

Geographic Data Science - Lecture III

(Geo-)Visualization

Dani Arribas-Bel

Today

- Visualization
 - *What* and *why*
 - History
 - Examples
- Geovisualization
 - *What*
 - "A map for everyone"
 - Dangers of geovisualization

Visualization

"Data graphics visually display measured quantities by means of the combined use of points, lines, a coordinate system, numbers, symbols, words, shading, and color."

The Visual Display of Quantitative Information. Edward R. Tufte.

121 84 93 90 87 76 84 86 82 100 89 84 73 64 79 72 55 66 68 62 63 72 74 67 65 67 64 68 75 72 67 74 74 80 73 77 90 73
107 116 120 72 62 97 101 68 88 101 86 81 77 66 77 78 59 63 64 61 58 58 58 59 61 66 70 73 76 69 67 78 66 83 82 81 86
86 80 93 99 85 86 79 87 90 100 84 82 84 71 72 79 63 61 63 65 59 52 53 59 54 62 69 74 70 58 56 72 54 60 53 54 69 71 81
86 99 112 113 89 95 76 79 90 95 85 85 92 76 67 78 63 65 67 68 62 58 62 68 61 70 76 78 74 58 55 69 72 74 64 60 76 87
87 107 110 95 78 99 86 89 94 93 86 83 87 78 68 80 67 79 82 72 63 66 69 70 65 67 70 78 76 61 56 69 62 76 78 65 57 58
84 75 80 97 96 85 76 109 103 89 89 81 76 79 77 85 82 97 97 79 67 67 72 69 71 71 72 82 87 75 71 86 80 89 95 87 78 73
96 98 104 93 102 96 81 86 103 86 97 87 72 82 86 82 84 95 96 82 66 62 66 69 84 82 82 94 99 90 89 108 90 83 80 81 80
97 98 100 73 95 94 87 90 98 82 108 98 74 89 89 74 73 76 81 74 60 51 57 69 70 67 69 80 83 73 75 96 82 71 66 60 50 50
83 89 97 88 81 108 80 88 83 85 85 105 80 89 91 71 77 93 78 104 63 68 72 70 64 81 74 76 95 92 64 54 58 44 71 86 98 98
105 75 104 120 77 68 87 112 108 101 91 107 83 86 84 81 105 70 81 86 85 71 85 73 61 71 80 71 82 95 87 80 85 93 64
106 72 72 89 97 102 112 76 69 78 79 100 93 87 89 90 89 109 88 88 103 89 70 74 89 77 95 104 83 70 86 89 80 83 91 67 81
87 139 128 94 95 81 104 92 103 110 91 85 85 89 97 95 102 99 110 102 93 78 83 65 81 89 100 105 114 78 72 101 97 98 100
103 122 89 77 100 71 87 79 102 100 82 87 104 104 112 110 108 95 105 84 83 79 97 88 93 89 90 91 112 79 78 102 76 89 81
96 103 103 123 113 87 113 100 104 86 83 104 118 91 86 76 100 107 100 74 104 100 87 96 109 79 96 98 102 85 103 91 92
91 109 113 125 105 90 92 75 97 78 77 87 104 104 123 105 94 111 115 96 118 112 84 92 92 74 101 98 110 102 123 103 115
100 122 92 99 109 98 77 99 89 92 98 82 89 106 127 77 100 101 129 118 101 108 104 100 96 106 110 81 112 96 103 105 104
120 104 110 94 91 85 99 85 110 96 113 127 103 124 117 97 109 95 135 89 92 115 91 88 104 105 105 94 97 105 108 127 106
103 96 108 102 103 101 115 103 114 104 116 109 91 118 118 92 105 98 123 94 94 108 98 118 110 111 103 100 101 98 105
83 84 101 100 105 111 127 126 95 110 112 101 101 106 102 111 110 106 102 102 103 94 122 106 116 104 120 120 97 106
89 95 105 100 101 106 120 125 119 88 110 116 115 101 106 101 111 116 89 106 113 108 89 104 104 115 97 120 122 93 103
106 118 120 115 104 102 100 105 103 102 123 103 106 115 117 93 98 113 86 103 115 114 98 104 112 115 86 103 108 84 106
97 118 124 127 116 111 93 96 111 108 120 103 102 110 108 99 97 113 99 99 102 106 108 116 114 116 97 109 113 94 98 98
84 113 122 134 128 123 99 100 126 107 109 118 107 102 94 112 110 108 109 97 100 101 108 117 113 114 110 115 119 110
94 123 128 140 134 130 102 104 121 117 115 120 106 114 98 109 117 94 103 94 106 105 110 112 120 113 105 95 104 112 106
96 113 118 114 122 127 119 114 117 111 101 118 109 111 96 98 93 105 110 119 109 106 125 109 124 115 107 98 93 102 106
101 111 114 111 118 122 120 119 105 108 104 105 104 115 120 128 92 105 103 106 97 94 111 104 120 116 111 104 98 108
115 121 119 116 121 119 118 125 117 117 110 91 91 98 107 104 100 118 116 115 113 103 111 113 111 113 115 107 102 114
126 129 125 125 124 118 113 121 116 110 110 96 110 106 113 102 90 111 117 120 121 107 100 109 103 110 114 107 104 111
119 127 127 126 125 114 105 111 104 96 106 102 116 103 109 108 91 106 115 118 122 107 94 104 103 109 112 105 101 111
111 122 125 124 124 116 109 111 105 101 107 105 98 85 93 106 110 108 118 123 122 113 99 111 111 112 113 107 102 110
108 124 125 118 117 116 113 113 114 115 109 109 102 107 109 118 114 99 115 122 120 114 101 108 117 112 114 115 108 107
108 122 120 106 106 109 109 110 130 127 105 105 102 120 107 95 116 95 121 134 131 127 110 110 117 110 115 120 114 111
125 119 103 118 123 119 128 108 117 106 120 101 124 105 116 104 114 102 124 134 104 105 130 121 122 113 107 100 106
110 110 121 116 120 101 115 110 108 109 106 116 116 125 120 121 124 99 126 126 106 113 112 108 125 122 112 117 121 110
115 101 121 103 120 101 107 105 113 116 105 121 111 128 117 121 114 90 114 110 113 134 118 124 112 115 99 117 126 110
123 106 118 102 114 108 100 111 119 115 113 112 116 115 113 111 127 112 112 108 120 133 119 124 116 127 101 118 129

[Source]

```
121 84 93 90 87 76 84 86 82 100 89 84 73 64 79 72 55 66 68 62 63 72 74 67 65 67 64 68 75 72 67 74 74 80 73 77 90 73  
107 116 120 72 62 97 101 68 88 101 86 81 77 66 77 78 59 63 64 61 58 58 58 59 61 66 70 73 76 69 67 78 66 83 82 81 86  
86 80 93 99 85 86 79 87 90 100 84 82 84 71 72 79 63 61 63 65 59 52 53 59 54 62 69 74 70 58 56 72 54 60 53 54 69 71 81  
86 99 112 113 89 95 76 79 90 95 85 85 92 76 67 78 63 65 67 68 62 58 62 68 61 70 76 78 74 58 55 69 72 74 64 60 76 87  
87 107 110 95 78 99 86 89 94 93 86 83 87 78 68 80 67 79 82 72 63 66 69 70 65 67 70 78 76 61 56 69 62 76 78 65 57 58  
84 75 80 97 96 85 76 109 103 89 89 81 76 79 77 85 82 97 97 79 67 67 72 69 71 71 72 82 87 75 71 86 80 89 95 87 78 73  
96 98 104 93 102 96 81 86 103 86 97 87 72 82 86 82 84 95 96 82 66 62 66 69 84 82 82 94 99 90 89 108 90 83 80 81 80  
97 98 100 73 95 94 87 90 98 82 108 98 74 89 89 74 73 76 81 74 60 51 57 69 70 67 69 80 83 73 75 96 82 71 66 60 50 50  
83 89 97 88 81 108 80 88 83 85 85 105 80 89 91 71 77 93 78 104 63 68 72 70 64 81 74 76 95 92 64 54 58 44 71 86 98 98  
105 75 104 120 77 68 87 112 108 101 91 107 83 86 84 81 105 70 81 86 85 71 85 73 61 71 80 71 82 95 87 80 85 93 64  
106 72 72 89 97 102 112 76 69 78 79 100 93 87 89 90 89 109 88 88 103 89 70 74 89 77 95 104 83 70 86 89 80 83 91 67  
87 139 128 94 95 81 104 92 103 110 91 85 85 89 97 95 102 99 110 102 93 78 83 65 81 89 100 105 114 78 72 101 97 98 101  
103 122 89 77 100 71 87 79 102 100 82 87 104 104 112 110 108 95 105 84 83 79 97 88 93 89 90 91 112 79 78 102 76 89 101  
96 103 103 123 113 87 113 100 104 86 83 104 118 91 86 76 100 107 100 74 104 100 87 96 109 79 96 98 102 85 103 91 92  
91 109 113 125 105 90 92 75 97 78 77 87 104 104 123 105 94 111 115 96 118 112 84 92 92 74 101 98 110 102 123 103 115  
100 122 92 99 109 98 77 99 89 92 98 82 89 106 127 77 100 101 129 118 101 108 104 100 96 106 110 81 112 96 103 105 104  
120 104 110 94 91 85 99 85 110 96 113 127 103 124 117 97 109 95 135 89 92 115 91 88 104 105 105 94 97 105 108 127 104  
103 96 108 102 103 101 115 103 114 104 116 109 91 118 118 92 105 98 123 94 94 108 98 118 110 111 103 100 101 98 105  
83 84 101 100 105 111 127 126 95 110 112 101 101 106 102 111 110 106 102 102 103 94 122 106 116 104 120 120 97 104  
89 95 105 100 101 106 120 125 119 88 110 116 115 101 106 101 111 116 89 106 113 108 89 104 104 115 97 120 122 93 103  
106 118 120 115 104 102 100 105 103 102 123 103 106 115 117 93 98 113 86 103 115 114 98 104 112 115 86 103 108 84 101  
97 118 124 127 116 111 93 96 111 108 120 103 102 110 108 99 97 113 99 99 102 106 108 116 114 116 97 109 113 94 98 98  
84 113 122 134 128 123 99 100 126 107 109 118 107 102 94 112 110 108 109 97 100 101 108 117 113 114 110 115 119 110  
94 123 128 140 134 130 102 104 121 117 115 120 106 114 98 109 117 94 103 94 106 105 110 112 120 113 105 95 104 112 101  
96 113 118 114 122 127 119 114 117 111 101 118 109 111 96 98 93 105 110 119 109 106 125 109 124 115 107 98 93 102 101  
101 111 114 111 118 122 120 119 105 108 104 105 104 115 120 128 92 105 103 106 97 94 111 104 120 116 111 104 98 108  
115 121 119 116 121 119 118 125 117 117 110 91 91 98 107 104 100 118 116 115 113 103 111 113 111 113 115 107 102 114  
126 129 125 124 118 113 121 116 110 110 96 110 106 113 102 90 111 117 120 121 107 100 109 103 110 114 107 104 111  
119 127 127 126 125 114 105 111 104 96 106 102 116 103 109 108 91 106 115 118 122 107 94 104 103 109 112 105 101 114  
111 122 125 124 124 116 109 111 105 101 107 105 98 85 93 106 110 108 118 123 122 113 99 111 111 112 113 107 102 110  
108 124 125 118 117 116 113 113 114 115 109 109 102 107 109 118 114 99 115 122 120 114 101 108 117 112 114 115 108  
108 122 120 106 106 109 109 110 130 127 105 105 102 120 107 95 116 95 121 134 131 127 110 110 117 110 115 120 114 111  
125 119 103 118 123 119 128 108 117 106 120 101 124 105 116 104 114 102 124 134 104 105 130 121 122 113 107 100 106  
110 110 121 116 120 101 115 110 108 109 106 116 116 125 120 121 124 99 126 126 106 113 112 108 125 122 112 117 121 111  
115 101 121 103 120 101 107 105 113 116 105 121 111 128 117 121 114 98 114 110 113 134 118 124 112 115 99 117 126 111  
123 106 118 102 114 108 100 111 119 115 113 112 116 115 113 111 127 112 112 108 120 133 119 124 116 127 101 118 129
```



[Source]

A bit of history

Maps

A bit of history

Maps --> Data Maps (XVIIth.C.)

A bit of history

Maps --> Data Maps (XVIIth.C.) --> Time series
(1786)

A bit of history

Maps --> Data Maps (XVIIth.C.) --> Time series
(1786) --> Scatter plots

A bit of history

Maps --> Data Maps (XVIIth.C.) --> Time series
(1786) --> Scatter plots

- Surprisingly recent: 1750-1800 approx. (much later than many other advances in math and stats!)
- **William Playfair's "linear arithmetic":** encode/replace numbers in tables into visual representations.
- Other relevant names throughout history: Lambert, Minard, Marey.

Visualization

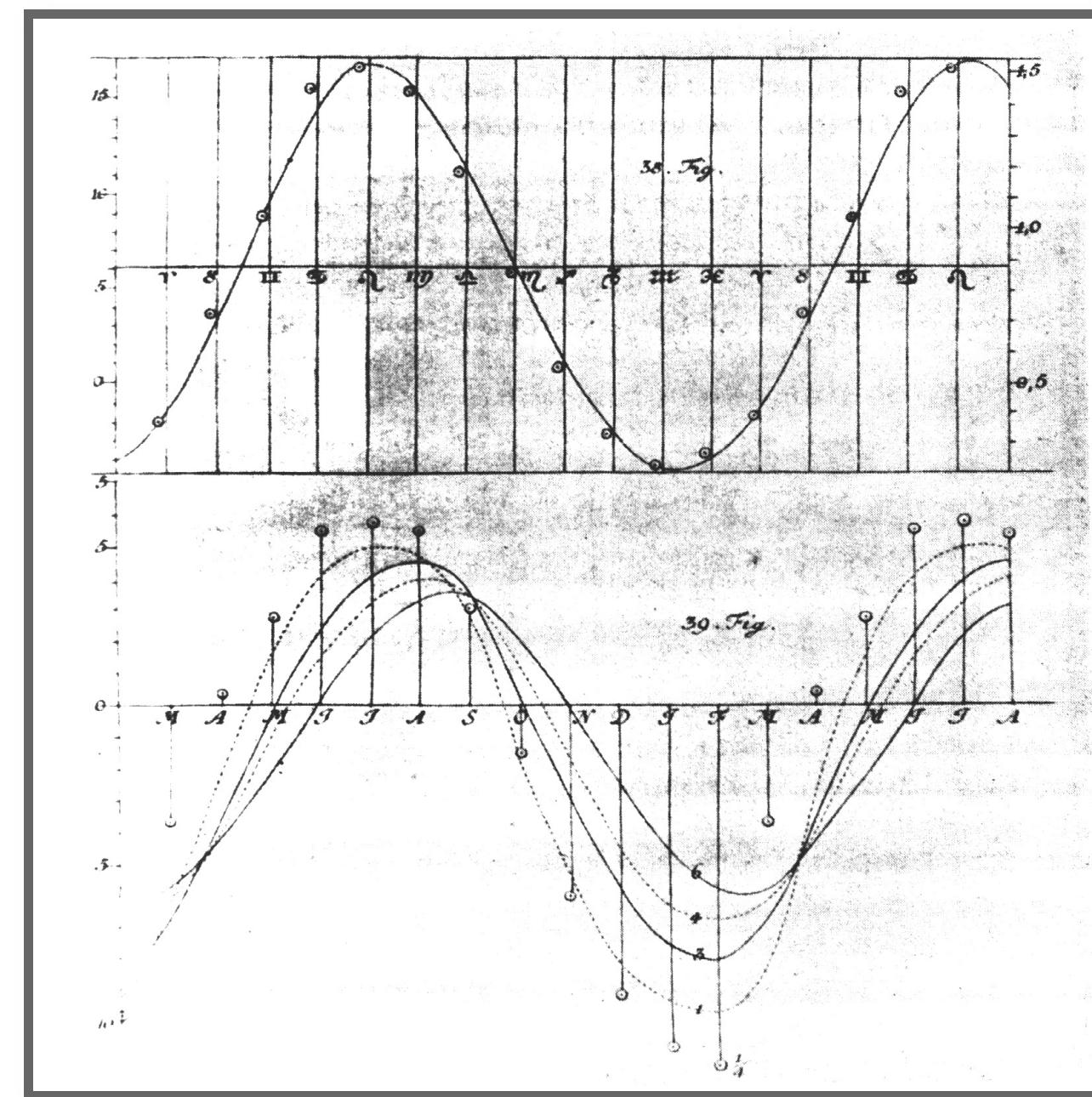
The Visual Display of Quantitative Information. Edward R. Tufte.

- By **encoding information visually**, they allow to present **large amounts** of numbers in a **meaningful** way.
- If well made, visualizations provide leads into the processes underlying the graphic.

Learning by seeing time...

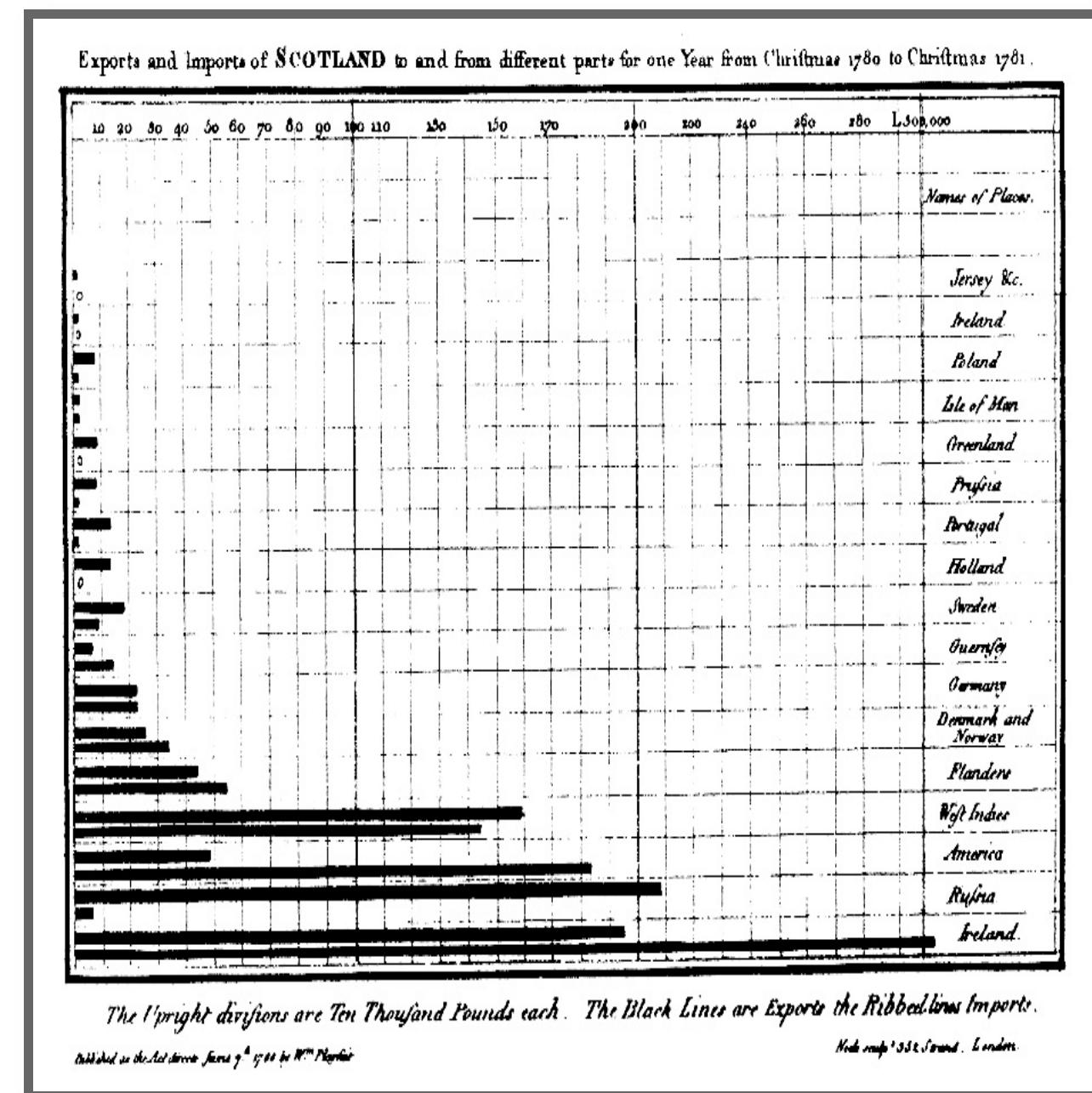
Time series

[Source] XVIIIth. Cent. - *Pyrometrie* by J. H Lambert



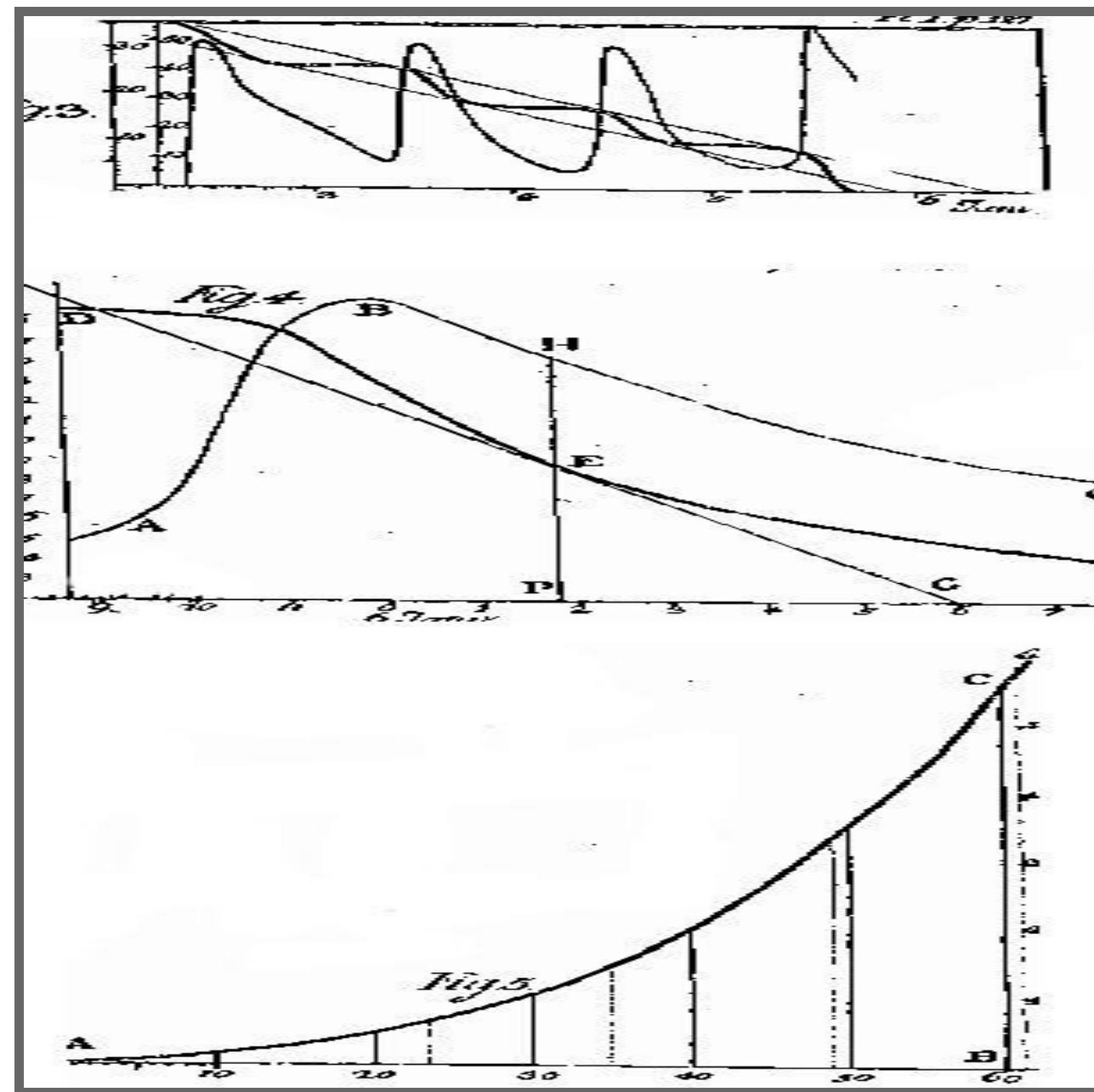
Bar chart

[Source] Playfair's bar chart in The Commercial and Political Atlas (1786)



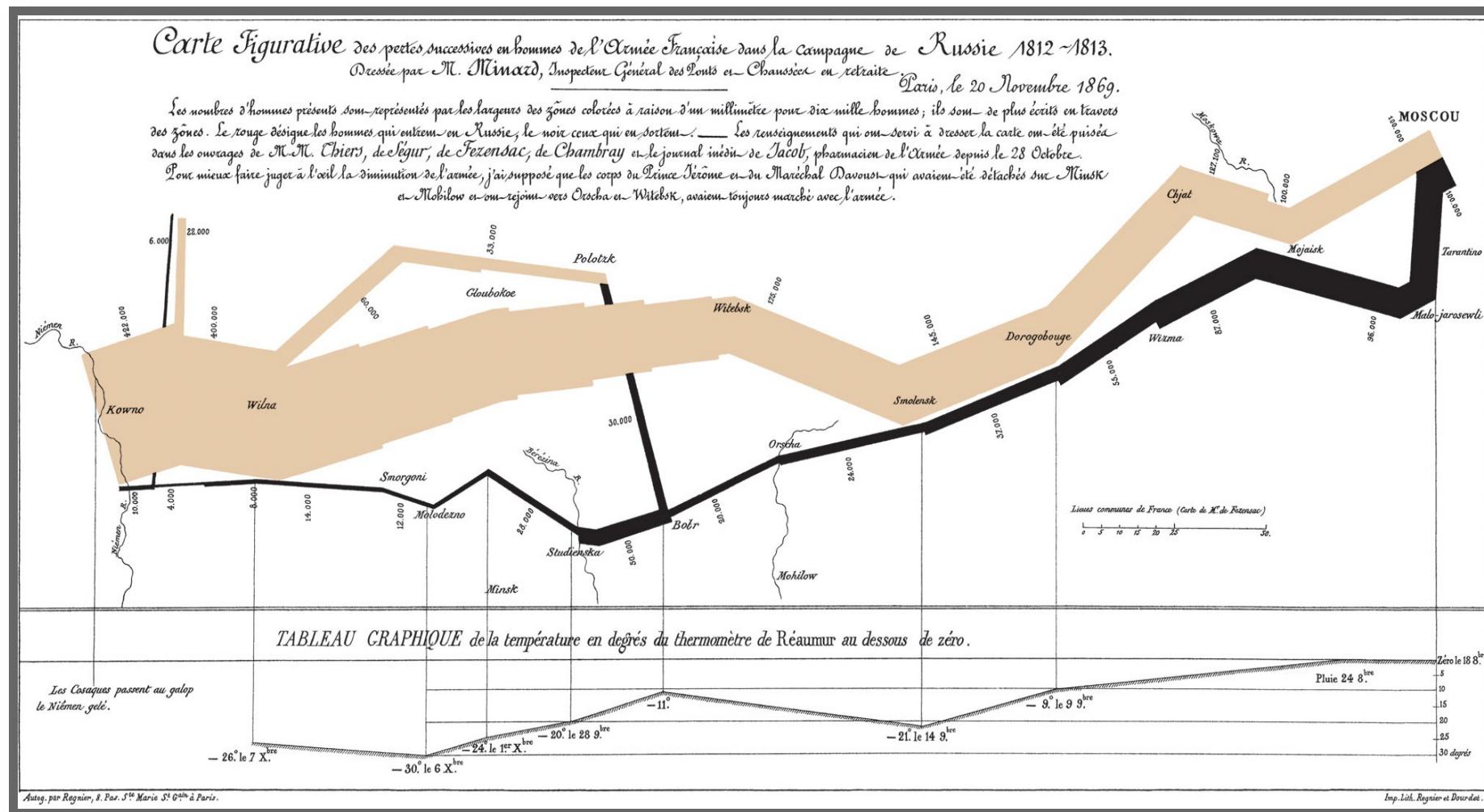
Abstract line plot

[Source] Lambert - Evaporation rate against temperature, 1769



Minard - Napoleon army map (XIXth. Cent.)

[Source] "It may well be the best statistical graphic ever drawn" (E. R. Tufte)



Geovisualization

Tufte (1983)

"The most extensive data maps [...] place millions of bits of information on a single page before our eyes. No other method for the display of statistical information is so powerful"

MacEachren (1994)

"Geographic visualization can be defined as the use of concrete visual representations --whether on paper or through computer displays or other media--to make spatial contexts and problems visible, so as to engage the most powerful human information processing abilities, those associated with vision."

GeoVisualization

- End goal is not to replace the human *in the loop*, but to **augment** her/him.
- Augmentation here comes through engaging the **pattern recognition** capabilities that our brain inherently has.
- Combines:
 - Traditional maps
 - Statistical maps
 - Statistical devices of other kind (charts, scatter plots, etc.)
- **Different roles** in the analysis process...

A map for everyone

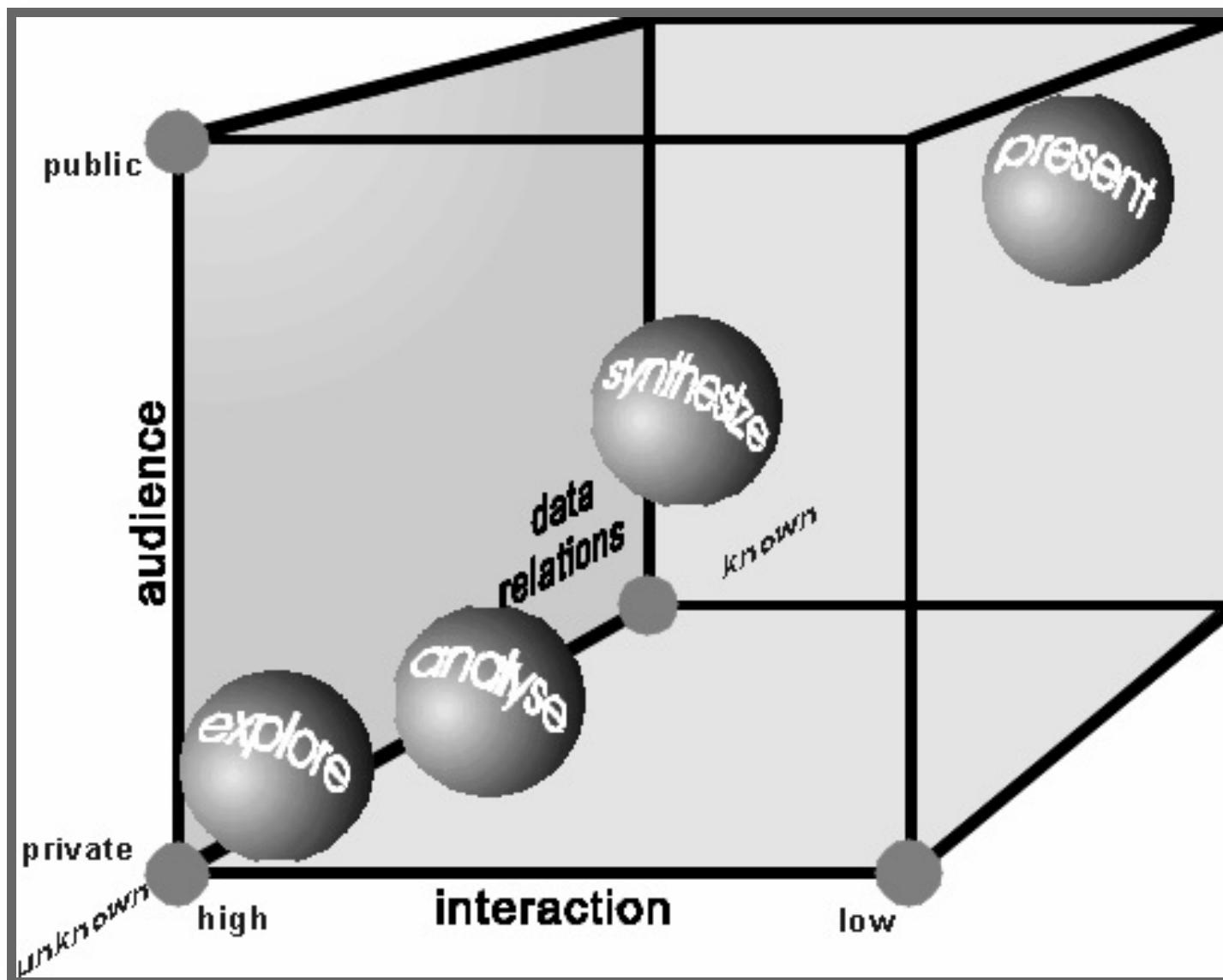
Maps can fulfill several needs

Depending on which one we want to stress, the best map will look very different

MacEachren & Kraak (1997) identify three main dimensions:

- Knowledge of what is being plotted
- Target audience
- Degree of interactivity

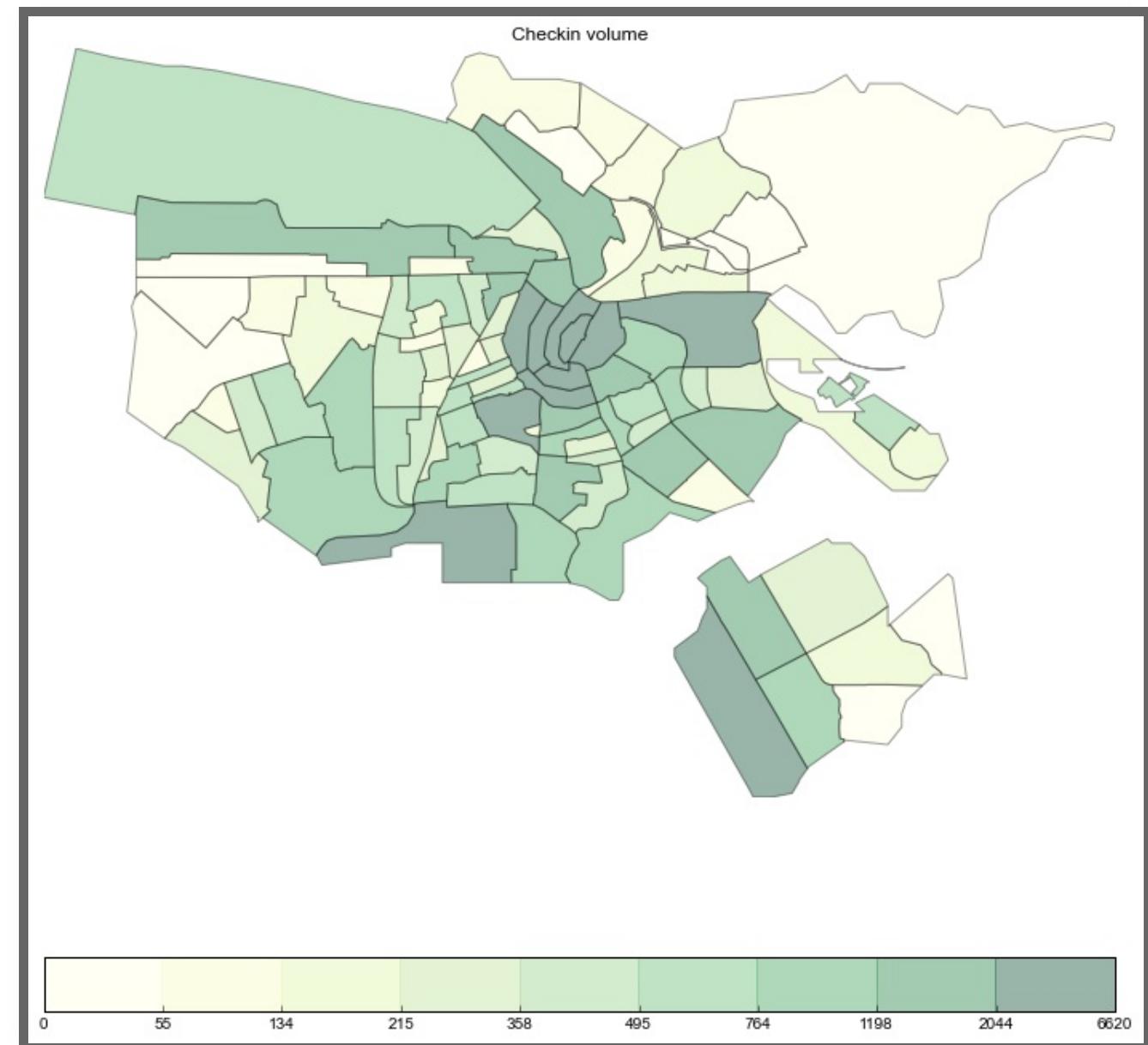
MacEachren & Kraak (1997) map cube



[Source]

Un/known: *fast* and *slow* maps

Fast maps [Source]



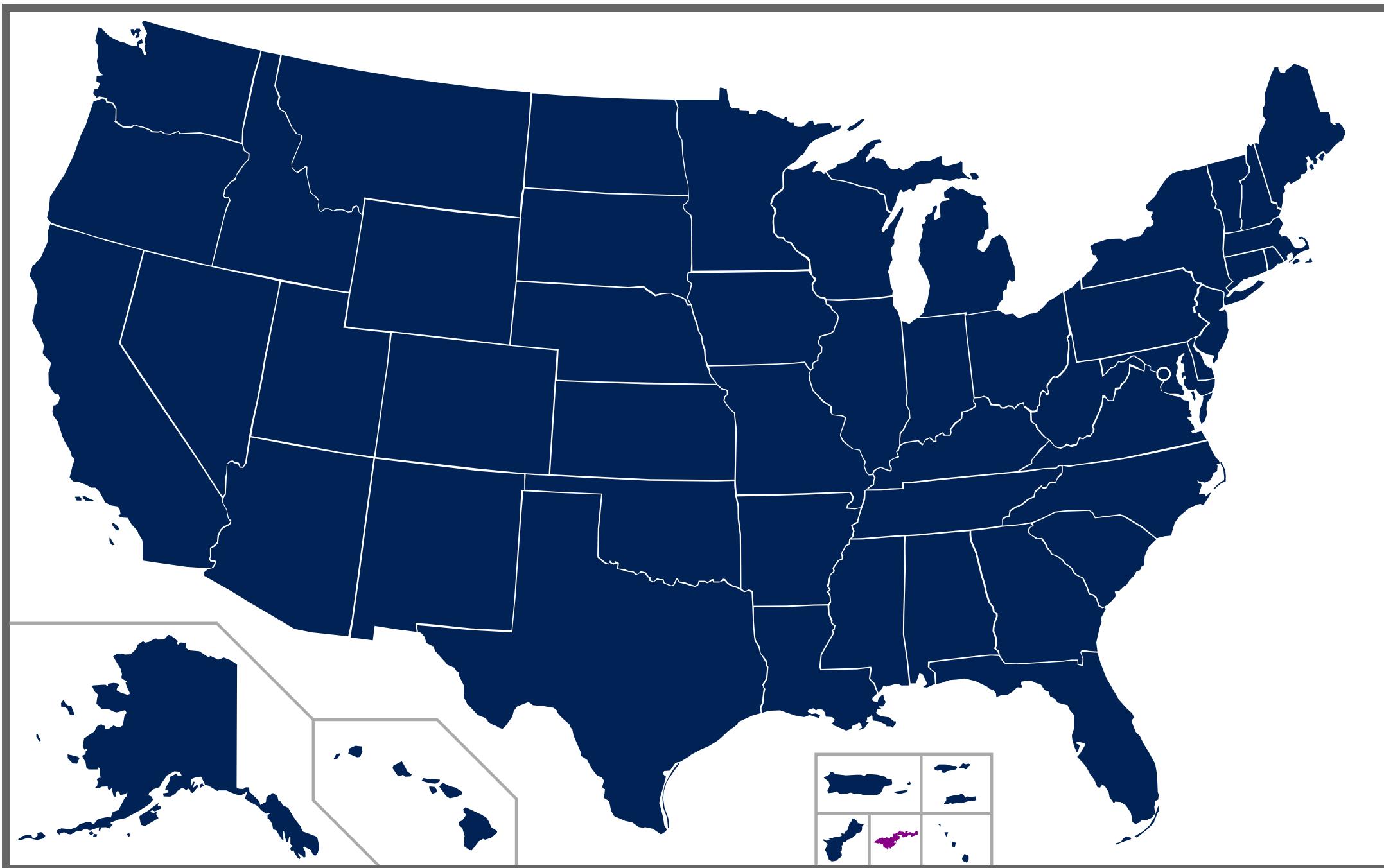
Slow maps [Source]



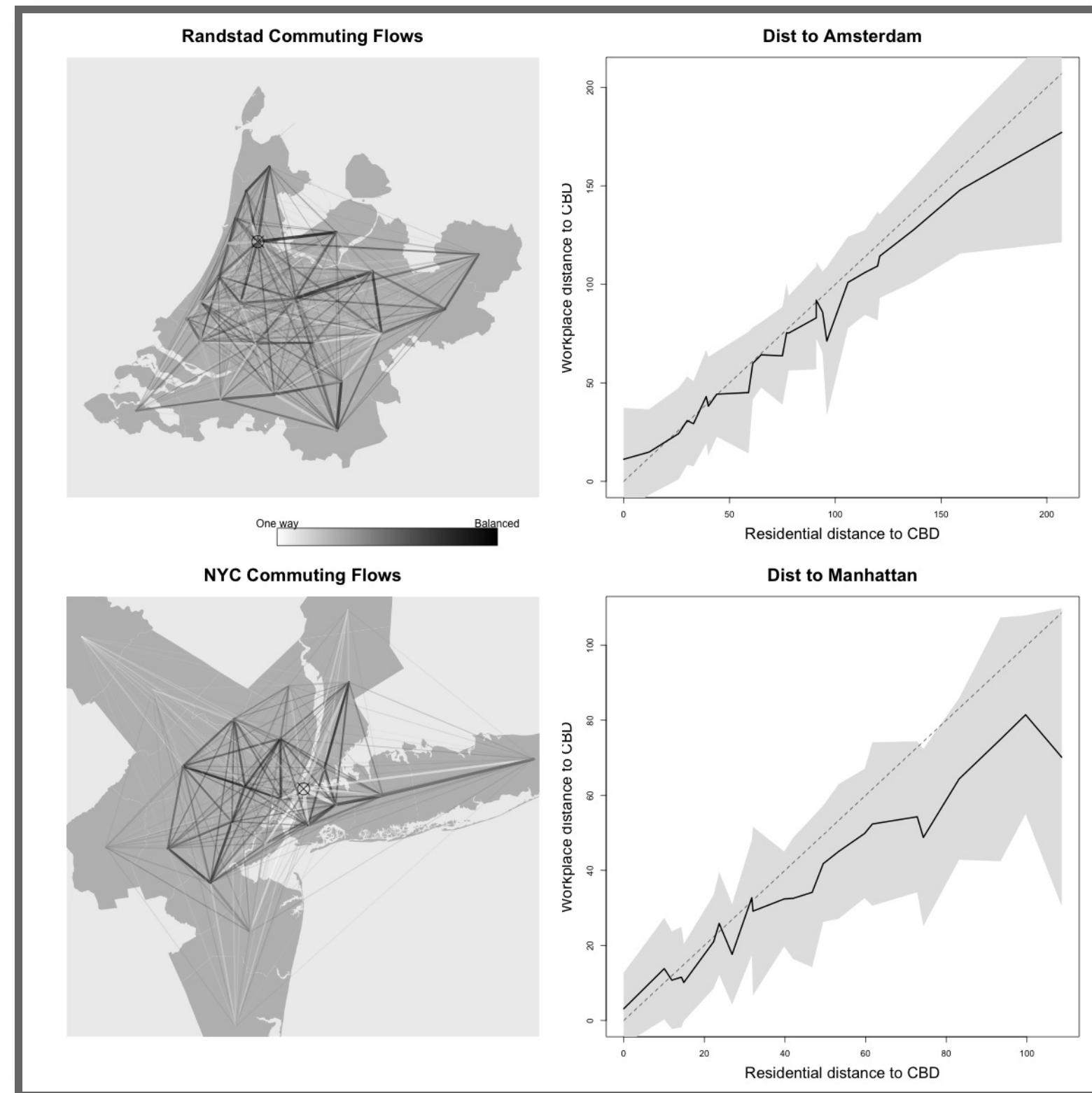
Audience: *easy* and *hard* maps

Easy map

[Source] Map of same-sex marriage in the US, 2015

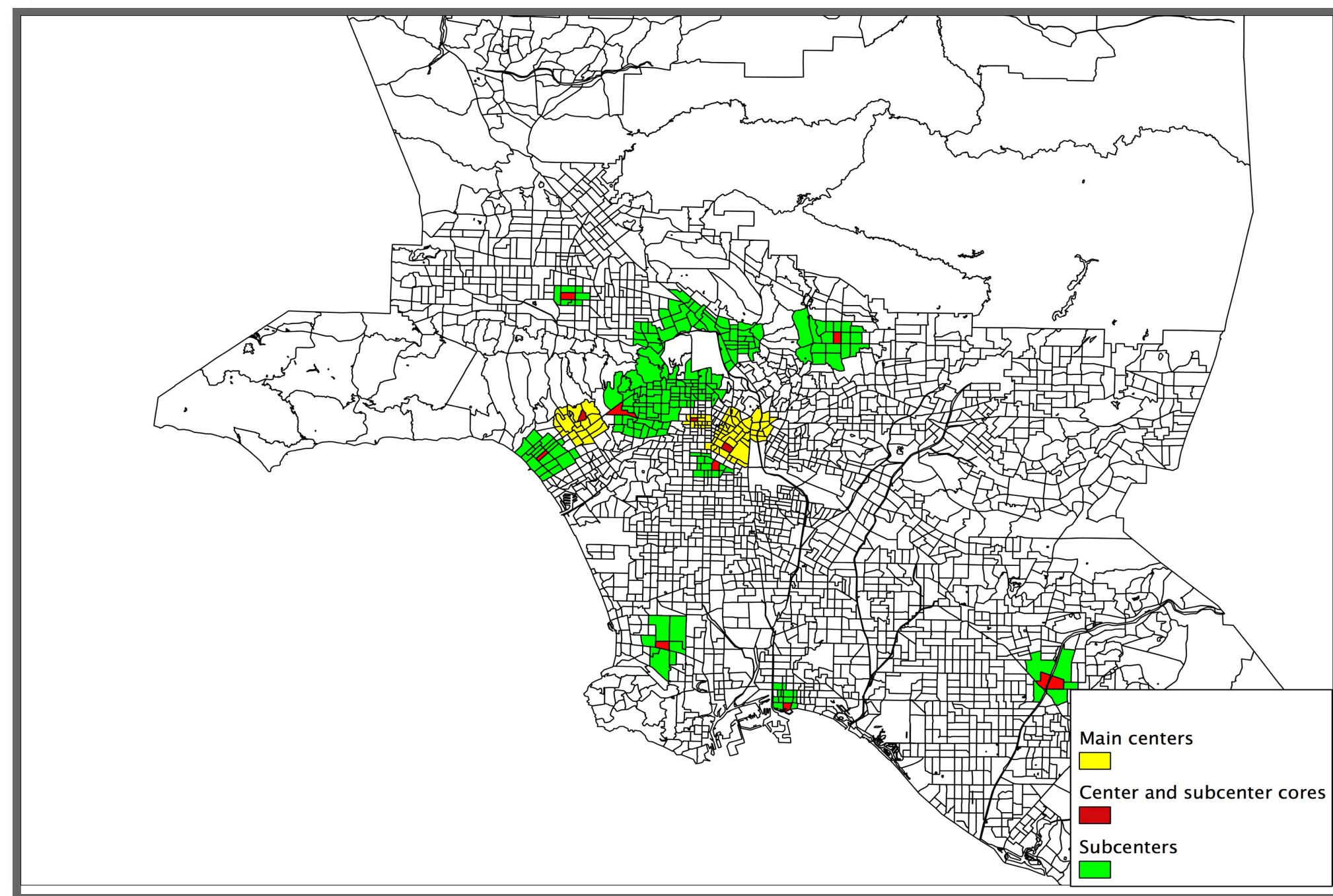


Hard map [Source]

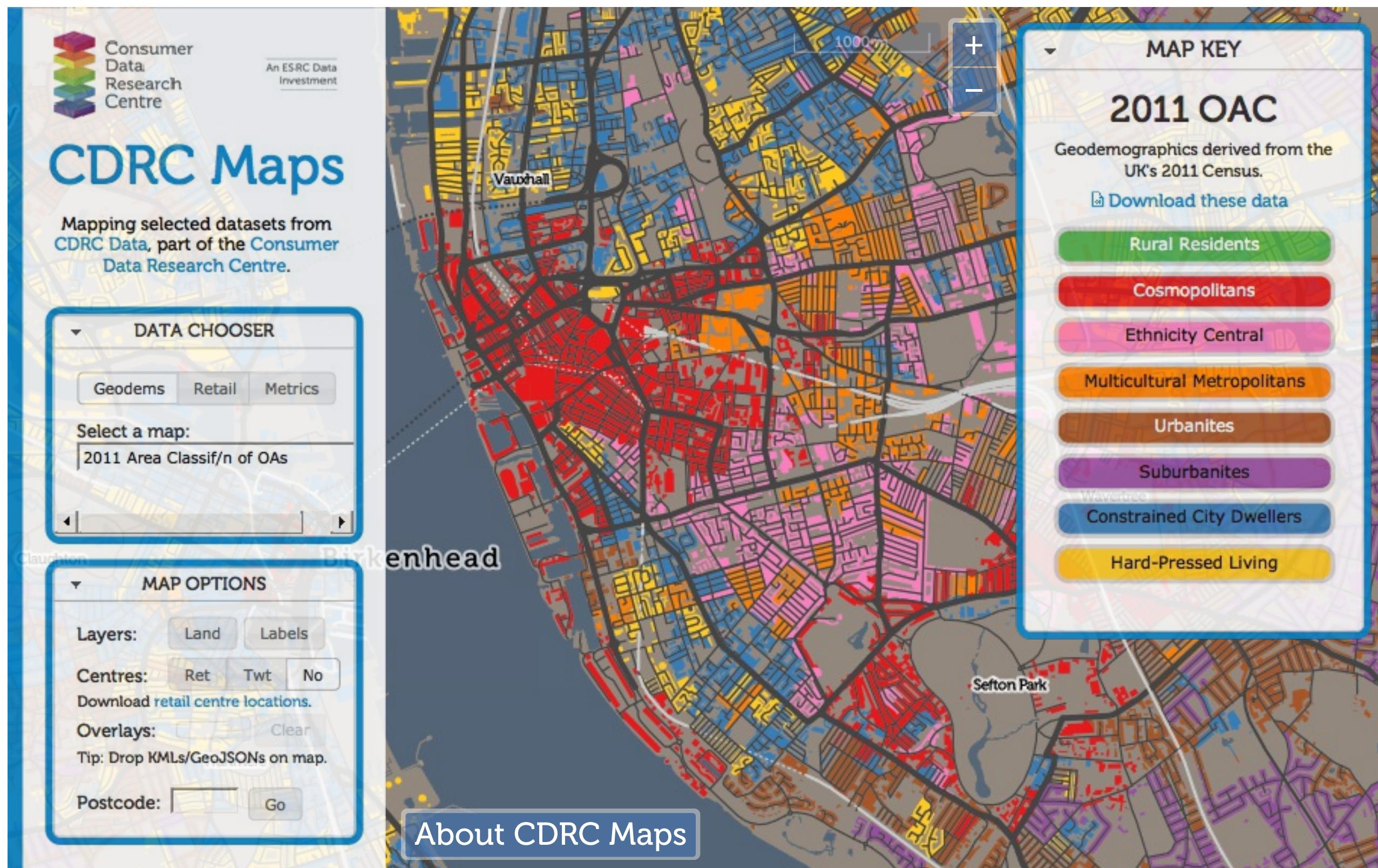


Interaction: one or many maps in
one

Static map



Interactive map



Dangers of GeoVisualization

Mark Monmonier

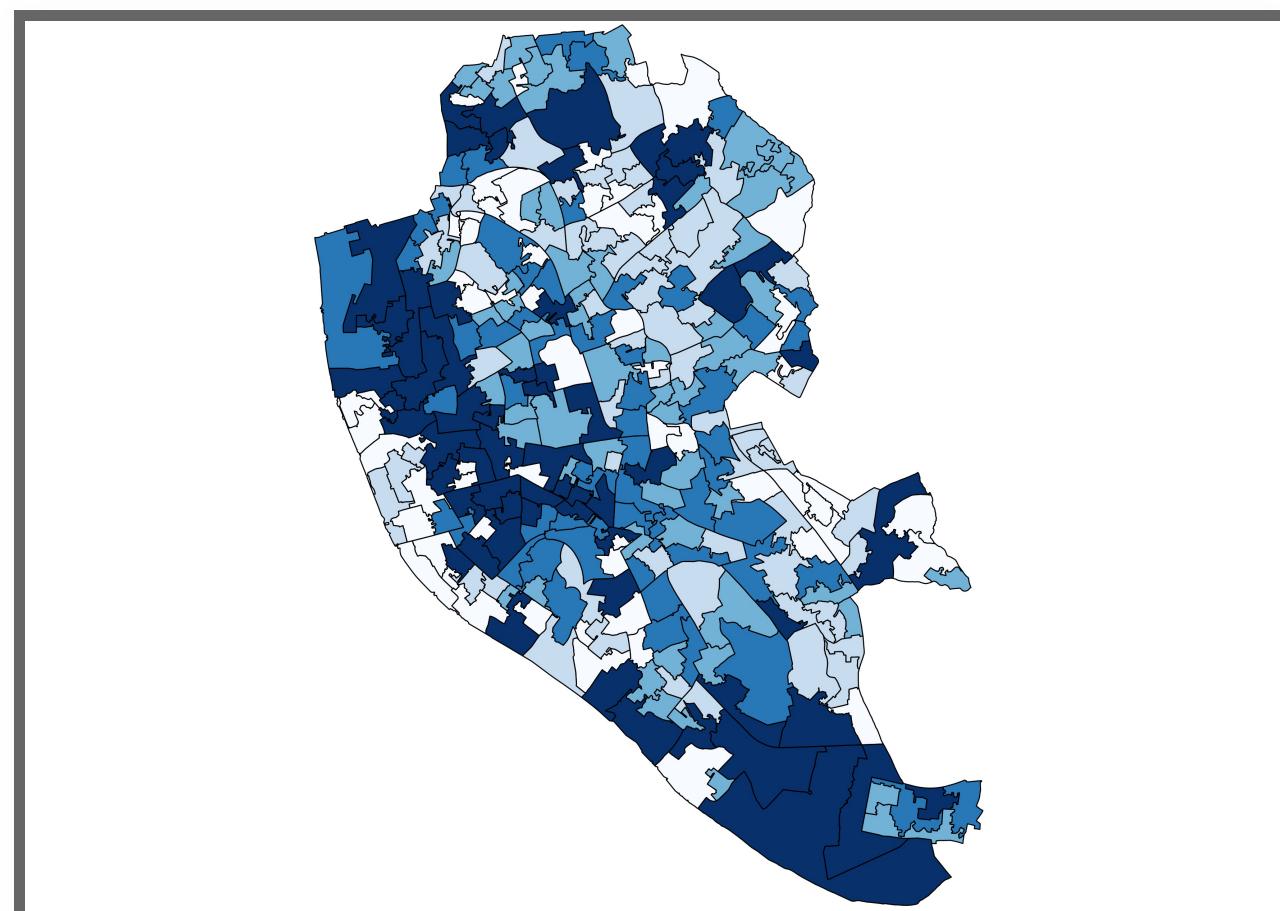
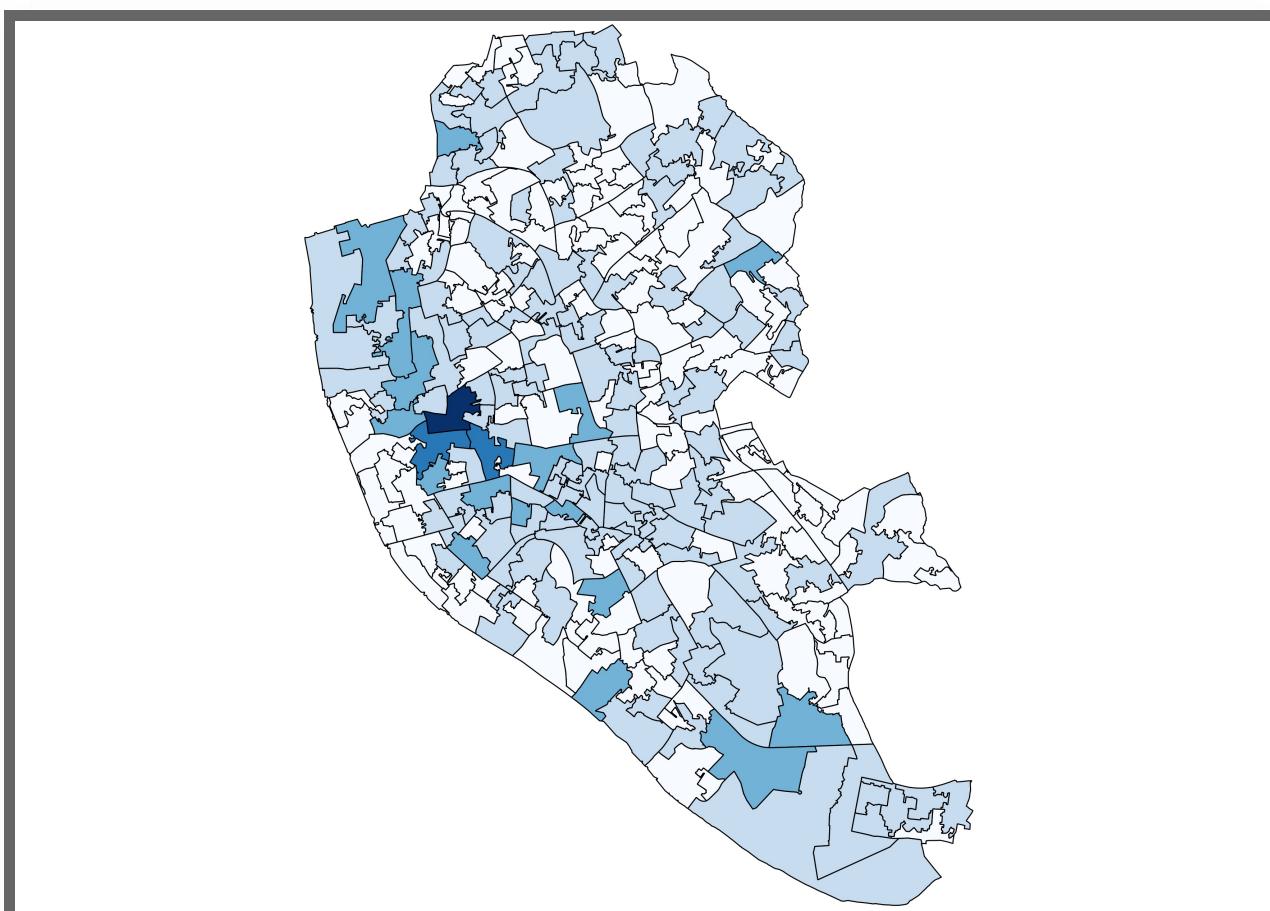
How to Lie with Maps

Second Edition



With a new Foreword by H. J. de Blij

How to lie with maps



How to lie with maps

The human brain is so good at picking up patterns...

How to lie with maps

The human brain is so good at picking up patterns...
... that it finds them even where they don't exist!

How to lie with maps

The human brain is so good at picking up patterns...

... that it finds them even where they don't exist!

Patternicity (Shermer, 2008) *The tendency to find meaningful patterns in meaningless noise*

How to lie with maps

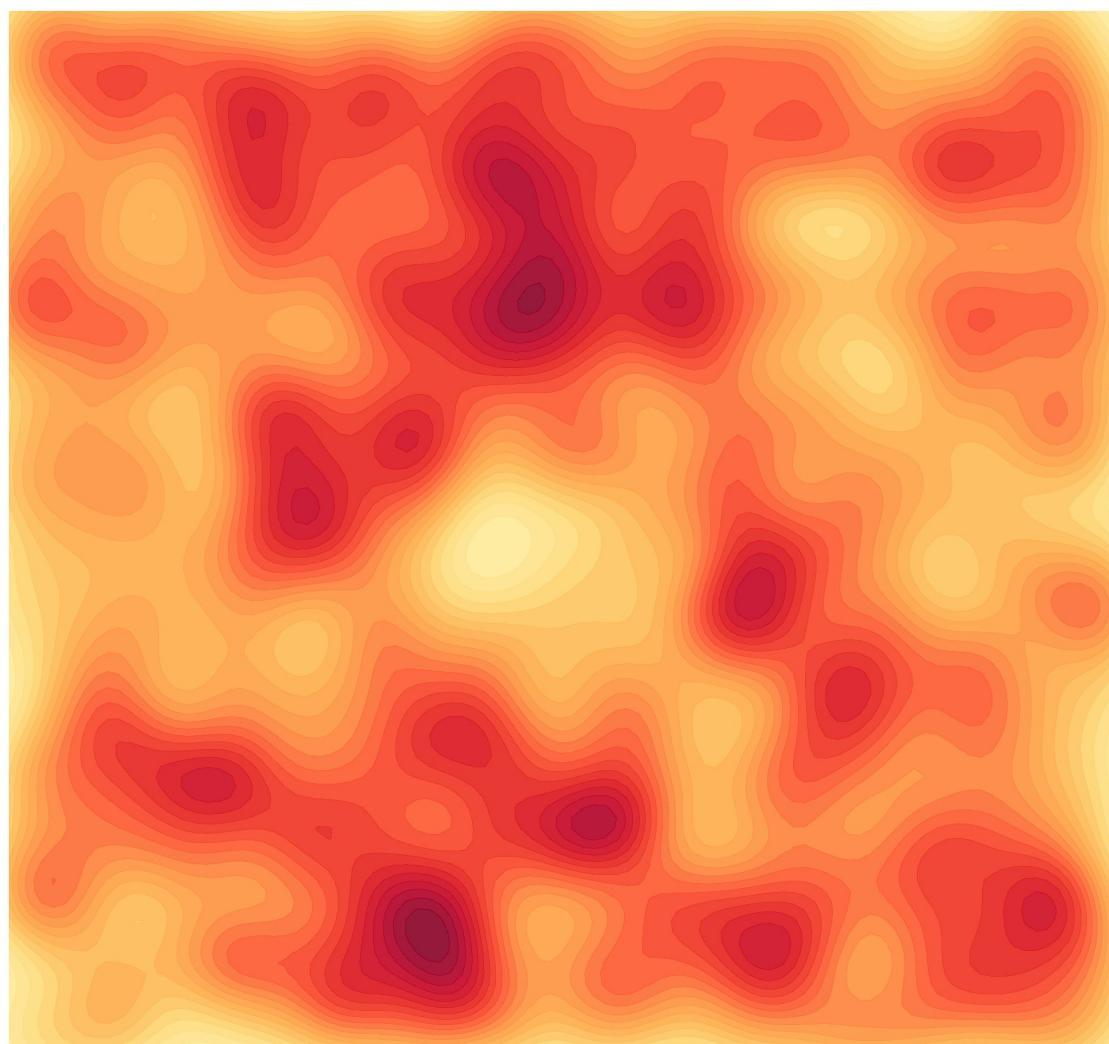
The human brain is so good at picking up patterns...

... that it finds them even where they don't exist!

Patternicity (Shermer, 2008) *The tendency to find meaningful patterns in meaningless noise*

Apophenia (Konrad, 1958) *The experience of seeing patterns or connections in random or meaningless data*

Twitter clusters



How to *be truthful* with maps

"With great power comes great responsibility"

How to *be truthful* with maps

"With great power comes great responsibility"

Statistics to the rescue!!!

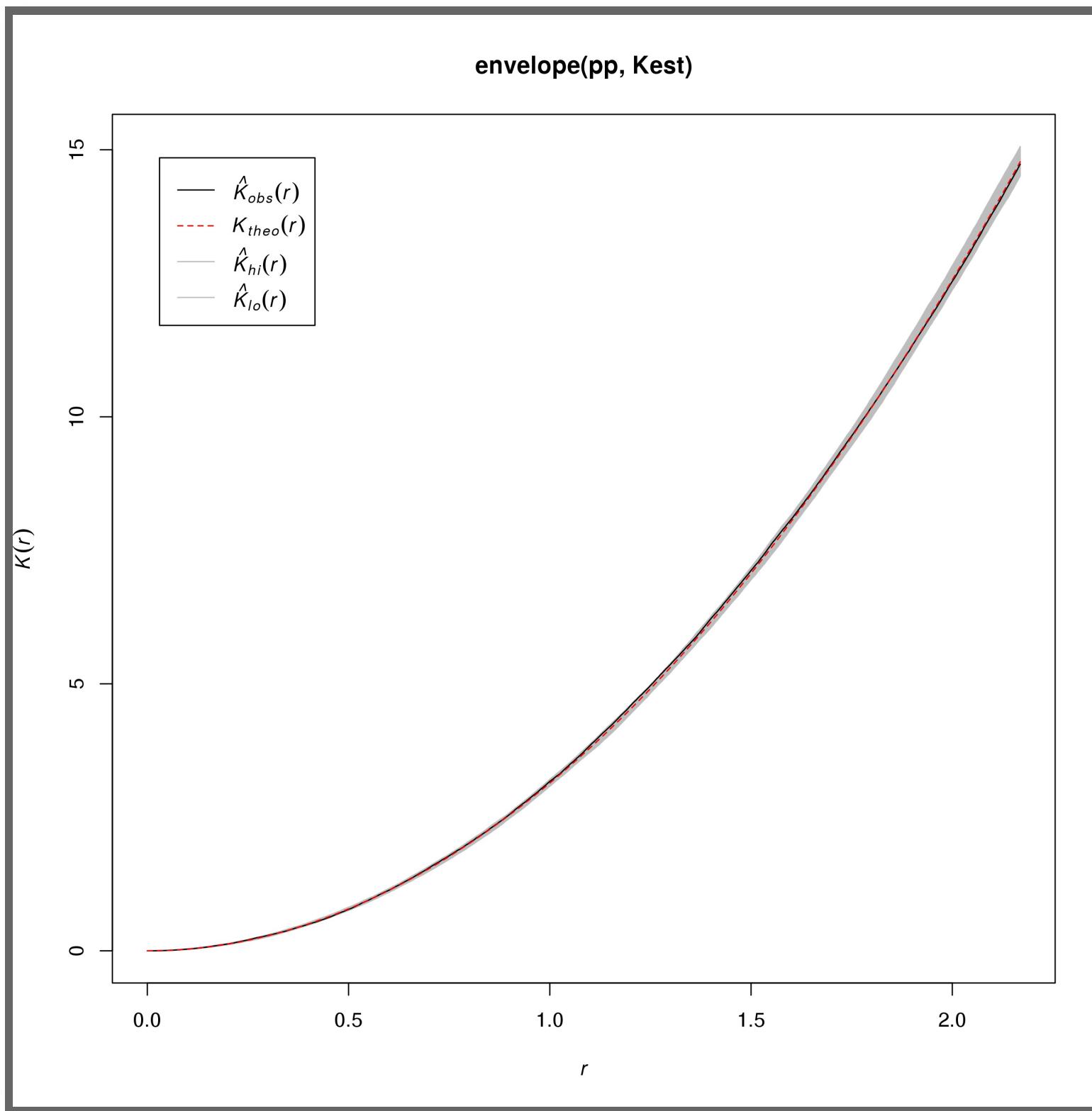
How to *be truthful* with maps

"With great power comes great responsibility"

Statistics to the rescue!!!

- **Complement** and enhance visuals
- Help disentangling **true** from **spurious** patterns
(a.k.a. identifying the "Jesus on the toast")
- **Reciprocity:** GeoVis can also enhance statistics
and make them more useful

Statistics for Twitter clusters



Recapitulation

- Visualization of statistical data is a fairly **recent** phenomenon.
- Its power comes from engaging and **augmenting** the human in the loop, rather than replacing her/him.
- Its power **can be misused**, but there are methods to limit this risk.



Geographic Data Science'16 - Lecture 3 by [Dani Arribas-Bel](#) is licensed under a [Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License](#).