

At the end of the rainbow – Scientific Colour Maps for science and society

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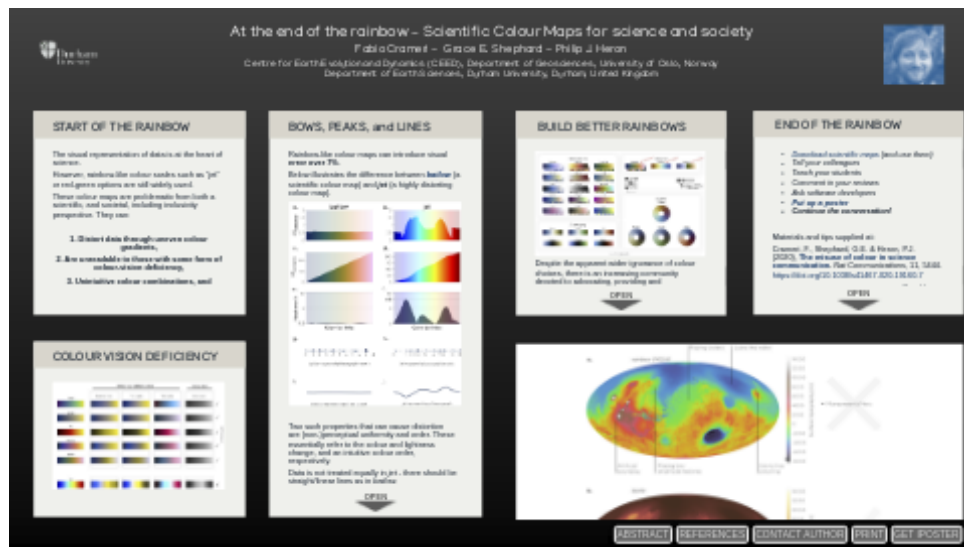
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Abstract

The visual representation of data is at the heart of science. From weather forecasts, to hazard maps, to the topography of planets, the choice of colors is critical to conveying information. Yet, largely due to historical usage, default software options, and an apparent attraction to multiple bright colors, color maps such as rainbow-like “jet” are still widely used. These color maps are problematic from both a scientific and societal perspective. For instance, they can distort data because they use uneven color gradients, which lose meaning when printed in black and white, and color combinations are often applied that are unintuitive to the data they are trying to represent. From an inclusivity standpoint, such rainbow maps are also unreadable for the population with some form of color-vision deficiency. Here, we present the work that has been accomplished by the scientific (inc. visualization) community, as well as the readily available solution - “Scientific Colour Maps” (Crameri 2018, Zenodo; Crameri et al. (2020; Nature Coms); www.fabiocrameri.ch/colourmaps). This initiative features freely available, citable color map downloads for an extensive suite of software programs, and handy how-to guide, and discussion around data types and coloring options. There is a pot of scientific gold at the end of every rainbow. Crameri, F. (2018). Scientific colour-maps. Zenodo. <http://doi.org/10.5281/zenodo.1243862> Crameri, F., Shephard, G.E. Heron, P.J. The misuse of colour in science. (2020 v11; Nature Communications) <https://doi.org/10.1038/s41467-020-19160-7>

At the end of the rainbow – Scientific Colour Maps for science and society



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Department of Earth Sciences, Durham University, Durham, United Kingdom



PRESENTED AT:



START OF THE RAINBOW

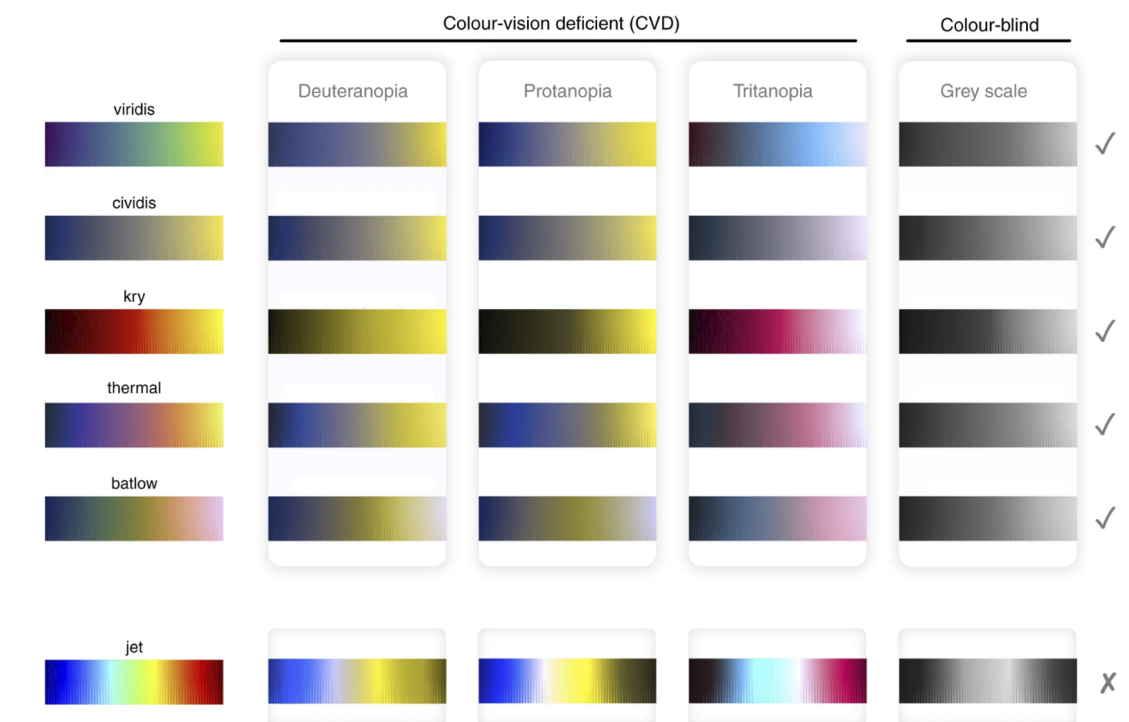
The visual representation of data is at the heart of science.

However, rainbow-like colour scales such as “jet” or red-green options are still widely used.

These colour maps are problematic from both a scientific, and societal, including inclusivity perspective. They can:

- 1. Distort data through uneven colour gradients,**
- 2. Are unreadable to those with some form of colour-vision deficiency,**
- 3. Unintuitive colour combinations, and**
- 4. Loose meaning when printed in black and white.**

COLOUR VISION DEFICIENCY

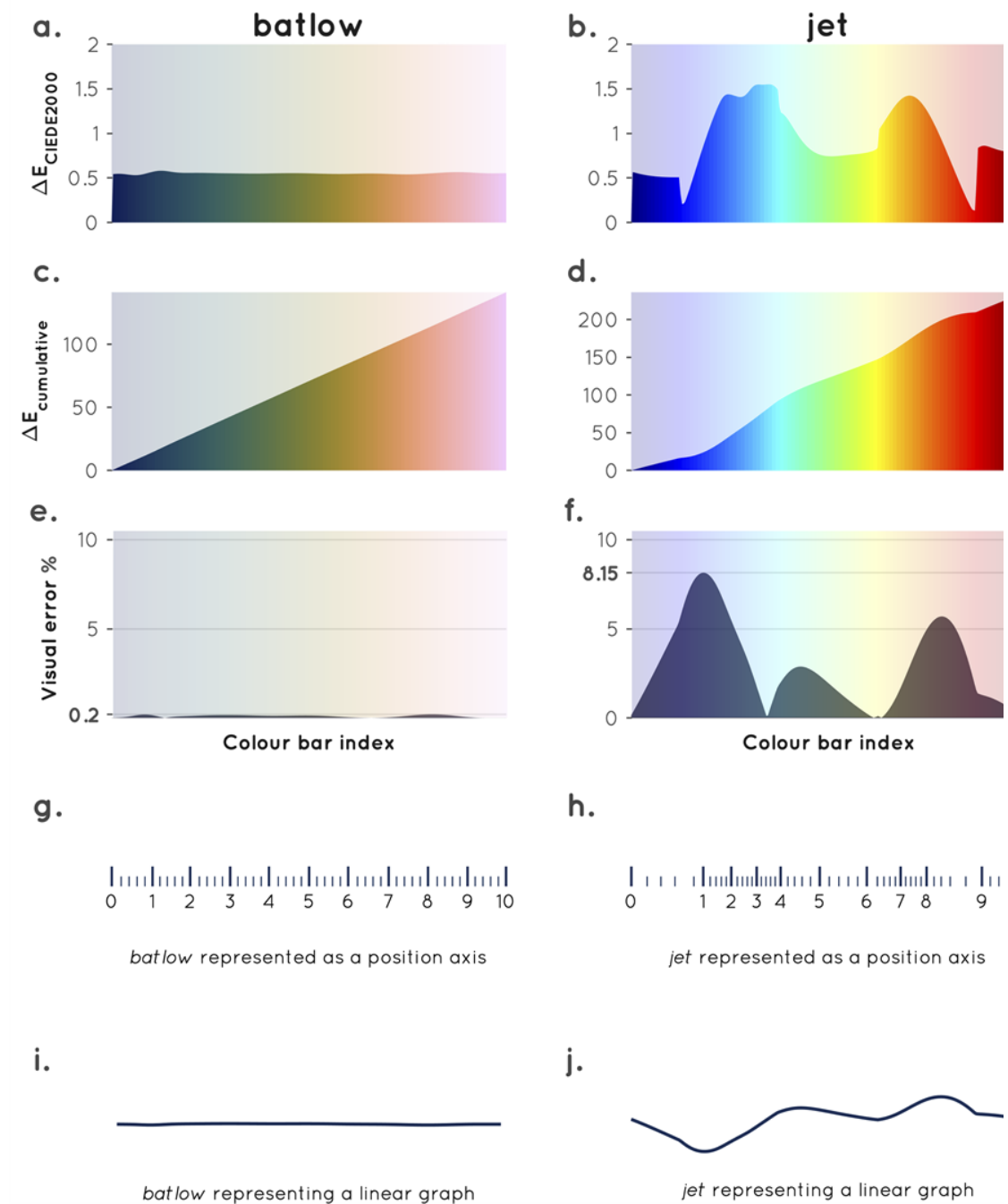


Examples of how those with colour vision deficiencies see alternative colour maps

BOWS, PEAKS, AND LINES

Rainbow-like colour maps can introduce visual **error over 7%**.

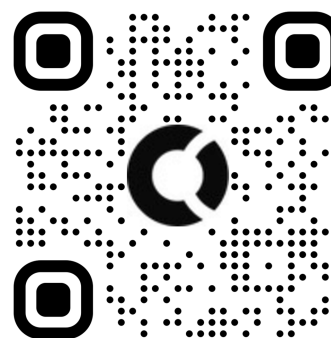
Below illustrates the difference between *batlow* (<http://www.fabiocrameri.ch/batlow>) (a scientific colour map) and *jet* (a highly distorting colour map).



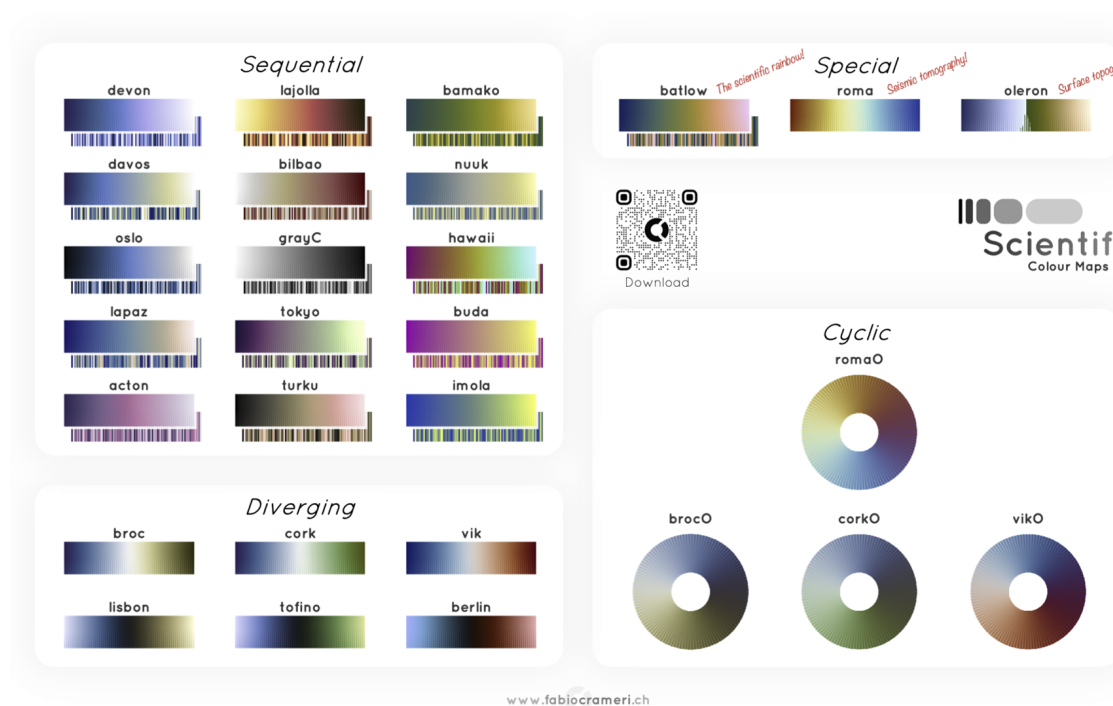
Two such properties that can cause distortion are (non-)perceptual uniformity and order. These essentially refer to the colour and lightness change, and an intuitive colour order, respectively.

Data is not treated equally in *jet* - there should be straight/linear lines as in *batlow*.

For full caption see Crameri et al. (2020) (<https://rdcu.be/b9lm1>) here:



BUILD BETTER RAINBOWS



(<http://www.fabiocrameri.ch/colourmaps>)

Despite the apparent wider ignorance of colour choices, there is an increasing community devoted to advocating, providing and implementing scientific colouring options.

These include, but are not limited to *Colorbrewer*, *MPL* (Matplotlib), *Cividis*, *CMOcean*, and *CET*.

Here, we highlight the "Scientific colour maps" (<http://www.fabiocrameri.ch/colourmaps>)" from

www.fabiocrameri.ch/colourmaps (<http://www.fabiocrameri.ch/colourmaps>)

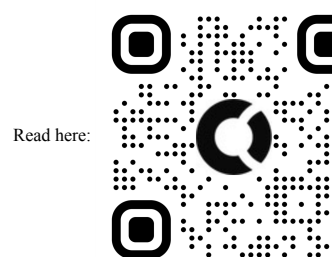


END OF THE RAINBOW

- *Download scientific maps* (<http://www.fabiocrameri.ch/colourmaps>) (and use them)
- *Tell your colleagues*
- *Teach your students*
- *Comment in your reviews*
- *Ask software developers*
- *Put up a poster* (http://www.fabiocrameri.ch/resources/ColourMaps/PosterScientificColourMaps_Crameri_EtAl2020.pdf)
- *Continue the conversation!*

Materials and tips supplied at:

Crameri, F., Shephard, G.E. & Heron, P.J. (2020), **The misuse of colour in science communication** (<https://rdcu.be/b9lm1>). *Nat Communications*, 11, 5444. <https://doi.org/10.1038/s41467-020-19160-7> (<http://doi.org/10.1038/s41467-020-19160-7>)



Editors, journalists, educators, and all scientists need to take note!

Scientific colour maps

A “scientific colour map” uses a methodology that prevents data distortion, offers intuitive colouring, and is accessible for people with colour-vision deficiencies. However, most scientists use colour maps that distort data through uneven colour

- ✓ Intuitive
- ✓ Distortion free
- ✓ Inclusive
- ✓ Freely available



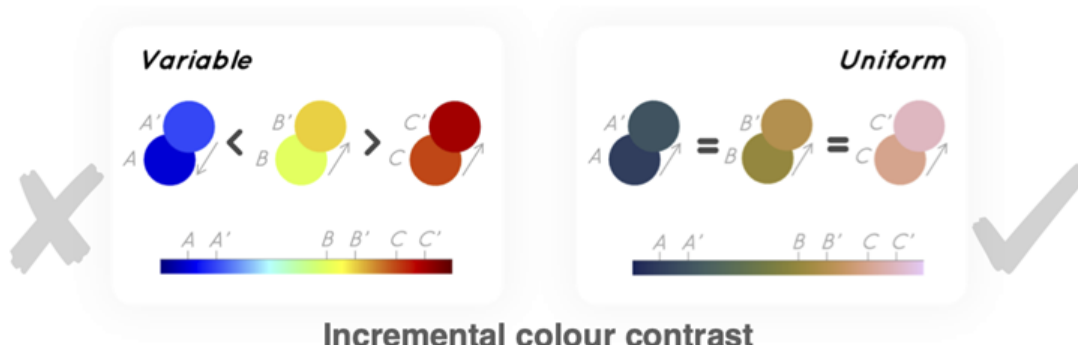
Scientific
Colour Maps

For every figure, think... is it scientific?

Your software... look beyond the default!

Your poster... accessible to the colour blind?

Your peers... say ‘no’ to rainbow!



For maps and
more

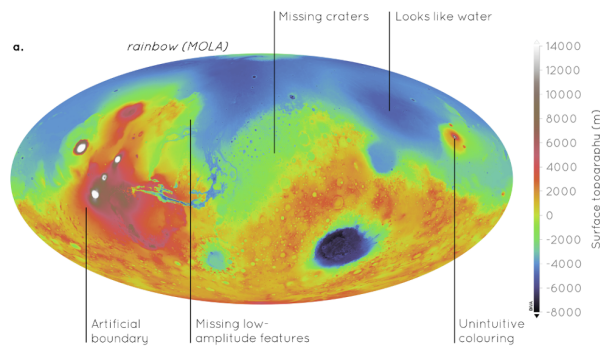
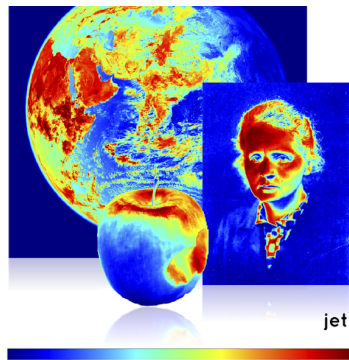
www.fabiocrameri.ch

Download the
paper

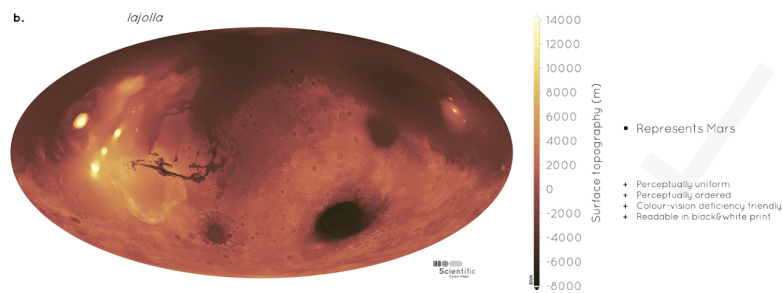


(http://www.fabiocrameri.ch/resources/ColourMaps/PosterScientificColourMaps_Crameri_EtAl2020.pdf)



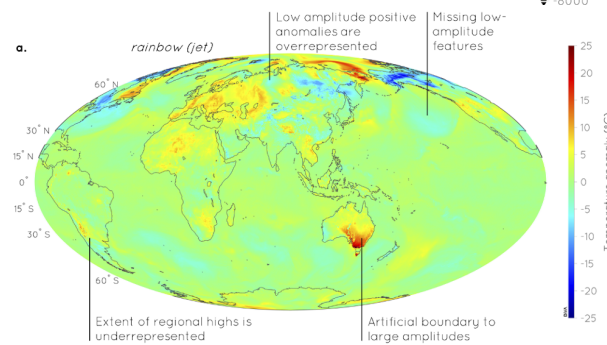


✗ Misrepresents Mars

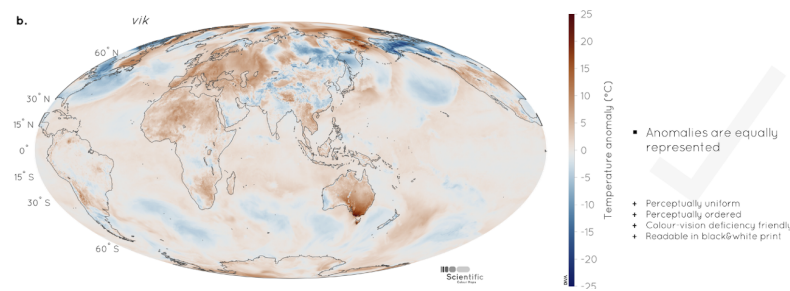


✓ Represents Mars

- + Perceptually uniform
- + Perceptually ordered
- + Colour-vision deficiency friendly
- + Readable in black&white print

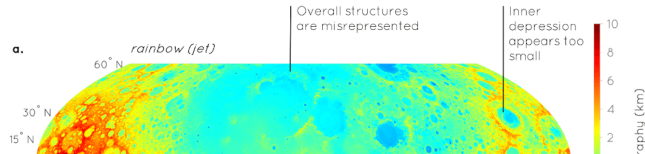


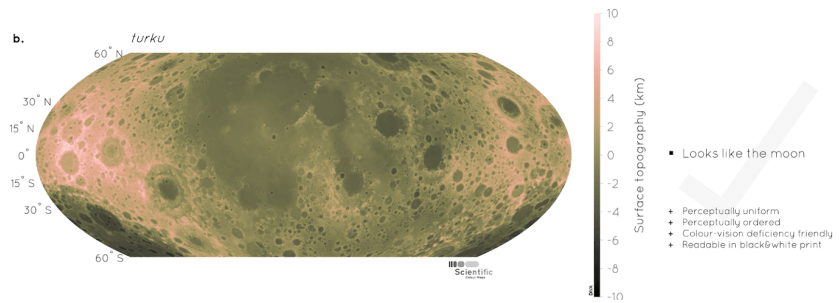
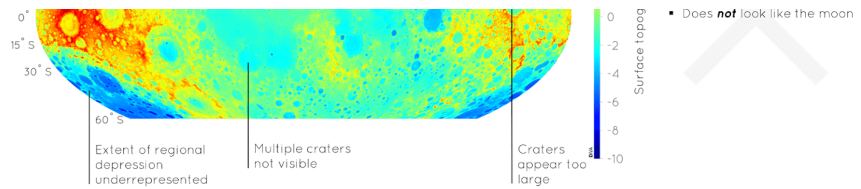
✗ Anomalies are **not** equally represented



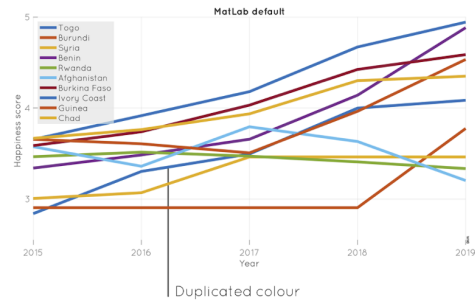
✓ Anomalies are equally represented

- + Perceptually uniform
- + Perceptually ordered
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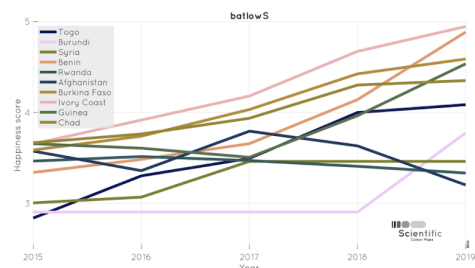


a. *MatLab default colouring*



▪ Non-unique colouring

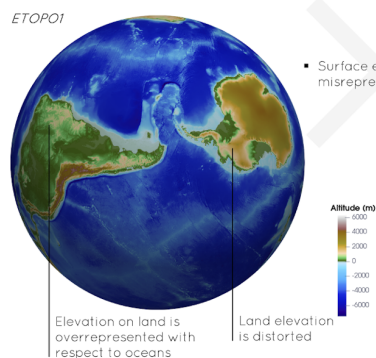
b. *batlowS*



▪ Unique colouring

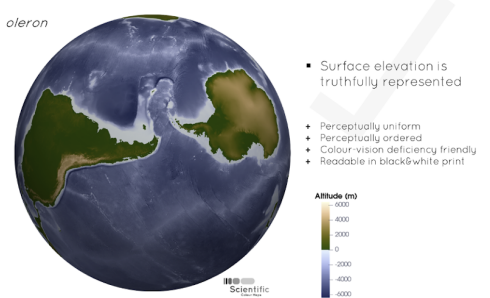
+ Colour-vision deficiency friendly
+ Readable in black&white print

a. *ETOPO1*



▪ Surface elevation is misrepresented

b. *oleron*

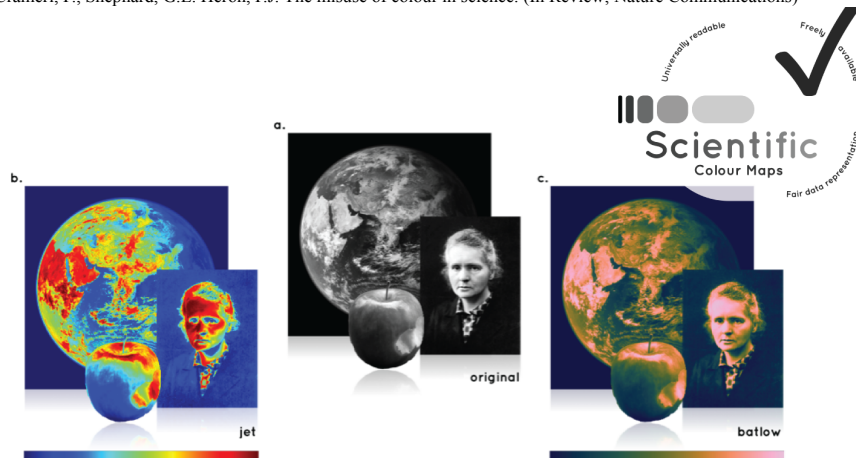


ABSTRACT

The visual representation of data is at the heart of science. From weather forecasts, to hazard maps, to the topography of planets, the choice of colors is critical to conveying information. Yet, largely due to historical usage, default software options, and an apparent attraction to multiple bright colors, color maps such as rainbow-like “jet” are still widely used. These color maps are problematic from both a scientific and societal perspective. For instance, they can distort data because they use uneven color gradients, which lose meaning when printed in black and white, and color combinations are often applied that are unintuitive to the data they are trying to represent. From an inclusivity standpoint, such rainbow maps are also unreadable for the population with some form of color-vision deficiency. Here, we present the work that has been accomplished by the scientific (inc. visualization) community, as well as the readily available solution - “Scientific Colour Maps” (Crameri 2018, Zenodo; Crameri et al. (In Review); www.fabiocrameri.ch/colourmaps). This initiative features freely available, citable color map downloads for an extensive suite of software programs, and handy how-to guide, and discussion around data types and coloring options. There is a pot of scientific gold at the end of every rainbow.

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(https://agu.confex.com/data/abstract/agu/fm20/4/4/Paper_725244_abstract_691064_0.png)

REFERENCES

Crameri, F. (2018). **Scientific colour maps**. *Zenodo*. <http://doi.org/10.5281/zenodo.1243862> (<http://doi.org/10.5281/zenodo.1243862>)

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