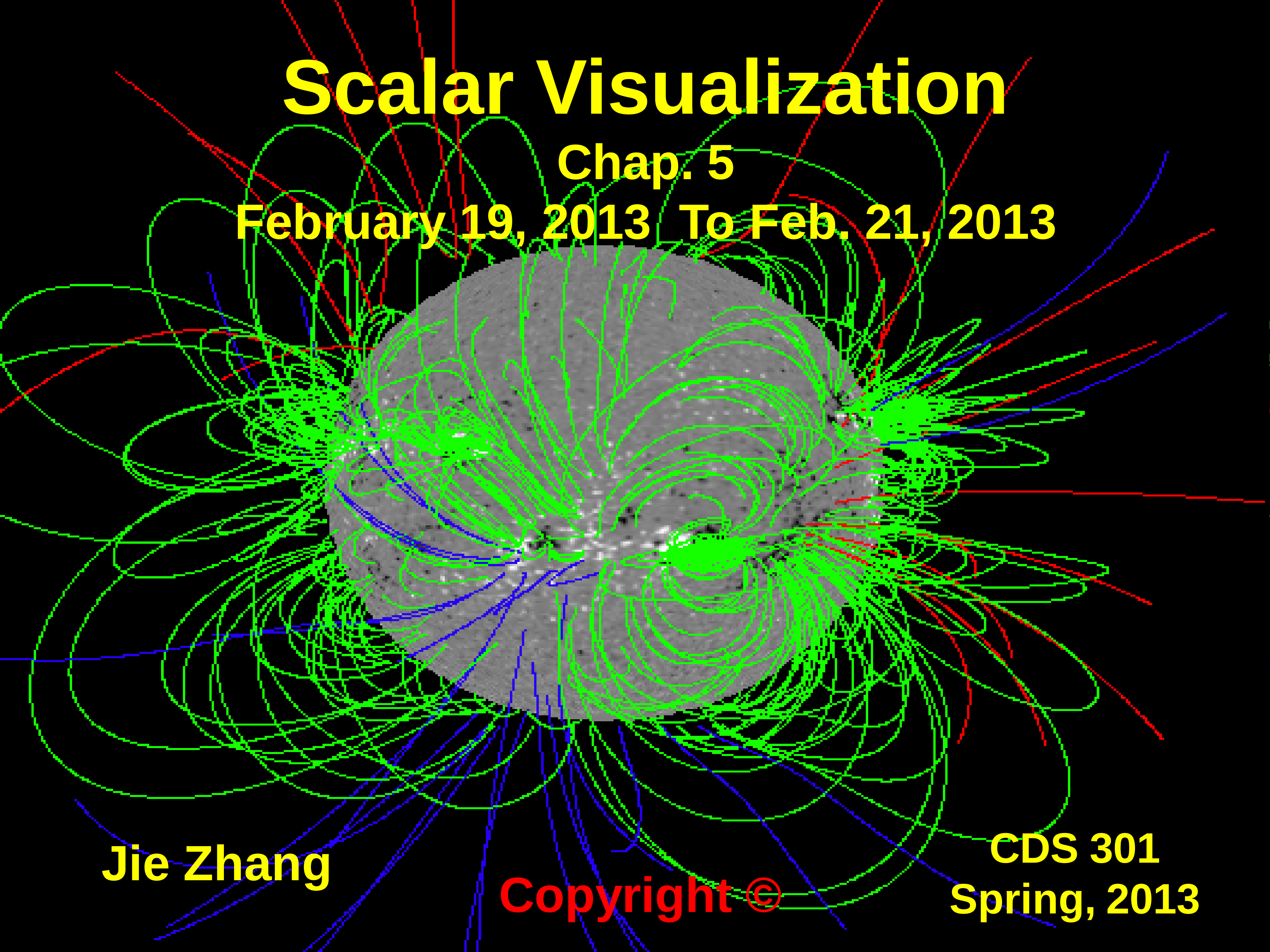
Scalar Visualization

Chap. 5

February 19, 2013 To Feb. 21, 2013



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CDS 301
Spring, 2013

Outline

5.0. Introduction

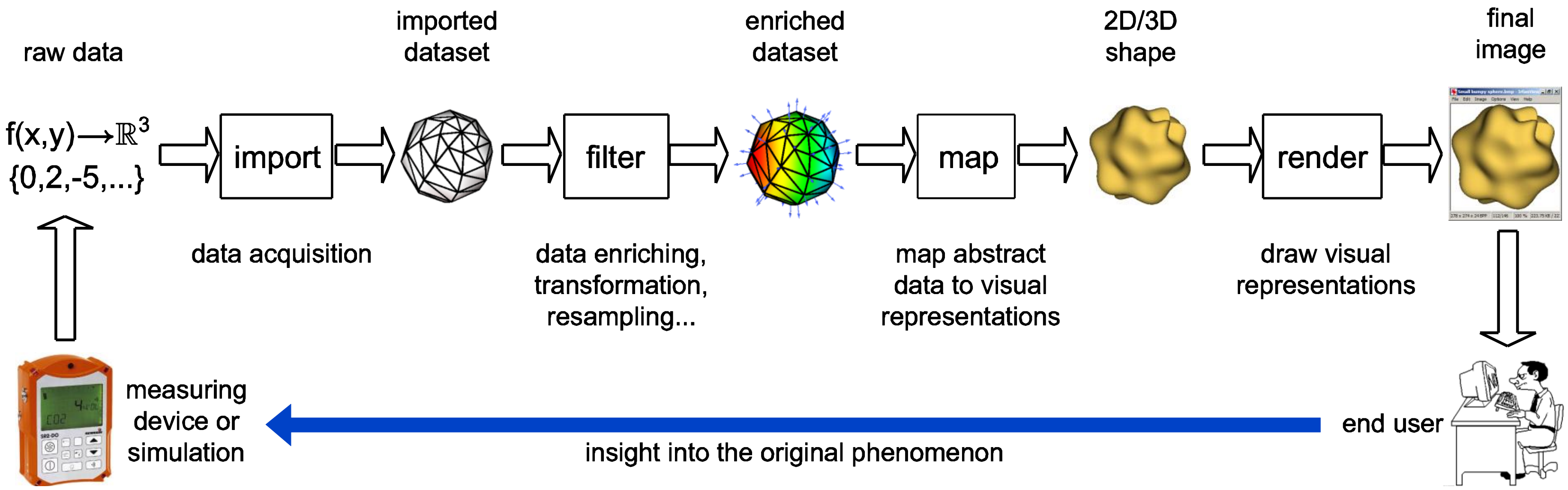
5.1. Color Mapping

5.2. Designing Effective Colormaps

5.3. Contouring

5.4. Height Plots

Visualization Pipeline
A Summary of Chap. 4



Processes:

1. Data Importing (measurement → raw data)
2. Data Filtering (raw data → enriched dataset)
3. Data Mapping (enriched data set → 3D scene)
4. Date Rendering (3D scene → displayed image)

CH5.0 Introduction: Scalar Function

$f: \boldsymbol{R} \to \boldsymbol{R}$

(1-D, height plot; histogram; bar chart..)

$f: \boldsymbol{R}^2 \to \boldsymbol{R}$

(2-D, e.g., height-plot; color mapping; contouring)

$f: \boldsymbol{R}^3 \to \boldsymbol{R}$

(3-D, e.g., Isosurface; Volume Visualization [Chap.10])

CH 5.1 Color Mapping

- **color look-up table**
- Associate a specific color with every scalar value
- Assuming you specify a color table of N colors

$$C = \{c_i\}_{i=1,2,\ldots N}$$

$$f \rightarrow c_i$$

Where

$$i = \frac{f - f_{\min}}{f_{\max} - f_{\min}} \cdot N$$

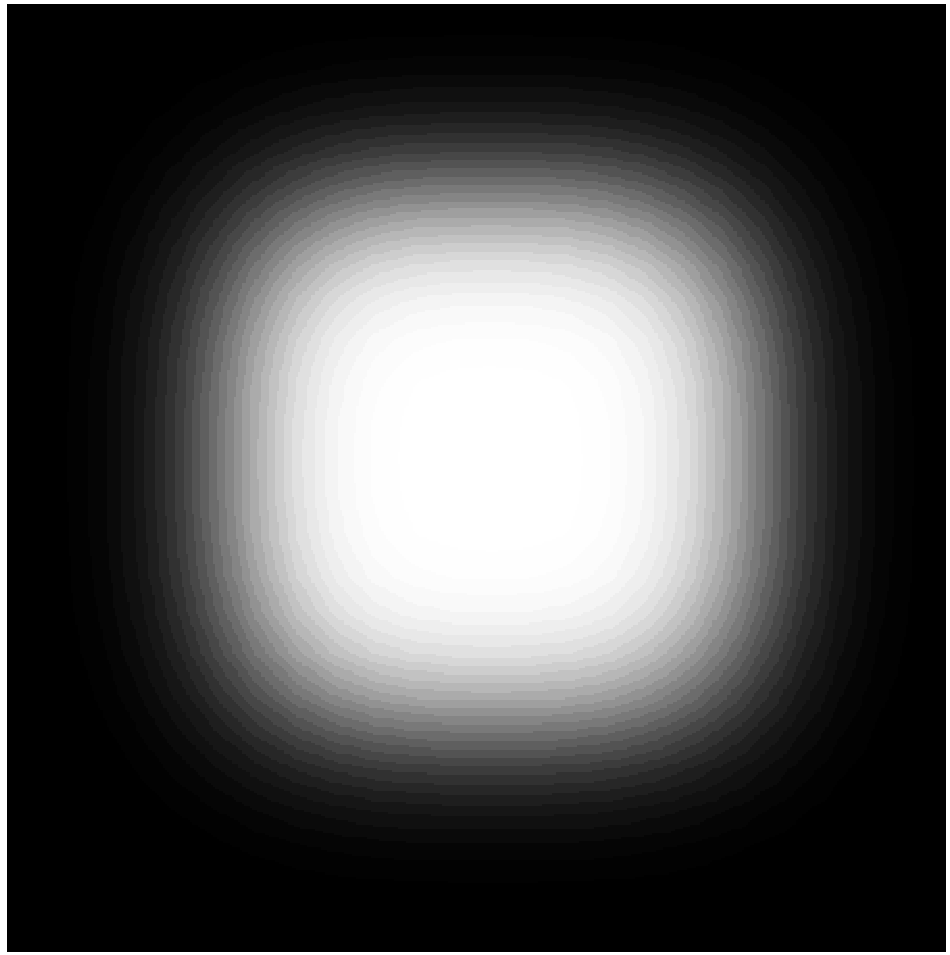
CH 5.2 Designing Effective Colormaps

Luminance Colormap

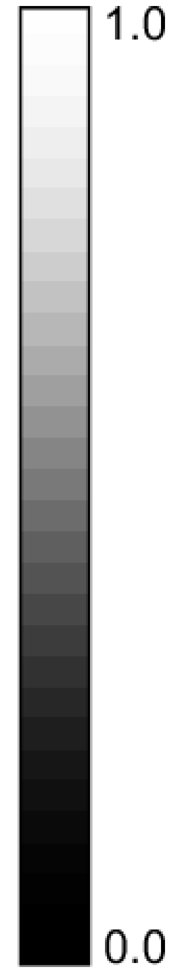
- Use grayscale to represent scalar value

$$f = e^{-10(x^4+y^4)}$$

- Most scientific data (through measurement, observation, or simulation) are intrinsically grayscale; there is no intrinsic color



Luminance Colormap



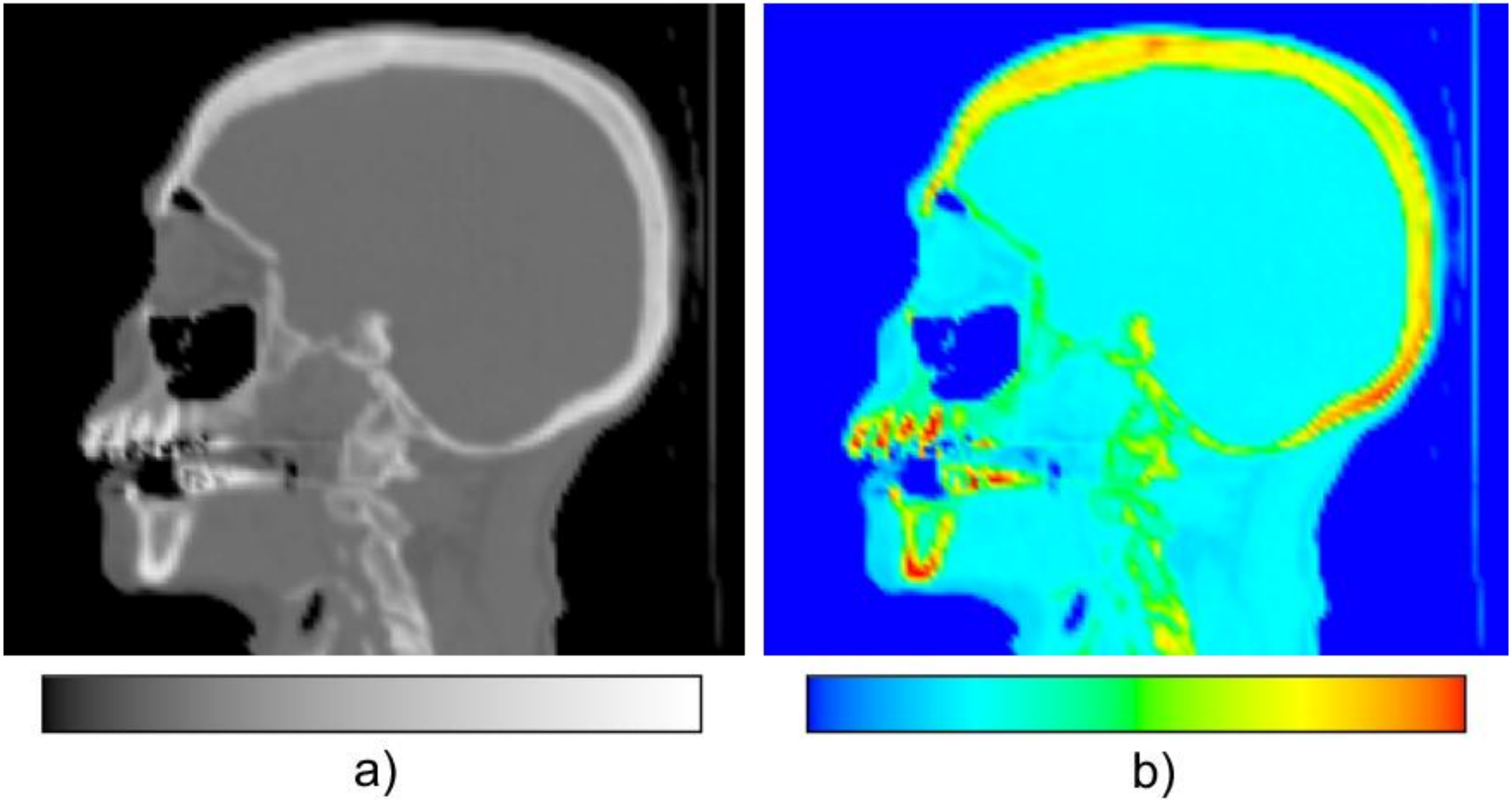
Legend

MATLAB: “image”; “imagesc”

```
[x,y]=meshgrid([-1:0.1:1]);   %create the domain
z=exp(-10*(x.^4+y.^4));        %create the functional
surf(z)                        %surface   f in [0:1]

image(z)                        %create a 2-D image
                                %but what is the problem?
%manipulate the colormap and the scaling
colorbar                        %64 colors; f in [1:64]

%need scale the data range for colormaping
h=image(z)
set(h,’CDataMapping’,’scaled’)   %not “direct”
                  %allowing scaling of colormapping
```

Rainbow Colormap

- Red: high value; Blue: low value
- A commonly used colormap

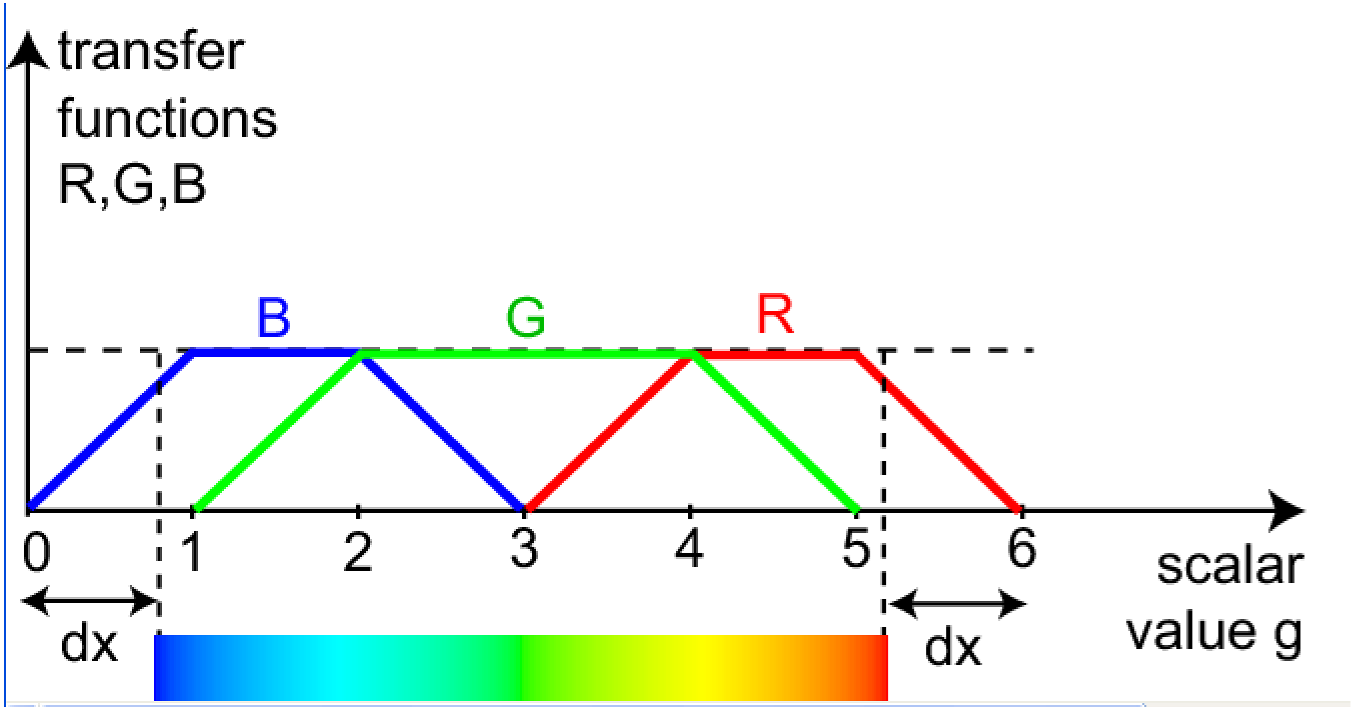


Luminance Map

Rainbow Colormap

Rainbow Colormap

- Construction



- f<dx: R=0, G=0, B=1
- f=2: R=0, G=1, B=1
- f=3: R=0, G=1, B=0
- f=4: R=1, G=1, B=0
- f>6-dx: R=1, G=0, B=0

Rainbow Colormap

Implementation

$$\mathbf{c : D \rightarrow Dv}$$

$$\mathbf{c : R \rightarrow R^3}$$

```
void c(float f, float & R, float & G, float &B)
{
        const float dx=0.8
        f=(f<0) ? 0: (f>1)? 1 : f   //clamp f in [0,1]
        g=(6-2*dx)*f+dx             //scale f to [dx, 6-dx]
        R=max(0, (3-fabs(g-4)-fabs(g-5))/2);
        G=max(0,(4-fabs(g-2)-fabs(g-4))/2);
        B=max(0,(3-fabs(g-1)-fabs(g-2))/2);
}
```

Rainbow Colormap

Question

What is the color attribute for f=0.5 in the rainbow colormap?

Rainbow Colormap

Answer

f = 0.5

g = 3

R =max(0,(3-1-2)/2)=max(0,0)=0
G=max(0,(4-1-1)/2)=max(0,1)=1
B=(max(0,(3-2-1)/2)=max(0,0)=0

C=[0,1,0]   %the green color

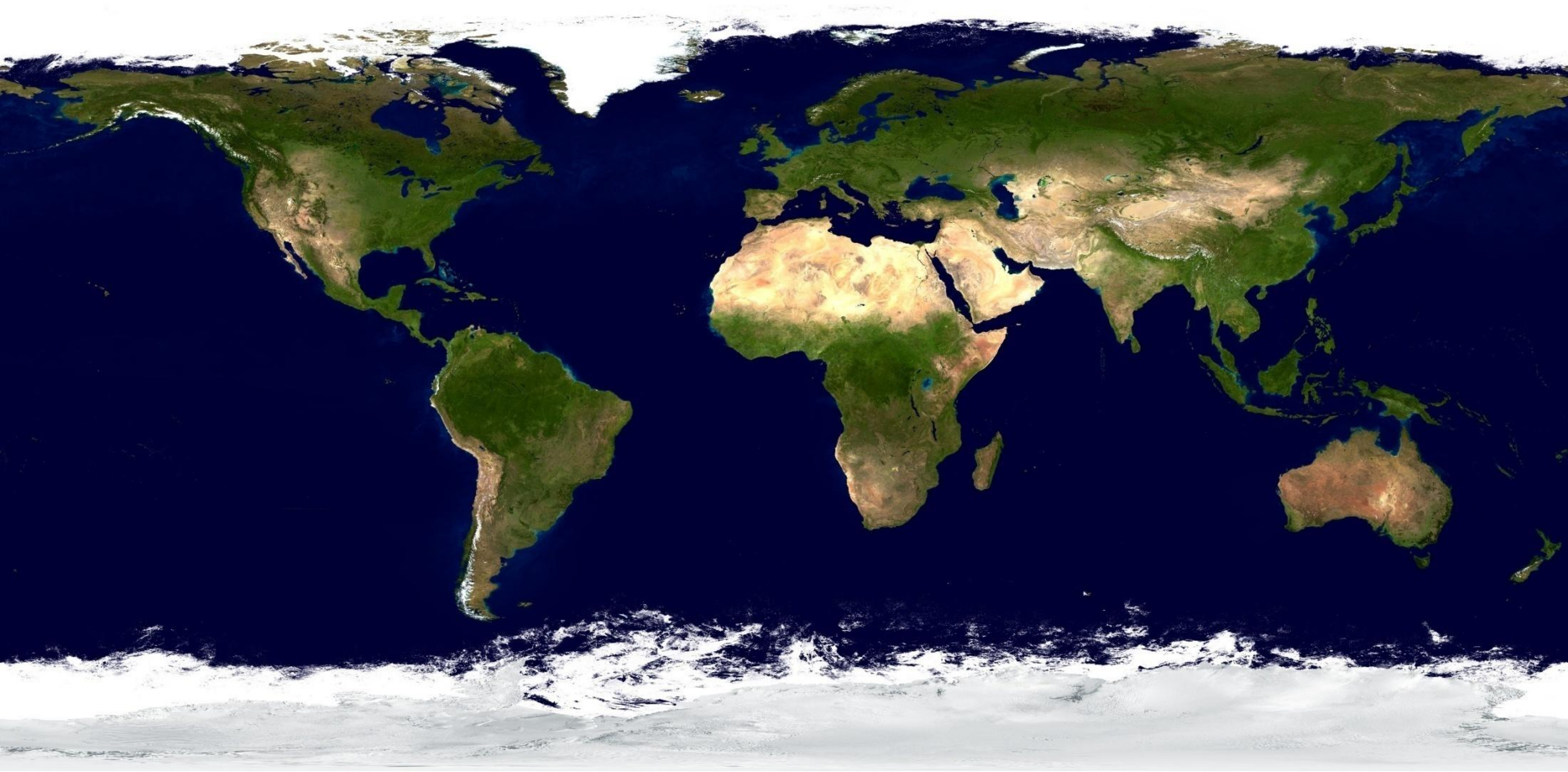
Colormap: Designing Issues

- Choose right color map for correct perception
  - Grayscale: good in most cases
  - Rainbow: e.g., temperature map
  - Rainbow + white: e.g., landscape
    - Blue: sea, lowest
    - Green: fields
    - Brown: mountains
    - White: mountain peaks, highest

Rainbow Colormap

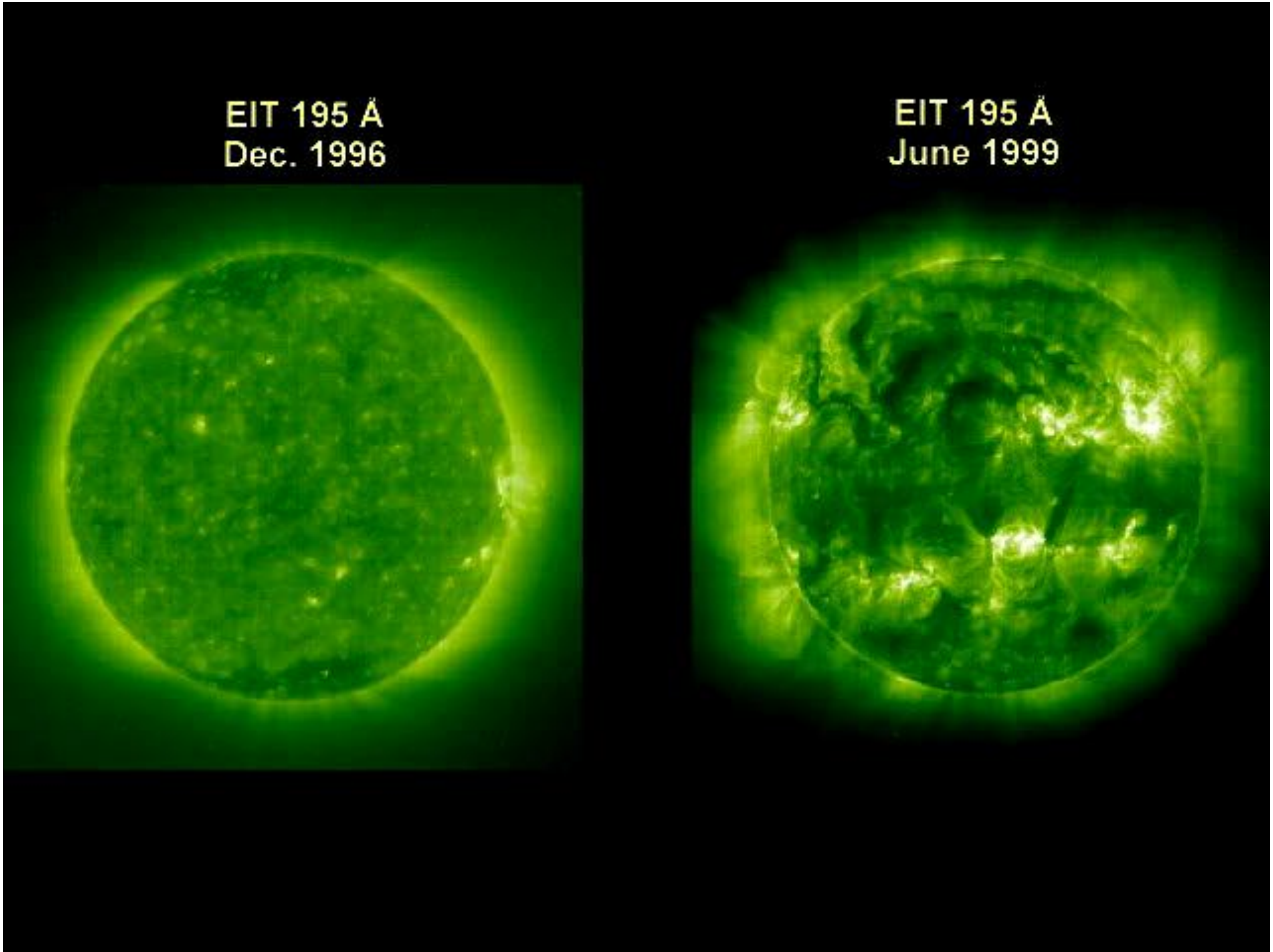
http://atmoz.org/img/weatherchannel_national_temps.png

Rainbow + White

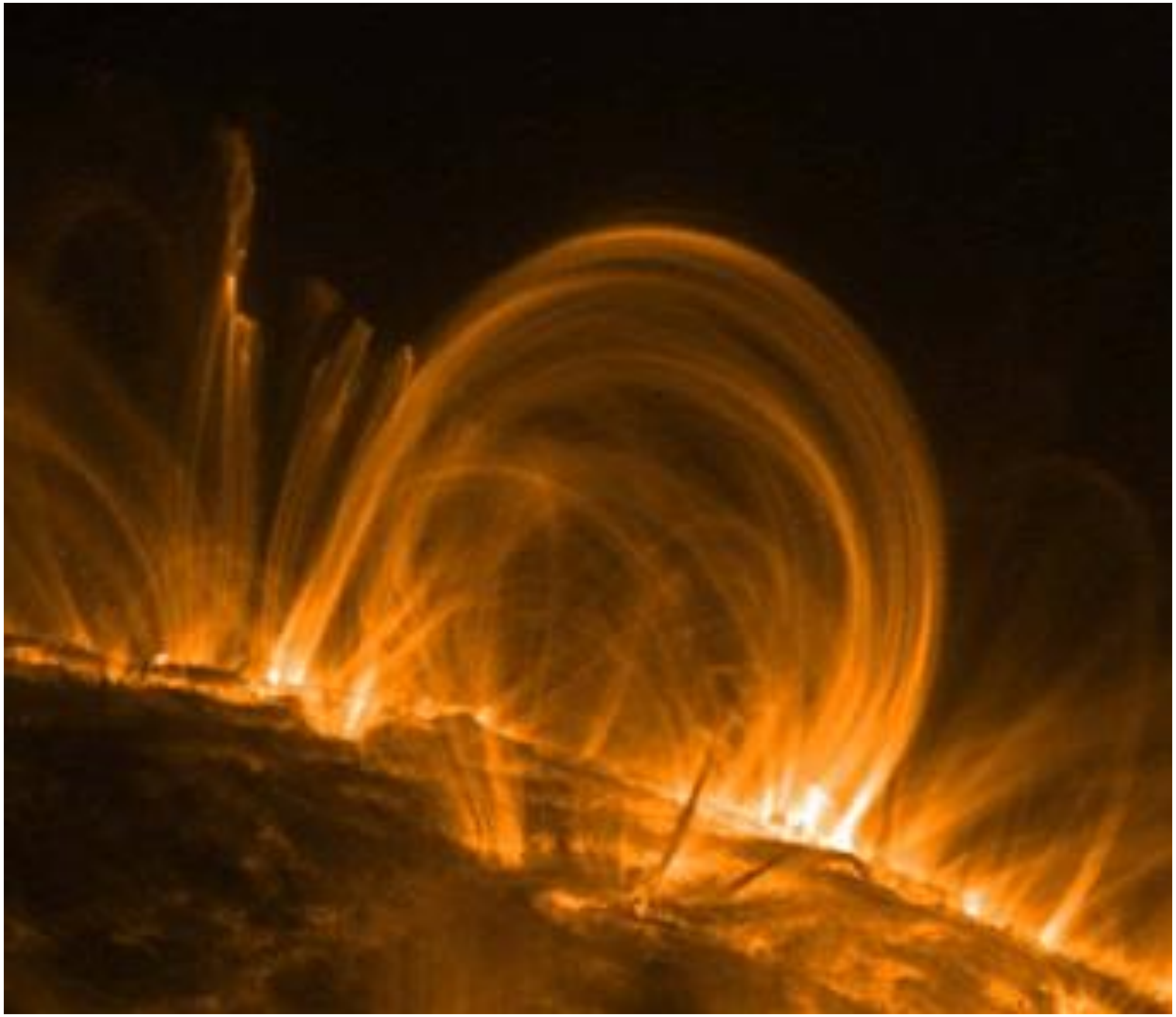


http://www.oera.net/How2/PlanetTexs/EarthMap_2500x1250.jpg

Exp: Sun in green-white colormap

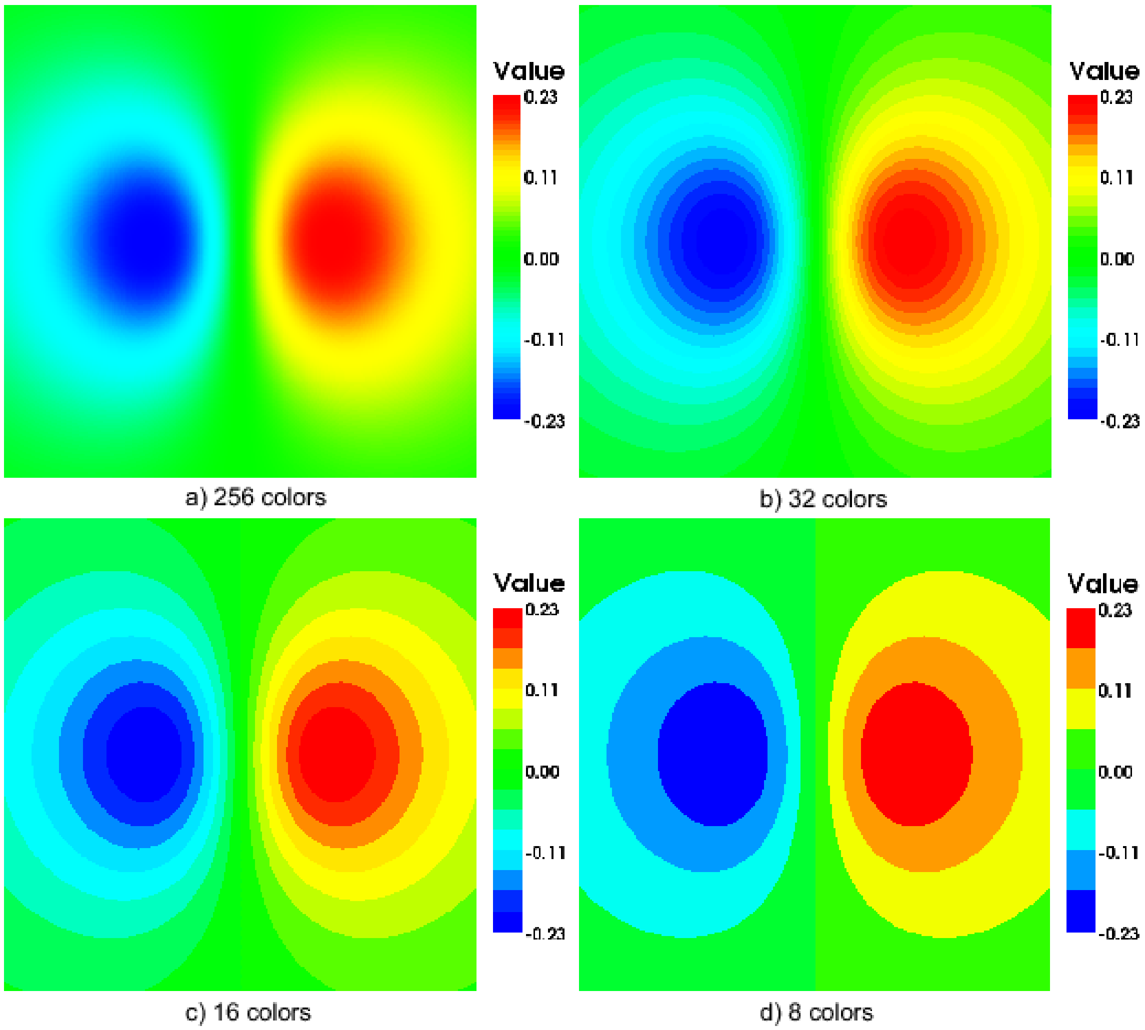


Exp: Coronal loop



http://media.skyandtelescope.com/images/SPD+on+CME+image+5+--+TRACE.gif

Color Banding Effect



Caused by a small number of colors in a look-up table

CH5.3. Contouring

- A contour line C is defined as all points p in a dataset D that have the same scalar value x, or isovalue s(p)=x

$$C(x) = \{ p \in D \mid s(p) = x \}$$

- A contour line is also called an isoline

- In 3-D dataset, a contour is a 2-D surface, called isosurface

Contouring

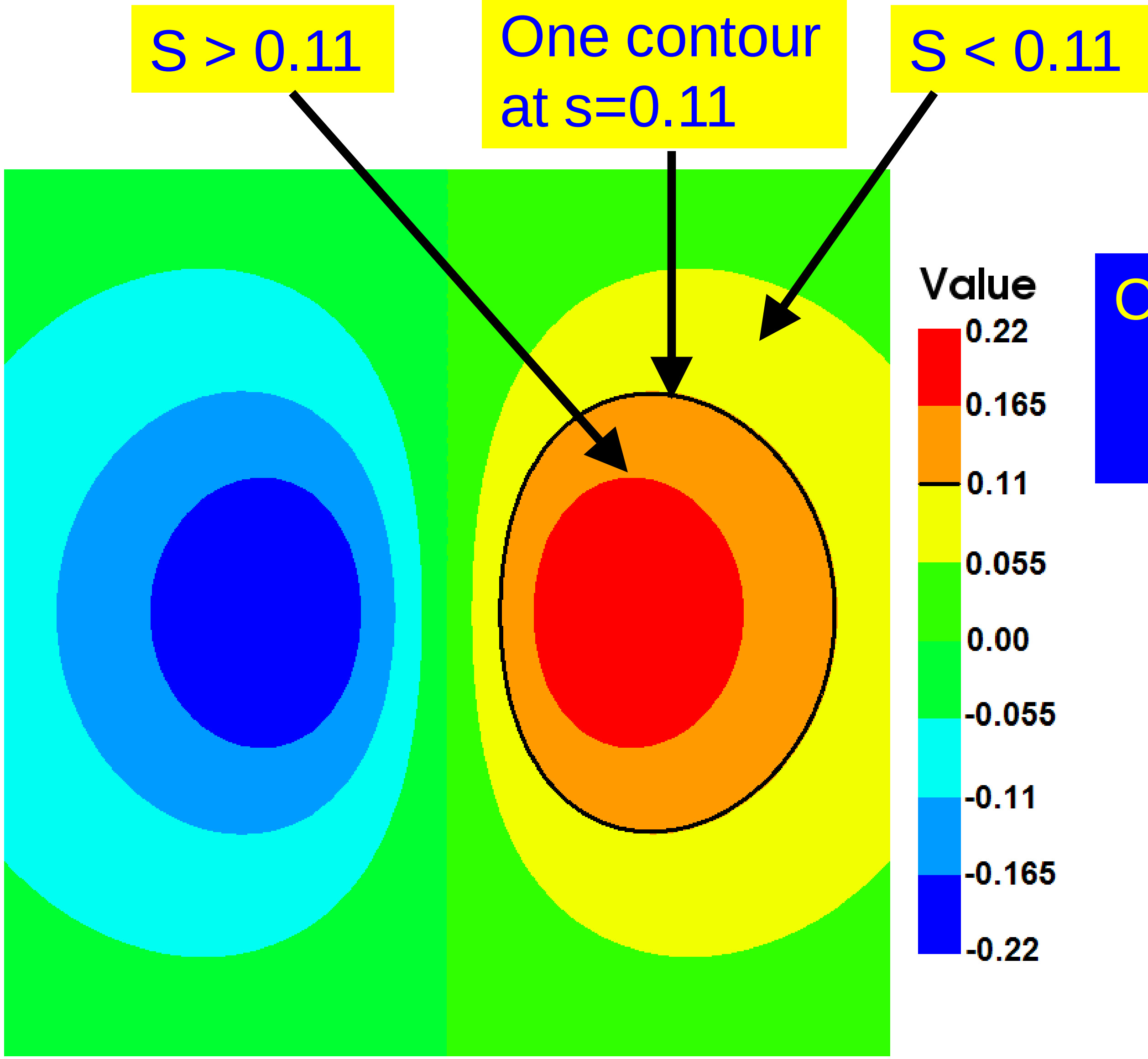
Cartograph

The Landscape

A Relief Model

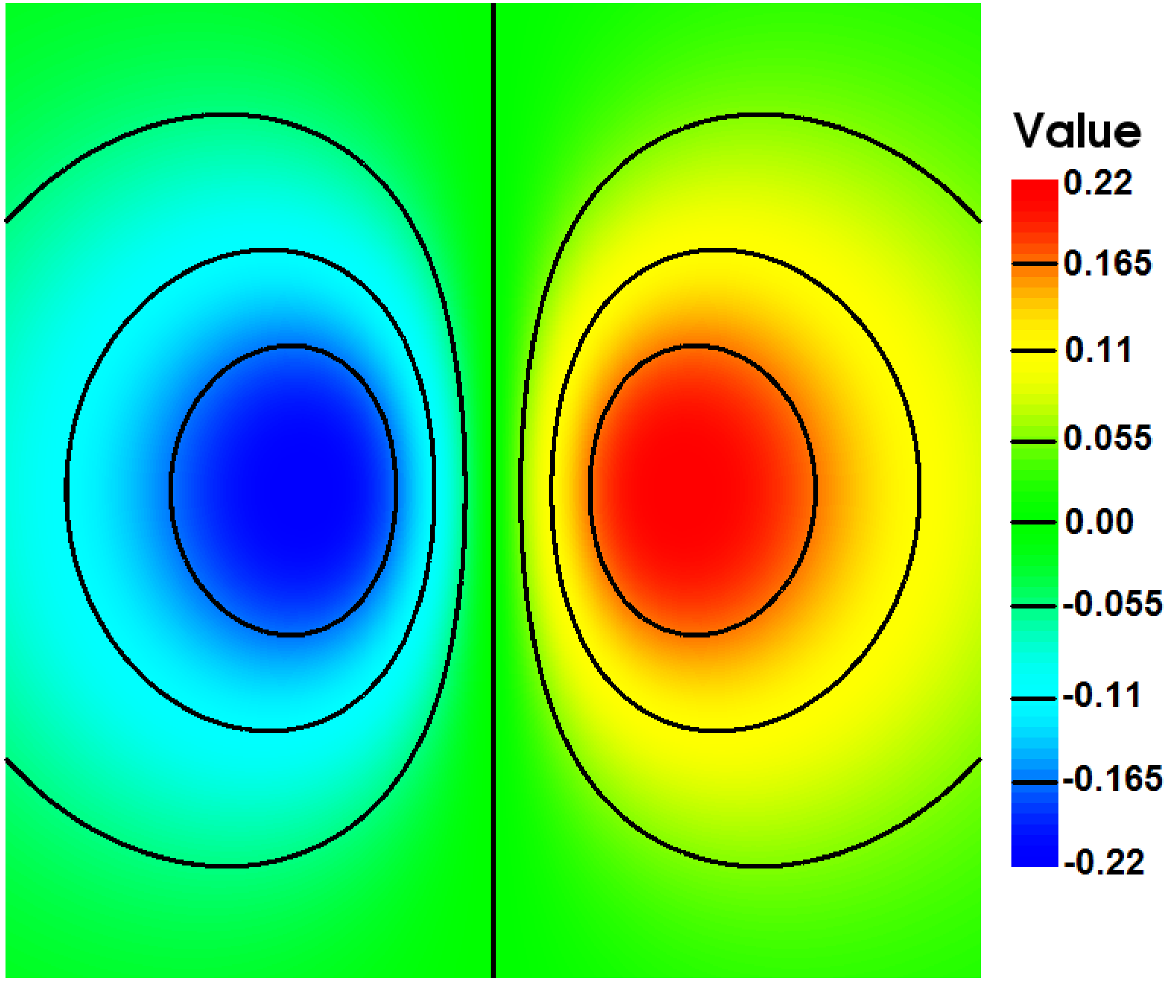
Contour Lines

Contouring



Contouring and Color Banding

Contouring



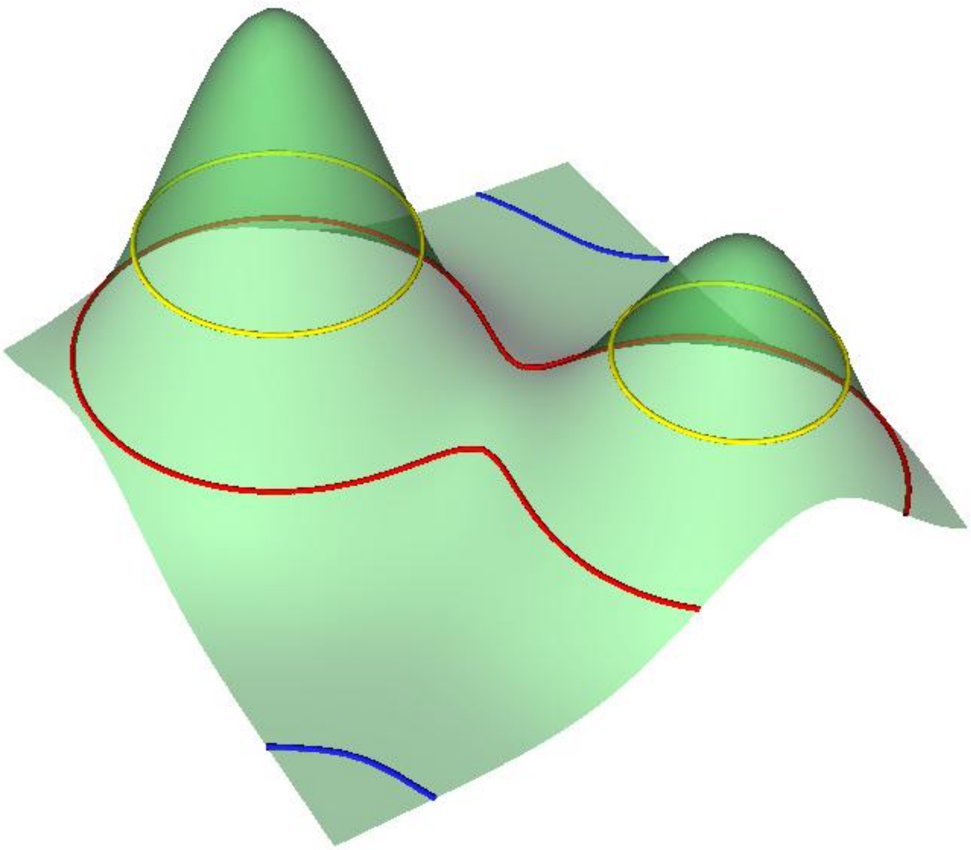
7 contour lines

Contouring and Colormapping:

Show (1) the smooth variation and (2) the specific values

Properties of Contours

- Indicating specific values of interest
- In the height-plot, a contour line corresponds with the interaction of the graph with a horizontal plane of s value

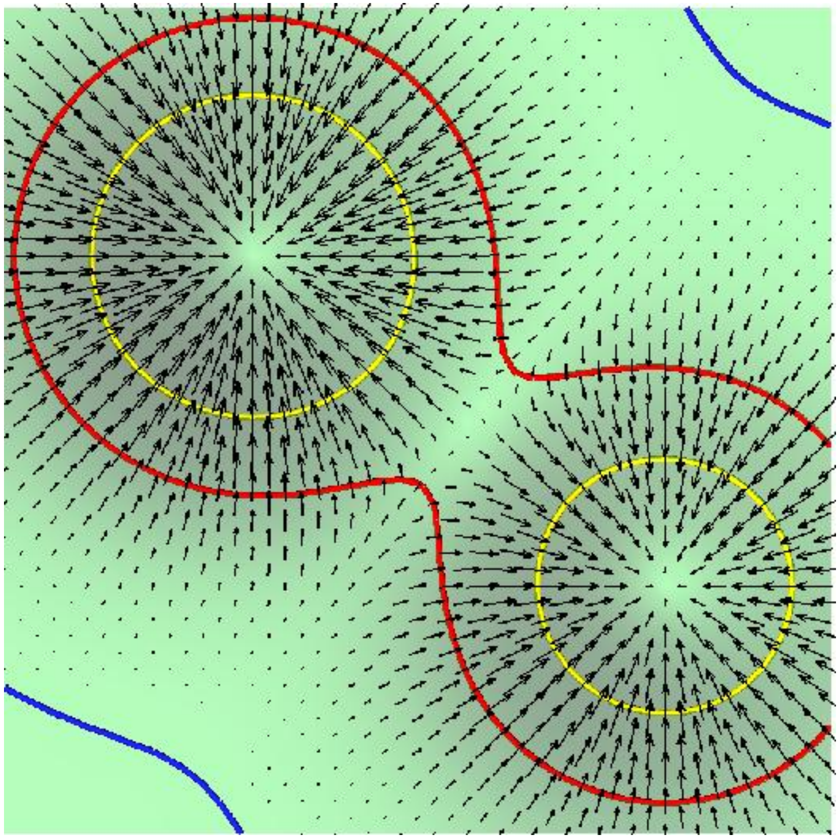


Properties of Contours

•The tangent to a contour line is the direction of the function's minimal (zero) variation
•The perpendicular to a contour line is the direction of the function's maximum variation: **the highest gradient**

Contour lines

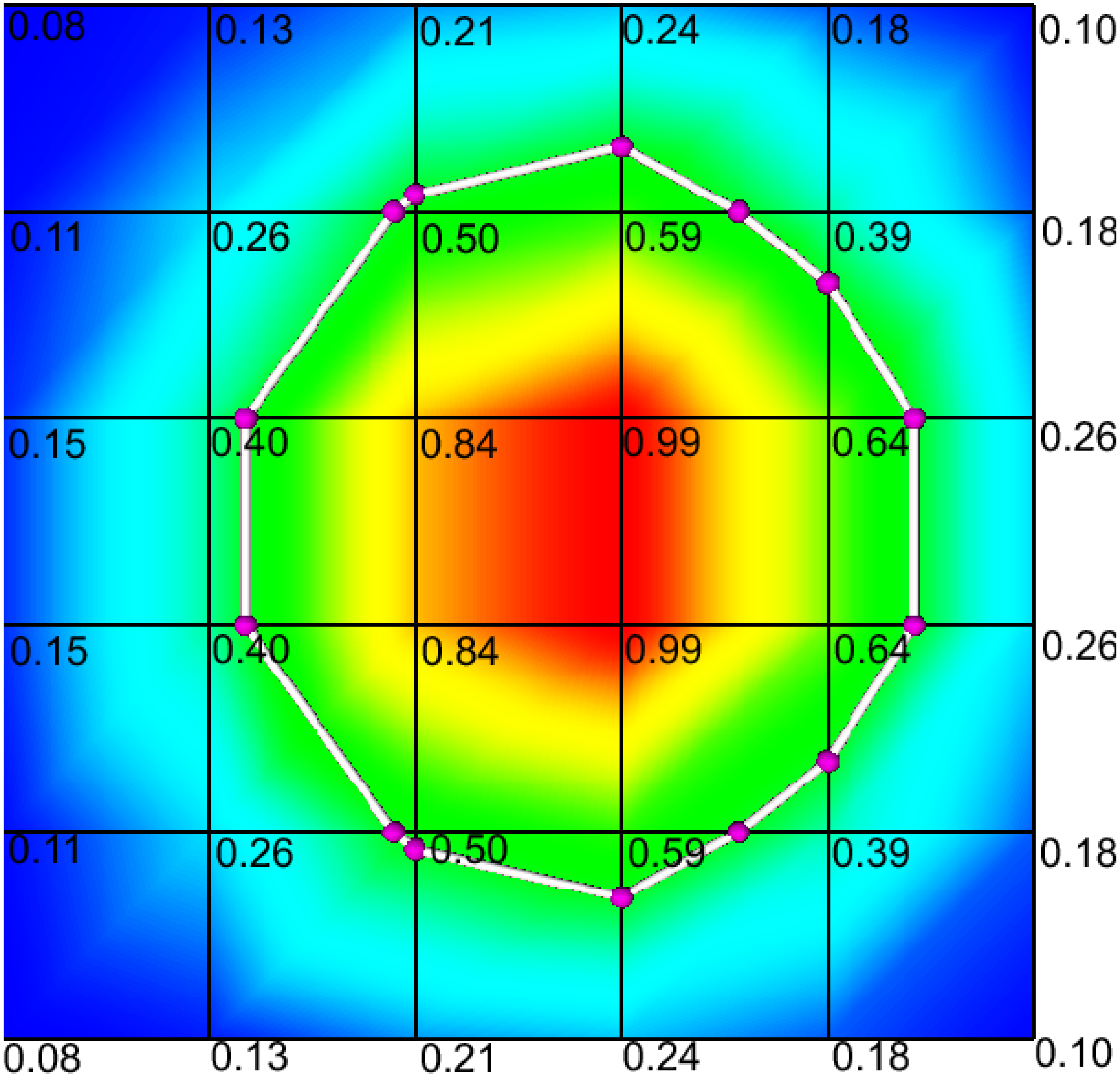
Gradient vector



MATLAB: “contour”

```
[x,y]=meshgrid([-1:0.01:1]);   %create the domain
z=x.*exp(-(x.^4+y.^4));        %create the functional
%surf(z)                          %surface   f in [0:1]

imagesc(z)

hold on

%contour(z,10,’Color’,’k’)     %10 contour lines in black

contour(z, [-0.2,-0.2],’Color’, ’r’,’LineWidth’,5)
```

Constructing Contours



V=0.48

Finding line segments within cells

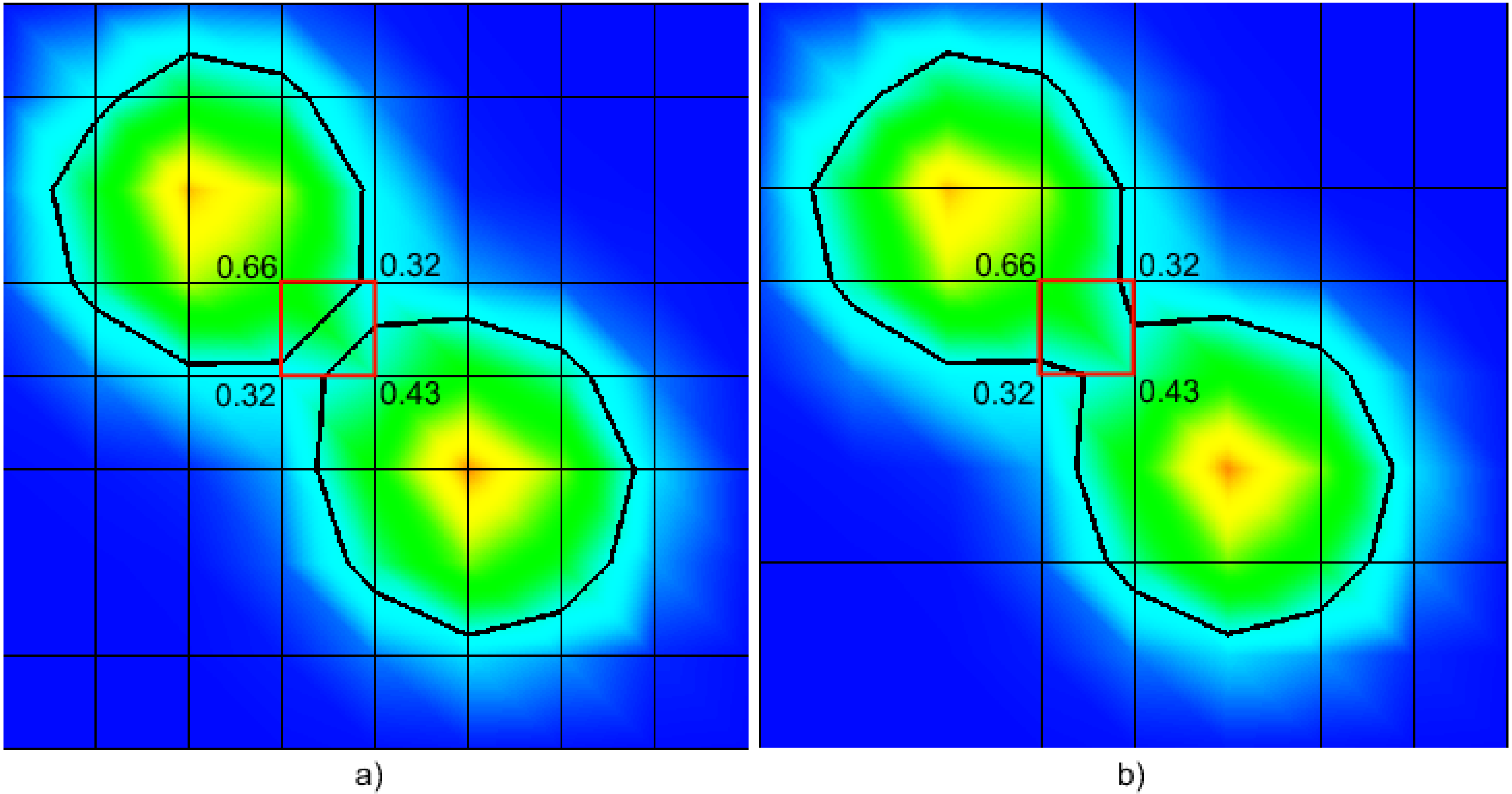
Constructing Contours

- For each cell, and then for each edge, test whether the isoline value v is between the attribute values of the two edge end points (v_i, v_j)
- If yes, the isoline intersects the edge at a point q, which uses linear interpolation

$$q = \frac{p_i(v_j - v) + p_j(v - v_i)}{v_j - v_i}$$

- For each cell, at least two points, and at most as many points as cell edges
- Use line segments to connect these edge-intersection points within a cell
- **A contour line is a polyline**.

Constructing Contours



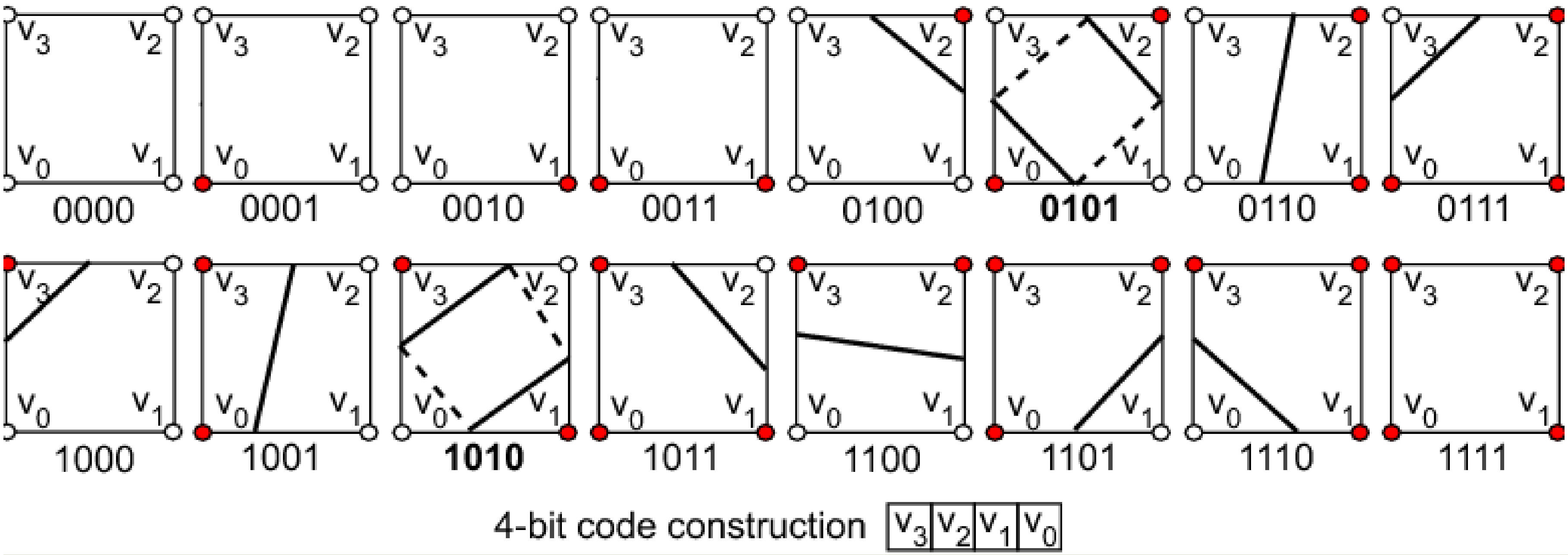
V=0.37: 4 intersection points in a cell

-> Contour ambiguity

Implementation: Marching Squares

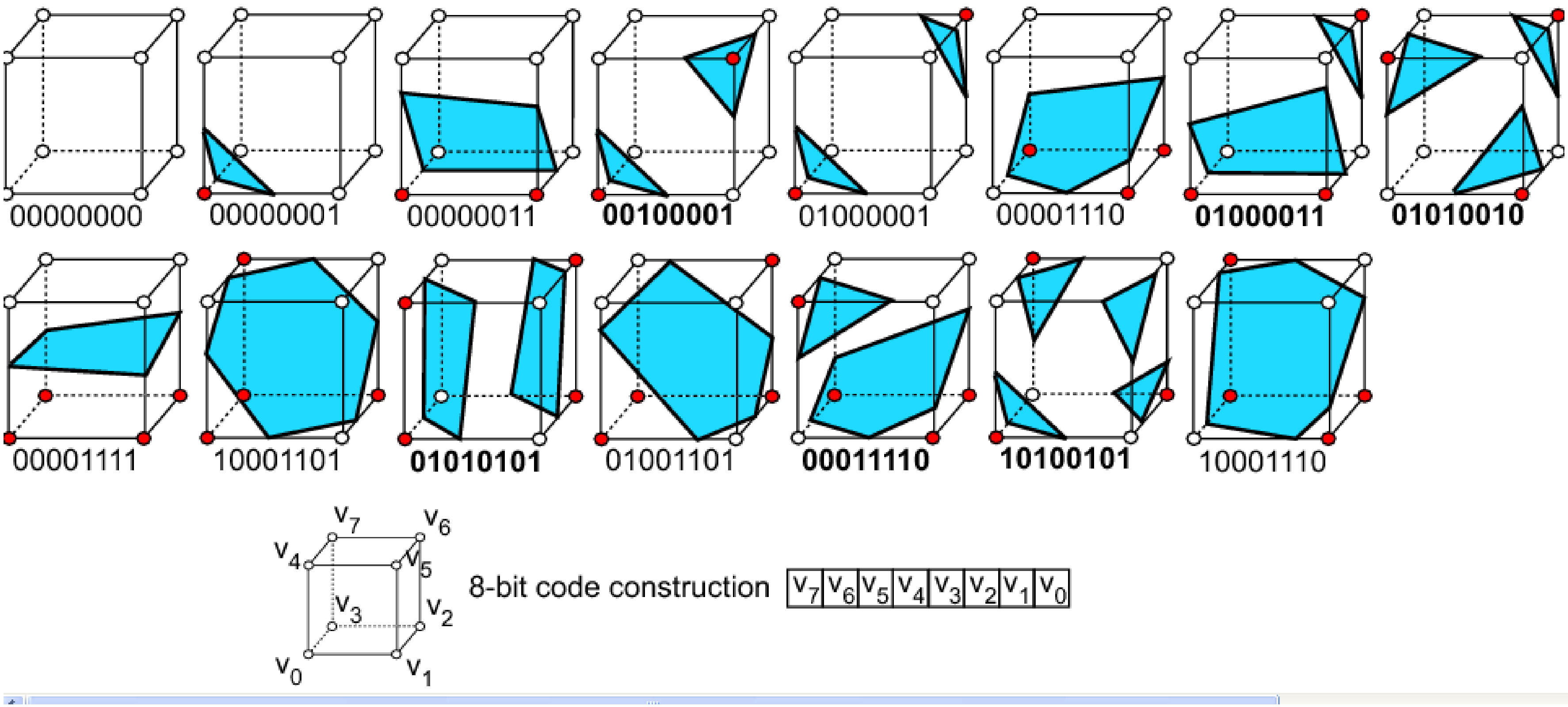
- Determining the topological state of the current cell with respect to the isovalue v
  - Inside state (1): vertex attribute value is less than isovalue
  - Outside state (0): vertex attribute value is larger than isovalue
  - A quad cell: $(S_3S_2S_1S_0)$, $2^4=16$ possible states
    - (0001): first vertex inside, other vertices outside
- Use optimized code for the topological state to construct independent line segments for each cell
- Merge the coincident end points of line segments originating from neighboring grid cells that share an edge

Implementation: Marching Squares



Topological State of a Quad Cell

Implementation: Marching Cube



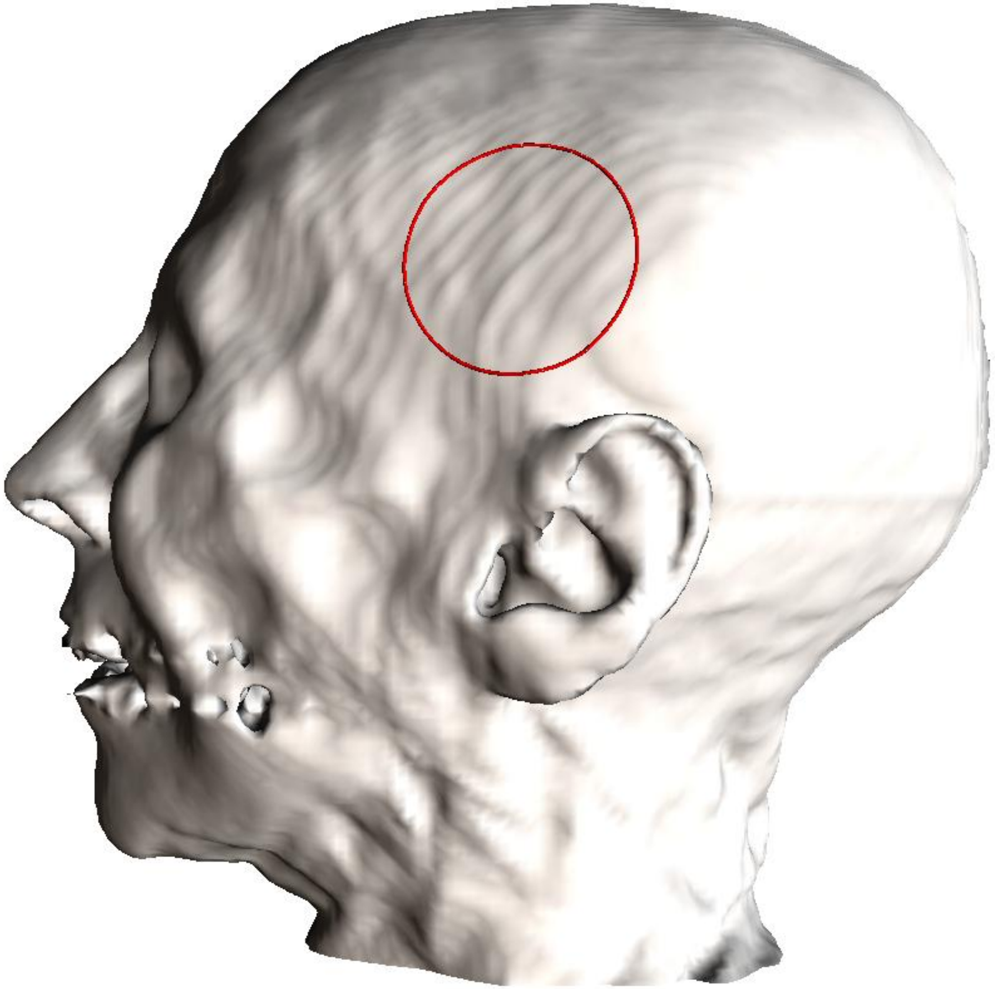
Topological State of a hex Cell

Marching cube generates a set of polygons for each contoured cell: triangle, quad, pentagon, and hexagon

Contours in 3-D

- In 3-D scalar dataset, a contour at a value is an isosurface

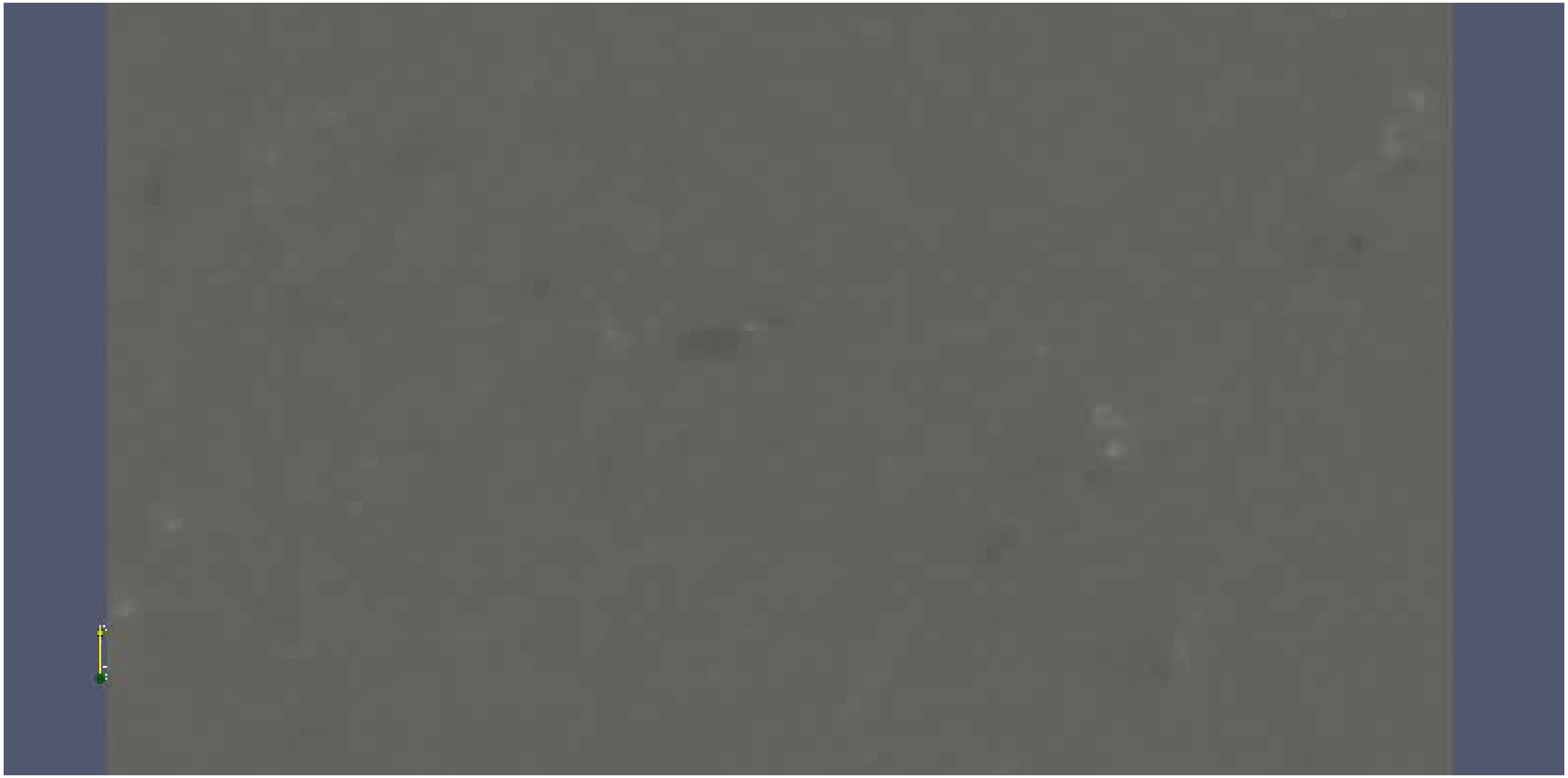
Isosurface for a value corresponding to the skin tissue of an MRI scan 128^3 voxels



Contours in 3-D

Two nested
isosurface:
the outer isosurface is
transparent

Exp: 3-D Active Region



We stopped here on

February 19, 2013

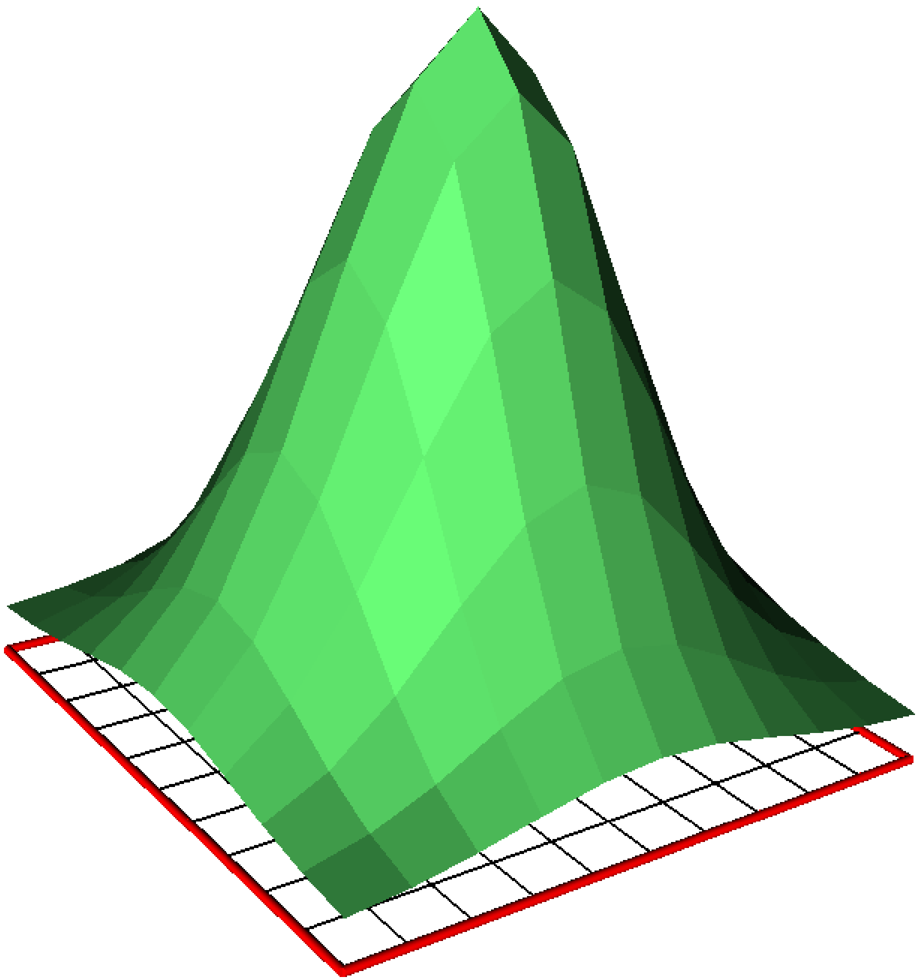
February 21, 2013

CH 5.4. Height Plots

- The height plot operation is to “warp” the data domain surface along the surface normal, with a factor proportional to the scalar value

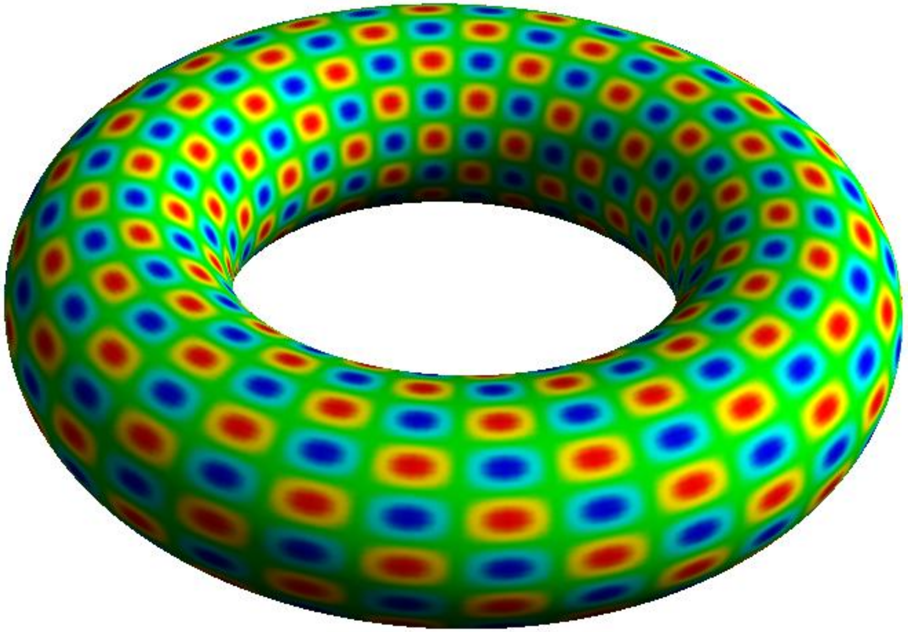
$$
\begin{aligned}
& m : D_s \to D_h, \\
& m(x) = x + s(x)\vec{n}(x), \\
& \forall x \in D_s
\end{aligned}
$$

Height Plots

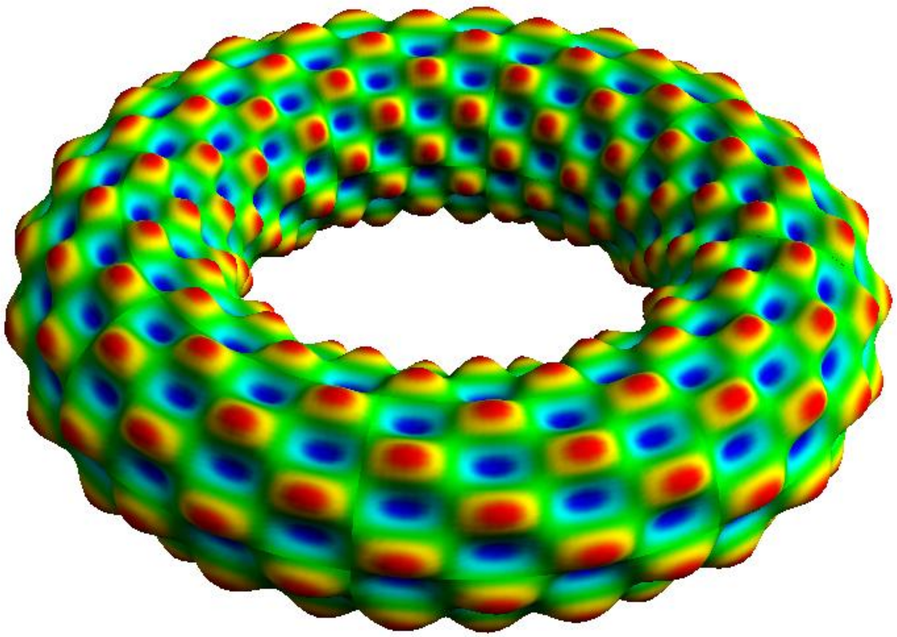


Height plot over a planar 2-D surface

Height Plots



Non-planar torus surface: Function value is encoded by color



Warped torus surface: Function value is encoded (1) by color, and (2) by the warping of the surface

End
of Chap. 5
(Feb. 21, 2013)