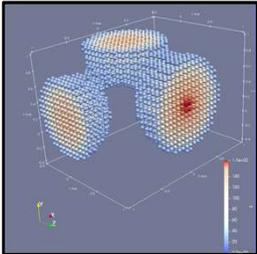
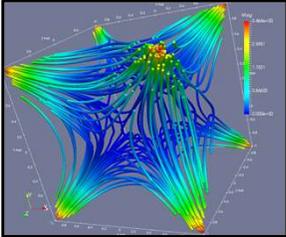


1

## ParaView

<http://cs.oregonstate.edu/~mjb/paraview>

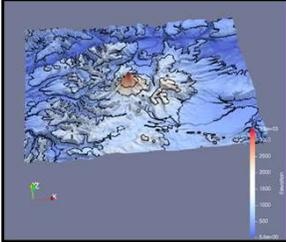




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Mike Bailey  
mjb@cs.oregonstate.edu



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paraview.pptx

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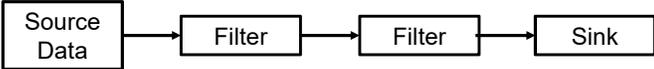
2

## What is ParaView?

ParaView is a free interactive visualization package produced by **KitWare**, <https://www.kitware.com/>

It is built upon VTK, the Visualization Toolkit, <https://vtk.org/>

It uses a dataflow paradigm:



```

graph LR
    A[Source Data] --> B[Filter]
    B --> C[Filter]
    C --> D[Sink]
  
```

In which data arrives via sources (typically files), is filtered by various numeric algorithms, and is sent to various sinks (typically the computer graphics display).

Besides the interactive interface, ParaView also has a Python scripting interface, so that you can create these dataflow networks auto-magically.

**These notes have been written against ParaView version 5.11**



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<http://www.paraview.org> 3

Click here to download ParaView

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**In these notes, what do these icons mean?** 4



scalar.csv



scalar.ogv

They tell you that if you go to our notes web site:

<http://cs.oregonstate.edu/~mjb/paraview>

you will find pre-created ParaView input data (\*.csv) and pre-created animation movie files (\*.ogv).

You can read a .csv file right into ParaView so that you can experiment with these examples without having to first create them yourself.

You can play an .ogv movie file right from your browser so that you can see how these examples look without having to run ParaView at all.



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**A warning about me and the Notes**

5

What ParaView does

What I know

What the notes cover



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6

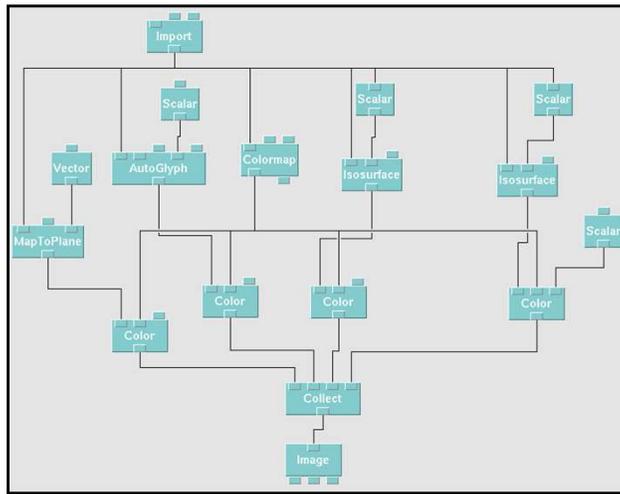
**Screen Layout, Color Editor,  
and 3D Display**



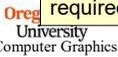
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### In the Beginning, there was OpenDX ...

7



“DX” stands for “IBM Data Explorer”. Like the name implies, it let you **explore!** But, once it became “open” instead of commercial, all reliable support went away. Also, it required a lot of screen area just to hold the block diagram.



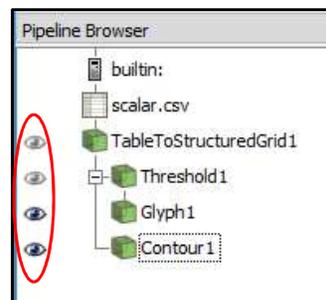
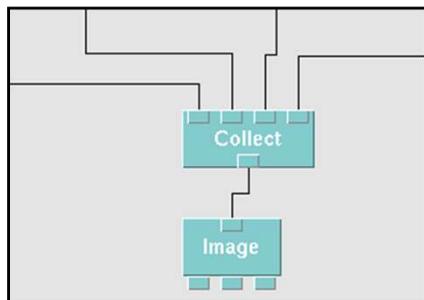
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### Fan-In to the Full Scene

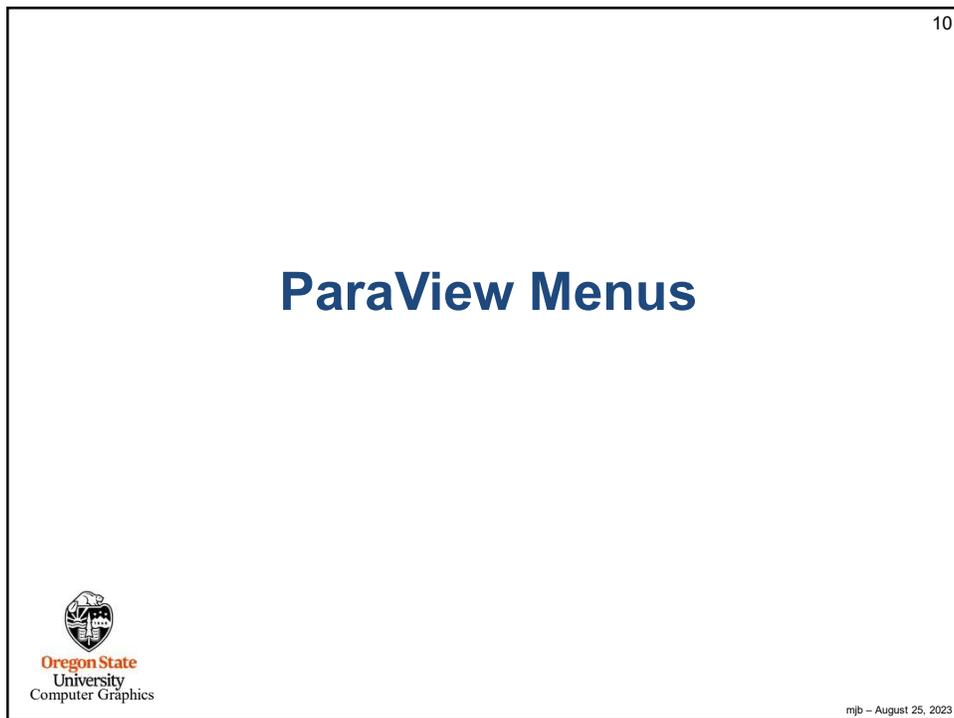
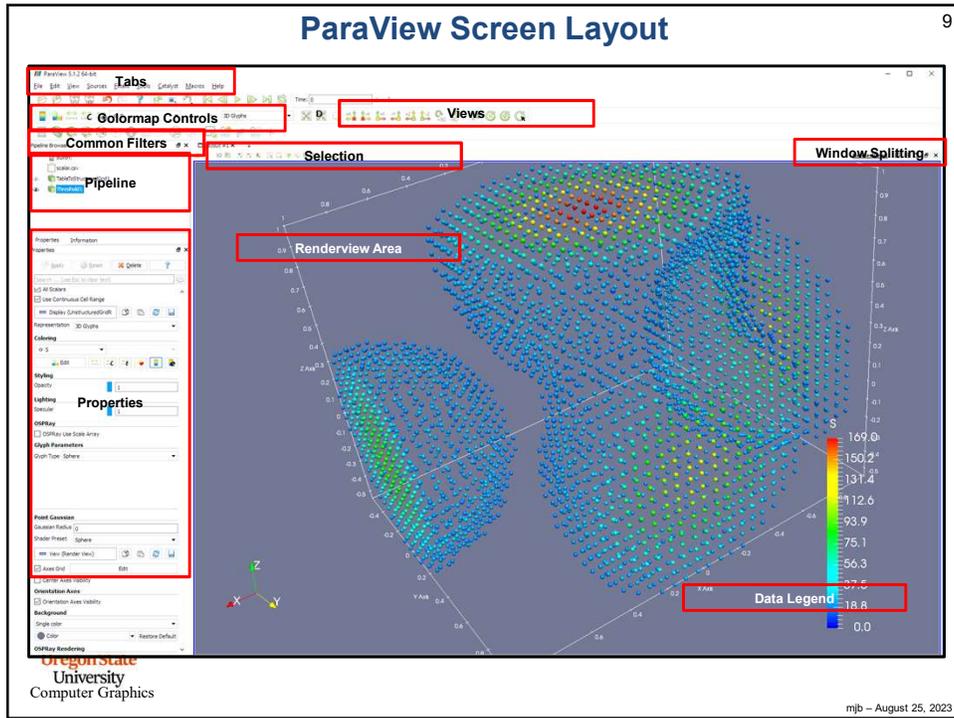
8

OpenDX:

ParaView:



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### Window Layout Menu 11

The screenshot shows a toolbar with various icons. Red arrows point from text labels to specific icons:

- Camera undo and redo
- Toggle between 2D and 3D interaction
- Adjust camera
- Add, subtract, and toggle selections
- Selecting cells, points, and blocks
- Clear selection
- Save screenshot
- Split a window left-right
- Split a window up-down
- Maximize a window
- Restore after maximizing
- Eliminate a window

**RenderView1** [Window Management Icons]

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### Commonly-used Filters Menu 12

The screenshot shows a toolbar with icons for various filters. Below the icons are their names:

- Calculator
- Contour
- Clip
- Slice
- Threshold
- Extract Subset
- Glyph
- Stream Tracer
- Warp by Vector
- Group Datasets
- Extract Level

Some will be activated and some will be greyed-out, depending on what data you would be trying to use them for

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### ParaView Menus

13

Animation Controls

Open	Save State	Save Catalyst State	Disconnect	Undo	Apply Changes Automatically	Load Color Palette
Save	Save Extracts	Connect	Reset Session	Redo	Find Data Matching	

Directional Camera Positions

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### ParaView Menus

14

Color Legend Visibility	Use Separate Color Map	Rescale to Custom Data Range	Rescale to Visible Data Range	Graphical Representation
Edit Color Map	Rescale to Data Range	Rescale to Data Range over all Time Steps	What to Color Based On	

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### ParaView Menus

15



Reset      Reset Camera Closest      Zoom to Box  
Zoom to Data      Zoom Closest to Data



Compute Quantities      Histogram      Plot Over Line      Probe Location      Ruler  
Extract Selection      Plot Variables Over Time      Plot Selection Over Time      Programmable Filter



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16

# 3D Scene Manipulation



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### Sources → Geometric Shapes → Sphere

Computer Graphics

**Pick Solid Color**

Basic colors

Custom colors

Hue: 0 Sat: 0 Val: 255

Red: 255 Green: 255 Blue: 255

HTML: #FFFFFF

OK Cancel

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### 3D Scene Manipulation

By default, these are the 3D Scene Manipulators (plus the mouse wheel, which is also a Zoom):

(You can change these in the **Edit → Settings → Camera** menu)

**3D Interaction Options**

**Camera3D Manipulators:** Select how interactions are mapped to camera movements when in 3D interaction mode.

	Left Button	Middle Button	Right Button
	Rotate	Pan	Zoom
Shift +	Roll	Rotate	Pan
Ctrl +	Zoom	Rotate	ZoomToMouse

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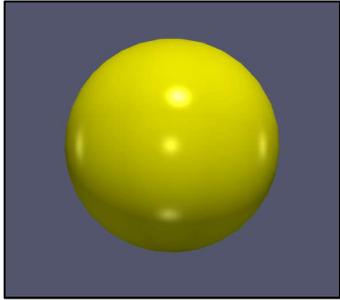
### You Can Change Sphere Properties

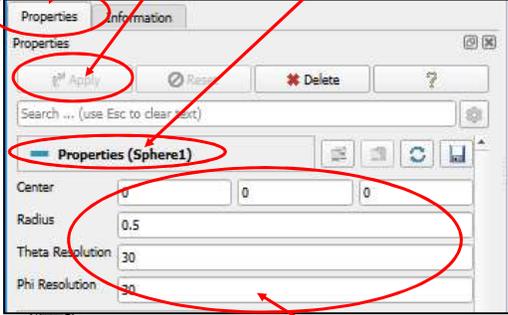
19

Properties Tab

If the **Apply** button is highlighted, click it to make your changes take effect

Show/Hide the Geometric Properties





The Geometric Properties of the Sphere



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### You Can Change the Sphere's Display Properties

20

Show/Hide the Display Properties

How to Represent the Sphere

How to Color the Sphere

Edit the Sphere Color

Set the Sphere Opacity

Set the Sphere Specular Lighting

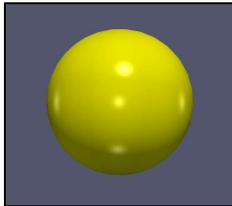
Bring up other Features to Color-Edit

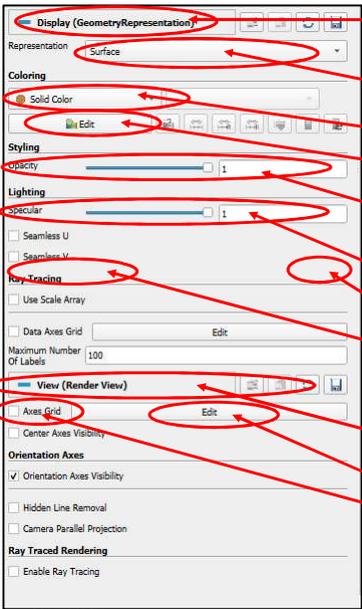
Edit the Edge Color

Show/Hide the Render View Properties

Edit the Features of the **Axis Grid**

Turn on/off the **Axis Grid**





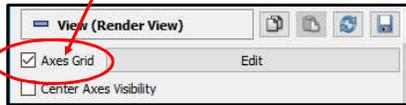
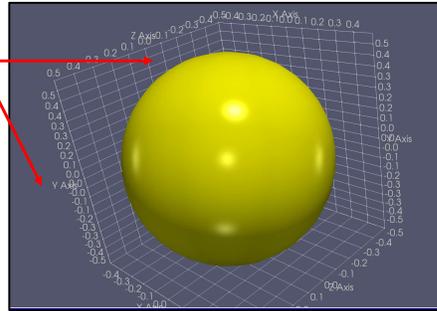


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### The Axes Grid

21

ParaView has a nice **Axes Grid** feature. Scroll way down in the Properties area to the **Render View** menu to turn it on.

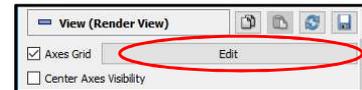


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### Editing the Axes Grid

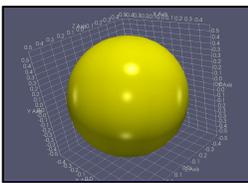
Show more/less options

22

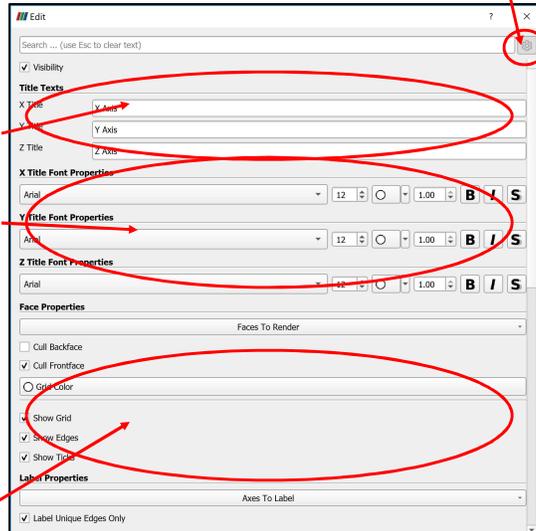


Titles for the axes

Title font styles



Number label font styles



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### Editing the Axes Grid

23

**Title font styles**

**Number label font styles**

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### Filters → Alphabetical → Shrink

24

Be sure the Shrink eyeballs are clicked on and the Sphere eyeballs are clicked off

**Step #1:** Set the Shrink Factor (1. = no shrinking, 0. = all shrinking)

**Step #2:** Hit Apply

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## Are You Getting Tired of Hitting Apply All the Time?

25

In Edit → Settings → General, turn on Auto Apply

Show more/less options

**General Options**

- Show Welcome Dialog: Show welcome screen at startup.
- Show Save State On Exit: Prompt to save state when exiting ParaView.
- Crash Recovery: On a crash, attempt to save a state file to potentially restore the application state to that before the crash.
- Force Single Column Menus: Force the sources/filters menus to be presented as a single scrollable column to ensure that all the filters are selectable on low resolution screens.

**GUI Font**

- Override Font: Override the GUI font size. Uncheck to use system default.

**View Options**

**Default View Type:** Set the view to create when ParaView starts up.

Render View

**Screen Pixels Per Inch:** Set pixels per inch on the current screen/monitor. This is used for determining pixel sizes for fonts and other 2D annotations.

96

**Properties Panel Options**

- Auto Apply: Automatically apply changes in the 'Properties' panel.

 Be careful about doing this with large datasets that are slow to display.

*Don't do this until after you have completed the entire **TableToStructuredGrid** operation.*

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26

# Visualizing Scalar Data, I



scalar.csv

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## What File Formats Can ParaView Read?

27

AVS UCD	BYU	CML Molecule	<b>CSV</b>
DEM	DICOM	ENZO AMR Particles	EnSight
Enzo	ExodusIIReader	FLASH AMR Particles	FacetReader
Flash	Fluent Case	Gaussian Cube	Image
JPEG Series	LSDynaReader	Legacy VTK	MFIXReader
MRC Series	Meta File Series	NetCDF	Nrrd
OpenFOAMReader	PDB	PLOT3D	PLY
PNG Series	PTS	PVD	Particles
Partitioned Legacy VTK	Phasta	ProSTAR (STARCD)	RTXMLPolyDataReader
Restarted Sim	SLAC	Spcth History	STL
Spy Plot	TIFF	Tecplot	Unstructured NetCDF POP
VPIC	VRML	Wavefront OBJ	WindBlade
XDMF	XML	XYZ	



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## Creating Scalar Data in a CSV File

28

```

x32, y32, z32, s
-1.00, -1.00, -1.00, 0.00
-0.94, -1.00, -1.00, 0.00
-0.87, -1.00, -1.00, 0.00
-0.81, -1.00, -1.00, 0.00
-0.74, -1.00, -1.00, 0.00
-0.68, -1.00, -1.00, 0.00
-0.61, -1.00, -1.00, 0.00
-0.55, -1.00, -1.00, 0.00
-0.48, -1.00, -1.00, 0.00
-0.42, -1.00, -1.00, 0.00
-0.35, -1.00, -1.00, 0.00
-0.29, -1.00, -1.00, 0.00
-0.23, -1.00, -1.00, 0.00
-0.16, -1.00, -1.00, 0.00
-0.10, -1.00, -1.00, 0.00
-0.03, -1.00, -1.00, 0.00
    
```

Go to the **Edit** → **Settings** menu and turn on **Auto-Apply**.  
 Do a **File** → **Open** and navigate to your CSV file.  
 Hit the **Apply** button to actually do the read.



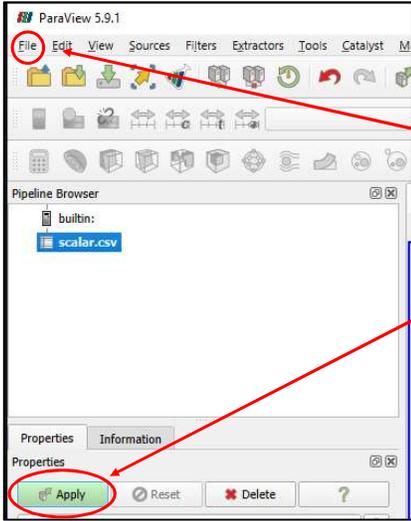

scalar.csv



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### Reading and Converting the CSV File

29



1. Select **File** → **Open** and navigate to **scalar.csv**

2. Then, click **Apply**

Row ID	X32	Y32	Z32
0	0	0	-1
1	1	0	-0.94
2	2	0	-0.87
3	3	0	-0.81
4	4	0	-0.74
5	5	0	-0.68
6	6	0	-0.61
7	7	0	-0.55
8	8	0	-0.48
9	9	0	-0.42
10	10	0	-0.35
11	11	0	-0.29
12	12	0	-0.23
13	13	0	-0.16
14	14	0	-0.1
15	15	0	-0.03
16	16	0	0.03
17	17	0	0.1
18	18	0	0.16

3. This will bring up a table window to confirm that the data has been read properly. You can close it if you want.

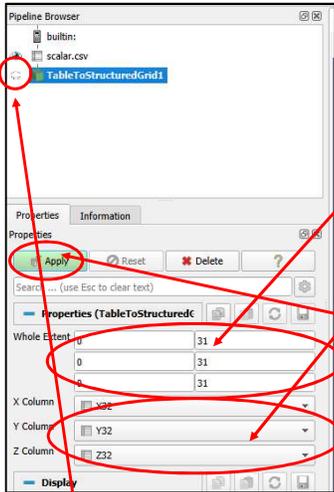


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### Reading and Converting the CSV File

30



4. Now, go to **Filters** → **Alphabetical** → **TableToStructuredGrid**

5. Fill in the **Whole Extent** boxes showing the first and last index in each dimension (the last index is one less than the number of points in that dimension). In this case, the numbers are **0** and **31**.

6. Fill in the **{X,Y,Z} Column** information so ParaView knows how to make your 3D display. In this case, the names are **X32**, **Y32**, and **Z32**.

7. Hit the **Apply** button to actually do the conversion.

Turn on the "eyeballs" so that you can view this data



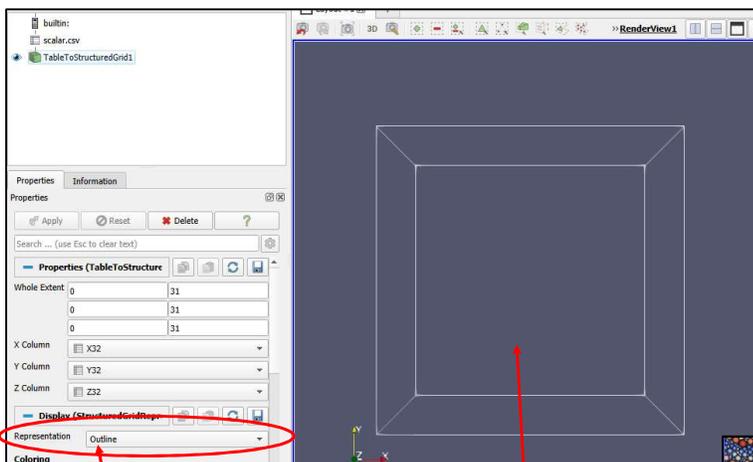


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## Reading and Converting the CSV File

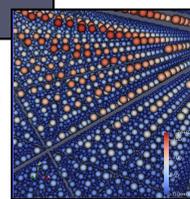
31



The default Display Representation is **Outline**.  
Click here and try some of the others. **Point Gaussian** is cool!

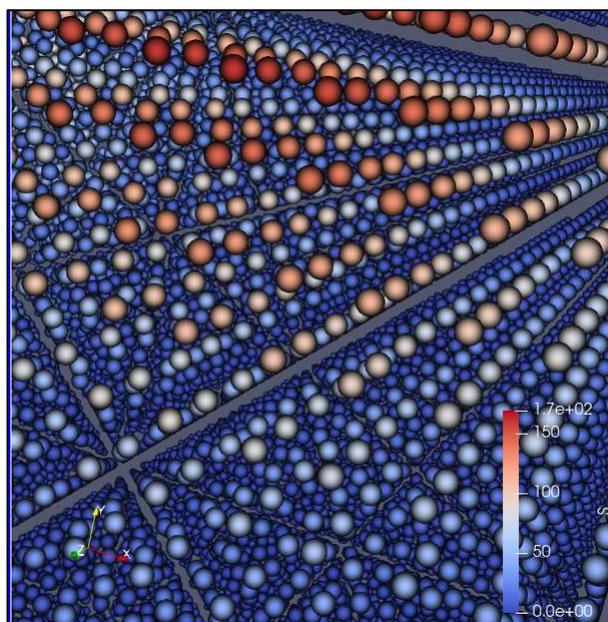


At this point, you should probably go to the **Edit**  
→ **Settings** menu and turn off **Auto-Apply**



## As Point Gaussian

32



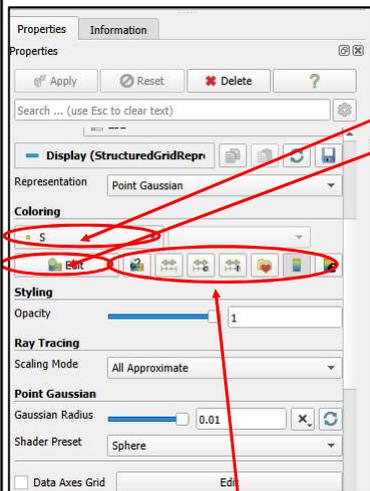
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# A Side Trip: Choosing Colors

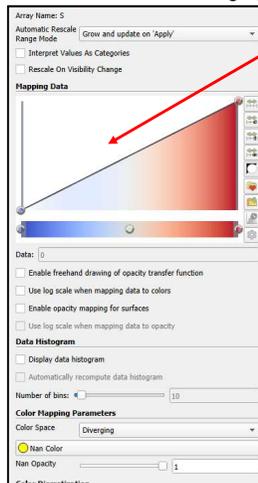


## Turning on Color

The default coloring is by scalar value, **S** in this case. You can also click here and change it to **Solid Coloring**.



The **Edit** button will bring up a color map editor

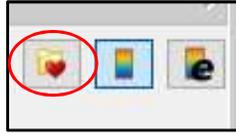


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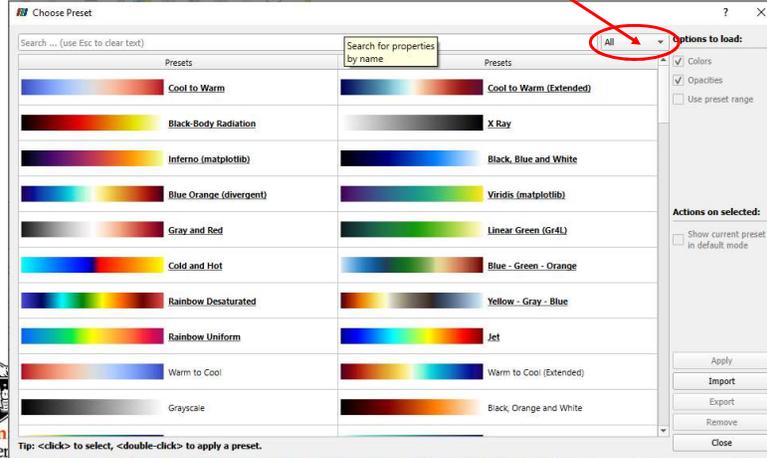
This is a row of color options.

## Choose Among Standard Color Transfer Functions

35



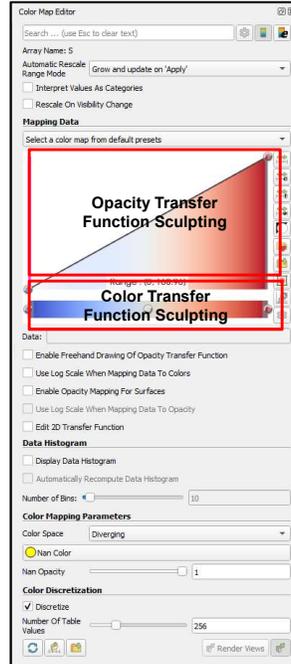
Click here to see all the categories of Transfer Functions available to you. Click **All** to see them all at once. (You will need to scroll down a lot.)



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## Color Map Editor

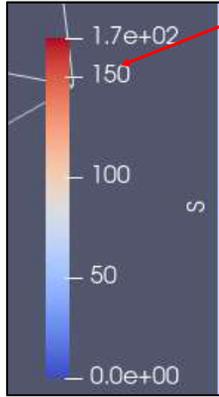
36



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### Changing the Legend

37



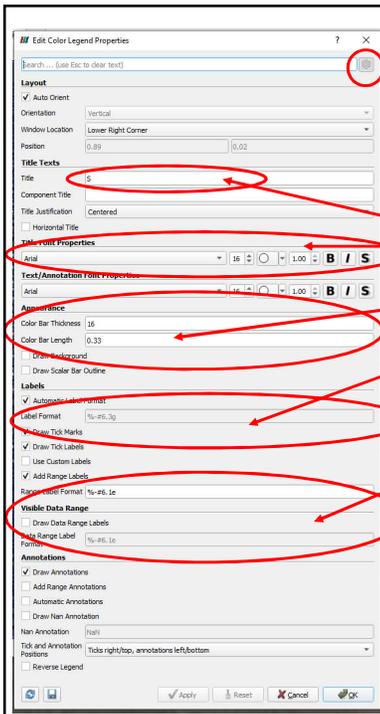
The default legend is good, but you can make it better. Start by clicking here.



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### Changing the Legend

38



Click on the "gear" to bring up *all* of the options. (This is a good idea on *all* ParaView dialog boxes.)

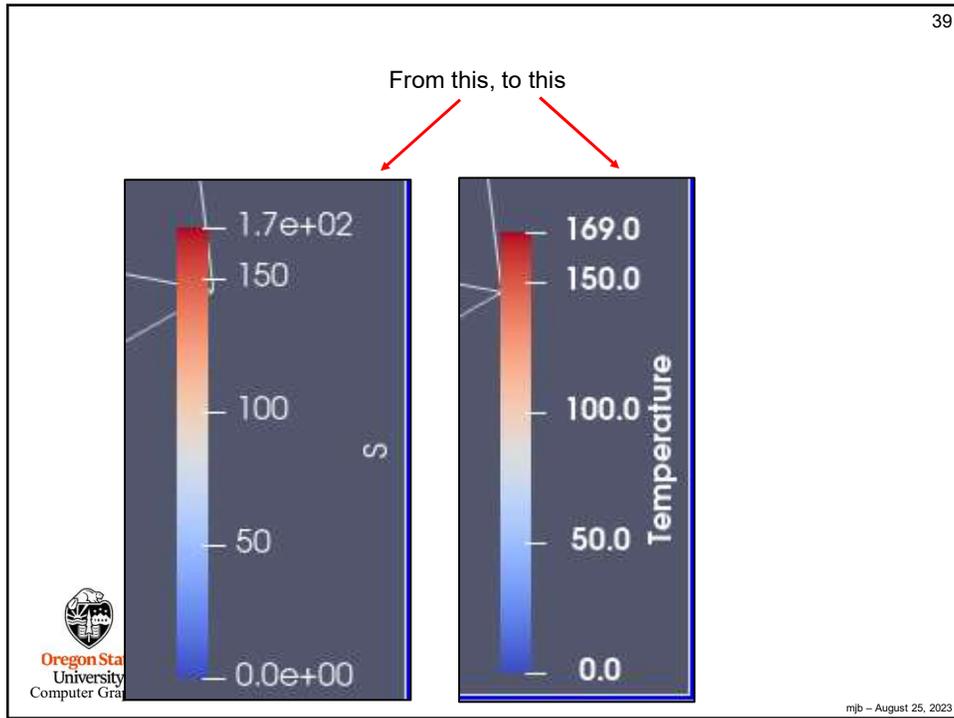
Legend title and font

Color bar

Tick mark font and number format ("printf-style")

Range numbers at the end of the legend

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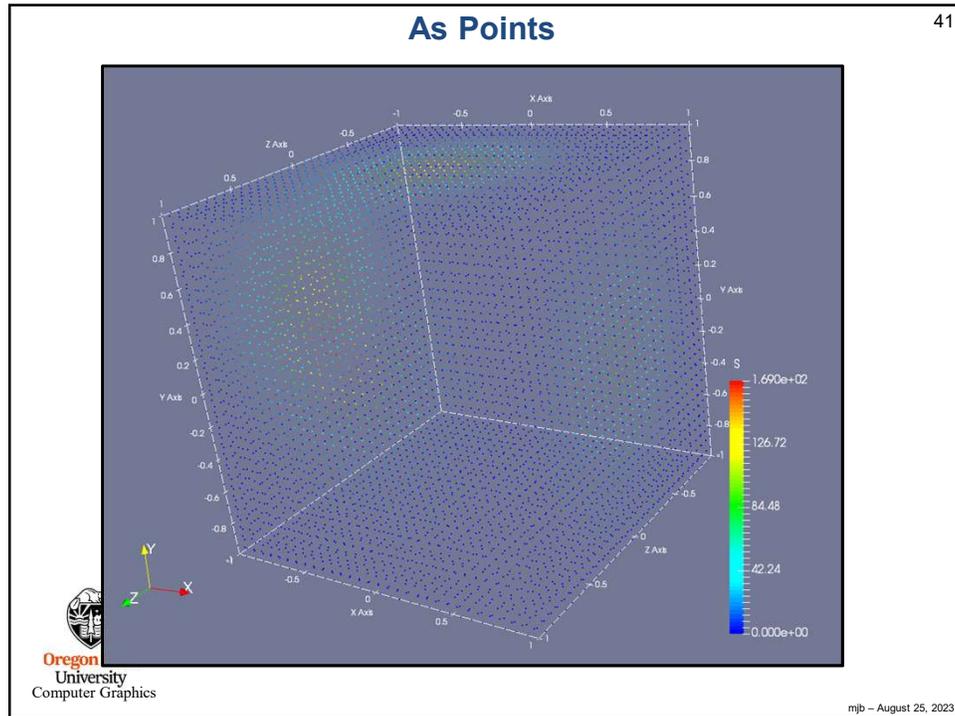
40

## Visualizing Scalar Data, II

scalar.csv

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### Pipeline Element and Filter Observations

42

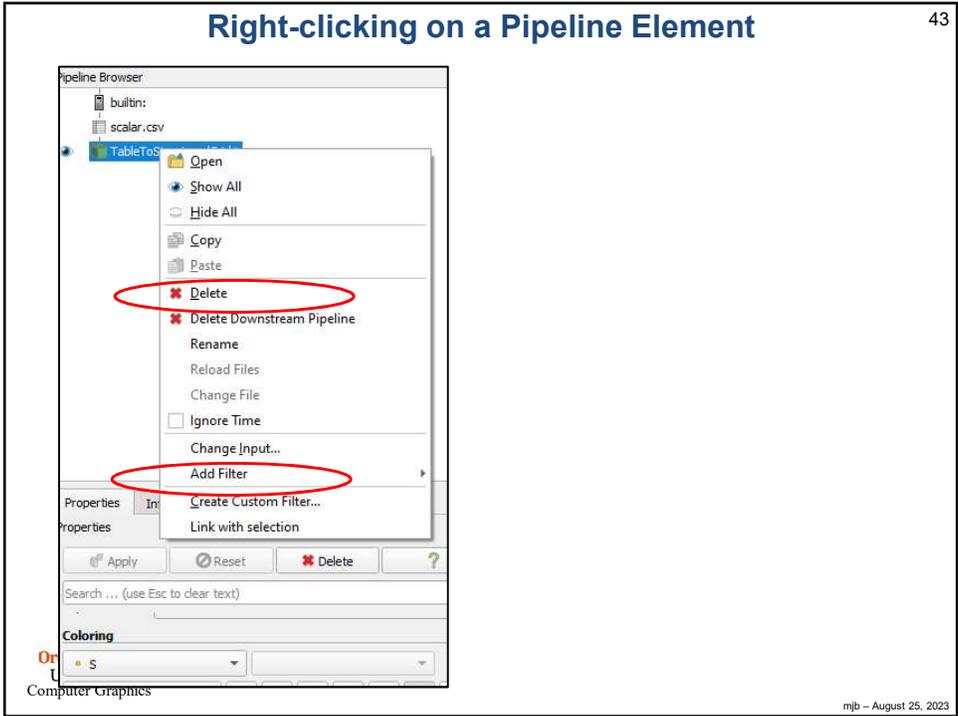
- Whatever pipeline element you have most-recently clicked on, that's what Properties you will see.
- Whatever pipeline element you have most-recently clicked on, that will be the parent of the next Filter you select. The parent's output will become the Filter's input.
- Be careful of Filter order. In general, Filters are not commutative or associative.
- For data-size reasons, it is helpful if any datasize reduction Filters are included early in the pipeline.
- As far as I can tell, you can't inject a filter in the middle of a pipeline. You can re-parent it. You can delete it and pipeline elements around it and start over. But, adding a new Filter between two existing pipeline elements creates a tee from the parent, not a new pipeline.
- Whatever "eyeballs" you have clicked on, that's what pipeline elements' visual representations you will see in the display.
- Turn on the **TableToStructuredGrid** "eyeballs" and set the Representation to **Outline**. That keeps ParaView displaying the data as 3D-fullsize, regardless of what downstream pipeline elements do.

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### Right-clicking on a Pipeline Element

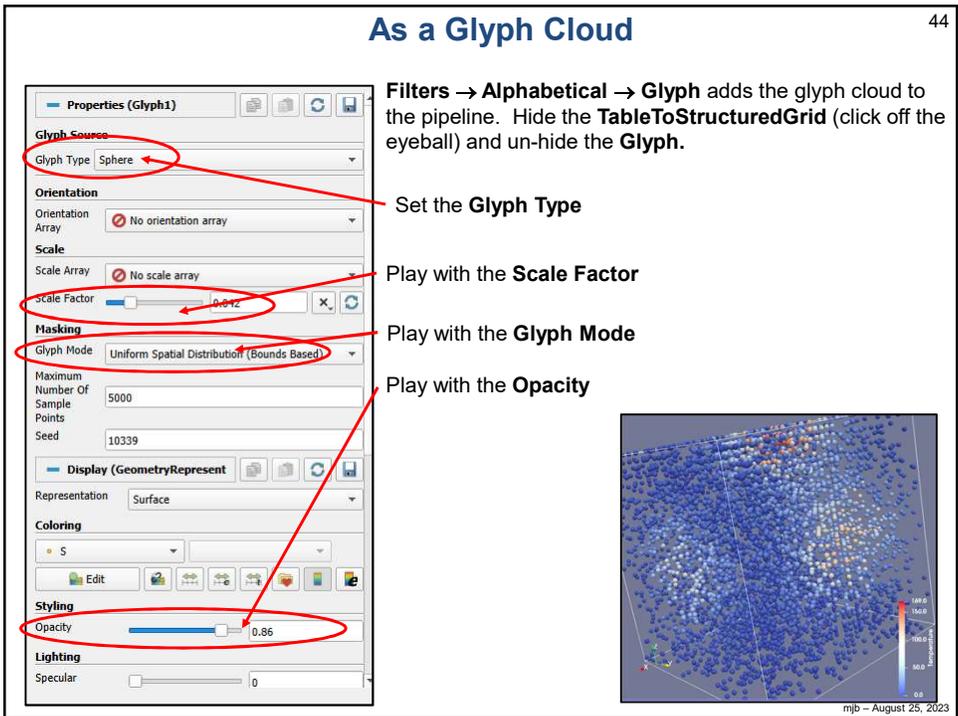
43



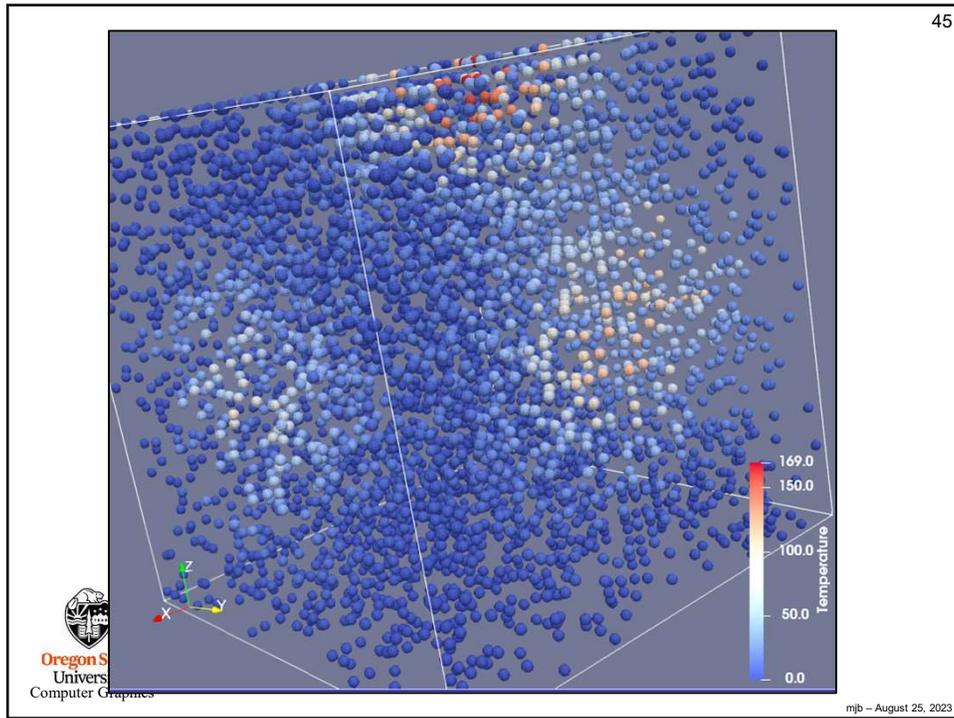
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### As a Glyph Cloud

44



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### As a Threshold Glyph Cloud

46

Click on **TableToStructuredGrid**, then **Right-click** → **Add Filter** → **Alphabetical** → **Threshold**.

But, this is the wrong order. We want to threshold the data first. So, select **Glyph1**, right-click on it, select **Change Input...**

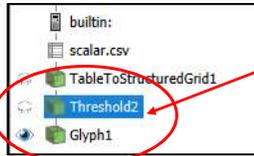
Then select **Threshold1**

You now have this order

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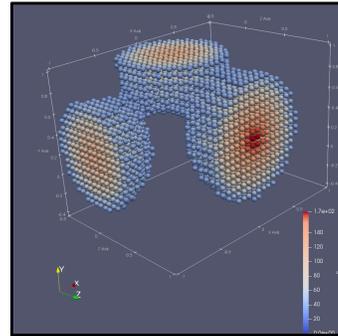
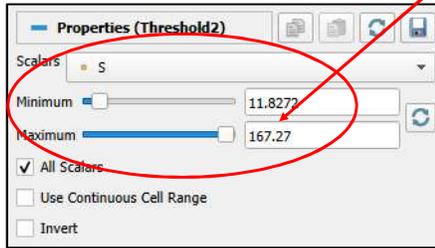
### As a Threshold Glyph Cloud

47



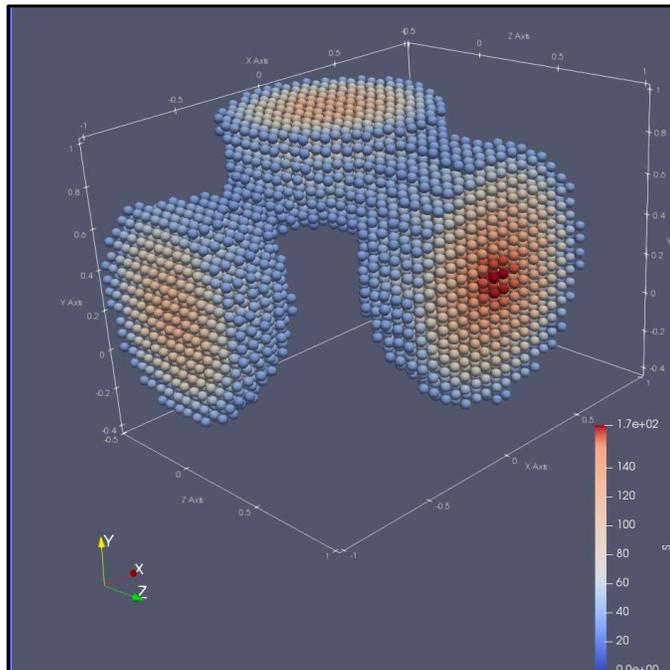
Hide the **TableToStructuredGrid** and the **Threshold**, then un-hide the **Glyph**.

Set the **Minimum** and **Maximum**. (Be sure to click on **Apply** if needed.)



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48



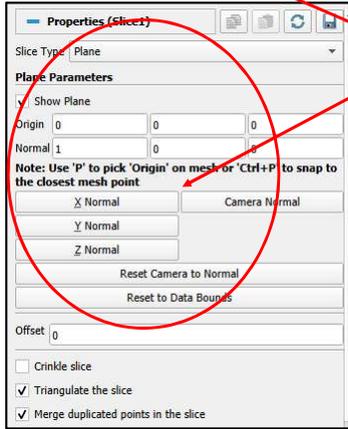
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### As a Colored Cutting Plane

49

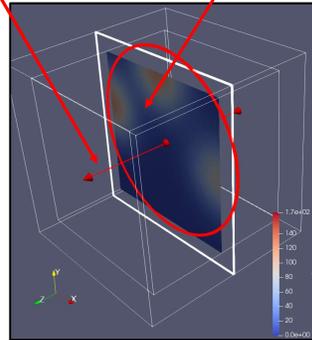


ParaView trick – turn on the **TableToStructuredGrid** display and set the Representation to **Outline**. That keeps ParaView from displaying the plane as 2D-only



Right-click on **TableToStructuredGrid**, then select **Add Filter** → **Alphabetical** → **Slice**

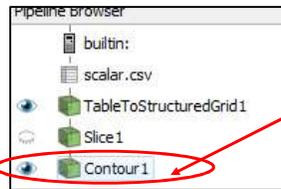
Click in here to change the slice parameters.  
Click on the colored plane itself to move the plane.  
Click on the arrow to rotate the plane.



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### Turning the Slice into Contours

50



Right-click on **Slice1**, then select **Add Filter** → **Alphabetical** → **Contour**



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### Changing the Contour Isovalue

51

**Value Range: [0, 153.575]**

1	30
2	0
3	18.773333333333333

Add a contour isovalue

Delete a contour isovalue

Add a range of contour isovalues

**Generate Number Series**

Range: 0 - 166.01

Type: Linear

Number of Samples: 10

Sample series: 0, 18.4456, 36.8912, 55.3368, 73.7824, 92.228, 110.674, 129.119, 147.565, 166.01

Generate Cancel

**Isosurfaces**

**Value Range: [0, 166.01]**

1	0
2	18.445609830402176
3	36.89121966080435
4	55.33682949120653
5	73.7824393216087
6	92.22804915201088
7	110.67365898241306
8	129.11926881281522
9	147.5648786432174
10	166.0104884736196

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### As Contours

52

**Display (GeometryRepresent**

Representation: **Wireframe**

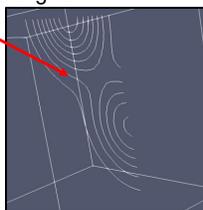
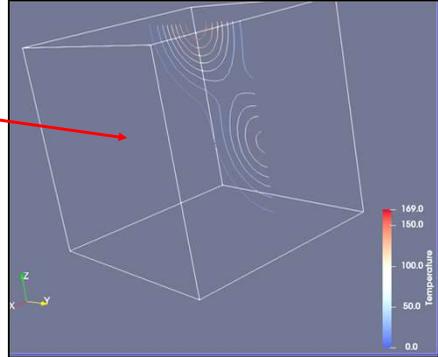
Coloring: **S**

Edit

This needs to be **Wireframe** to get contour lines

Coloring by **S** will give you colored contour lines.

Coloring by **Solid Color** will give you a single color.



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### As Contours

53

Pipeline Browser

- builtin:
- scalar.csv
- TableToStructuredGrid1
- Slice 1**
- Contour 1

Clicking on the Slice filter will bring up these slice handles so that you can move and re-orient the slice plane

Click on the plane itself to move the plane.  
Click on the arrow to rotate the plane.

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### As Contours

54

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### As Contours

55

**Styling**

Opacity

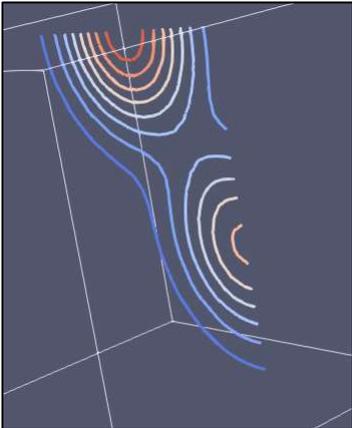
Line Width

Render Lines As Tubes

**Lighting**

Specular

Adjusting the **Line Width**




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### As 3D Isosurfaces

56

Pipeline browser

- scalar.csv
- TableToStructuredGrid
- Contour
- Slice1
- Contour1
- Contour2

Note – This instance of **Contour** needs to be parented from **TableToStructuredGrid**, not **Slice**

**Properties (Contour2)**

Contour By: s

Compute Normals

Compute Gradients

Generate Triangles

**Isosurfaces**

Value Range: [0, 168.96]

1	84.48	+	-	...	x	o
---	-------	---	---	-----	---	---

**Display (GeometryRepresent)**

Representation: Surface

**Coloring**

S

**Styling**

Opacity

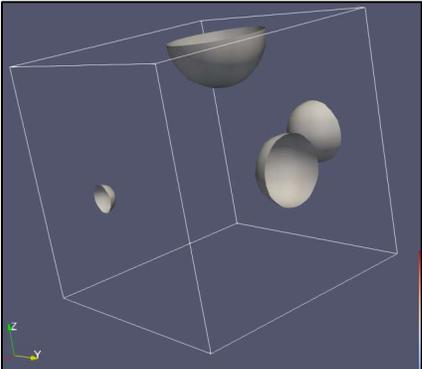
**Lighting**

Specular

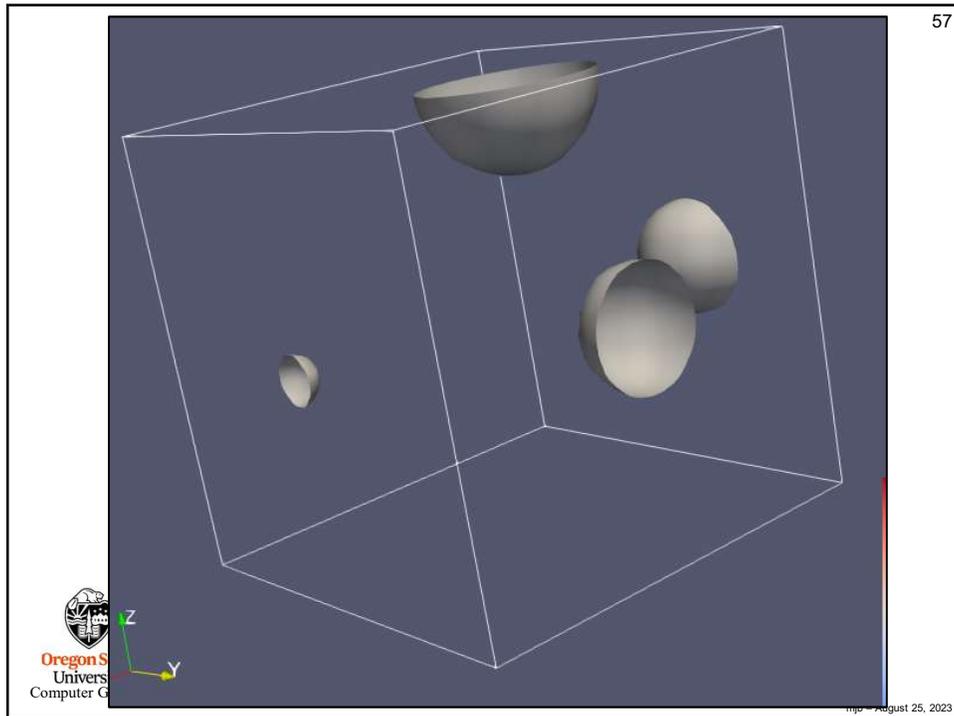
Add an isosurface isovalue

Delete an isosurface isovalue

Add a range of isosurface isovalue




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### Using the Calculator to Duplicate S to be Able to Color by Scalar Value

58

Add a Calculator filter parented by **TableToStructuredGrid**. The isosurface **Contour2** should be parented by the **Calculator**.

In the **Calculator**, this is like saying: **Scalar = S**

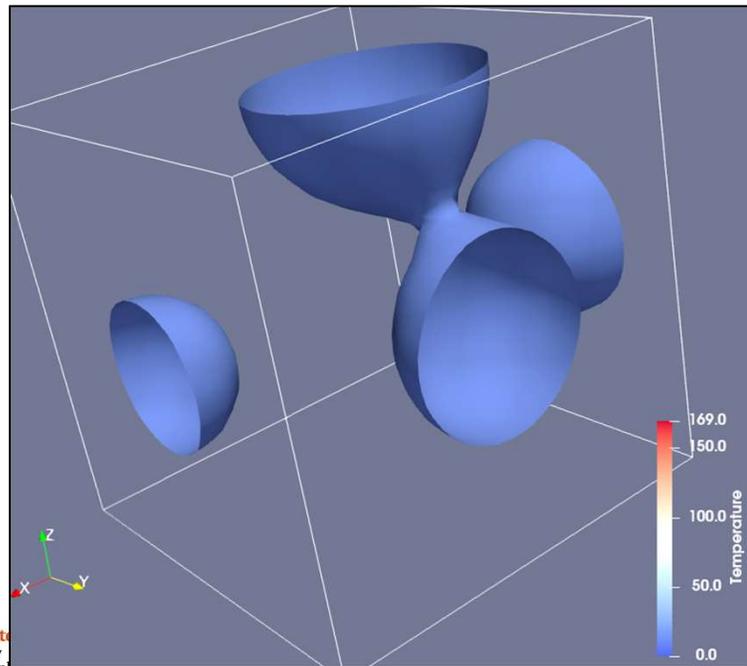
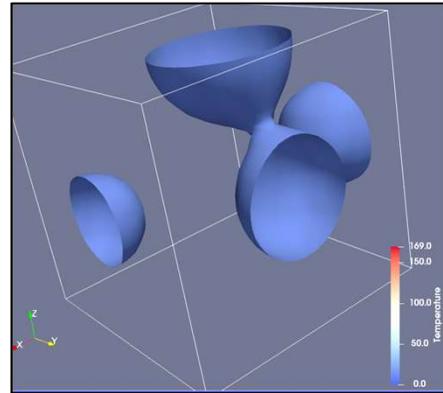
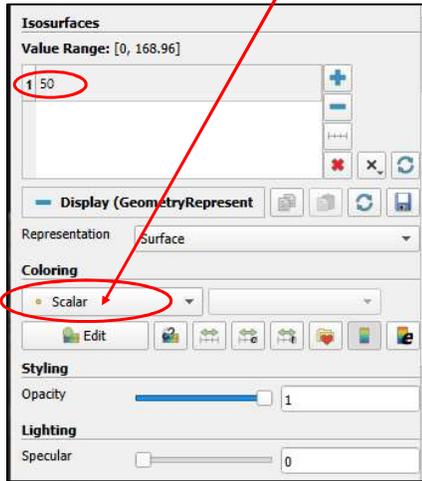
Clear	(	)	iHat	jHat	kHat
sin	cos	tan	abs	sqrt	+
asin	acos	atan	ceil	floor	-
sinh	cosh	tanh	x^y	exp	*
v1.v2	mag	norm	ln	log10	/
Scalars			Vectors		

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### Using the Calculator to Duplicate S to be Able to Color by Scalar Value

59

Now change the **Coloring** to color by **Scalar** instead of **S**.



60

## Experimenting with the Opacity and Specular is Fun Too 61

**Coloring**

Scalar

**Styling**

Opacity

**Lighting**

Specular  1

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## How the Calculator Works 62

Properties (Calculator 1)

Attribute Mode: Point Data

Coordinate Results

Result Array Name: **Scalar**

S

Clear	(	)	iHat	jHat	kHat
sin	cos	tan	abs	sqrt	+
asin	acos	atan	ceil	floor	-
sinh	cosh	tanh	x^y	exp	*
v1.v2	mag	norm	ln	log10	/

Scalars      Vectors

Name of the output field

X, Y, and Z unit vectors

A list of the current vector variables in the dataset

A list of the current scalar variables in the dataset

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### As a Volume

63

builtin:  
scalar.csv  
**TableToStructuredGrid1**  
Slice1  
Contour1  
Calculator1  
Contour2

**Display (StructuredGridRepr)**  
Representation: **Volume**  
Coloring: **S**  
Edit

Mapping Data  
27.097: 0.000  
Data: 27.0974

169.0  
150.0  
100.0  
50.0  
0.0  
Temperature

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### Sculpting the Alpha Transfer Function

64

Hover over the black line and **left-click** to add a new sculpting point there

Hover over a point and hit the **Delete** key or **Middle Mouse Button** to delete a point

Mapping Data  
27.097: 0.000  
Data: 27.0974

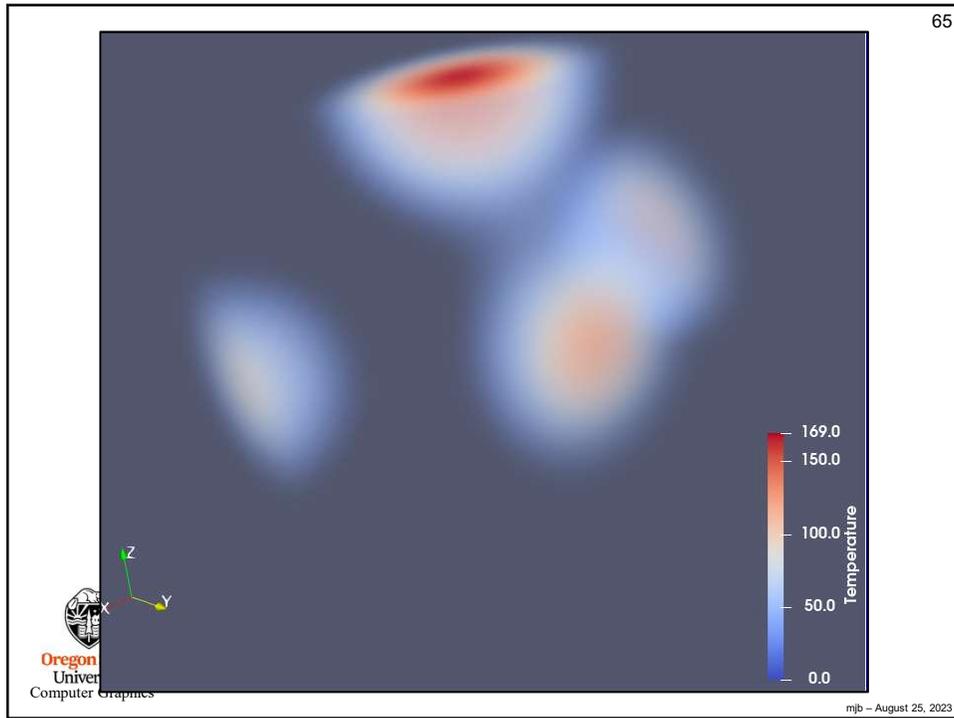
Alpha=1.  
(opaque)

Alpha=0.  
(transparent)

Data value range

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### IsoVolumes

66

Start with this

The **IsoVolume** properties start out at "allow all values" to pass through. We're going to change this.

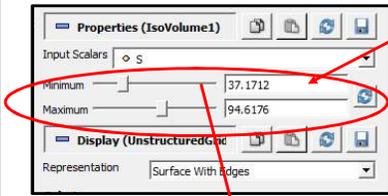
I chose the **Surfaces with Edges** representation so you can see the cells. You'll see why in a moment.

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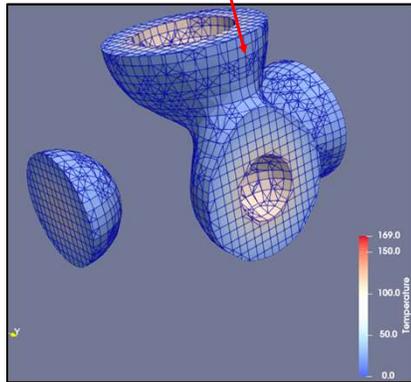
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## IsoVolumes

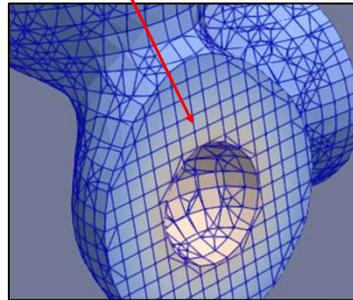
67



Now adjust the Minimum and Maximum to something else.



Note that the **IsoVolume** filter turned your nice, efficient structured grid into an unstructured grid. This can balloon the size of the data that is being operated on.



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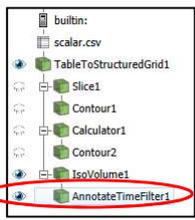
68

## Annotating

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### Adding Titles

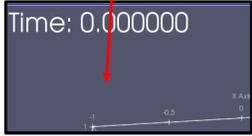
69

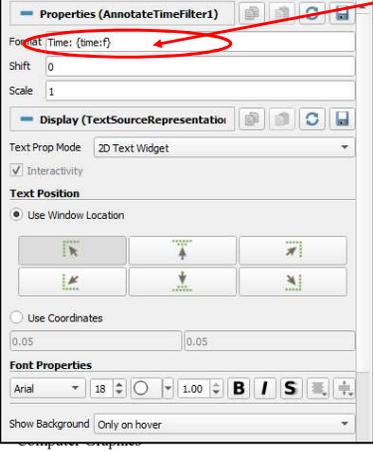


builtin:  
scalar.cov  
TableToStructuredGrid1  
Slice1  
Contour1  
Calculator1  
Contour2  
IsoVolume1  
**AnnotateTimeFilter1**

Add an **Annotate Time Filter** to the pipeline

The default annotation looks like this. We will change that.





Format: Time: (time:f)

Shift: 0

Scale: 1

Display (TextSourceRepresentation)

Text Prop Mode: 2D Text Widget

Interactivity:

Text Position

Use Window Location

Use Coordinates

0.05 0.05

Font Properties

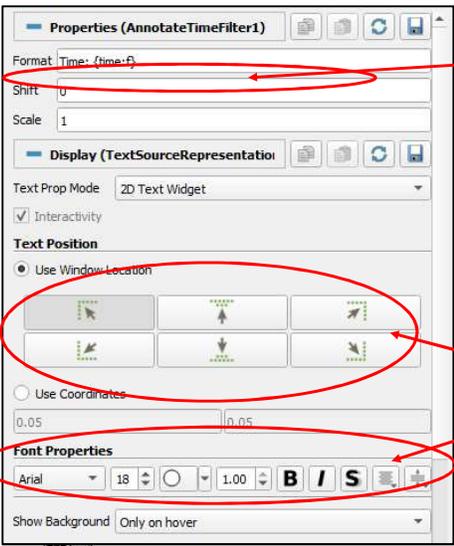
Arial 18 1.00 **B** **I** **S**

Show Background: Only on hover

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### Adding Titles

70



Format: Time: (time:f)

Shift: 0

Scale: 1

Display (TextSourceRepresentation)

Text Prop Mode: 2D Text Widget

Interactivity:

Text Position

Use Window Location

Use Coordinates

0.05 0.05

Font Properties

Arial 18 1.00 **B** **I** **S**

Show Background: Only on hover

The label to use (the printf-notation is to format the Time – get rid of this if you just want a title)

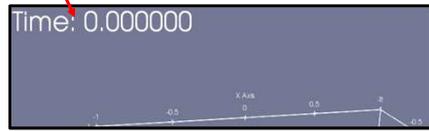
The position for the title

The font, size, color, opacity, style, and justification to use

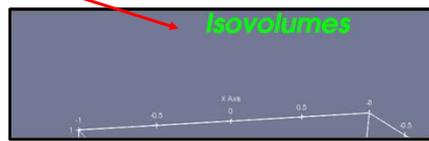


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From this:



to this:



# Multiple Views

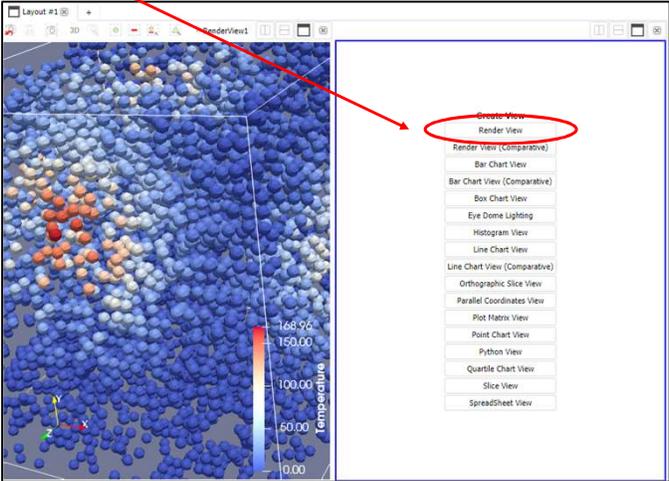
### Multiple Views

73

Step #1: Split the Window



Step #2: Click on **Render View**

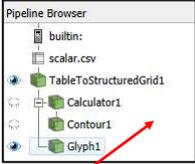


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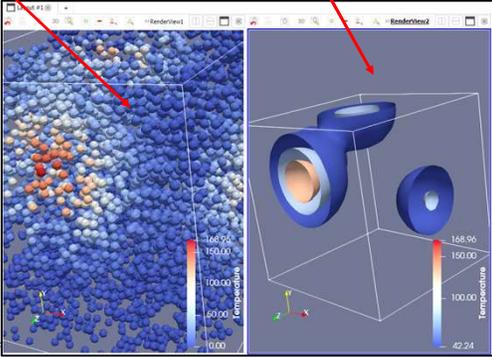
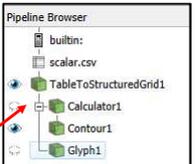
### Multiple Views

74

Step #3: Click in one Window and setup one visualization



Step #4: Click in the other Window and setup a separate visualization (stay aware of how the visualizations are parented!)



... and, you get this – with each Window being allowed its own viewing transformation



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## Multiple Views with Linked Viewing Transformations

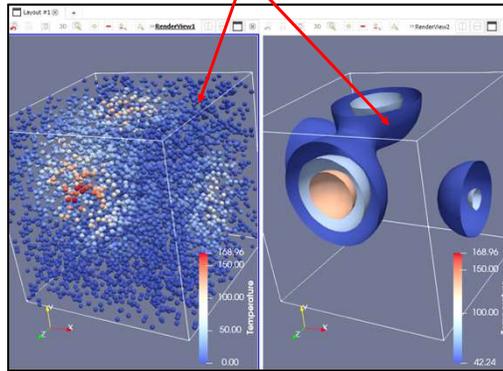
75

Step #5: Right-click in one of the Windows and select **Link Camera...**



Step #6: You get this dialog box – now click in the other Window that you want to be linked with

Your Windows now share a single transformation

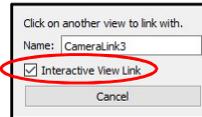


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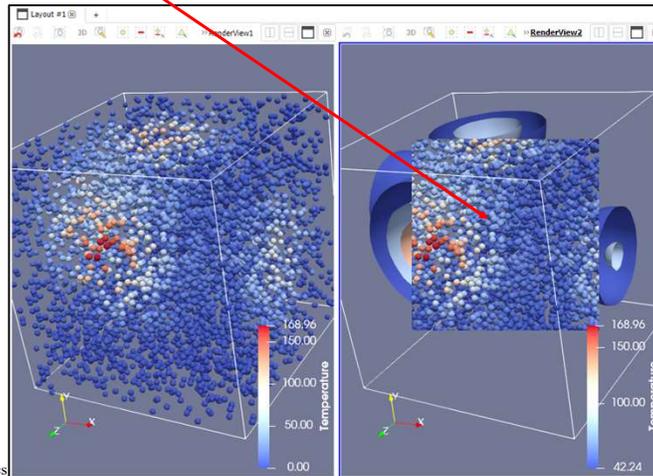
## Multiple Views with Linked Viewing Transformations

76

If you click on this checkbox and then click in another Window ...

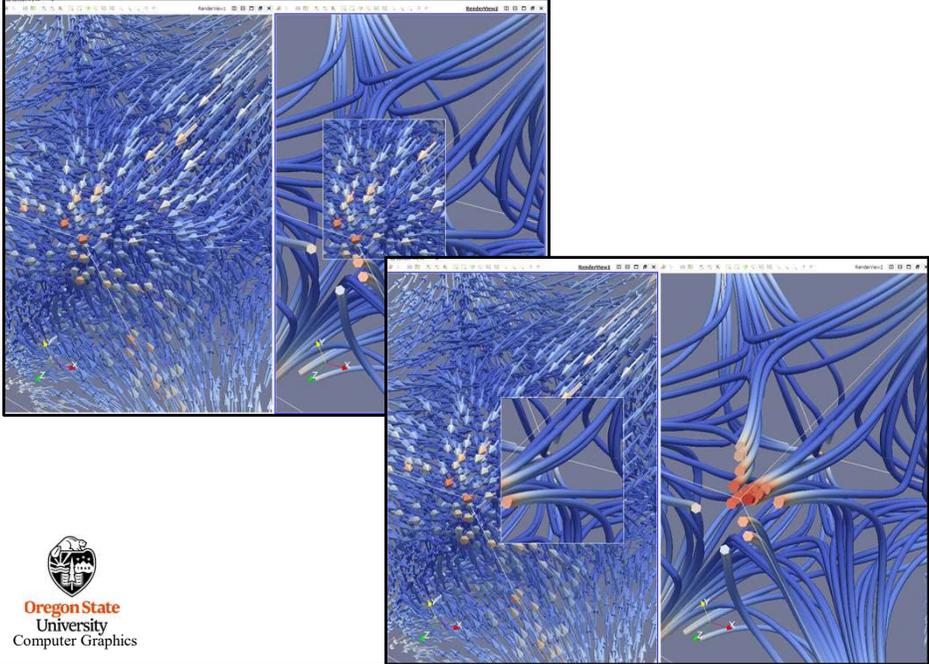


... you get a Magic Lens



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### Order Matters!


77



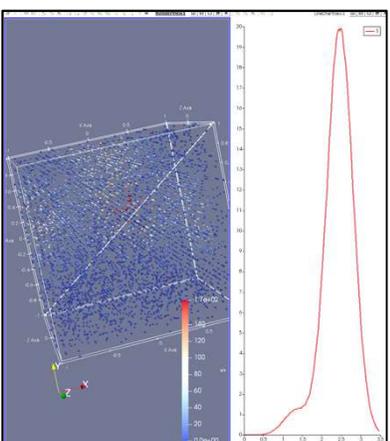
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### Using Plot Over Line

Pipeline Browser

- builtin:
- scalar.csv
- TableToStructuredGrid1
- Calculator1
- Contour1
- Glyph1

1. Create this Pipeline
2. Split the Render window and ask for a **Line Chart View**
3. When you click in the Render window, make the eyeballs look like this, with the **TableToStructuredGrid** representation set to **Outline** and the **Glyph** representation set to **Surface**



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## Using Plot Over Line

1. Click in the **Line Chart View** window. Add a **PlotOverLine** filter that is parented to the **TableToStructuredGrid**
2. Setup the PlotOverLine Properties like this
3. Be sure **Auto-Apply** is turned on

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## Using Plot Over Line

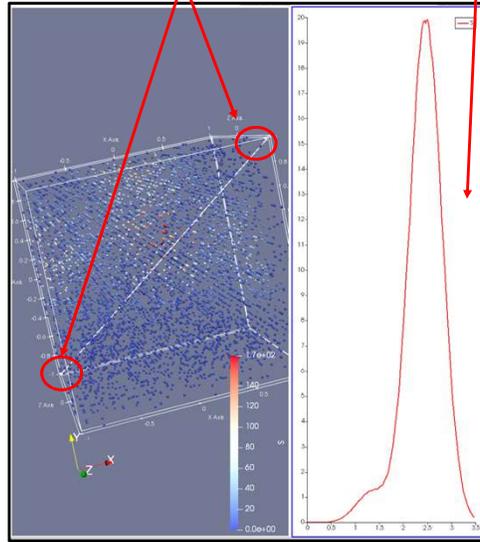
Setup the **Display (XYChartRepresentation)** Properties like this

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## Using Plot Over Line

81

Now, when you click on the **Line** endpoints and move them, the graph changes



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## Comparative Visualization

82



scalarcompare.pvsm



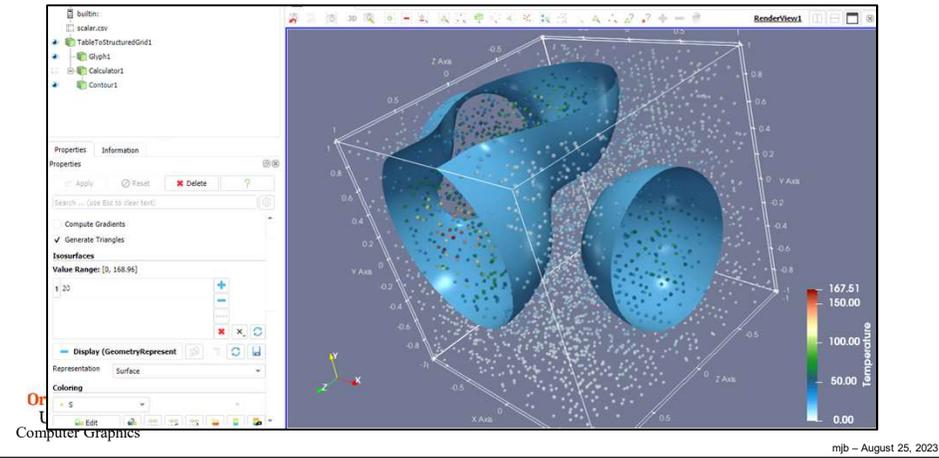
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## Comparative Visualization

83

ParaView can setup a side-by-side visualization comparison with different vis parameters in each view.

Start by creating a 3D Render view visualization. This case is using the isosurface demonstration shown earlier.



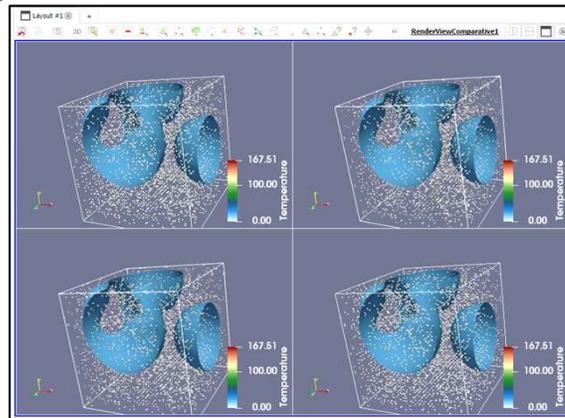
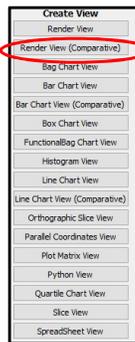
## Comparative Visualization

84

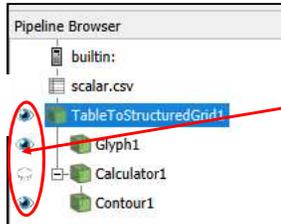
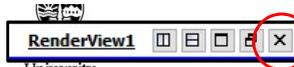
Now, split the window



and select:  
**Render View  
(Comparative).**



You can now eliminate the left-hand window if you want.



Click all the eyeballs on for the visualization features you want to see.

## Comparative Visualization

85

Select **View** → **Comparative View Inspector** These two areas are created

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## Comparative Visualization

86

Here's where you get to select how to vary the parameter(s).

1. Select the layout dimensions of the comparative window grid
2. Select the pipeline module that owns the parameter
3. Select the parameter
4. Hit the Big Plus Sign

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## Comparative Visualization

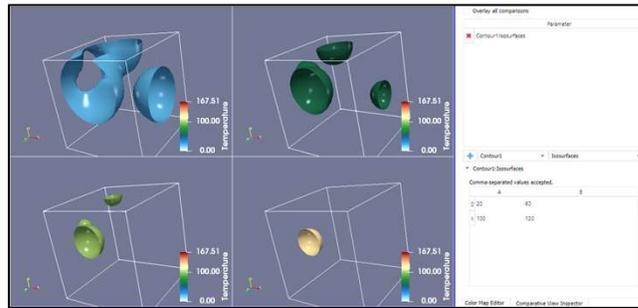
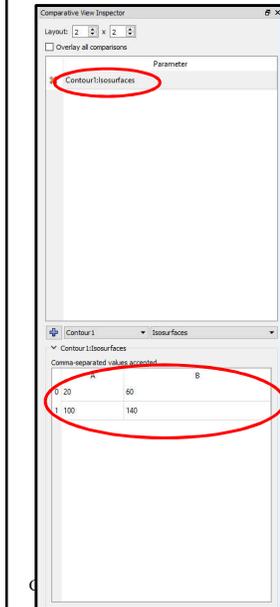
87

ParaView stocks the number grid with evenly-spaced values and applies them to each visualization, respectively.

Usually, these are not what you wanted to see. But you can type your own numbers in each cell

(I eliminated the Glyphs to better see the isosurfaces)

The windows are all transform-linked



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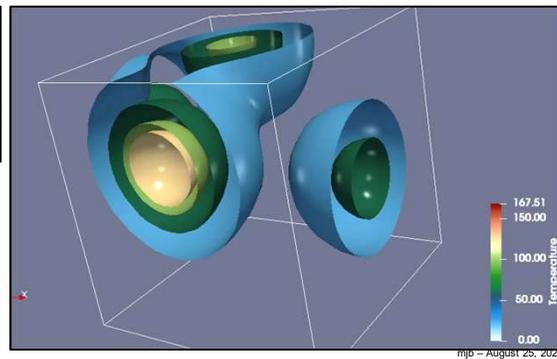
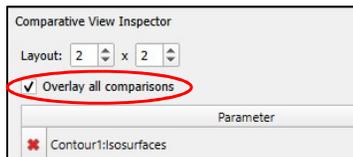
## Comparative Visualization

88

Clicking **Overlay all comparisons**, well, overlays all comparisons

You can vary multiple parameters – just setup multiple pipeline elements and parameters and put numbers separated by commas in the cells

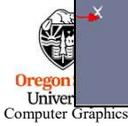
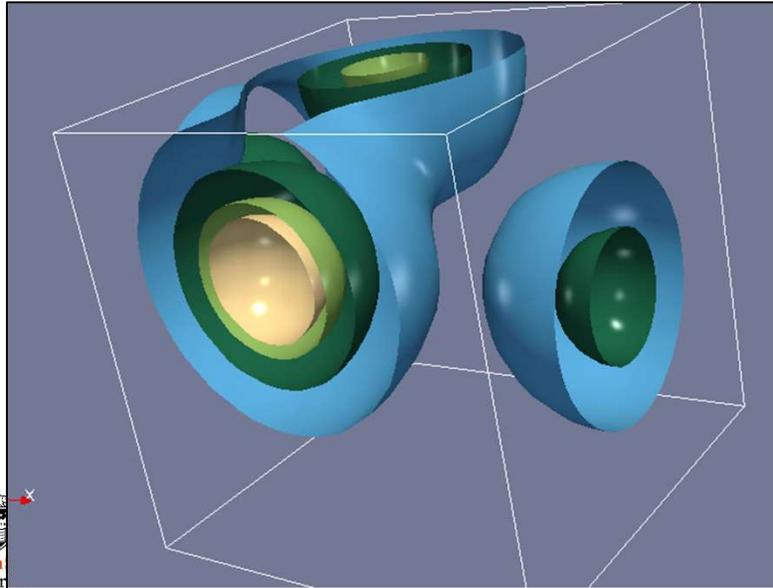
In this case, now could be a good time to also vary the opacity of the isosurfaces



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## Comparative Visualization

89



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90

## Visualizing Vector Data



vector.csv



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## Creating Vector Data in a CSV File

91

```
X32, Y32, Z32, Vx, Vy, Vz  
-1.00, -1.00, -1.00, 2.00, 2.00, 2.00  
-1.00, -1.00, -0.94, 1.75, 1.75, 2.00  
-1.00, -1.00, -0.87, 1.53, 1.53, 2.00  
-1.00, -1.00, -0.81, 1.33, 1.33, 2.00  
-1.00, -1.00, -0.74, 1.15, 1.15, 2.00  
-1.00, -1.00, -0.68, 0.99, 0.99, 2.00  
-1.00, -1.00, -0.61, 0.84, 0.84, 2.00  
-1.00, -1.00, -0.55, 0.71, 0.71, 2.00  
-1.00, -1.00, -0.48, 0.60, 0.60, 2.00  
-1.00, -1.00, -0.42, 0.49, 0.49, 2.00  
-1.00, -1.00, -0.35, 0.40, 0.40, 2.00  
-1.00, -1.00, -0.29, 0.31, 0.31, 2.00  
-1.00, -1.00, -0.23, 0.24, 0.24, 2.00  
-1.00, -1.00, -0.16, 0.17, 0.17, 2.00  
-1.00, -1.00, -0.10, 0.10, 0.10, 2.00  
-1.00, -1.00, -0.03, 0.03, 0.03, 2.00
```

Do a **File** → **Open** and navigate to your CSV file.  
Hit the **Apply** button to actually do the read.



vector.csv



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## How to Read the Vector Data in the CSV File

92

Whole Extent	0	31
	0	31
	0	31
X Column	X32	
Y Column	Y32	
Z Column	Z32	



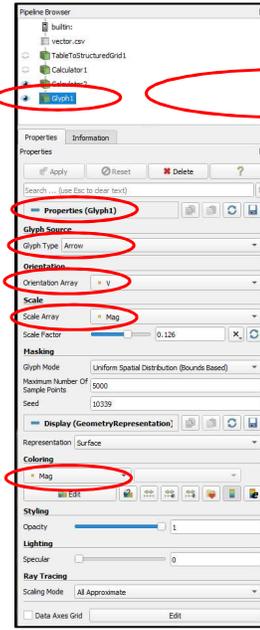
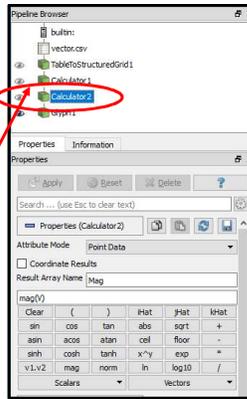
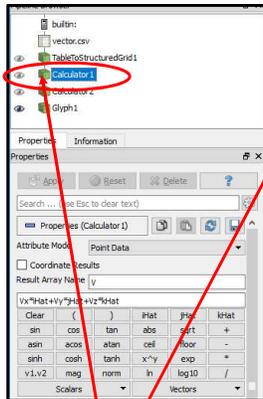
vector.csv



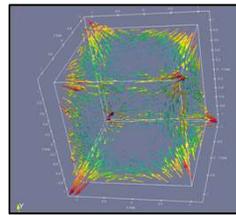
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### Vector Visualization As Glyphs

93



Add the 2 Calculator filters for now. The reason will be explained in the next slide.

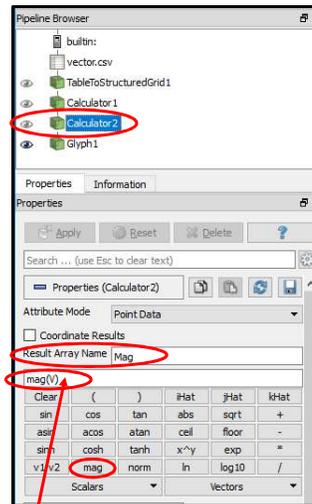
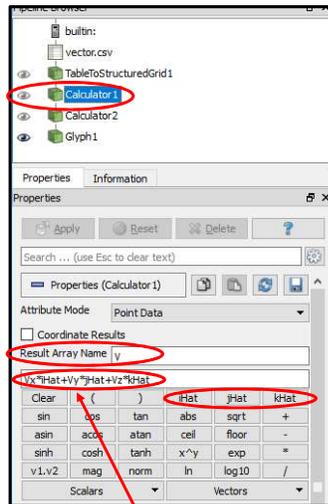
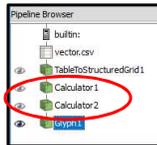


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### Why Are the Two Calculator Filters There?

94



The **vector.csv** file brought in the three vector components  $V_x$ ,  $V_y$ , and  $V_z$ . ParaView's vector vis filters want a 3-element vector instead. **Calculator1** is used to create that 3-element vector using the **iHat**, **jHat**, and **kHat** buttons (unit vectors in x, y, and z) :

$$V = V_x \hat{i} + V_y \hat{j} + V_z \hat{k}$$

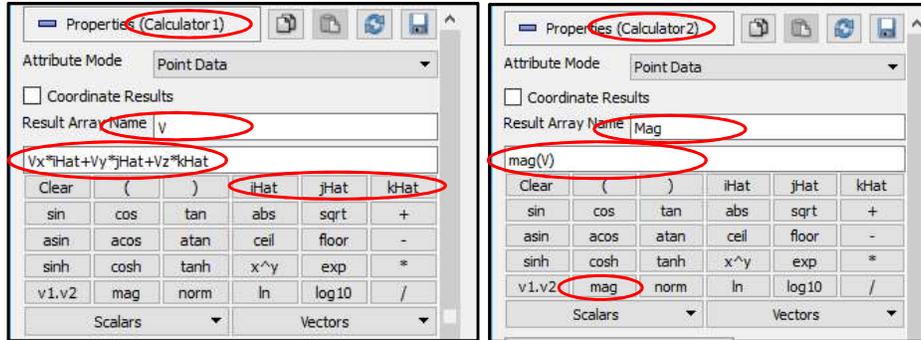
We want to color the vector visualizations by the magnitude of the vector. **Calculator2** computes that magnitude using the **mag** button:

$$Mag = \|V\|$$

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### Why Are the Two Calculator Filters There?

95



$$V = V_x \hat{i} + V_y \hat{j} + V_z \hat{k}$$

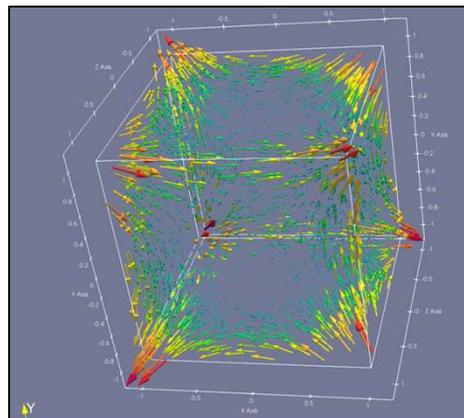
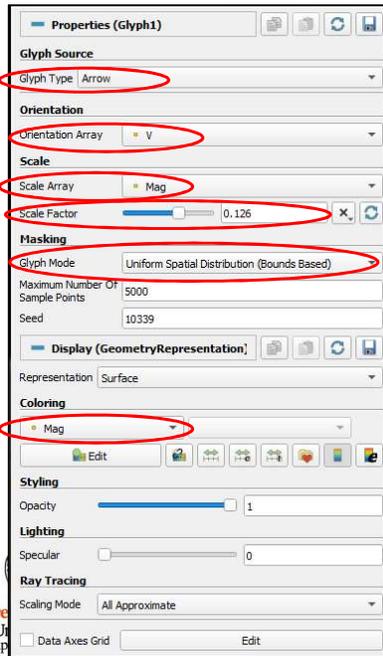
$$Mag = \|V\|$$



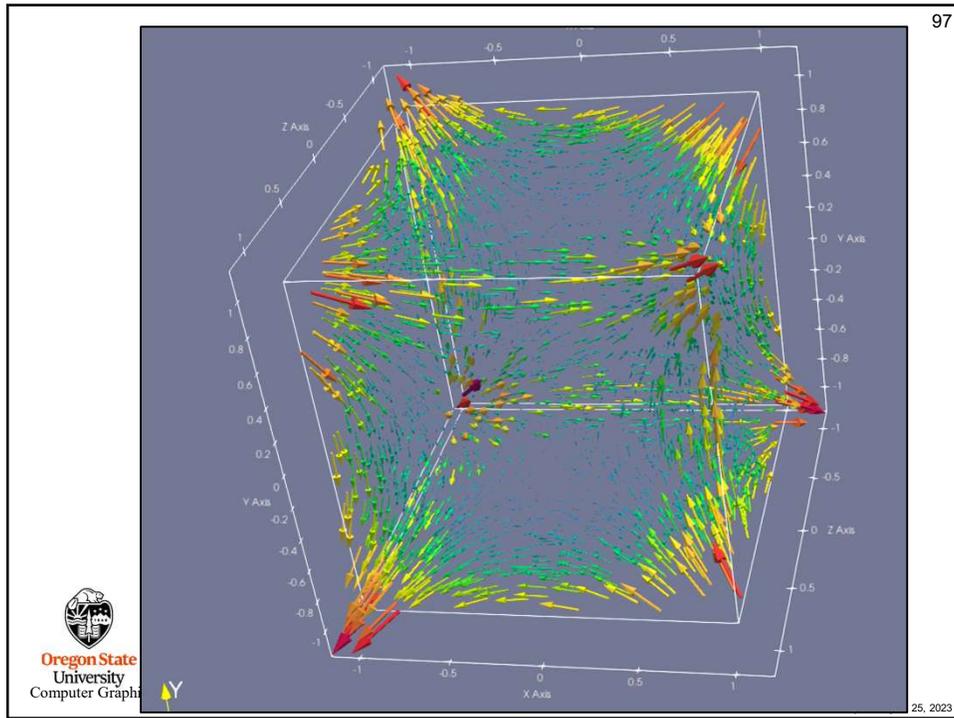
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### Setting Up the Glyph and its Coloring

96



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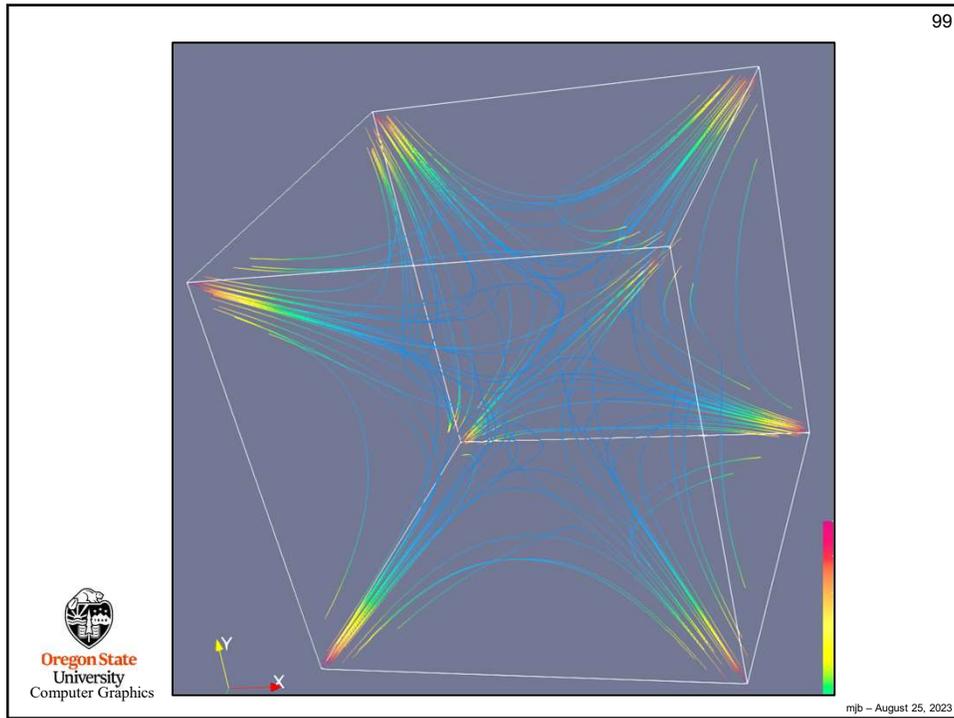
### As Streamlines

**StreamTracer filter, parented from the second Calculator**

Will start the streamlines from within this sphere. You can move it and resize it.

The screenshot shows the 'Properties (StreamTracer1)' panel in Houdini. Key settings are circled in red: 'StreamTracer1' in the object list, 'V' in the Vectors field, 'Point Cloud' in the Seed Type field, '0 0 0' in the Point Cloud Parameters Center field, and '100' in the Number of Points field. A note at the bottom of the panel reads: 'Note: Use 'P' to a center on mesh or Ctrl+P to snap to the closest mesh point'. The panel also shows 'Integration Parameters' (Runge-Kutta 4-5) and 'Display (GeometryRepresentation)' set to 'Surface'. The panel is titled 'Computer Graphics' at the bottom.

A 3D plot showing streamlines starting from a small sphere. The streamlines are colored with a gradient from blue to red. The plot is titled '98' in the top right corner. In the bottom left corner, there is a logo for Oregon State University Computer Graphics and the date 'mjb - August 25, 2023'.



### As Ribbon Traces 100

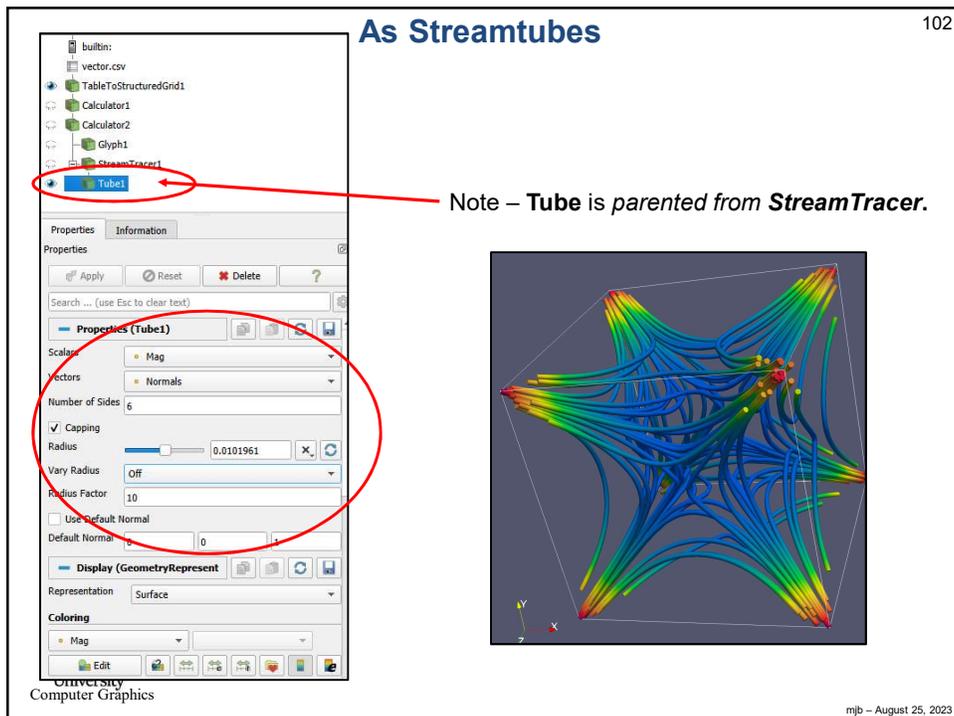
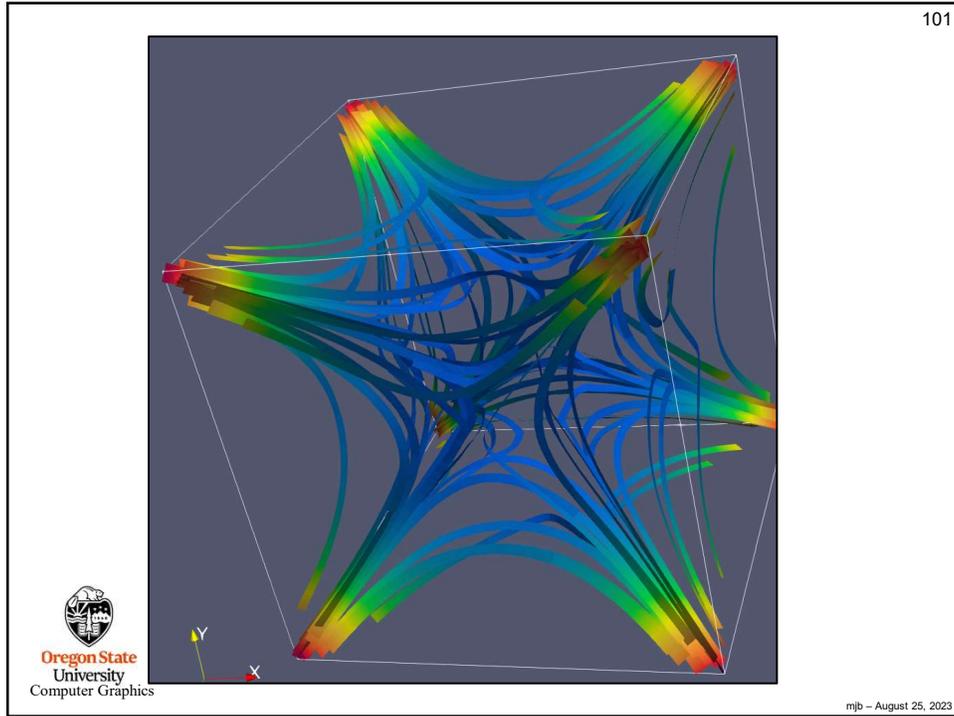
Note – **Ribbon** is parented from **StreamTracer**.

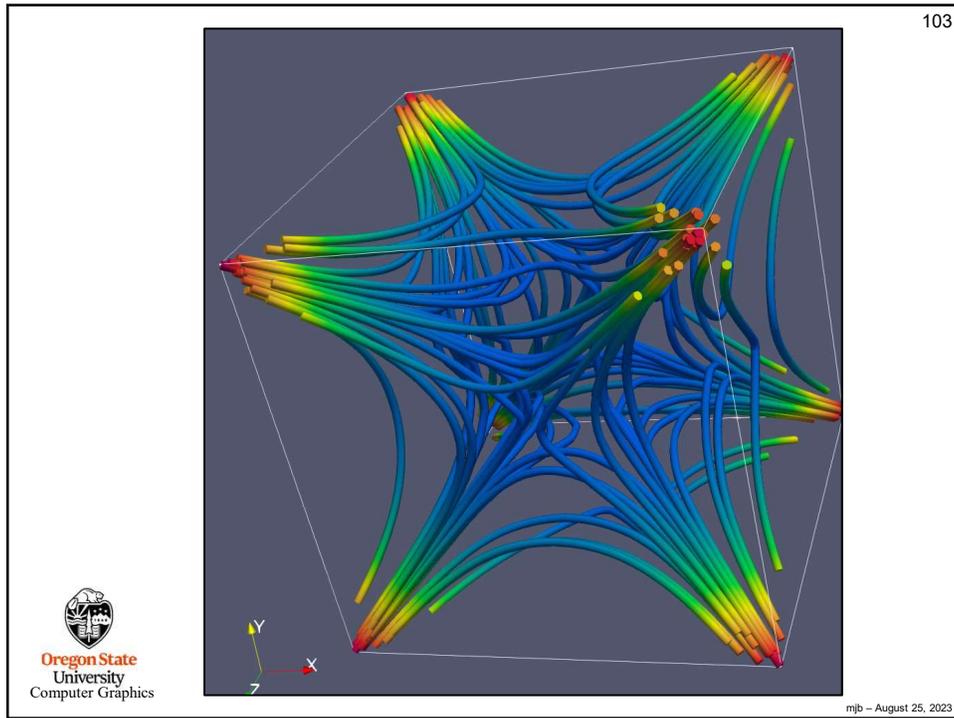
Ribbon Traces are especially good for showing **twisting** in the vector field. This dataset is not a great example of that.

The **Scalar** setting tells what will be used to size the width of the ribbons.

The **Vector** setting tells what will be used to decide which way the ribbon is facing.

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## Streamtubes are Especially Useful if You Want to Map Scalar Values to the Streamlines

104

In this case, we will map curvature (defined by the curl of the vector field)

builtin:

- vector.csv
- TableToStructuredGrid1
- Calculator 1
- Calculator 2
- Glyph1
- PythonCalculator 1**
- StreamTracer 1
- Tube 1

**Properties (PythonCalculator)**

Expression: `curl(V)`

Array Association: Point Data

Array Name: Curl

Copy Arrays

**Coloring**

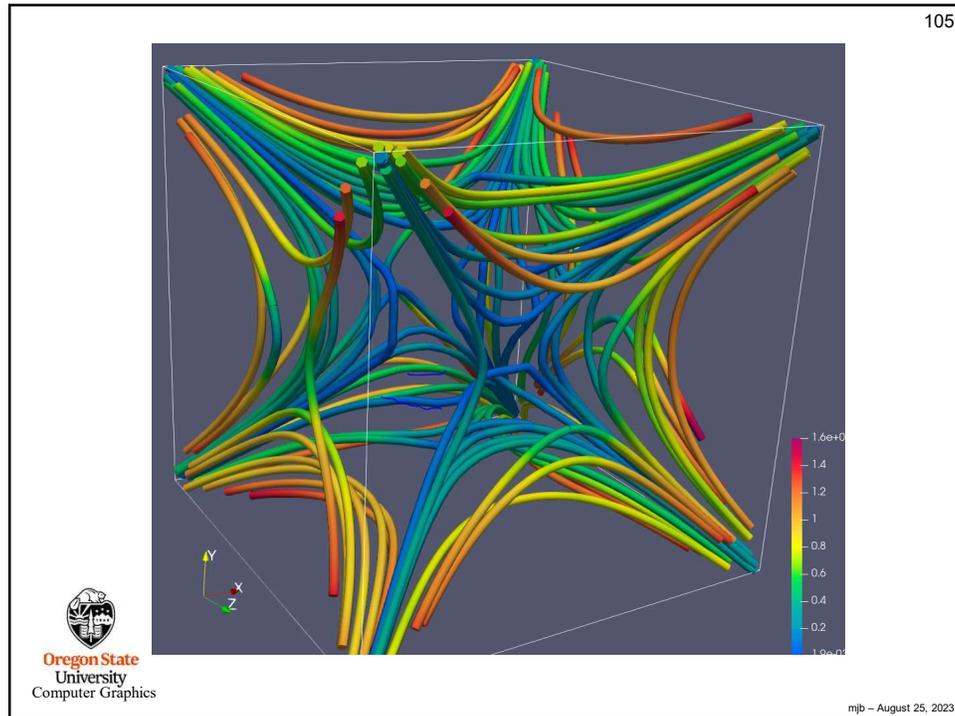
Curl

Magnitude

Edit

- The **Python Calculator** filter was used to produce the **Curl** of the vector field (it has a built-in `curl()` function – the Calculator does not)
- The StreamTube's coloring was changed from **Mag** to **Curl**
- The color mapping was changed to cut down on the amount of blue (lots of low curl values)

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106

## Functions Available in the Python Calculator

- `area( dataset )`
- `aspect( dataset )`
- `cos( array )`
- `cross( X,Y )` where X and Y are two 3D vector arrays
- `curl( array )`
- `divergence( array )`
- `dot( a1,a2 )`
- `eigenvalue( array )`
- `eigenvector( array )`
- `gradient( array )`
- `max( array )`
- `mean( array )`
- `min( array )`
- `norm( array )`
- `sin( array )`
- `strain( array )`
- `volume( array )`
- `vorticity( array )`

From: [https://www.paraview.org/Wiki/Python\\_calculator\\_and\\_programmable\\_filter](https://www.paraview.org/Wiki/Python_calculator_and_programmable_filter)

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## Visualizing Terrain Data



terrain.csv

## Creating Terrain Data in a CSV File

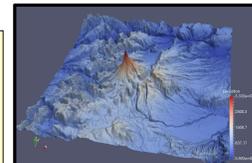
```

UTMx512,UTMy361,Z,Longitude,Latitude,Elevation
-6909.865,-6870.170,1174.991,-122.200,45.010,1174.991
-6882.896,-6870.356,1268.436,-122.198,45.010,1268.436
-6855.759,-6870.542,1308.478,-122.196,45.010,1308.478
-6828.789,-6870.728,1266.755,-122.193,45.010,1266.755
-6801.820,-6870.911,1203.239,-122.191,45.010,1203.239
-6774.682,-6871.095,1127.675,-122.189,45.010,1127.675
-6747.544,-6871.279,1074.388,-122.187,45.010,1074.388
-6720.575,-6871.461,1060.748,-122.185,45.010,1060.748
-6693.606,-6871.642,1056.135,-122.182,45.010,1056.135
-6666.468,-6871.823,1050.158,-122.180,45.010,1050.158
-6639.499,-6872.002,1029.548,-122.178,45.010,1029.548
-6612.361,-6872.182,1001.763,-122.176,45.010,1001.763
-6585.391,-6872.360,975.069,-122.174,45.010,975.069
-6558.254,-6872.539,980.551,-122.172,45.010,980.551
-6531.284,-6872.715,1029.739,-122.169,45.010,1029.739

```

Do a **File** → **Open** and navigate to your CSV file.  
Hit the **Apply** button to actually do the read.

UTM data is in meters, which makes a more reality-looking base than longitude and latitude do. It is good to have both Z and Elevation, even though they are the same number because once you use a variable for a geometric dimension, you can't also use it again for a data value (e.g., to color or contour by elevation).



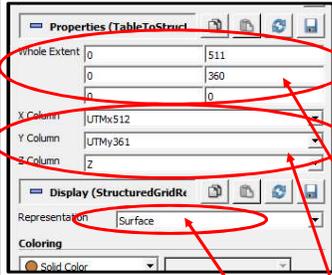
### Reading and Converting the CSV File

109



This will bring up a table window to confirm that the data has been read properly. You can delete this now if you want.

The table window displays a grid of numerical data with columns labeled 'X', 'Y', and 'Z'. The data represents terrain coordinates.



Now, go to **Filters** → **Alphabetical** → **TableToStructuredGrid**

Fill in the **Whole Extent** boxes showing the first and last index in each dimension (the last index is one less than the number of points in that dimension).

Fill in the **{X,Y,Z} Column** information so ParaView knows how to make your 3D display.

Hit the **Apply** button to actually do the conversion.

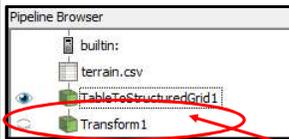
Be sure the **Representation** is **Surface**



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### The Correct Scale Factor

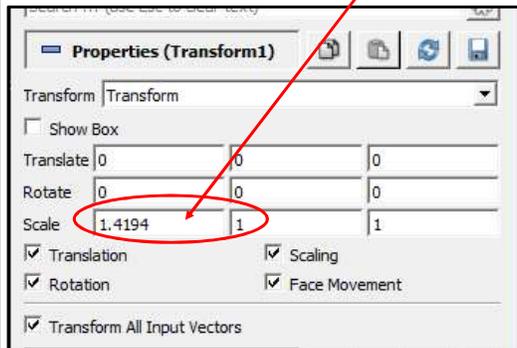
110



This will bring up a square terrain, which isn't what we want. We notice that the UTM coordinates are 511 and 360, so we really want to scale by  $511/360 = 1.4194$  in the X direction.

Now, go to **Filters** → **Alphabetical** → **Transform**

Set the X scale factor to 1.4194



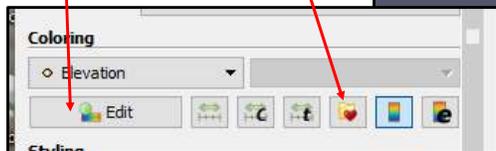
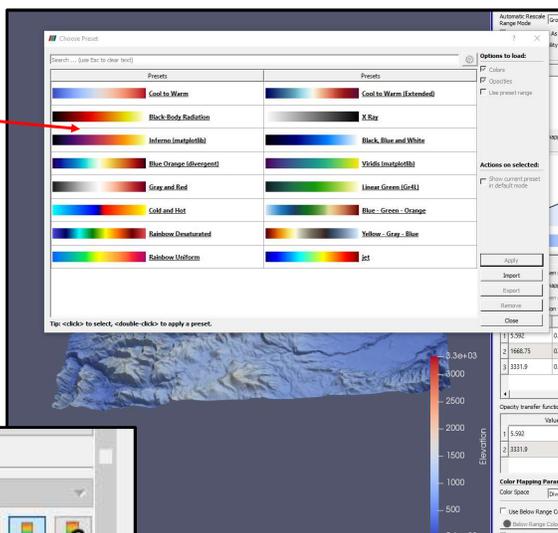
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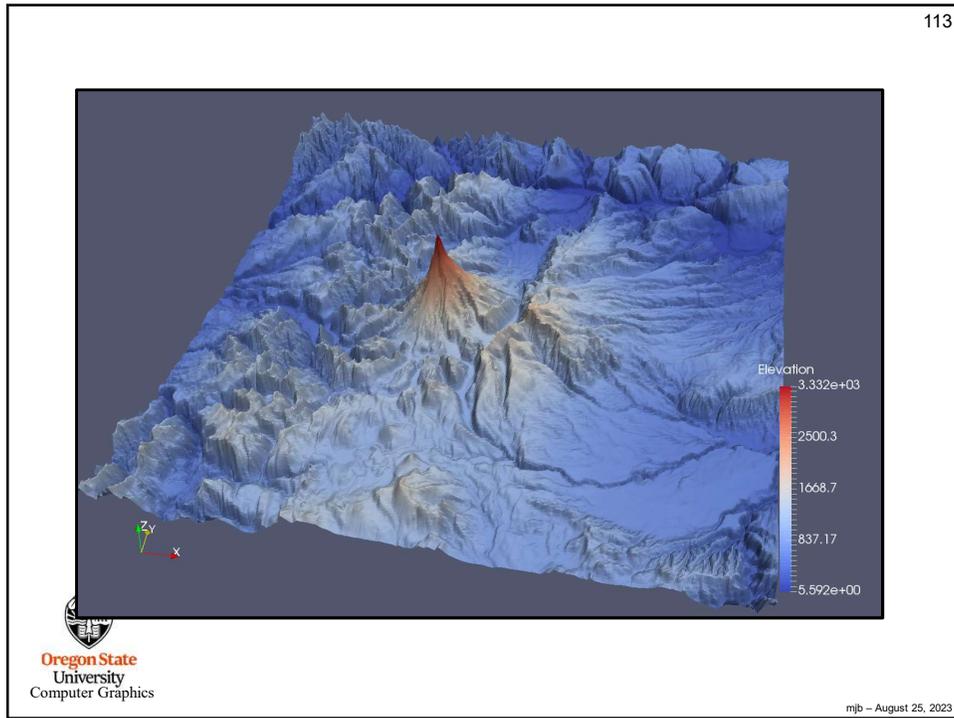
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### Color by Elevation

Try coloring by **Elevation**. The heart icon brings up popular color scales. You can pick one of these or sculpt your own.



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## Contouring

114

Now, go to **Filters** → **Alphabetical** → **Contour** and select **Contour by Elevation**

ParaView gives one default contour elevation, but you can add more.

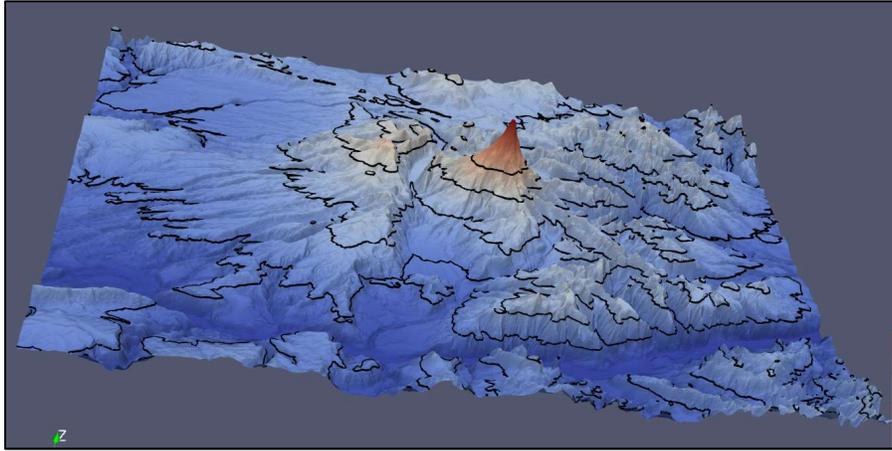
Display as Wireframe.

**Edit** to select a contour color.

Enter a **Line Width**.

Be sure the eyeballs are turned on.

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### Changing the Vertical Exaggerations

Re-click on the **Transform** filter, turn on the Box, and move the scaling knob

**Properties (Transform1)**

Transform | Transform

Show Box

Translate: 0 0 0

Rotate: 0 0 0

Scale: 1,4194 1 1

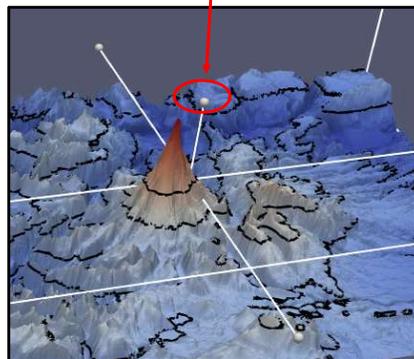
**Interactivity Controls**

Translation  Scaling

Rotation  Face Movement

Reset Bounds

Transform All Input Vectors

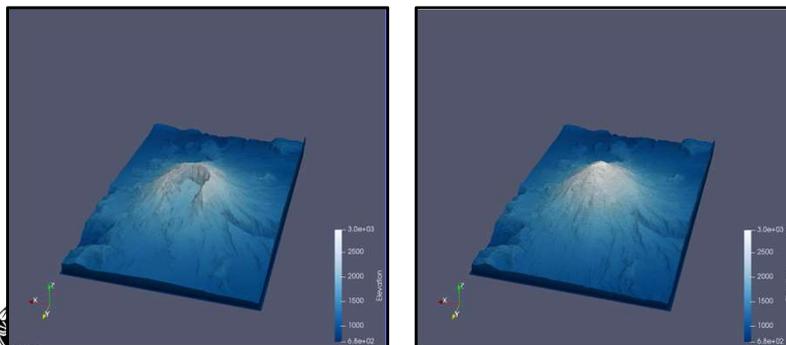


## Reading ARCGIS DEM Files

117

I was able to get to get two DEM files loaded into ParaView, and while not straightforward it's not too hard to do. You need to load in the file, add the **Extract Surface** filter to it, and then the **Warp By Scalar** filter.

Without these filters, ParaView will leave your data as a 2D surface.



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Louis Panton

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118

## Parallel Coordinates



vector.pvsm  
parallelcoords.pvsm

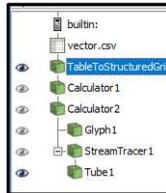
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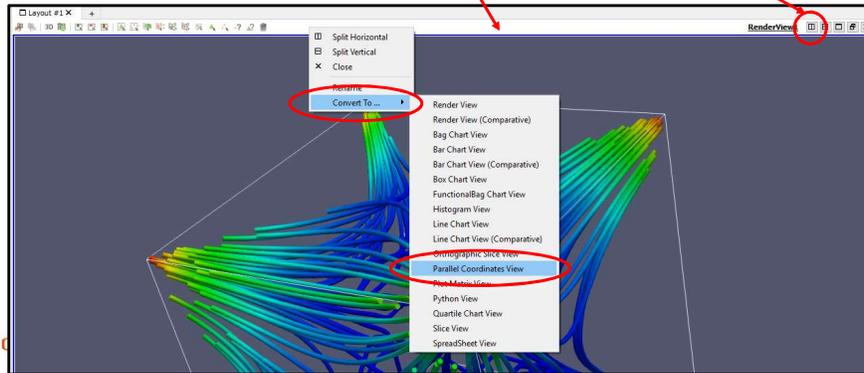
## Parallel Coordinates – Correlating Fields

119

Let's say you were to start with this:



Either convert the **Render View** window to a **Parallel Coordinate View** window by **right-clicking** anywhere in the window header bar, or by splitting the window



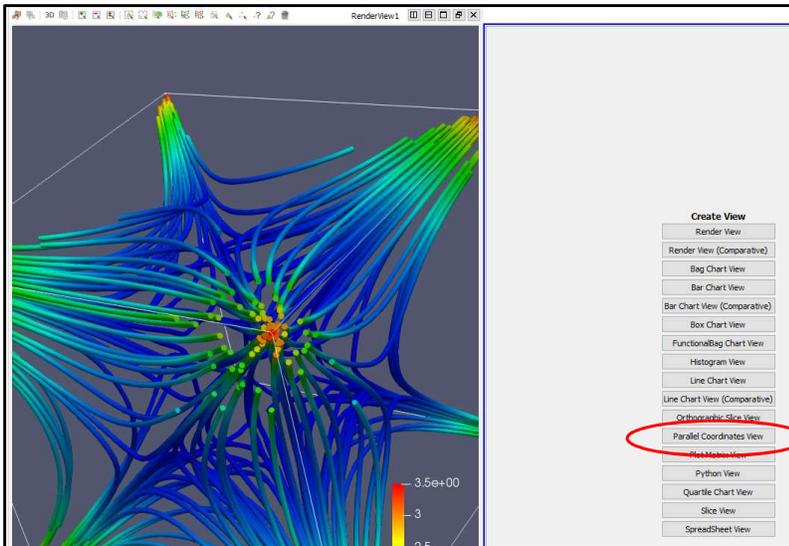
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## Parallel Coordinates

120

Splitting the window looks like this. Select **Parallel Coordinates View**.



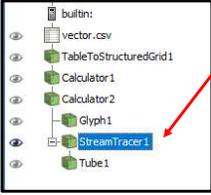
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Computer

I'm going to do it the first way to give more room for the Parallel Coordinates display.

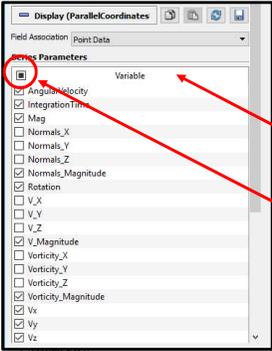
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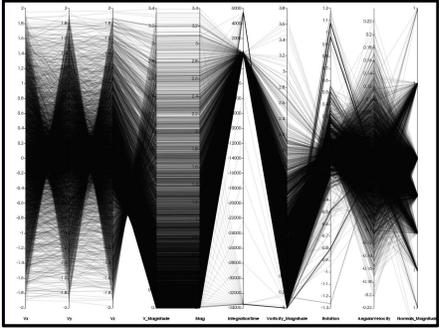
### Parallel Coordinates

121



Turn the eyeballs on for the **StreamTracer**. It turns out StreamTracer creates a bunch of derived variables, so this will give us more to look at.





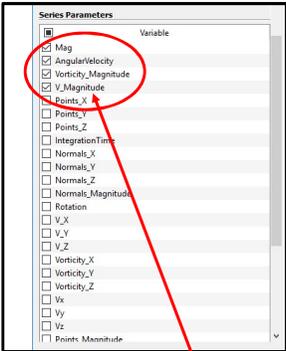
The **Parallel Coordinates Display Properties** shows what variables will be displayed. No matter what, they are probably not exactly the variables you wanted to see and they are not in the desired horizontal order.

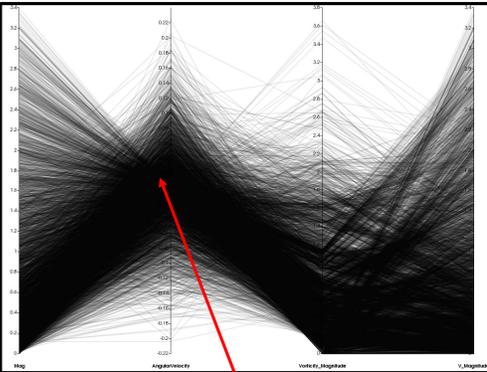
So, click them all off and turn them back on in the horizontal order you want to see them.

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### Parallel Coordinates

122





So, click them all off and turn them back on in the horizontal order you want to see them.

You can left-click-drag them to a new vertical position in the list to make re-clicking on them in a different order much easier.

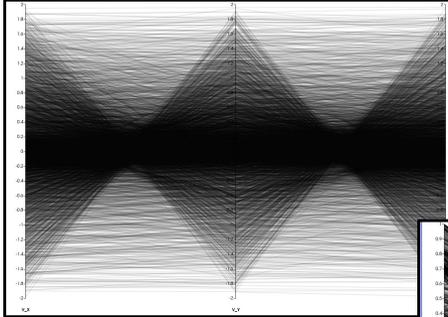
The narrowness of the bundle of lines shows the strength of the positive and negative correlations.

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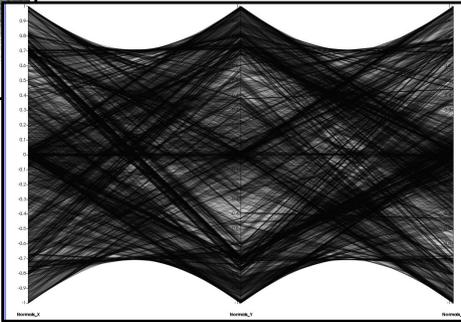
### Parallel Coordinates

123

Lots of (negative) correlation



Little correlation

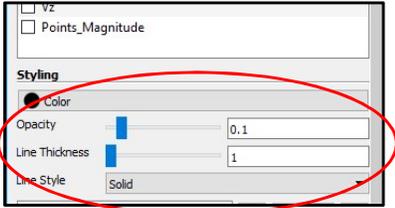


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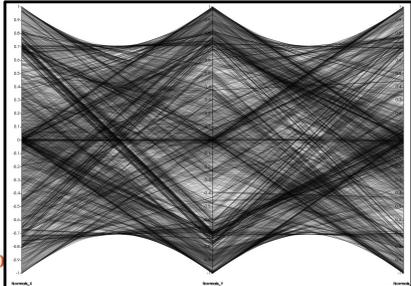
### Parallel Coordinates

124

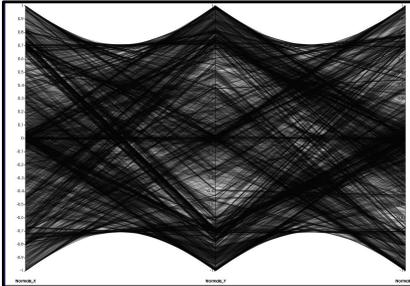
Scroll down a little more in the properties menu and you will find the **Parallel Coordinates Styling** menu:



Line Thickness = 1



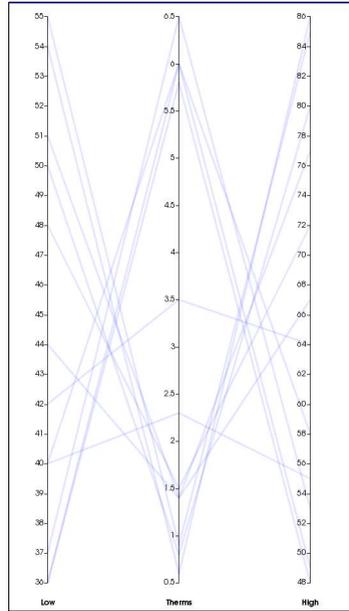
Line Thickness = 2



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### Therms on my Natural Gas Bill vs. Average Corvallis Low and High Temperatures

125



These Parallel Coordinates show that when temperatures are high, natural gas consumption goes down. (Duh, ...)



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### Saving an Image of the Screen

126



scalar.pvsm



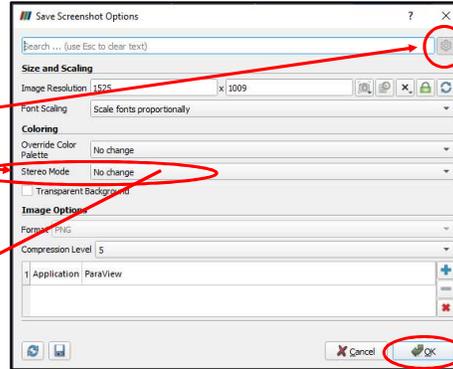
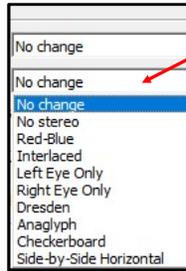
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## Creating Stereographics Images

129

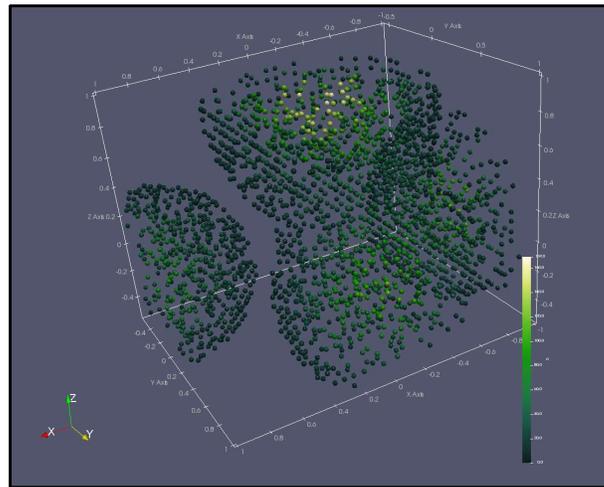
Turning on the **Advanced Settings** enables **Stereo Mode**



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## An Original Visualization

130

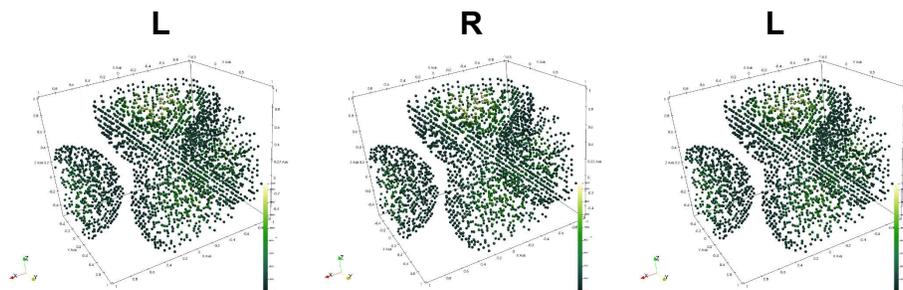


This is using the **Linear Green** color scale because it seems to work better for Red-Cyan Anaglyphs than do color scales with blue or red in them

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### Side-by-Side Stereopairs

131



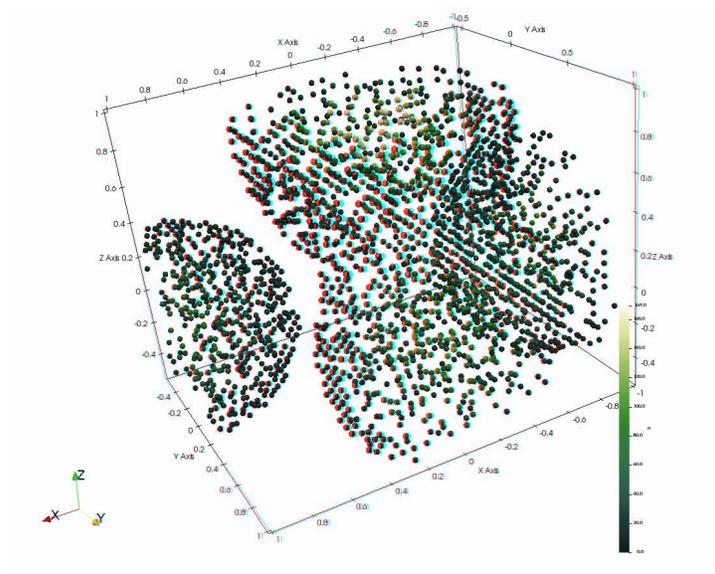
If you can parallel freeview, use the left two images.  
If you can cross-eyes freeview, use the right two images  
If you can't do either, then never mind



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### Red-Cyan Anaglyph

132

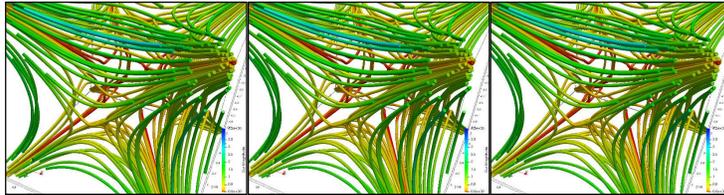


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### The Left Two Images Work Well Together in my Handheld Stereo Viewer

133

L R L



Print this page and cut out the left two images



Note to self: don't resize these images, as much as you are tempted to – they fit perfectly in the viewer as they are now.

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## Exporting the Scene Geometry

134

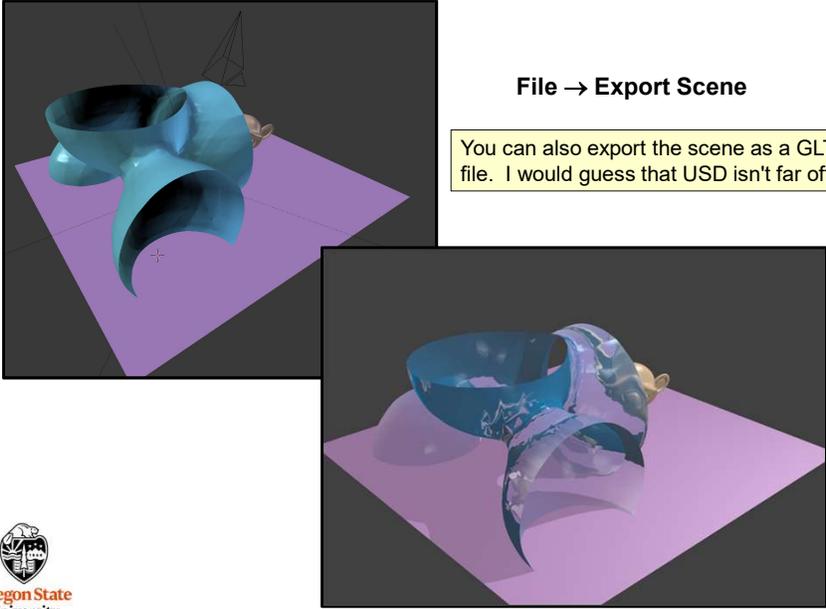


scalar.pvsm



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You can export the scene *geometry* (in this case to Blender) via X3D files 135



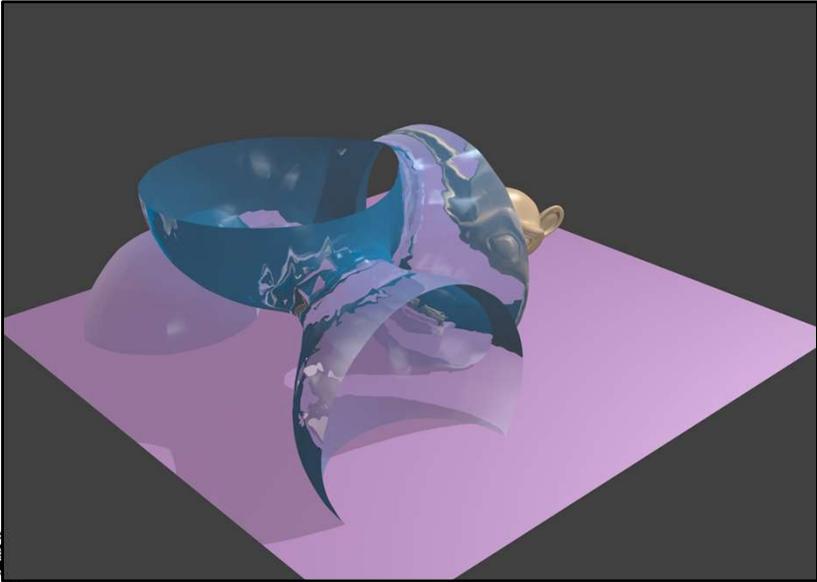
**File → Export Scene**

You can also export the scene as a GLTF file. I would guess that USD isn't far off.



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You can export the scene *geometry* (in this case to Blender) via X3D files 136



**Un** "Should" be able to create STL files from legal solid geometry (e.g., isovolumes) this way, too



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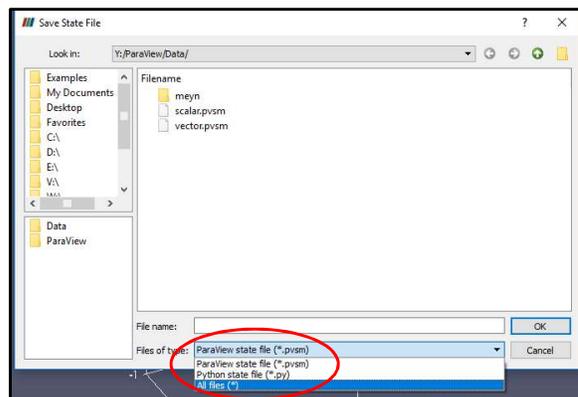
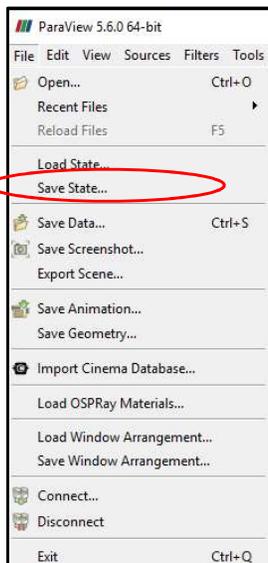
# Saving the ParaView State



- anim.pvsm
- scalar.csv
- scalar.pvsm
- scalar.py
- vector.csv
- vector.pvsm
- vector.py
- terrain.csv
- terrain.pvsm
- terrain.py



# Saving the State in Either a Native Format or as a Python Script



“State” means the entire state of the user interface (pipeline, properties, etc.). The data is not part of the state. When you read the state back in, ParaView will prompt you to show it what data file you want included with this state.



## scalar.py

139

```

# state file generated using paraview version 5.1.2

# -----
# setup views used in the visualization
# -----

#### import the simple module from the paraview
from paraview.simple import *
#### disable automatic camera reset on 'Show'
paraview.simple._DisableFirstRenderCameraReset()

# Create a new 'Render View'
renderView1 = CreateView('RenderView')
renderView1.ViewSize = [1160, 912]
renderView1.AxesGrid = 'GridAxes3DActor'
renderView1.StereoType = 0
renderView1.CameraPosition = [3.76687547966054, 5.62637881722241, 4.44163730510425]
renderView1.CameraFocalPoint = [0.0241978424871666, -0.0474471125809167, 0.0405907851464954]
renderView1.CameraViewUp = [-0.384789750616684, -0.393723993522038, 0.834816305989173]
renderView1.CameraParallelScale = 1.73205080756888
renderView1.Background = [0.32, 0.34, 0.43]
# init the 'GridAxes3DActor' selected for 'AxesGrid'
renderView1.AxesGrid.Visibility = 1
# -----
# setup the data processing pipelines
# -----
# create a new 'CSV'
scalarcsv = CSVReader(FileName=['Y:\\ParaView\\Data\\scalar.csv'])
. . .

```

140

## Animation in ParaView

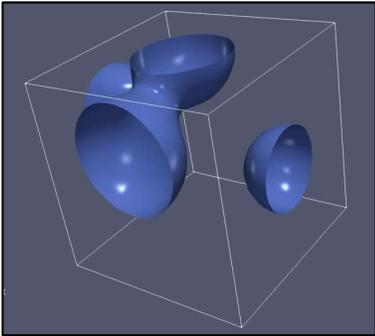


anim.pvsm

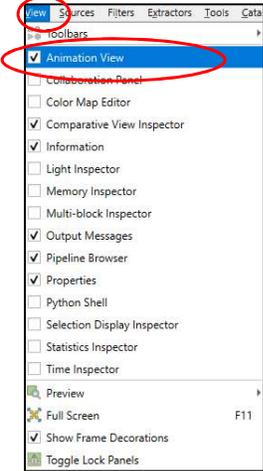
## Animation in ParaView

141

Start with this:

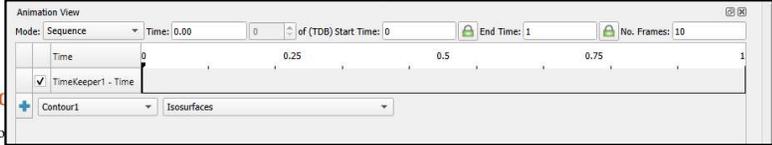


Select this:




anim.pvsm

And this appears at the bottom:



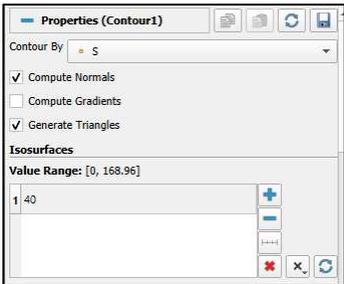
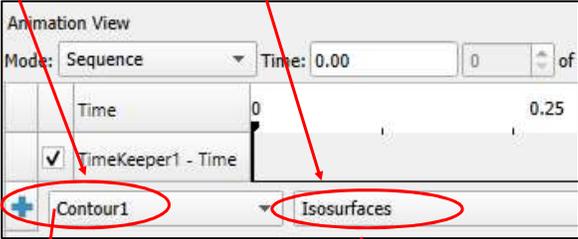
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## Animation in ParaView – Pick Something to Animate

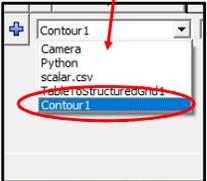
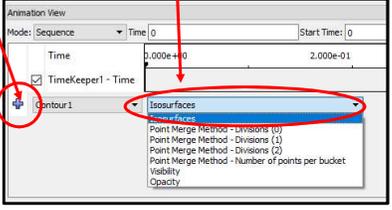
142

Conveniently, the user interface for animation in ParaView looks a lot like the user interface for Comparative Visualization:

Select a Pipeline Element and a Parameter within that Element

Hit the + when you are done

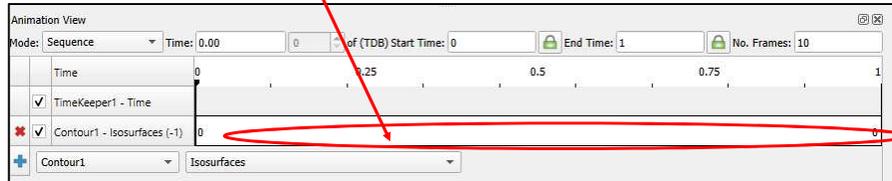




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## Animation in ParaView – Bring up a Keyframe Menu

143

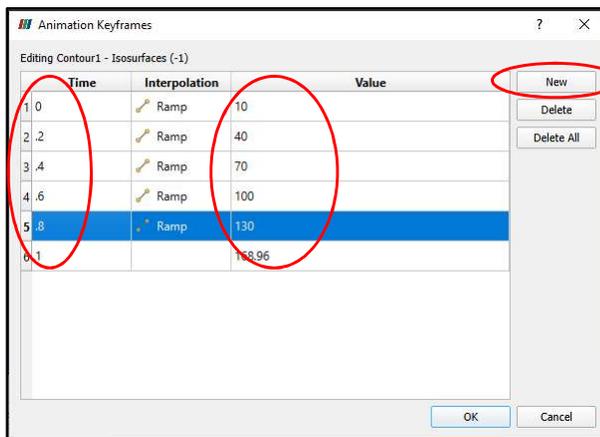
The, double-click in the white space to the right of the Property-Parameter you selected:



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## Animation in ParaView – Setting Parameter Keyframes

144

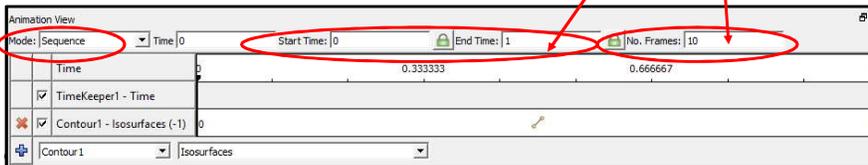


Click **New** to add a new row

The first column is the **Time**, the third column is the **Parameter** value at that time.

By default, the **Time** starts at **0**. and goes to **1**. – I just left it that way.

I did change the **10** frames to **100** frames, though.

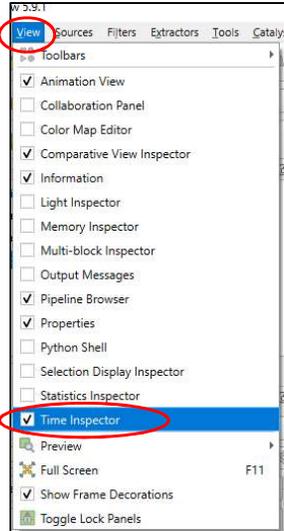


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## Animation in ParaView – the Time Inspector

145

Select this:



Unless you've been living in a cave, you know what to do with these – hit **Play**:



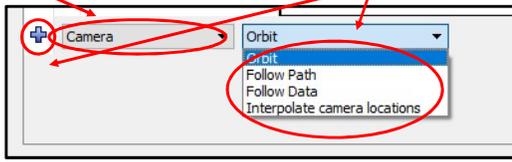
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## Animation in ParaView -- Animating the Camera

146

Here's how to animate the **Camera** – select **Camera** from the list of **Properties** and select one of these from the list of **Parameters**, then hit the **+**:



**Orbit:** animate the camera in a circle around a specific point  
**Follow Path:** set keyframes for the camera position and look-at point  
**Follow Data:** ??  
**Interpolate camera locations:** Manually specify keyframe camera locations

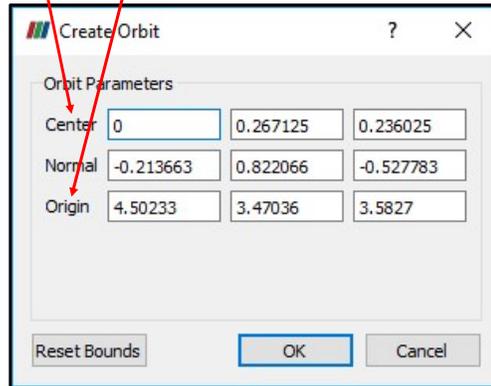
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## Animation in ParaView -- Orbiting the Camera

147

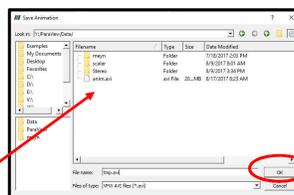
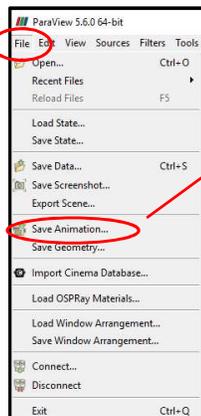
By default, the **Center** (look-at point) is the center of the data currently selected in the Pipeline. The Camera starts at its **Origin** and orbits at its current radius around that point.



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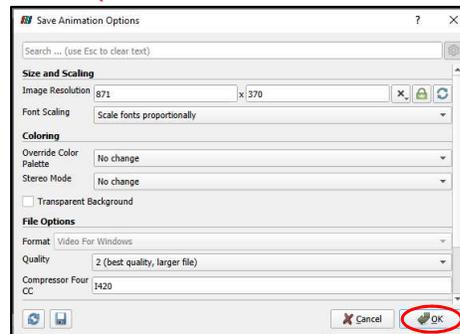
## Saving the Animation

148



You can then set some animation parameters.

Clicking **Save Animation** brings up a file navigator dialog. You can save the animation in either **AVI** or **OGV** formats.



I haven't done an exhaustive study of this, but I can tell you that OGV files play in Firefox, Edge, and Chrome – but not in PowerPoint. AVI files play in PowerPoint. The OGV files are much smaller than the AVI files.

mjb - August 25, 2023

# References

149

<http://cs.oregonstate.edu/~mjb/paraview>

Utkarsh Ayachit. *The ParaView Guide: A Parallel Visualization Application*, Kitware, 2015.

A free PDF of the book can be found here:  
<https://www.paraview.org/paraview-guide/>

The ParaView tutorial:  
[https://www.paraview.org/Wiki/The\\_ParaView\\_Tutorial](https://www.paraview.org/Wiki/The_ParaView_Tutorial)

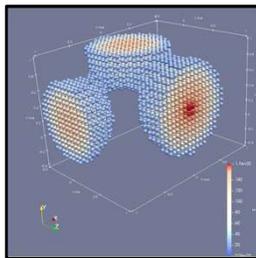


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# ParaView

150

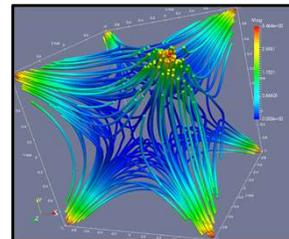
<http://cs.oregonstate.edu/~mjb/paraview>



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paraview.pptx

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