Designing objective figures and avoid color bias in science

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The challenges of data representation

“Language is inherently biased, but through visualization, we can let the data speak for [themselves]” - Phillip Wolfram

How to avoid misrepresentation ?

What should a colourmap convey for data representation ?

- Optimize the contrast,
- Provide an objective representation, without blind interpretation,
- Create an intuitive visual order

1. Choose the type of colourmap according to the type of scalar to be represented

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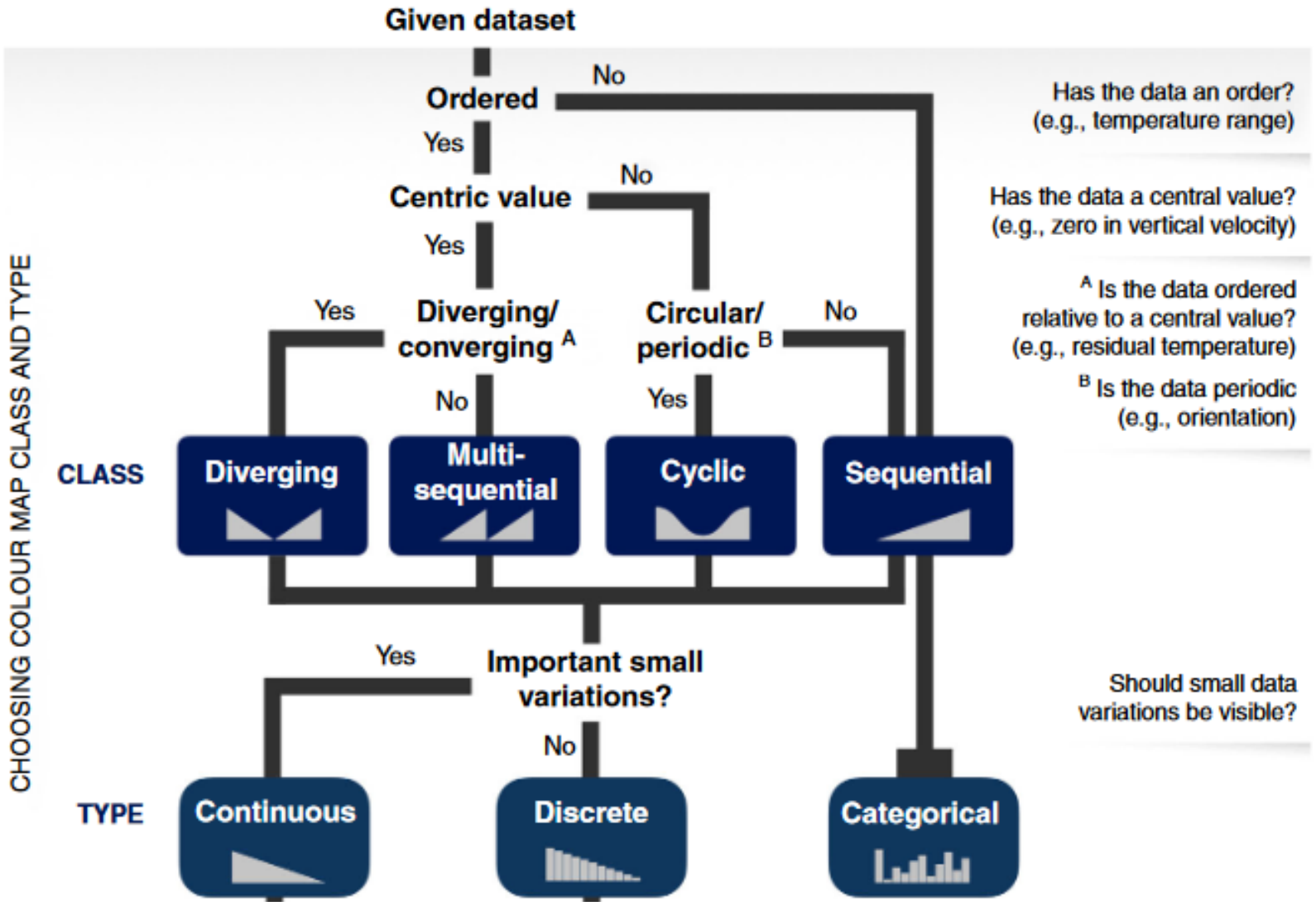
Crameri et al.
The misuse of colour in science communication, 2020



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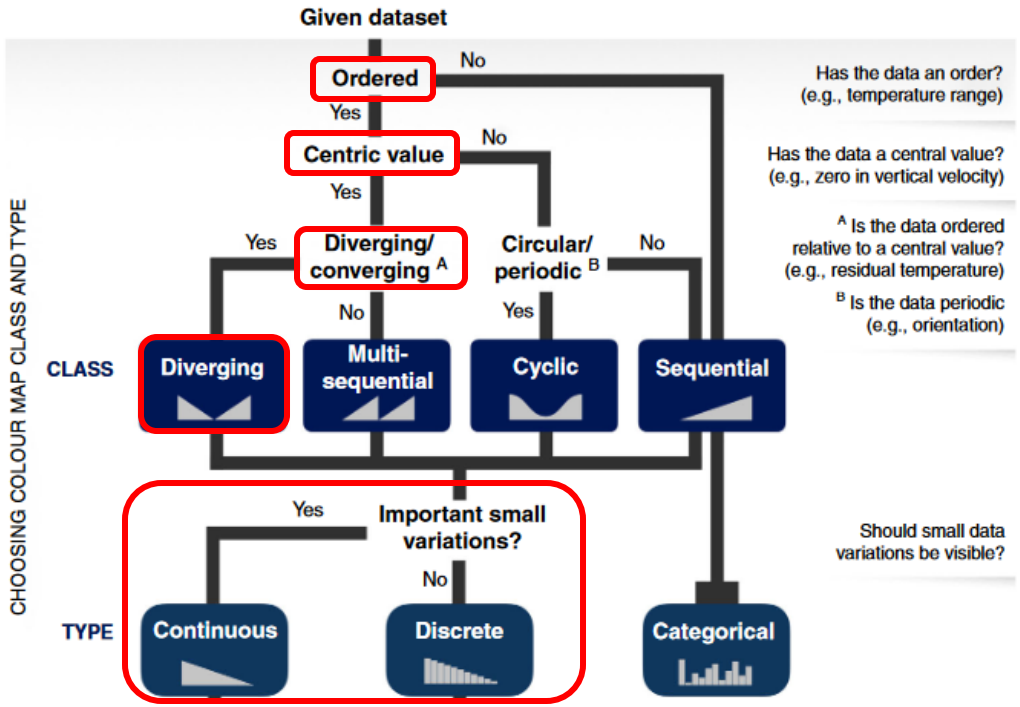
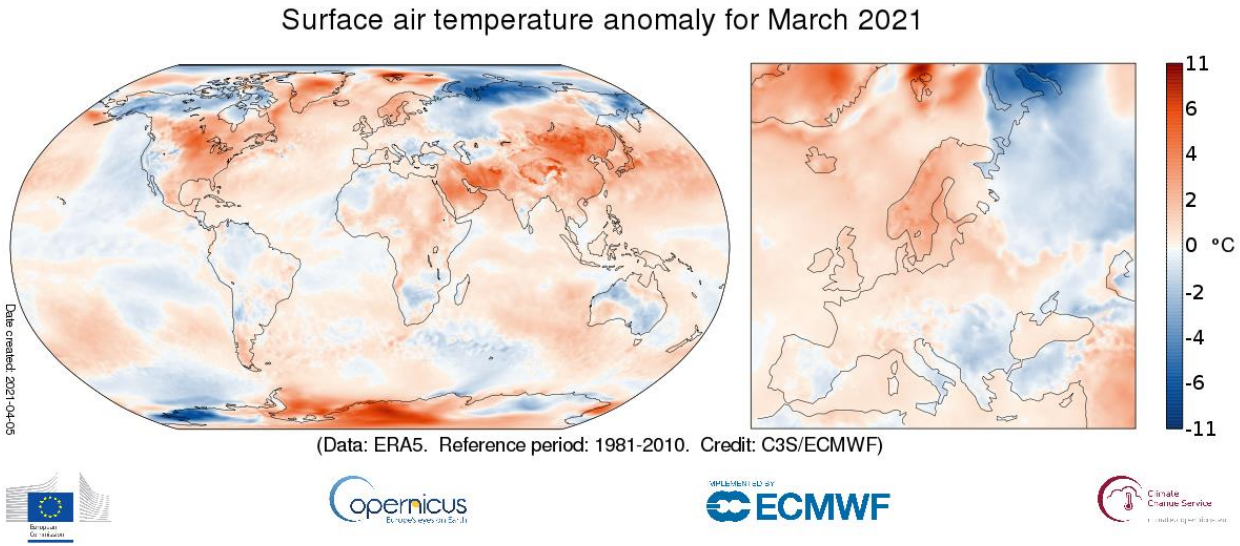
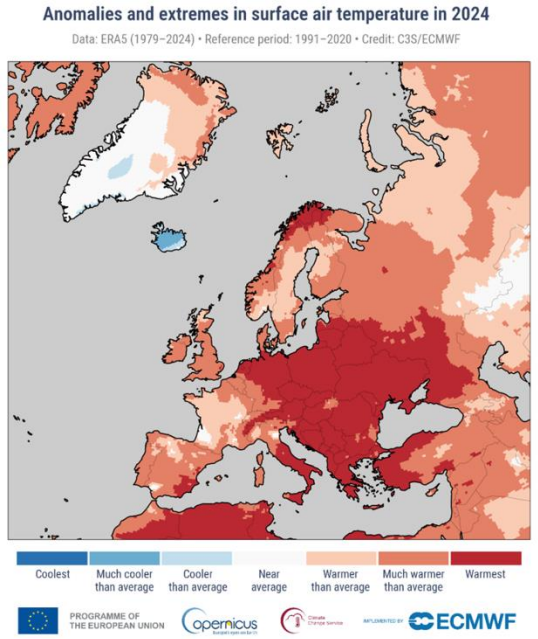
Example : temperature anomaly maps







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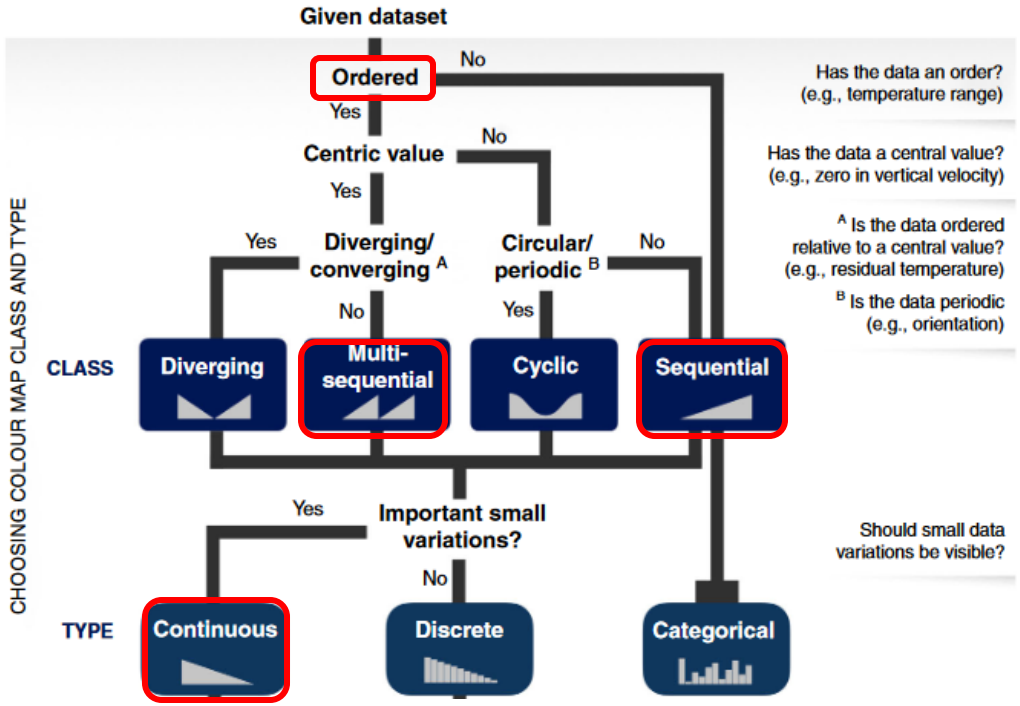
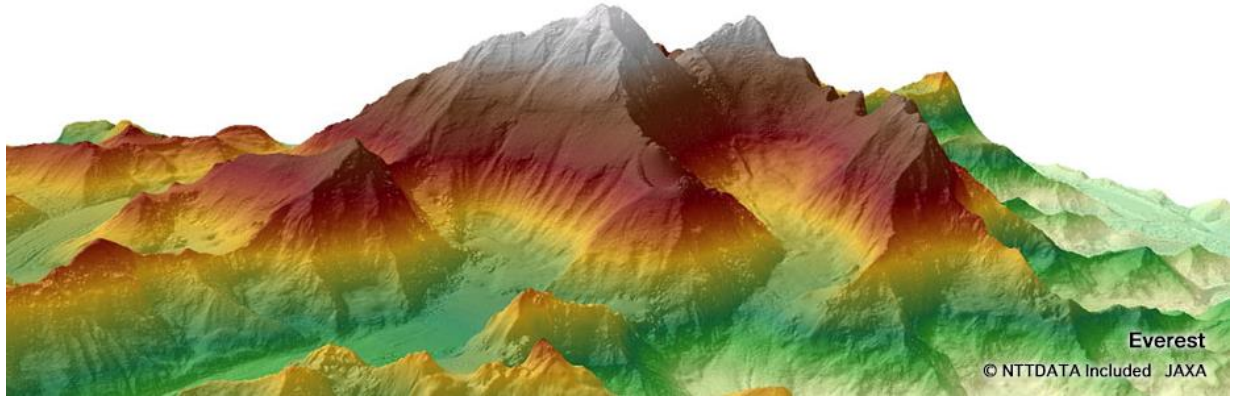
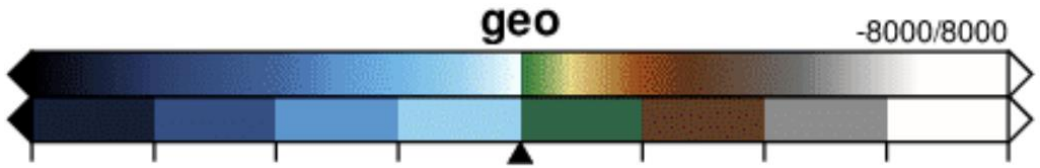
Example : Digital Elevation Model







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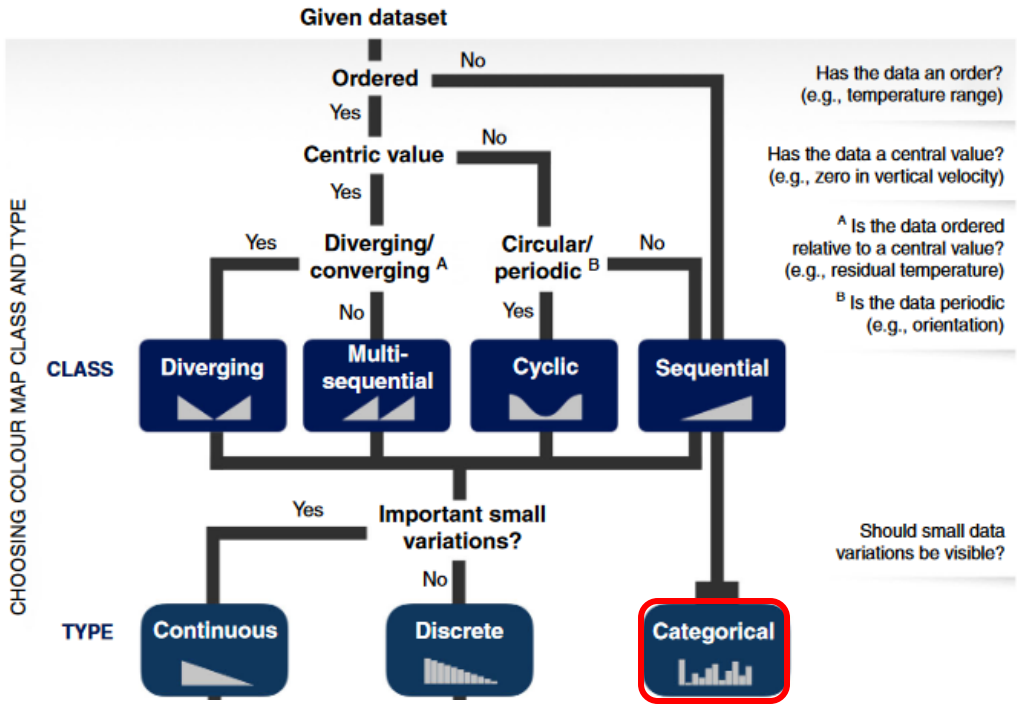
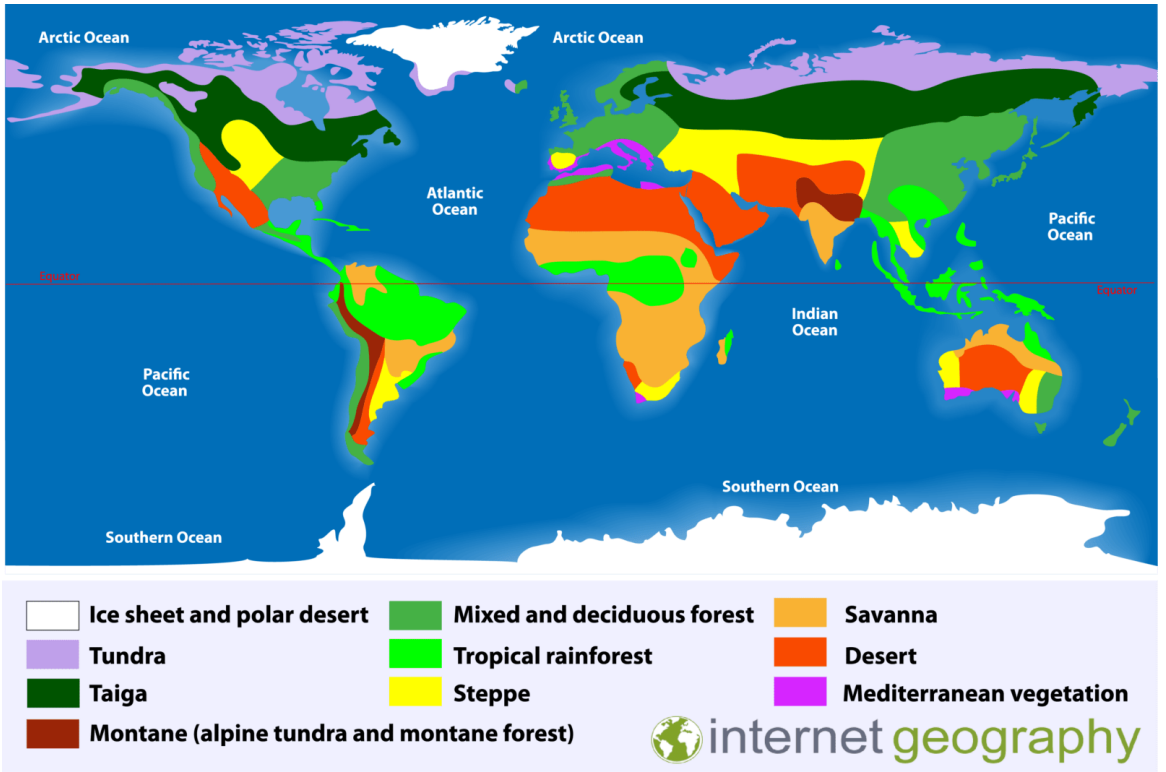
Example : Global map of biomes



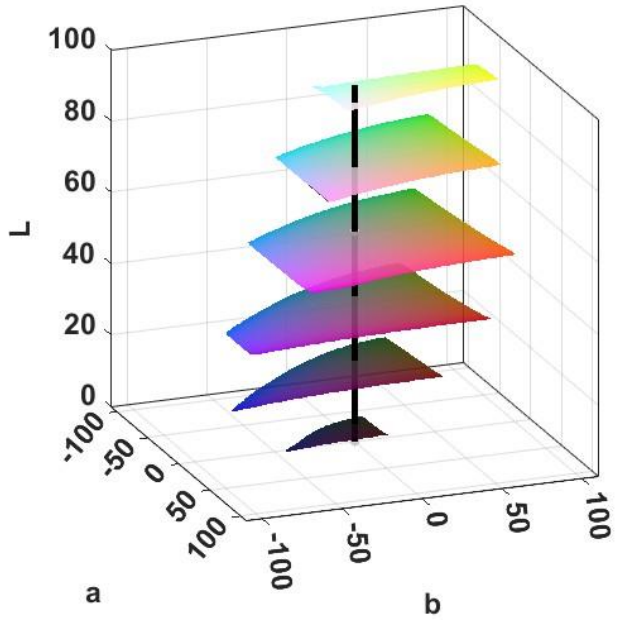


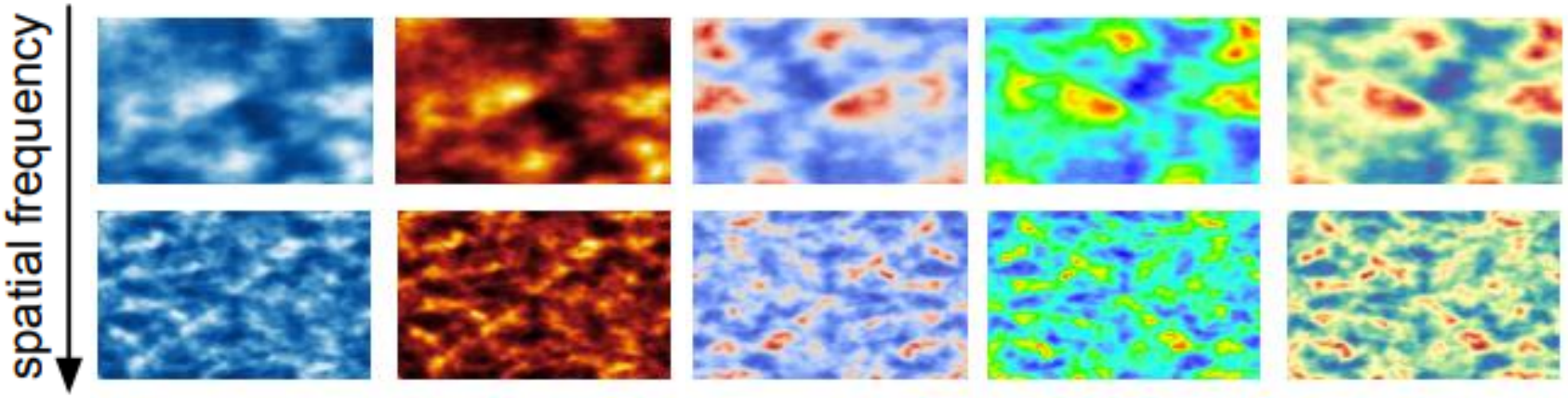
2. What colours ?

2.1. Optimize the contrast

- Two colours are clearly distinguishable if they are separated by more than 40 units in the CIELab colour space.
  (Carter and Carter, 1982)

- For quantity estimation, use colourmap with hue changes.
- For pattern and gradient perception, especially for high frequency data, use colourmap with luminance changes.
  (Reda et al., 2018, Kovesi, 2015)

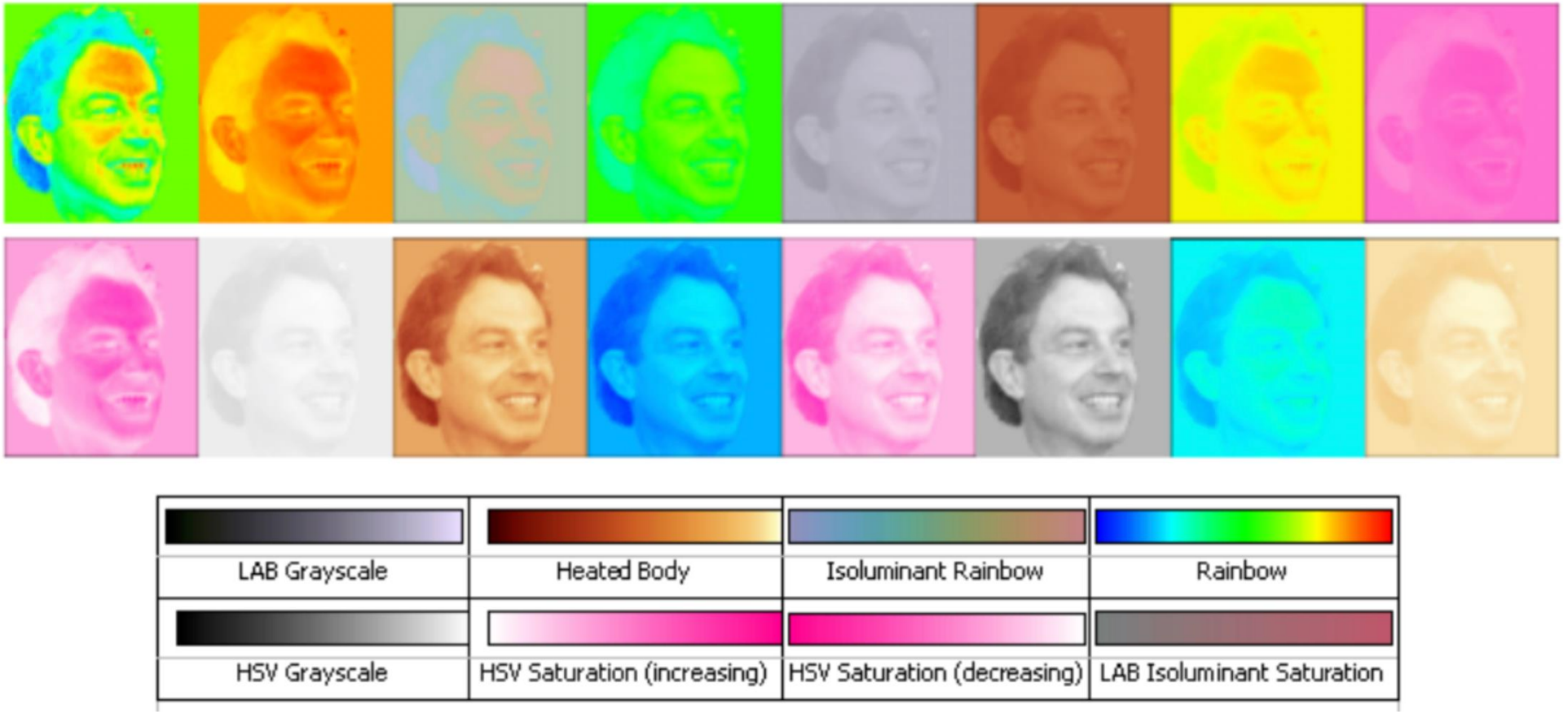




2.2. Convey order

The human eye is sensitive to changes in luminance to convey order.

Use colourmap with monotonic and linear increase in luminance.



Rogowitz et al. The « Which Blair Project »: a quick visual method for evaluating perceptual color maps. 2001

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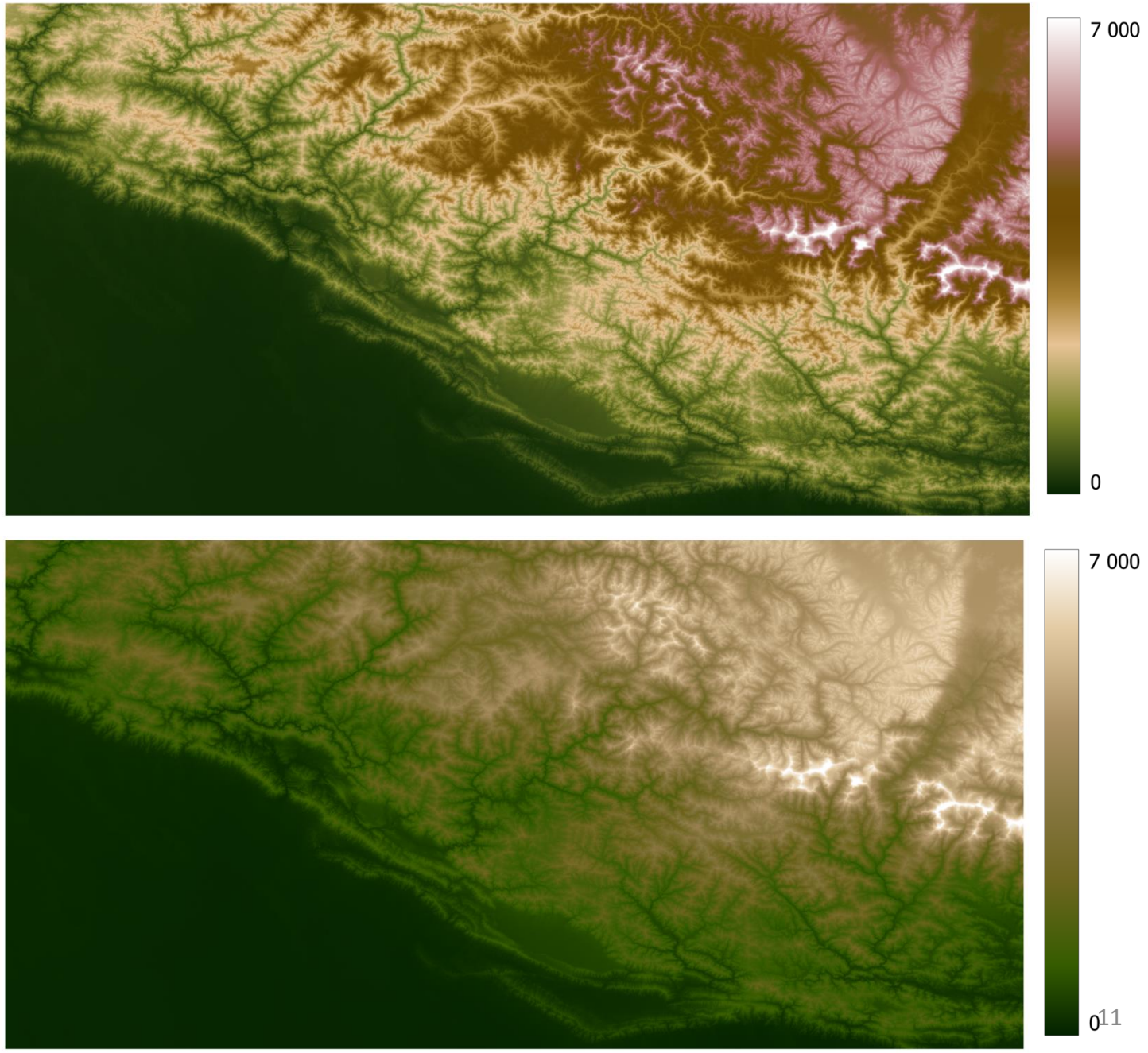

SRTM DEM, Nepal

3. Avoid bias in the representation

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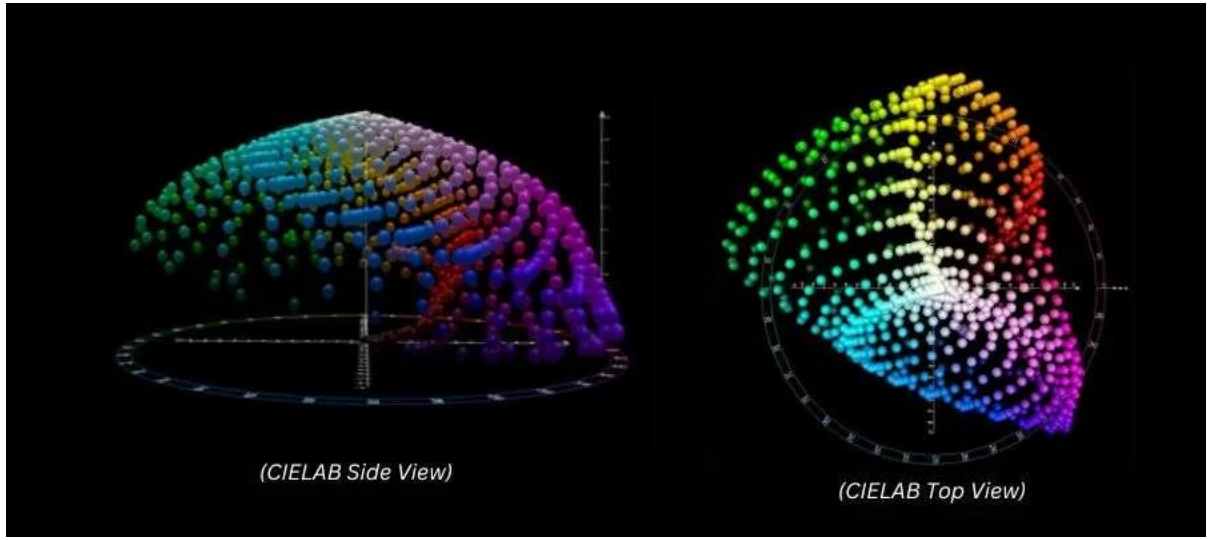
2 types of color spaces :

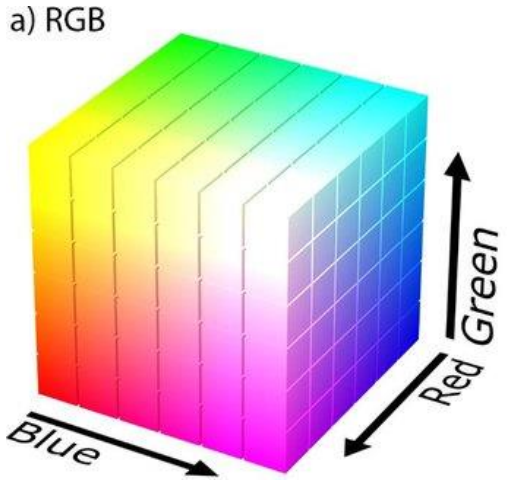


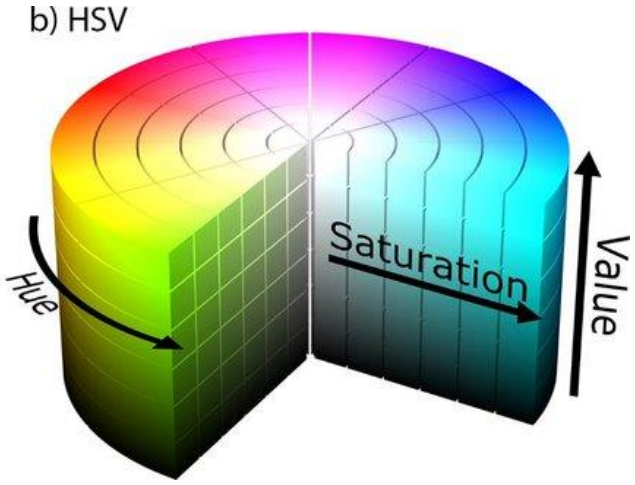
<u>Absolute</u>

- Based on human perception
- Perceptually uniforms: equal distances in space are perceived as equal changes in colours

<u>Non-absolute</u>

- Based on devices (cameras, printers…)
- Non perceptually uniforms



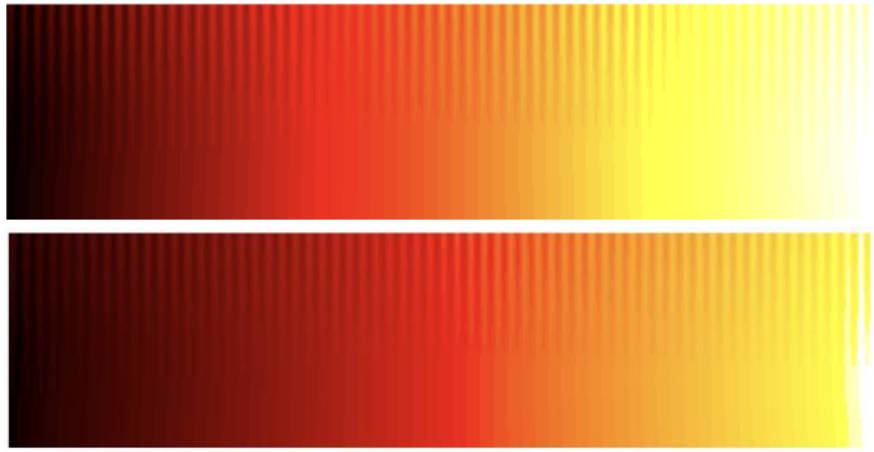


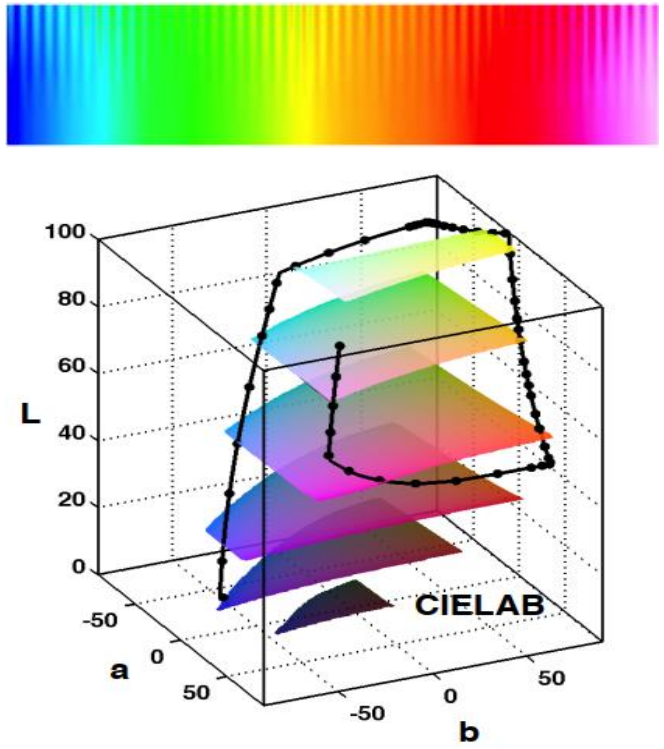
3. Avoid bias in the representation

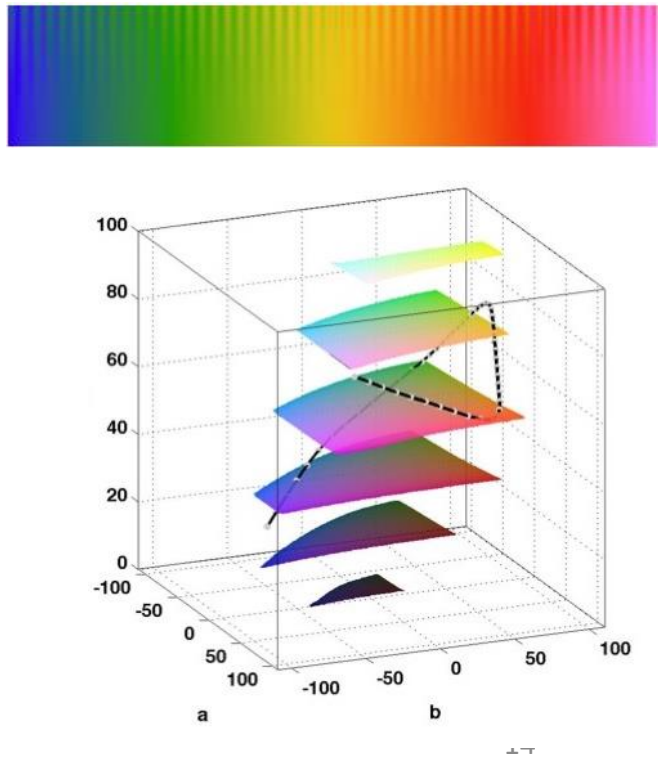
Perceptually uniforms colourmaps are defined such that equal steps in data are perceived as equal changes in colours.

They prevent segmentation or concealed variations in the data representation.

They are built from a linear interpolation of dots on a path through an absolute colourspace.

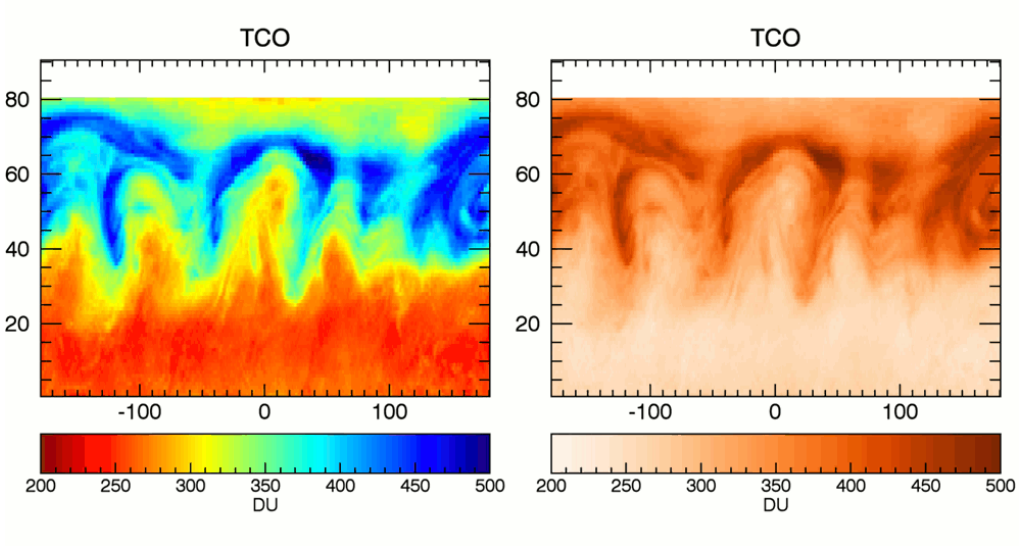


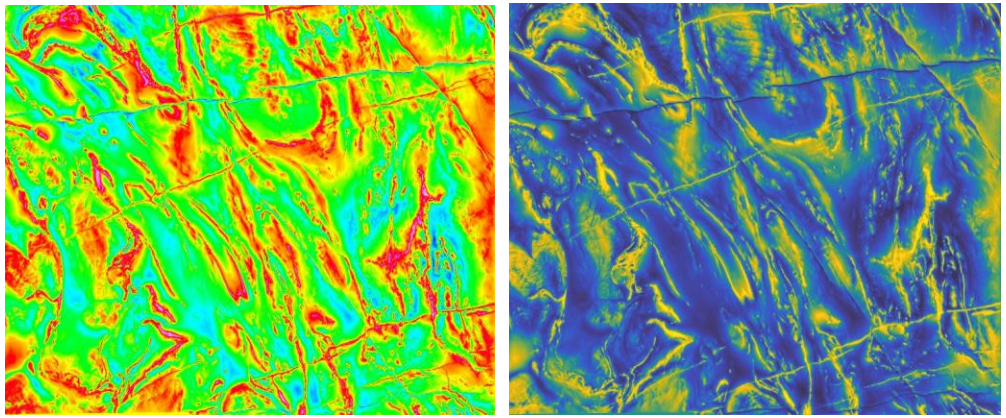


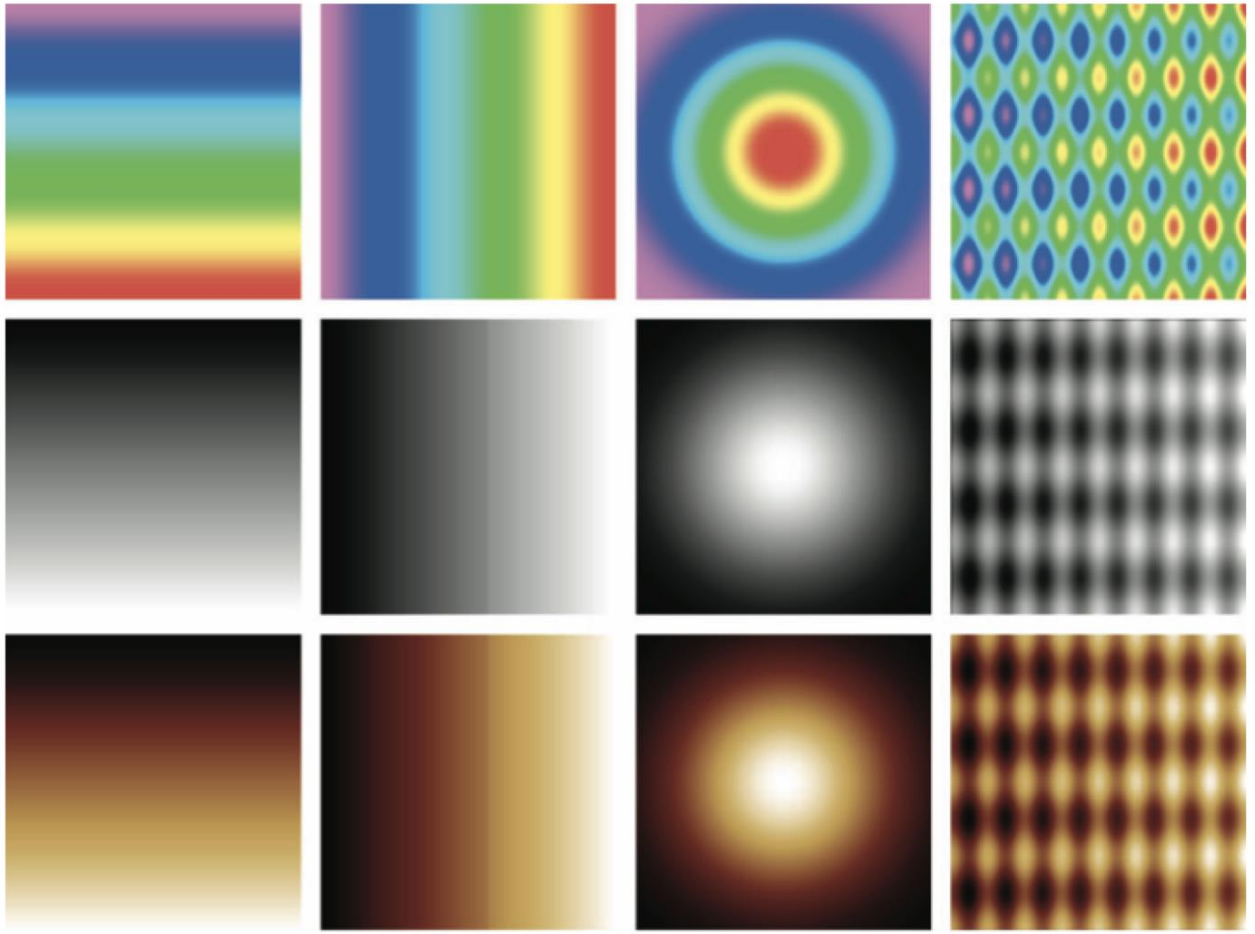


3. Avoid bias in the representation

The rainbow colourmap is often used by default in software. It must be banned as it is non-uniform.







Peter Kovesi, NOAA, David Borland and Russell M. Taylor

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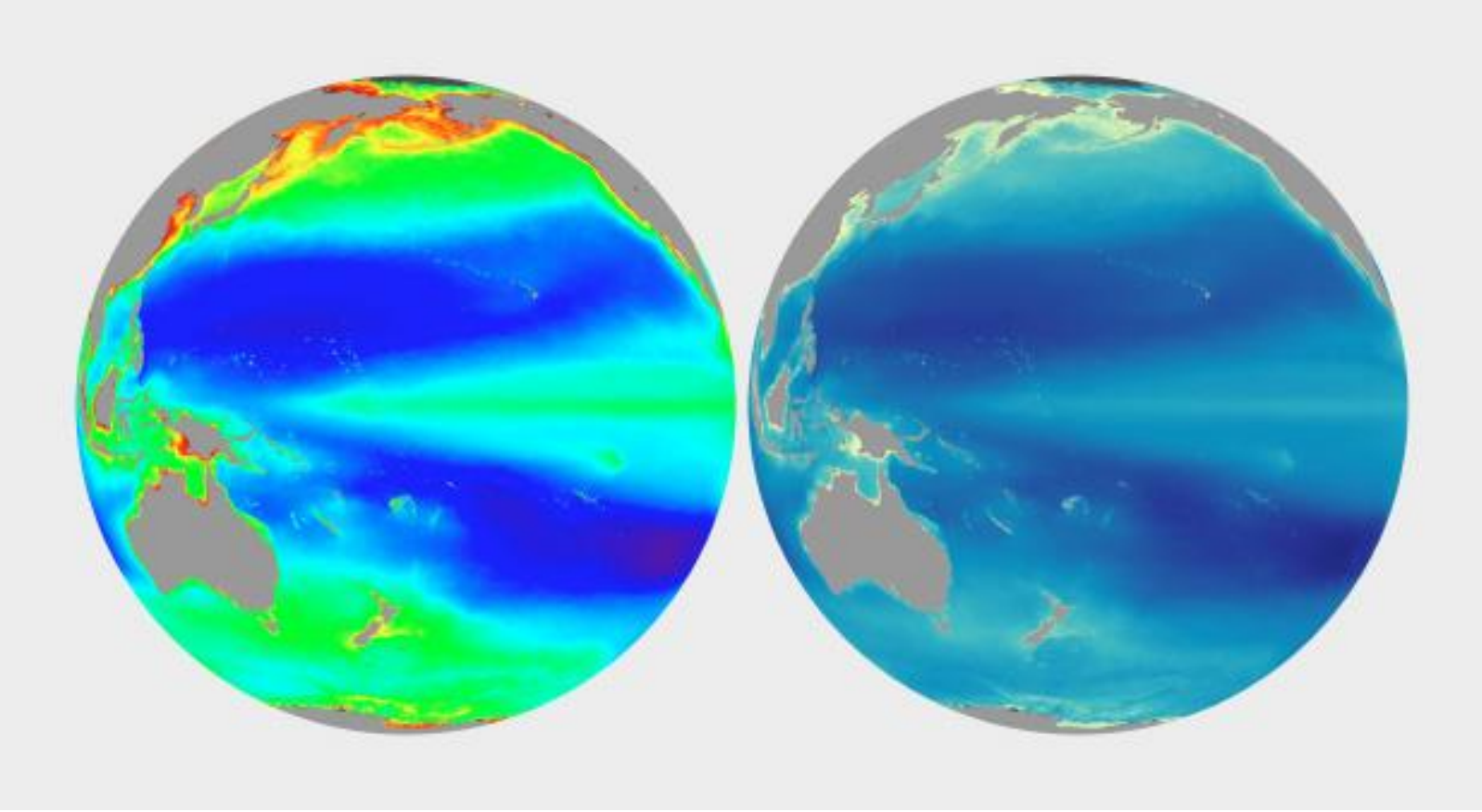
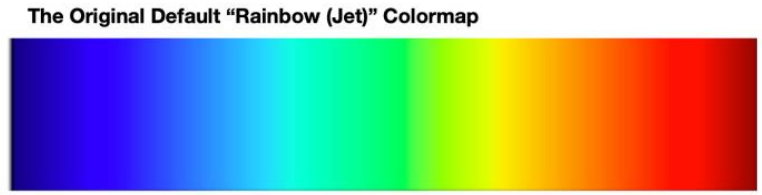
map of ocean phytoplankton distribution





NASA

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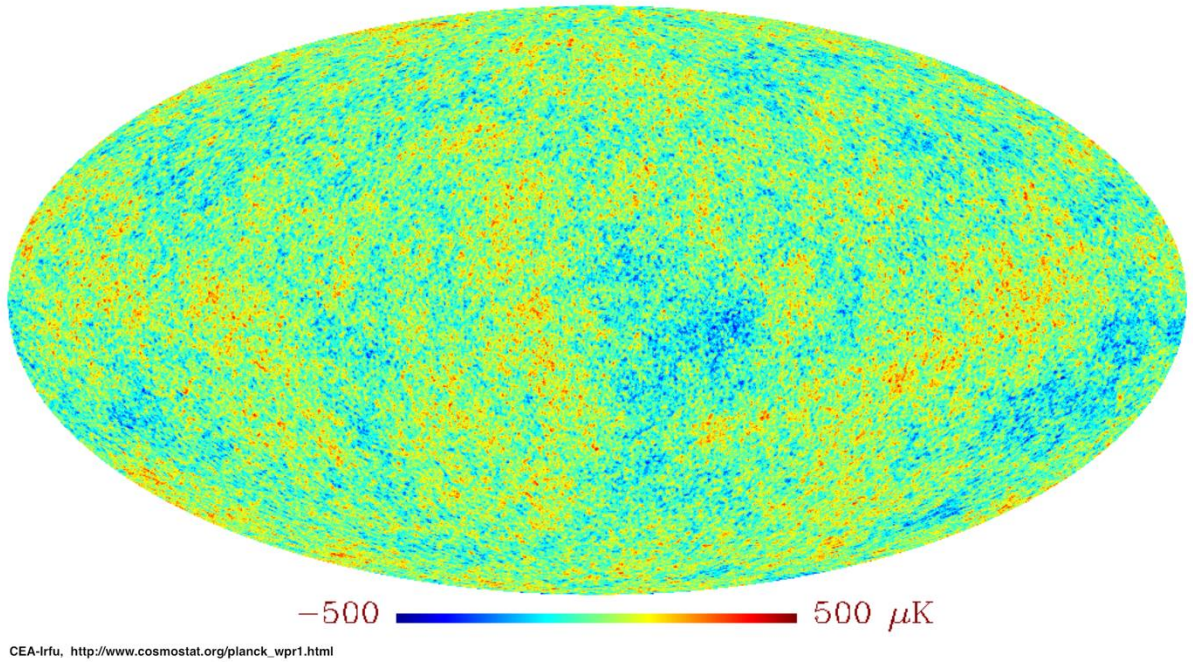
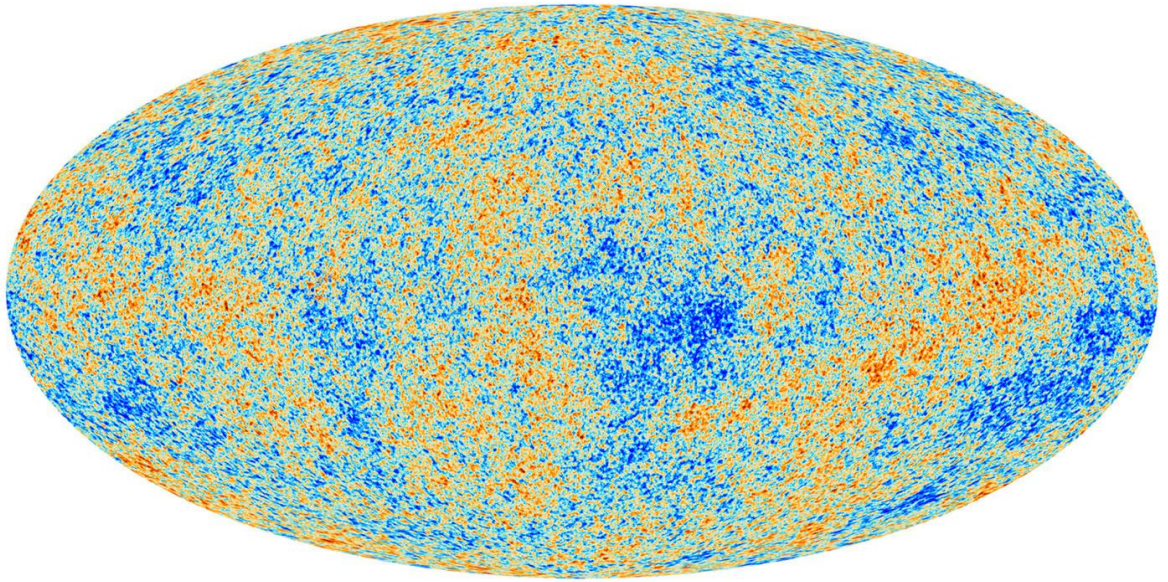
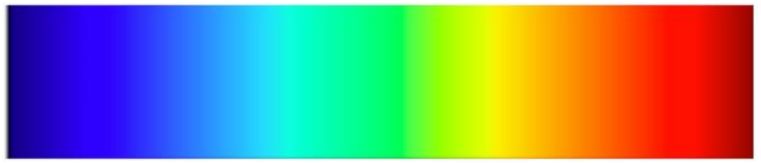
CMB map







CEA, ESA, Fabio Crameri,

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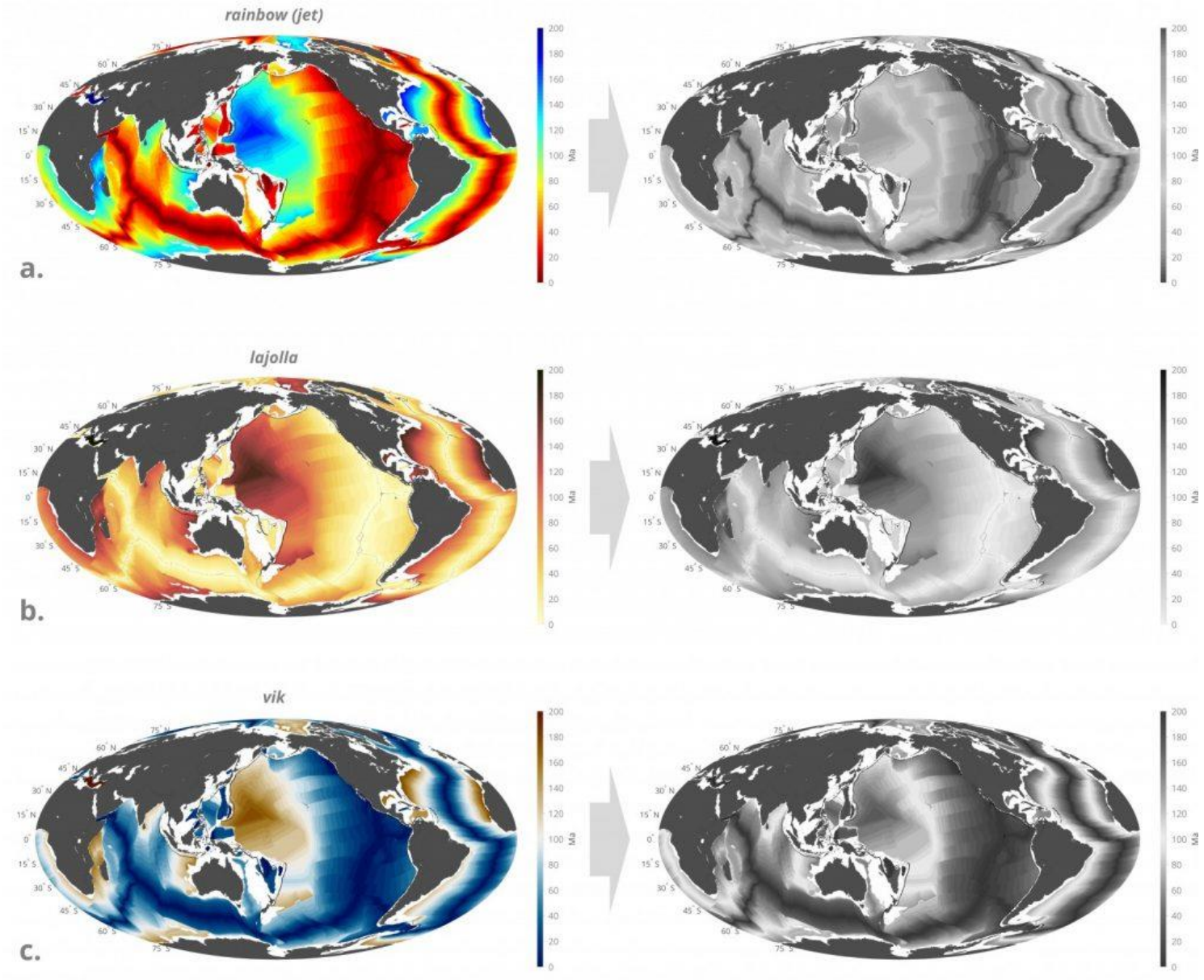


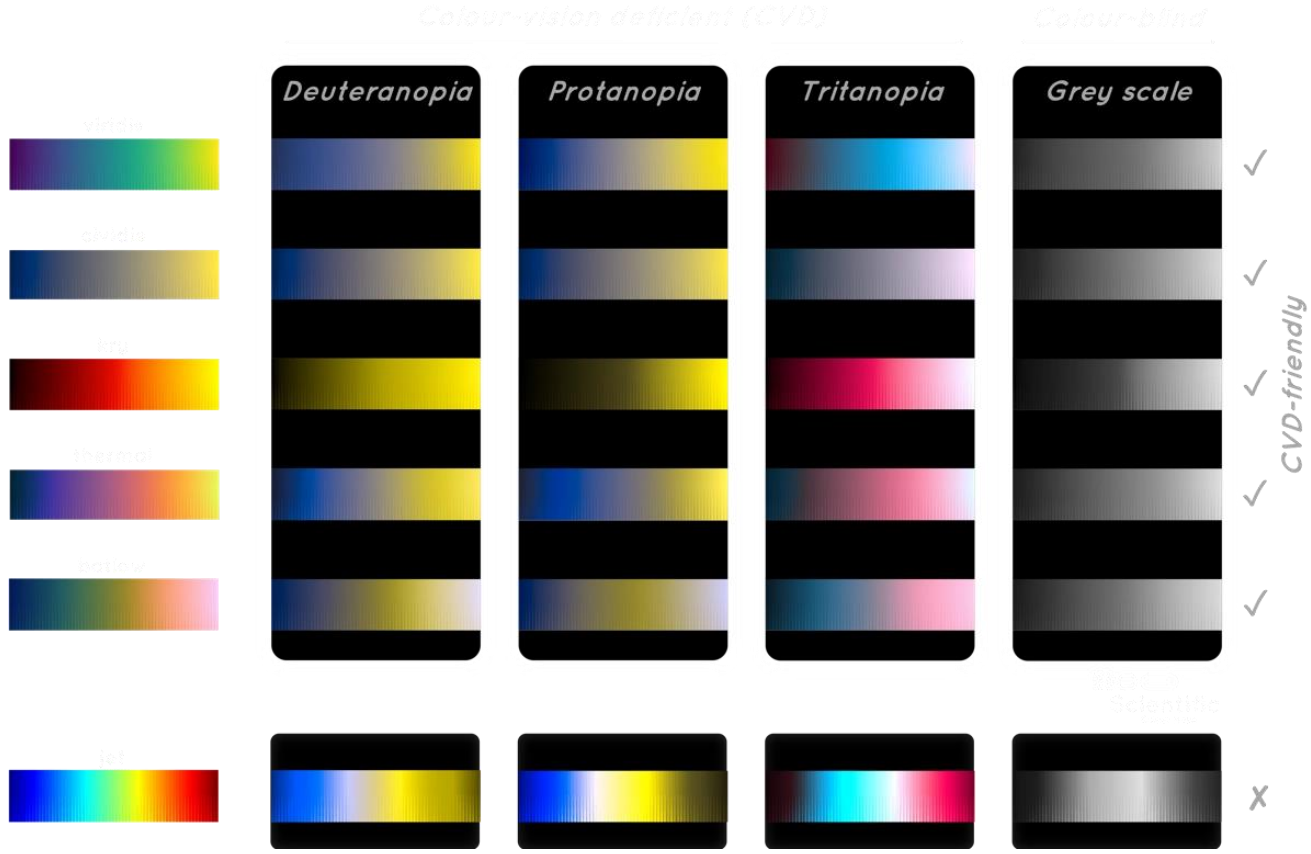
Always keep in mind that the figures you publish may be printed in black and white.

Fabio Crameri EGU2018

4. Consider color vision deficiencies

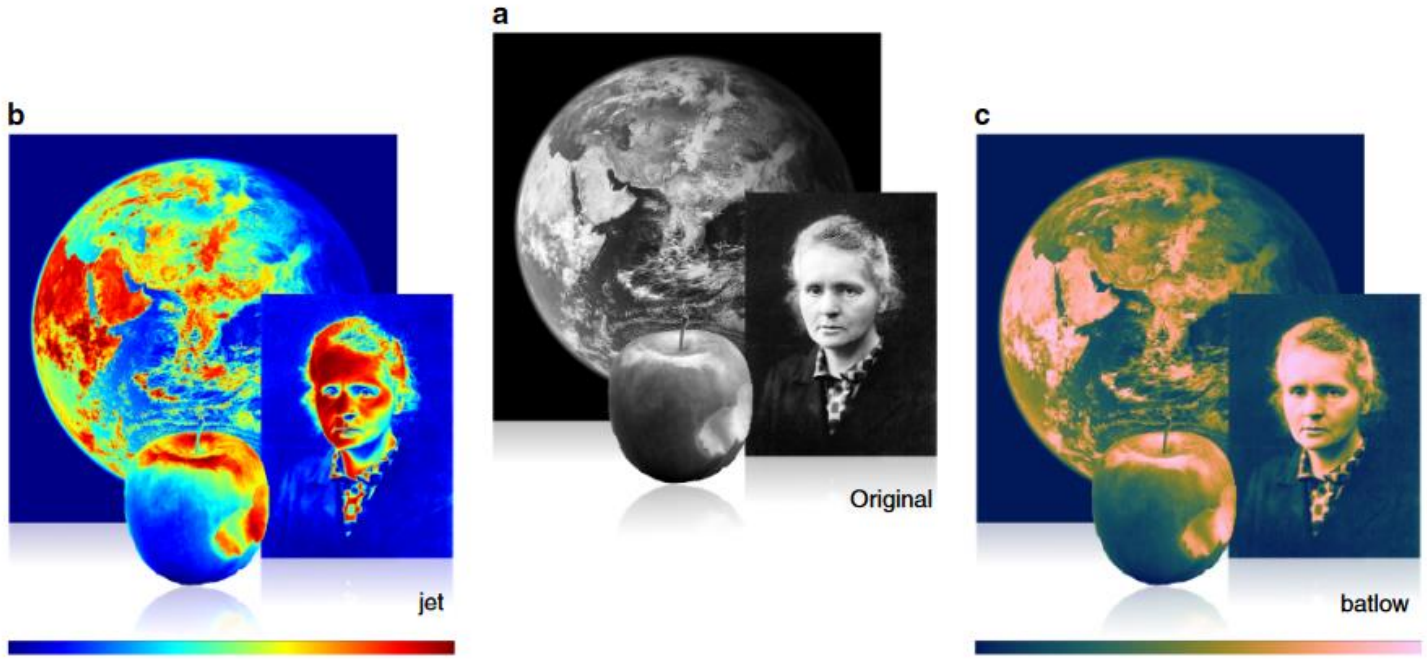
- Red and green are difficult to differenciate for most of the blind people.
- Use blue and yellow instead.
- Online tools can help you check that your colourmap is suitable for them.

https://davidmathlogic.com/colorblind/
https://www.fabiocrameri.ch/colourmaps/



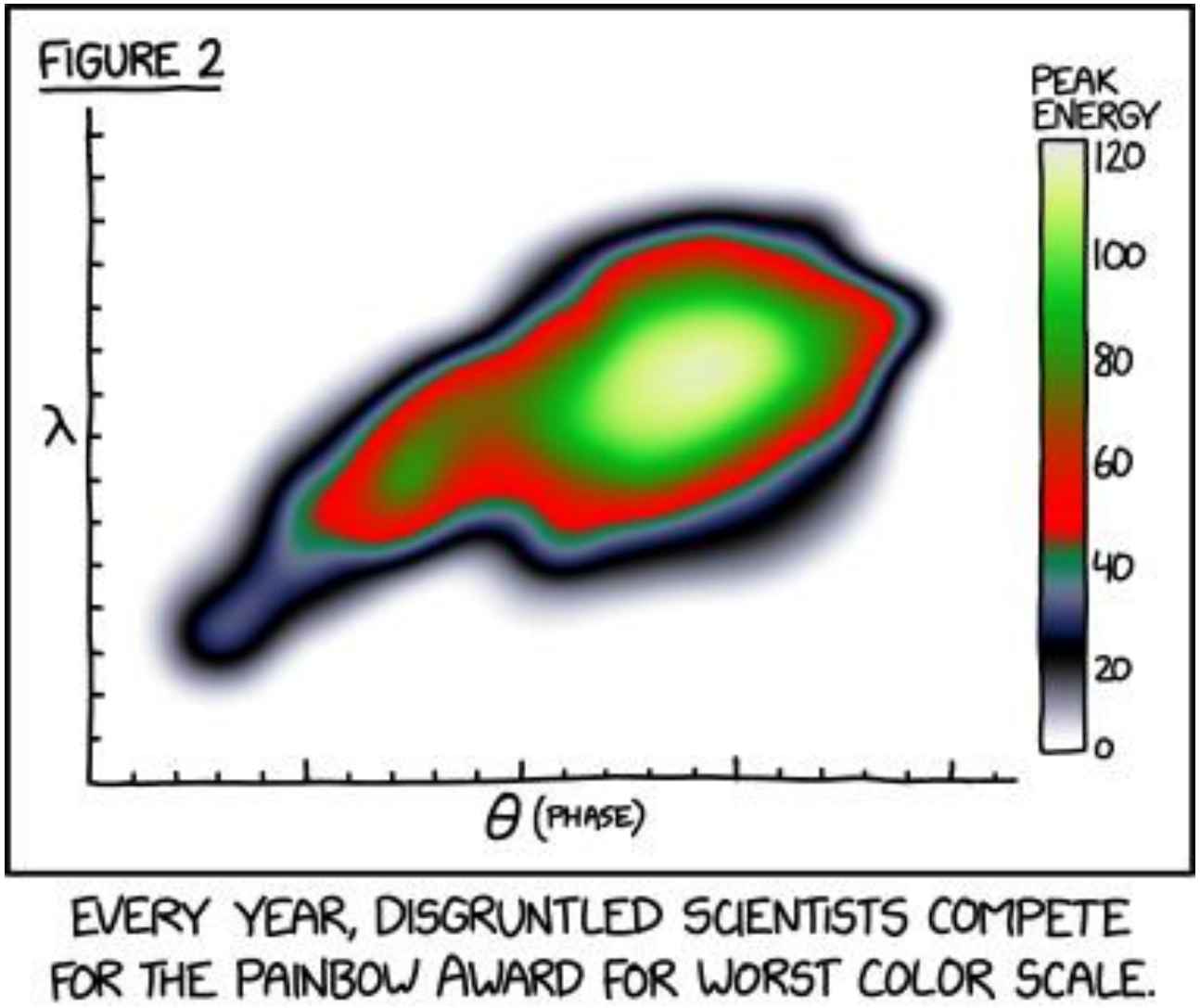
Conclusion

Stop blindly use default colourmaps in software. Adapt your colourmap to your data (type, order, spatial frequency...). Use perceptually uniform ramps to avoid bias in representation.



Fabio Crameri

https://www.fabiocrameri.ch/colourmaps/ (Fabio Crameri)
https://colorcet.com/index.html (Peter Kovesi)



Xkcd webcomic

ErrantScience