Less color, more science

Perceptual alternatives to rainbow colormaps

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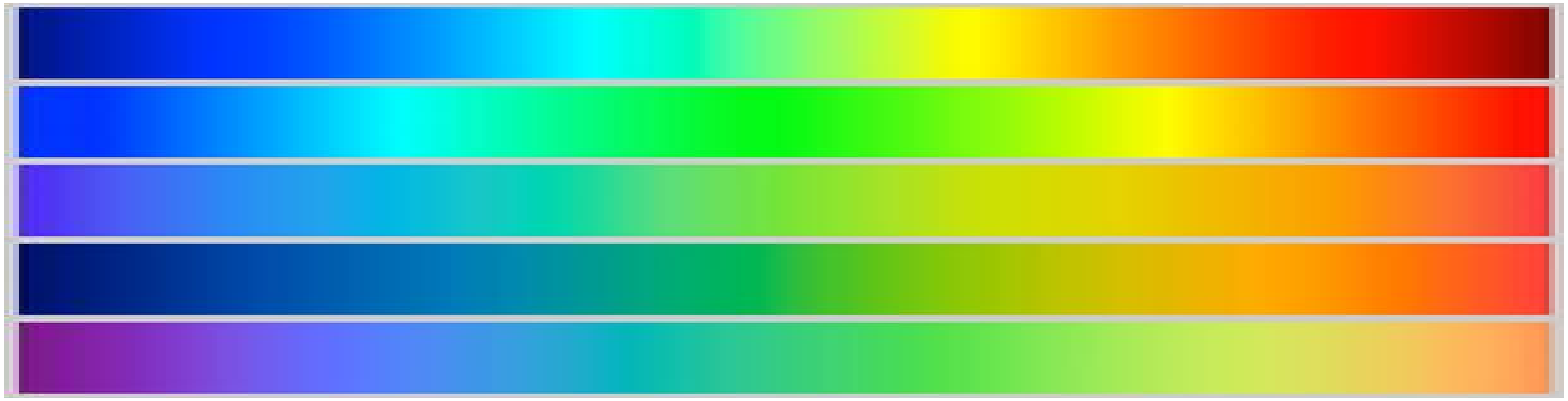
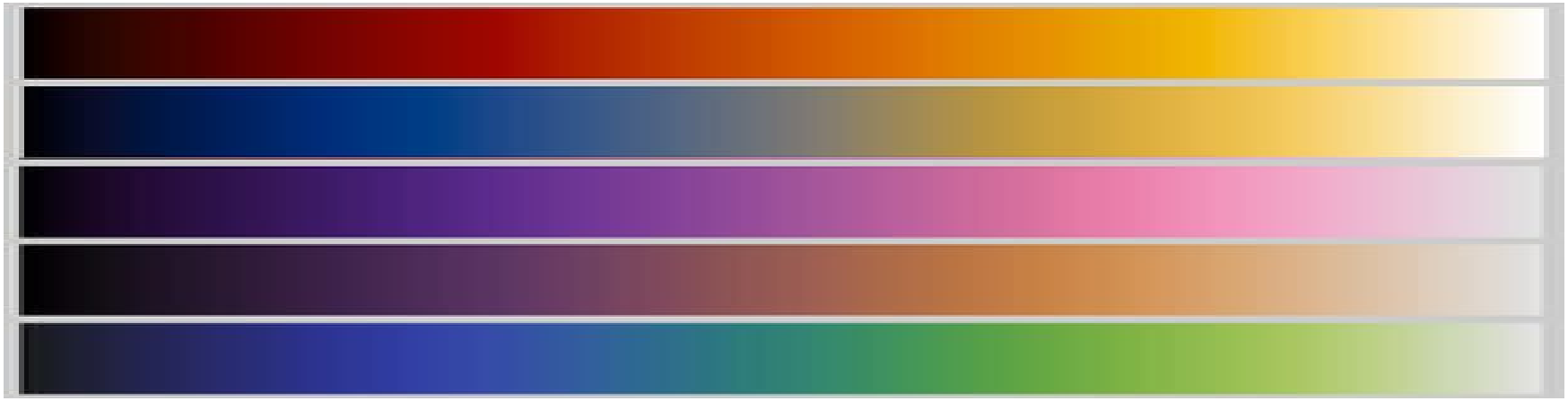
In science, rainbow color maps are everywhere:

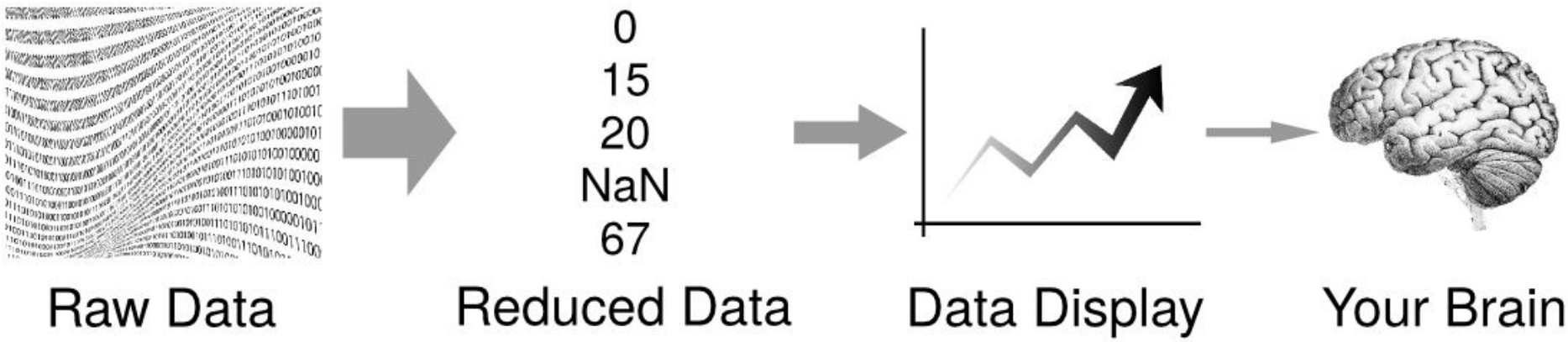


Rainbow colormaps distort data and impair judgment.

We can do better:

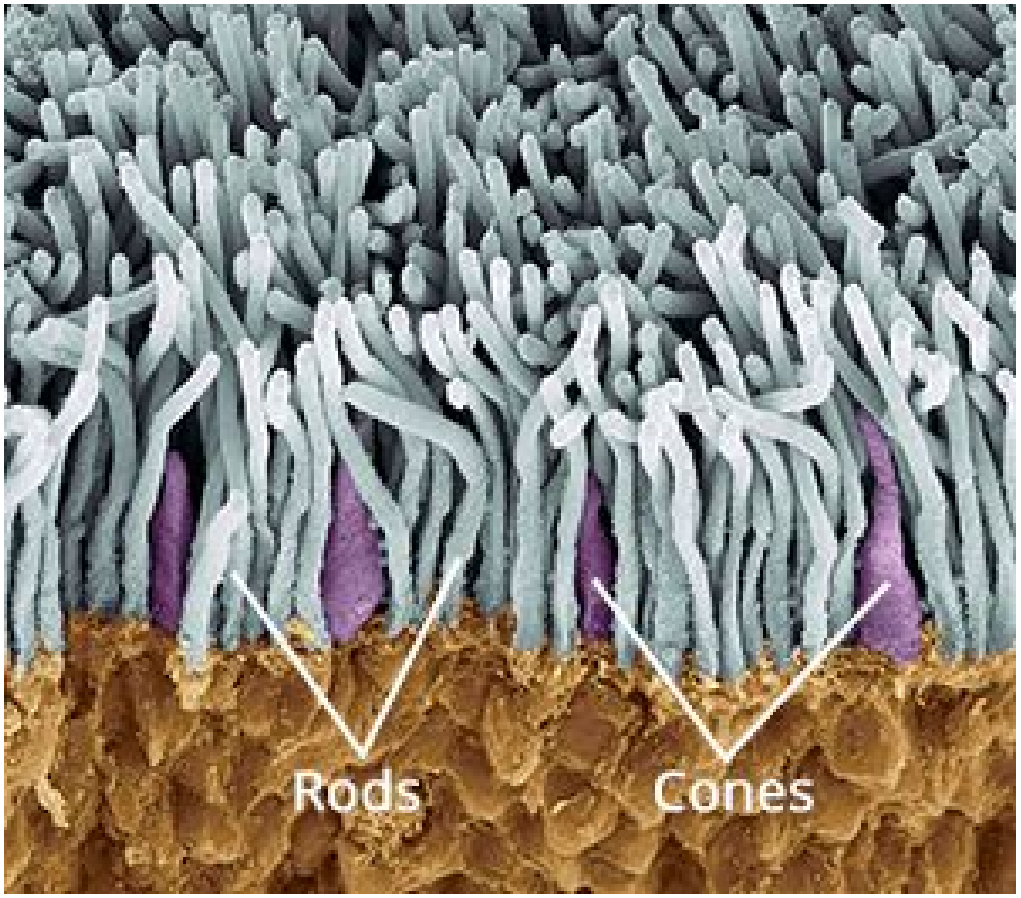


For accuracy and impact when displaying data,
you must consider the way human vision works.



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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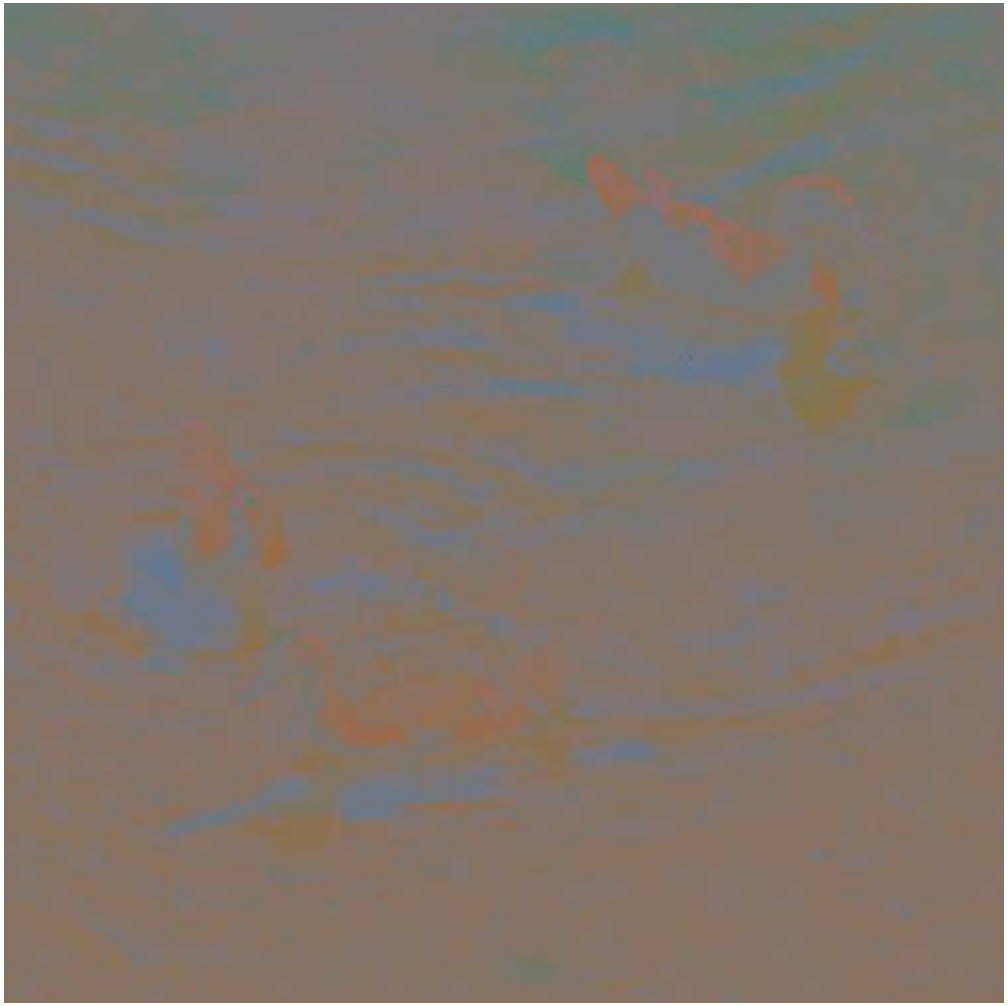

Given only color, images are confusing:
the eye cannot detect edges.

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.

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Color maps without a monotonic increase in brightness often mislead:

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

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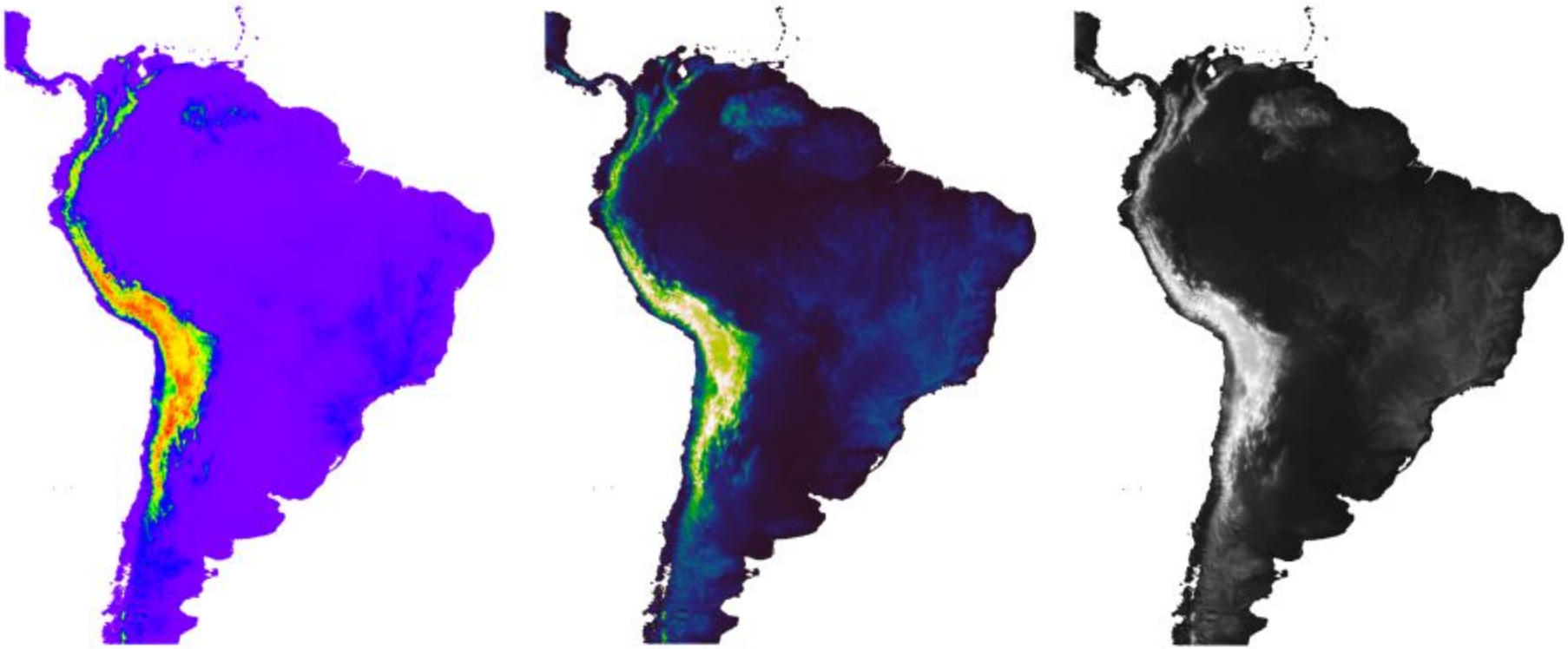

But this turns out to be an artifact of a misleading color bar!

mycarta.wordpress.com

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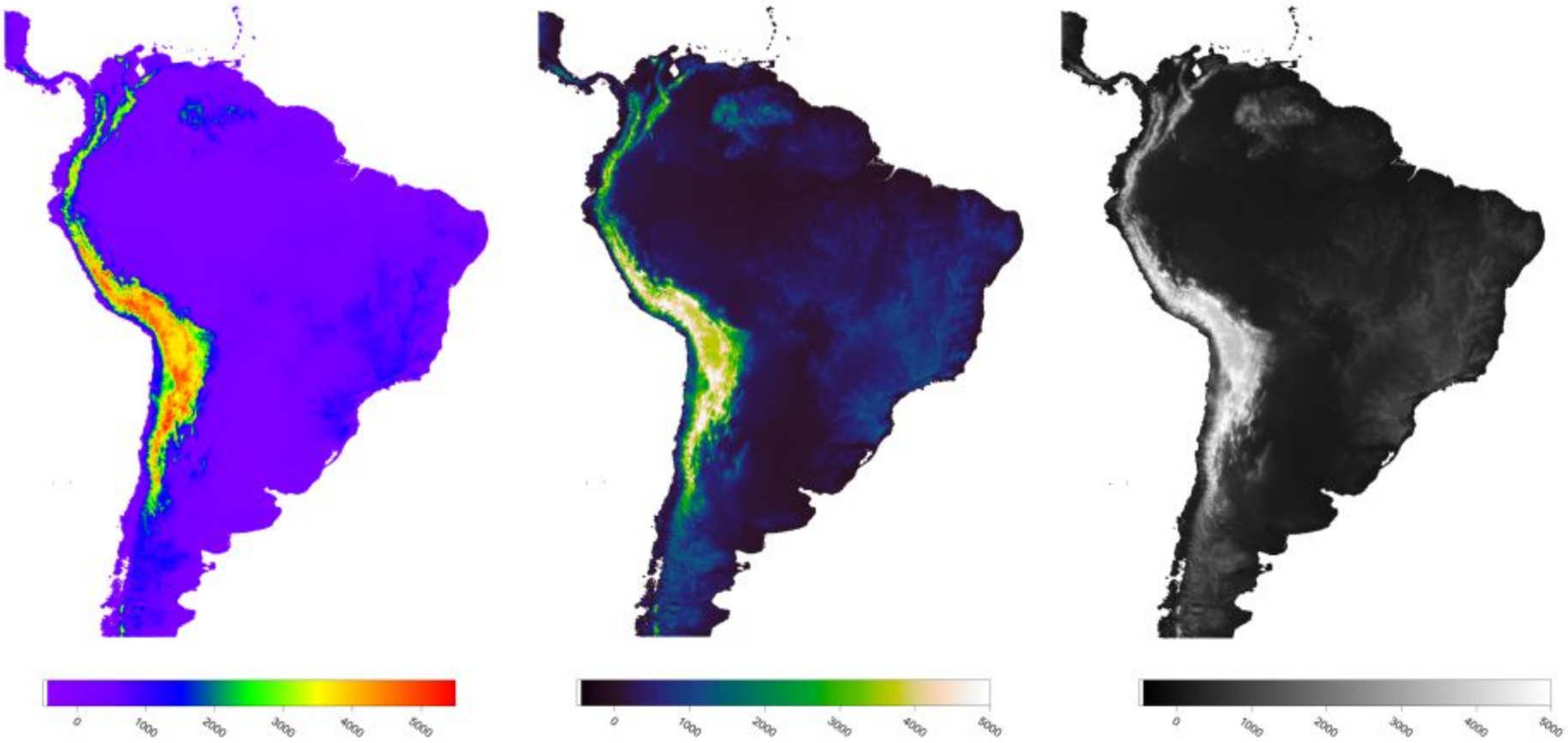
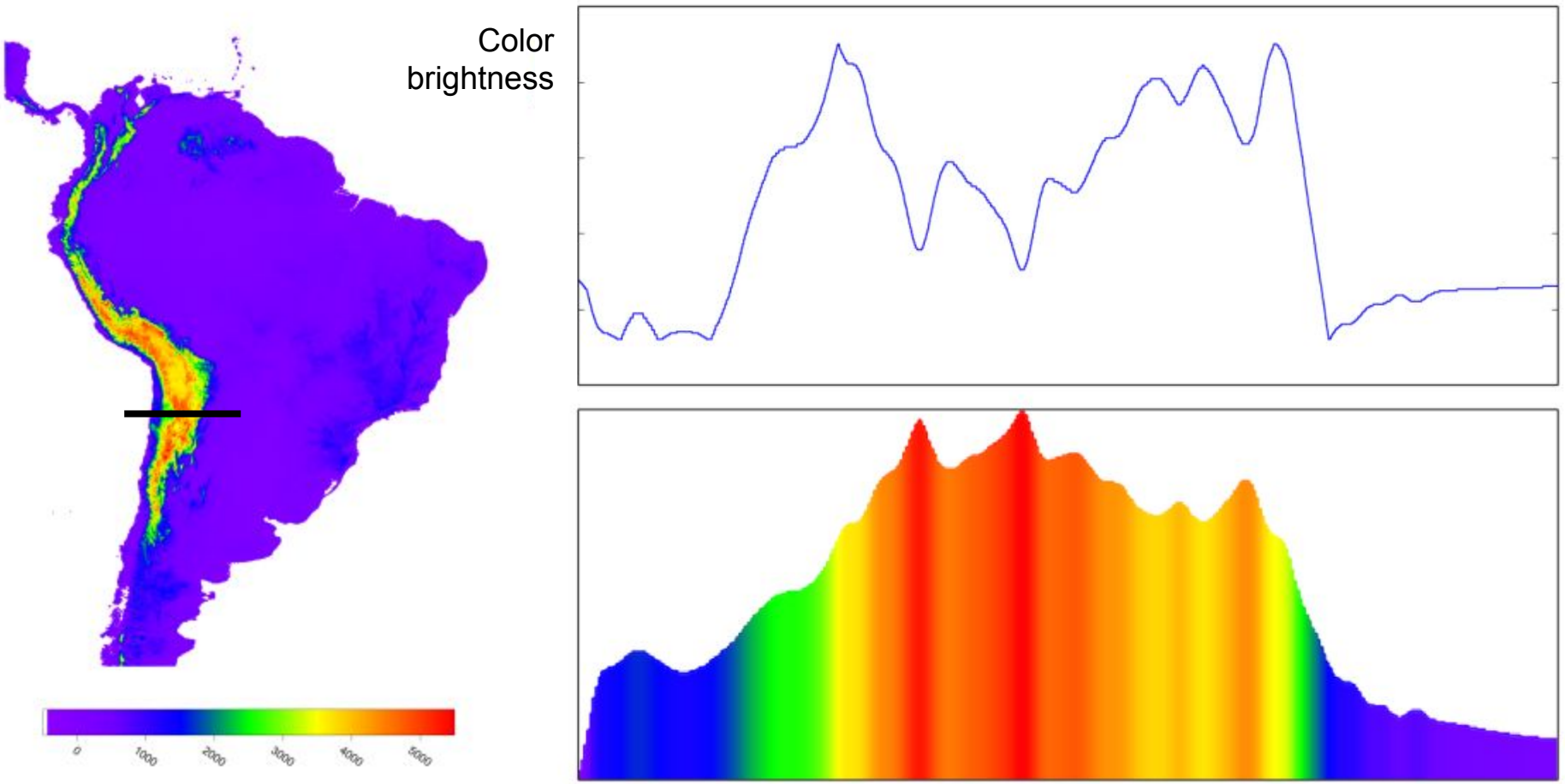


A good color map should be intuitive WITHOUT a color scale. This saves time and avoids mistakes.

mycarta.wordpress.com

Color maps without a monotonic increase in brightness often mislead:

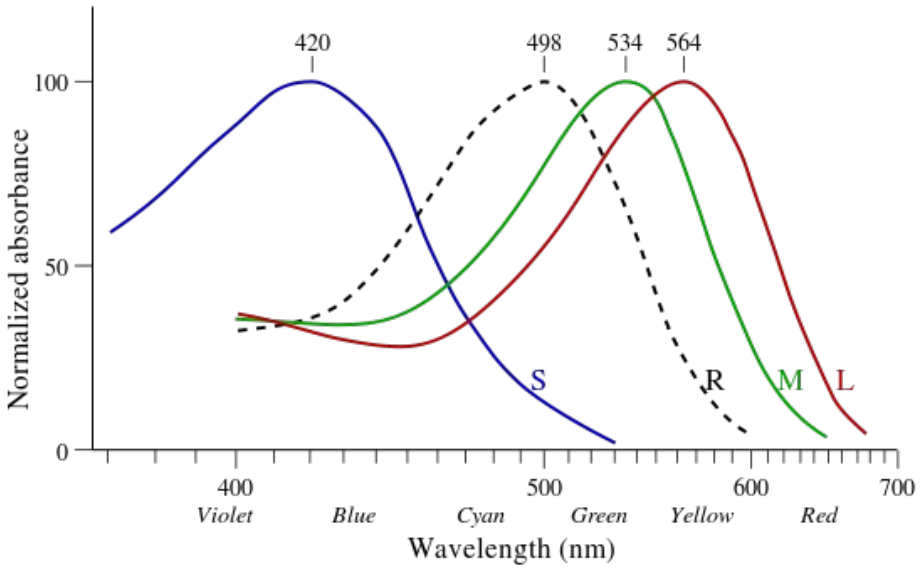


The blue looks lower (dimmer) than the purple, and the red lower than the yellow.

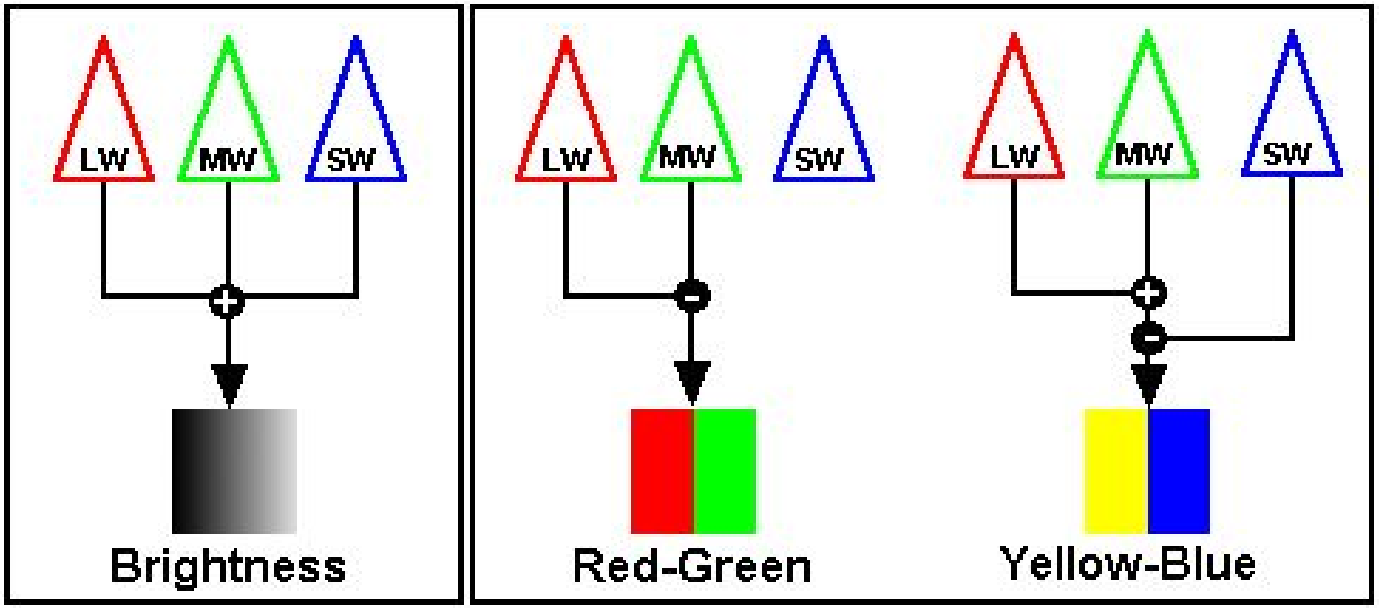
mycarta.wordpress.com

The brain sees color differences, not absolute colors

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

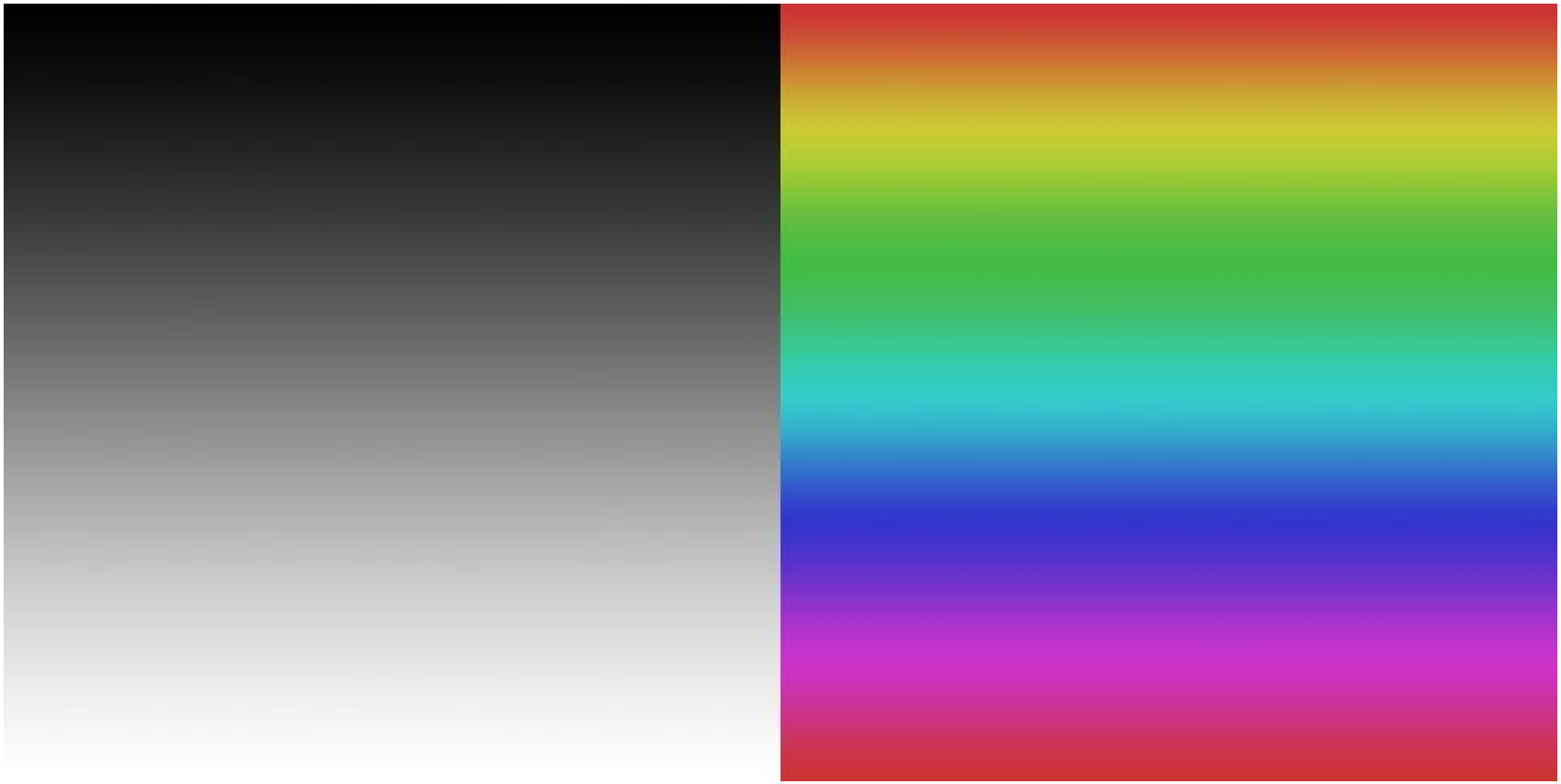


Wikipedia



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

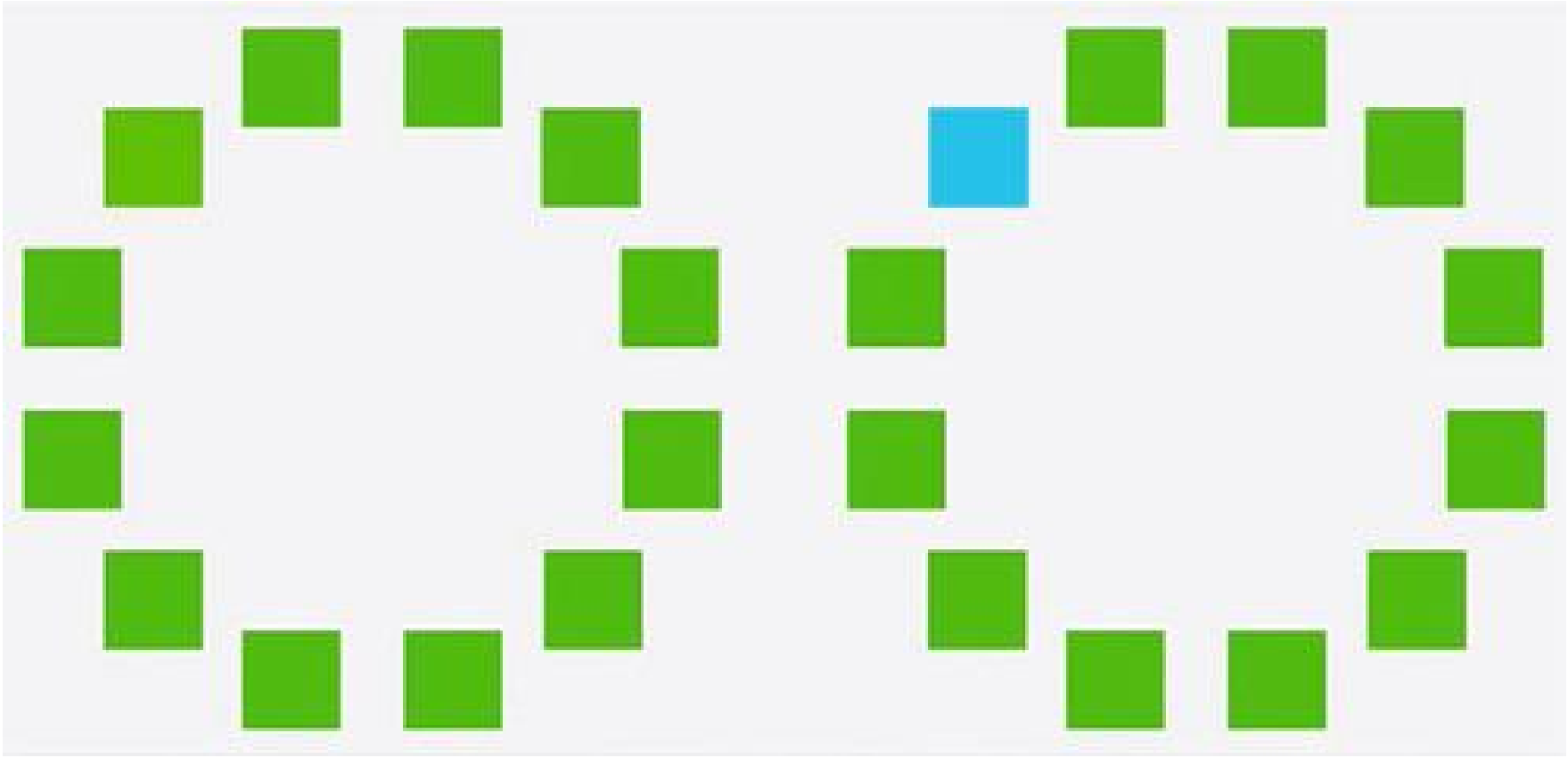
Opponent colors lead to sharp edges in color gradients



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

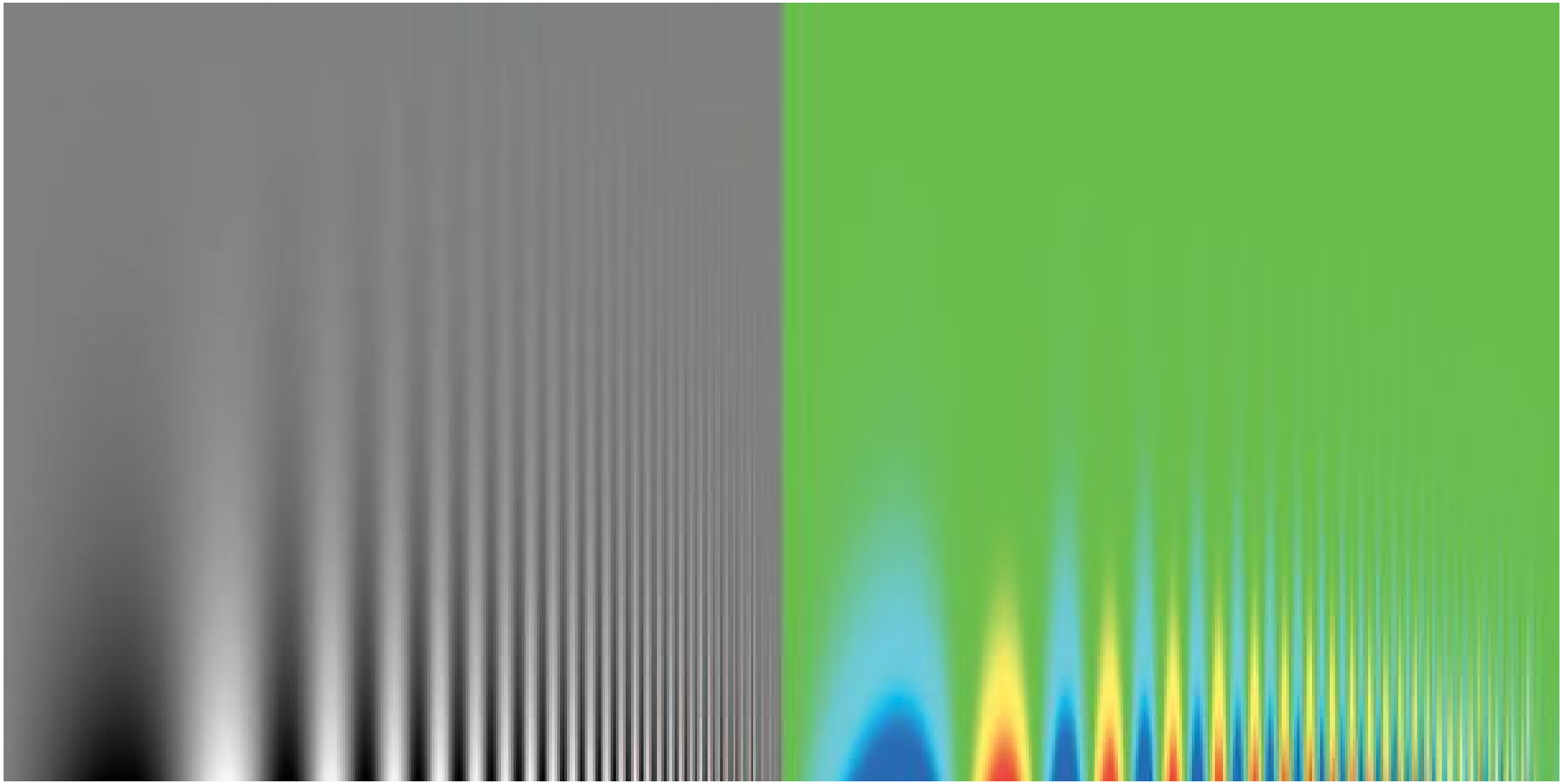
Hue perception can depend on culture

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?

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Bad color maps can distort data interpretation

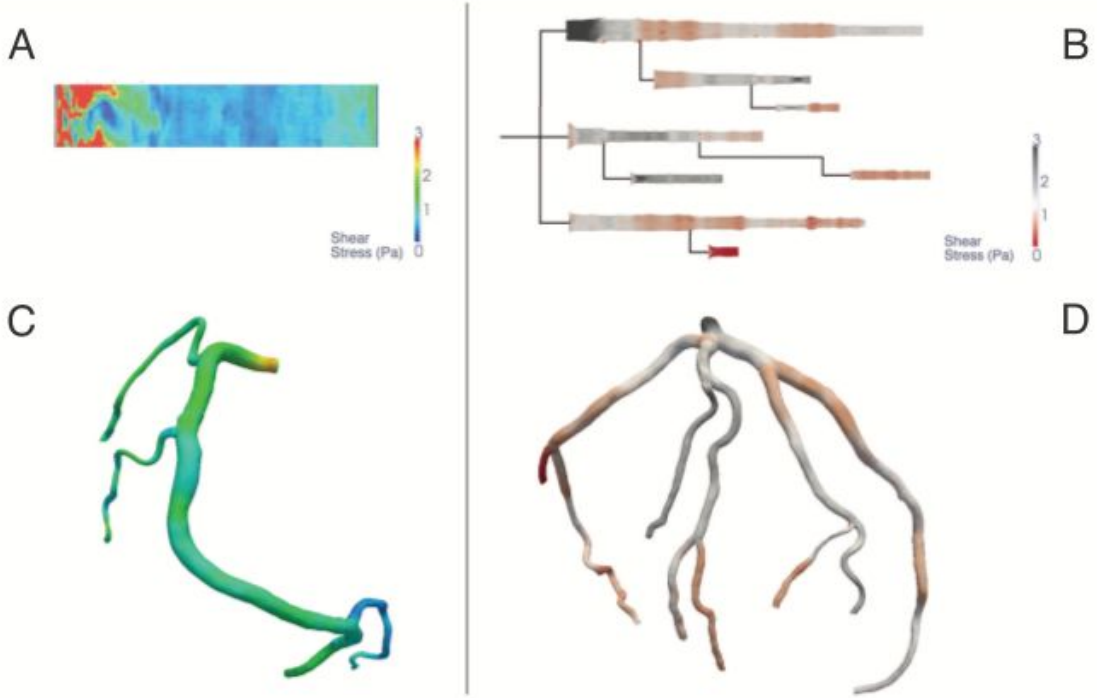
Figure 12. Various color maps applied to a face image. The color maps in the bottom row have monotonically increasing lightness, resulting in a natural, recognizable image.

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*



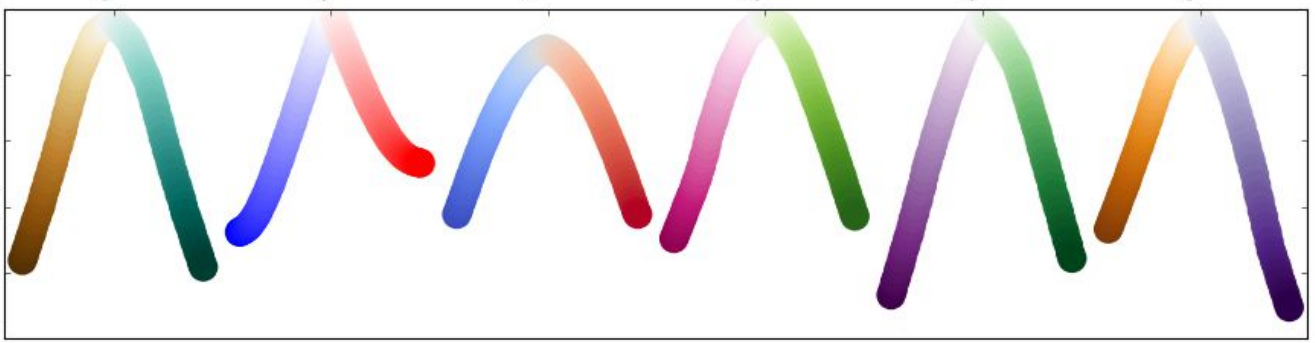
Physicians were faster and better at diagnosing heart disease when using a perceptual color scheme, even though they claimed to prefer the rainbow.

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)

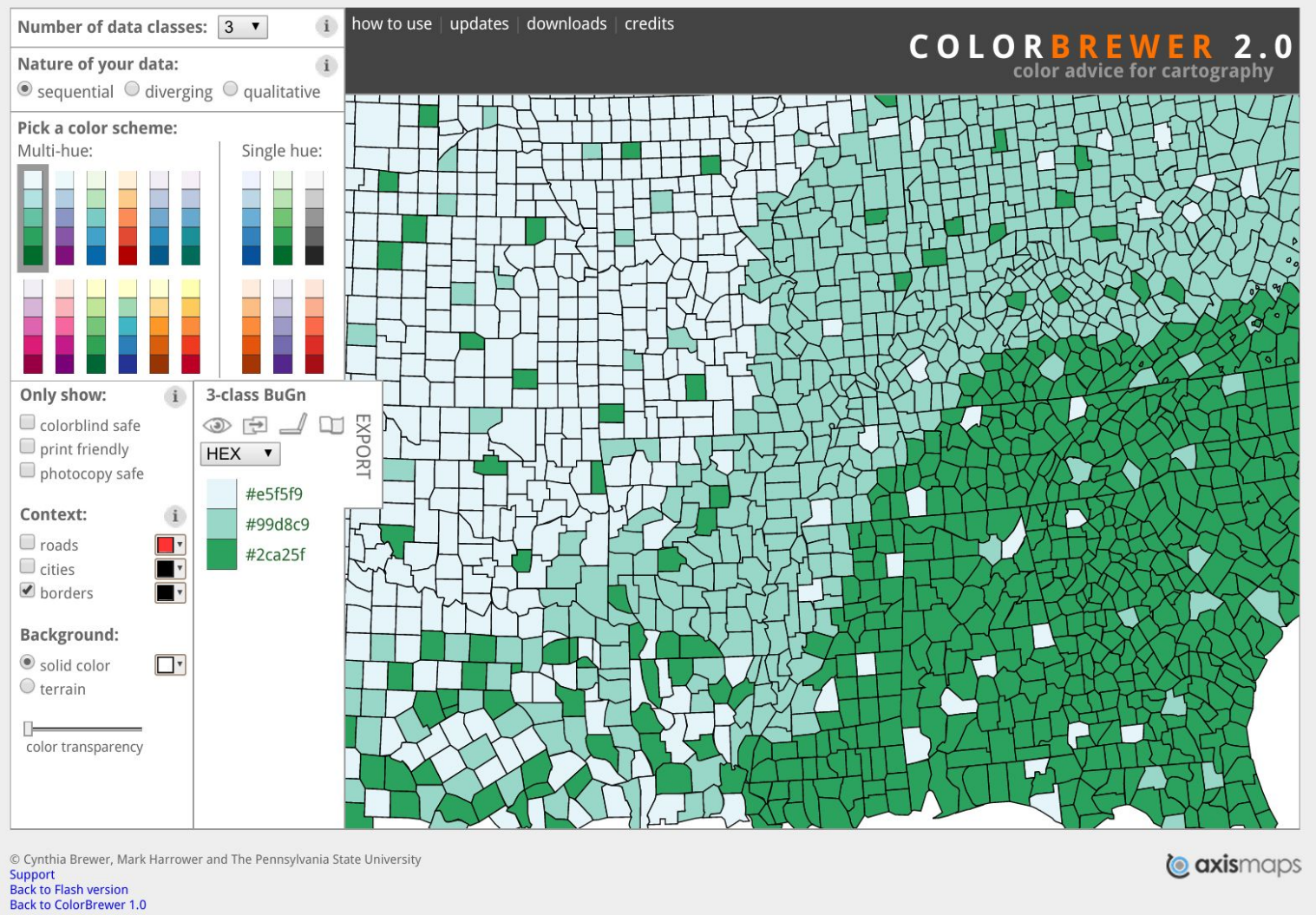
   - Diverging data, with a critical transition (velocity, flux)



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

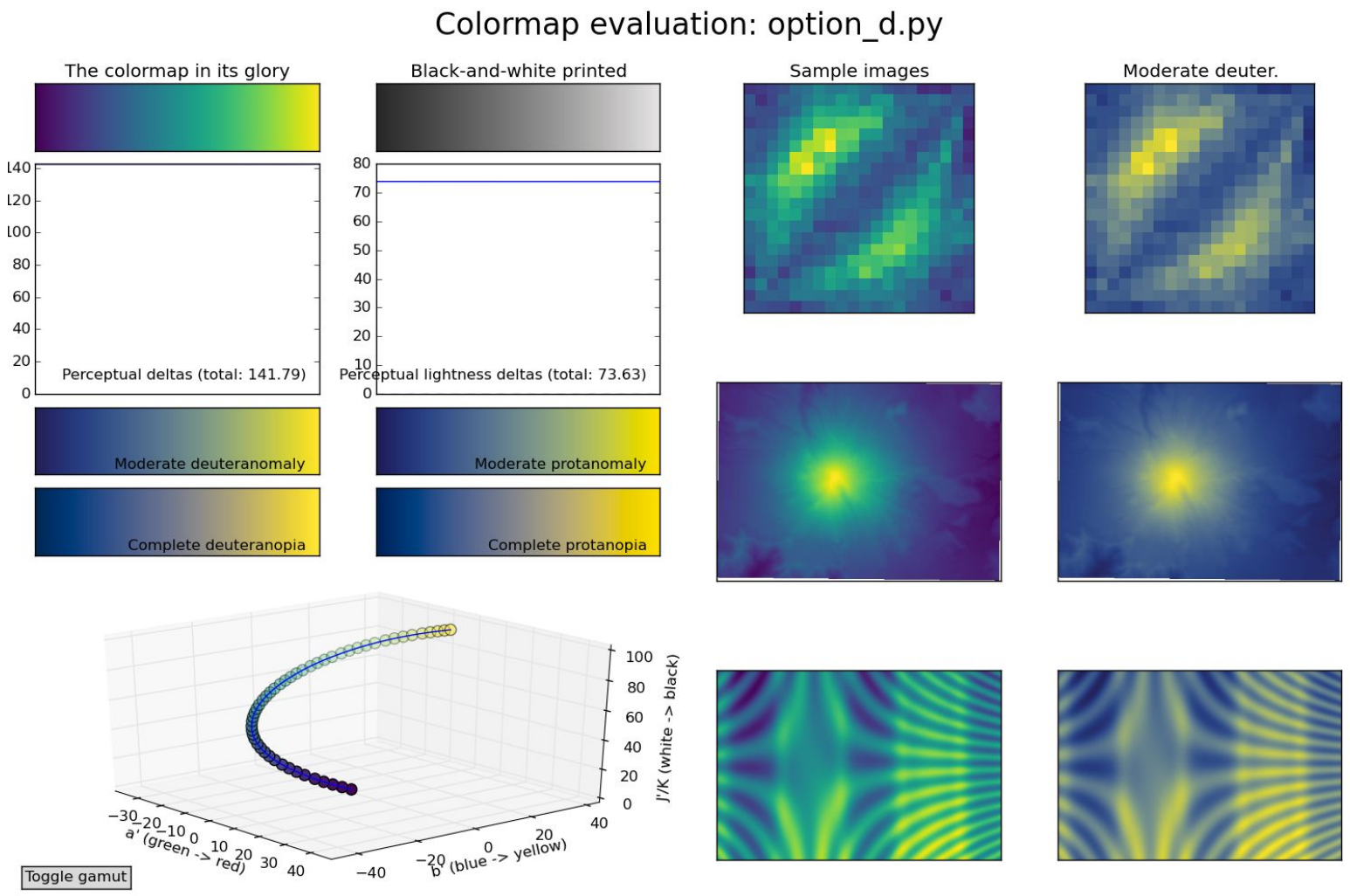
But remember to use brightness as the primary encoding!

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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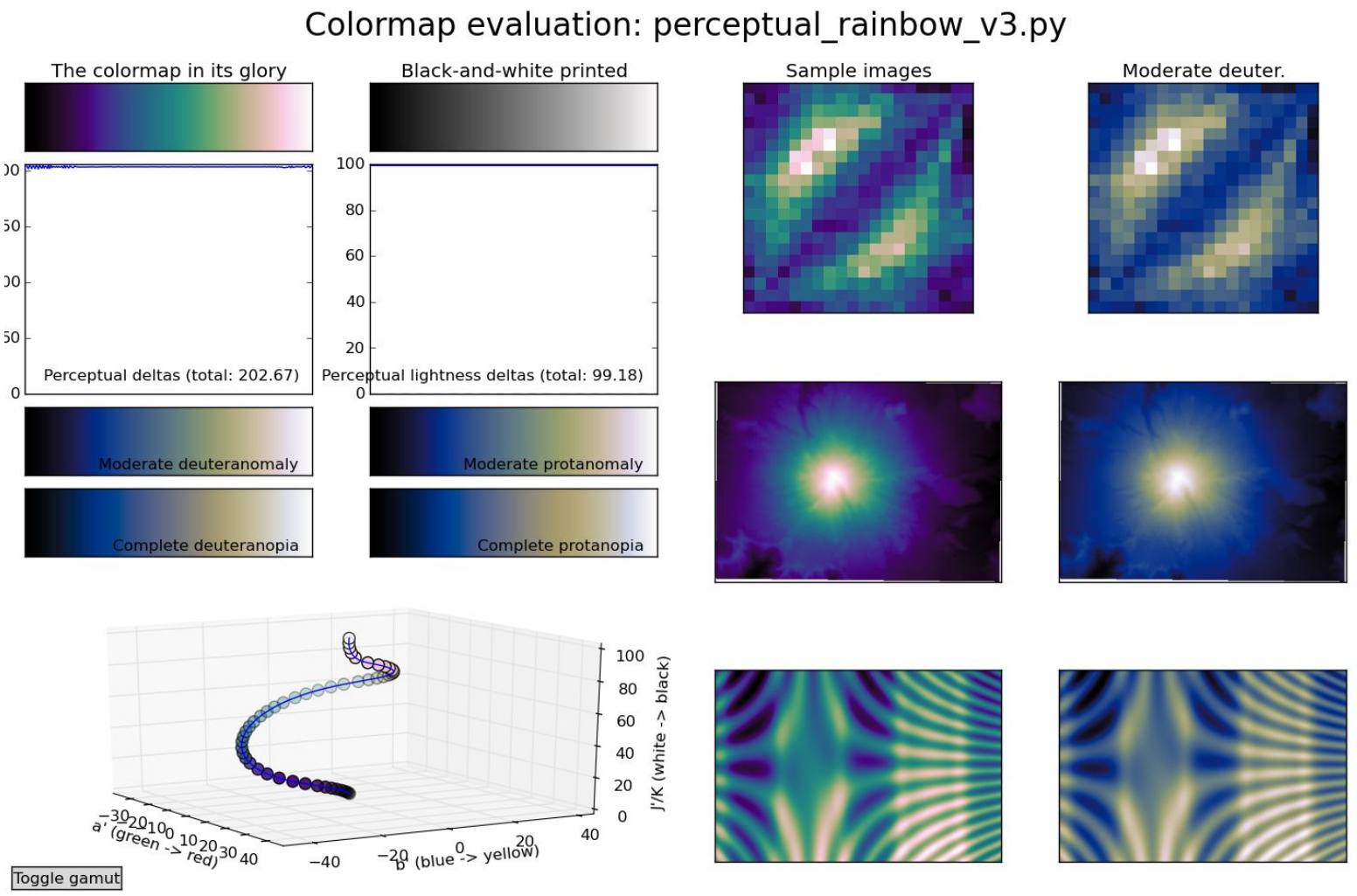

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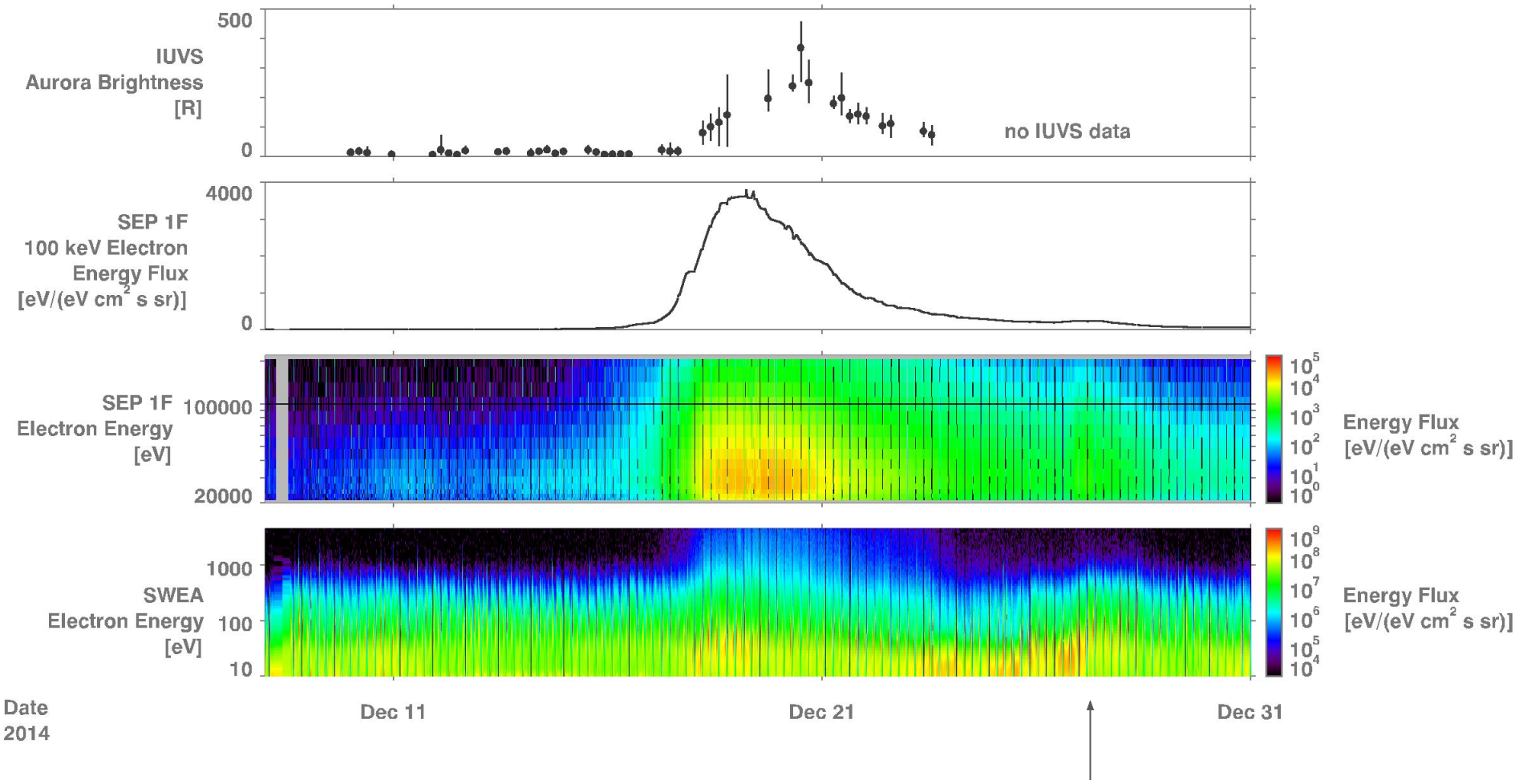
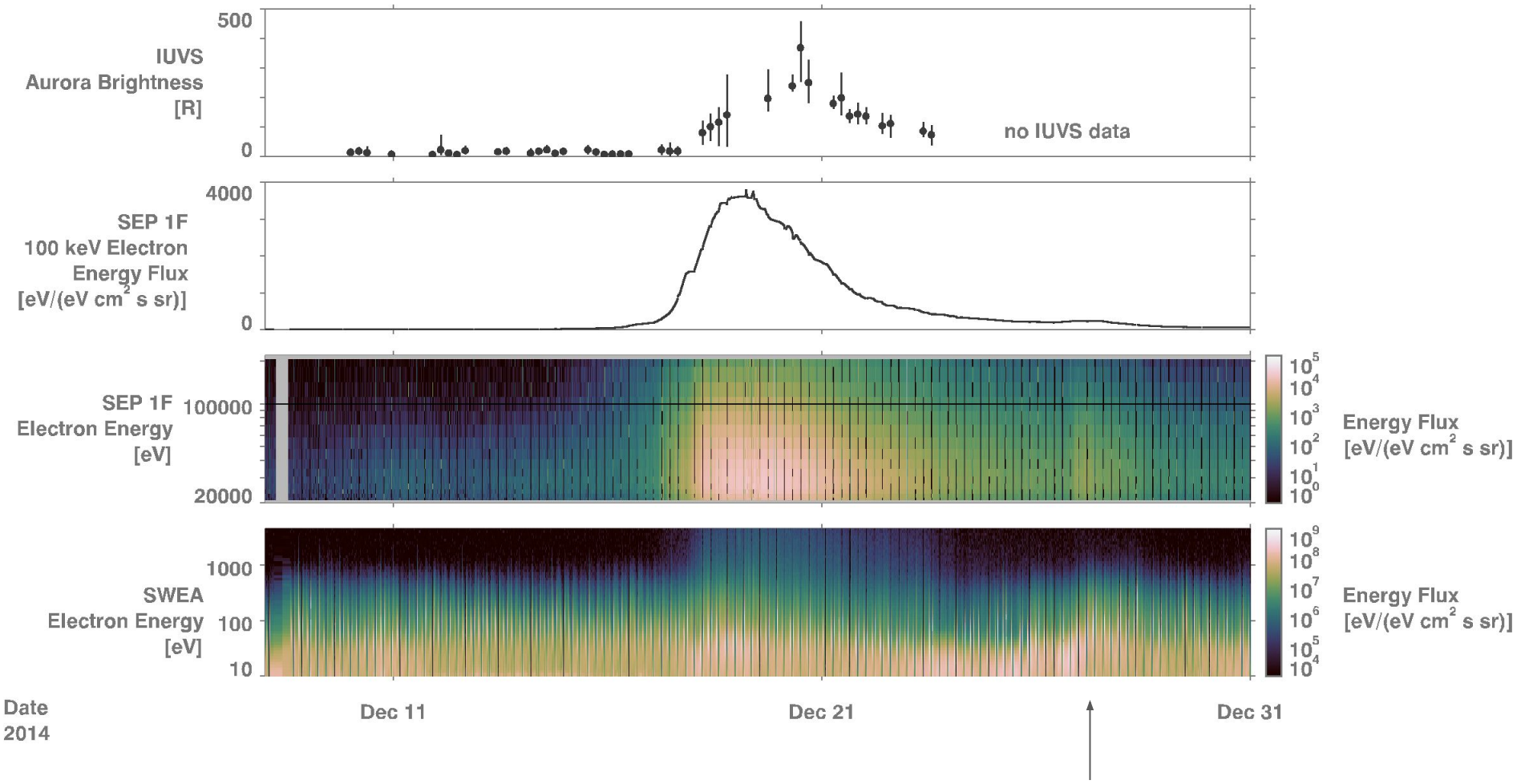
Perceptual colormaps improve data analysis



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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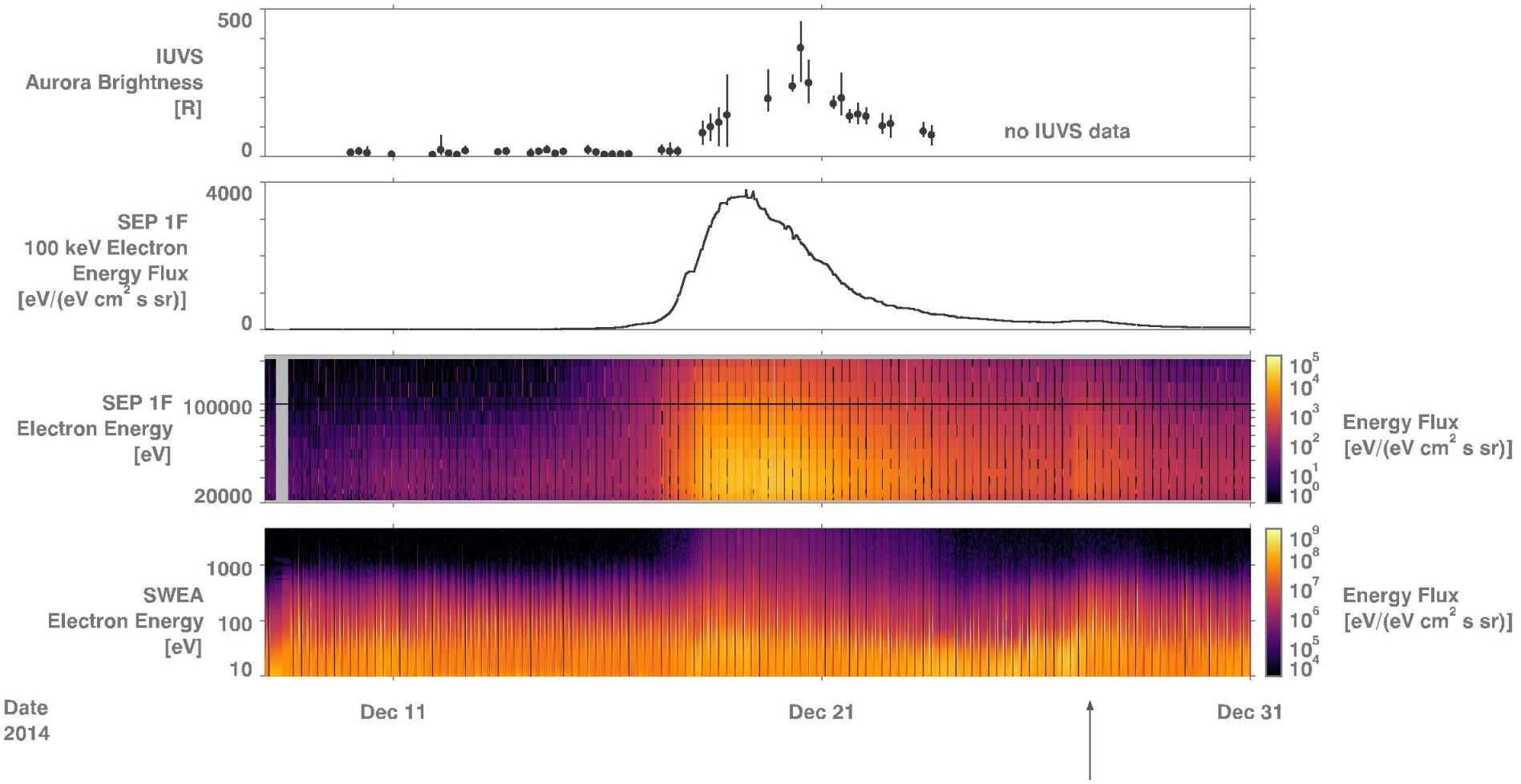

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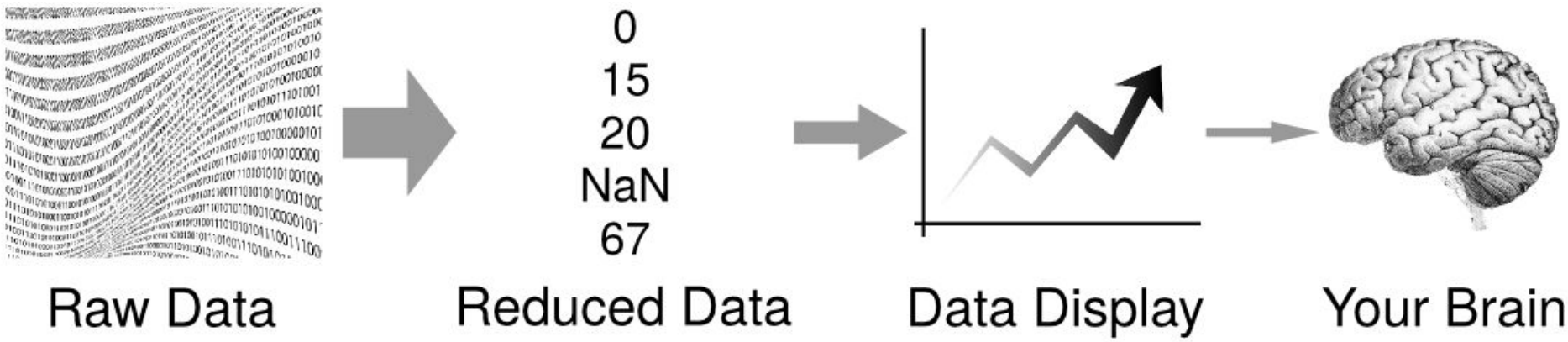

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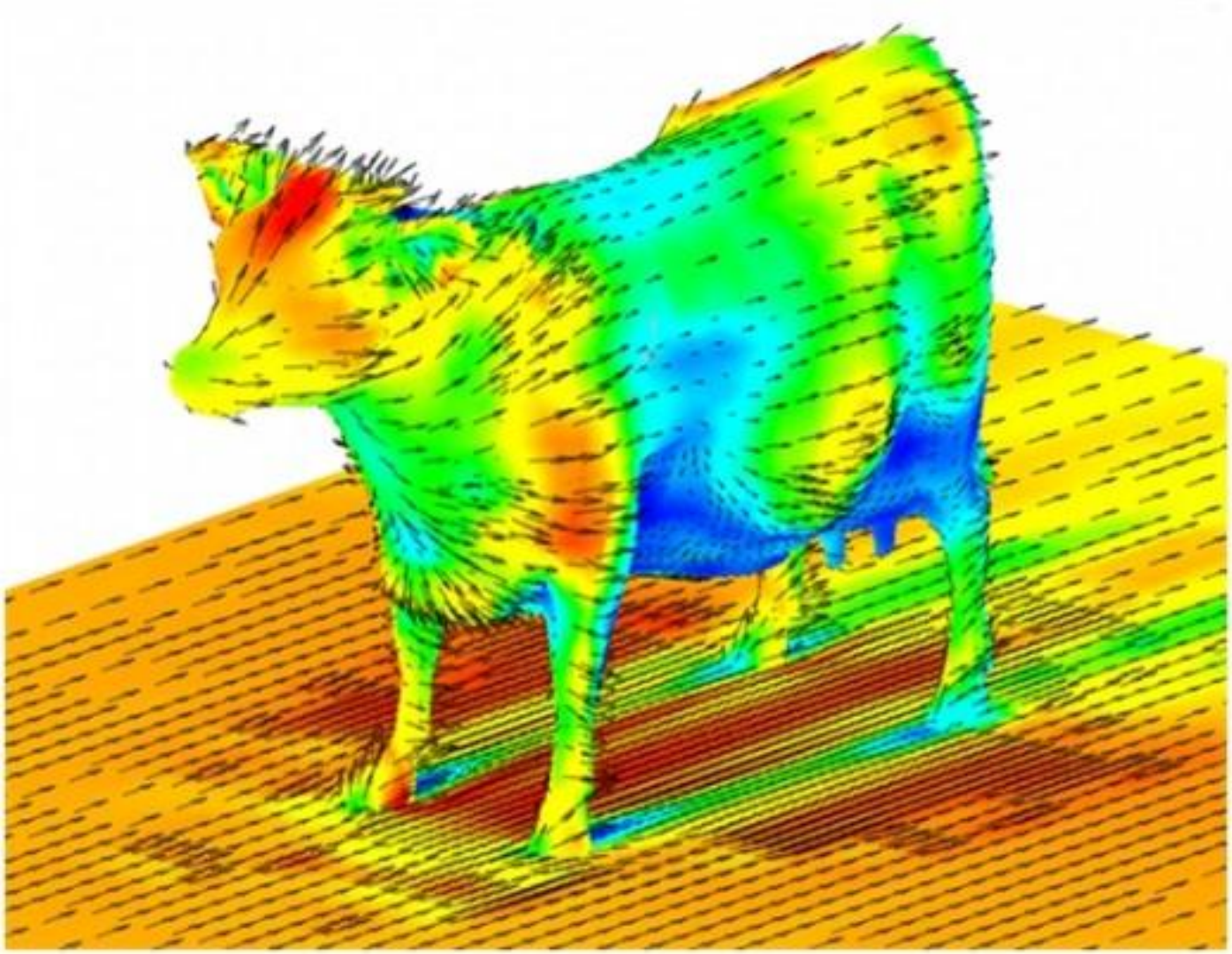


Friends don’t let friends use bad color maps!

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.

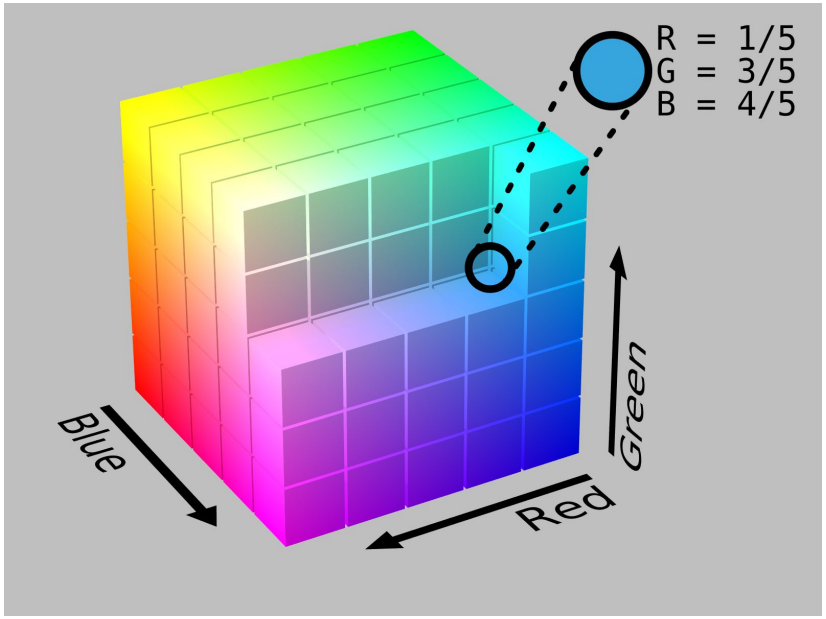
"The Smallest Effective Difference", chapter 4 of *Visual Explanations* by Edward Tufte

This chapter contains essential information for producers of data graphics, explaining that subtle, natural distinctions are almost always better than trying to make everything obvious and bold.

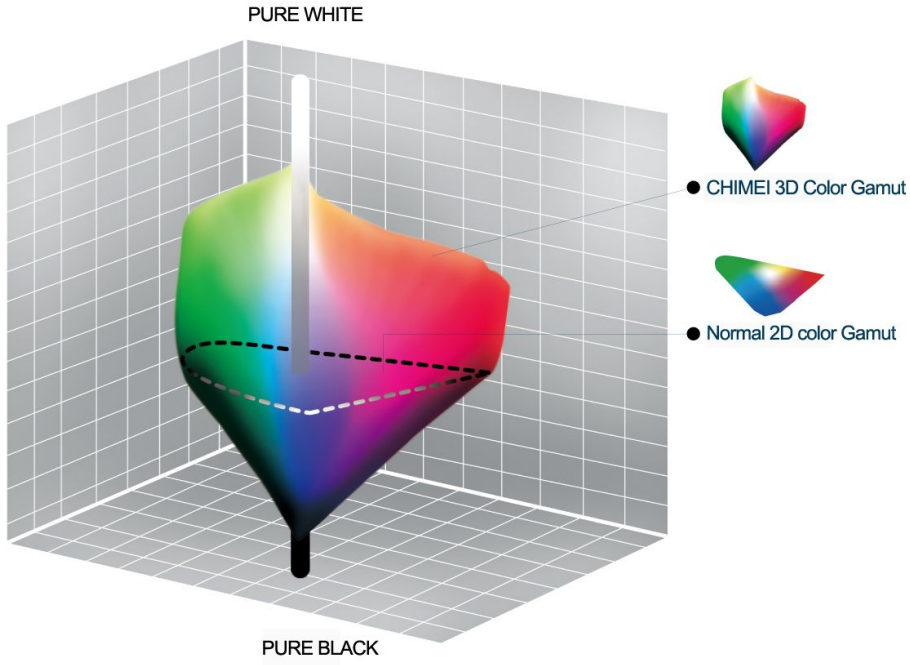
Backup

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.

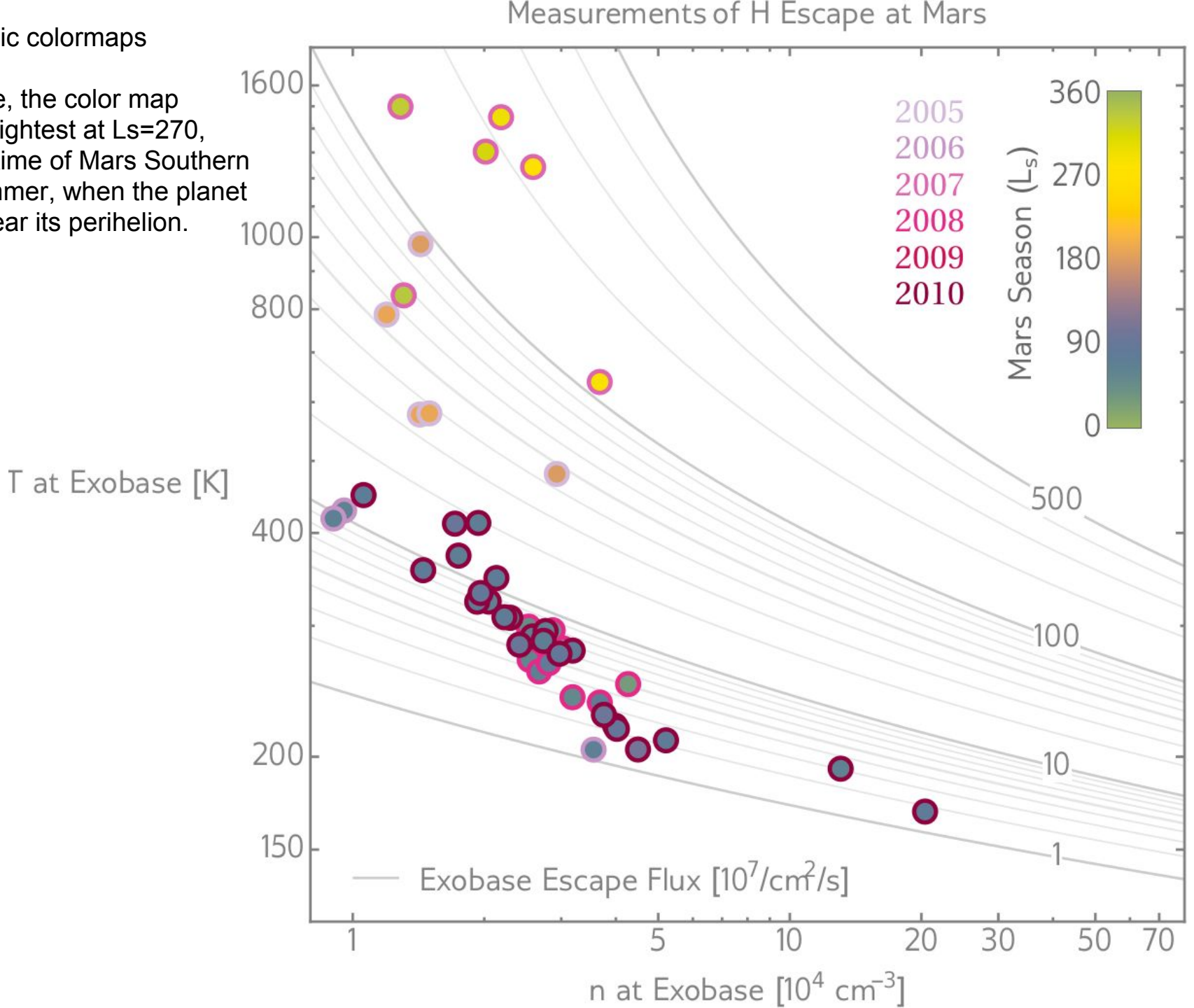


In a perceptual color space,
euclidean distance is
perceived color difference.

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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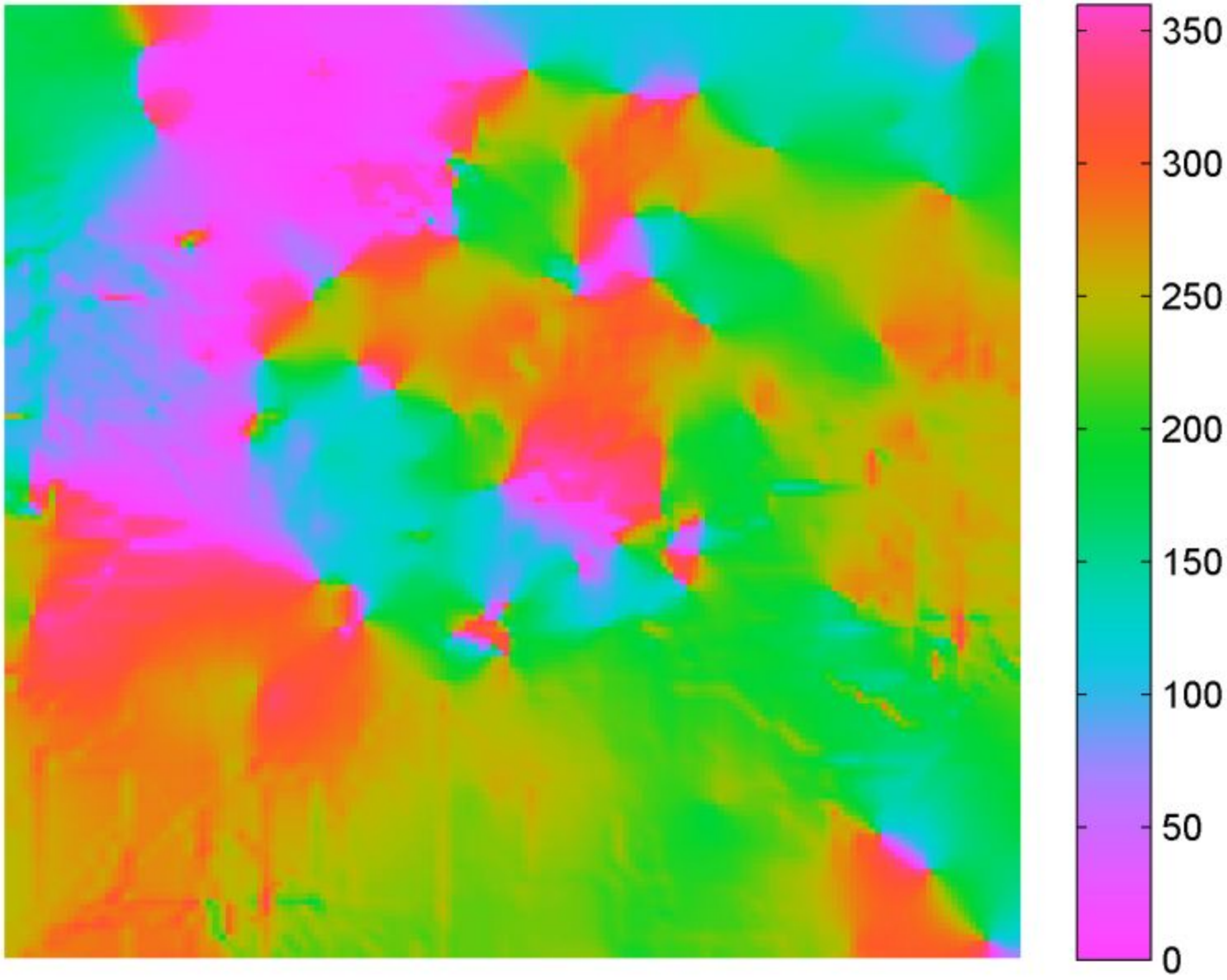
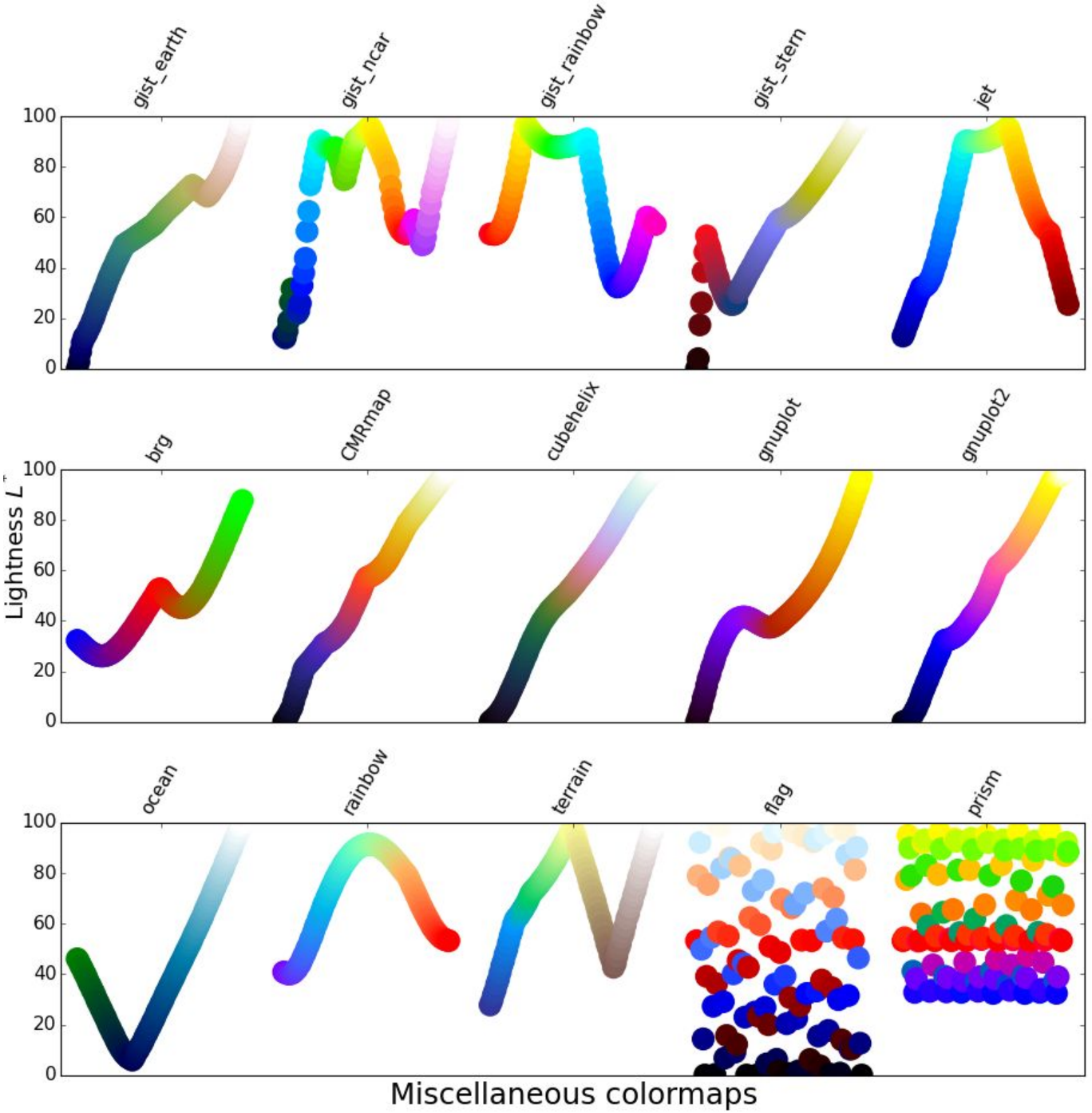


BAD: brightness is not the primary encoding!


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