Visualization with ParaView

Greg Johnson

Before we begin…

- Make sure you have ParaView 3.8.0 installed so you can follow along in the lab section
  - http://paraview.org/paraview/resources/software.html

Background

- http://www.paraview.org/
- Open-source, multi-platform parallel data analysis and visualization application
- Mature, feature-rich interface
- Good for general-purpose, rapid visualization
- Built upon the Visualization ToolKit (VTK) library
- Primary contributors:
  - Kitware, Inc.
  - Sandia National Laboratory
  - Los Alamos National Laboratory
  - Army Research Laboratory

Data Types

- Supports a wide variety of data types
  - Structured grids
    - uniform rectilinear, non-uniform rectilinear, and curvilinear
  - Unstructured grids
  - Polygonal data
  - Images
  - Multi-block
  - AMR
- Time series support

Visualization Algorithms

- Supports a wide variety of visualization algorithms
  - Isosurfaces
  - Cutting planes
  - Streamlines
  - Glyphs
  - Volume rendering
  - Clipping
  - Height maps
  - …

Special Features

- Supports derived variables
  - New scalar / vector variables that are functions of existing variables in your data set
- Scriptable via Python
- Saves animations
- Can run in parallel / distributed mode for large data visualization

Data Formats

- Supports a wide variety of data formats
  - VTK (http://www.vtk.org/VTK/img/file-formats.pdf)
  - EnSight
  - Plot3D
  - Various polygonal formats
- Users can write data readers to extend support to other formats
- Conversion to the VTK format is straightforward

Data Formats

- VTK Simple Legacy Format
  - ASCII or binary
  - Supports all VTK grid types
  - Easiest for data conversion
- *Note: use VTK XML format for parallel I/O*

```
# vtk DataFile Version 2.0                    ] (1)
Really cool data                              ] (2)
ASCII | BINARY                                ] (3)
DATASET type                                  ]
...                                           ] (4)
POINT_DATA n                                  ]
...                                           ] (5)
CELL_DATA n                                   ]
...                                           ]
```

Part 1: Header

Part 2: Title (256 characters maximum, terminated with newline `\n` character)

Part 3: Data type, either ASCII or BINARY

Part 4: Geometry/topology. *Type* is one of:

```
STRUCTURED_POINTS
STRUCTURED_GRID
UNSTRUCTURED_GRID
POLYDATA
RECTILINEAR_GRID
FIELD
```

Part 5: Dataset attributes. The number of data items *n* of each type must match the number of points or cells in the dataset. (If *type* is `FIELD`, point and cell data should be omitted.

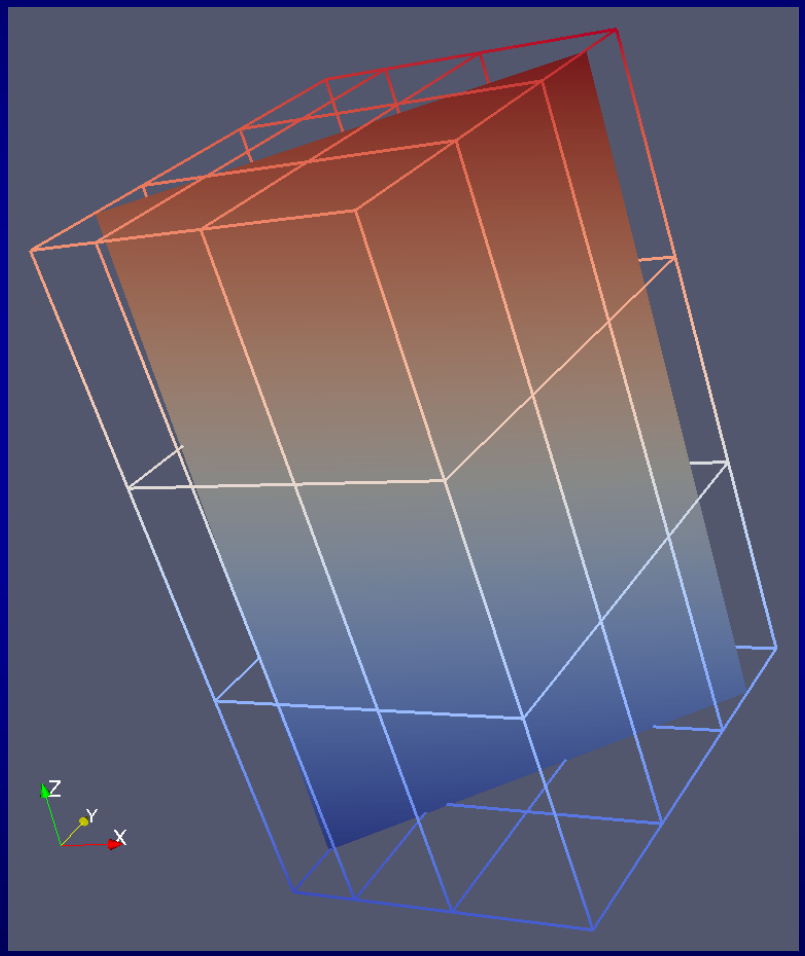
VTK simple legacy format (http://www.vtk.org/VTK/img/file-formats.pdf)

Data Formatting Example

- Data set: 4x4x4 rectilinear grid with one scalar variable

example.vtk

```
# vtk DataFile Version 2.0
one scalar variable on a rectilinear grid
ASCII
DATASET RECTILINEAR_GRID
DIMENSIONS 4 4 4
X_COORDINATES 4 float
0 1 2.5 4.5
Y_COORDINATES 4 float
0 2 4 6
Z_COORDINATES 4 float
0 3 6 9
POINT_DATA 64
SCALARS scalar_variable float 1
LOOKUP_TABLE default
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
17 18 19 20 21 22 23 24 25 26 27 28 29 30
31 32 33 34 35 36 37 38 39 40 41 42 43 44
45 46 47 48 49 50 51 52 53 54 55 56 57 58
59 60 61 62 63
```

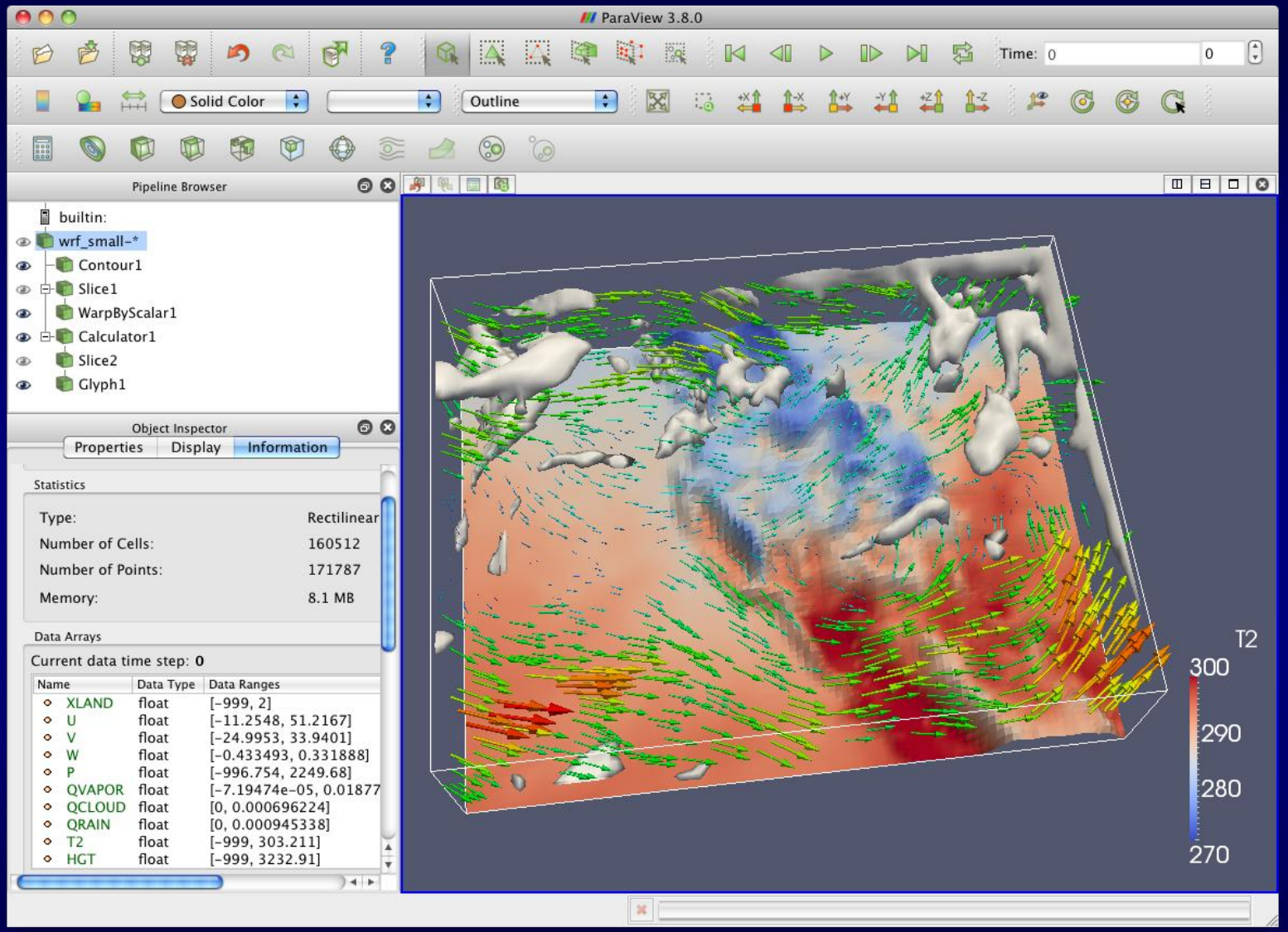


ParaView Visualization Pipeline

- All processing operations (filters) produce data sets
- Can further process the result of every operation to build complex visualizations
  - e.g. can extract a cutting plane, and apply glyphs (i.e. vector arrows) to the result
    - Gives a plane of glyphs through your 3D volume

Demonstration

- WRF weather forecast data set
  - Rectilinear grid
  - Multiple scalar and vector variables
  - Time series
- Can show:
  - Clouds
  - Wind
  - Temperature
  - …


ParaView 3.8.0
Time: 0
0
Solid Color
Outline
Pipeline Browser
builtin:
wrf_small-*
Contour1
Slice1
WarpByScalar1
Calculator1
Slice2
Glyph1
Object Inspector
Properties
Display
Information
Statistics
Type: Rectilinear
Number of Cells: 160512
Number of Points: 171787
Memory: 8.1 MB
Data Arrays
Current data time step: 0
Name
Data Type
Data Ranges
XLAND float [-999, 2]
U float [-11.2548, 51.2167]
V float [-24.9953, 33.9401]
W float [-0.433493, 0.331888]
P float [-996.754, 2249.68]
QVAPOR float [-7.19474e-05, 0.01877
QCLOUD float [0, 0.000696224]
QRAIN float [0, 0.000945338]
T2 float [-999, 303.211]
HGT float [-999, 3232.91]
T2
300
290
280
270

TACC

ParaView Test-Drive

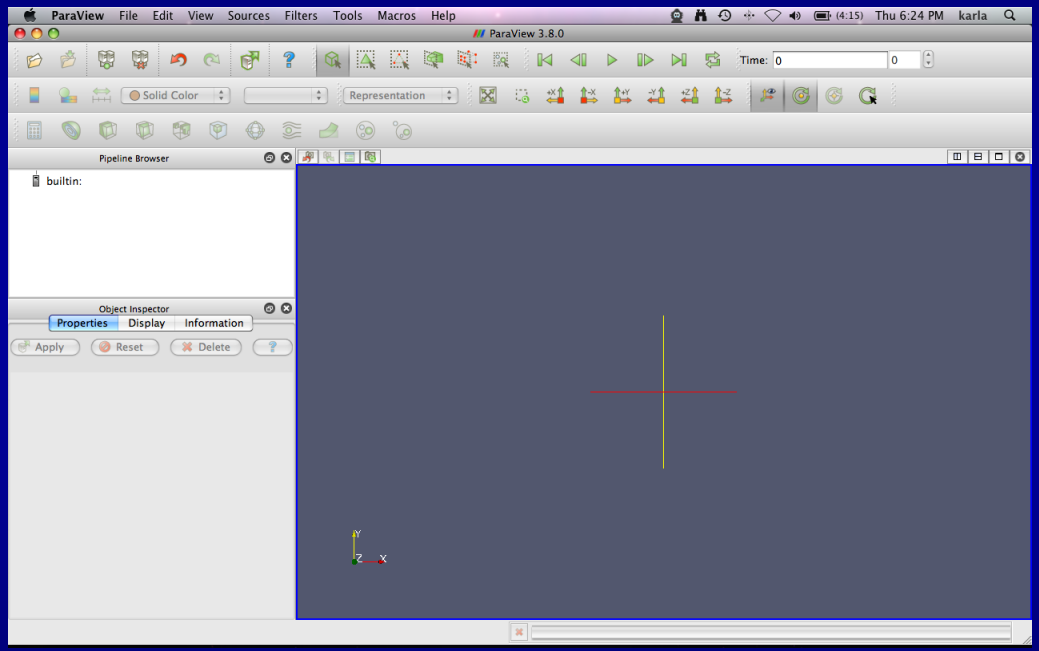
Getting Started

- Download example data file ‘RectGrid2.vtk’
  - http://portal.longhorn.tacc.utexas.edu/training/
  - Right-click, Save link as…
- Open ParaView

ParaView

Today we will:

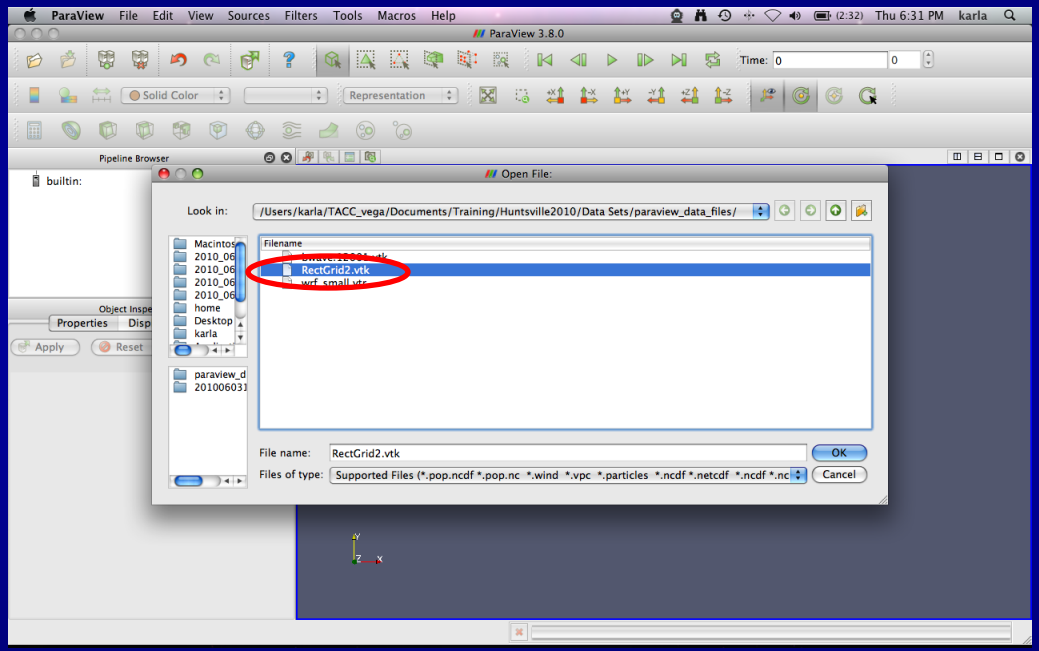
- Create isosurfaces for a scalar variable
- Clip and slice the isosurfaces
- Use glyphs to display a vector field
- Use streamlines to show flow through a vector field
- Edit color maps
- Add slices to show variable values over a plane
- Adjust opacities of filters
- Add color legends
- Create volume rendering



ParaView

Open the file
`RectGrid2.vtk`

- Click `File -> Open`
- Select `RectGrid2.vtk`
- Click `OK`
- Click blue `Apply`
- Box outline of dataset extent displayed



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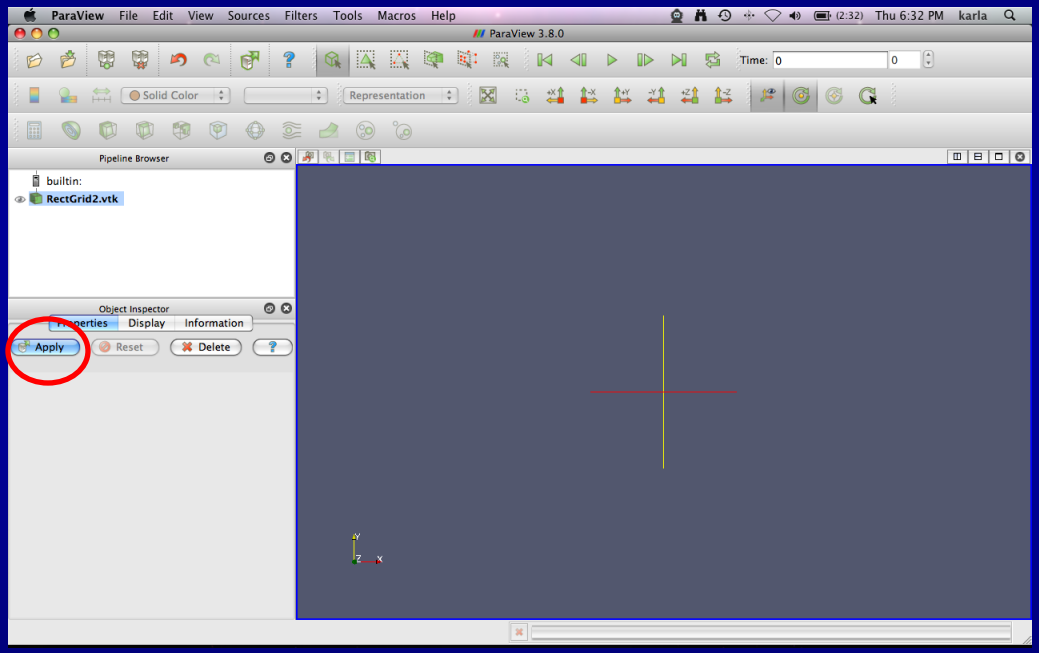

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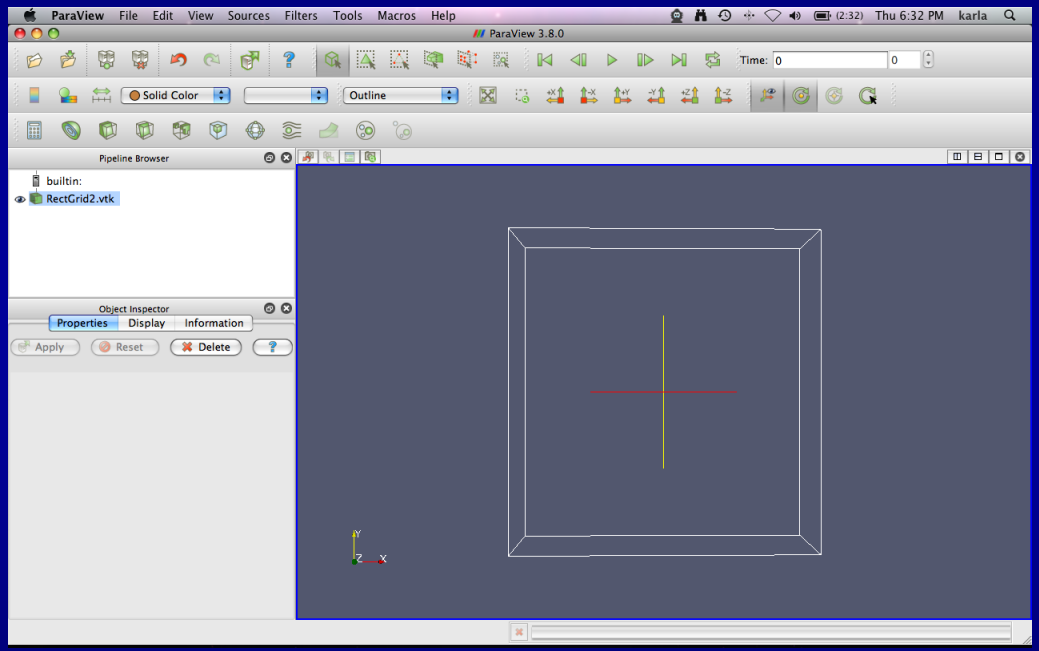
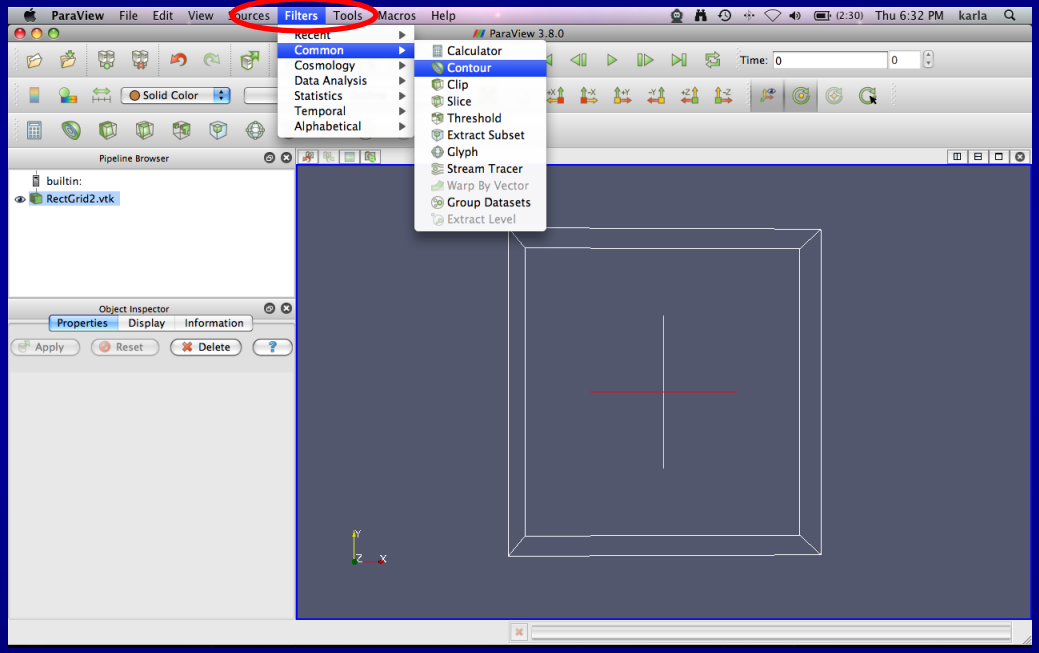


ParaView

Create isosurfaces

- Click `Filters -> Common -> Contour`
- In Isosurfaces box, click `Delete All`
- Click `New Range`
- Keep defaults, click `OK`
- Click blue `Apply`
- Click `Display` tab
- In `Color by` box, select `vectors`



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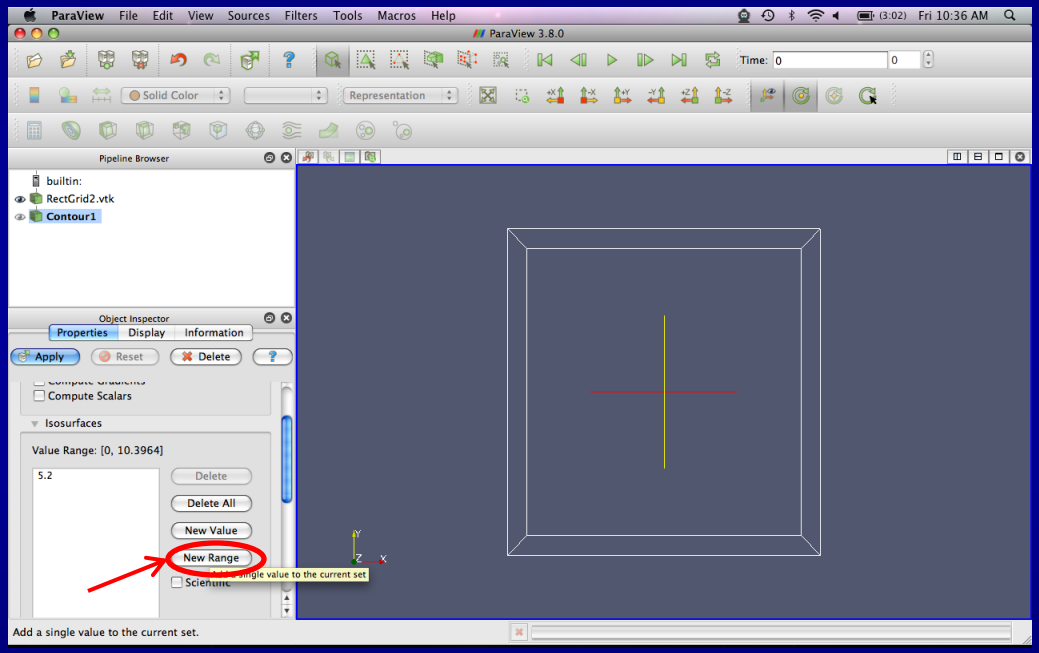

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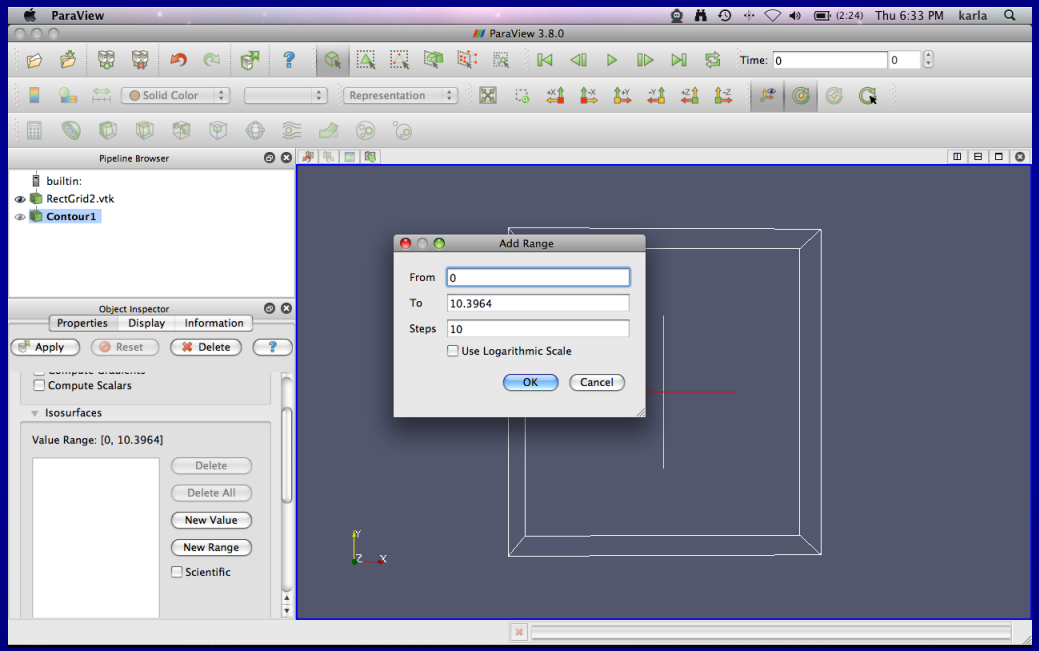

TACC

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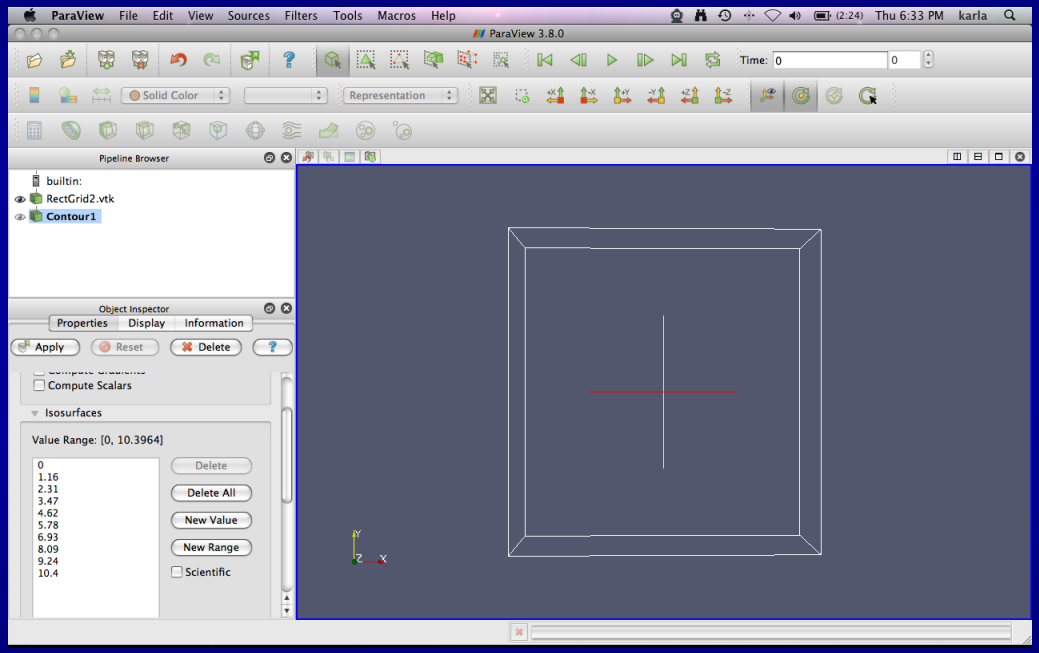

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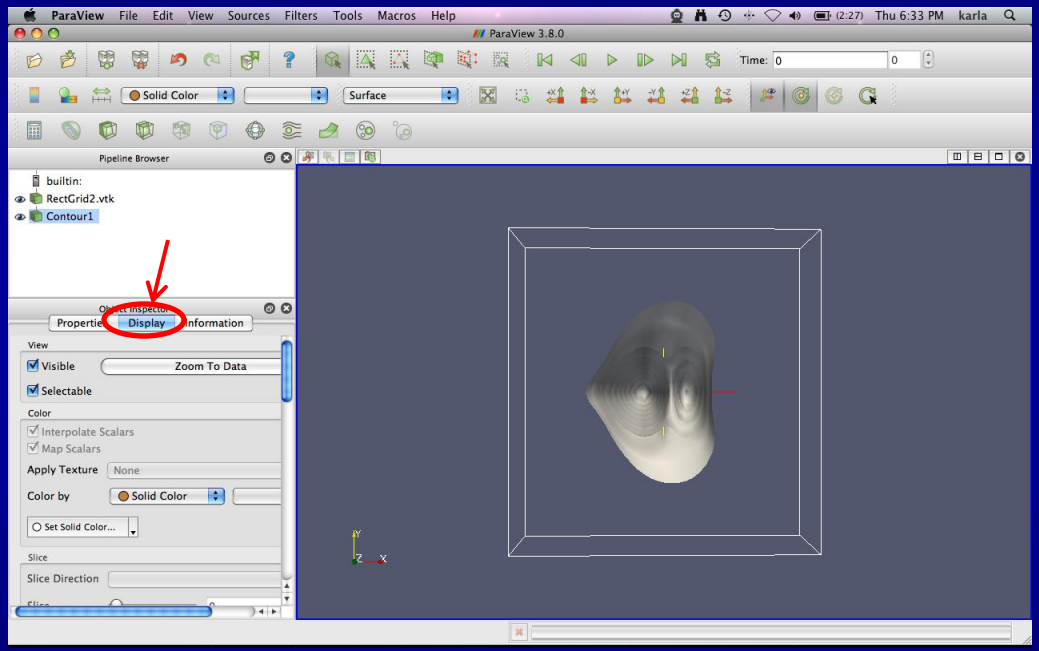

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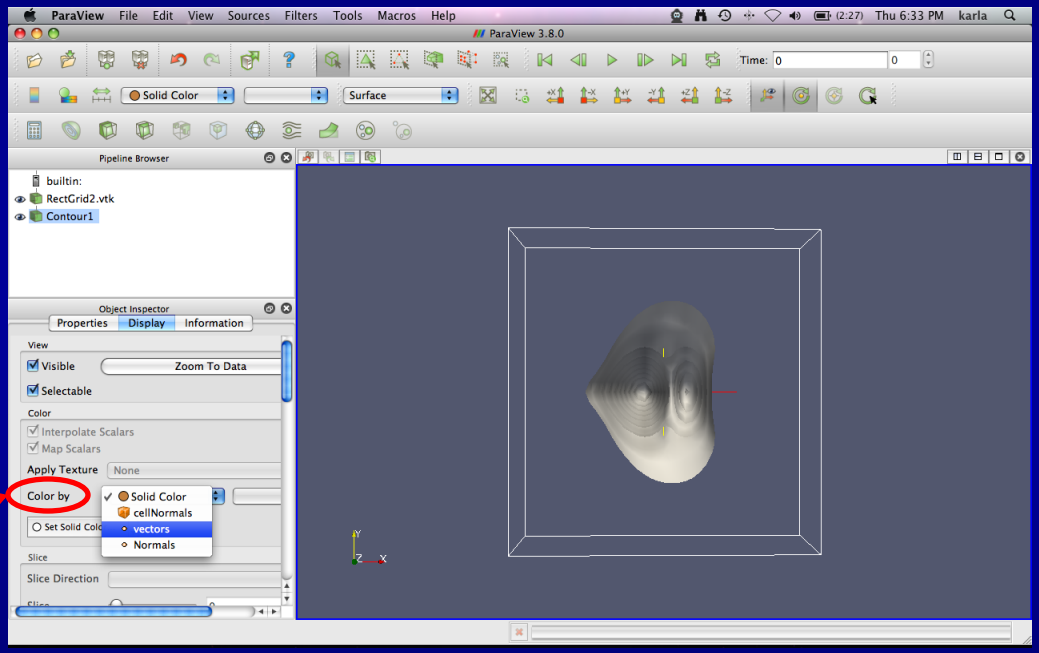

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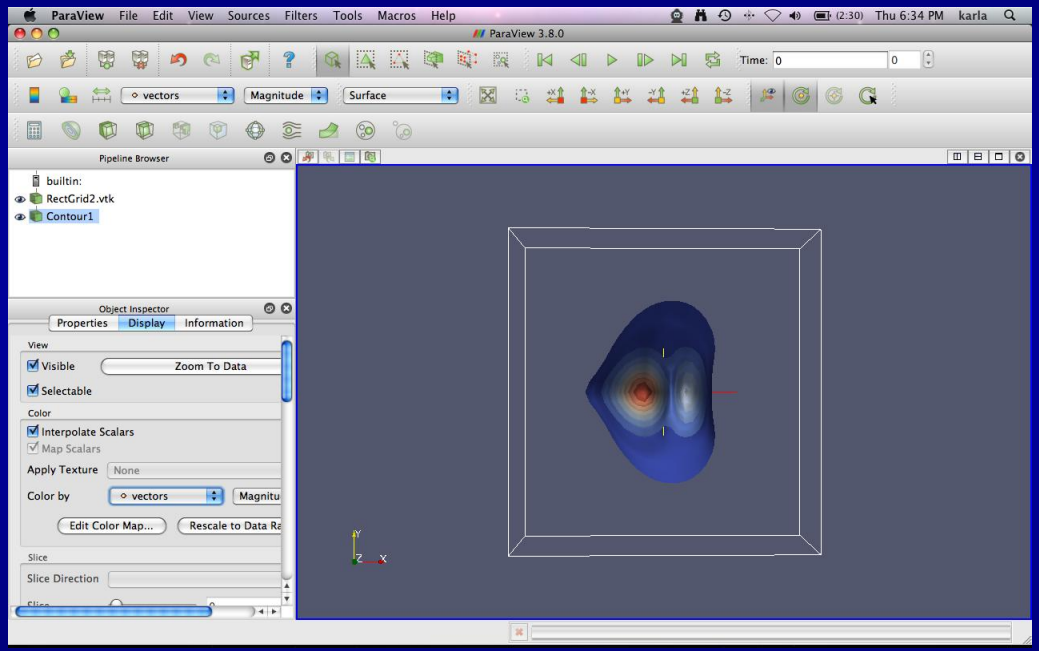
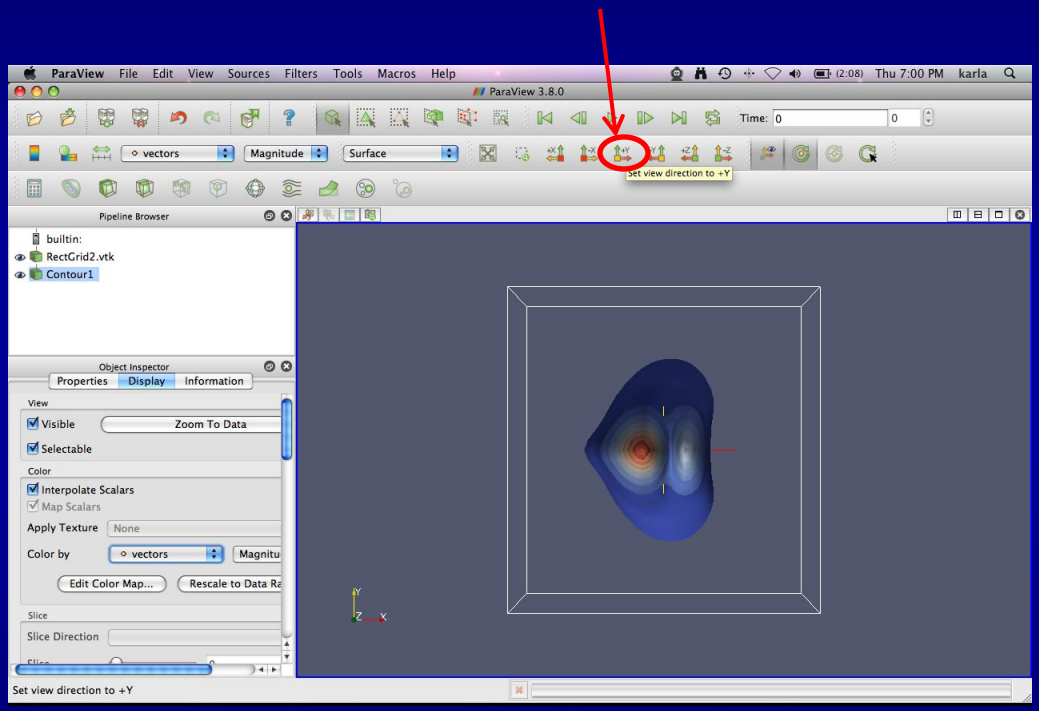


ParaView

Clip isosurfaces

- Click `+Y` view button
- Click `Filters -> Common -> Clip`
- Drag arrow point around to front of surface (arrow turns red when selected)
- Click blue `Apply`
- Click `Inside Out` checkbox
- Click blue `Apply`
- Click `Show Center` button to remove crosshairs



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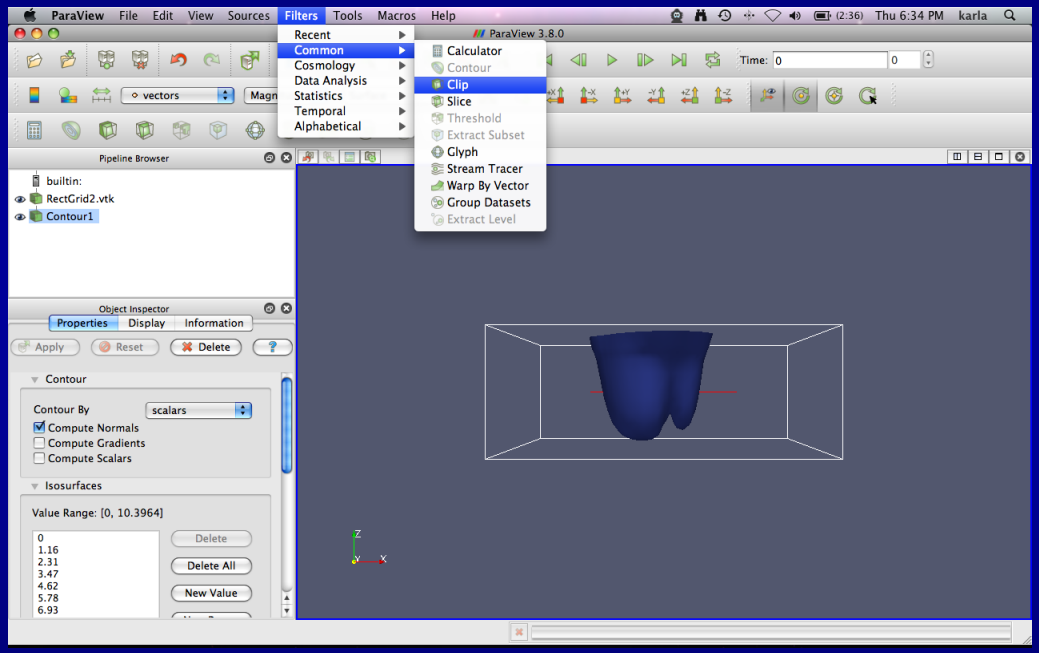

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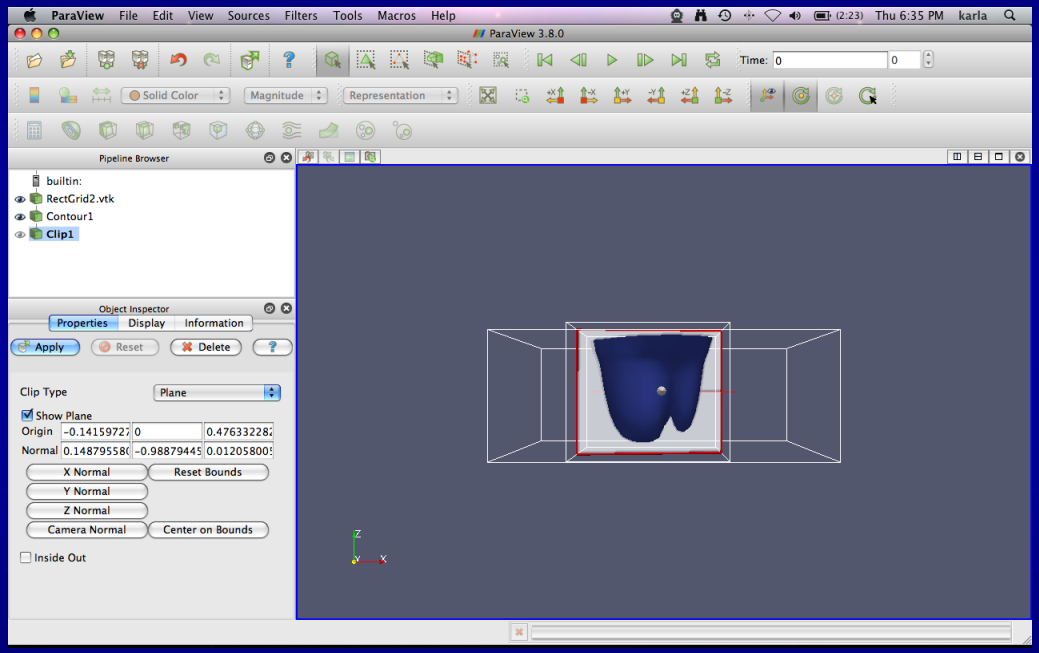

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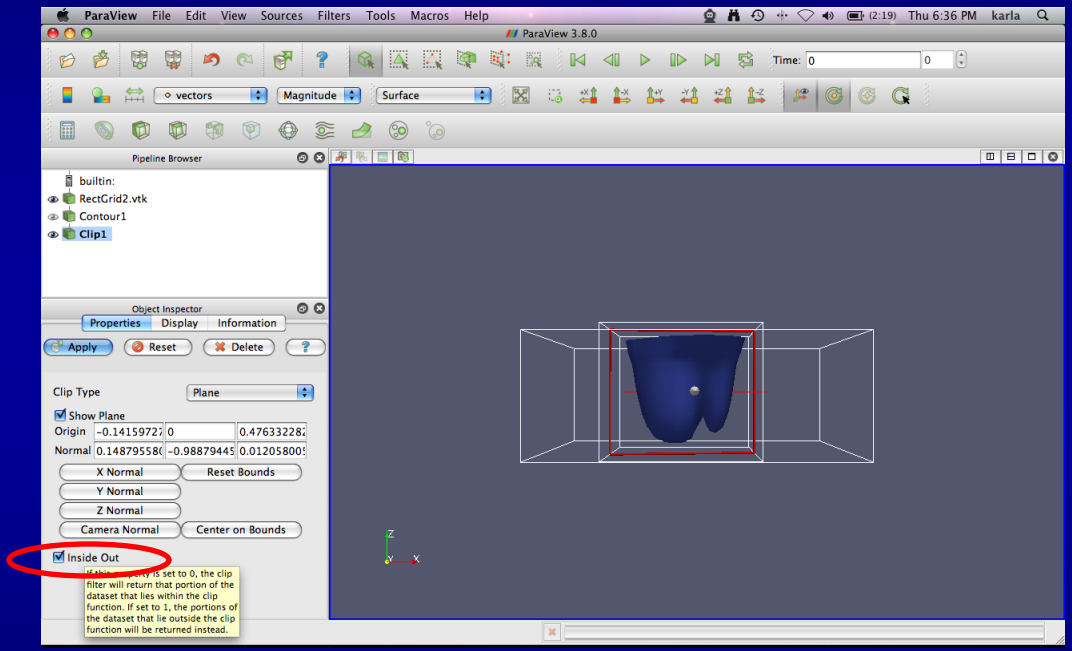

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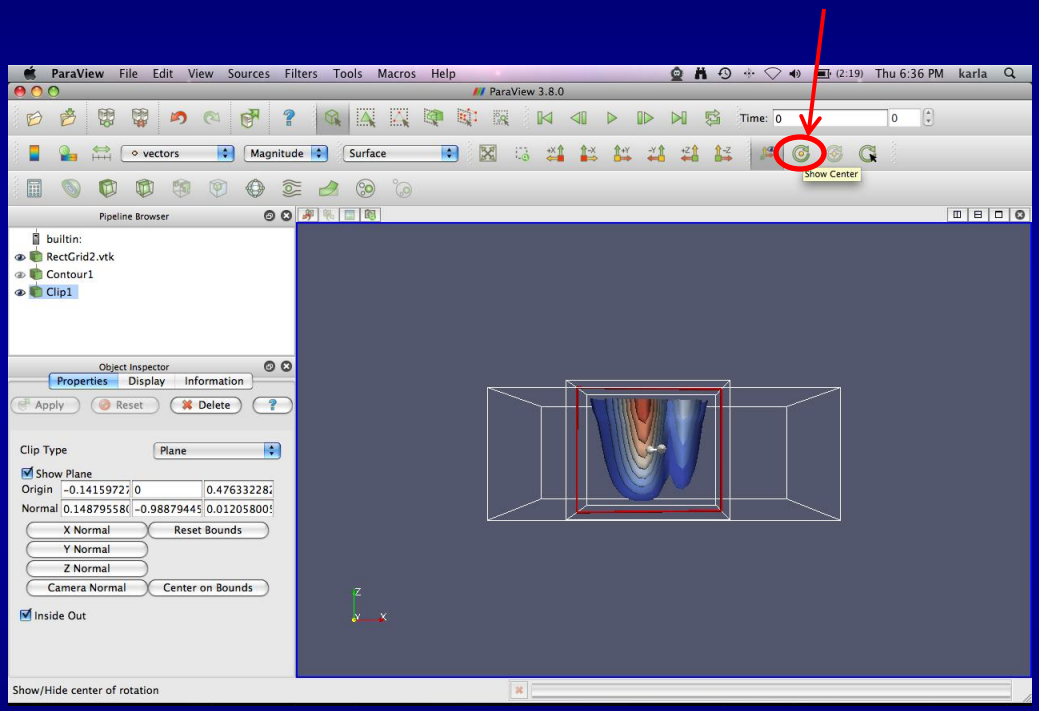

ParaView

Slice isosurfaces

- Click eye next to `Clip1` to hide clip plot
- Click `Contour1` in Pipeline Browser
- Click `Filters -> Common -> Slice`
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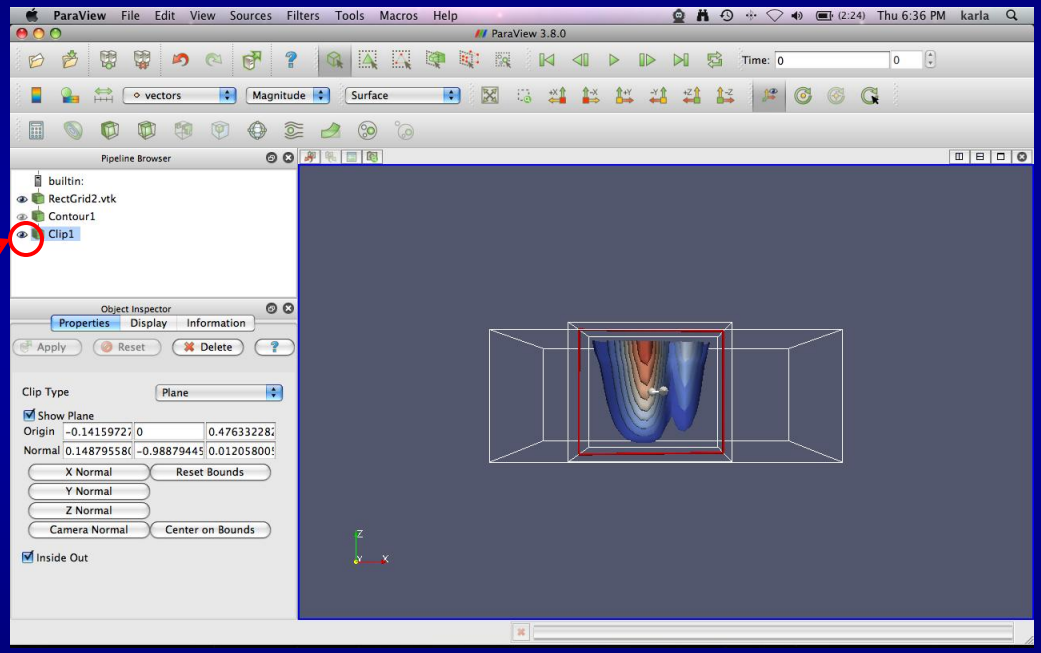

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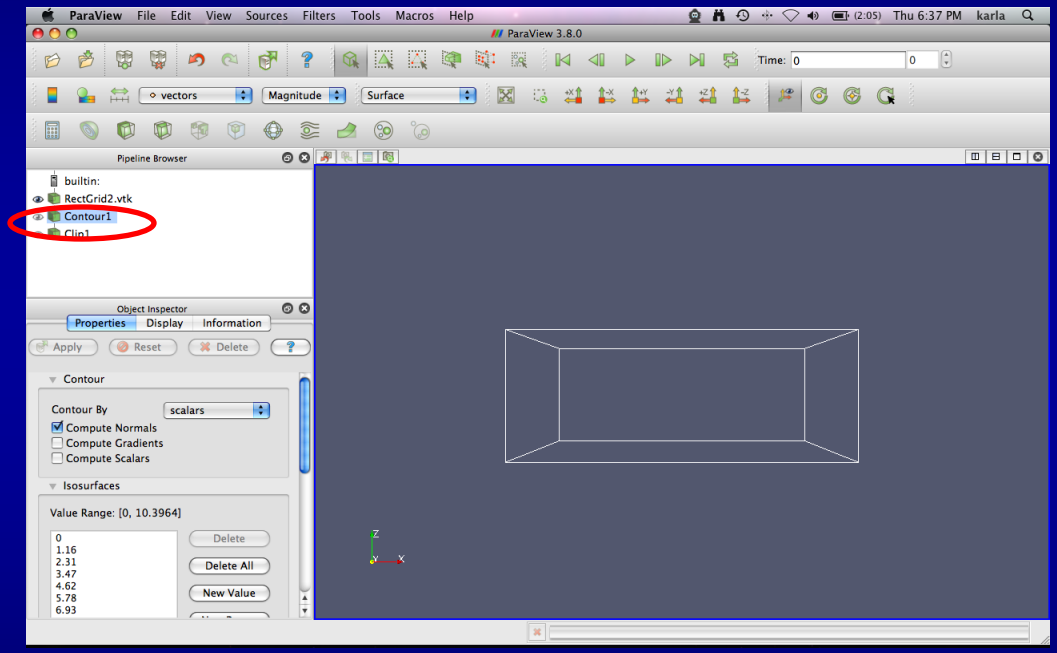

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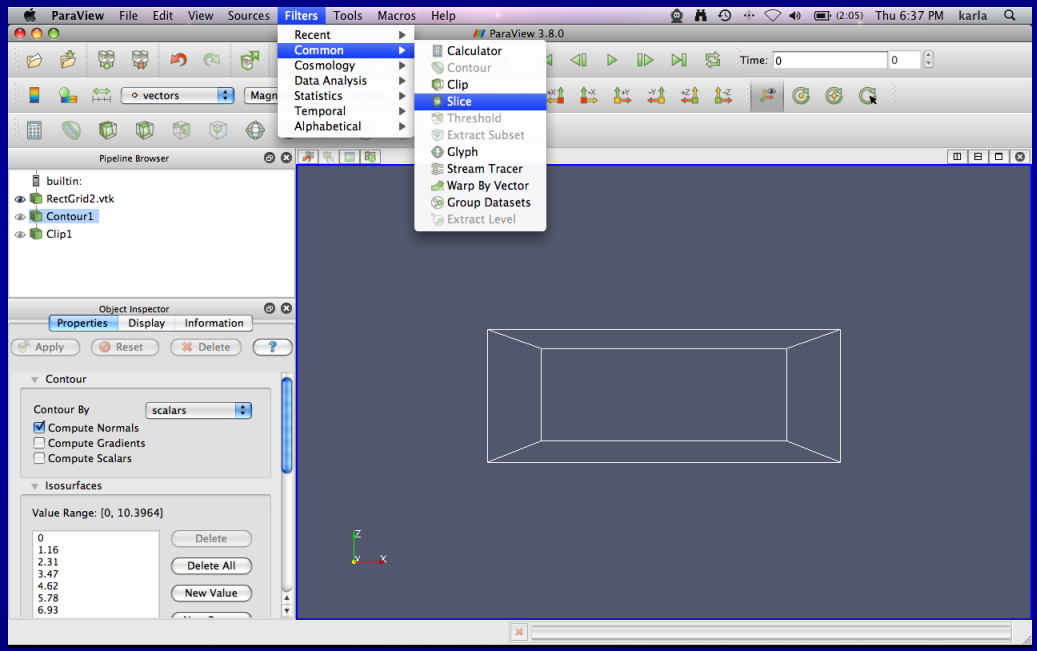

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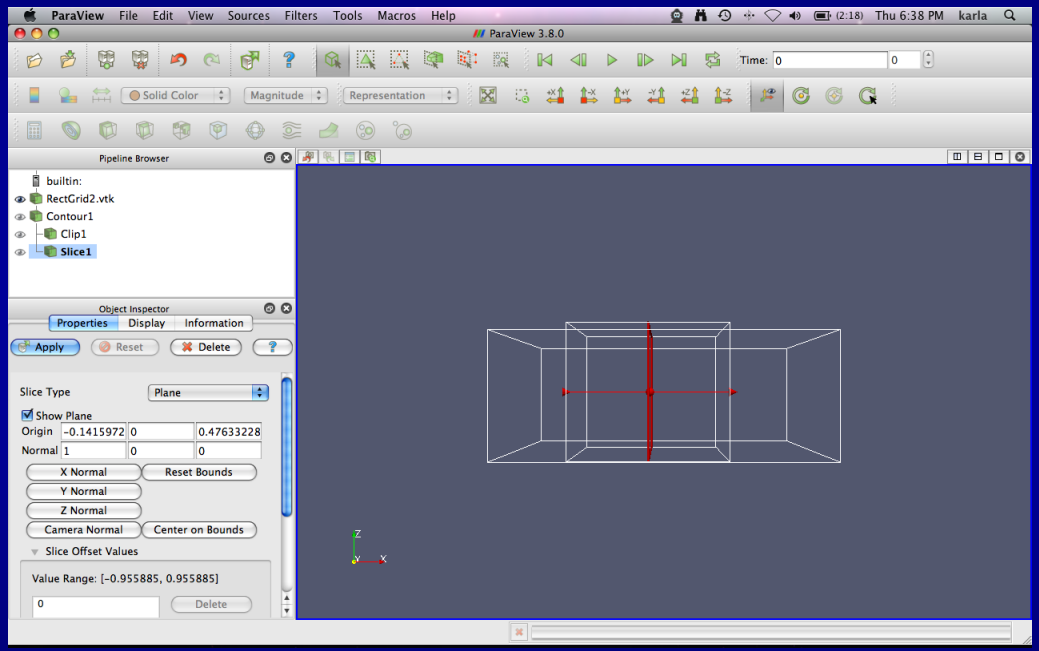

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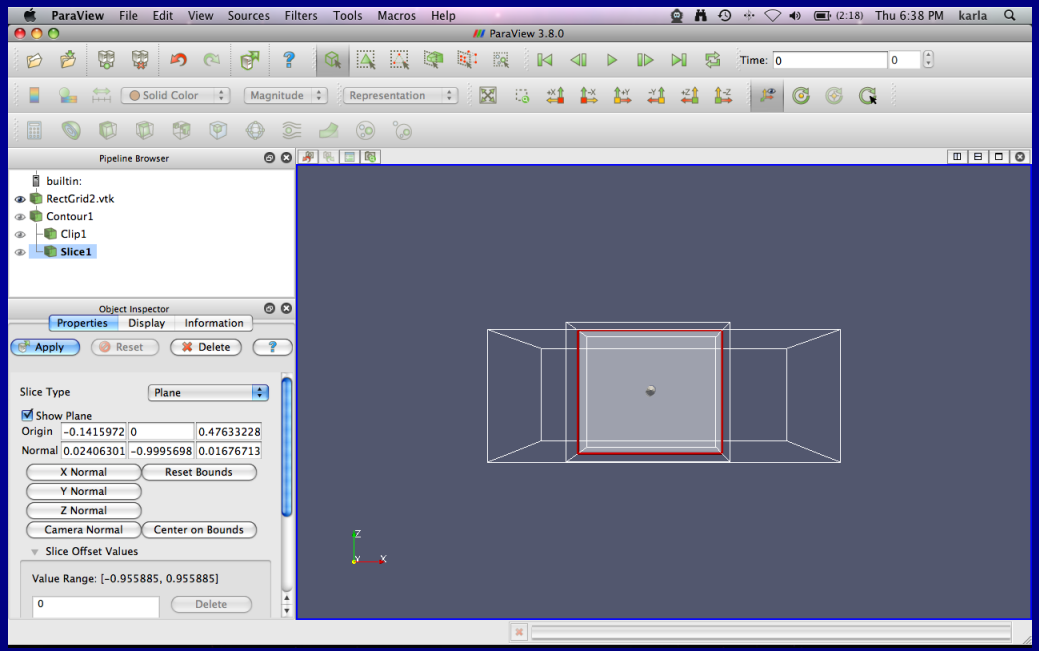

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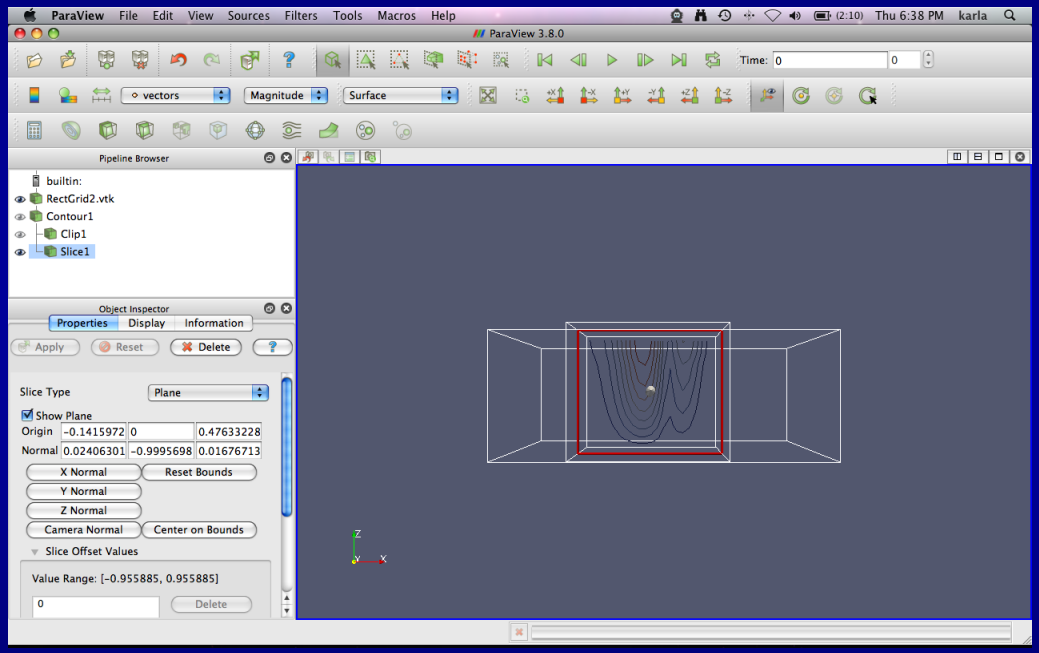
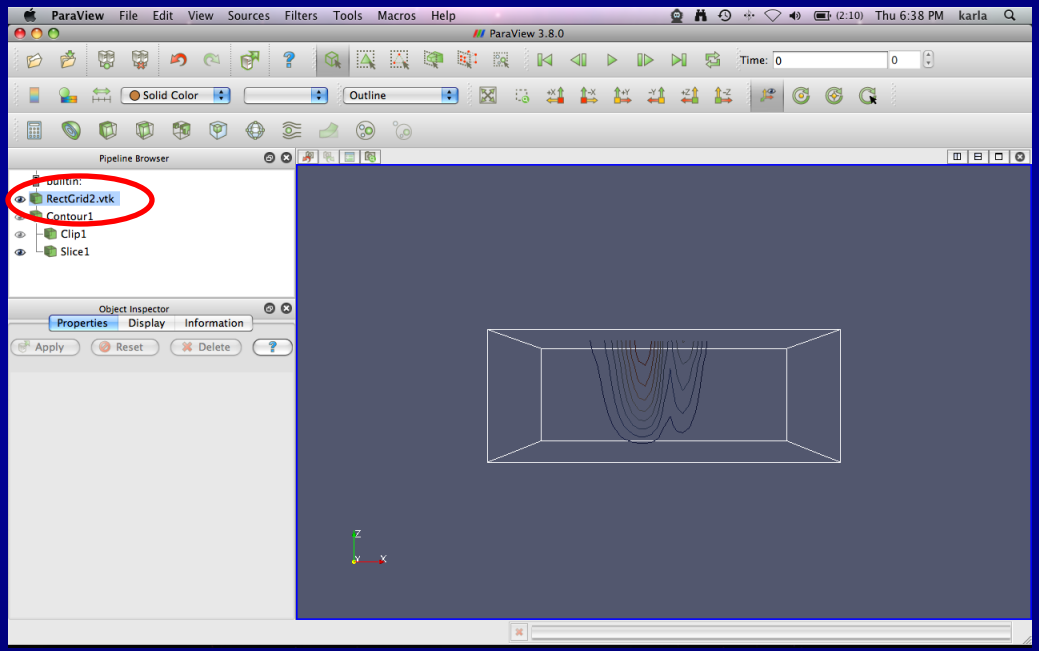


ParaView

Create Glyph of Vector Field

- Click `RectGrid2.vtk` in Pipeline Browser
- Click `Filters -> Common -> Glyph`
- Click blue `Apply`



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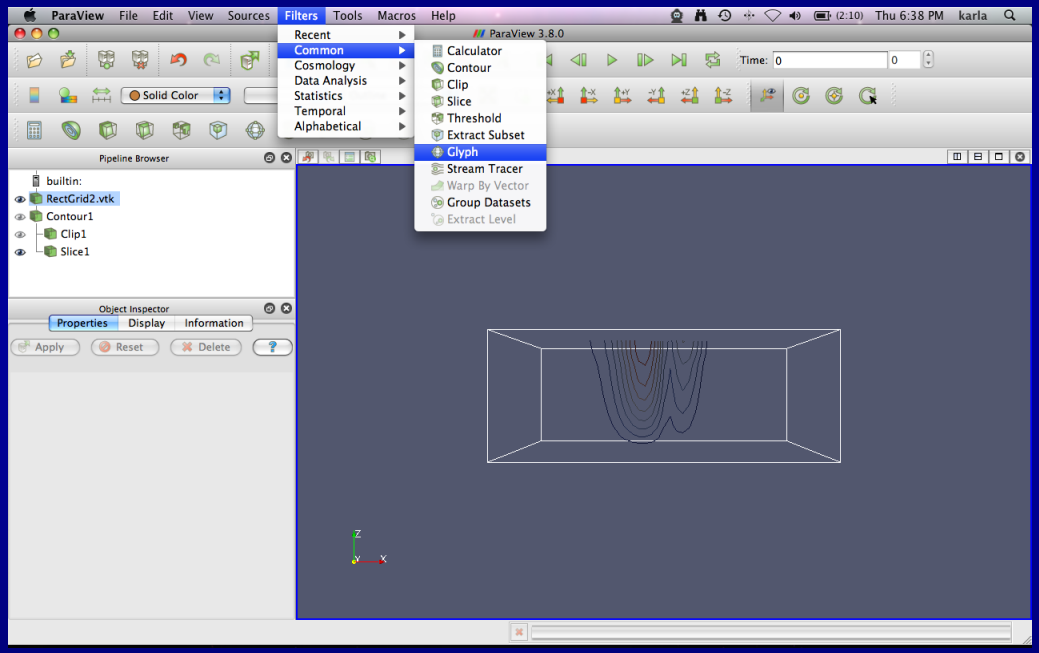

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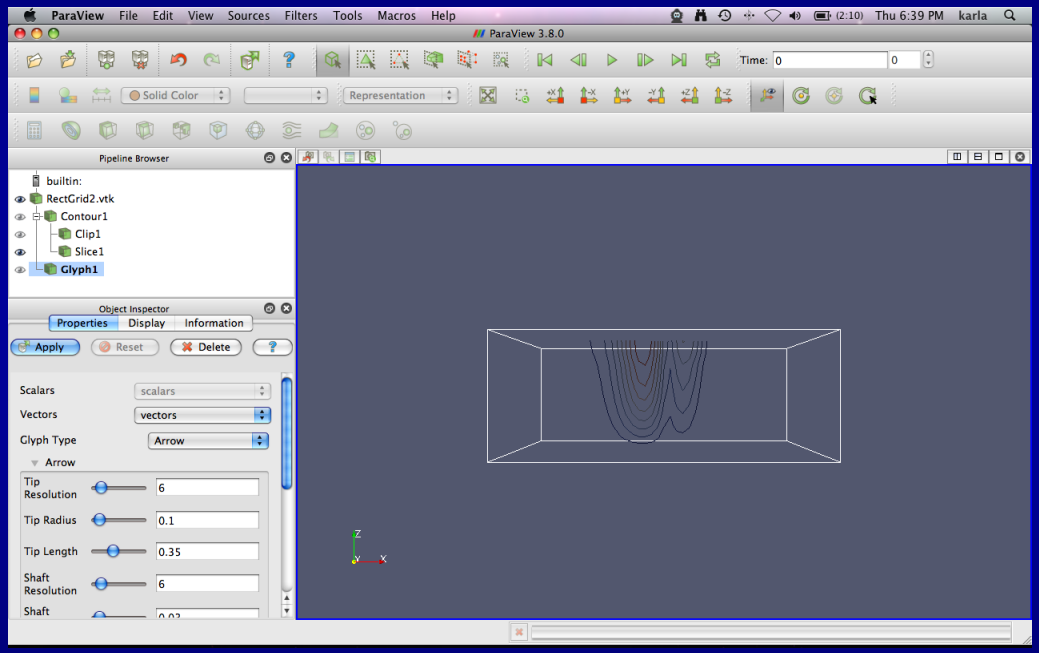

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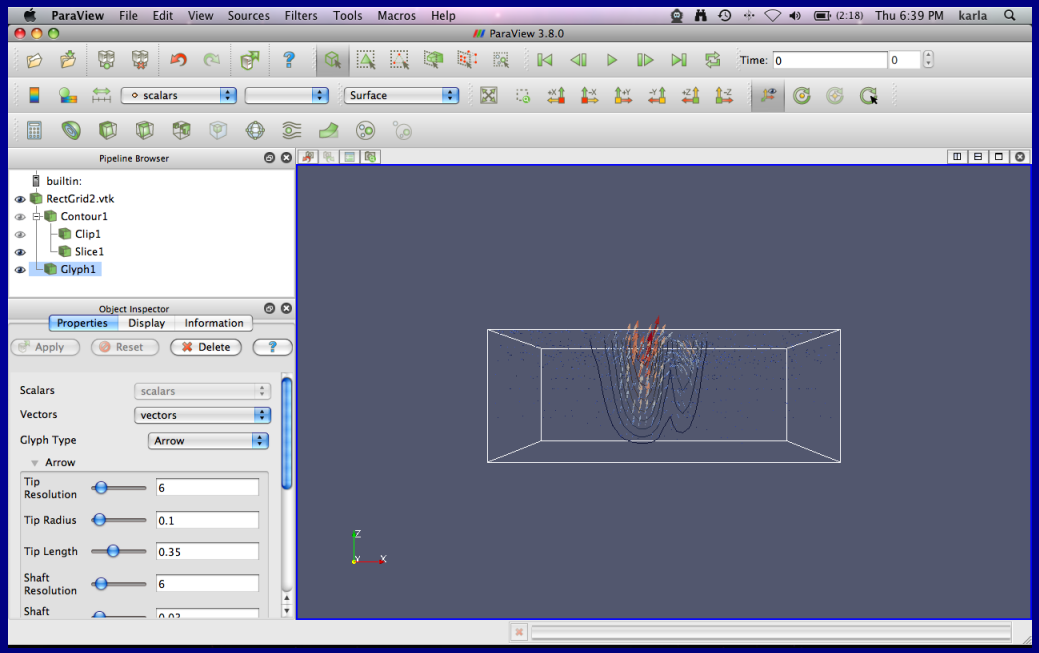
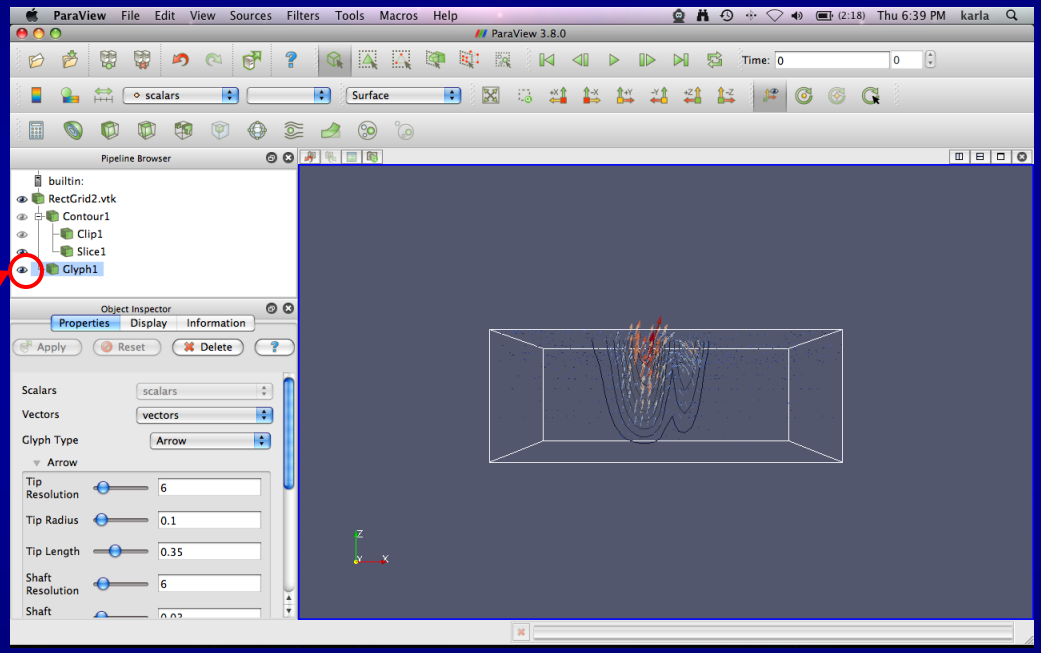


ParaView

Create Streamlines

- Click eye next to `Glyph1` to hide glyph plot
- Click `RectGrid2.vtk` in Pipeline Browser
- Click `Filters -> Common -> Stream Tracer`
- Click blue `Apply`
- Under `Display` tab, in the `Color by` box, select `Vorticity`



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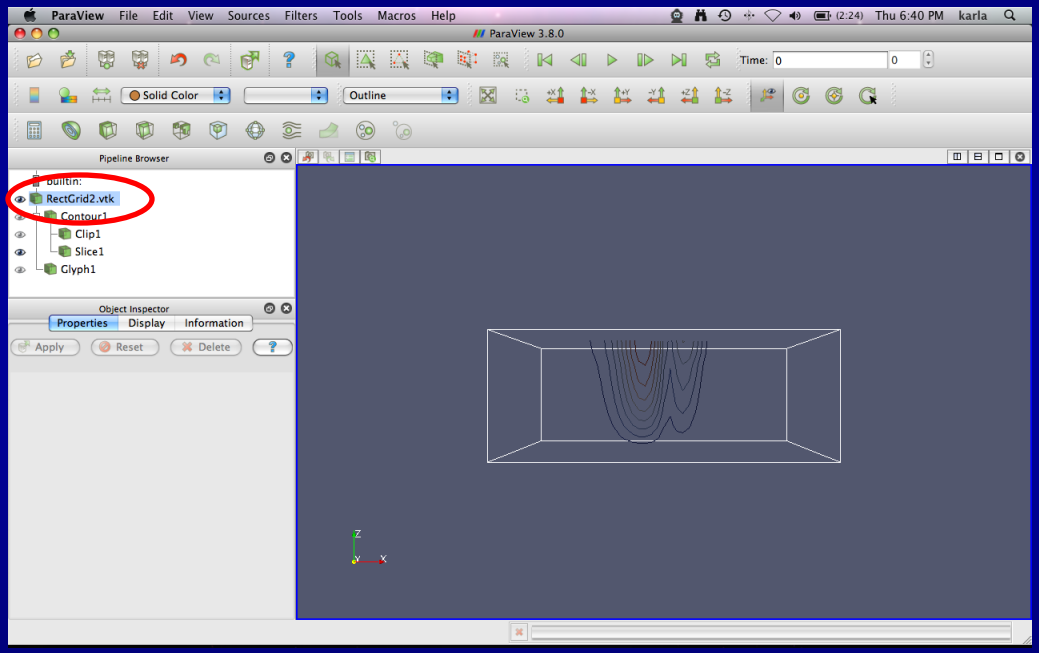

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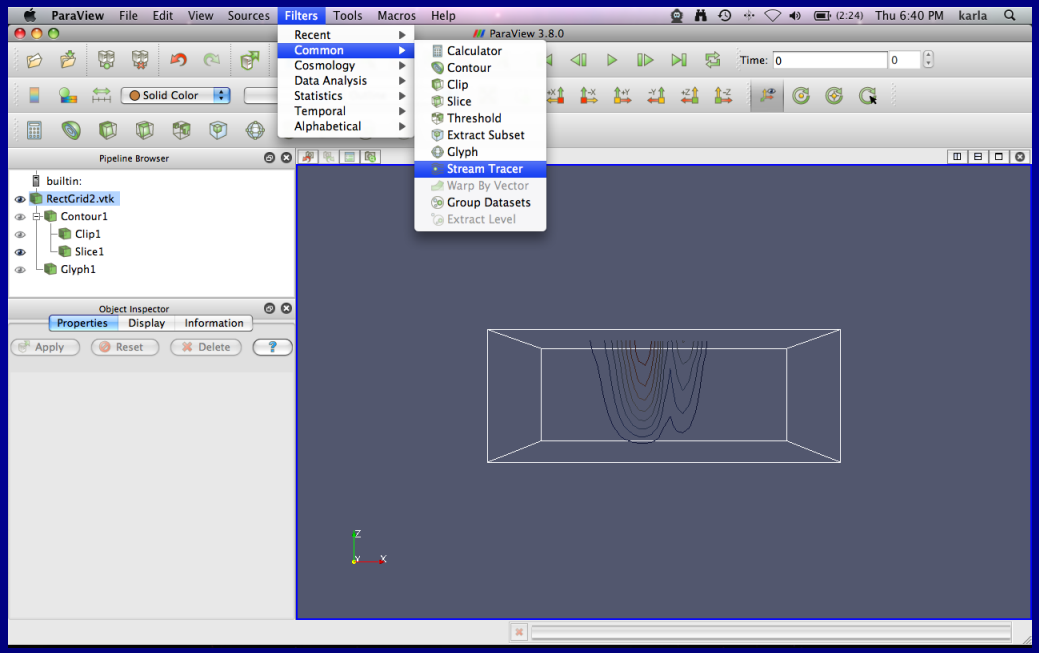

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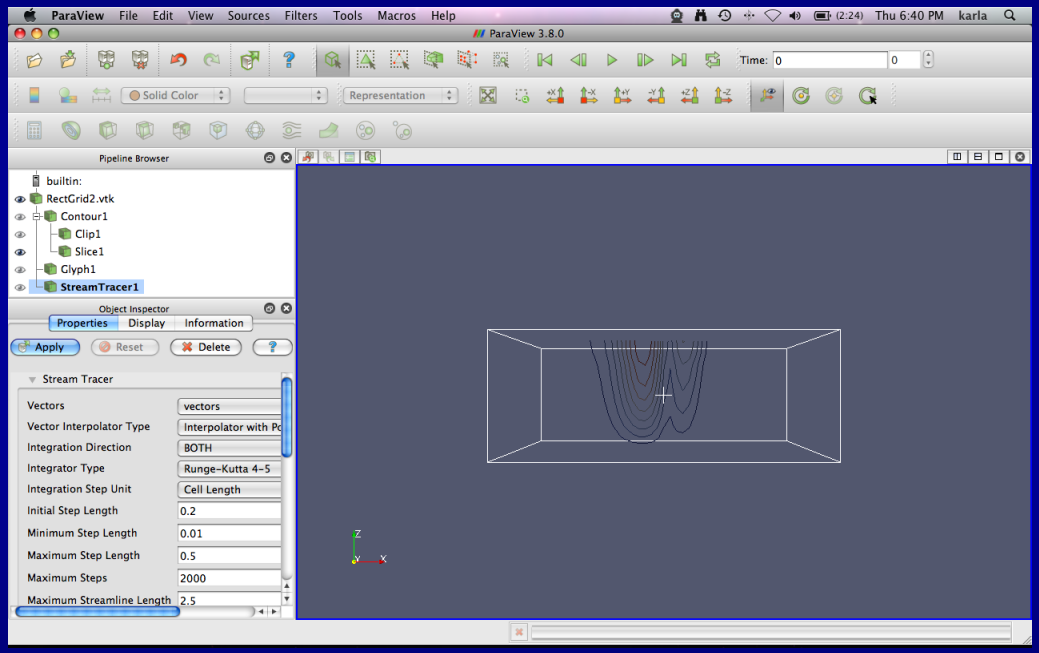

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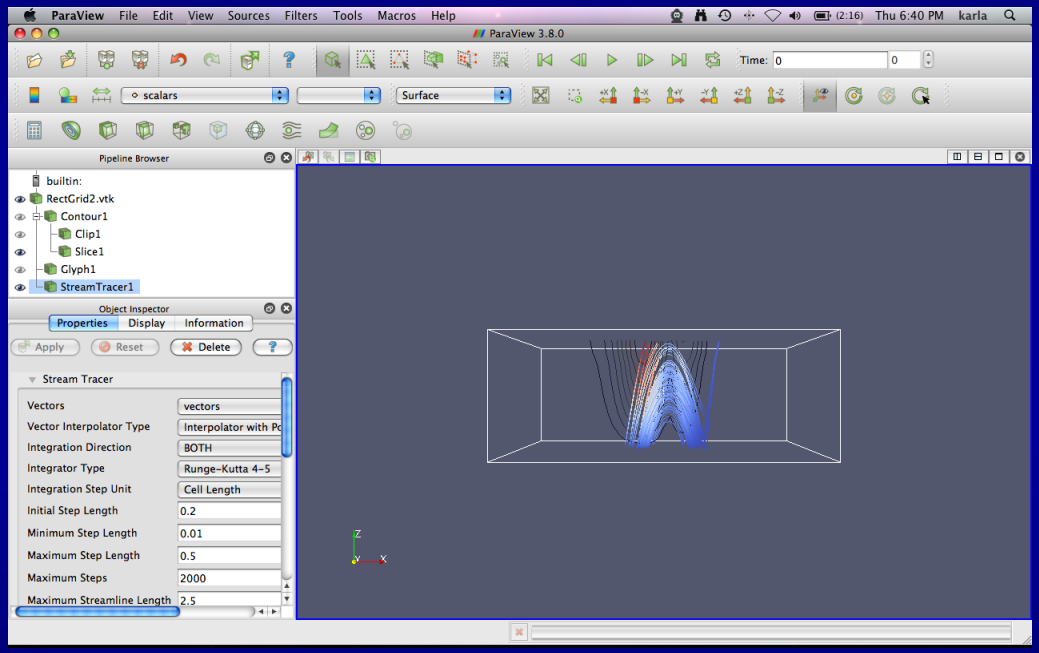
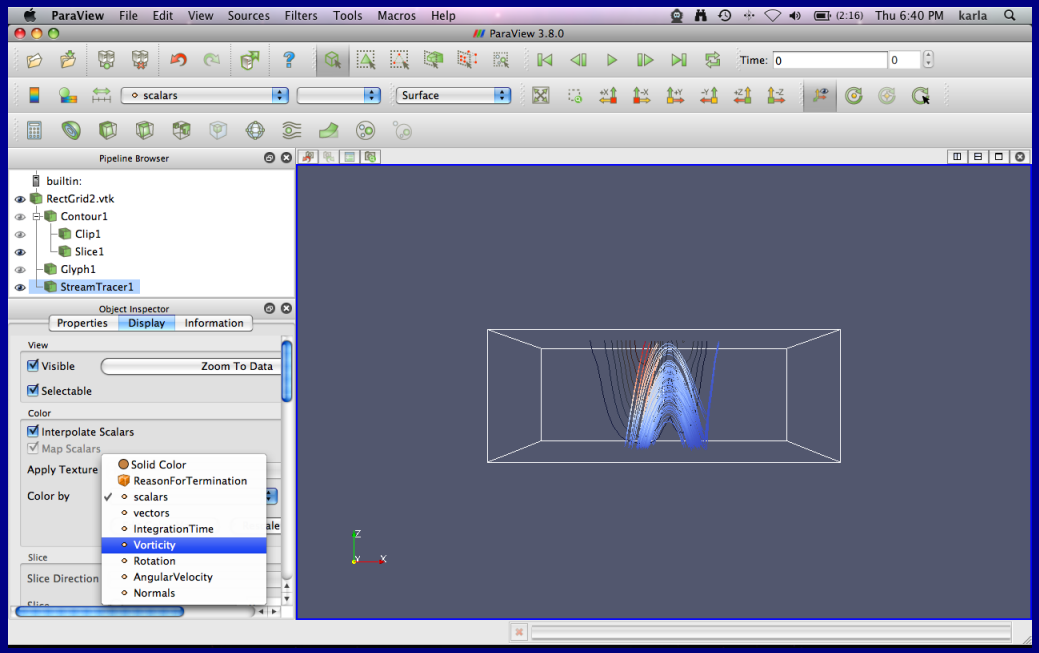


ParaView

Create Streamlines

- Click eye next to `Glyph1` to hide glyph plot
- Click `RectGrid2.vtk` in Pipeline Browser
- Click `Filters -> Common -> Stream Tracer`
- Click blue `Apply`
- Under `Display` tab, in the `Color by` box, select `Vorticity`



ParaView

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- Click blue `Apply`
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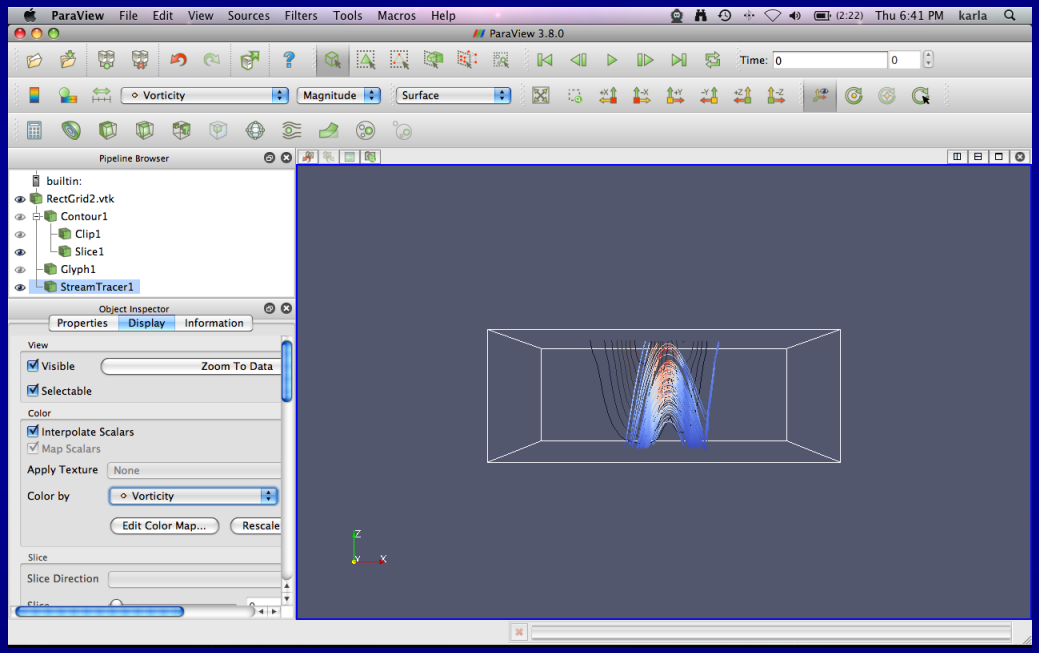
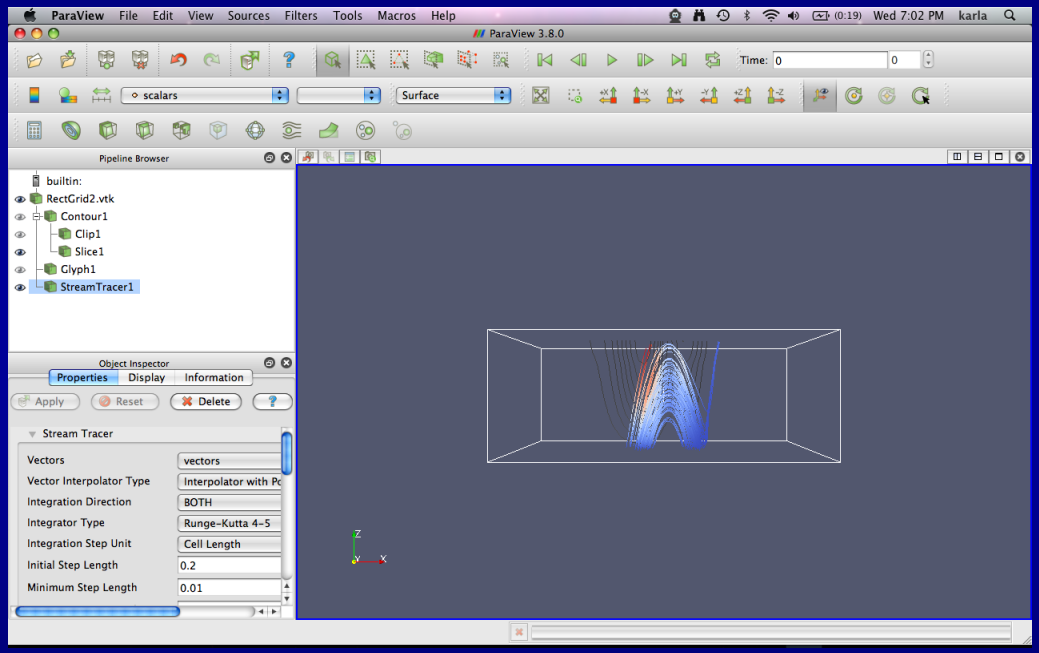


ParaView

Create Tubes

- Click `StreamTracer1` in Pipeline Browser
- Click `Filters -> Alphabetical -> Tube`
- Click blue `Apply`



ParaView

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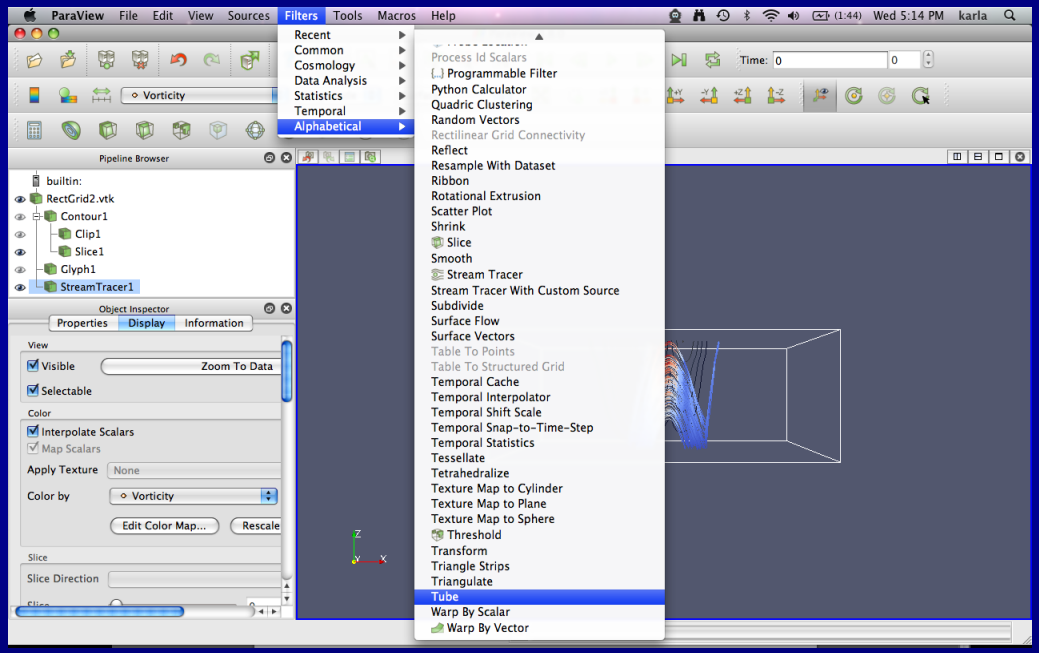
- Click blue `Apply`



ParaView

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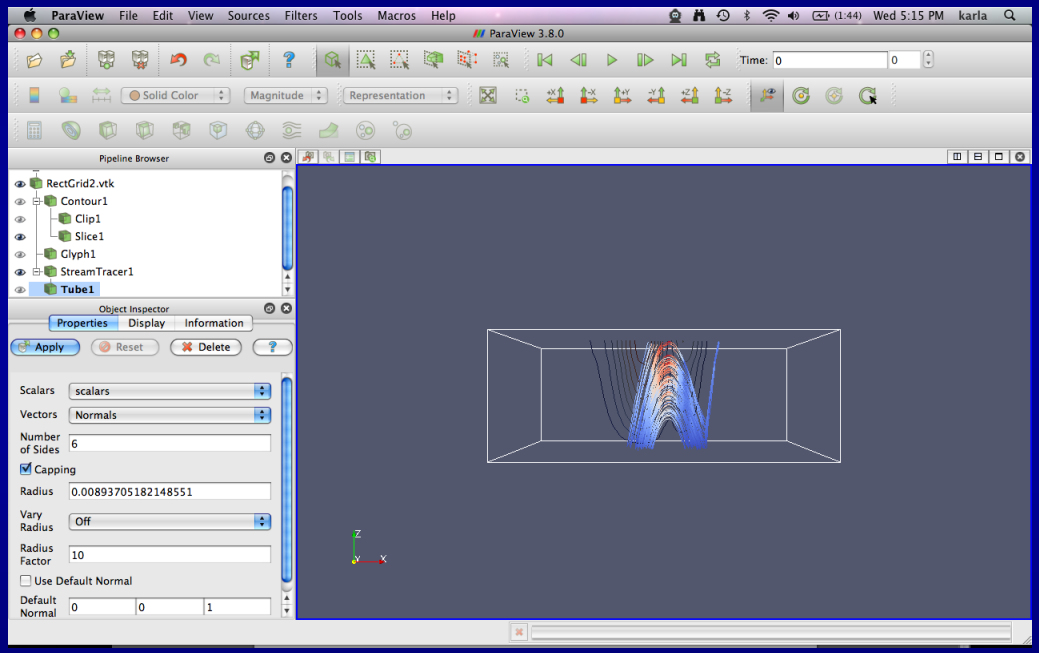

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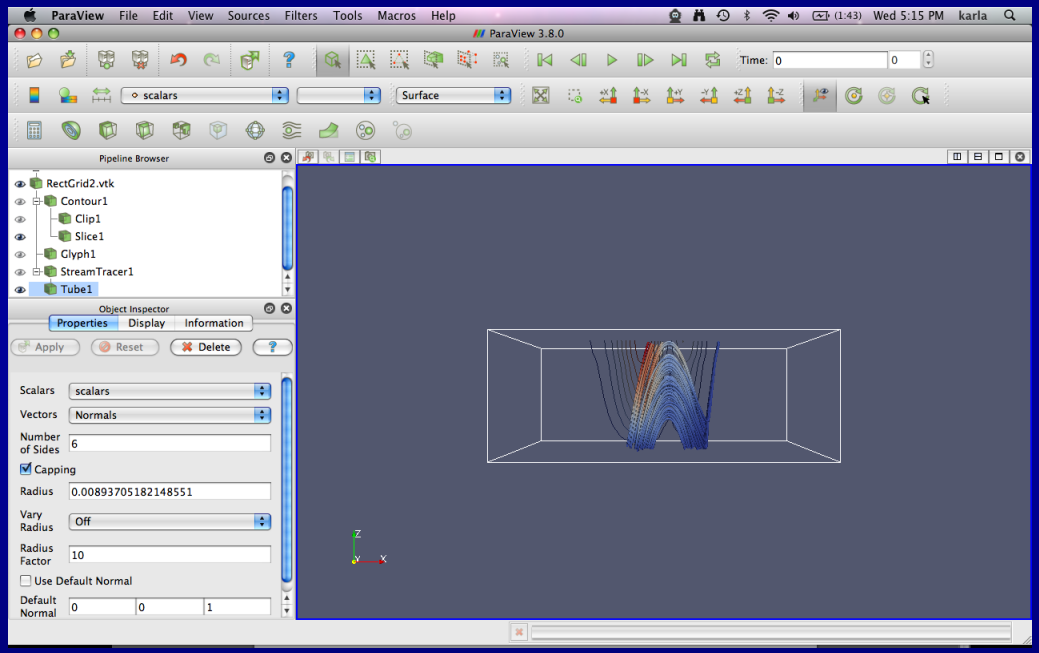
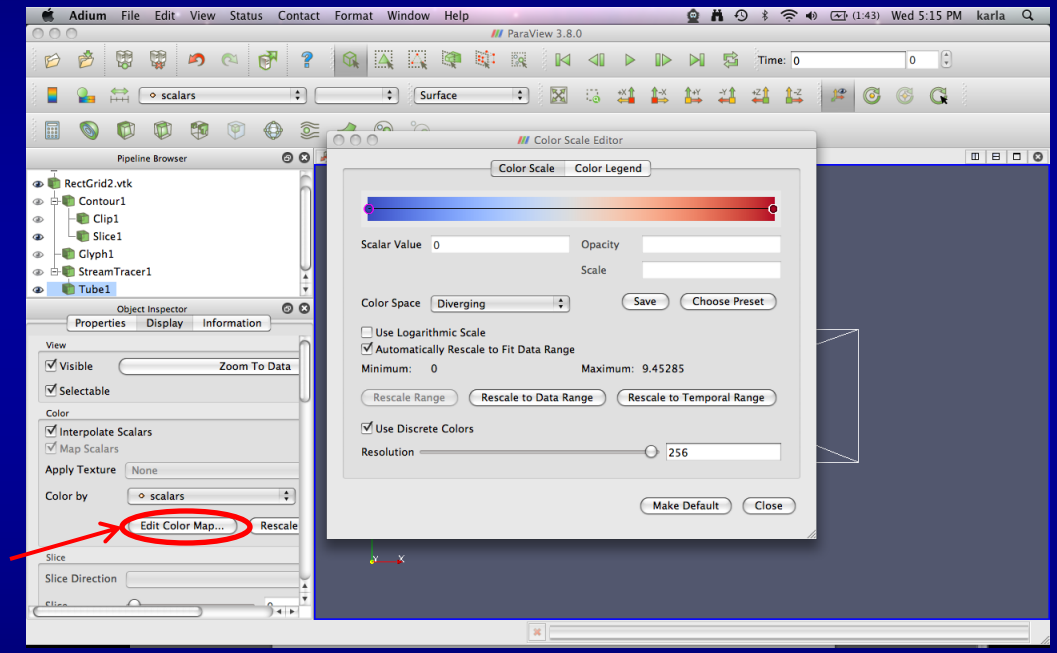


ParaView

Edit Color Map

- Click Edit Color Map
- Click `Choose Preset`
- Select `BLUE...HSV`
- Click blue `OK`
- Click blue `Close`



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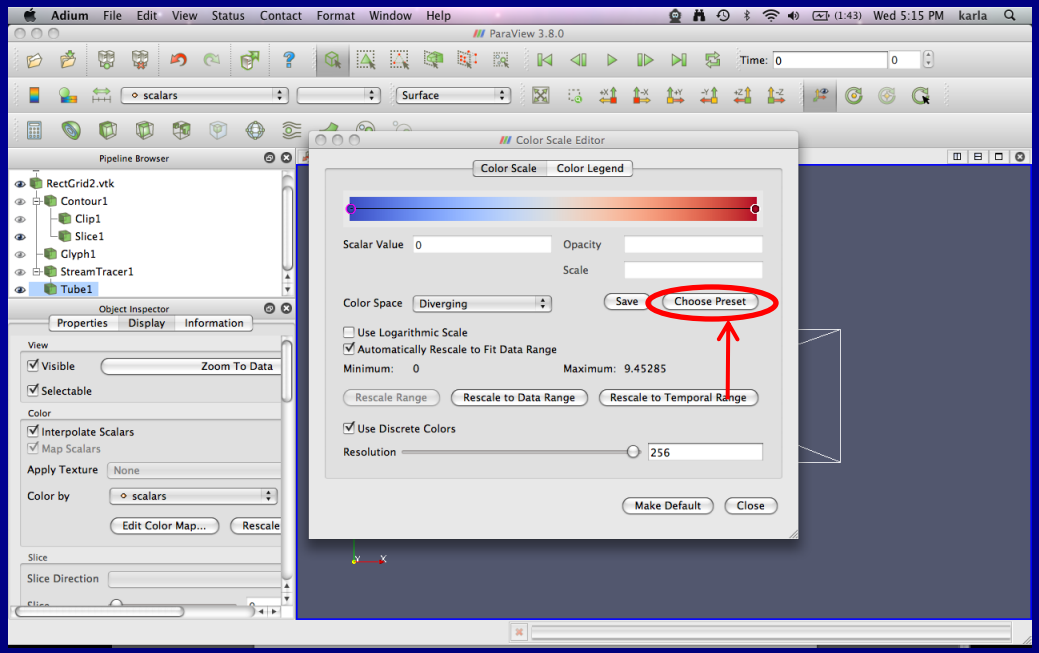

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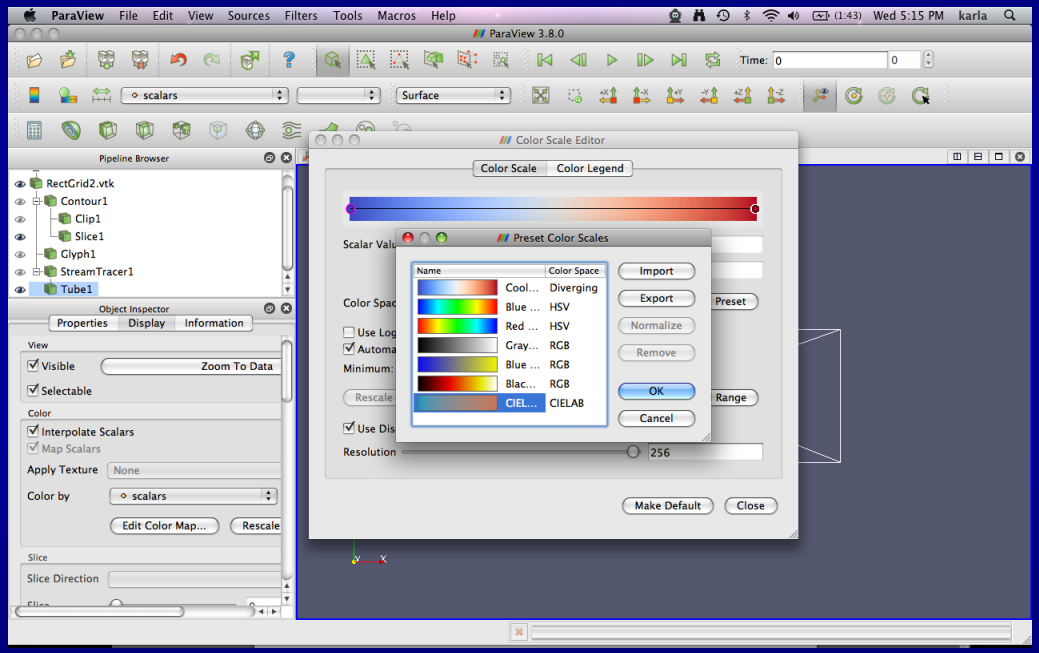

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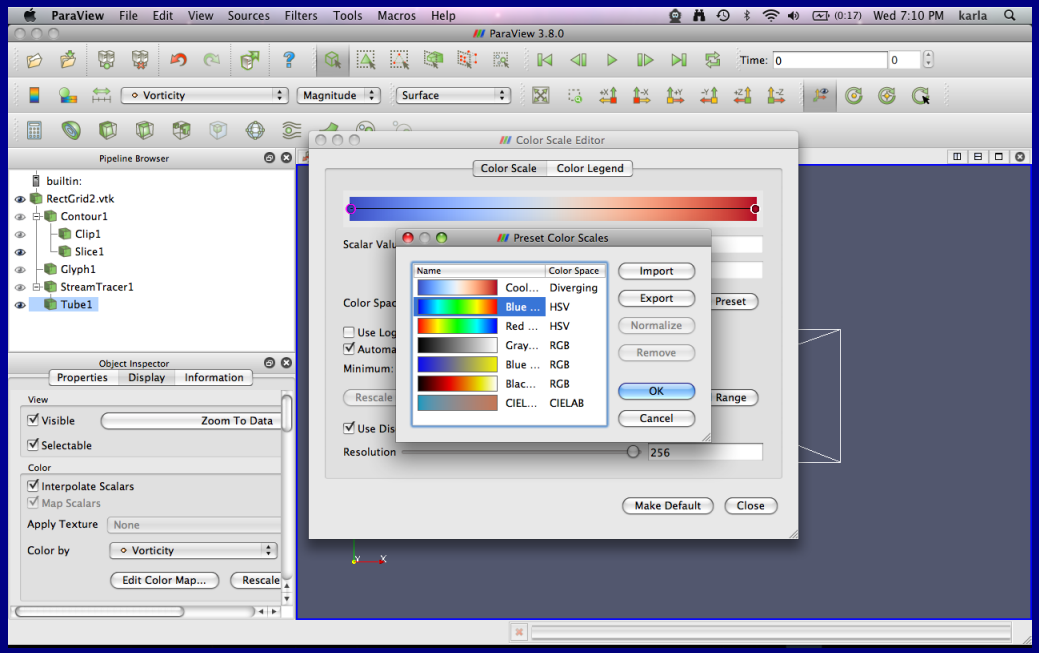

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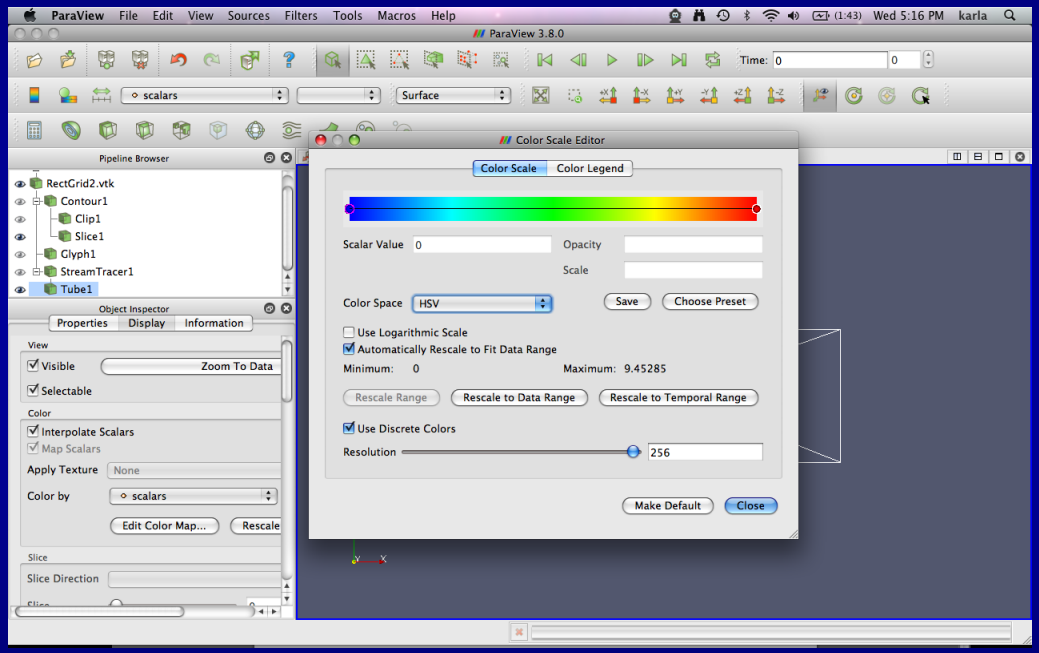

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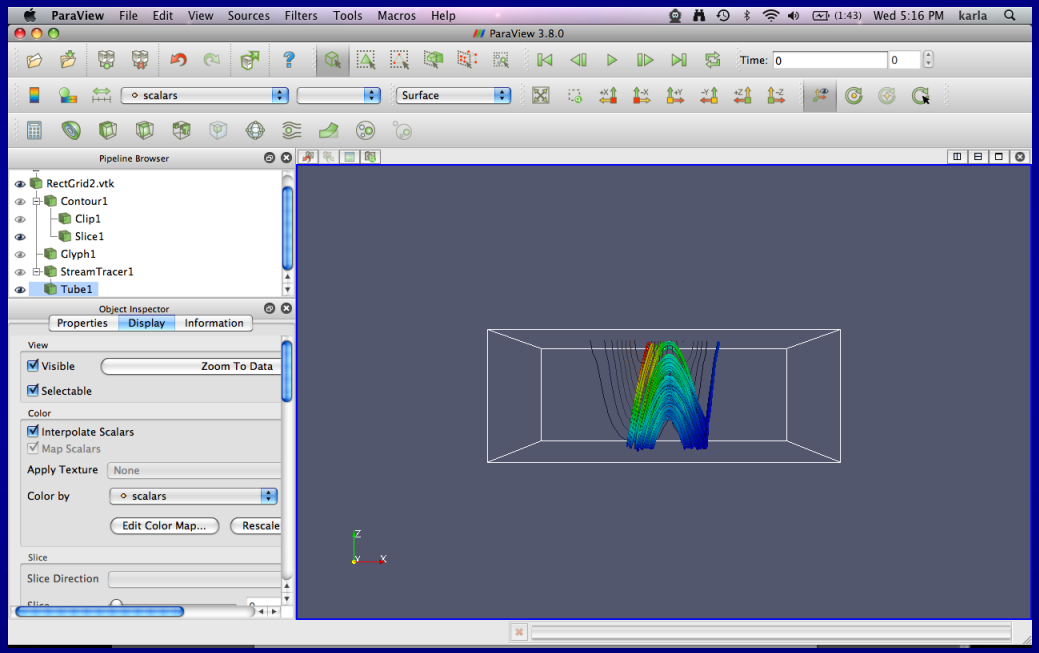
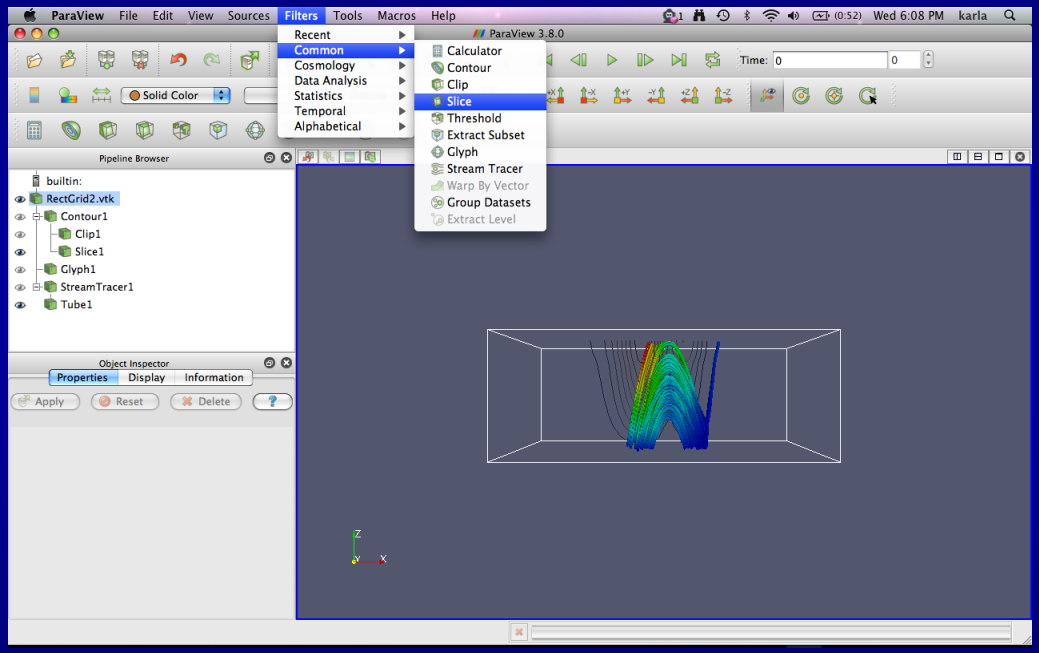


ParaView

Create Slice

- Click `RectGrid2.vtk` in Pipeline Browser
- Click `Filters -> Common -> Slice`
- Drag arrow point around to front of surface (arrow turns red when selected)
- Or click `Y Normal`
- Click blue `Apply`
- Click `Show Plane`



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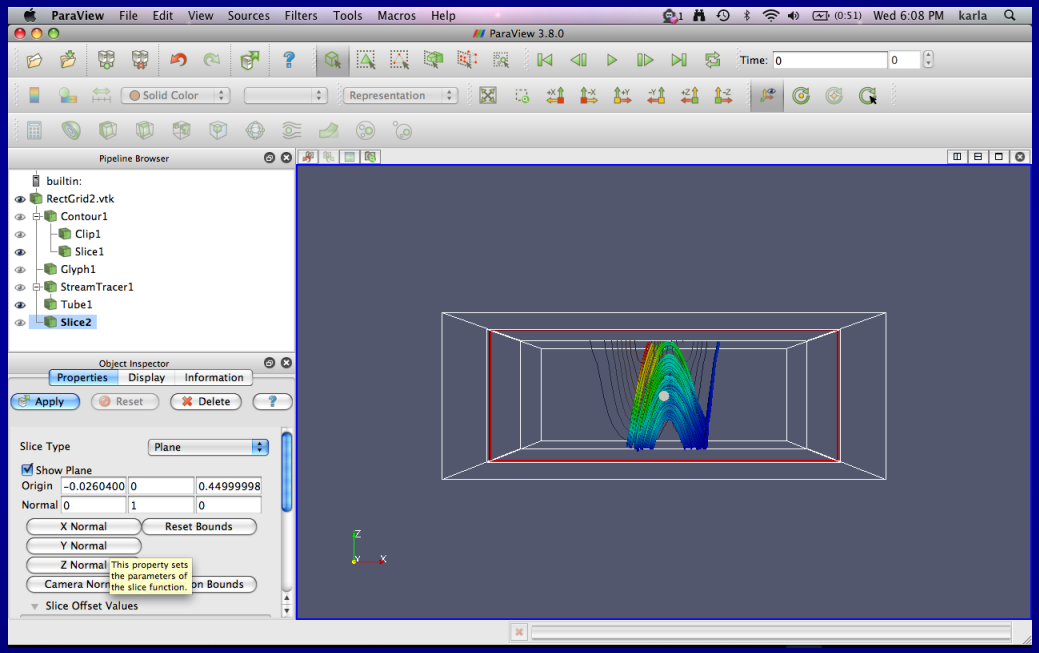

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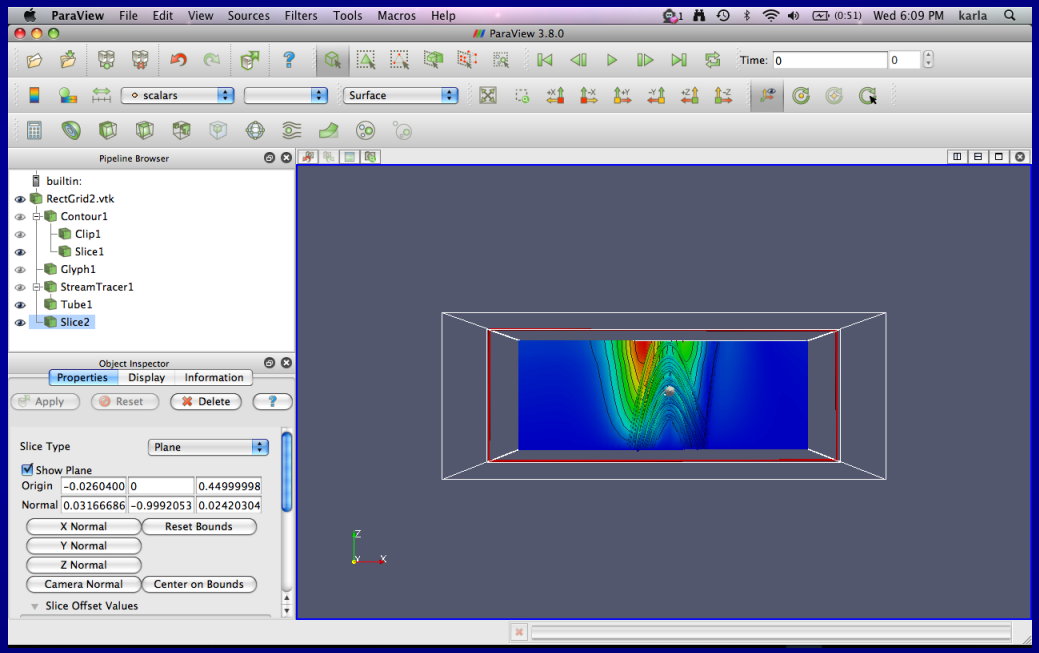

TACC

ParaView

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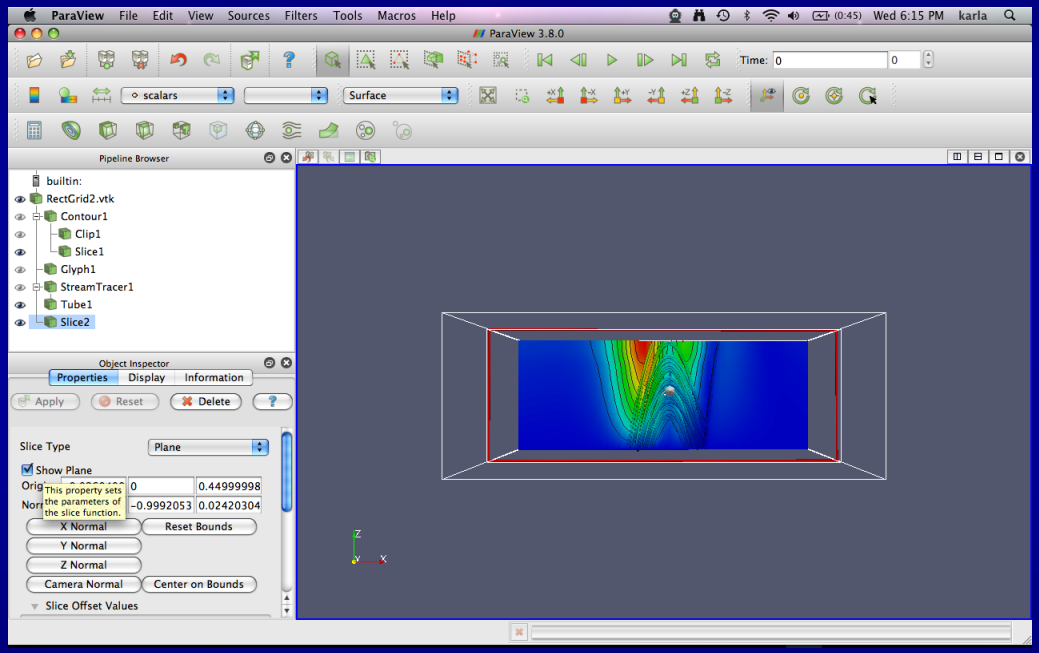

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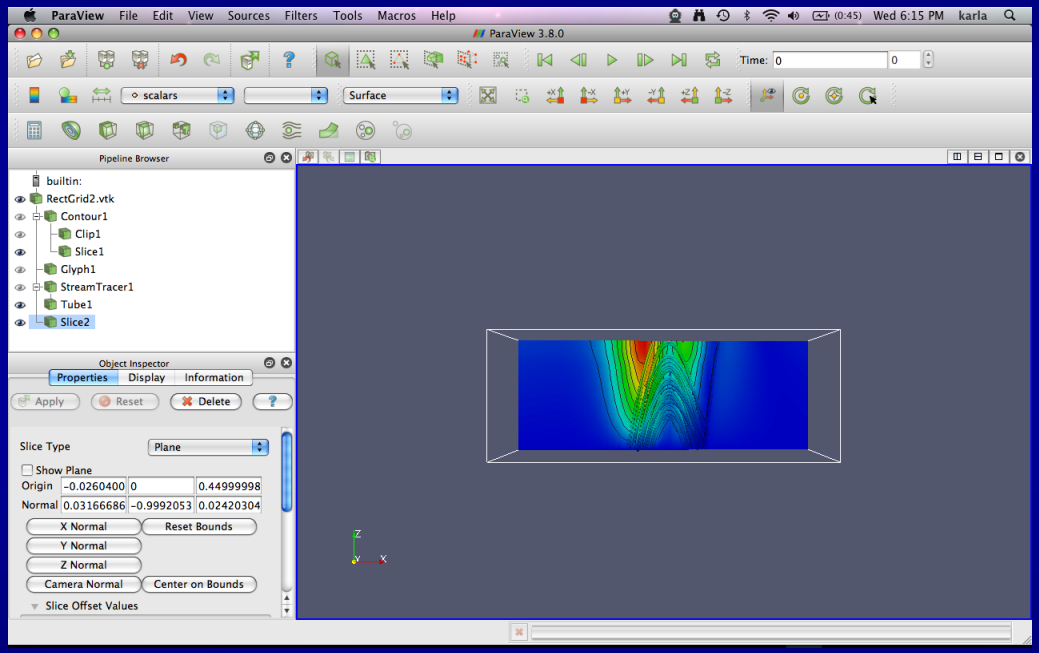
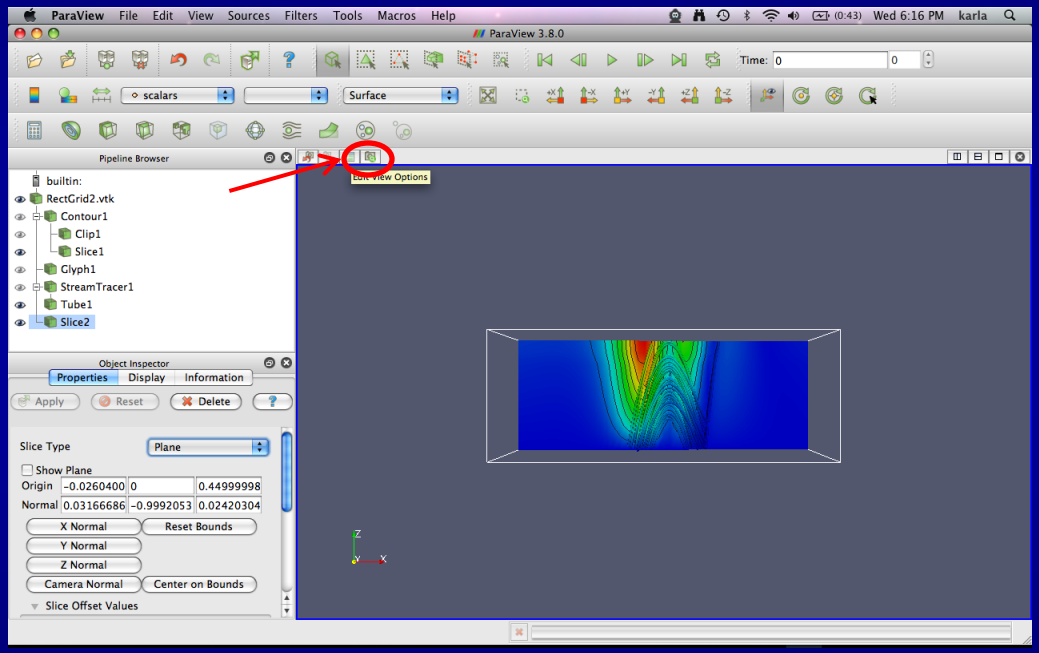


ParaView

Background Color

- Click the button above the 3D view
- Click `Choose Color`
- Drag box to black
- Click blue `Ok`
- Click blue `Ok`



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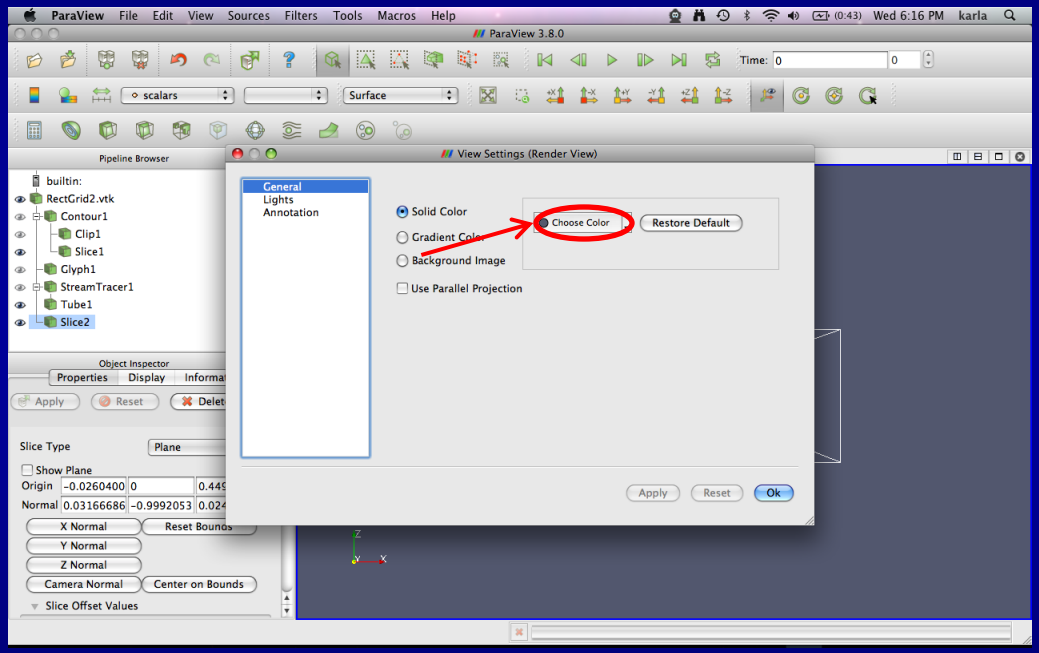

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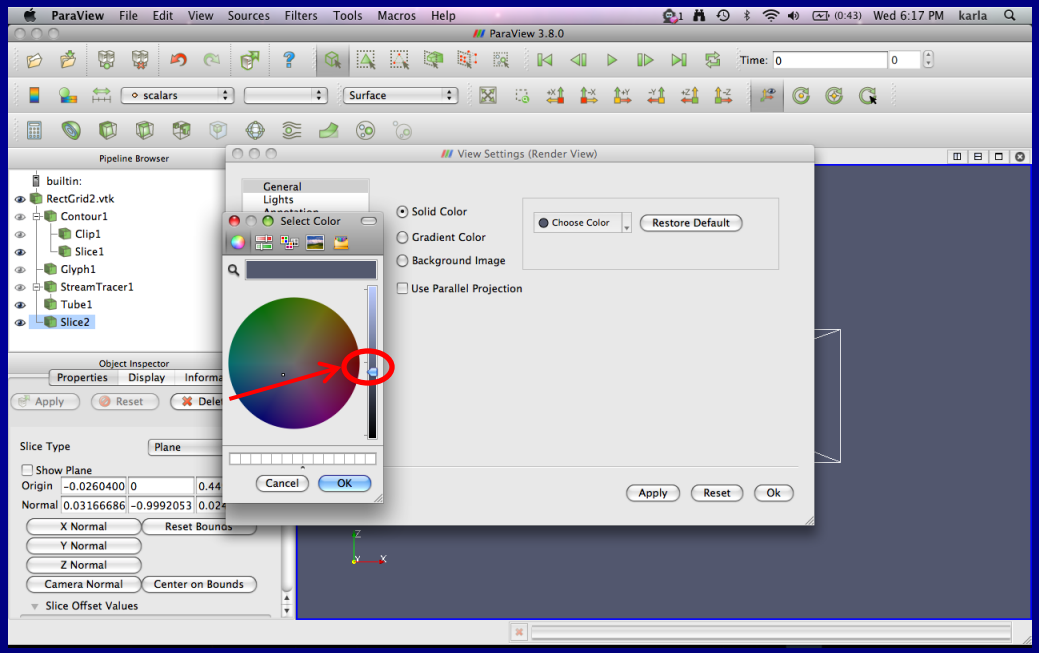

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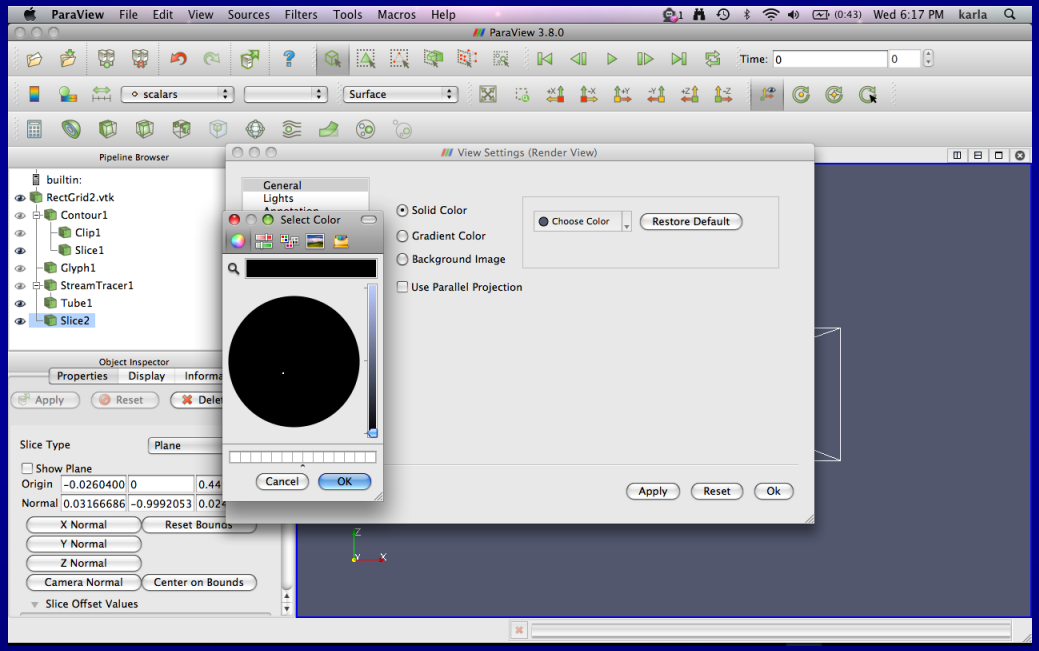

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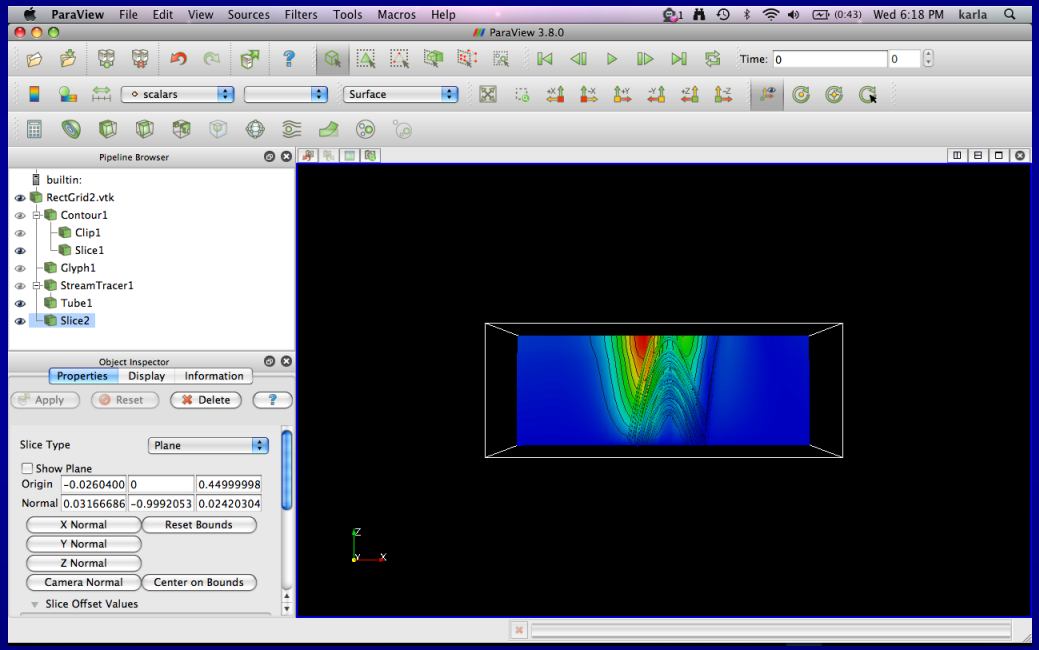
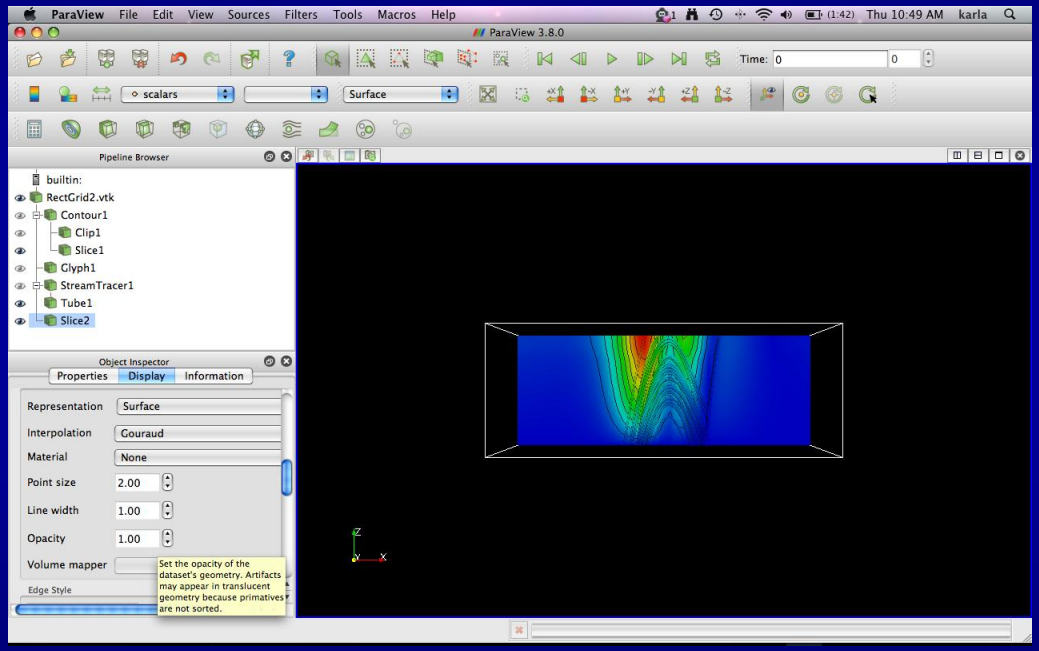


ParaView

Object Opacity

- Click `Slice2` in Pipeline Browser
- Click `Display`
- Change `Opacity to 0.70 -> Enter`
- Click Color by `vectors`
- Click eye next to `RectGrid2.vtk` to hide box outline



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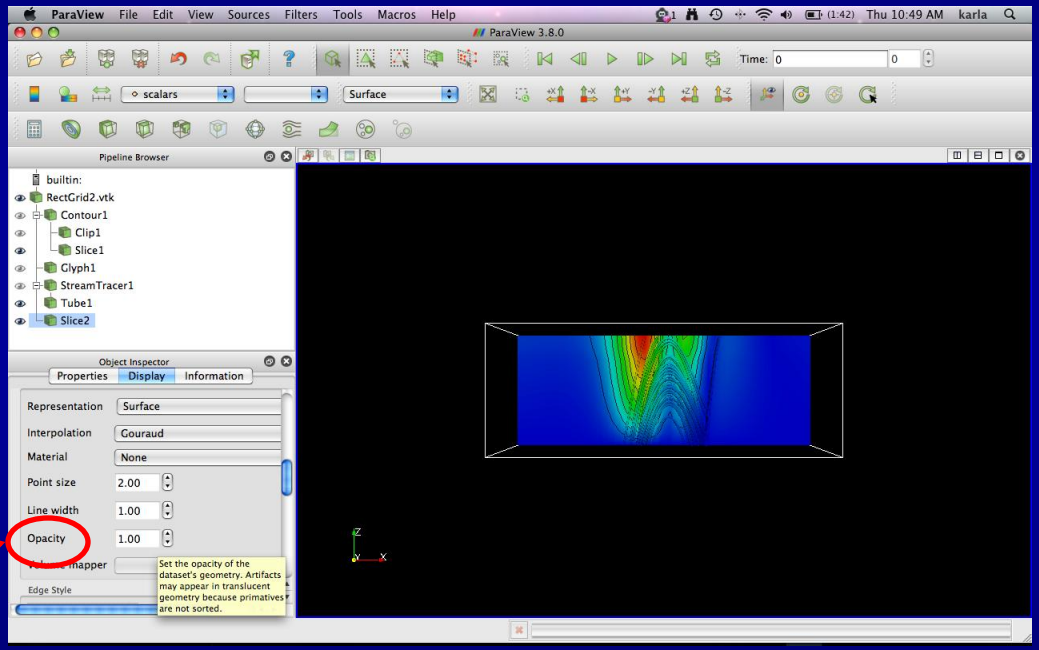

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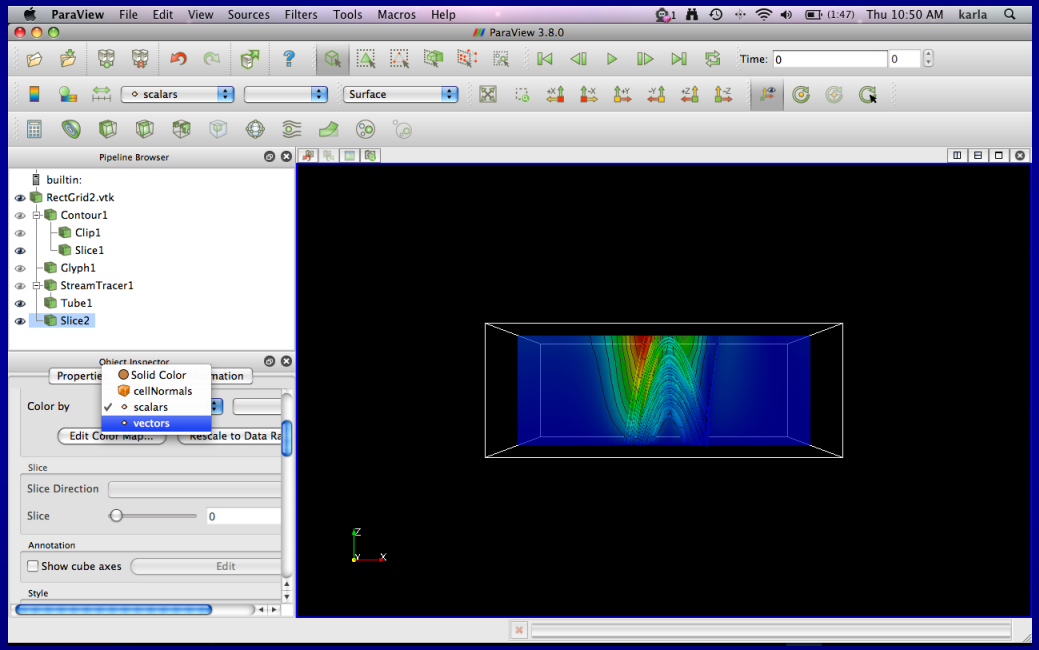

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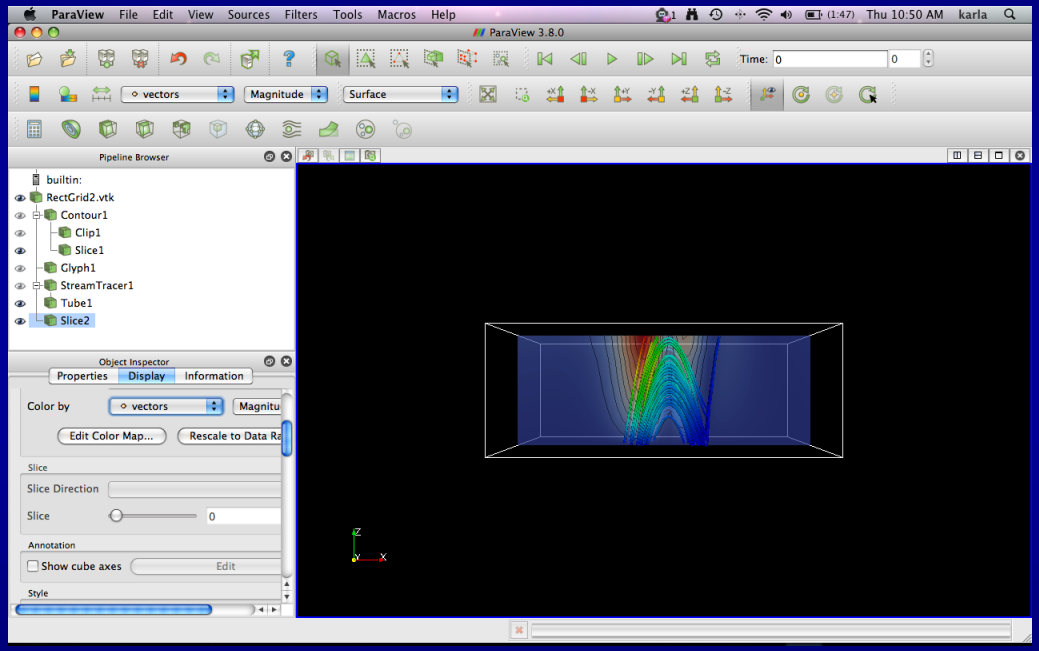

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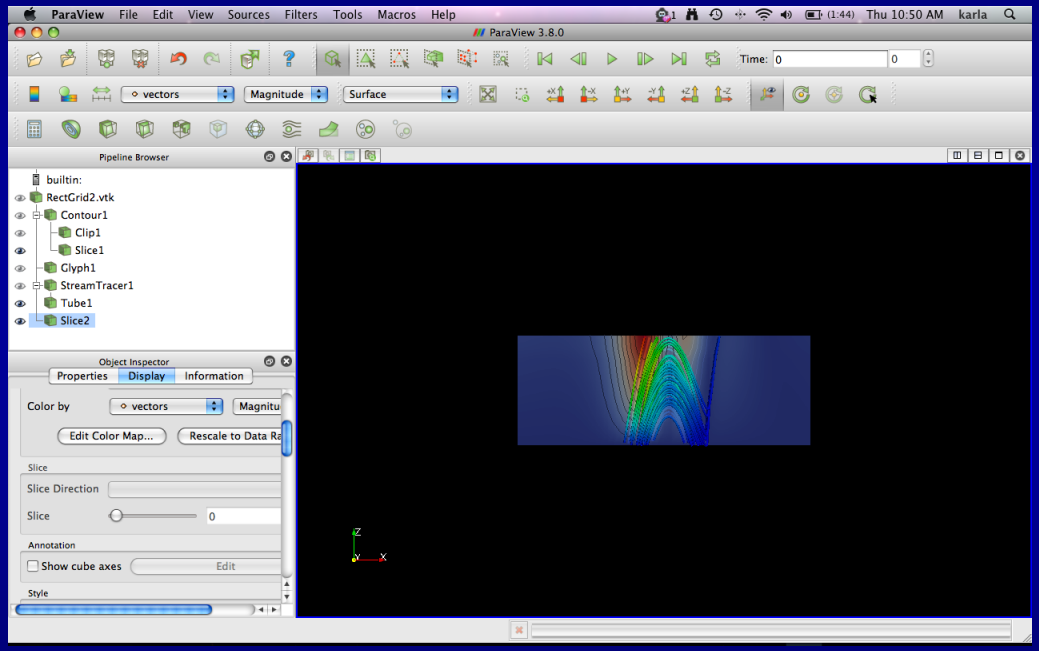
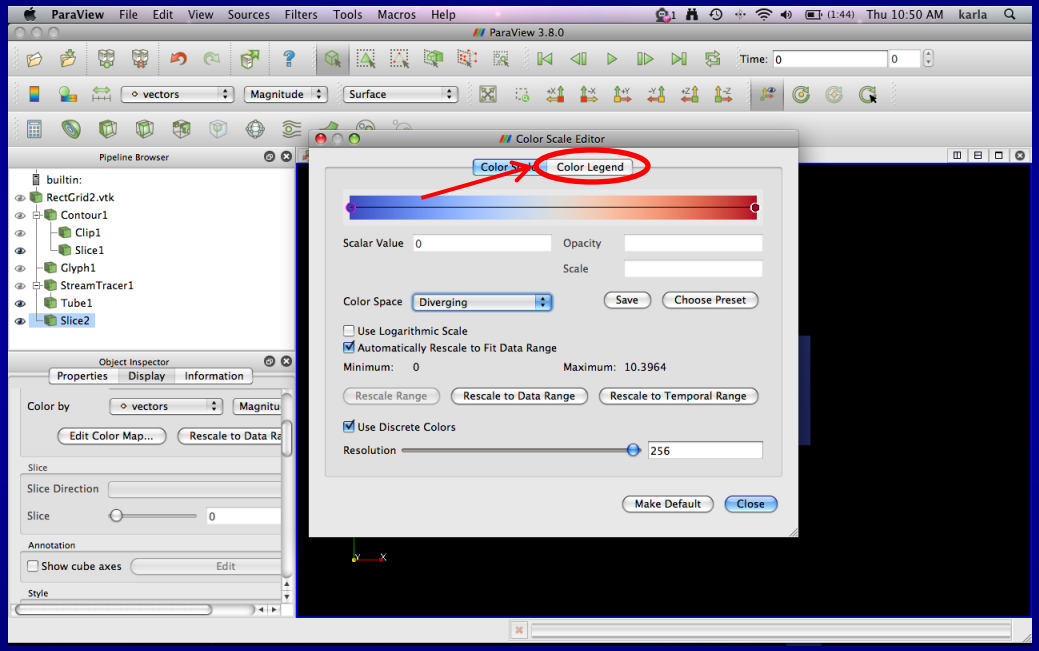


ParaView

Enable Color Legend

- Click `Display`
- Click `Edit Color Map`
- Click `Color Legend`
- Click `Show Color Legend`
- Click `-> Blue Close`
- Select Color Legend (notice white rectangle) and move to top of 3D viewer



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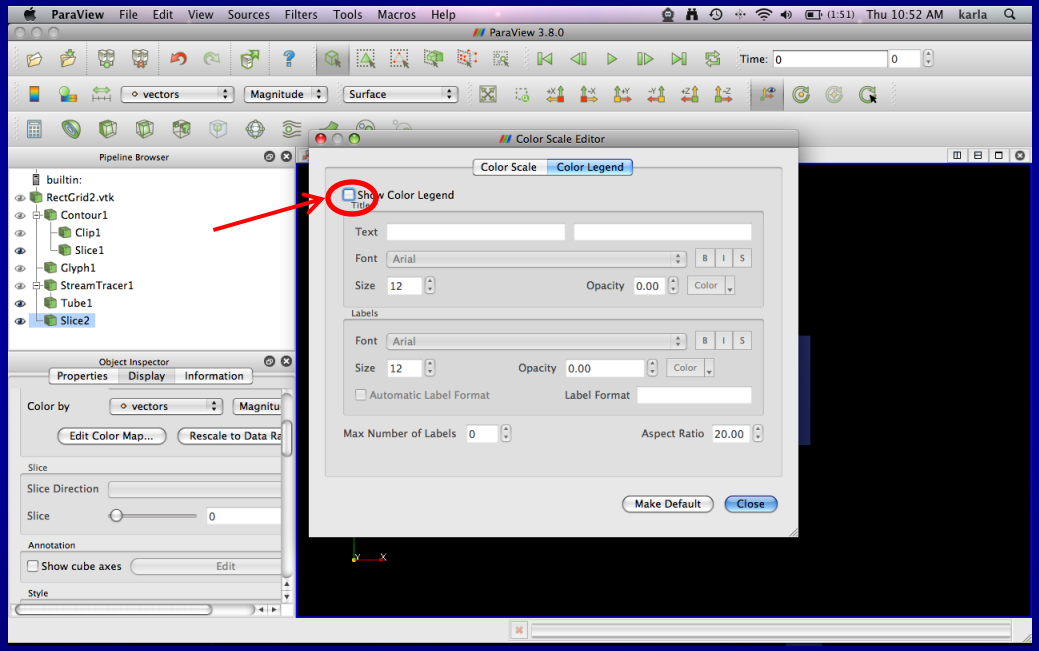

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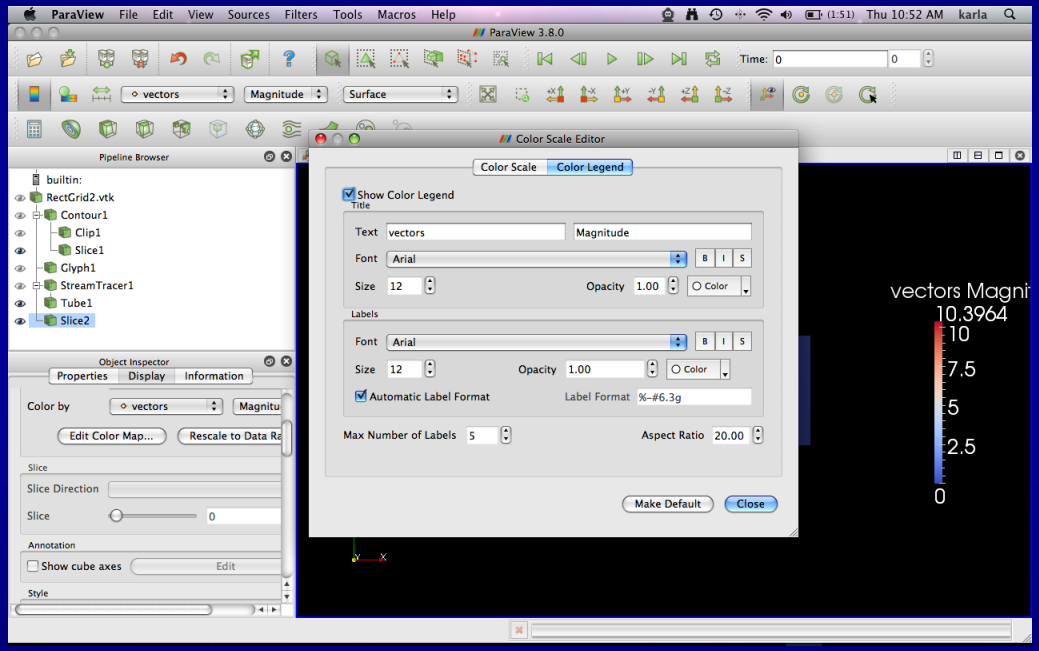

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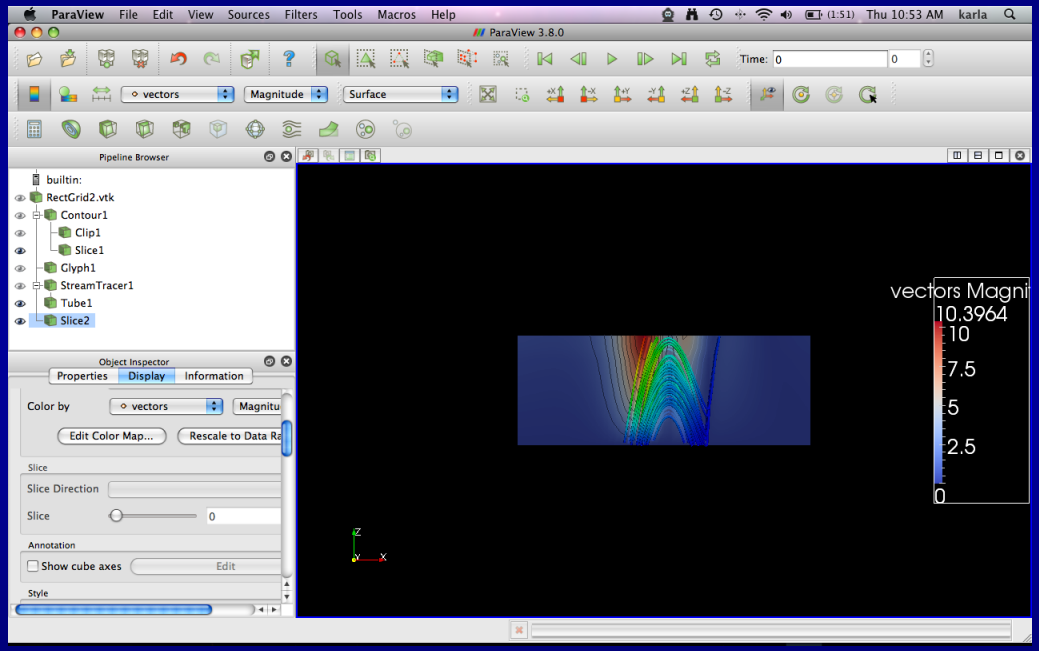

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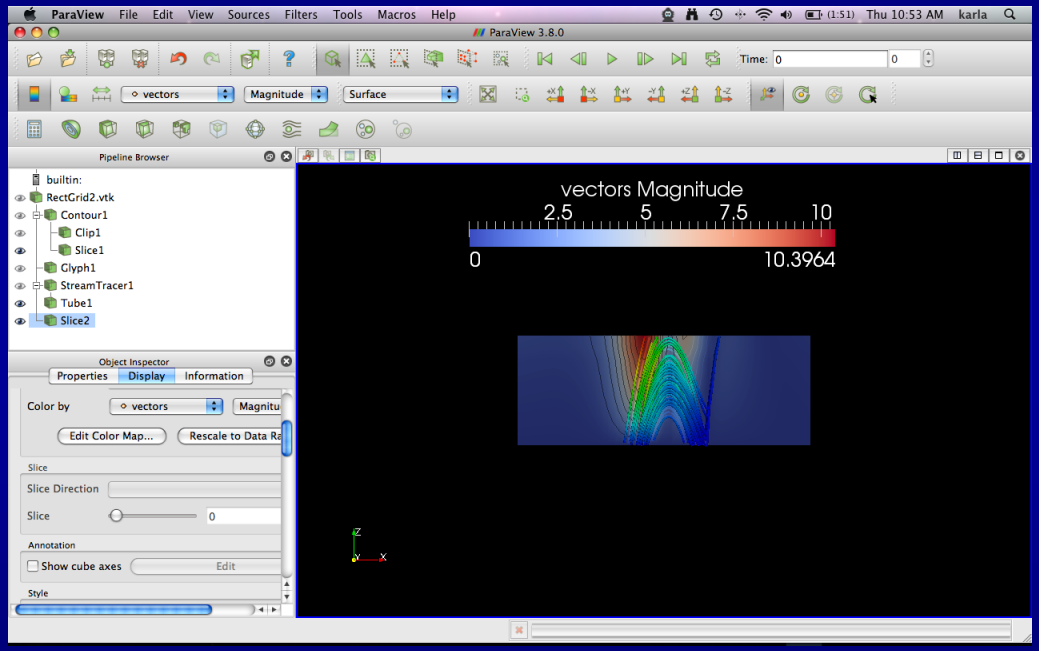
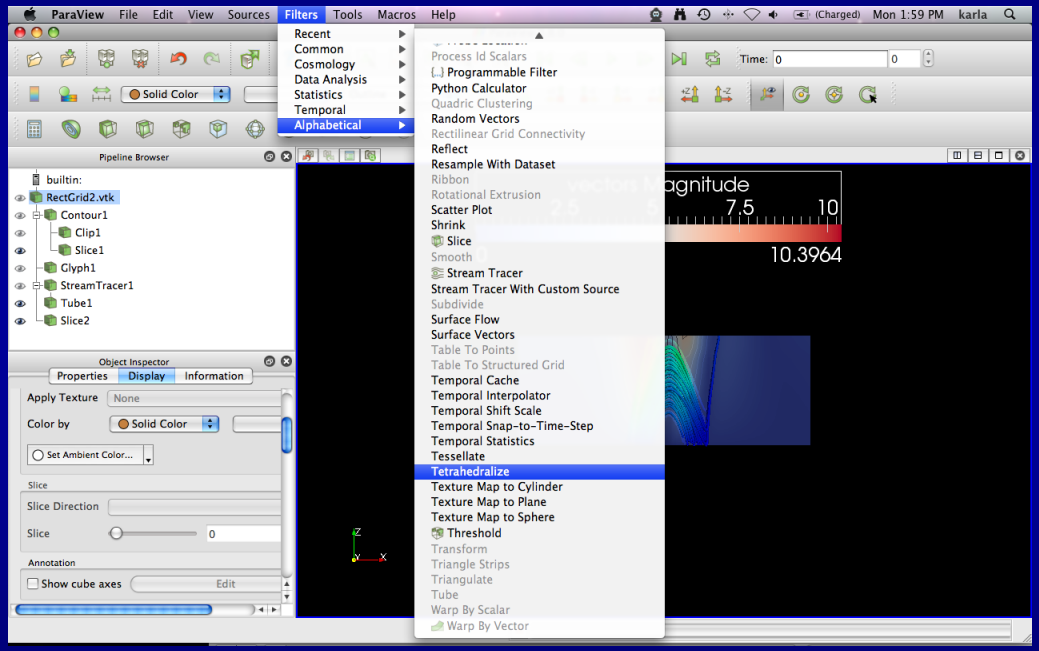


ParaView

Create Volume Rendering

- Click `RectGrid2.vtk` in Pipeline Browser
- Click `Filters -> Common -> Tetrahedralize`
- Click `-> Apply`
- Click `Display`
- Click `Representation`
- Select `Volume`
- Click `-> Edit Color Map (To edit transfer function)`



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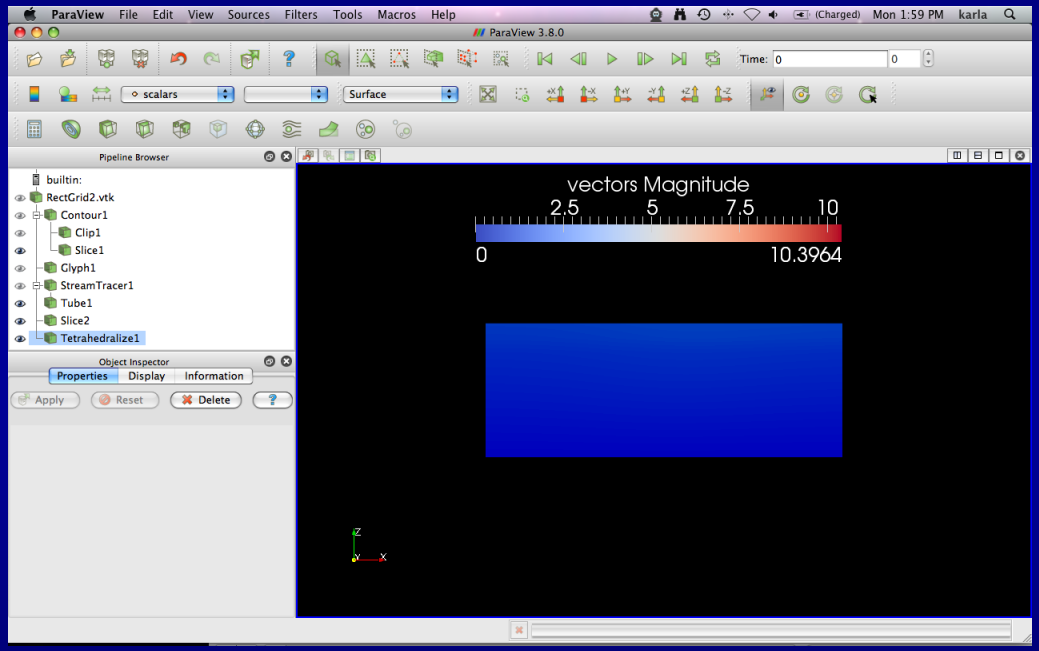

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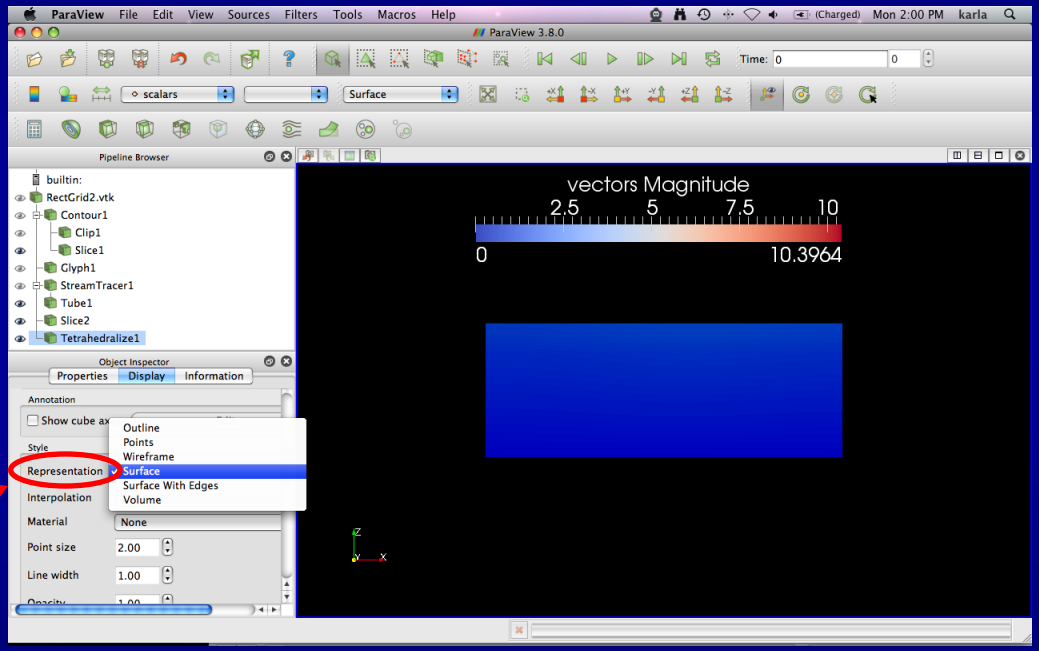

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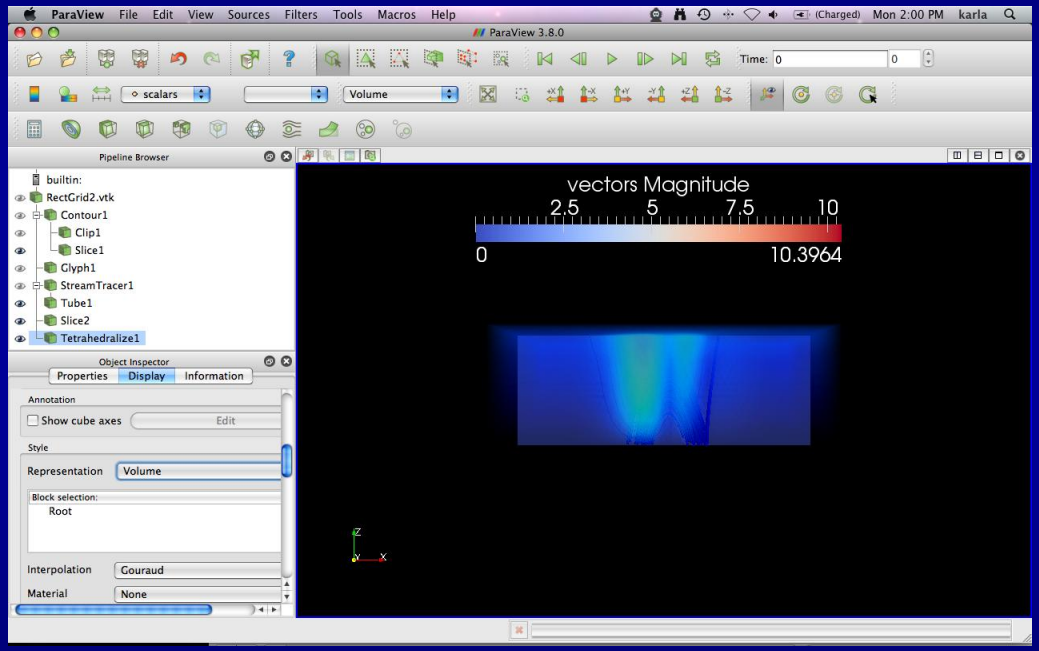

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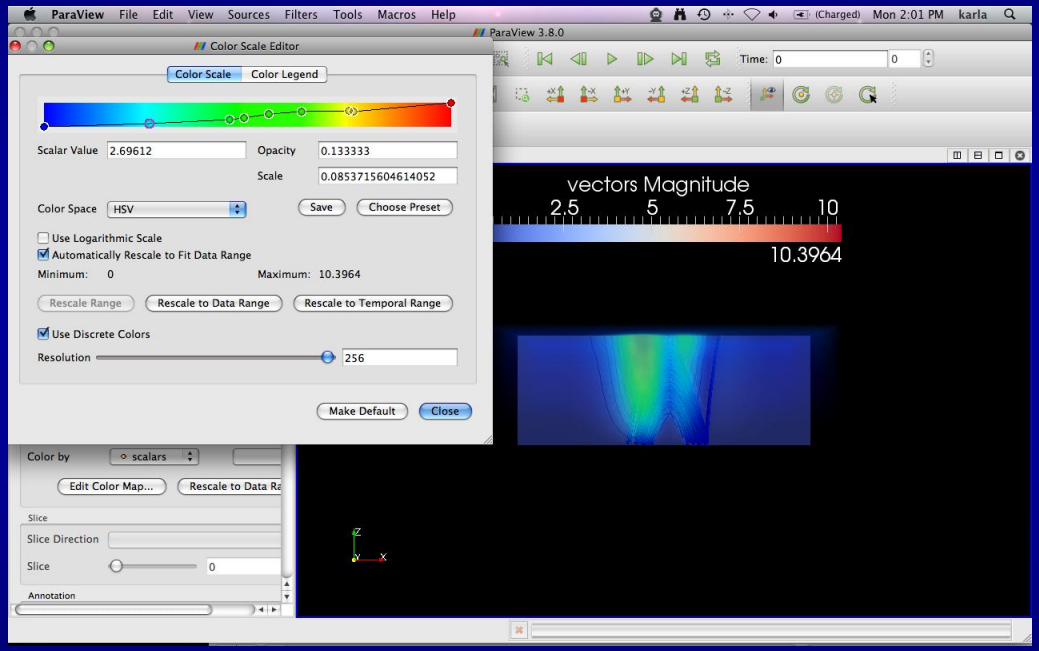

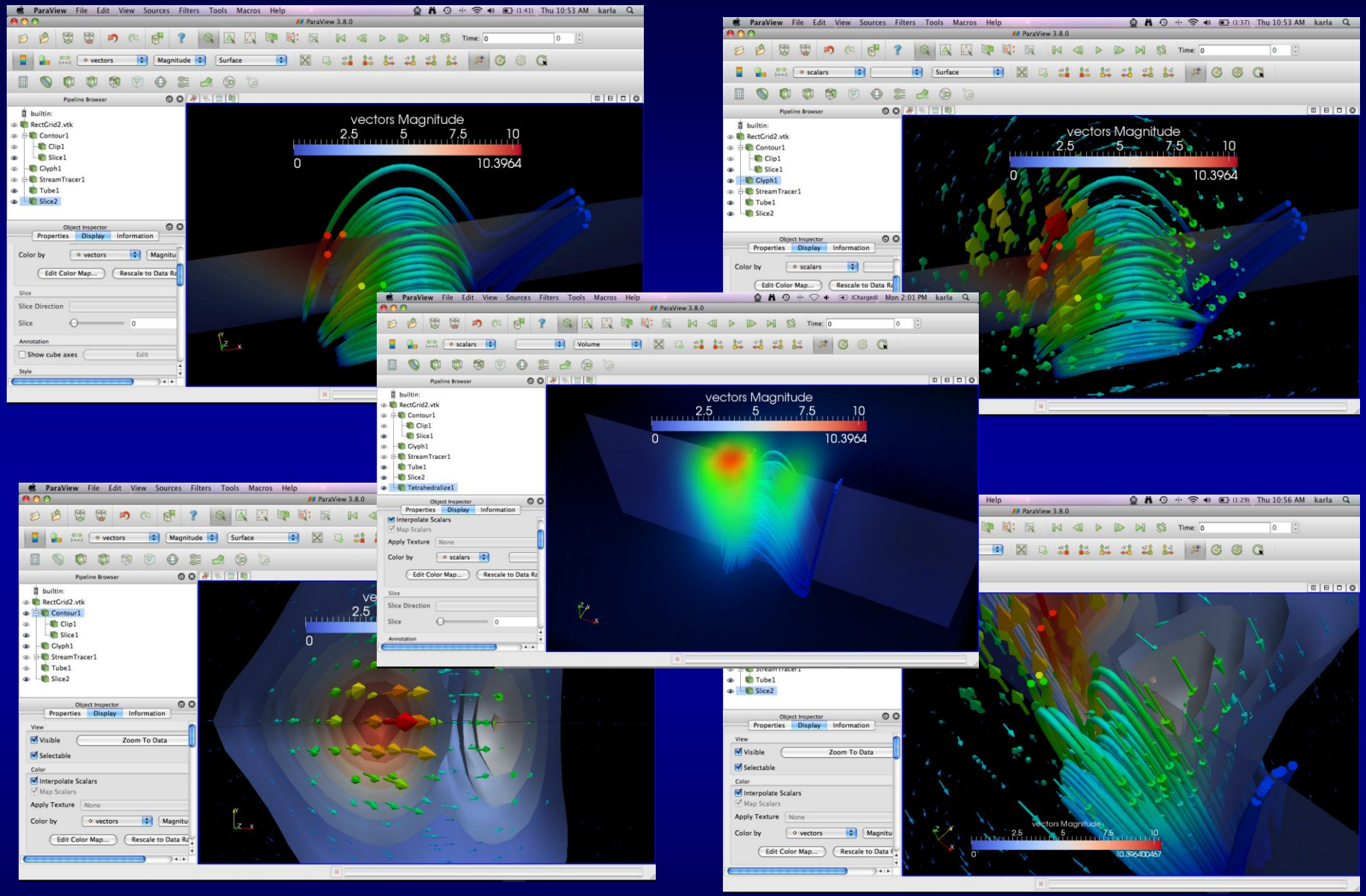
ParaView File Edit View Sources Filters Tools Macros Help
ParaView 3.8.0
Pipeline Browser
builtin:
RectGrid2.vtk
Contour1
Clip1
Slice1
Glyph1
StreamTracer1
Tube1
Slice2
Tetrahedralize1
Object Inspector
Properties Display Information
vectors Magnitude
2.5 5 7.5 10
0 10.3964
Color by
Edit Color Map...
Rescale to Data Range
Slice
Slice Direction
Annotation
Show cube axes
Interpolate Scalars
Map Scalars
Apply Texture
Visible
Zoom To Data
Selectable
Color
Style

Questions?

- More tutorials available:
  - http://www.paraview.org/Wiki/The_ParaView_Tutorial