Color Visualization

Thanks to Penny Rheingans (UMBC) and Chuck Hansen (Utah)

February 04, 2013

Overview

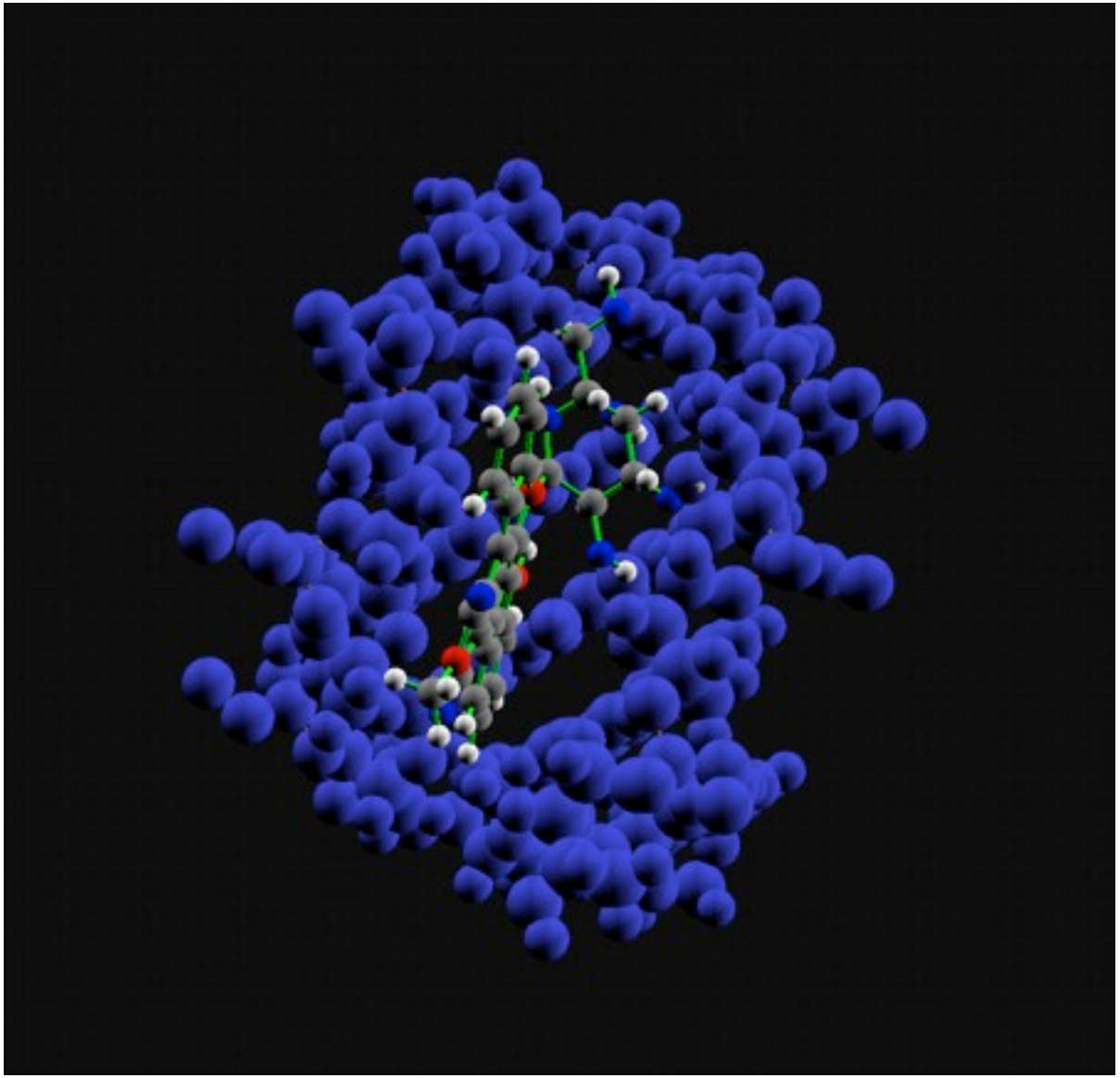
- Uses of Color
- Survey of Color Scales
- Evaluating Color Scales
- Visualization Tasks
- Design Considerations

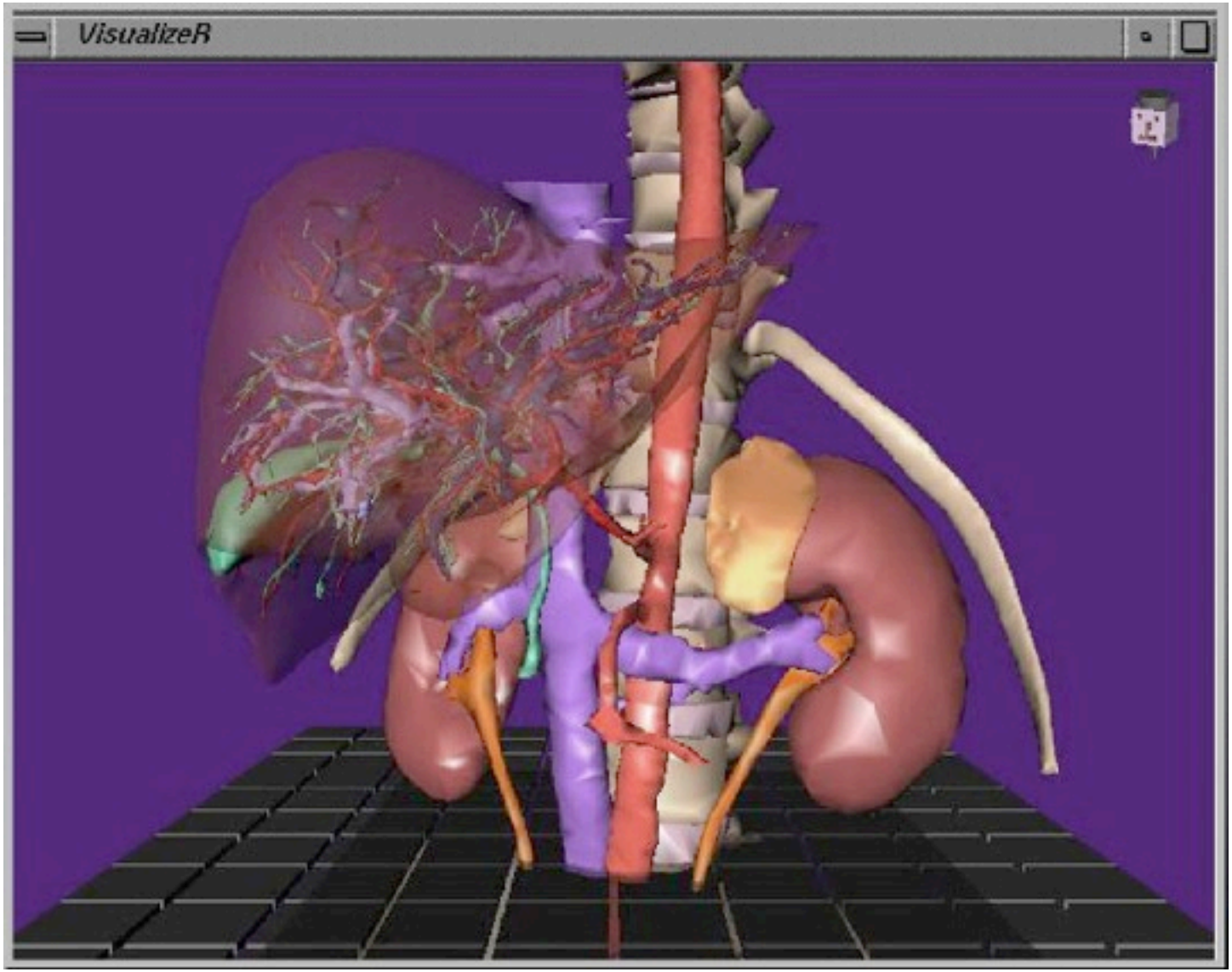
Uses of Color

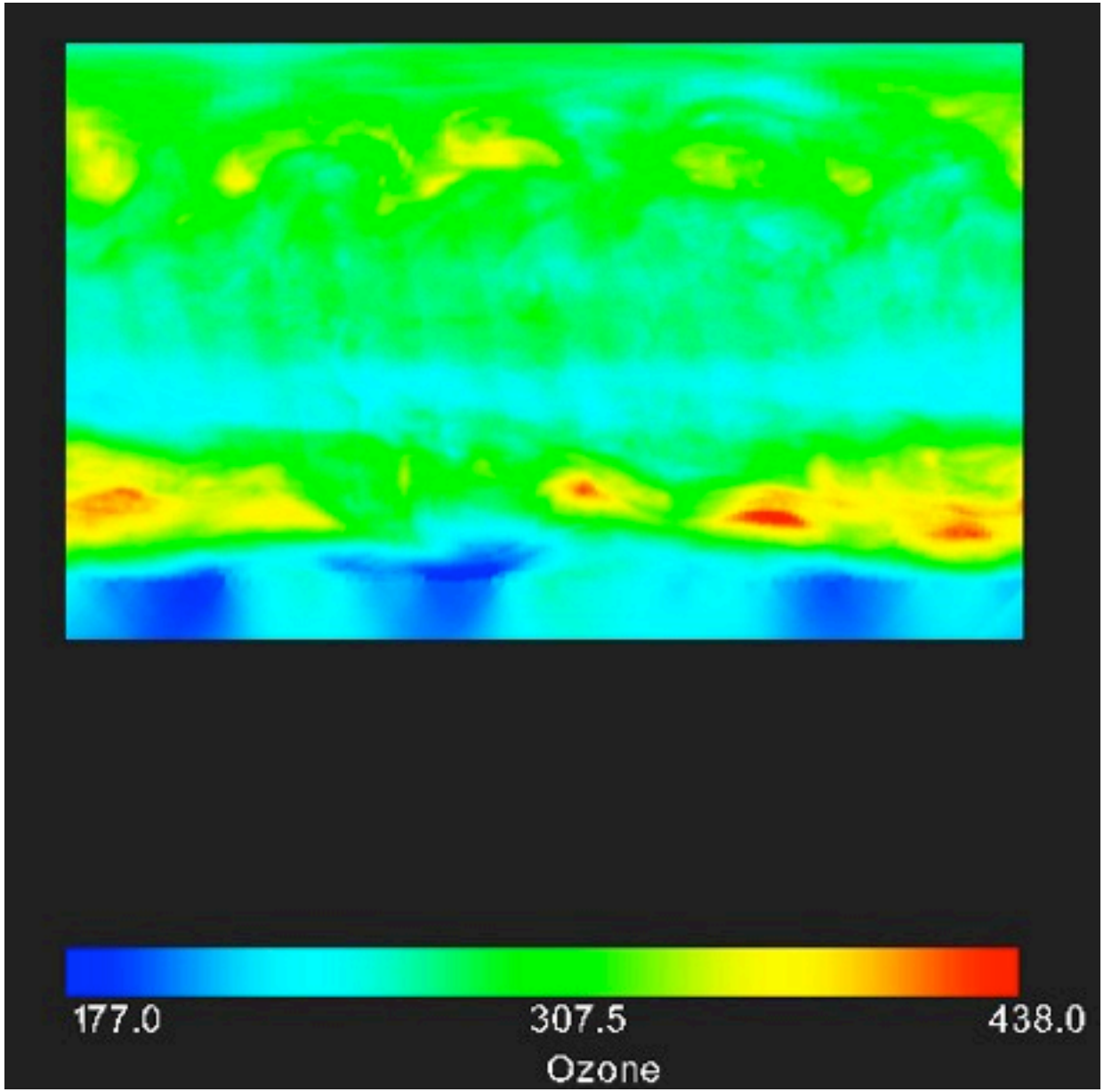
- Show classification
- Mimic reality
- Show value
- Draw attention
- Show grouping

Important Note

- What we see depends on the particular display device
- Things appear different on different monitors
- Reminder: effectiveness of color choices depends on
  - Display, data set, application, observers, etc...




VisualizeR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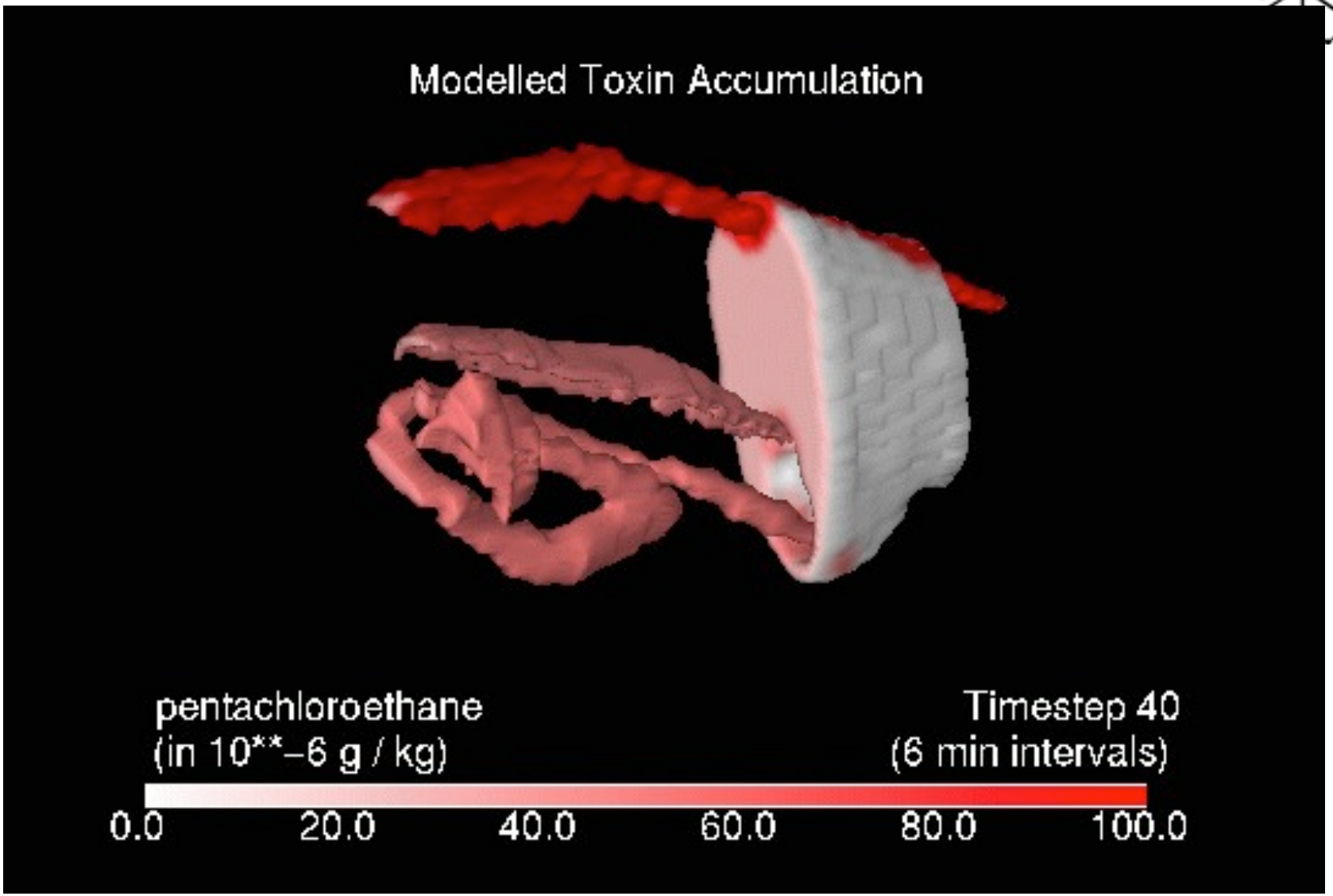
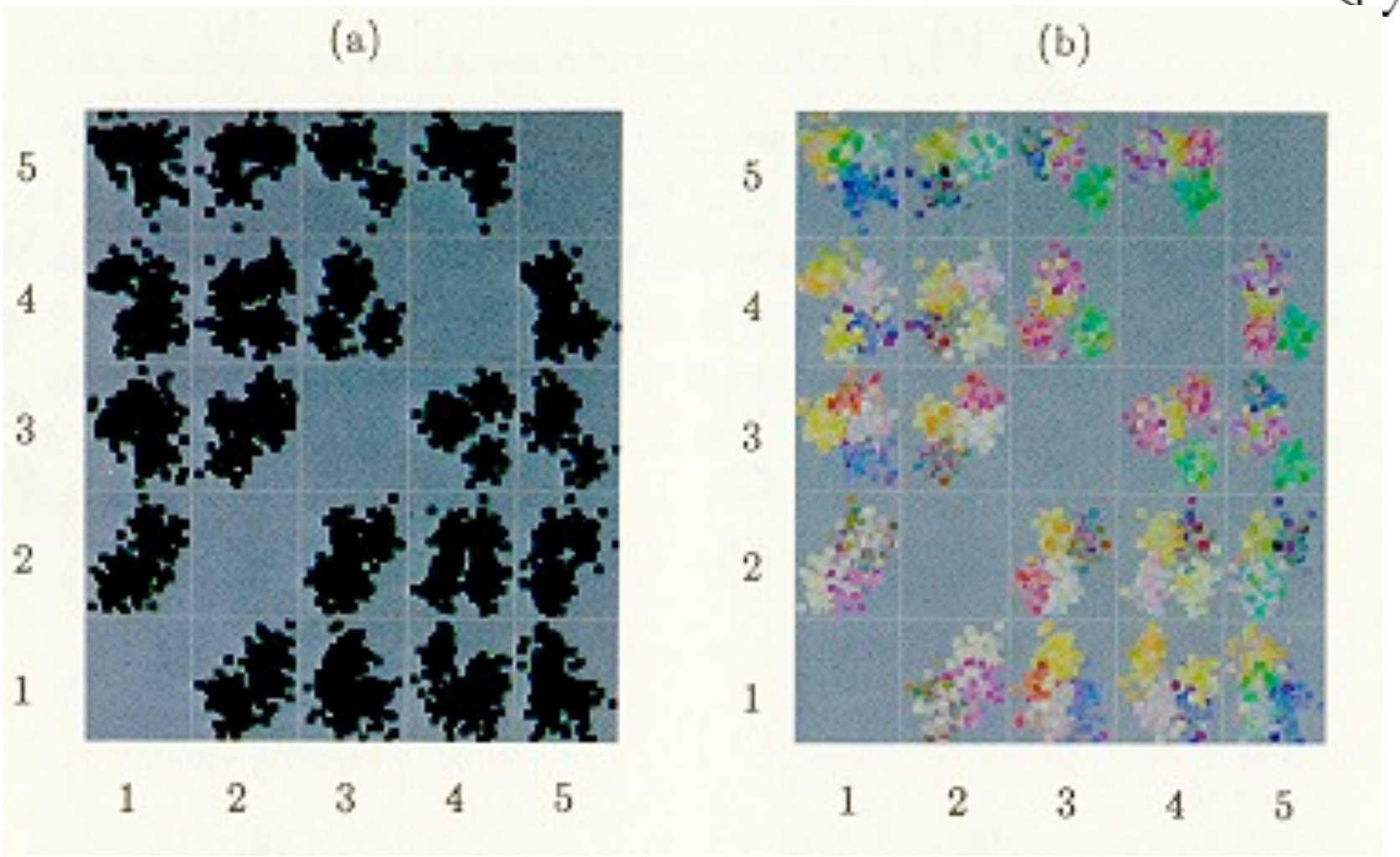
307.5
438.0
Ozone


Modelled Toxin Accumulation
pentachloroethane
(in 10**–6 g / kg)
Timestep 40
(6 min intervals)
0.0
20.0
40.0
60.0
80.0
100.0



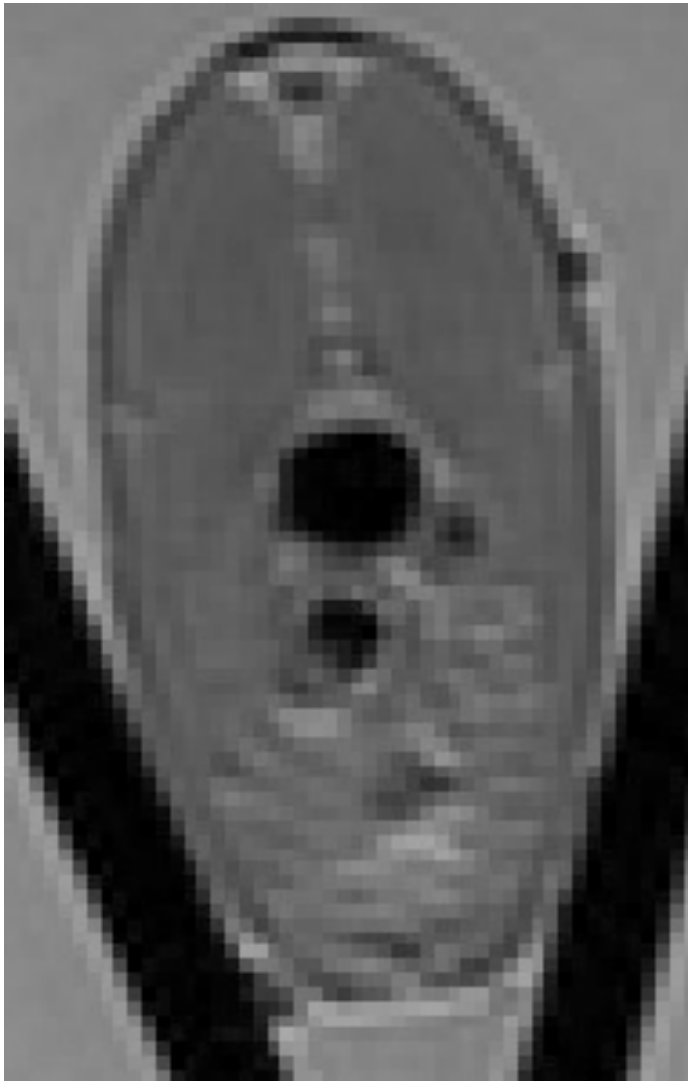
Ware and Beatty '85, p. 22

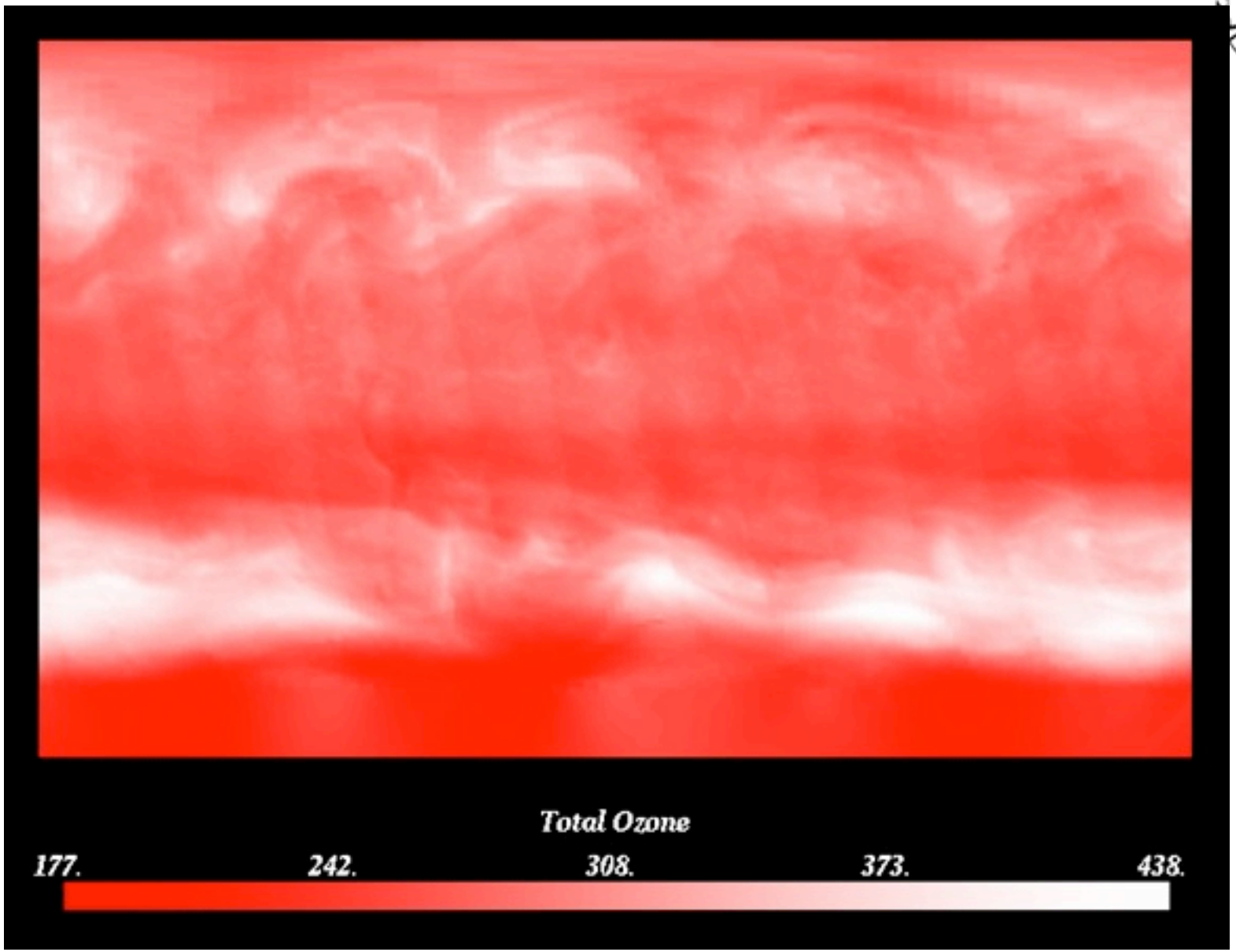
Some Univariate Color Scales

- Paths through color space
- Color model component
- Redundant scales
- Double-ended
- Banded
- Standard color scales

Color Model Component Scales Strategies

- Value a single color model component with other components held constant
- Examples
  - Grey scale
  - Saturation scale
  - Spectrum scale

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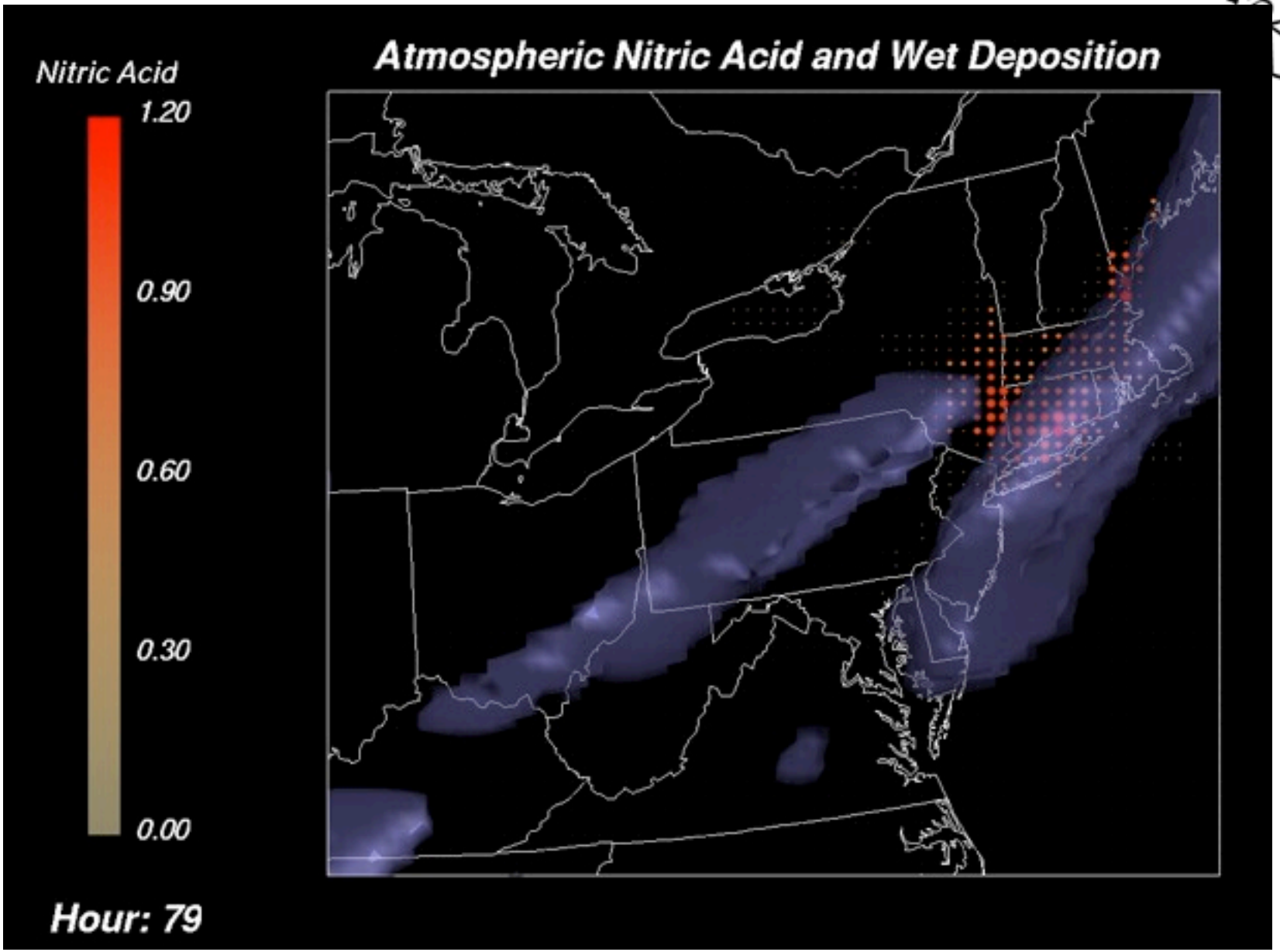
242.
308.
373.
438.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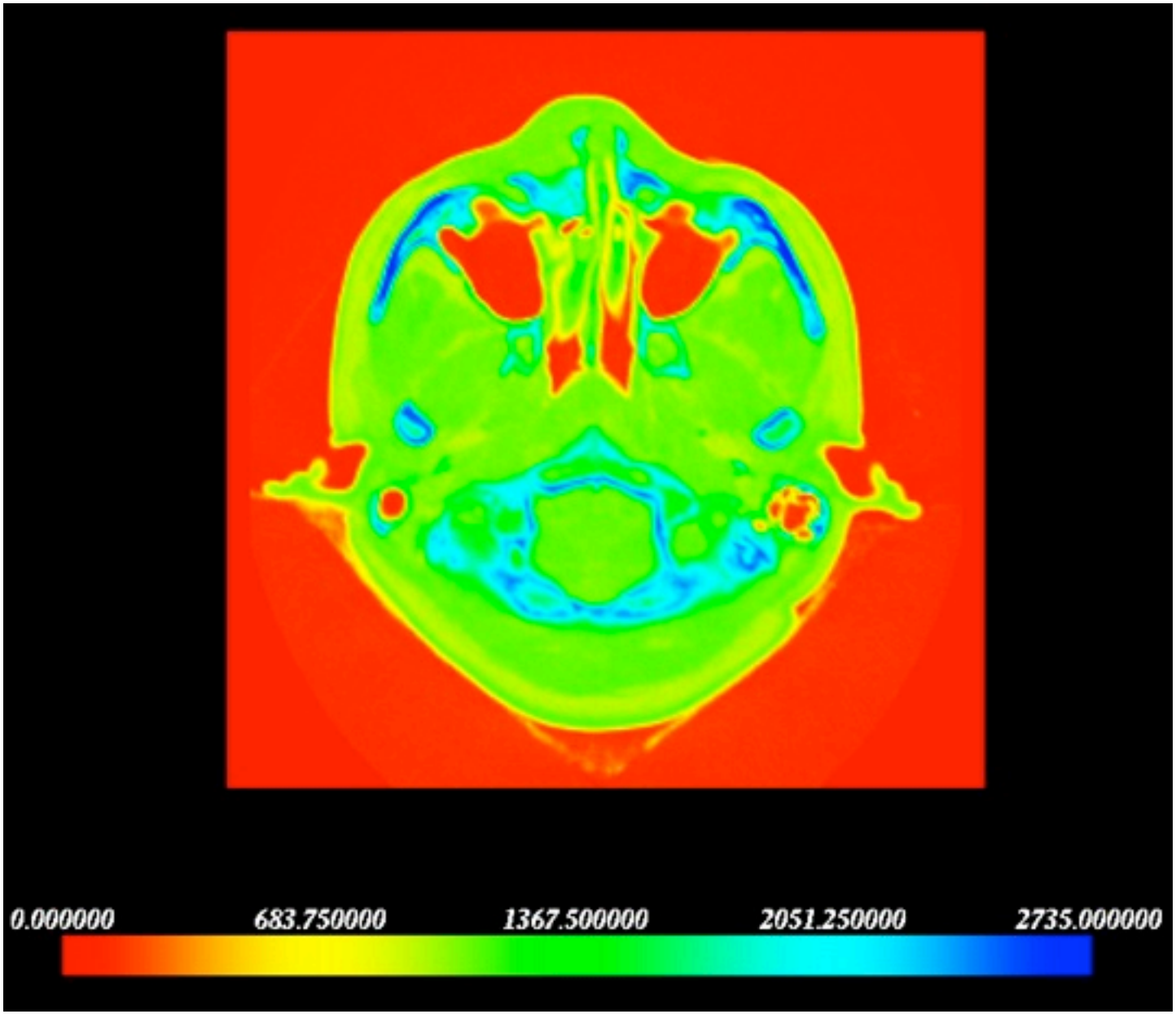
Nitric Acid
1.20
0.90
0.60
0.30
0.00
Hour: 79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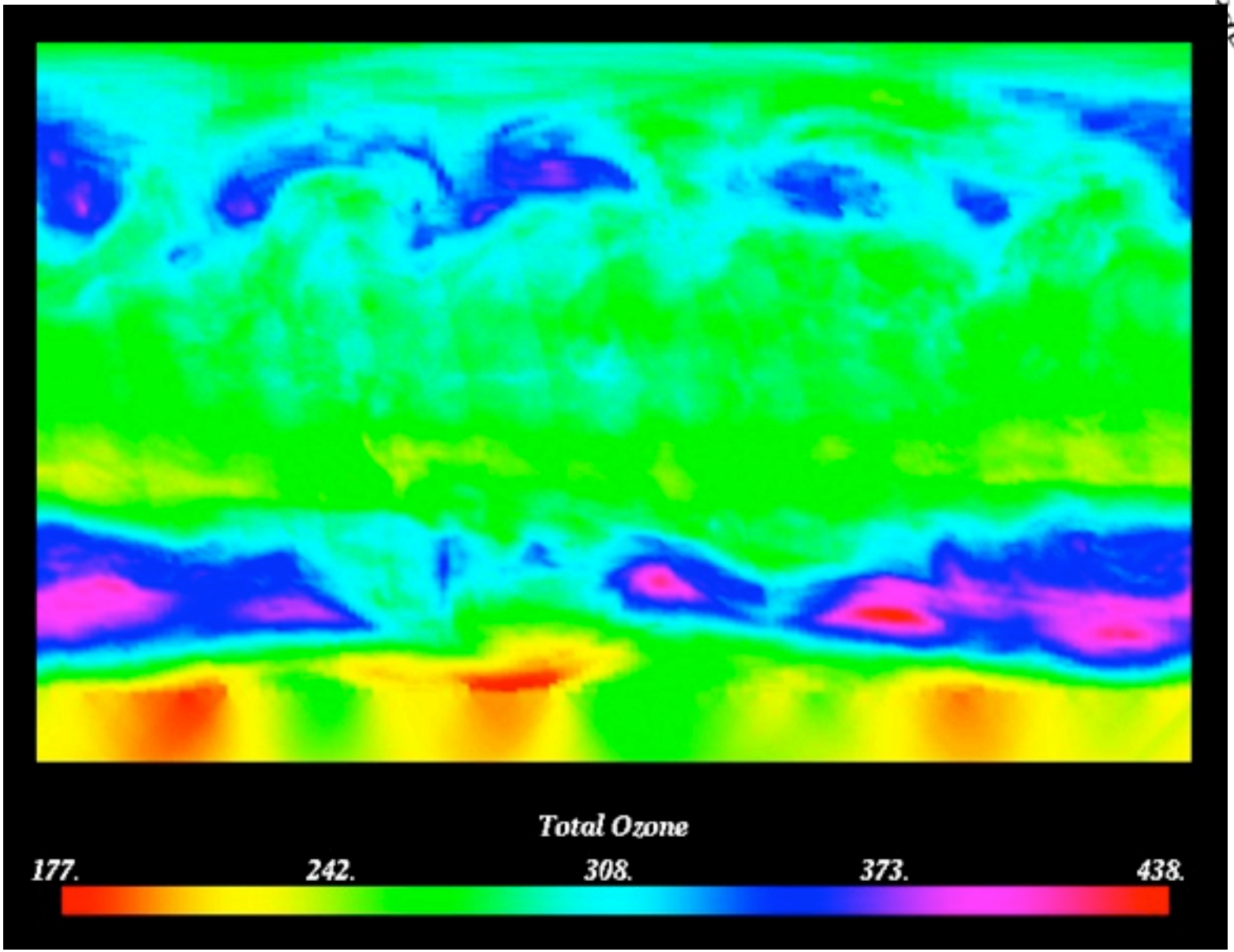
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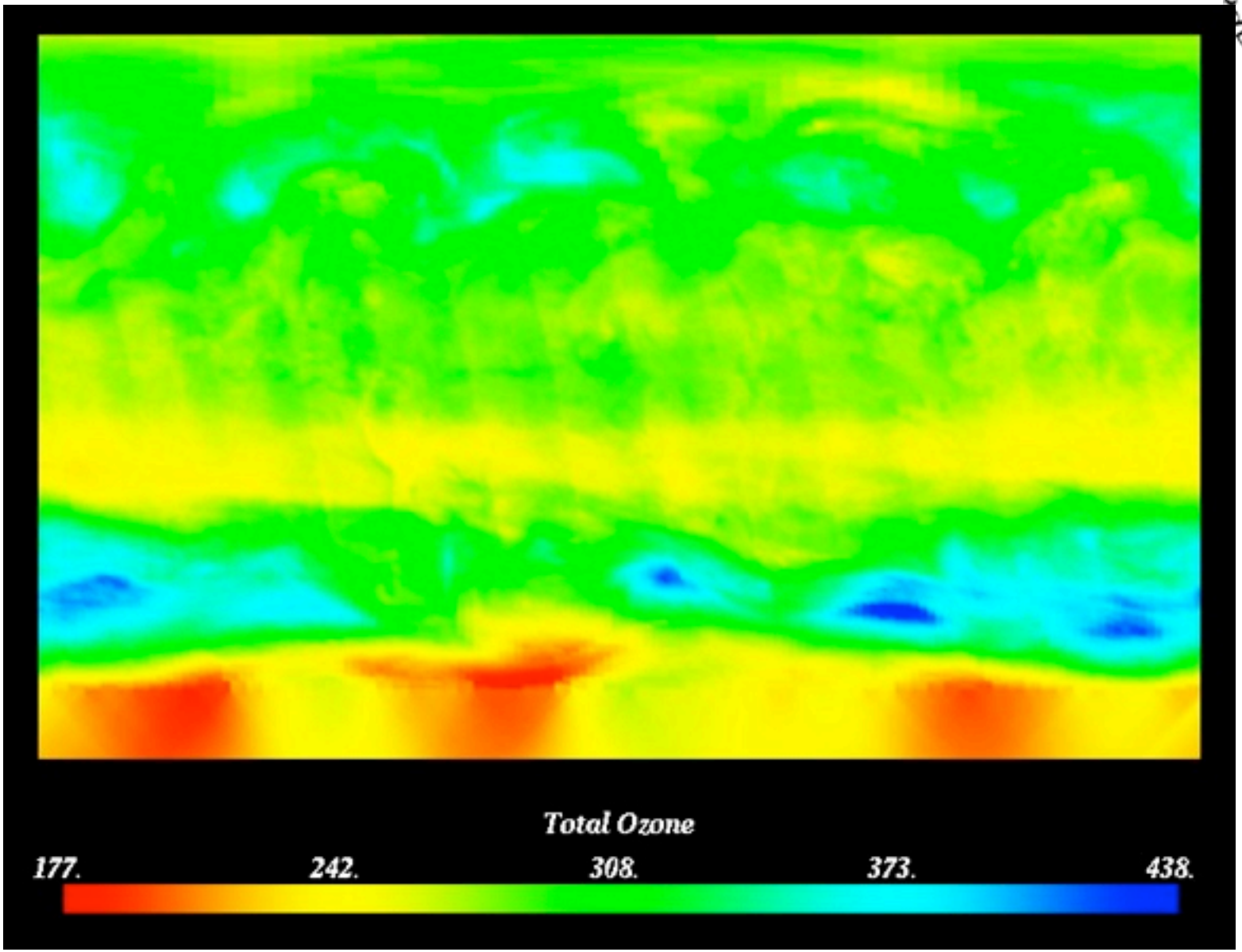
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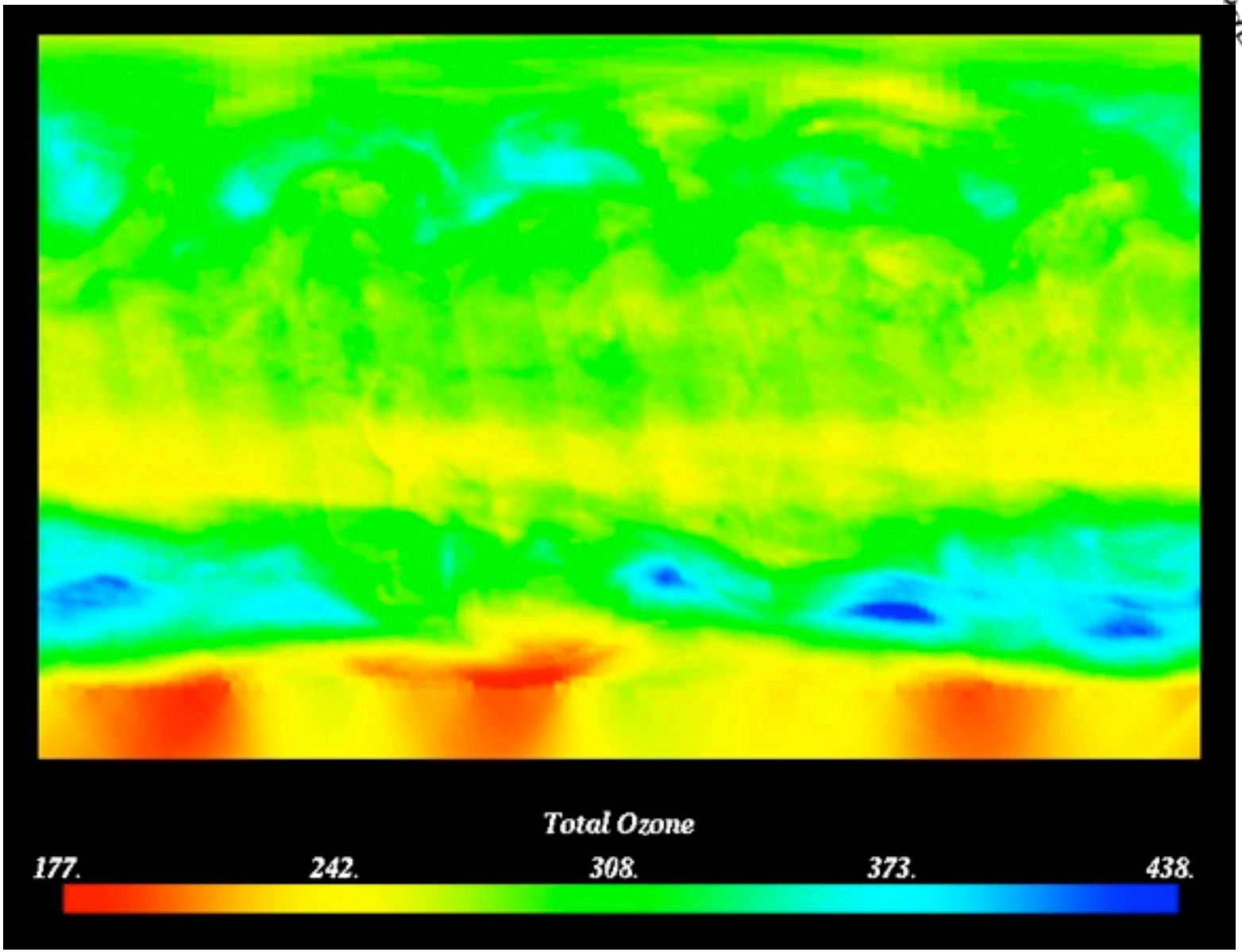
373.
438.

Redundant Color Scales

- Two or more color components varied together
- Examples
  - Hue with lightness
  - Heated object scale
  - Levkowitz's optimal scales
- Characteristics
  - Reinforces signal
  - Combines characteristics of simpler scales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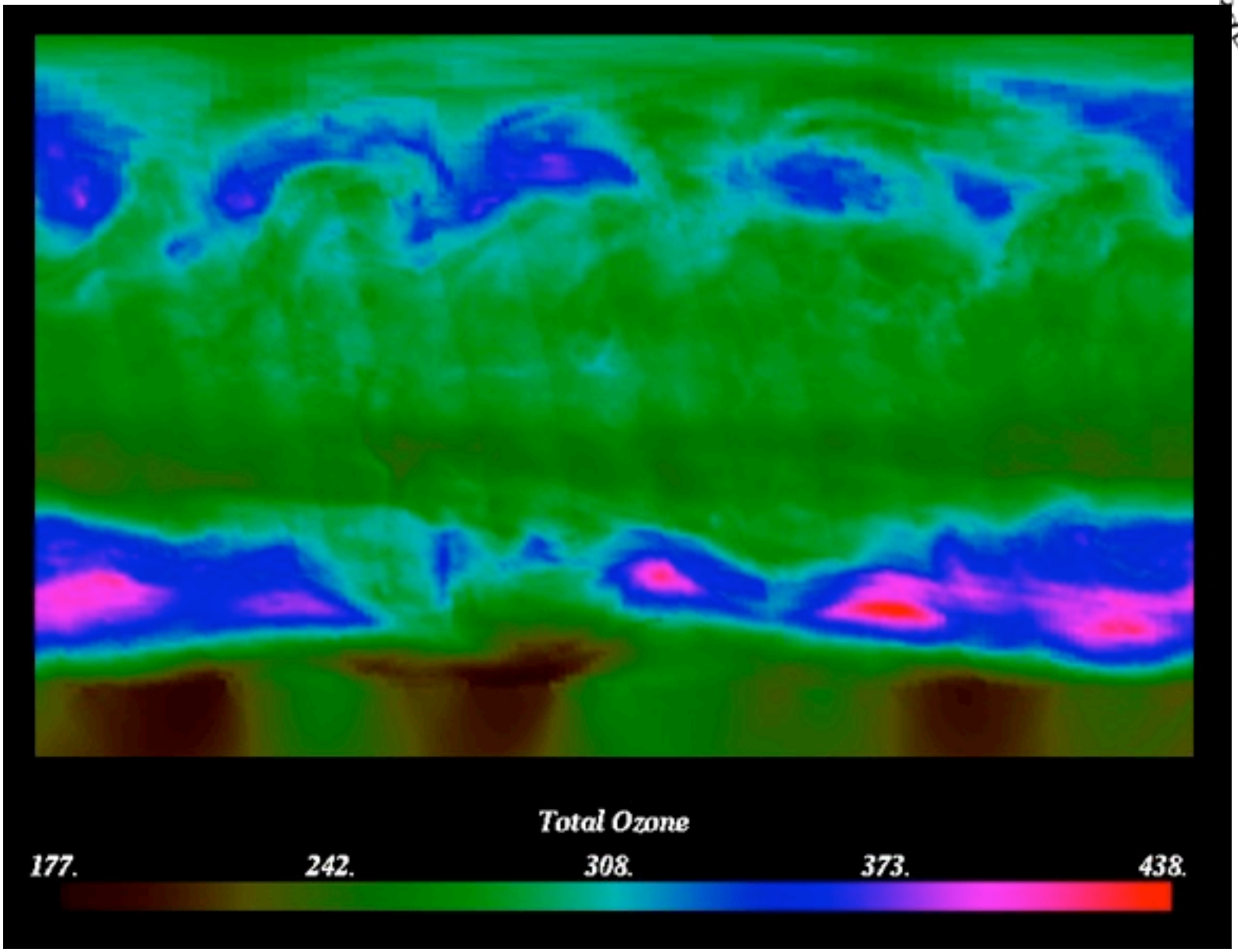
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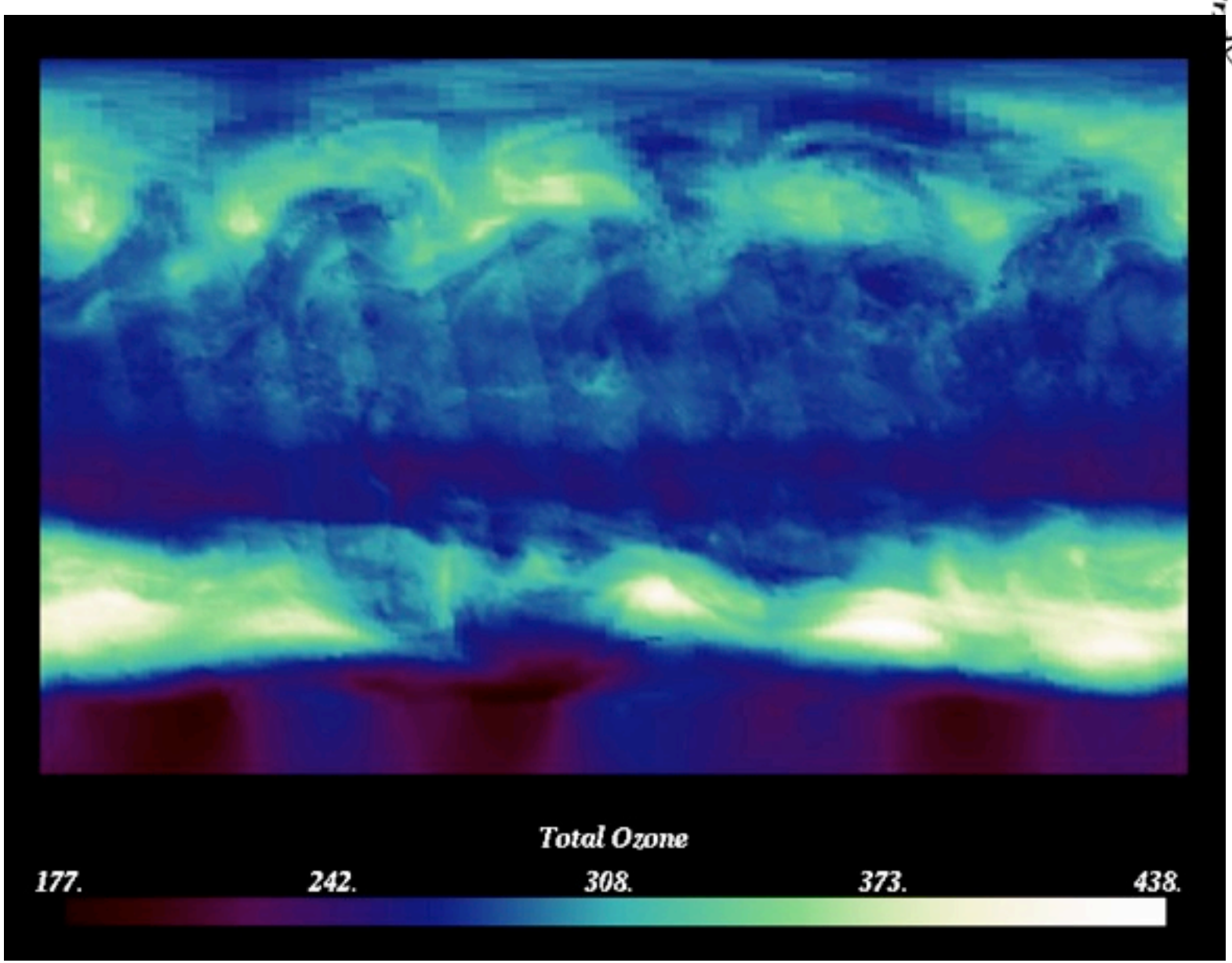
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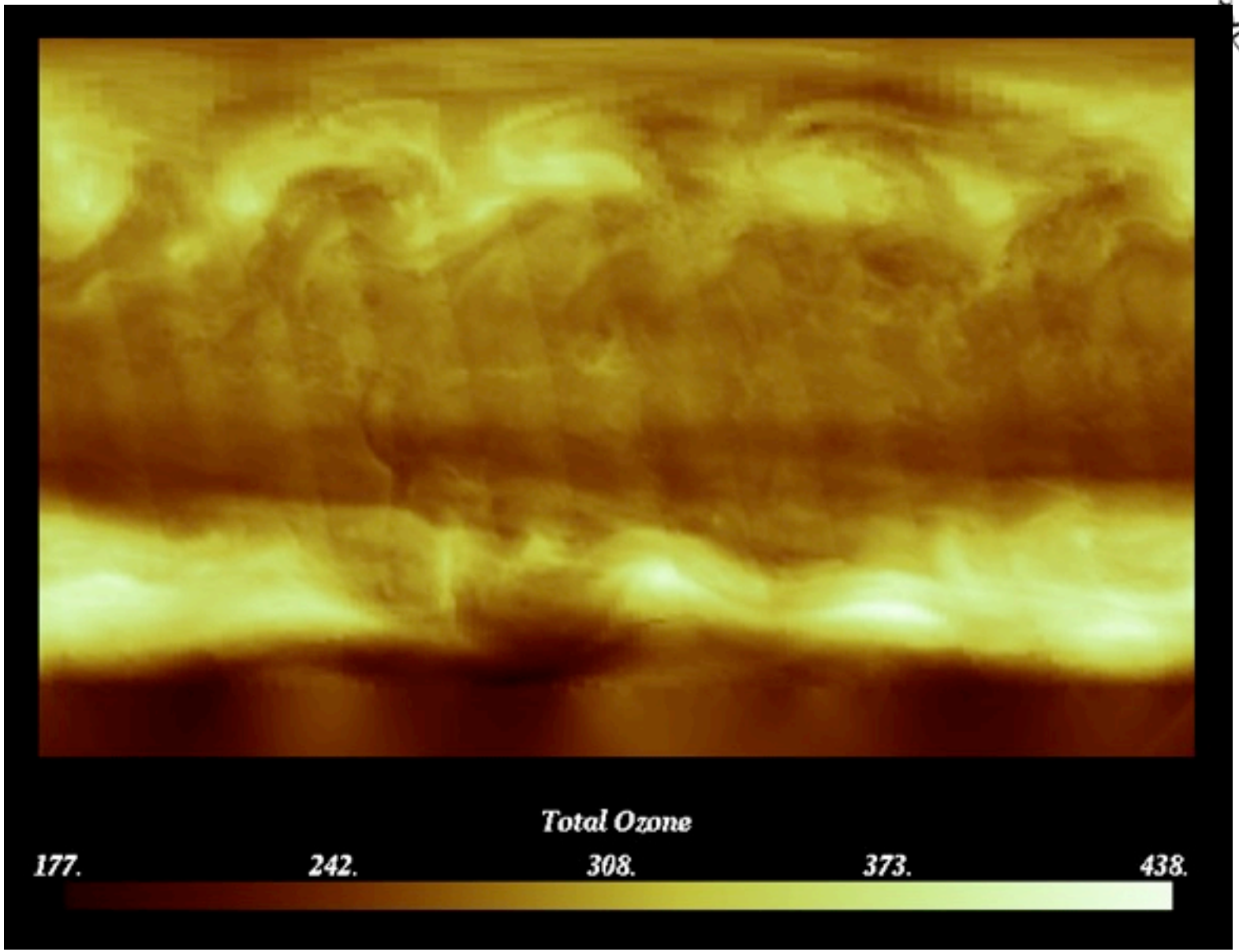
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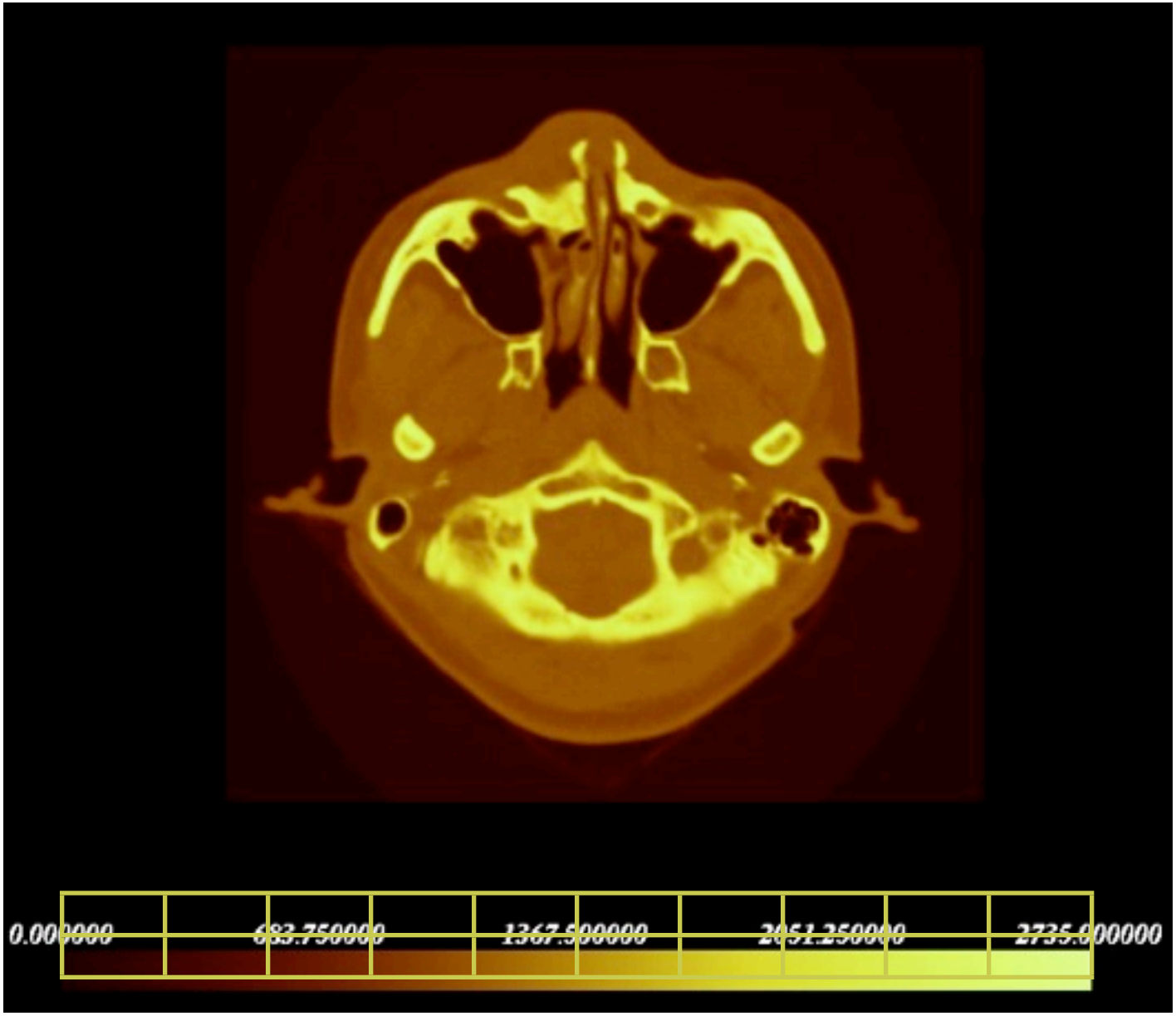
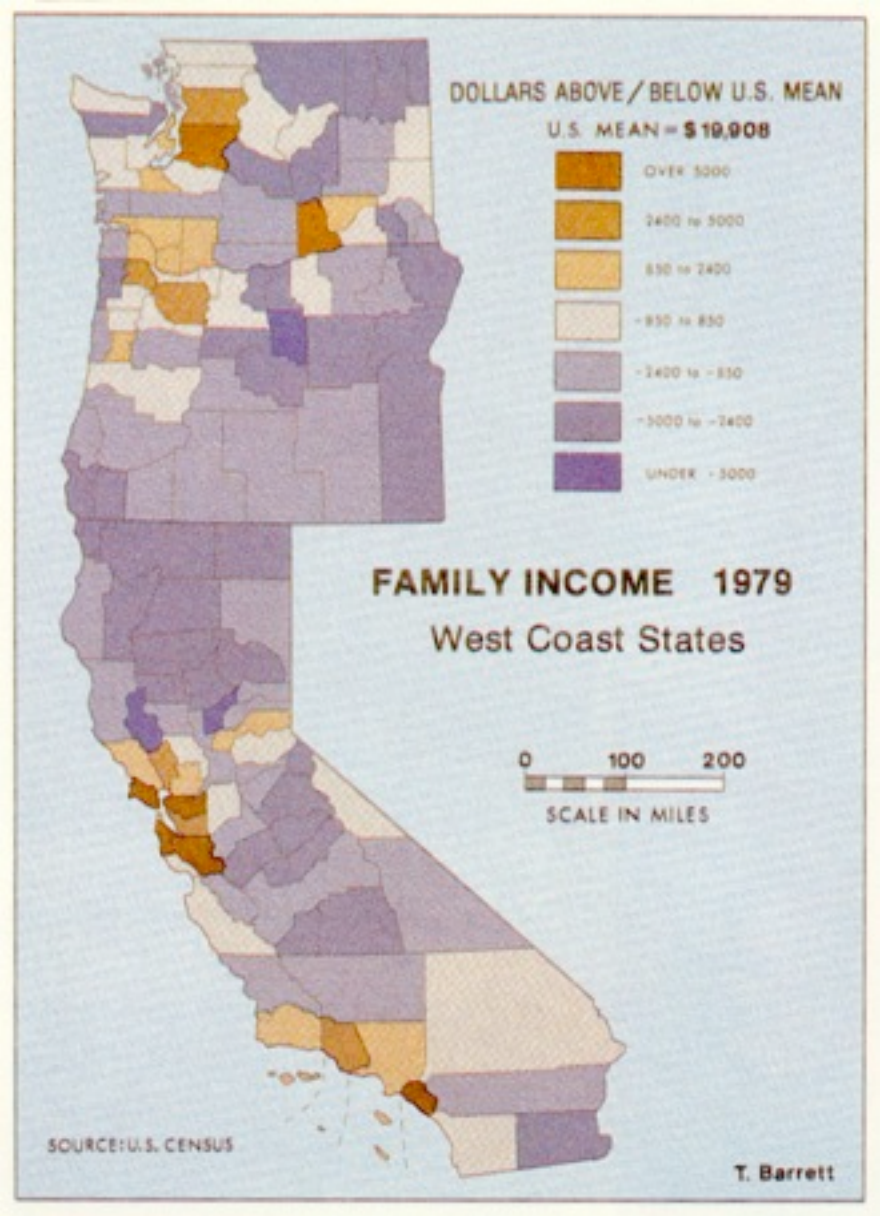
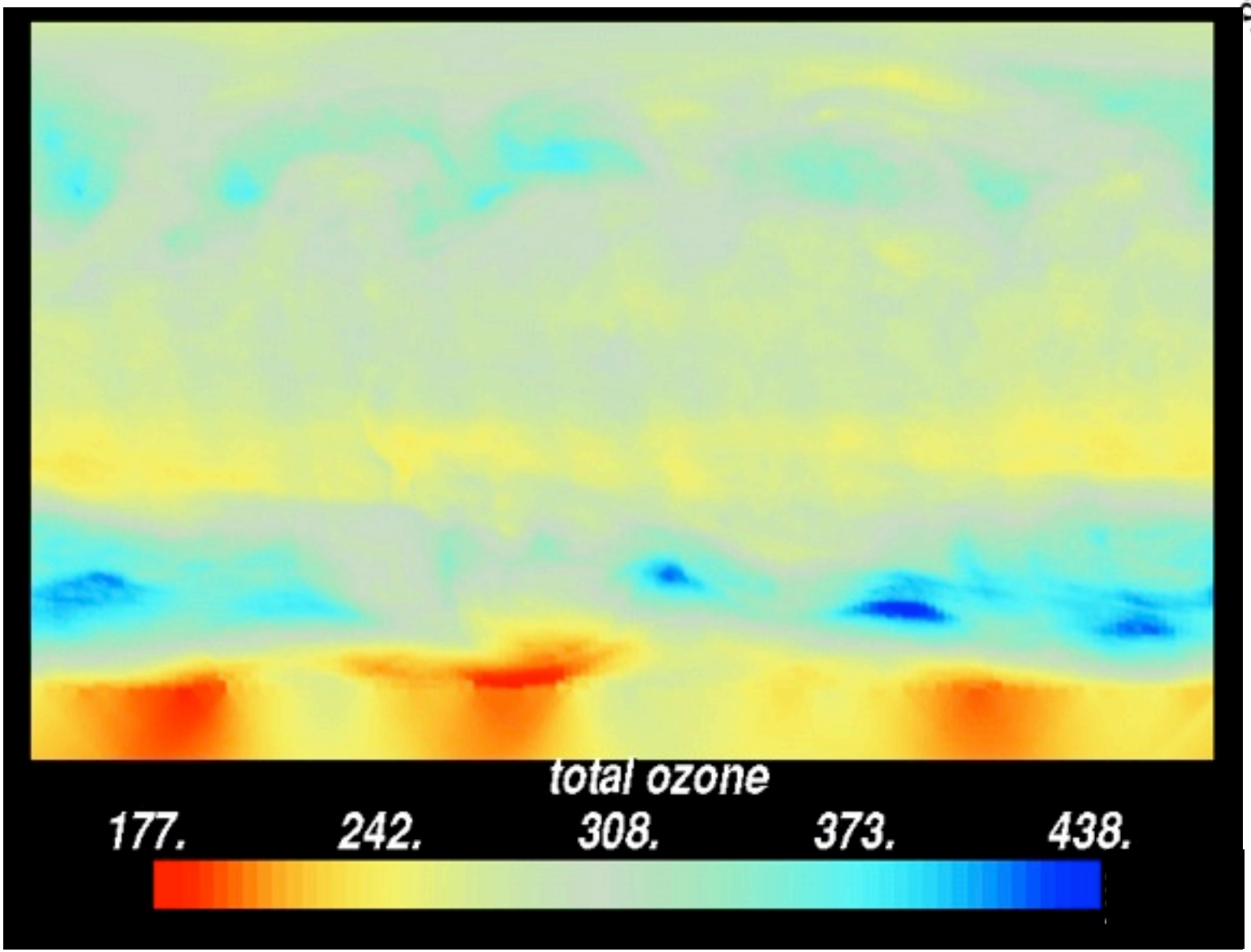

0.000000
683.750000
1367.500000
2051.250000
2735.000000

Double-ended Scale

- Two distinct scales joined at neutral middle
- Characteristics
  - segments values into two groups
  - can emphasize both extremes of data range



Olson '97, fig. 11-8.


total ozone
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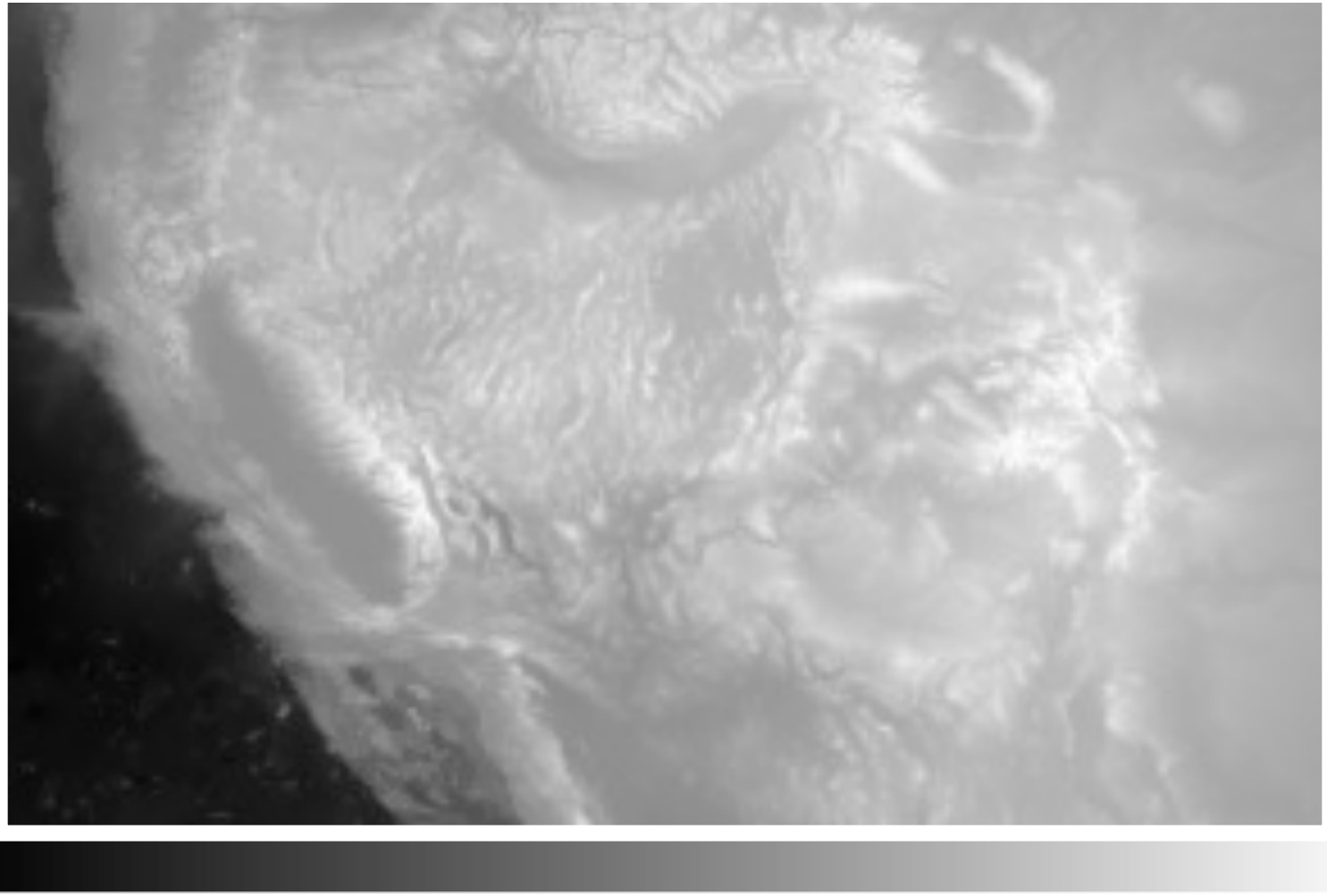
438.

Some Standard Color Scales

- Grey
- Linearized grey
- Rainbow
- Magenta
- Heated
- Optimal
- Linearized optimal
- Blue-cyan
- Blue-yellow

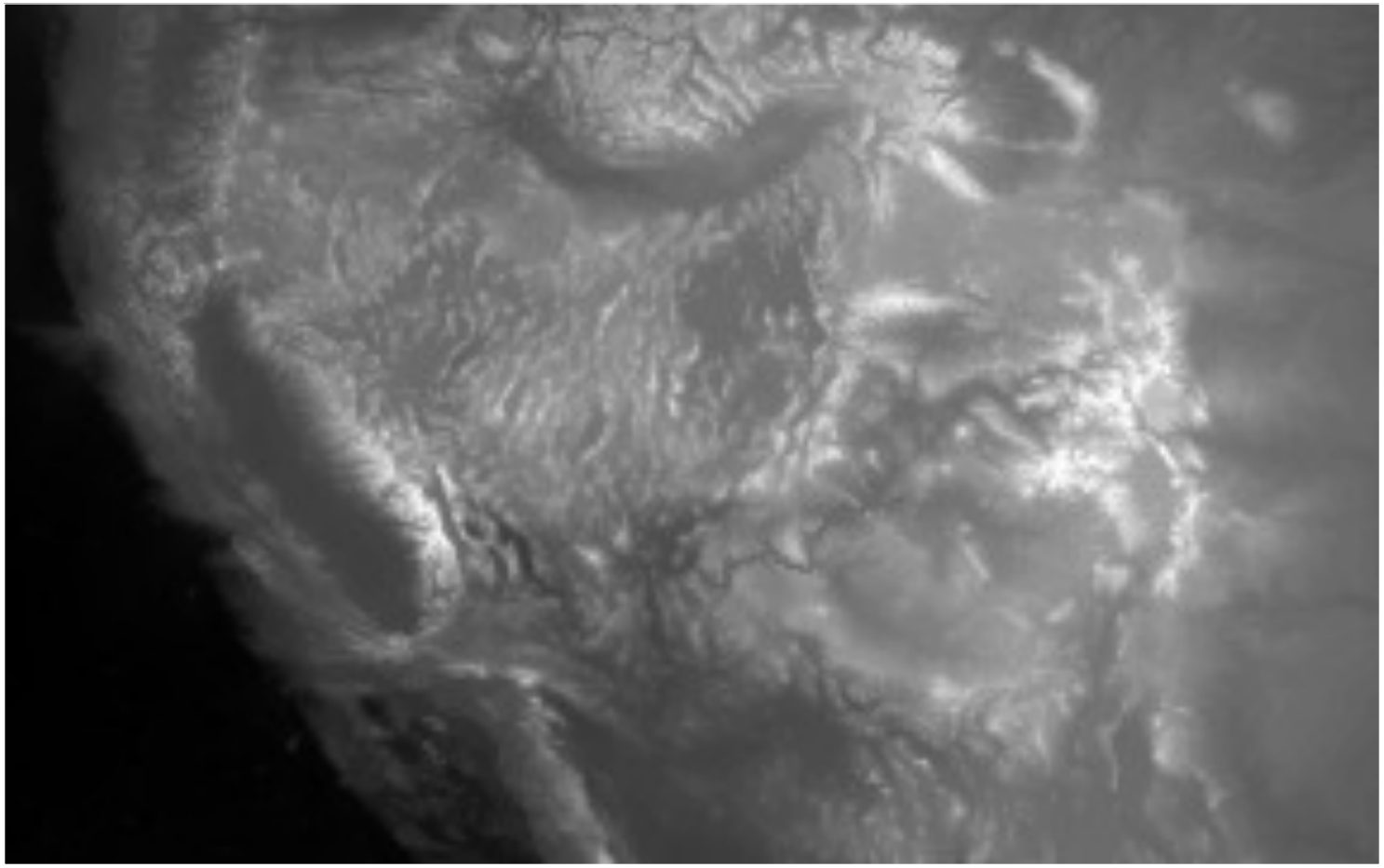
Greyscale

Greyscale



Linearized Greyscale

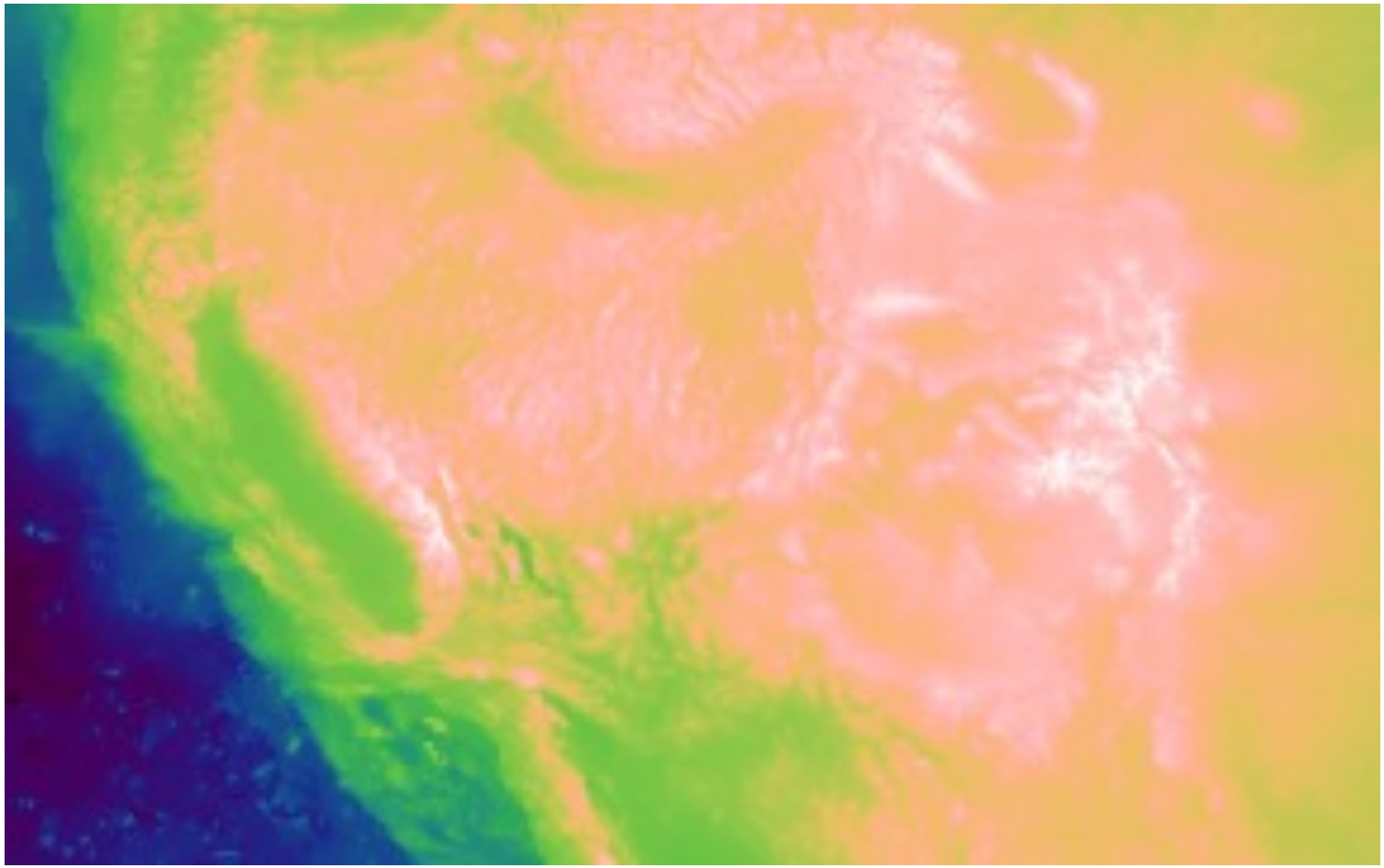
Linearized Greyscale



Rainbow

S. Pizer

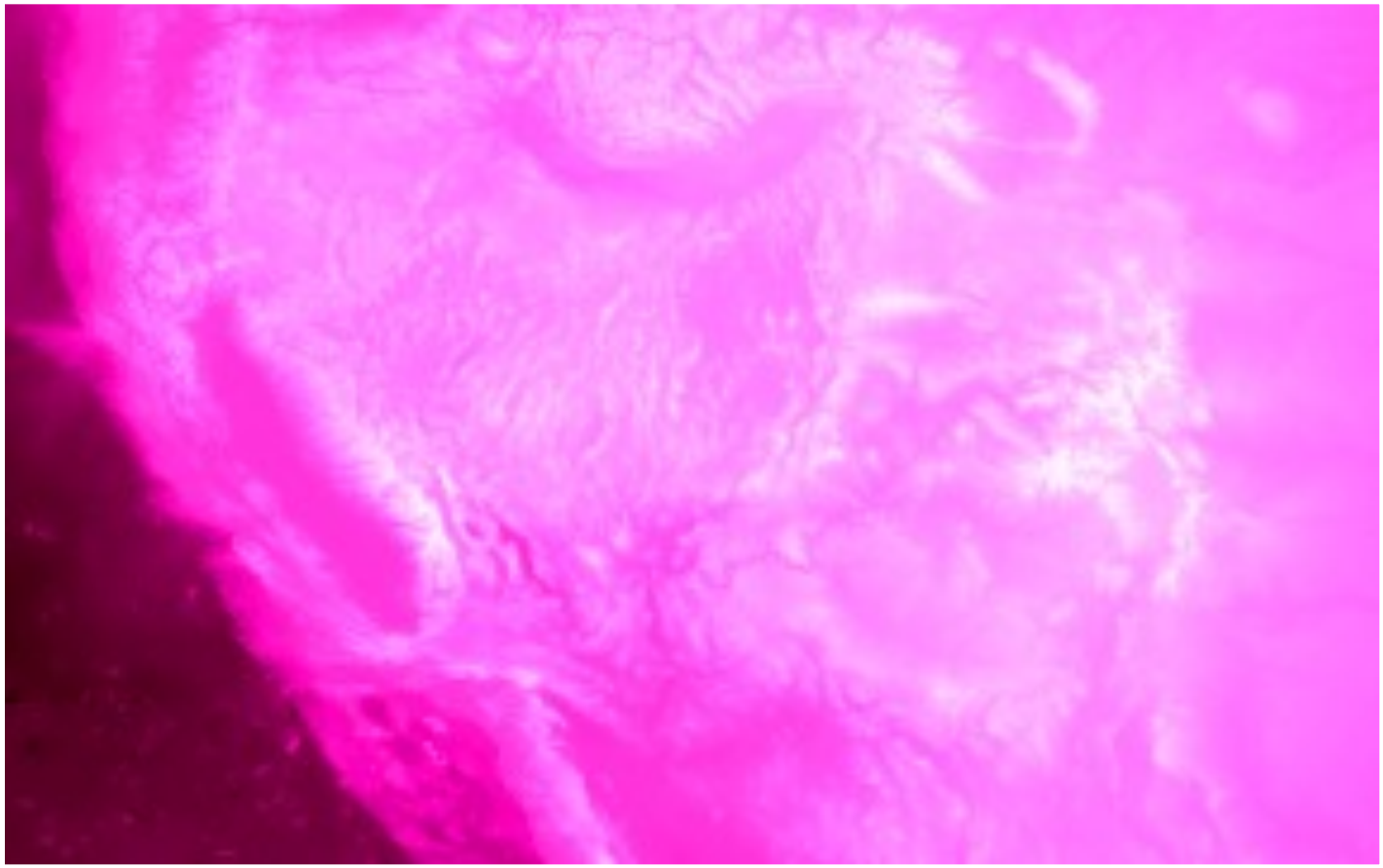
Rainbow



Magenta

S. Pizer

Magenta

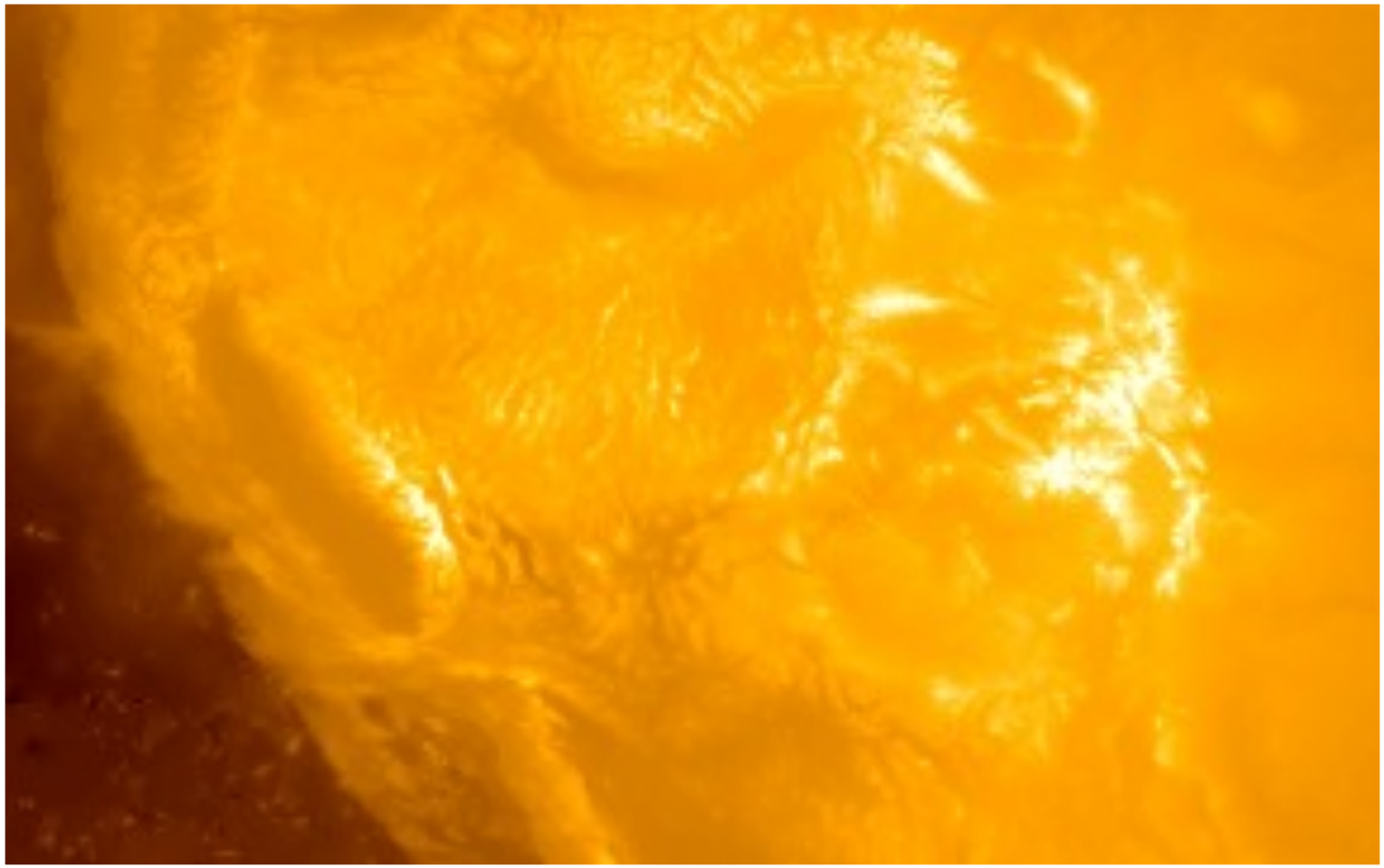


Heated

S. Pizer

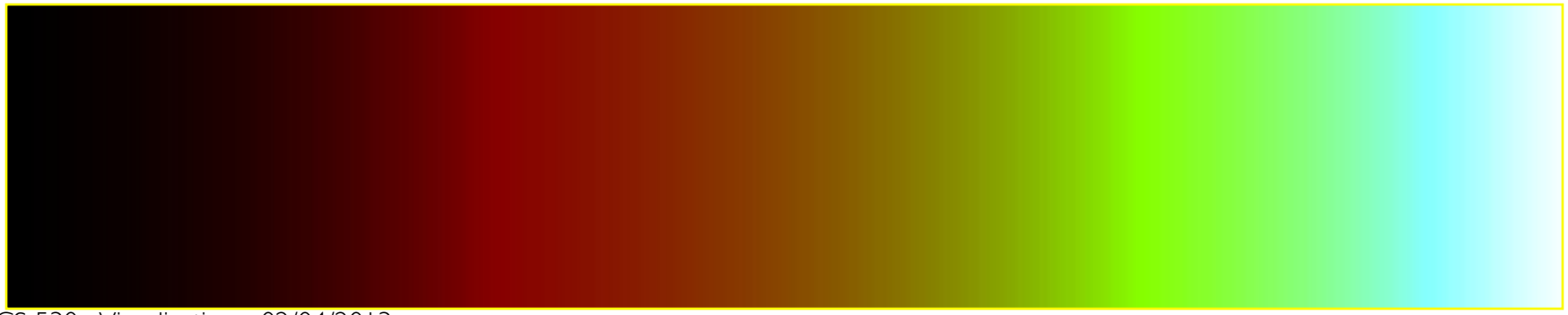
- **Natural scale**
- Intuition

Heated

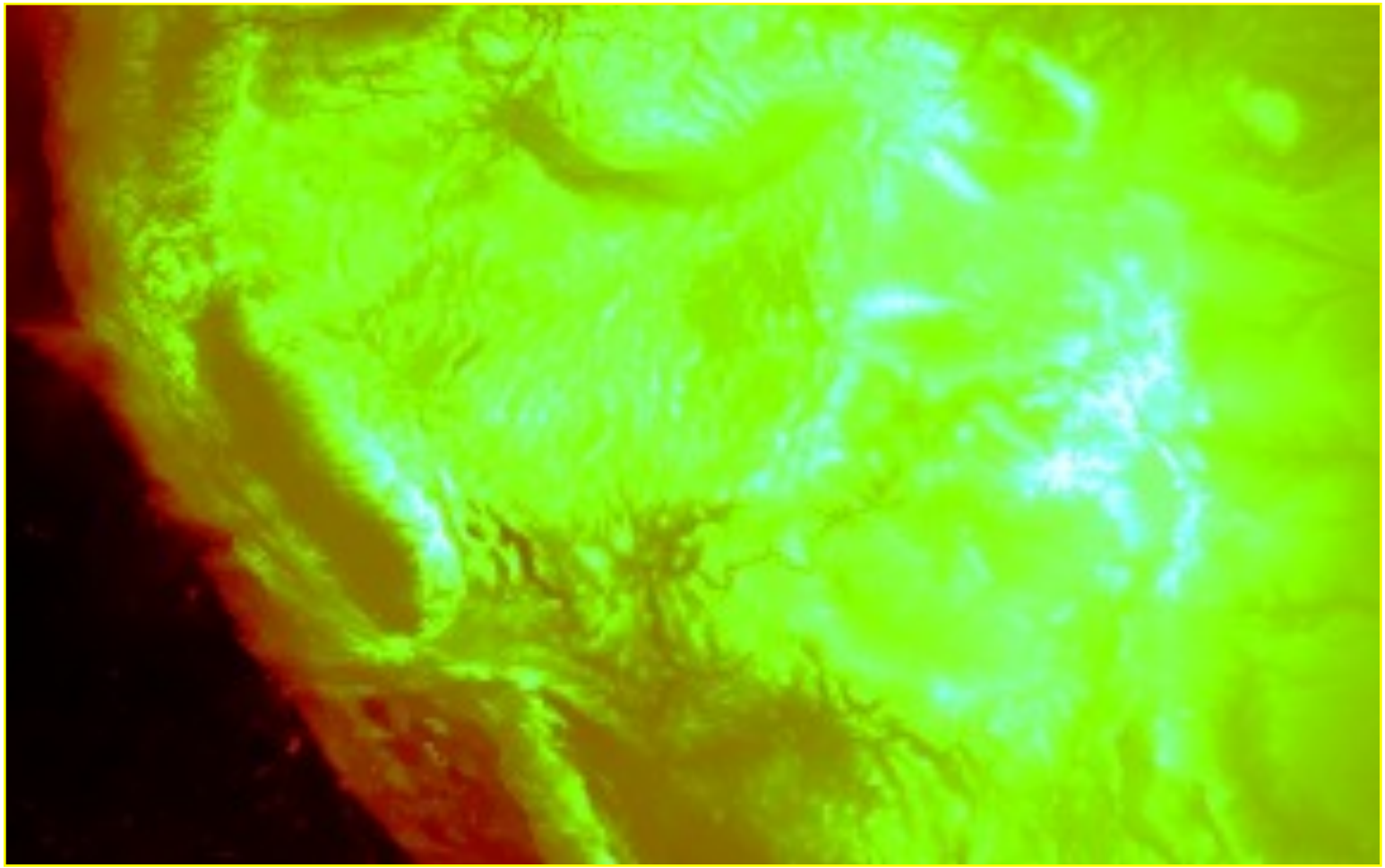


Linearized Optimal
Levkowitz

- No perceived boundaries
- Ordering
- Distance

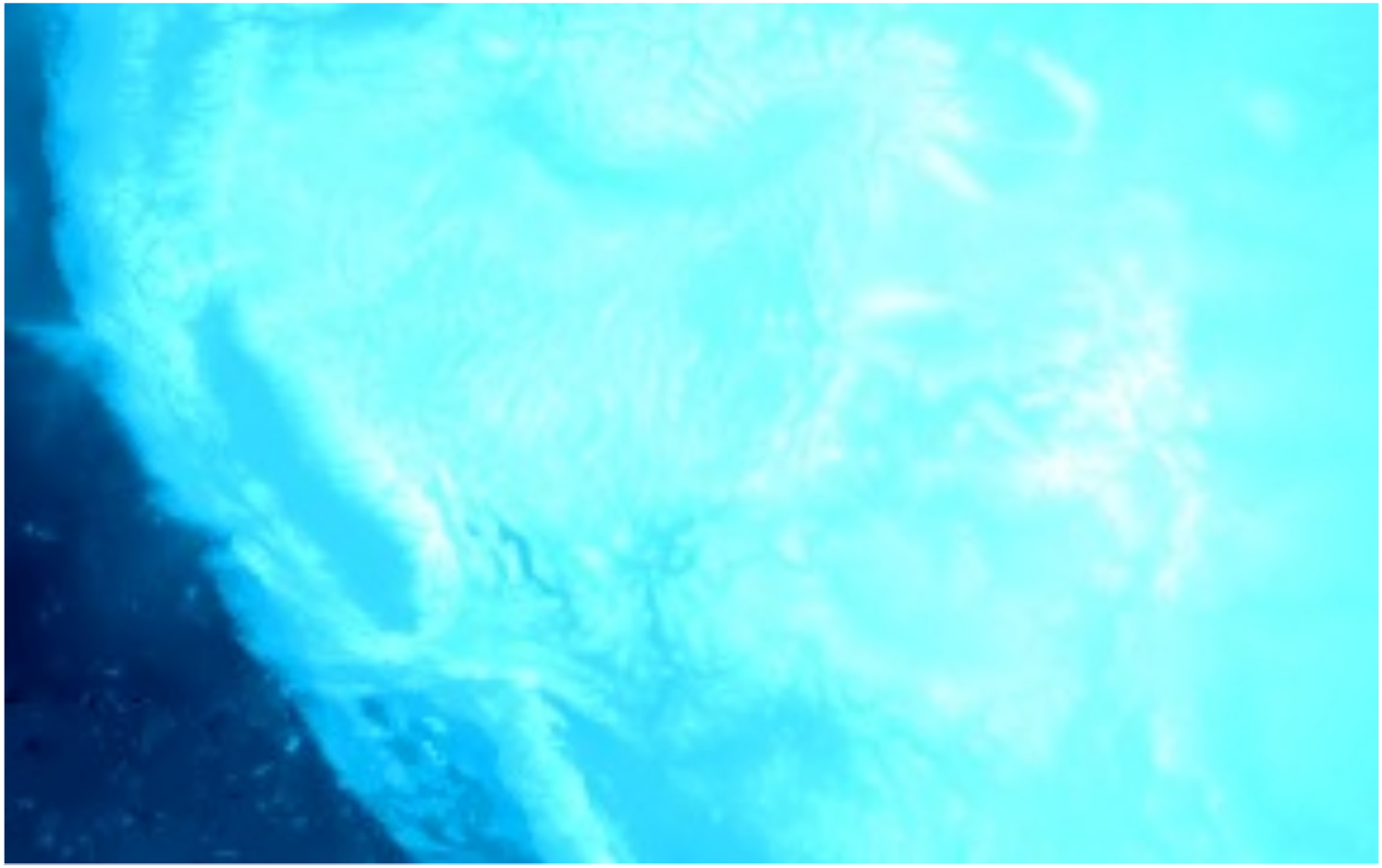


Linearized Optimal



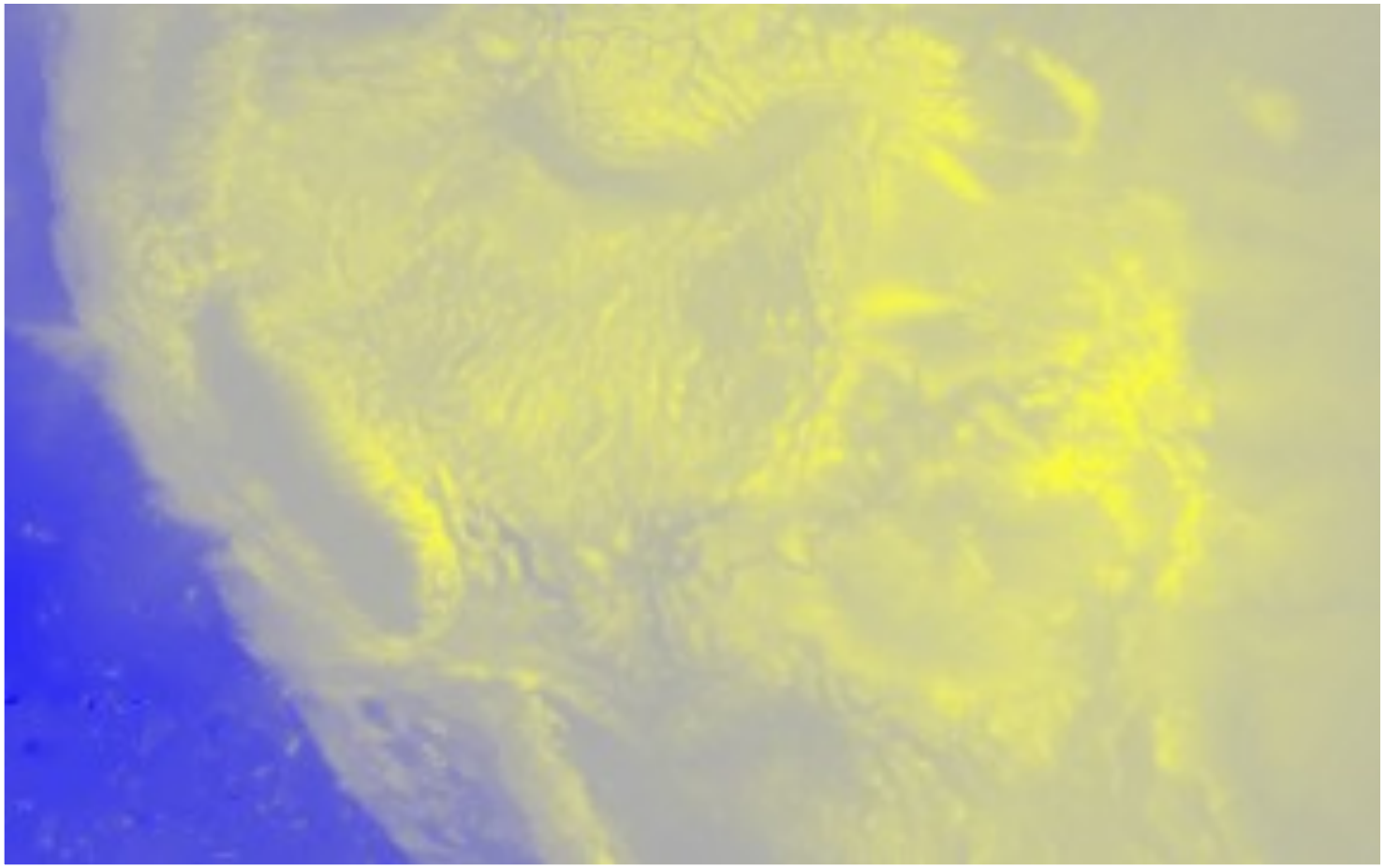
Blue-Cyan

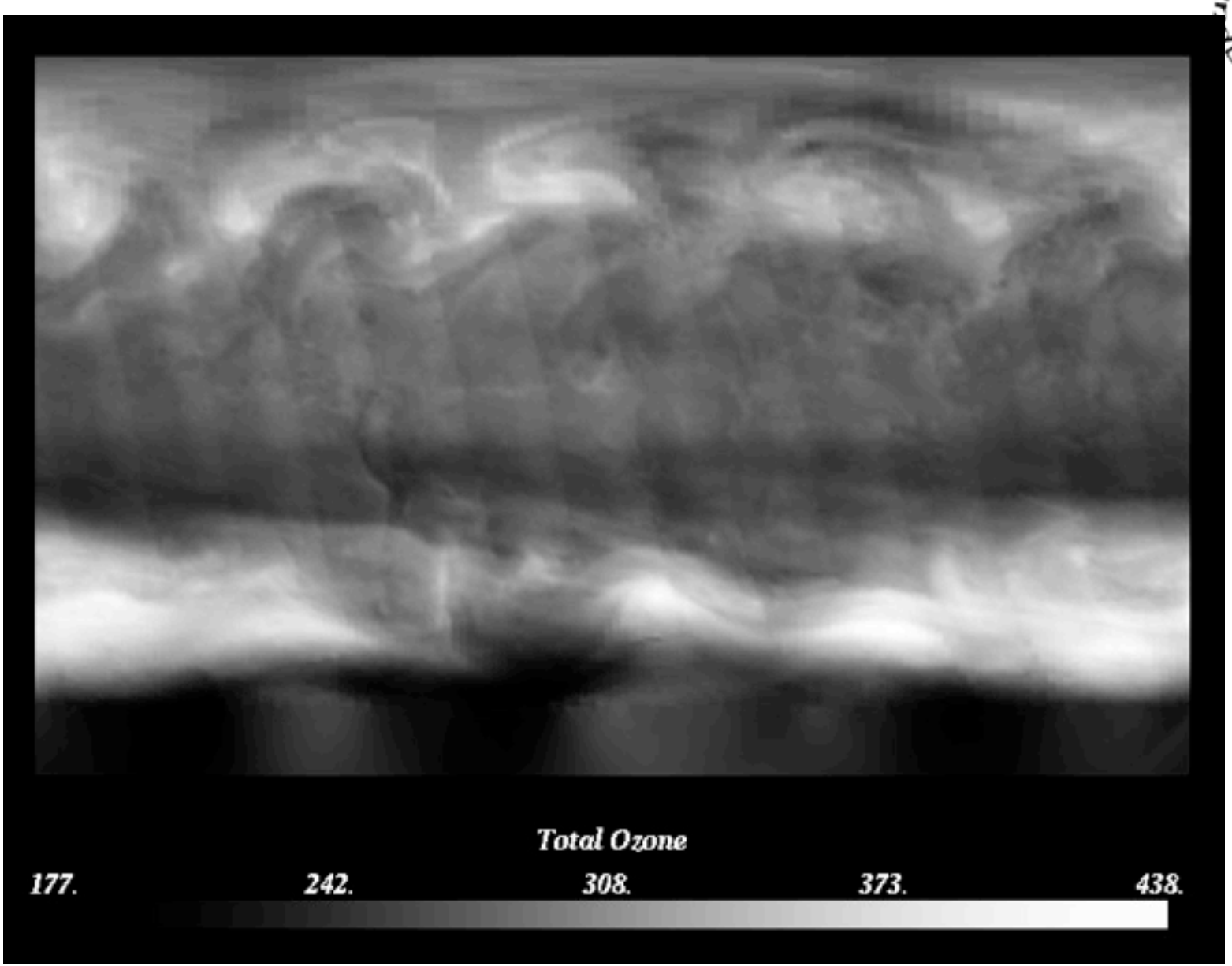
Blue-Cyan



Blue-Yellow

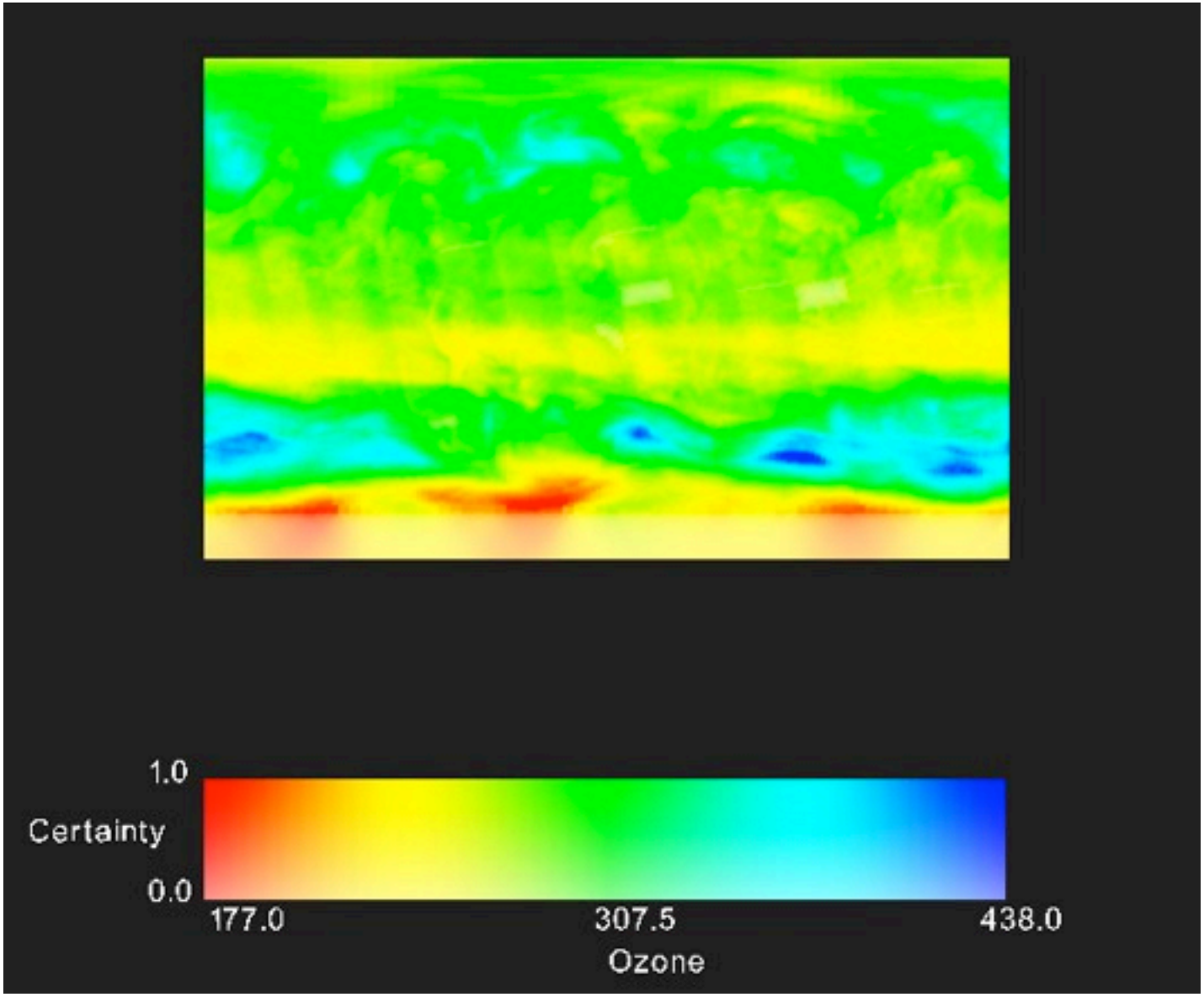
Blue-Yellow




Total Ozone
177.
242.
308.
373.
438.

Some Multivariate Color Scales

- Color model components
- Census Bureau
- Complementary display parameters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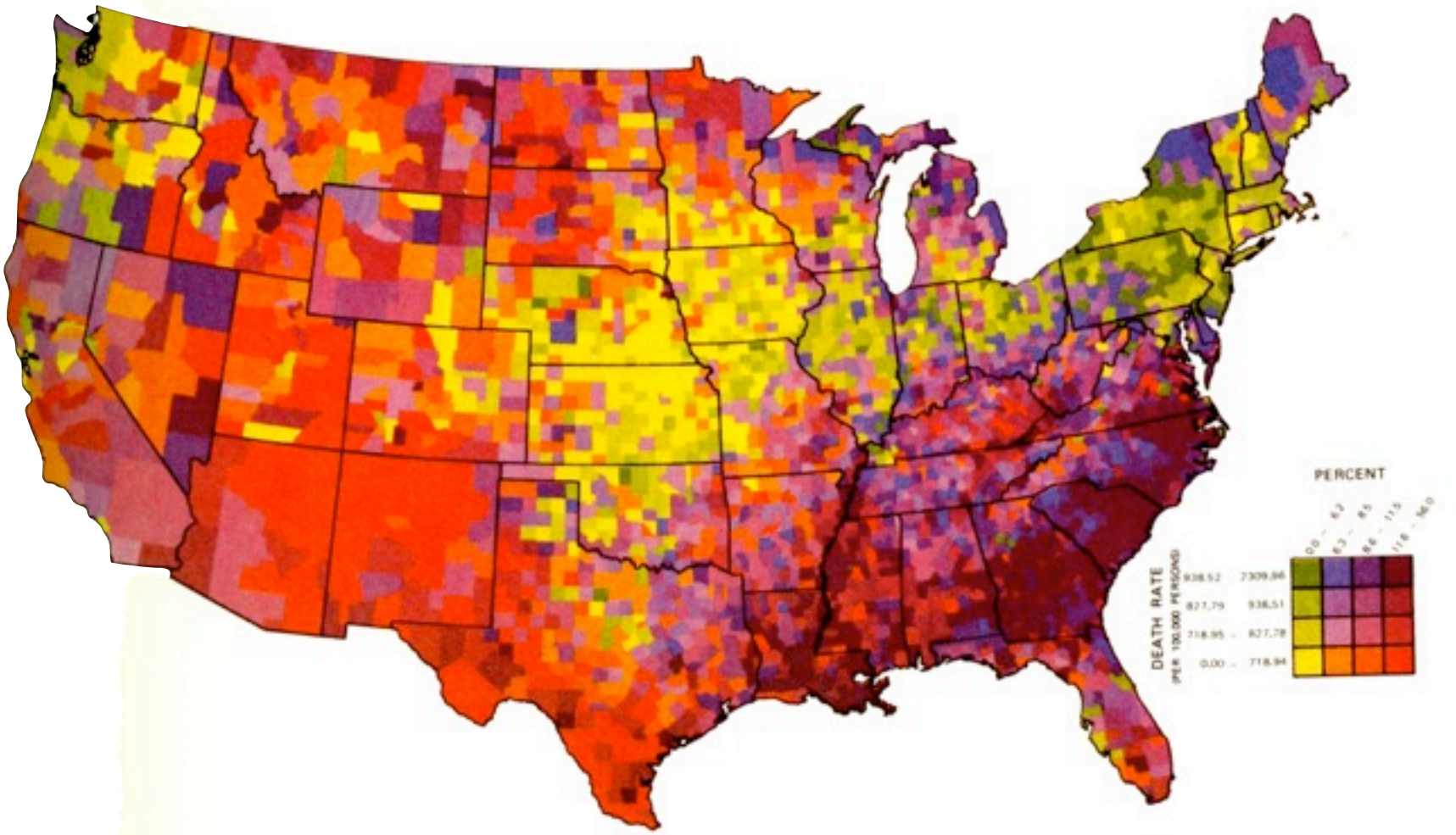
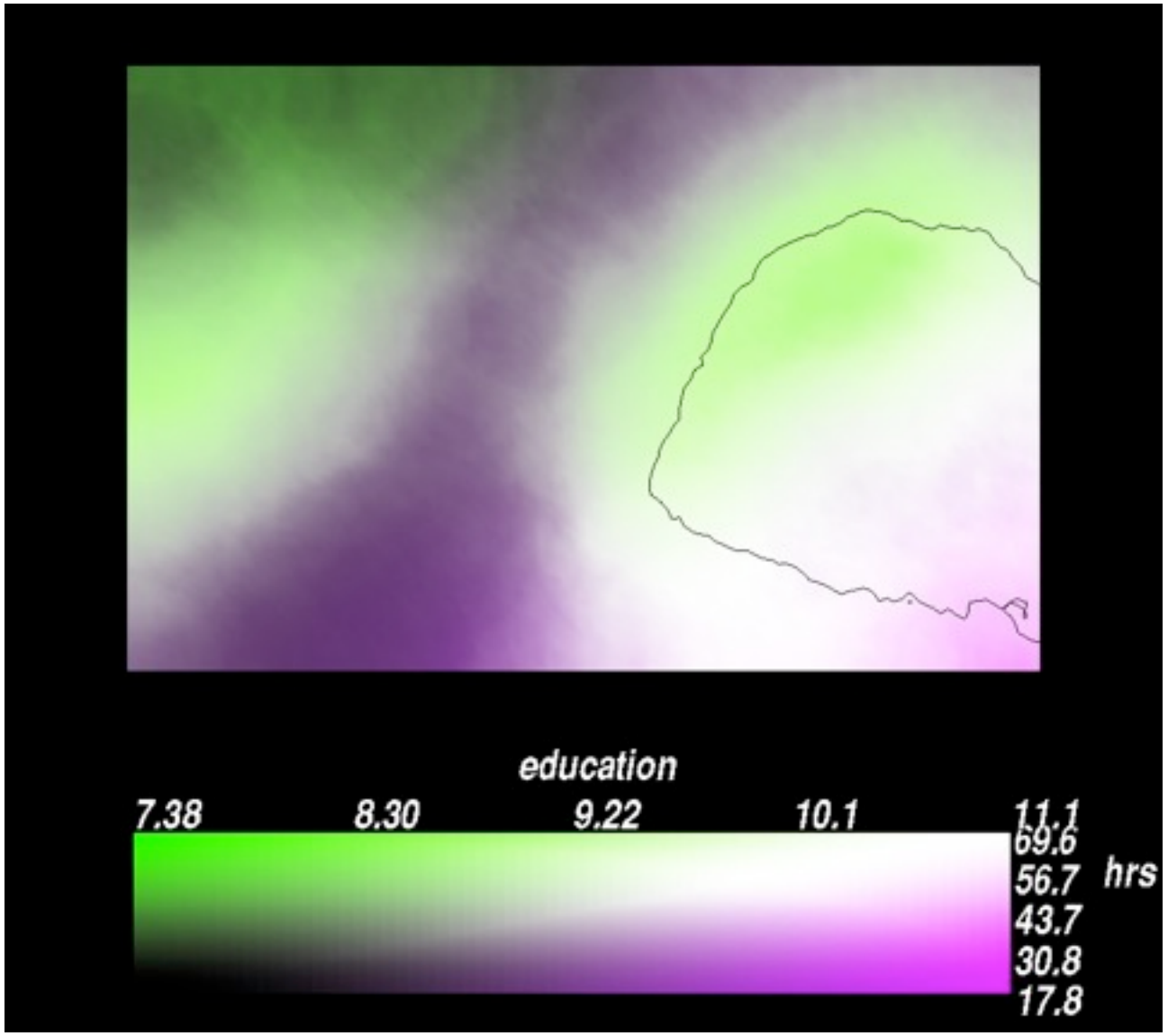
Certainty
0.0
177.0
307.5
438.0
Ozone



- Tufte '83, pg. 153.

CVD + Person/Room


education
7.38
8.30
9.22
10.1
11.1
69.6
56.7
43.7
30.8
17.8
hrs

Constructing Scales

- Manually
  - element
  - curves/ranges for components
- Rule-based approach
  - PRAVDAcolor in IBM DX
  - ex: Bergman95
- Search-based approaches
  - automatically generate and evaluate scales
  - ex: He96

Evaluating Color Scales

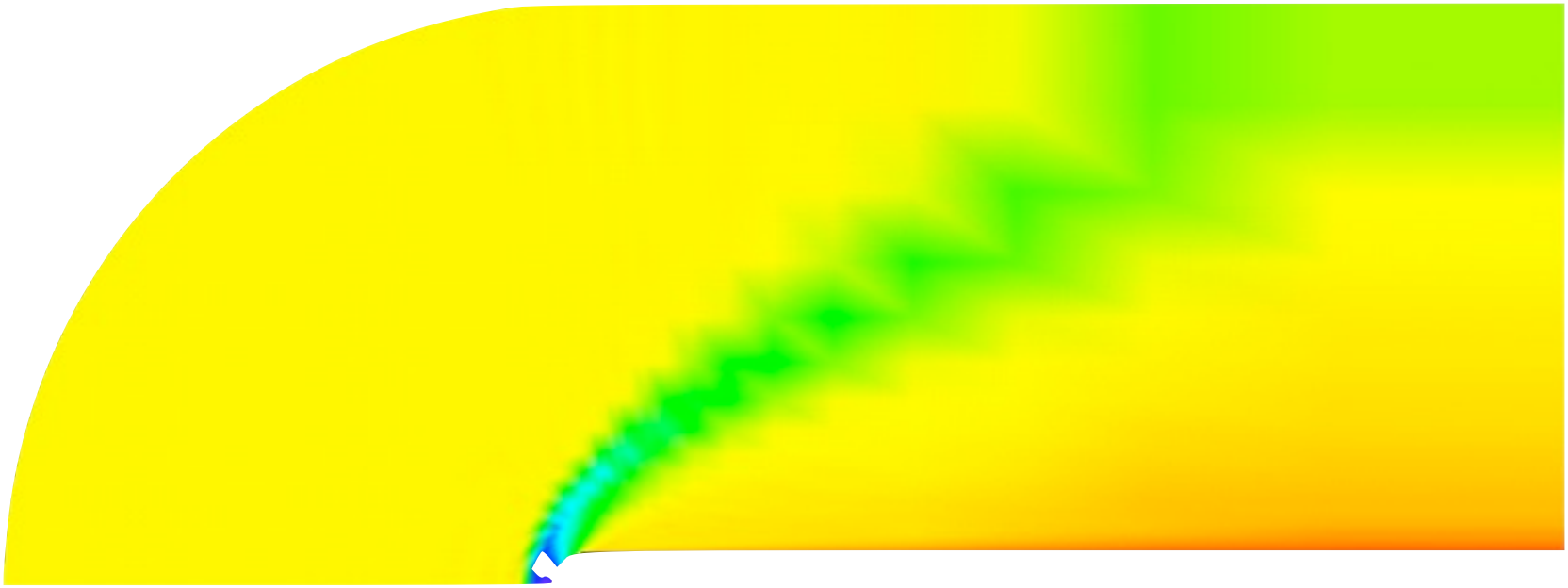
Trumbo's Principles

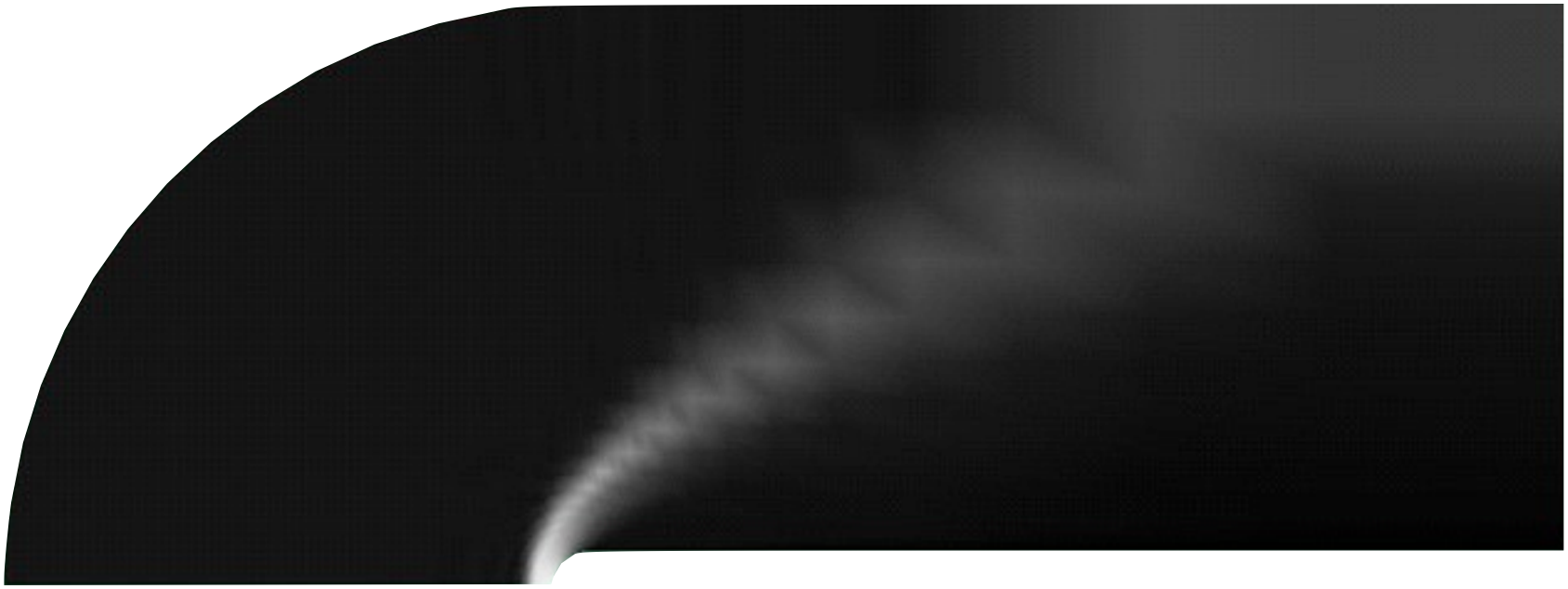
Order: ordered values should be represented by ordered colors

Separation: significantly different levels should be represented by distinguishable colors

Rows and columns: to preserve univariate information, display parameters should not obscure one another

Diagonal: to show positive association, displayed colors should group into three perceptual classes: diagonal, above, below





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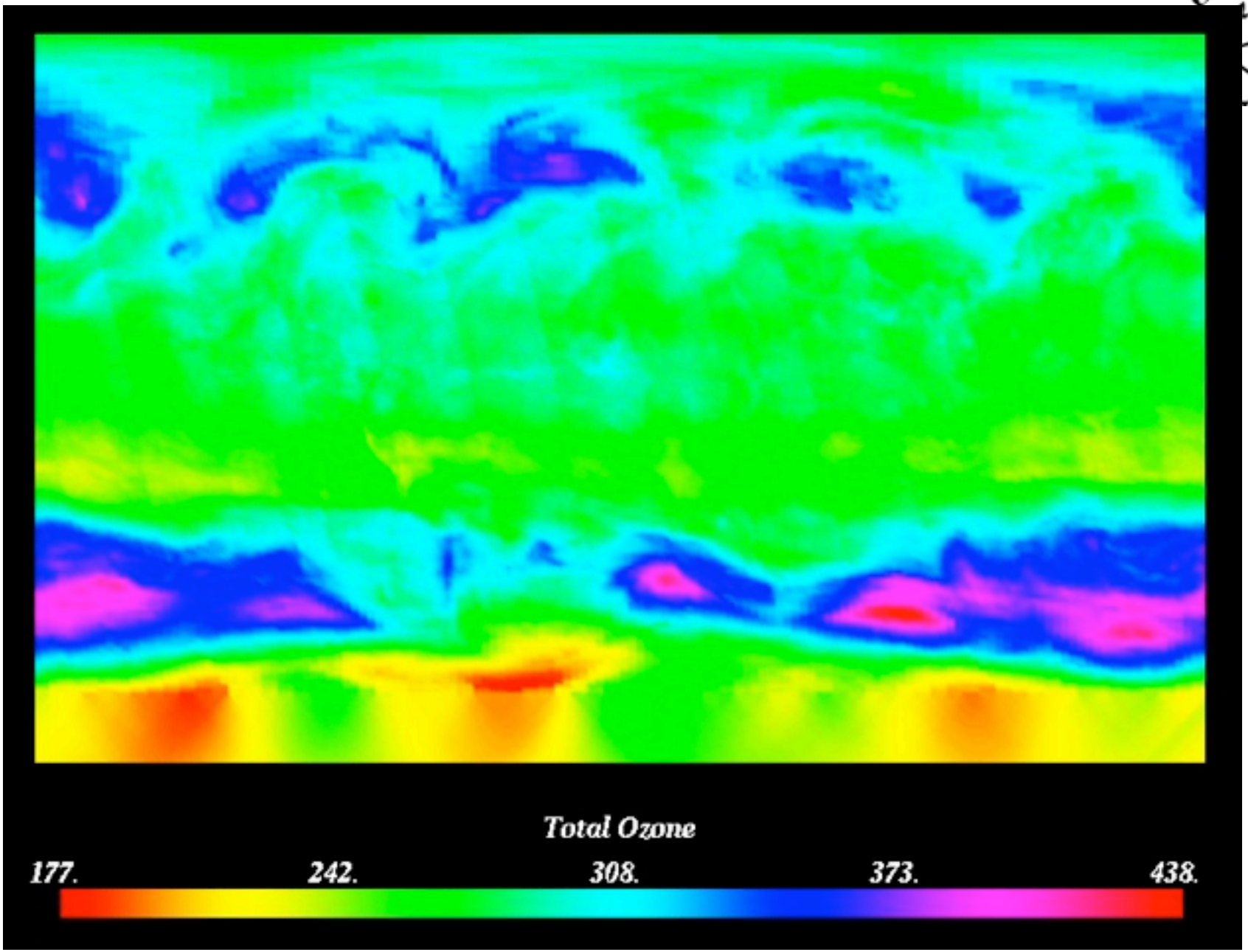
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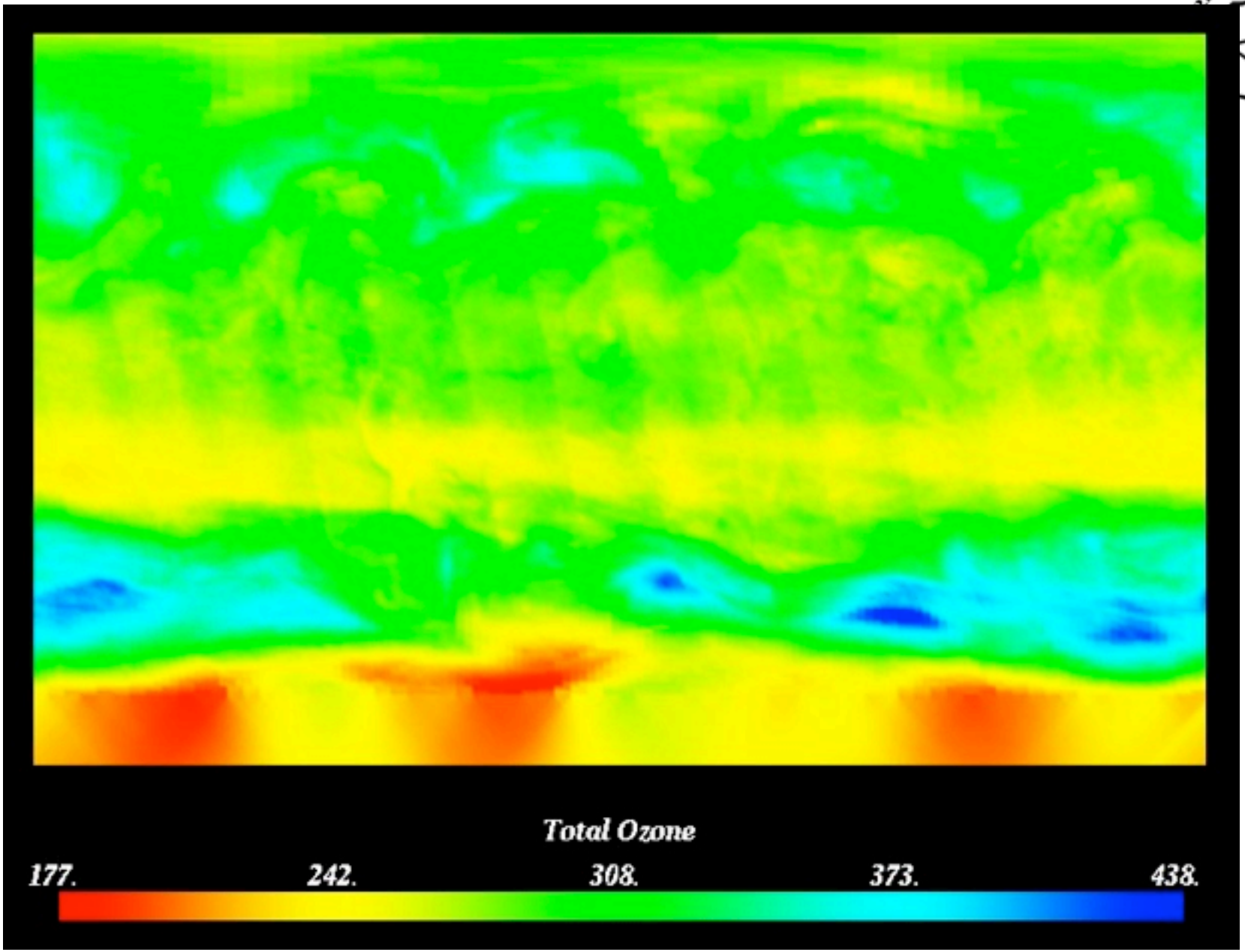
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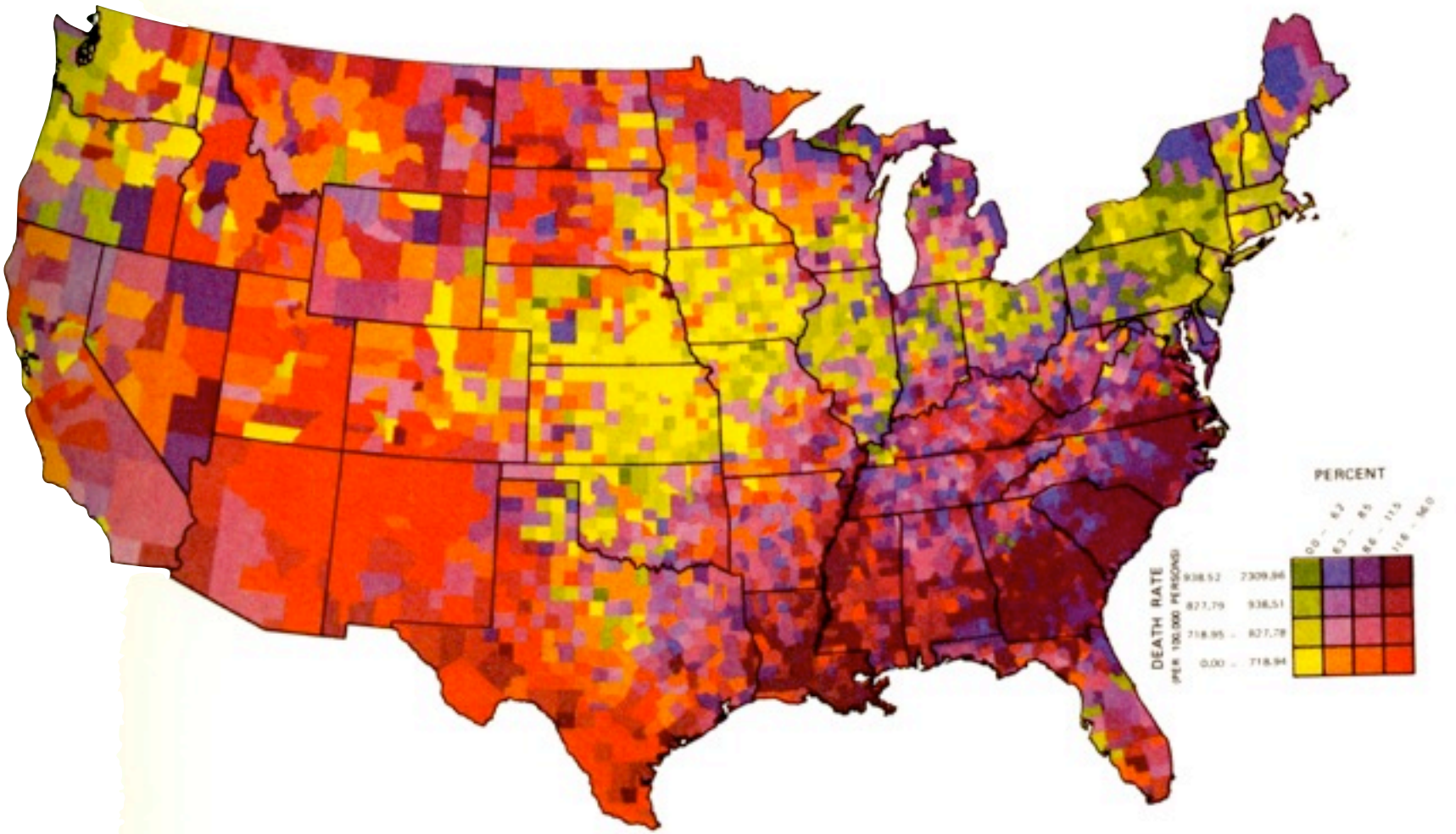
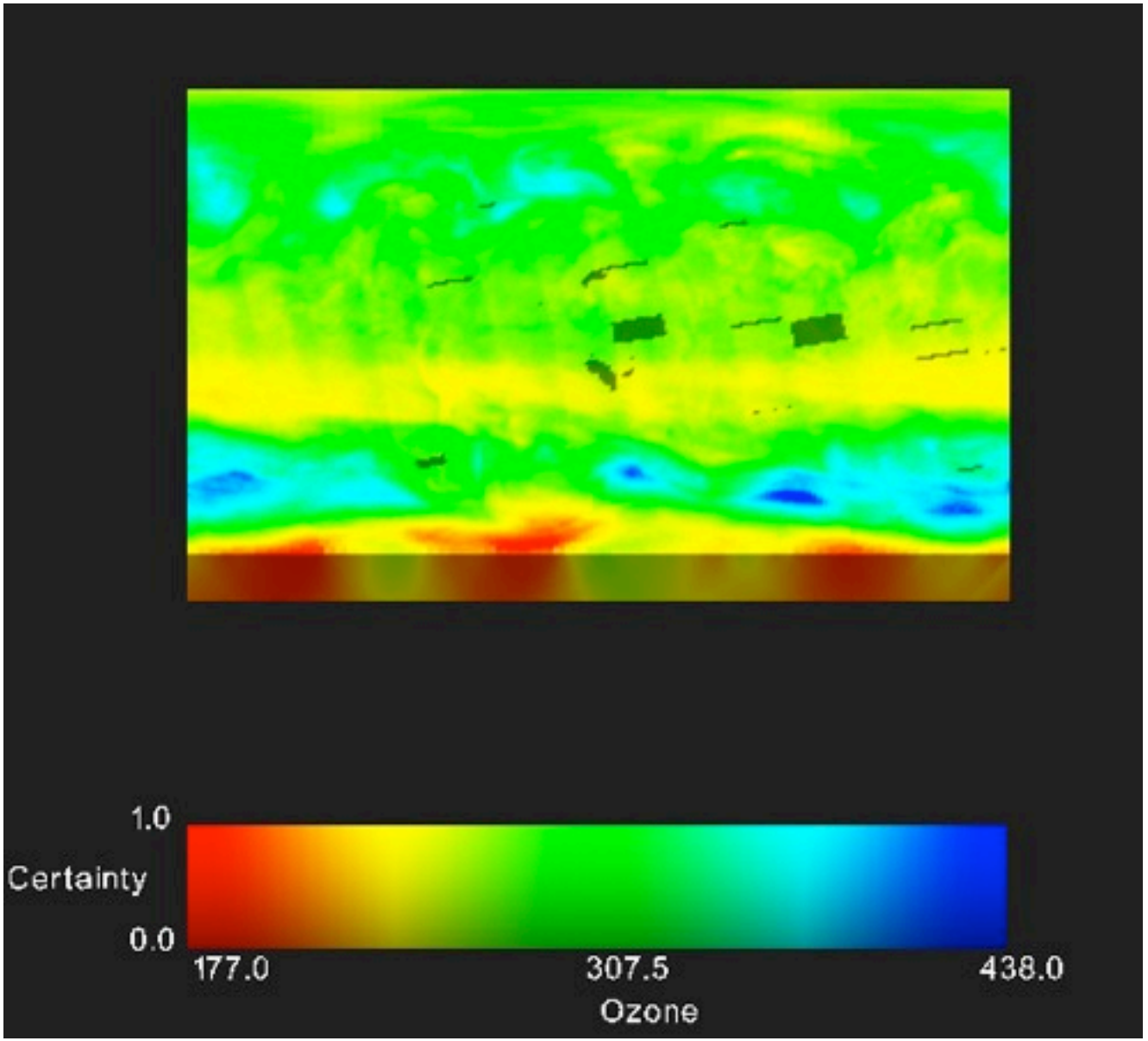


- Tufte '83, pg. 153.


1.0
Certainty
0.0
177.0
307.5
438.0
Ozone

Evaluating Color Scales

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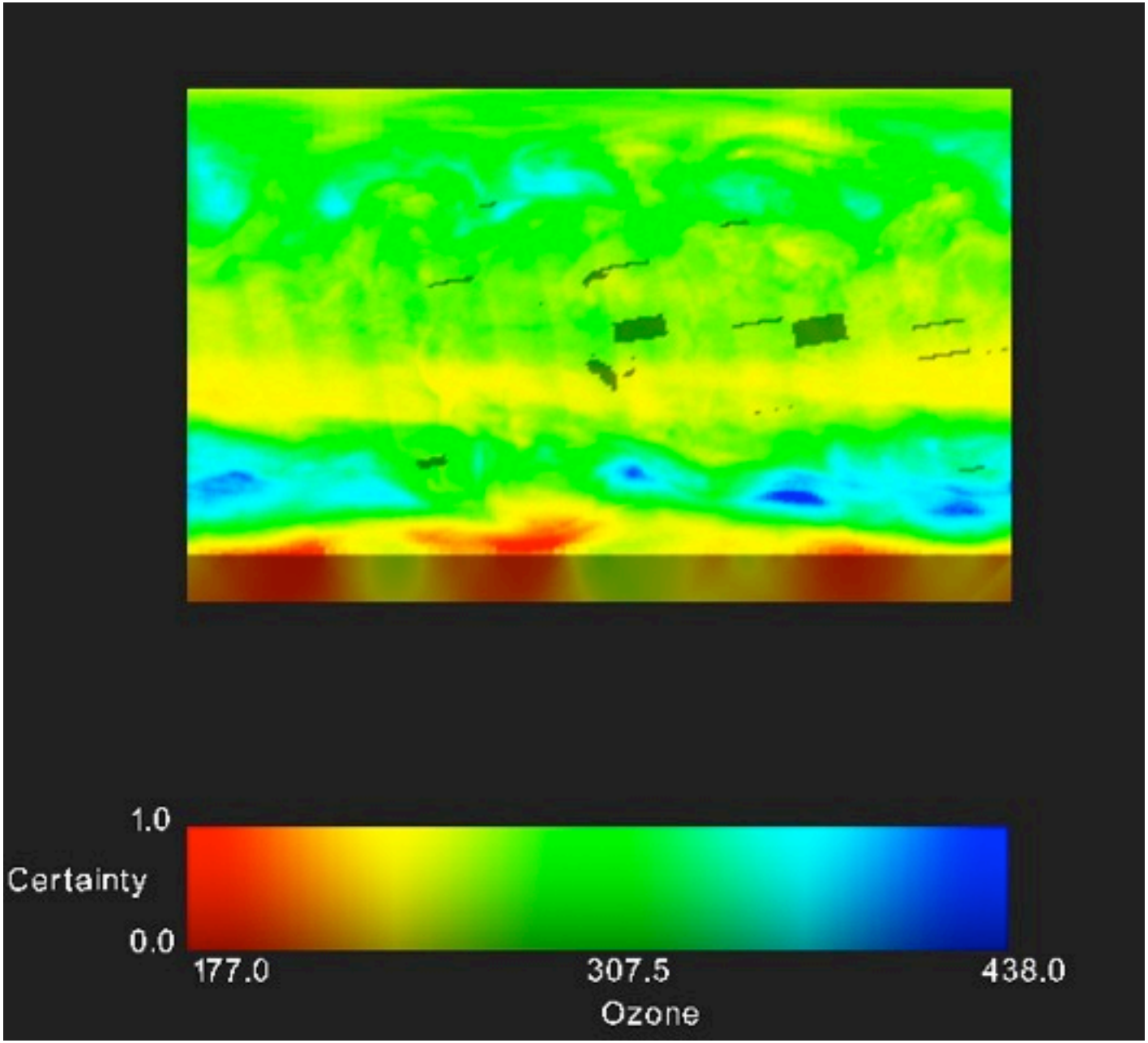
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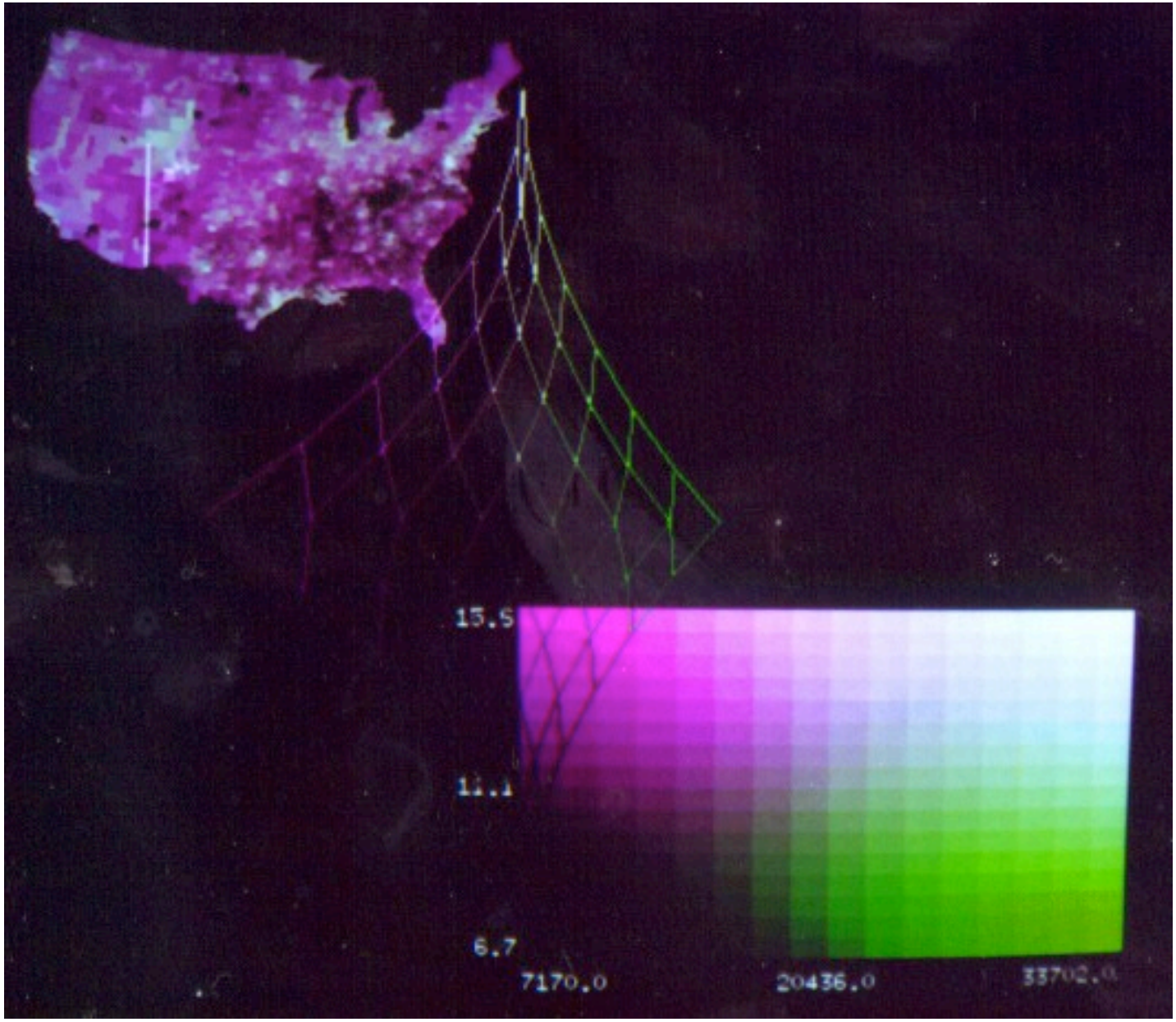

15.5
11.1
6.7
7170.0
20436.0

Exploration Tasks

- Discover extrema
- Look up metric information
- Identify clusters
- Recognize pattern/structure

Evaluating Color Scales (again)

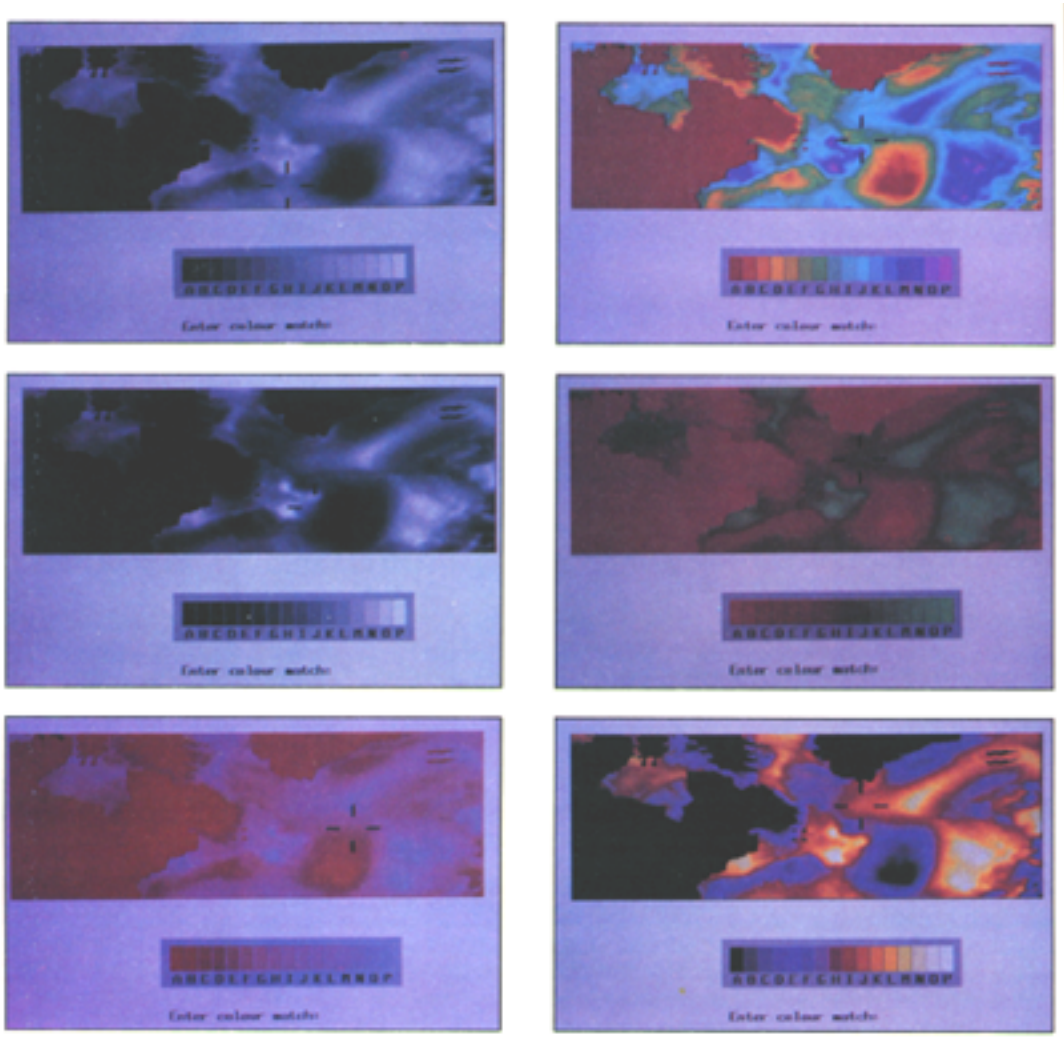
Ware's experiments

- metric (quantitative) judgements
- surface (qualitative) judgements
- redundant color scales

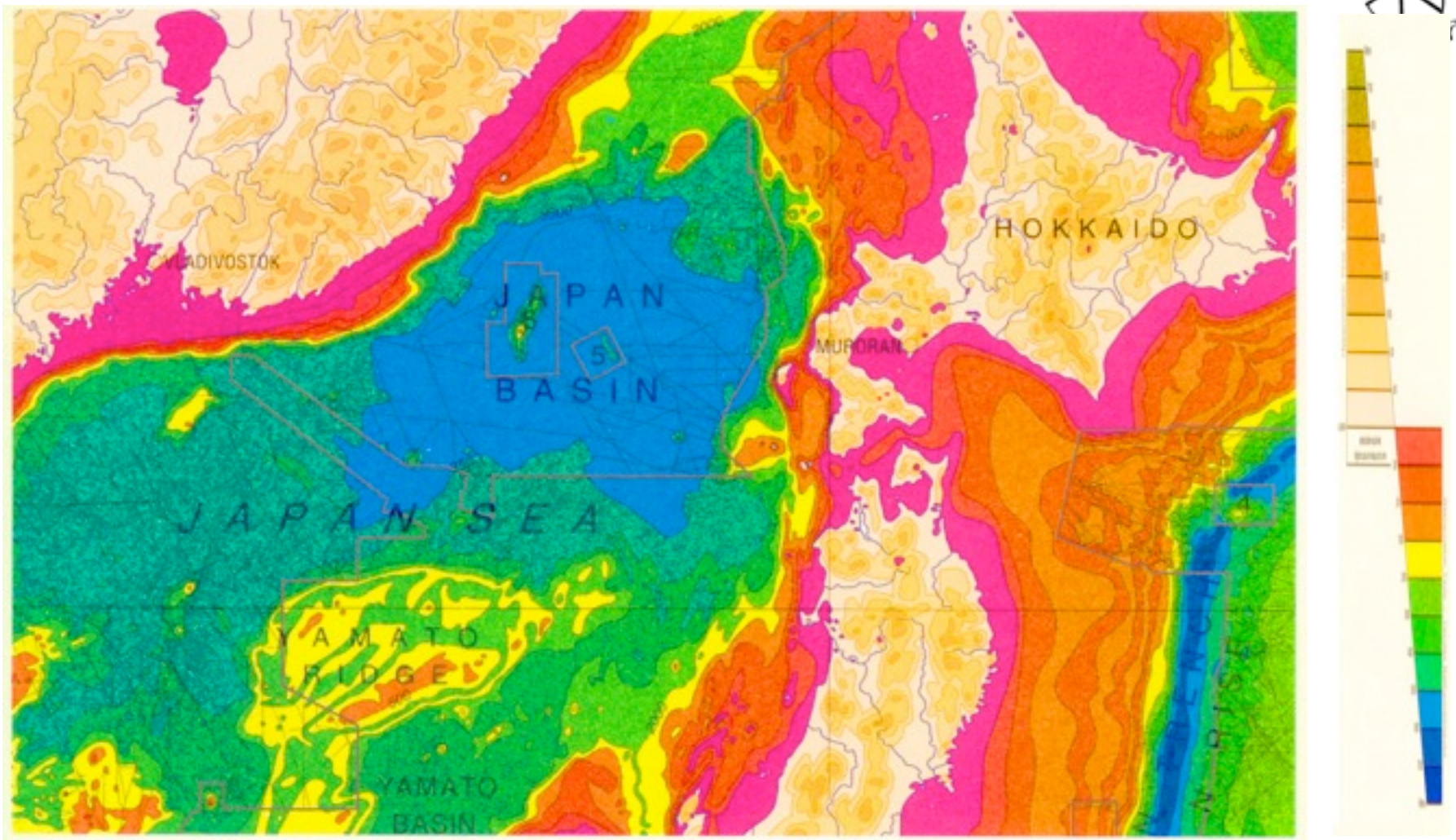
Results

- Some scales are better at qualitative judgments
  - Relative shapes and sizes
- Other color scales are better for quantitative judgments
  - Looking up values

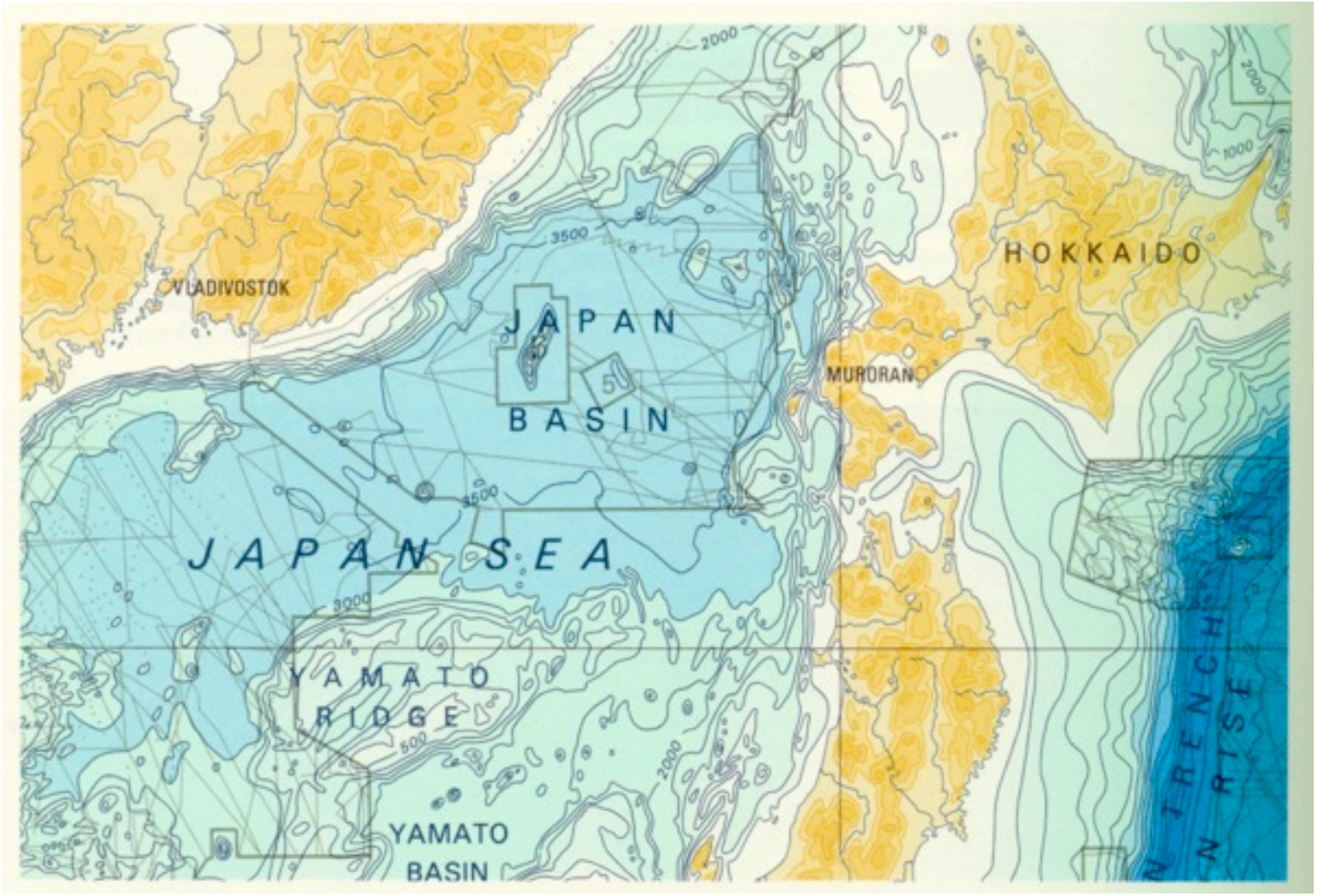
Ware's Color Scales



Ware '88.



Tufte ‘97, pg. 77.



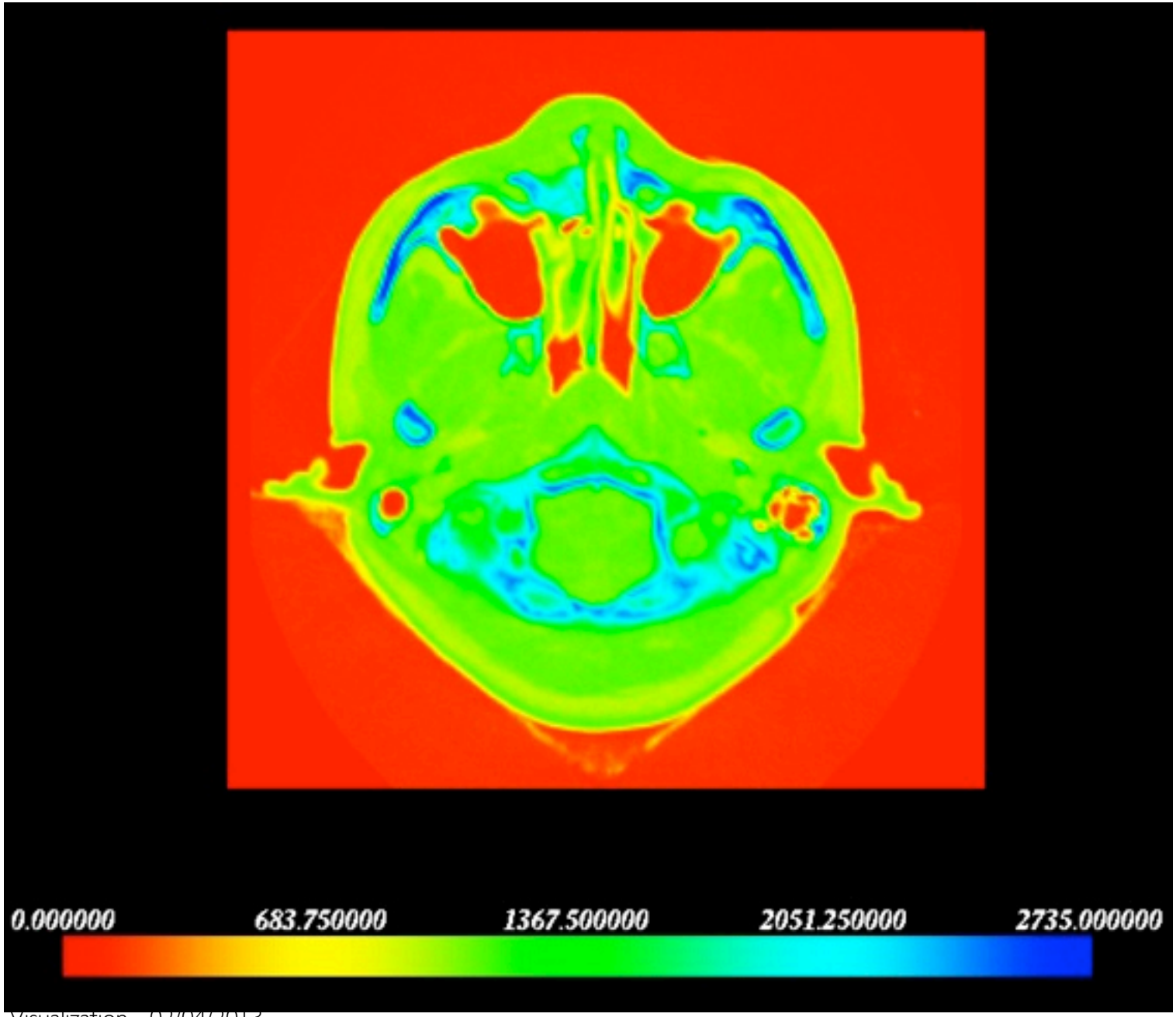
Tufte '97, pg. 76.

Considerations

- Consider task
- Consider data
- Consider whole visualization
- Consider audience
- Consider color connotations

Consider Task

- Quantitative comprehension?
  - Vary across opponent color channels
- Qualitative comprehension?
  - Vary lightness
- Other judgements?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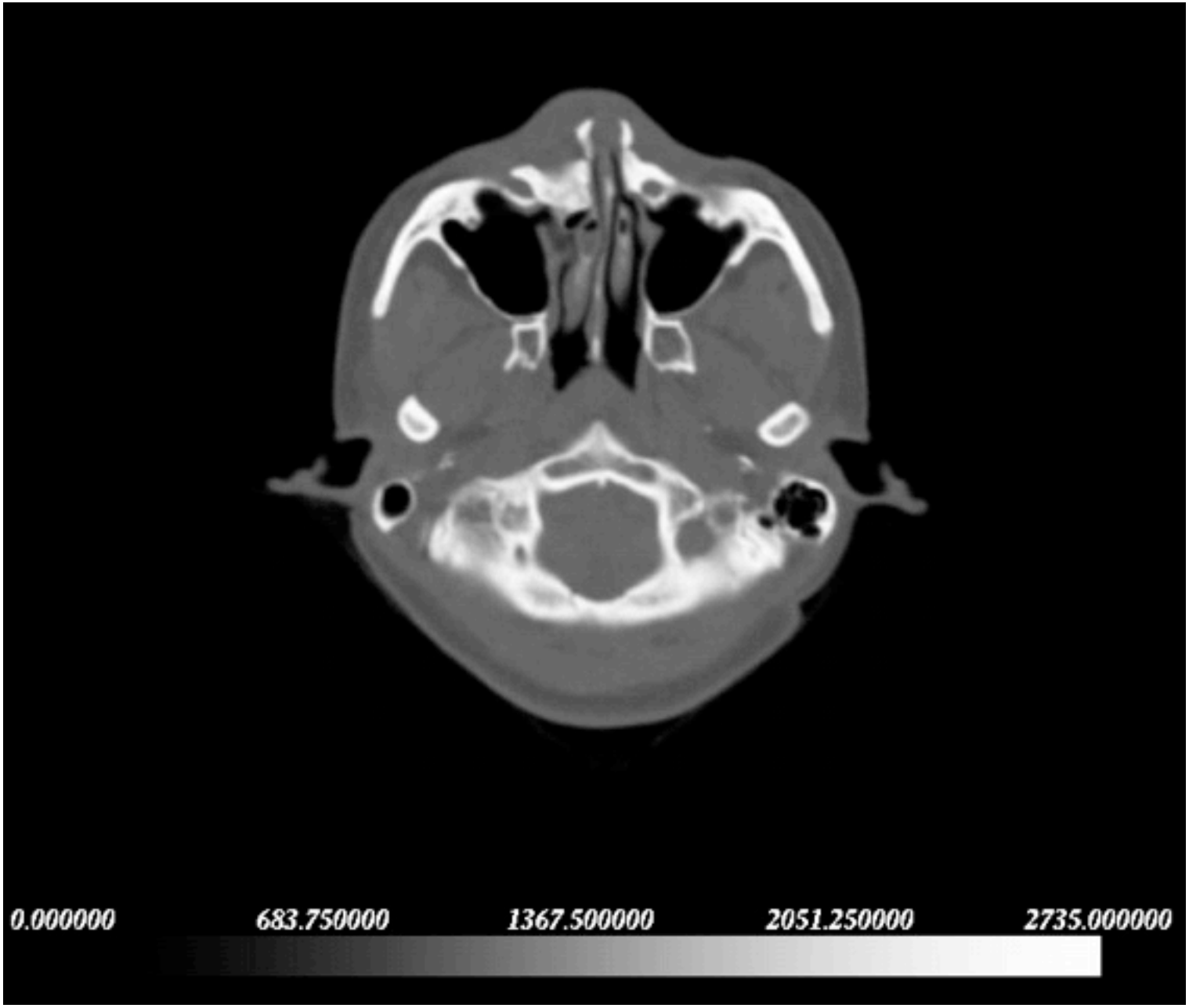
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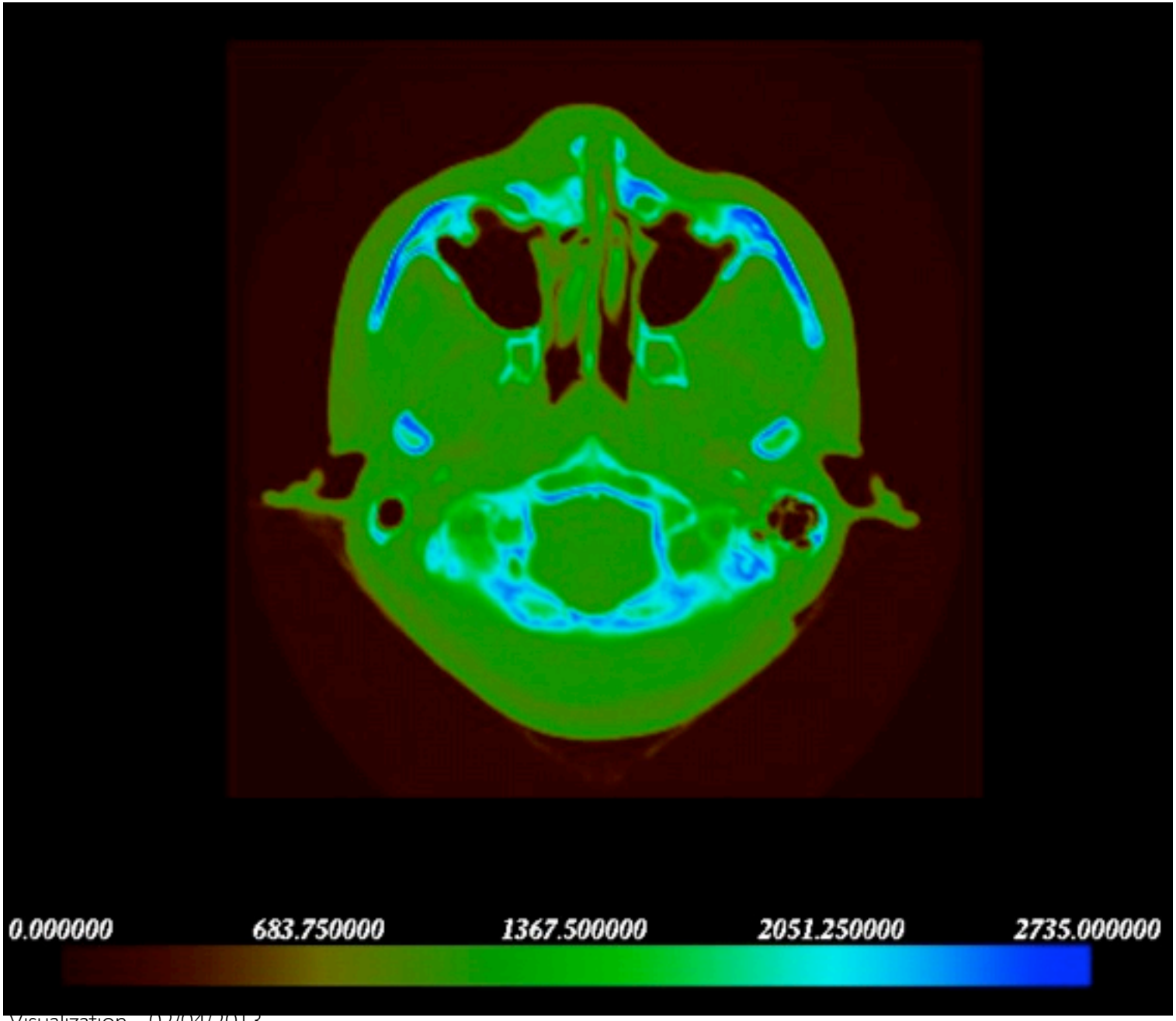
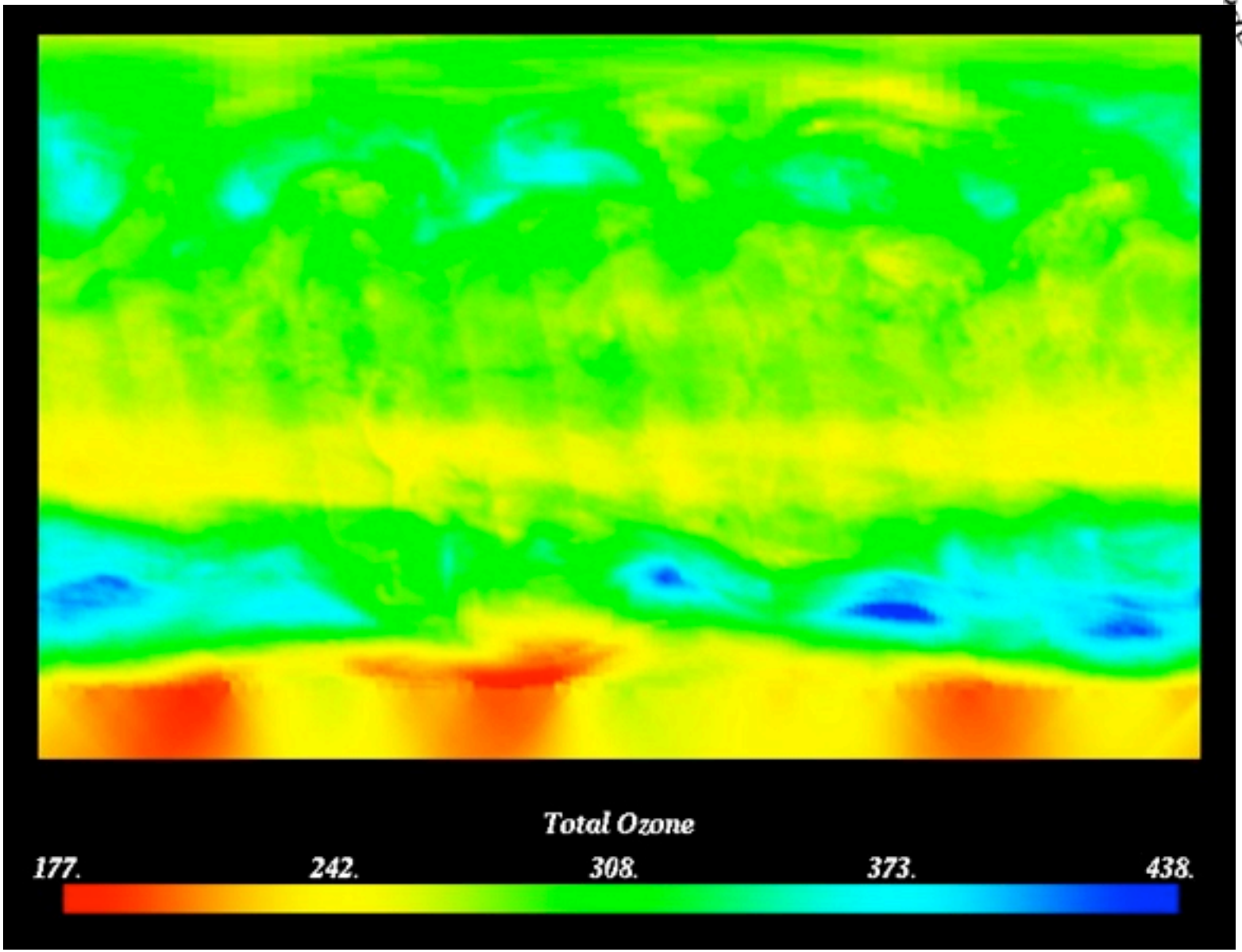
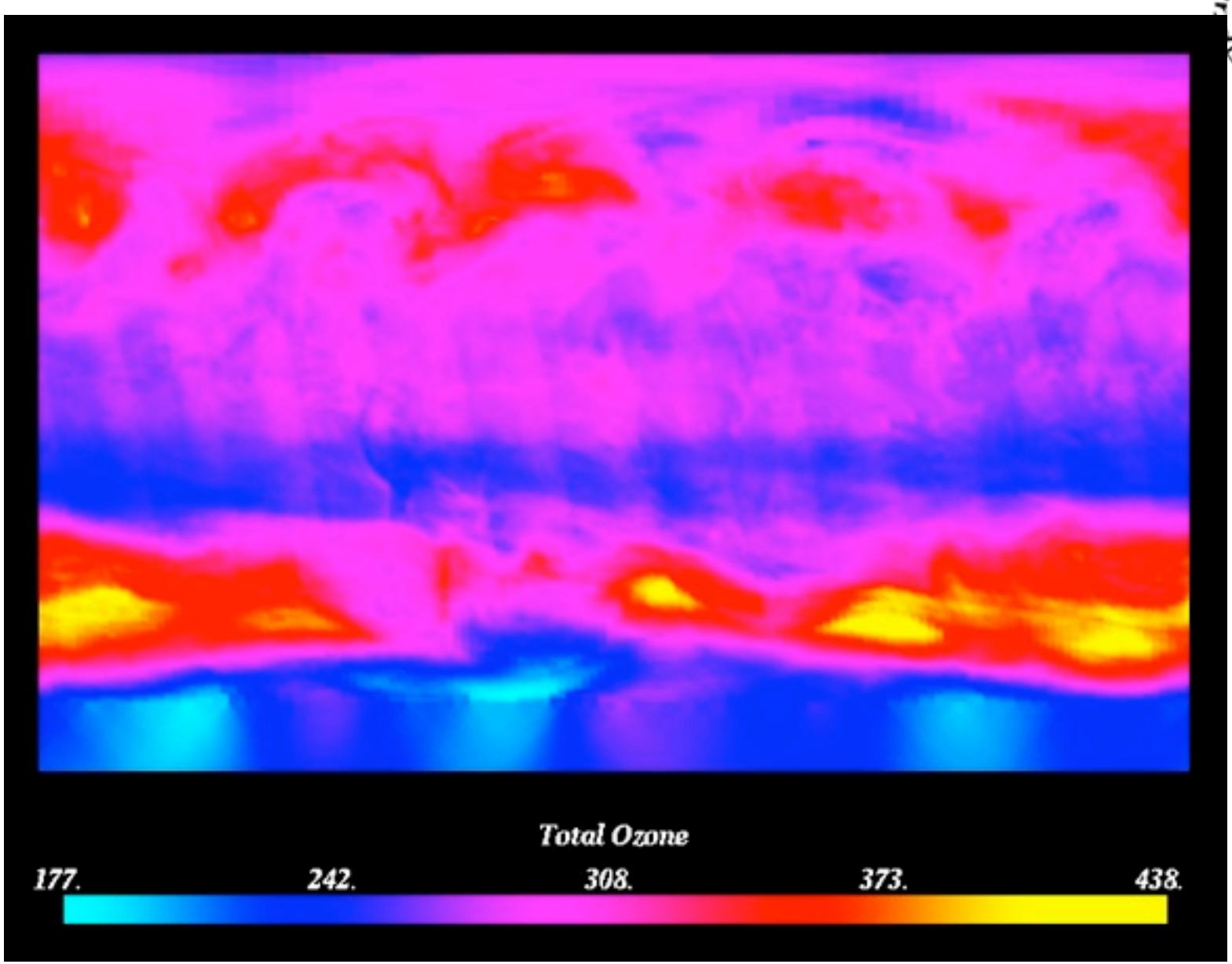
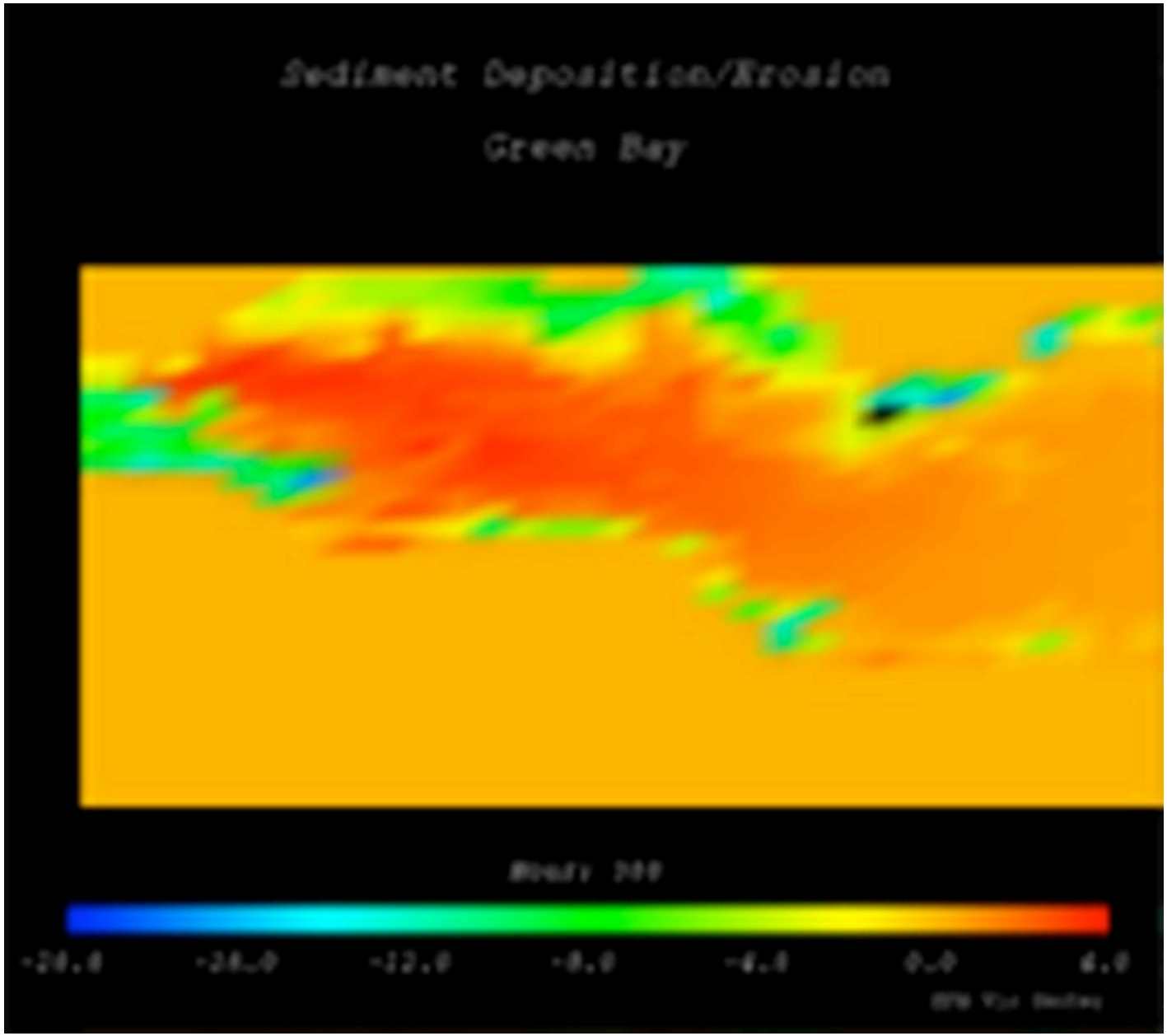

0.000000
683.750000
1367.500000
2051.250000
2735.000000

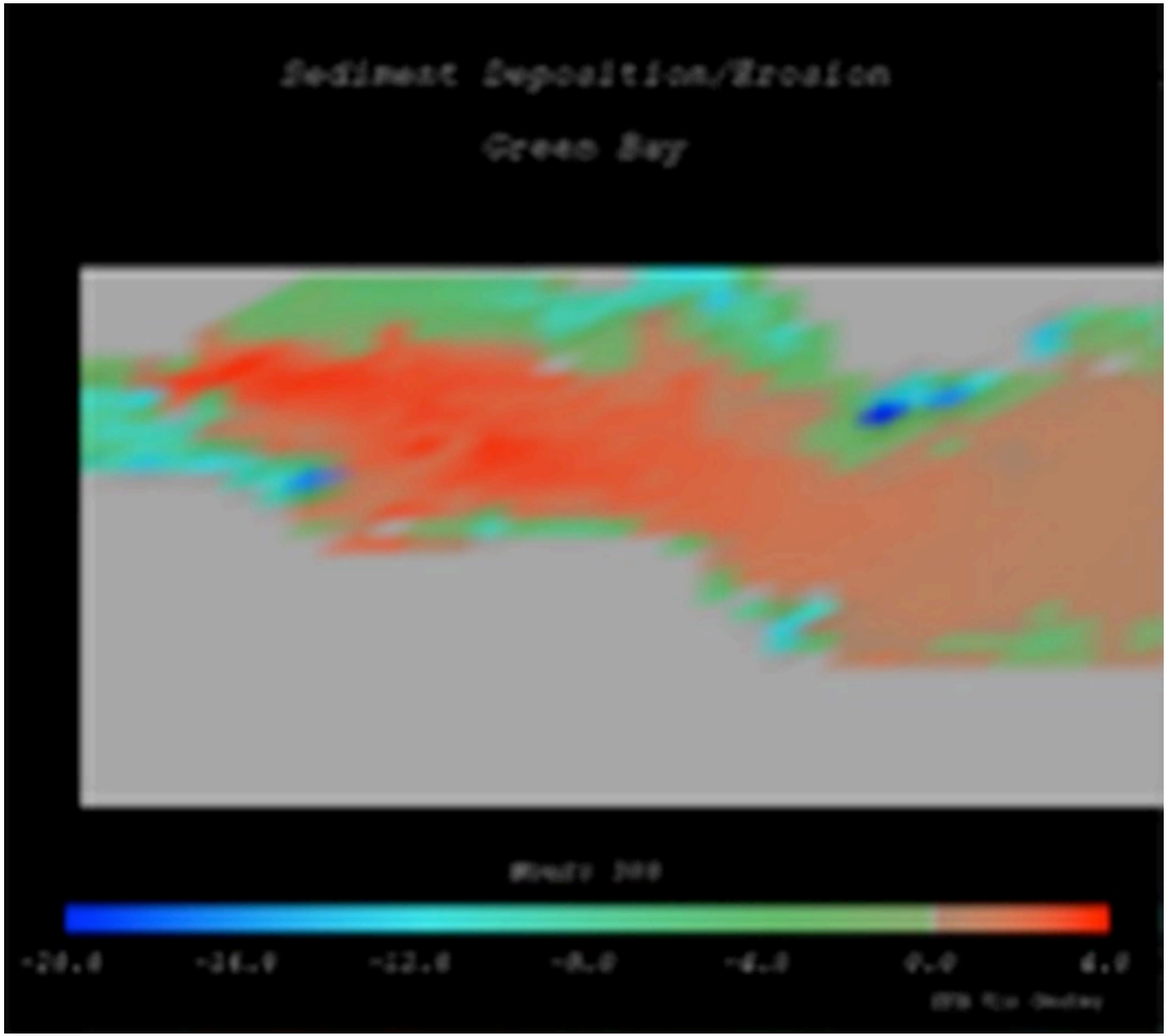
Consider Data

- Interesting values?
  - Position striking colors at interesting values
- Zero in range?
  - Double-ended scale
- High spatial frequency?
  - Vary lightness


Total Ozone
177.
242.
308.
373.
438.

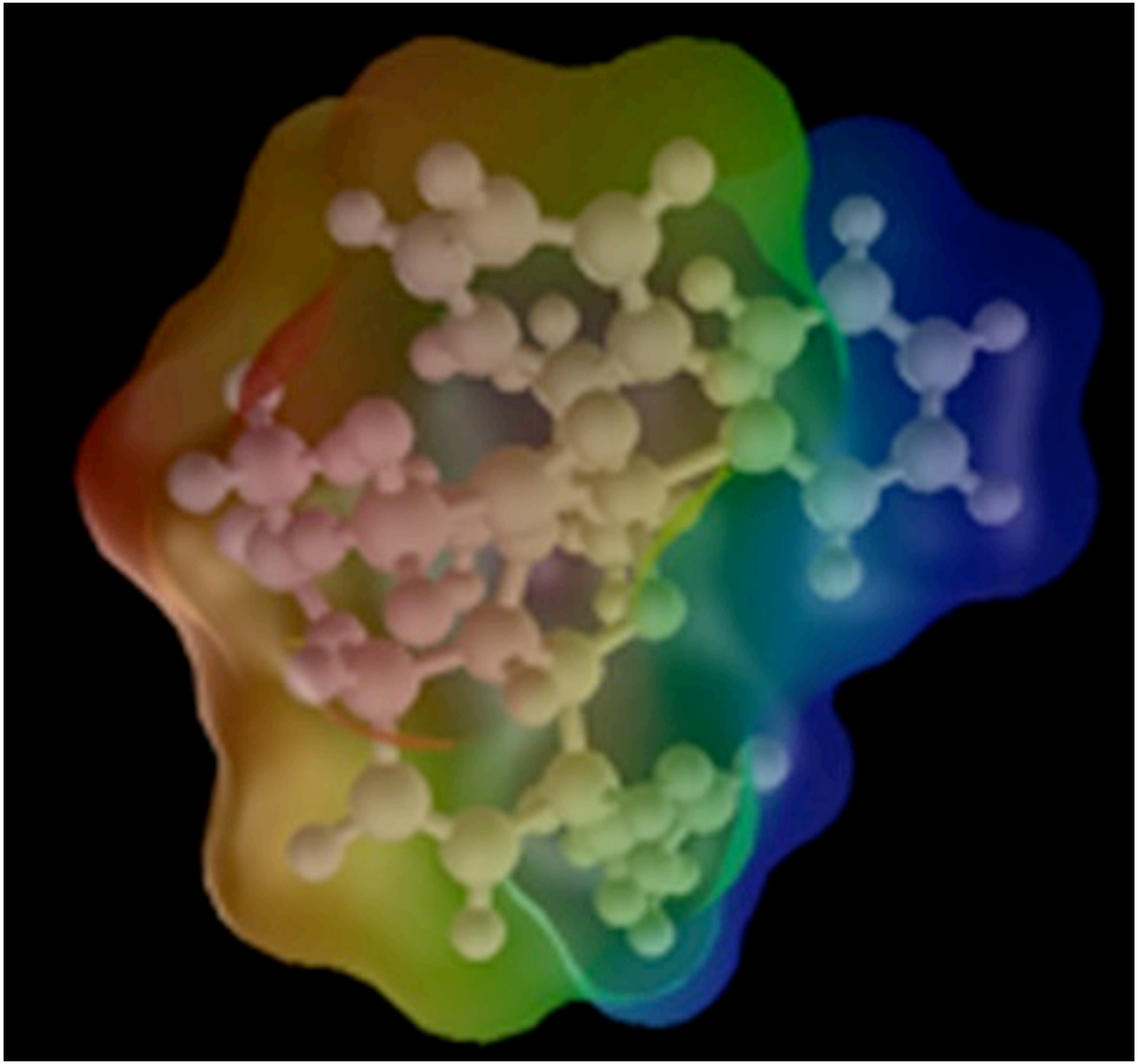

Total Ozone
177.
242.
308.
373.
438.

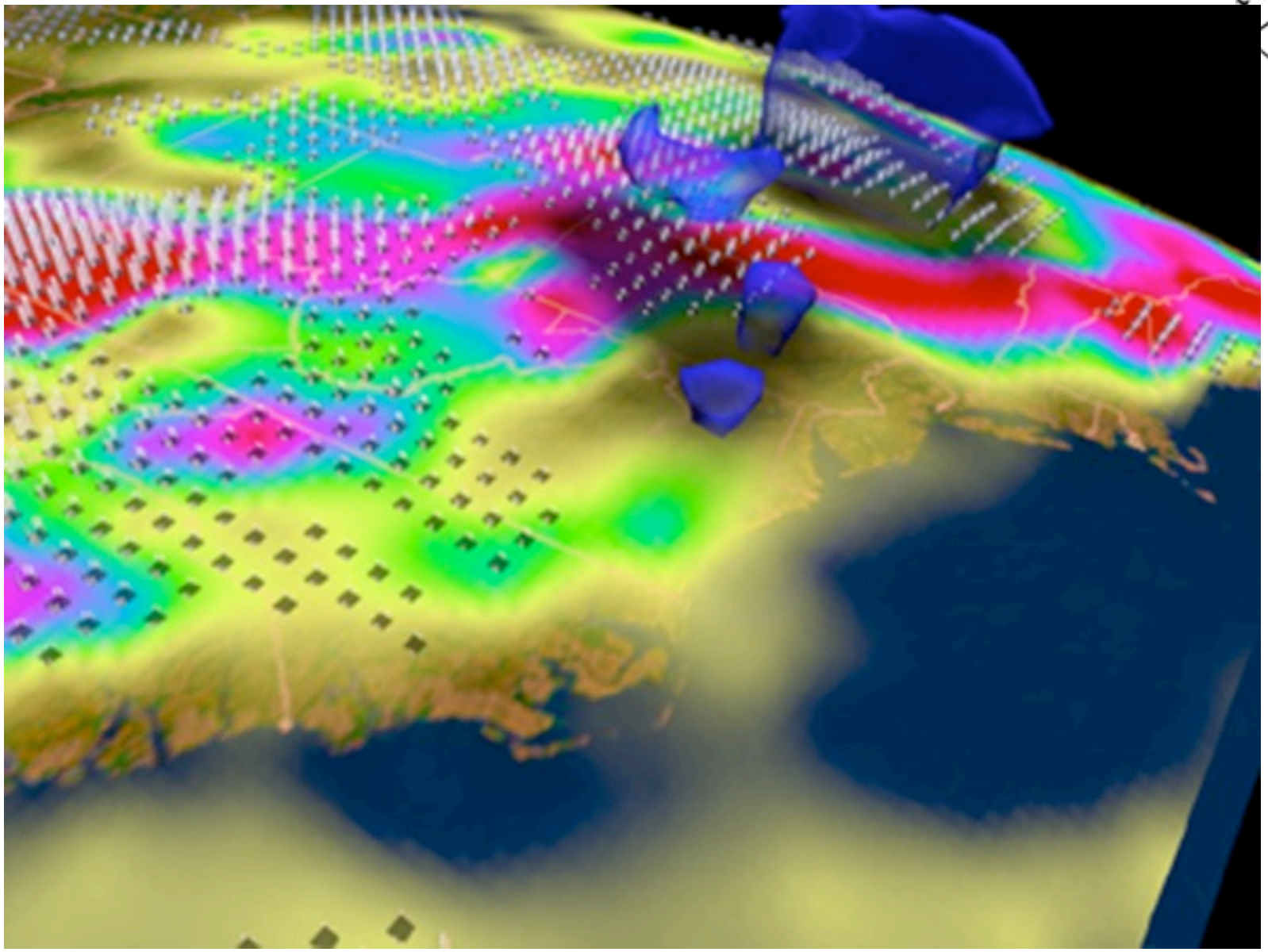

Sediment Deposition/Erosion
Green Bay
-20.0
-16.0
-12.0
-8.0
-4.0
0.0
4.0


Sediment Deposition/Erosion
Green Bay
-20.0
-16.0
-12.0
-8.0
-4.0
0.0
4.0

Consider Whole Visualization

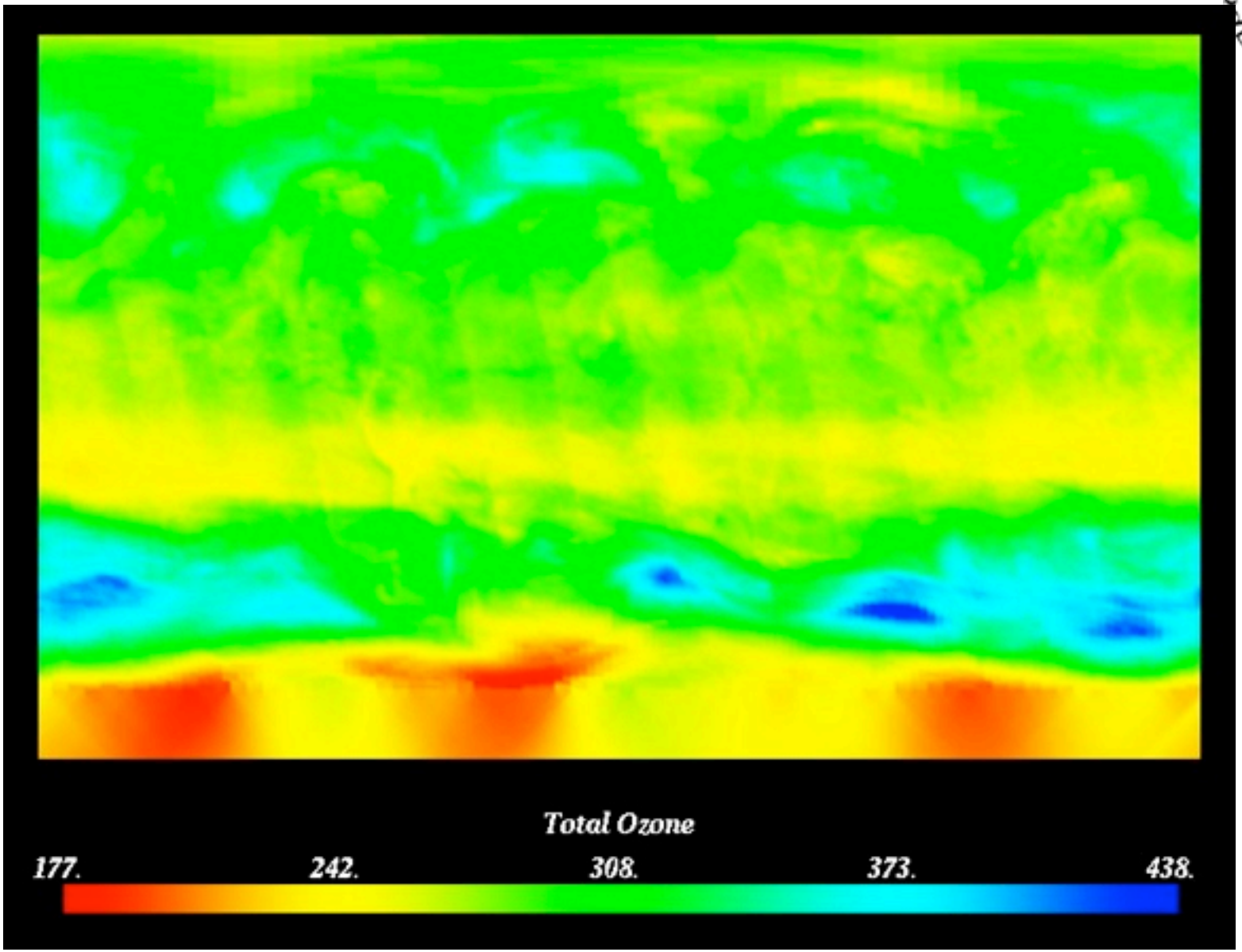
- 3D color mapped objects?
  - Don't vary lightness in color scale
- Multiple variables displayed?
  - Map to different perceptual channels

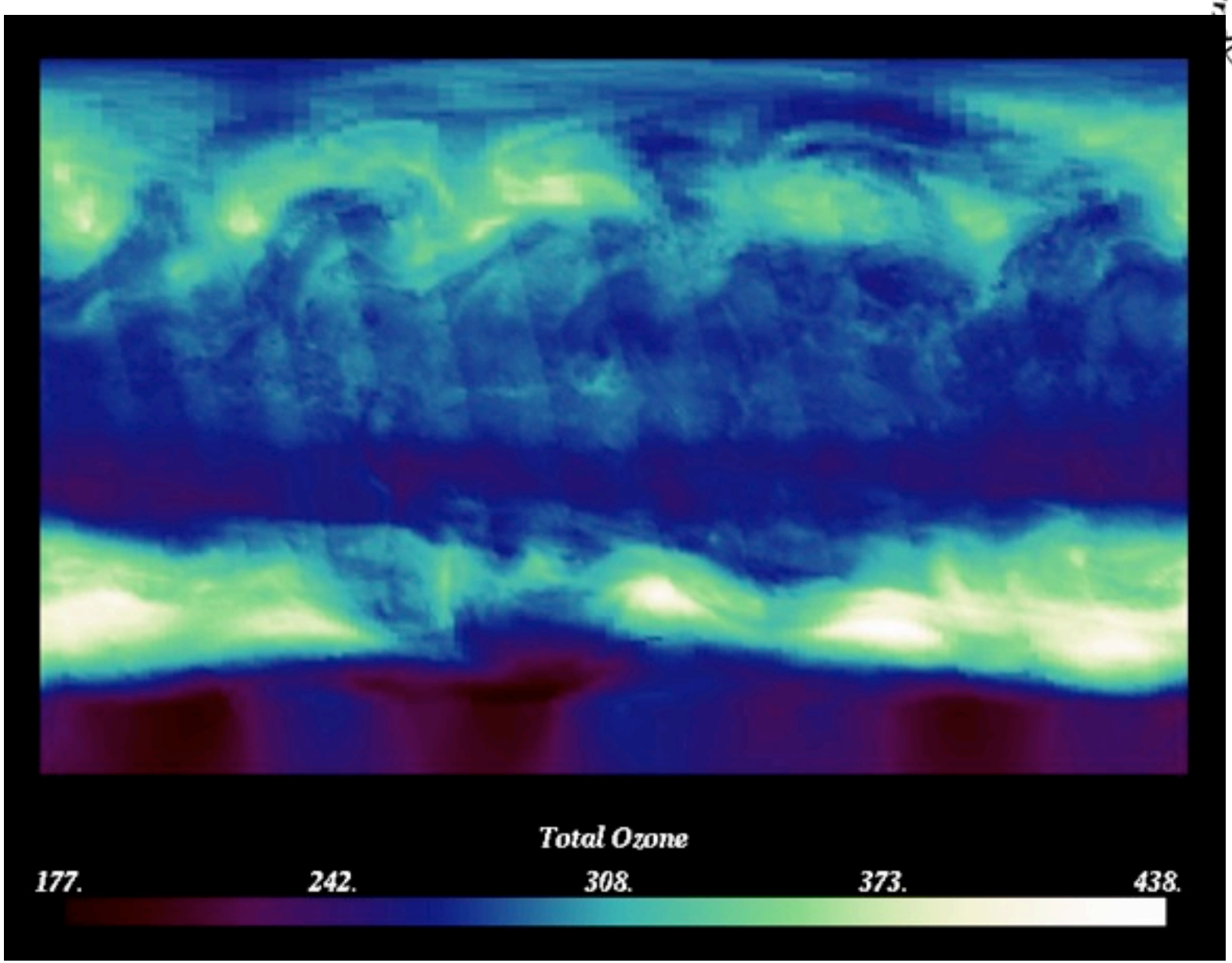


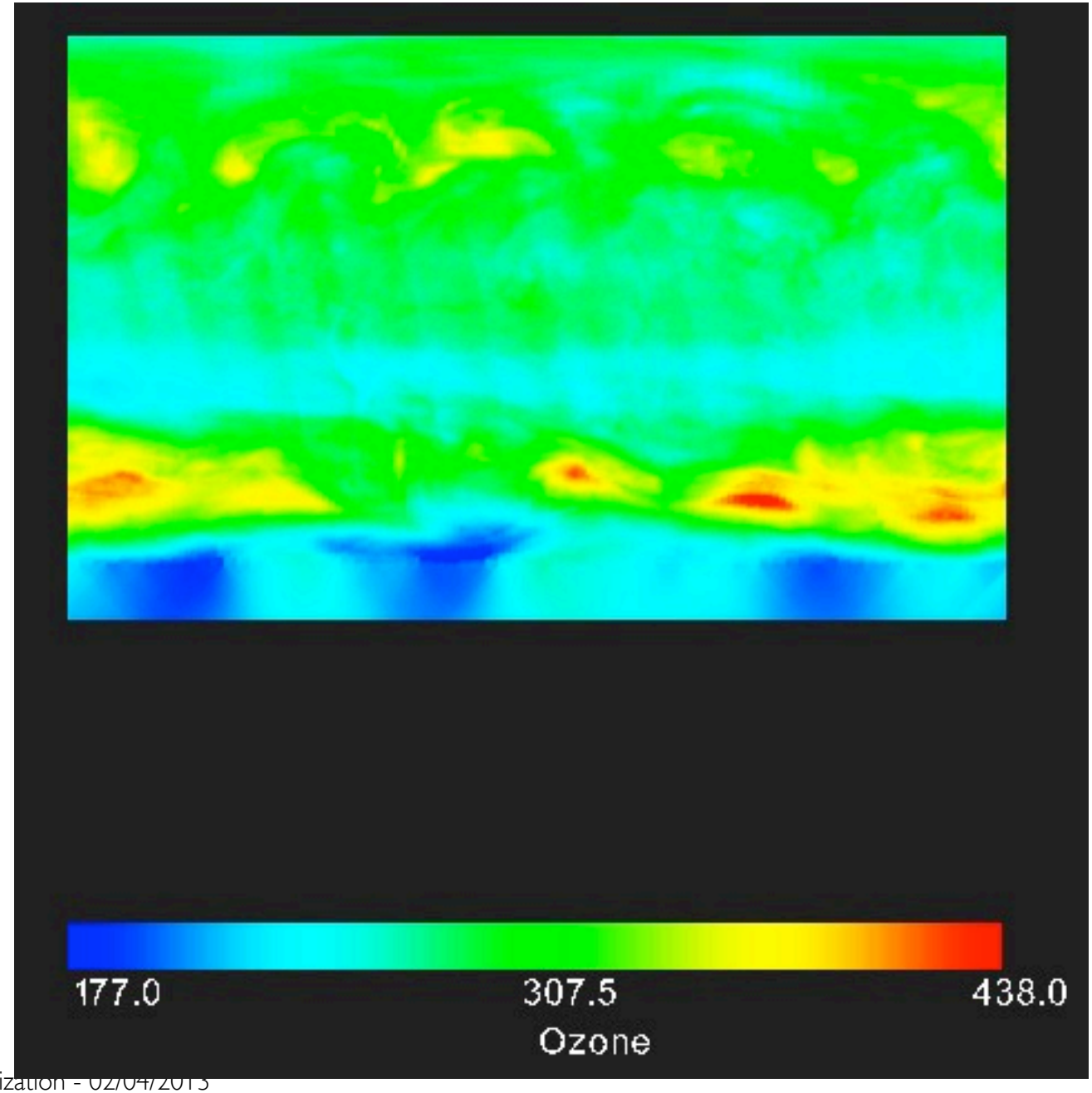


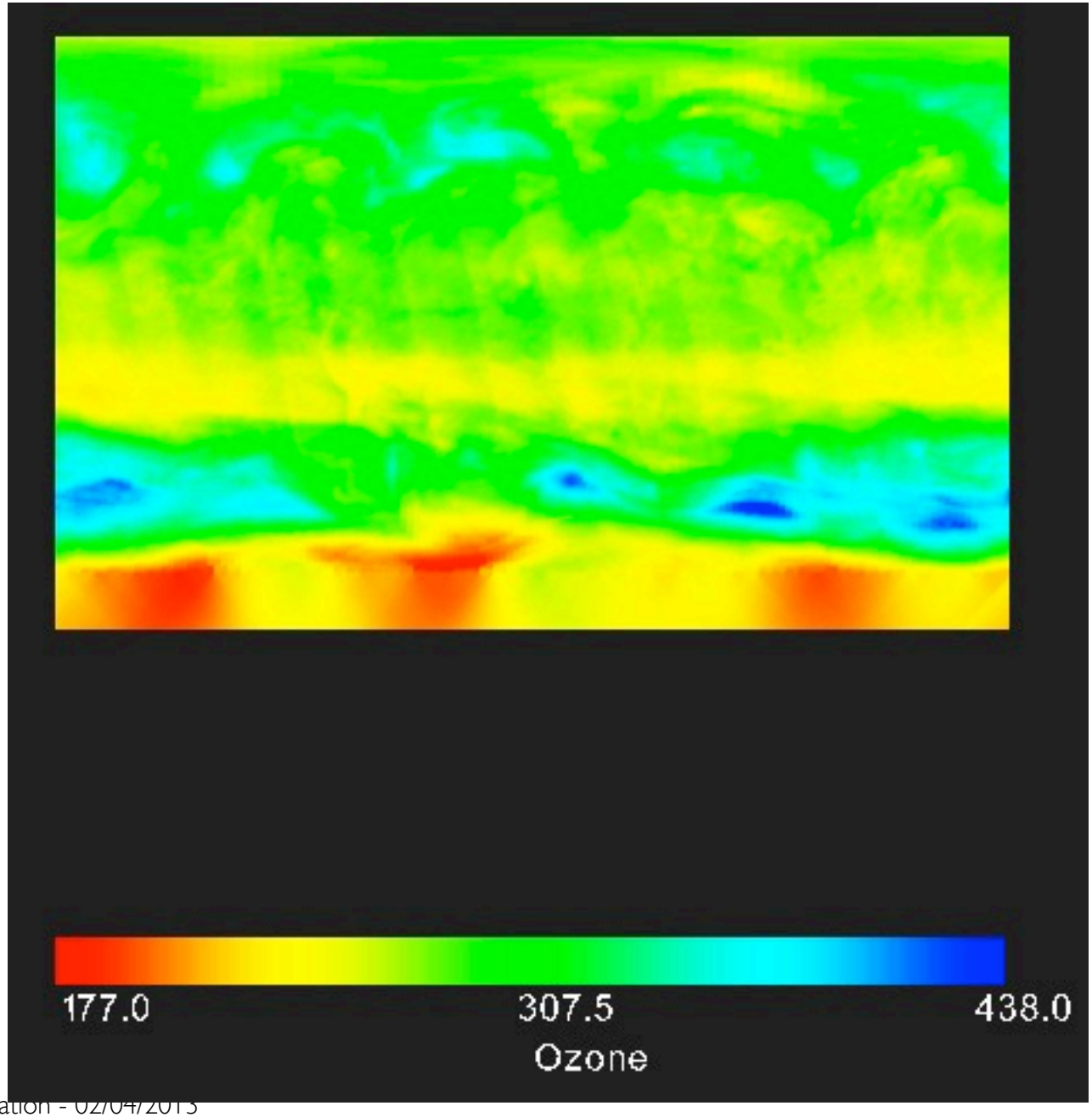
Consider Audience

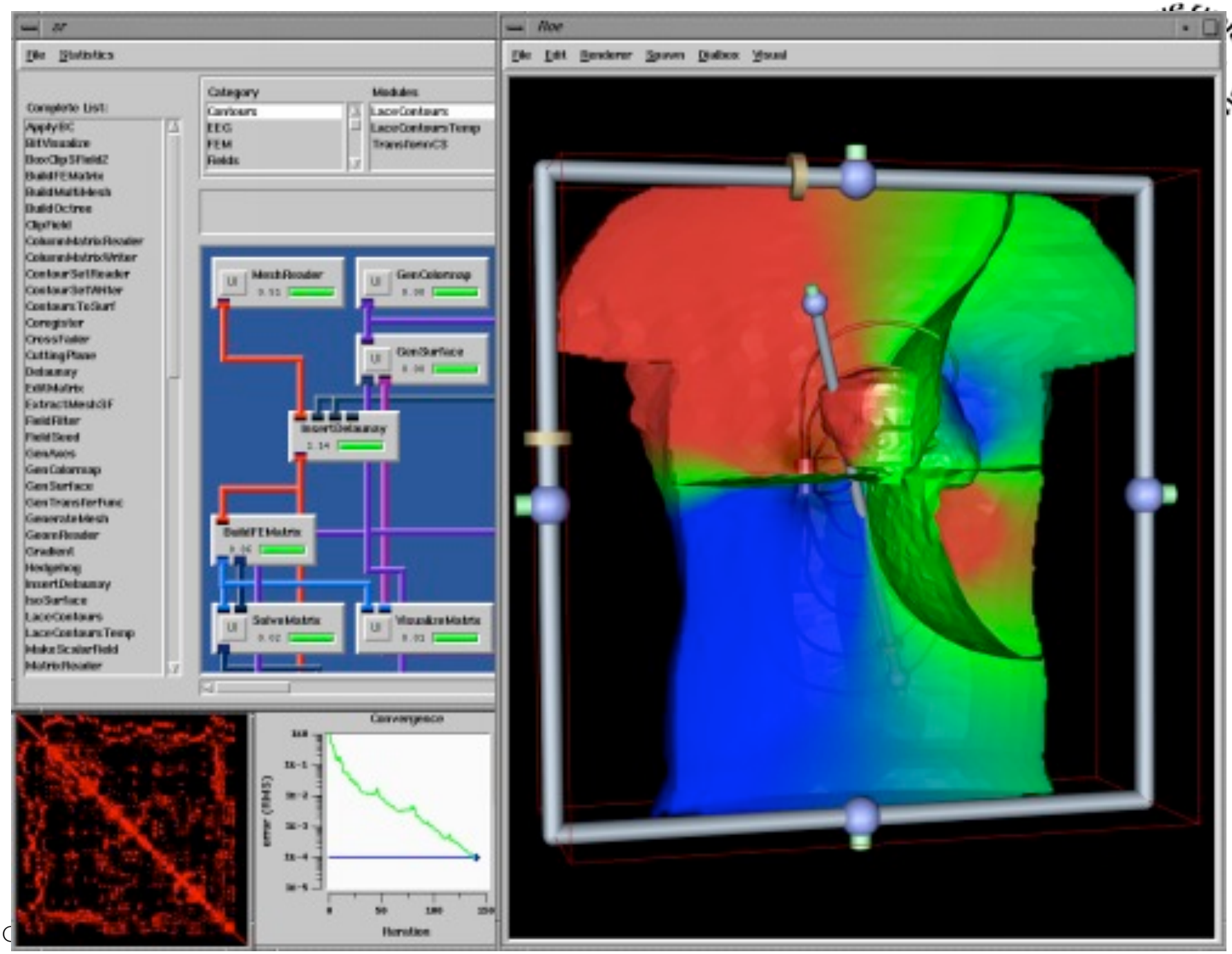
- Color deficient viewers?
  - Don't depend on red-green differentiation
  - Use redundant scales
- Application area conventions?
  - Use familiar scales (or at least know when you're not)


Total Ozone
177.
242.
308.
373.
438.


Total Ozone
177.
242.
308.
373.
438.

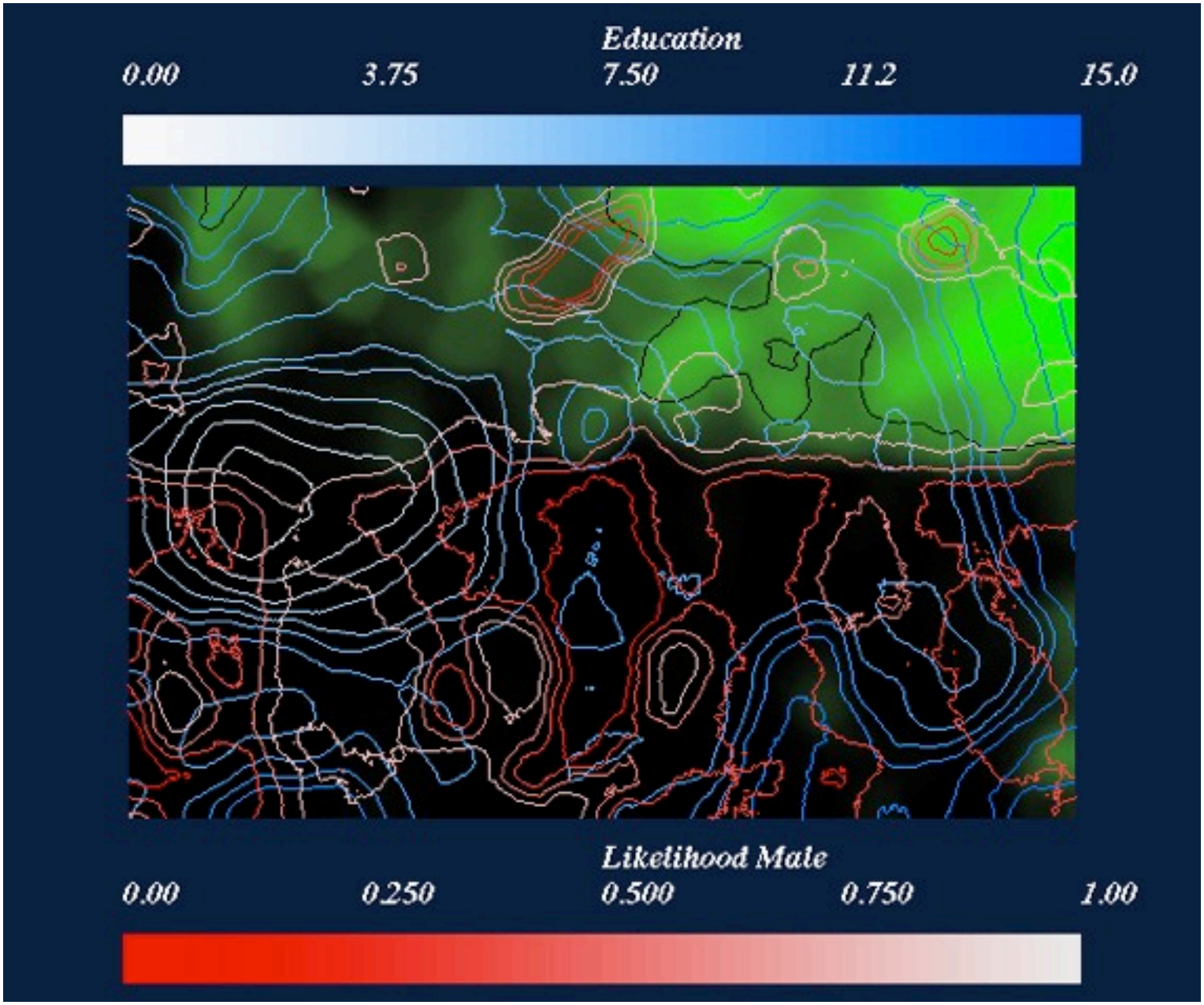

177.0
307.5
438.0
Ozone


177.0
307.5
438.0
Ozone


File Edit Renderer Spawn DialBox Visual
File Statistics
Category
Modules
Complete List
Convergence
Error (RMS)
Iteration

Consider Cultural Connotations

- Color associations with variables?
  - Use associated color
- Color associations with data ranges?
  - Use red for bad range
  - Use red for hot


Education
0.00
3.75
7.50
11.2
15.0
Likelihood Male
0.00
0.250
0.500
0.750
1.00