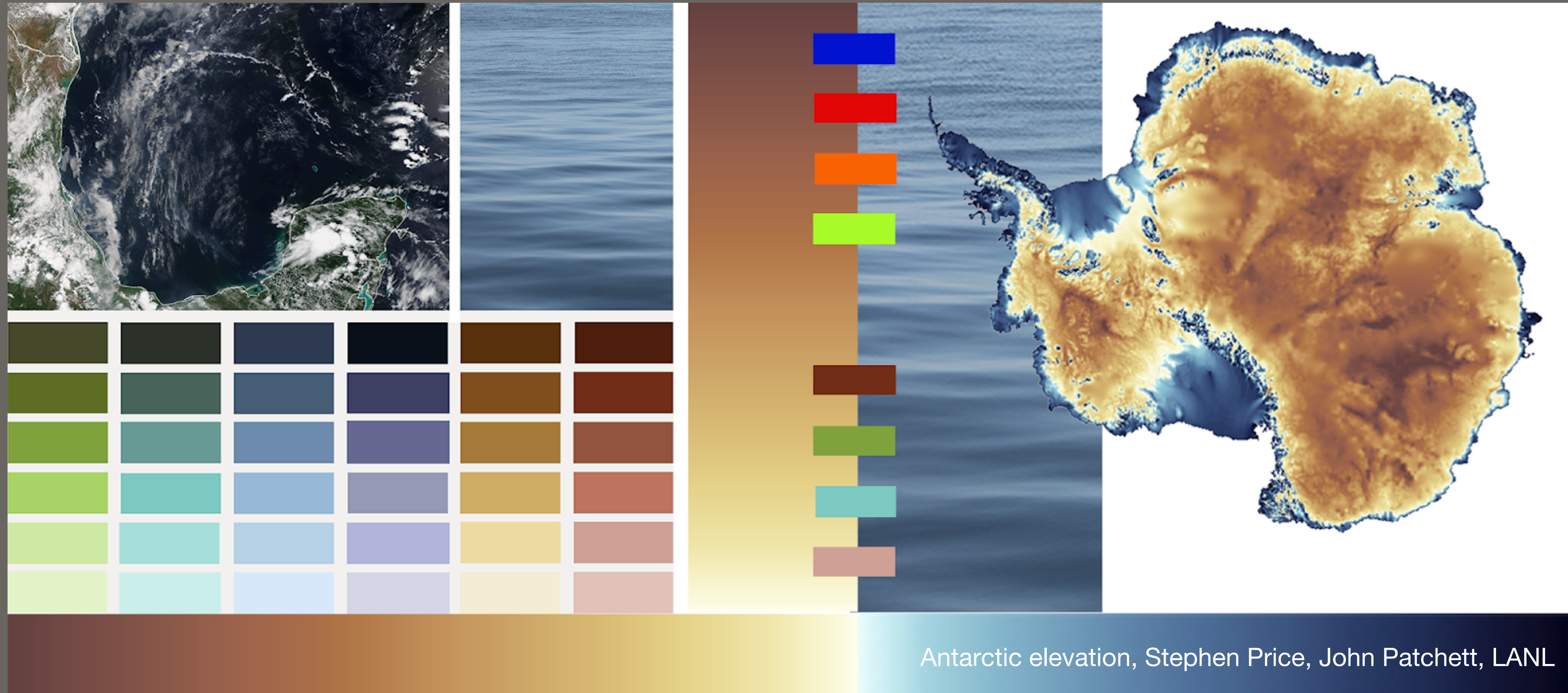


Optimizing Color Application for Clear, Complex, Communicative Visualization



A lifetime ago....



Woven Gifts

Francesca Samsel

2008



Black Rock, White Japan

TACC Visualization Lab
University of Texas at Austin

Color in scientific visualization
is complicated because

*our perception of hues
is based on surroundings*

colors

and in scientific visualization

*the data distribution
determines*

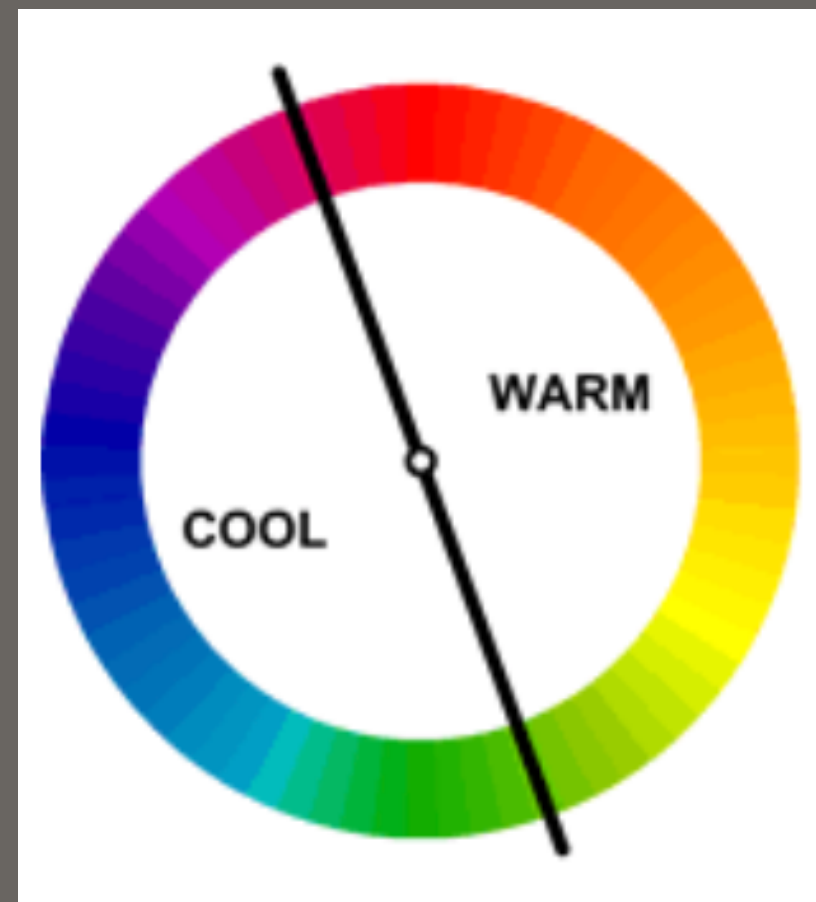
*the surrounding color,
not an artist.*



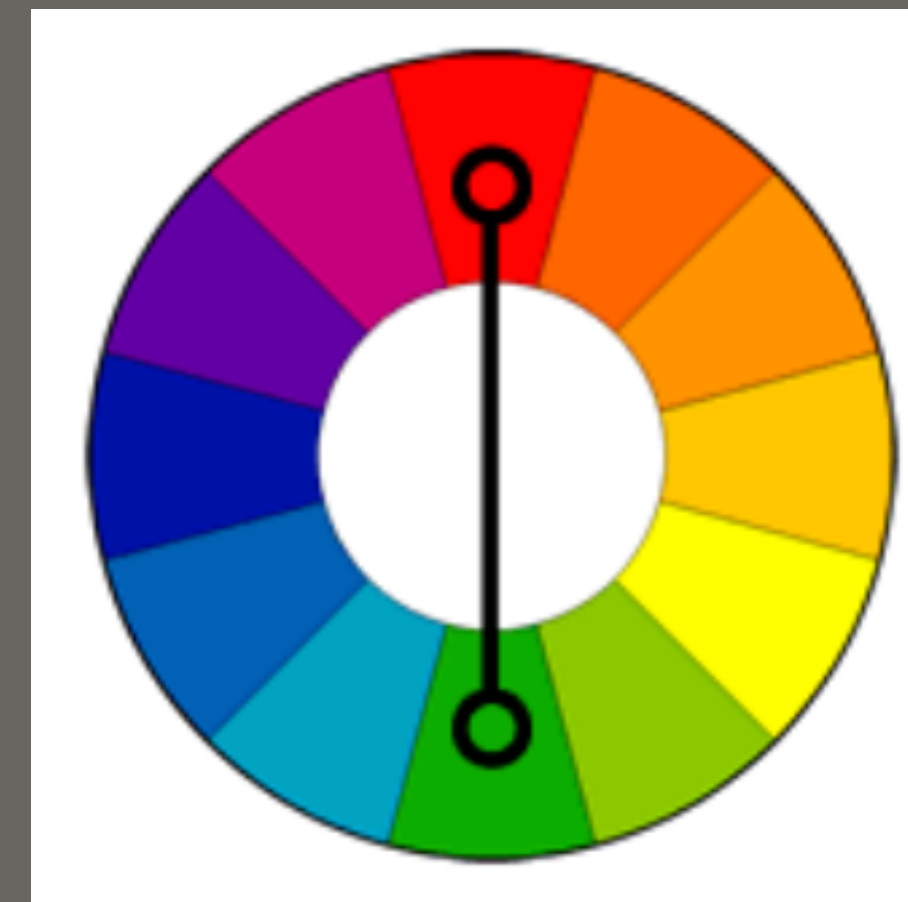
Types of color contrast

1. hue
2. value
3. saturation
4. complimentary
5. cool warm
6. proportion
7. **simultaneity**

Color CONTRAST Theory



cool / warm



complimentary

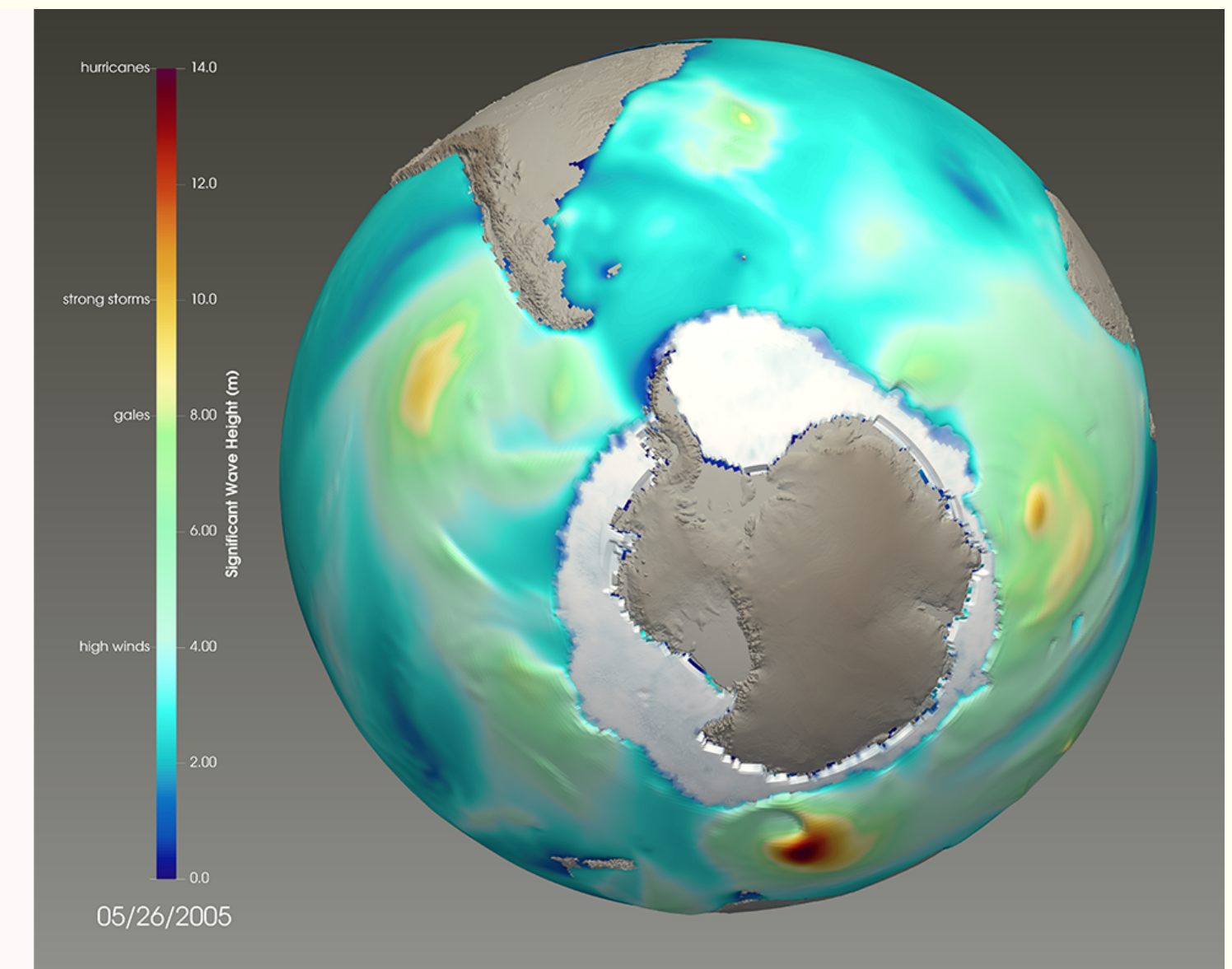
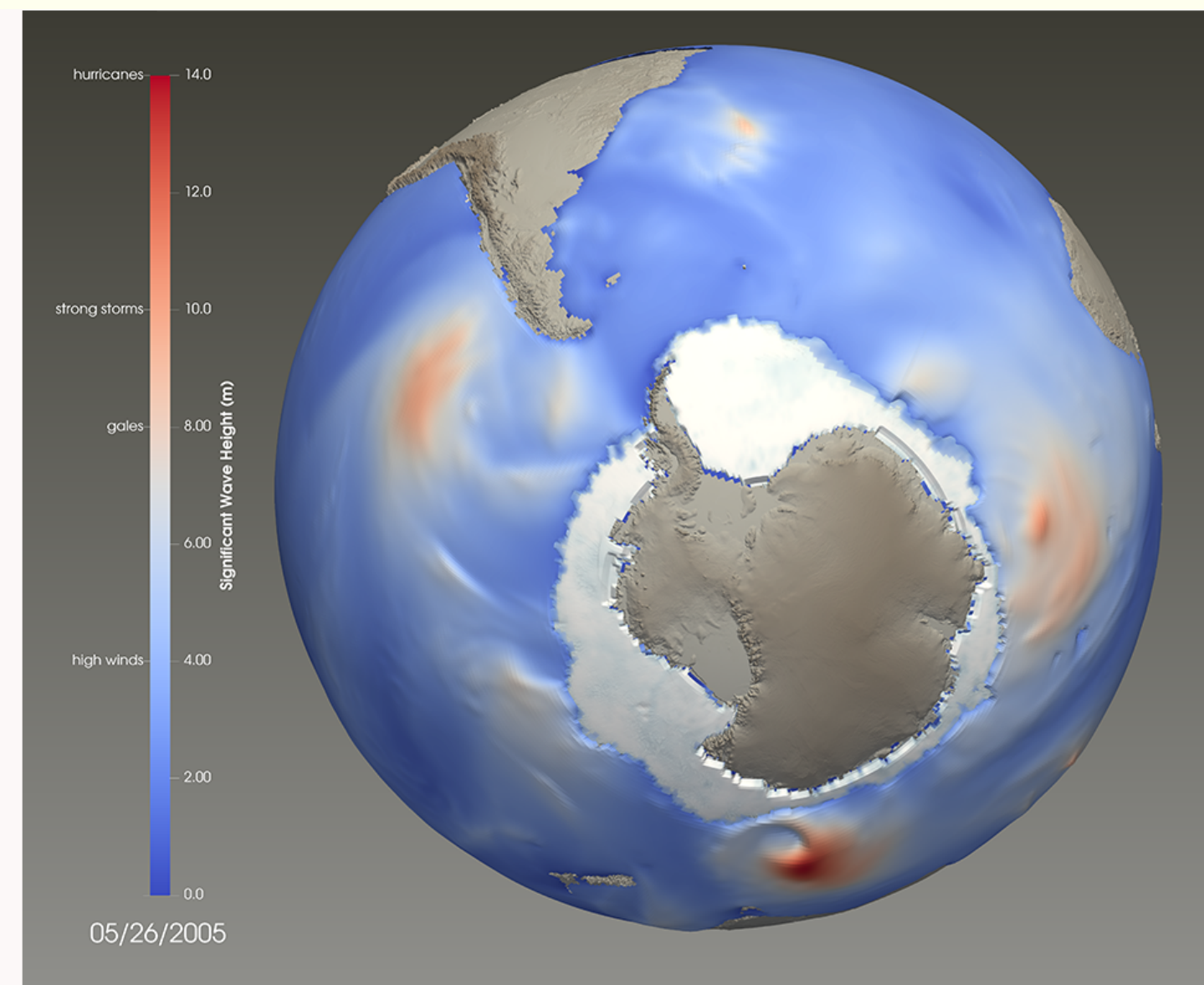
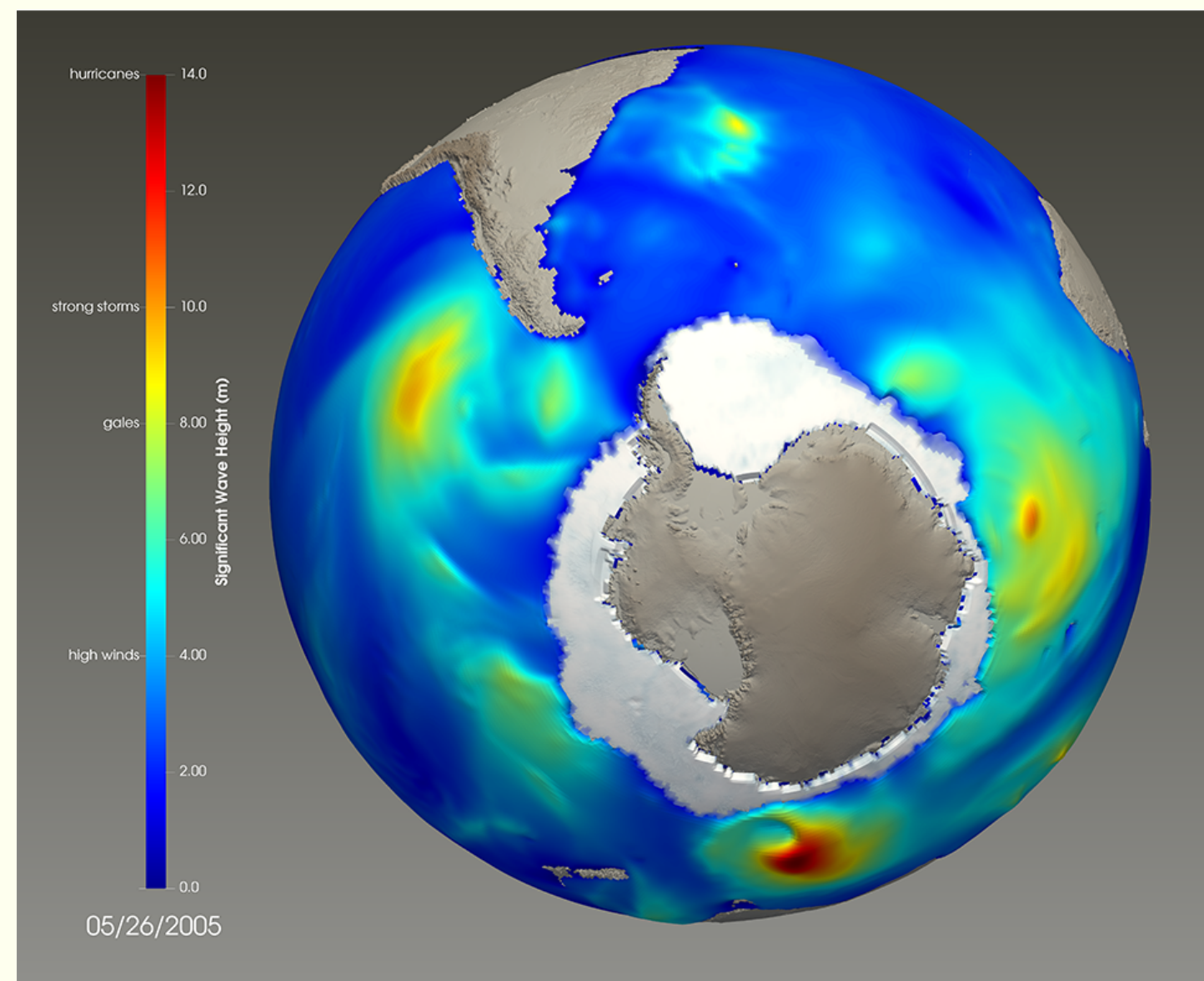


analogous

Color CONTRAST Theory

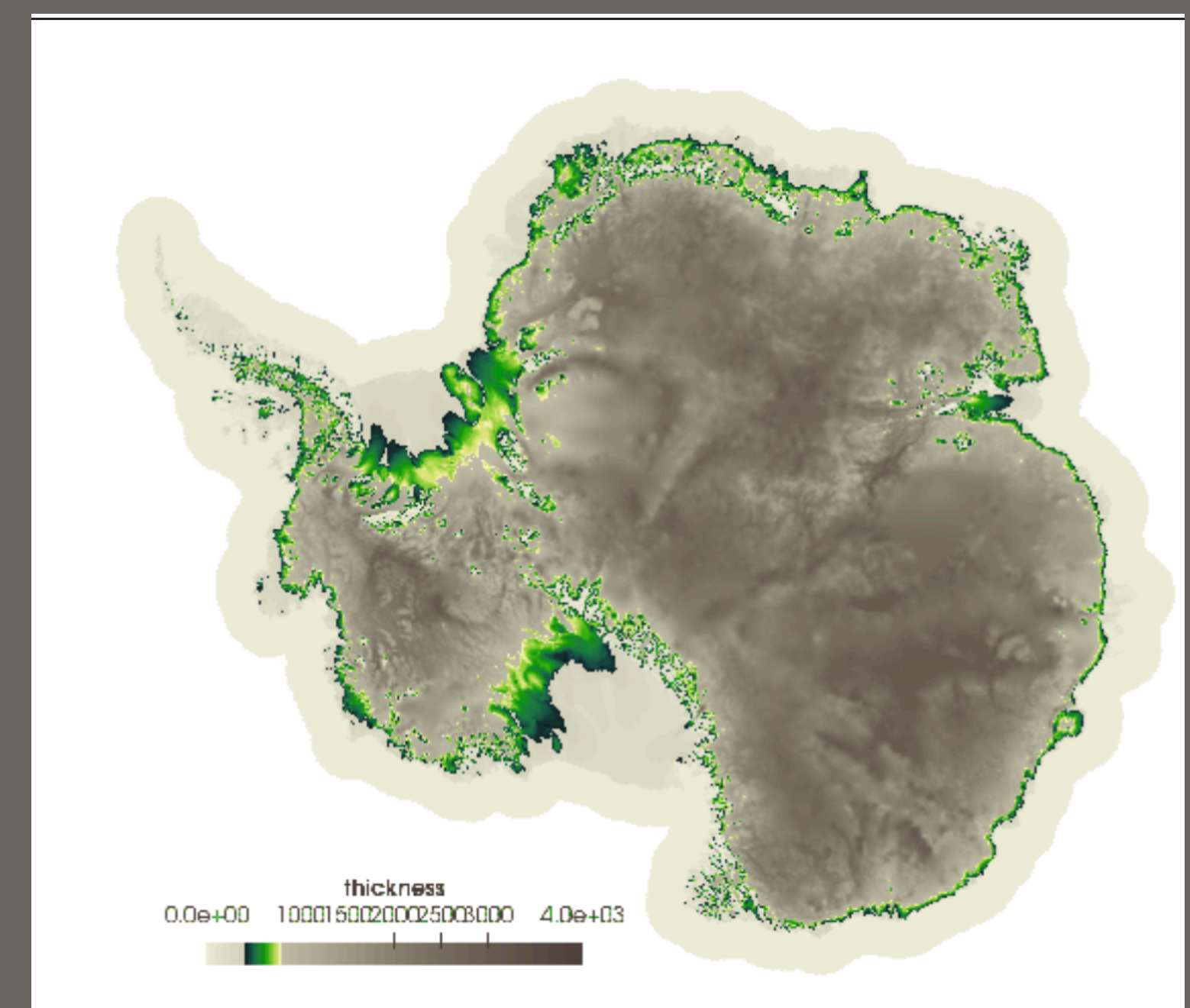
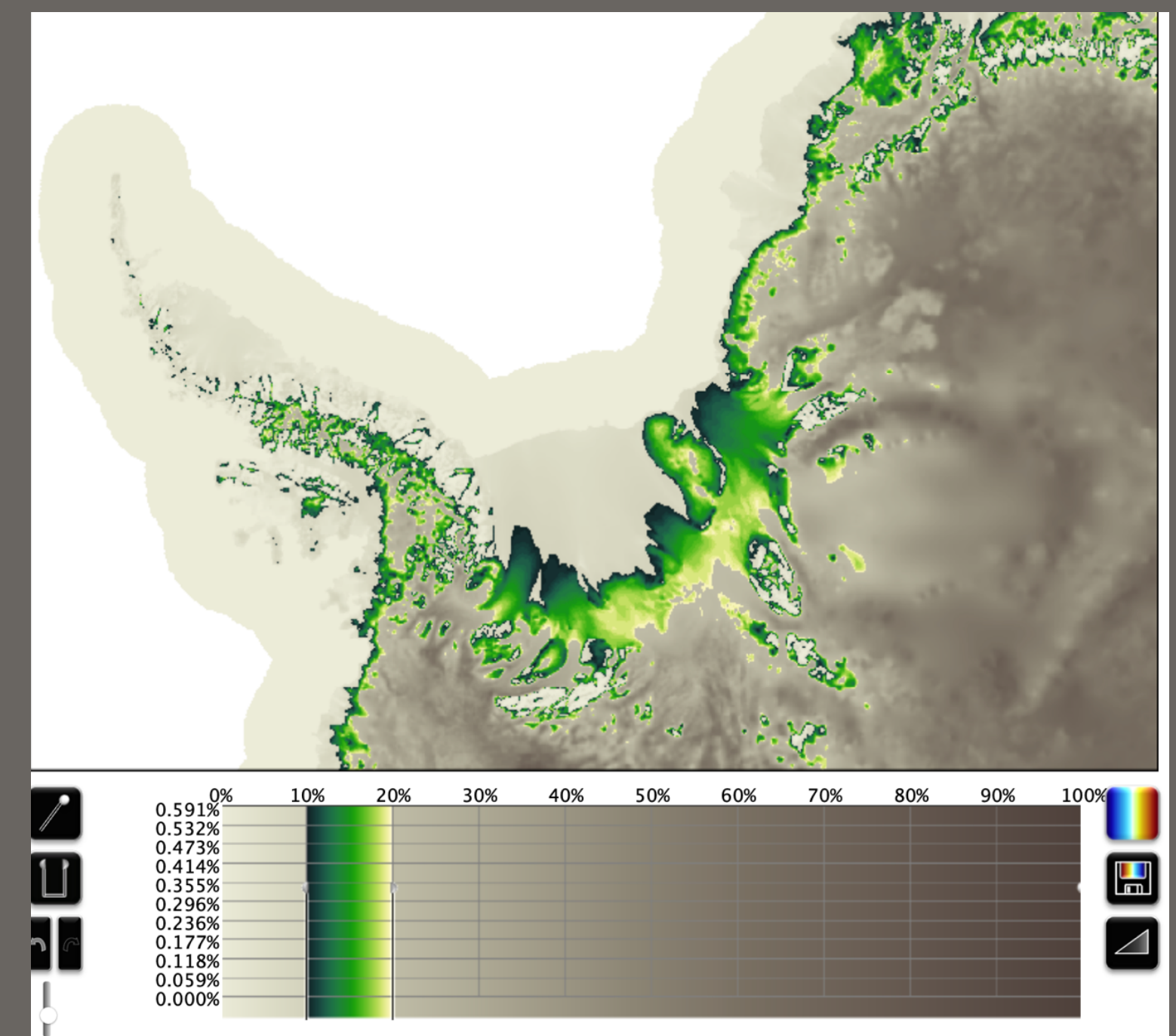
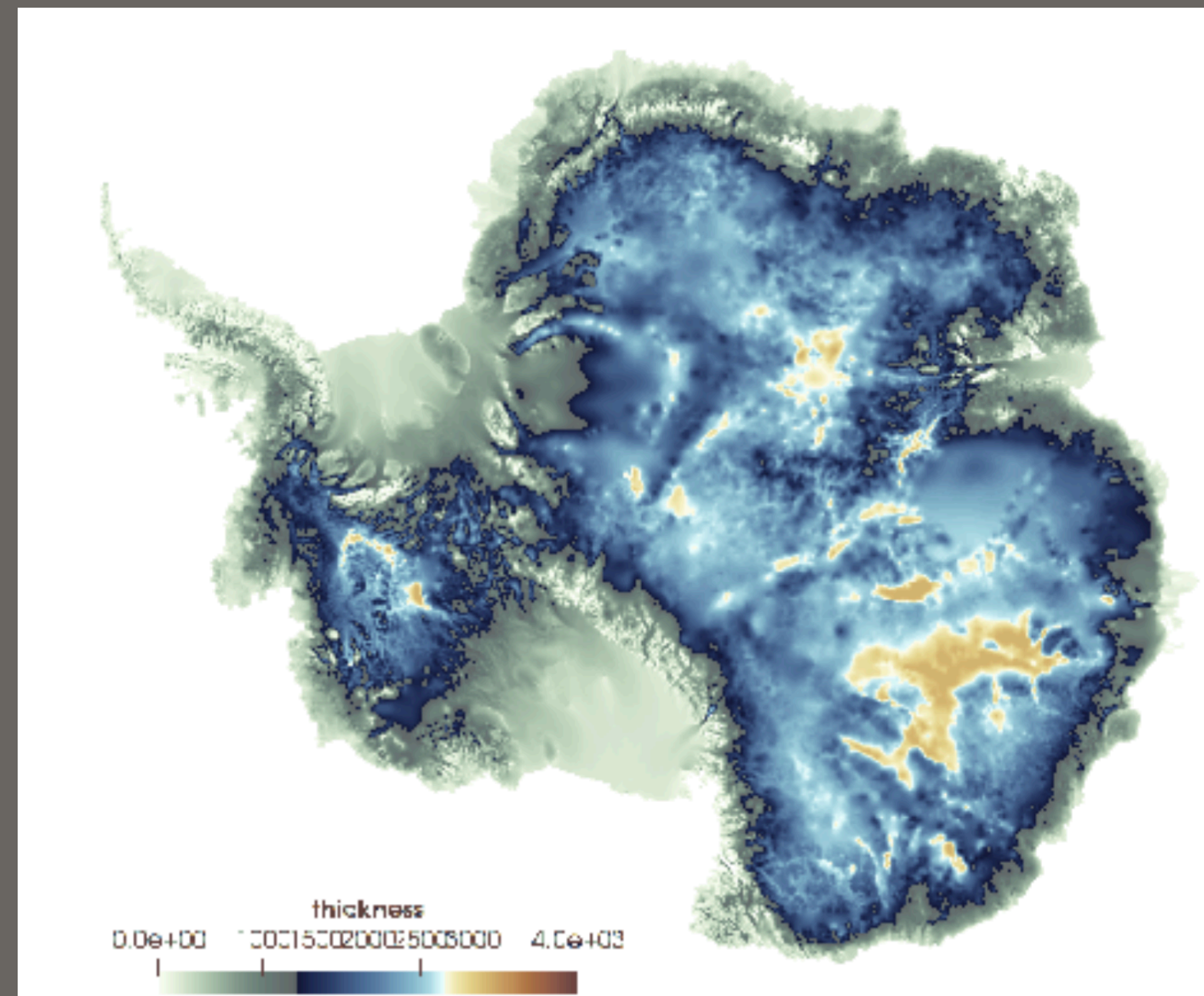
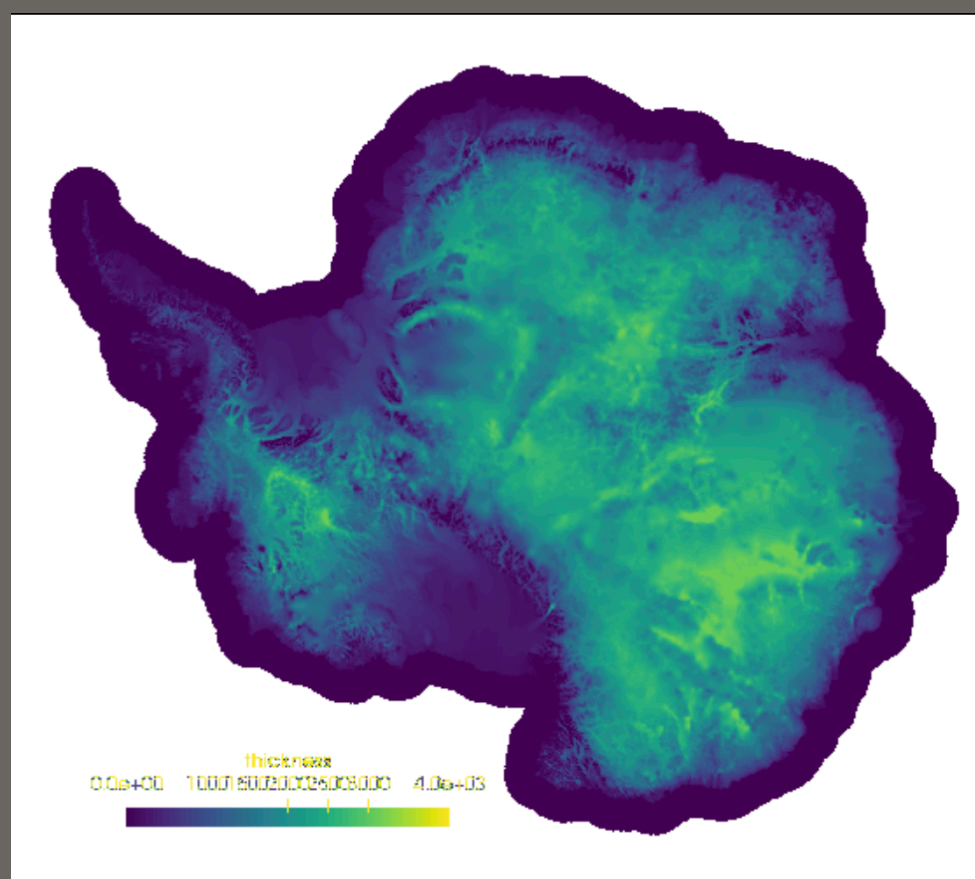
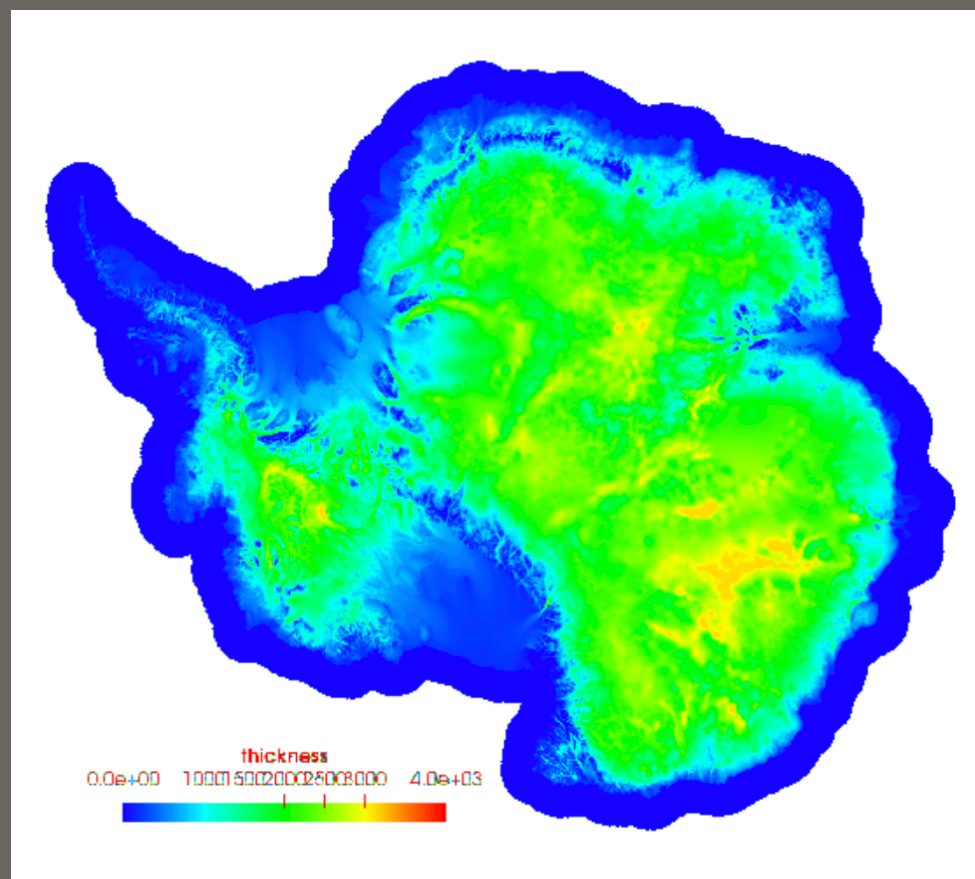
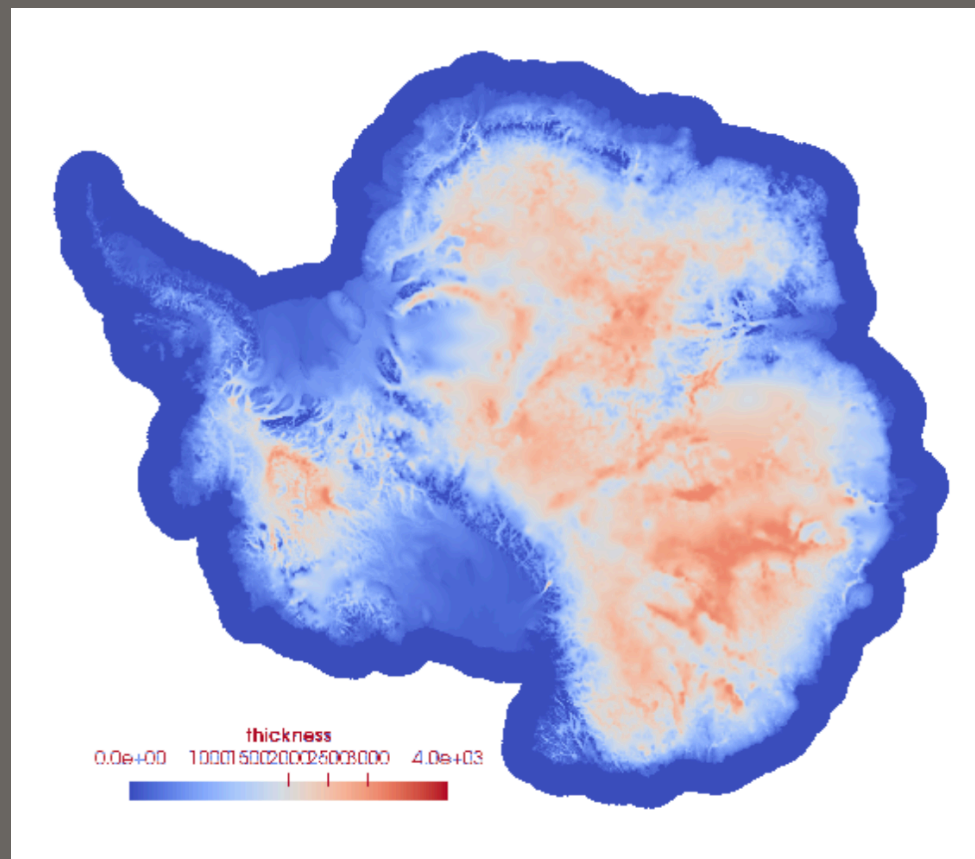
It is about **contrast**, not **color**.

The key is to understand
the types of contrast and
allocate the intensity of contrast.

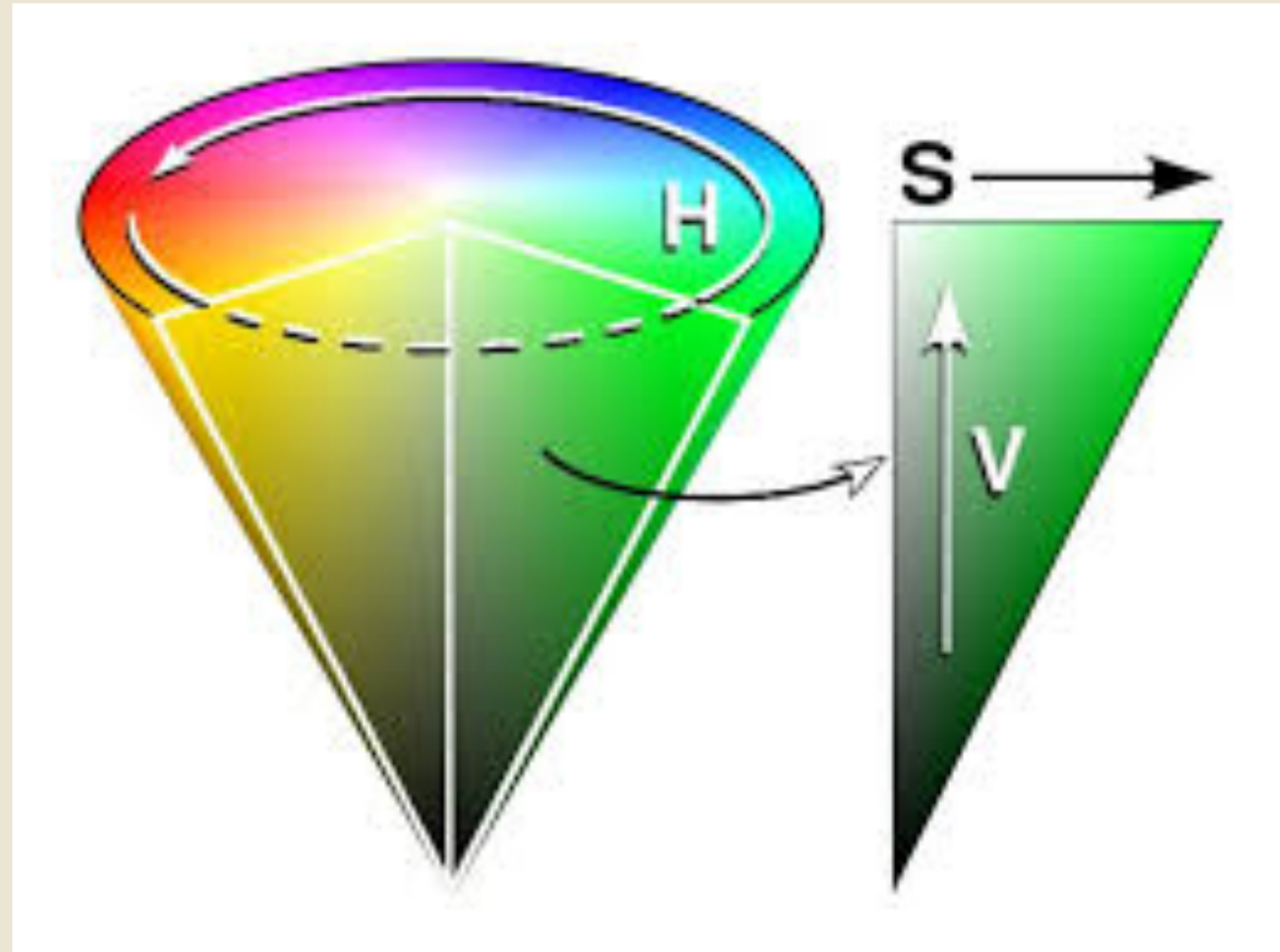


One size does not fit all.

Aligning the colormap
selection with the
data and the task.



Hue, Saturation and Value the human color space

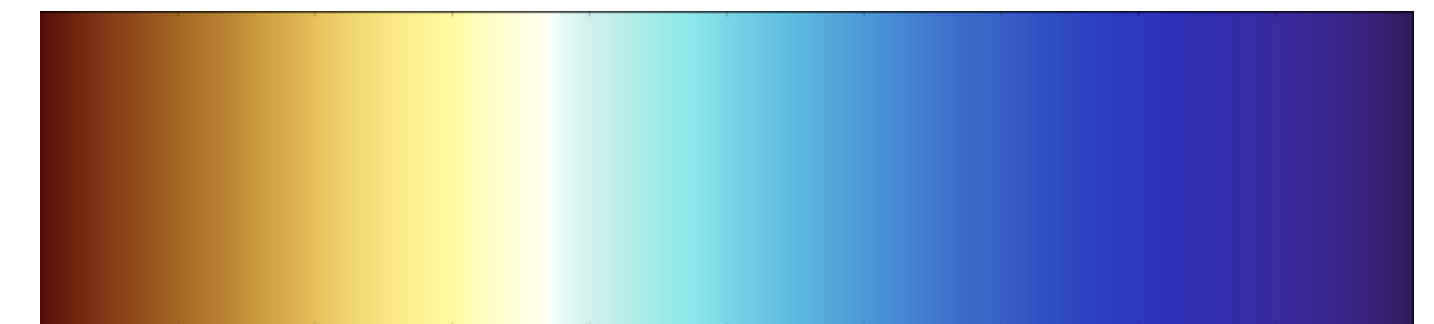
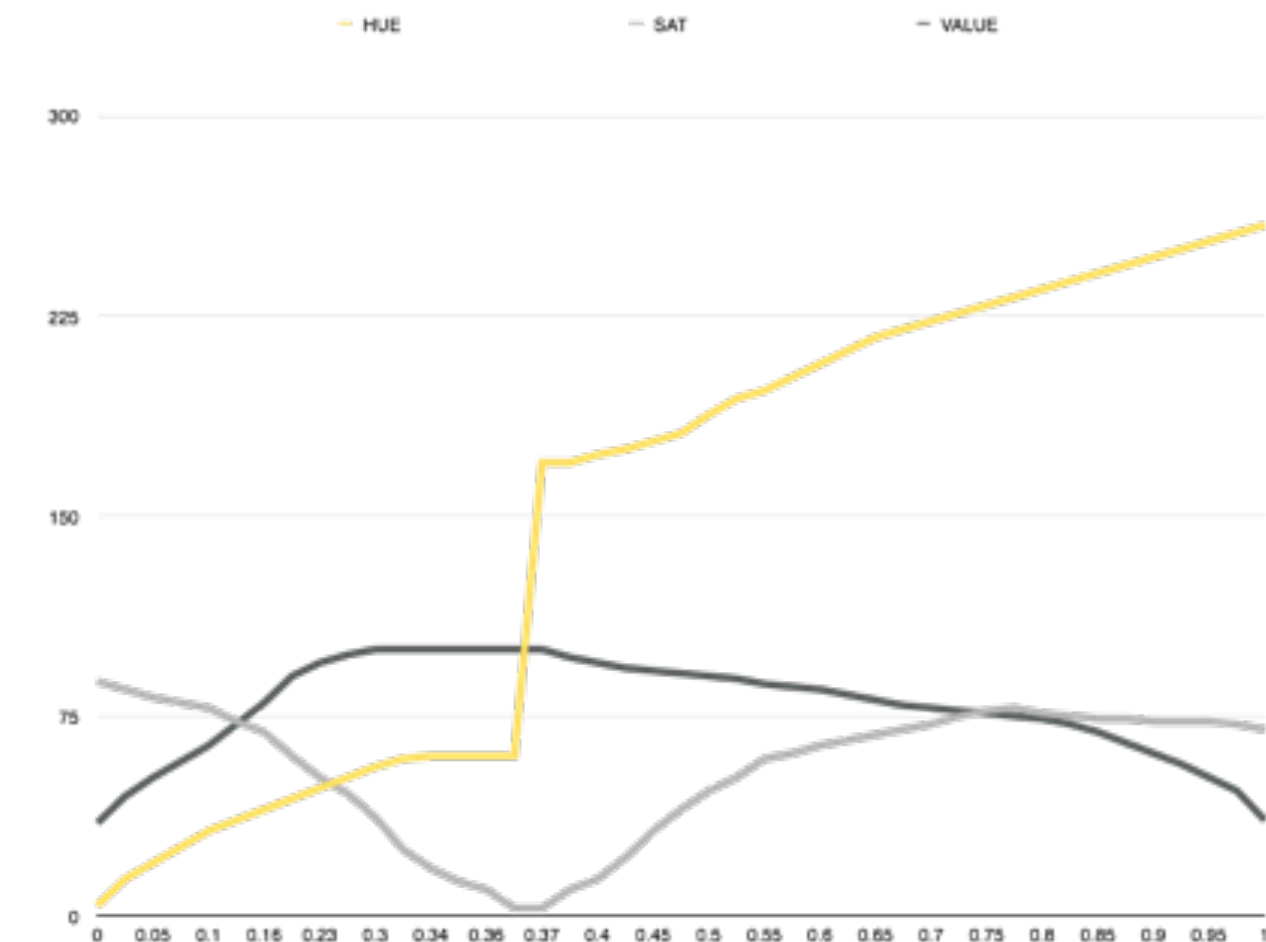


HSV, HSB colorspace

Hue, Saturation and Value --
The language of color theory.
The human context for color.

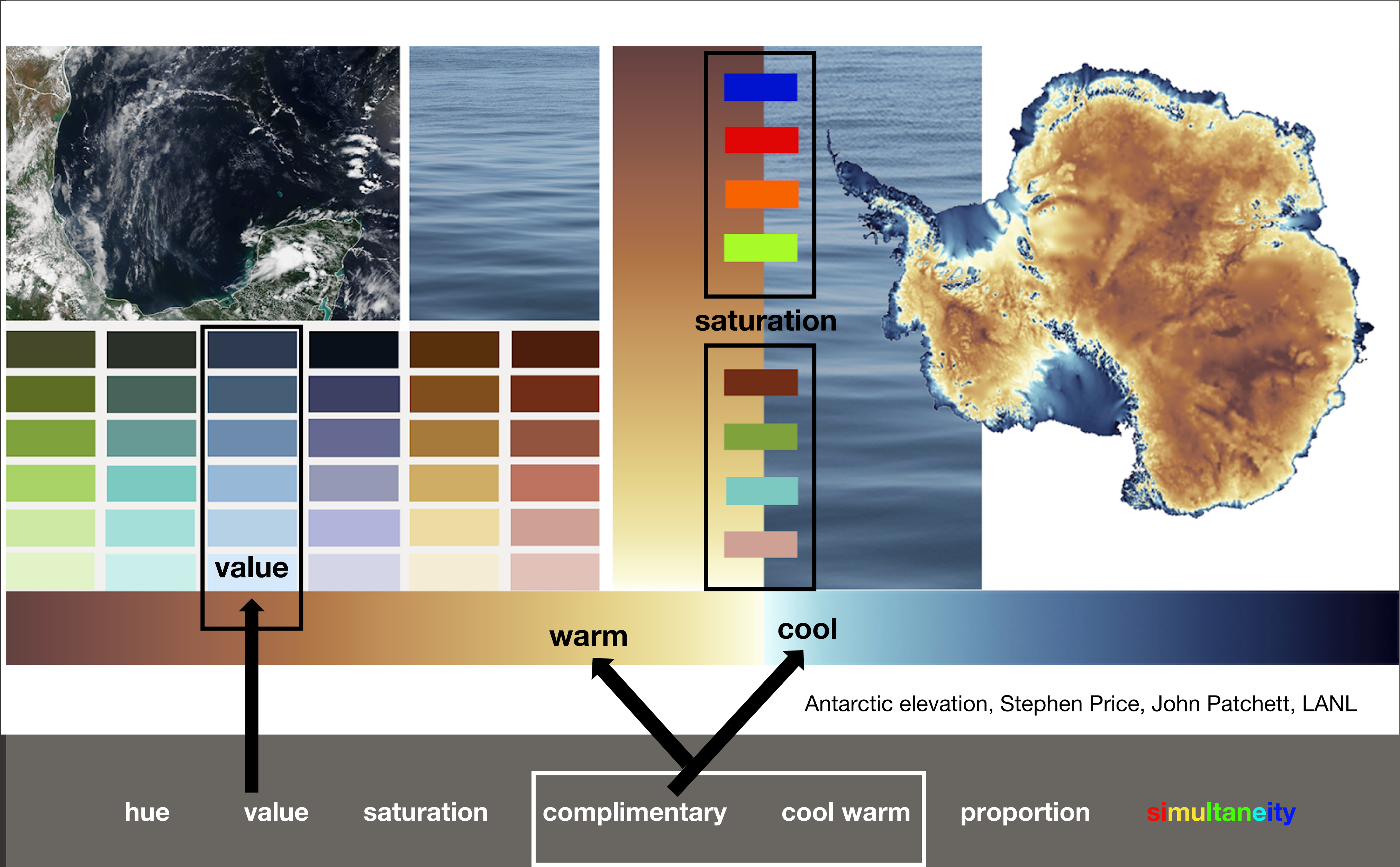
Table 1

	HUE	SAT	VALUE
0	4	88	35
0.025	14	85	45
0.05	20	82	52
0.075	26	80	58
0.1	32	78	64
0.13	36	73	72
0.16	40	69	80
0.2	44	60	90
0.23	48	52	95
0.26	52	46	98
0.3	56	37	100
0.32	59	25	100
0.34	60	18	100
0.35	60	13	100
0.36	60	10	100
0.37	60	3	100
0.37	170	3	100
0.385	170	10	97
0.4	173	14	95
0.425	175	22	93
0.45	178	32	92
0.475	181	40	91
0.5	188	47	90
0.525	194	52	89
0.55	197	59	87
0.575	202	61	86
0.6	207	64	85
0.625	212	66	83
0.65	217	68	81
0.675	220	70	79
0.7	223	72	78
0.725	226	75	77
0.75	229	77	76
0.775	232	78	75
0.8	235	76	74
0.825	238	75	72
0.85	241	74	69
0.875	244	74	65
0.9	247	73	61
0.925	250	73	57
0.95	253	73	52
0.975	256	72	47
1	259	70	36



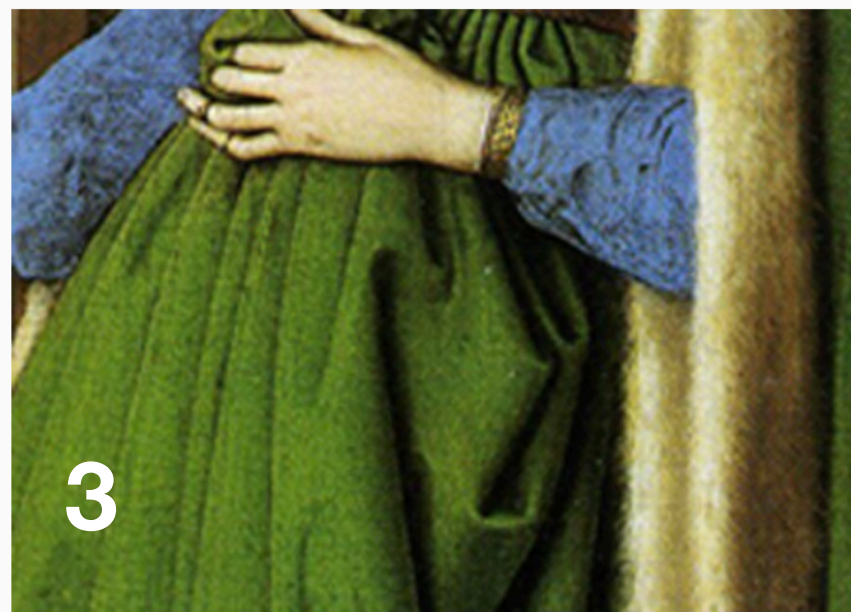
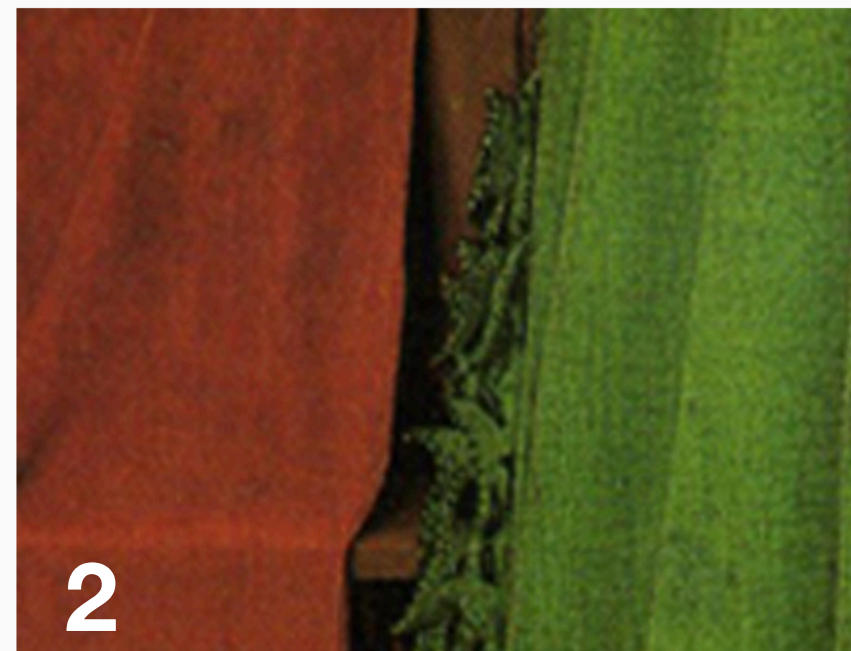
Types of
color contrast

- 1. hue
- 2. value
- 3. saturation
- 4. complimentary
- 5. cool warm
- 6. proportion
- 7. **simultaneity**





The Arnolfini Wedding Portrait
Van Eyck, 1491



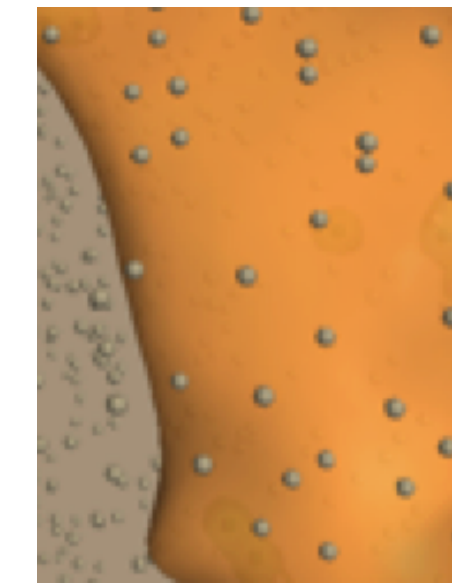
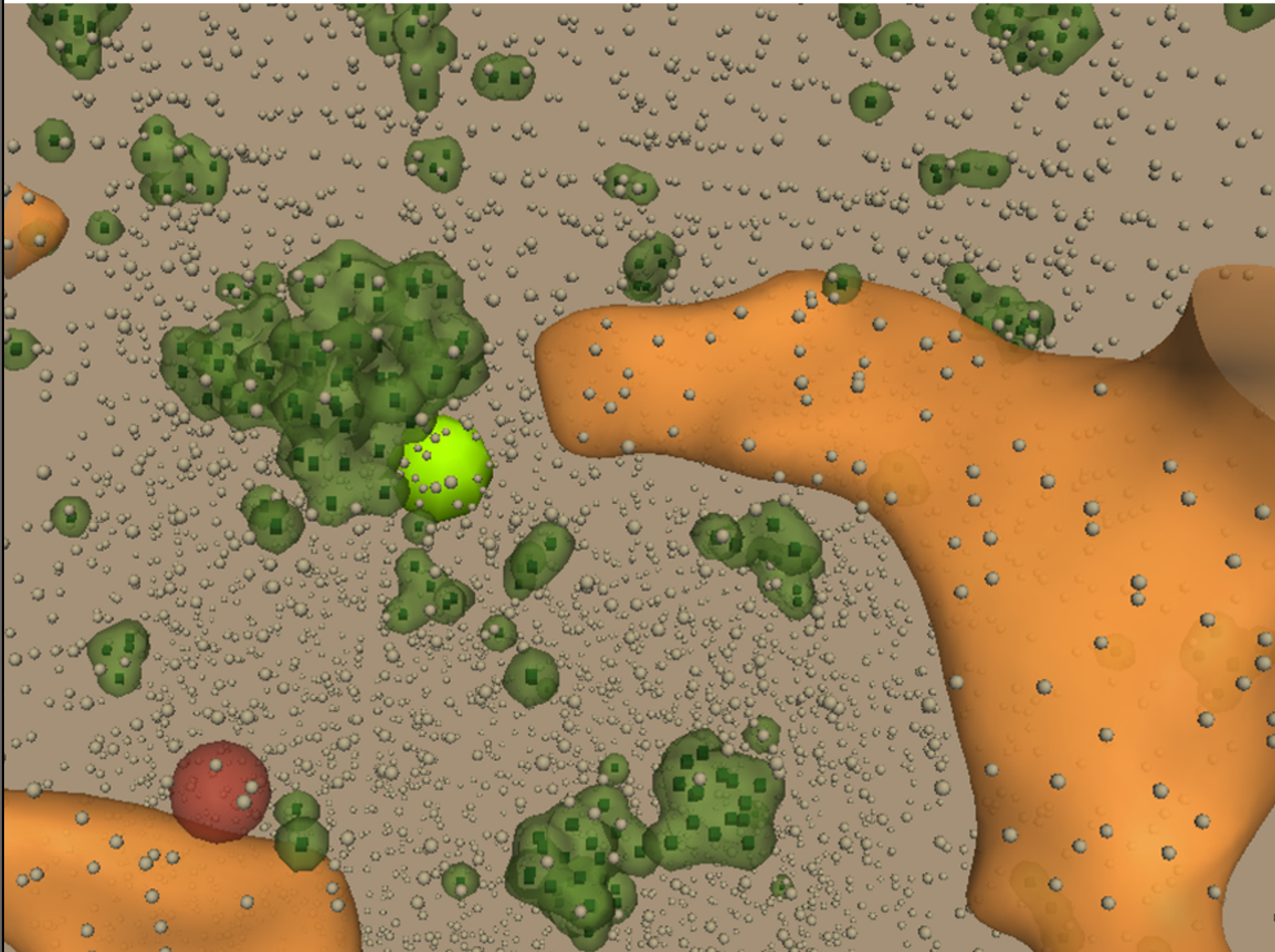
1. Value
2. Complimentary, Cool
Warm
3. Analogous
4. Associative / Semantic

Artists closely the location,
proportion, distribution of hues
and types of contrast to
direct attention
and convey content.

In scientific visualization
the color distribution is
determined by the data.

**This talk is about creating clarity
from the cacophony of data.**

Cool / warm contrast



related

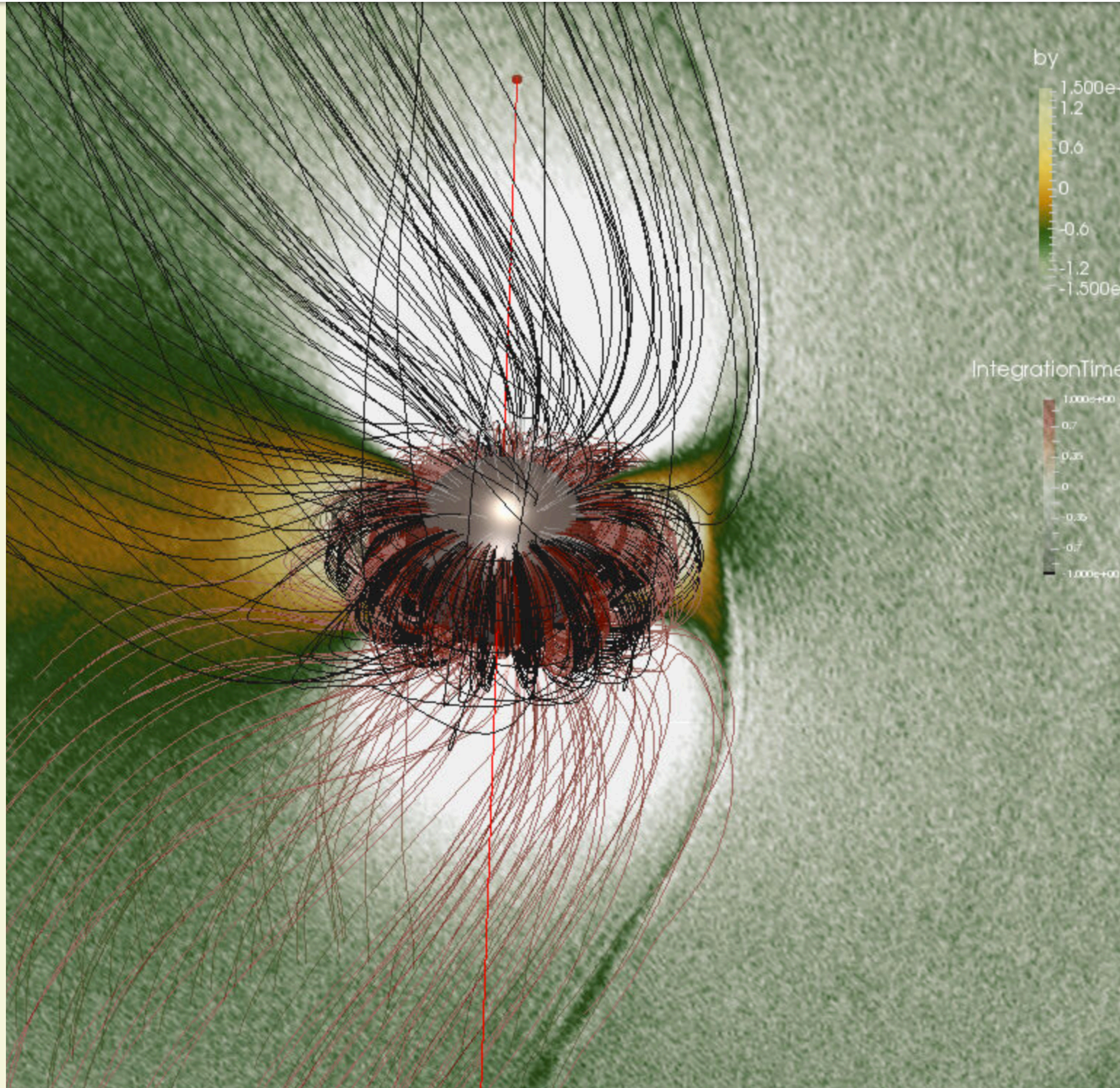


different

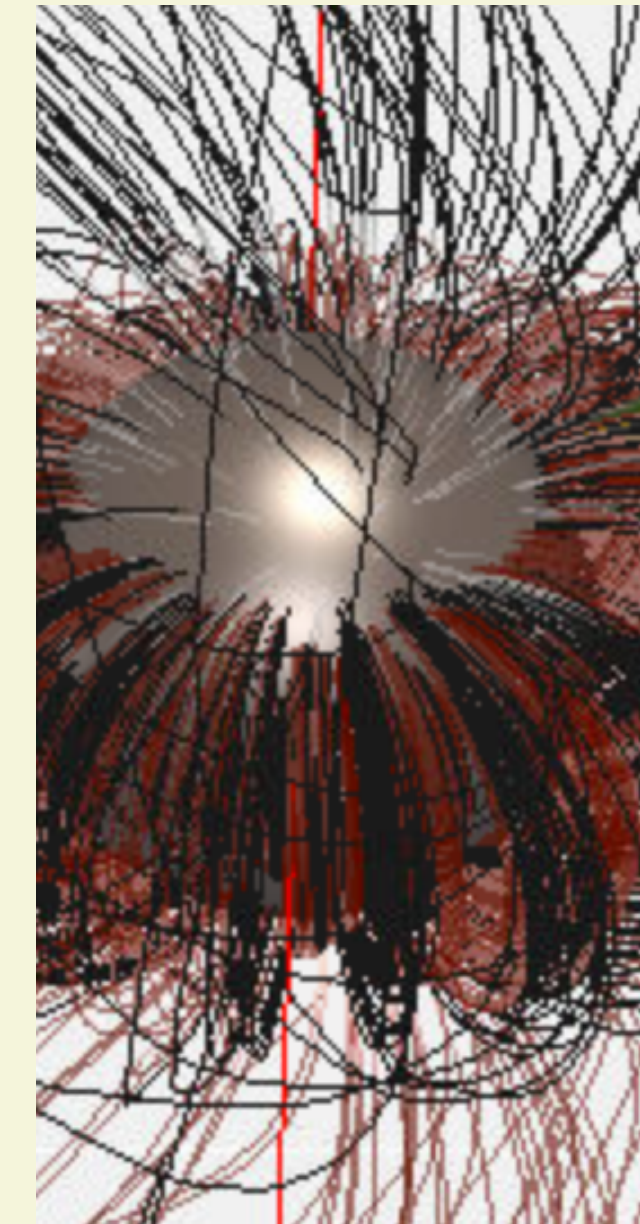


related

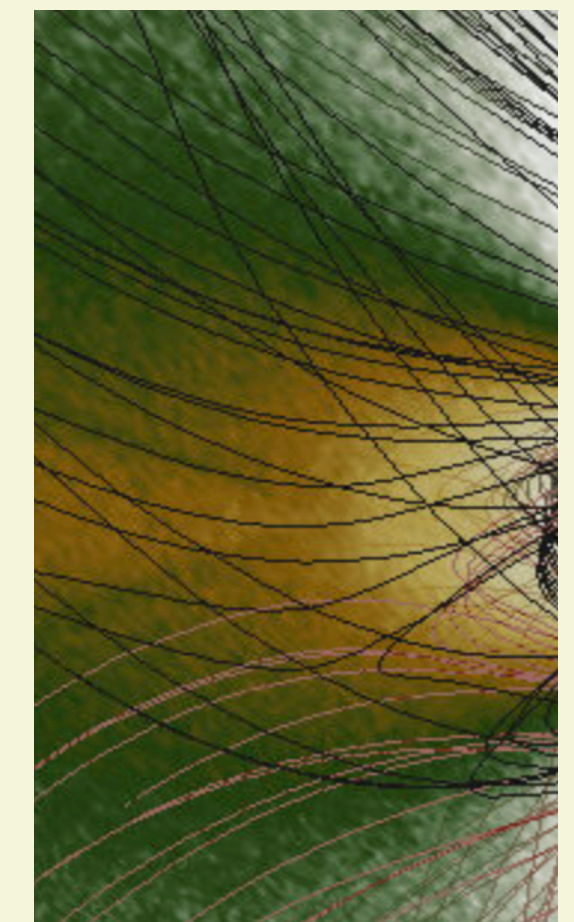
Multiple types of contrast allocated for clarity



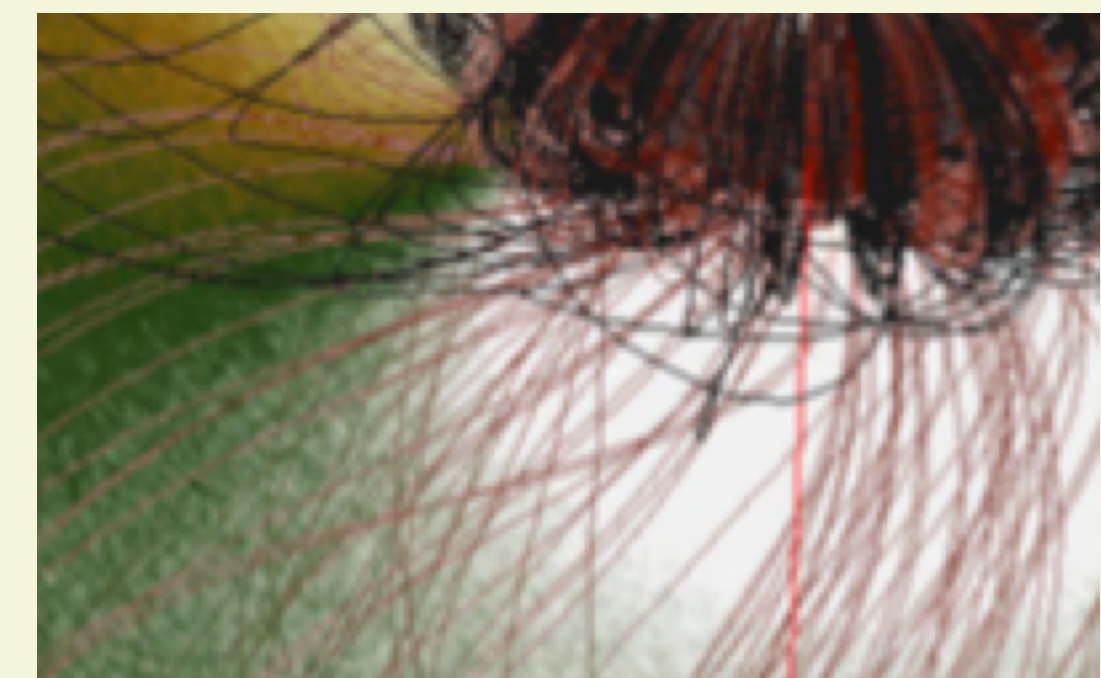
Saturation and value



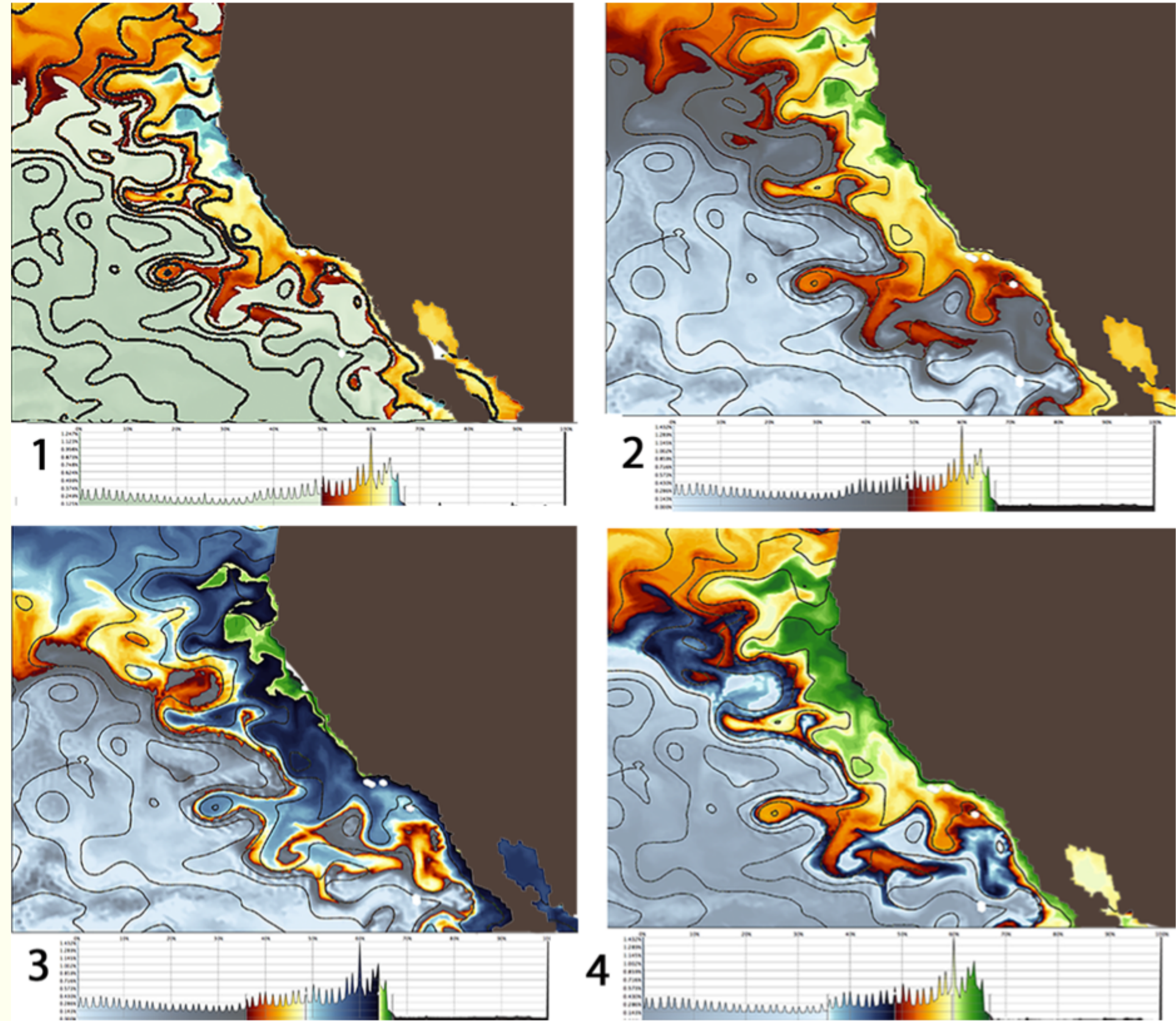
Analogous
color



Complimentary color



Associative Color



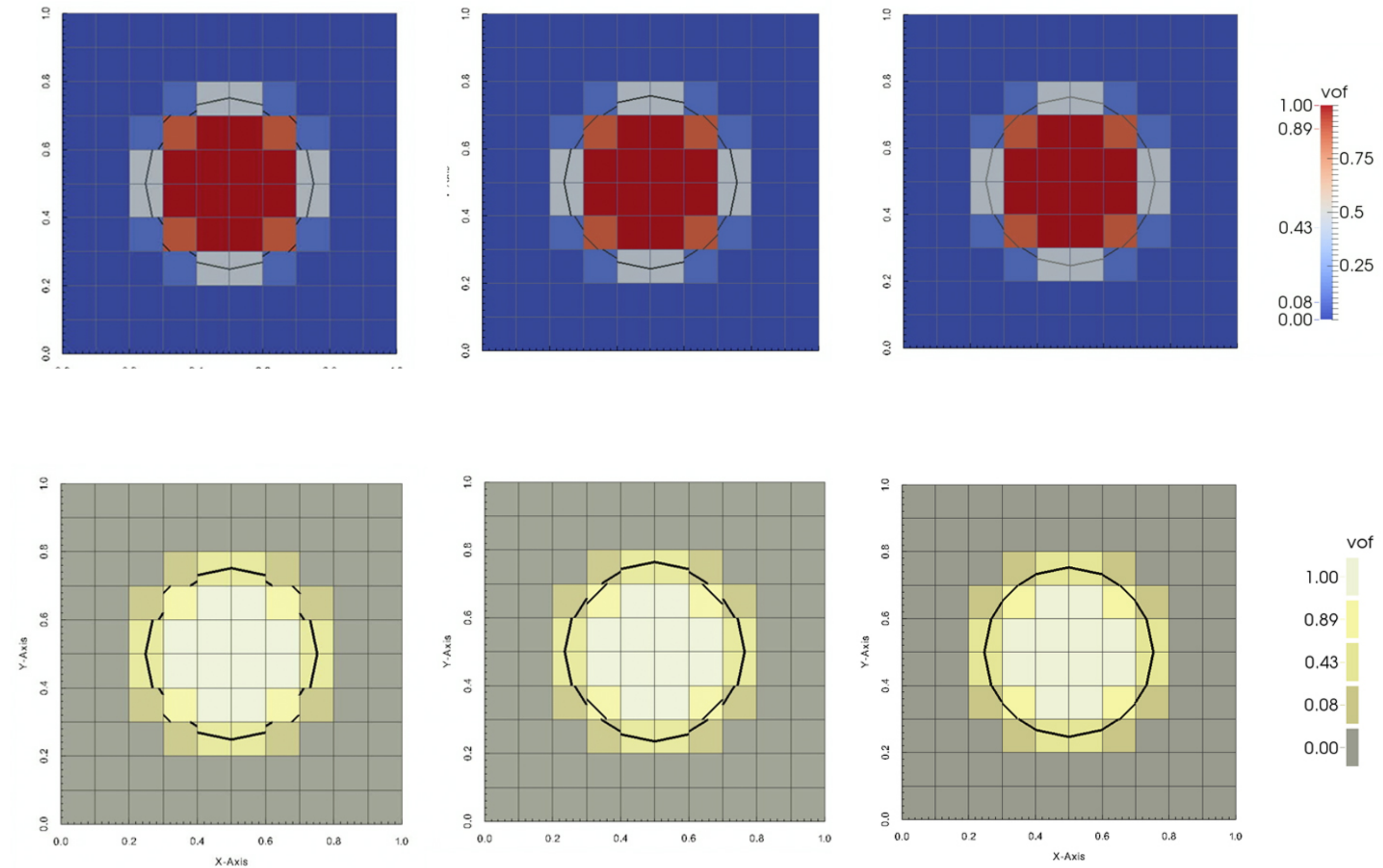
California coast
region of study

Semantic
Color
Association

Three categories:

1. Optimal location for algae growth
2. Algae will not grow
3. Open ocean

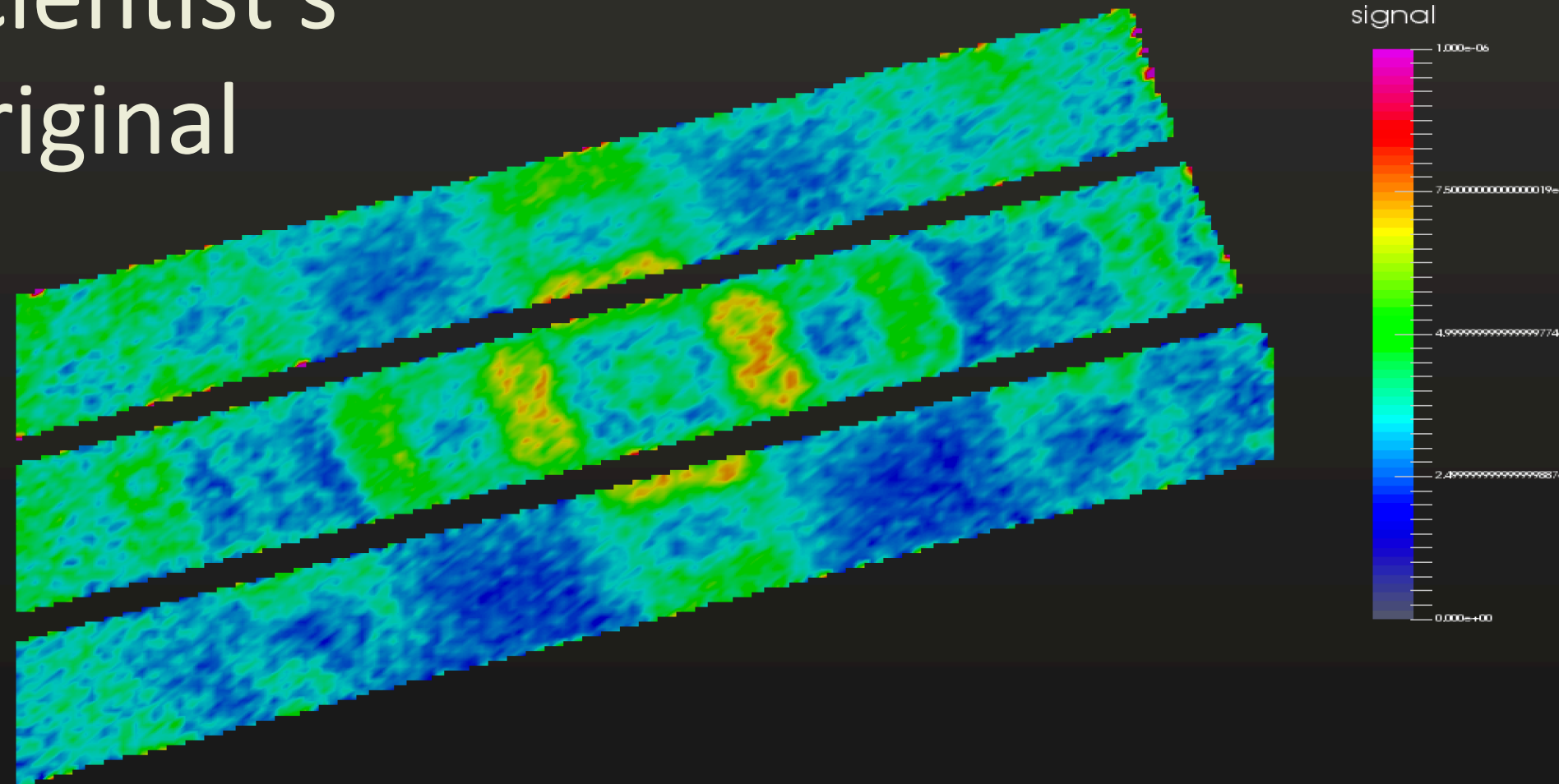
Value Contrast



The important element is the position of the black line and how close it is to a true circle.
The second most important is the position of line within the light blue, light red and light yellow squares

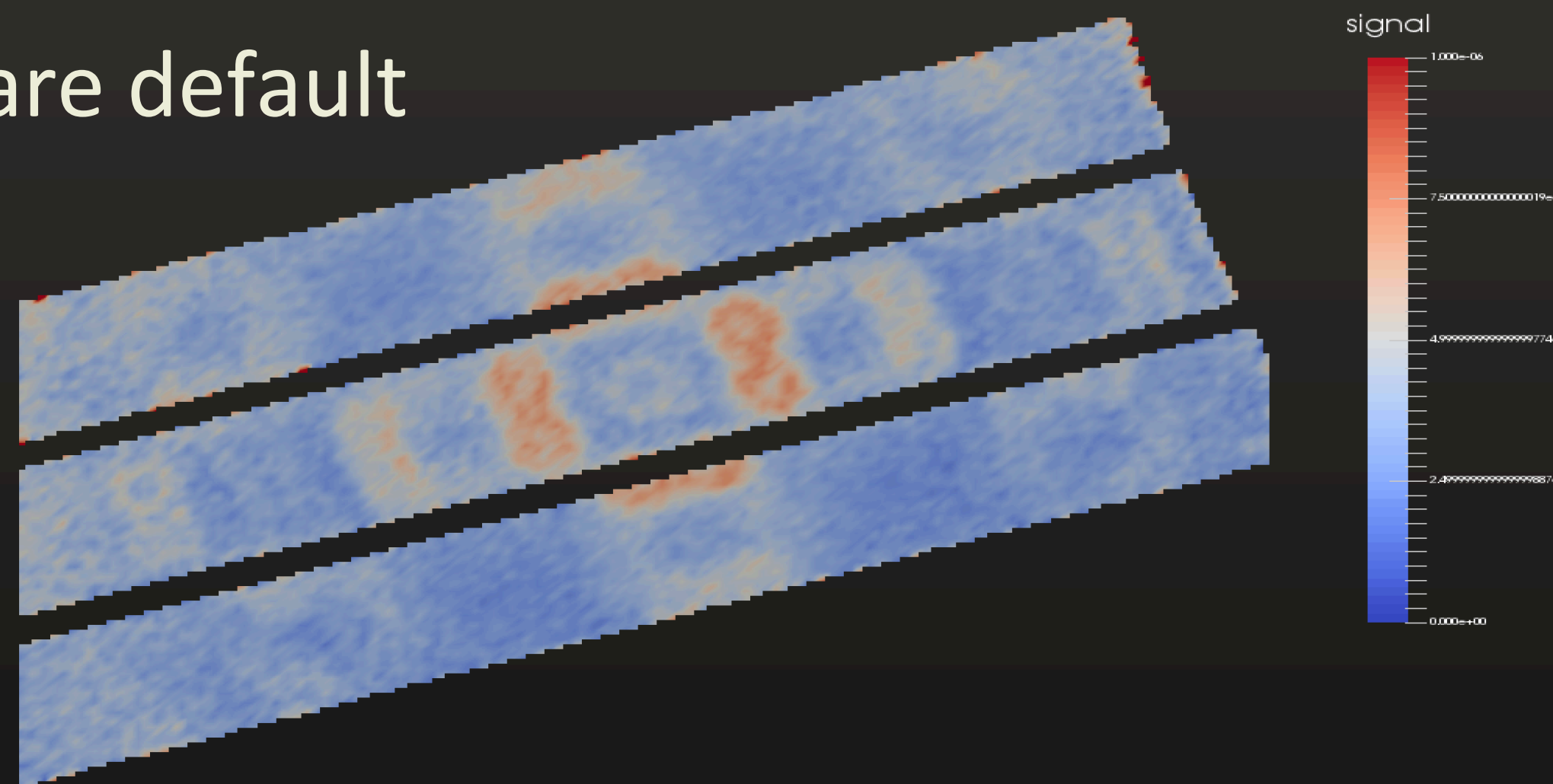
Place the contrast where you need it,
using only as much as you need.

scientist's
original

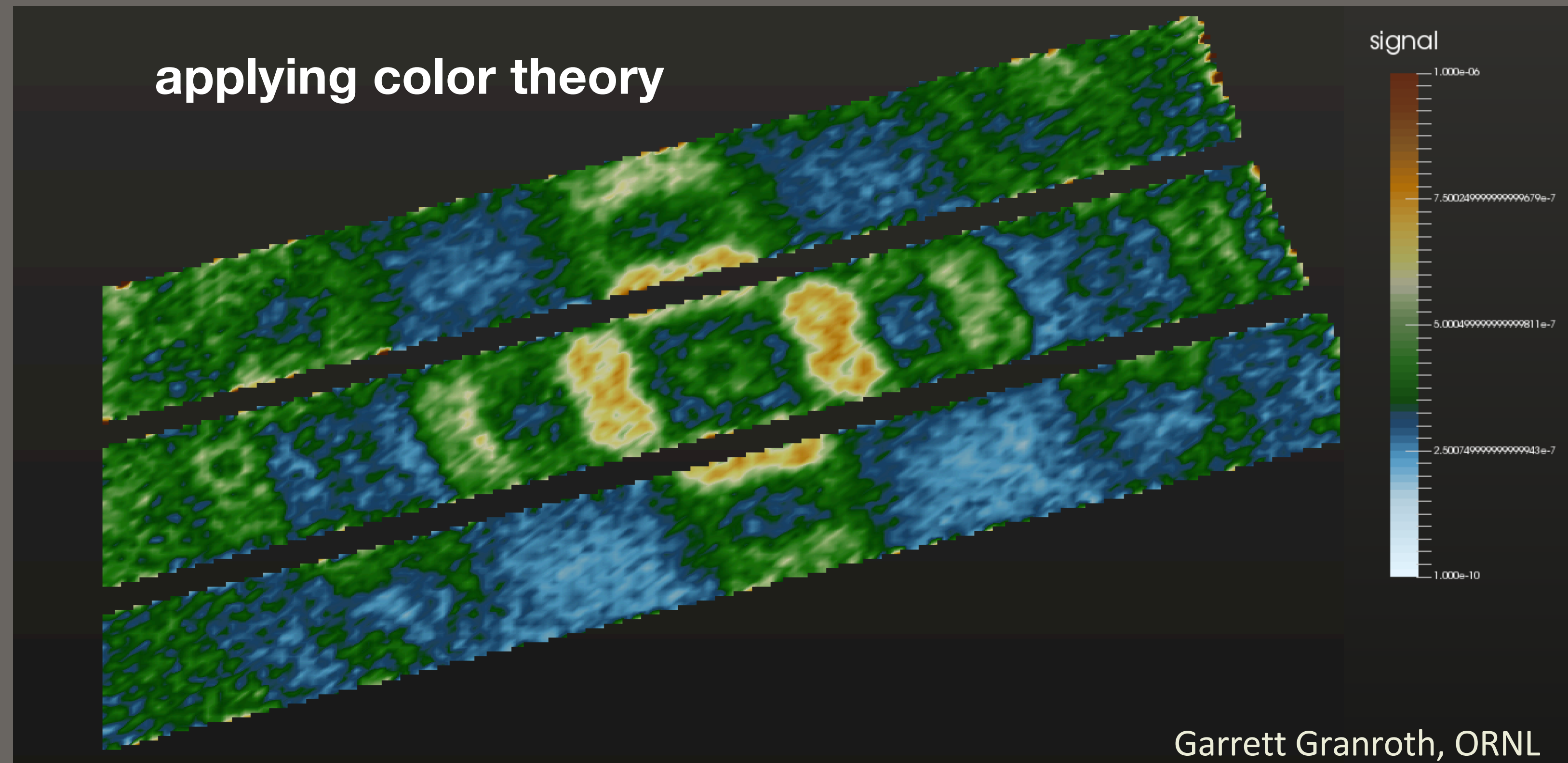
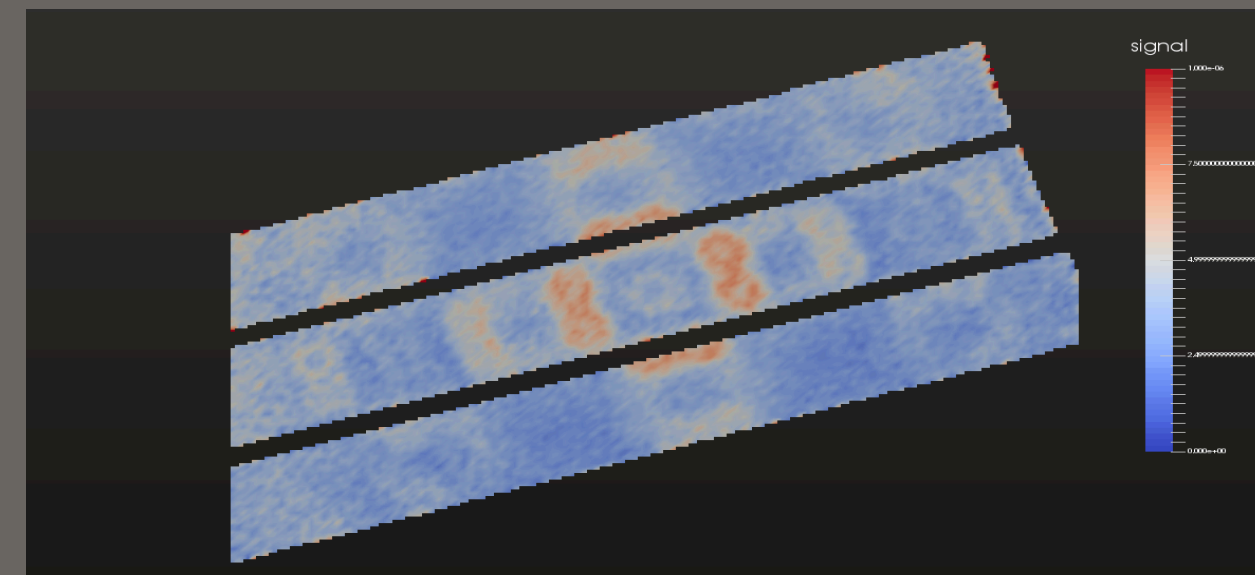
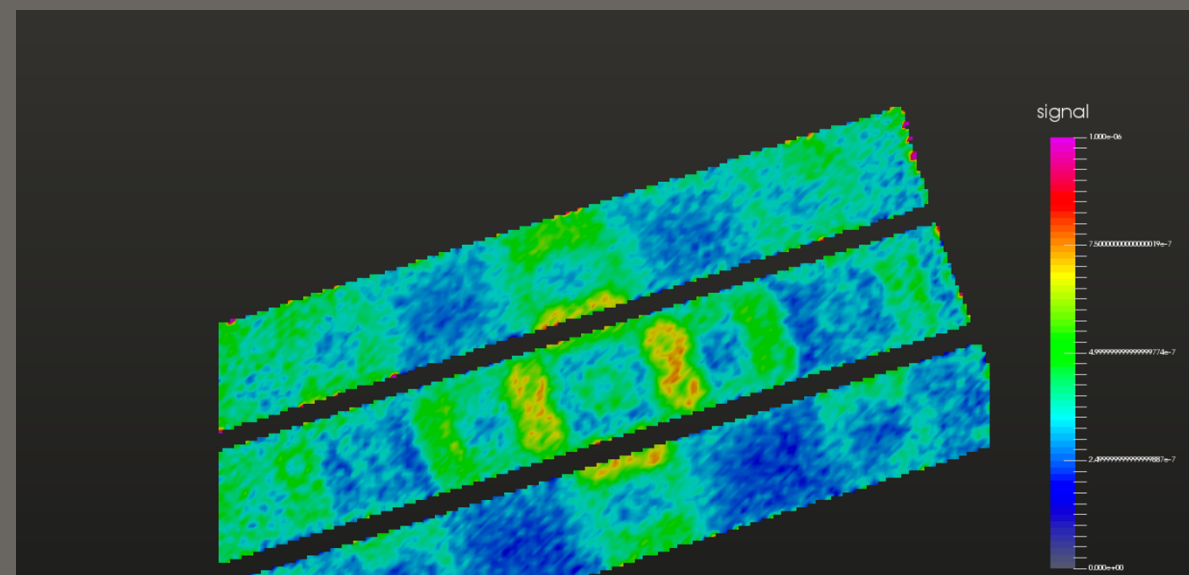


moving beyond the defaults

software default



Garrett Granroth, ORNL

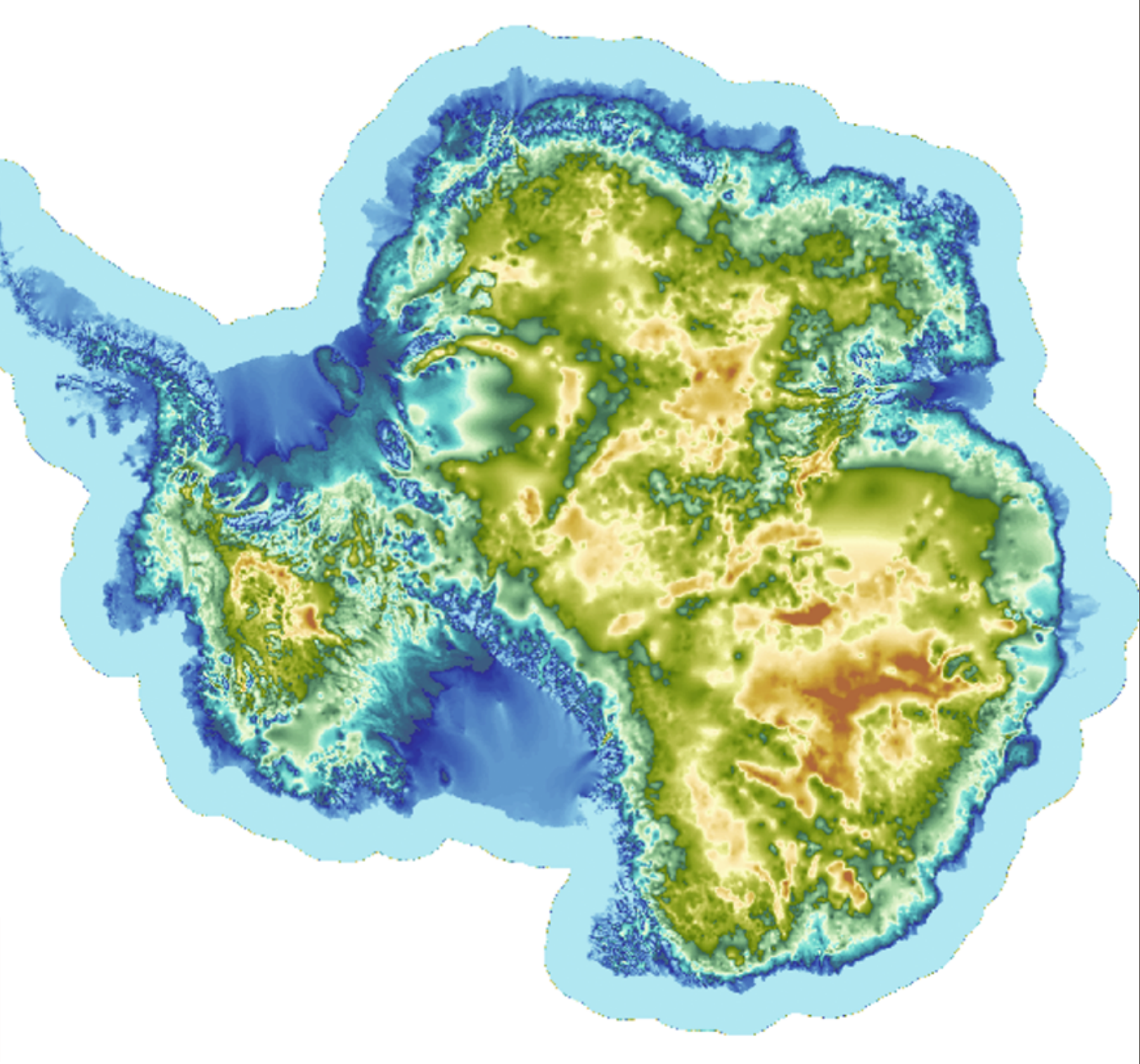


was very happy.

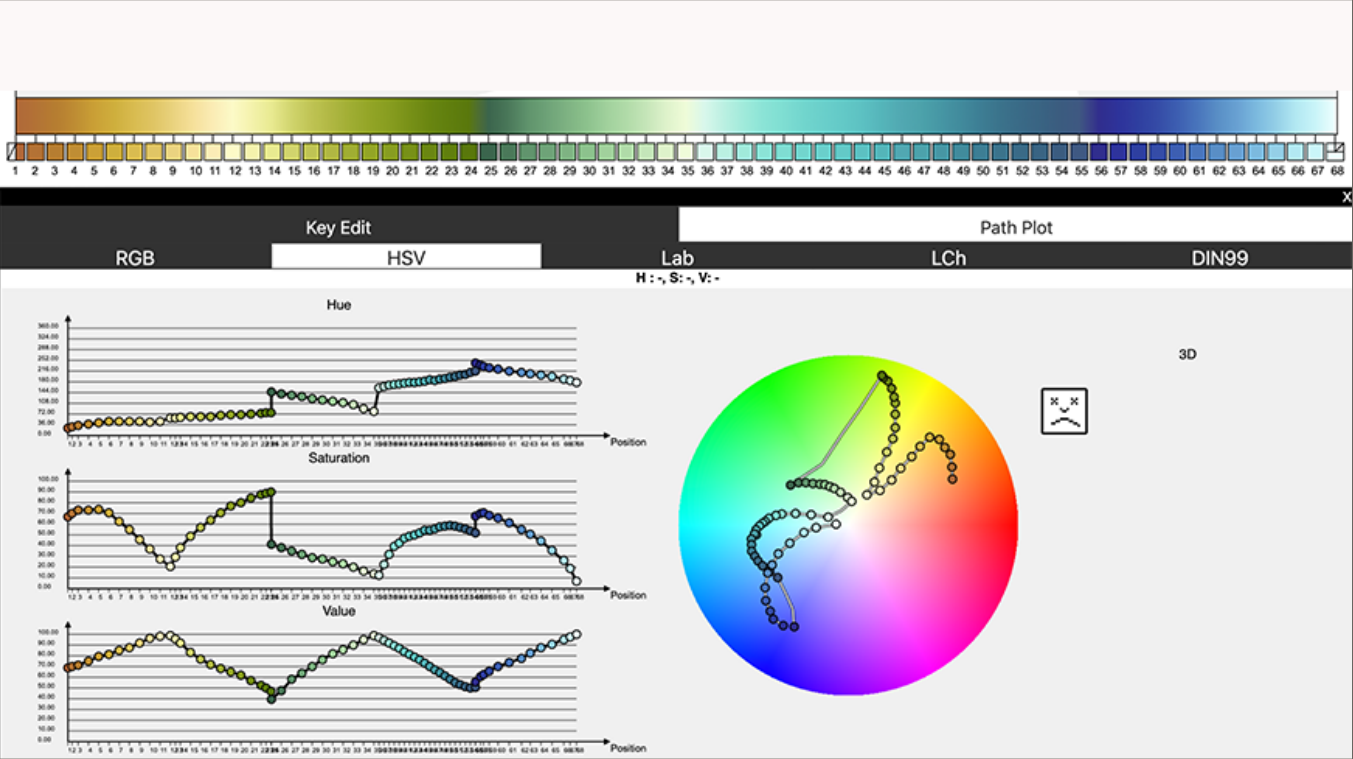
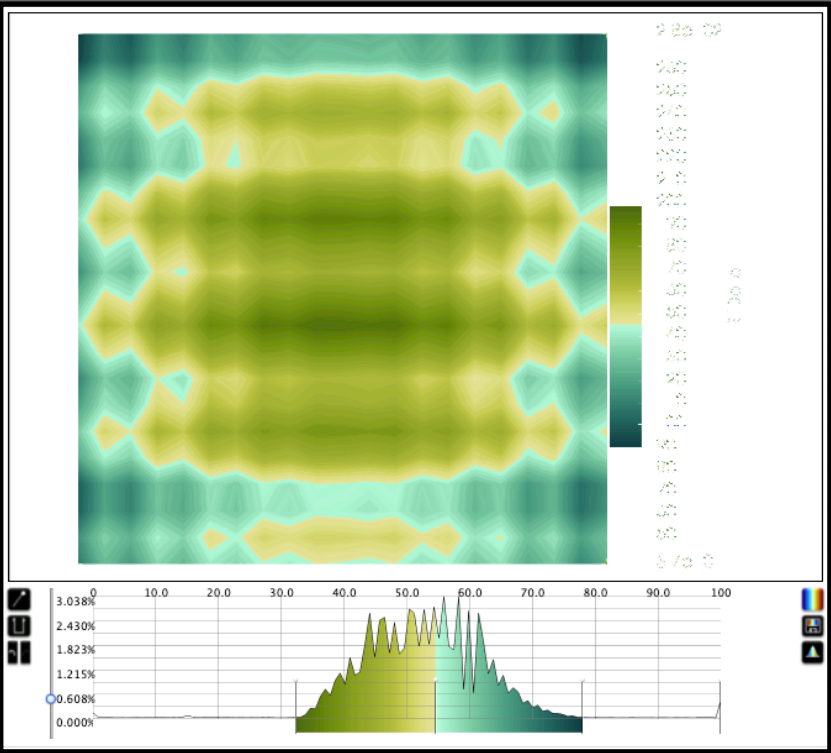
Analogous palettes for noisy data

Employing the full power of color by allocating contrast

Hue contrast
Value contrast
Analogous contrast

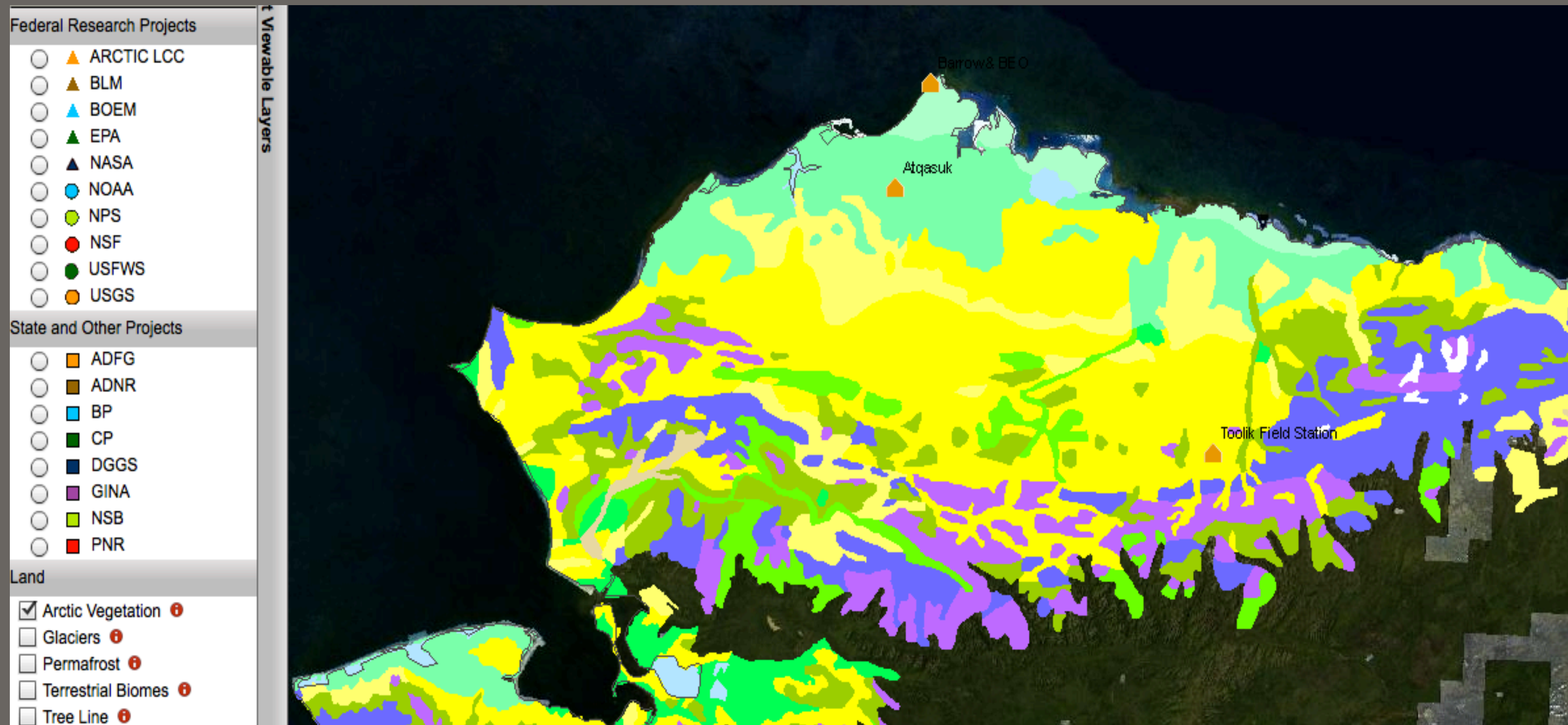


Nature trained us to see subtle differences!

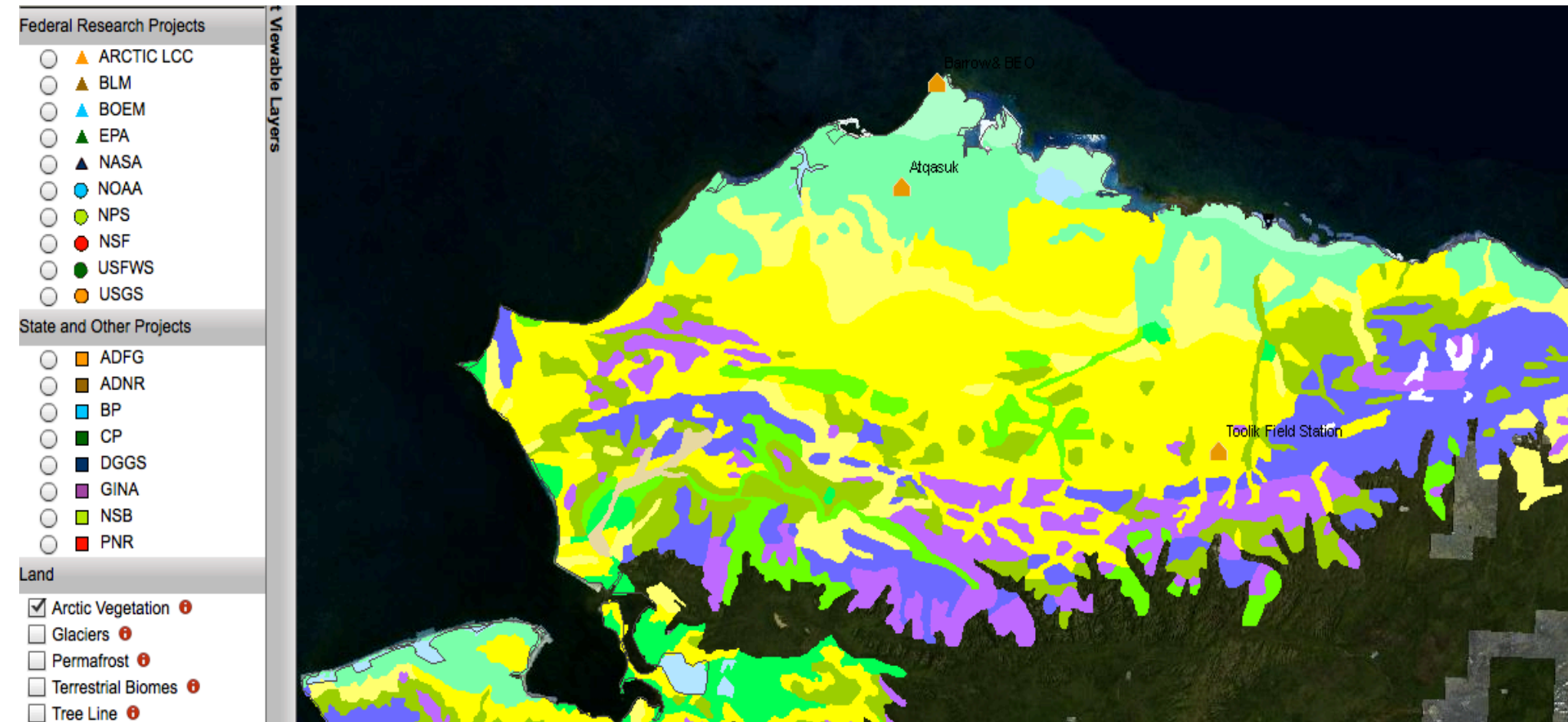


Simultaneity

full saturation to gain contrast..... not always your best option



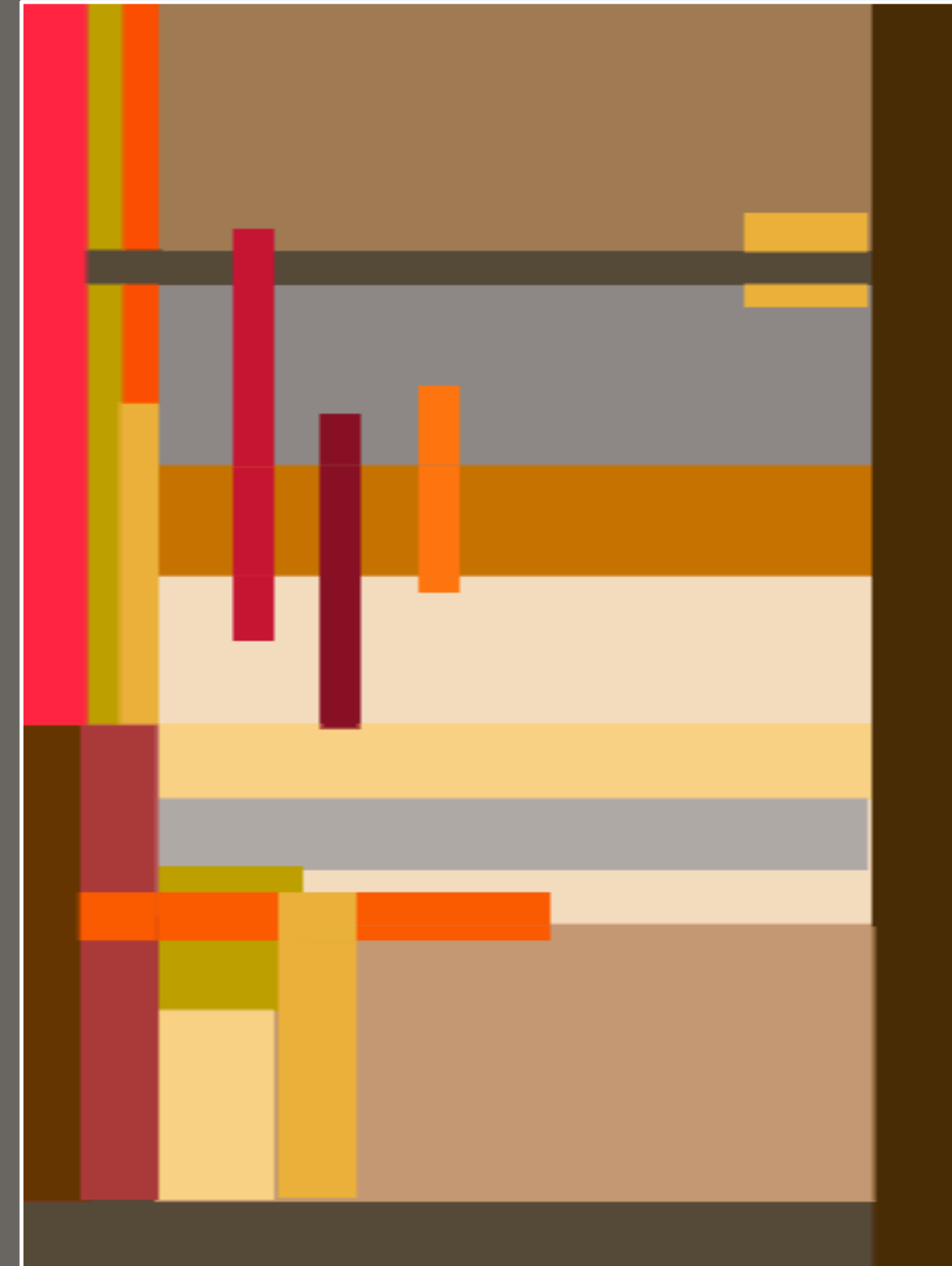
Tundra vegetation, northern Alaska, UTEP



Decor choice #1?



Contrast
providing clarity
without cacophony.



Creating an environment for contemplation

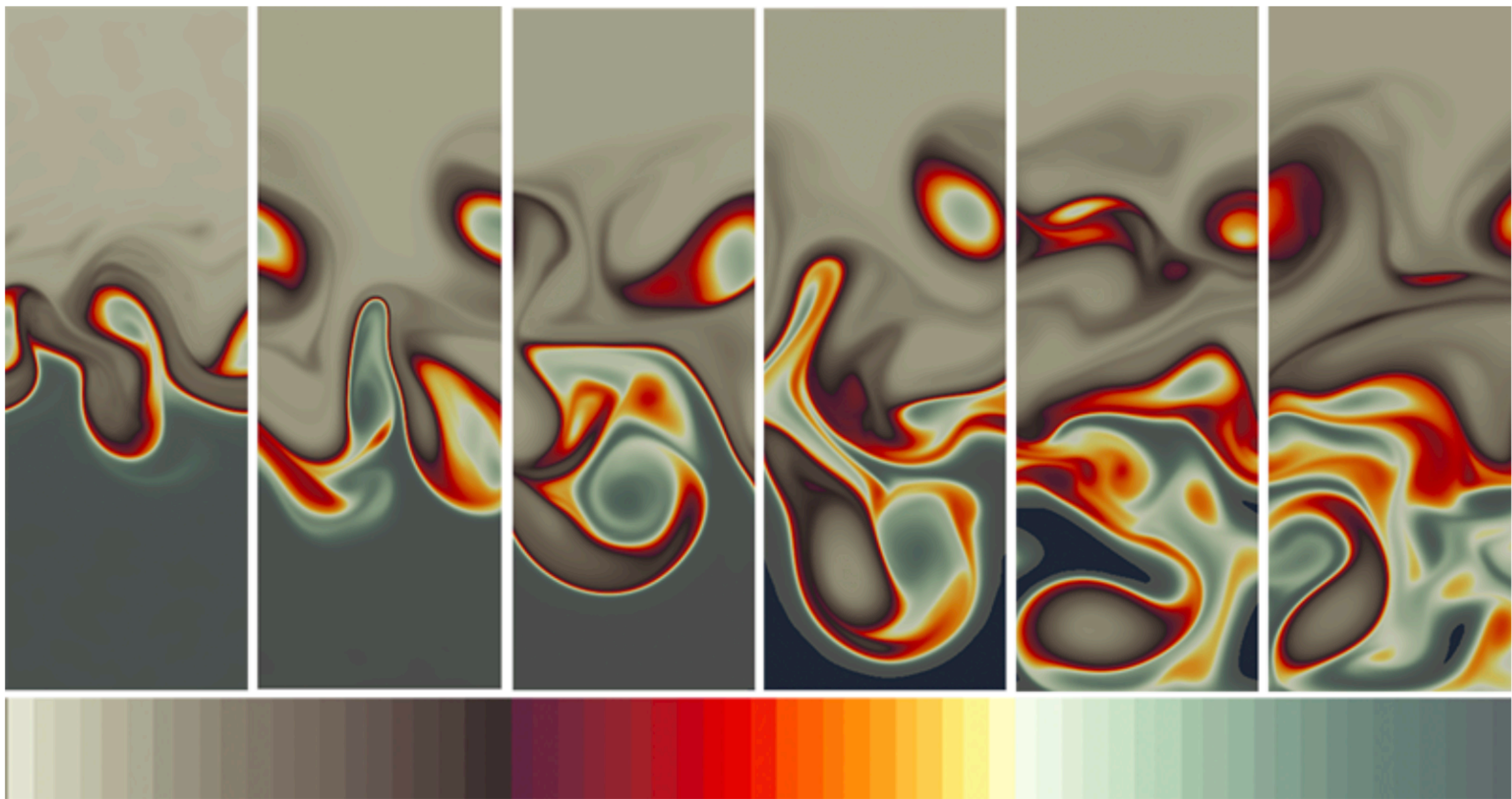
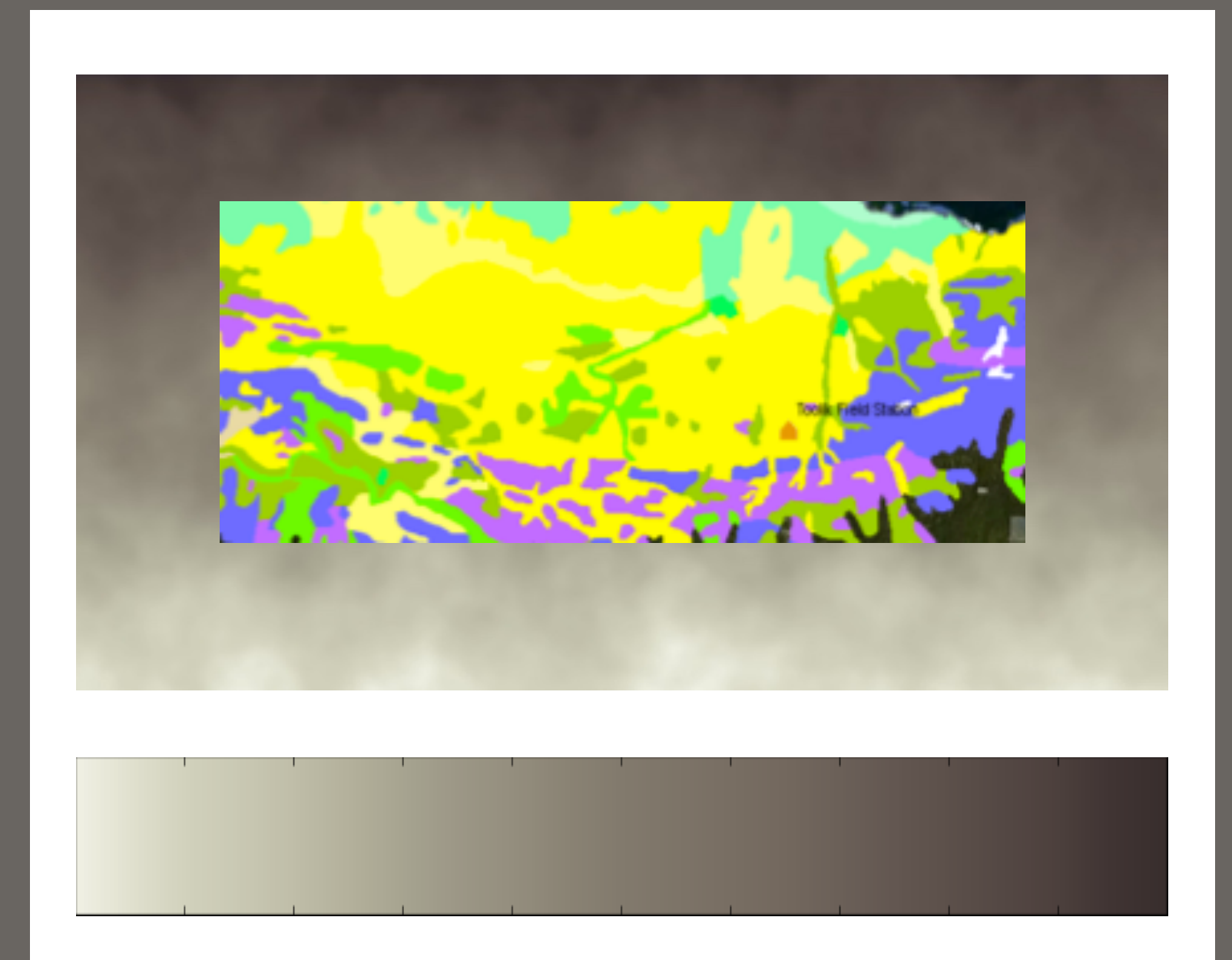


Fig. 4. In a “wave” colormap like this one created by Francesca Samsel, selective saturation is used to isolate and “foreground” specific data ranges so these data are easier to follow over time. In the colormap, desaturated colors surround a saturated section to focus attention while providing context. Credit: Graphic created by Francesca Samsel with data processed and provided by M. Petersen, LANL, using [MPAS-Ocean](#)

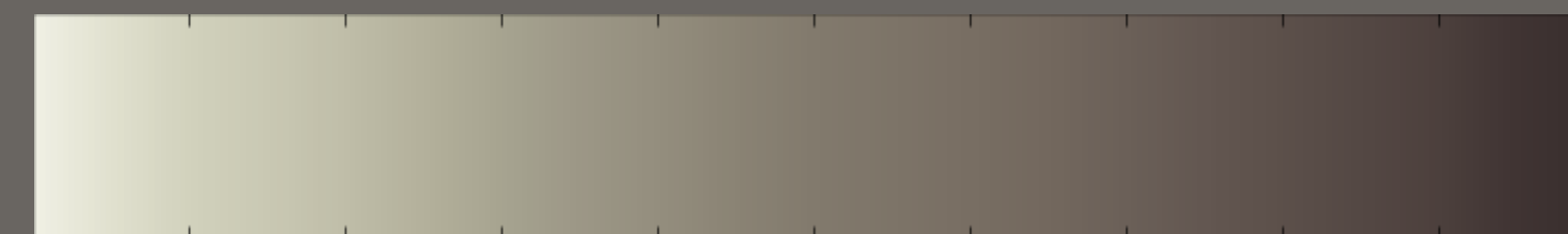
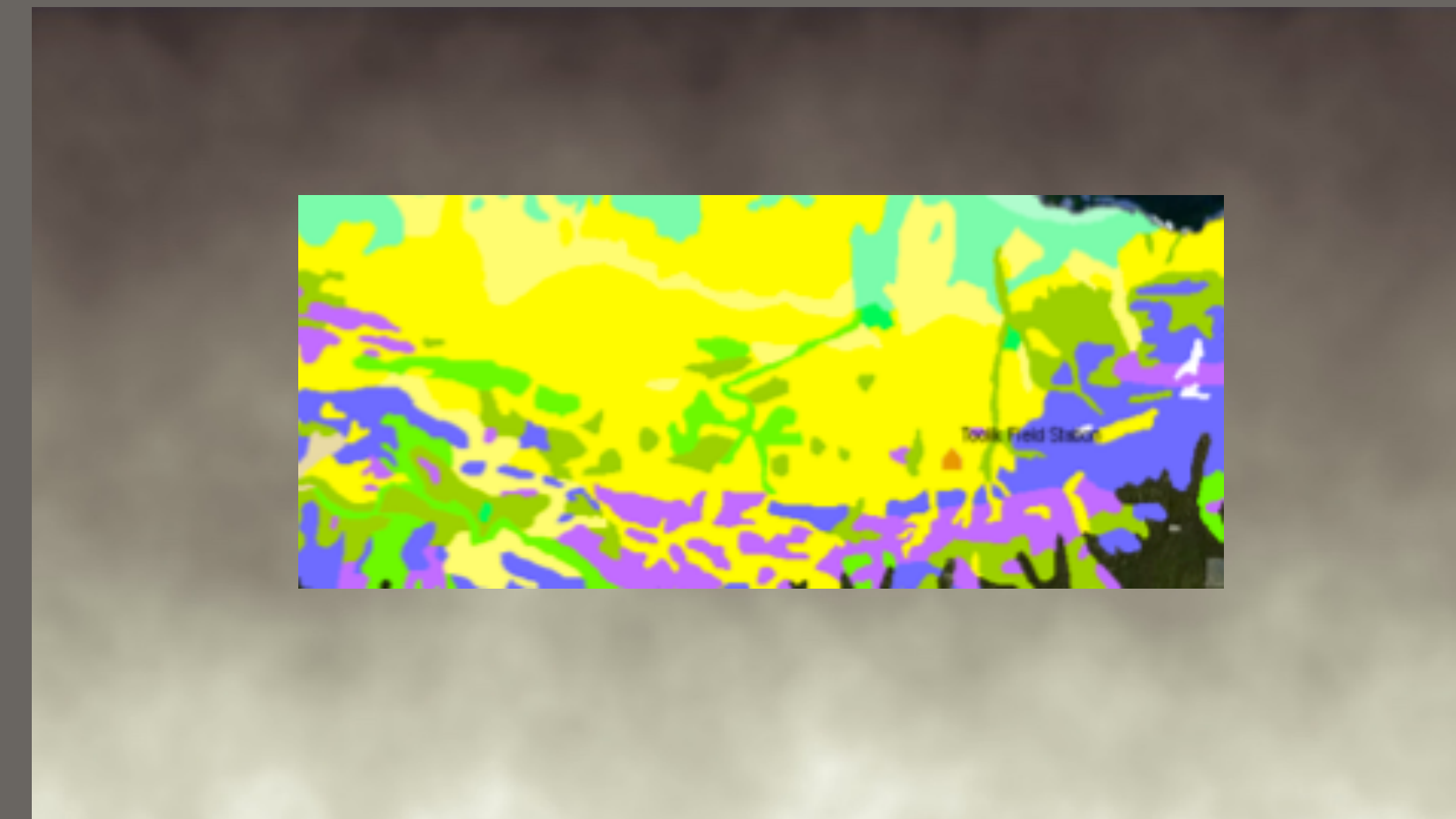
Neutral hues



a little color goes
a long way



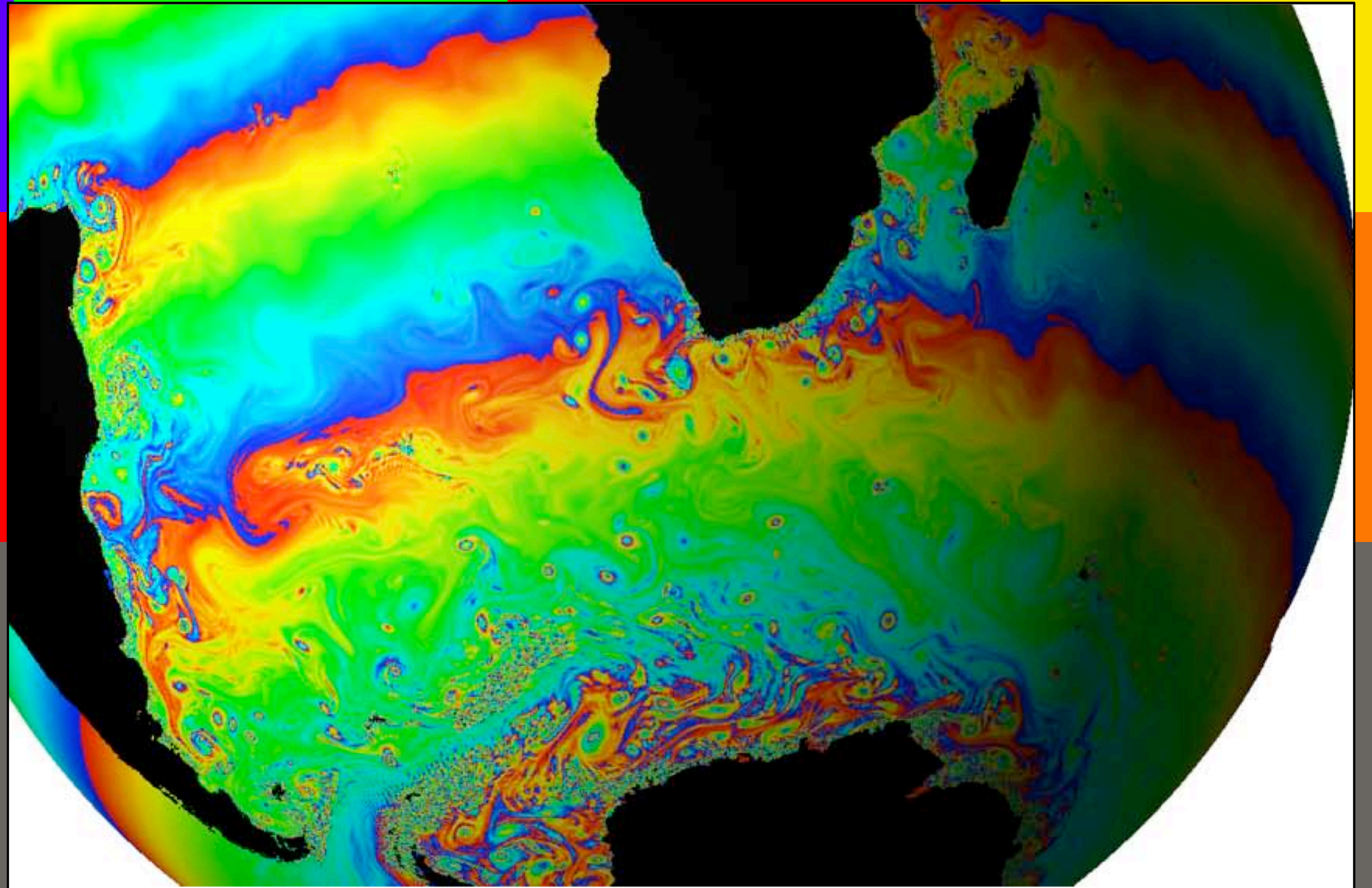
Grays frame the focal hues.

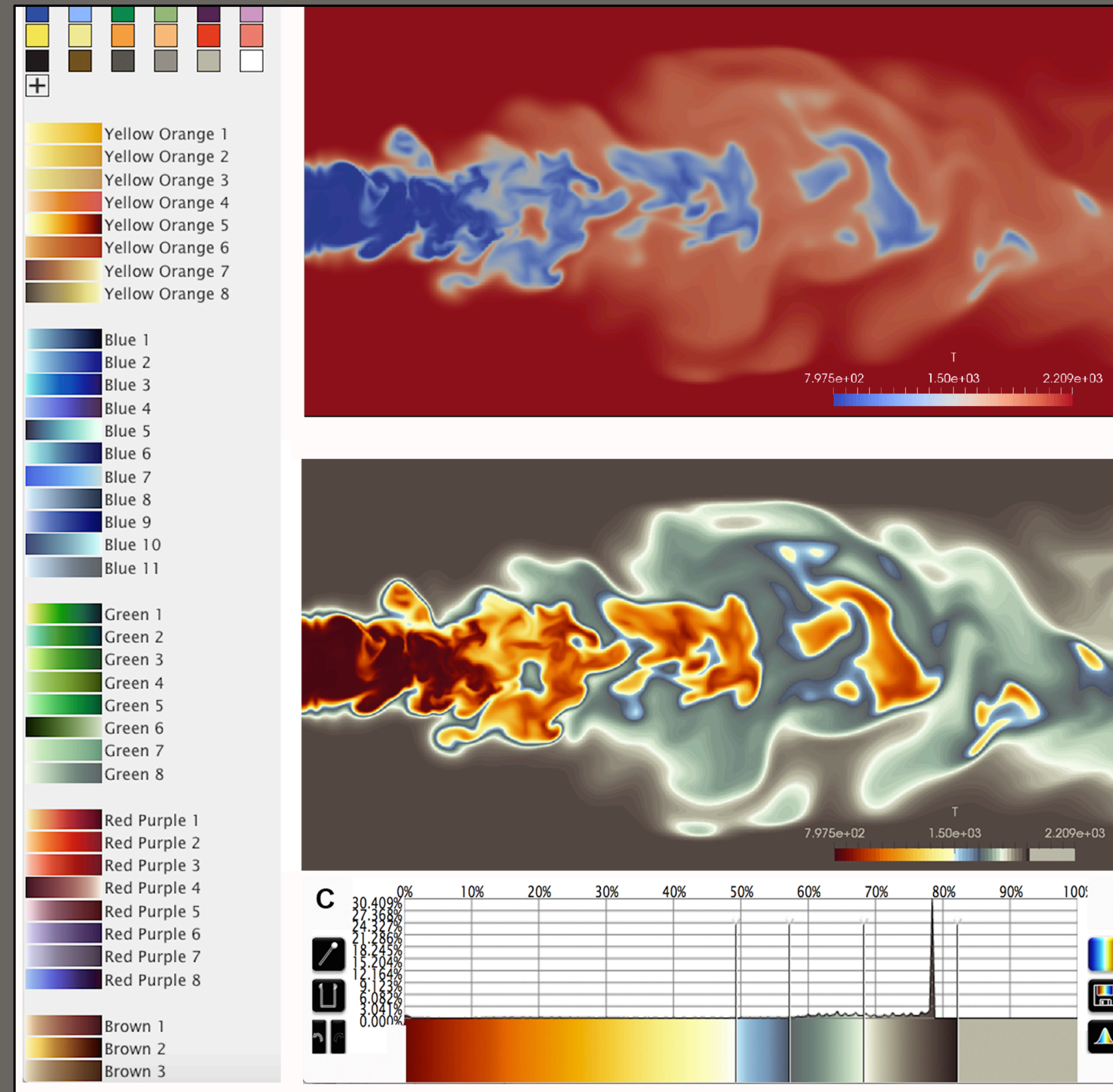


Grays frame the focus colors.

Why to apply Color Contrast Theory to data...

Simultaneity of Color

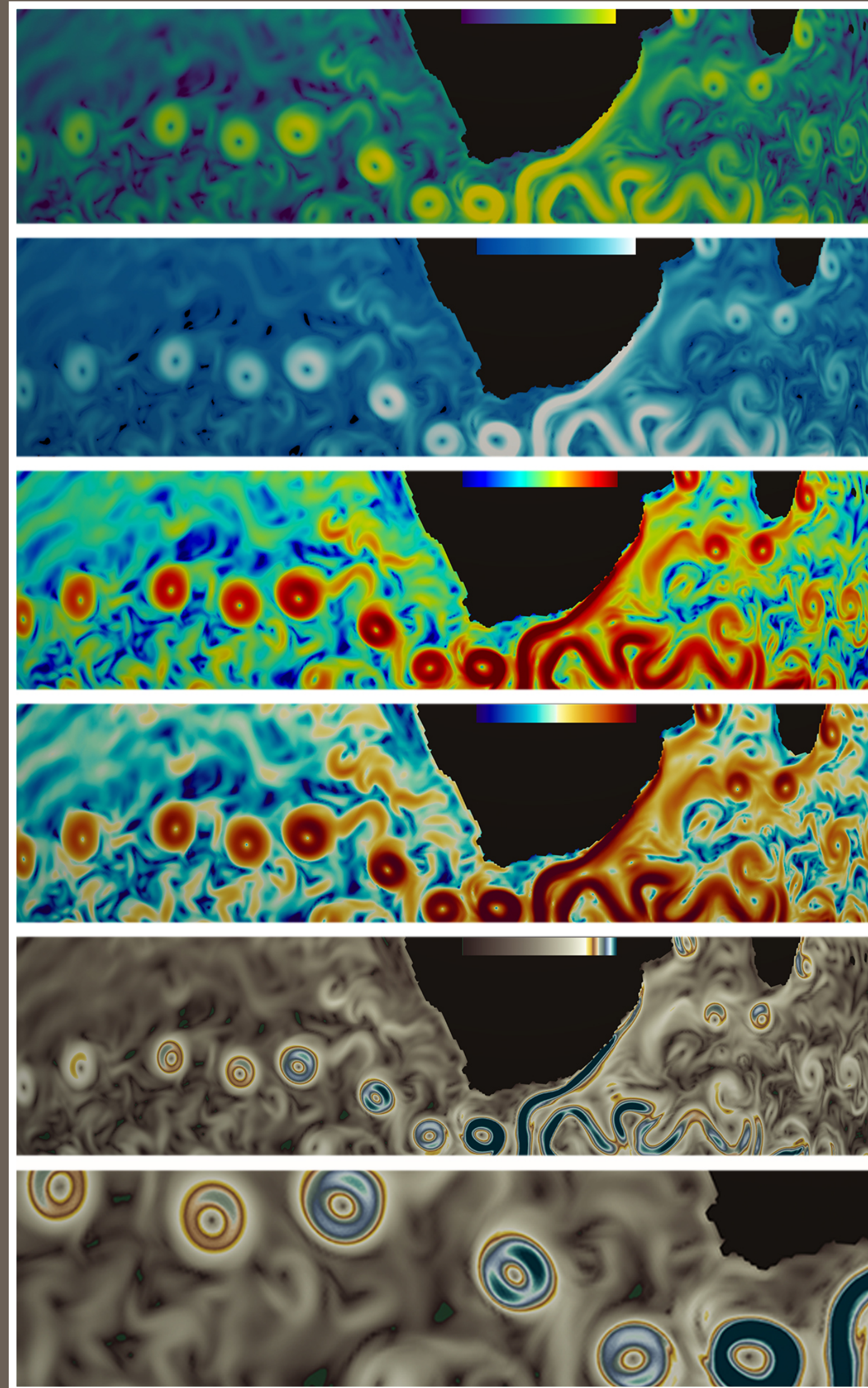




Hierarchy of attention

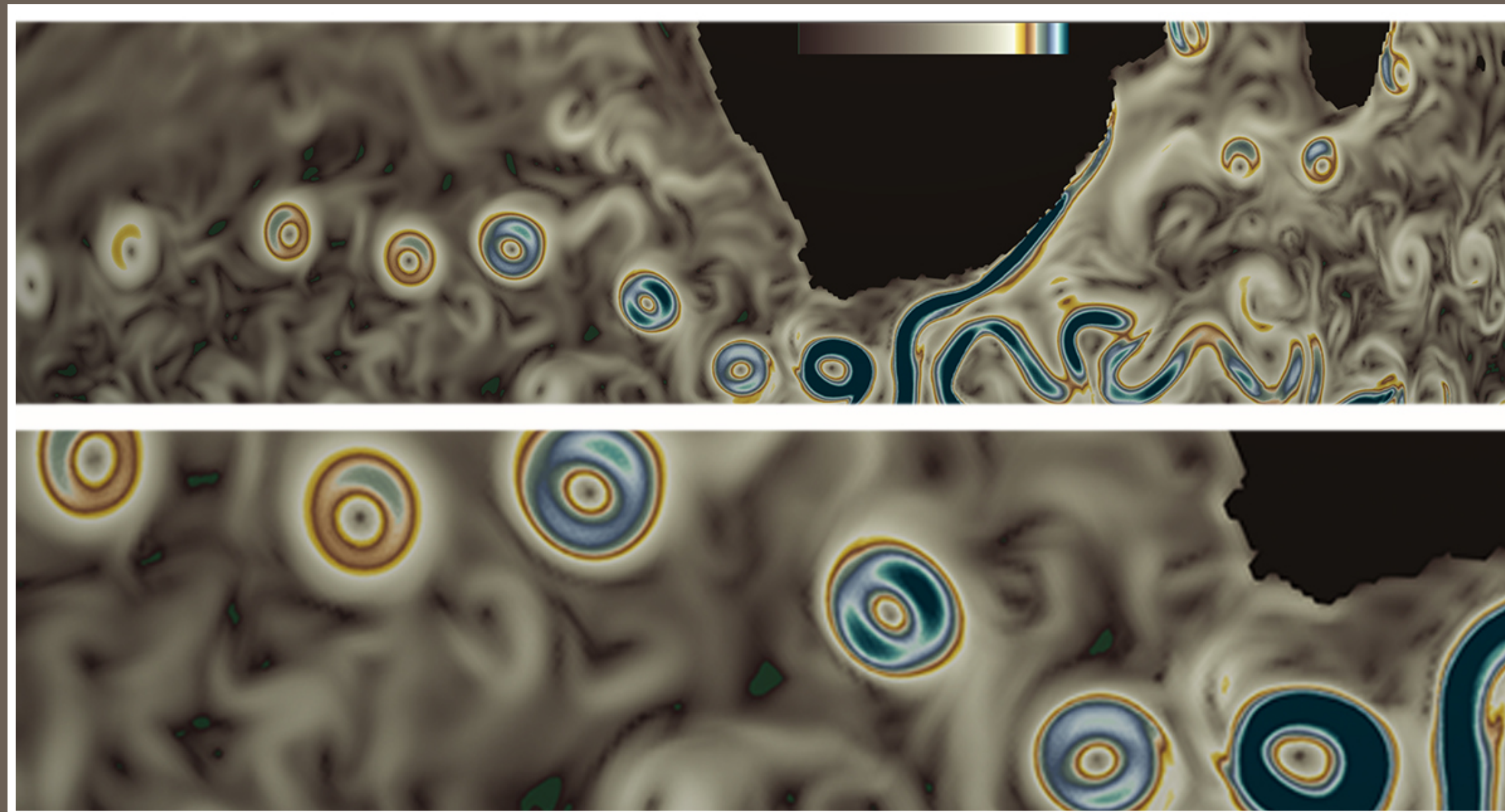
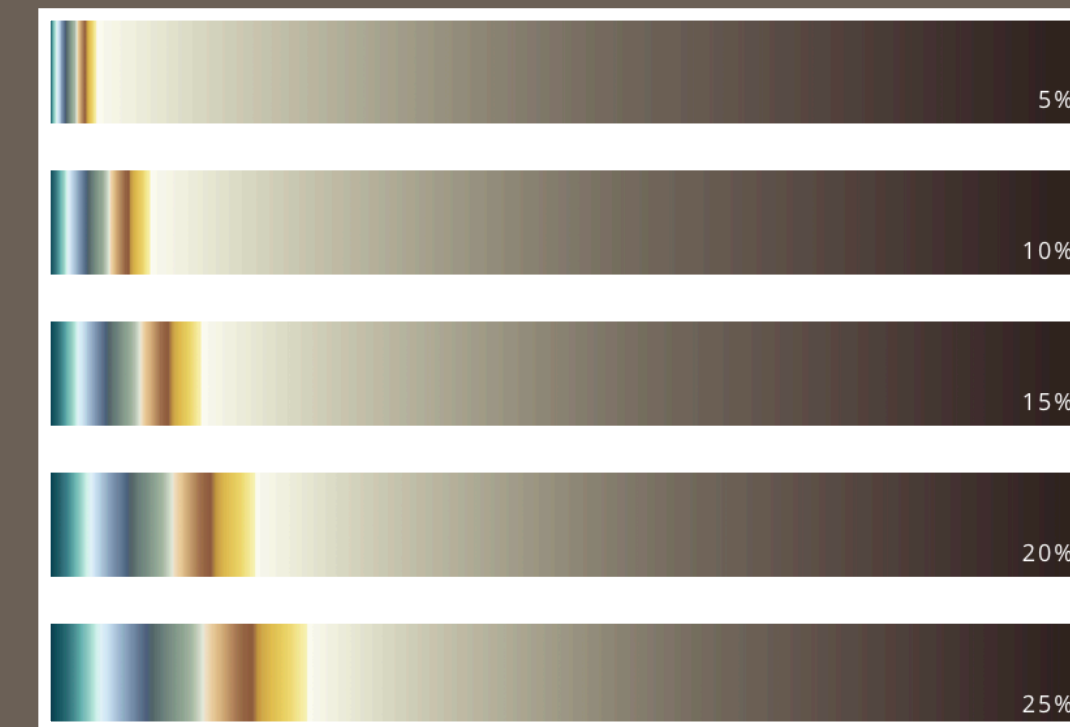
Hue
Value
Saturation
Complimentary
Cool – Warm
NO simultaneity
Analogous hues group
Use of neutrals

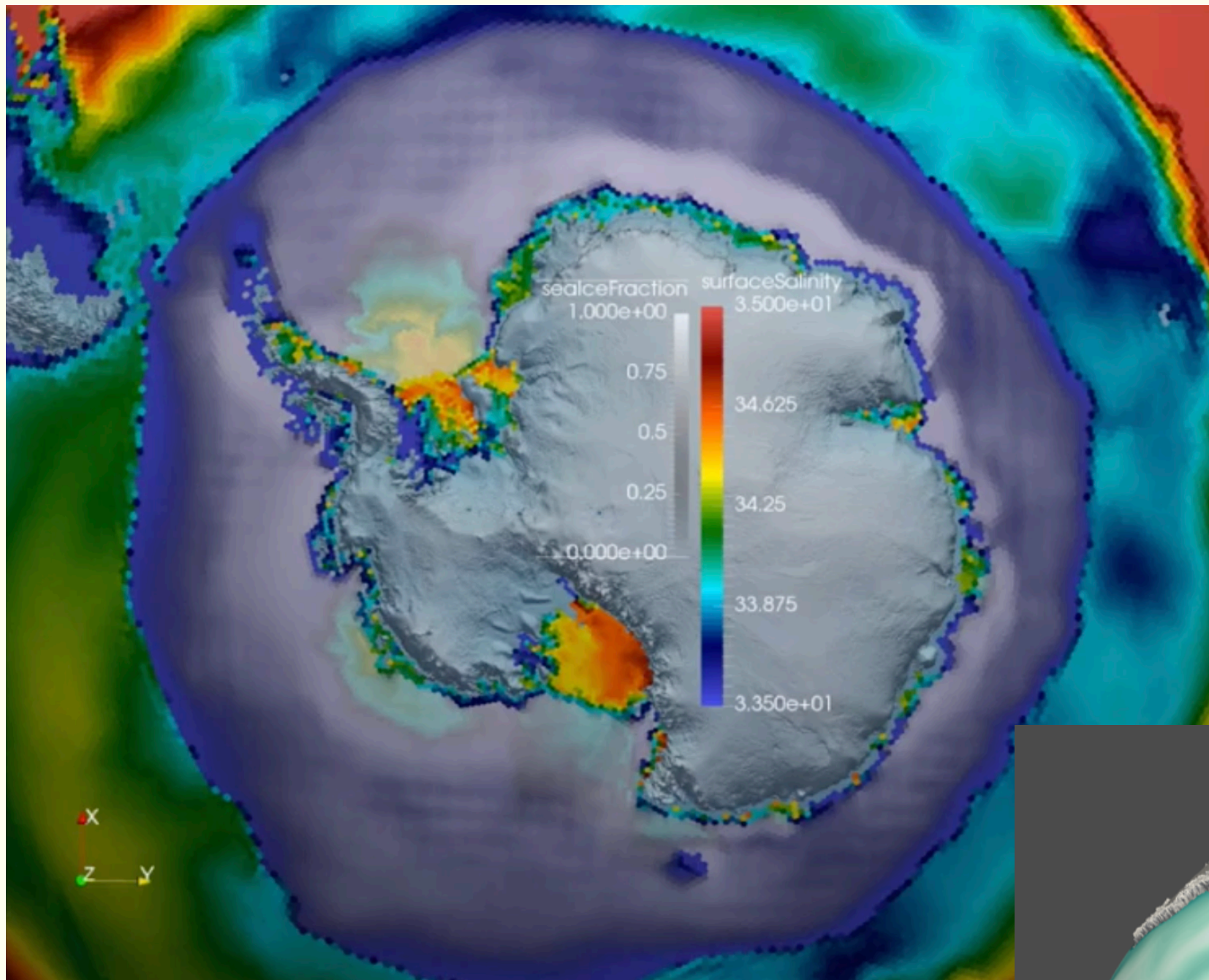
Luminance distribution (value)



In Color Sets / Structured Maps

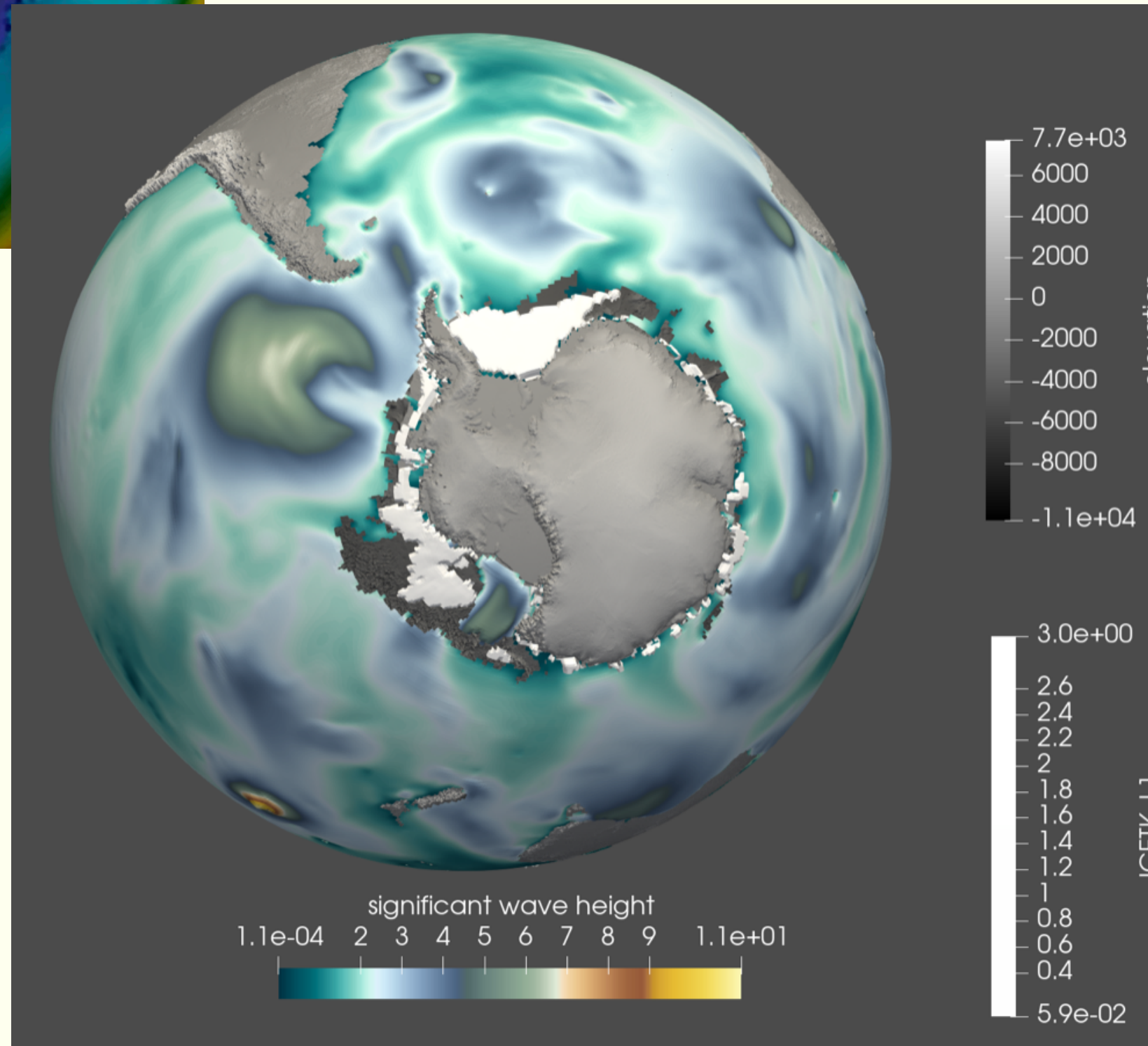
Seeing the
desired detail



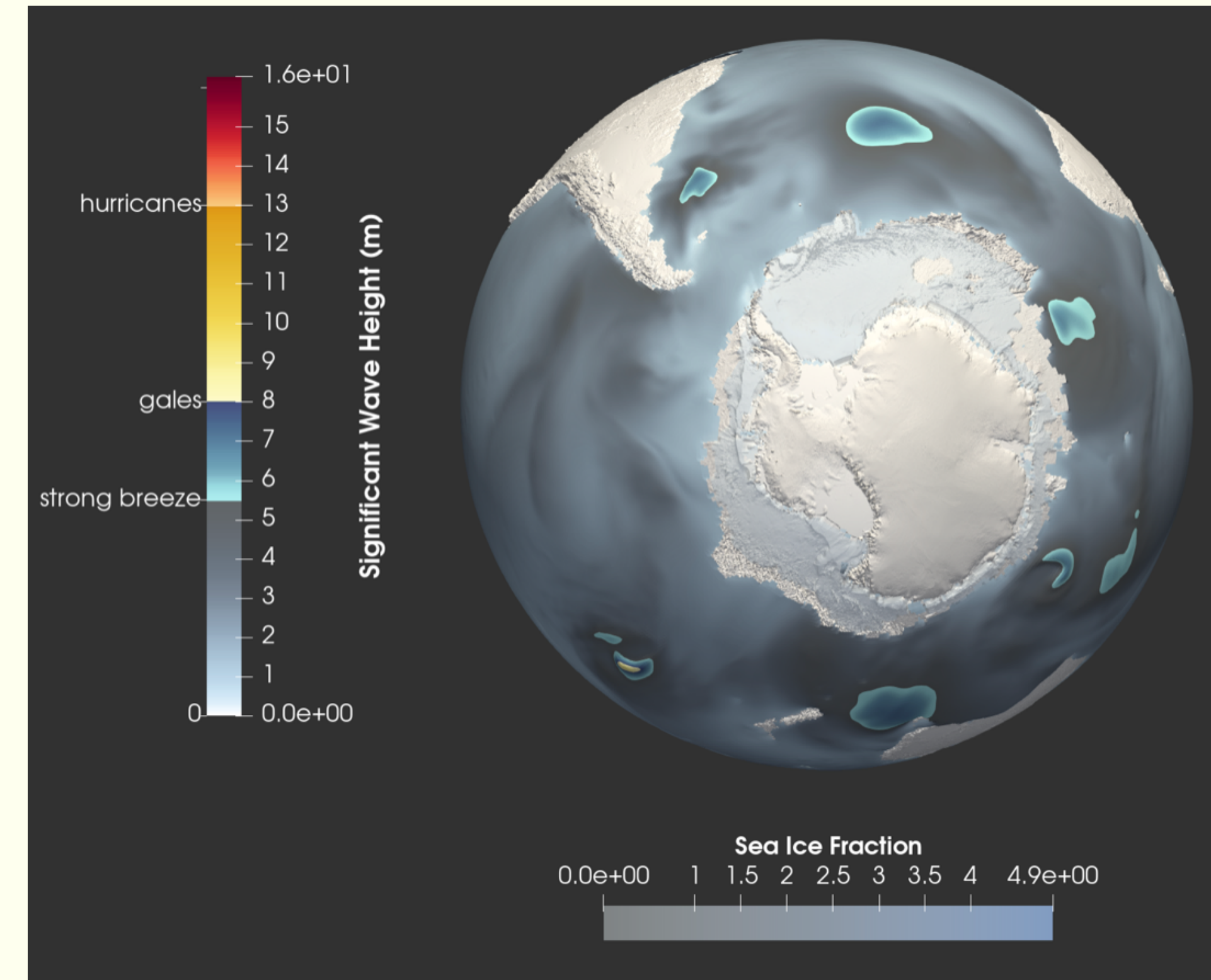


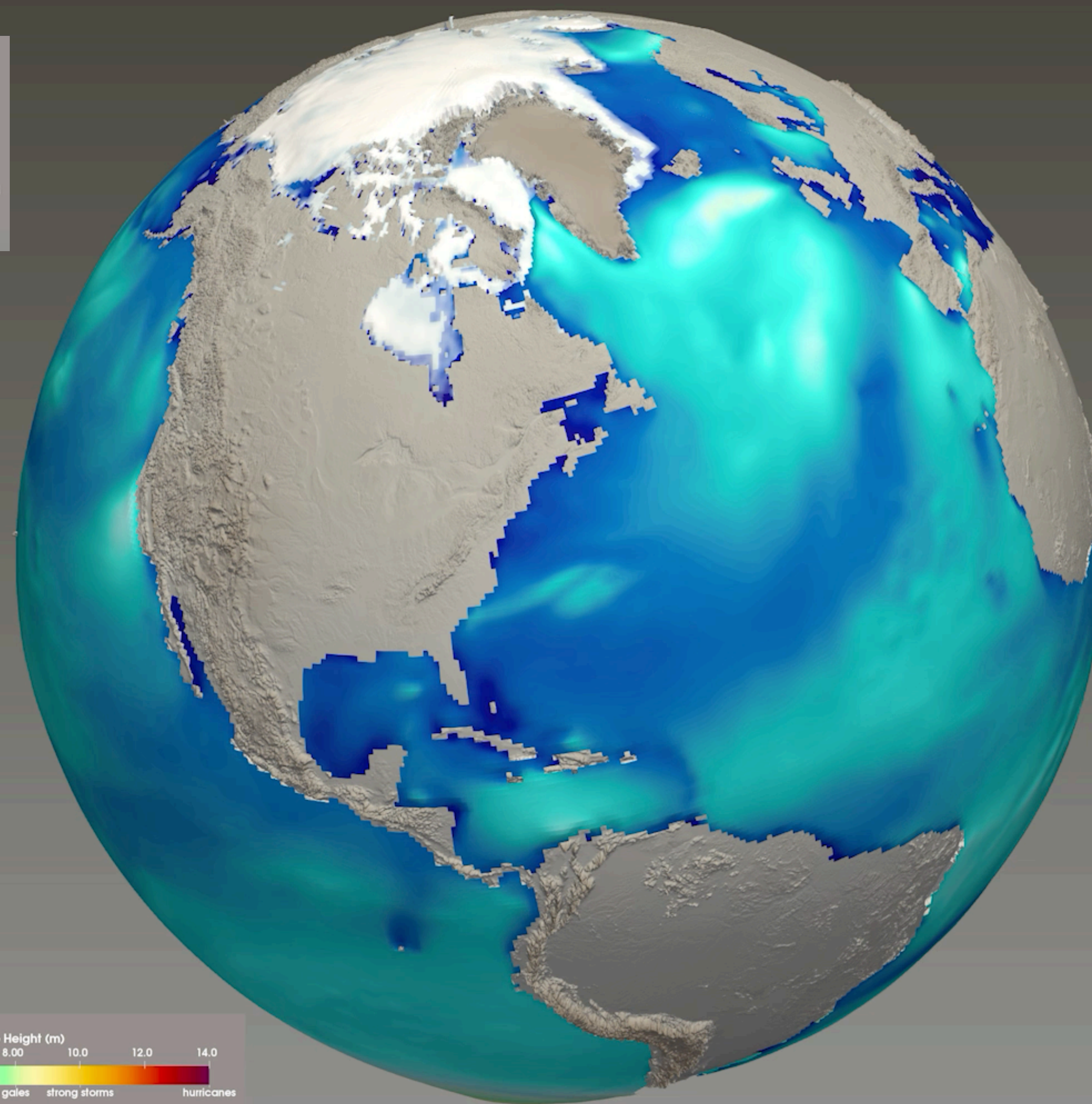
original

Calm detail



Categorical color scales





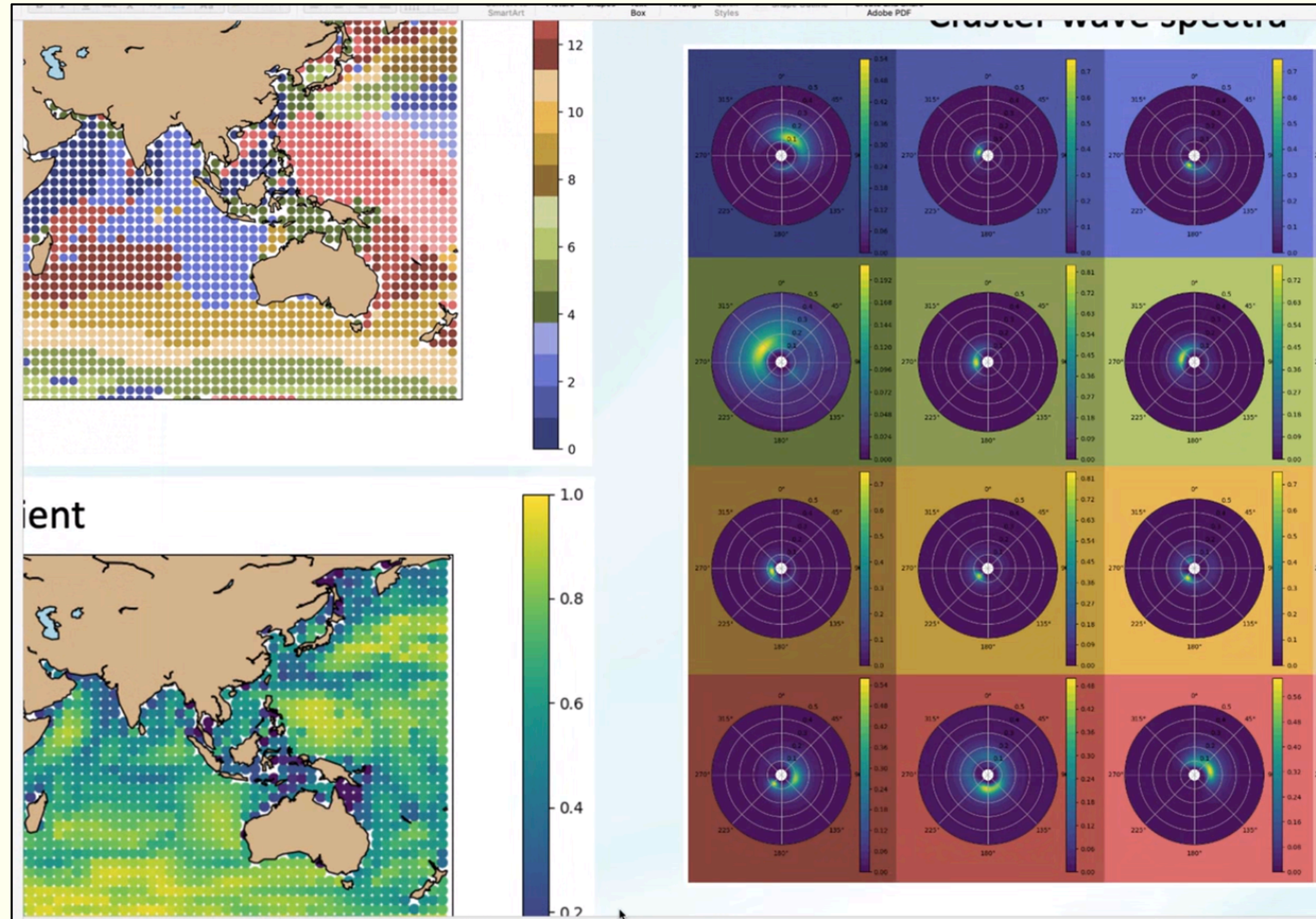
06/01/2005



video

E3SM, Wolfram, LANL

Unintended organization



Value contrast
defined only by hue

Color **CONTRAST** Theory

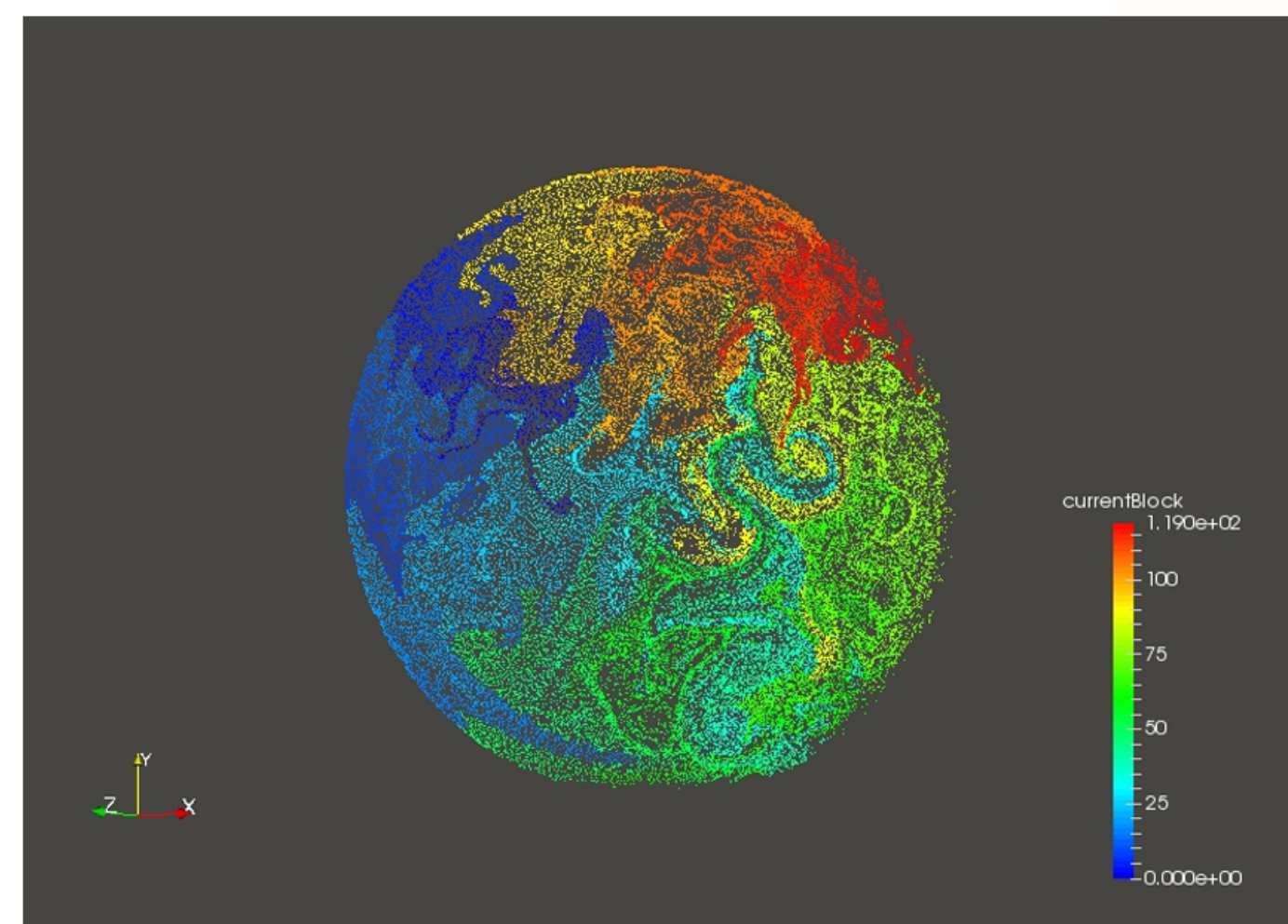
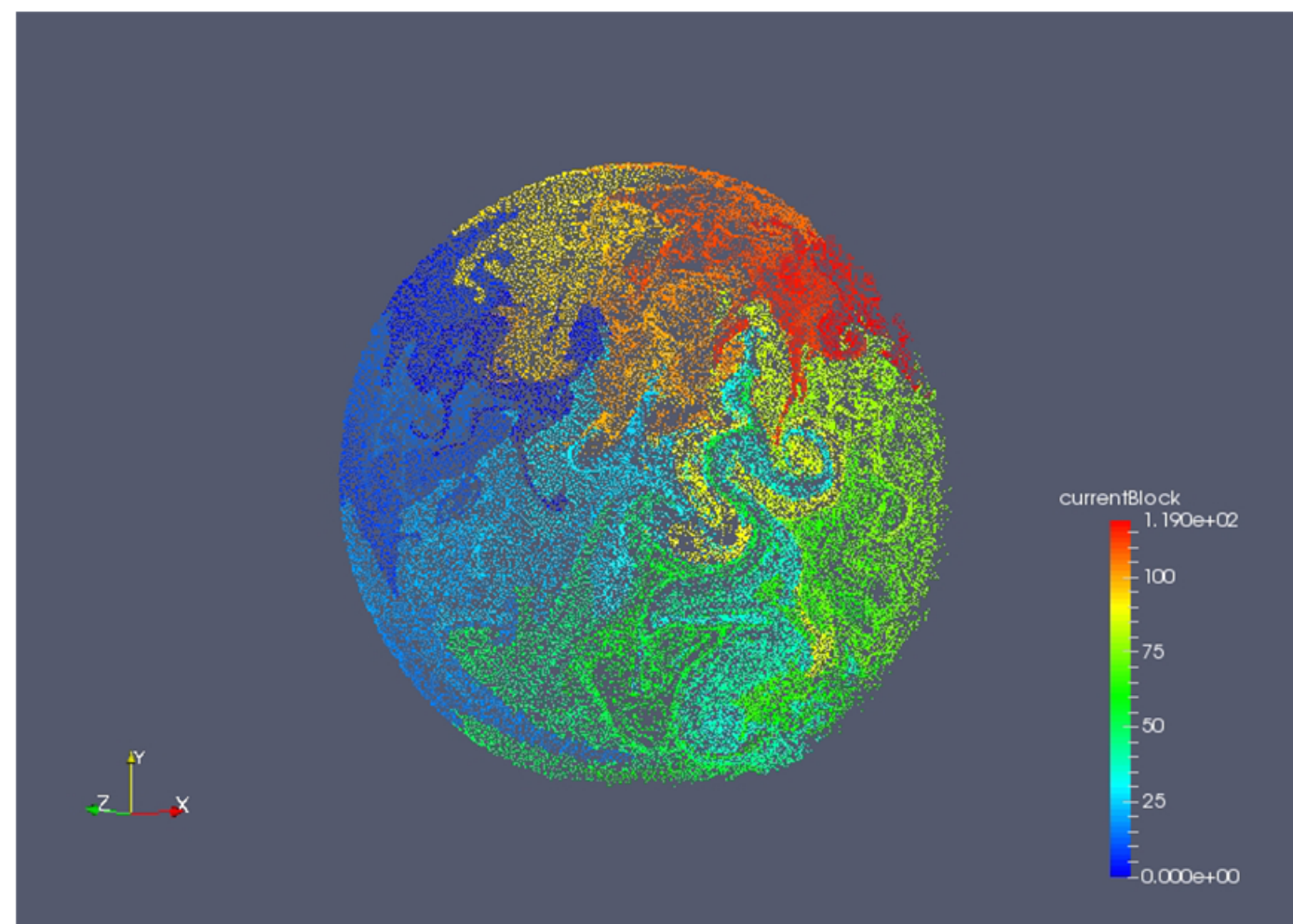
It is about **contrast**, not **color**.

HOWEVER, You have a **contrast** budget!

HOWEVER, You have a **contrast** budget!

➡ Allocation is important.

➡ Less is more.

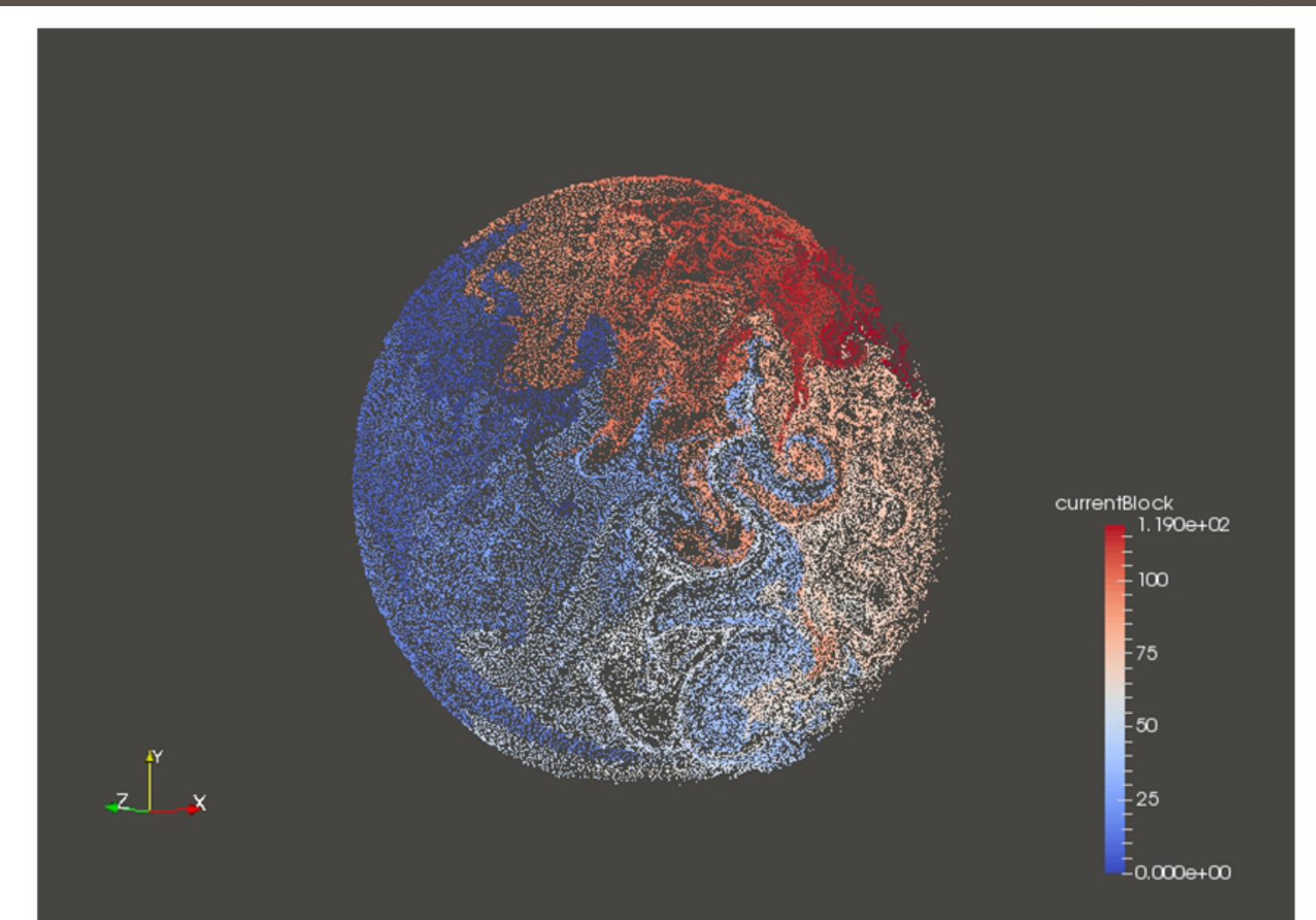
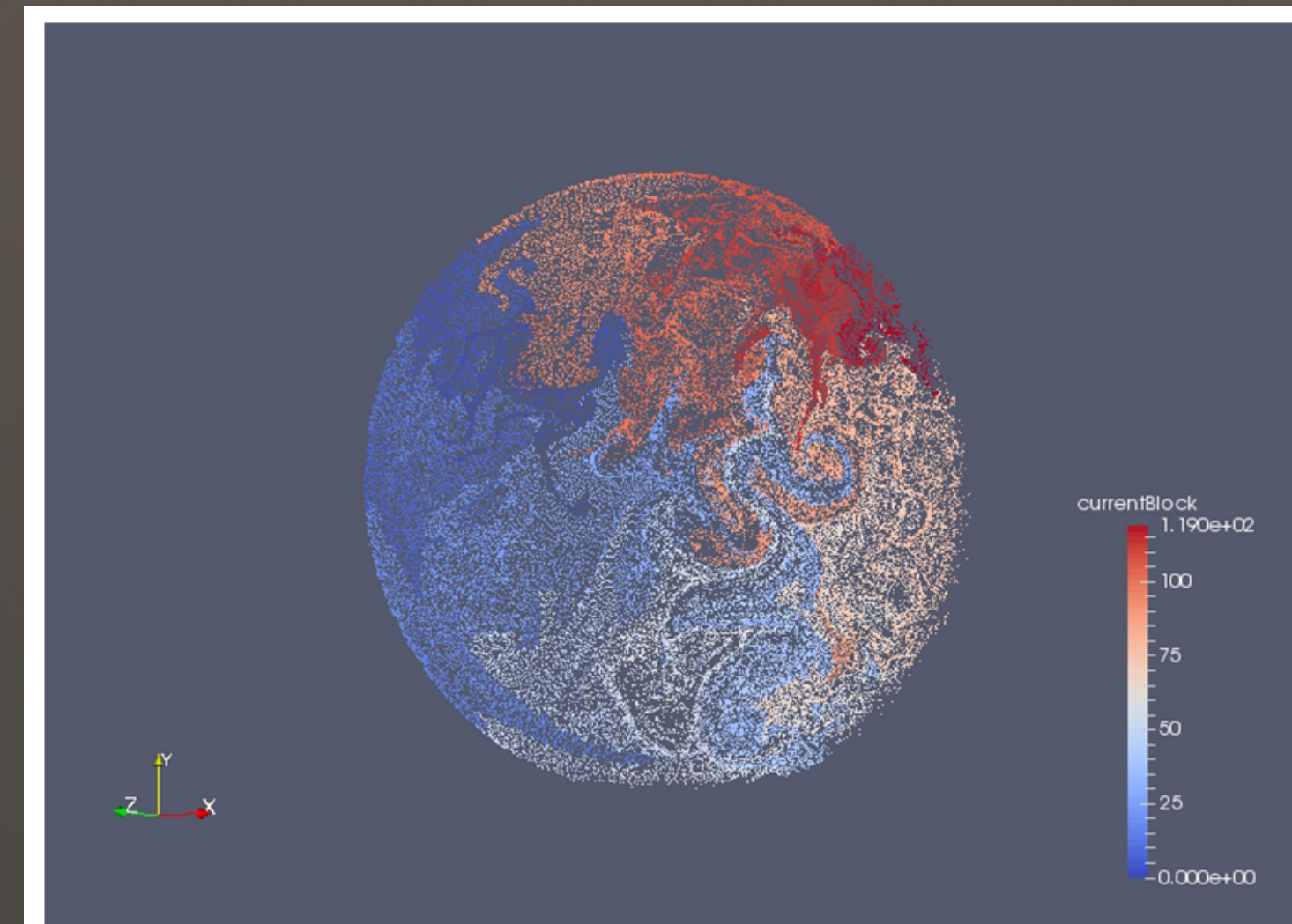


Change the Paraview
background default!

Your life and vis will be calmer.

RGB 107 107 107

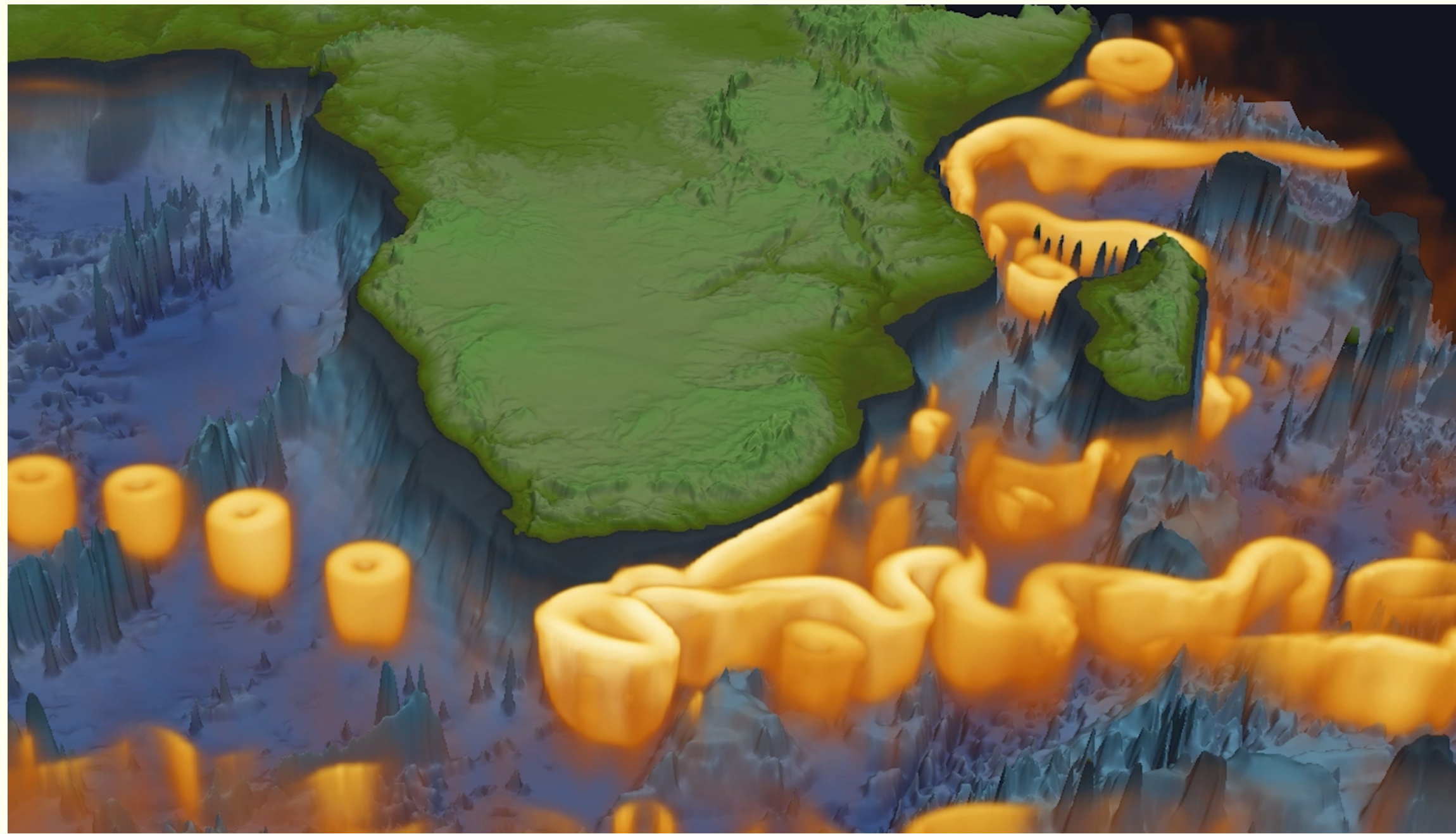
The only difference is
the background color.



In general, cool colormaps such as the ParaView default,
need a warm background but in reality,
the ParaView background is almost always worse.

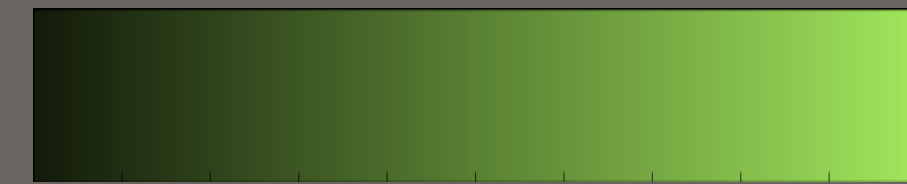
3D multivariate data

Color Strategies and Color Sets



yellow 15

contextual color



isolating and
highlighting
a variable

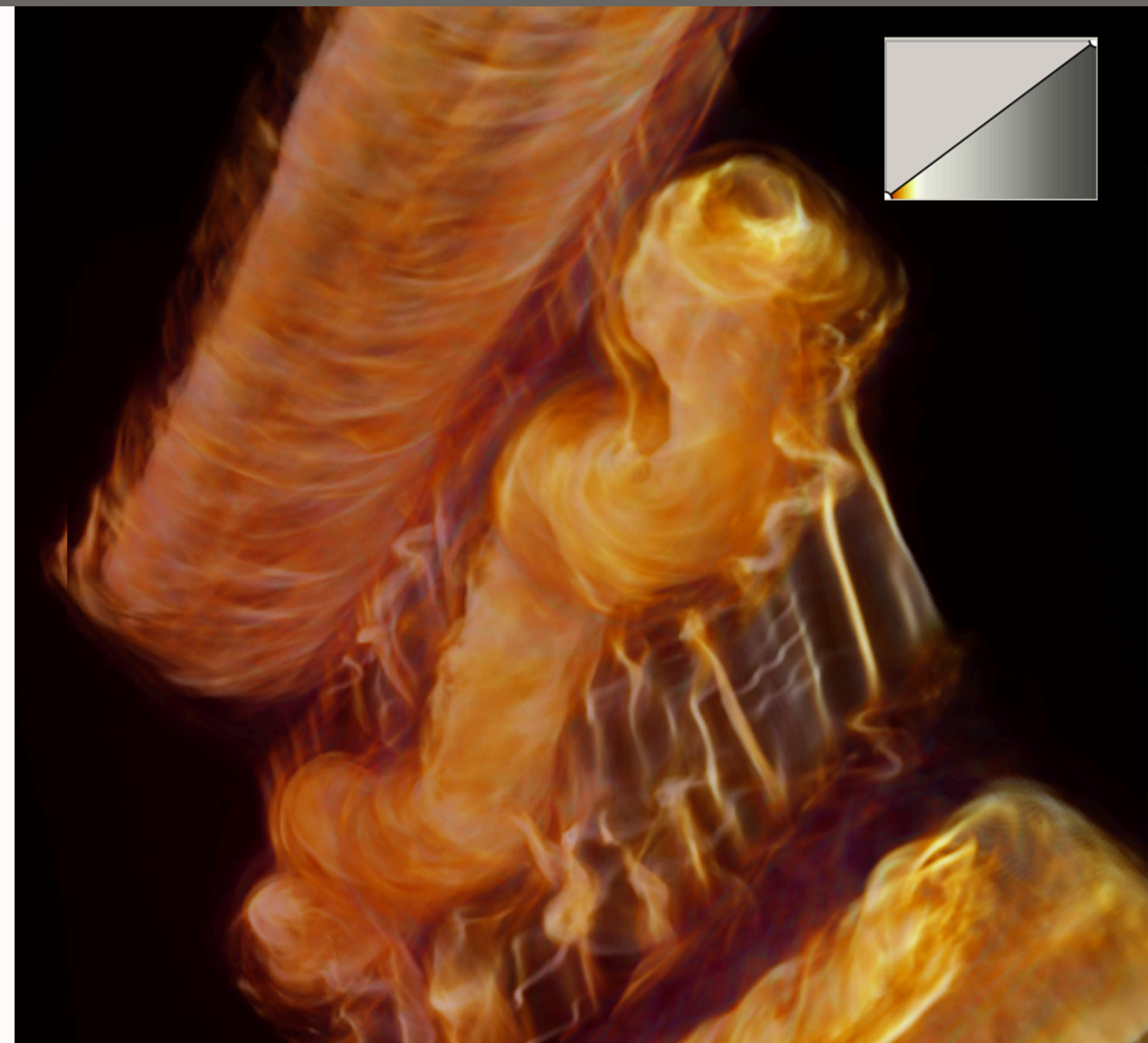
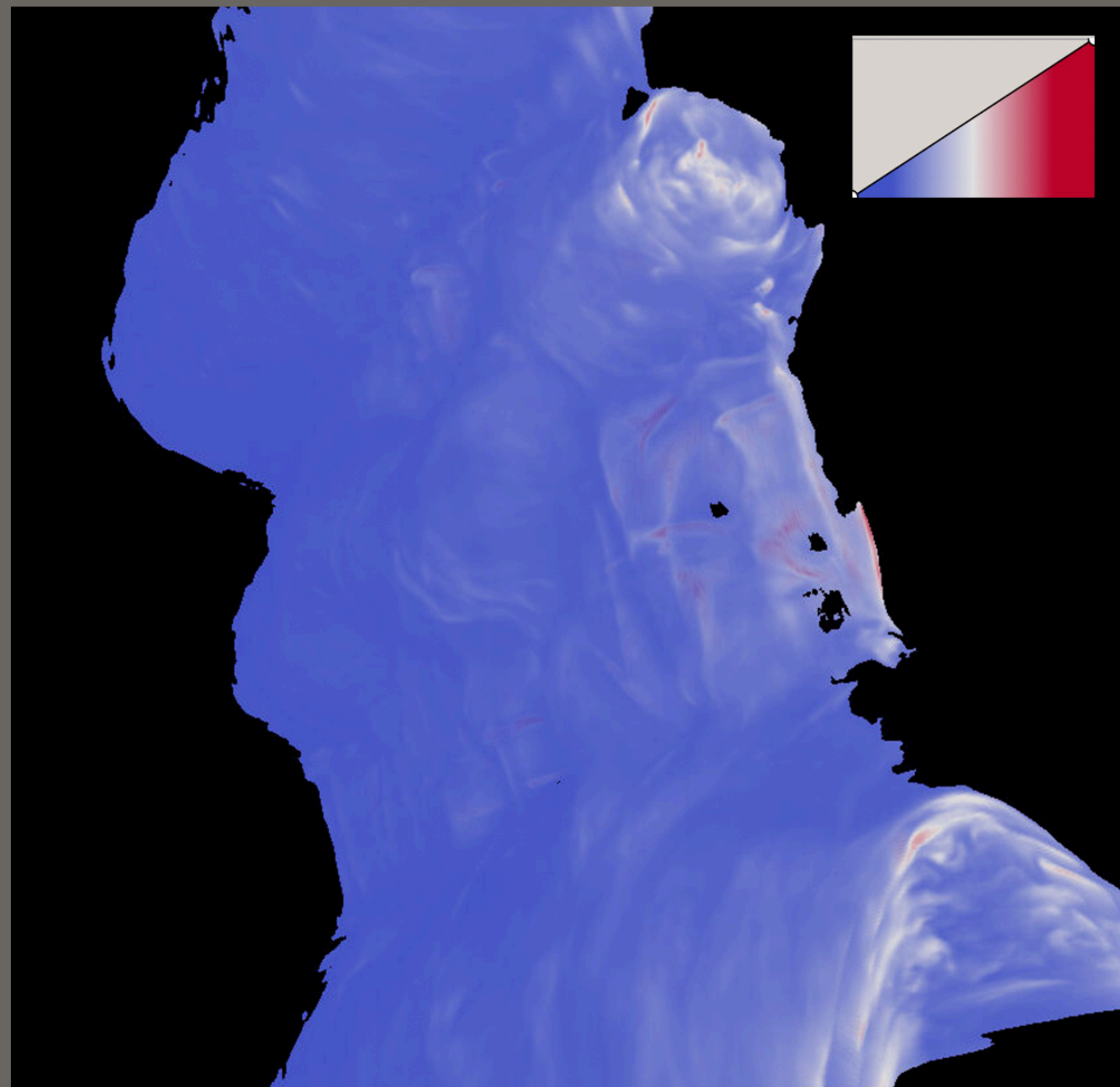
3D Data, single variable

Many choices:

volume,
slices, isosurfaces
streamlines

opaque, transparent
glyphs or points

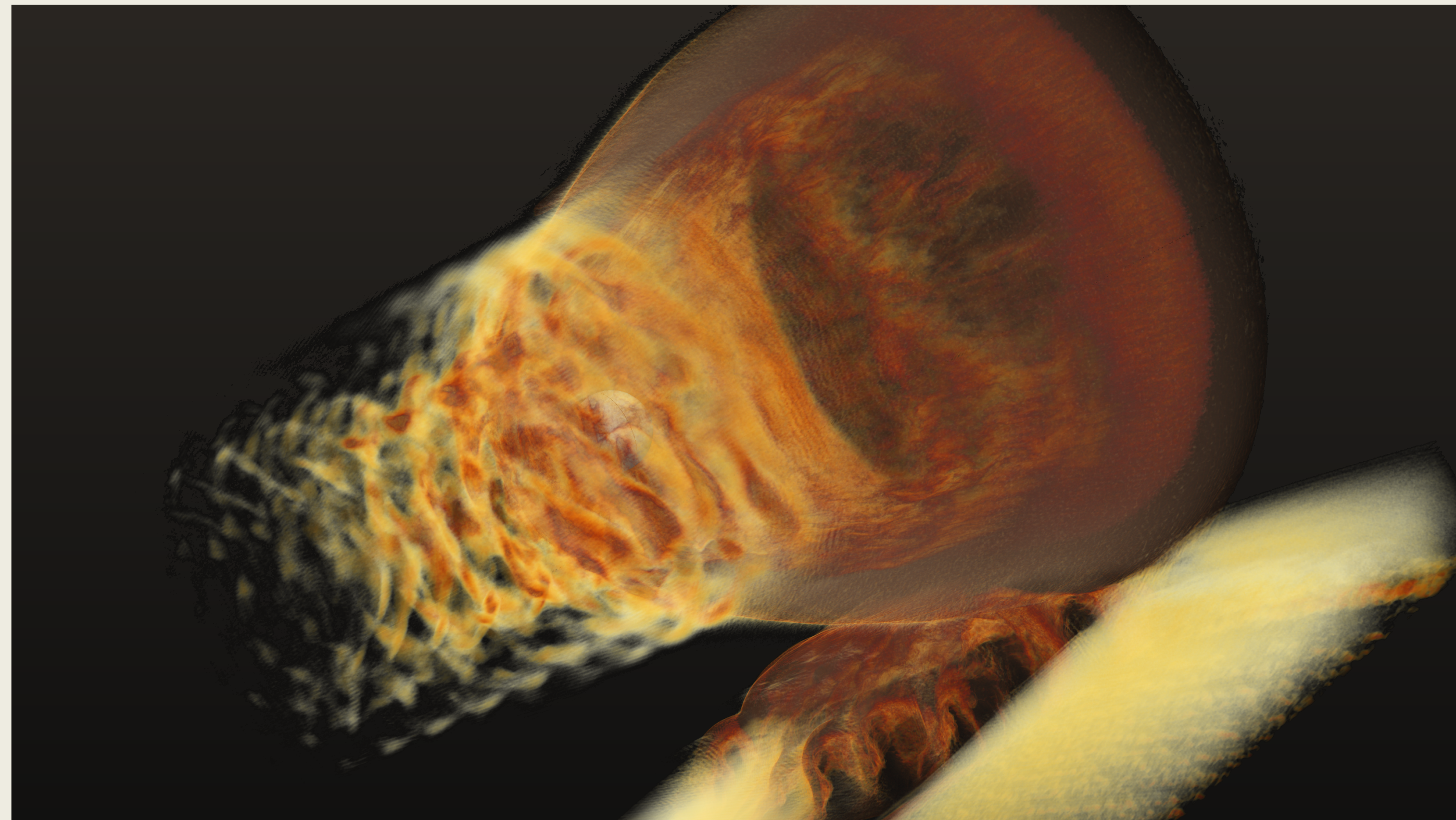
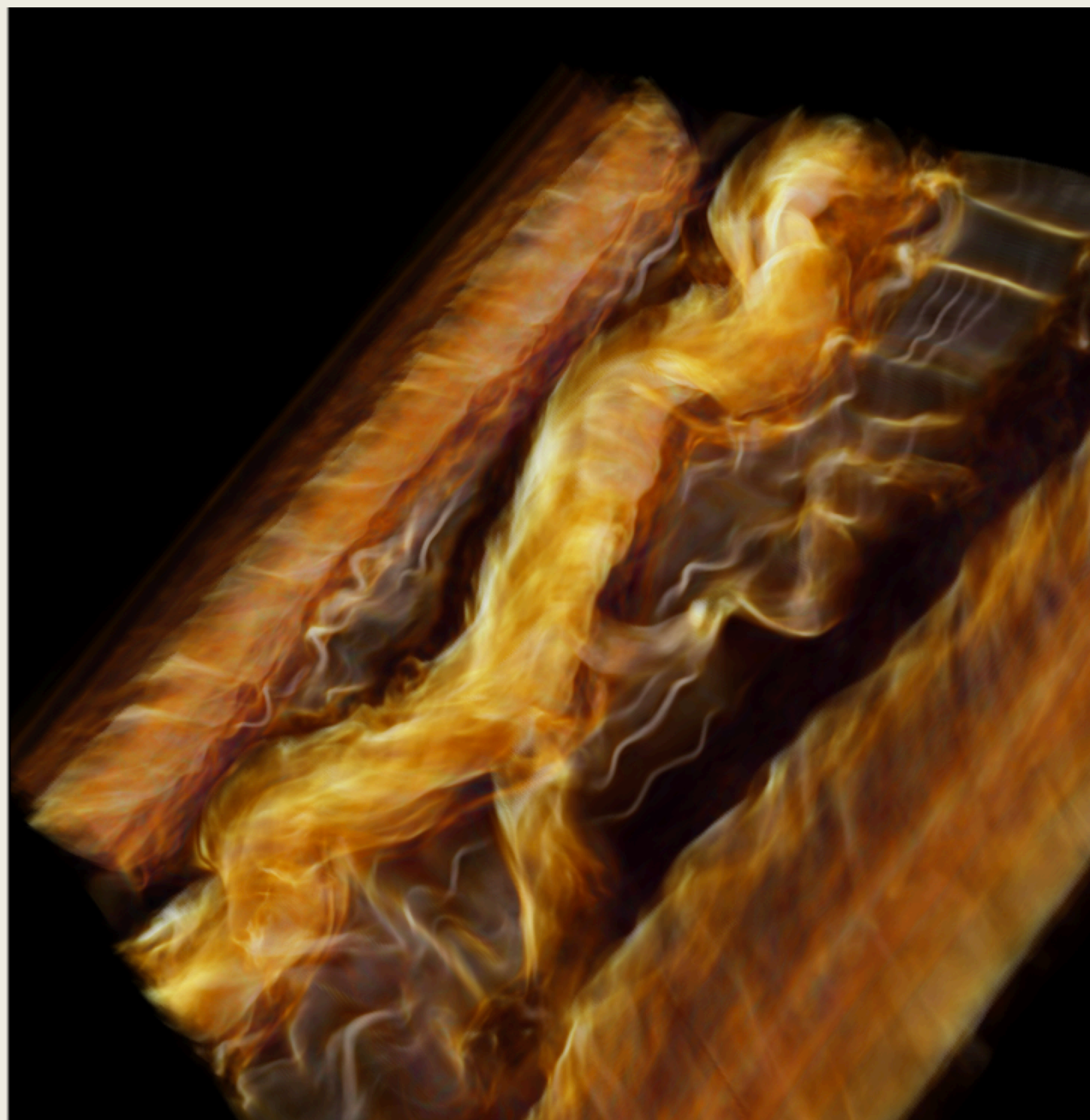
Start with
THE GOAL.



Experimenting with the opacity distribution is key.

Volume Rendering

Some colormaps work well for specific uses.



H3D, Daughton, LANL



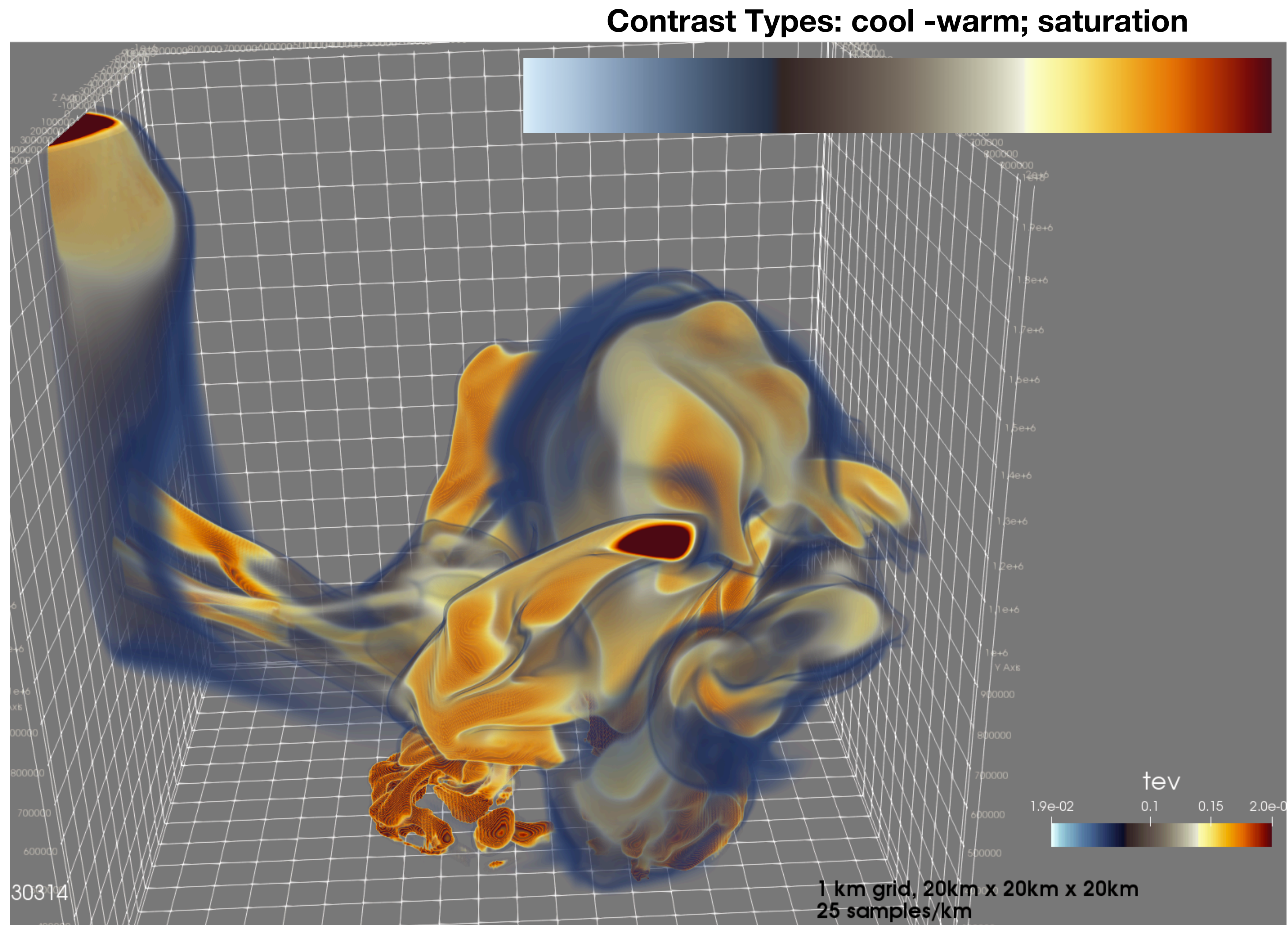
This colormap works well for many volume renderings because of the combination of multiple light hues and the intuitive continuous scale.

Beautiful?

There is a reason
why we identify
certain images,
environments, etc.,
as beautiful.

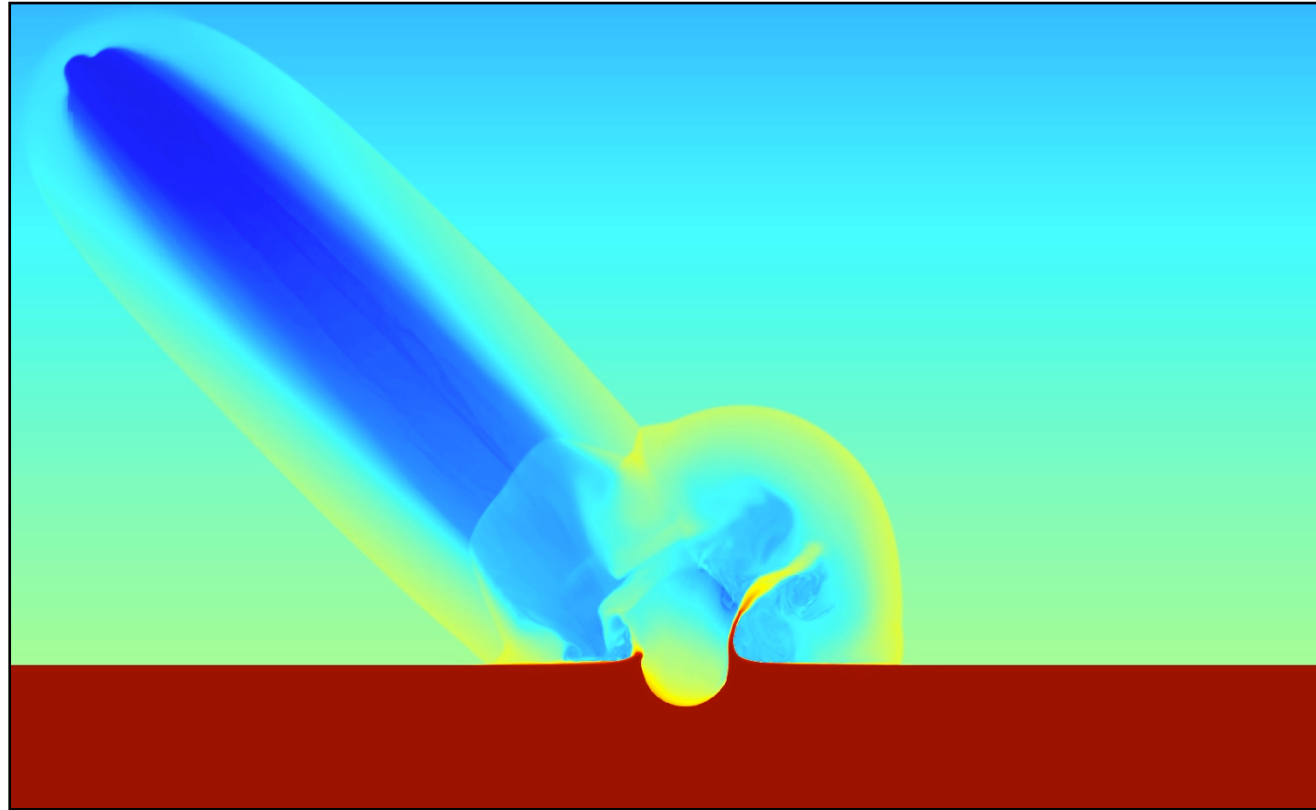
It has to do with
balance and harmony.

It engages and
makes you want
to linger.

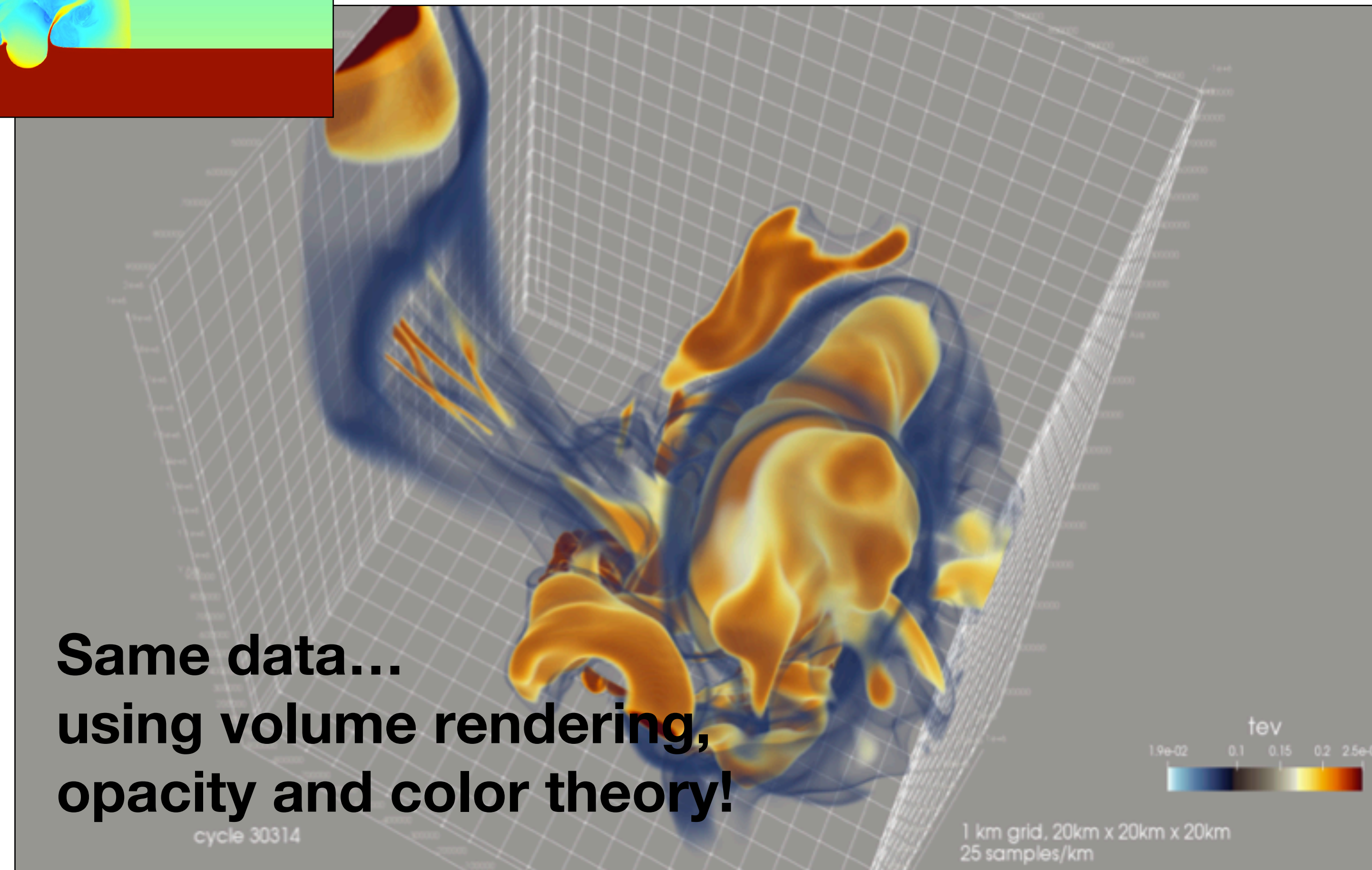




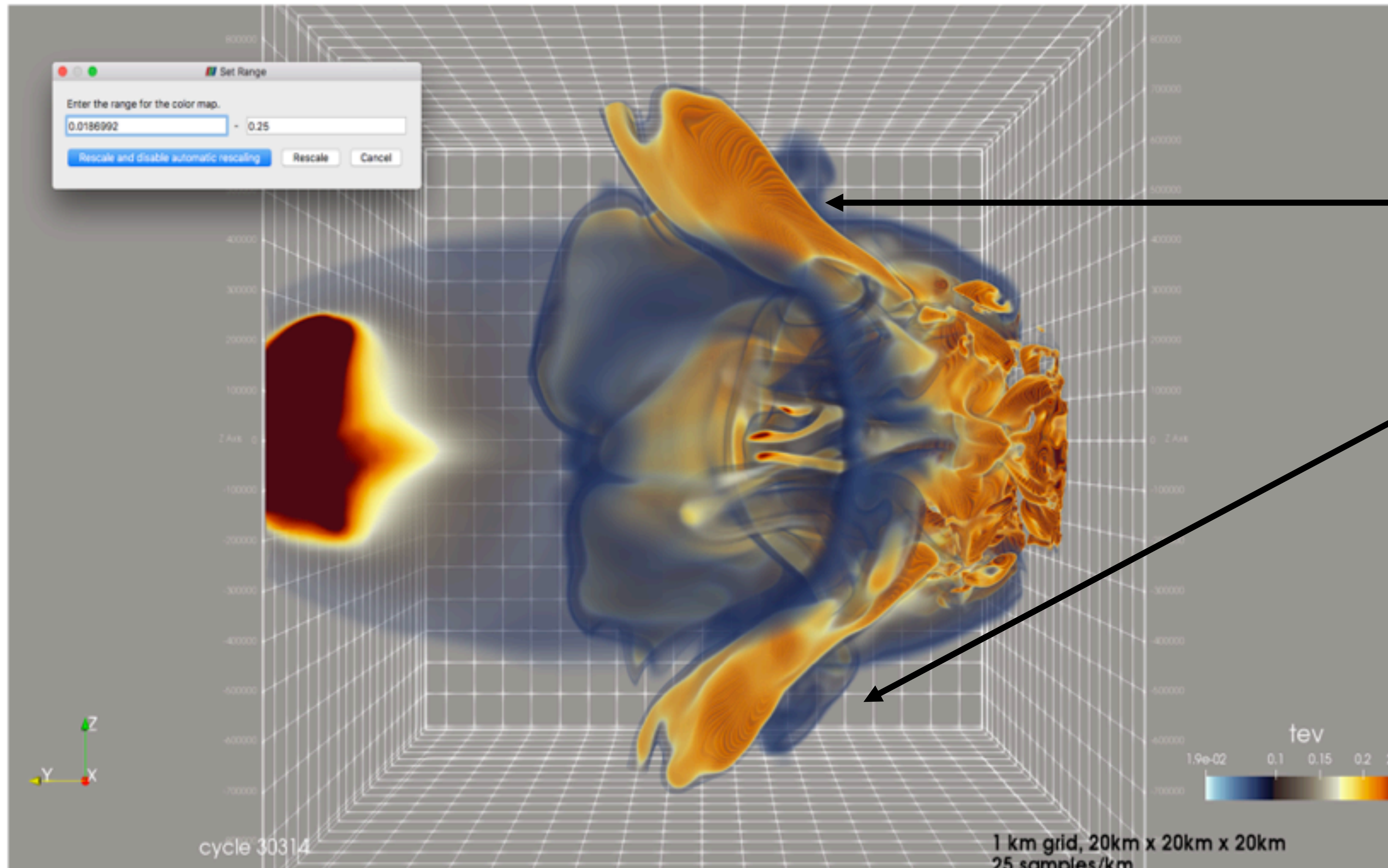
Getting from this...



to this...



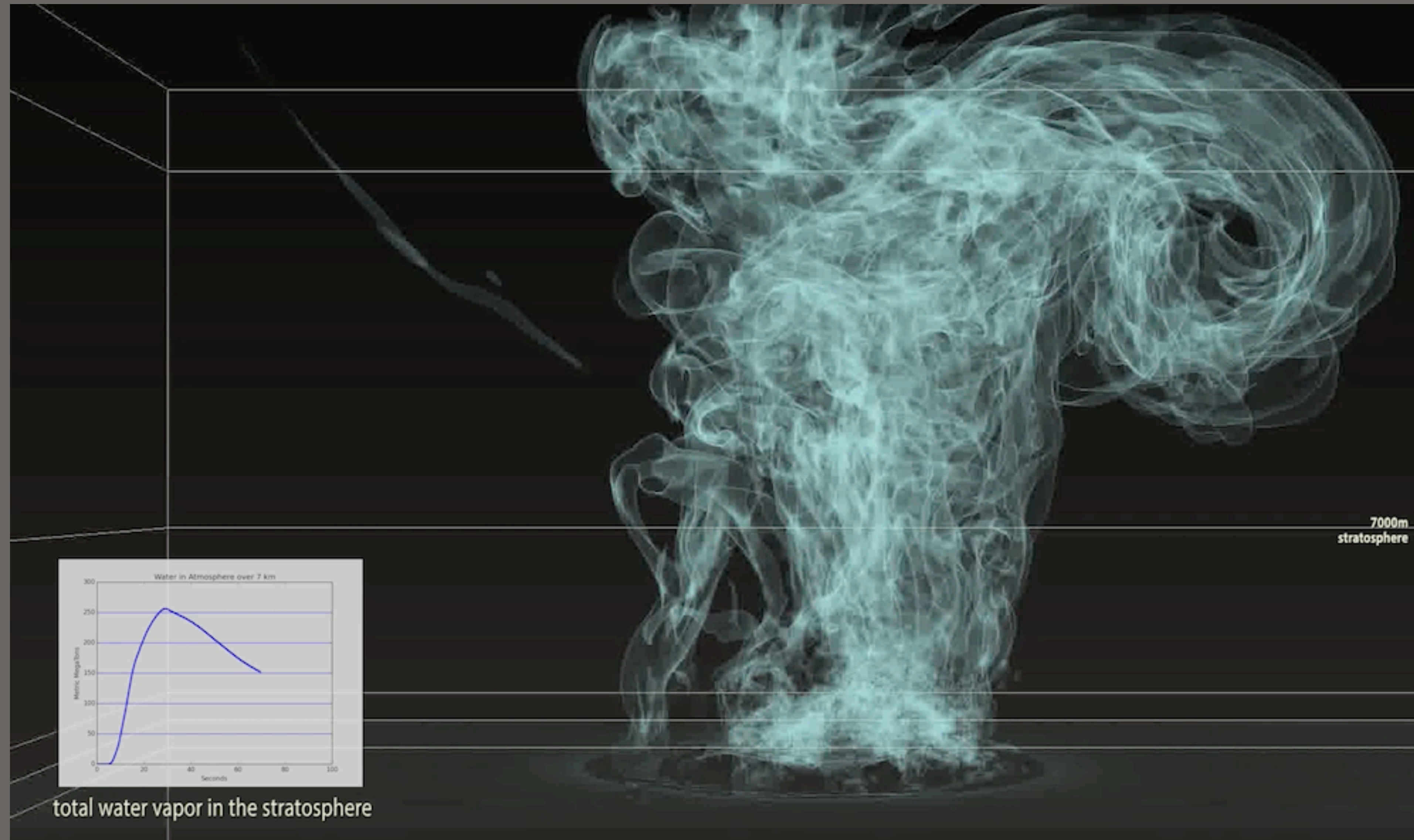
**Same data...
using volume rendering,
opacity and color theory!**



asymmetrical

**Verification
and validation**

Surprises

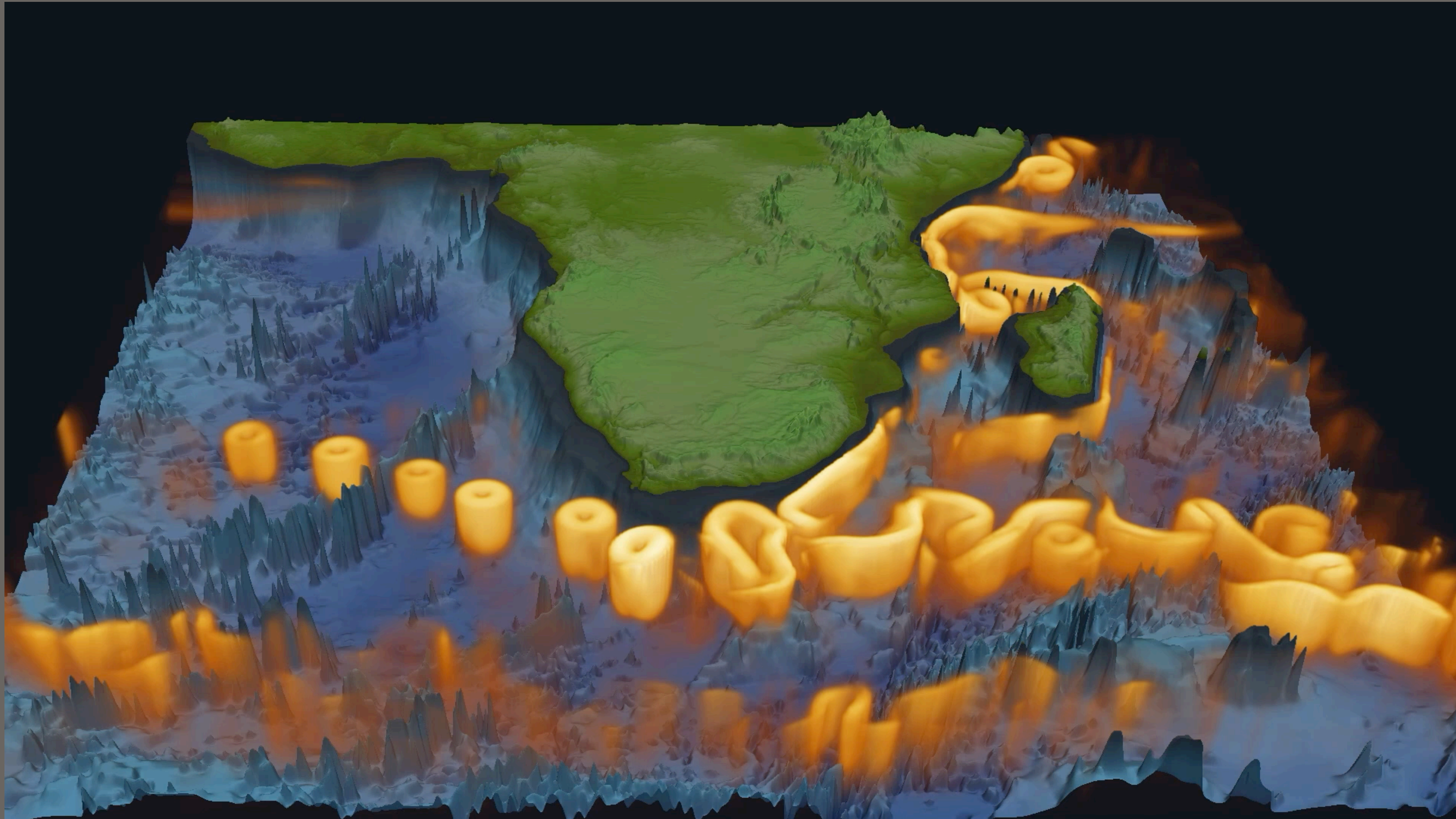


Combining the data with the structure.

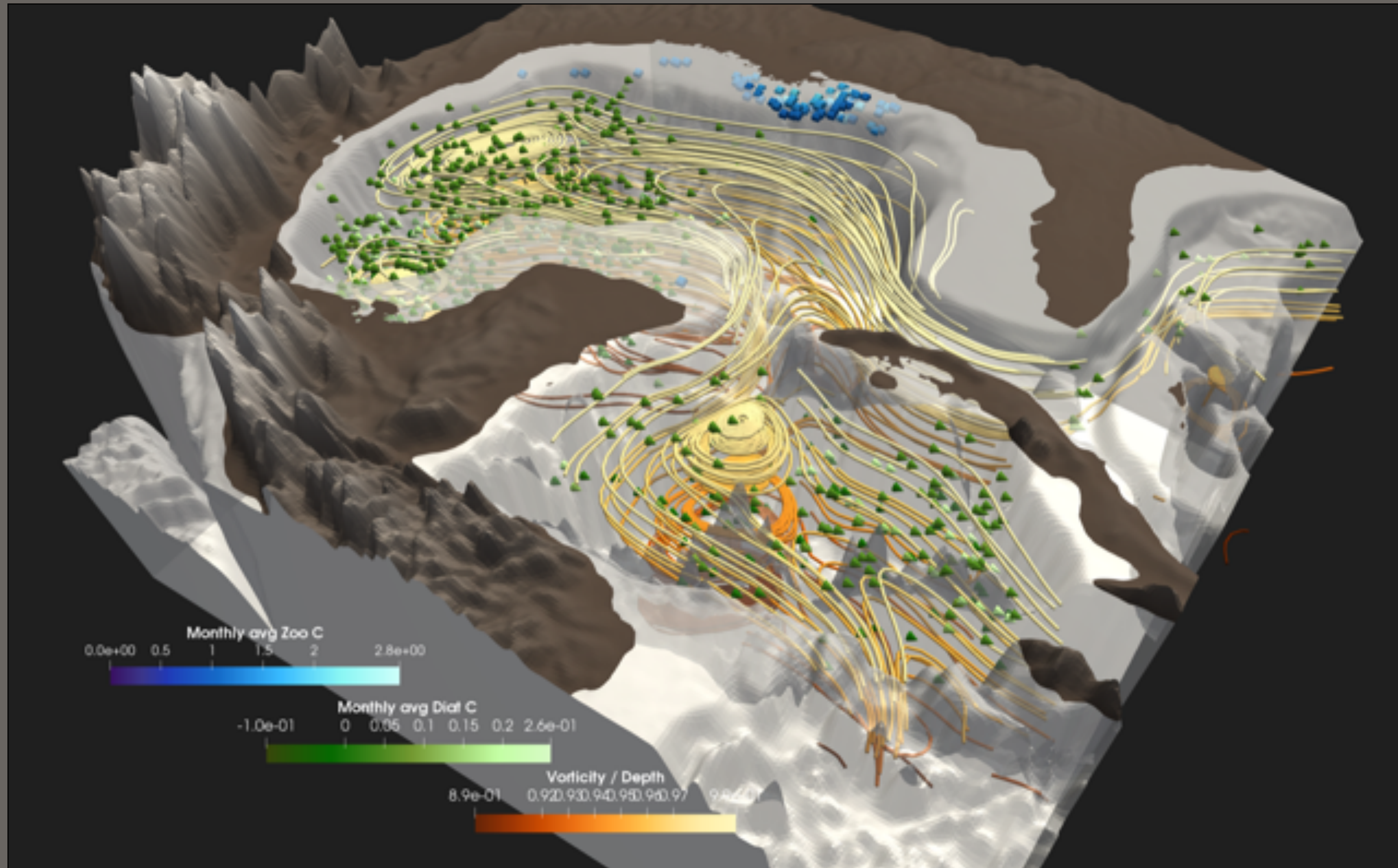
G. Gisler, LANL

Contrast Types: saturation; cool - warm

Focusing on the data of importance by removing other data with opacity function.

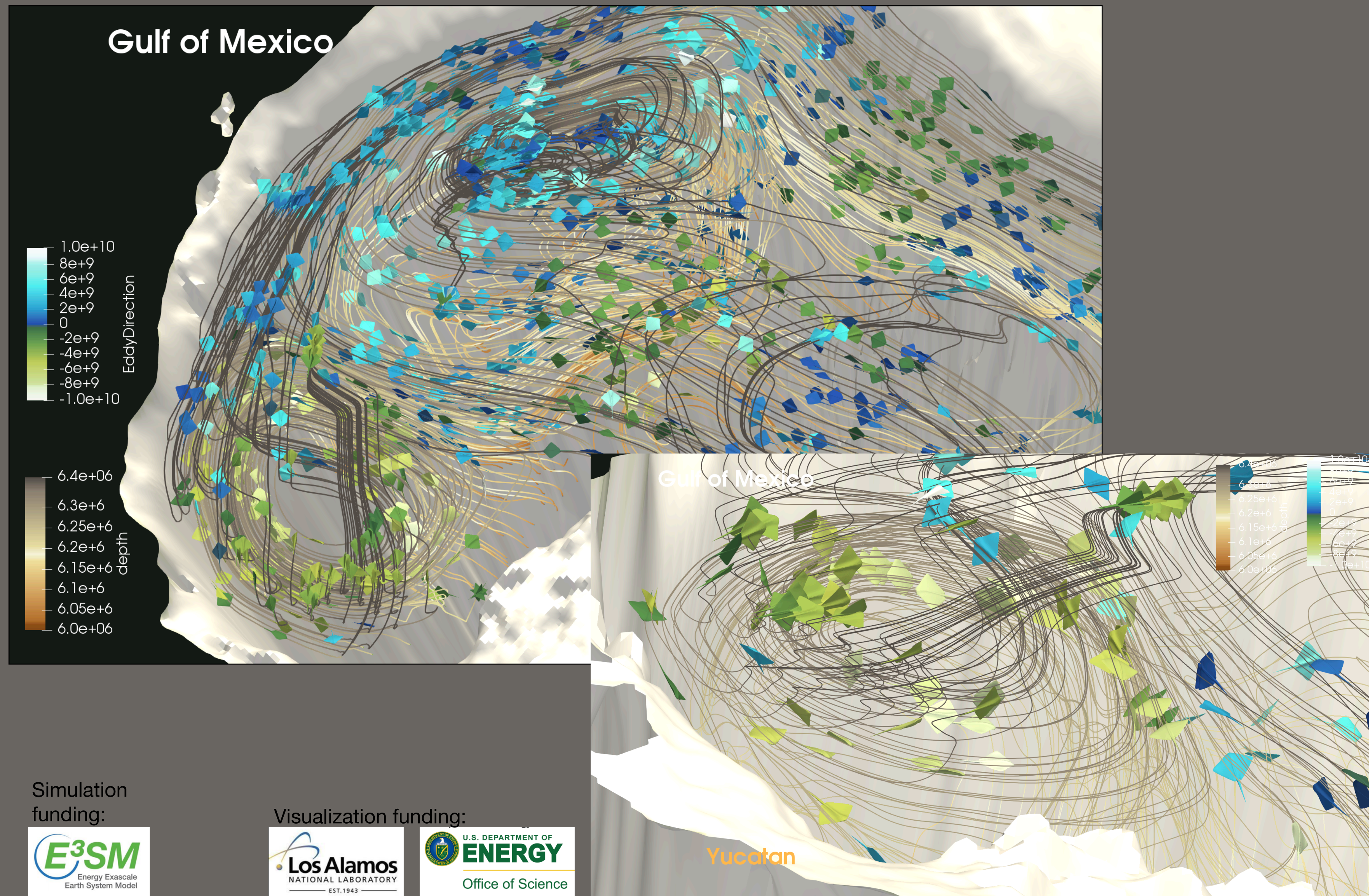


2D representation of sampled Gulf of Mexico biogeochemistry data

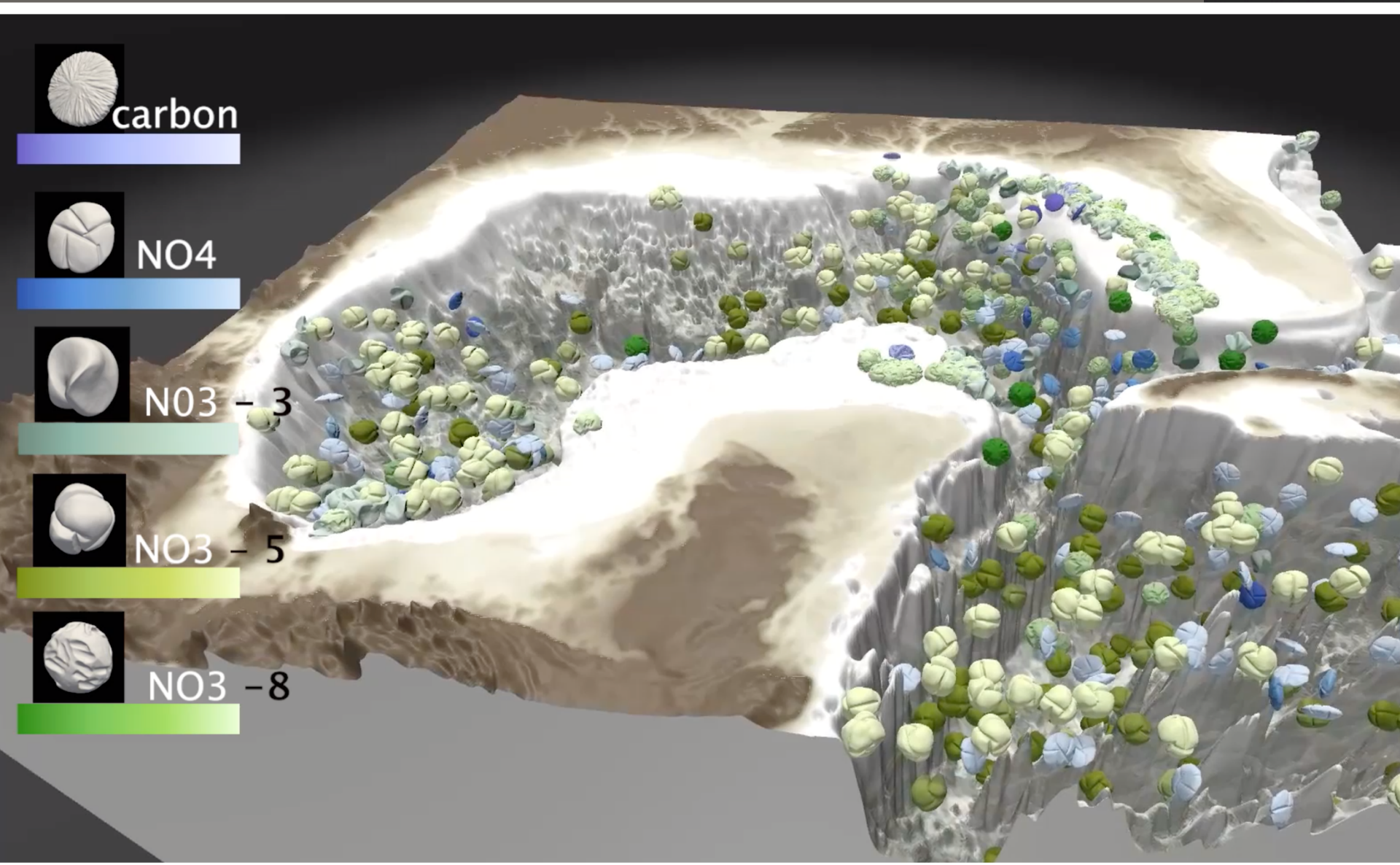


sampling enabling multiple volumetric data variables to be rendered
clearly in a 3D representation

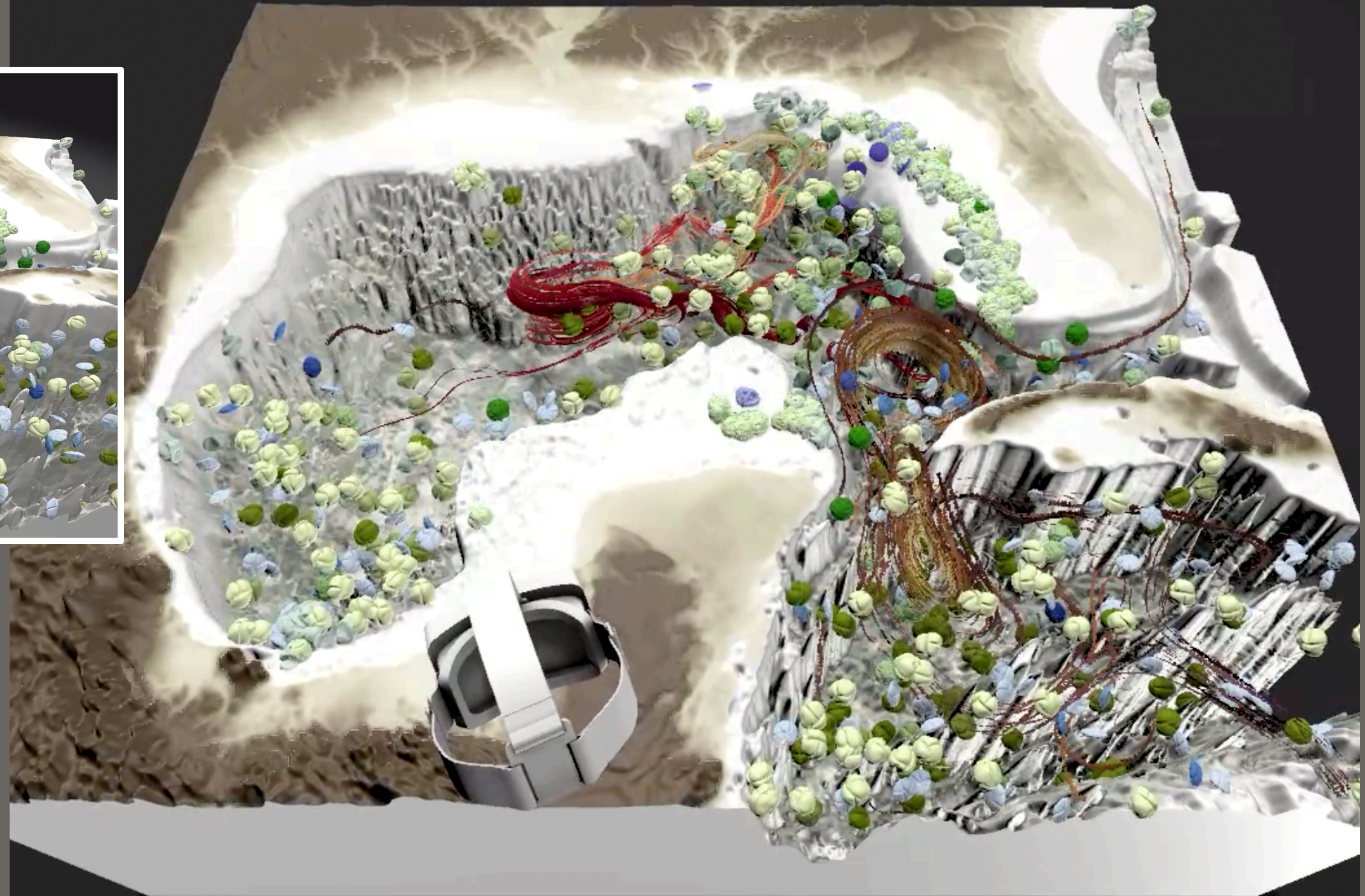
Assisting understanding of the depth changes and vector orientation



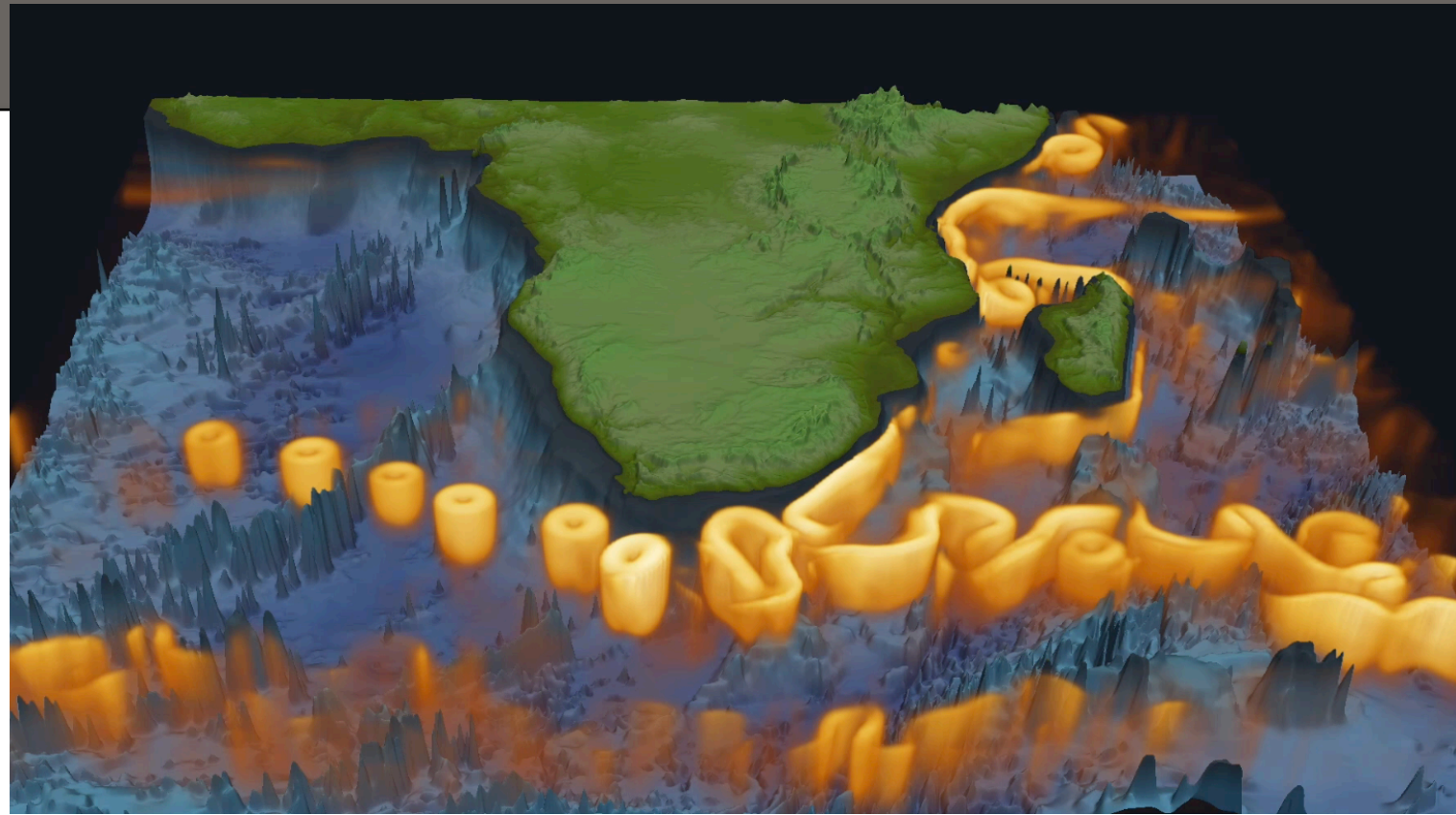
Gulf of Mexico



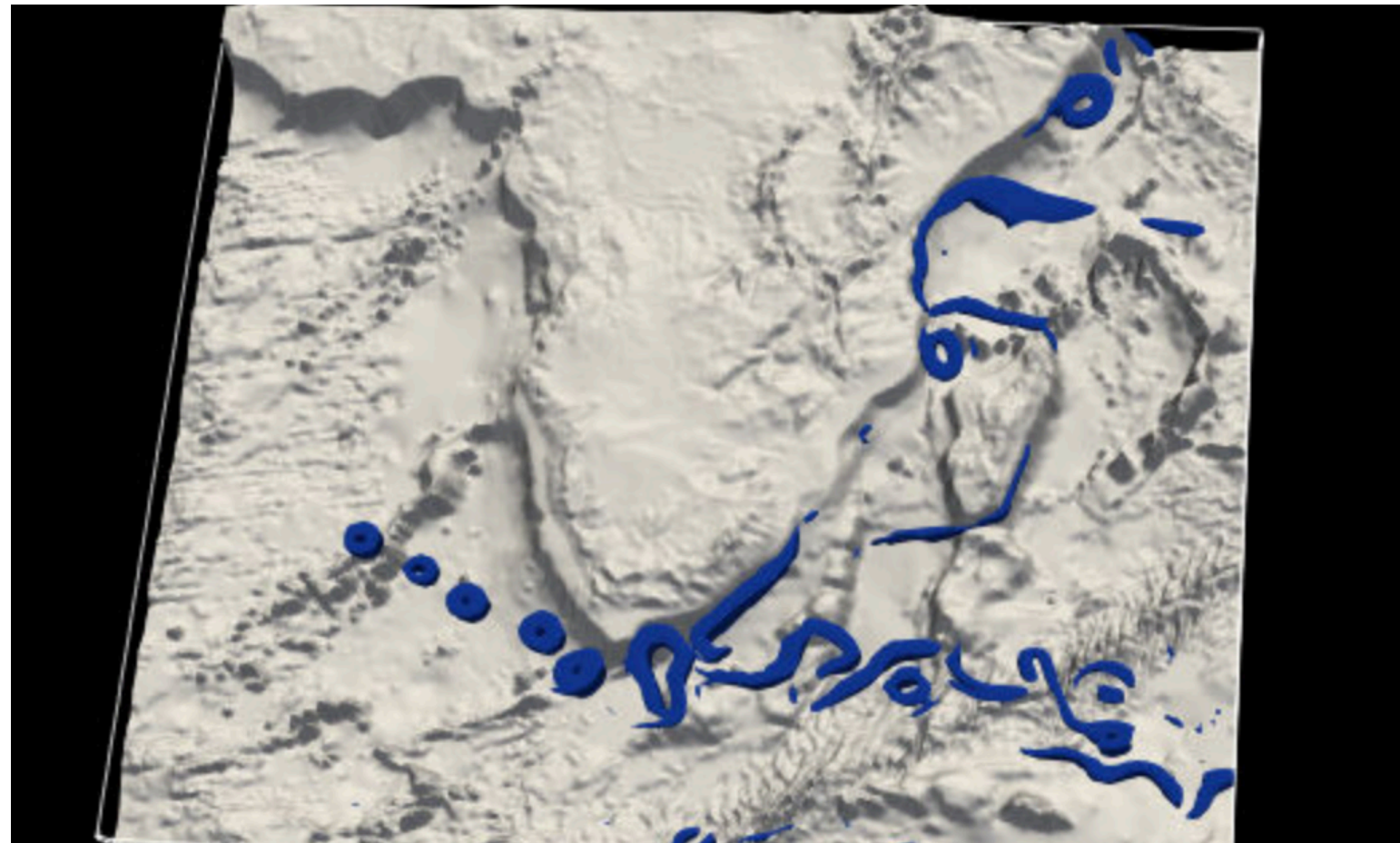
Future Work



Augmented Reality (MagicLeap)



Agulhaus current, kinetic energy



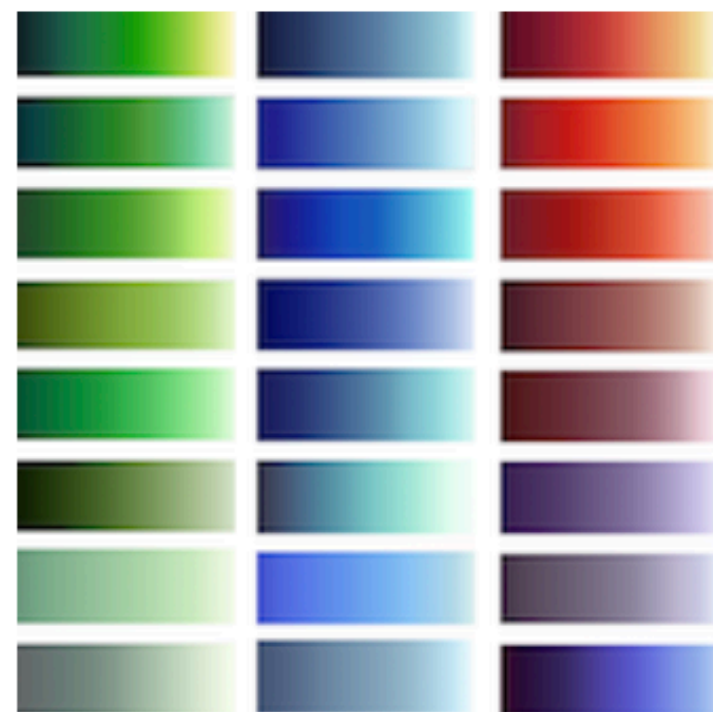
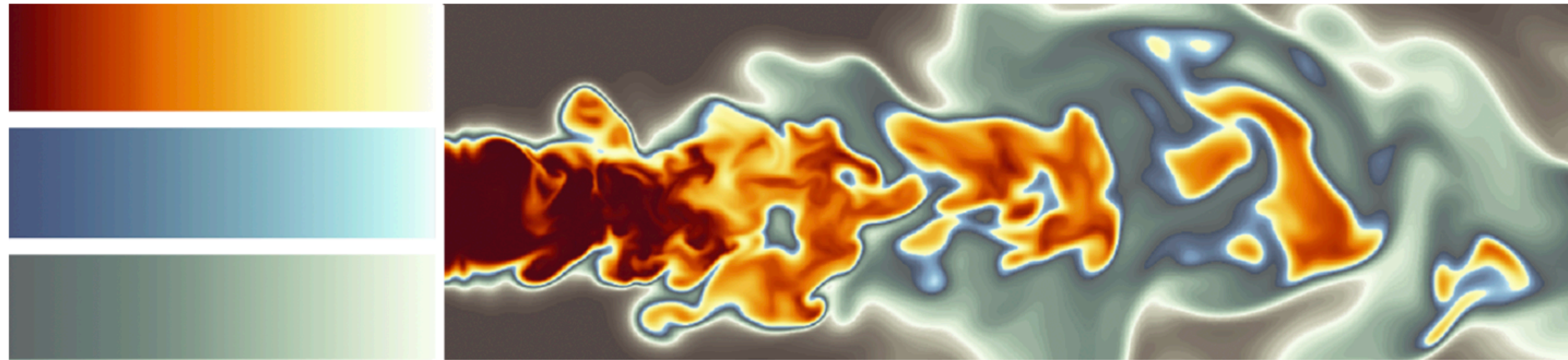
digitally printed
bathymetry

AR rendering of time-varying kinetic energy (blue).

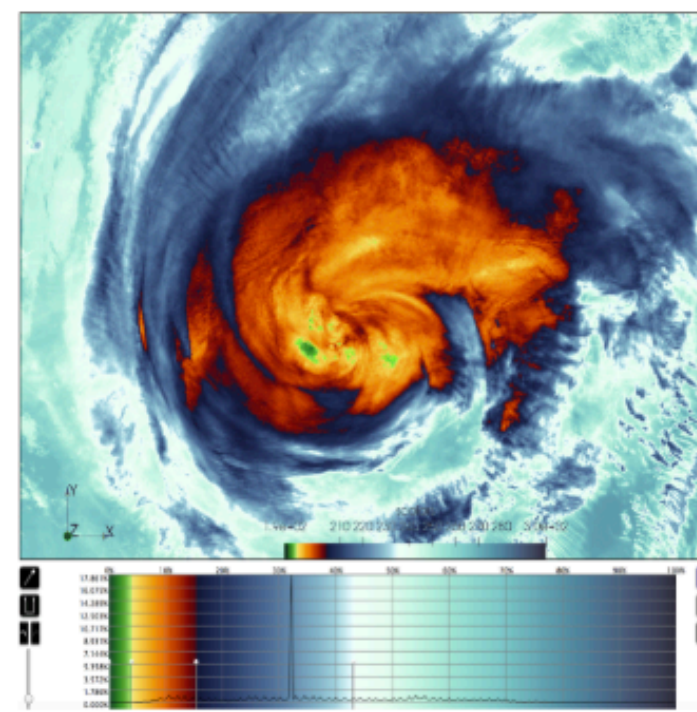


phone interface

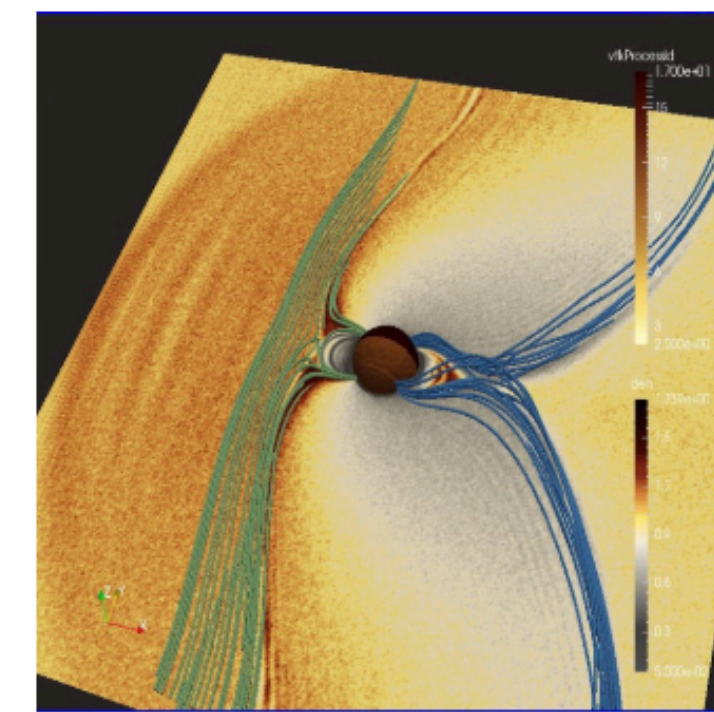
SciVisColor: Color Tools and Strategies for Scientific Visualization



Colormaps



ColorMoves

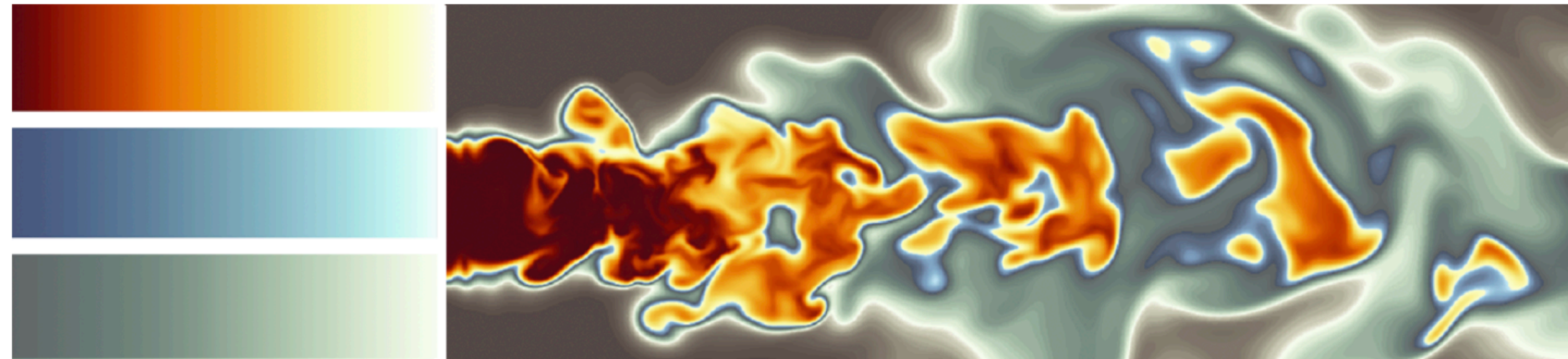


Color Sets

SciVisColor.org

SciVisColor.org

SciVisColor: Color Tools and Strategies for Scientific Visualization



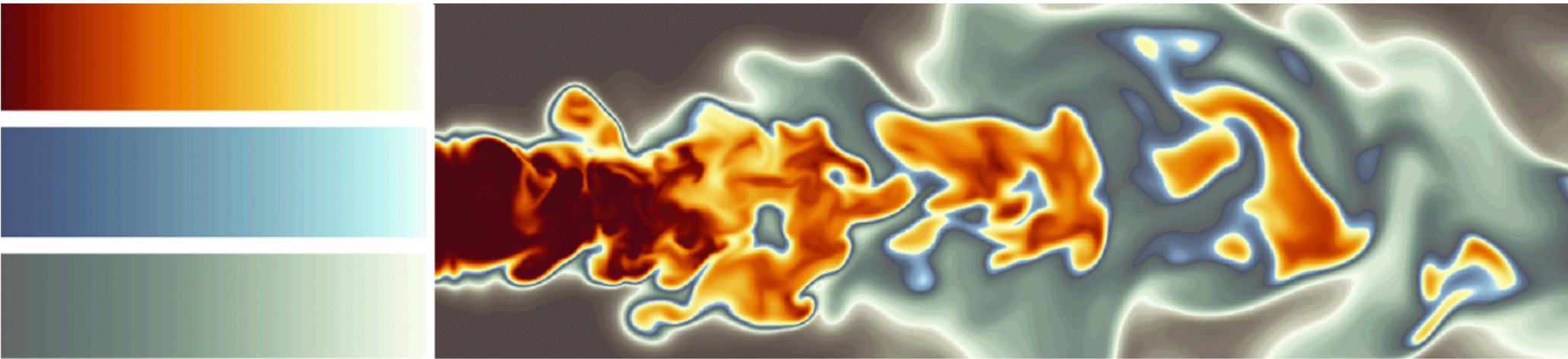
The site today
Plans in the works

Overhaul the summer...

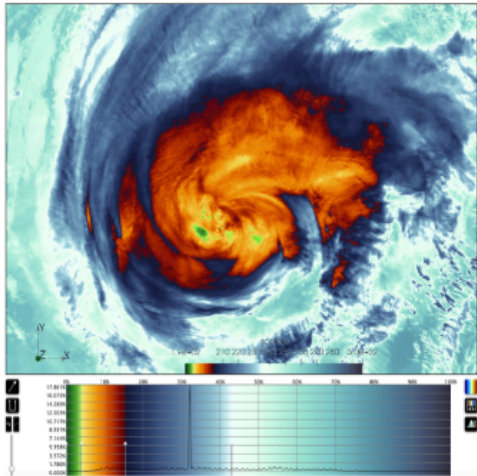
Your suggestions / requests please!

fsamsel@tacc.utexas.edu stephaniezeller@utexas.edu

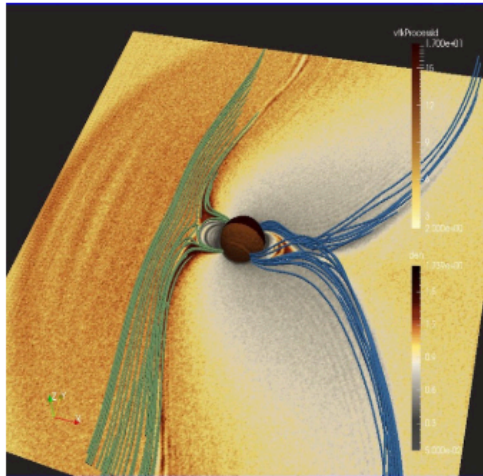
SciVisColor: Color Tools and Strategies for Scientific Visualization



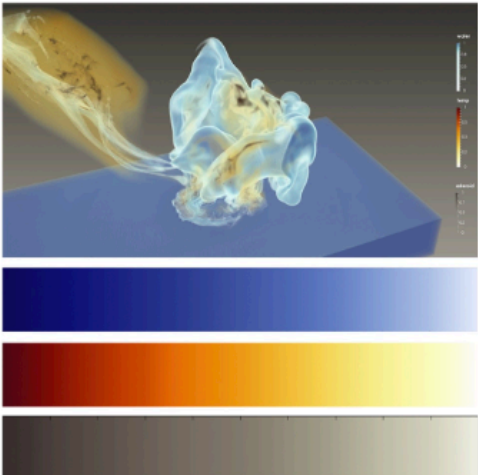
Colormaps



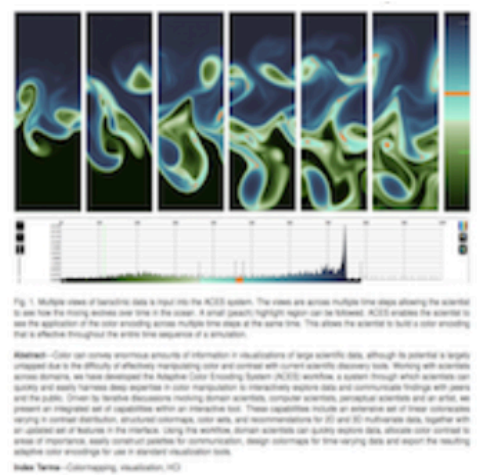
ColorMoves



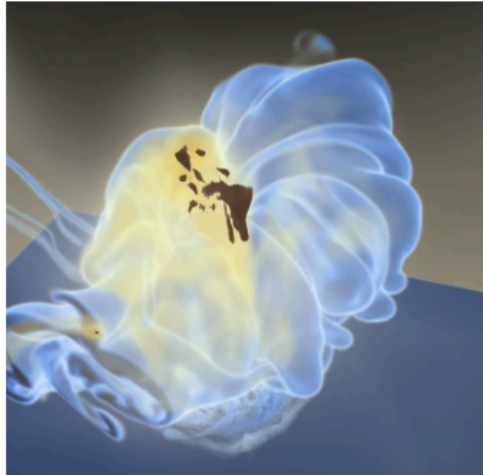
Color Sets



Color Strategies



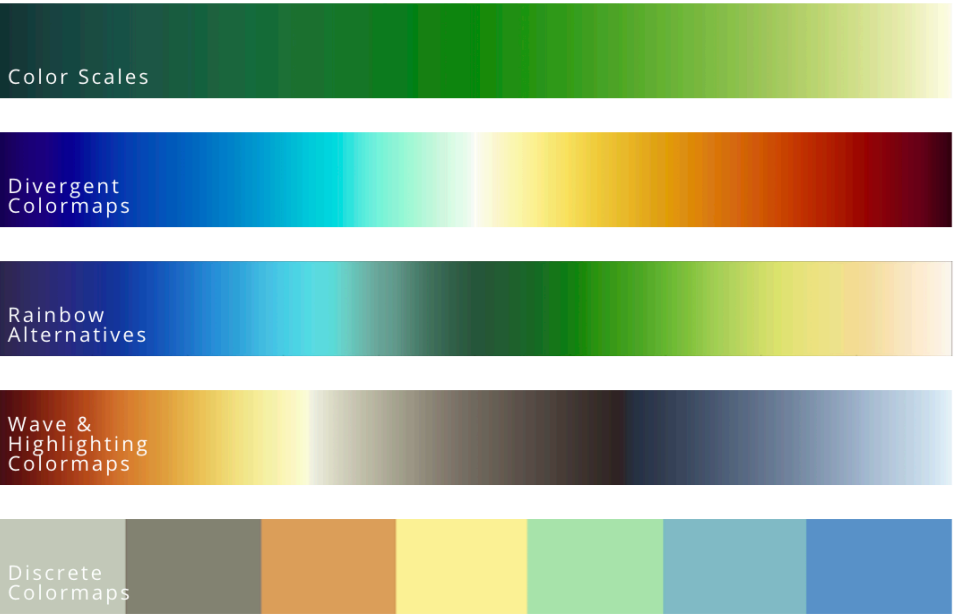
Publications



Tutorials

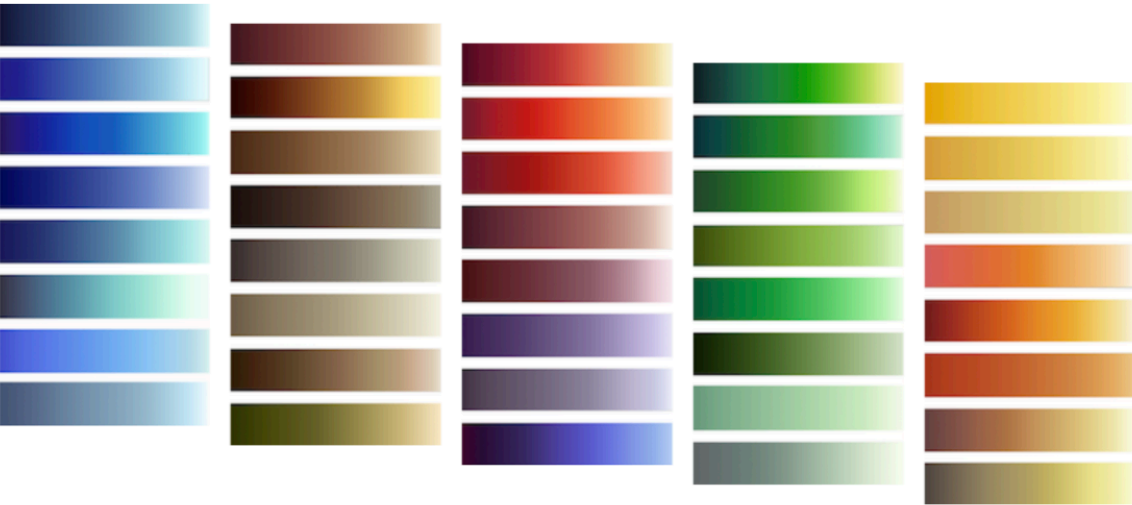
Colormaps

Click on the type to see the range of maps available. To download a selection of key colormaps: [\(zip\)](#)
Matplotlib and MATLAB users click [here](#) for instructions on using these colormaps.



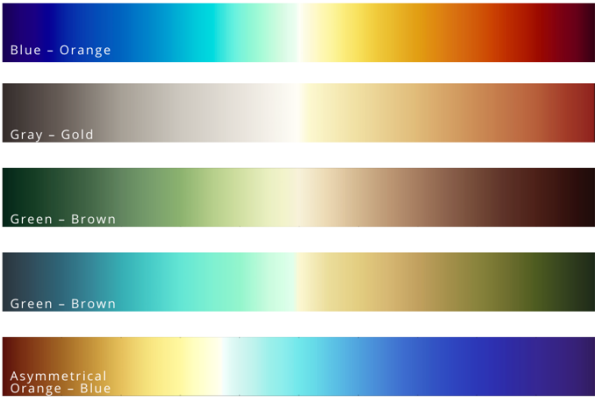
ColorScales

Click on a hue range to go to its page
XML files are available for all of the color scales shown here.



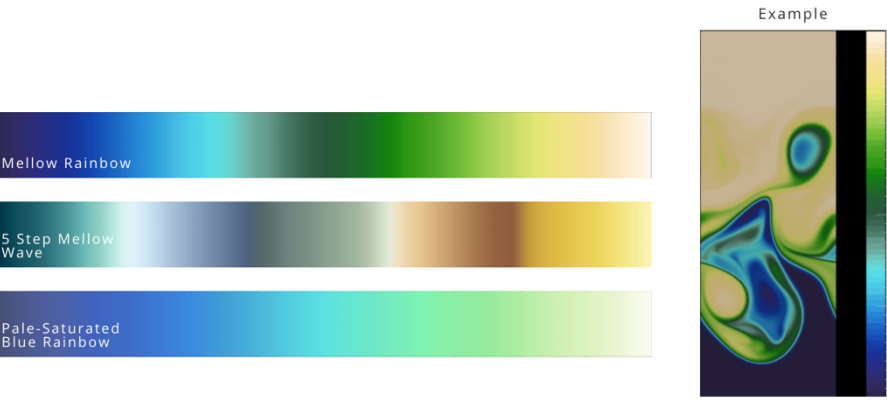
Divergent Colormaps

Contrasting Color Scales
(Click the colormap to download its .xml file)



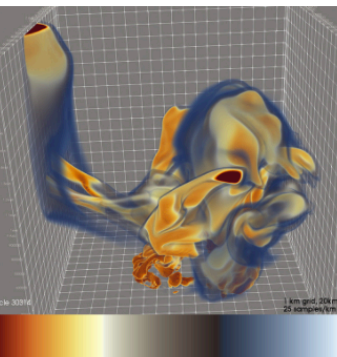
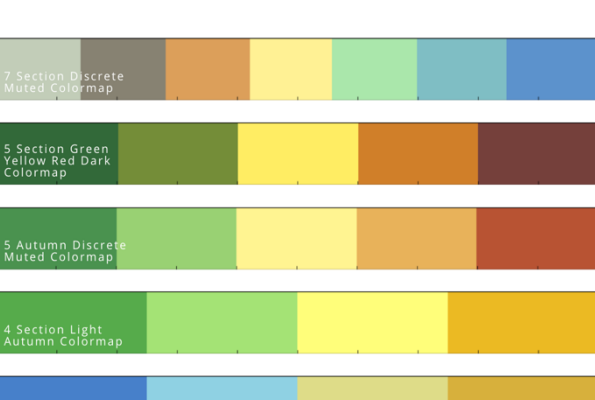
Rainbow Alternatives

(Click the colormap to download its .xml file)

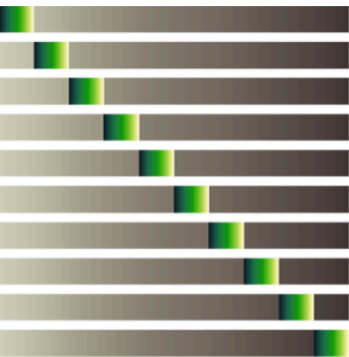


Discrete Colormaps

(Click the colormap to download its .xml file)

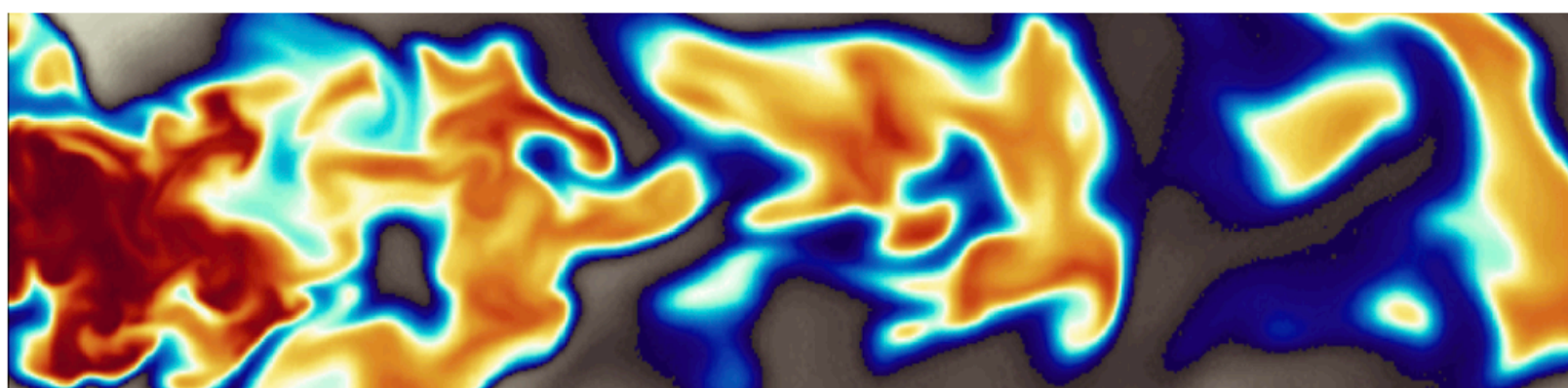


Wave Colormaps



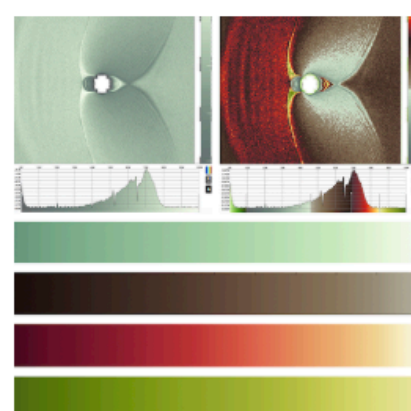
Highlight Inserts

ColorMoves – An Interactive Colormap Construction Tool

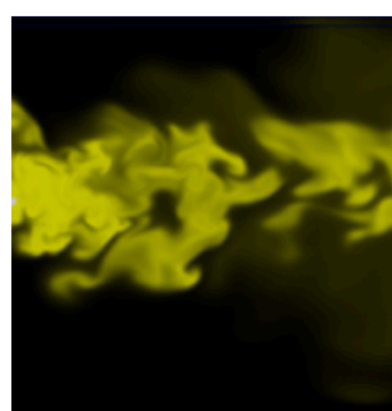


IEEE – ColorMoves: An Interactive Tool that Visualizes Scientific Data in a Colorful, Artistic, and Transformative Way

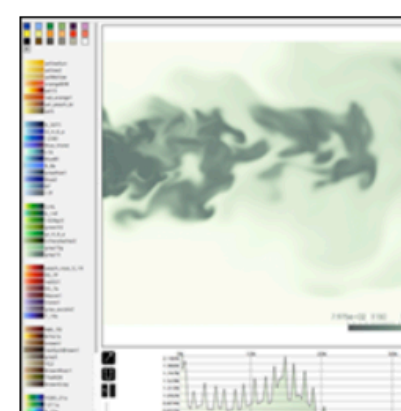
ColorMoves [GitHub](#)



ColorMoves Instructions



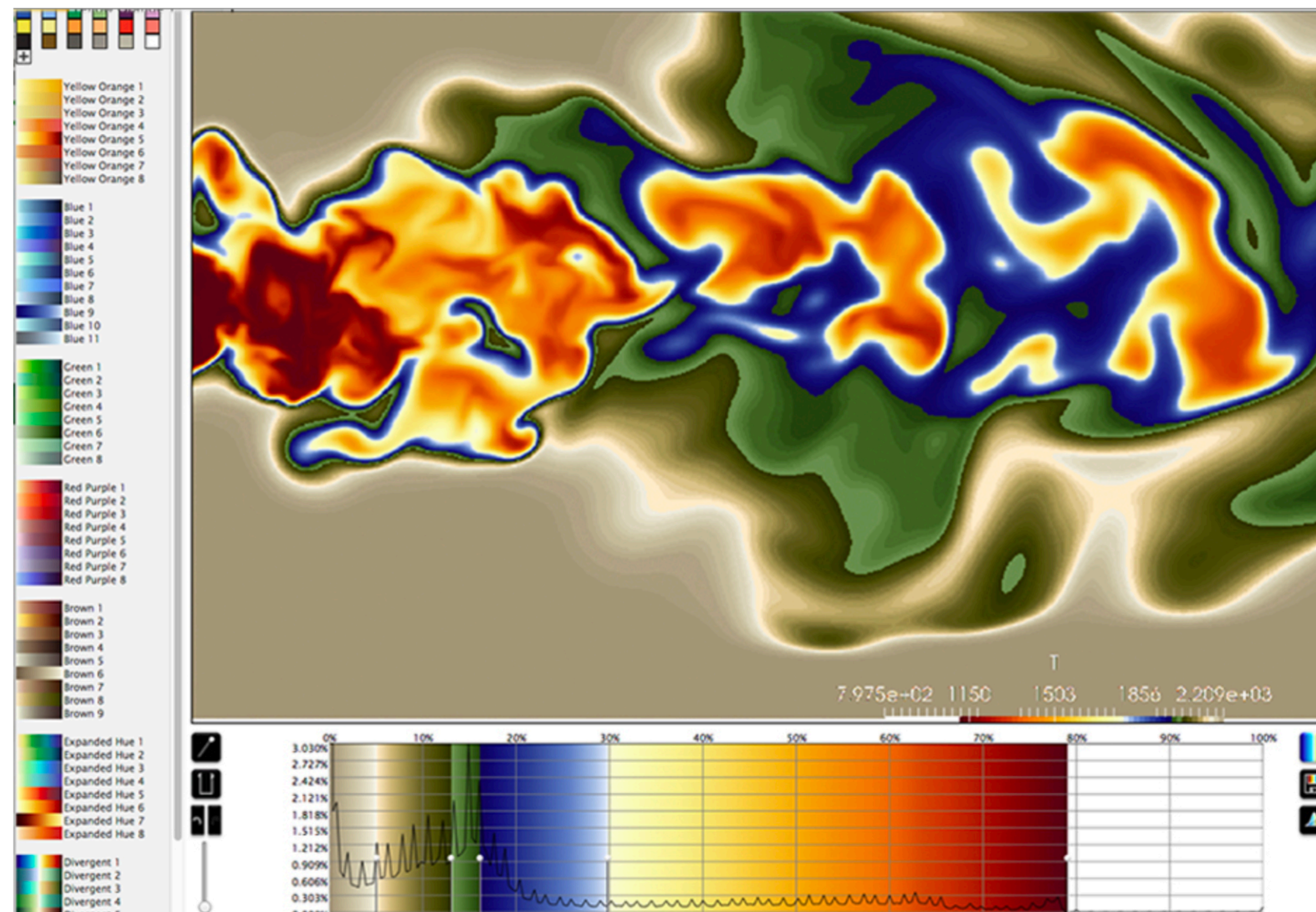
Float Files Instructions
Download Examples



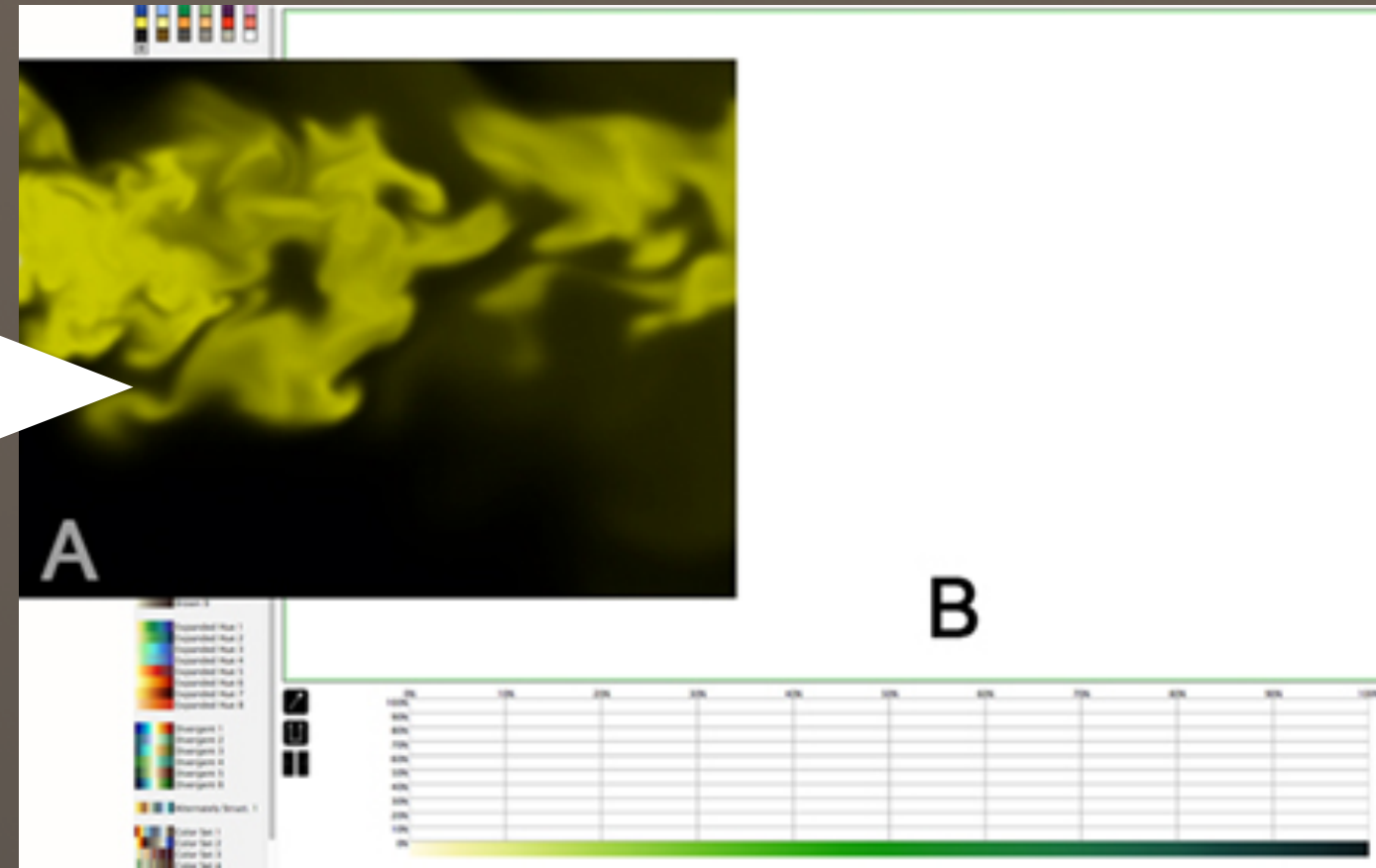
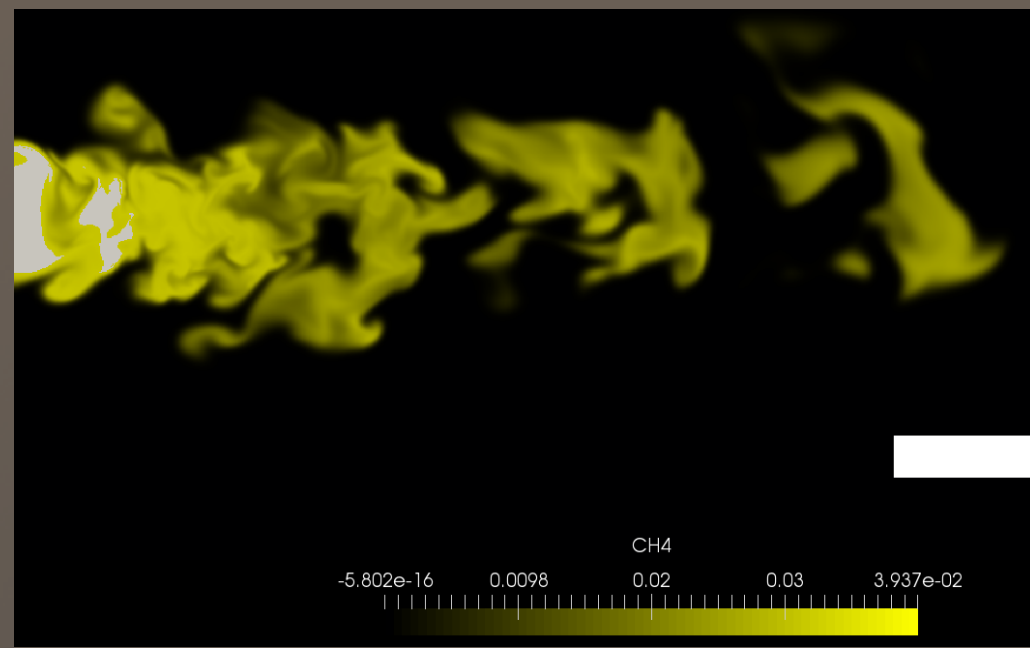
[CLICK HERE TO USE COLORMOVES!](#)

SciVisColor.org

Creating Custom Colormaps

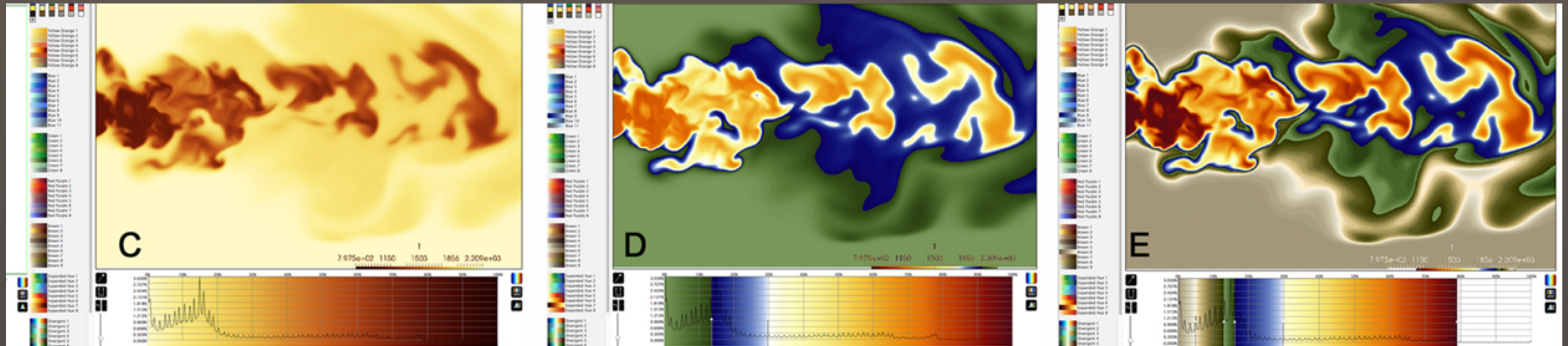


ColorMoves



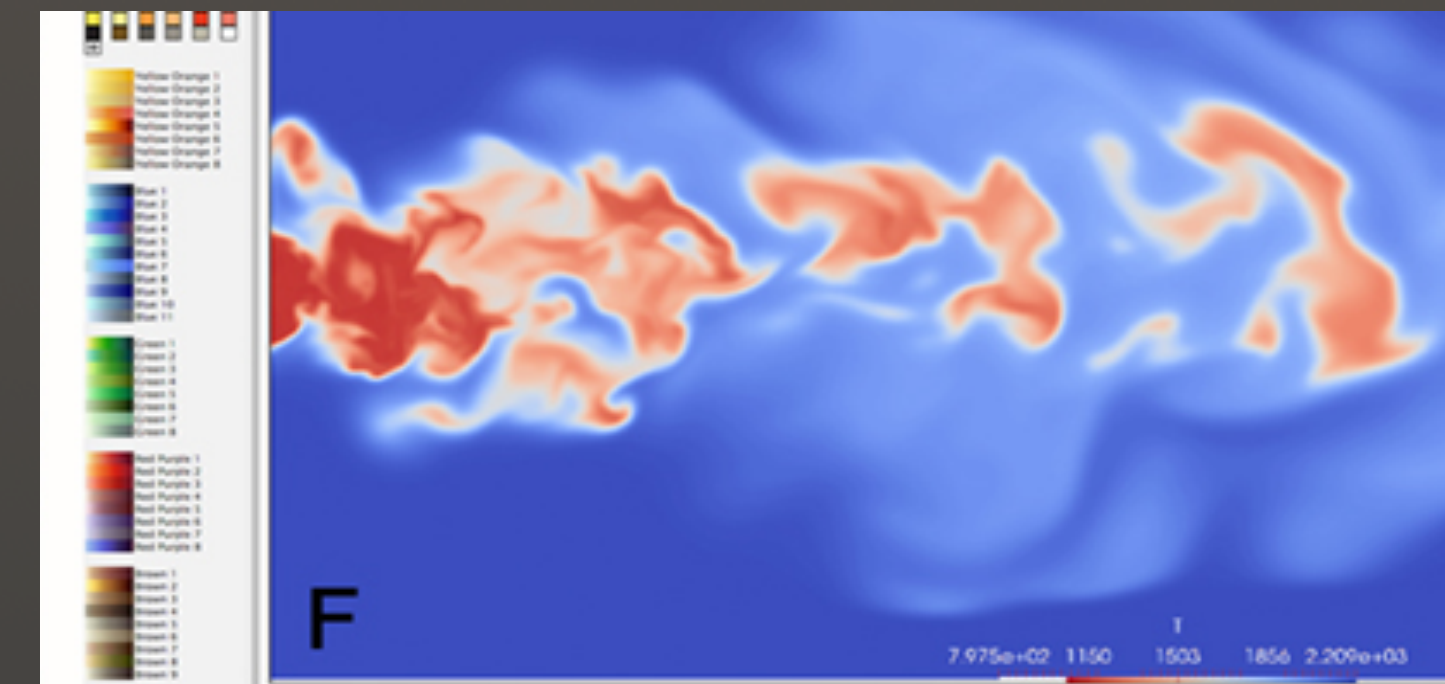
ColorMoves

SciVisColor.org



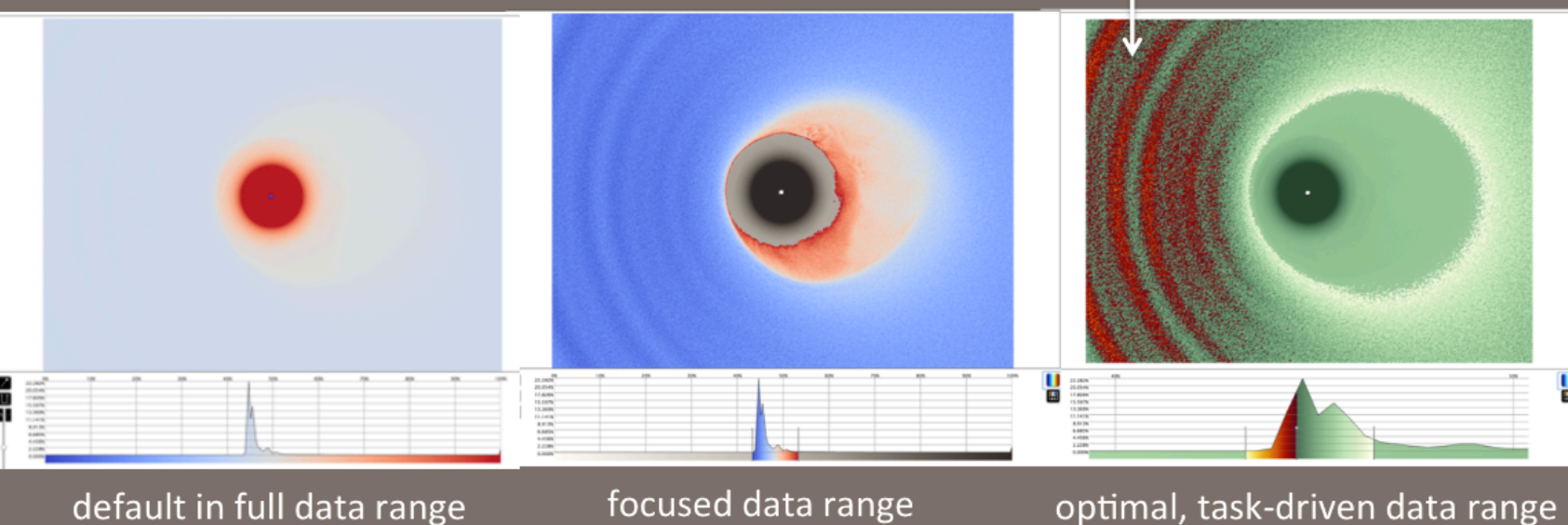
Constructing colormaps tuned to the data structures and visualization tasks.

Commonly used
cool warm colormap



Honing the data range

bow fronts of interest

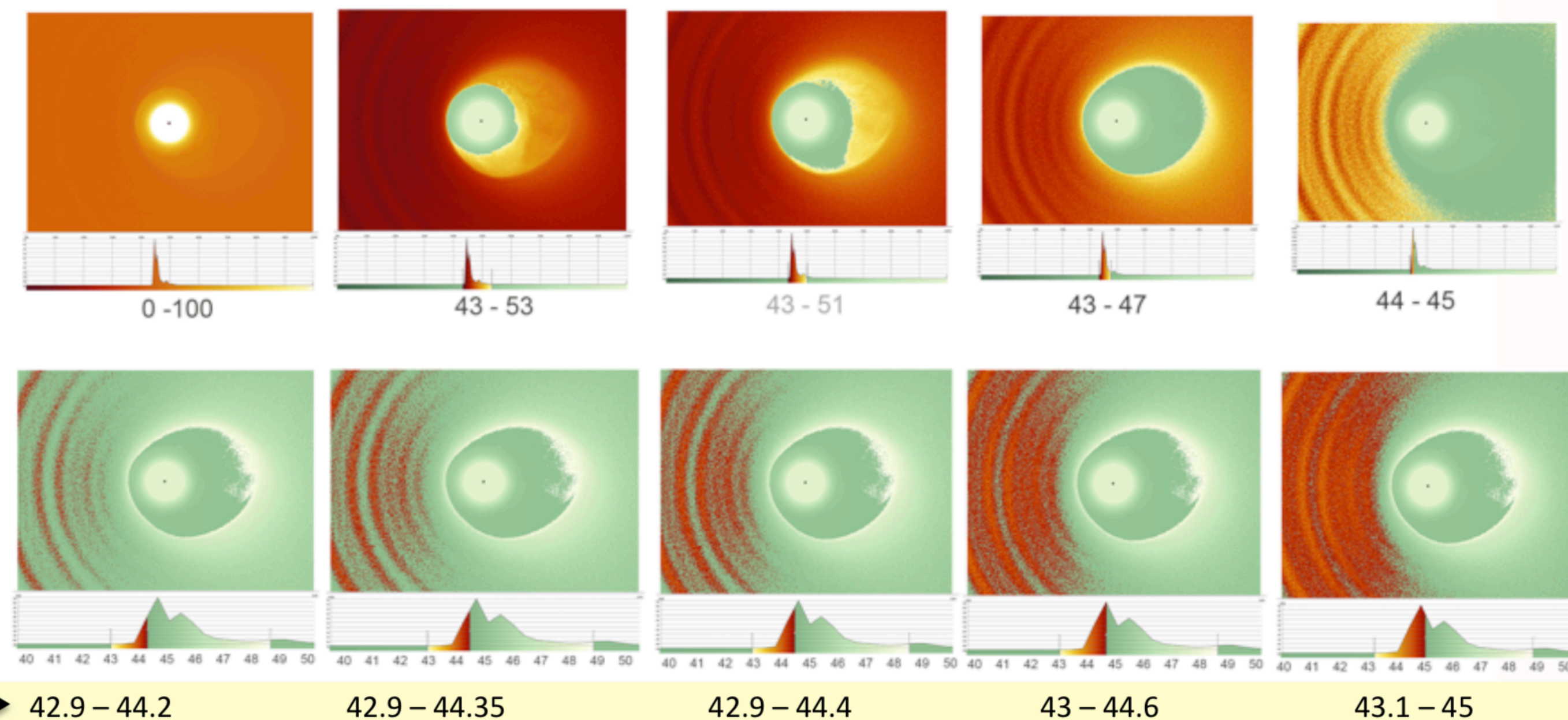


H3D Ganymede bow fronts
Daughton, LANL

ColorMoves

The power of interactivity

Finding the optimal data range









The interactivity enables the fidelity of control.

Expanding the range of color resources

Prepping for Automation of colormap guidance

Step 1: Organizing the selections

	red	orange	yellow	green	turquoise	blue	purple
clear							
low sat							
med sat							
high sat							
cool							

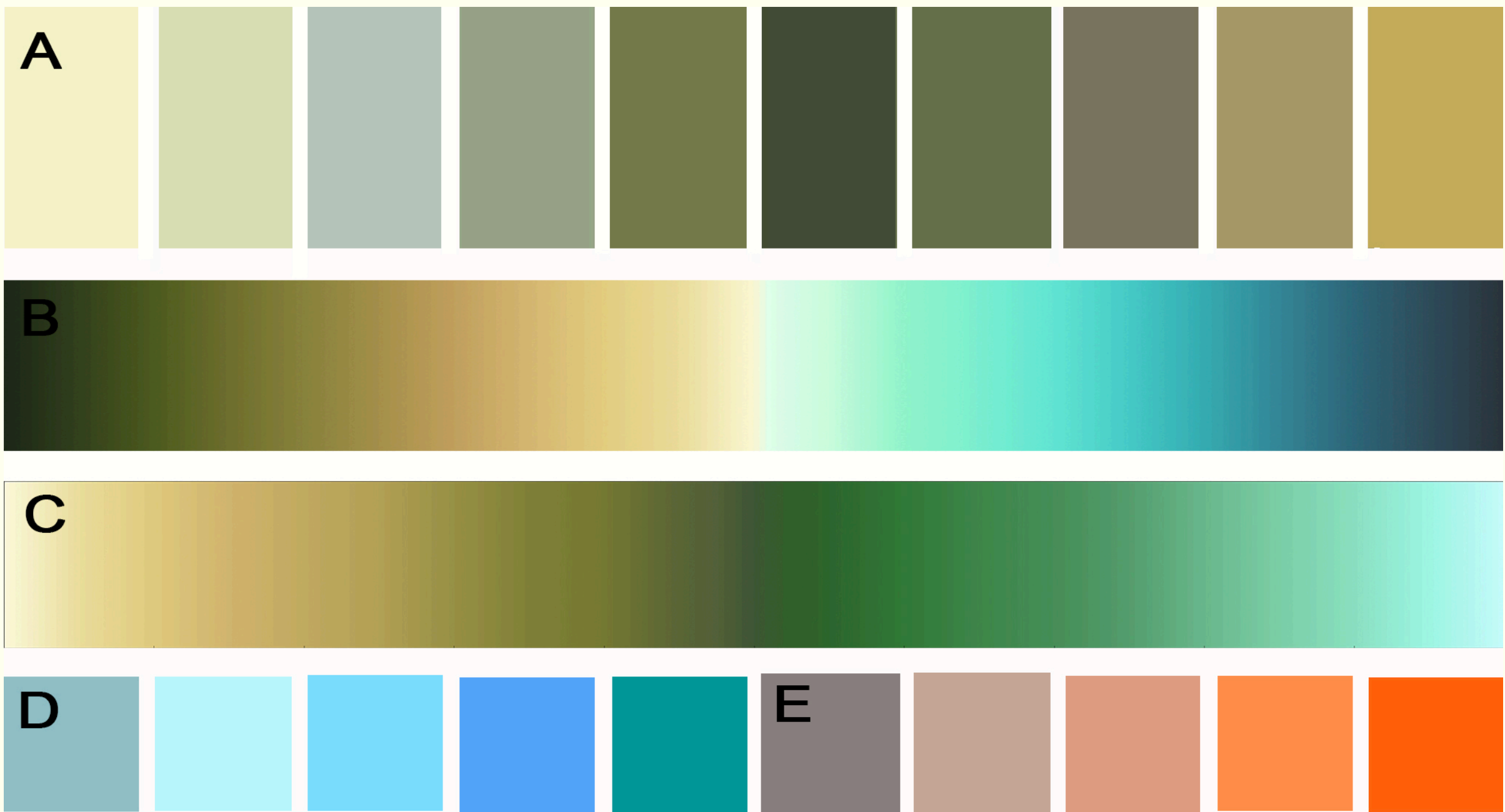


Next Steps in Color:

1. Color Sets for 3D multivariate visualization
2. Automation

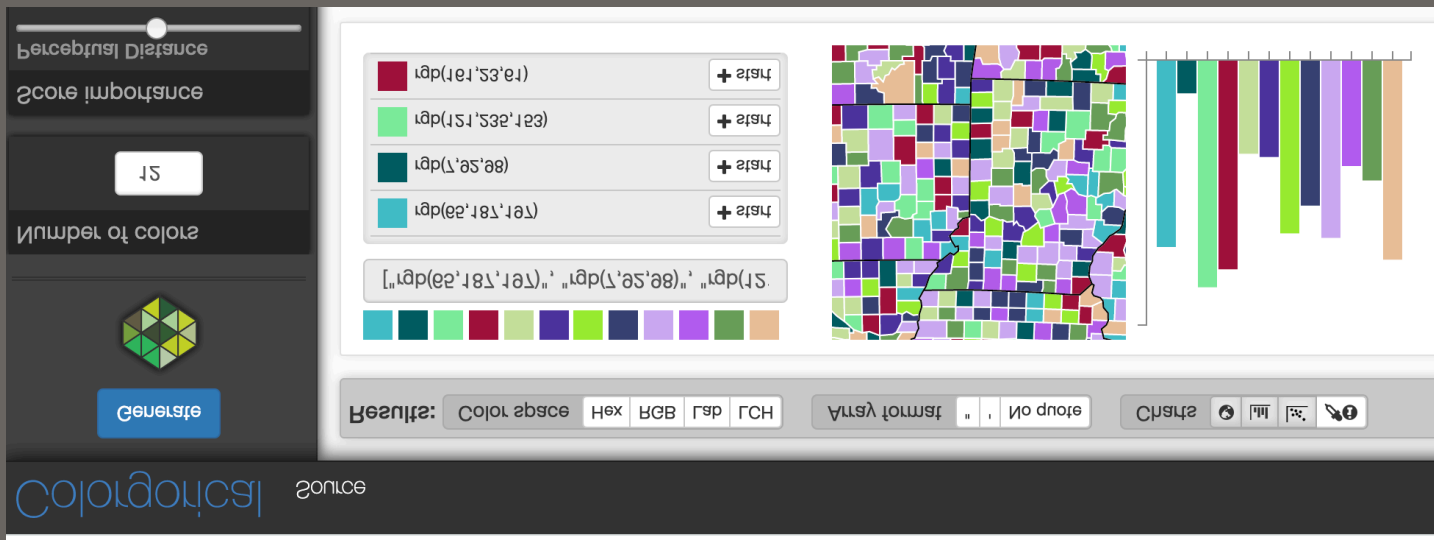
3D multivariate visualization...

To that end – color sets
3D vis sampling



It takes a village,
so we are assembling one!

Art, design, perception,
cognition, mathematics,
computer science, machine learning



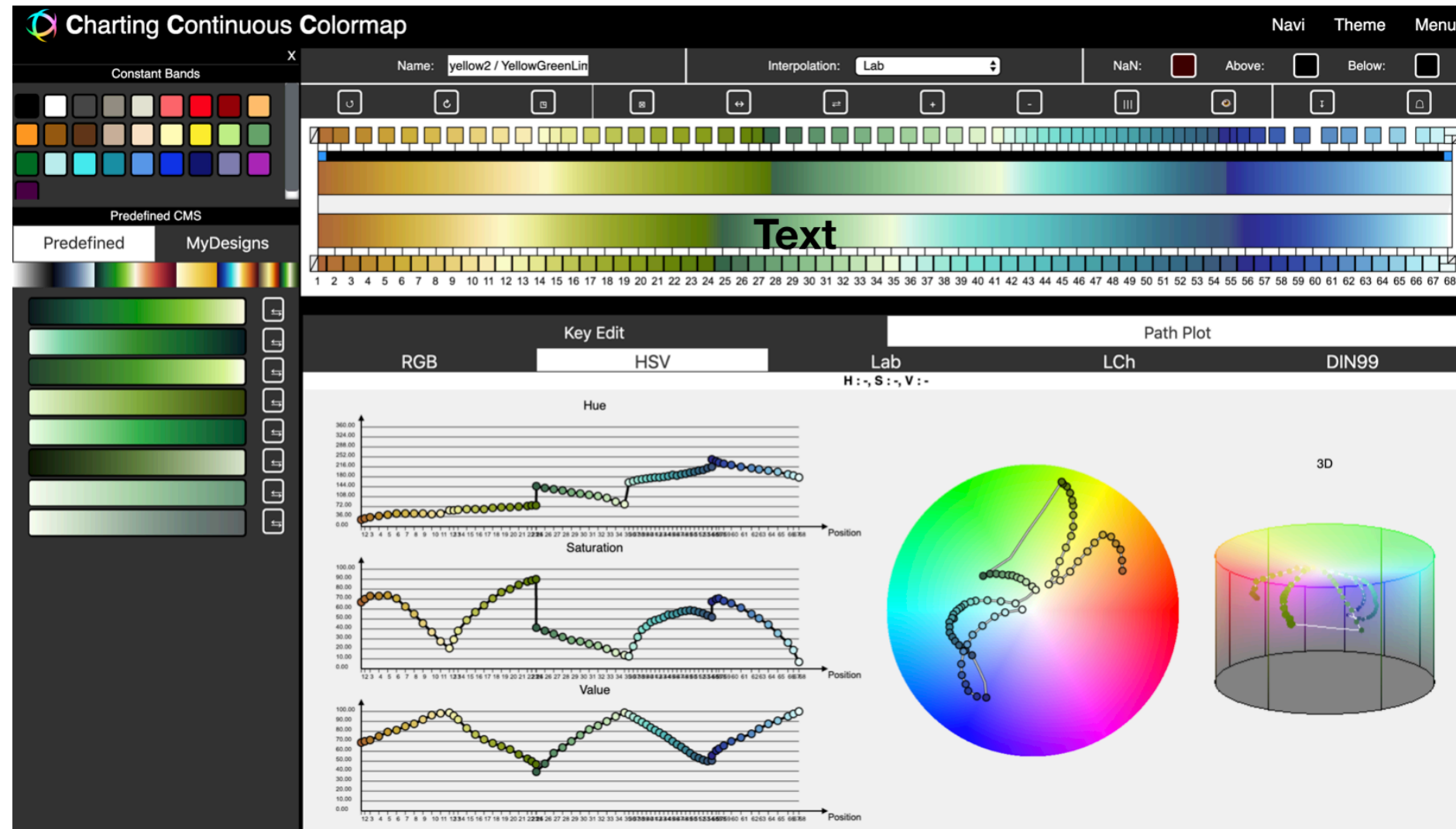
Color Tools of Interest

The Making of Continuous Colormaps

P. Nardini, M. Chen, *Member, IEEE*, F. Samsel, R. Bujack, M. Böttinger, and G. Scheuermann, *Member, IEEE*

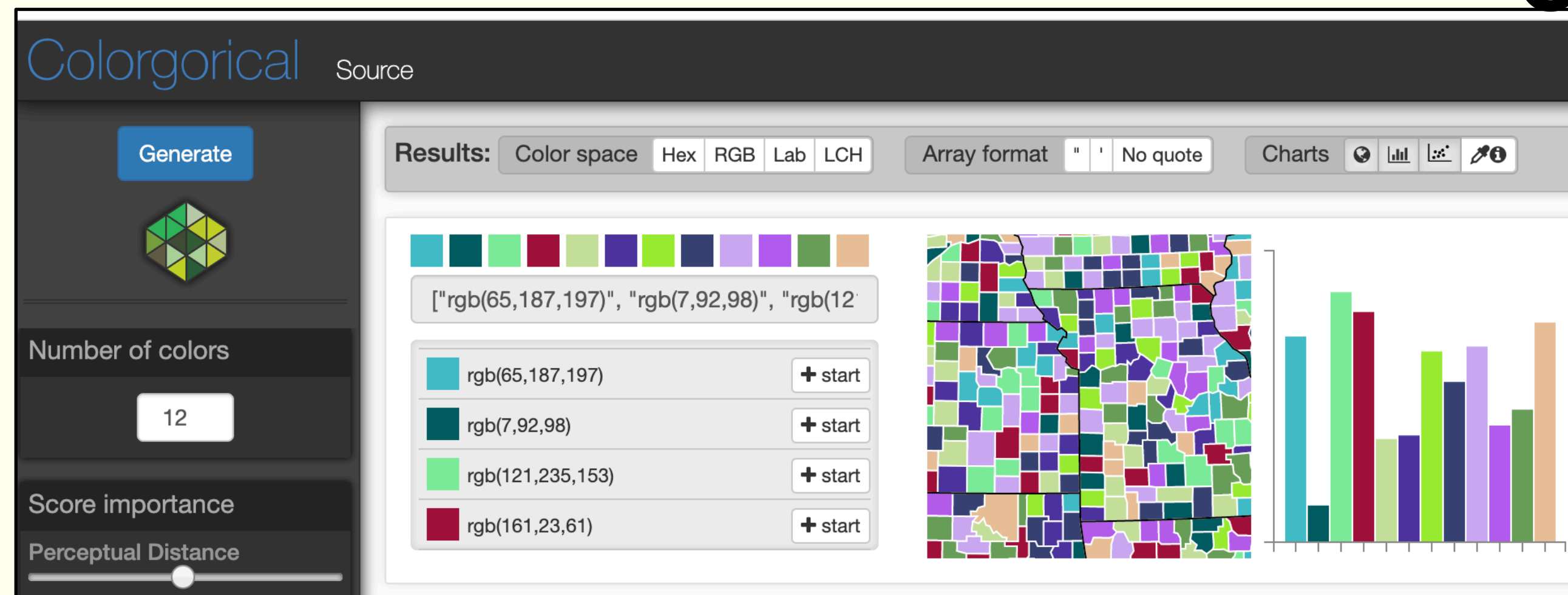
Abstract—Continuous color maps are integral parts of many visualization techniques, such as heat-maps, surface plots, and flow visualizations. Despite that the critiques of rainbow color maps have been around and well-acknowledged for three decades, rainbow color maps are still widely used today. One reason behind the resilience of rainbow color maps is the lack of tools for analyzing a color map and its quality attributes. In this paper, we present CCC-Tool, a web-based tool for analyzing a color map and its quality attributes. CCC-Tool is a part of the CCC-Tool system. CCC-Tool (short for Charting Continuous Colormaps) under the URL <http://ccc-tool.com>, for creating, editing, and creating such application-specific color maps. We introduce the notion of "colormap specification (CMS)" that maintains the essential semantics required for defining a color mapping scheme. We provide users with a set of advanced utilities for constructing CMSs with various levels of abstraction, exporting their quality attributes to different plots, and exporting the CMS to external application software. We present two case studies, demonstrating that the CCC-Tool can help domain scientists as well as visualization experts in designing semantically-rich color maps.

Index Terms—CCC-Tool, charting continuous colormaps, colormap specification, perceptual uniformity, colormap analysis.



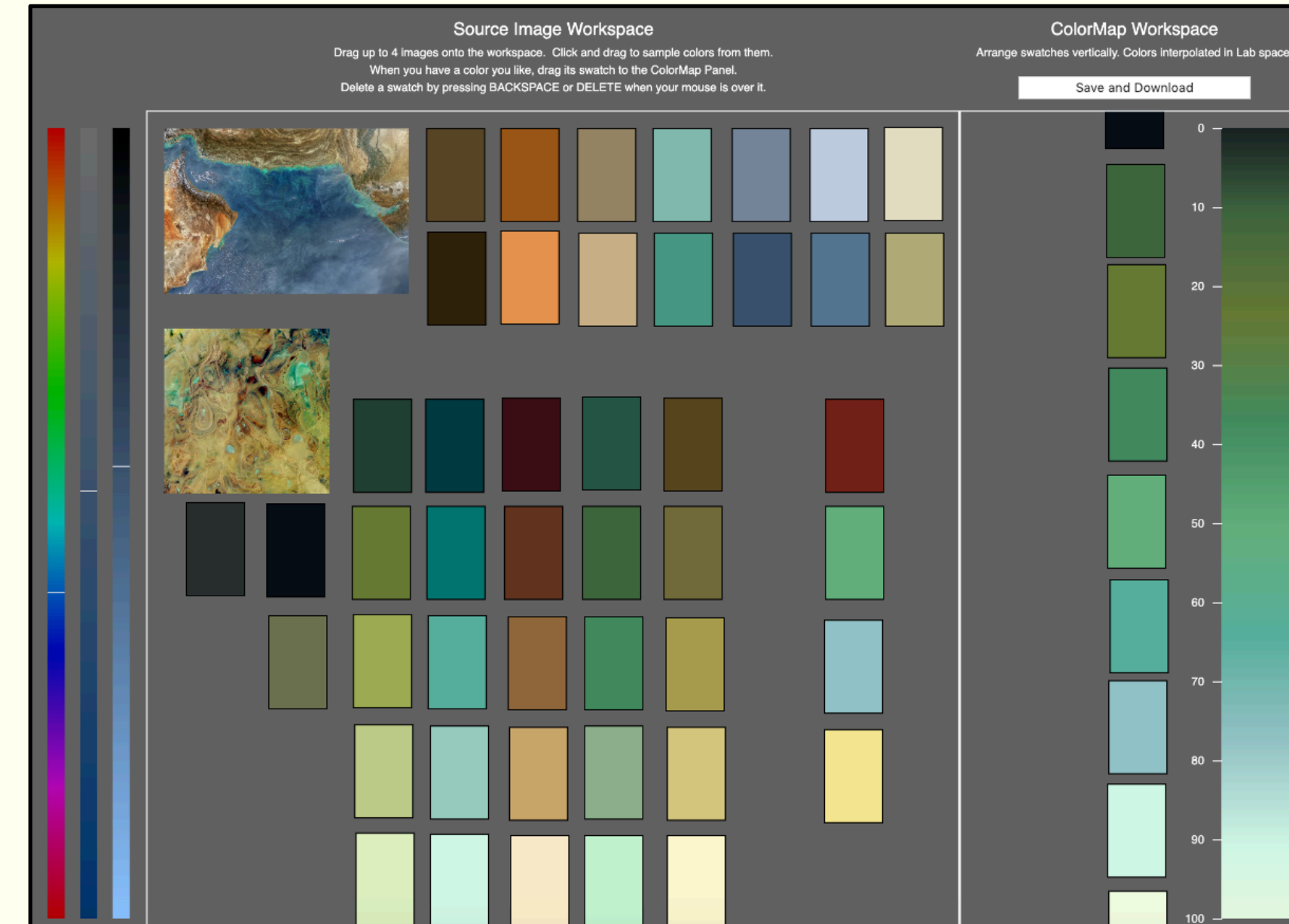
CCCTool

Pascal Nardini



ColorLoom

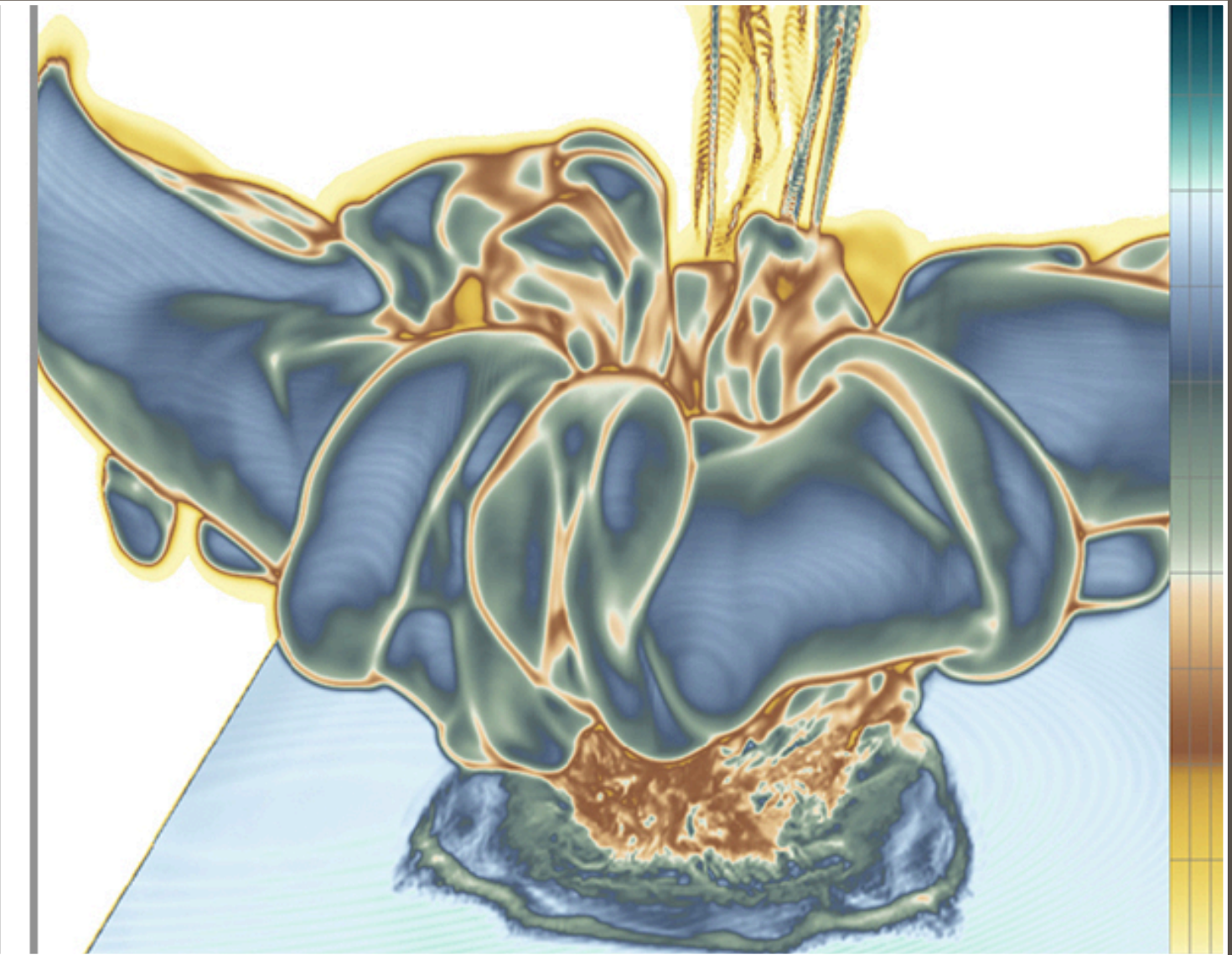
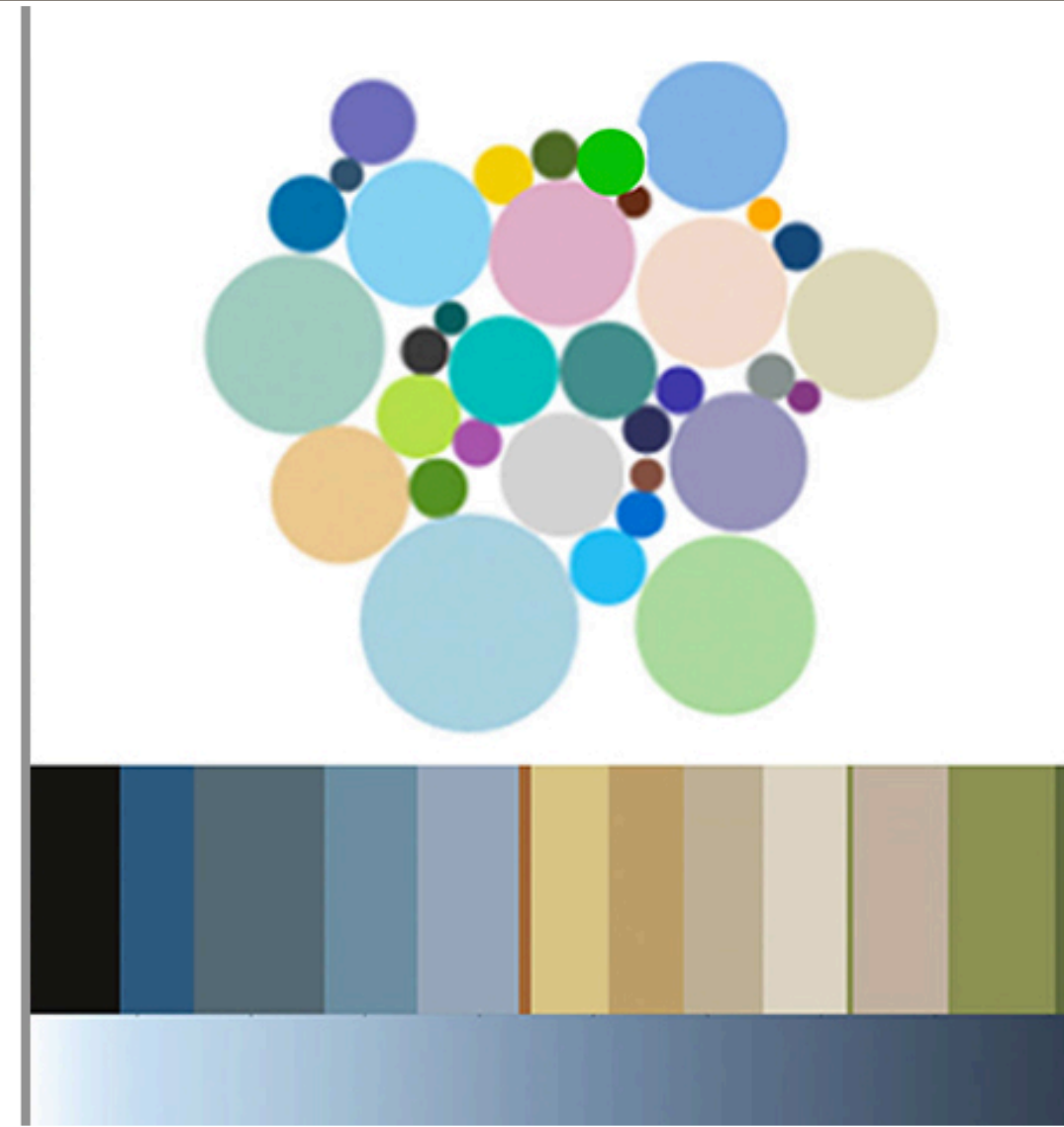
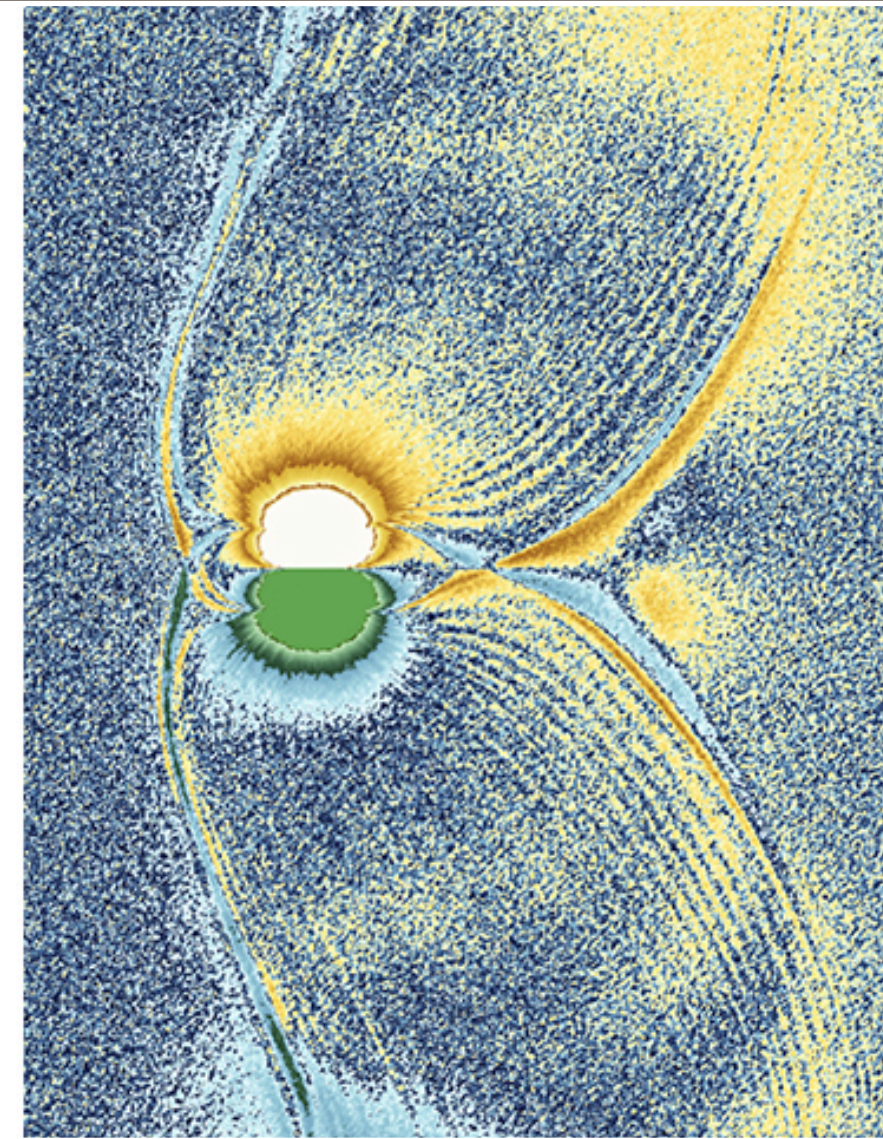
Daniel Keefe



Colorgorical

Karen Schloss

Art, Affect and Color: Creating Engaging Expressive Scientific Visualizations



Francesca Samsel
University of Texas at Austin

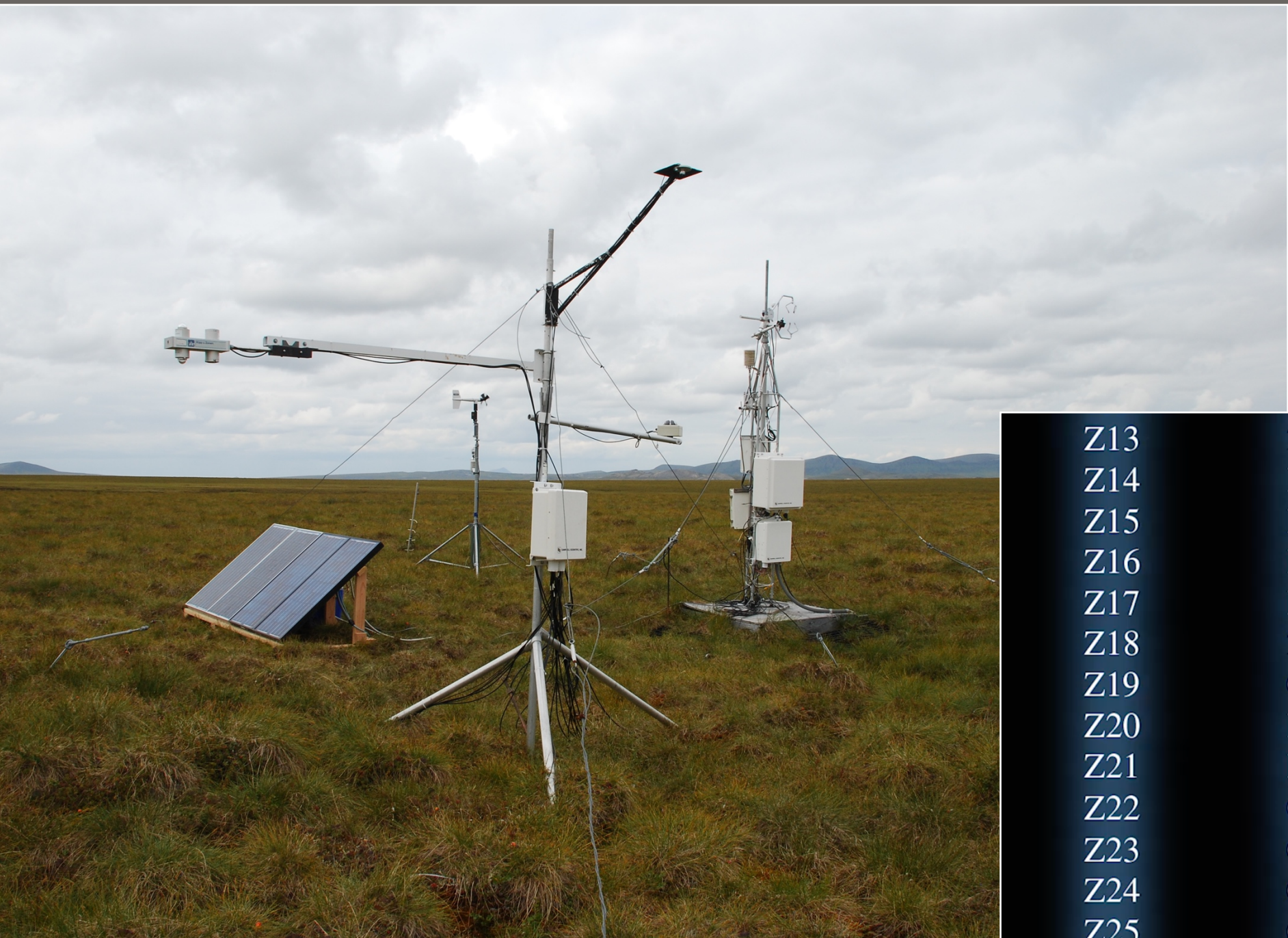
Lyn Bartram
Simon Fraser University

Annie Bares
University of Texas at Austin

Most *read* publication

IEEE VIS 2018 - VISAP

1. How was the data collected?



Tell a story

2. What goes into making the simulation?

Z13	$2\text{OH} \rightarrow \text{H}_2\text{O} + \text{O}$	$k_{Z13} = 1.65 \times 10^{-12} (T/300\text{K})^{1.14} \exp(-50/T)$	M97
Z14	$\text{H}^+ + \text{OH} \rightarrow \text{OH}^+ + \text{H}$	$k_{Z14} = 2.10 \times 10^{-9}$	M97
Z15	$\text{H}^+ + \text{H}_2\text{O} \rightarrow \text{H}_2\text{O}^+ + \text{H}$	$k_{Z15} = 6.90 \times 10^{-9}$	M97
Z16	$\text{H} + \text{OH} \rightarrow \text{H}_2 + \text{O}$	$k_{Z16} = 7.00 \times 10^{-14} (T/300)^{2.80} \exp(-1950/T)$	M97
Z17	$\text{H} + \text{H}_2\text{O} \rightarrow \text{OH} + \text{H}_2$	$k_{Z17} = 6.83 \times 10^{-12} (T/300)^{1.60} \exp(-9720/T)$	M97
Z18	$2\text{O} \rightarrow \text{O}_2 + \gamma$	$k_{Z18} = 4.90 \times 10^{-20} (T/300)^{1.58}$	M97
Z19	$\text{O} + \text{OH} \rightarrow \text{O}_2 + \text{H}$	$k_{Z19} = 4.34 \times 10^{-11} (T/300)^{-0.50} \exp(-30/T)$	M97
Z20	$\text{H} + \text{O}_2 \rightarrow \text{OH} + \text{O}$	$k_{Z20} = 3.30 \times 10^{-10} \exp(-8460/T)$	M97
Z21	$\text{H}^+ + \text{O}_2 \rightarrow \text{O}_2^+ + \text{H}$	$k_{Z21} = 2.00 \times 10^{-9}$	M97
Z22	$\text{O}_2^+ + \text{e} \rightarrow 2\text{O}$	$k_{Z22} = 1.95 \times 10^{-7} (T/300)^{-0.70}$	M97
Z23	$\text{O} + \text{CH} \rightarrow \text{CO} + \text{H}$	$k_{Z23} = 6.60 \times 10^{-11}$	M97
Z24	$\text{C} + \text{OH} \rightarrow \text{CO} + \text{H}$	$k_{Z24} = 1.10 \times 10^{-10} (T/300)^{0.50}$	M97
Z25	$\text{C} + \text{O}_2 \rightarrow \text{CO} + \text{O}$	$k_{Z25} = 3.30 \times 10^{-11}$	M97
Z26	$\text{C}^+ + \text{O}_2 \rightarrow \text{O}^+ + \text{CO}$	$k_{Z26} = 6.20 \times 10^{-10}$	
Z27	$\text{OH} + \text{CO} \rightarrow \text{CO}_2 + \text{H}$	$k_{Z27} = 1.00 \times 10^{-13}$	
Z28	$\text{C}^+ + \text{e} \rightarrow \text{C} + \gamma$	$k_{Z28} = 4.40 \times 10^{-12} (T/300)^{-0.50}$	
Z29	$\text{C}^+ + \text{OH} \rightarrow \text{CO}^+ + \text{H}$	$k_{Z29} = 7.70 \times 10^{-10}$	
Z30	$\text{CO}^+ + \text{H} \rightarrow \text{H}^+ + \text{CO}$	$k_{Z30} = 7.50 \times 10^{-10}$	
Z31	$\text{C} + \text{H} \rightarrow \text{CH} + \gamma$	$k_{Z31} = 1.00 \times 10^{-17}$	
Z32	$\text{C} + \text{H}_2 \rightarrow \text{CH} + \text{H}$	$k_{Z32} = 6.64 \times 10^{-10} \exp(-1100/T)$	


3. Why should I care?




Humanities:

*the study of how people process
and document the human experience.*


Provide Context and Wonder



Topping
a shaky rise I see

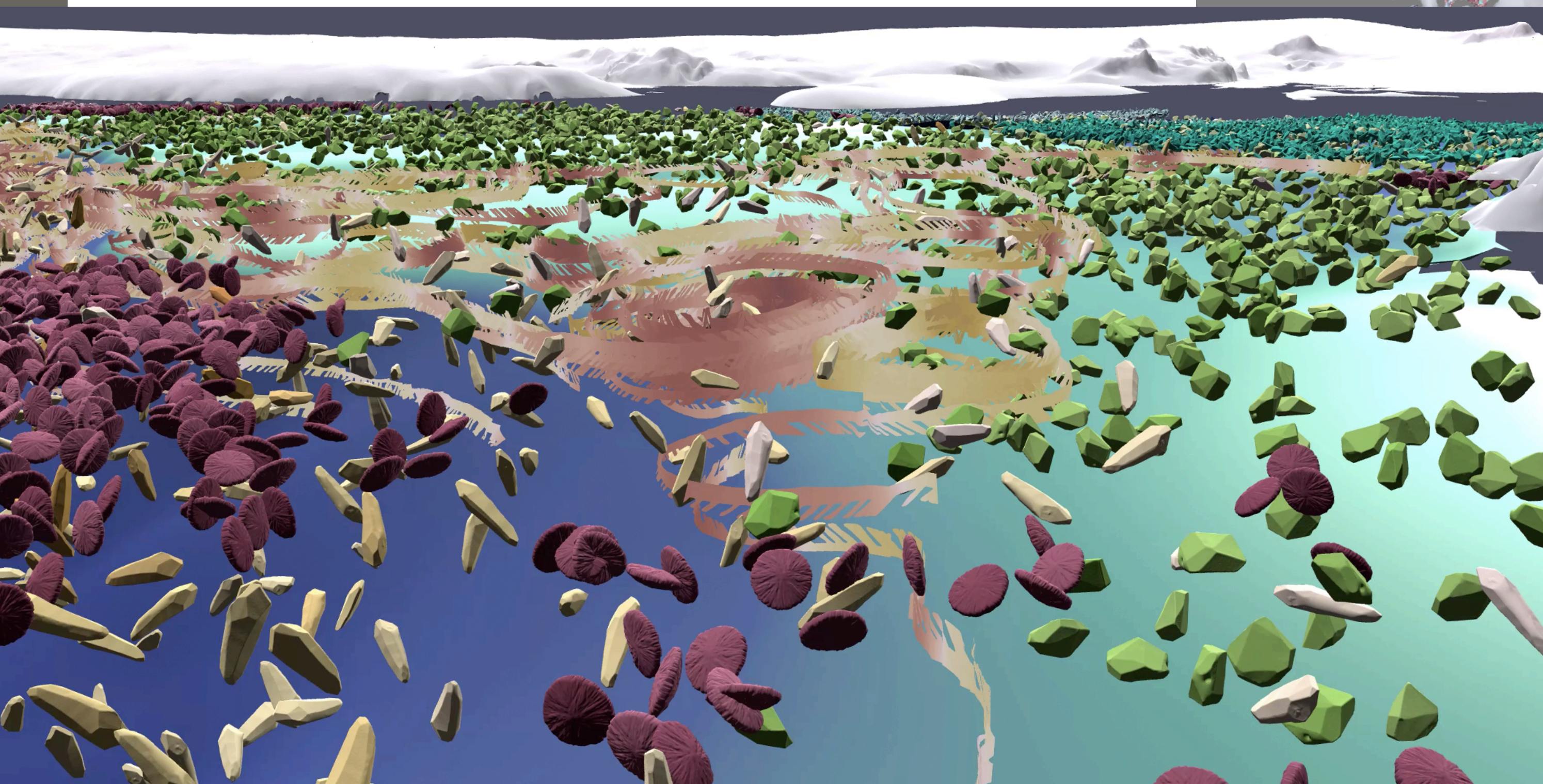
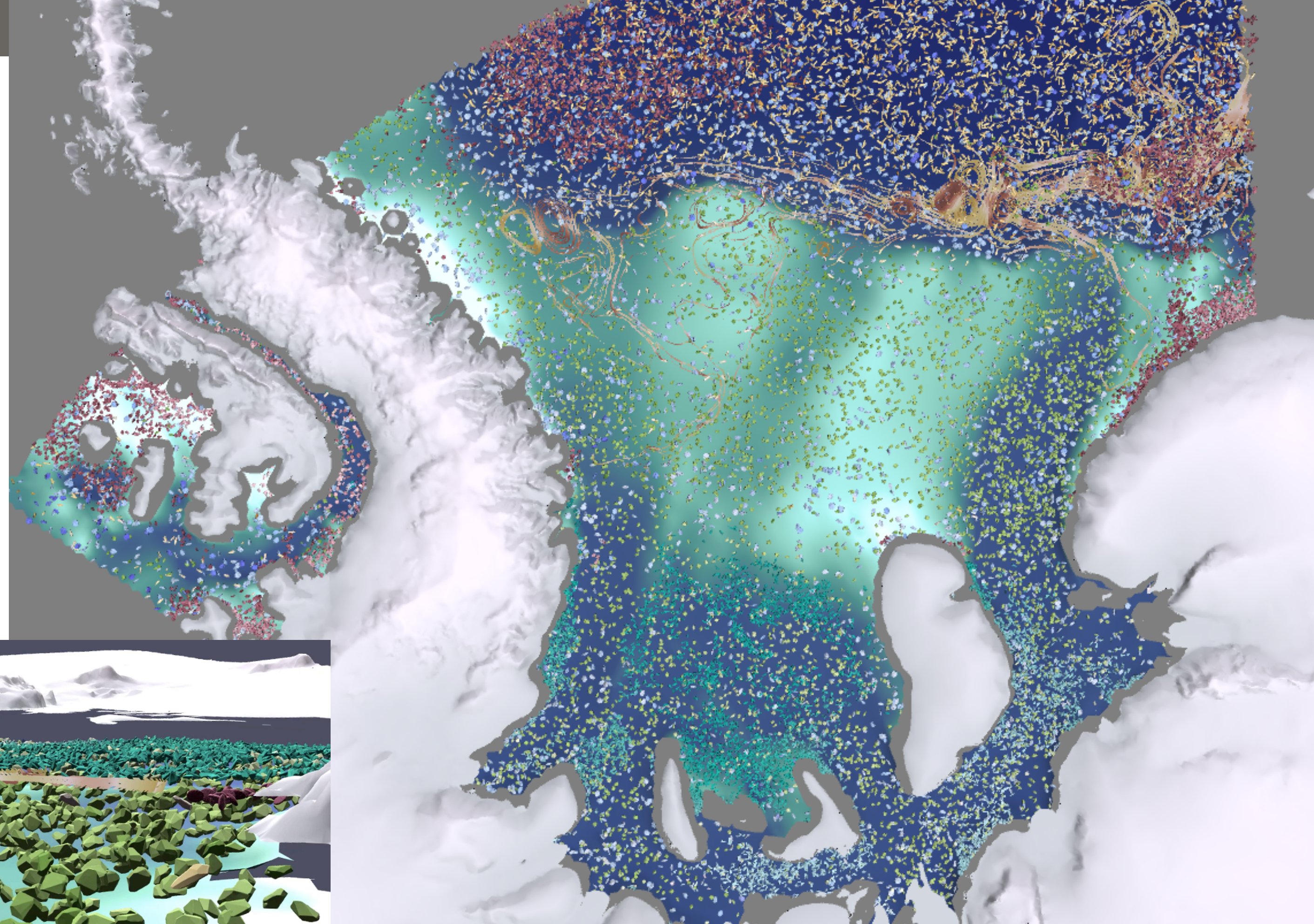


translated the results
of a wrong kind of living
– new muddy lagoon,



your calved bergs blue messengers praying they are arks.

AGU funded work with Michael Smith, poet.



Francesca Samsel
fsamsel@tacc.utexas.edu

SciVisColor.org