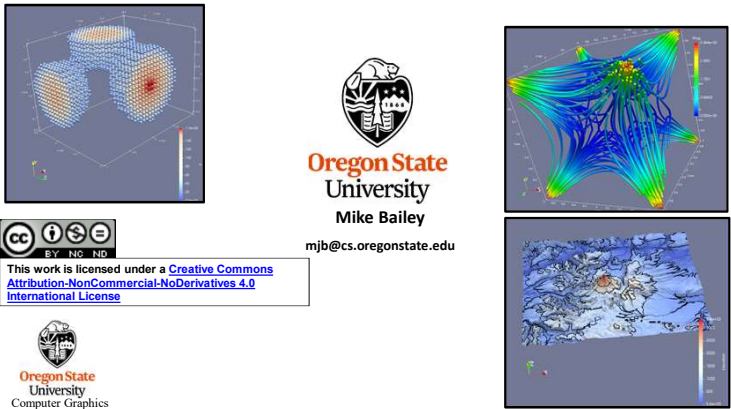




**ParaView**

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






**Oregon State University**  
Mike Bailey  
mjb@cs.oregonstate.edu



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paraview.pptx mjb - August 25, 2023

**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>

Click here to download ParaView




**DOWNLOAD PARAVIEW 5.11.0.**




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



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

What ParaView does

What I know

What the notes cover

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

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

Import

Vector

Scalar

Scalar

Scalar

MapToPlane

AutoGlyph

Colormap

Isosurface

Isosurface

Color

Color

Color

Color

Color

Collect

Image

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"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.

### Fan-In to the Full Scene

OpenDX:

ParaView:

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### ParaView Screen Layout

9

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## ParaView Menus

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### Window Layout Menu

11

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### Commonly-used Filters Menu

Calculator      Contour      Slice      Threshold      Extract Subset      Glyph      Stream Tracer      Warp by Vector      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

Animation Controls

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

Directional Camera Positions

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### ParaView Menus

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

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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# 3D Scene Manipulation

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### Sources → Geometric Shapes → Sphere

ParaView 5.8.0

File Edit View Sources Filters Tools Create Macros Help

Pipeline Browser

- Sources
- Spheres

Properties Information

Properties (Spheres1)

Center: 0 0 0

Radius: 0.5

Theta Resolution: 30

Phi Resolution: 30

Display (GeometryRepresentation)

Representation: Surface

Coloring

Solid Color

Styling

Opacity: 1

Lighting

Specular: 1

Pick Solid Color

Basic colors

Custom colors

Back Screen Color

Hue: 0 Sat: 0 Bright: 255

Green: 255 Blue: 255

Alpha: 255

Color: #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

Camera3DManipulators: 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

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

Properties Tab

Show/Hide the Geometric Properties

Properties Information

Apply Delete

Search ... (Use Esc to clear text)

Properties (Spheres1)

Center: 0 0 0

Radius: 0.5

Theta Resolution: 30

Phi Resolution: 30

The Geometric Properties of the Sphere

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

Display (GeometryRepresentation)

Representation: Surface

Coloring

Solid Color

Styling

Opacity: 1

Lighting

Specular: 1

Seamless UI

Seamless V

Use Scale Array

Data Axes Grid

Maximum Number of Labels: 100

View (Render View)

Axis Grid

Center Axes Visibility

Orientation Axes

Orientation Axes Visibility

Hidden Line Removal

Camera Parallel Projection

Ray Traced Rendering

Enable Ray Tracing

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 Axes Grid

Turn on/off the Axes 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.

**View (Render View)**  
 Axes Grid Edit  
 Center Axes Visibility

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### Editing the Axes Grid

22

Show more/less options

**View (Render View)**  
 Axes Grid Edit  
 Center Axes Visibility

Titles for the axes

Title font styles

Number label font styles

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### Editing the Axes Grid

23

**View (Render View)**  
 Axes Grid Edit  
 Center Axes Visibility

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

Pipeline Browser  
 Sphere1  
 Shrink

Properties Information  
 Shrink Factor: 0.5

Display (UnstructuredGridR)

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

In **Edit** → **Settings** → **General**, turn on **Auto Apply**

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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## Visualizing Scalar Data, I

scalar.csv

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### What File Formats Can ParaView Read?

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	LSDynReader	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

```
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**

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

0	0	-1	-1	-1
1	0	-0.94	-1	-1
2	0	-0.87	-1	-1
3	0	-0.81	-1	-1
4	0	-0.74	-1	-1
5	0	-0.68	-1	-1
6	0	-0.61	-1	-1
7	0	-0.55	-1	-1
8	0	-0.48	-1	-1
9	0	-0.42	-1	-1
10	0	-0.35	-1	-1
11	0	-0.28	-1	-1
12	0	-0.22	-1	-1
13	0	-0.16	-1	-1
14	0	-0.09	-1	-1
15	0	0.01	-1	-1
16	0	0.11	-1	-1
17	0	0.21	-1	-1
18	0	0.31	-1	-1
19	0	0.41	-1	-1

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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**

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### As Point Gaussian

32


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33

## A Side Trip: Choosing Colors



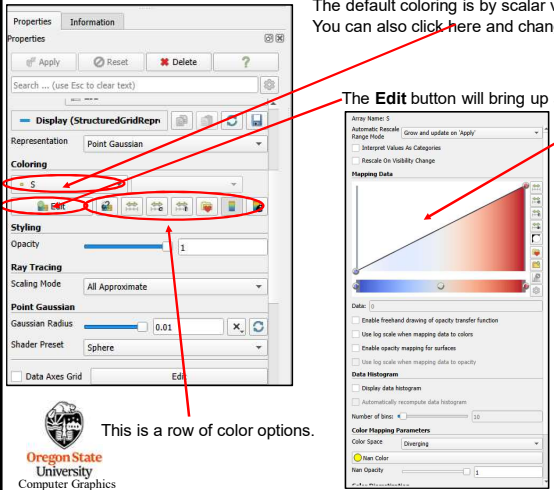
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34


### 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



This is a row of color options.

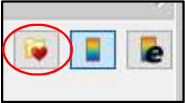
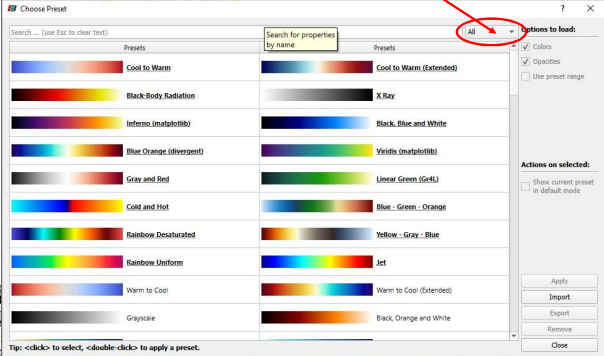


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35

### Choose Among Standard Color Transfer Functions

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.)


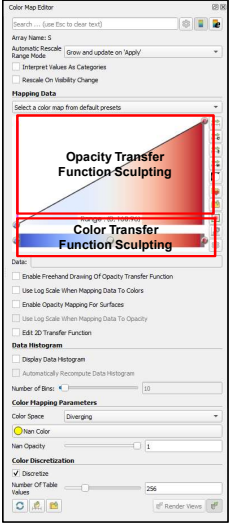

Tip: **click** to select, **double-click** to apply a preset.



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36

### Color Map Editor

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### Changing the Legend

37

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

**Coloring**

S

Edit

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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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### From this, to this

39

From this, to this

S

Temperature

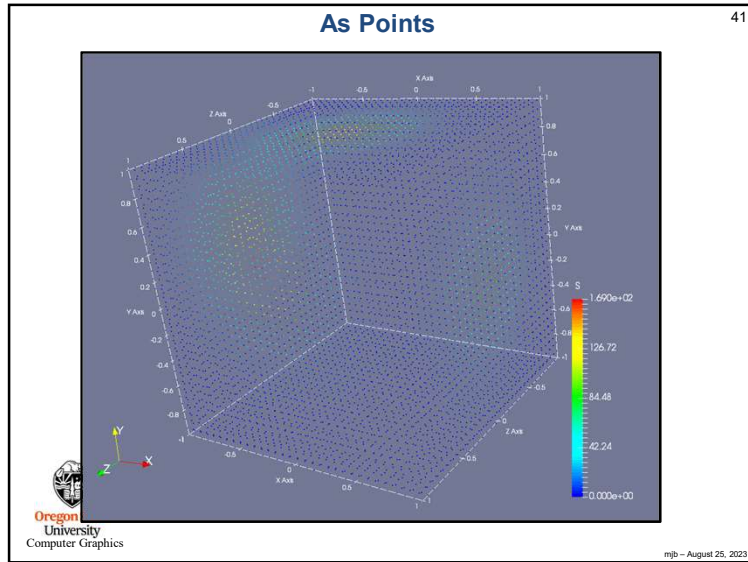
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## Visualizing Scalar Data, II

40

scalar.csv

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### Pipeline Element and Filter Observations

- 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.

42

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### Right-clicking on a Pipeline Element

43

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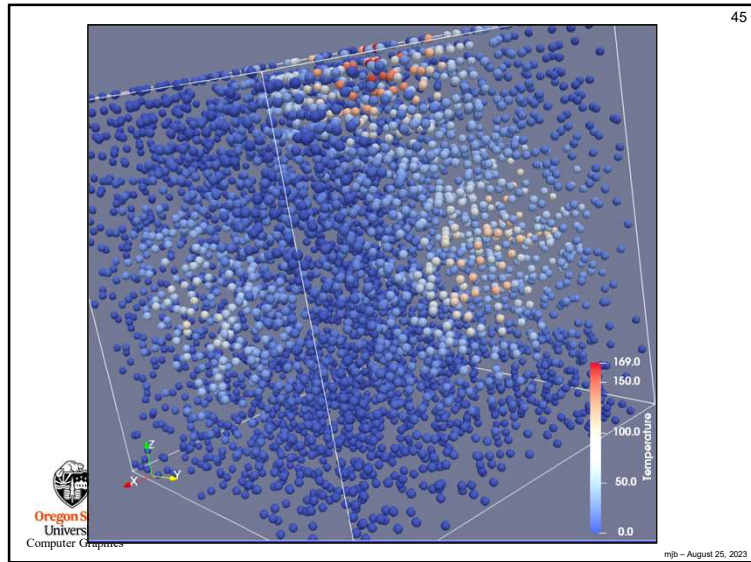
### As a Glyph Cloud

**Filters → Alphabetical → Glyph** adds the glyph cloud to the pipeline. Hide the **TableToStructuredGrid** (click off the eyeball) and un-hide the **Glyph**.

- Set the **Glyph Type**
- Play with the **Scale Factor**
- Play with the **Glyph Mode**
- Play with the **Opacity**

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

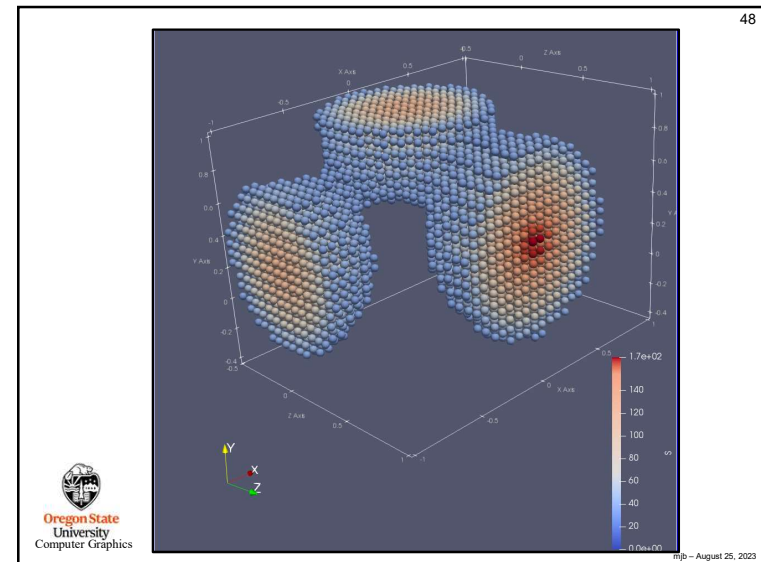
47

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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### As a Colored Cutting Plane

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

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

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### Changing the Contour Isovalue

Add a contour isovalue

Delete a contour isovalue

Add a range of contour isovalues

Generate Number Series

Isosurfaces

Value Range: [0, 153.575]
1 30
2 0
3 18.773333333333333

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

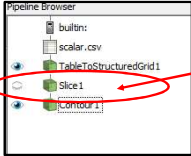
This needs to be **Wireframe** to get contour lines

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

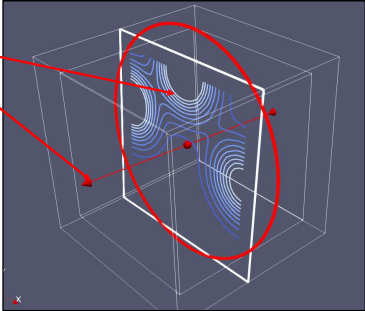
Coloring by **Solid Color** will give you a single color.

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### As Contours



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



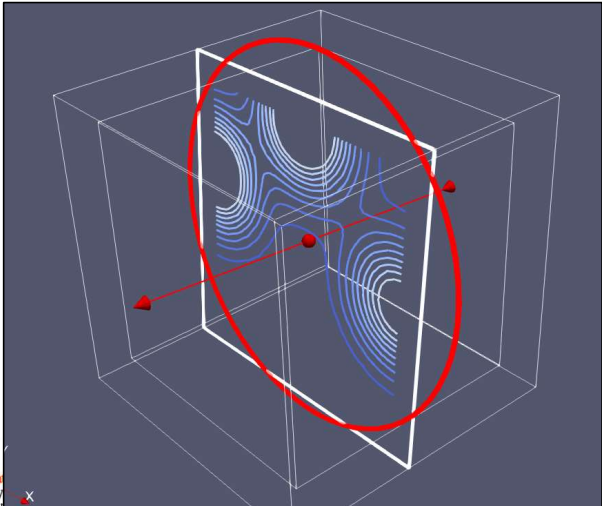
Click on the plane itself to move the plane.  
Click on the arrow to rotate the plane.




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### As Contours

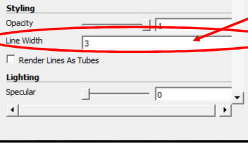




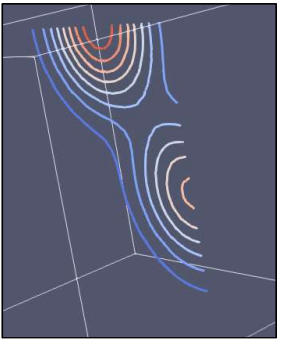
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### As Contours



Adjusting the Line Width

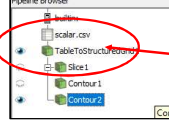




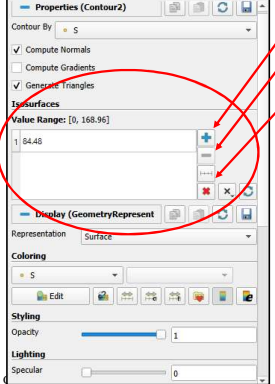
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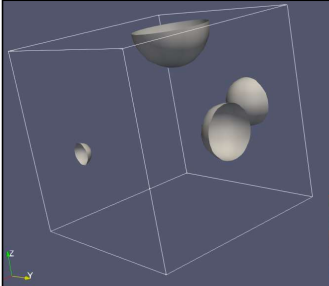
### As 3D Isosurfaces




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



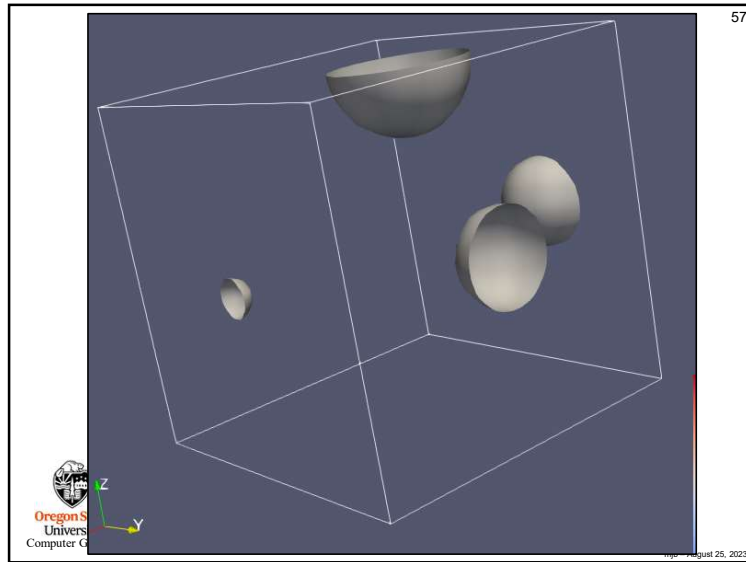
Add an isosurface isovalue  
Delete an isosurface isovalue  
Add a range of isosurface isovalues





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58

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

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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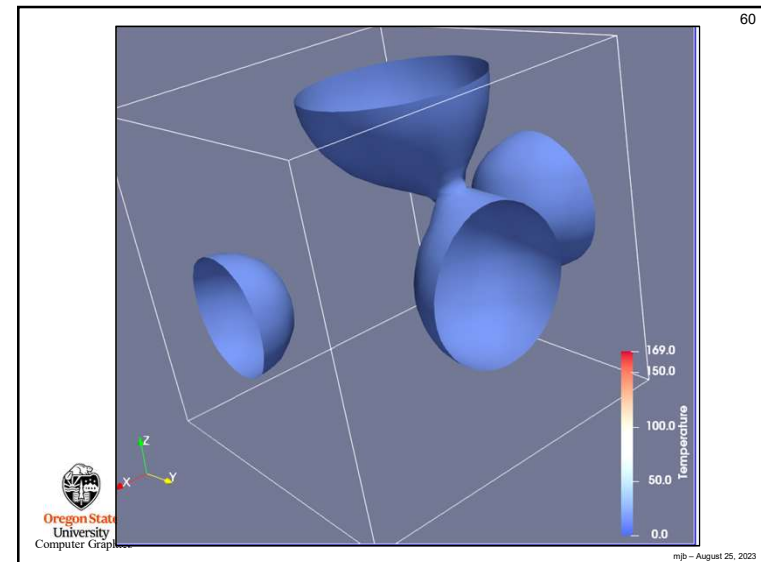
59

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

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

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

61

The 'Coloring' panel shows the following settings:

- Scalar
- Styling: Edit, Copy, Paste, Undo, Redo, Refresh, Help
- Opacity: 0.76
- Lighting:
- Specular: 1

The 3D scene displays several blue spheres of varying sizes and positions. A color scale on the right ranges from 0.0 to 169.0. The Oregon State University logo is in the bottom left.

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### How the Calculator Works

62

The calculator interface shows the following elements:

- Properties (Calculator 1)
- Attribute Mode: Point Data
- Coordinate Results:
- Result Array Name: **Scalar** (circled in red)
- Unit vectors: iHat, jHat, kHat (circled in red)
- Scalar variables: Scalars (dropdown menu, circled in red)
- Vector variables: Vectors (dropdown menu, circled in red)

Annotations:

- 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

The Oregon State University logo is in the bottom left.

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### As a Volume

63

The interface shows a scene tree with the following nodes:

- builtin:
- scalar.csv
- TableToStructuredGrid1** (circled in red)
- Slice1
- Contour1
- Calculator1
- Contour2

The 'Display (StructuredGridRepr)' panel shows:

- Representation: **Volume** (circled in red)
- Coloring: S (circled in red)

The 3D scene shows a volume rendering of the blue spheres. A 'Mapping Data' window shows a gradient from blue to red. The Oregon State University logo is in the bottom left.

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### Sculpting the Alpha Transfer Function

64

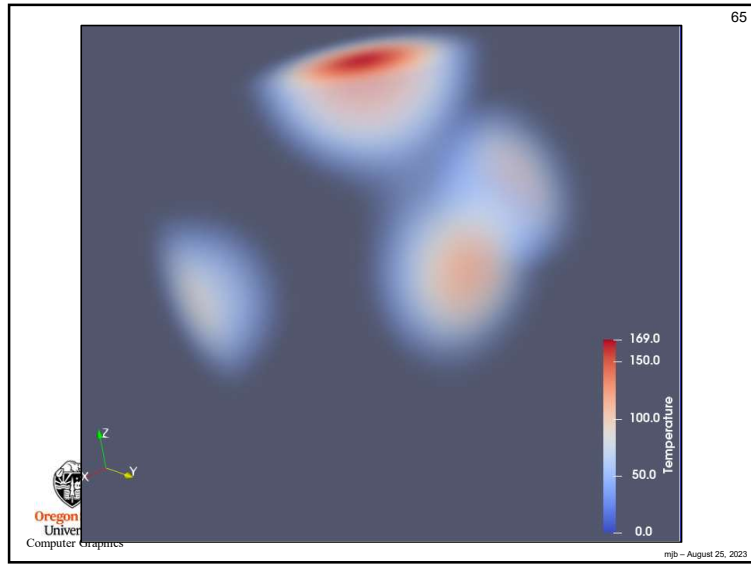
Annotations:

- 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
- Alpha=1. (opaque)
- Alpha=0. (transparent)
- Data value range

The 'Mapping Data' window shows a gradient from blue to red with a black line for sculpting. A point is shown at 27.097; 0.000. The Oregon State University logo is in the bottom left.

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### IsoVolumes

66

Pipeline Browser

- builtin:
- scalar.csv
- TableToStructuredGrid1
- Slice1
- Contour1
- Calculator1
- Contour2
- IsoVolume1

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.

Properties (IsoVolume1)

Input Scalars: s

Minimum: 0

Maximum: 168.96

Display: UnstructuredGridRe

Representation: Surface With Edges

Coloring: s

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### IsoVolumes

67

Properties (IsoVolume1)

Input Scalars: s

Minimum: 37.1712

Maximum: 94.6176

Display: UnstructuredGridRe

Representation: Surface With Edges

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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### Annotating

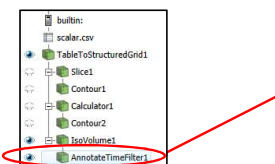
68

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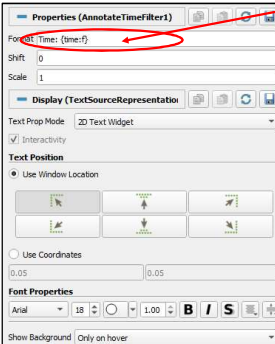
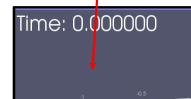
### Adding Titles


69



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

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

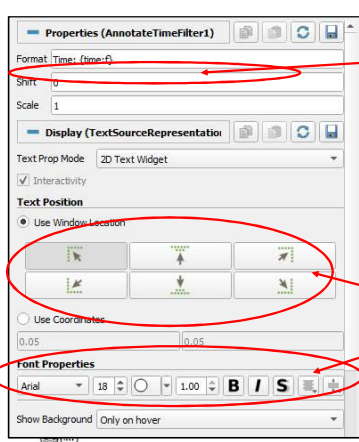





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### Adding Titles


70



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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71

From this:



to this:






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72

## Multiple Views




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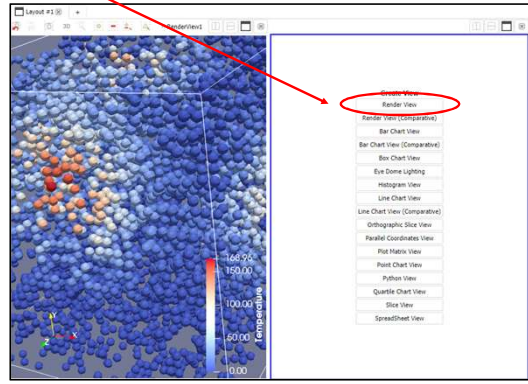
### Multiple Views

73

Step #1: Split the Window



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




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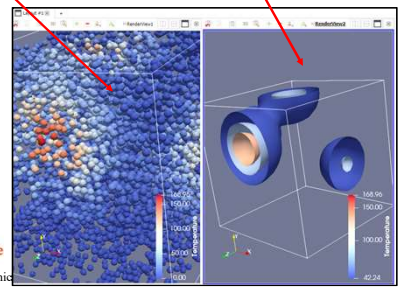
### Multiple Views

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!)



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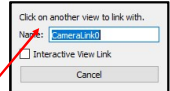
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... and, you get this – with each Window being allowed its own viewing transformation

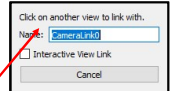
### Multiple Views with Linked Viewing Transformations

75

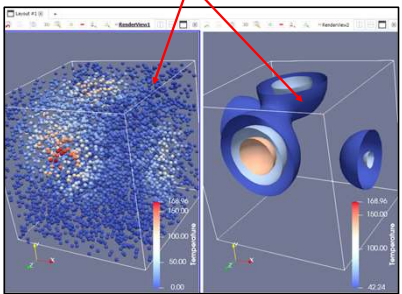
Step #5: Right-click in one of the Windows and select **Link Camera...**



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



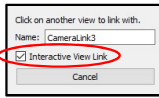
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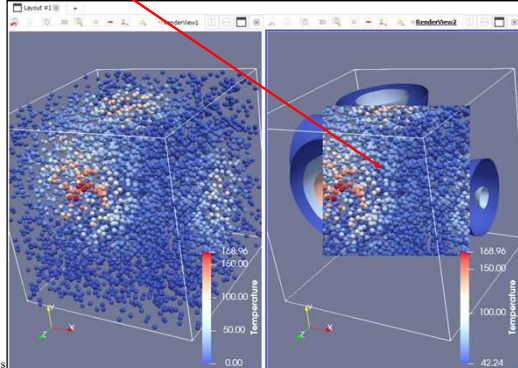
### Multiple Views with Linked Viewing Transformations

76

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



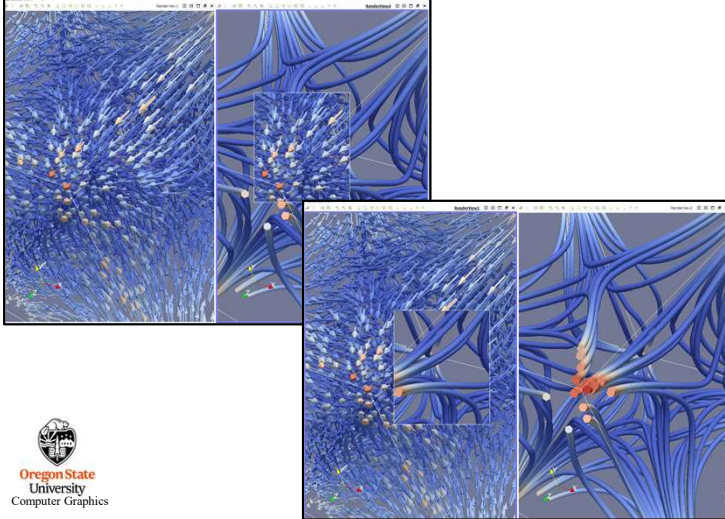
... you get a Magic Lens




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### Order Matters!

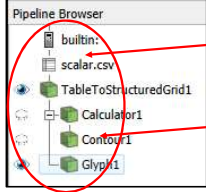




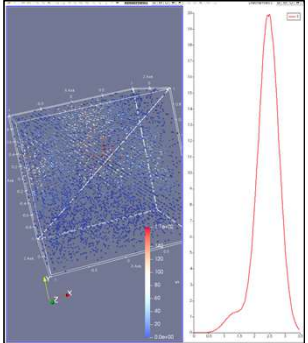
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77

### Using Plot Over Line



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**

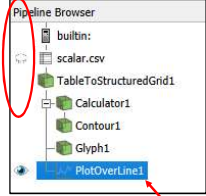




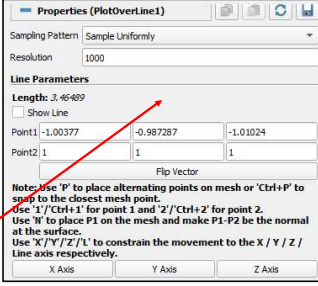
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78

### 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



**Properties (PlotOverLine1)**

Sampling Pattern: Sample Uniformly  
Resolution: 1000

**Line Parameters**


Length: 2.46469  
 Show Line

Point1: -1.00377    -0.987287    -1.01024  
Point2: 1    1    1

Flip Vector

Notes: Use 'P' to place alternating points on mesh or 'Ctrl+P' to snap to the closest mesh point.  
Use '1'/'Ctrl+1' for point 1 and '2'/'Ctrl+2' for point 2.  
Use 'N' to place P1 on the mesh and make P1-P2 be the normal at the surface.  
Use 'X'/'Y'/'Z'/'L' to constrain the movement to the X / Y / Z / Line axis respectively.

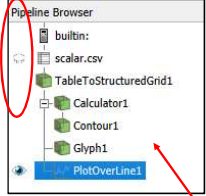
X Axis    Y Axis    Z Axis



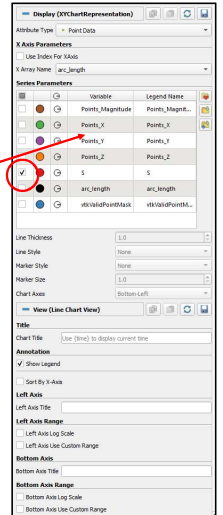
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79

### Using Plot Over Line



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



**Display (XYChartRepresentation)**

Abstract Type: Part Data

**X Axis Parameters**

Use Index For Axis  
X Array Name: Len\_length

**Series Parameters**

Color	Variable	Legend Name
Red	Points_Magnitude	Points_Magntud...
Green	Points_X	Points_X
Blue	Points_Y	Points_Y
Yellow	Points_Z	Points_Z
Grey	S	S
Light Blue	arc_length	arc_length
Light Green	vtkColorMask	vtkColorMask...

Line Thickness: 1.0  
Line Style: None  
Marker Style: None  
Marker Size: 1.0  
Chart Axes: Bottom Left

**View (Line Chart View)**

Table

Chart Title: Use (time) to display current time

Annotations:  
 Show Legend

Sort By: X-Axis

**Left Axis**

Left Axis Title:

**Left Axis Range**


Left Axis Log Scale:  
 Left Axis Use Custom Range

**Bottom Axis**

Bottom Axis Title:

**Bottom Axis Range**

Bottom Axis Log Scale:  
 Bottom Axis Use Custom Range



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80

### Using Plot Over Line

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

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## Comparative Visualization

scalarcompare.pvsm

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## Comparative Visualization

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.

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## Comparative Visualization

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.

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### 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

vector.csv

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## Visualizing Vector Data

90

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

vector.csv

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### Vector Visualization As Glyphs

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?

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?

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

$$Mag = \|V\|$$

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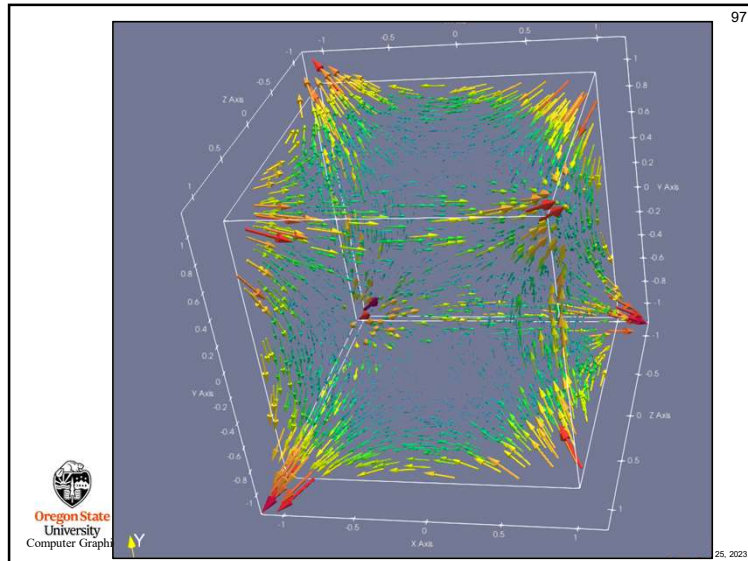
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### Setting Up the Glyph and its Coloring

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97

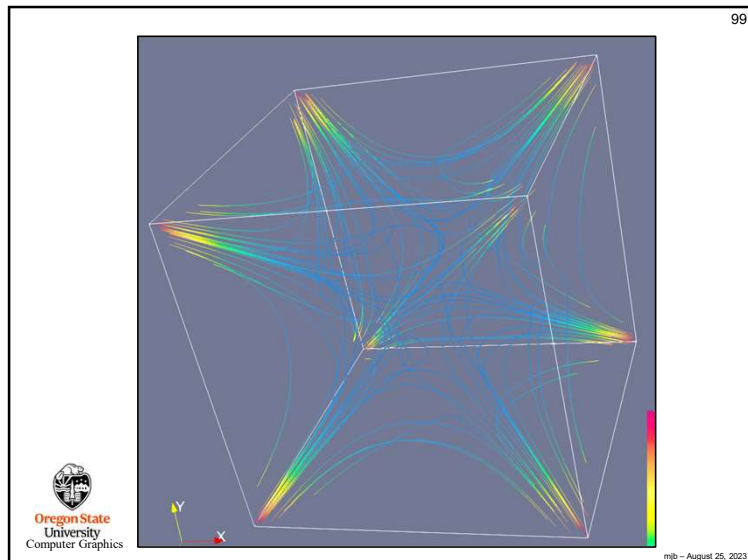
### As Streamlines

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

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

Number of points to start from

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99

### As Ribbon Traces

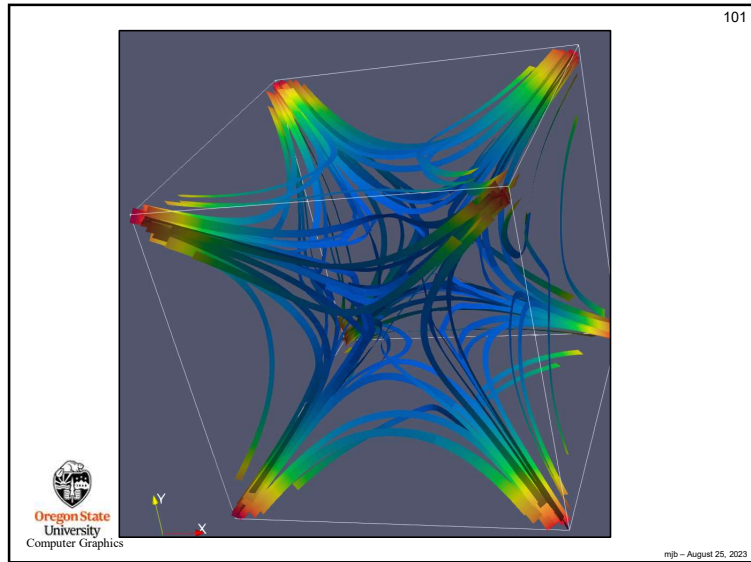
Note – **Ribbon** is parented from **StreamTracer**.

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.

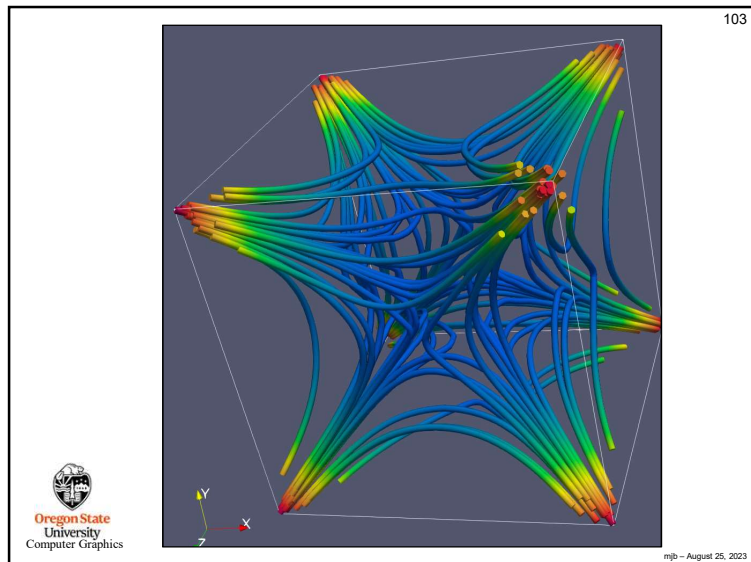
The **Vector** setting tells what will be used to decide which way the ribbon is facing.

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### As Streamtubes

The screenshot shows the software's interface. In the top-left hierarchy, 'Tube1' is highlighted with a red circle. A red arrow points from this circle to a text note: "Note – Tube is parented from StreamTracer." Below this, the 'Properties (Tube1)' panel is shown, with a red circle around the 'Clipping' section, which includes a 'Radius' slider set to 0.0101961. To the right is a smaller version of the 3D streamtube visualization.

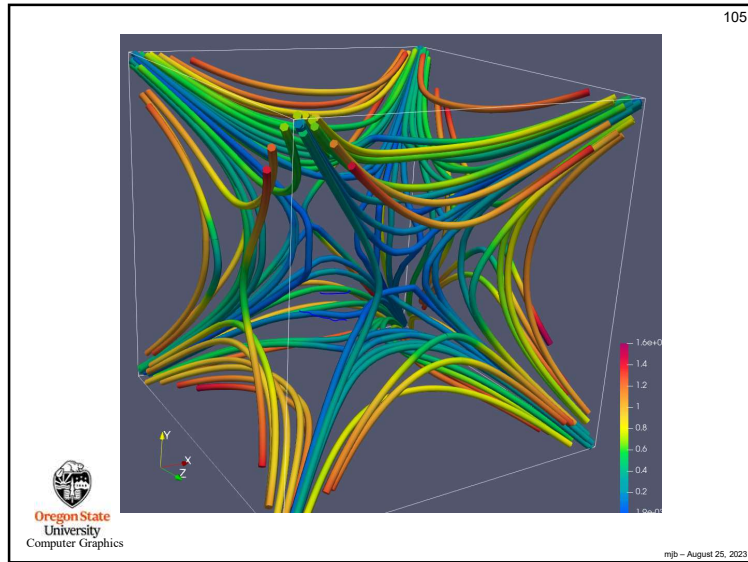


### Streamtubes are Especially Useful if You Want to Map Scalar Values to the Streamlines

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

The screenshot shows the software interface. The 'PythonCalculator' panel has 'Expression' set to 'curl(v)'. The 'Coloring' panel has 'Curvature' selected as the scalar value to map. A red circle highlights the 'Curvature' label in the coloring panel. A color scale legend for 'Curvature' is shown, ranging from -1.0e+00 (blue) to 1.4e+00 (red). A smaller 3D visualization shows the streamtubes colored by curvature.

- 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)



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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107

## Visualizing Terrain Data

terrain.csv

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108

### 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, 5.010,1308.478
-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).

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### Reading and Converting the CSV File

Pipeline Browser

- builtin:
  - terrain.csv
  - TableToStructuredGrid1
  - Transform1

Properties (TableToStruct...)

Whole Extent: [0, 0, 0] [511, 360, 0]

X Column: JTMX512

Y Column: JTMX361

Z Column: Z

Display (StructuredGridR...)

Representation: Surface

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

Point	X	Y	Z	Value
1	10000	10000	10000	10000
2	10000	10000	10000	10000
3	10000	10000	10000	10000
4	10000	10000	10000	10000
5	10000	10000	10000	10000
6	10000	10000	10000	10000
7	10000	10000	10000	10000
8	10000	10000	10000	10000
9	10000	10000	10000	10000
10	10000	10000	10000	10000
11	10000	10000	10000	10000
12	10000	10000	10000	10000
13	10000	10000	10000	10000
14	10000	10000	10000	10000
15	10000	10000	10000	10000
16	10000	10000	10000	10000
17	10000	10000	10000	10000
18	10000	10000	10000	10000
19	10000	10000	10000	10000
20	10000	10000	10000	10000
21	10000	10000	10000	10000
22	10000	10000	10000	10000
23	10000	10000	10000	10000
24	10000	10000	10000	10000
25	10000	10000	10000	10000
26	10000	10000	10000	10000
27	10000	10000	10000	10000
28	10000	10000	10000	10000
29	10000	10000	10000	10000
30	10000	10000	10000	10000
31	10000	10000	10000	10000
32	10000	10000	10000	10000
33	10000	10000	10000	10000
34	10000	10000	10000	10000
35	10000	10000	10000	10000
36	10000	10000	10000	10000
37	10000	10000	10000	10000
38	10000	10000	10000	10000
39	10000	10000	10000	10000
40	10000	10000	10000	10000
41	10000	10000	10000	10000
42	10000	10000	10000	10000
43	10000	10000	10000	10000
44	10000	10000	10000	10000
45	10000	10000	10000	10000
46	10000	10000	10000	10000
47	10000	10000	10000	10000
48	10000	10000	10000	10000
49	10000	10000	10000	10000
50	10000	10000	10000	10000
51	10000	10000	10000	10000
52	10000	10000	10000	10000
53	10000	10000	10000	10000
54	10000	10000	10000	10000
55	10000	10000	10000	10000
56	10000	10000	10000	10000
57	10000	10000	10000	10000
58	10000	10000	10000	10000
59	10000	10000	10000	10000
60	10000	10000	10000	10000
61	10000	10000	10000	10000
62	10000	10000	10000	10000
63	10000	10000	10000	10000
64	10000	10000	10000	10000
65	10000	10000	10000	10000
66	10000	10000	10000	10000
67	10000	10000	10000	10000
68	10000	10000	10000	10000
69	10000	10000	10000	10000
70	10000	10000	10000	10000
71	10000	10000	10000	10000
72	10000	10000	10000	10000
73	10000	10000	10000	10000
74	10000	10000	10000	10000
75	10000	10000	10000	10000
76	10000	10000	10000	10000
77	10000	10000	10000	10000
78	10000	10000	10000	10000
79	10000	10000	10000	10000
80	10000	10000	10000	10000
81	10000	10000	10000	10000
82	10000	10000	10000	10000
83	10000	10000	10000	10000
84	10000	10000	10000	10000
85	10000	10000	10000	10000
86	10000	10000	10000	10000
87	10000	10000	10000	10000
88	10000	10000	10000	10000
89	10000	10000	10000	10000
90	10000	10000	10000	10000
91	10000	10000	10000	10000
92	10000	10000	10000	10000
93	10000	10000	10000	10000
94	10000	10000	10000	10000
95	10000	10000	10000	10000
96	10000	10000	10000	10000
97	10000	10000	10000	10000
98	10000	10000	10000	10000
99	10000	10000	10000	10000
100	10000	10000	10000	10000


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

Pipeline Browser

- builtin:
  - terrain.csv
  - TableToStructuredGrid1
  - Transform1

Properties (Transform1)

Translate: [0, 0, 0]

Rotate: [0, 0, 0]

Scale: [1.4194, 1, 1]

Translation  Scaling


Rotation  Face Movement

Transform All Input Vectors

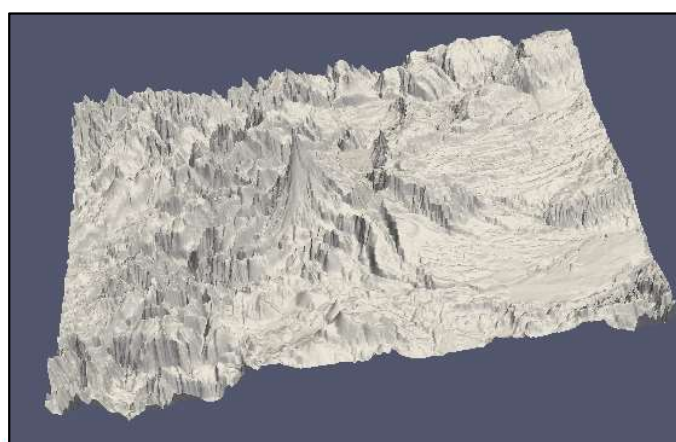
This will bring up a square terrain, which isn't what we want. We notice that the UTM coordinates are 511 and 360, so we really want to scale by  $511/360 = 1.4194$  in the X direction.

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

Set the X scale factor to 1.4194



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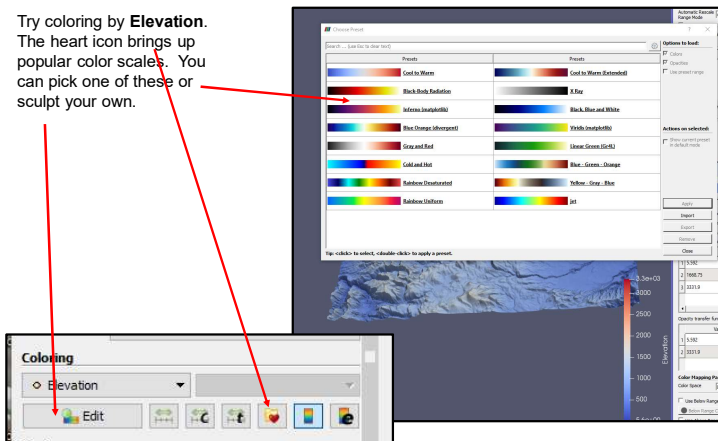



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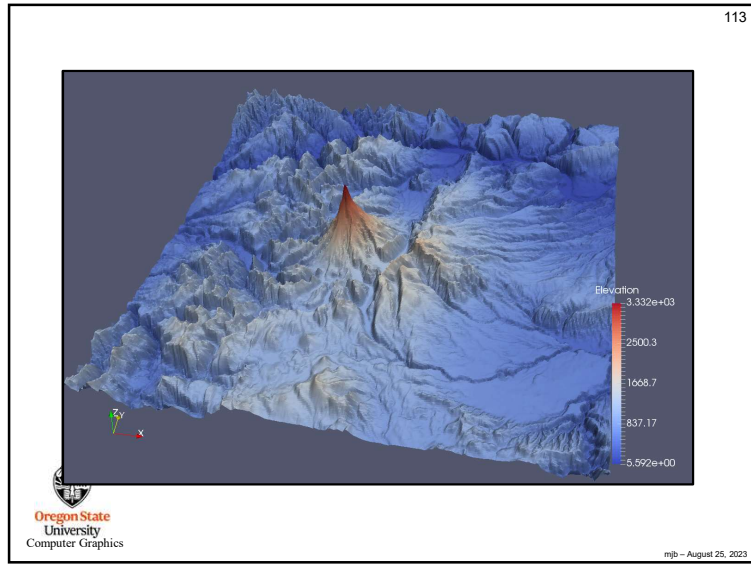
### Color by Elevation

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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114

### Contouring

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

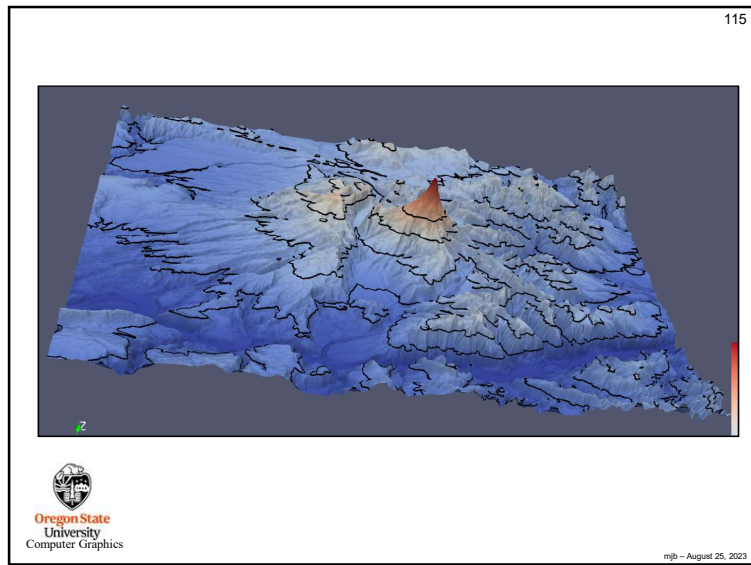
ParaView gives one default contour elevation, but you can add more.  
Display as Wireframe.

**Edit** to select a contour color.  
Enter a **Line Width**.

Be sure the eyeballs are turned on.

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116

### Changing the Vertical Exaggerations

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

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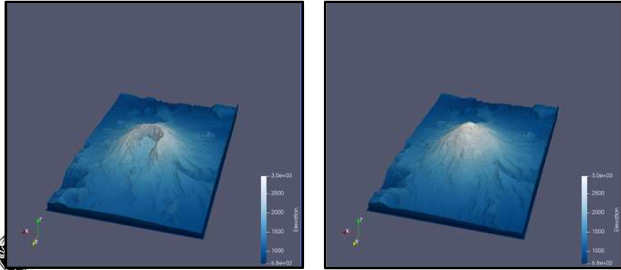
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### Reading ARCGIS DEM Files

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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## Parallel Coordinates

118



vector.pvsm  
parallelscoords.pvsm



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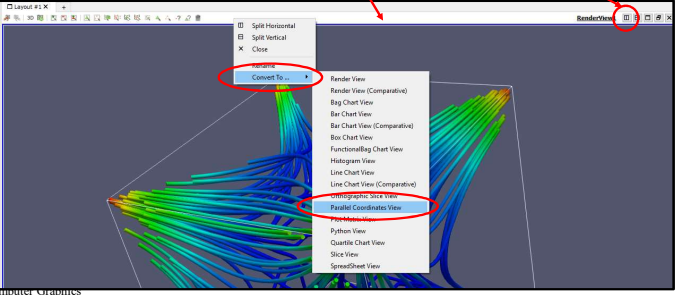
### Parallel Coordinates – Correlating Fields

119

Let's say you were to start with this:

- bulletin
- vector.csv
- TableToStructuredGrid
- Calculator 1
- Calculator 2
- Glyph 1
- StreamTracer 1
- Tube 1

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



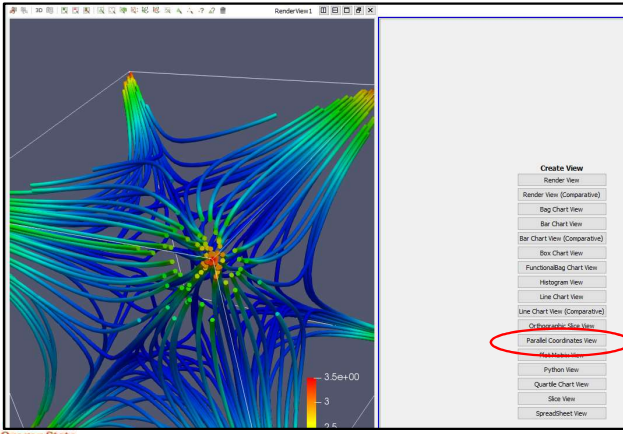
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### Parallel Coordinates

120

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



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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

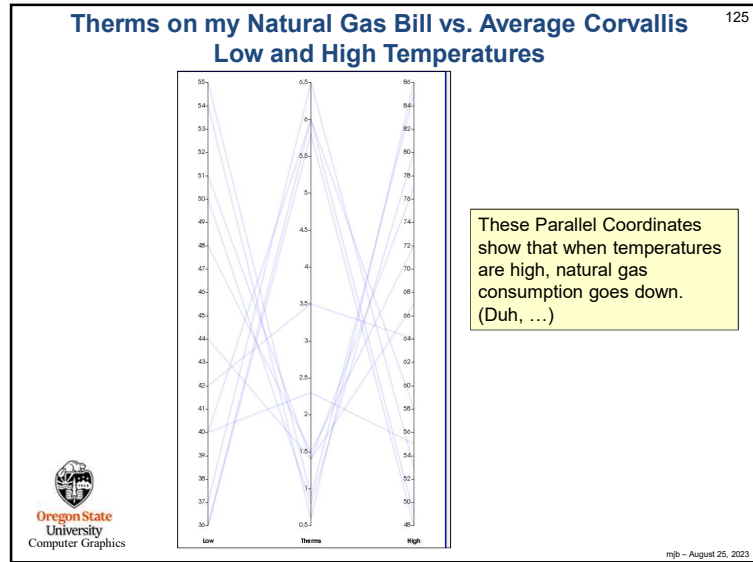
Scroll down a little more in the properties menu and you will find the **Parallel Coordinates Styling** menu:

Line Thickness = 1

Line Thickness = 2

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## Saving an Image of the Screen

scalar.pvsm

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### File → Save Screenshot

Select the gear to show all options (I recommend this)

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### Changing the Background Color

You can override the existing background color just long enough to create the screenshot

You can also force the image background to be transparent. (This only works on some image file formats, such as PNG.)

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### Creating Stereographics Images

129

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

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### An Original Visualization

130

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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

**L**

**R**

**L**

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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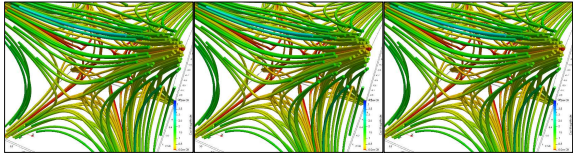
### Red-Cyan Anaglyph

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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134

## Exporting the Scene Geometry

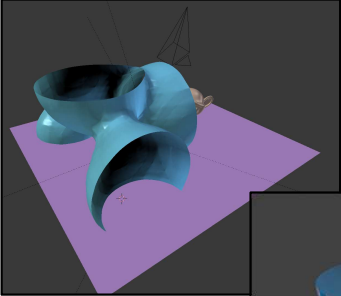


scalar.pvsm



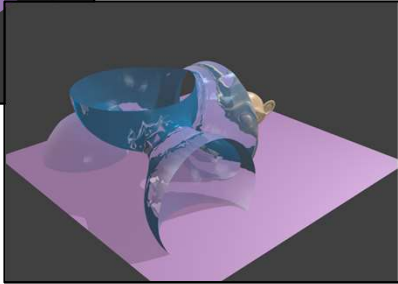

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You can export the scene *geometry* (in this case to Blender) via X3D files 135



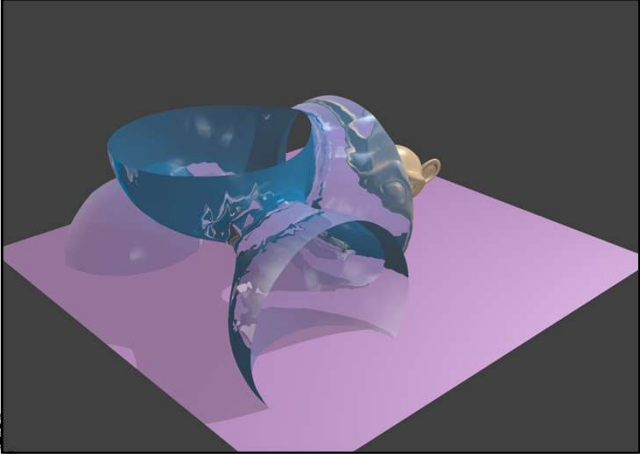
File → Export Scene

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

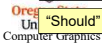



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You can export the scene *geometry* (in this case to Blender) via X3D files 136




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




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137

## Saving the ParaView State



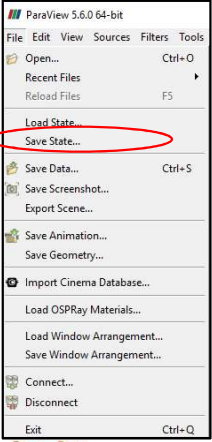
anim.pvsm  
 scalar.csv  
 scalar.pvsm  
 scalar.py  
 vector.csv  
 vector.pvsm  
 vector.py  
 terrain.csv  
 terrain.pvsm  
 terrain.py

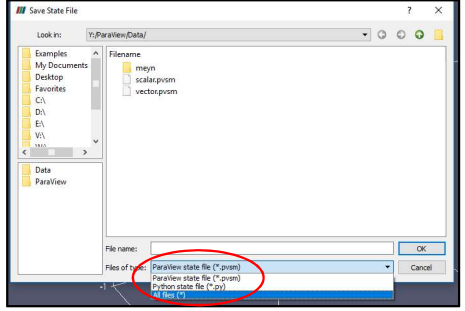


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138

## 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.



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139

## scalar.py


```

# 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'])
    
```




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140

## Animation in ParaView



anim.pvsm

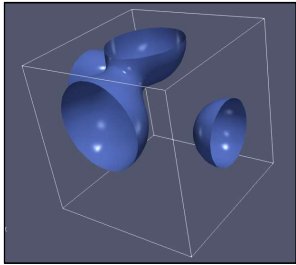


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### Animation in ParaView

141

Start with this:

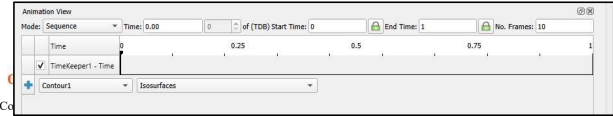


Select this:

- Animation View

anim.pvsm

And this appears at the bottom:



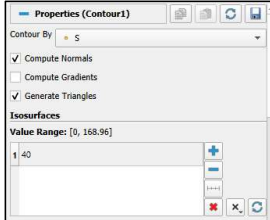
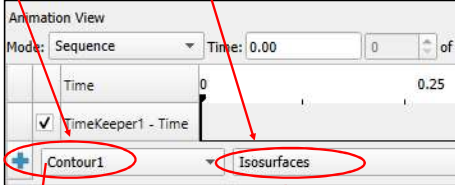
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### Animation in ParaView – Pick Something to Animate

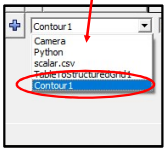
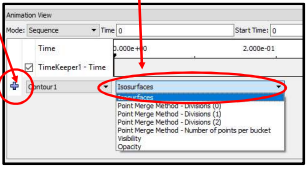
142

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

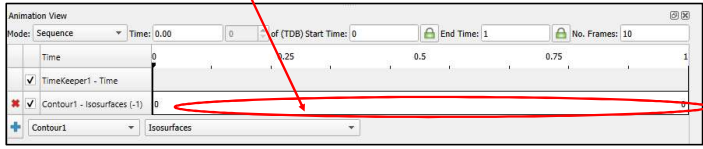

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### Animation in ParaView – Bring up a Keyframe Menu

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

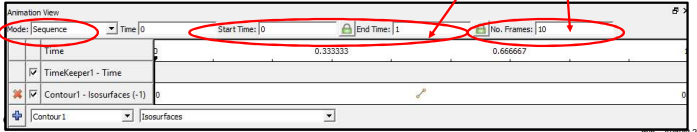
Click **New** to add a new row

Time	Interpolation	Value	New
1.0	Ramp	10	Delete
2.2	Ramp	40	Delete All
3.4	Ramp	70	
4.6	Ramp	100	
5.8	Ramp	130	
7.1		168.96	

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.



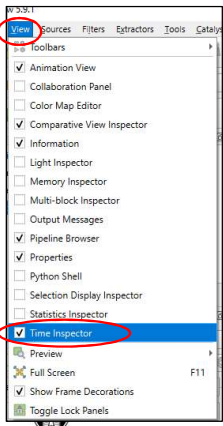
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### Animation in ParaView – the Time Inspector

145

Select this:



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



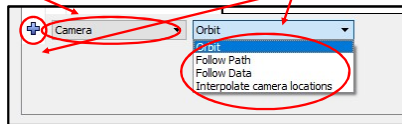
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### Animation in ParaView -- Animating the Camera

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

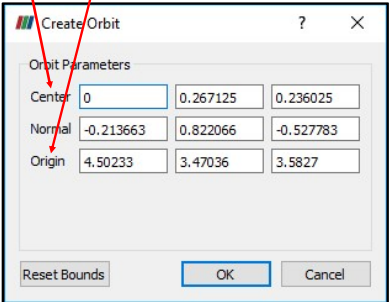
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### Animation in ParaView -- Orbiting the Camera

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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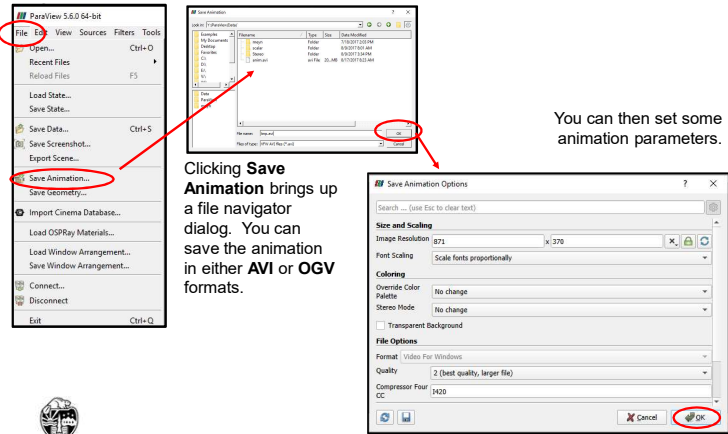
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### Saving the Animation

148

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

You can then set some animation parameters.



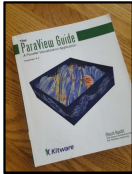
I haven't done an exhaustive study of this, but I can tell you that OGV files play in Firefox, Edge, and Chrome – but not in PowerPoint. AVI files play in PowerPoint. The OGV files are much smaller than the AVI files.

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149

## References




<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)




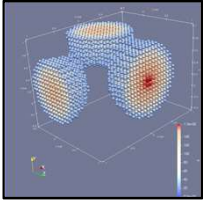
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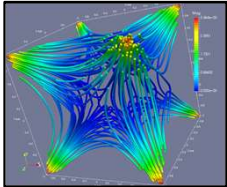
150

## ParaView


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



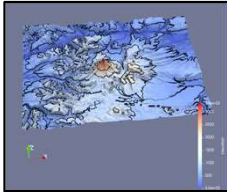
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Mike Bailey  
mjb@cs.oregonstate.edu



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