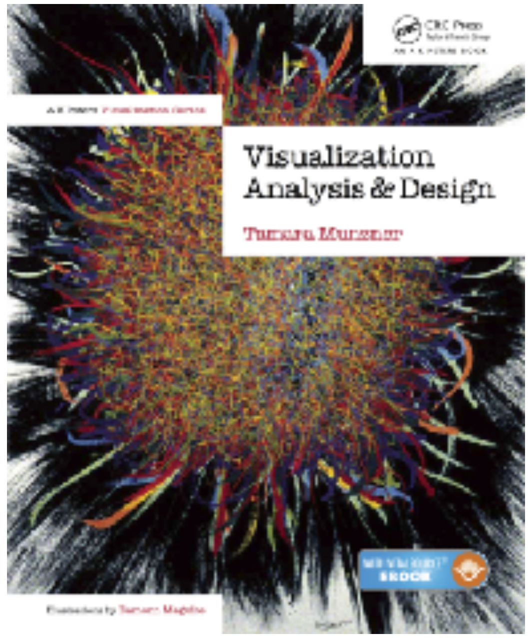
Visualization Analysis & Design

Spatial Data (Ch 9)



Tamara Munzner
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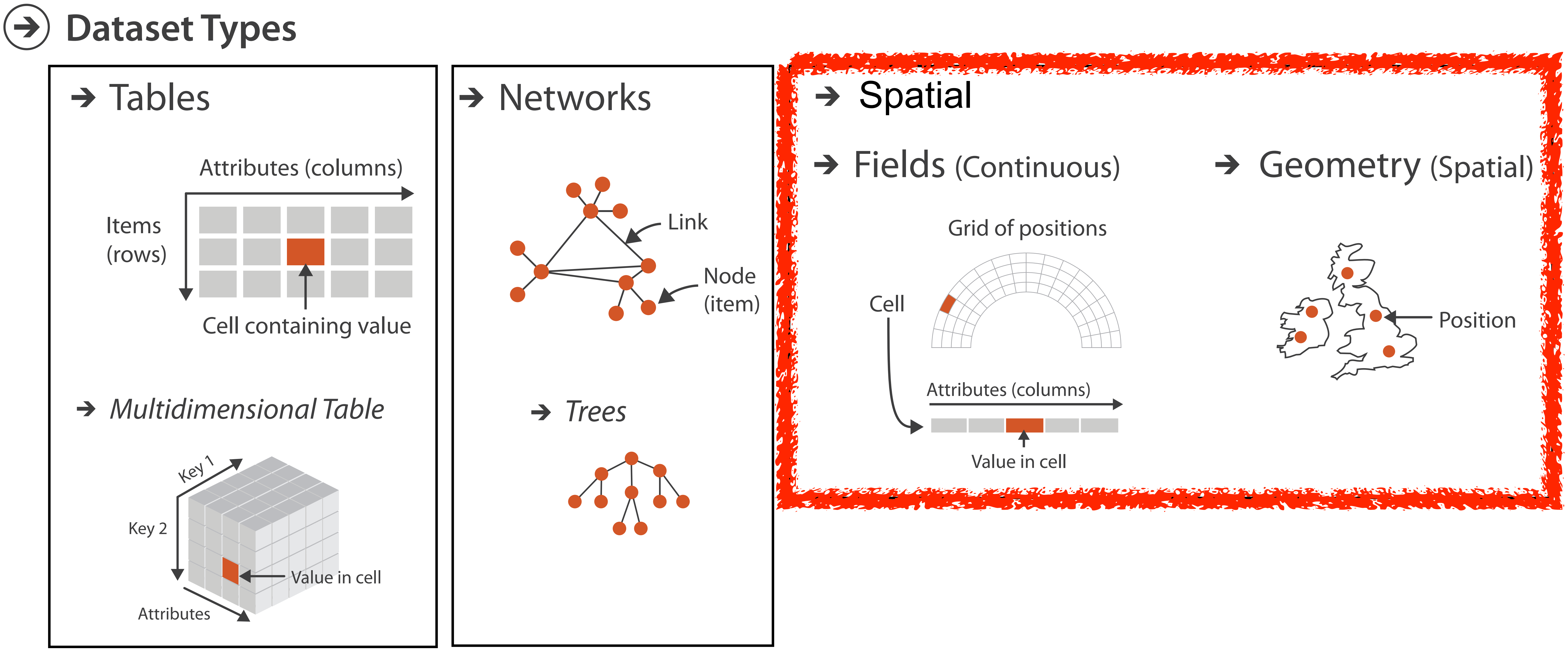
Focus on Spatial



How?

Encode

Arrange
- Express
- Separate
- Order
- Align
- Use

Map
from categorical and ordered attributes

- Color
  - *Hue*
  - *Saturation*
  - *Luminance*
- Size, Angle, Curvature, ...
- Shape
- Motion
  - *Direction, Rate, Frequency, ...*

Manipulate
- Change
- Select
- Navigate

Facet
- Juxtapose
- Partition
- Superimpose

Reduce
- Filter
- Aggregate
- Embed

What?

Why?

How?

How?

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- Express
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What?

Why?

How?

Spatial data

- 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

Geographic Map

Interlocking marks

- **shape** coded
- **area** coded
- **position** coded

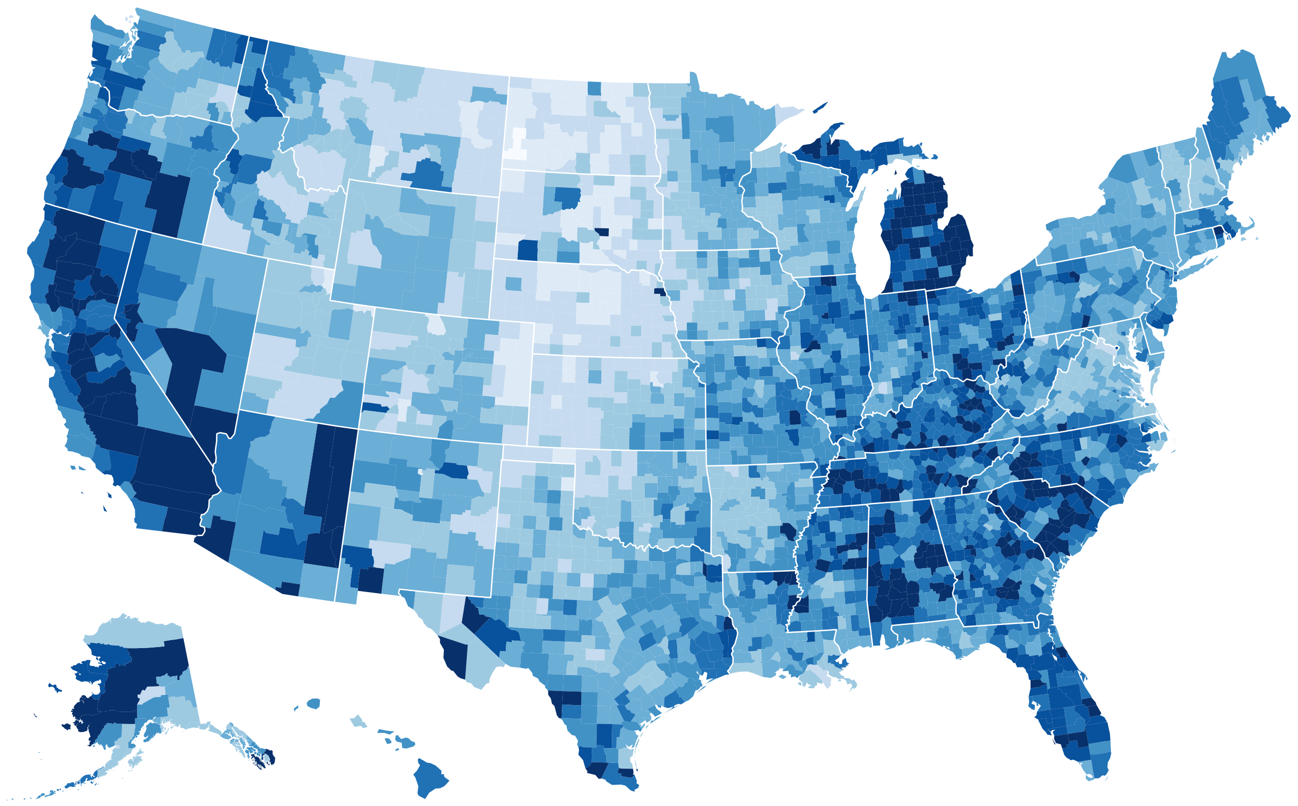
- cannot encode another attribute with these channels, they're "taken"

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

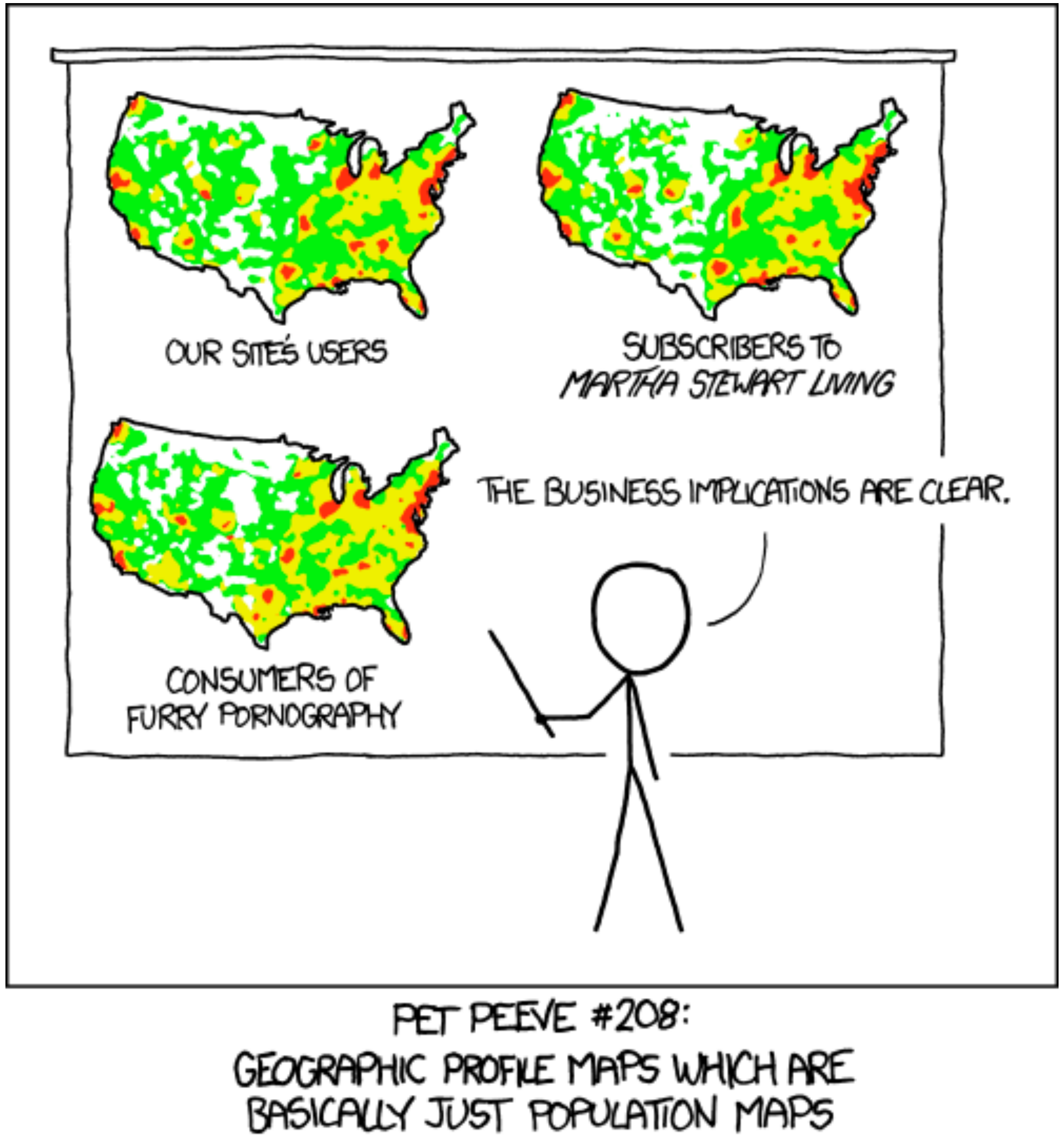
Idiom: **choropleth map**

- 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

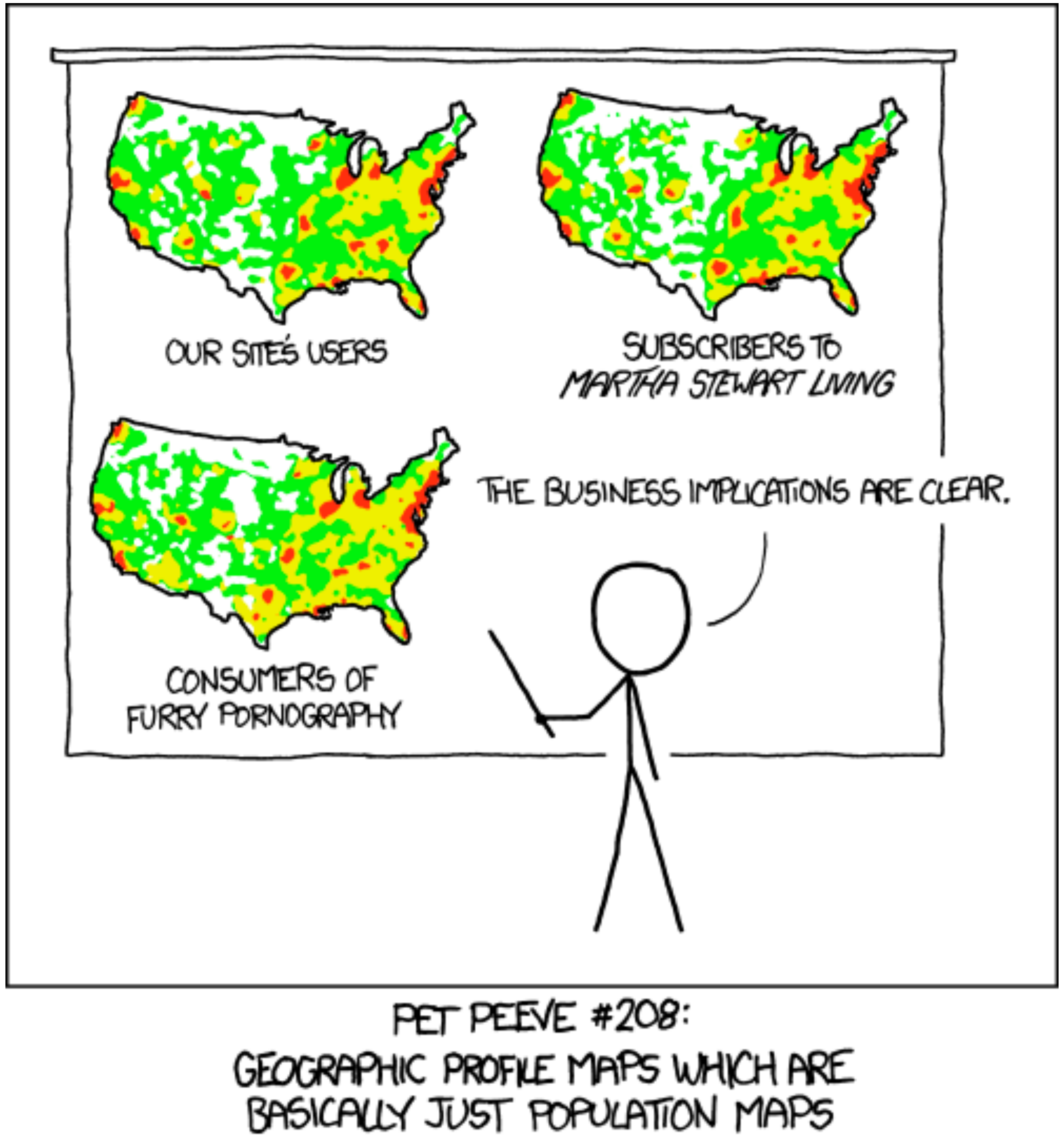
Beware: Population maps trickiness!



[https://xkcd.com/1138]

Beware: Population maps trickiness!

- spurious correlations: most attributes just show where people live



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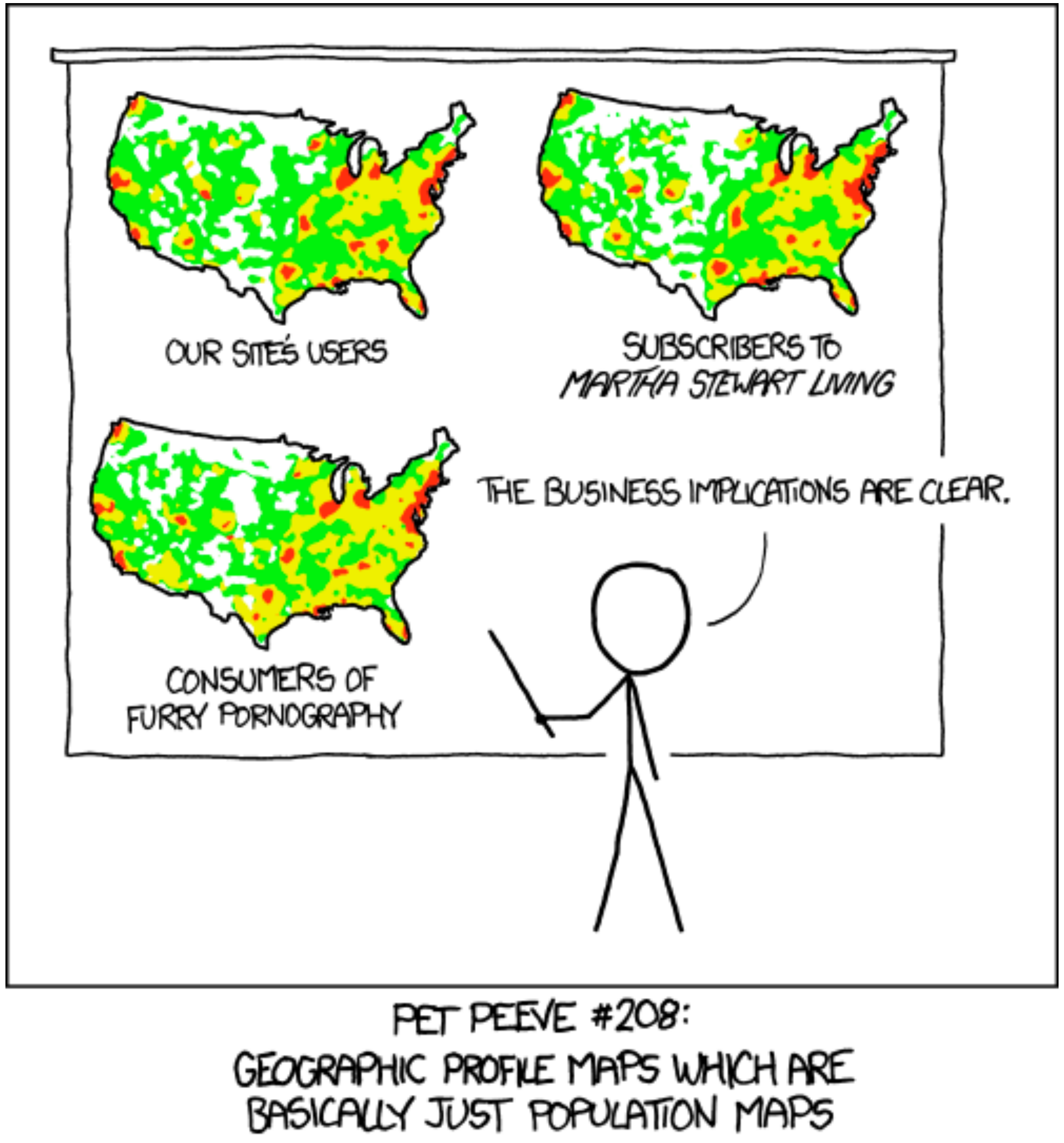
Beware: Population maps trickiness!

- 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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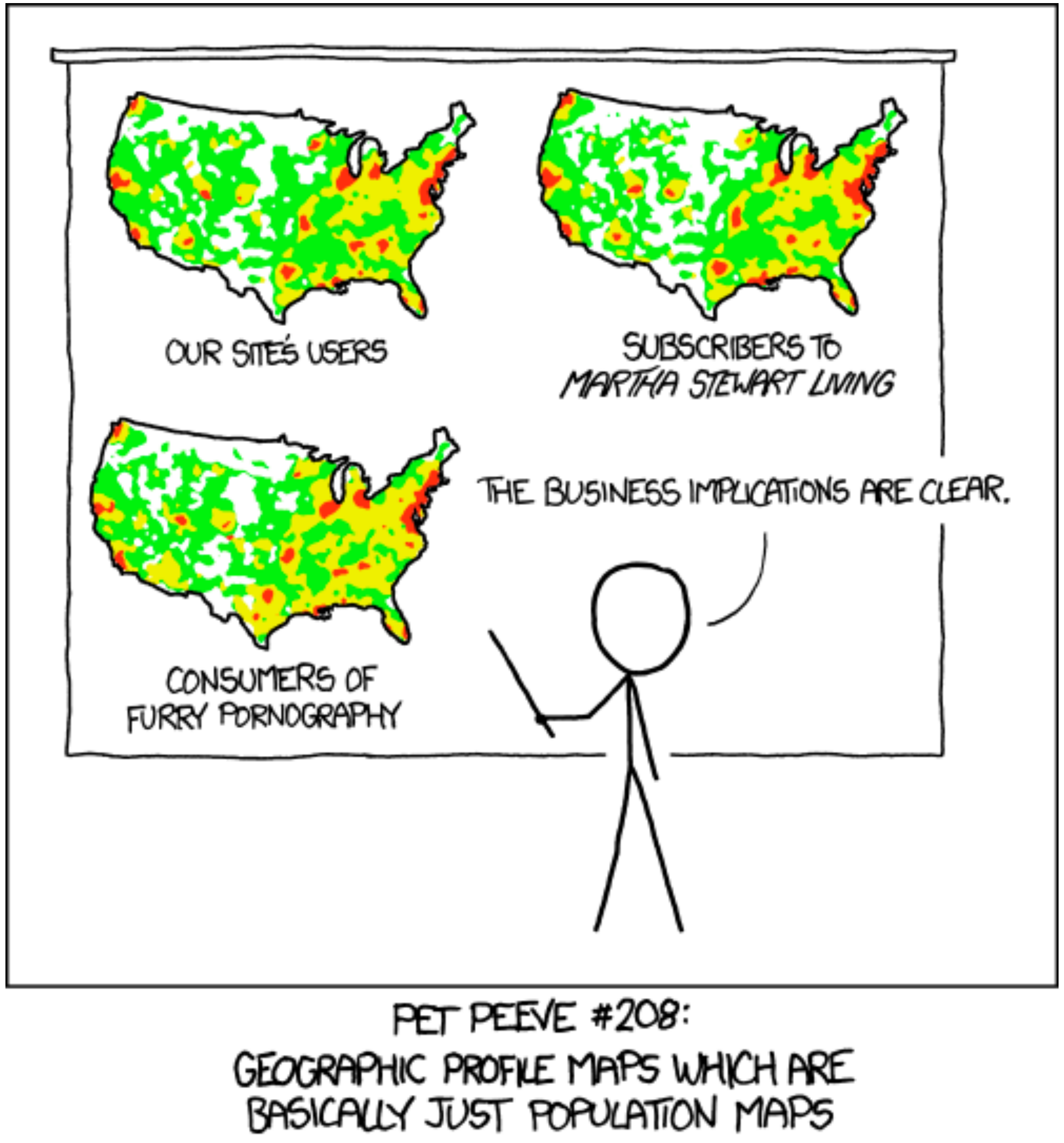
Beware: Population maps trickiness!

- 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
- general issue
  - absolute counts vs relative/normalized data
  - failure to normalize is common error



[https://xkcd.com/1138]

Choropleth maps: Recommendations

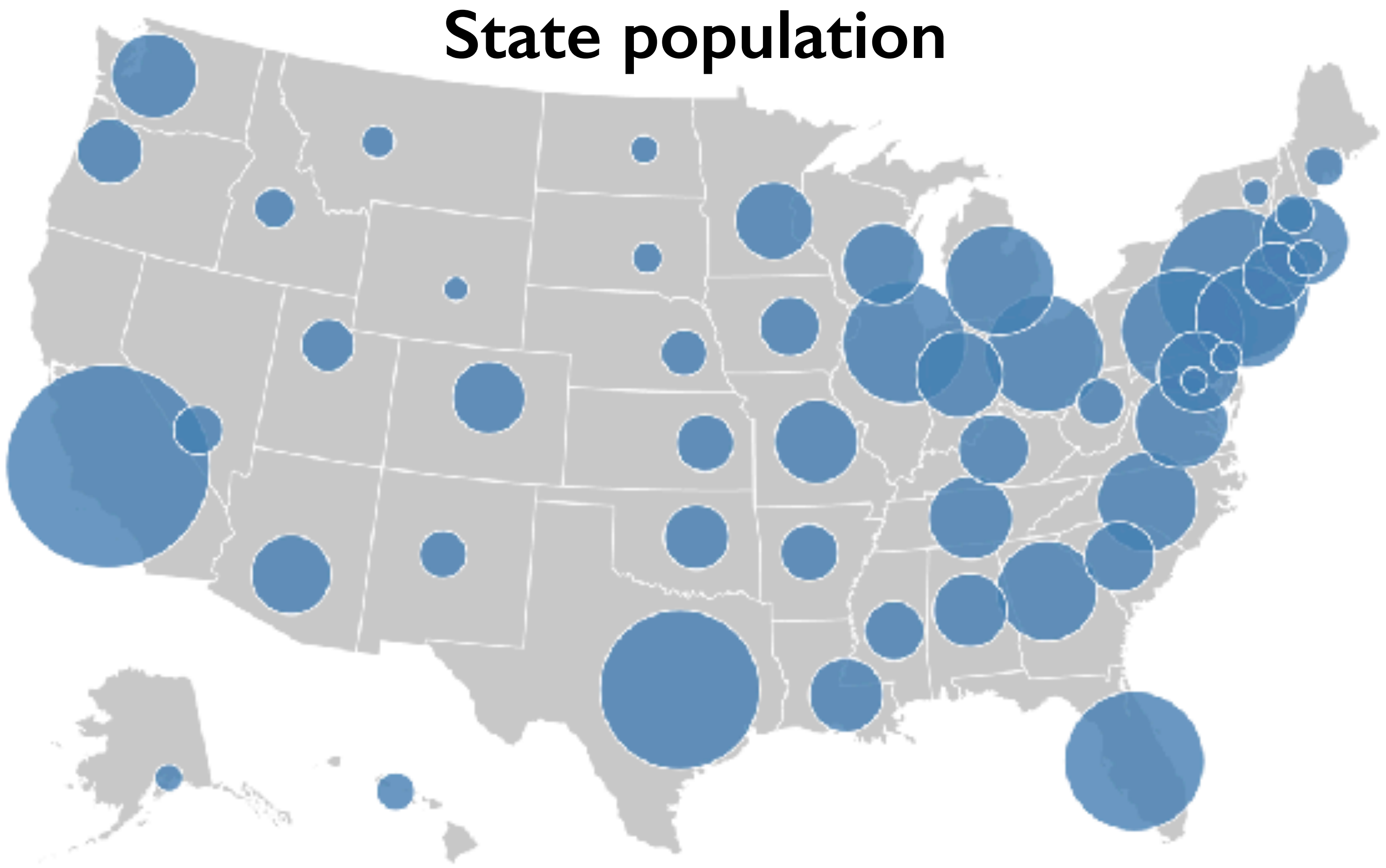
- only use when central task is understanding spatial relationships
- show only one variable at a time
- normalize when appropriate
- be careful when choosing colors & bins
- best case: regions are roughly equal sized

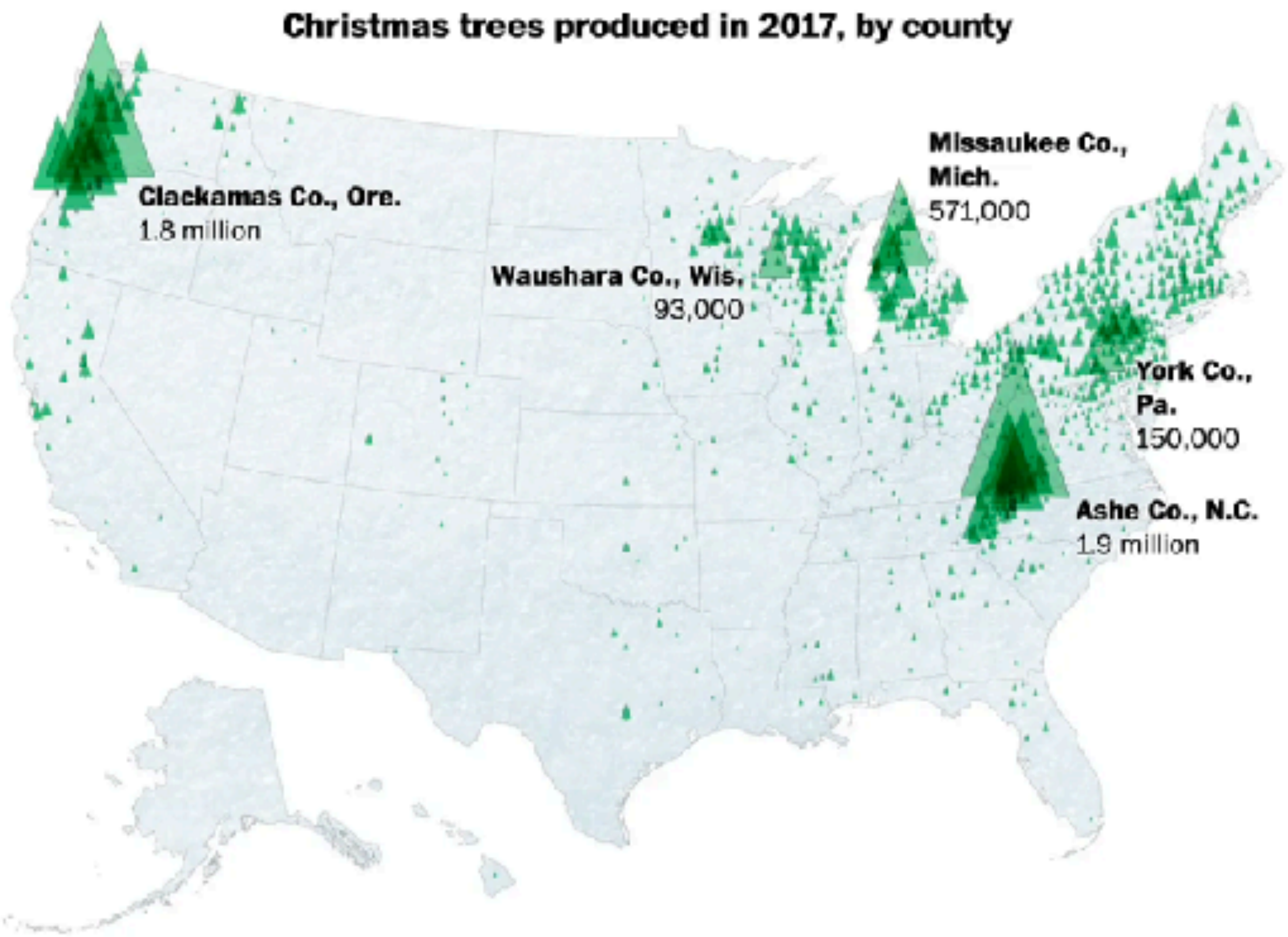
Choropleth map: Pros & cons

- 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

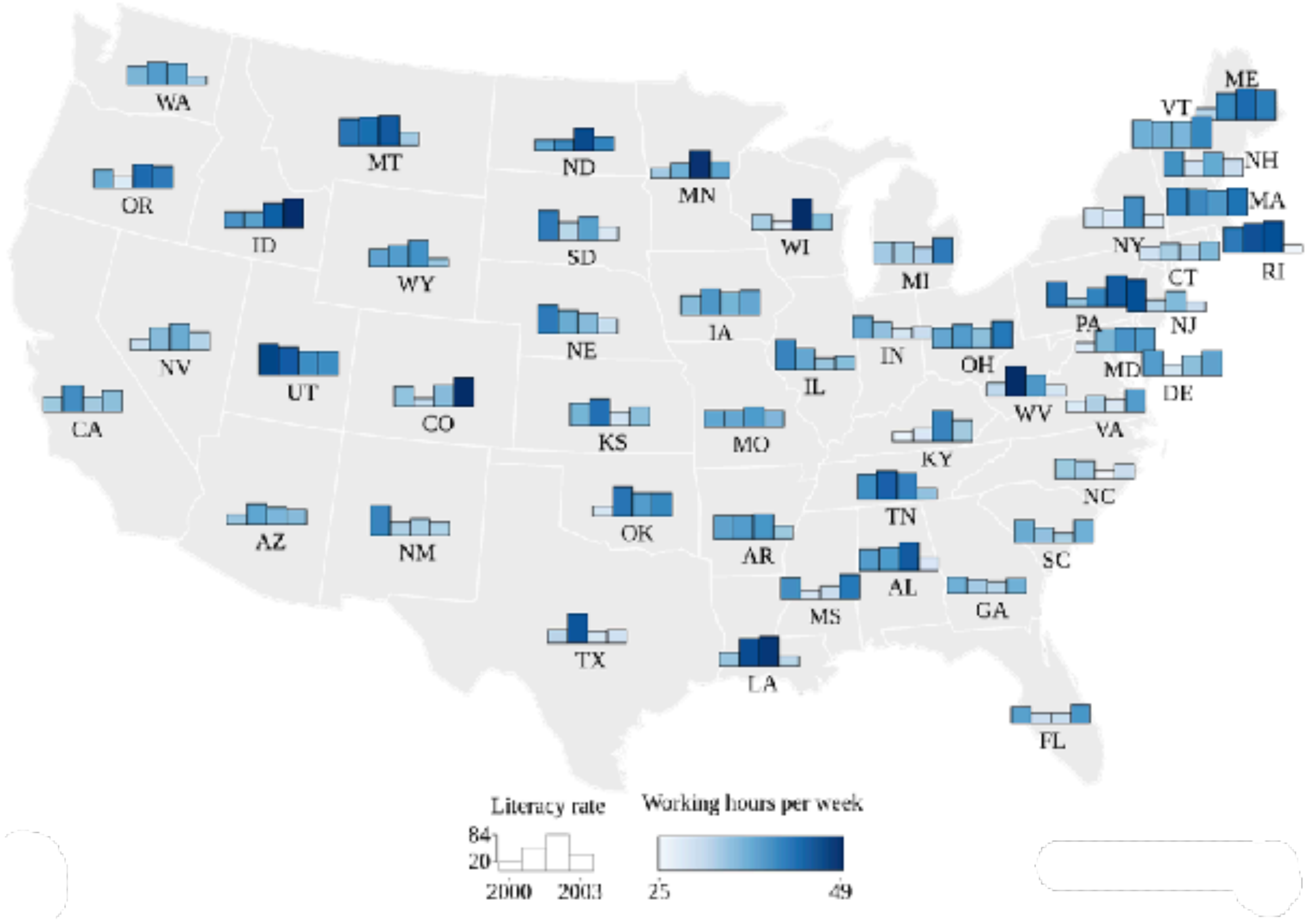
Idiom: **Symbol maps**

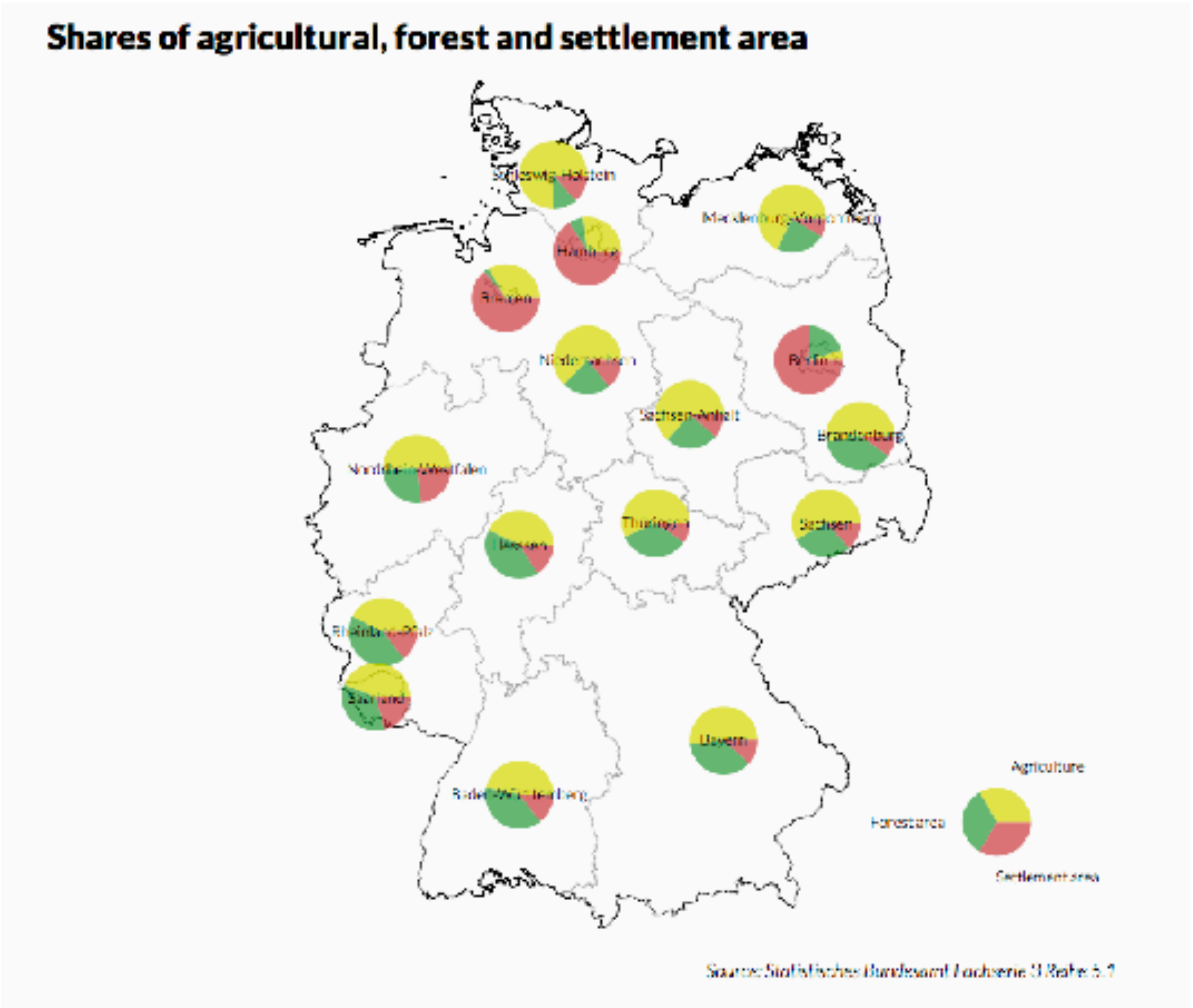
- symbol is used to represent aggregated data (mark or glyph)
  - allows use of size and shape and color channels
    - aka proportional symbol maps, graduated symbol maps
- keep original spatial geometry in the background
- often a good alternative to choropleth maps





Symbol maps with glyphs



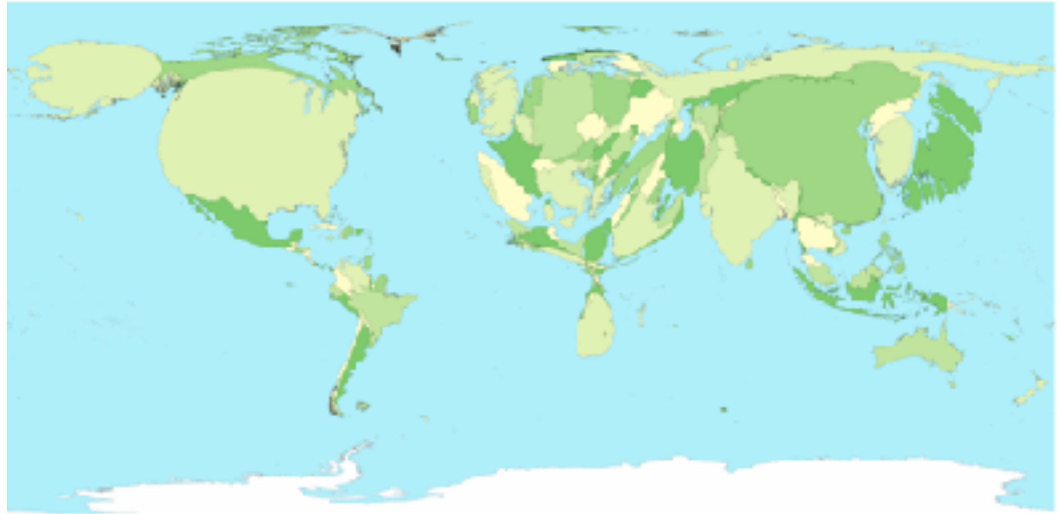


Symbol map: Pros & cons

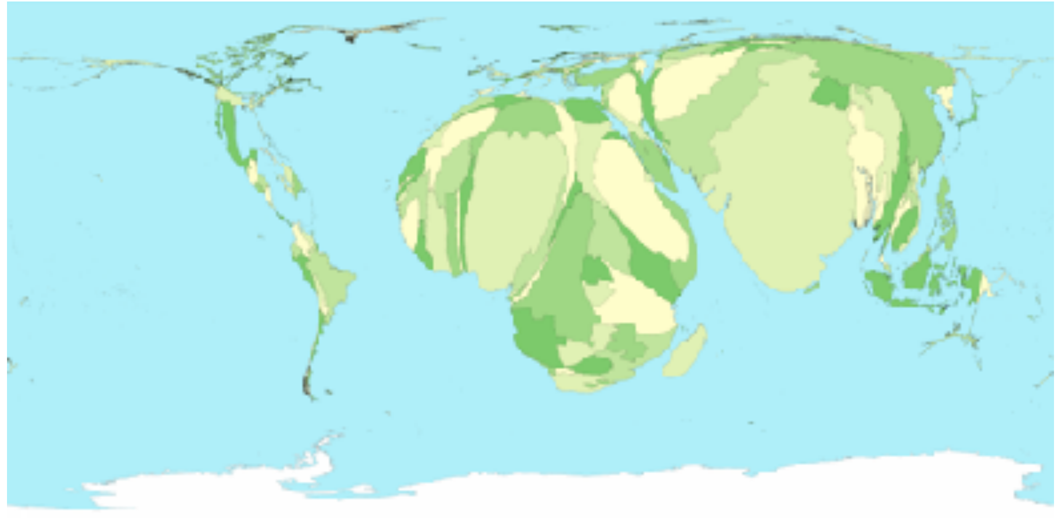
- pros
  - somewhat intuitive to read and understand
  - mitigate problems with region size vs data salience
    - marks: symbol size follows attribute value
    - glyphs: symbol size can be uniform
- cons
  - possible occlusion / overlap
    - symbols could overlap each other
    - symbols could occlude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

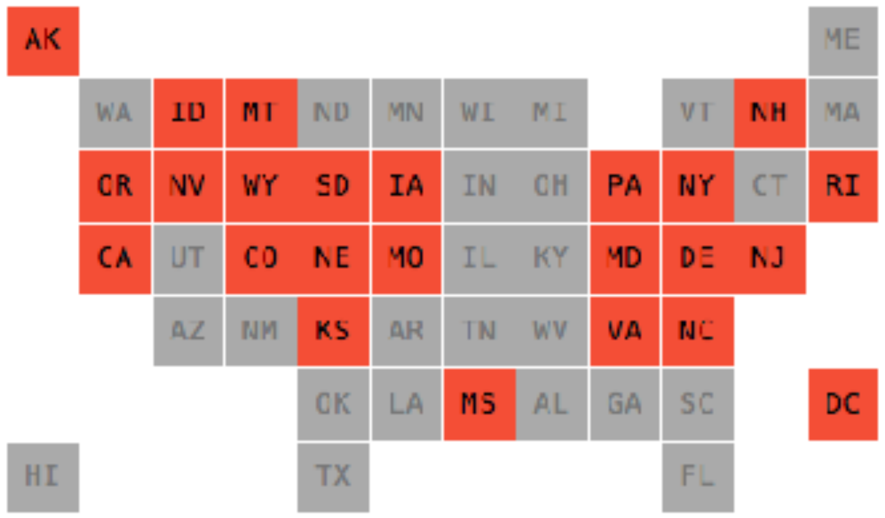


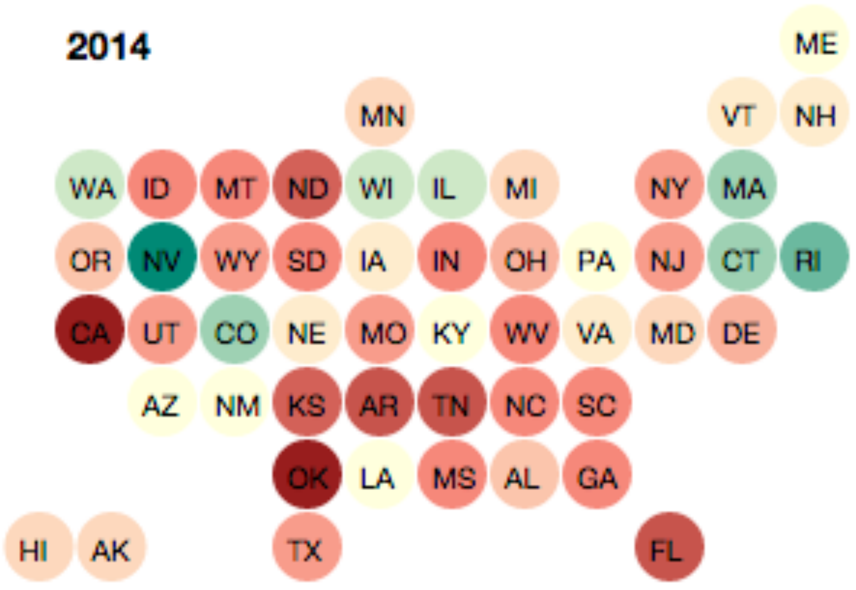
Greenhouse Emissions



Child Mortality

Idiom: **Grid Cartogram**





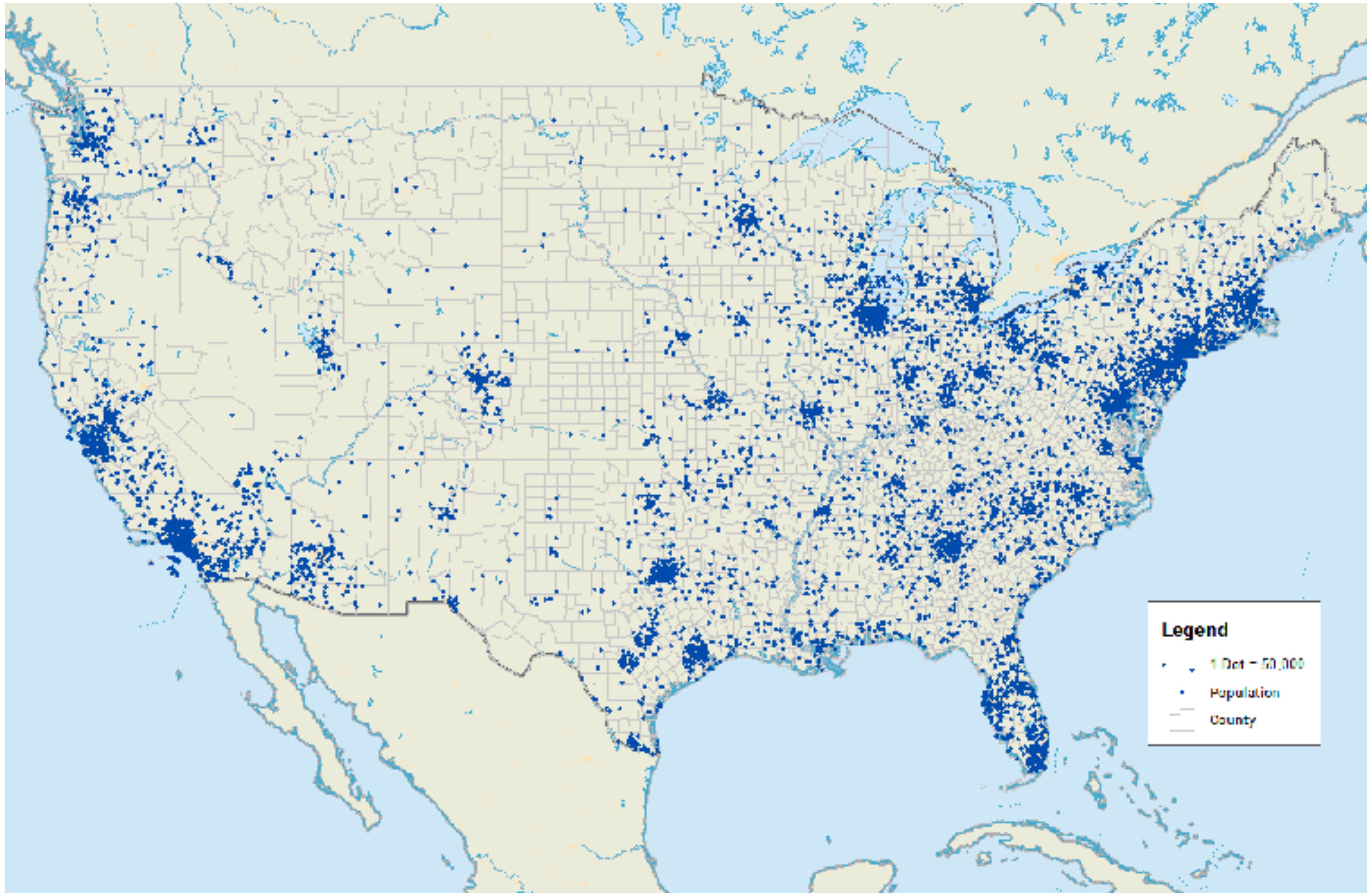
- uniform-sized shapes arranged in rectilinear grid
- maintain approximate spatial position and arrangement

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

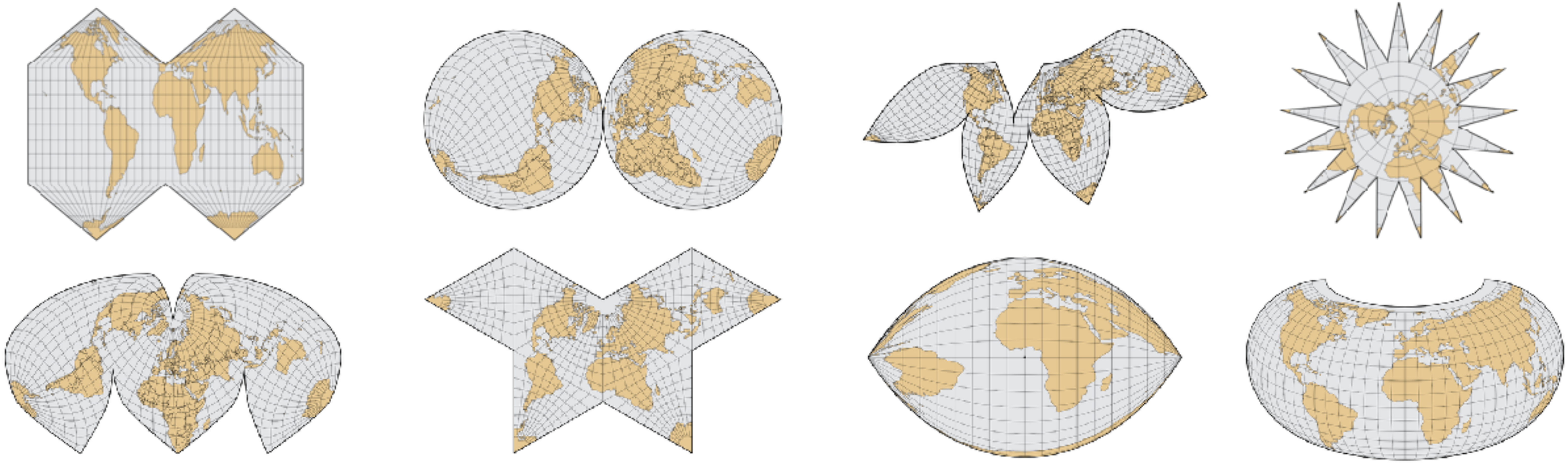


Dot density maps: Pros and cons

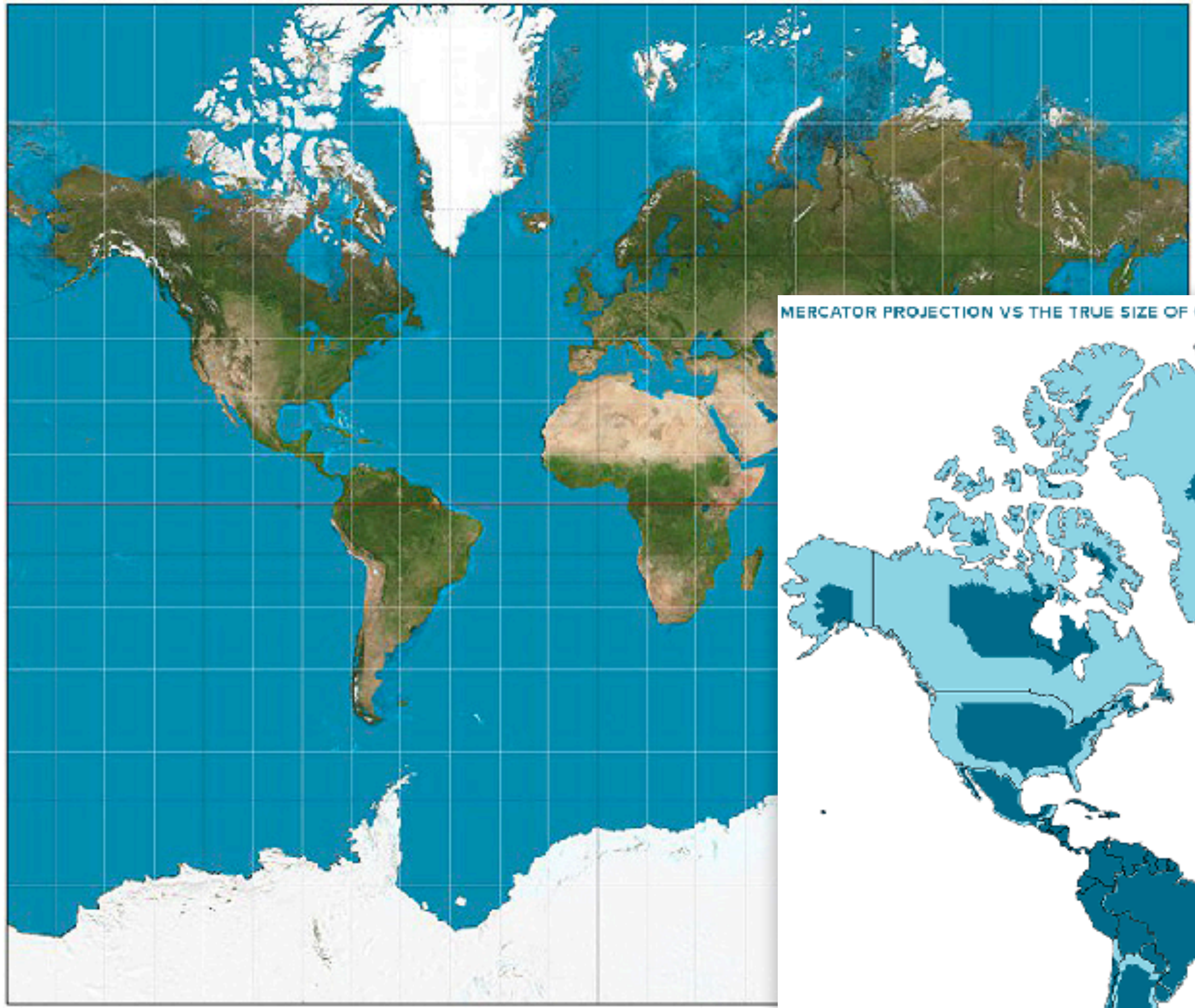
- pros
  - straightforward to understand
  - avoids choropleth non-uniform region size problems
- cons
  - challenge: normalization, just like choropleths
    - show population density (correlated with attribute), not effect of interest
  - perceptual disadvantage:
    difficult to extract quantities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

Map Projections

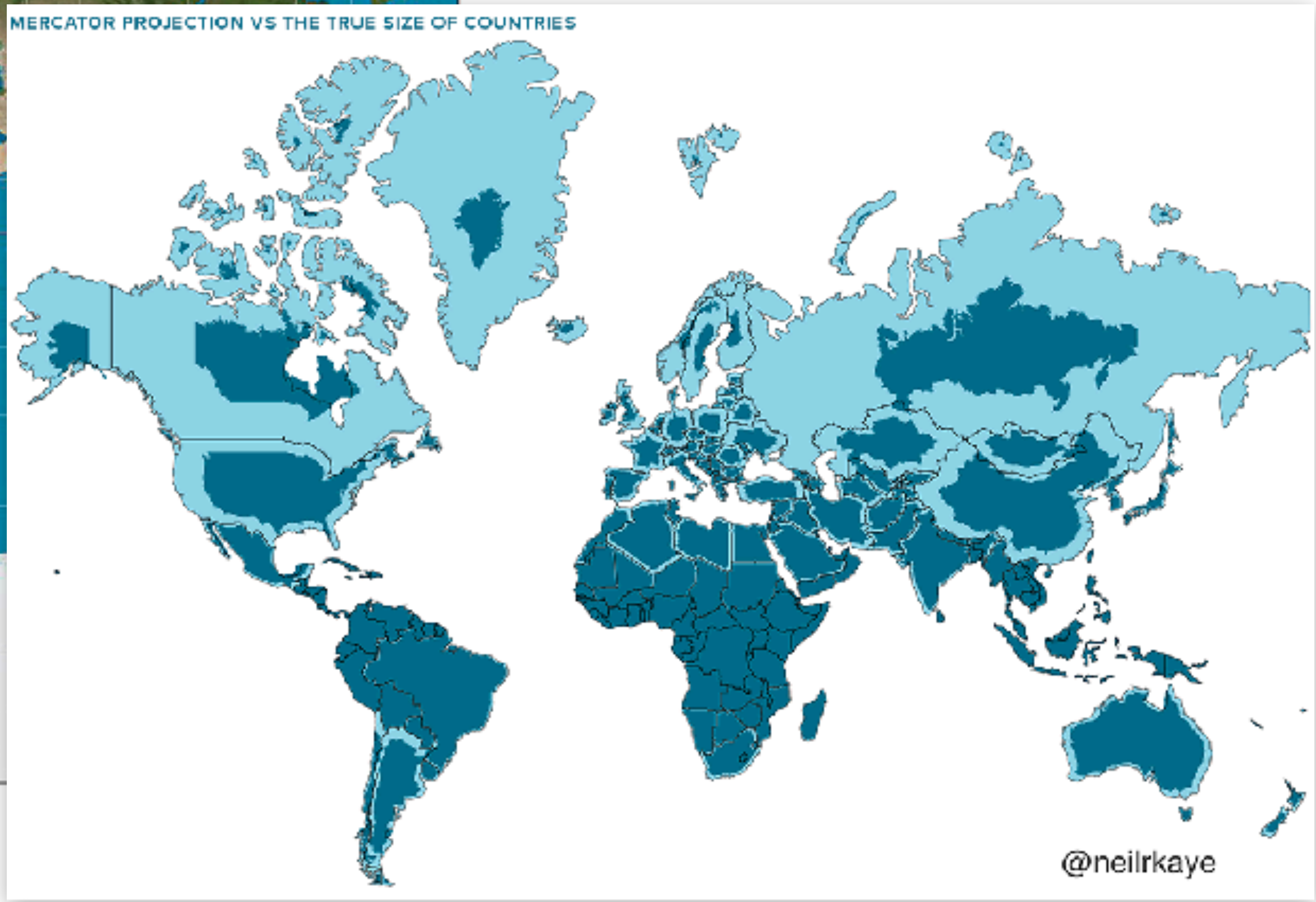
- mathematical functions that map 3D surface geometry of the Earth to 2D maps
- all projections of sphere on plane necessarily distort surface in some way
- interactive: philogb.github.io/page/myriahedral/ and jasondavies.com/maps/

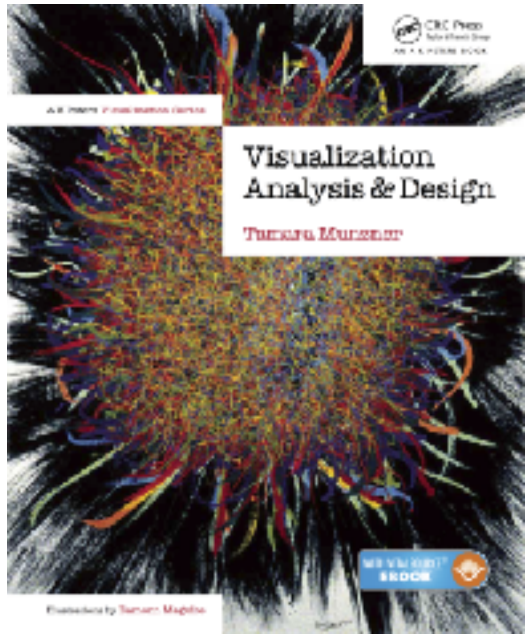


Mercator Projection



» Heavily distorts country sizes; particularly close to the poles.





Visualization Analysis & Design

Spatial Data (Ch 9) II

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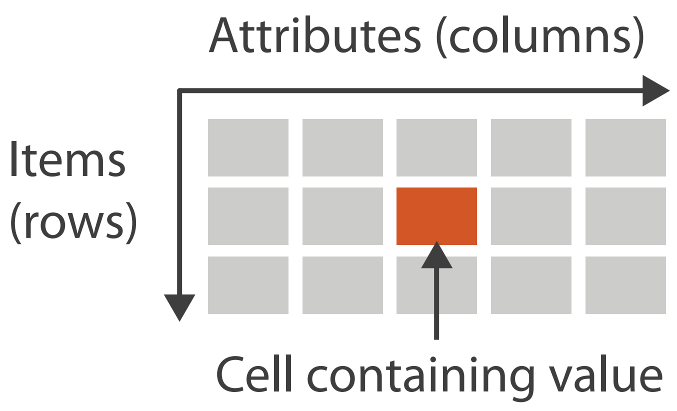
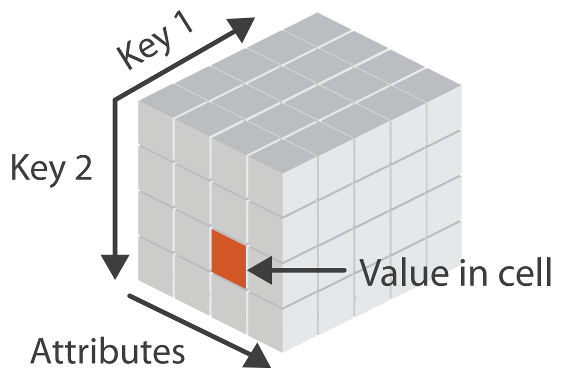
Focus on Spatial

➔ Dataset Types

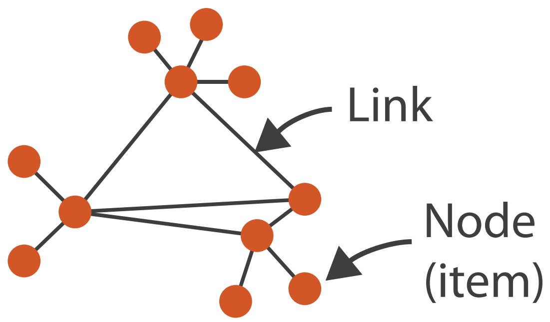
➔ Tables



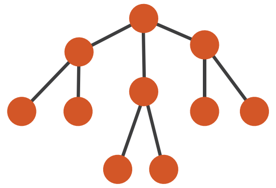
➔ *Multidimensional Table*



➔ Networks

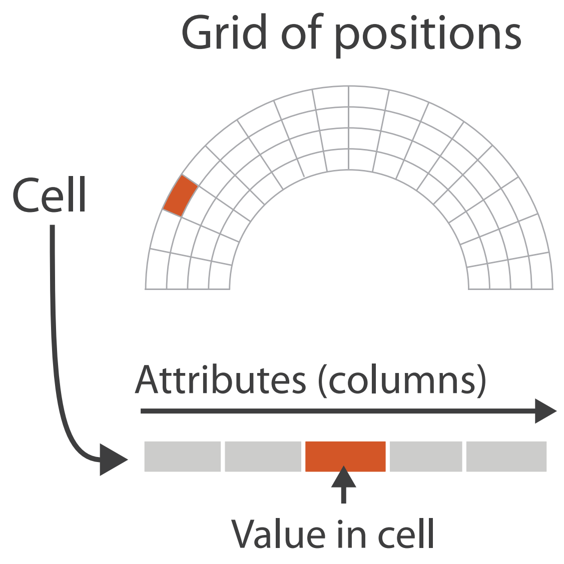


➔ *Trees*

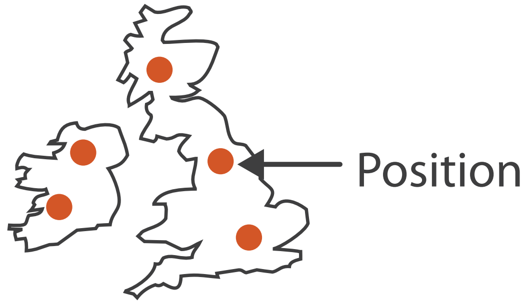


➔ Spatial

➔ Fields (Continuous)



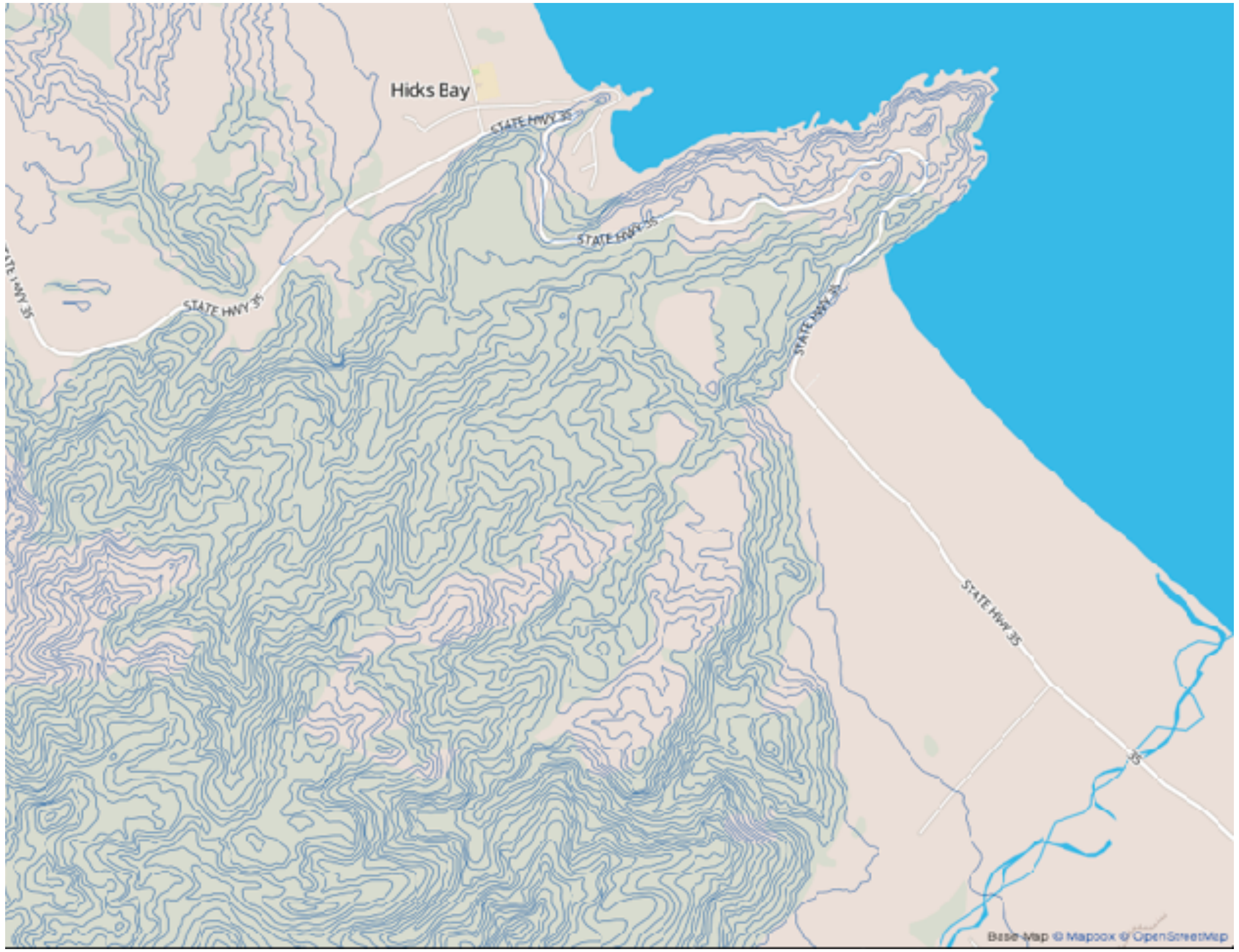
➔ Geometry (Spatial)



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

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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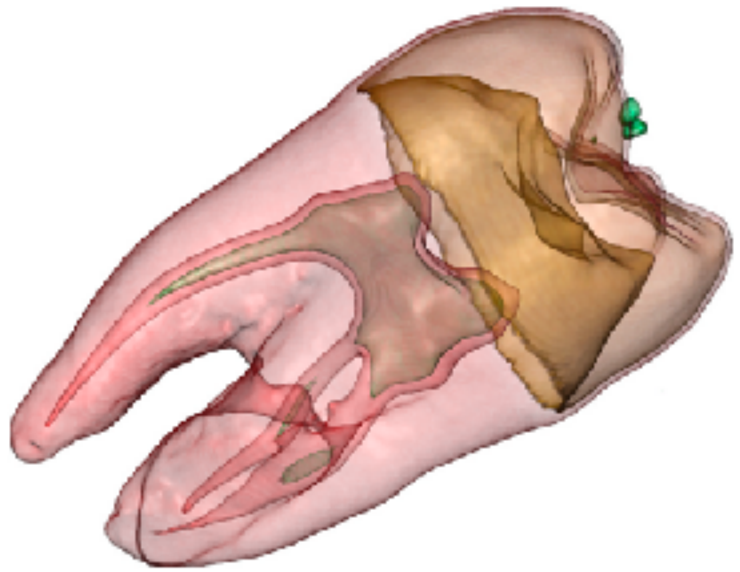

- data
  - scalar spatial field (3D volume)
    - 1 quant attribute per grid cell
- task
  - shape understanding, spatial relationships
- isosurface
  - derived data: isocontours computed for specific levels of scalar values

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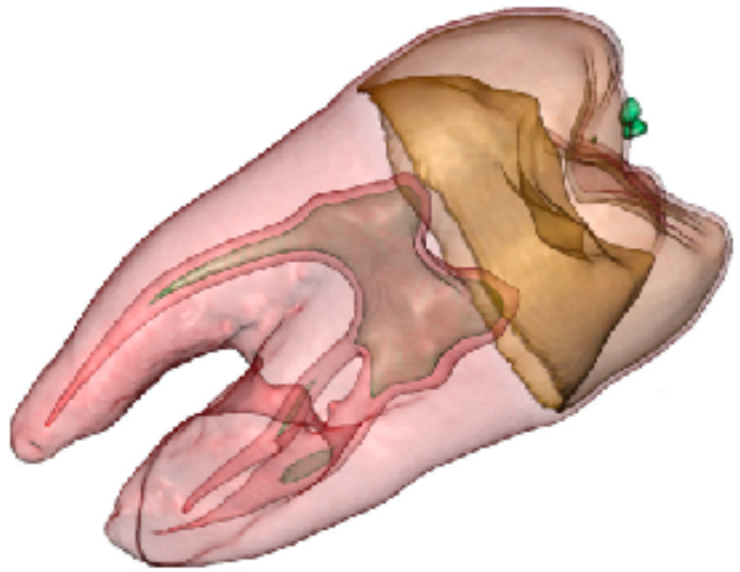
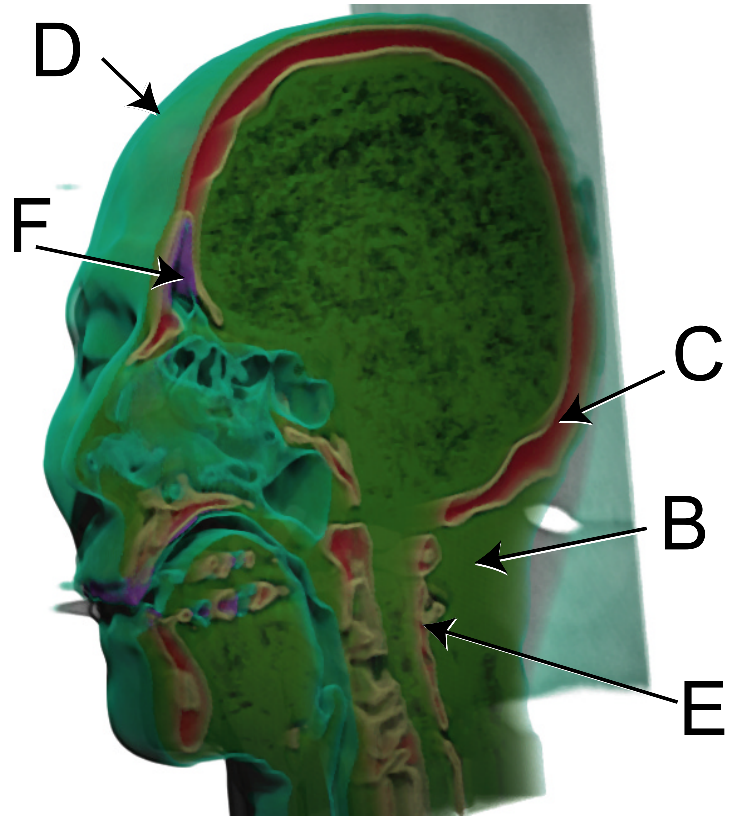




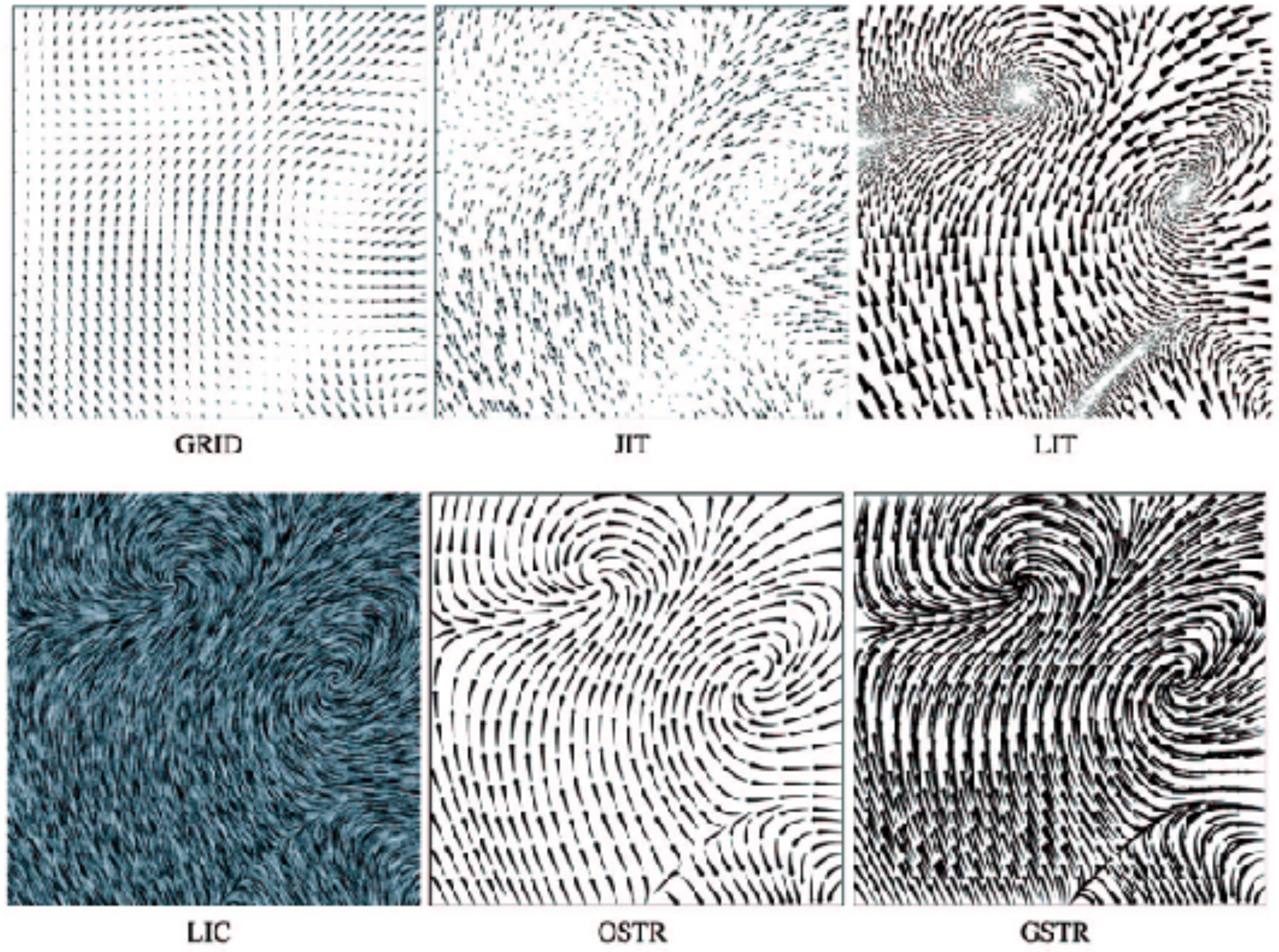
- data
  - scalar spatial field (3D volume)
    - 1 quant attribute per grid cell
- task
  - shape understanding, spatial relationships
- isosurface
  - derived data: isocontours computed for specific levels of scalar values
- direct volume rendering
  - transfer function maps scalar values to color,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

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

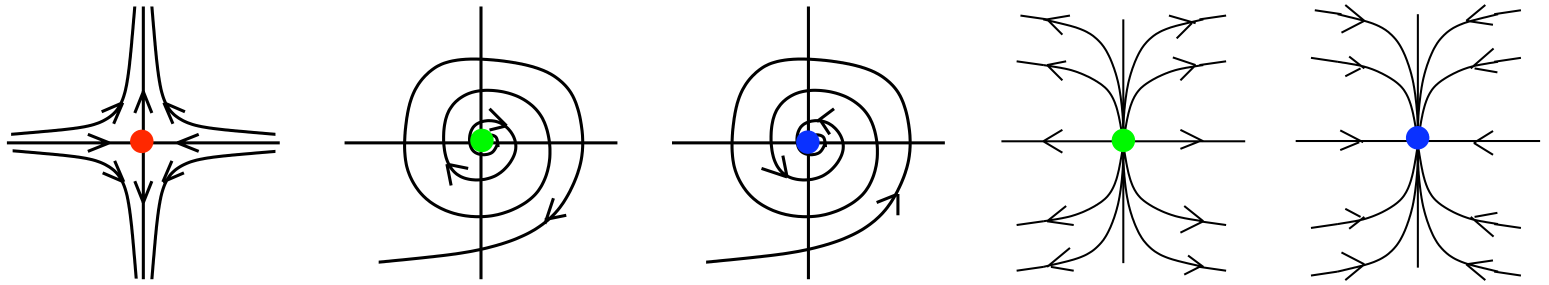
[Multidimensional Transfer Functions for Volume Rendering. Kniss, Kindlmann, and Hansen. In The Visualization Handbook, edited by Charles Hansen and Christopher Johnson, pp. 189–210. Elsevier, 2005.]

Vector and tensor fields

- data
  - multiple attribs per cell (vector: 2)
- idiom families
  - flow *glyphs*
    - purely local
  - *geometric* flow
    - derived data from tracing particle trajectories
    - sparse set of seed points
  - *texture* flow
    - derived data, dense seeds
  - *feature* flow
    - global computation to detect features



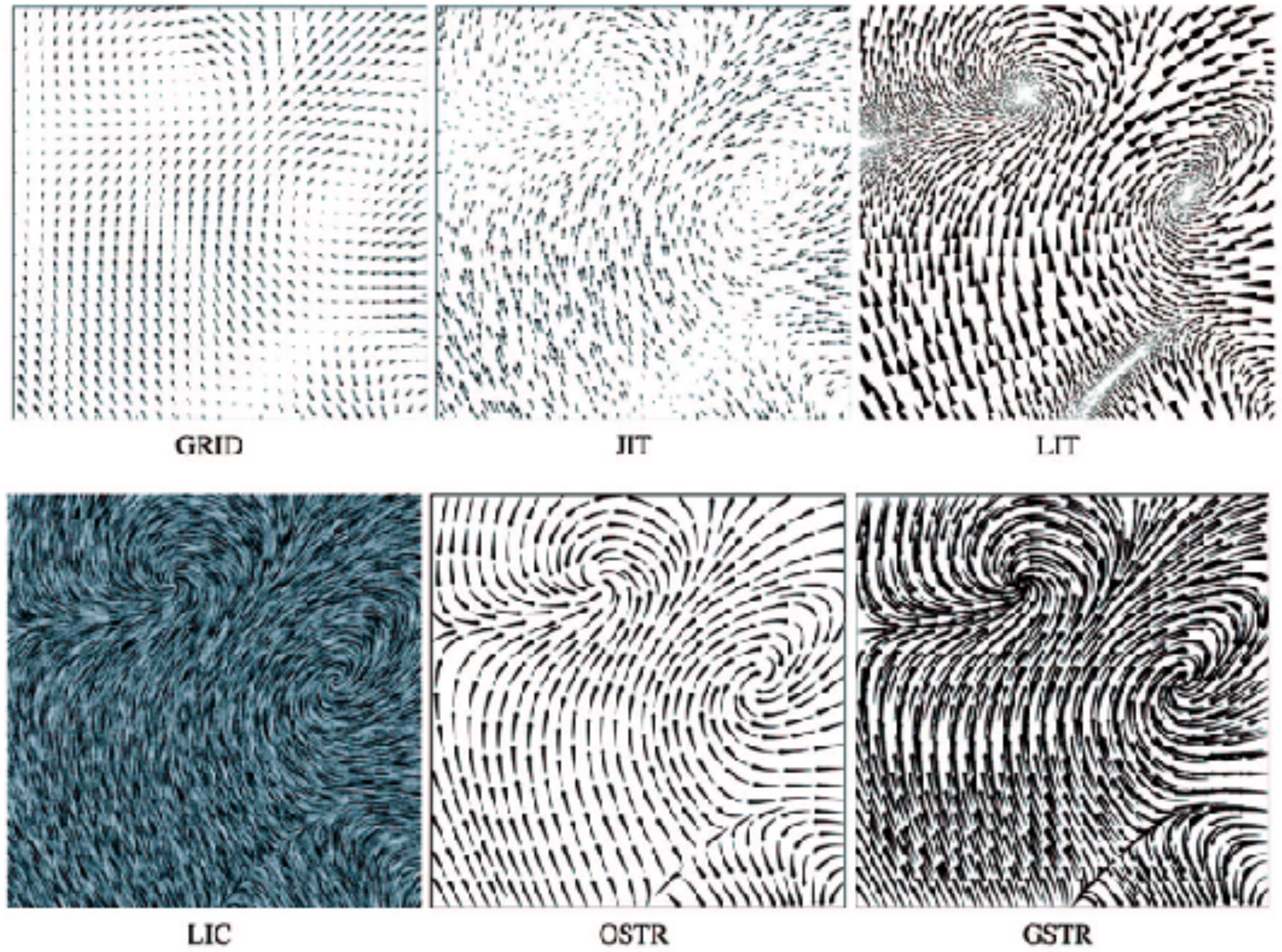
[Comparing 2D vector field visualization methods: A user study. Laidlaw et al. IEEE Trans. Visualization and Computer Graphics (TVCG) 11:1 (2005), 59–70.]



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

Vector fields

- empirical study 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)



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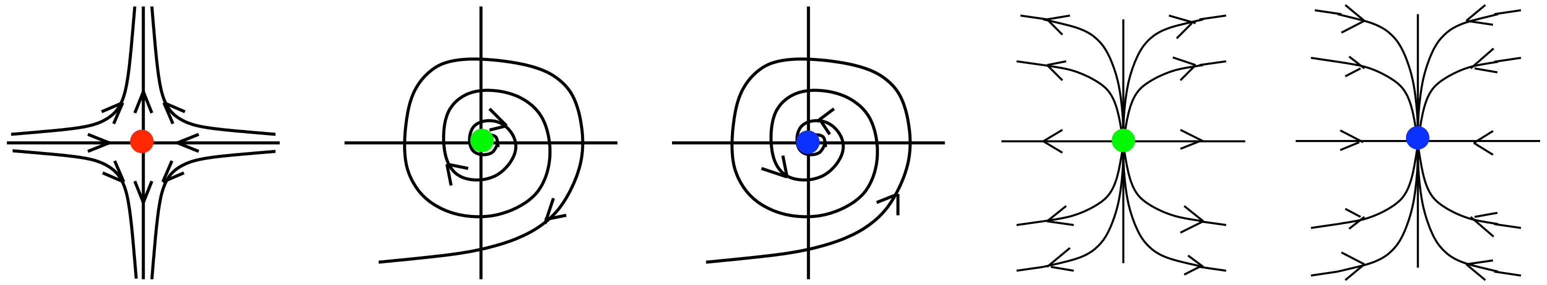
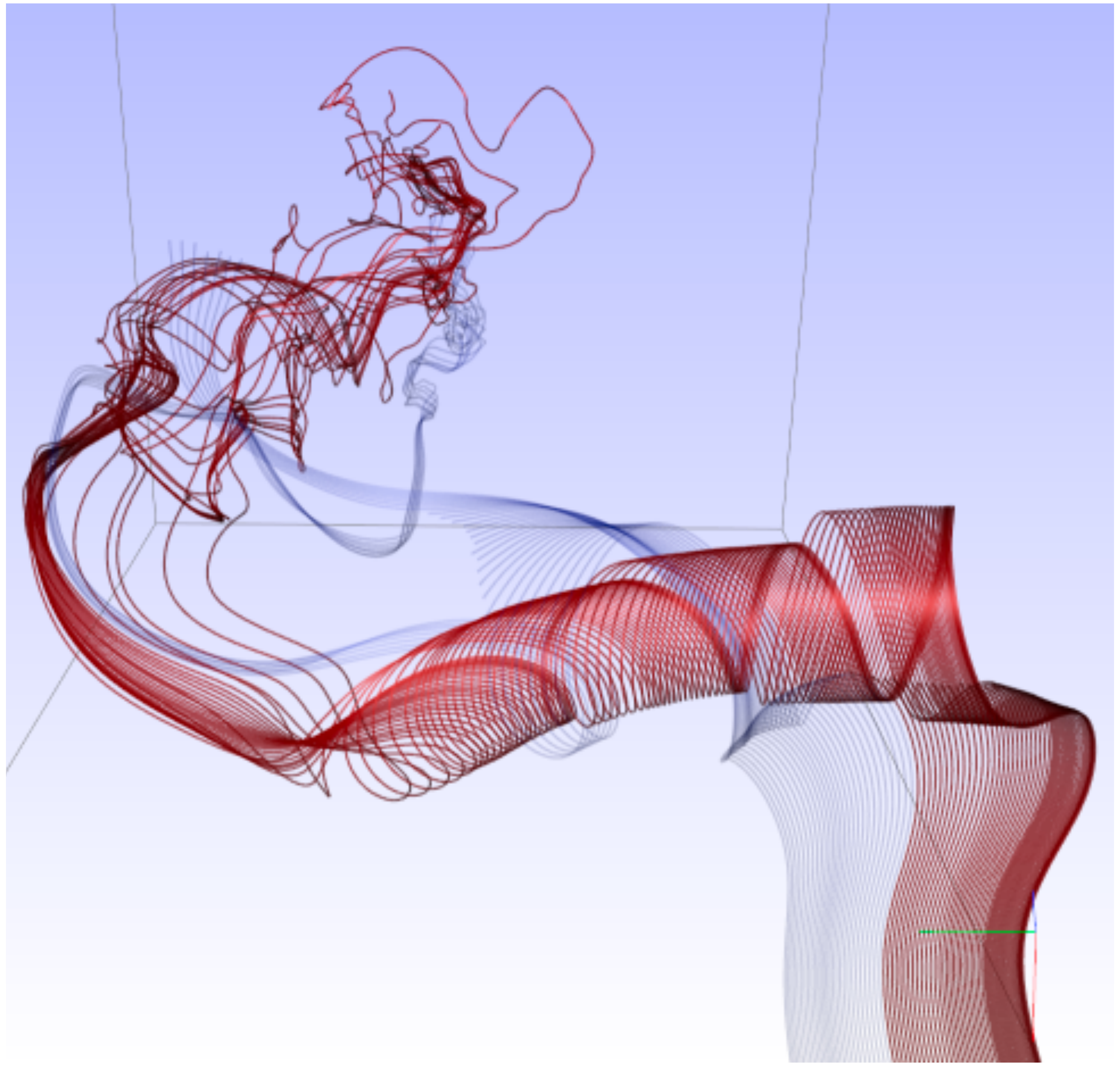


[Topology tracking for the visualization of time-dependent two-dimensional flows. Tricoche, Wischgoll, Scheuermann, and Hagen. Computers & Graphics 26:2 (2002), 249–257.]

Idiom: **similarity-clustered streamlines**

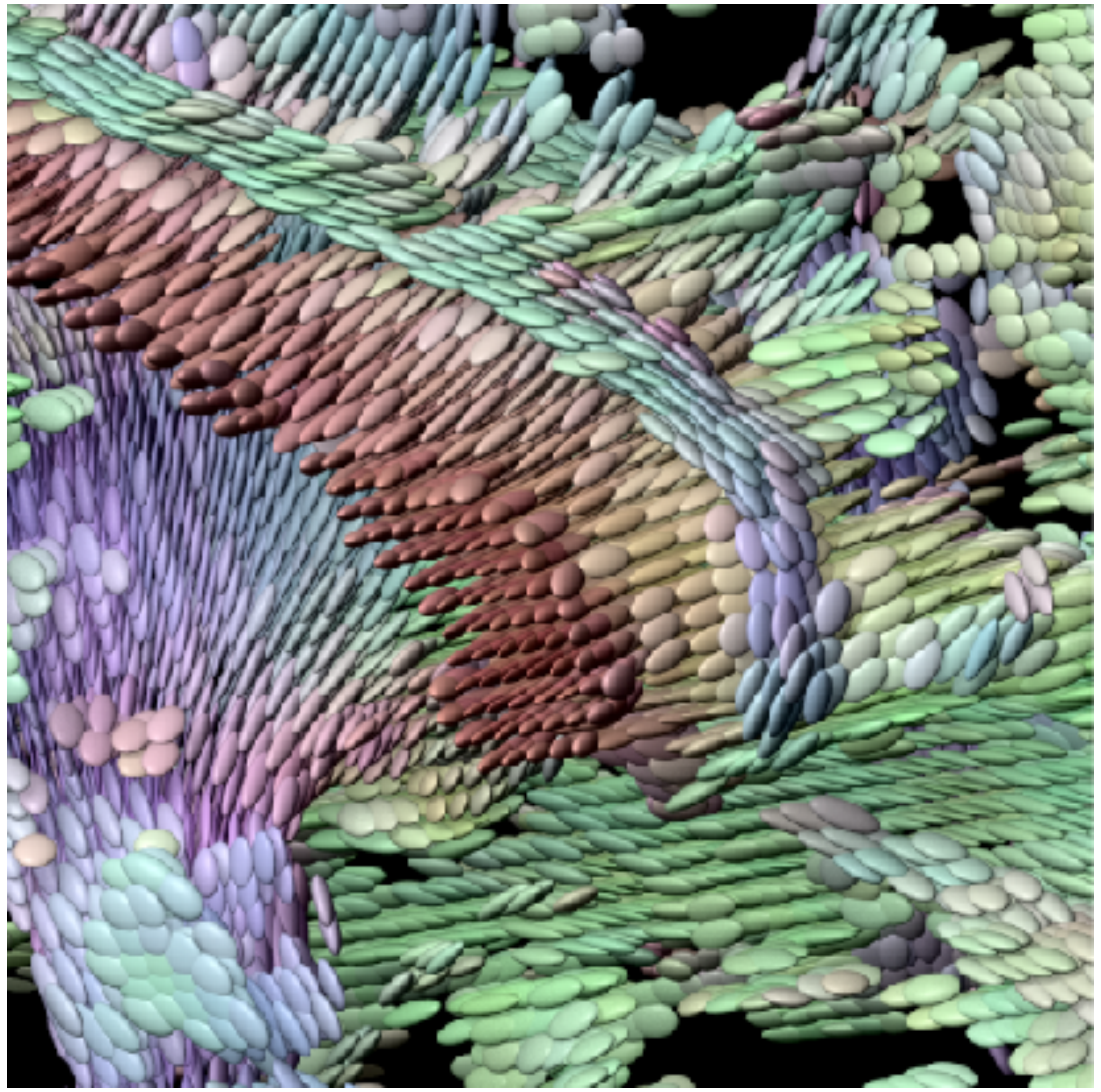
- data
  - 3D vector field
- derived data (from field)
  - streamlines: trajectory particle will follow
- derived data (per streamline)
  - curvature, torsion, tortuosity
  - signature: complex weighted combination
  - compute cluster hierarchy across all signatures
  - encode: color and opacity by cluster
- tasks
  - find features, query shape
- scalability
  - millions of samples, hundreds of streamlines



[Similarity Measures for Enhancing Interactive Streamline Seeding. McLoughlin,. Jones, Laramee, Malki, Masters, and. Hansen. IEEE Trans. Visualization and Computer Graphics 19:8 (2013), 1342–1353.]

Idiom: Ellipsoid Tensor Glyphs

- data
  - tensor field: multiple attributes at each cell (entire matrix)
    - stress, conductivity, curvature, diffusivity...
  - derived data:
    - shape (eigenvalues)
    - orientation (eigenvectors)
- visual encoding
  - glyph: 3D ellipsoid

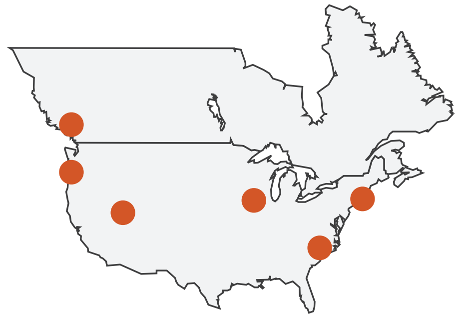


[Superquadric Tensor Glyphs. Kindlmann. Proc. VisSym04, p147-154, 2004.]

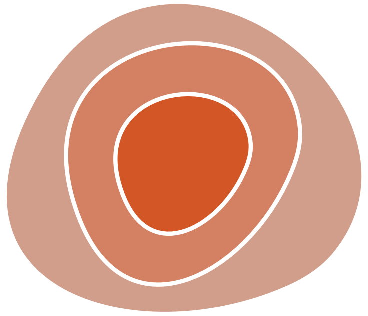
Arrange spatial data

➔ Use Given

- ➔ Geometry
  - ➔ *Geographic*



- ➔ Spatial Fields
  - ➔ *Scalar Fields (one value per cell)*
    - ➔ *Isocontours*
    - ➔ *Direct Volume Rendering*



  - ➔ *Vector and Tensor Fields (many values per cell)*
    - ➔ *Flow Glyphs (local)*
    - ➔ *Geometric (sparse seeds)*
    - ➔ *Textures (dense seeds)*
    - ➔ *Features (globally derived)*