



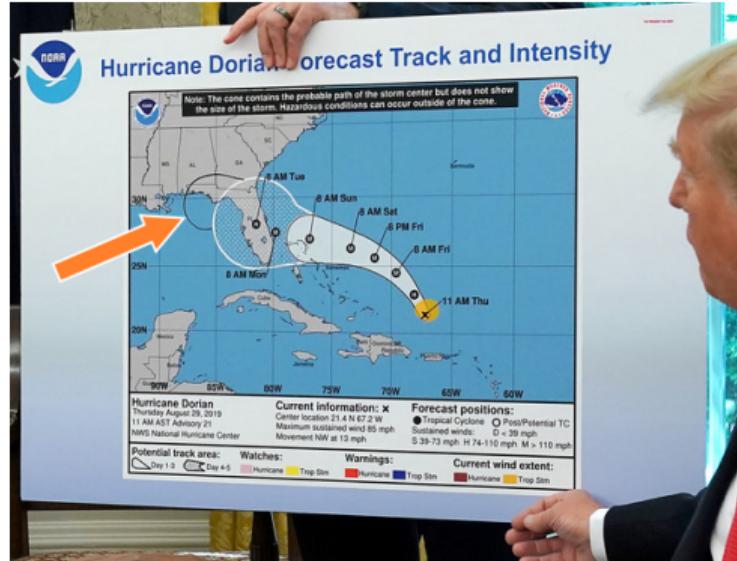
colorspace

Robust Color Maps That Work for Most Audiences
(Including the U.S. President)

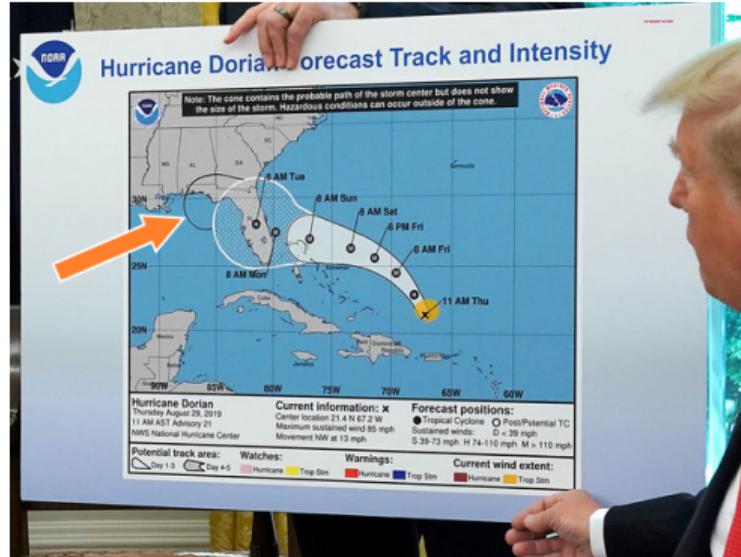
Reto Stauffer, Achim Zeileis

<http://hclwizard.org/>

Motivation



Motivation



Projected track and wind speed forecast of hurricane Dorian. Screenshot of a video released by the White House (Sep. 4, 2019), tweet by the U.S. president (Sep. 5, 2019).

Problem



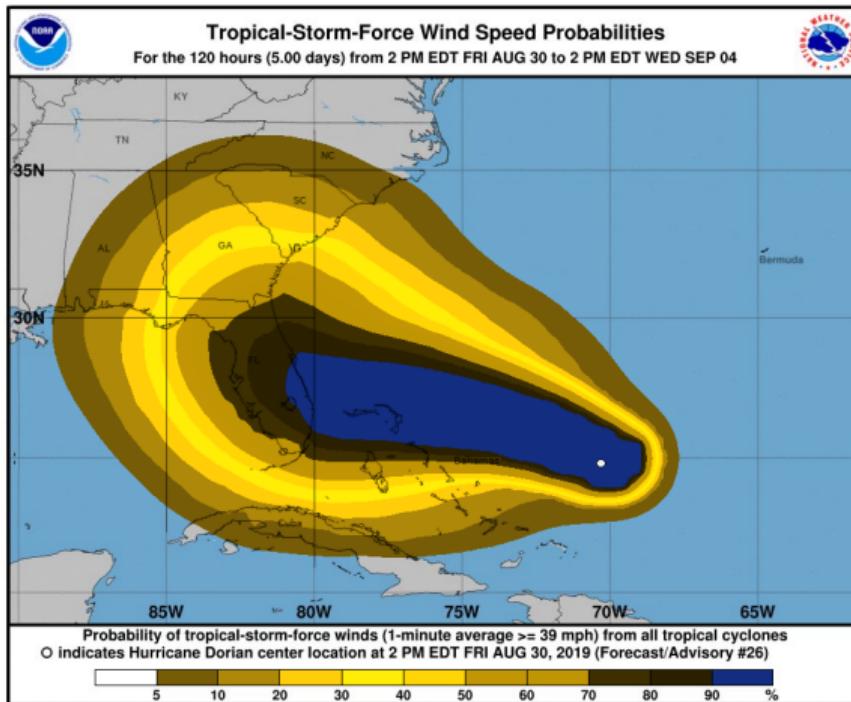
Probability of exceeding wind speeds of 39 mph (63 km h^{-1}), Aug 30 – Sep 04, 2019 (noaa.gov).

Problem



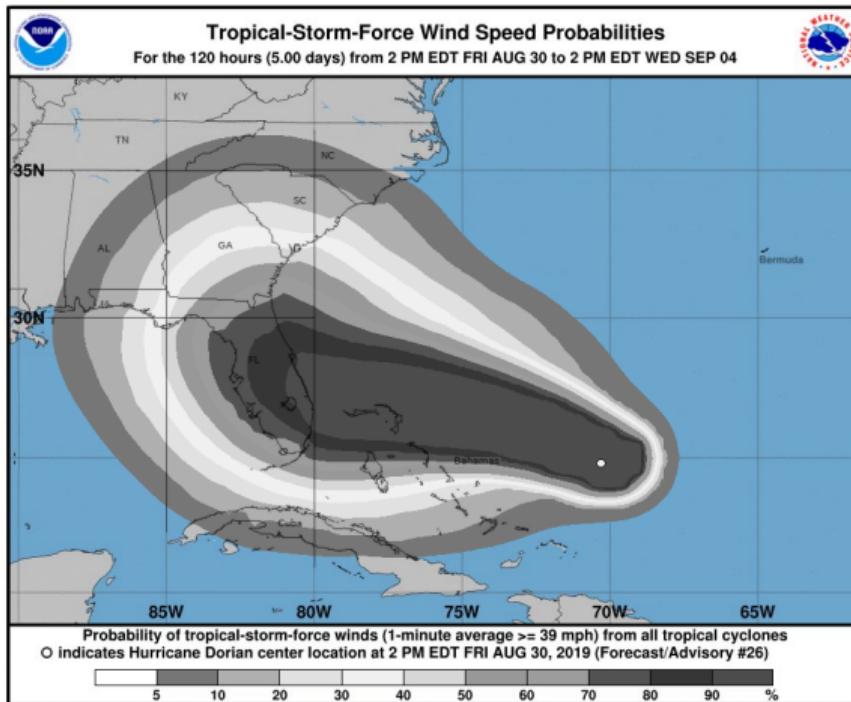
Probability of exceeding wind speeds of 39 mph (63 km h^{-1}), Aug 30 – Sep 04, 2019 (noaa.gov).

Problem



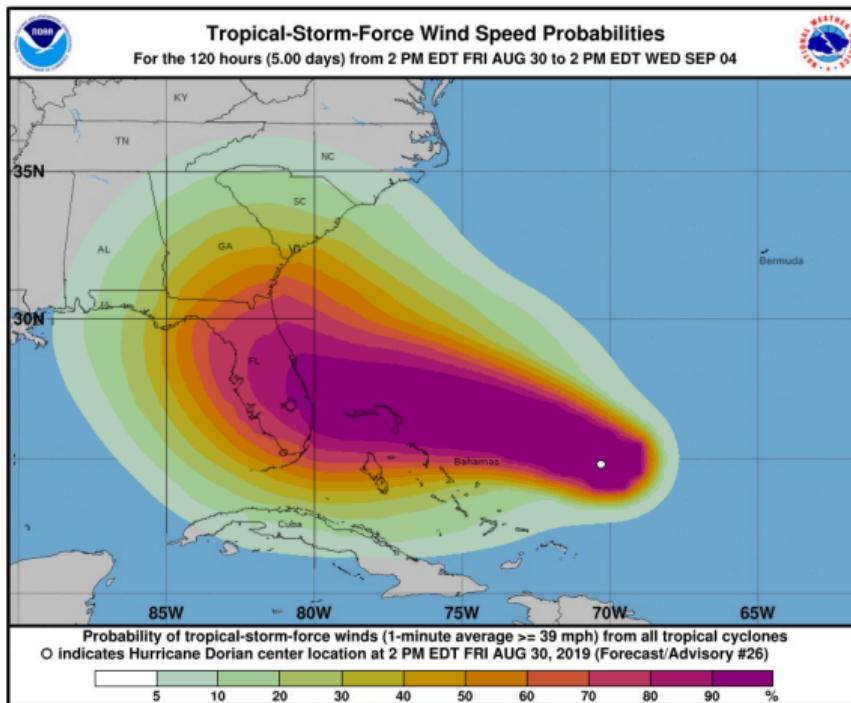
Probability of exceeding wind speeds of 39 mph (63 km h^{-1}), Aug 30 – Sep 04, 2019 (noaa.gov).

Problem



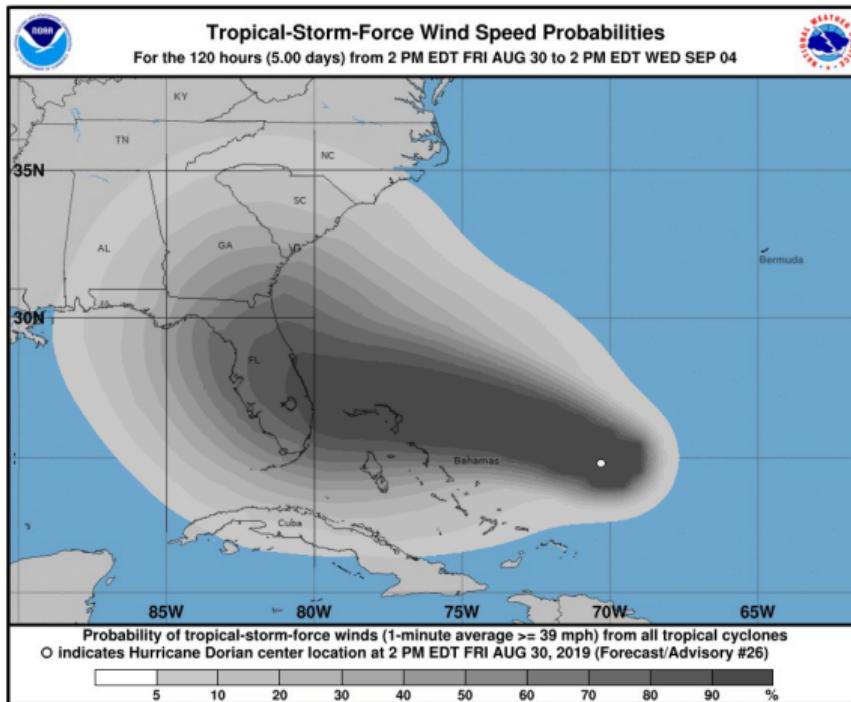
Probability of exceeding wind speeds of 39 mph (63 km h^{-1}), Aug 30 – Sep 04, 2019 (noaa.gov).

Solution



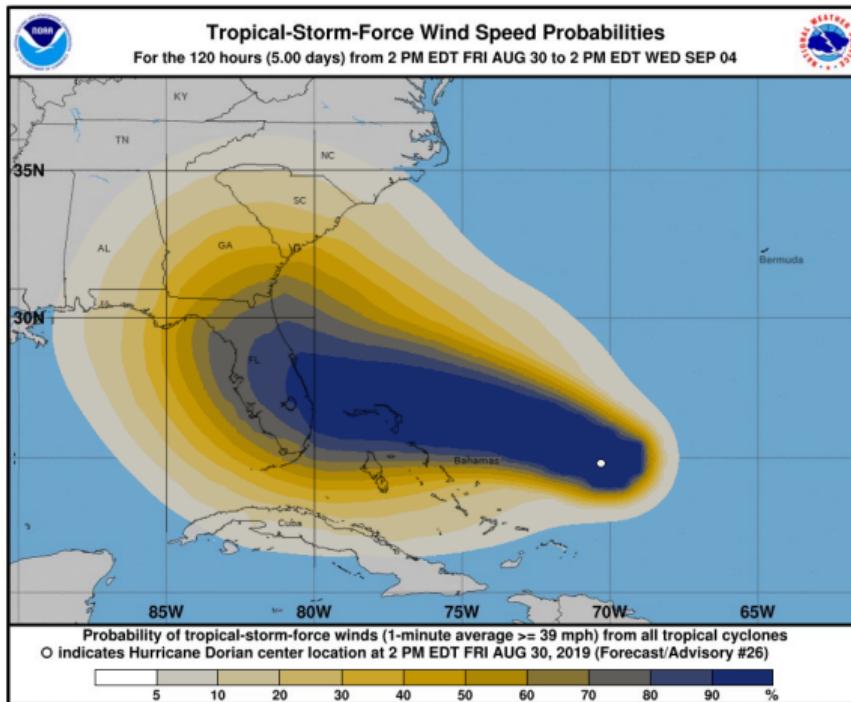
Probability of exceeding wind speeds of 39 mph (63 km h^{-1}), Aug 30 – Sep 04, 2019 (noaa.gov).

Solution



Probability of exceeding wind speeds of 39 mph (63 km h^{-1}), Aug 30 – Sep 04, 2019 (noaa.gov).

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Probability of exceeding wind speeds of 39 mph (63 km h^{-1}), Aug 30 – Sep 04, 2019 (noaa.gov).

HCL vs. RGB

HCL: Polar coordinates in CIELUV.
Captures perceptual dimensions of
the human visual system very well.



HCL vs. RGB

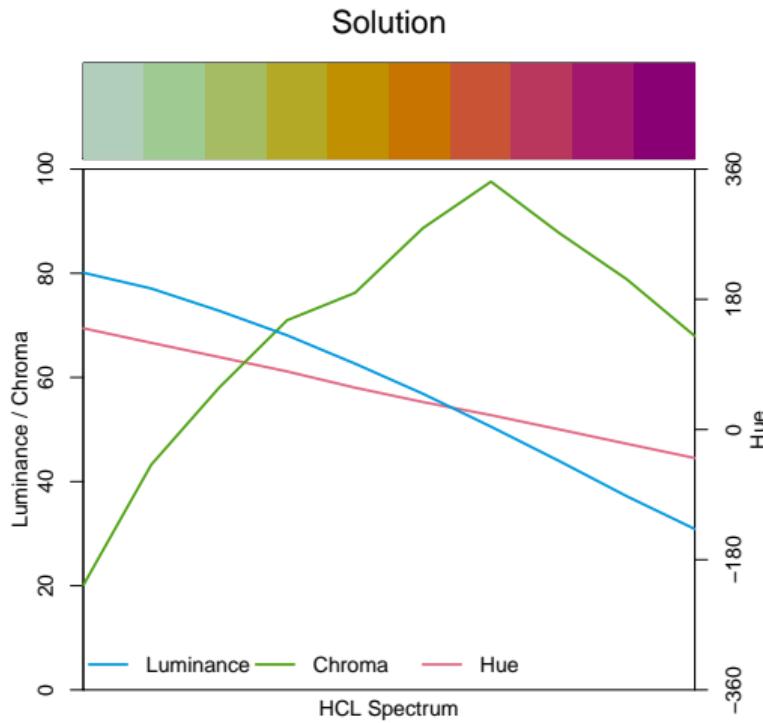
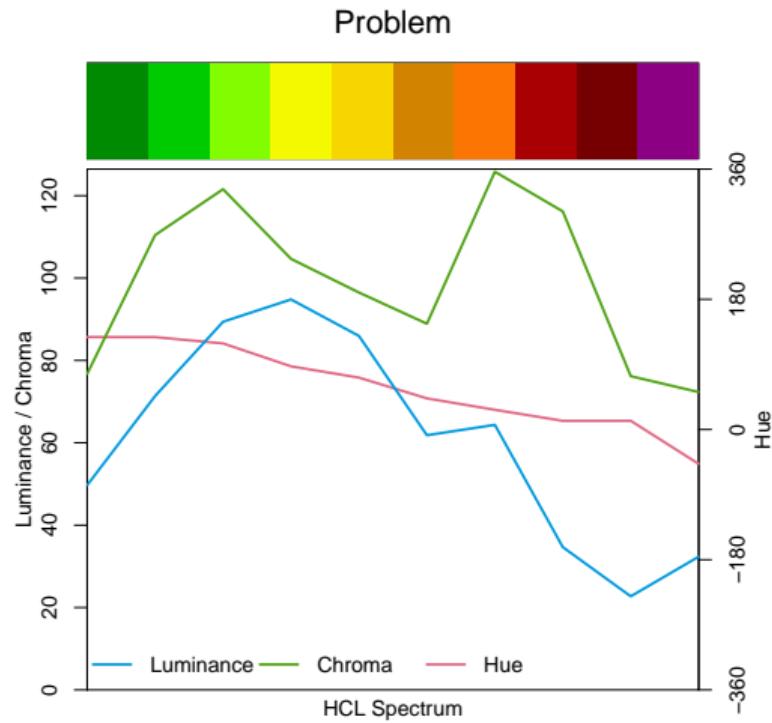
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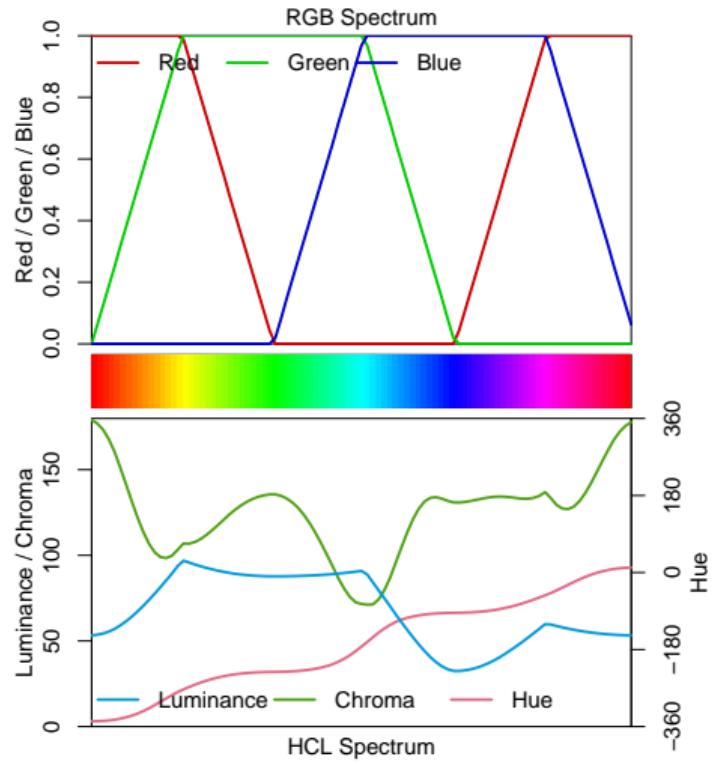
RGB: Motivated by how computers/TVs used to generate and still represent color.



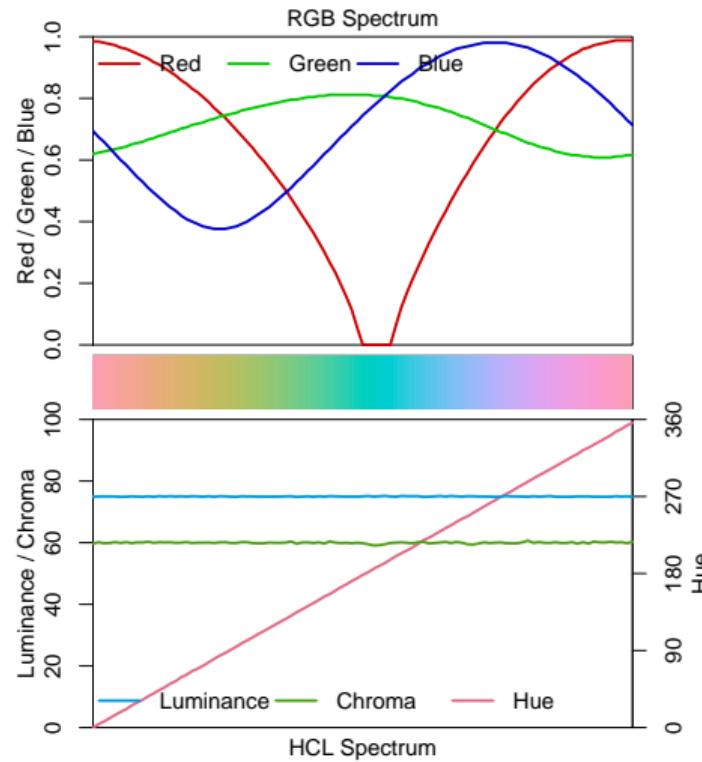
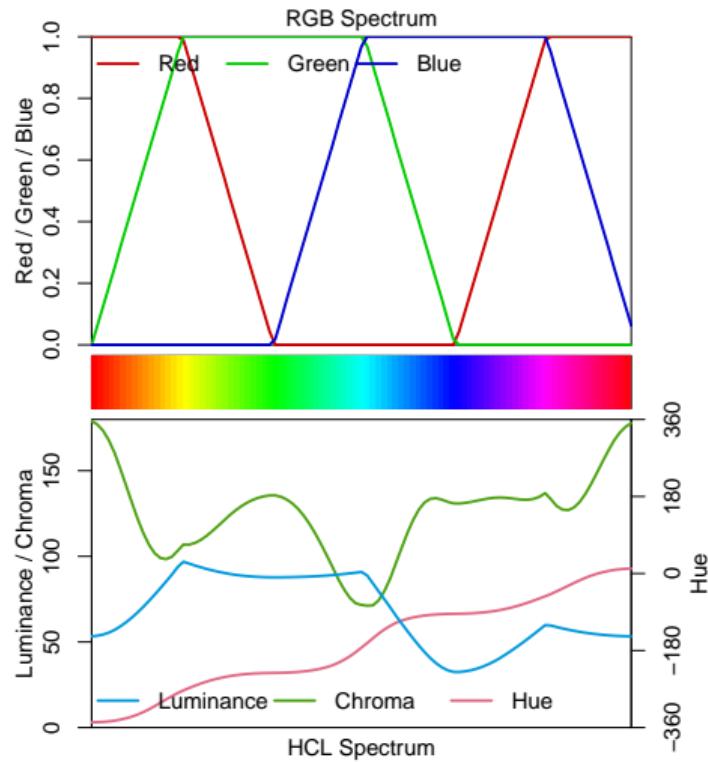
HCL vs. RGB



HCL vs. RGB: The End of the Rainbow



HCL vs. RGB: The End of the Rainbow

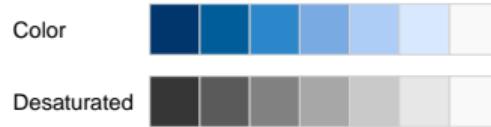


Color palettes: Somewhere over the Rainbow

Qualitative (Set 2)



Sequential (Blues 3)

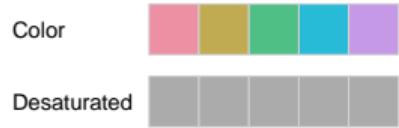


Diverging (Green–Brown)

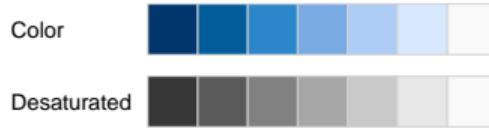


Color palettes: Somewhere over the Rainbow

Qualitative (Set 2)



Sequential (Blues 3)



Diverging (Green–Brown)



Qualitative: For categorical information, i.e., where no particular ordering of categories is available. Function: `qualitative_hcl()`.

Color palettes: Somewhere over the Rainbow

Qualitative (Set 2)



Sequential (Blues 3)



Diverging (Green–Brown)



Qualitative: For categorical information, i.e., where no particular ordering of categories is available. Function: `qualitative_hcl()`.

Sequential: For ordered/numeric information, i.e., where colors go from high to low (or vice versa). Function: `sequential_hcl()`.

Color palettes: Somewhere over the Rainbow

Qualitative (Set 2)



Sequential (Blues 3)



Diverging (Green–Brown)



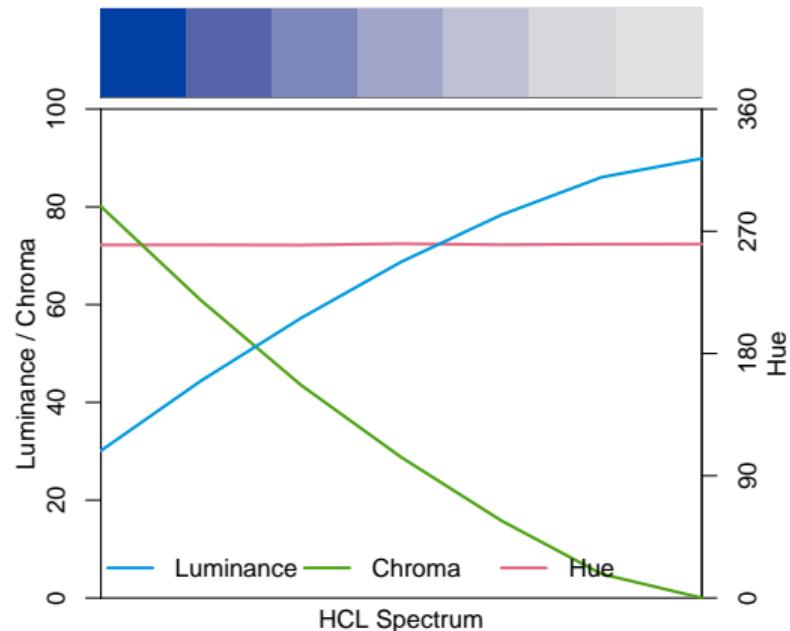
Qualitative: For categorical information, i.e., where no particular ordering of categories is available. Function: `qualitative_hcl()`.

Sequential: For ordered/numeric information, i.e., where colors go from high to low (or vice versa). Function: `sequential_hcl()`.

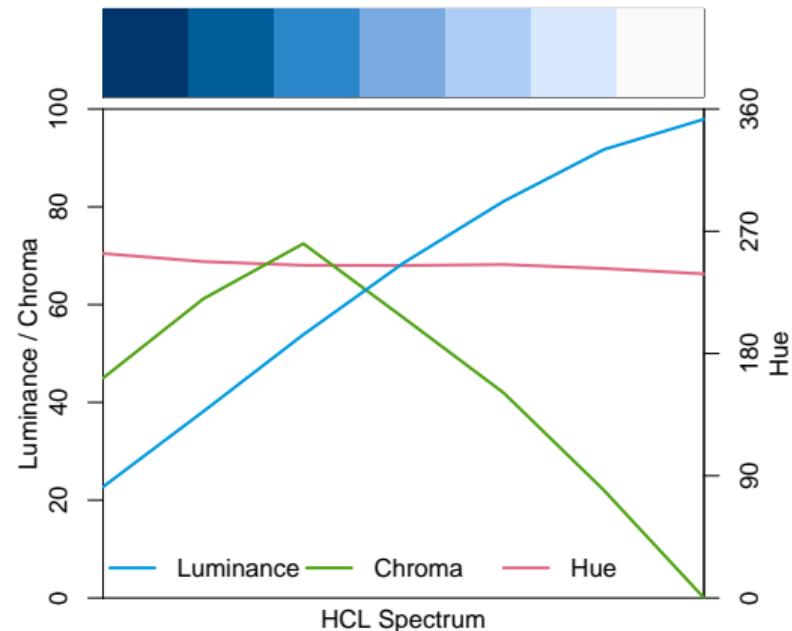
Diverging: For ordered/numeric information around a central neutral value, i.e., where colors diverge from neutral to two extremes. Function: `diverging_hcl()`.

Color palettes: Somewhere over the Rainbow

Blues 2: Single hue. Decreasing chroma with increasing luminance.

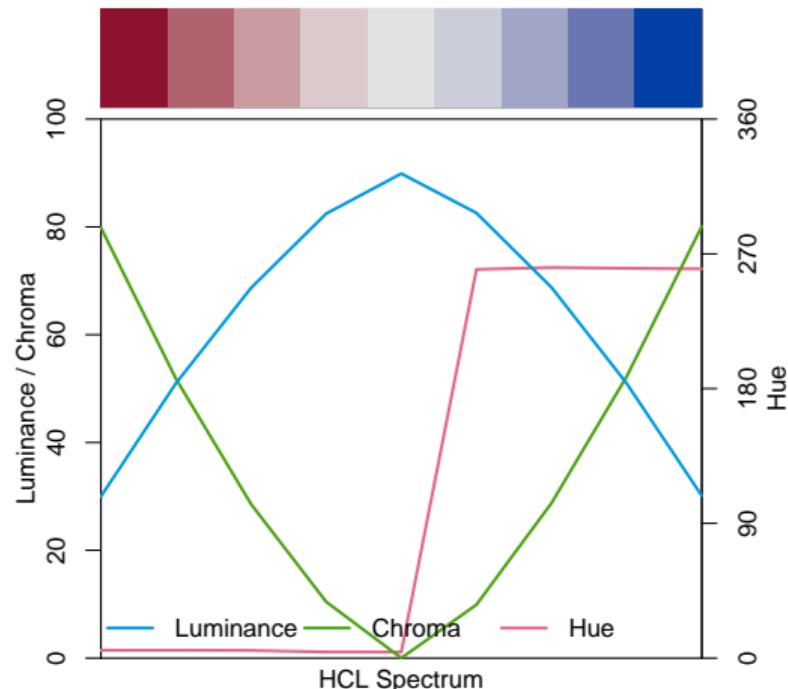


Blues 3: Single hue. Triangular chroma to achieve higher luminance contrast.



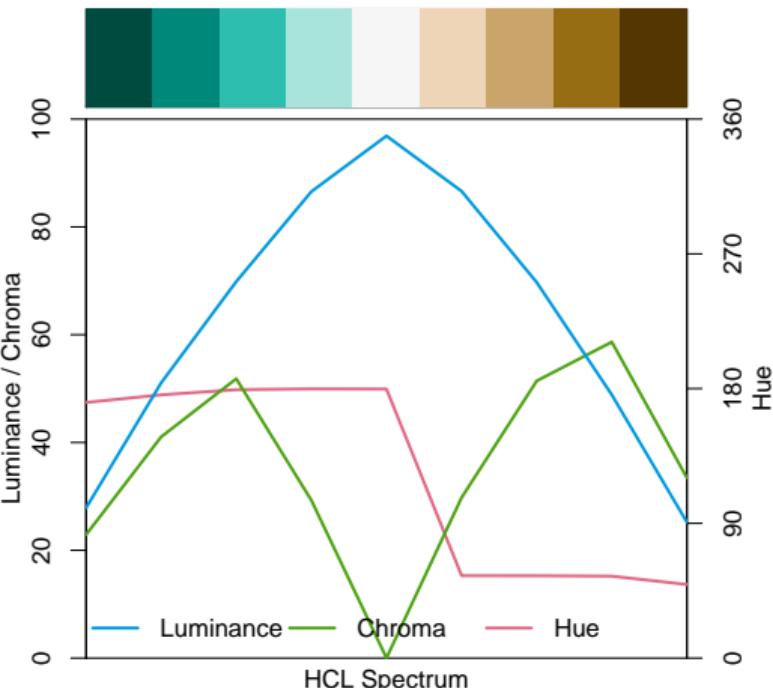
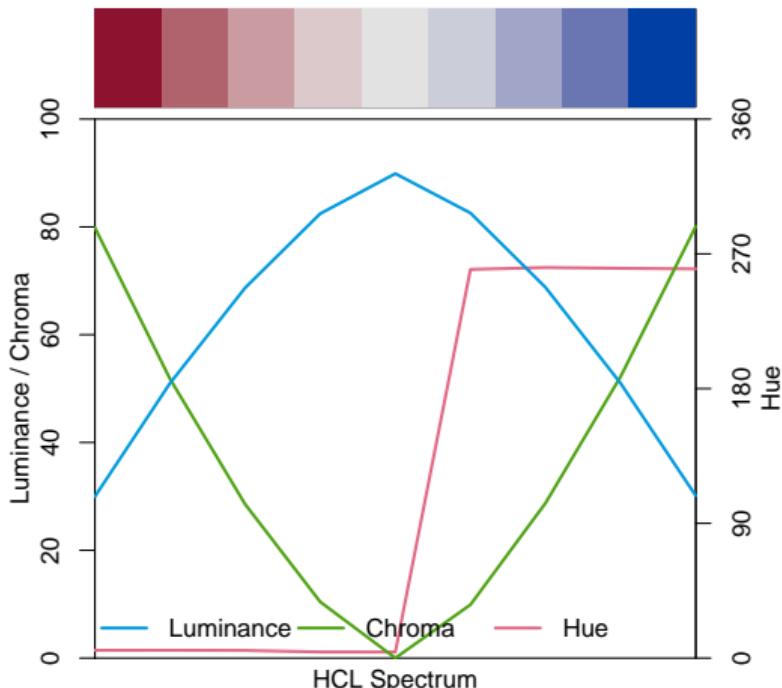
Color palettes: Somewhere over the Rainbow

Diverging: Combine two sequential palettes with balanced chroma/luminance.



Color palettes: Somewhere over the Rainbow

Diverging: Combine two sequential palettes with balanced chroma/luminance.



Color palettes: Somewhere over the Rainbow

```
> hcl_palettes(plot = TRUE)
```



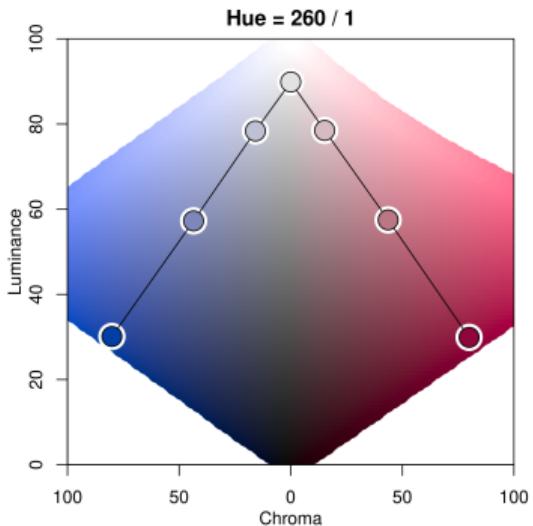
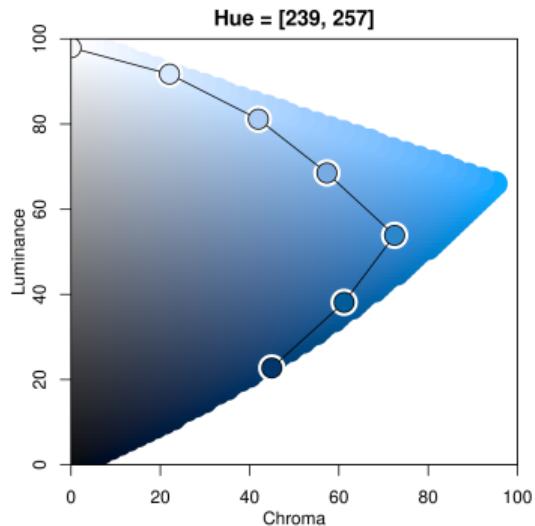
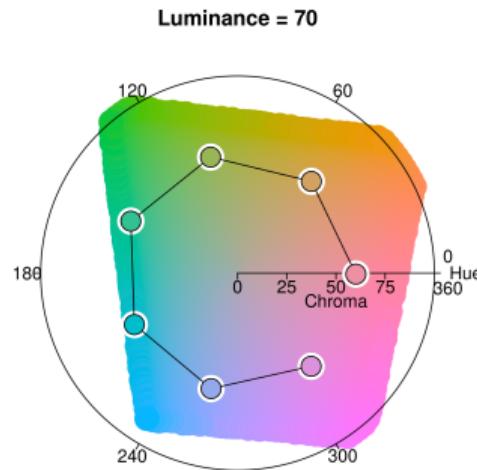
Visualization and assessment

Visualizations: Based on vector of colors.

- `swatchplot()`: Color swatches.
- `specplot()`: Spectrum of HCL and/or RGB trajectories.
- `hclplot()`: Trajectories in 2-dimensional HCL space projections.
- `demoplot()`: Illustrations of typical (and simplified) statistical graphics.

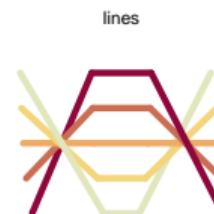
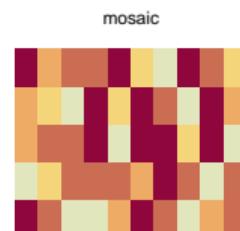
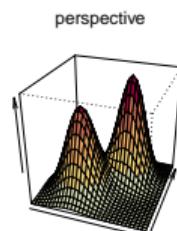
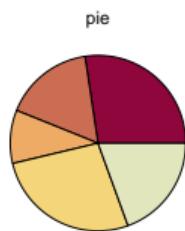
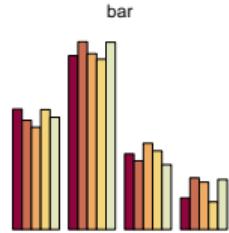
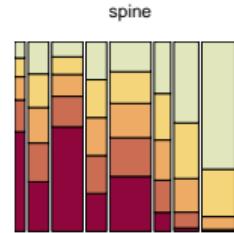
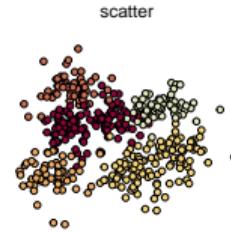
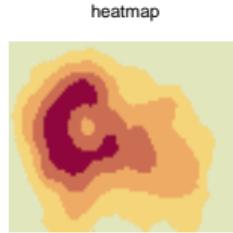
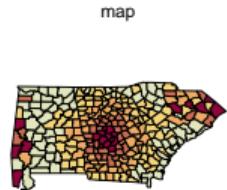
Visualization and assessment: hclplot()

```
> hclplot(qualitative_hcl(7, palette = "Set 2"))
> hclplot(sequential_hcl(7, palette = "Blues 3"))
> hclplot(diverging_hcl(7, palette = "Blue-Red"))
```



Visualization and assessment: demoplot()

```
> cl <- sequential_hcl(5, palette = "Heat")
> demoplot(cl, type = "...")
```

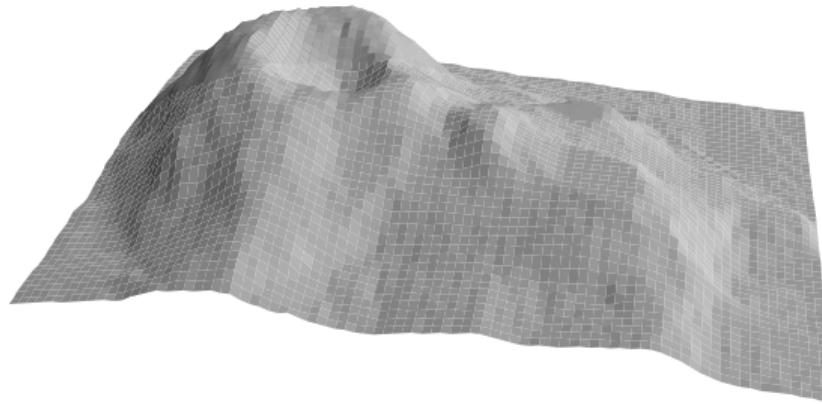


Color vision deficiency

Emulate: Color vision deficiencies.

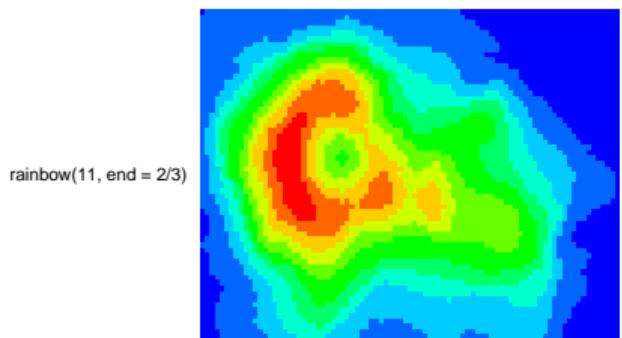
- `deutan()`: Deuteranopia (green deficient).
- `protan()`: Protanopia (red deficient).
- `tritan()`: Tritanopia (blue deficient).

Example: Maunga Whau volcano data.

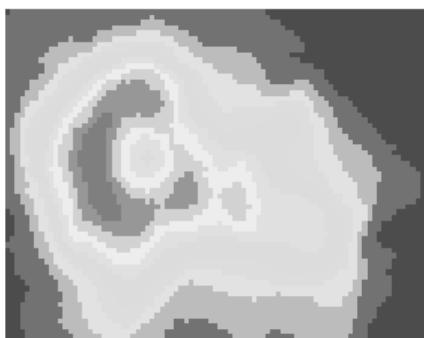


Color vision deficiency

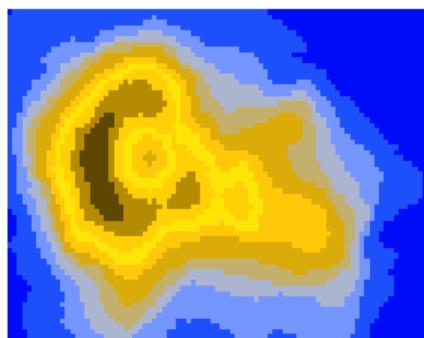
Original



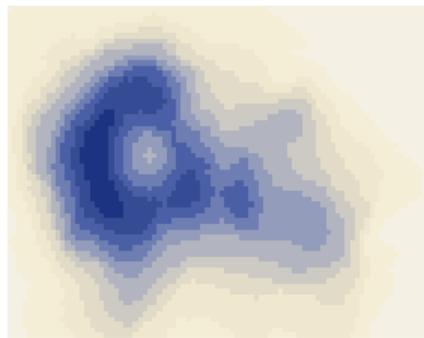
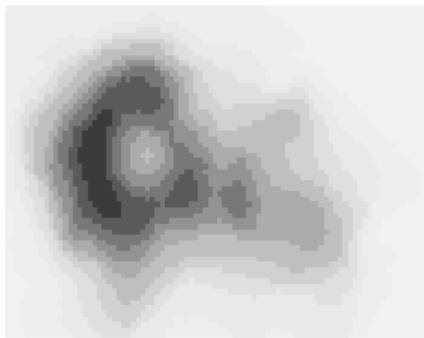
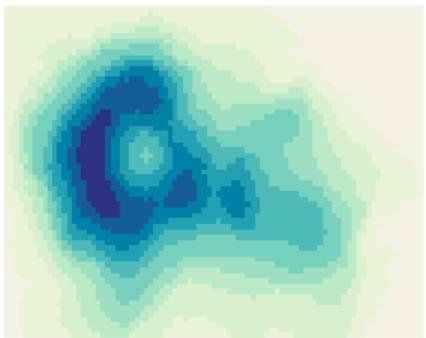
Desaturated



Deutanope

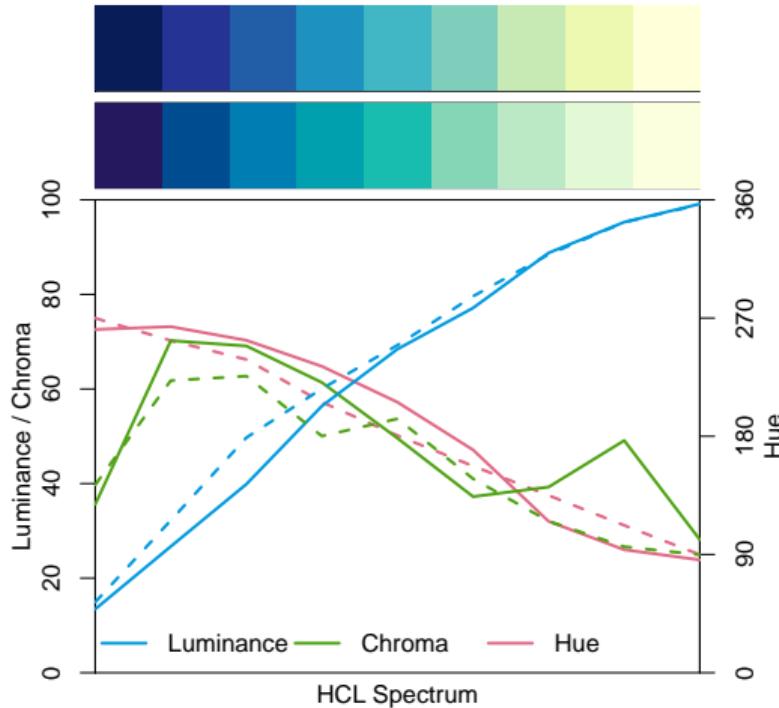


sequential_hcl(11, "Blue-Yellow")



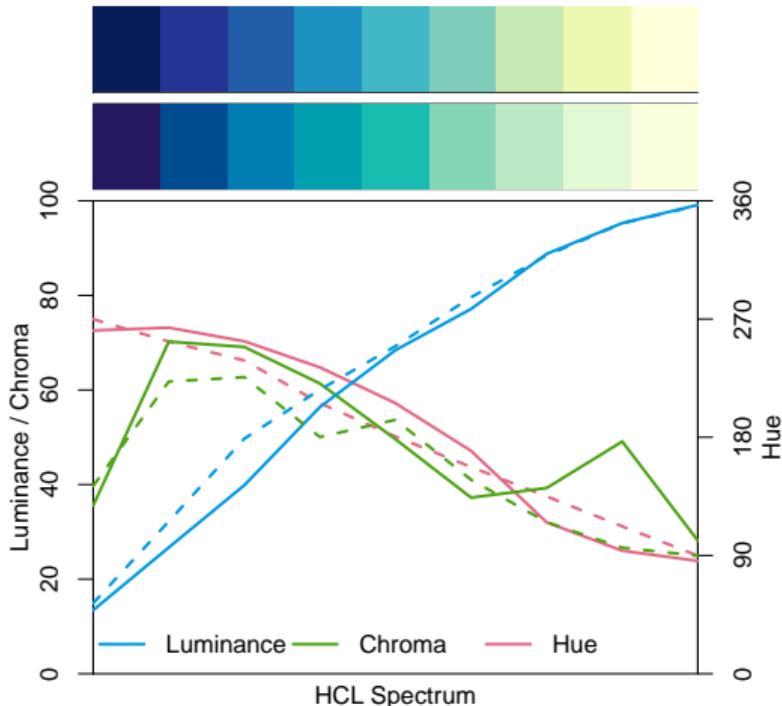
Approximations of other palettes

ColorBrewer.org: YIGnBu

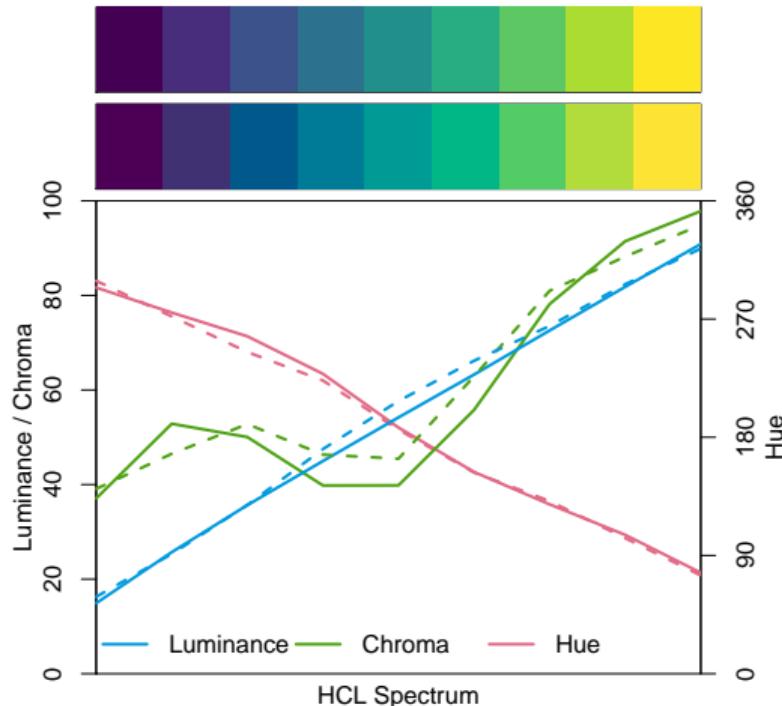


Approximations of other palettes

ColorBrewer.org: YIGnBu



Viridis



Base R

In 3.6.0: All prespecified palettes also via `grDevices::hcl.colors()`.



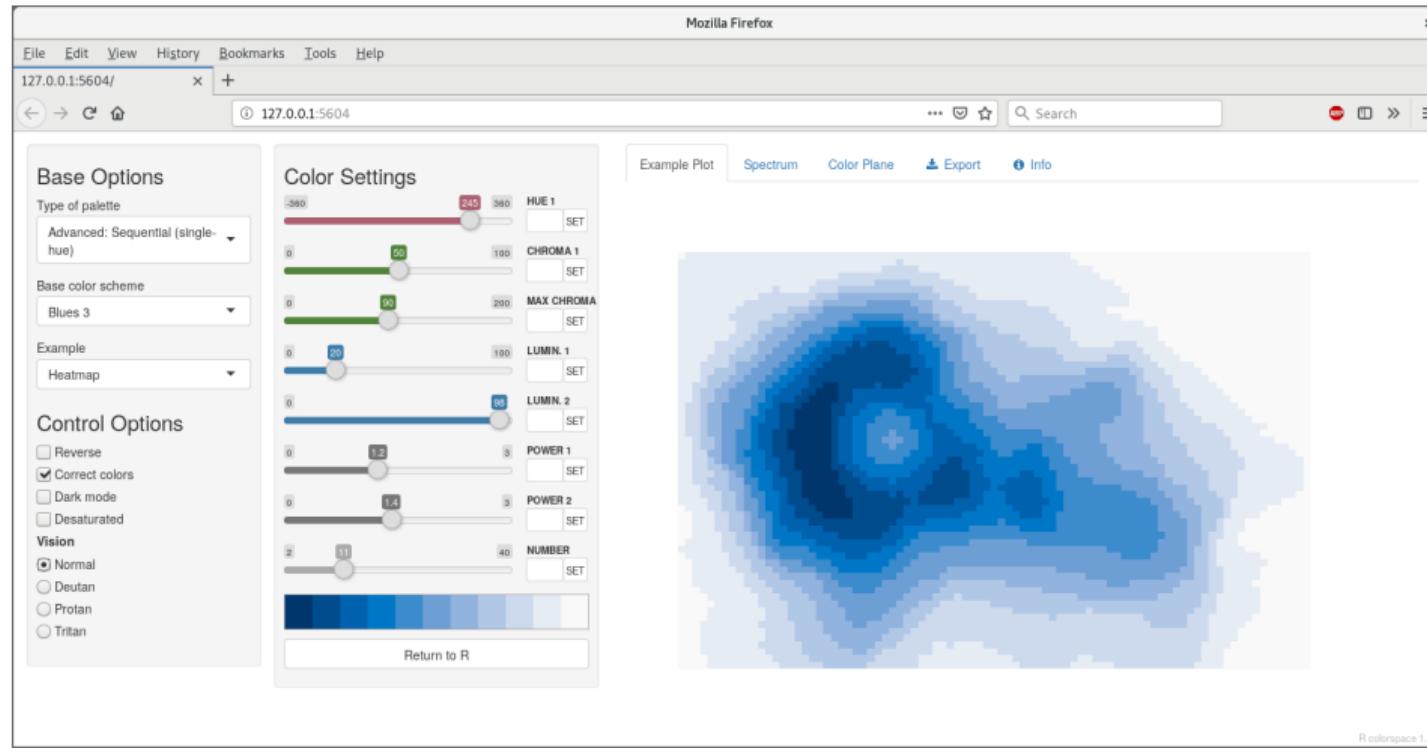
Color apps

Facilitate exploration: Graphical user interfaces as shiny apps.

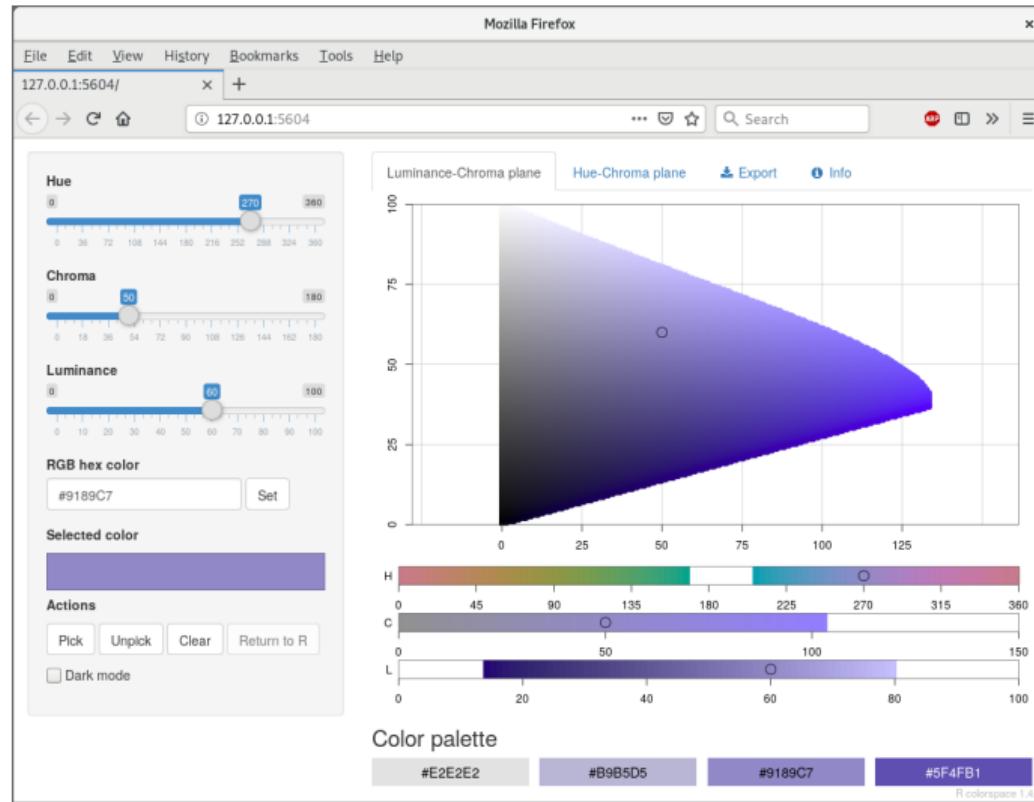
- *Palette constructor:* `choose_palette()` or `hclwizard()` (also in `tcltk`).
- *Color picker:* `choose_color()` or `hcl_color_picker()`.
- *Color vision deficiency emulator:* `cvd_emulator()`.

Online versions: <http://hclwizard.org/>

Color apps: choose_palette() / hclwizard()



Color apps: choose_color() / hcl_color_picker()



Color apps: cvd_emulator()

Mozilla Firefox

File Edit View History Bookmarks Tools Help

127.0.0.1:5604/

127.0.0.1:5604

Upload Original Desaturated Deutanope Protanope Tritanope

All Info

Severity

0 10 20 30 40 50 60 70 80 90 100

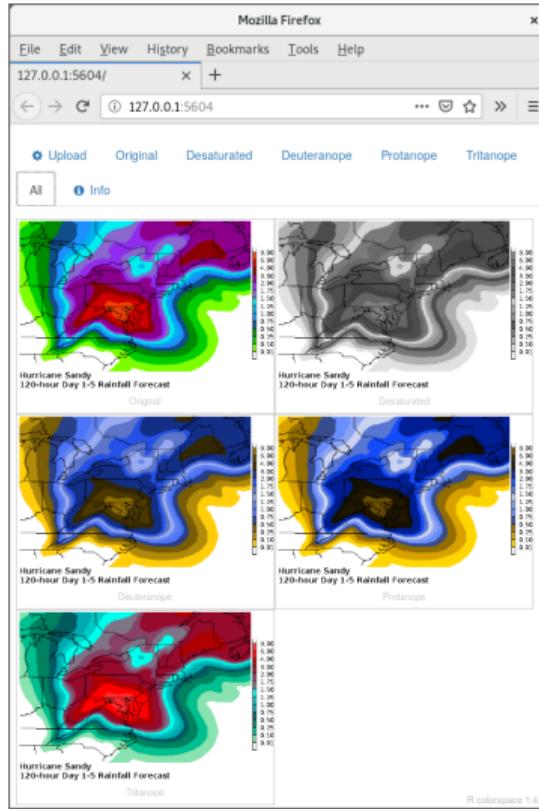
Different levels of severity for the color vision deficiency can be emulated. A value of 100% means maximum deficiency, a value of 0% no deficiency at all. This value has to be adjusted before uploading the Image.

Upload Image

Browse No file selected

Select an image from your local disc (PNG/JPG/JPEG) for which the color vision deficiency should be emulated. Please note that the file size is limited to 50.0 Megabyte.

R colorspace 1.4.0



Recommendations

Colors and palettes:

- Do not overestimate the effectiveness of color.
- Choose type of palette based on the data to be visualized.
- For areas use light colors (higher luminance, lower chroma).
- For points/lines darker colors are needed (lower luminance, higher chroma).
- For palettes with more colors stronger luminance contrasts are needed.
- Triangular chroma trajectories useful for distinguishing central colors.

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R packages:

- *colorspace* facilitates exploration, manipulation, and assessment.
- HCL approximations of palettes from *RColorBrewer*, *rcartocolor*, *scico*, ...
- Prespecified palettes are also easily available in base R.

Do it yourself

Software: *colorspace*.

- R (mature): <http://colorspace.R-Forge.R-project.org/>.
- Python (beta): <https://github.com/retostauffer/python-colorspace>.
- Web (interactive): <http://www.hclwizard.org/>.

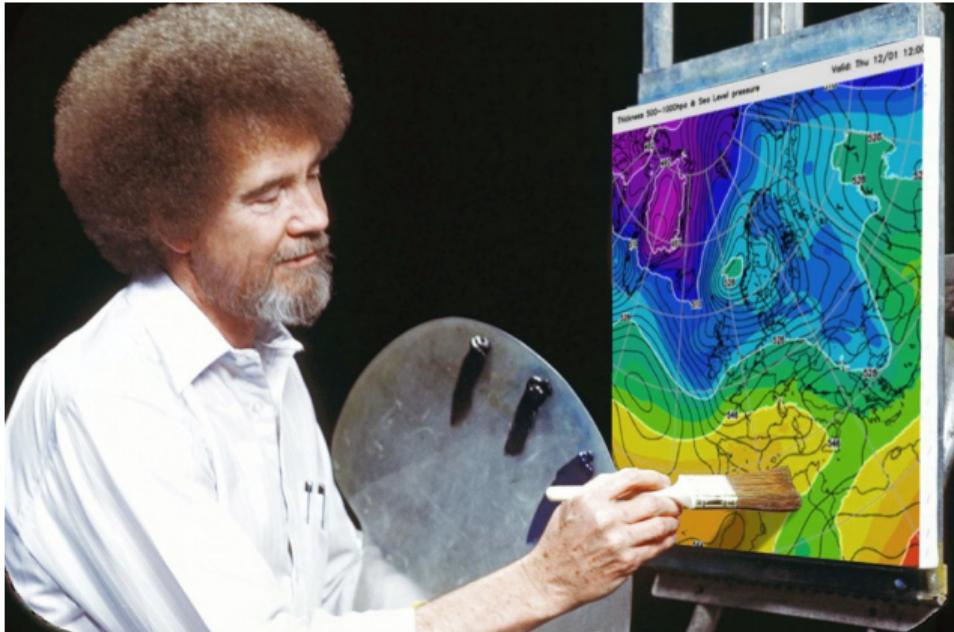
Take-home messages:

- Choose colors carefully.
- Make areas of interest stand out from background.
- Check robustness.
- Software helps you.

References

- Zeileis A, Fisher JC, Hornik K, Ihaka R, McWhite CD, Murrell P, Stauffer R, Wilke CO (2019). “colorspace: A Toolbox for Manipulating and Assessing Colors and Palettes.” arXiv:1903.06490, arXiv.org E-Print Archive. <http://arxiv.org/abs/1903.06490>
- Zeileis A, Hornik K, Murrell P (2009). “Escaping RGBland: Selecting Colors for Statistical Graphics.” *Computational Statistics & Data Analysis*, **53**, 3259–3270.
doi:10.1016/j.csda.2008.11.033.
- Stauffer R, Mayr GJ, Dabernig M, Zeileis A (2015). “Somewhere over the Rainbow: How to Make Effective Use of Colors in Meteorological Visualizations.” *Bulletin of the American Meteorological Society*, **96**(2), 203–216. doi:10.1175/BAMS-D-13-00155.1

Thank you for your interest!



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