Thanks to the authors of the

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Introduction to ParaView

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Irish Centre for High-End Computing

Visualisation Training Day @ EPCC
Prace Summer of HPC, July 2013

ParaView

Outline

- ParaView – What is it? Why use it? Who uses it?
- GUI intro, Graphics Pipeline, File Formats
- Filters
- Views and Multi-View
- Streamlines, Line Plots
- Time Dependent Data
- Selections
- Python traces
- Advanced Topics – Paraview at scale

To try this at home…

- Install ParaView 3.98.1 (or 4.0.0).
  - http://www.paraview.org ▪ Download
- Get example material.
  - http://www.paraview.org/Wiki/The_ParaView_Tutorial
  - Data also available on tutorial handout USB stick.

Help / Information

- Online Help – F1

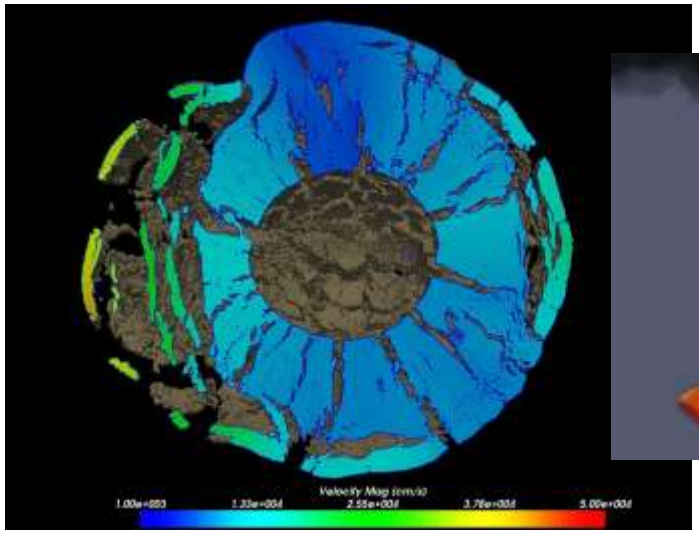
- *The ParaView User's Guide*
  - http://paraview.org/Wiki/ParaView/Users_Guide/Table_Of_Contents

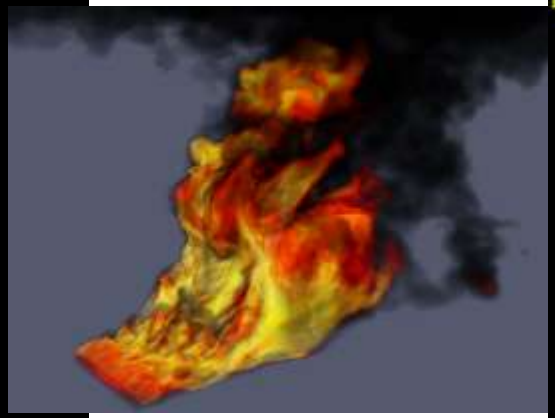
- The ParaView web page
  - www.paraview.org
- ParaView mailing list
  - paraview@paraview.org

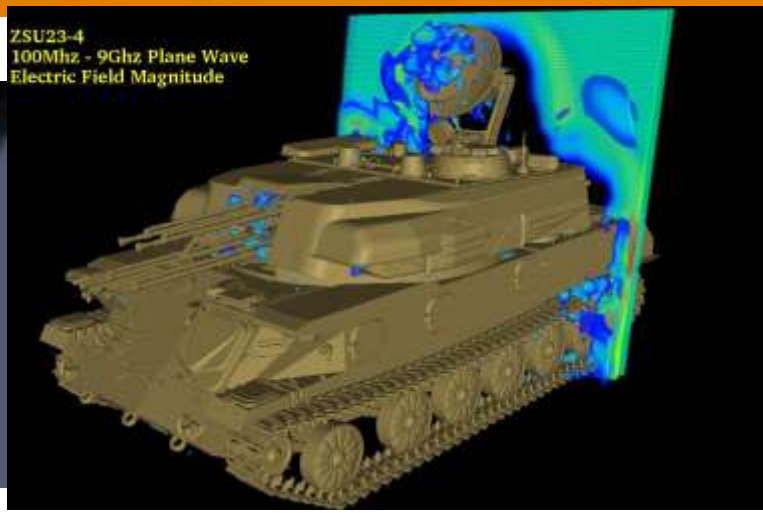
Why ParaView?

- Open-source
- Multi-platform
- Easy (open, flexible, and intuitive UI).
- Scalable (does large visualisations on clusters)

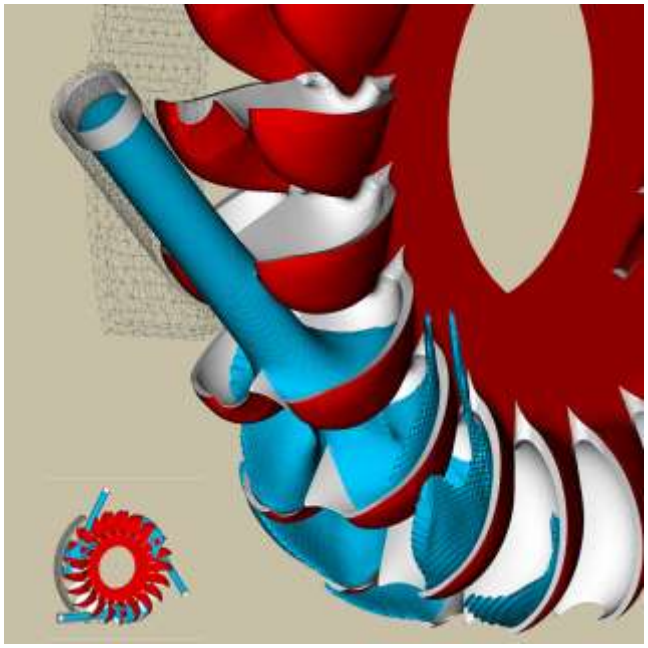
- An extensible, modular architecture based on open standards.
- A flexible BSD 3 Clause license
- Commercial maintenance and support.



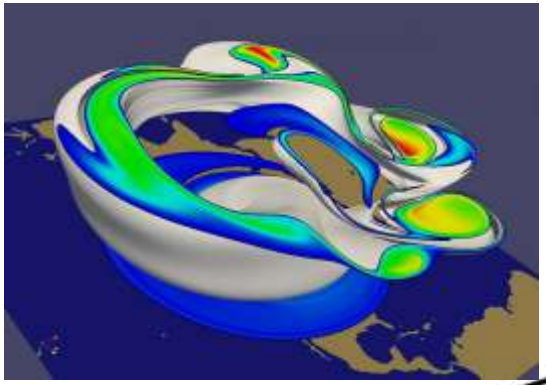


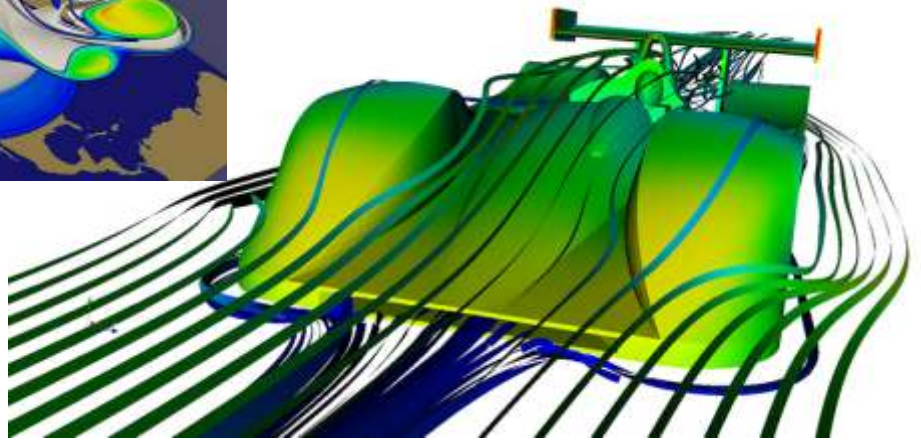


Jerry Clarke, US Army Research Laboratory



Swiss National Supercomputing Centre





Renato N. Elias, NACAD/COPPE/UFRJ, Rio de Janerio, Brazil

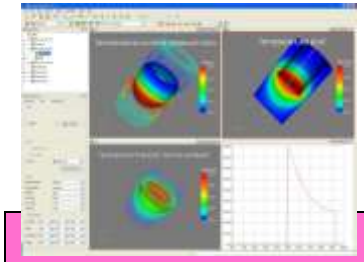
Current ParaView Usage

- Used by academic, government, and commercial institutions worldwide.
- Downloaded ~100K times per year.

- HPCwire Editors' Choice and HPCwire Readers' Choice 2010 Awards for Best Visualization Product or Technology.

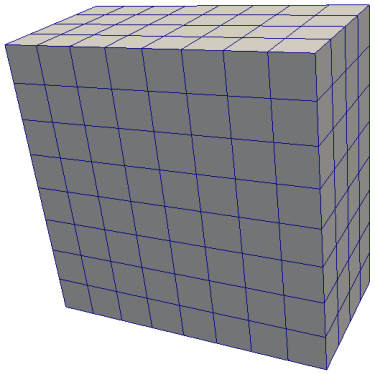
ParaView

ParaView Application Architecture

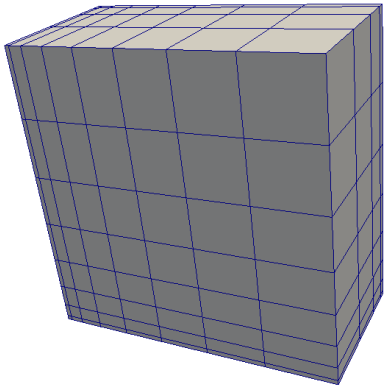


ParaView Client	pvpython	Custom App
UI (Qt Widgets, Python Wrappings)		
ParaView Server		
VTK		
OpenGL	MPI	IceT	Etc.

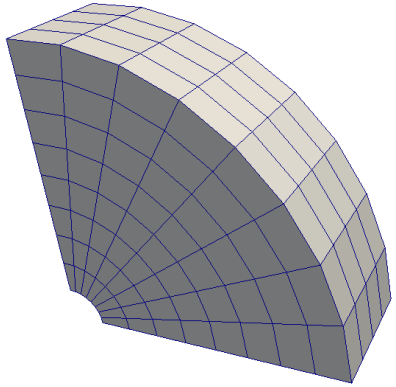
Data Types



Uniform Rectilinear
(vtkImageData)

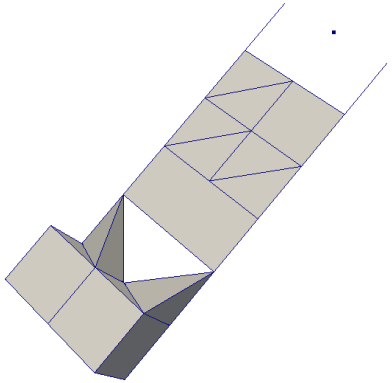


Non-Uniform Rectilinear
(vtkRectilinearData)



Curvilinear
(vtkStructuredData)

Polygonal
(vtkPolyData)



Unstructured Grid
(vtkUnstructuredGrid)

Multi-block

Hierarchical Adaptive Mesh Refinement (AMR)

Hierarchical Uniform AMR

Octree

Graphical User Interface (GUI)

User Interface

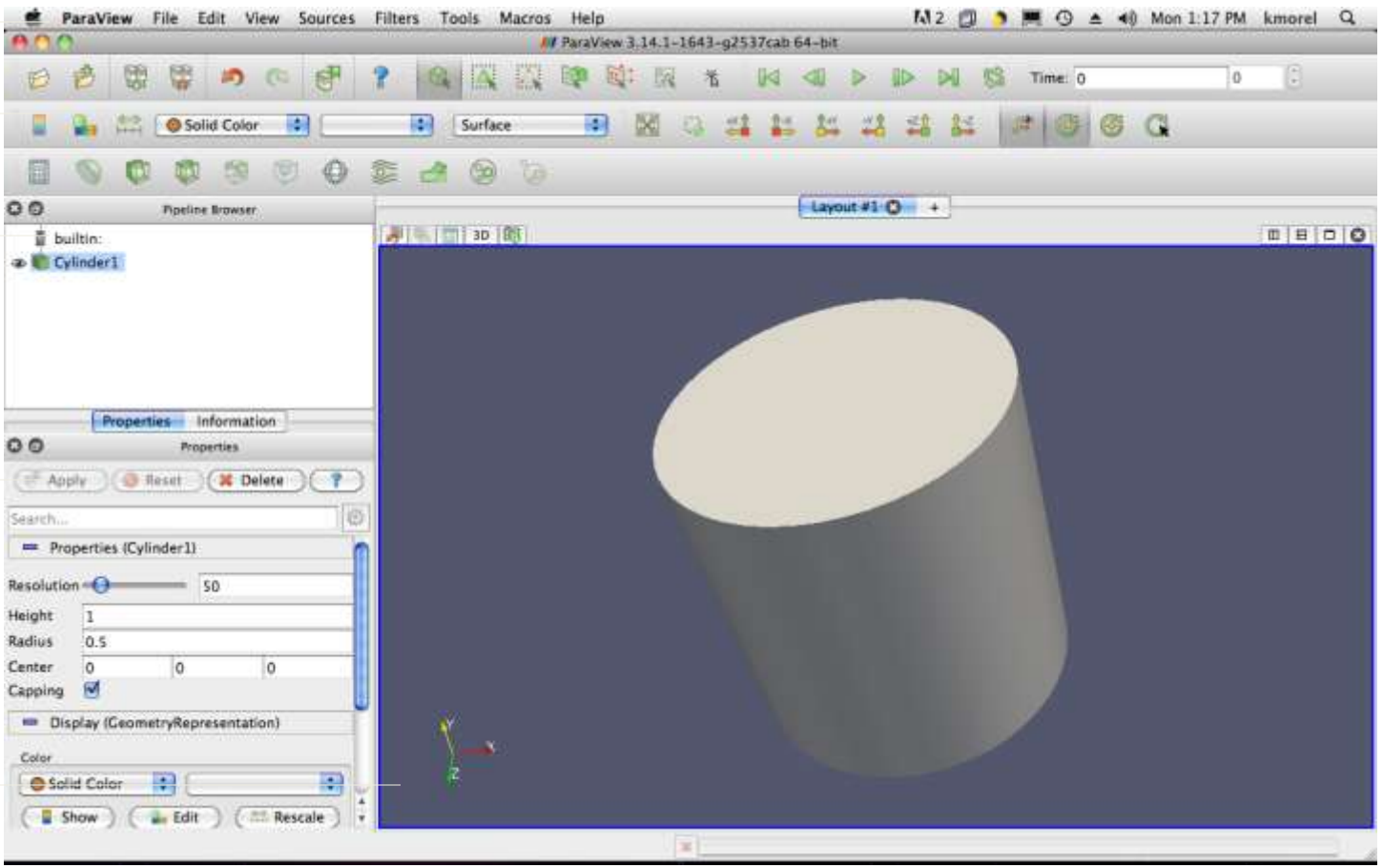
Menu Bar

Toolbars

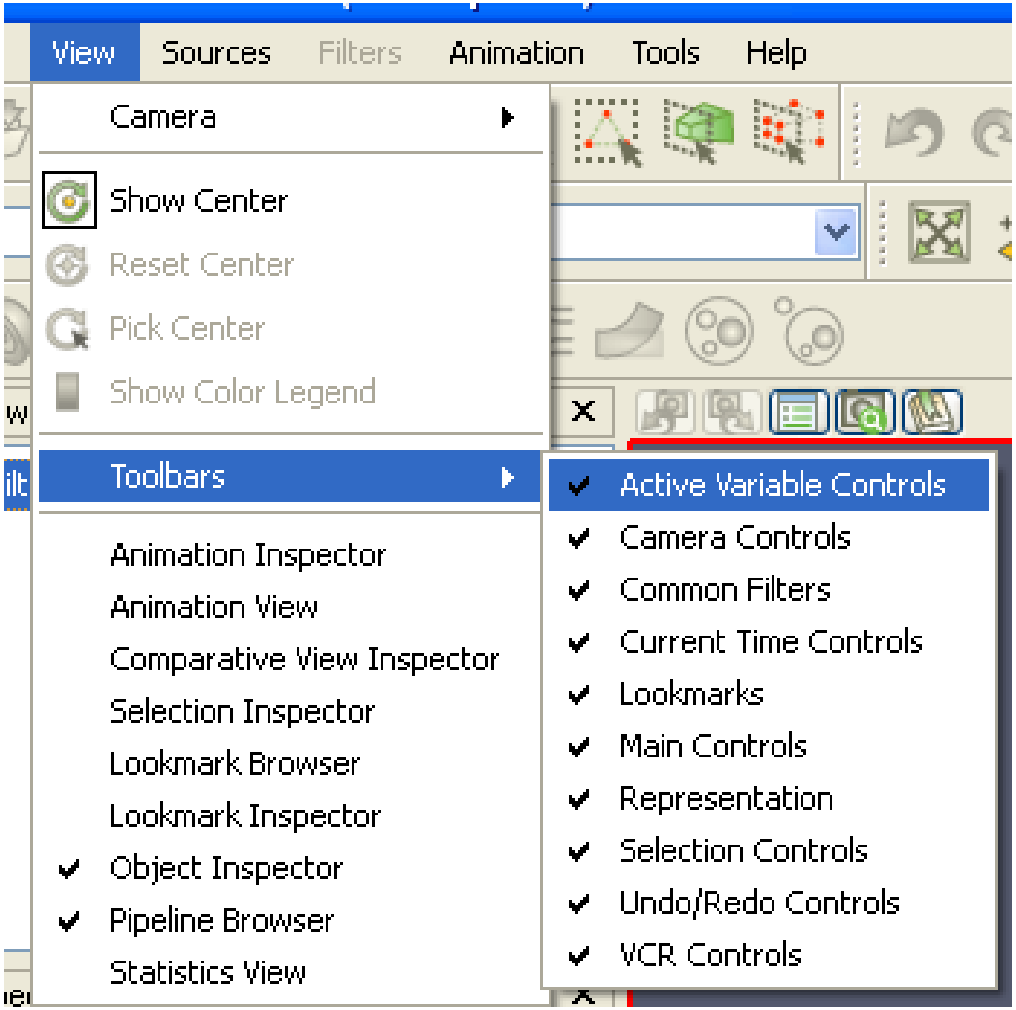
Pipeline Browser

Properties Panel

3D View



Getting Back GUI Components



Creating a Cylinder Source

1. Go to the "Sources" menu and select Cylinder.
2. Click the 

button to accept the default parameters.

Simple Camera Manipulation

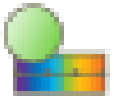
- Drag left, middle, right ▪ rotate, pan, zoom.
  - Also use Shift, Ctrl, Alt modifiers.

Creating a Cylinder Source

1. Go to the Sources menu and select Cylinder.
2. Click the Apply button to accept the default parameters. 

3. Change the Height parameter to 0.1.
4. Click the Apply button again. 

Creating a Cylinder Source

5. Look / Scroll down to the Display properties.
6. Click the  Edit button under Color.
7. Change the color.

Creating a Cylinder Source

8. Click on the  button at the top of the properties panel.
9. Increase the Resolution parameter.

10. Click the Apply button again. 

11. Click  again to hide advanced properties.

Pipeline Object Controls

Undo Redo

Undo

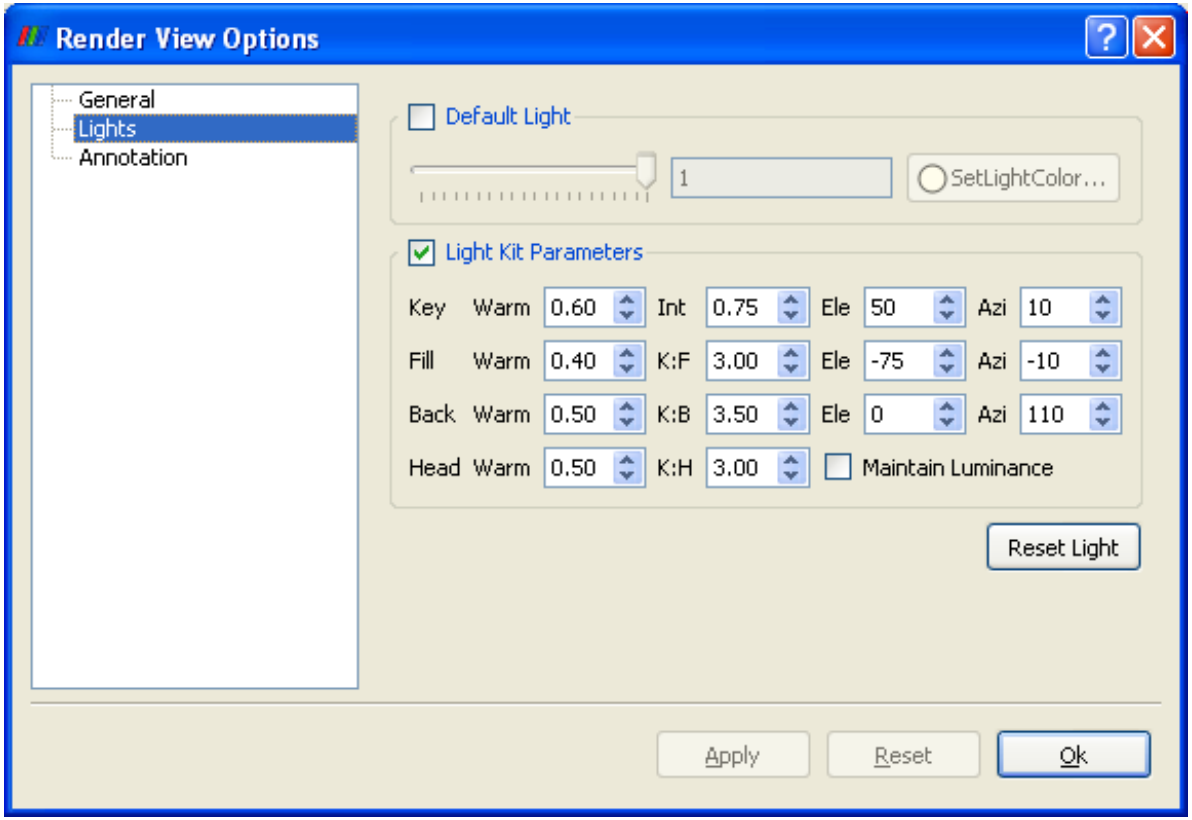
Redo

Camera
Undo

Camera
Redo

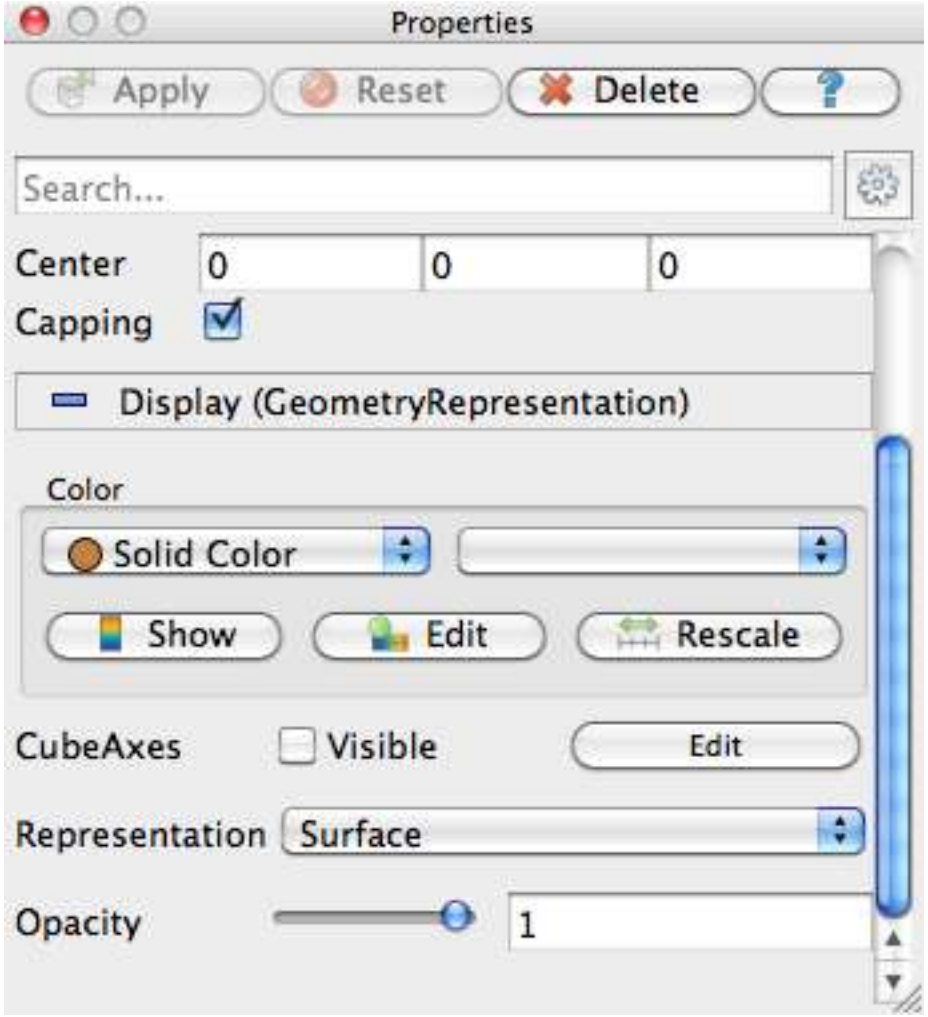
Render View Options

@ top of layout window



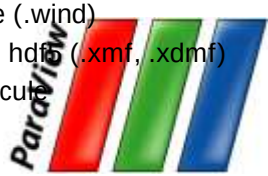
Alternatively, go to Edit -> View Settings...

Display Properties



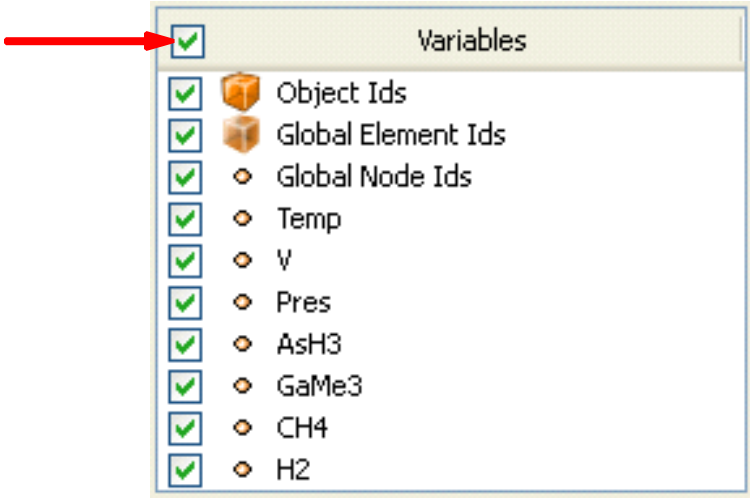
Supported Formats (USE ONE!)

- ParaView Data (.pvd)
- VTK (.vtp, .vtu, .vti, .vts, .vtr)
- VTK Legacy (.vtk)
- VTK Multi Block (.vtm,.vtmb,.vtmg,.vthd,.vthb)
- Partitioned VTK (.pvtu, .pvti, .pvts, .pvtr)
- ADAPT (.nc, .cdf, .elev, .ncd)
- ANALYZE (.img, .hdr)
- ANSYS (.inp)
- AVS UCD (.inp)
- BOV (.bov)
- BYU (.g)
- CAM NetCDF (.nc, .ncdf)
- CCSM MTSD (.nc, .cdf, .elev, .ncd)
- CCSM STSD (.nc, .cdf, .elev, .ncd)
- CEAucd (.ucd, .inp)
- CMAT (.cmat)
- CML (.cml)
- CTRL (.ctrl)
- Chombo (.hdf5, .h5)
- Claw (.claw)
- Comma Separated Values (.csv)
- Cosmology Files (.cosmo, .gadget2)
- Curve2D (.curve, .ultra, .ult, .u)
- DDCMD (.ddcmd)
- Digital Elevation Map (.dem)
- Dyna3D(.dyn)
- EnSight (.case, .sos)
- Enzo boundary and hierarchy
- ExodusII (.g, .e, .exe, .ex2, .ex2v.., etc)
- ExtrudedVol (.exvol)
- FVCOM (MTMD, MTSD, Particle, STSD)
- Facet Polygonal Data
- Flash multiblock files
- Fluent Case Files (.cas)
- GGCM (.3df, .mer)
- GTC (.h5)
- GULP (.trg)
- Gadget (.gadget)
- Gaussian Cube File (.cube)
- JPEG Image (.jpg, .jpeg)
- LAMPPS Dump (.dump)
- LAMPPS Structure Files
- LODI (.nc, .cdf, .elev, .ncd)
- LODI Particle (.nc, .cdf, .elev, .ncd)
- LS-DYNA (.k, .lsdyna, .d3plot, d3plot)
- M3DCl (.h5)
- MFIX Unstructred Grid (.RES)
- MM5 (.mm5)
- MPAS NetCDF (.nc, .ncdf)
- Meta Image (.mhd, .mha)
- Miranda (.mir, .raw)
- Multilevel 3d Plasma (.m3d, .h5)
- NASTRAN (.nas, .f06)
- Nek5000 Files
- Nrrd Raw Image (.nrrd, .nhdr)
- OpenFOAM Files (.foam)
- PATRAN (.neu)
- PFLOTRAN (.h5)
- PLOT2D (.p2d)
- PLOT3D (.xyz, .q, .x, .vp3d)
- PLY Polygonal File Format
- PNG Image Files
- POP Ocean Files
- ParaDIS Files
- Phasta Files (.pht)
- Pixie Files (.h5)
- ProSTAR (.cel, .vrt)
- Protein Data Bank (.pdb, .ent, .pdb)
- Raw Image Files
- Raw NRRD image files (.nrrd)
- SAMRAI (.samrai)
- SAR (.SAR, .sar)
- SAS (.sasgeom, .sas, .sasdata)
- SESAME Tables
- SLAC netCDF mesh and mode data
- SLAC netCDF particle data
- Silo (.silo, .pdb)
- Spheral (.spheral, .sv)
- SpyPlot CTH
- SpyPlot (.case)
- SpyPlot History (.hscth)
- Stereo Lithography (.stl)
- TFT Files
- TIFF Image Files
- TSurf Files
- Tecplot ASCII (.tec, .tp)
- Tecplot Binary (.plt)
- Tetrad (.hdf5, .h5)
- UNIC (.h5)
- VASP CHGCA (.CHG)
- VASP OUT (.OUT)
- VASP POSTCAR (.POS)
- VPIC (.vpc)
- VRML (.wrl)
- Velodyne (.vld, .rst)
- VizSchema (.h5, .vsh5)
- Wavefront Polygonal Data (.obj)
- WindBlade (.wind)
- XDMF and hdf5 (.xmf, .xdmf)
- XMol Molecule



Load disk_out_ref.ex2

1. Open the file disk_out_ref.ex2.
2. Load all data variables.

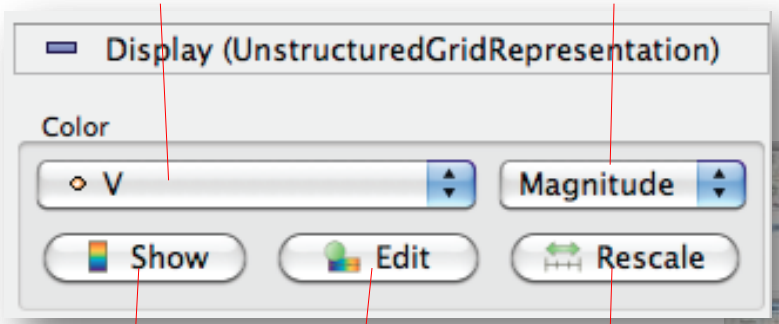


3. Click 

Data Representation

Mapped Variable

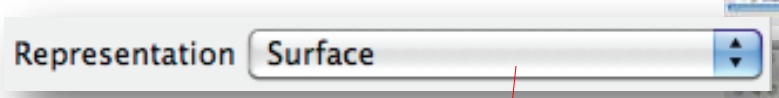
Vector Component



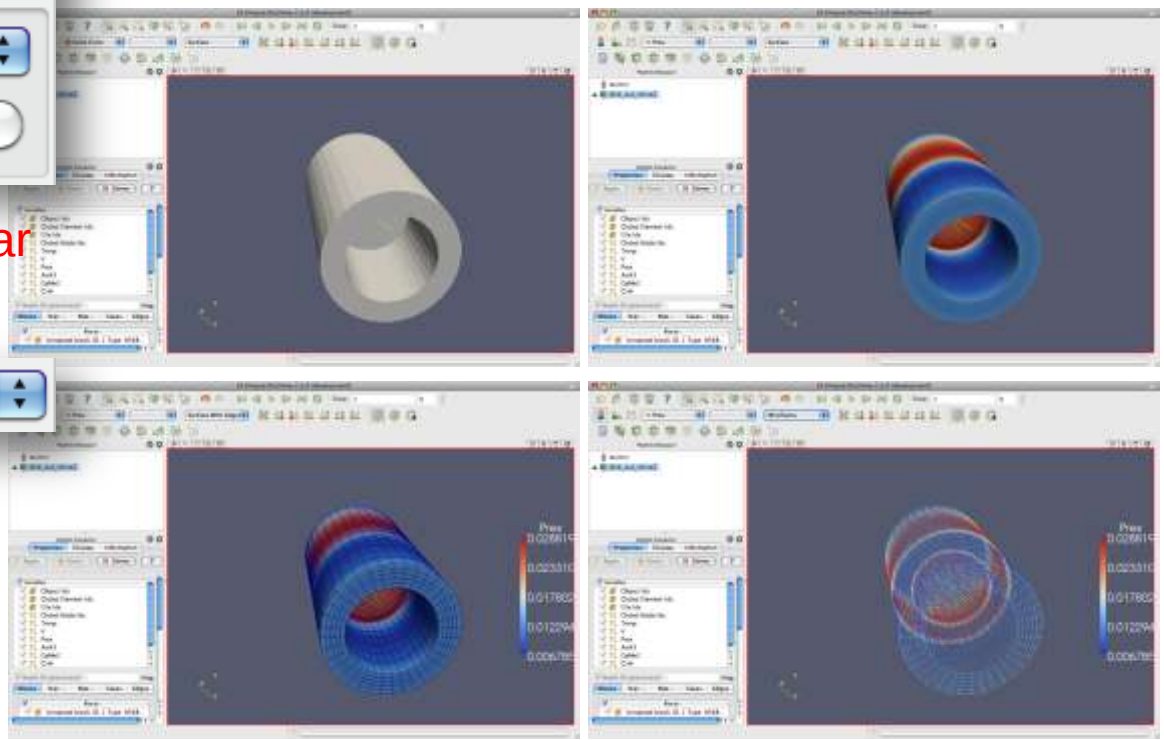
Toggle Color Legend

Edit Colors

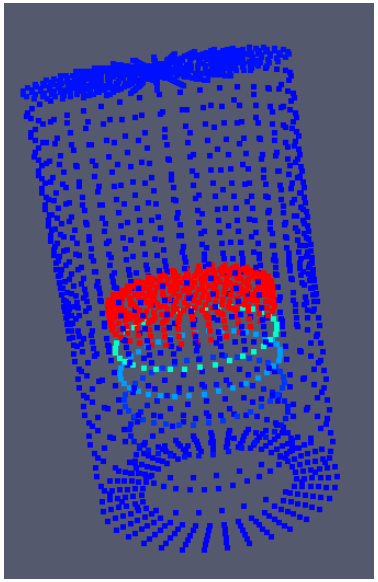
Reset Scalar Range



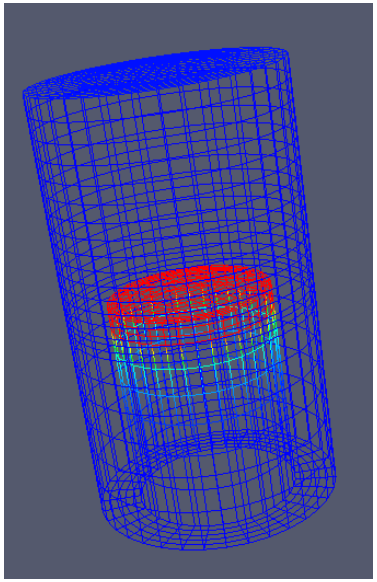
Representation



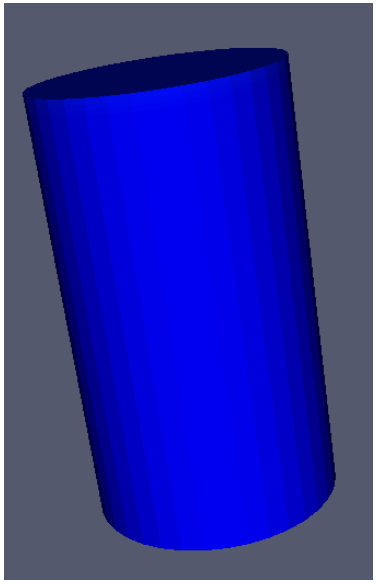
Geometry Representations



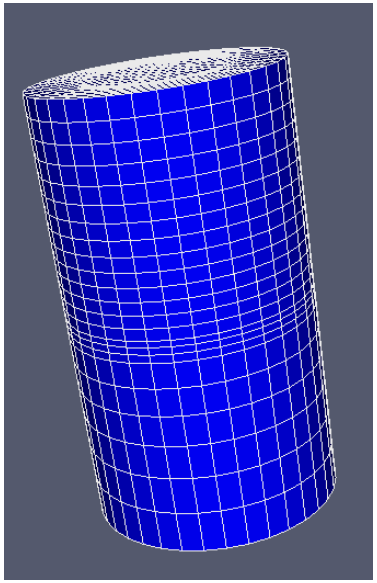
Points



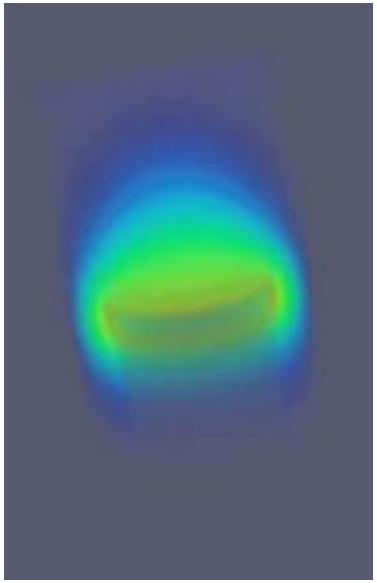
Wireframe



Surface



Surface
with Edges



Volume

Introduction to Filters

Common Filters


Calculator


Contour


Clip


Slice


Threshold


Extract Subset


Glyph

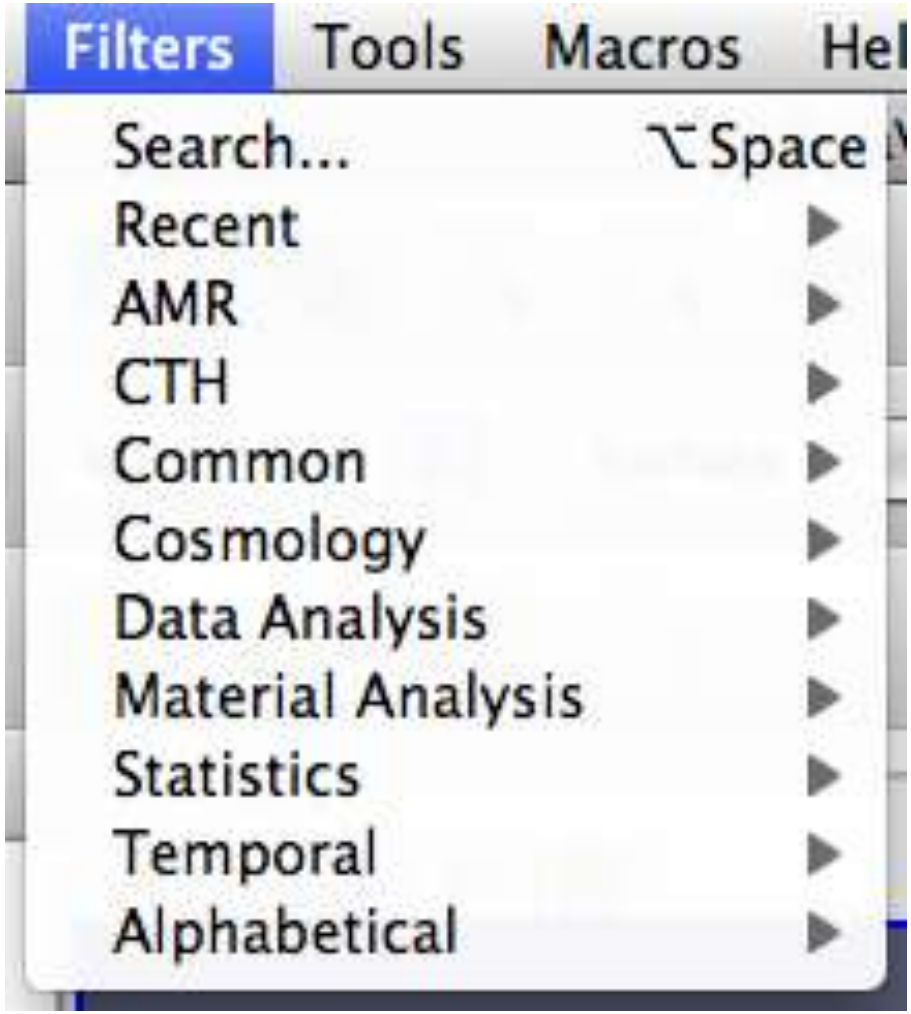

Stream Tracer


Warp (vector)

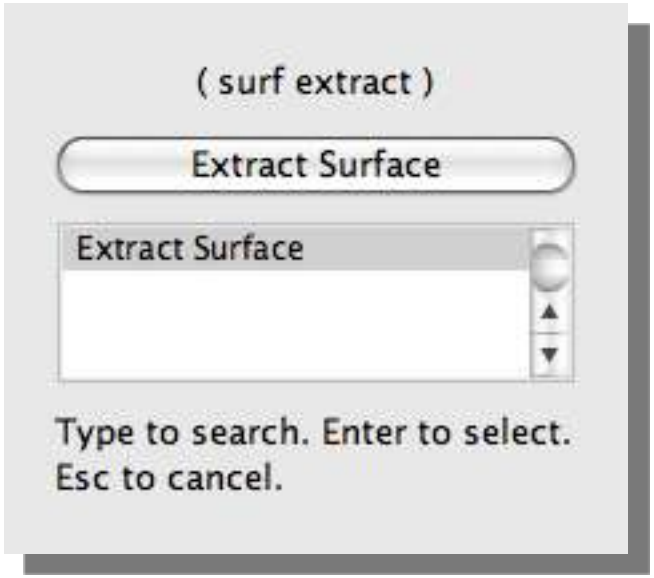

Group Datasets


Extract Level

Filters Menu



Quick Launch



- Used for searching for filters by name
- Keyboard shortcut
  - Ctrl-space for Windows & Linux
  - Alt-space for Mac

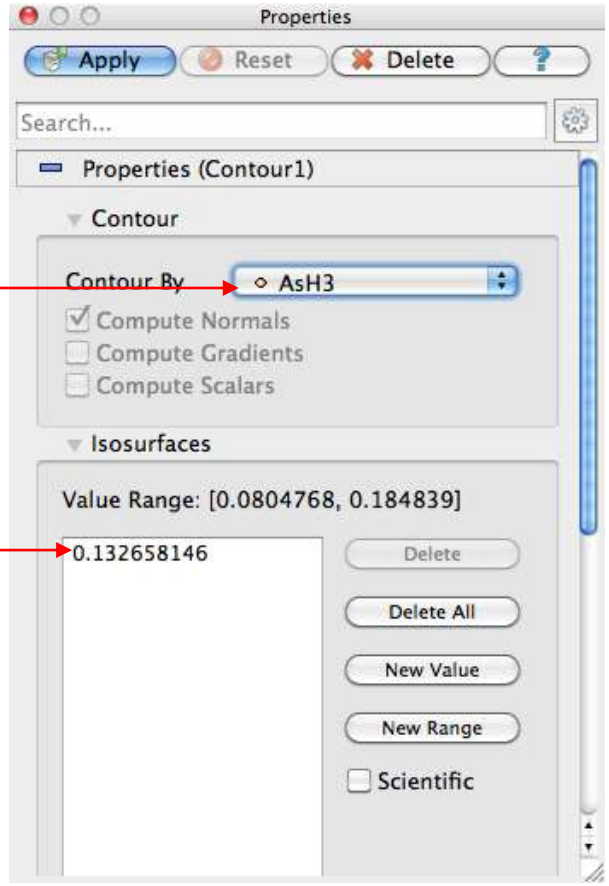
Alternatively, go to Filters -> Search...

Apply a Filter

1. Make sure that disk_out_ref.ex2 is selected in the pipeline browser.
2. Select the contour filter. 

Apply a Filter

3. Change parameters to create an isosurface at Temp = 400K.



Change to Temp

Change to 400

Apply a Filter

1. Make sure that disk_out_ref.ex2 is selected in the pipeline browser.
2. Select the contour filter. 
3. Change parameters to create an isosurface at Temp = 400K.
4. 

Create a Cutaway Surface

1. Select disk_out_ref.ex2 in the pipeline browser.
2. From the quick launch, select Extract Surface.
3. 

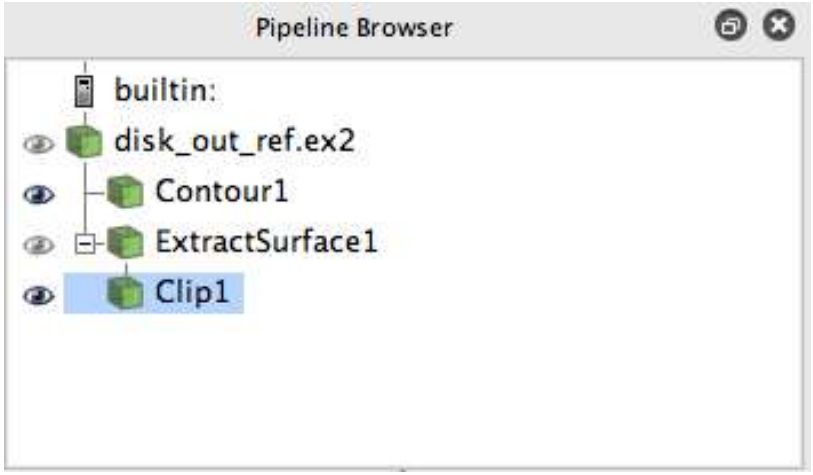
Create a Cutaway Surface

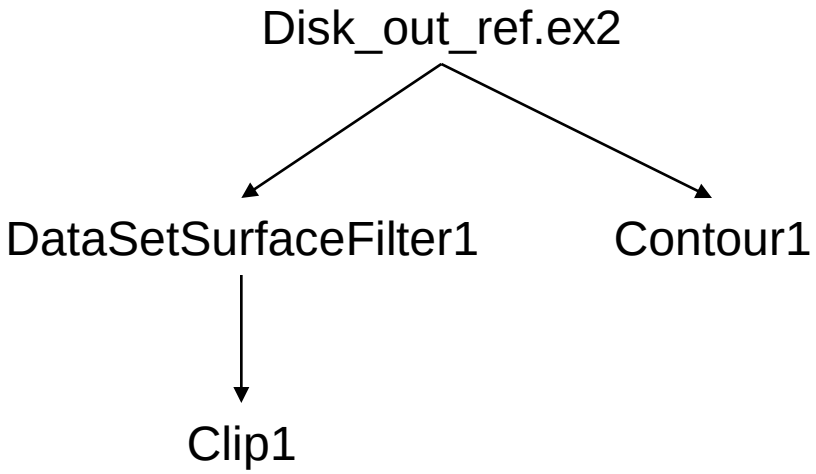
1. Select disk_out_ref.ex2 in the pipeline browser.
2. From the quick launch, select Extract Surface.
3. 

4. Create a clip filter. 
5. Uncheck Show Plane. 

6. 

Pipeline Browser Structure

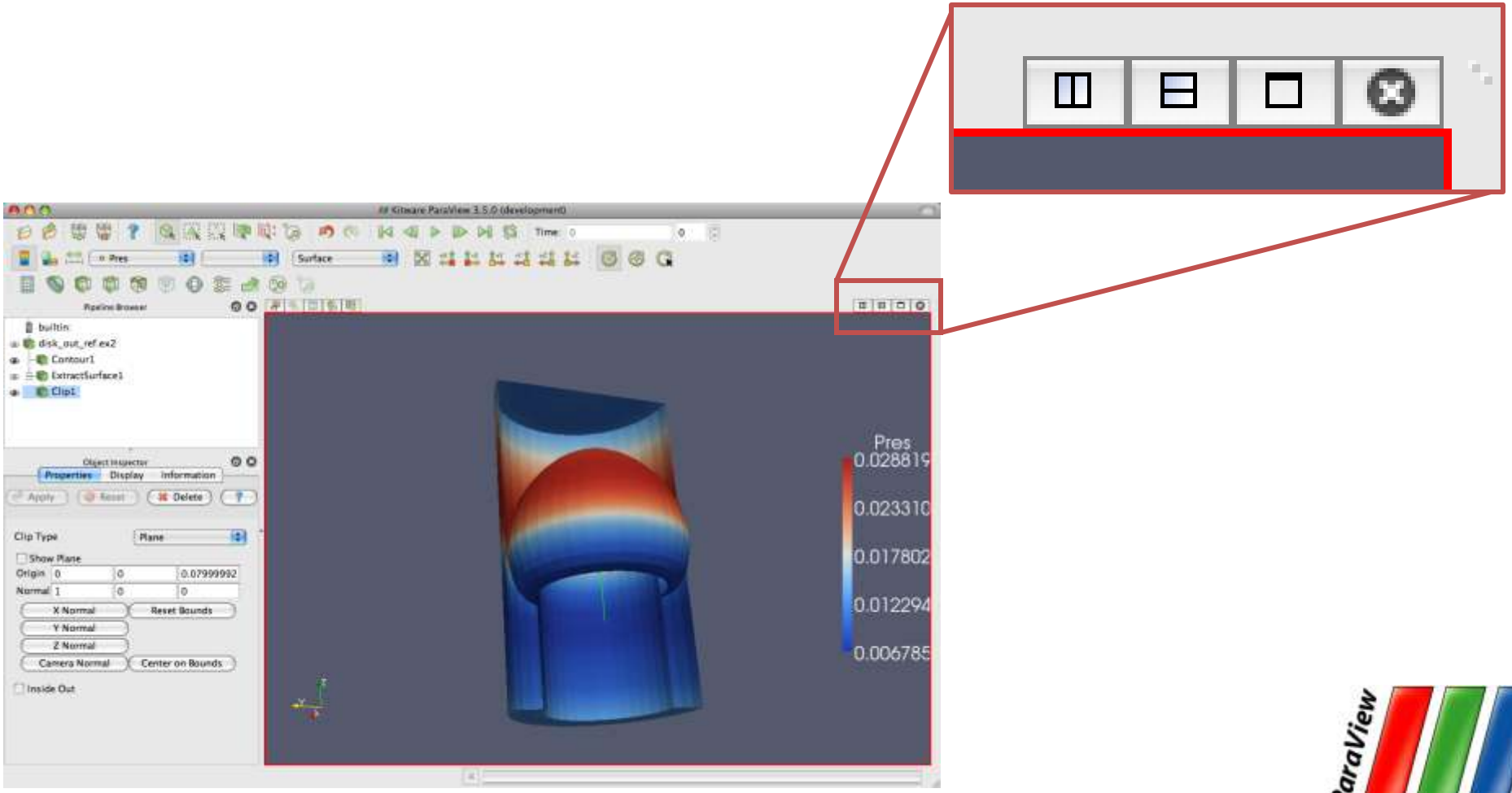




Reset ParaView

Views and Multiview

Multiview


builtin
disk_out_ref.ex2
Contour1
ExtractSurface1
Clip1
Properties
Display
Information
Apply
Reset
Delete
Clip Type
Plane
Show Plane
Origin
Normal
X Normal
Y Normal
Z Normal
Reset Bounds
Camera Normal
Center on Bounds
Inside Out
Pres
0.028819
0.023310
0.017802
0.012294
0.006785

Multiview

1. Open disk_out_ref.ex2. Load all variables 

2. Add clip filter. 
3. Uncheck Show Plane. 

4. 

5. Color surface by Pres.

Multiview

1. Split the view horizontally. 
2. Make Clip1 visible. 
3. Color surface by Temp.

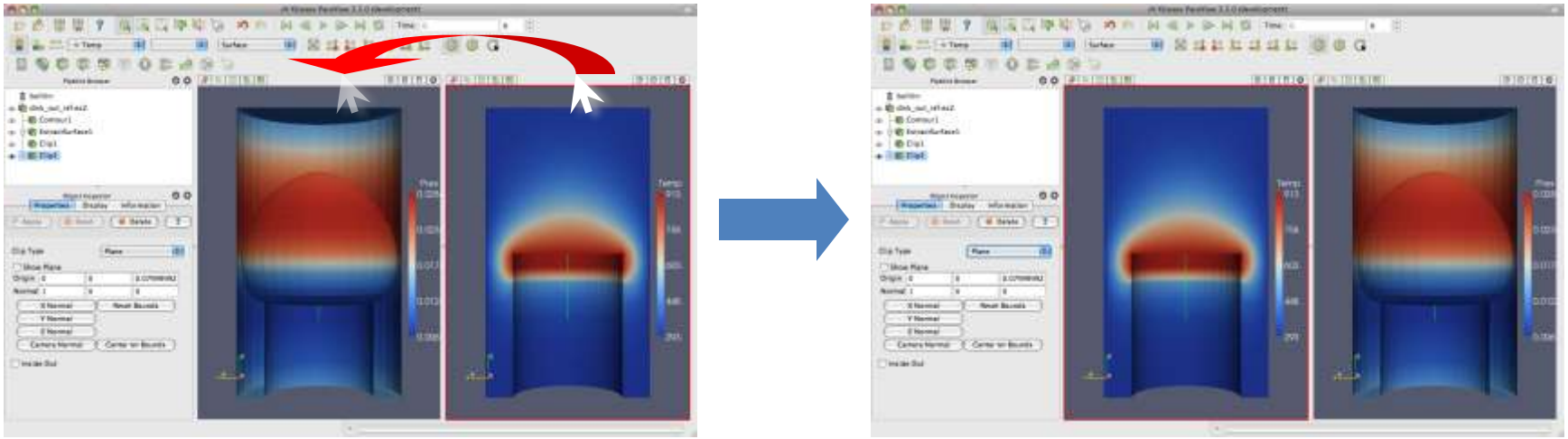
Multiview

1. Split the view horizontally. 
2. Make Clip1 visible. 
3. Color surface by Temp.
4. Right-click view background, Link Camera...
5. Click other view.

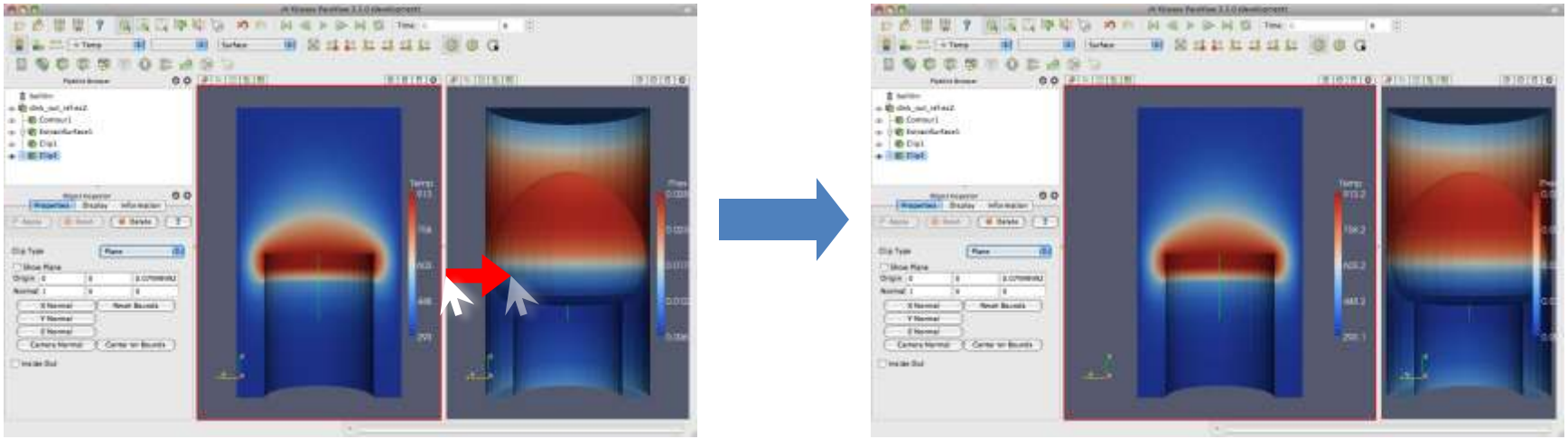
Multiview

1. Split the view horizontally.
2. Make Clip1 visible.
3. Color surface by Temp.
4. Right-click view background, Link Camera...
5. Click other view.
6. Click 

Modifying Views



Modifying Views



Reset ParaView

Streamlines

1. Open disk_out_ref.ex2. Load all variables. 

2. Add stream tracer. 
3. 

Streamlines

1. Open disk_out_ref.ex2. Load all variables. 

2. Add stream tracer. 
3. 

4. From the quick launch, select Tube
5. 

Getting Fancy

1. Select StreamTracer1.
2. Add glyph filter. 
3. Change Vectors to V.
4. Change Glyph Type to Cone.
5. 

Getting Answers

- Where is the air moving the fastest? Near the disk or away from it? At the center of the disk or near its edges?
- Which way is the plate spinning?
- At the surface of the disk, is air moving toward the center or away from it?

Reset ParaView

Plotting

1. Open disk_out_ref.ex2. Load all variables. 

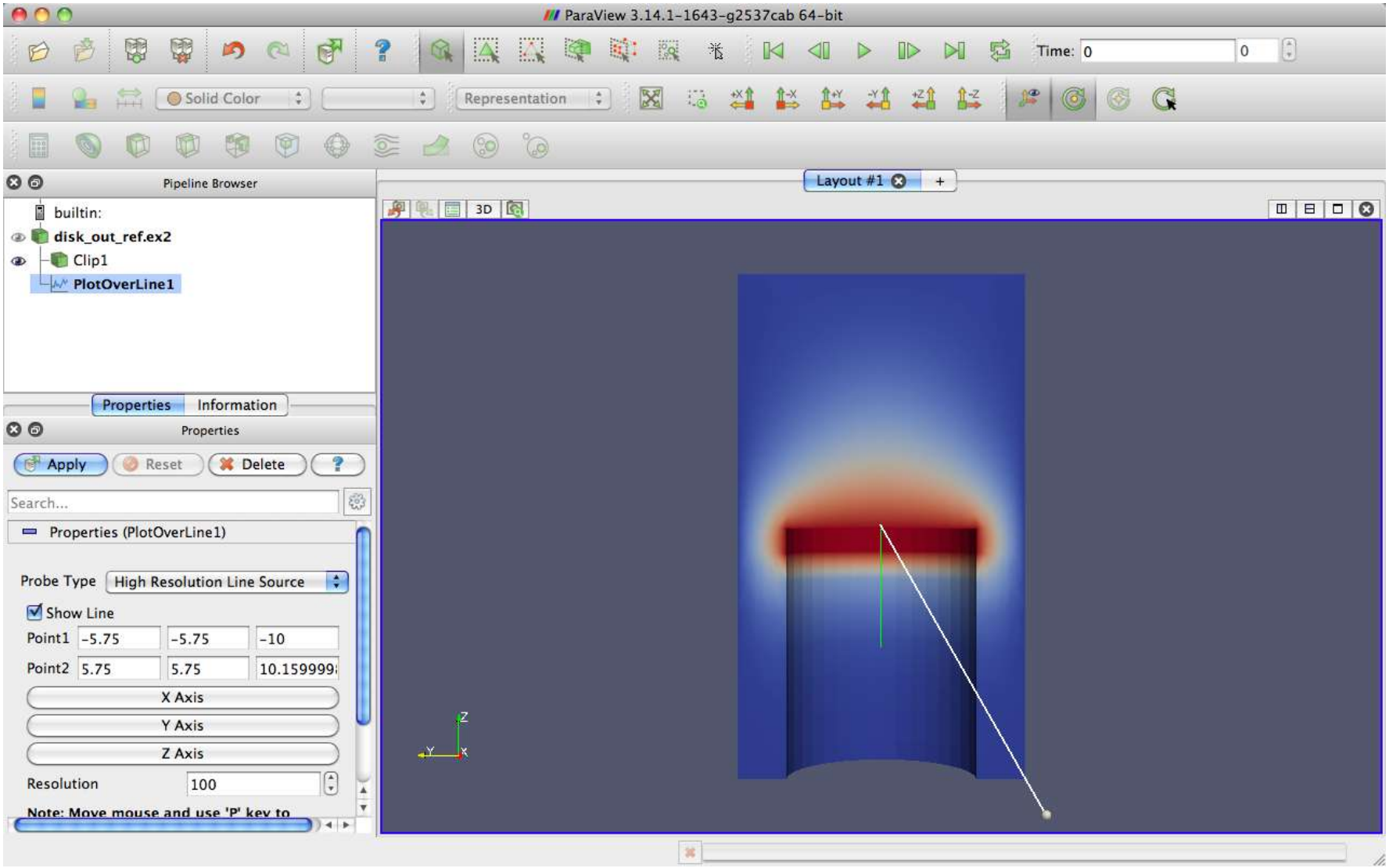
2. Clip,  uncheck, 

, 

3. Select disk_out_ref.ex2
4. Filters → Data Analysis → Plot Over Line. 

ParaView

3D Widgets


ParaView 3.14.1-1643-g2537cab 64-bit
Time: 0
Solid Color
Representation
Pipeline Browser
builtin:
disk_out_ref.ex2
Clip1
PlotOverLine1
Properties
Information
Properties
Apply
Reset
Delete
Search...
Properties (PlotOverLine1)
Probe Type
High Resolution Line Source
Show Line
Point1 -5.75 -5.75 -10
Point2 5.75 5.75 10.159999
X Axis
Y Axis
Z Axis
Resolution 100
Note: Move mouse and use 'P' key to
Layout #1
3D

Plotting

1. Open disk_out_ref.ex2. Load all variables. 

2. Clip,  uncheck, 

, 

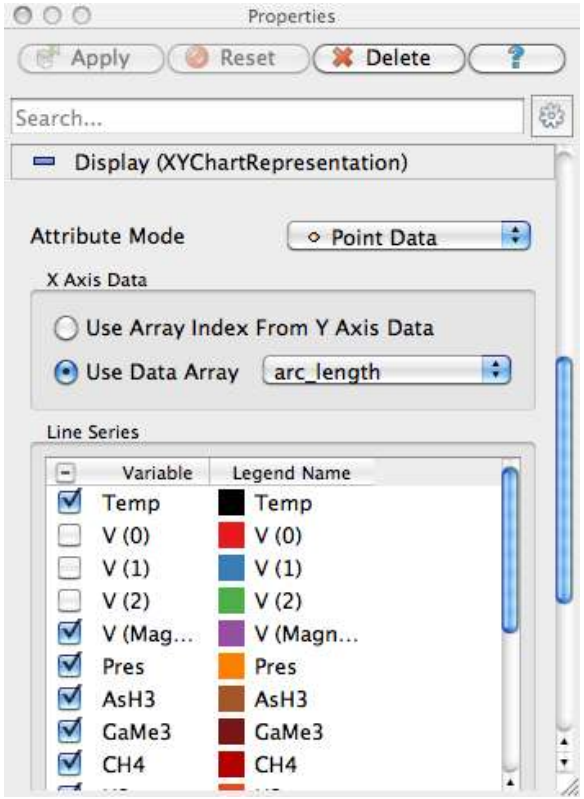
3. Select disk_out_ref.ex2
4. Filters → Data Analysis → Plot Over Line. 
5. Once line satisfactorily located, 

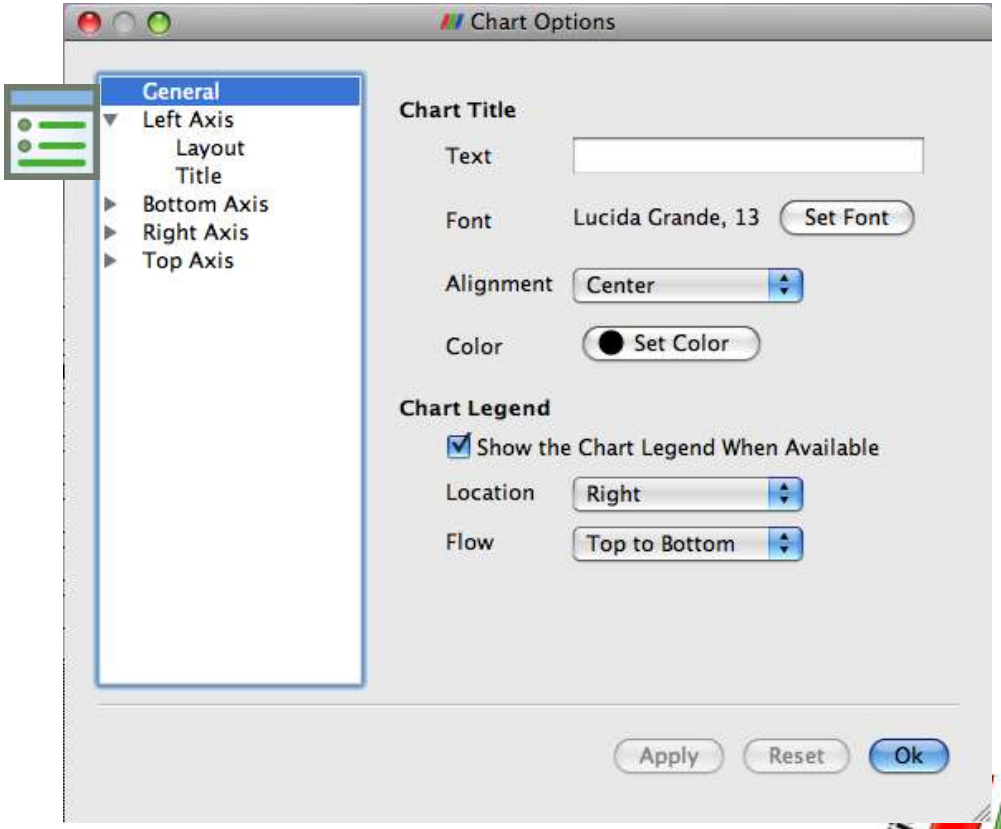
Interacting with Plots

- Left, middle, right buttons to pan, zoom.
- Mouse wheel to zoom.
- Reset view to plot ranges. 

Plots are Views

- Move them like Views.
- Save screenshots.





Adjusting Plots

1. In Display tab, turn off all variables except Temp and Pres.
2. Select Pres in the Display tab.
3. Change Chart Axis to Bottom – Right.
4. Verify the relationship between temperature and pressure.

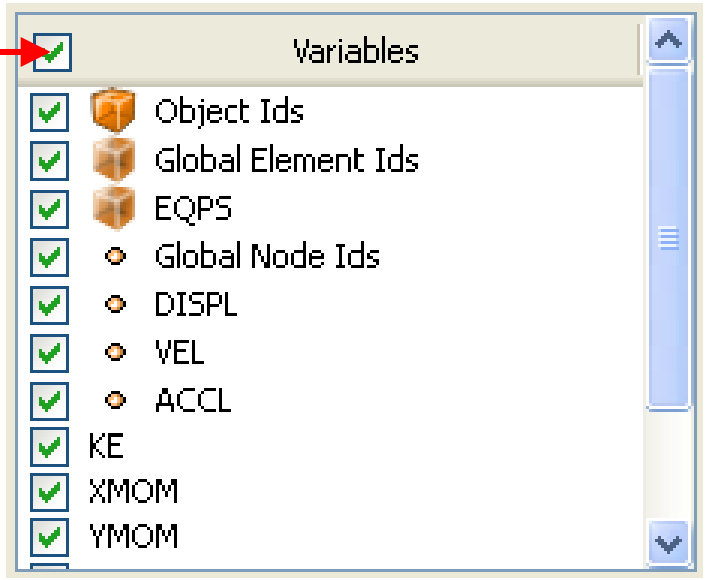
Reset ParaView

Loading Data with Time

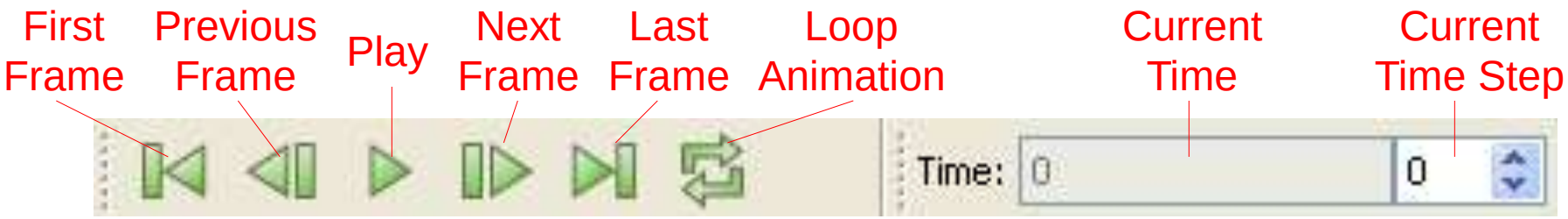
1. Open the file can.ex2.
2. Select all variables.
3. 

4. 

5. 

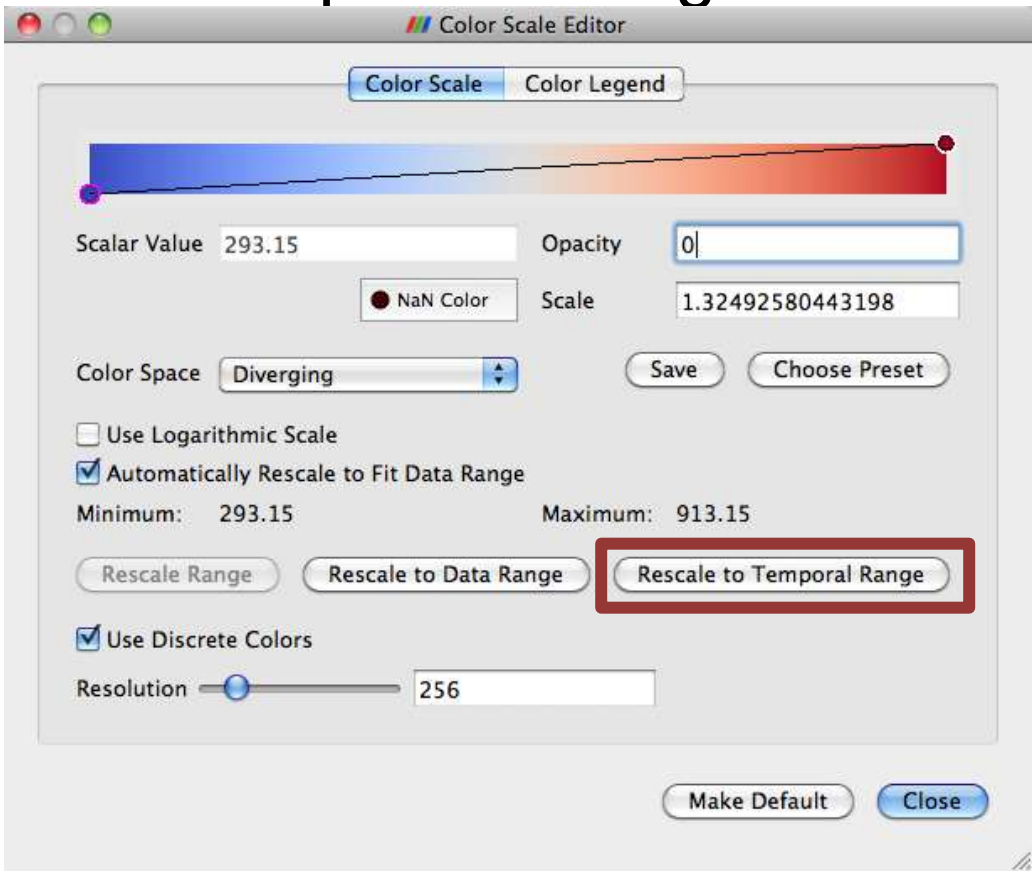


Animation Toolbar

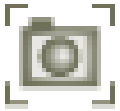


Data Range Workarounds

- Open color scale editor dialog 
- Rescale to Temporal Range



Save Screenshot / Animation

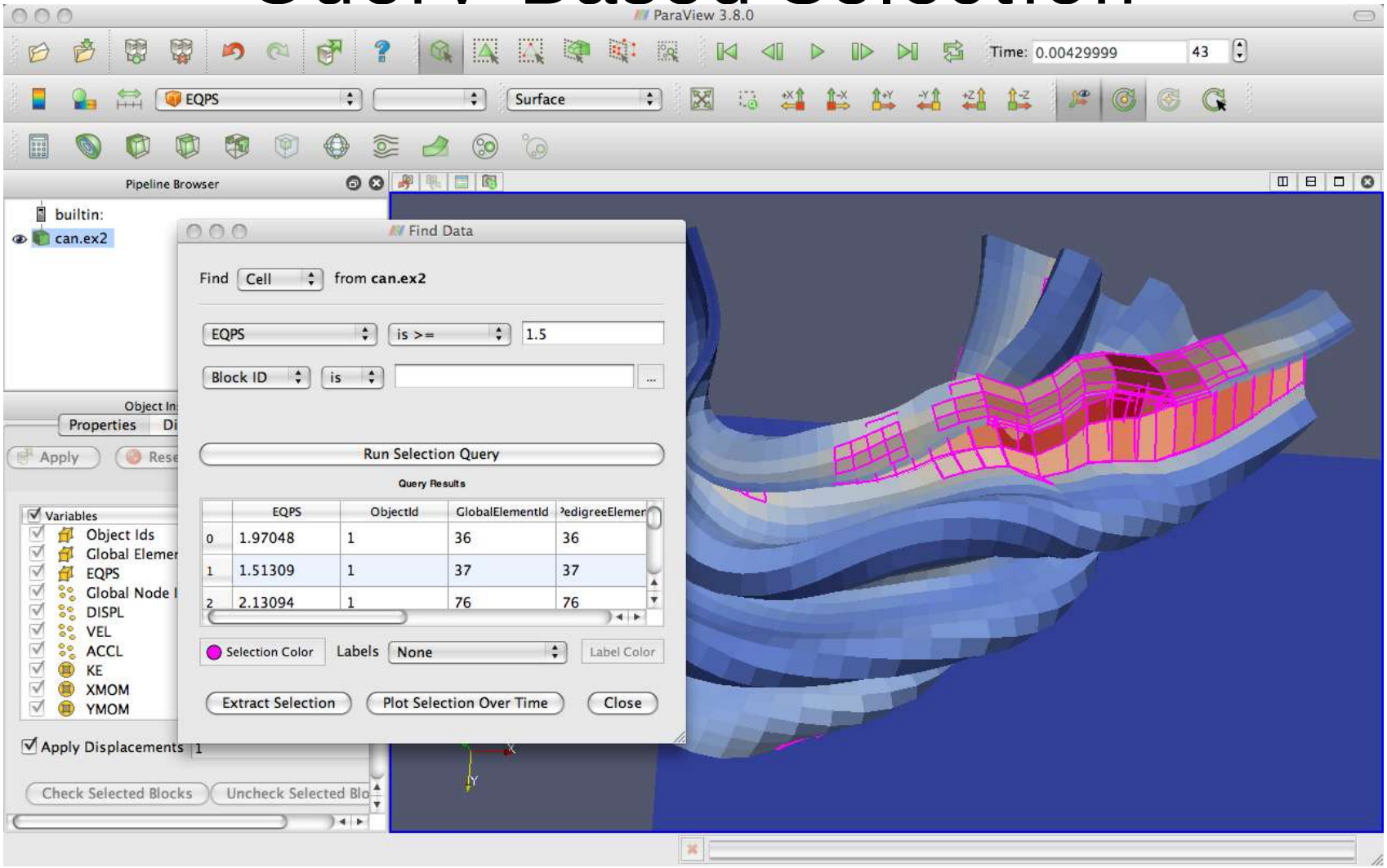
1. Choose File →  Save Screenshot...
2. Complete the subsequent dialogs to save an image.
3. Chose File →  Save Animation...
4. Complete the subsequent dialogs to save a movie.

Query-Based Selection

1. Open can.ex2. All variables. 

2. Go to last time step. 
3. Edit → Find Data.
4. Top combo box: find Cells.
5. Next row: EQPS, is >=, and 1.5.
6. Click Run Selection Query.

Query-Based Selection



Brush Selection


Surface Cell Selection (shortcut: s)

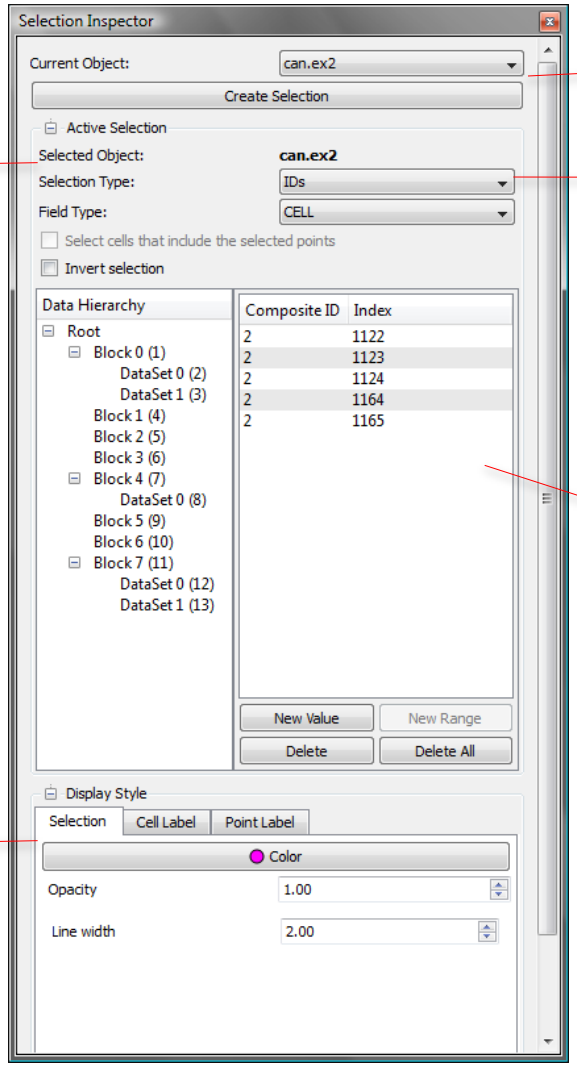

Surface Point Selection


Through Cell Selection


Through Point Selection


Block Selection (shortcut: b)

Selection Inspector



Active selection properties

Create new selection

Selection type

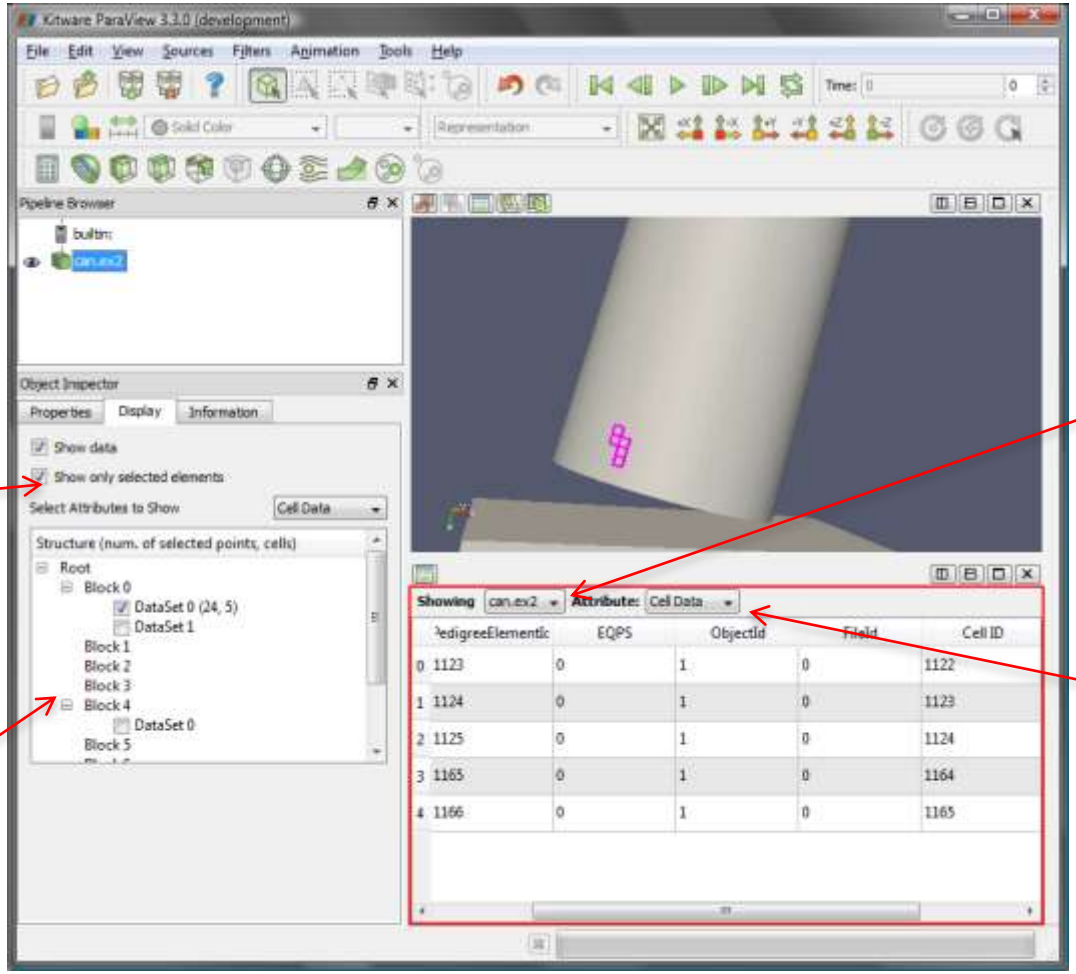
Selected cells ids

Selection display Properties/Labeling

Spreadsheet View

1. Split the view 
2. In new view, click Spreadsheet View.

Spreadsheet View



Show only selected items

Select block to inspect

What is shown in the view

Attribute shown

Plot Selection Over Time

1. Select a single cell where something "interesting" happens.
2. From the quick launch, select Plot Selection Over Time 
3. 

4. In Display panel, select different blocks to plot.

Reset ParaView

Extracting a Selection

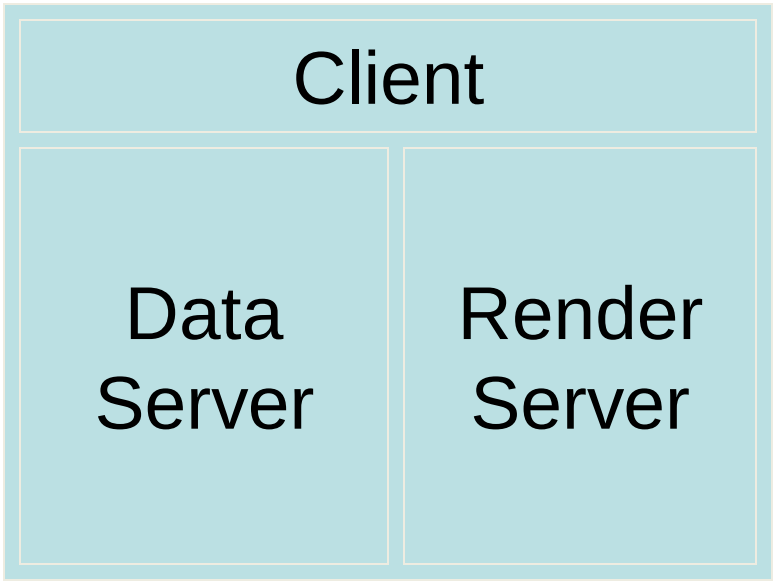
1. Open can.ex2. Load all variables. 

2. Turn off cell labels.
3. Perform a sizeable selection.
4. From the quick launch, select Extract Selection 
5. 

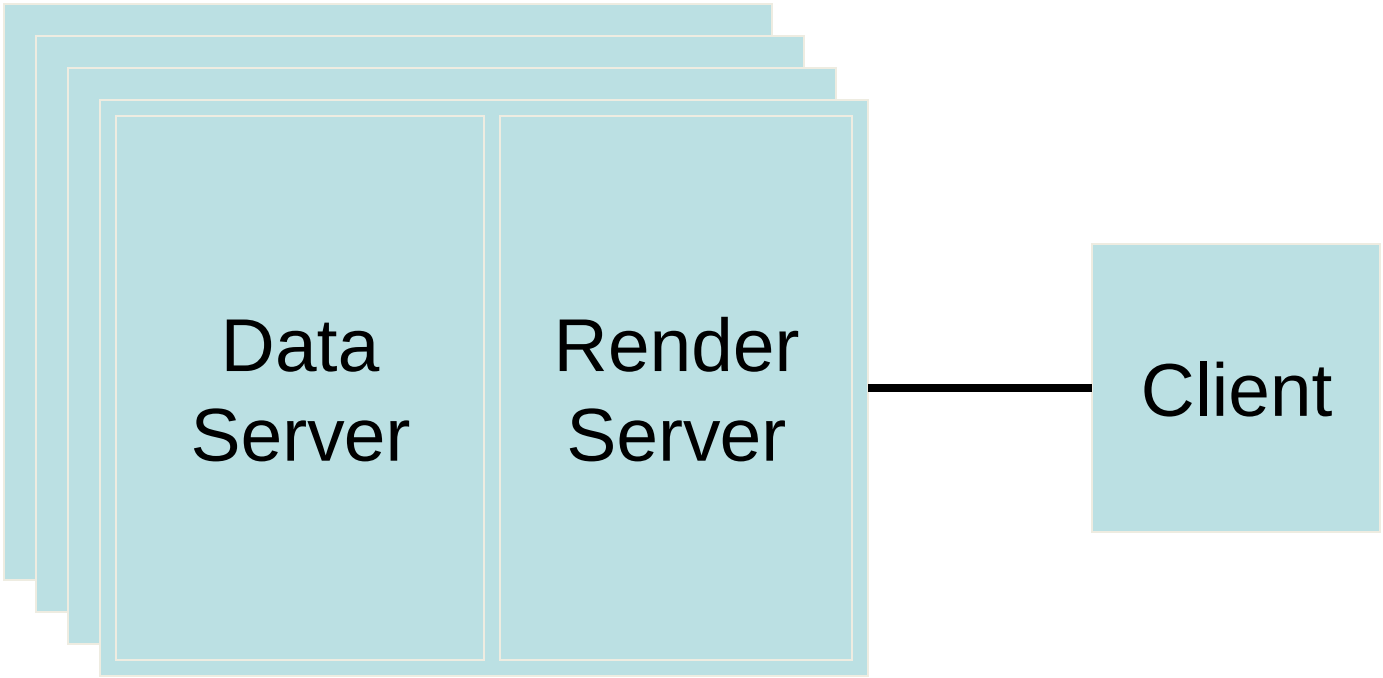
Python Trace Demo

Visualizing Large Models

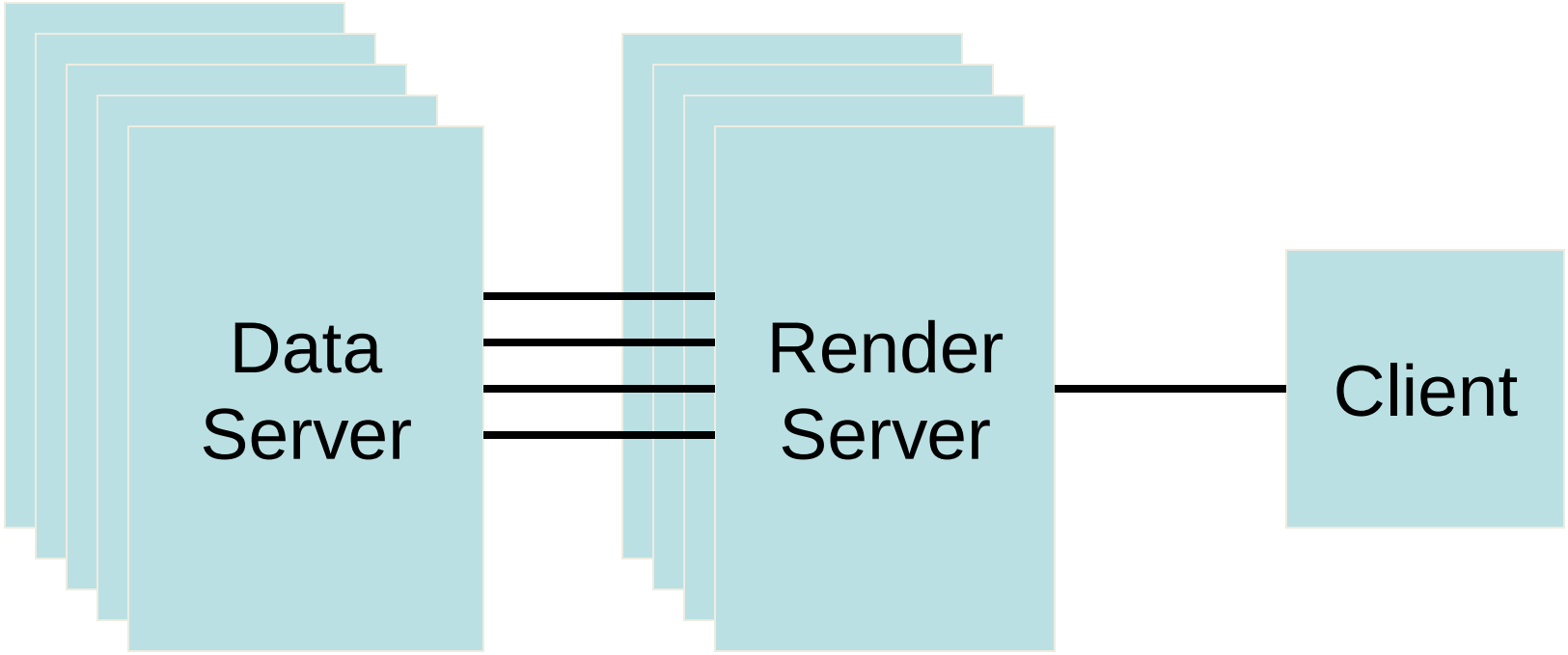
Standalone



Client-Server



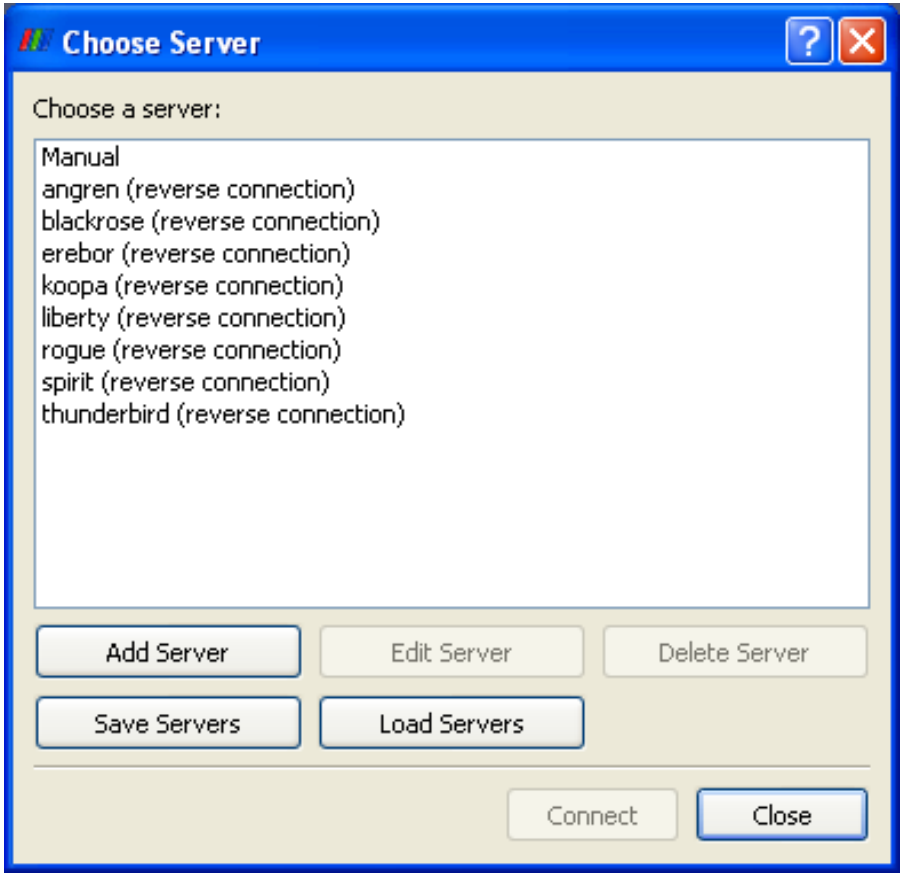
Client-Render Server-Data Server



Requirements for Installing ParaView Server

- C++
- CMake (www.cmake.org)
- MPI
- OpenGL (or Mesa3D www.mesa3d.org)
- Qt 4.6 (optional)
- Python (optional)
- http://www.paraview.org/Wiki/Setting_up_a_ParaView_Server#Compiling

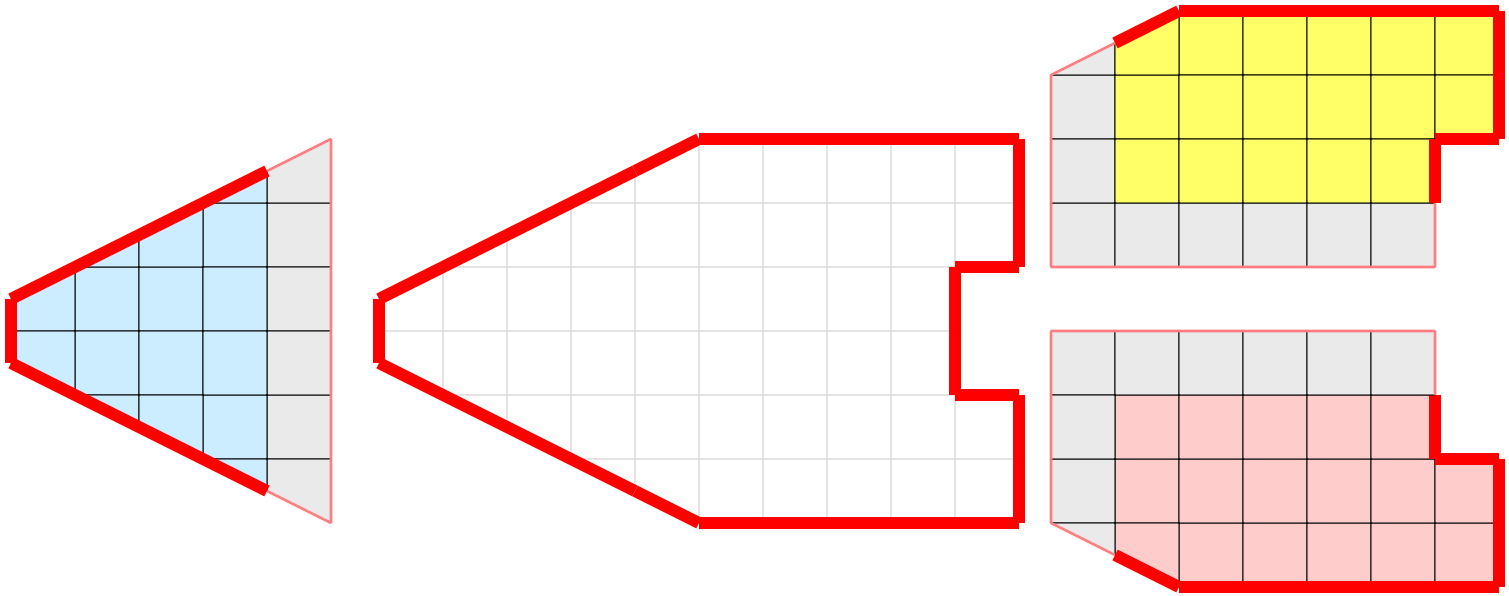
Connecting to a ParaView Server



http://www.paraview.org/Wiki/Setting_up_a_ParaView_Server#Running_the_Server

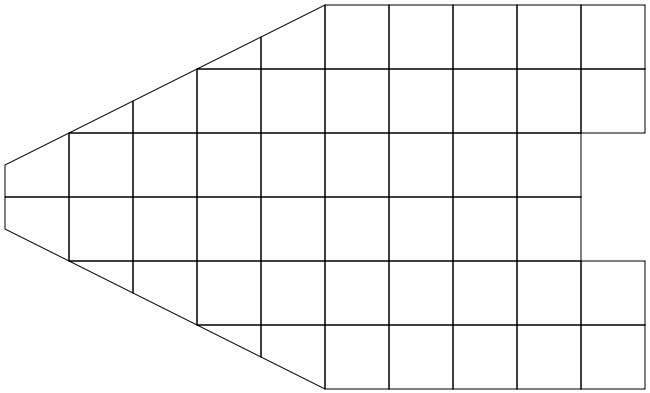
Data Parallel Pipelines

- Ghost cells can solve most of these problems.



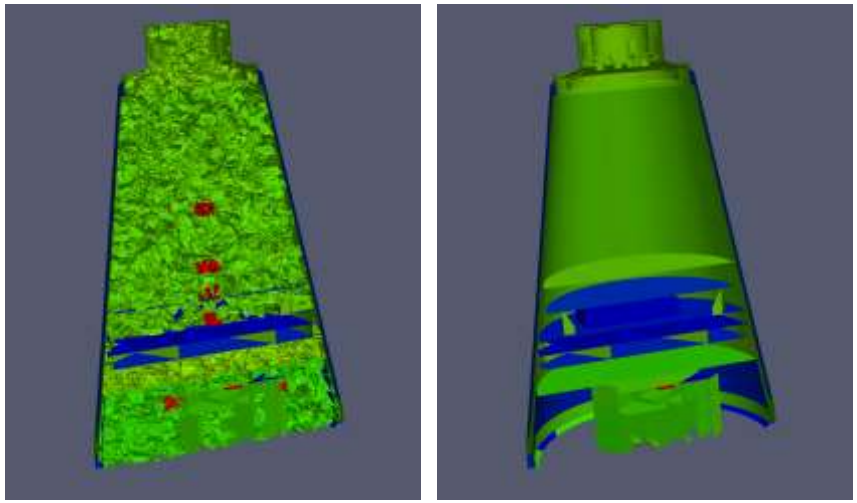
Data Partitioning

- Partitions should be load balanced and spatially coherent.



Load Balancing/Ghost Cells

- Automatic for Structured Meshes.
- Partitioning/ghost cells for unstructured is "manual."
- Use the D3 filter for unstructured
  - (Filters → Alphabetical → D3)



Job Size Rules of Thumb

- Structured Data
  - Try for max 20 M cell/processor.
  - Shoot for 5 – 10 M cell/processor.
- Unstructured Data
  - Try for max 1 M cell/processor.
  - Shoot for 250 – 500 K cell/processor.

Avoiding Data Explosion

- Pipeline may cause data to be copied, created, converted.
- This advice only for dealing with very large amounts of data.
  - Remaining available memory is low.

Topology Changing, No Reduction

- Append Datasets
- Append Geometry
- Clean
- Clean to Grid
- Connectivity
- D3
- Delaunay 2D/3D
- Extract Edges
- Linear Extrusion
- Loop Subdivision
- Reflect
- Rotational Extrusion
- Shrink
- Smooth
- Subdivide
- Tessellate
- Tetrahedralize
- Triangle Strips
- Triangulate

Topology Changing, Moderate Reduction

- Clip 
- Decimate
- Extract Cells by Region

- Extract Selection 
- Quadric Clustering
- Threshold 

Similar: Extract Subset 

Topology Changing, Dimension Reduction

- Cell Centers
- Contour 
- Extract CTH Fragments
- Extract CTH Parts
- Extract Surface
- Feature Edges
- Mask Points
- Outline (curvilinear)
- Slice 
- Stream Tracer 

Adds Field Data

- Block Scalars
- Calculator 
- Cell Data to Point Data
- Compute Derivatives
- Curvature
- Elevation
- Generate Ids
- Gen. Surface Normals
- Gradient
- Level Scalars
- Median
- Mesh Quality
- Octree Depth Limit
- Octree Depth Scalars
- Point Data to Cell Data
- Process Id Scalars
- Random Vectors
- Resample with dataset
- Surface Flow
- Surface Vectors
- Texture Map to...
- Transform
- Warp (scalar)
- Warp (vector) 

Total Shallow Copy or Output Independent of Input

- Annotate Time
- Append Attributes
- Extract Block
- Extract Datasets
- Extract Level 
- Glyph 
- Group Datasets 
- Histogram 
- Integrate Variables
- Normal Glyphs
- Outline
- Outline Corners
- Plot Global Variables Over Time
- Plot Over Line 
- Plot Selection Over Time 
- Probe Location 
- Temporal Shift Scale
- Temporal Snap-to-Time-Steps
- Temporal Statistics

ParaView

Culling Data

- Reduce dimensionality early.
  - Contour and slice "see" inside volumes.
- Prefer data reduction over extraction.
  - Slice instead of Clip.
  - Contour instead of Threshold.
- Only extract when reducing an order of magnitude or more.
  - Can still run into trouble.

Culling Data

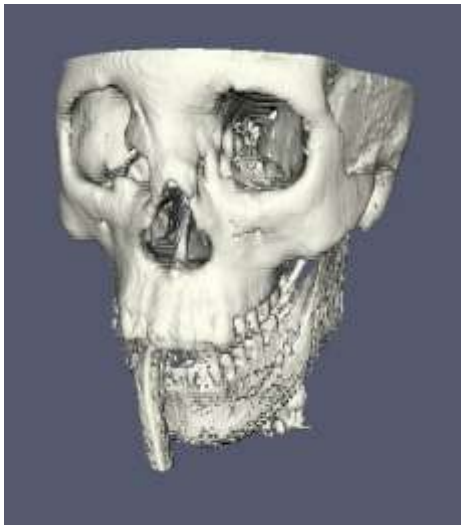
- Experiment with subsampled data.
  - Extract Subset
- Use caution.
  - Subsampled data may be lacking.
  - Use full data to draw final conclusions.

Rendering Modes

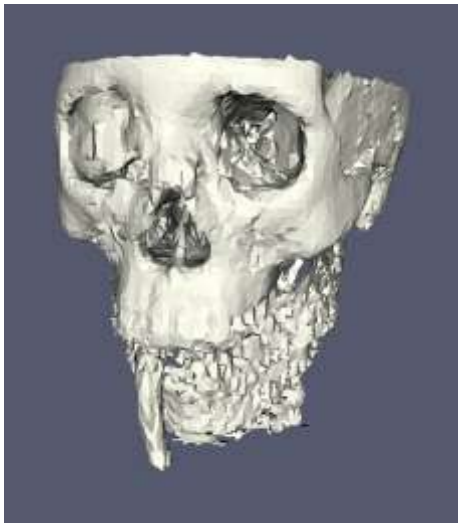
- Still Render
  - Full detail render.
- Interactive Render
  - Sacrifices detail for speed.
  - Provides quick rendering rate.
  - Used when interacting with 3D view.

Level of Detail (LOD)

- Geometric decimation
- Used only with Interactive Render



Original Data



Divisions: 50x50x50

Divisions: 10x10x10

3D Rendering Parameters

Edit → Settings, Render View → General

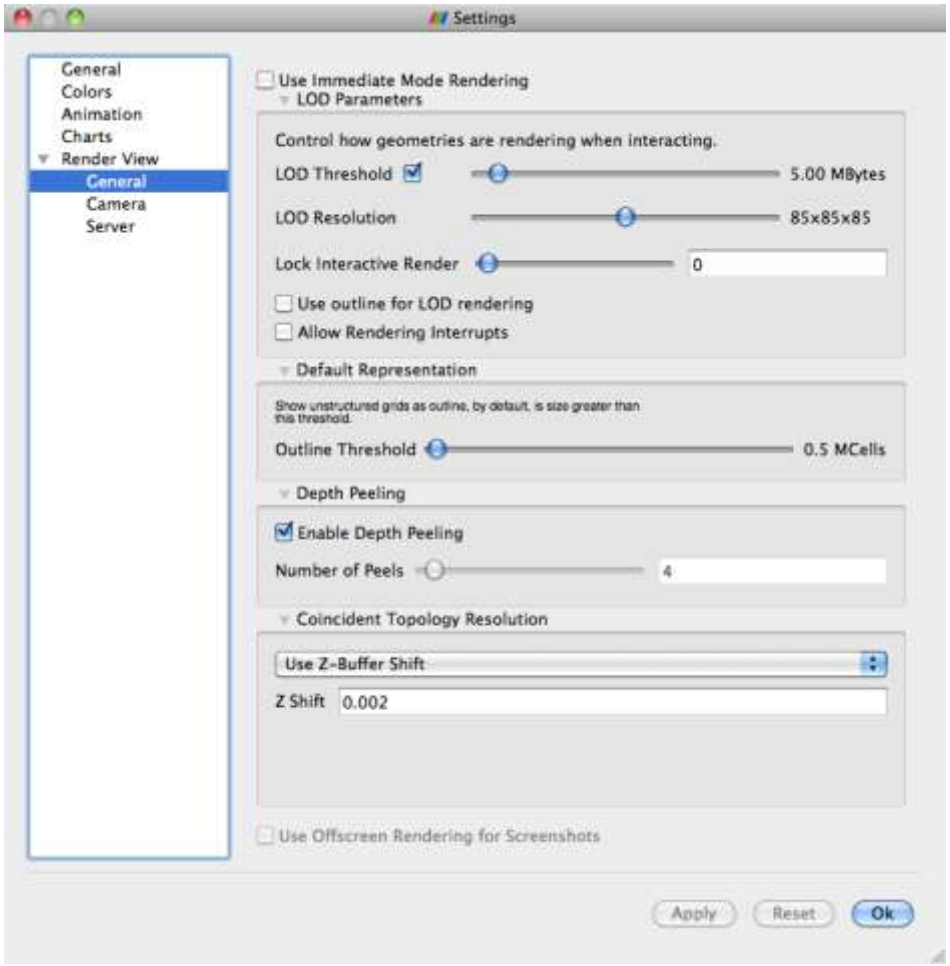
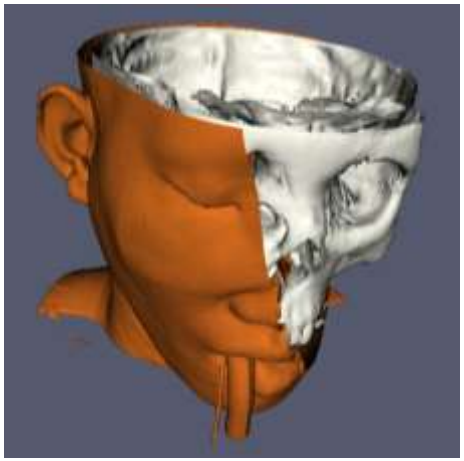
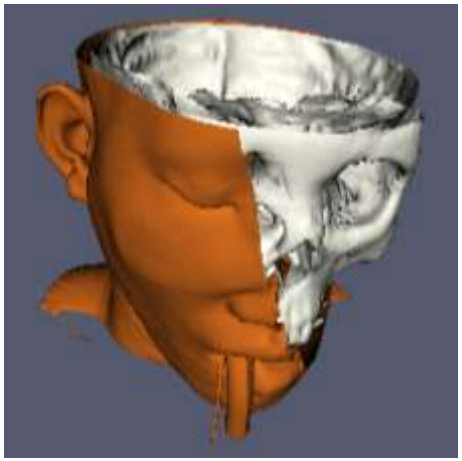


Image Size LOD

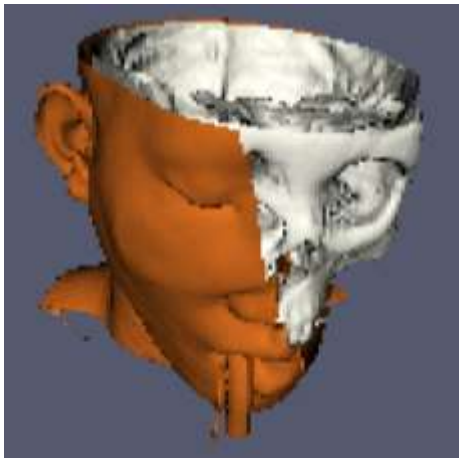
- ParaView's parallel rendering overhead proportional to image size.
- Can use smaller images for interactive rendering.



Original Data



Subsample Rate: 2 pixels

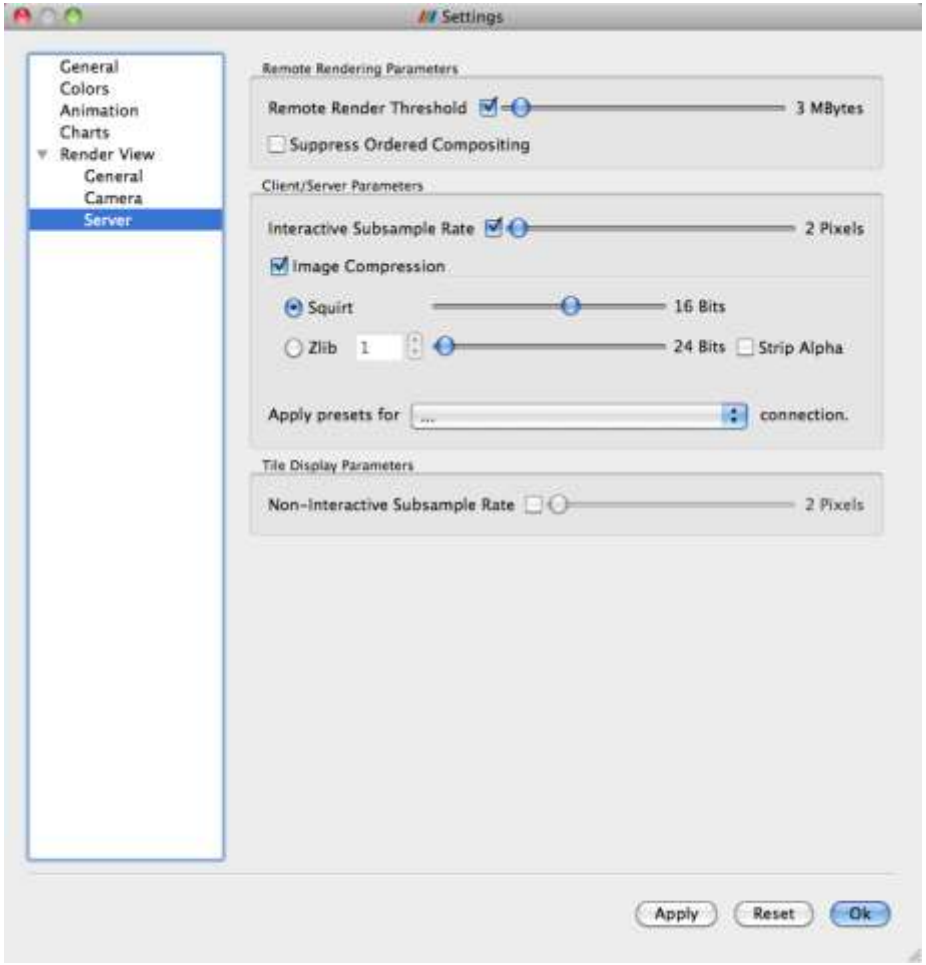


Subsample Rate: 4 pixels

Subsample Rate: 8 pixels

Parallel Rendering Parameters

Edit → Settings, Render View → Server



Parameters for Large Data

- Use Immediate Mode Rendering off for GPU, on for CPU.
- Try LOD Threshold *off*.
  - Also try LOD Resolution 10x10x10.
- Always have remote rendering on.
- Turn on subsampling.
- Image Compression on.

Parameters for Low Bandwidth

- Try larger subsampling rates.
- Try Zlib compression and fewer bits.

Parameters for High Latency

- Turn up Remote Render Threshold.
- Turn on Use outline for LOD rendering if necessary.
- Play with the LOD Threshold and LOD Resolution to control geometry sent to client.
- Try turning on Lock Interactive Render.

Further Reading

- Amy Henderson Squillacote. *The ParaView Guide*. Kitware, Inc., 2006.
- http://www.paraview.org/Wiki/ParaView
- http://www.paraview.org/Wiki/Setting_up_a_ParaView_Server