Elmer

Post-processing utilities

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Alternative postprocessors for Elmer

Open source

- ElmerPost
  - Postprocessor of Elmer suite
- ParaView, Visit
  - Use ResultOutputSolve to write .vtu or .vtk
  - Visualization of parallel data
- OpenDX
  - Supports some basic elementtypes
- Gmsh
  - Use ResultOutputSolve to write data
- Gnuplot, R, Octave, …
  - Use SaveData to save results in ascii matrix format
  - Line plotting

Commercial

- Matlab, Excel, …
  - Use SaveData to save results in ascii matrix format
  - Line plotting

Visualization tools – Poll (3/2014)

What visualization software do you use?

You may select up to **10** options

ElmerPost	☑	12	18%
ElmerGUI VTK postprocessor	☑	7	11%
Paraview	☑	27	41%
ViSit	☐	3	5%
Mayavi	☐	0	No votes
Gmsh	☐	2	3%
GiD	☐	1	2%
Matlab	☑	5	8%
gnuplot	☐	4	6%
Something else (please specify)	☐	5	8%

Total votes : 66

Submit vote

Exporting 2D/3D data: ResultOutputSolve

- Apart from saving the results in .ep format it is possible to use other postprocessing tools
- ResultOutputSolve offers several formats
  - vtk: Visualization tookit legacy format
  - vtu: Visualization tookit XML format
  - Gid: GiD software from CIMNE: http://gid.cimne.upc.es
  - Gmsh: Gmsh software: http://www.geuz.org/gmsh
  - Dx: OpenDx software
- **Vtu** is the recommended format!
  - offers parallel data handling capabilities
  - Has binary and single precision formats for saving disk space
  - Suffix **.vtu** in Post File does this automatically

Exporting 2D/3D data: ResultOutputSolve

An example shows how to save data in unstructured XML VTK (.vtu) files to directory ”results” in single precision binary format.

```
Solver n
  Exec Solver = after timestep
  Equation = "result output"
  Procedure = "ResultOutputSolve" "ResultOutputSolver"
  Output File Name = "case"
  Output Format = String ”vtu”
  Binary Output = True
  Single Precision = True
End
```

Overcoming bottle-necks in postprocessing

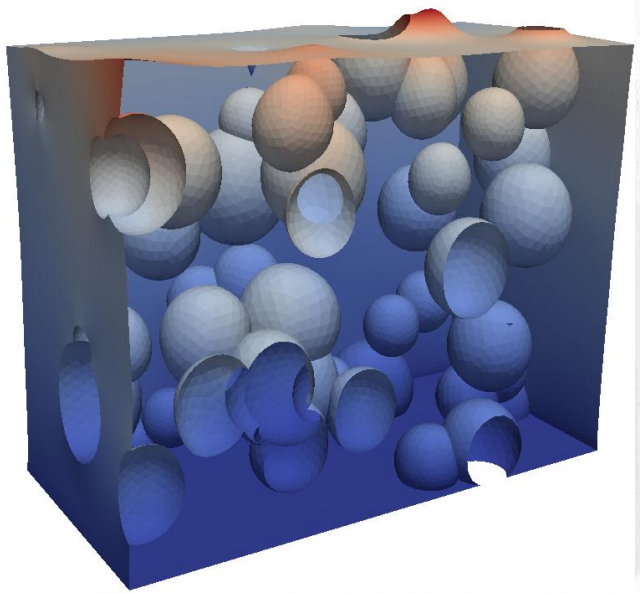
- Excellent tools available: Paraview & Visit
- Reducing data
  - Saving only boundaries
  - Uniform point clouds
  - A priori defined isosurfaces
  - Using coarser meshes for output when hierarchy of meshes exist
- Extracting data
  - Dimensional reduction (3D -> 2D)
  - Averaging over time
  - Integrals over BCs & bodies
- More robust I/O
  - Not all cores should write to disk in massively parallel simulations
  - HDF5+XDML output available for Elmer, mixed experiences

Example, File size in Swiss Cheese

- Memory consumption of vtu-files (for Paraview) was studied in the ”swiss cheese” case
- Saving just boundaries in single precision binary format may save over 90% in files size compared to full data in ascii
- With larger problem sizes the benefits are amplified

Binary output	Single Prec.	Only bound.	Bytes/ node
-	X	-	376.0
X	-	-	236.5
X	X	-	184.5
X	-	X	67.2
X	X	X	38.5

Simulation Peter Råback, CSC, 2012.



Derived fields

- Many solvers have internal options for computing derived fields (fluxes, heating powers,…)
- Elmer offers several auxiliary solvers
  - SaveMaterials: makes a material parameter into field variable
  - Streamlines: computes the streamlines of 2D flow
  - FluxComputation: given potential, computes the flux $q = - c \nabla \phi$
  - VorticitySolver: computes the vorticity of flow, $w = \nabla \times \phi$
  - PotentialSolver: given flux, compute the potential $- c \nabla \phi = q$
  - Filtered Data: compute filtered data from time series (mean, fourier coefficients,…)
  - …
- Usually auxiliary data need to be computed only after the iterative solution is ready
  - Exec Solver = after timestep
  - Exec Solver = after all
  - Exec Solver = before saving

Derived lower dimensional data

- Derived boundary data
  - SaveLine: Computes fluxes on-the-fly
- Derived lumped (or 0D) data
  - SaveScalars: Computes a large number of different quantities on-the-fly
  - FluidicForce: compute the fluidic force acting on a surface
  - ElectricForce: compute the electrostatic froce using the Maxwell stress tensor
  - Many solvers compute lumped quantities internally for later use
    (Capacitance, Lumped spring,…)

Saving 1D data: SaveLine

- Lines of interest may be defined on-the-fly
- Flux computation using integration points on the boundary – not the most accurate
- By default saves all existing field variables

Saving 1D data: SaveLine…

```
Solver n
 Equation = "SaveLine"
 Procedure = File "SaveData" "SaveLine"
 Filename =  "g.dat"
 File Append = Logical True
 Polyline Coordinates(2,2) = Real 0.0 1.0 0.0 2.0
End

Boundary Condition m
  Save Line = Logical True
End
```

Saving 0D data: SaveScalars

Operators on bodies

- Statistical operators
  - Min, max, min abs, max abs, mean, variance, deviation
- Integral operators (quadratures on bodies)
  - volume, int mean, int variance
  - Diffusive energy, convective energy, potential energy

Operators on boundaries

- Statistical operators
  - Boundary min, boundary max, boundary min abs, max abs, mean, boundary variance, boundary deviation, boundary sum
  - Min, max, minabs, maxabs, mean
- Integral operators (quadratures on boundary)
  - area
  - Diffusive flux, convective flux

Other operators

- nonlinear change, steady state change, time, timestep size,…

Saving 0D data: SaveScalars…

```
Solver n
  Exec Solver = after timestep
  Equation = String SaveScalars
  Procedure = File "SaveData" "SaveScalars"
  Filename = File "f.dat"
  Variable 1 = String Temperature
  Operator 1 = String max
  Variable 2 = String Temperature
  Operator 2 = String min
  Variable 3 = String Temperature
  Operator 3 = String mean
End

Boundary Condition m
  Save Scalars = Logical True
End
```

Case: TwelveSolvers

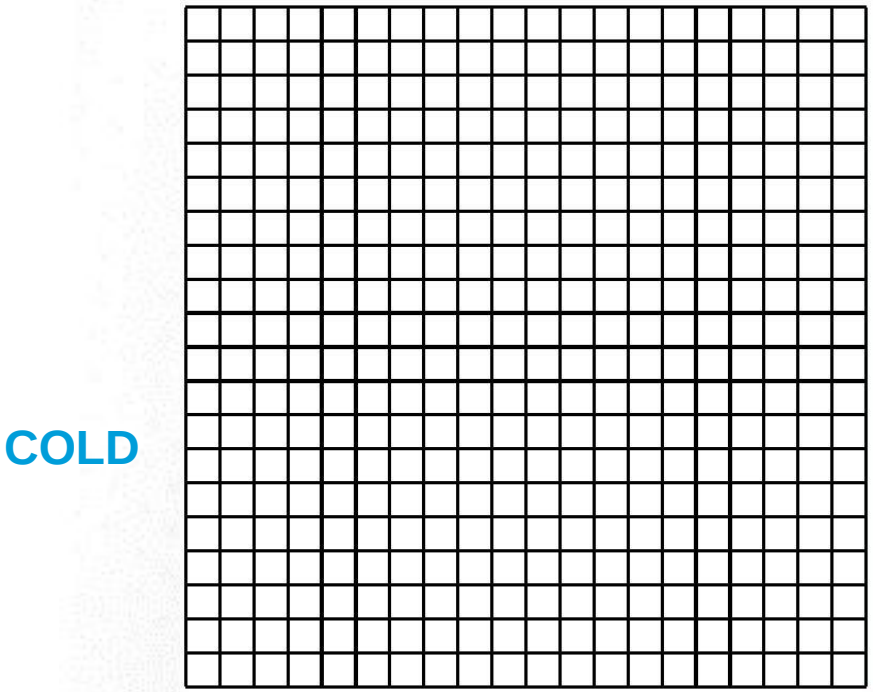
Natural convection with ten auxialiary solvers

Case: Motivation

- The purpose of the example is to show the flexibility of the modular structure
- The users should not be afraid to add new atomistic solvers to perform specific tasks
- A case of 12 solvers is rather rare, yet not totally unrealitistic

Case: preliminaries

- Square with hot wall on right and cold wall on left
- Filled with viscous fluid
- Bouyancy modeled with Boussinesq approximation
- Temperature difference initiates a convection roll



Case: 12 solvers

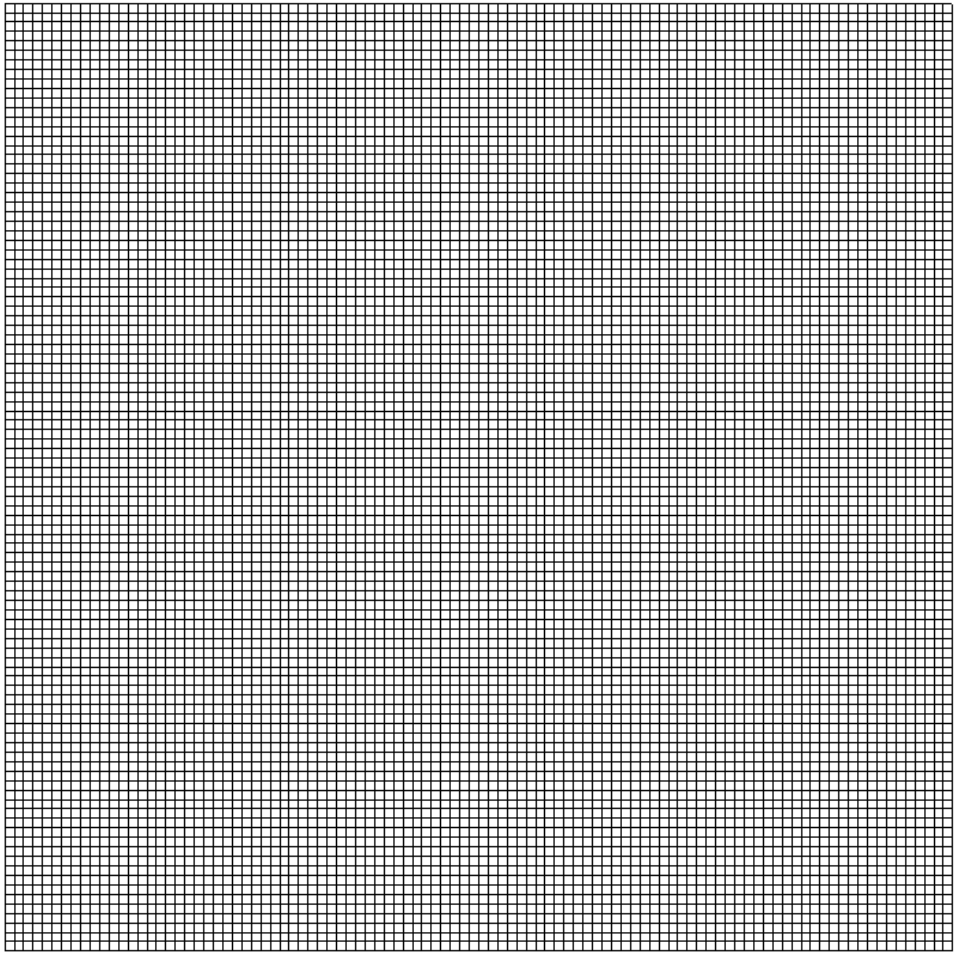
1. Heat Equation
2. Navier-Stokes

---

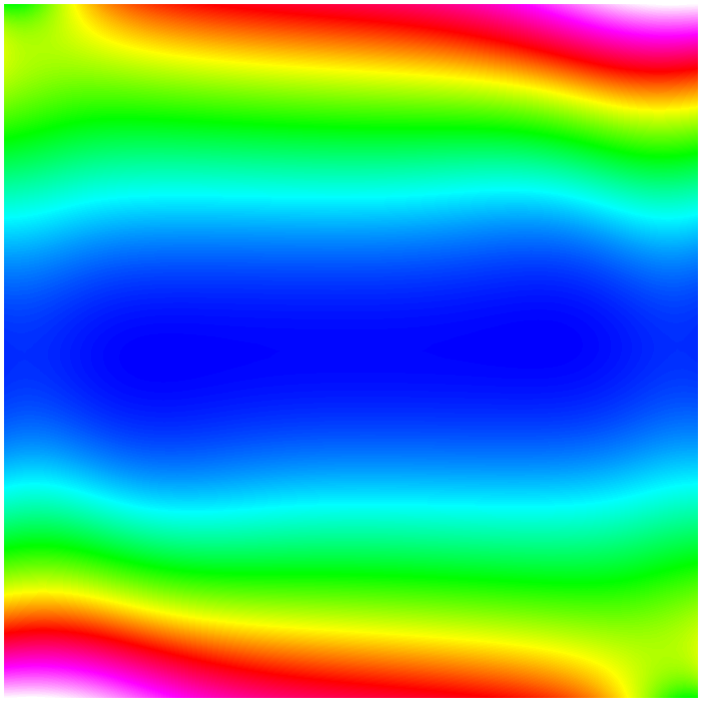
3. FluxSolver: solve the heat flux
4. StreamSolver
5. VorticitySolver
6. DivergenceSolver
7. ShearrateSolver
8. IsosurfaceSolver
9. ResultOutputSolver
10. SaveGridData
11. SaveLine
12. SaveScalars

Case: Computational mesh

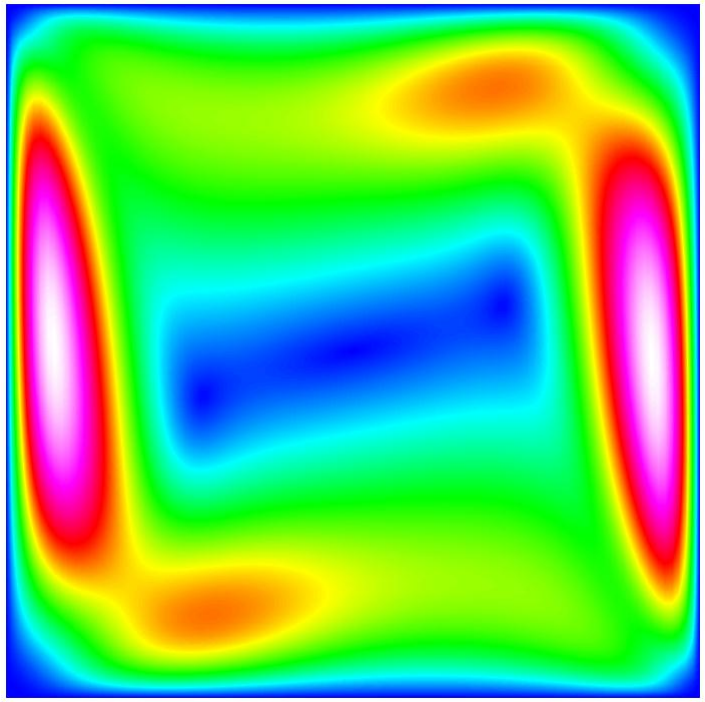
10000 bilinear elements



Case: Navier-Stokes, primary fields

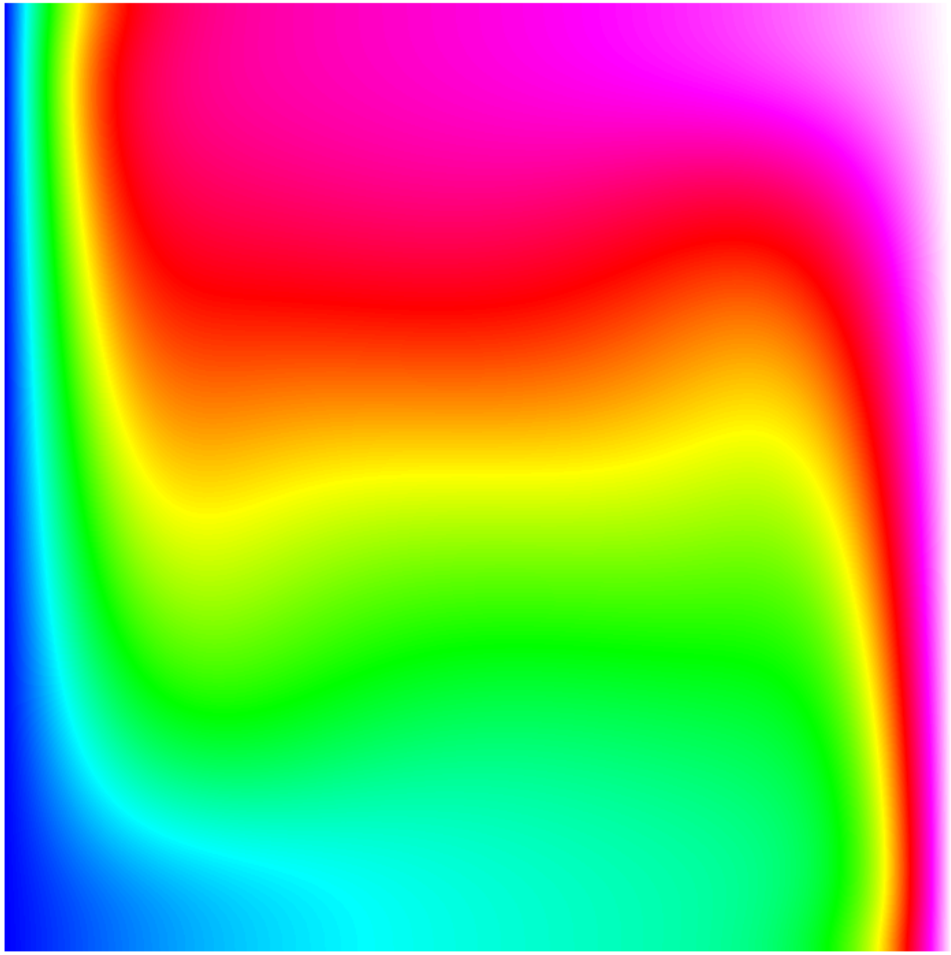


Pressure

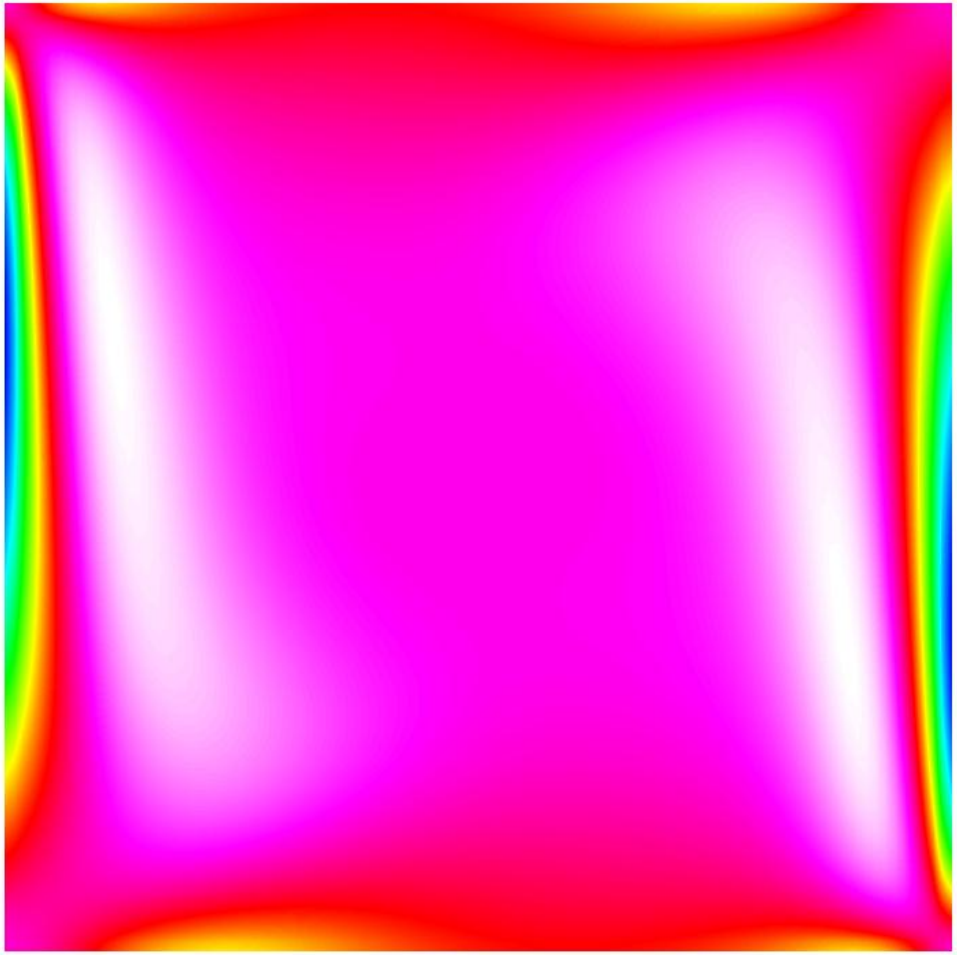


Velocity

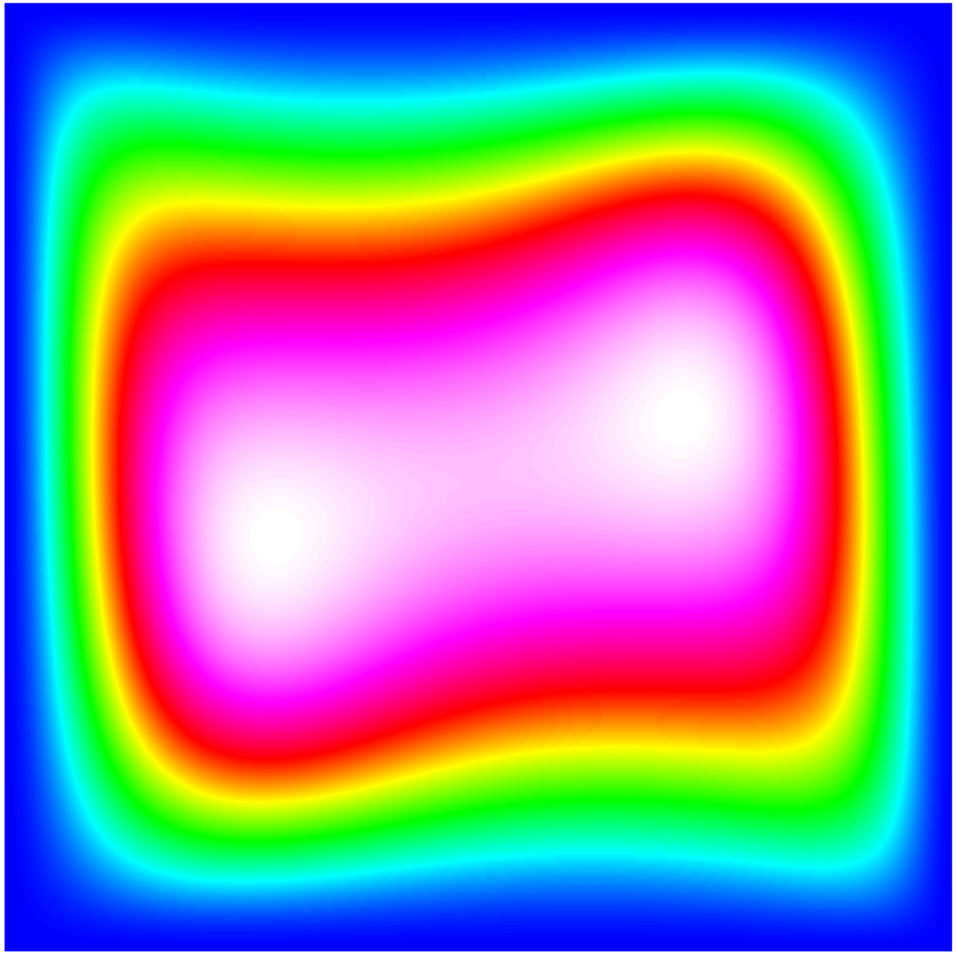
Case: Heat equation, primary field



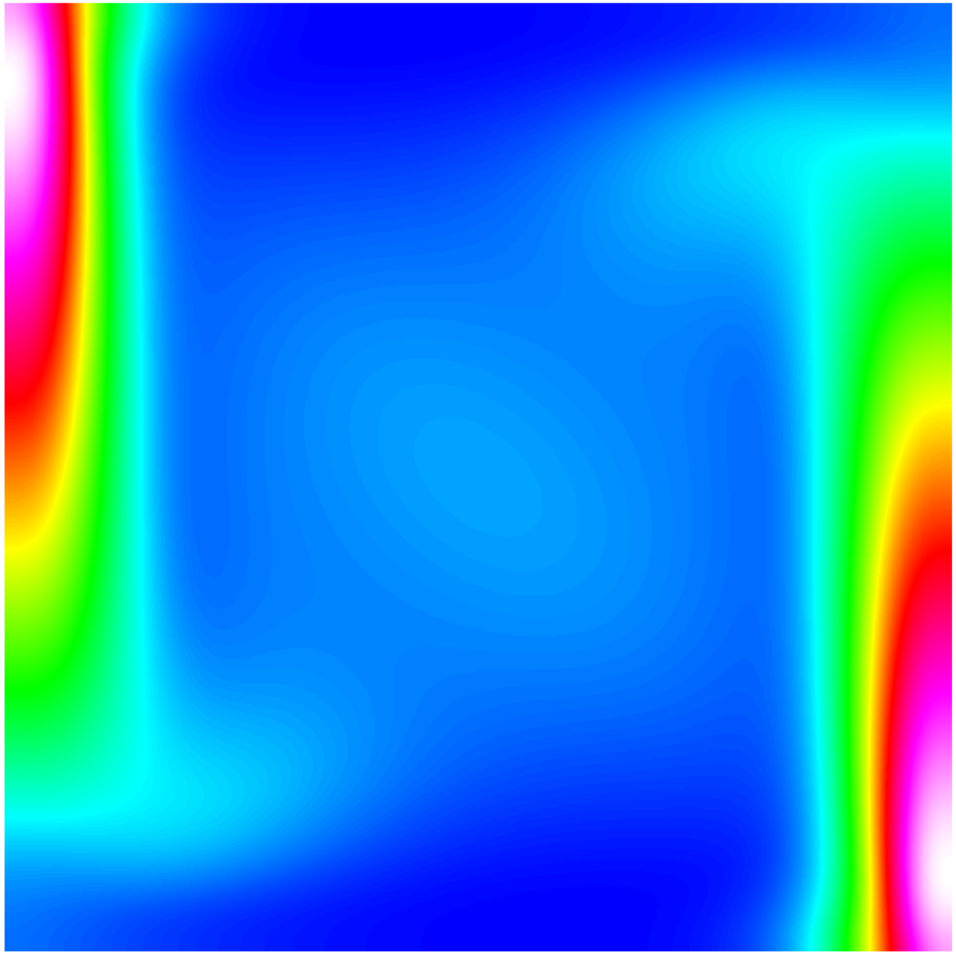
Case: Derived field, vorticity



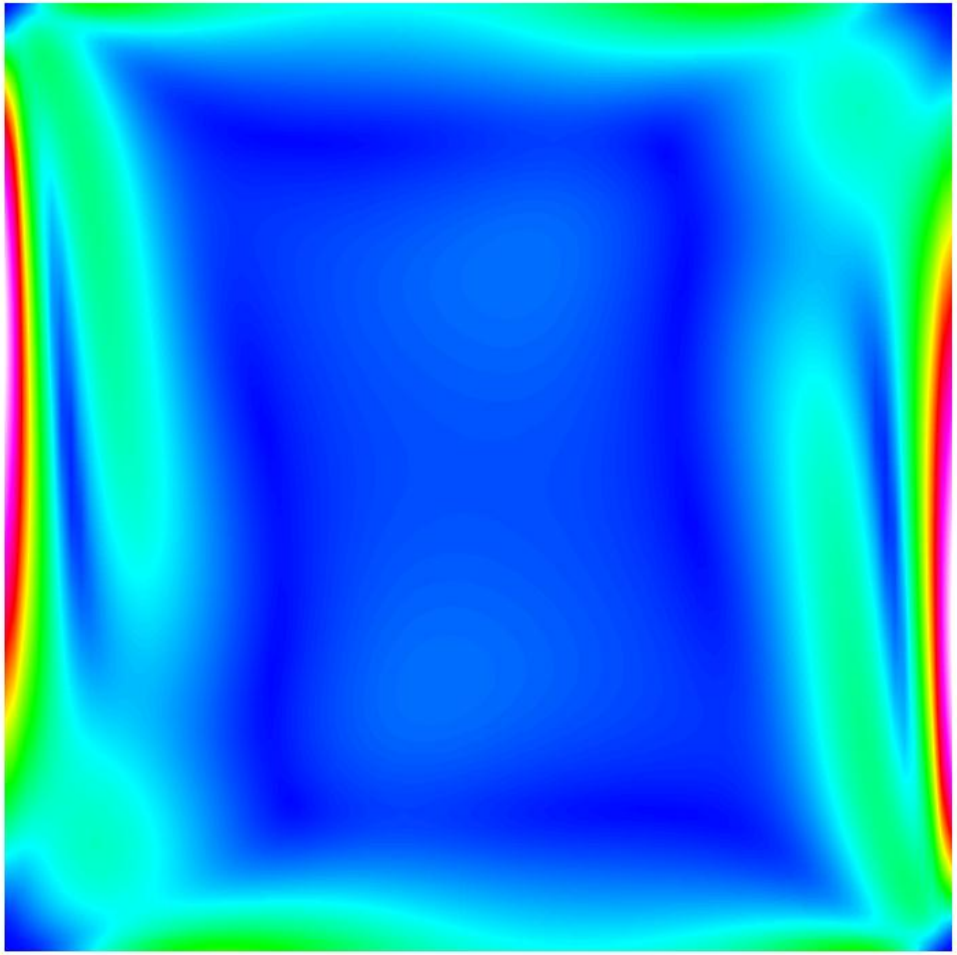
Case: Derived field, Streamlines



Case: Derived field, diffusive flux

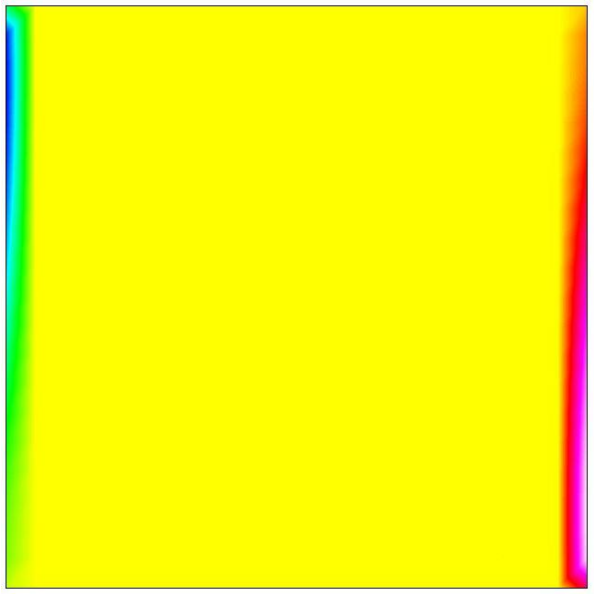


Case: Derived field, Shearrate



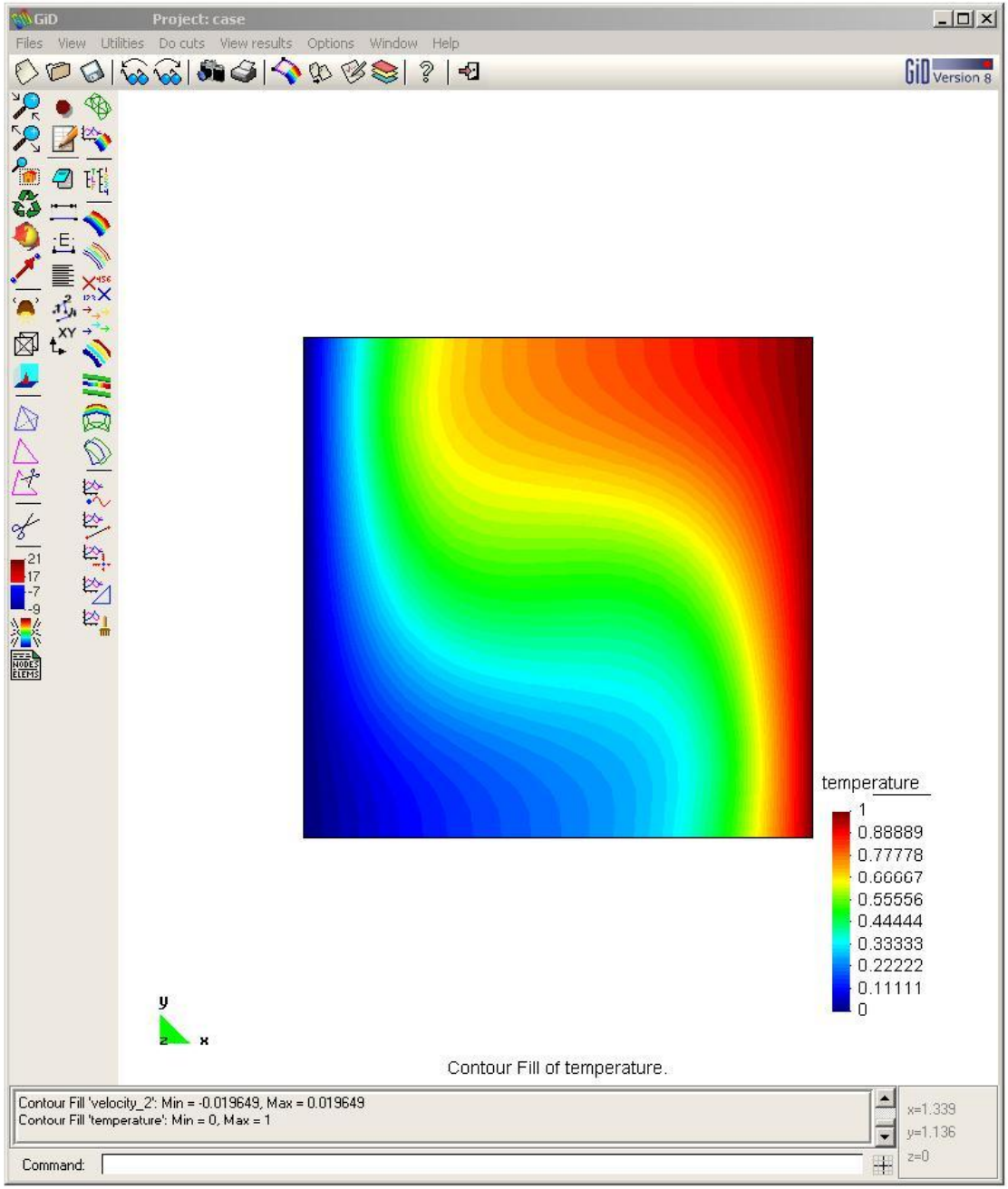
Example: nodal loads

- If equation is solved until convergence nodal loads should only occur at boundaries
- Element size h=1/20 ~weight for flux

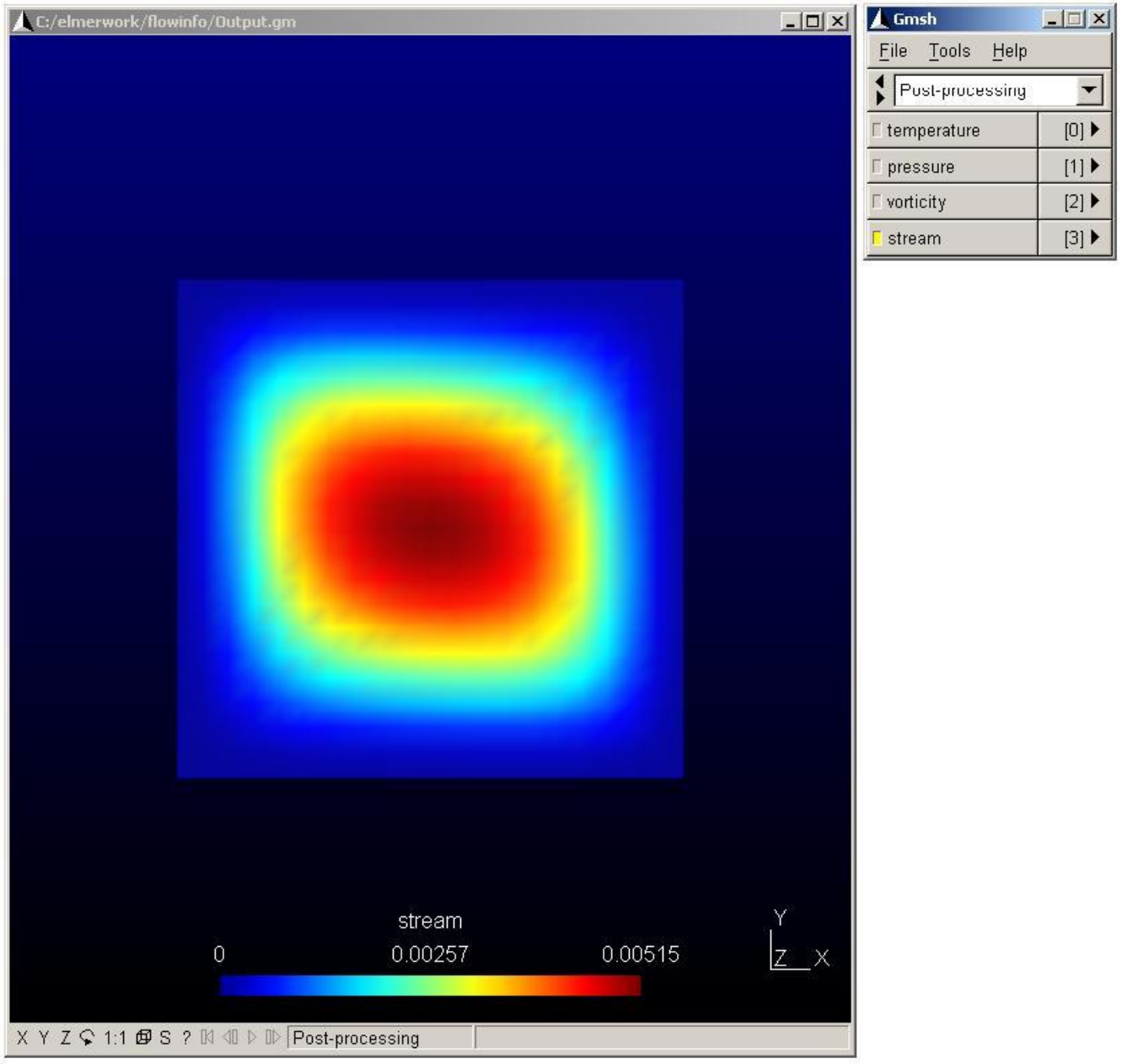


Nodal heat loads

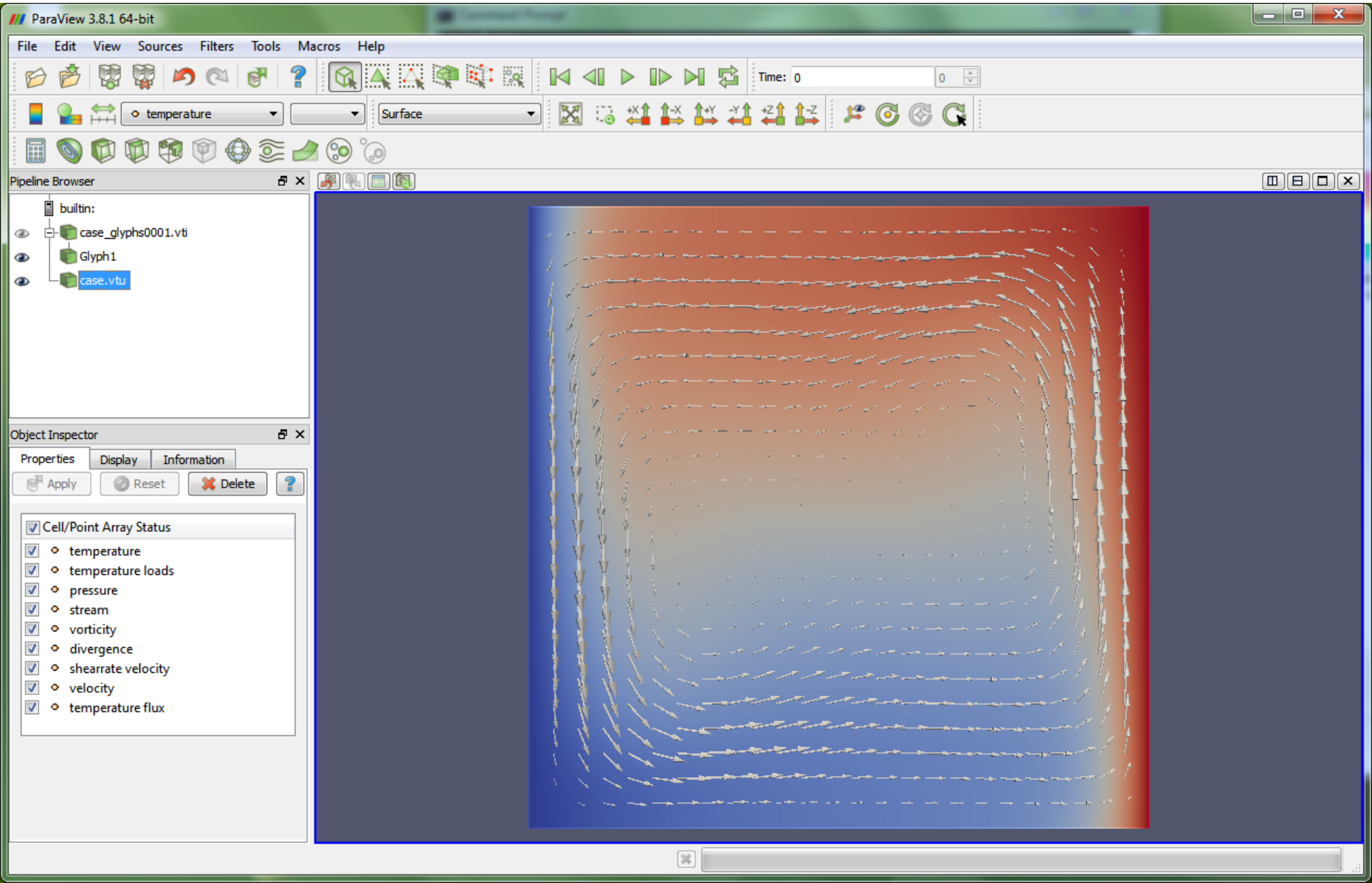
Example:
view in GiD



Example: view in Gmsh

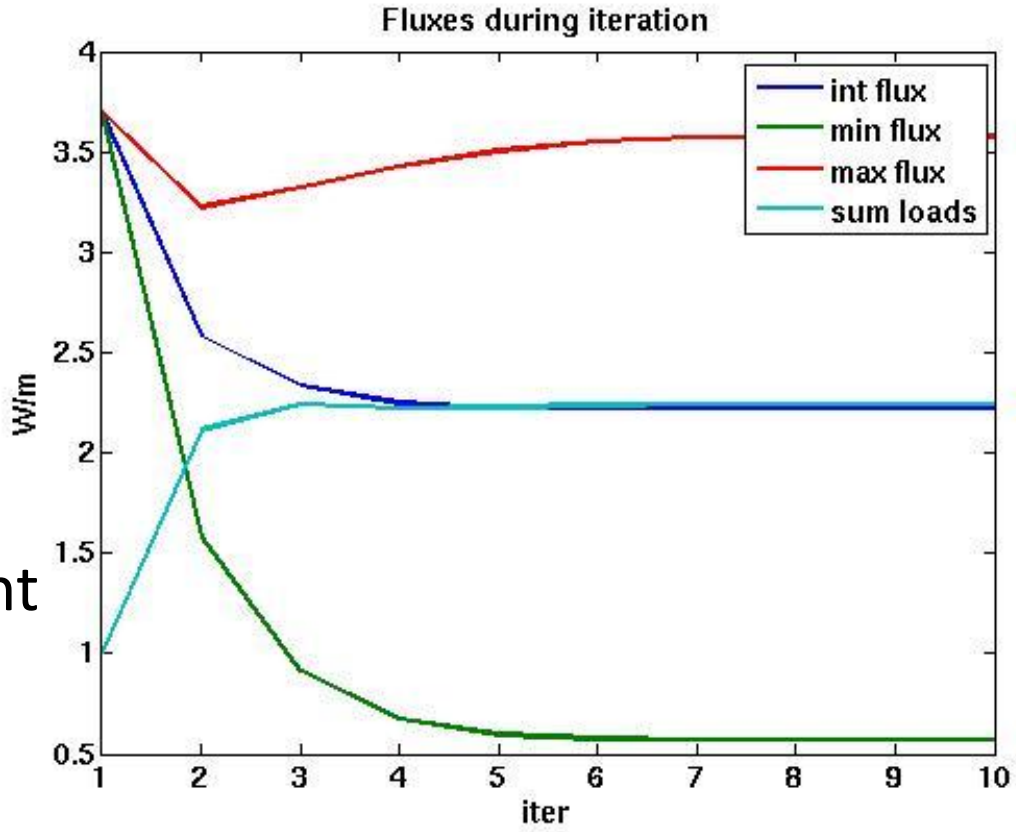


Case: View in Paraview



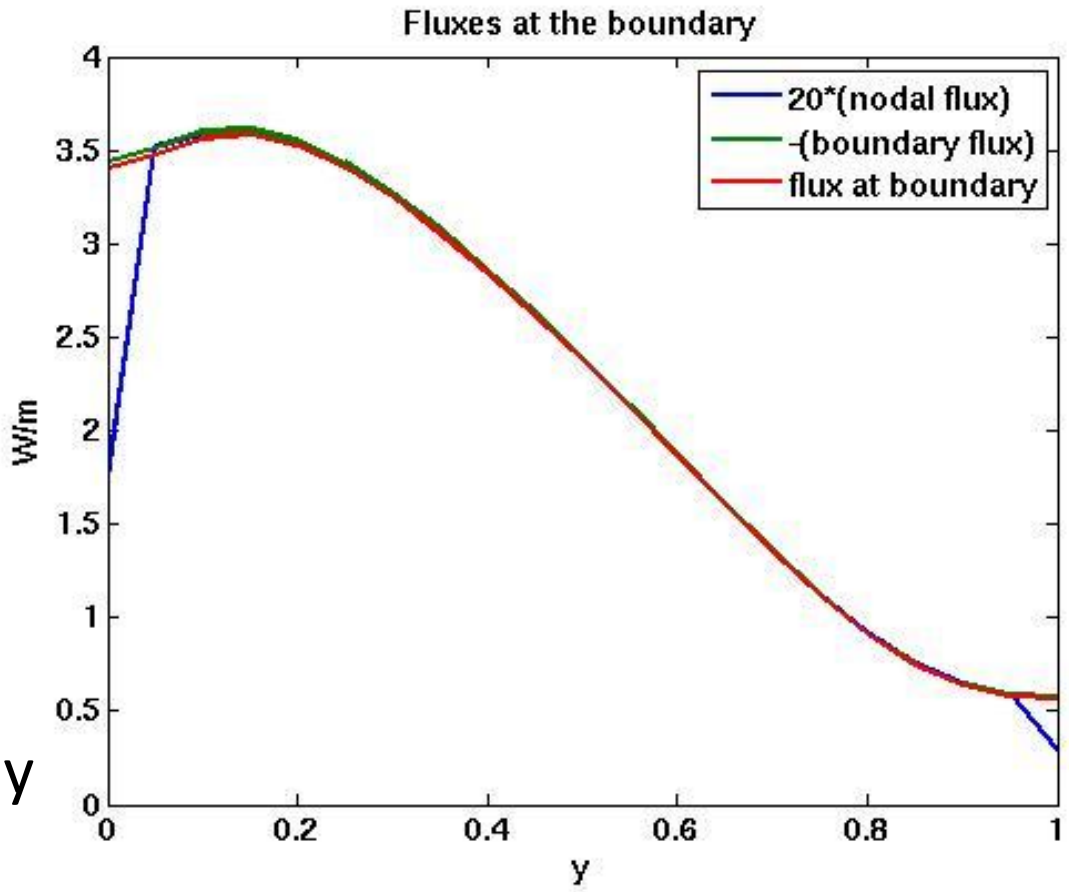
Example: total flux

- Saved by SaveScalars
- Two ways of computing the total flux give different approximations
- When convergence is reached the agreement is good



Example: boundary flux

- Saved by SaveLine
- Three ways of computing the boundary flux give different approximations
- At the corner the nodal flux should be normalized using only *h/2*



Exercise

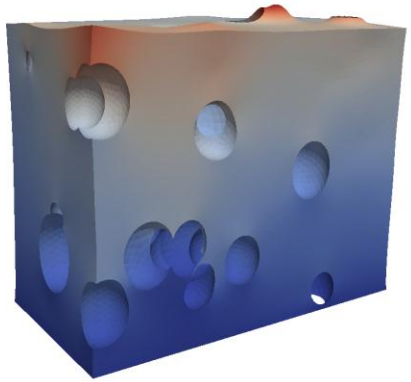
- Study the command file with 12 solvers
- Copy-paste an appropriate solver from there to some existing case of your own
  - ResultOutputSolver for VTU output
  - StreamSolver, VorticitySolver, FluxSolver,…
- Note: Make sure that the numbering of Solvers is consistant
  - Solvers that involve finite element solution you need to activate by **`Active Solvers`**
- Run the modified case
- Visualize results in ElmerPost or Paraview

Overcoming bottle-necks in postprocessing

- Despite good visualization tools sometimes the amount of data may become a bottle-neck
- Reducing data
  - Saving only boundaries
  - Uniform point clouds
  - A priori defined isosurfaces
  - Using coarser meshes for output when hierarchy of meshes exist
- Extracting data
  - Dimensional reduction (3D -> 2D)
  - Averaging over time
  - Integrals over BCs & bodies
- More robust I/O
  - Not all cores should write to disk in massively parallel simulations
  - Preliminary HDF5+XDML output available for Elmer, mixed experiences

Example, File size in Swiss Cheese

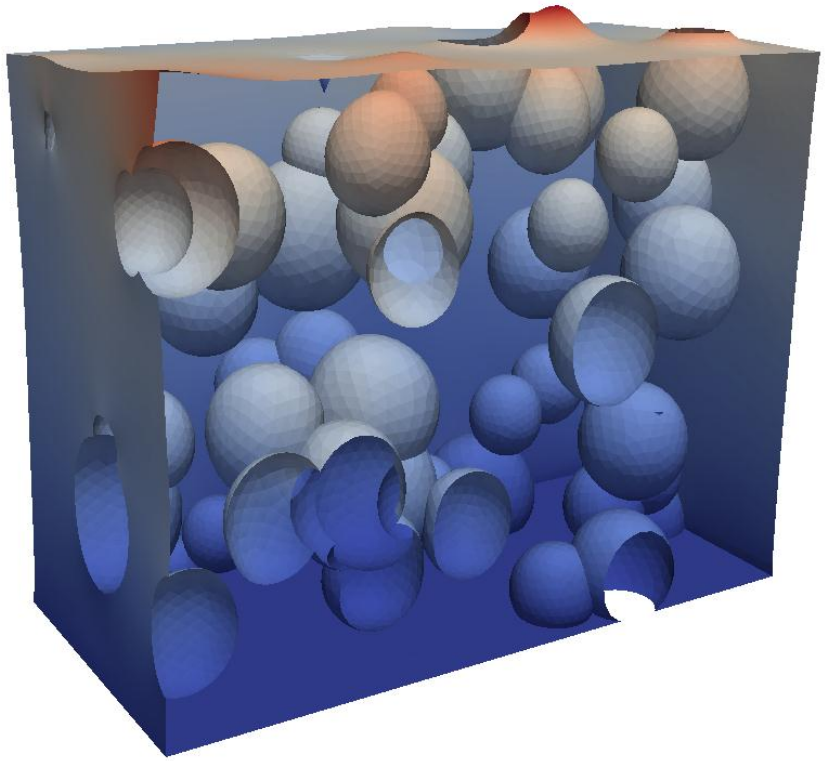
- Memory consumption of vtu-files (for Paraview) was studied in the ”swiss cheese” case
- The ResultOutputSolver with different flags was used to write output in parallel
- Saving just boundaries in single precision binary format may save over 90% in files size compared to full data in ascii
- With larger problem sizes the benefits are amplified



Binary output	Single Prec.	Only bound.	Bytes/node
-	X	-	376.0
X	-	-	236.5
X	X	-	184.5
X	-	X	67.2
X	X	X	38.5

Example, saving boundaries in .sif file

```
Solver 2
  Exec Solver = Always
  Equation = "result output"
  Procedure = "ResultOutputSolve" "ResultOutputSolver"
  Output File Name = case
  Vtu Format = Logical True
  Save Boundaries Only = Logical True
End
```



Conclusions

- It is good to think in advance what kind of data you need
  - 3D volume and 2D surface data
  - Derived fields
  - 1D line data
  - 0D lumped data
- Often the same operations may be done also at later stages but with significantly greater effort

Visualization with Paraview

Exporting 2D/3D data: ResultOutputSolve

By setting suffix for **`Post File`** to **`.vtu`** paraview format is saved automatically.

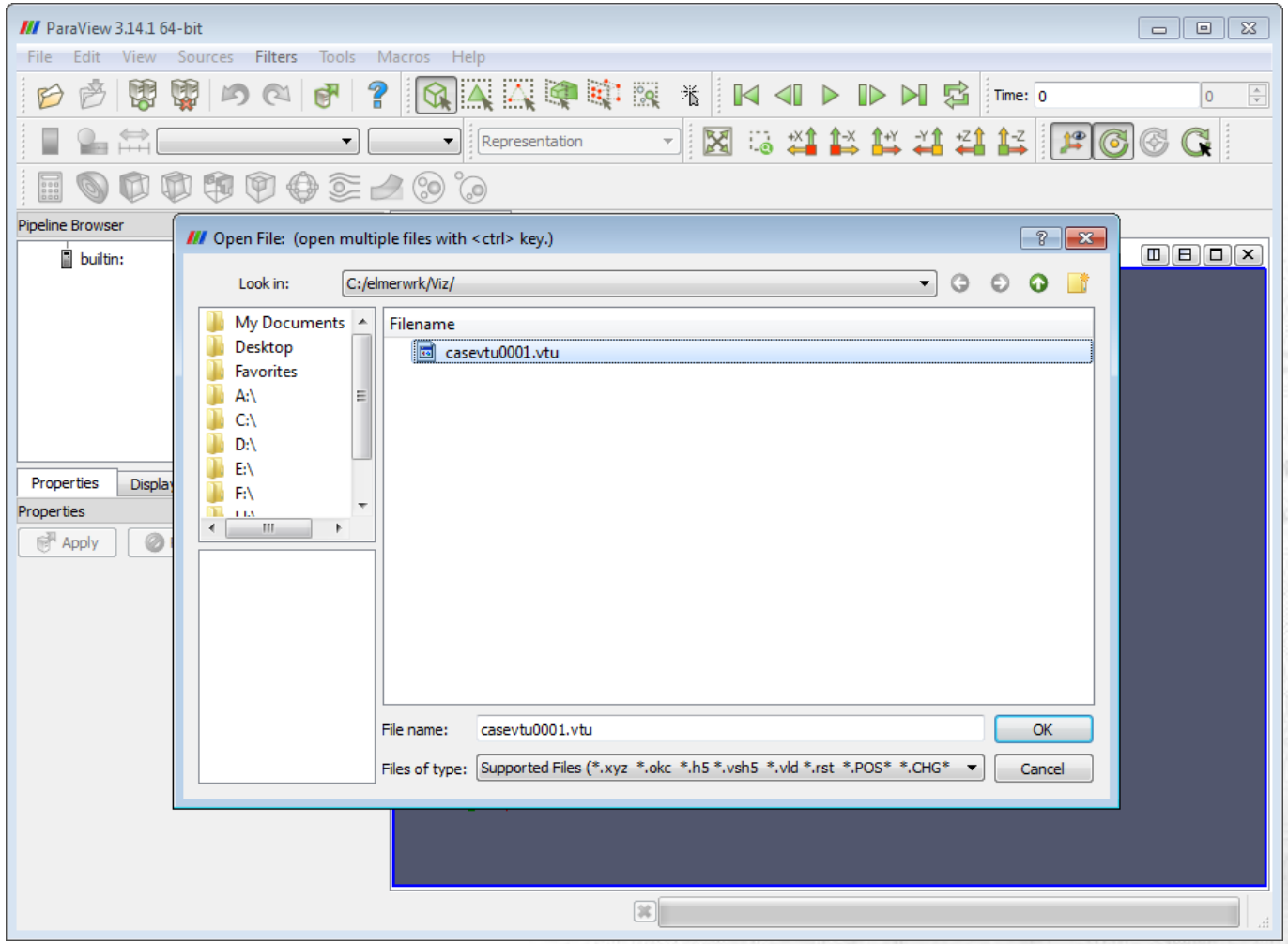
An example shows how to save data in unstructured XML VTK (.vtu) files to directory ”results” in single precision binary format.

```
Solver n
  Exec Solver = after timestep
  Equation = "result output"
  Procedure = "ResultOutputSolve" "ResultOutputSolver"
  Output File Name = "case"
  Output Format = String ”vtu”
  Binary Output = True
  Single Precision = True
  Save Geometry Ids = True
End
```

Filename conventions

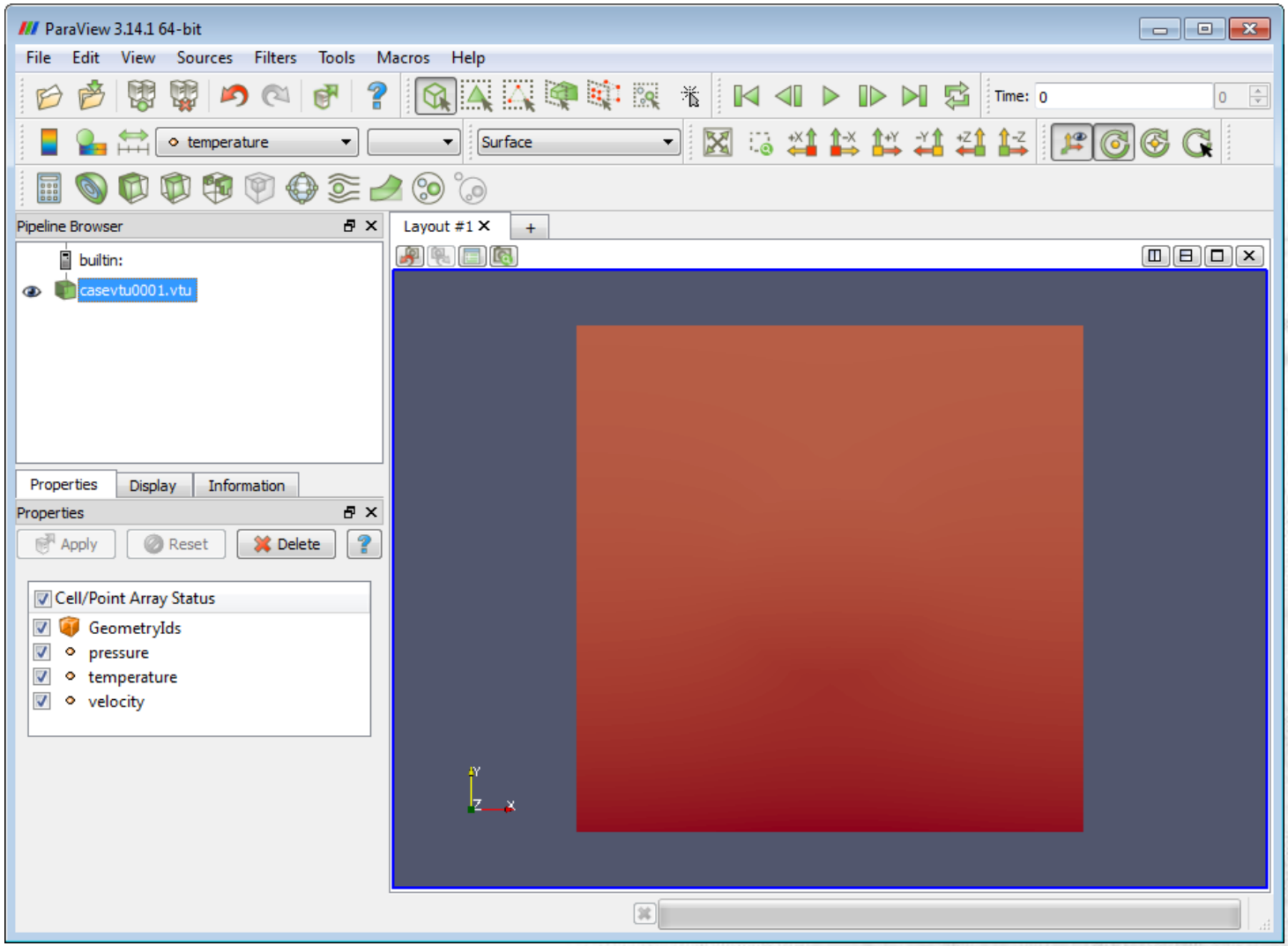
- Suffix of unstructured XML based VTU file is `.vtu`
- Timesteps numbered `#step`
- Partitions numbered with `#part`**par**`#step`
- Holder for vtu files in parallel is `.pvtu`

Loading data



Note: Paraview may have several datasets at the same time!

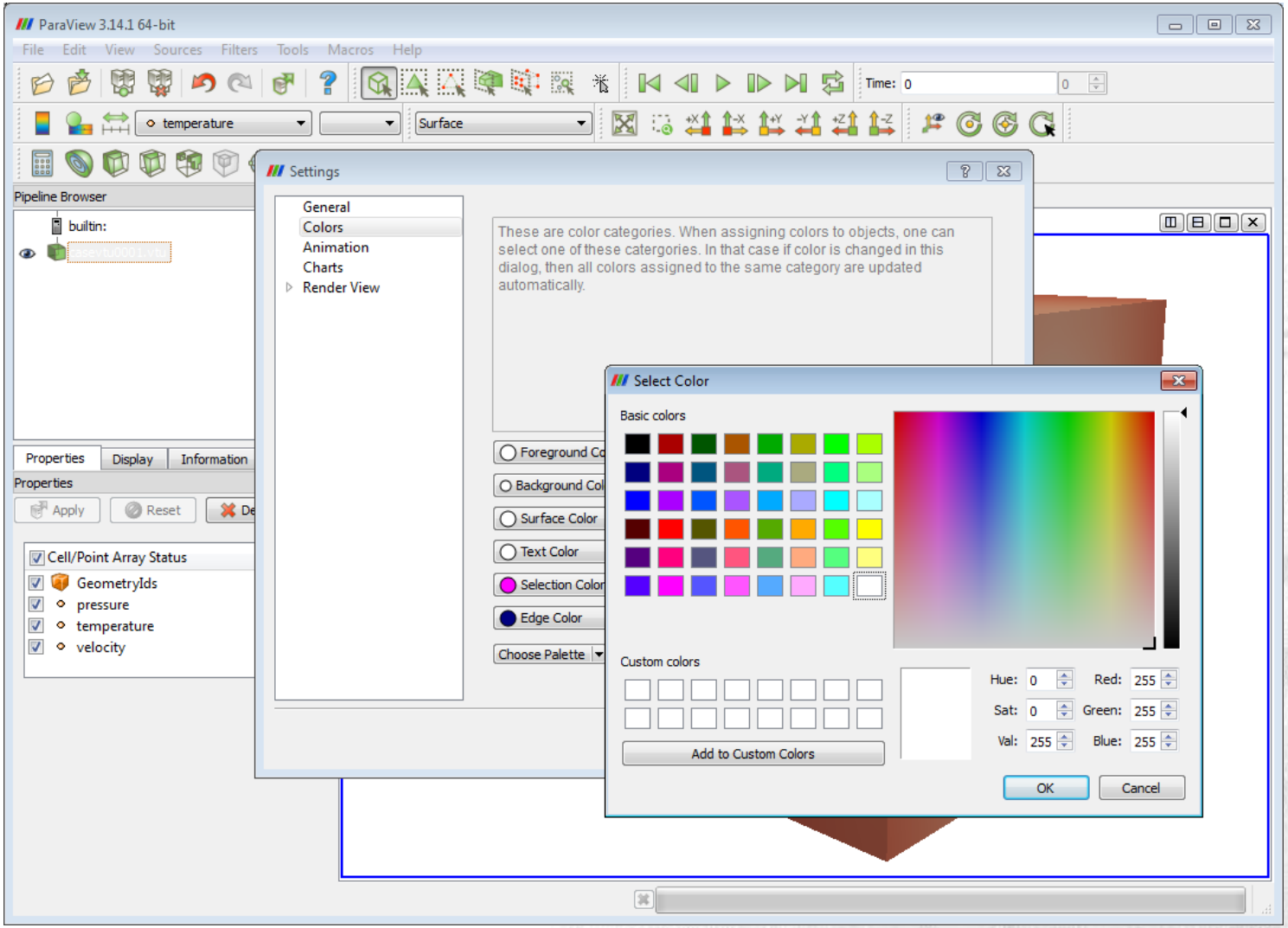
Solid color


ParaView 3.14.1 64-bit
File Edit View Sources Filters Tools Macros Help
Time: 0
temperature
Surface
Pipeline Browser
builtin:
casevtu0001.vtu
Properties Display Information
Properties
Apply Reset Delete
Cell/Point Array Status
GeometryIds
pressure
temperature
velocity
Layout #1

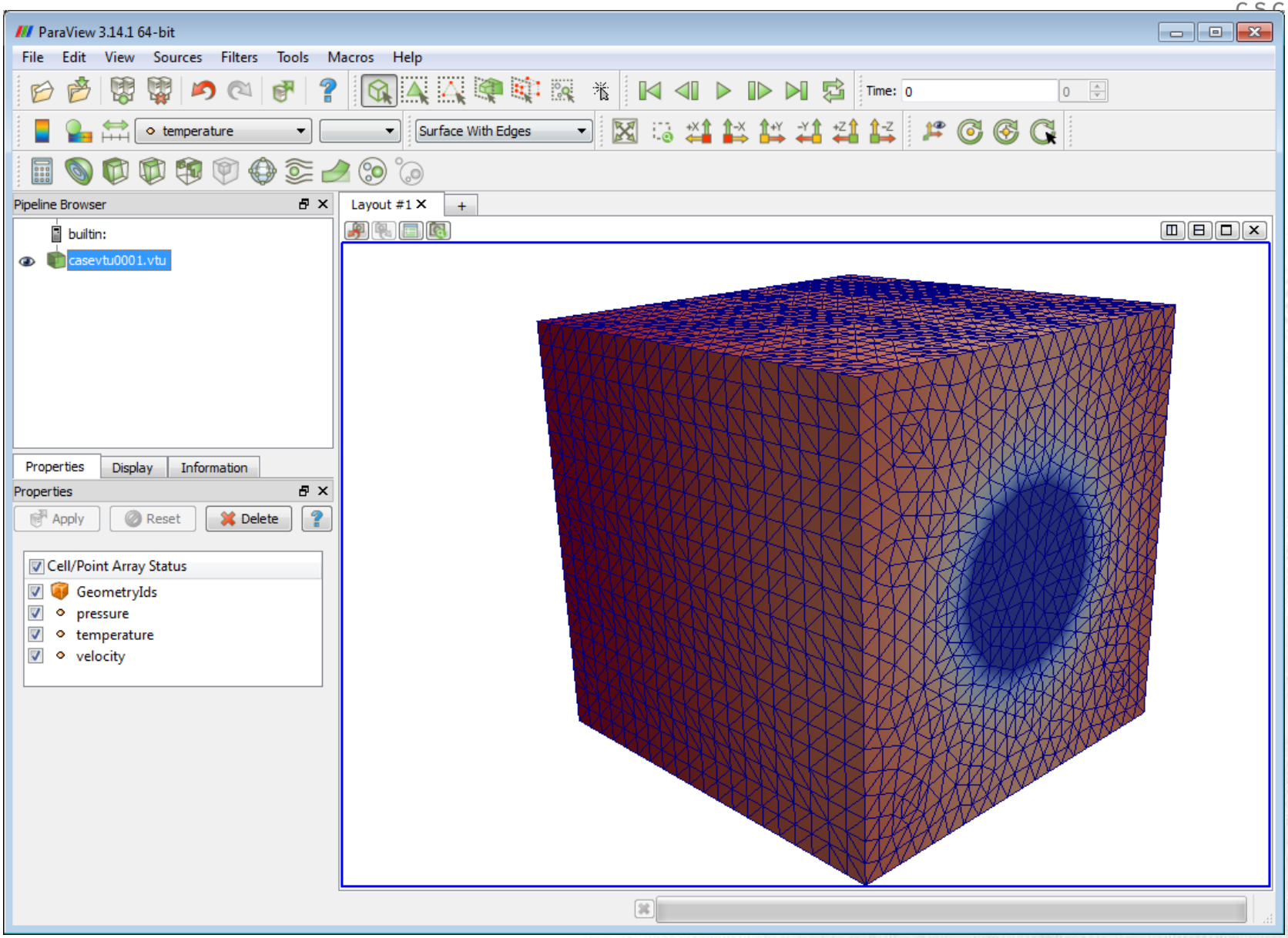
Moving object in Paraview

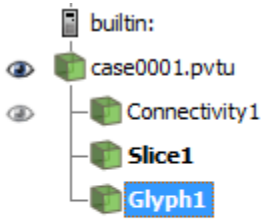
- Rotate
  - Mouse: Left bottom
- Scale
  - Mouse: Right bottom
- Translate
  - Mo*u*se: Center bottom

Setting background color



Color mesh with surface + edges

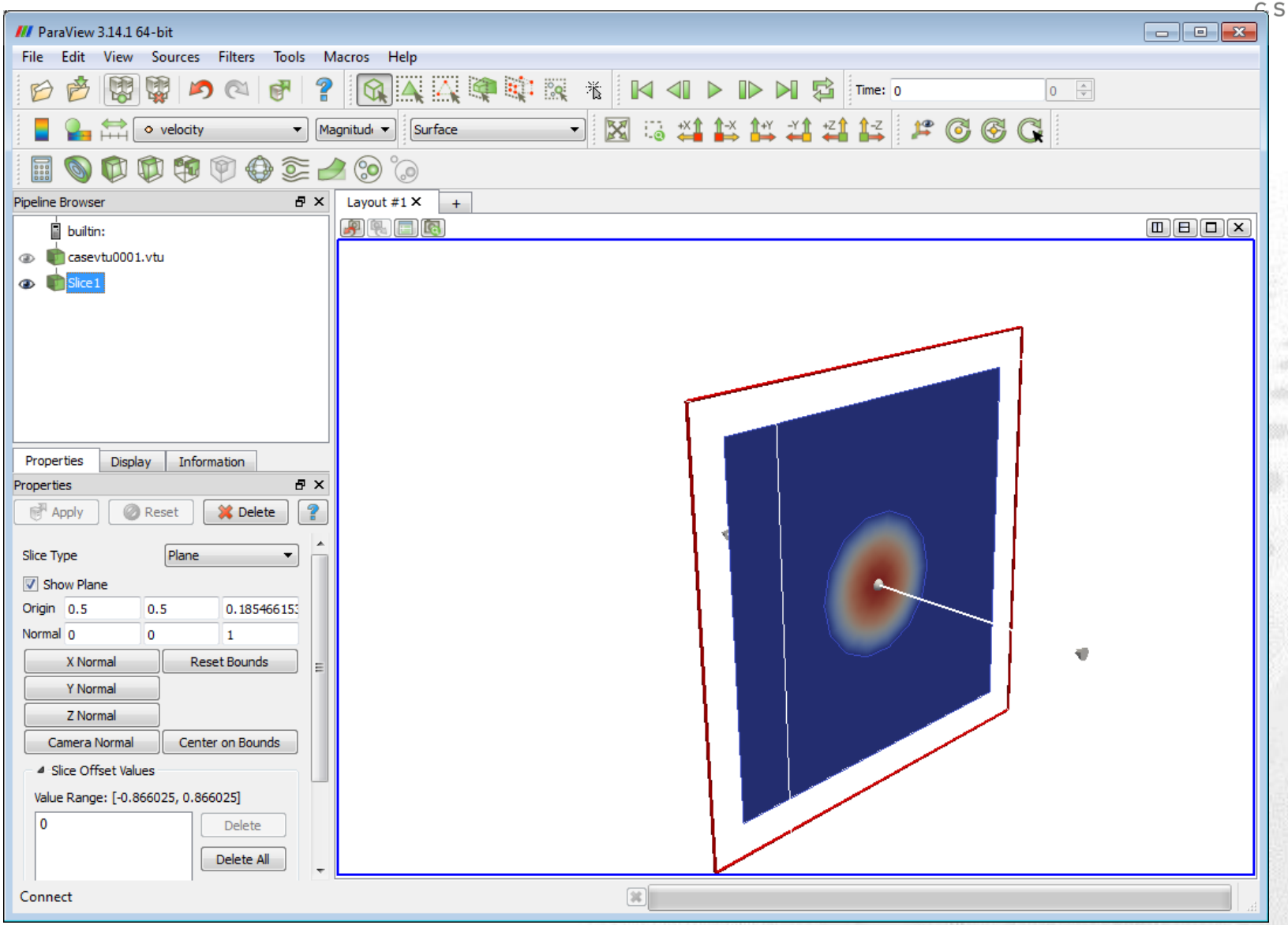




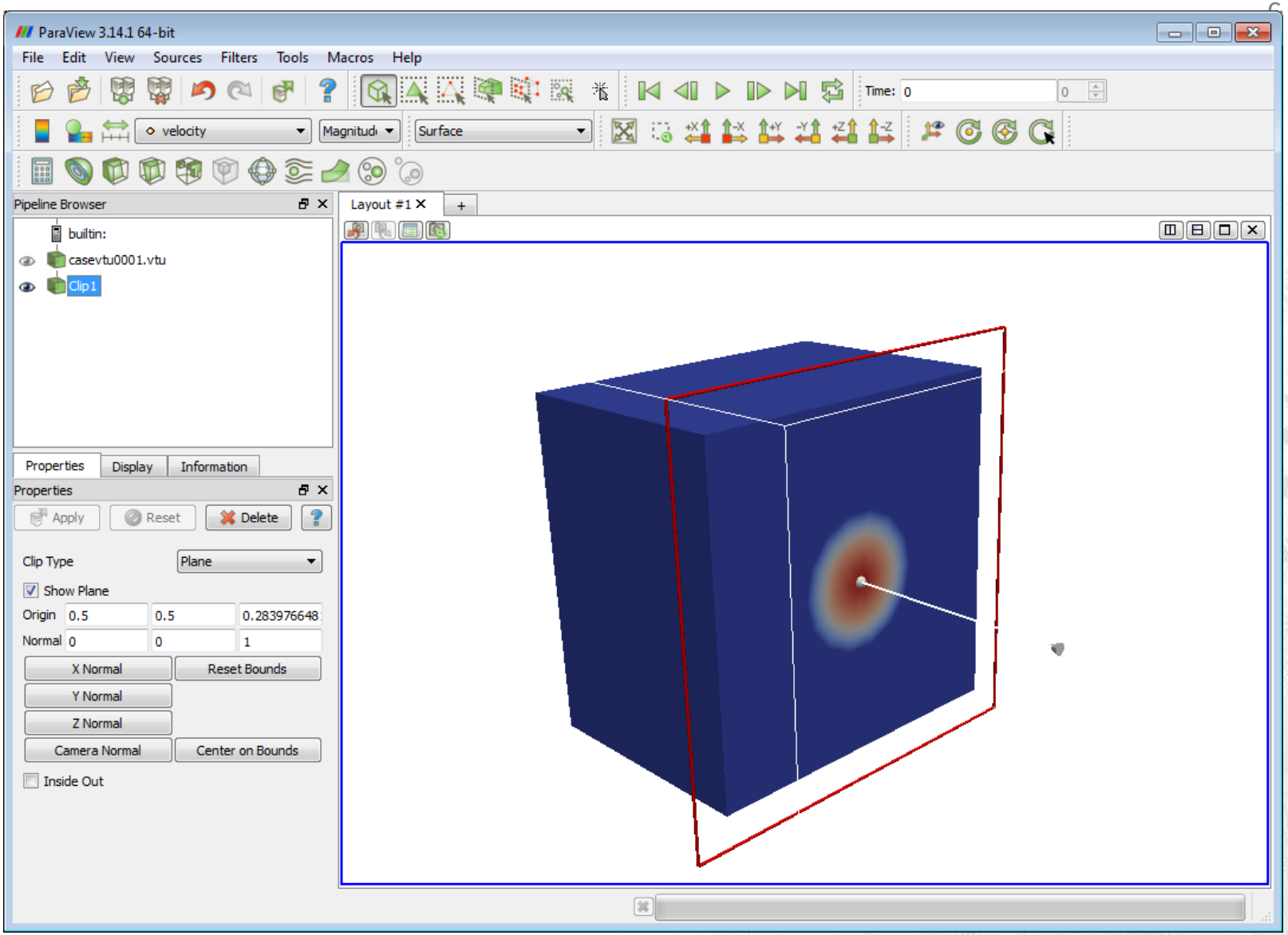
CSC

- Paraview uses extensively *filters* to create new datasets
- Filters and datasets may be set active or passive by clicking the eye
- Several datasets may be visualized at the same time

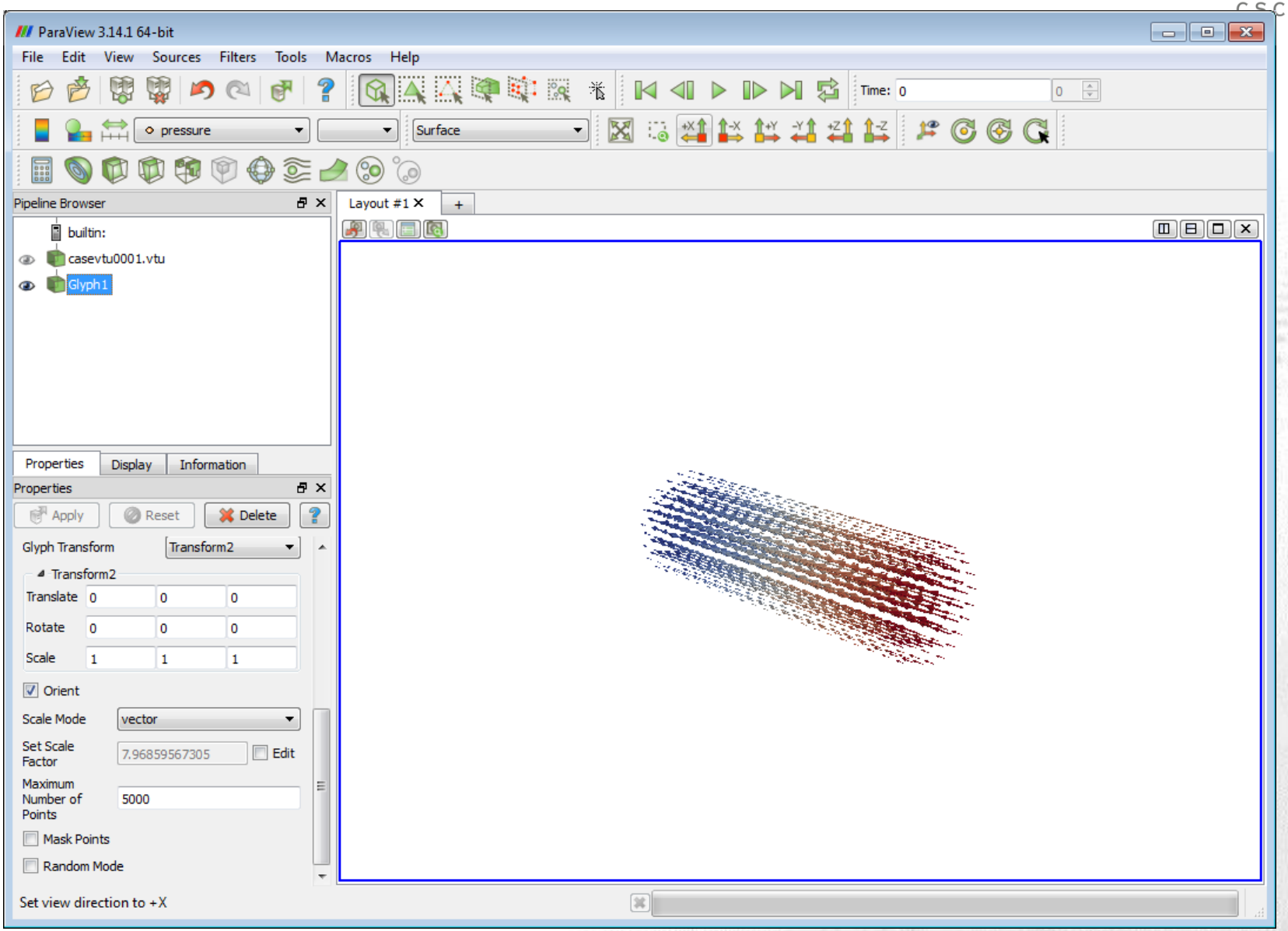
Plotting a slice



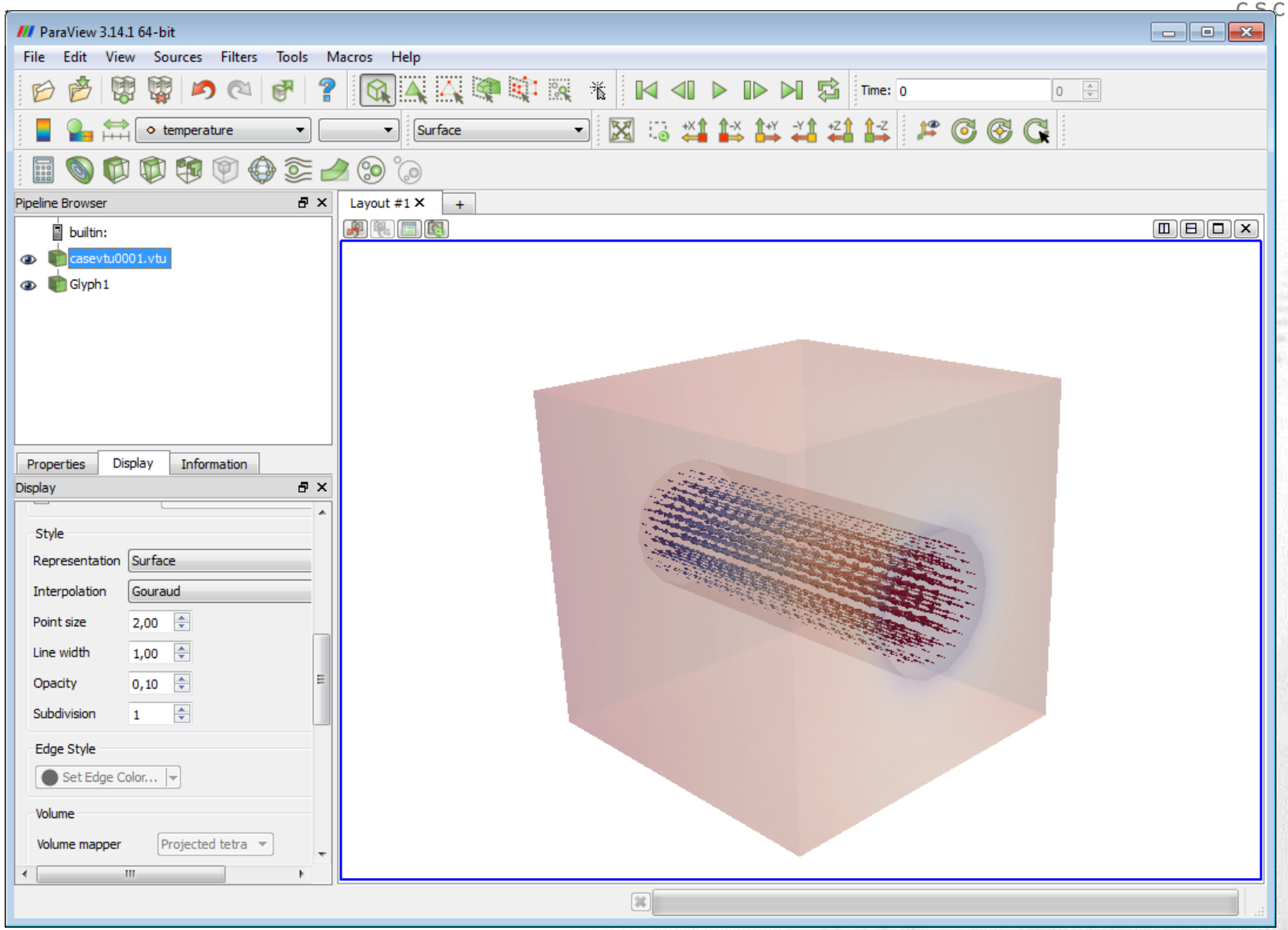
Plotting a clip



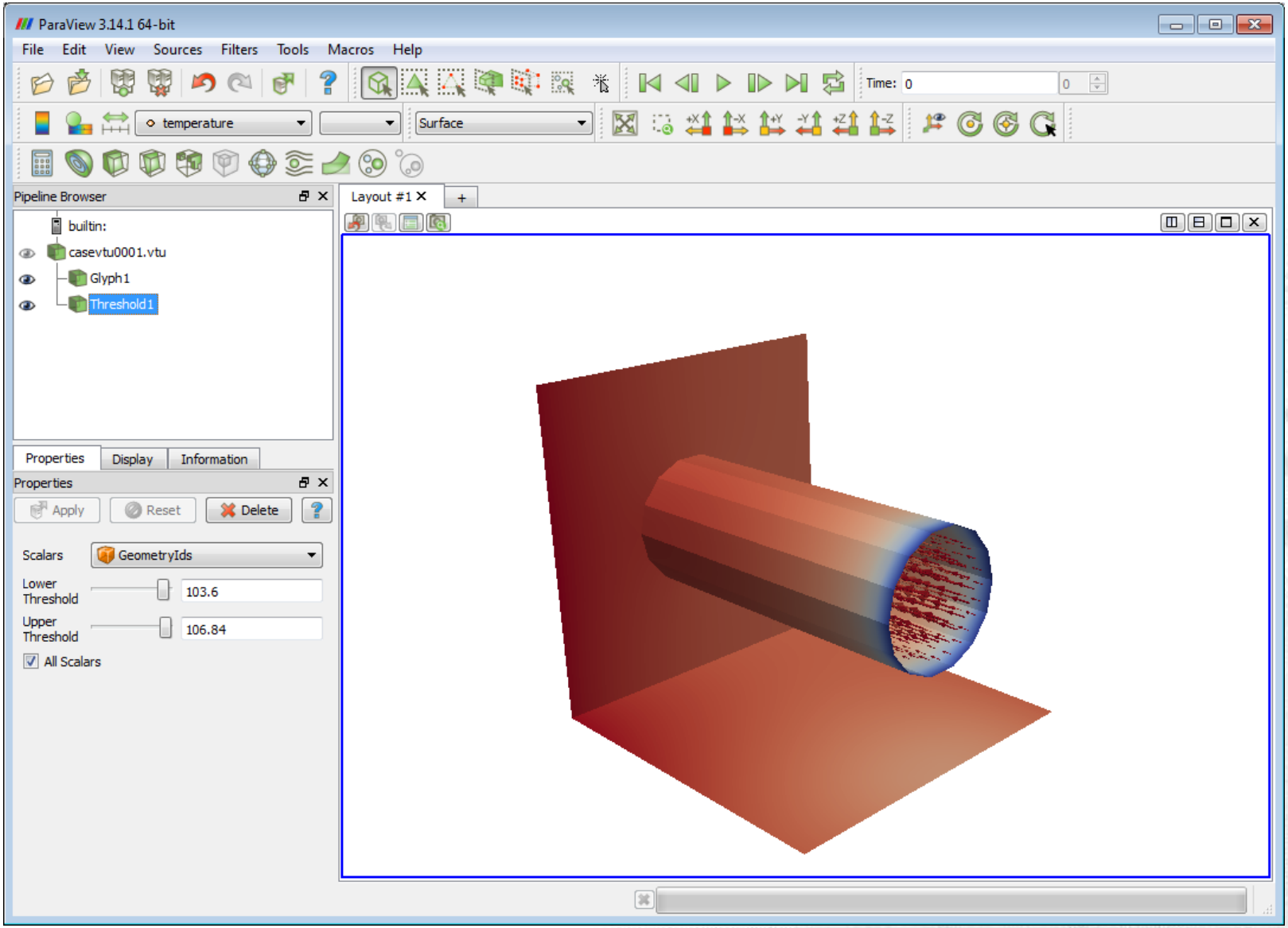
Vector plot


ParaView 3.14.1 64-bit
File Edit View Sources Filters Tools Macros Help
Time: 0
pressure
Surface
Pipeline Browser
builtin:
casevtu0001.vtu
Glyph1
Layout #1
Properties Display Information
Properties
Apply Reset Delete
Glyph Transform Transform2
Transform2
Translate 0 0 0
Rotate 0 0 0
Scale 1 1 1
Orient
Scale Mode vector
Set Scale Factor 7.96859567305 Edit
Maximum Number of Points 5000
Mask Points
Random Mode
Set view direction to +X

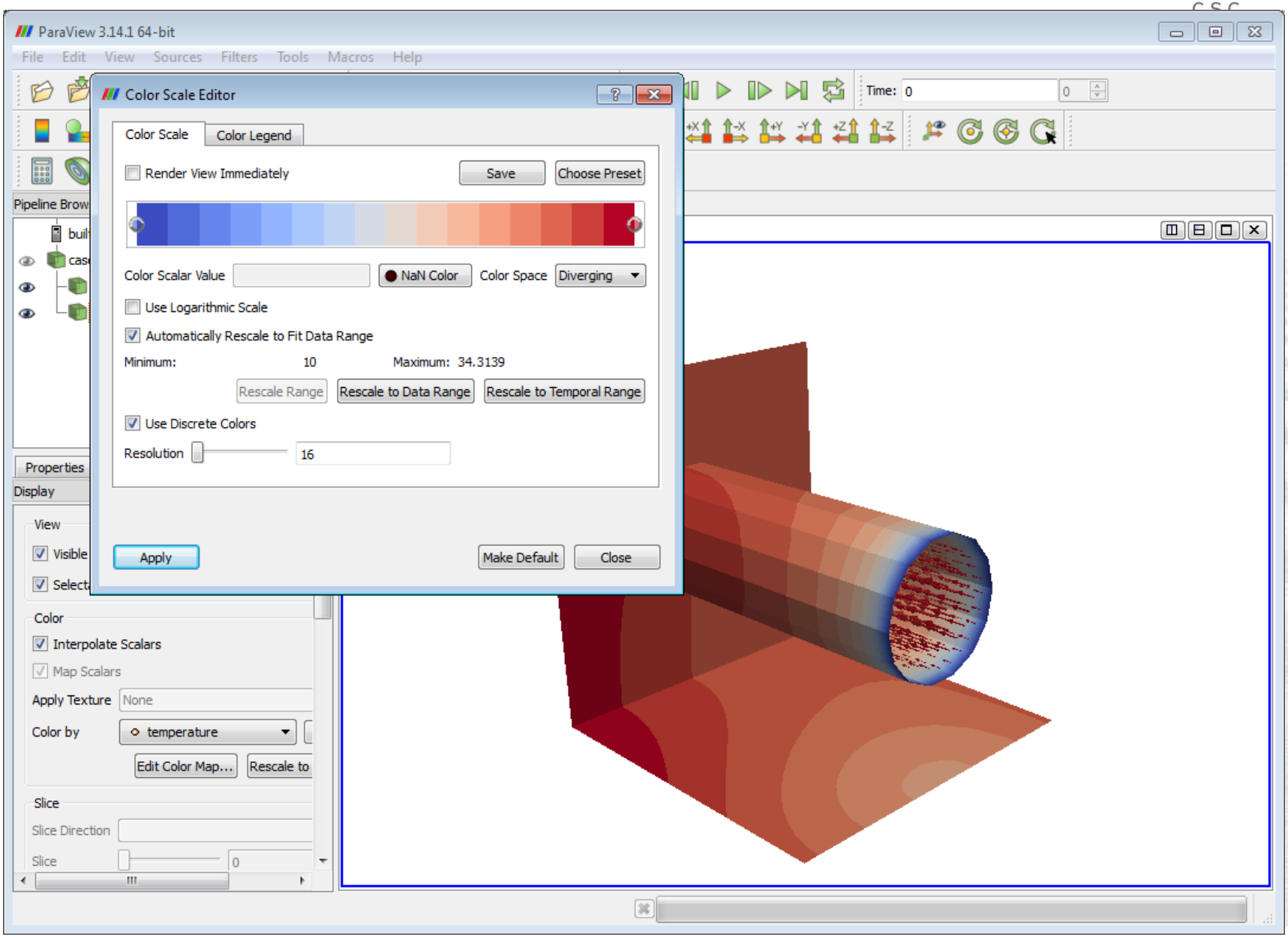
Vector plot + opaque solid surface



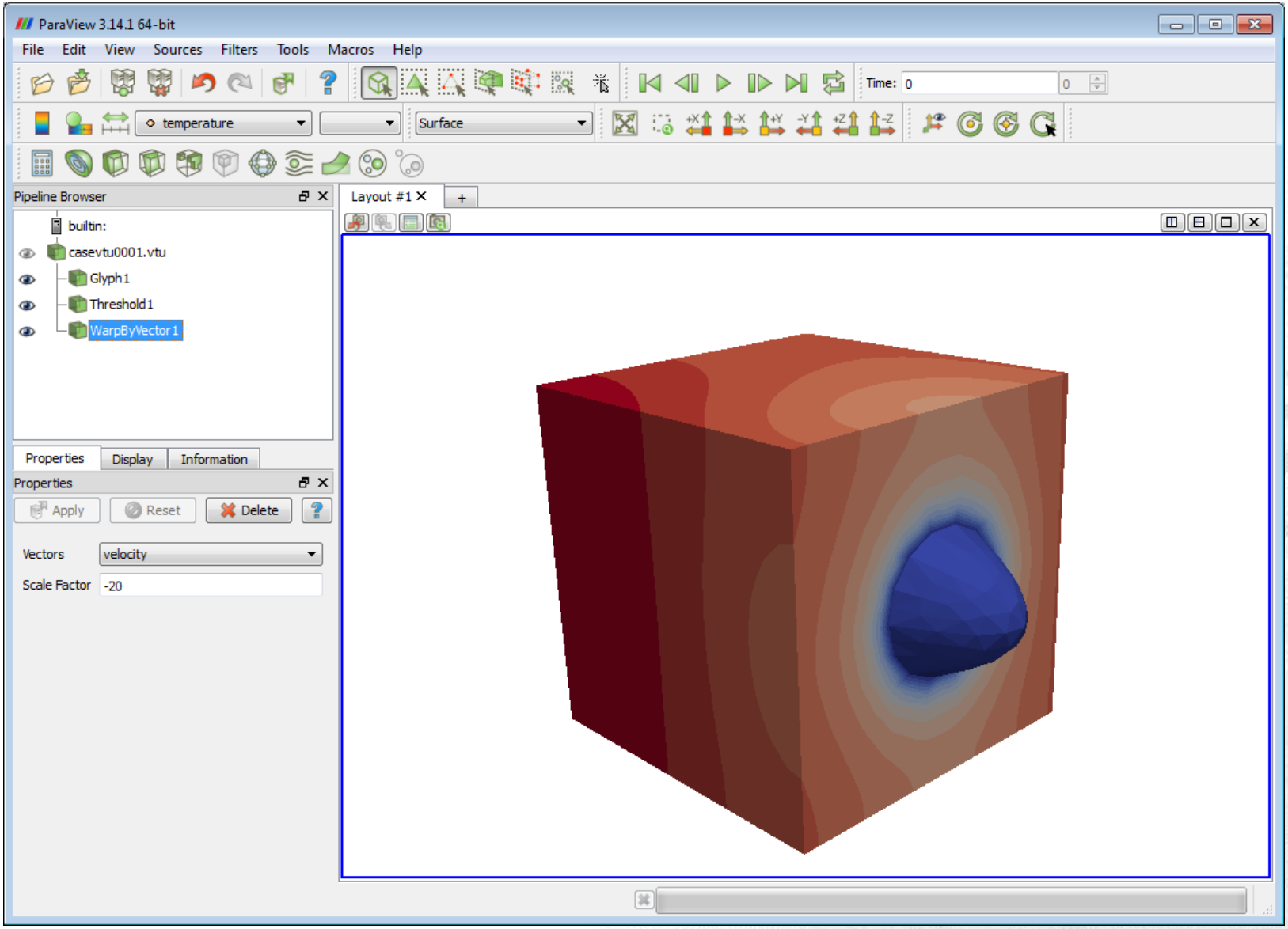
Vector plot + solid surface with Id treshold



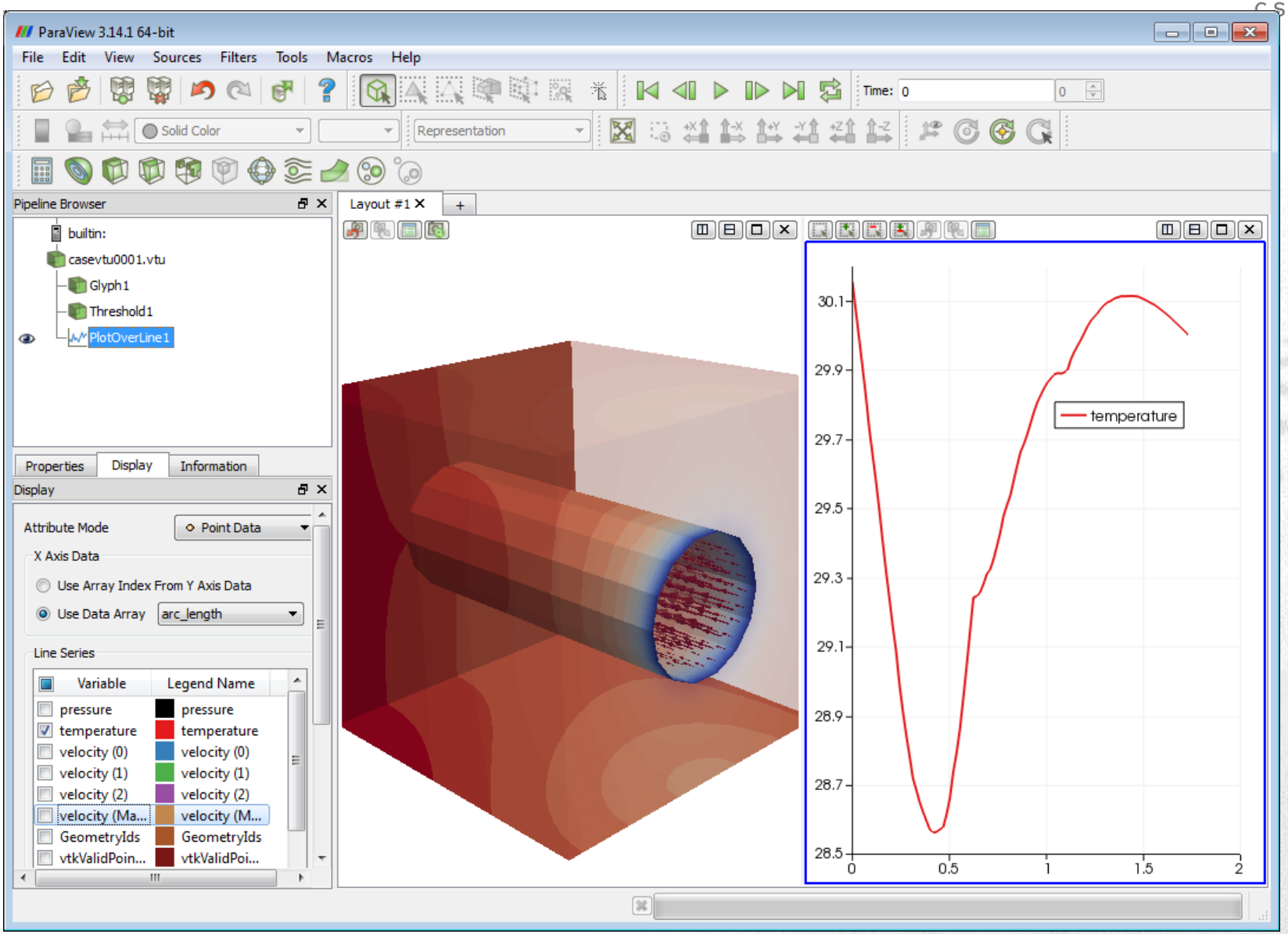
Change of colormap



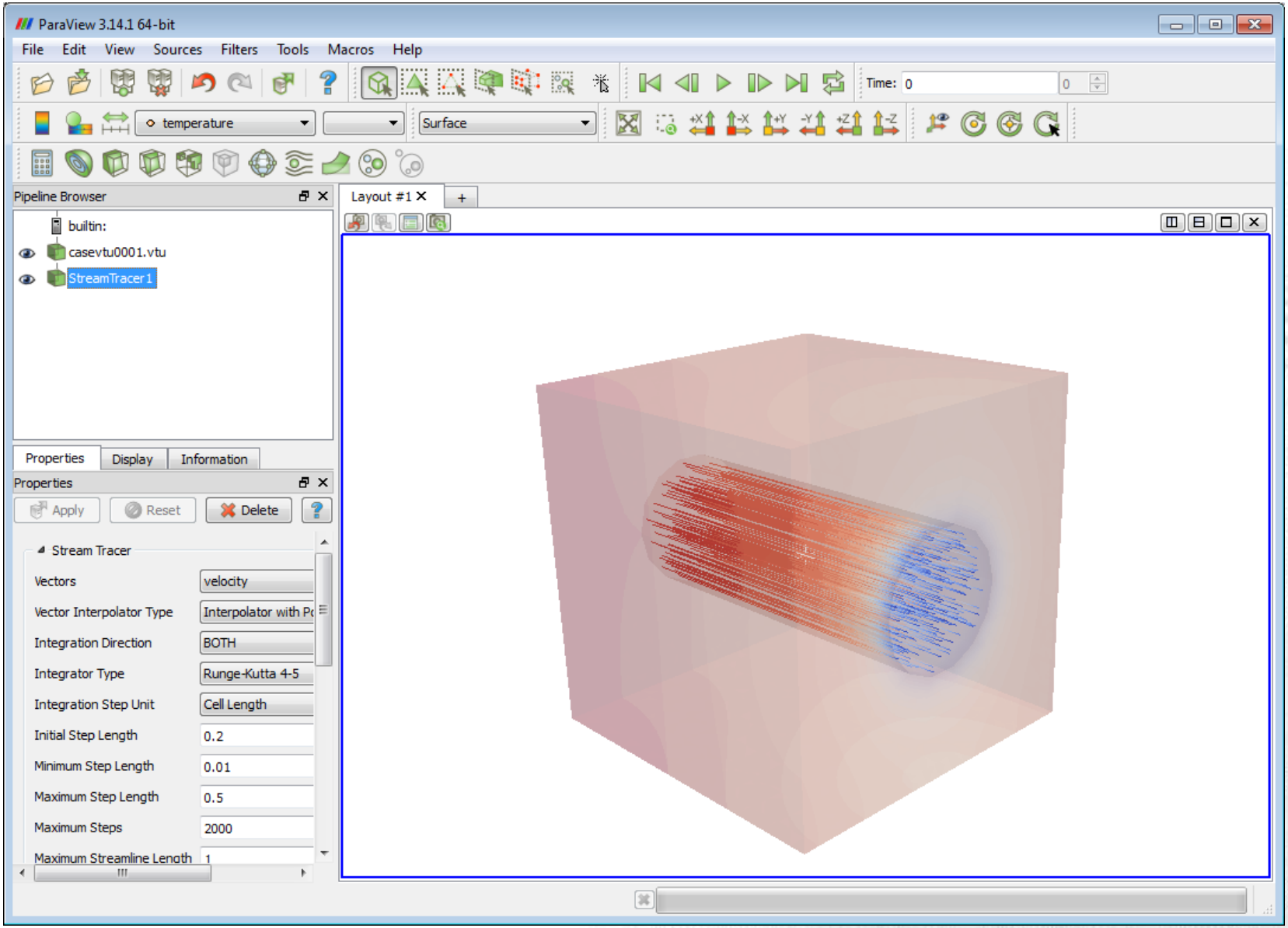
Deformation – WarpByVector filter



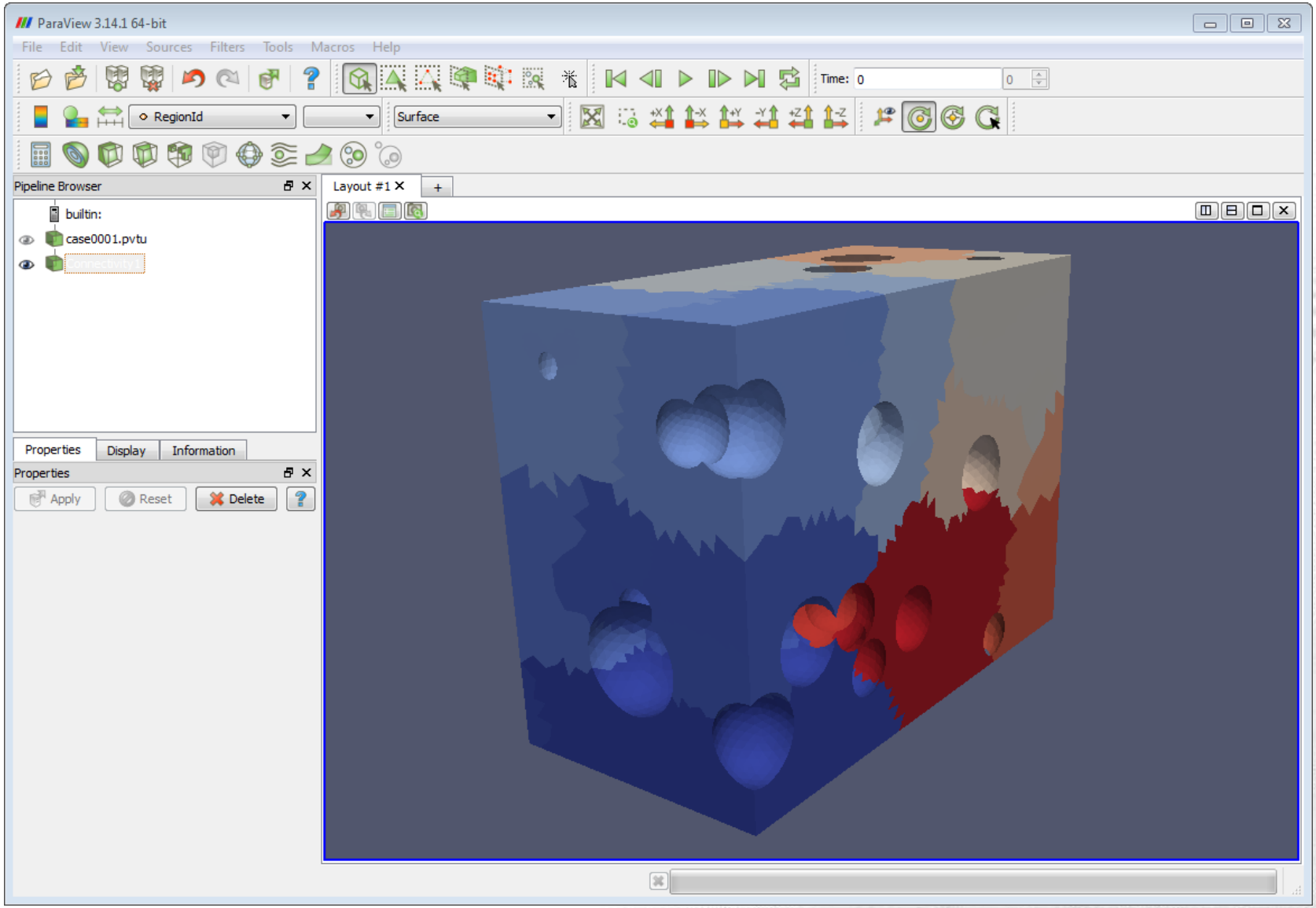
Plot line – PlotOverLine filter



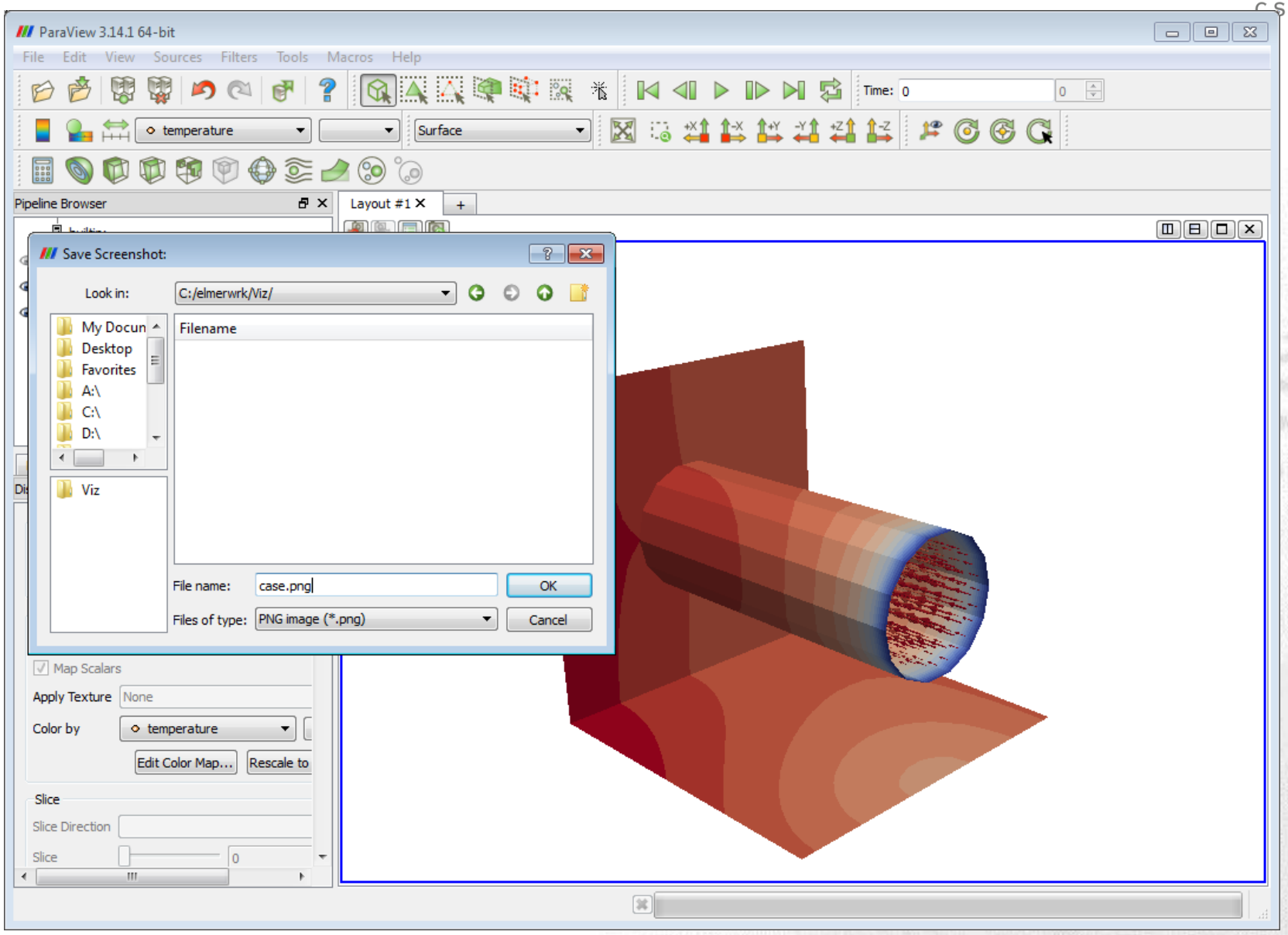
Streamlines – Filter StreamTracer



Partitioning – Connectivity filter



Saving figures



Saving animations with Paraview

- The only packing method that comes with Paraview by default is motion AVI
- It is advicable to save the animation as separate files
- You may use ElmerClips to make mpg animations of the separate png figures

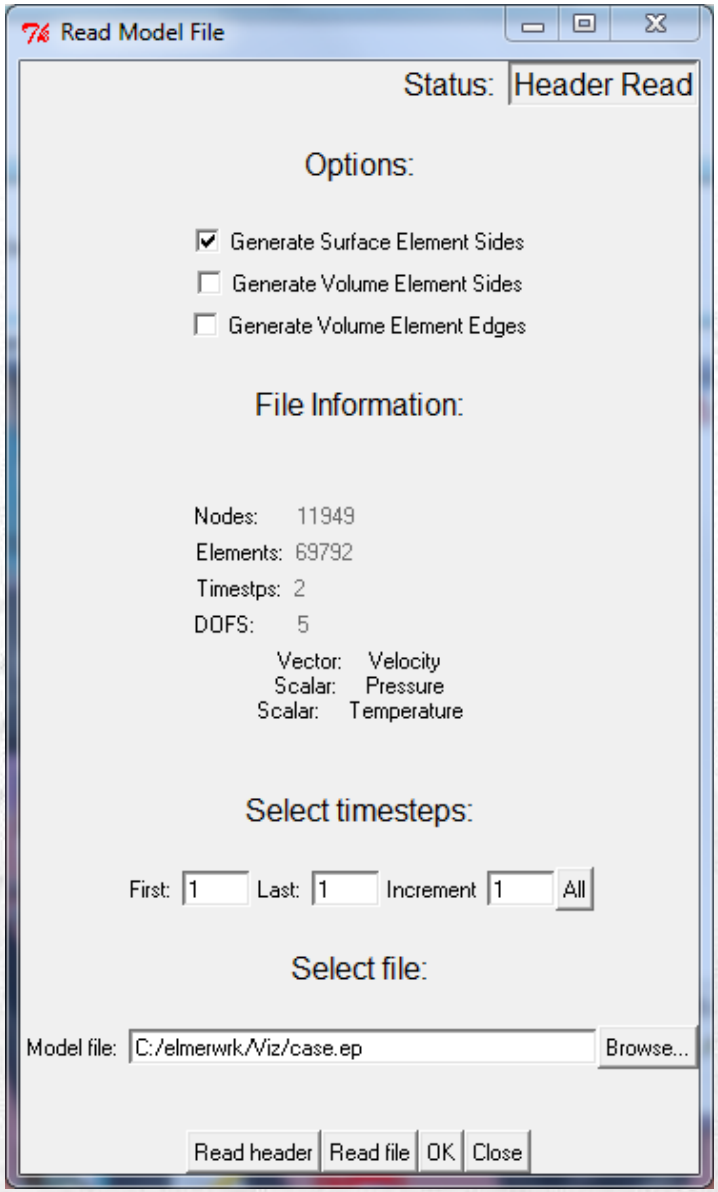
Visualization with ElmerPost

How to write files for ElmerPost

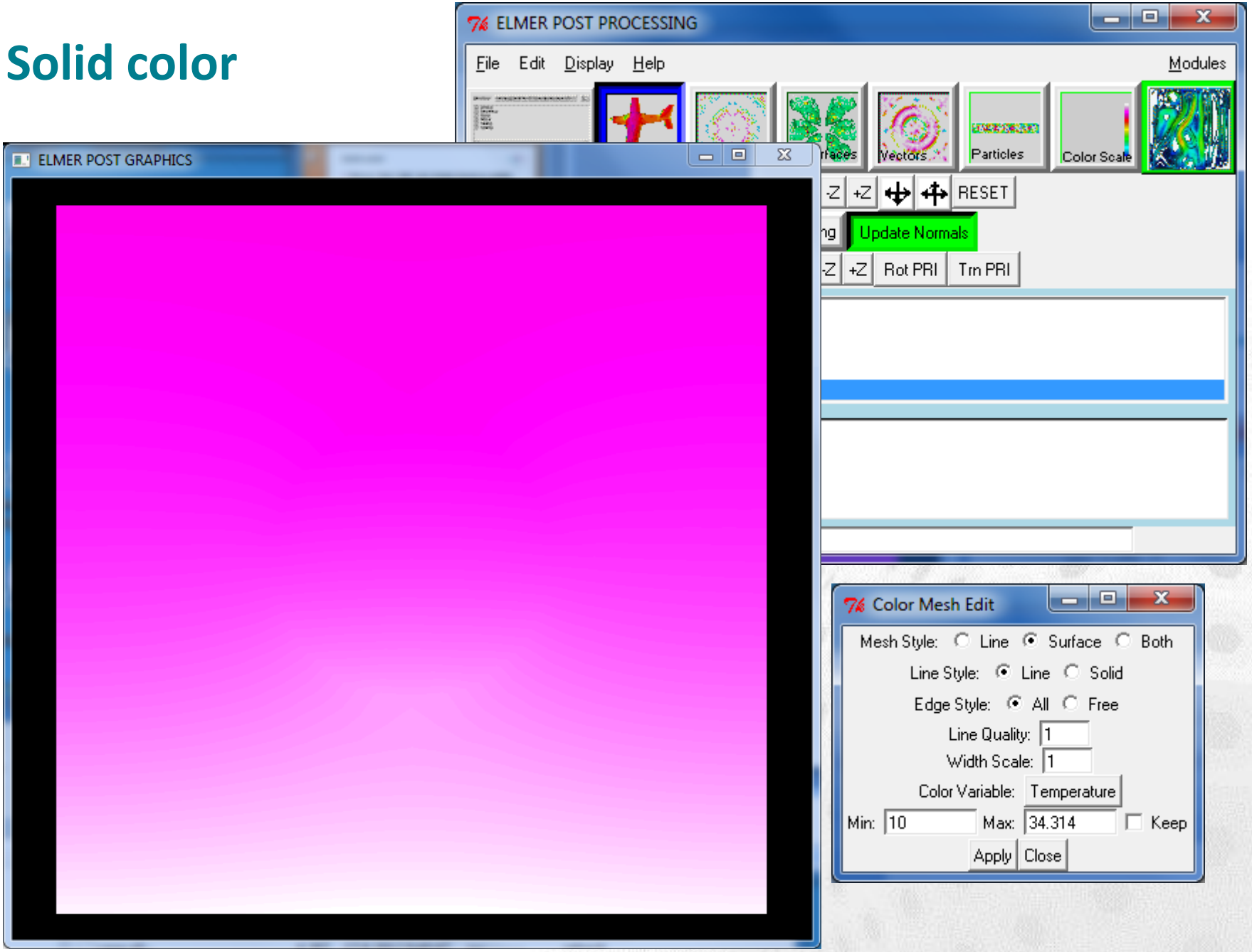
- Default suffix is `.ep`
- May be requested in Simulation section
  `Post File = case.ep`
- Or using ResultOutputSolver with
  `Output format = ElmerPost`

Loading data

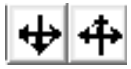
- Assume data in case.ep
- `File -> Open -> case.ep`
- Here the timesteps are chosen
- If element edges or sides are not defined for BCs they may have to be created here



Solid color

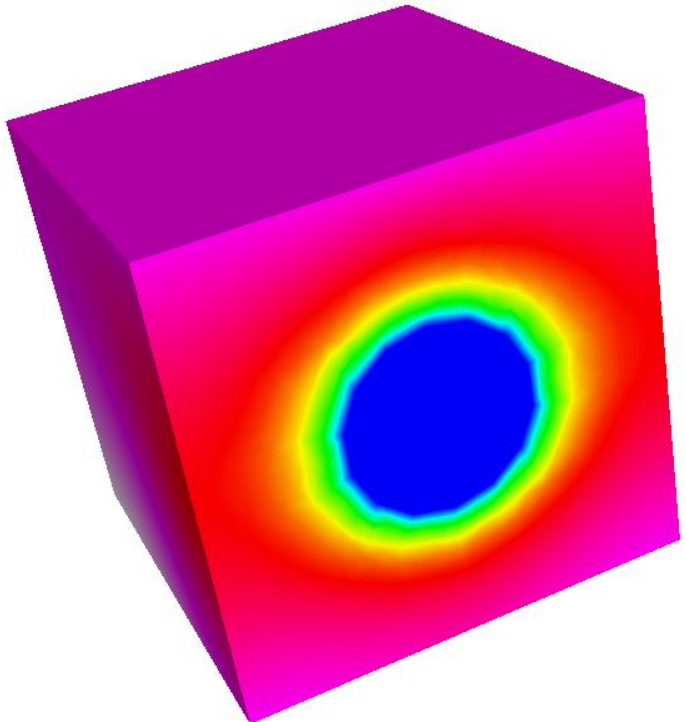

ELMER POST PROCESSING
File
Edit
Display
Help
Modules
Vectors
Particles
Color Scale
RESET
Update Normals
Rot PRI
Trn PRI
ELMER POST GRAPHICS
Color Mesh Edit
Mesh Style: Line Surface Both
Line Style: Line Solid
Edge Style: All Free
Line Quality: 1
Width Scale: 1
Color Variable: Temperature
Min: 10
Max: 34.314
Keep
Apply
Close

Moving object in ElmerPost

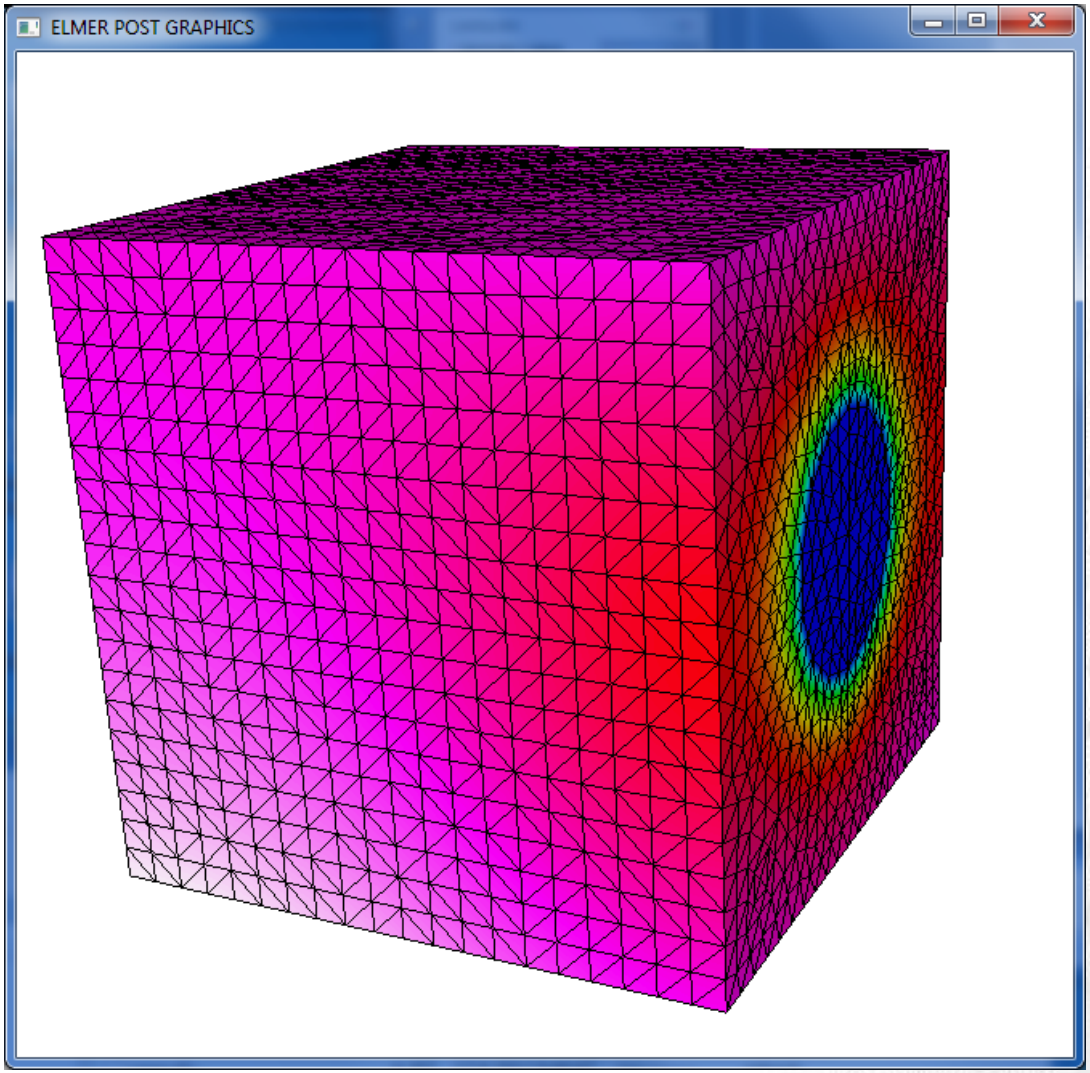
- Rotate
  - Mouse: Right bottom
  - Click: 
  - Command line, e.g.: `rotate 30 45 60`
- Scale
  - Mouse: Both bottoms
  - Click: 
  - Command line: `scale 1 10 1`
- Translate
  - Mouse: Left bottom
  - Click: 
  - Command line: `translate 1 2 3`

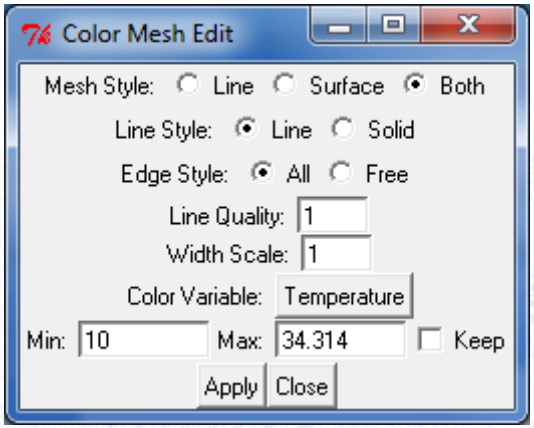
Setting background color

- Click:
  - Edit -> Background
  - Set 100.0 100.0 100.0 for white
- Command line
  - `background 100 100 100`

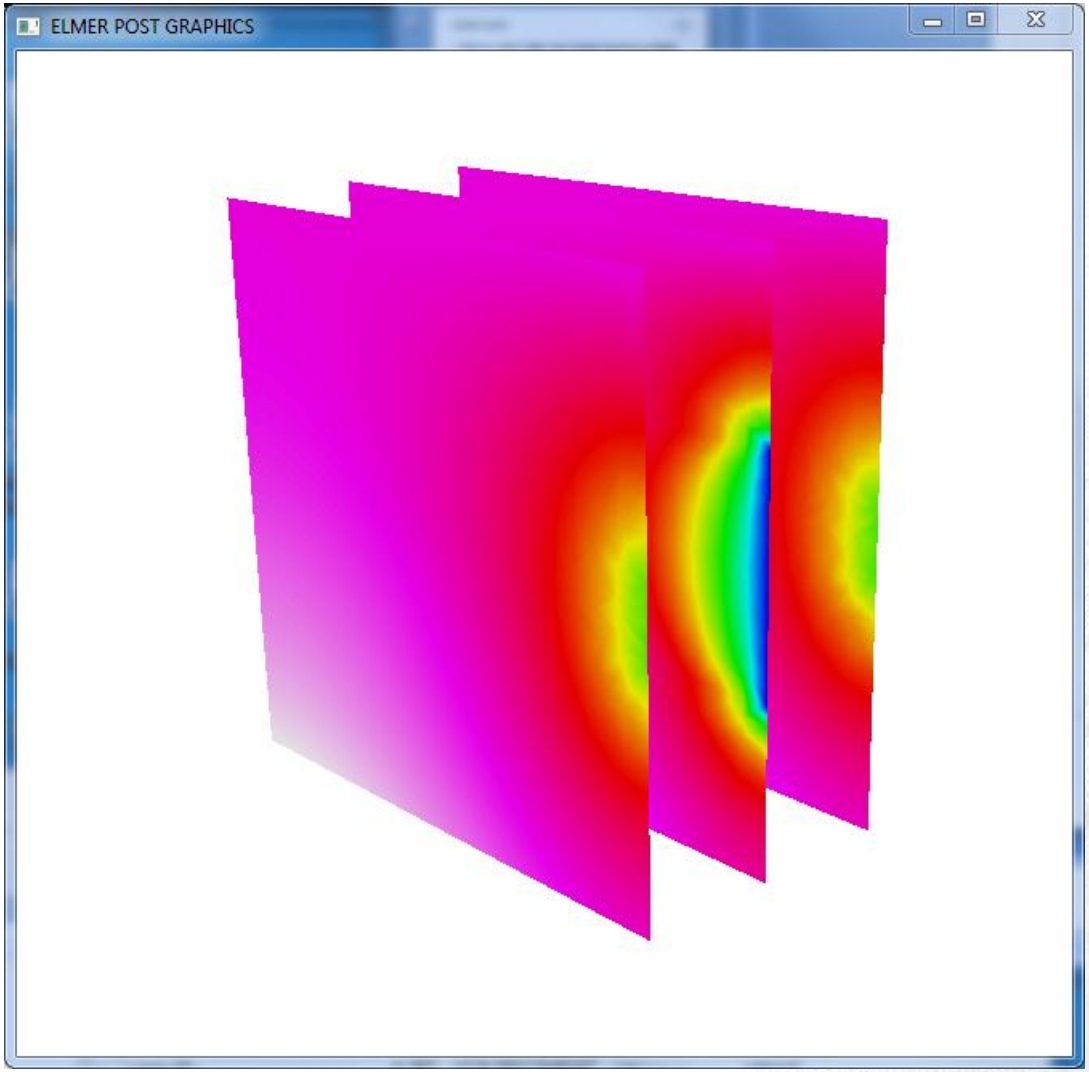


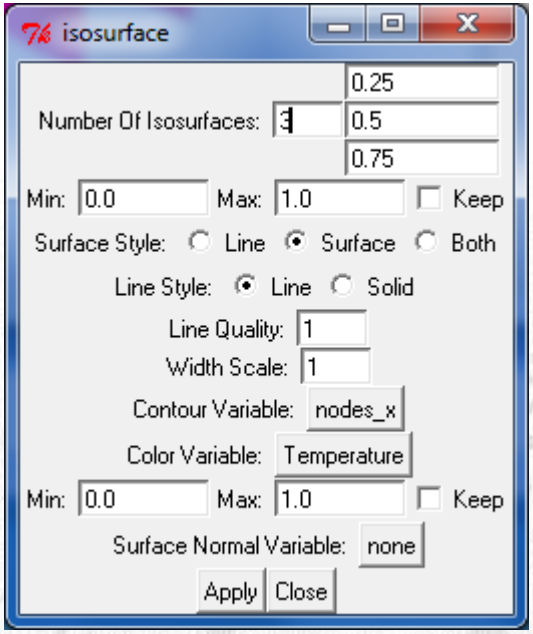
Color mesh with surface + edges



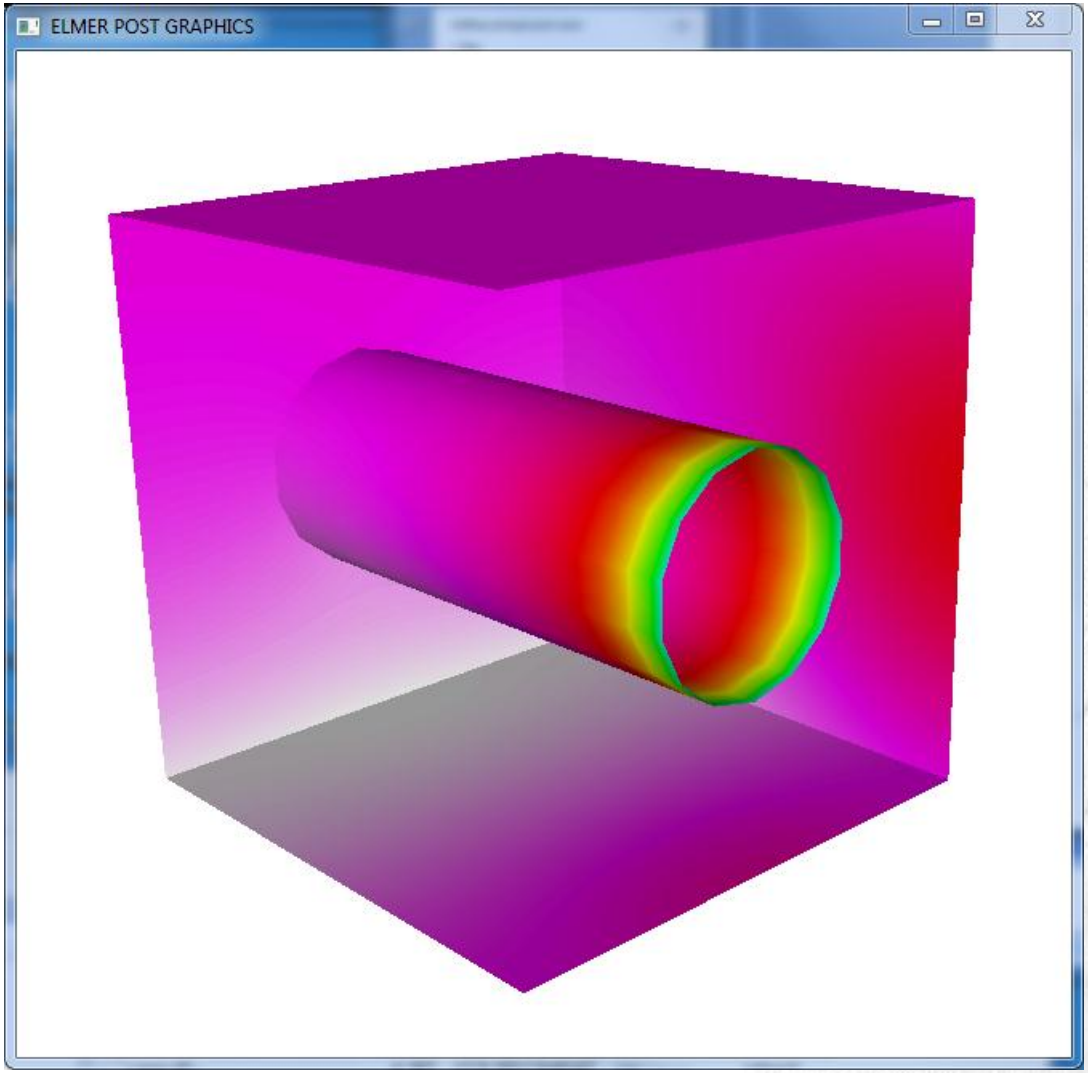


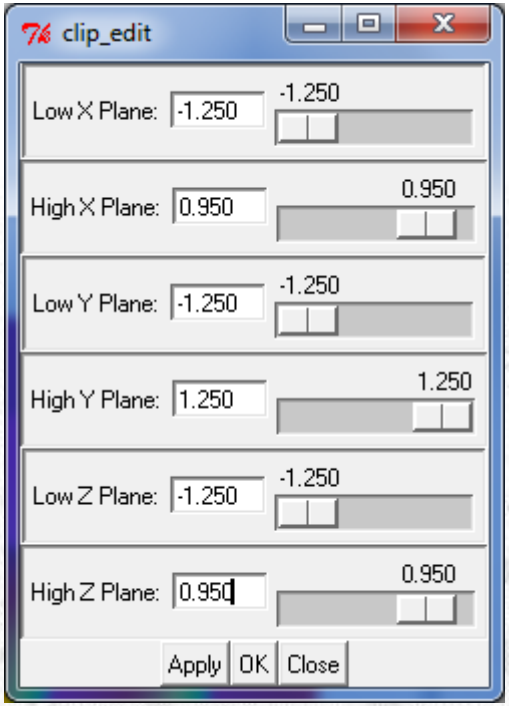
Plotting isosurfaces



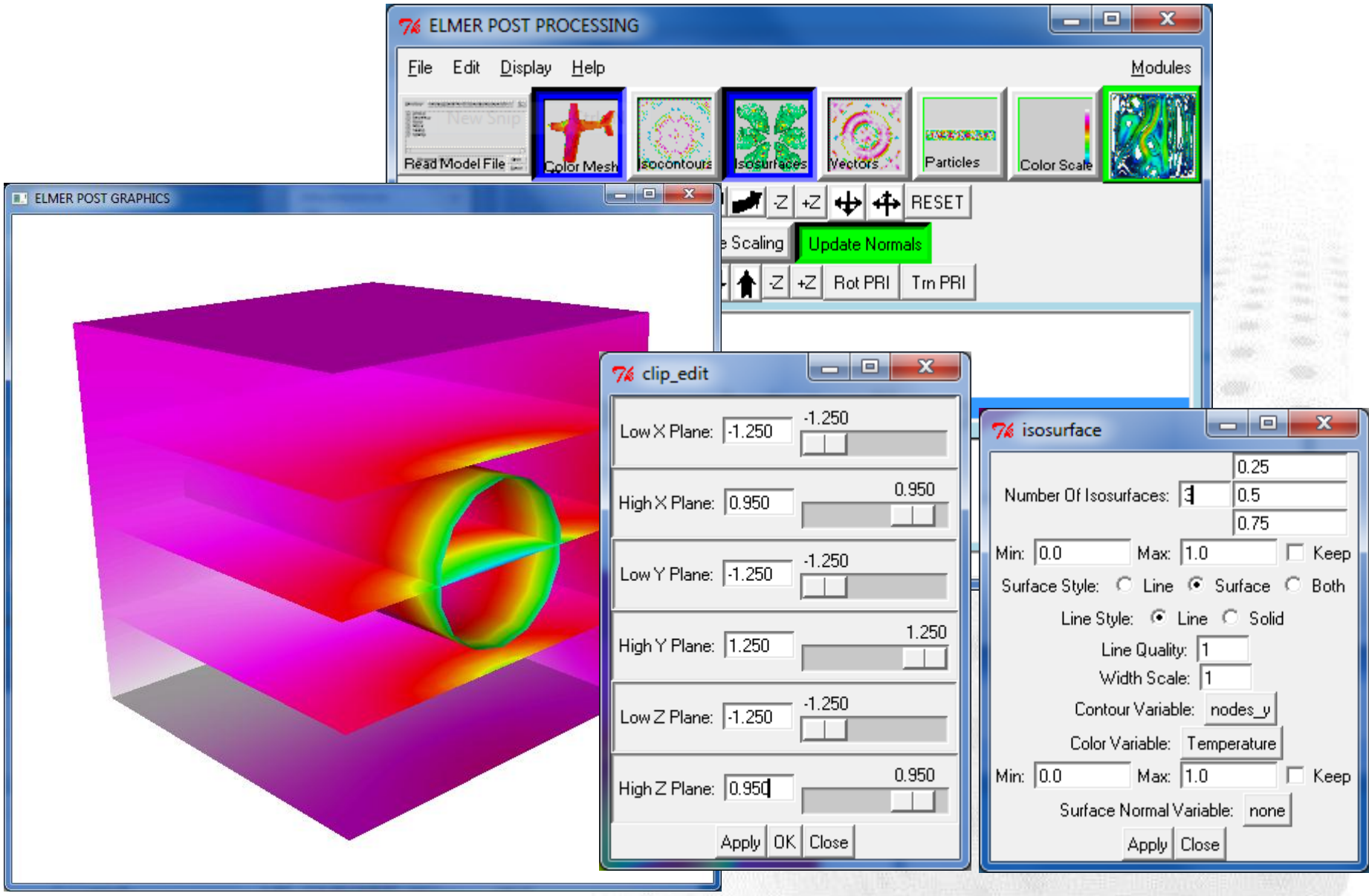


Using clip planes

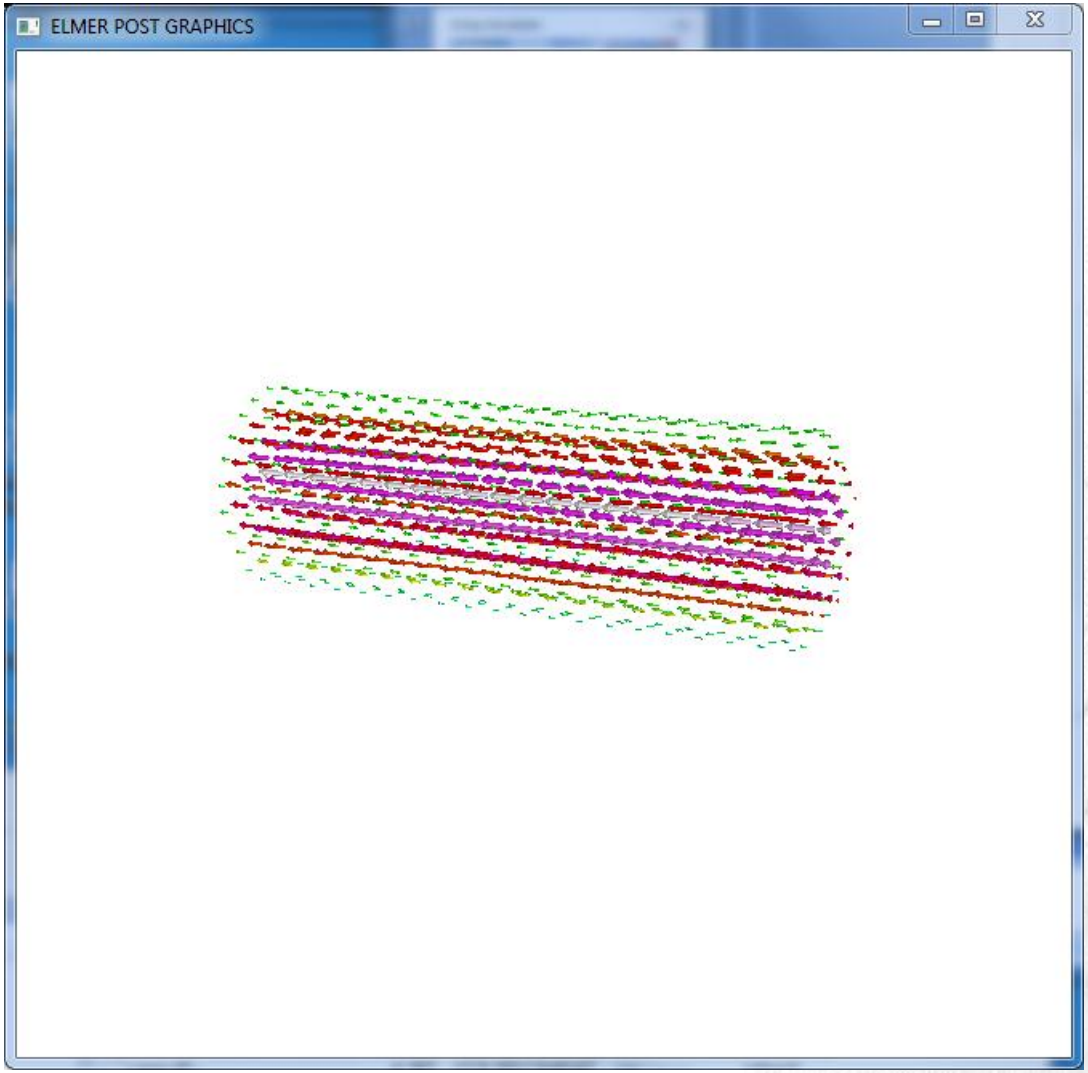


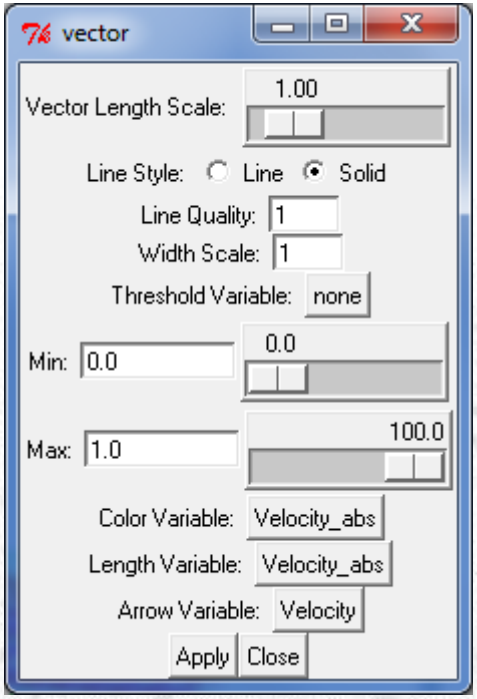


Isosurface + surface plot + clip planes

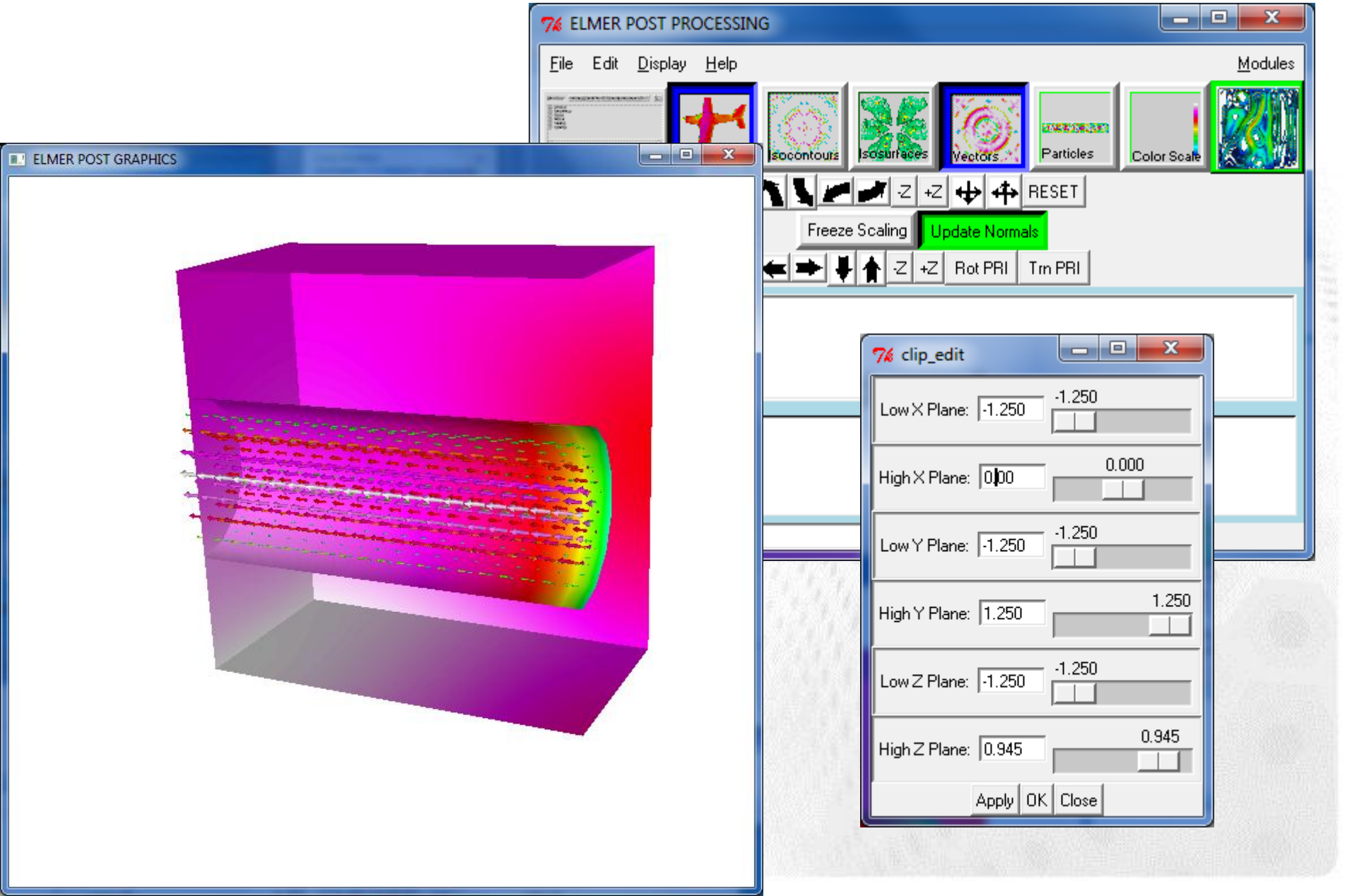


Vector plots

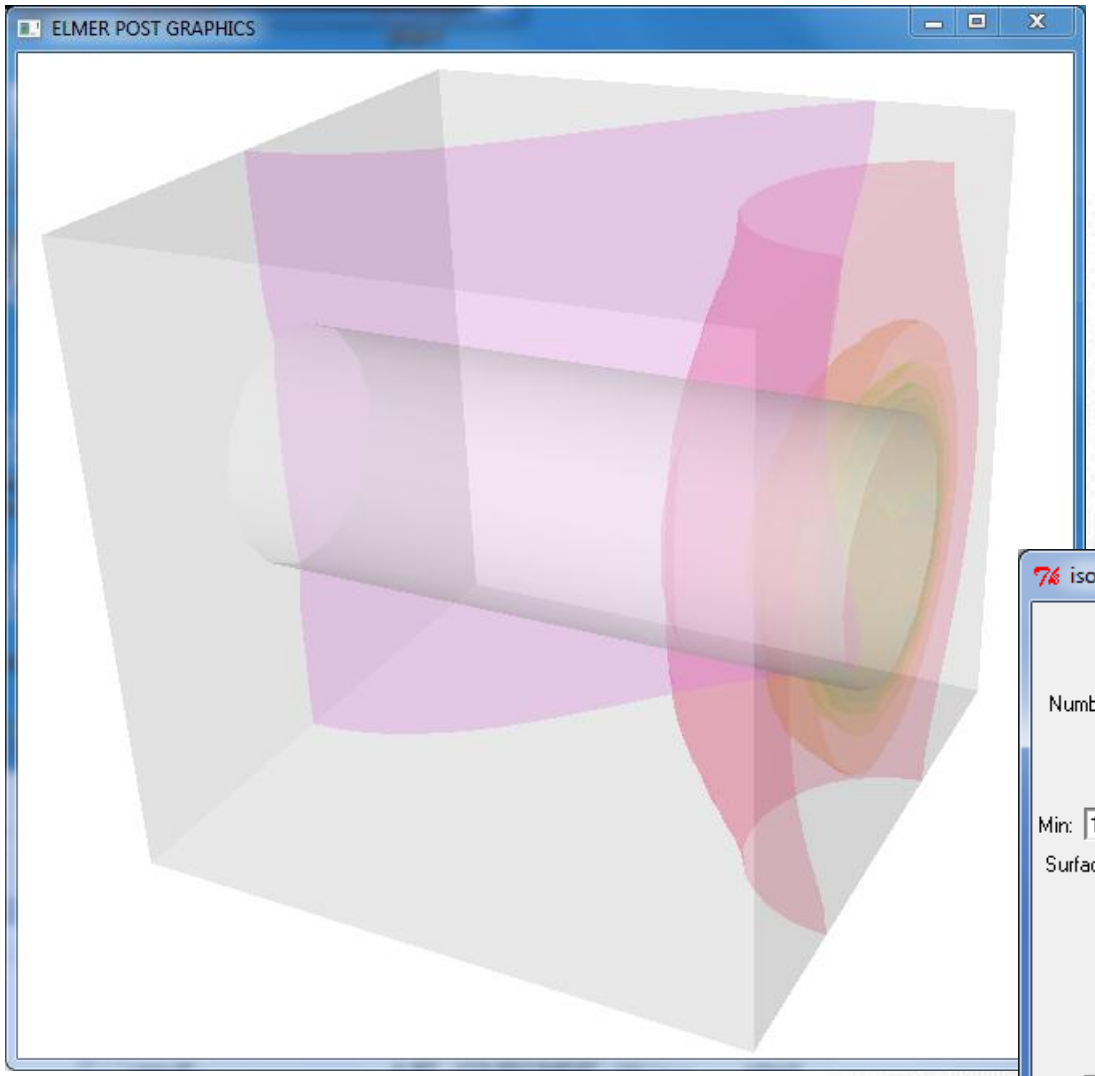


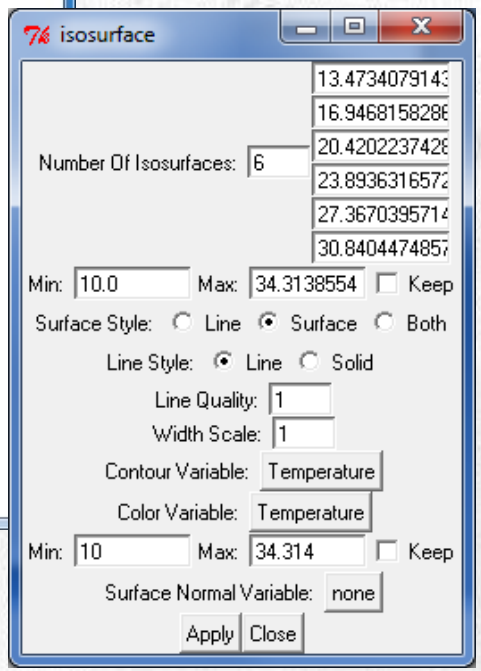


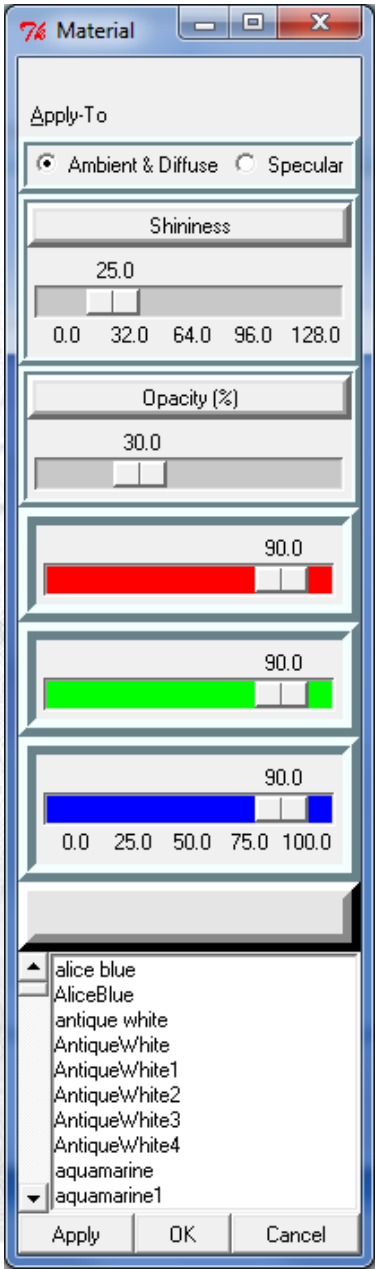
Vector plot + solid surface



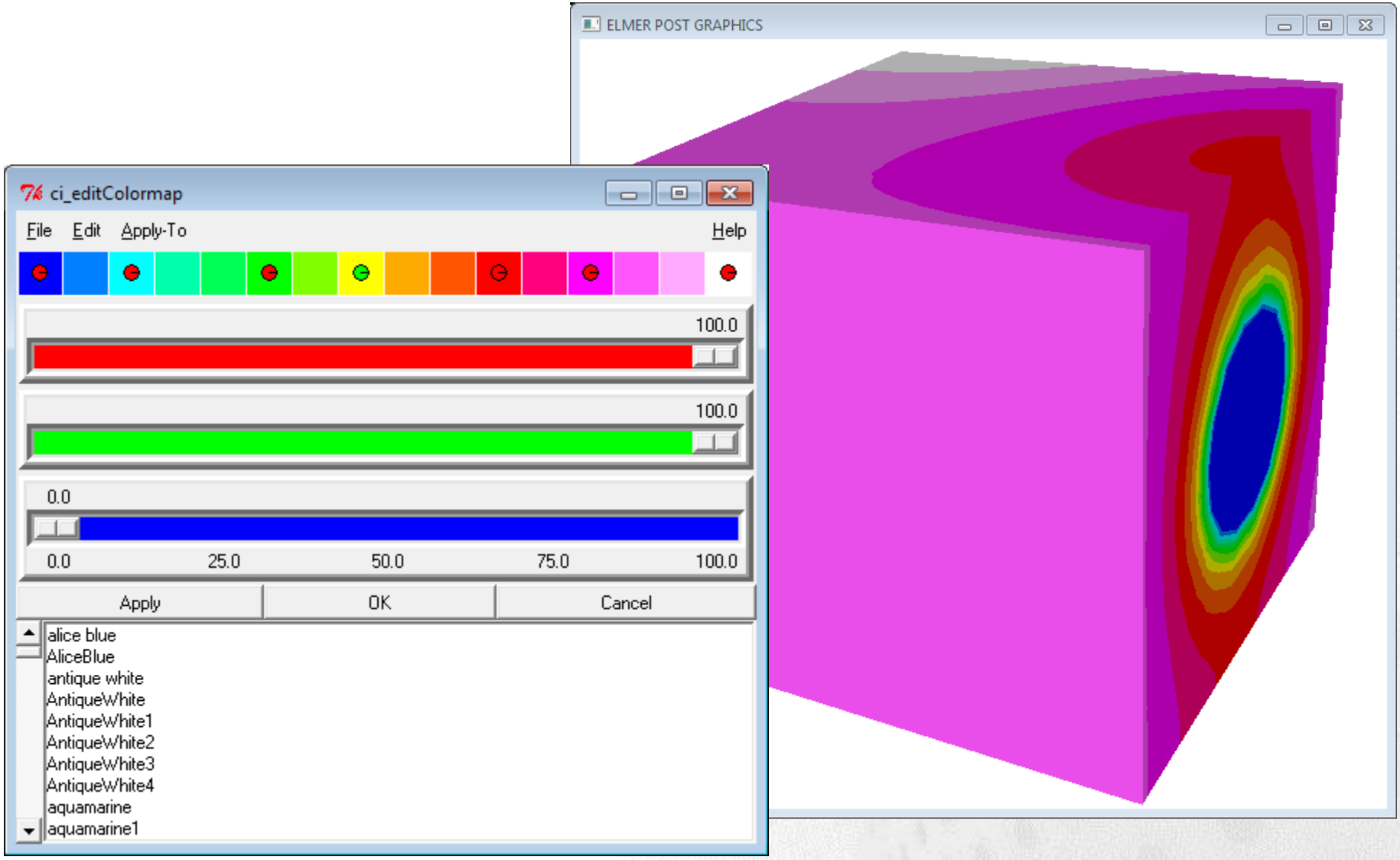
Surface plot + Isosurfaces + Opaque



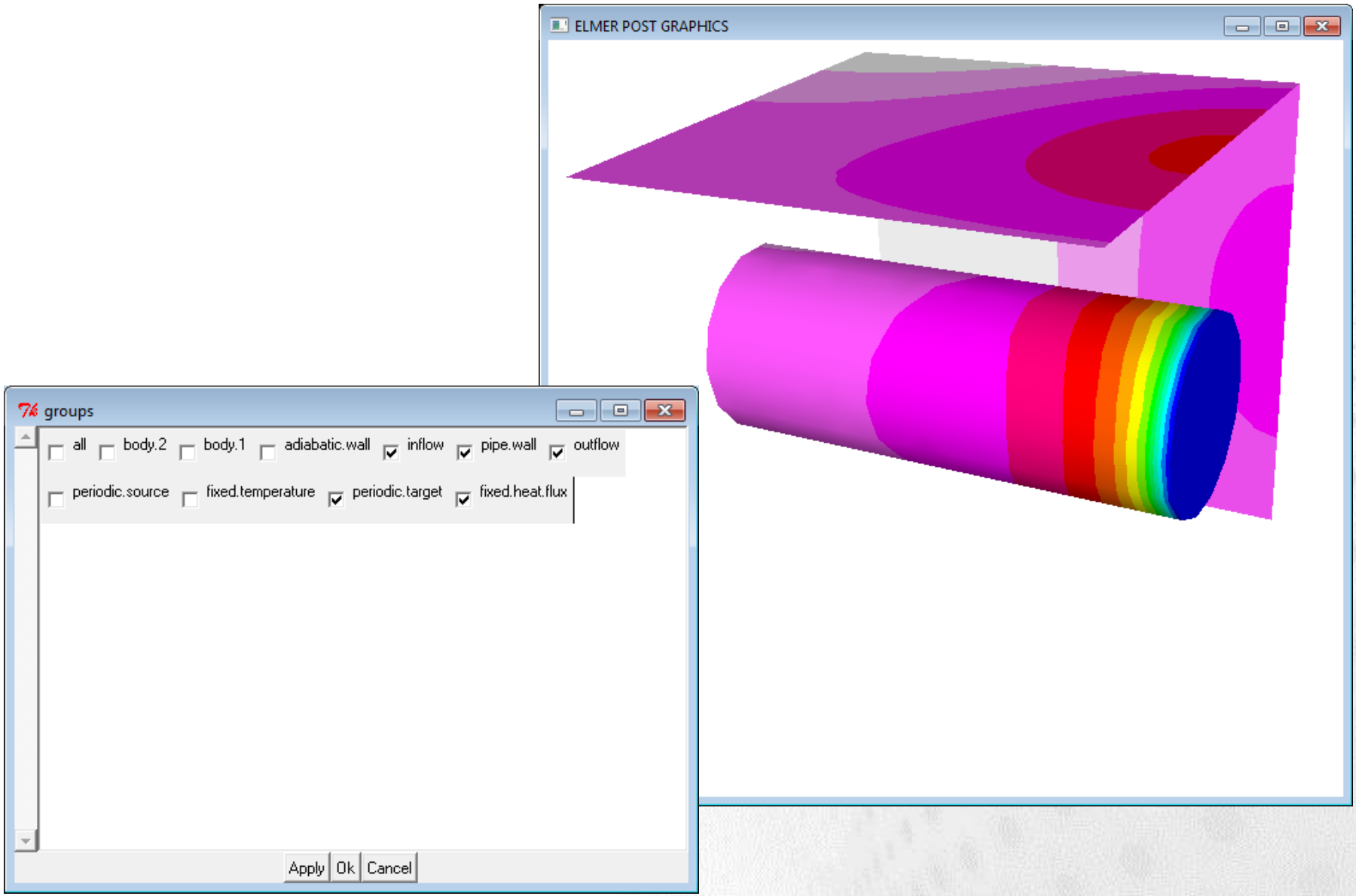




Change of colormap

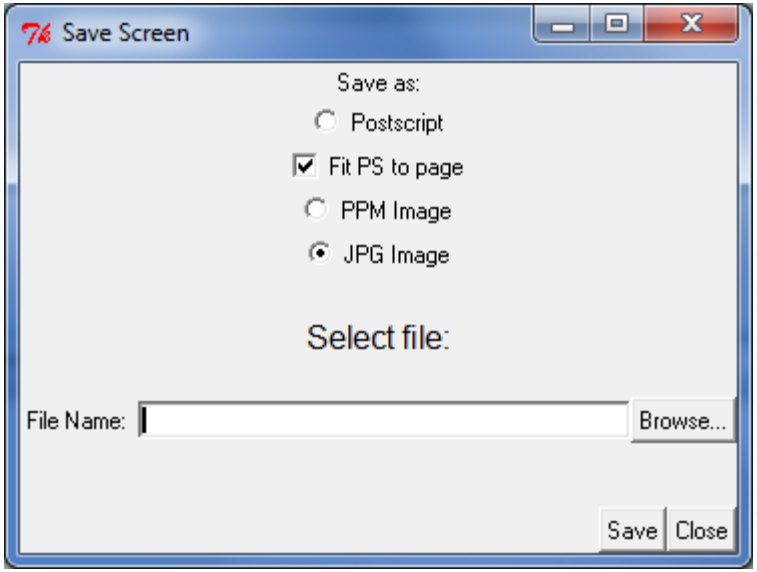


Selecting active geometric entities



Saving figures

- File -> Save Image -> jpg



Deformation in geometry

- Assume displacement field in variable
  `”Displacement”`
- Set in command windows:

```
math n0=nodes
math nodes=n0+Displacement
```

- Replot