Mapping and Geovisualization

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http://spatial.uchicago.edu

from mapping to geovisualization to ESDA

map design primer

statistical maps

mapping rates

From Mapping to Geovisualization to ESDA

- Definitions

  a map is "a collection of spatially defined objects" (Monmonier)

  beyond mapping

  - map as analysis vs map as presentation

    geovisualization

    geospatial visual analytics

    exploratory spatial data analysis (ESDA)

- Geovisualization

“the creation and use of visual representations to facilitate thinking, understanding and knowledge construction” (MacEachren)

exploration, synthesis, presentation, analysis

- Geospatial Visual Analytics

computer science perspective

visual analytics (Thomas and Cook 2005)

detect the expected and discover the unexpected (Kielman et al 2009) = facilitate analytical reasoning

bring in space = geospatial visual analytics

- Exploratory Spatial Data Analysis

  "a collection of techniques to describe and visualize spatial distributions, identify atypical locations or spatial outliers, discover patterns of spatial association, clusters or hot spots and suggest spatial regimes or other forms of spatial heterogeneity" (Anselin 1999)

- Traditional Knowledge Discovery

    deductive approach

        hypothesis first, data later

    inductive approach

        data first, hypothesis later

- Alternative Knowledge Discovery
  - abductive approach

    pattern discovered along with hypothesis

    interaction between data exploration and human perception

    visual popout = aha moment

- Geovisual Analytics

  leverages both geovisualization and visual analytics

  interactive mapping

  animation

  linking and brushing


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SITE SEARCH

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Or Search: Penn State, People, Departments

RESEARCH THEMES

- GeoVisual Analytics
- Knowledge Management & Geocollaboration
- Spatial Cognition & Human Factors
- Risk Assessment & Spatial Decision Support
- Geographic Representation
- GeoSemantics

SOFTWARE TOOLS

- GeoViz Toolkit
- Visual Inquiry Toolkit
- GeoVISTA CrimeViz
- HerbariaViz
- United States Cancer Atlas

RELATED RESOURCES

- Video: Flu Data Analysis with GeoViz Toolkit

GeoVisual Analytics

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Representing, analyzing, modeling and extracting meaning from complex heterogeneous geospatial datasets requires new approaches that can scale up to current and future data complexity and data volume. Our work addresses a wide variety of issues, including:

- the development of 'complex' spatiotemporal systems with emergent properties,
- new techniques for data mining, knowledge discovery, visualization (for application to geospatial and spatiotemporal information about the past, present, and future),
- advanced and semantically aware spatial databases that can represent and integrate both the data and the various higher level knowledge constructs, such as categories and relationships that emerge from the data during knowledge construction and
- developing a geographical agent modeling environment for investigating human activities.

These activities, when integrated, support the entire geo-scientific process, from initial exploration of data, hypothesis generation, concept discovery, model formulation, analysis and validation, and, when fused together seamlessly in GeoVISTA Studio, will form a complete Problem Solving Environment (PSE) for teams of scientists to use, thus supporting our geocollaboration focus. By bringing these activities together in GeoVISTA Studio we avoid many of the integration problems that plague traditional computational analysis. To accomplish this goal, Center affiliates and their collaborators are working to integrate methods and tools that span many disciplines including machine learning, pattern recognition, agent and cellular modeling, data mining, multivariate information visualization and spatial statistics.

RELATED PROJECTS

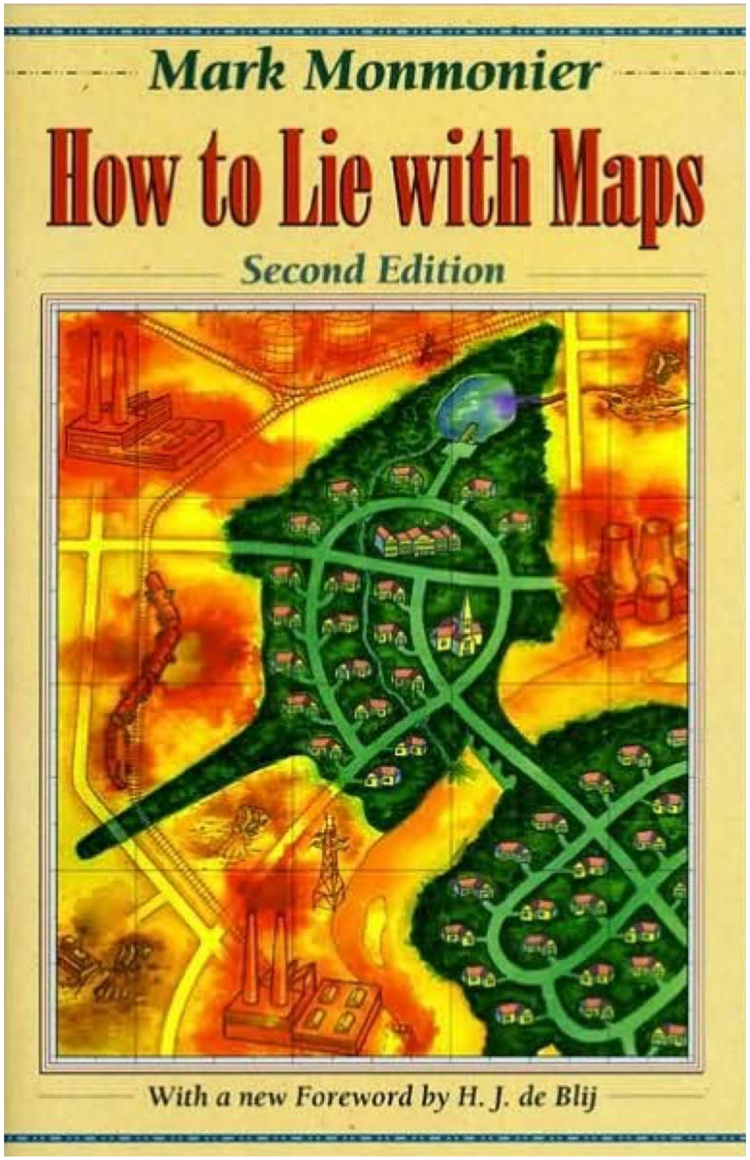
- VACCINE: Visual Analytics for Command, Control, and Interoperability Environments
- GAIDD: Geovisual Analytics for Infectious Disease Dynamics
- Vaccine Modeling Initiative
- Geovisualization and Spatial Analysis of Cancer Data
- STNexus: An Integrated Database and Visualization Enviroment for Space-Time Information Exploitation
- See all projects . .

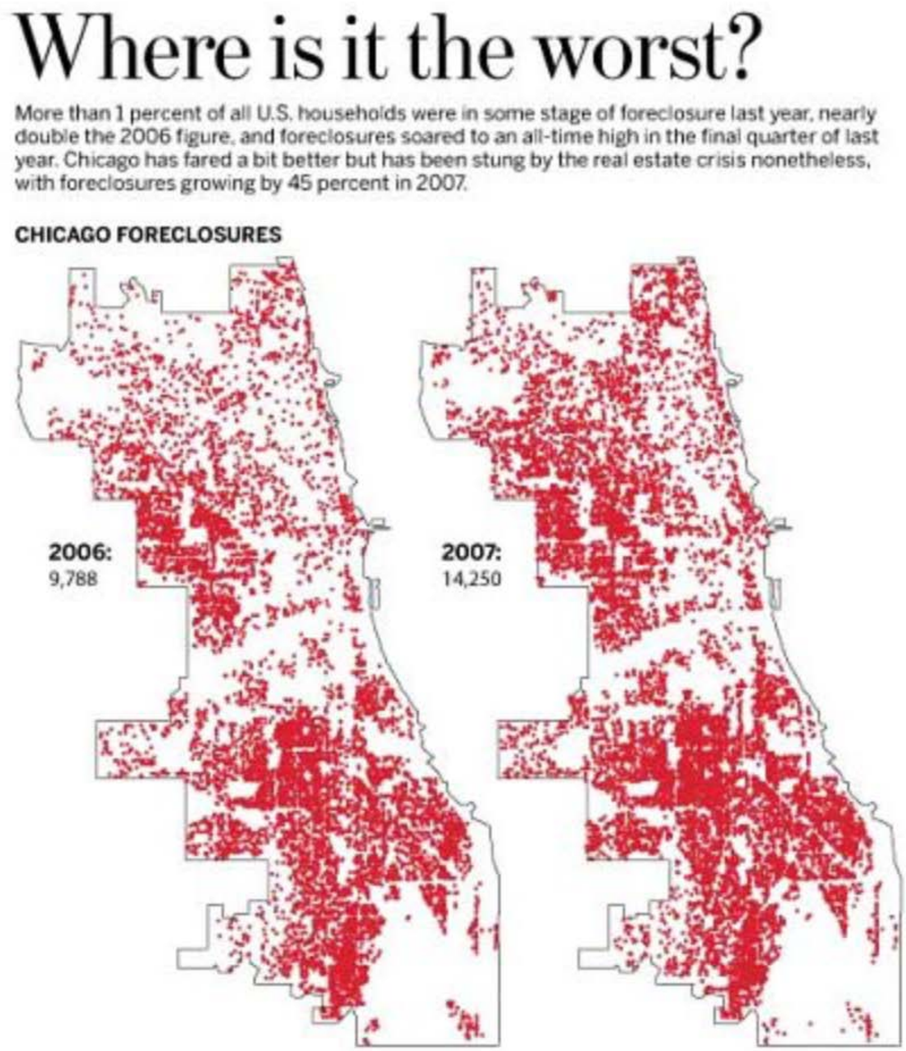
RELEVANT PAPERS

- Robinson, A. (2009). Needs Assessment for the Design of Information Synthesis Visual Analytics Tools, IEEE International Conference on Information Visualization
- Roth, R.E, MacEachren, A., McCabe, C. (2009). A workflow learning model to improve geovisual analytics utility. Proceedings of the

www.geovista.psu.edu

- How to Lie with Maps (Monmonier)
    - manipulate map design parameters
        - legends, colors, intervals, scale
    - choice of projection
        - manipulate area through choice of projection (political maps)
        - larger areas seem more important
    - human perception can be tricked





http://xefer.com//2008/04/maps

Map Design Primer

- Choropleth Map

    choro from region, NOT chloro

    visualizing a spatial distribution

        values at locations

    map counterpart of histogram

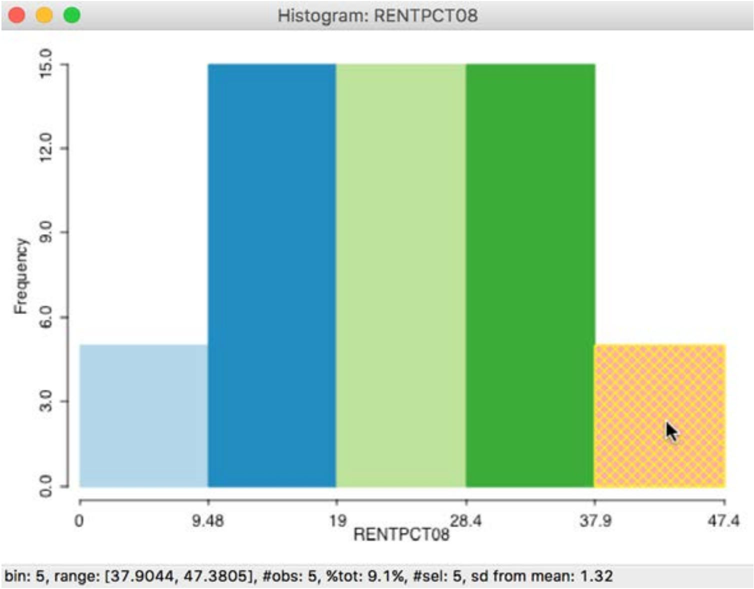
    values for discrete spatial units

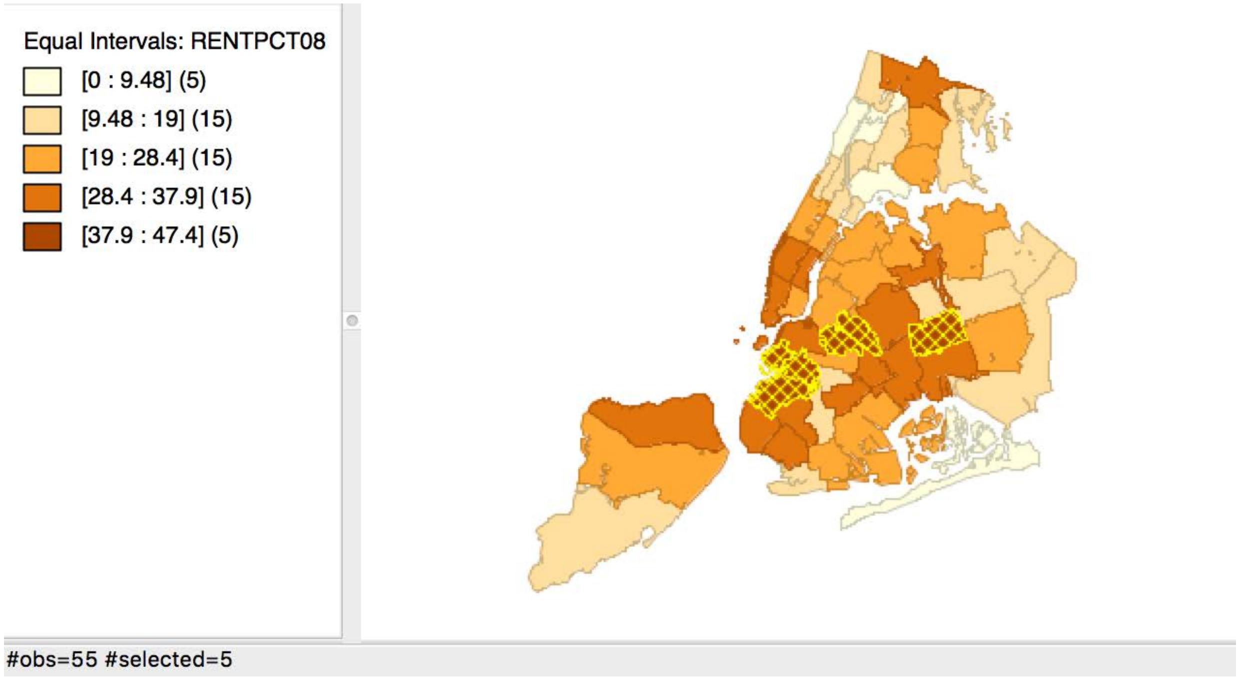
- Map Design Parameters
    - datum and coordinate system (geodesy)
    - scale
    - projection
        - shape, area, distance, direction
    - classification
    - color
    - legend

- Representing Value
  - discrete
    - selection of intervals
    - all data points in same interval obtain the same color or shading
  - continuous
    - color ramp
    - cross-hatch density
  - symbol
    - doesn’t really work for large data sets

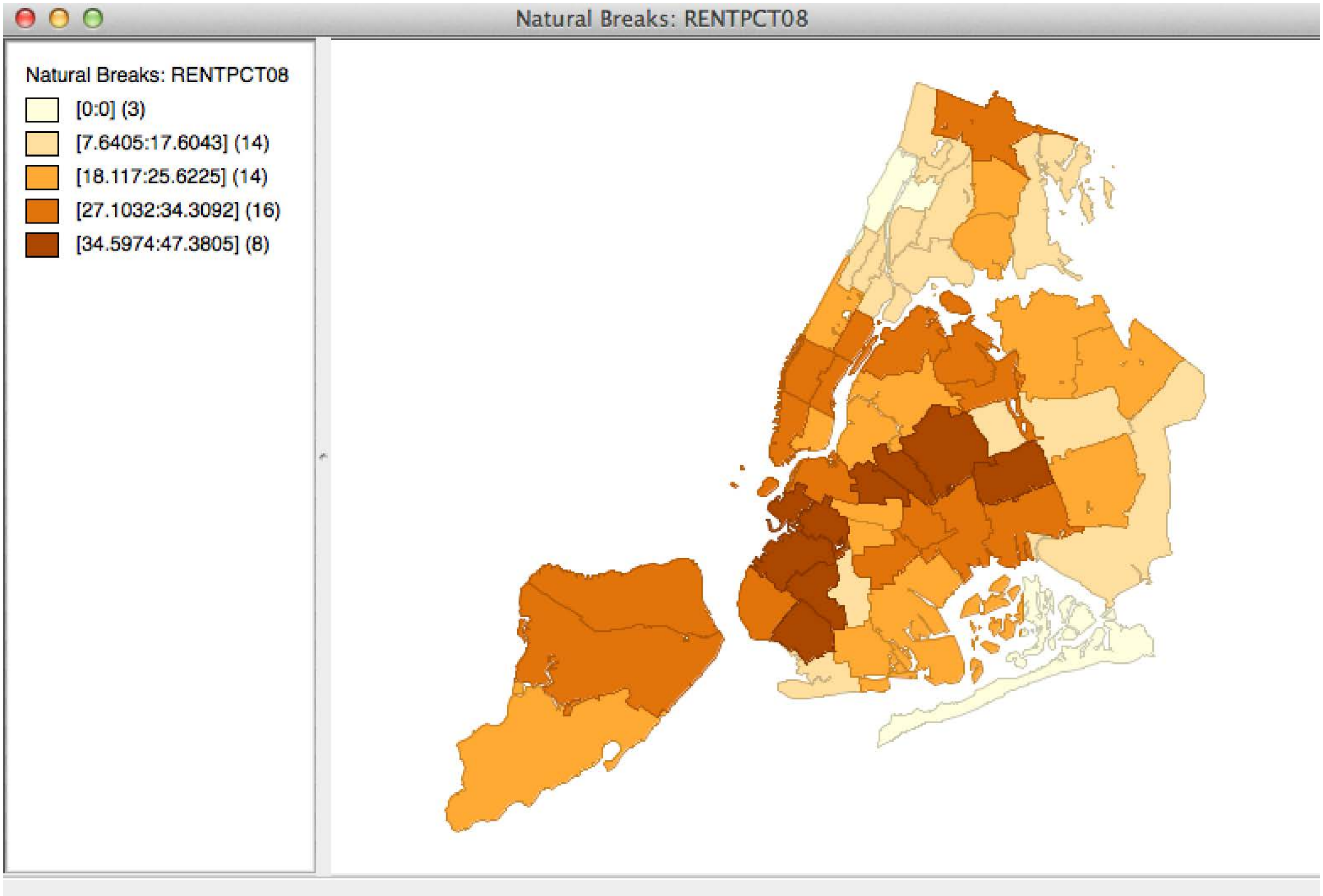
Classification

- Map Classification
    - choice of intervals
    - selection of cut points
        - equal interval, natural breaks (Jencks), manual
    - statistical criteria
        - equal share (quantile), standard deviation
        - extreme values

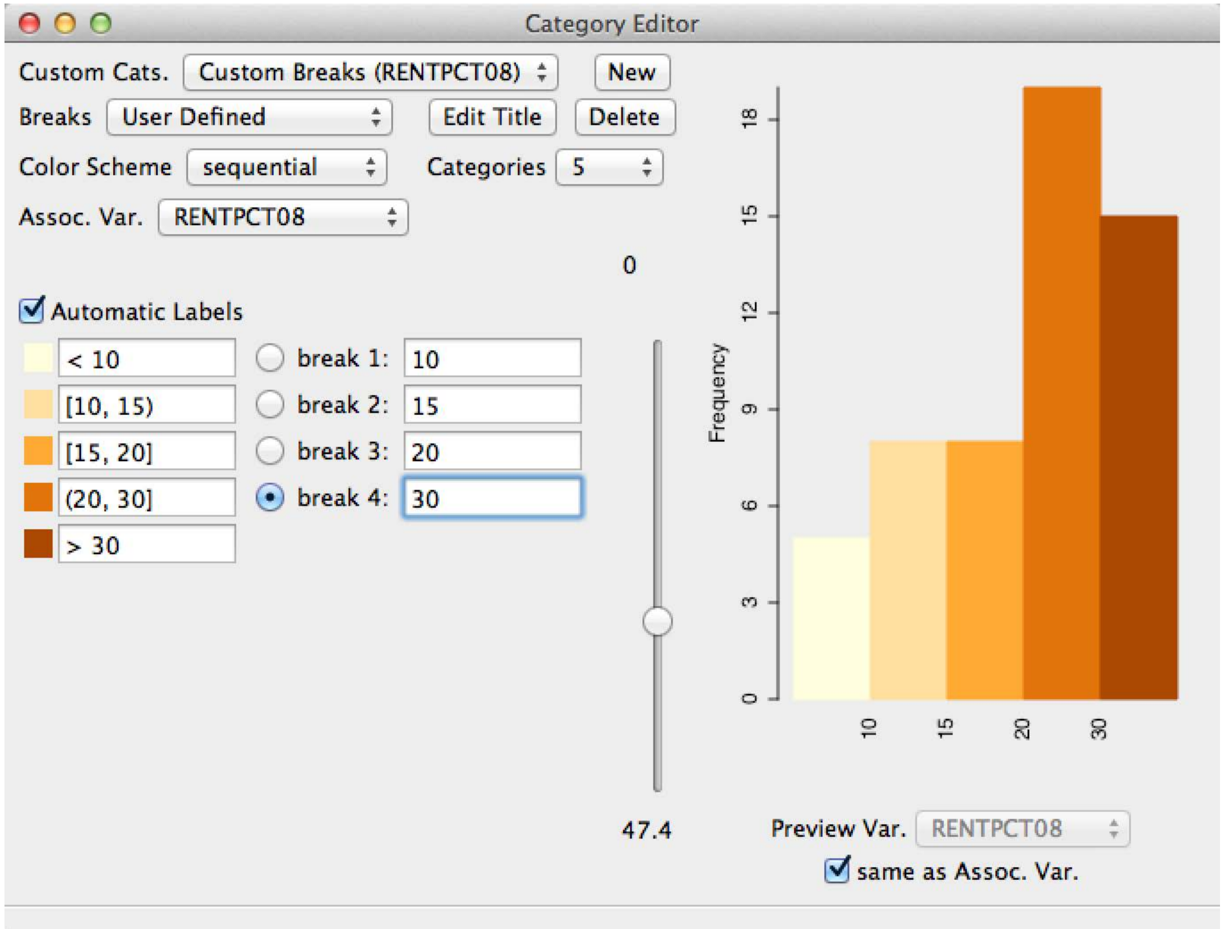




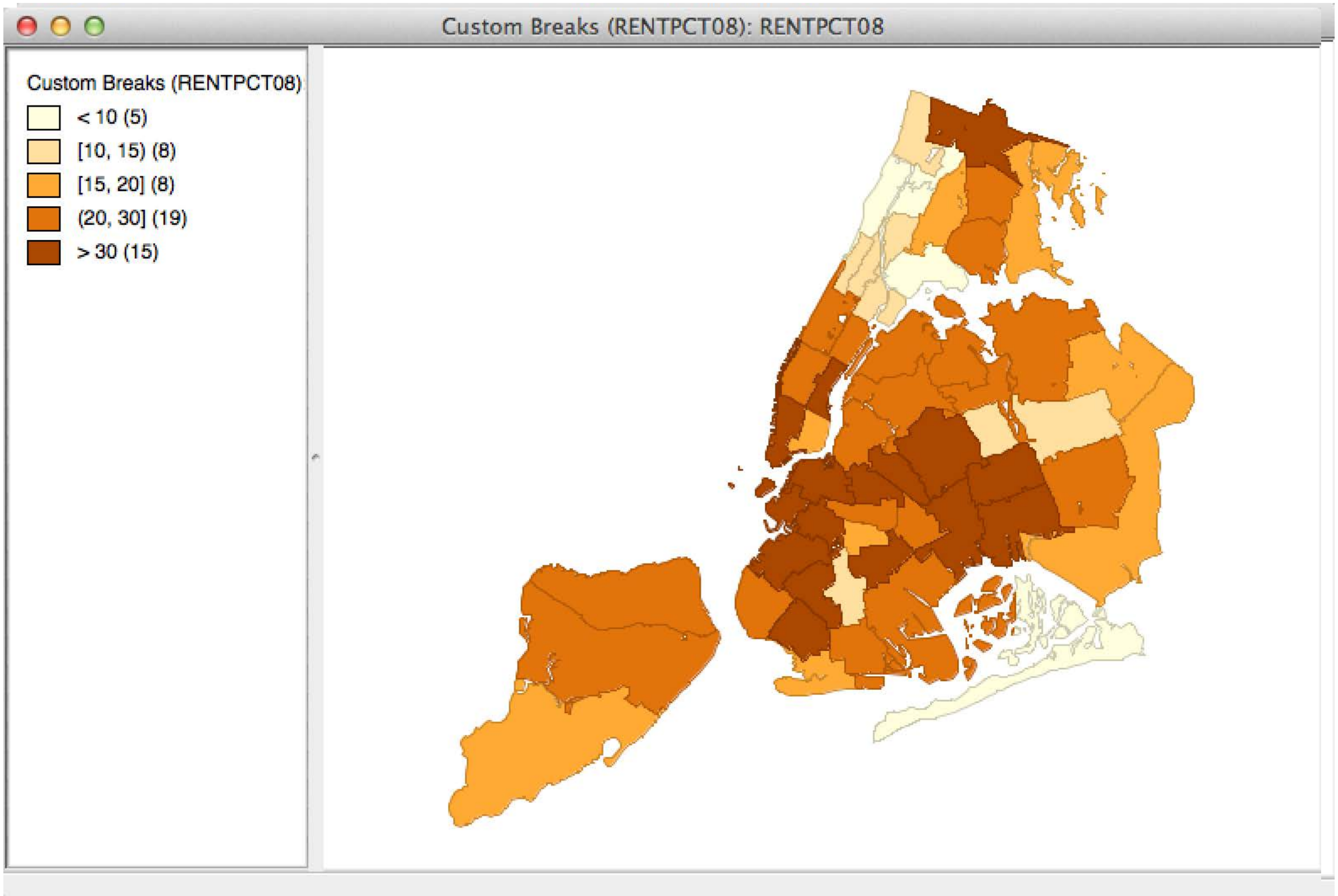
histogram and equal intervals choropleth map



NYC Sub-boroughs - % rental
Natural Breaks



GeoDa Custom Category Editor



NYC Sub-boroughs - % rental
Custom Intervals

Colors

- Color Choice

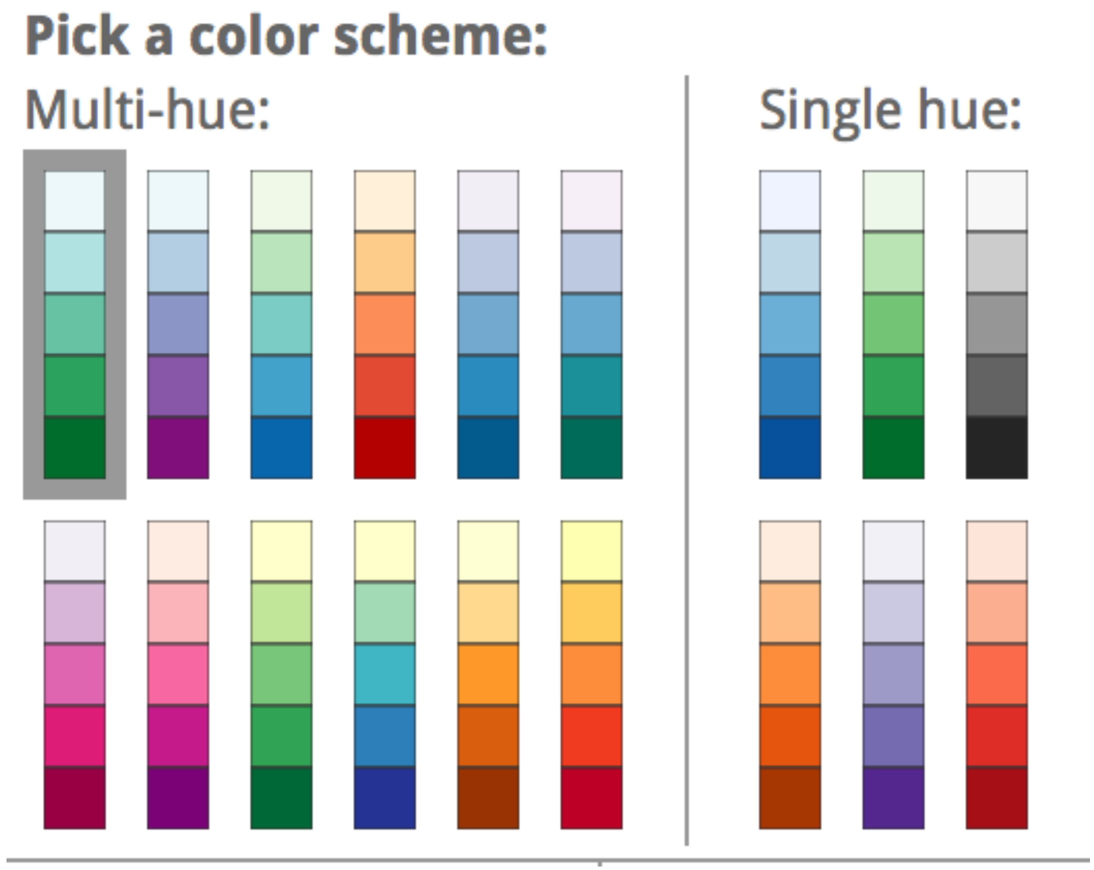
  perception of value

  perception of pattern

  - reds = hot, blues = cold

  red = danger

  colorbrewer2.org (Cynthia Brewer)



Color Brewer recommended color schemes

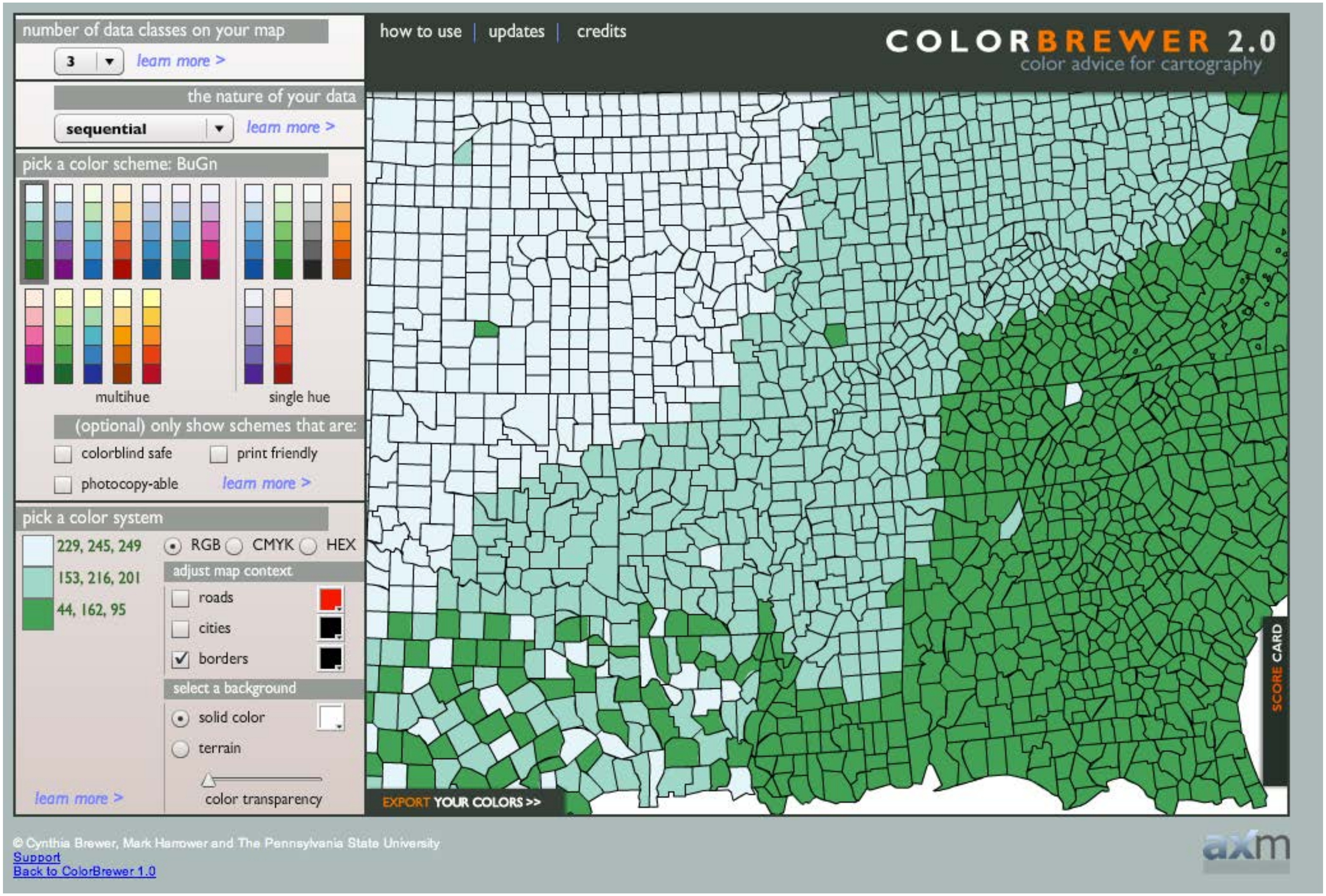
Legends

- Sequential Legend

  ordered data

  low to high

  not appropriate for categorical data

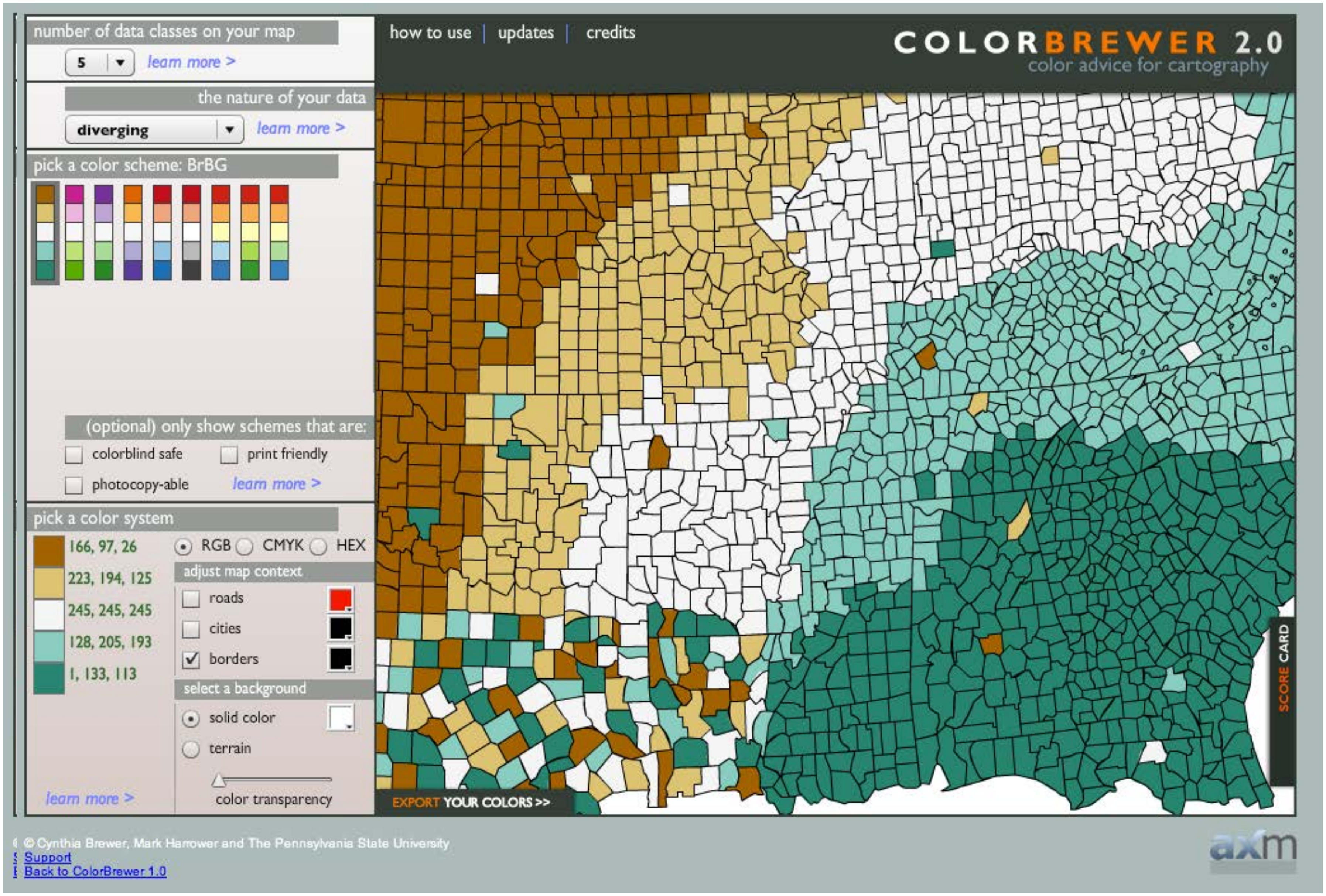


ColorBrewer sequential legend

- Diverging Legend

  equal emphasis on mid-range and extremes in either direction

  stresses difference from central tendency, rather than ordering of data



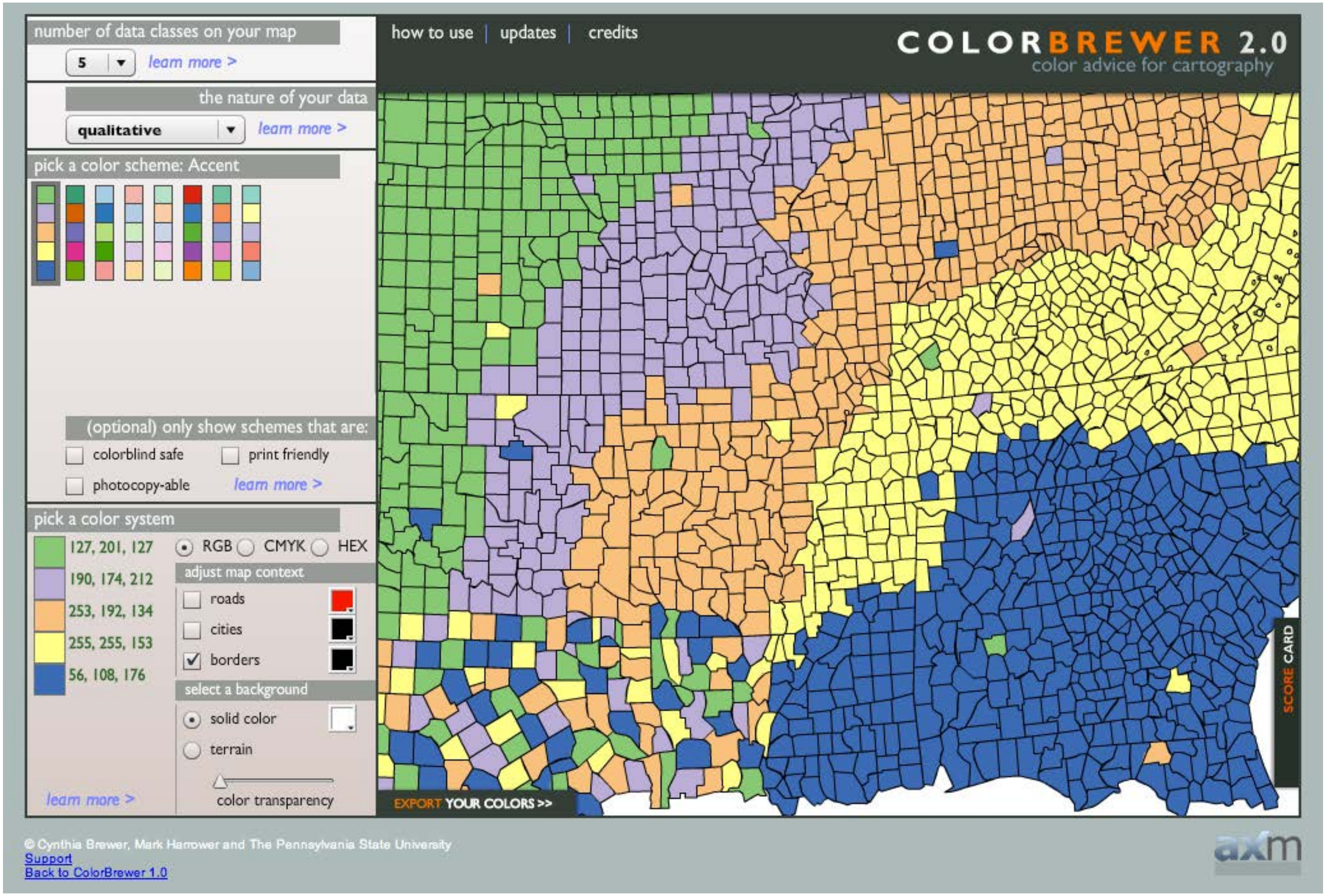
ColorBrewer diverging legend

- Qualitative Legend

    for categorical data

    no ordering, no high or low

    stress discrete categories, not values



ColorBrewer qualitative legend

Statistical Maps

- Quantile Map

  data sorted from low to high

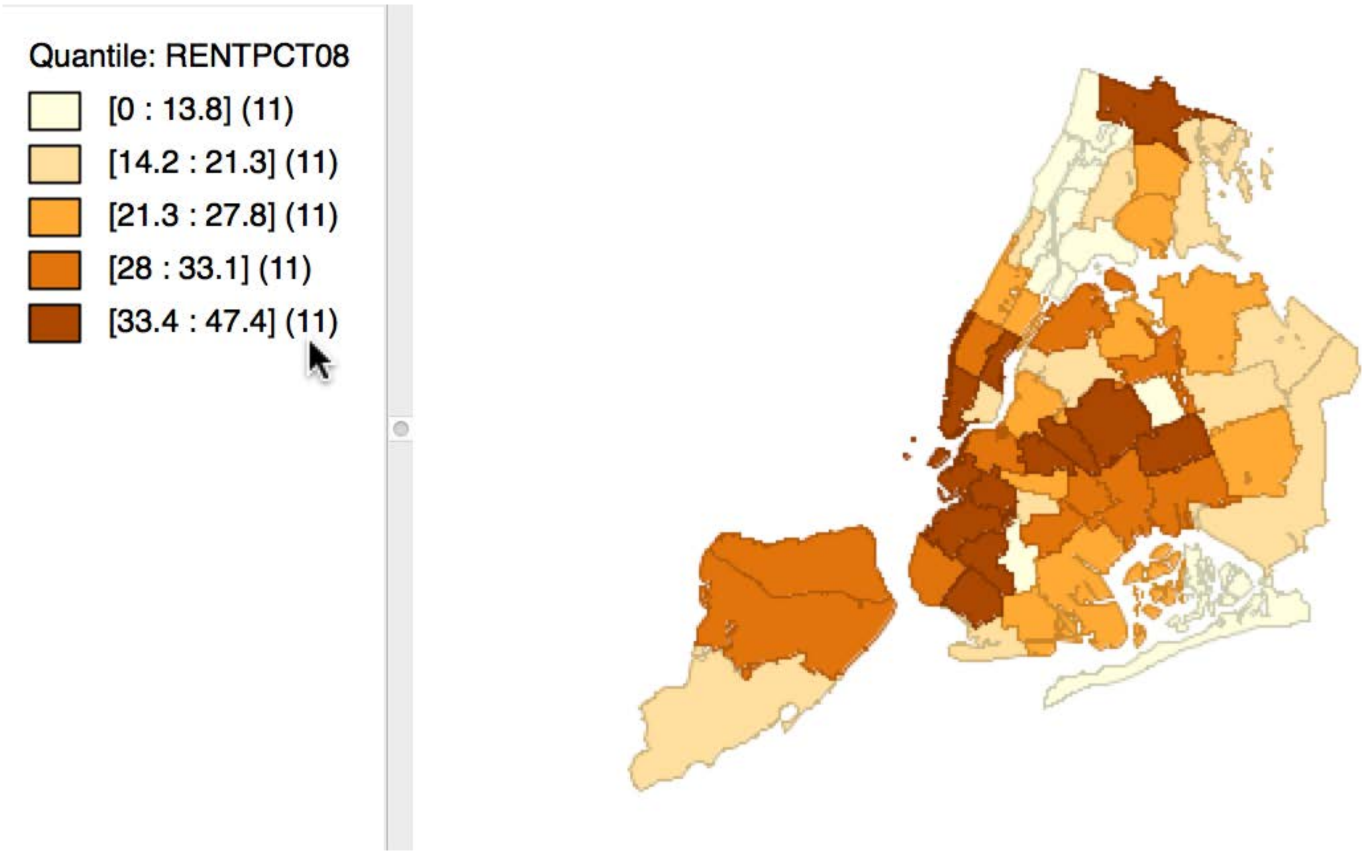
  equal number of observations in each interval

  examples

    quartile map (4 categories)

    quintile map (5 categories)

  possible issues with ties



quintile map (NYC % rental units)

- Box Map

  identifying outliers

    same principle as in box plot

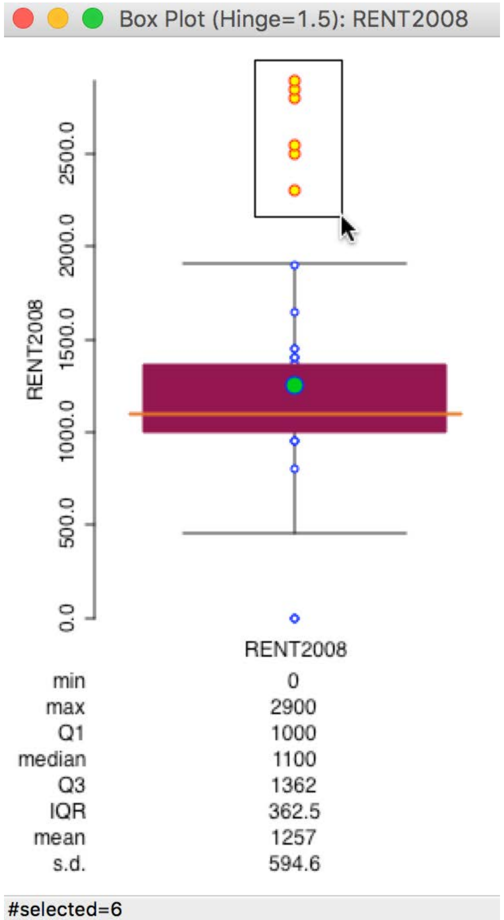
    fence = median + 1.5 IQR or + 3 IQR

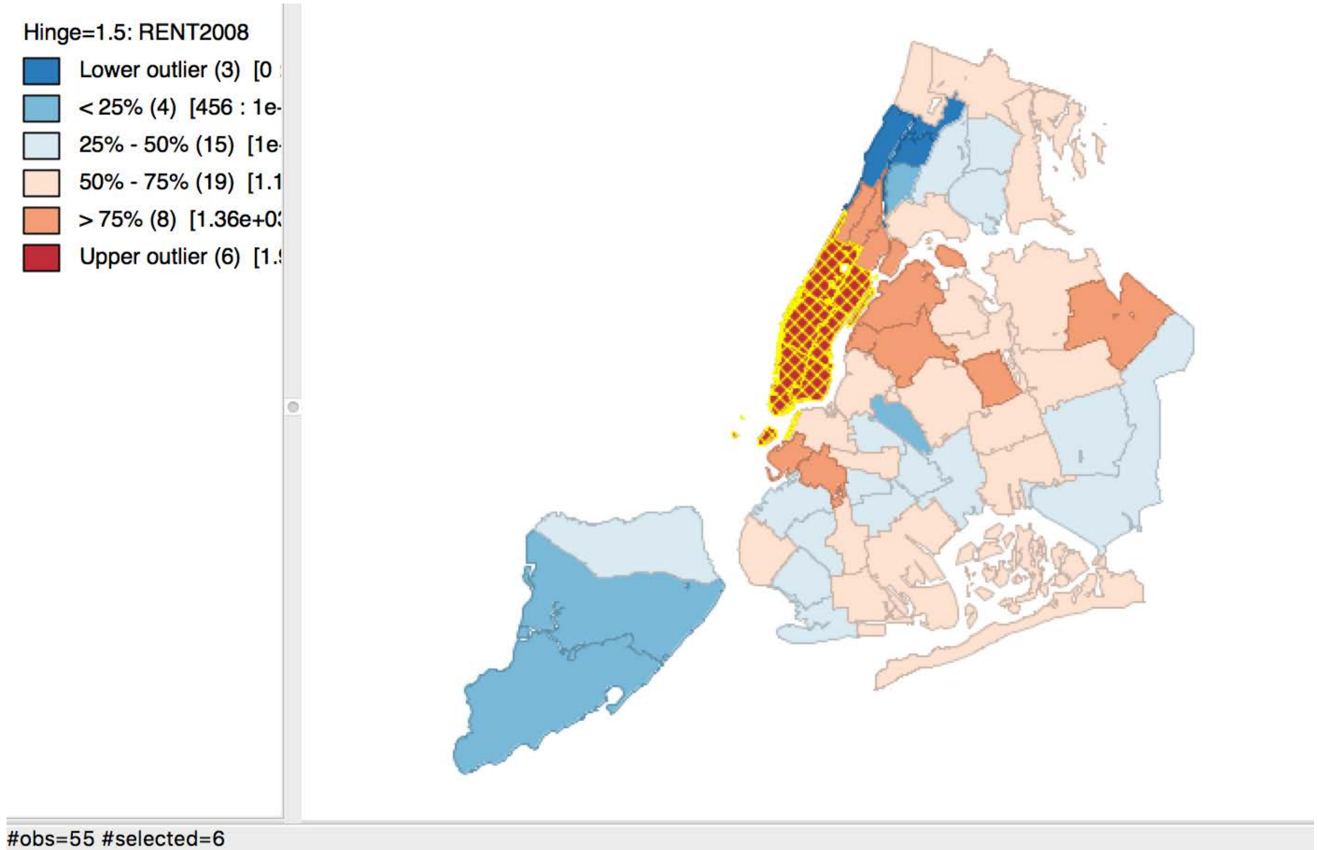
      IQR = inter quartile range, 25% to 75%

  six intervals

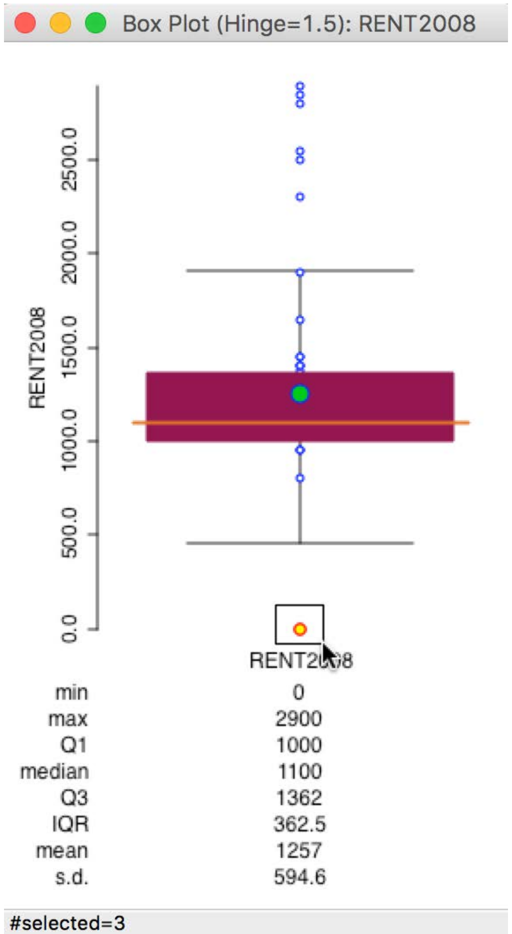
    same principle as quartile map

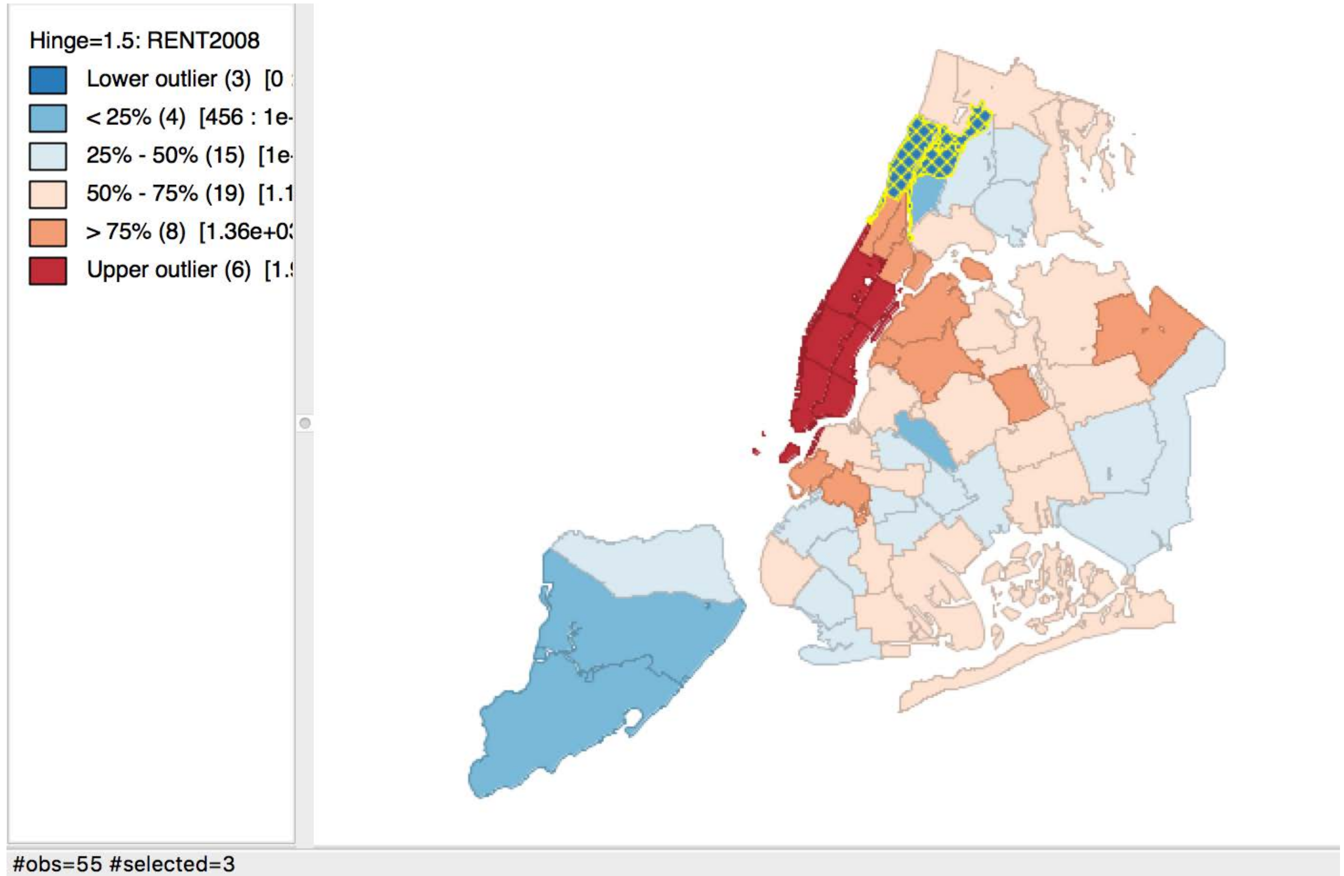
    outliers identified as a separate category





upper outliers in box plot and box map
(NYC median rent 2008)





lower outliers in box plot and box map
(NYC median rent 2008)

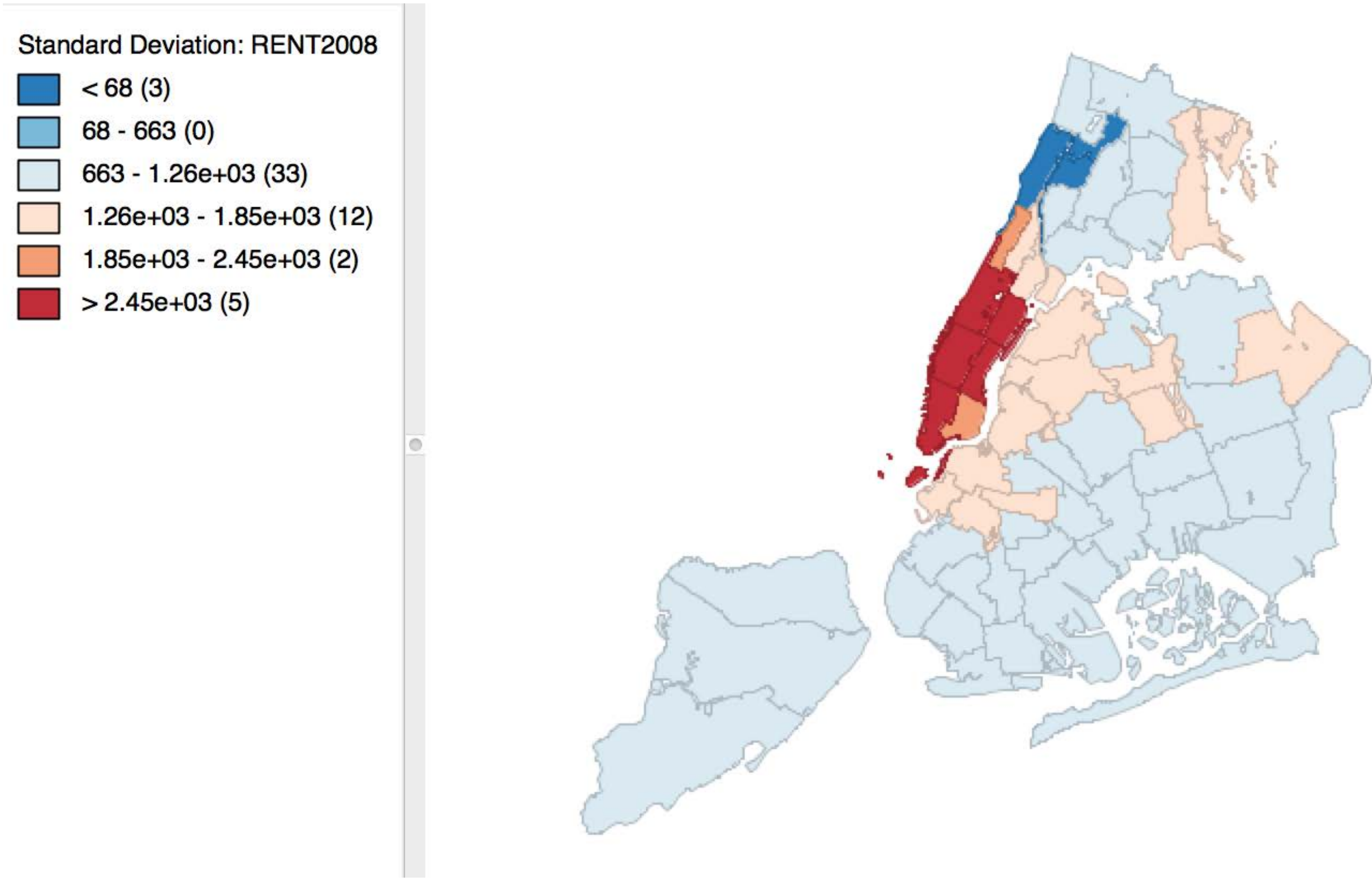
- Standard Deviational Map

  based on standardized data values

    mean = 0, standard deviation = 1

  intervals correspond to one standard deviation

  outliers are more than 2 standard deviations from the mean



standard deviational map
(NYC median rent 2008)

- Cartogram

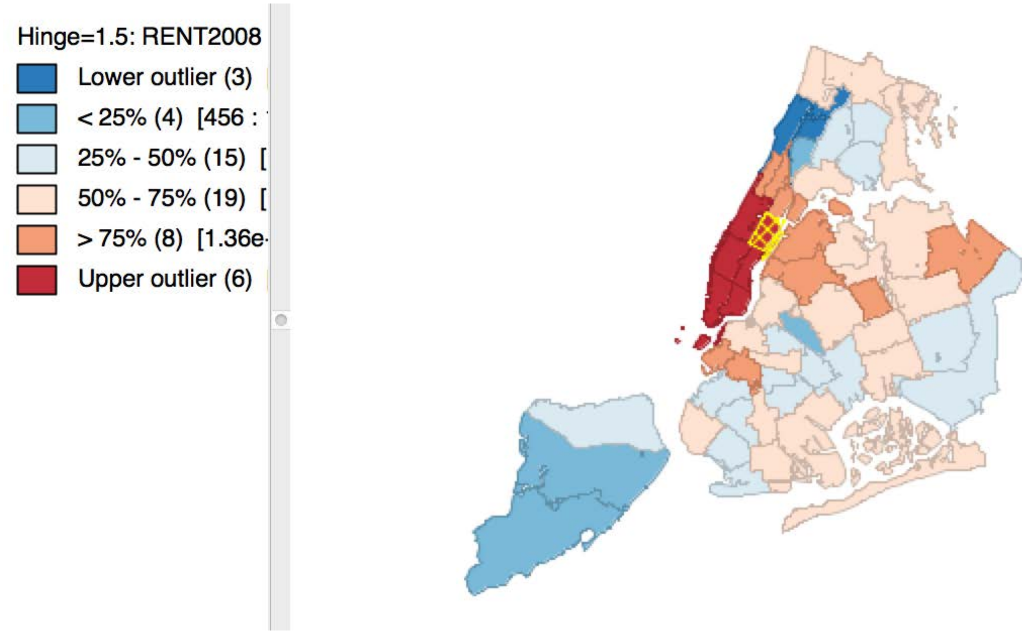
  areal unit proportional to variable of interest

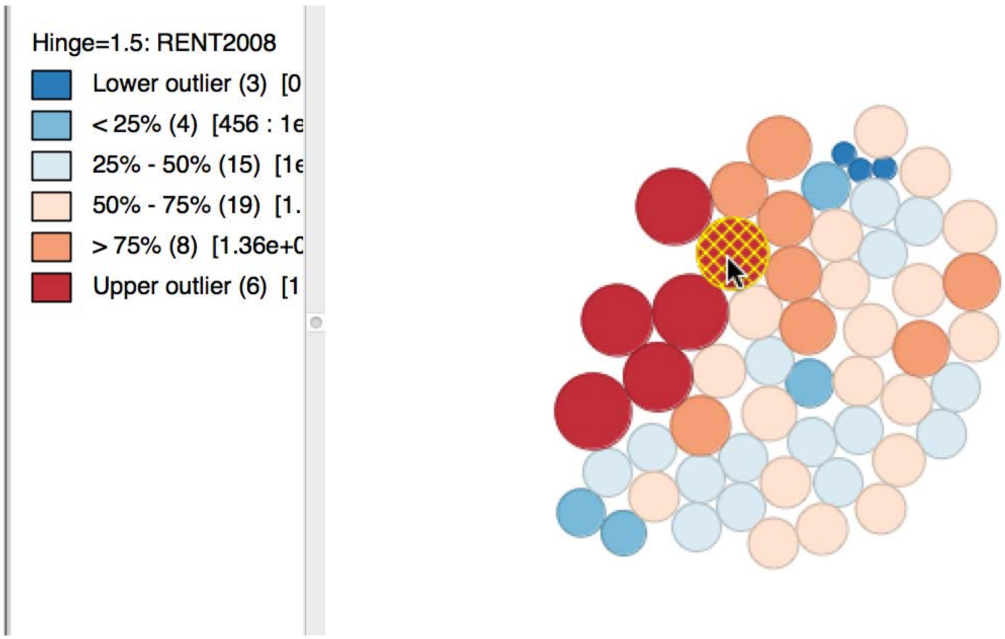
  avoid misleading effect of area

  use transformed shapes

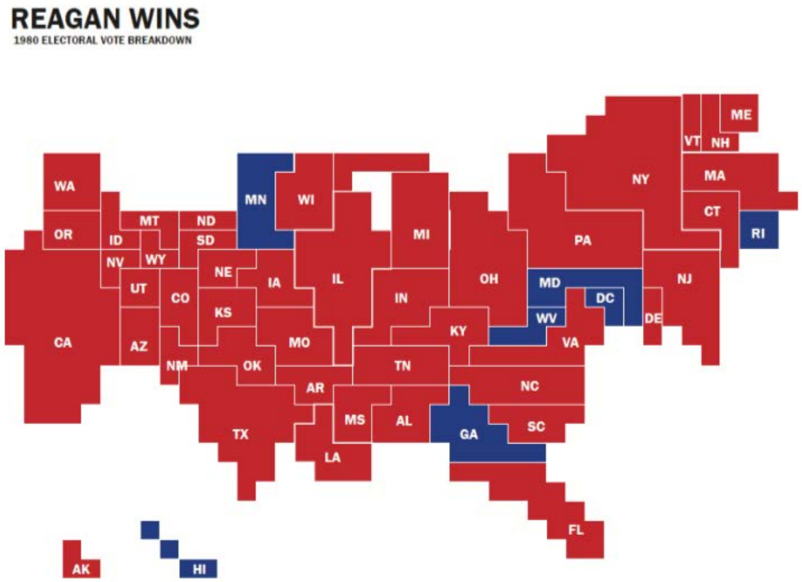
    circular cartogram

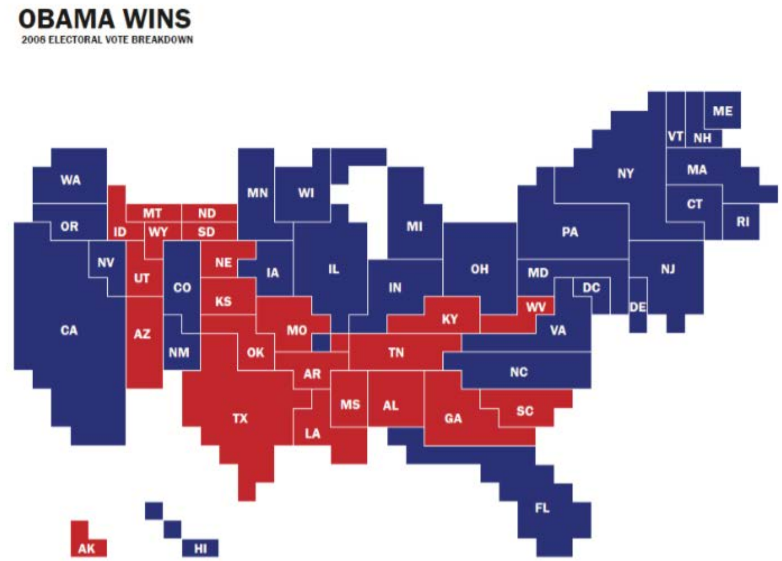
    contiguous cartogram





box map and circular cartogram





contiguous cartogram
area = number of votes in electoral college
source: Sarah Williams

- Conditional Maps

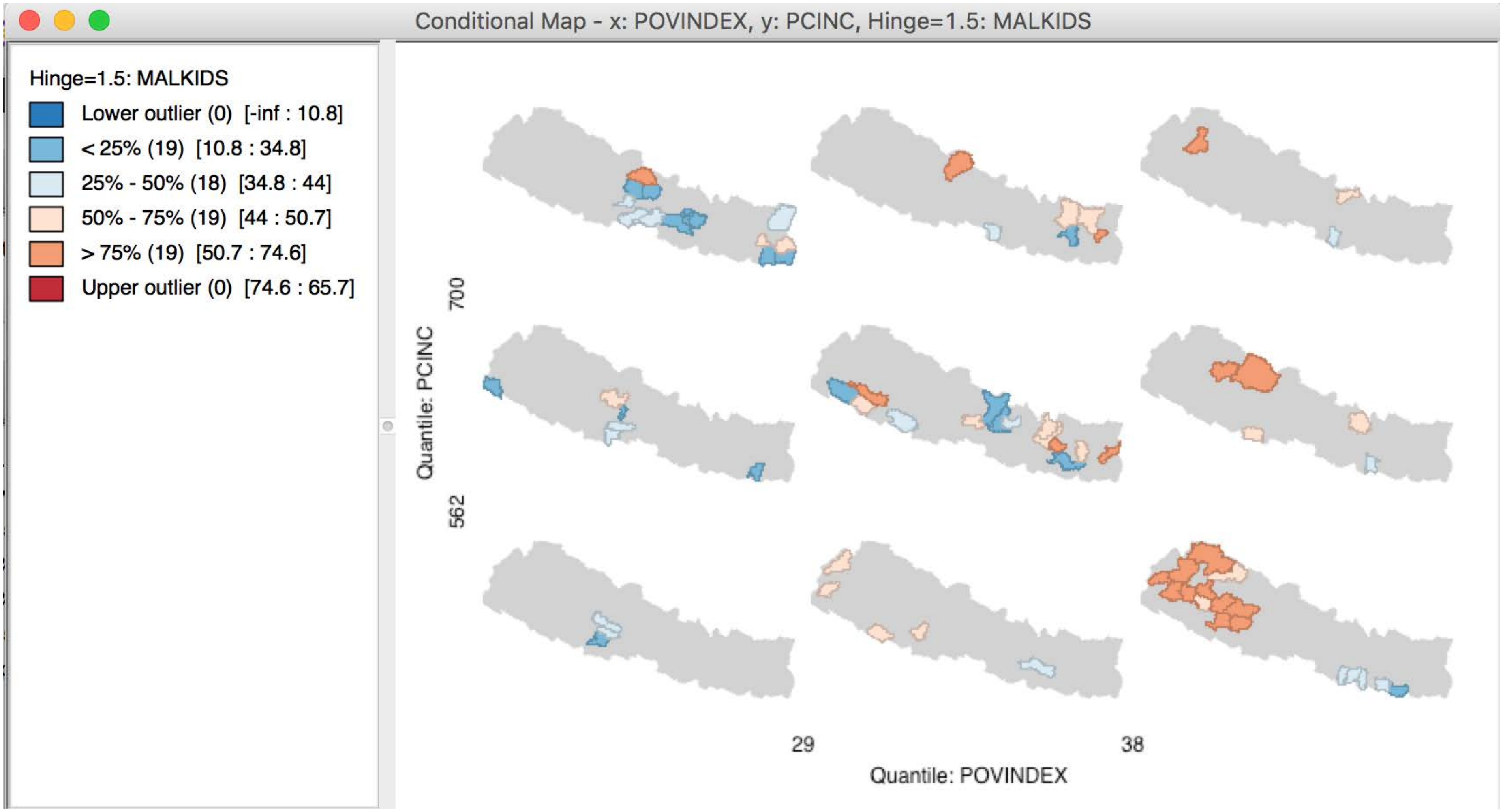
    cc maps, conditioned choropleth maps (Carr)

    special case of trellis graphs

    micromap matrix

        conditioning variables on the axes

        matrix of mini maps for the variable of interest conditioned by the values on the axes



child malnutrition cc map conditioned on poverty index and per capita income (Nepal districts)

- Map Animation

  map movie

  highlight observations in increasing or decreasing order

    one at a time

    cumulative

  visual impression of patterning/clustering

Mapping Rates

Risk and Rates

- Concept of Risk

    many meanings

    risk = probability that an event may occur

    actual risk is not observed

        only events are observed

- Risk Estimate

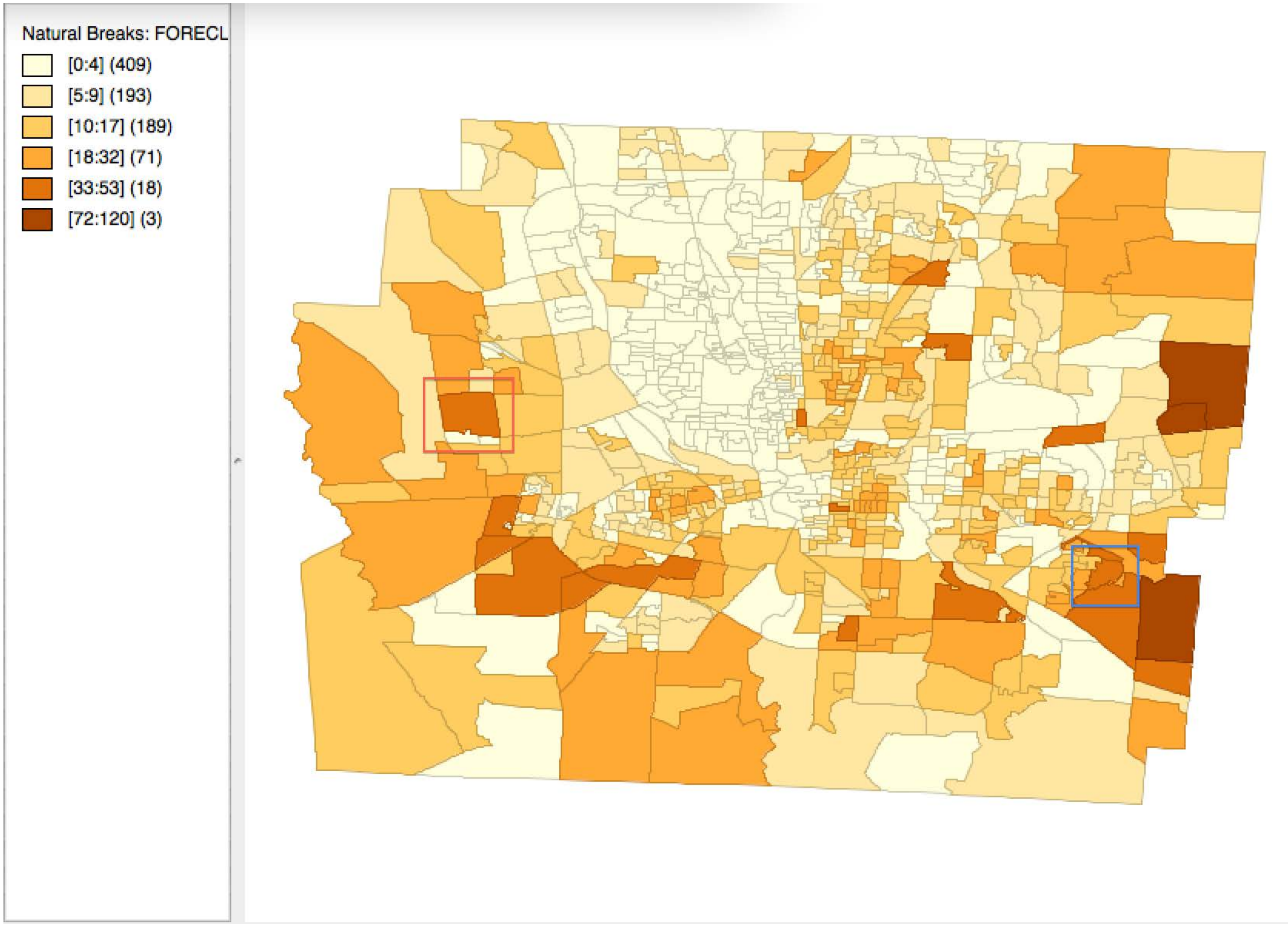
  raw rate or crude rate

  number of events / population at risk

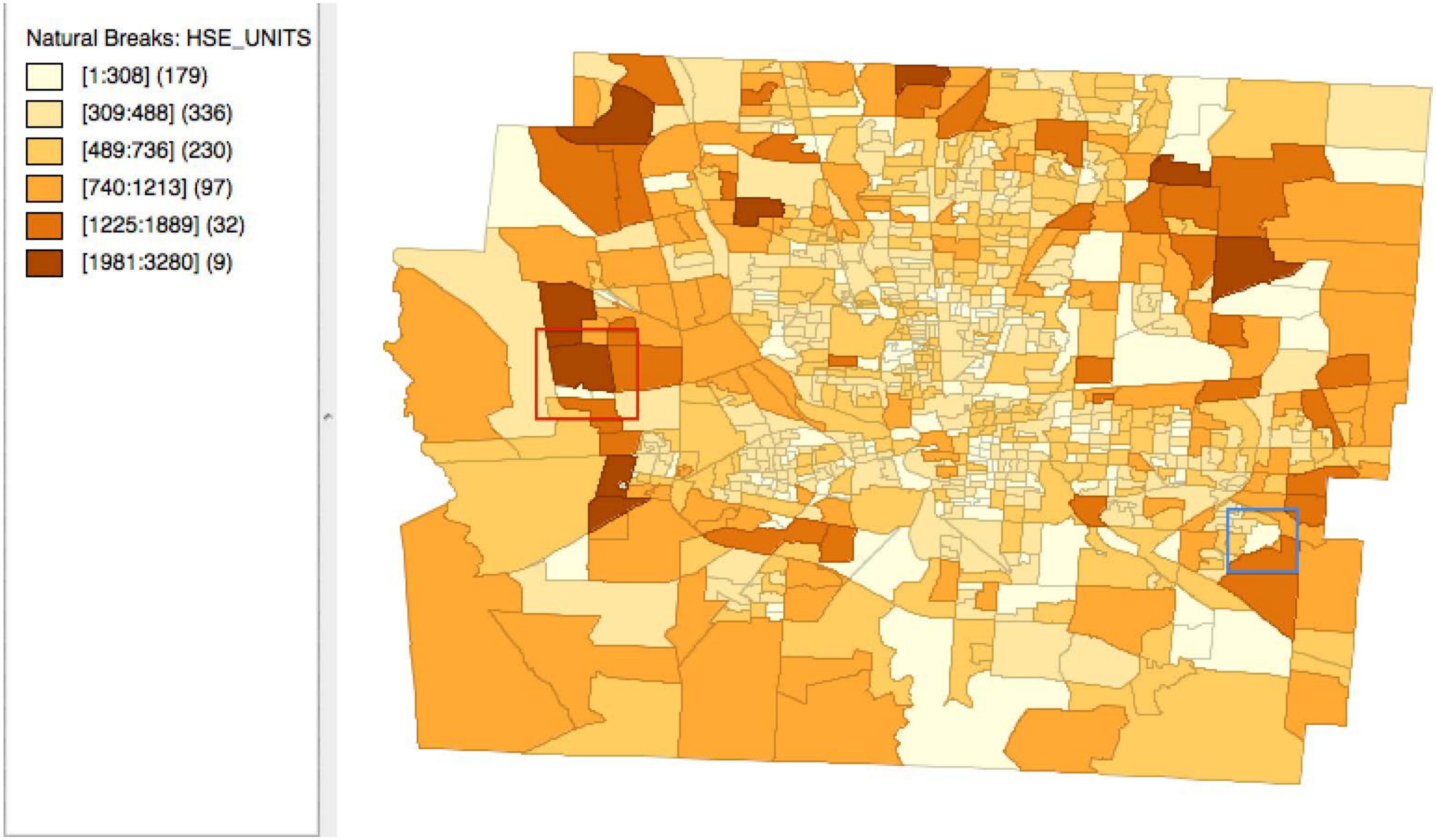
    typically expressed in per 1,000 or some multiple

  crude rate is maximum likelihood estimate

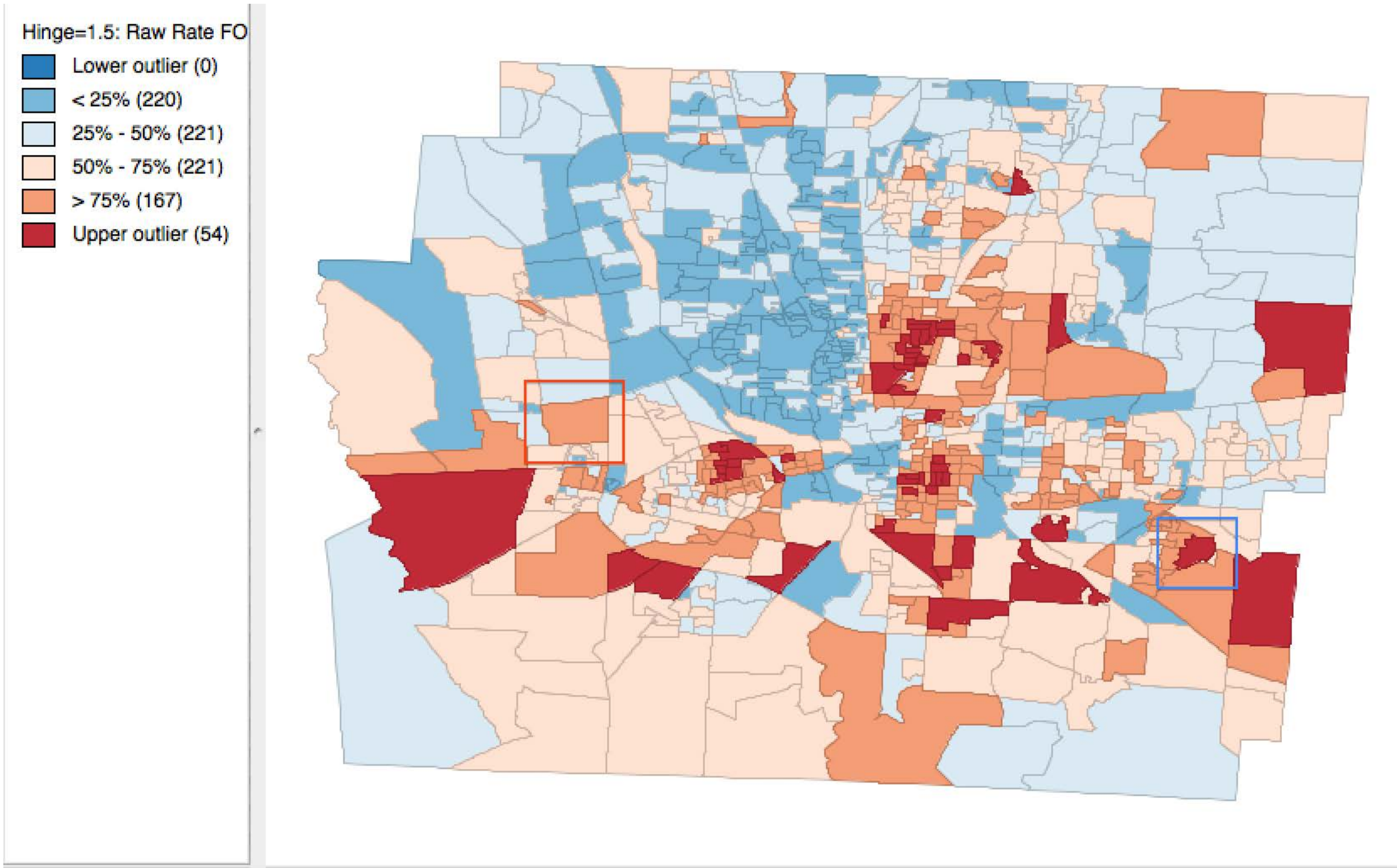
- Rate Maps
  - focus on spatial heterogeneity
  - risk is not uniform across space
    - interest in identifying areas of elevated risk
    - associate elevated risk with causal factors



Foreclosure Count in Franklin county (OH), 2007



Housing Units in Franklin county (OH), 2007



Foreclosure Rate Outliers in Franklin county (OH), 2007

Excess Risk

- What is Excess Risk?

  elevated risk = higher than some standard

  what is the standard

    rate computed for a reference group

    e.g., foreclosure for the whole city

- Average Risk

  not the average of the rates

  total number of events / total population

    e.g., all the foreclosed homes in the metro area over all the homes in the metro area

    weighted average of the rates, weighted by their population share

- Average Risk Computation

O_i : observed number of events

P_i : "population at risk"

r_i : rate for i, $r_i = O_i / P_i$

average risk $r = (\Sigma_i O_i) / (\Sigma_i P_i)$

- Expected Events

$E_i = r \times P_i$

expected events = average rate times the "population" in area i

e.g., if average risk of an event is 1 per 10,000, then a county of 30,000 would have 3 expected events

- Relative Risk

compare observed to expected

observed = number of events, O_i

expected = number of events if average were applied to population, E_i

relative risk

observed / expected, O_i / E_i

- Excess Risk Map

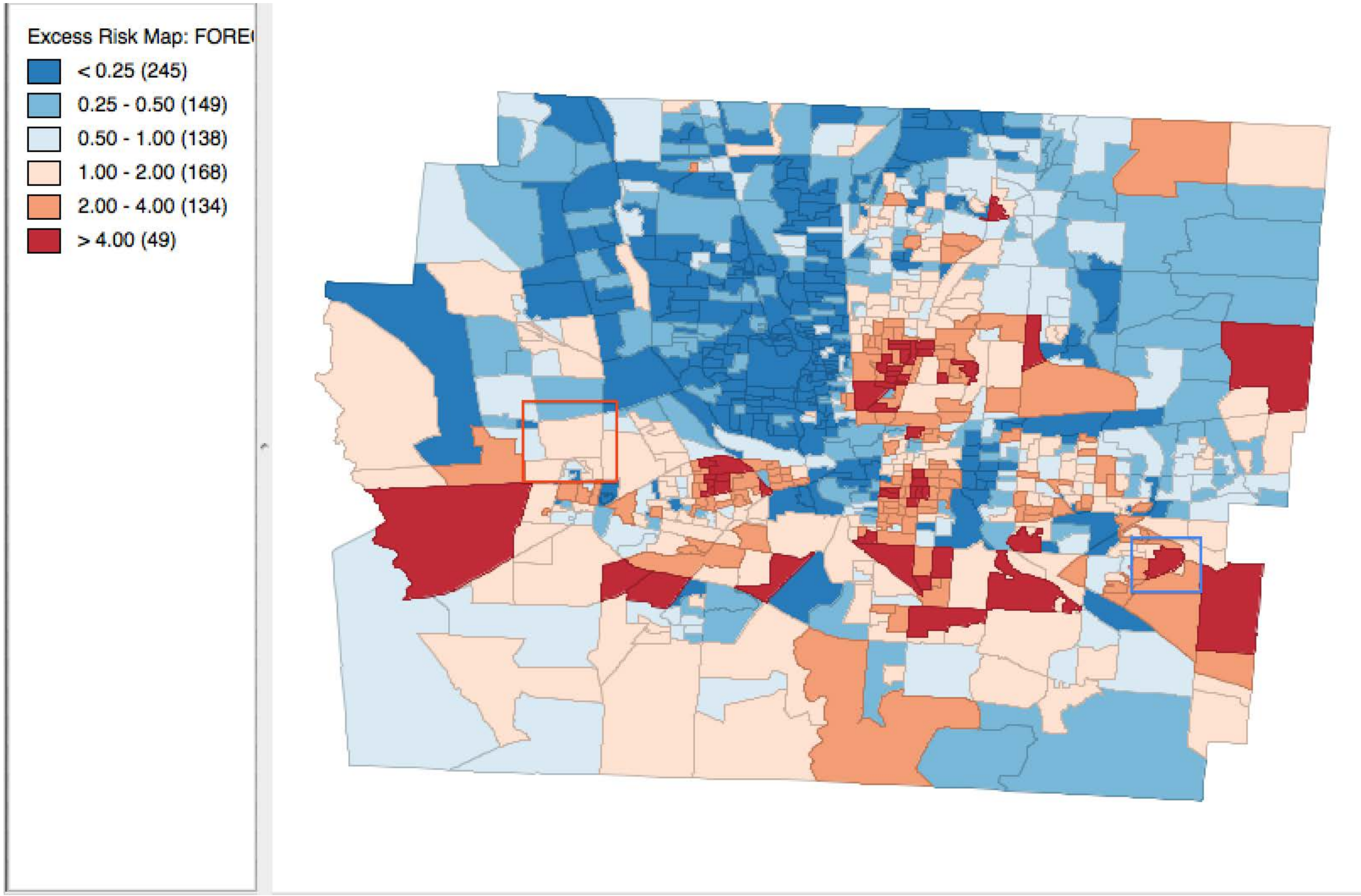
  compare relative risk to unity

  > 1: more events than on average

  higher (excess) risk

  < 1: fewer events than on average

  choropleth map of excess risk



Franklin County 2007 foreclosures excess risk

Smoothing Rates

number of events as draws from a binomial distribution

$$\text{Prob}[O = x] = \binom{P}{x} \pi^x (1-\pi)^{P-x}, \text{for } x = 0, 1, \ldots, P.$$

probability of x events given risk of π

mean: E [O] = π.P

variance: V [O] = π (1 - π).P

- Moments of the Rate Estimate

O is random variable, P is not

$r = O / P$ O events, P population

$E[r] = E[O]/P = \pi P / P = \pi$

$Var[r] = Var[O] / P^2 = \pi (1 - \pi) P / P^2$
$= \pi (1 - \pi) / P$

- Variance Instability

P in denominator

smaller areas have larger variance = less precision

Example

with true (unknown) $\pi = 0.1$

Pop 1 = 500 and Pop 2 = 100,000

SE1 = 0.013 and SE2 = 0.0009

- Why Smooth?

  rate estimates have variable reliability

    less precision for smaller areas

    why trust (e.g., no events = zero risk?)

  borrow strength

    use additional information to improve estimate

- Shrinkage (James-Stein)

    new estimate that improves overall precision while sacrificing some bias

        bias-variance tradeoff

    shrink crude rate towards overall mean

        overall mean contains useful information

        shrink (smooth) rate as inverse function of variance

- **Effect of Shrinkage**

smoothing depends on variance

small population > large variance
> a lot of smoothing

large population > small variance
> little smoothing

- Empirical Bayes Smoothing

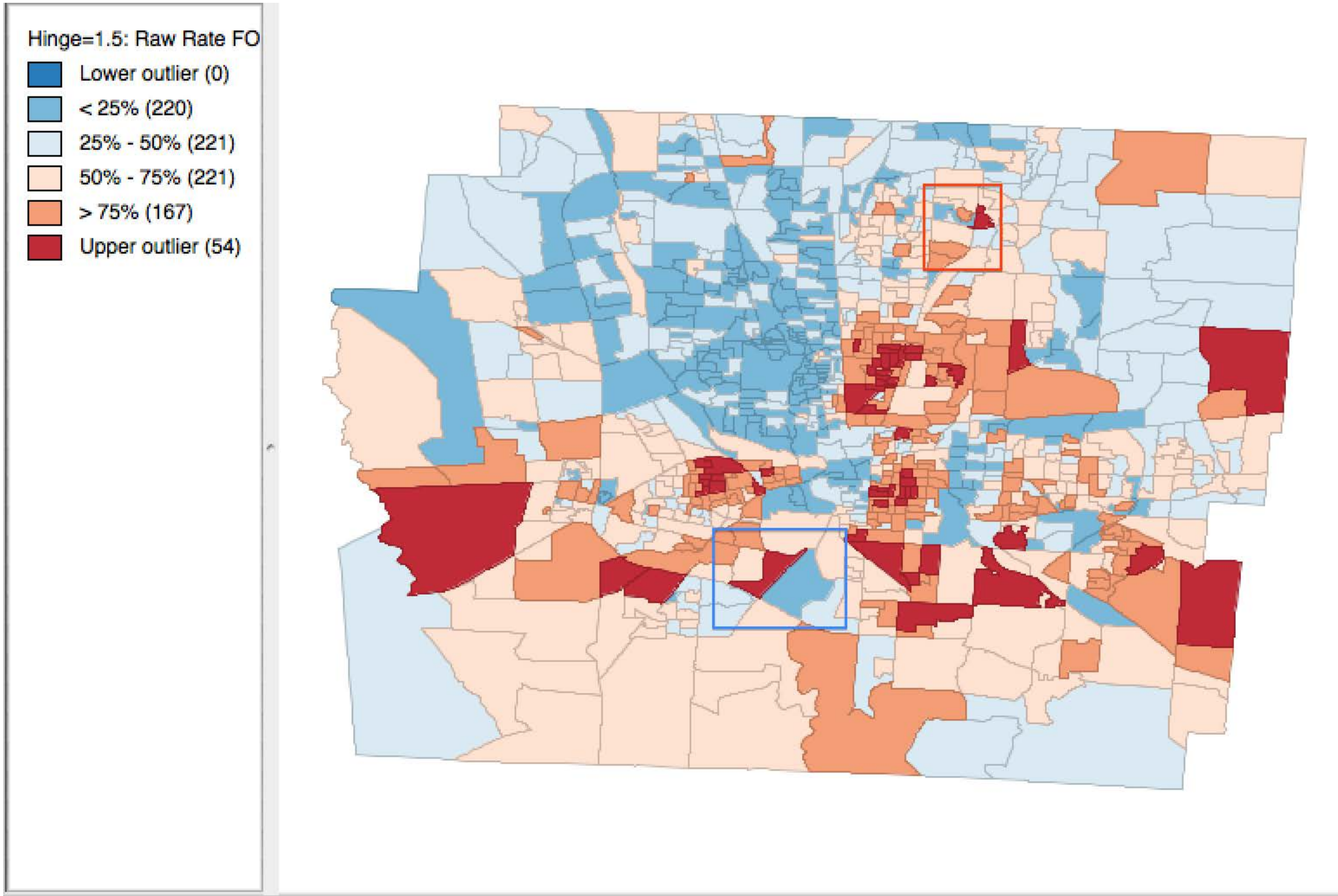
shrinkage estimate as a weighted average of the crude rate and a prior

prior estimated from the data (reference rate)

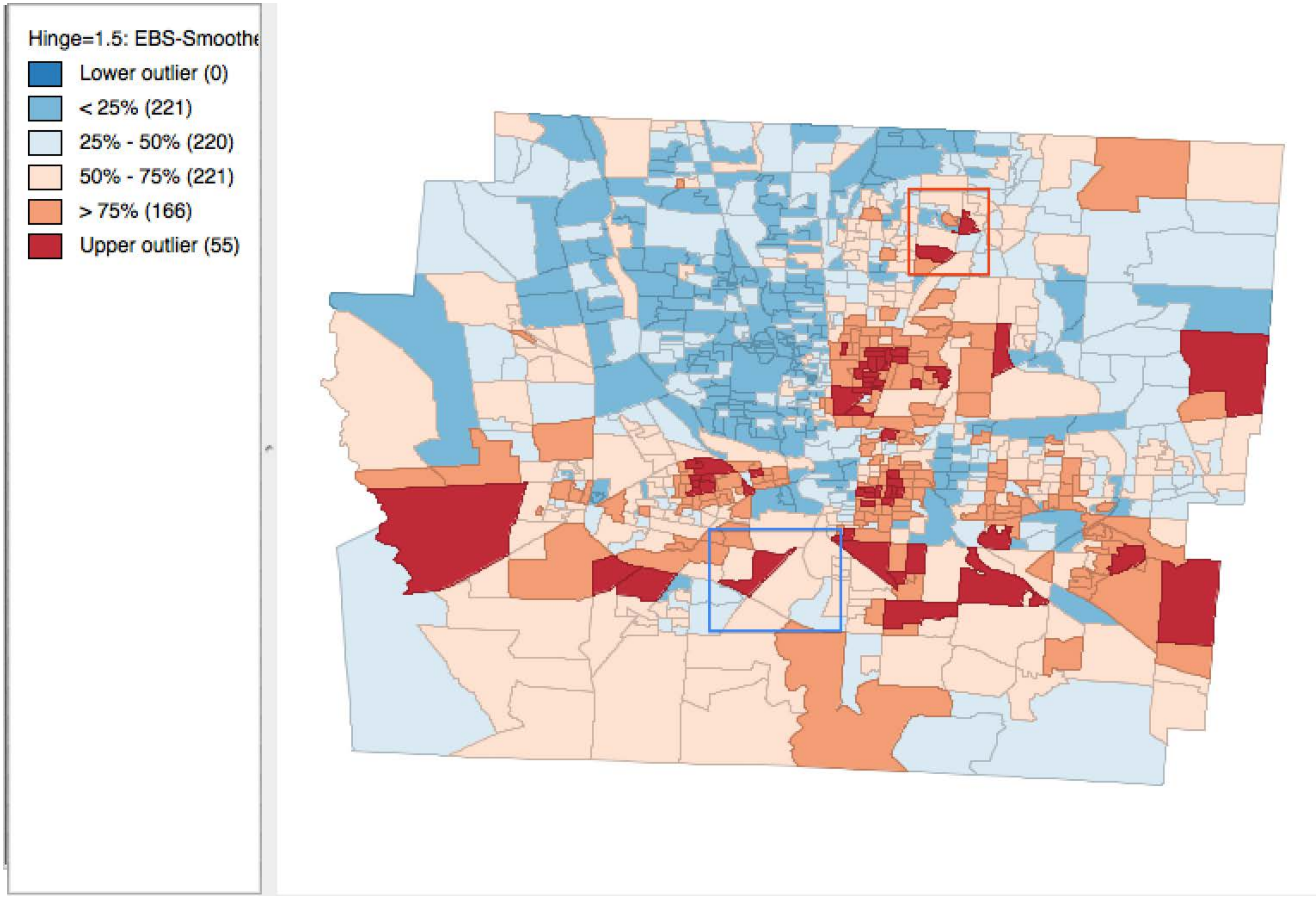
hence "empirical" Bayes

$\pi_i = w_i r_i + (1 - w_i)\theta$ with θ as reference rate

weights inversely proportional to variance



Foreclosure Raw Rate in Franklin county (OH), 2007



Foreclosure EB Rate in Franklin county (OH), 2007

- Effect of Empirical Bayes Smoothing

    position changes in cumulative distribution

        small outlier areas move towards the overall mean

        large high/low value areas may become outliers

    spurious outliers are removed

To Smooth or Not To Smooth

- Pros of Smoothing

    better estimates in MSE sense

    adjusts for variance instability

    removes spurious outliers

    better estimates of true extremes

- Cons of Smoothing

    - degree of arbitrariness

        - sensitive to smoothing method

        - oversmoothing hides interesting "outliers"

- Smoothing in Practice
  - some healthy debate
    - use of original data vs transformed data
    - many options
  - need for sensitivity analysis