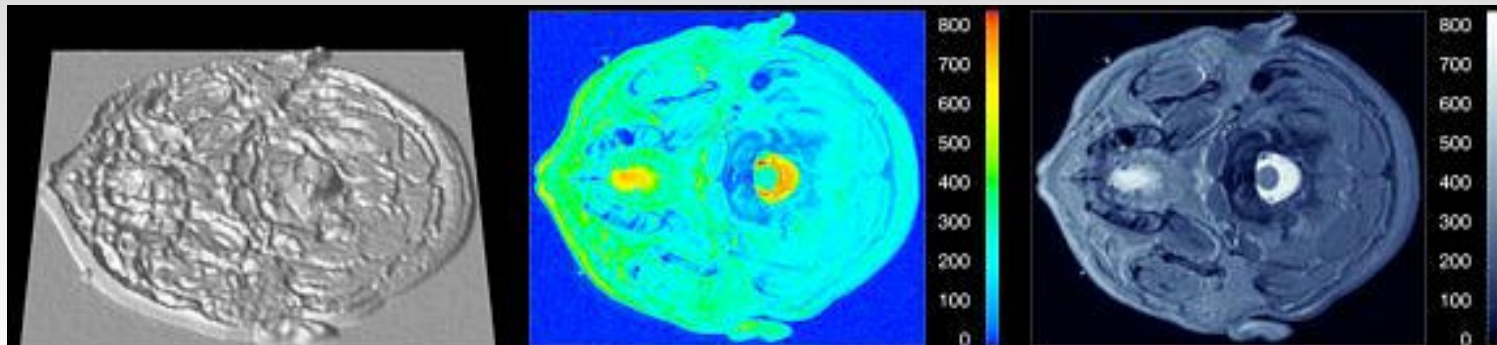


There is More to Color Scales than Meets the Eye

Samuel Silva, Joaquim Madeira, Beatriz Sousa Santos
DETI/IEETA – University of Aveiro, Portugal



Summary

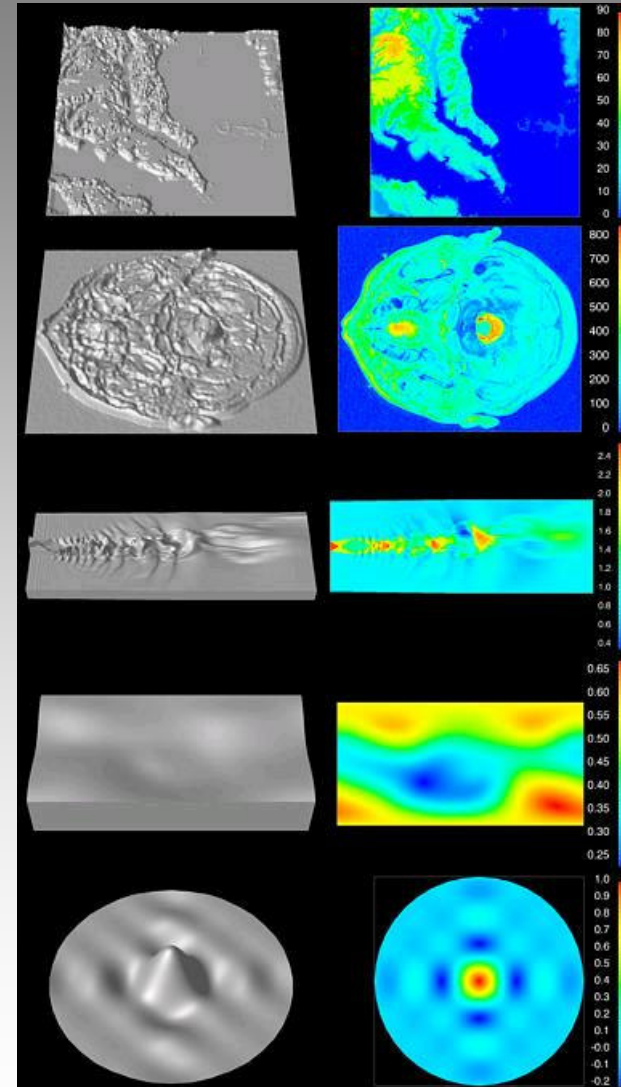
- Introduction
- Desired properties for color scales
- Common color scales
- What should drive color scale selection
- Perceptual color scales: examples
- Auxiliary tools and methods
- Conclusions

Introduction

- Good science: careful treatment of data
- Interactive systems: many visual dimensions
- An important problem is the correct use of color
- Users are not aware of all the implications
- Not enough to provided them with a library of color scales

Introduction

Typical solution:
Provide a spectrum color scale
(e.g. *spectrum* color scale)



Desired Properties

- Order
- Uniformity and Representative Distance
- Boundaries
- Rows and Columns Principle
- Diagonal Principle

Color Scales

- Single variable

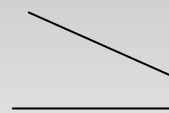
-grayscale,

-saturation,

-spectrum,

-Hue – Brightness

-Heated-object

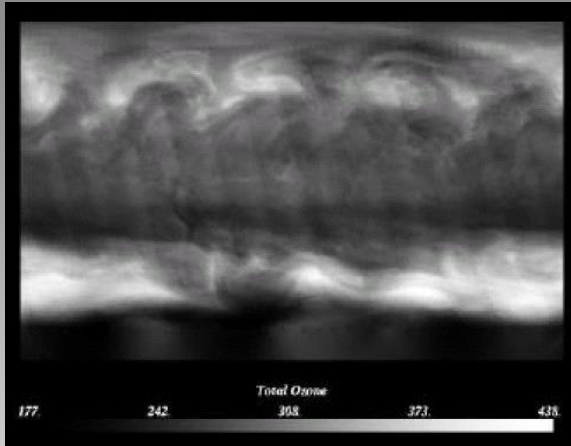


redundant scales

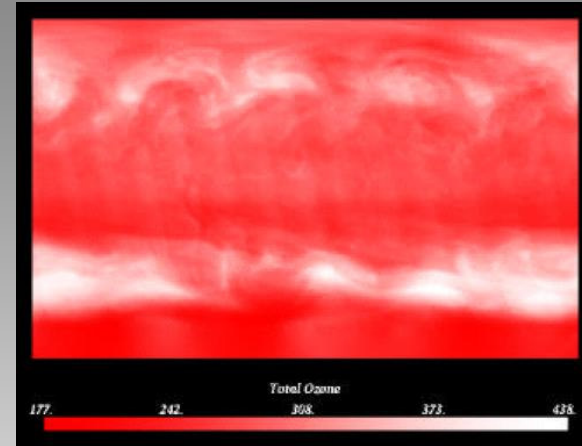
-Multivariate

Color Scales – Single Variable

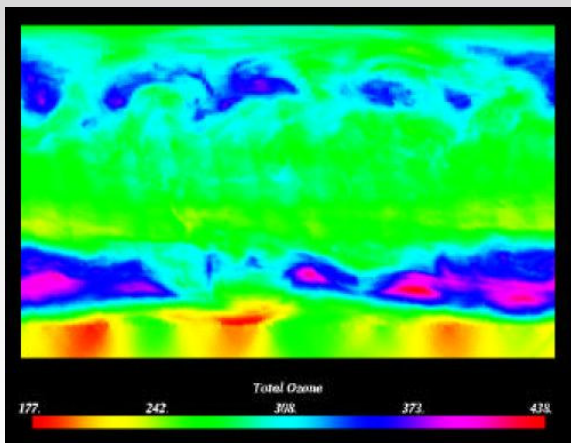
Color Model Components



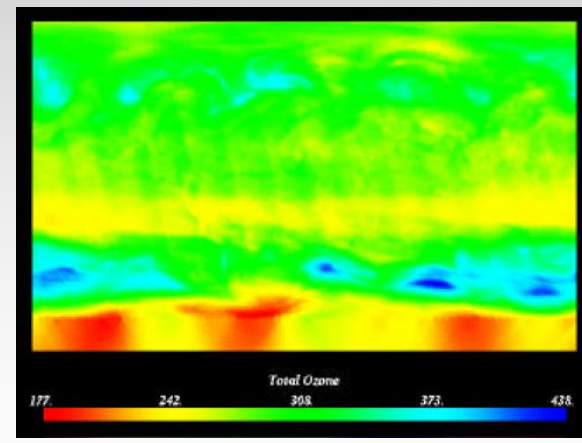
Greyscale



Saturation



Spectrum

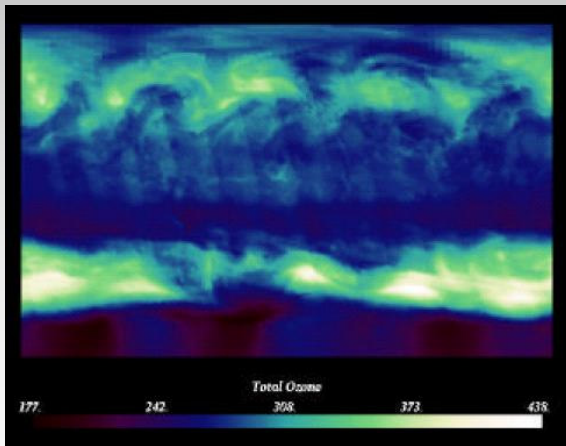


Limited Spectrum

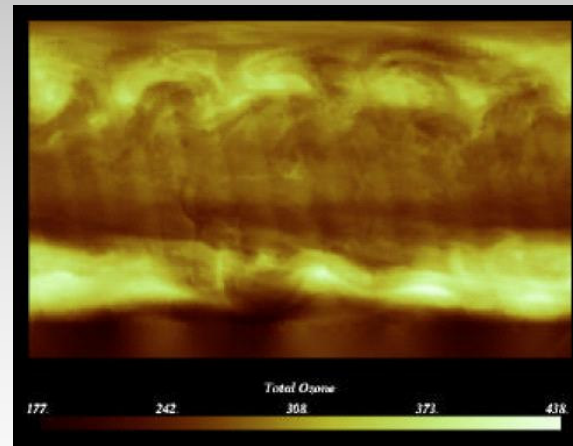
Color Scales – Single Variable

Redundant Color Scales

- Brightness to convey shape; hue for distinguishable display levels
- Overcome visual deficiencies
- Multiple parameters reinforce each other



Hue – Brightness color scale

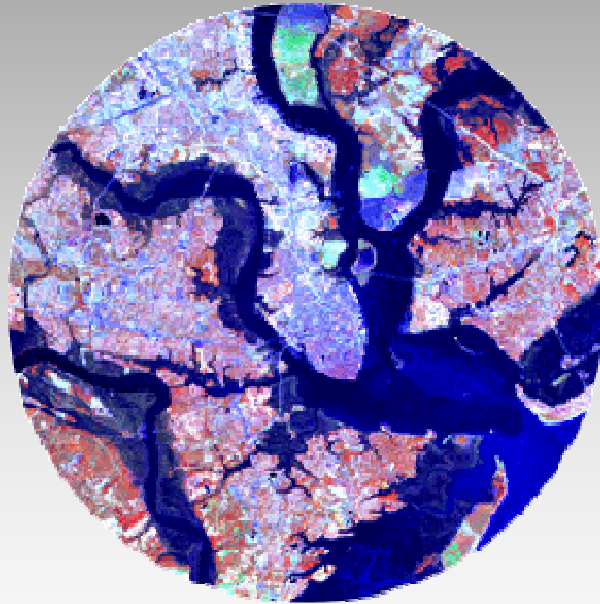


Heated-object color scale

Color Scales – Multivariate

color Model Primaries

Display Primaries (e.g., RGB)



Landsat “false color” image of South Carolina

What Should Drive Color Scale Selection

- Data type
- Spatial frequency
- Goals and tasks
- Cultural connotations
- Type of Visualization

taking into account the properties of the Human perceptual system

What Should Drive color Scale Selection

Data Types

- Nominal Data
 - Representation should not order data
- Ordinal Data
 - No equal distance
 - Representation should allow discrimination
- Interval Data
 - Equal distance Vs Equal perception
- Ratio Data
 - Increase/decrease about a zero/threshold

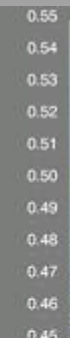
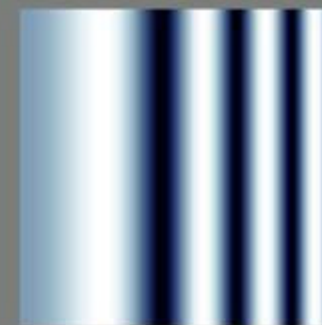
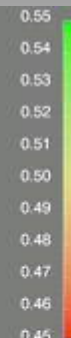
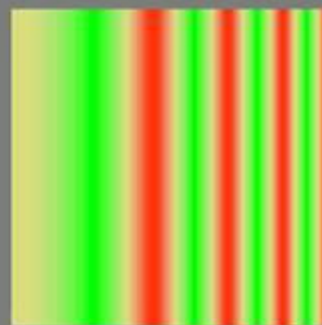
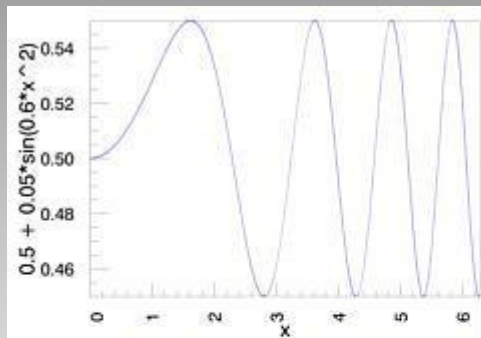
What Should Drive Color Scale Selection

Spatial Frequency

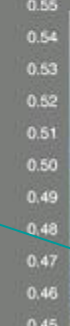
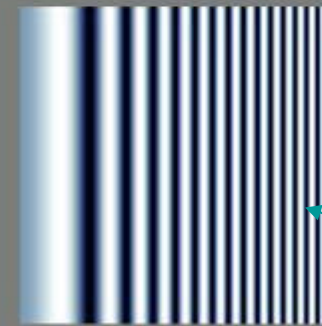
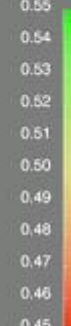
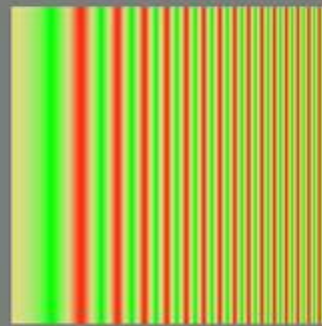
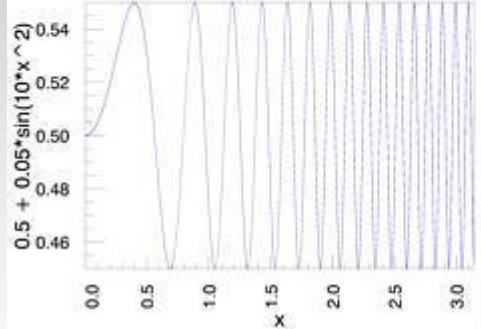
Saturation

Luminance

Low spatial freq.



High spatial freq.



More cycles visible

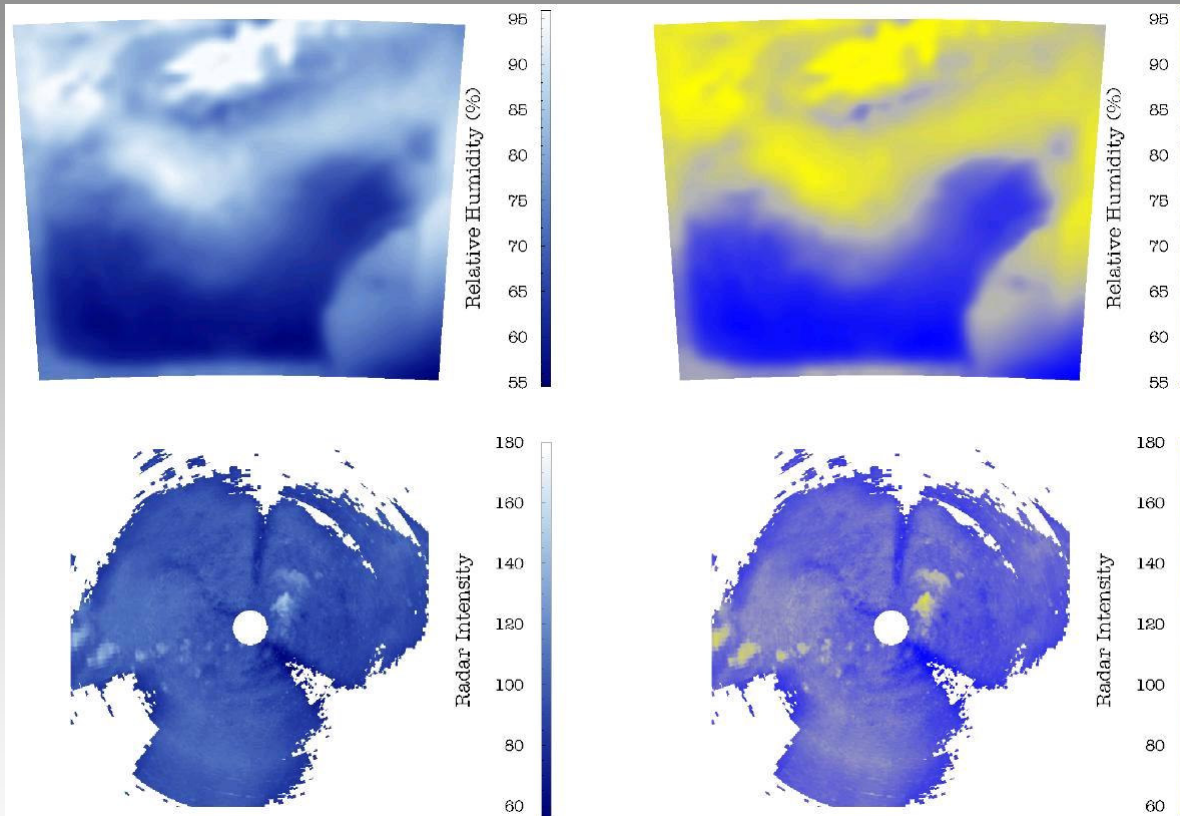
Low spatial Frequency color scale

High spatial frequency color scale

What Should Drive Color Scale Selection

Spatial Frequency

Low spatial freq.



High spatial freq.

High spatial frequency
color scale

Low spatial frequency
color scale

What Should Drive Color Scale Selection

Task / Goal

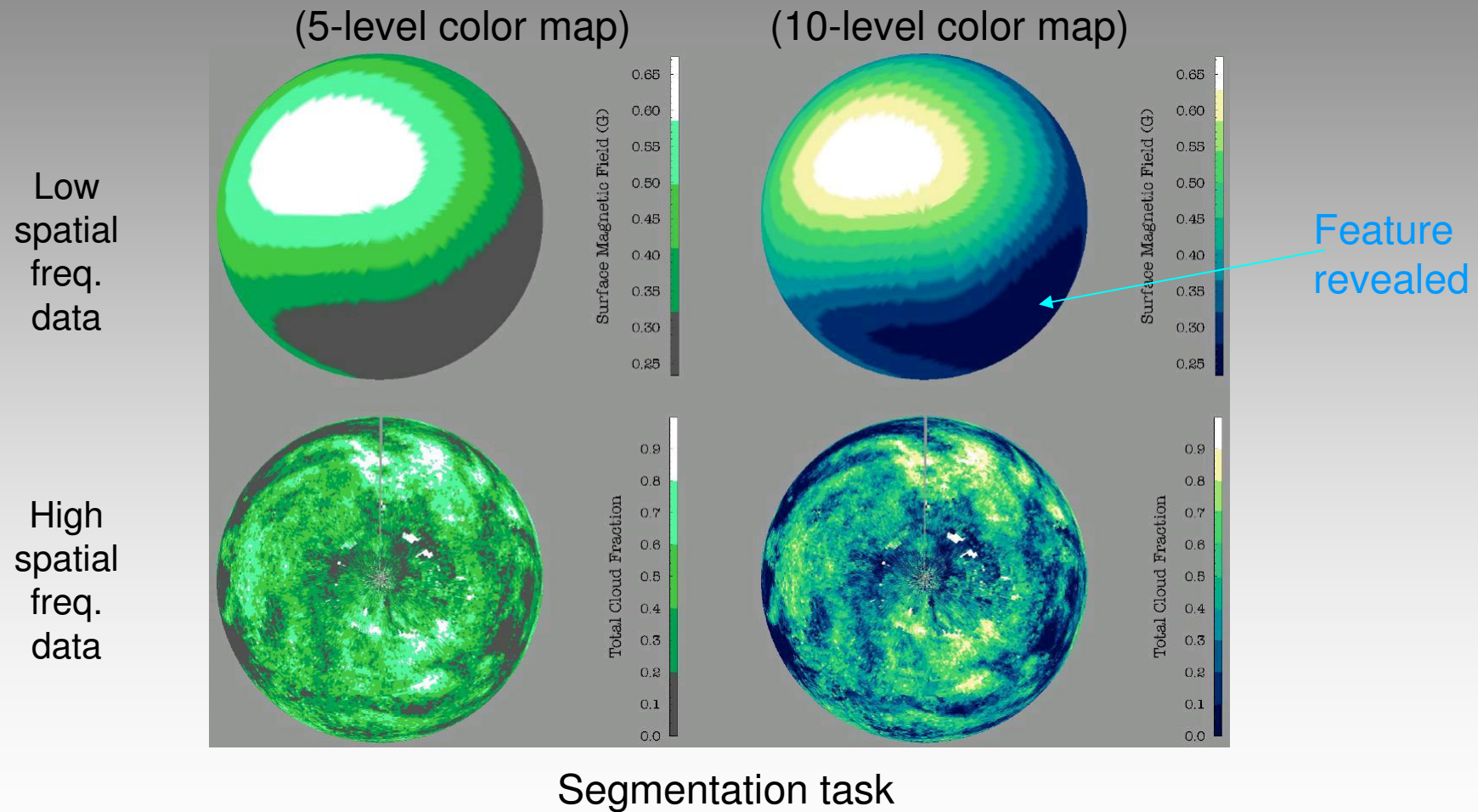
- Consider the task to perform in order to design the color scale

e.g.

- Tasks involving size judgment – warm colors appear larger
- Segmentation tasks – more steps can be effectively discriminated for low spatial-frequency data than for high

What Should Drive Color Scale Selection

Task / Goal



What Should Drive Color Scale Selection

Audience / Cultural Connotations

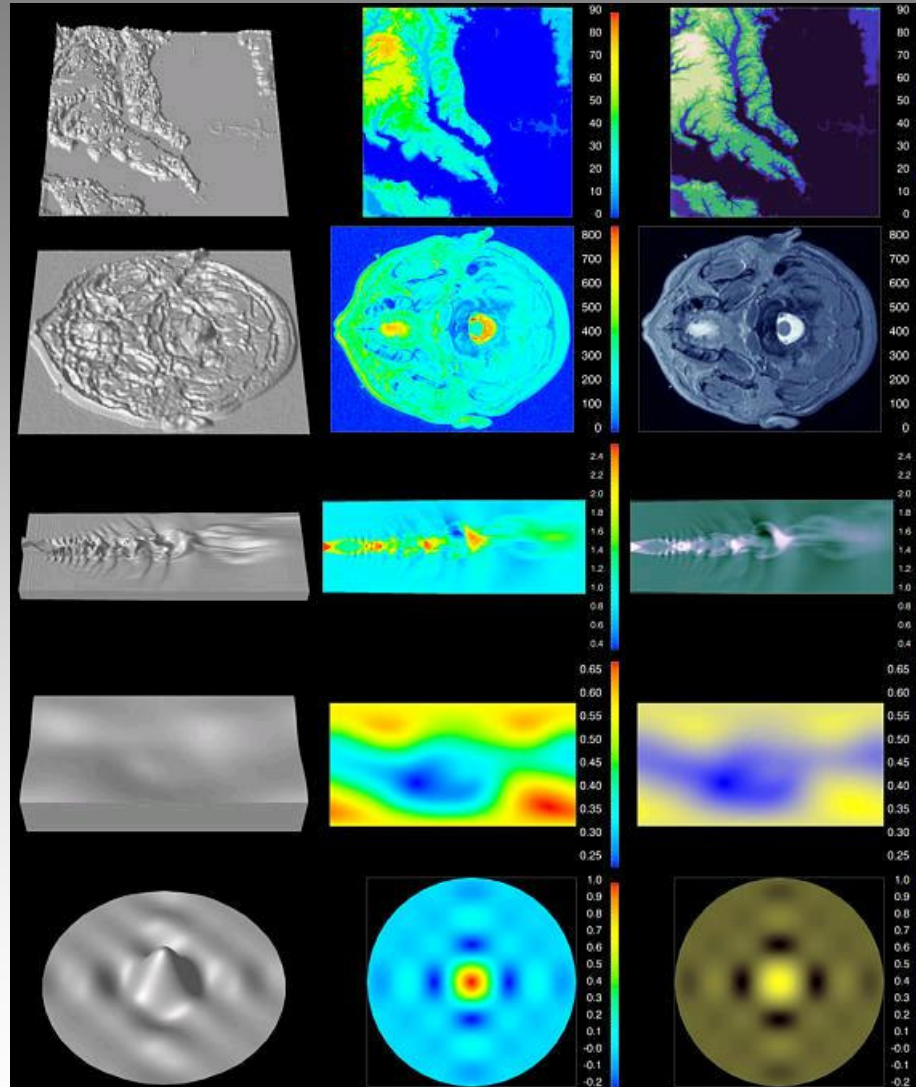
- Area conventions
- Use color connotations that suggest natural linkings (e.g., temperature)

Visualization Type

- 2D Vs 3D
- Shading vs brightness varying color scale

Perceptual Color Scales

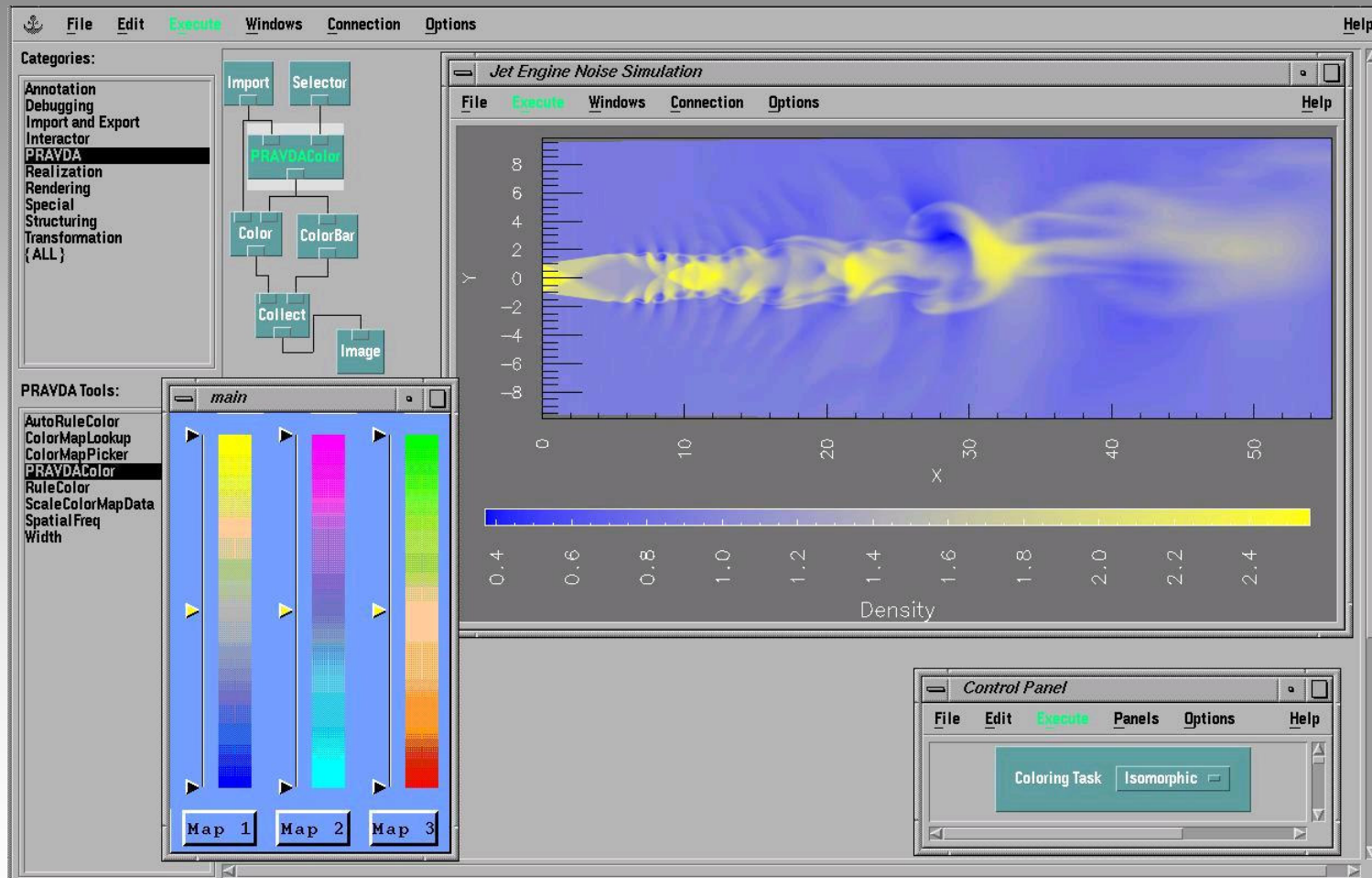
Previous data sets now represented using perceptual color scales



The structure of the data is better perceived

Example of Tools and Methods: PRAVDAColor

IBM Data Explorer Visual Program incorporating PRAVDAColor



Example of Tools and Methods: PRAVDAColor

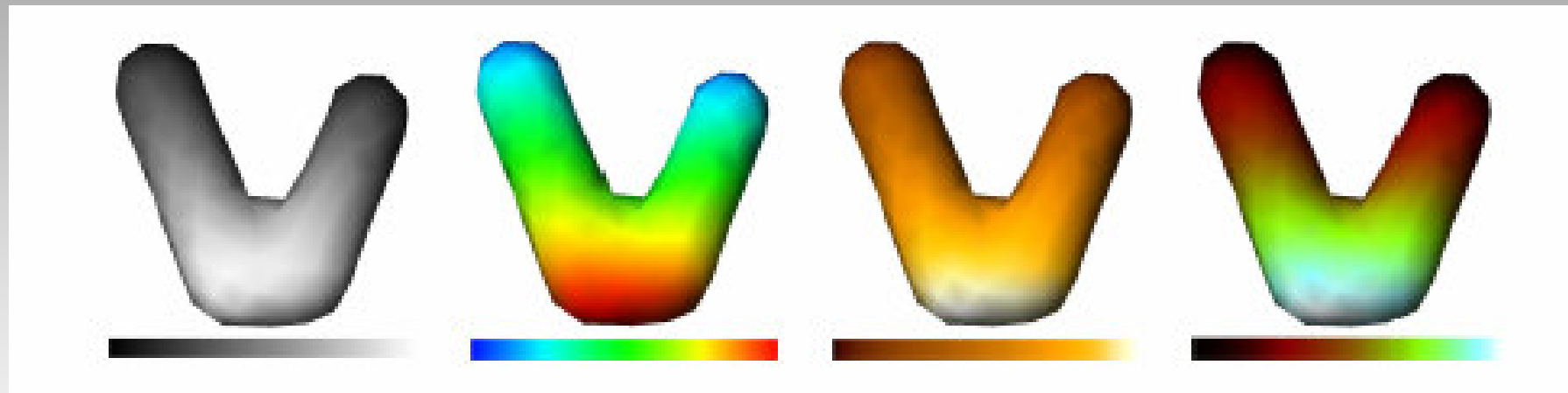
Taxonomy

Data Type	Spatial Frequency	Representation Task		
		Isomorphic	Segmentation	Highlighting
Ratio (true zero)	Low	<i>Luminance</i> : uniform <i>Hue</i> : opponent or complementary pairs <i>Saturation</i> : monotonically increasing from gray	- Even number of segments - Many segments OK	Larger range for highlighted features
	High	<i>Luminance</i> : monotonically increasing <i>Hue</i> : opponent or complementary pairs <i>Saturation</i> : monotonically increasing from gray	- Even number of segments - Fewer segments	Smaller range for highlighted features
Interval	Low	<i>Luminance</i> : uniform <i>Hue</i> : opponent pairs <i>Saturation</i> : monotonically increasing from gray	- Many segments OK	Larger range for highlighted features
	High	<i>Luminance</i> : monotonically increasing <i>Hue</i> : uniform or small hue variation <i>Saturation</i> : monotonically decreasing	- Fewer segments	Smaller range for highlighted features

Conclusions

- Not a simple subject
- Several guidelines proposed by researchers
- Guidelines proved to be useful in building perceptually corrected representations
- Often ignored in Visualization

Thank you!

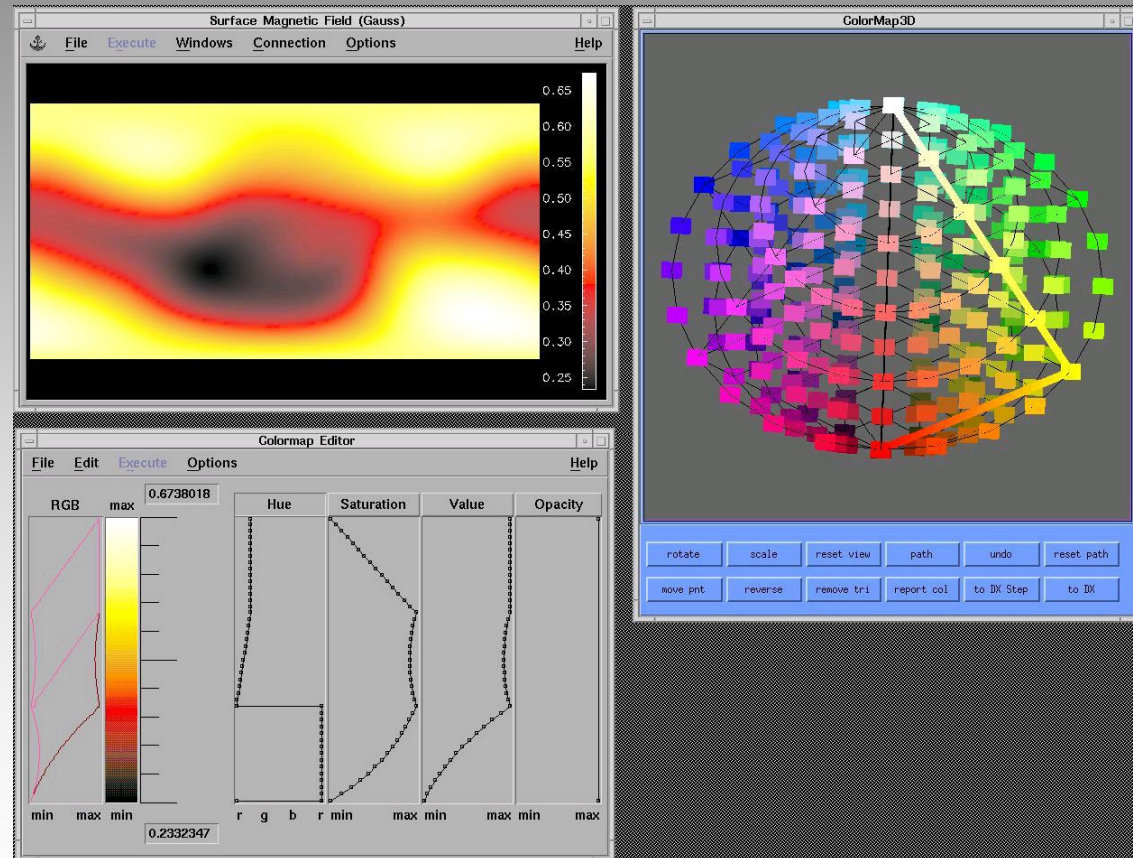


- D. Borland and R. Taylor. Rainbow color map (still) considered harmful. *IEEE Computer Graphics & Applications*, 27(2):14–17, 2007
- B. Rogowitz and A. D. Kalvin. The “Which Blair Project”: A quick visual method for evaluating perceptual color maps. In *Proc. IEEE Visualization '01*, pages 21–26, 2001
- L. D. Bergman, B. E. Rogowitz, and L. A. Treimish. A rule-based tool for assisting color map selection. In *Proc. IEEE Visualization '95*, pages 118–125, 1995
- B. Rogowitz and L. Treinish. How not to lie with Visualization. *Computers in Physics*, 10(3):268–273, 1996.
- B. Rogowitz and L. Treinish. Why should engineers and scientists be worried about color? <http://www.research.ibm.com/people/l/loyd/color/color.htm>
- C. A. Brewer. COLORBREWER. <http://www.ColorBrewer.org>

Example of Tools and Methods: PRAVDAColor

Color Maker

- Build a path along a color space (HLS)



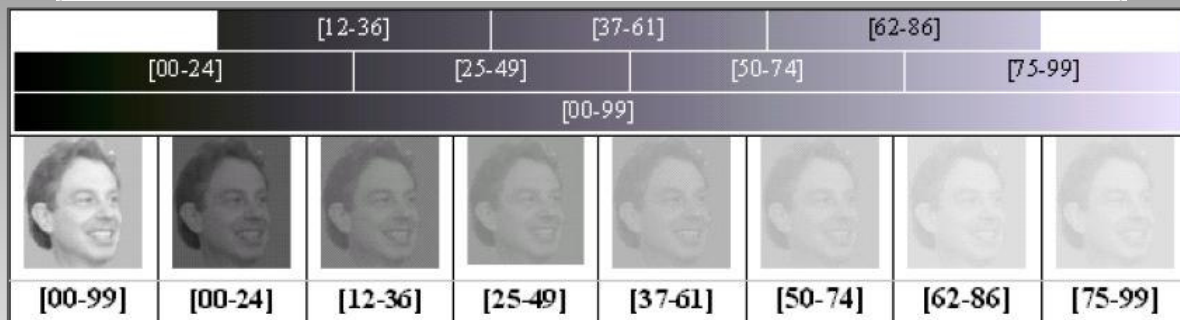
Learning Through Experimentation

Which Blair Project

- Rate each picture according to the degree to which the image appears to be a recognizable face

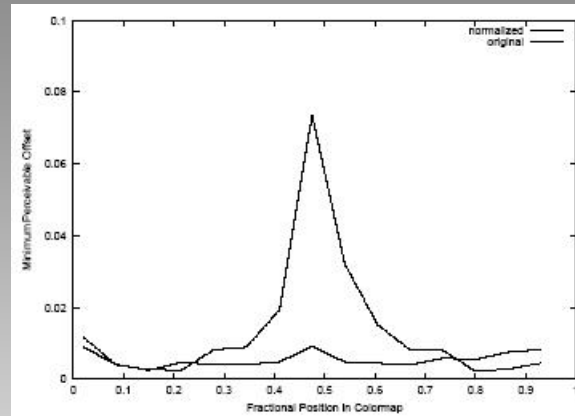
- Quick procedure to identify color scales with monotonically increasing luminance

- Doesn't require display calibration; nor lengthy psychological procedures



Tools and Methods

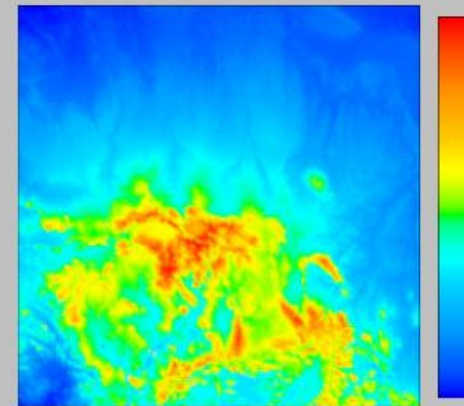
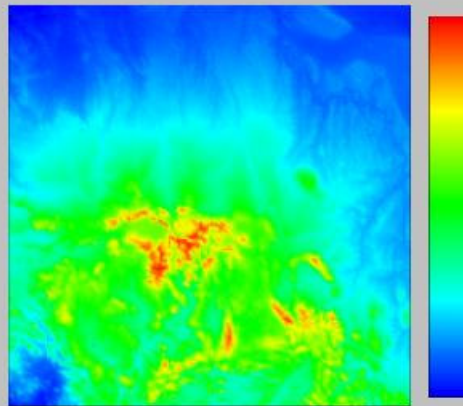
Self-Corrected Perceptual Colormaps



Measured perception function

Standard

Normalized



Learning Through Experimentation

Face-based Luminance Matching for Perceptual Colormap Generation

- Replace black with a shade of gray; white with a color.

- Match luminance between 2 regions.



Double-face Image

- Create color scales with any pre-determined pattern of luminance