SCIENTIFIC VISUALIZATION

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Slides: http://users.sdsc.edu/~amit/presentations/scivis-lecture.pdf

LECTURE OVERVIEW

- Introduction to Visualization
- Visualization Techniques
- Application Examples
- Best Practices
- Q & A

VIS PERCEPTIONS

- Viz is an art not science or engineering
- Viz is a one time task
- Viz is useful for presentation/communication only
- I am not an artist thus can’t do viz

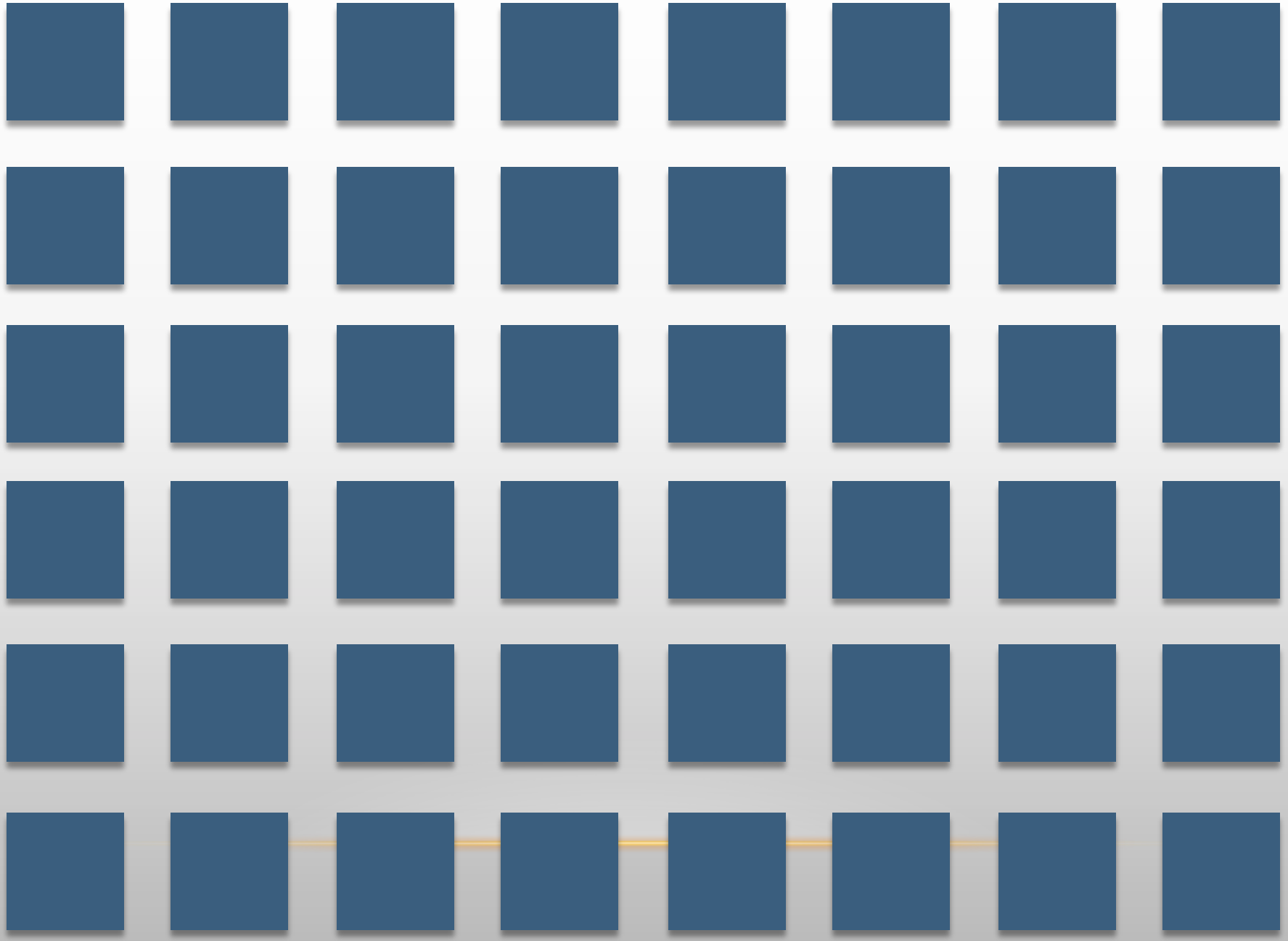
Why should you care about visualization?

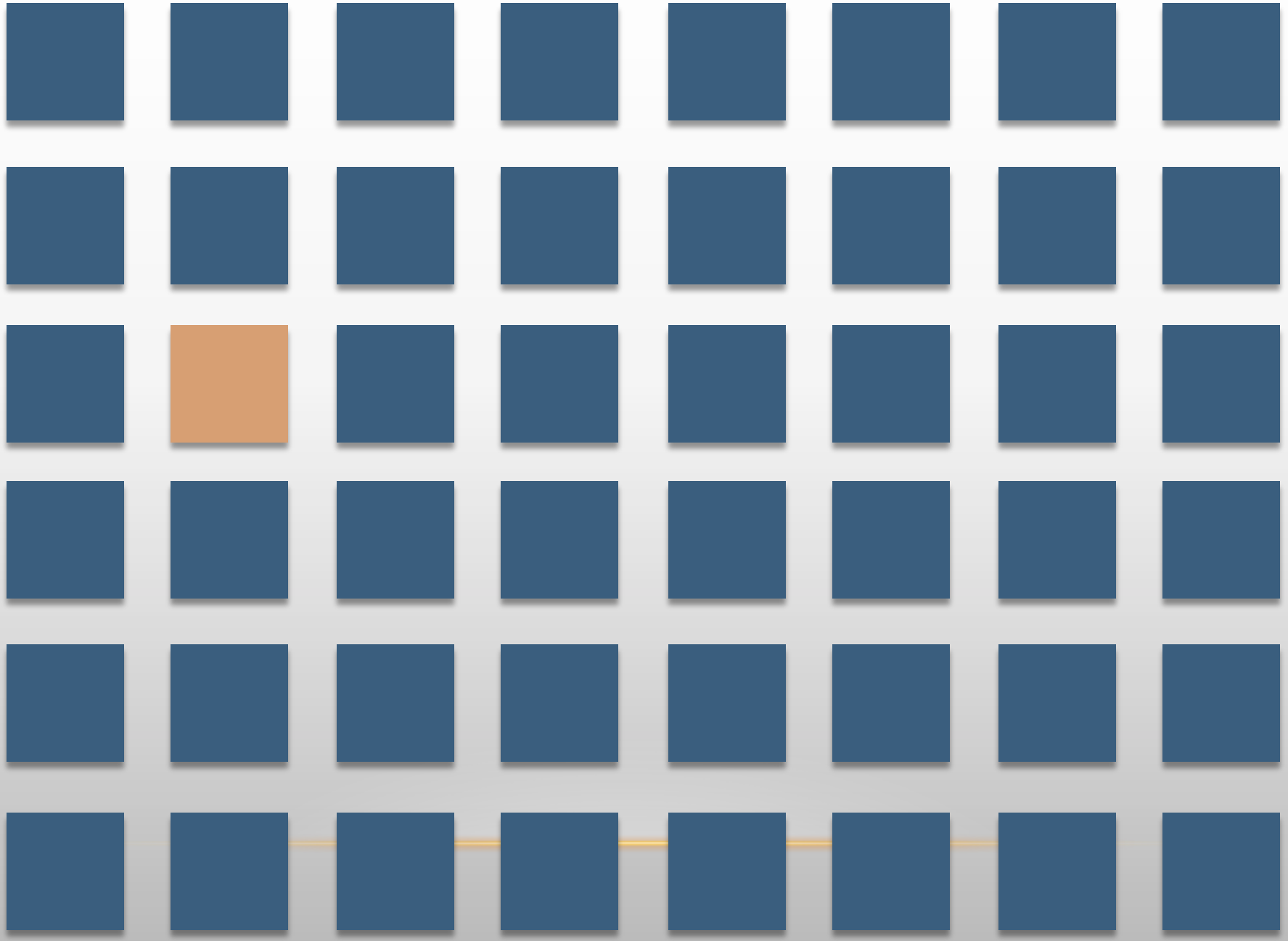
HOW MANY 3'S IN FIRST 350 NUMBERS OF PI?

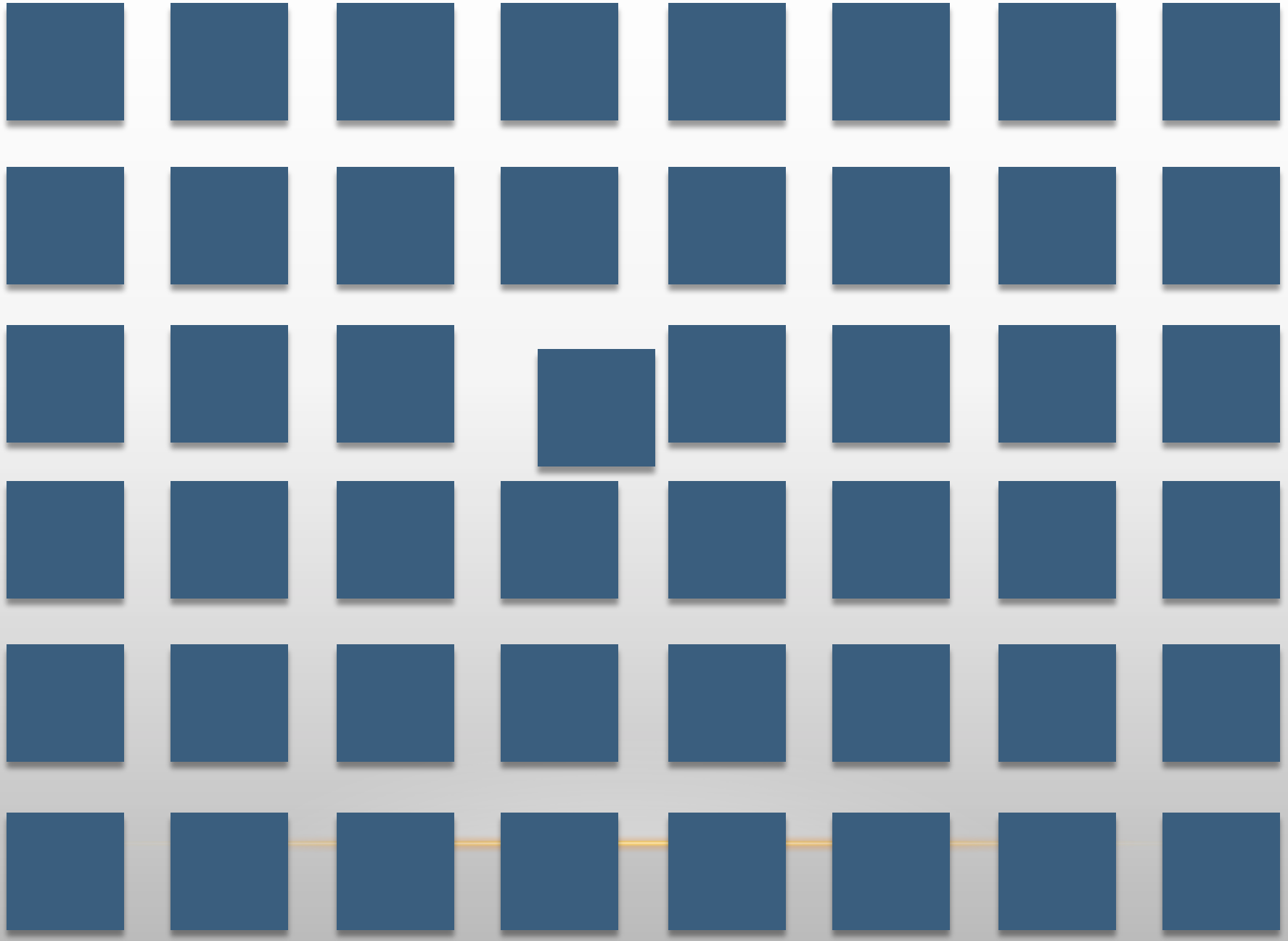
3.14159265358979323846264338327950288419716939937510582097494459230781640628620
89986280348253421170679821480865132823066470938446095505822317253594081284811174
50284102701938521105559644622948954930381964428810975665933446128475648233786
78316527120190914564856692346034861045432664821339360726024914127372458700660631
5588174881520920962829254091715364 3

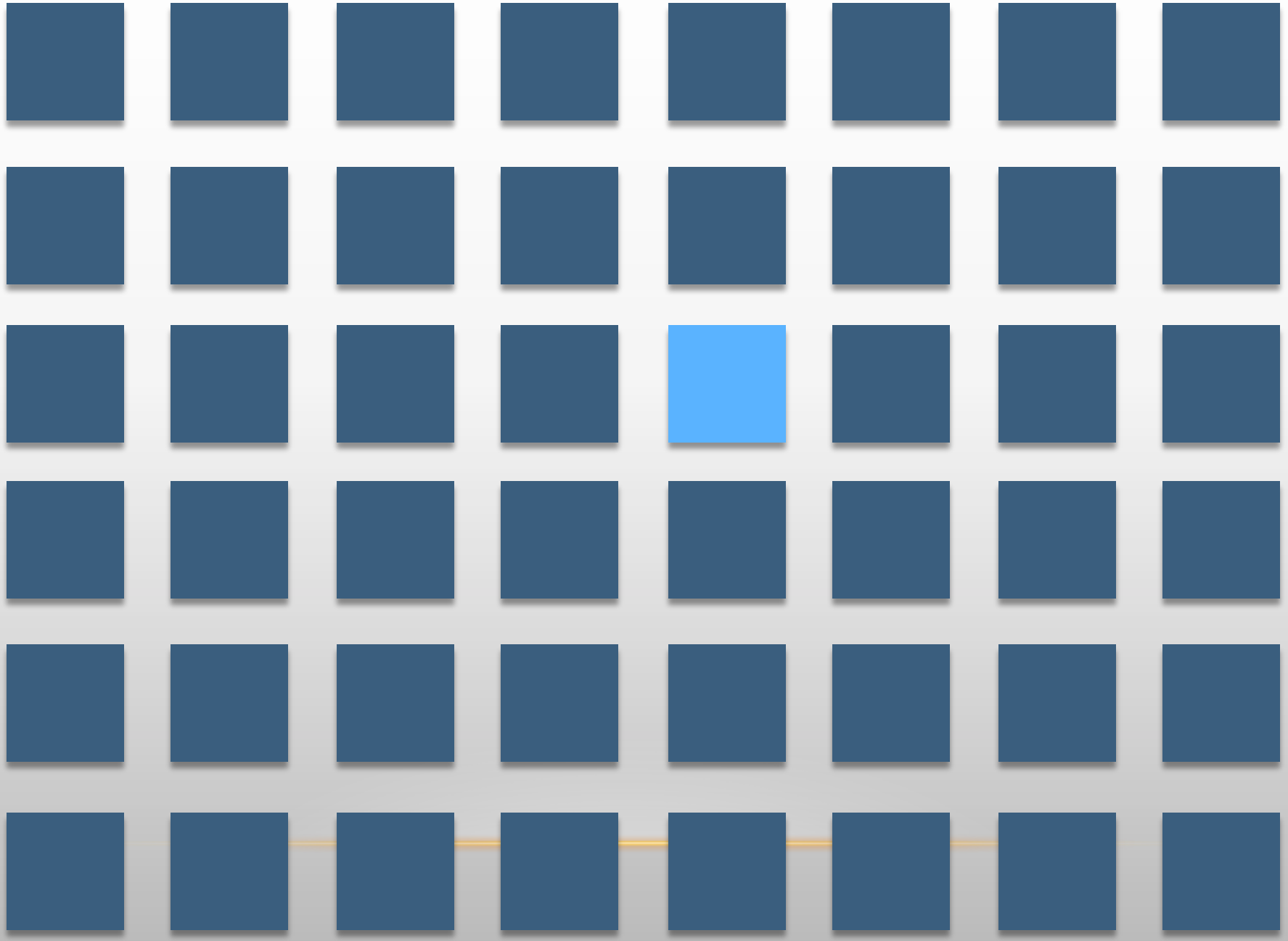
HOW MANY 3'S IN FIRST 350 NUMBERS OF PI?

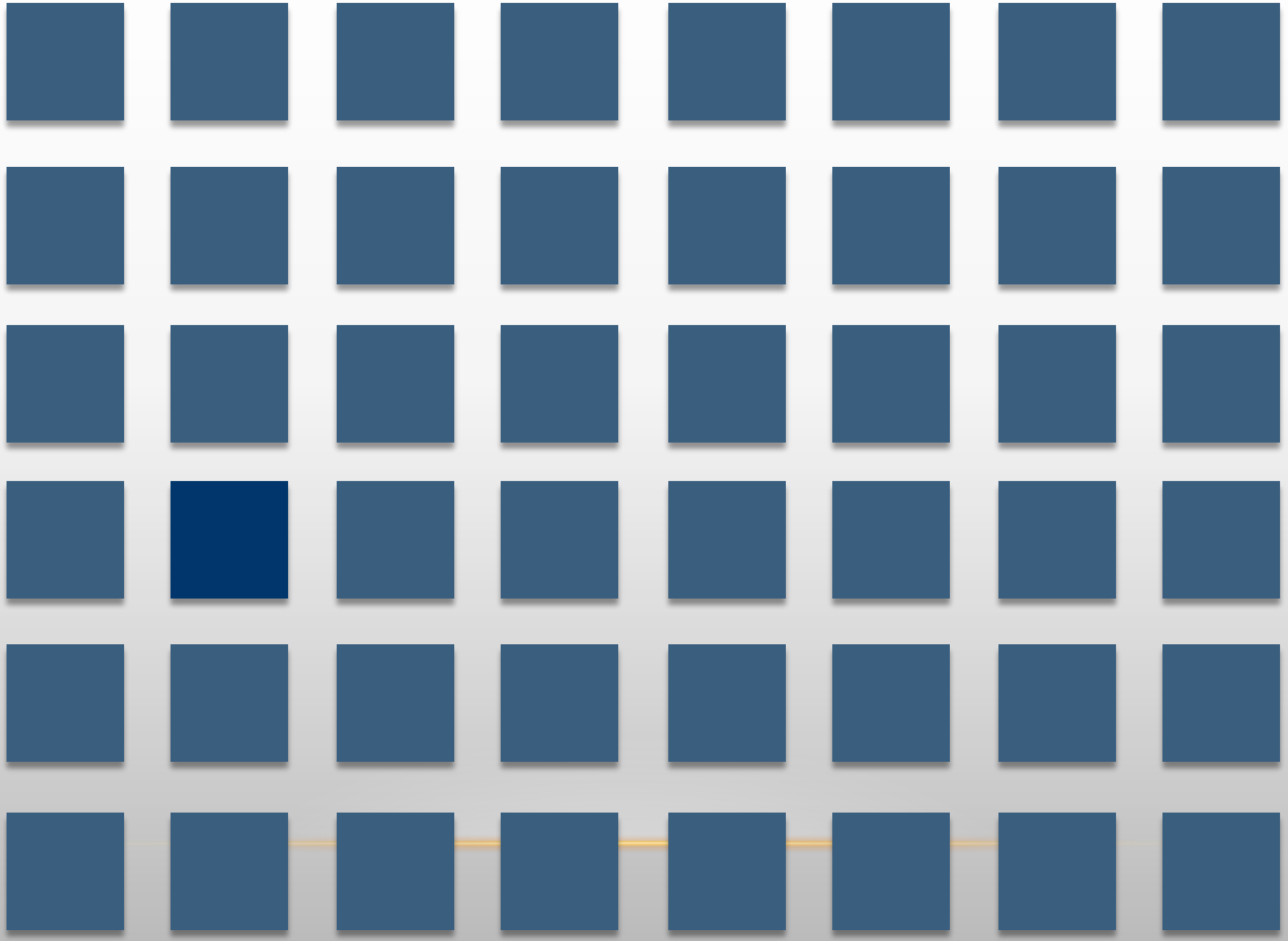
Total 33

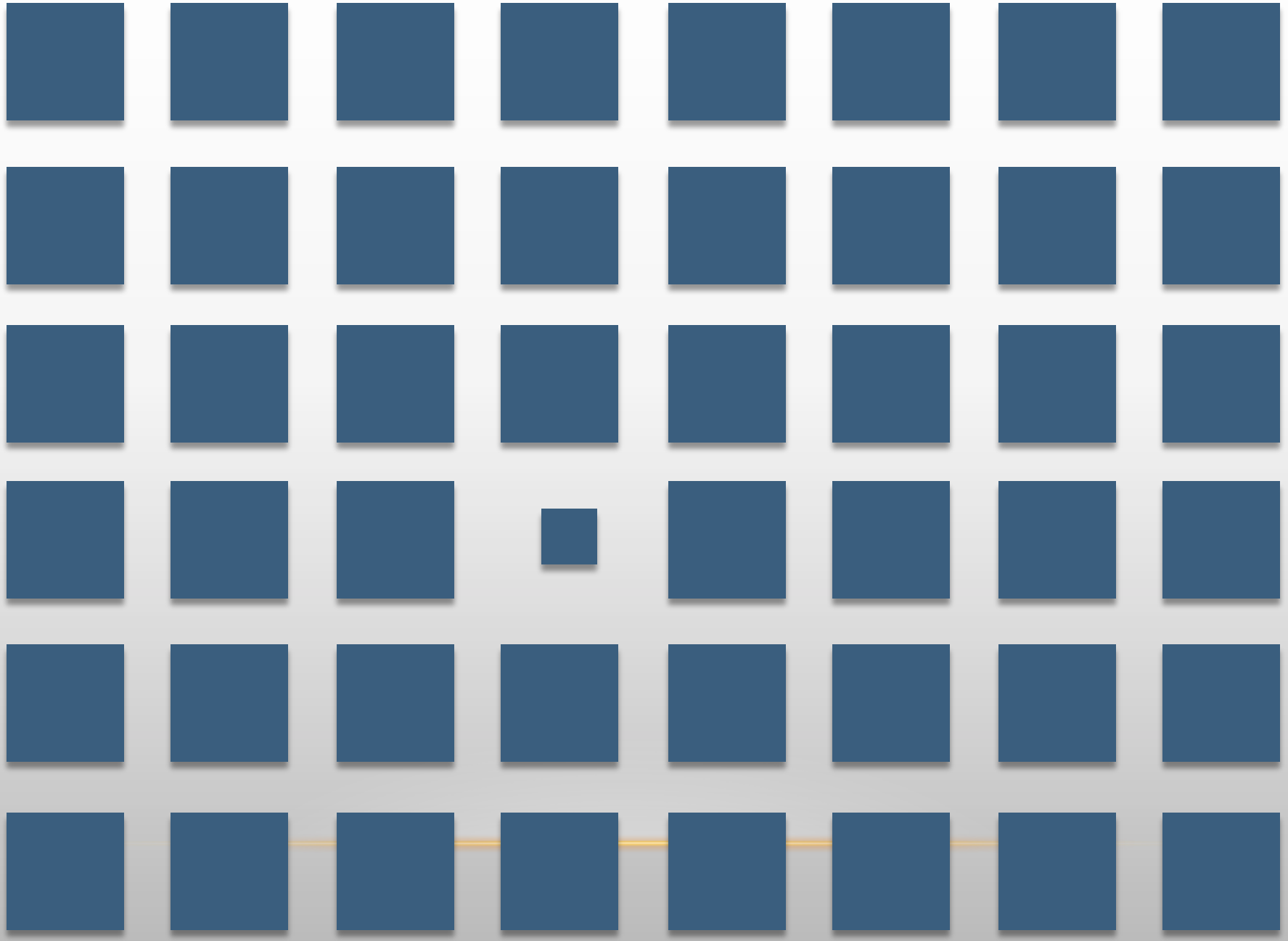


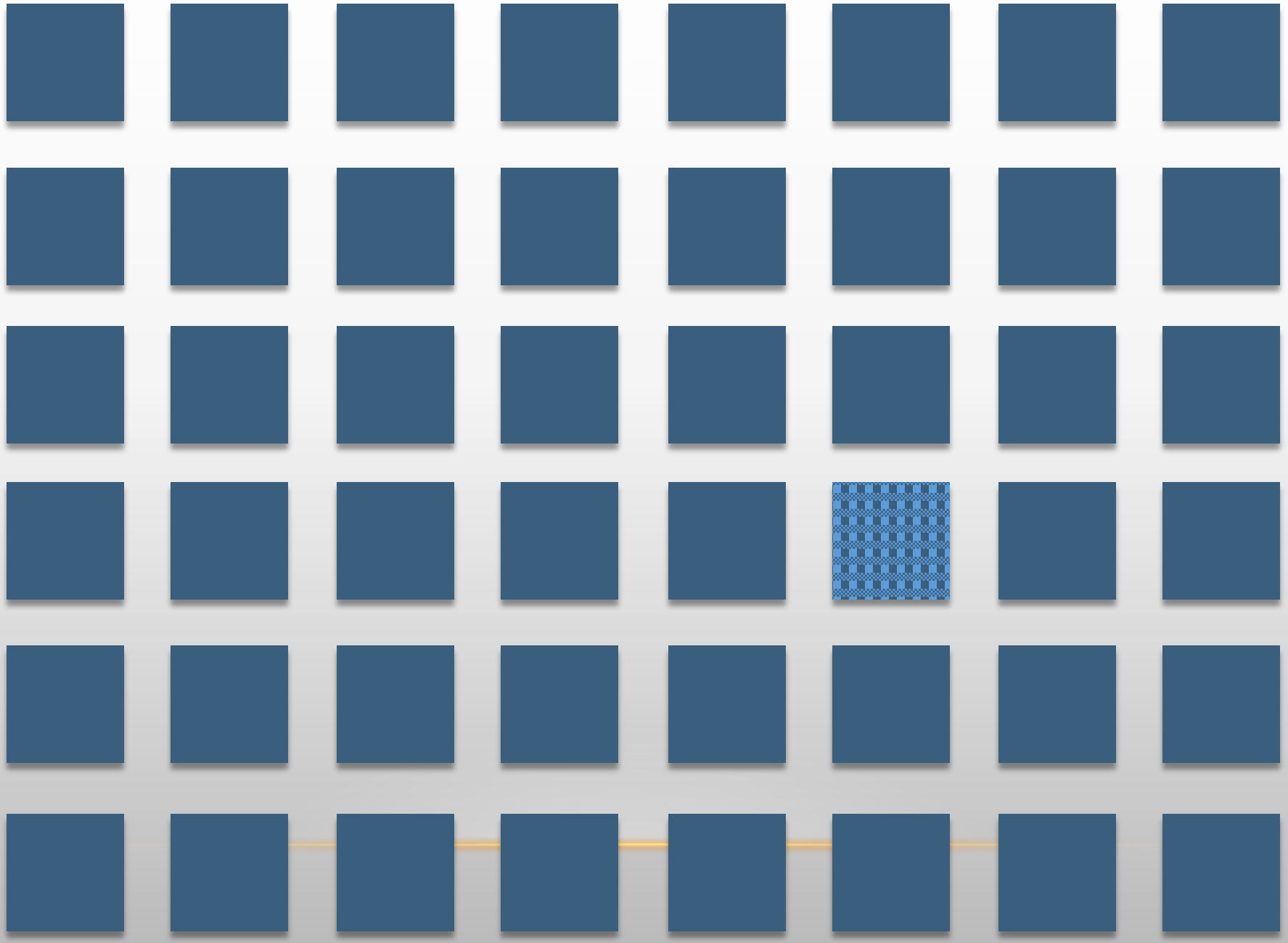


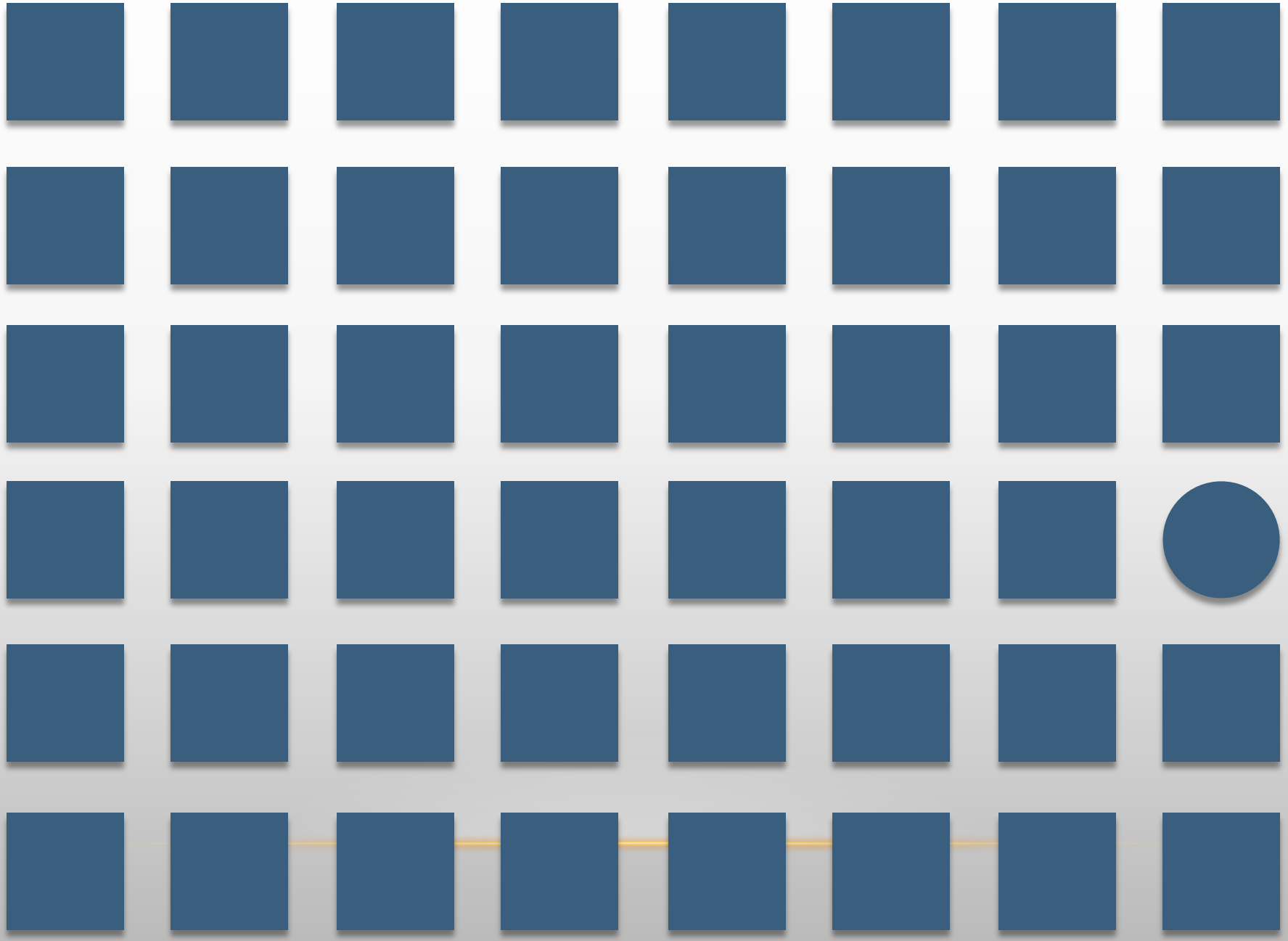












What did you observe?

PREATTENTIVE PROCESSING

Unconsciously gathering information from the environment

Preattentive Attributes(partial list):

position, orientation, scale

color, brightness, saturation

shape, texture

WHAT IS SCIENTIFIC VISUALIZATION?

Working Definition

Visually gaining/extracting insight from a scientific **data** using computational methods

Or

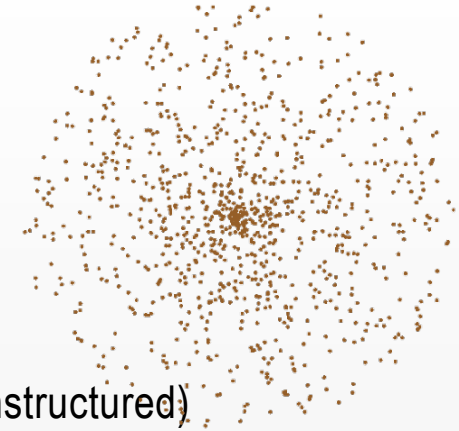
Creating a visual representation of **data** using algorithms

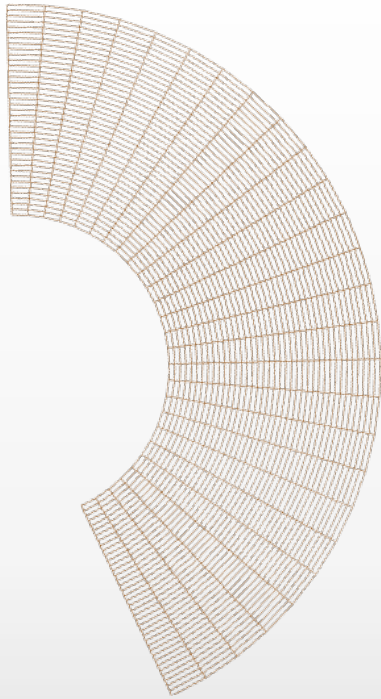
Trivia

Are charts visualizations?

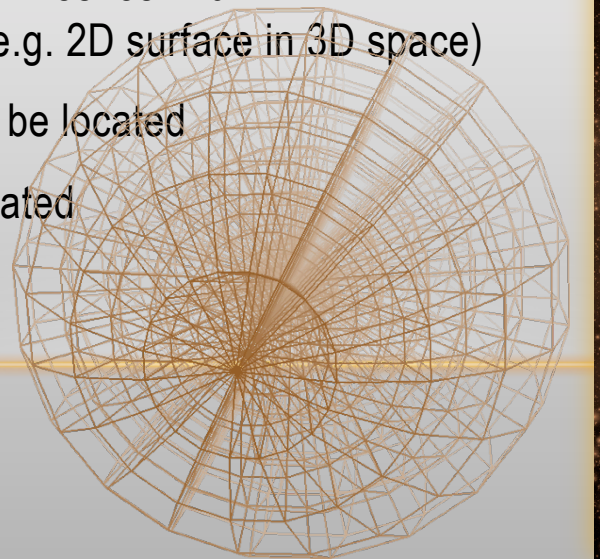
Are illustrations visualizations?

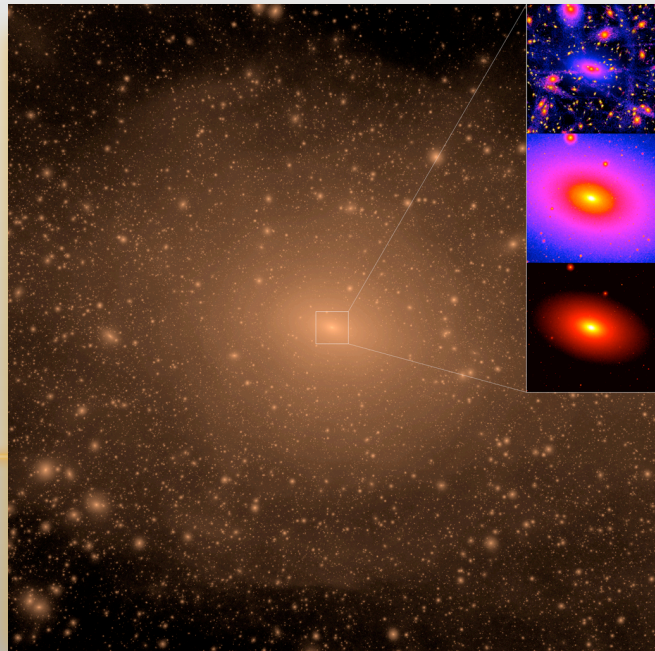
DATA





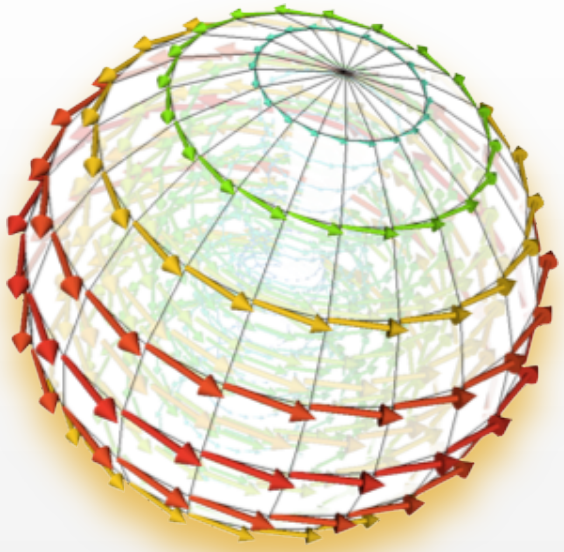
- Data
  - High Dimensional (structured and Unstructured)
  - Mesh
- Meshes Discretizes space into points and cells
  - 1D, 2D, 3D
  - All of these over time (up to 4D)
  - Can have lower-dimensional meshes in a higher-dimensional space (e.g. 2D surface in 3D space)
  - Provides a place for data to be located
  - Defines how data is interpolated



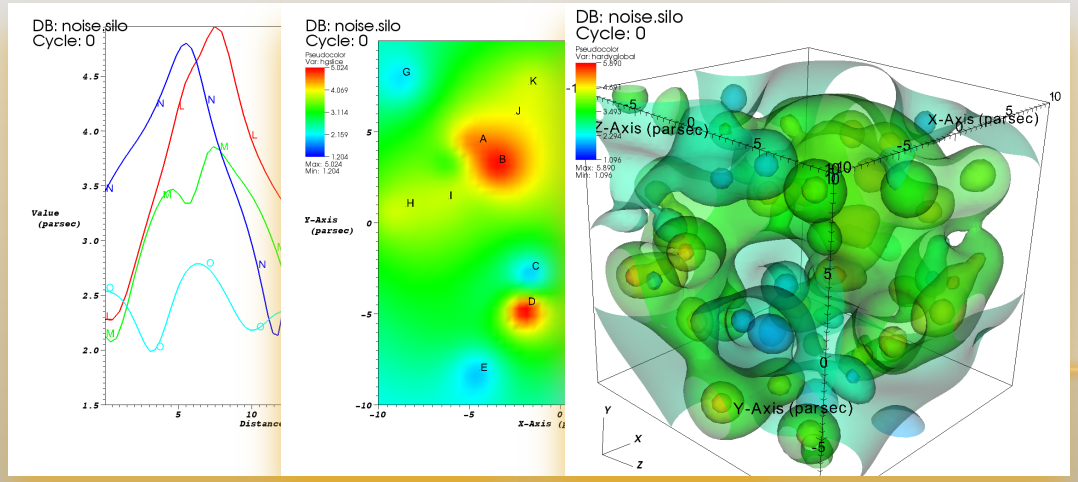


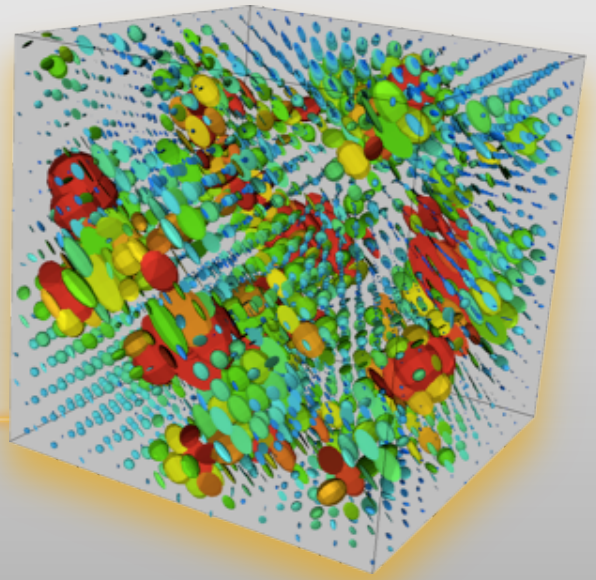
Slide: Courtesy of Sean Ahern, NICS

VARIABLES



- Scalars, Vectors, Tensors
- Sits on points or cells of a mesh
  - Points: linear interpolation
  - Cells: piecewise constant
- Could have different dimensionality than the mesh (e.g. 3D vector data on a 2D mesh)





Slide: Courtesy of Sean Ahern, NICS

MOTIVATION FOR VISUALIZATION

Create visual representations based on underlying data that are

- Concise (Yes)
- Unambiguous (Preferably)
- Intuitive (Trainable)
- Interactive (Desirable)
- Scalable (We wish)

VISUALIZATION BUILDING BLOCKS

Viz Elements

- Glyphs (e.g. Alphabets, Arrows)
- Lines
- Triangles
- Voxels* (volume element)

*Cannot be directly represented on displays

Viz Attributes

- Transforms (Position, Rotation, Scale)
- Color
- Opacity

View Attributes

- Viewpoint
- Projection (Orthographic, Perspective)
- Canvas

Viz Reinforcement

- Texture
- Light
- Distortion (e.g. displacement)
- Motion (e.g. Camera, time steps)
- Filter (e.g. threshold, resample, subset, slice, clip)
- Add Context (e.g. Connectivity, Map Overlay)

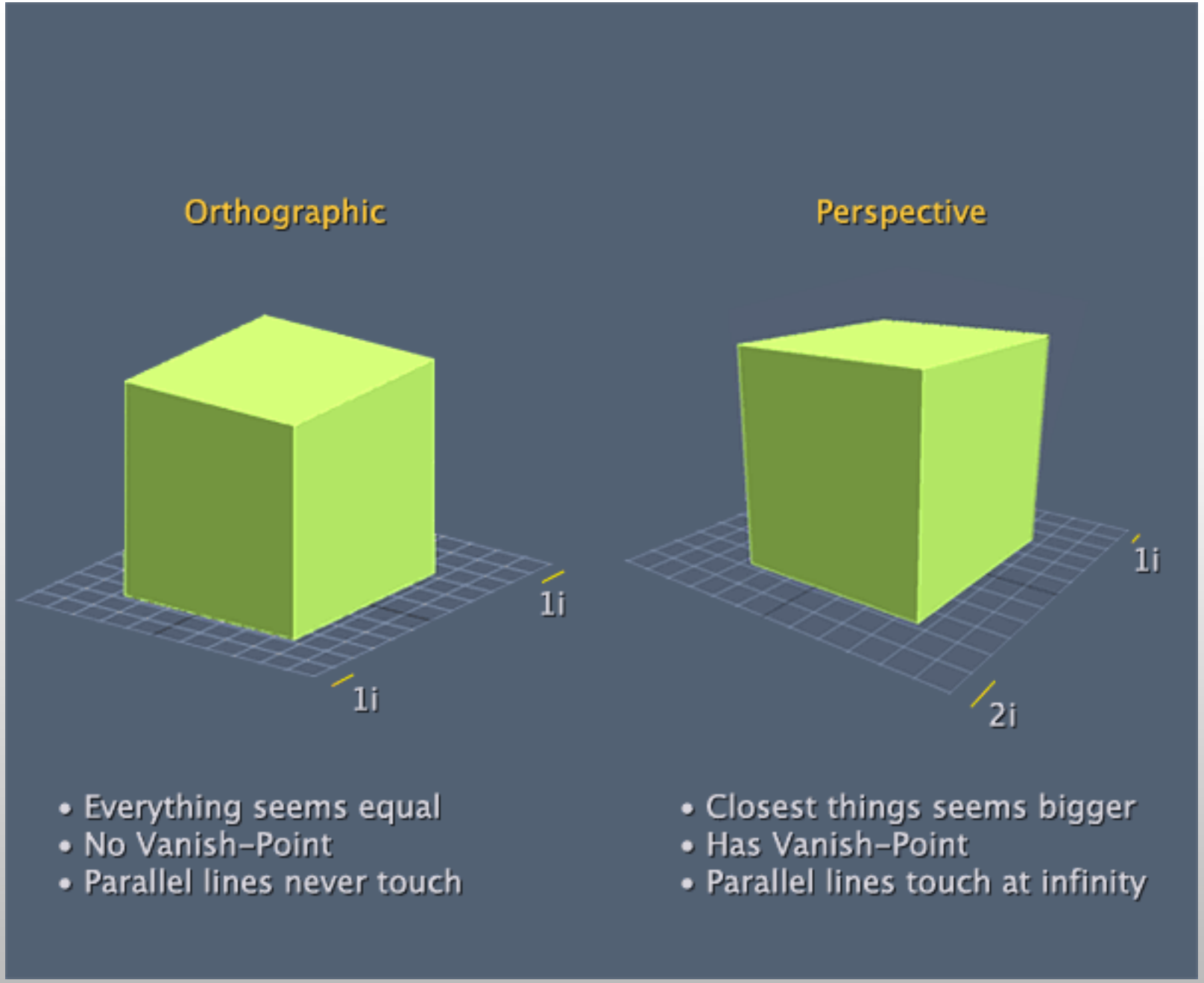


Image Credit: Diney Bomfim - http://blog.db-in.com/cameras-on-opengl-es-2-x/

VISUALIZATION TECHNIQUES

COMMON VISUALIZATION TECHNIQUES

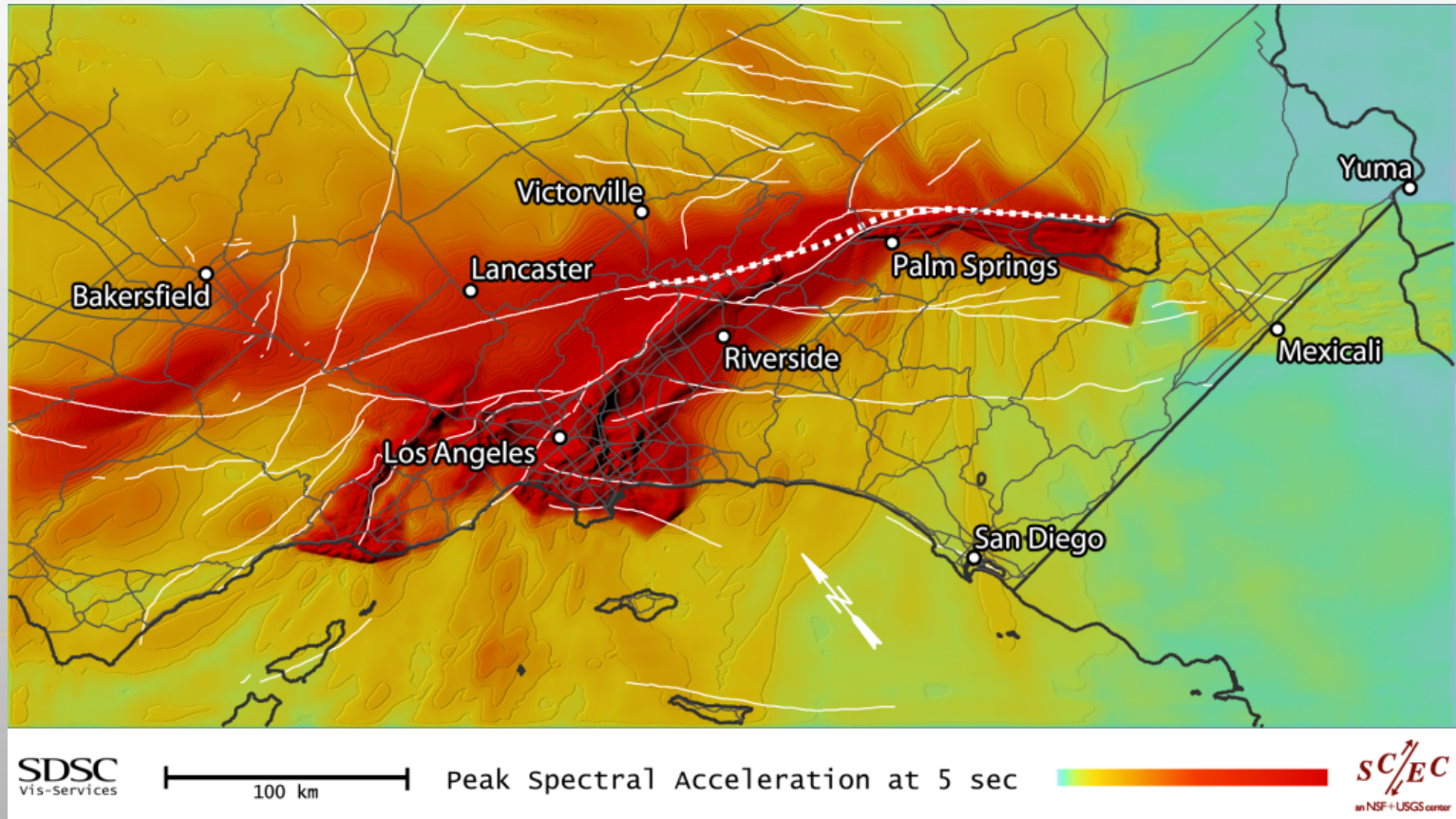
- COLOR MAP (Pseudocolor)*
- CONTOURS*, ISOSURFACE* AND EXPLICIT GEOMETRY
- VOLUMETRIC*
- STREAMLINES
- LINE INTEGRAL CONVOLUATION
- GLYPHS
- TOPOLOGICAL
- PARALLEL COORDINATES*, NETWORKS, ETC

VIZ TECHNIQUES: COLOR MAP (PSUEDOCOLOR PLOT)

Process: Map scalar data to a color table

Utility: To investigate range of data

Fast and great for Error Diagnostic and Visual Validation



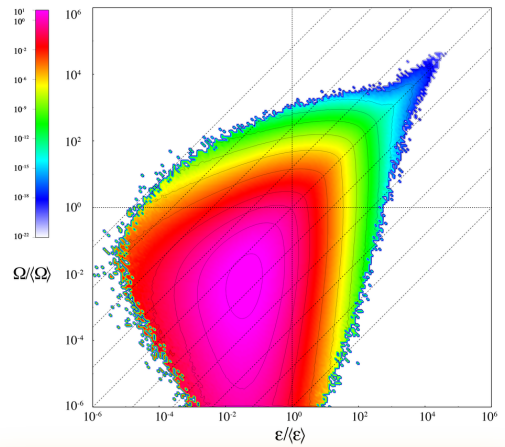
VIZ TECHNIQUES: GEOMETRIC

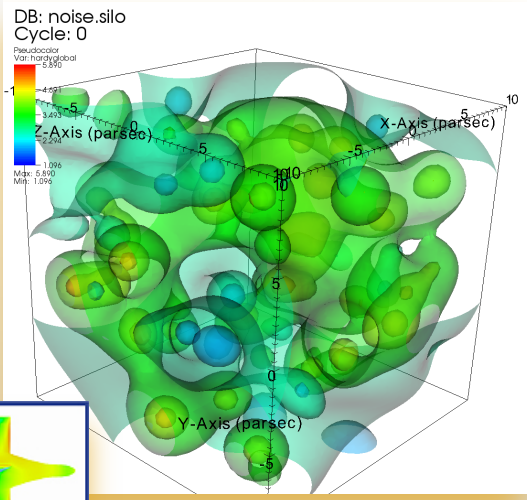
Process & Utility: Identify regions of same scalar value

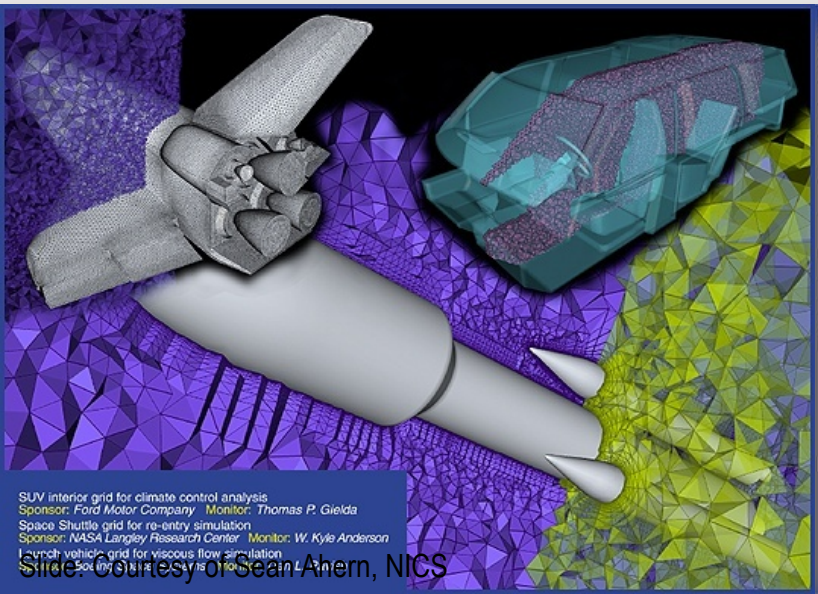
2D: Contours

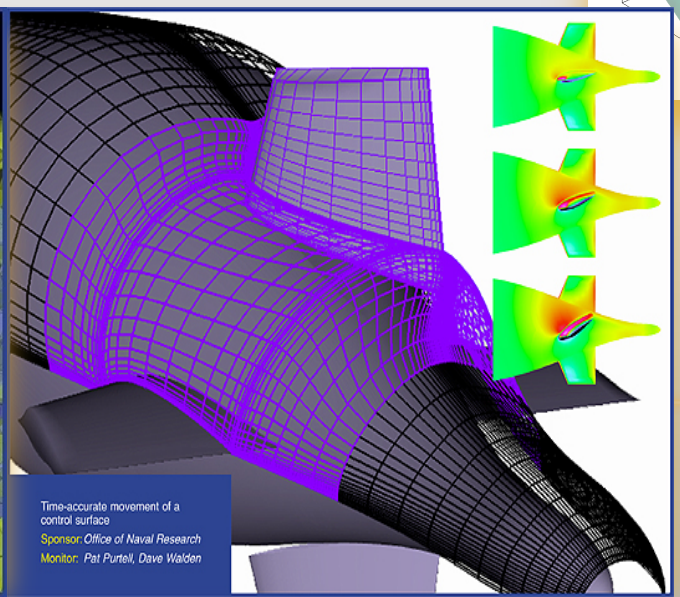
3D: Isosurface (Marching cubes, Marching tetra)

Process: Draw Explicit Geometry (Tri Mesh, Tet Mesh)









Slide: courtesy of Sean Ahern, NICS

VIZ TECHNIQUES: VOLUMETRIC

Process: Volumetrically map scalar data to a transfer function (Color + Opacity)

Utility: To investigate interior/density of scalar volumetric data

Results are very sensitive to

- Transfer Function
- Sampling Interval
- Output Resolution

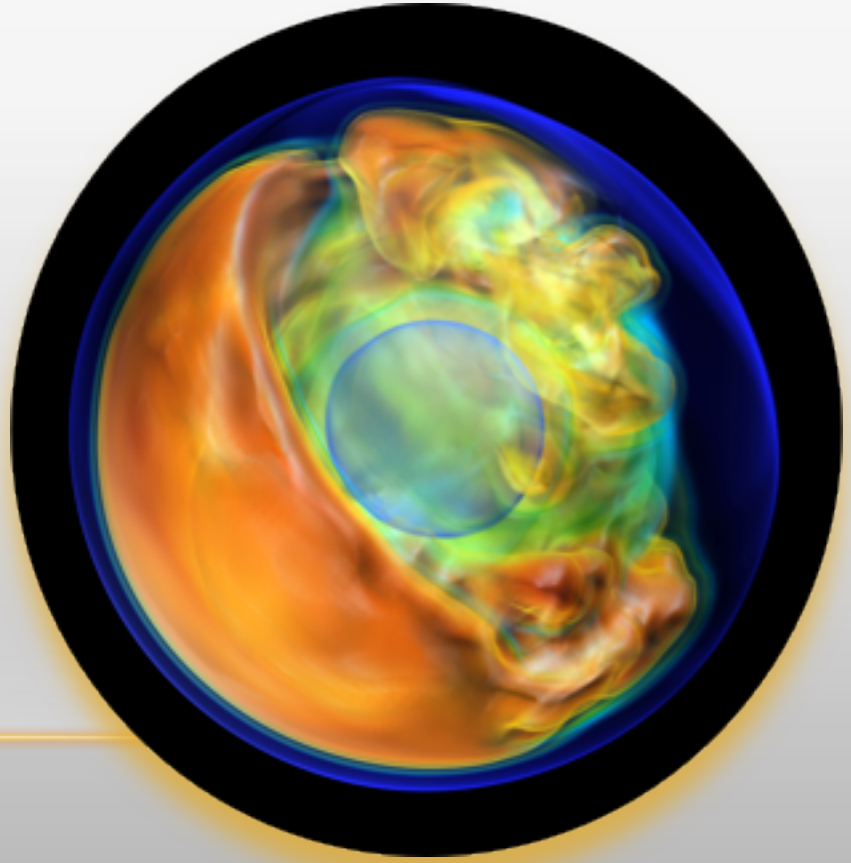


Image: Courtesy of Sean Ahern, NICS

VIZ TECHNIQUES: STREAMLINES

Process: Find curves that are instantaneously tangent to the velocity vector of the flow

Utility: To investigate nature of flow

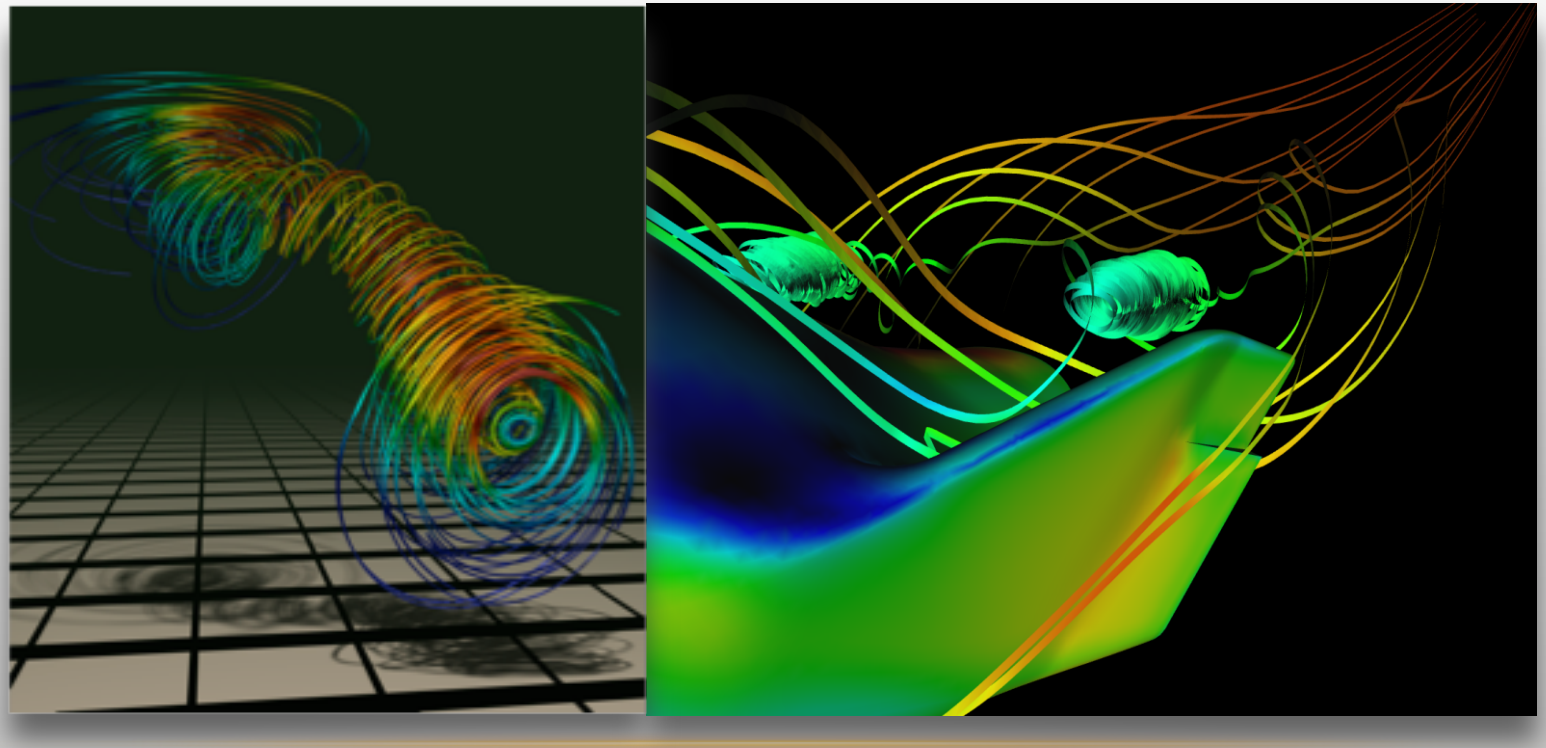
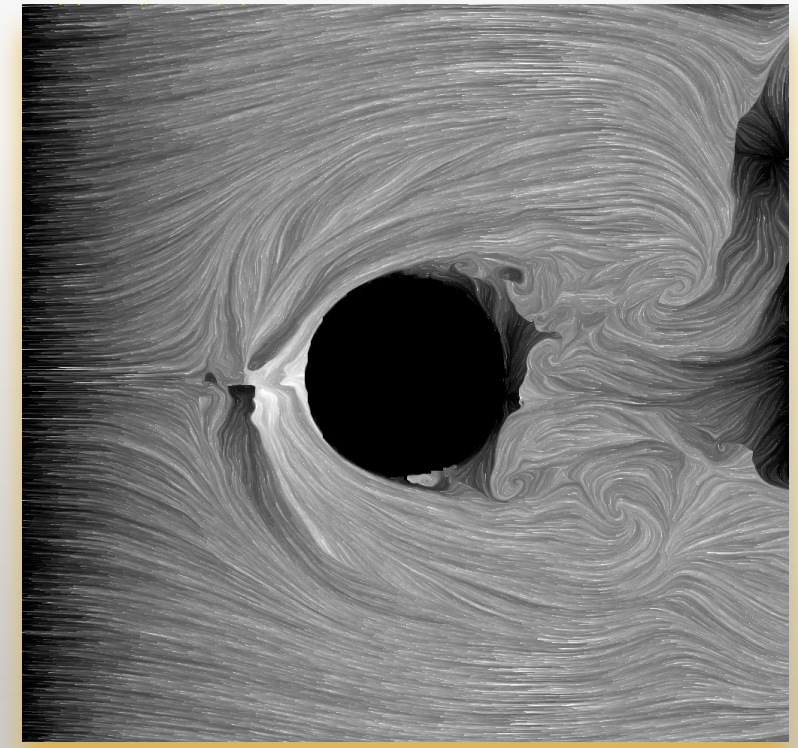


Image: Courtesy of Sean Ahern, NICS

VIZ TECHNIQUES: LIC

Line Integral Convolution

Utility: To investigate nature of flow

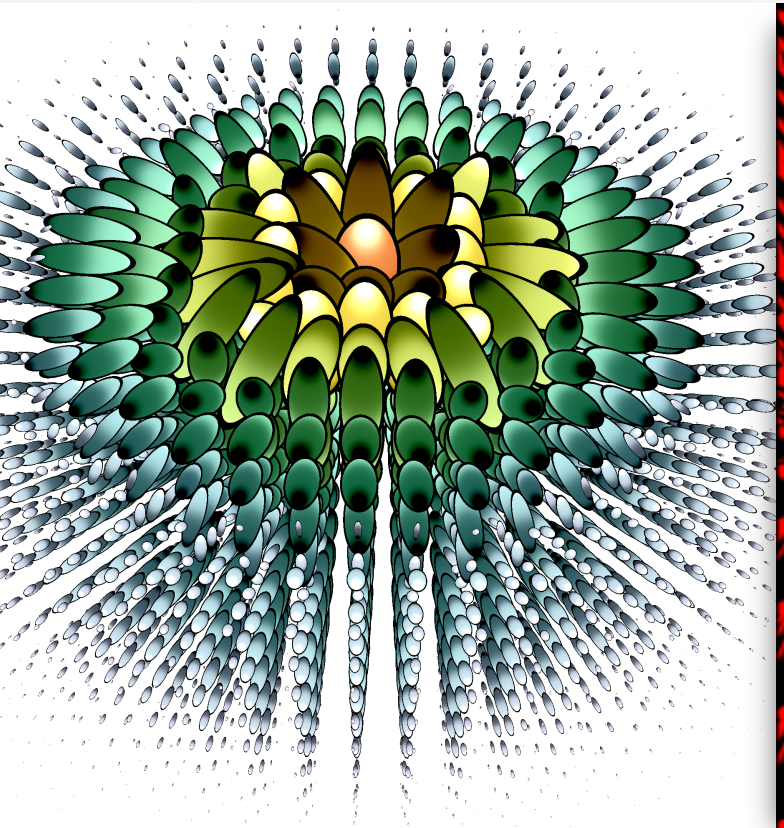


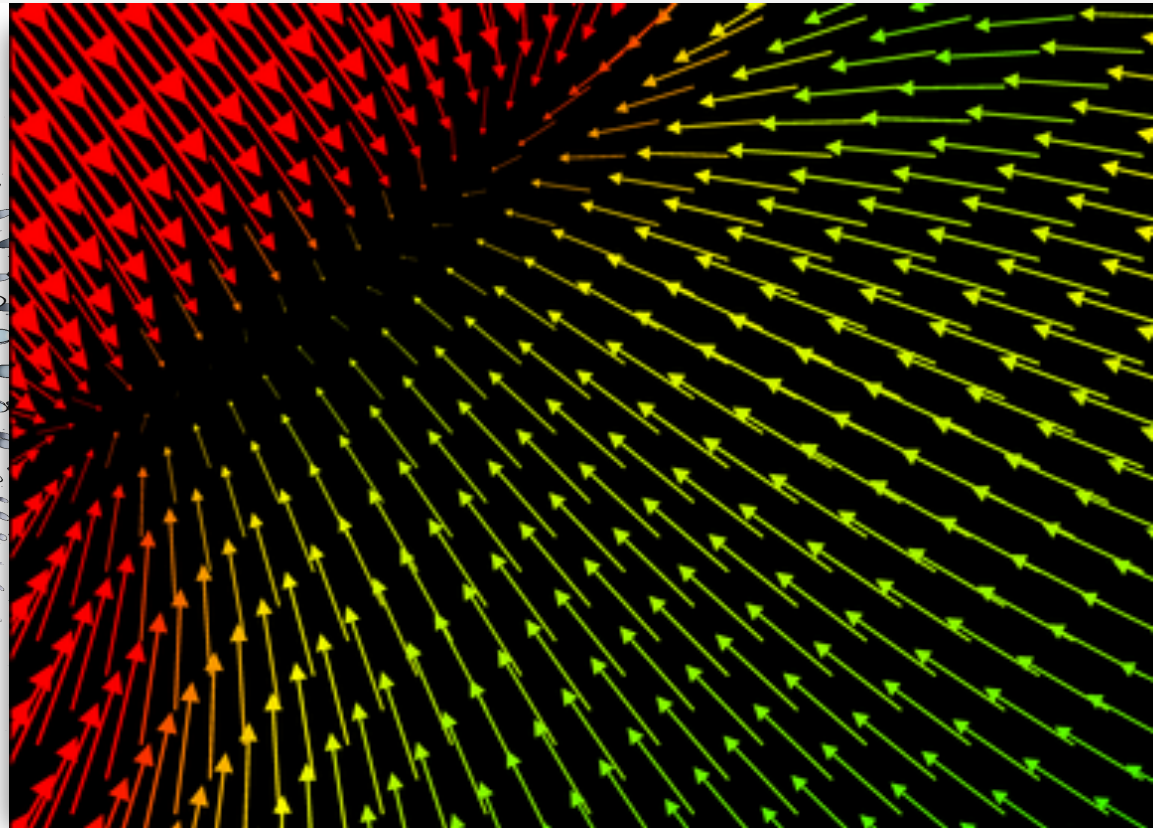
Image/movie: Courtesy of Sean Ahern, NICS

VIZ TECHNIQUES:
GLYPHS

Map the scalar or vector data to a shape

Utility: To investigate flow of vector data or distribution of scalar/vector data

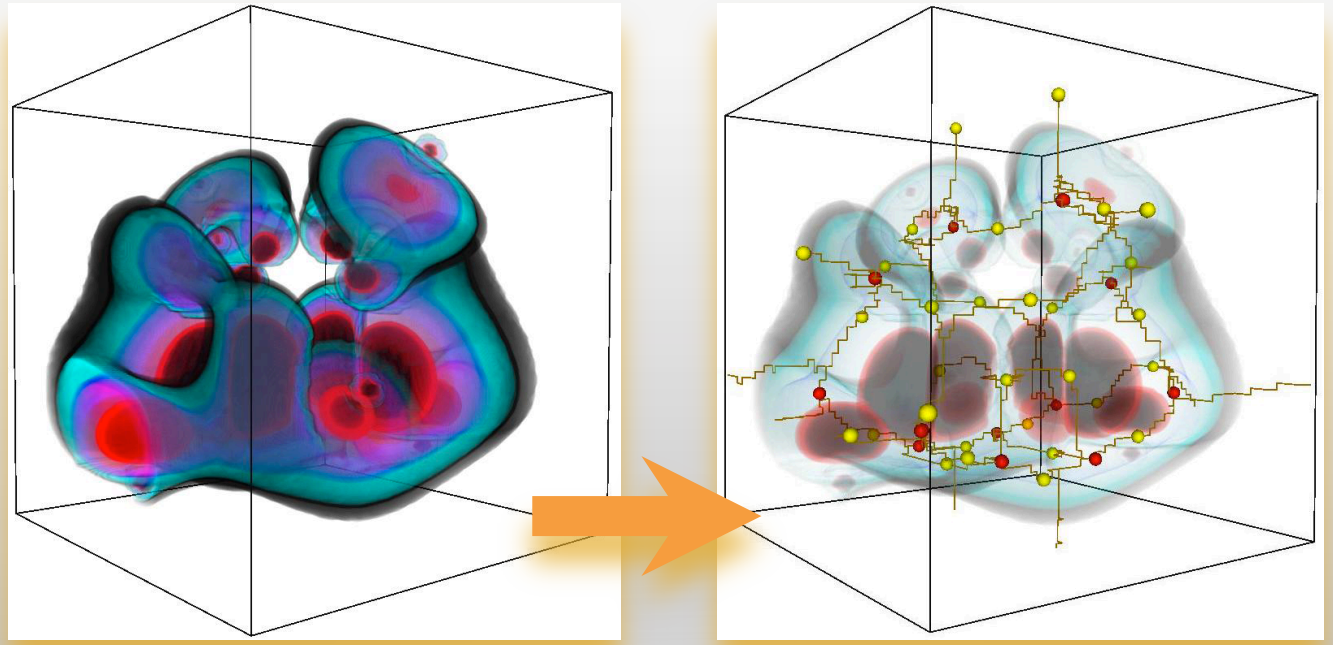




VIZ TECHNIQUES: TOPOLOGICAL

Process: Compute topology of underlying data

Utility: To investigate local maxima, minima saddle points, etc



Images: Courtesy of Sean Ahern, NICS

VIZ TECHNIQUES: TENSOR ANALYSIS

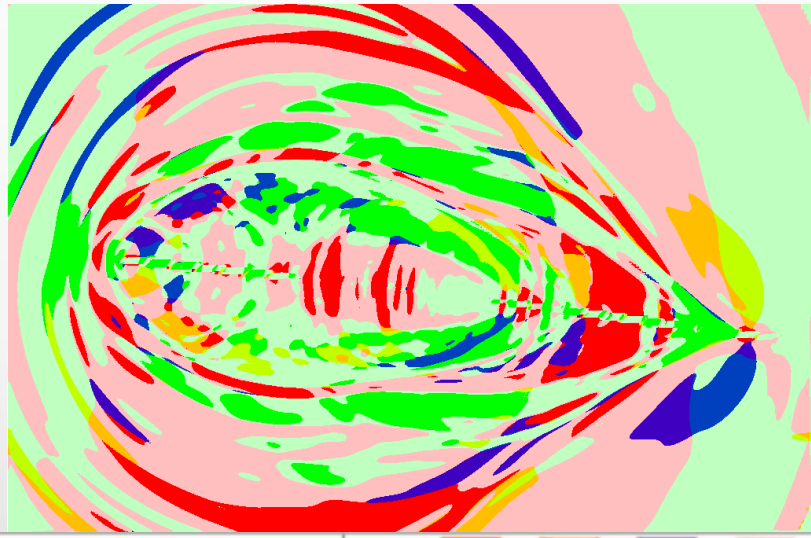
References

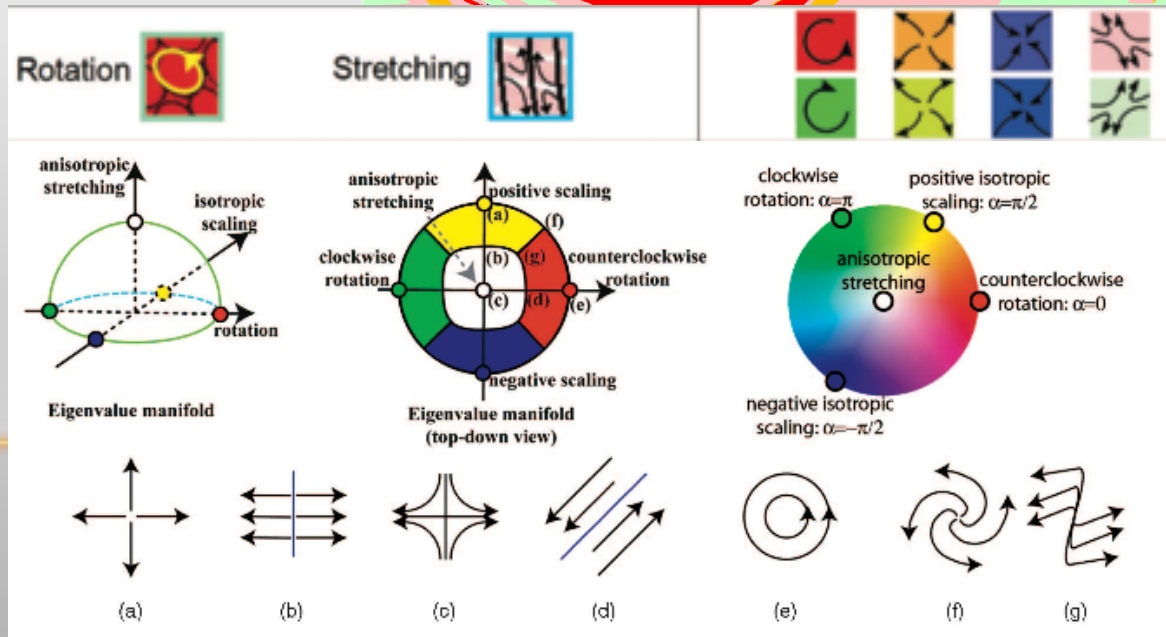
Asymmetric Tensor Analysis for Flow Visualization

Eugene Zhang, Harry Yeh, Zhongzang Lin, and Robert S. Laramee

Asymmetric Tensor Field Visualization for Surfaces

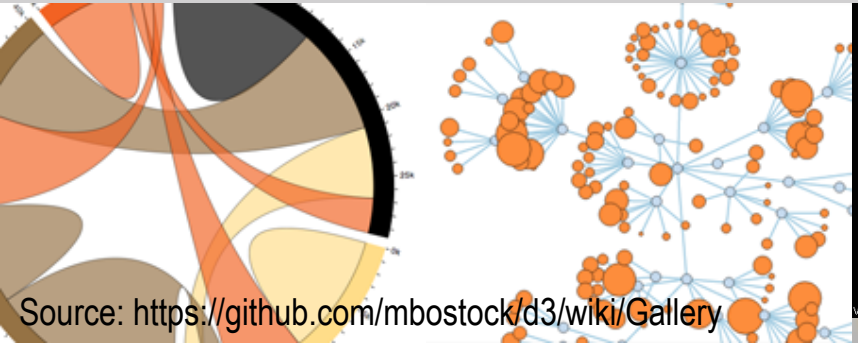
Guoning Chen, Darrel Palke, Zhongzang Lin, Harry Yeh, Paul Vincent, Robert S. Laramee and Eugene Zhang

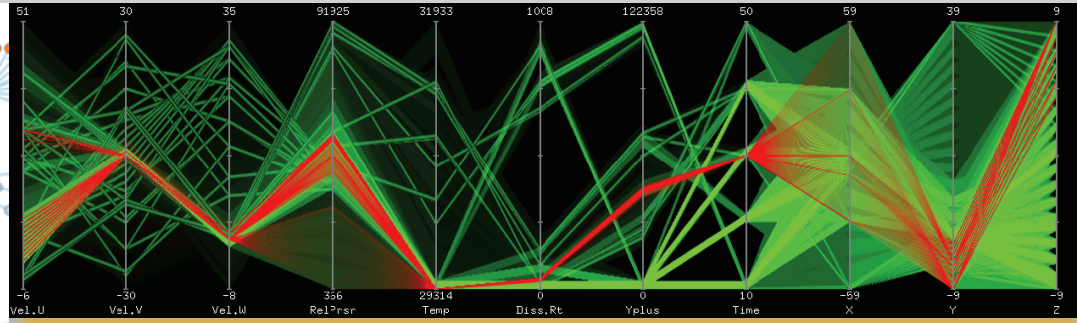




OTHER VIZ TECHNIQUES

- **Parallel Coordinates**
- Chord
- Tree (e.g. Dendograms, Sunbursts, Treemaps, etc)
- Many others



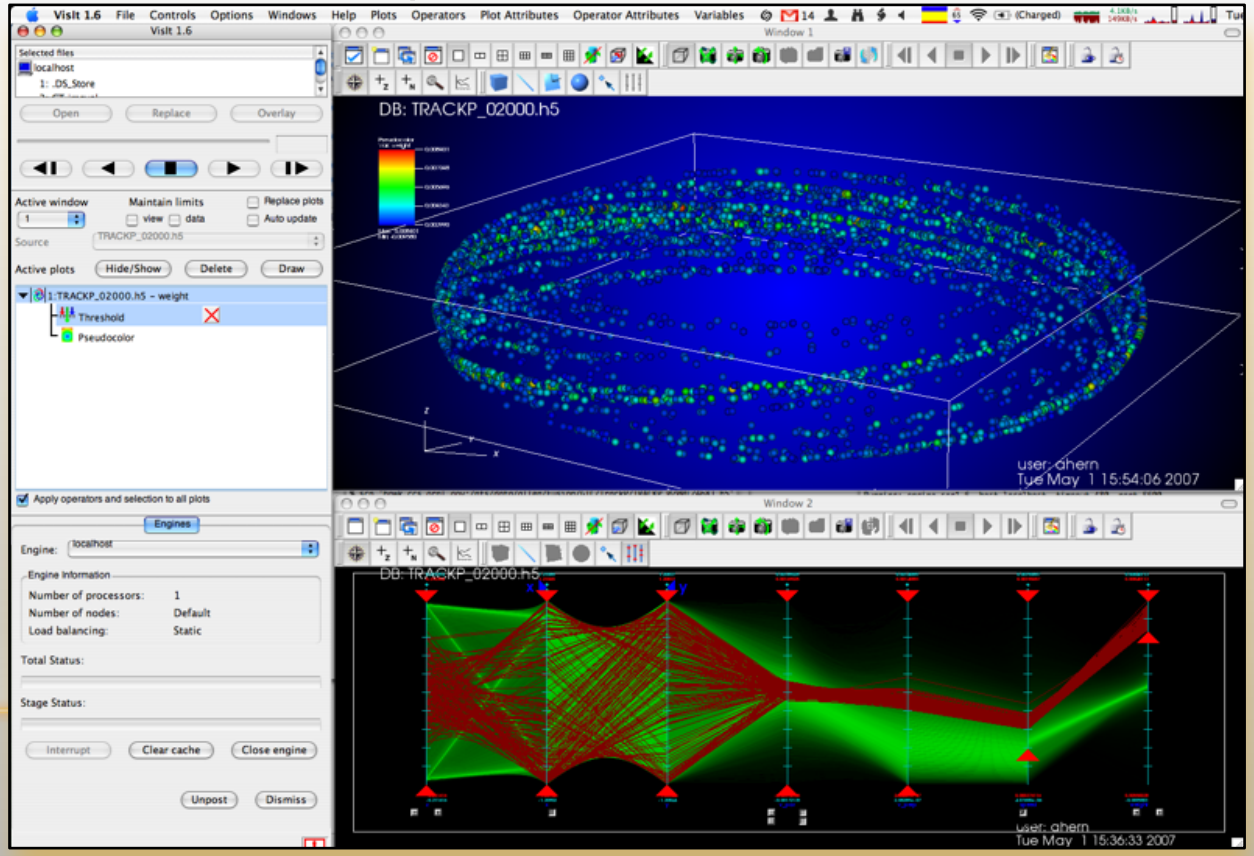


Source: https://github.com/mbostock/d3/wiki/Gallery

HIGH-DIMENSIONAL VISUALIZATION

Parallel coordinates summarize high-dimensional information

Utility: To find trends and relationships



VISUALIZATION APPLICATIONS

- Communication
- Confirmation
- Inspection and Exploration

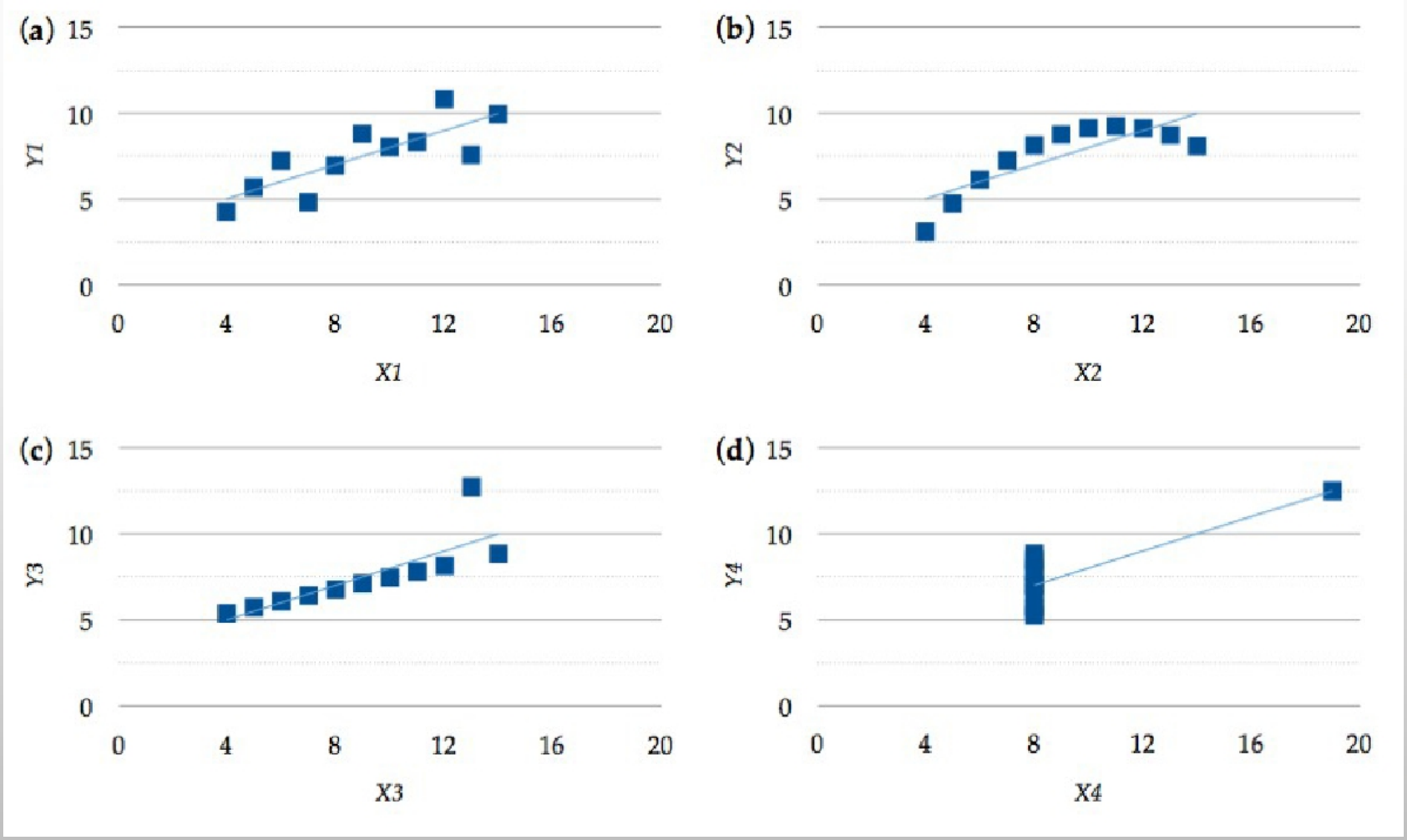
APPLICATION OF VIZ -CONFIRMATION

X_1	Y_1	X_2	Y_2	X_3	Y_3	X_4	Y_4
10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58
8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76
13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71
9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84
11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
4.0	4.26	4.0	3.10	4.0	5.39	19.0	12.50
12.0	10.84	12.0	9.13	12.0	8.15	8.0	5.56
7.0	4.82	7.0	7.26	7.0	6.42	8.0	7.91
5.0	5.68	5.0	4.74	5.0	5.73	8.0	6.89

mean(X) = 9, var(X) = 11, mean(Y) = 7.5, var(Y) = 4.12,
cor(X,Y) = 0.816, linear regression lineY = 3 + 0.5*X

Anscombe 1973, The American Statistician

Anscombe's Quartet

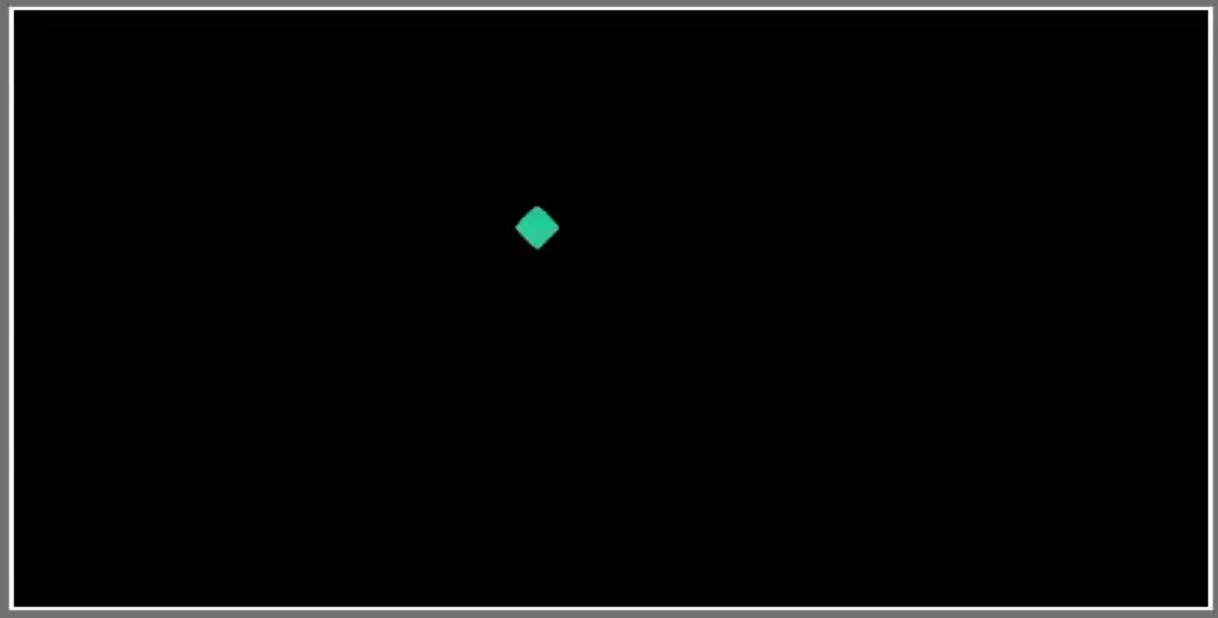


Slide: Courtesy of N Gehlenborg & M Meyer / Bio-IT World 2011

APPLICATION OF VIZ
- INSPECTION AND EXPLORATION

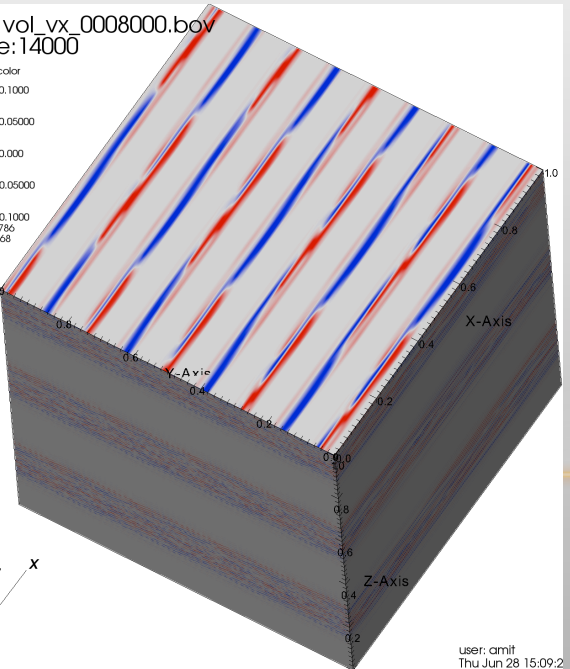
SALIENT APPLICATIONS OF VISUALIZATION

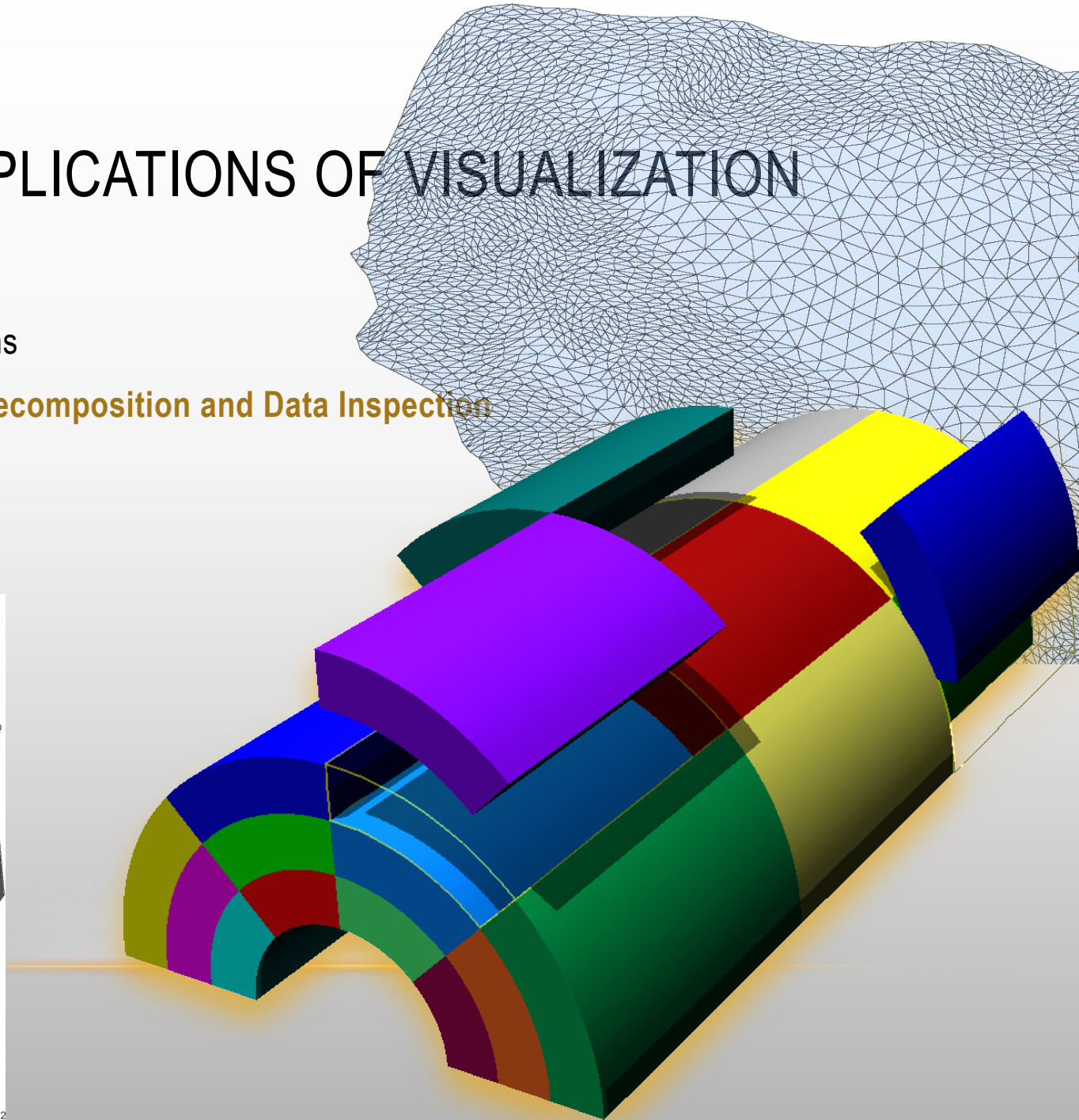
- **“nan” Inspection**
- **Boundary Conditions**



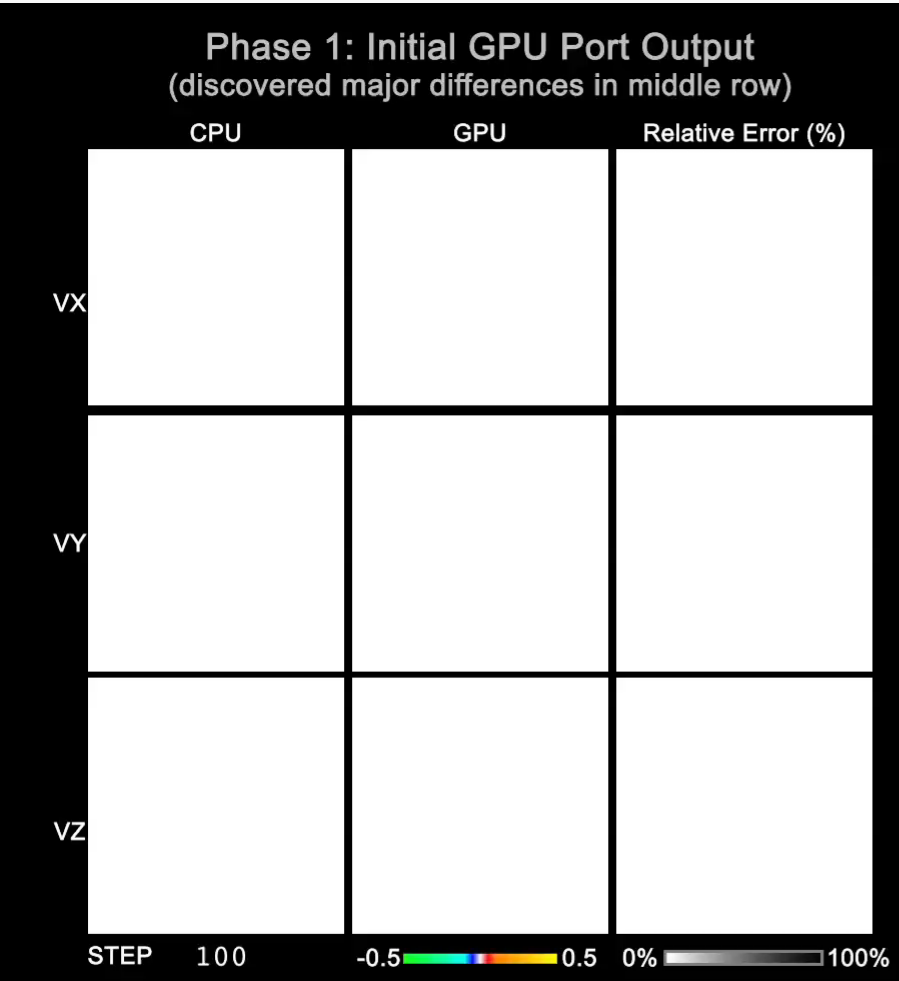
SALIENT APPLICATIONS OF VISUALIZATION

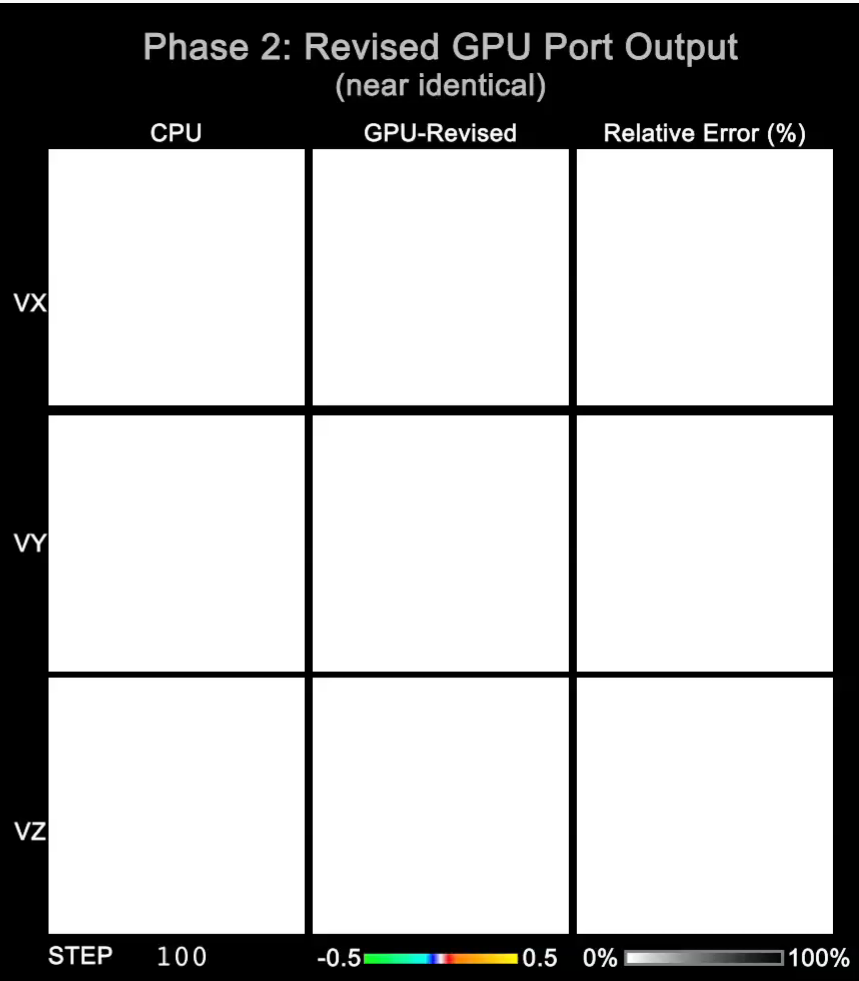
- “nan” Inspection
- Boundary Conditions
- **Mesh Topology, Decomposition and Data Inspection**





SALIENT APPLICATIONS OF VISUALIZATION

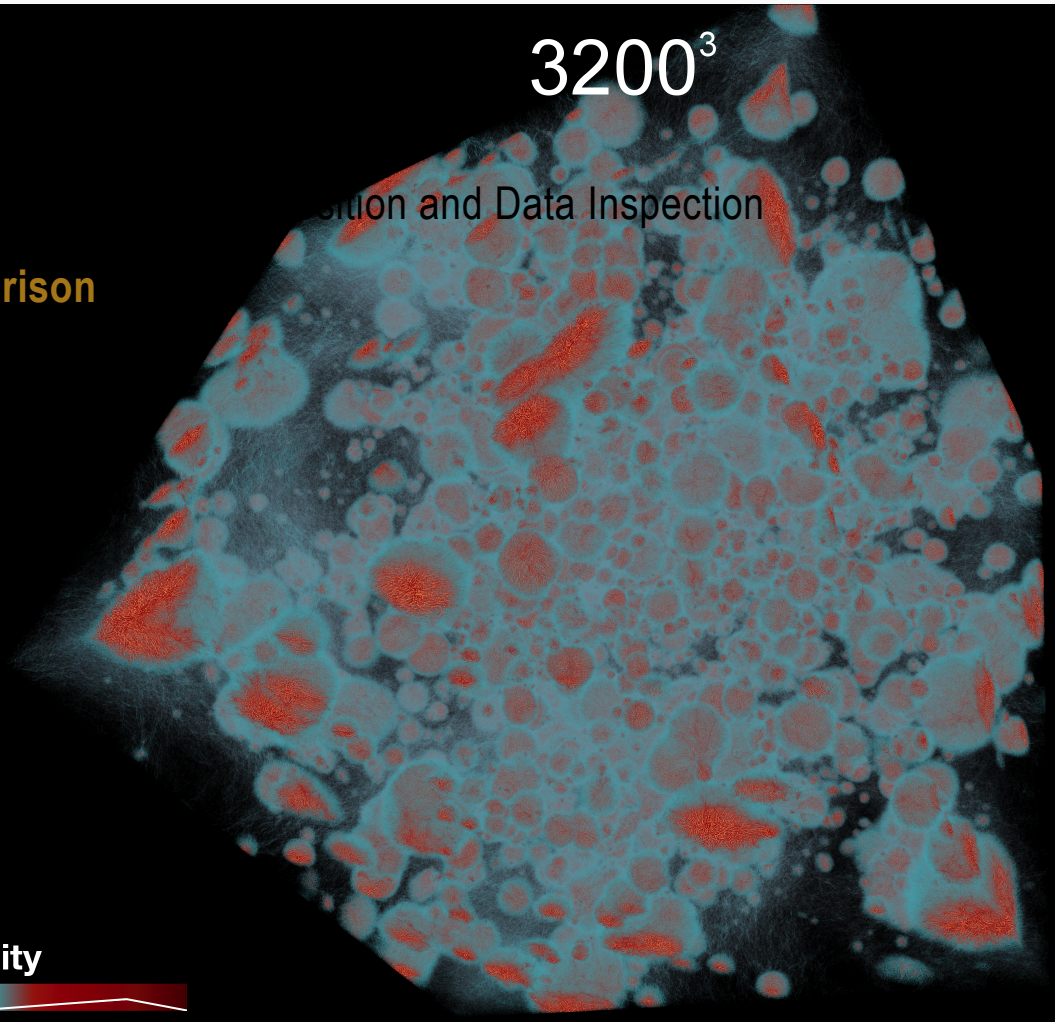




SDSC

SALIENT APPLICATIONS OF VISUALIZATION

- 3200^3
- ...tion and Data Inspection
- **Comparison**



Density

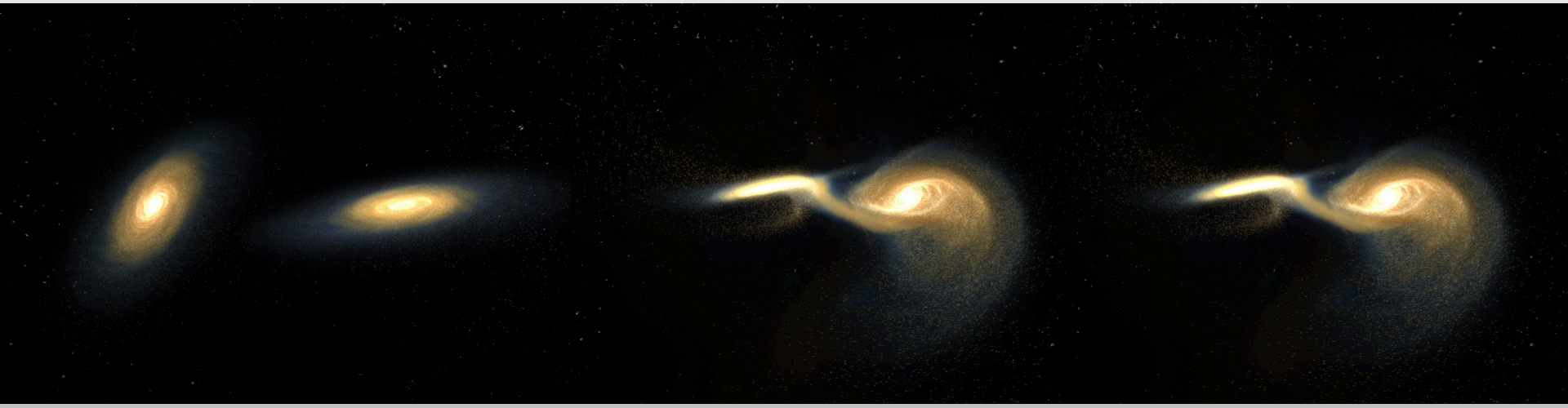
Non-Radiative No Difference Radiative

SDSC
SAN DIEGO SUPERCOMPUTER CENTER

Argonne
NATIONAL LABORATORY

SALIENT APPLICATIONS OF VISUALIZATION

- “nan” Inspection
- Boundary Conditions
- Mesh Topology, Decomposition and Data Inspection
- Comparison
- **Collisions and Mergers**



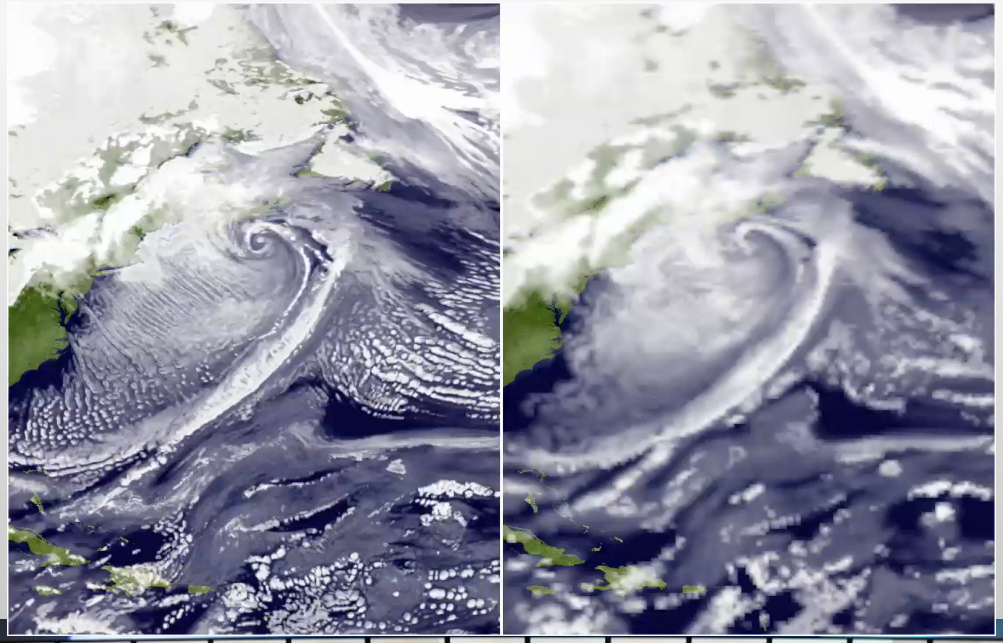
“Deep Sea Adventure” CalTech, NCSA, ADLER PLANETARIUM

SALIENT APPLICATIONS OF VISUALIZATION

SCEC
an NSF+USGS center
SDSC

DISPLAYING DATA

- High resolution devices (latest tablets and laptops)
- High resolution monitors (30” flat panels, 4 megapixel, 2500x1600)
- Tile Displays (array of monitors)

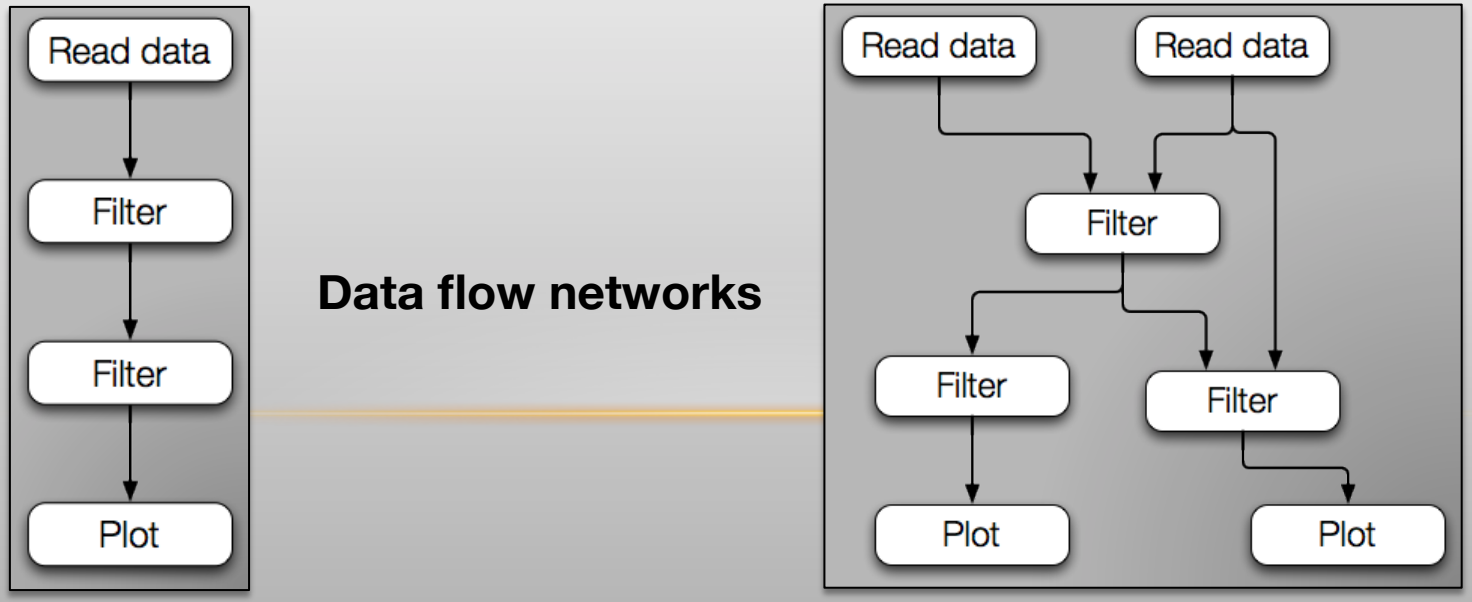


Slide: Courtesy of Sean Ahern, NICS

MISCELLANEOUS

FLOW NETWORKS (PIPELINES)

- Data reading: NetCDF, HDF, text, CSV, PDB
- Data operations: Slicing, resampling, mesh transforms
- Data plotting: Pseudocolor, isosurface, volume rendering



BEST PRACTICES

- Colors
  - Parsimony of color, Grey scale is excellent at many things
  - Don’t use rainbow color map: http://blog.visual.ly/rainbow-color-scales/
  - Good Color map design:
    - colorbrewer2.org (excellent)
    - kuler.adobe.com
    - Use HSV color scale for color map design and interpolation
- Always include legend
- Visualizations have their own unpredictable life cycle. Writing non technical captions will help you extremely in long run.
- Carefully set Sampling, Interpolation and Seeds
- Write data in parallel read friendly format
- Reduce/Minimize Data Movement: Visualize as close to the data as possible

VIZ MODES

- Post Visualization (after the simulation)

  Pros:

  - Maximum flexibility
  - Operational simplicity

  Cons:

  - Data reload
  - Time consuming
  - Delayed access to results
- Co-located Visualization (during simulation but on different nodes)
- In-Situ Visualization (during simulation on same nodes)

  Pros:

  - Enables swift visual validation of results
  - Least/moderate data movement/replication

  Cons:

  - Difficult implementation
  - Additional complexity an longer runtime
  - Fixed visualization outputs

VIZ LIMITATIONS

- Domain knowledge
- Interpolation
- Multivariate data
- Temporal coherence
- Precision loss (compression)
- Perceptual issues (color blindness)
- Personal bias (author & viewer)

VIZ MISCONCEPTIONS (BUSTED)

- I am not an artist thus can't do viz (Stick around. Try again and ask for help this time)
- Viz is an art not science (Viz is driven by algorithms, some very sophisticated)
- Viz is a one time task (Viz is a process like any other analysis)
- Viz is useful only for communication (Think about error and diagnostics)
- Viz SU's are insignificant (Welcome to Viz World)

FEW TOOLS

Open Source

- Paraview
- VisIt
- YT
- MayaVi

Proprietary

- Amira
- IDL
- Matlab
- Ensight

Toolkits

- VTK
- VTK-m (HPC focus)

SeedMe.org

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- Post data from HPC jobs.
- Create videos from image sequences.

Slides http://users.sdsc.edu/~amit/presentations/scivis-lecture.pdf

Hands on learning

VisIt Class and Tutorial Materials

https://wci.llnl.gov/simulation/computer-codes/visit/manuals

Follow along video recording

Session 2 and 3

http://www.sdsc.edu/Events/gordonviz2012/

Meta Reference

Christopher Johnson and Charles Hansen. 2004. *Visualization Handbook*. Academic Press, Inc., Orlando, FL, USA.