VISUAL ENCODING

Please find a different seat from last week!

1. INTRODUCTION

2. VISUAL ENCODING

3. BASIC CHART TYPES

Basics

4. INTERACTION

5. VISUALIZATION DESIGN

6. DATA PREPROCESSING

Visualization Building Blocks & Processes

7. RECAP 1st Half

8. MULTIVARIATE DATAVIS

9. TEMPORAL DATAVIS

10. GEOSPATIAL DATAVIS

11. GRAPH DATAVIS

Visualization Techniques

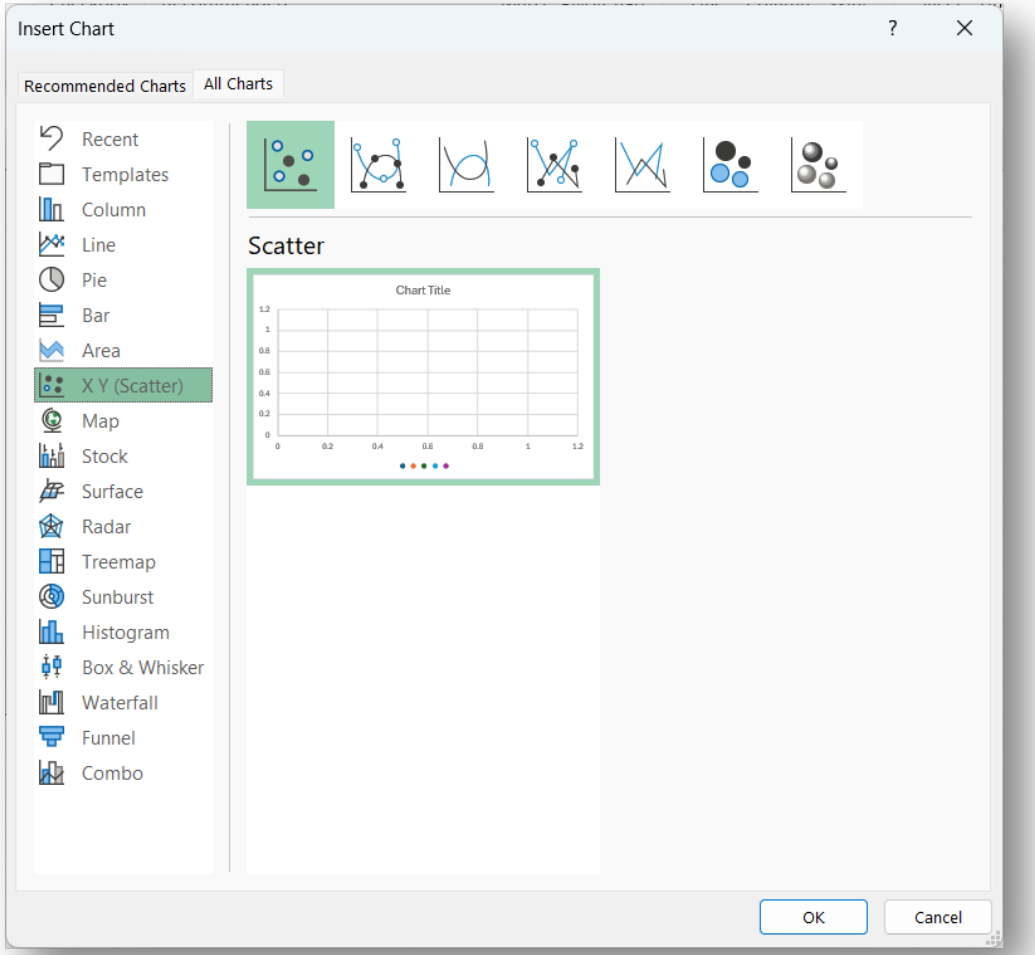
12. 3D DATAVIS

13. VISUAL ANALYTICS

Visualization Applications

14. RECAP 2nd Half

WHY TALK ABOUT VISUAL MAPPING?



- **Need to parametrize a preset chart**
  -> e.g., which color scale to use
- **Need to adjust a base chart**
  -> e.g., to counter a perceptual bias
- **Need to build your own chart type**
  -> e.g., to tailor it to a dataset
- **Need to detect when someone tries to deceive you with a chart**
  -> Visual Literacy

OVERVIEW

- Marks & Channels
- Dimensionality
- Labeling
- Rendering

MARKS & CHANNELS

MARKS = VISUAL OBJECTS

Points

Lines

Areas

Image source: Munzner 2014

CHANNELS = PROPERTIES OF MARKS

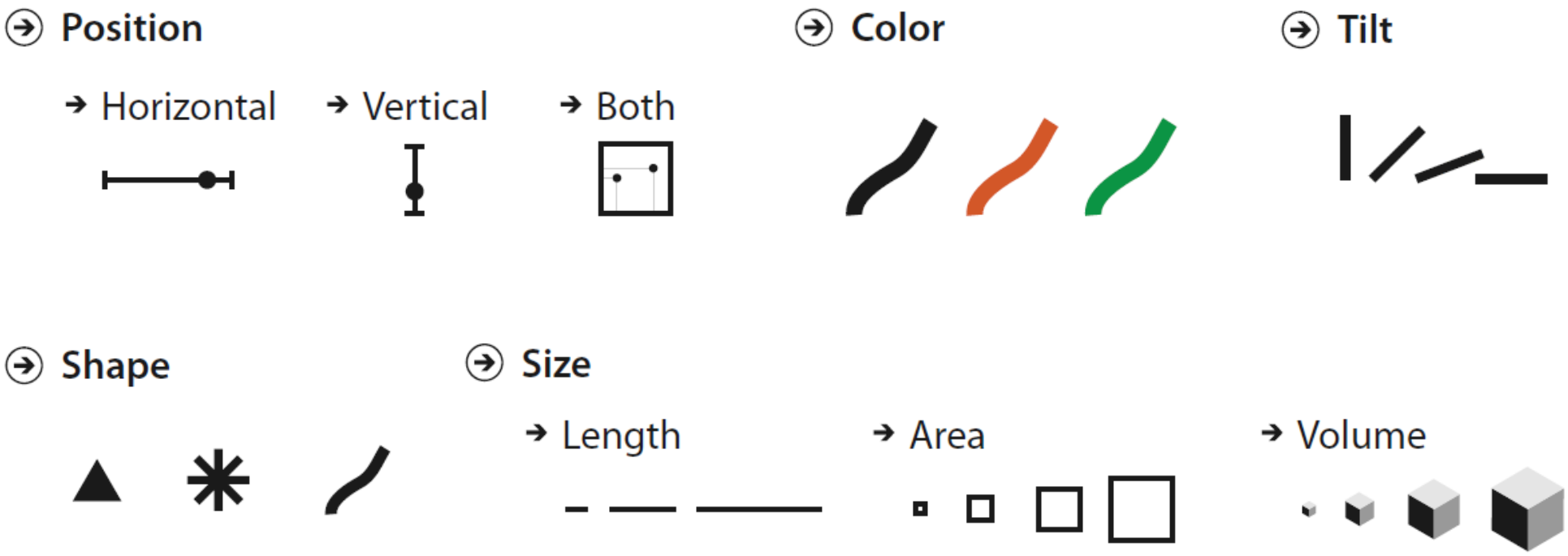


Image source: Munzner 2014

DATA TYPES

	Quantitative Data		Qualitative Data	
	Continuous Data	Discrete Data	Ordinal Data	Categorical Data
Interpolate	✓			
Difference	✓	✓		
Sort	✓	✓	✓	
Match	✓	✓	✓	✓

Adapted from [Stevens 1946] – DOI: 10.1126/science.103.2684.677

MAPPING CRITERION 1: EXPRESSIVENESS

categorical data:

ordinal data:

discrete data:

continuous data:

MAPPING CRITERION 2: EFFECTIVENESS

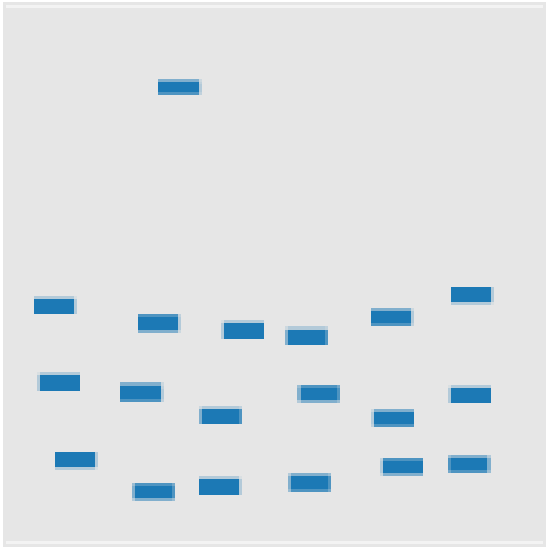
categorical data:

ordinal data:

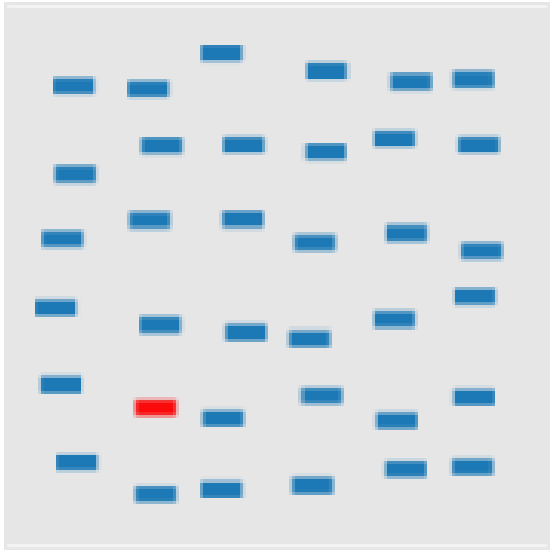
discrete data:

continuous data:

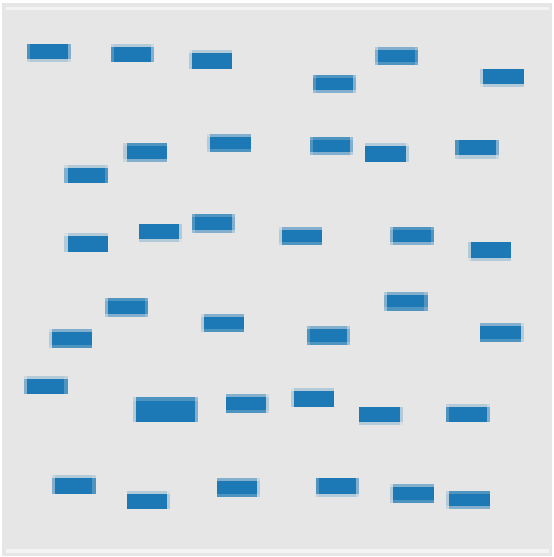
PRECEDENCE AMONG VISUAL SIGNALS: PREATTENTIVE VISUAL CUES



Position



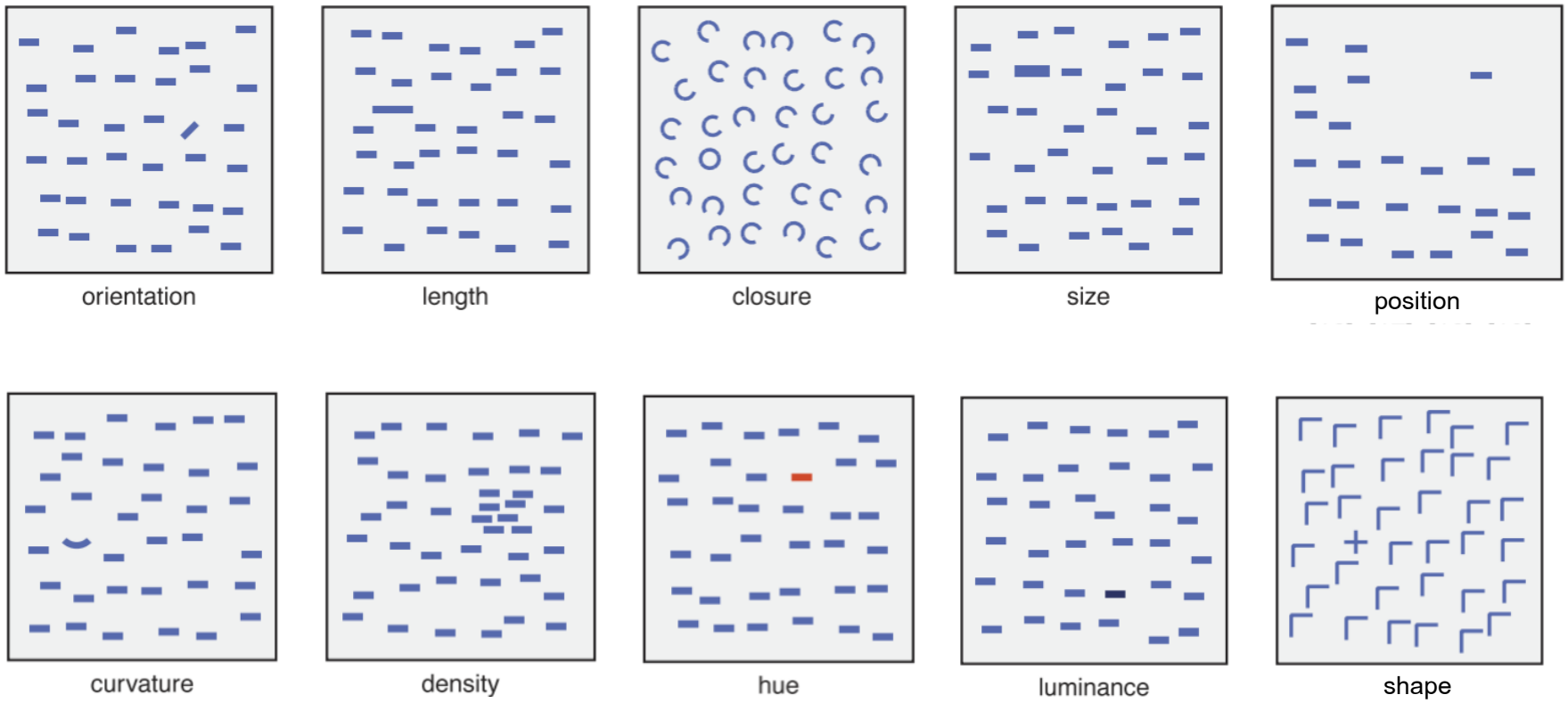
Color



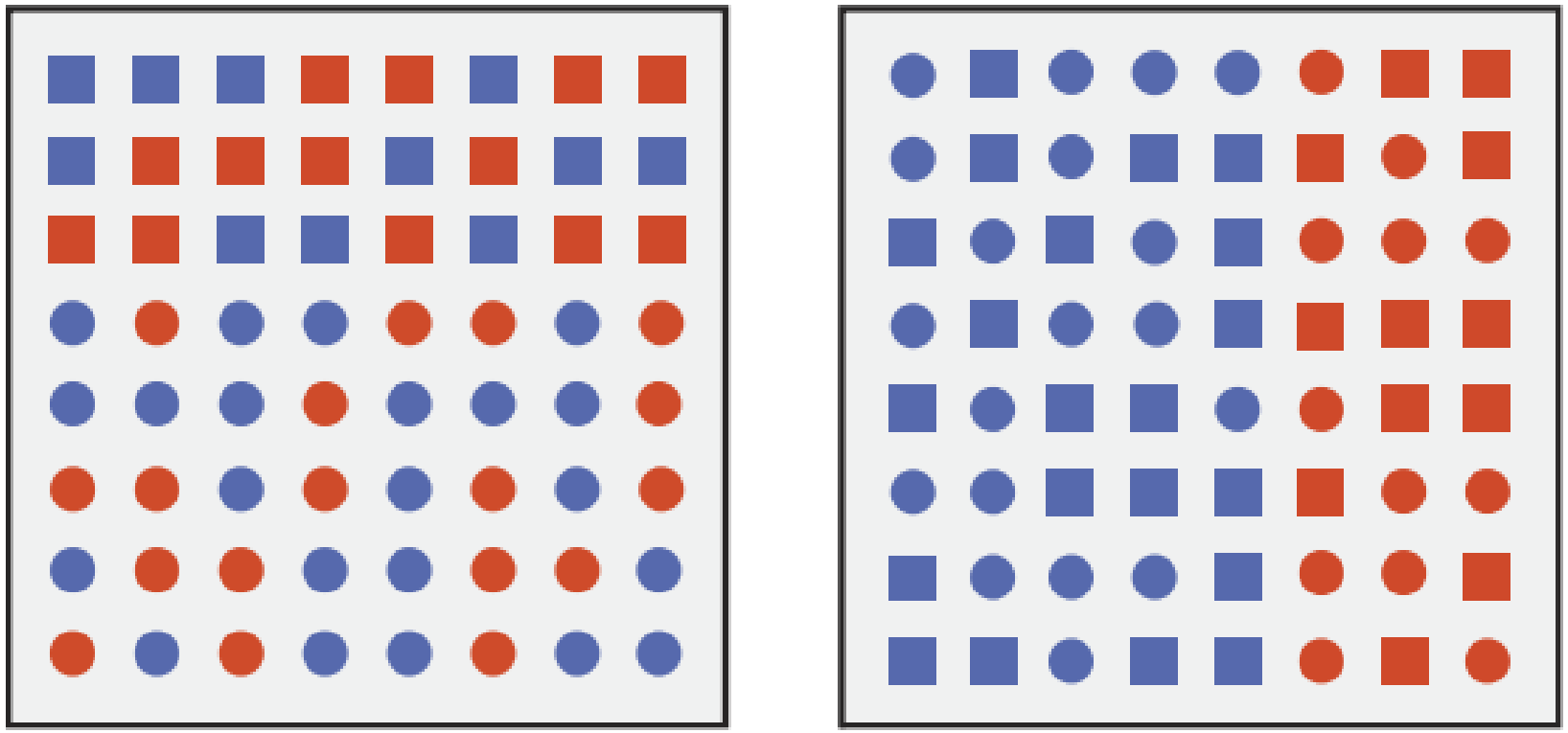
Size

Image source: uxpractical.com

PREATTENTIVE VISUAL CUES

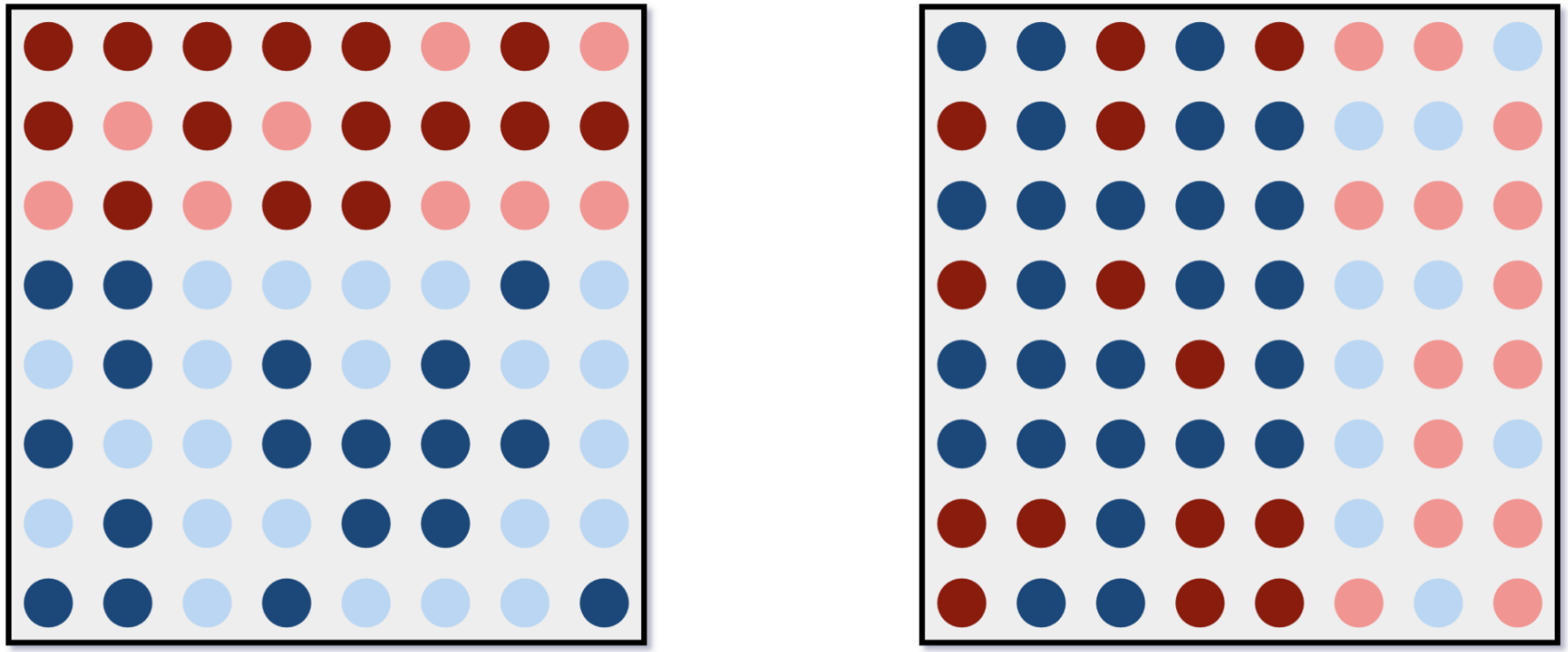


PREATTENTIVE VISUAL CUES



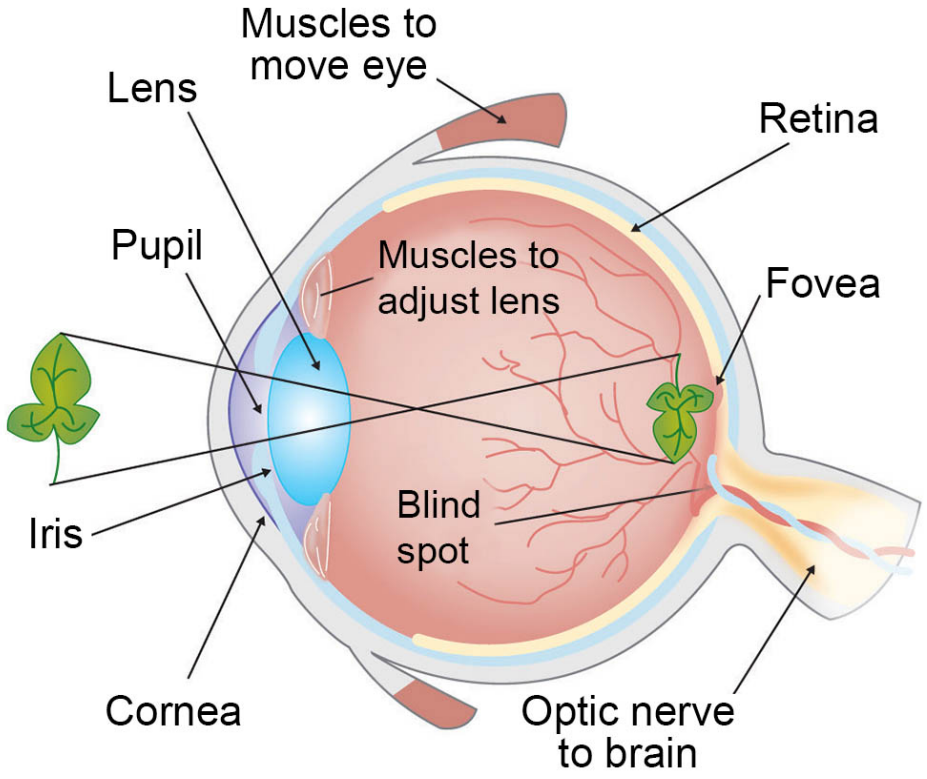
Hue-on-form hierarchy

PREATTENTIVE VISUAL CUES



Luminance-on-hue hierarchy

INTERLUDE: THE HUMAN EYE



Pupil: to adjust brightness
Lens: to adjust focus
Retina: the projection surface at the back of the eye

Fovea/Macula: for high-res color perception under daylight (photopic vision)

-> ca. 64% red cones
-> ca. 32% green cones
-> ca. 2% blue cones

6-7 million cones

Remainder of Retina: for low-res brightness perception under low light levels (scotopic vision)

-> 120 million rods

Blind spot where the optic nerve runs from the eye to the brain

MAPPING CRITERION 2: EFFECTIVENESS

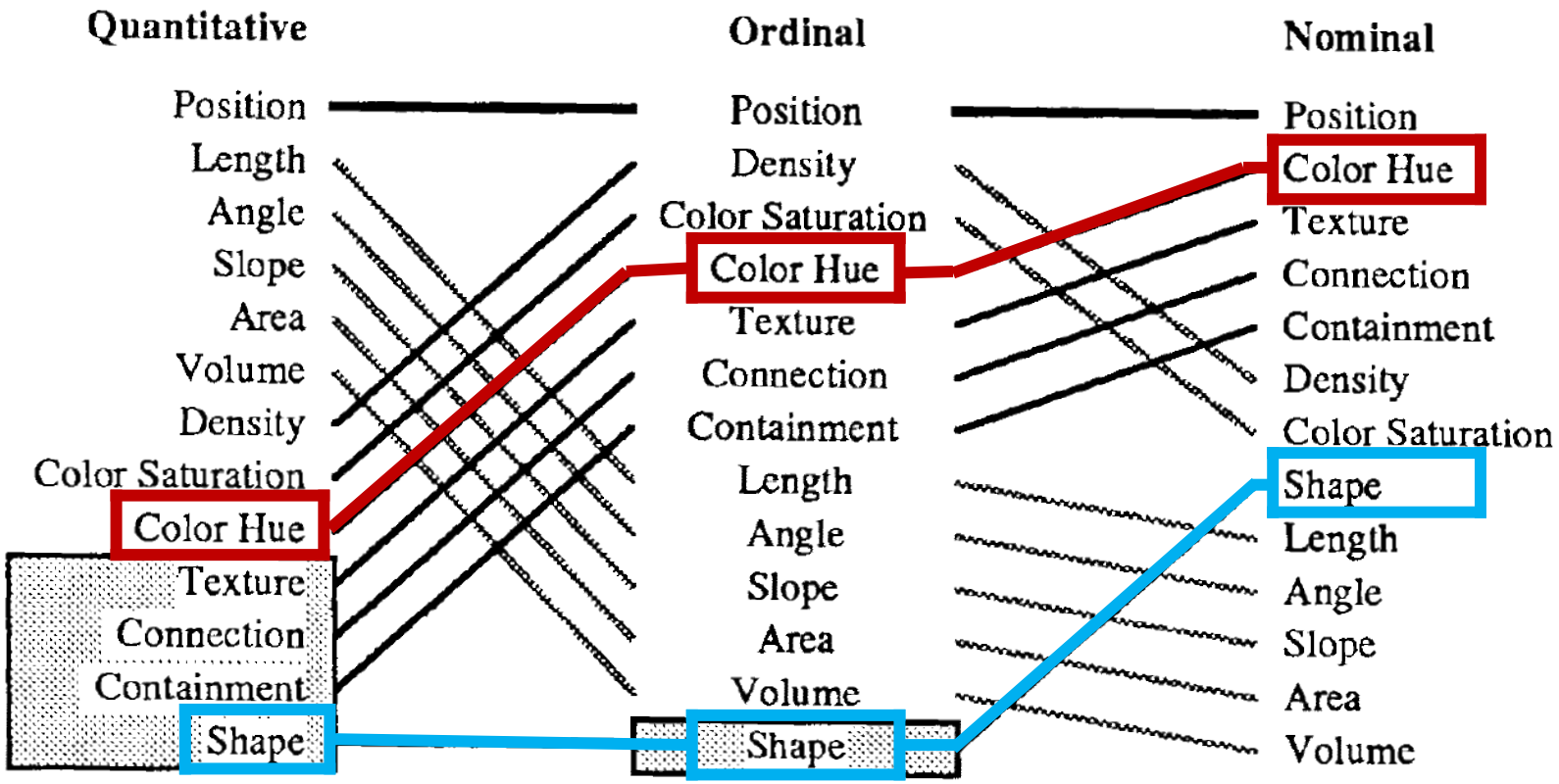


Fig. 15. Ranking of perceptual tasks. The tasks shown in the gray boxes are not relevant to these types of data.

Image source: Mackinlay 1986

ON PIE CHARTS (& DONUT CHARTS)

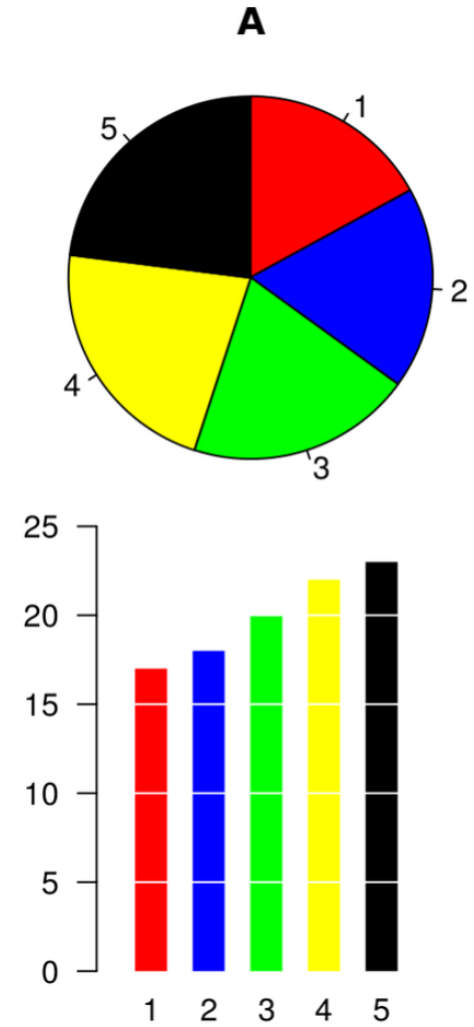


Image source: Wikipedia

LET'S REVISIT MACKINLAY'S SCHEMA

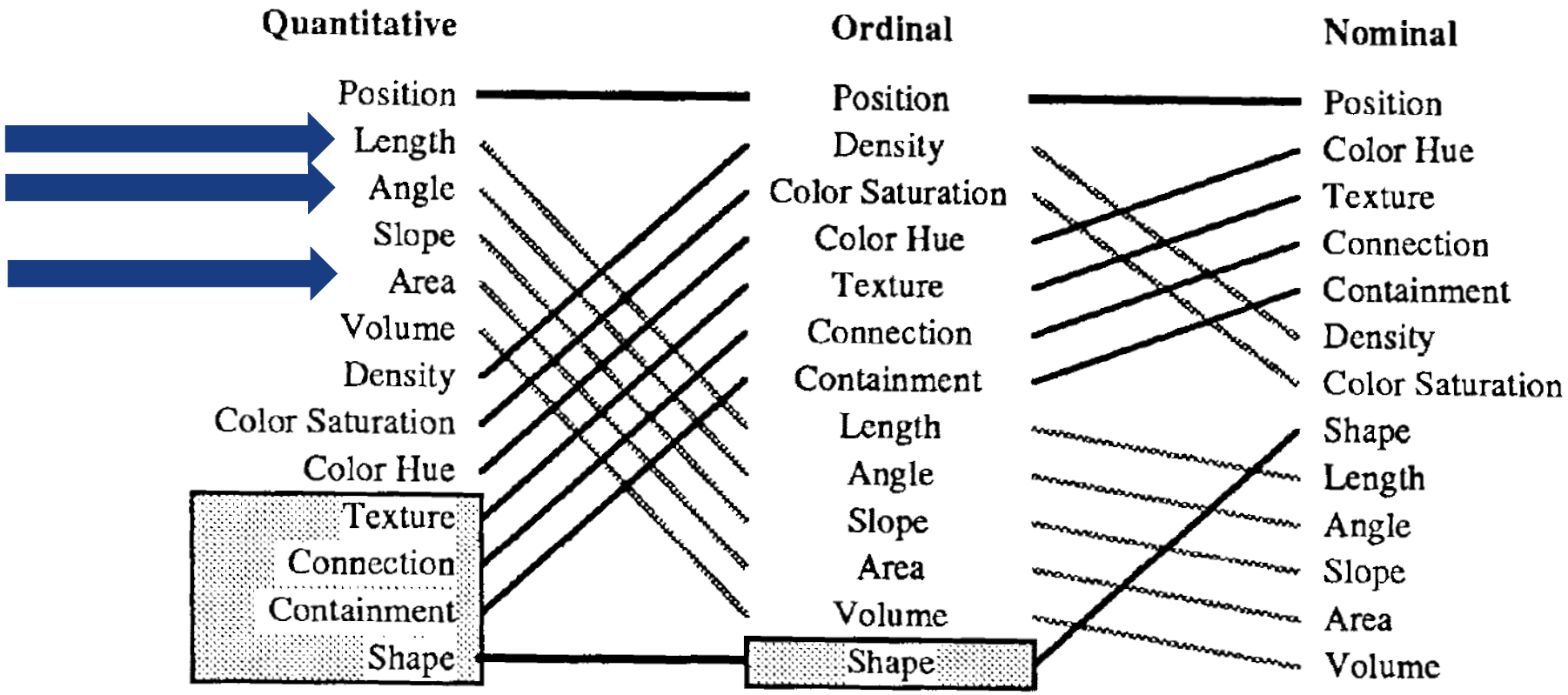


Fig. 15. Ranking of perceptual tasks. The tasks shown in the gray boxes are not relevant to these types of data.

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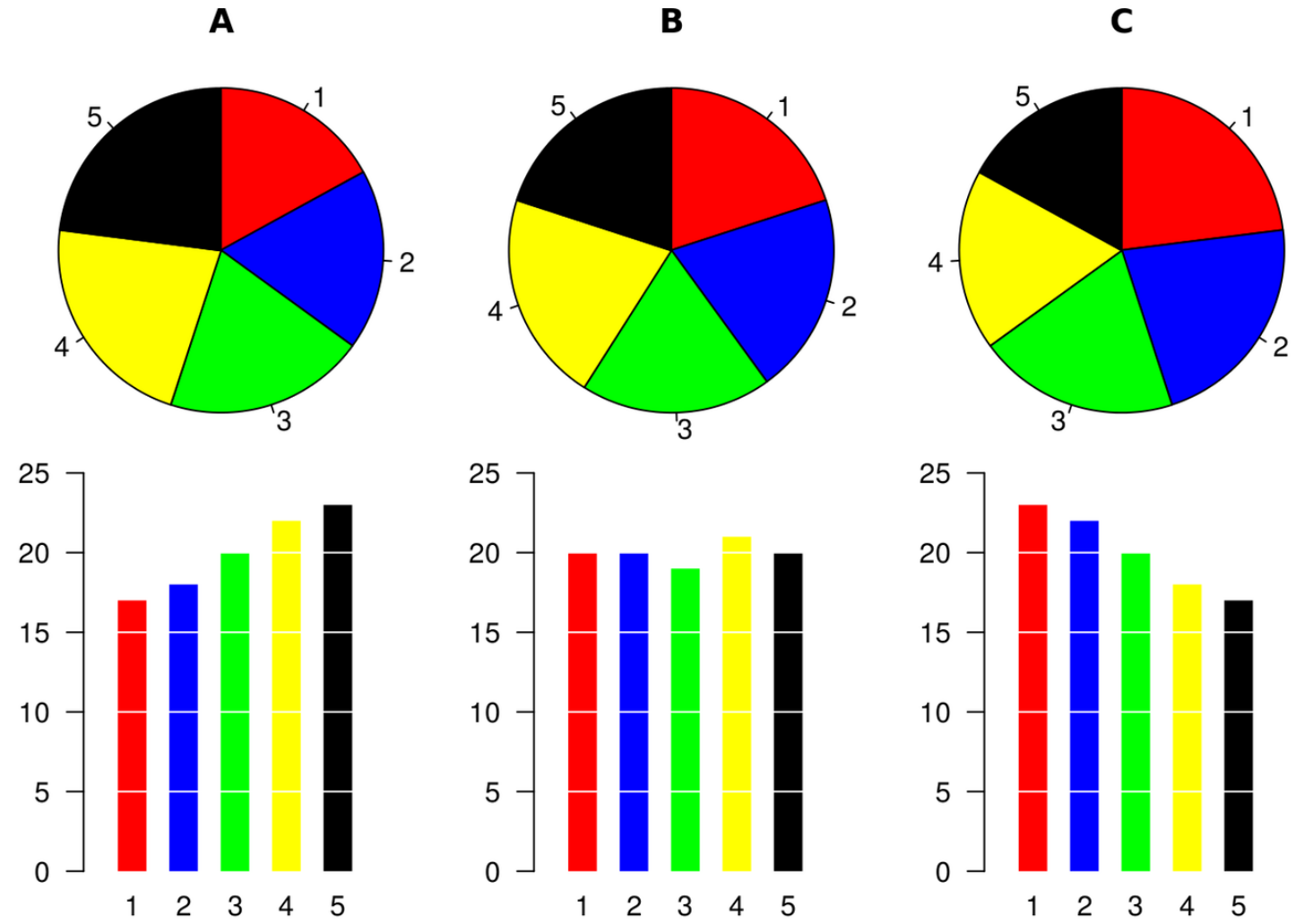
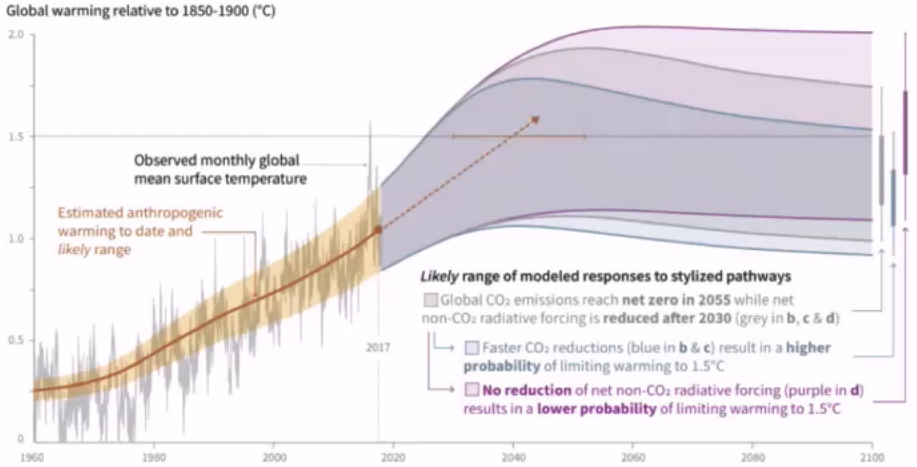


Image source: Wikipedia

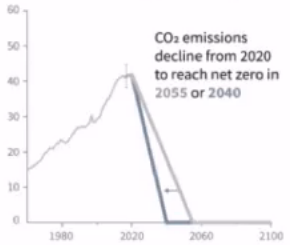
Cumulative emissions of CO_2 and future non-CO_2 radiative forcing determine the probability of limiting warming to 1.5°C

a) Observed global temperature change and modeled responses to stylized anthropogenic emission and forcing pathways



b) Stylized net global CO_2 emission pathways

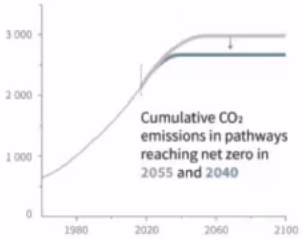
Billion tonnes CO_2 per year ($GtCO_2$/yr)



Faster immediate CO_2 emission reductions limit cumulative CO_2 emissions shown in panel (**c**).

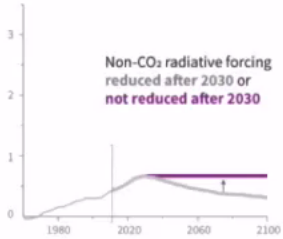
c) Cumulative net CO_2 emissions

Billion tonnes CO_2 ($GtCO_2$)



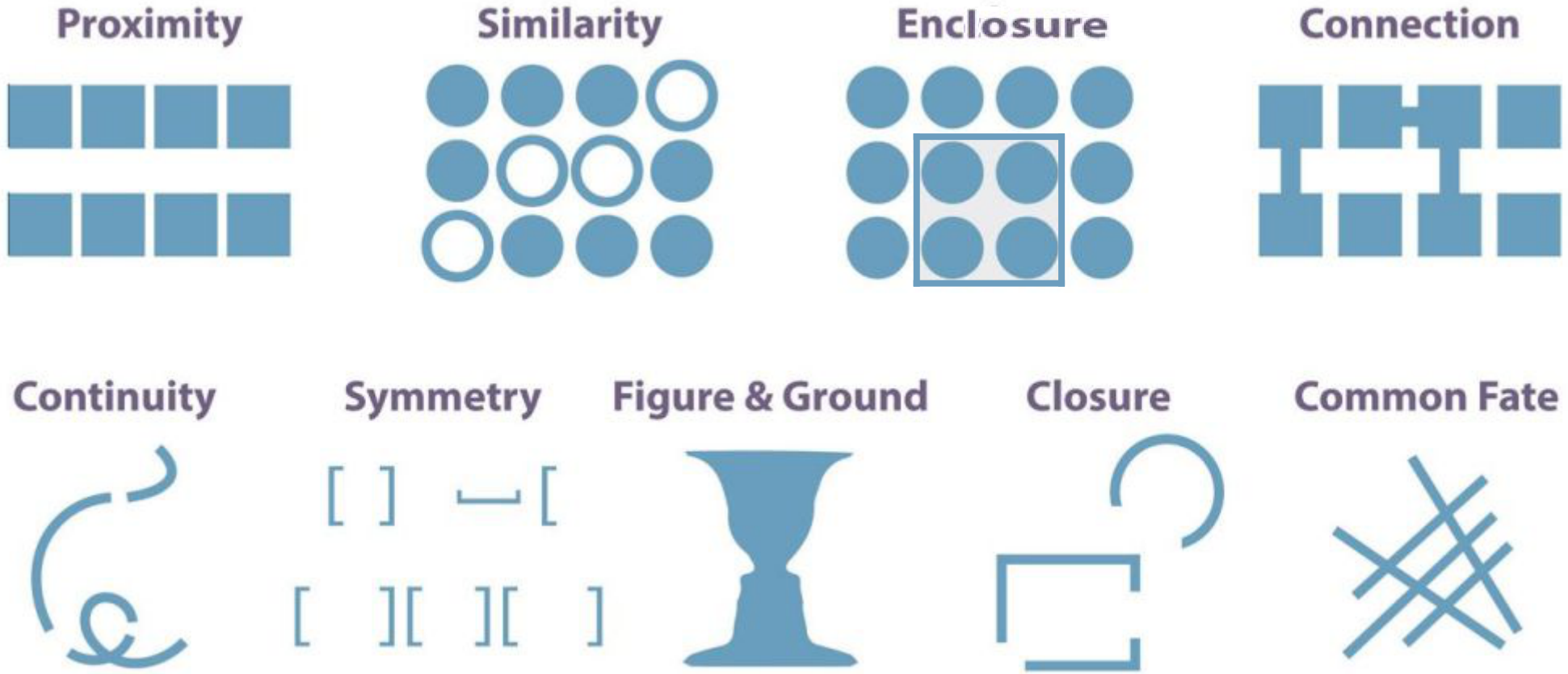
d) Non-CO_2 radiative forcing pathways

Watts per square metre (W/m^2)

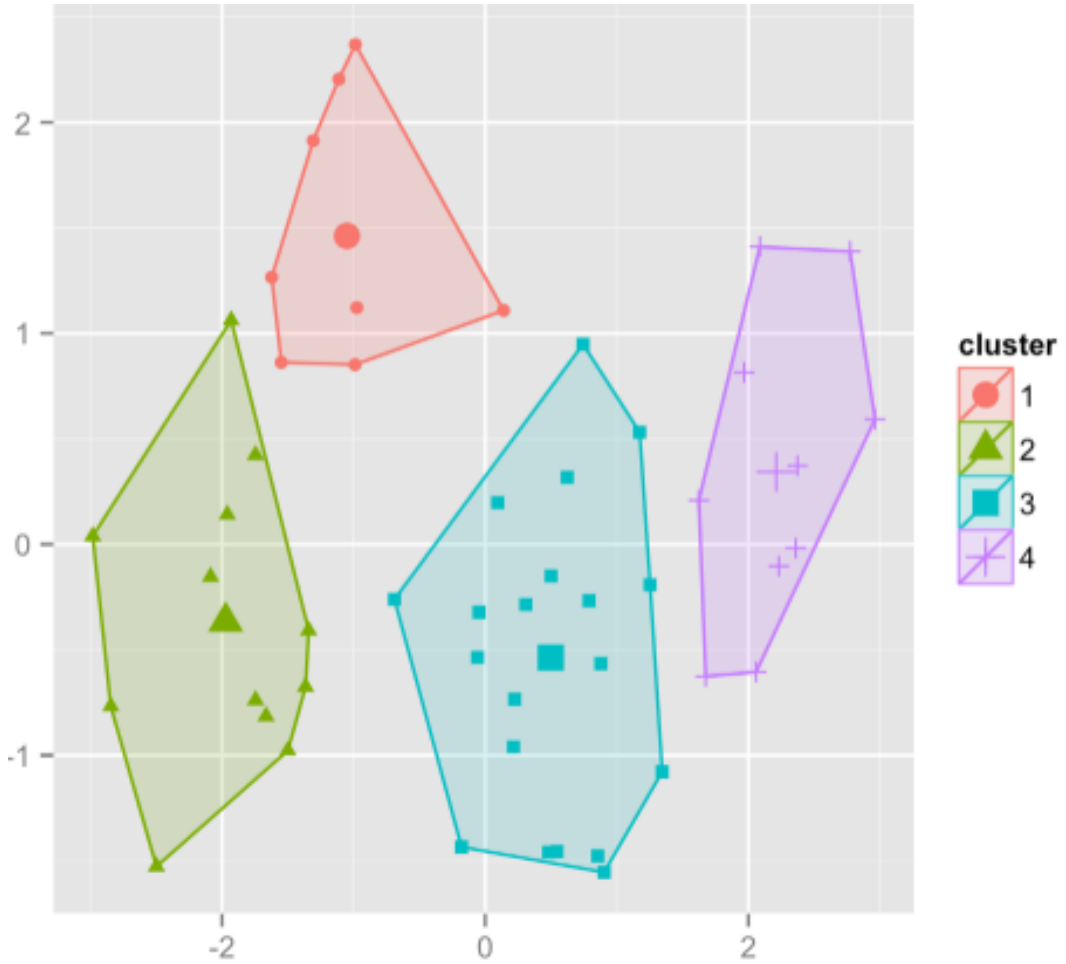


Maximum temperature rise is determined by cumulative net CO_2 emissions and net non-CO_2 radiative forcing due to methane, nitrous oxide, aerosols and other anthropogenic forcing agents.

GESTALT PRINCIPLES OF GROUPING



WHEN TO USE THE GESTALT PRINCIPLES?



Which Gestalt principles can you find in this visualization?

- Proximity
- Similarity in Color
- Similarity in Shape
- Enclosure

DEFINITIONS

A visualization is **expressive** if it encodes all the data relations intended and no other data relations.

A visualization is **effective** if it best exploits the capabilities of the output medium and the human visual system (and supports the task).

Mapping Criterion 3: Appropriateness (Book: Efficiency)

A visualization is **appropriate** if it balances the tradeoff between efforts required for creating it and the benefits yielded by it.

MARKS: DIMENSIONALITY

THE PERILS OF 3D

- **Occlusion**
- Perspective Distortion
- Non-anchored points
- Navigation / Orientation (Lost in Space)
- Selection

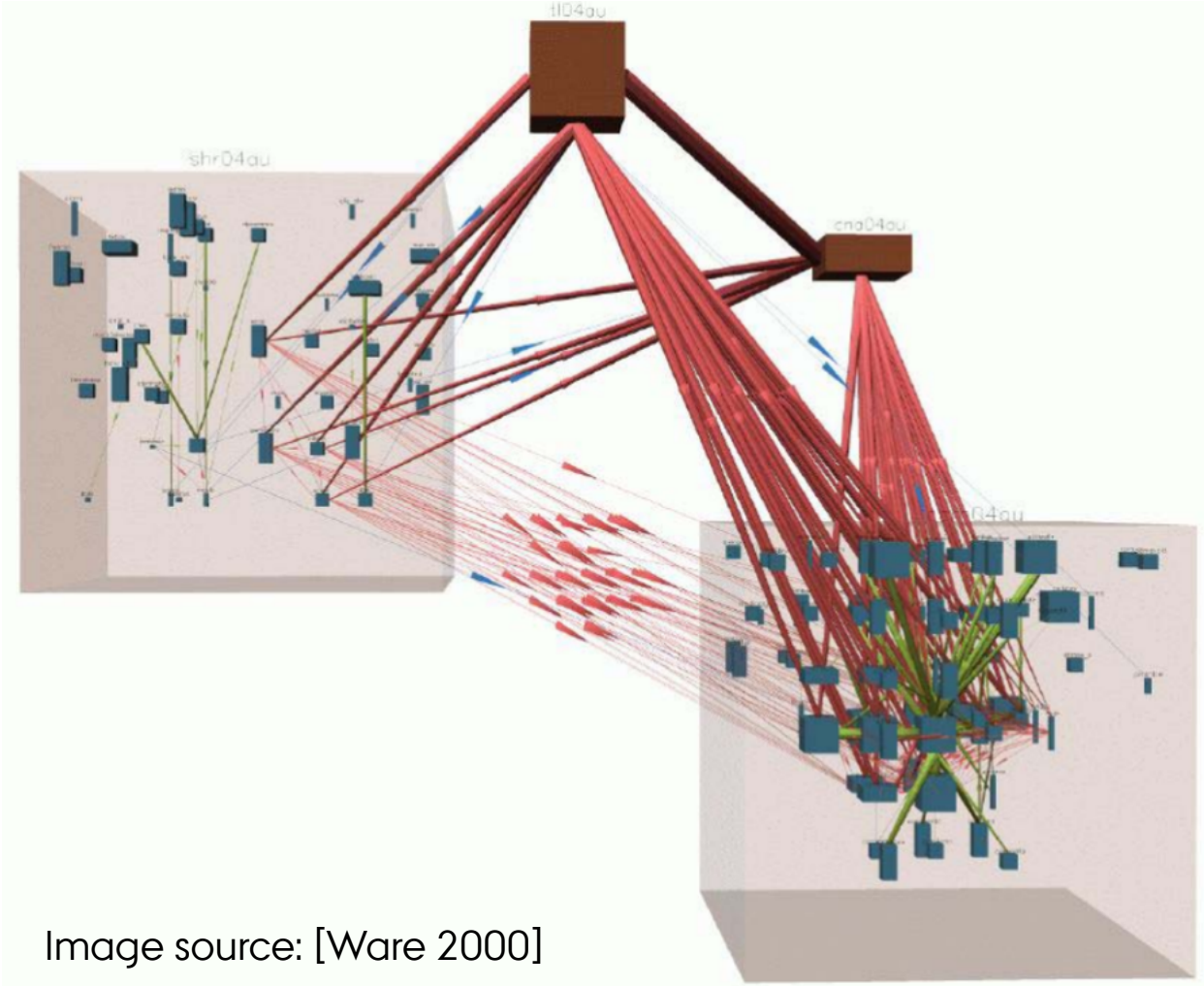


Image source: [Ware 2000]

Adapted from Brath 2014:
3D InfoVis is here to stay: Deal with it

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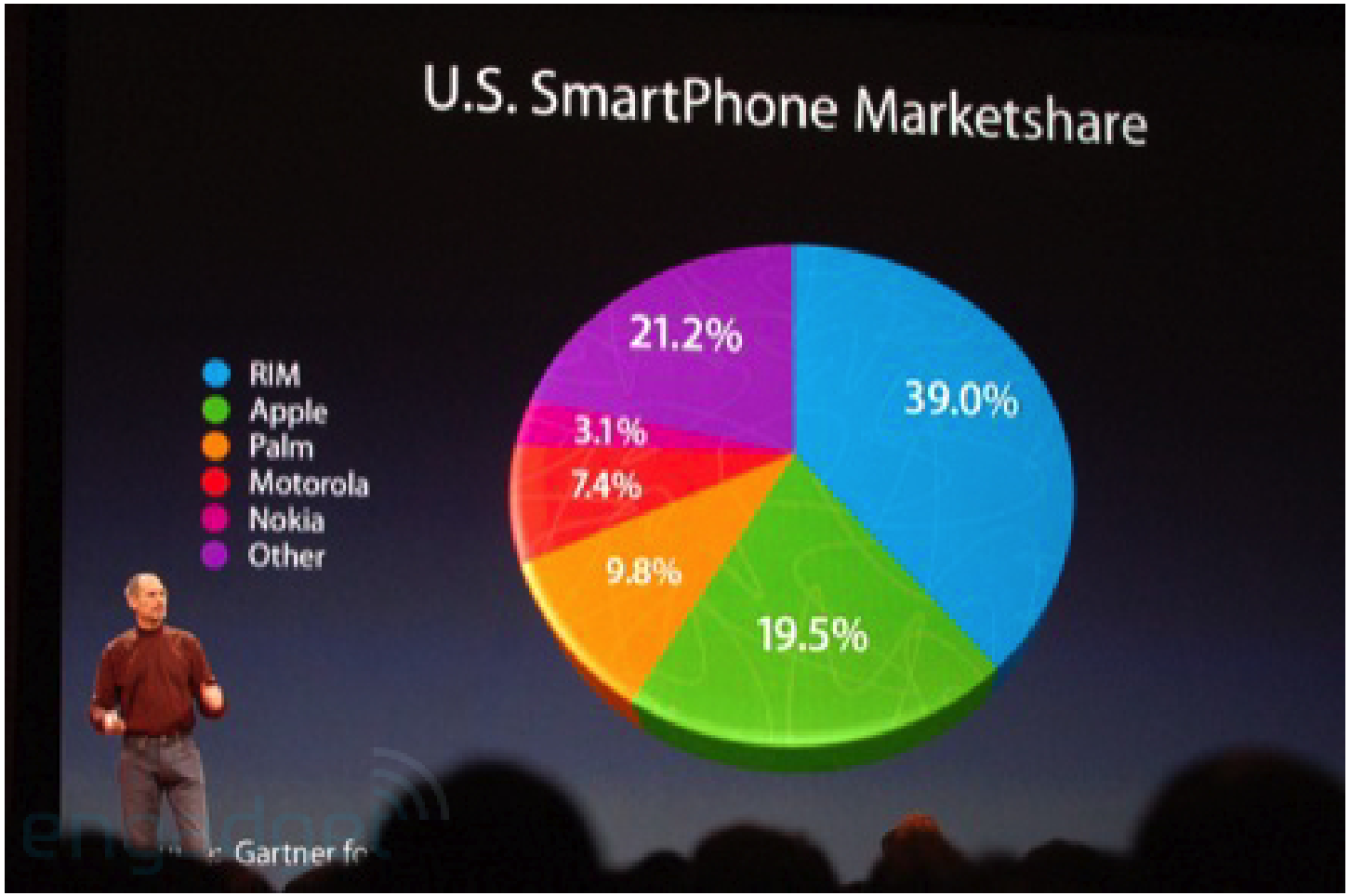

Image source: Macworld 2008, engadget.com

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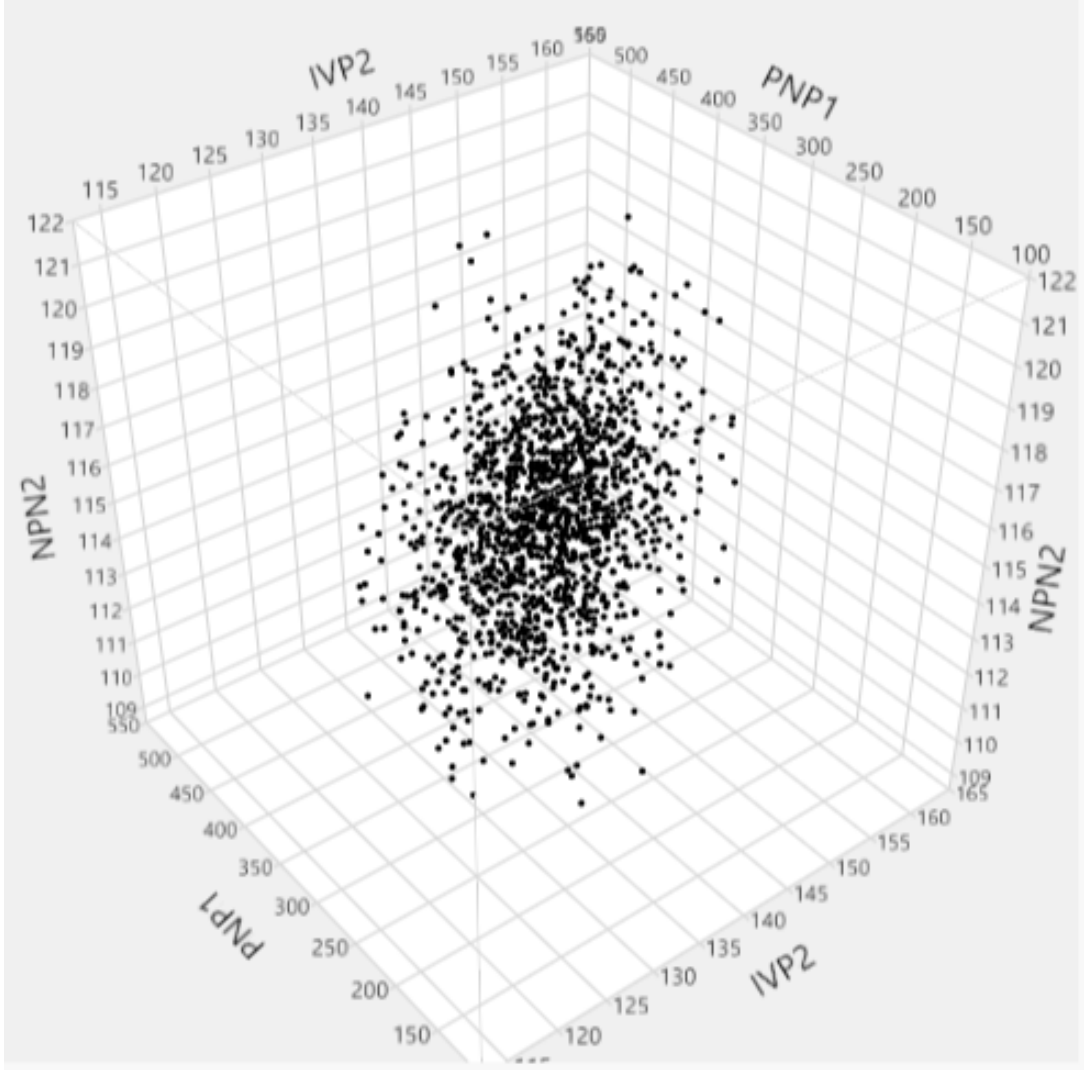

Adapted from Brath 2014:
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Image source:
https://community.jmp.com/t5/Discussions/3D-Scatterplot-Animation/td-p/49016

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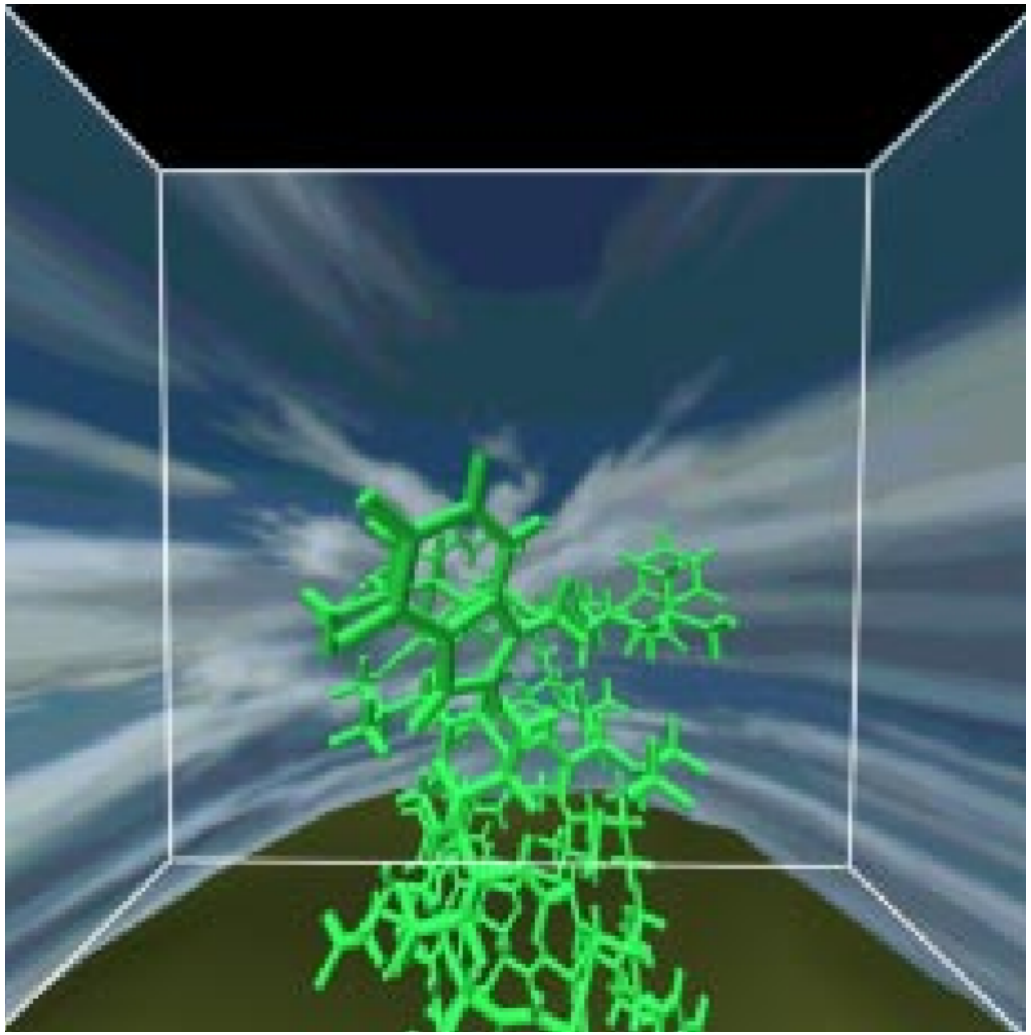

Image source: [Hanson et al.1997]

THE PERILS OF 3D

- Occlusion
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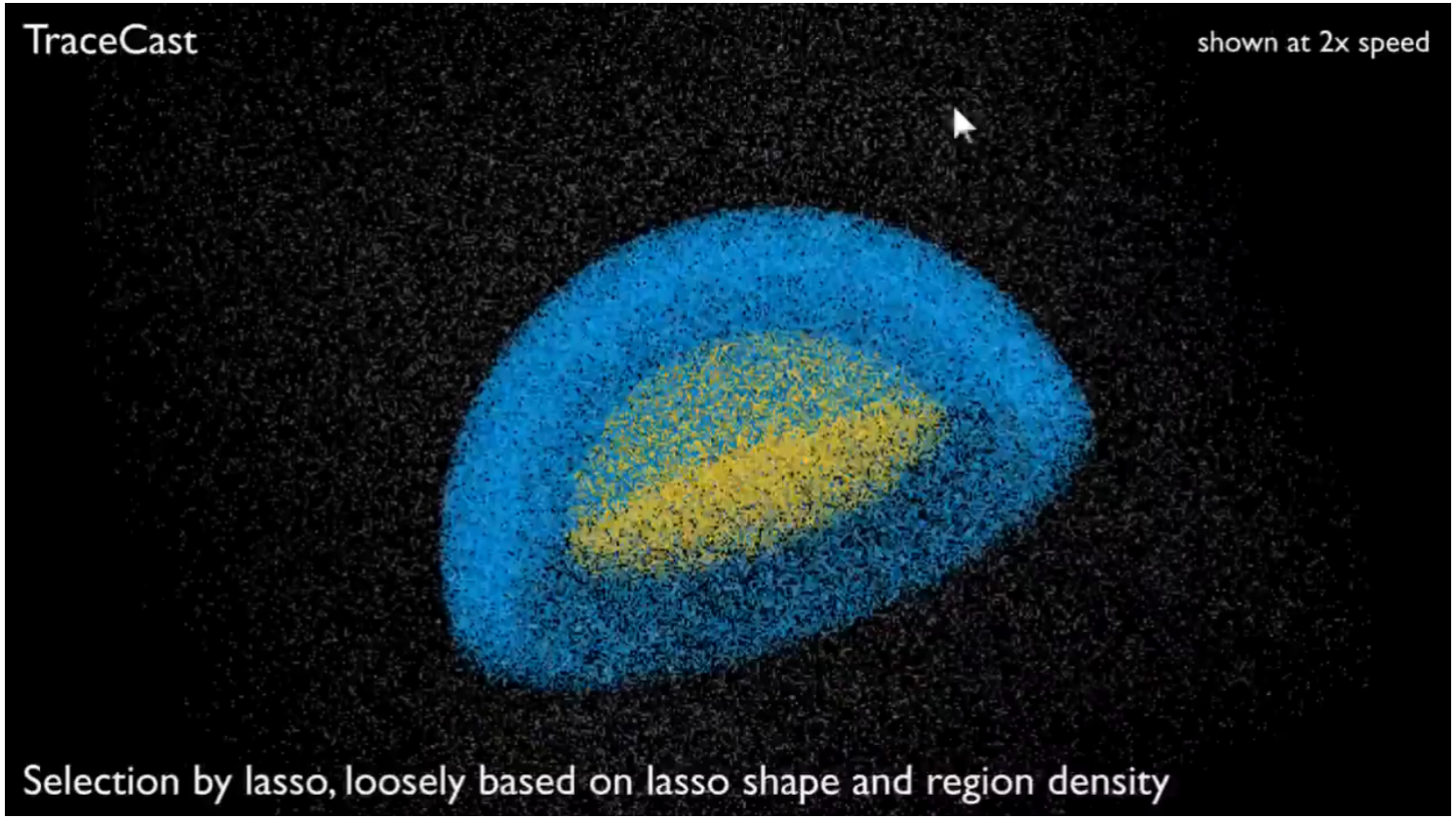
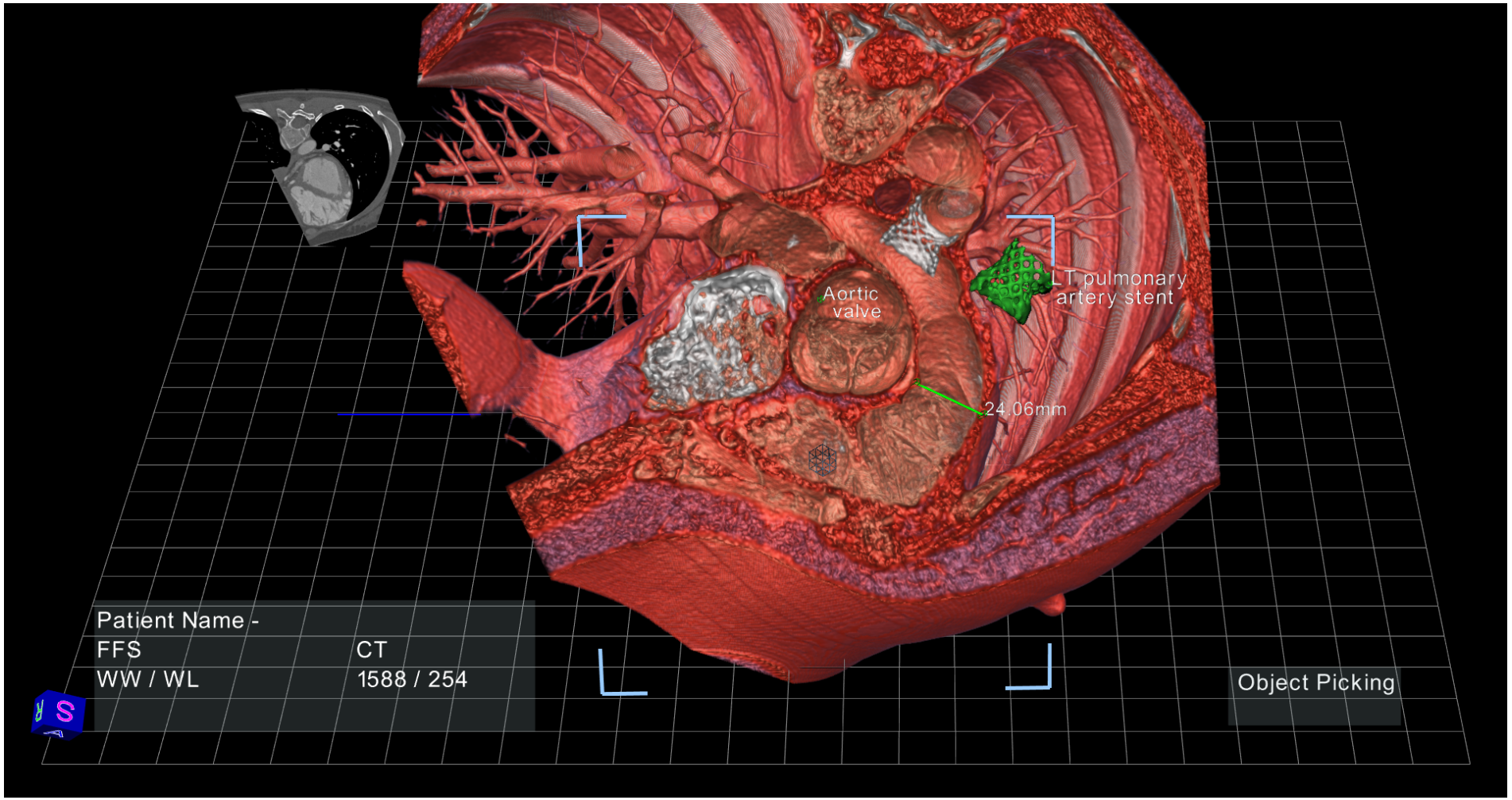
- **Selection**



Adapted from Brath 2014:
3D InfoVis is here to stay: Deal with it

Video source: Yu et al. 2016

ONLY USE 3D VIS FOR 3D DATA (VOLVIS)



USE 2.5D IF YOU MUST GO BEYOND 2D...

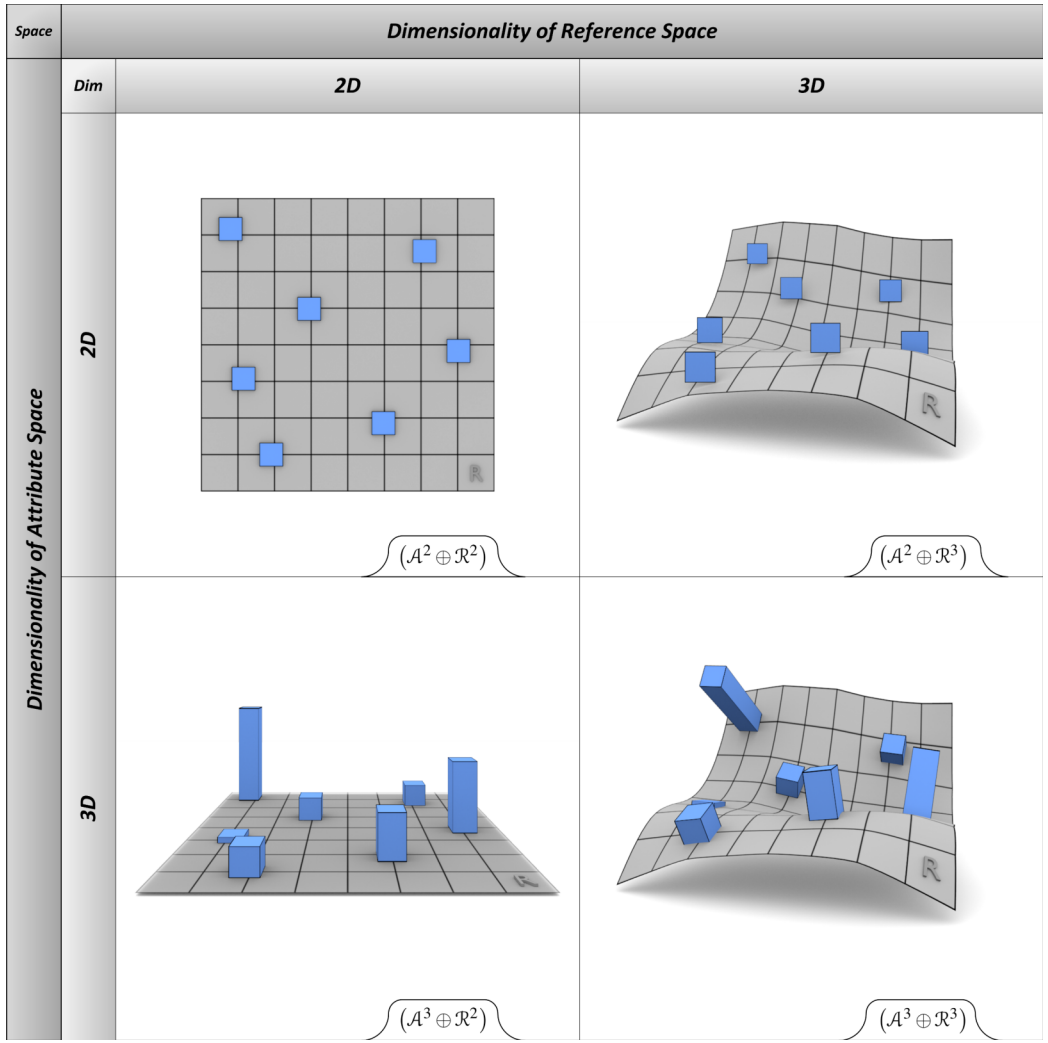


Image source: Dübel et al. 2014

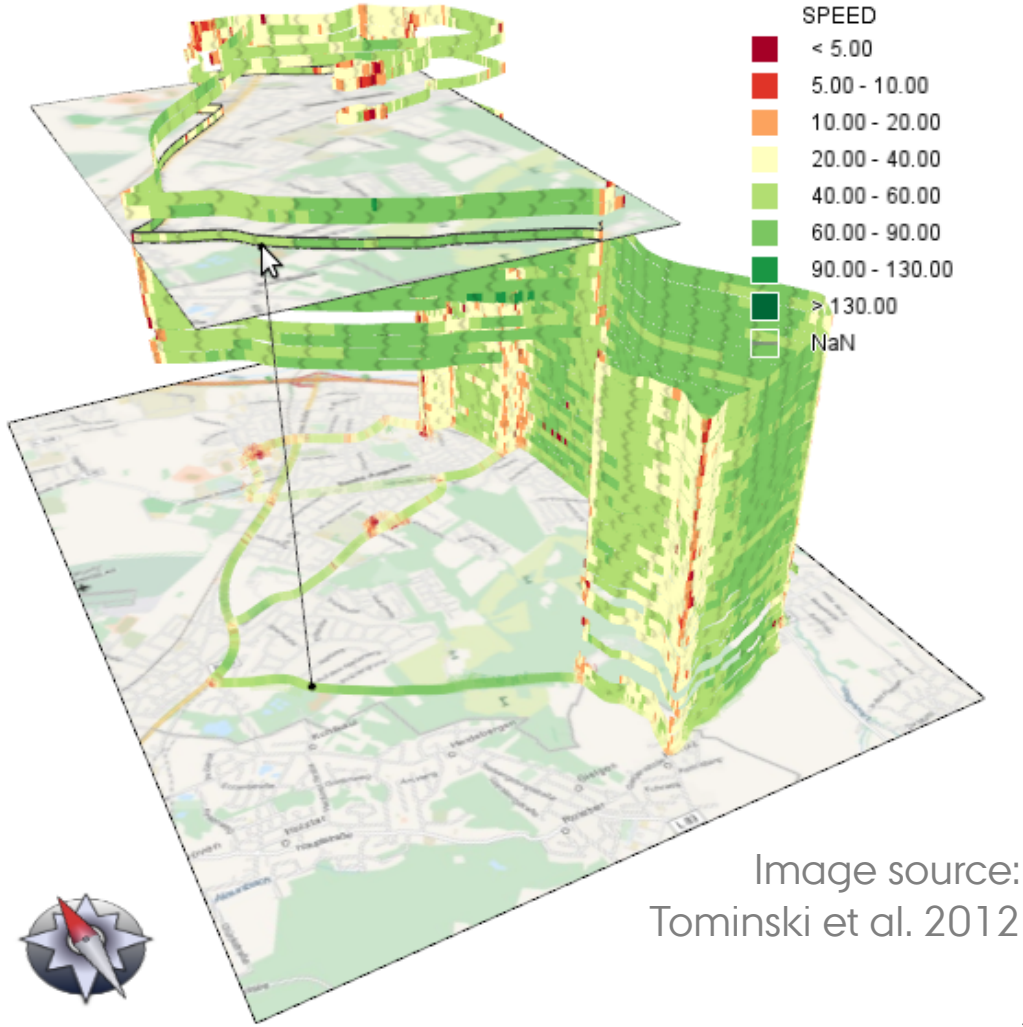
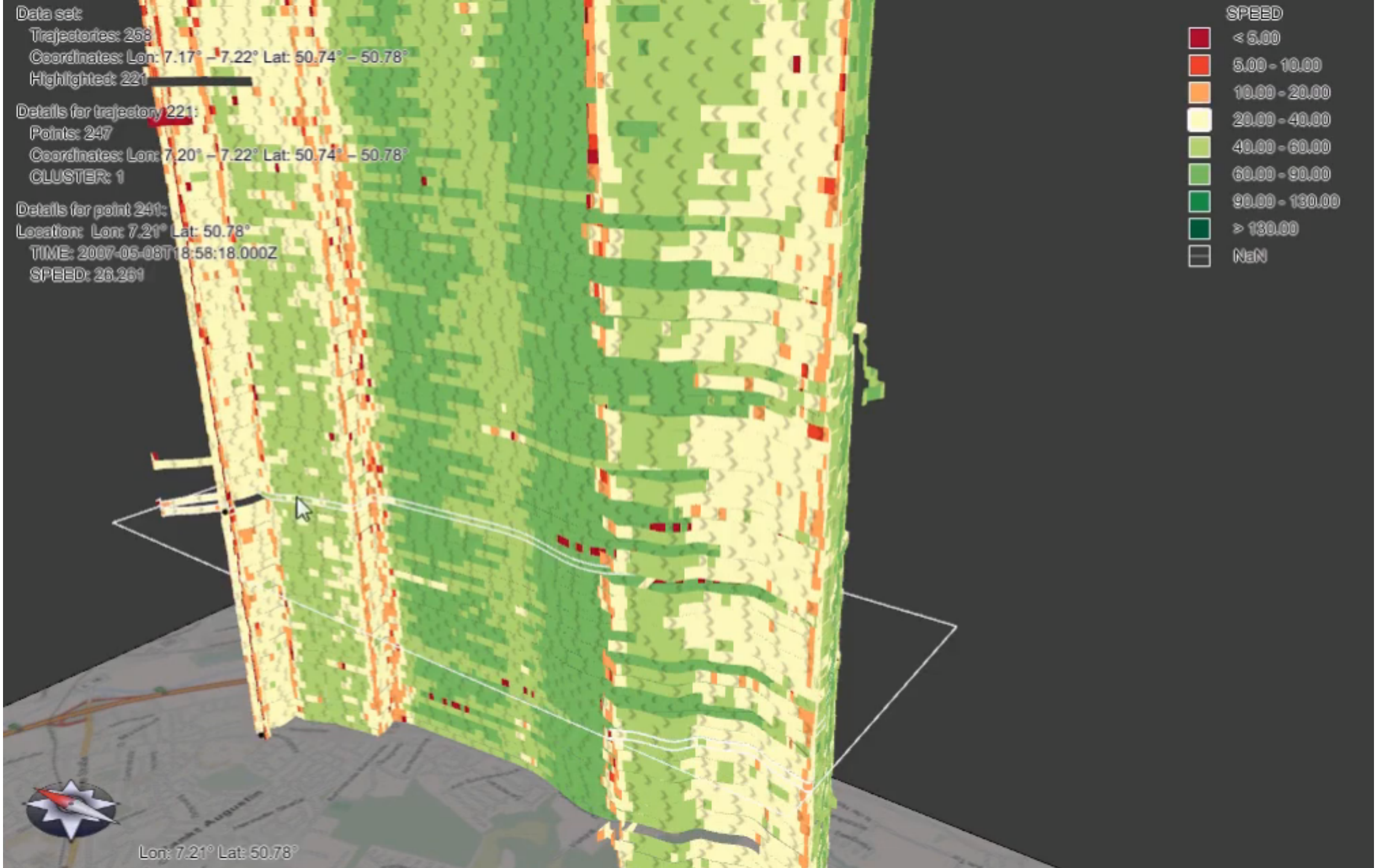


Image source: Tominski et al. 2012

Video source: Tominski et al. 2012



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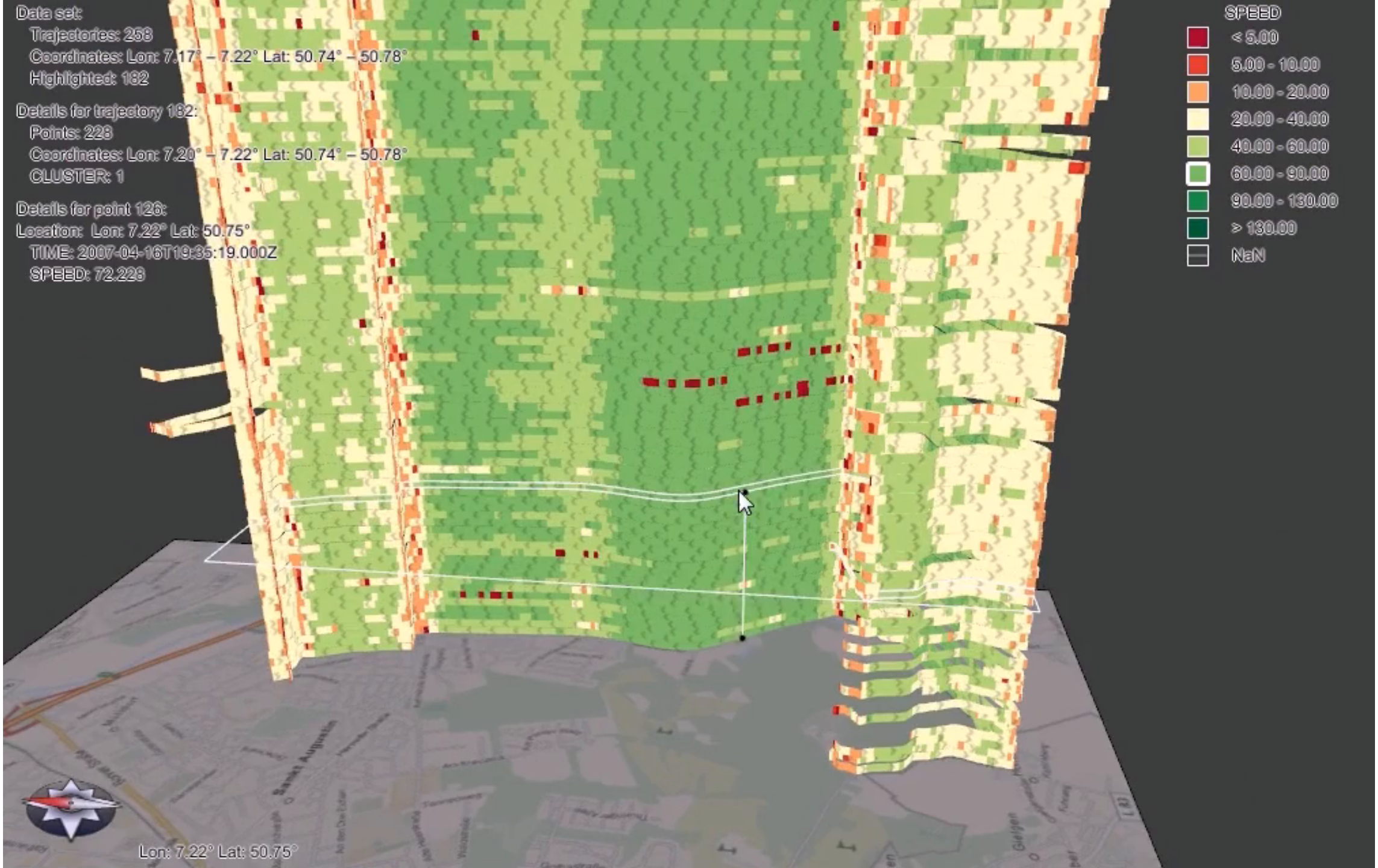


Video source: Tominski et al. 2012

CHANNELS: COLOR

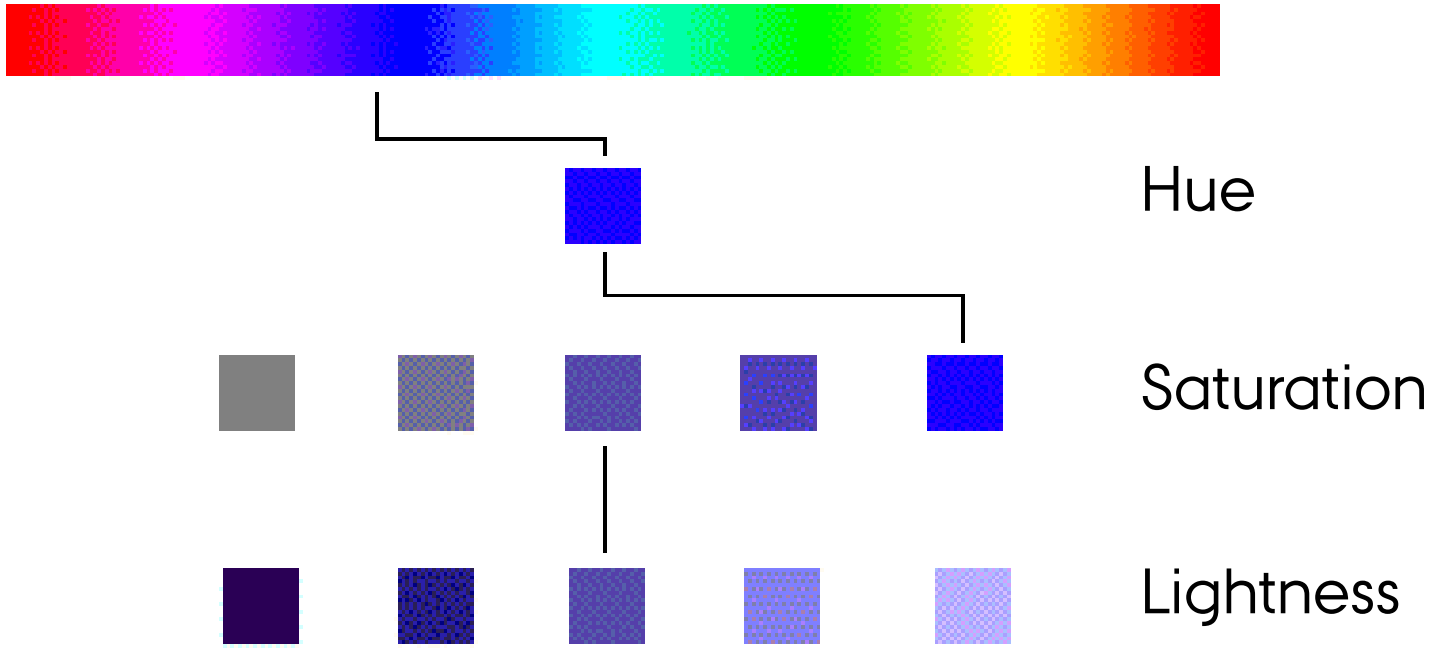
WHAT IS COLOR?

Color = Composite of *Hue*, *Saturation*, and *Lightness*

Hue = Wavelength

Saturation = Intensity from gray to pure, vivid color

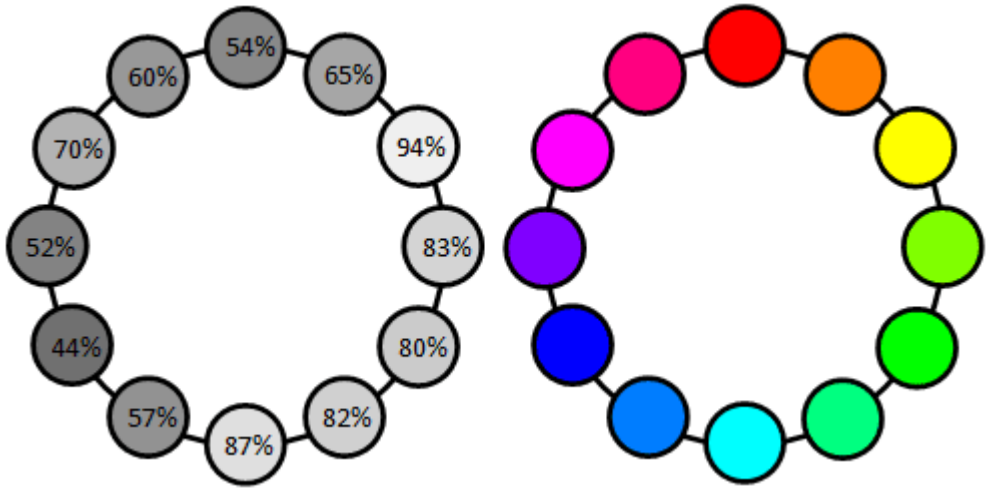
Lightness = Brightness from black to colorful to white



WHAT IS CONTRAST?

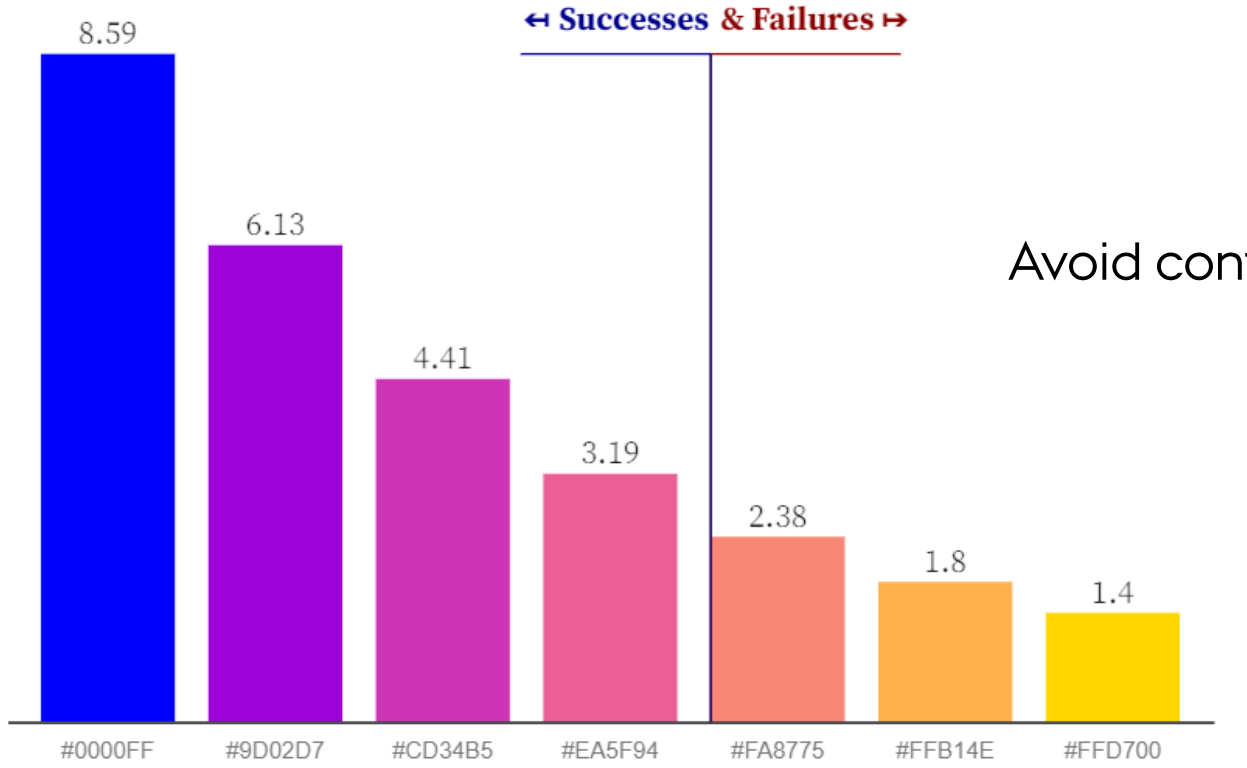
Luminance = visually perceived brightness
(sometimes *Color Temperature*)

Contrast = difference in luminance



Luminance Std. = (0.2126*R + 0.7152*G + 0.0722*B)
Luminance Photoshop = sqrt($0.299*R^2 + 0.587*G^2 + 0.114*B^2$)

HIGH CONTRAST GRAPHICS



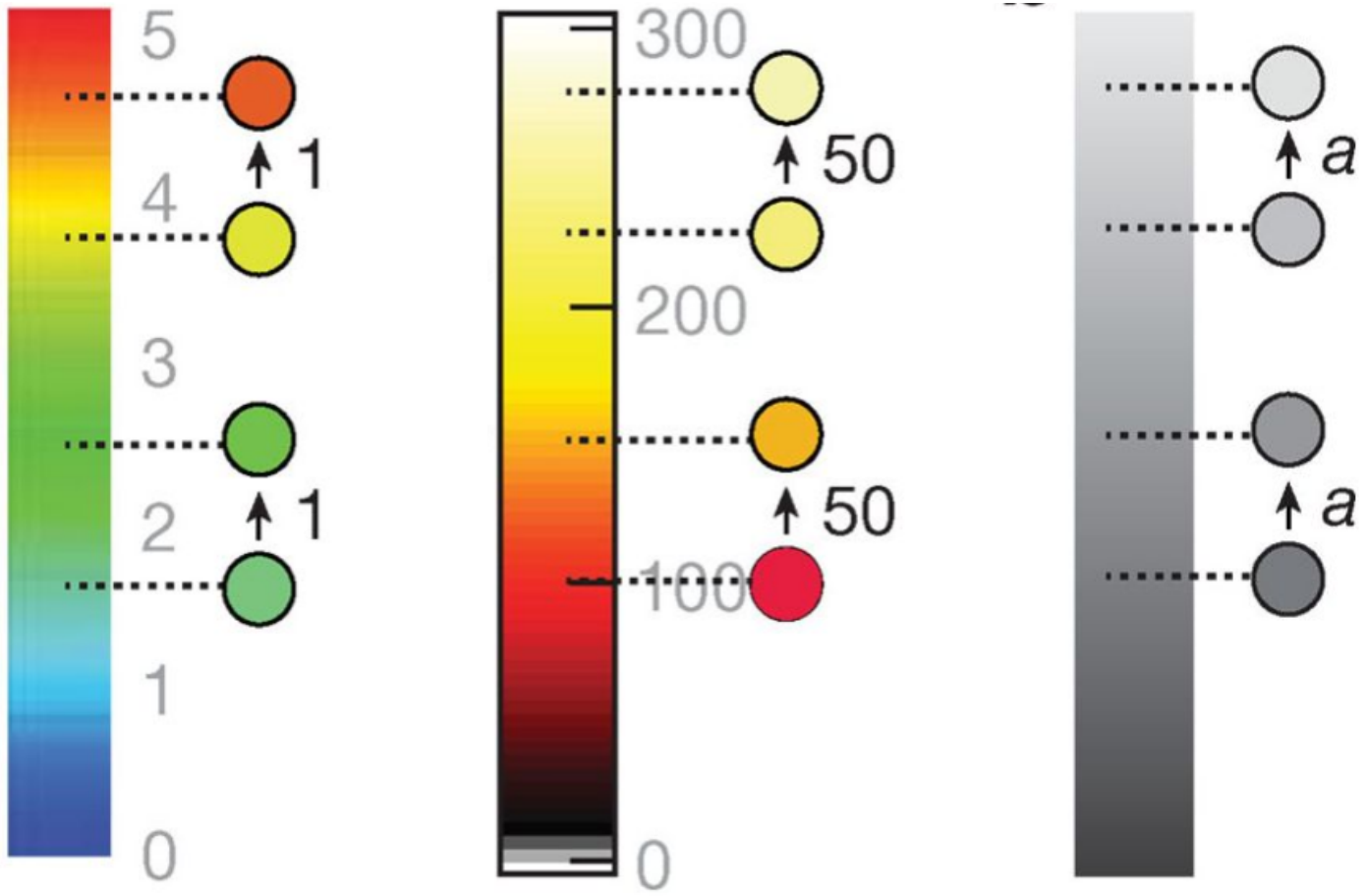
Avoid contrast ratios < 3:1

Formula @ https://www.w3.org/TR/WCAG20-TECHS/G18.html#G18-tests

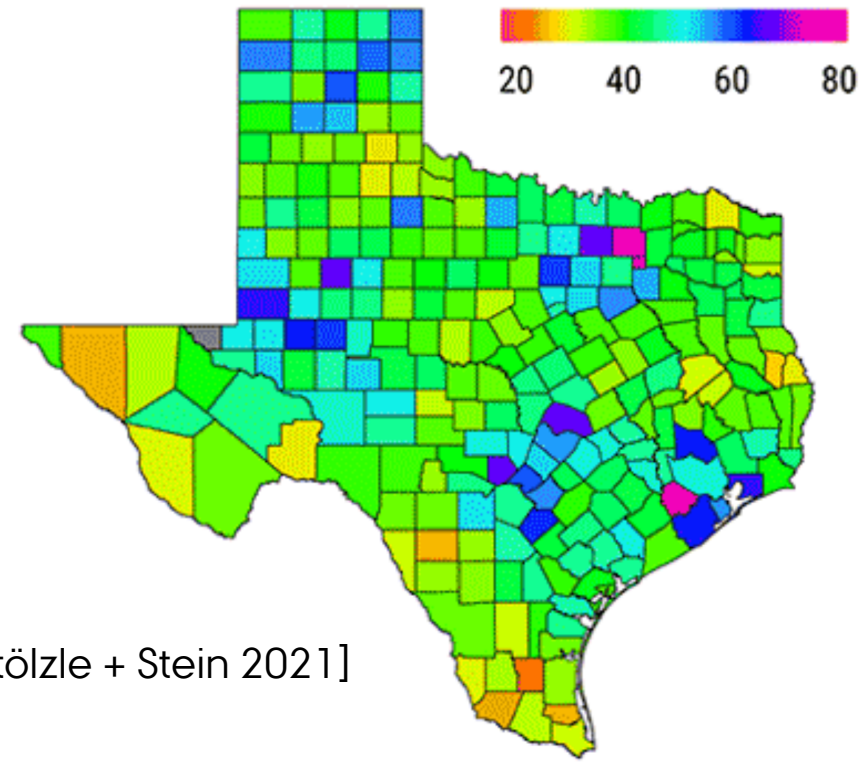
Image source: https://observablehq.com/@frankelavsky/high-contrast-for-data-visualization-with-examples

1. PERCEPTUALLY EQUIDISTANT COLOR SCALES

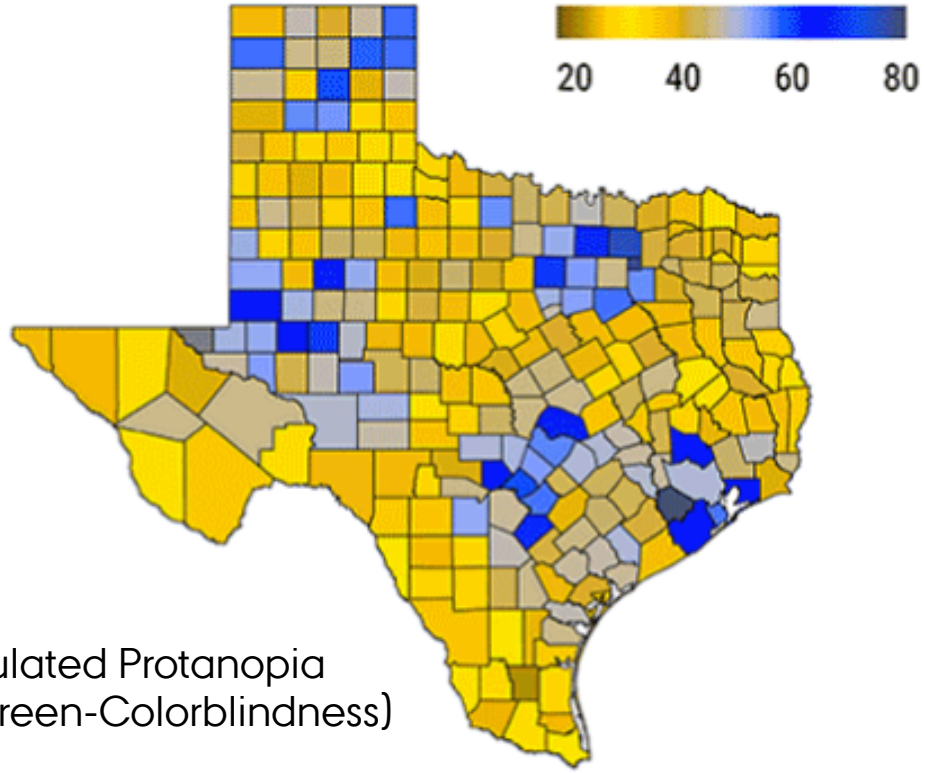
Not all color scales are created ~~equal~~ equidistant!



2. COLORBLIND-SAFE COLOR SCALES



[Stölzle + Stein 2021]



Simulated Protanopia
(Red-Green-Colorblindness)

Coblis — Color Blindness Simulator

If you are not suffering from a color vision deficiency it is very hard to imagine how it looks like to be colorblind. The **C**olor **BLI**ndness **S**imulator can close this gap for you. Just play around with it and get a feeling of how it is to have a color vision handicap.

As all the calculations are made on your local machine, no images are uploaded to the server. Therefore you can use images as big as you like, there are no restrictions. Be aware, there are some issues for the “Lens feature” on Edge and Internet Explorer. All others should support everything just fine.

So go ahead, choose an image through the upload functionality or just drag and drop your image in the center of our **C**olor **BLI**ndness **S**imulator. It is also possible to zoom and move your images around using your mouse – try it out, I hope you like it.

Drag and drop or paste your file in the area below or: Choose File No file chosen

Search

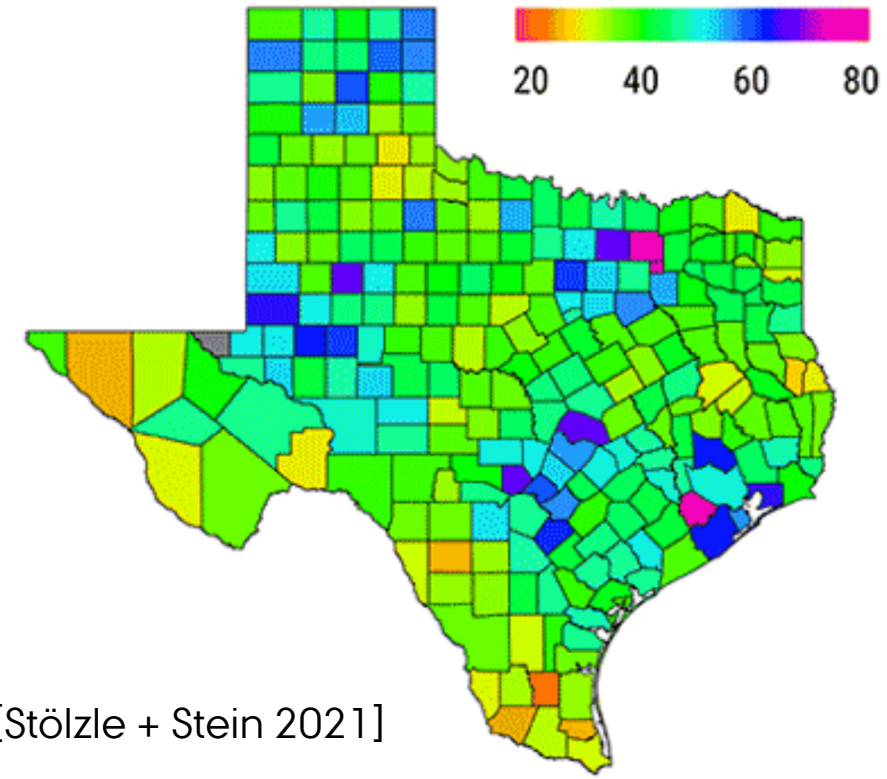
FREE Color Blind Check

New kind of color blindness test! Try Color Blind Check and test type and severity of your color vision deficiency. Easy and fun!
Info at www.colorblindcheck.com

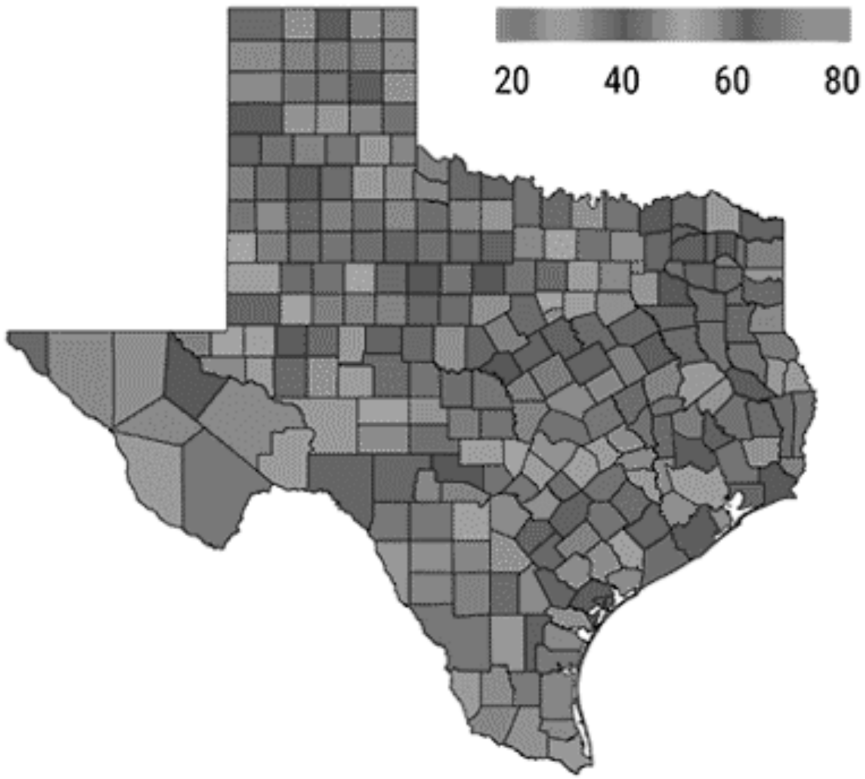
ANDROID APP ON Google play

CVD Categories

3. COLOR SCALES W/ INCREASING LUMINANCE



[Stölzle + Stein 2021]



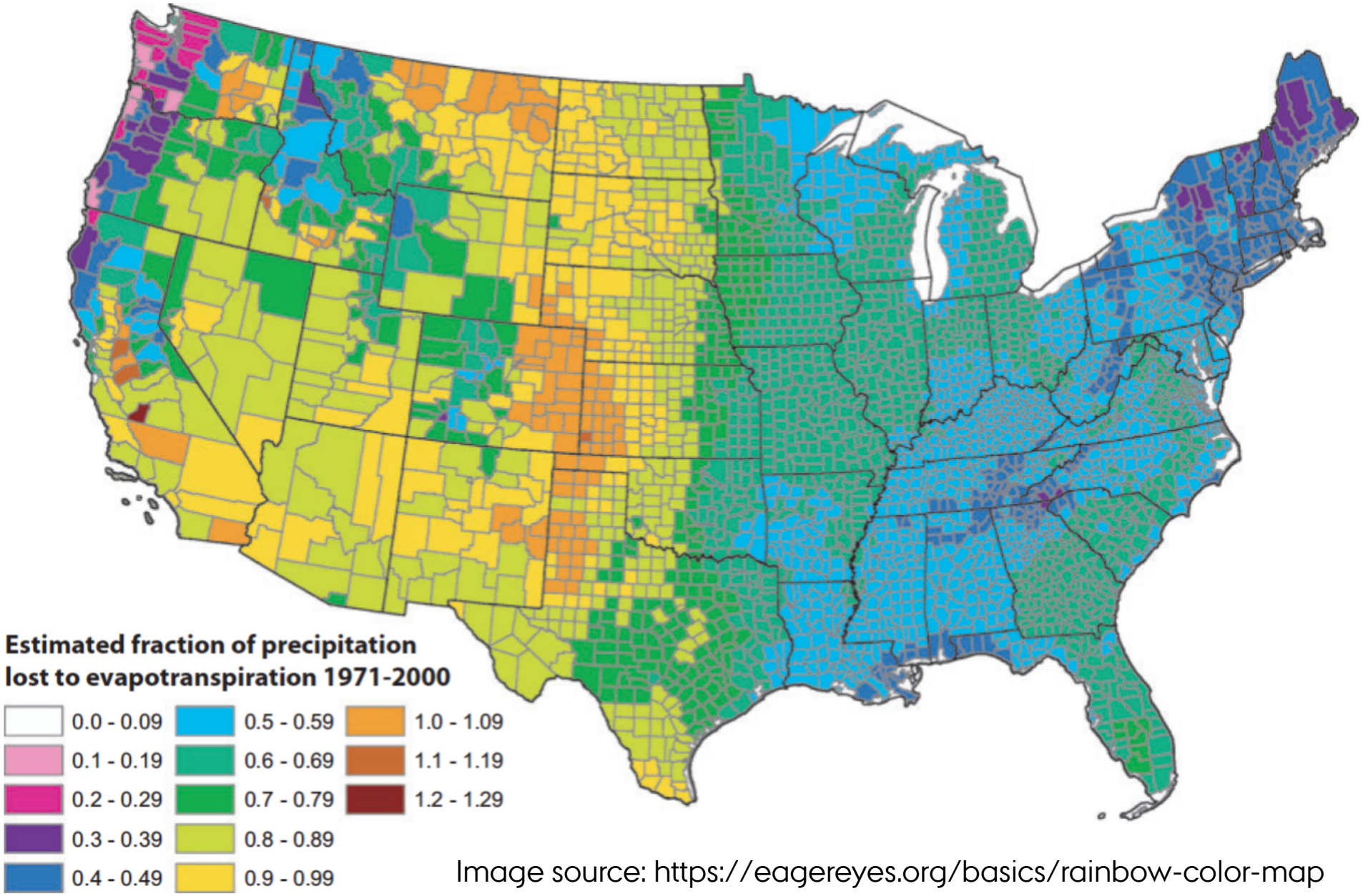
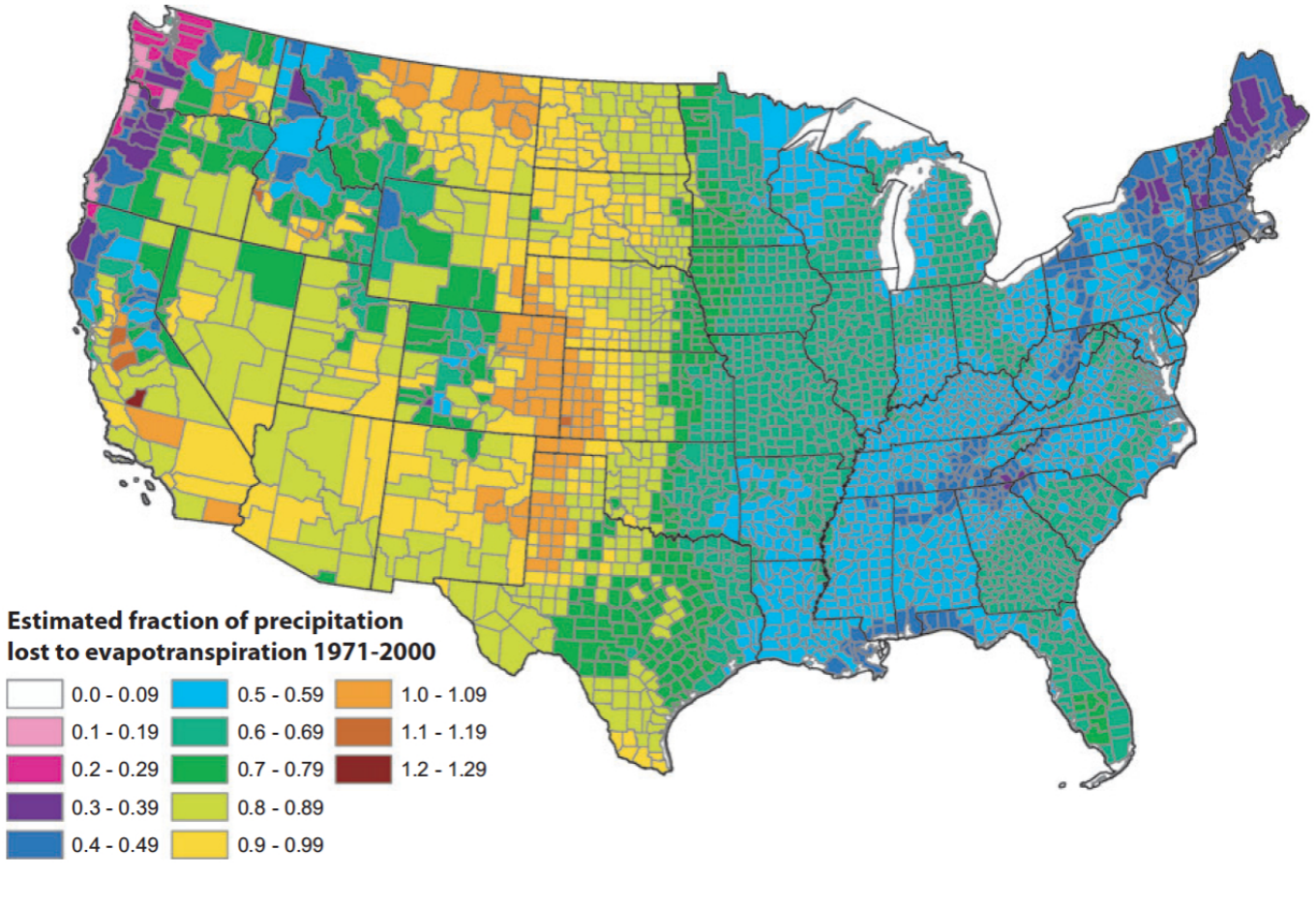
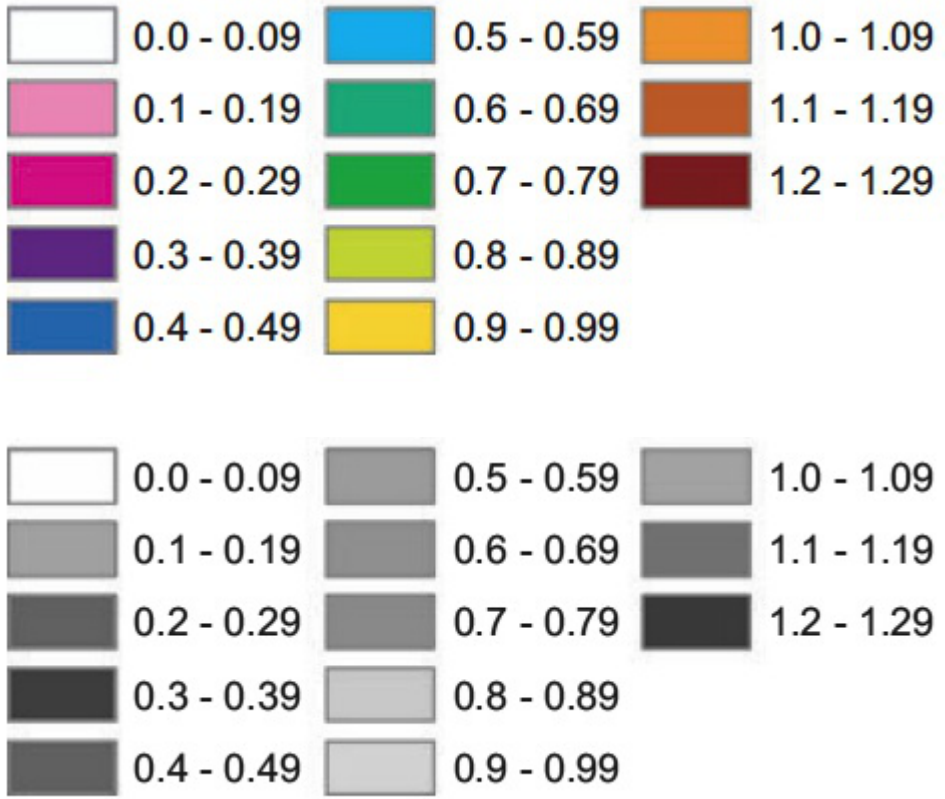


Image source: https://eagereyes.org/basics/rainbow-color-map





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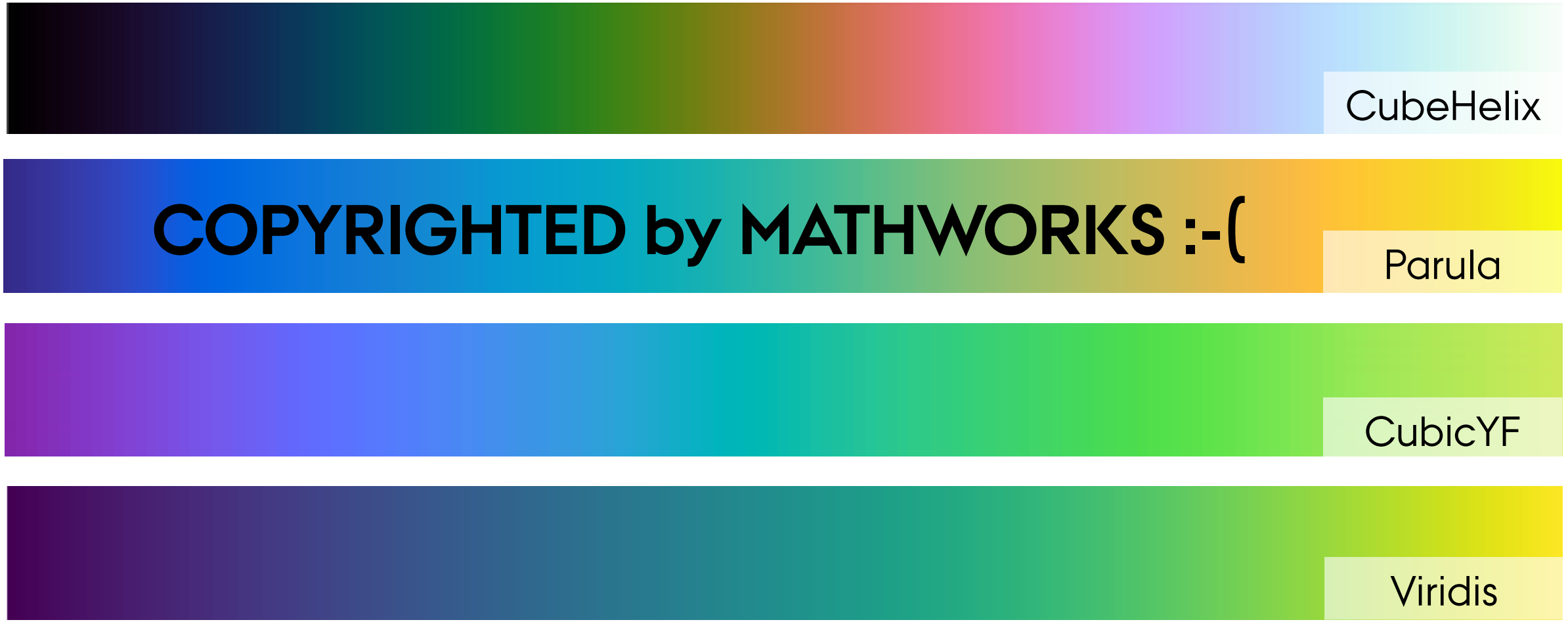
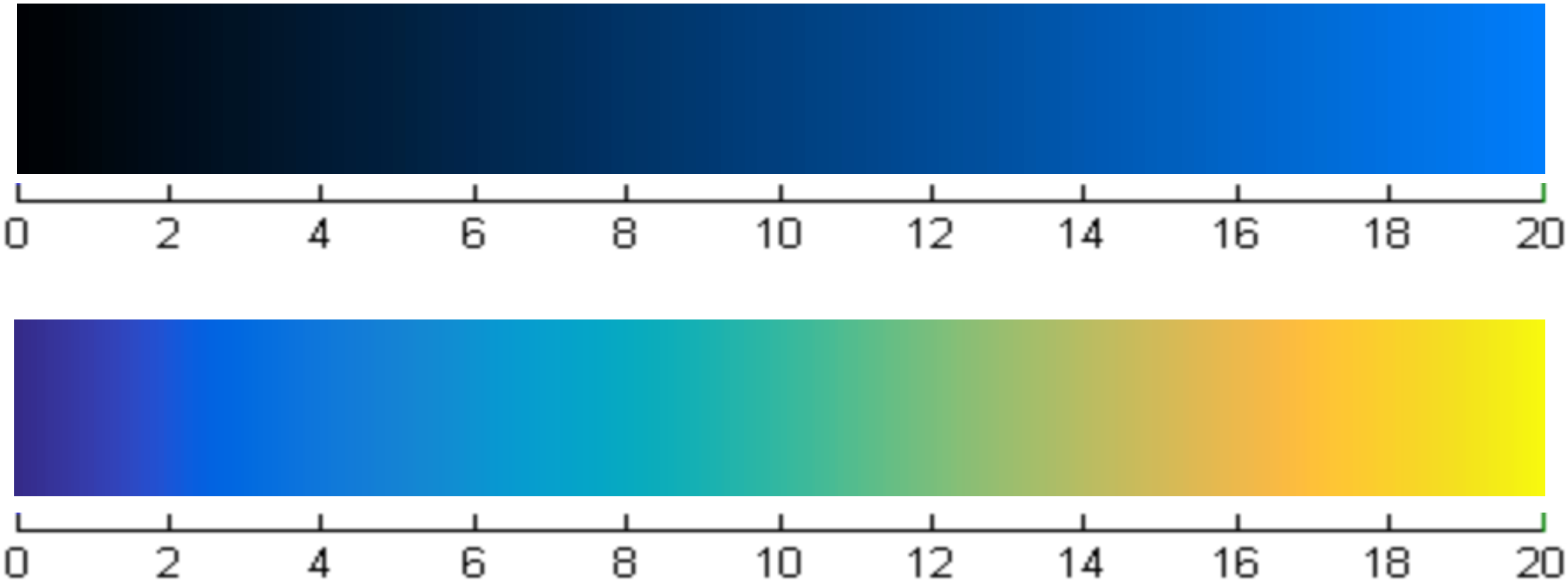
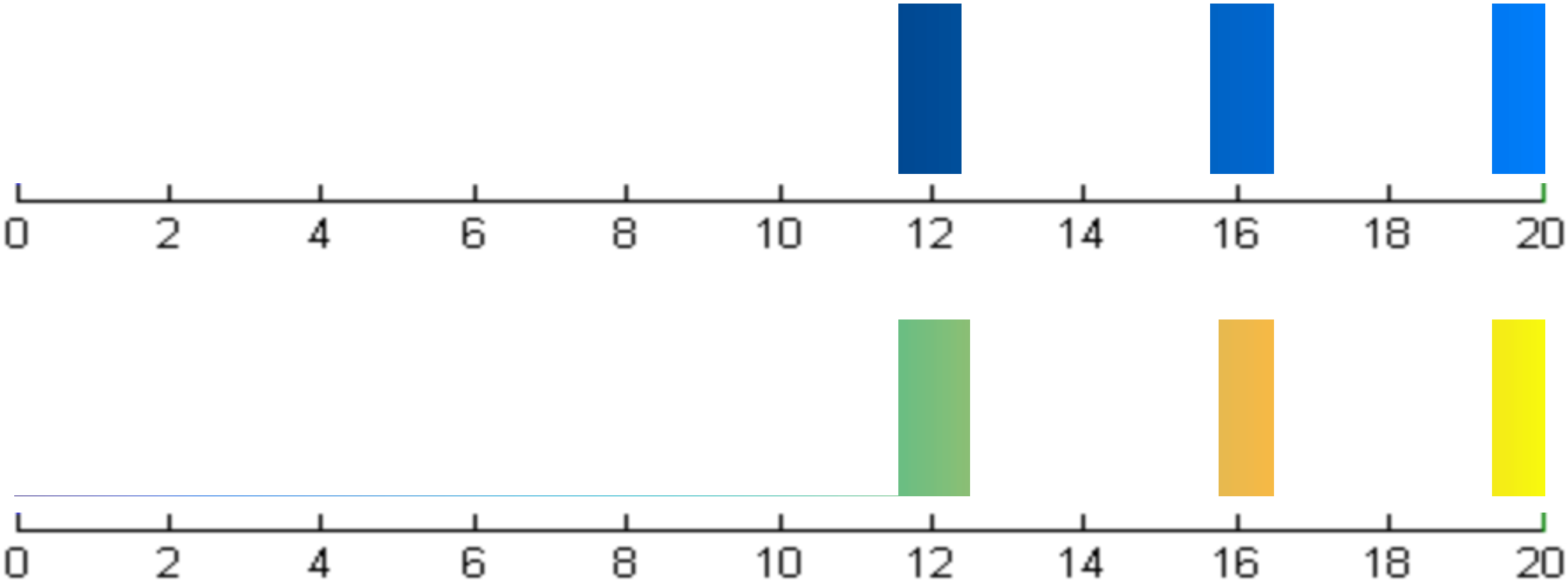
SEQUENTIAL, MULTI-HUE COLOR SCALES



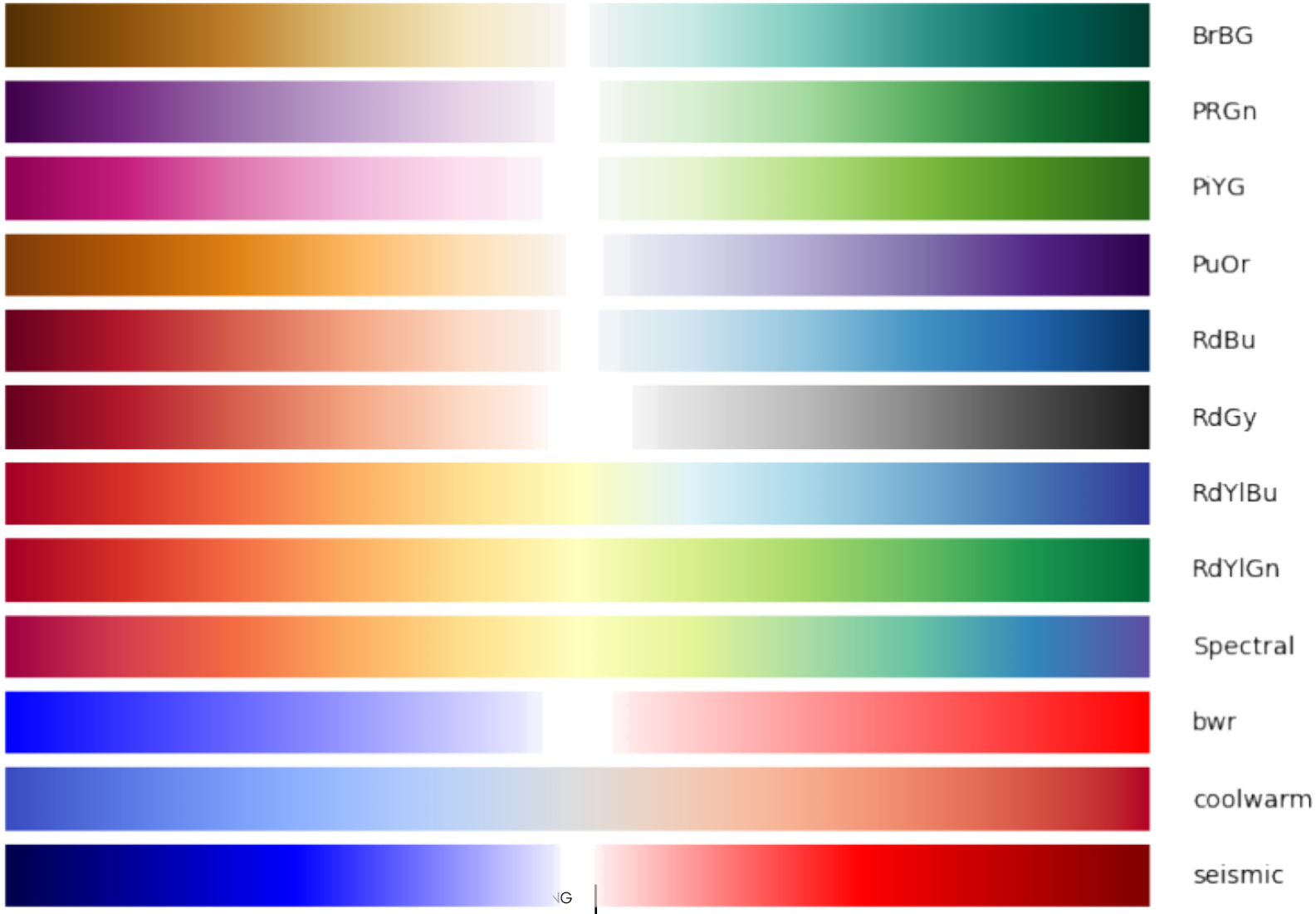
MULTI-HUE VS. SINGLE-HUE COLOR SCALES



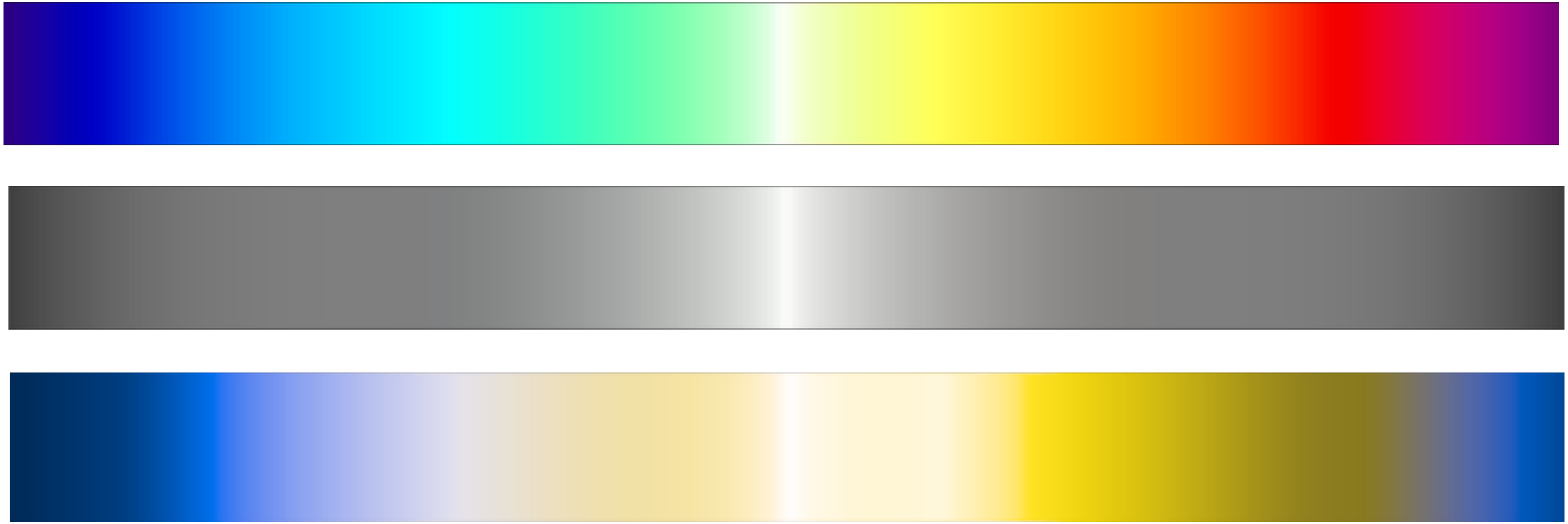
MULTI-HUE VS. SINGLE-HUE COLOR SCALES



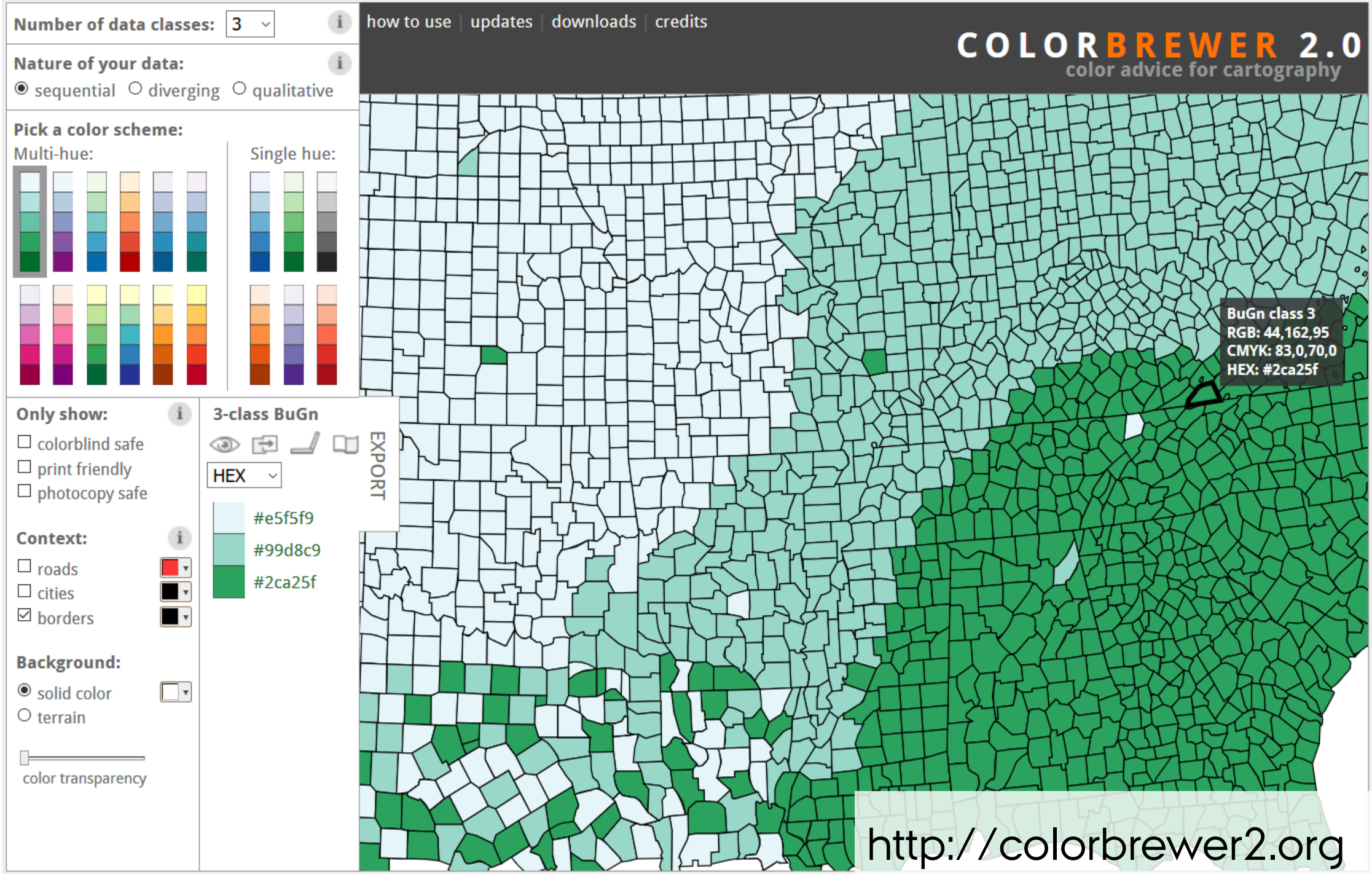
DIVERGING COLOR SCALES



IS IT POSSIBLE TO HAVE A DIVERGING MULTI-HUE COLOR SCALE?



https://www.ncl.ucar.edu/Document/Graphics/ColorTables/NCV_jaisnd.shtml


Number of data classes: 3
Nature of your data:
sequential
diverging
qualitative
Pick a color scheme:
Multi-hue:
Single hue:
Only show:
colorblind safe
print friendly
photocopy safe
Context:
roads
cities
borders
Background:
solid color
terrain
color transparency
3-class BuGn
EXPORT
HEX
#e5f5f9
#99d8c9
#2ca25f
how to use
updates
downloads
credits
COLORBREWER 2.0
color advice for cartography
BuGn class 3
RGB: 44,162,95
CMYK: 83,0,70,0
HEX: #2ca25f
http://colorbrewer2.org

Colorgorical Source

Generate

Number of colors

5

Score importance

Perceptual Distance

Name Difference

Pair Preference

Name Uniqueness

Select hue filters

90°

180°

0°

270°

Drag wheel, or add angle:

to # +

Select lightness range

25 to 85

Add starting colors

#F00, rgb(0,0,0)

+

Results: Color space Hex RGB Lab LCH Array format " ' No quote Charts Clear all

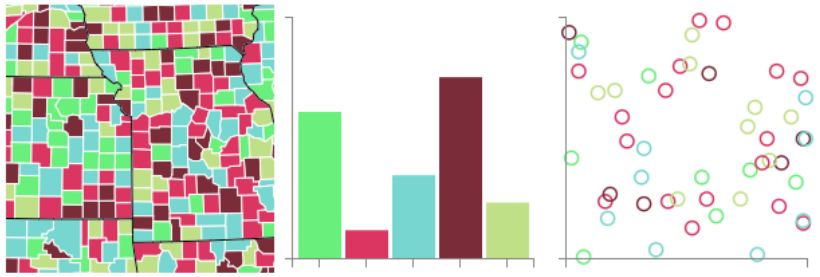
["rgb(105,239,123)", "rgb(218,54,97)", "rgb(119,214

rgb(105,239,123) + start

rgb(218,54,97) + start

rgb(119,214,207) + start

rgb(122,44,57) + start



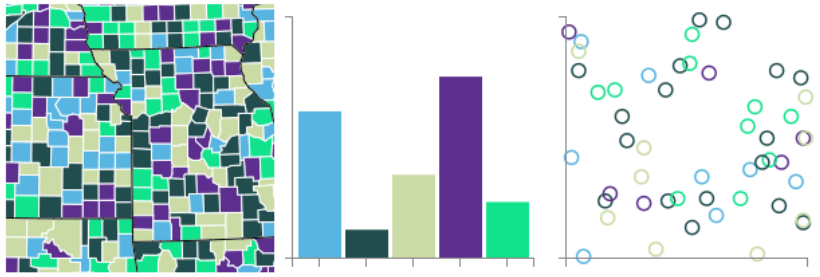
["rgb(88,181,225)", "rgb(33,77,78)", "rgb(202,219,16

rgb(88,181,225) + start

rgb(33,77,78) + start

rgb(202,219,165) + start

rgb(92,47,142) + start



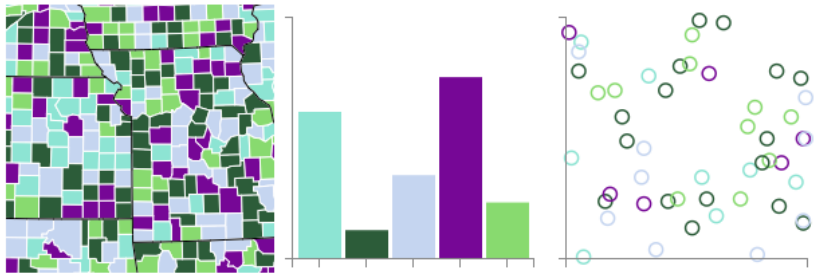
["rgb(141,228,211)", "rgb(44,92,57)", "rgb(197,213,2

rgb(141,228,211) + start

rgb(44,92,57) + start

rgb(197,213,240) + start

rgb(118,7,150) + start



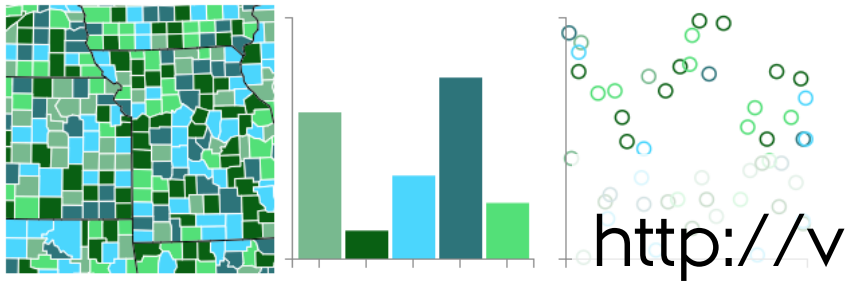
["rgb(120,185,143)", "rgb(9,96,19)", "rgb(75,214,25

rgb(120,185,143) + start

rgb(9,96,19) + start

rgb(75,214,253) + start

rgb(45,116,122) + start



http://vrl.cs.brown.edu/color

PAUL TOL'S QUANTITATIVE COLORS

Incandescent

Iridescent

Nightfall

https://personal.sron.nl/~pault/

PAUL TOL'S QUALITATIVE COLORS

https://personal.sron.nl/~pault/

LABELING

FAVOR DIRECT LABELING OVER LEGENDS

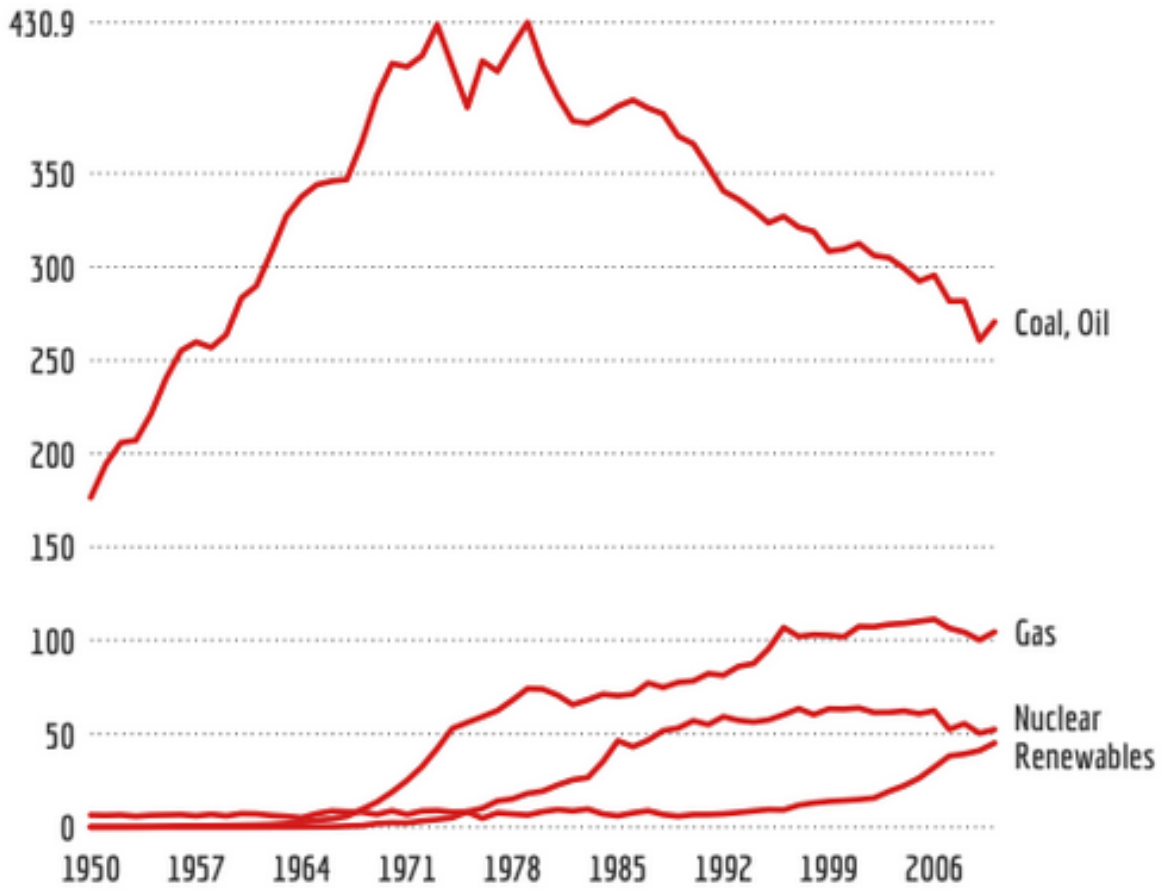
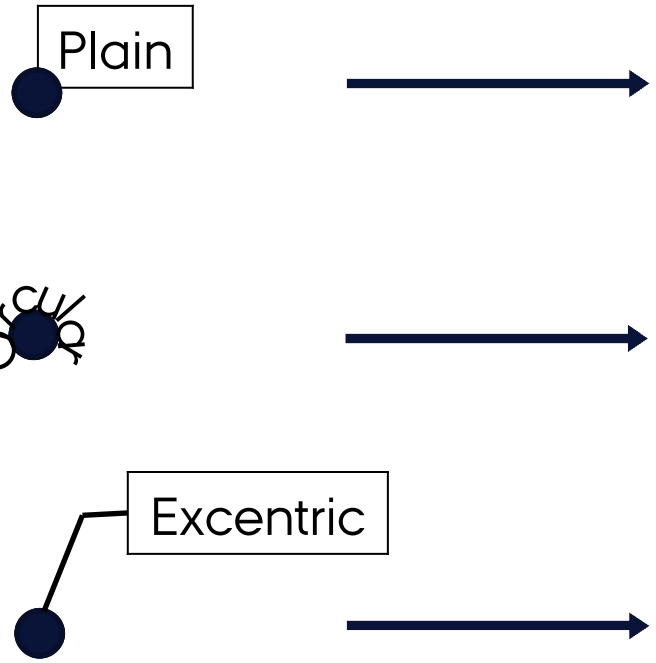


Image Source: https://www.vis4.net/blog/2012/06/doing-the-line-charts-right/

LABEL TYPES FOR DIRECT LABELING



- simple placement
- good attribution
- high likelihood of occlusion in dense areas

- good attribution
- hampered readability
- problematic for longer labels

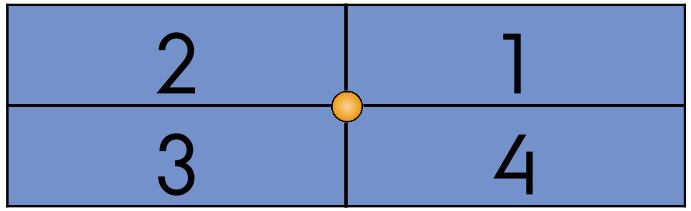
- connecting link adds to visual complexity (especially in the presence of edges)
- can alleviate occlusion to some degree

PARTICLE-BASED LABELING

adapted from [Luboschik et al. 2008]
DOI: 10.1109/TVCG.2008.152

STAGE 1: Attempt to place a plain label

1. The 4-Position Model



2. The 8-Position Model

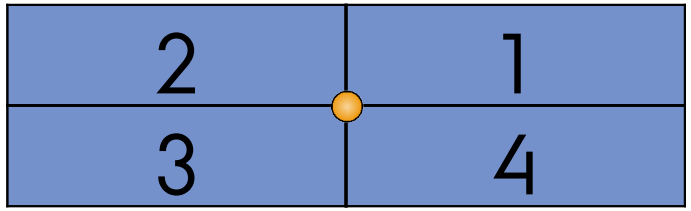
3. The Slider Model

PARTICLE-BASED LABELING

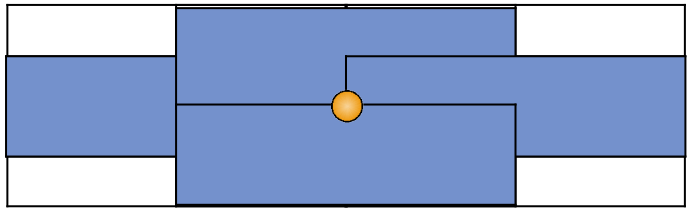
adapted from [Luboschik et al. 2008]
DOI: 10.1109/TVCG.2008.152

STAGE 1: Attempt to place a plain label

1. The 4-Position Model



2. The 8-Position Model



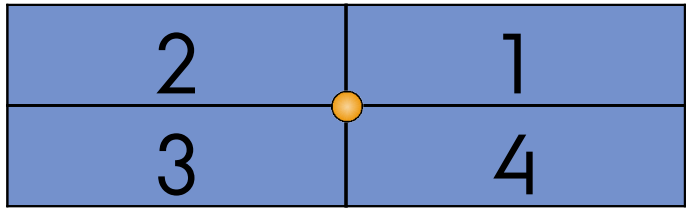
3. The Slider Model

PARTICLE-BASED LABELING

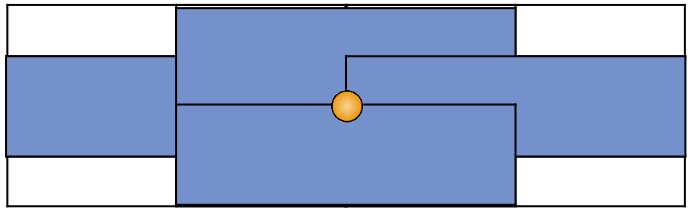
adapted from [Luboschik et al. 2008]
DOI: 10.1109/TVCG.2008.152

STAGE 1: Attempt to place a plain label

1. The 4-Position Model



2. The 8-Position Model



3. The Slider Model

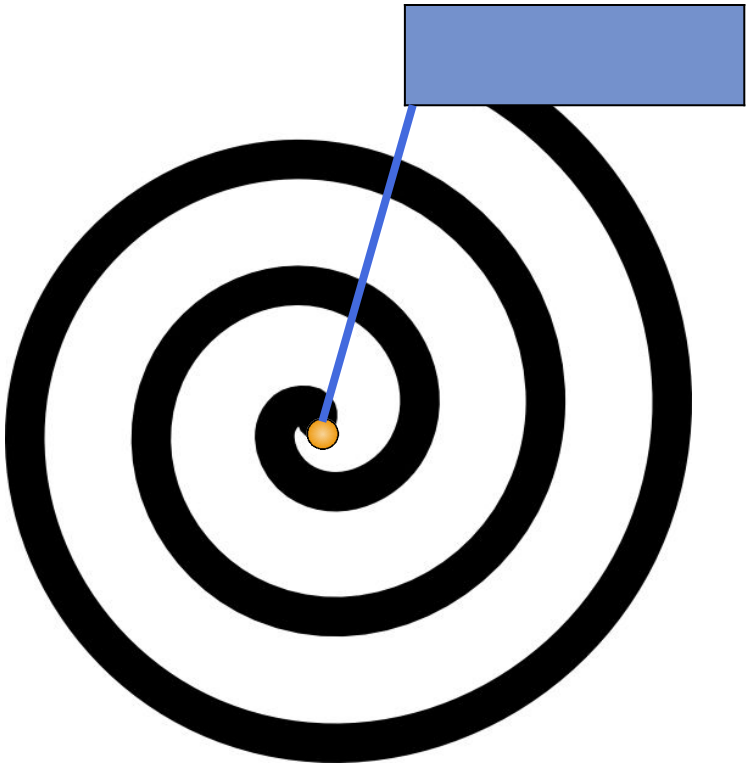
A PRINCIPAL LABELING PROCEDURE

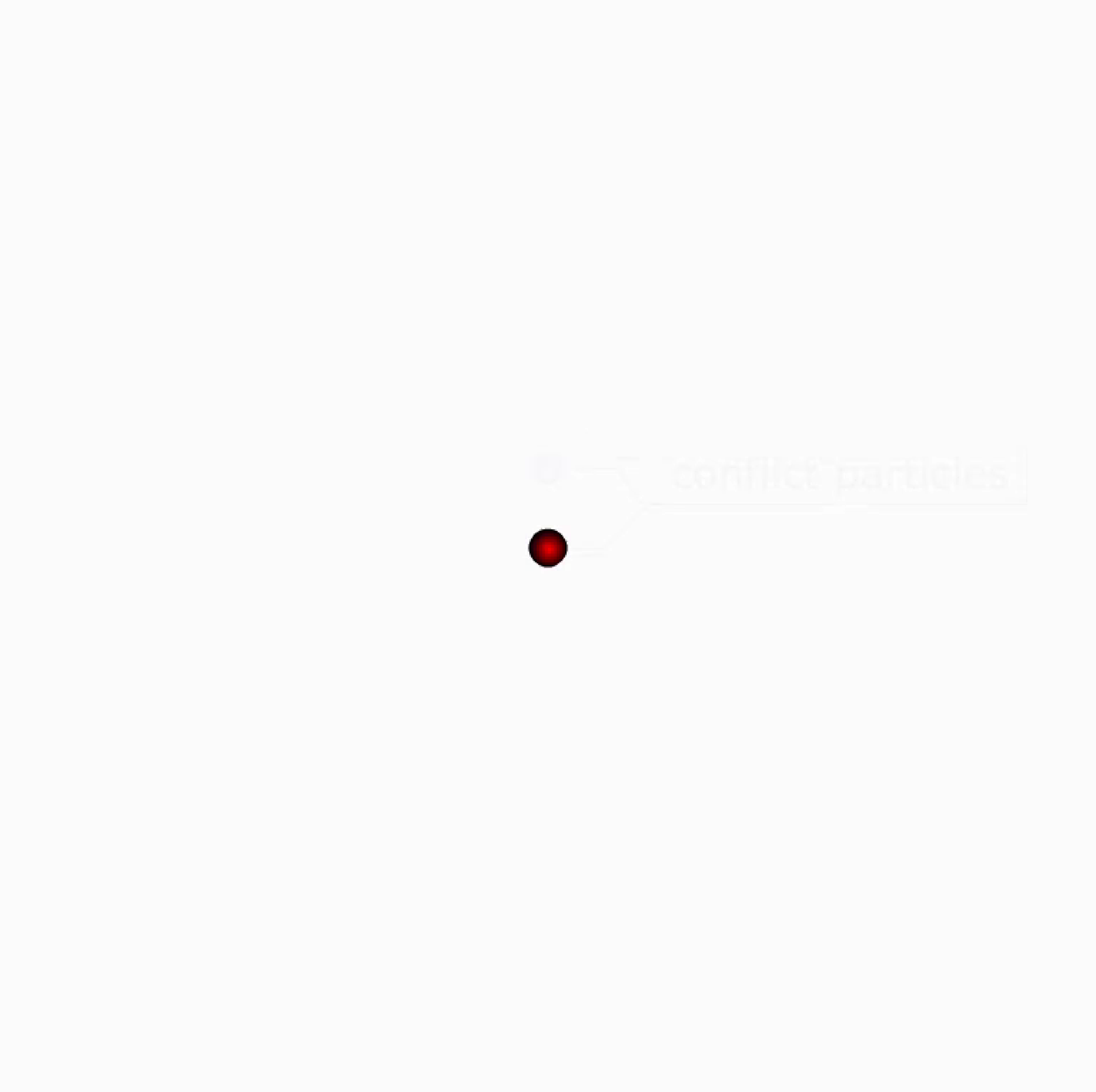
adapted from [Luboschik et al. 2008]
DOI: 10.1109/TVCG.2008.152

STAGE 2: Attempt to place an excentric label

Move the label along a spiral path until a suitable position is found.

How to do the collision detection efficiently?
Particles → Video





[Luboschik et al. 2008]
DOI: 10.1109/TVCG.2008.152

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RENDERING

ALL KINDS OF DRAWING STYLES...

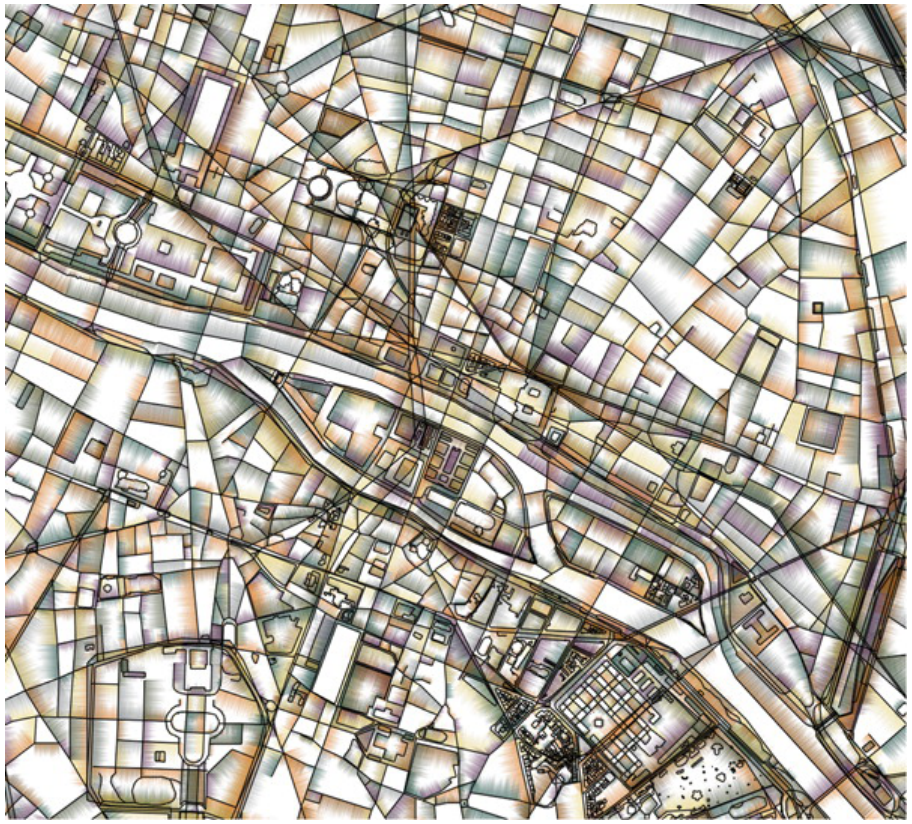


Image source: [Isenberg 2013]

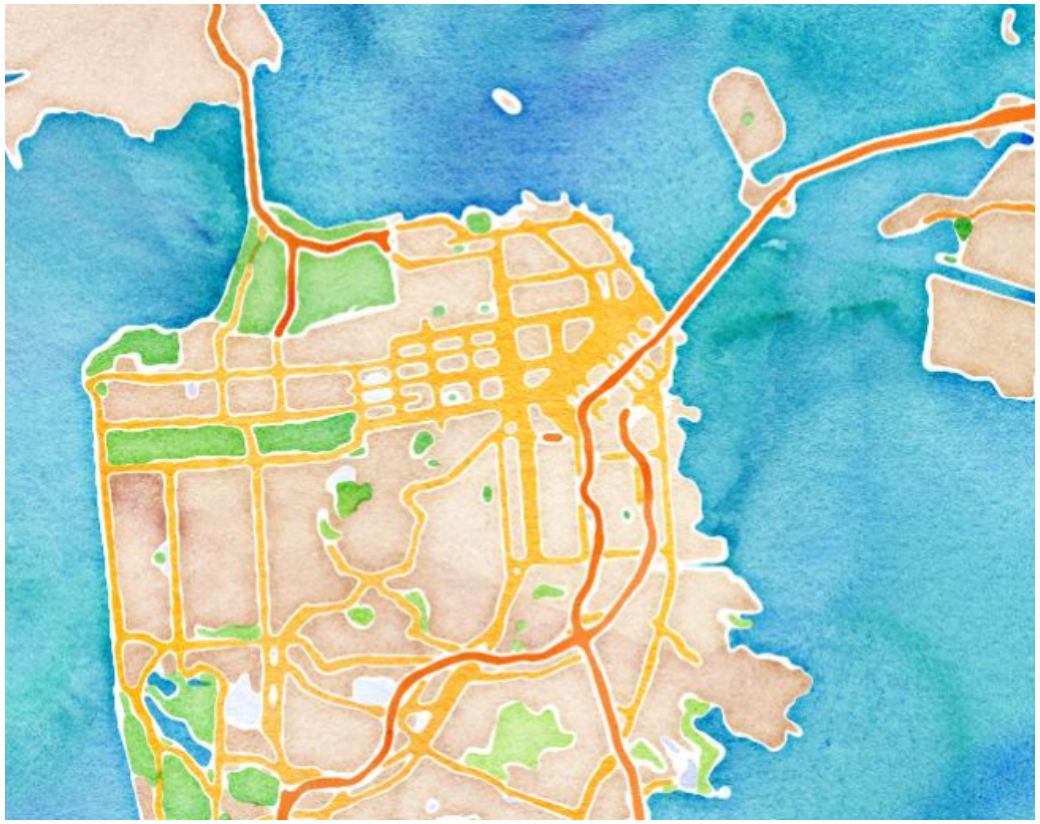


Image source: http://kelsocartography.com/blog/?p=4228

IMPRESSIONISTIC VISUALIZATION

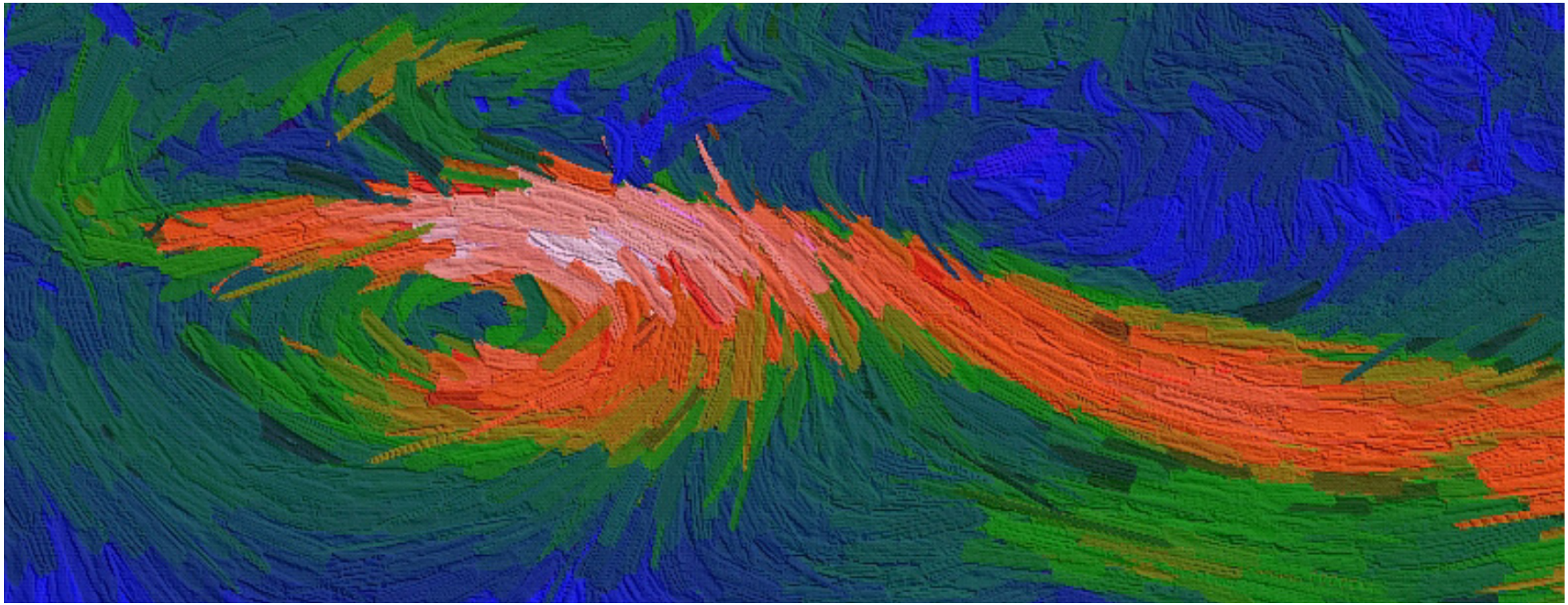


Image source: [Tateosian et al. 2007]

...NOT ONLY FOR MAPS

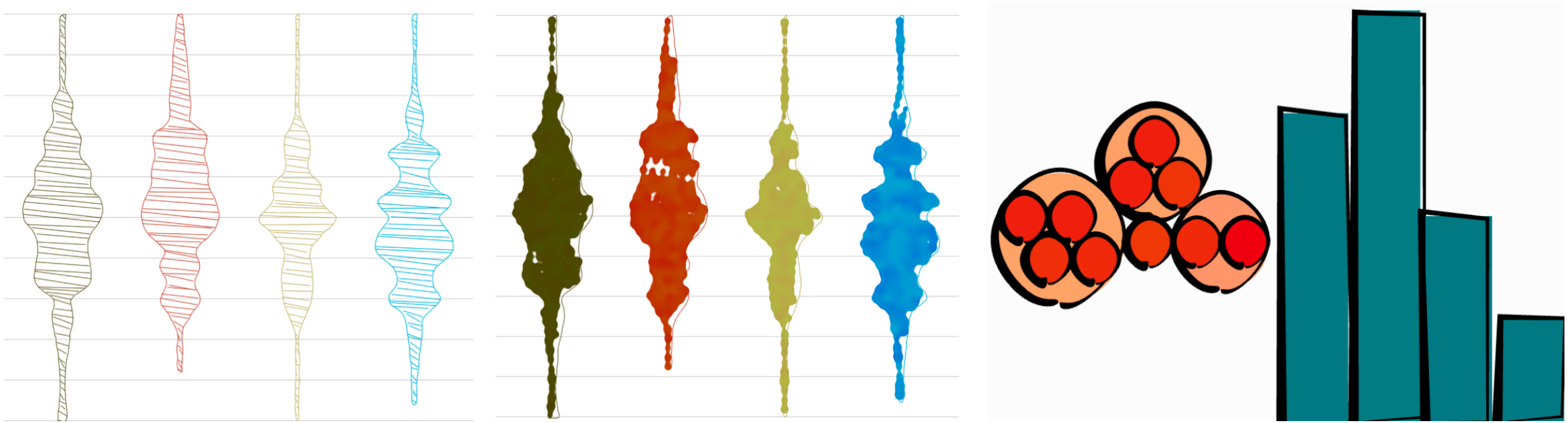


Image source: https://medium.com/@Elijah_Meeks/sketchy-data-visualization-in-semiotic-5811a52f59bc

rough.js (+ wired.js)

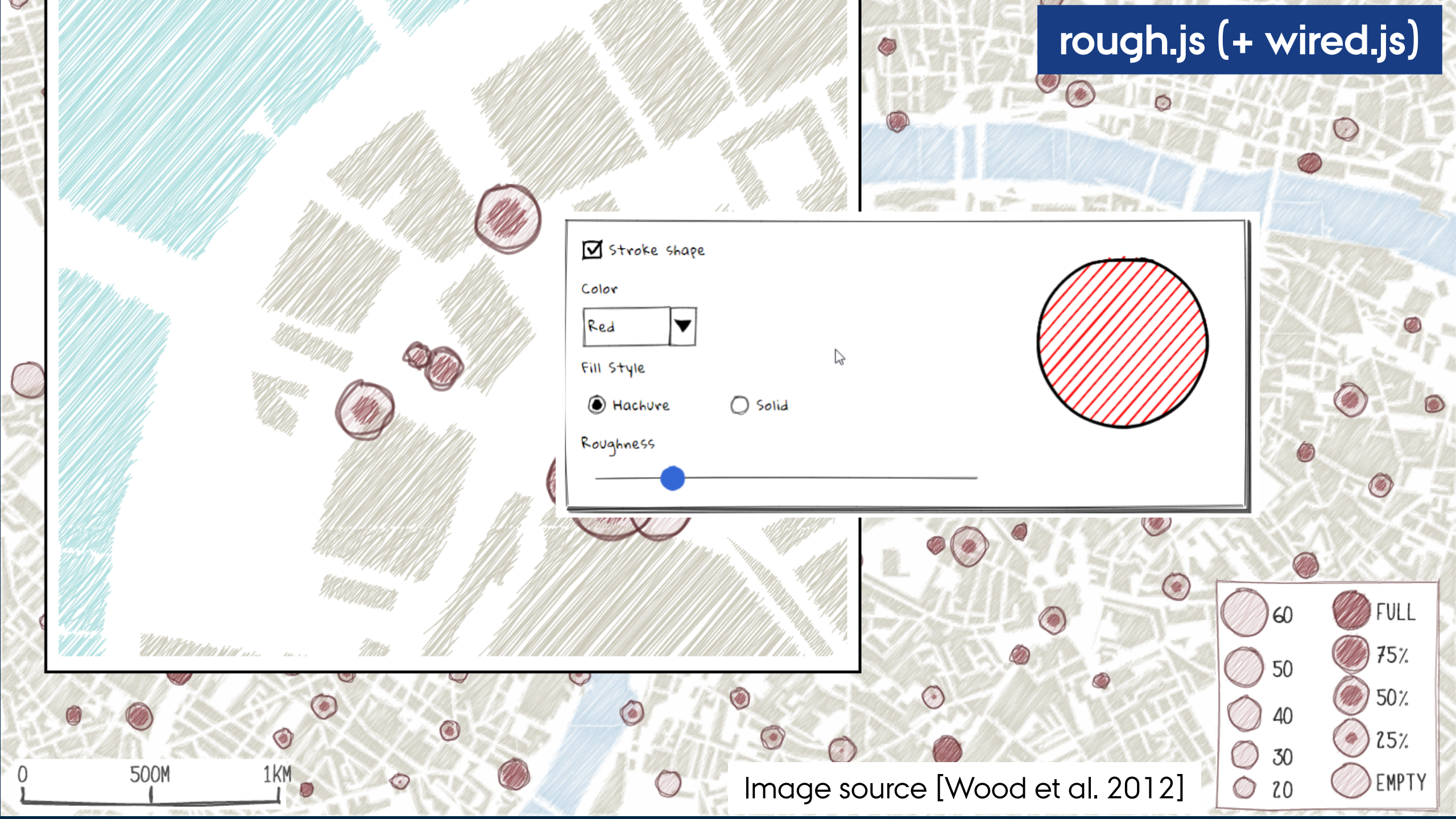


Image source [Wood et al. 2012]

HOW TO HATCH

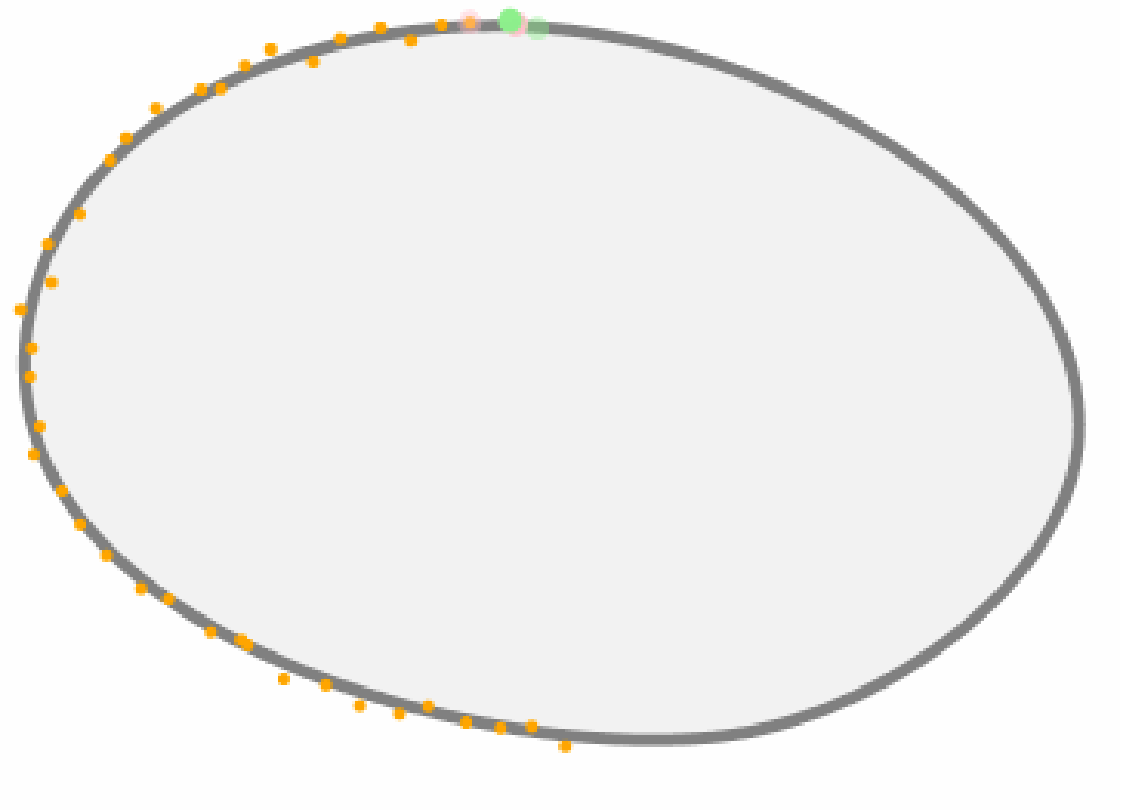
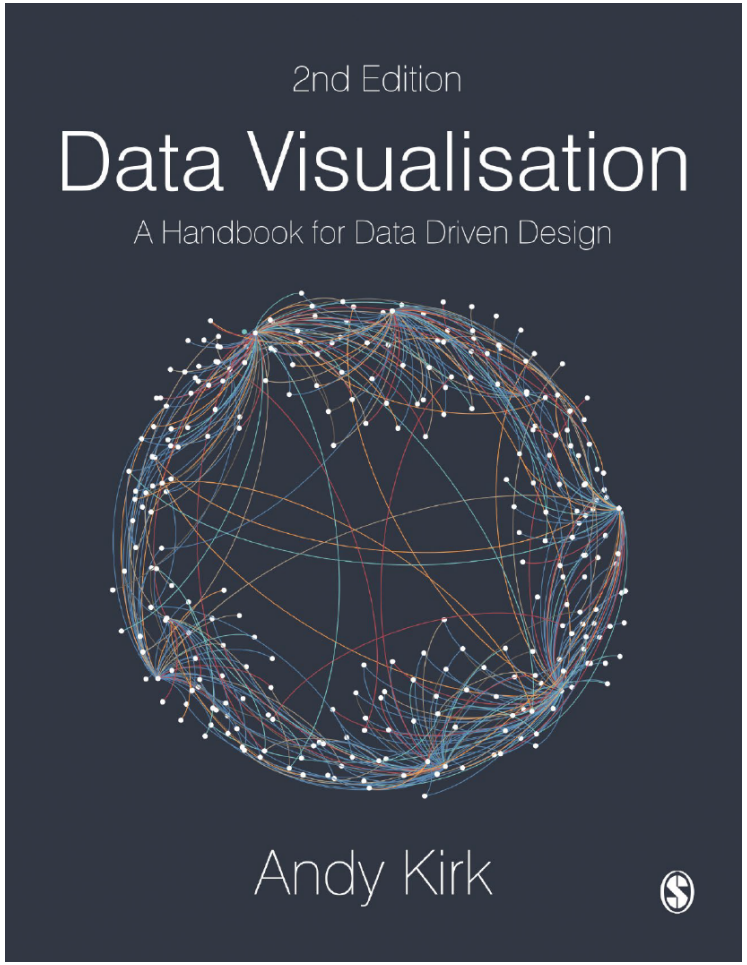


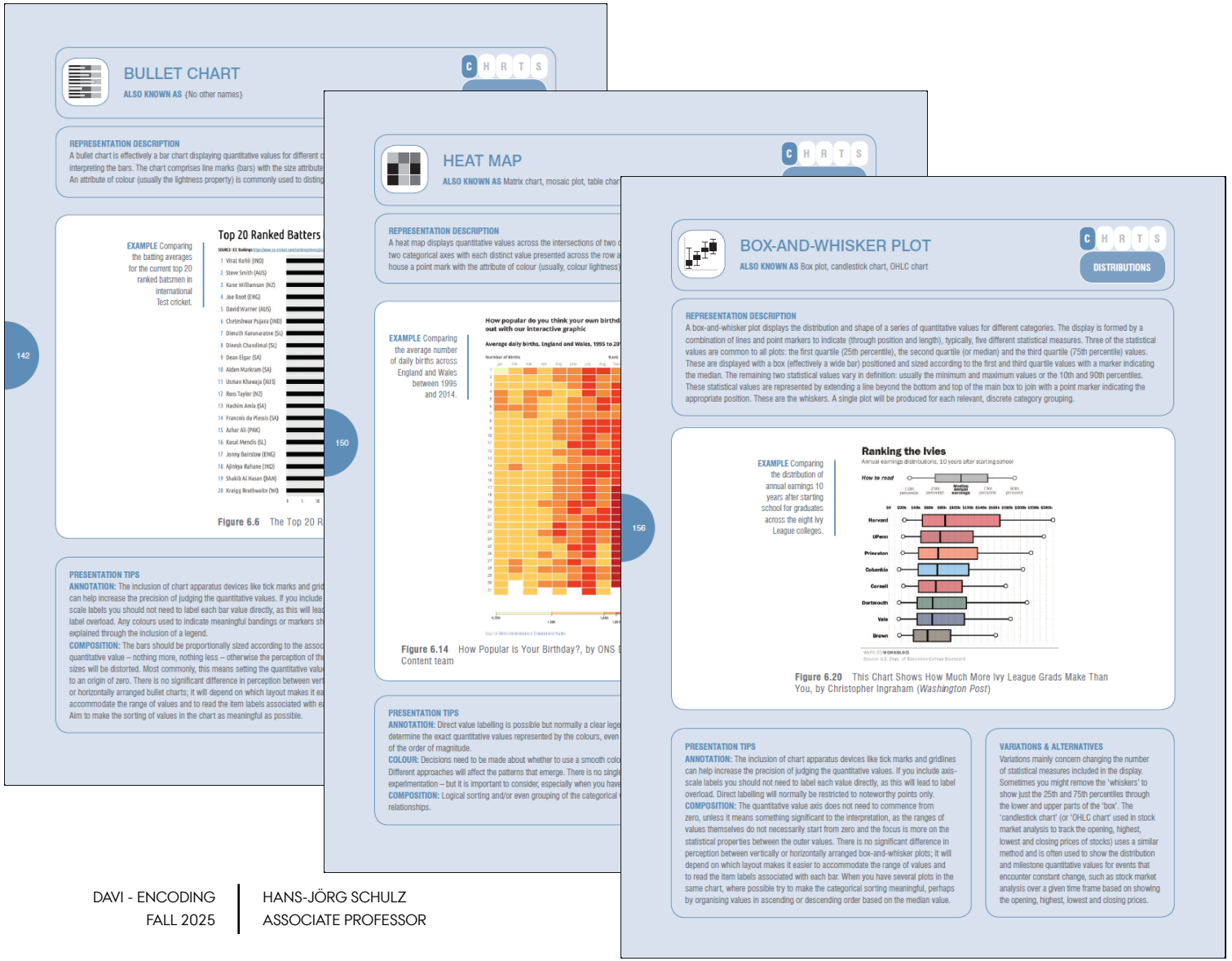
Image source: https://medium.com/@Elijah_Meeks/sketchy-data-visualization-in-semiotic-5811a52f59bc

LIST OF LITERATURE SOURCES

- Perception in Visualization: https://www.csc2.ncsu.edu/faculty/healey/PP/
  Paper: https://doi.org/10.1109/TVCG.2011.127
- Gregory 1991 – Optical Illusions: https://doi.org/10.1068/p200001
- Stevens 1946 – Data Types/Scales: https://doi.org/10.1126/science.103.2684.677
- Mackinley 1986: https://doi.org/10.1145/22949.22950
- Munzner 2014: https://www.cs.ubc.ca/~tmm/vadbook/ (chapter 5)
- Brath 2014 – 3D: https://doi.org/10.1109/3DVis.2014.7160096
- Ware 2000: https://doi.org/10.1075/idj.10.3.07war
- Hanson et al. 1997: https://doi.org/10.1109/DAGSTUHL.1997.1423106
- Yu et al. 2016: https://doi.org/10.1109/tvcg.2015.2467202
- Dübel et al. 2014: https://doi.org/10.1109/3DVis.2014.7160094
- Tominski et al. 2012: https://doi.org/10.1109/TVCG.2012.265
- Stoelzle + Stein 2021: https://doi.org/10.5194/hess-25-4549-2021
- Luboschik et al. 2008: https://doi.org/10.1109/TVCG.2008.152
- Gooch 2010: https://doi.org/10.1145/1809939.1809958
- Tateosian et al. 2007: https://doi.org/10.1145/1274871.1274886
- Isenberg 2013: https://doi.org/10.1179/1743277412Y.0000000007

WEEKLY READING FOR NEXT WEEK





ADVANCED COLORS

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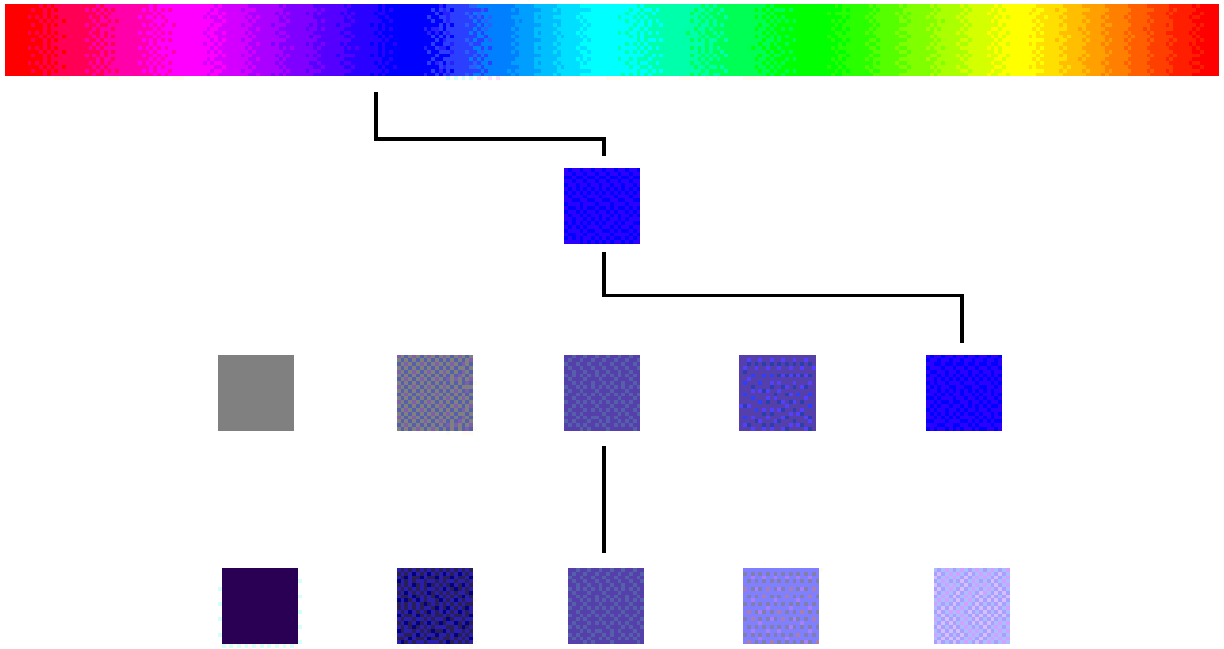
UNIVERSITY
DEPARTMENT OF COMPUTER SCIENCE

HANS-JÖRG SCHULZ
ASSOCIATE PROFESSOR

SOLIDUM PETIT IN PROFUNDIS · UNIVERSITAS ARHUSIENSIS

THE HSL COLOR DEFINITION



Hue

Saturation

Lightness

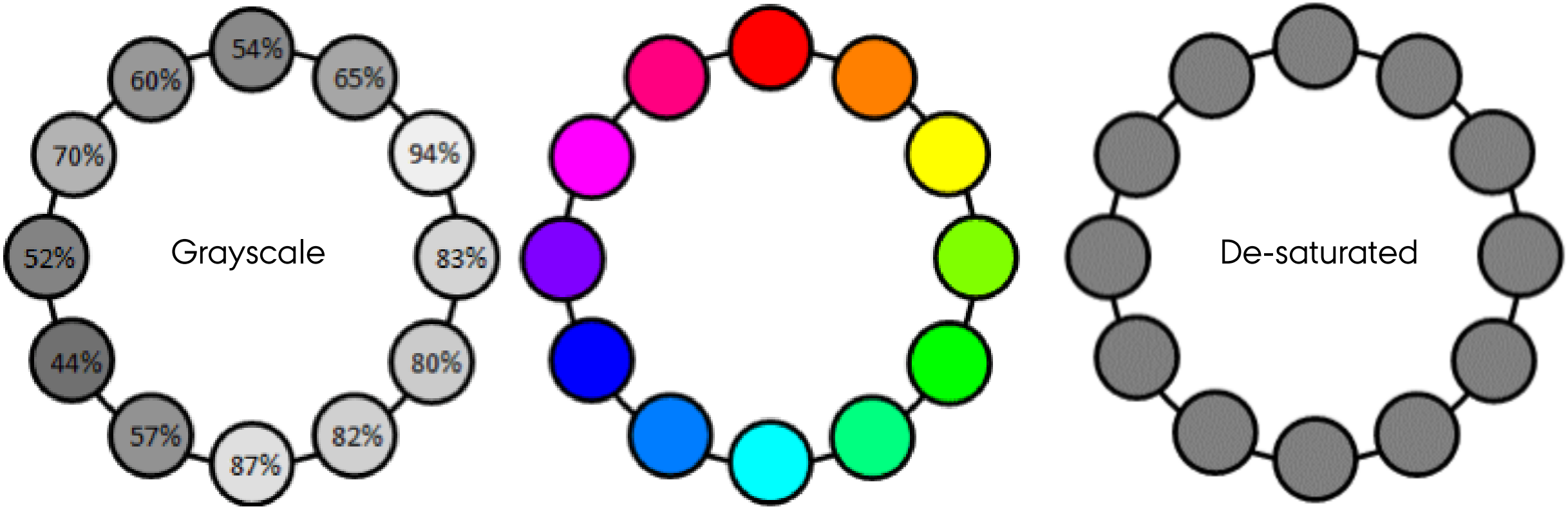
A DESIGNER'S VIEW ON COLOR

Tone := color + gray

Tint := color + white

Shade := color + black

LUMINANCE VS. LIGHTNESS

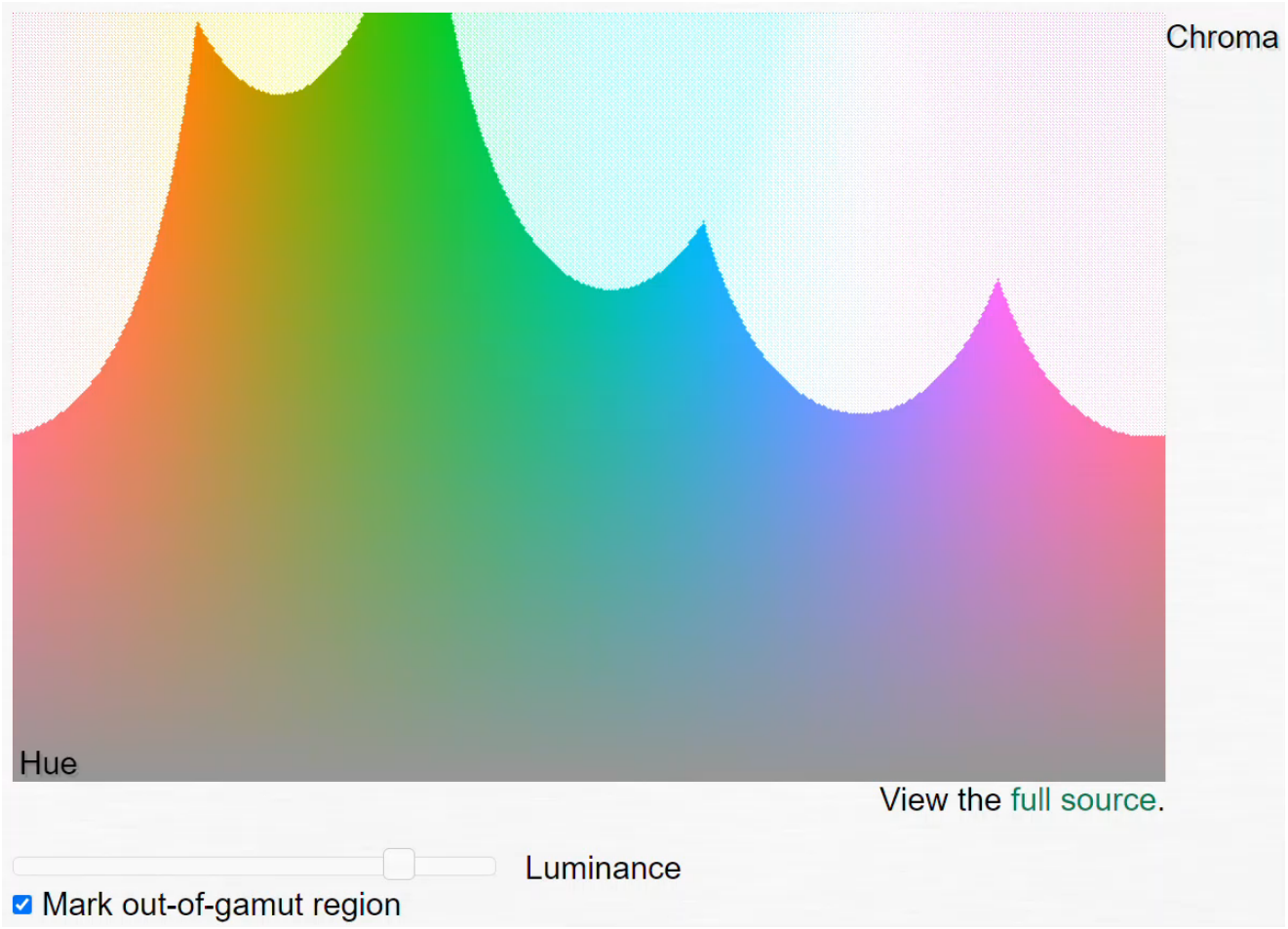


HCL – A PERCEPTUAL COLOR SPACE

H = hue

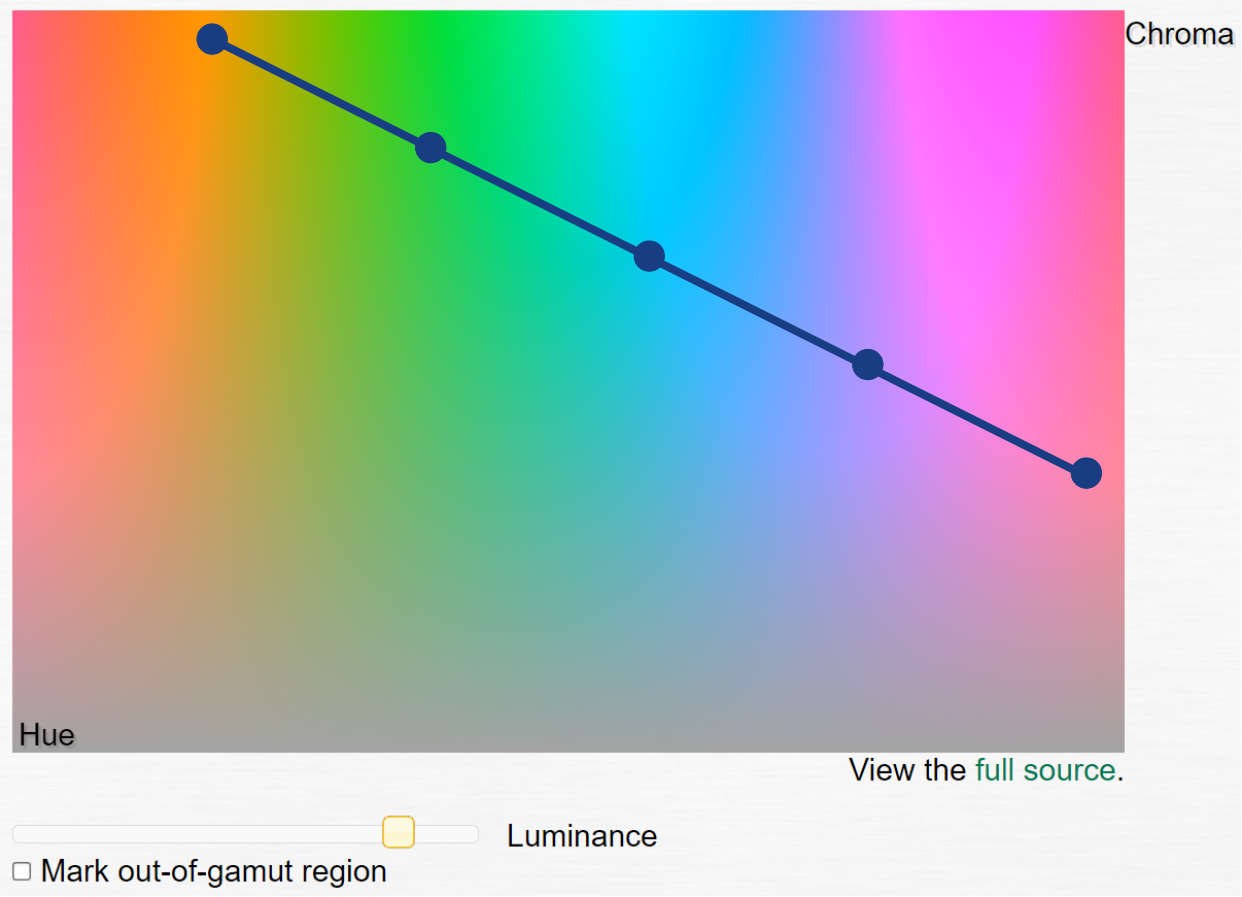
C = chroma

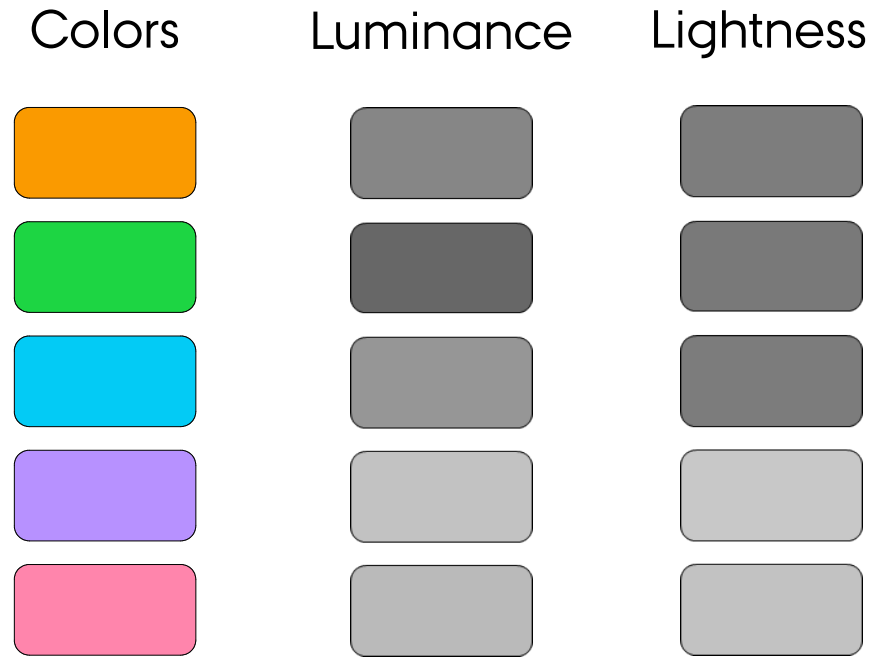
L = luminance



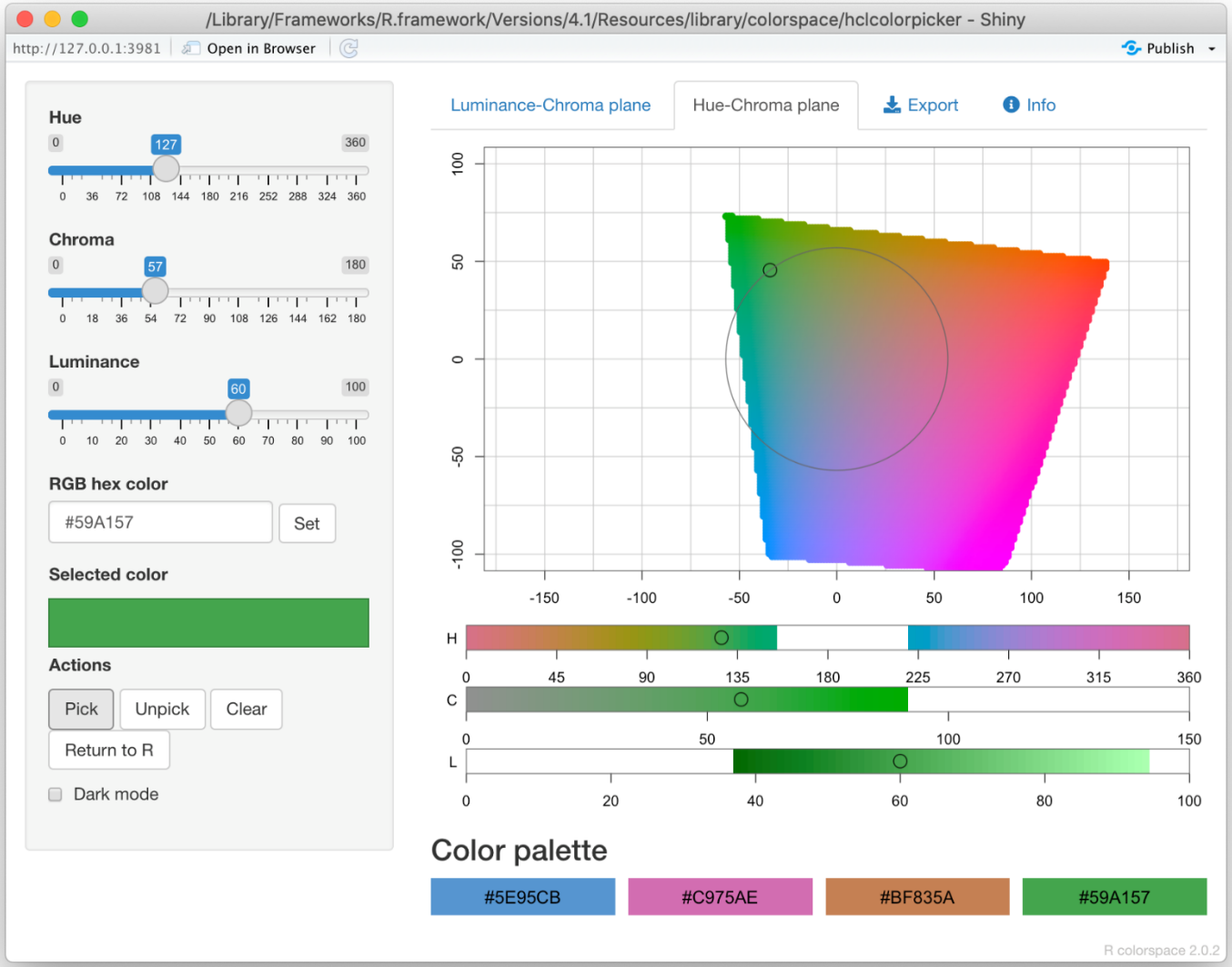
https://cscheid.github.io/lux/demos/hcl/hcl.html

HCL – A PERCEPTUAL COLOR SPACE





HCL COLOR PICKER



COLOR CODING FOR DIFFERENT DATA CHARACTERISTICS

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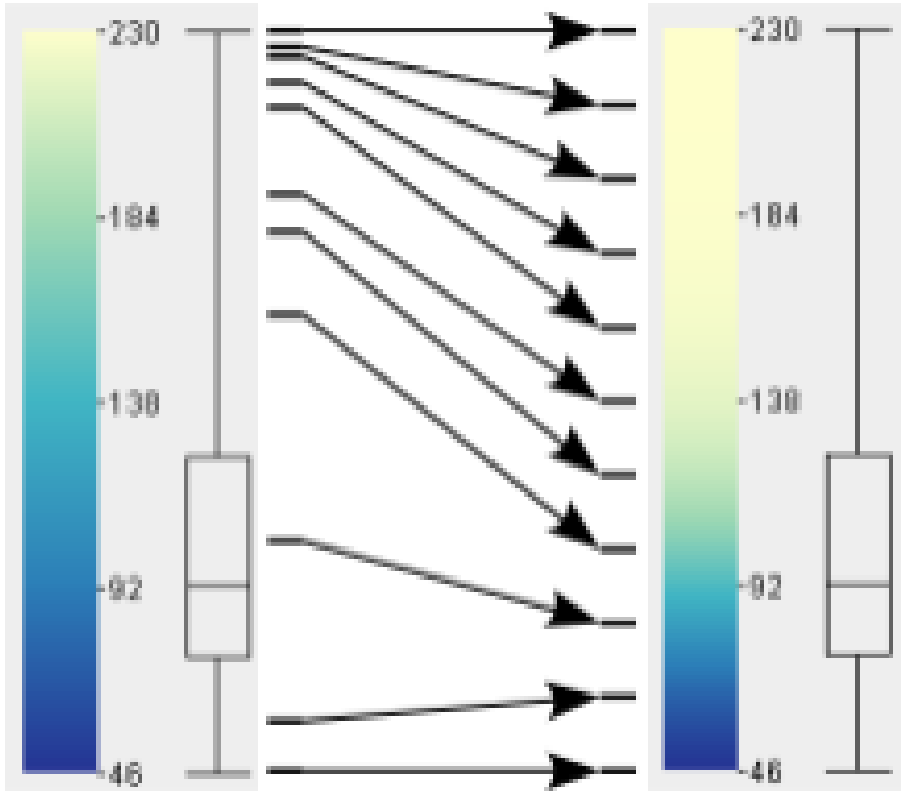
DEPARTMENT OF COMPUTER SCIENCE

HANS-JÖRG SCHULZ
ASSOCIATE PROFESSOR

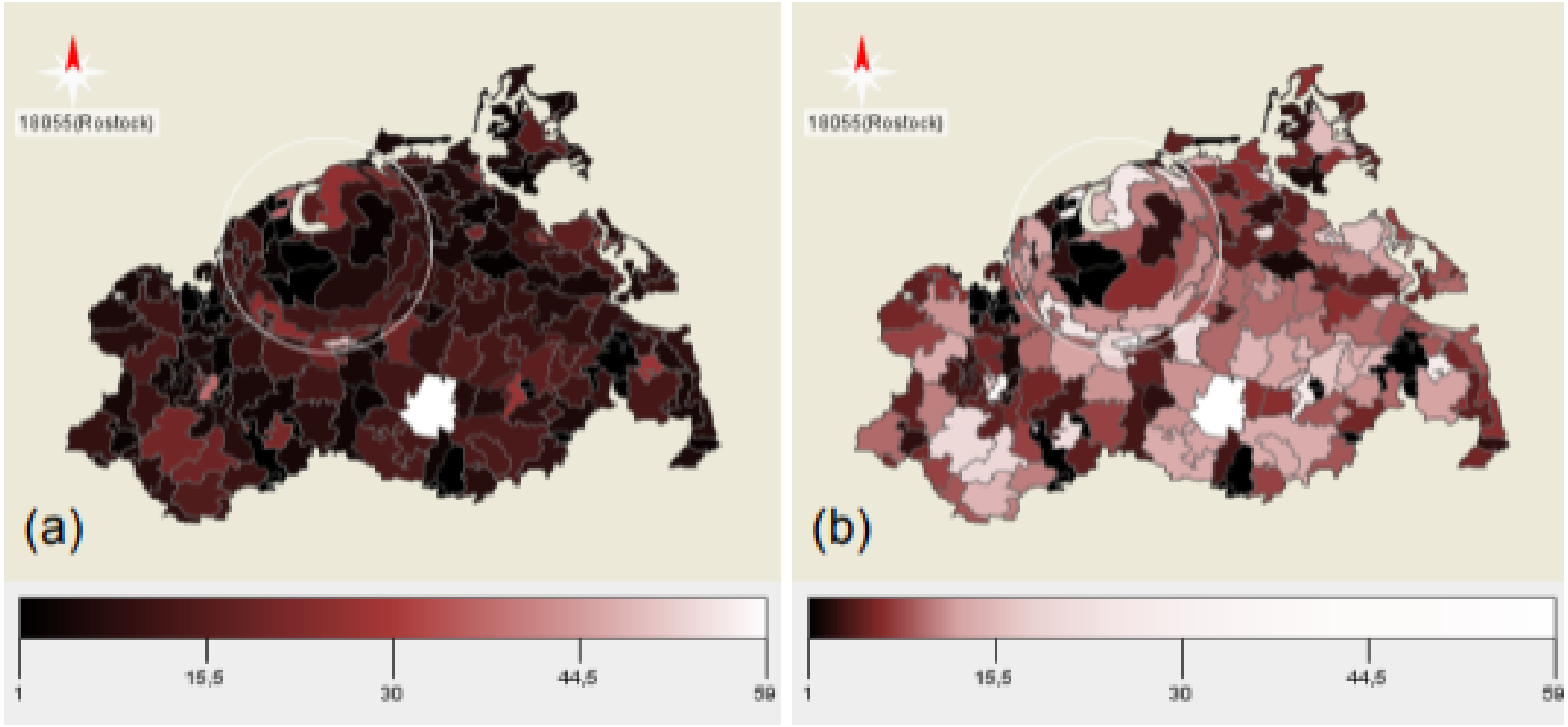
HISTOGRAM EQUALIZED COLOR CODING

[Tominski et al. 2008]

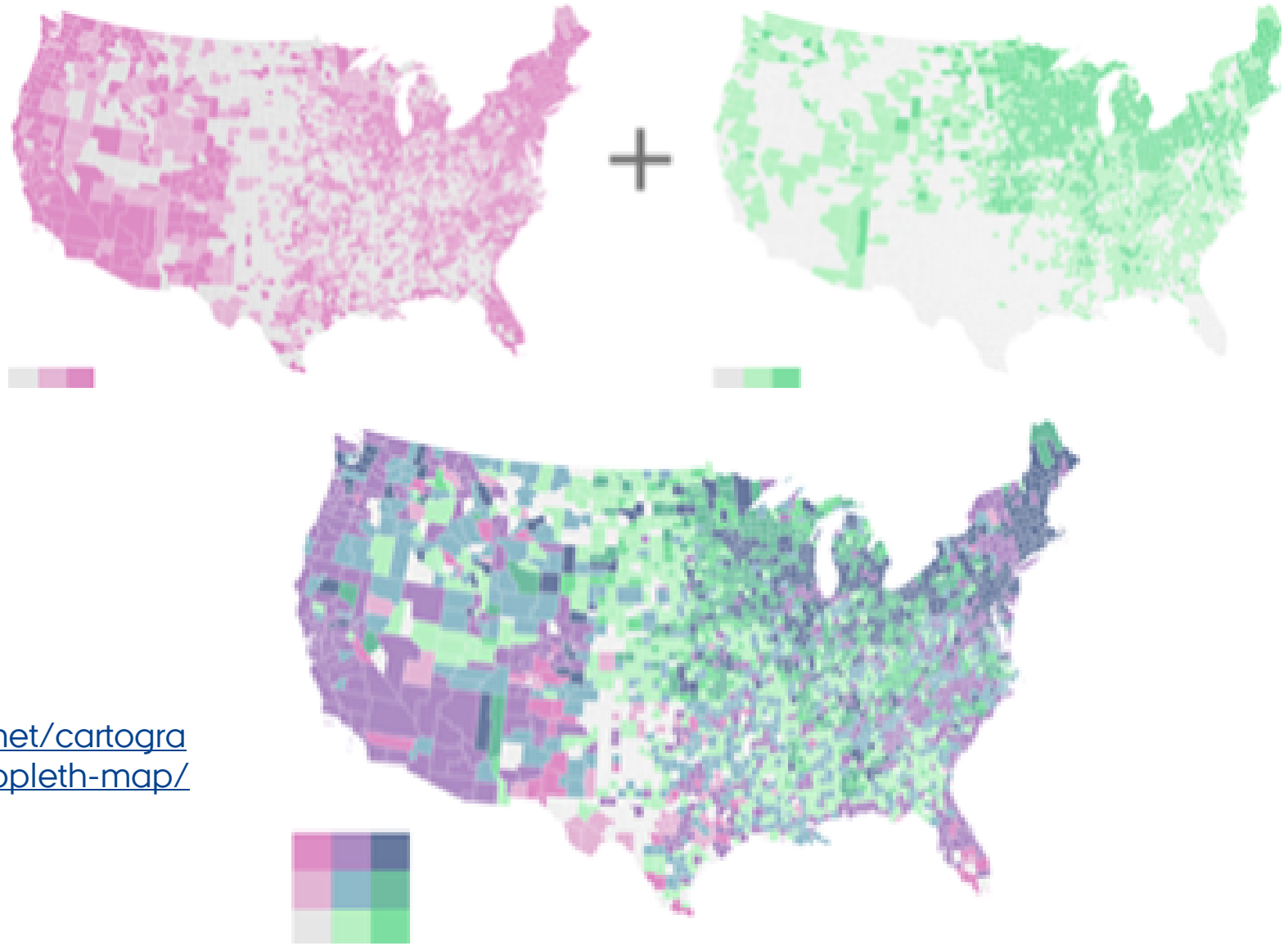


HISTOGRAM EQUALIZED COLOR CODING

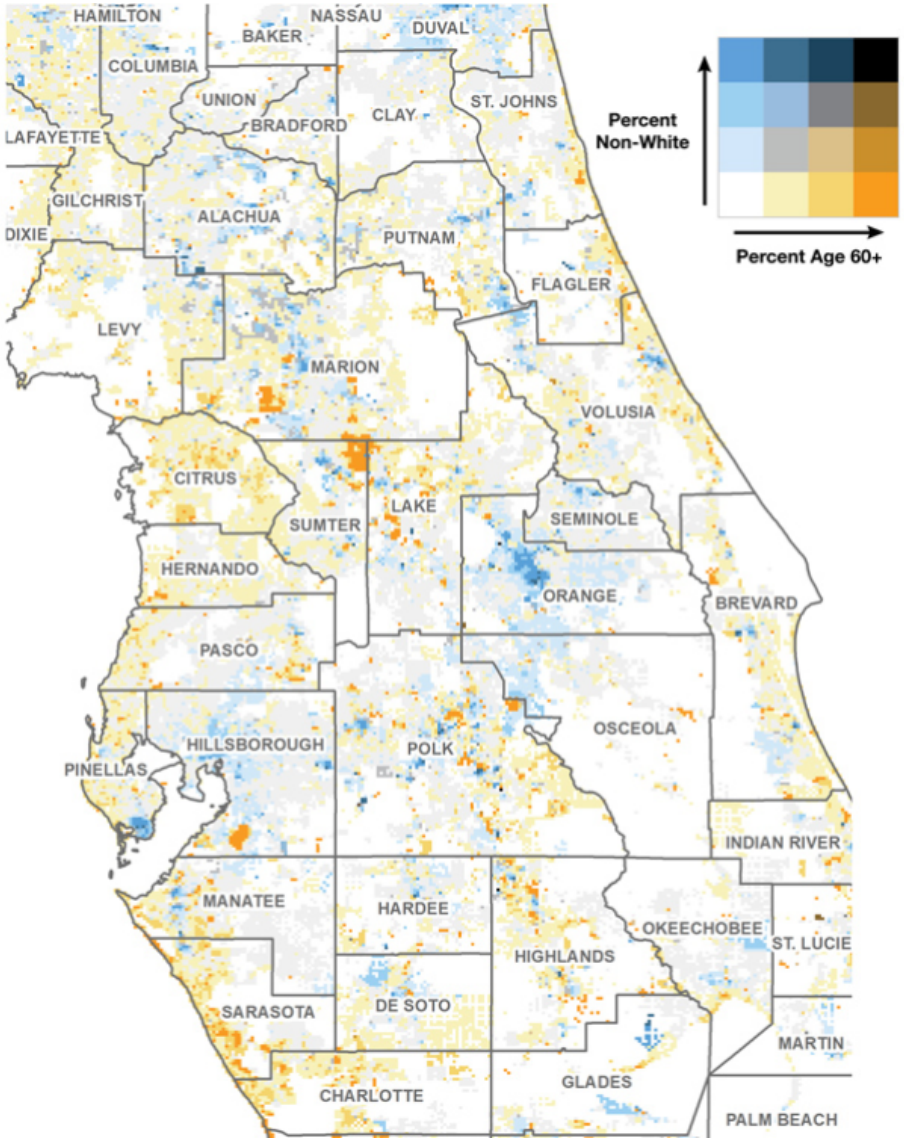
[Tominski et al. 2008]

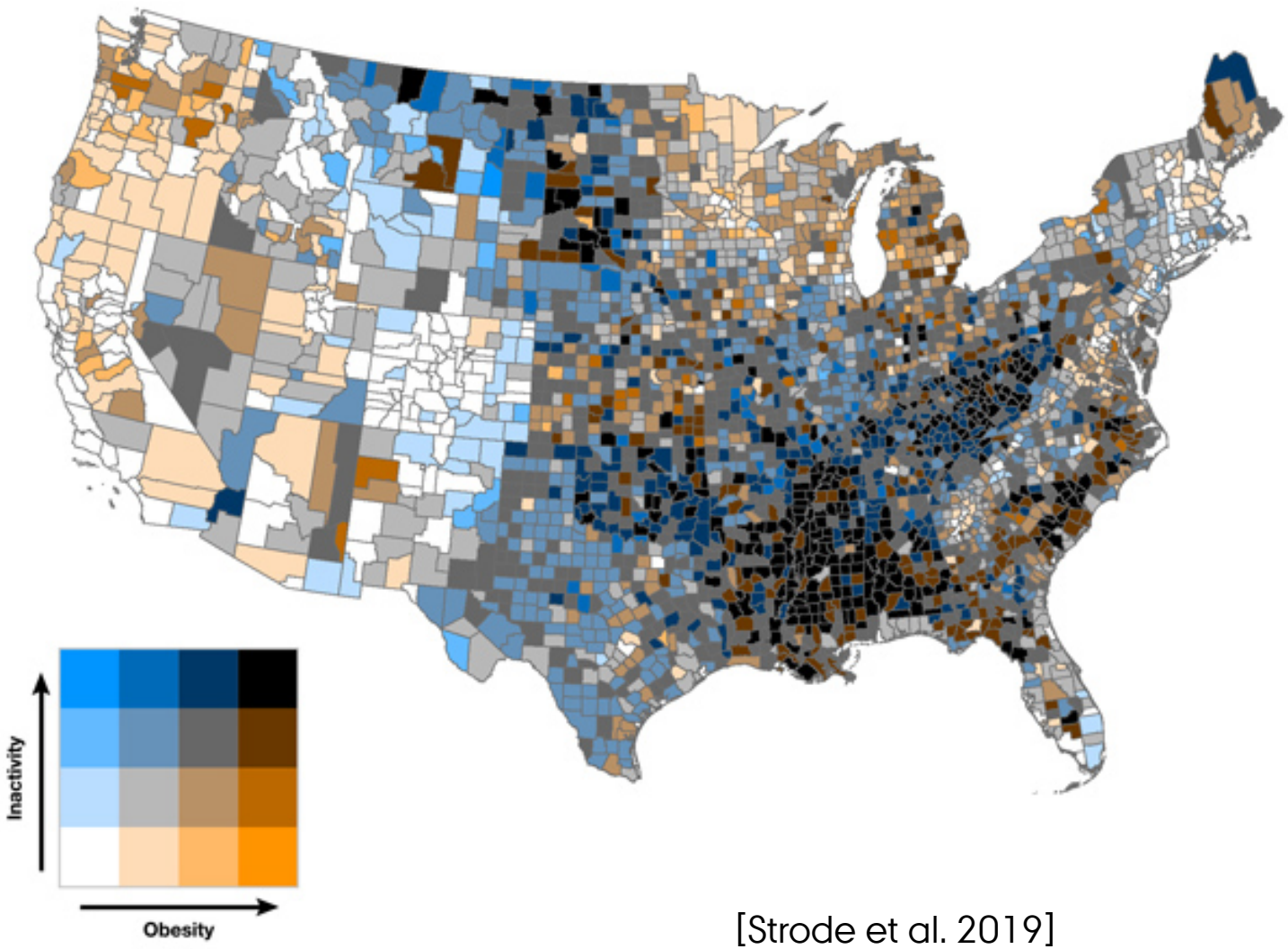


BIVARIATE COLOR SCALES

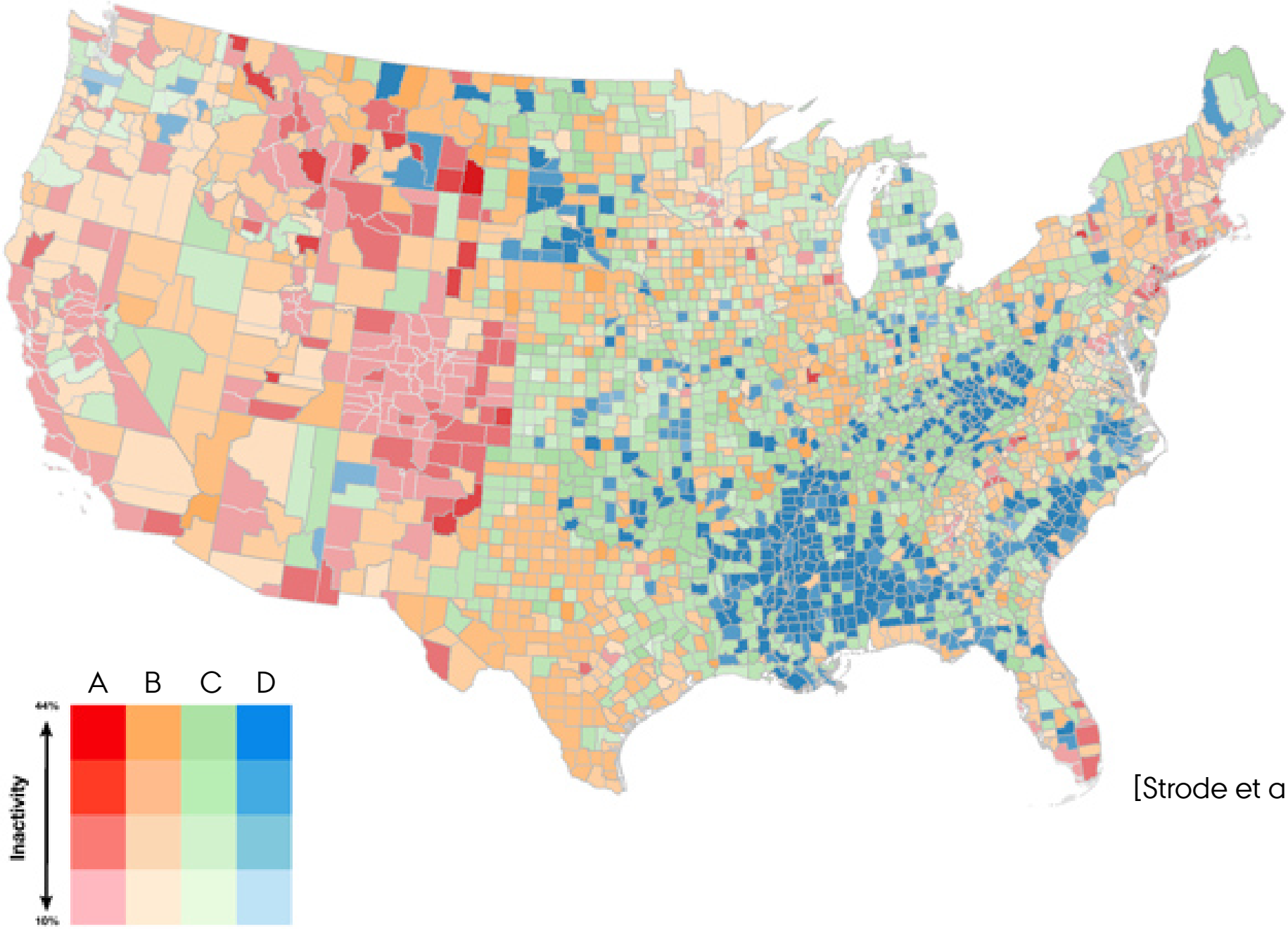


https://www.joshuastevens.net/cartography/make-a-bivariate-choropleth-map/

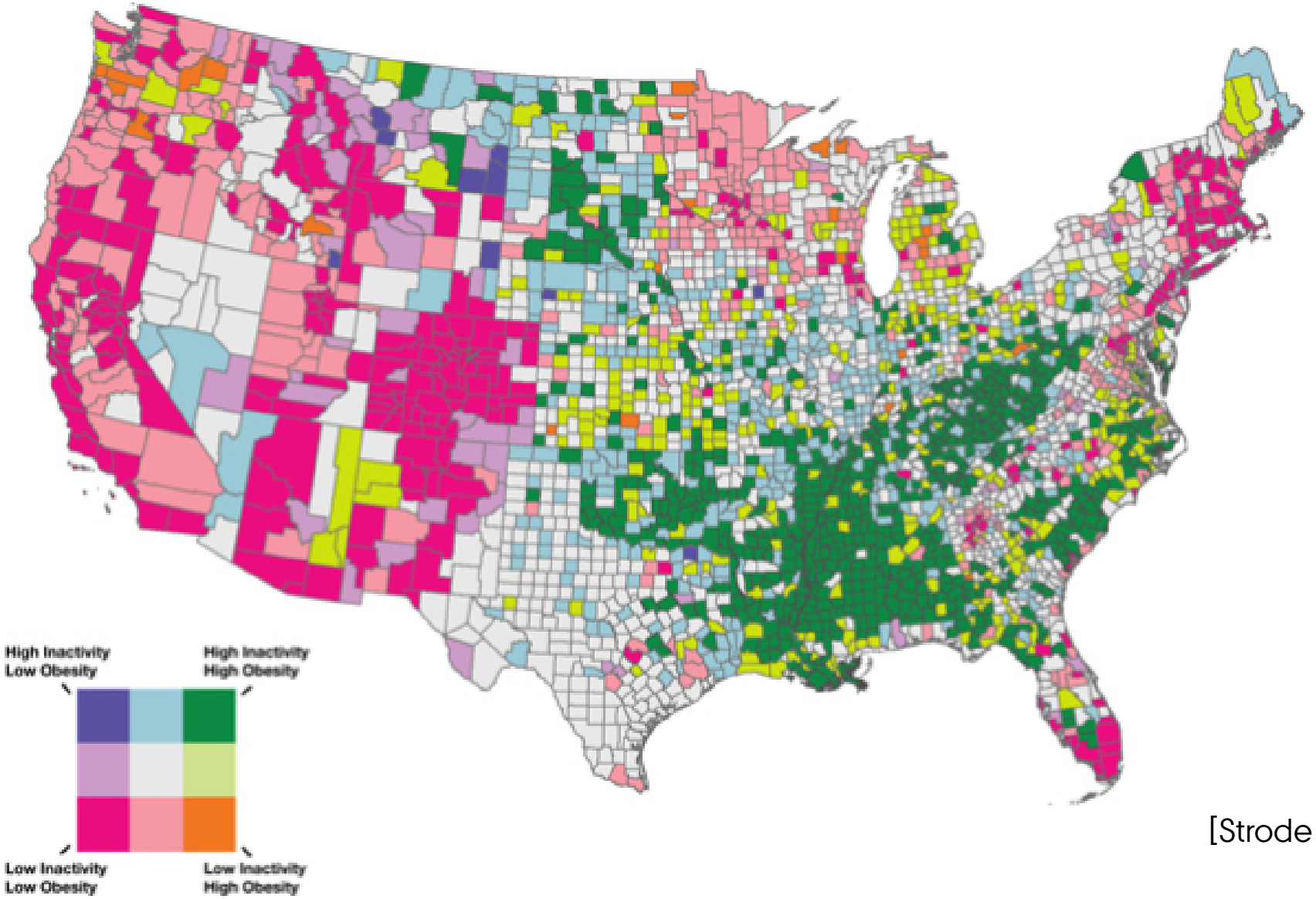




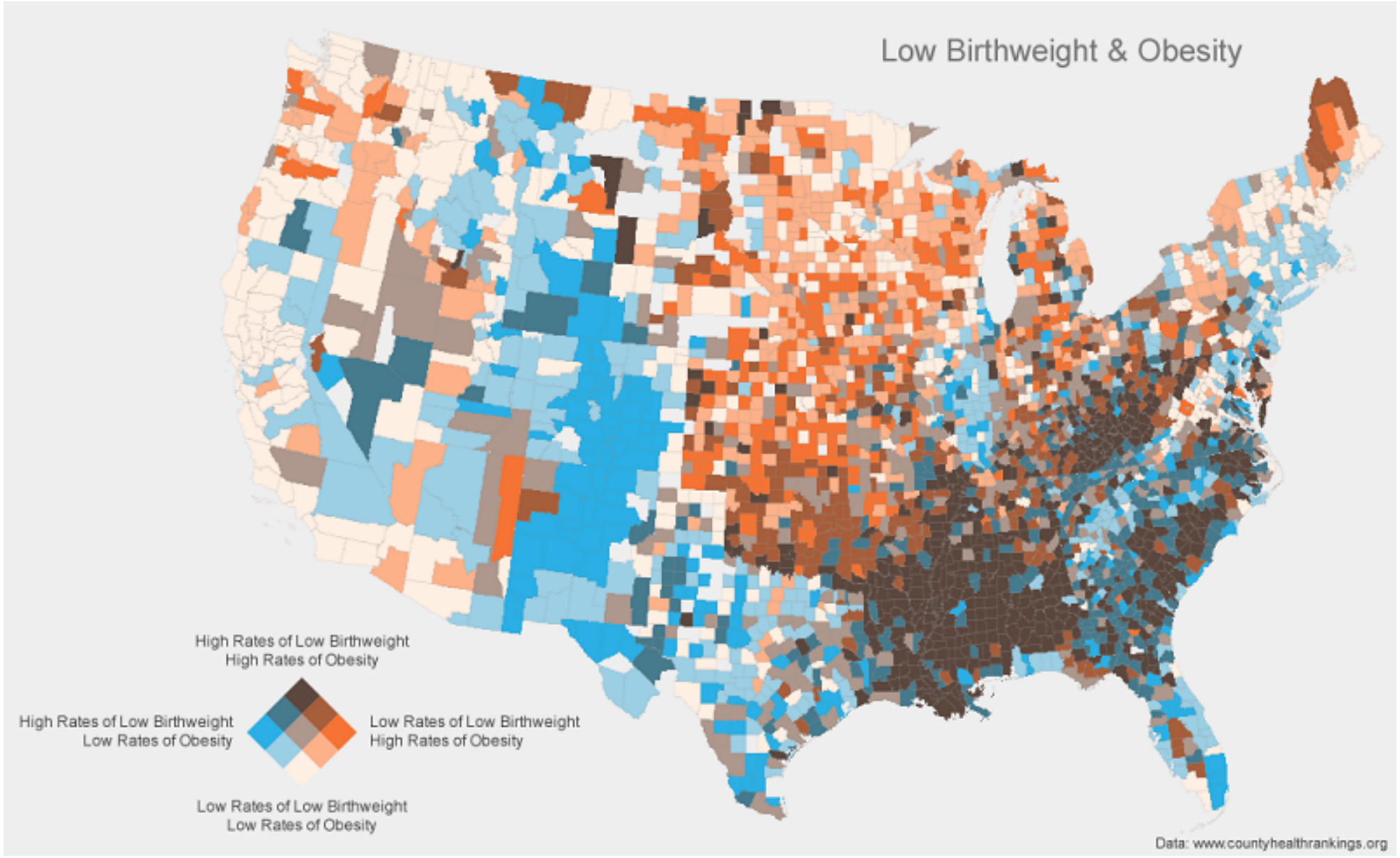
[Strode et al. 2019]



[Strode et al. 2019]

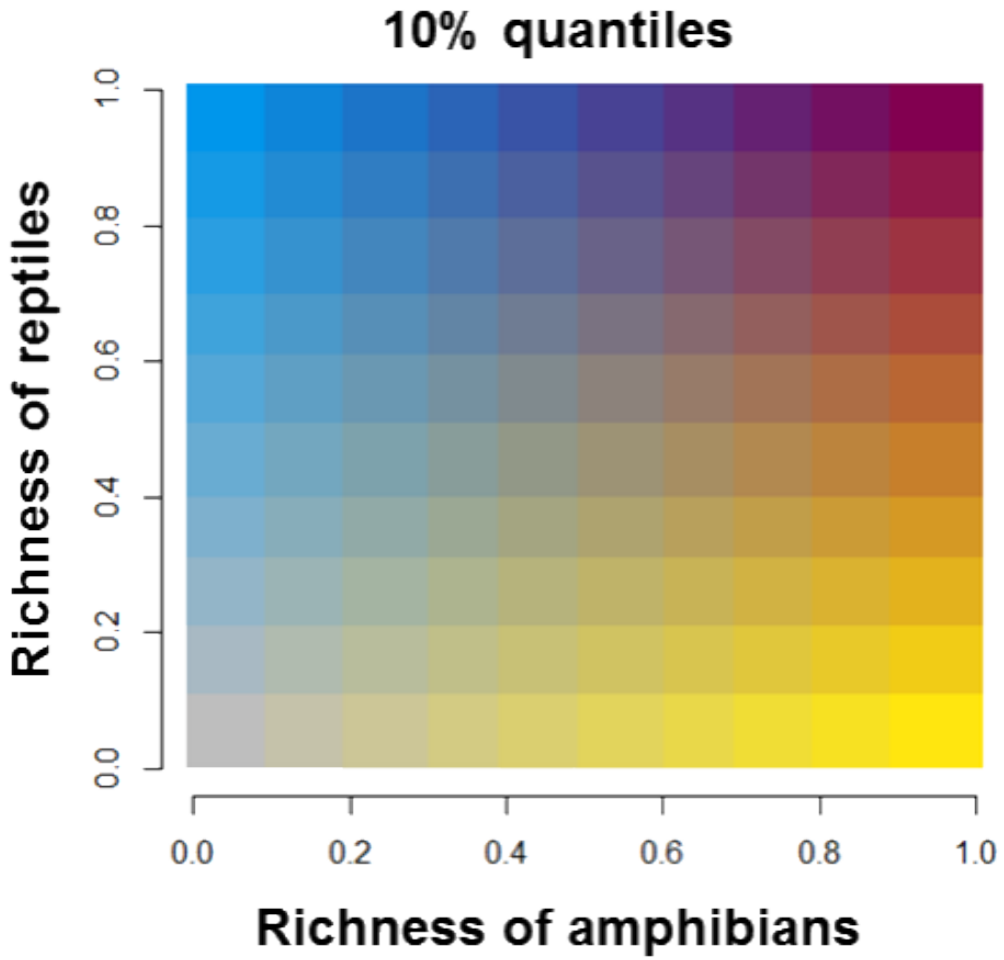


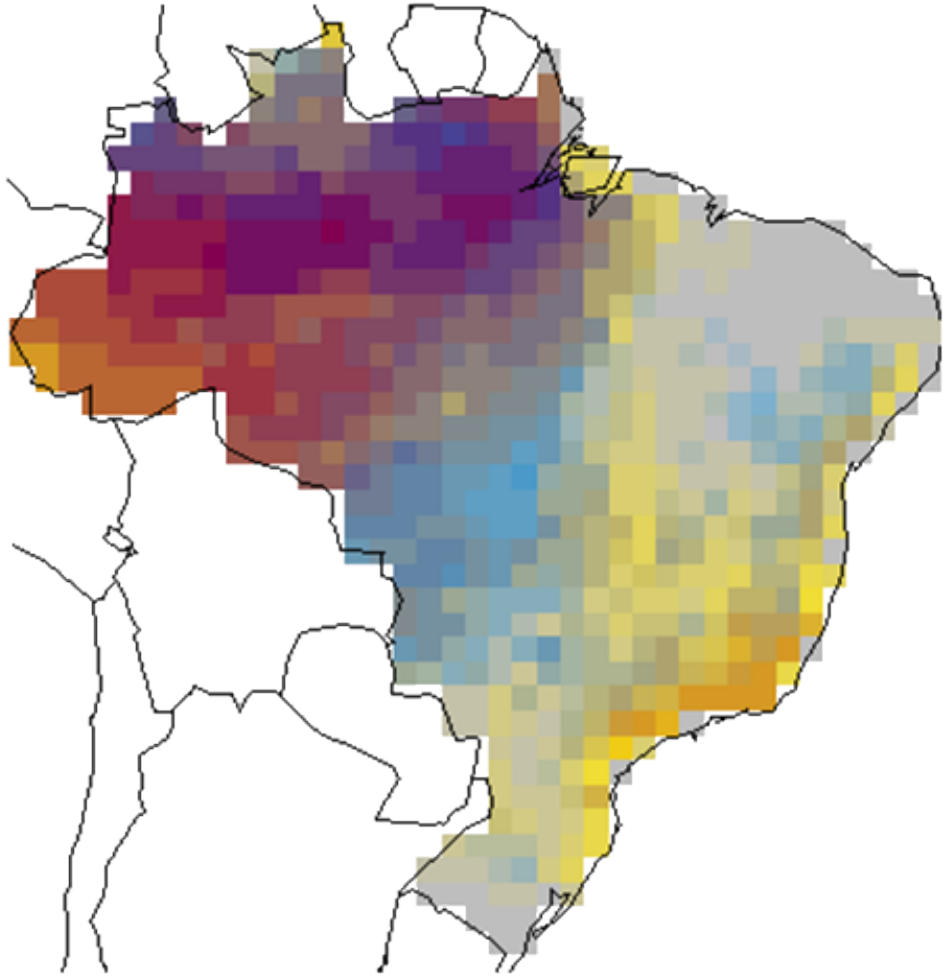
[Strode et al. 2019]


Low Birthweight & Obesity
High Rates of Low Birthweight
High Rates of Obesity
High Rates of Low Birthweight
Low Rates of Obesity
Low Rates of Low Birthweight
High Rates of Obesity
Low Rates of Low Birthweight
Low Rates of Obesity
Data: www.countyhealthrankings.org

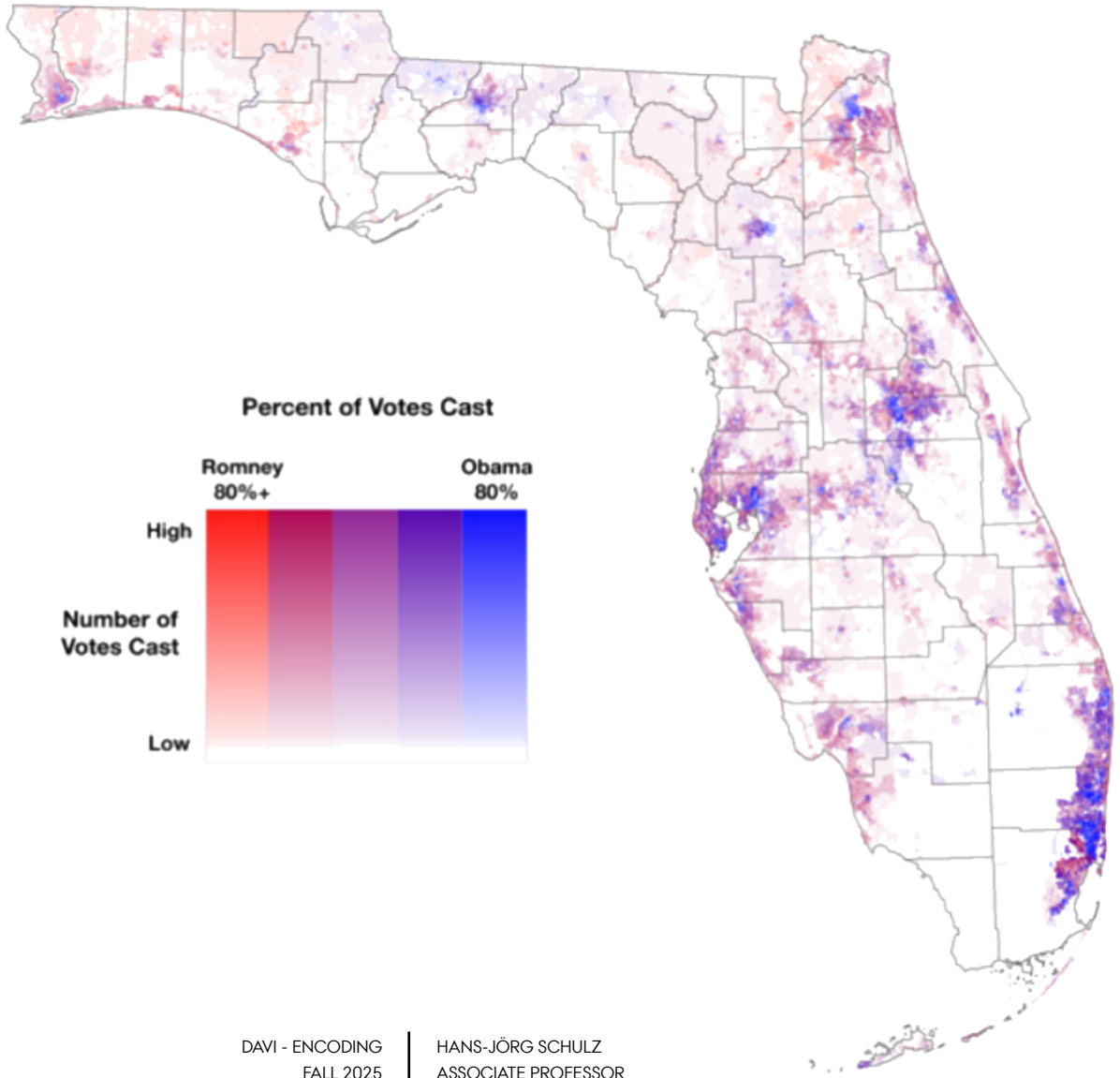
TOO MANY SUBDIVISIONS

https://rfunctions.blogspot.com/2015/03/bivariate-maps-bivariatemap-function.html





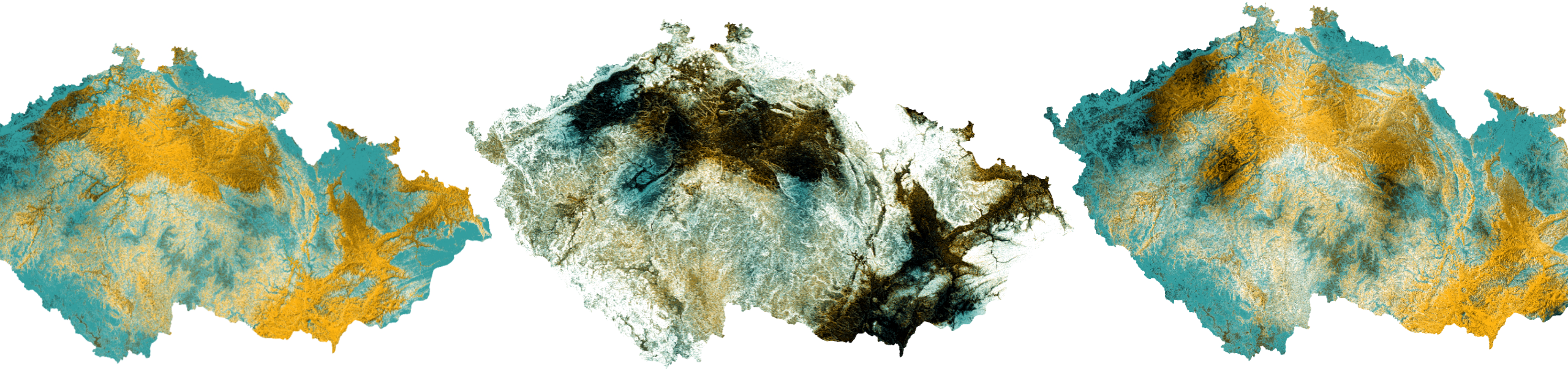
NO SUBDIVISIONS AT ALL

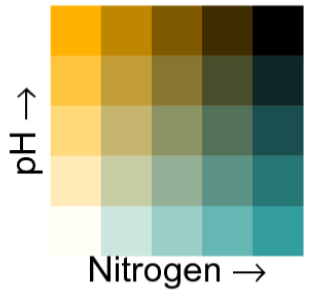


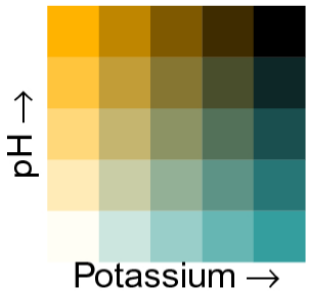
[Strode et al. 2019]

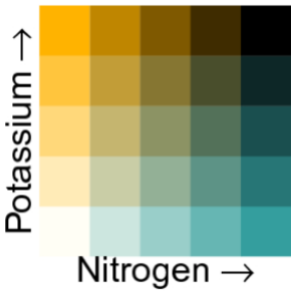
TOO MANY ATTRIBUTES

[Kebonye et al. 2022]



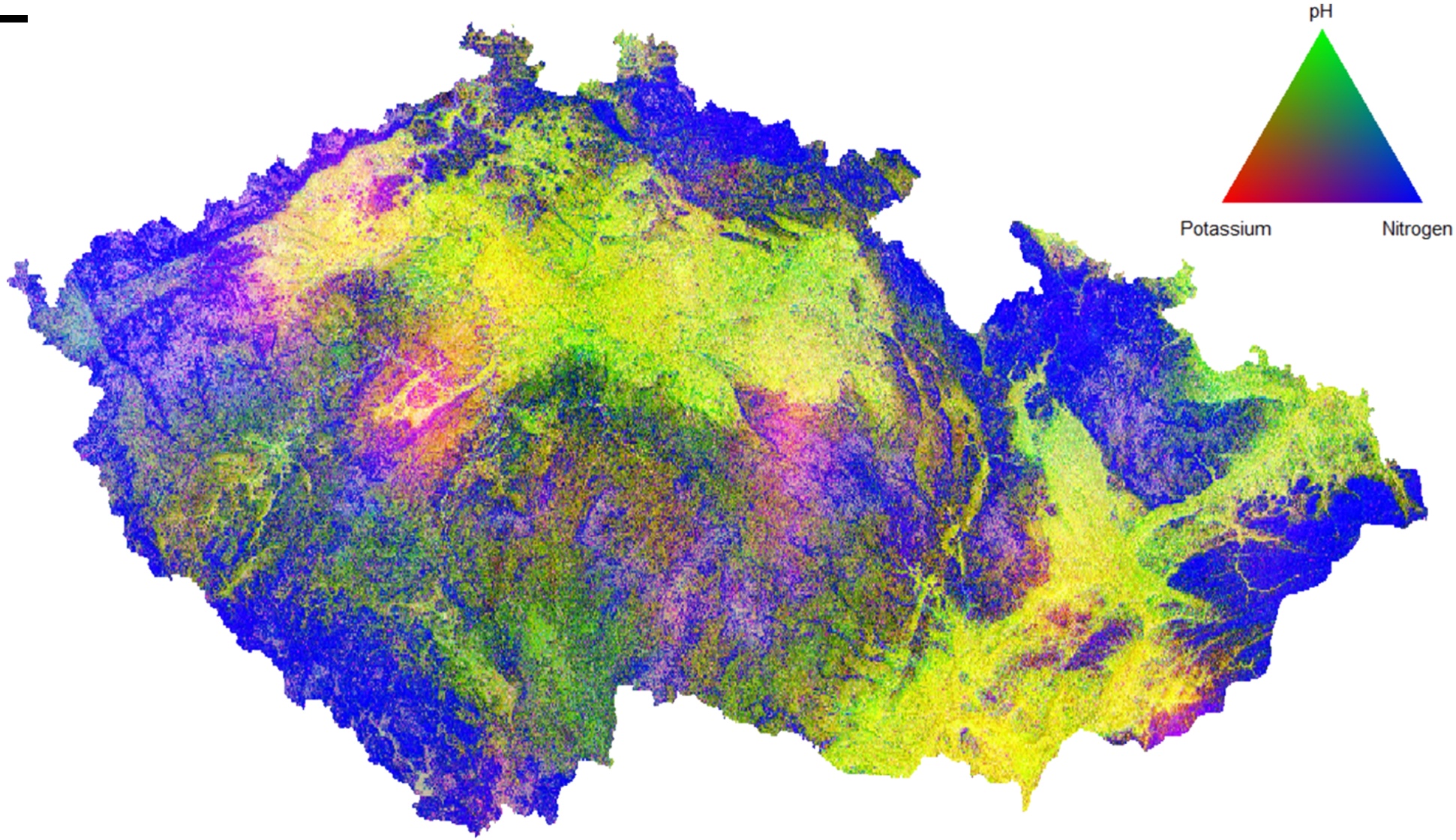






TOO MANY ATTRIBUTES

[Kebonye et al. 2022]



COLOR PALETTES TO GET YOU STARTED

https://www.joshuastevens.net/cartography/make-a-bivariate-choropleth-map/

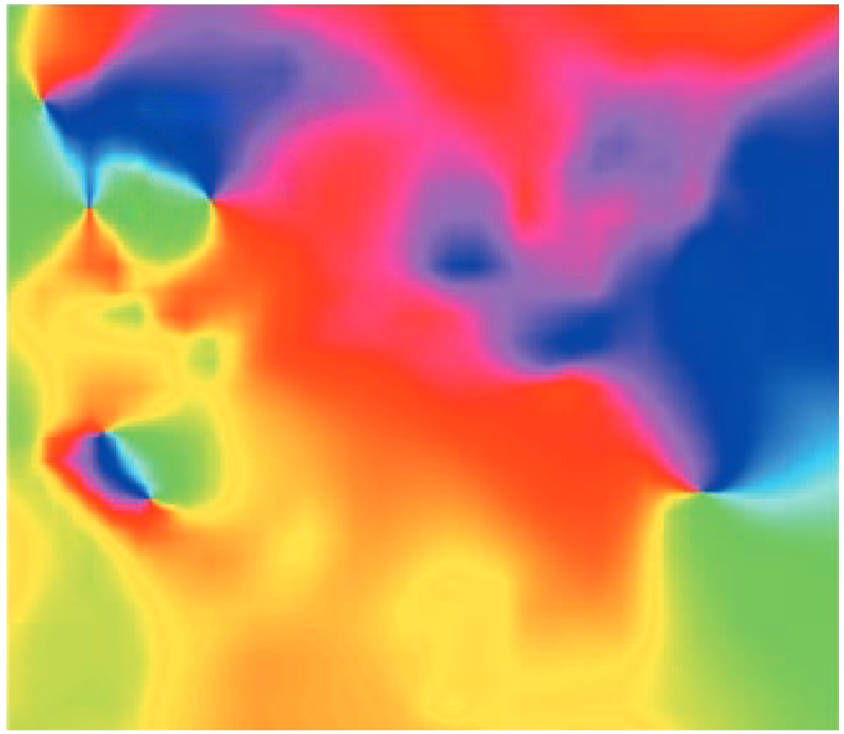
COLOR CODING FOR DIFFERENT TASKS

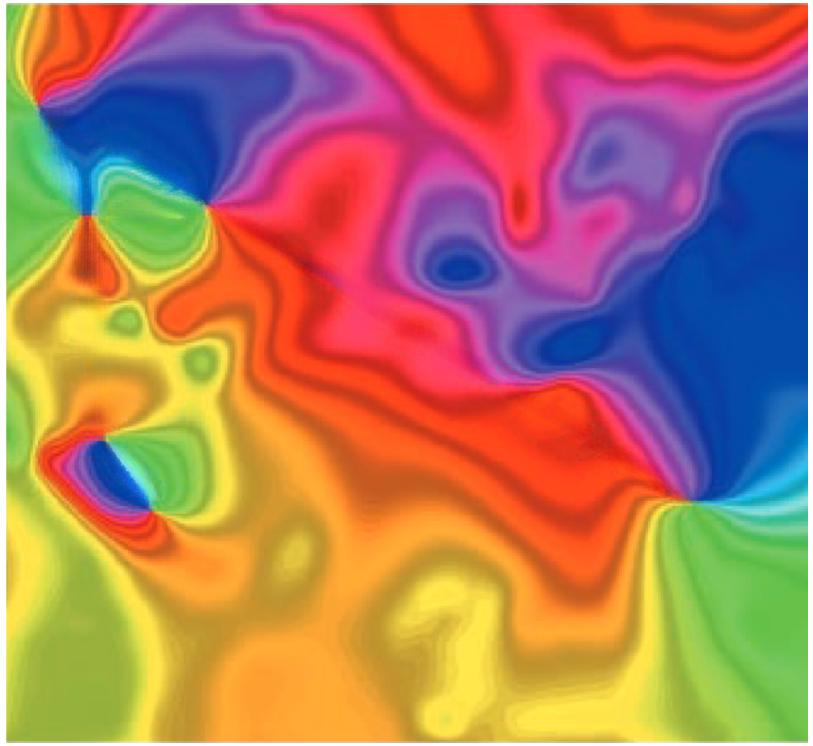
TASK-DRIVEN COLOR CODING

[Tominski et al. 2008]

ENHANCED COLOR MAPS

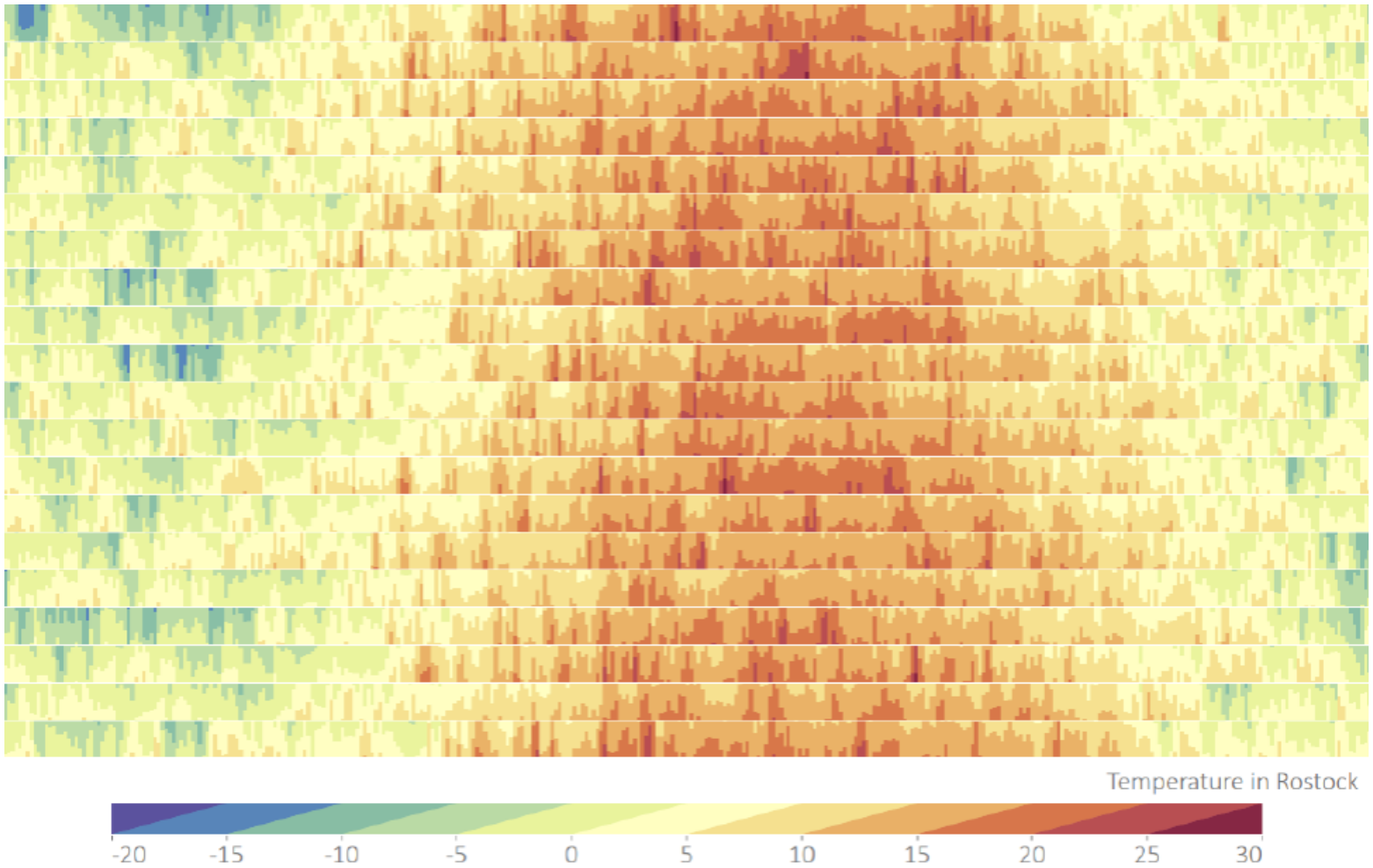
[Wong et al. 2002]

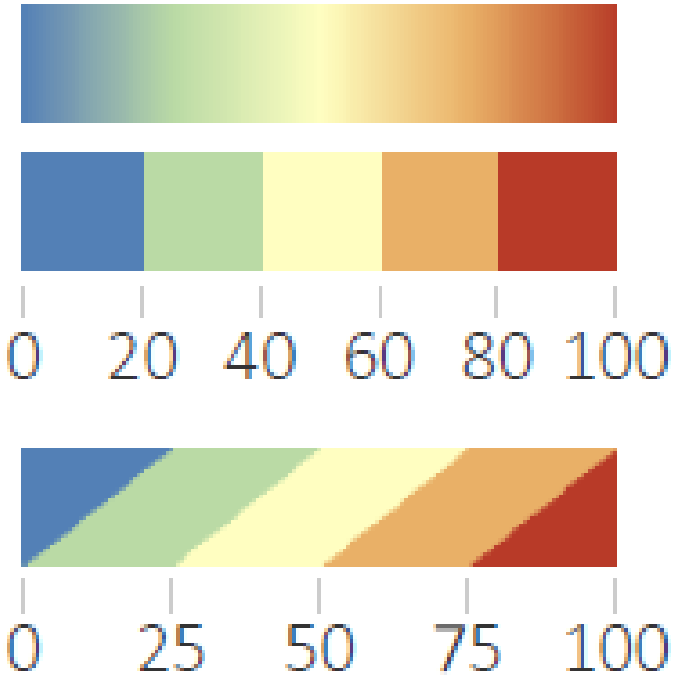


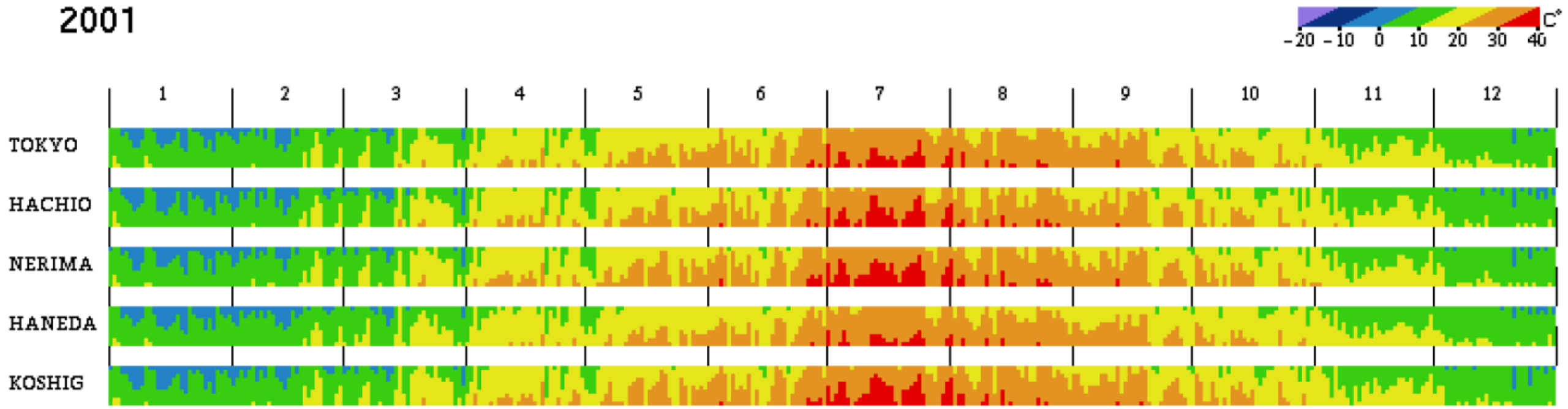


TWO-TONE PSEUDO COLORS

[Saito et al. 2005]

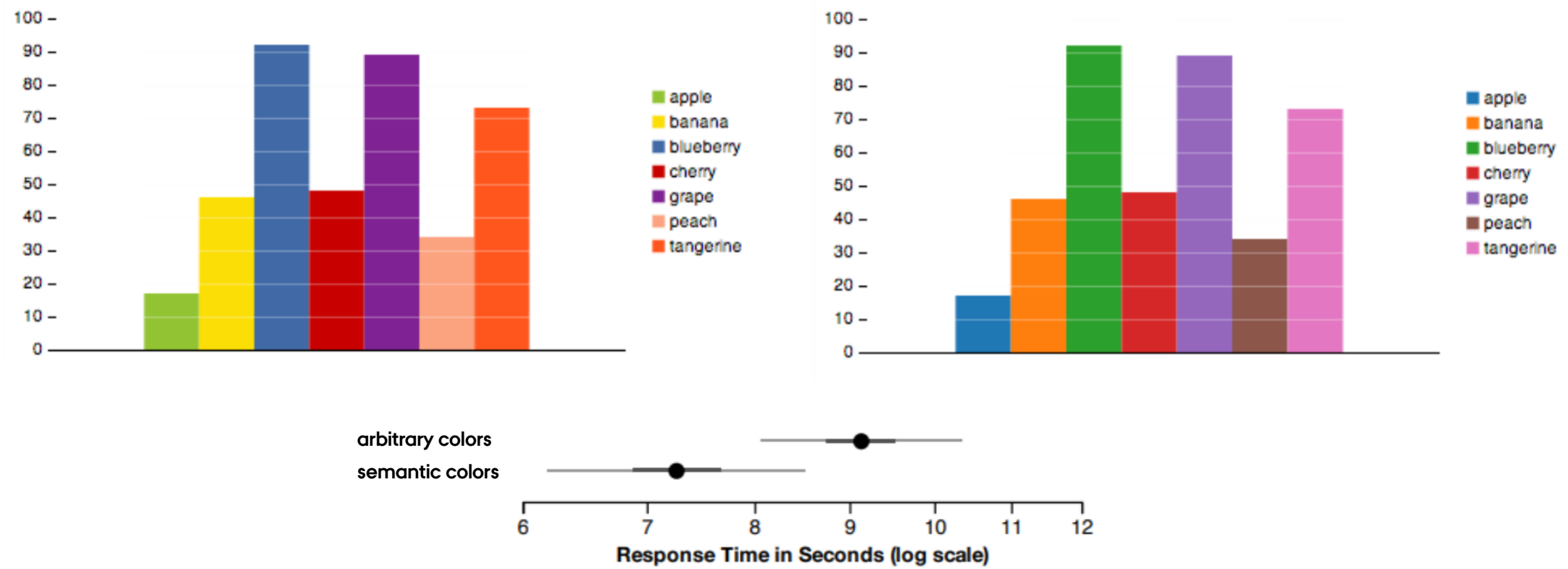






(a) maximum temperature

SEMANTIC COLOR CODING



Lin et al.: “Selecting Semantically-Resonant Colors for Data Visualization”, EuroVis 2013

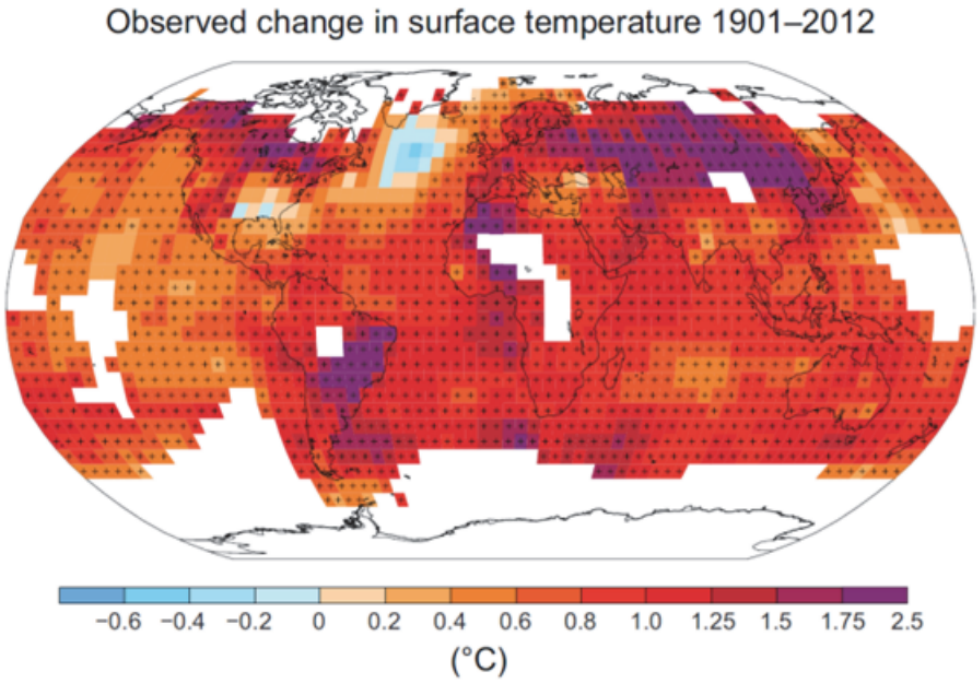
COLOR USE ACROSS CULTURES

- In many cultures, blue is a masculine symbol. But in China, it is associated with women.
- In many Asian countries, red is the color of long life, happiness, celebrations, prosperity, joy, and good luck. On the other hand, some African countries associate red with death.
- In Western cultures, brides wear white, because it is associated with cleanliness, purity, peace and elegance. However, in Korea, China and other countries in Asia, it's a symbol of bad luck, mourning and death, thus the color is worn only during funerals.

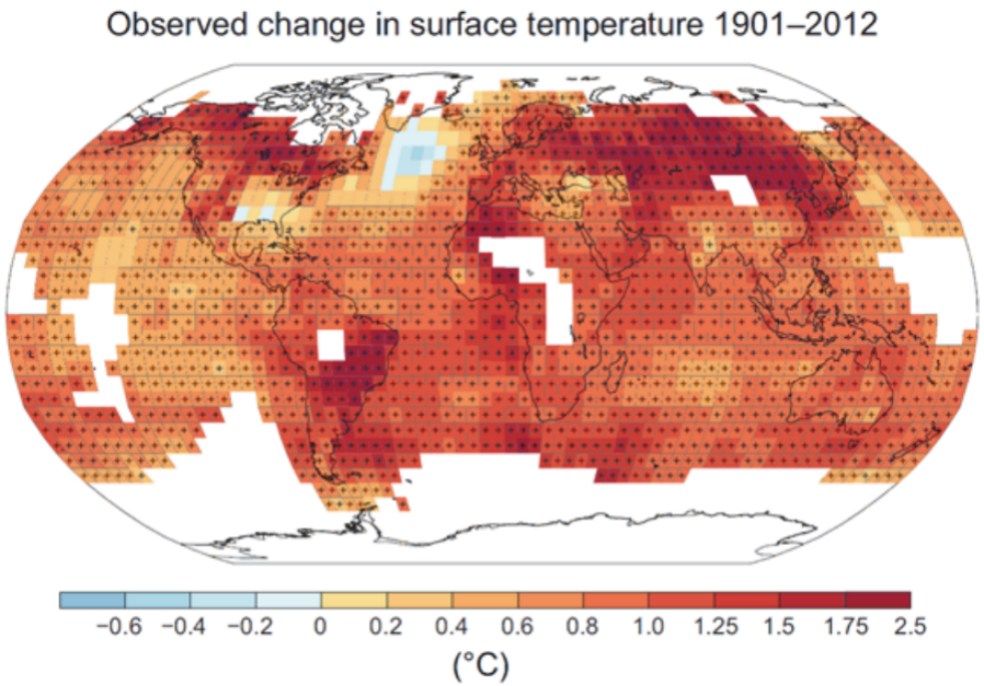
Source: https://www.daytranslations.com/blog/color-psychology/

-> Ahmad et al.: "When Red Means Good, Bad, or Canada: Exploring People's Reasoning for Choosing Color Palettes", IEEE VIS 2021

IMPLICATIONS FOR VISUALIZATION



Powerlessness, disillusioning, discouraging, fear

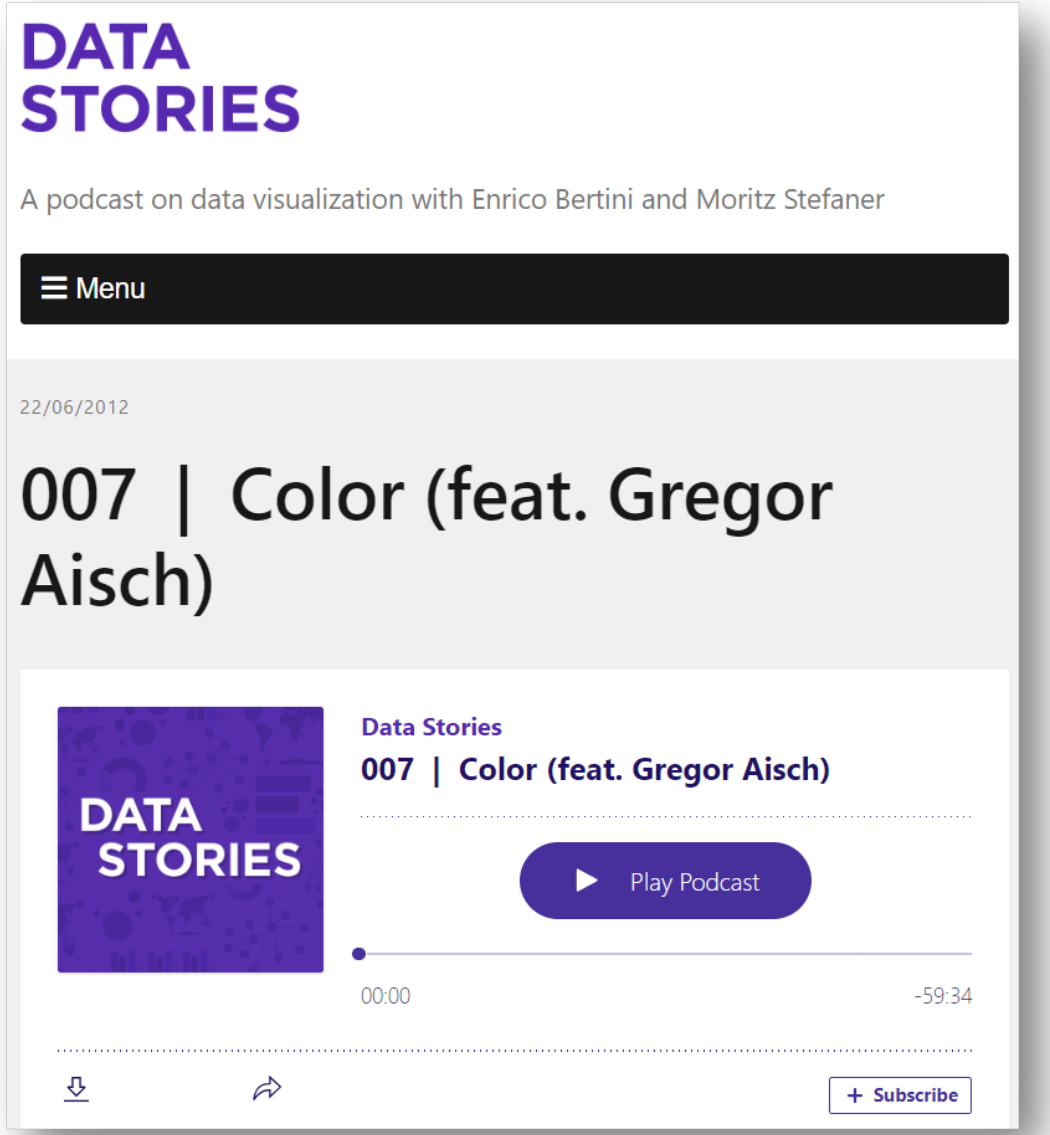


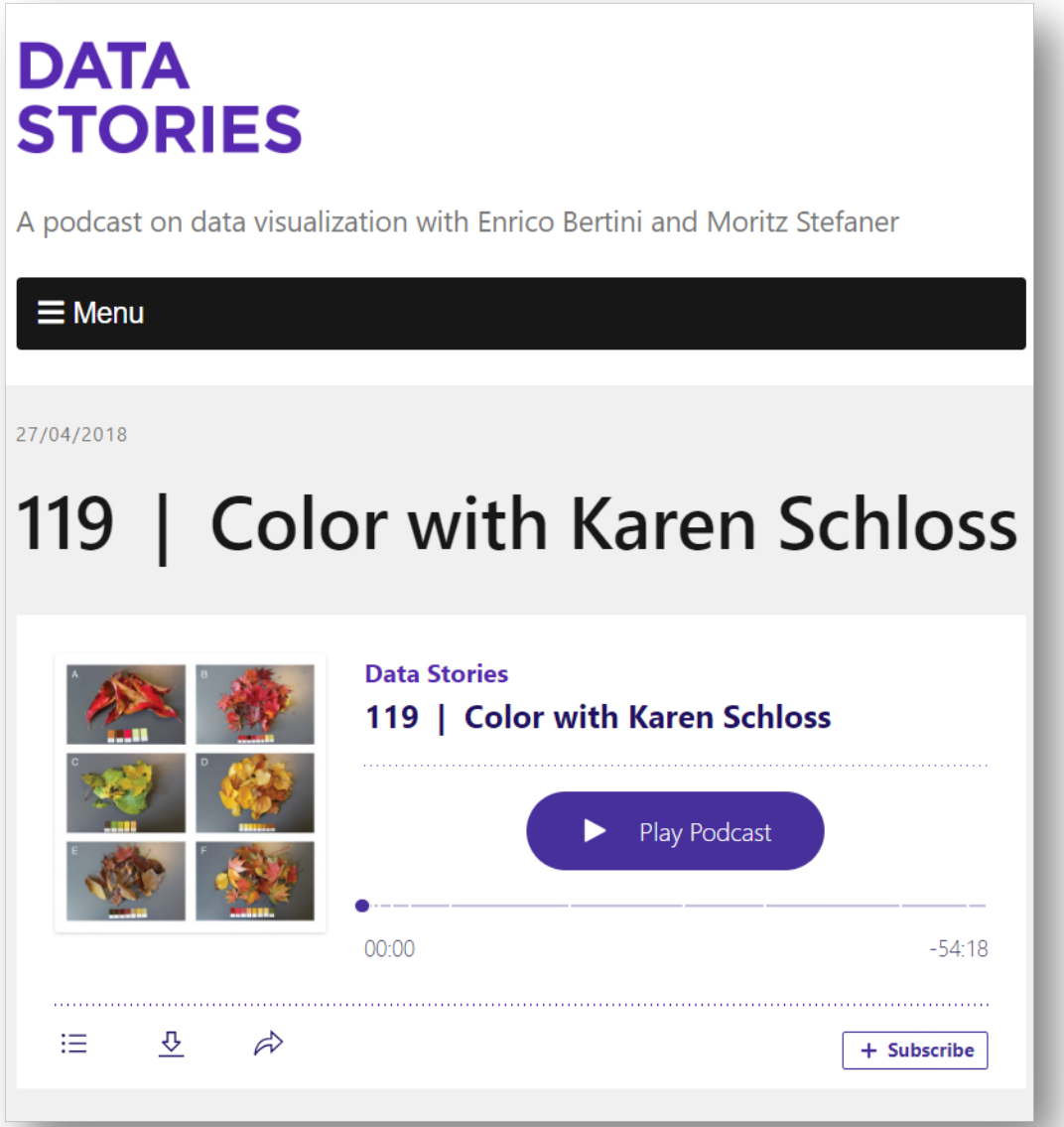
Call for action, more hope, less judgmental

Schneider, Nocke: “The Feeling of Red and Blue – A Constructive Critique of Color Mapping in Visual Climate Change Communication”, Handbook of Climate Change Communication: Vol. 2, pp.289-303, 2017

RECOMMENDED LISTENING

https://datastori.es





COLOR RESOURCES

- https://colorbrewer2.org
- http://vrl.cs.brown.edu/color
- https://davidjohnstone.net/lch-lab-colour-gradient-picker
- http://www.ccctool.com
- https://www.color-blindness.com/coblis-color-blindness-simulator/
- https://personal.sron.nl/~pault/
- https://vis4.net/chromajs/

  -> https://gka.github.io/palettes/
  -> http://tristen.ca/hcl-picker/

- https://hihayk.github.io/scale/
- https://jenniferbourn.com/color-tools/

LIST OF LITERATURE SOURCES

- Tominski et al. 2008: https://doi.org/10.1109/IV.2008.24
- Wong et al. 2002: https://doi.org/10.1057/PALGRAVE.IVS.9500024
- Saito et al. 2005: https://doi.org/10.1109/INFVIS.2005.1532144
- Schneider, Nocke 2017: https://doi.org/10.1007/978-3-319-70066-3_19
- Strode et al. 2019: http://doi.org/10.14714/CP94.1538
- Kebonye et al. 2022: https://doi.org/10.1007/s11119-022-09955-7
- Ahmad et al. 2021: https://doi.org/10.1109/VIS49827.2021.9623314
- Lin et al. 2013: https://doi.org/10.1111/cgf.12127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