Seismic2024

RECOMMENDATIONS FOR SCIENTIFIC DATA VISUALIZATION

In many visualization toolkits the default colourmaps (e.g. rainbows) have not been designed with accuracy in mind. In many cases, they cause visual distortion of the data, and often contain both red and green at similar luminosity and therefore are not inclusive for those with Colour Vision Deficiency (CVD).

For scientific data visualisation, use a colourmap that respects the data and which is intuitive and accessible for all (Crameri et al., 2020).

1. Use a scientific colourmap. They are perceptually uniform, which ensures accurate representation of the regular interval relationship in scientific data. Perceptually uniform colourmaps have:

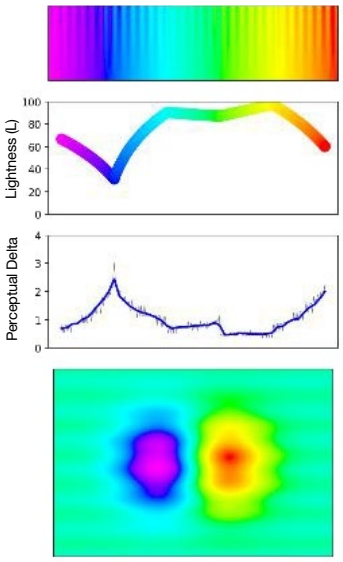
- Monotonically increasing lightness
- Perceptual colour order

2. Ensure colour accessibility for all: **avoid colourmaps that contain red and green at a similar luminosity**. These two colours cannot be distinguished by a large fraction of the population (~1 in 12 men have CVD).

3. The common rainbow colourmap should not be used for scientific data visualisation. No rainbow colourmaps are perceptually uniform or inclusive for those with CVD.

Useful test: Change the limits of the colourmap – a scientific colourmap will only dim or brighten the image, a nonscientific colourmap will alter the appearance of the displayed features/artefacts.

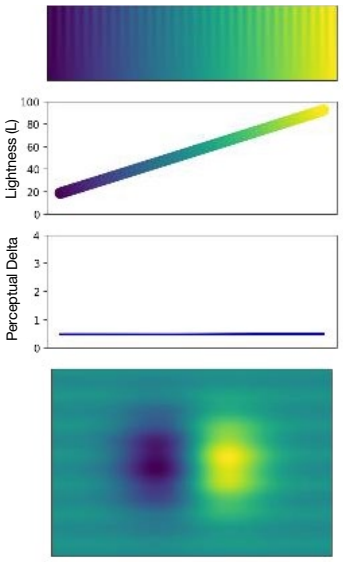
EXAMPLE DEFAULT RAINBOW



✗

Artefacts and artificial contours are created where there are large jumps in perceptual delta. Detail is lost where the lightness profile is flat. Red and green are difficult for those with CVD.

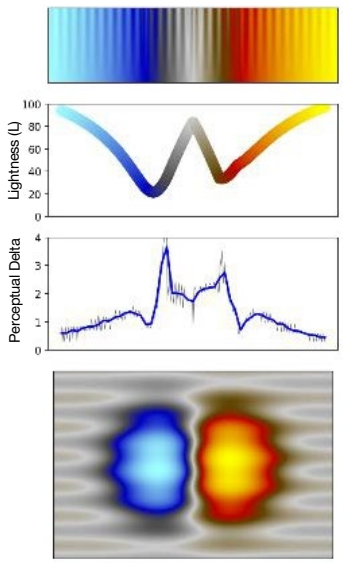
SEQUENTIAL PERCEPTUALLY UNIFORM (VIRIDIS)



✓

Linear lightness profile and perceptual colour order ensure the data are displayed accurately with no artefacts or areas where detail is lost.

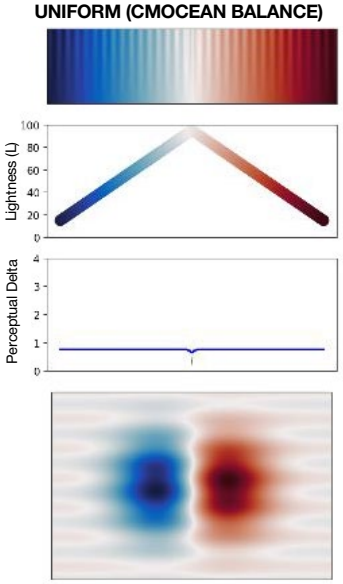
EXAMPLE DEFAULT RED/BLUE



✗

Not symmetric and lightness profile results in added contours and visual exaggeration of the size of the anomalies. In this example the anomaly on the red side also appears bigger than the blue.

SYMMETRIC PERCEPTUALLY UNIFORM (CMOCEAN BALANCE)



✓

A symmetric lightness profile and perceptual colour order ensure the data are displayed accurately around a central, critical value.

For further advice and information contact
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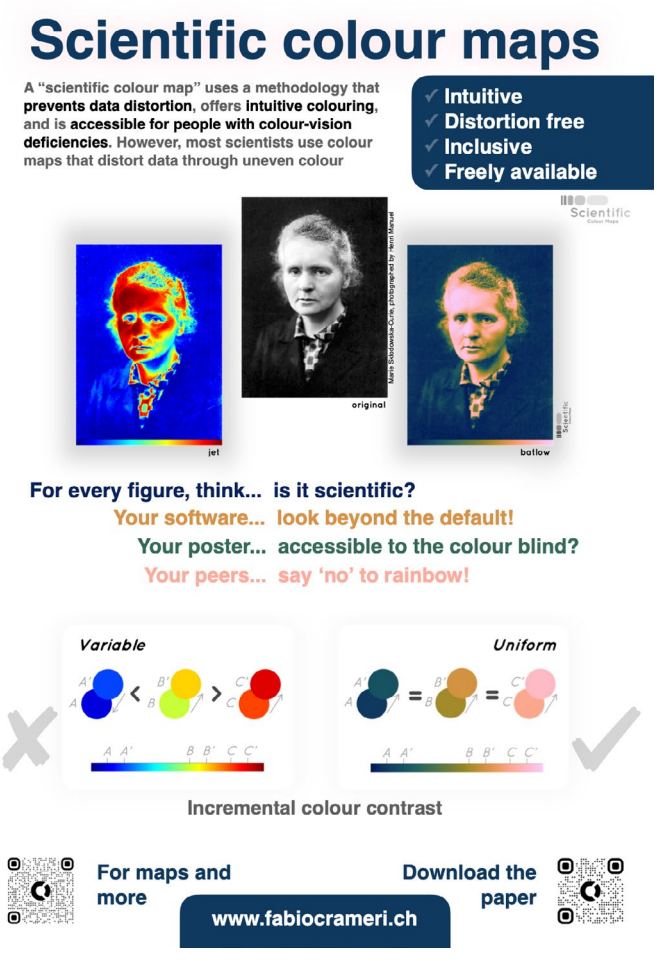
CLASS	COLOURMAP DESCRIPTION	EXAMPLE DATA	SUGGESTED COLOUR MAP	EXAMPLE
Sequential 	**Perceptually uniform colour tables must have:** 1. Monotonically increasing lightness 2. Perceptual colour order 3. No red and green at similar luminosity	Elevation Thickness Amplitude Velocity etc	Any sequential perceptually uniform colourmap	Viridis David Green's Cubehelix
		Structural attributes: Coherency Edge Detection etc	Greyscale or any sequential Perceptually Uniform colourmap	CMOCEAN Gray
Diverging 	Diverging data should be plotted with either a **perceptually uniform colour map** e.g. greyscale, or a diverging colourmap combining two sequential colourmaps, with mirrored linear lightness values, to plot the values relative to a critical or central value	Reflectivity Impedance Difference (e.g. 4D)	Greyscale (e.g. for identifying structural detail in reflectivity data) Any diverging colourmap combining two sequential colourmaps, with mirrored linear lightness values	CMOCEAN Gray or CMOCEAN Balance



Fabio Crameri's scientific colourmap poster

Useful References

- Agile Scientific Blog post: No more rainbows!

Useful papers on the subject:

- 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
- Thyng et al. 2016. True colors of oceanography: Guidelines for effective and accurate colormap selection. Oceanography 29(3):9-13
- Evaluation of rainbows in medical imaging (Borkin et al, 2011): paper.dvi (harvard.edu)

Useful videos:

- An introduction to Viridis by Nathaniel Smith and Stefan Van der Walt https://youtu.be/xAoljeRJ3lU
- Kristen Thyng's presentation on colourmaps: Perceptual Color Maps in matplotlib for Oceanography | SciPy 2015 | Kristen Thyng – YouTube
- Colour vision deficiency simulator: coblis-color-blindness-simulator

Open-source Scientific Colourmaps

(listed in Crameri et al., 2020):

1. Colourbrewer: https://colorbrewer2.org/
2. Matplotlib (MPL): https://bids.github.io/colormap
3. Cividis: https://www.doi.org/10.1371/journal.pone.0199239.s002
4. CMOcean: http://matplotlib.org/cmocean
5. Scientific Colourmaps: http://www.fabiocrameri.ch/colourmaps