Less color, more science

Perceptual alternatives to rainbow colormaps

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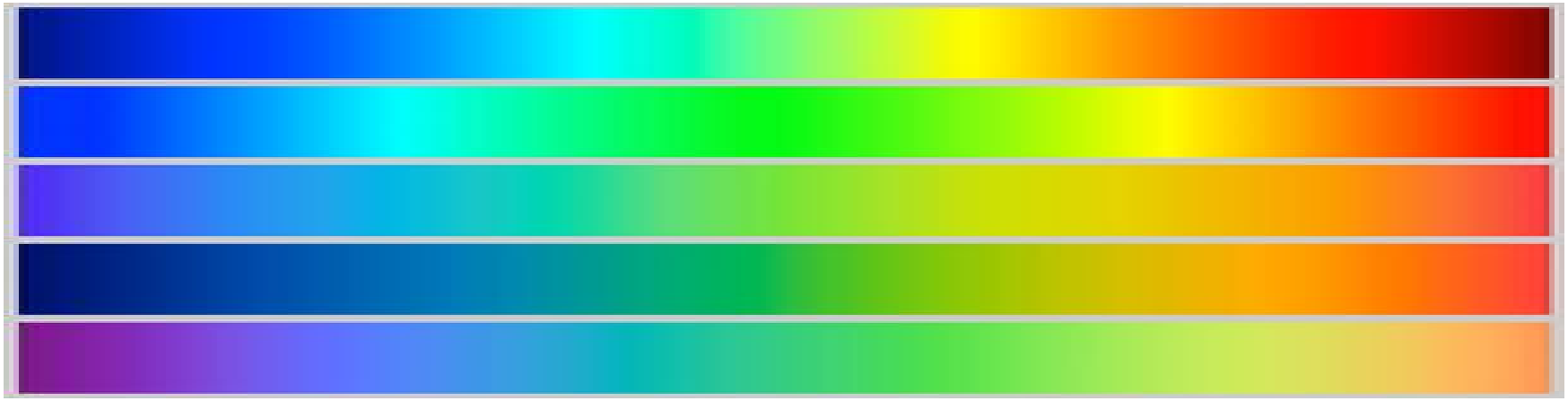
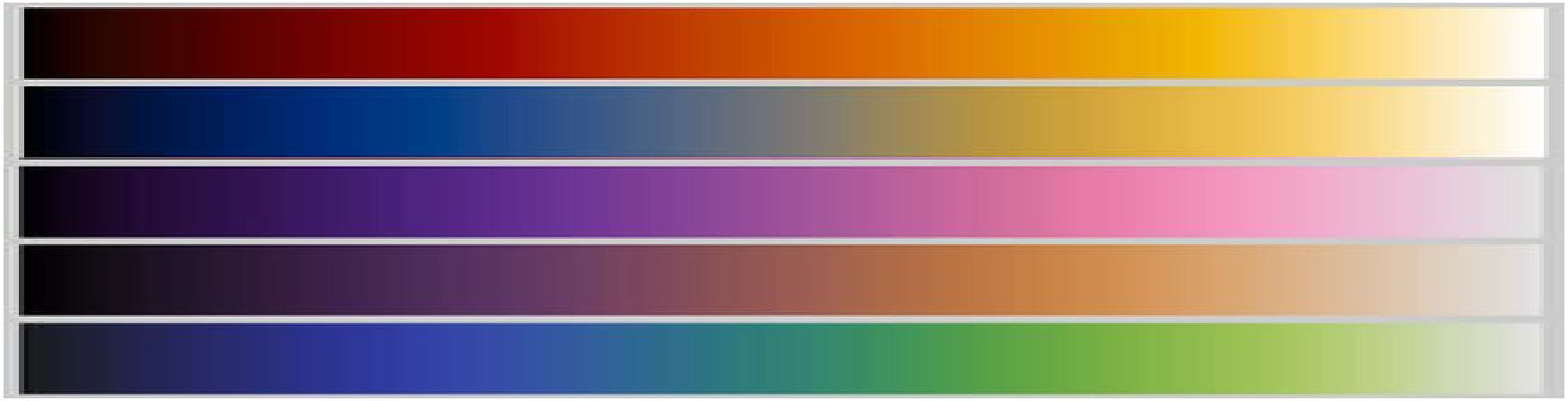
17 September 2015

In science, rainbow color maps are everywhere:

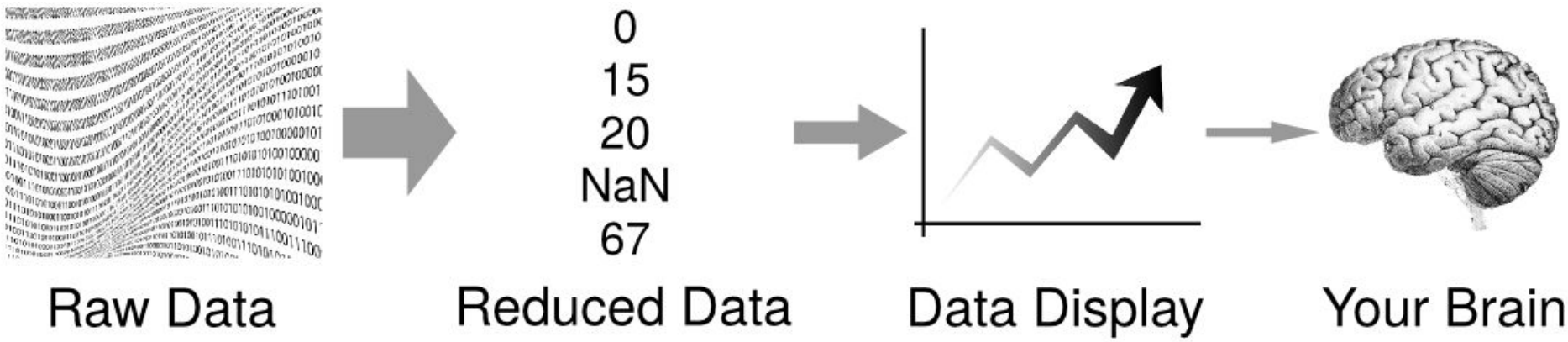


Rainbow colormaps distort data and impair judgment.

We can do better:

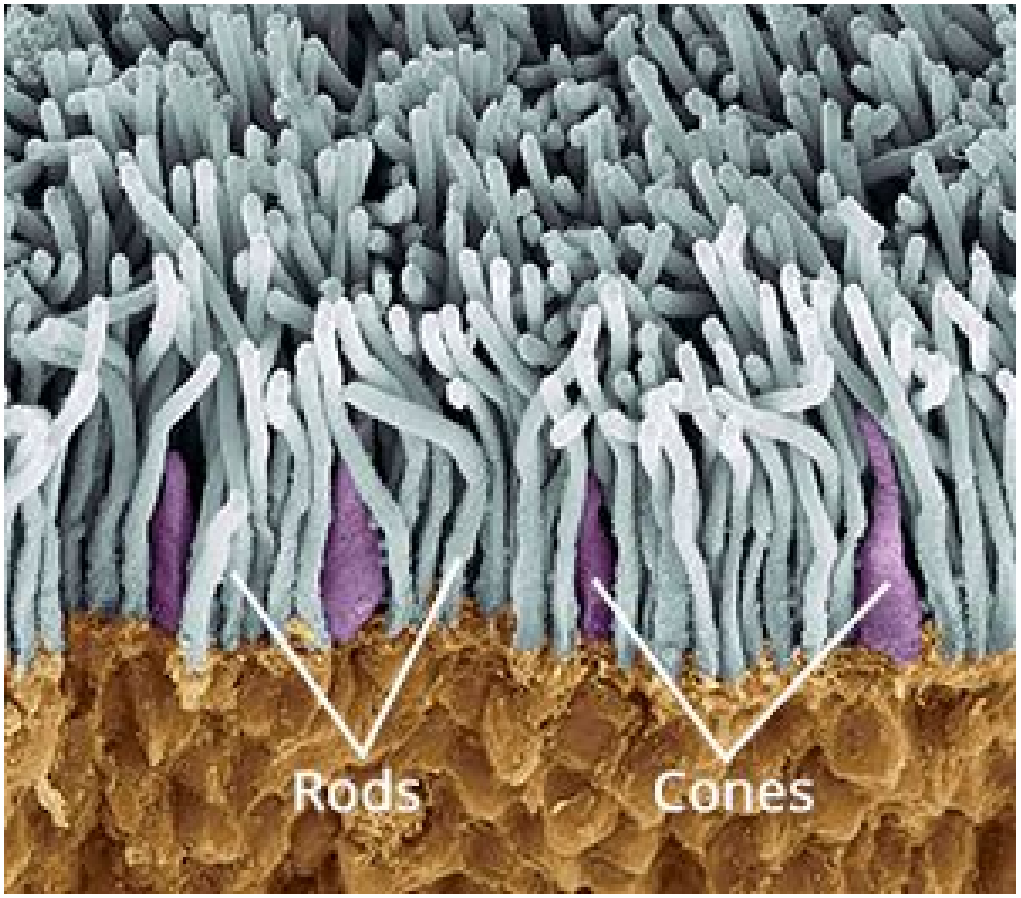


For accuracy and impact when displaying data,
you must consider the way human vision works.



This is especially true when using color!

The eye has more rods (light-sensitive cells)
than cones (color-sensitive cells).



Brightness is more important than color.

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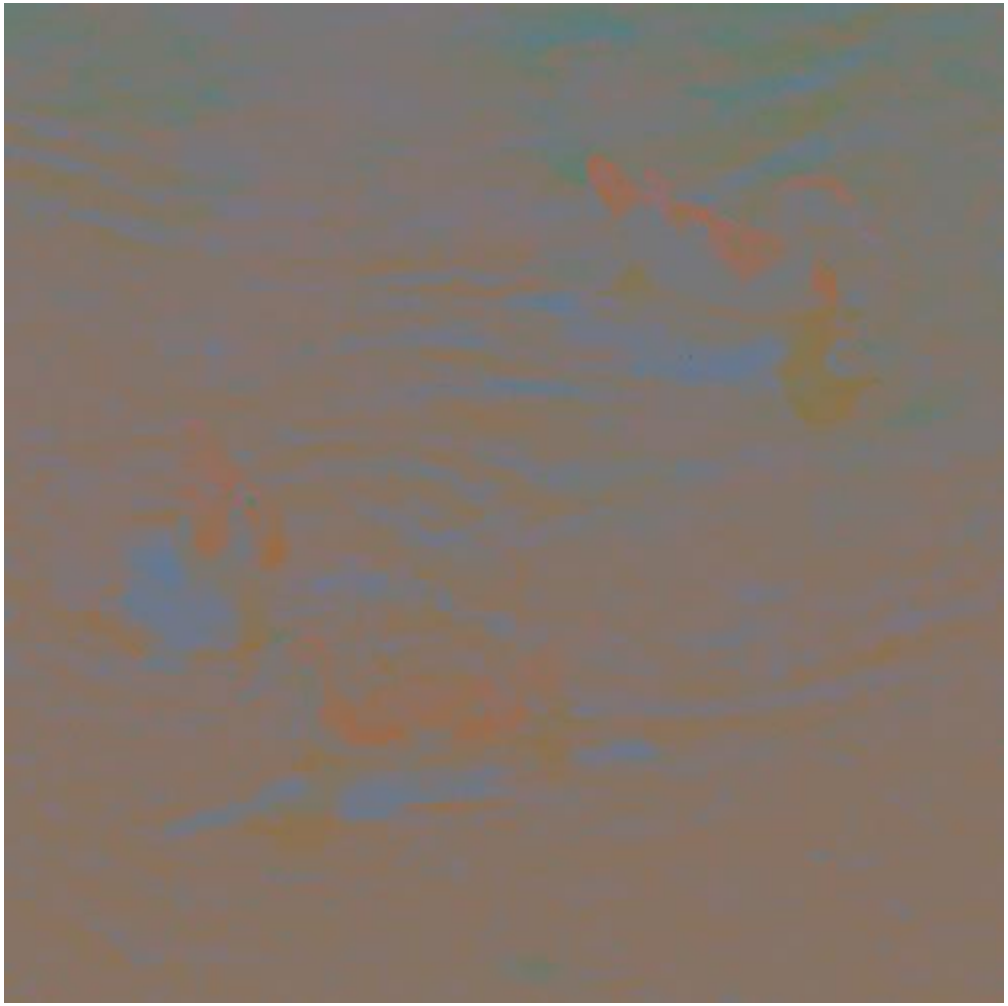

Given only color, images are confusing: the eye cannot detect edges.

http://therefractedlight.blogspot.com/2010/06/luminance-is-more-important-than-color.html

Brightness is more important than color.

Given only brightness, what we're looking at is obvious.

http://therefractedlight.blogspot.com/2010/06/luminance-is-more-important-than-color.html

Color maps without a monotonic increase in brightness often mislead:

The blue region looks lower than the surrounding purple...

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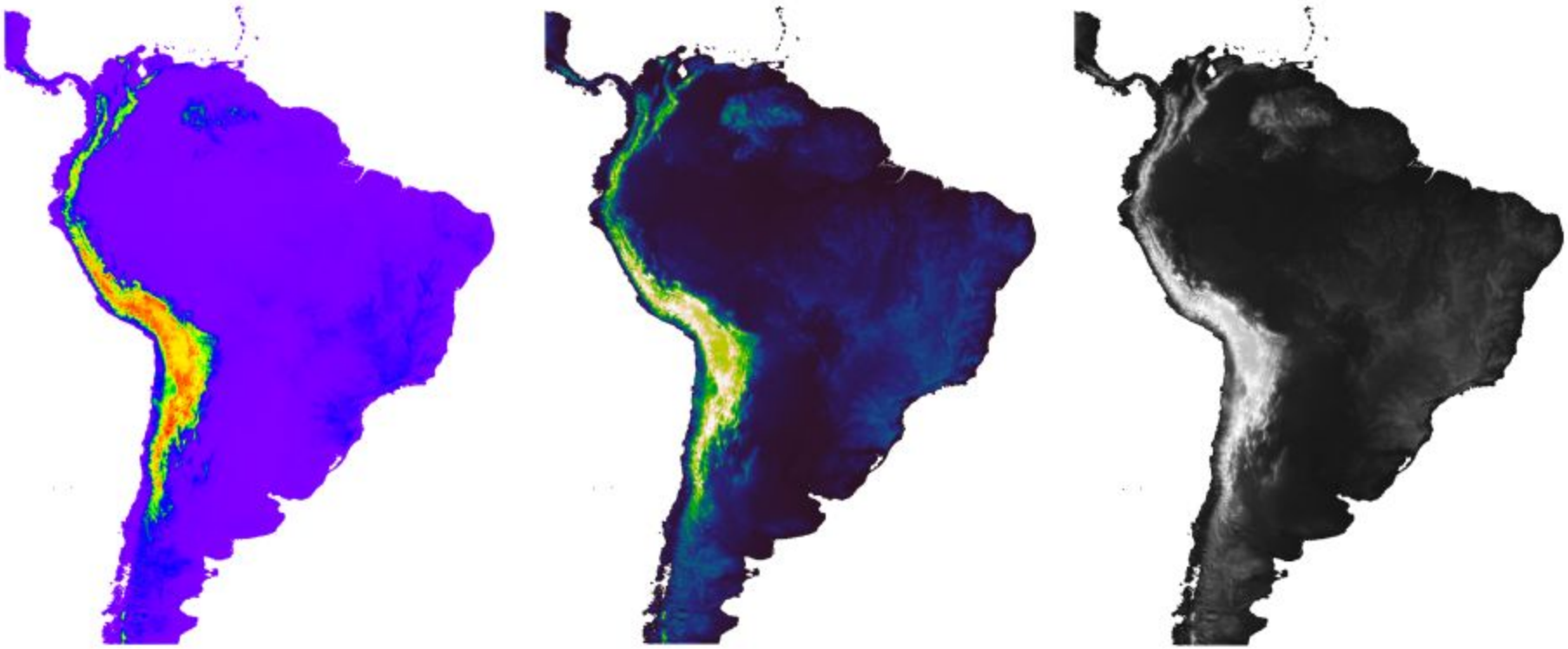

But this turns out to be an artifact of a misleading color bar!

mycarta.wordpress.com

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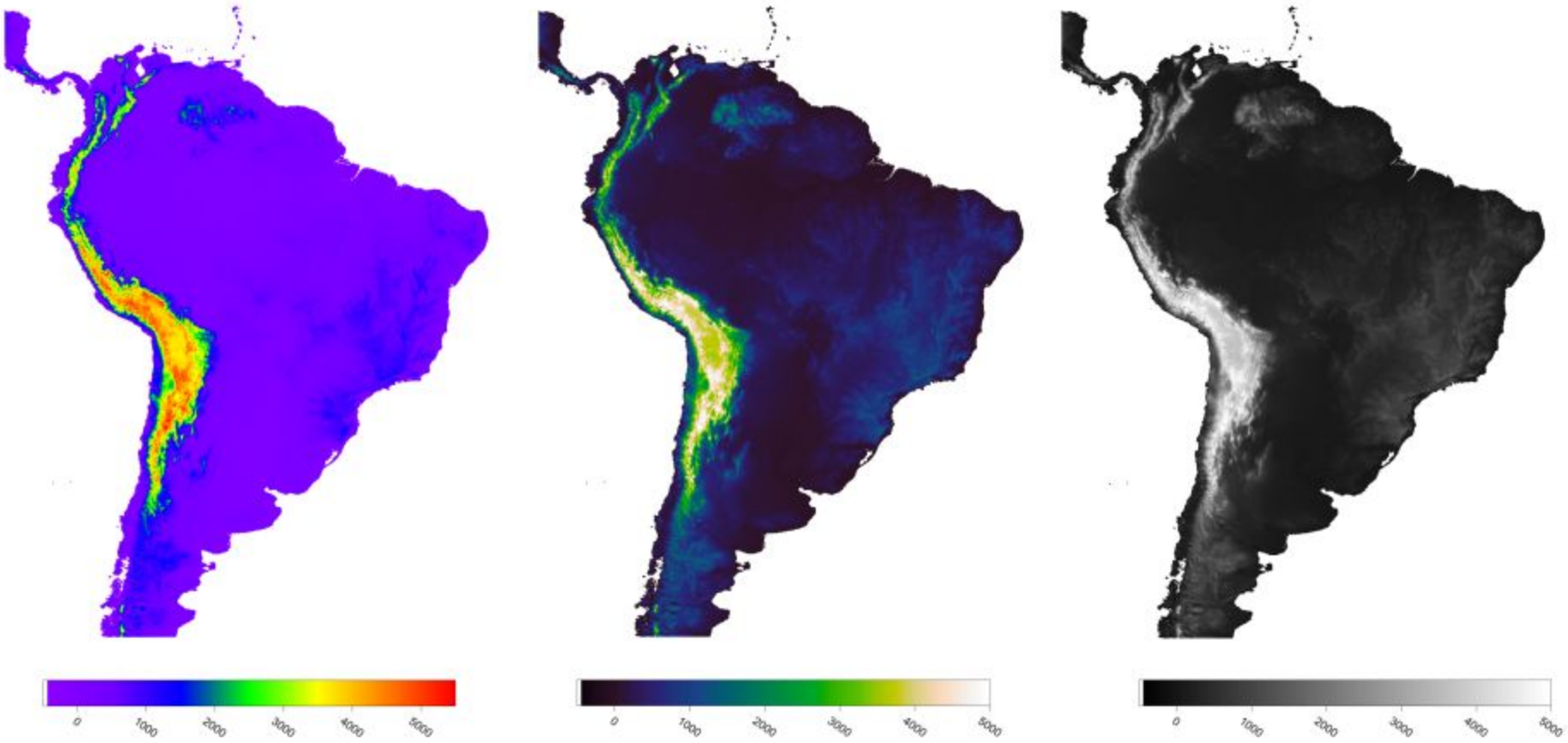

A good color map should be intuitive WITHOUT a color scale. This saves time and avoids mistakes.

mycarta.wordpress.com

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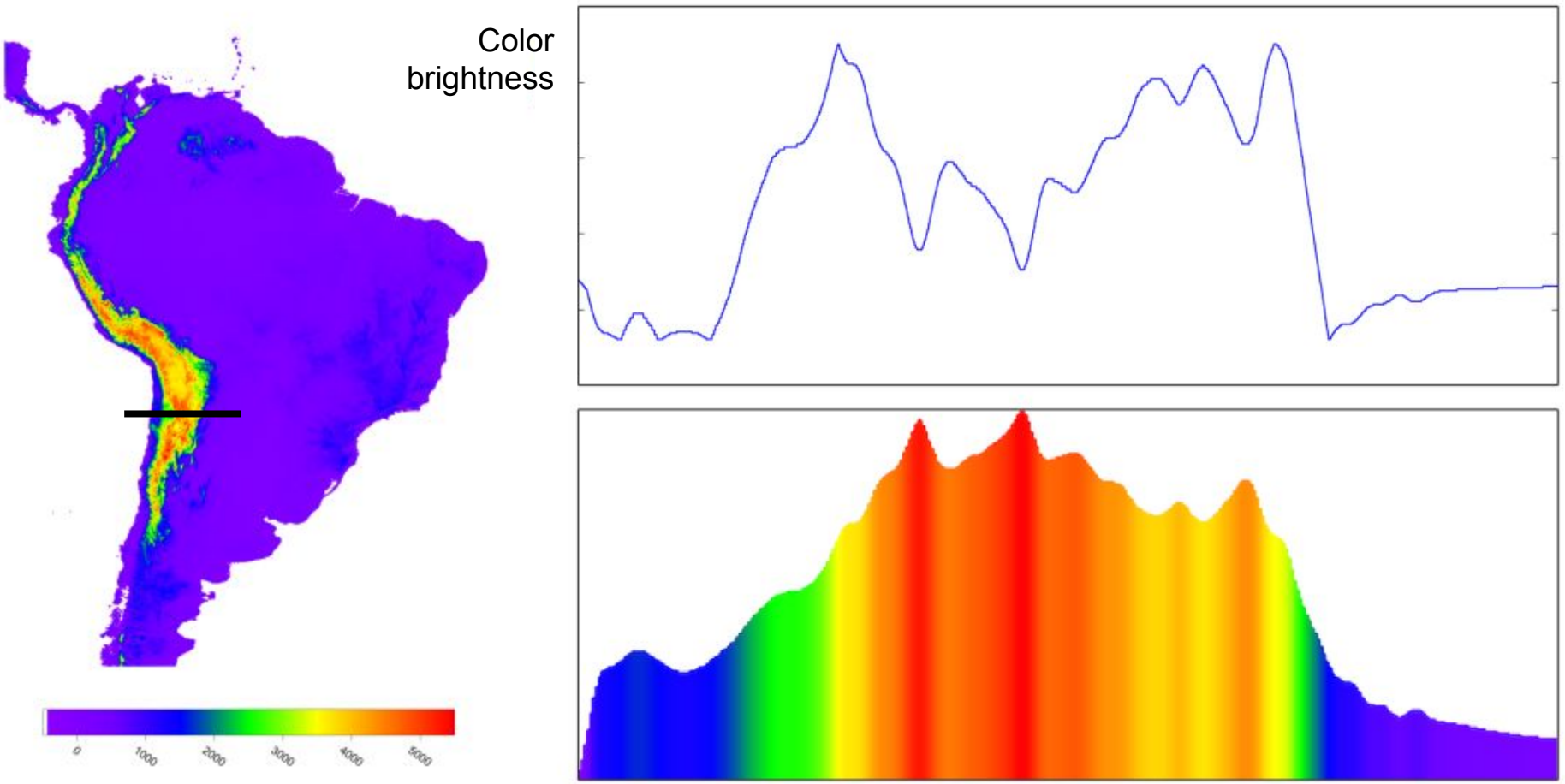
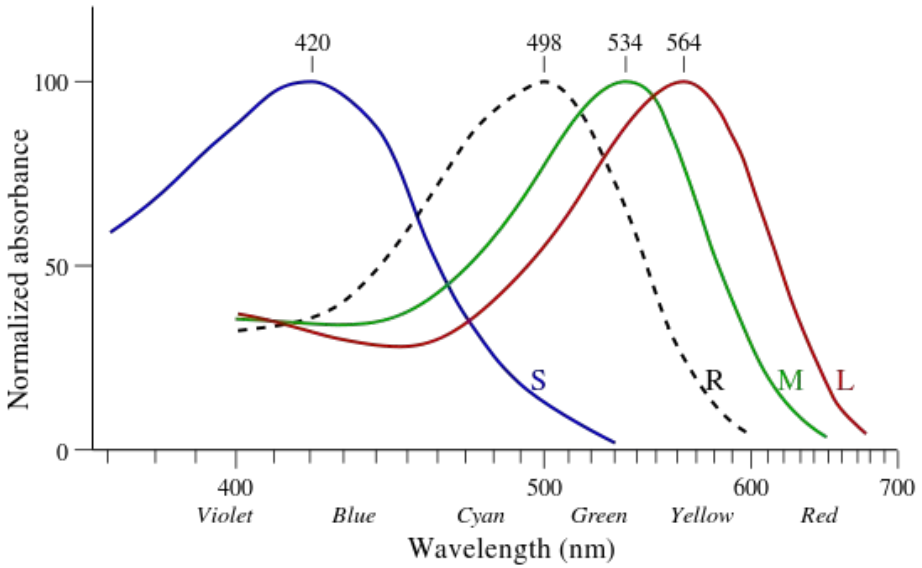


The blue looks lower (dimmer) than the purple, and the red lower than the yellow.

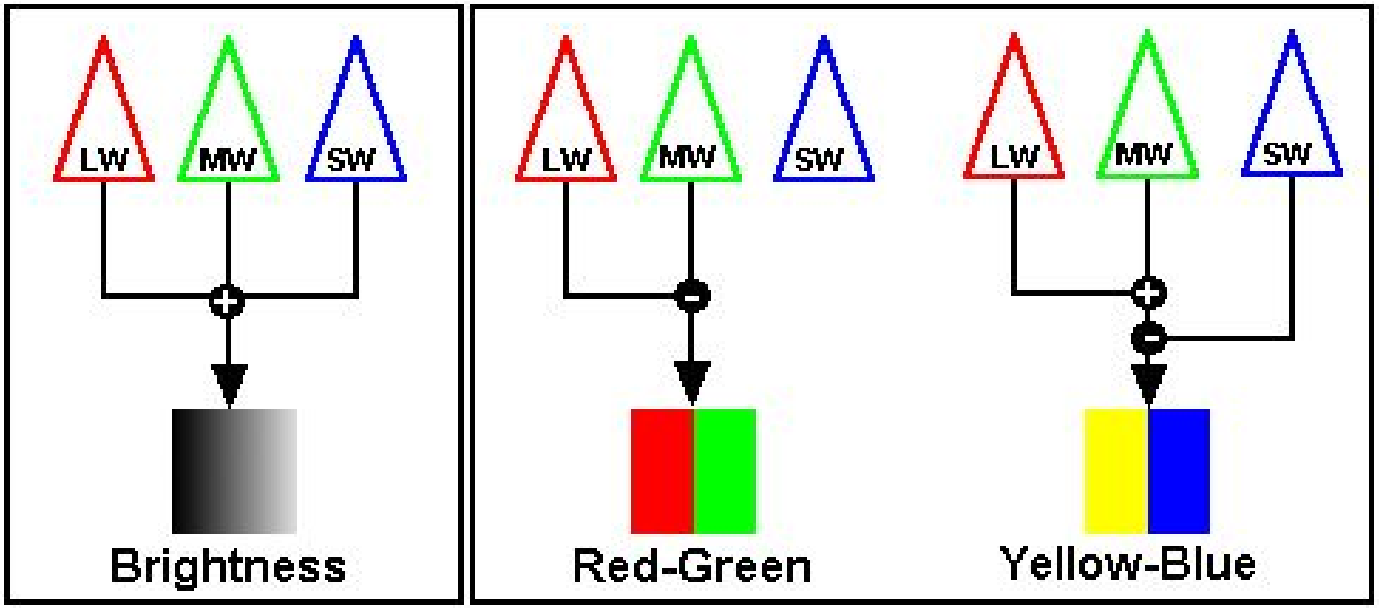
mycarta.wordpress.com

The brain sees color differences, not absolute colors

red/green and blue/yellow are *opponent pairs*

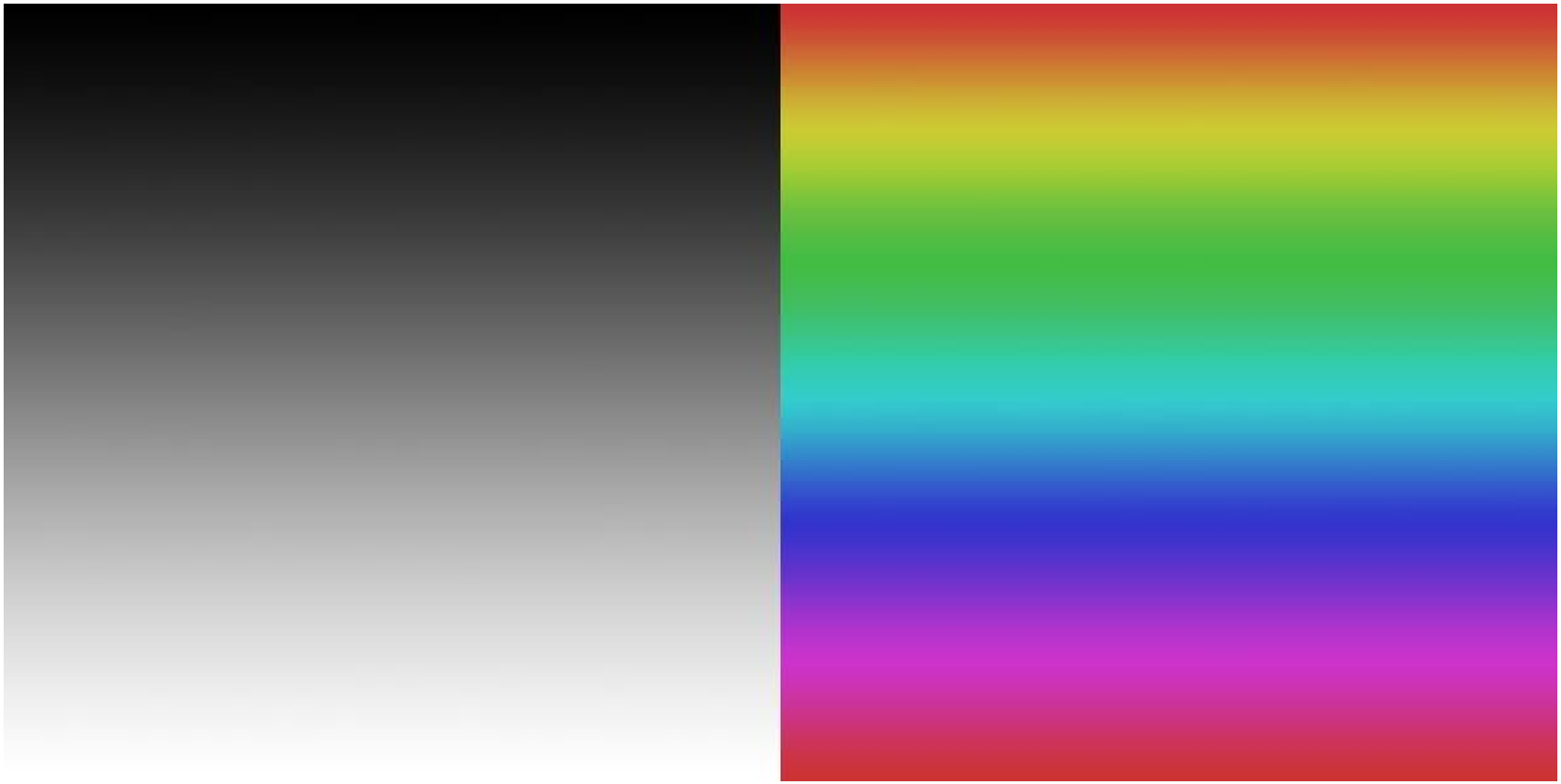


Wikipedia



http://www.visualexpert.com/FAQ/Part1/cfaqPart1.html

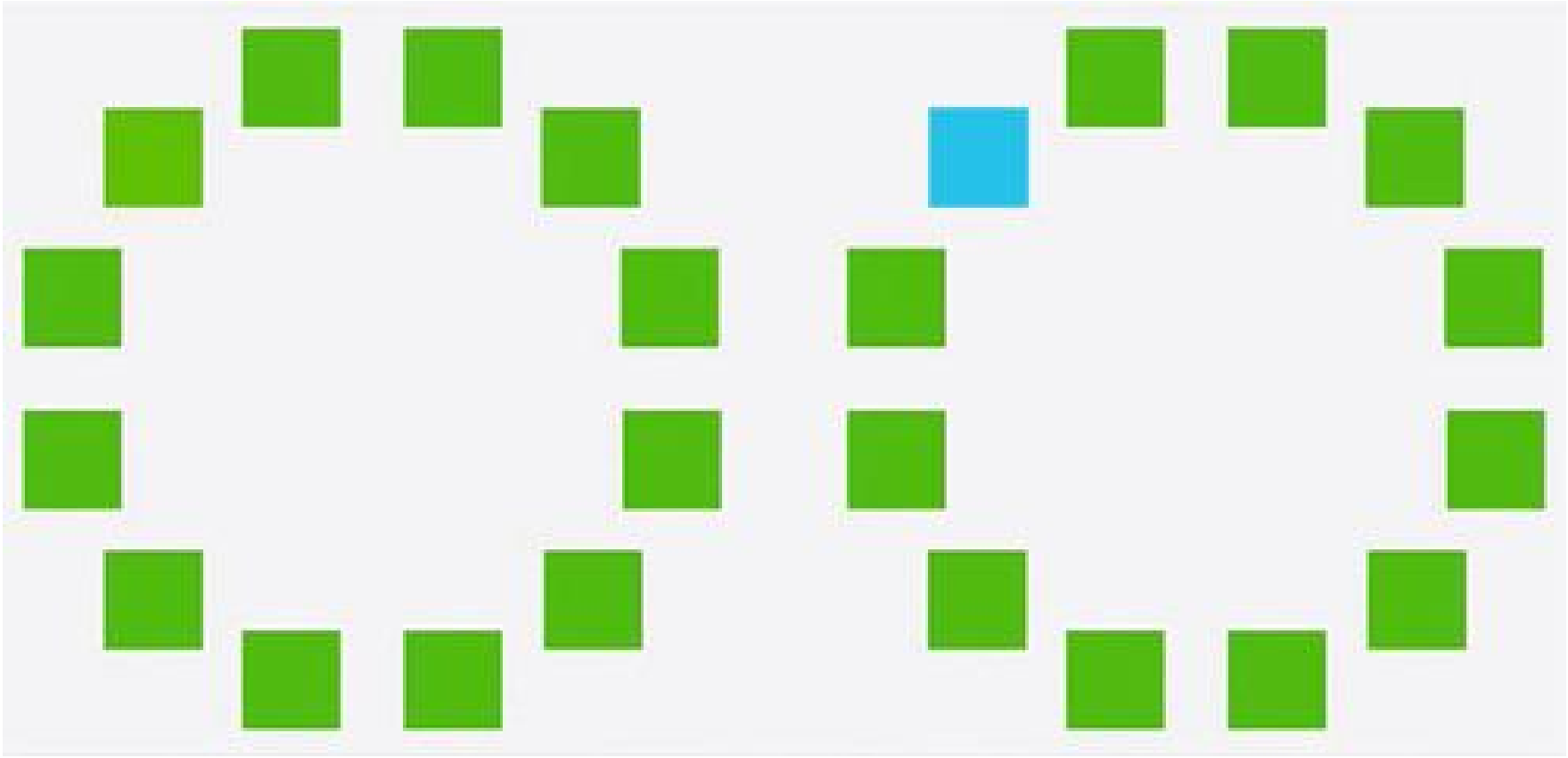
Opponent colors lead to sharp edges in color gradients



Borland and Taylor, “Rainbow Color Map (Still) Considered Harmful”
doi:10.1109/MCG.2007.323435

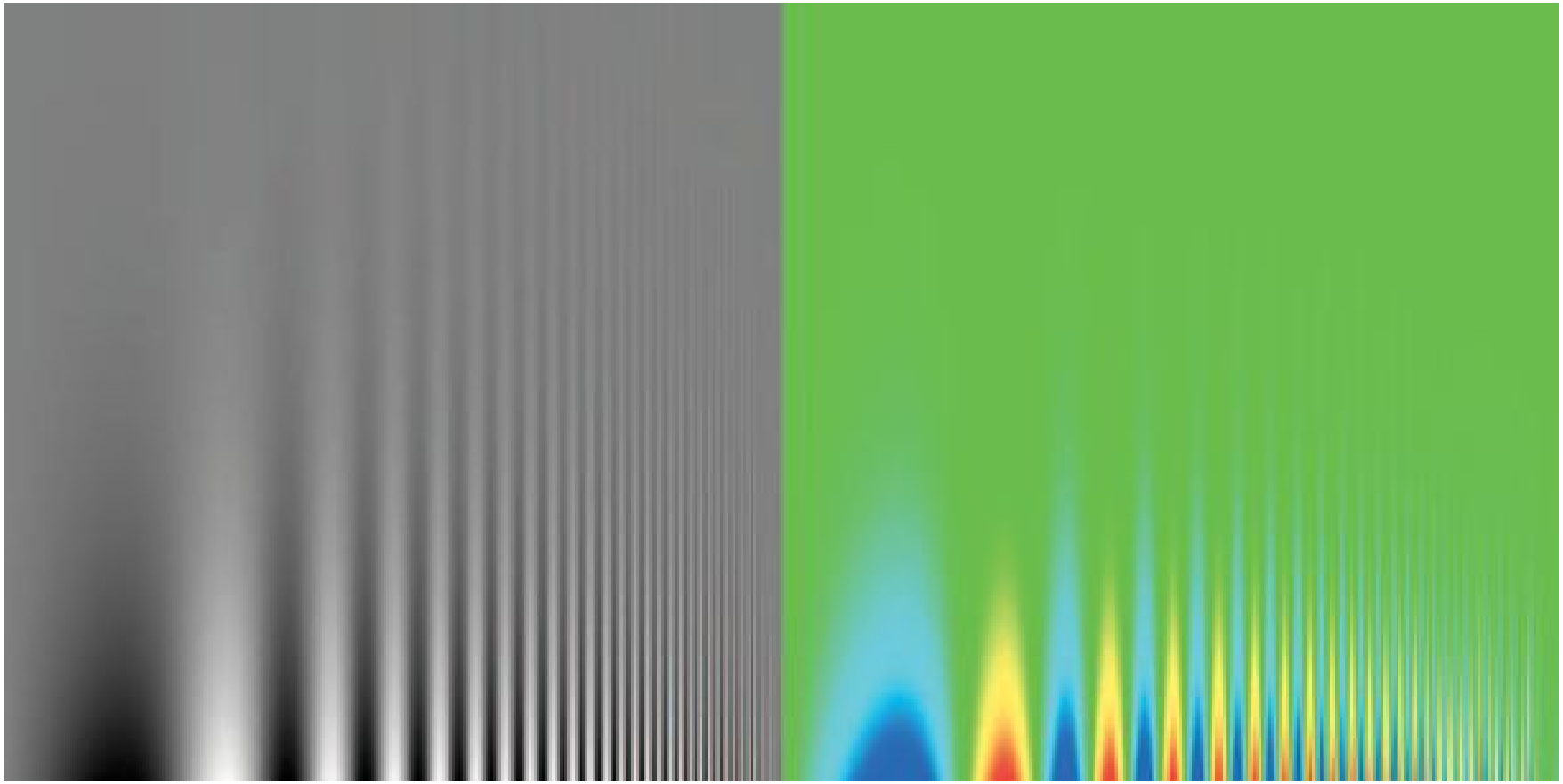
Hue perception can depend on culture

Himba children more easily spot the outlier on the left than the one on the right.



http://www.apa.org/monitor/feb05/hues.aspx

Bad color maps can distort data interpretation



Same data: which colormap better shows the fine distinctions?

Borland and Taylor, “Rainbow Color Map (Still) Considered Harmful”
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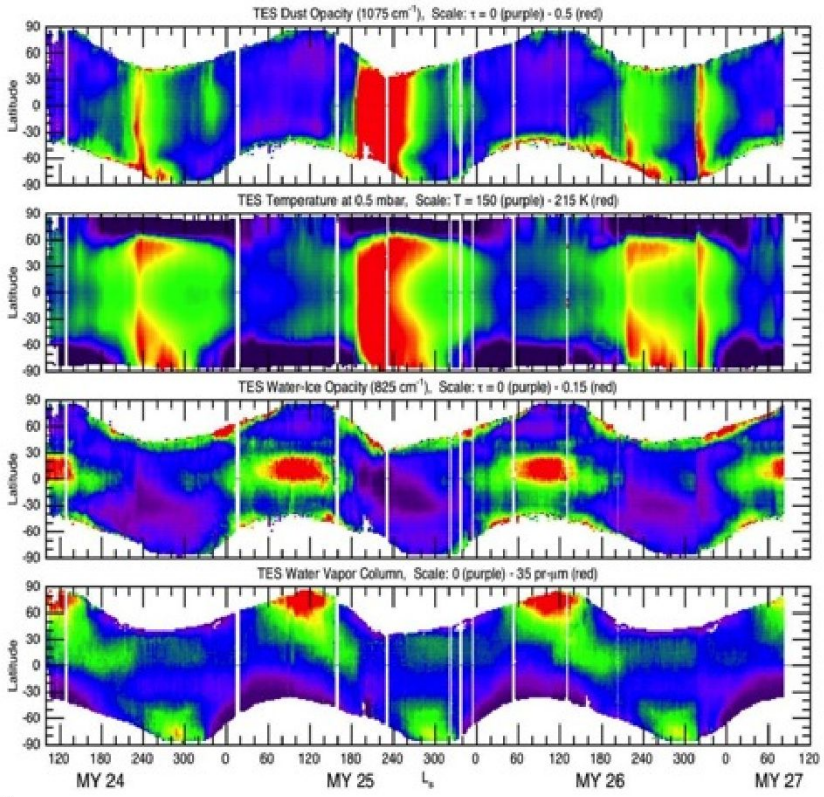
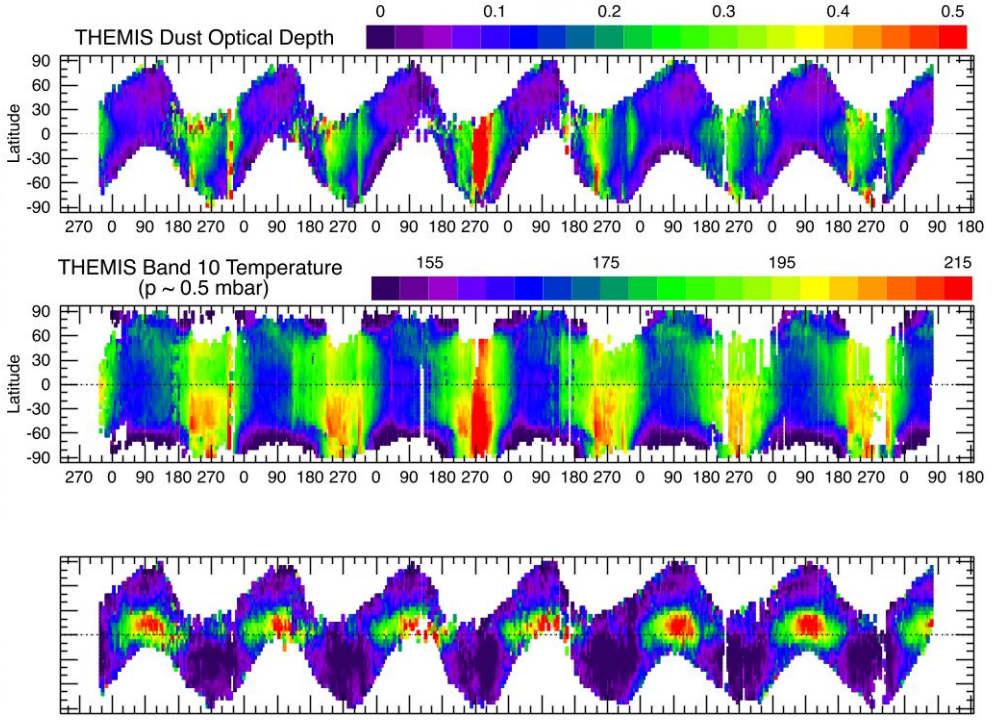
TES



THEMIS



Beautiful dataset, great analysis...

is the color map doing it justice?

Bad color maps can distort data interpretation

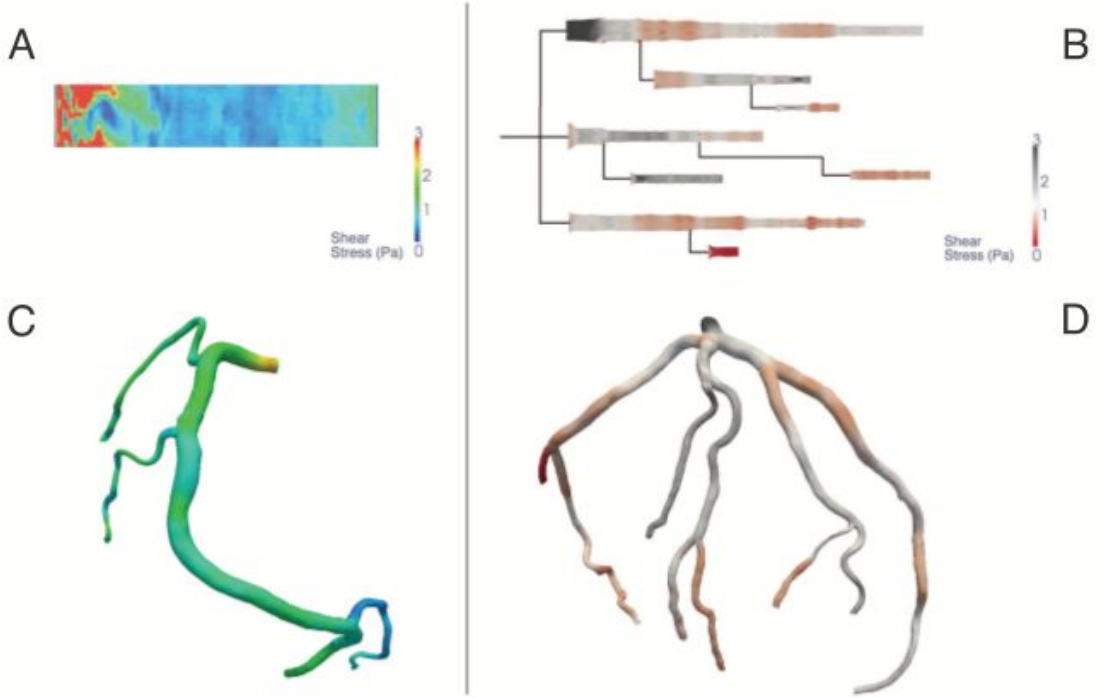
Figure 12. Various color maps applied to a face image. The color maps in the bottom row have monotonically increasing lightness, resulting in a natural, recognizable image.

Rainbow Color Map Critiques: An Overview and Annotated Bibliography
Steve Eddins, MathWorks

Bad color maps impair diagnostic accuracy

Evaluation of Artery Visualizations for Heart Disease Diagnosis

Michelle A. Borkin, *Student Member, IEEE*, Krzysztof Z. Gajos, Amanda Peters, Dimitrios Mitsouras, Simone Melchionna, Frank J. Rybicki, Charles L. Feldman, & Hanspeter Pfister, *Senior Member, IEEE*



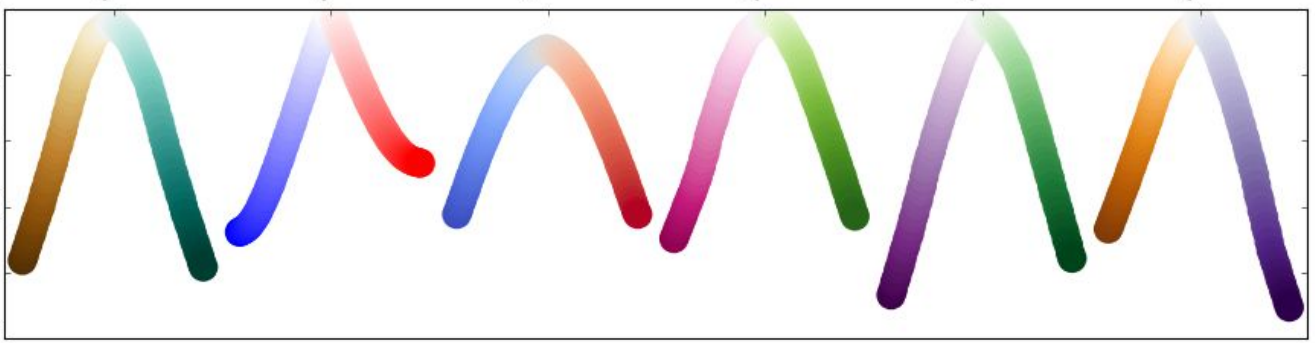
Physicians were faster and better at diagnosing heart disease when using a perceptual color scheme, even though they claimed to prefer the rainbow.

So which color map should you use?

A good color map should:

1) Use brightness as the primary encoding, and
2) Reflect the nature of the data.
   - Sequential, monotonic data (magnitude, intensity, brightness)

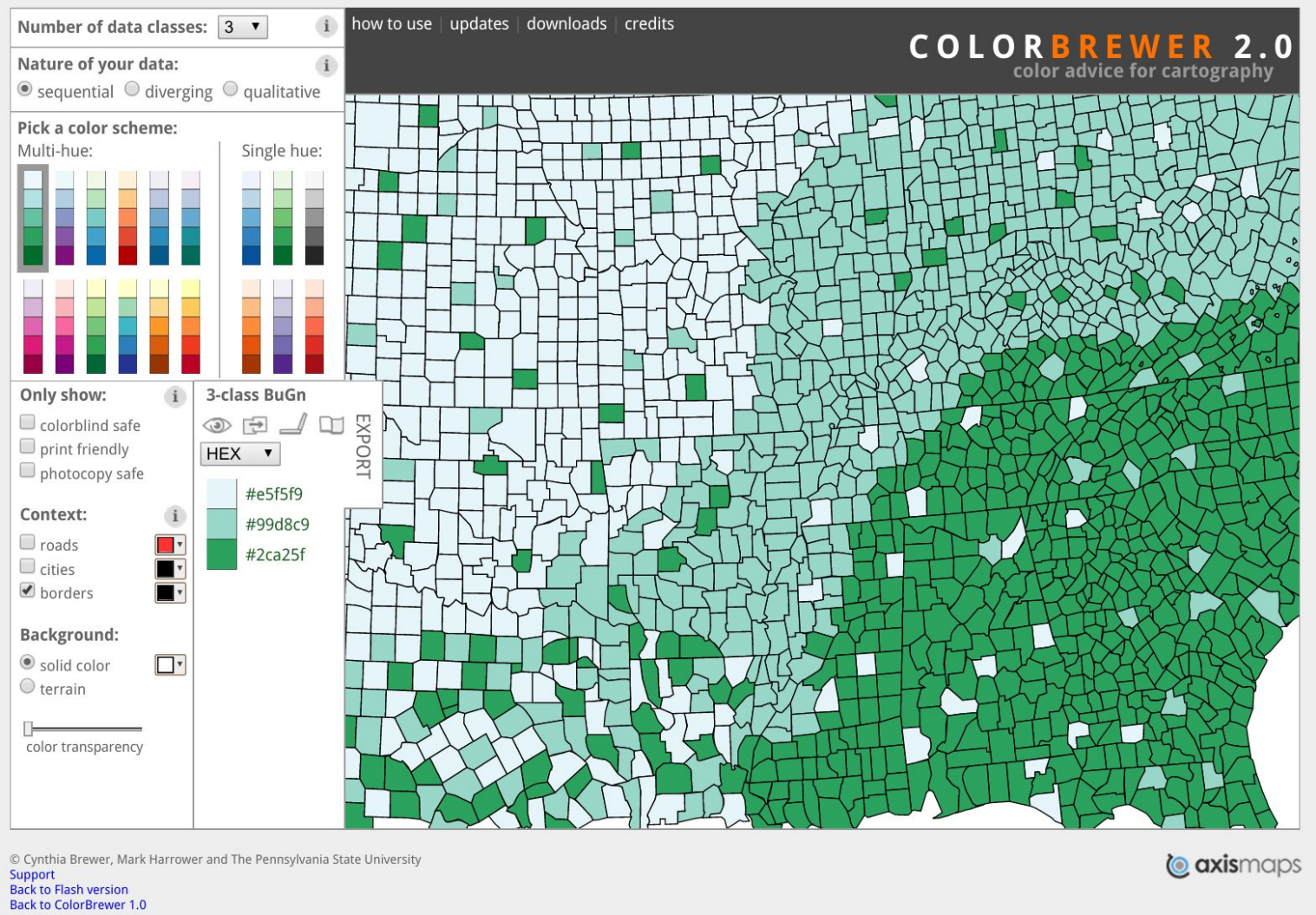
   - Diverging data, with a critical transition (velocity, flux)



   - Colormaps must be carefully designed for other data types (cyclic)

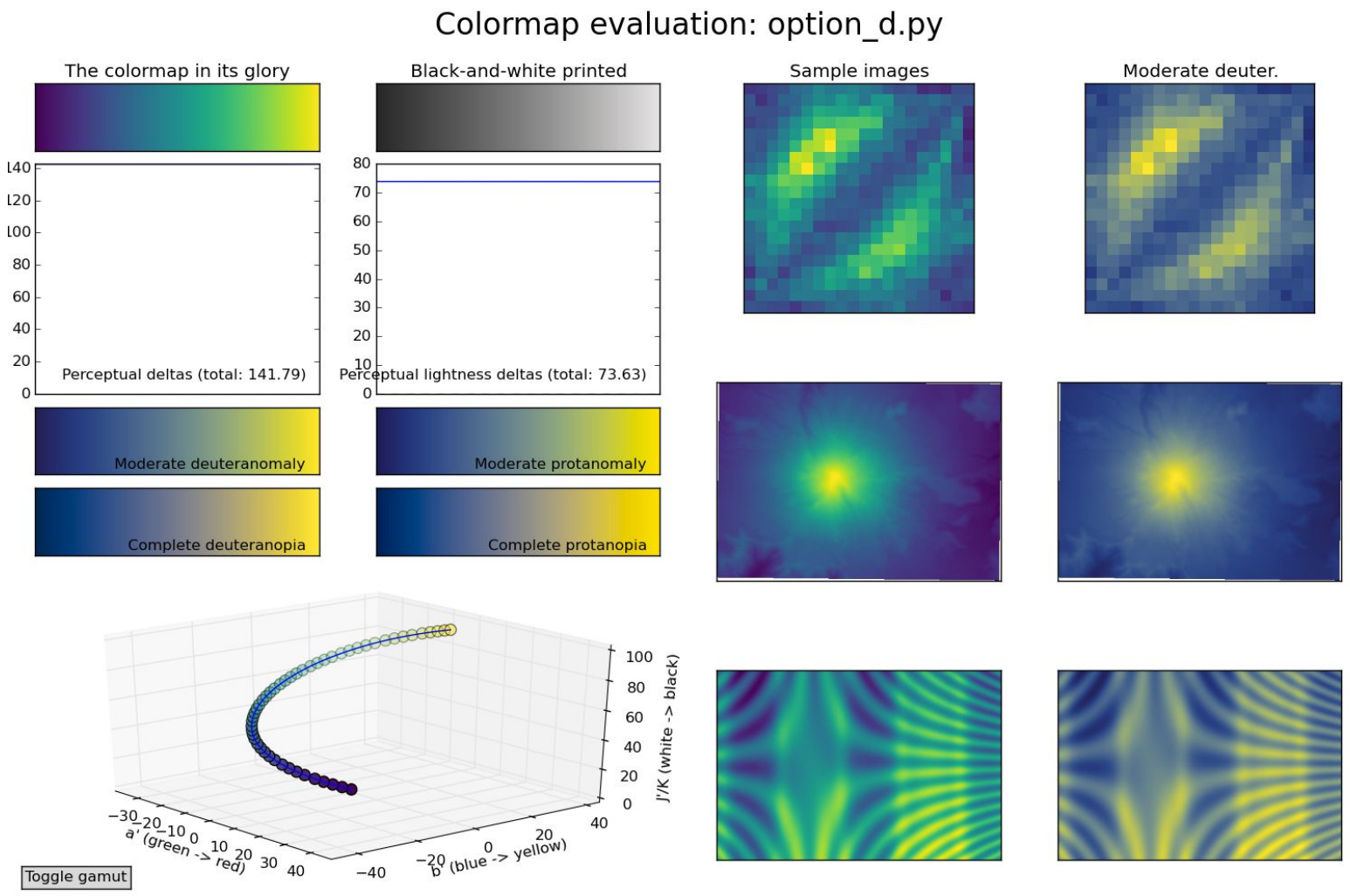
But remember to use brightness as the primary encoding!

Great color schemes can be found on colorbrewer2.org :



These colormaps are built into IDL 8 (schemes 41-74)

Even better color maps are accessible with Python:



These color maps (and the colorbrewer maps) are available via IDL code available from me or my github page: github.com/planetarymike/IDL-Colorbars

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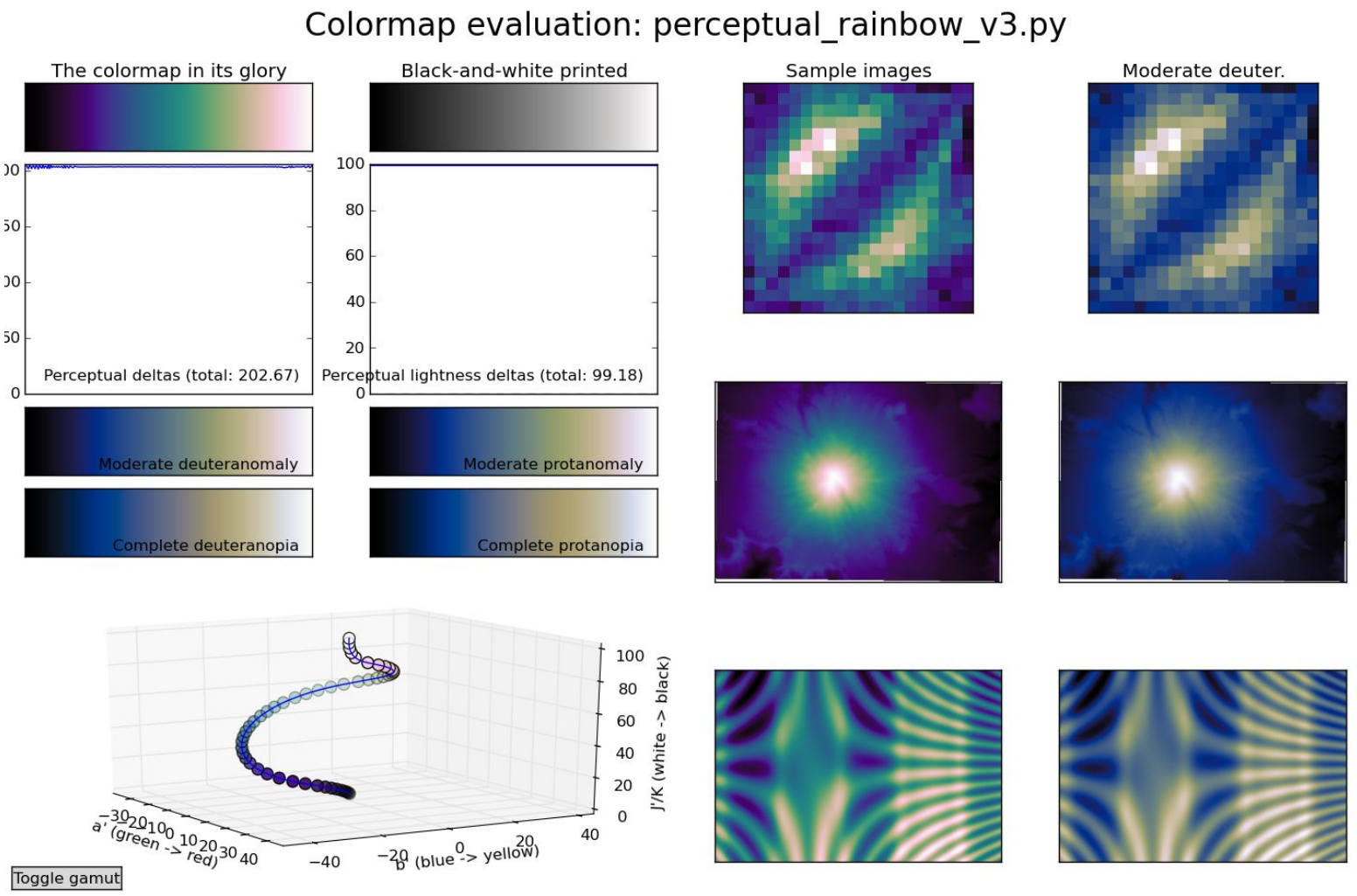

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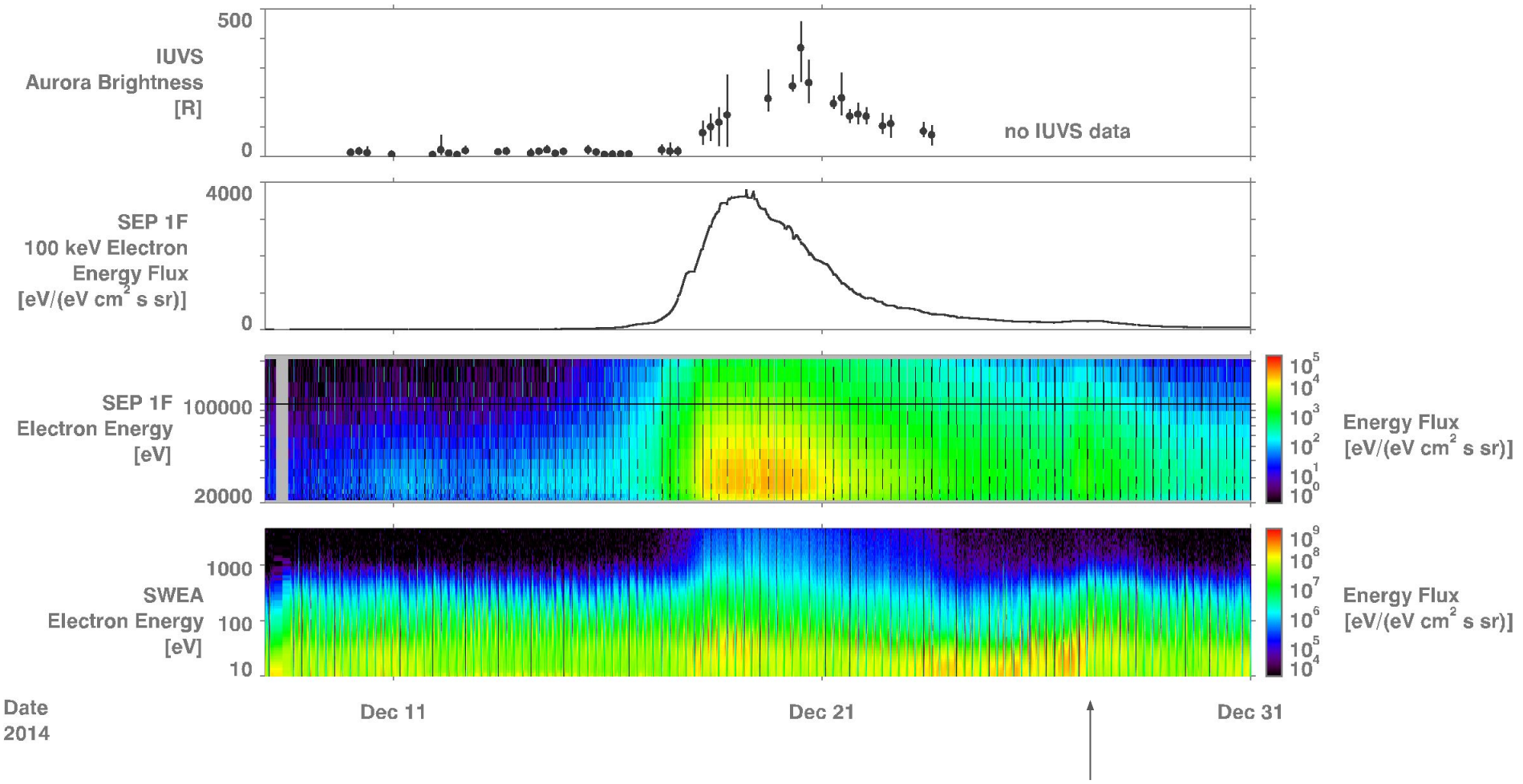
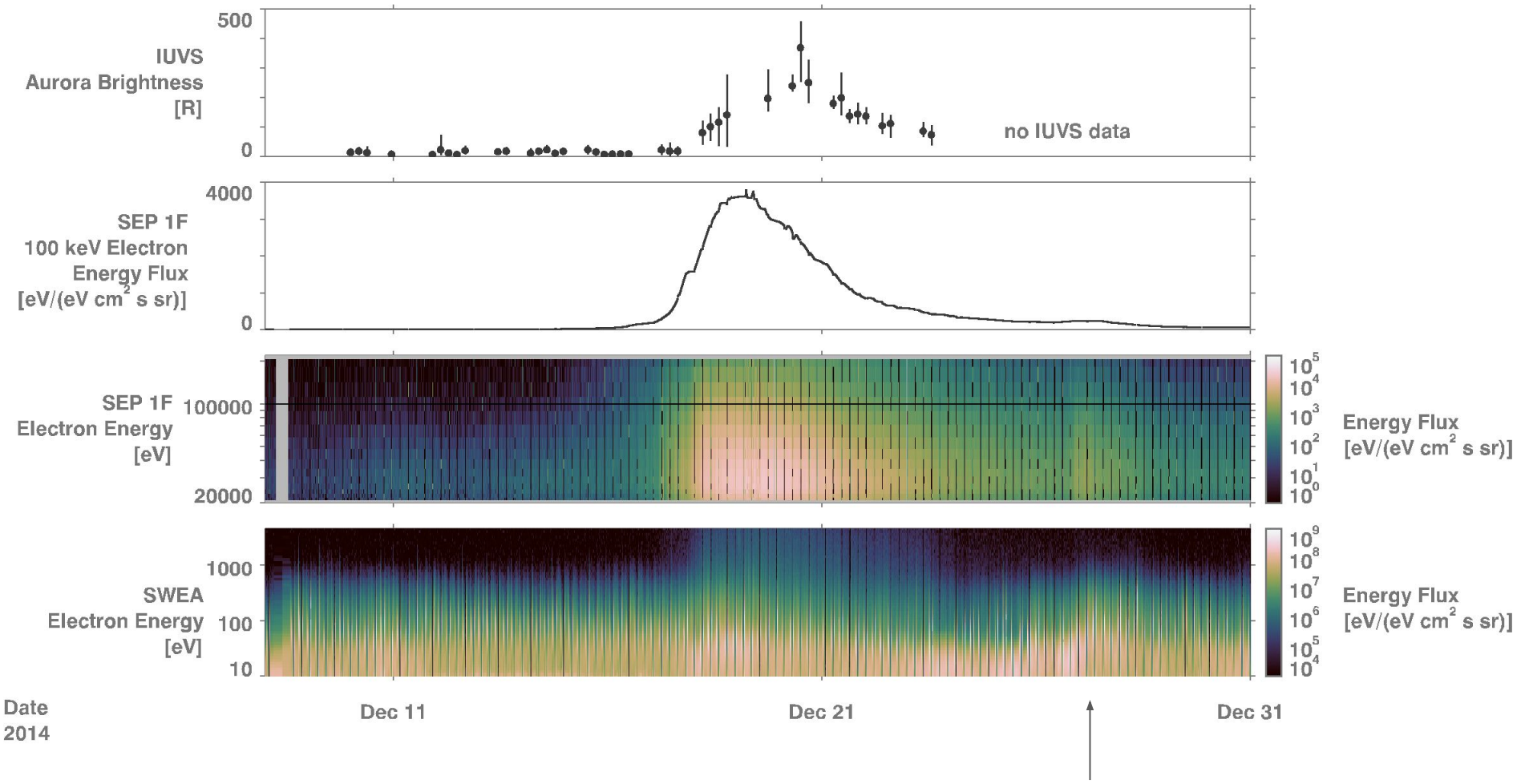
Perceptual colormaps improve data analysis



Which colormap does a better job of showing all the data, rather than highlighting a few specific transitions?

Perceptual colormaps improve data analysis



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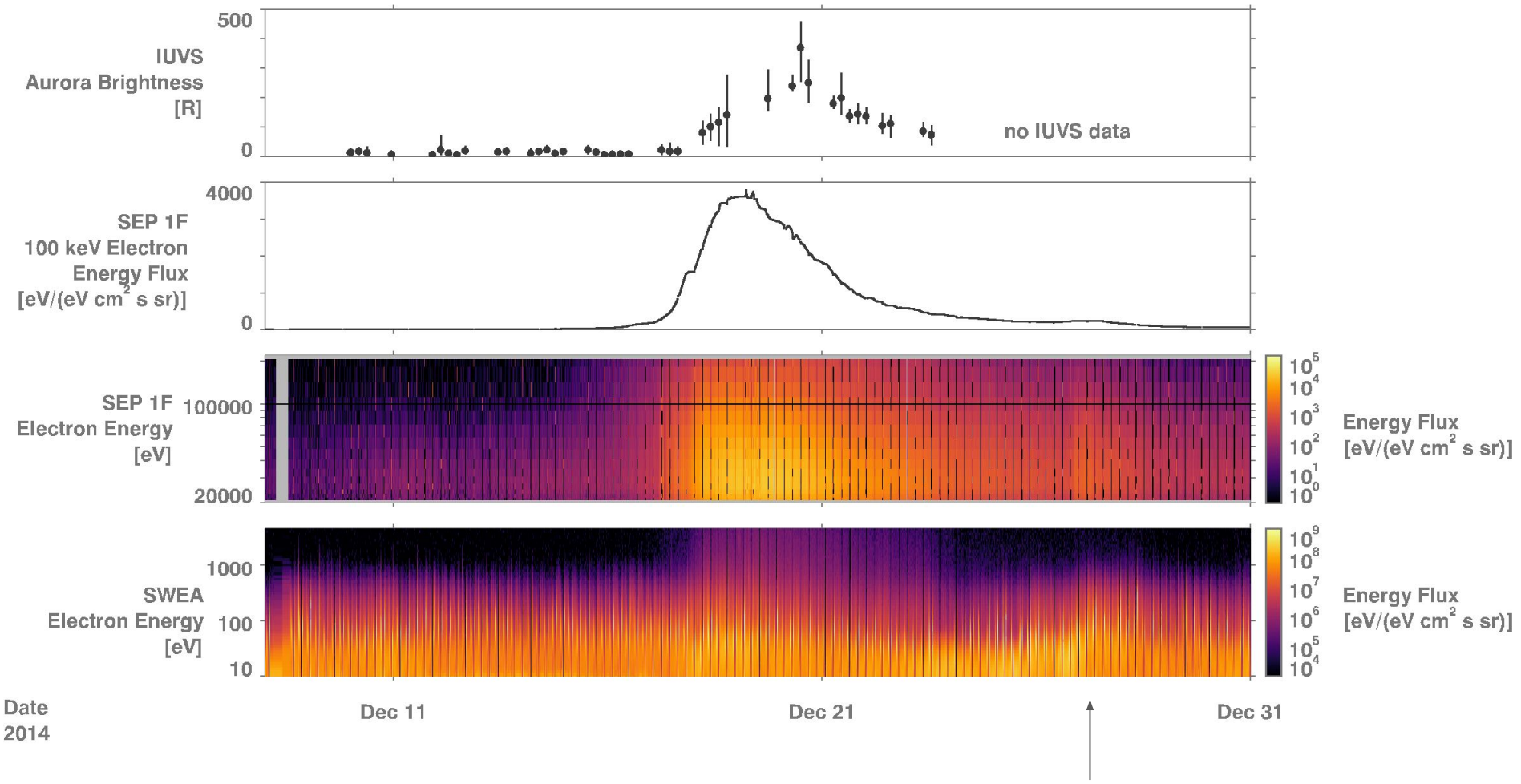

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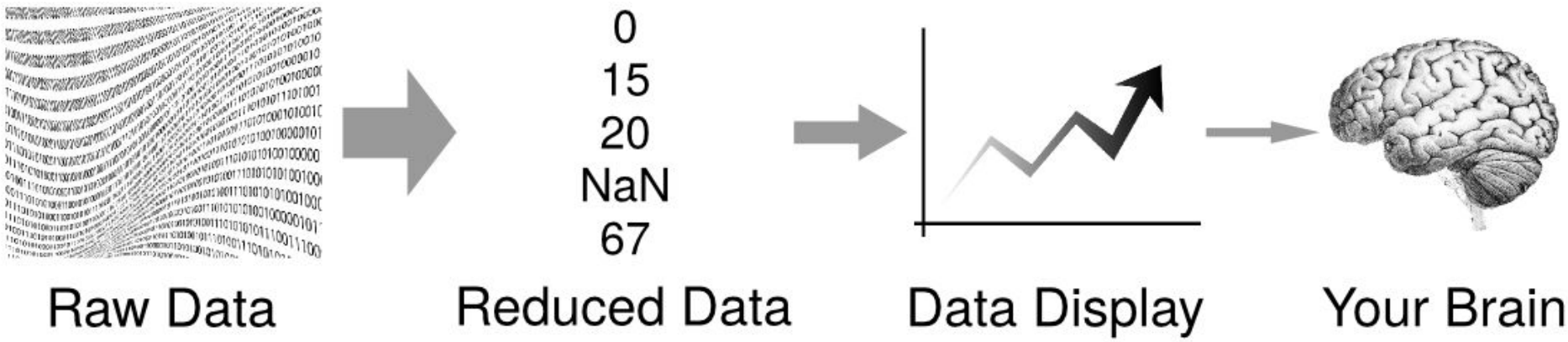

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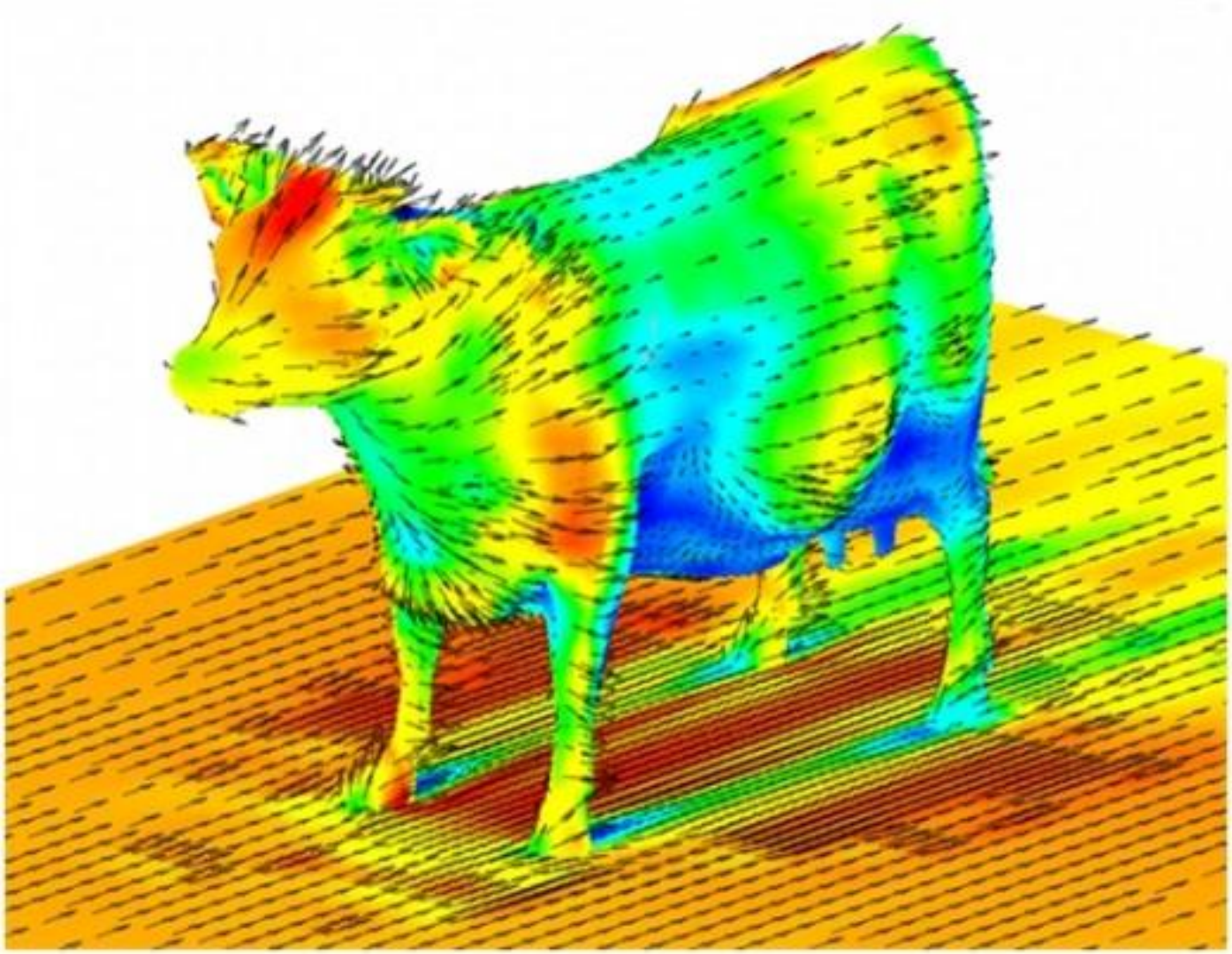


Friends don’t let friends use bad color maps!

Backup

Additional reading:

http://www.mathworks.com/tagteam/81137_92238v00_RainbowColorMap_57312.pdf

^^This MATLAB discussion of rainbow color bars and alternatives includes an excellent annotated bibliography.

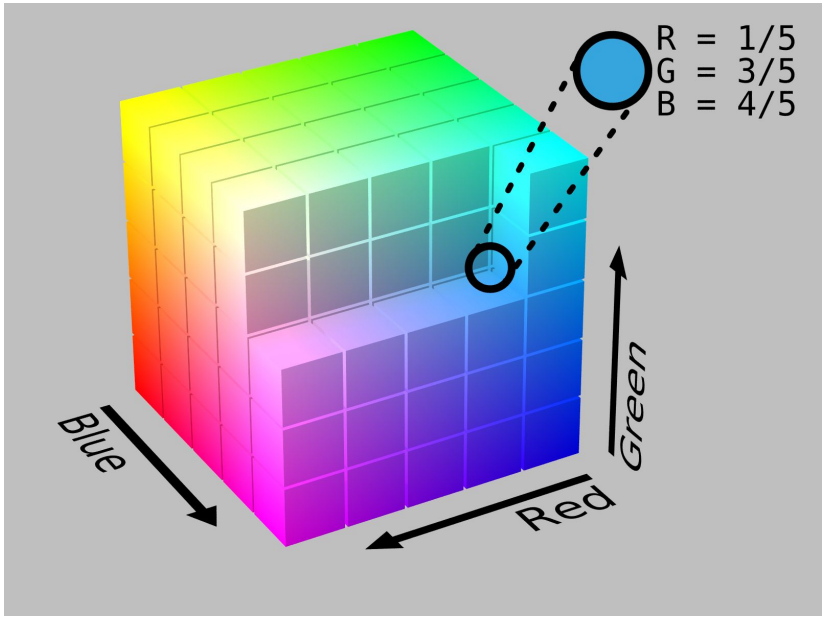
http://ieeexplore.ieee.org/xpl/login.jsp?tp=&arnumber=4118486&url=http%3A%2F%2Fieeexplore.ieee.org%2Fxpls%2Fabs_all.jsp%3Farnumber%3D4118486

^^"Rainbow color map (still) considered harmful."
A valiant attempt to convince the scientific community that rainbow color maps are as dangerous and unnecessary as GOTO statements in computer code.

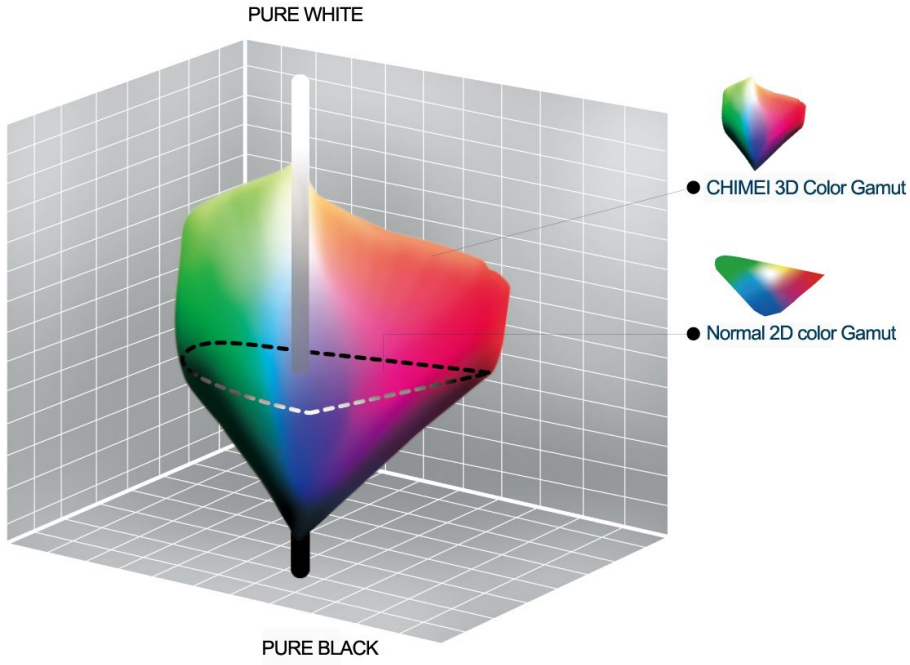
"The Smallest Effective Difference", chapter 4 of *Visual Explanations* by Edward Tufte

Good color maps work with the visual system, not against it!

They are designed in perceptual color spaces:



RGB color space:
good for monitors, not people.

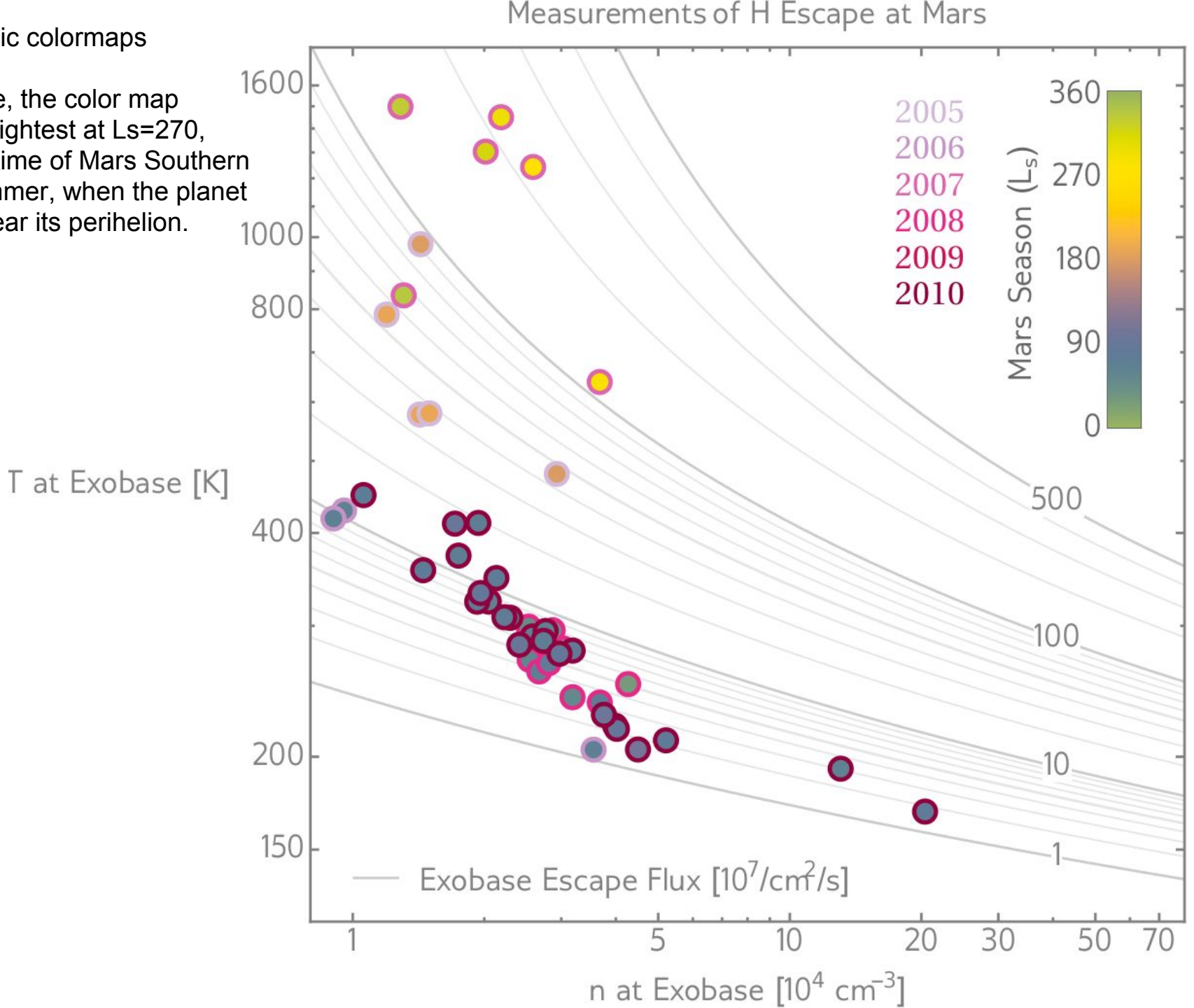


In a perceptual color space,
euclidean distance is
perceived color difference.

There are *excellent* python tools to do color map design:
github.com/matplotlib/viscm

Cyclic colormaps

Here, the color map is brightest at Ls=270, the time of Mars Southern Summer, when the planet is near its perihelion.



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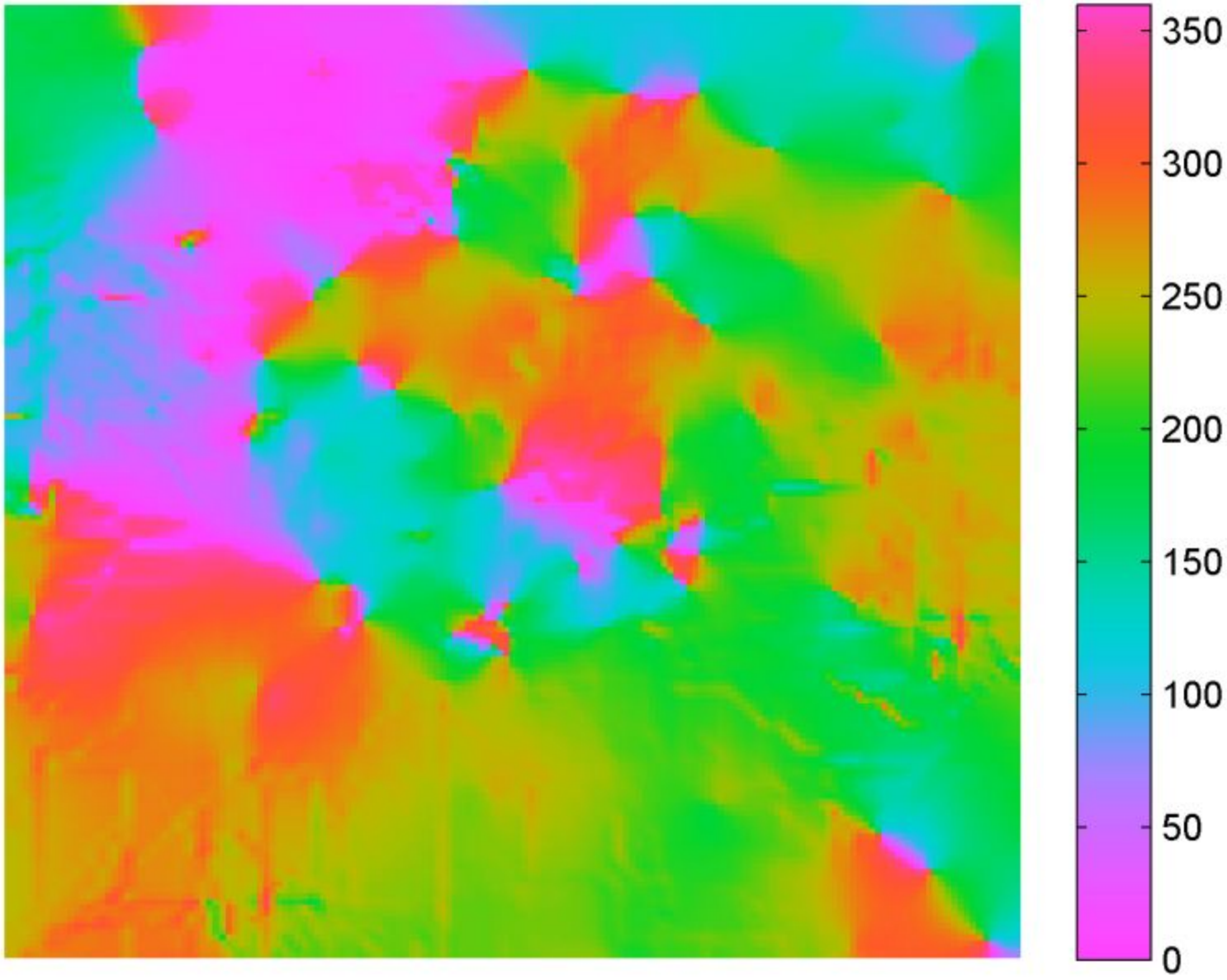
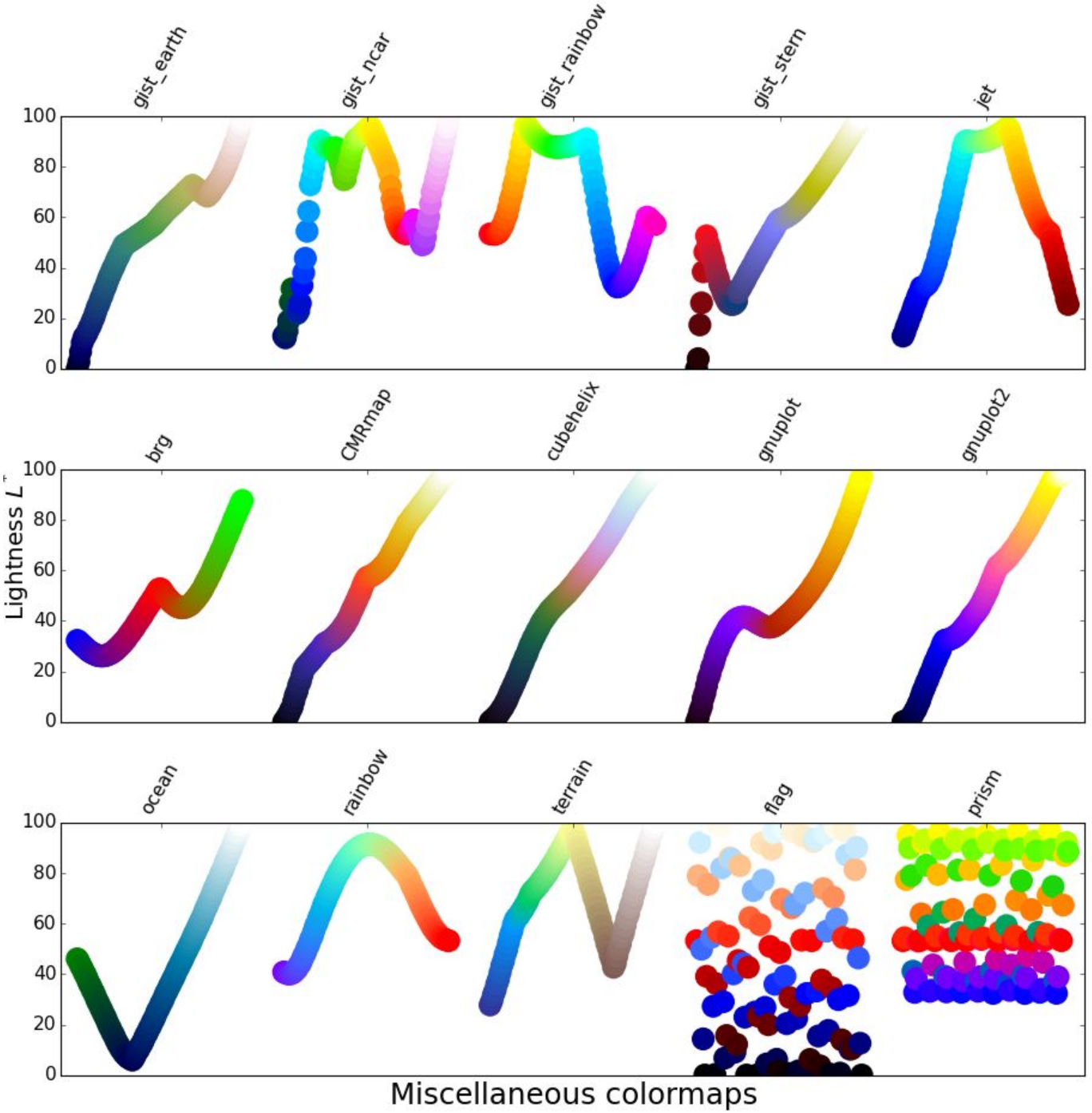


BAD: brightness is not the primary encoding!


gist_earth
gist_ncar
gist_rainbow
gist_stern
jet
brg
CMRmap
cubehelix
gnuplot
gnuplot2
ocean
rainbow
terrain
flag
prism
Lightness L^*
0
20
40
60
80
100
Miscellaneous colormaps