



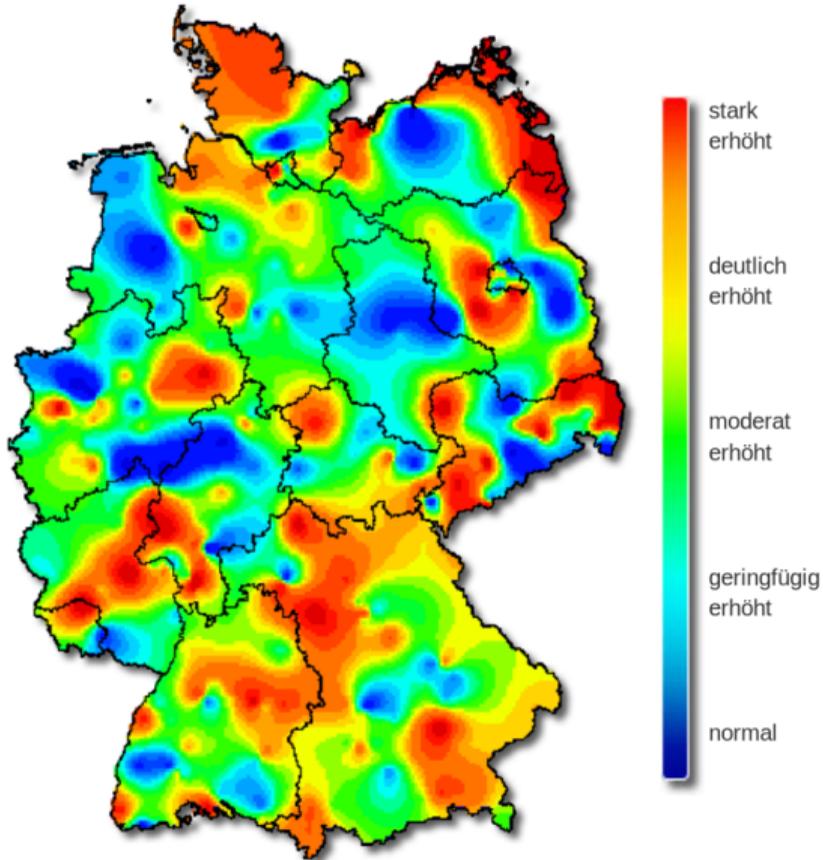
# colorspace

## A Toolbox for Manipulating and Assessing Color Palettes

Achim Zeileis, Jason C. Fisher, Kurt Hornik, Ross Ihaka, Claire D. McWhite, Paul Murrell,  
Reto Stauffer, Claus O. Wilke

<http://colorspace.R-Forge.R-project.org/>

# Motivation

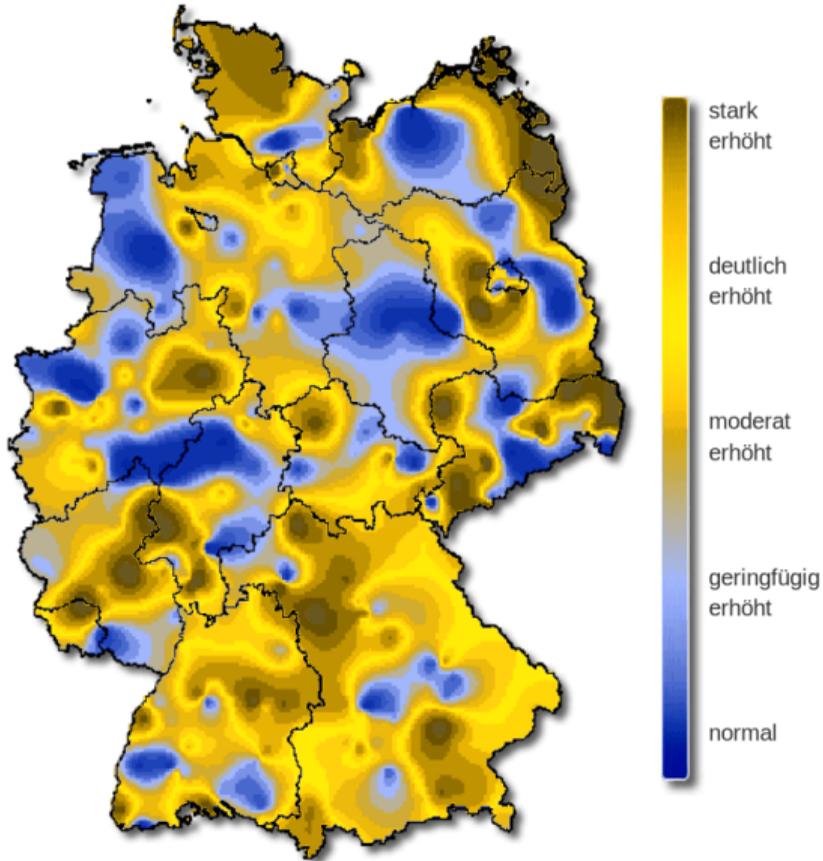


**Map:** Influenza severity in Germany (week 8, 2019).

**Source:** Arbeitsgemeinschaft Influenza, Robert-Koch-Institut.

**Reported in:** SPIEGEL Online, Tagesschau, ...

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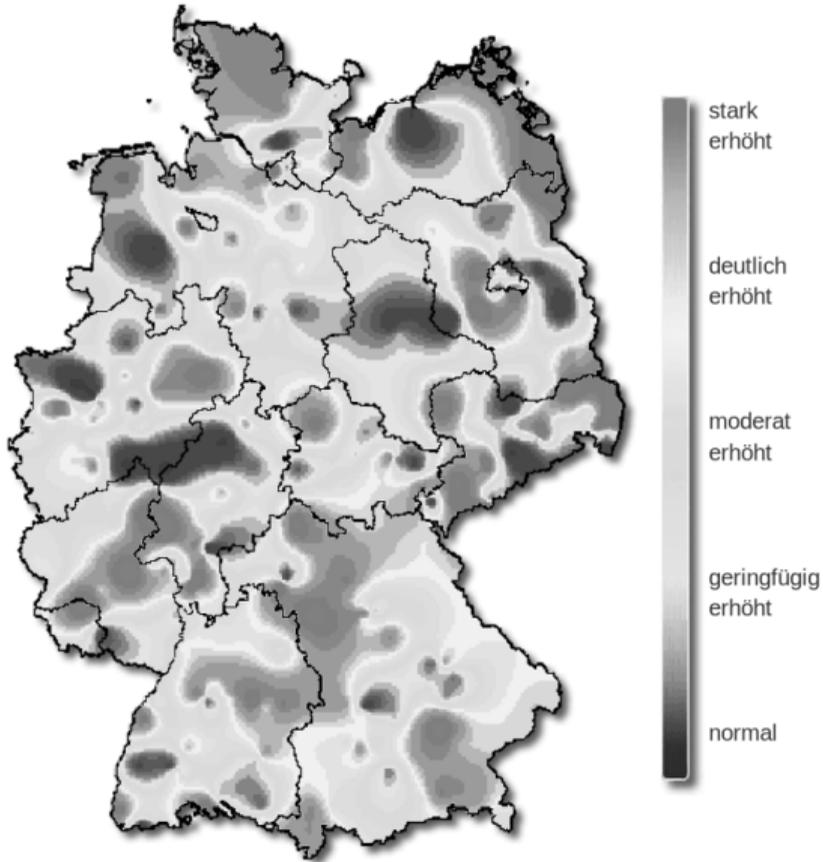
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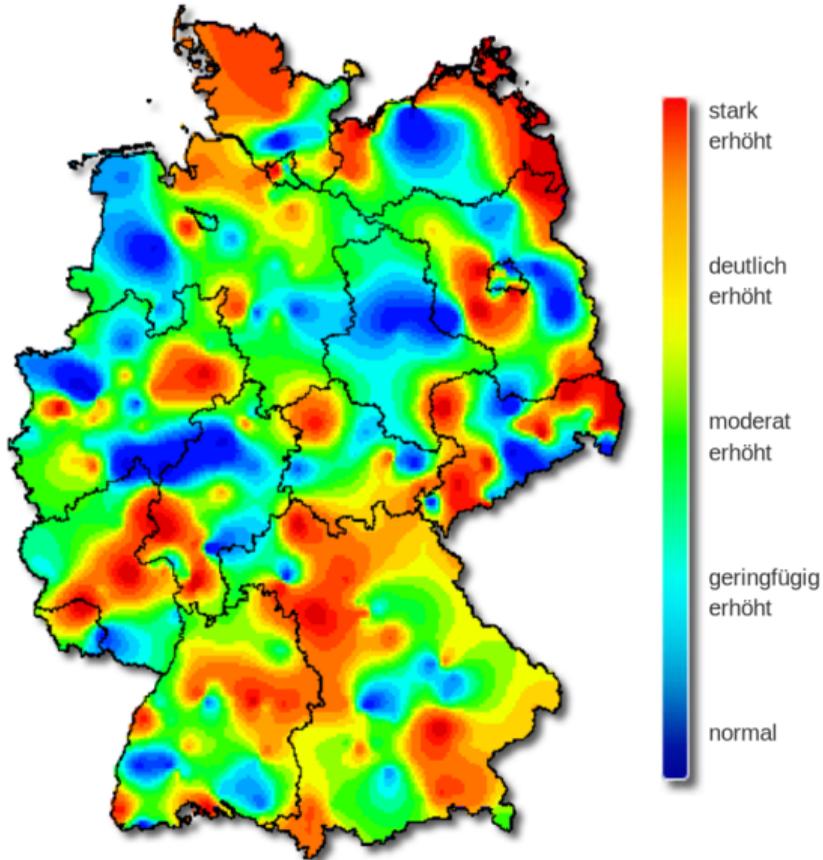
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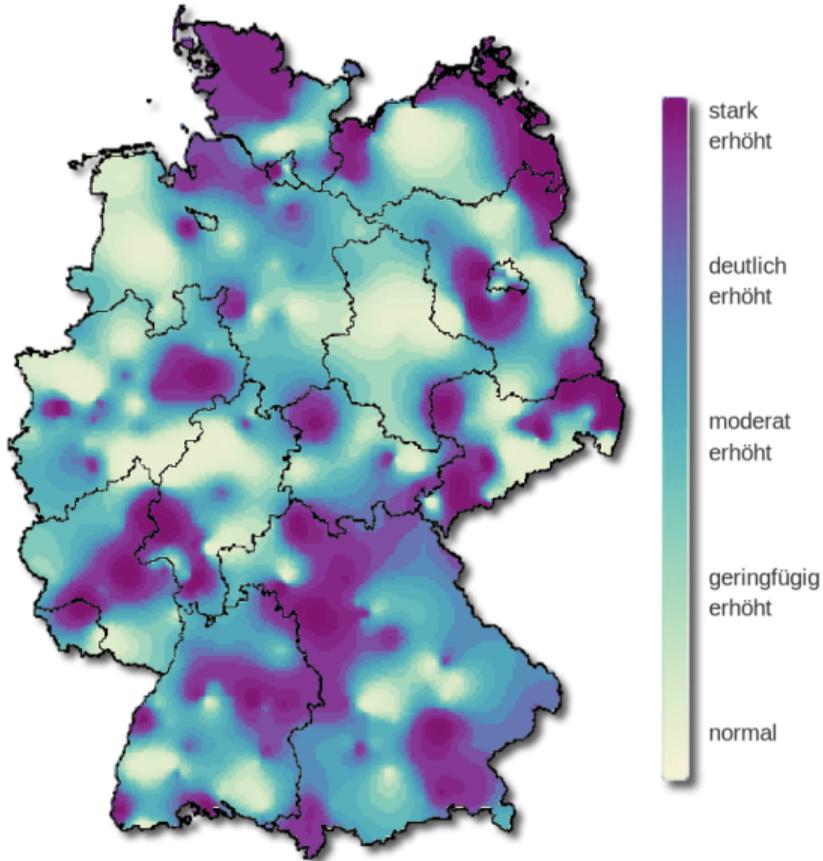
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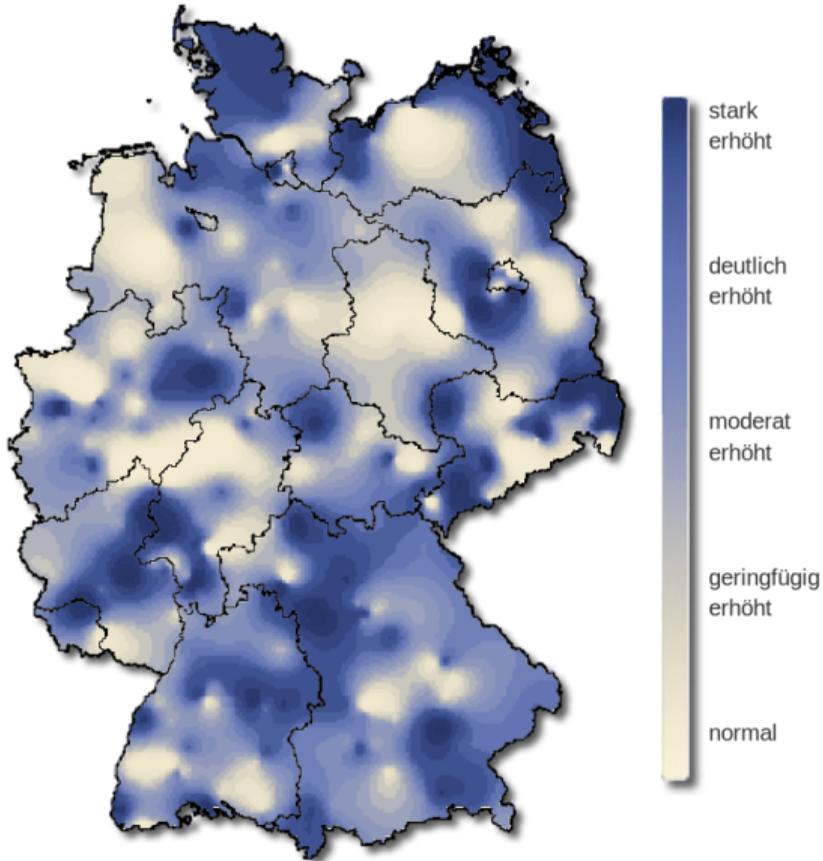
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**Alternative:** HCL-based sequential palette.

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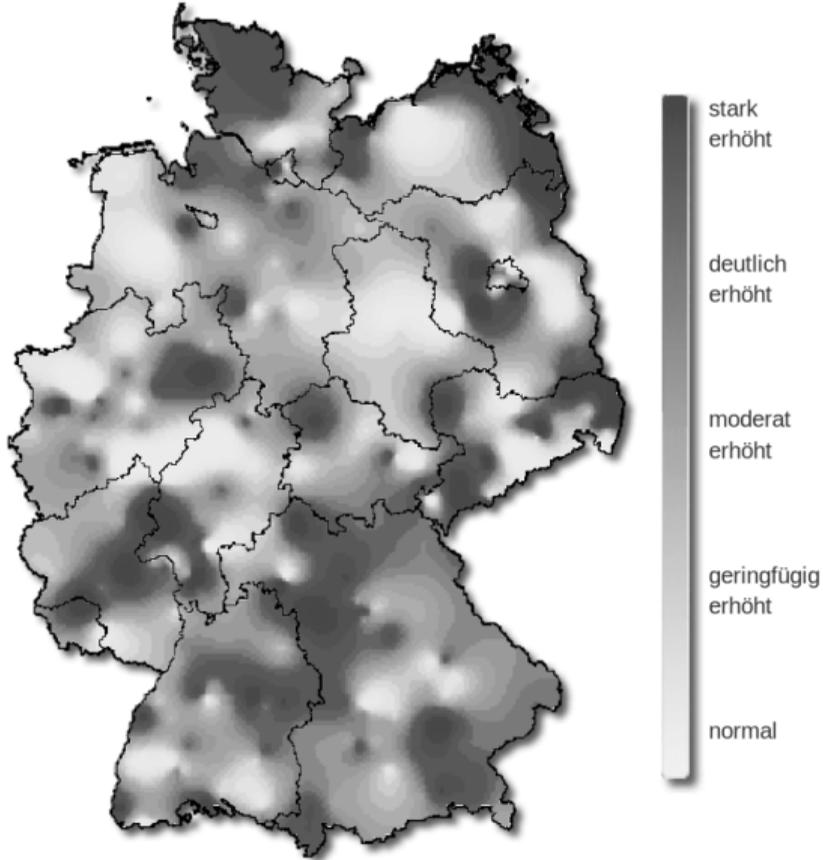
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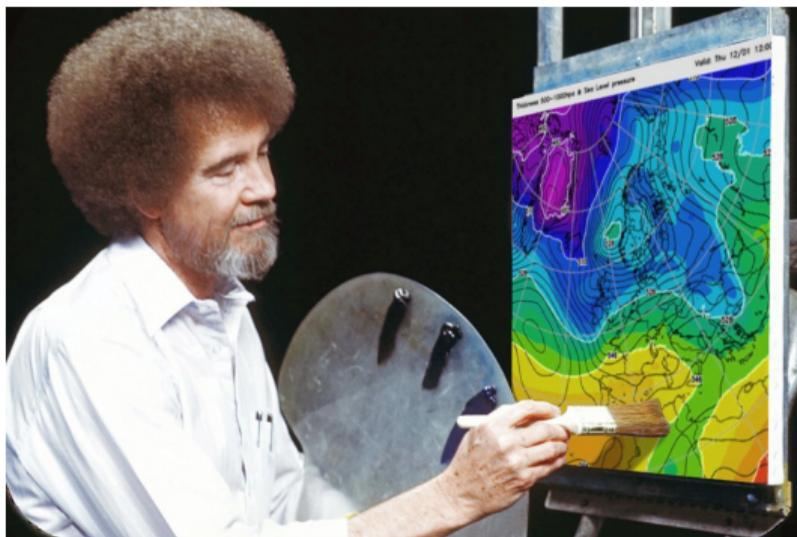
## **Need tools for:**

- Construction of palettes with better perceptual properties.
- Assessment of color palettes.
- Manipulation of colors.

# Motivation

## Need tools for:

- Construction of palettes with better perceptual properties.
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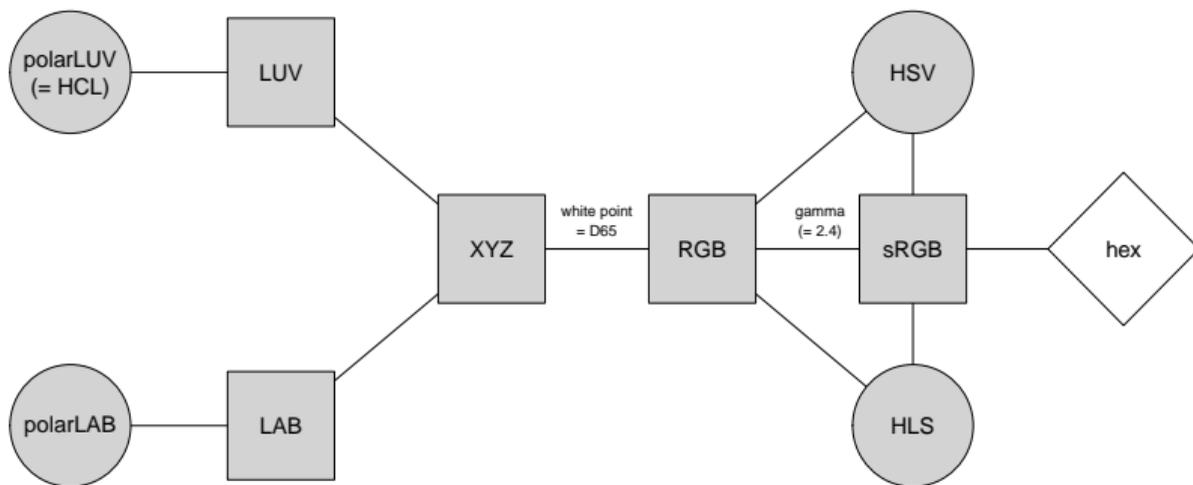


Because Bob Ross would not approve of this!

# Color spaces

**Origin of the package:** Convert colors between various three-dimensional representations of color.

**In particular:** From the perceptually-based HCL (Hue-Chroma-Luminance) to standard Red-Green-Blue (sRGB, and corresponding hex codes) space.



# HCL vs. RGB

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

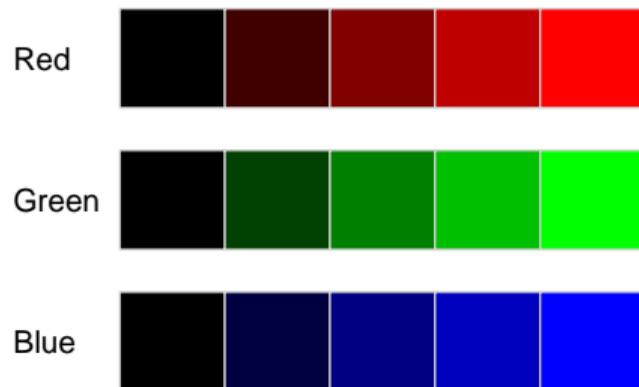


# HCL vs. RGB

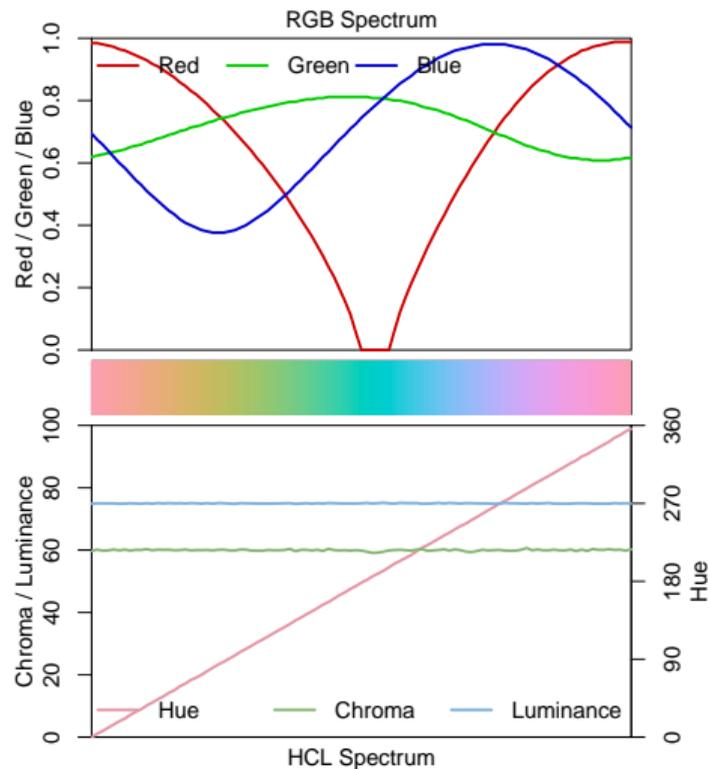
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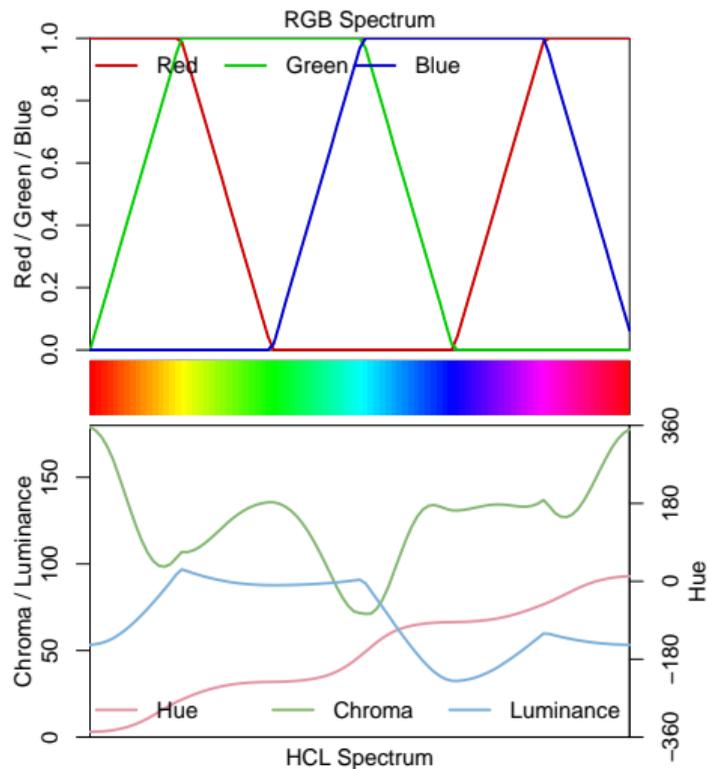
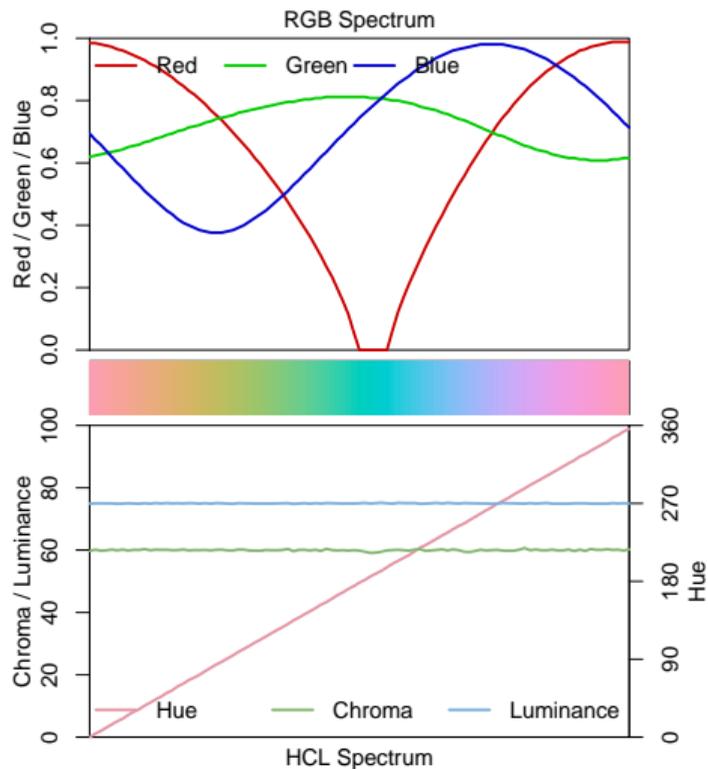
**RGB:** Motivated by how computers/TVs used to generate and still represent color.



# HCL vs. RGB: 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)

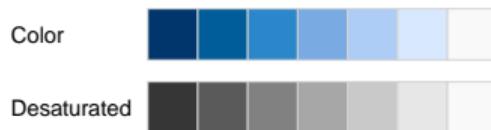


# Color palettes: Somewhere over the Rainbow

**Qualitative (Set 2)**



**Sequential (Blues 3)**



**Diverging (Green–Brown)**



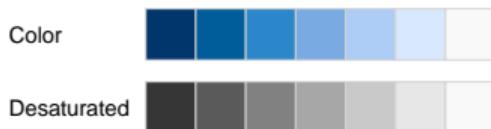
**Qualitative:** For categorical information, i.e., where no particular ordering of categories is available. Function: `qualitative_hcl()`.

# 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()`.

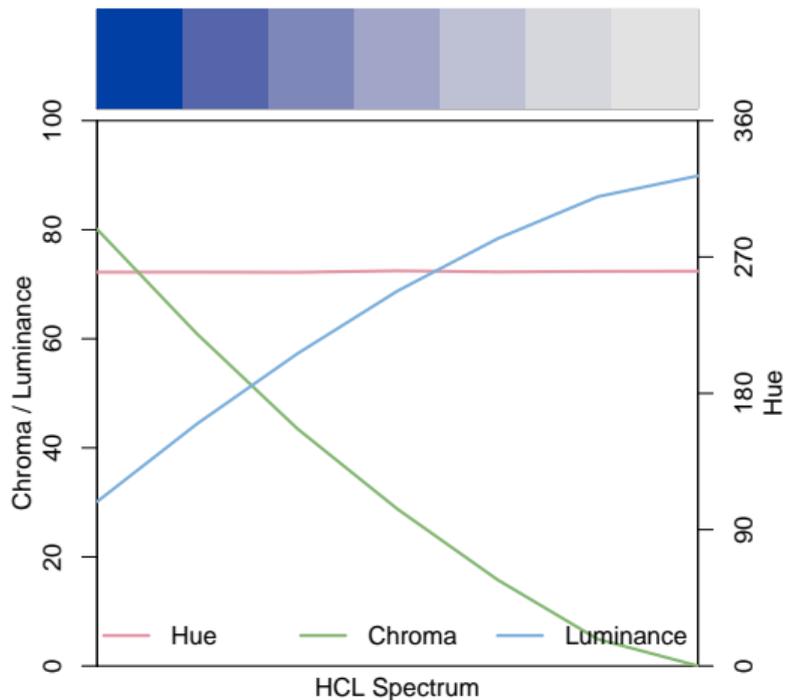
# Color palettes: Somewhere over the Rainbow

**Sequential:** Luminance contrast is crucial (dark to light or vice versa).



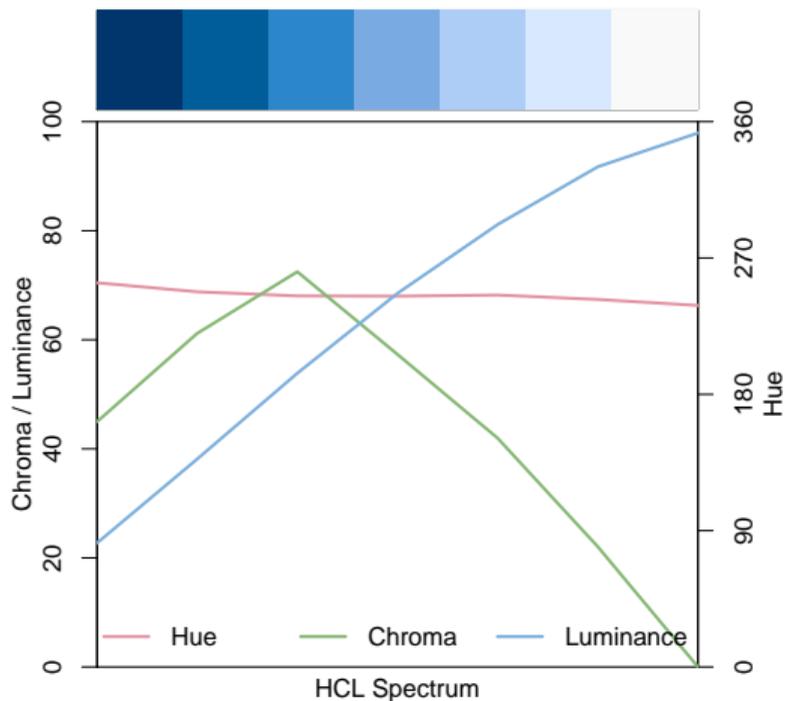
# Color palettes: Somewhere over the Rainbow

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



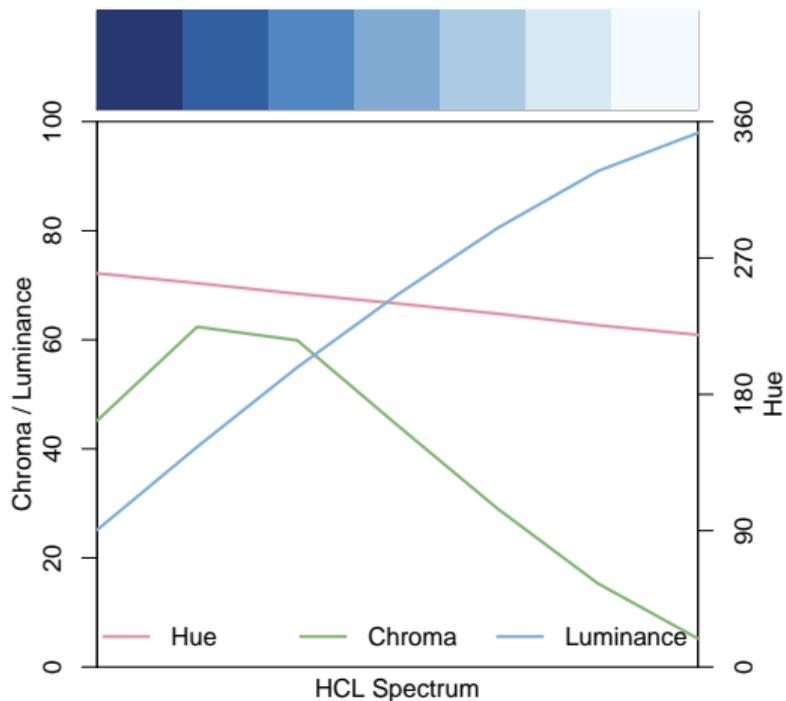
# Color palettes: Somewhere over the Rainbow

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



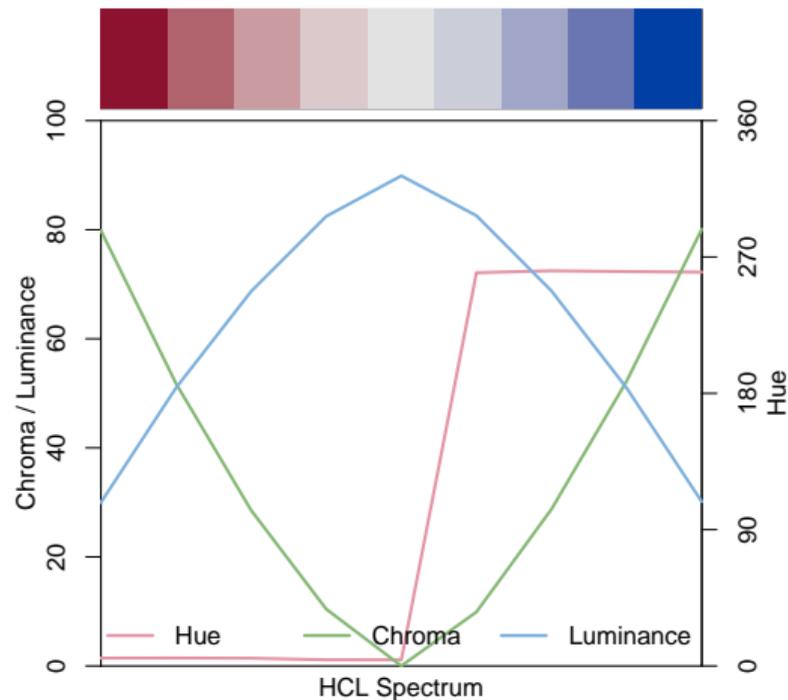
# Color palettes: Somewhere over the Rainbow

**Blues:** Multi hue. Triangular chroma. High luminance contrast.



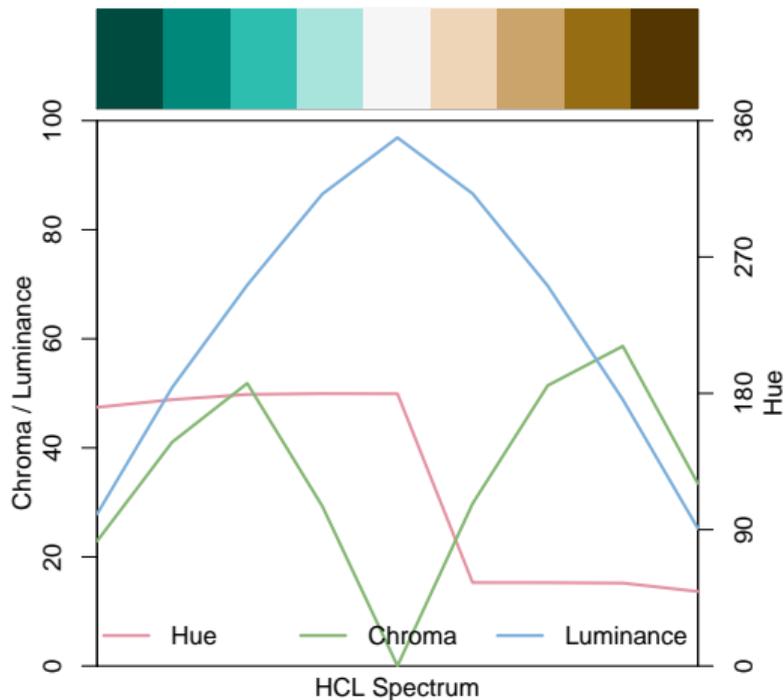
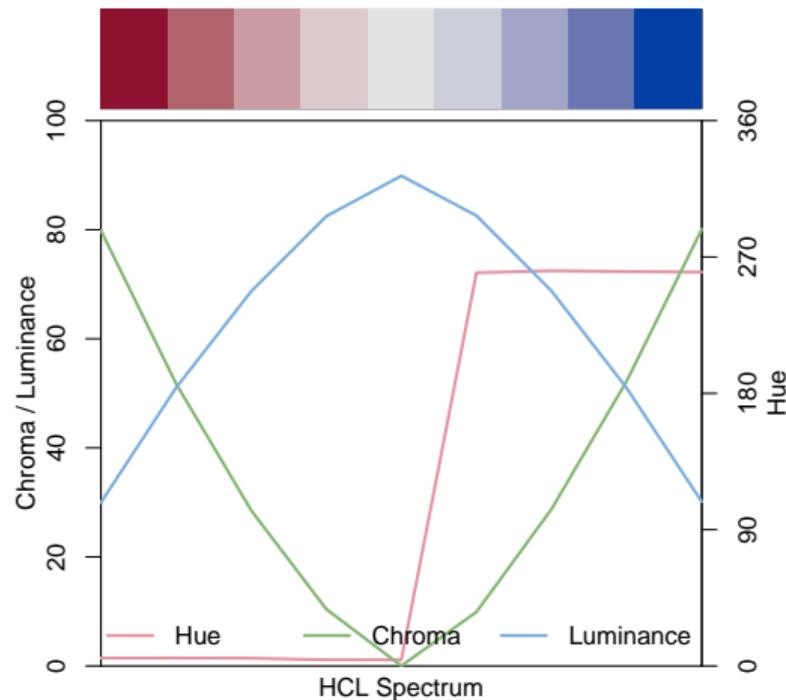
# Color palettes: Somewhere over the Rainbow

**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

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

## Qualitative



## Sequential (single-hue)



## Sequential (multi-hue)



# Statistical graphics

## Base:

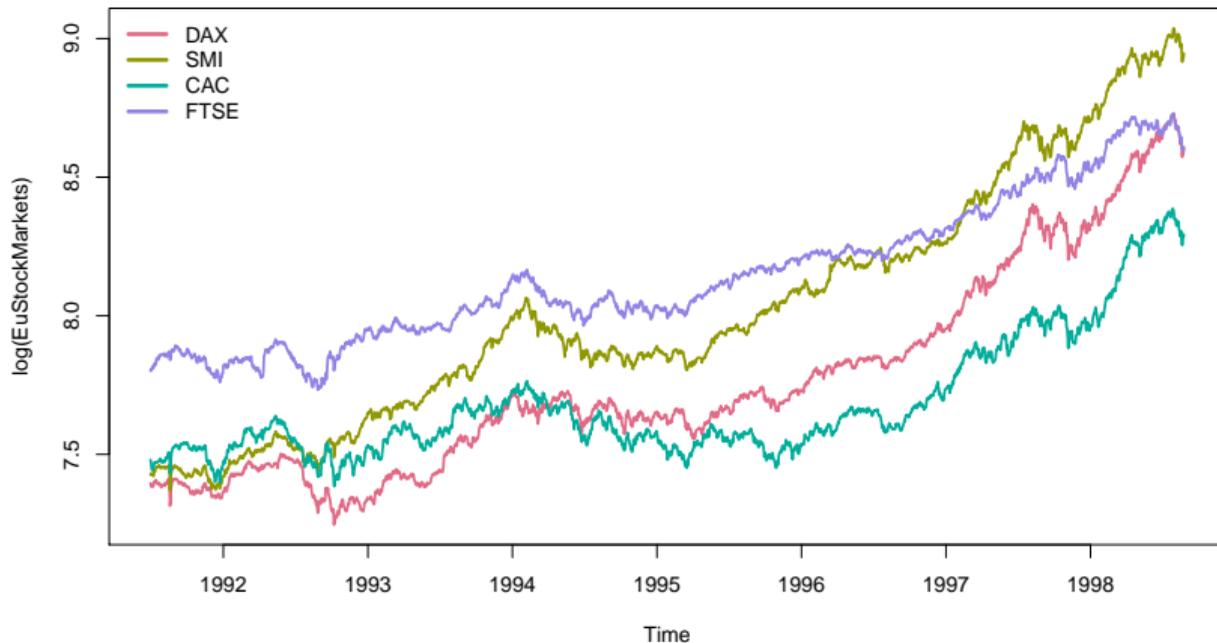
- HCL palette functions return hex color vector.
- Typically passed to `col =` argument of base plotting functions.

## ggplot2:

- Scales of type `scale_<aesthetic>_<datatype>_<colorscale>()`.
- `<aesthetic>` is `fill` or `color/colour`.
- `<datatype>` is `discrete` or `continuous`.
- `<colorscale>` is `qualitative`, `sequential`, `diverging`, or `divergingx`.

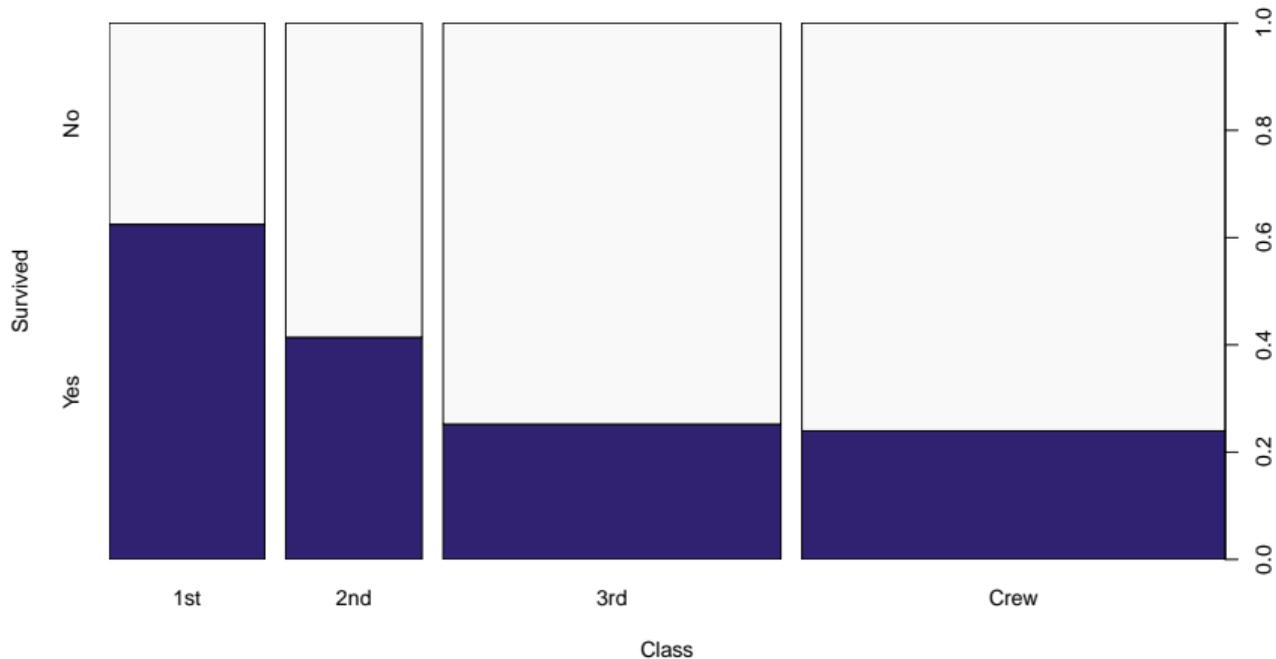
# Statistical graphics: Base

```
R> q4 <- qualitative_hcl(4, palette = "Dark 3")  
R> plot(log(EuStockMarkets), plot.type = "single", col = q4, lwd = 2)  
R> legend("topleft", colnames(EuStockMarkets), col = q4, lwd = 3, bty = "n")
```



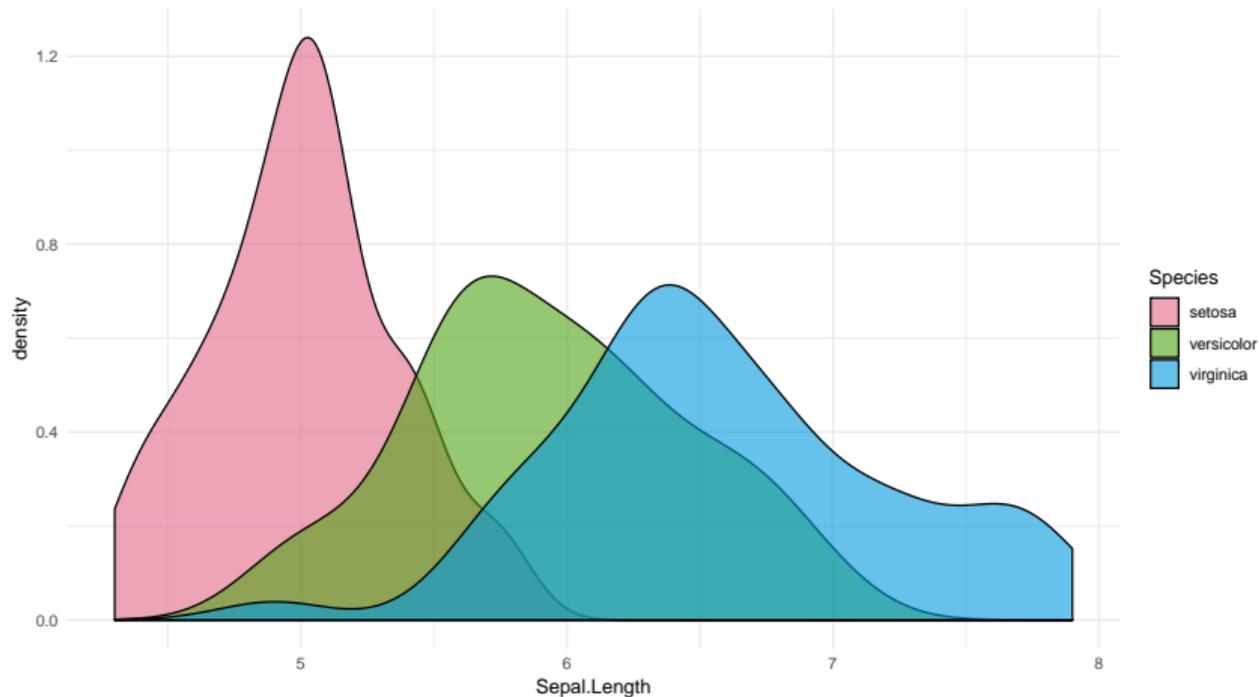
# Statistical graphics: Base

```
R> ttnc <- margin.table(Titanic, c(1, 4))[, 2:1]  
R> spineplot(ttnc, col = sequential_hcl(2, palette = "Purples 3"))
```



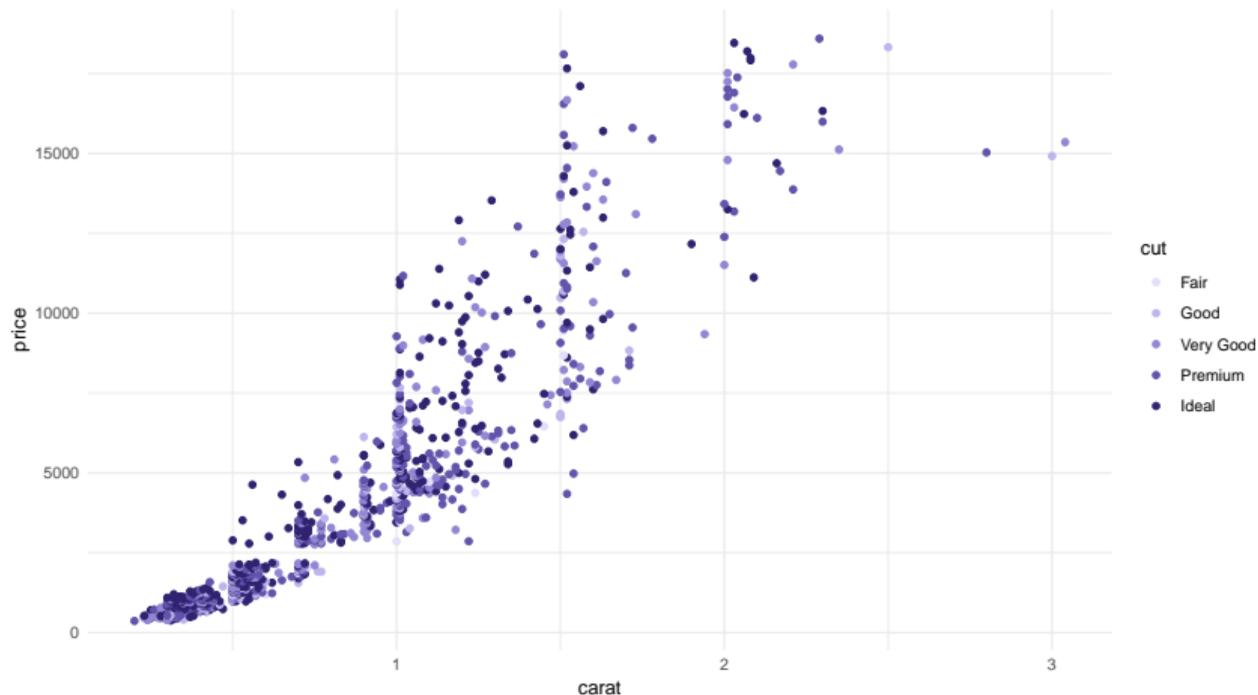
# Statistical graphics: ggplot2

```
R> library("ggplot2")  
R> ggplot(iris, aes(x = Sepal.Length, fill = Species)) + geom_density(alpha = 0.6) +  
+   scale_fill_discrete(palette = "Dark 3")
```



# Statistical graphics: ggplot2

```
R> dsamp <- diamonds[1 + 1:1000 * 50, ]  
R> ggplot(dsamp, aes(carat, price, color = cut)) + geom_point() +  
+   scale_color_discrete_sequential(palette = "Purples 3", nmax = 6, order = 2:6)
```



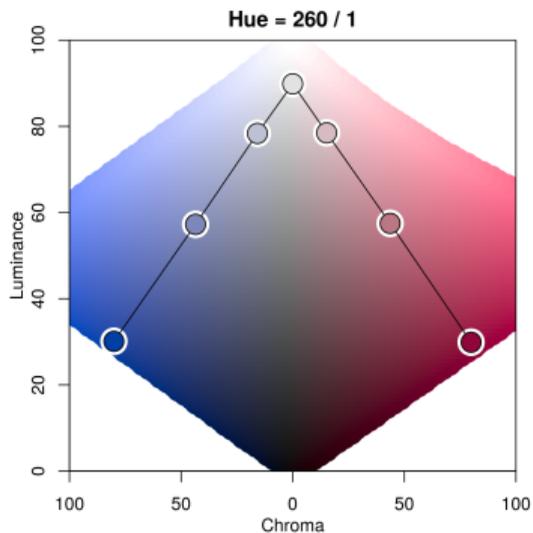
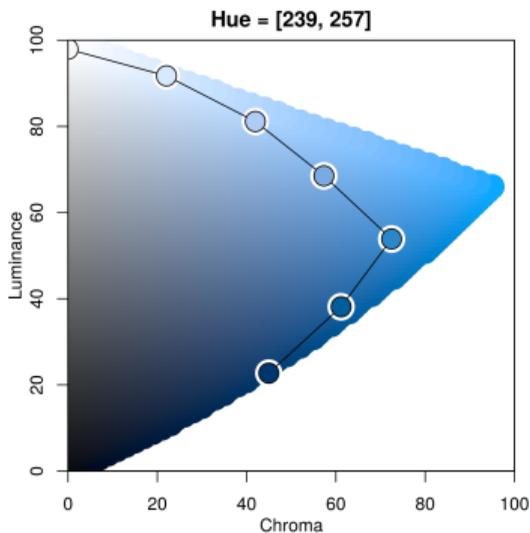
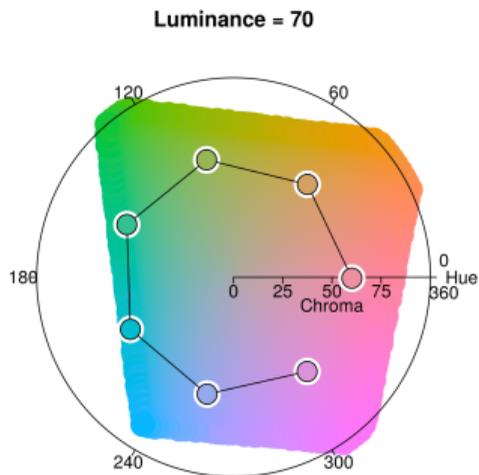
# Visualization and assessment

**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()

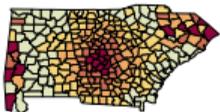
```
R> hclplot(qualitative_hcl(7, palette = "Set 2"))  
R> hclplot(sequential_hcl(7, palette = "Blues 3"))  
R> hclplot(diverging_hcl(7, palette = "Blue-Red"))
```



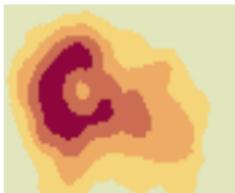
# Visualization and assessment: demoplot()

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

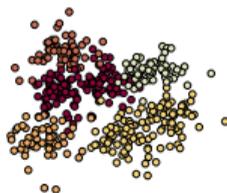
map



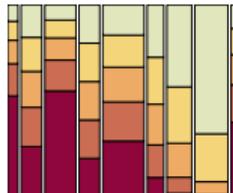
heatmap



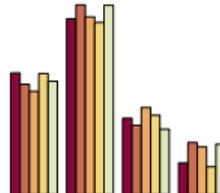
scatter



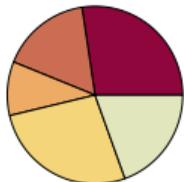
spine



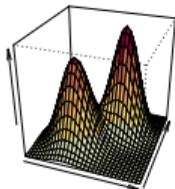
bar



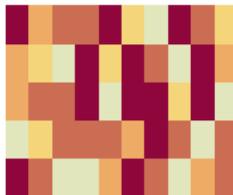
pie



perspective



mosaic



lines

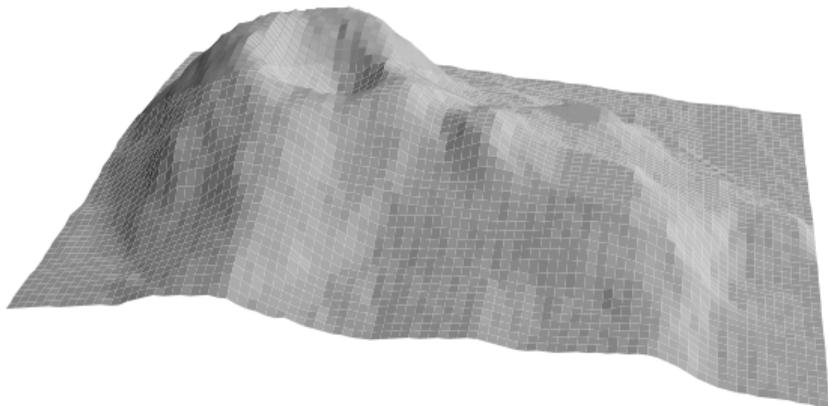


# Color vision deficiency

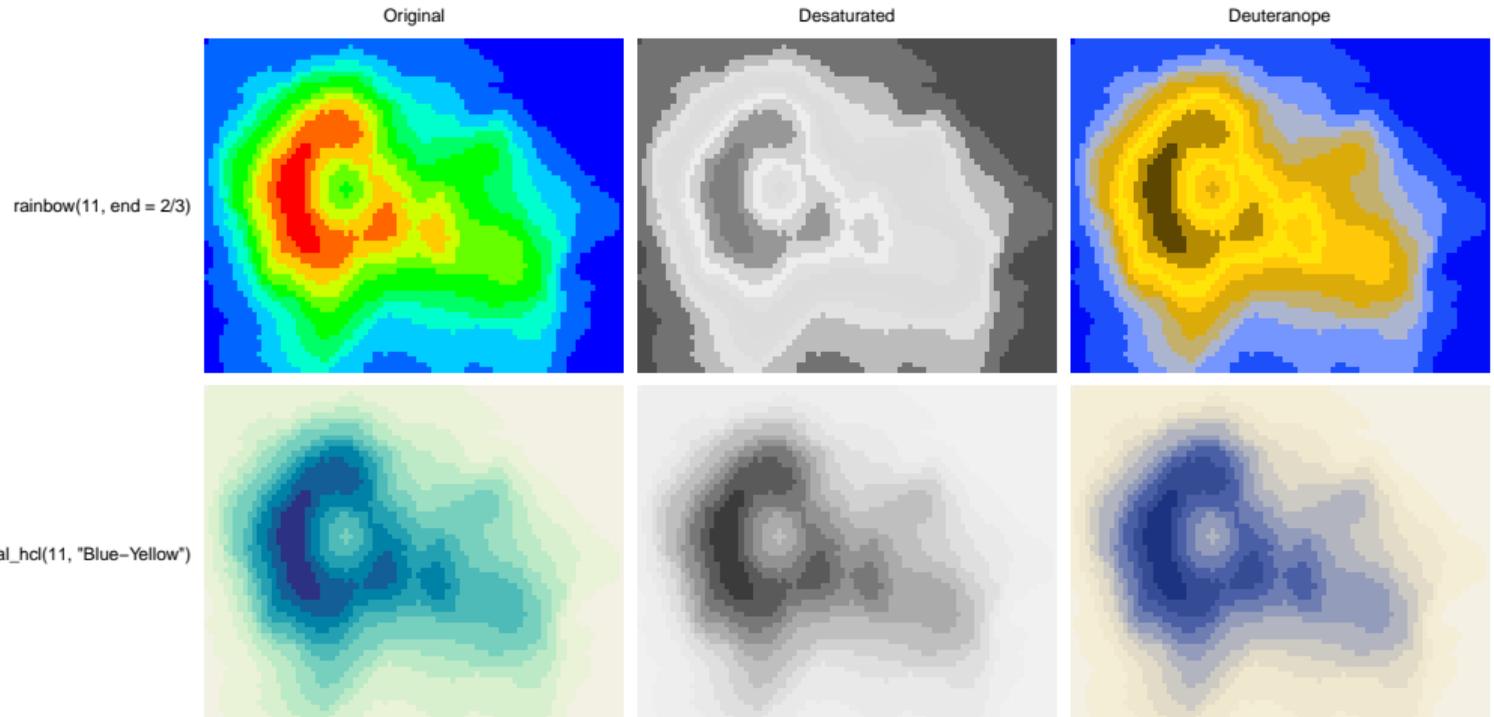
**Emulate:** Color vision deficiencies.

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

**Example:** Maunga Whau volcano data.

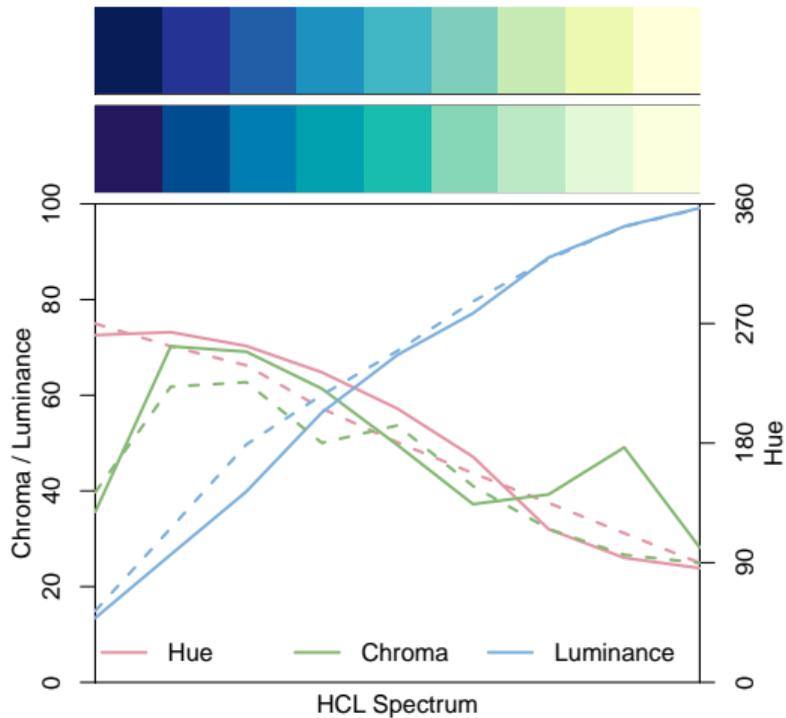


# Color vision deficiency



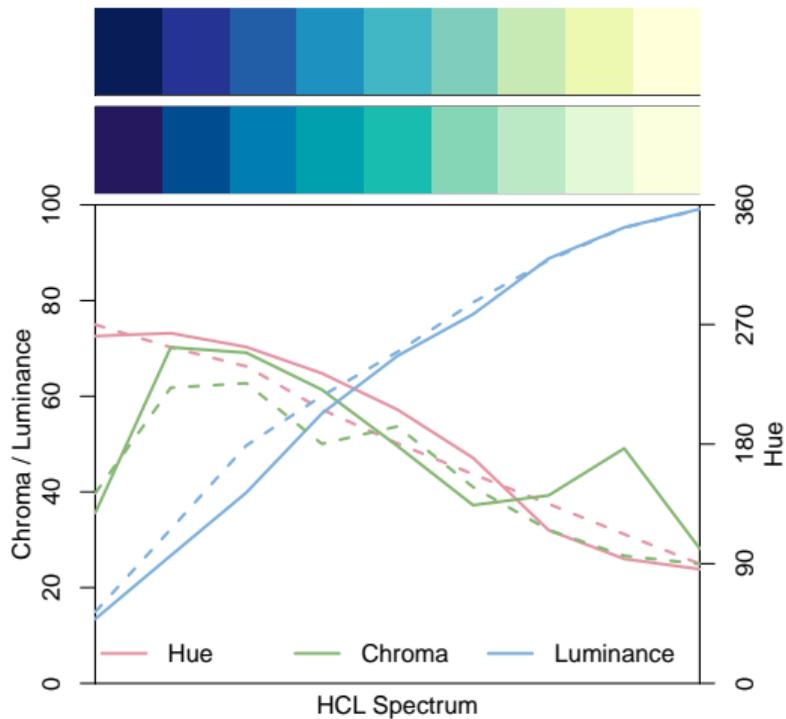
# Approximations of other palettes

ColorBrewer.org: YlGnBu

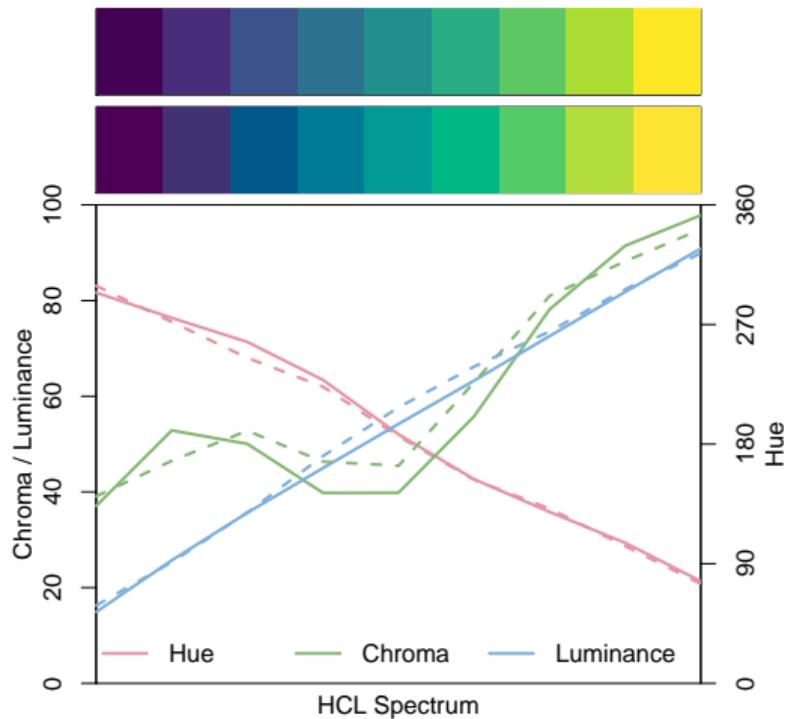


# Approximations of other palettes

ColorBrewer.org: YlGnBu



Viridis



# 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()

Mozilla Firefox

File Edit View History Bookmarks Tools Help

127.0.0.1:5604/ x +

127.0.0.1:5604

Search

Base Options

Type of palette  
Advanced: Sequential (single-hue)

Base color scheme  
Blues 3

Example  
Heatmap

Control Options

Reverse  
 Correct colors  
 Dark mode  
 Desaturated

Vision

Normal  
 Deutan  
 Protan  
 Tritan

Color Settings

HUE 1: 240 SET

CHROMA 1: 20 SET

MAX CHROMA: 50 SET

LUMN. 1: 20 SET

LUMN. 2: 95 SET

POWER 1: 1.2 SET

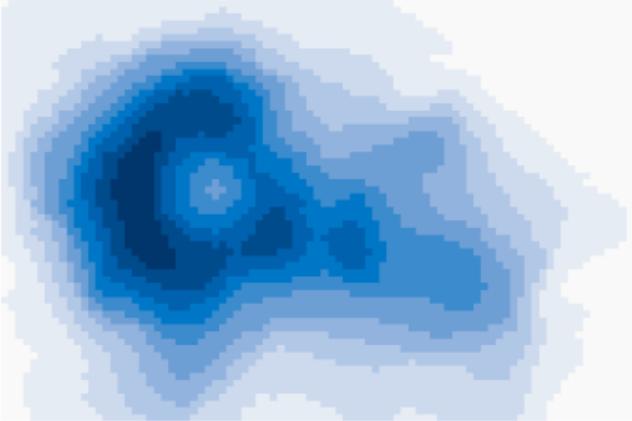
POWER 2: 1.4 SET

NUMBER: 11 SET

Return to R

Example Plot

Spectrum Color Plane Export Info



R colorspace 1.4.5

# Color apps: choose\_color() / hcl\_color\_picker()

The screenshot shows a Mozilla Firefox browser window displaying a color picker application. The browser's address bar shows the URL `127.0.0.1:5604/`. The application interface includes:

- Left Panel:** Three sliders for **Hue** (set to 270), **Chroma** (set to 50), and **Luminance** (set to 60). Below them is an **RGB hex color** input field containing `#9189C7` and a **Set** button. A **Selected color** bar shows the current color. **Actions** include **Pick**, **Unpick**, **Clear**, and **Return to R**. A **Dark mode** checkbox is also present.
- Main Area:** A **Luminance-Chroma plane** plot with a **Hue-Chroma plane** overlay. The plot shows a color gradient from black to purple. A small circle indicates the selected color. Below the plot are three horizontal color bars for **H** (Hue, 0-360), **C** (Chroma, 0-150), and **L** (Luminance, 0-100), each with a marker for the selected color.
- Bottom:** A **Color palette** with four color swatches: `#E2E2E2`, `#B9B5D5`, `#9189C7`, and `#5F4FB1`.

R colorspace 1.4.0

# Color apps: cvd\_emulator()

Mozilla Firefox

File Edit View History Bookmarks Tools Help

127.0.0.1:5604/ x +

127.0.0.1:5604

Upload Original Desaturated Deuteranope 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% means 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.



© colorspace 1.4.0

Mozilla Firefox

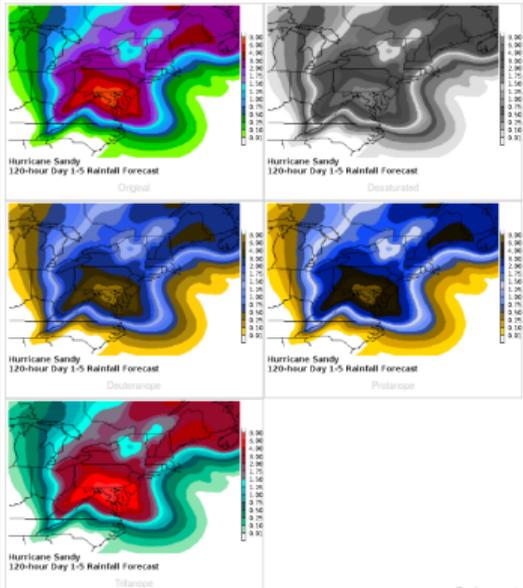
File Edit View History Bookmarks Tools Help

127.0.0.1:5604/ x +

127.0.0.1:5604

Upload Original Desaturated Deuteranope Protanope Tritanope

All Info



The image displays a 3x2 grid of rainfall forecast maps for Hurricane Sandy, 120-hour Day 1-5. Each map is labeled 'Original' or with a specific color vision deficiency type: 'Desaturated', 'Deuteranope', 'Protanope', and 'Tritanope'. The maps show rainfall intensity with a color scale from 0 to 100. The 'Original' map uses a rainbow color scheme. The 'Desaturated' map is in grayscale. The 'Deuteranope' map uses a blue and yellow color scheme. The 'Protanope' map uses a blue and orange color scheme. The 'Tritanope' map uses a red and cyan color scheme. Each map includes a vertical color scale legend on its right side.

Hurricane Sandy 120-hour Day 1-5 Rainfall Forecast

© colorspace 1.4.0

# Base R

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



# Base R: Why you might not need our package after all

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



# 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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- Triangular chroma trajectories useful for distinguishing central colors.

## 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.

# 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