universität innsbruck

Choosing Color Palettes for Data Visualization

Tools and Technologies for Supporting Algorithm Fairness and Inclusion

Achim Zeileis

https://www.zeileis.org/

Motivation

Colors in data visualization:

- Ubiquitous.
- Not always easy to choose.
- But also perceived as fun.

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- Power of color often overestimated.
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- Other physical or technical limitations.

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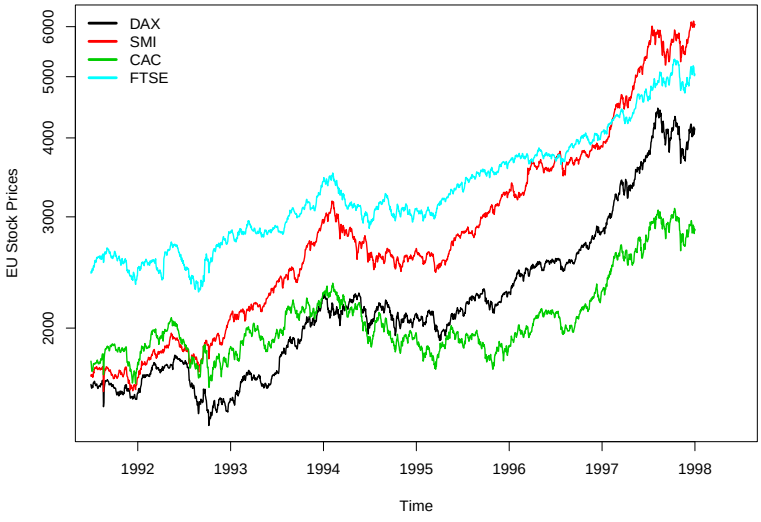
Illustration: Time series line plot using base graphics.

```
R> p <- c(1:3, 5)
R> plot(EuStockMarkets, log = "y", plot.type = "single", col = p, ...)
R> legend("topleft", colnames(EuStockMarkets), col = p, ...)
```

Motivation



Palette: R $\leq$ 3 default

Emulation: None

Labeling: Legend

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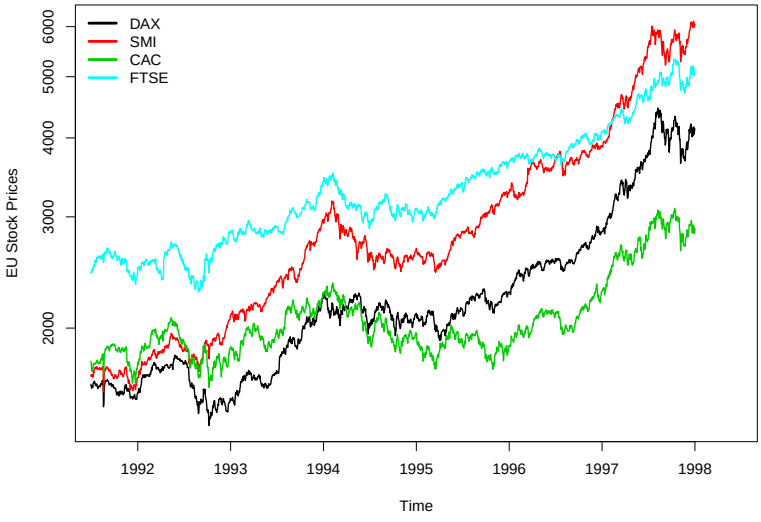

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Comments:

Too flashy

Cyan too light

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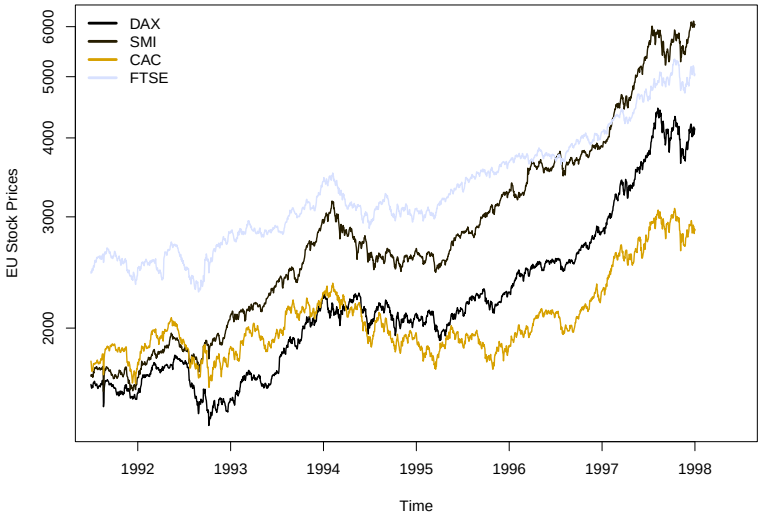

Palette: R $\leq$ 3 default

Emulation: Protanope

Labeling: Legend

Comments:

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Cyan too light

Hard to distinguish for protanope viewers

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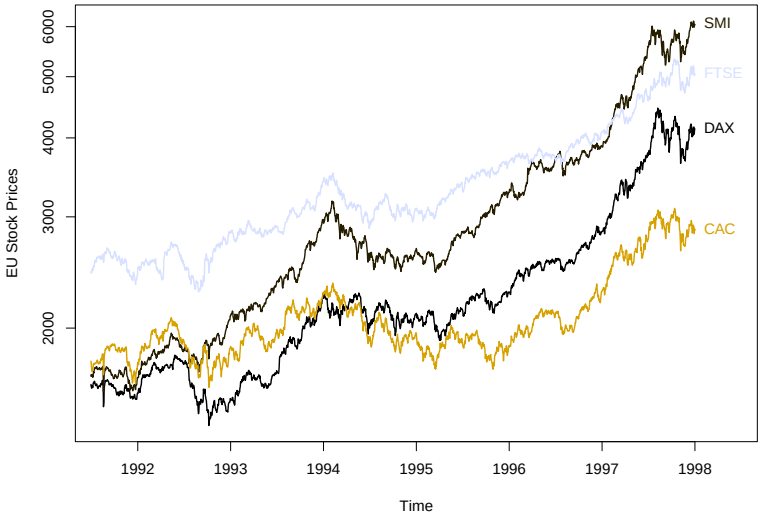

Palette: R $\leq$ 3 default

Emulation: Protanope

Labeling: Direct

Comments:

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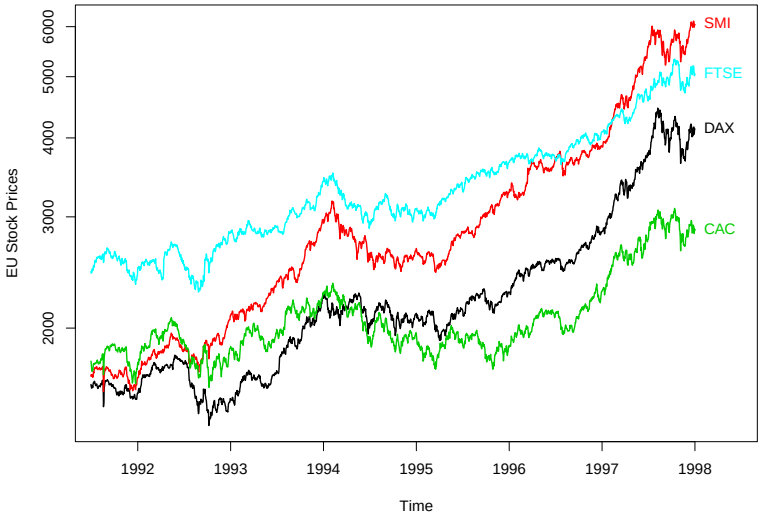

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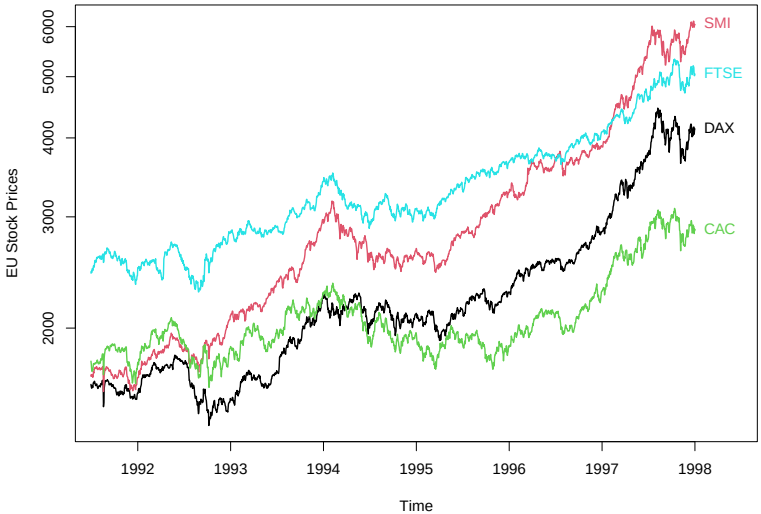


Palette: R $\geq$ 4 default

Emulation: None

Labeling: Direct

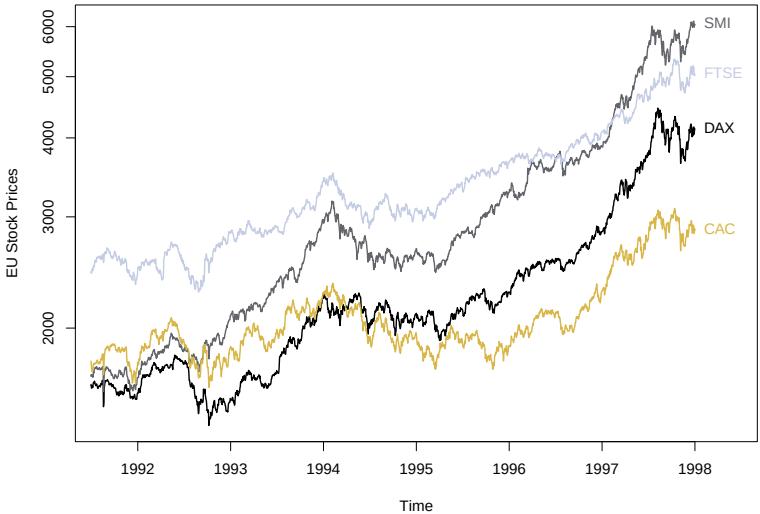
Comments:

Similar hues

More balanced brightness

Avoid garish colors

Motivation



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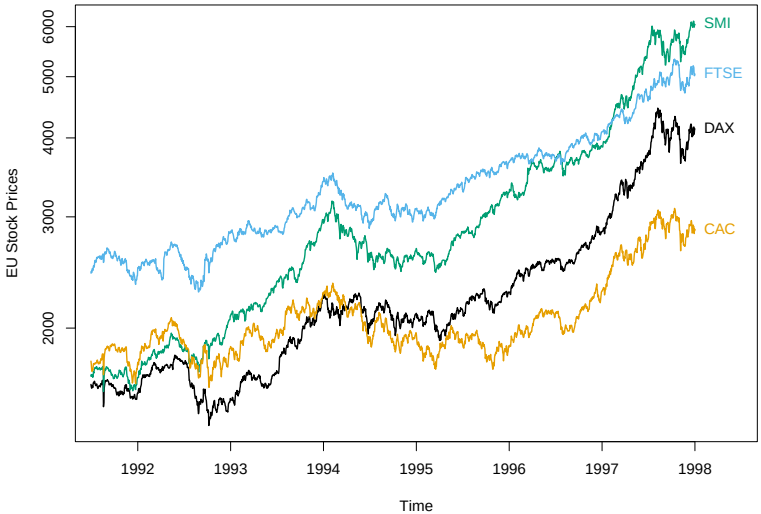


Palette: Okabe-Ito

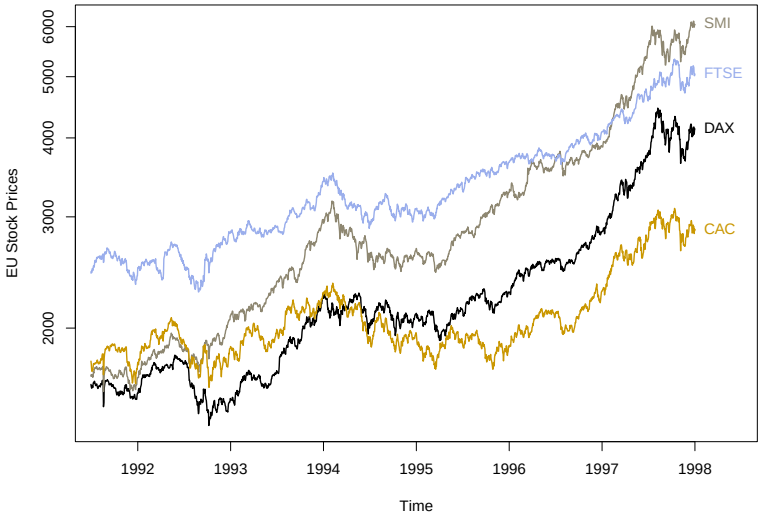
Emulation: None

Labeling: Direct

Comments:

Designed to be robust against color vision deficiencies

Motivation



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Source: Mara Averick via Twitter

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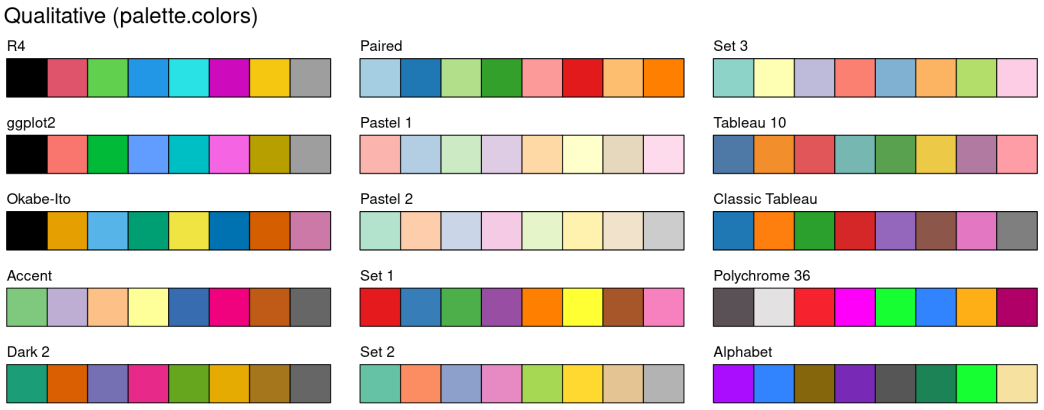
Base R: Neglected better color palettes for a long time.

Earlier packages: RColorBrewer, colorspace, ggplot2, viridis, rcartocolor, Polychrome, scico, pals, paletteer, . . .

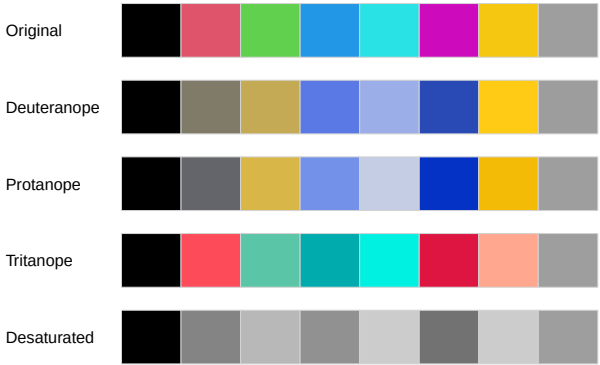
Thus: Many good palettes easily available.

Motivation


Qualitative (palette.colors)
R4
Paired
Set 3
ggplot2
Pastel 1
Tableau 10
Okabe-Ito
Pastel 2
Classic Tableau
Accent
Set 1
Polychrome 36
Dark 2
Set 2
Alphabet

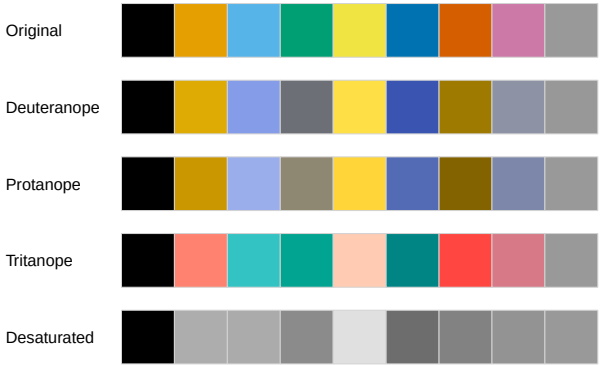
Motivation

```
R> palette.colors(palette = "R4") |>
+    colorspace::swatchplot(cvd = TRUE)
```



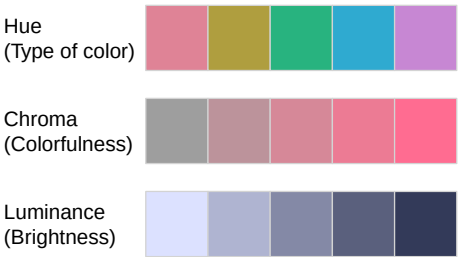
Motivation

```
R> palette.colors(palette = "Okabe-Ito") |>
+    colorspace::swatchplot(cvd = TRUE)
```



Color palette construction

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



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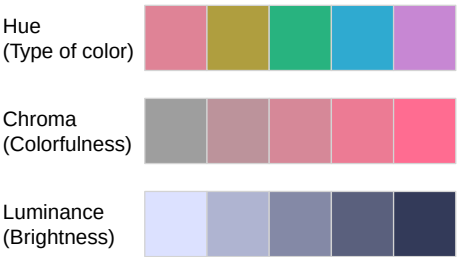
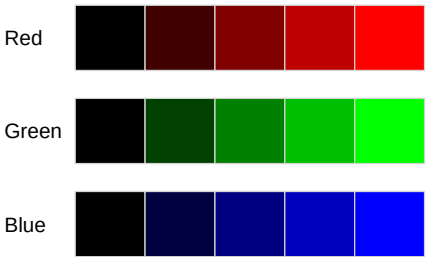


RGB: Motivated by how computers and TVs used to generate and still represent color.



Color palette construction

Qualitative (Set 2)

Color

Desaturated

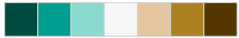
Sequential (Blues 3)

Color

Desaturated

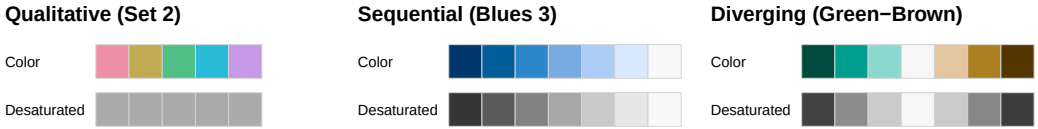
Diverging (Green–Brown)

Color



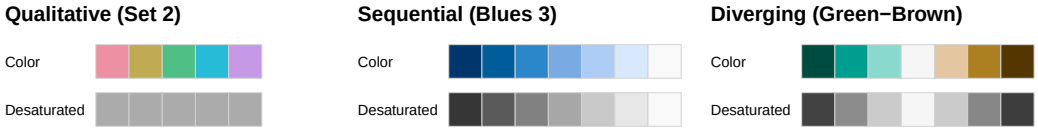
Desaturated

Color palette construction



Qualitative: For categorical information with no particular ordering. Luminance differences should be limited.

Color palette construction



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Sequential: For ordered/numeric information from high to low (or vice versa).

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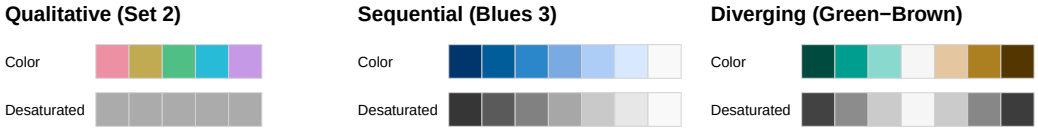


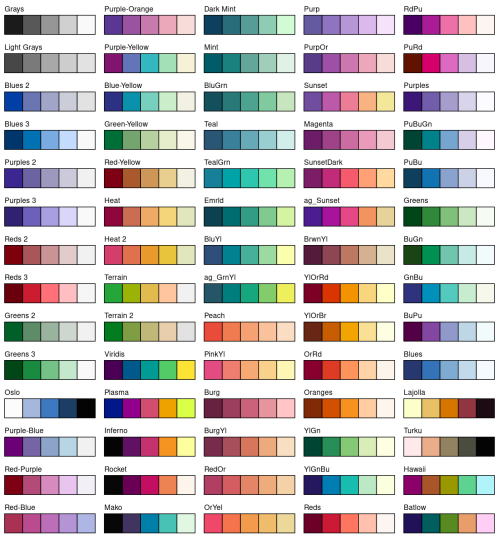
Qualitative: For categorical information with no particular ordering. Luminance differences should be limited.

Sequential: For ordered/numeric information from high to low (or vice versa).

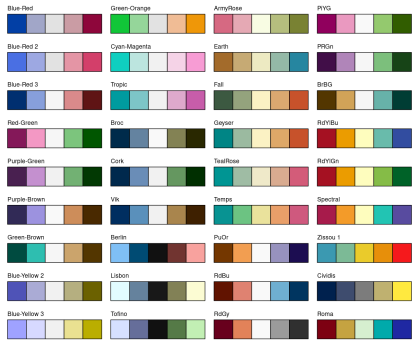
Diverging: For ordered/numeric information diverging from a central neutral value to two extremes.

Color palette construction

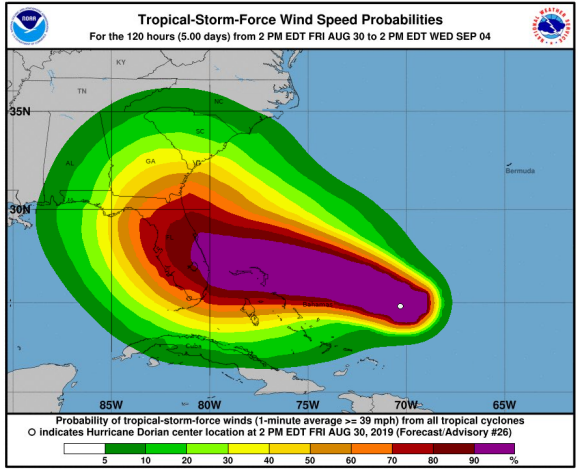
Sequential (hcl.colors)



Diverging (hcl.colors)



Risk maps and communication to the public



Risk map: Probability of wind speeds $> 39\,\text{mph}$ ($63\,\text{km}\,\text{h}^{-1}$), 2019-08-30–2019-09-04

Source: National Oceanic and Atmospheric Administration (noaa.gov)

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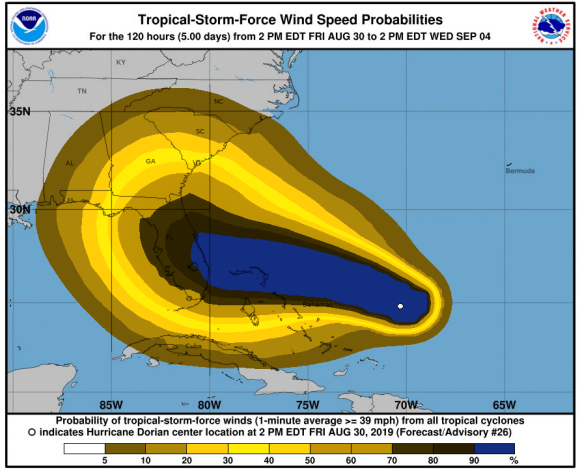

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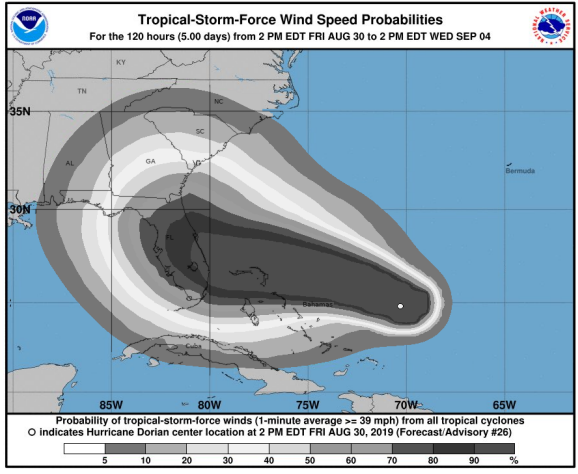

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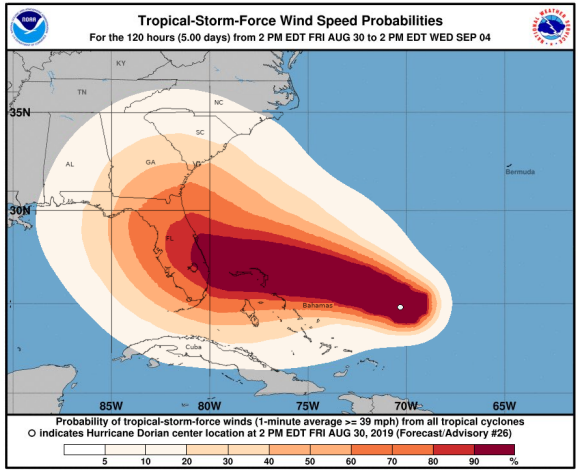

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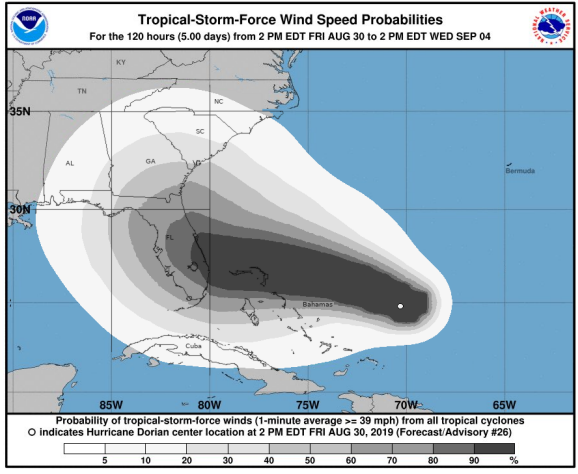

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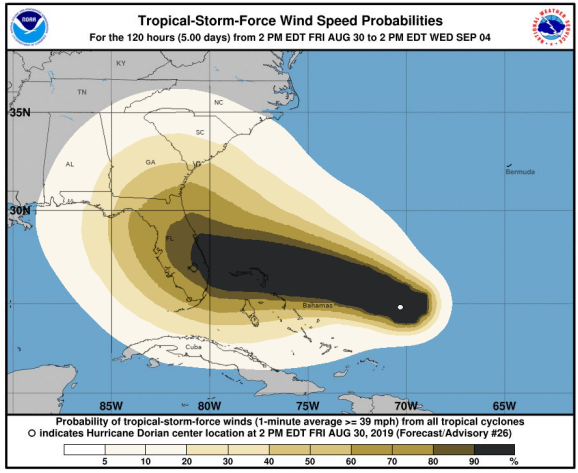

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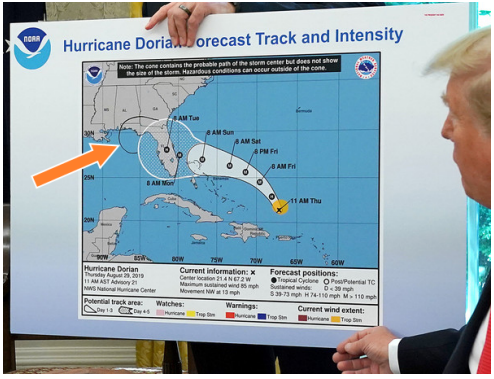

Source: White House (2019-09-04)

Source: U.S. president via Twitter (2019-09-05)

Colors by designers, painters, and directors?

Movie: *Todo sobre mi madre* (*All About My Mother*, 1999)

Source: Sony Pictures Classics via MoMA

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Palette: Hadley Mendelsohn

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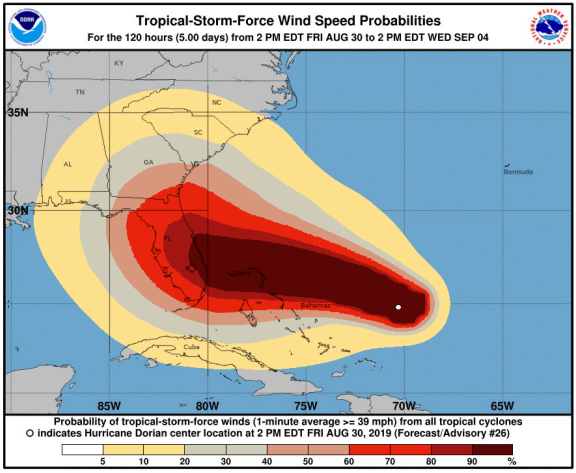

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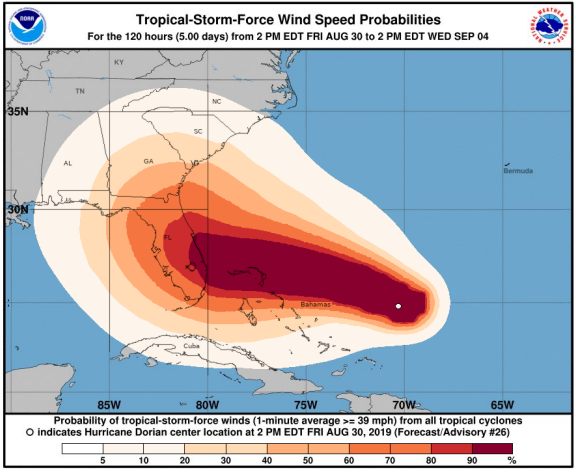

Palette: OrRd (ColorBrewer.org, HCL version)

Colors by designers, painters, and directors?

Movie: *Tacones lejanos* (*High Heels*, 1991)

Source: El Deseo S.A. via Twitter

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Palette: Bibiana Fernandez

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Wrap-up

Tools:

- *grDevices:* `palette.colors()`, `hcl.colors()`.
- *colorspace:* `swatchplot(..., cvd = TRUE)`.
- Interactive shiny apps on `https://www.hclwizard.org/`.

Wrap-up

Tools:

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- *colorspace:* `swatchplot(..., cvd = TRUE)`.
- Interactive shiny apps on `https://www.hclwizard.org/`.

Strategy:

- Check whether color is appropriate for coding your information.
- Use appropriate type of palette.
- Don’t reinvent the wheel, start out from well-established palettes.
- Check robustness of palette.
- Be careful with palettes with too much chroma.

References

Zeileis A, Fisher JC, Hornik K, Ihaka R, McWhite CD, Murrell P, Stauffer R, Wilke CO (2020). "colorspace: A Toolbox for Manipulating and Assessing Colors and Palettes." *Journal of Statistical Software*, **96**(1), 1–49. doi:10.18637/jss.v096.i01

Zeileis A, Murrell P, Maechler M, Sarkar D (2019). "A New `palette()` for R." *R Foundation Blog*, 2019-11-21. https://developer.R-project.org/Blog/public/2019/11/21/a-new-palette-for-r/

Zeileis A, Murrell P (2019). "HCL-Based Color Palettes in grDevices." *R Foundation Blog*, 2019-04-01. https://developer.R-project.org/Blog/public/2019/04/01/hcl-based-color-palettes-in-grdevices/

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