Visualization using Matlab

April 10, 2007

Rachael Brady

CSEM Matlab Workshop

Today's Topics

- Color in Matlab
- 2D and 3D plots
- Rendering data as an image
- 3D volumetric techniques
  - IsoSurface
  - Volume Rendering

Resources

- Get an idea of what Matlab can do by looking at the 3-D visualization “Contents” and Graphics “Contents” (execute ‘demo’ on the command line)
- At Duke, the ISDS had made some nice webpages giving another view on several of these commands

  http://www.isds.duke.edu/comp/internal/matlab/techdoc/visualize/intro_vi.html

- The mathworks file exchange website is an excellent resource

  http://www.mathworks.com/matlabcentral/fileexchange

- For color map help, see colorbrewer.org

Human Perception

Humans perceive COLOR and SHAPE before anything else. Pay attention to these two attributes when making any kind of visual representation of your data

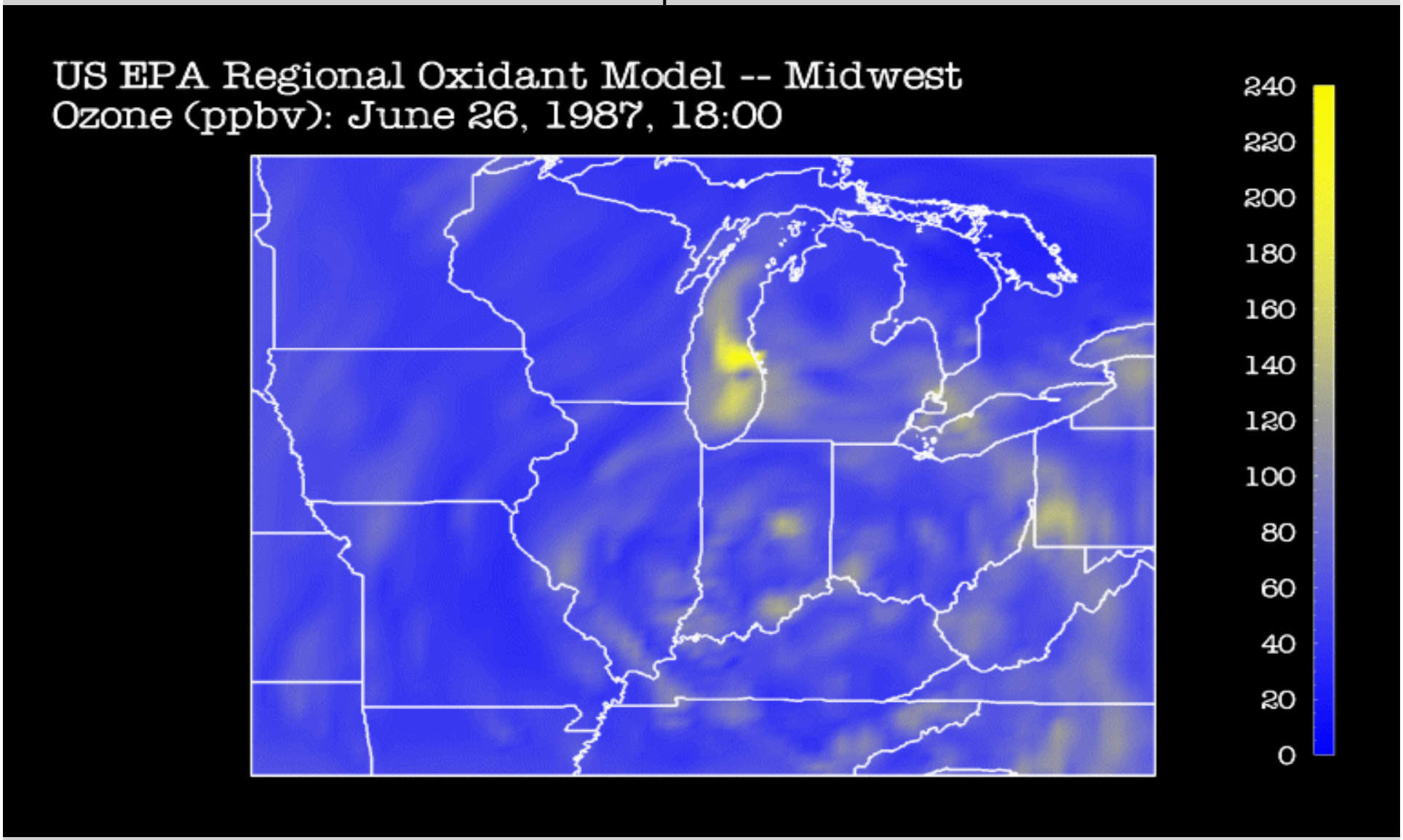
(show Healey pre-attentive application)

A word about color

Humans do not perceive color linearly. We see lightness to darkness in a linear fashion. When coloring isomorphic data (i.e. showing data value through color in a continuous manner), the color ramp should go from dark to light (or vice-versa). Exceptions include 2-ended color schemes.

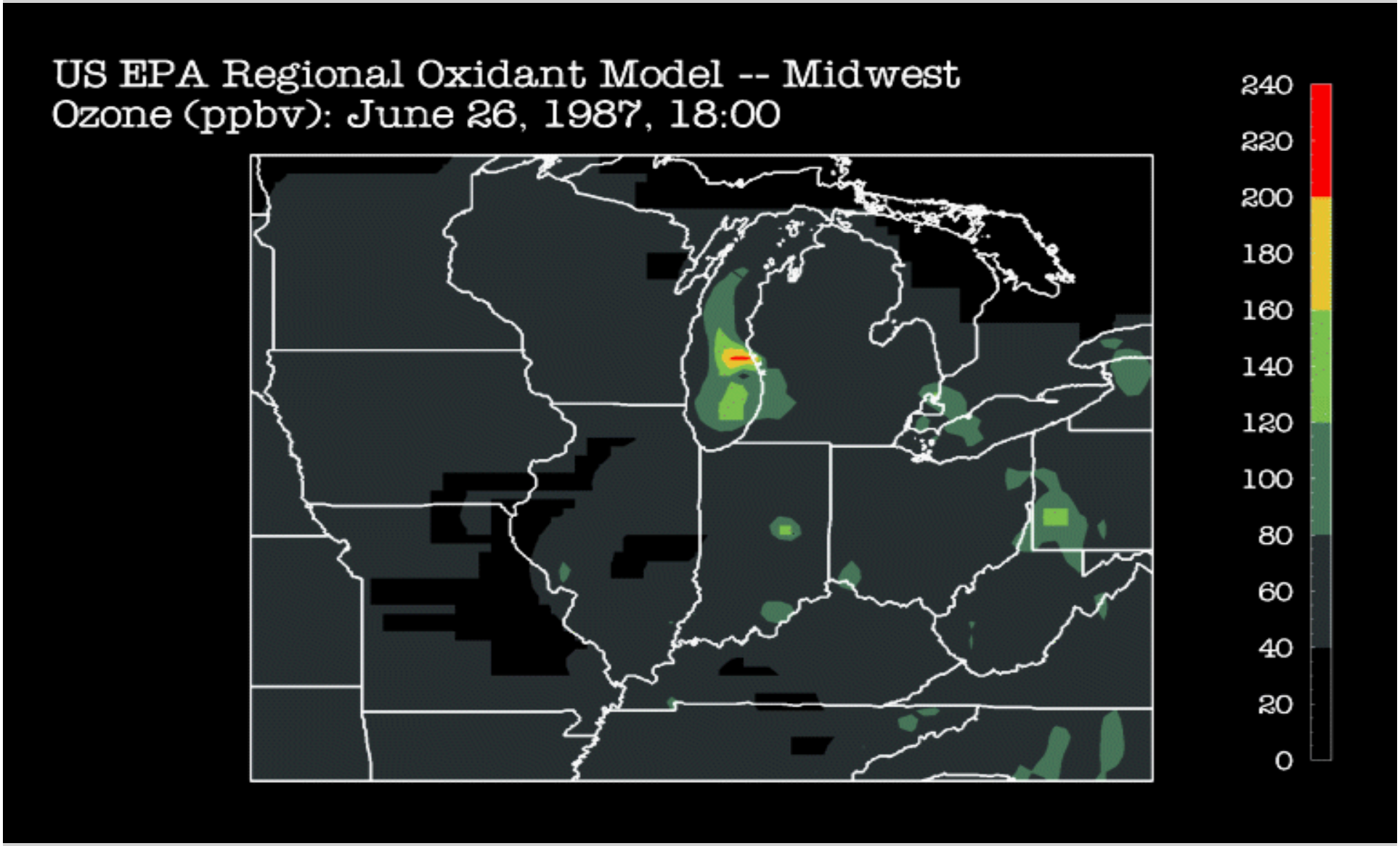
Different color schemes should be used when the task is different. For example, showing discrete steps such as map contours should be shown with gradations in color. Showing different data belonging to categories should be shown with divergent colors.

Colormap Choice Should be Linked to Task
Atmospheric Motion



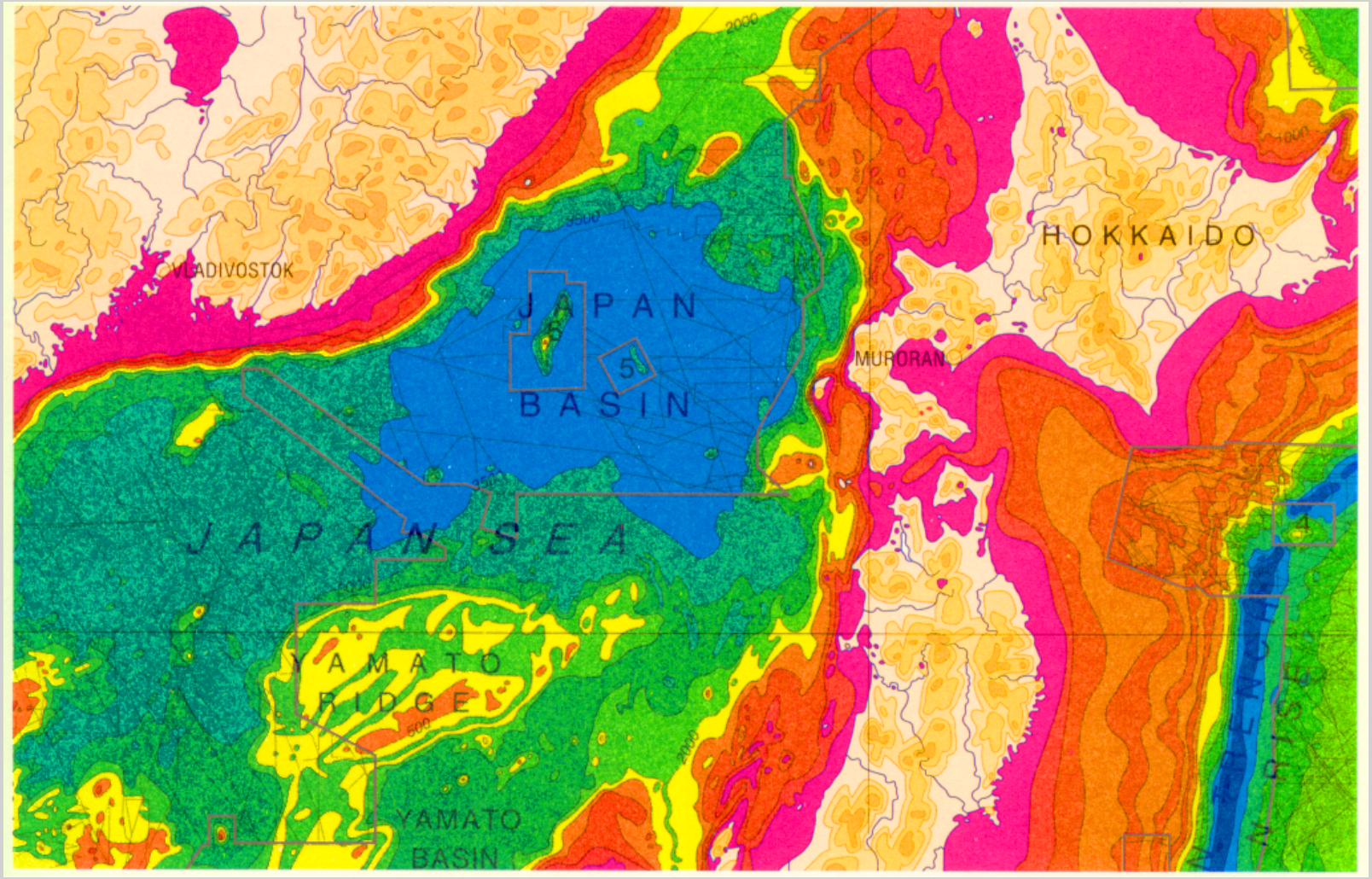
Bergman, Rogowitz, Treinish, IEEE Vis ‘95

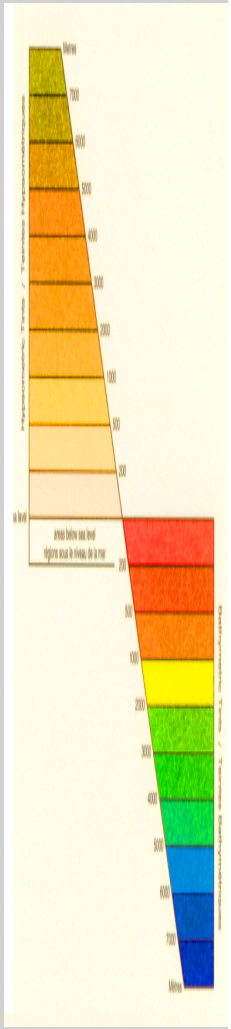
Colormap Choice Should be Linked to Task
Pollution Levels



Bergman, Rogowitz, Treinish, IEEE Vis ‘95

Not ordered (double ended)

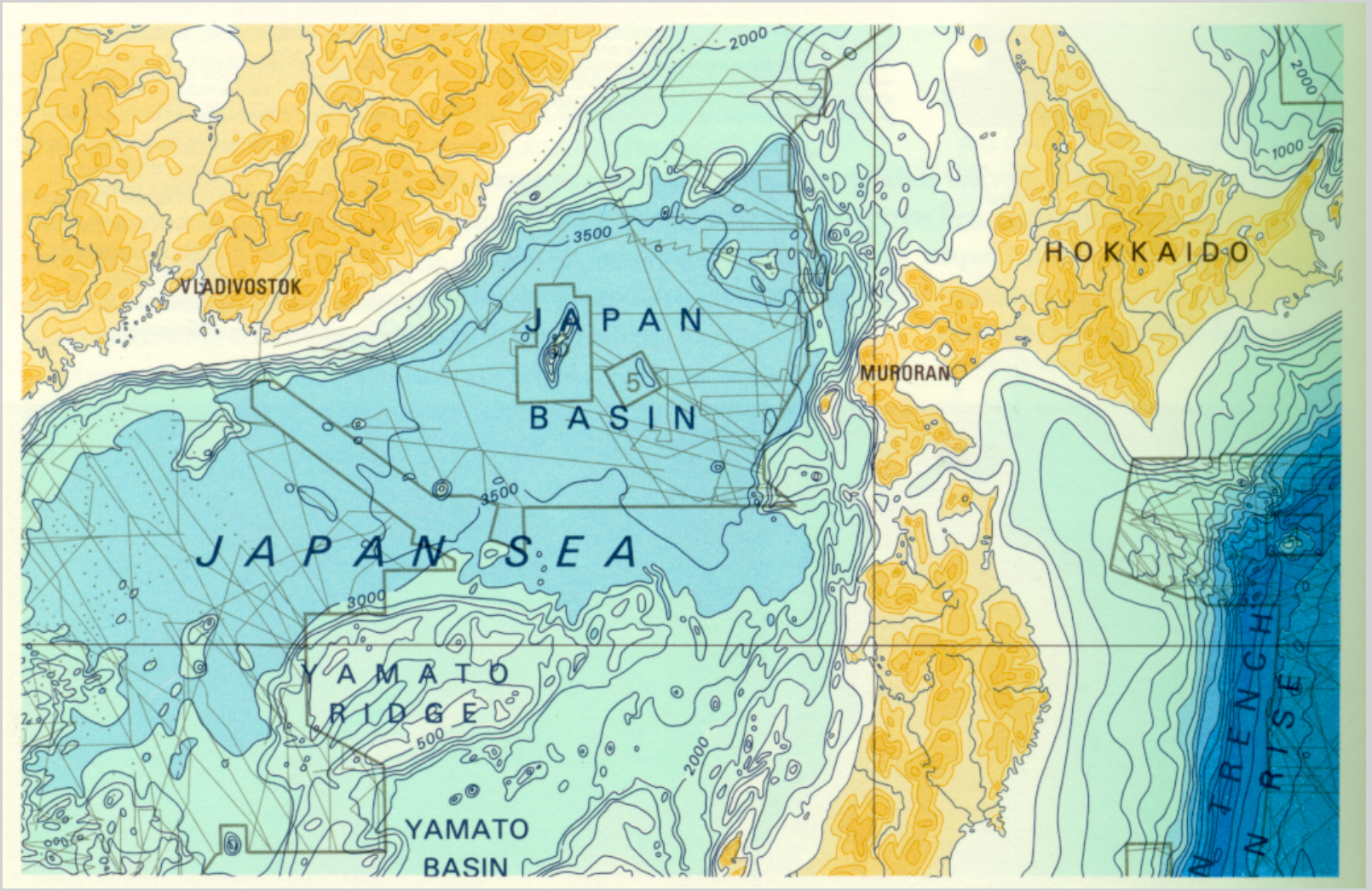


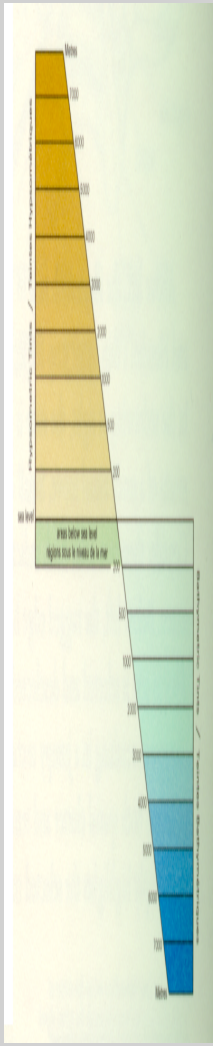


- Tufte ‘97, pg. 77.

Taken from Russell Taylor II, UNC CS 290 Course Notes

Ordered (and double-ended)

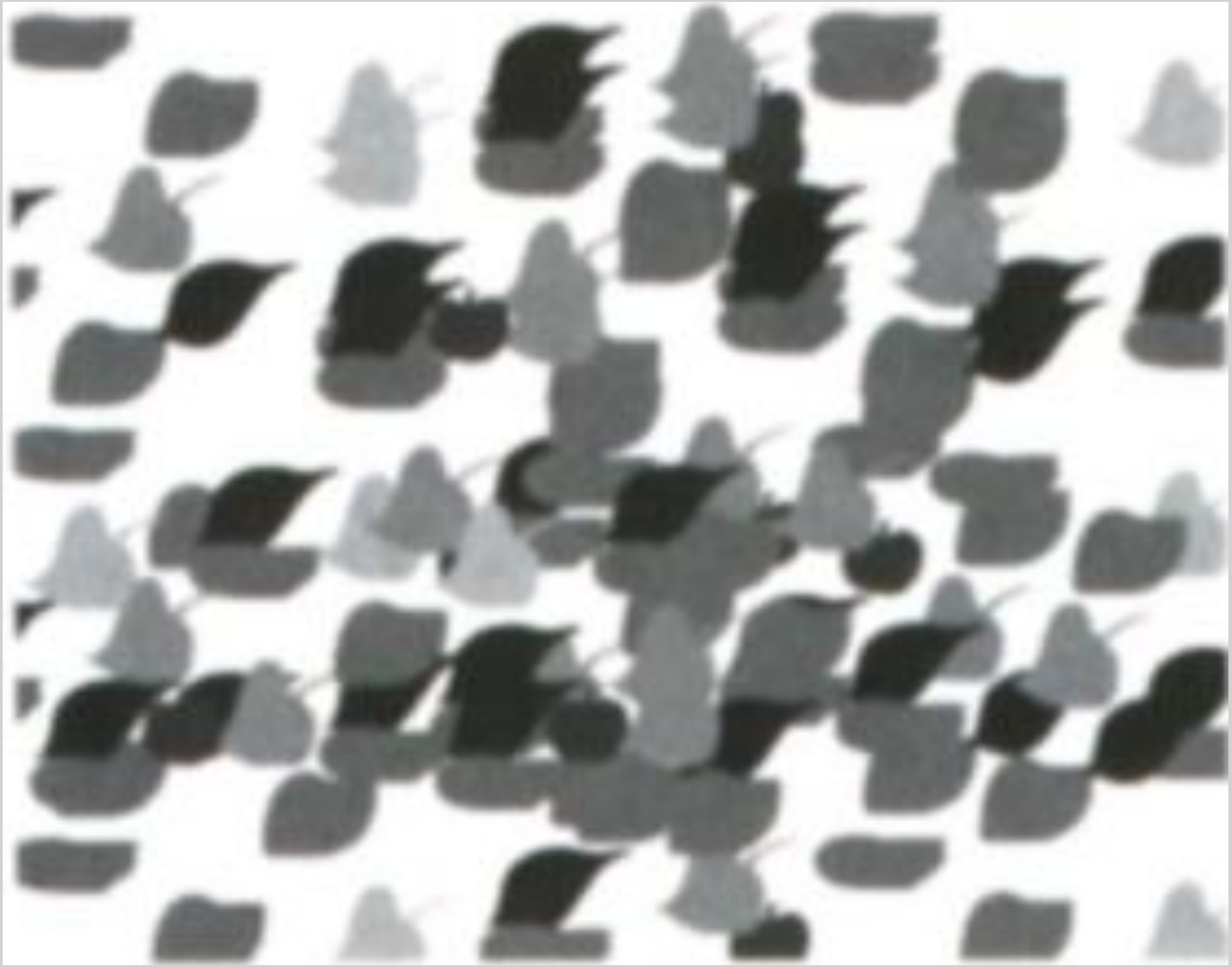




Taken from Russell Taylor II, UNC CS 290 Course Notes

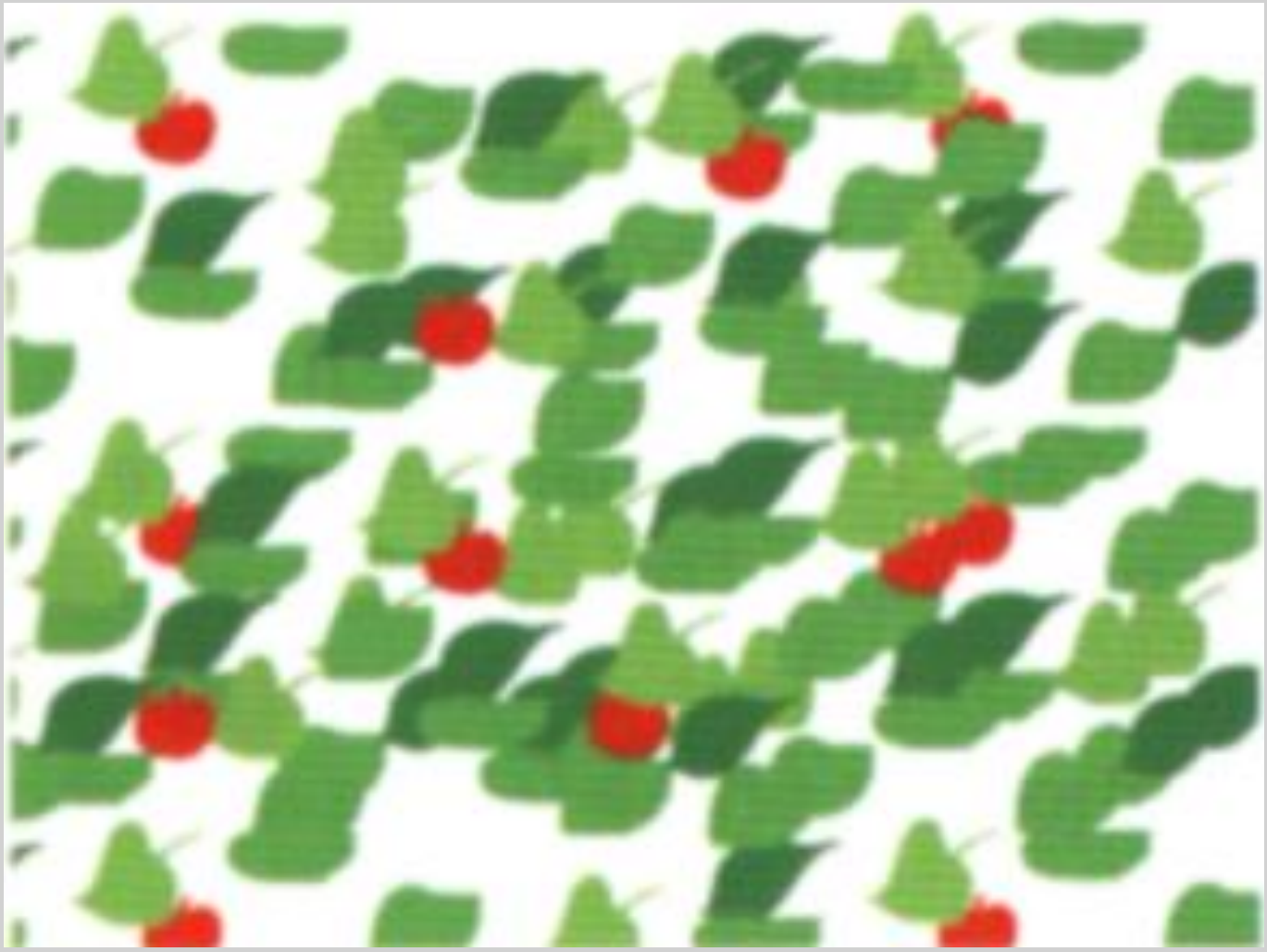
- Tufte ‘97, pg. 76.

Color is useful for classification



Taken from Russell Taylor II, UNC CS 290 Course Notes

Color is useful for classification



Taken from Russell Taylor II, UNC CS 290 Course Notes

Color in Matlab

Matlab only "knows" eight colors:

Yellow (y)	Green (g)
Magenta (m)	Red (r)
Cyan (c)	Blue (b)
White (w)	Black (k)

All other colors must be specified as rgb triplets

See colorbrewer.org for good colors and their rgb specifications

Color in Matlab

Matlab contains many default colormaps. Perceptually linear ones are Gray, Hot, Summer, Bone, Pink

(show col_bar, 2, 3)

Use the 'colormap' command to reset the current colormap to one of the defaults, or create one of your own. A cmap is merely an nx3 vector of values from [0-1].

A good test for a dark->light colormap is to make a black and white xerox the color image. Do the colors separate?

Don’t use color if you don’t need to.

Color is not needed to understand shape, spatial relationships of objects, or movement.

Laboratory assistant went 21 years without realizing he was color-blind

Taken from Russell Taylor II, UNC CS 290 Course Notes

Plots

Default 2d (‘plot’) and 3d (‘plot3’) plots in Matlab are generally good. The only recommended change is to avoid the legend (‘legend hide’). Replace this with direct annotation.

The functions mesh and surf are the same, except mesh draws in wireframe. High frequency information on surfaces are easier seen with lighting and shadows.

lighting gouraud or lighting phong

Normally, surfaces would need to have their properties set (FaceColor, EdgeColor, etc) to make lighting work. One can also use the ‘shading’ command: flat, interp, faceted as a shortcut

(run surfExample)

imagesc vs. pcolor

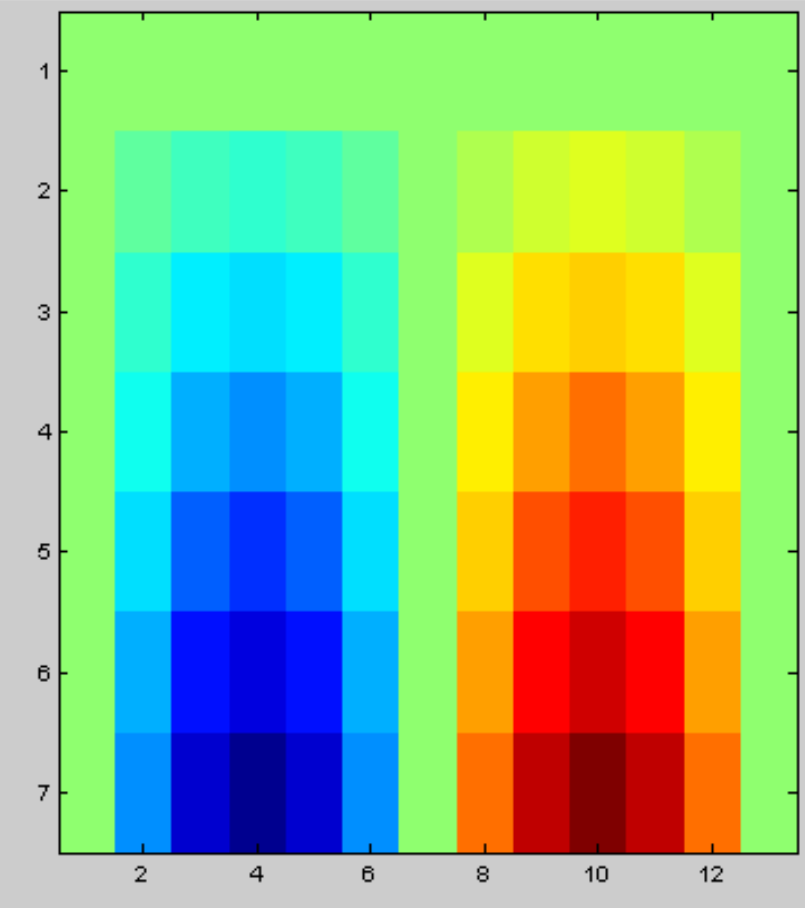
- Both image and pcolor generate a 2-D colored image from a 2D matrix.
- An image coordinate system is left handed with the origin in the upper left corner. A pseudocolor plot (pcolor) uses a right handed coordinate system with the origin in the lower left corner.
- An image plot is pixel centered, a pcolor plot is vertex centered.

Consider the matrix Y generated from the following code:

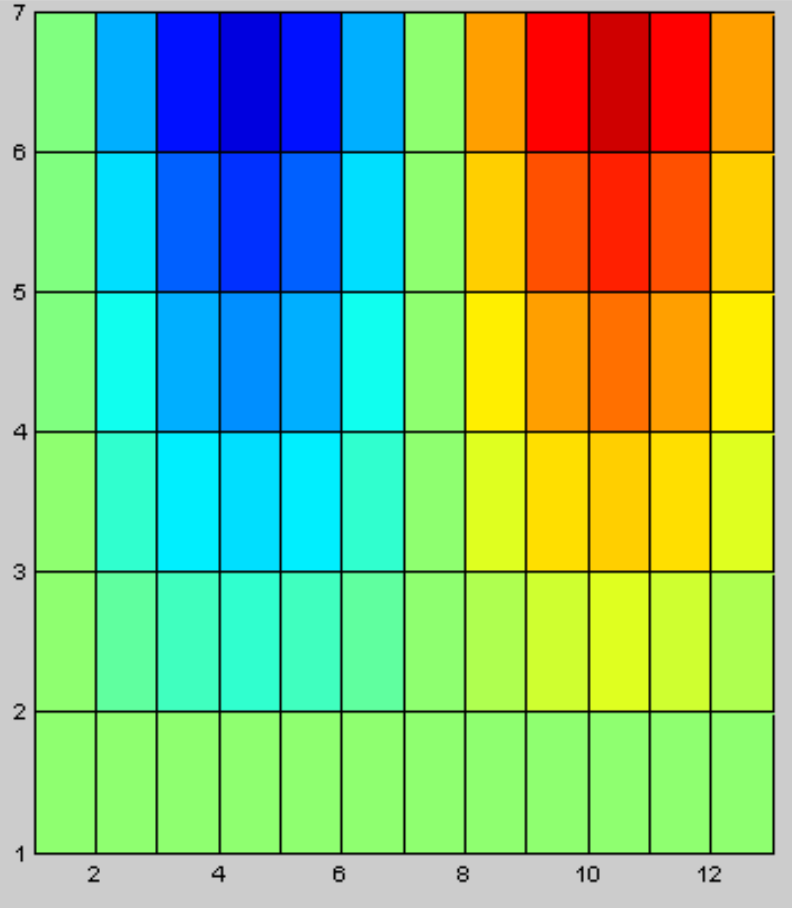
```
n=6;
r=(0:n)'/n;
theta=pi*(-n:n)/n;
Y=r*sin(theta);
```

Y is a 7x13 matrix

0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	-0.0833	-0.1443	-0.1667	-0.1443	-0.0833	0.0000	0.0833	0.1443	0.1667	0.1443	0.0833	0.0000
0.0000	-0.1667	-0.2887	-0.3333	-0.2887	-0.1667	0.0000	0.1667	0.2887	0.3333	0.2887	0.1667	0.0000
0.0000	-0.2500	-0.4330	-0.5000	-0.4330	-0.2500	0.0000	0.2500	0.4330	0.5000	0.4330	0.2500	0.0000
0.0000	-0.3333	-0.5774	-0.6667	-0.5774	-0.3333	0.0000	0.3333	0.5774	0.6667	0.5774	0.3333	0.0000
0.0000	-0.4167	-0.7217	-0.8333	-0.7217	-0.4167	0.0000	0.4167	0.7217	0.8333	0.7217	0.4167	0.0000
0.0000	-0.5000	-0.8660	-1.0000	-0.8660	-0.5000	0.0000	0.5000	0.8660	1.0000	0.8660	0.5000	0.0000



Imagesc(Y)



Pcolor(Y)

3D Data Vis - Isosurface

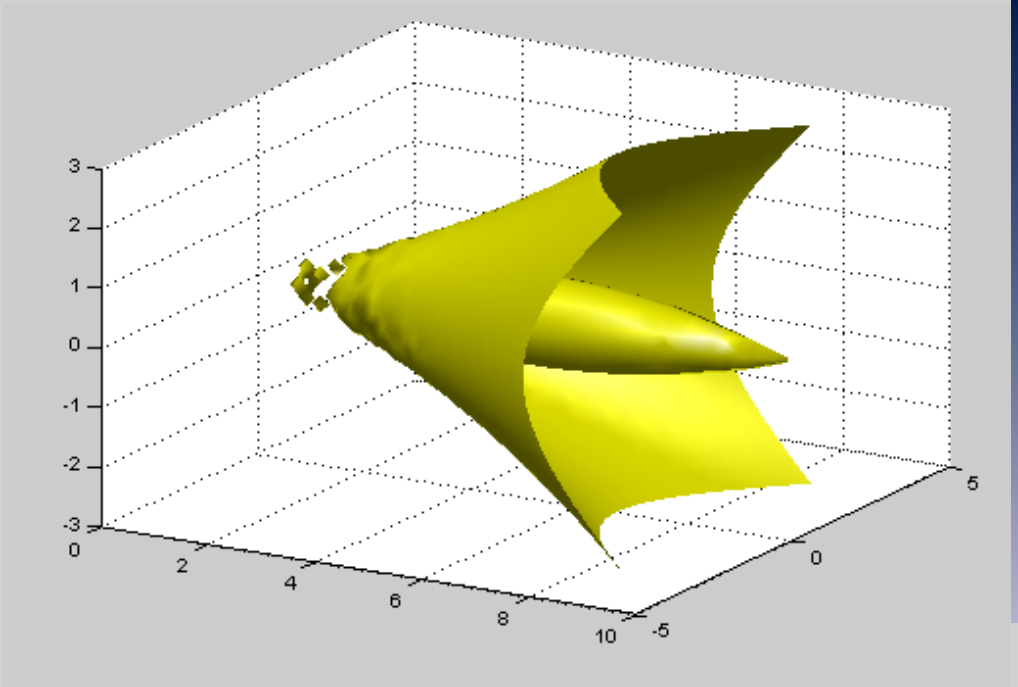
An Isosurface is the equivalent to a contour line in one dimension higher. An isosurface of value 10 has volumetric data on one side whose values are all larger than 10, and on the other side whose values are all smaller than 10.

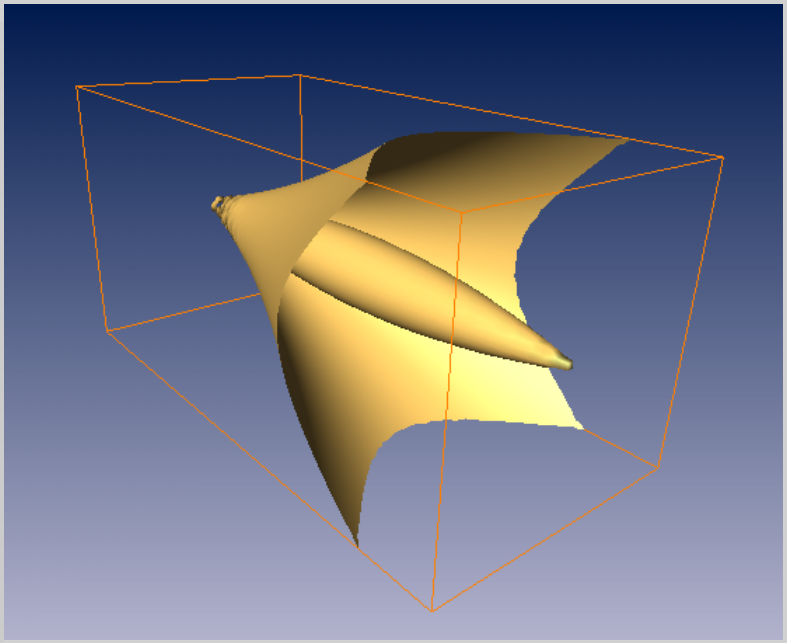
- Perception of 2D surfaces in 3D is what the visual system is tuned for
- A surface requires an underlying mesh. The calculation of this mesh and the surface introduces errors to the viewed data.
- Surfaces can occlude each other. Transparency on surfaces does not work well since we lose the shape information from the lighting function.

Matlab Isosurface

- Isosurface(x, y, z, v, <threshold>) calculates the surface mesh. It must be rendered with the 'patch' command.

(run isoSurf)





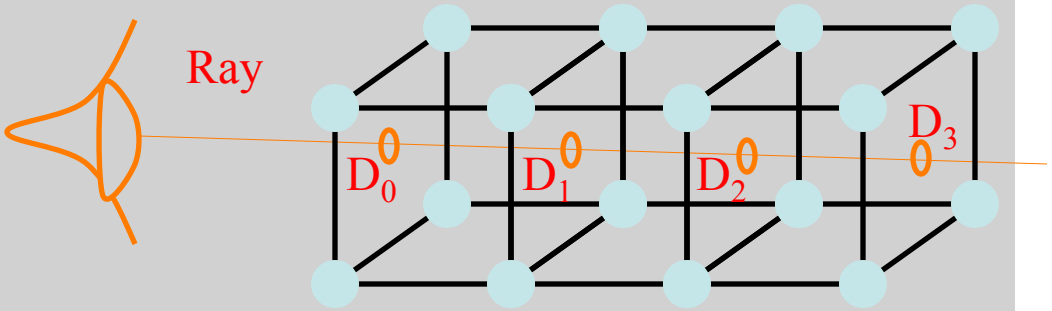
Show ring at end of surface

3D Data Vis - Volume Rendering

- Image is generated directly from data volume
- Advantages
  - No need to calculate geometrical surface
  - Very compelling “what you see is what is there”
- Disadvantages
  - Computationally expensive
  - Difficult to perceive structure without motion

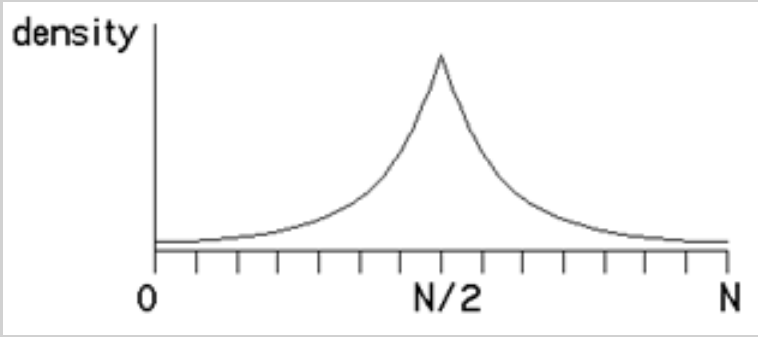
Volume Rendering

- Basic Idea:
  - Integrate through volume

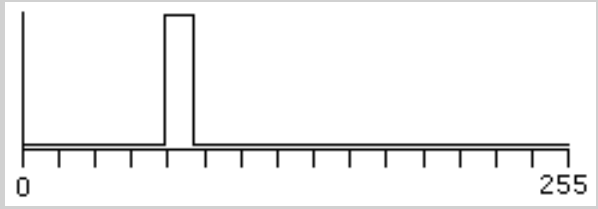


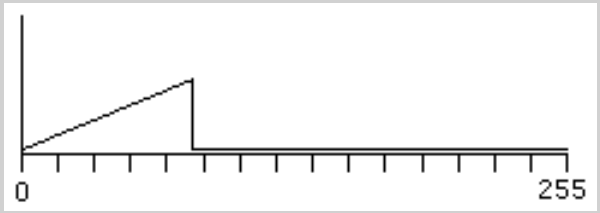
- "Every voxel contributes to image"
- No intermediate geometry extraction
- Greater flexibility than isosurfaces
  - May be X-ray-like
  - May be surface-like
  - Results depend on the transfer function (see next)

Transfer Function



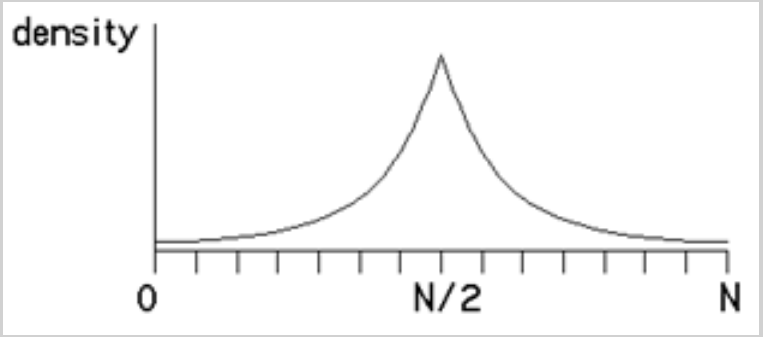
- Maps from density value to Opacity



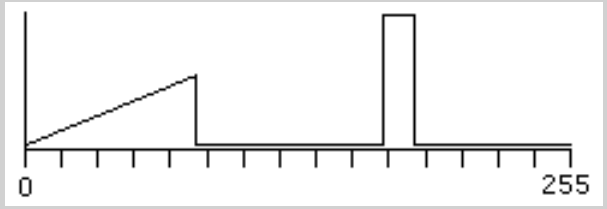


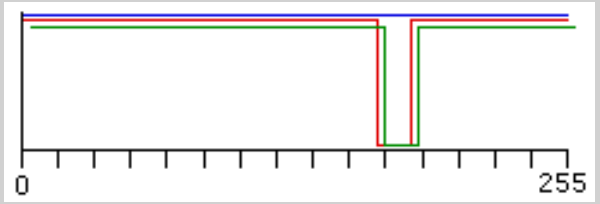
Taken from Russell Taylor II, UNC CS 290 Course Notes

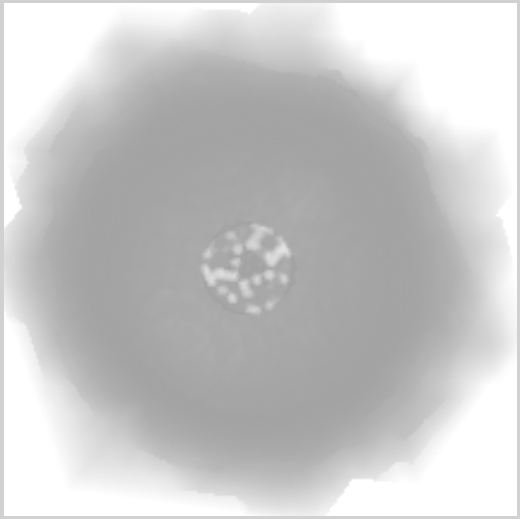
Transfer Function

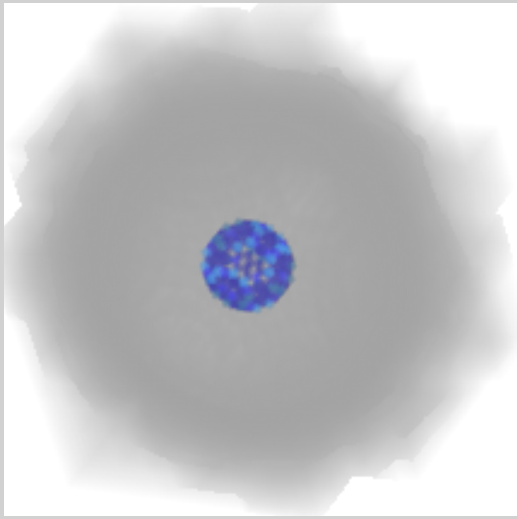


- Opacity and color maps may differ



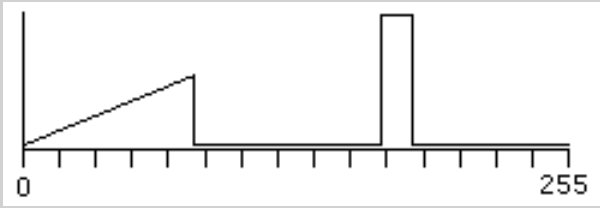




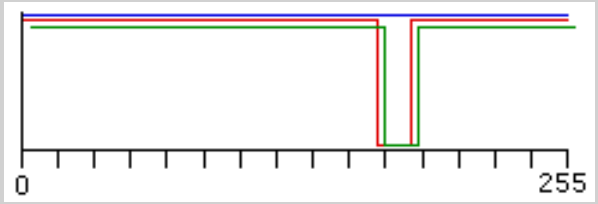


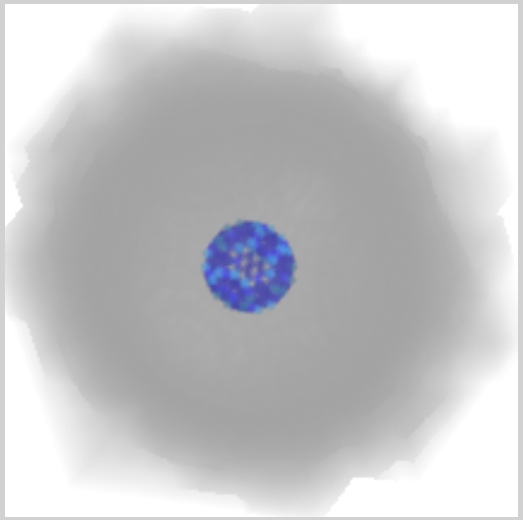
Taken from Russell Taylor II, UNC CS 290 Course Notes

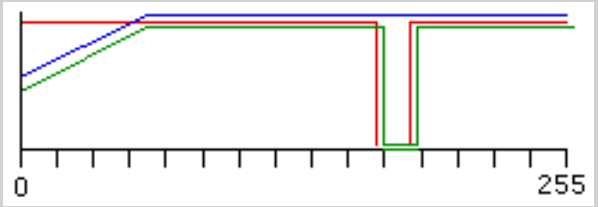
Transfer Function

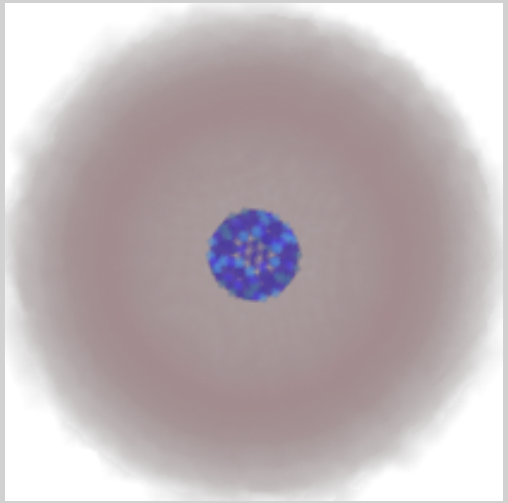


- Different colors, same opacity



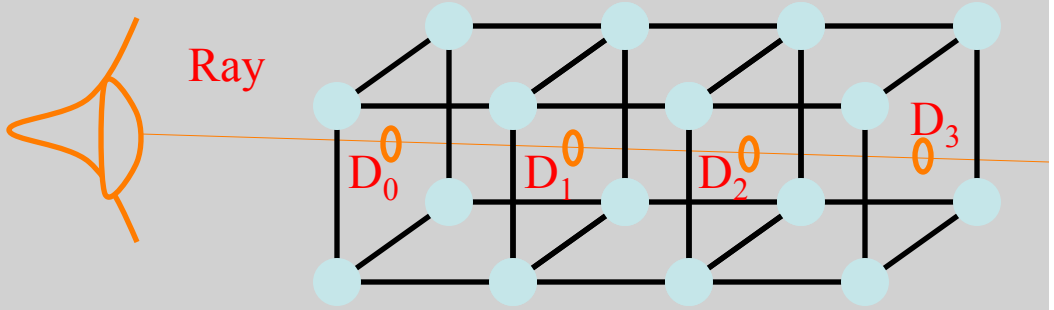


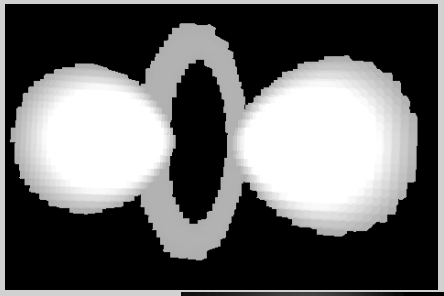


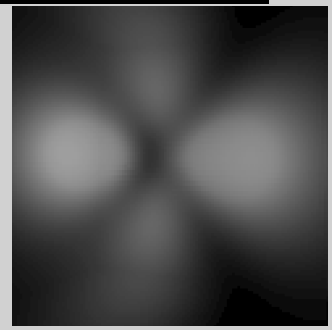


Taken from Russell Taylor II, UNC CS 290 Course Notes

Common Mixing Functions







- Maximum Intensity Projection (MIP)

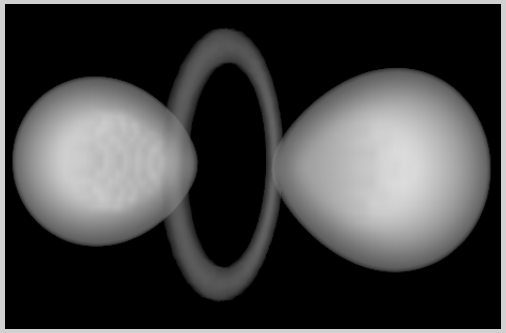
  Value = max(D_0, D_1, D_2, D_3)

- X-ray-like (inverse of density attenuation)

  Value = sum(D_0, D_1, D_2, D_3)

- Composite (back-to-front, no color)

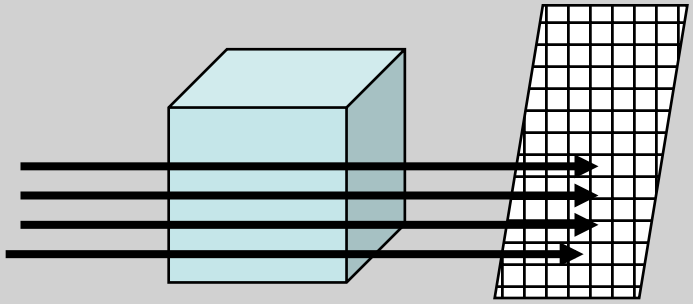
  Value(i) = D_i + (Value(i+1) * (1-D_i))

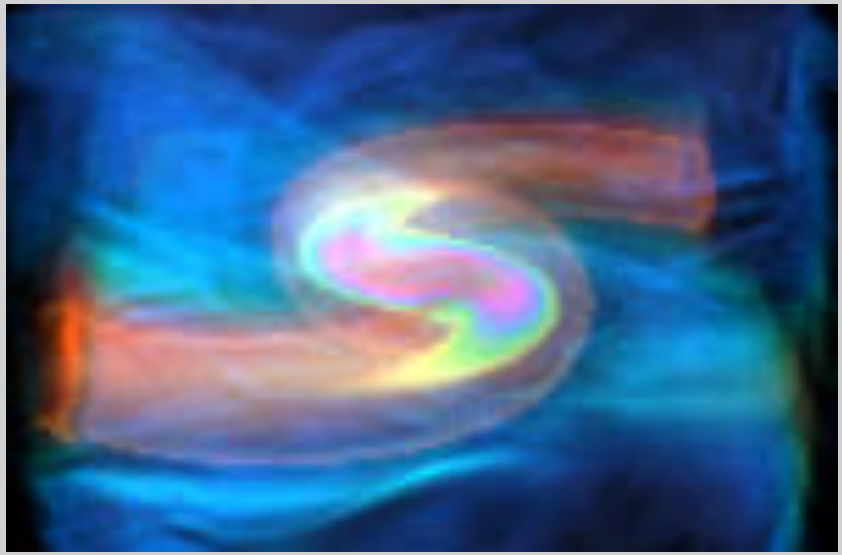


Modified from Russell Taylor II, UNC CS 290 Course Notes

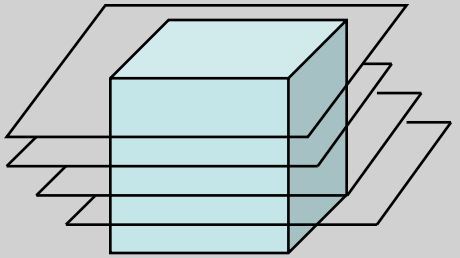
Volume Rendering

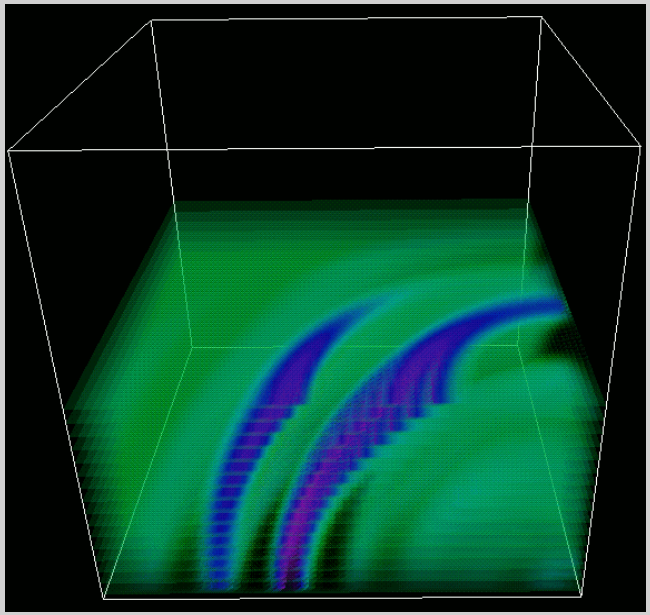
- Ray Traced





- Texture Mapped

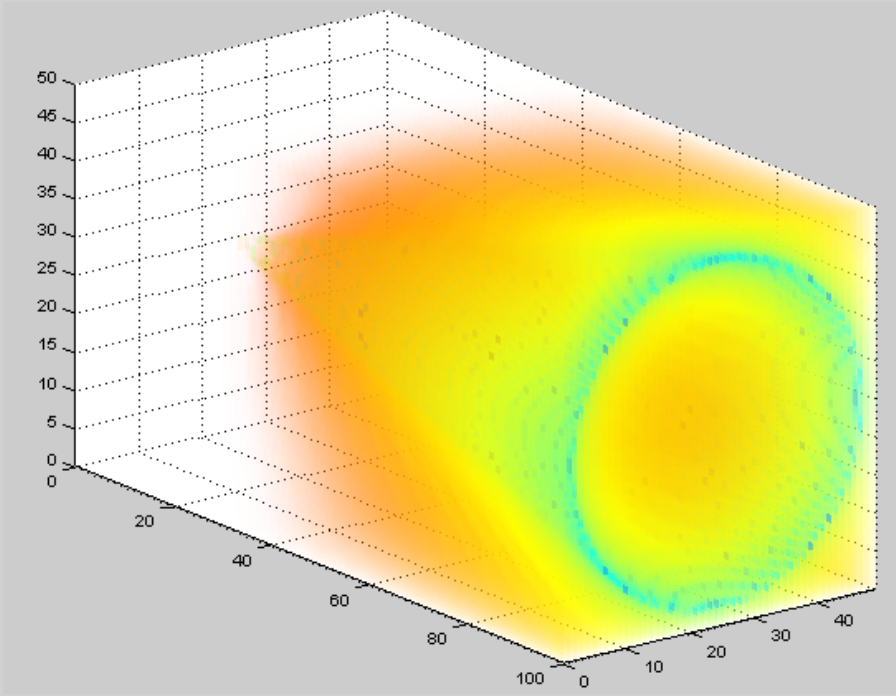


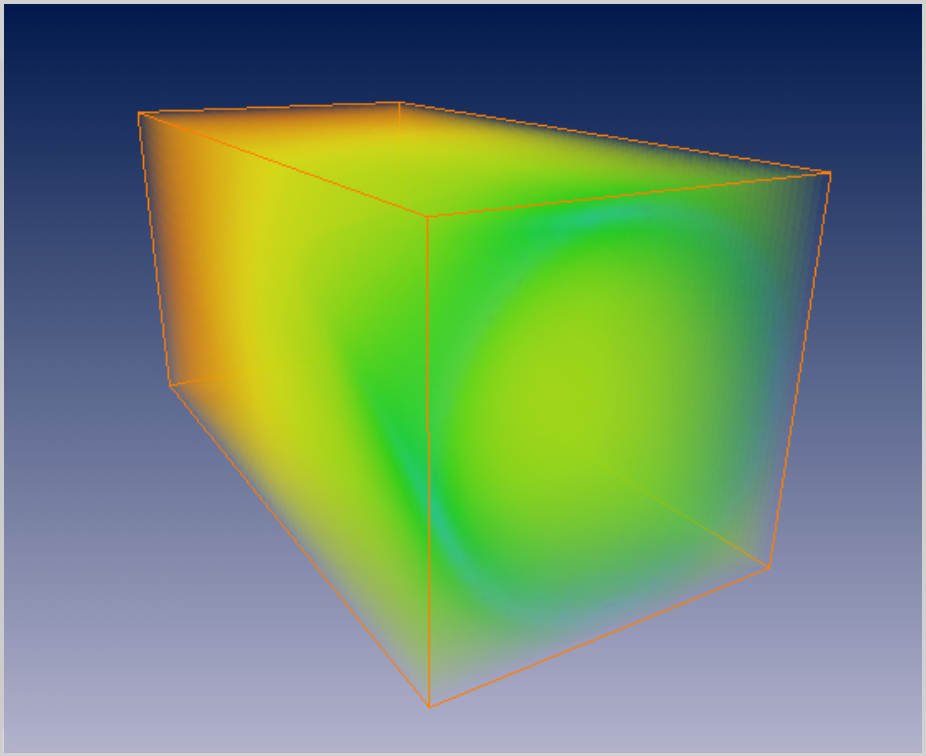


Volume Rendering in Matlab

- Joe Conti has submitted a very nice volume renderer at the matlab file exchage, called vol3d.m. It uses 2D texture maps to do the volume rendering.

(run vol3dExample)





Thank You

rbrady@duke.edu

Resources

- Get an idea of what Matlab can do by looking at the 3-D visualization “Contents” and Graphics “Contents” (execute ‘demo’ on the command line)
- At Duke, the ISDS had made some nice webpages giving another view on several of these commands

  http://www.isds.duke.edu/comp/internal/matlab/techdoc/visualize/intro_vi.html

- The mathworks file exchange website is an excellent resource

  http://www.mathworks.com/matlabcentral/fileexchange

- For color map help, see colorbrewer.org