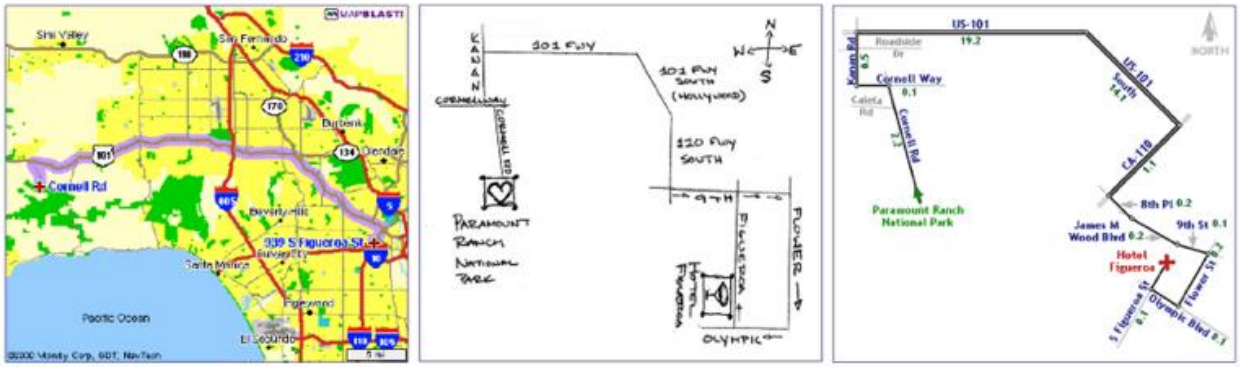


Figure 1: Three route maps for the same route rendered by (left) a standard computer-mapping system, (middle) a person, and (right) LineDrive, our route map rendering system. The standard computer-generated map is difficult to use because its large, constant scale factor causes the short roads to vanish and because it is cluttered with extraneous details such as city names, parks, and roads that are far away from the route. Both the handdrawn map and the LineDrive map exaggerate the lengths of the short roads to ensure their visibility while maintainaing a simple, clean design that emphasizes the most essential information for following the route. Note that the handdrawn map was created without seeing either the standard computer-generated map or the LineDrive map. *(Handdrawn map courtesy of Mia Trachinger.)*

Abstract

Route maps, which depict a path from one location to another, have emerged as one of the most popular applications on the Web. Current computer-generated route maps, however, are often very difficult to use. In this paper we present a set of cartographic generalization techniques specifically designed to improve the usability of route maps. Our generalization techniques are based both on cognitive psychology research studying how route maps are used and on an analysis of the generalizations commonly found in handdrawn route maps. We describe algorithmic implementations of these generalization techniques within LineDrive, a real-time system for automatically designing and rendering route maps. Feedback from over 2200 users indicates that almost all believe LineDrive maps are preferable to using standard computer-generated route maps alone.

Keywords: Information Visualization, Non-Realistic Rendering, WWW Applications, Human Factors

1 Introduction

Route maps, which depict a path from one location to another, are one of the most common forms of graphic communication. Al-

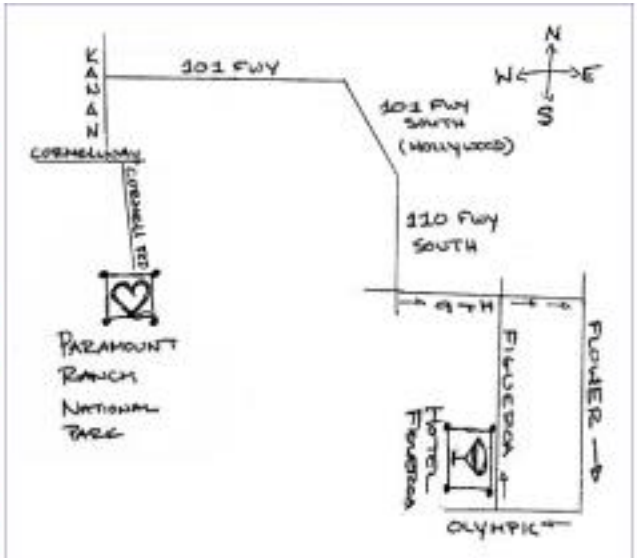
clarity of the map and to emphasize the most important information [16, 21]. This type of generalization, performed either consciously or sub-consciously, is prevalent both in quickly sketched maps and in professionally designed route maps that appear in print advertisements, invitations, and subway schedules [25, 13].

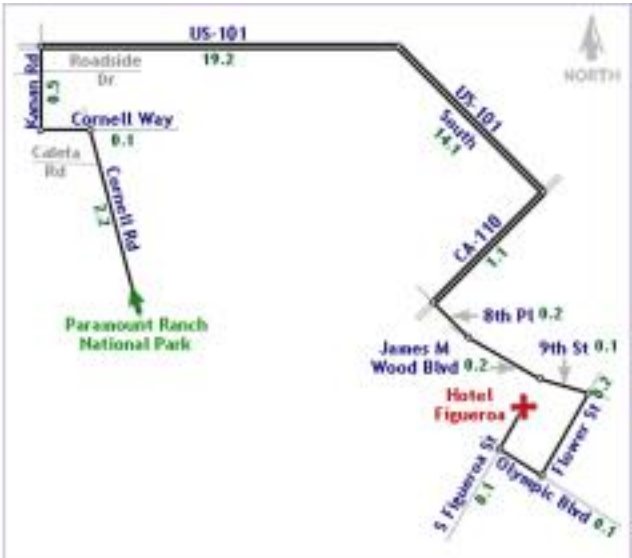
Recently, route maps in the form of driving directions have become widely available through the Web. In contrast to hand-designed route maps, these computer-generated route maps are often more precise and contain more information. Yet these maps are more difficult to use. The main shortcoming of current systems for automatically generating route maps is that they do not distinguish between essential and extraneous information, and as a result, cannot apply the generalizations used in hand-designed maps to emphasize the information needed to follow the route.

Figure 1 shows several problems arising from the lack of differentiation between necessary and unnecessary information. The primary problem is that current computer-mapping systems maintain a constant scale factor for the entire map. For many routes, the lengths of roads can vary over several orders of magnitude, from tens of feet within a neighborhood to hundreds of miles along a highway. When a constant scale factor is used for these routes, it

LineDrive

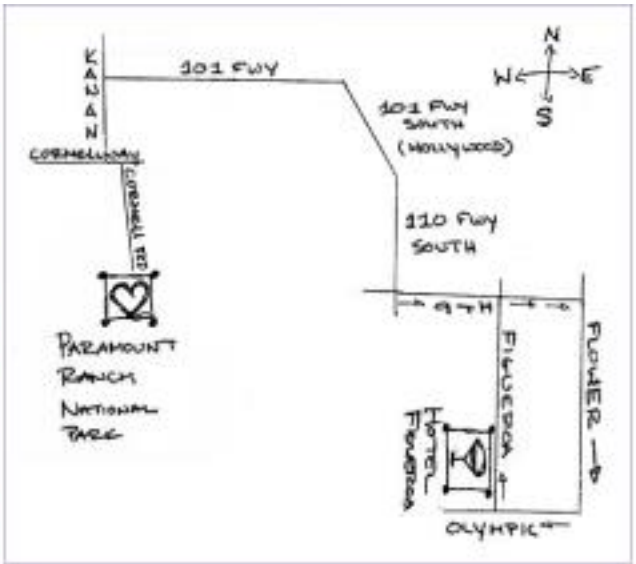
- cartographic generalization techniques specifically designed to improve the usability of route maps
- The generalization techniques are based both on cognitive psychology research studying how route maps are used and on an analysis of the generalizations commonly found in hand drawn route maps
- They describe algorithmic implementations of these generalization techniques within LineDrive, a real-time system for automatically designing and rendering route maps

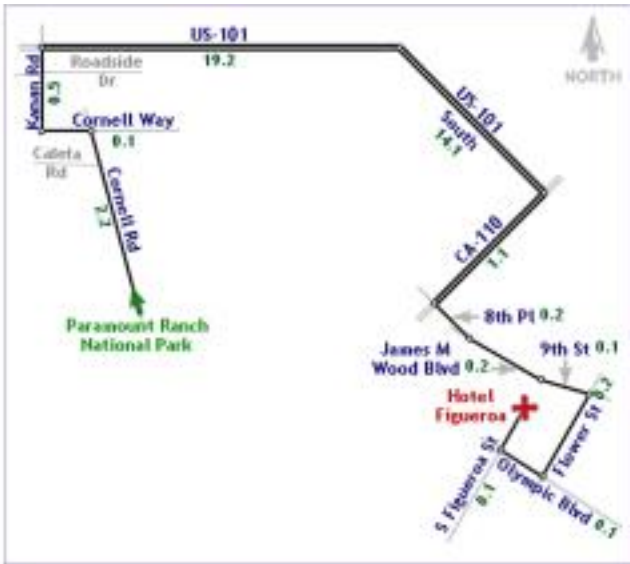




LineDrive

- straighten wiggly lines
- snap turns to right angles
- expand regions with turns
- contract long straight roads
- label carefully
- maintain overall orientation

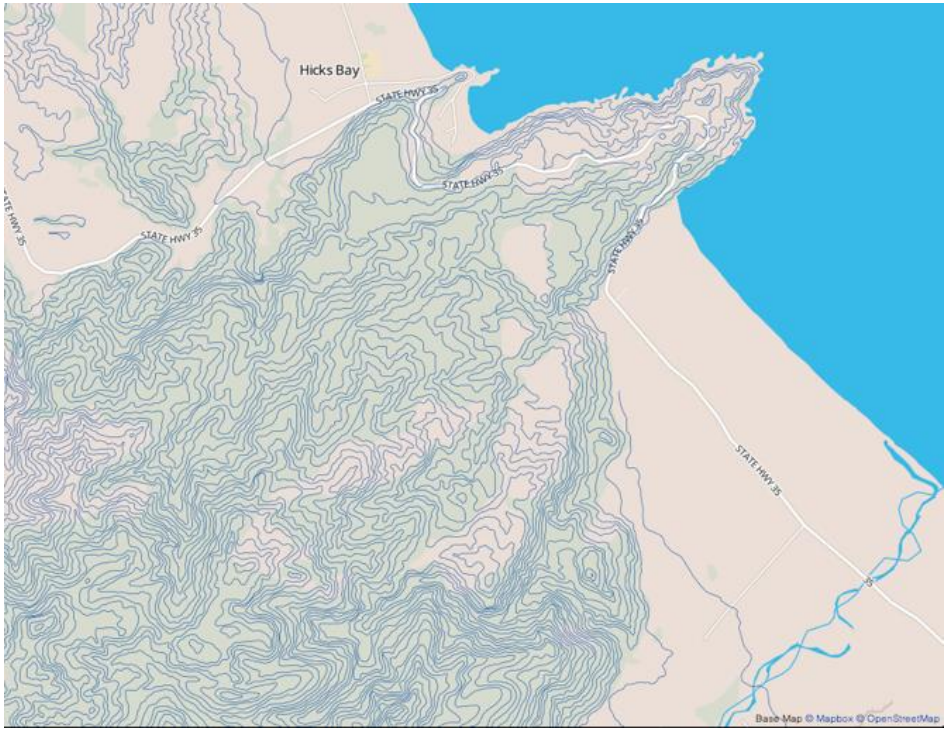




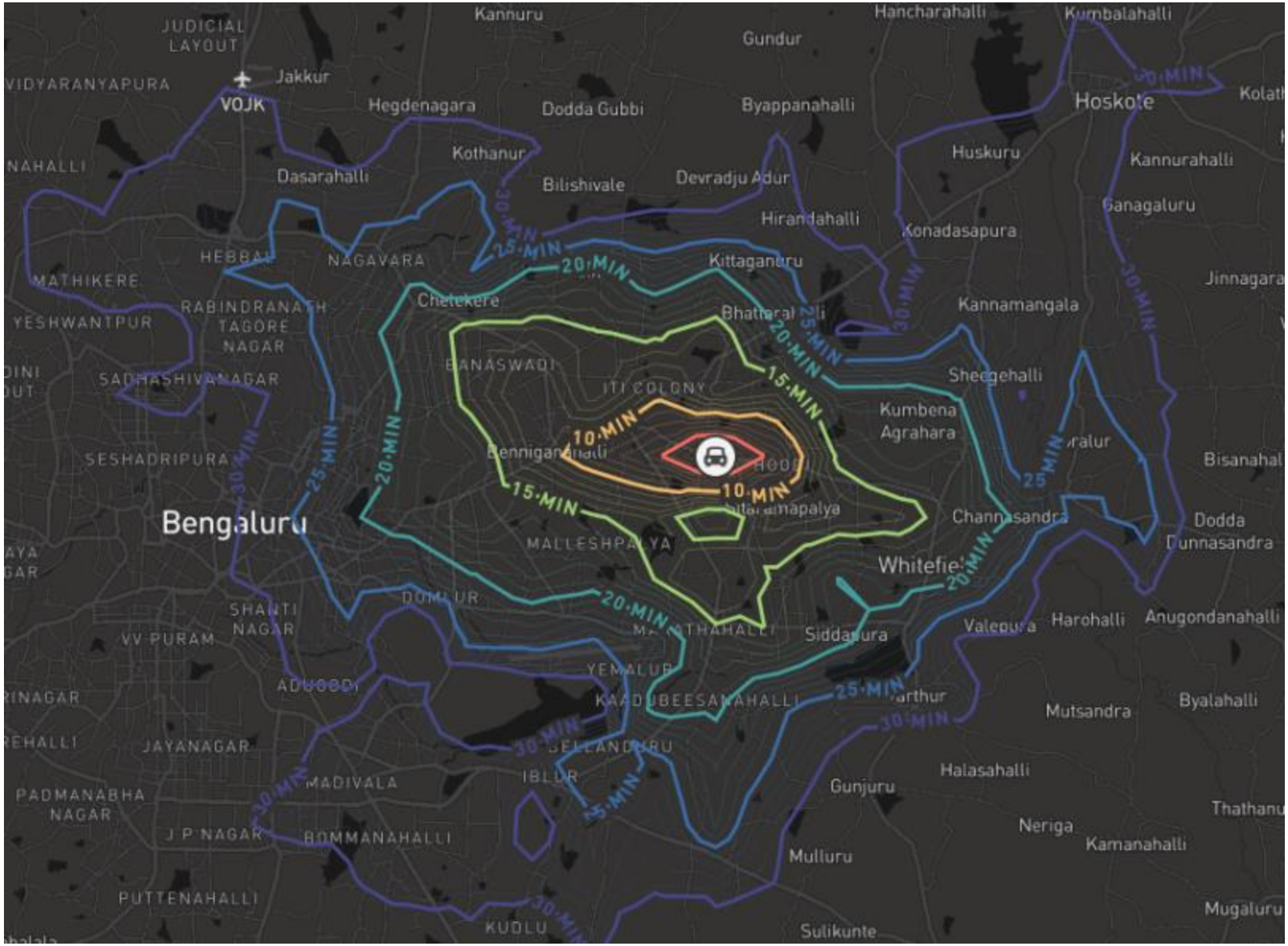
Spatial Fields

Idiom: **topographic map**

- data
  - geographic geometry
  - scalar spatial field
    - 1 quant attribute per grid cell
- derived data
  - isoline geometry
    - isocontours computed for specific levels of scalar values
- task
  - understanding terrain shape
    - densely lined regions = steep
- pros
  - use only 2D position, avoid 3D challenges
  - color channel available for other attributes
- cons
  - significant clutter from additional lines



Land Information New Zealand Data Service


Bengaluru
Whitefield
Hoskote
Kannuru
Gundur
Hancharahalli
Kumbalahalli
JUDICIAL LAYOUT
VIDYARANYAPURA
Jakkur
VOJK
Hegdenagara
Dodda Gubbi
Byappanahalli
Kothanur
Dasarahalli
Bilishivale
Devradju Adur
Huskuru
Kannurahalli
Hirandahalli
Konadasapura
Ganagaluru
Kittaganeru
HEBBAL
NAGAVARA
MATHIKERE
RABINDRANATH TAGORE NAGAR
YESHWANTPUR
Chetekere
Bhatharalli
Kannamangala
Jinnagara
BANASWADI
ITI COLONY
SADASHIVANAGAR
Sheegehalli
Kumbena Agrahara
SESHADRIPURA
Bisanahal
Channasandra
Dodda Gunnasandra
MALLESHPALYA
SHANTI NAGAR
DOMLUR
VV PURAM
Siddapura
Valepura
Harohalli
Anugondanahalli
YEMALUR
ADUGODI
JAYANAGAR
Mutsandra
Byalahalli
MADIVALA
IBLUR
Halasahalli
Gunjuru
PADMANABHA NAGAR
J P NAGAR
BOMMANAHALLI
Neriga
Kamanahalli
Mulluru
PUTTENAHALLI
KUDLU
Sulikunte
Mugaluru
10 MIN
15 MIN
20 MIN
25 MIN
30 MIN

Idioms: **isosurfaces, direct volume rendering**

- data
  - scalar spatial field (3D volume)
    - 1 quant attribute per grid cell
- task
  - shape understanding, spatial relationships

[Interactive Volume Rendering Techniques. Kniss. Master's thesis, University of Utah Computer Science, 2002.]

[Multidimensional Transfer Functions for Volume Rendering. Kniss, Kindlmann, and Hansen. In The Visualization Handbook, edited by Charles Hansen and Christopher Johnson, pp. 189–210. Elsevier, 2005.]

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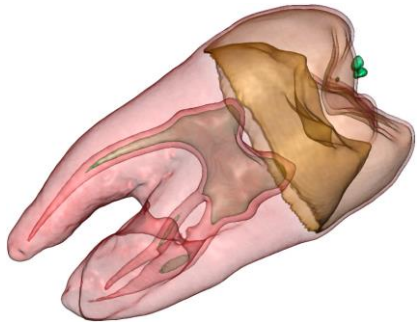
  - derived data: isocontours computed for specific levels of scalar values



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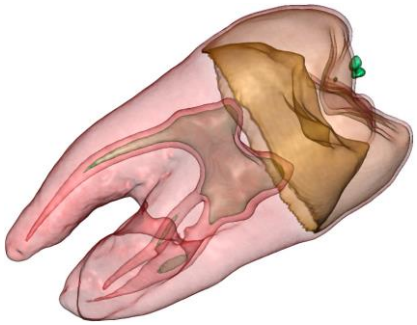
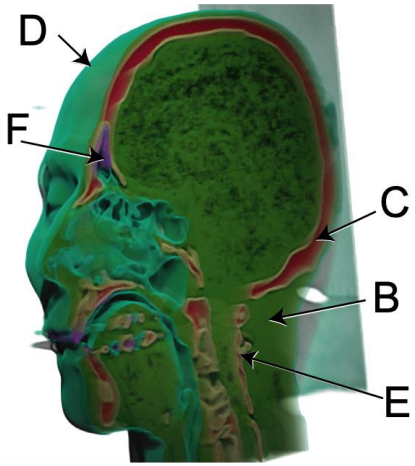
Idioms: **isosurfaces, direct volume rendering**

- data
  - scalar spatial field (3D volume)
    - 1 quant attribute per grid cell
- task
  - shape understanding, spatial relationships
- isosurface
  - derived data: isocontours computed for specific levels of scalar values
- direct volume rendering
  - transfer function maps scalar values to color, opacity
    - no derived geometry





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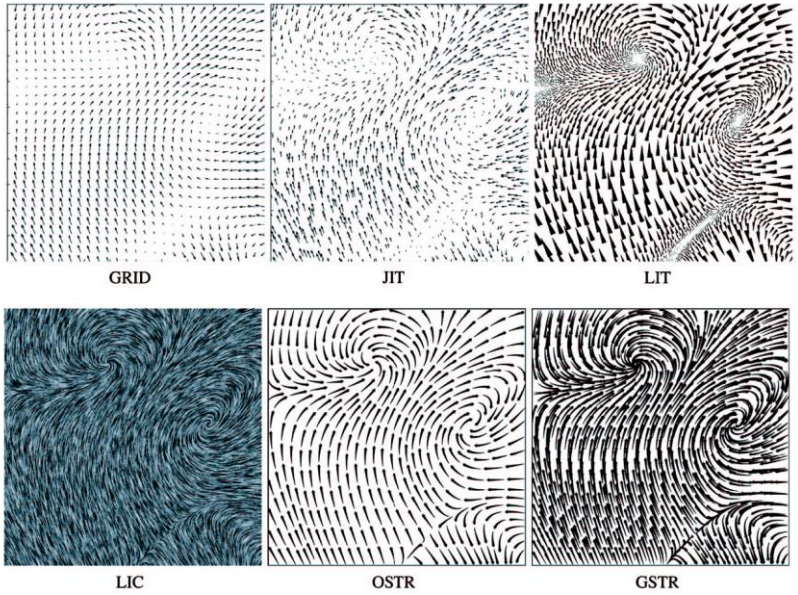
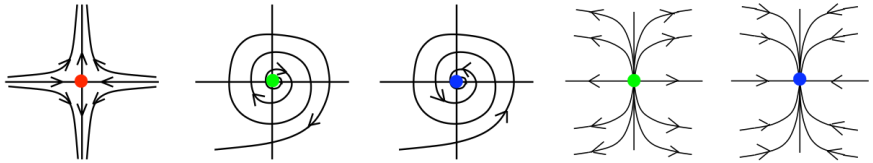
Vector and tensor fields

- data
  - multiple attribs per cell (vector: 2)
- tasks
  - finding critical points, identifying their types
  - identifying what type of critical point is at a specific location
  - predicting where a particle starting at a specified point will end up (advection)

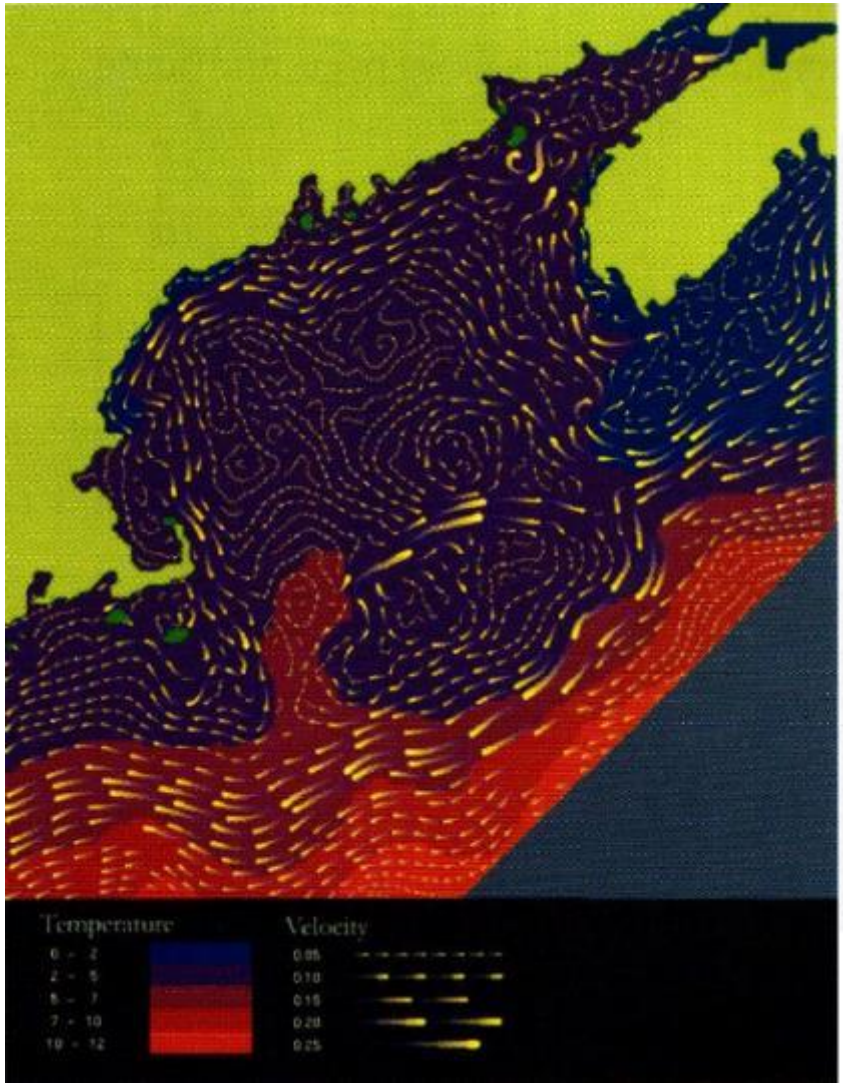


[Comparing 2D vector field visualization methods: A user study. Laidlaw et al. IEEE Trans. Visualization and Computer Graphics (TVCG) 11:1 (2005), 59–70.]



[Topology tracking for the visualization of time-dependent two-dimensional flows. Tricoche, Wischgoll, Scheuermann, and Hagen. Computers & Graphics 26:2 (2002), 249–257.]

Vector Field Map



Map of water currents and temperature. Supports reasoning about currents in the Western North Atlantic. The ocean current patterns are represented using streaklets of different length and width. The background color provides information about water temperature.

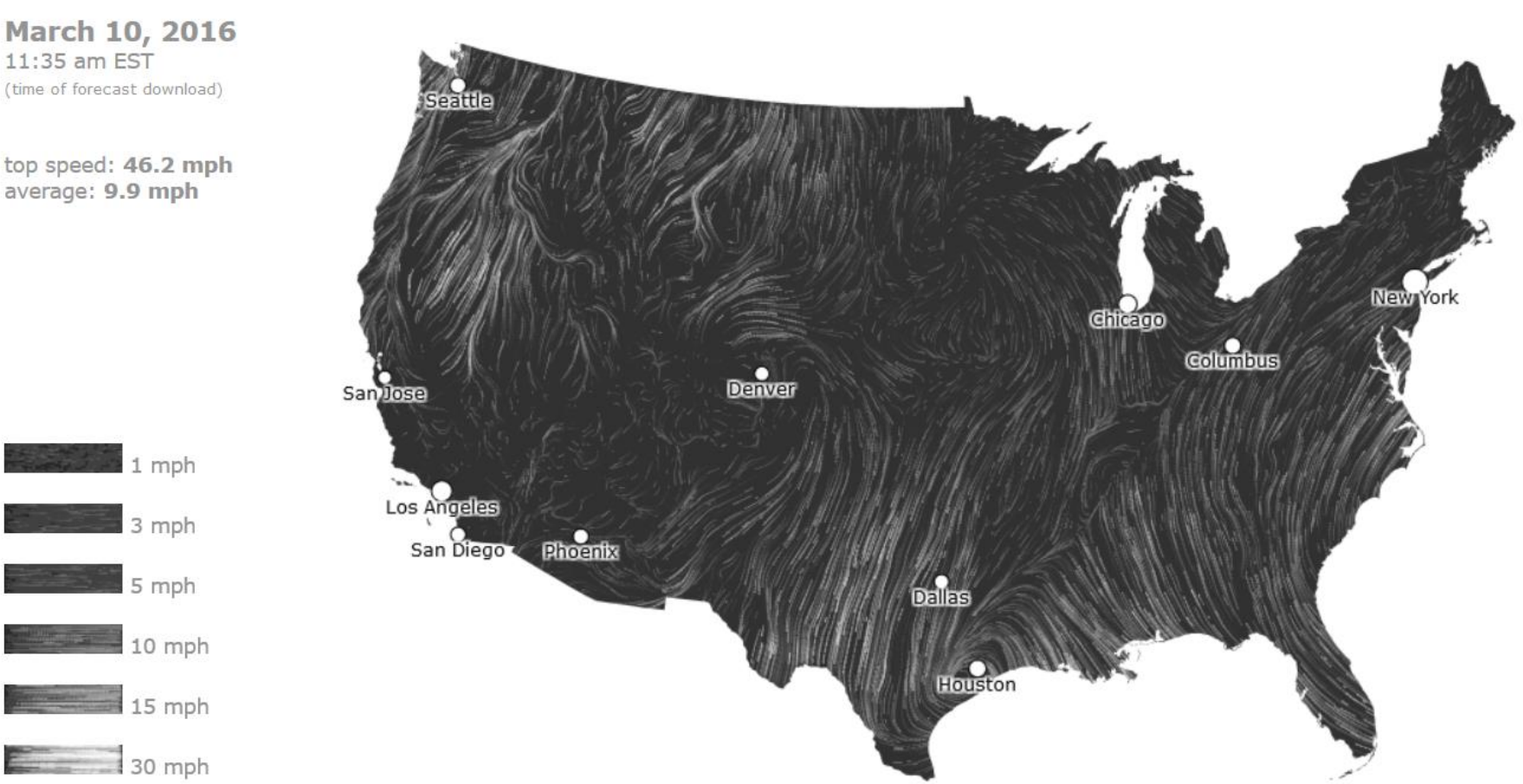
Example: Find where the strongest currents are located. *[Query, find locations of the fat long streaklets].*

Example: Find out where something that was dropped in the water (for example, fish larvae) might end up after a period of time. *[Query, find where a particular train of streaklets leads].*

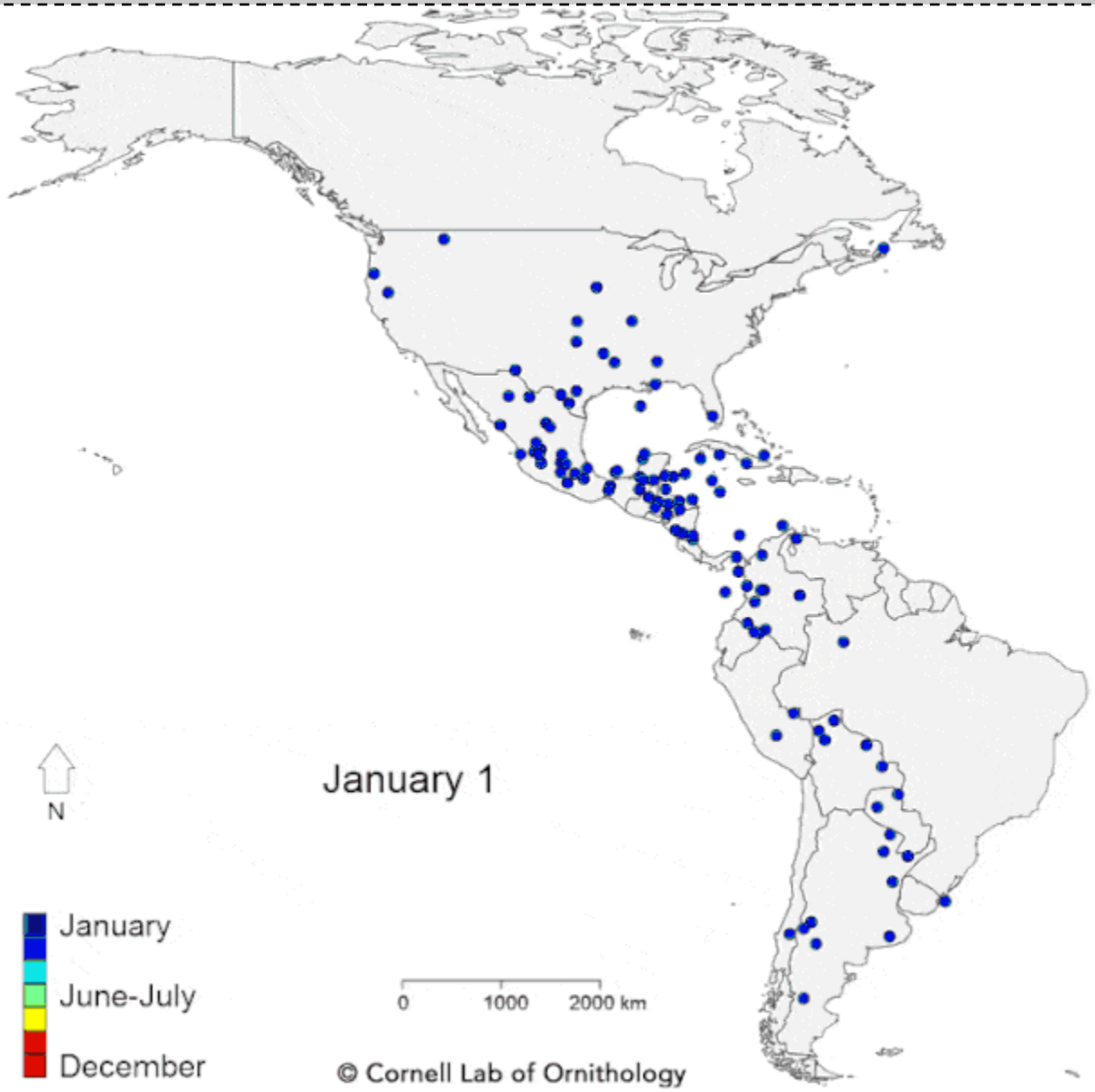
Example: Find the regions with the coldest water. *[Query, find locations of darkest blue color].*

Design comment: In the regions where the current velocity is slow (thin lines), the direction is unclear.

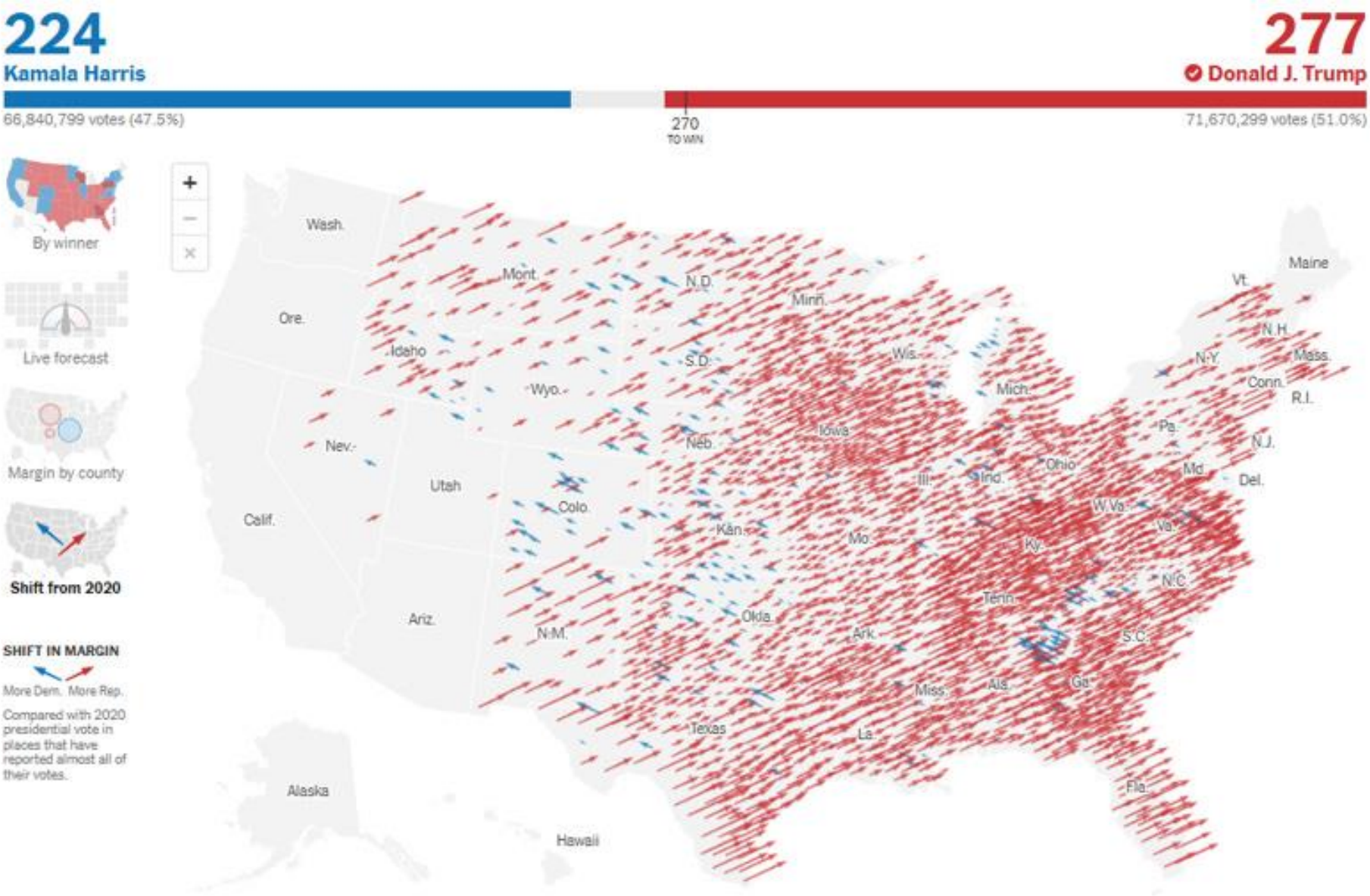
Vector Field Map



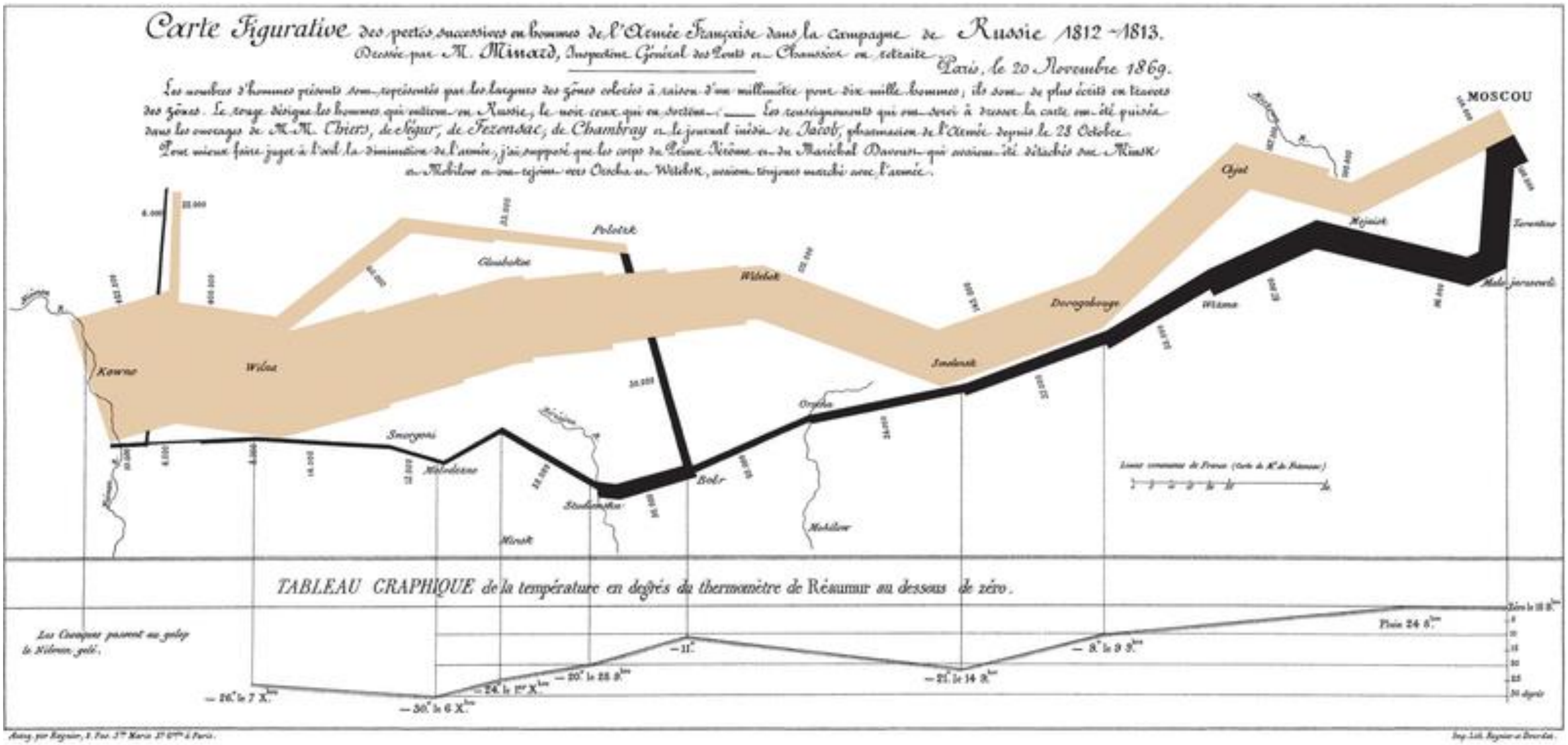
Vector Field Map



Vector Field Map



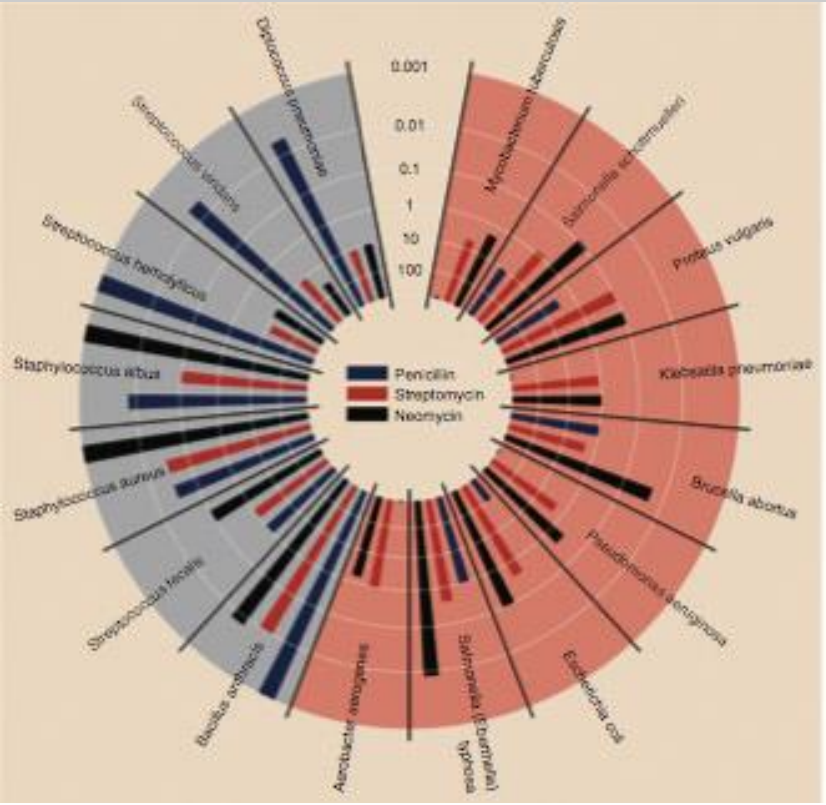
Flow Maps



Carte Figurative des pertes successives en hommes de l'Armée Française dans la campagne de Russie 1812–1813.
Paris, le 20 Novembre 1869.
MOSCOU
Polotzk
Witebsk
Smolensk
Dorogobouge
Wiasma
Mojaisk
Kowno
Wilna
Smorgoni
Molodezno
Bobr
Studienska
Minsk
Orscha
Mohilow
TABLEAU GRAPHIQUE de la température en degrés du thermomètre de Réaumur au dessous de zéro.

Assignment 4 Review

Assignment 4 - Visualise Burtin's Antibiotic Dataset



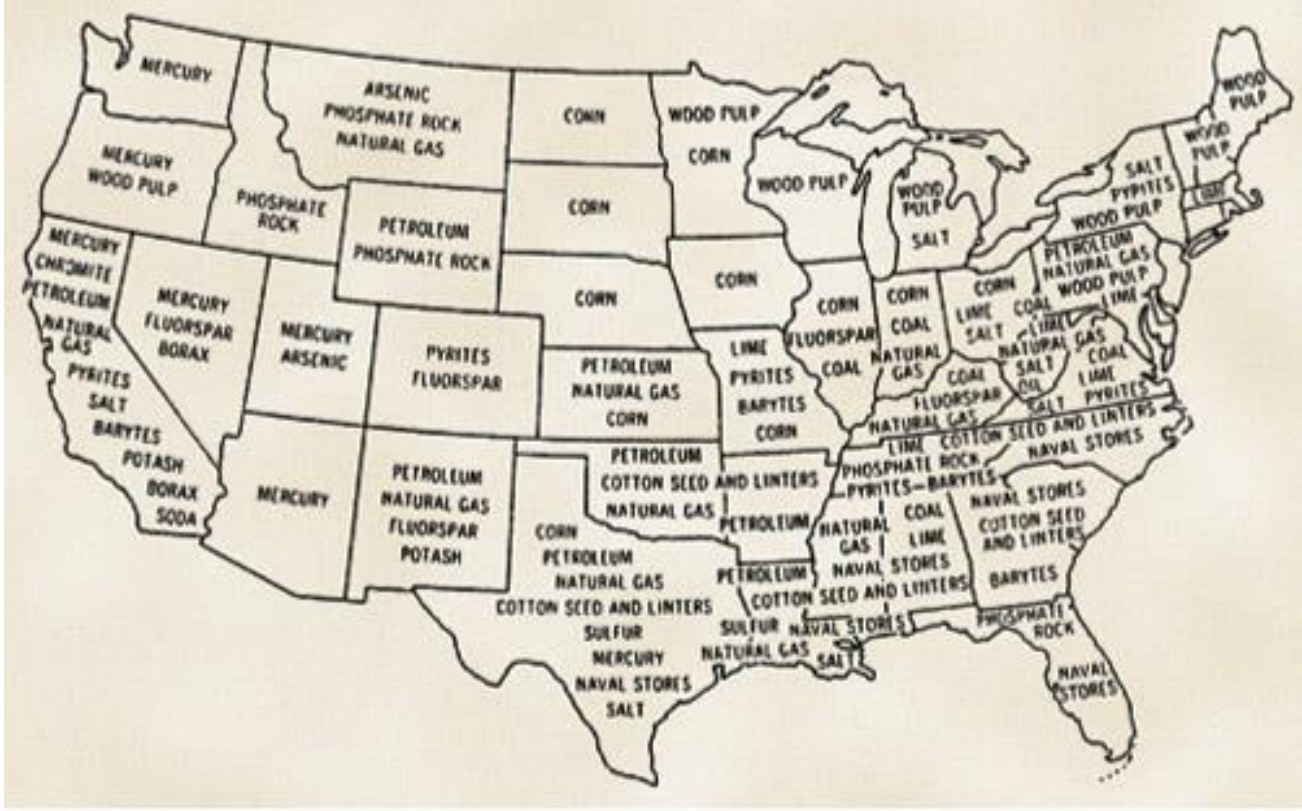
Bacteria	Penicillin	Antibiotic Streptomycin	Neomycin	Gram stain
Aerobacter aerogenes	870	1	1.6	–
Brucella abortus	1	2	0.02	–
Bacillus anthracis	0.001	0.01	0.007	+
Diplococcus pneumoniae	0.005	11	10	+
Escherichia coli	100	0.4	0.1	–
Klebsiella pneumoniae	850	1.2	1	–
Mycobacterium tuberculosis	800	5	2	–
Proteus vulgaris	3	0.1	0.1	–
Pseudomonas aeruginosa	850	2	0.4	–
Salmonella (Eberthella) typhosa	1	0.4	0.008	–
Salmonella schottmuelleri	10	0.8	0.09	–
Staphylococcus albus	0.007	0.1	0.001	+
Staphylococcus aureus	0.03	0.03	0.001	+
Streptococcus fecalis	1	1	0.1	+
Streptococcus hemolyticus	0.001	14	10	+
Streptococcus viridans	0.005	10	40	+

- 3 antibiotics, penicillin, neomycin and streptomycin on 16 bacteria
- minimum concentration of the drug required to prevent the growth of the bacteria in vitro -- the minimum inhibitory concentration (MIC)
- their efficacy varied over six orders of magnitude
- scale varies from 1,000 micrograms per milliliter on the innermost ring to .001 micrograms per milliliter on the outermost
- the longer the bar, the greater the efficacy of the antibiotic.

Assignment 2 - Visualise Burtin's Antibiotic Dataset

- How do the drugs compare?
- How do the bacteria group together?

- What is produced in Nebraska?
- Where is corn produced?



- What is produced in Nebraska?
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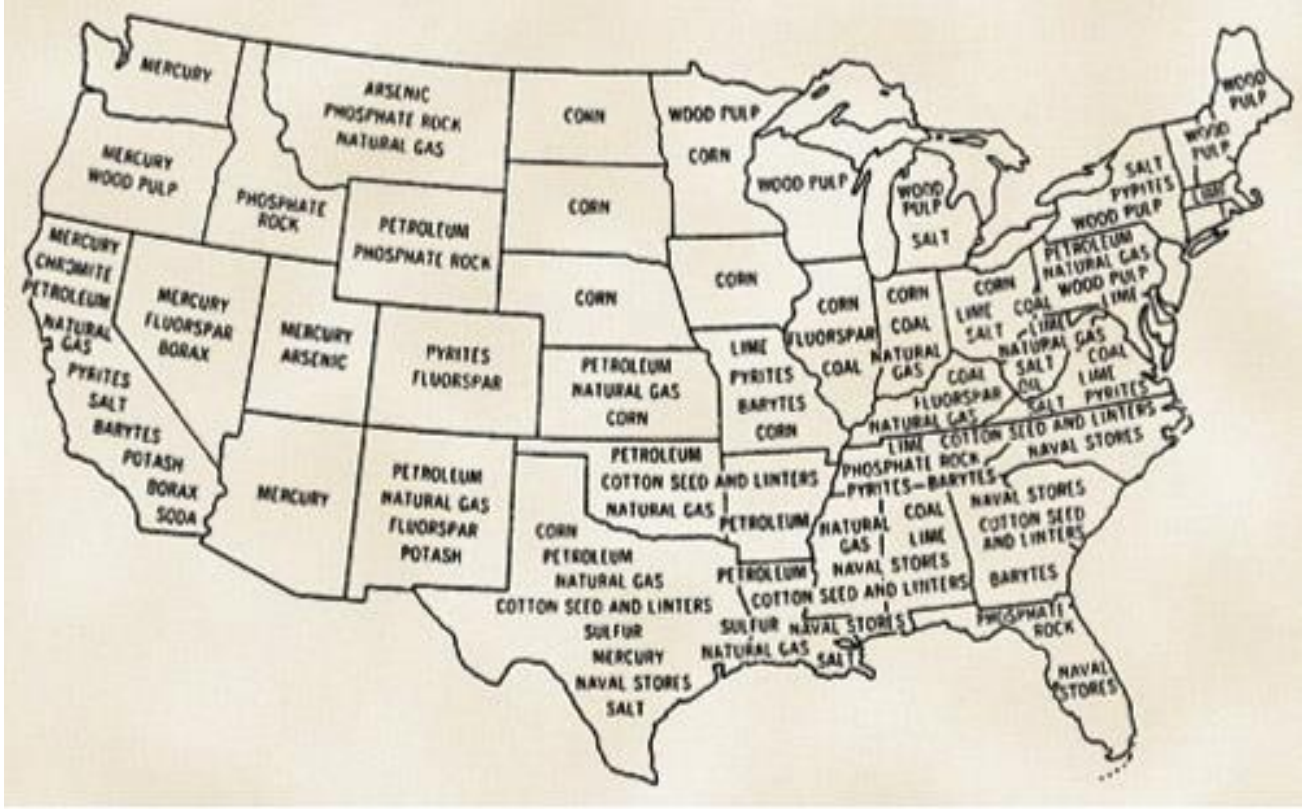
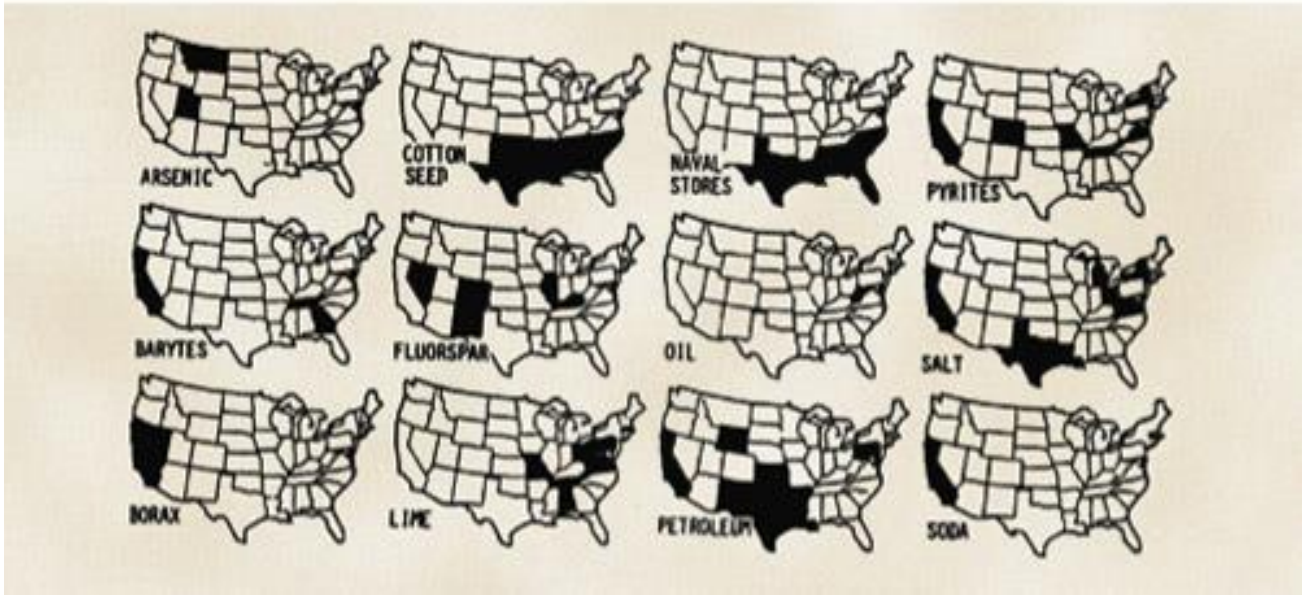
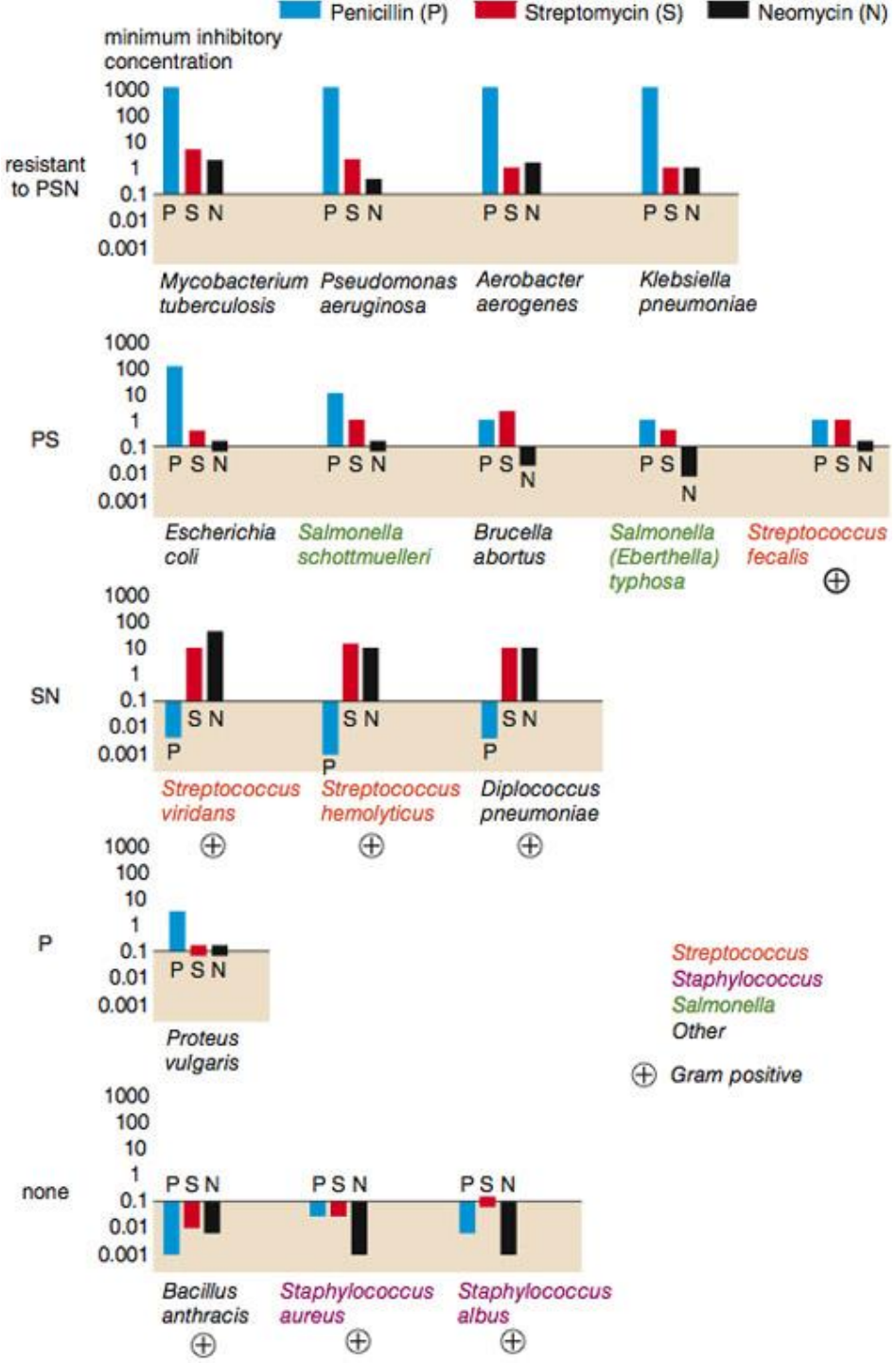




- The pattern of response to the antibiotics of all three bacteria is essentially identical—yet two of these bacteria are Streptococcus and one is not.

- What is Diplococcus pneumoniae doing there? And why does the third Strep bacteria, Streptococcus fecalis appear to be so different?

- One would think that bacteria within a genus would be vulnerable to the same compounds.



- The clustering of bacterial types and sensitivity to antibiotics becomes even more evident with a simple scatterplot in which we plot each bacteria's MIC for both neomycin and penicillin

- But these more specific plots were only generated after we knew what to look for—after the display shown above allowed us to see what we hadn't expected