Scientific Visualization

Scott King

Summer School in Geophysical Porous Media: Multidisciplinary Science from Nano- to Global- Scale

July 17-28th
Purdue University, West Lafayette

Define Scientific Visualization

Define Scientific Visualization

"There are three kinds of lies: lies, damn lies, and statistics."

Define Scientific Visualization

"There are three kinds of lies: lies, damn lies, and statistics."

-> you could replace statistics with scientific visualization

Define Scientific Visua…on

Verisimilitude (from Latin *verisimilitudo*, from *verus* true + *similitudo* similitude) is the state or quality of something which exhibits the appearance of truth or reality.

Define Scientific Visua…on

Verisimilitude (from Latin *verisimilitudo*, from *verus* true + *similitudo* similitude) is the state or quality of something which exhibits the appearance of truth or reality.

* usually incorporates massive amounts of data

Define Scientific Visua…on

Verisimilitude (from Latin *verisimilitudo*, from *verus* true + *similitudo* similitude) is the state or quality of something which exhibits the appearance of truth or reality.

* usually incorporates massive amounts of data
* aim for verisimilitude with the phenomena represented

Define Scientific Visua…on

Verisimilitude (from Latin *verisimilitudo*, from *verus* true + *similitudo* similitude) is the state or quality of something which exhibits the appearance of truth or reality.

* usually incorporates massive amounts of data
* aim for verisimilitude with the phenomena represented
* aim to represent entire phenomena represented holistically by interpolation from data

Define Scientific Visua…on

Verisimilitude (from Latin *verisimilitudo*, from *verus* true + *similitudo* similitude) is the state or quality of something which exhibits the appearance of truth or reality.

* usually incorporates massive amounts of data
* aim for verisimilitude with the phenomena represented
* aim to represent entire phenomena represented holistically by interpolation from data
* use color extensively to encode magnitude of variables

Define Scientific Visua…on

Verisimilitude (from Latin *verisimilitudo*, from *verus* true + *similitudo* similitude) is the state or quality of something which exhibits the appearance of truth or reality.

* usually incorporates massive amounts of data
* aim for verisimilitude with the phenomena represented
* aim to represent entire phenomena represented holistically by interpolation from data
* use color extensively to encode magnitude of variables
* animation? - often time

Define Scientific Visua…on

Verisimilitude (from Latin *verisimilitudo*, from *verus* true + *similitudo* similitude) is the state or quality of something which exhibits the appearance of truth or reality.

* usually incorporates massive amounts of data
* aim for verisimilitude with the phenomena represented
* aim to represent entire phenomena represented holistically by interpolation from data
* use color extensively to encode magnitude of variables
* animation? - often time
* usually spatial data

The Goal: Clear Communication

ANDERSEN

The Arthur Andersen partner was on his cell phone when he said,

"Ship the Enron documents to the feds,"

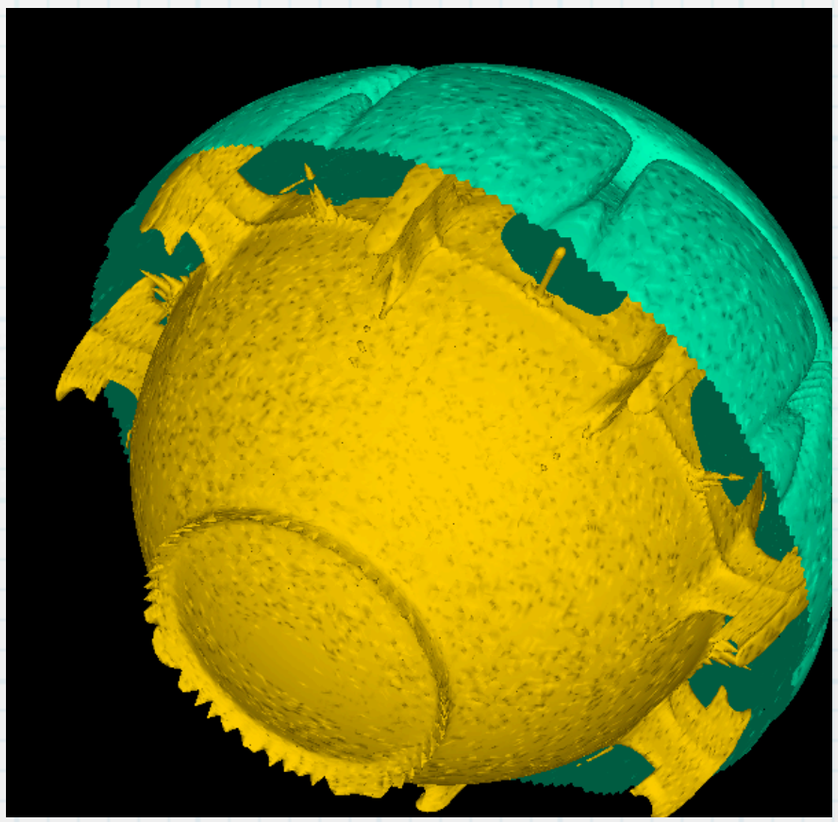
but his Secretary heard,

"Rip the Enron documents to shreds."

It turns out that it was all just a case of bad cellular.

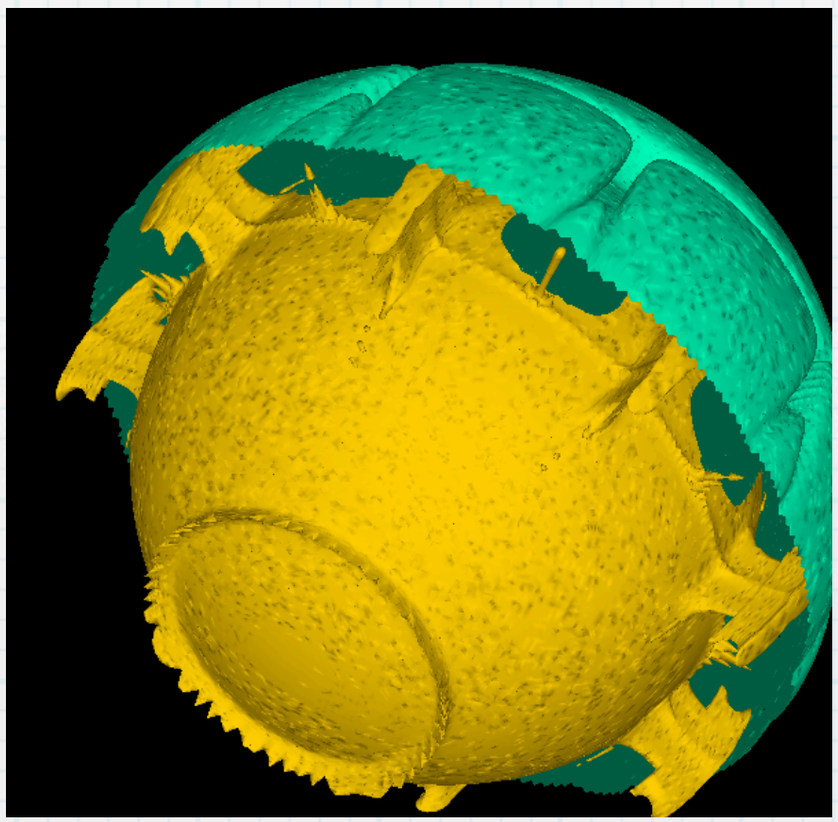
Sprint PCS The clear alternative to cellular℠

A True Story



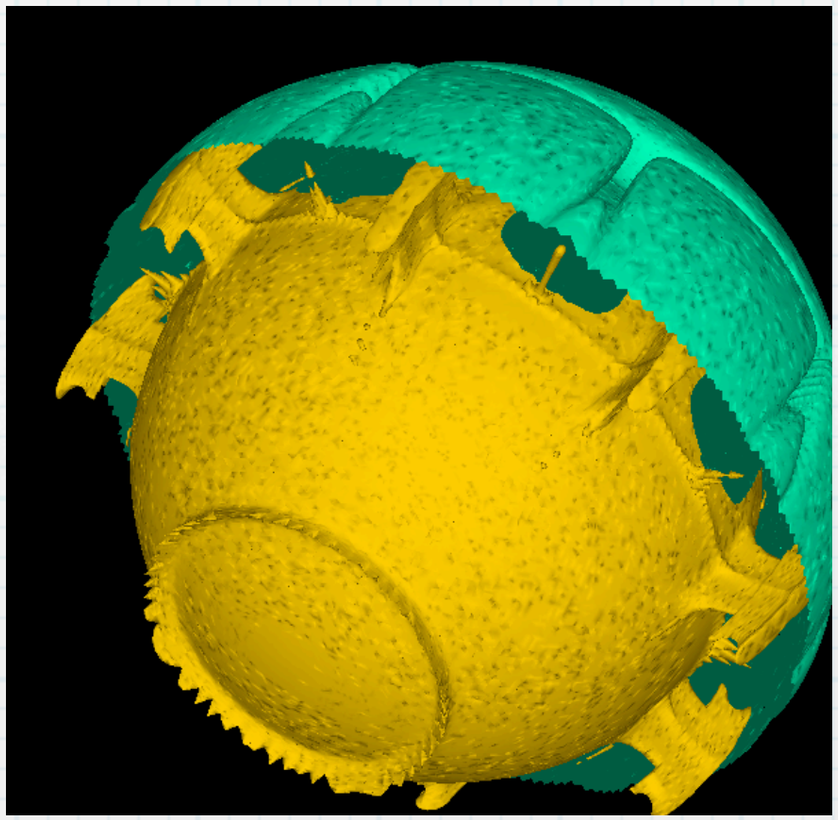
A True Story

* 2 hour run on IBM BlueGene - 16k processors



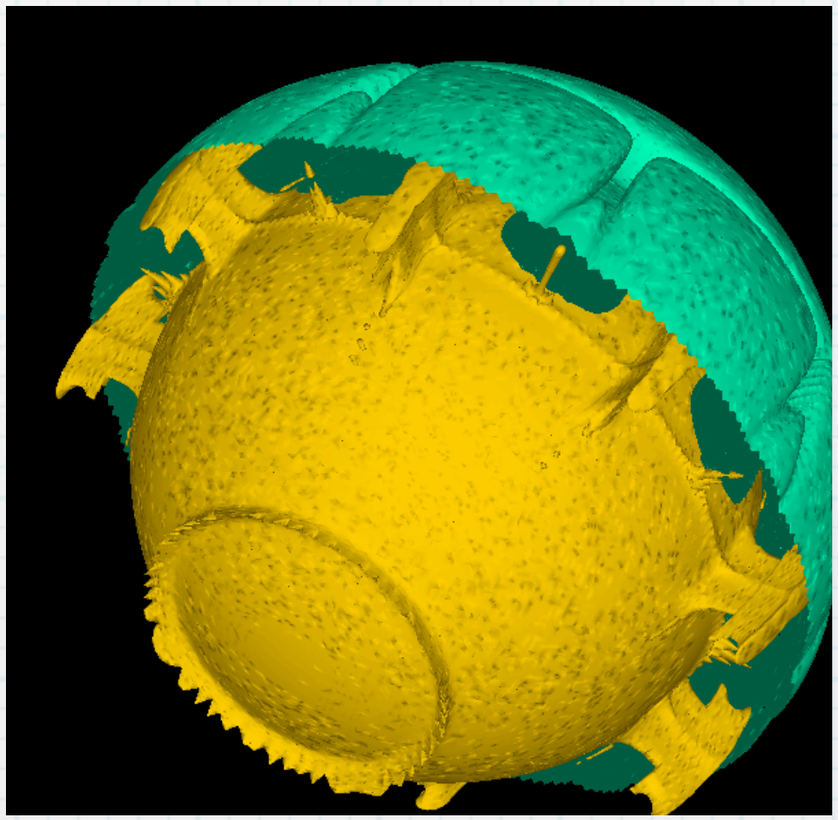
A True Story

* 2 hour run on IBM BlueGene - 16k processors
* 2.5 Billion years of evolution of Mercury



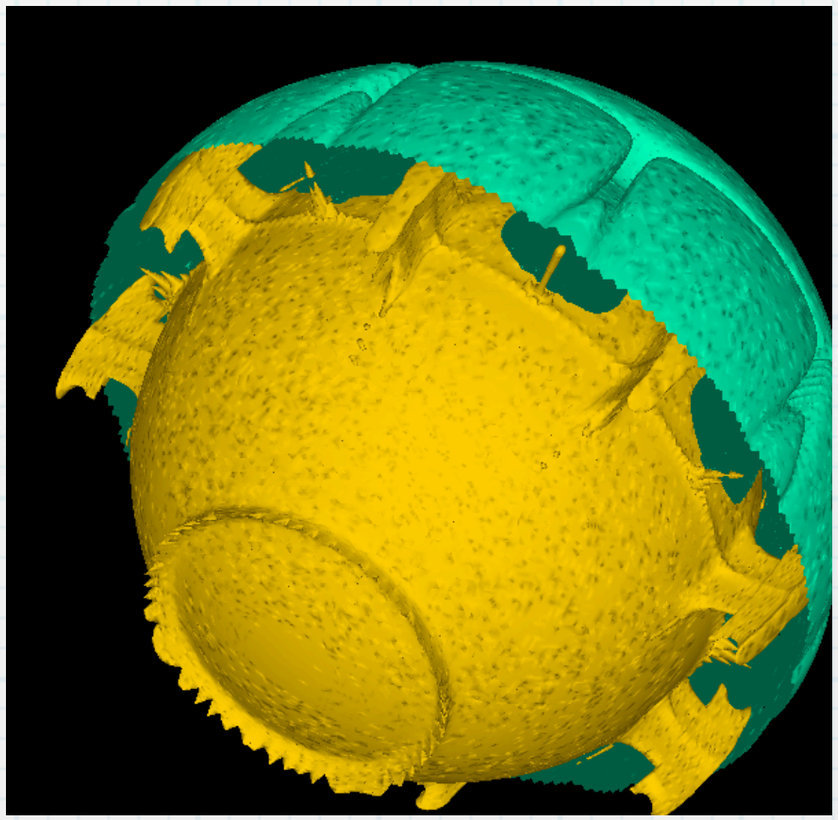
A True Story

* 2 hour run on IBM BlueGene - 16k processors
* 2.5 Billion years of evolution of Mercury
* >250,000 output files, >16 hours to tar and gzip



A True Story

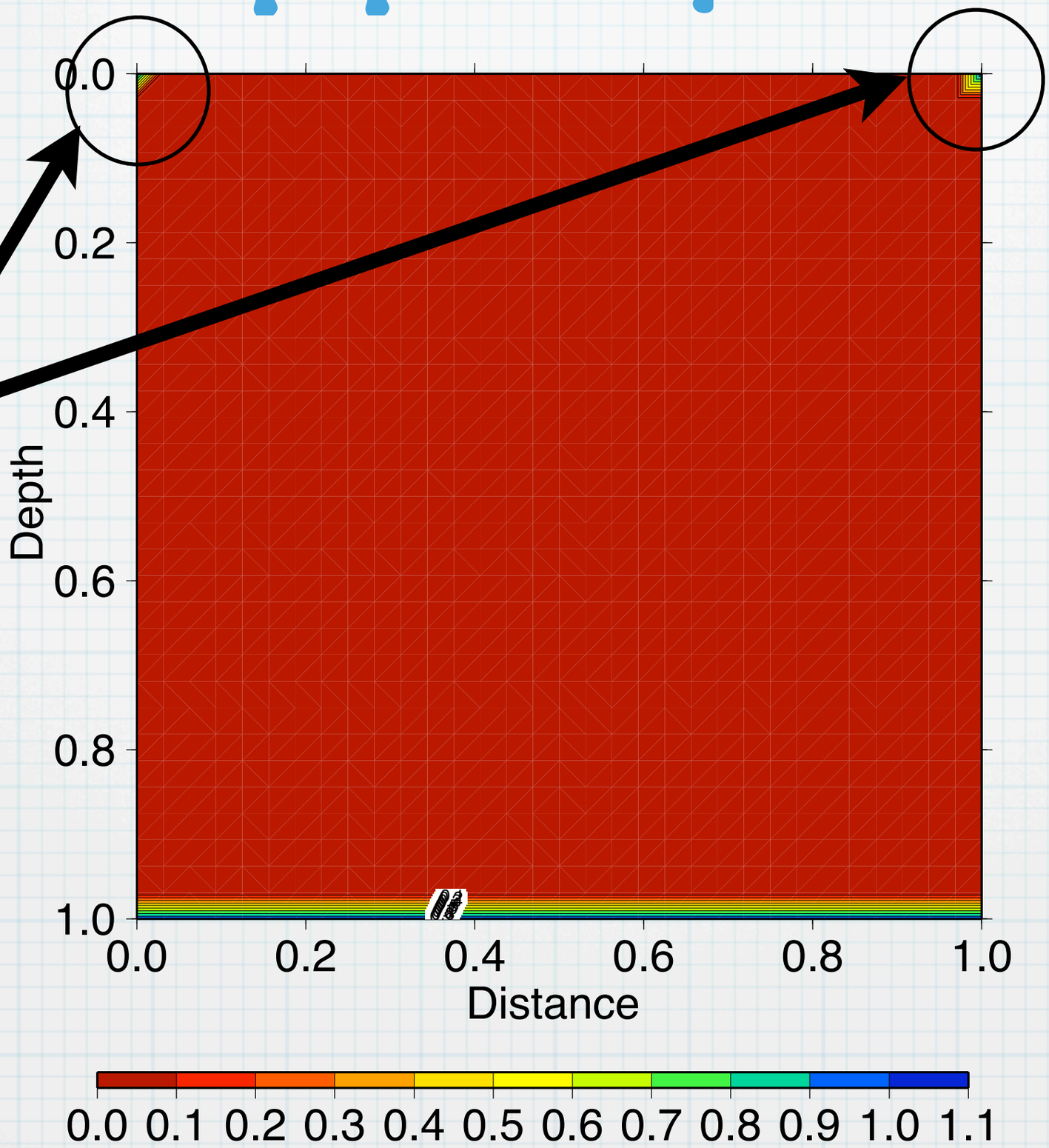
* 2 hour run on IBM BlueGene - 16k processors
* 2.5 Billion years of evolution of Mercury
* >250,000 output files, >16 hours to tar and gzip
* took 2 weeks to visualize result




I Have
Seen
The Light!

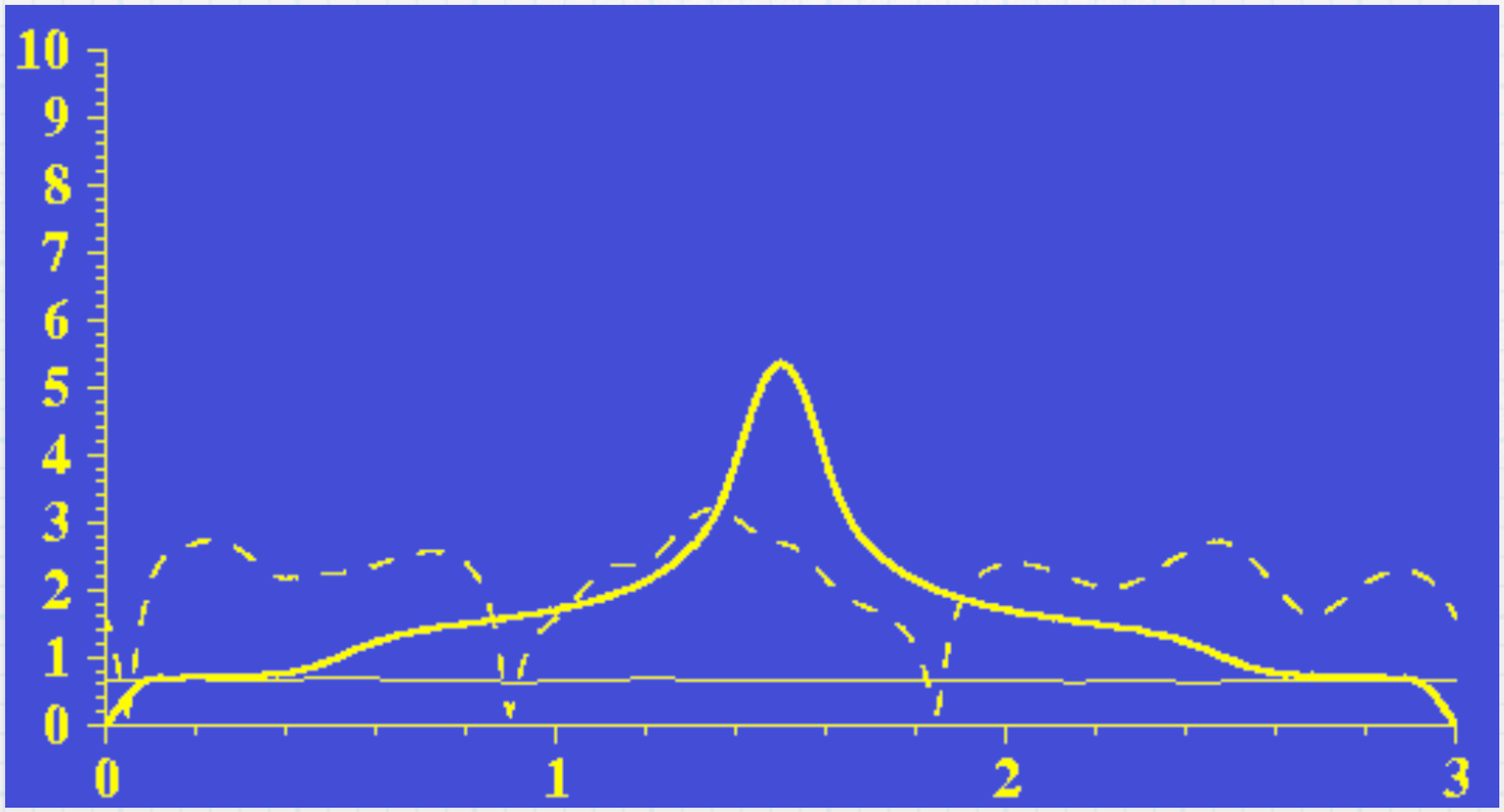
Epiphany #1

Find Errors in boundary condition



Epiphany #2

* trying to look at plate topography from 2D convection models
* theory: heatflow -> age$^{(-1/2)}$



Why?

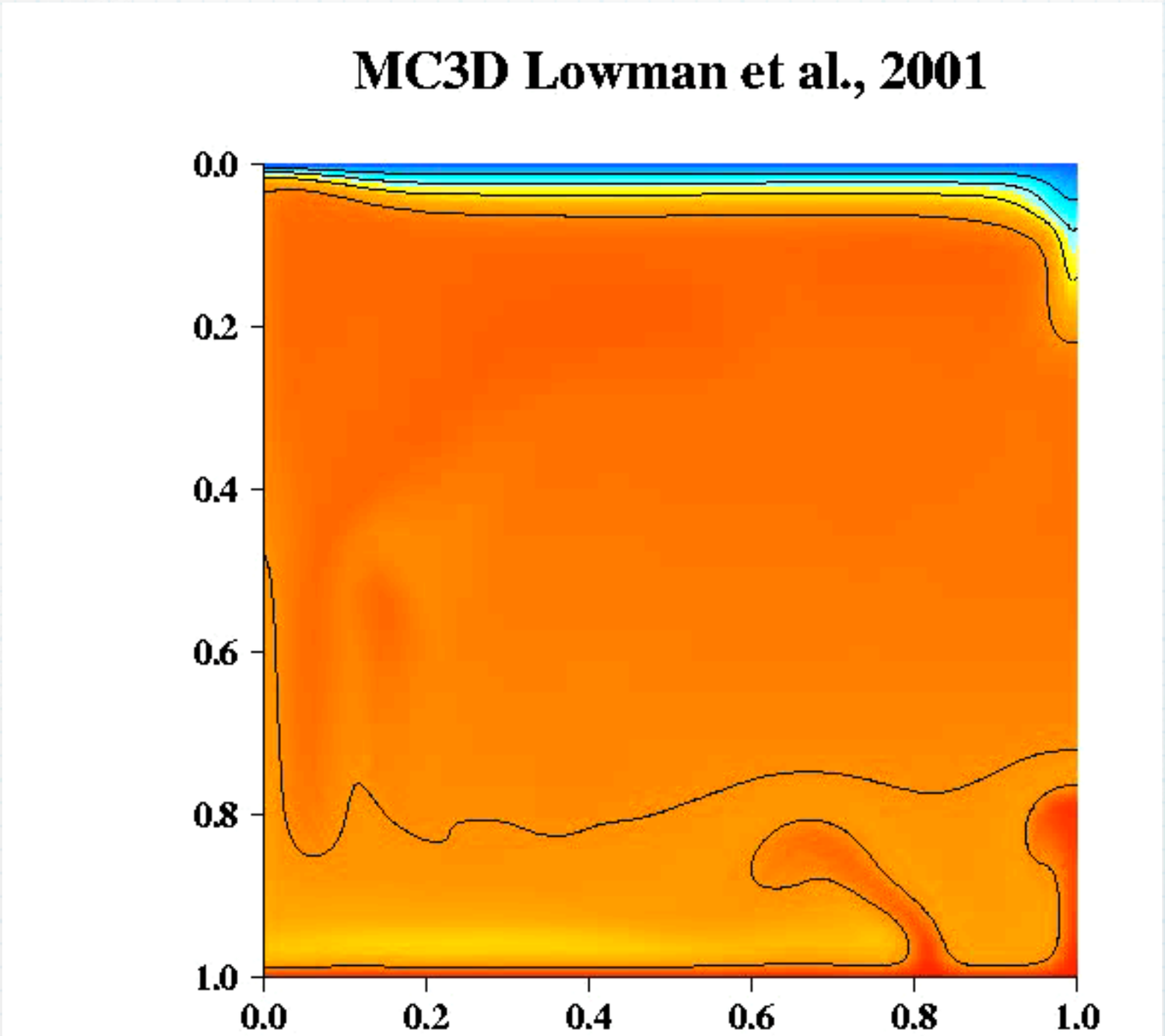
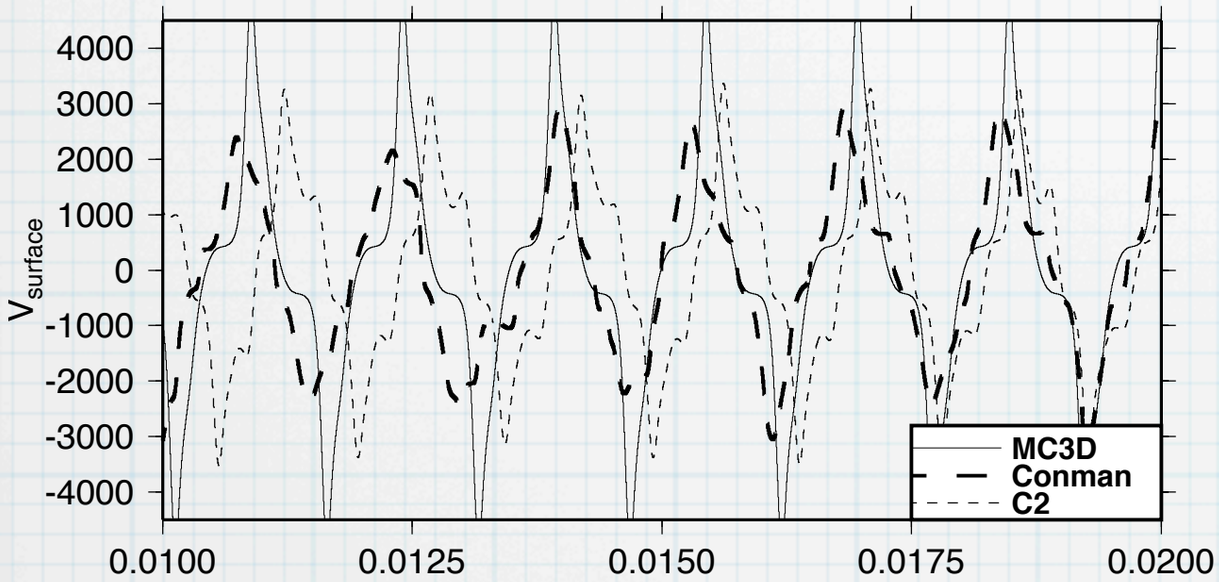
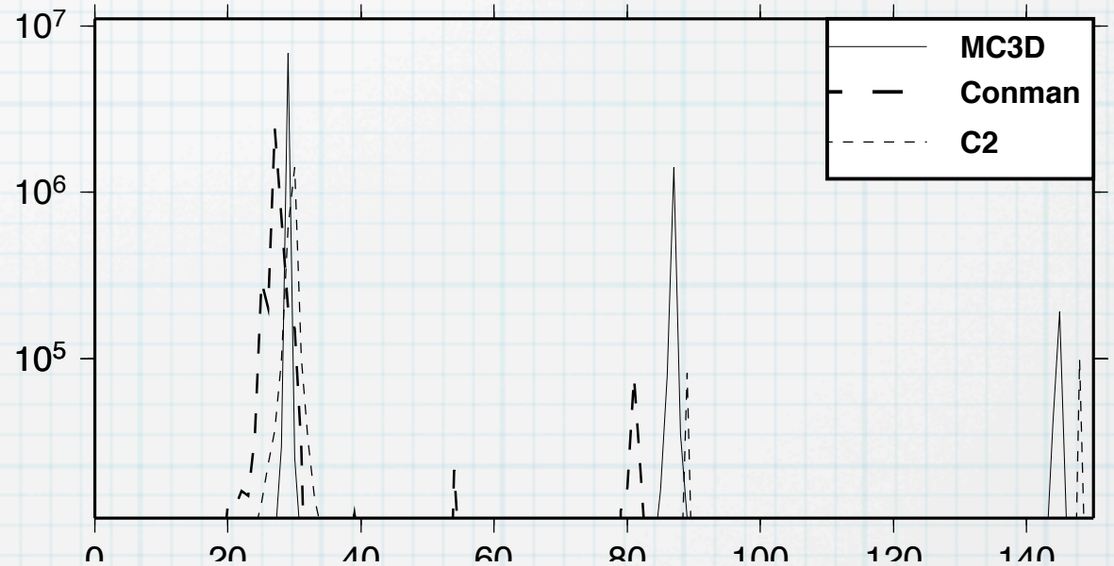


Plate Time Series





What is driving advances in scientific visualization?: Graphics Cards

What is driving advances in scientific visualization?: Graphics Cards

* 780 Mtriangles/sec

What is driving advances in scientific visualization?: Graphics Cards

* 780 Mtriangles/sec
* 31.2 Gpixels/sec

What is driving advances in scientific visualization?: Graphics Cards

* 780 Mtriangles/sec
* 31.2 Gpixels/sec
* cost $500 (Radeon X1900 XTX)

What is driving advances in scientific visualization?: Graphics Cards

* 780 Mtriangles/sec
* 31.2 Gpixels/sec
* cost $500 (Radeon X1900 XTX)
* thanks gamers...

What is driving advances in scientific visualization?: Graphics Cards

* 780 Mtriangles/sec
* 31.2 Gpixels/sec
* cost $500 (Radeon X1900 XTX)
* thanks gamers...
* high-end cards pushing 150 Watts!

What is driving advances in scientific visualization?: Graphics Cards

* 780 Mtriangles/sec
* 31.2 Gpixels/sec
* cost $500 (Radeon X1900 XTX)
* thanks gamers...
* high-end cards pushing 150 Watts!
* projects exploring using the card as a parallel (array) processor

An Example of Bad Graphics

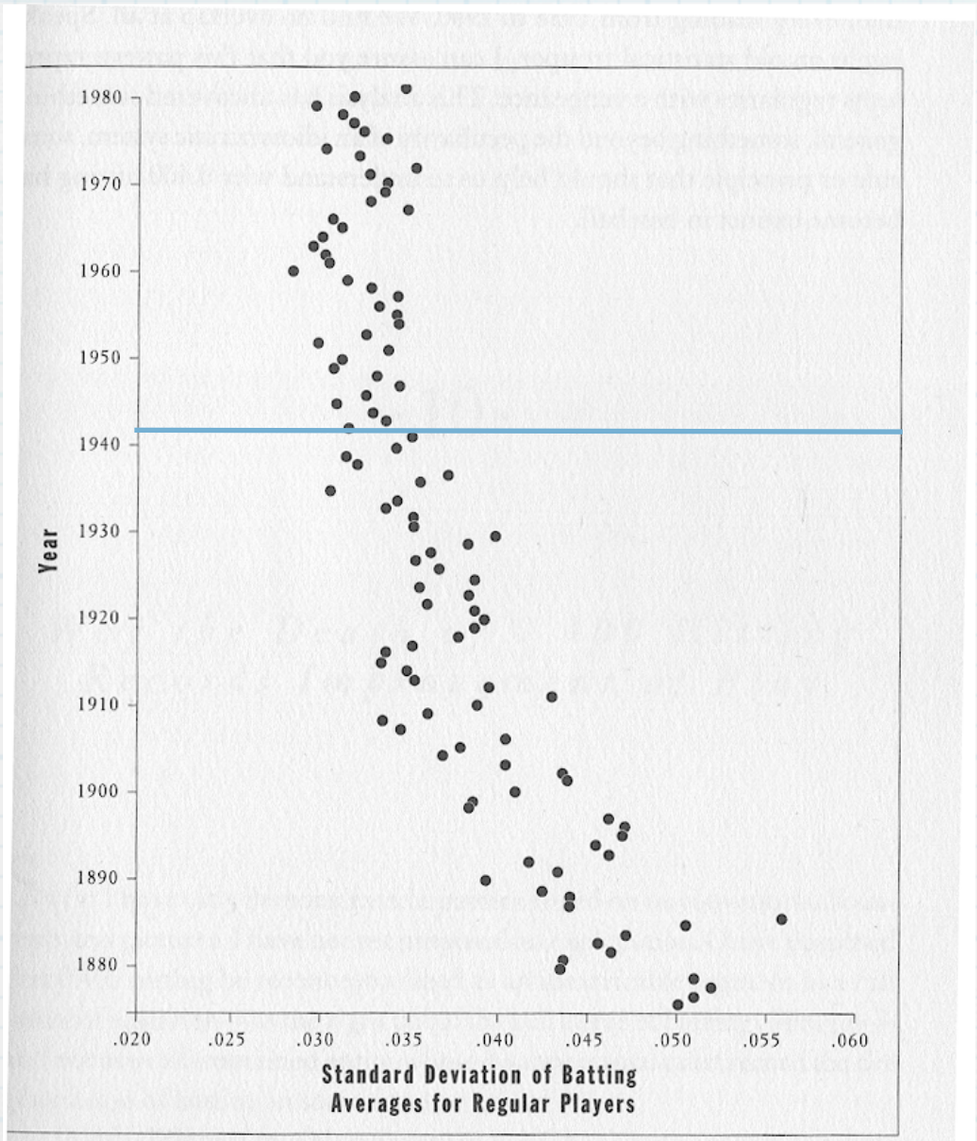


FIGURE 16
Standard deviation of batting averages for all full-time players by year for the first 100 years of professional baseball. Note the regular decline.

From S. J. Gould, "Full House" (1996) p. 109, Fig. 16

Gould argues that the absence of 400 hitters in baseball since Ted William's 0.406 average in 1941 is the result of decrease in variability of players rather than an overall decline in talent.

An Example of Bad Graphics

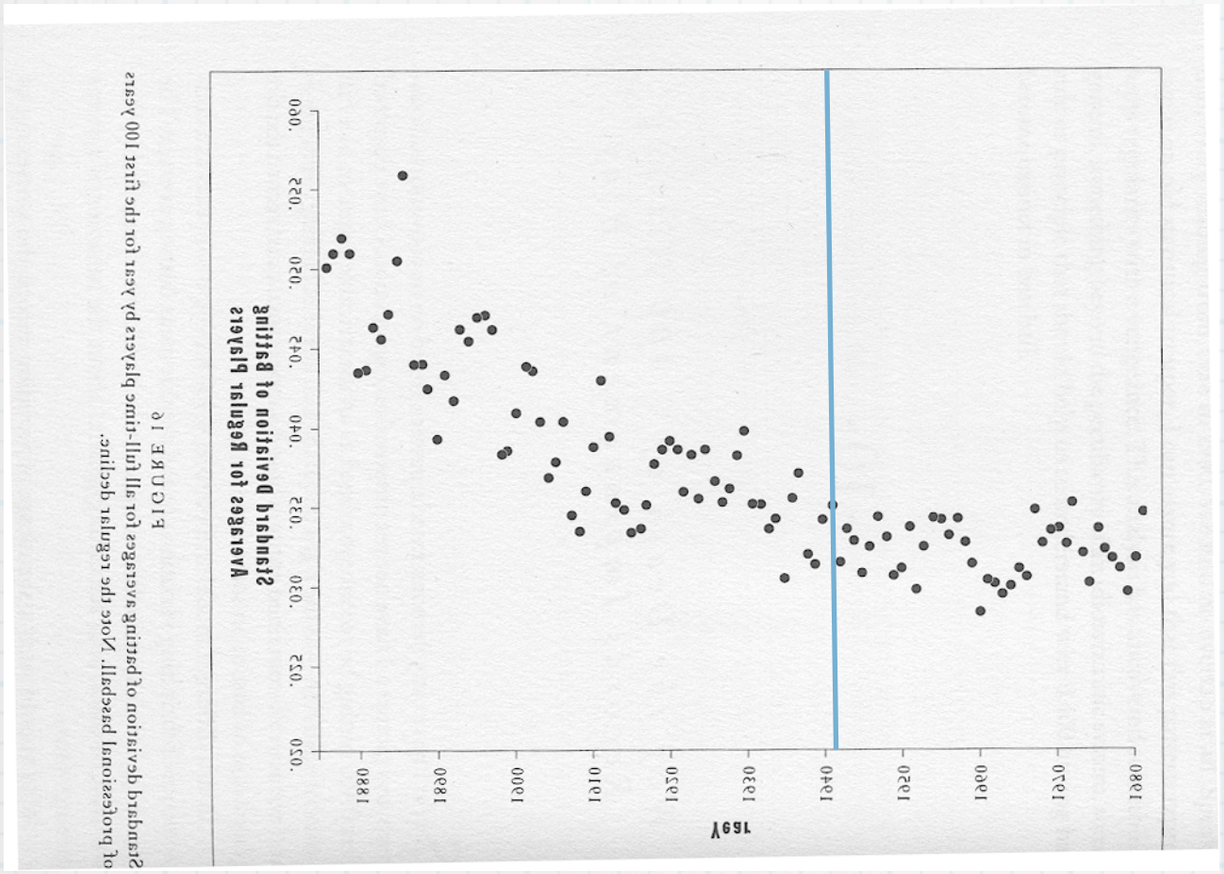


FIGURE 1.9
Standard deviation of batting averages for all full-time players per year for the first 100 years of professional baseball. Note the regular decline.

Plotted correctly, it is harder to see a trend supporting the argument, and in fact the most interesting change seems to be from 1880-1910 and not post 1940.

2D Domains

2D Domains

* scalar - line contour, color code

2D Domains

* scalar - line contour, color code
* vector - arrows, color for magnitude

2D Domains

* scalar - line contour, color code
* vector - arrows, color for magnitude
* tensor - represent principal components?

2D Domains

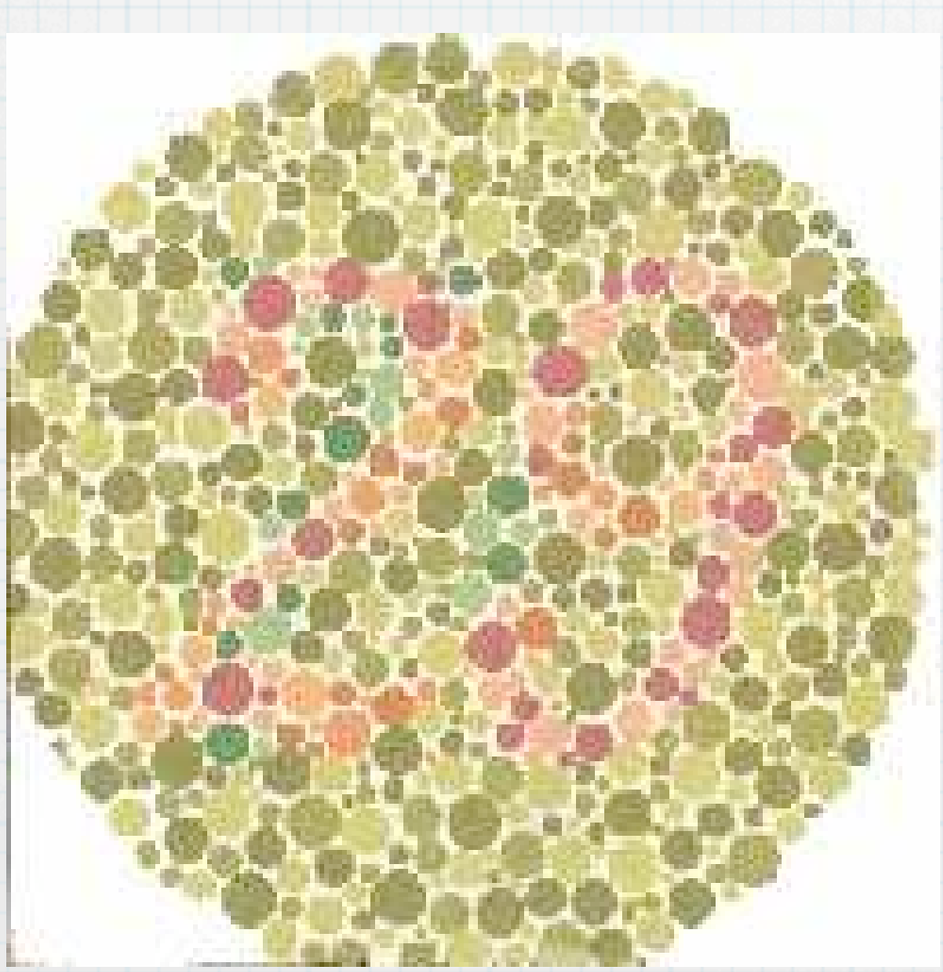
* scalar - line contour, color code
* vector - arrows, color for magnitude
* tensor - represent principal components?
* multiple fields? - composition + temperature

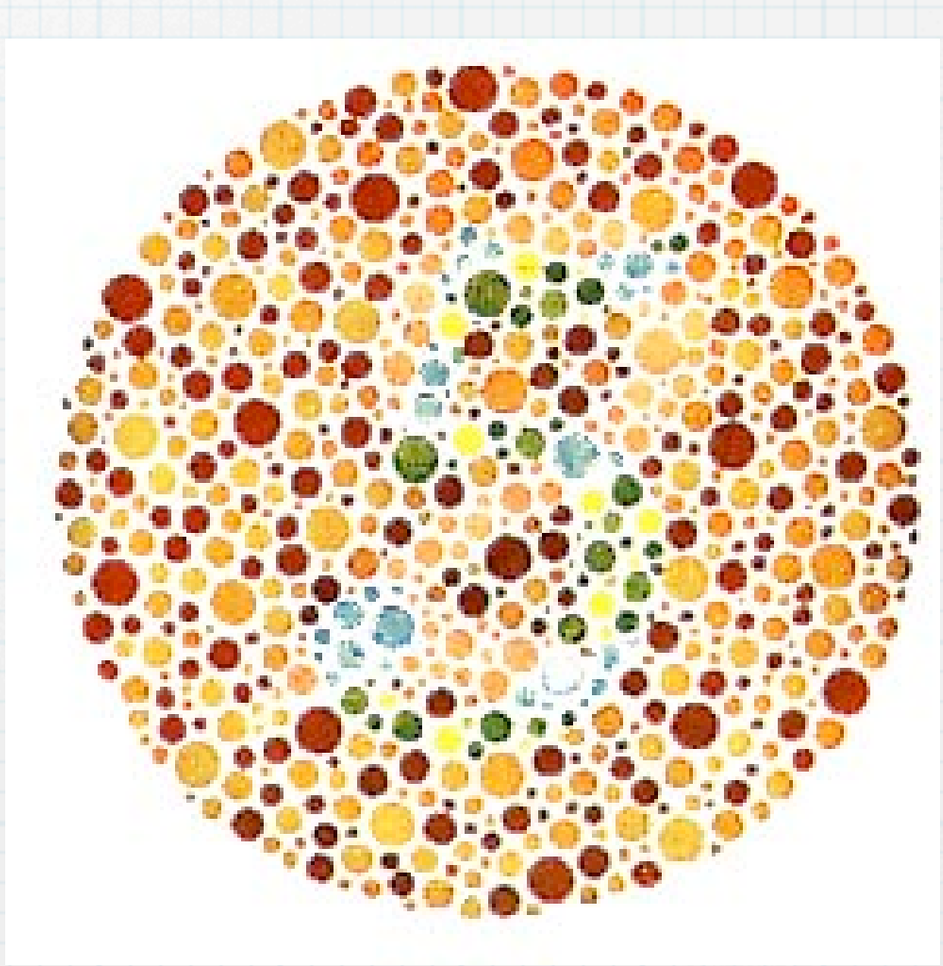
2D Domains

* scalar - line contour, color code
* vector - arrows, color for magnitude
* tensor - represent principal components?
* multiple fields? - composition + temperature
* make use of third dimension?

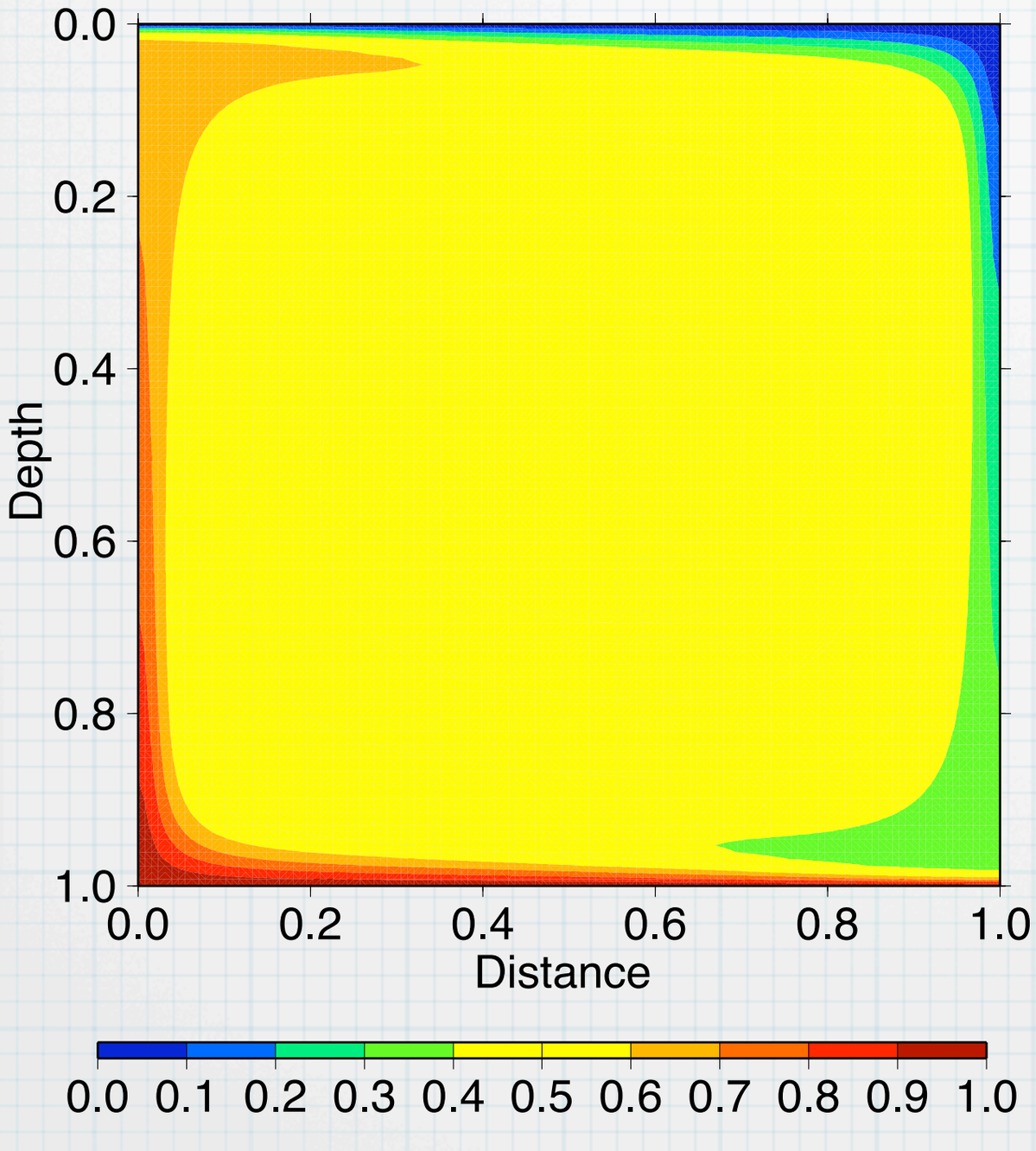
Color Blindness

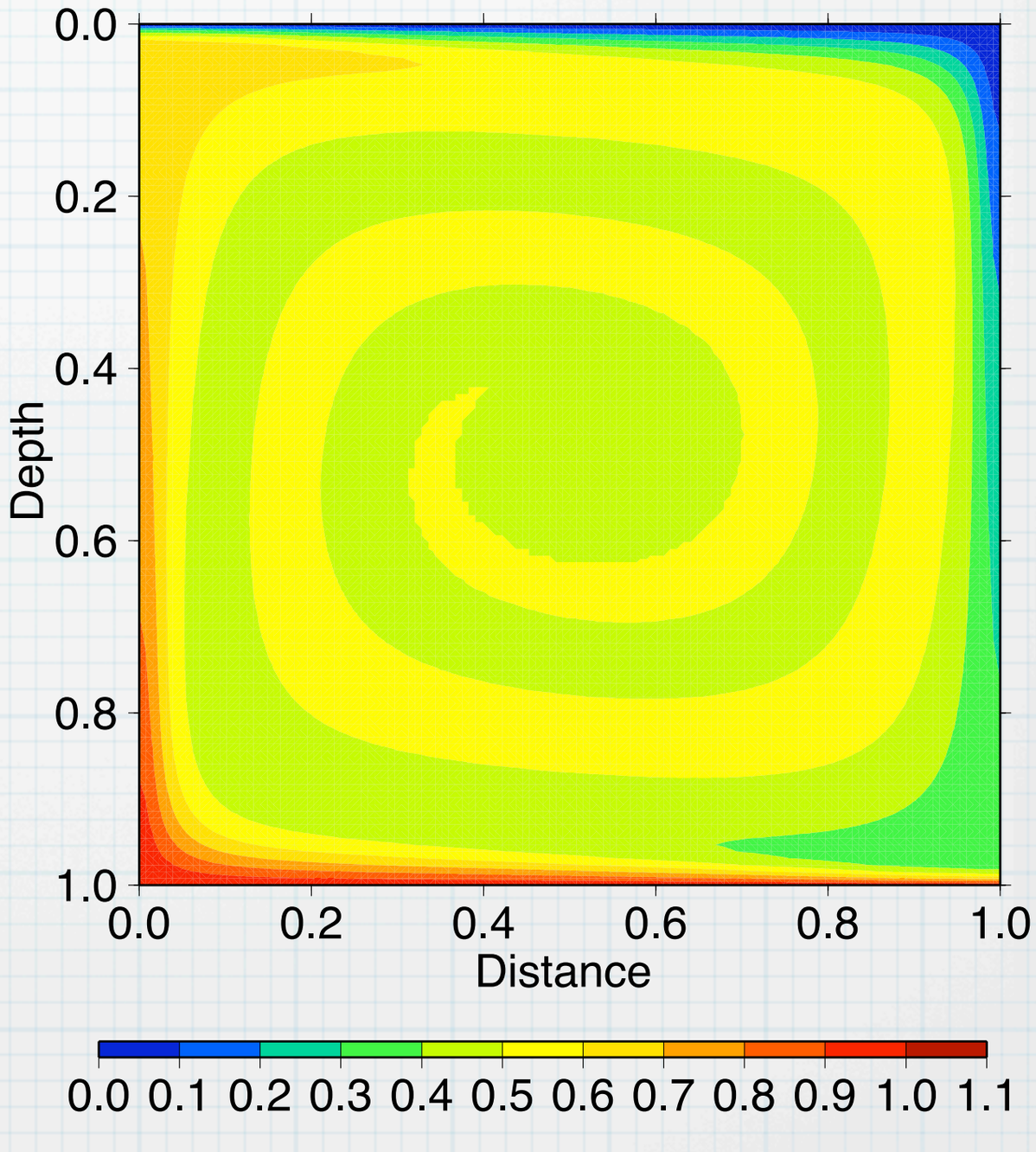
* 8-12% of adult male population
* 0.5 % of female population
* most common is red-greed deficiency



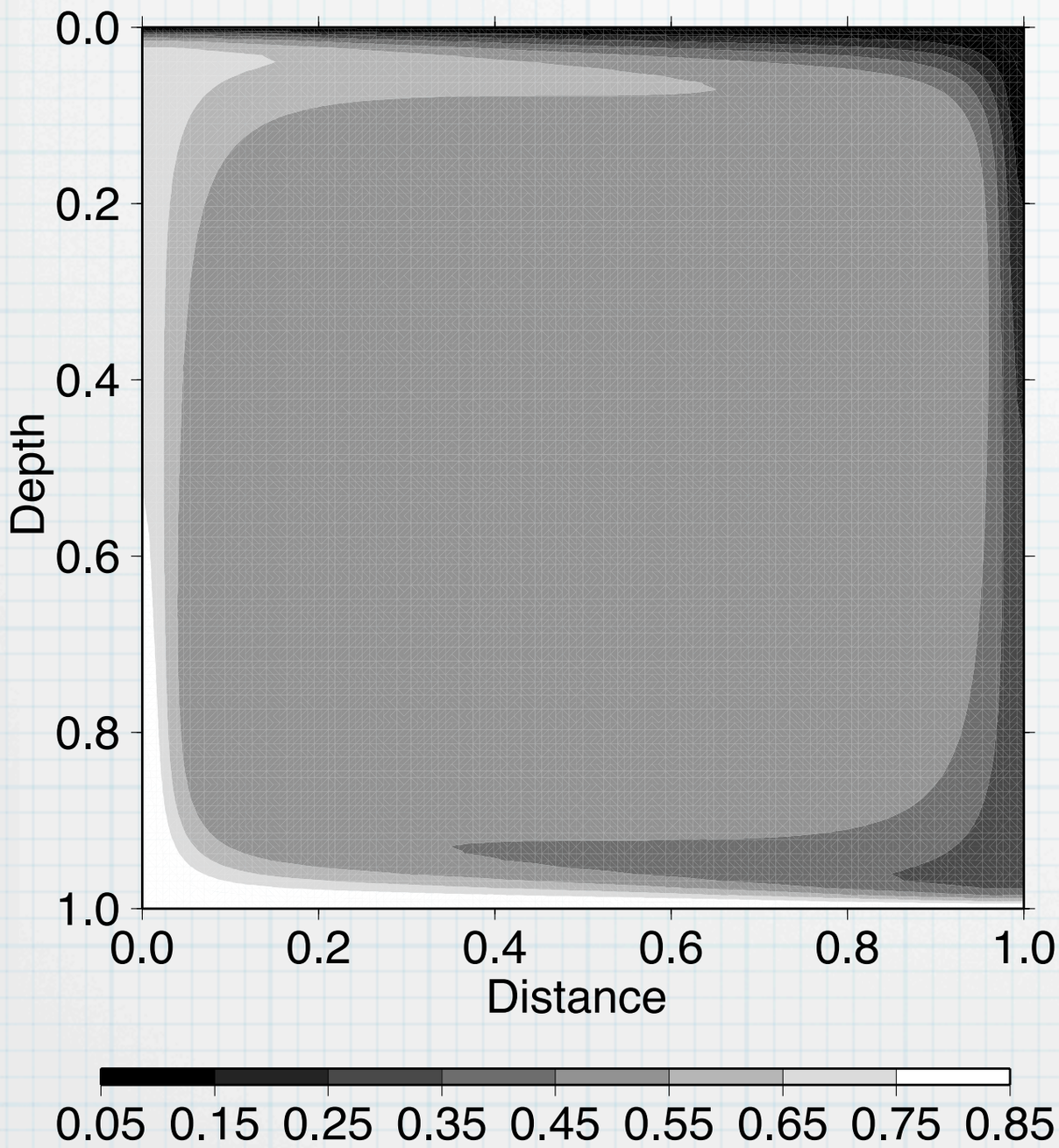


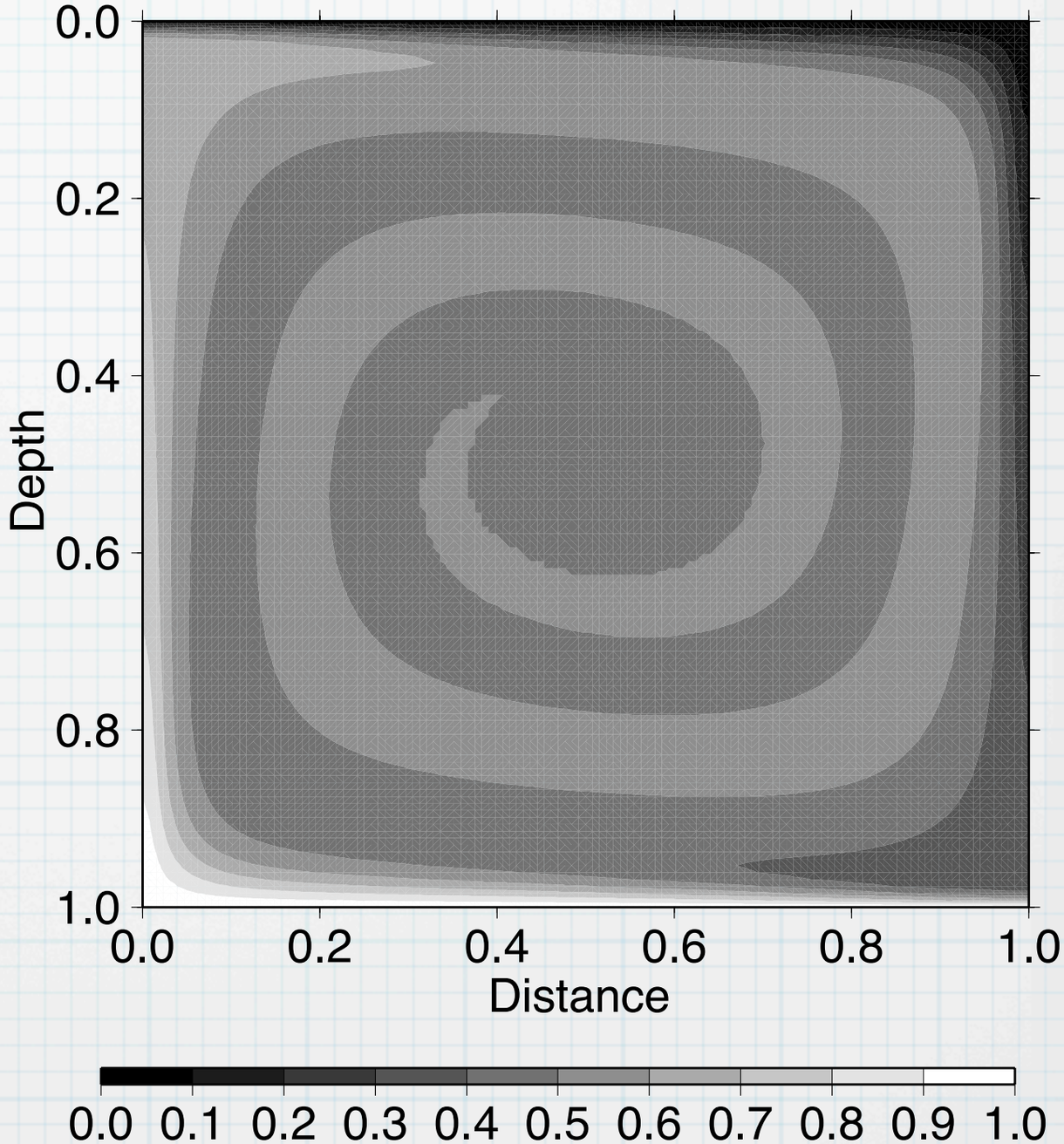
2D Examples...


0.0
0.2
0.4
0.6
0.8
1.0
Depth
0.0
0.2
0.4
0.6
0.8
1.0
Distance
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0


0.0
0.2
0.4
0.6
0.8
1.0
Depth
0.0
0.2
0.4
0.6
0.8
1.0
Distance
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1

2D Examples...


0.0
0.2
0.4
0.6
0.8
1.0
Depth
0.0
0.2
0.4
0.6
0.8
1.0
Distance
0.05 0.15 0.25 0.35 0.45 0.55 0.65 0.75 0.85

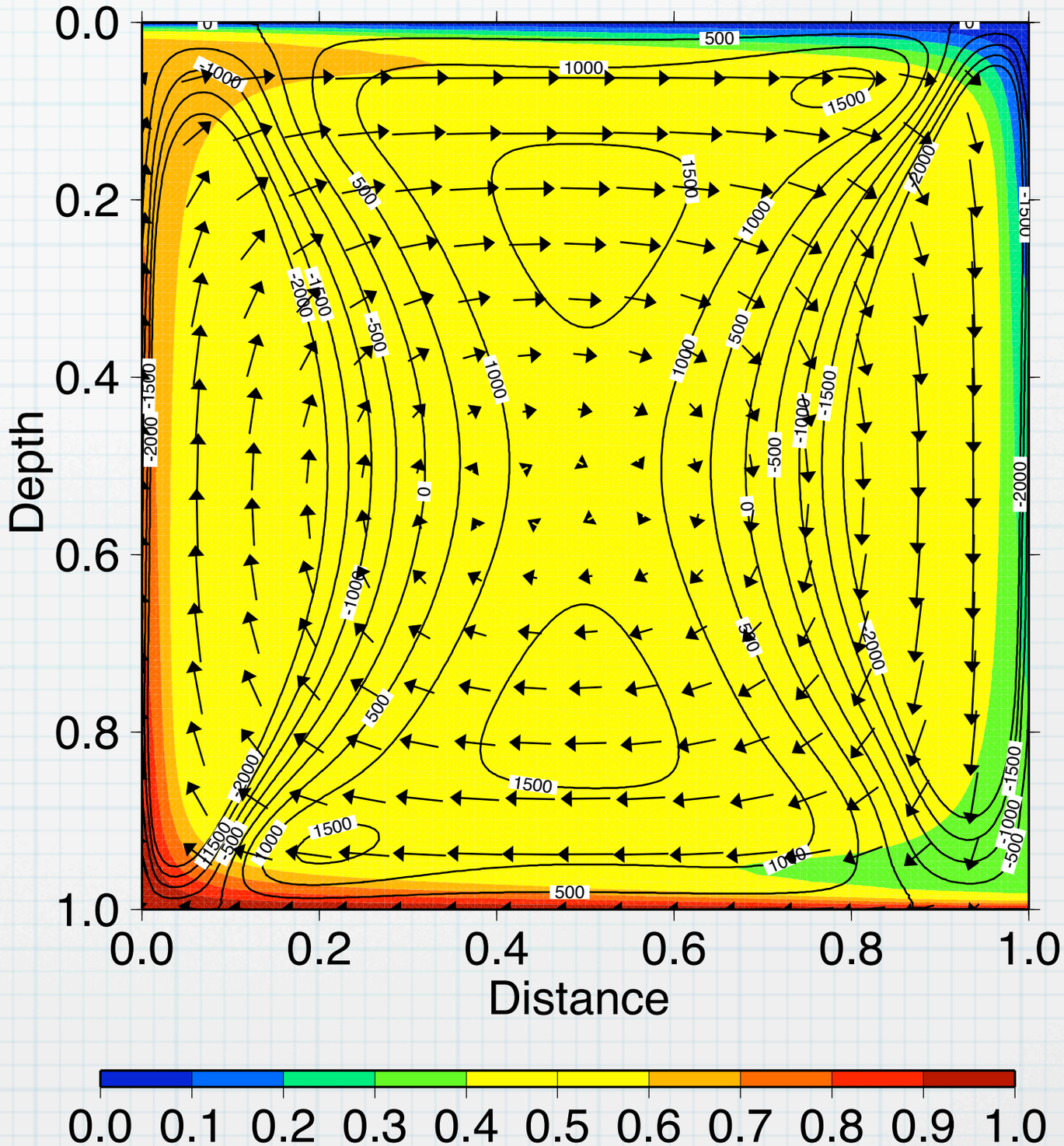

0.0
0.2
0.4
0.6
0.8
1.0
Depth
0.0
0.2
0.4
0.6
0.8
1.0
Distance
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0

Multiple 2D Fields?

* temperature + composition
* temperature + velocity (superimpose)
* temperature + velocity + pressure

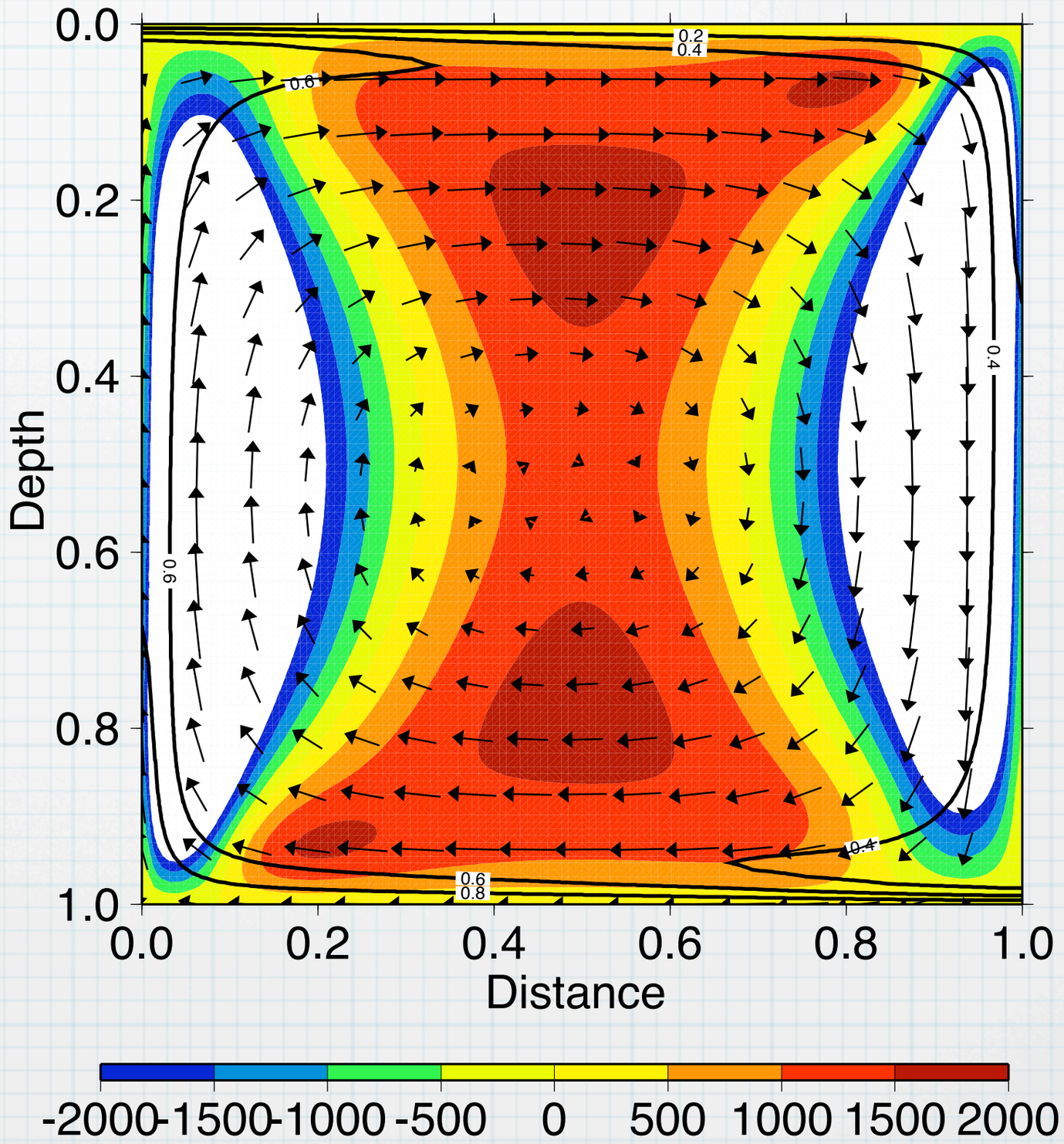
2D Examples...

* color - temperature
* contour - pressure
* arrows - velocity



2D Examples...

* color - pressure
* contour - temperature
* arrows - velocity



3D Visualization Techniques

Visualization techniques can be divided into surface rendering techniques, and (direct) volume rendering techniques.

- Surface rendering is an indirect geometry based technique which is used to visualize structures in 3D scalar or vector fields by converting these structures into surface representations first and then using conventional computer graphics techniques to render these surfaces.
- Direct volume rendering is a technique for the visualization of 3D scalar data sets without a conversion to surface representations.

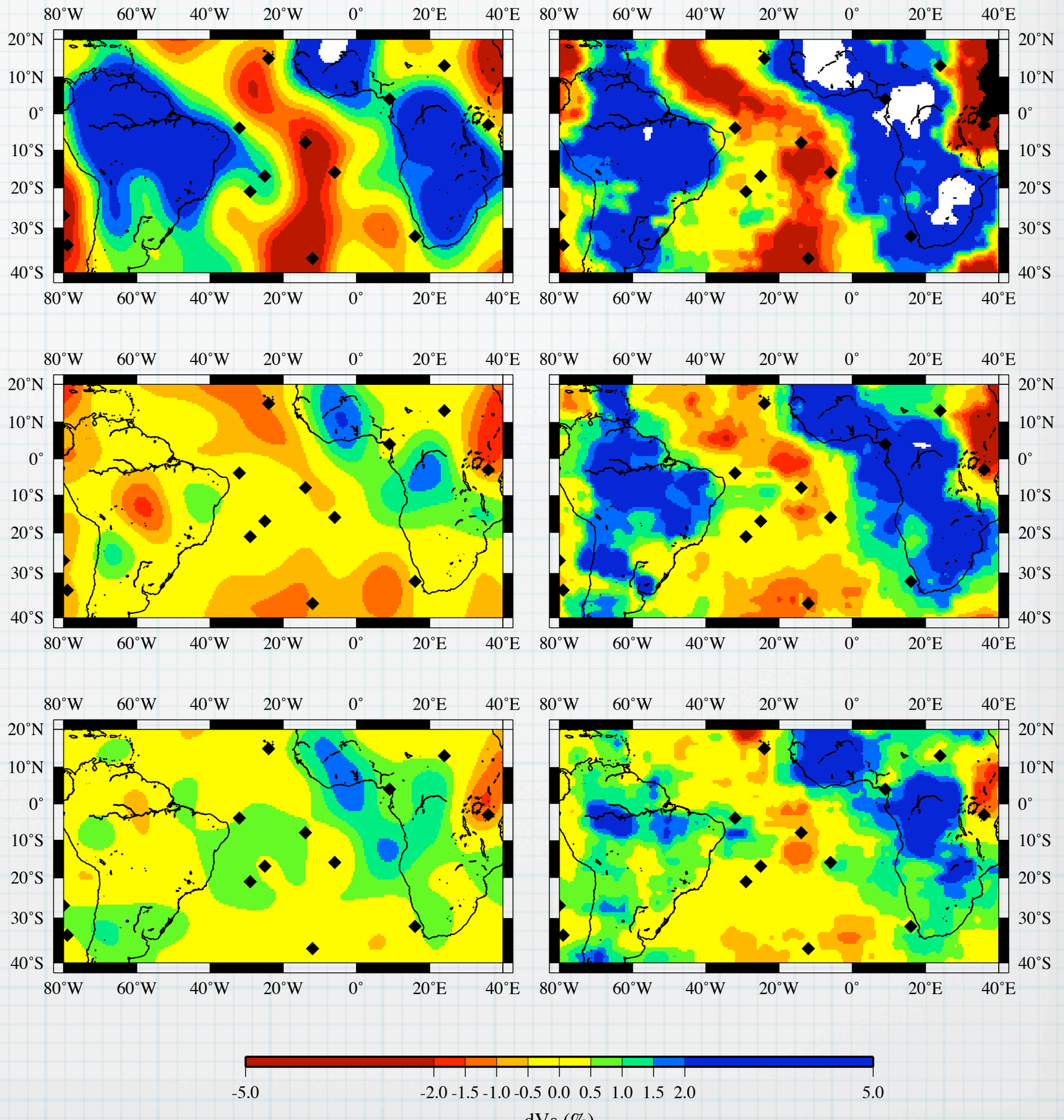
3D Fields

* Surface Rendering
  * isosurface
  * orthogonal slicers
  * vector glyphs (arrows, etc.)
  * streamlines, streaklines

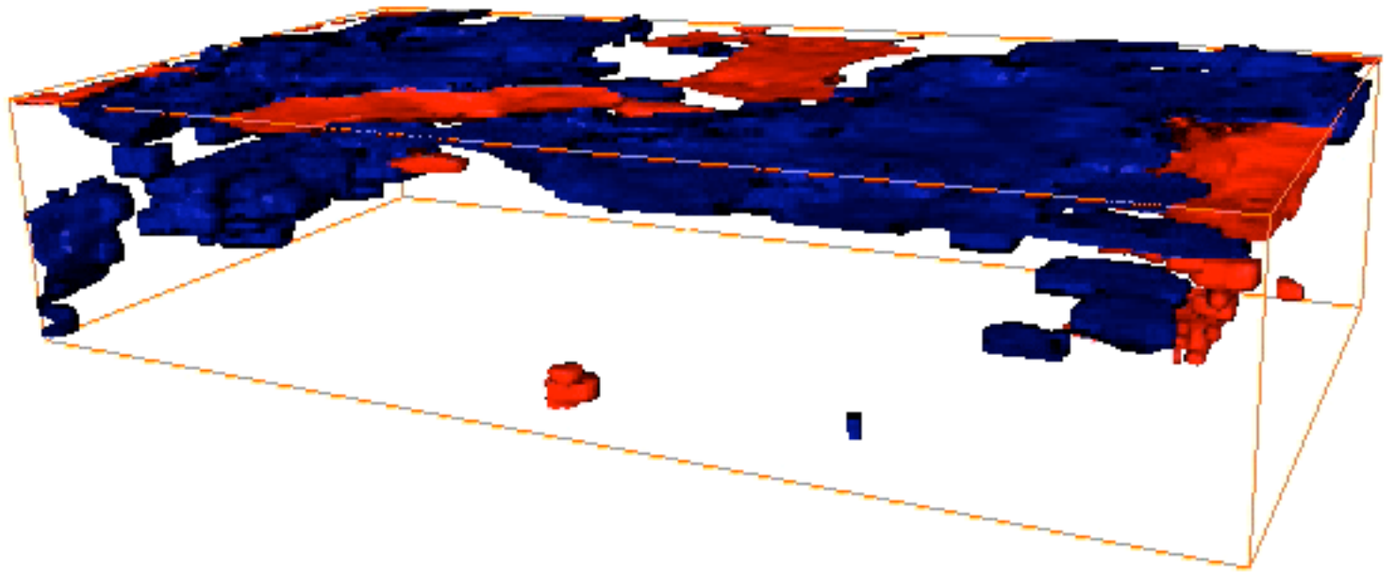
Volume Rendering - Ray Casting

* Several implementations exist for ray casting. Here is the implementation used in Visualization Data Explorer.
* For every pixel in the output image a ray is shot into the data volume.
* At a predetermined number of evenly spaced locations along the ray the color and opacity values are obtained by interpolation.
* The interpolated colors and opacities are merged with each other and with the background by compositing in back-to-front order to yield the color of the pixel.
* These compositing calculations are simply linear transformations. Specifically, the color of the ray Cout as it leaves each sample location, is related to the color Cin of the ray, as it enters, and to the color c(xi) and the opacity a(x) at that sample location by a transparency formula...

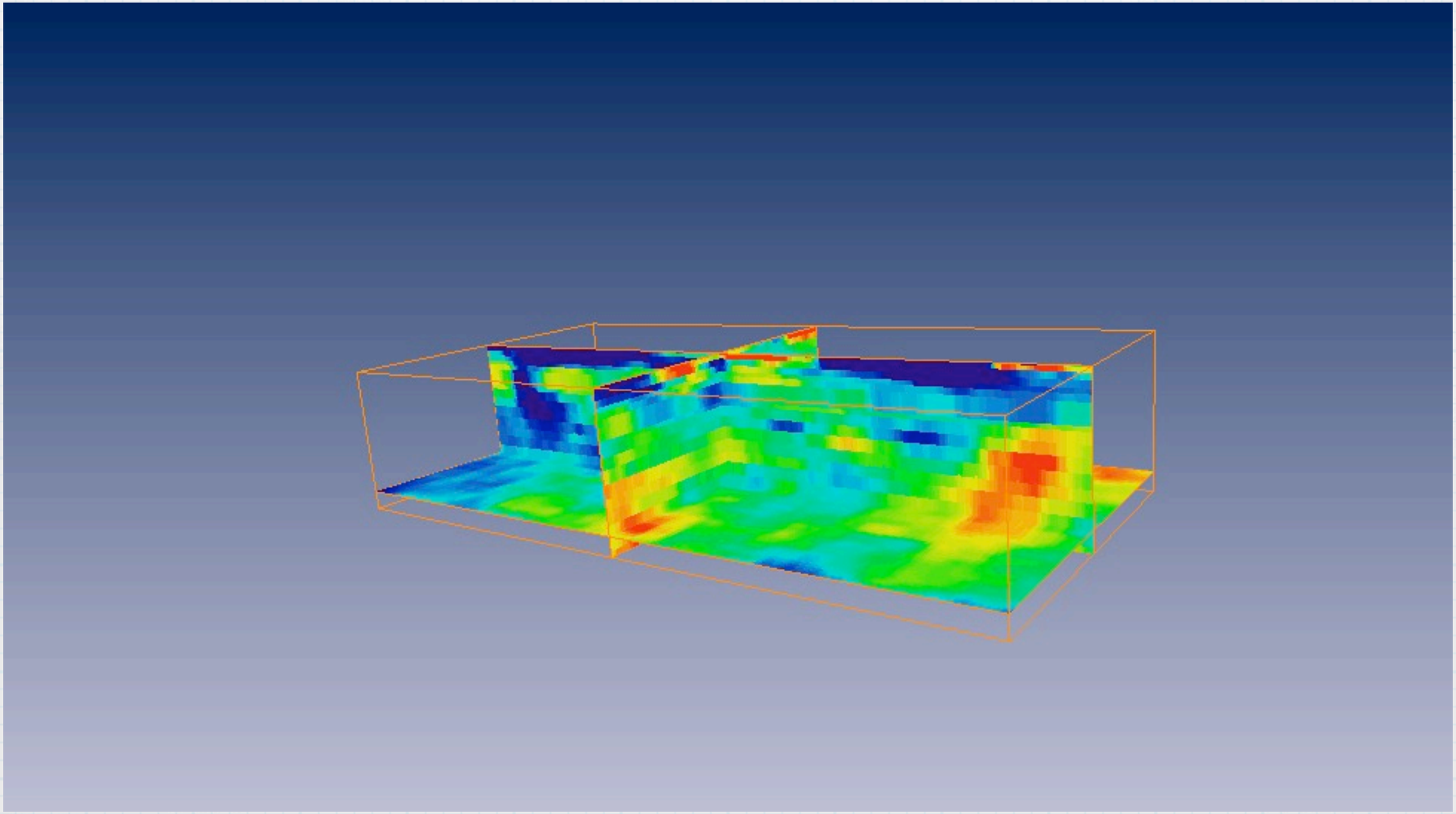
3D Seismic Velocity Perturbations



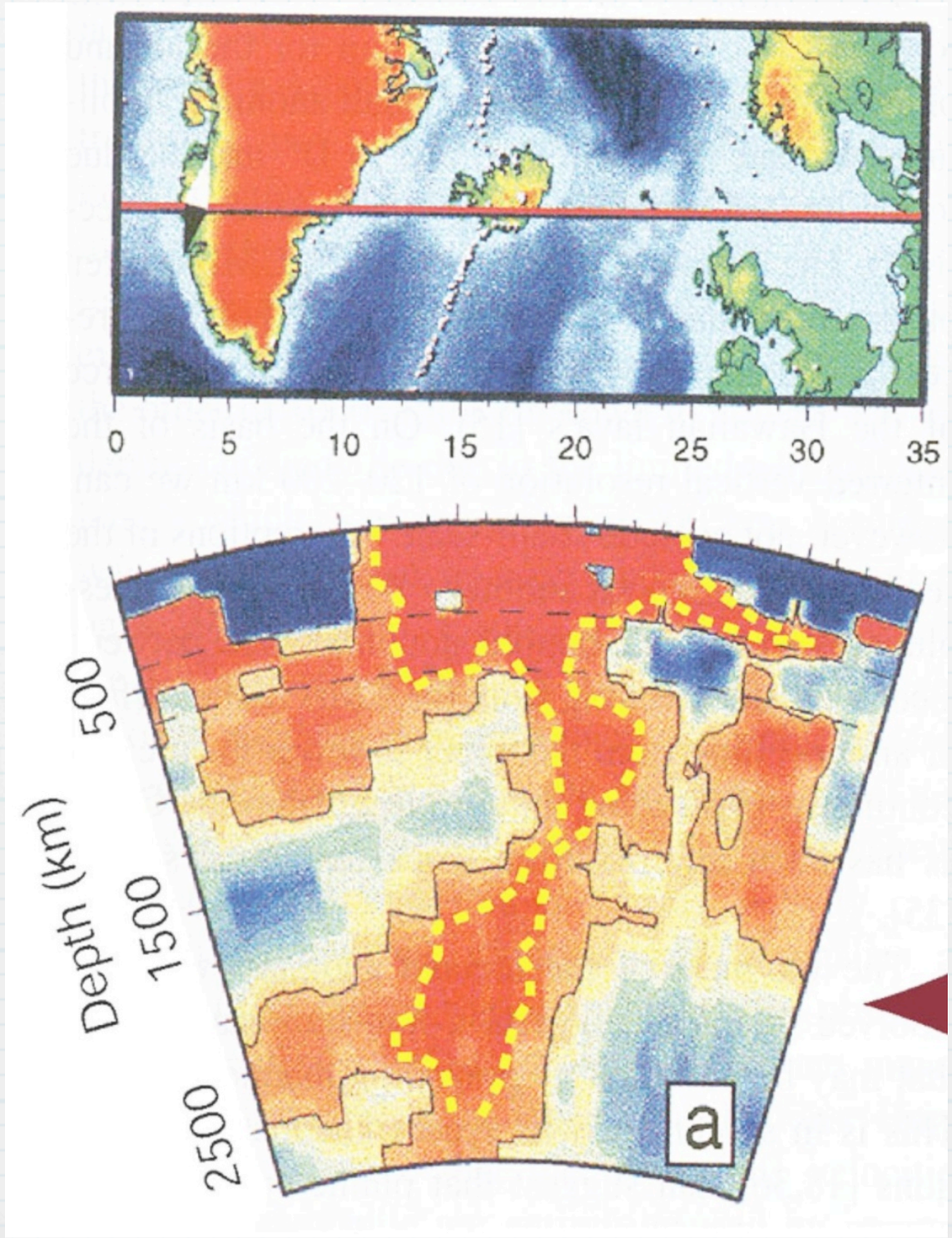
Isosurfaces



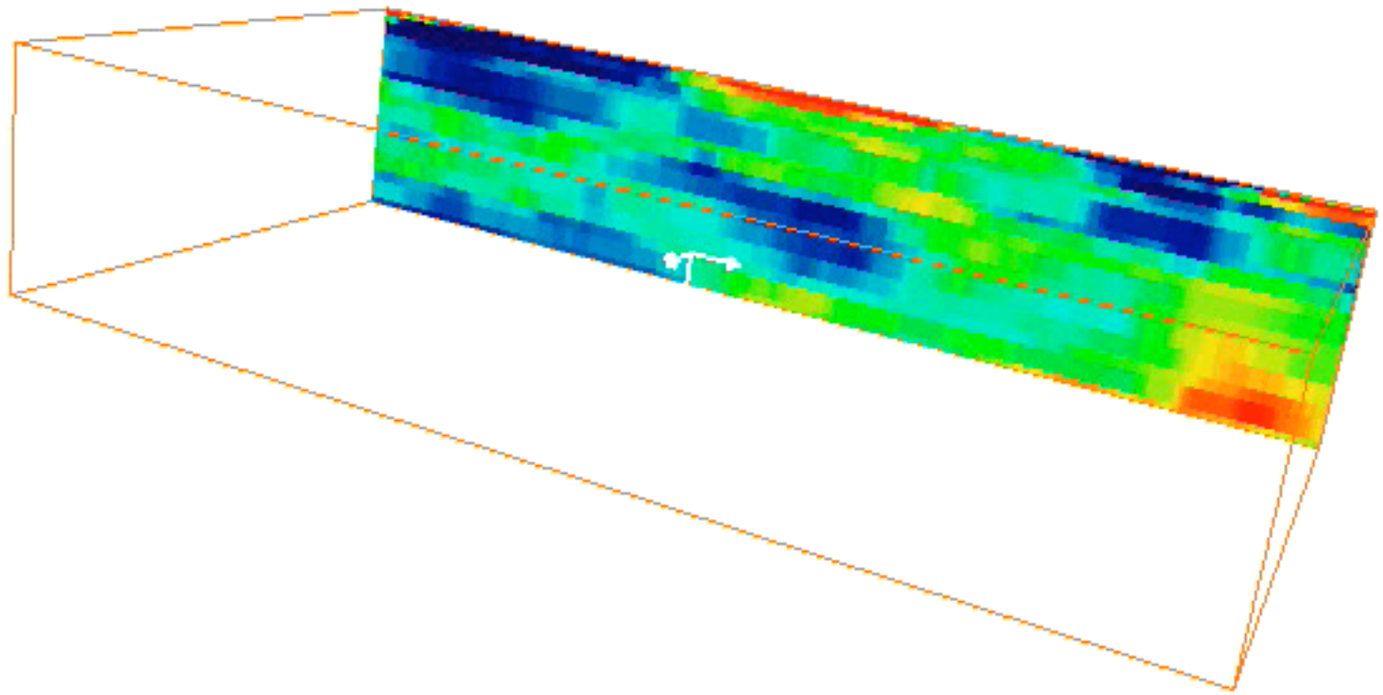
Orthogonal Slices



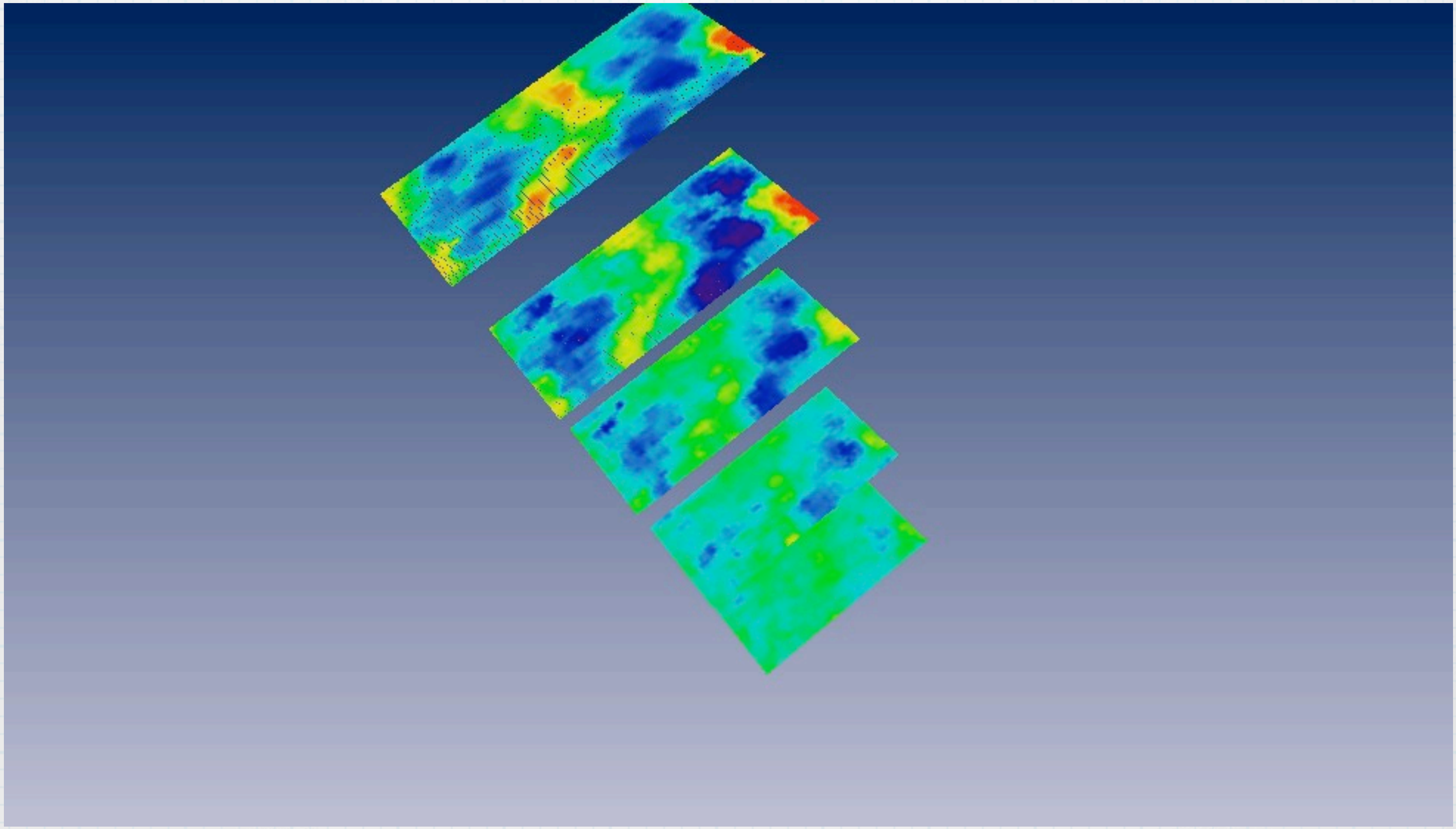
The problem with slices...



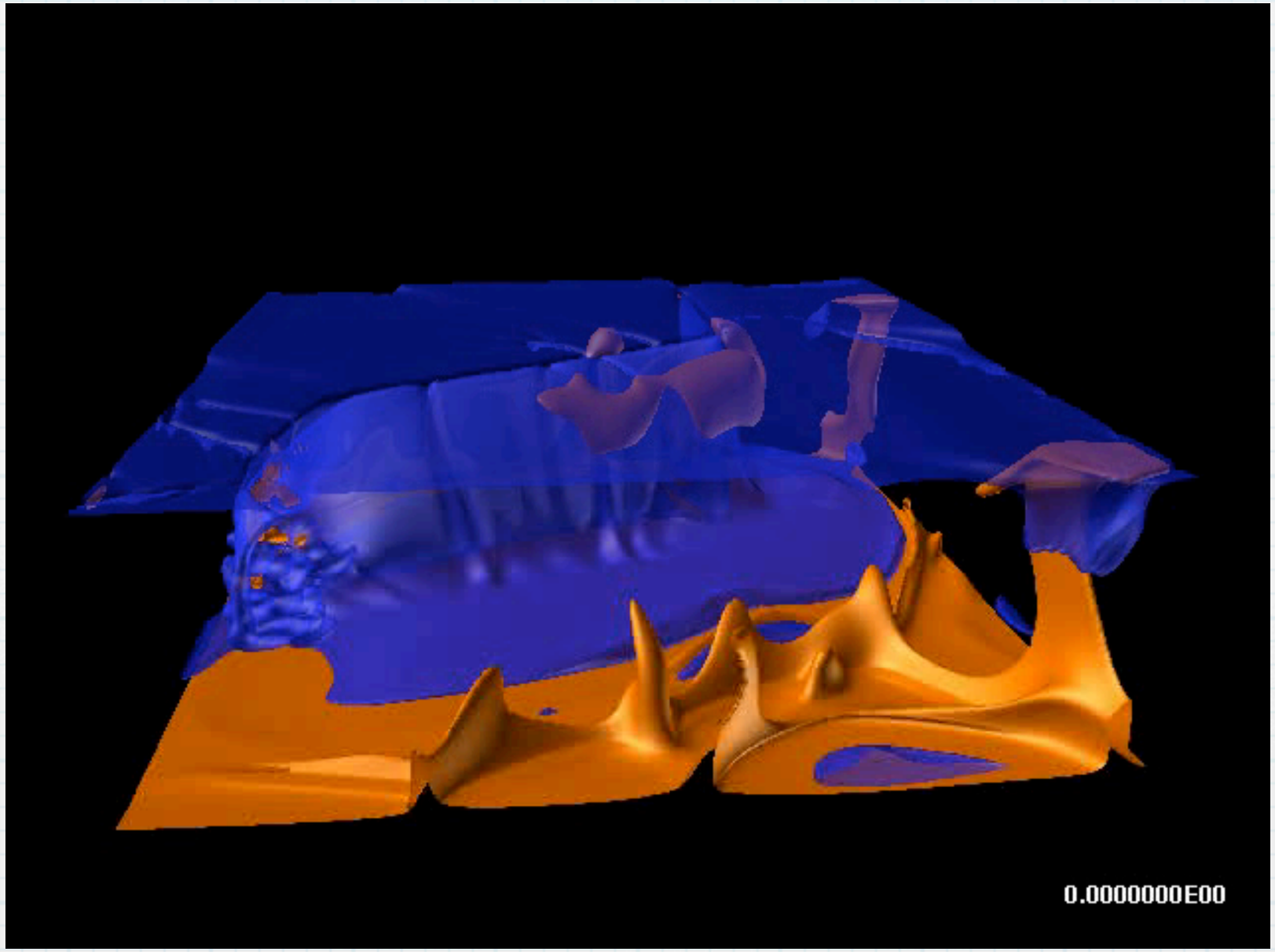
Orthogonal Slices



Stack Layers



3D Plate Movie

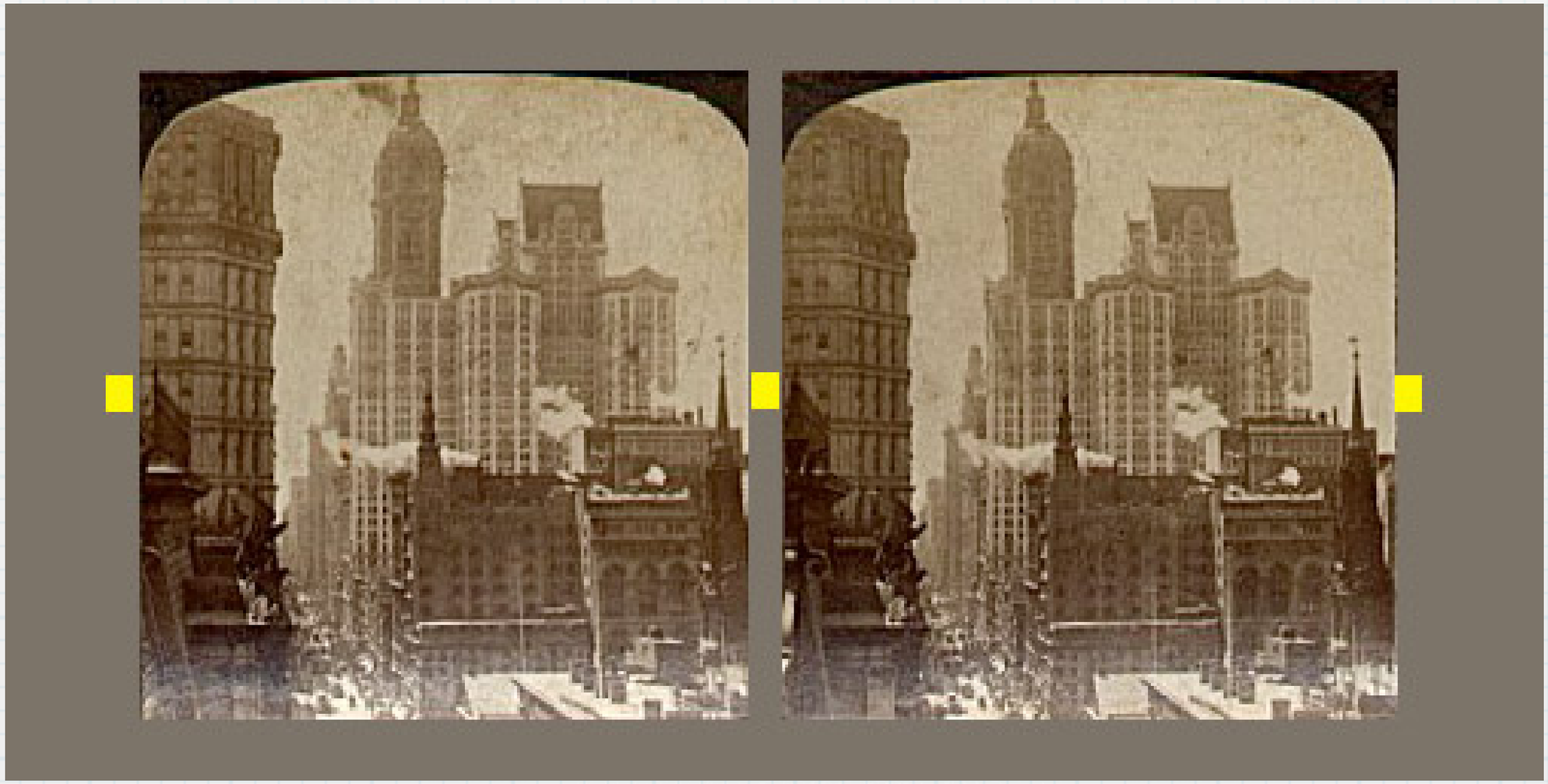


Stereo Visualization

Stereo Visualization

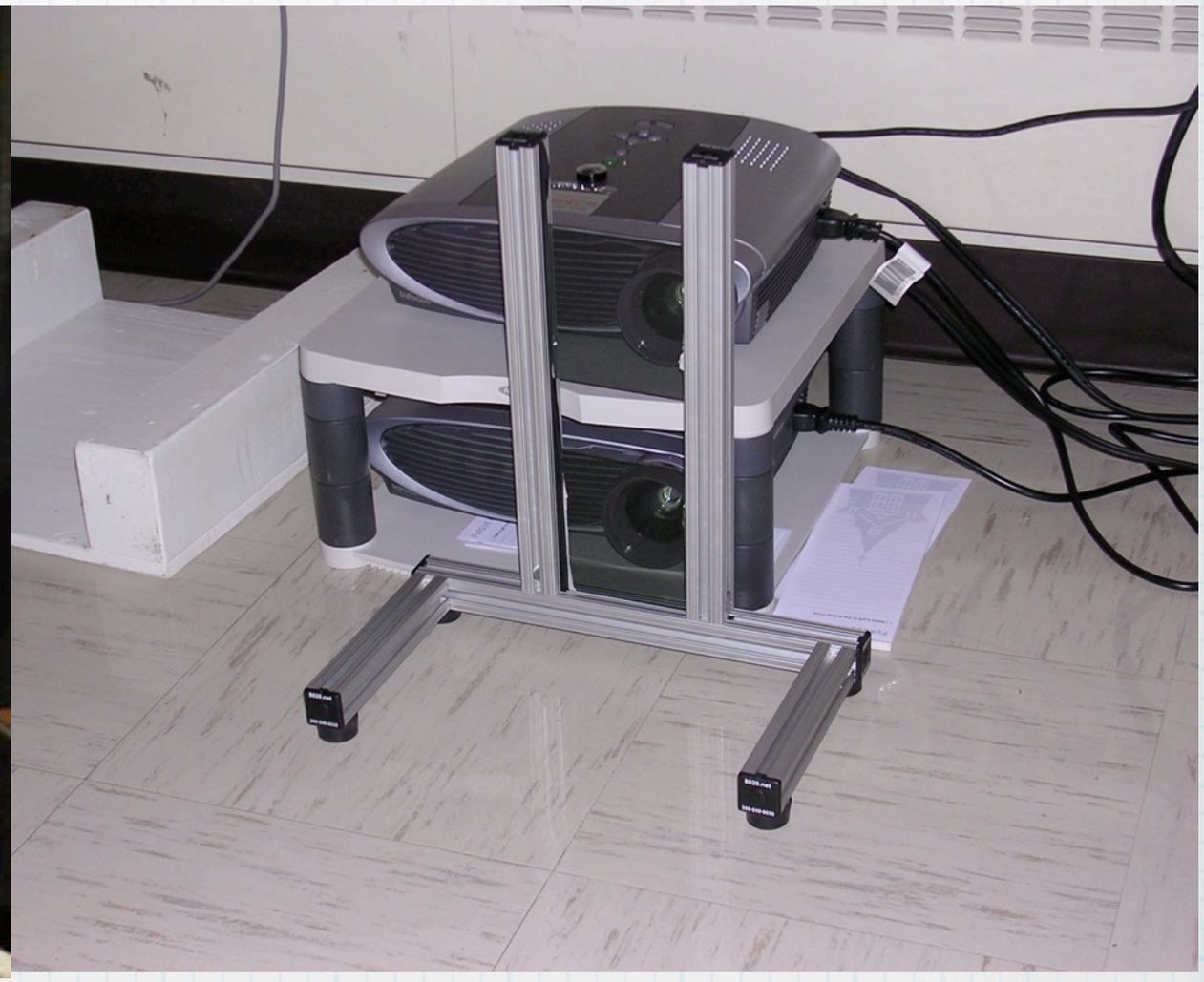
* CAVE
  * big
  * expensive ($500k)
    * people to maintain it
    * access?
* Passive Stereo (GeoWall)

Passive Stereo, an old idea



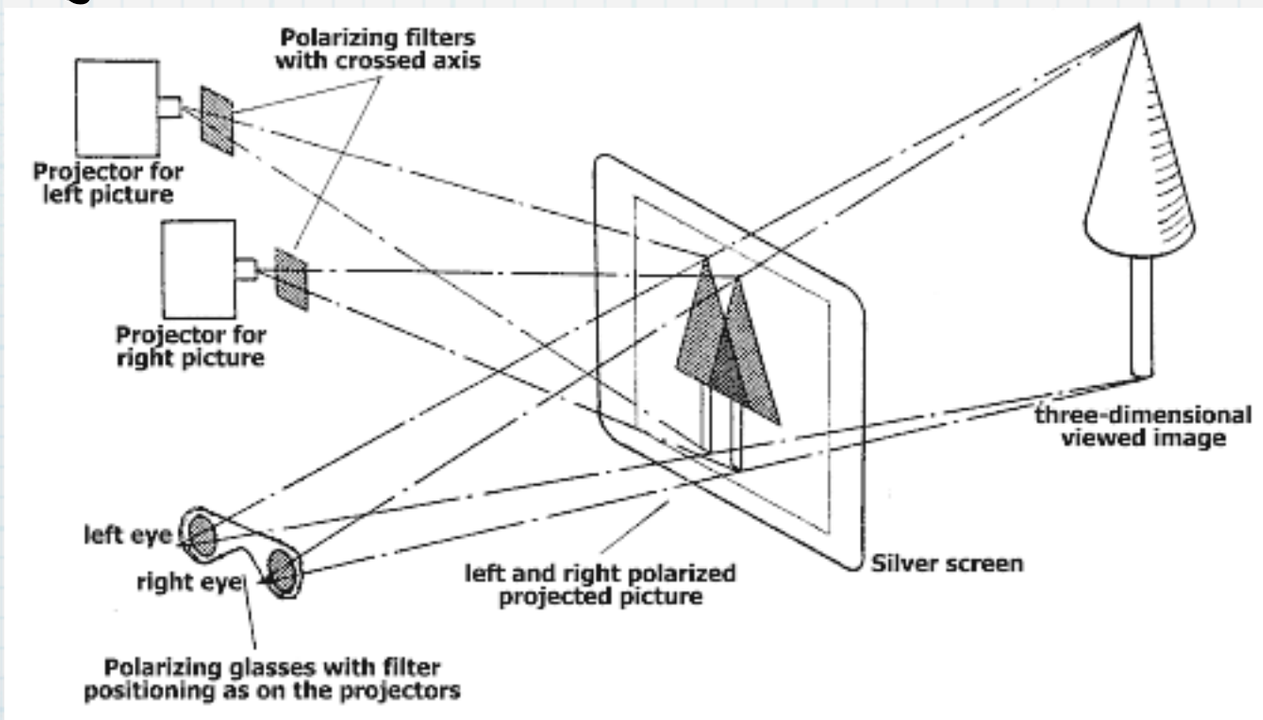
Geowall - $5,000 solution

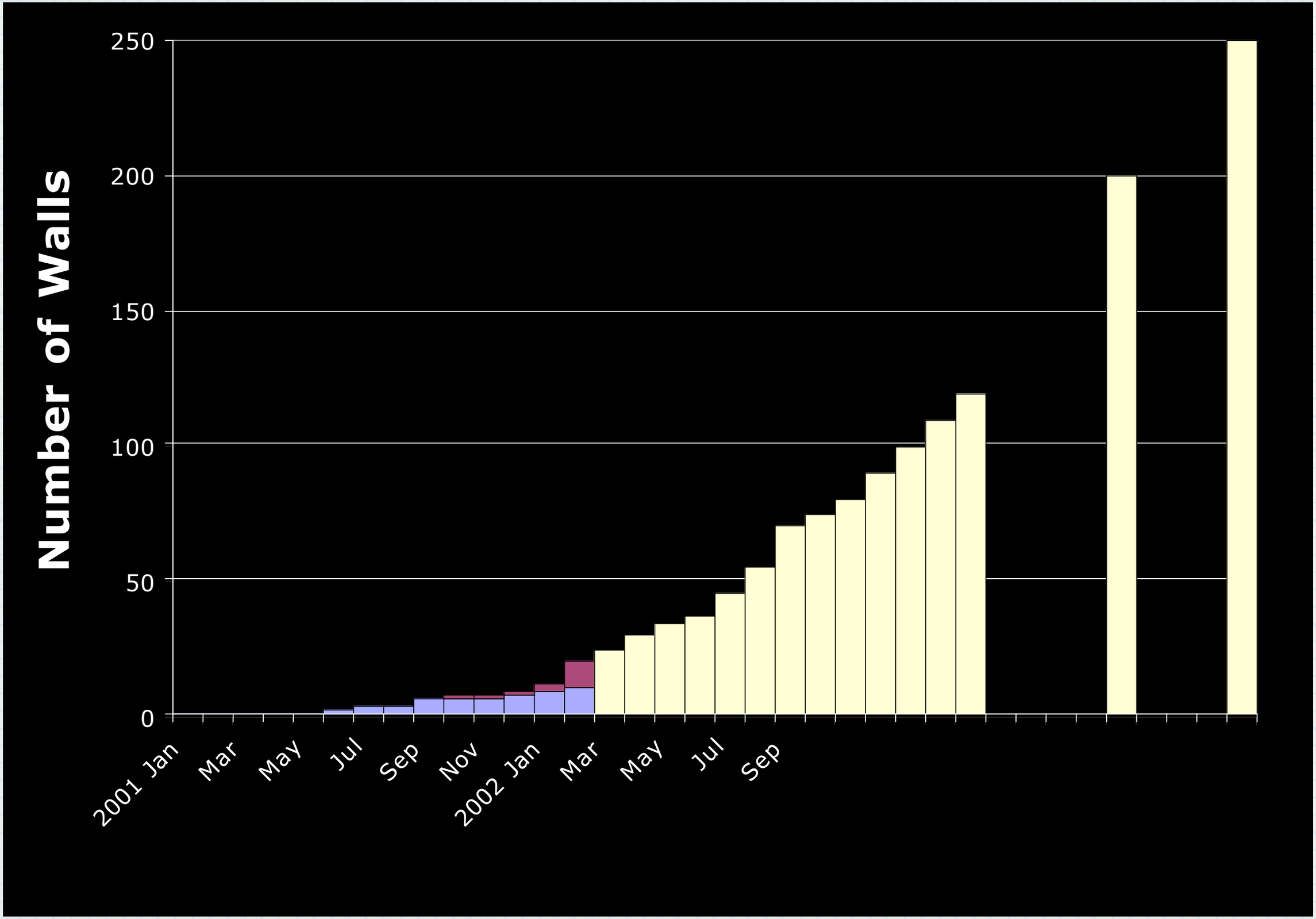
www.geowall.org



Projection of 3D slides

* Dual-lens projector, or two single lens projectors
* Polarized filters over each projection lens, aligned at right angles
* An aluminum (silver) or lenticular screen, not a white one. A white screen will de-polarize the light projected, destroying the stereo effect.
* Polarized glasses that match the alignment of the projector lens polarizing filters.





from Paul Morin

Red-Blue Anaglyphs

A stereoscopic picture where the left and right eye images are superimposed, but in different colors. A color filter over each eye only transmits the image component suitable for that eye and the brain interprets the result in 3D.

Got photoshop? You can do it too: nzphoto.tripod.com/sterea/anaglyph_make.html

Tools

Tools

* maps
  * matlab map package
  * GMT (gmt.soest.hawaii.edu) - free!
* many problem solving environments have their own graphics
* avs, dx, IRIS Explorer, IBM Data Explorer, dx is free! www.opendx.org
* gnuplot - www.gnuplot.info
* amira - www.tgs.com
* IDL - www.ittvis.com
* NCAR = National Center for Atmospheric Research - ngwww.ucar.edu ; www.ncl.ucar.edu