Introduction to Graphs, Maps, and Visualization

sic parvis magna

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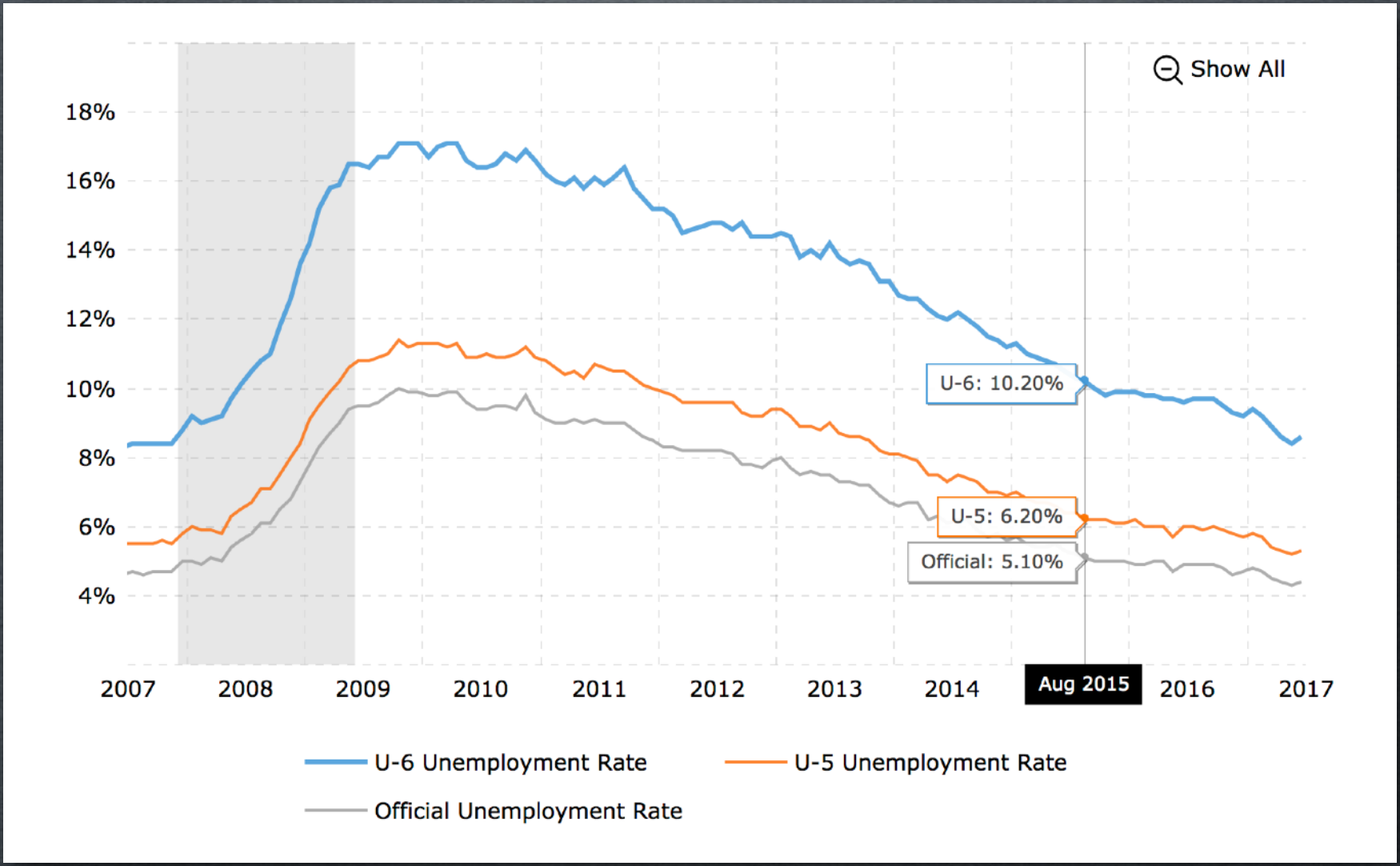
Overview

1. Present an overview of graphs and maps
   - graphs and guidelines on usage
   - thematic maps and guidelines on usage
2. Discuss perceptual foundations that underlie some of these methods
   - color, texture, motion
   - visual attention
   - visual memory
3. Describe methods in the context of application domains similar to those participating in the proposal
   - marine biology, astrophysics, elections

Graphs

- Traditional method for comparing data attributes
  - E.g., line chart, bar chart, scatterplot, histogram
- Different graphs are used for different tasks:
  - tracking changes (line graph)
  - correlations, relationships (X-Y plot)
  - correlations, clustering (scatterplot)
  - category comparison (bar chart)
  - distributions (pie chart)
  - uniqueness and overlap (Venn diagram)
- Graph elements can represent multiple attribute values

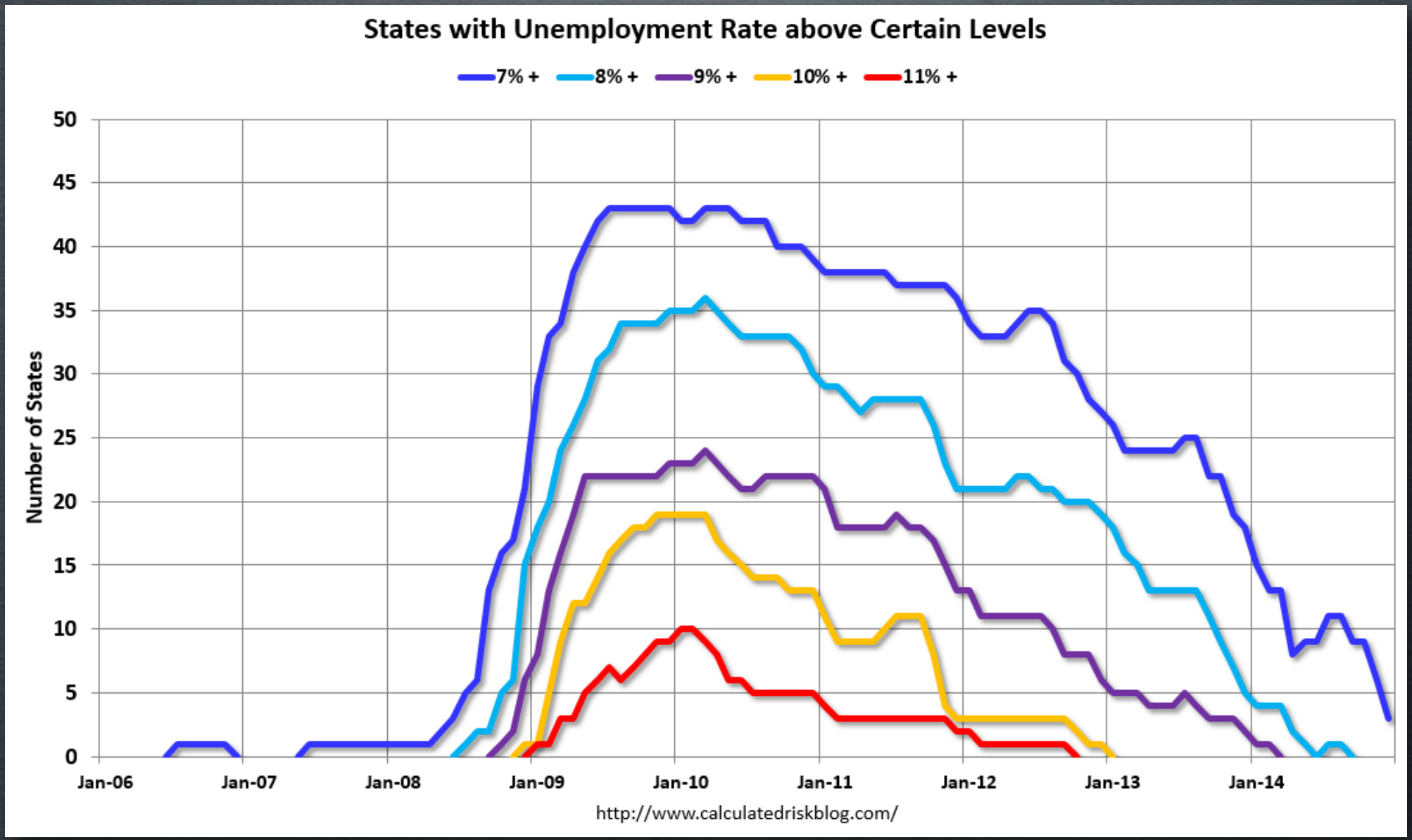
Line Chart



U.S. Unemployment Line Chart

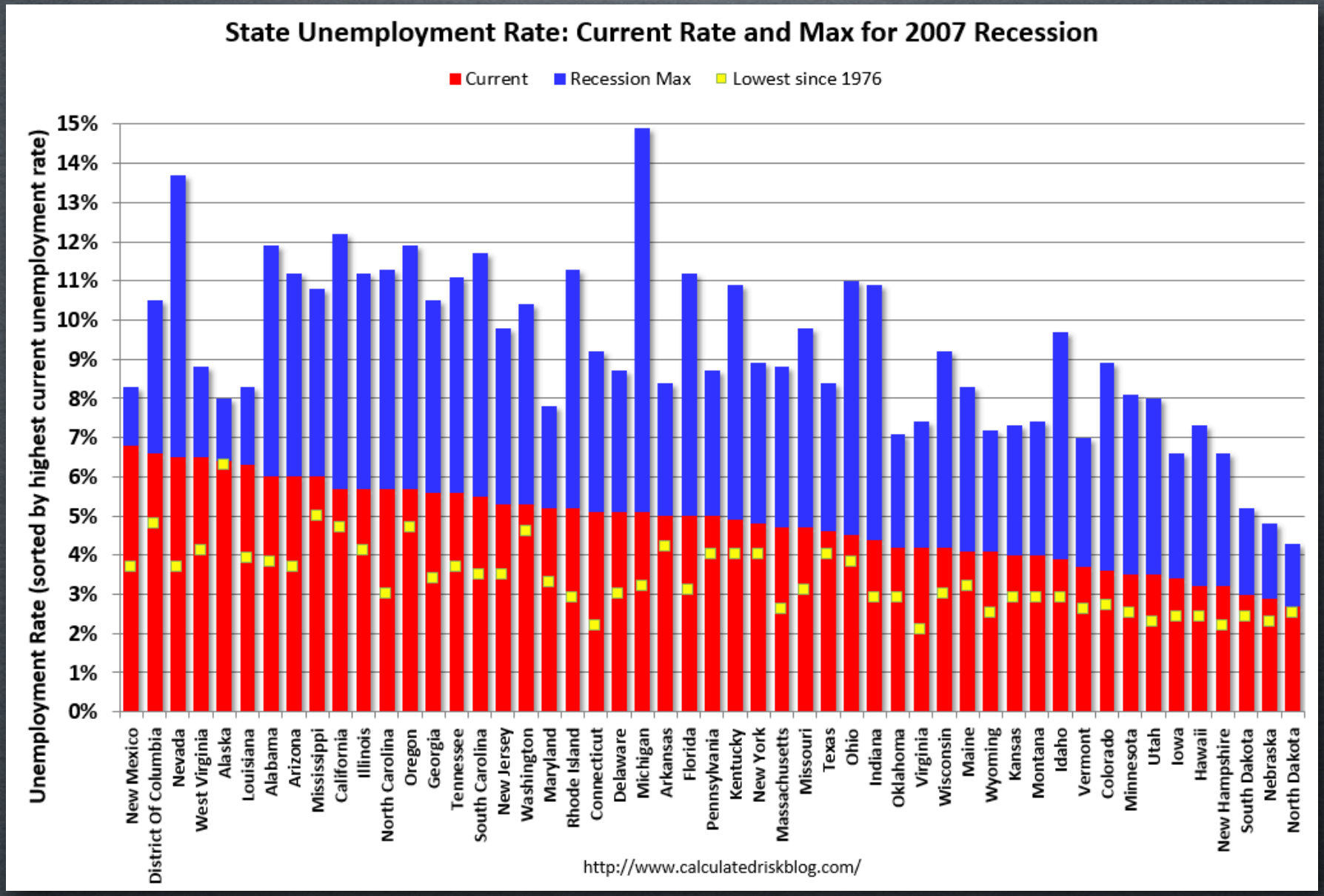
U5: Unemployed, discouraged, marginally attached
U6: Unemployed, Discouraged, Marginally Attached, Part Time Seeking Full Time

Line Chart



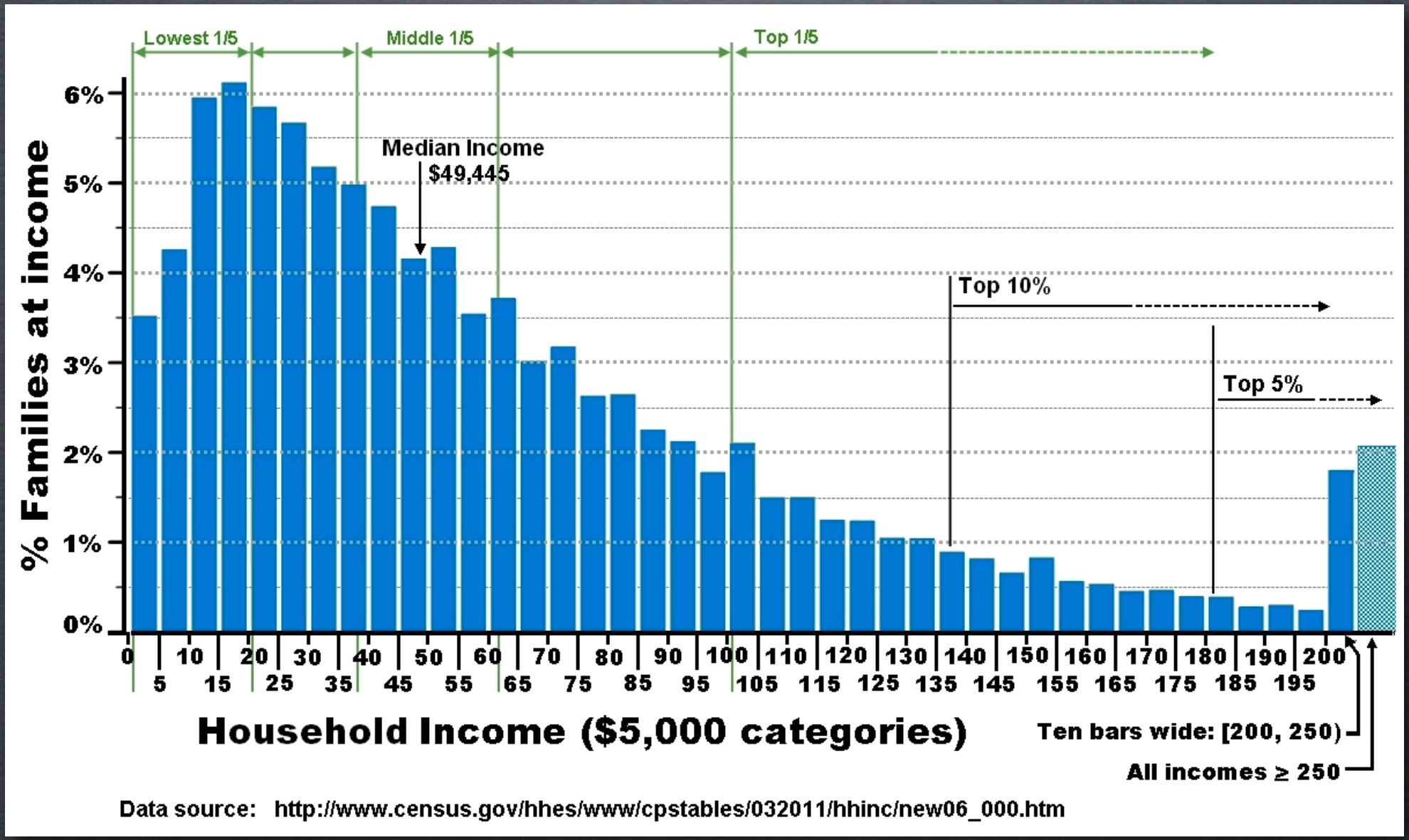
Line Chart of Number of States Above 2006 Unemployment Level By Quarter

Bar Chart



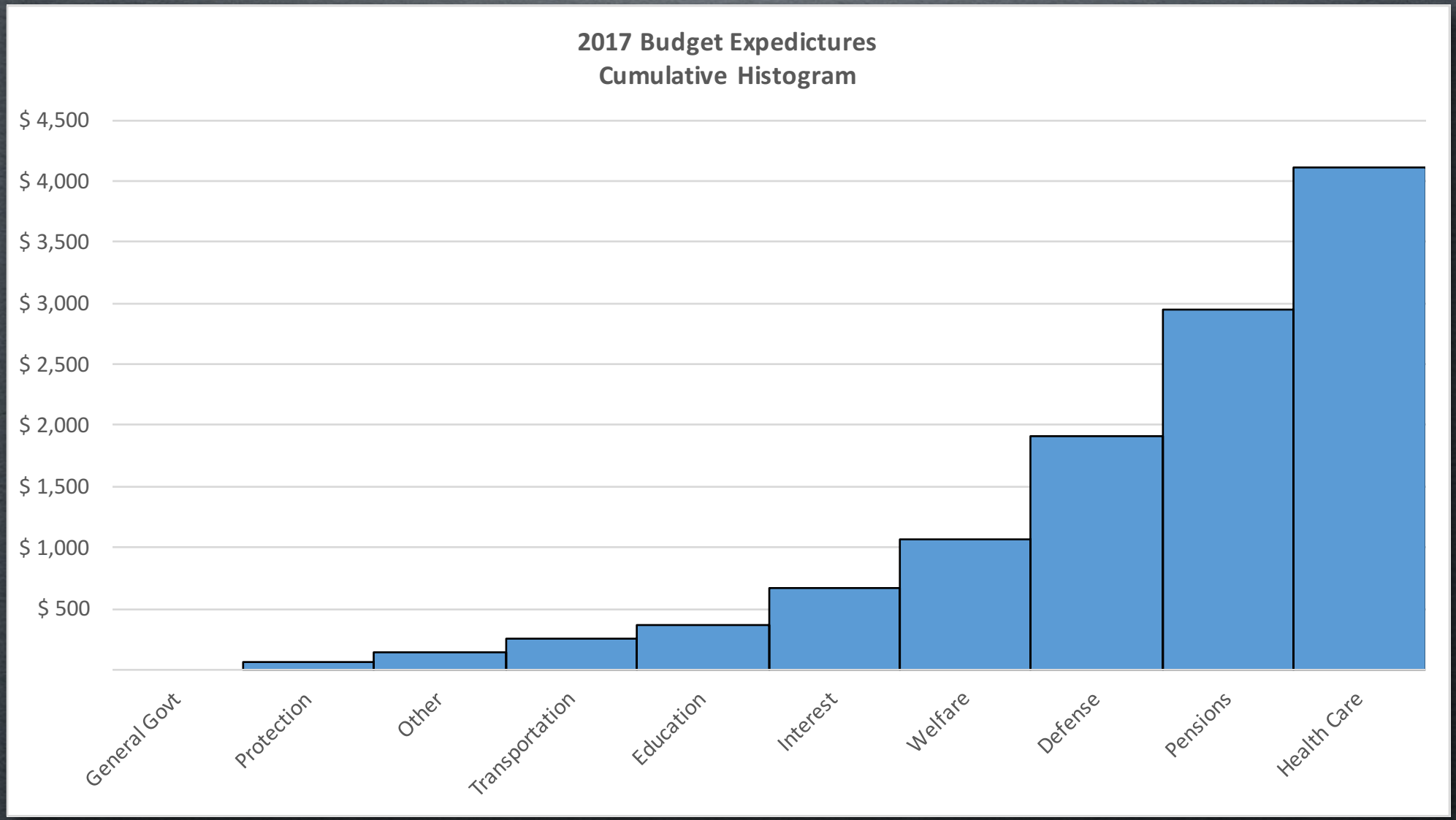
Stacked Bar Chart of December 2015 Unemployment By State

Histogram



Histogram of 2013 US Household Income by $5000 Bins

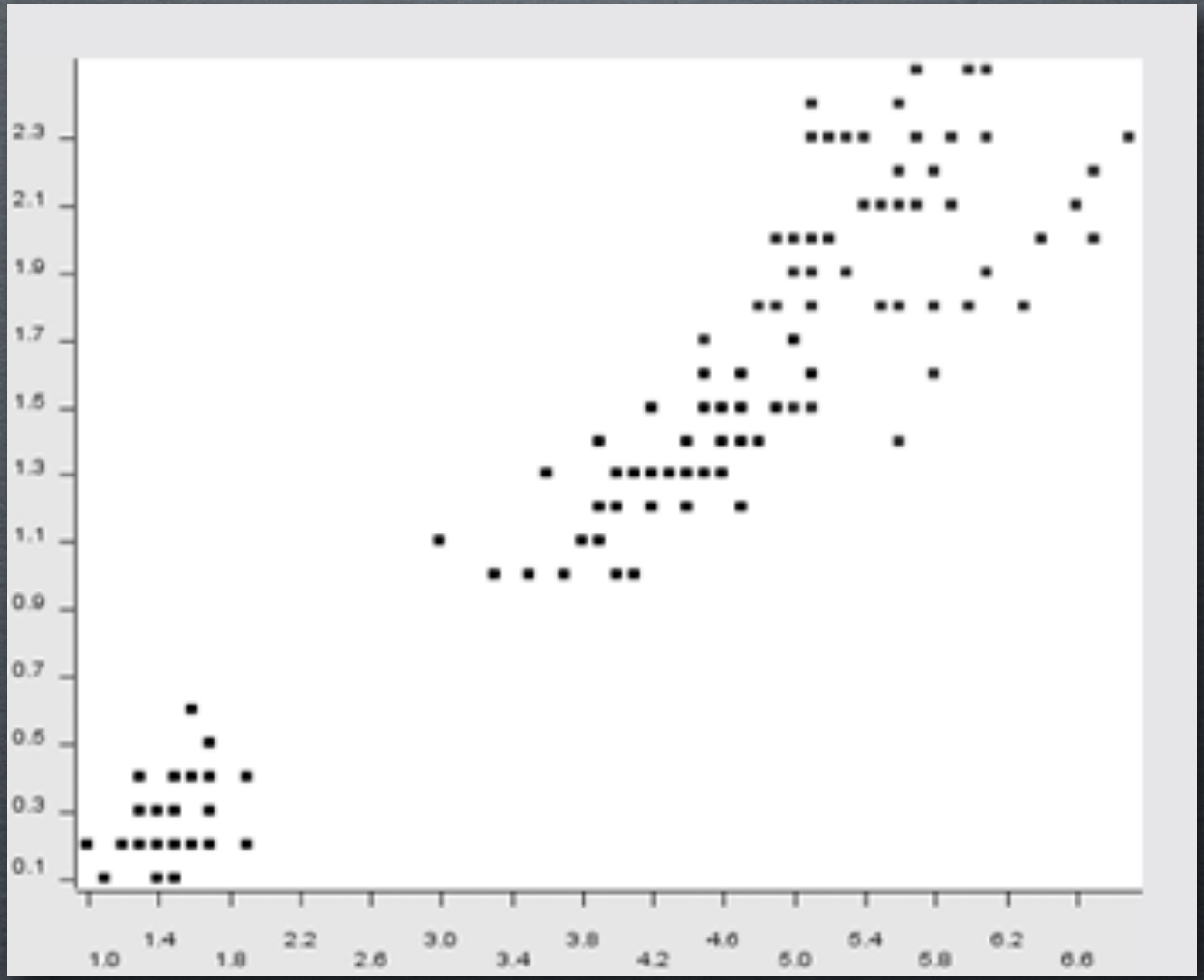
Cumulative Histogram



Cumulative Histogram of 2017 Federal Budget Expenditures

SCATTERPLOTS

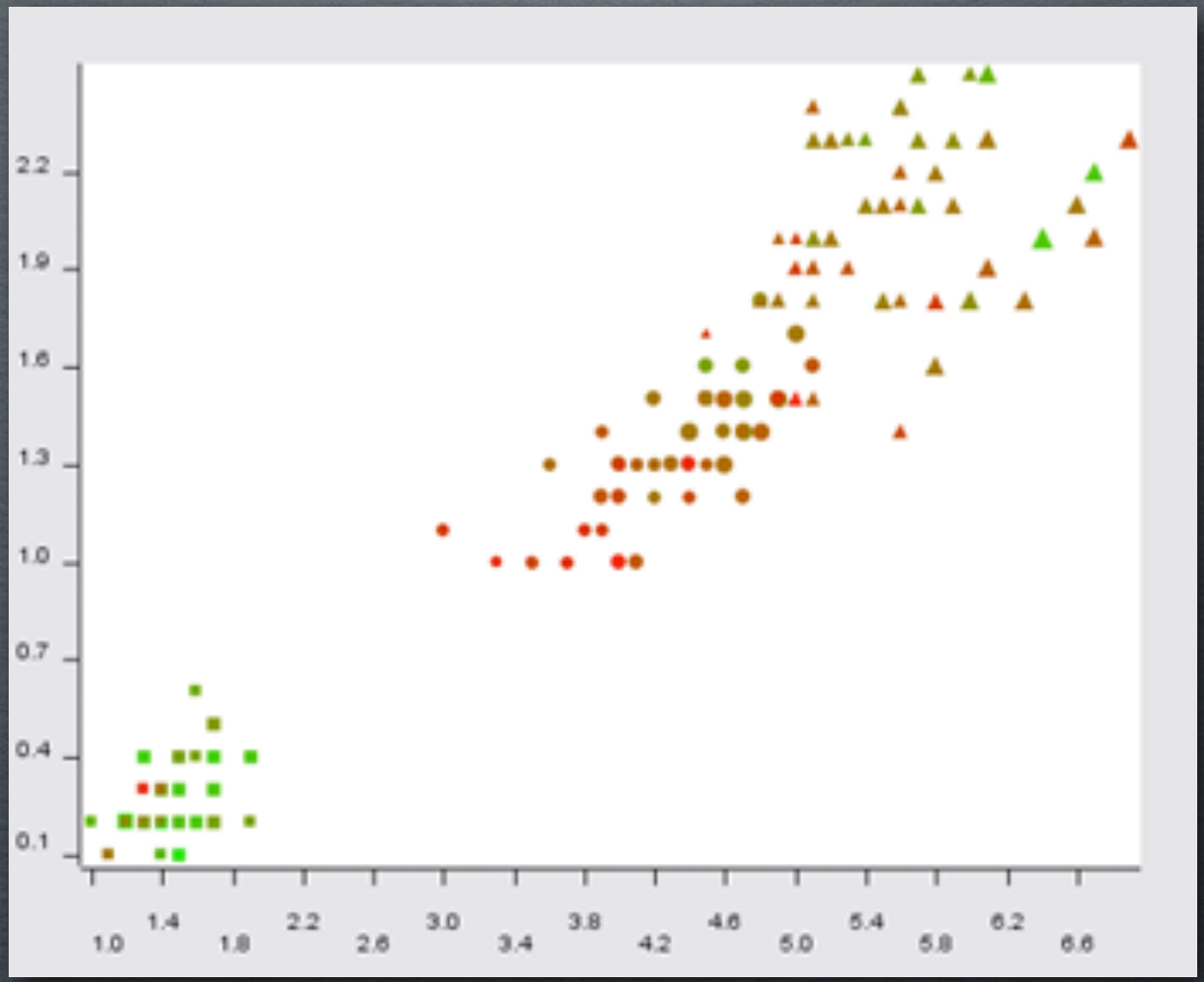
Iris Plant Database
Petal Length → X, Petal Width → Y



SCATTERPLOTS

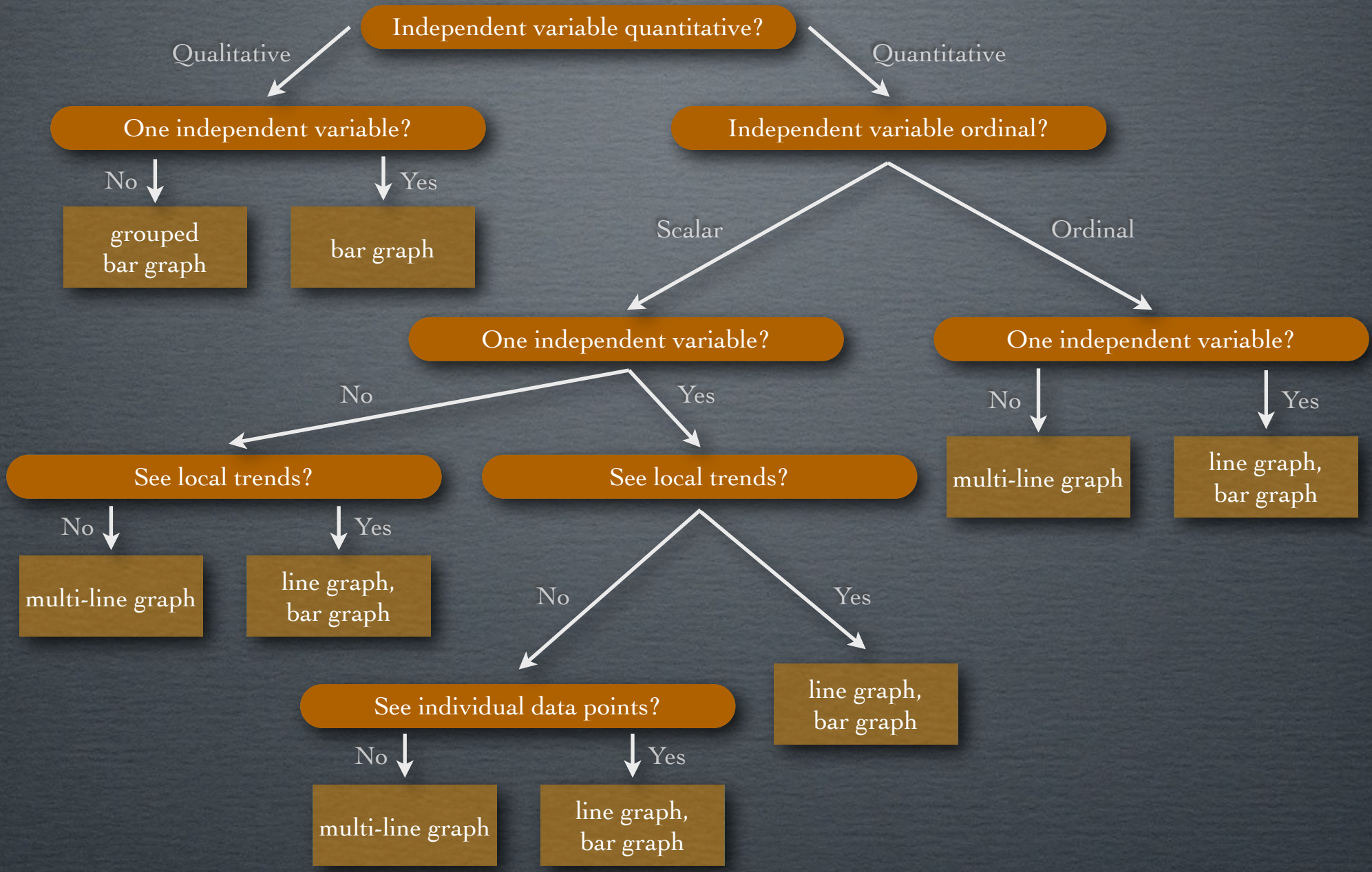
Iris Plant Database

Petal Length → X, Petal Width → Y, Sepal Width → colour, sepal length → size, class → shape



(Number of sepals on a flower is its merosity)

Graph Selection

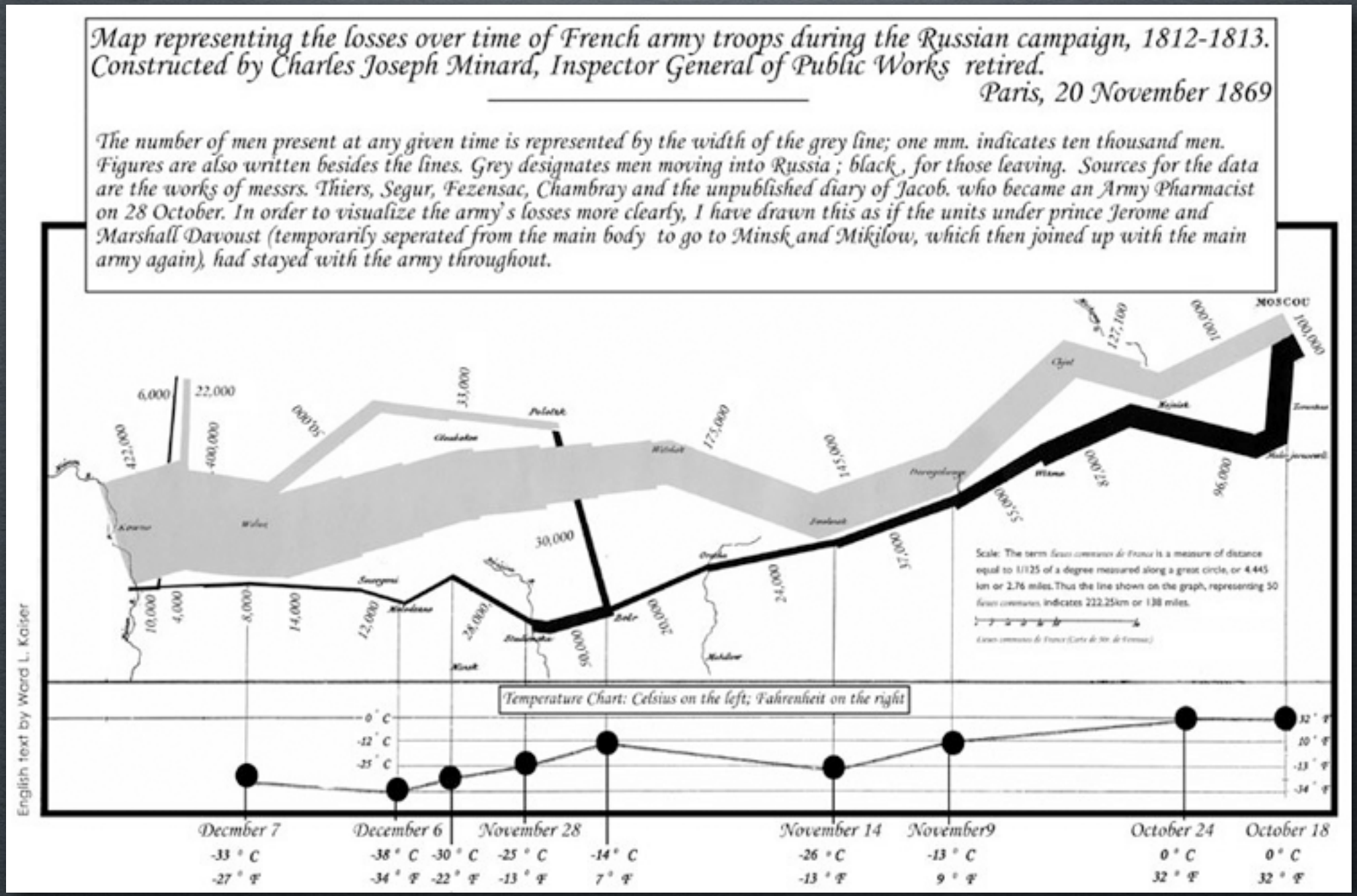


Maps

- Traditional method for presenting geographic and geospatial data
  - E.g., topographic, planimetric, base
- Different maps are used for different tasks:
  - choropleth (charting value distributed by region)
  - isarithmic (contour lines)
  - proportional symbol (point location data)
  - dot (presence or absence of a feature)
- Maps can be extended to visualize multidimensional data

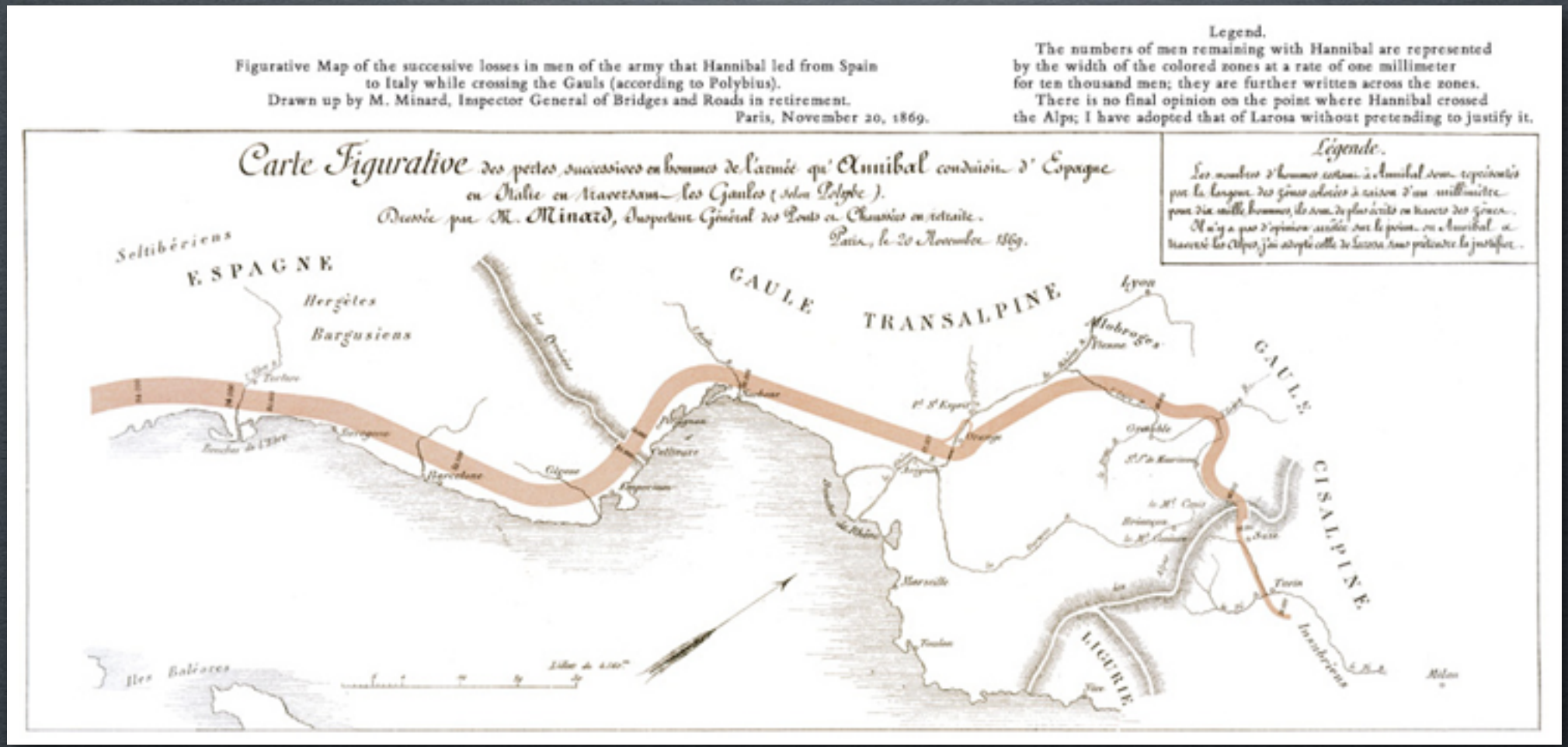
Topographic map from Indiana Jones and the Last Crusade

Napolean's March on Russia



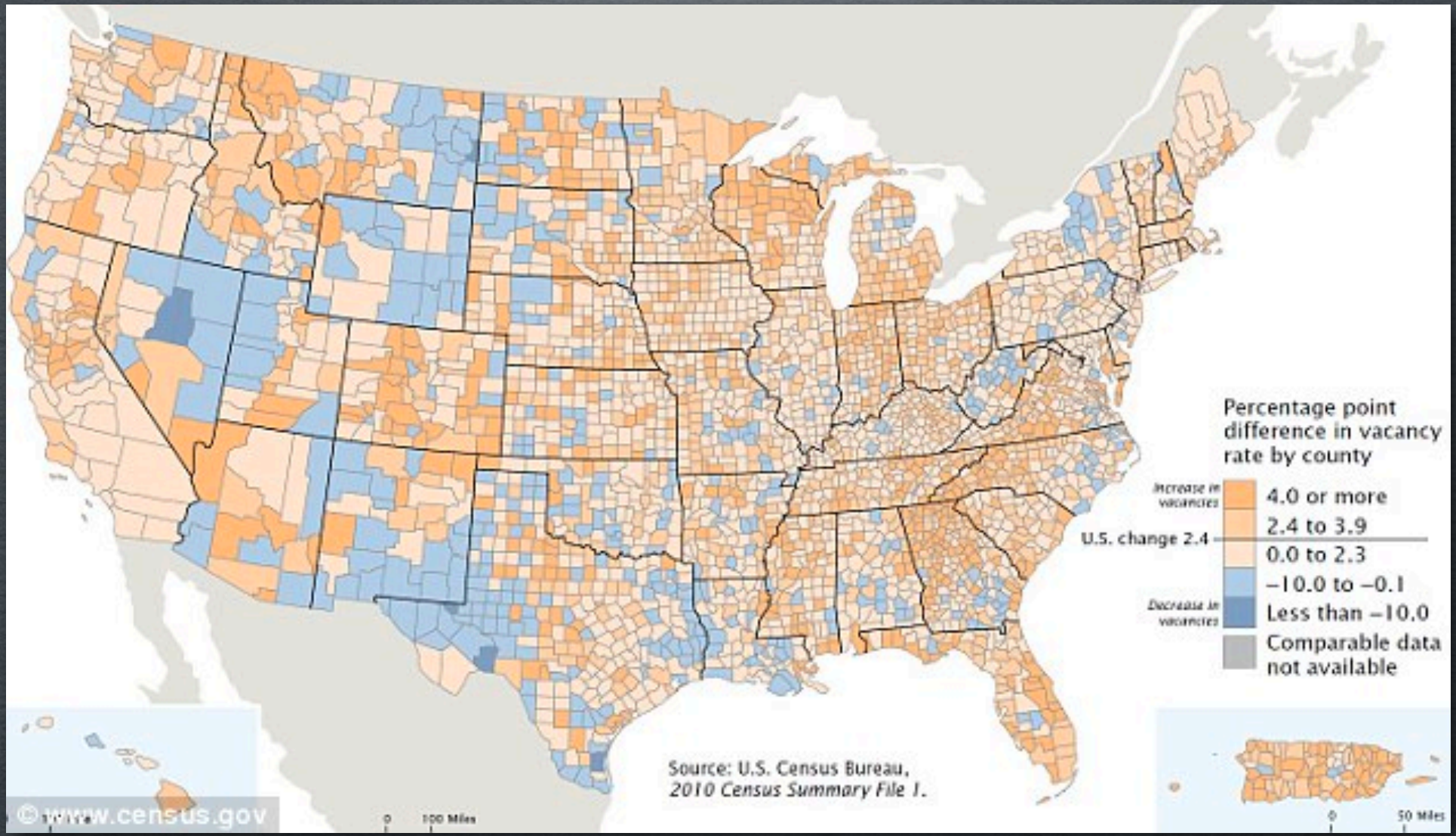
Charles Joseph minard, 1869, flow map of napolean's march on russia

Hannibal's March on Rome



Charles Joseph minard, 1869, flow map of Hannibal's march on Rome

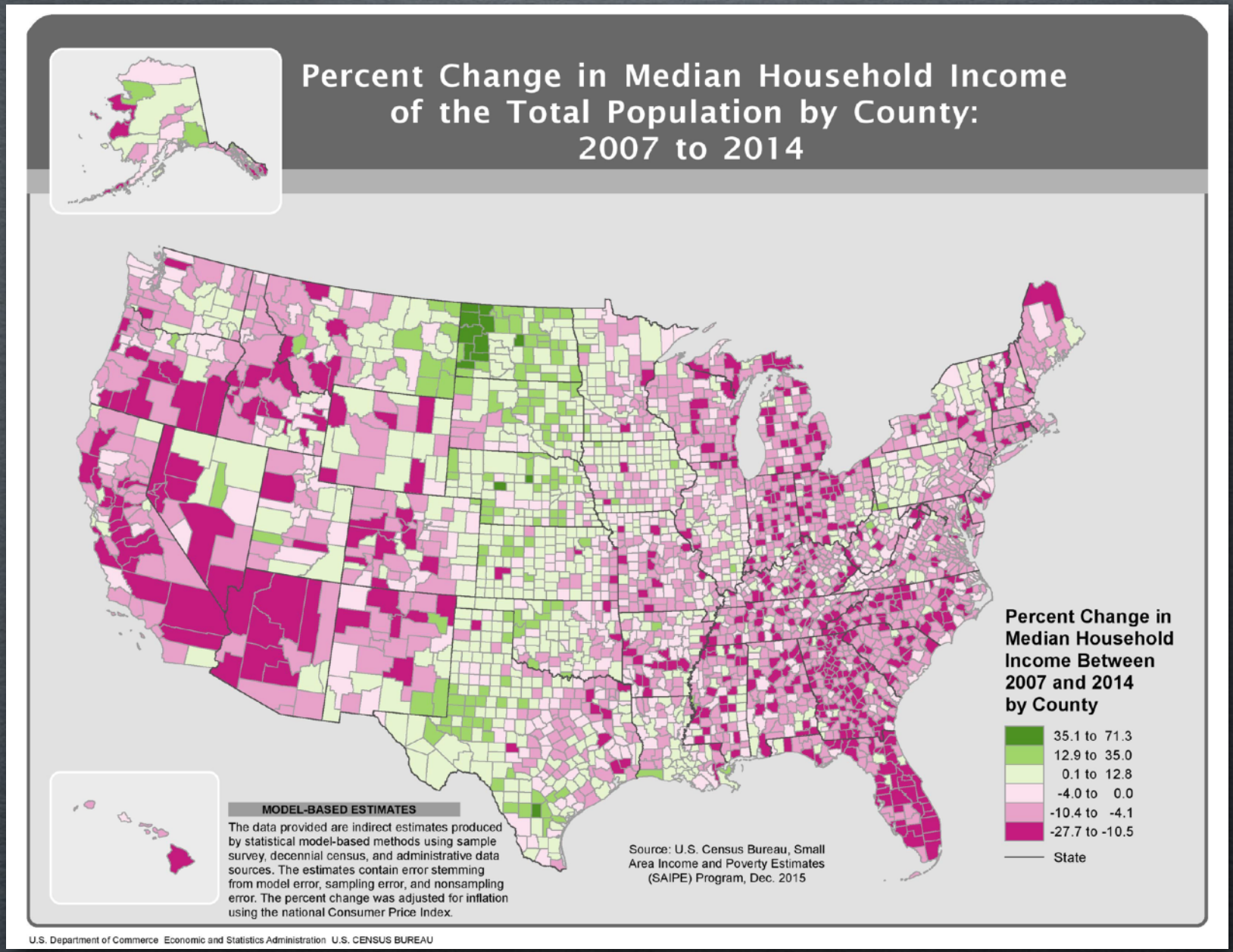
2010 Census Vacancy Rate Change



Data courtesy UK Daily Mail

http://www.dailymail.co.uk/news/article-2176433/Revealed-The-10-emptiest-U-S-cities.html

2007–2014 Household Income Change

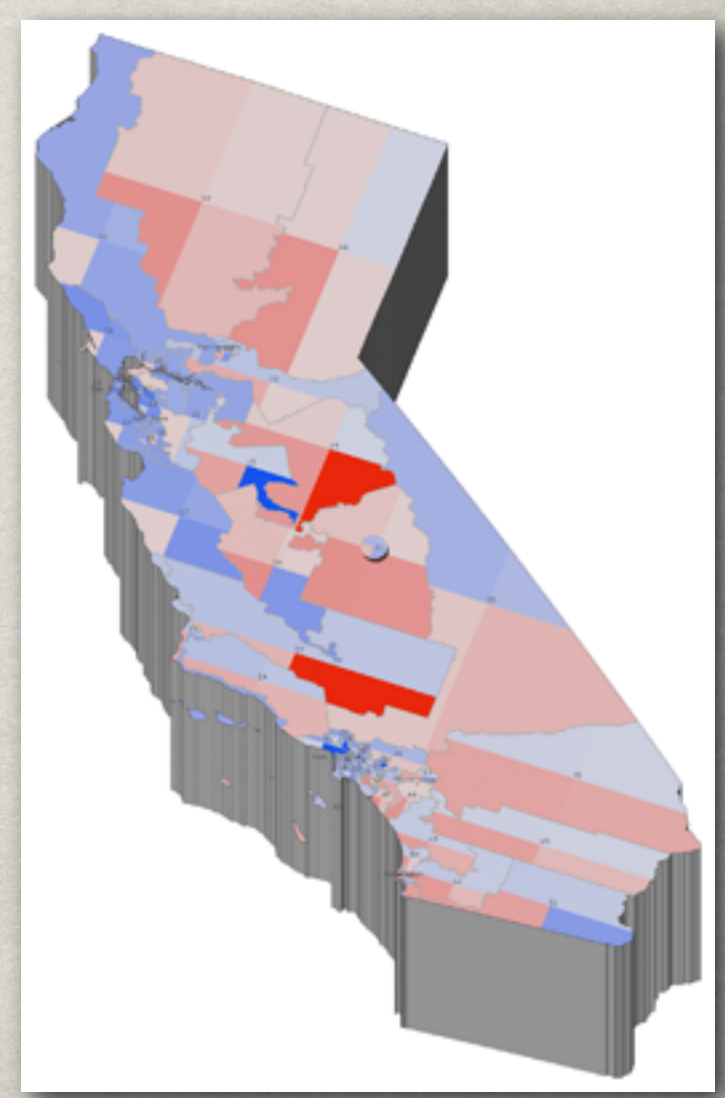


Data courtesy Reboot Illinois

http://www.rebootillinois.com/2016/03/10/whats-hot/kevin-hoffmanrebootillinois-com/top-30-counties-with-the-largest-decline-in-median-household-income-in-illinois-from-2000-2014/53994/

Multidimensional Glyphs

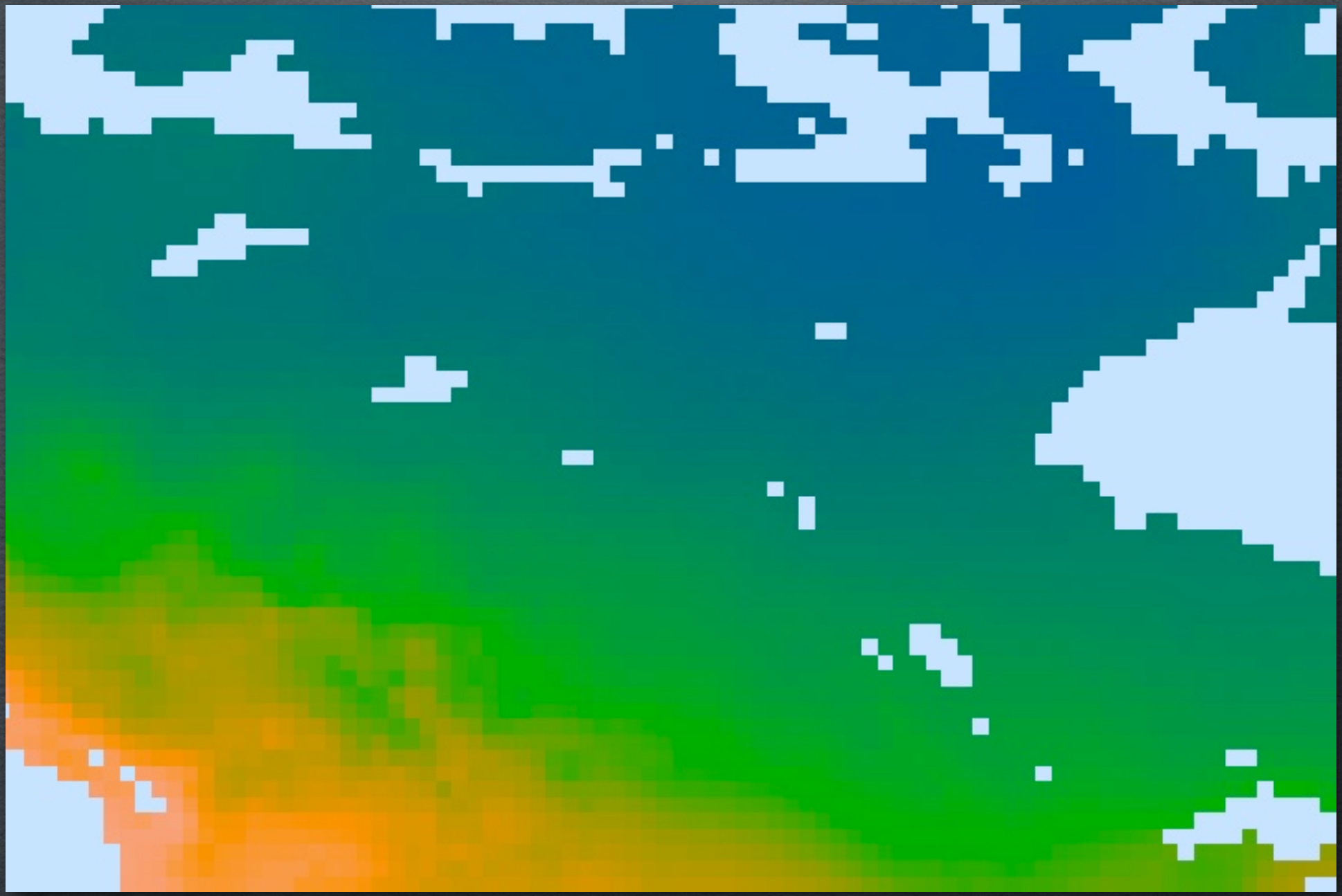
- Method to visualize high dimensional data
  - Data samples represented as a geometric glyphs
  - Samples' attribute values used to vary their glyphs' appearance
- Human visual perception used to select "salient" properties of colour, texture, and motion
- Harness visual system's ability to rapidly, accurately, and effortlessly perform high-level analysis tasks



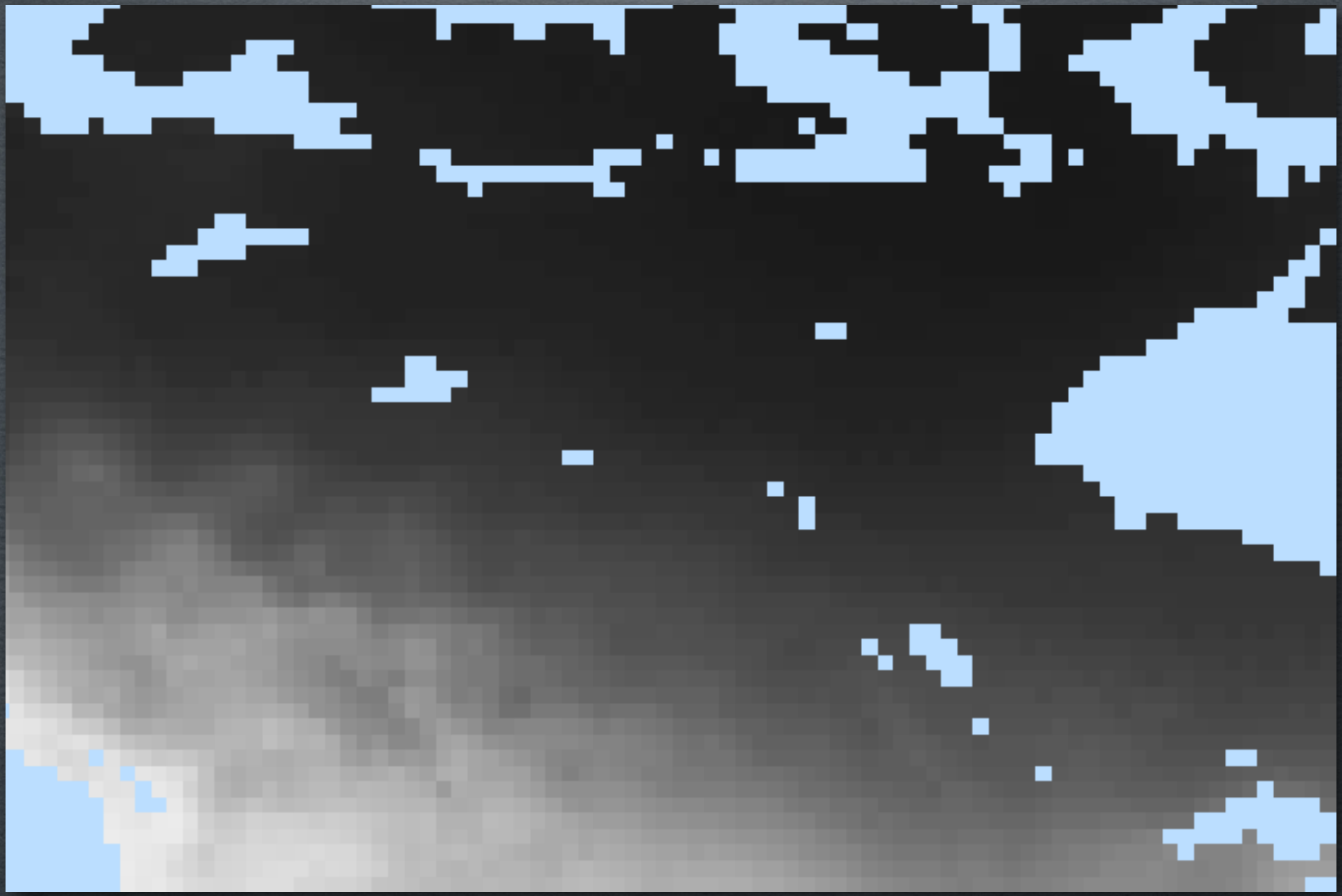
California voting patterns for President, Senate, House, and Governor by Congressional district

http://www.csc.ncsu.edu/faculty/healey/US_election

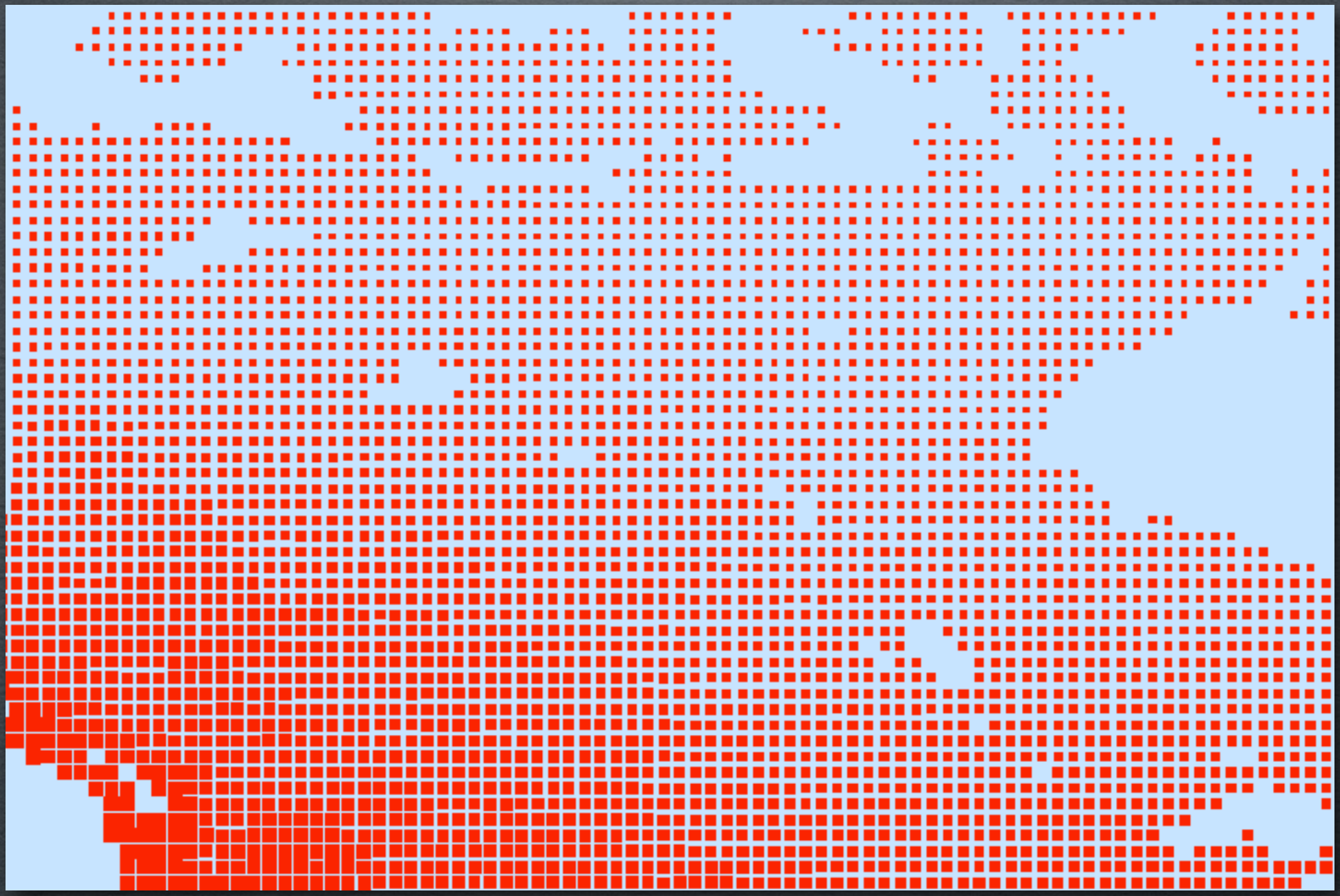
January Monthly Average Temperature



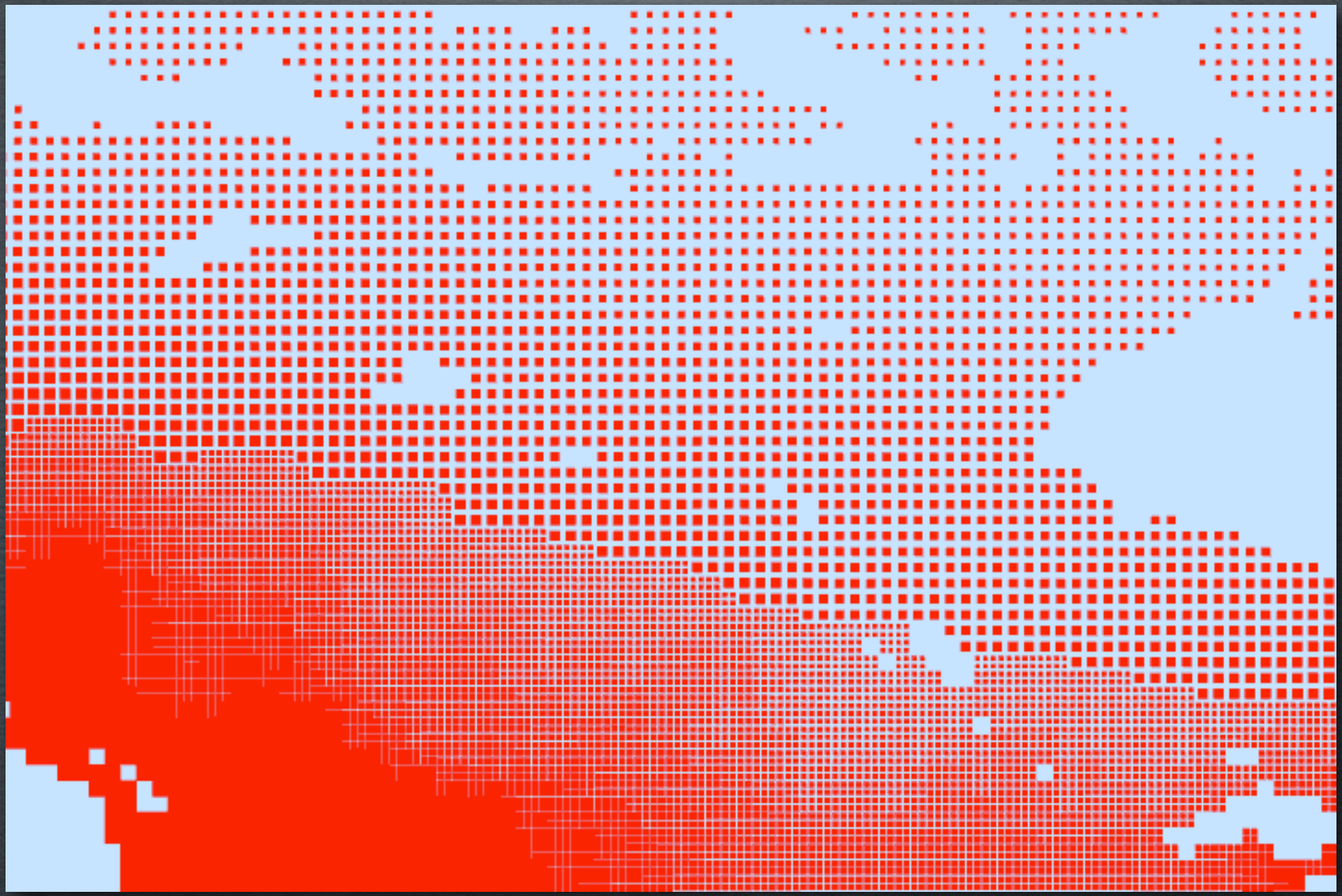
Data courtesy Climatic Research Unit, University of East Anglia



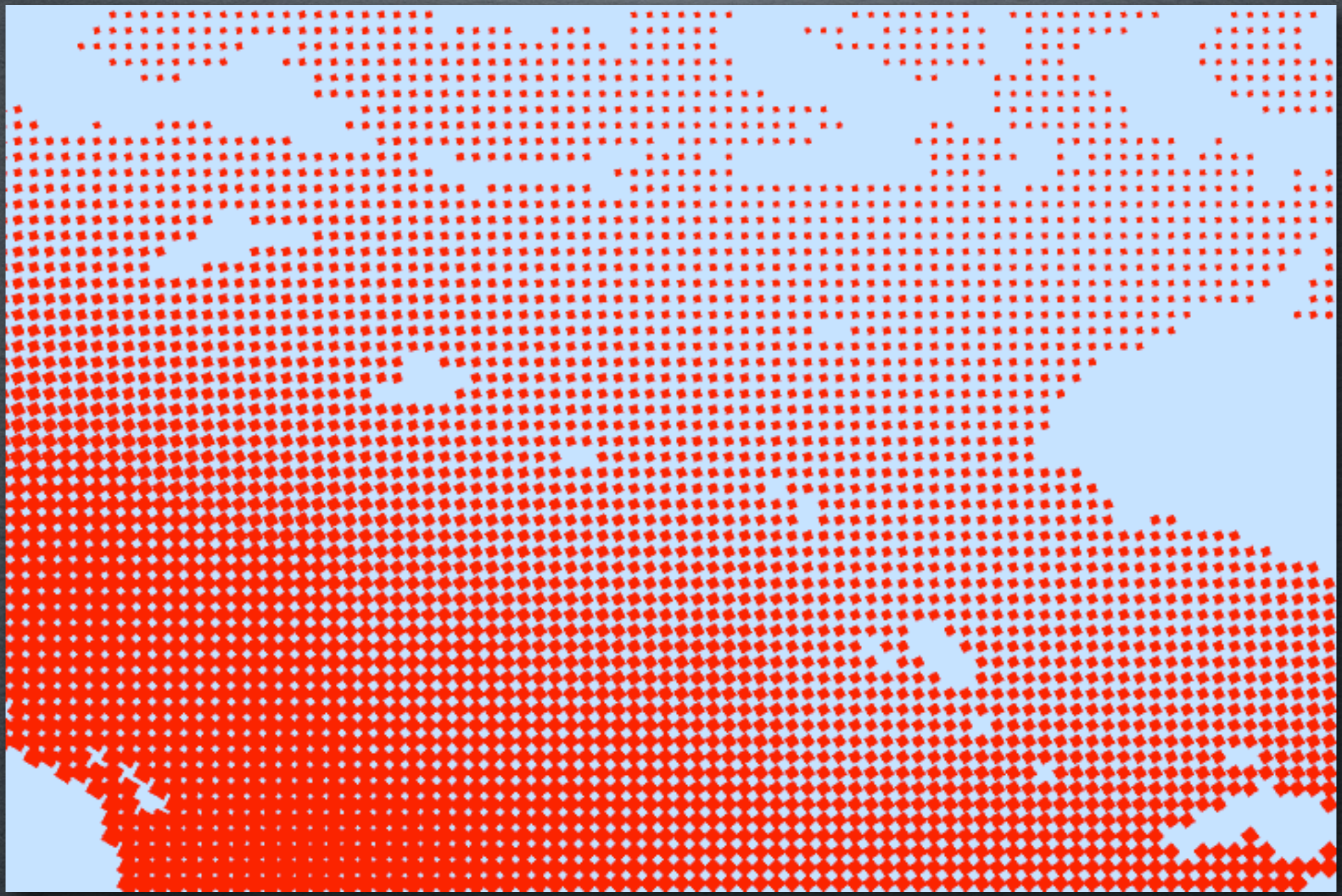
Data courtesy Climatic Research Unit, University of East Anglia



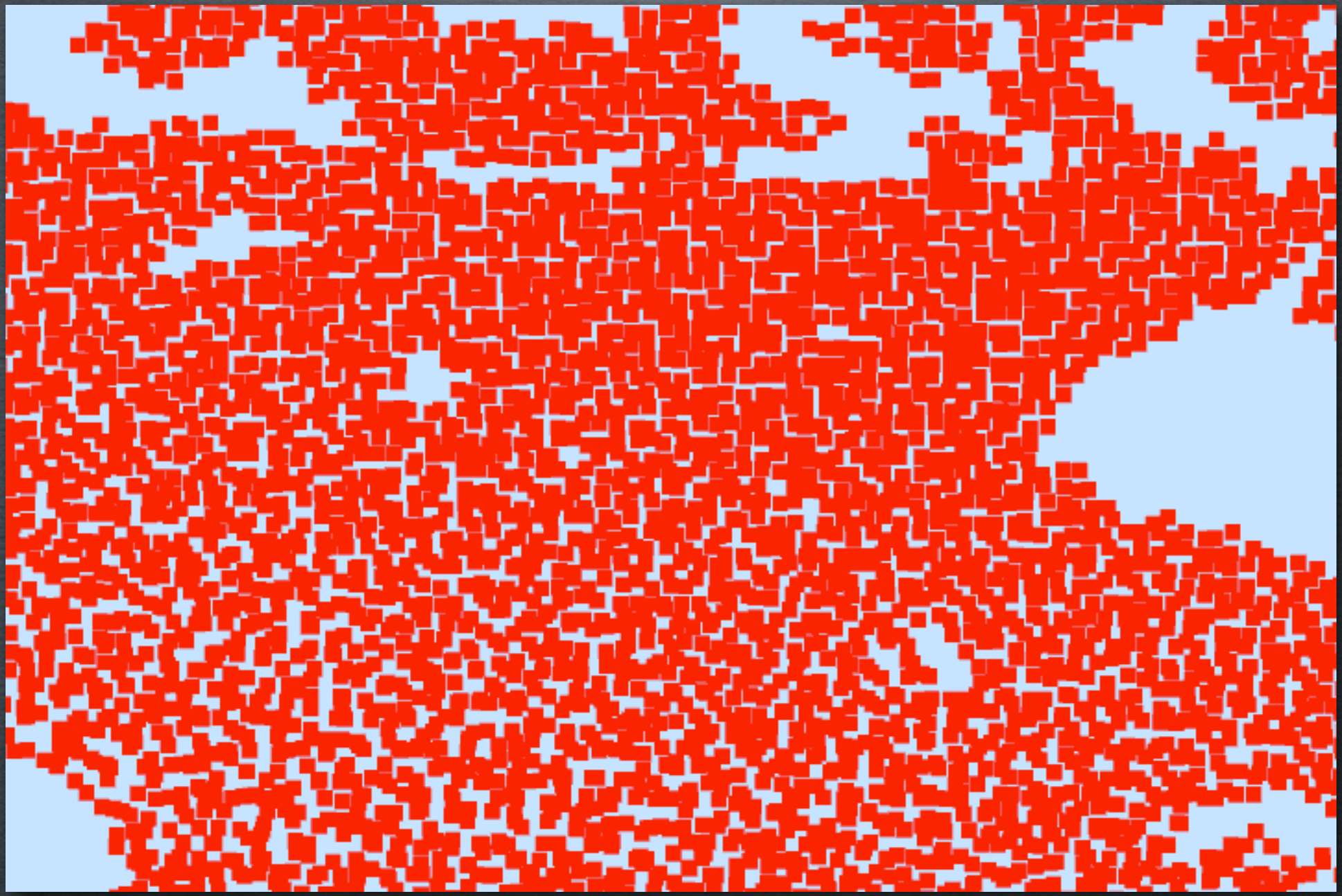
Data courtesy Climatic Research Unit, University of East Anglia



Data courtesy Climatic Research Unit, University of East Anglia

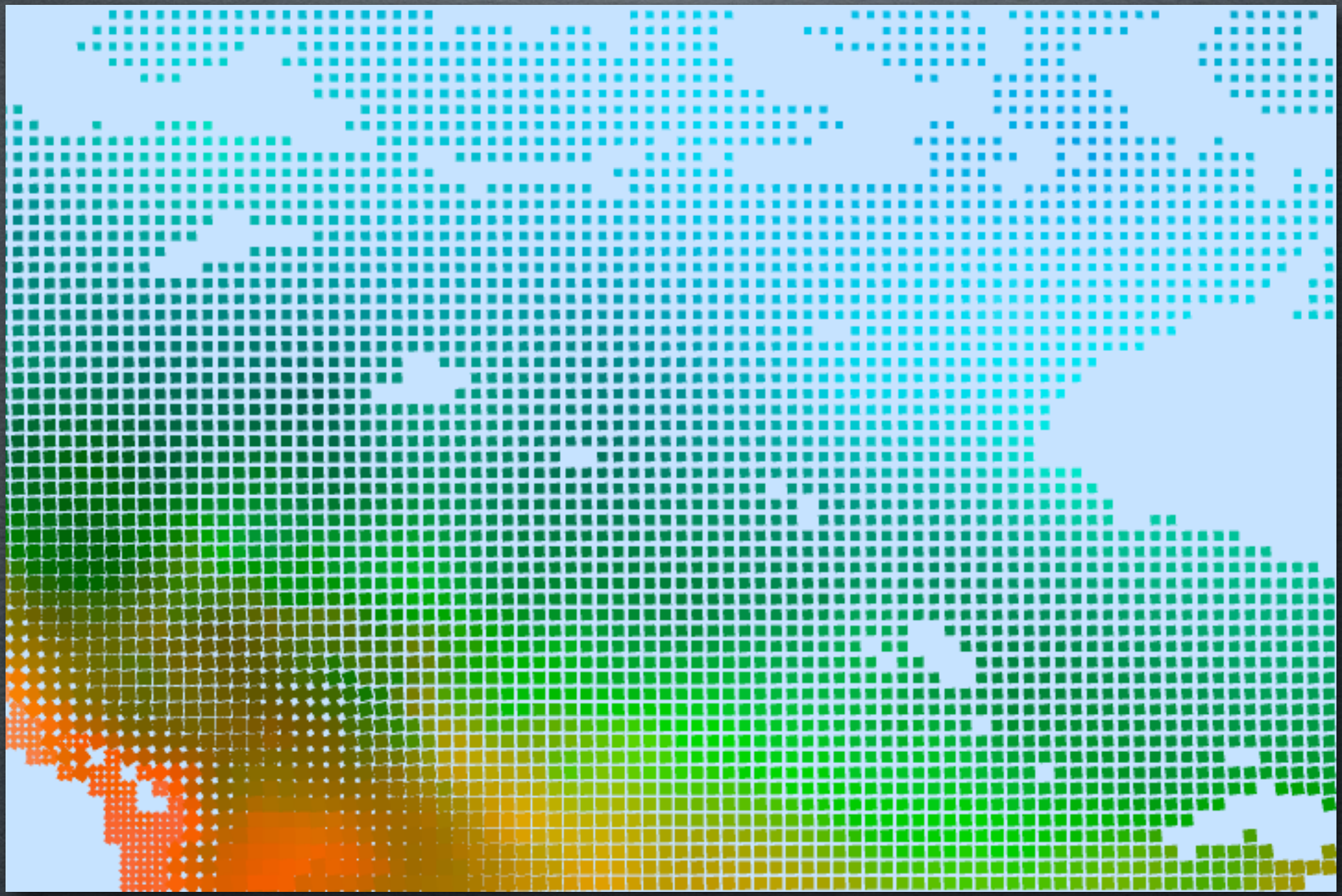


Data courtesy Climatic Research Unit, University of East Anglia



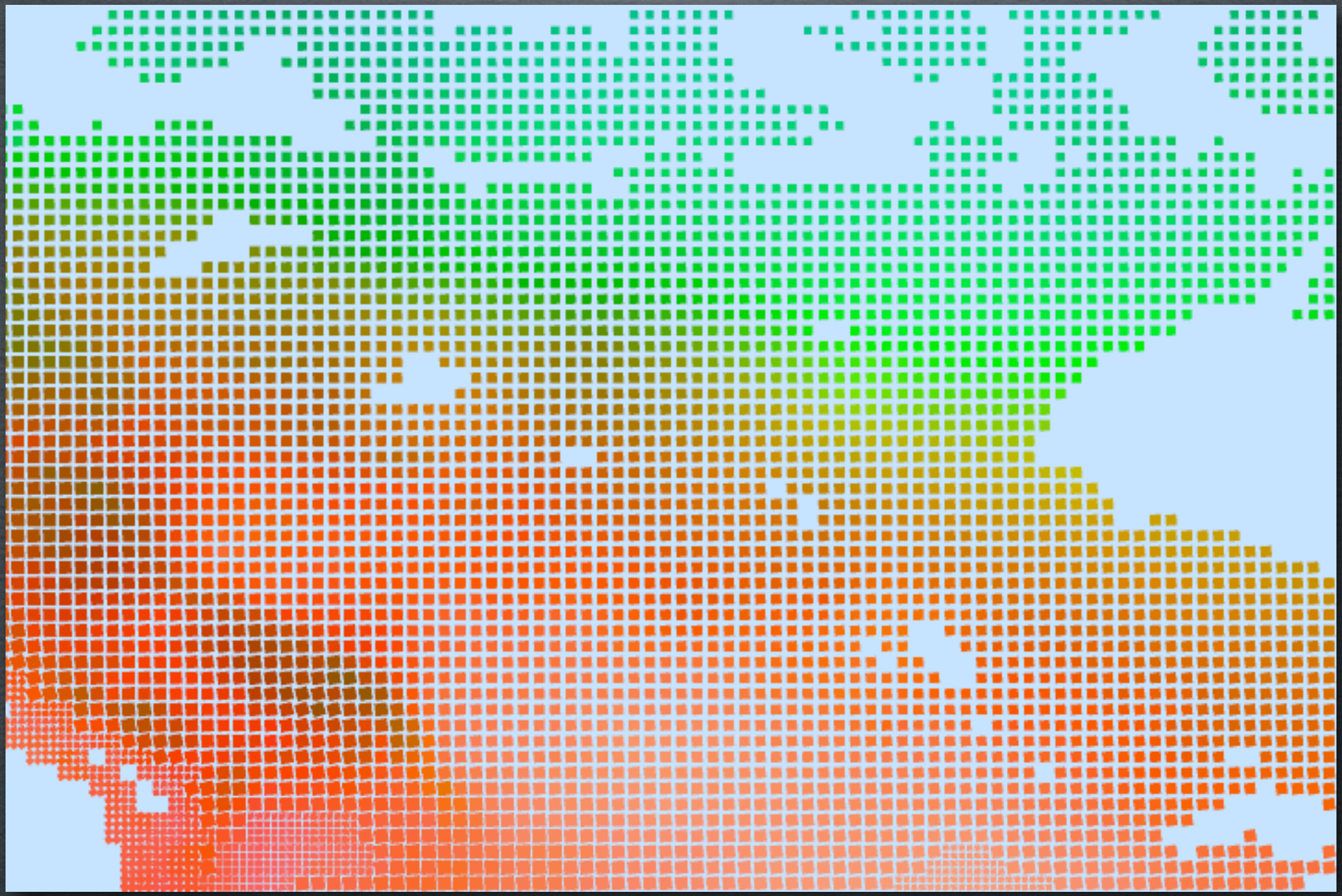
Data courtesy Climatic Research Unit, University of East Anglia

January Monthly Averages



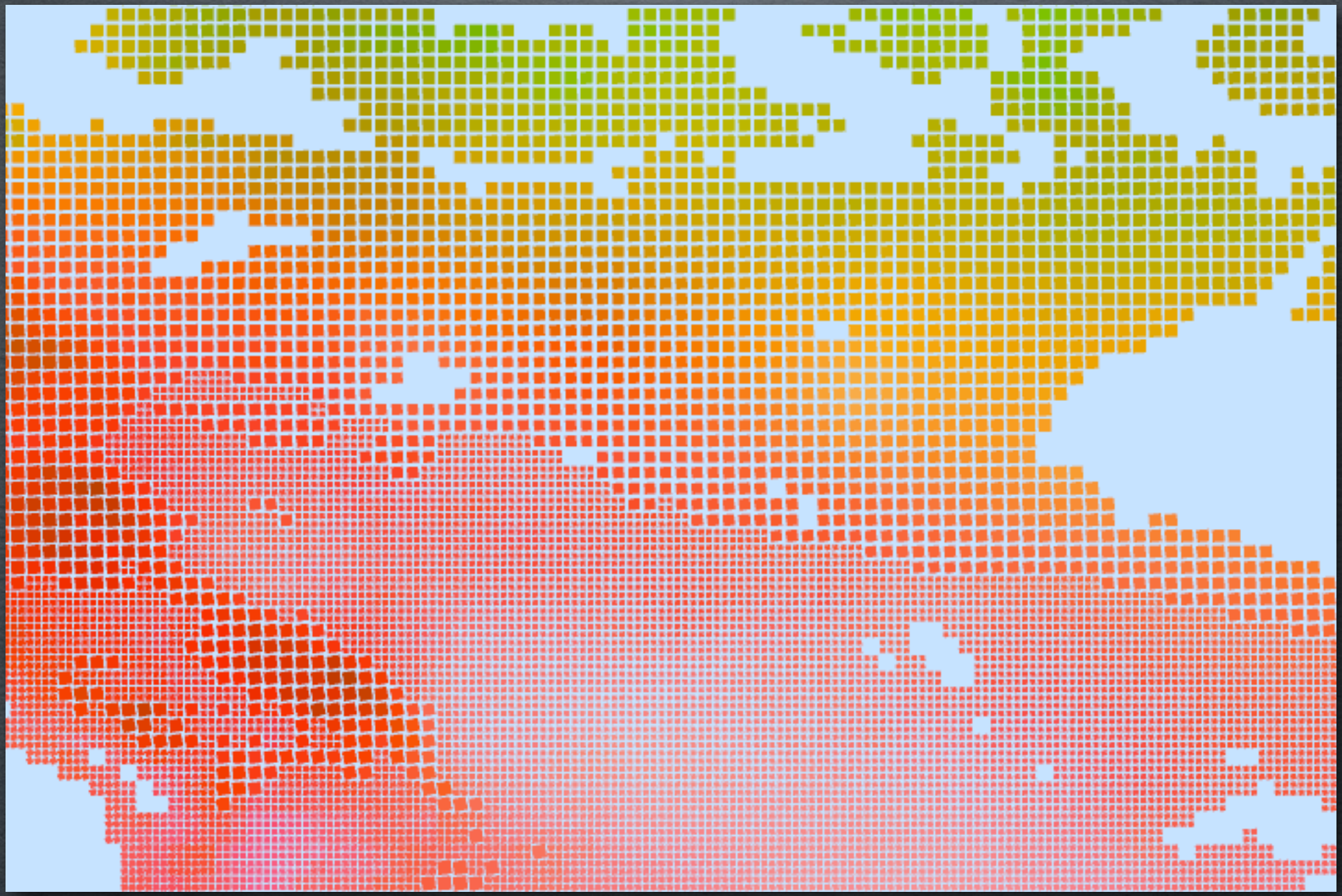
temperature → colour, wind speed → greyscale, clouds → size, pressure → density, rainfall → orientation

April Monthly Averages



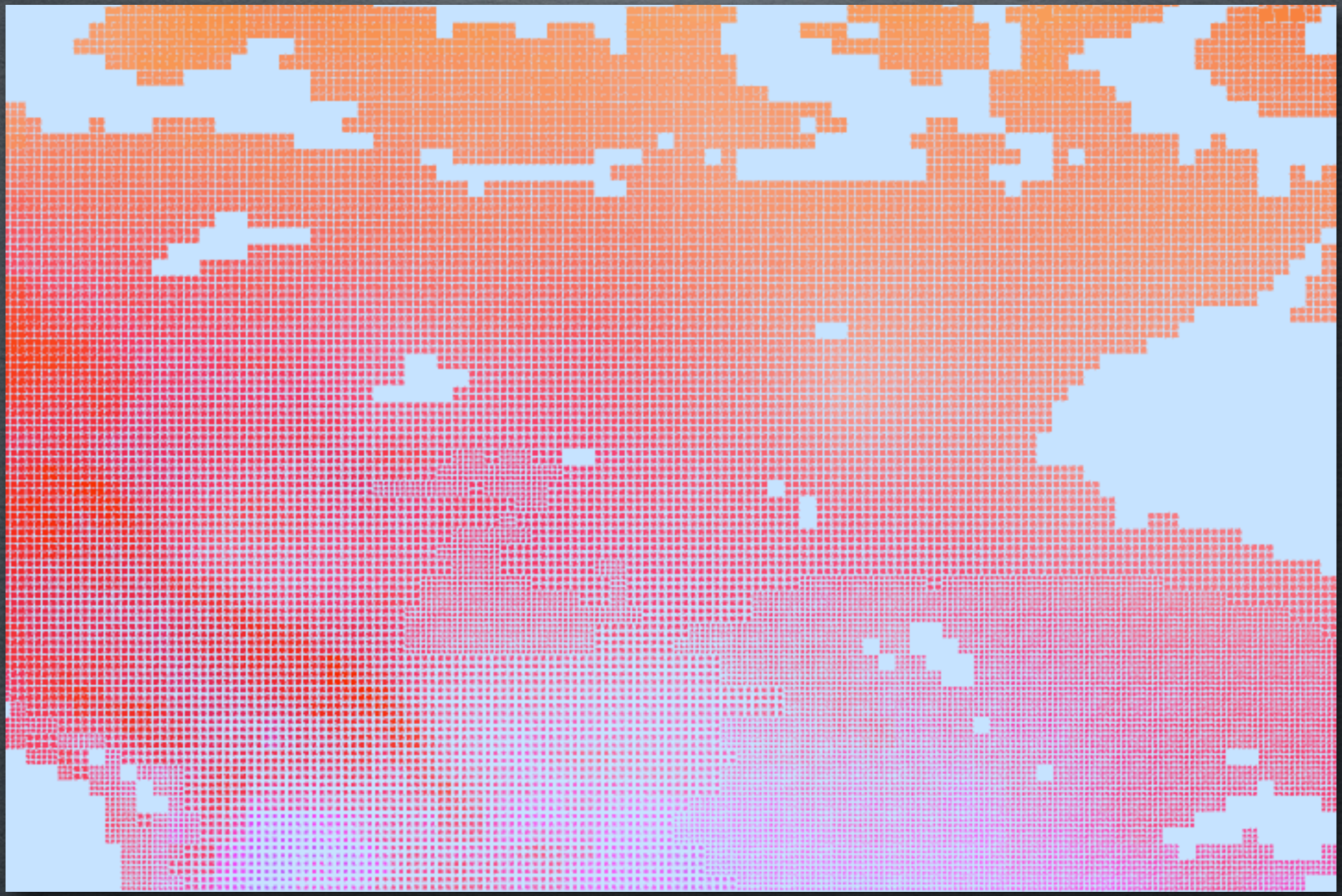
temperature → colour, wind speed → greyscale, clouds → size, pressure → density, rainfall → orientation

May Monthly Averages



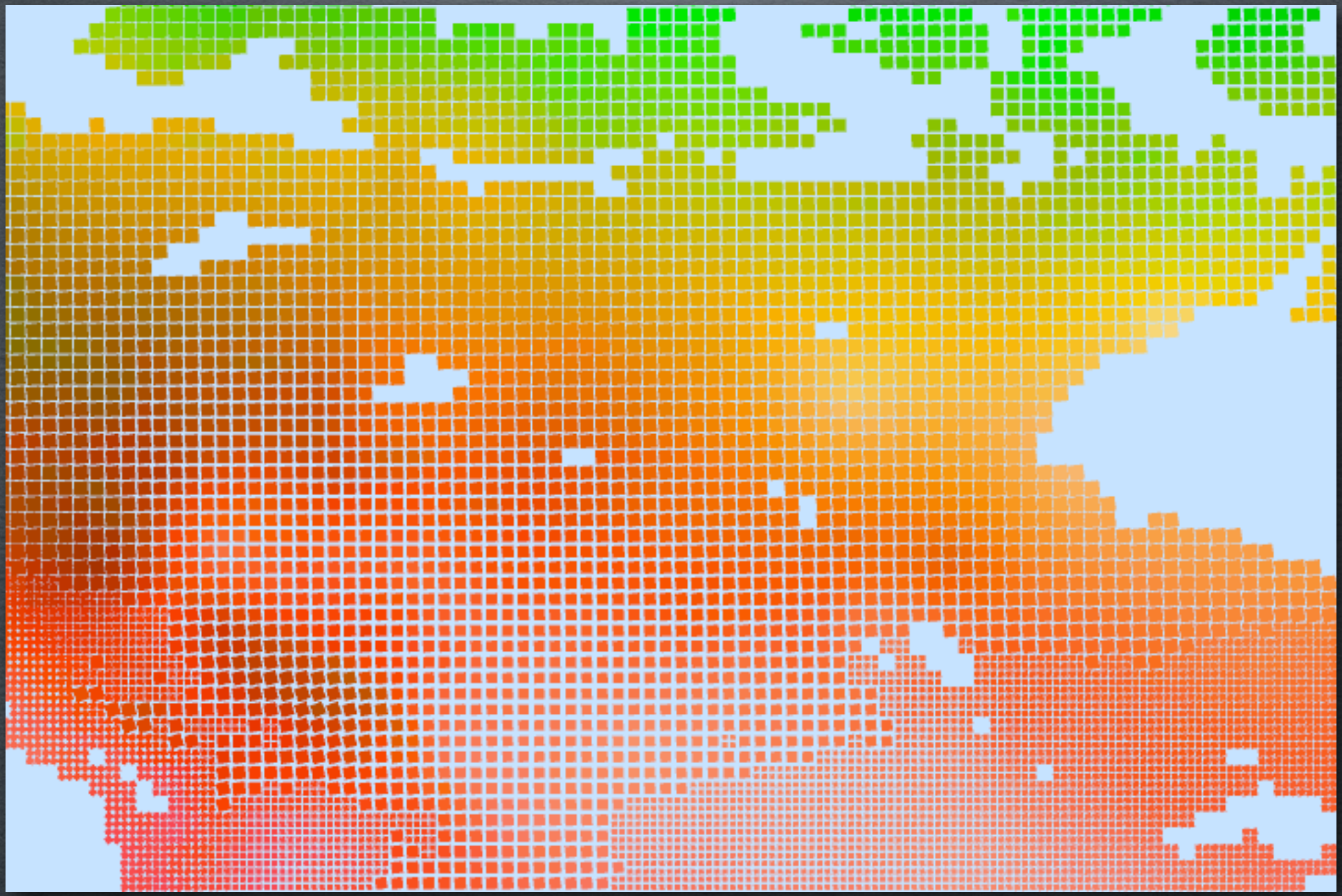
temperature → colour, wind speed → greyscale, clouds → size, pressure → density, rainfall → orientation

August Monthly Averages



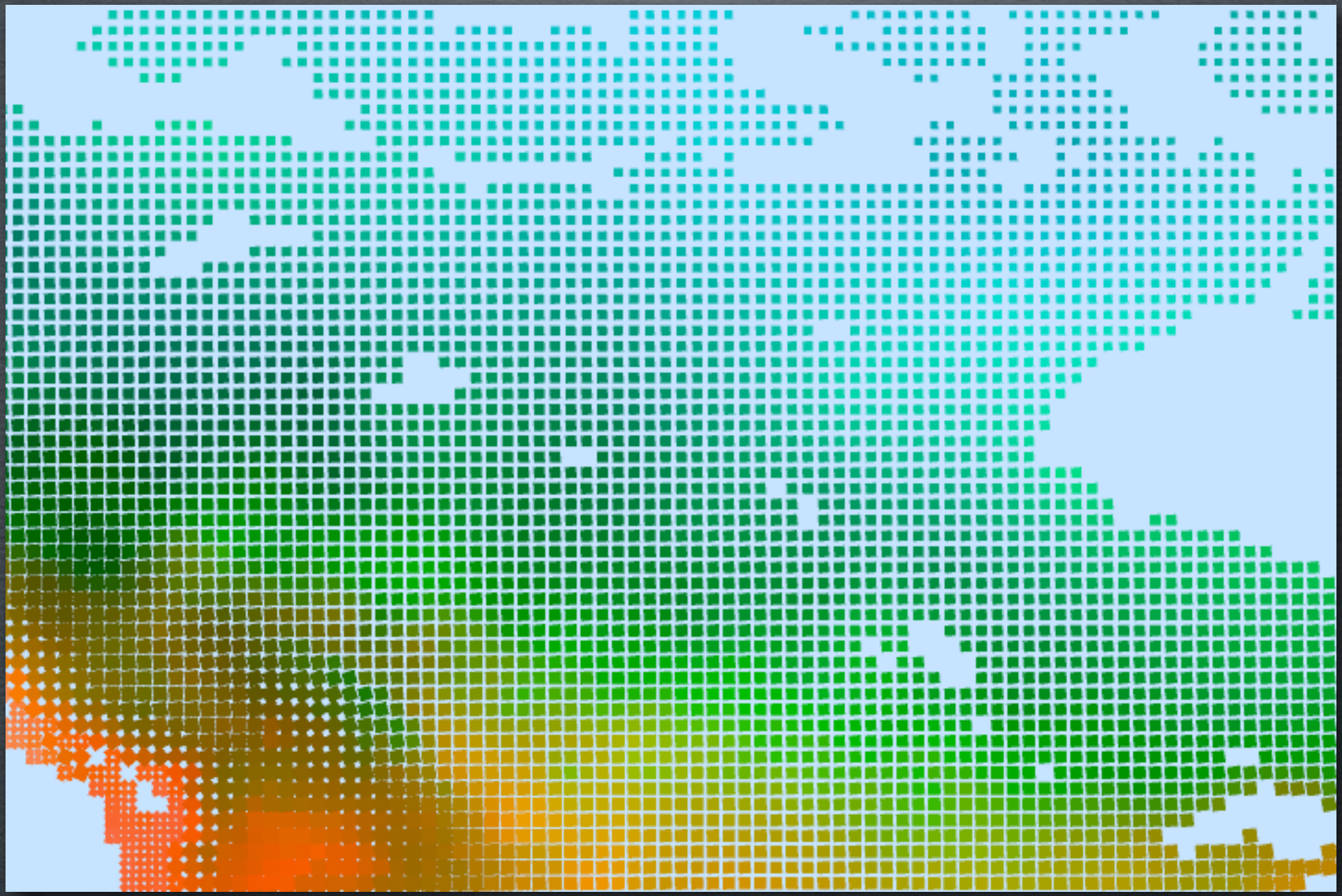
temperature → colour, wind speed → greyscale, clouds → size, pressure → density, rainfall → orientation

October Monthly Averages



temperature → colour, wind speed → greyscale, clouds → size, pressure → density, rainfall → orientation

December Monthly Averages

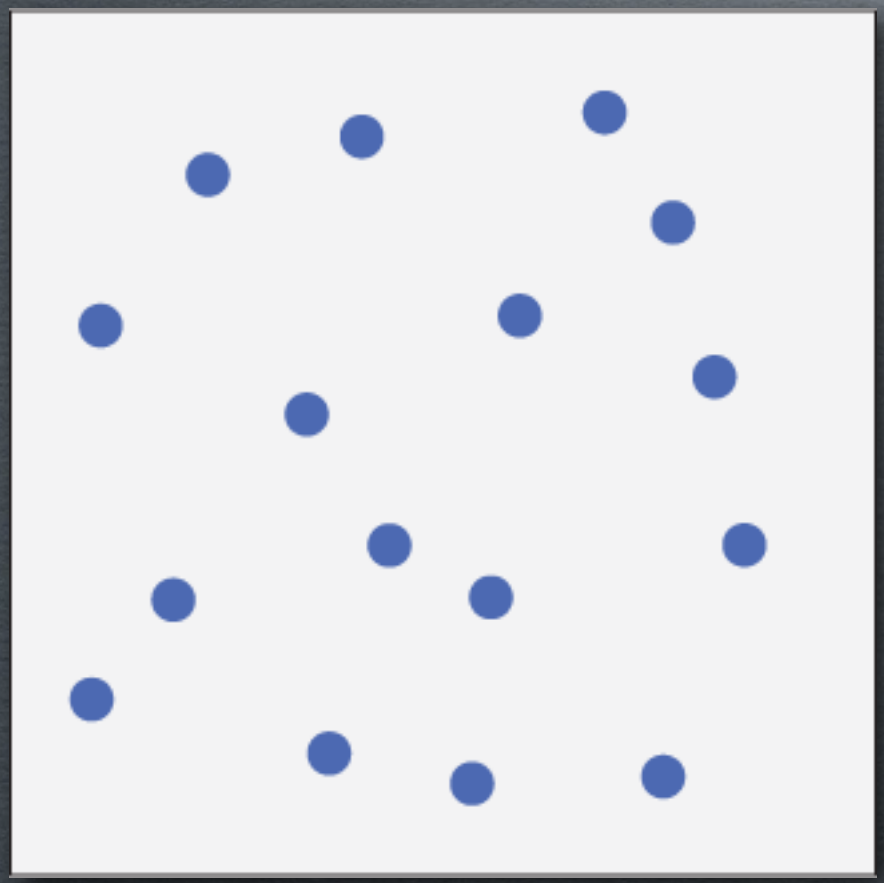


temperature → colour, wind speed → greyscale, clouds → size, pressure → density, rainfall → orientation

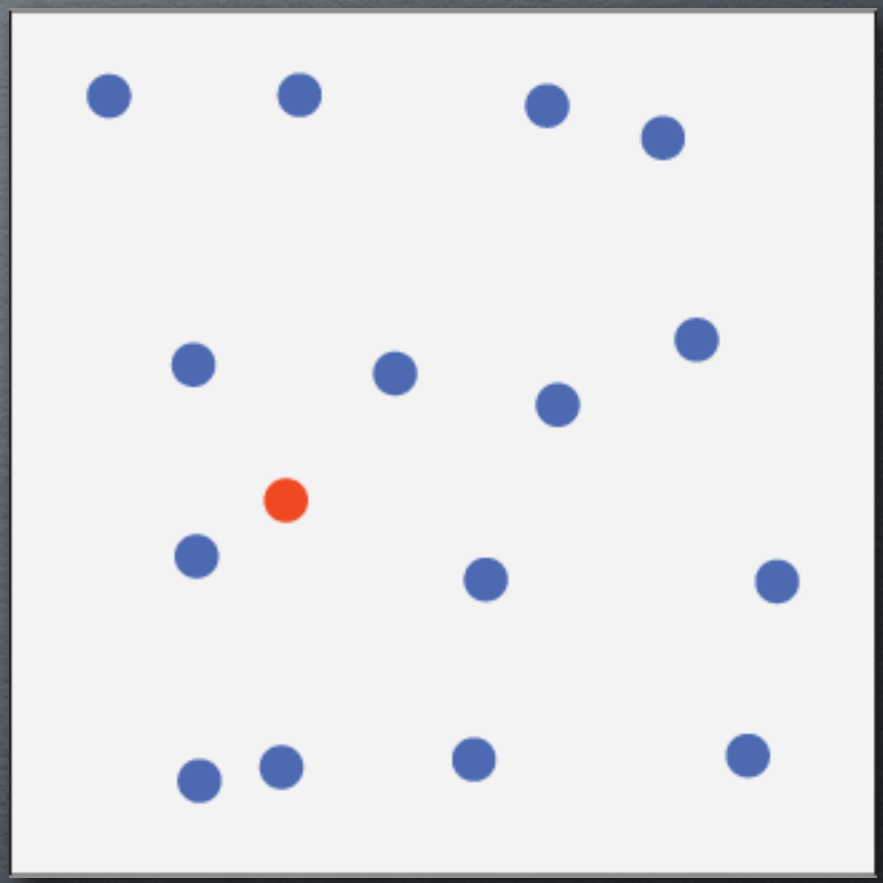
"Preattentive" Features

- Certain basic visual features are detected by our low-level visual system
  - detection is rapid, usually in one "glance" of 100-250 msec
  - can determine presence or absence, possibly amount
  - unique features can capture our focus of attention
- Initially proposed as an automatic, bottom-up phenomena
  - Treisman's feature map theory
  - Feature hierarchies
- Combined bottom-up and top-down models also exist
  - Wolfe's guided search
  - Huang et. al's boolean maps

Hue Target



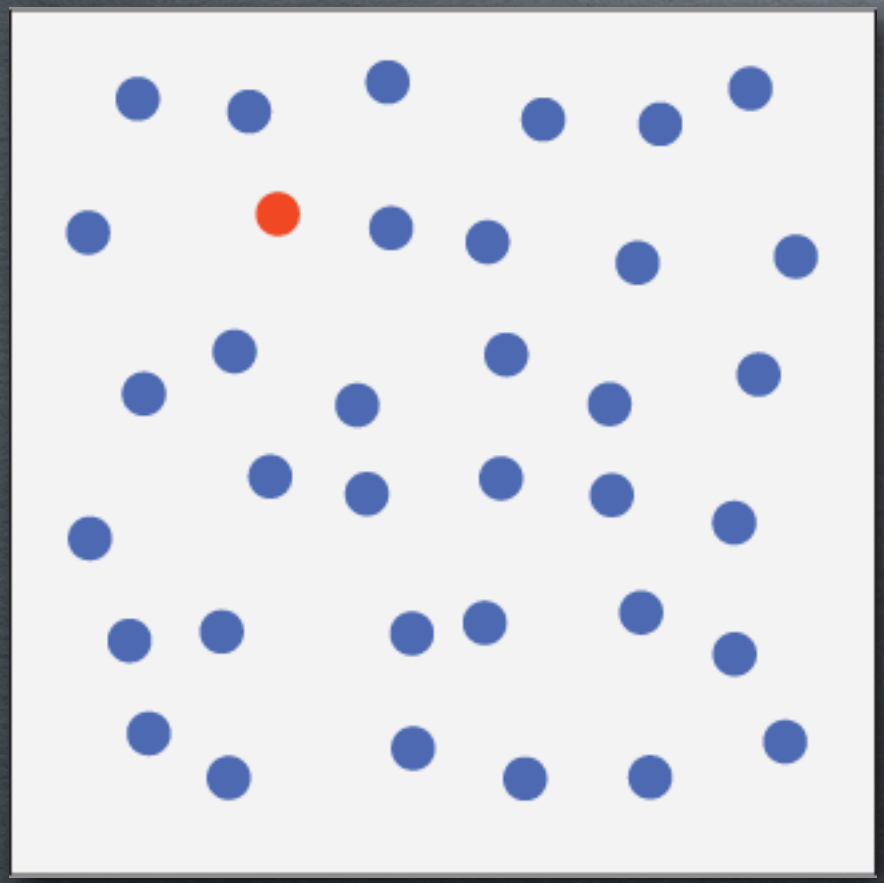
Absent



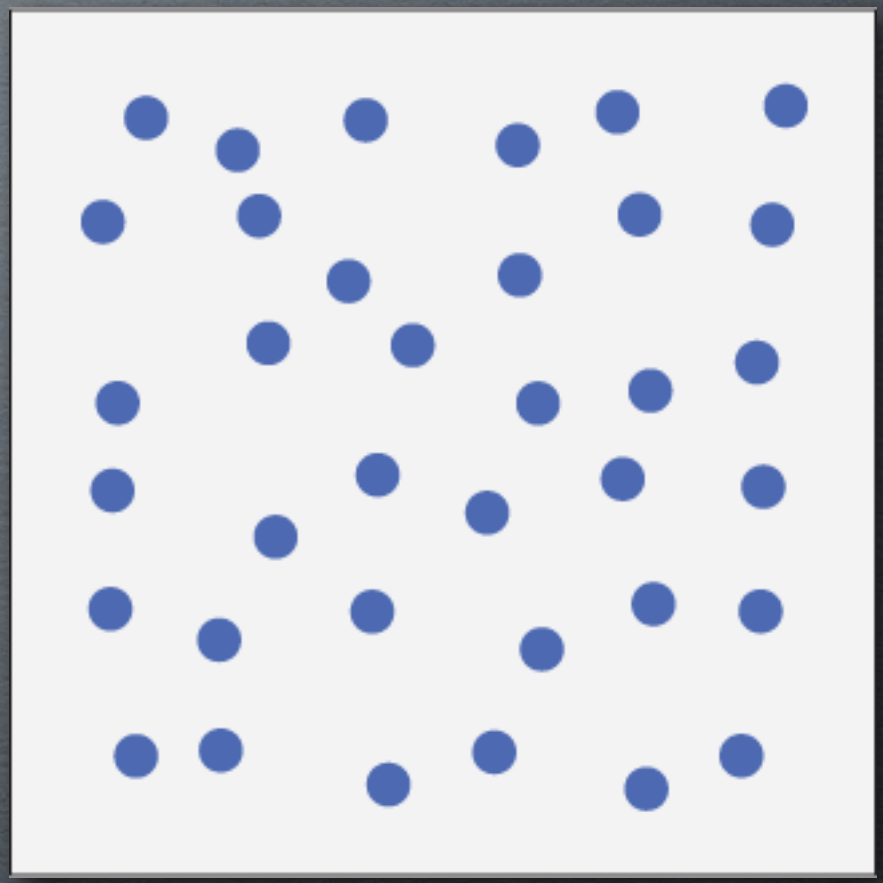
Present

http://www.csc.ncsu.edu/faculty/healey/PP

Hue Target



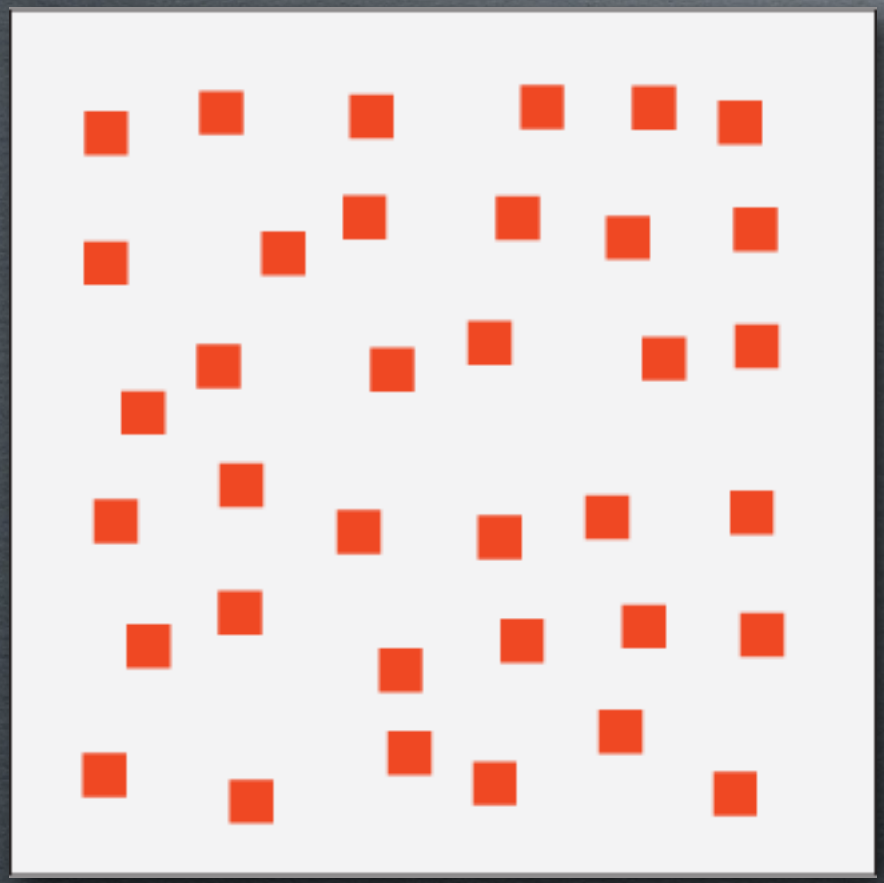
Present



Absent

http://www.csc.ncsu.edu/faculty/healey/PP

Curvature Target



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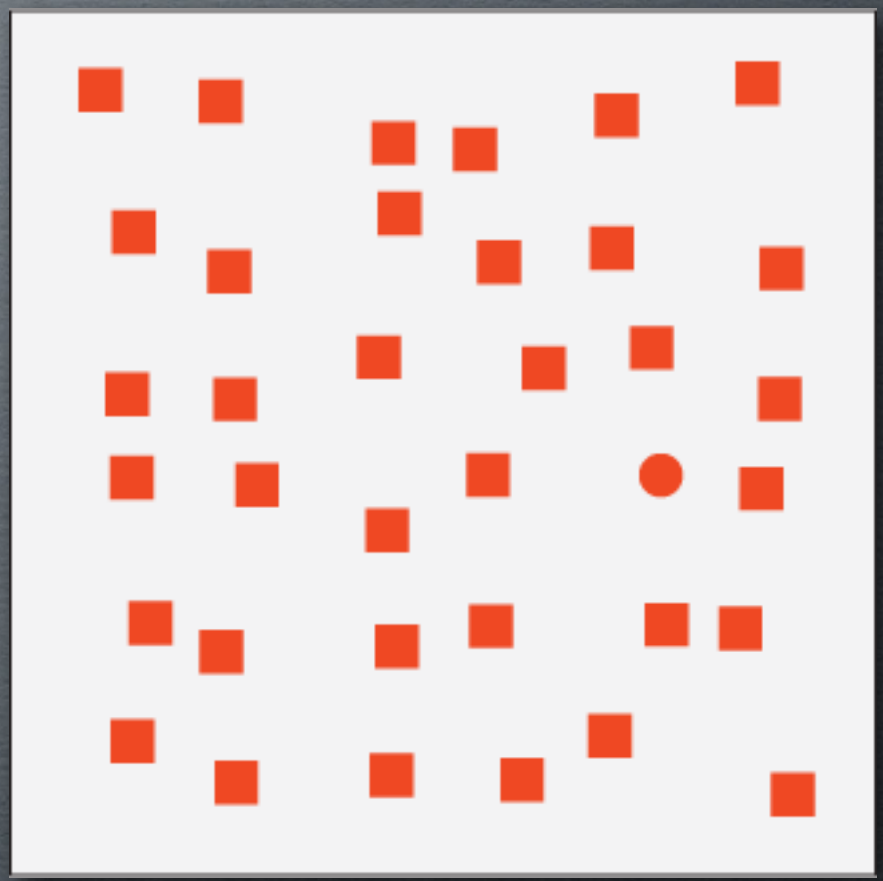
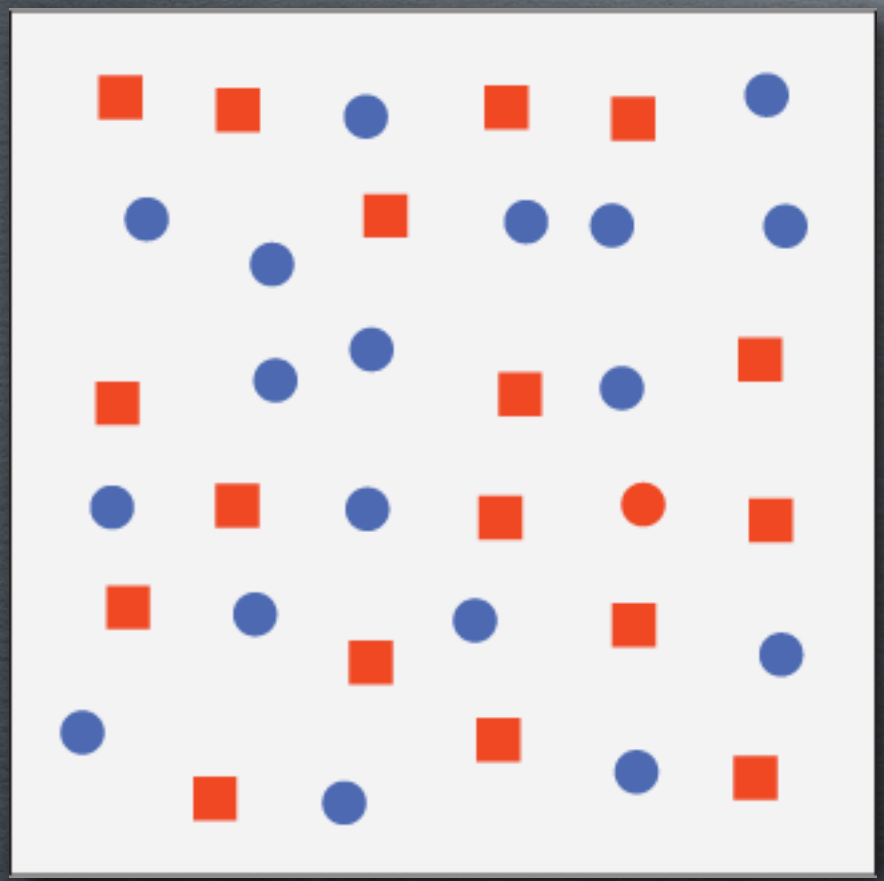


Present

http://www.csc.ncsu.edu/faculty/healey/PP

Conjunction Target



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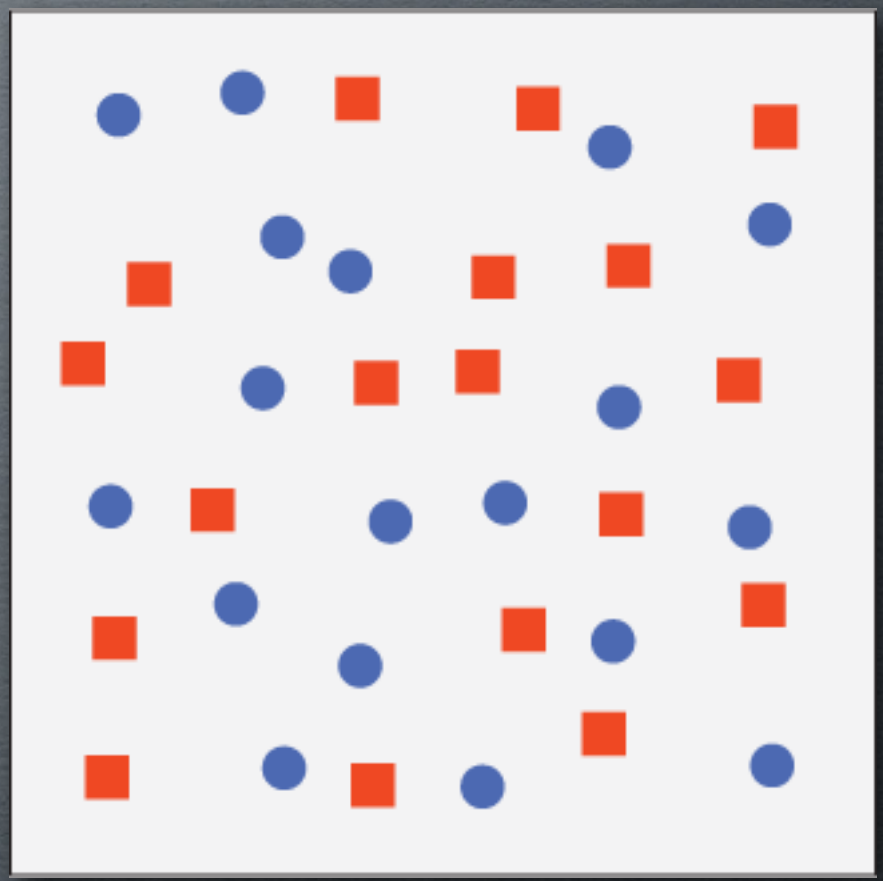

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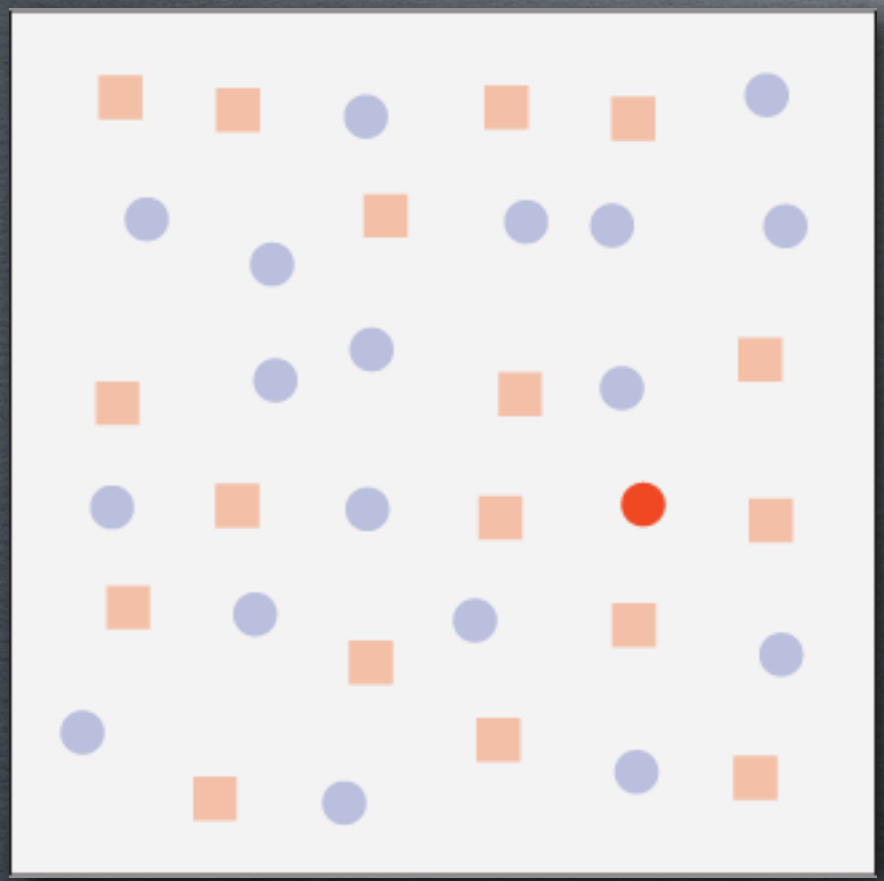
Conjunction Target



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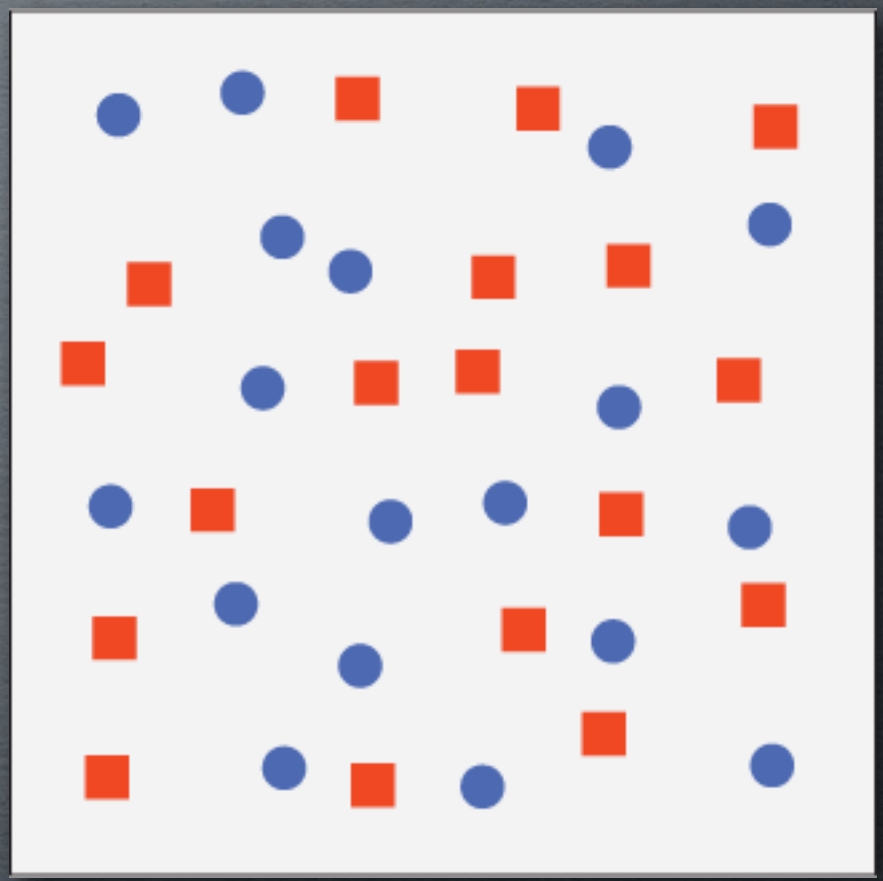
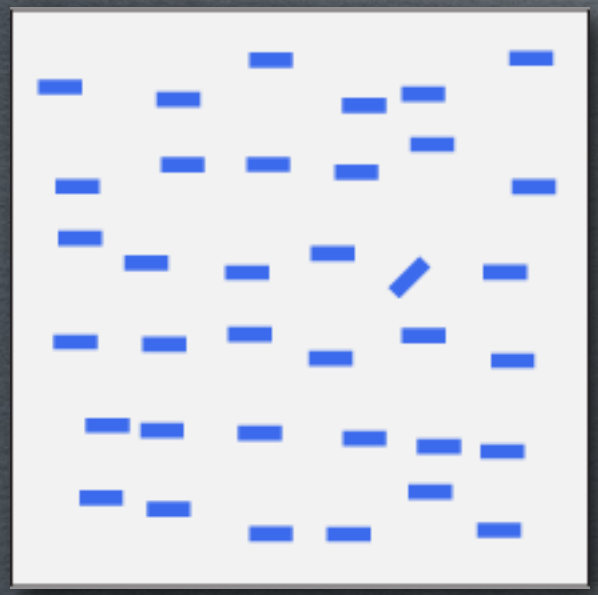


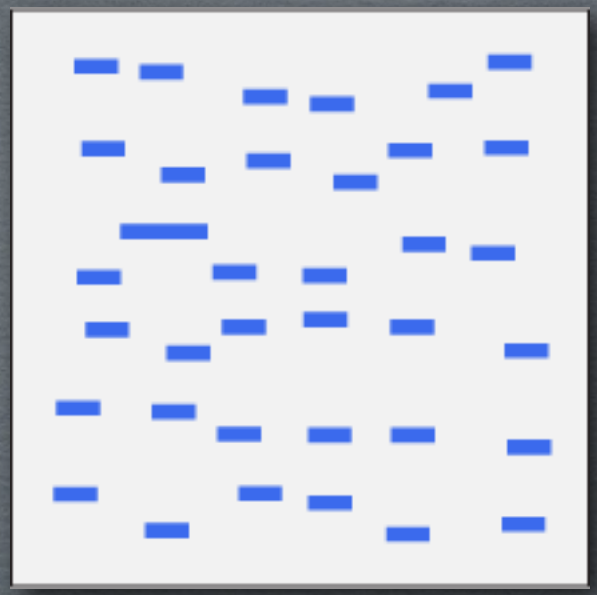
Absent

http://www.csc.ncsu.edu/faculty/healey/PP

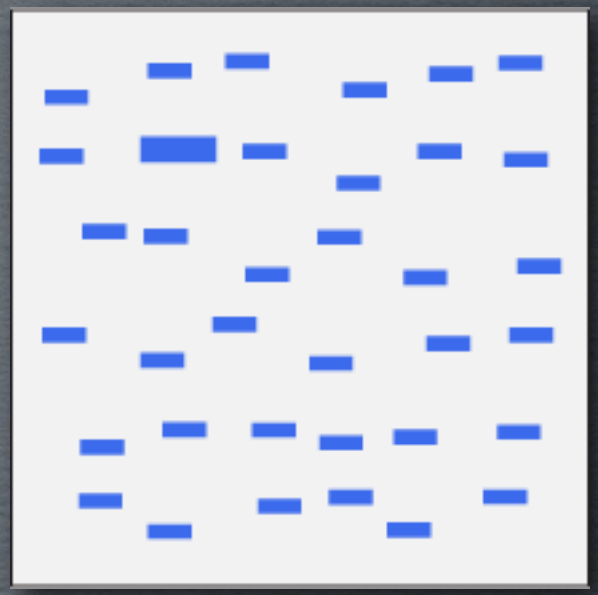
Preattentive Features



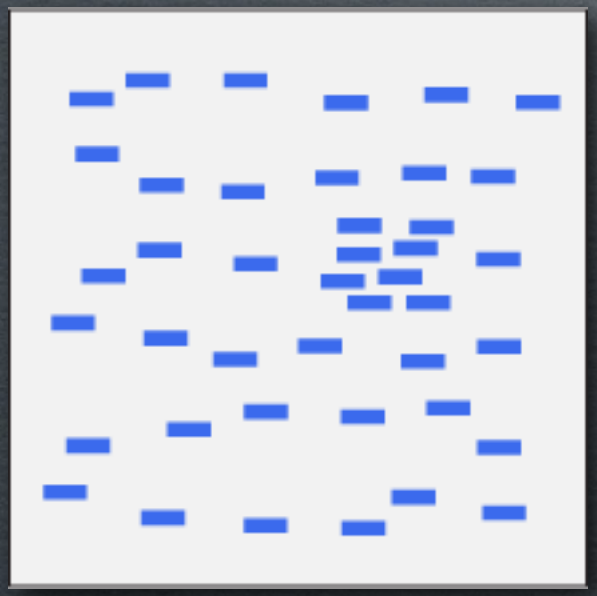
Orientation



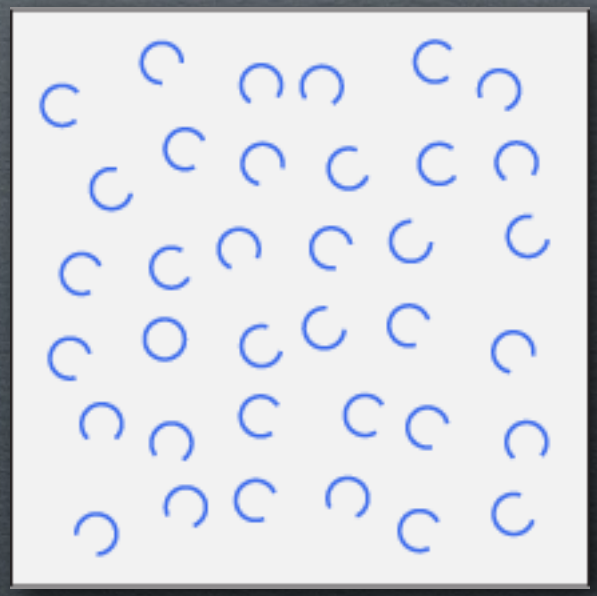
Length



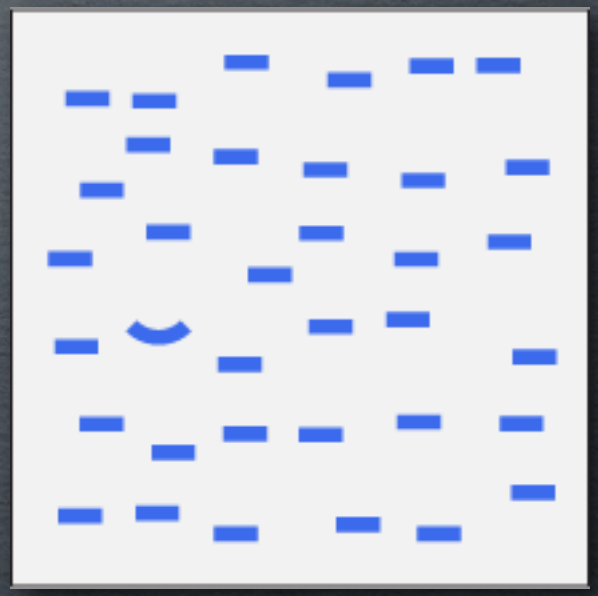
Size



Density



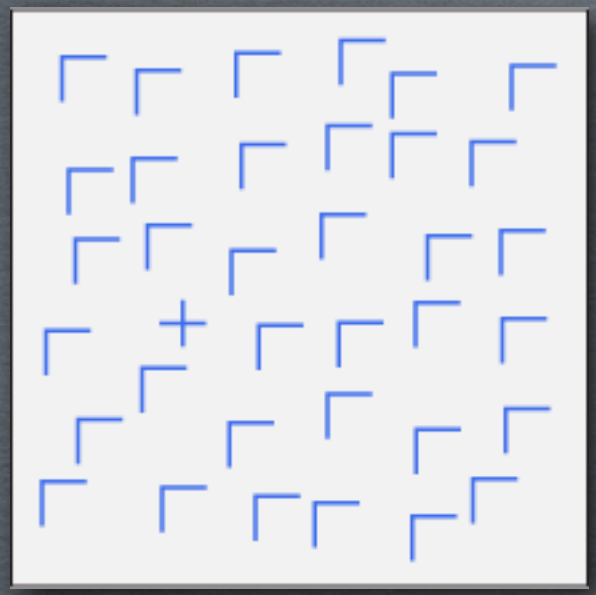
Closure



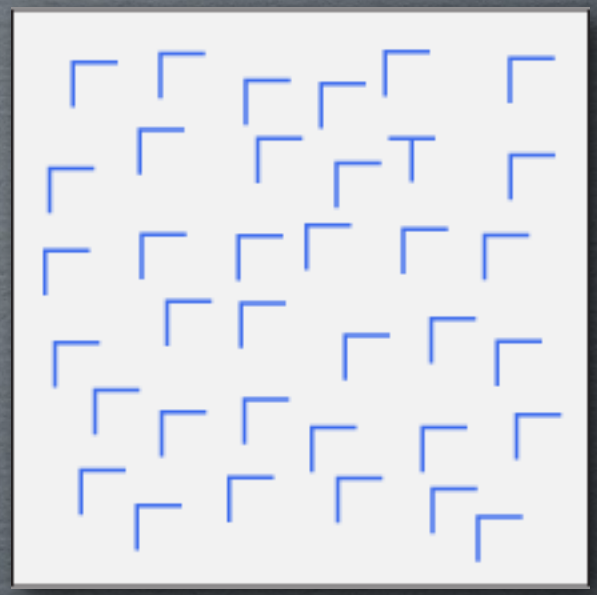
Curvature

http://www.csc.ncsu.edu/faculty/healey/PP

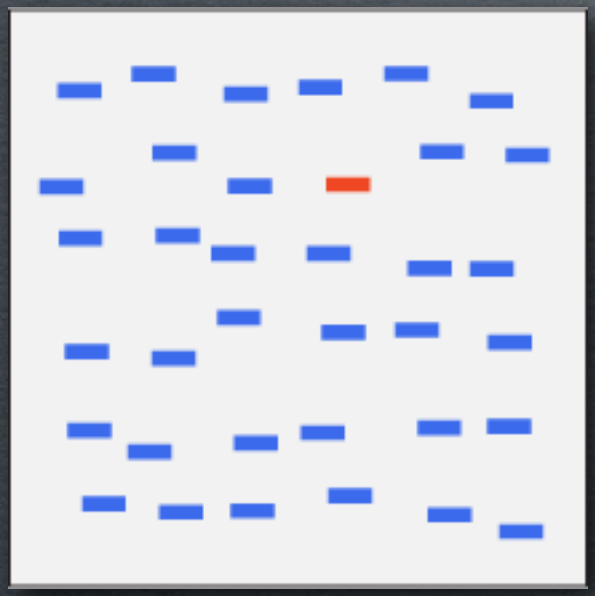
Preattentive Features



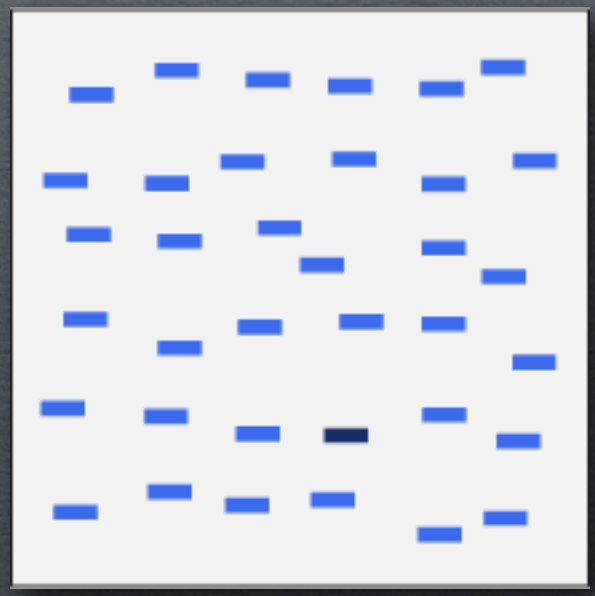
Intersection



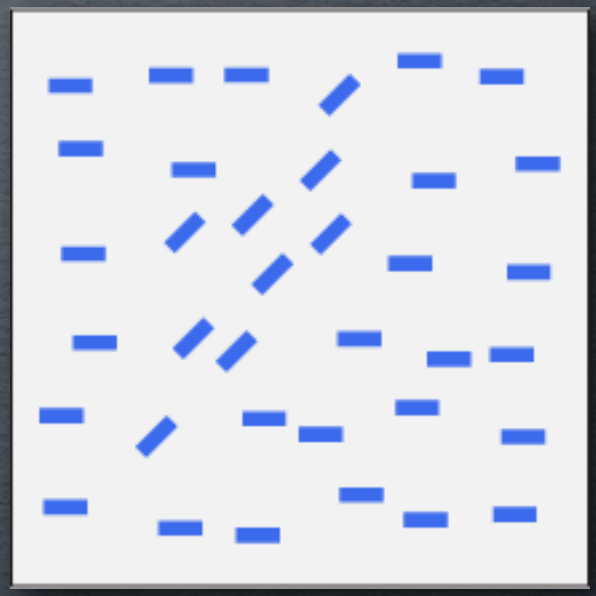
Terminators



hue



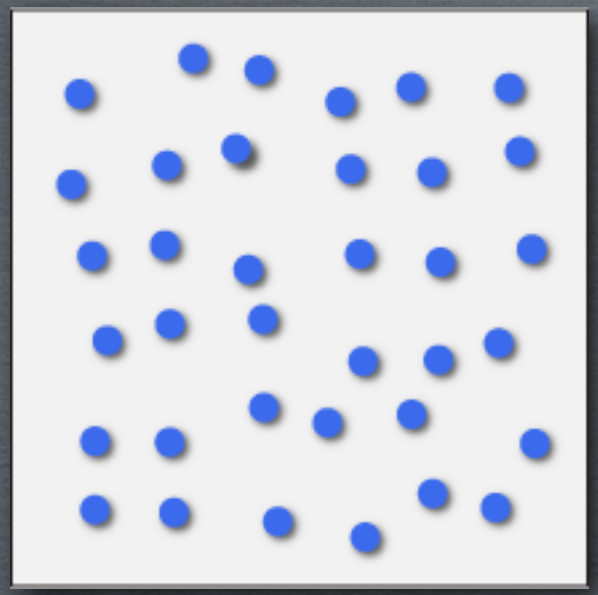
Luminance



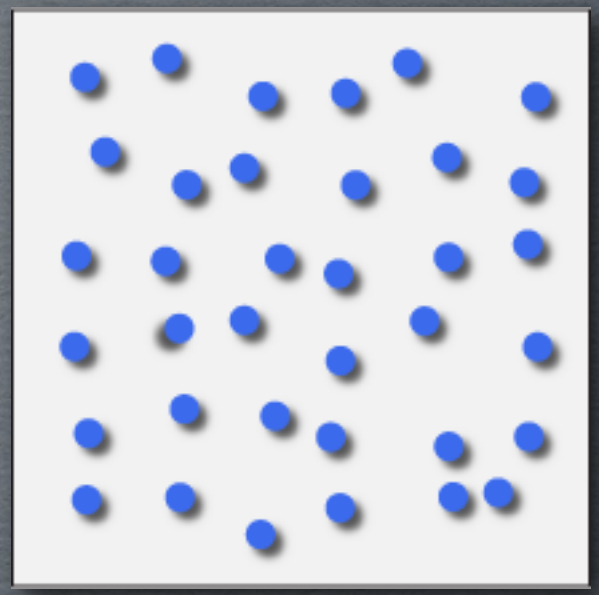
Number

http://www.csc.ncsu.edu/faculty/healey/PP

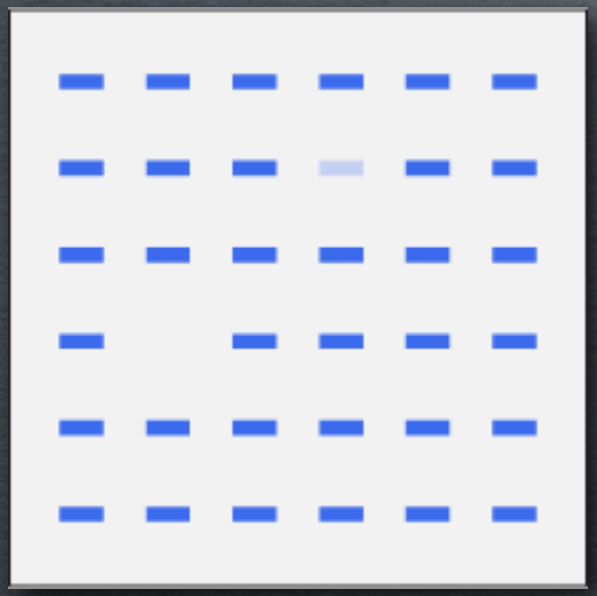
Preattentive Features



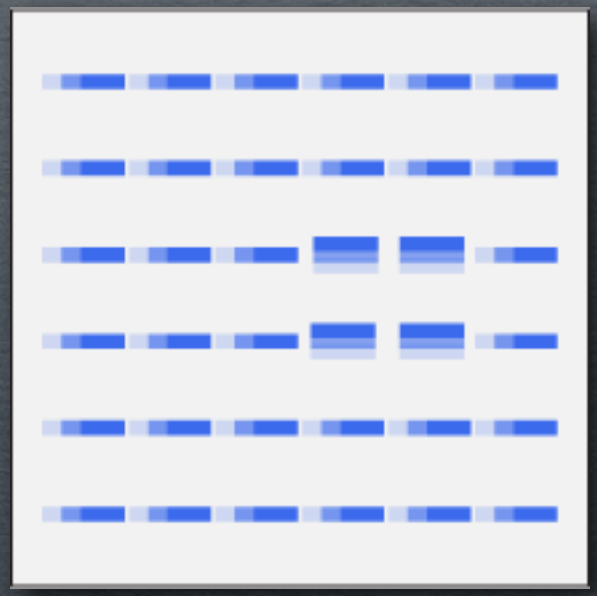
Depth



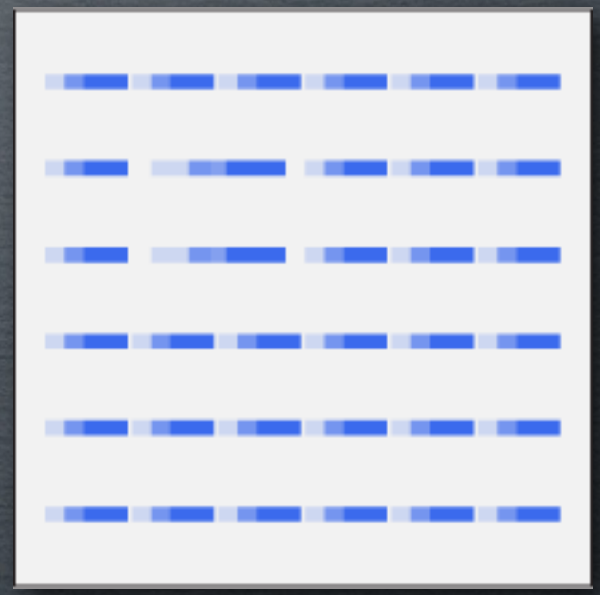
Direction of Lighting



Flicker



Direction of Motion

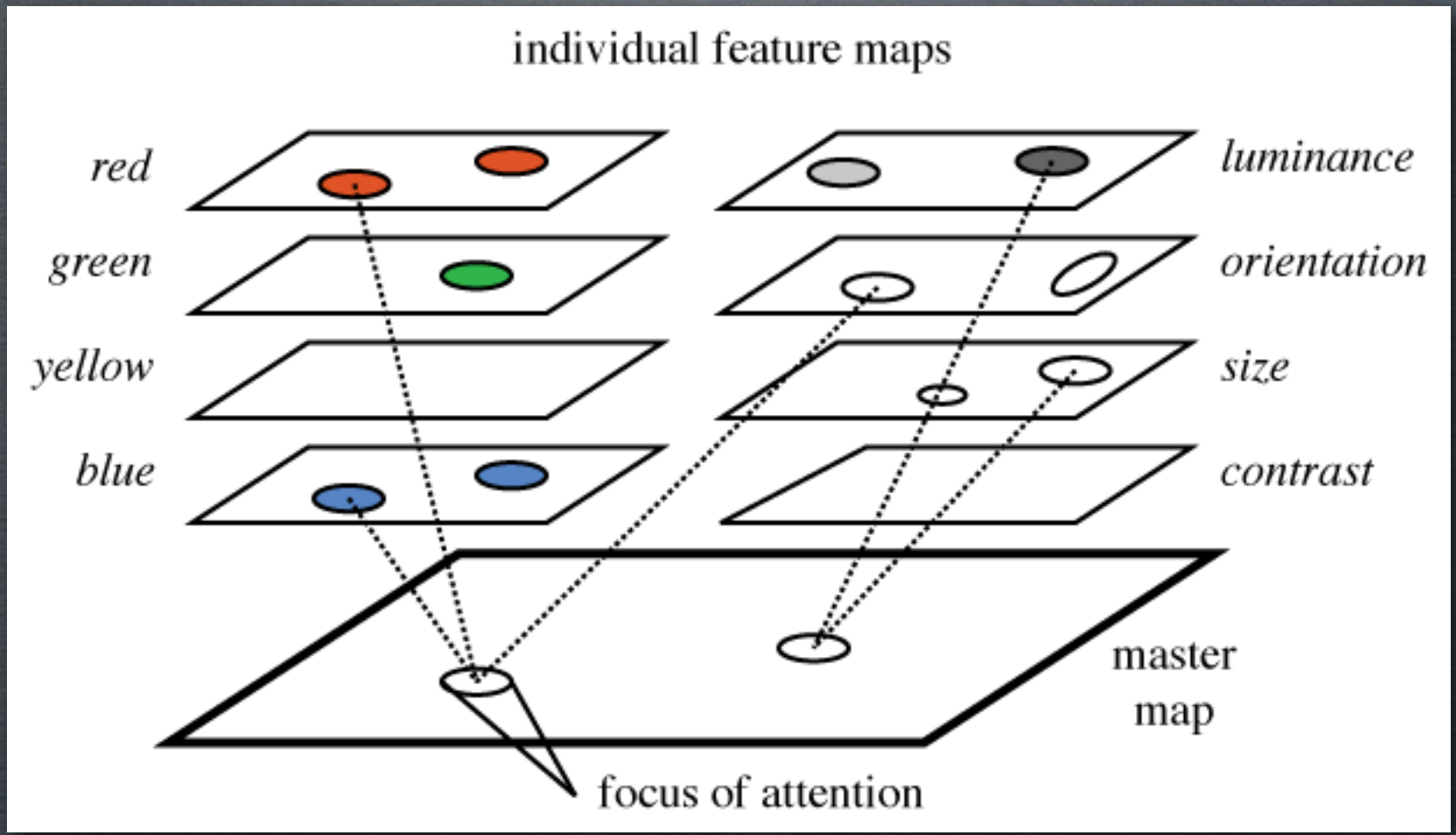


Velocity of Motion

http://www.csc.ncsu.edu/faculty/healey/PP

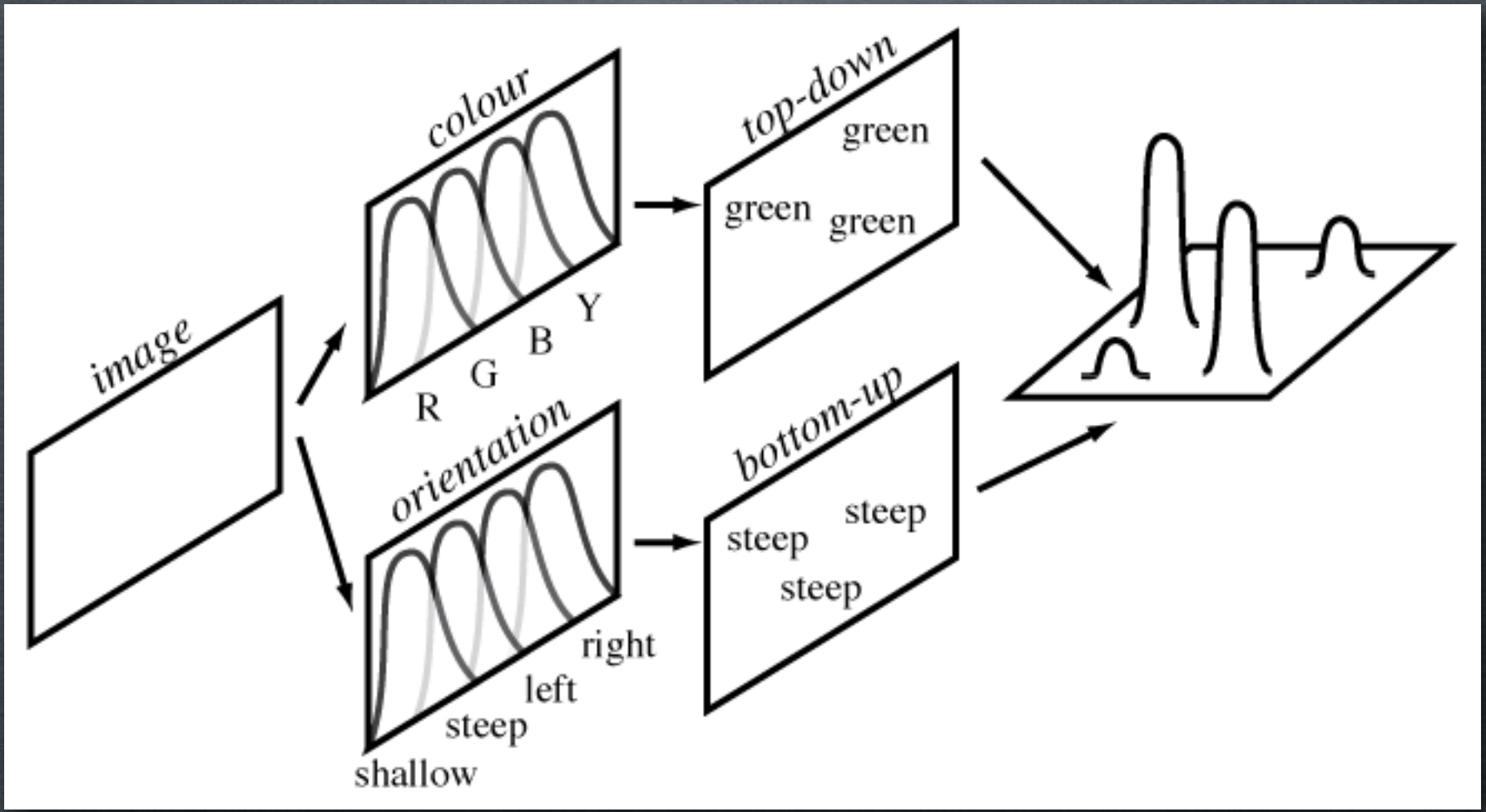
Feature Integration

Bottom-up Model



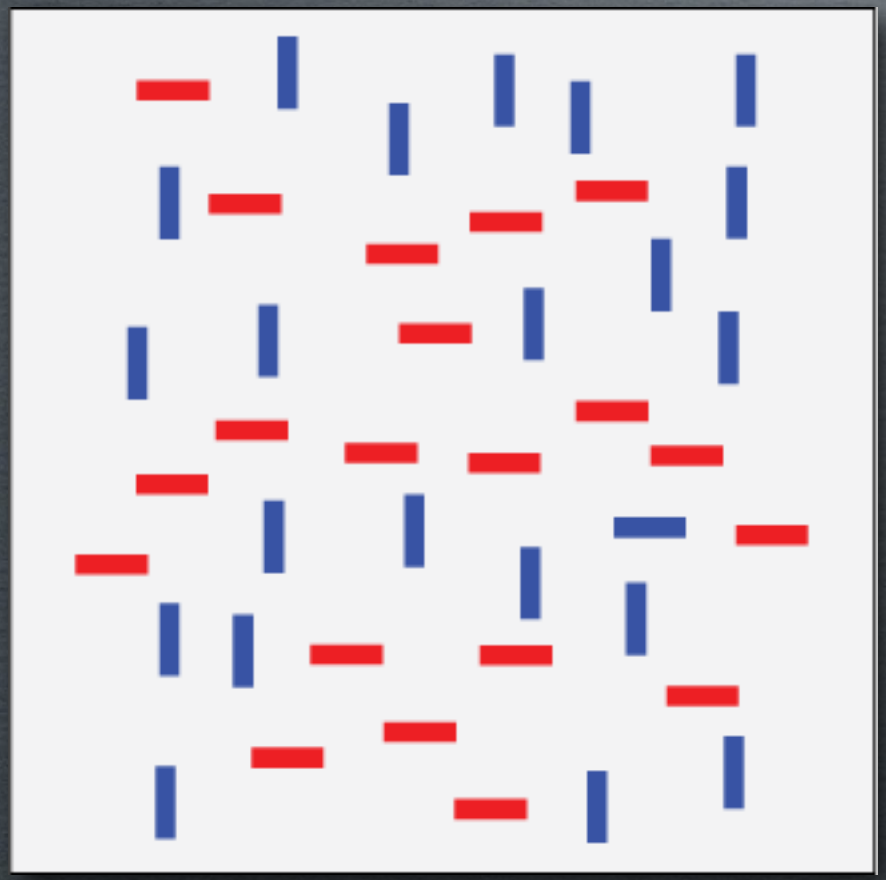
Guided Search

Bottom-up and Top-down Model

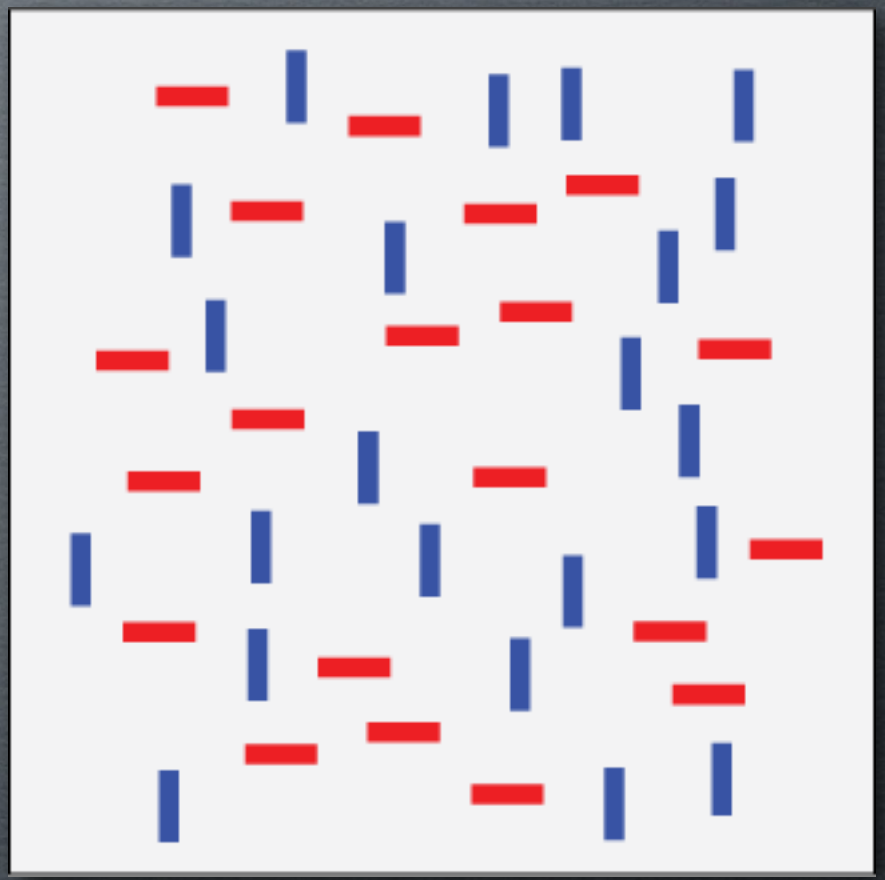


Boolean Maps

Search for a Blue Horizontal Target



Present

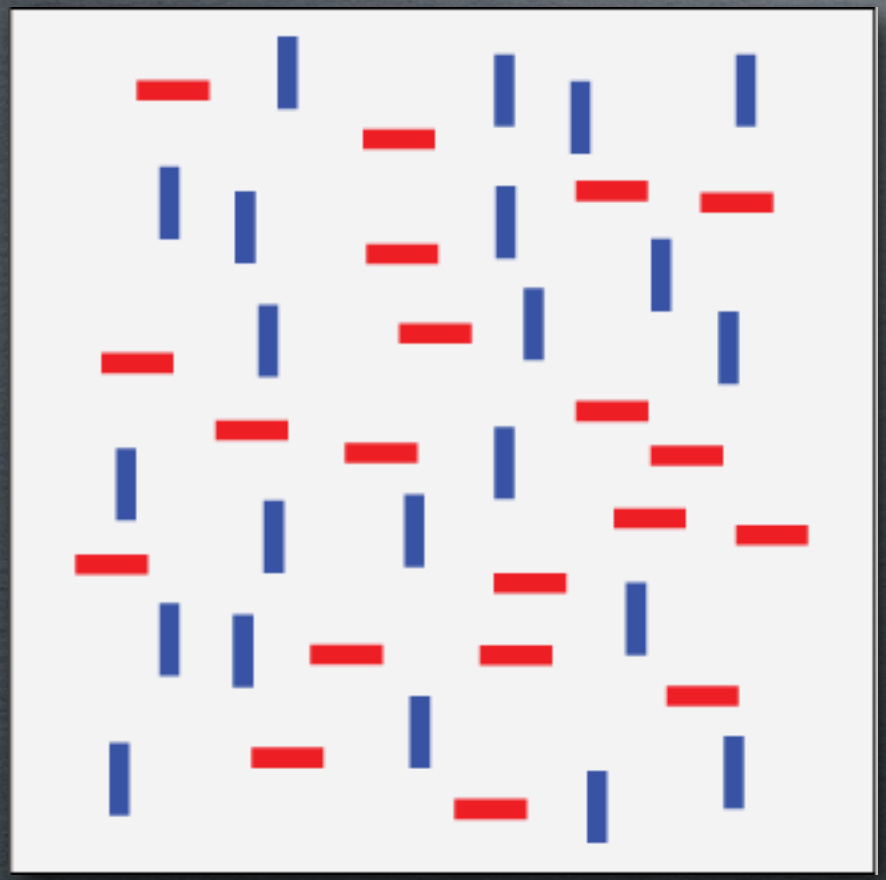


Absent

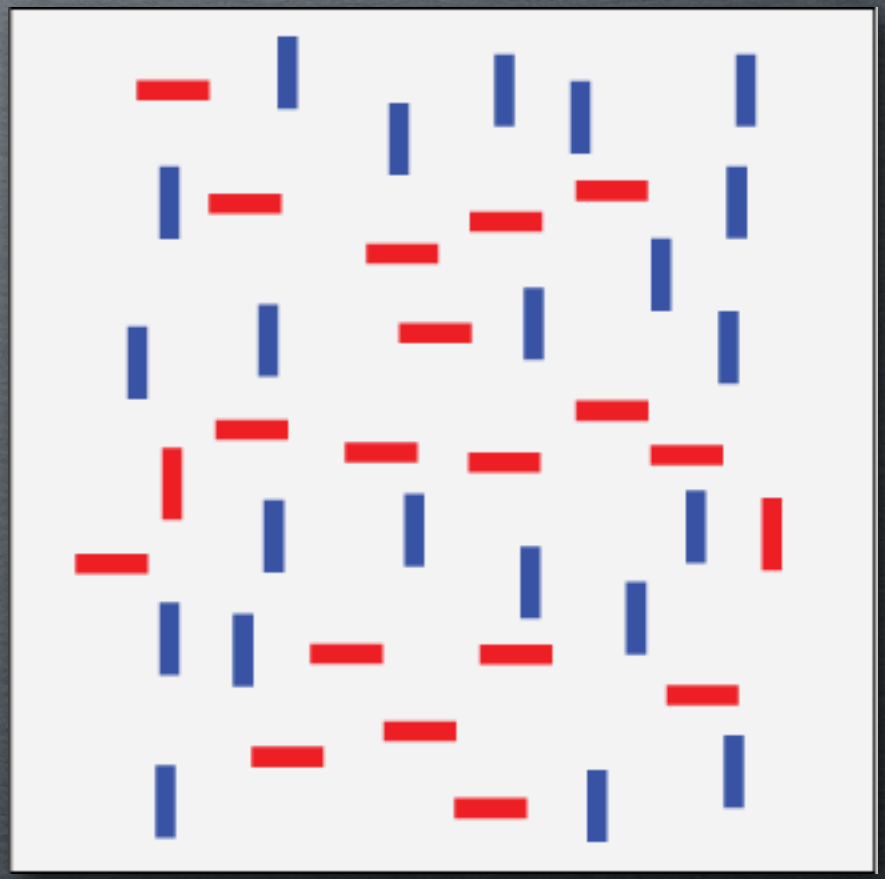
http://www.csc.ncsu.edu/faculty/healey/PP

Boolean Maps

Search for a Red Vertical Target



Absent

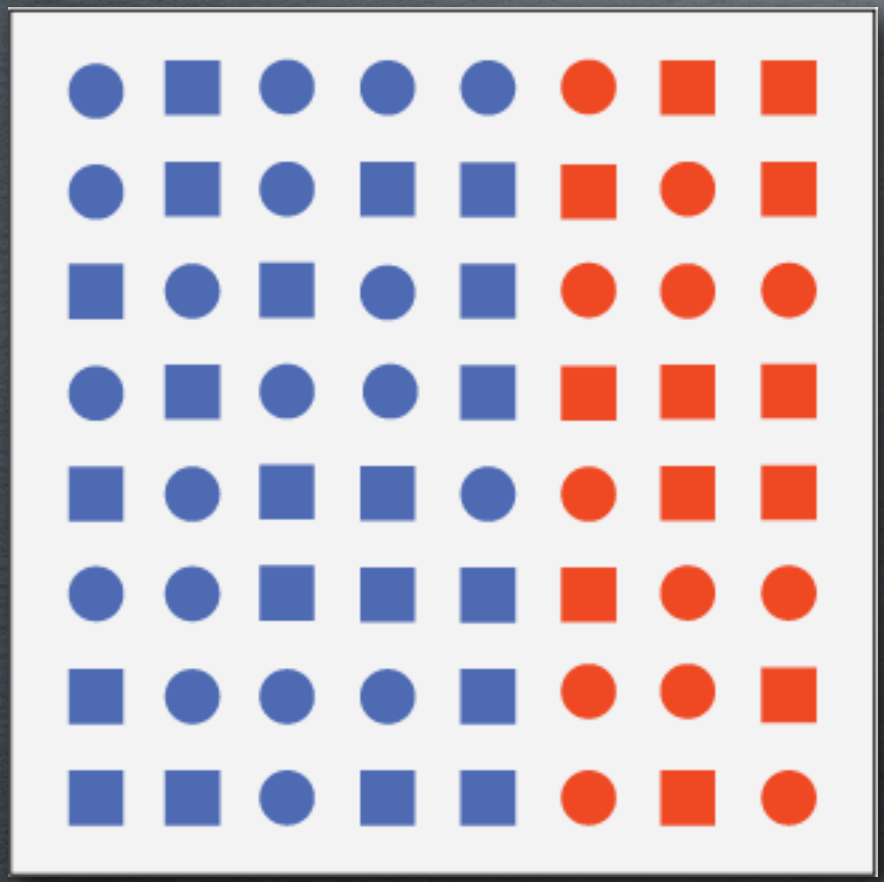


Present

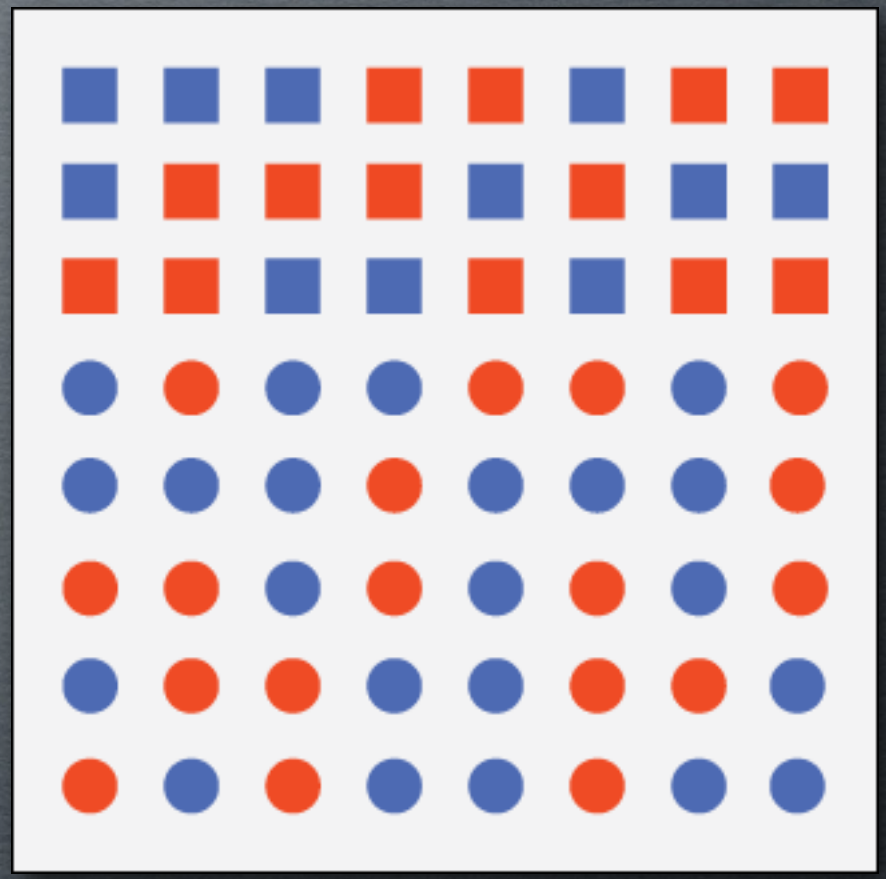
http://www.csc.ncsu.edu/faculty/healey/PP

Feature Hierarchy

Identify orientation of boundary



Hue Boundary

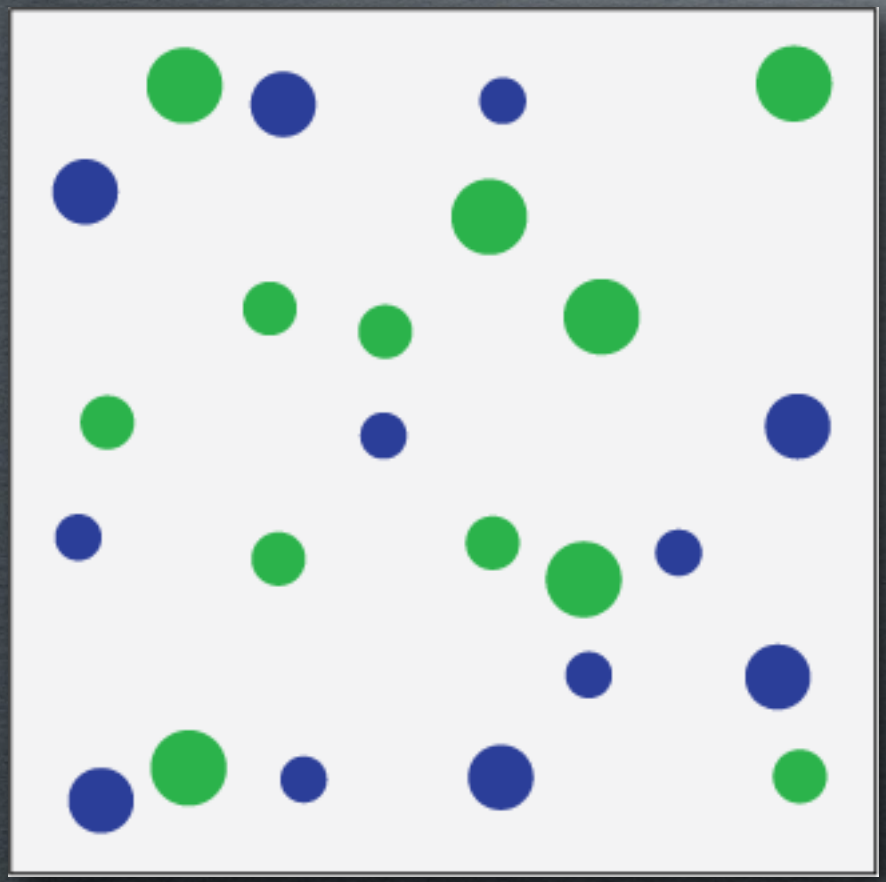


Shape Boundary

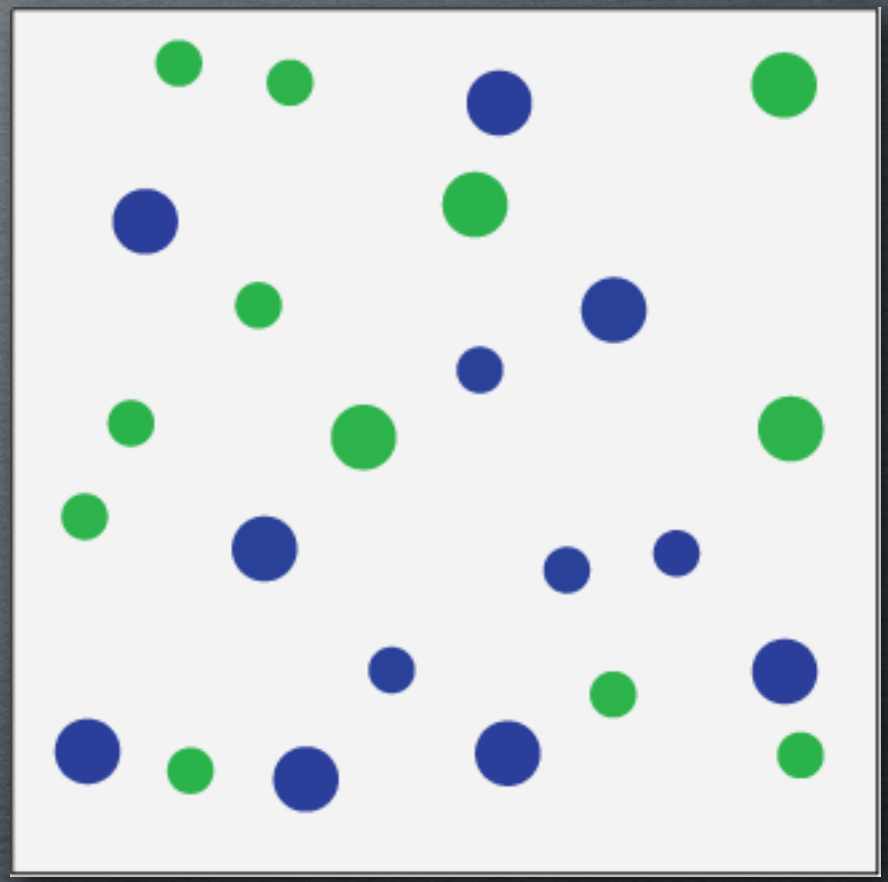
http://www.csc.ncsu.edu/faculty/healey/PP

Ensemble Coding

Identify Which Color Has Larger Average Size



All Green Circles > All Blue Circles



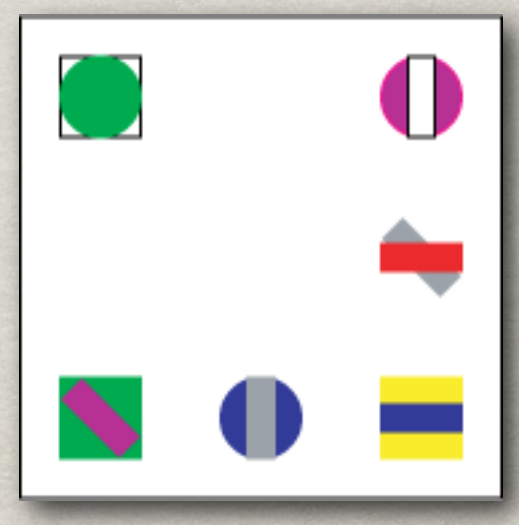
More Large Blue Circles

Perceptual Guidelines

- Choice of data-feature mapping guided by knowledge of human visual perception
  - Color is subdivided into hue, saturation, luminance, and/or chromaticity (hue + saturation)
  - Texture is subdivided into size, orientation, density, regularity of placement
  - Motion is subdivided into flicker, phase, direction, and velocity
- Feature "hierarchies" control order of data-feature mapping
- Luminance dominates hue, color dominates texture, regularity is perceptually weak, so:
  - most important data attributes are assigned to luminance,
  - then hue or chroma,

Postattentive Amnesia

- If viewers are allowed to preview a scene, will they be faster to answer questions about the details of the scene?
- Intuition suggest they will
  - Implies viewers have the ability to extract detail throughout a scene, access it rapidly on demand



Priming image

- Various experiments have shown that human vision does not work in this manner
  - Vision is not a camera that can “snapshot” a full-detail representation of a scene
  - Results suggest that detail is only available at the most recent focus of attention

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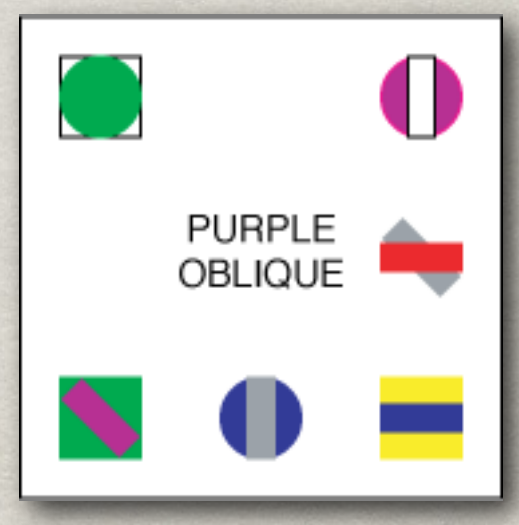

Search image

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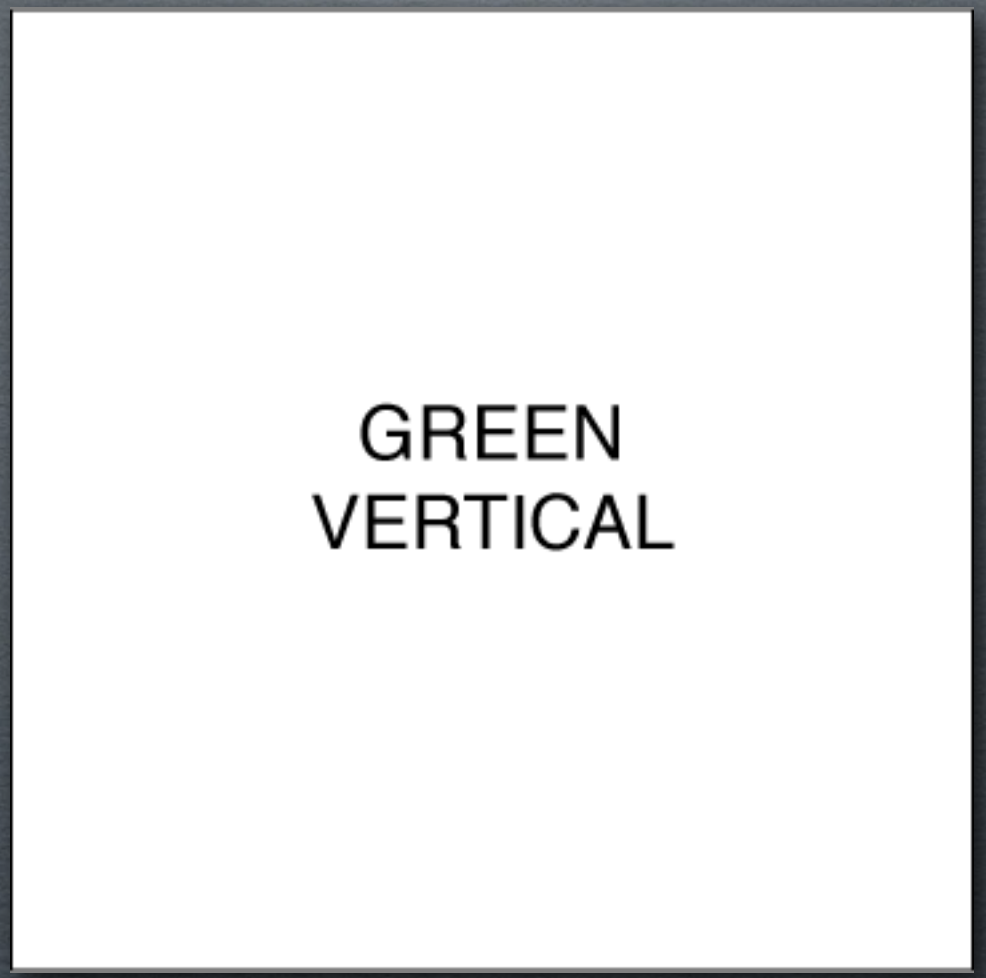
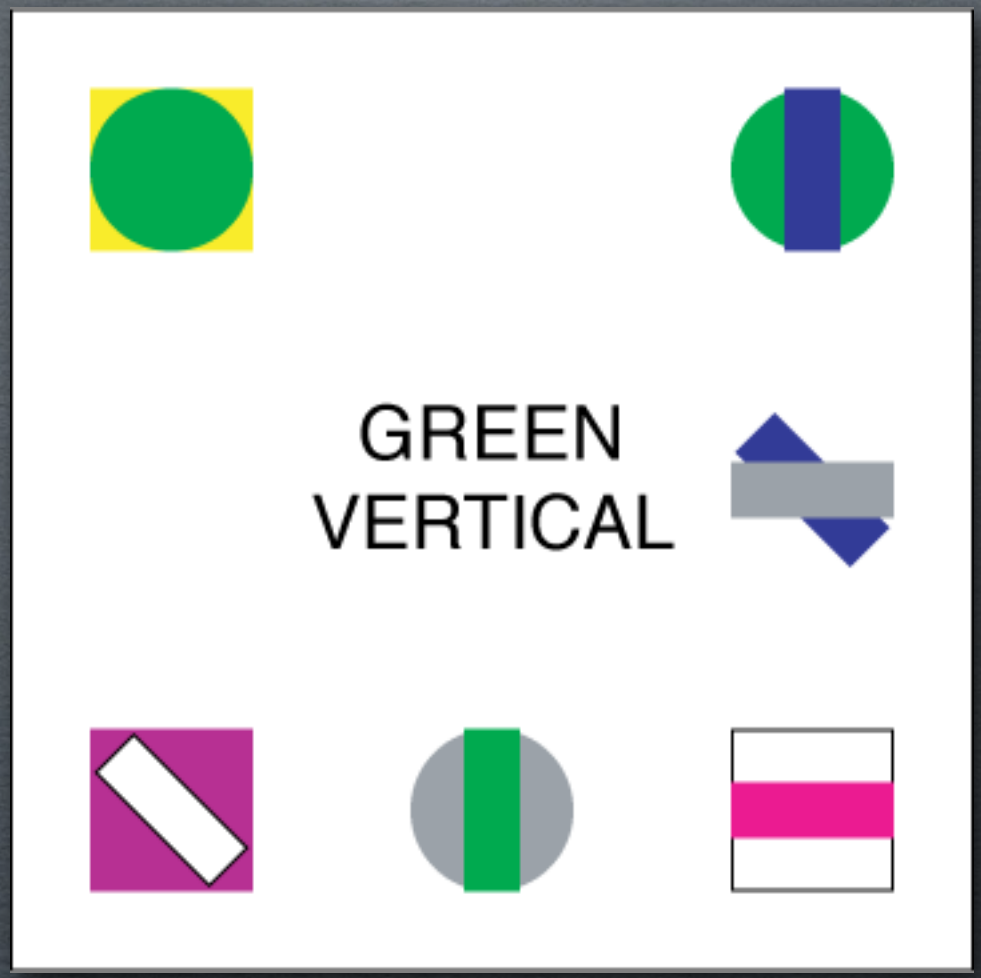
  - Vision is not a camera that can “snapshot” a full-detail representation of a scene
  - Results suggest that detail is only available at the most recent focus of attention

Search With no Priming

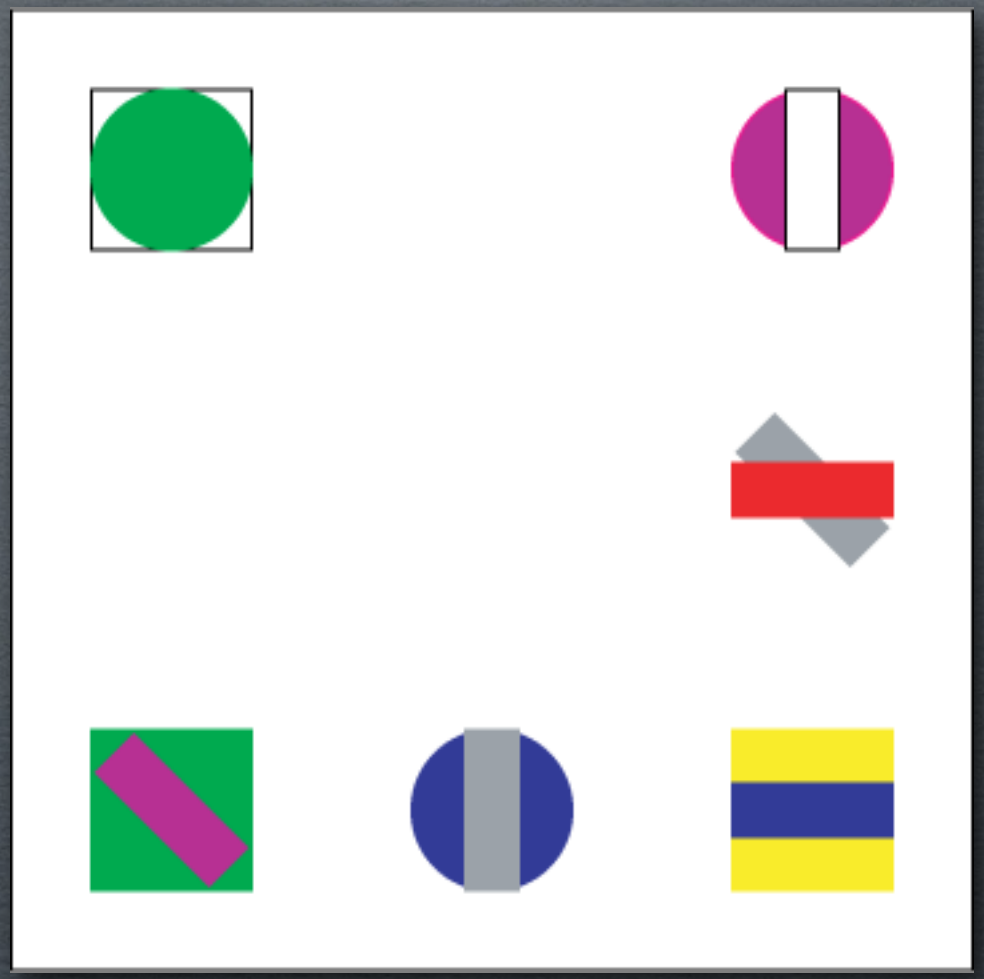


Search With no Priming

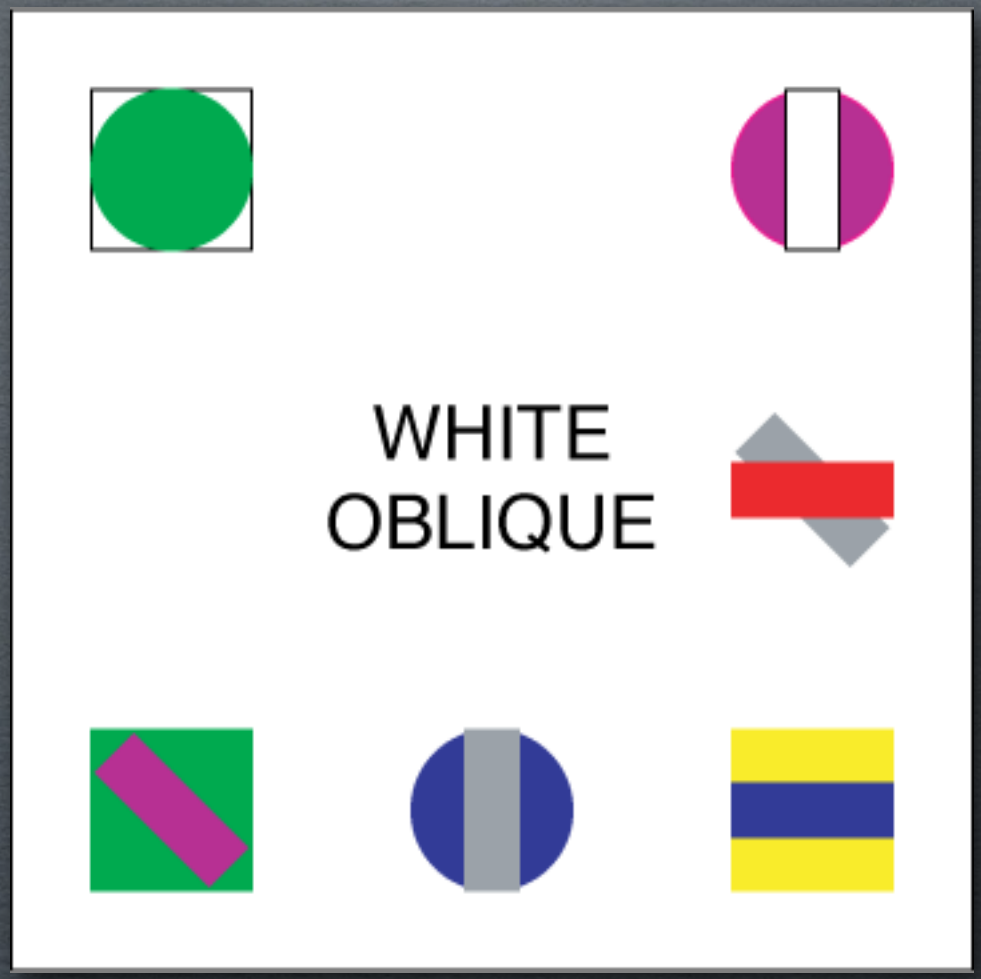


Present

Primed Search



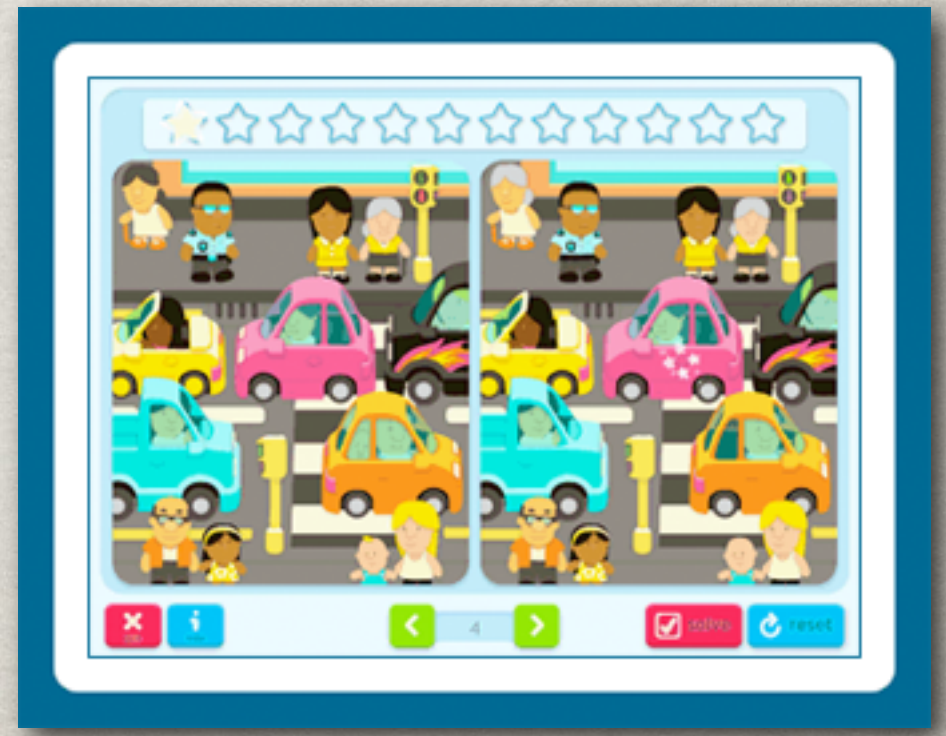
Primed Search



Absent

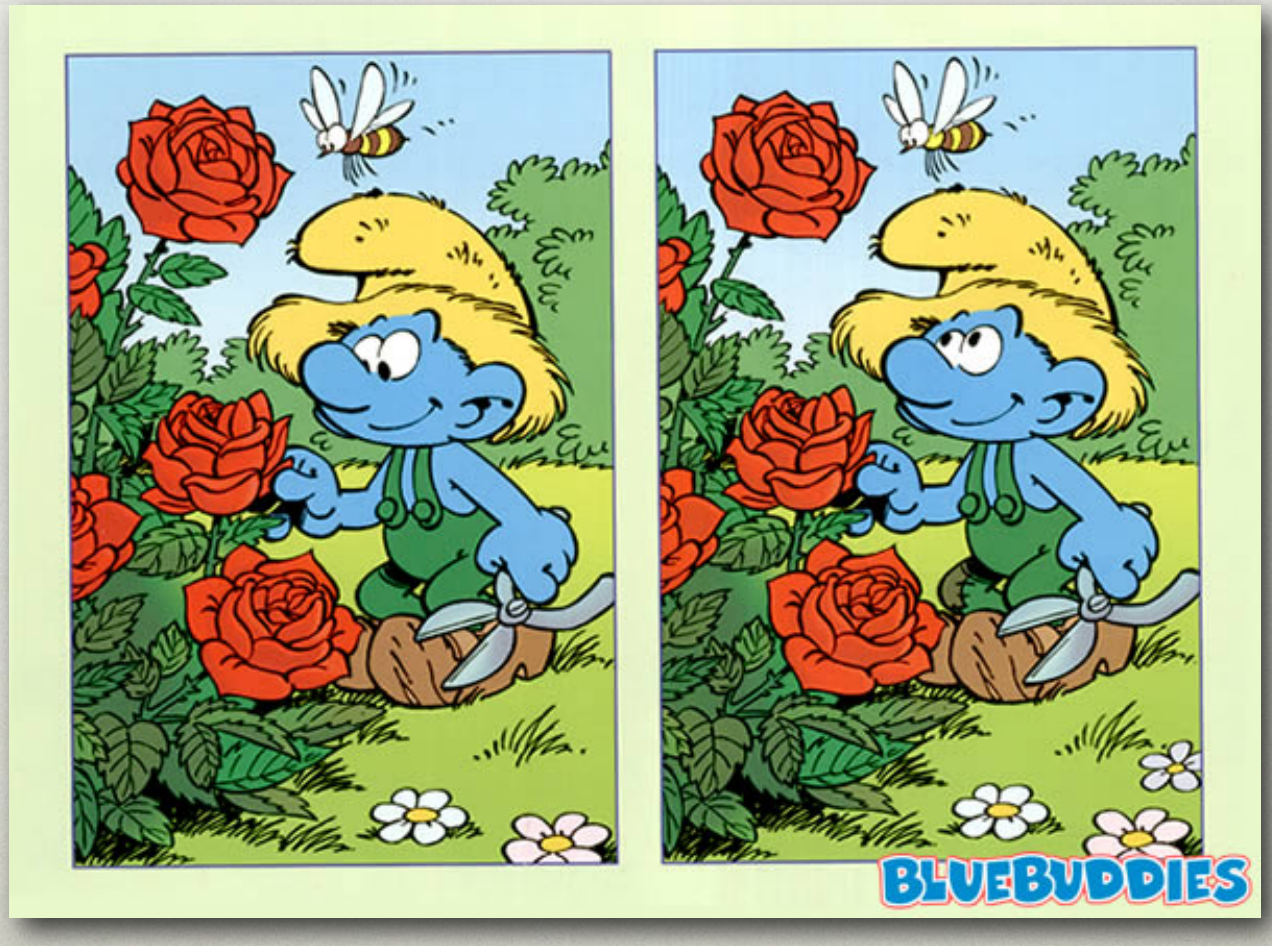
Change Blindness

- Visual system has limited memory for detail, often restricted to focus of attention
- **Visual disruption (e.g., eye saccade) can render us "blind" to changes in a scene**
- **Common example: newspaper game, find differences between two images**
- **Original experiments conducted at Nissan's Cambridge Basic Research**

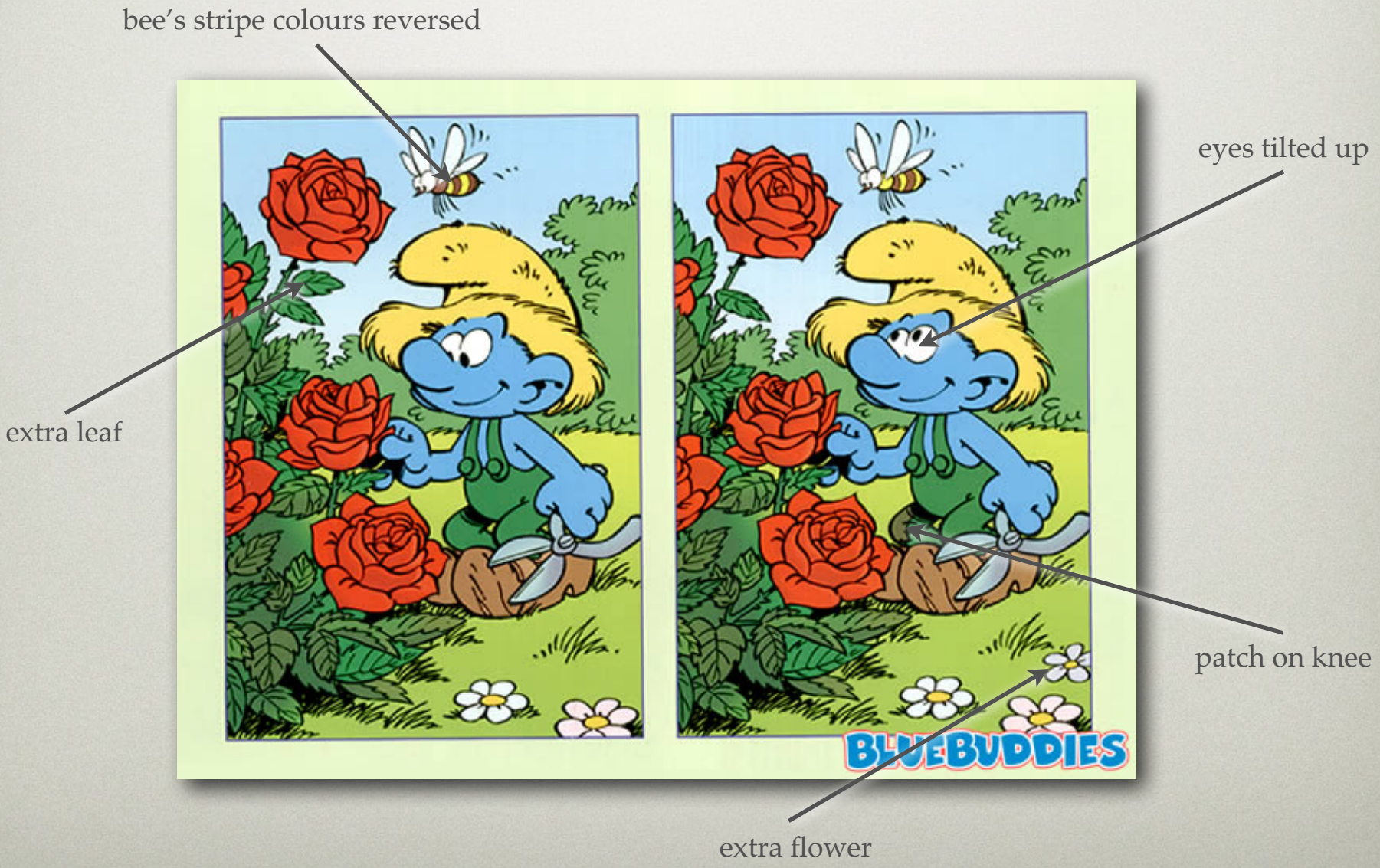


Find four differences between the two images

Find Five Differences



Find Five Differences



Change Blindness

Data courtesy Ron Rensink, Department of Psychology, UBC

Change Blindness

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Change Blindness

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Change Blindness Models

- Overwriting
  - current image overwritten by new one
- First impression
  - initial view abstracted
- Nothing is stored
  - scene abstracted with no details
- Feature combination
  - previous and new views combined
- Everything is stored, nothing is compared
  - details cannot be accessed without external stimulus

Main actor changes across movie cut

Determine Arm Orientation

Determine the orientation
of the longer arm of the cross:

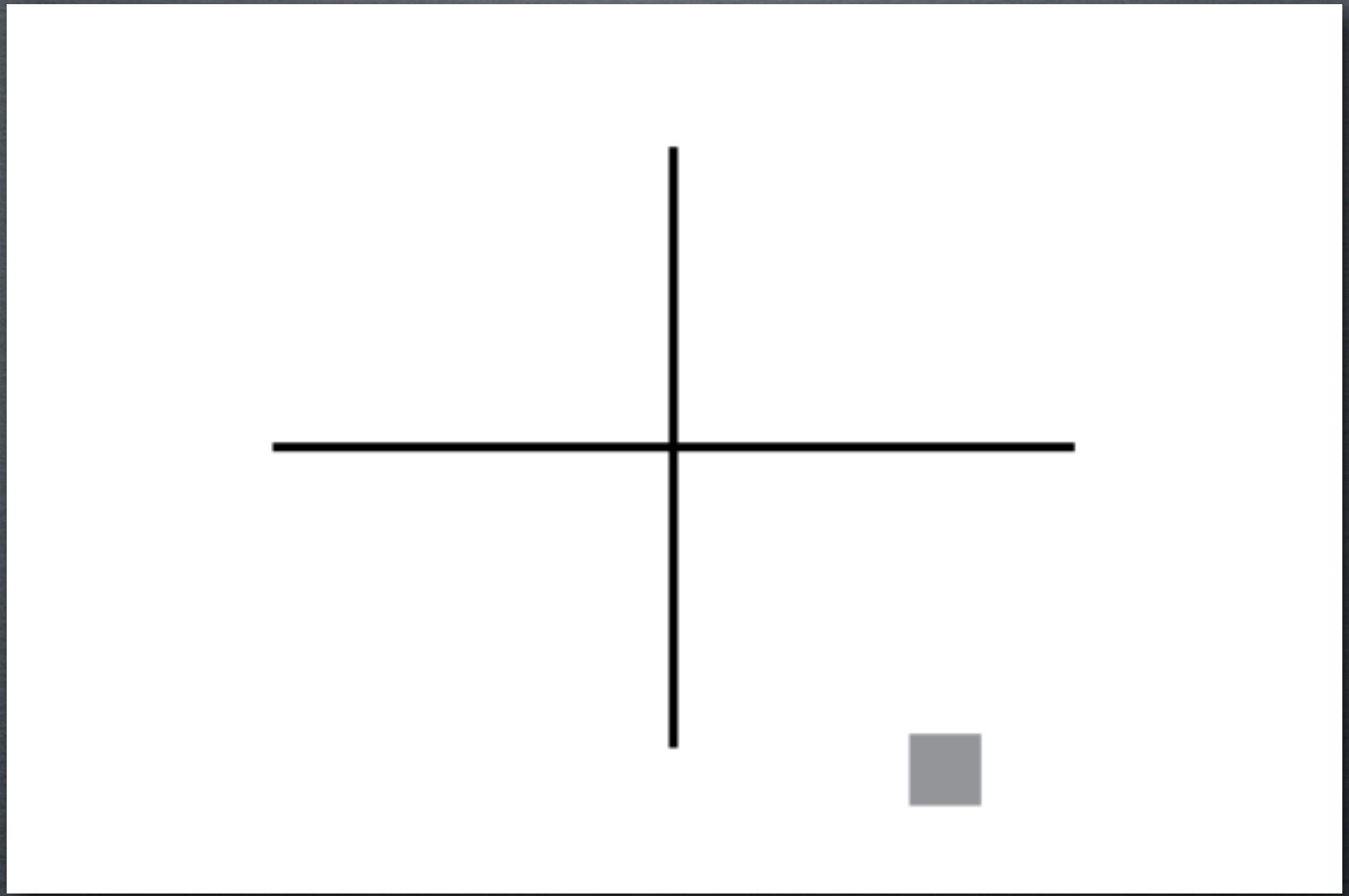
horizontal or vertical

Inattentional Blindness

Determine the orientation
of the longer arm of the cross:

horizontal or vertical

Grey Square in Frame



Inattentional Blindness

- During an attention-demanding task, viewers are “blind” to significant change in a scene
- These same change is easily identified when scene is viewed without any task
- Hypothesis: visual system has a limited amount of “visual attention” it can deploy over a scene
- Classic example, counting basketball passes
  - Two teams, black and white, viewer asked to count passes for one of the teams
  - During the passing, a woman in a gorilla suit walks through the scene
  - More than half the viewers did not notice the gorilla

SALMON MIGRATIONS

- Track salmon migration patterns in the Northern Pacific
- Migration patterns affected by:
  - sea surface temperature
  - plankton density
  - ocean current direction and velocity
- Approach determines which strait holds the bulk of the salmon run
- Estimations critical to setting

Migration occurs north through Strait of Georgia or south through Juan de Fuca Strait

http://www.csc.ncsu.edu/faculty/healey/HTML_papers/plankton/plankton.html

Known Plankton Densities

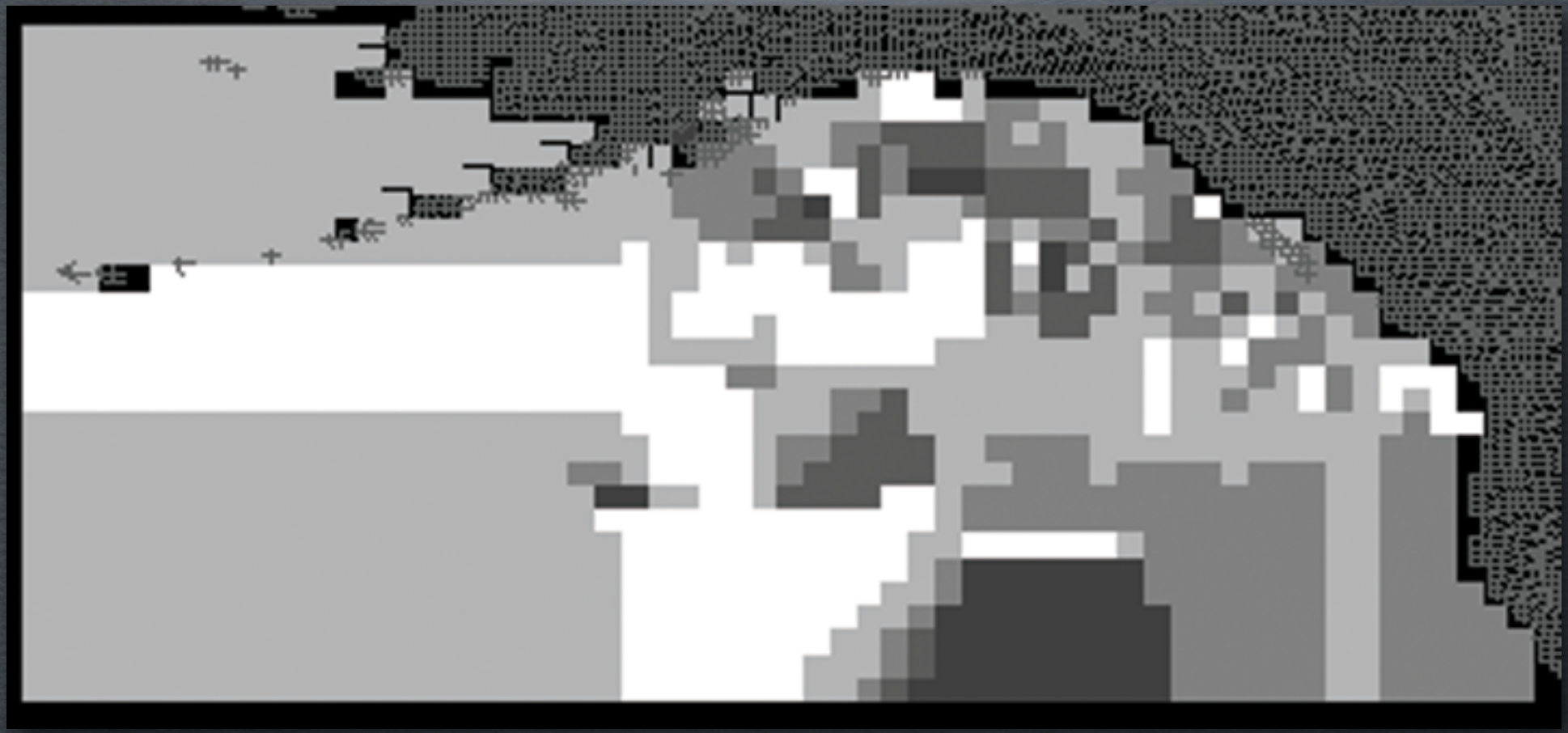
January

Plankton Density → Luminance

Data courtesy Keith Thompson, Department of Earth and Ocean Sciences, UBC

Interpolated Plankton Densities

January

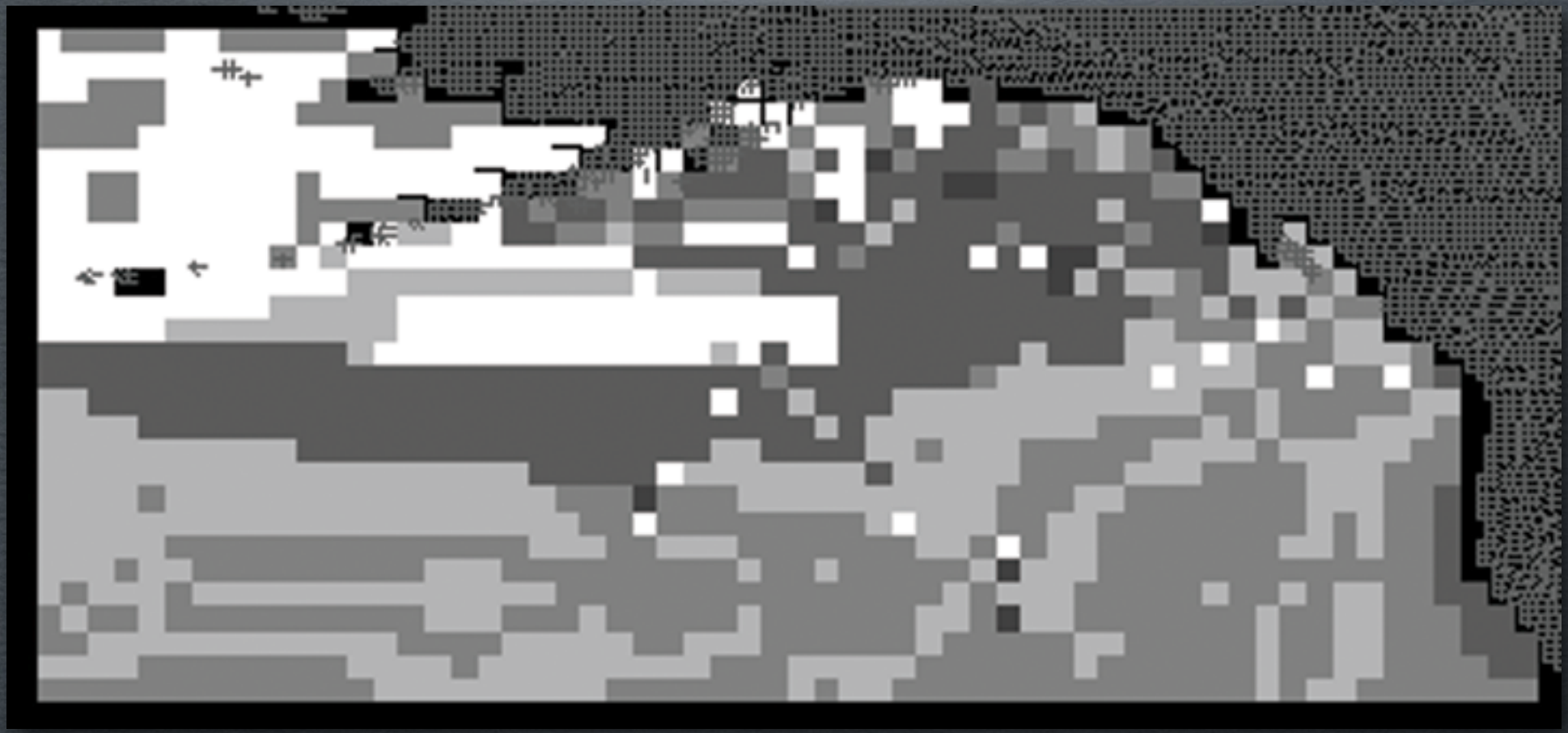


Plankton Density → Luminance

Data courtesy Keith Thompson, Department of Earth and Ocean Sciences, UBC

Data Mined Plankton Densities

January

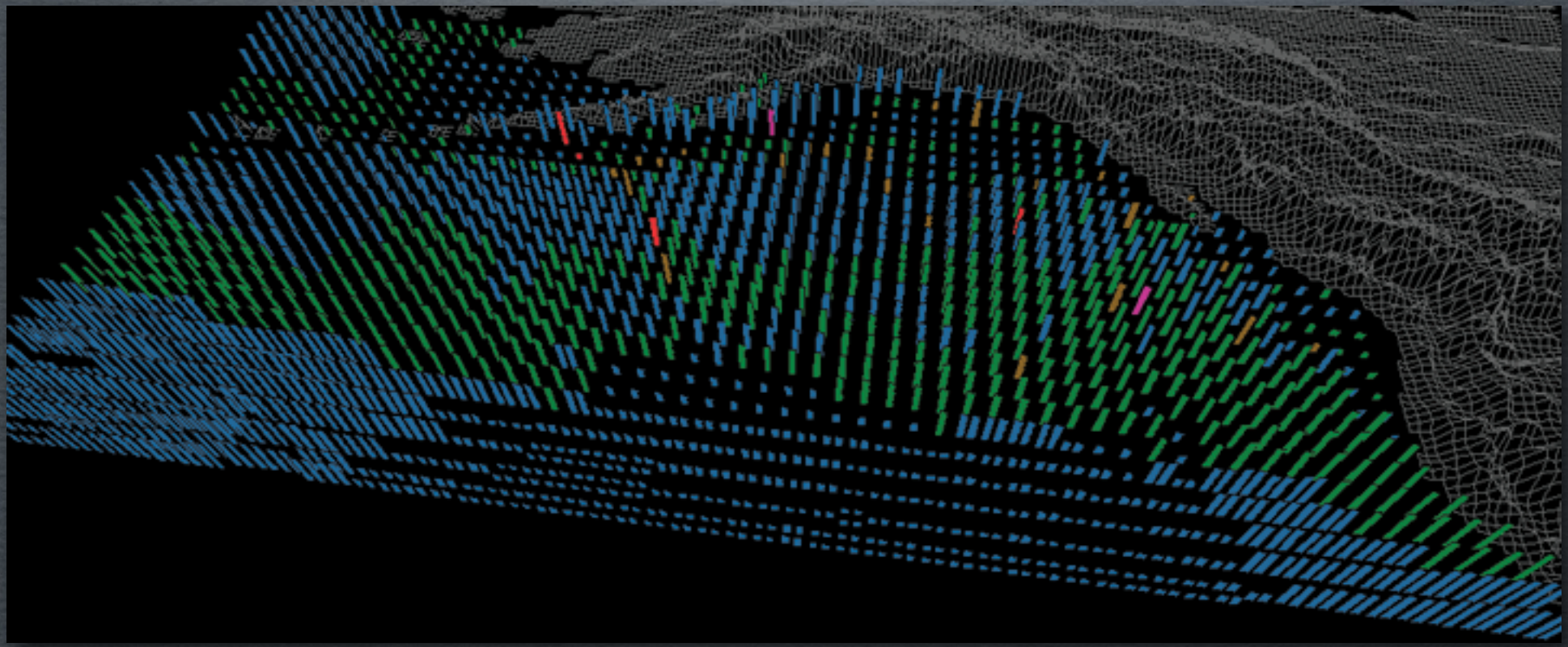


Plankton Density → Luminance

Data courtesy Keith Thompson, Department of Earth and Ocean Sciences, UBC

Migration Factors Visualizations

February

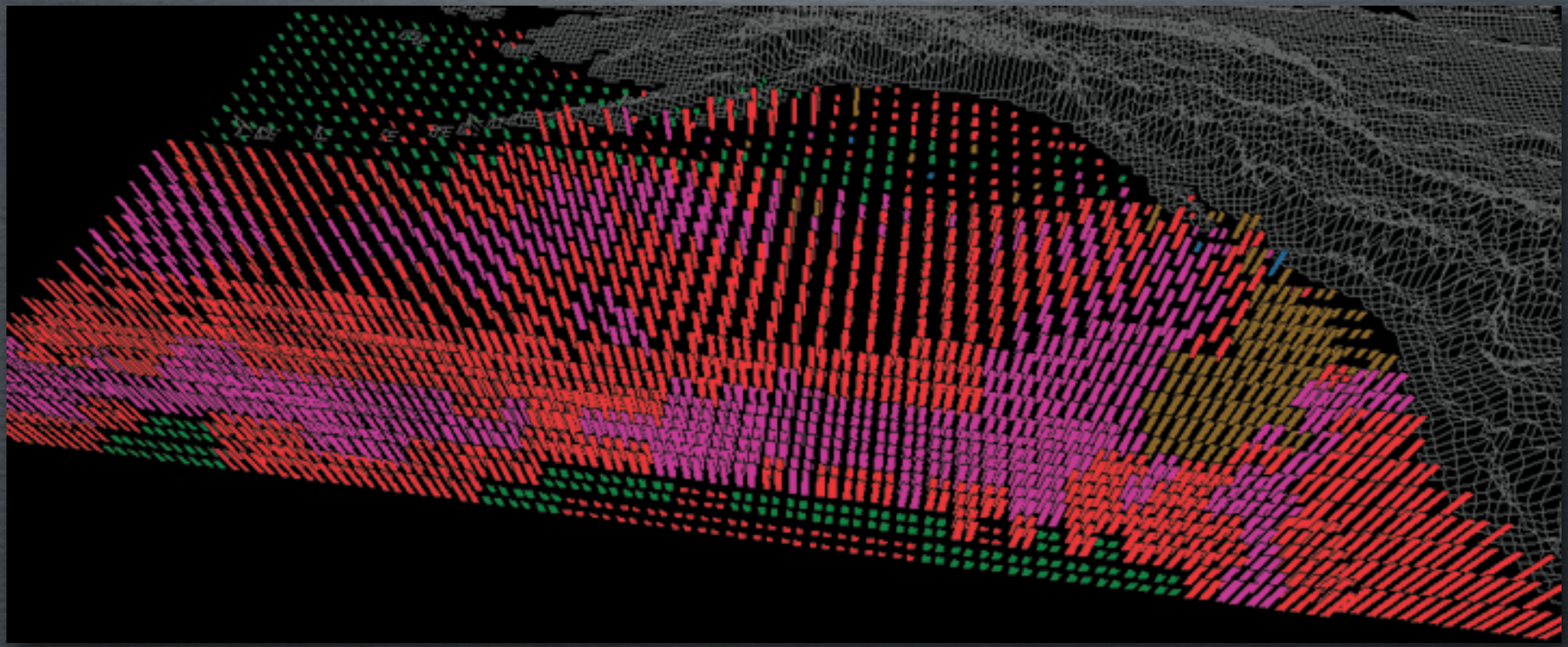


Plankton Density → Blue...Green...Brown...Red...Purple,
Current Strength → Height, Sea Surface Temperature → Density

Data courtesy Keith Thompson, Department of Earth and Ocean Sciences, UBC

Migration Factors Visualizations

June

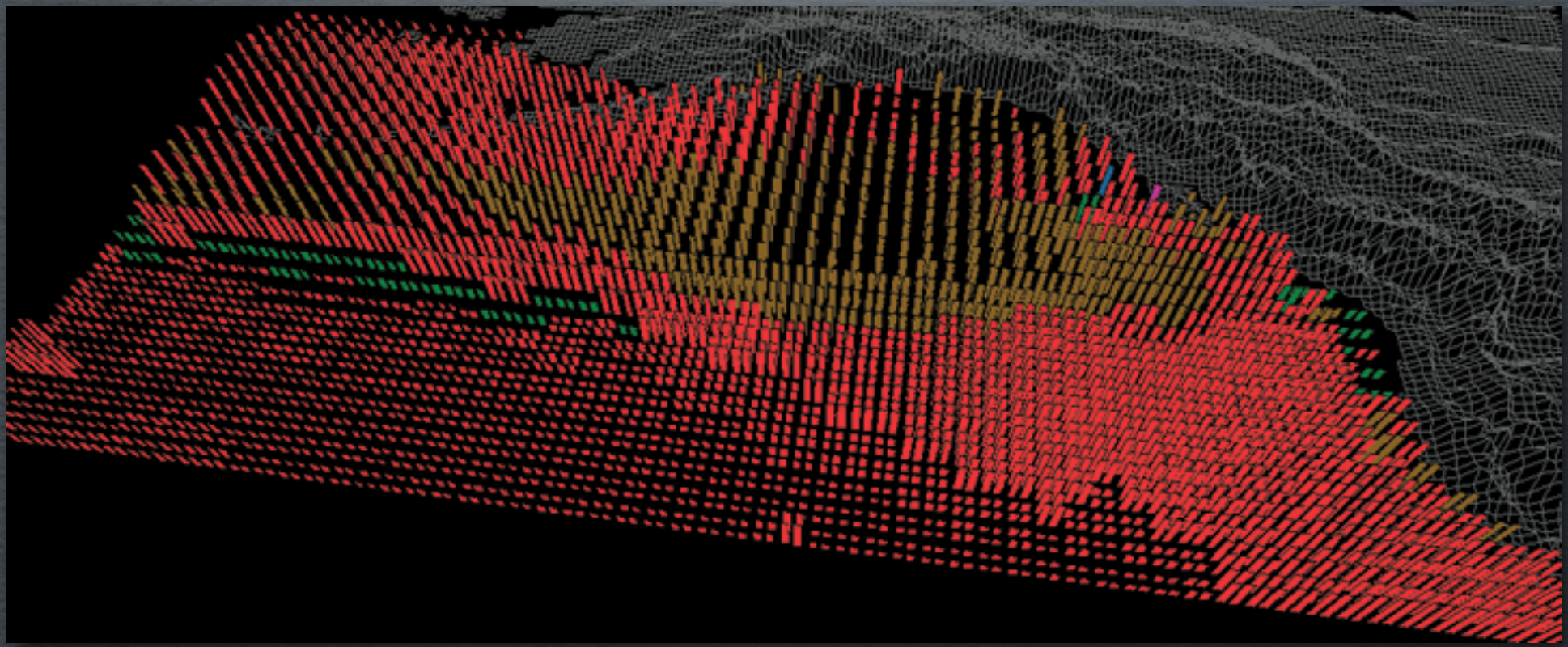


Plankton Density → Blue...Green...Brown...Red...Purple,
Current Strength → Height, Sea Surface Temperature → Density

Data courtesy Keith Thompson, Department of Earth and Ocean Sciences, UBC

Migration Factors Visualizations

October

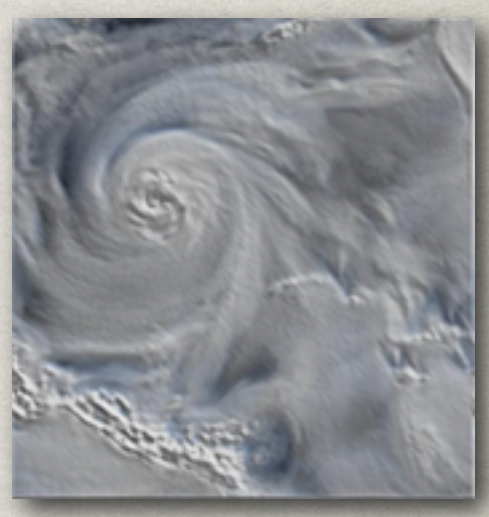


Plankton Density → Blue...Green...Brown...Red...Purple,
Current Strength → Height, Sea Surface Temperature → Density

Data courtesy Keith Thompson, Department of Earth and Ocean Sciences, UBC

Painterly Visualizations

- Can we build **aesthetically beautiful visualizations?**
- **Orientation versus engagement**
  - **Engage a viewer, promote increased recall for detail**
  - Motivate a more detailed examination of images
  - Highlight important properties of a dataset
- Enhance a visualization
  - highlight important data properties
  - remove extraneous detail
  - harness artistic techniques to convey difficult-to-visualize details

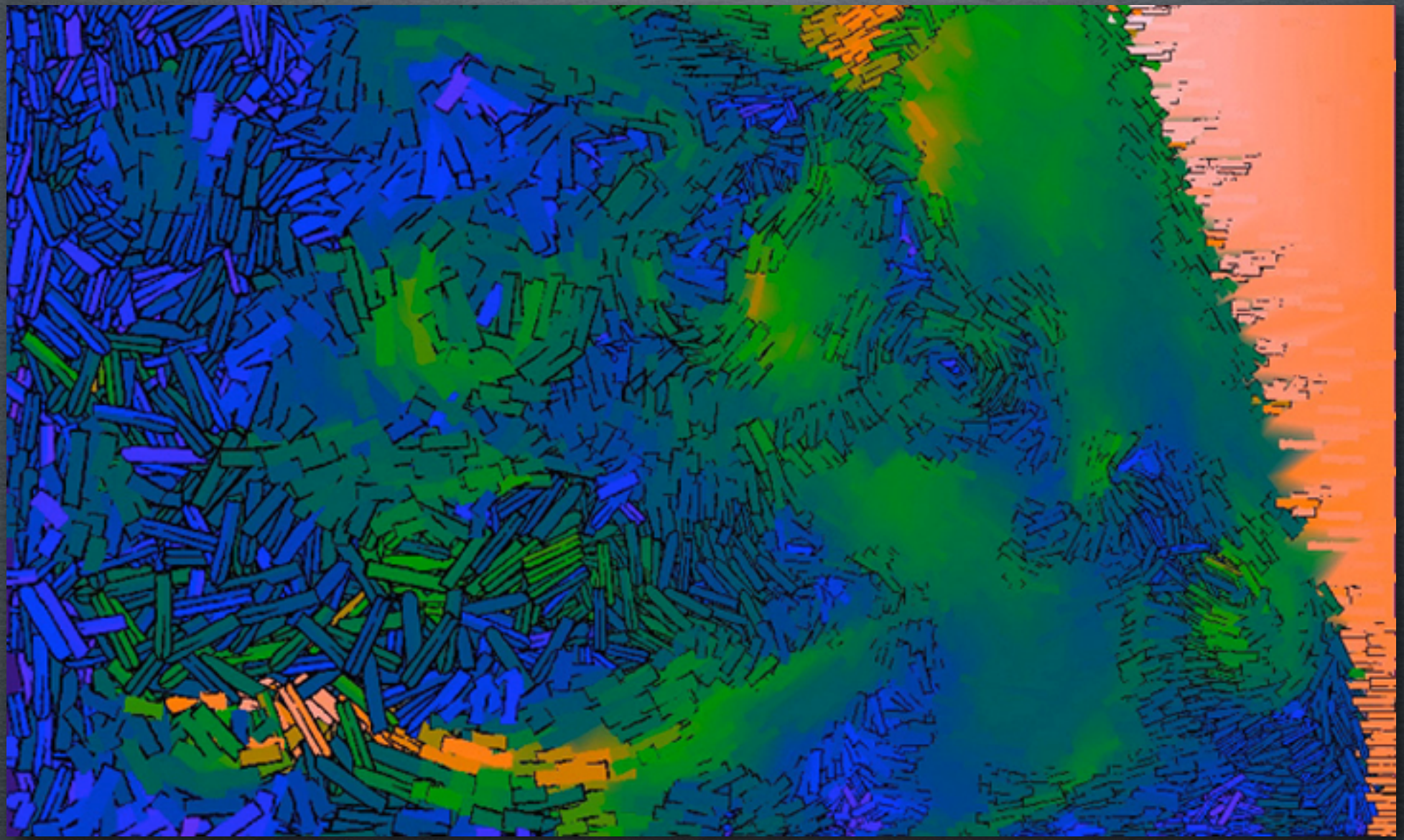


Original hurricane image

Boundaries enhanced

Case Study on Visualizing Hurricanes Using Illustration-Inspired Techniques, 2009. Alark Joshi, Jesus Caban, Penny Rheingans, Lynn Sparling, IEEE Transactions on Visualization and Computer Graphics 15, 5, pp 709-718.

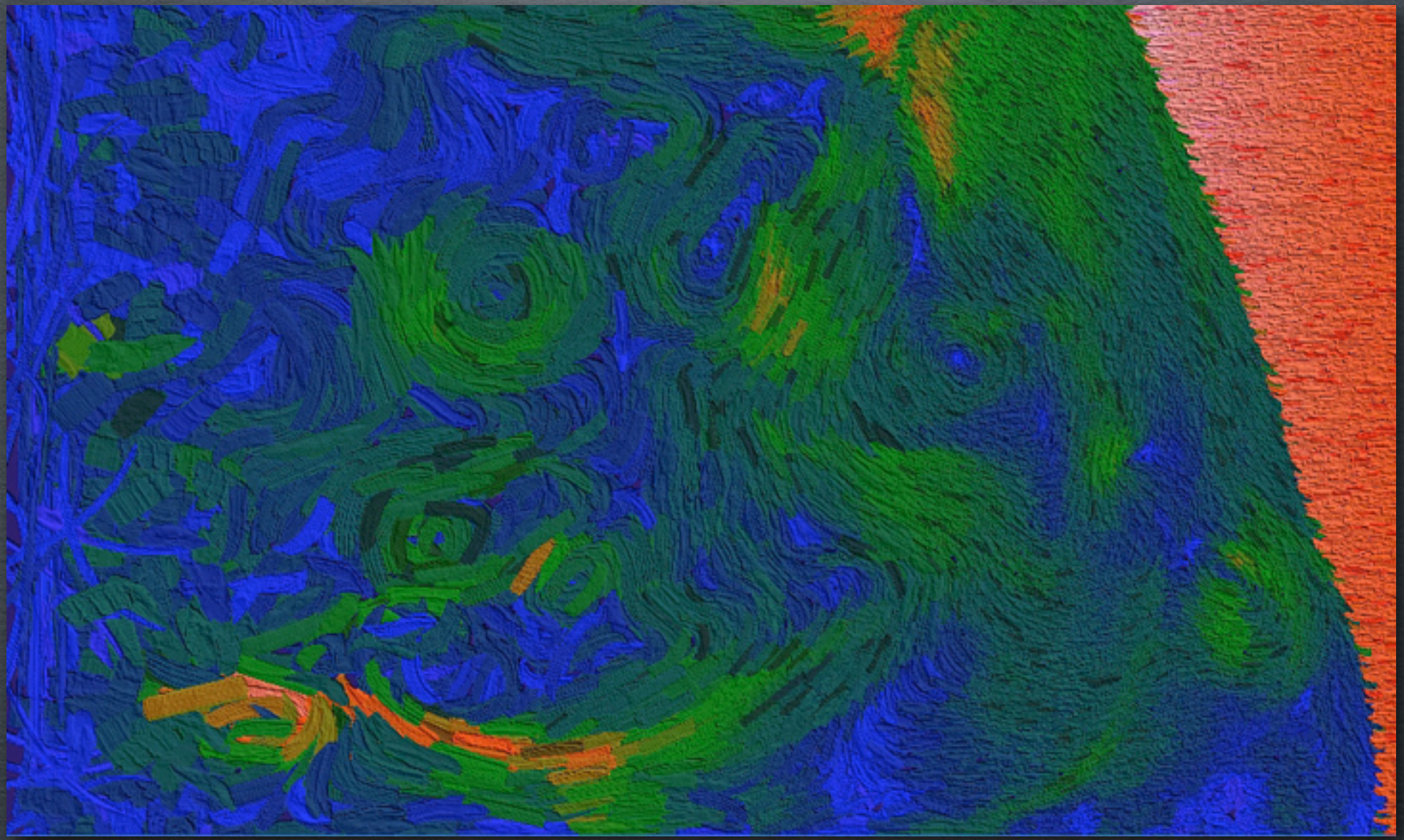
SupernovA Simulation



Flow Direction → orientation, Magnitude → Colour, Density → size

Data courtesy John Blondin, Department of Physics, NC State University

SupernovA Simulation

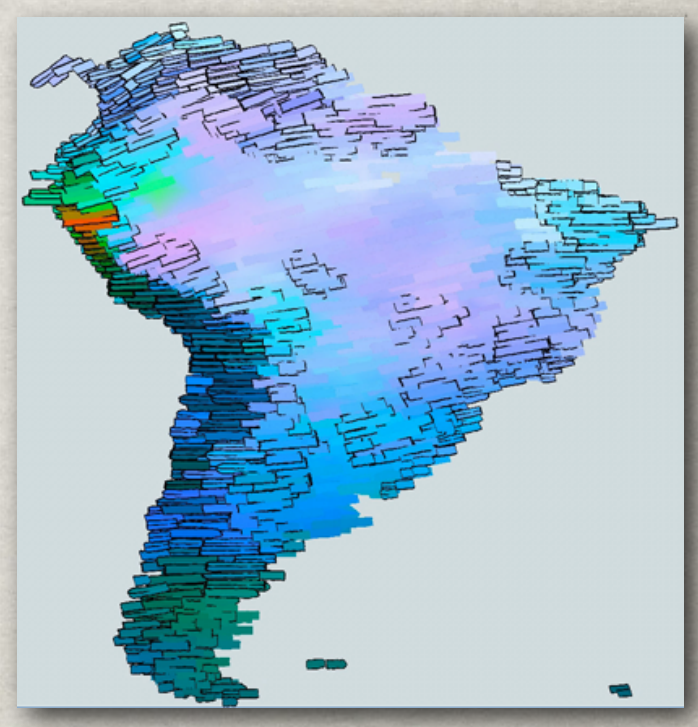


Flow Direction → orientation, Magnitude → Colour, Density → size, Pressure → aspect ratio

Data courtesy John Blondin, Department of Physics, NC State University

Nonphotorealism Results

- Nonphotorealistic visualizations have capabilities similar to glyph-based visualizations
- Visual complexity can be varied to systematically change perceived aesthetic
- In terms of enhancement:
  - more aesthetic visualizations produce improved memory for detail
  - the most aesthetic visualizations have similar memory for detail to glyph-based visualizations

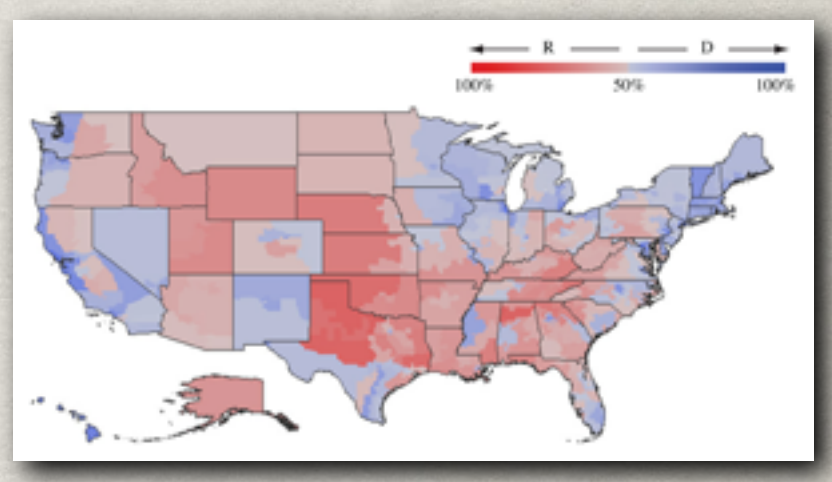


Wind Speed → Hue,
Minimum Temperature → Luminance,
Radiation → size,
Precipitation → Orientation

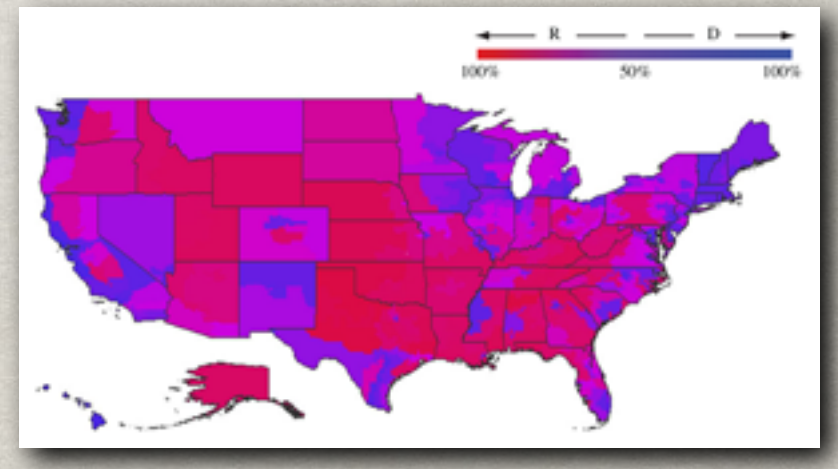
Data courtesy Climatic Research Unit, University of East Anglia

U.S. Election Patterns

- "Red" versus "Blue" states
- Visualize election patterns throughout the country
- How do participants vote for different elected offices?
  - President
  - U.S. Senate
  - U.S. House
  - Governor
- Subdivide country into congressional districts

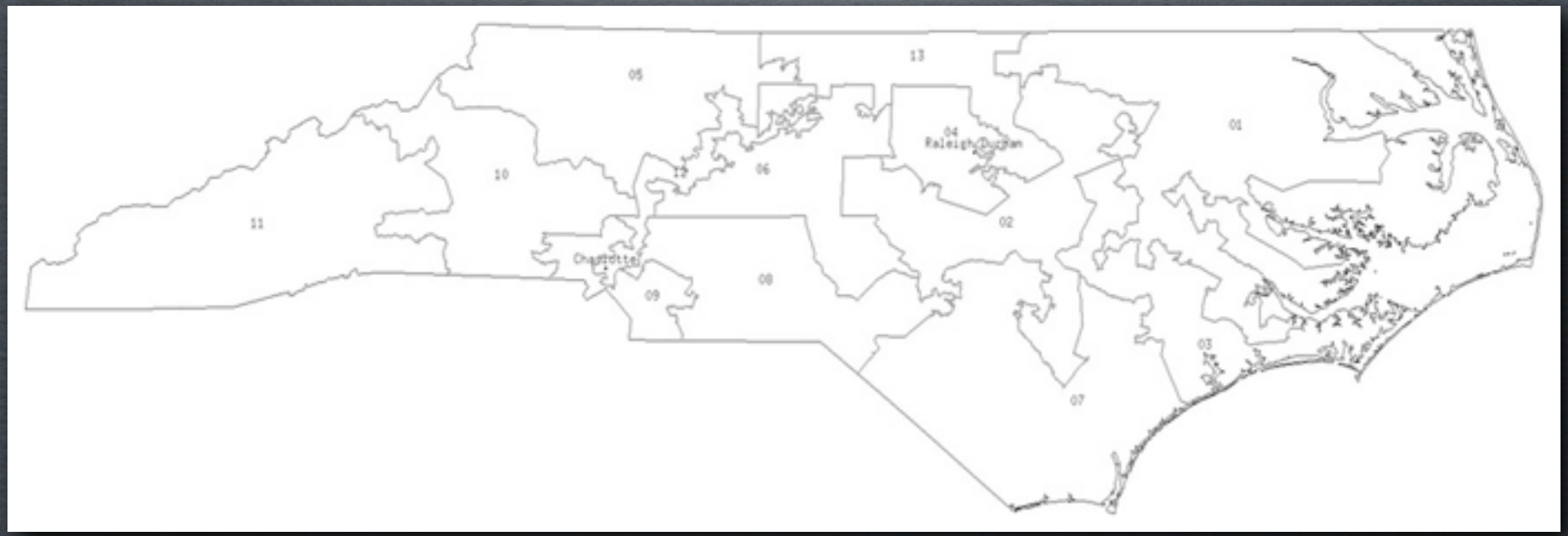


2008 double-ended red-blue Presidential map

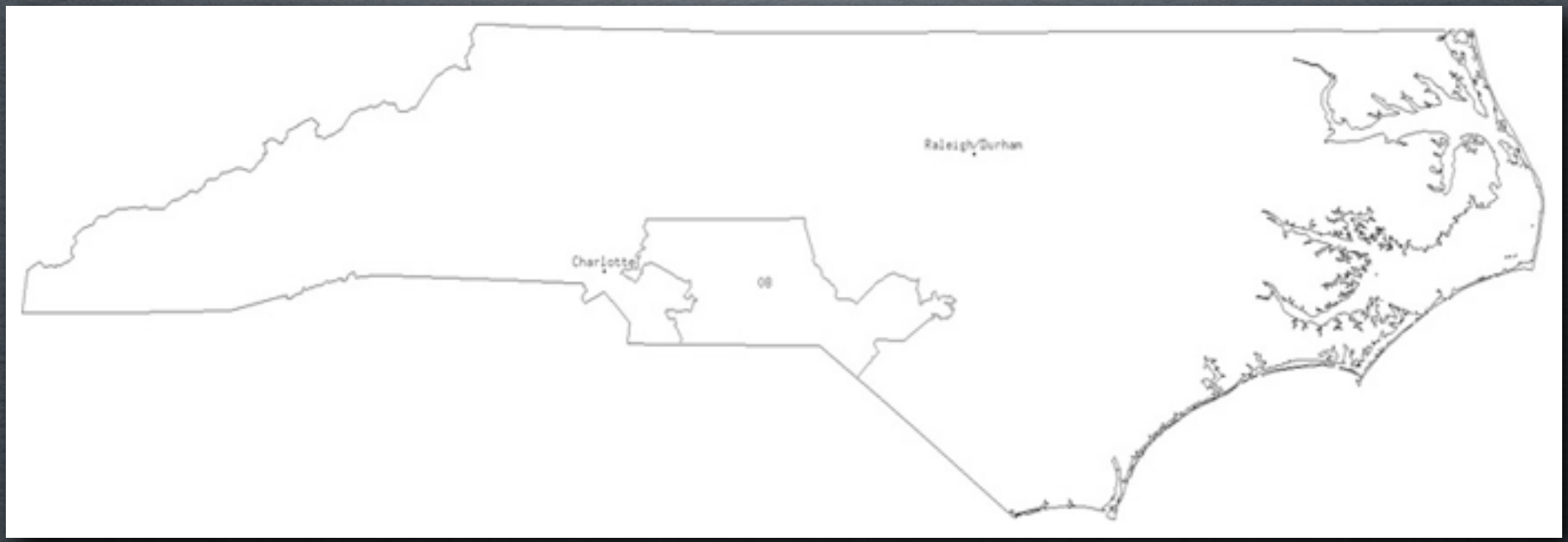


2008 continuous red-bluePresidential map

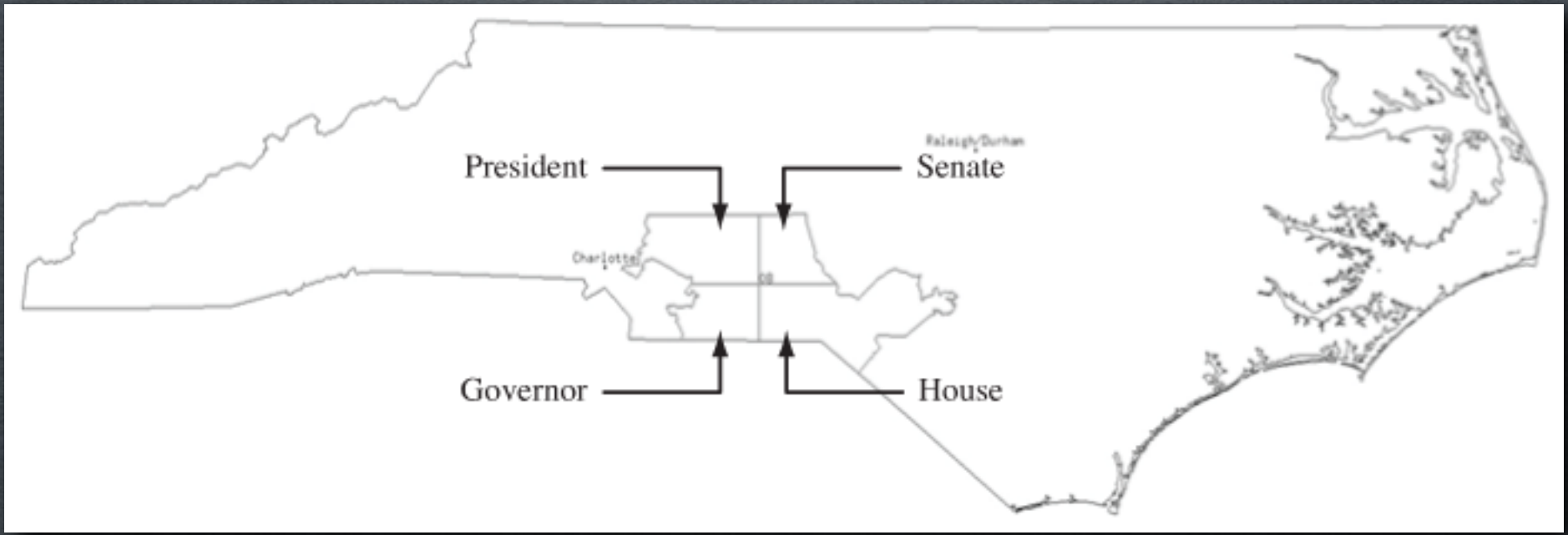
NC Congressional Districts



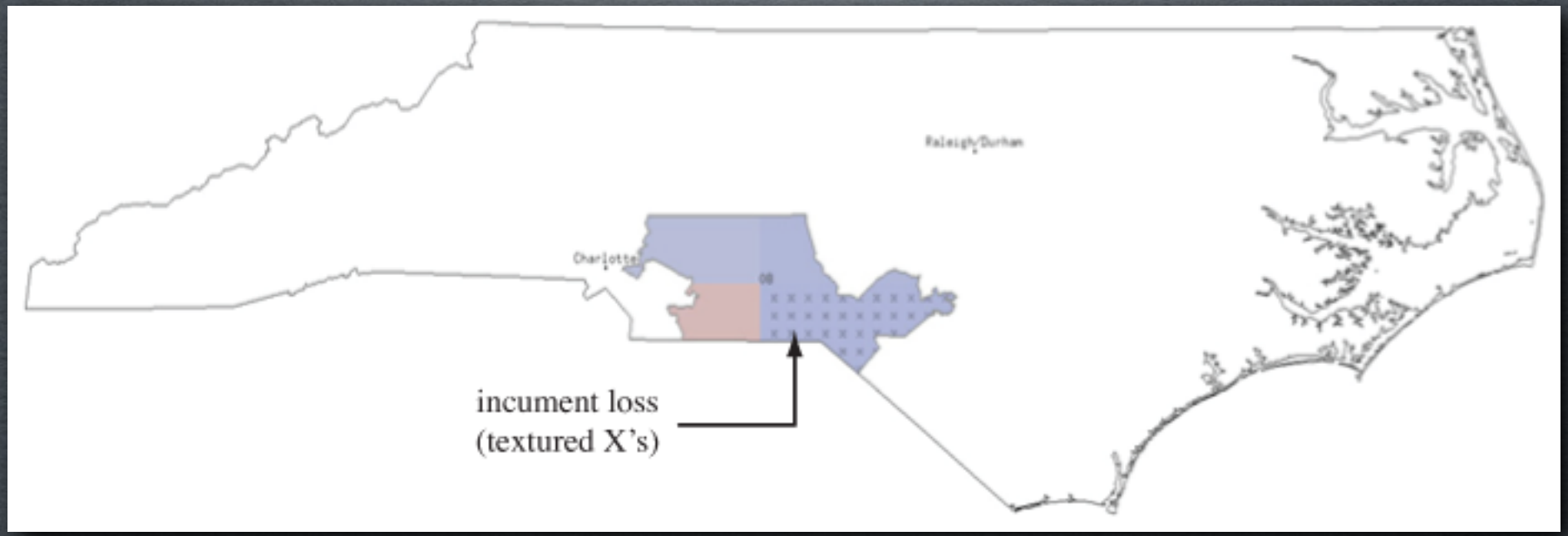
NC Congressional Districts



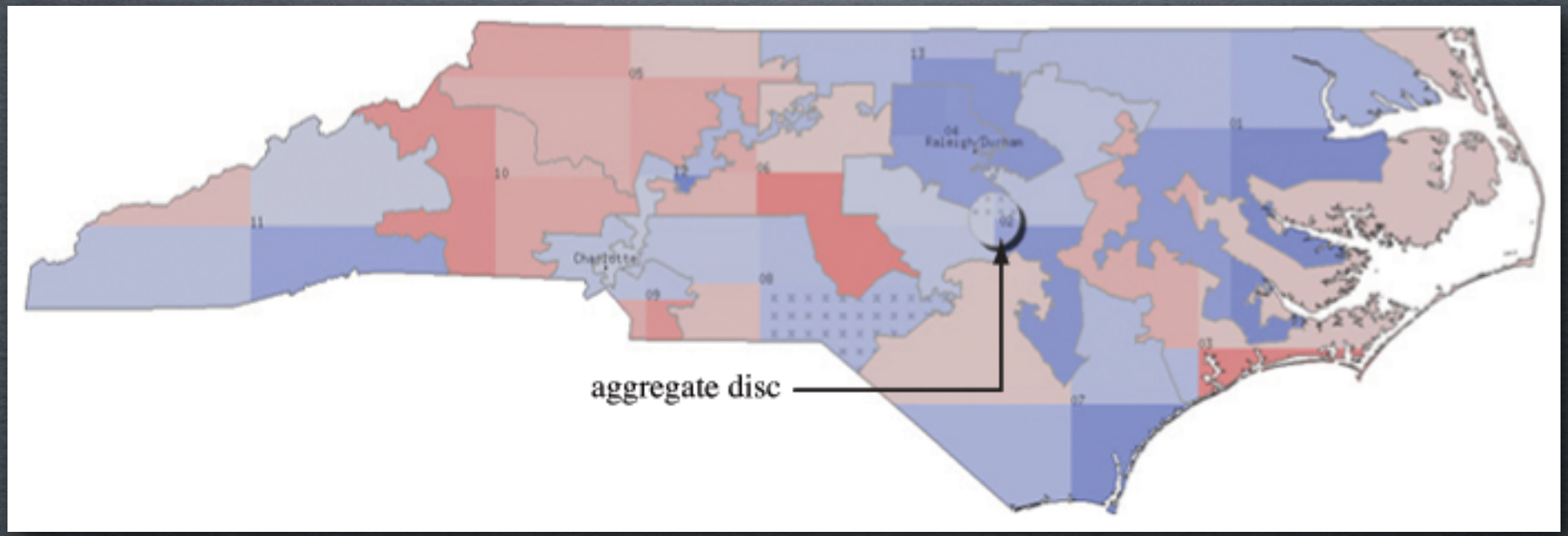
NC Congressional Districts



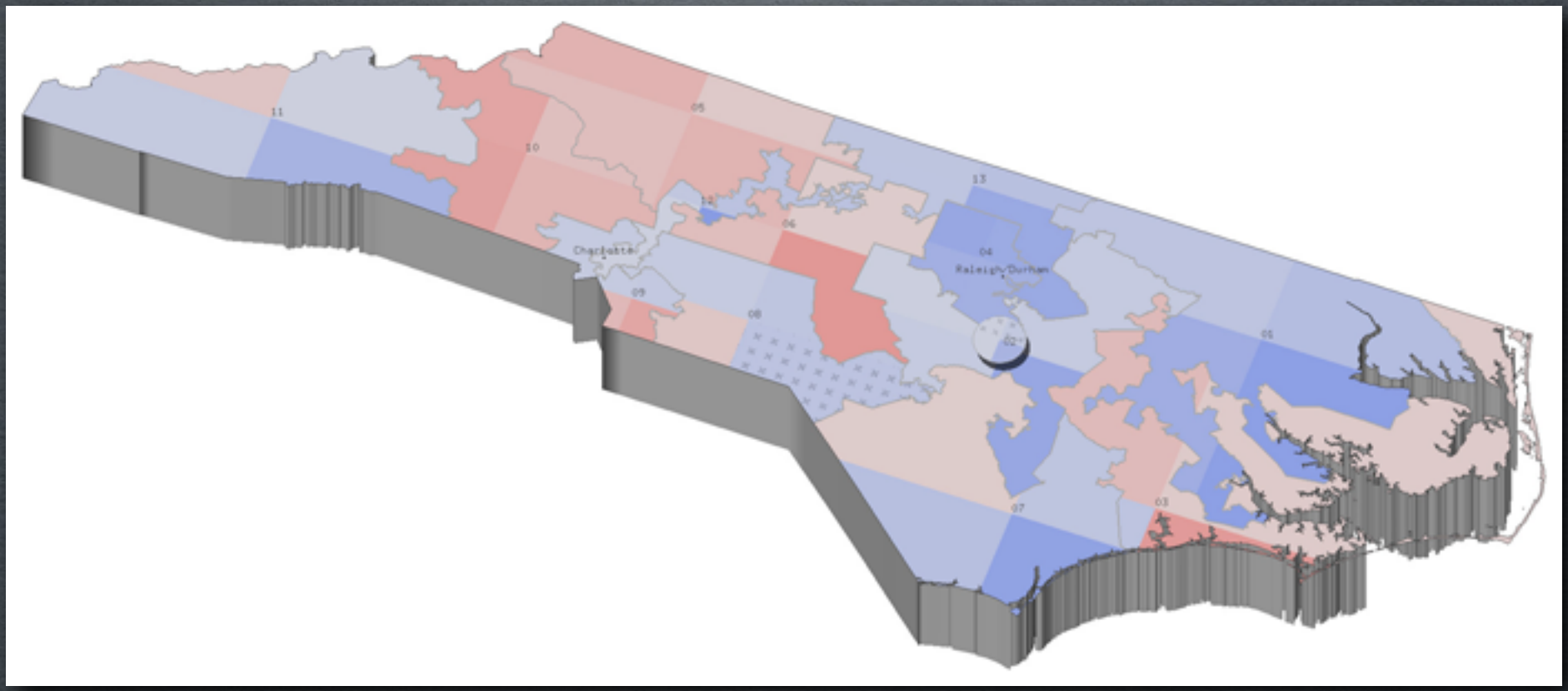
NC Congressional Districts



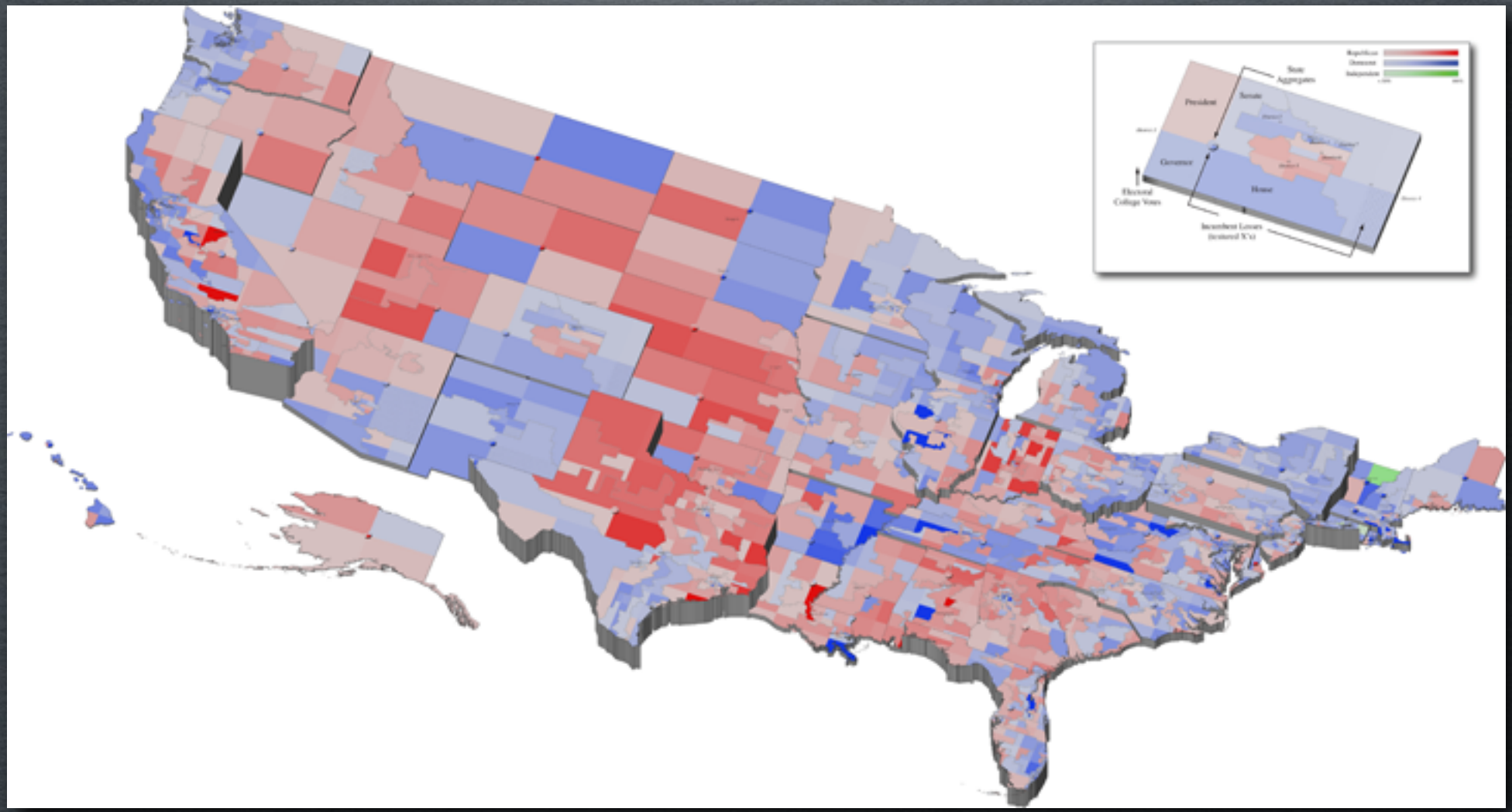
NC Congressional Districts



NC 3D District Map

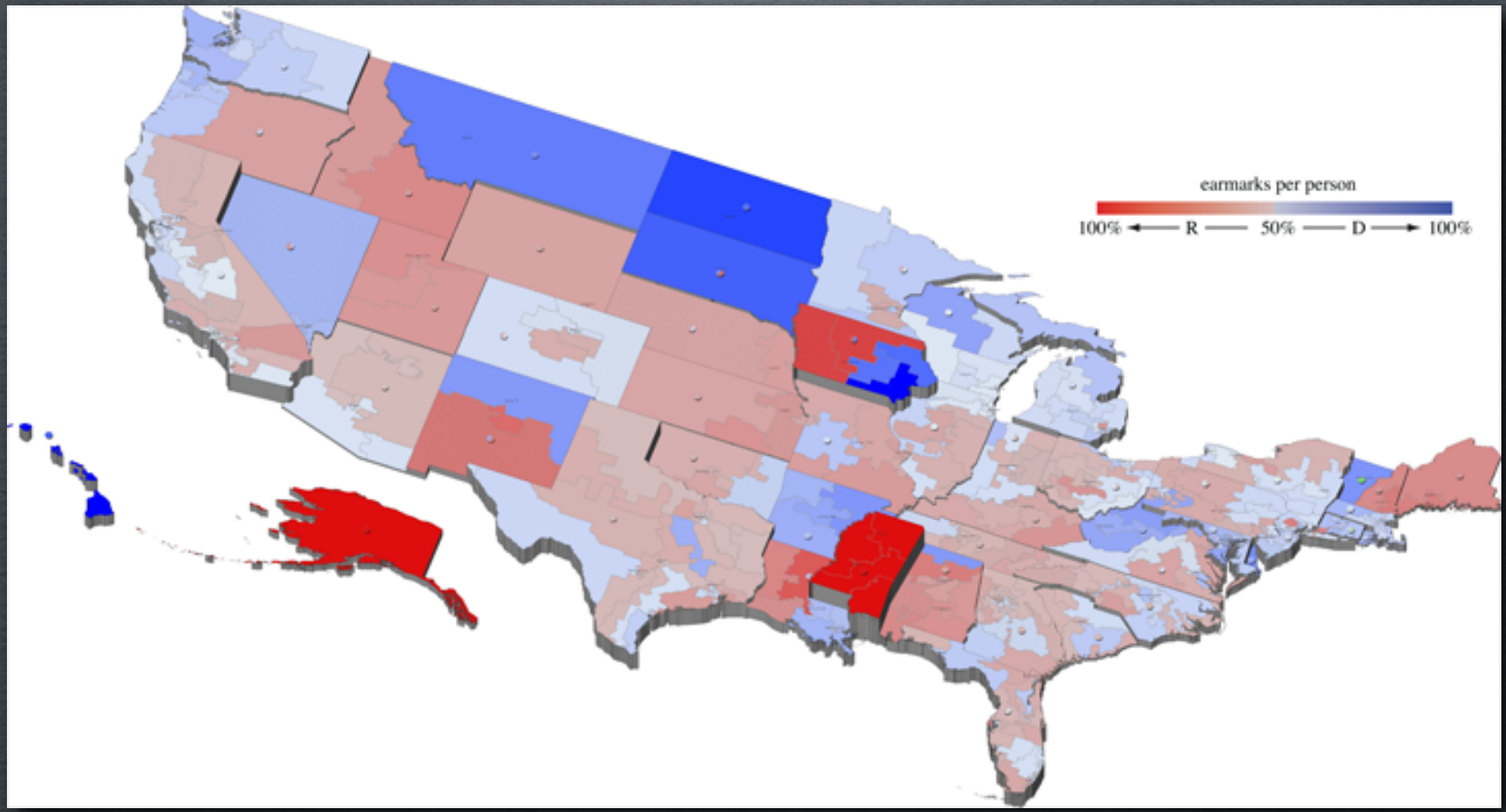


United States



http://www.csc.ncsu.edu/faculty/healey/US election

Earmarks



Majority Earmark Party → hue, Dollars Per Person → Saturation, absolute dollars → height

http://www.csc.ncsu.edu/faculty/healey/US election

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http://www.csc.ncsu.edu/faculty/healey

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