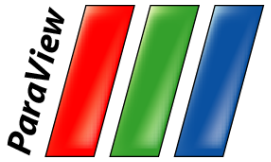


Large Scale Visualization with ParaView

ATPESC 2018

Dan Lipsa
Kitware, Inc.

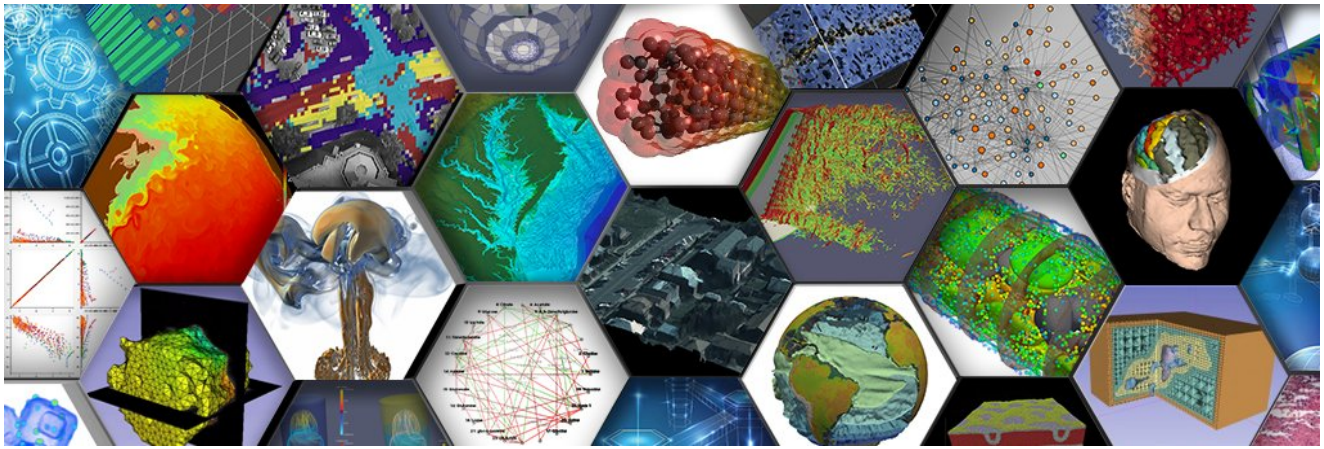
Kitware

Outline

- Kitware
- Introduction
- Basic Usage
- Visualizing Large Models

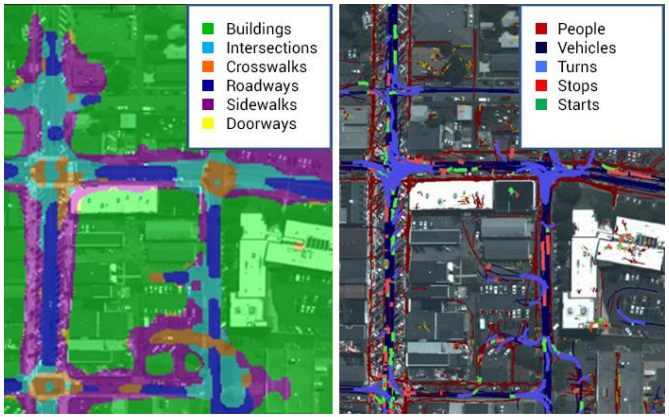
Kitware

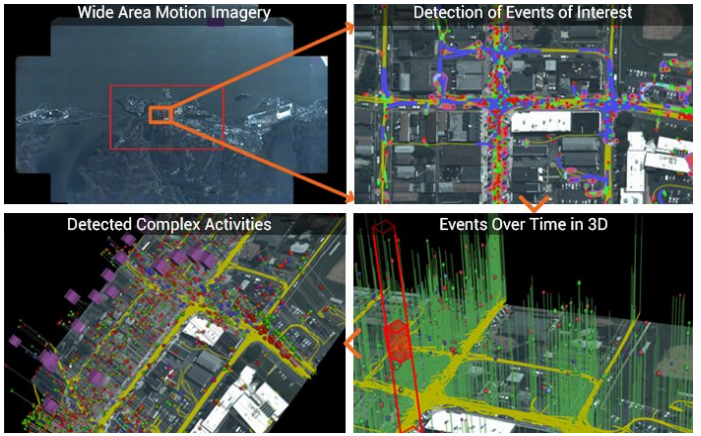
- Computer Vision
- Data and Analytics
- HPC and Visualization
- Medical Computing
- Software Process

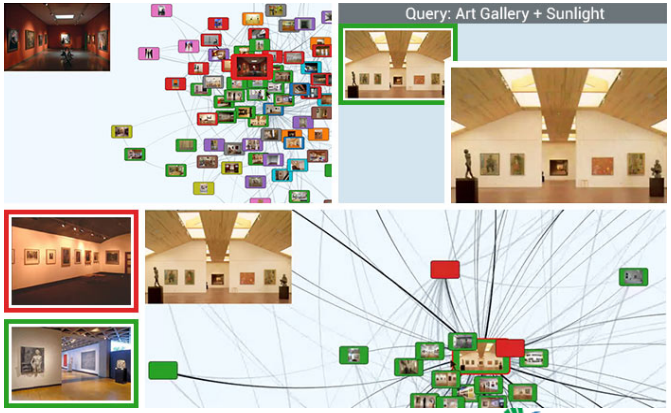


Kitware – Computer Vision

KWIVER



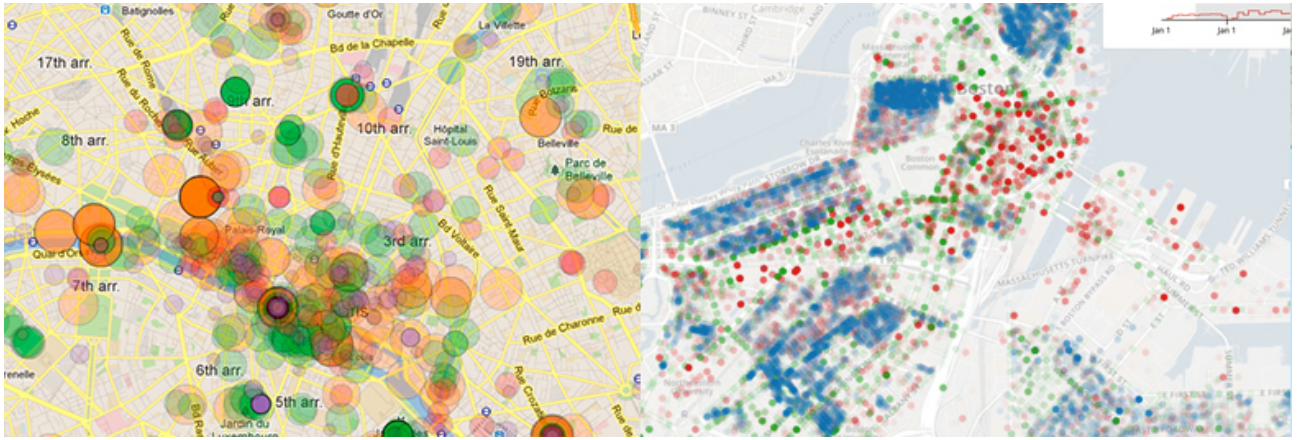


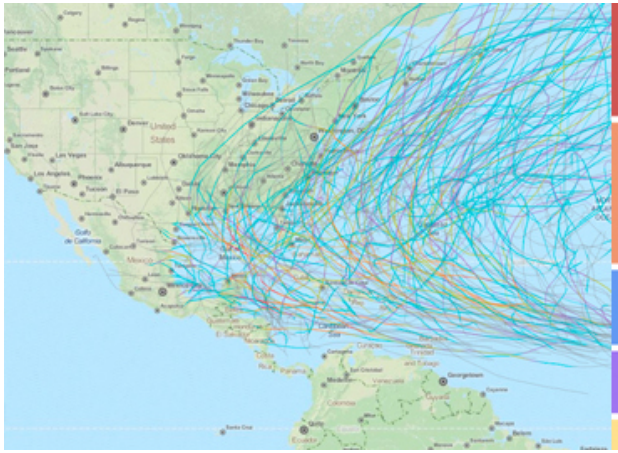


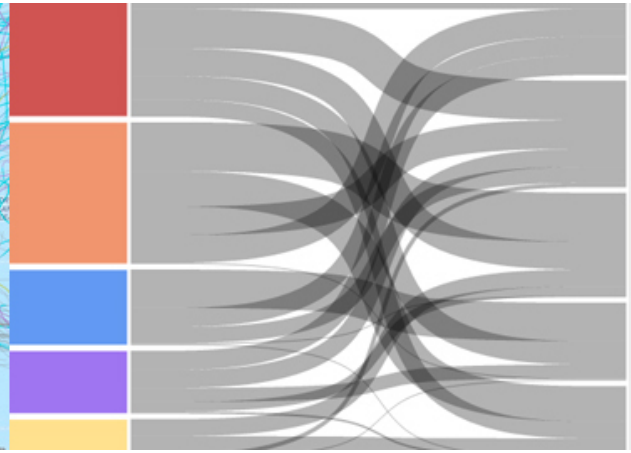
Kitware

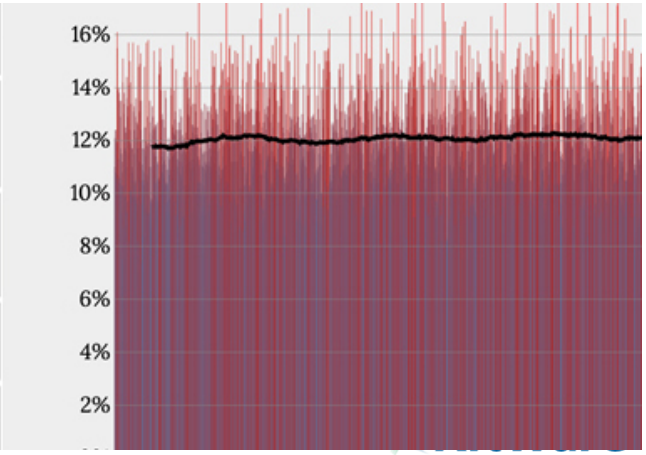
Kitware – Data and Analytics

Resonant



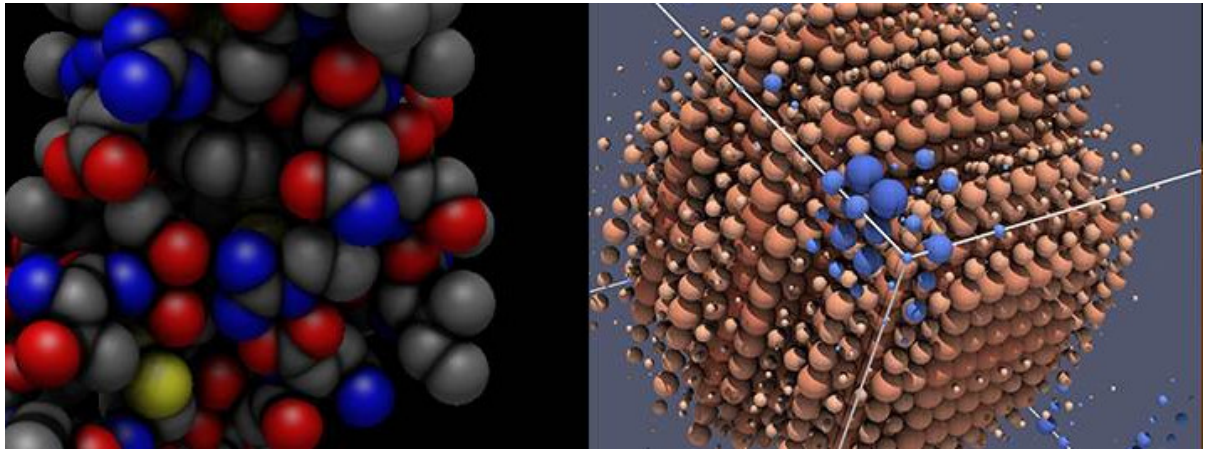


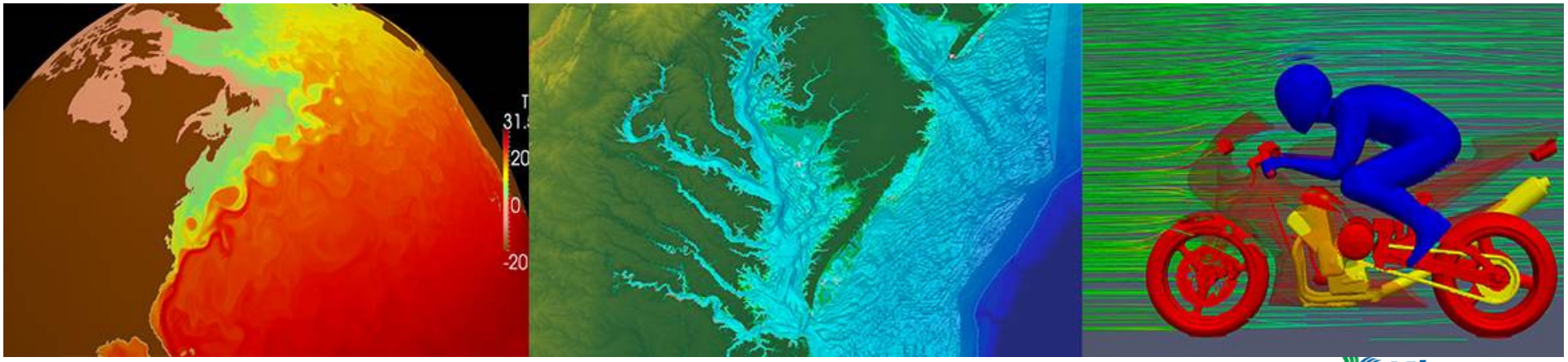




Kitware – HPC and Visualization

VTK ParaView CMB tomviz





Kitware

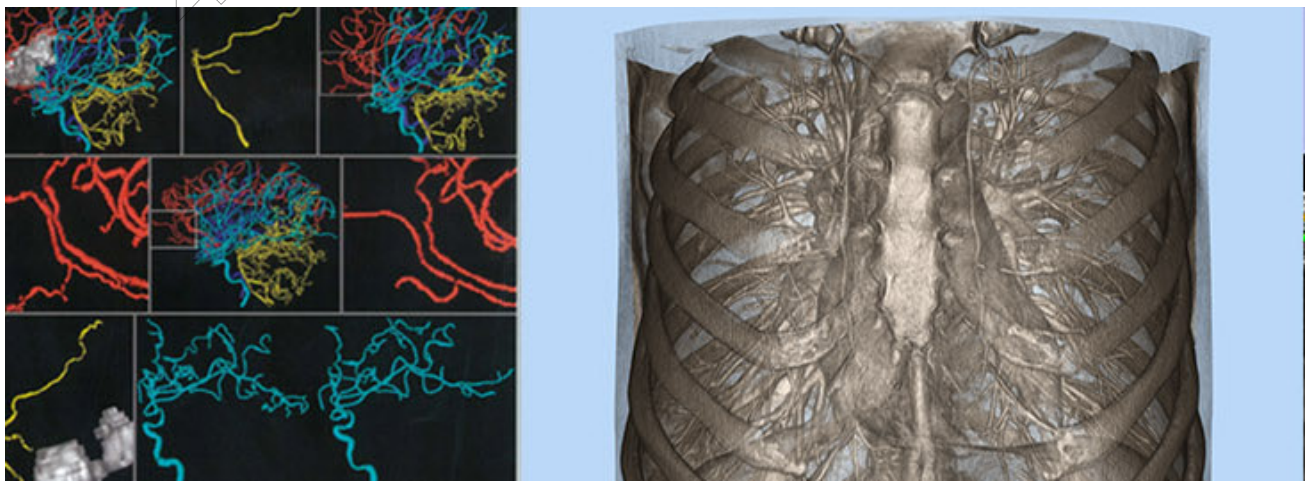
Kitware – Medical Computing

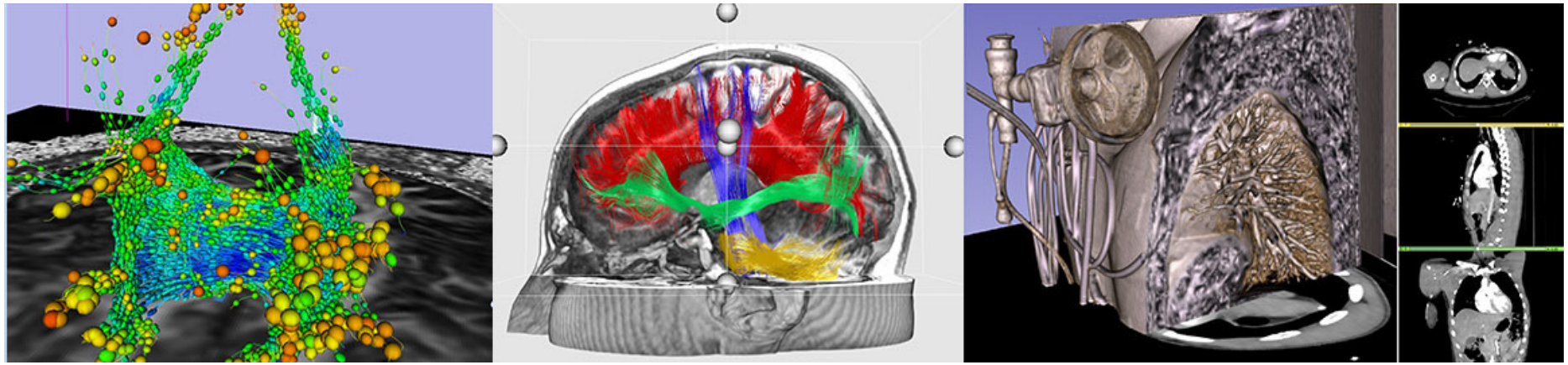
ITK

3DSlicer

Pulse
Physiology Engine

ParaView





Kitware – Software Process

- cmake, ctest, cdash

To Follow Along…

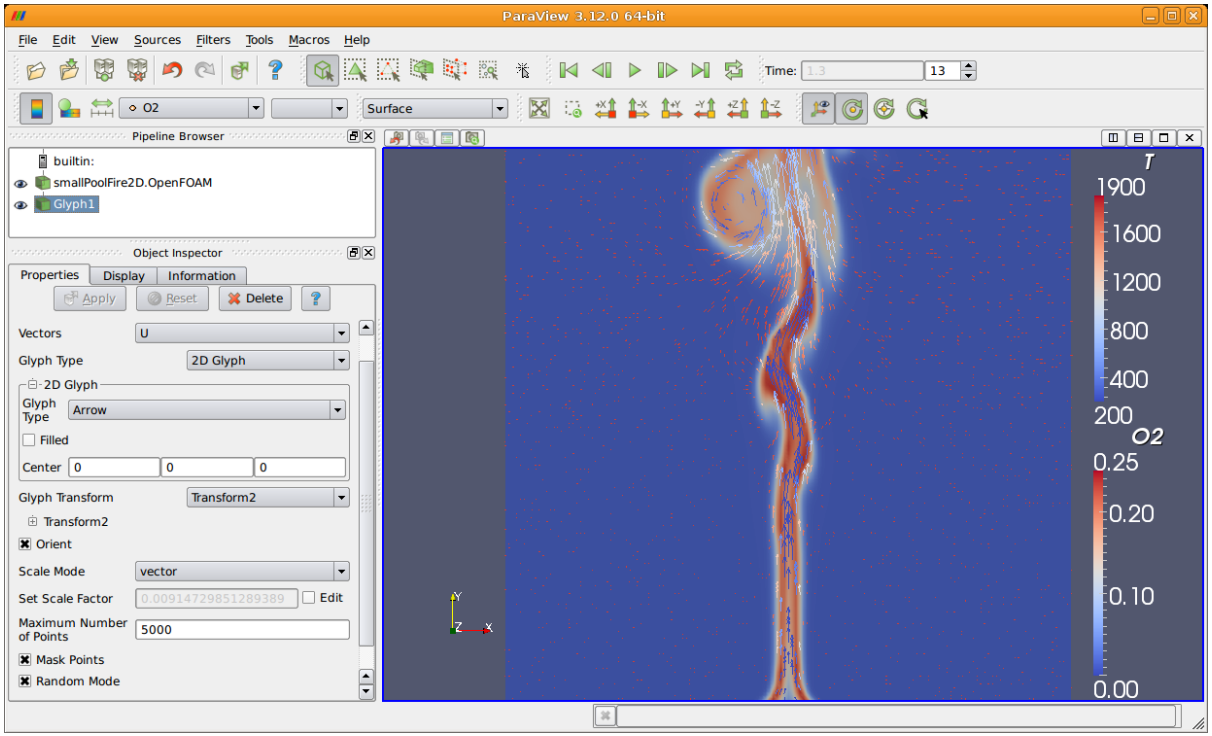
- Install ParaView 5.5.2
  - http://www.paraview.org → Download

Introduction

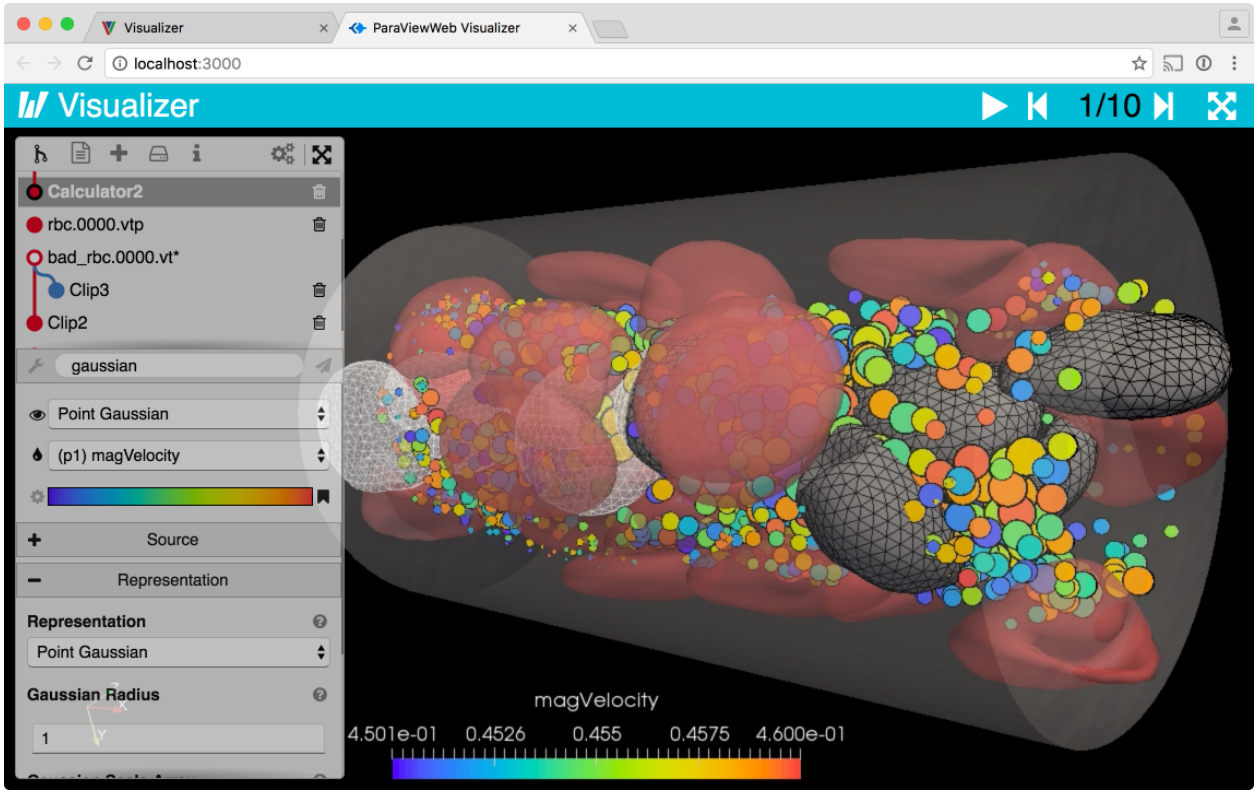
What is ParaView?

- An open-source, scalable, multi-platform visualization application.
- Support for distributed computation models to process large data sets.
- An open, flexible, and intuitive user interface.
- An extensible, modular architecture based on open standards.
- A flexible BSD 3 Clause license
- Commercial maintenance and support.

ParaView on the Desktop



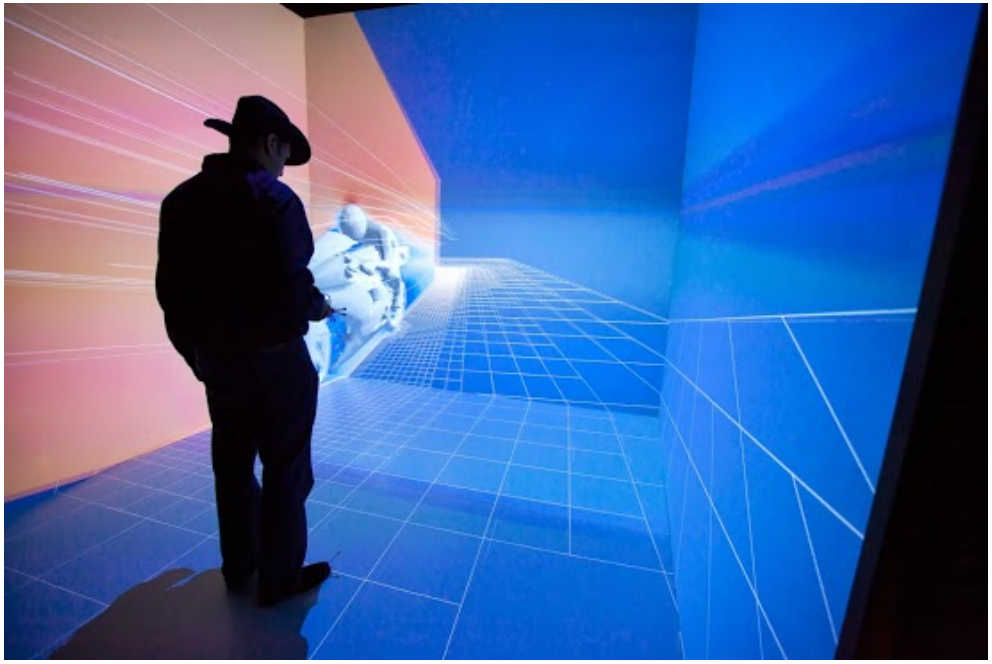
ParaView on the Web



ParaView Scripting - Python

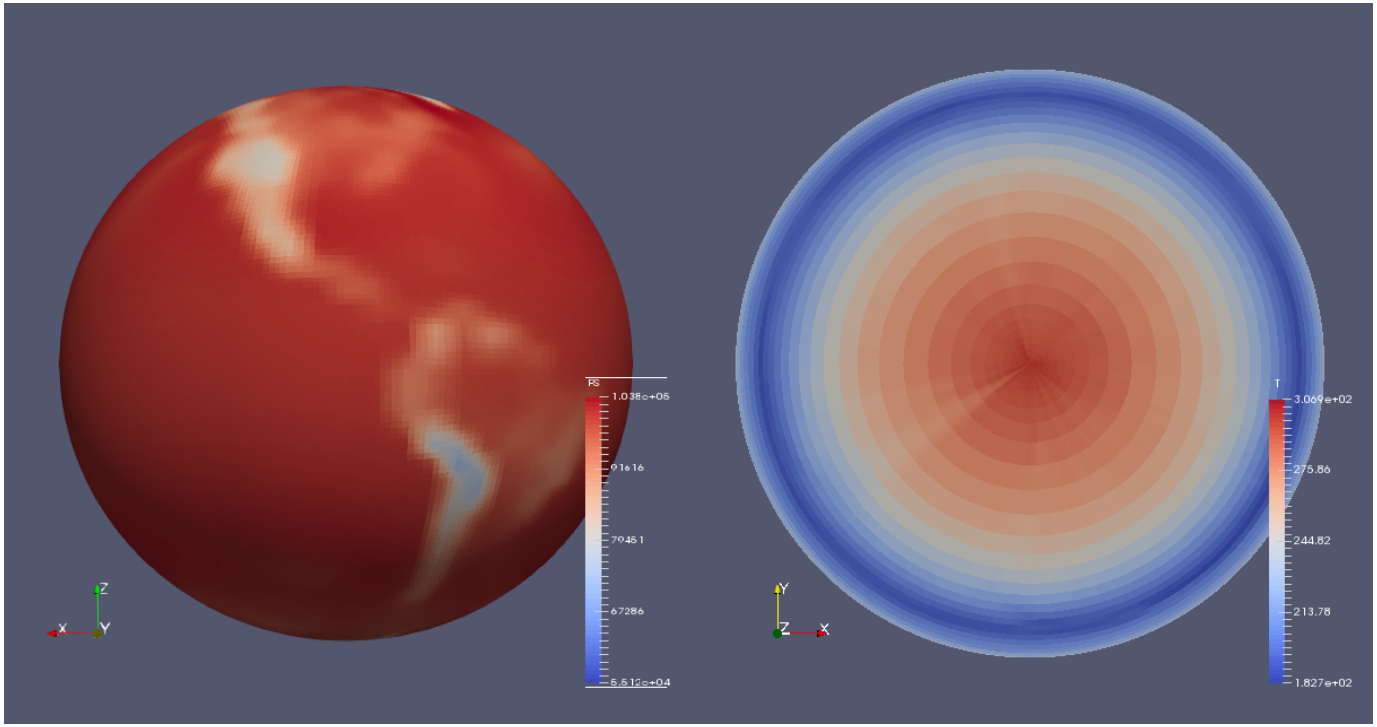
Python scripts can control ParaView with or without the GUI in order to create reproducible and customizable visualizations.

ParaView Immersive



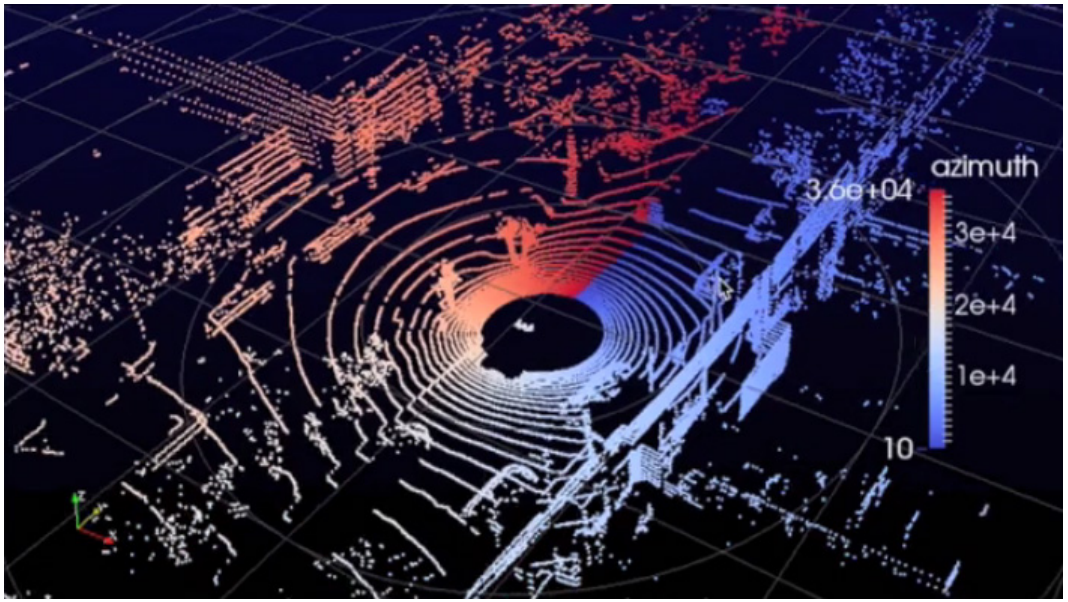
ParaView for HPC

ParaView Catalyst



Community Atmosphere Model (CAM5) 2D (PS) 3D data (T), Spectral Element dynamic module.

ParaView Custom Application VeloView



Visualization of 3D LIDAR data.

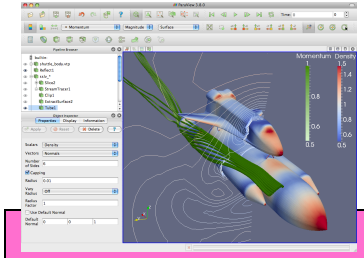
Current ParaView Usage

- Used by academic, government, and commercial institutions worldwide.
- Downloaded ~135K times per year.
- HPCwire Editors' Choice 2010/2016 and HPCwire Readers' Choice 2010/2012/2015 Awards for Best Visualization Product or Technology.

Data Ranges

- Used for all ranges of data size.
- Landmarks of usage:
  - 6 billion structured cells (2005).
  - 250 million unstructured cells (2005).
  - Billions of AMR cells (2008).
  - Scaling test over 1 Trillion cells (2010).
  - 6.33 billion unstructured cells in Catalyst (2016).

ParaView Application Architecture

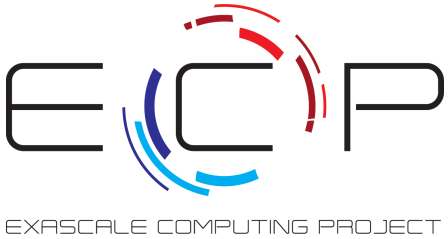


ParaView Client	pvpython	ParaWeb	Catalyst	Custom App
UI (Qt Widgets, Python Wrappings)				
ParaView Server				
VTK				
OpenGL	MPI	IceT	Etc.	

ParaView Development

- Started in 2000 as collaborative effort between Los Alamos National Laboratories and Kitware Inc. Sandia has been a major contributor since 2005.
  - ParaView 0.6 released October 2002.
- Paraview 3.0 release in May 2007.
  - GUI rewritten to be more user friendly and powerful.
- ParaView 4.0 released in June 2013.
  - Properties panel redesign for smoother interaction.
- ParaView 5.0 released in January 2016.
  - Updated to OpenGL 3.2 features. Huge performance improvements.

Current Funding



This research was supported by the Exascale Computing Project (17-SC-20-SC), a collaborative effort of the U.S. Department of Energy Office of Science and the National Nuclear Security Administration.

- ARL
- ERDC
- US Army (SBIR)
- US Air Force (STTR)
- ONR
- Support Contracts
  - Electricity de France
  - Microsoft

- Other contributors
  - Swiss National Supercomputing Centre
  - DOE SLAC
  - Ohio State
  - Mississippi State
  - RPI

Basics of Visualization

```
0265640 132304 133732 032051 037334 024721 015013 052226 001662
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0265720 134453 124327 176005 027034 107614 170774 073702 067274
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0266240 137055 062276 161755 115466 005322 132567 073216 002655
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0266620 075074 016744 044055 102230 110063 033350 052765 172463
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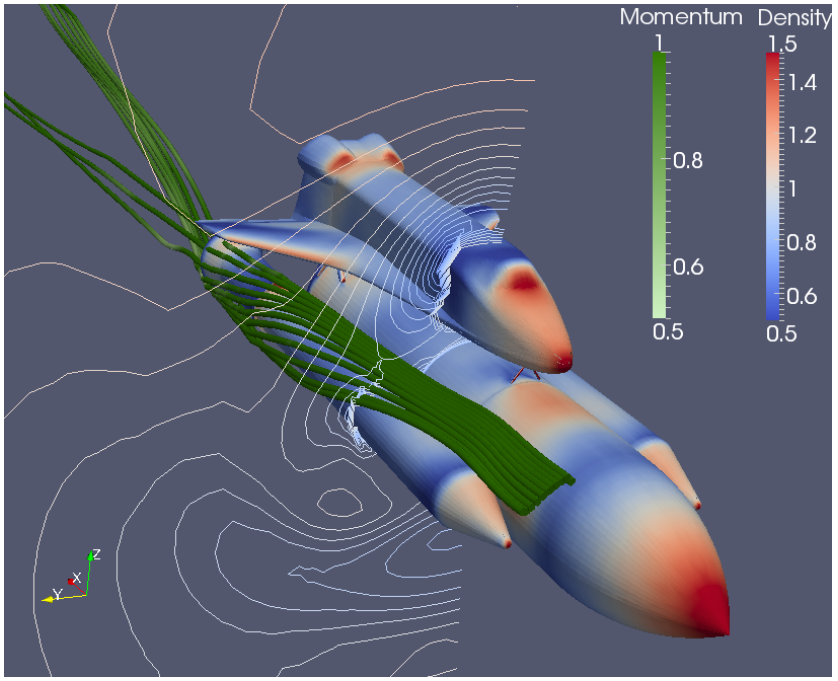
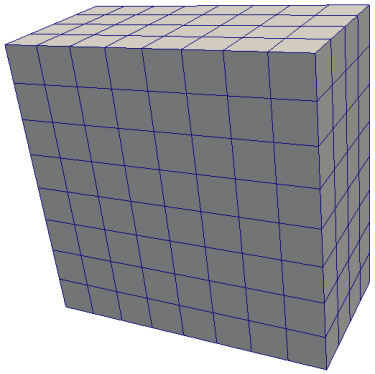
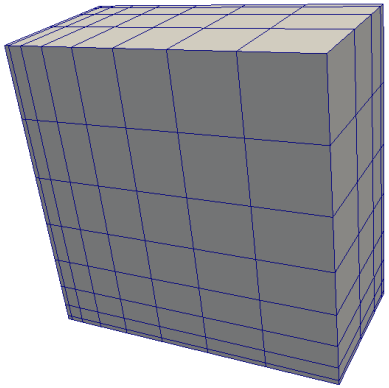


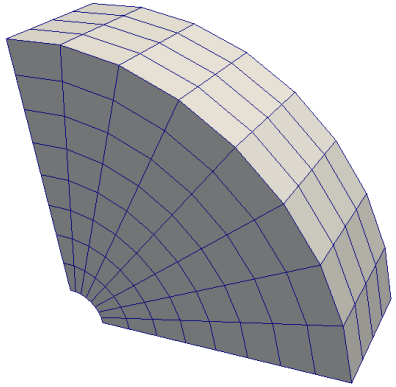
Data Types



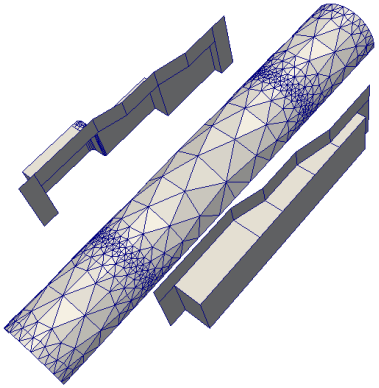
Uniform Rectilinear
(vtkImageData)



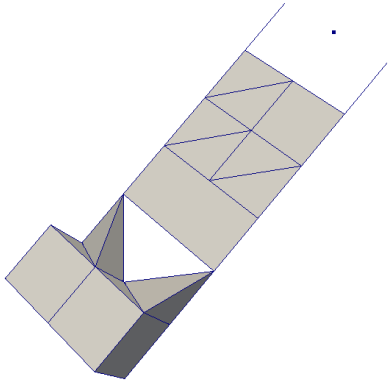
Non-Uniform Rectilinear
(vtkRectilinearData)



Curvilinear
(vtkStructuredData)



Polygonal
(vtkPolyData)



Unstructured Grid
(vtkUnstructuredGrid)

Multi-block

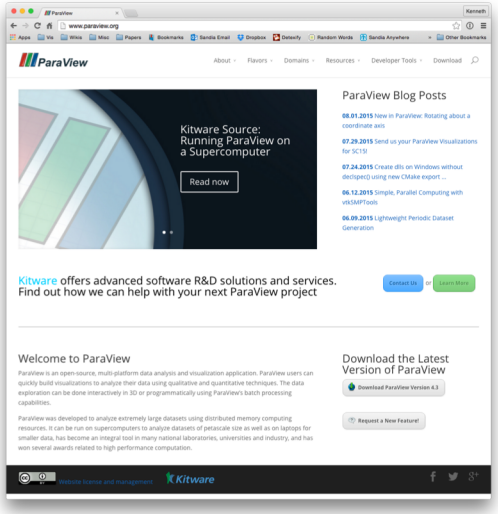
Hierarchical Adaptive Mesh Refinement (AMR)

Hierarchical Uniform AMR

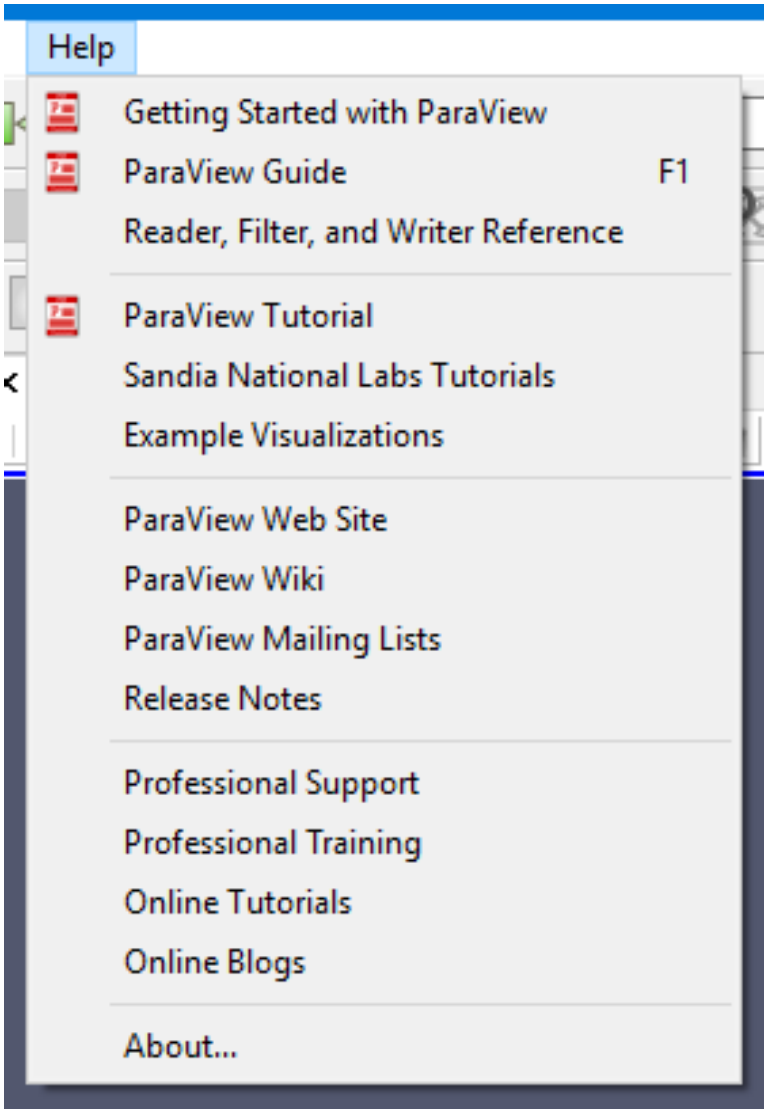
Octree

More Information

- Help Menu
- *The ParaView Guide*
  - http://www.paraview.org/paraview-guide/
- Tutorials
  - http://www.paraview.org/tutorials/
- The ParaView web page
  - www.paraview.org
- ParaView discussion forum
  - https://discourse.paraview.org/



Help Menu


Help
Getting Started with ParaView
ParaView Guide F1
Reader, Filter, and Writer Reference
ParaView Tutorial
Sandia National Labs Tutorials
Example Visualizations
ParaView Web Site
ParaView Wiki
ParaView Mailing Lists
Release Notes
Professional Support
Professional Training
Online Tutorials
Online Blogs
About...

Basic Usage

User Interface

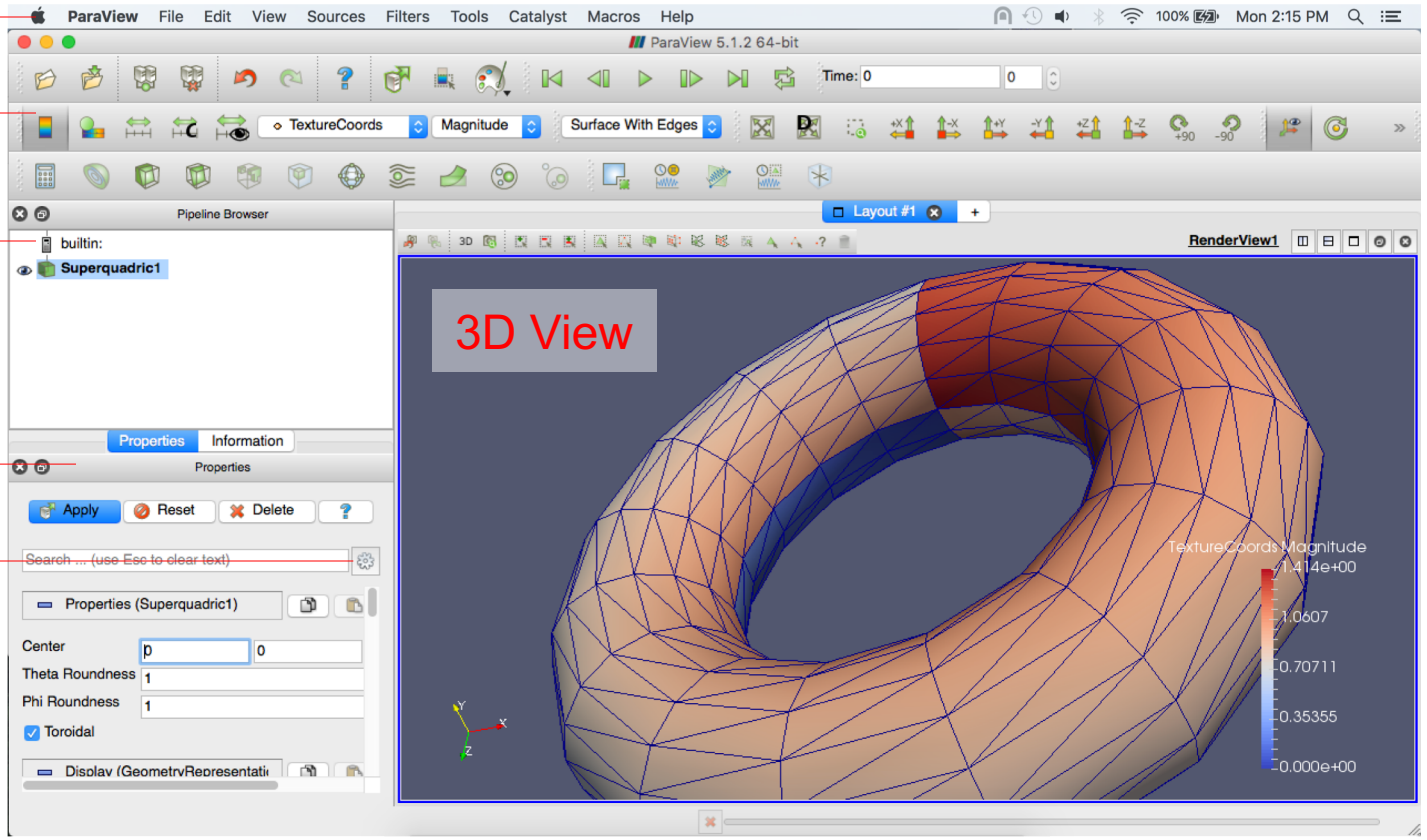
Menu Bar

Toolbars

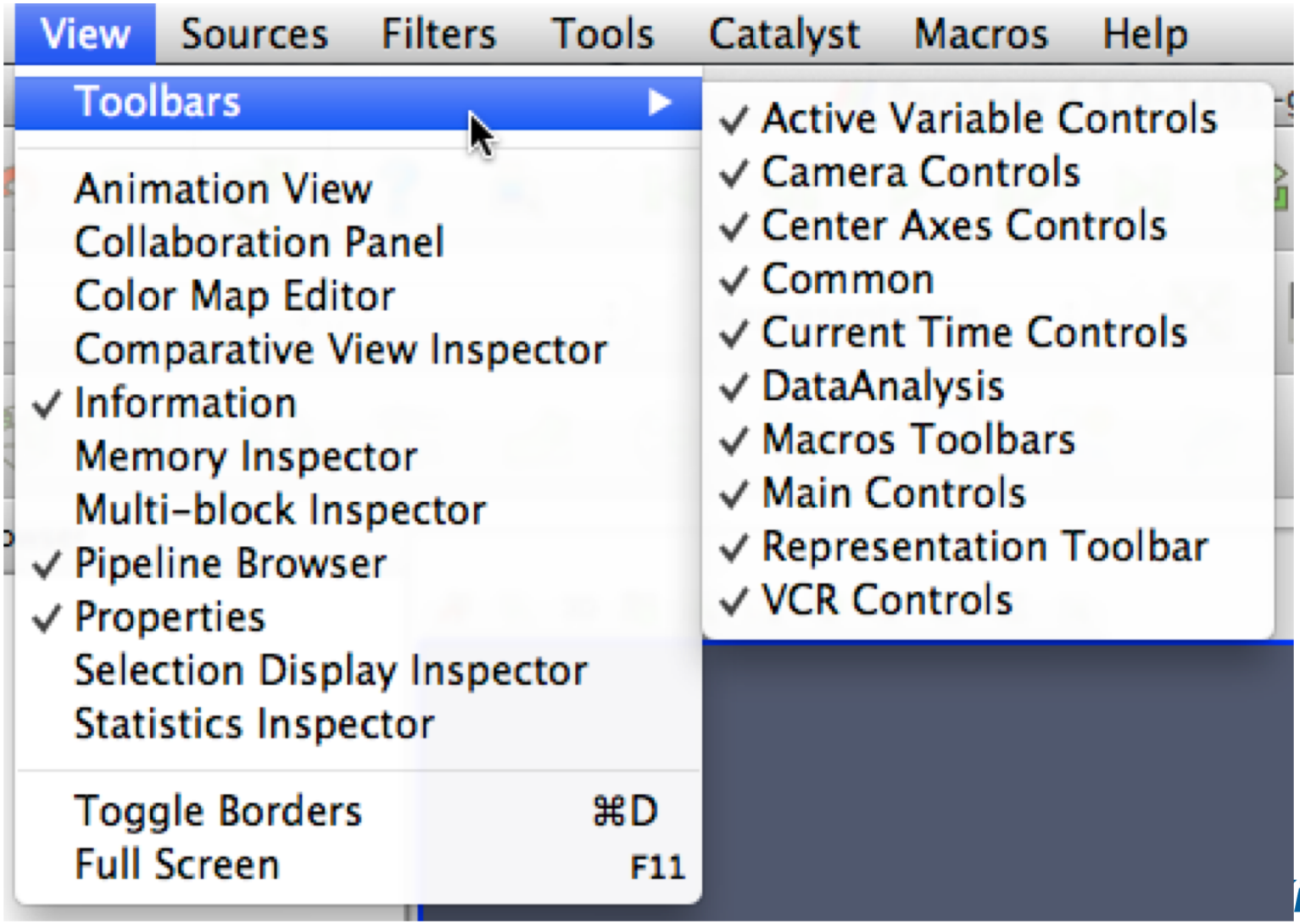
Pipeline Browser

Properties Panel

Advanced Toggle



Getting Back GUI Components

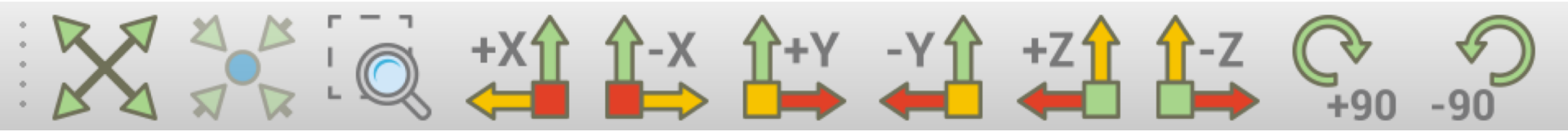


Creating a Cylinder Source

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

Simple Camera Manipulation

- Drag left, middle, right buttons for rotate, pan, zoom.
  - Also use Shift, Ctrl, Alt modifiers.
  - Also try holding down x, y, or z.



Creating a Cylinder Source

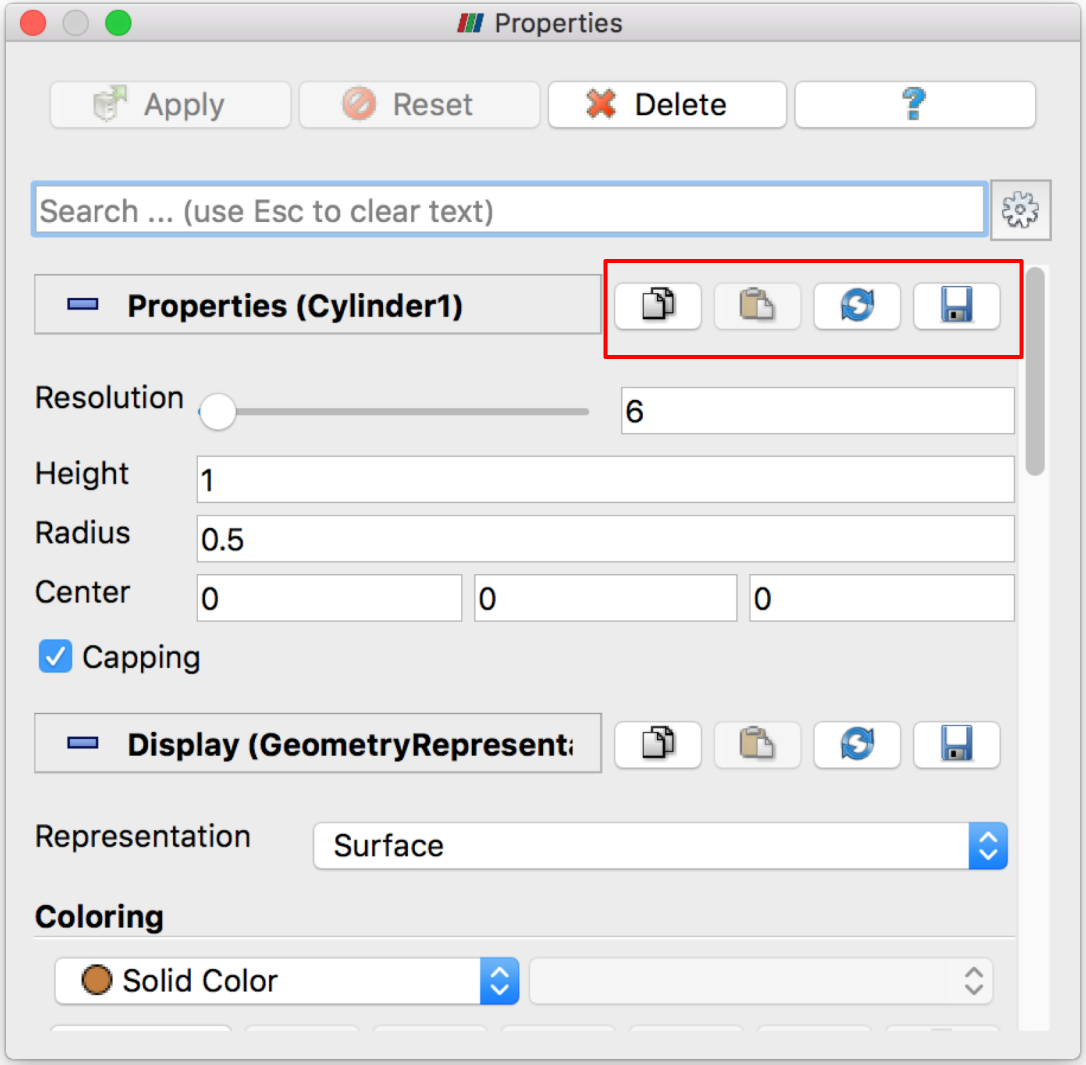
1. Go to the Source menu and select Cylinder.
2. Click the Apply button to accept the default parameters. 

3. Increase the Resolution parameter.

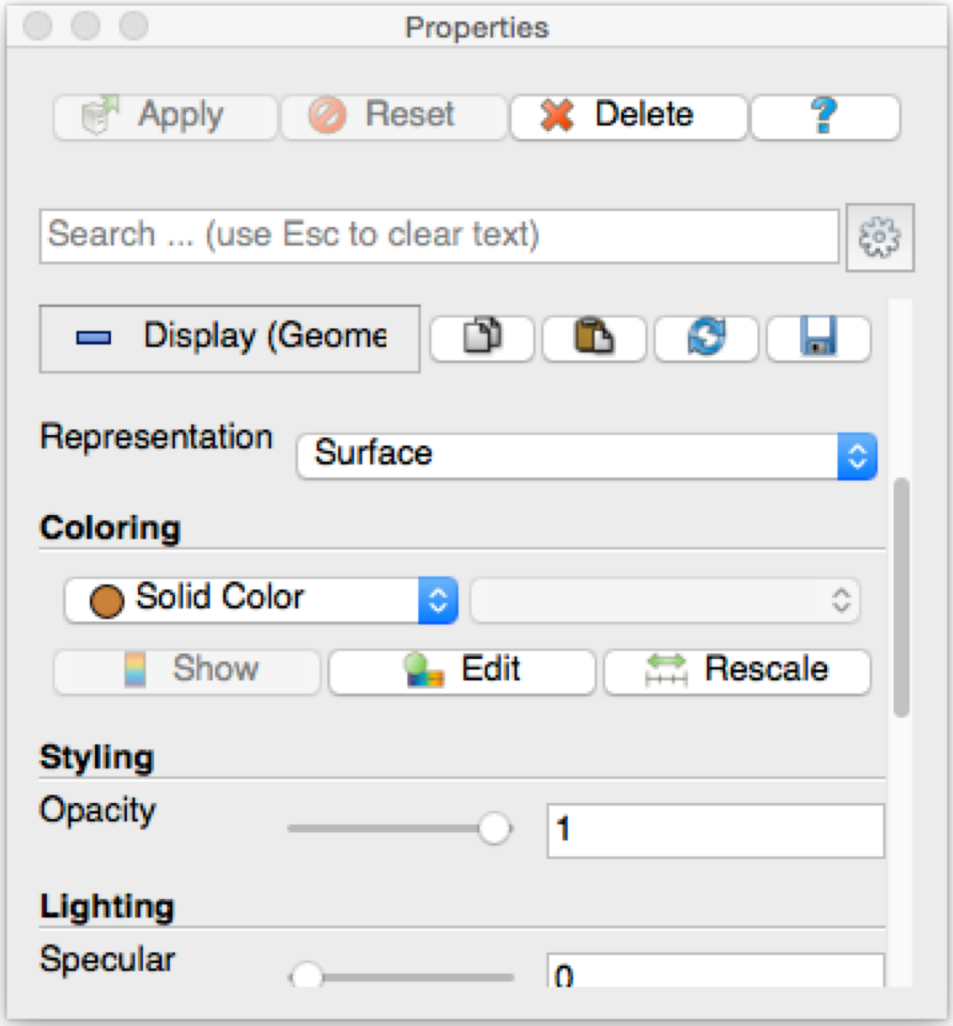
4. Click the  button again.

Pipeline Object Controls

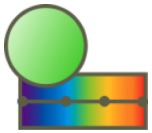
Copy/Paste/Reset/Save Parameters



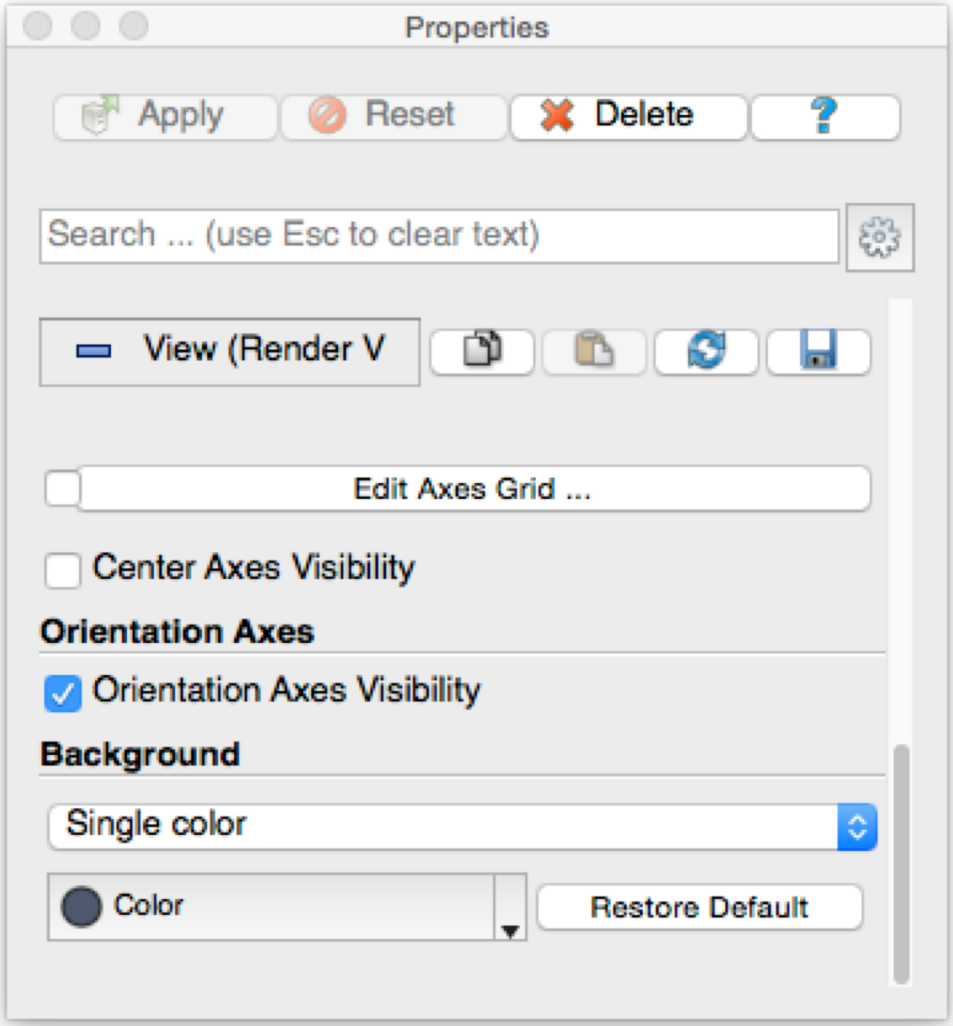
Display Properties



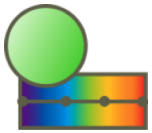
Change Render Properties

1. Scroll down to the Display group.
2. Click the  Edit button. (This button is replicated in the toolbar.)
3. Select a new color for the cylinder.

Render View Options

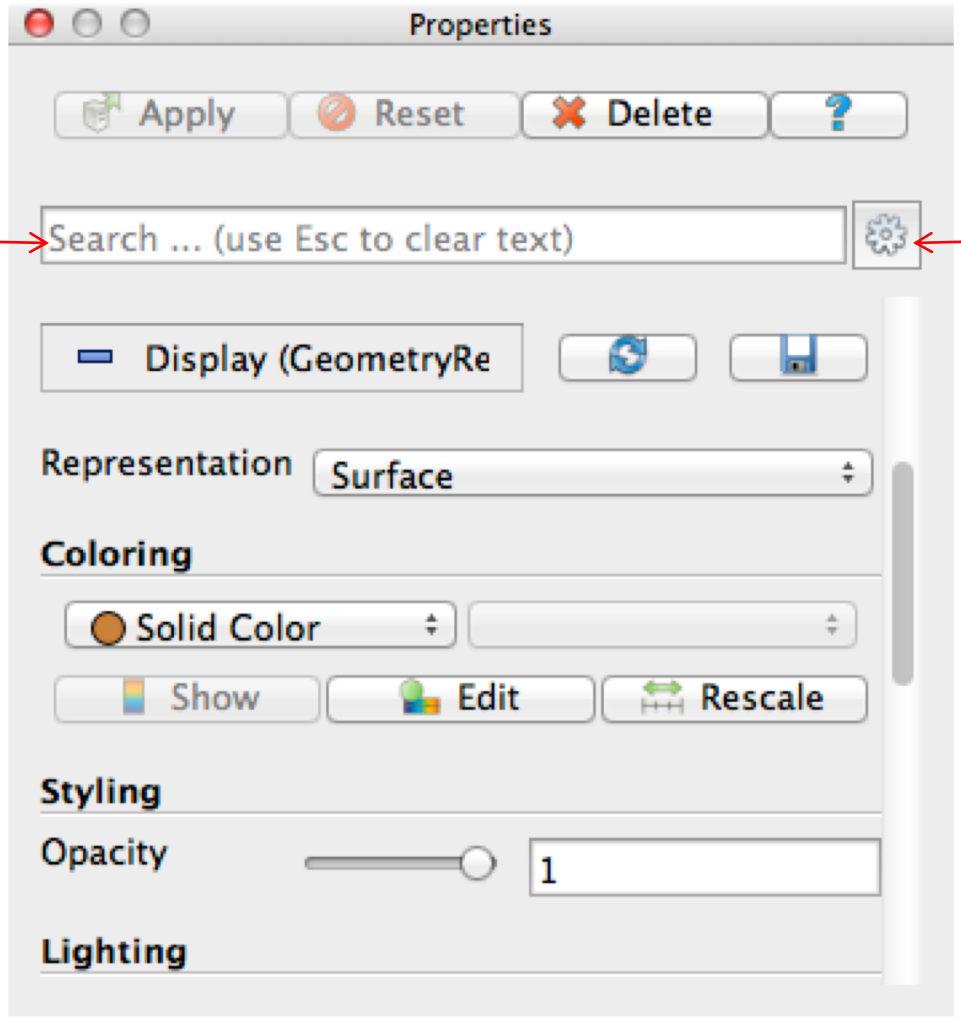


Change Render Properties

1. Scroll down to the Display group.
2. Click the  Edit button. (This button is replicated in the toolbar.)
3. Select a new color for the cylinder.
4. Scroll down to the View group.
5. Turn on the Axis Grid.

Advanced Properties

Search Properties



Toggle Advanced Properties

Searching Properties

1. Type “specular” in the properties search box
2. Change Specular value to 1 (makes the cylinder shiny)

Searching Properties

1. Type “specular” in the properties search box
2. Change Specular value to 1 (makes the cylinder shiny)

Other interesting properties:

- Axes Grid
- Opacity
- Lights

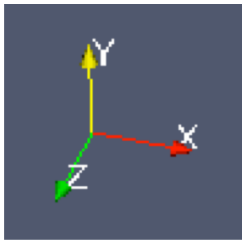
Using Auto Apply

1. Click Auto Apply. 
2. Change the Resolution parameter again. 

3. Note that the visualization automatically updates without having to hit Apply.

Changing the Color Palette

1. Make sure the orientation axes are visible in the lower left corner. 

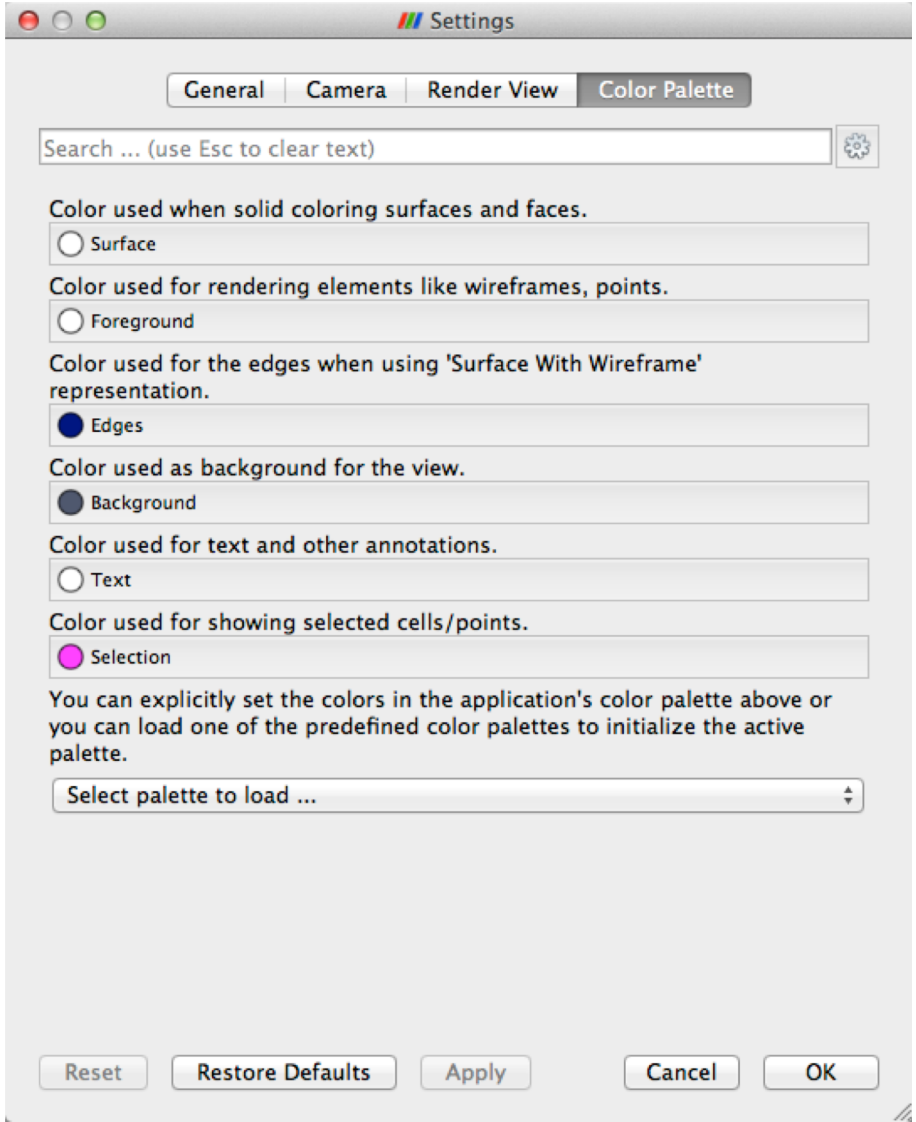


2. Click the color palette button  and change the colors.

3. Try several color palettes.

Color Palettes

→ Edit Current Palette…



Undo Redo

Undo

Redo

Camera Undo

Camera Redo

Creating a Cylinder Source

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

3. Increase the Resolution parameter.

4. Click the 

button again.
5. Delete the Cylinder. 

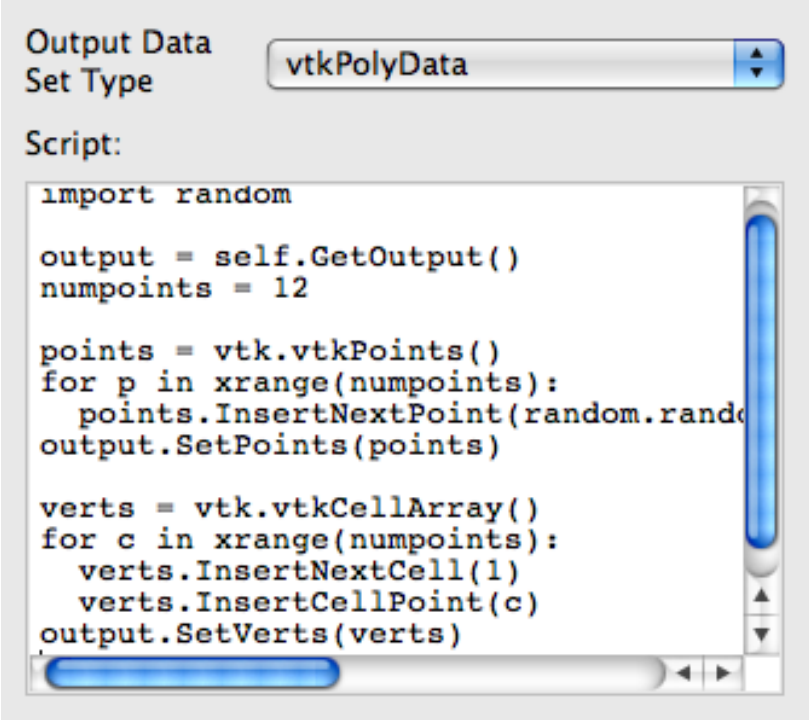
Supported Data Types

- 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)
- CGNS (.cgns)
- 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

Custom Data Import: Prototype with Python

- A “programmable source” lets you program data readers right in the GUI.
- Uses wrappings for the basic VTK classes.
- Good for prototyping readers.

https://www.vtk.org/doc/nightly/html/



Custom Data Import: Plugin Containing a Reader

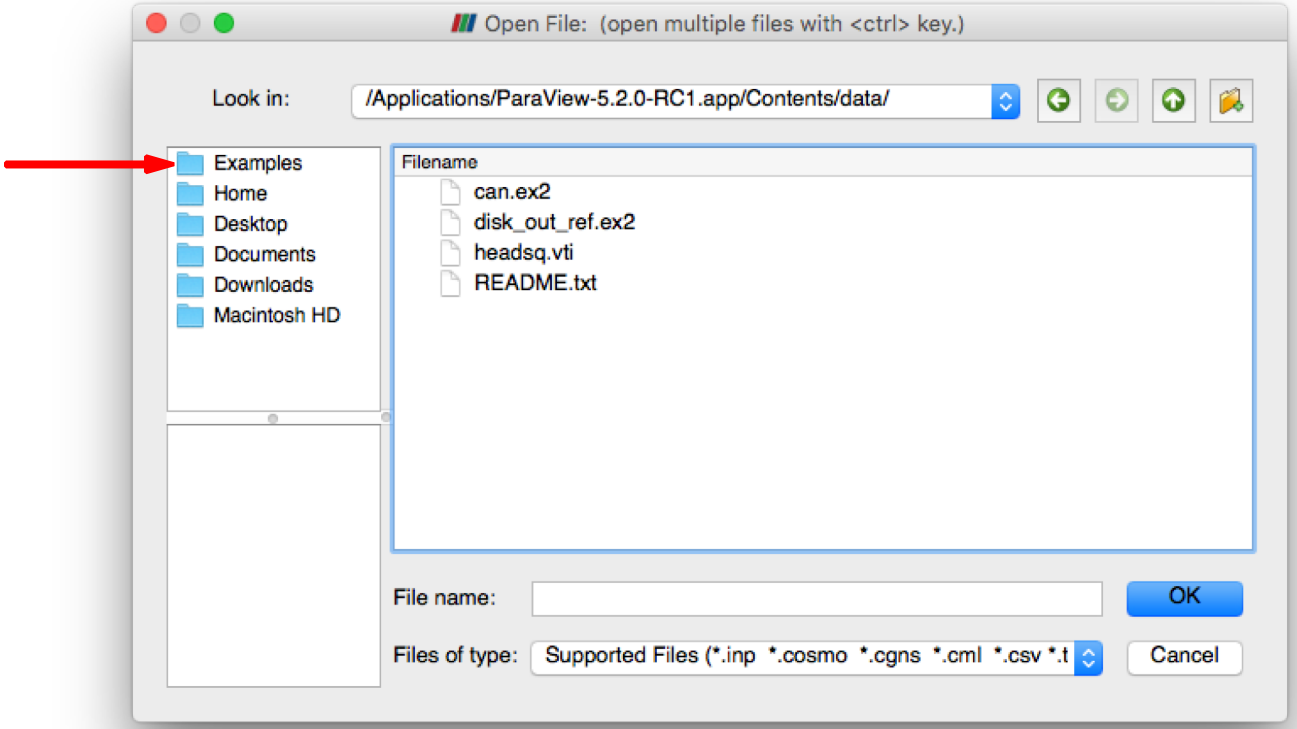
- Plugins: shared object libraries that can be dynamically loaded into ParaView.
- C++ code and XML description of the interface.
- Any VTK reader object can be added.

Custom Data Import: Python Reader/Filter Plugin

- Only available in releases greater than 5.5.2 or in the **nightly** binaries.
- Python code and python decorators description of the interface (similar with the XML description).
- PythonAlgorithmExamples.py

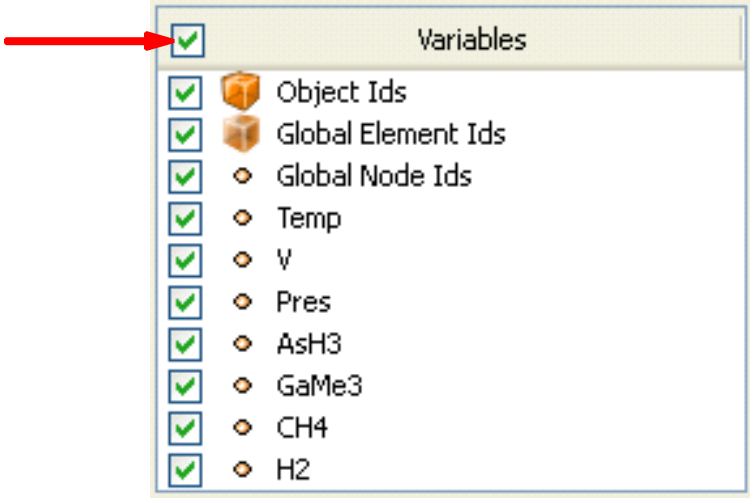
Load disk_out_ref.ex2

1. Open the file disk_out_ref.ex2 from the Examples directory.



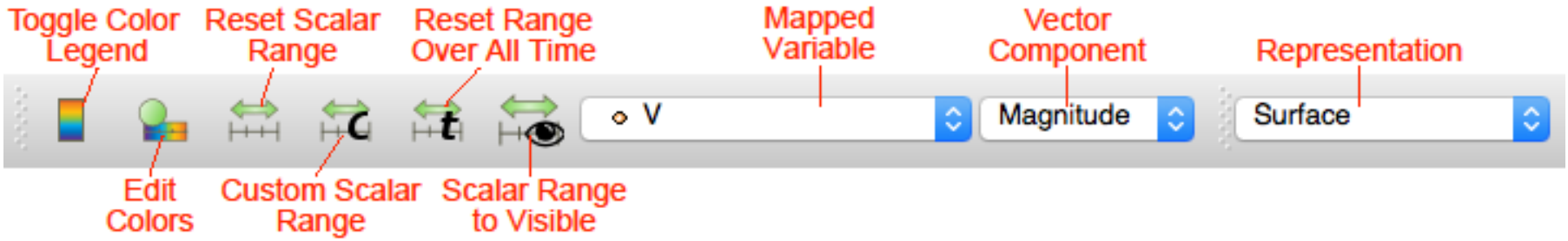
Load disk_out_ref.ex2

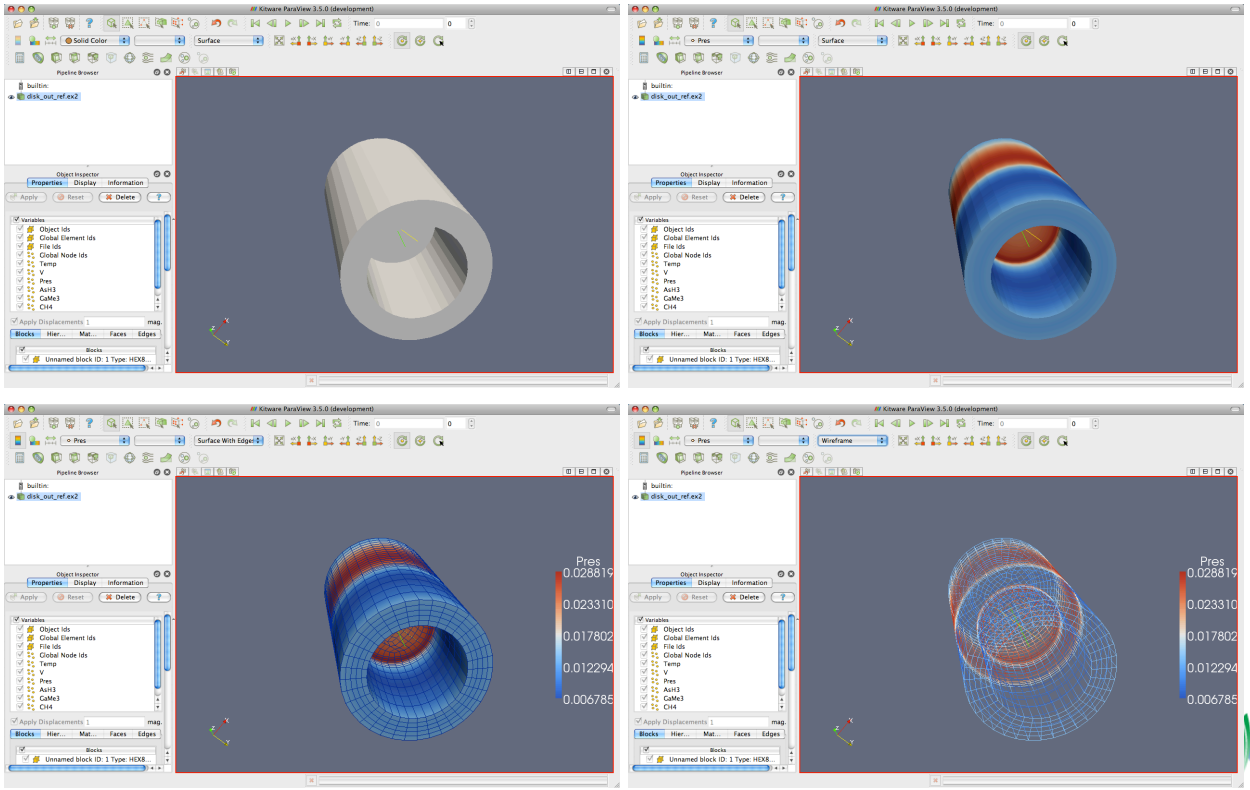
1. Open the file disk_out_ref.ex2 from the Examples directory.
2. Load all data variables.



3. Click 

Data Representation





Common Filters


Calculator


Contour


Clip


Slice


Threshold


Extract Subset


Glyph

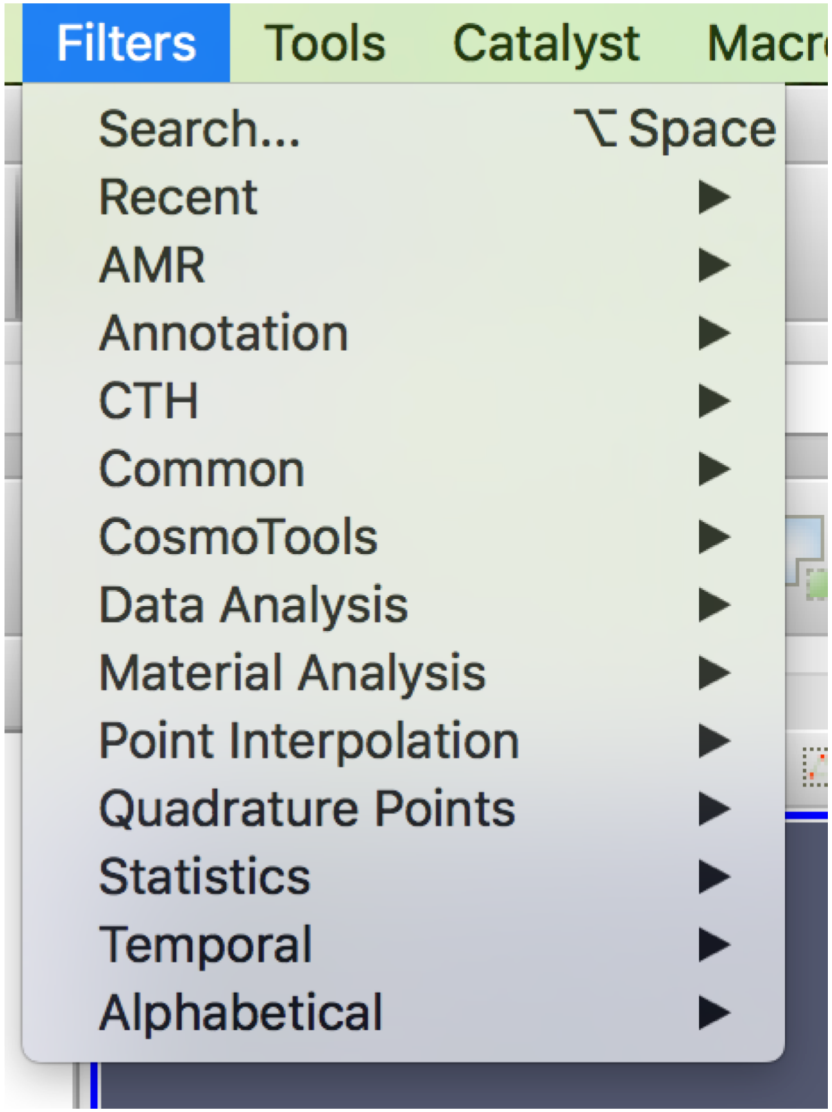

Stream Tracer


Warp (vector)


Group Datasets

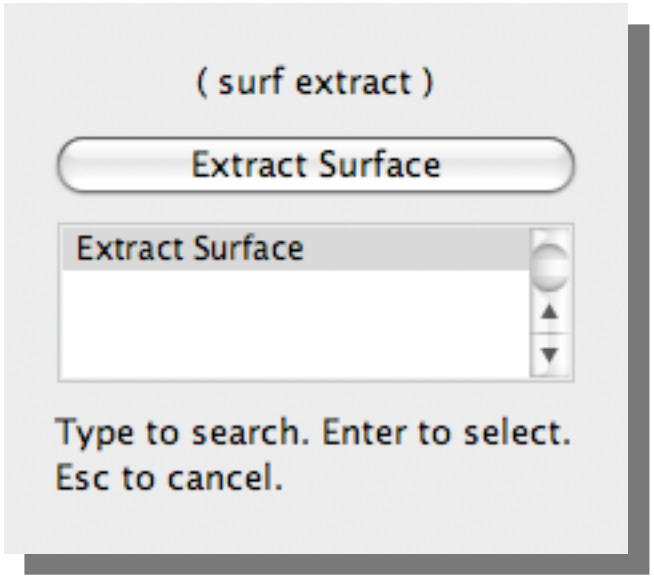

Extract Level

Filters Menu



~ 150 filters

Quick Launch



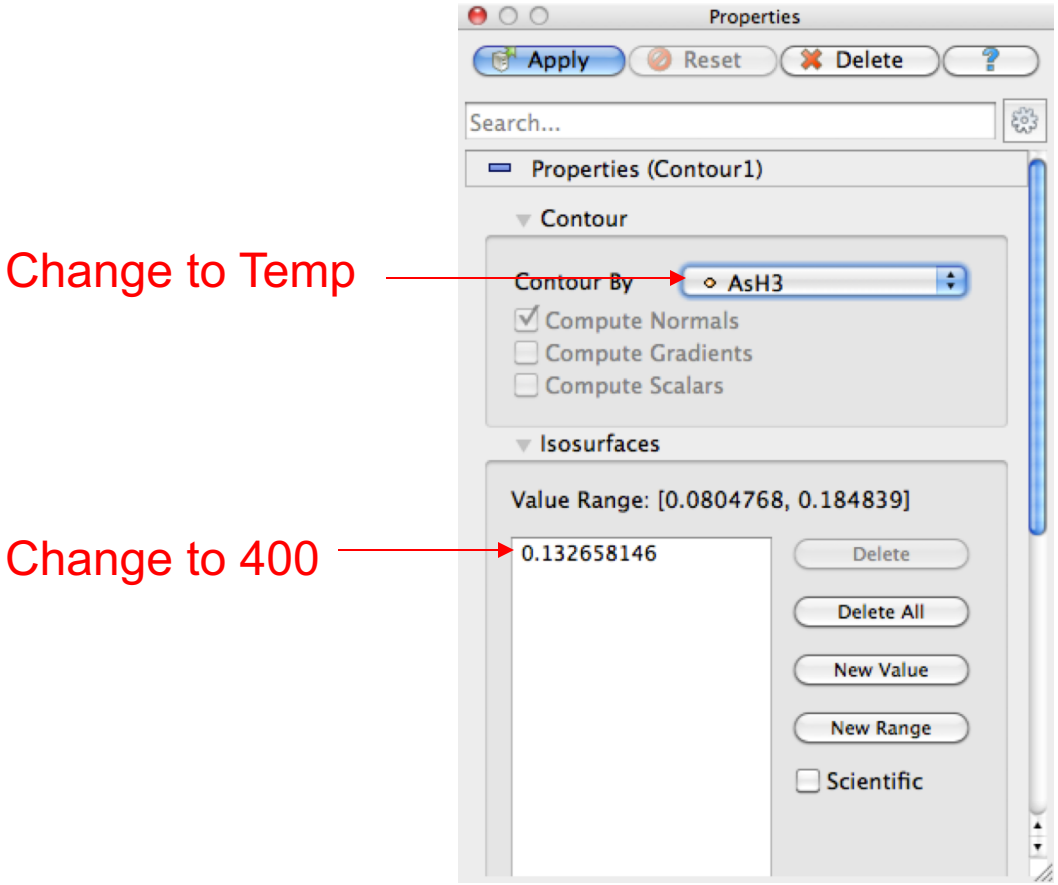
- Used for searching for filters by name
- Keyboard shortcut
  - Ctrl-space for Windows & Linux
  - Alt-space for Mac

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.



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. 

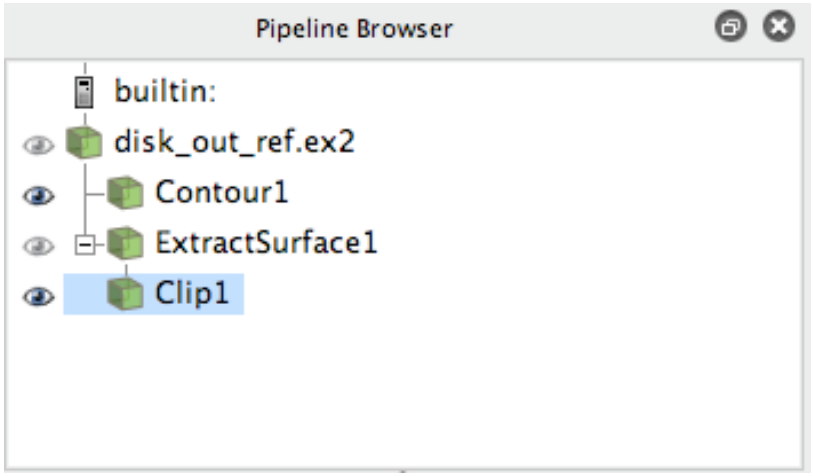
Create a Cutaway Surface

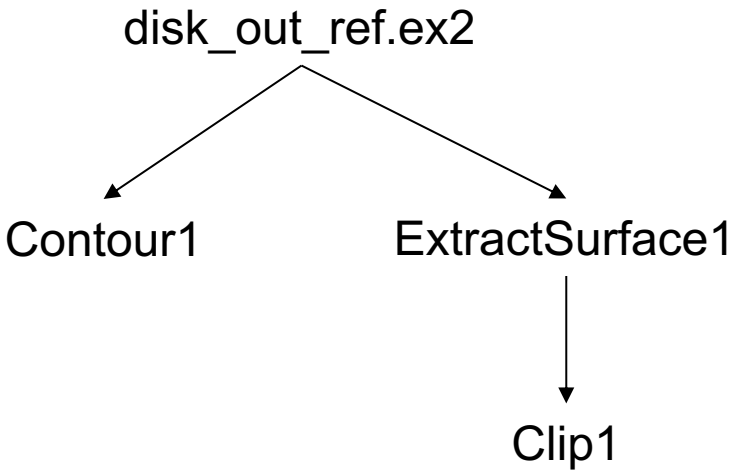
1. Select disk_out_ref.ex2 in the pipeline browser.
2. From the quick launch, select Extract Surface.
3. 

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

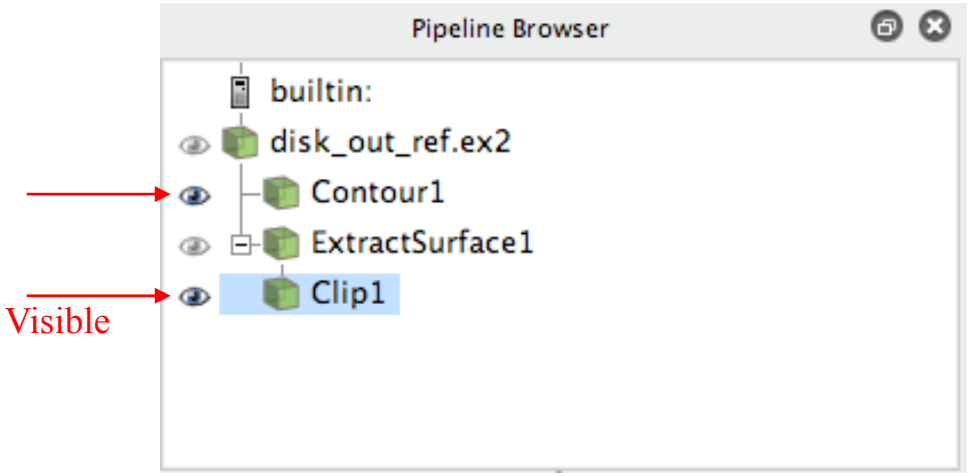
6. 

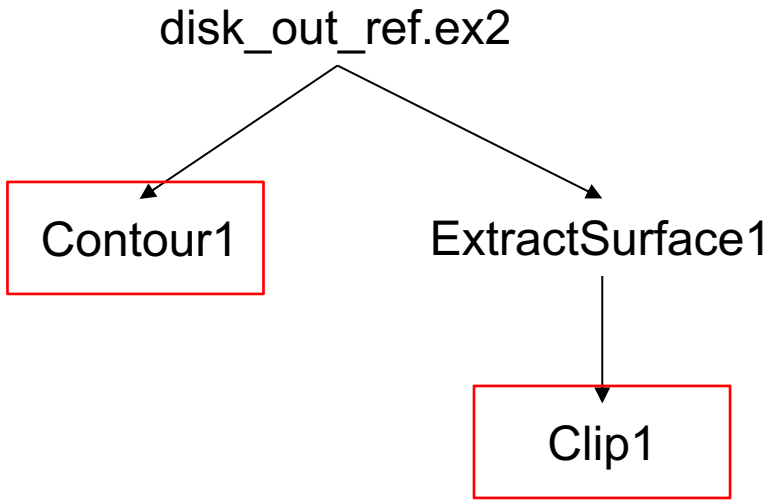
Pipeline Browser Structure



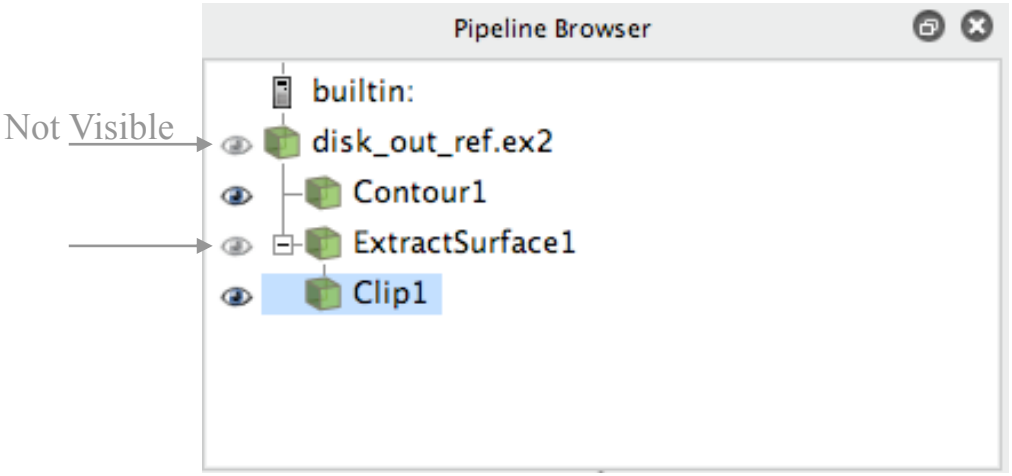


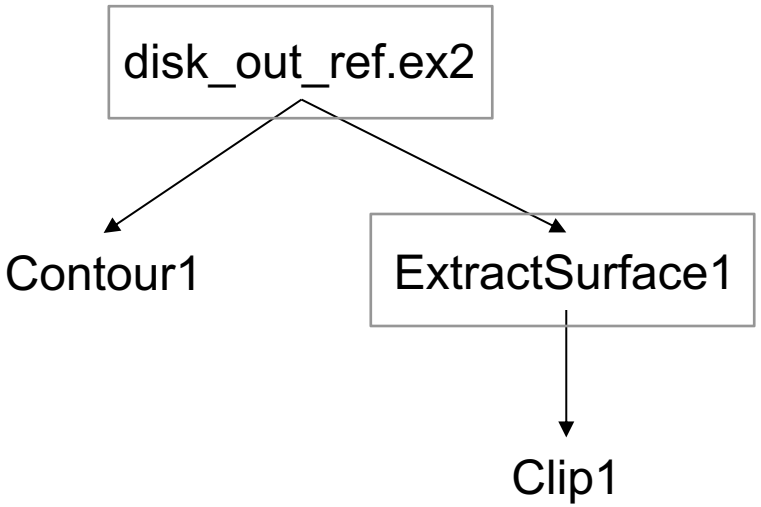
Pipeline Browser Structure





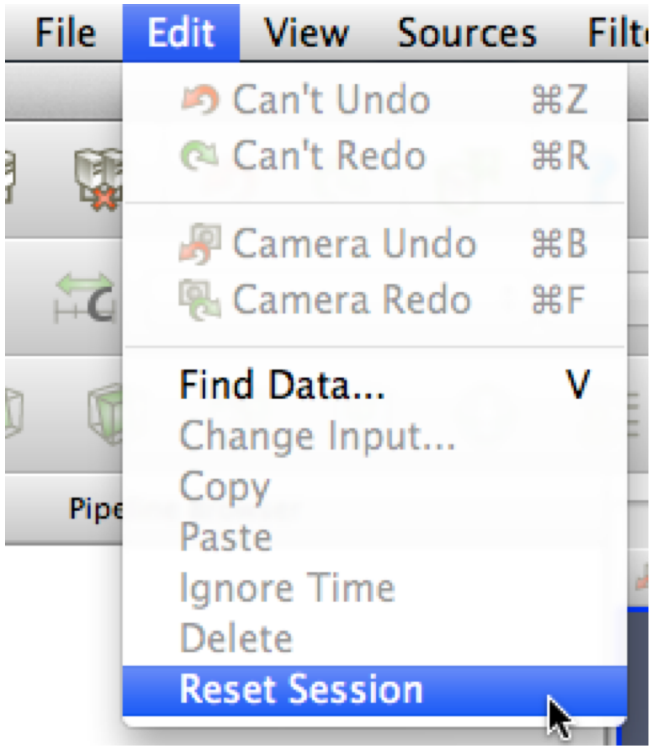
Pipeline Browser Structure



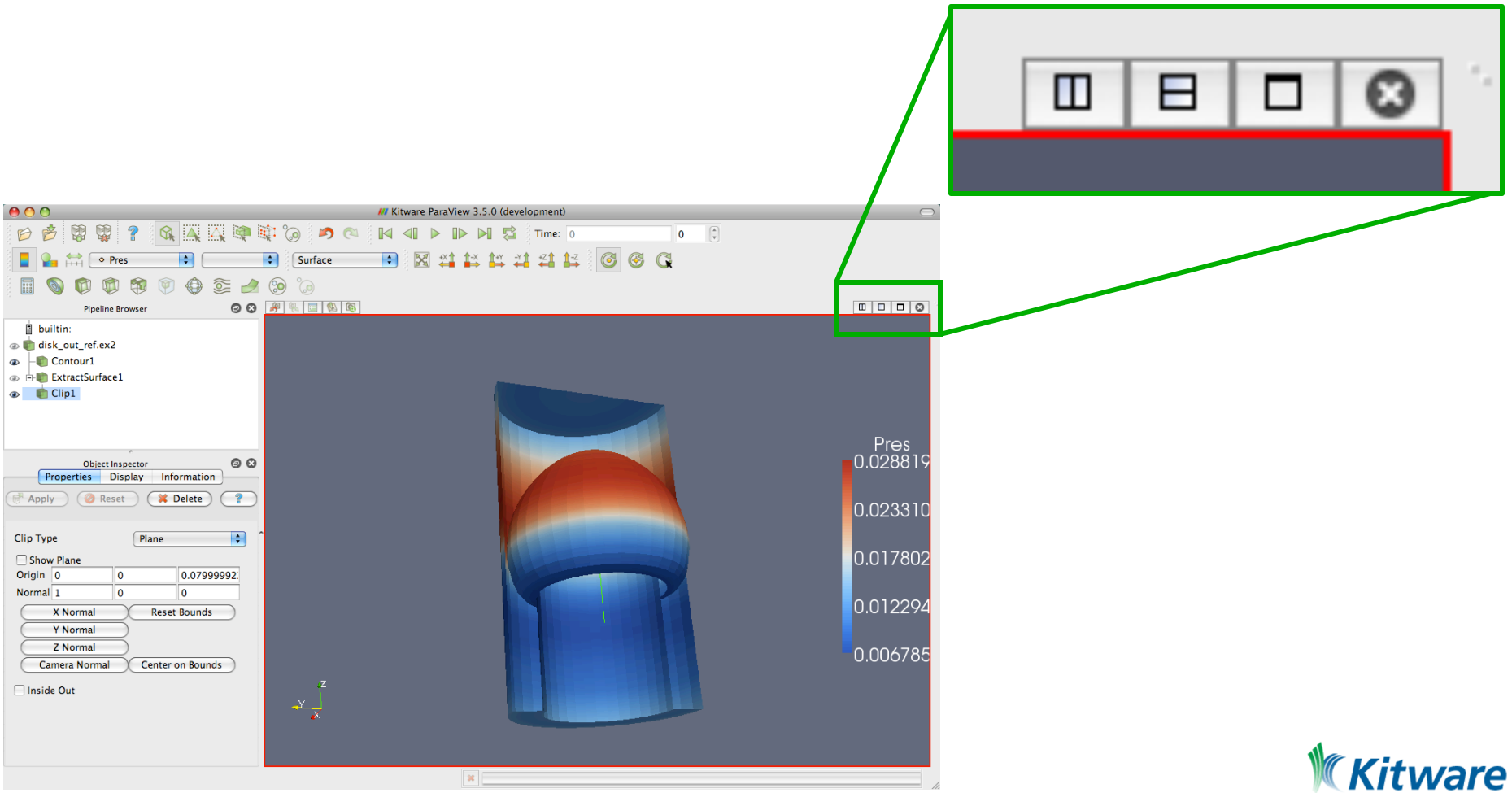


Reset ParaView

Edit → Reset Session



Multiview


Kitware ParaView 3.5.0 (development)
Time:
Pres
Surface
Pipeline Browser
builtin:
disk_out_ref.ex2
Contour1
ExtractSurface1
Clip1
Object Inspector
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

6. Split the view horizontally. 
7. Make Clip1 visible. 
8. Color surface by Temp.

Multiview

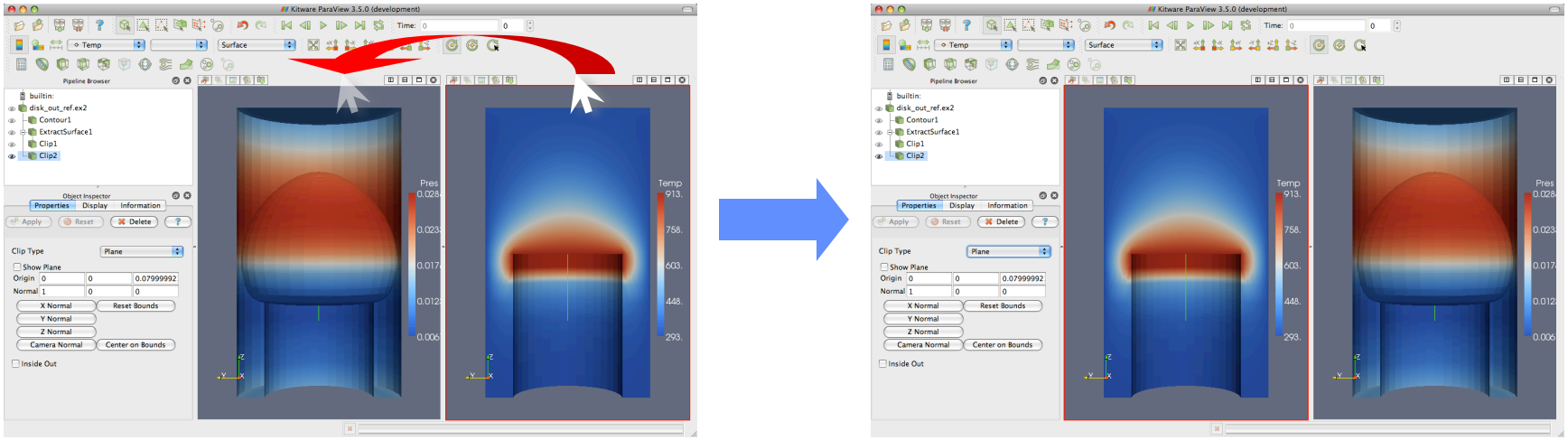
6. Split the view horizontally. 
7. Make Clip1 visible. 
8. Color surface by Temp.
9. Right-click view, Link Camera...
10. Click other view.

Multiview

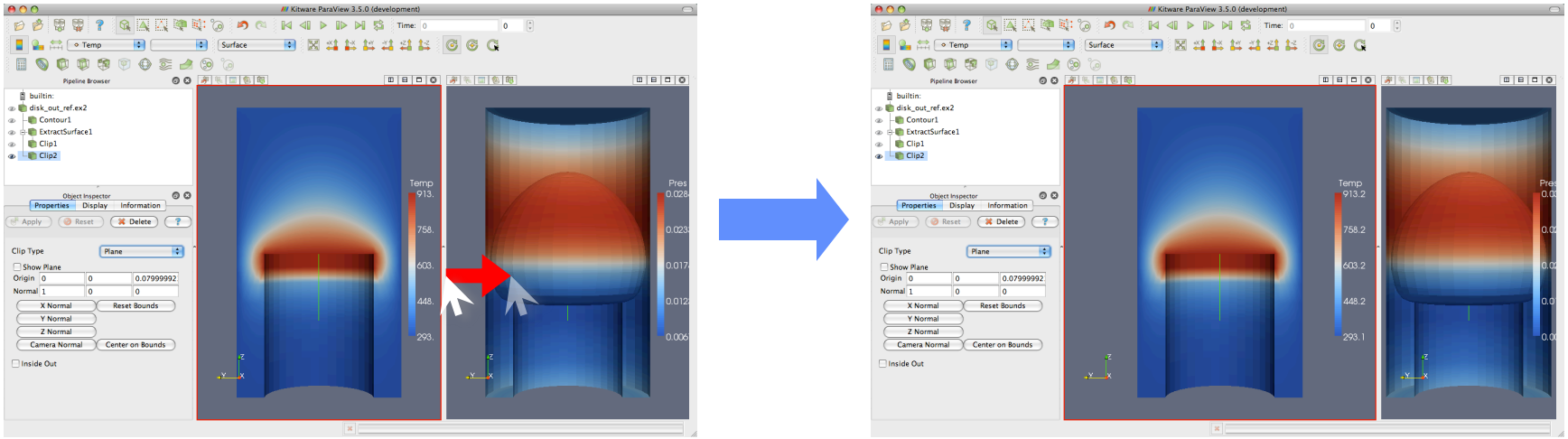
6. Split the view horizontally.
7. Make Clip1 visible.
8. Color surface by Temp.
9. Right-click view, Link Camera...
10. Click other view.
11. Click 

and zoom in a bit.

Modifying Views

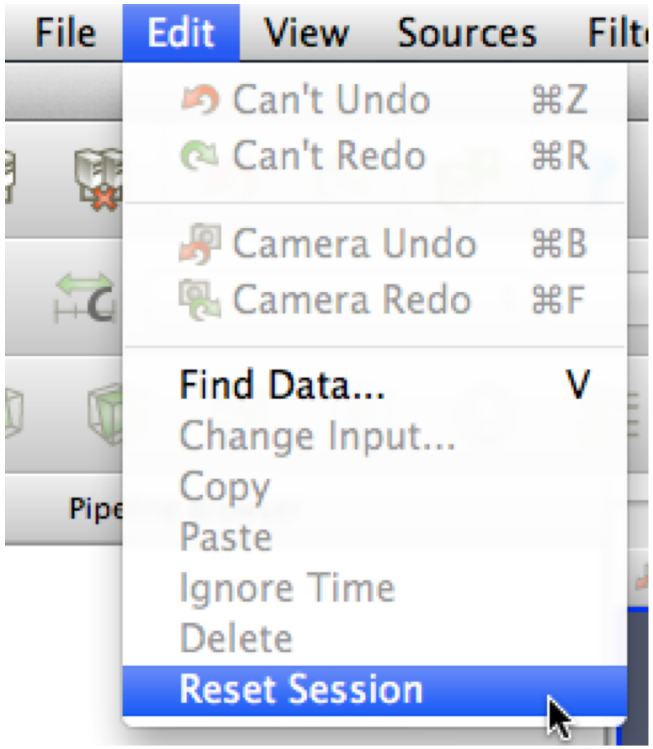


Modifying Views



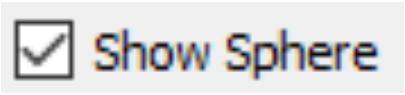
Reset ParaView

Edit → Reset Session



Streamlines

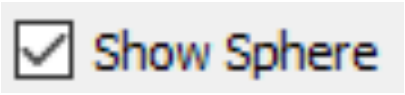
1. Open disk_out_ref.ex2. Load all variables. 

2. Add Stream Tracer. 
3. Change Seed Type to Point Source.
4. Uncheck Show Sphere. 

5. 

Streamlines

1. Open disk_out_ref.ex2. Load all variables. 

2. Add Stream Tracer. 
3. Change Seed Type to Point Source.
4. Uncheck Show Sphere. 

5. 

6. From the quick launch, select Tube
7. 

Getting Fancy

8. Select StreamTracer1.
9. Add Glyph filter. 
10. Change Glyph Type to Cone.
11. Change Vectors to V.
12. Change Scale Mode to vector.
13. Click reset  next to Scale Factor.
14. 

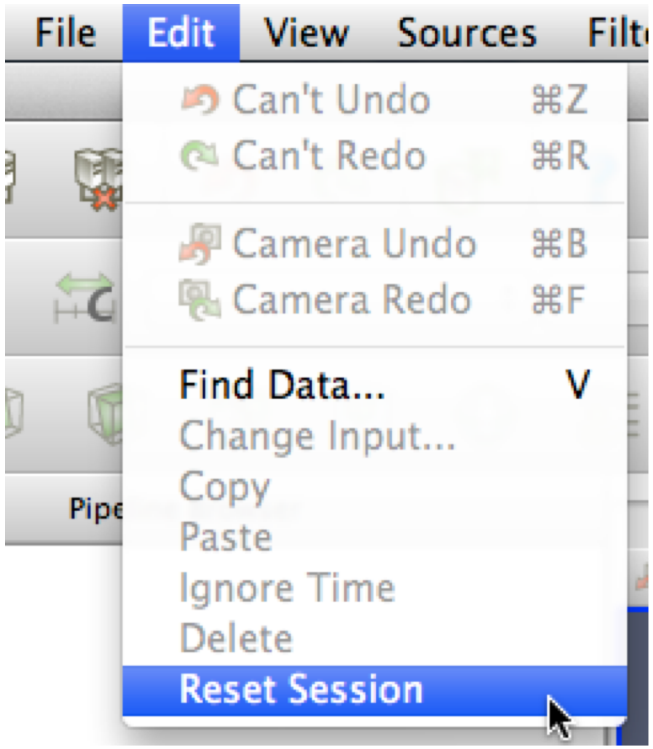
15. Color by Temp.

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?

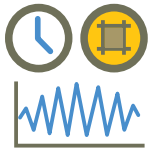
Reset ParaView

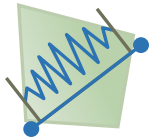
Edit → Reset Session



Common Data Analysis Filters


Extract Selection


Plot Global Variables Over Time


Plot Over Line


Plot Selection Over Time

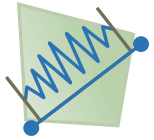

Probe Location

Plotting

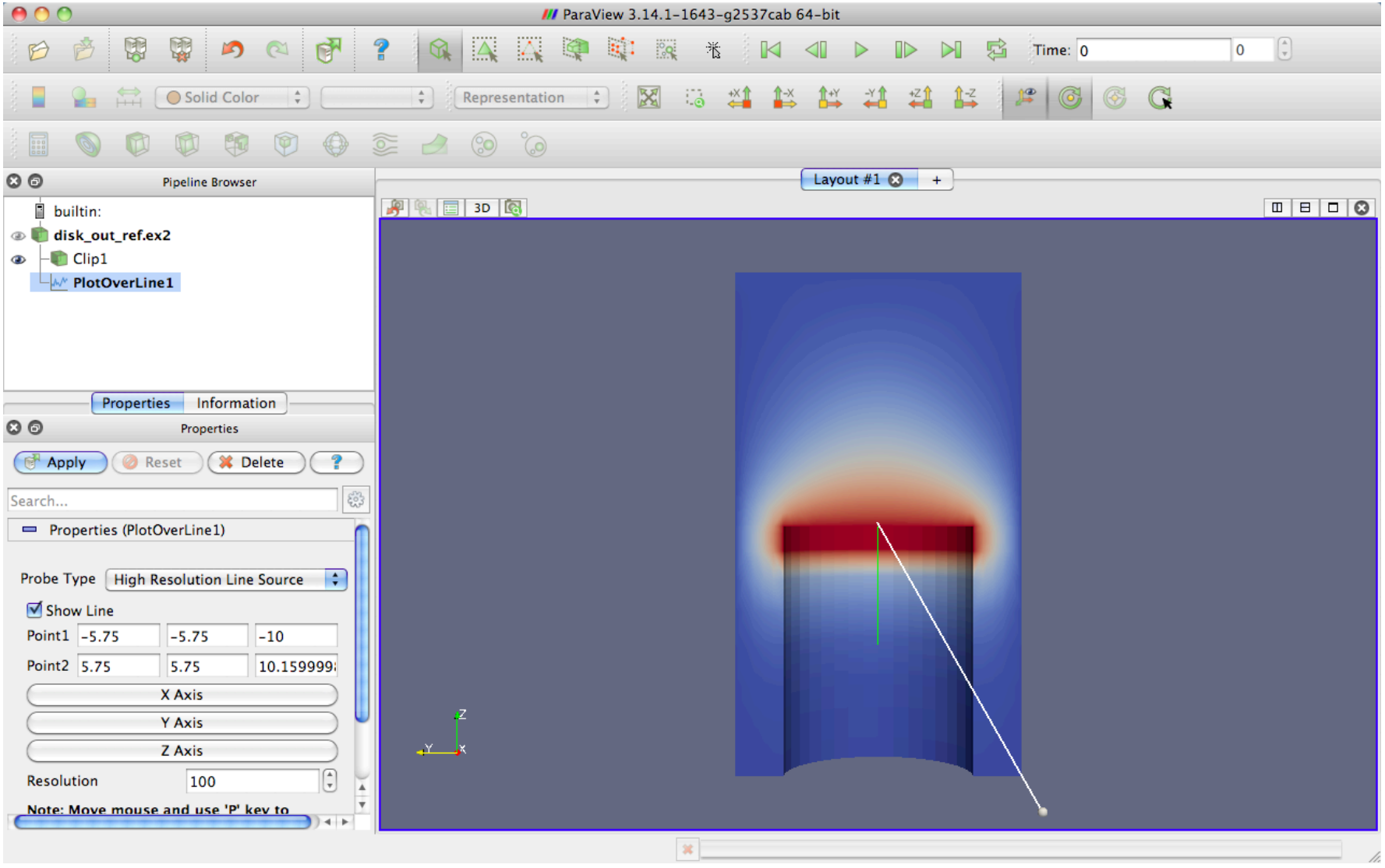
1. Open disk_out_ref.ex2. Load all variables. 

2. Clip,  uncheck, 

, 

3. Select disk_out_ref.ex2.
4. Add Plot Over Line filter. 

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

Placing 3D Line Widget Endpoints

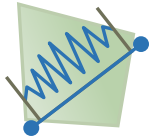
- Use the p key to place alternating points.
  - Ctrl+p places at nearest mesh point.
- Use the 1 or 2 key to place the start or end point.
  - Ctrl+1 or Ctrl+2 places at mesh point.
- Drag the endpoints.
  - Use x, y, or z key to constrain to axis.
- Use widgets in Properties panel
  - E.g. Use Z Axis button and then edit points to place from (0,0,0) to (0, 0, 10).

Plotting

1. Open disk_out_ref.ex2. Load all variables. 

2. Clip,  uncheck, 

, 

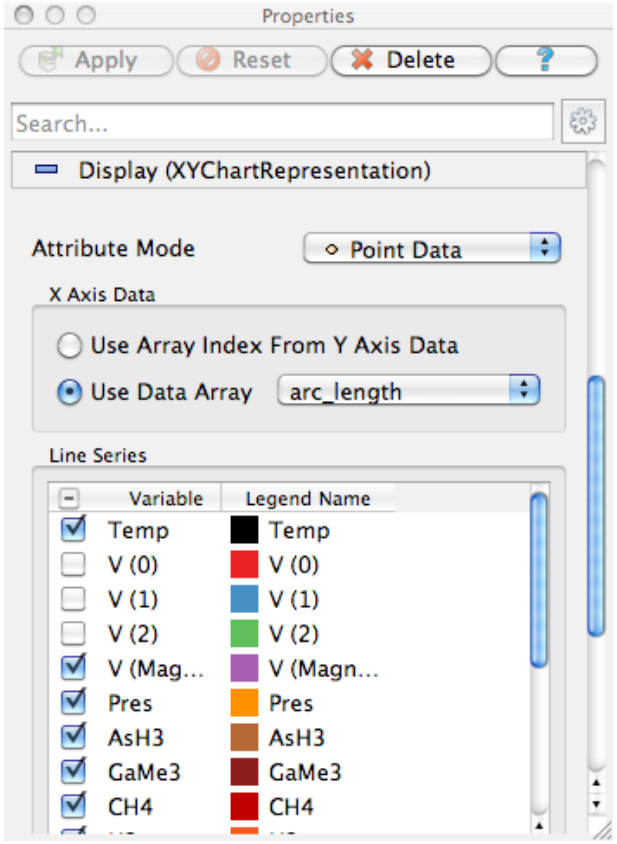
3. Select disk_out_ref.ex2.
4. Add Plot Over Line filter. 
5. Once line is satisfactorily located, 

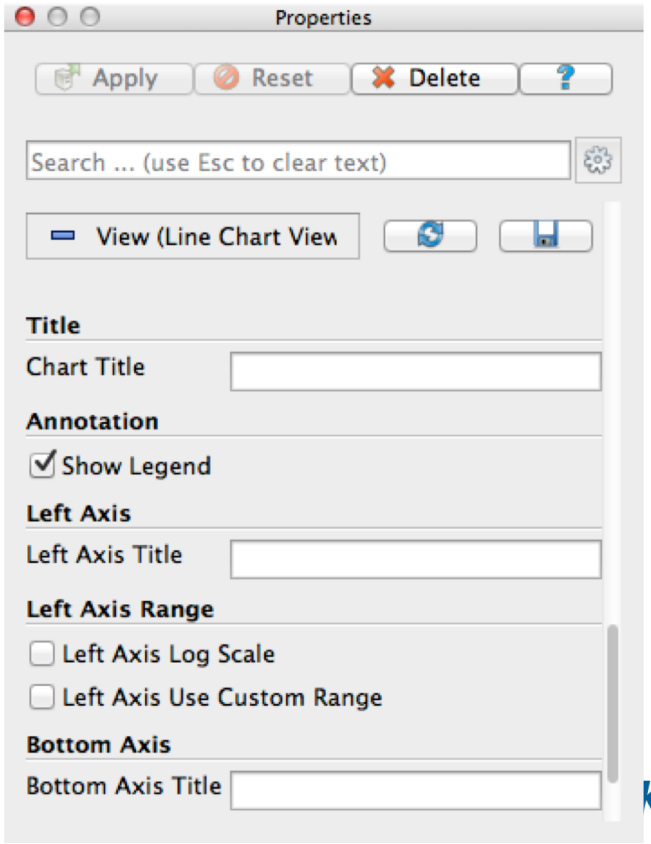
Interacting with Plots

- 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.





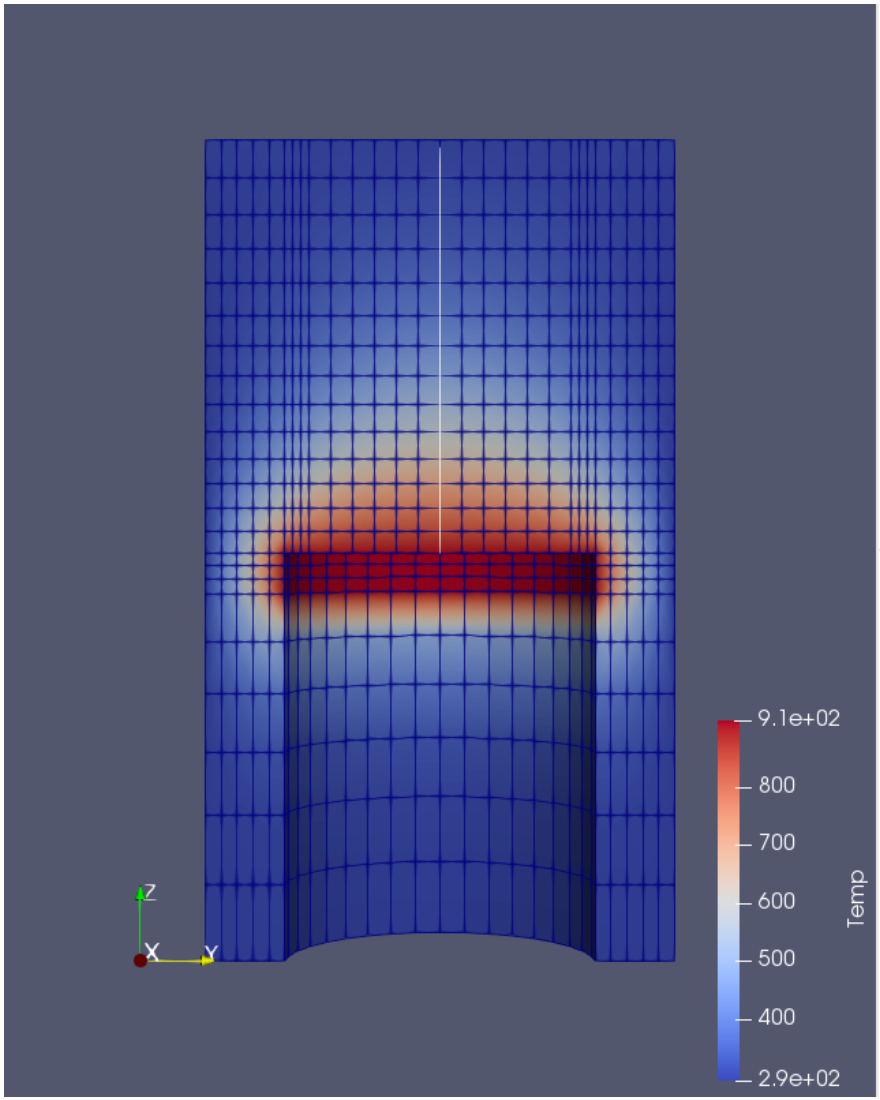
Adjusting Plots

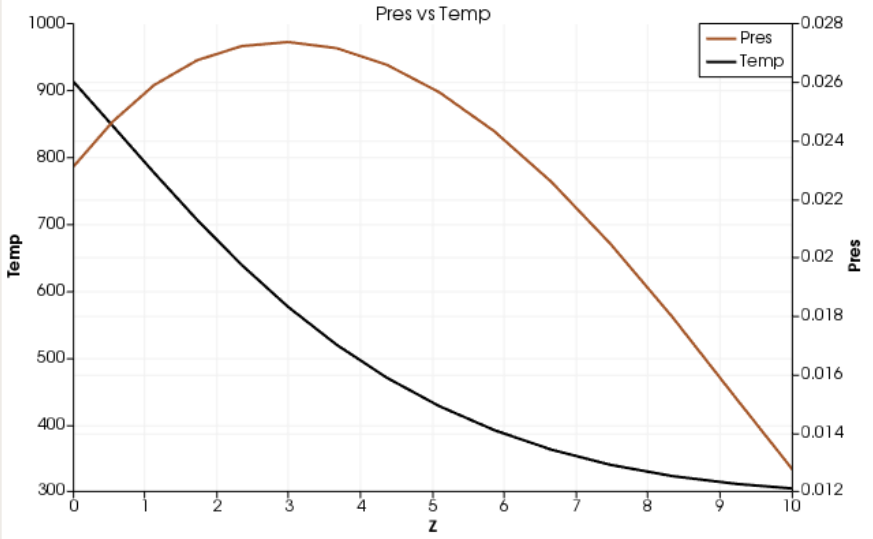
1. In Display section of properties panel, turn off all variables except Temp and Pres.
2. Select Pres in the Display options.
3. Change Chart Axis to Bottom – Right.
4. Verify the relationship between temperature and pressure.

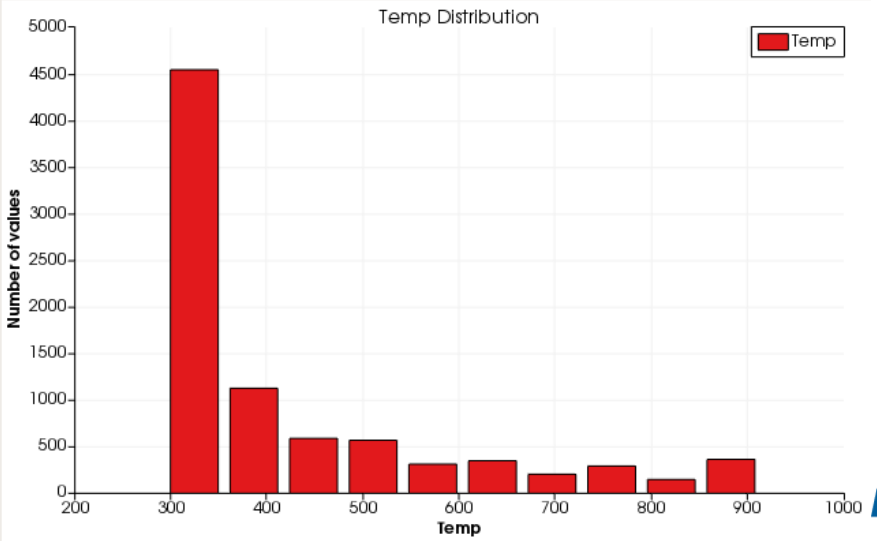
Histogram / Bar Chart

1. Select disk_out_ref.ex2.
2. Filters → Data Analysis → Histogram 
3. Change Input Array to Temp.
4. 

Histogram / Bar Chart

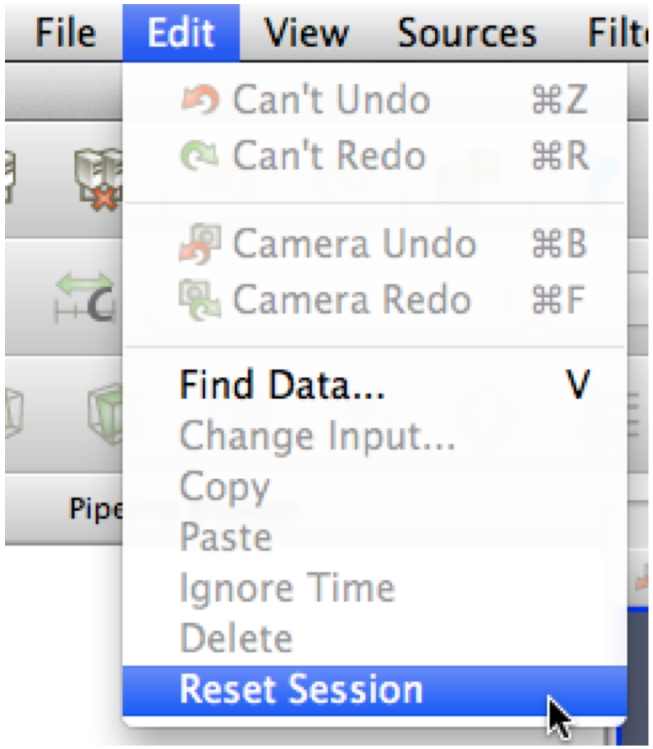






Reset ParaView

Edit → Reset Session



Volume Rendering

1. Open disk_out_ref.ex2. Load all variables. 

2. Change variable viewed to Temp.
3. Change representation to Volume.
4. In the Are you Sure dialog box, click Yes.

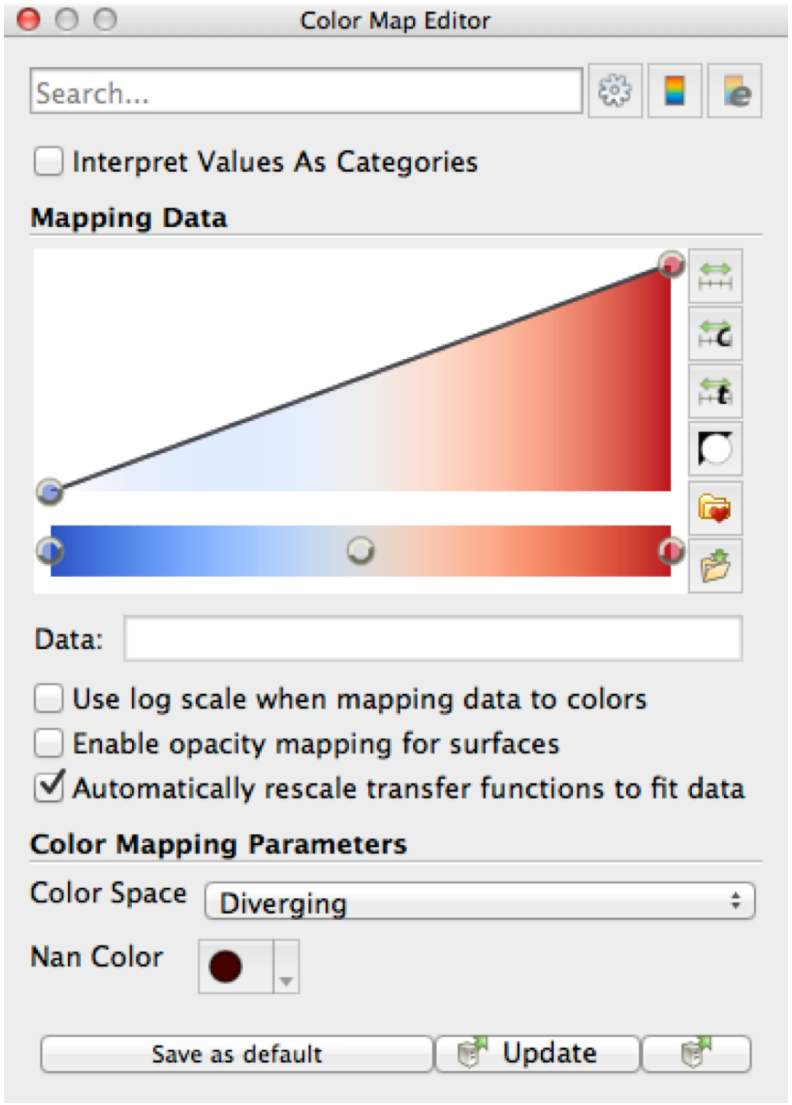
Volume Rendering + Surface Geometry

1. Open disk_out_ref.ex2. Load all variables. 

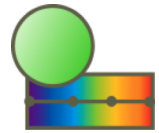
2. Change variable viewed to Temp.
3. Change representation to Volume.
4. Add Stream Tracer.  

5. Optional: Add Tubes and Glyphs.

Transfer Function Editor

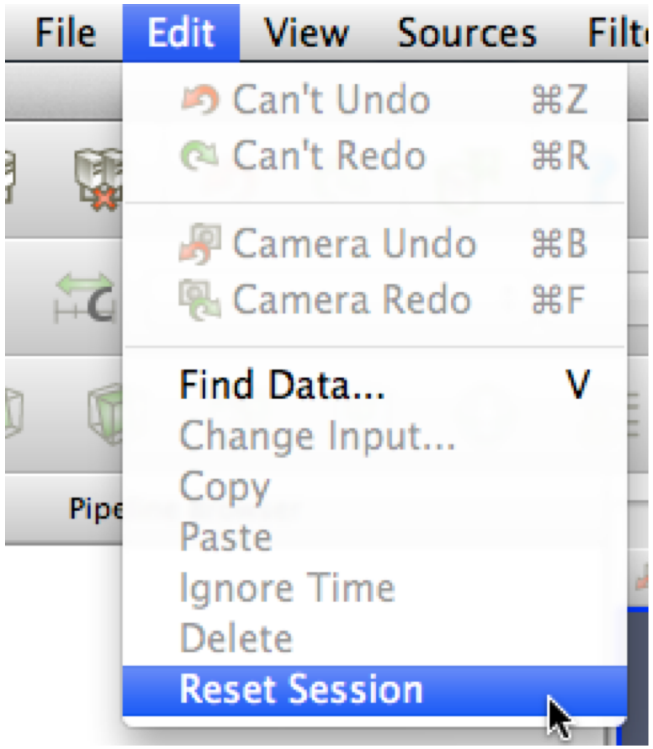


Modify Transfer Function

1. Select disk_out_ref.ex2.
2. Click Edit Color Map  .
3. Click Choose preset  .
4. Select Black-Body Radiation. Apply. Close.
5. Try adding and changing control points.

Reset ParaView

Edit → Reset Session

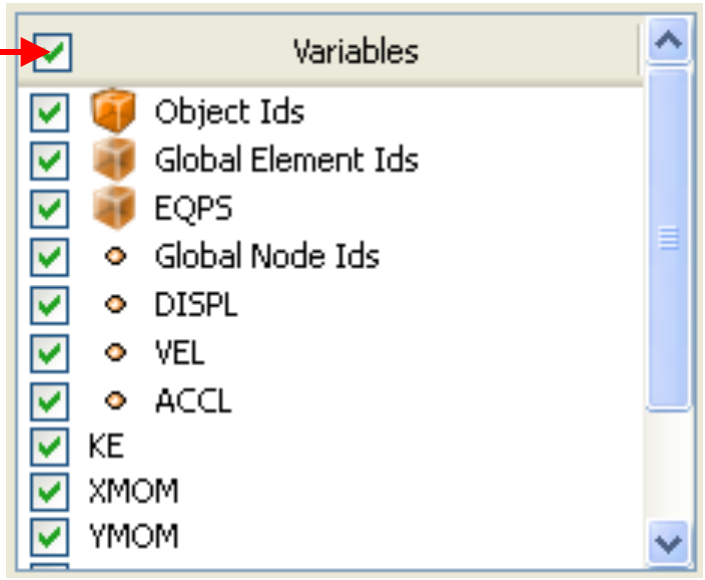


Loading Data with Time

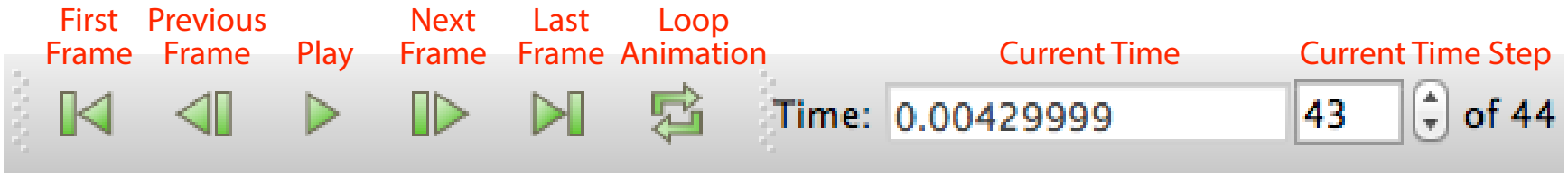
1. Open the file can.ex2.
2. Select all variables.
3. 

4. 

5. 



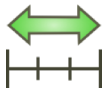
Animation Toolbar



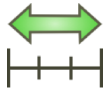
Animation Pitfall

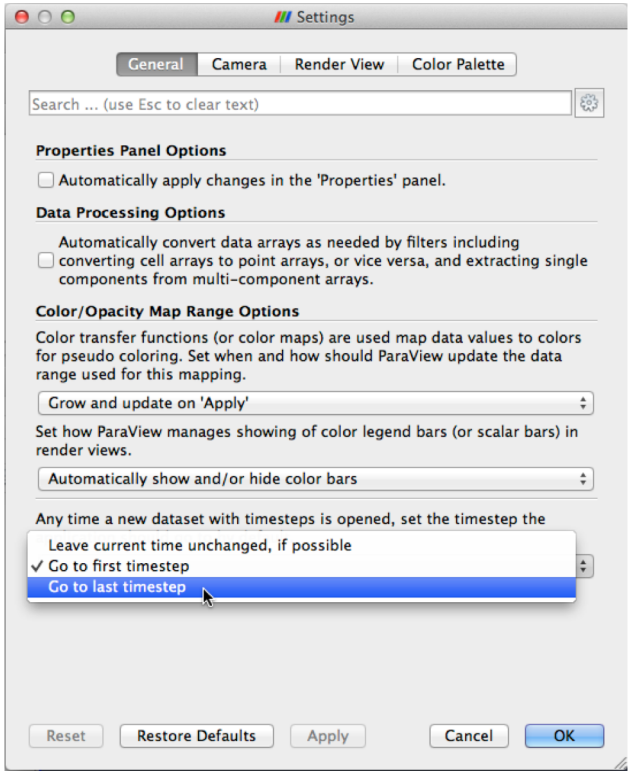
1. Go to first time step. 
2. Color by EQPS variable.
3. Play  (or skip to last time step ).

Animation Pitfall

1. Go to first time step. 
2. Color by EQPS variable.
3. Play  (or skip to last time step ).
4. Fix with Rescale to Data Range. 

Data Range Workarounds

- Go to representative time and hit 
- In Settings change On File Open to Goto last timestep.



Data Range Workarounds

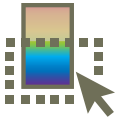
- Set a custom range.

Data Range Workarounds

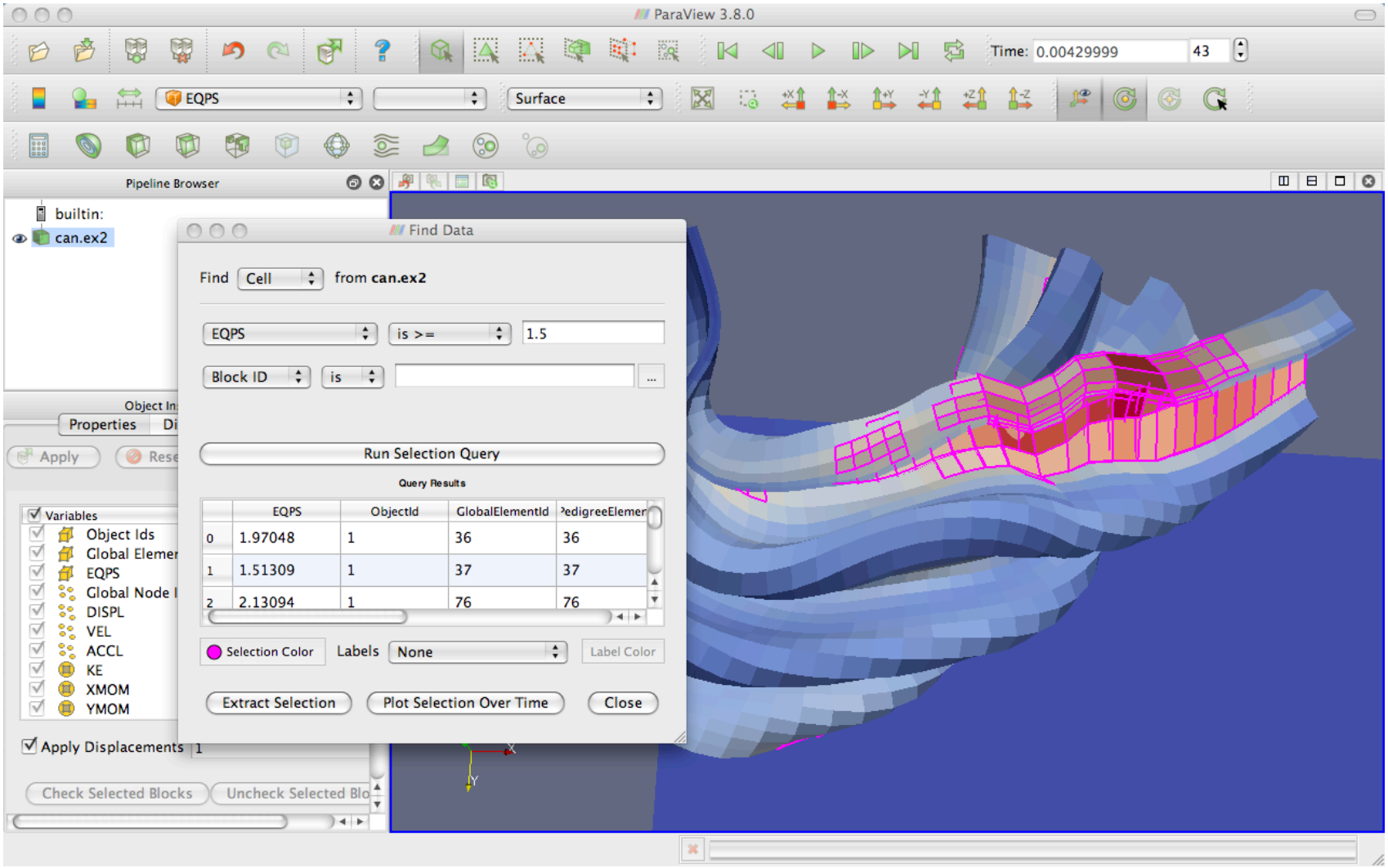
- Rescale to range over all timesteps

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
(shortcut: d)


Through Cell Selection
(shortcut: f)


Through Point Selection
(shortcut: g)


Select Cells (polygon)


Select Points (polygon)


Block Selection
(shortcut: b)

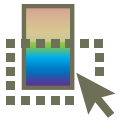

Interactively Select Cells


Interactively Select Points

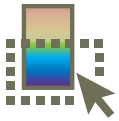

Hover Point Query


Hover Cell Query

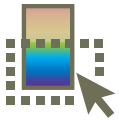
Selections

1. Open Find Data. 
2. Make various brush selections.
3. Observe results in the Find Data dialog box.
4. Play with the Invert Selection and Show Frustum options.

Adding Labels

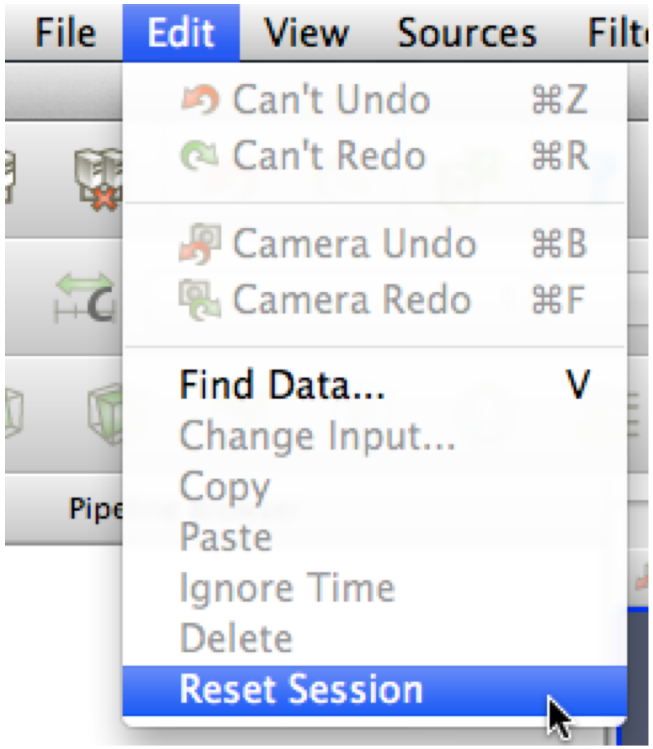
1. Go to the last time step. 
2. Open Find Data. 
3. Create query Global ID is min. Click Run Selection Query.
4. In the Cell Labels chooser, select EQPS.

Adding Labels

1. Go to the last time step. 
2. Open Find Data. 
3. Create query Global ID is min. Click Run Selection Query.
4. In the Cell Labels chooser, select EQPS.
5. When you are done, turn off the EQPS labels.

Reset ParaView

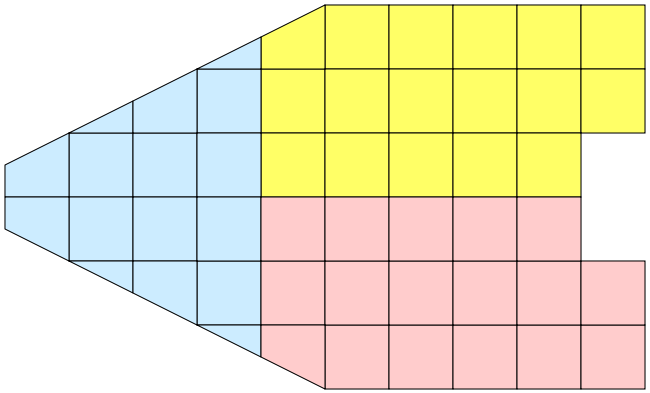
Edit → Reset Session



Visualizing Large Models

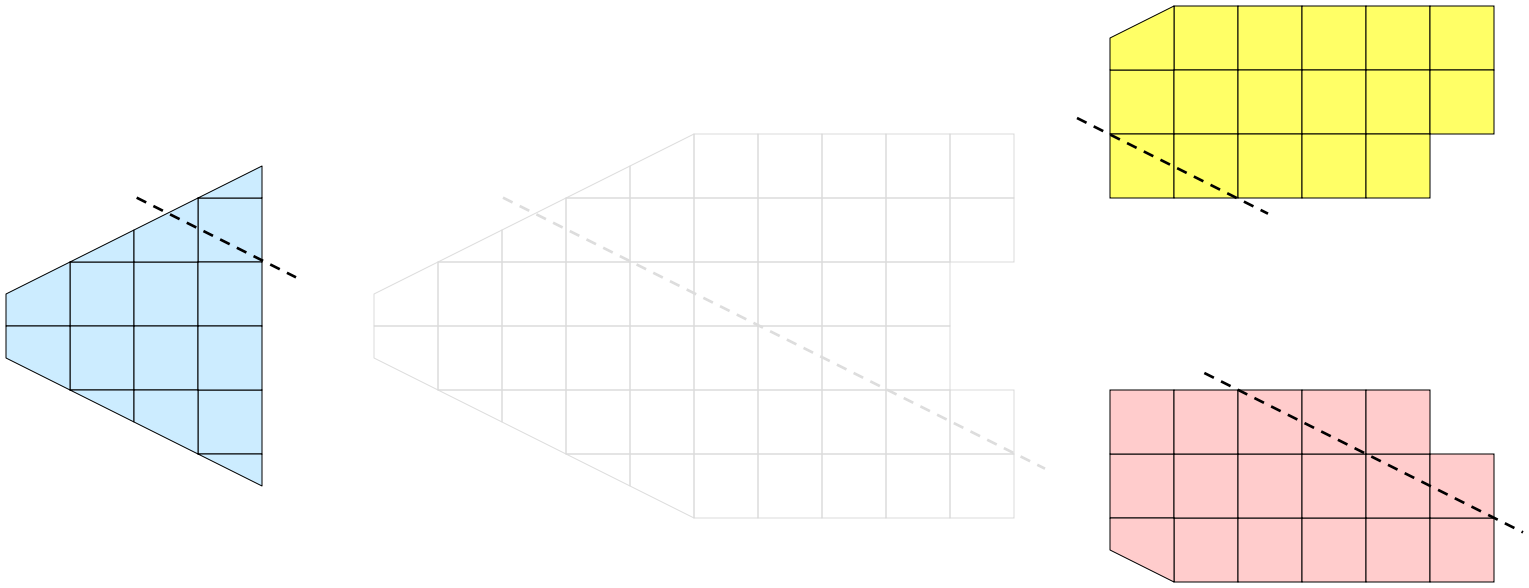
Data Parallel Pipelines

- Duplicate pipelines run independently on different partitions of data.



Data Parallel Pipelines

- Many operations will work regardless.
  - Example: Clipping.



Data Parallel Pipelines

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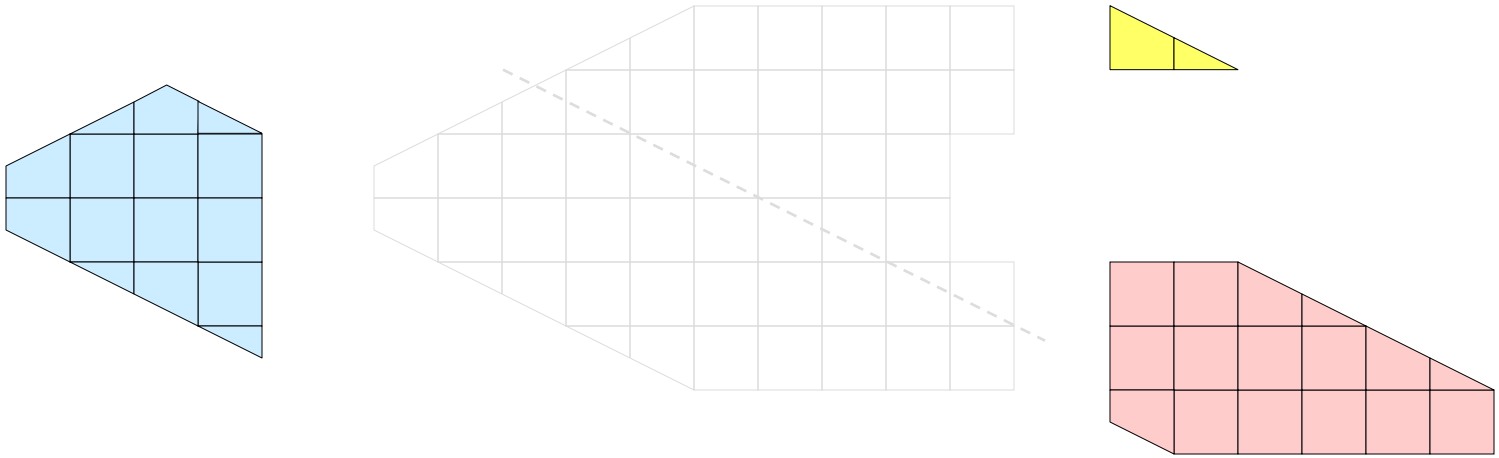

Data Parallel Pipelines

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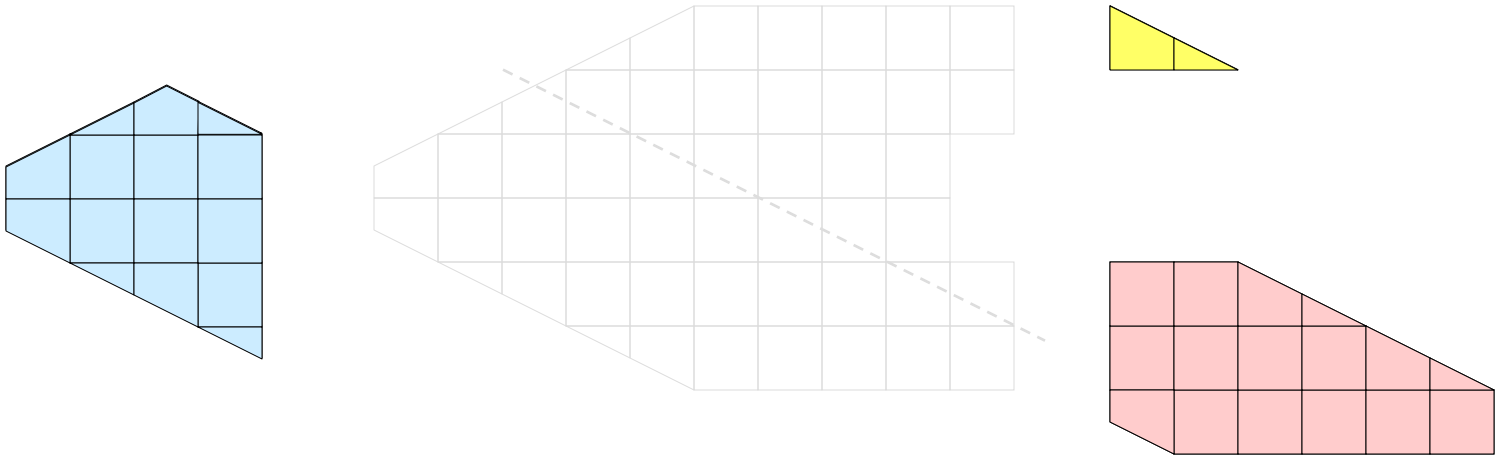
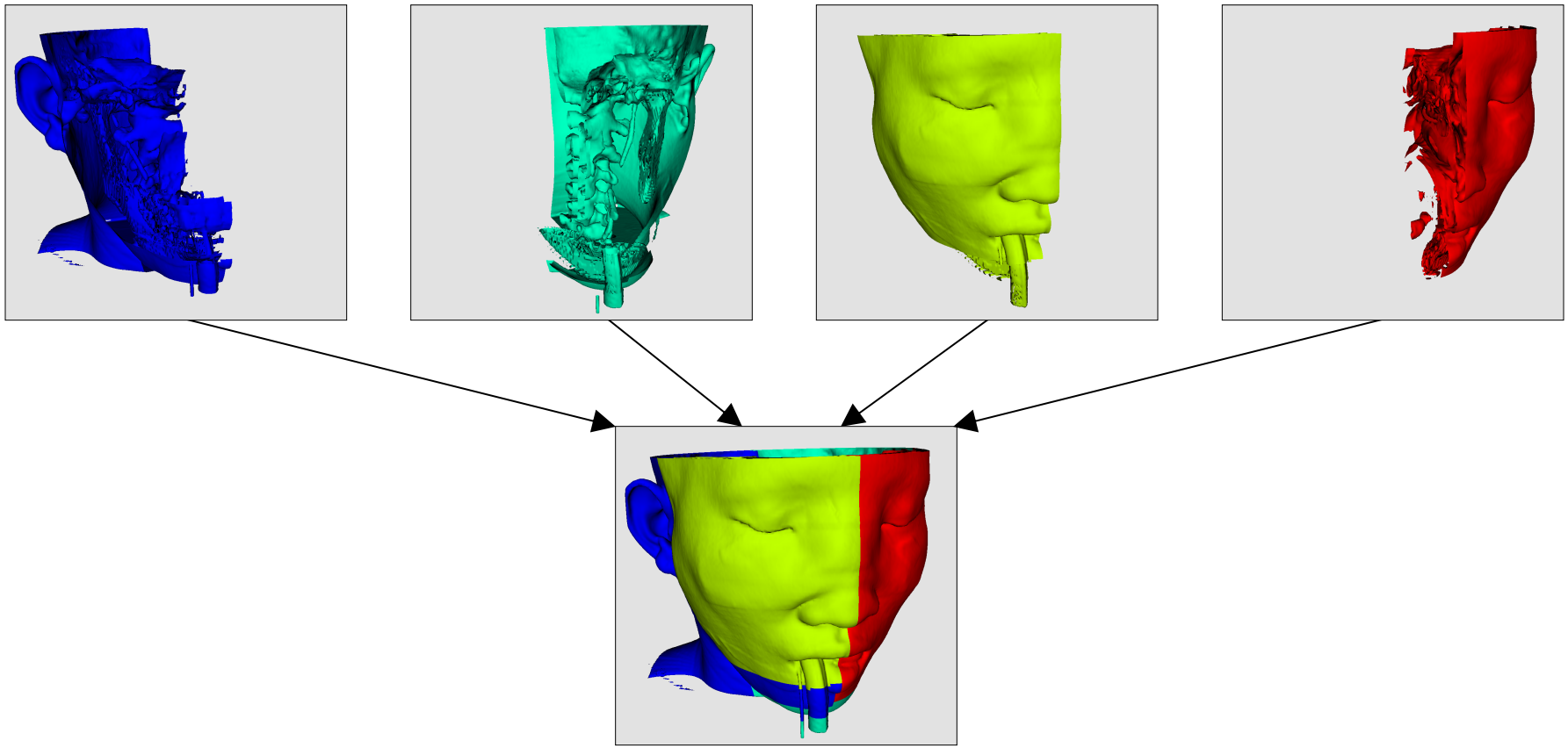
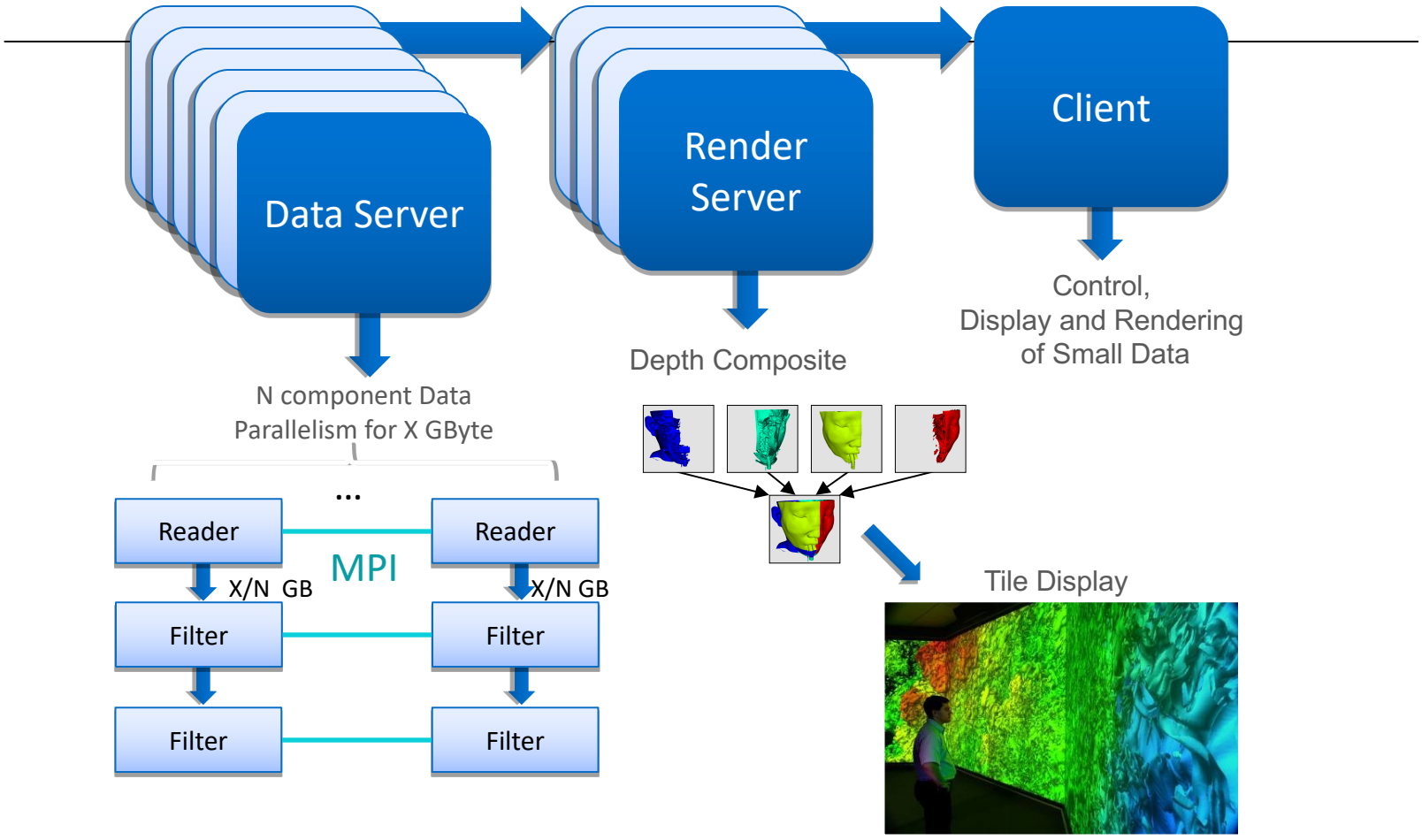


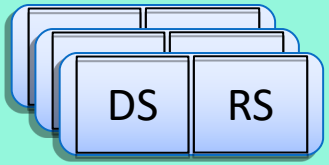
- Will discuss those that don't later

Parallel Rendering




Data Server
Render Server
Client
Control,
Display and Rendering
of Small Data
Depth Composite
N component Data
Parallelism for X GByte
...
Reader
Reader
MPI
X/N GB
X/N GB
Filter
Filter
Filter
Filter
Tile Display

ParaView's Running Modes

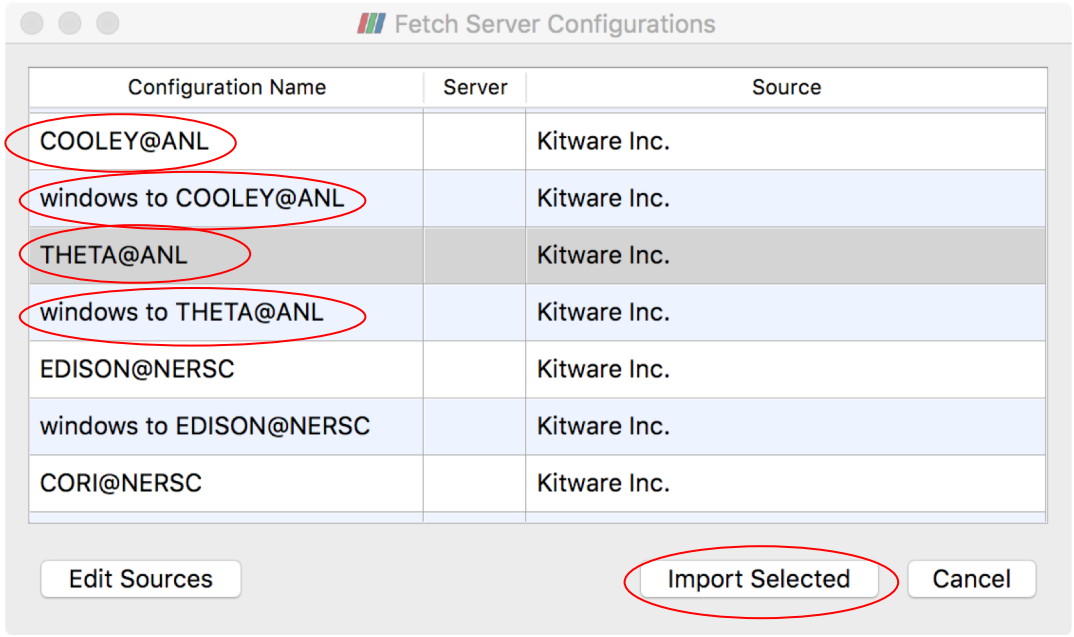
Builtin aka Standalone aka Serial		all components within one process (client may be GUI or pvpython) `paraview || pvpython`
Combined Server		data processing and parallel rendering in MPI job of combined processes. control from TCP connected client. `mpiexec -n x pvserver &; paraview #` or `pvpython #+ Connect`
Batch		server is an MPI job which directly runs a python script `mpiexec -n x pvbatch \ vis_script.py`

DS = data server

RS = render server

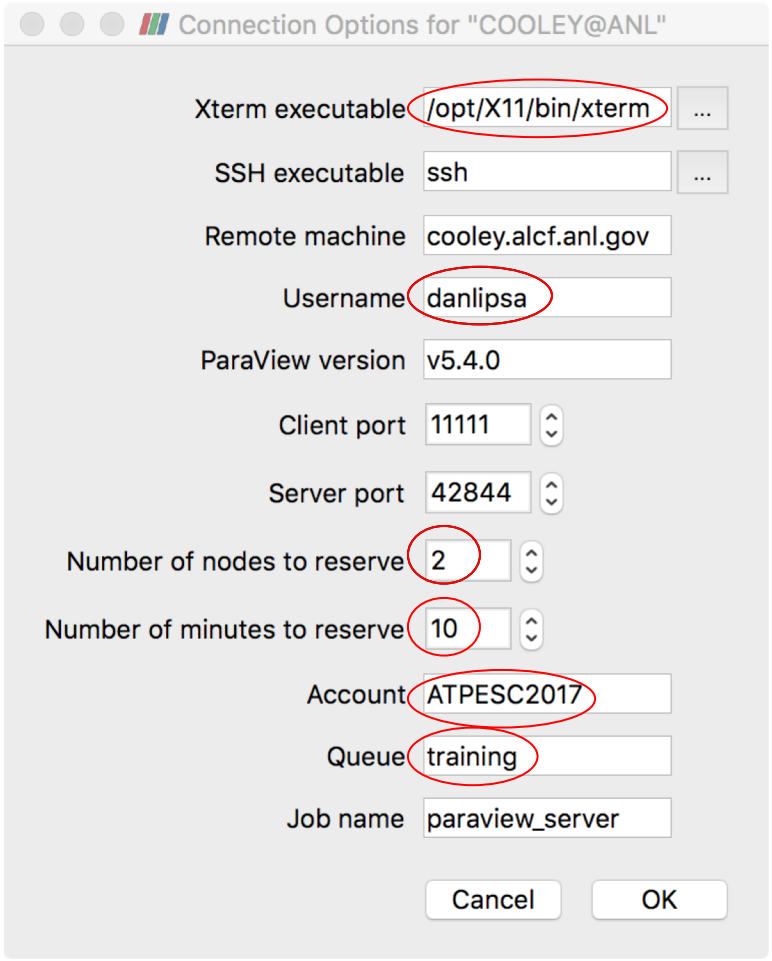
Fetch Server Configuration

- File > Connect > Fetch Servers



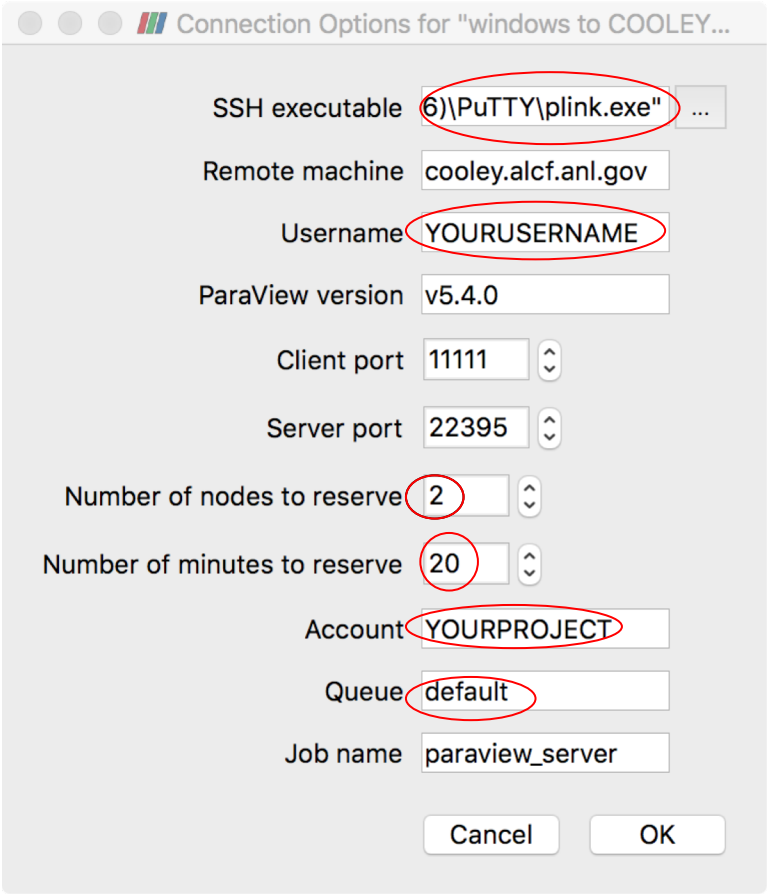
Connect Unix/Mac

Mac Os: Install Xquartz

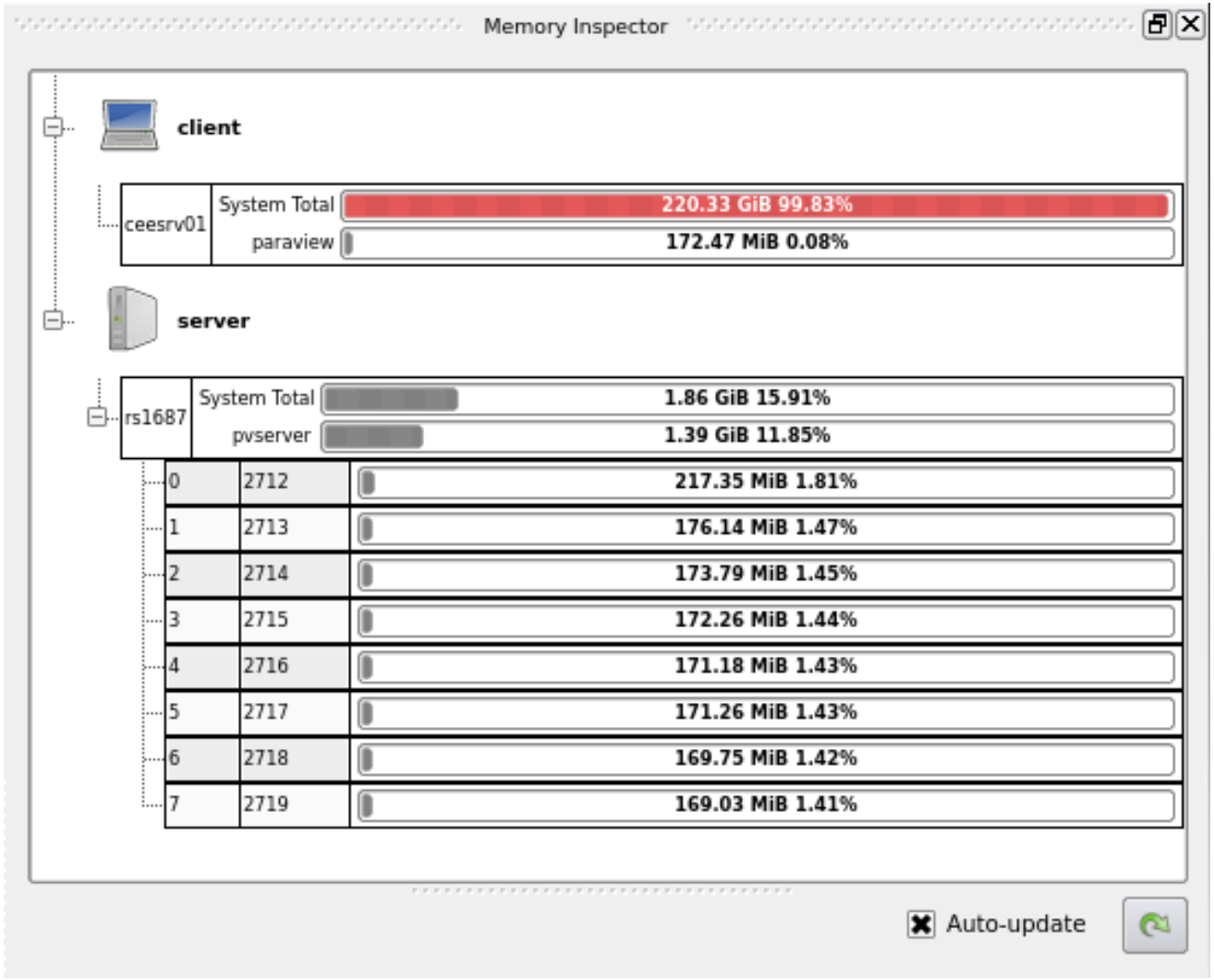


Connect Windows

Windows: Install PuTTY

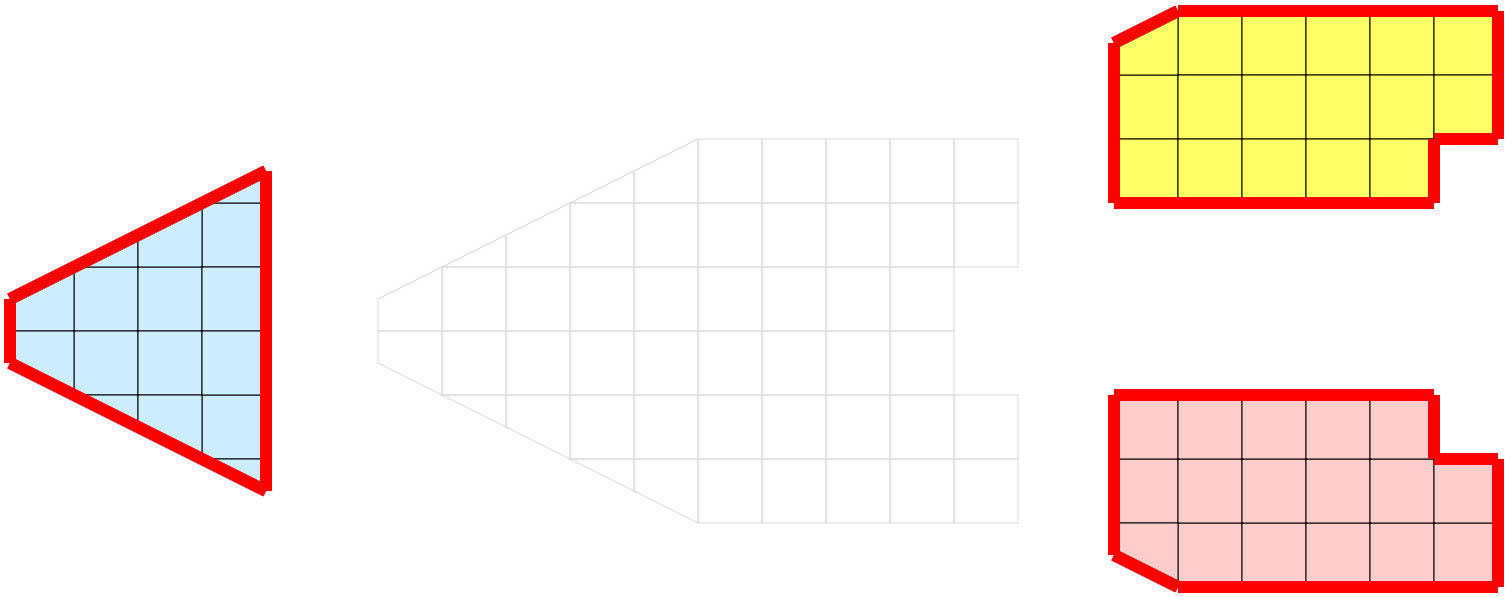


Memory Inspector



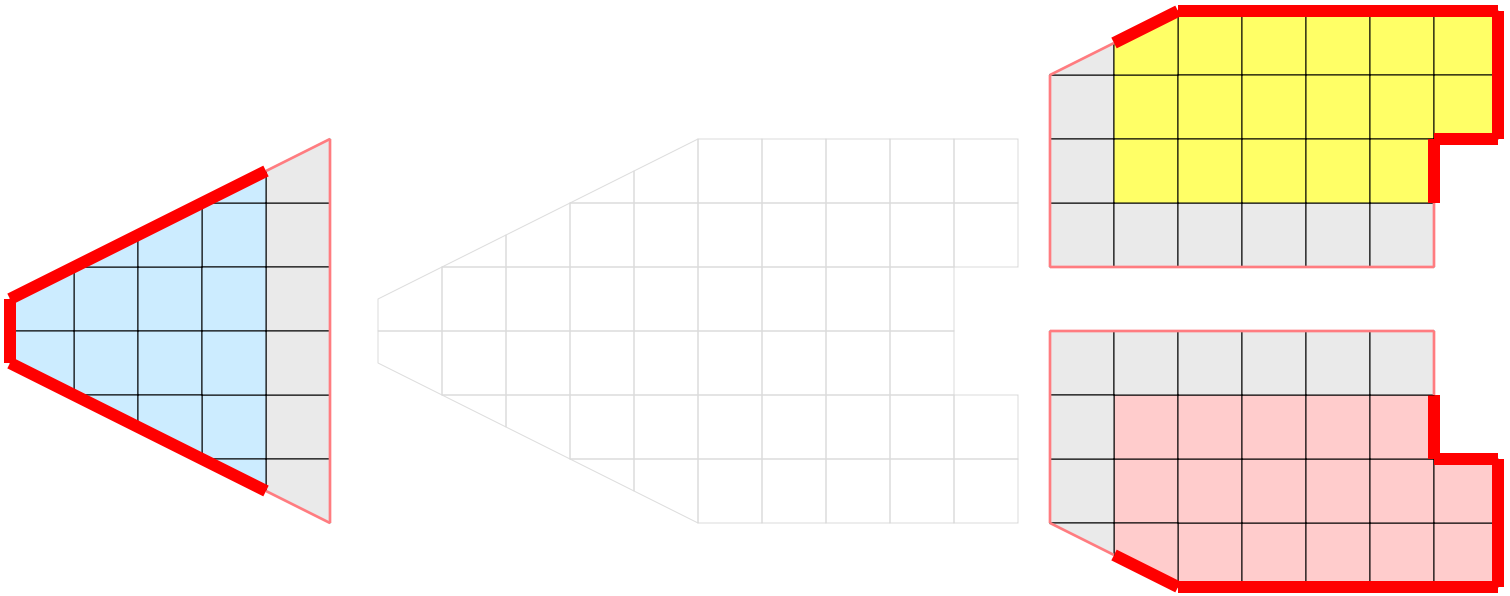
Advanced Data Parallel Pipelines

- Some operations will have problems.
  - Example: External Faces



Advanced Data Parallel Pipelines

- Ghost cells can solve most of these problems.



Advanced Data Parallel Pipelines

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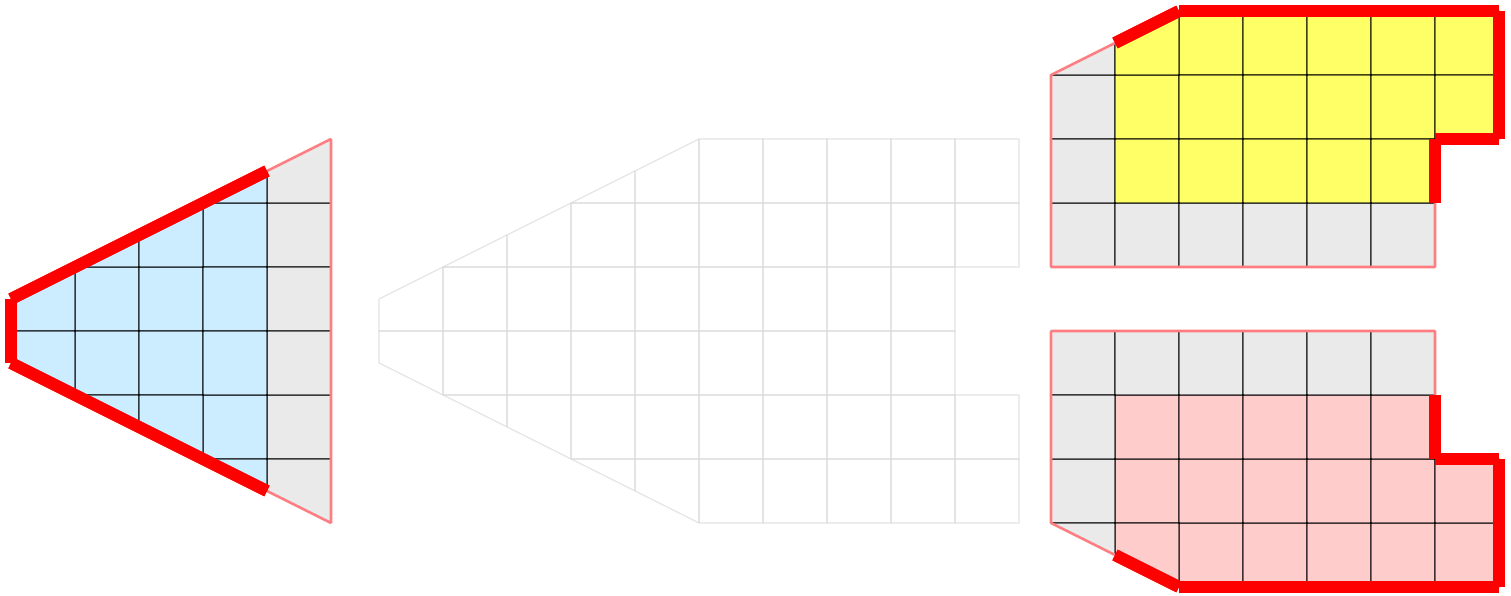
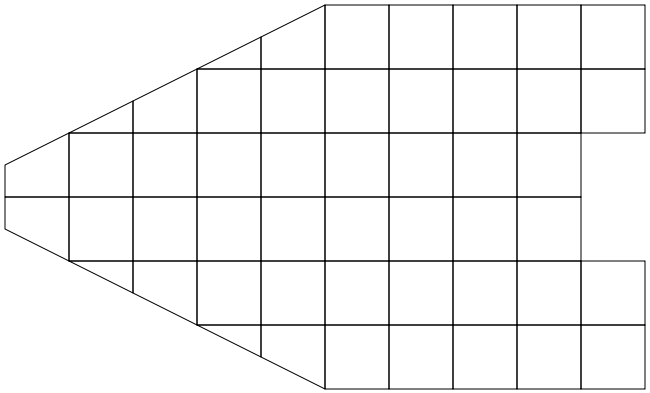


Data Partitioning

- Partitions should be **load balanced** and **spatially coherent**. Why?



Data Partitioning

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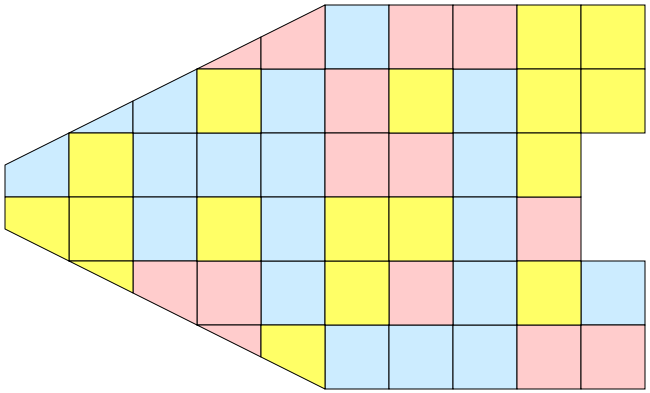
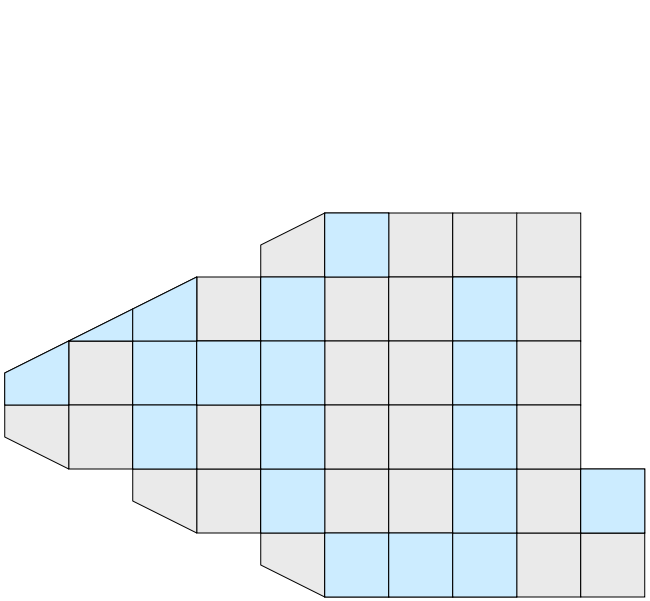
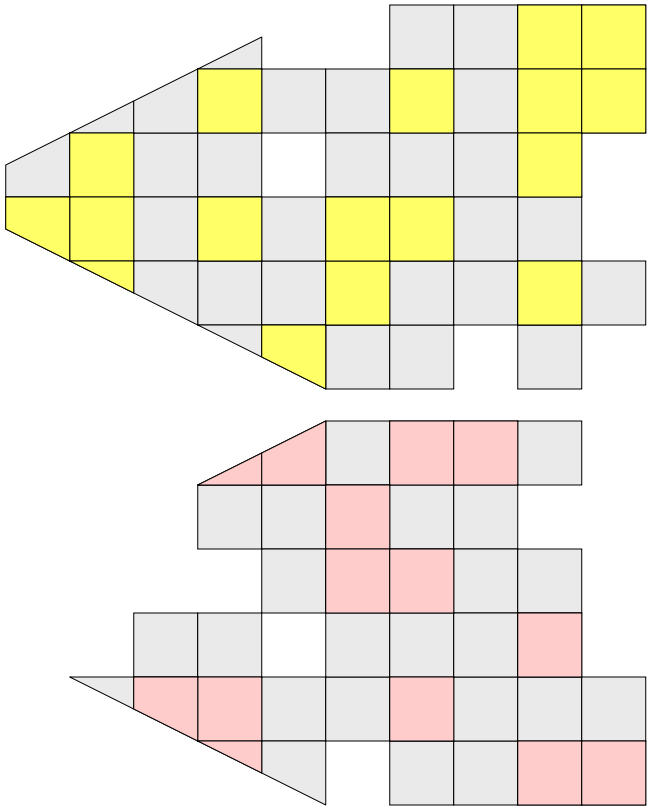


Data Partitioning

- Partitions should be load balanced and spatially coherent. A random partition with ghost cells will replicate the entire dataset on all nodes.

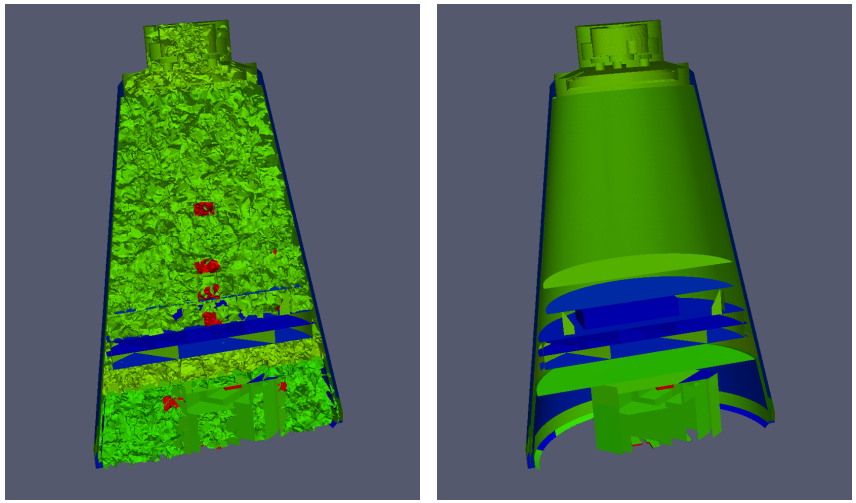




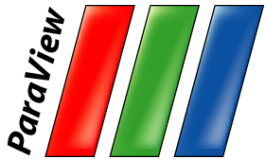
Load Balancing/Ghost Cells

- Automatic for Structured Meshes.
- Partitioning/ghost cells for unstructured is “manual.”
- Use Ghost Level Generator to create
- Legacy option: D3. Also repartitions

Extract Surface without ghost cells



Extract Surface after D3



Thank you!

Questions?