

The misuse of colour in science communication

Somewhere over the rainbow

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 @janbabaa

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06 juin 2021

Agenda

What is it about ?

How we see colour ?

The jet/rainbow colour map.

How to choose a *scientific* colour map?

Example of Greenland Ice Thickness

“In progress” Case study of Antarctica

Ressources

The misuse of colour in science communication.

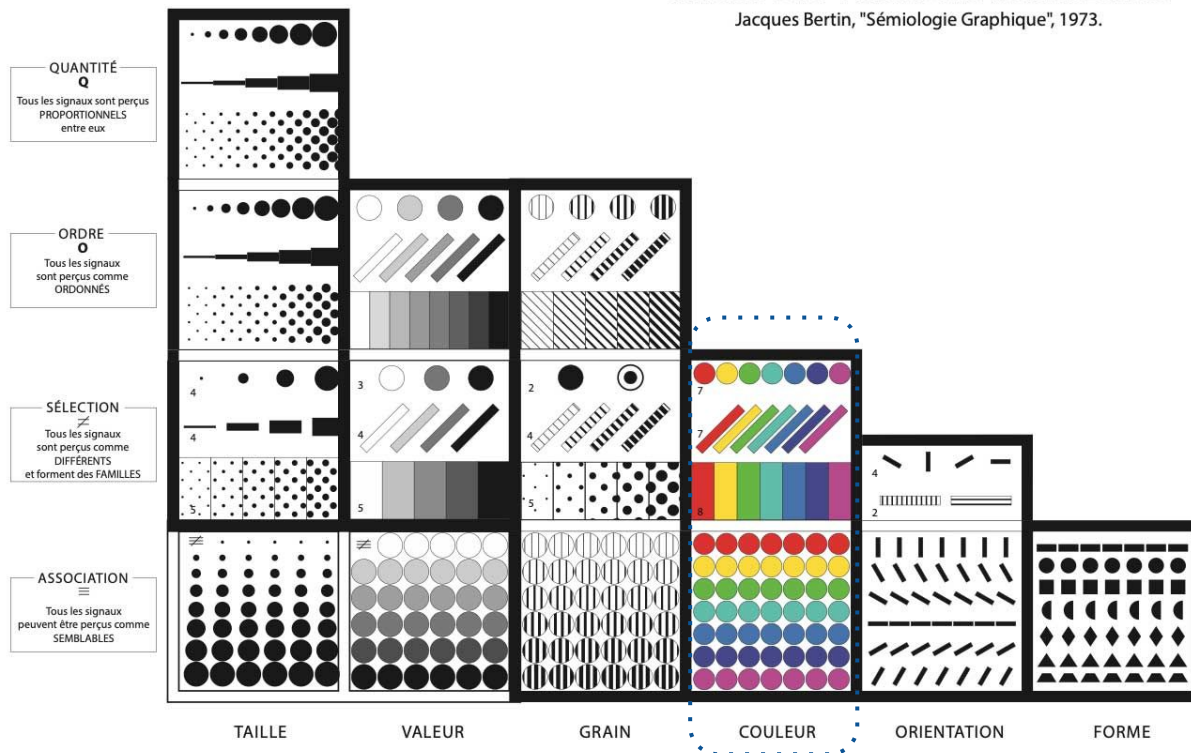
Nat Commun 11, Cramer, F., G.E. Shephard, and P.J. Heron (2020)

What is it about ?

Visual Encoding

NIVEAU DES VARIABLES RÉTINIENNES

Jacques Bertin, "Sémiologie Graphique", 1973.

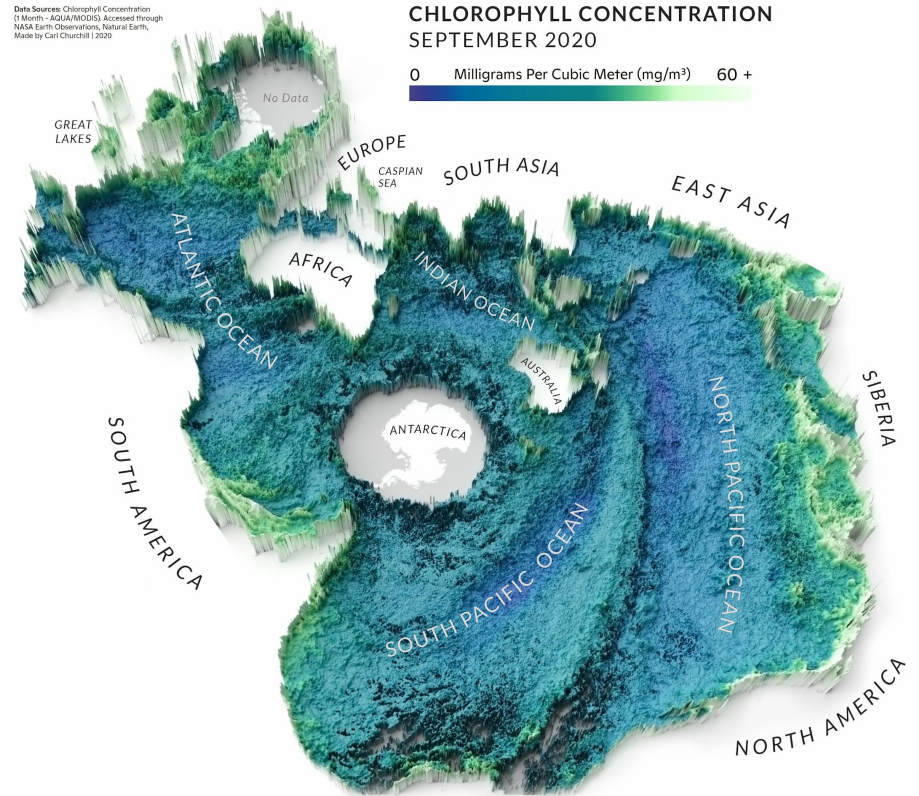


What is it about ?

The colour variable

The use of colours to **visually encode** one numerical quantity of interest.

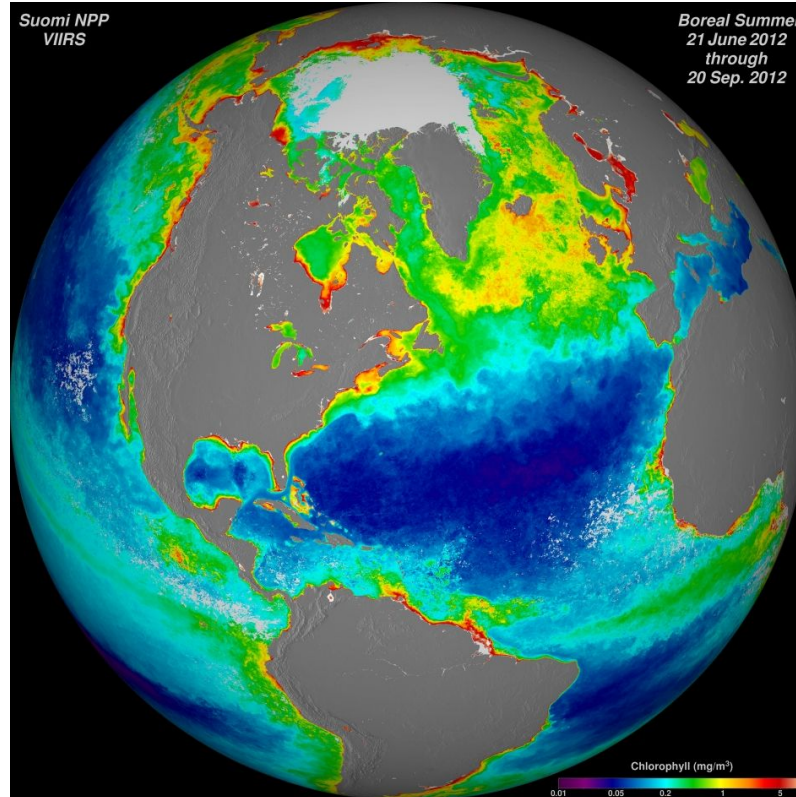
For Geoscientific data, this requires **a colour map**.



@Cchurchili

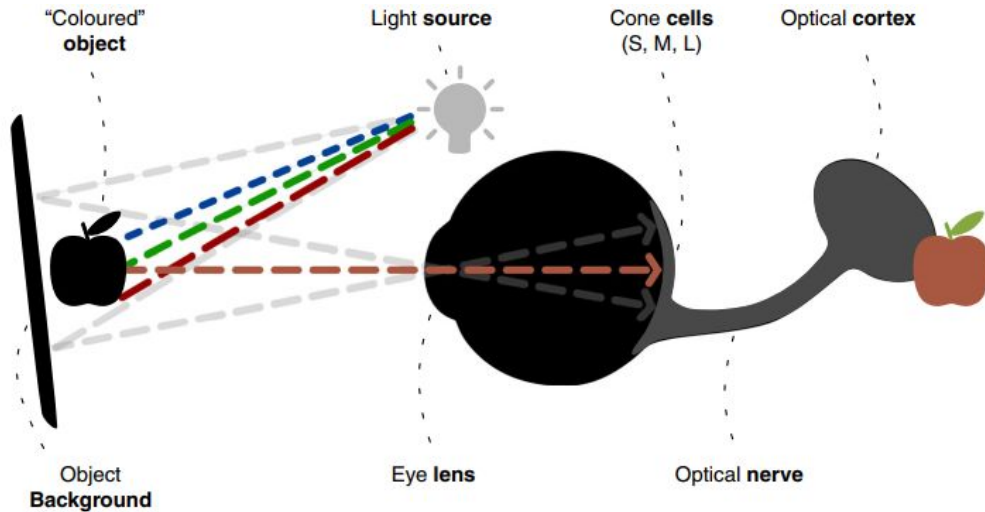
What is it about ?

The jet/rainbow colour map



How we see colour ?

The biology and physics together



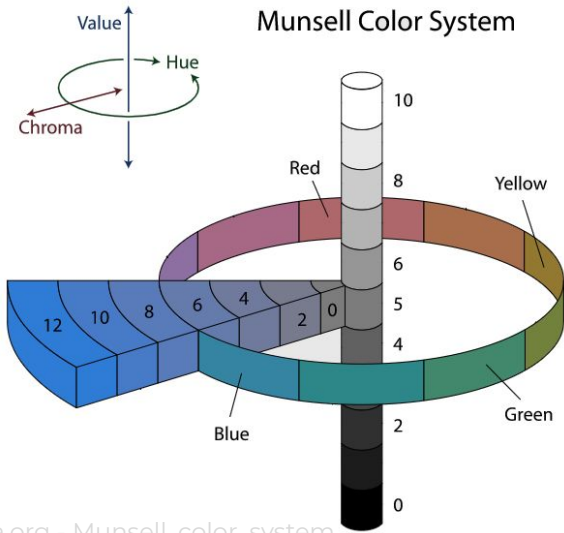
Cone cells transform light energy into neurological information.

No uniform colour perception among individuals.

The human eye can perceive more variations in warmer colors than cooler ones.

How we see colour ?

Color space and Color Appearance Model



Wikipedia.org - Munsell_color_system

CIECAM02/16

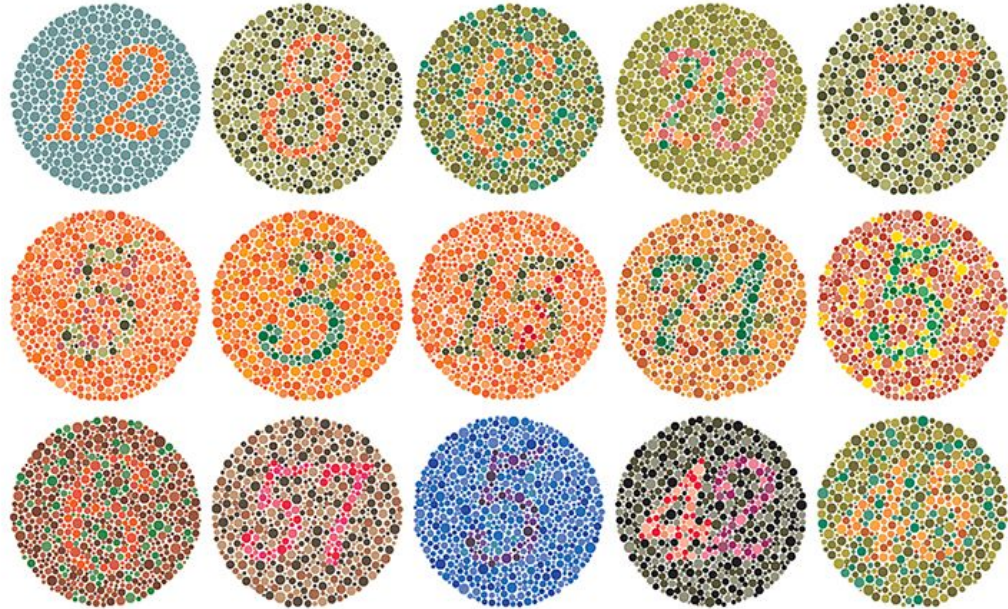
Color Appearance Modelling for Color Management Systems. Commission internationale de l'éclairage (CIE)

Accurate model of color based on six technically defined dimensions of color appearance: **brightness** (luminance), **lightness**, **colorfulness**, **chroma**, **saturation**, and **hue**.

Hue — another word for color. **Saturation** (chroma) - more or less grey. **Lightness** (value) - from black to white.

How we see colour ?

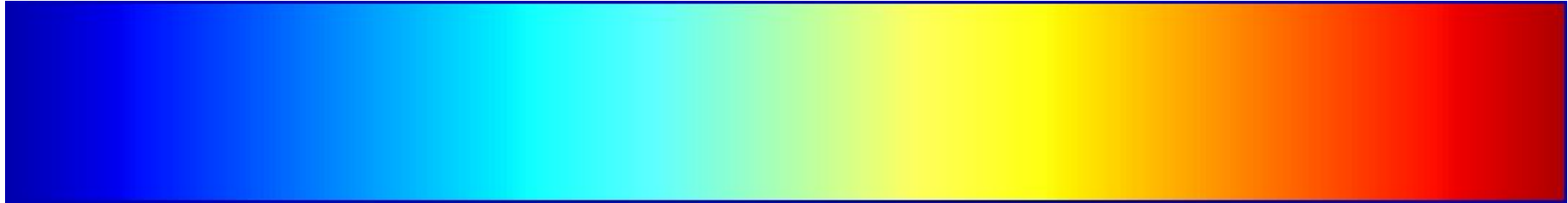
Colour-vision deficiency



Colour perception isn't uniform amongst individuals.

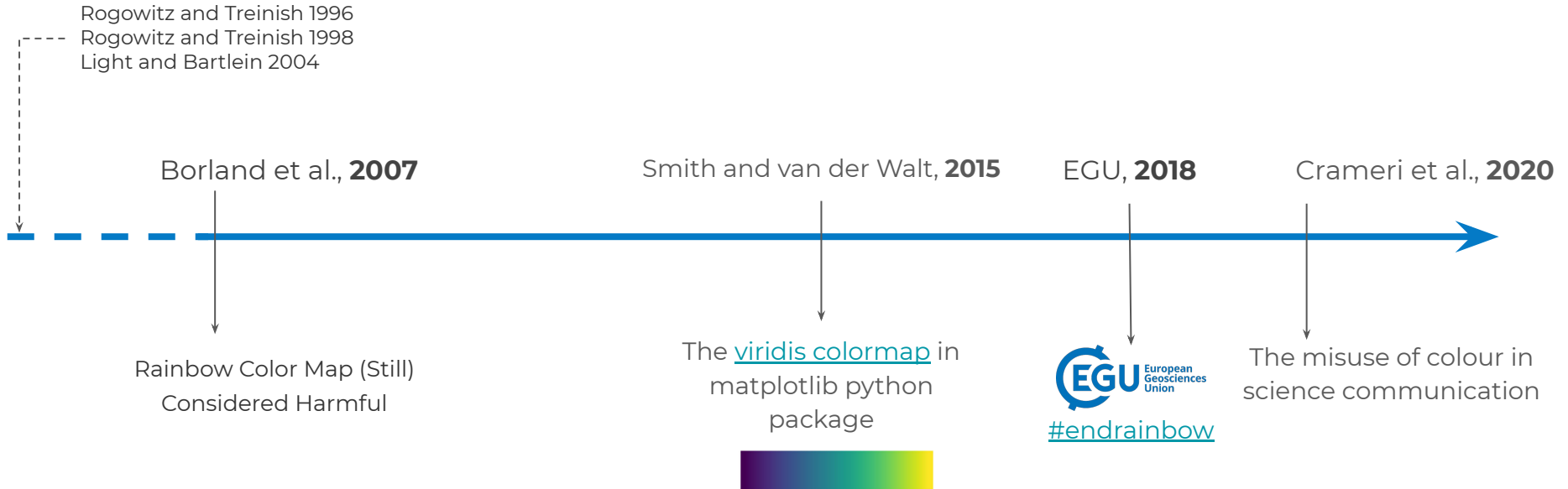
Want to know more ? color-blindness.com/coblis-color-blindness-simulator/

The jet/rainbow colour map



The jet/rainbow colour map

A long term discussion in science.



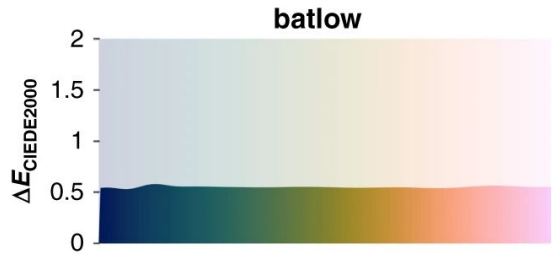
The jet/rainbow colour map

Perceptually uniform colormap: a colormap in which equal steps in data are perceived as equal steps in the color space.

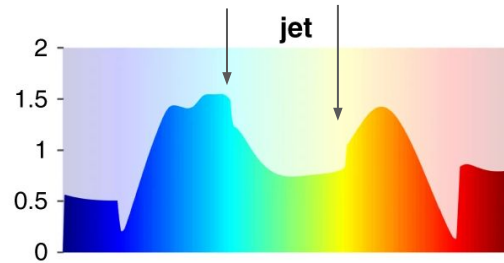
$\Delta E_{\text{CIEDE2000}}$

Incremental perceptual colour difference along a colour gradient.

Perceptually uniform colormap



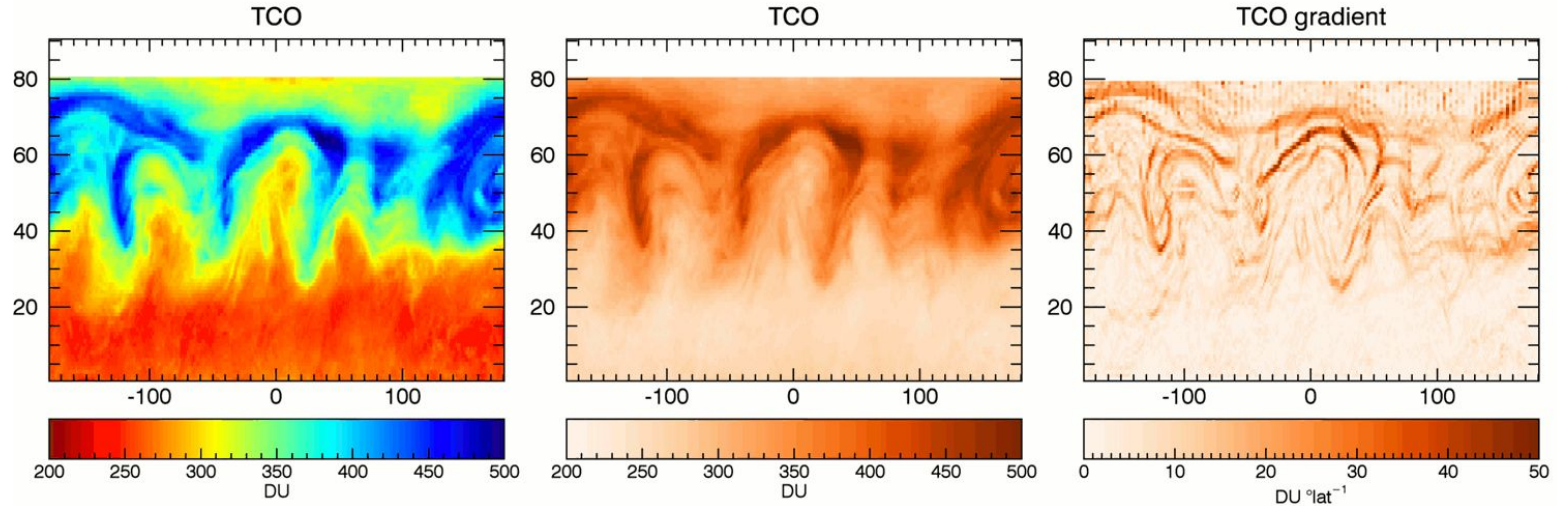
None Perceptually uniform colormap



Data are perceptually distorted.

The jet/rainbow colour map

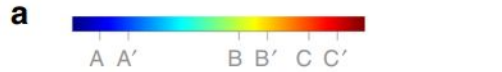
Example: the Total Column Ozone (TCO)



A clear apparent boundary between the yellow and green regions, which was identified as a 'sub-tropical' front, and highlighted with a blue line.

(Hudson et al. ,2006) revisited by Davis S. (NOAA)

The jet/rainbow colour map



Incremental contrast



Intuitive order



Batlow has intuitive colour order.

sequential ordering is not intuitively possible for jet.

Unscientific colour maps are...

- **distorting** the data,
- **unintuitive**,
- excluding and **discriminating** people with colour-vision deficiencies,
- not readable in black and white.

As a consequence:

Do not use unscientific colour maps in your scientific work,

Don't accept papers that publish graphics using unscientific colour maps.

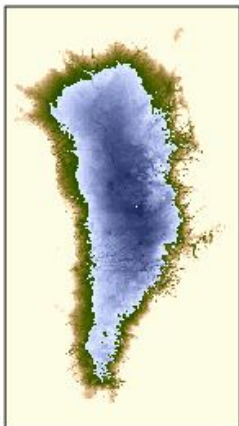
Scientific colour maps are...

- ✓ Perceptually uniform *i.e.*, NOT distorting the data,
 - ✓ Perceptually ordered *i.e.*, intuitively readable,
 - ✓ Colour-vision-deficiency friendly *i.e.*, NOT excluding certain readers,
 - ✓ Readable as black-and-white print *i.e.*, convenient,
-
- + Available in all major data formats *i.e.*, openly accessible,
 - + Including diagnostics; peer-reviewed; citable *i.e.*, tested and trustworthy

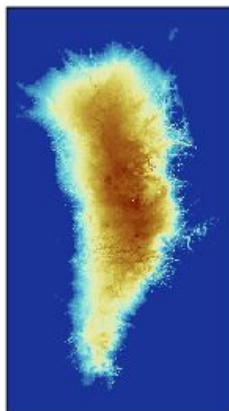
How to choose Scientific color maps ?



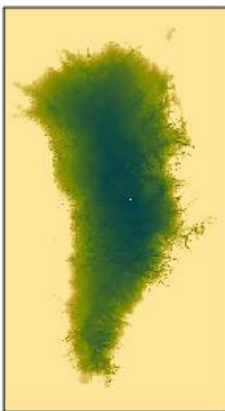
oleron



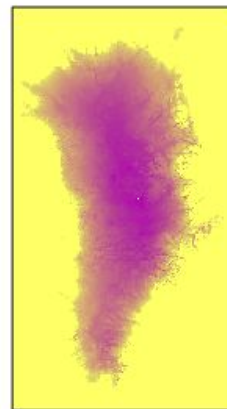
roma



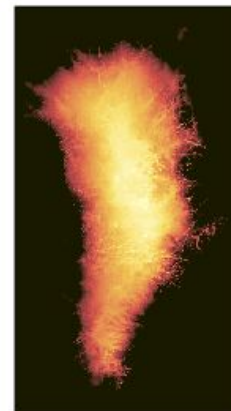
bamako



buda



lajolla



Greenland
ice
thickness

How to choose ?

They made them for us.

[Colobrewer](#)

[MPL Colour Maps](#)

[Cividis colour map](#)

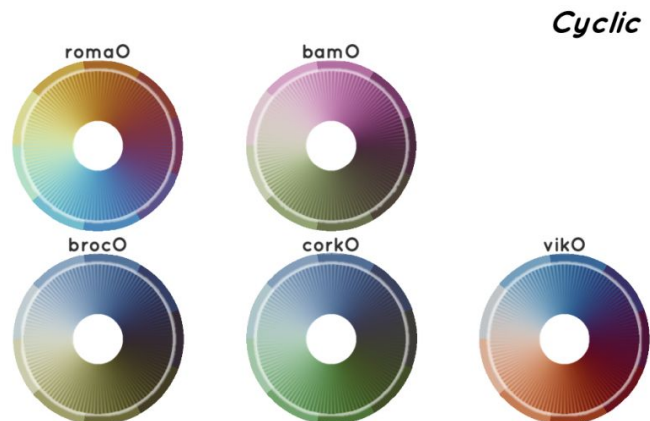
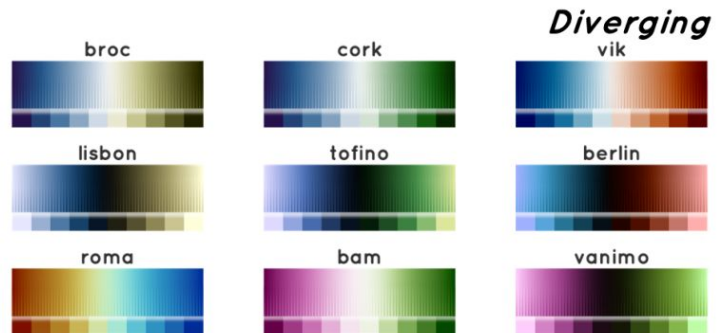
[CMOcean Colour Maps](#)

[CET Colour Maps](#)

[Scientific colour maps](#) → on [Zenodo](#)

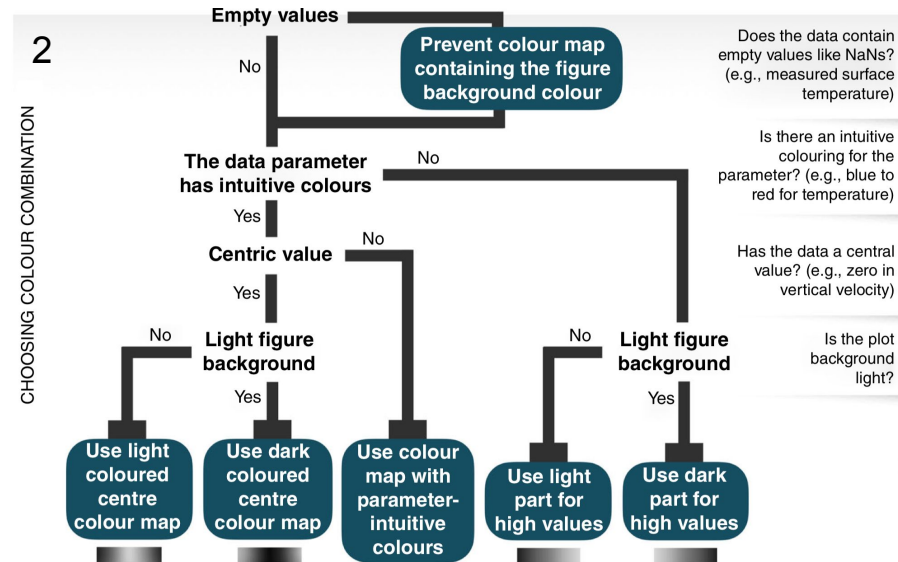
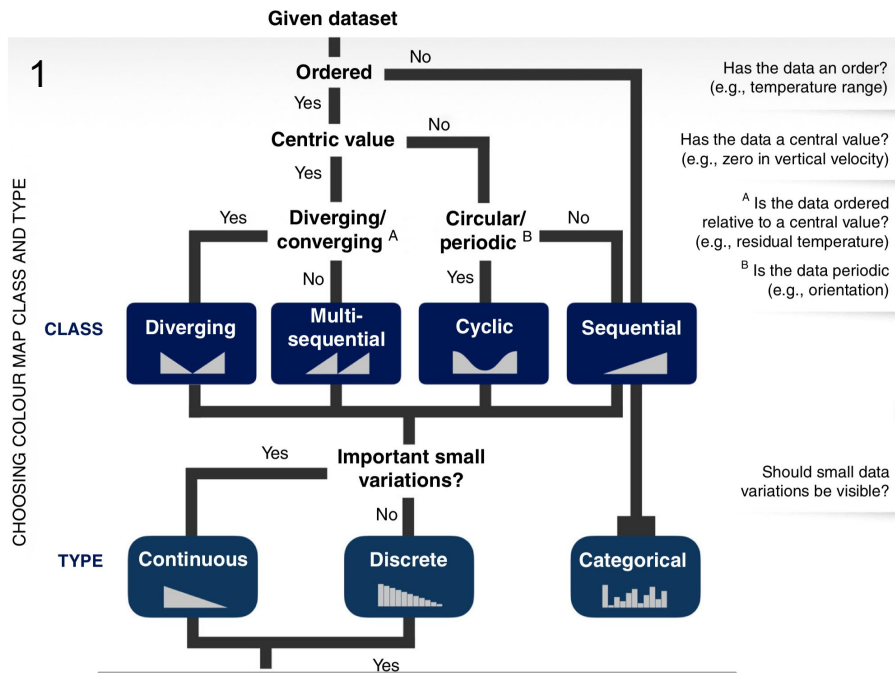
How to choose ?

Scientific colour map 7.0



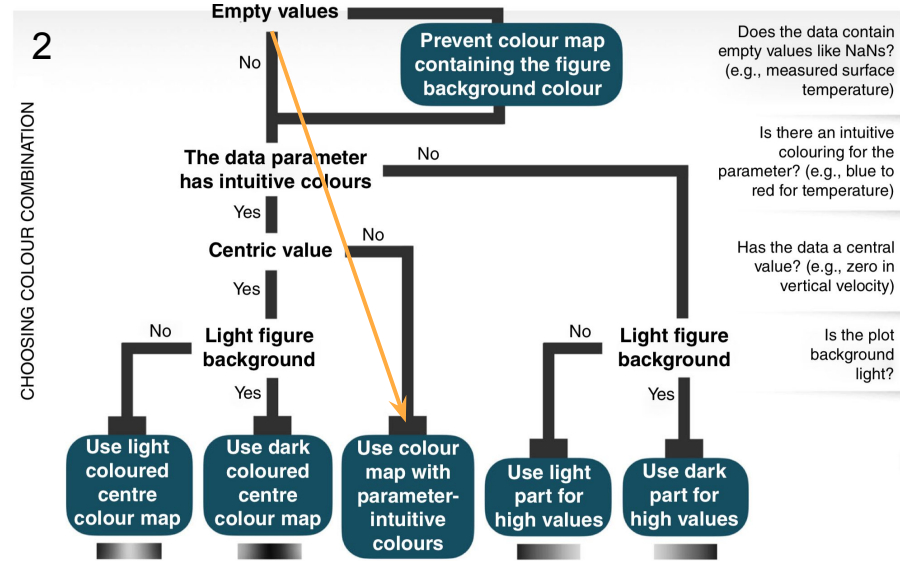
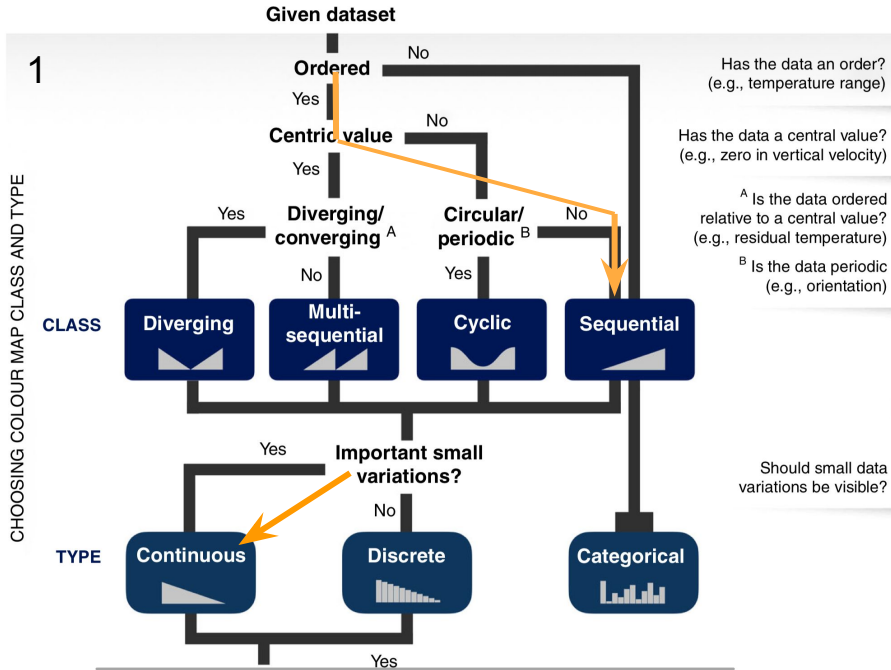
How to choose ?

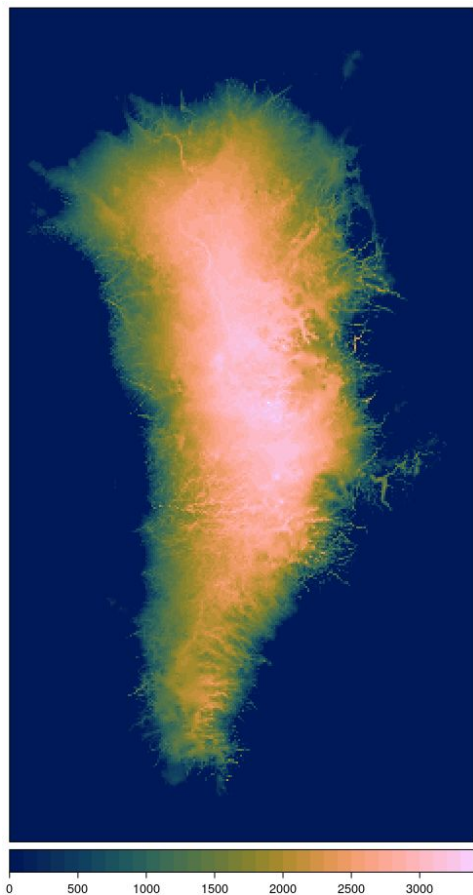
Authors methodology



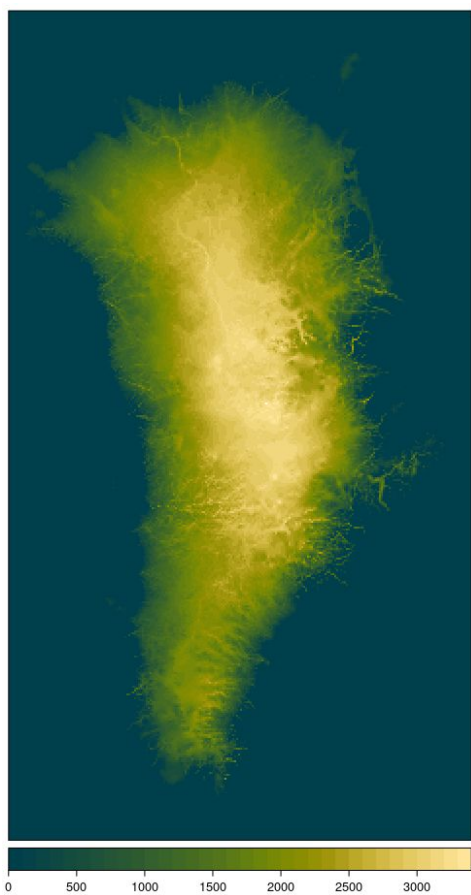
How to choose ?

Methodology applied to the Greenland ice thickness

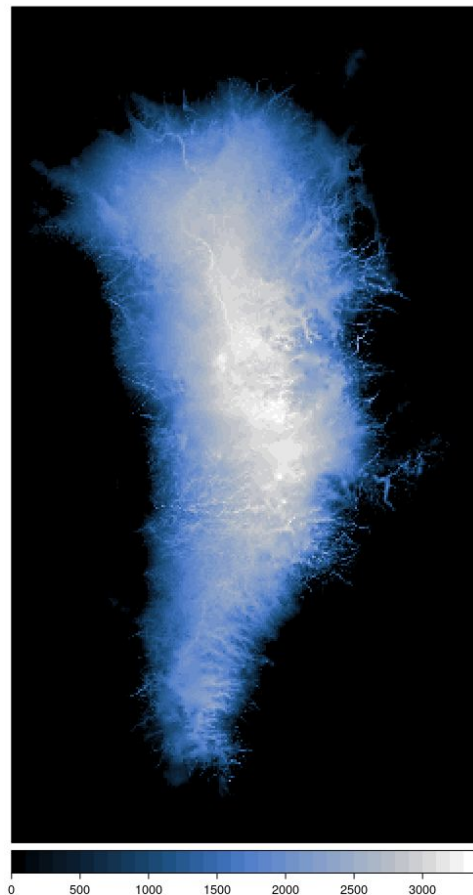




Batlow



Bamako



Oslo

How to choose for charts ?

VIZ PALETTE

By: Elijah Meeks & Susie Lu

PICK

Use Chroma.js

Add

Replace

Use ColorGorical

Use ColorBrewer

EDIT

7 Colors

Add

#hex rgb

hsl

- 1 #ffc700
- 2 #ffb14e
- 3 #fa8775
- 4 #ea5f94
- 5 #cd34b5
- 6 #9d02d7
- 7 #0000ff

GET

#hex rgb

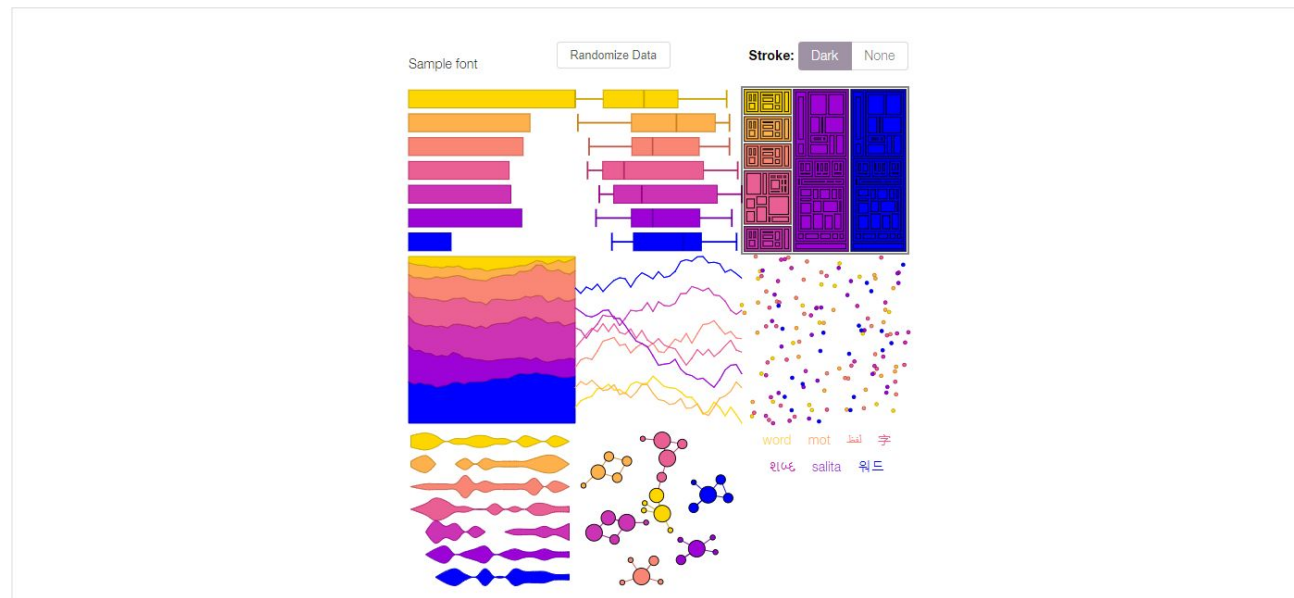
hsl

- String quotes
- Object with metadata

```
[["#ffc700",  
"#ffb14e",  
"#fa8775",  
"#ea5f94",  
"#cd34b5",  
"#9d02d7",  
"#0000ff"]]
```

COLORS IN ACTION

Color Population: No Color Deficiency - 96% Deuteranomaly - 2.7% Protanomaly - 0.66% Protanopia - 0.59% Deuteranopia - 0.56% Greyscale



Background color: #ffff

Font color: #000000

Charts made with Semiotic

How to choose ?

Ensure a perceptual relationship between the colour scale and the data,

Understand audience cultural expectations,

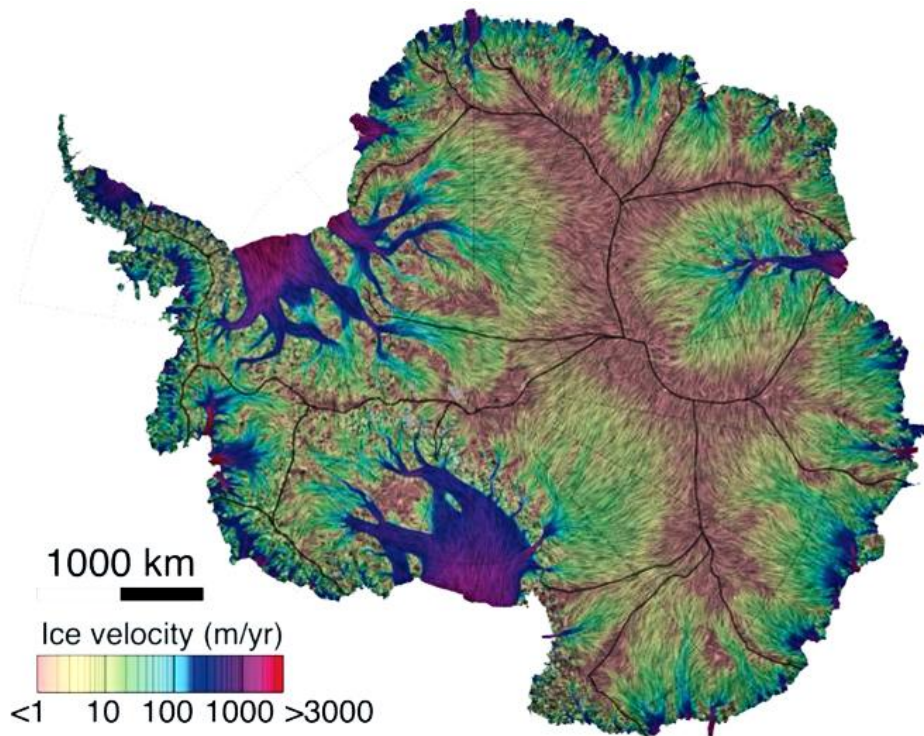
Use intuitive perception, like :

- Plant growth : green/greener
- High temperature : red
- Darker = 'more' (if light background)

Make some tests and discuss with colleagues about them !

Example of a custom colormap

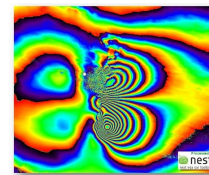
Antarctic Ice Velocity - Mouginot J. et al. , 2019



A colormap created by National Snow and Ice Data Center (NSIDC).

Accepted as a “standard” in the glacier scientists community.

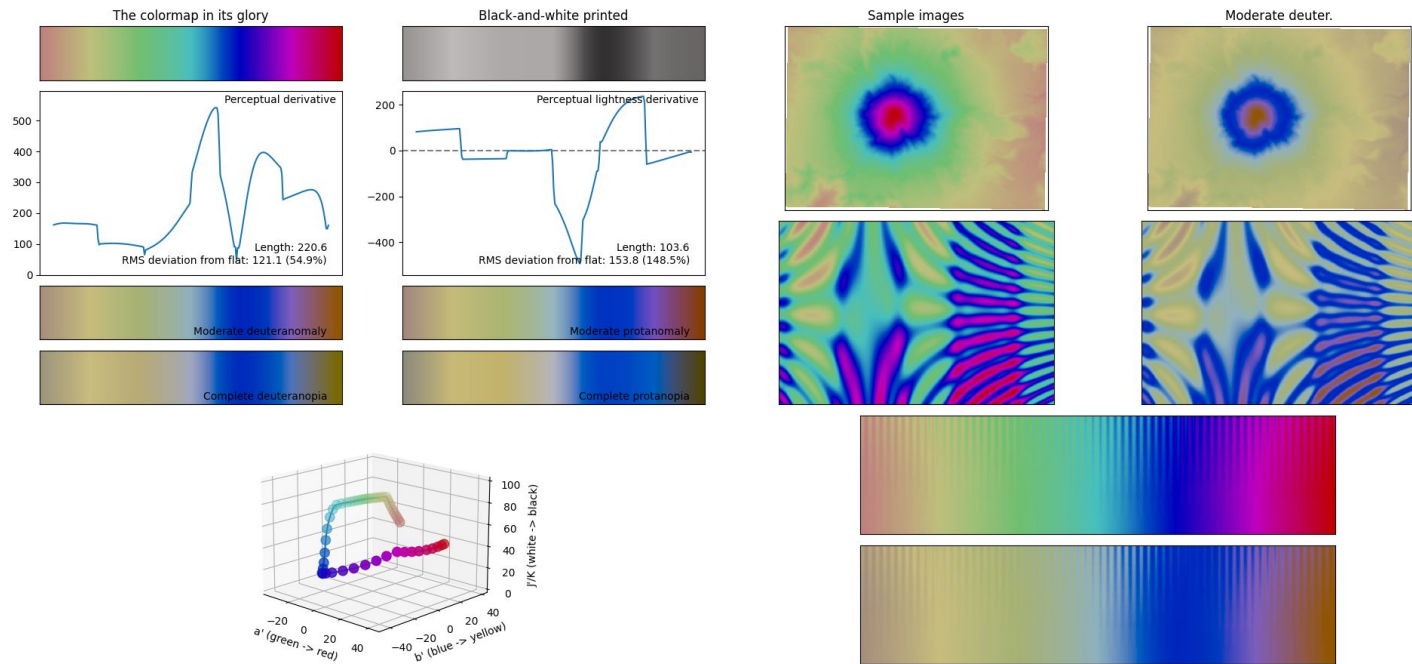
A history behind the colormap :



Example of a custom colormap

Colormap evaluation with Viscm - <https://github.com/matplotlib/viscm>

Colormap evaluation: d:\3_DataViz\2_glaciers\WorldwideGlaciers\tiles\colormap-master\NSIDC_glacier_cmap.py

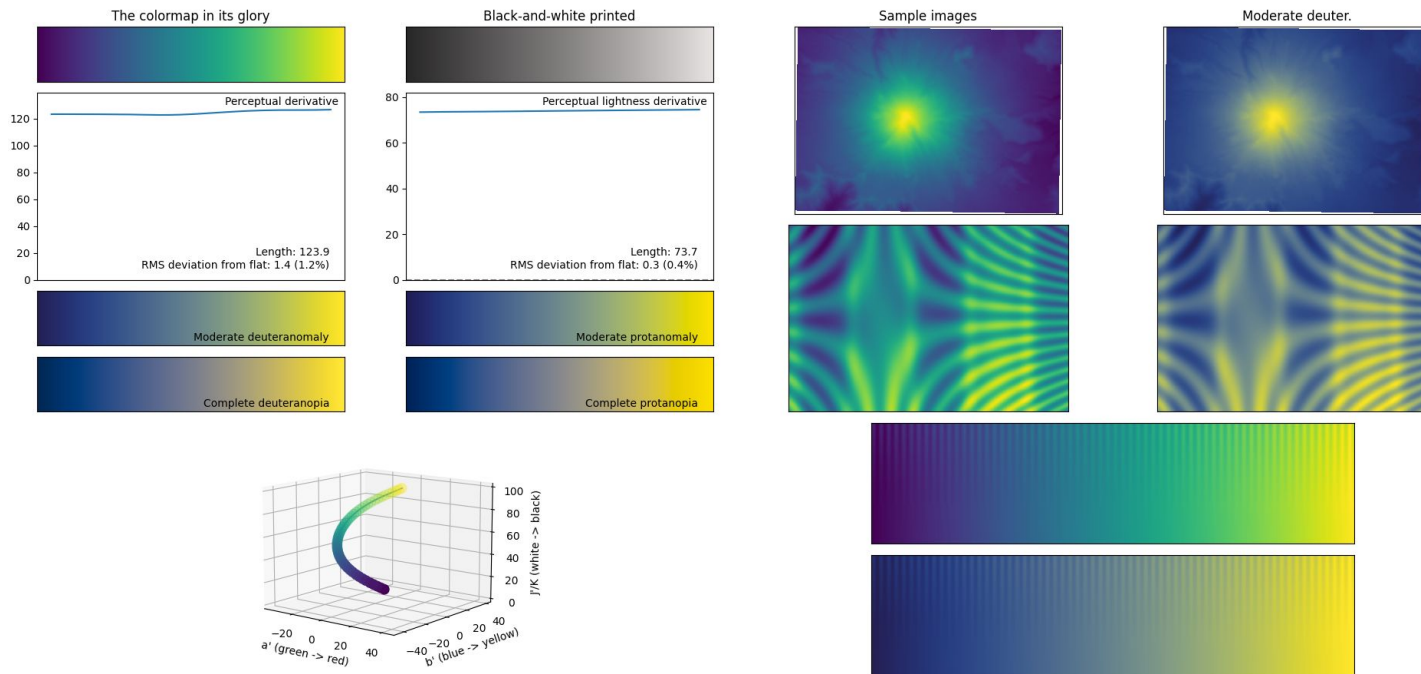


CAM02-UCS color space

Example of a custom colormap

Colormap evaluation with Vism - <https://github.com/matplotlib/vism>

Colormap evaluation: d:\3_DataViz\2_glaciers\WorldwideGlaciers\tiles\colormap-master\option_d.py



CAM02-UCS color space

Ressources

From Author

[Crameri's website](#)

The scientific material: <https://zenodo.org/record/4491293#.YCaXIGhKiUk>

Presentation of the paper by its author

Colour-vision deficiency

<https://blog.datawrapper.de/colorblindness-part1/>

<https://blog.datawrapper.de/colorblindness-part2/>

<https://blog.datawrapper.de/colorblindness-part3/>

Rainbow color scale

[The rainbow is dead ...long life to the rainbow](#)

Climate science

[Constructive criticism of the graphics of climate science](#)

Talks - Video

[Perceptual Color Maps in matplotlib for Oceanography \(K. Thyng - 2015\)](#)

[A Better Default Colormap for Matplotlib \(N.Smith and S.van der Walt - 2015\)](#)

Mur d'images à la Maison climat Planète

9 écrans fullHD de 55" - 18 Millions de pixels

Exploration
visuel de jeu
de données

Un travail
collaboratif à
plusieurs
mains





Bibliography

Borland D. and R. M. Taylor II, "Rainbow Color Map (Still) Considered Harmful," in *IEEE Computer Graphics and Applications*, vol. 27, no. 2, pp. 14-17, March-April **2007**, doi: [10.1109/MCG.2007.323435](https://doi.org/10.1109/MCG.2007.323435).

Crameri, F., Shephard, G.E. & Heron, P.J. The misuse of colour in science communication. *Nat Commun* 11, 5444 (**2020**).
<https://doi.org/10.1038/s41467-020-19160-7>

Hudson, R. D., Andrade, M. F., Follette, M. B., and Frolov, A. D.: The total ozone field separated into meteorological regimes – Part II: Northern Hemisphere mid-latitude total ozone trends, *Atmos. Chem. Phys.*, 6, 5183–5191, <https://doi.org/10.5194/acp-6-5183-2006>, **2006**.

Kovesi, P. Good Colour Maps: How to Design Them. [arXiv:1509.03700](https://arxiv.org/abs/1509.03700) [cs.GR] **2015**