

GEOSPATIAL VISUALIZATION

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AARHUS
UNIVERSITY
DEPARTMENT OF COMPUTER SCIENCE

GEOVISUALIZATIONS
DATAVIS FALL 2025 | HANS-JÖRG SCHULZ
ASSOCIATE PROFESSOR



1. INTRODUCTION

2. VISUAL ENCODING

3. BASIC CHART TYPES

4. INTERACTION

5. VISUALIZATION DESIGN

6. DATA PREPROCESSING

7. RECAP 1st Half

8. MULTIVARIATE DATAVIS

9. TEMPORAL DATAVIS

10. GEOSPATIAL DATAVIS

11. GRAPH DATAVIS

12. 3D DATAVIS

13. VISUAL ANALYTICS

14. RECAP 2nd Half

Basics

Visualization
Building Blocks
& Processes

Visualization
Techniques

Visualization
Applications



WHY TALK ABOUT GEOVISUALIZATION?

Geovis / Thematic Cartography is in many ways the foundations of data vis.

→ Points



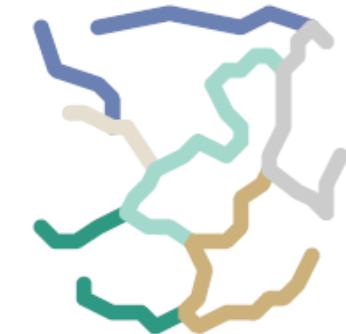
→ Lines



→ Areas



(a) Points.



(b) Lines.



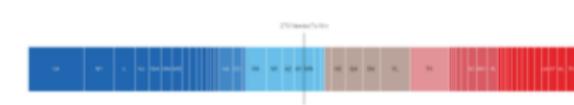
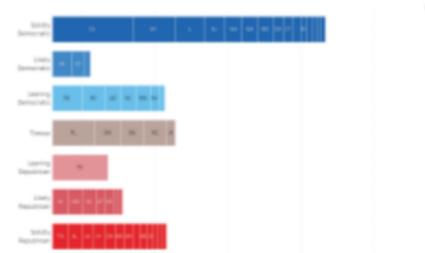
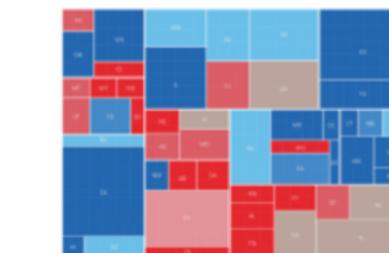
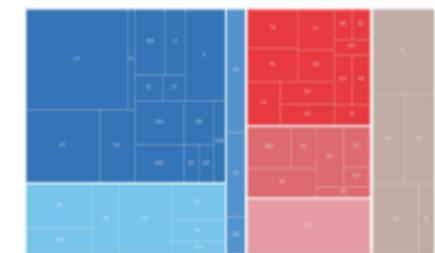
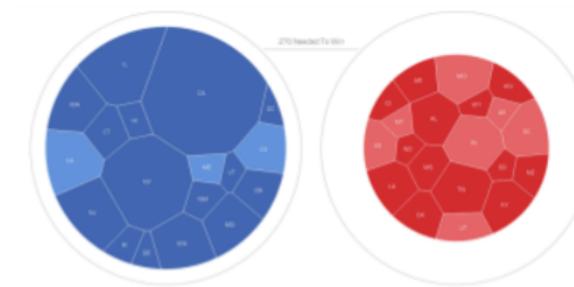
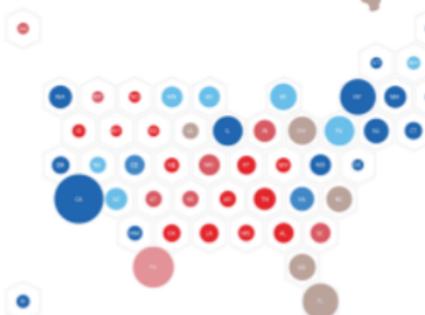
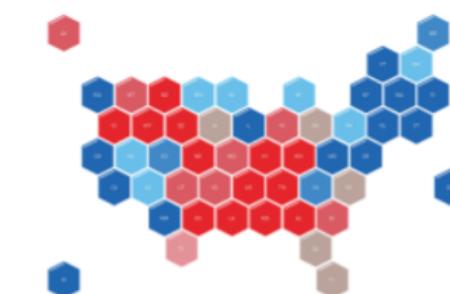
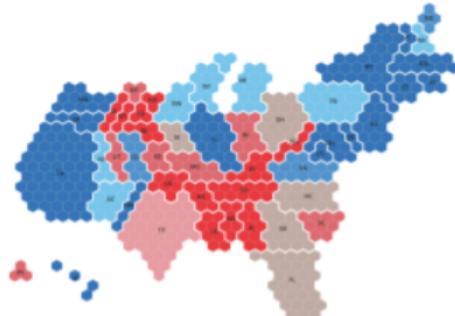
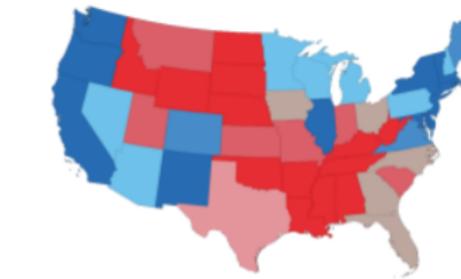
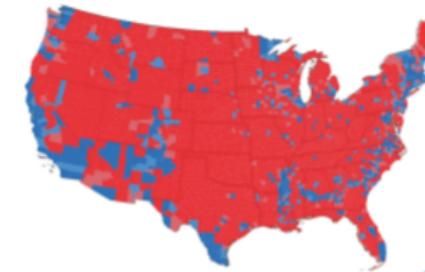
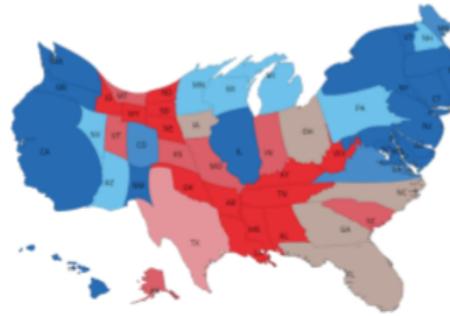
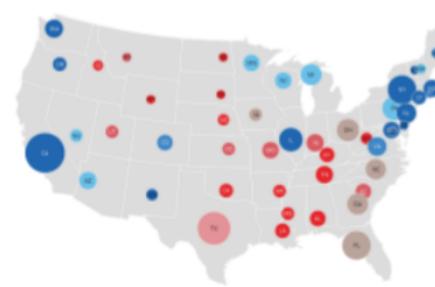
(c) Areas.

A world map with red lines indicating distances from Europe to North America and Asia. The top red line connects Europe to North America, labeled "6400 km". The bottom red line connects Europe to Asia, labeled "7200 km".

6400 km

7200 km

VISUALIZING THE PRESIDENTIAL ELECTION

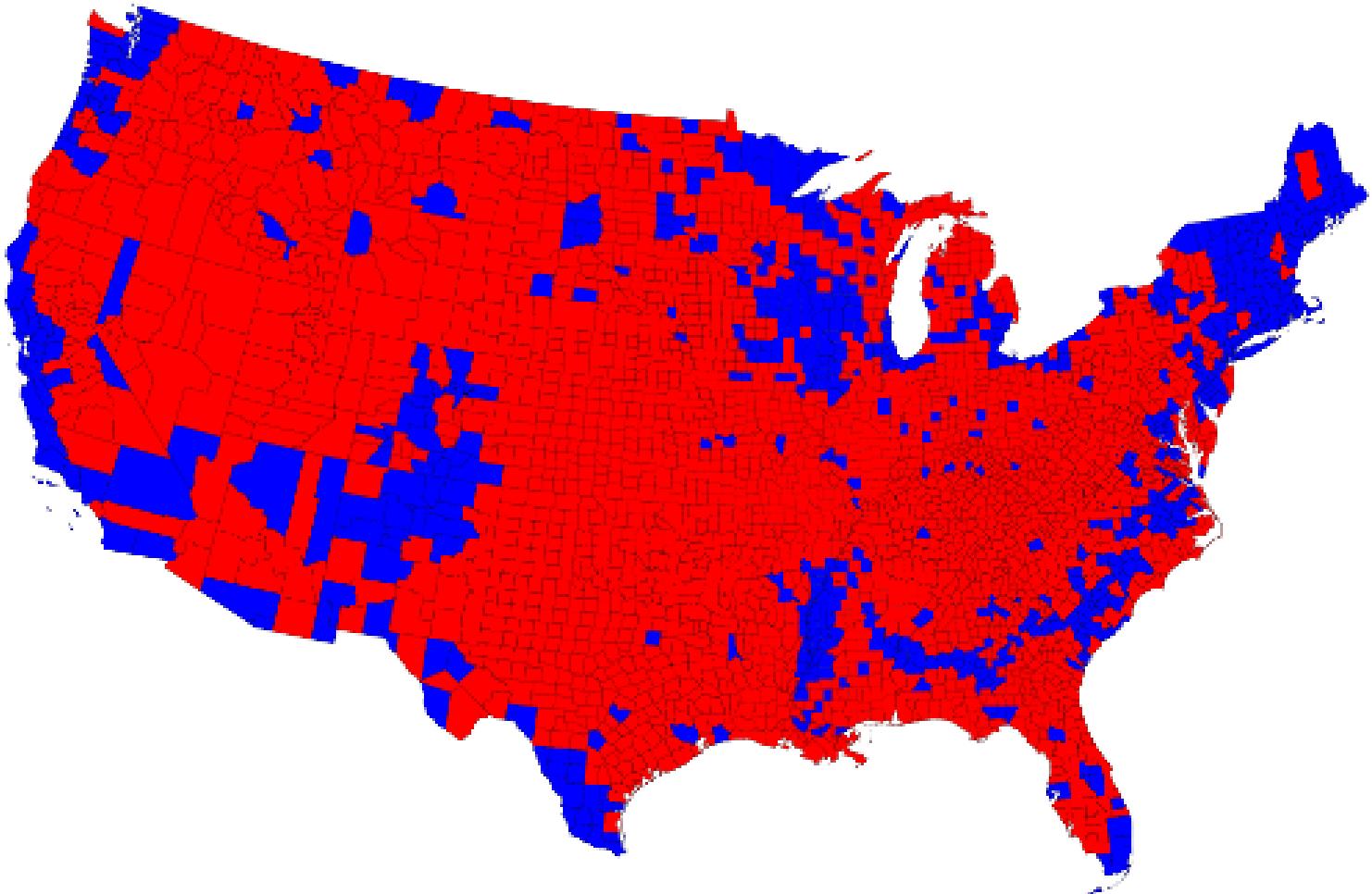


SEE THE VISUALS >>

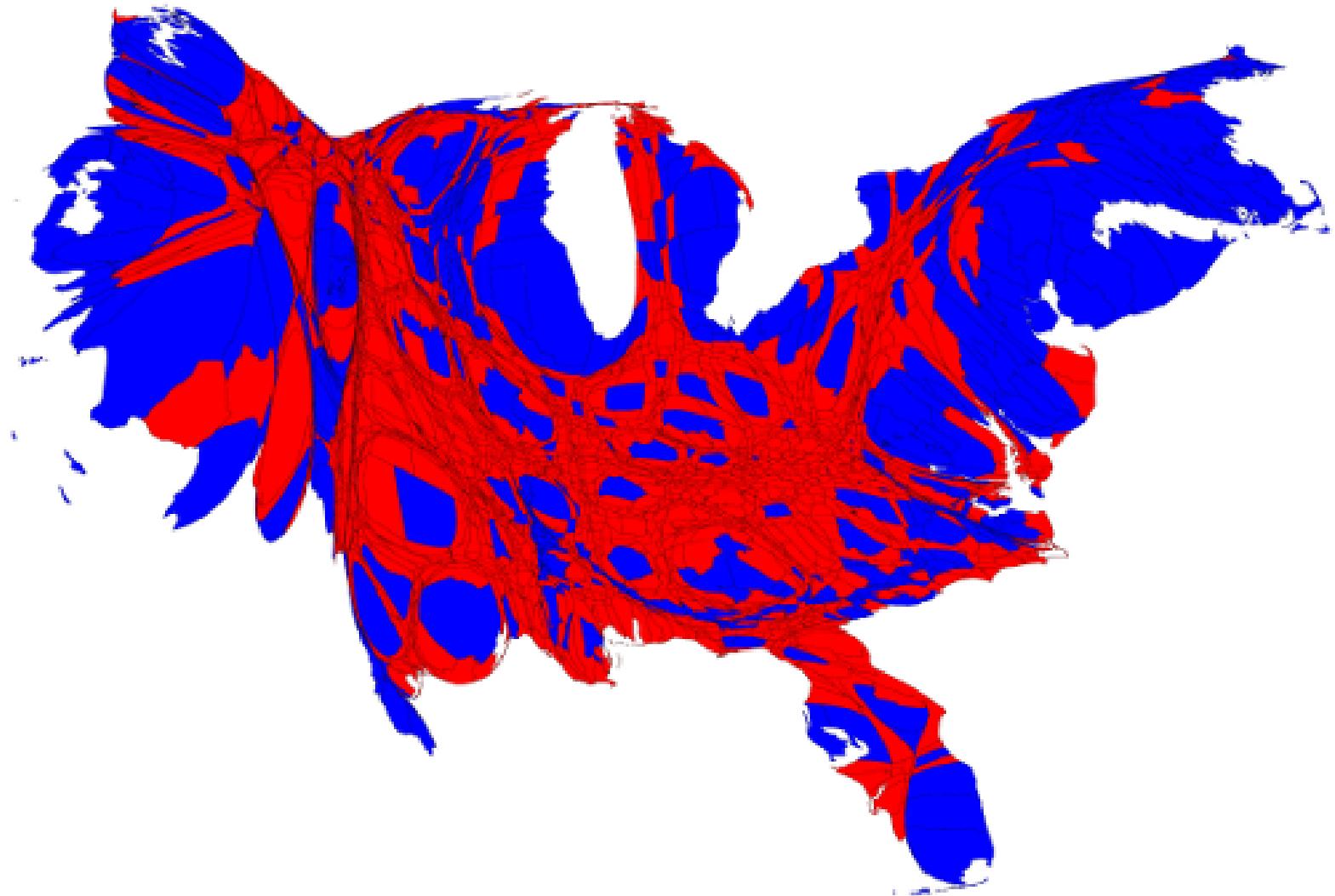
INSPIRED BY CHART CHAT

Image source: [10](https://public.tableau.com/app/profile/ken.flrlage/viz/VisualizingthePresidentialElection>Title</p></div><div data-bbox=)

MODIFIABLE AREAL UNIT PROBLEM



MODIFIABLE AREAL UNIT PROBLEM



OVERVIEW

1. Spatial Statistics

- Spatial Mean, Median,...

2. How to create a Map

- Maps & Map Projections

3. Data on Maps

- Dot Maps, Flow Maps
- Choropleth Maps
- Isopleth Maps

4. Data as Maps

- Cartograms
- Metromaps
- Map Schematization

5. Spatio-temporal Visualization

- Space-Time Cube
- Isochrone Maps

6. Spatial Vis beyond Geospace



SPATIAL STATISTICS

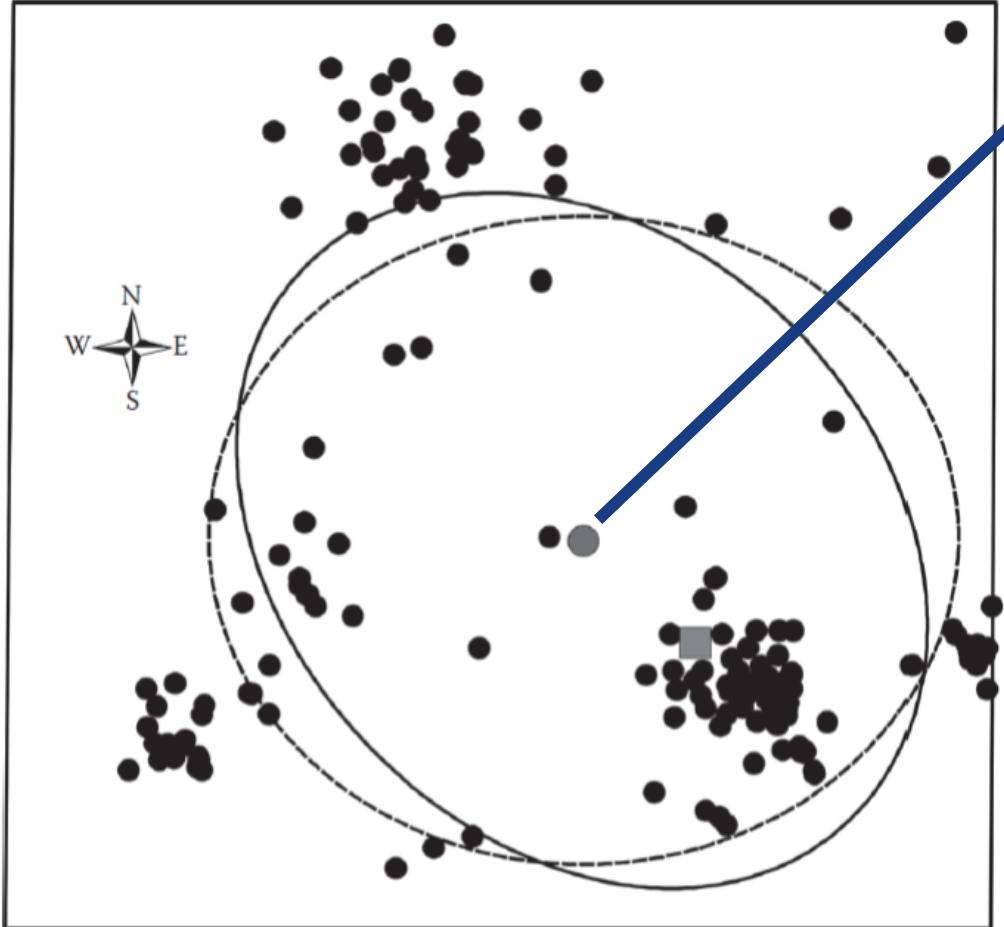


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SPATIAL DESCRIPTIVE STATISTICS



Spatial Mean:

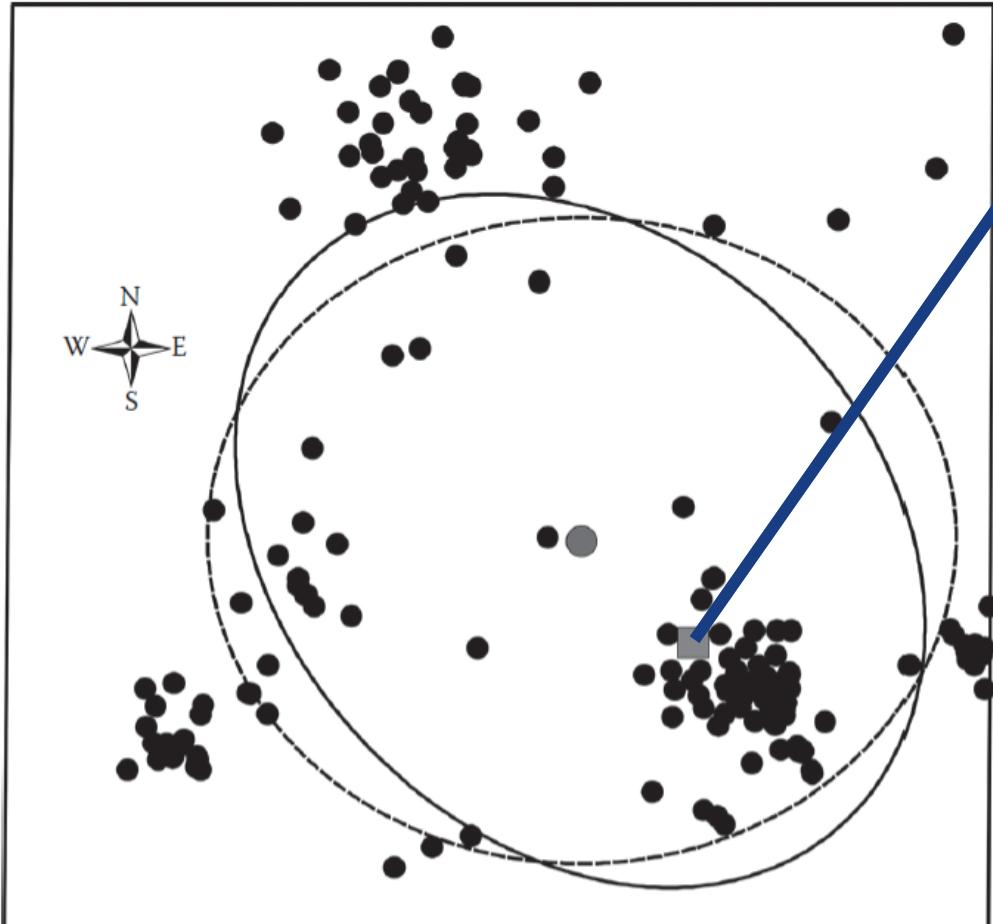
$$\bar{X} = \frac{\sum_{i=1}^n X_i}{n} \quad \bar{Y} = \frac{\sum_{i=1}^n Y_i}{n}$$

Weighted Spatial Mean:

$$\bar{X} = \frac{\sum_{i=1}^n X_i W_i}{\sum_{i=1}^n W_i} \quad \bar{Y} = \frac{\sum_{i=1}^n Y_i W_i}{\sum_{i=1}^n W_i}$$



SPATIAL DESCRIPTIVE STATISTICS

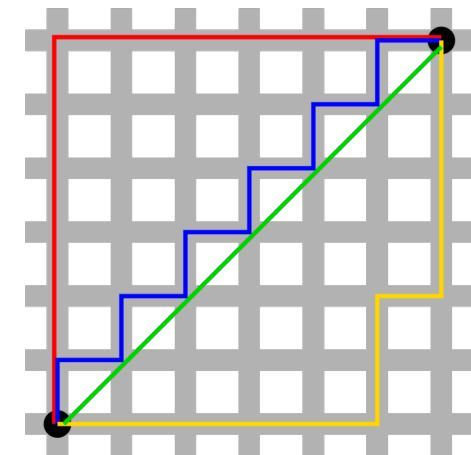


Spatial Median (Geometric Median):

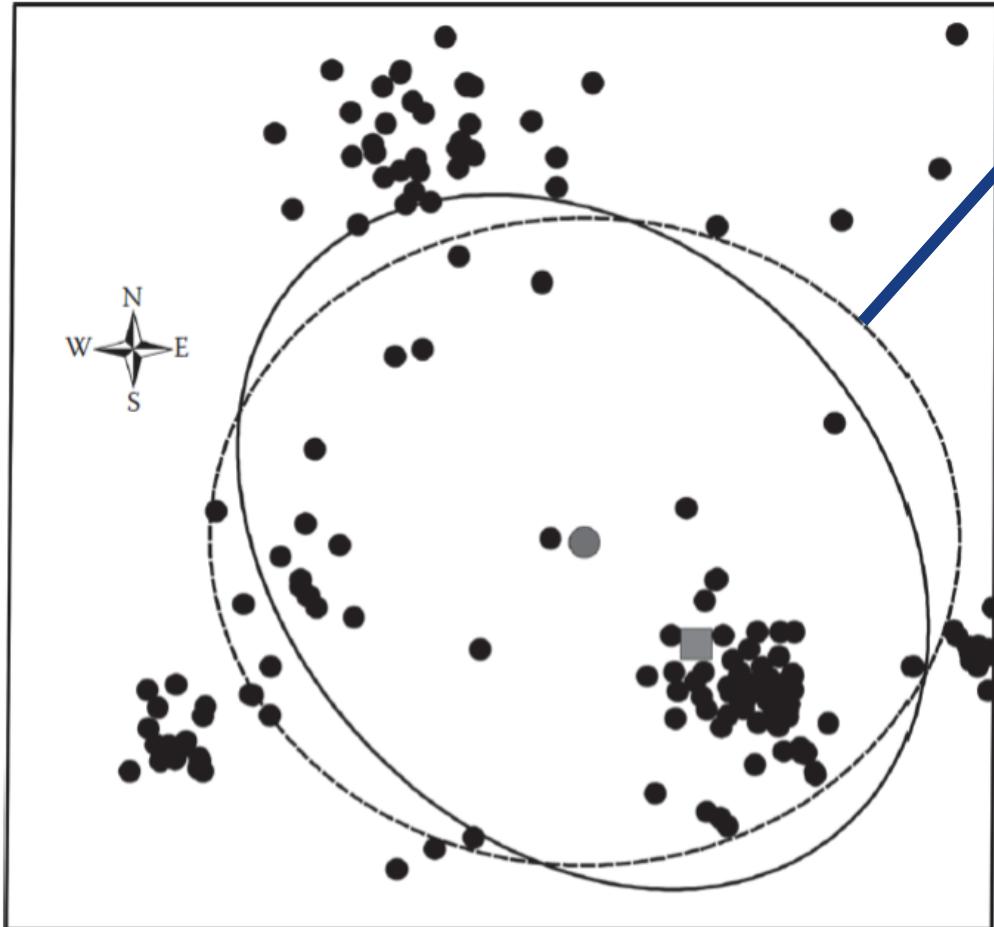
$$\arg \min_{y \in \mathbb{R}^n} \sum_{i=1}^m \|x_i - y\|_2$$

Distances can be computed using different norms:

- Euclidian Distance
- Manhattan Distance



SPATIAL DESCRIPTIVE STATISTICS



Standard Distance:

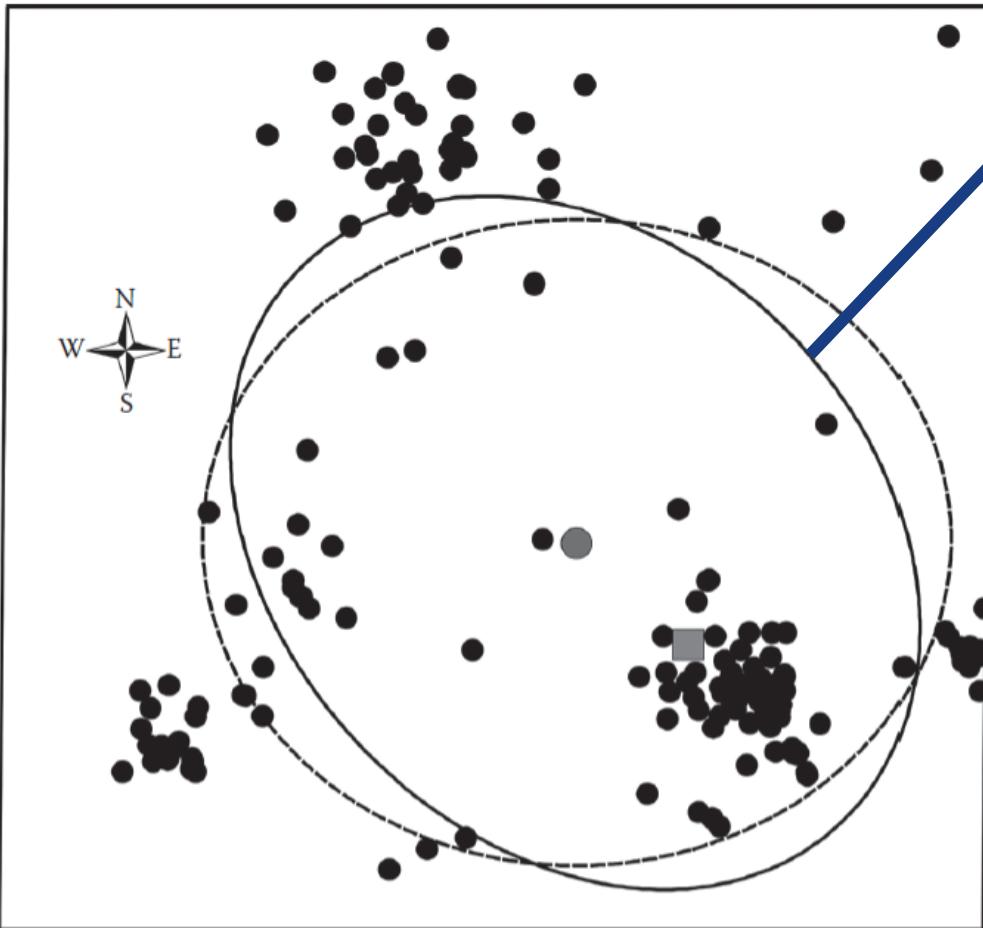
$$SD = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{X})^2 + \sum_{i=1}^n (y_i - \bar{Y})^2}{n}}$$

Weighted Standard Distance:

$$SD_w = \sqrt{\frac{\sum_{i=1}^n w_i (x_i - \bar{X})^2 + \sum_{i=1}^n w_i (y_i - \bar{Y})^2}{\sum_{i=1}^n w_i}}$$



SPATIAL DESCRIPTIVE STATISTICS



Standard Deviational Ellipse:

$$\tan \theta = \frac{\left(\sum_{i=1}^n x_i'^2 - \sum_{i=1}^n y_i'^2 \right) + \sqrt{\left(\sum_{i=1}^n x_i'^2 - \sum_{i=1}^n y_i'^2 \right) + 4 \left(\sum_{i=1}^n x_i' y_i' \right)^2}}{2 \sum_{i=1}^n x_i' y_i'}$$

x'_i and y'_i are the distances of x_i and y_i from the mean (\bar{x}, \bar{y})

$$\delta_x = \sqrt{\frac{\sum_{i=1}^n (x_i' \cos \theta - y_i' \sin \theta)^2}{n}}$$

$$\delta_y = \sqrt{\frac{\sum_{i=1}^n (x_i' \sin \theta - y_i' \cos \theta)^2}{n}}$$

HOW TO CREATE A MAP



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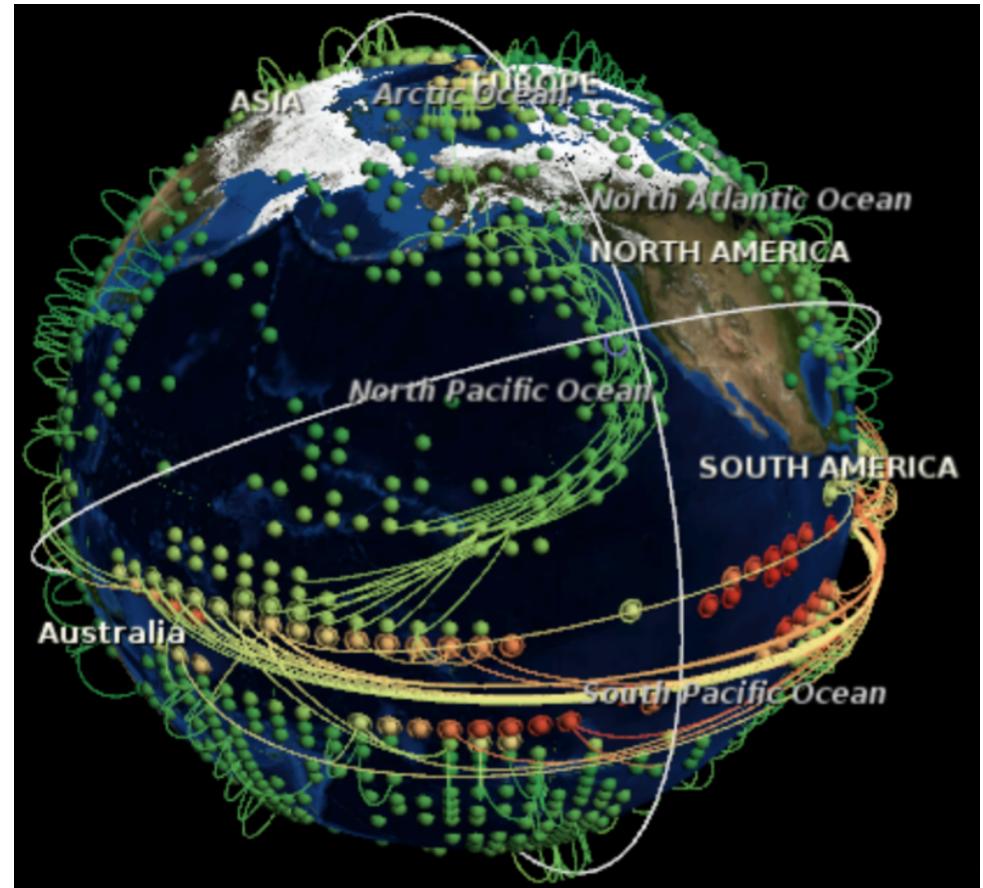


VISUALIZATION OF GEOSPATIAL DATA

Representation of the Data Context in 3D



Globe



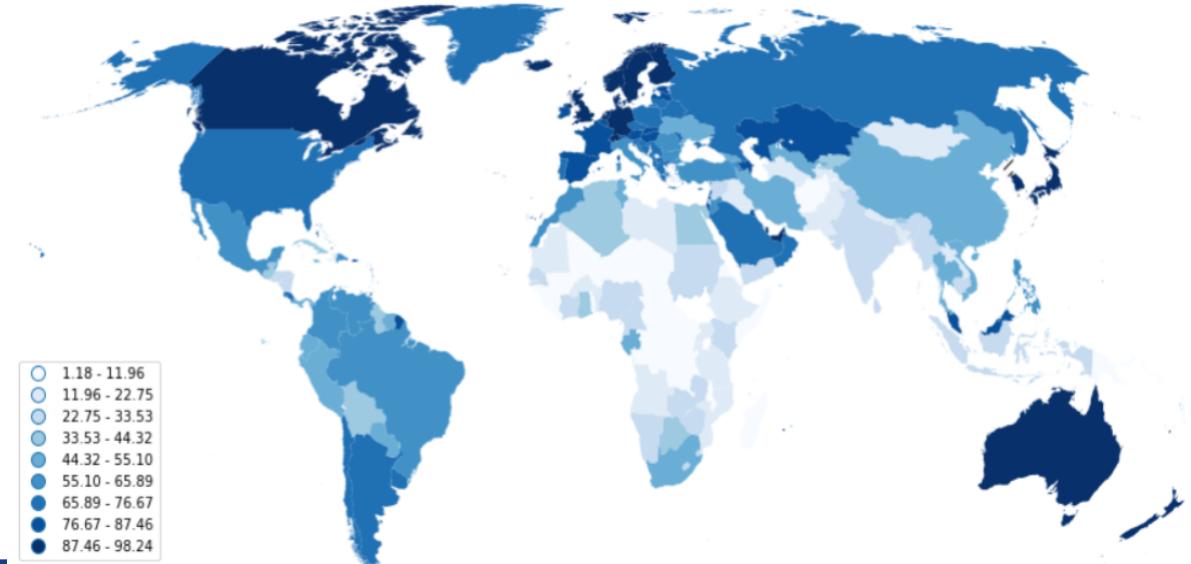
VISUALIZATION OF GEOSPATIAL DATA

Representation of the Data Context in 2D



Map

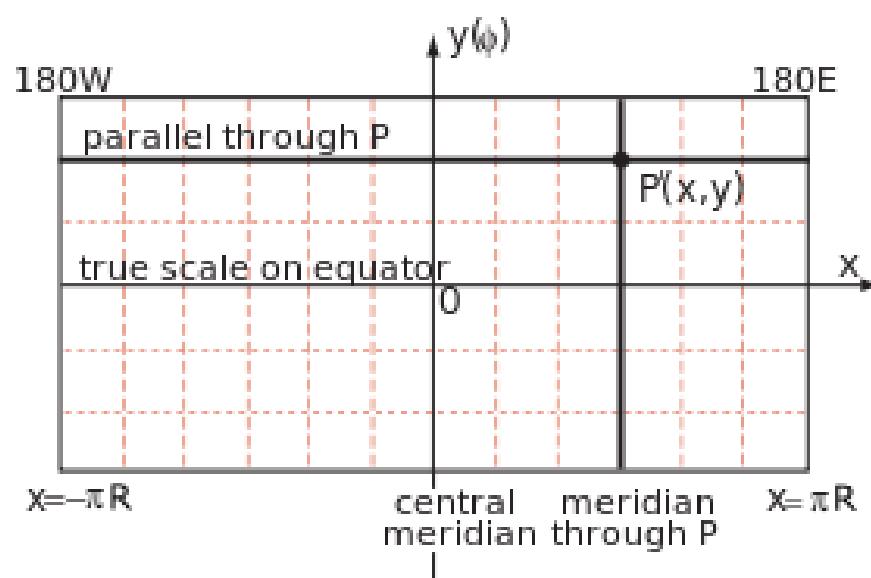
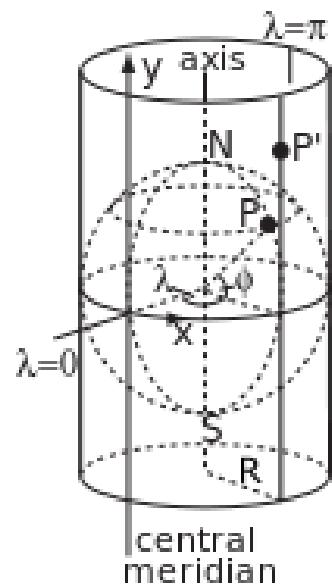
Individuals using the Internet (% of population) in 2016



ON MAP PROJECTIONS

Map projection := transformation from lat/lon into Cartesian coordinates

Mercator projection:



ON MAP PROJECTIONS

<https://gevian.github.io/GITTA-MP/>

GITTA Map Projector

geometry

position

radius

light source

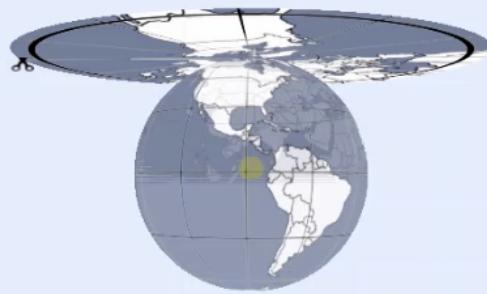
offset

layers

borders

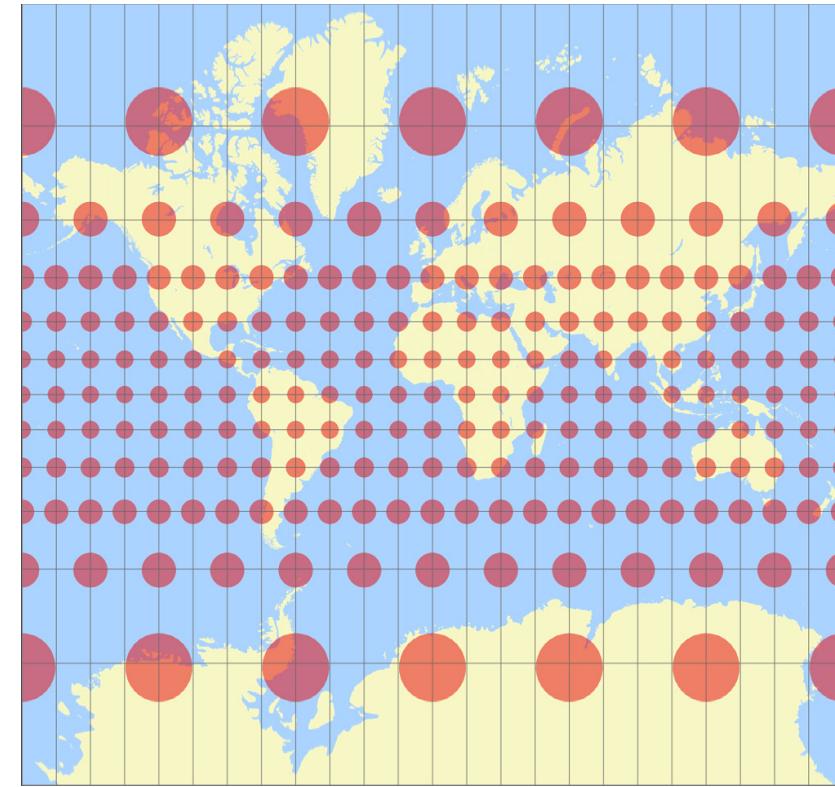
graticule

[reset](#) [remove line](#) [flatten](#)



ON MAP PROJECTIONS - DEFORMATION

Tissot's indicatrix for visualizing local distortions due to map projection



Mercator projection

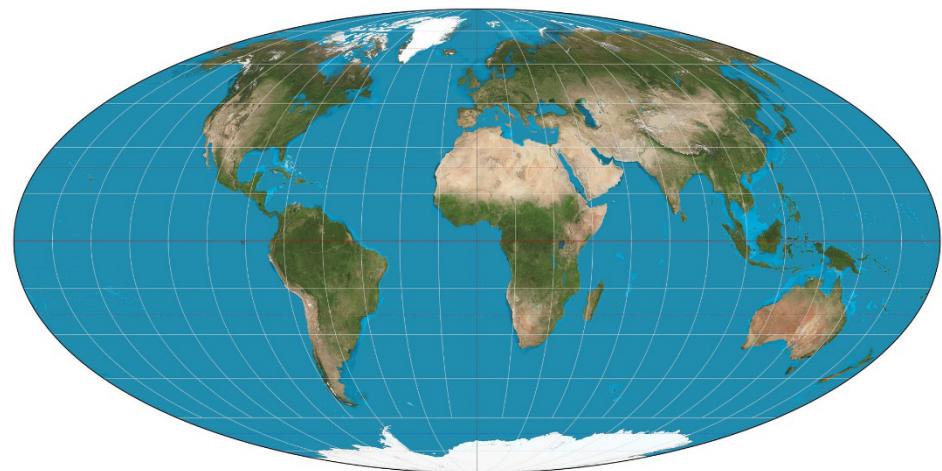


ON MAP PROJECTIONS

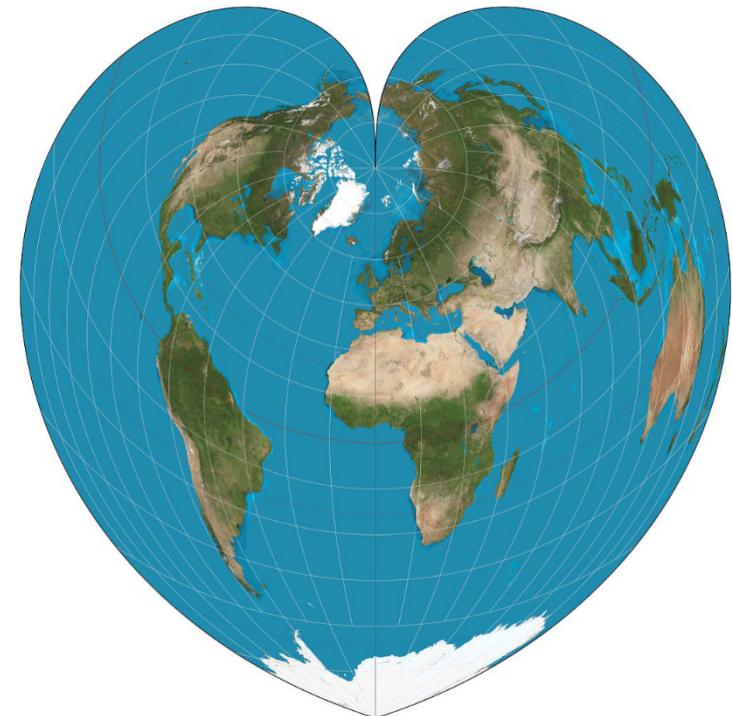
What we ideally want from a map projection:



Preserving angles:
Mercator projection



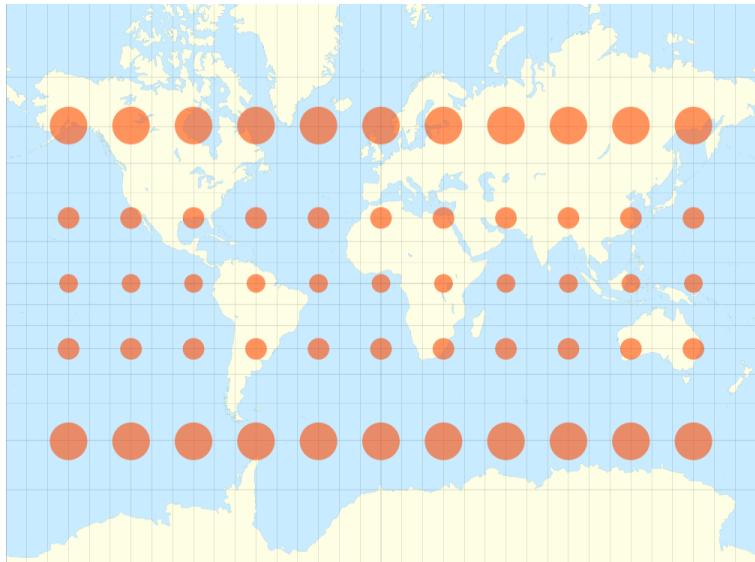
Preserving areas:
Mollweide projection



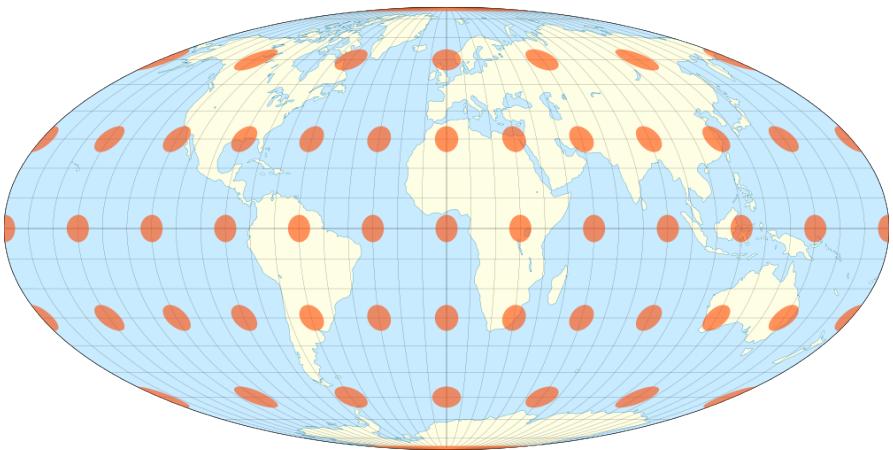
Preserving distances:
Werner projection

ON MAP PROJECTIONS

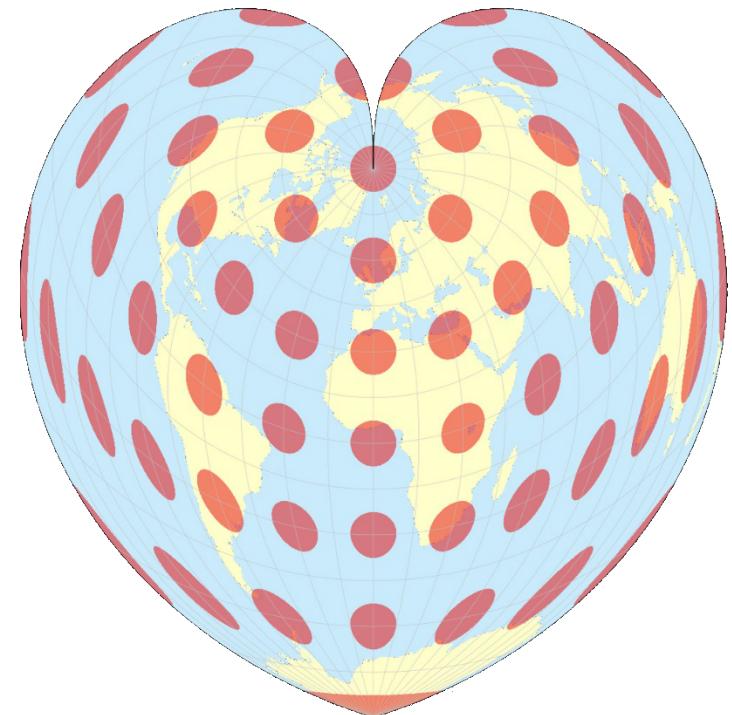
What we ideally want from a map projection:



Preserving angles:
Mercator projection

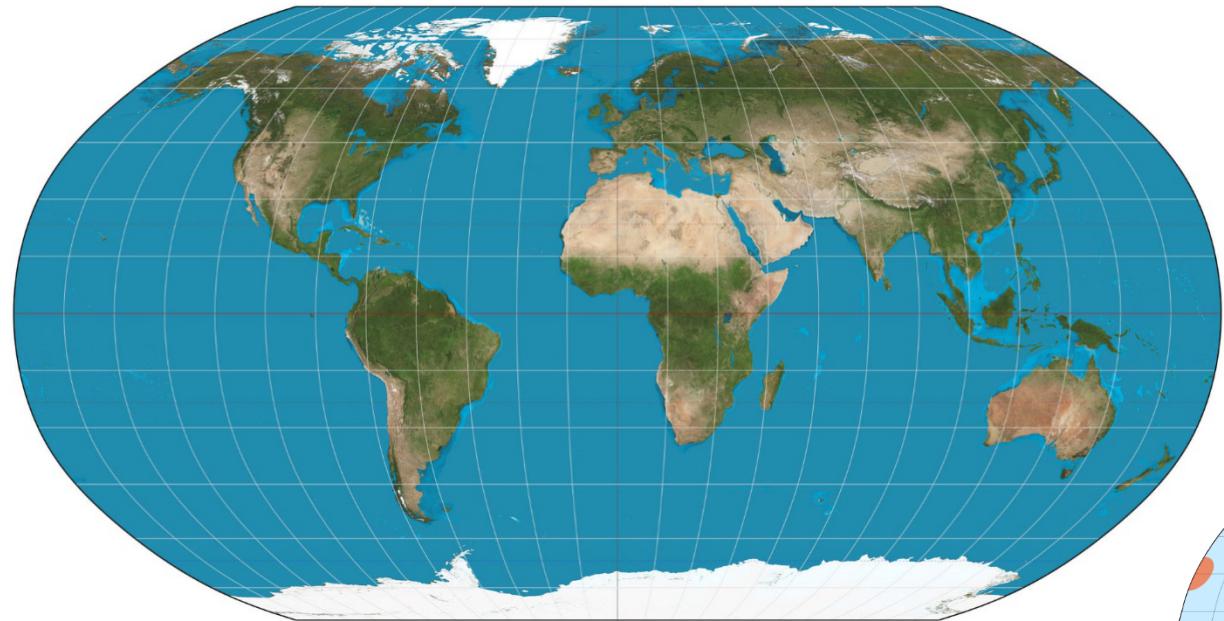


Preserving areas:
Mollweide projection



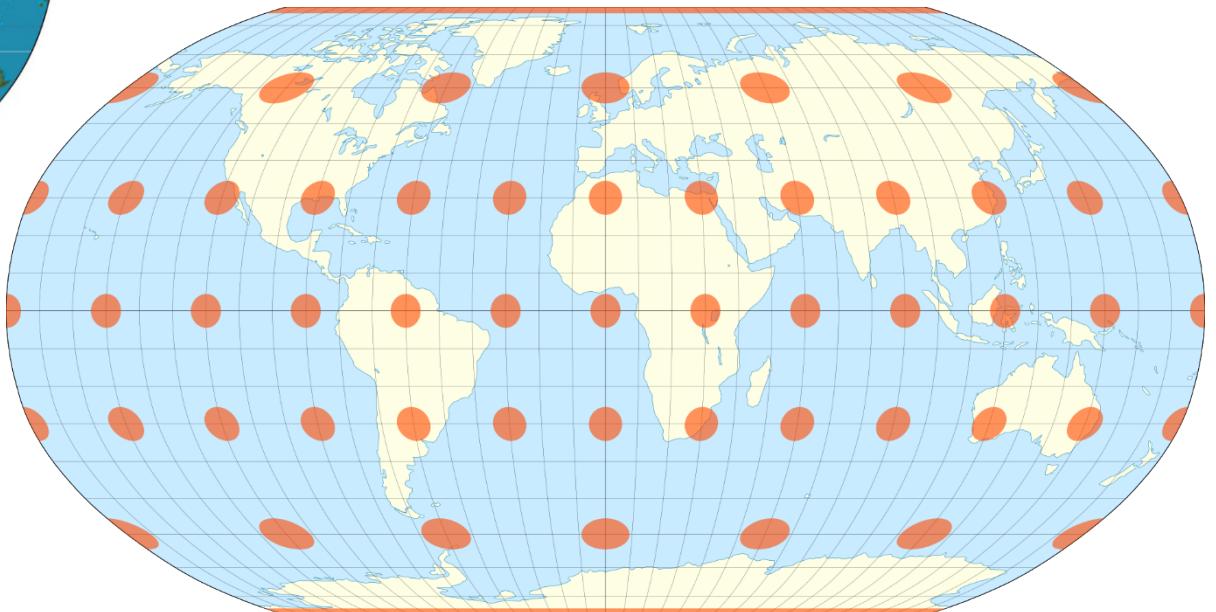
Preserving distances:
Werner projection

COMPROMISE PROJECTIONS



Robinson Projection (1963)

For more information see
<https://map-projections.net>

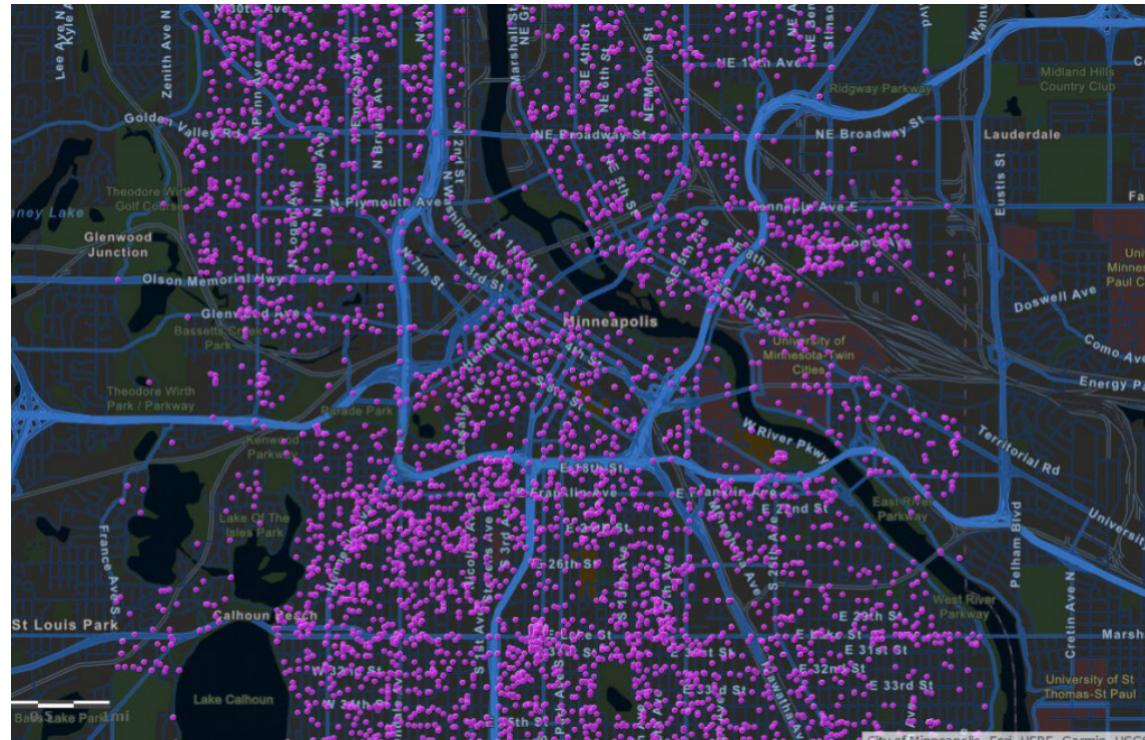


DATA ON MAPS



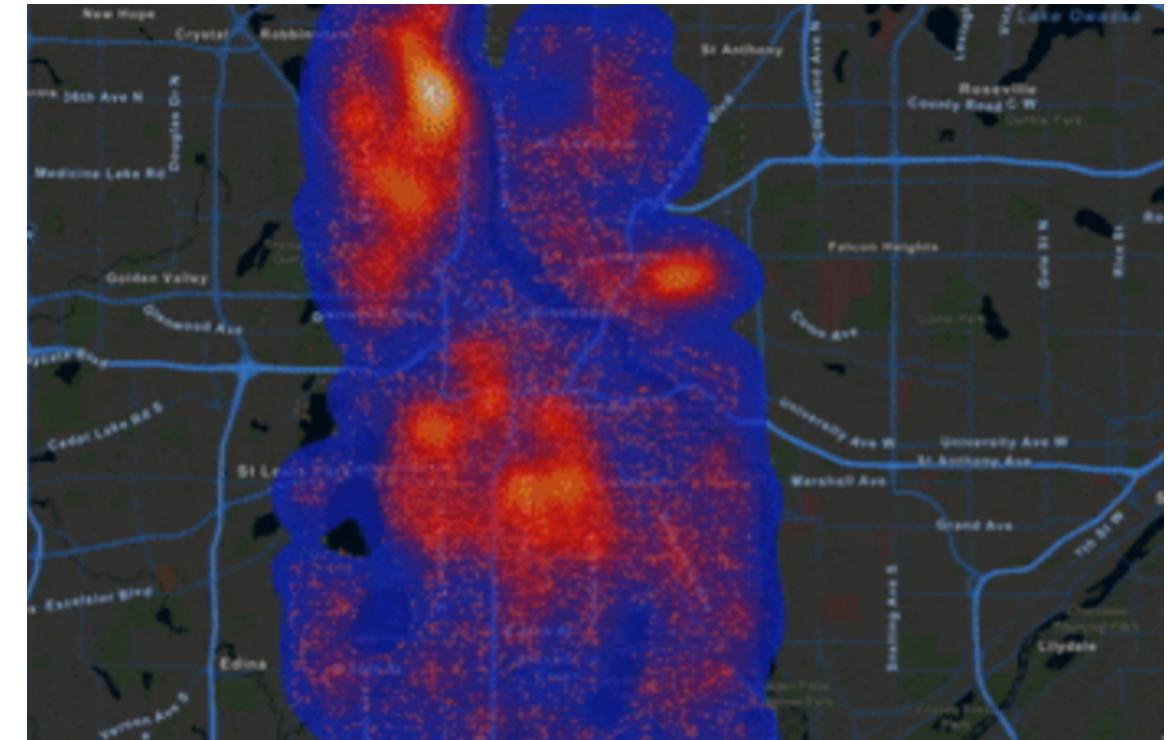
HOW TO PUT DATA ON A MAP? - POINTS

Point features for occurrences, events, instances



Dot Map

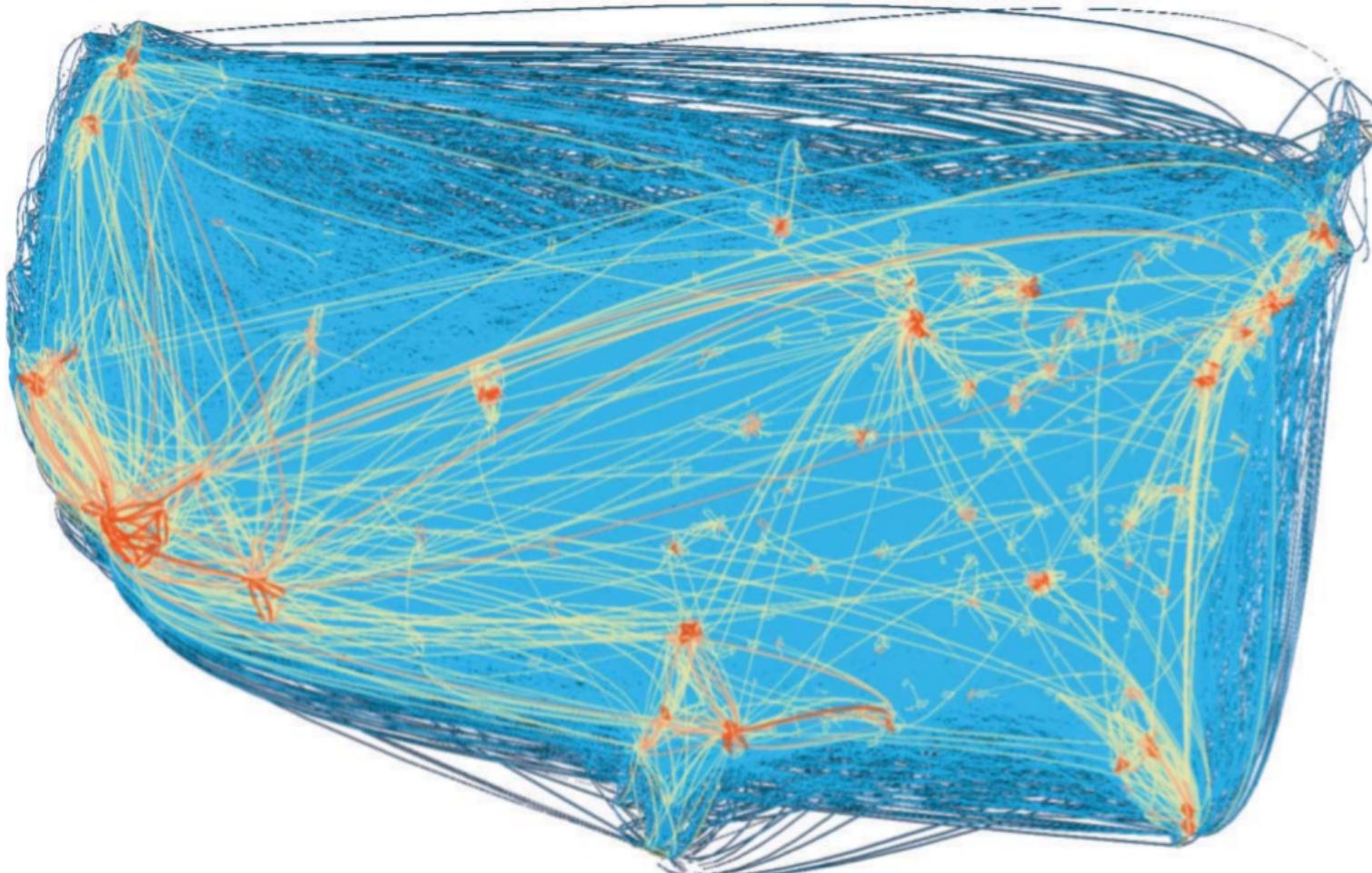
Aggregated to resolve overplotting



Heat Map

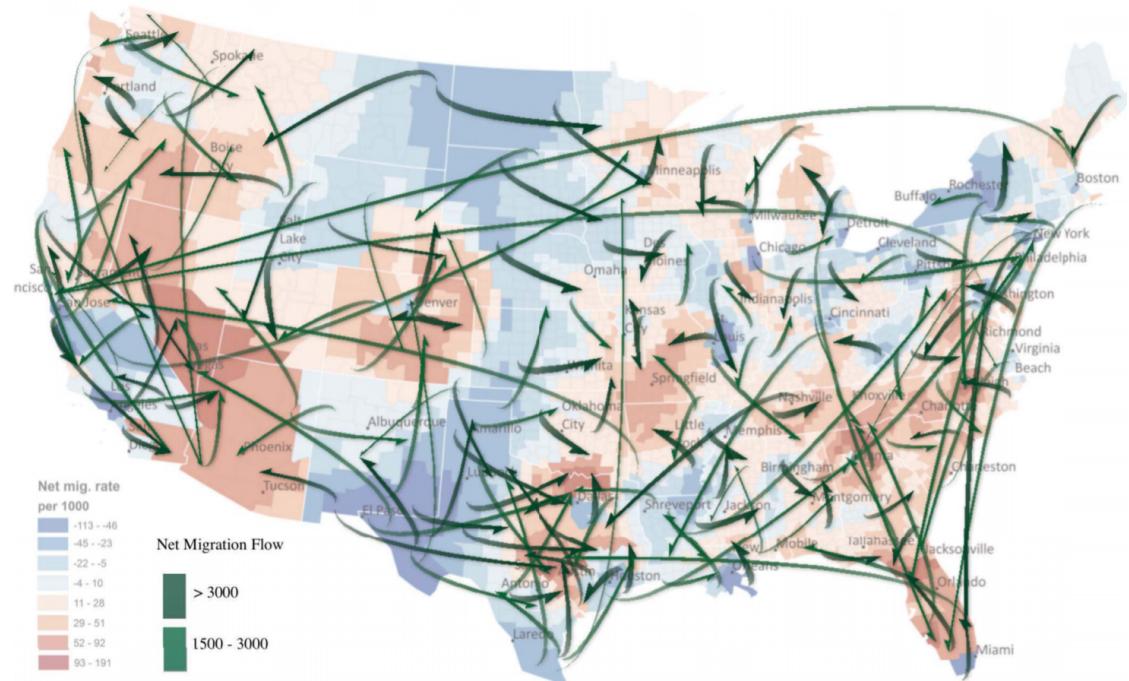


HOW TO PUT DATA ON A MAP? - LINES



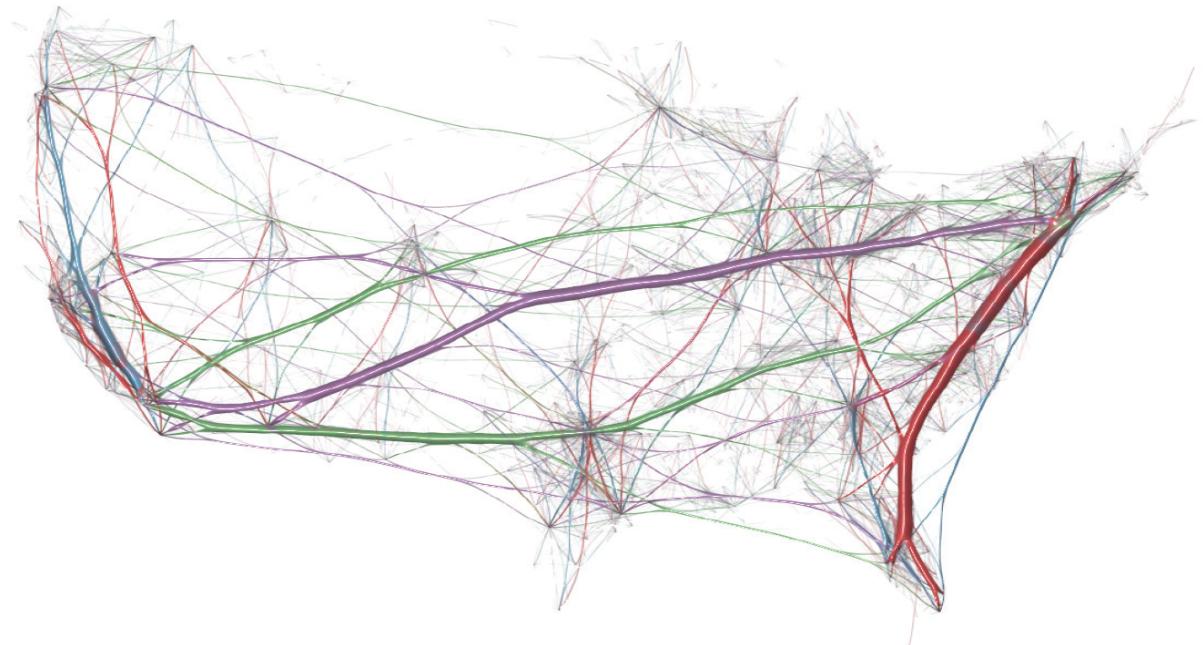
HOW TO PUT DATA ON A MAP? - LINES

Line features for flows, trajectories, connections



Flow Map

Aggregated to resolve cluttered representation

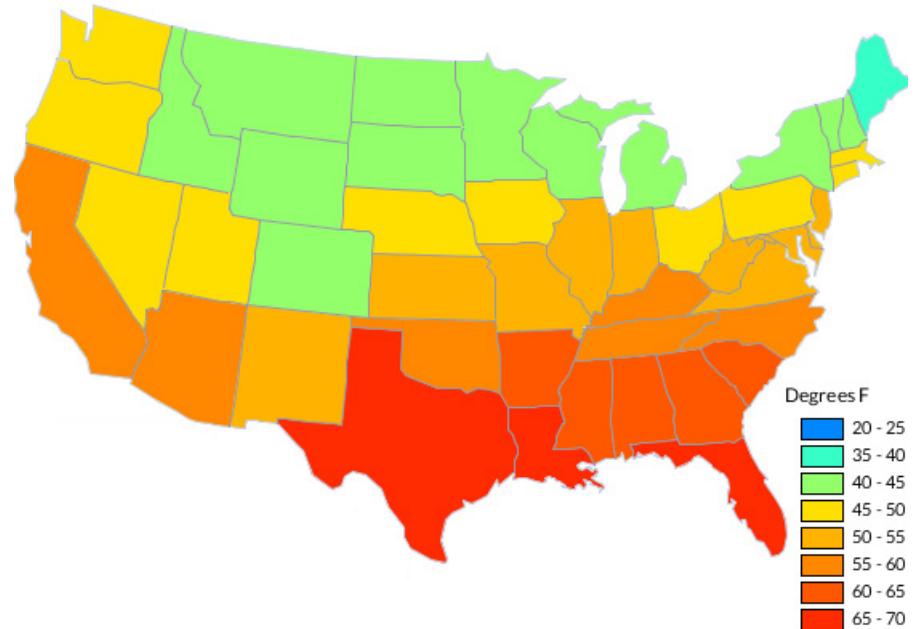


Edge-bundled Map



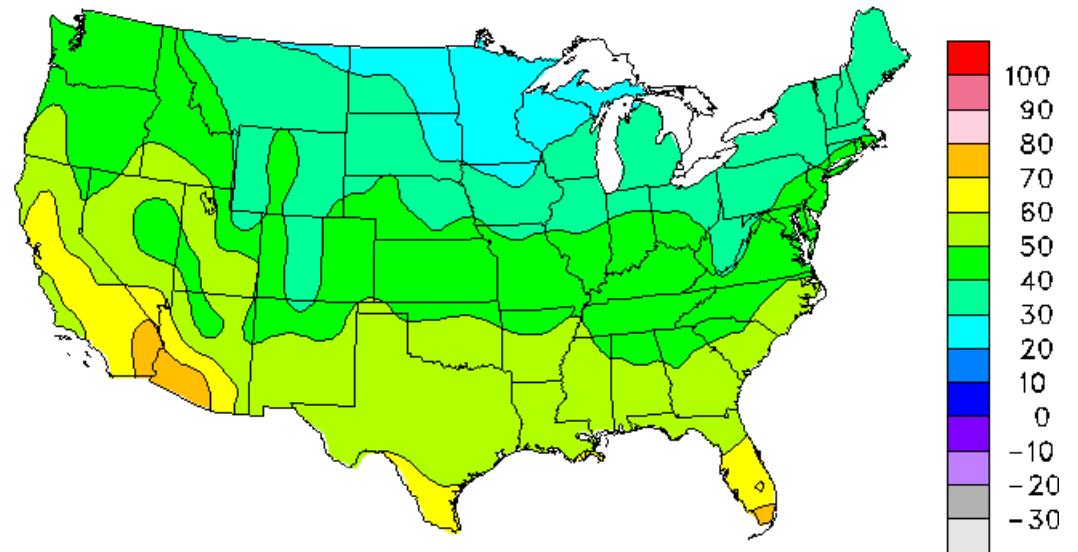
HOW TO PUT DATA ON A MAP? – AREAS

Area features defined by the data context



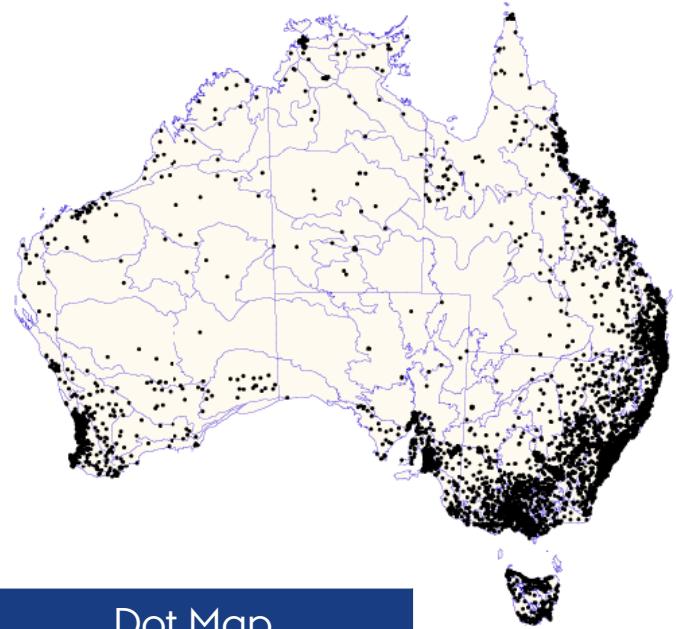
Choropleth Map

Area features defined by the data content

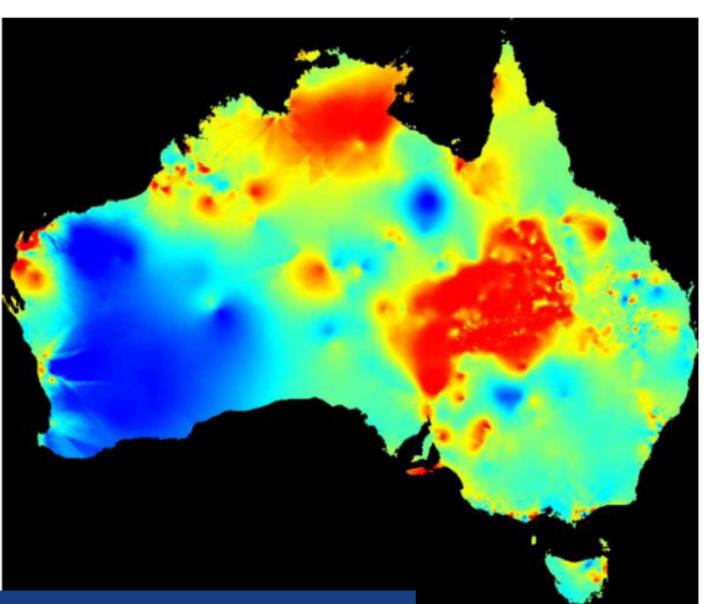


Isopleth Map

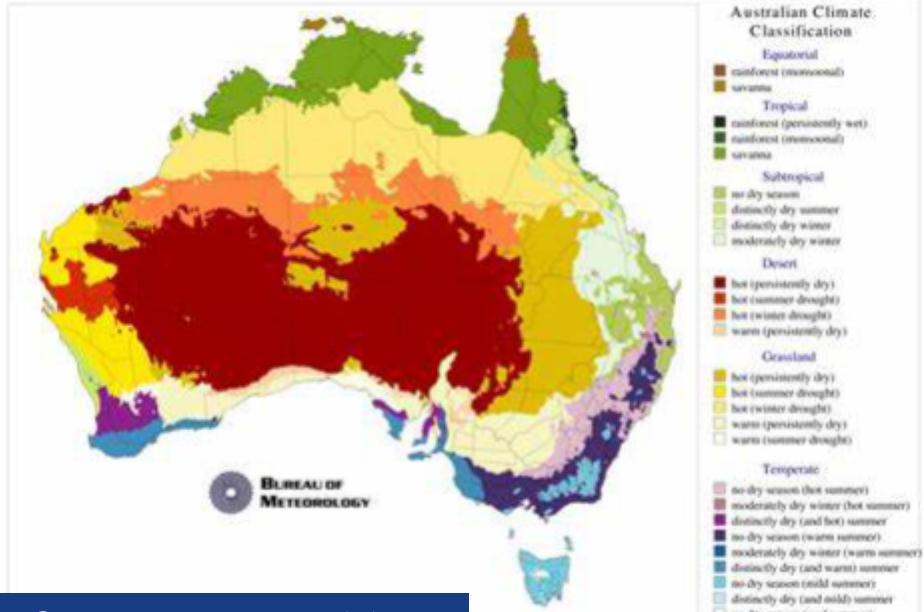




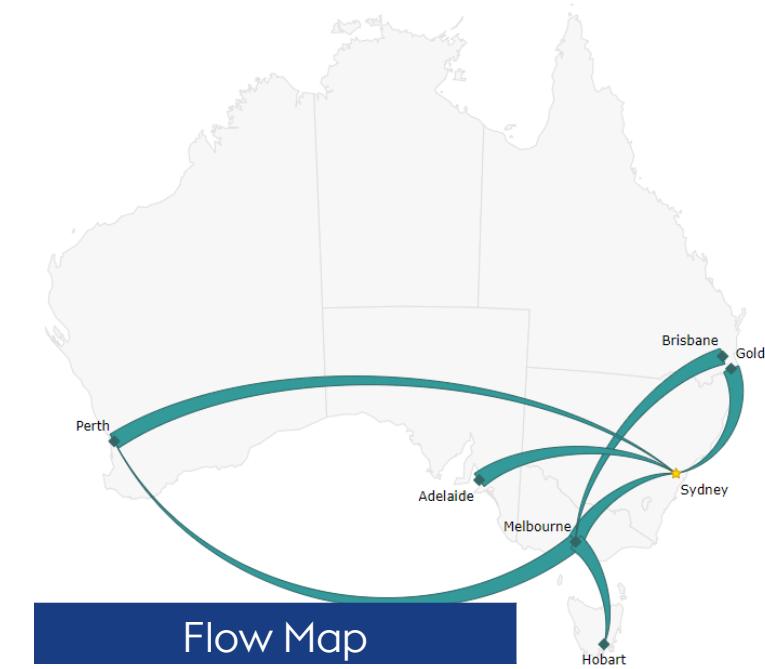
Dot Map



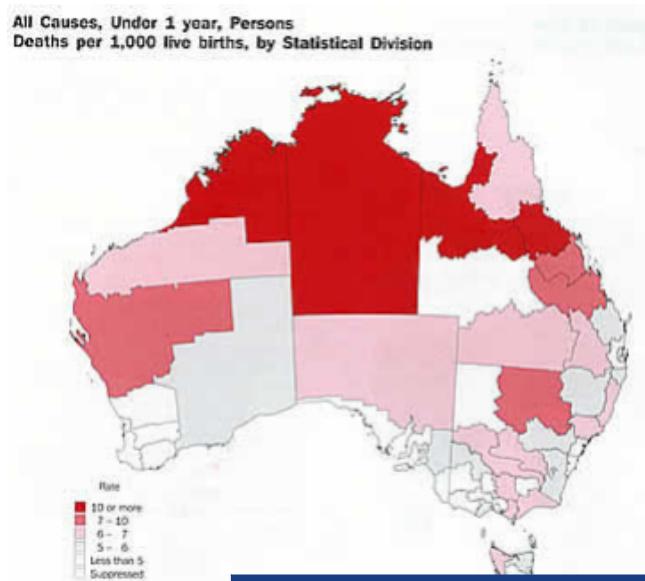
Heat Map



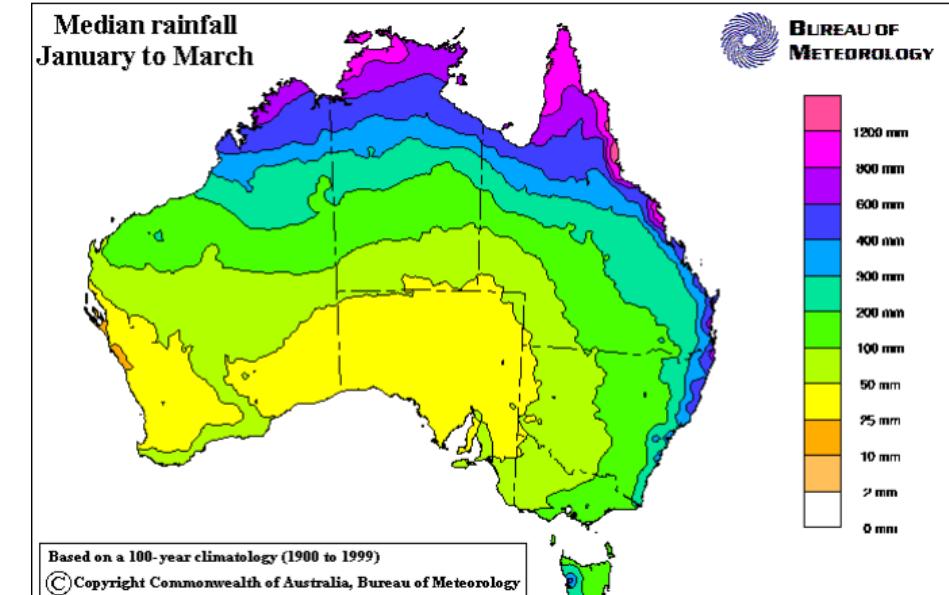
Chorochromatic Map



Flow Map



Choropleth Map



Isopleth Map

Australian Climate Classification

Equatorial	rainforest (monsoonal)
Tropical	rainforest (perennial wet)
Subtropical	no dry season
Desert	hot (perennially dry)
Grassland	hot (perennially dry)
Temperate	no dry season (hot summer)

rainforest (monsoonal)

rainforest (perennial wet)

no dry season

hot (perennially dry)

hot (summer drought)

hot (winter drought)

warm (perennially dry)

warm (summer drought)

moderately dry (warm summer)

moderately dry winter (warm summer)

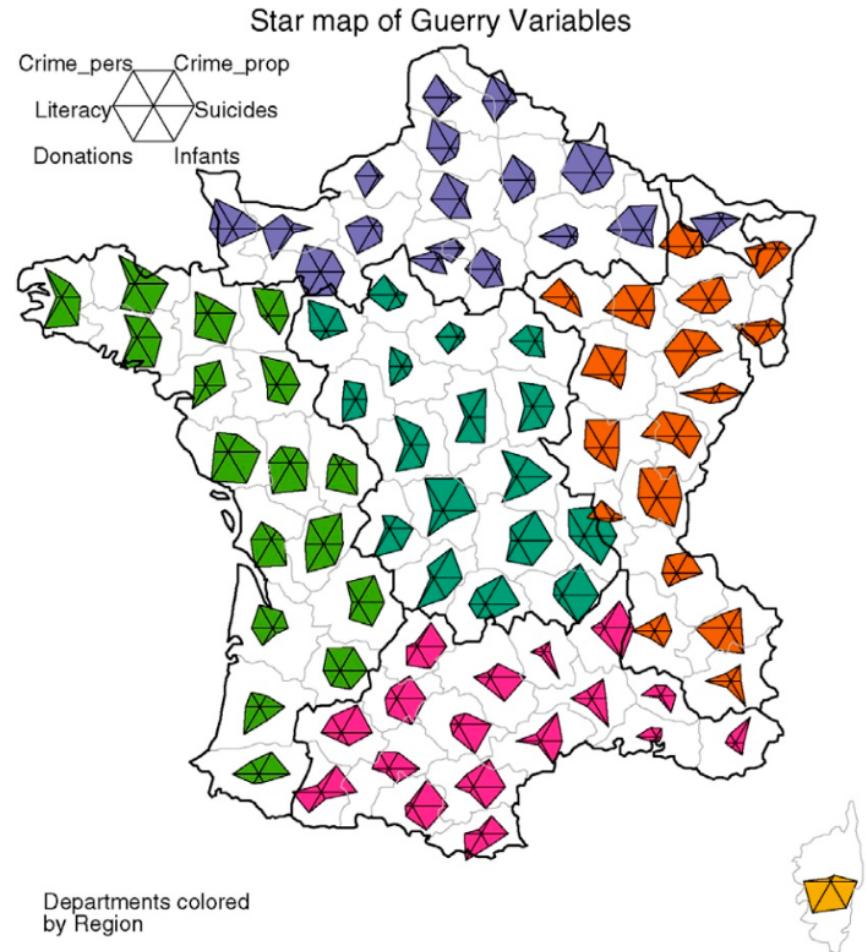
moderately dry (and warm) summer

moderately dry winter (cool summer)

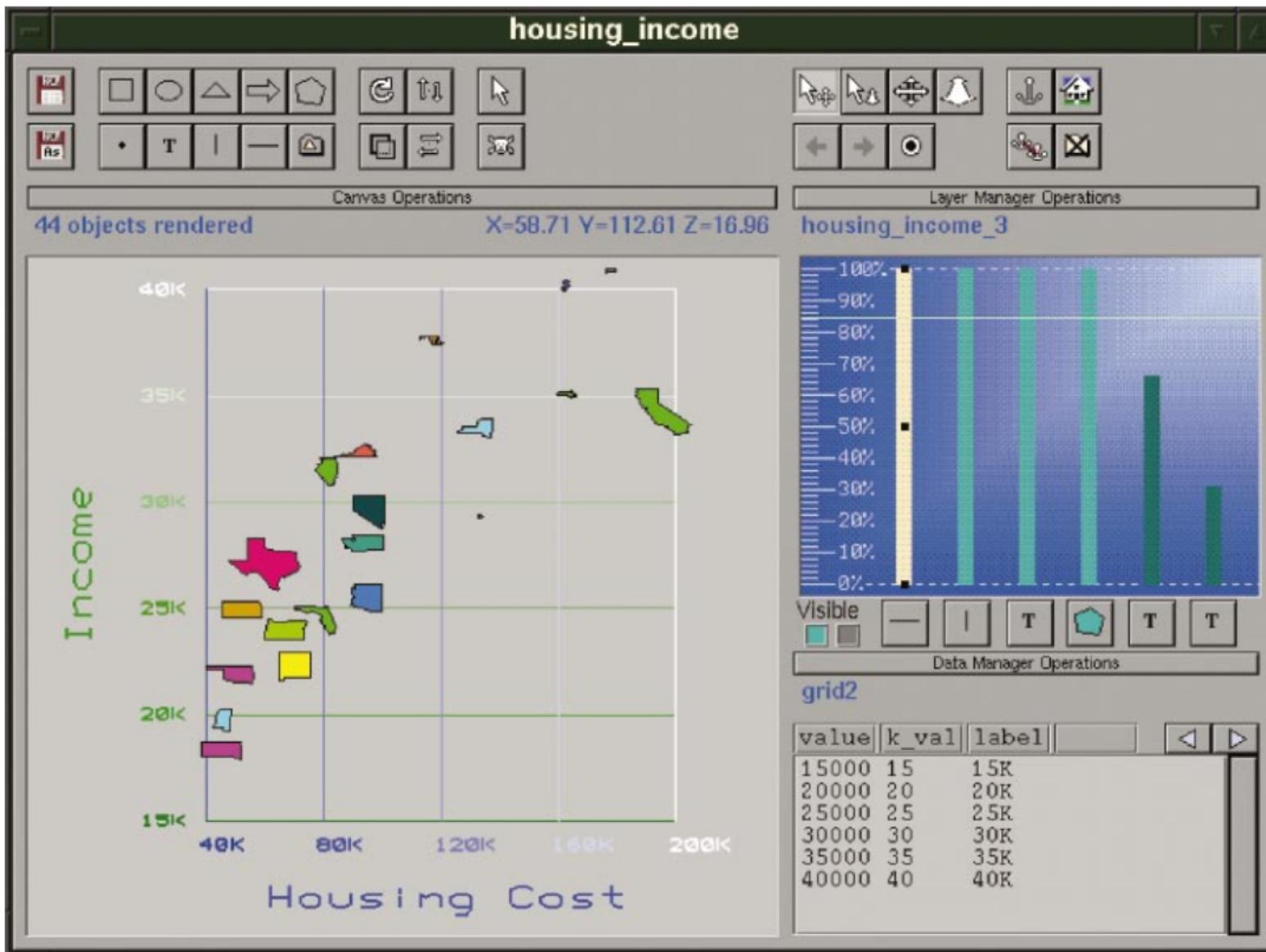
moderately dry (and cold) summer

no dry season (cool summer)

HOW TO PUT MULTIVAR. DATA ON A MAP?



PUTTING THE MAP INSIDE THE CHART



DATA AS MAPS



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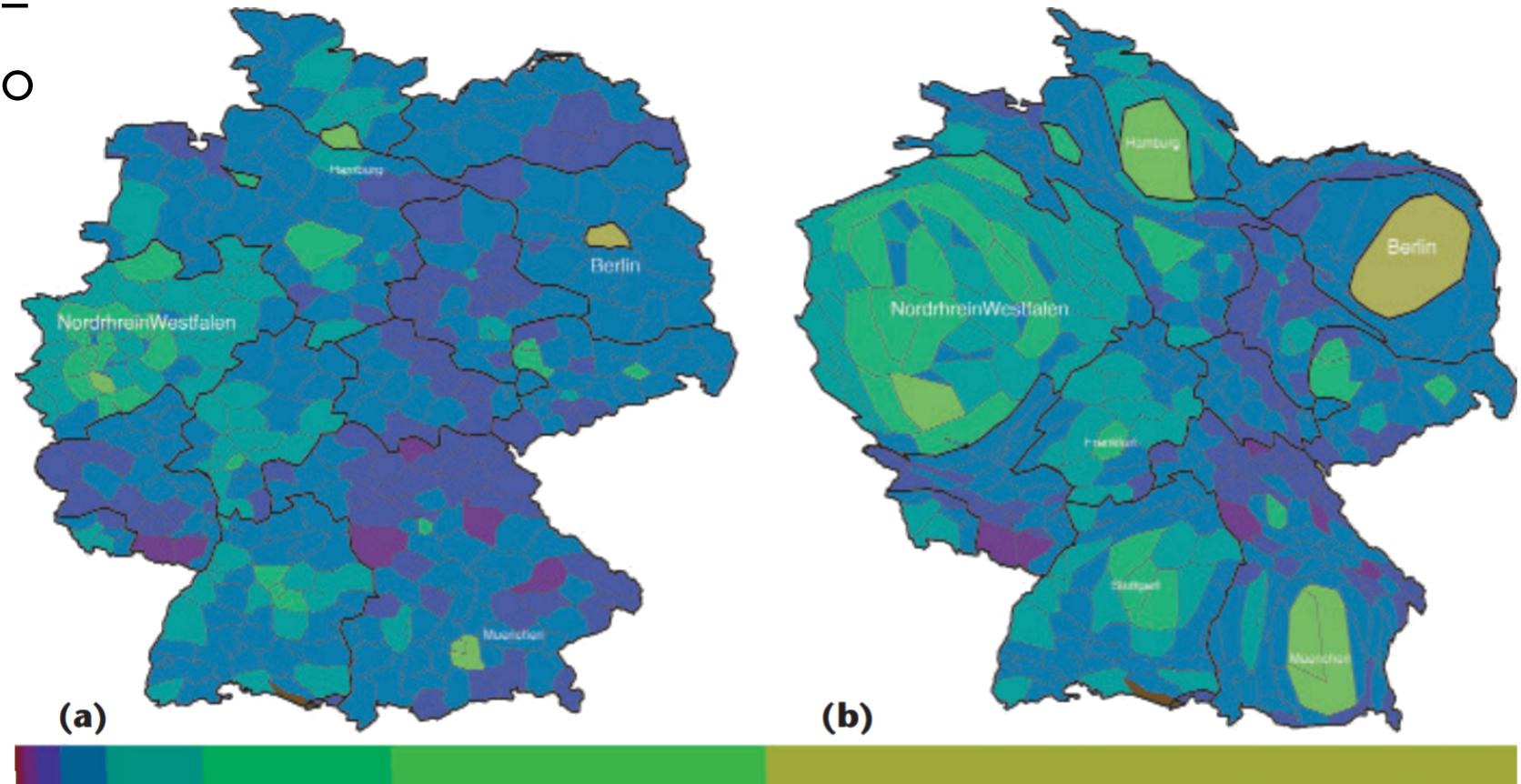


ADJUSTING THE MAP TO THE DATA

[Keim et al. 2005]

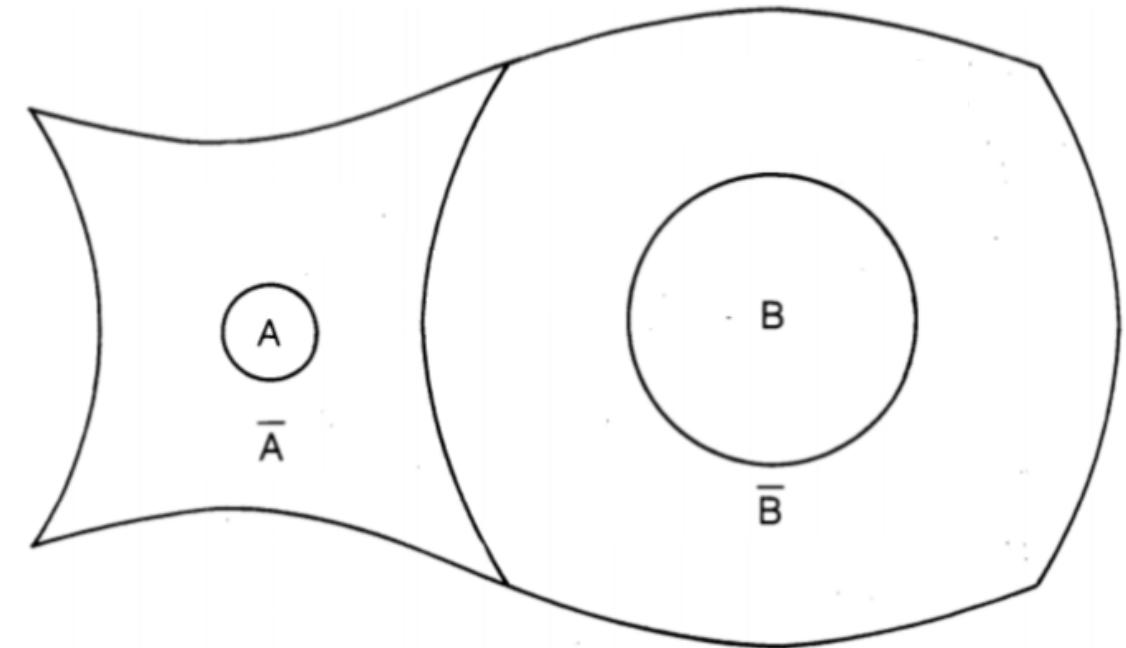
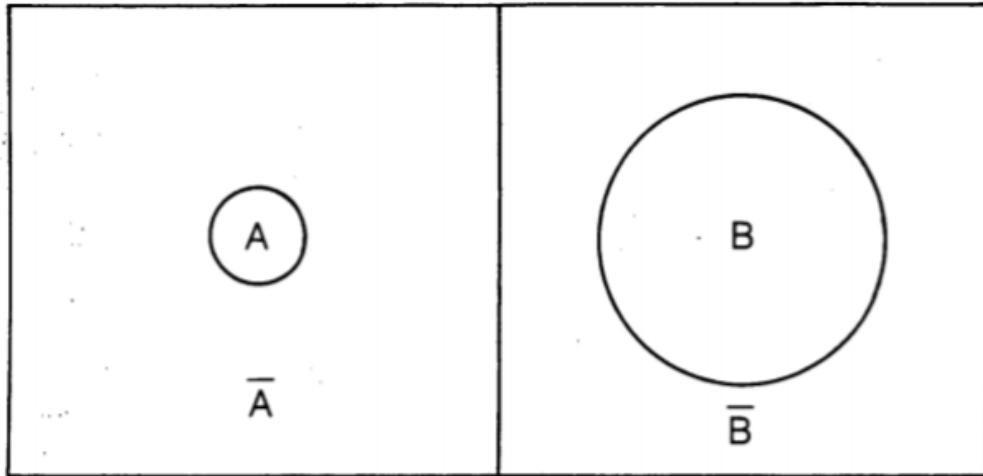
Area Cartograms :=

distort map areas to
match a given
numerical data
attribute – e.g.,
population



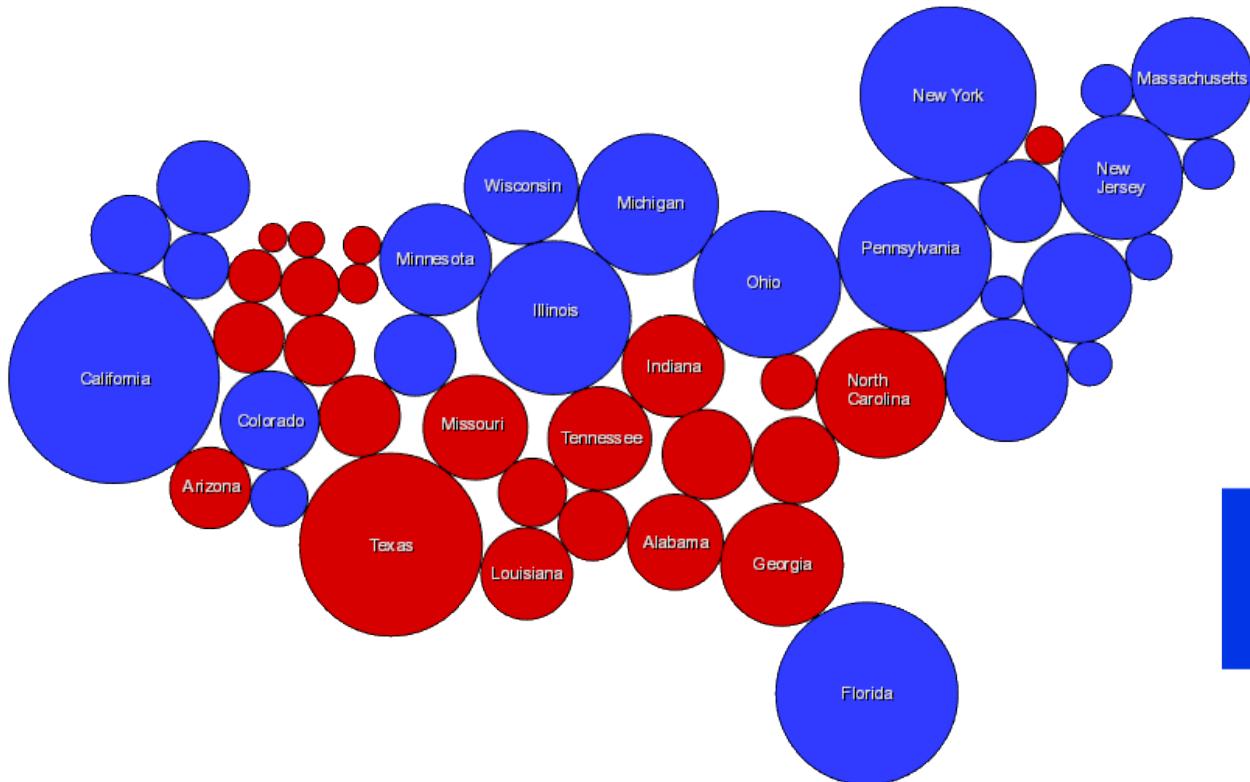
ADJUSTING THE MAP TO THE DATA

Creating Area Cartograms

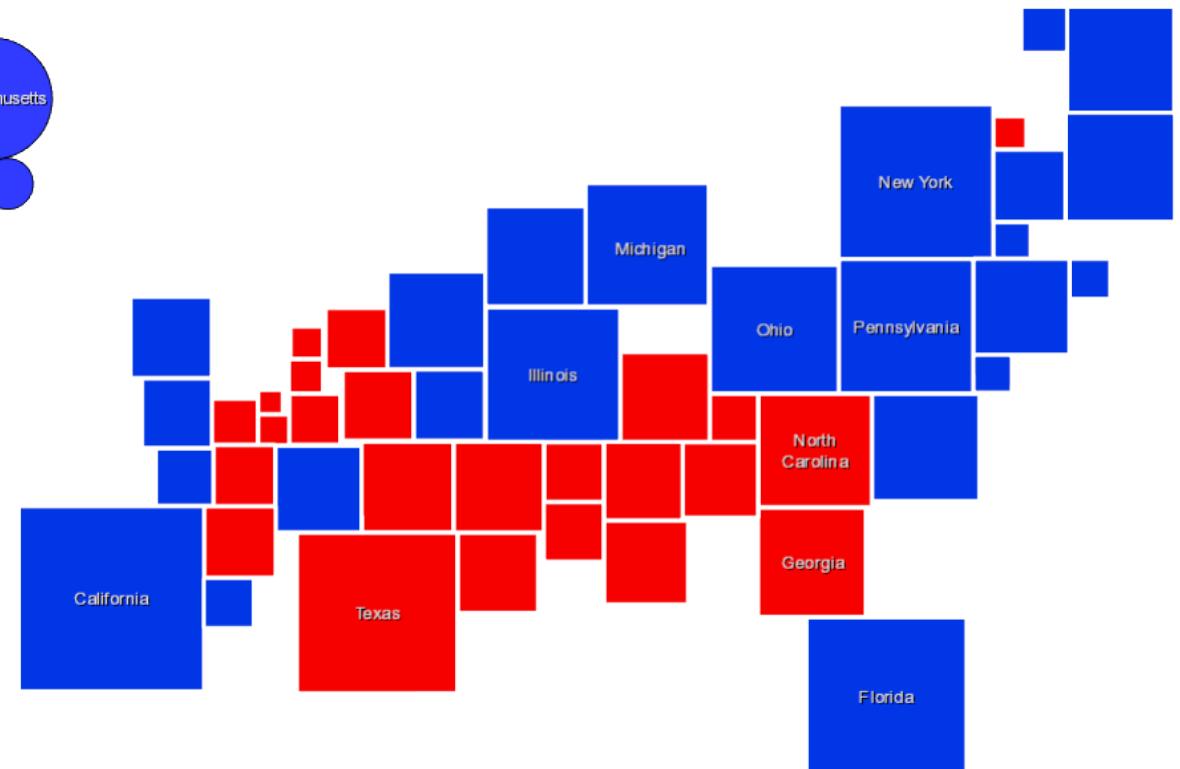


ADJUSTING THE MAP TO THE DATA

Dorling Cartogram



Demers Cartogram



ADJUSTING THE MAP TO THE DATA

The RecMap Algorithm

cost function $F(pos) = a^*A(pos) + e^*E(pos) + s^*S(pos) + t^*T(pos) + r^*R(pos)$

function $A(pos)$: quantification of the discrepancies of the area

function $E(pos)$: quantification of the unused drawing space

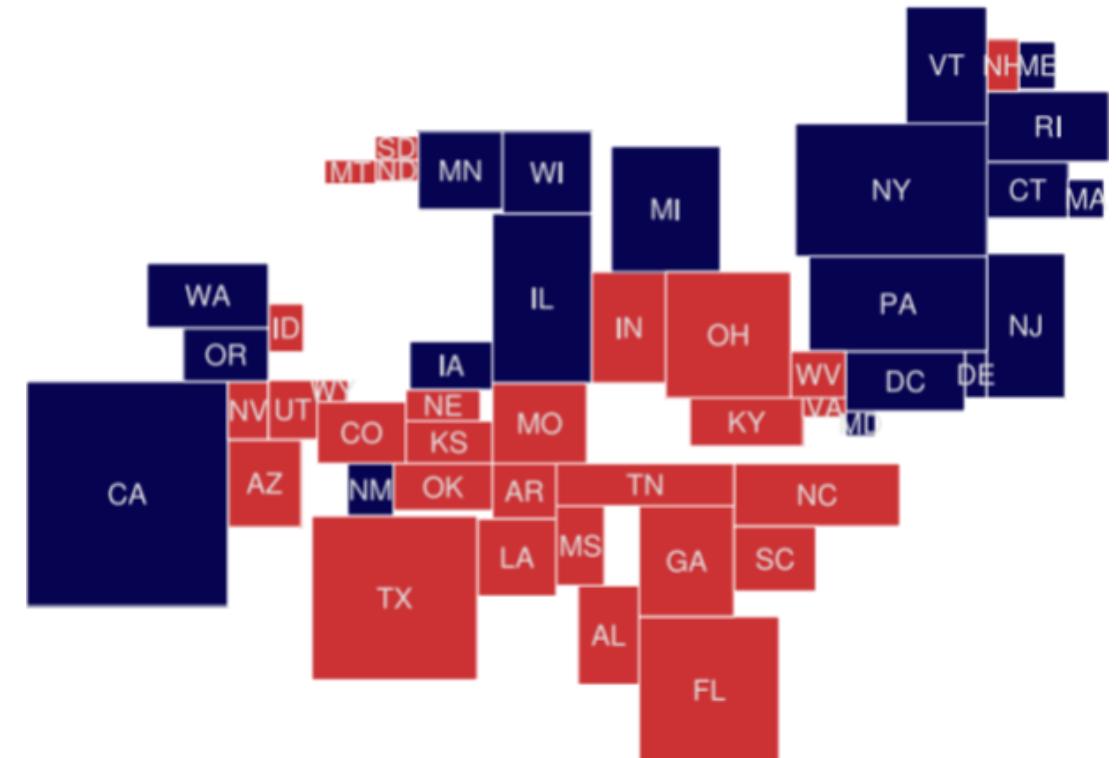
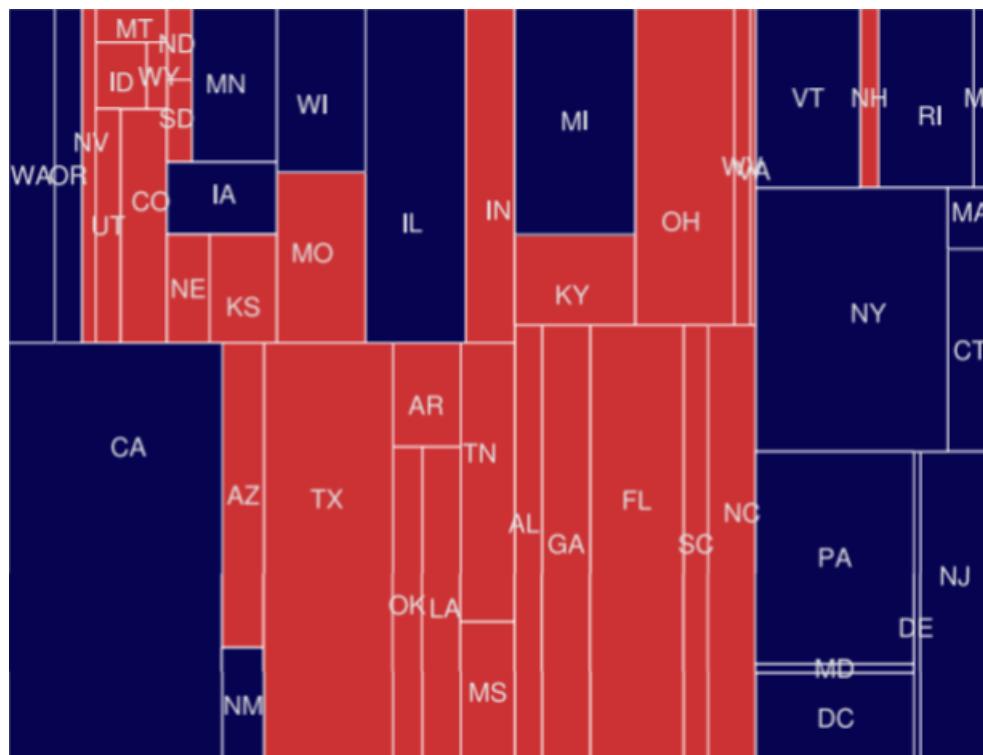
function $S(pos)$: quantification of the discrepancies of the form

function $T(pos)$: quantification of topology violations

function $R(pos)$: quantification of the displacement

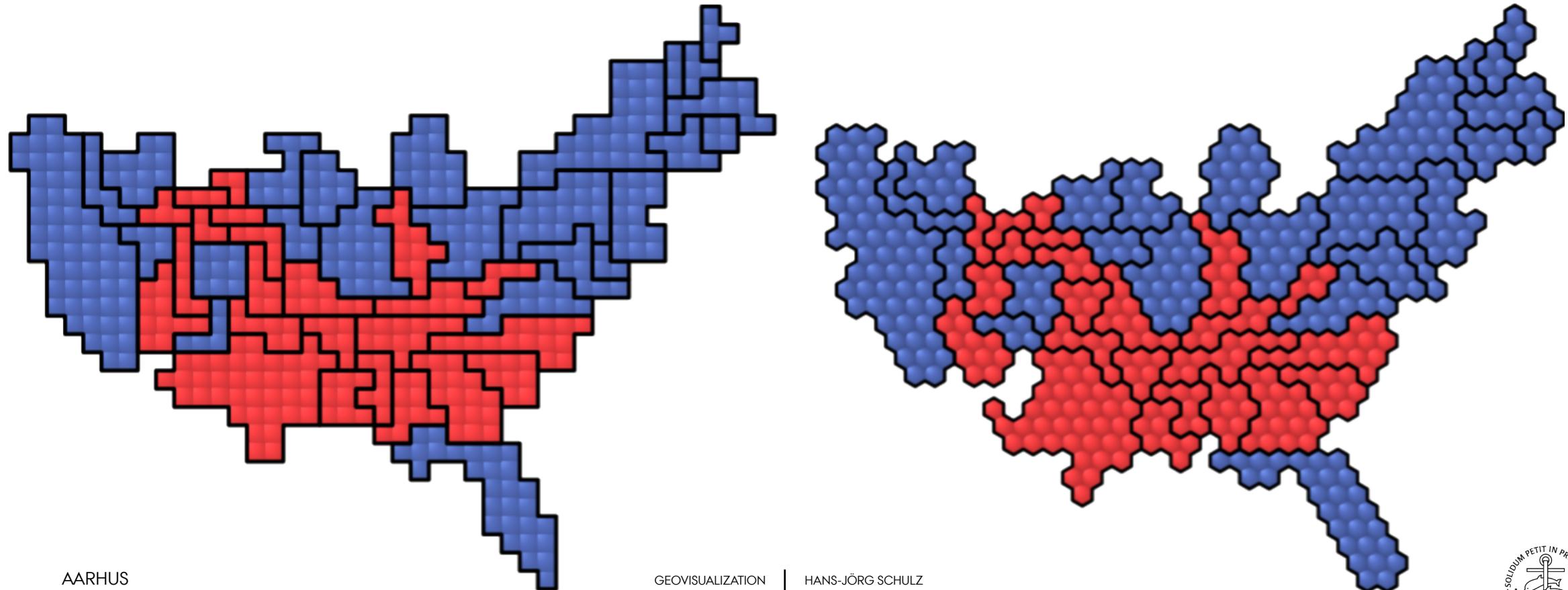
ADJUSTING THE MAP TO THE DATA

The RecMap Algorithm



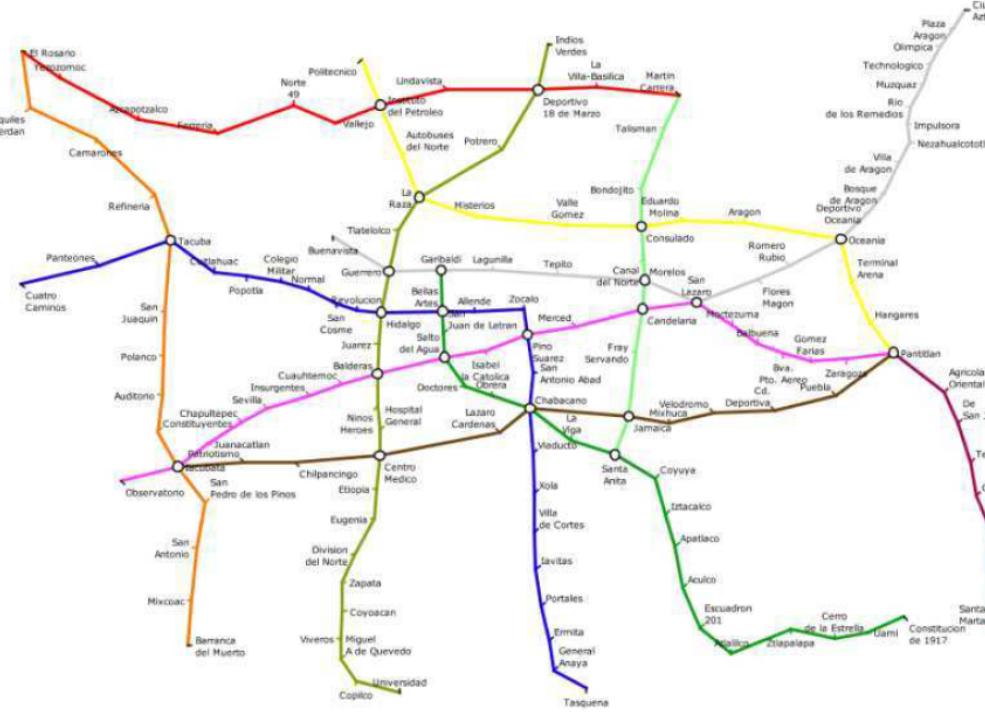
ADJUSTING THE MAP TO THE DATA

Gridded / Mosaic Cartograms := use multiples of simple tiles to represent regions for communicating data that consist of small integer units

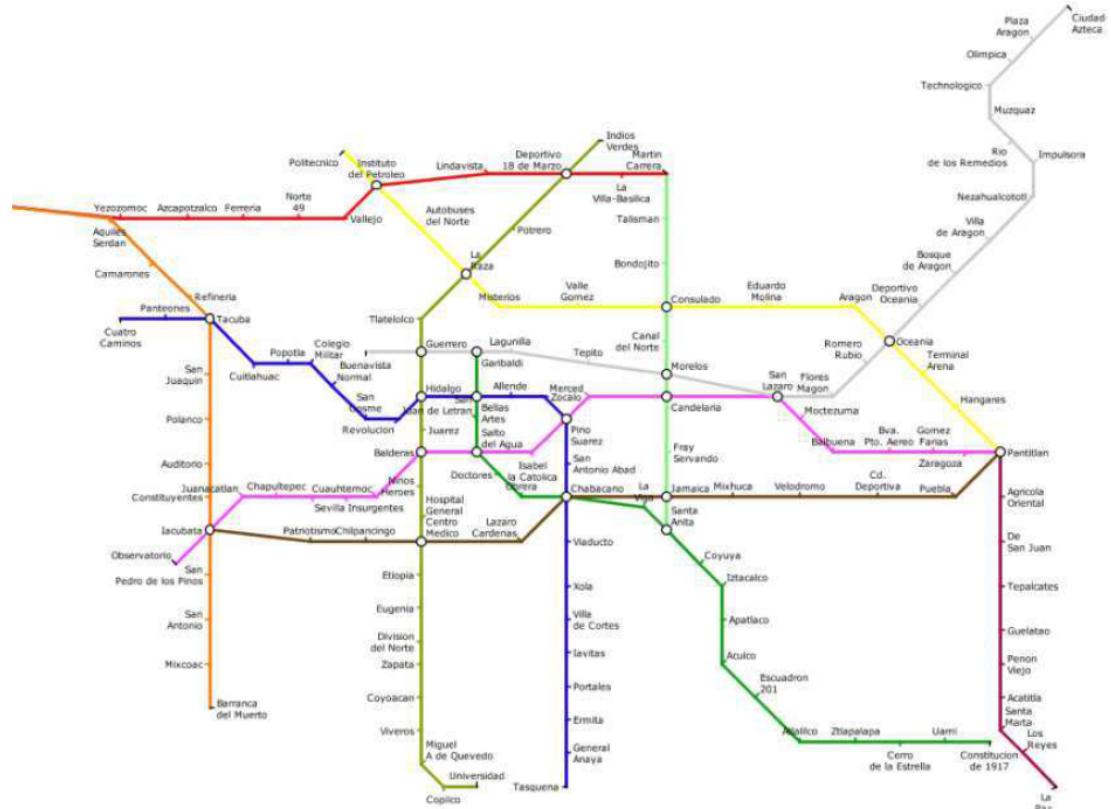


ADJUSTING THE MAP TO THE TASK

Metromap Layout

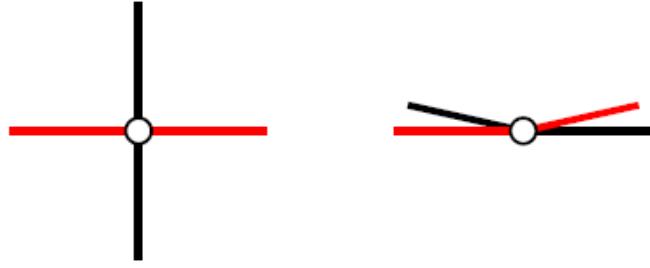


Geographically correct Public Transport Map Mexico City

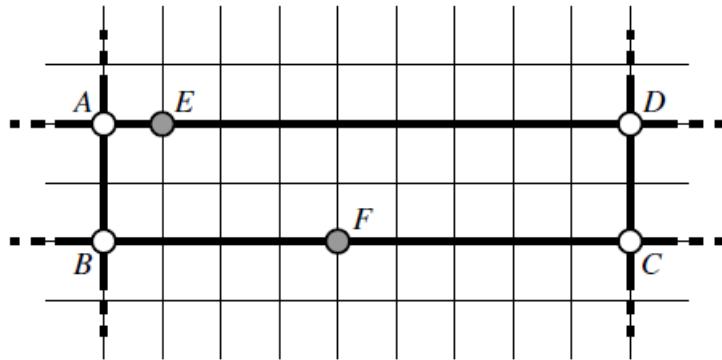


Metromap Layout of Public Transport Map Mexico City

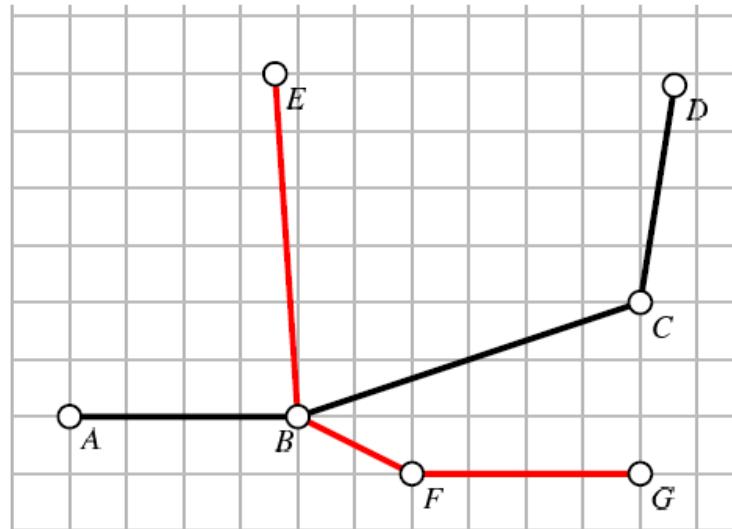
REPRESENTATIONAL CONSIDERATIONS



Angular Resolution



Balanced Edge Lengths



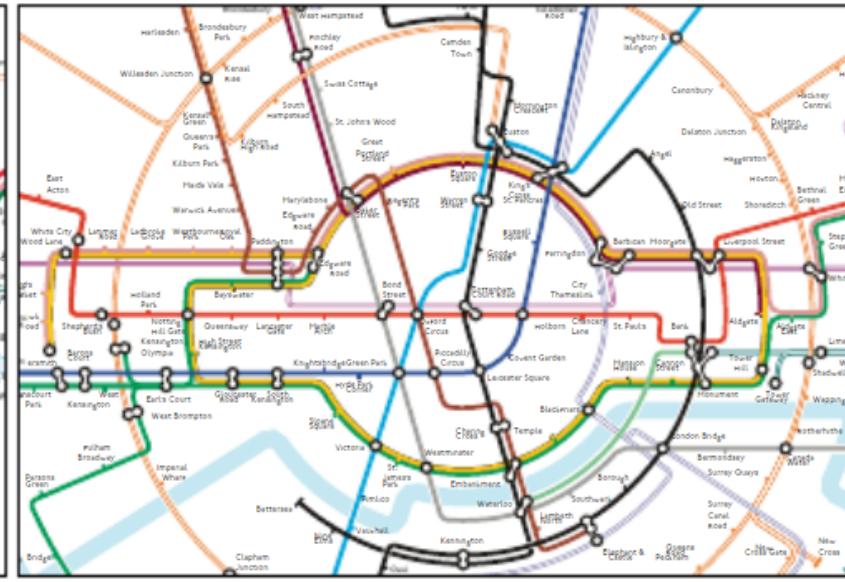
Octilinearity



(a) Spatially representative (Curvilinear)



(b) Schematised Curvilinear



(c) Concentric circles



(d) Multilinear

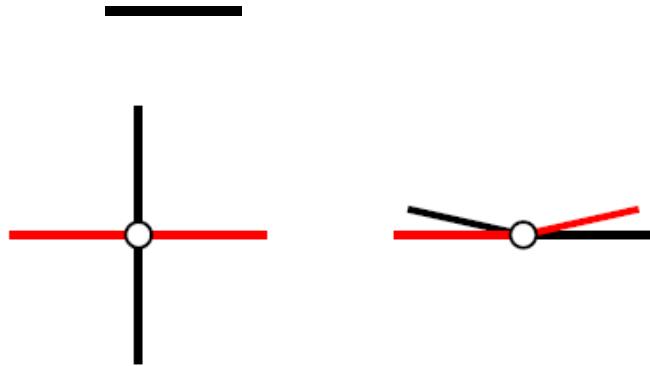


(e) Octolinear (Octilinear)

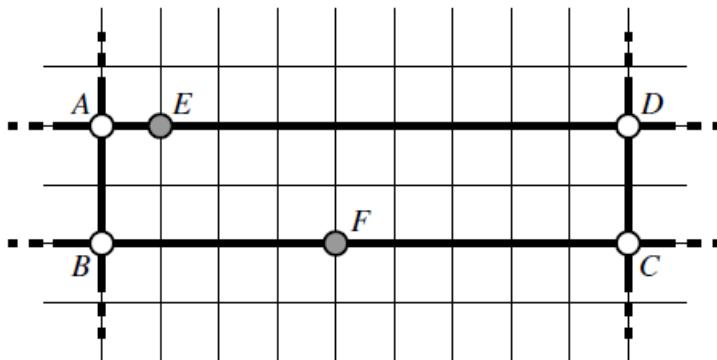


(f) Hexalinear

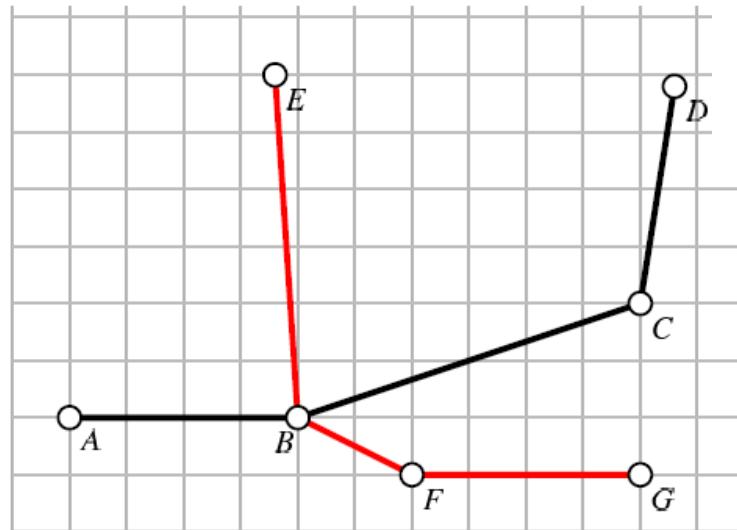
REPRESENTATIONAL CONSIDERATIONS



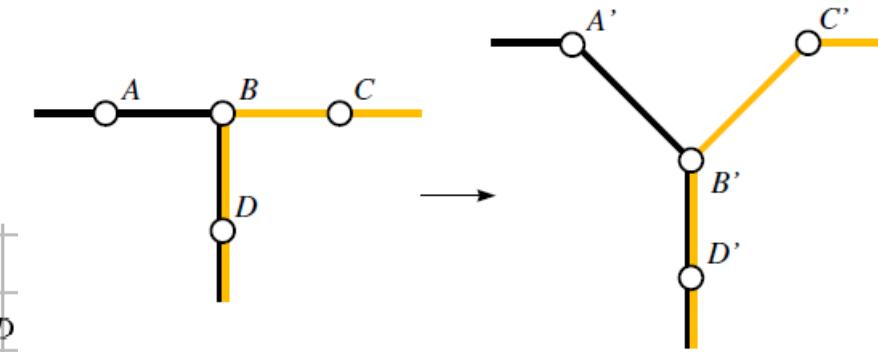
Angular Resolution



Balanced Edge Lengths



Octilinearity



Line Straightness



Label Consistency

MAP SCHEMATIZATION USING ARCS



(a) Input, 238 arcs



(b) 100 arcs



(c) 50 arcs



(d) 35 arcs



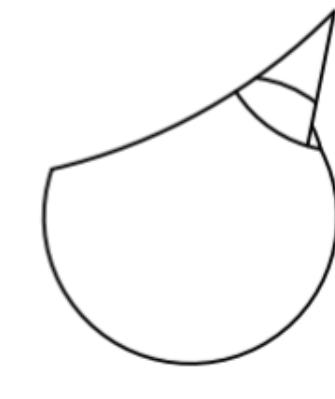
(e) 25 arcs



(f) 18 arcs



(g) 12 arcs



(h) 6 arcs

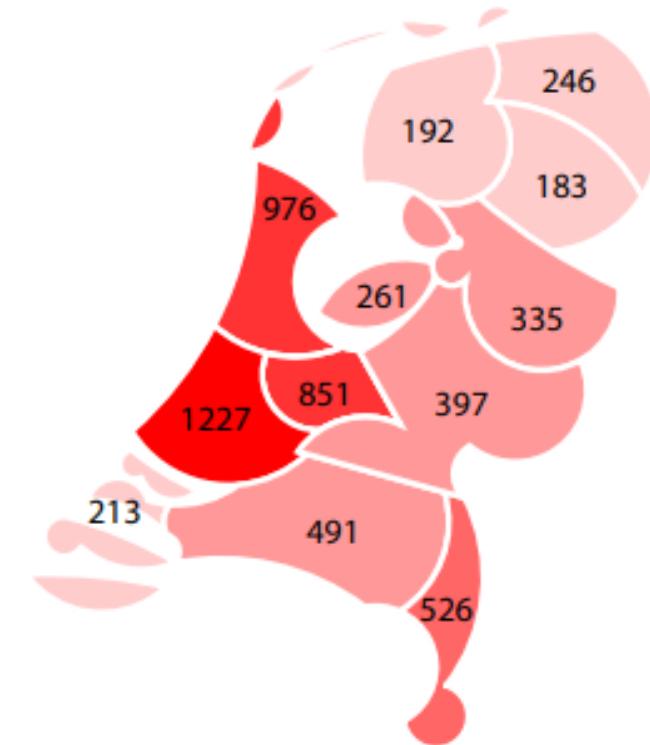
MAP SCHEMATIZATION USING ARCS



(a) Geographic map



(b) 54 circular arcs



(c) Population density



SPATIO-TEMPORAL VISUALIZATION



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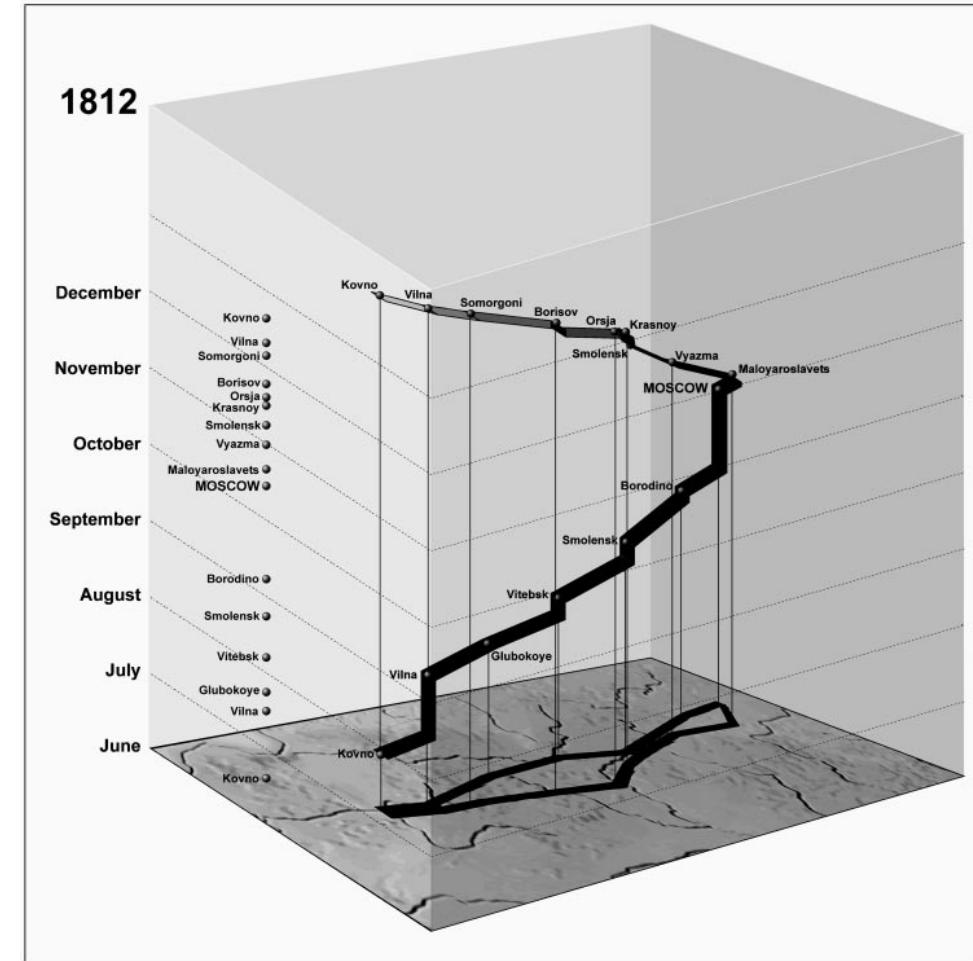
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THE SPACE-TIME CUBE

X/Y-plane: geospace

Z-axis: time

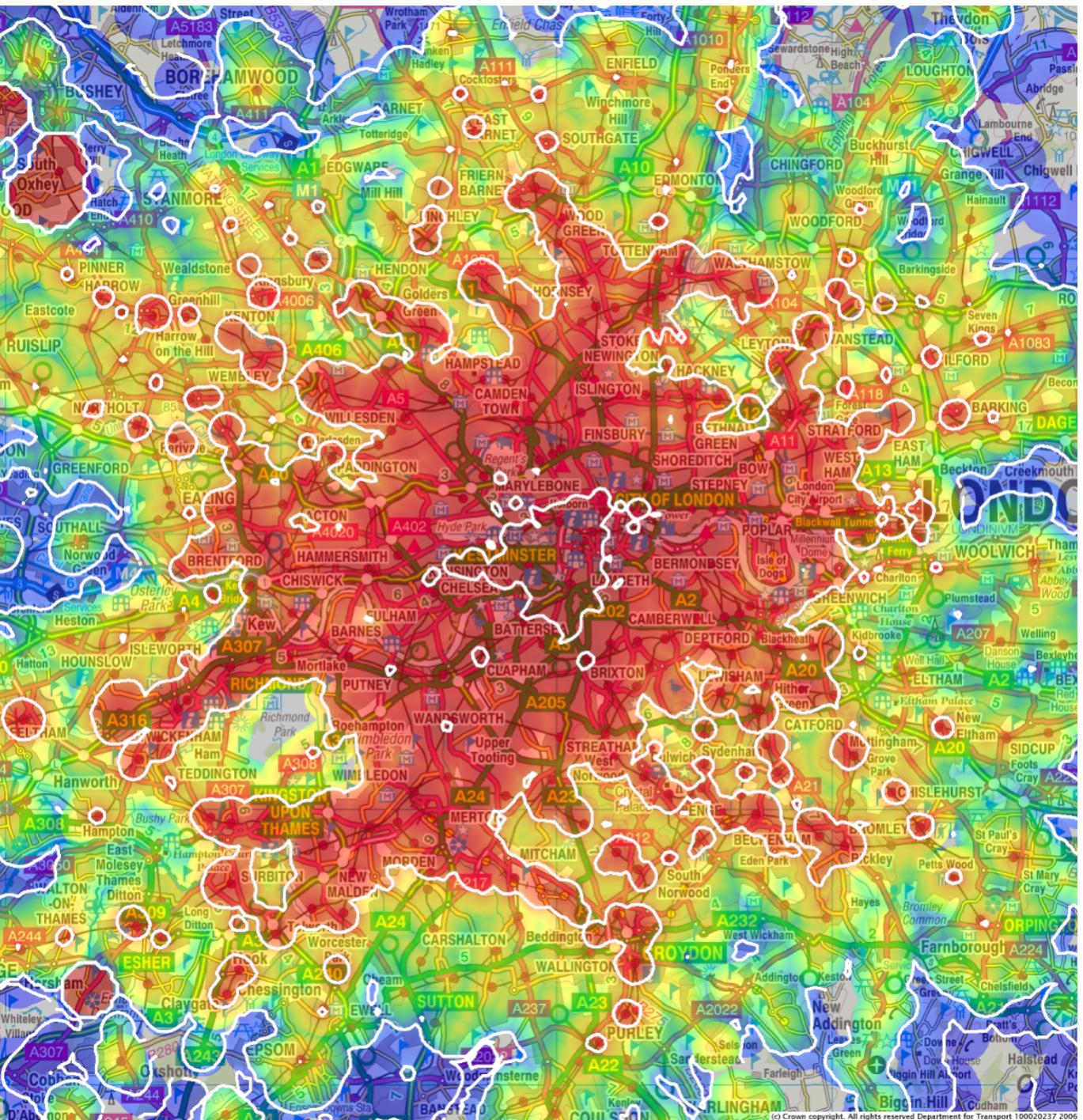


TRAVEL TIME MAP

Color encodes commute times
with public transportation

Red = location can be
reached quickly

Blue = location cannot be
reached quickly



BEYOND GEOSPACE

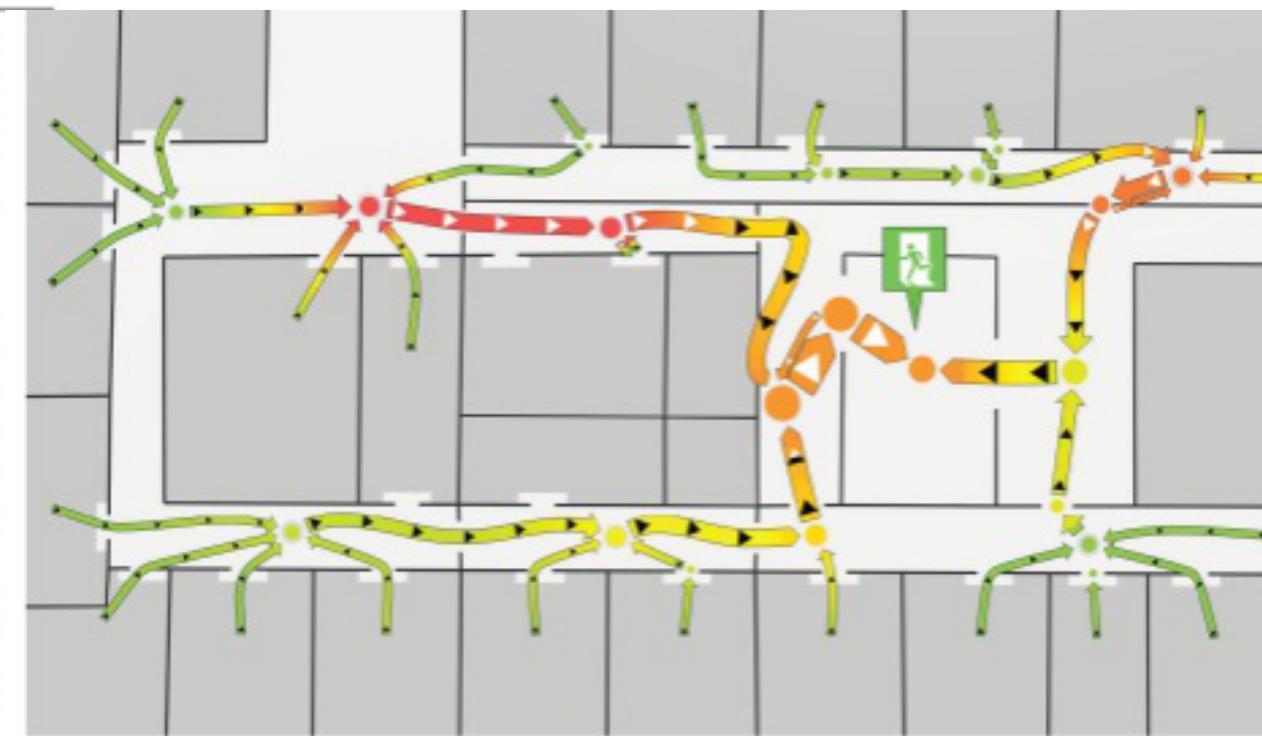
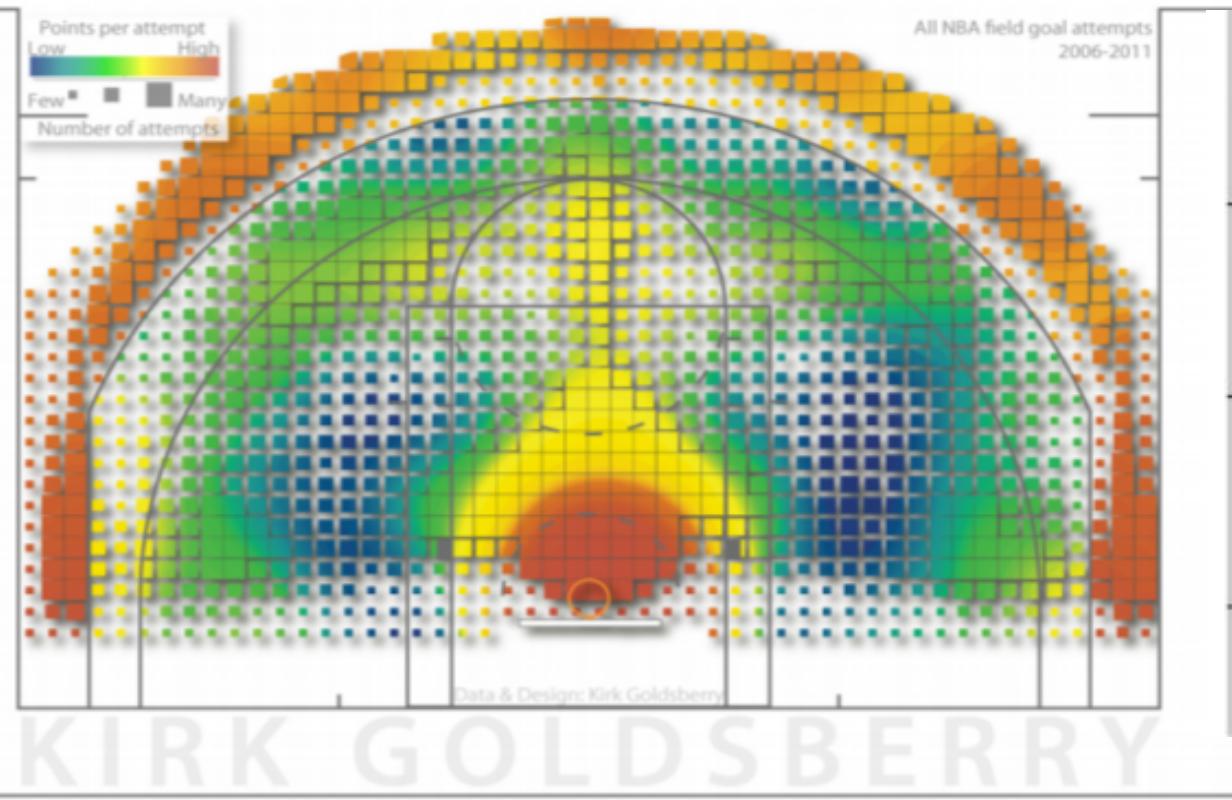


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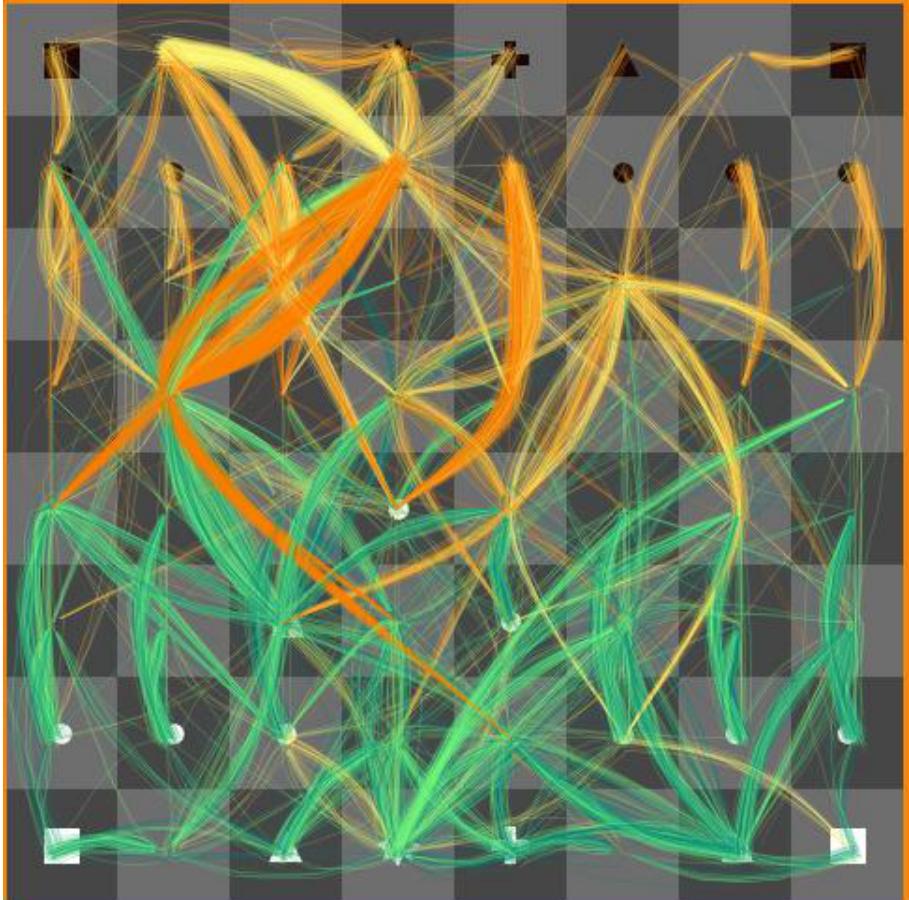
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GEOSPATIAL VISUALIZATIONS



GEOSPATIAL VISUALIZATIONS



LIST OF LITERATURE SOURCES

- Spatial Statistics: <https://doi.org/10.1201/b18808>
-> newer edition: <https://doi.org/10.1201/9781003021643>
- Flow Maps: <https://doi.org/10.1109/TVCG.2014.2346271>
- Edge Bundling: <https://doi.org/10.1111/cgf.13213>
- Thematic Map Types: <https://doi.org/10.22224/gistbok/2021.2.7>
- Cartograms: <https://doi.org/10.22224/gistbok/2017.3.8>
- Cartograms: <https://doi.org/10.1111/cgf.12932>
- Keim et al. 2005: <https://doi.org/10.1109/MCG.2005.64>
- Recmaps: <https://doi.org/10.1109/INFVIS.2004.57>
- Mosaic Cartograms: <https://doi.org/10.1111/cgf.12648>
- Metromap Considerations: <https://doi.org/10.1109/TVCG.2010.24>
- Map schematization using arcs: https://doi.org/10.1007/978-3-319-11593-1_1
- Space-Time Cubes: <https://doi.org/10.1111/cgf.12804>
- Isochrone Mapping: <https://doi.org/10.1080/02697459.2017.1329487>

