



## Somewhere Over the Rainbow: How to Make Effective Use of Colors

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# Introduction

Everyday challenges:



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## Everyday challenges:

- big, highly complex data sets

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- better understanding via visualizations

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- one to four-dimensional (time and space)

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## Everyday challenges:

- big, highly complex data sets
- better understanding via visualizations
- one to four-dimensional (time and space)
- visualizing: important part

# Introduction

## Common software:

- large variety of software packages

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- **most common** default palettes: Red-Green-Blue rainbow (RGB)

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## Choosing colors:

- wrong colors can **cause** (a variety of) **problems**

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## Common software:

- large variety of software packages
- **most common** default palettes: Red-Green-Blue rainbow (RGB)

## Choosing colors:

- wrong colors can **cause** (a variety of) **problems**
- choosing effective colors is **not** a **trivial** task

# Introduction

## Main goal of our work:

- to sensitize

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- to sensitize
- Hue-Chroma-Luminance (HCL) concept

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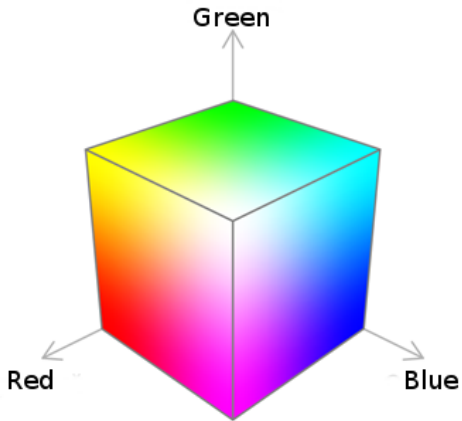
- to sensitize
- Hue-Chroma-Luminance (HCL) concept
- based on human perception
- full control choosing color palettes



## The standard way

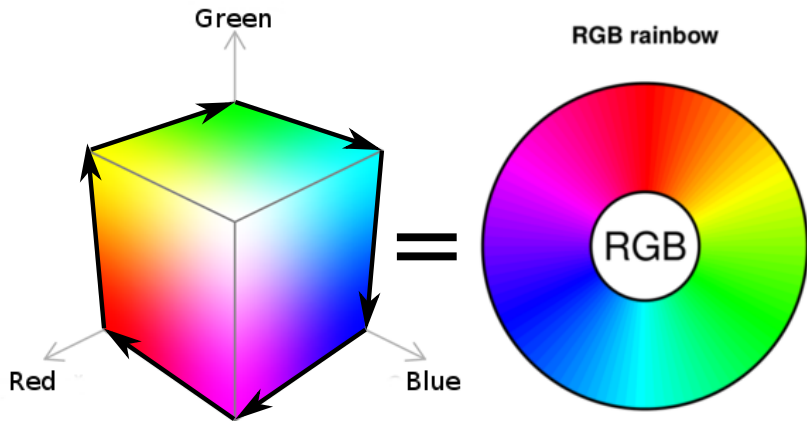
Using Red-Green-Blue based color maps

# The standard way: using RGB



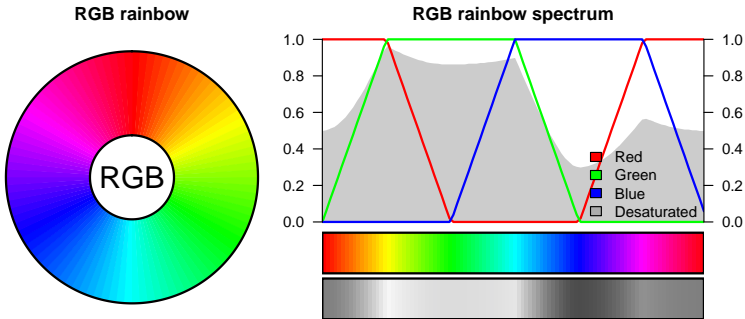
*The RGB color space – and it's famous rainbow color scheme.*

# The standard way: using RGB



*The RGB color space – and it's famous rainbow color scheme.*

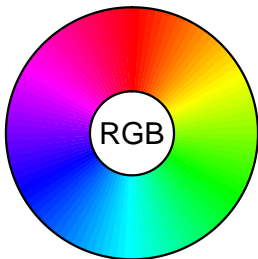
# The standard way: using RGB



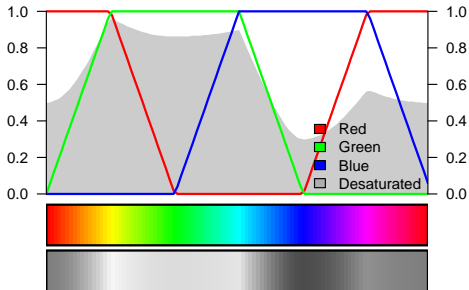
- the easiest way: use default color palettes in software packages
- **most packages** provide RGB color palettes  
e.g.: IDL, GrADS, Python, matlab, R (by default)

# The standard way: using RGB

RGB rainbow



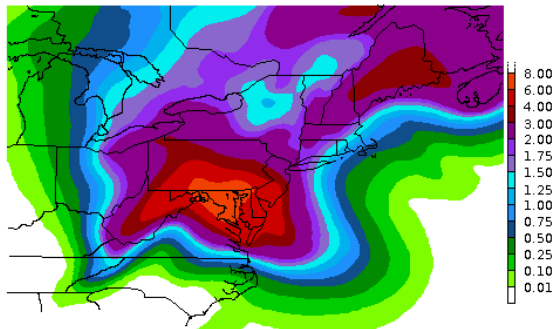
RGB rainbow spectrum



Question

“Everybody does it – why should it be wrong?”

# What's wrong?

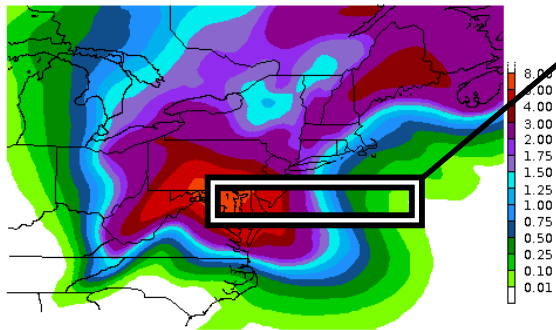


Hurricane Sandy  
120-hour Day 1-5 Rainfall Forecast

*Original figure as published by the NOAA.*

NOAA forecast, [www.noaa.gov](http://www.noaa.gov), 2012-10-27.

# What's wrong?

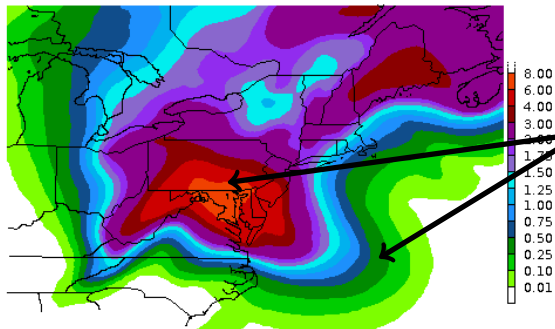


Gradients  
very strong

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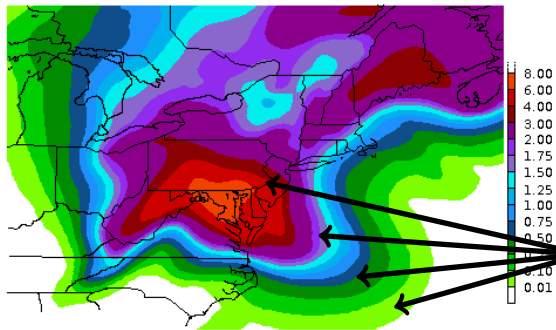
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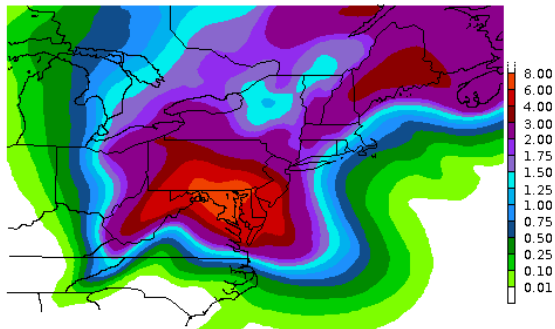
Saturation  
highly-saturated colors

Discontinuous  
Bright, dark, bright, dark, ...

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120-hour Day 1-5 Rainfall Forecast

*Original figure as published by the NOAA.*

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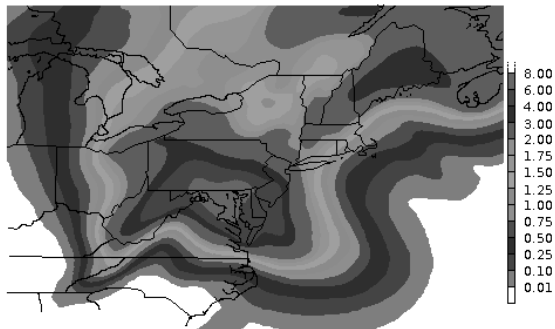
Discontinuous

Bright, dark, bright, dark, ...

Basic color guidelines:

**Colors should be:** assisting; simple; clear; appealing

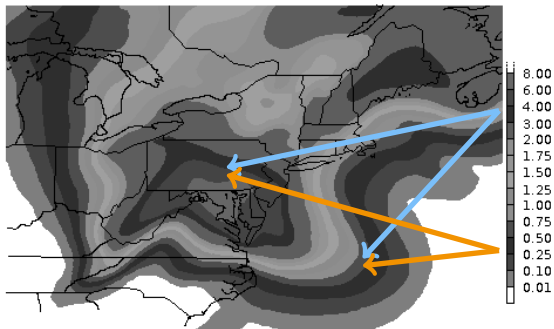
# What's wrong?



Hurricane Sandy  
120-hour Day 1-5 Rainfall Forecast

*Desaturated version of the original figure.*

# What's wrong?



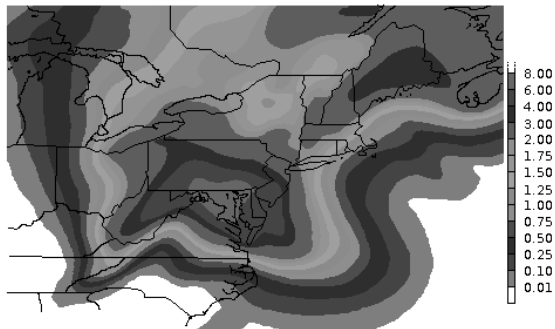
Hurricane Sandy  
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*Desaturated version of the original figure.*

Assignment

no longer unique

# What's wrong?



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*Desaturated version of the original figure.*

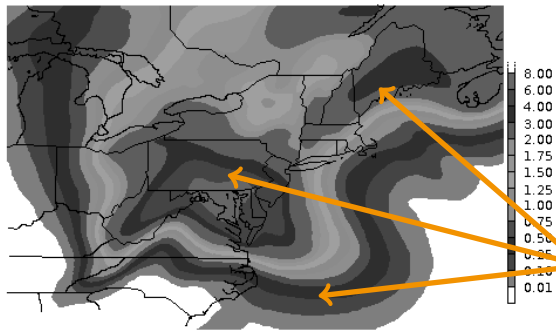
Assignment

no longer unique

Interpretation

Where is the maximum?

# What's wrong?



Assignment  
no longer unique

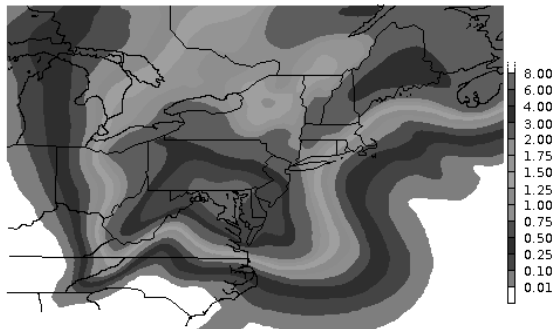
Interpretation  
Where is the maximum?

**Focus**  
on dark artefacts

Hurricane Sandy  
120-hour Day 1-5 Rainfall Forecast

*Desaturated version of the original figure.*

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Hurricane Sandy  
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Assignment

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Interpretation

Where is the maximum?

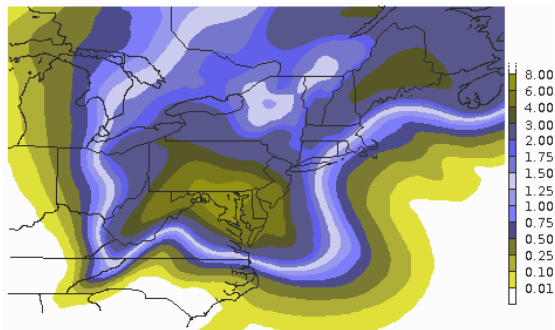
Focus

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Colors should

work everywhere; point and guide to important information

# What's wrong?

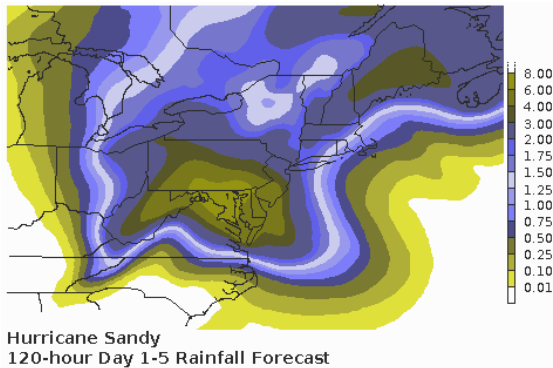


Hurricane Sandy  
120-hour Day 1-5 Rainfall Forecast

*What color-blind people see (red-green weakness).*

*About 4.5% of all Europeans are affected.*

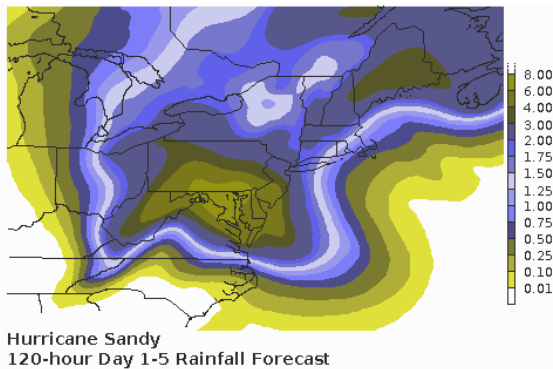
# What's wrong?



End-user  
Who is it?

*What color-blind people see (red-green weakness).  
About 4.5% of all Europeans are affected.*

# What's wrong?



End-user

Who is it?

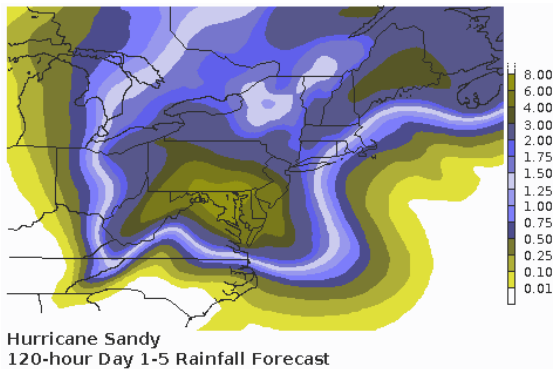
To regard

visual constraints?

*What color-blind people see (red-green weakness).*

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End-user

Who is it?

To regard

visual constraints?

*What color-blind people see (red-green weakness).*

*About 4.5% of all Europeans are affected.*

Colors should consider

end-user needs

# Requirements to the colors

## Summary:

- + simple and natural

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- + point to important information
- + do not mislead the reader

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- + customer tailored

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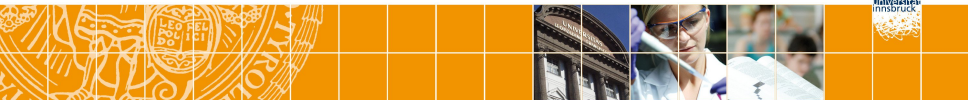
- + simple and natural
- + point to important information
- + do not mislead the reader
- + be appealing
- + customer tailored
- + should work everywhere

# Requirements to the colors

## In reality:

- people often do not think about it at all
- ... and simply use default colors

This can lead to various problems for your **end-users** (reviewer, supervisor, colleague), your **customers**, or **your own** day-by-day **work**.

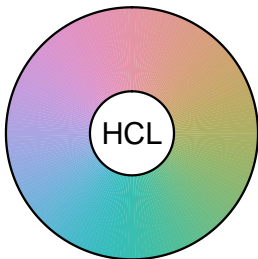


## A perception-based color scheme

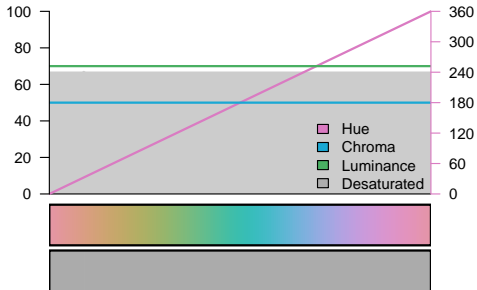
Introduction to the Hue-Chroma-Luminance (HCL) concept

# Perception-based way: HCL

A HCL rainbow



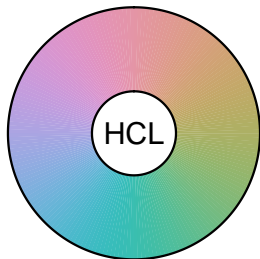
HCL rainbow spectrum



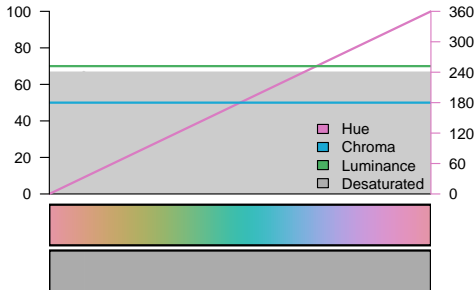


# Perception-based way: HCL

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HCL rainbow spectrum

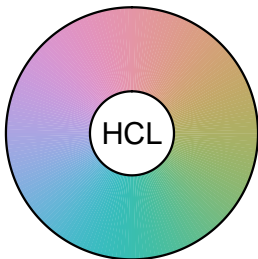


Triplet of:

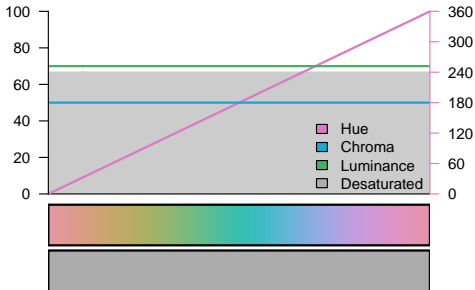
- **Hue** (*defines the color*)
- **Chroma** (*defines the coloriness*) and

# Perception-based way: HCL

A HCL rainbow



HCL rainbow spectrum



Triplet of:

- **Hue** (*defines the color*)
- **Chroma** (*defines the colorness*) and
- **Luminance** (*defines the brightness*)

# Perception-based way: HCL

## Advantages:

- based on human perception

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- easy to control

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- additional information

# Perception-based way: HCL

## Advantages:

- based on human perception
- easy to control
- simple to use
- improves your work
- additional information
- helps understanding complex concepts

### Hue



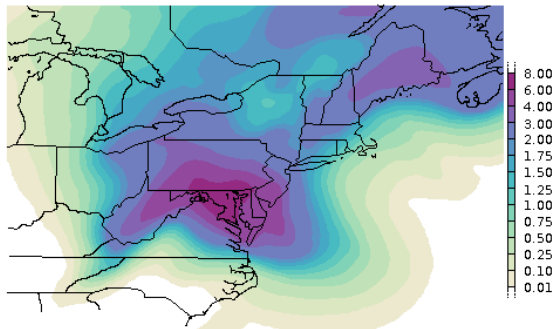
### Chroma



### Luminance



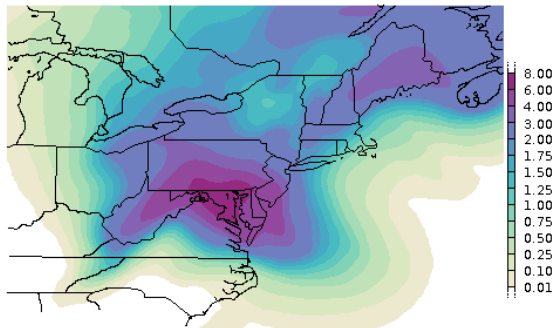
# HCL version



Hurricane Sandy  
120-hour Day 1-5 Rainfall Forecast

*Same information, changed color scheme.*

# HCL version



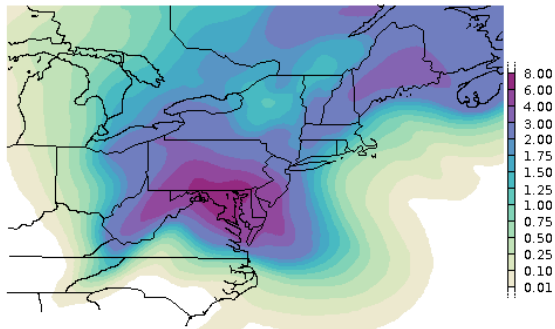
## Colors

only two colors;  
no irritating gradients

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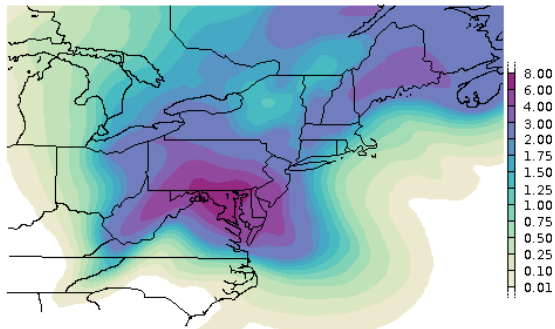
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## Information

guiding; no hidden in-  
formation

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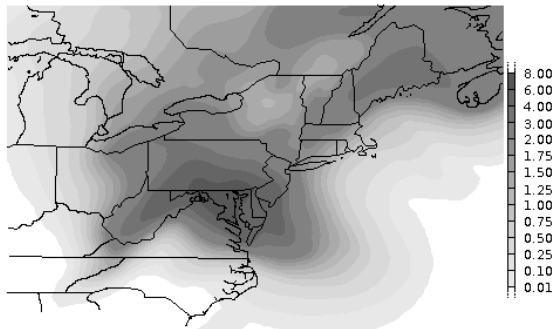
## Information

guiding; no hidden in-  
formation

## Works

screen;  
projector;  
gray-scale device

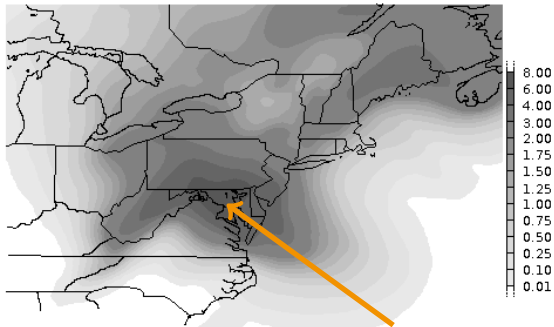
# HCL version



Hurricane Sandy  
120-hour Day 1-5 Rainfall Forecast

*Desaturated representation of the HCL-version.*

# HCL version



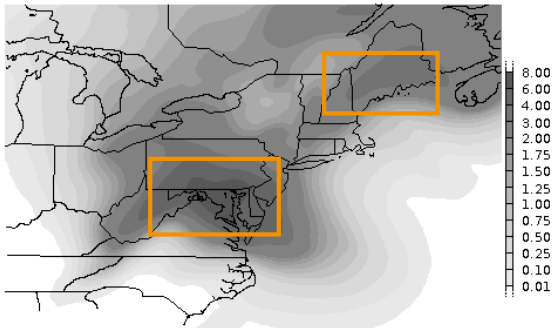
Hurricane Sandy  
120-hour Day 1-5 Rainfall Forecast

*Desaturated representation of the HCL-version.*

## Assignment

Higher precipitation  
→ lower luminance

# HCL version



Hurricane Sandy  
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*Desaturated representation of the HCL-version.*

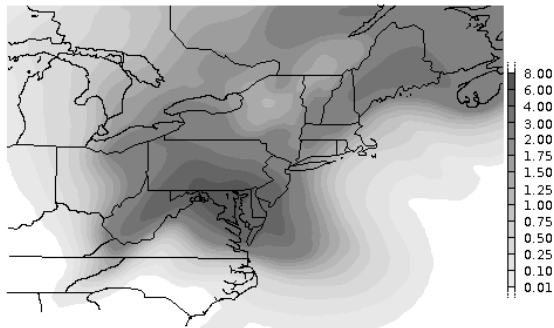
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Focus

on most  
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# HCL version



Hurricane Sandy  
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*Desaturated representation of the HCL-version.*

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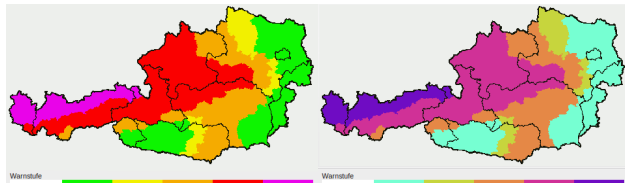
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## Summary

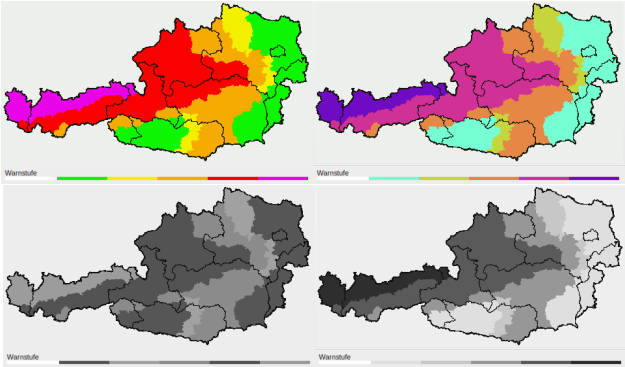
Solved a lot of problems by changing the color palette

# Warning map example



Colorized  
*Original (left)*  
*HCL idea (right)*

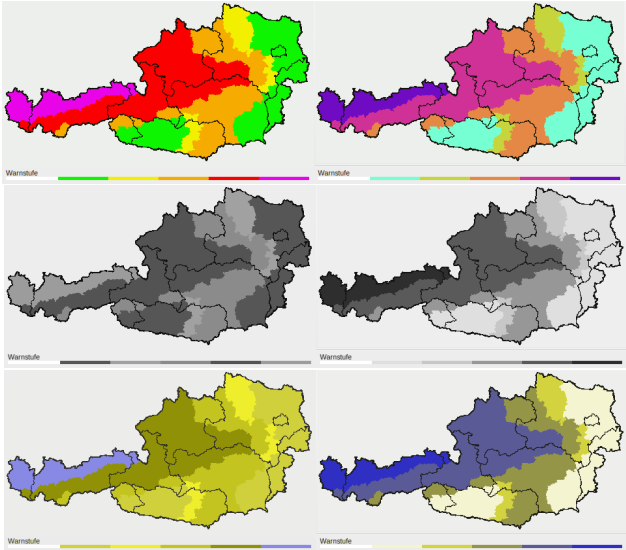
# Warning map example



**Colorized**  
*Original (left)*  
*HCL idea (right)*

**Gray-scale**

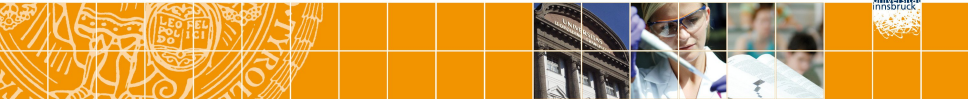
# Warning map example



**Colorized**  
*Original (left)*  
*HCL idea (right)*

**Gray-scale**

**Deuteranopia**  
Red-Green  
weakness



## Experiences with HCL scheme

# Experiences with the HCL scheme

## In the beginning

- hesitation of the colleagues

# Experiences with the HCL scheme

## In the beginning

- hesitation of the colleagues
- “not necessary”
- “why should we change existing products”
- “everybody does it like this”

# Experiences with the HCL scheme

A few days later

+ mainly positive feedback

# Experiences with the HCL scheme

## A few days later

- + mainly positive feedback
- + “how can I make use of those palettes?”
- + “does that work in my coding language?”

# Experiences with the HCL scheme

## A few days later

- + mainly positive feedback
- + “how can I make use of those palettes?”
- + “does that work in my coding language?”
- + “much easier to interpret”
- + decrease of misinterpretation

# Experiences with the HCL scheme

## Complex concepts

- + easier to read

# Experiences with the HCL scheme

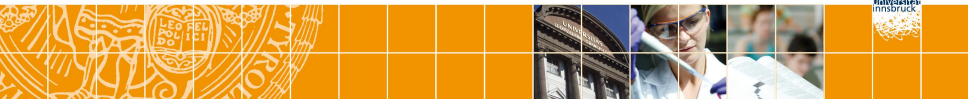
## Complex concepts

- + easier to read
- + better to understand

# Experiences with the HCL scheme

## Complex concepts

- + easier to read
- + better to understand
- + HCL: powerfull tool for teaching



## Tools and further reading

The HCL wizard: [www.hclwizard.org](http://www.hclwizard.org)

hcl wizard | Online HCL Creator - Chromium

hcl wizard | Online HCL Creator


# hcl wizard

Online HCL Creator

[Home](#) [Why HCL](#) [HCL Color scheme](#) [Online HCL Creator](#) [How to use](#) [References](#) [ertel2](#)

## New export button

July 20, 2015 Feature



Hello everyone

Another small update today. I got asked by Arne Spek at if it would be possible to have an export button to download a tailored color palette. Of course it is :).

The [Online HCL Creator](#) now offers a Download-Button (choose your personal palette and open the "Export Options: RAW" panel) for the three different types (RGB float, RGB integer base, and HEX colors). The tool then sends a clean ASCII (simple text file) to your browser. If there is a need to change/extend the format for an easier use - please let me know!

Have a nice day,  
D...

*Side note*

Most of us are working with colors day-by-day. Often, the default color schemes are used which is not always the most effective way.

The page gives you some first information to get in touch with the Hue-Chroma-Luminance color concept. Furthermore, we offer you a tool ready for "try and use".

*Get full article*

The [\(open access\) article "Somewhere over](#)

Online Creator eeecon | hcl wizard - Chromium

hclwizard.org/online-creator-eeeecon/

Home Why HCL HCL Color scheme *Online HCL Creator* How to use References ertel2

### Export Options

R py m GvADS RAW

### Examples

#### METEOROLOGY


- Austria
- Equiv. Pot. Temperature
- Geopot. Temperature
- Topography
- Chlorophyll

#### COLORSPACE

- Map
- Lineplot
- Scatterplot
- Perspective
- Pieplot
- Mosaicplot
- Barplot
- Spline

### Color Settings

Type: Diverging



H1 130

H2 43

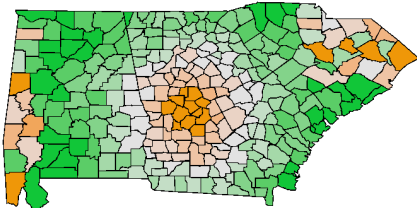
C1 100

L1 70

L2 90

P1 1.0

N 11



Color fixup  
 Reversed colors

Online Creator eeecon | hcl wizard - Chromium

Online Creator eeecon x

hclwizard.org/online-creator-eeeecon/

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### Export Options

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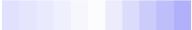
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### Color Settings

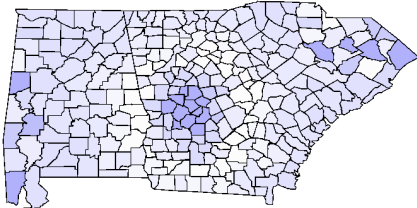
Type R default color schemes



N



- Color fixup
- Reversed colors
- Colorized
- Desaturate
- Color Blindness
  - Deutan
  - Protan
  - Tritan



Online Creator eecon | hcl wizard - Chromium

hclwizard.org/online-creator-eecon/

Home Why HCL HCL Color scheme *Online HCL Creator* How to use References ertel2

### Export Options

R py m GrADS RAW

### Color Settings

Type: Diverging

H1: 250  
H2: 0  
C1: 50  
L1: 50  
L2: 95  
P1: 1  
N: 11

Color fixup  
 Reversed colors

### Color Export and Example Snippet

RGB values, range [0-1]	RGB values, range [0-255]	HEX colors, no alpha
0.333 0.471 0.675	85 120 172	#5578AC
0.467 0.561 0.725	119 143 185	#778FB9
0.588 0.651 0.776	150 166 198	#96A6C6
0.706 0.749 0.831	180 191 212	#B4BFD4
0.824 0.843 0.886	210 215 226	#D2D7E2
0.945 0.945 0.945	241 241 241	#F1F1F1
0.894 0.827 0.839	228 211 214	#E4D3D6
0.847 0.714 0.737	216 182 188	#DBB6BC
0.792 0.600 0.635	202 153 162	#CA99A2
0.737 0.490 0.537	188 125 137	#BC7D89
0.678 0.376 0.443	173 96 113	#AD6071

[Download](#) [Download](#) [Download](#)

Tue Sep 22 2015 10:19:24 GMT+0200 (CEST) This is the RAW output

References | hcl wizard - Chromium

References | hcl v x

hclwizard.org/references/

## References

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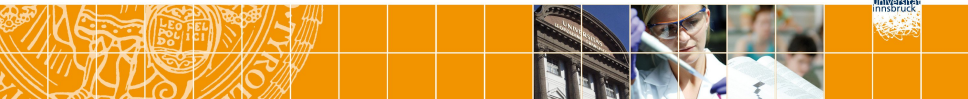
*Side note*

Most of us are working with colors day-by-day. Often, the default color schemes are used which is not always the most effective way.

The page gives you some first information to get in touch with the Hue-Chroma-Luminance color concept. Furthermore, we offer you a tool ready for "try and use".

*Get full article*

The (open access) article "[Somewhere over the Rainbow: How to Make Effective Use of Colors in Meteorological Visualizations](#)" (R. Stauffer, G. J. Mayr, A. Zeileis and M. Dabernig) is now available online. *BAMS*, Volume 96, Issue 2, February 2015.



## How is it in your field?

Some examples from the latest issues

# Ecological Economics

Type	Count
No colors in article	8
Only simple plots/graphs	6
Suboptimal colors (RGB rainbow)	1

*Articles currently "in press".*

*All articles checked for color-usage and  
subjectively classified (Reto, Sept. 2015).*

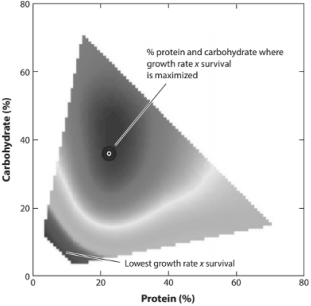
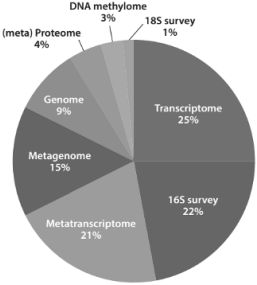
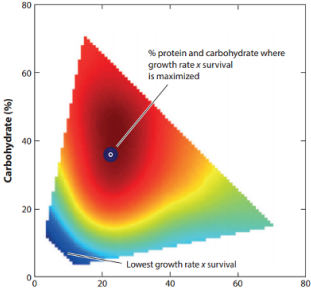
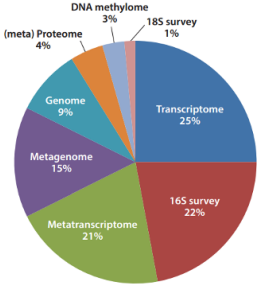
# Annual Review of Entomology

Type	Count
No colors in article	13
Only simple plots/graphs	8
Suboptimal colors (RGB rainbow)	4
Good color choice	2

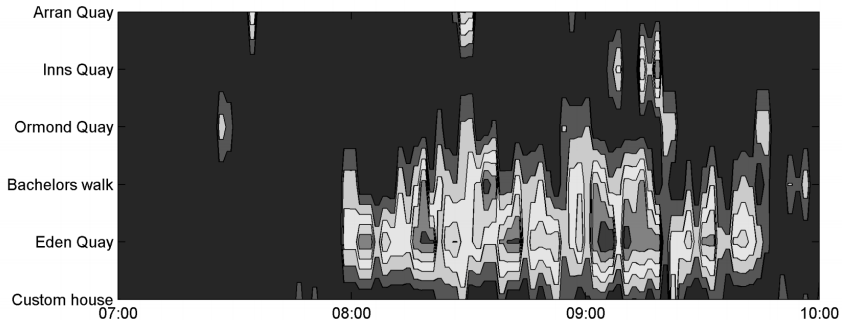
*Current volume, v60 (2015).*

*All articles checked for color-usage and  
subjectively classified (Reto, Sept. 2015).*

# Annual Review of Entomology

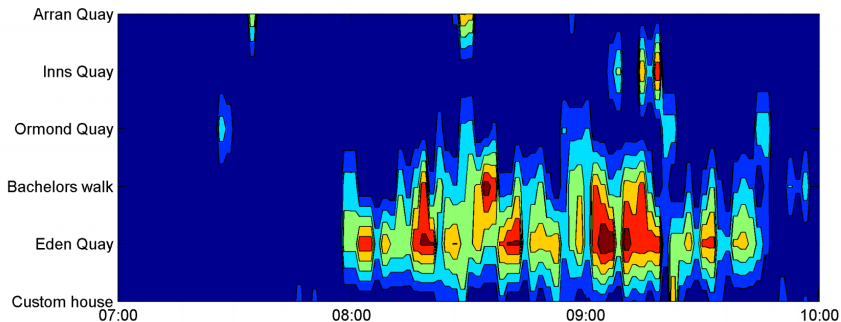


# Transportation Research Procedia



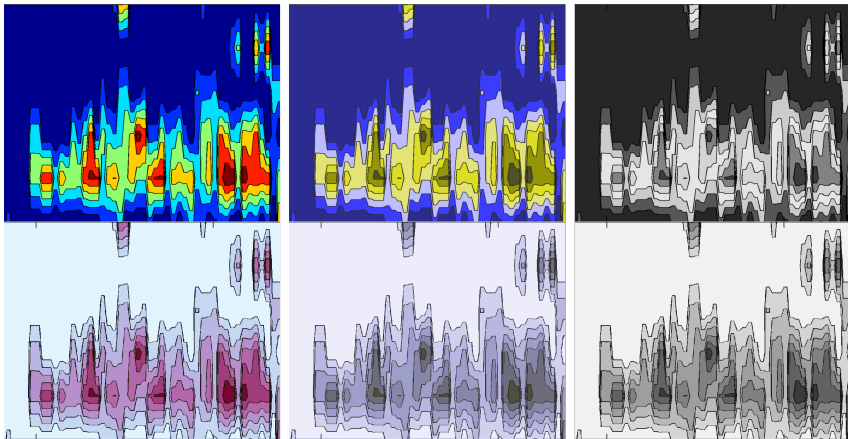
Alessandra Pascale, Hoang Thanh Lam, Rahul Nair, Characterization of Network Traffic Processes Under Adaptive Traffic Control Systems, *Transportation Research Procedia*, Volume 9, 2015, Pages 205-224, ISSN 2352-1465.

# Transportation Research Procedia



Alessandra Pascale, Hoang Thanh Lam, Rahul Nair, Characterization of Network Traffic Processes Under Adaptive Traffic Control Systems, *Transportation Research Procedia*, Volume 9, 2015, Pages 205-224, ISSN 2352-1465.

# Transportation Research Procedia



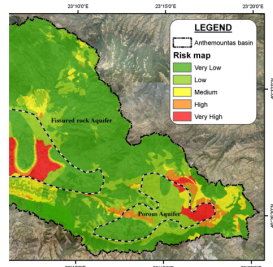
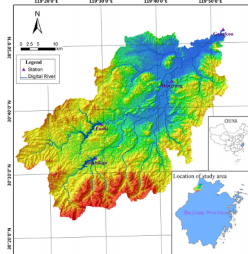
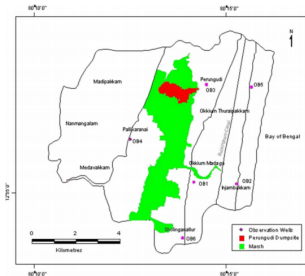
*Manipulated/adapted versions of the original figure (Pascale 2015). Top: original colors; bottom: re-drawn using a HCL color map. Left to right: original colors; deutan (red-green weakness); desaturated.*

# Environmental Earth Sciences

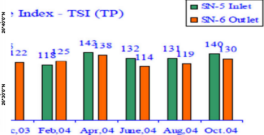
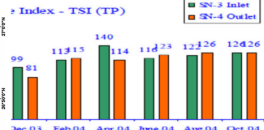
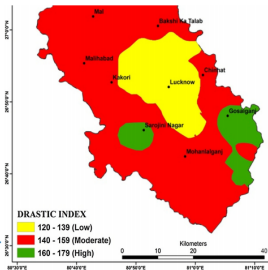
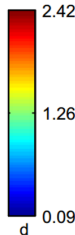
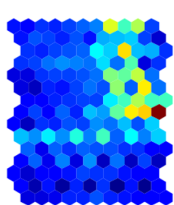
Type	Count
No colors in article	6
Only simple plots/graphs	4
Suboptimal colors (RGB rainbow)	7
Good color choice	3

*Current issue (v47 i7, October 2015).  
All articles checked for color-usage and  
subjectively classified (Reto, Sept. 2015).*

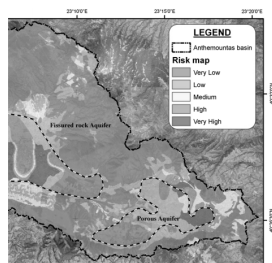
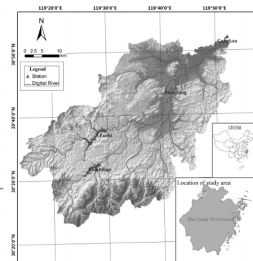
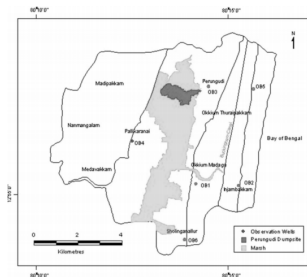
# Environmental Earth Sciences



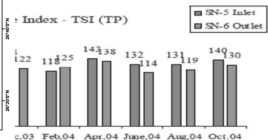
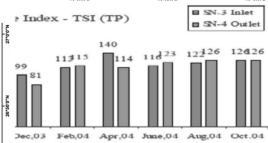
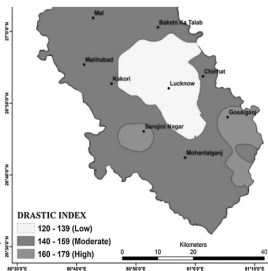
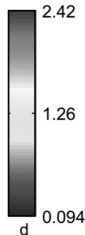
U-matrix



# Environmental Earth Sciences



U-matrix





Colors are a powerful tool and can be very effective (and pretty) if used correctly!

