

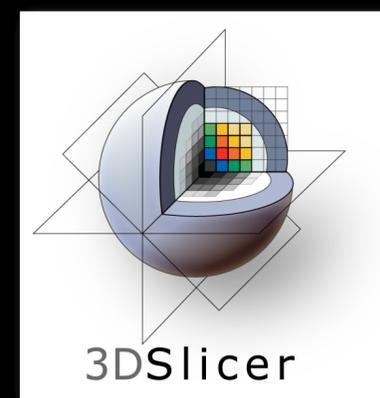
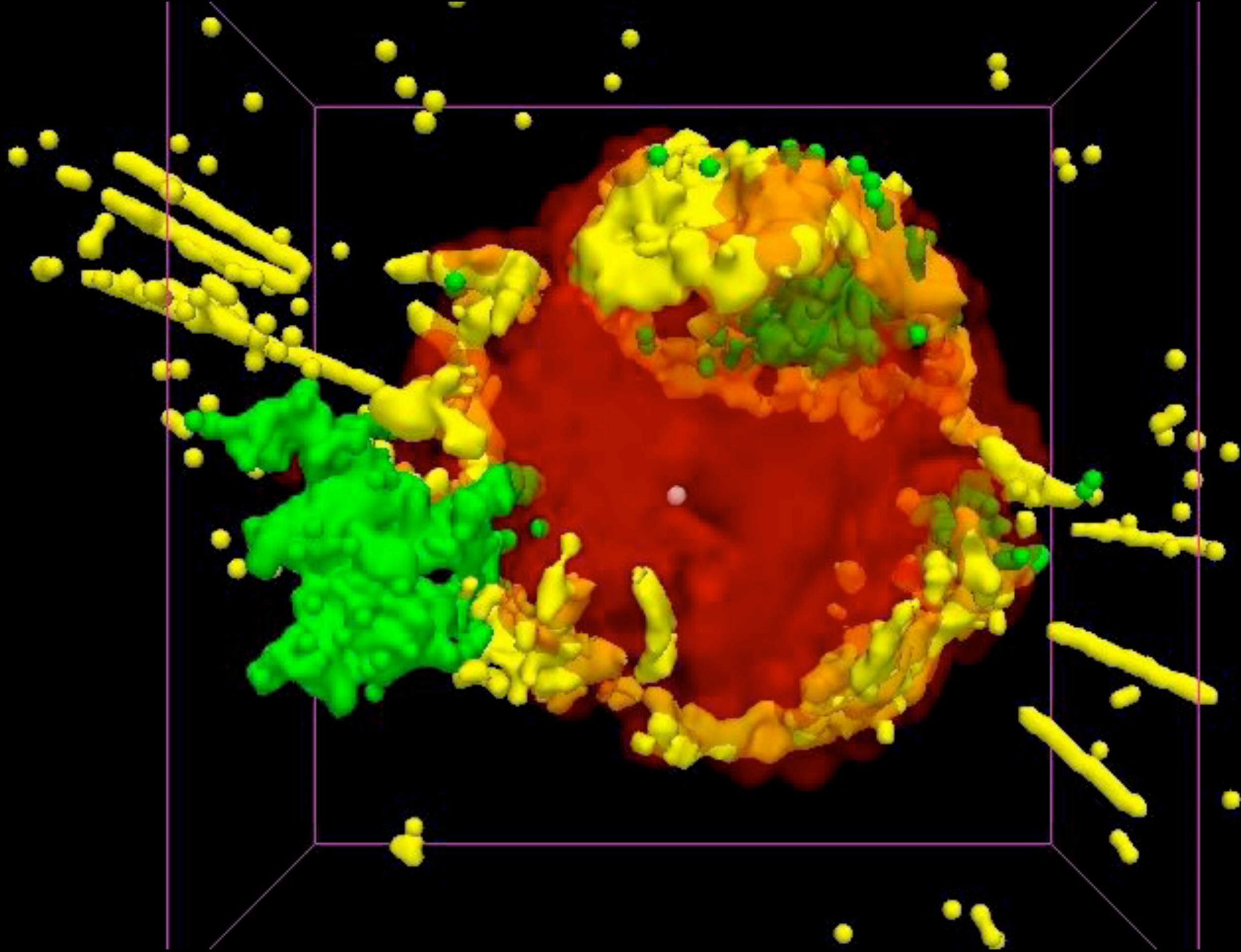
# PERCEPTION, COGNITION, AND EFFECTIVENESS OF VISUALIZATIONS WITH APPLICATIONS IN SCIENCE AND ENGINEERING

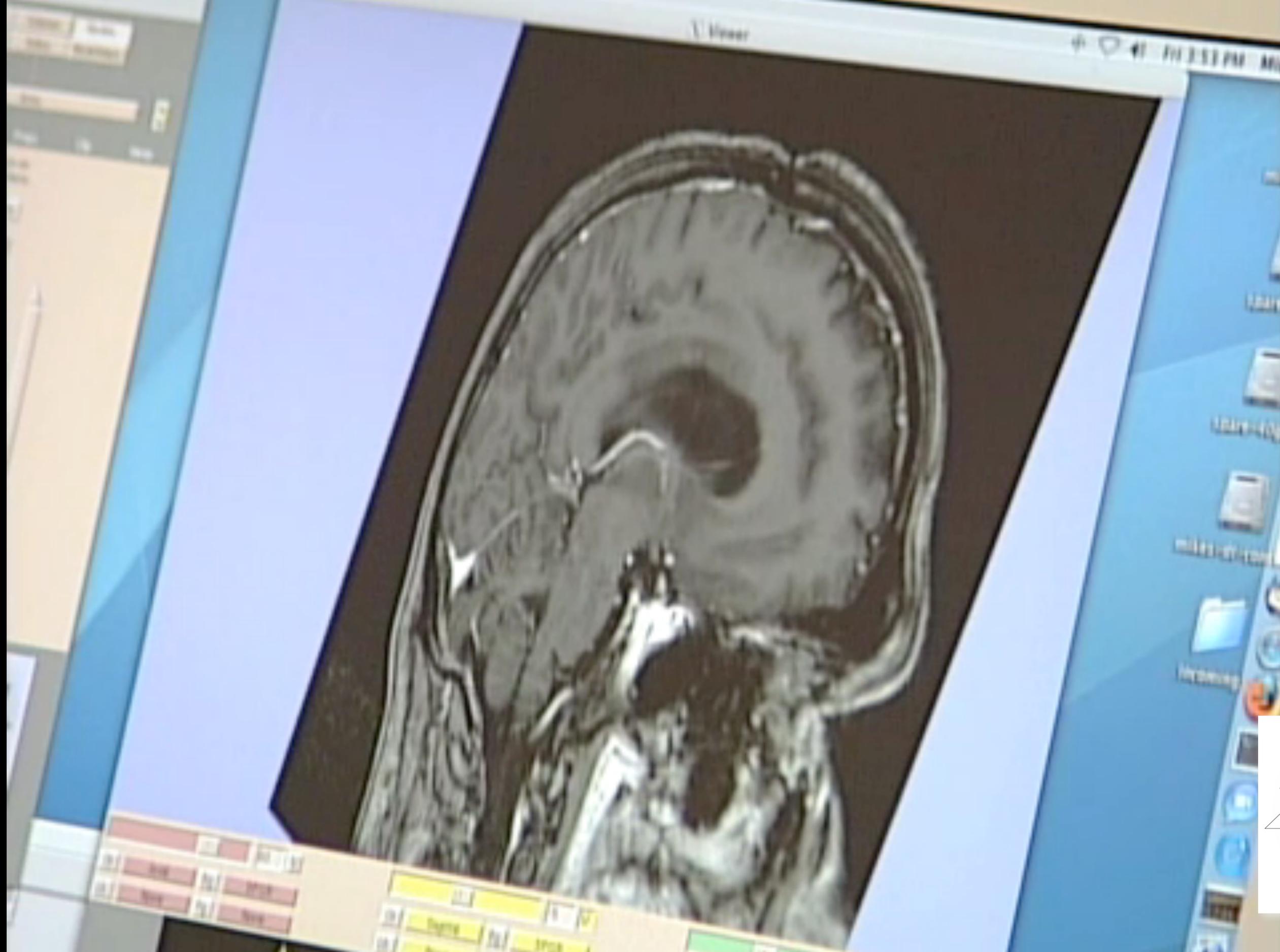
Michelle Borkin

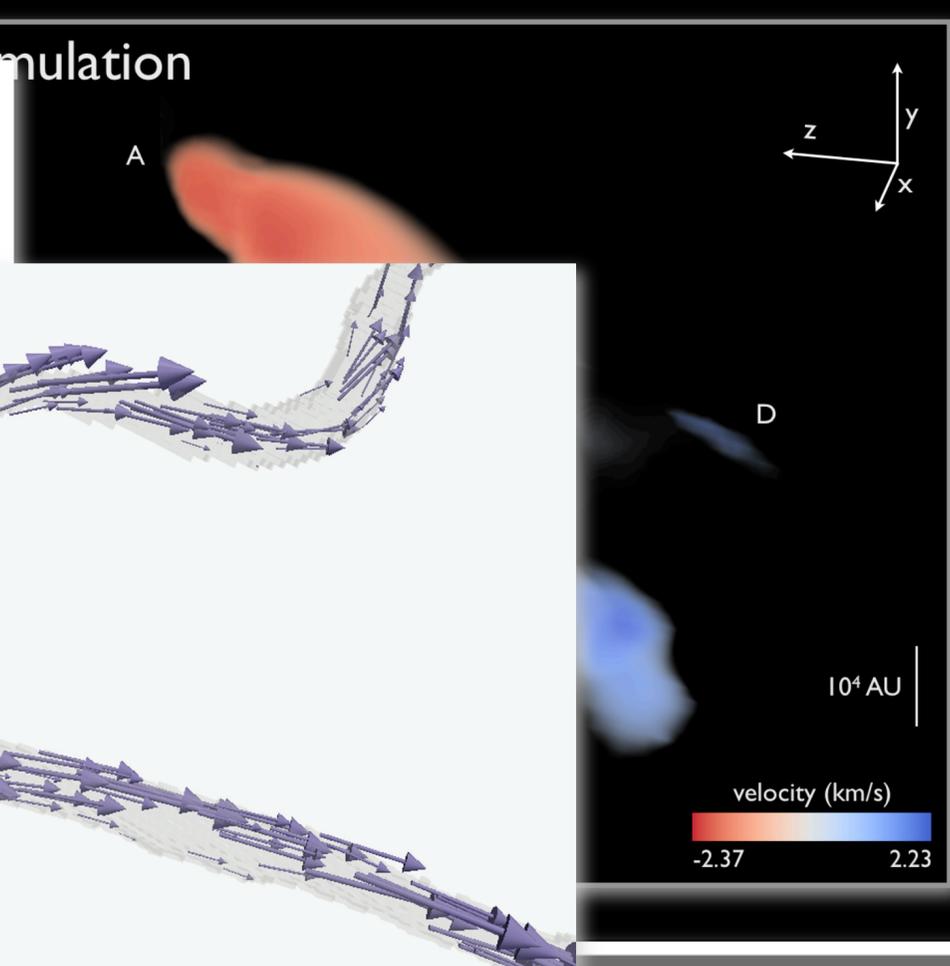
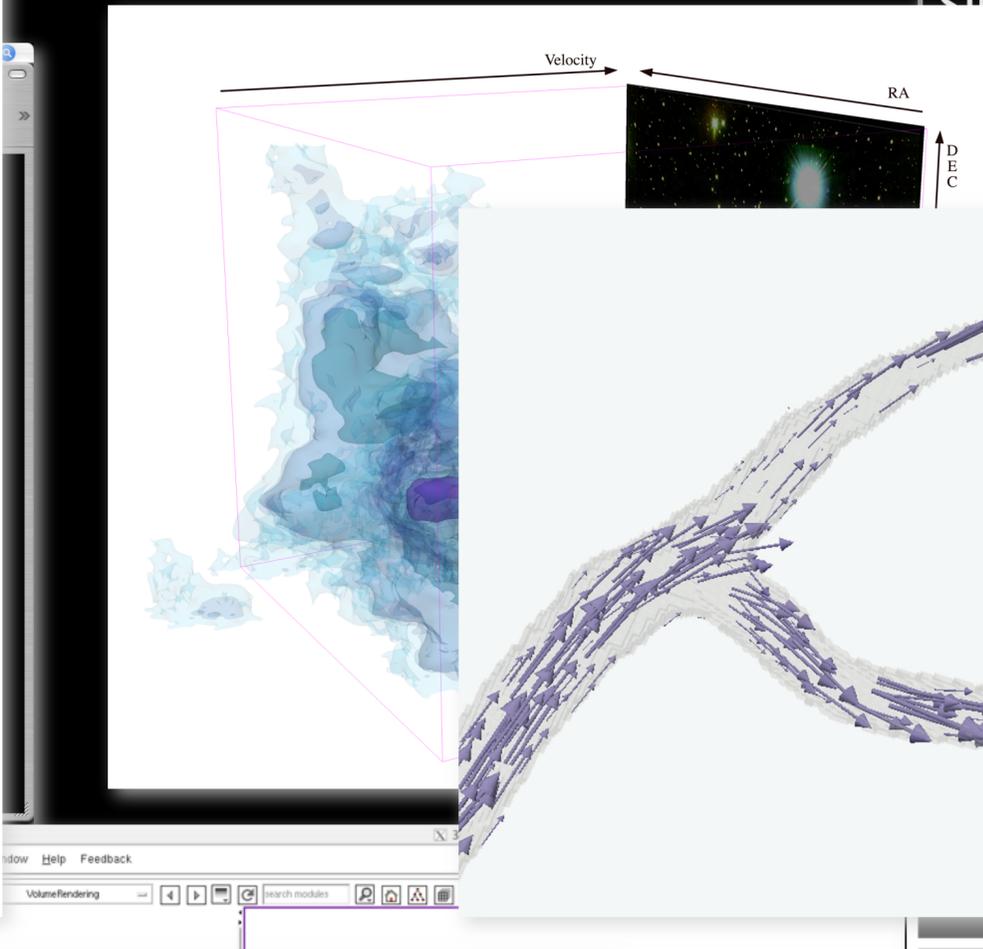
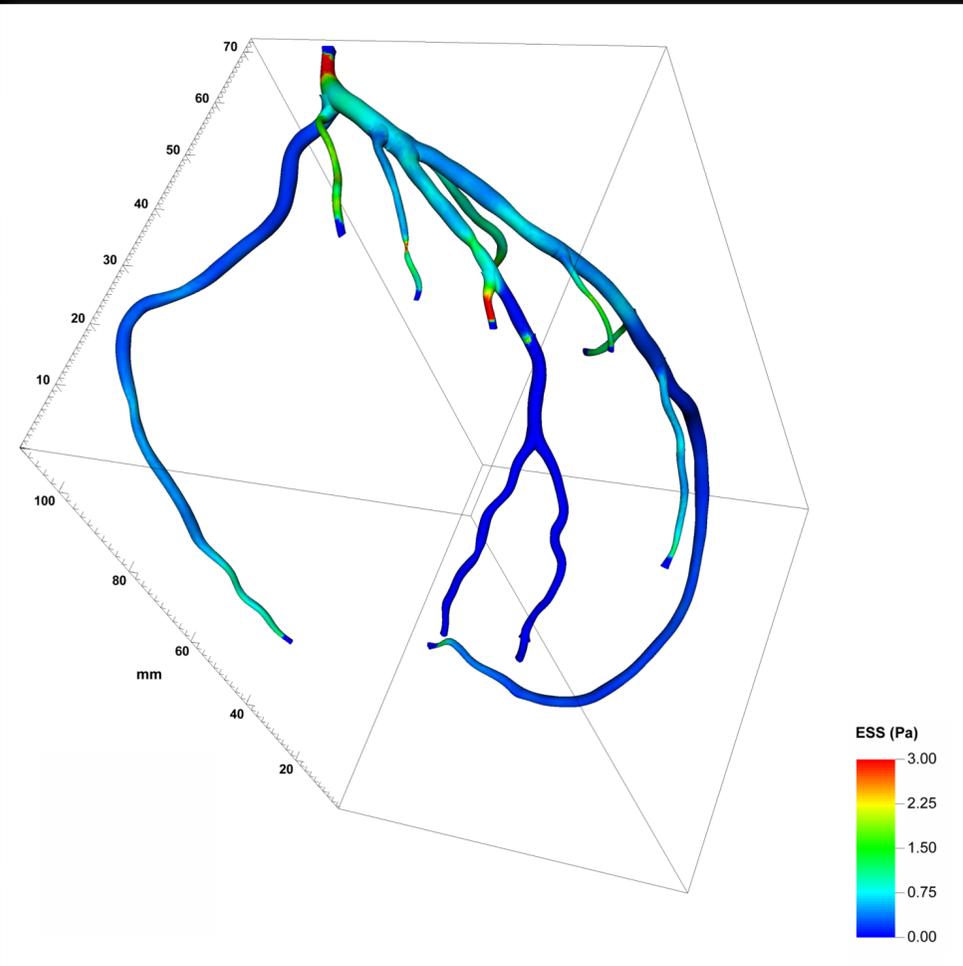
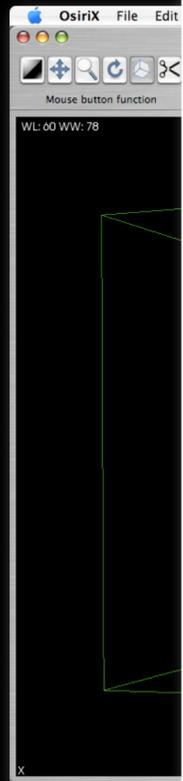
*(University of British Columbia & Harvard University)*

*CPSC 547, UBC - September 24, 2014*

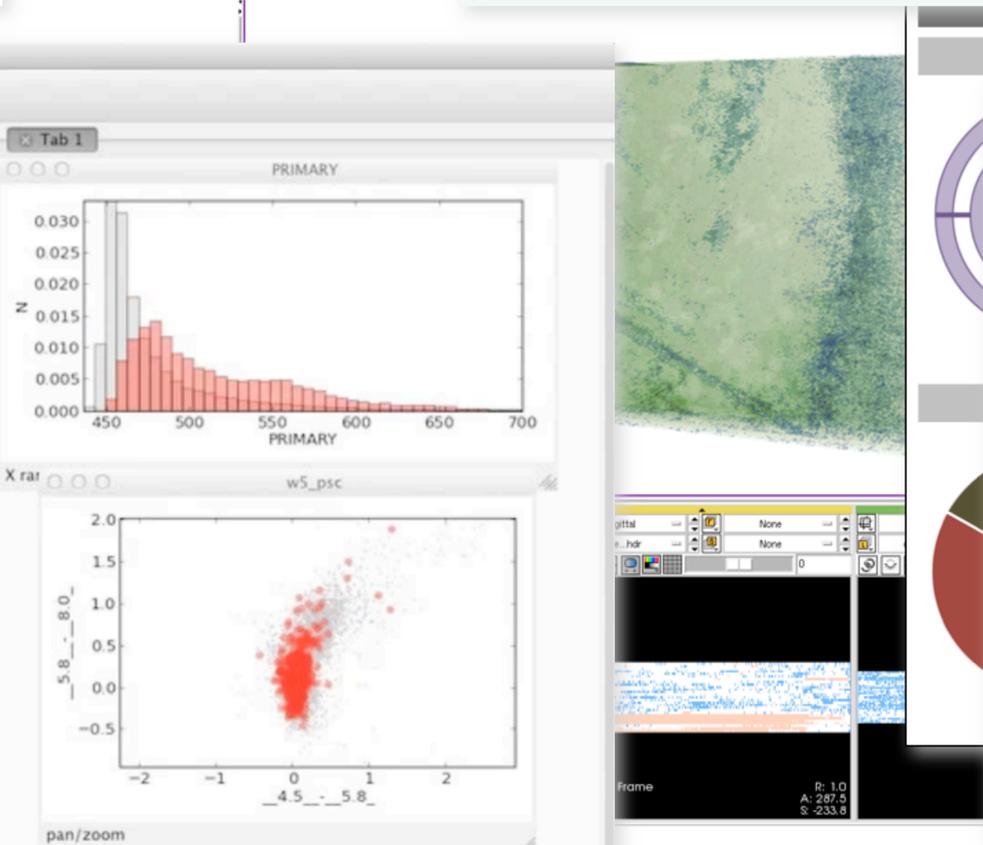








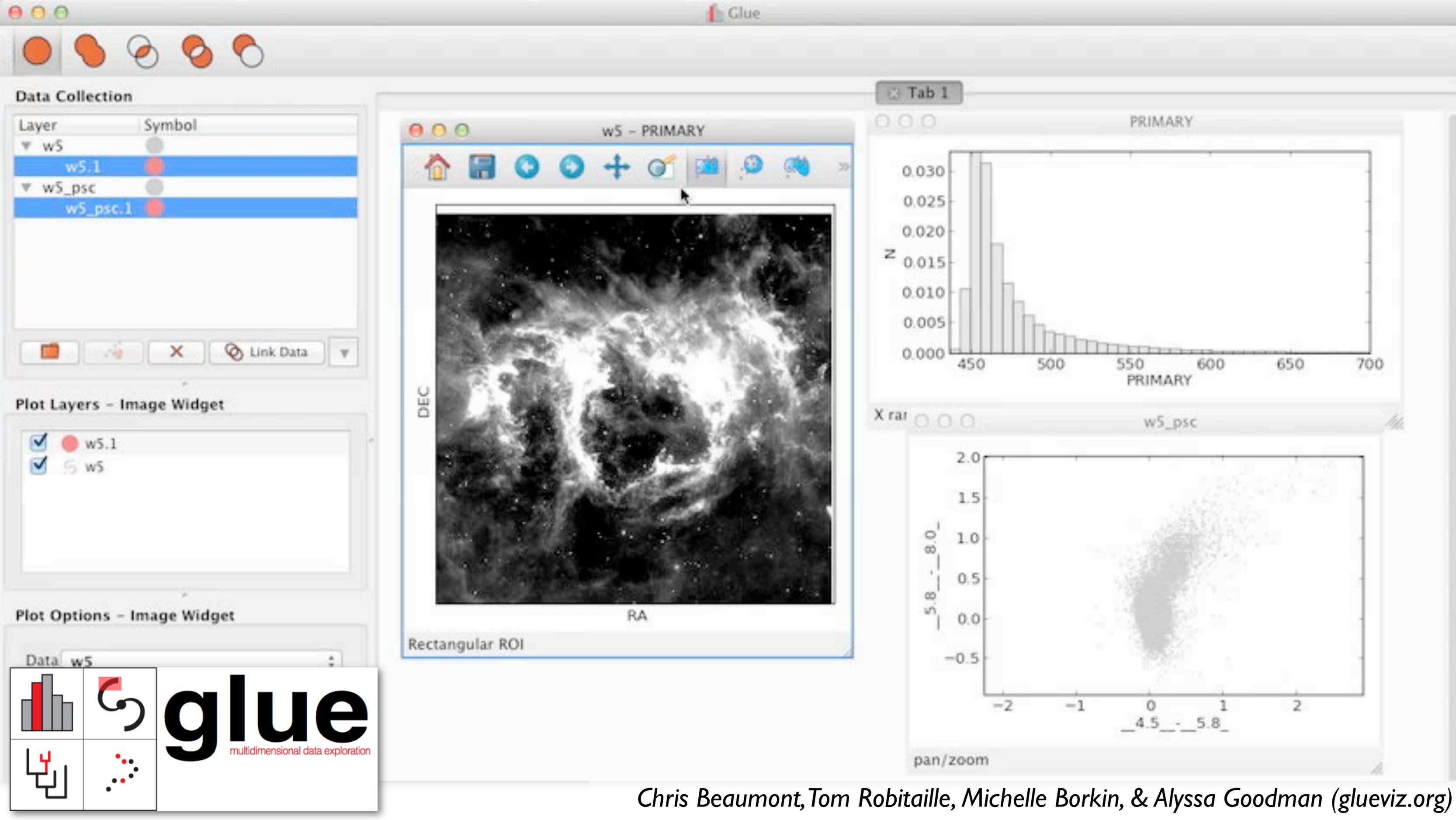
Layer	Symbol
w5	
w5.1	
w5_psc	
w5_psc.1	



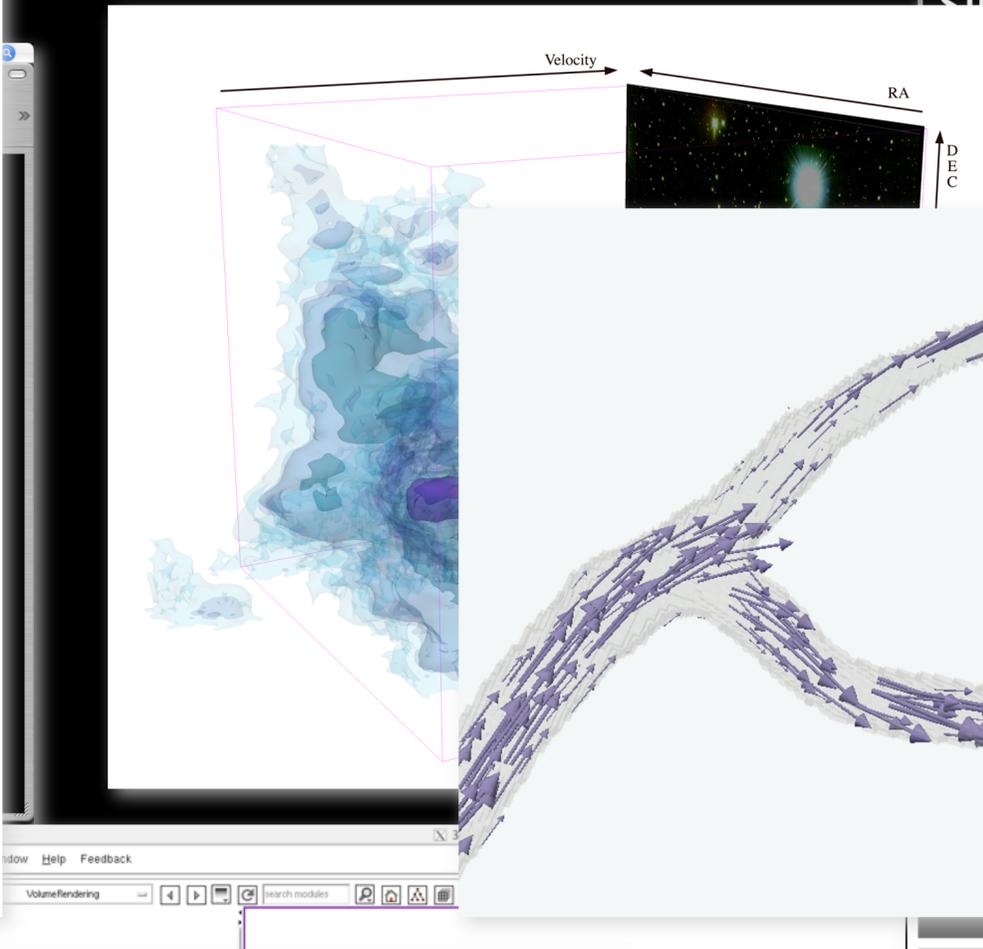
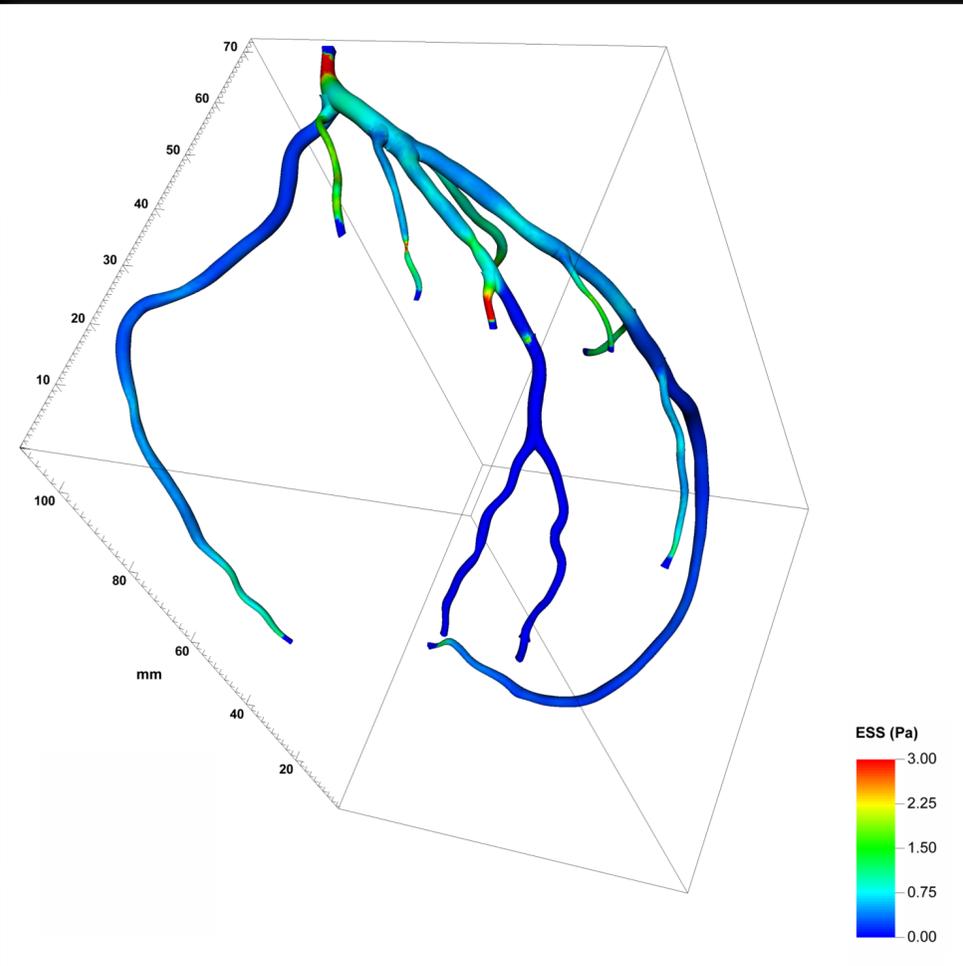
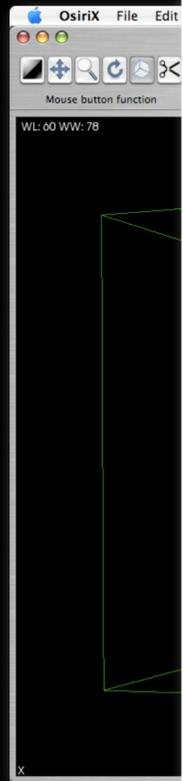
Timeline: B, D, E (1995-2005)

Venn Diagram: A, B

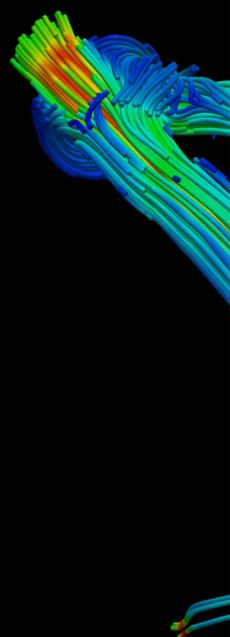
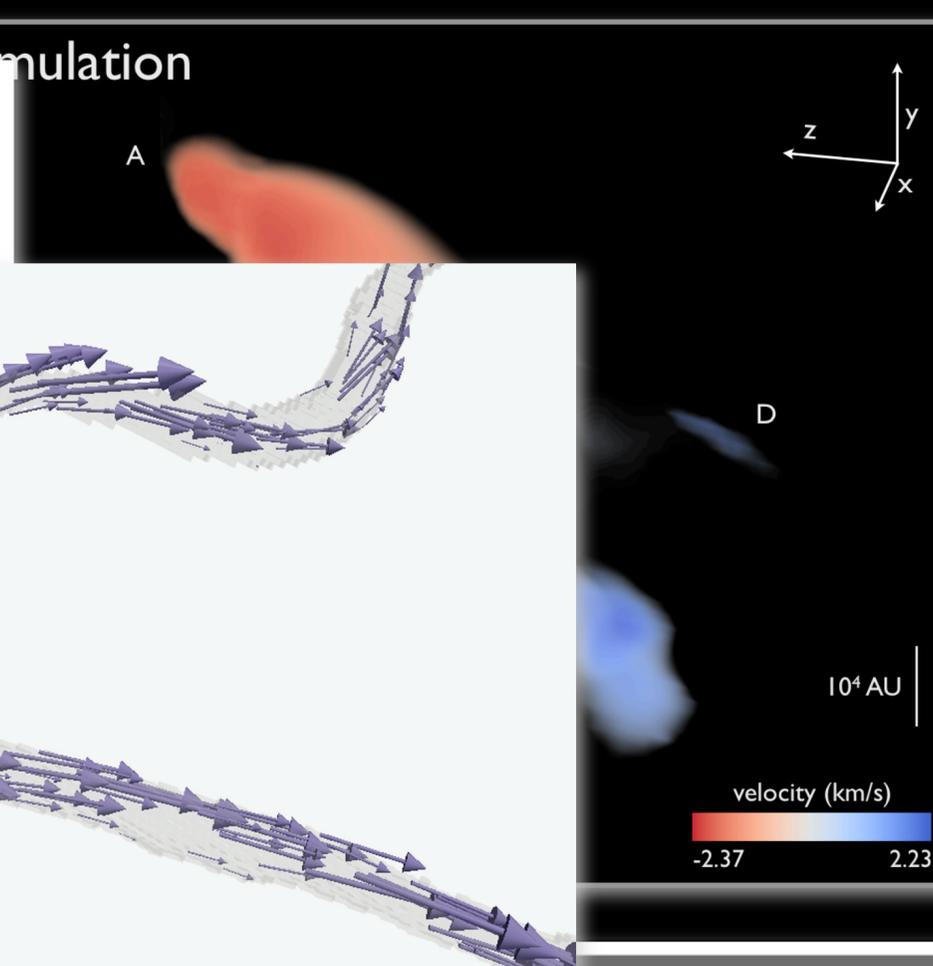
Labels: formatb, formatdb, formatdb.log, blastsh, blastall, peri, seacode.val, meminfo, Hinf.faa.phr, Hinf.faa.psq, Hinf.faa.pin, Mpne.faa.phr, Mpne.faa.psq, Mpne.faa.pin, A\_B, A\_B.best, A\_B, BLOSUM62, A\_B.best, B\_A, BLOSUM62, A\_B.best, B\_A, BLOSUM62



Chris Beaumont, Tom Robitaille, Michelle Borkin, & Alyssa Goodman (glueviz.org)



# Simulation



Data Collection

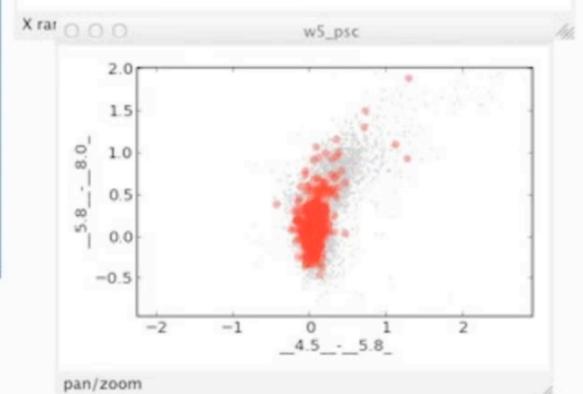
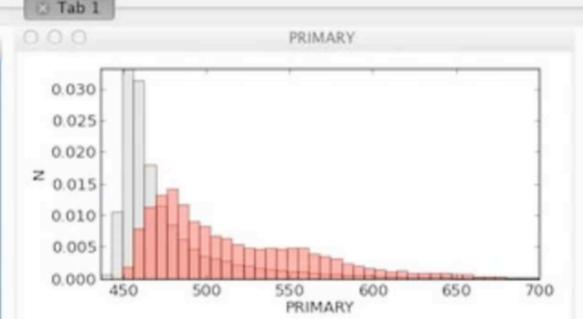
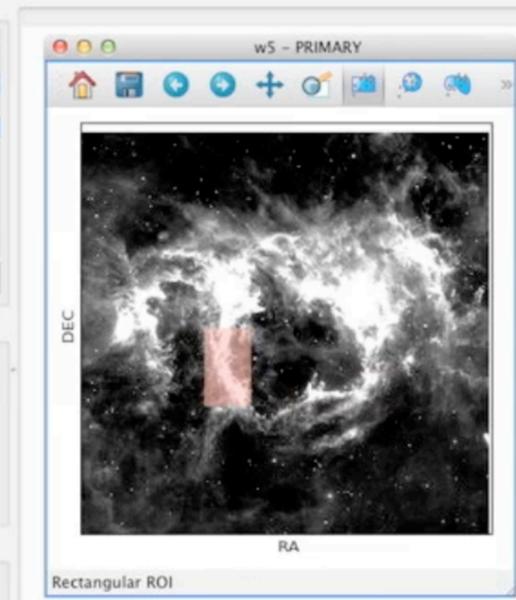
Layer	Symbol
w5	
w5.1	
w5_psc	
w5_psc.1	

Plot Layers - Image Widget

- w5.1
- w5

Plot Options - Image Widget

Data: w5  
Attribute: PRIMARY



gital  
hdr  
Frame  
R: 1.0  
A: 287.5  
S: -233.8

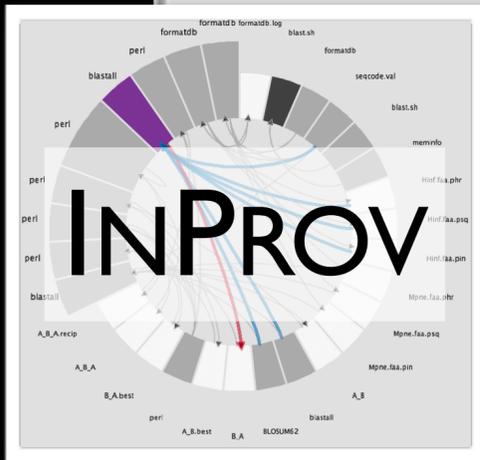
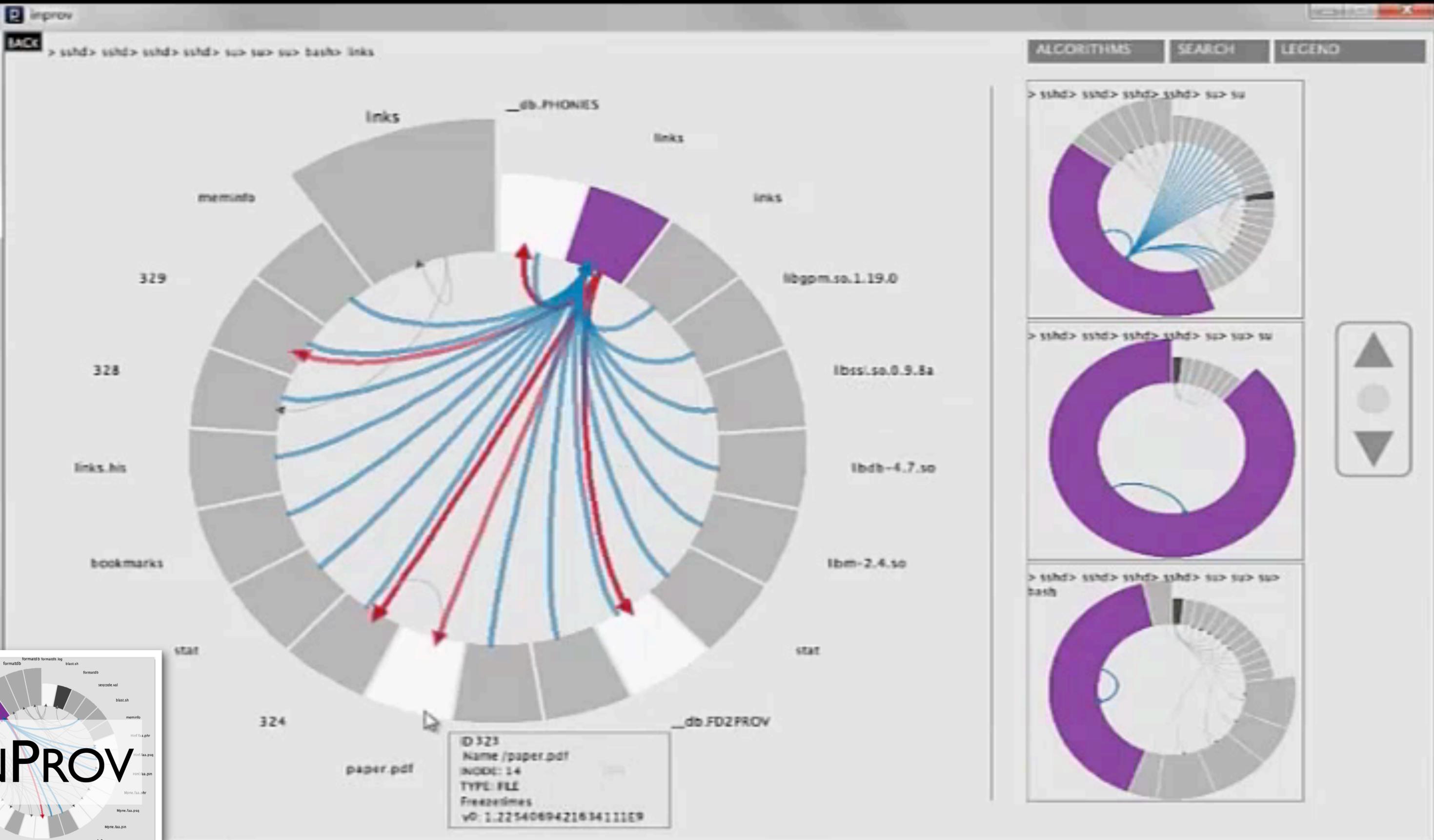
Diagram

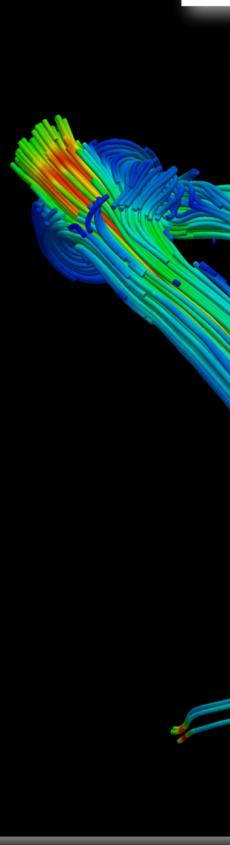
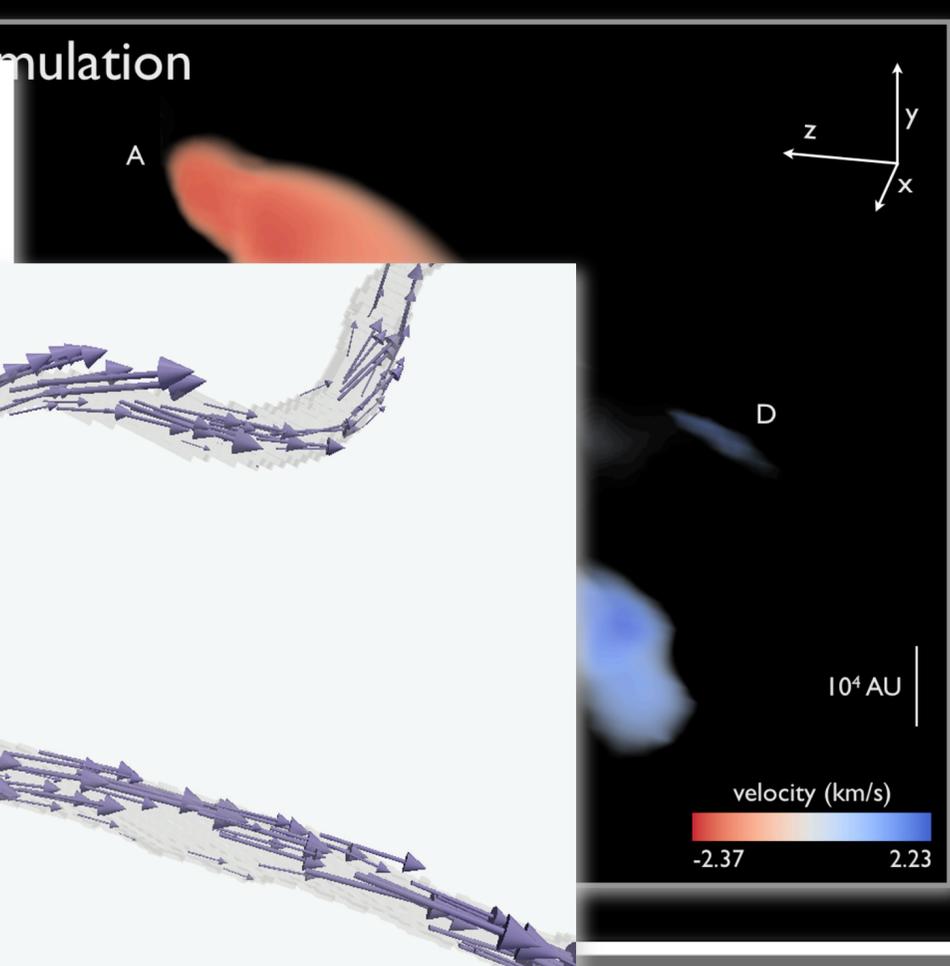
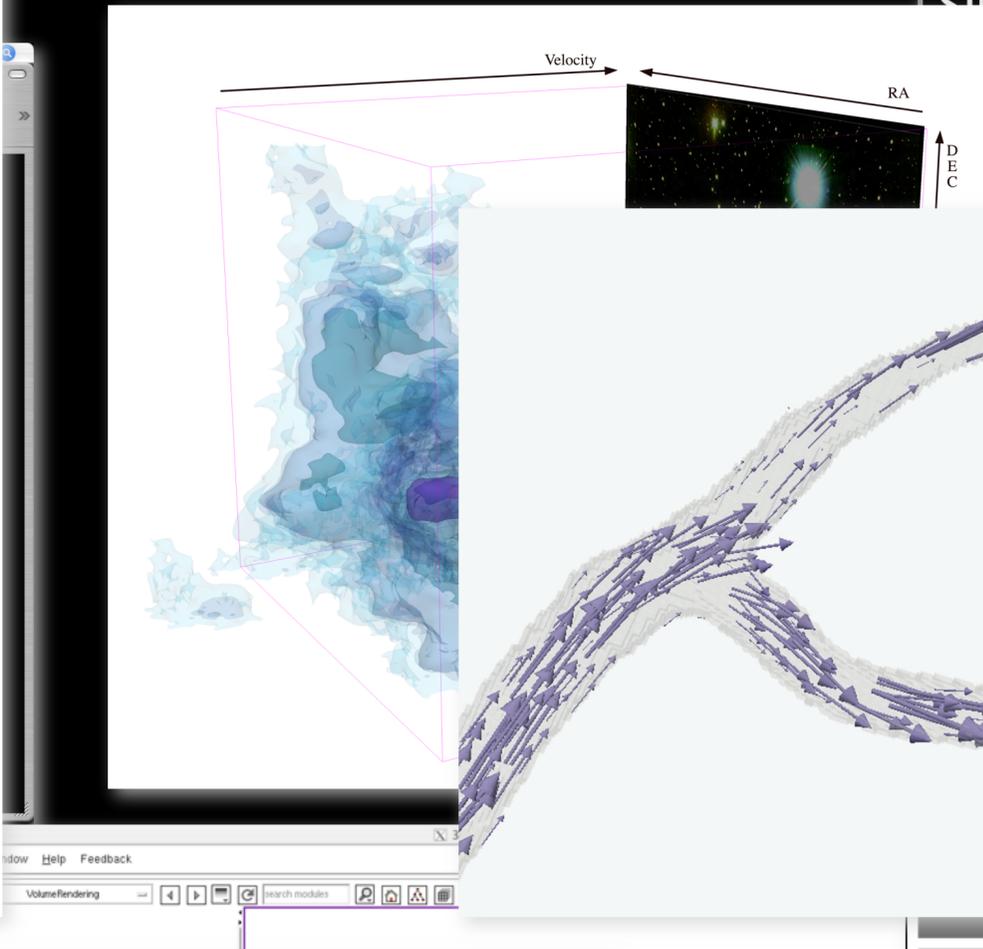
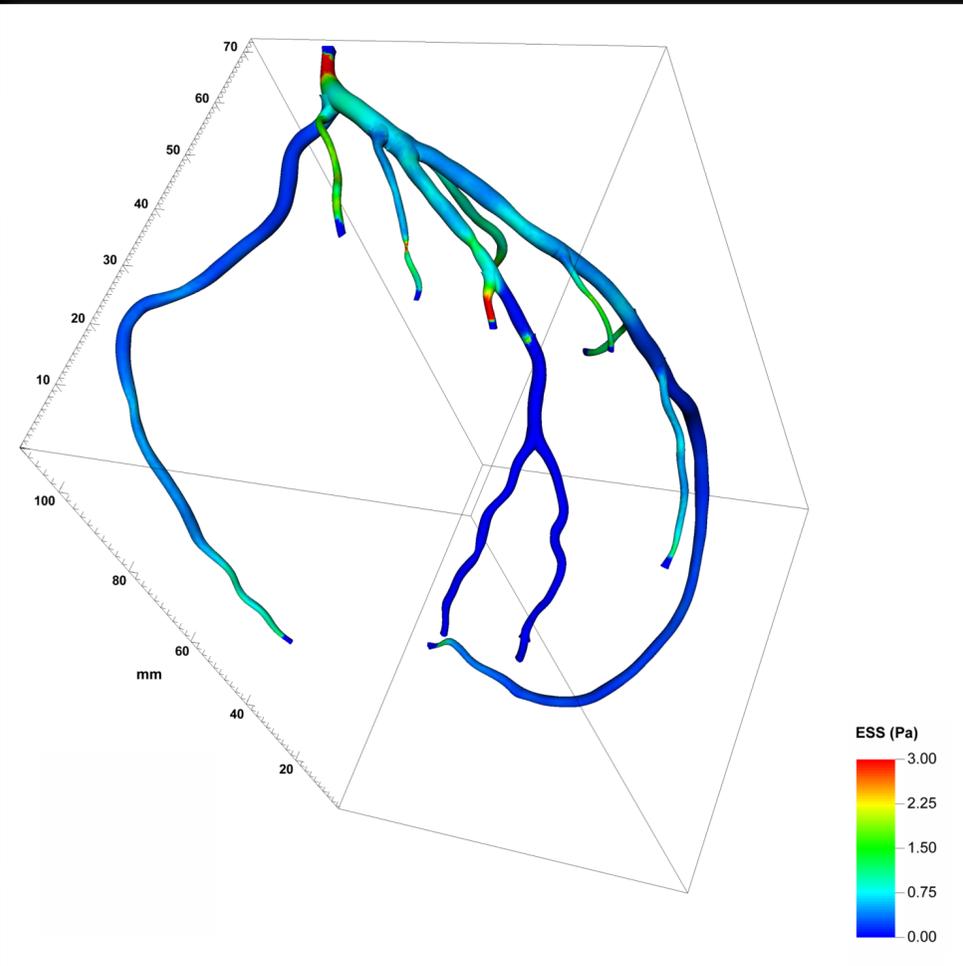
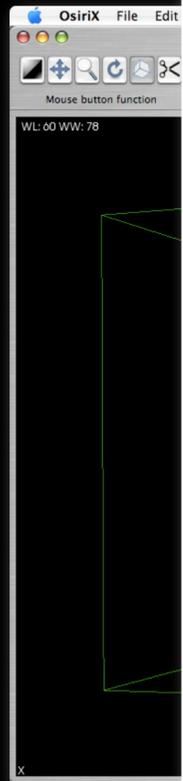
Belt Chart Donut Chart Flow Chart Illustration (or Rendering)

formatdb formatdb formatdb.log blastsh  
perli  
blastall  
perli  
perli  
perli  
perli  
blastall  
A\_B.recip  
A\_B.A  
B\_A.best  
perli  
A\_B.best B\_A BLOSUM62  
blastall  
seacode.val  
blast.sh  
meminfo  
Hinfaa.phr  
Hinfaa.psq  
Hinfaa.pin  
Mpne.faa.phr  
Mpne.faa.psq  
Mpne.faa.pin  
A\_B

Timeline

Venn Diagram





Data Collection table with columns Layer and Symbol, listing w5, w5.1, w5\_psc, and w5\_psc.1.

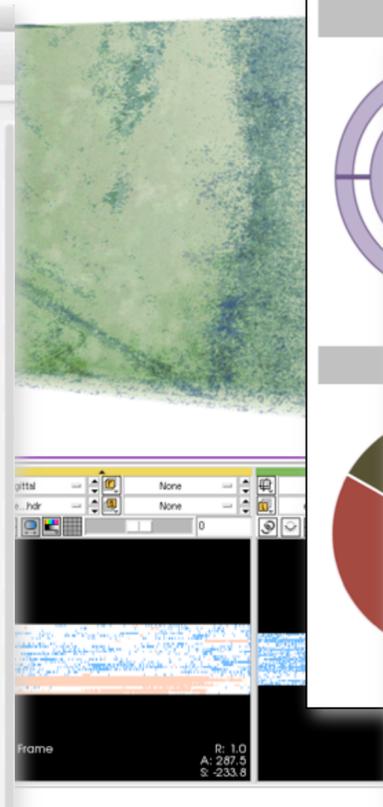
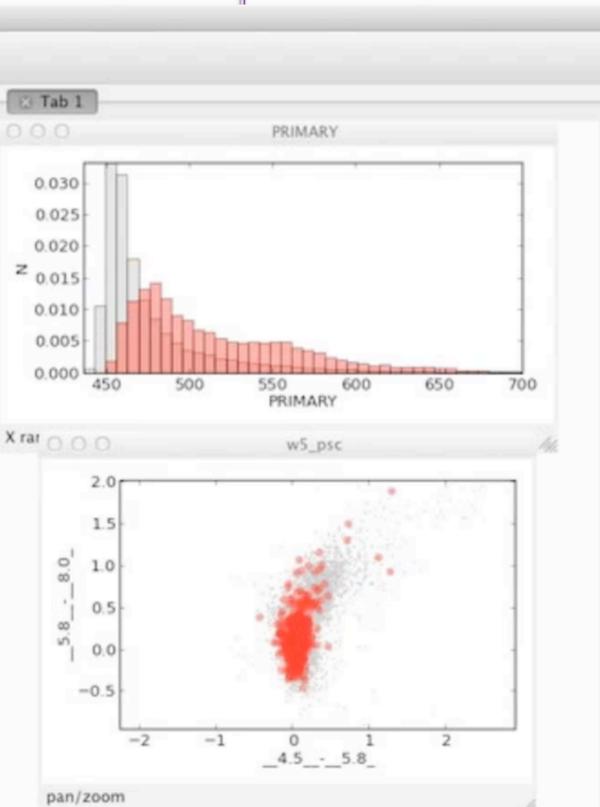
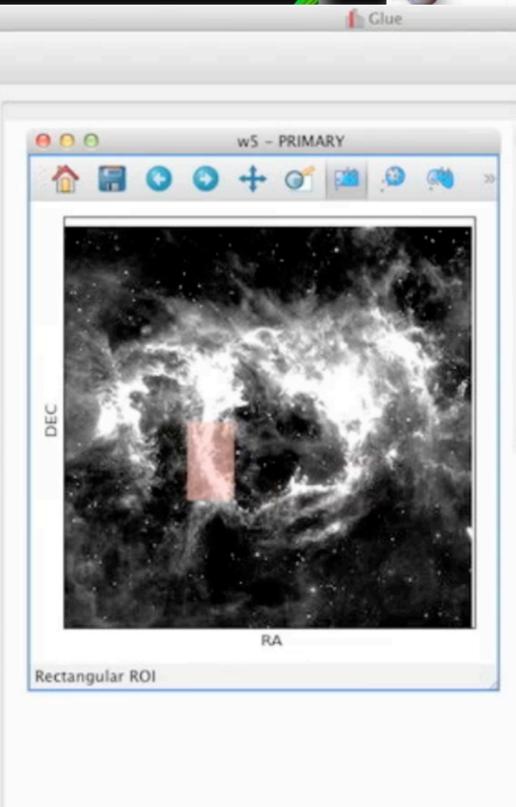
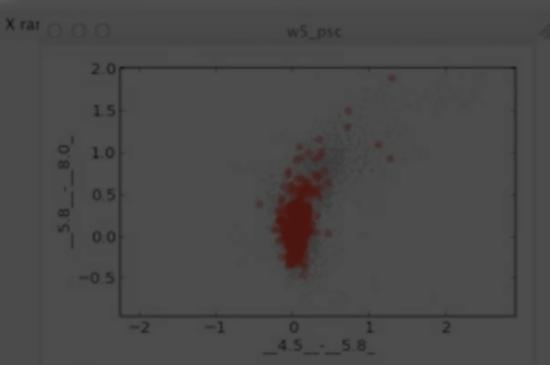
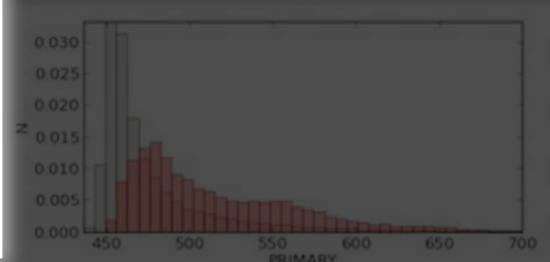
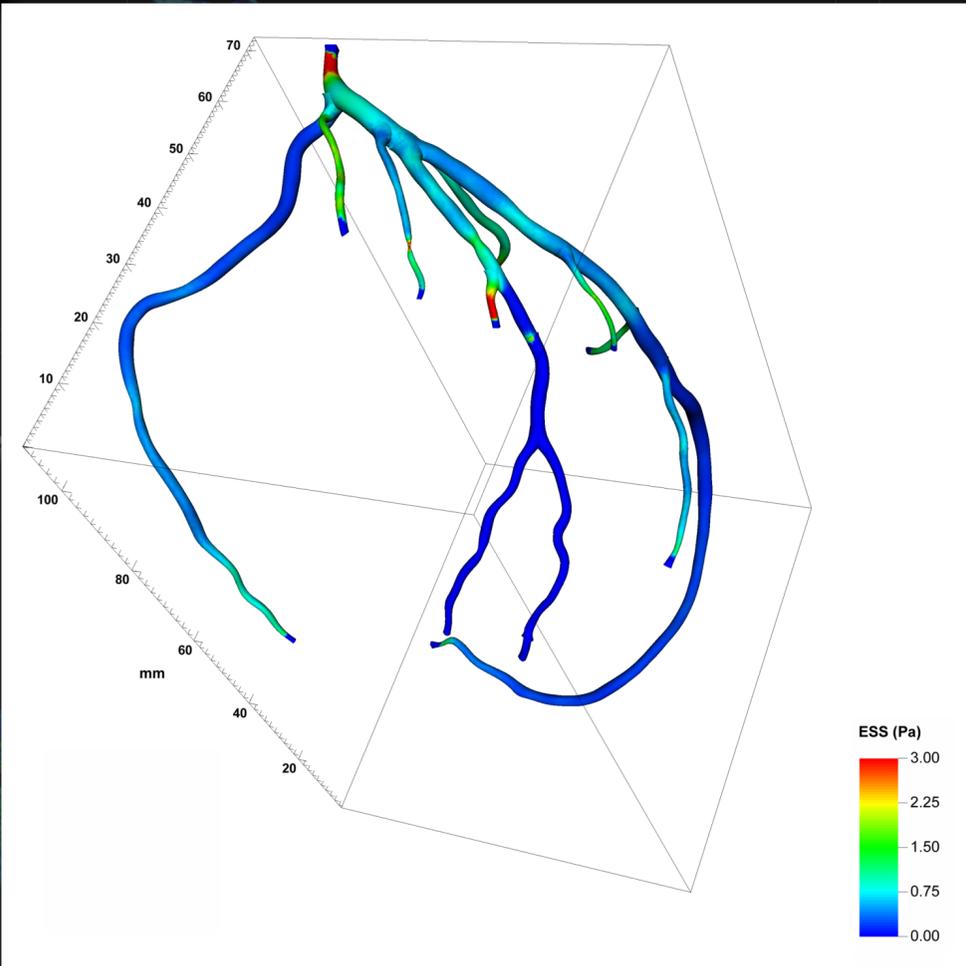
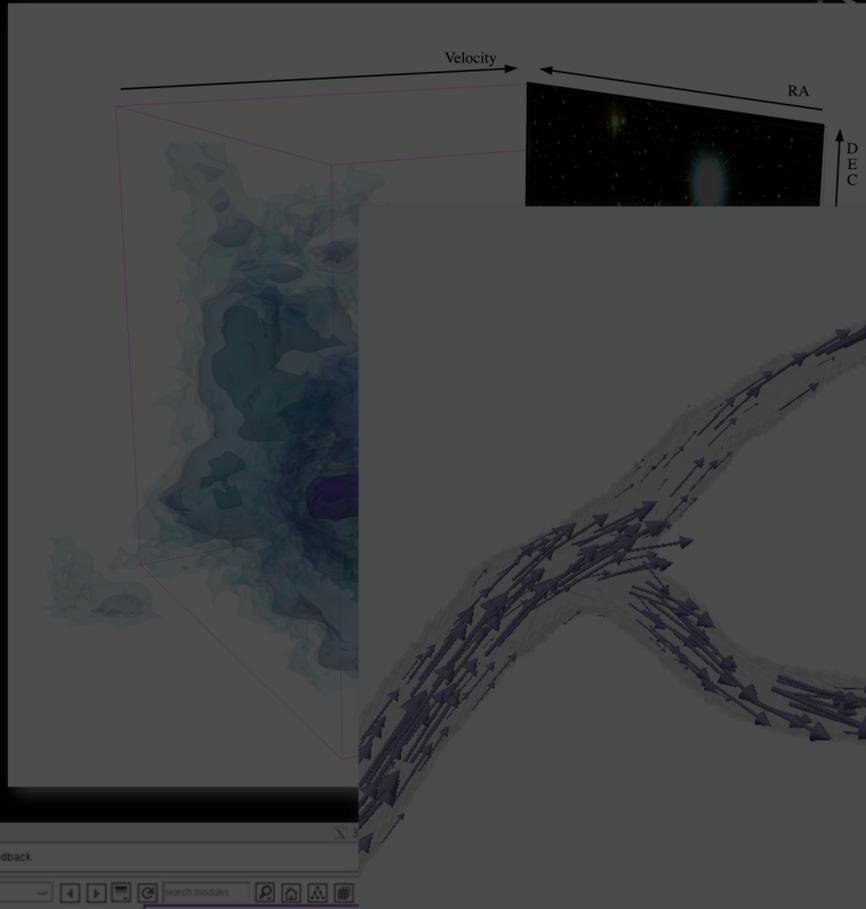


Diagram interface with various charts: Belt Chart, Donut Chart, Flow Chart, Illustration (or Rendering), Timeline, and Venn Diagram.

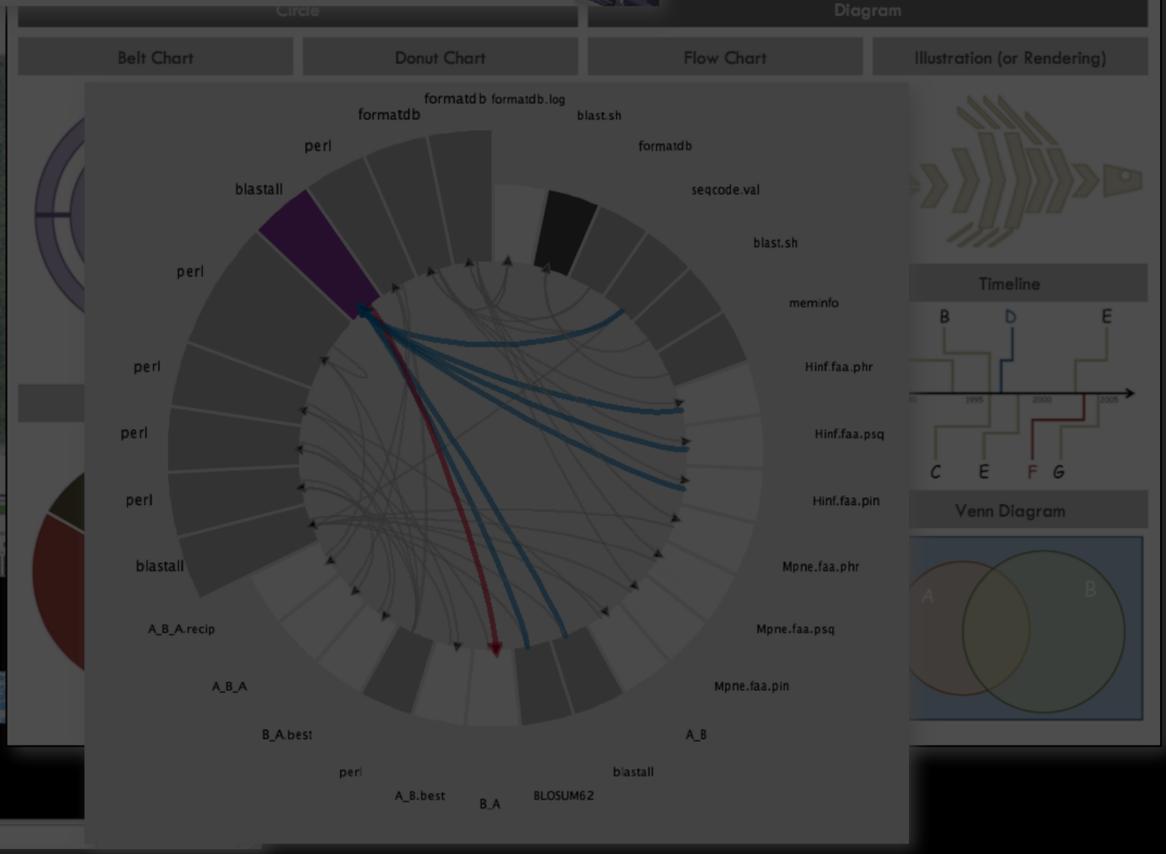
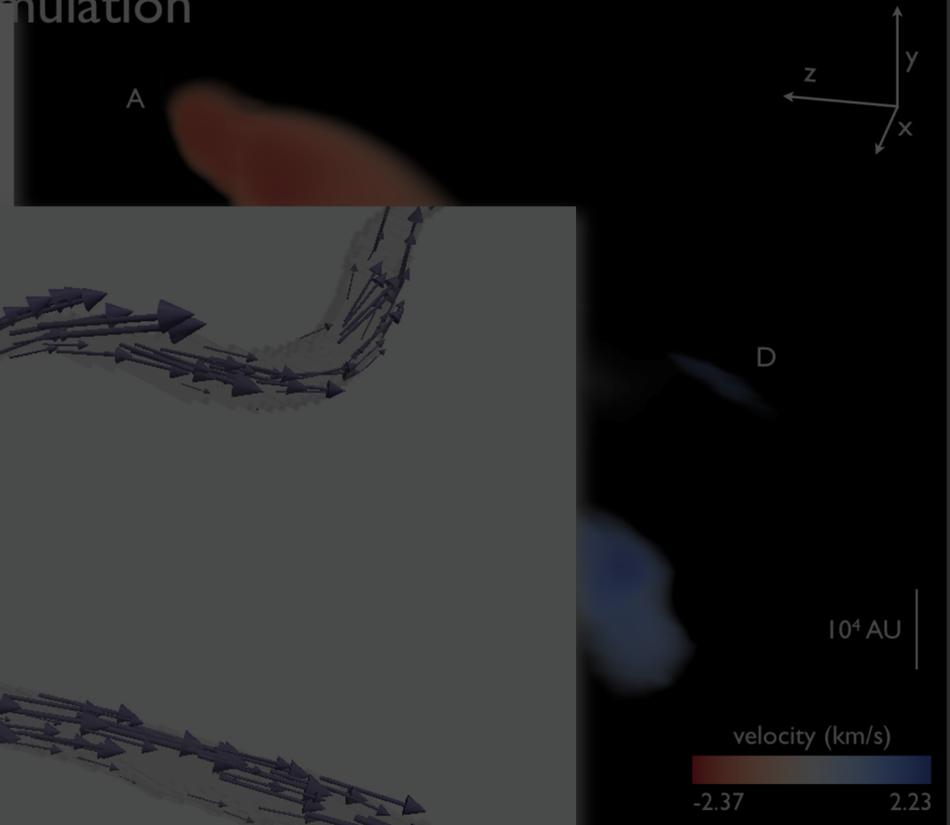
OsiriX File Edit Format 2D Viewer 3D Viewer ROI Plugins Window Help  
3D Reconstruction  
Volume Rendering  
CLUT: Spectrum  
Opacity: Logarithmic Inverse  
Shading Ambient: 0.2 Diffuse: 0.8 Specular: 0.2-10.0  
Parallel (faster) Perspective (slower) Percentage: -



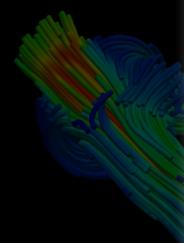
pan/zoom

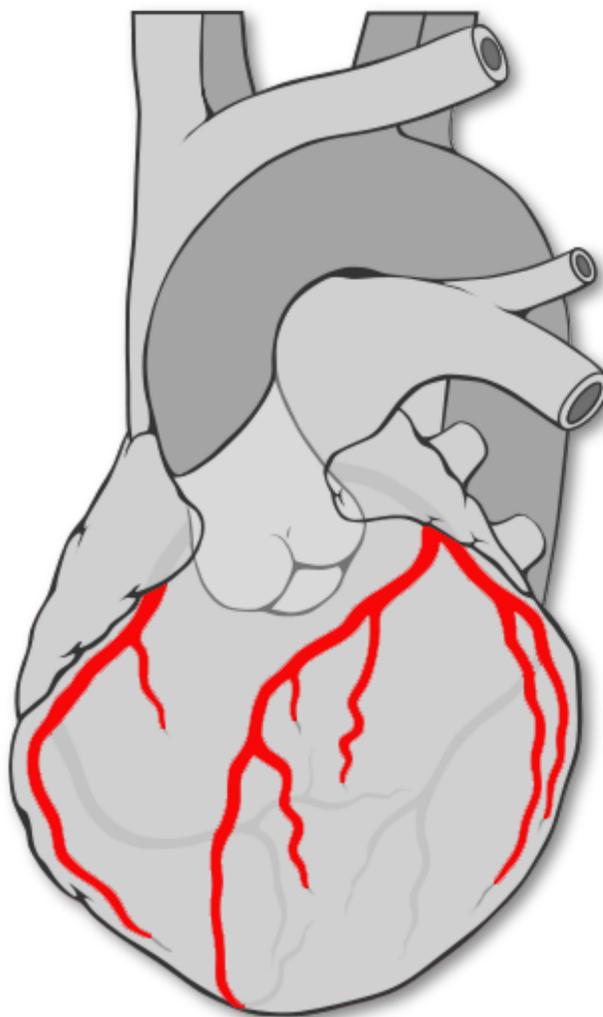
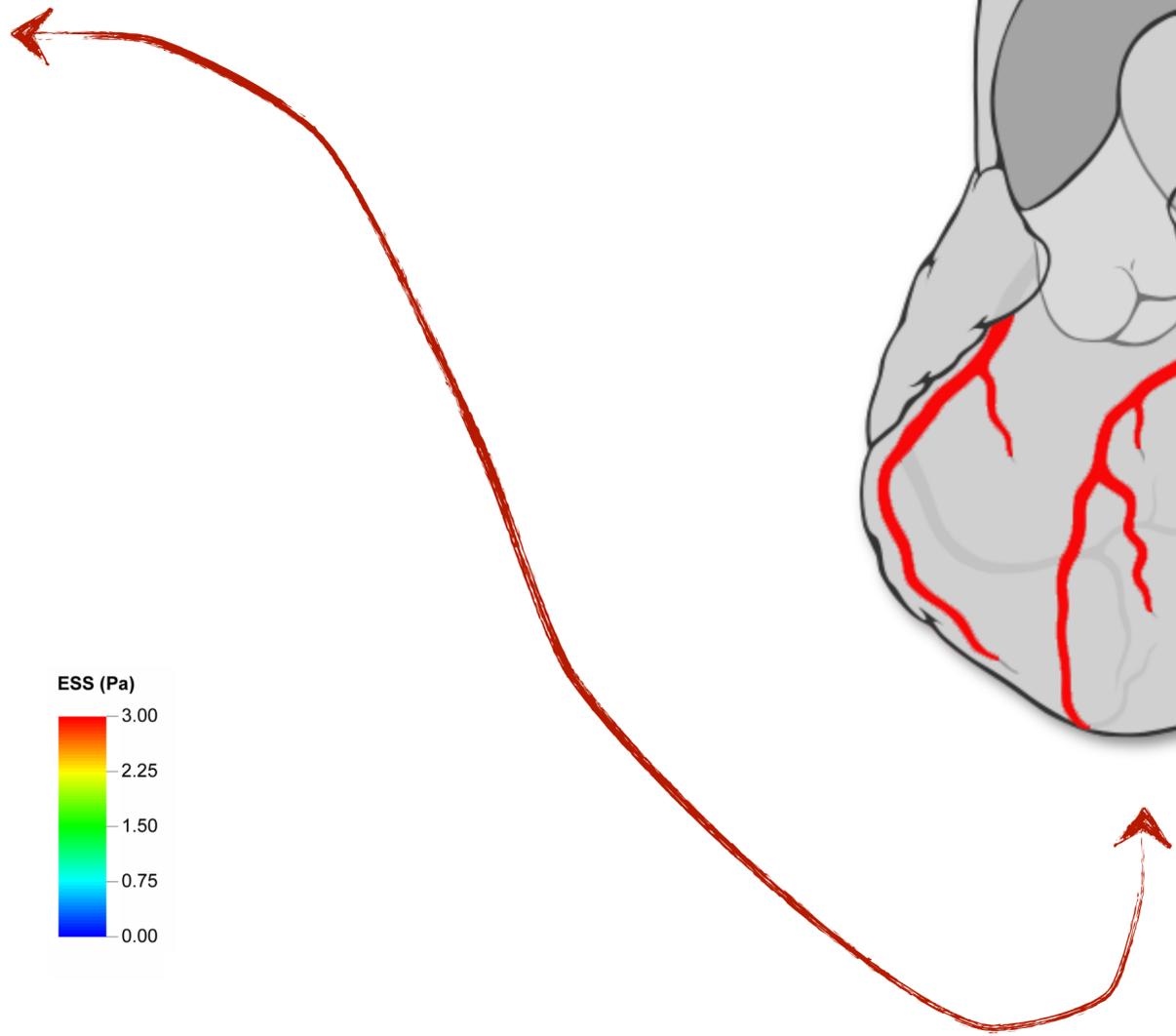
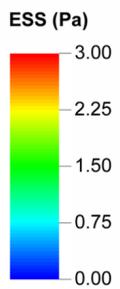
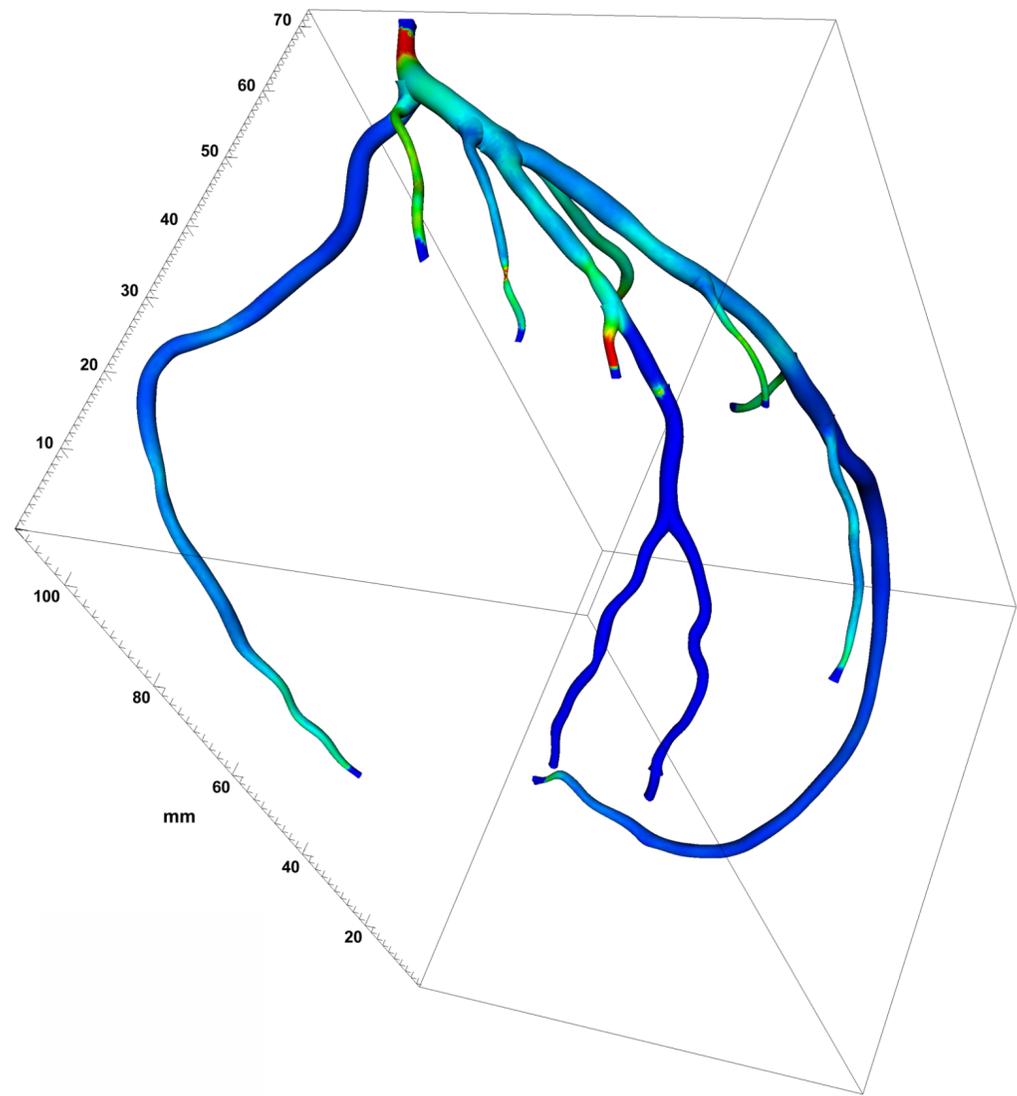


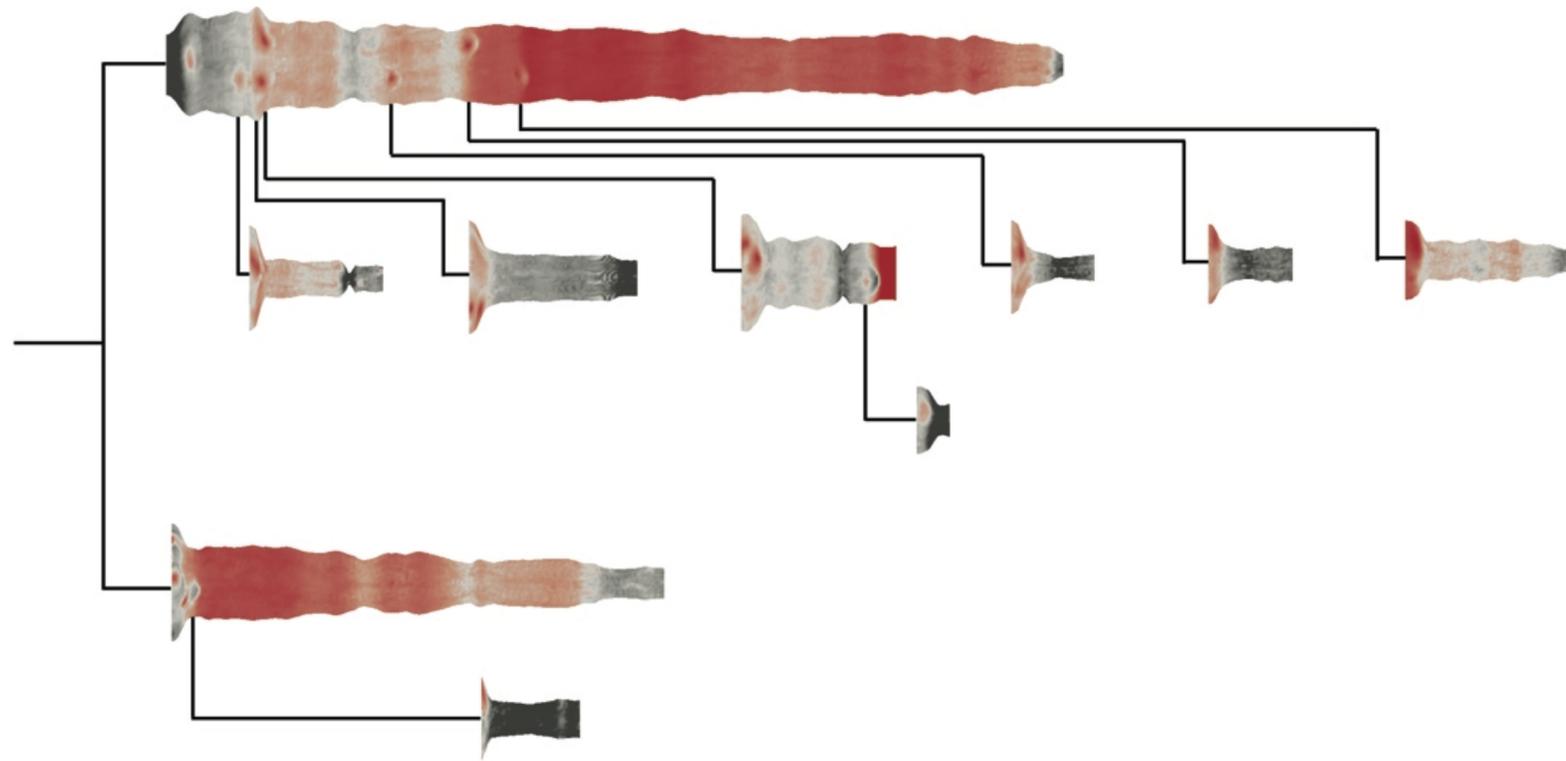
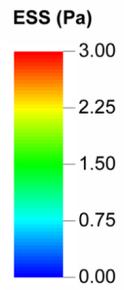
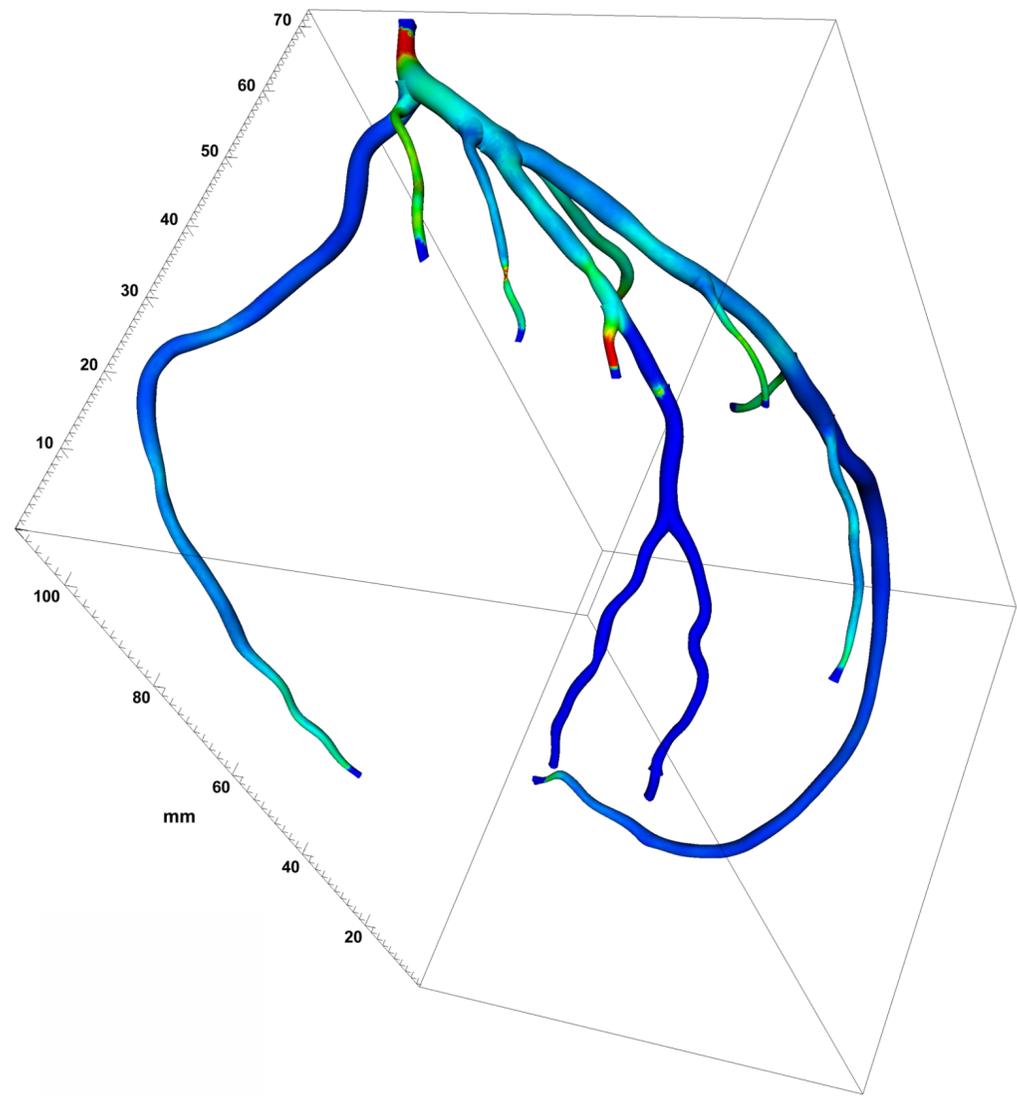
Simulation

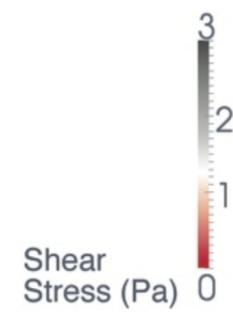
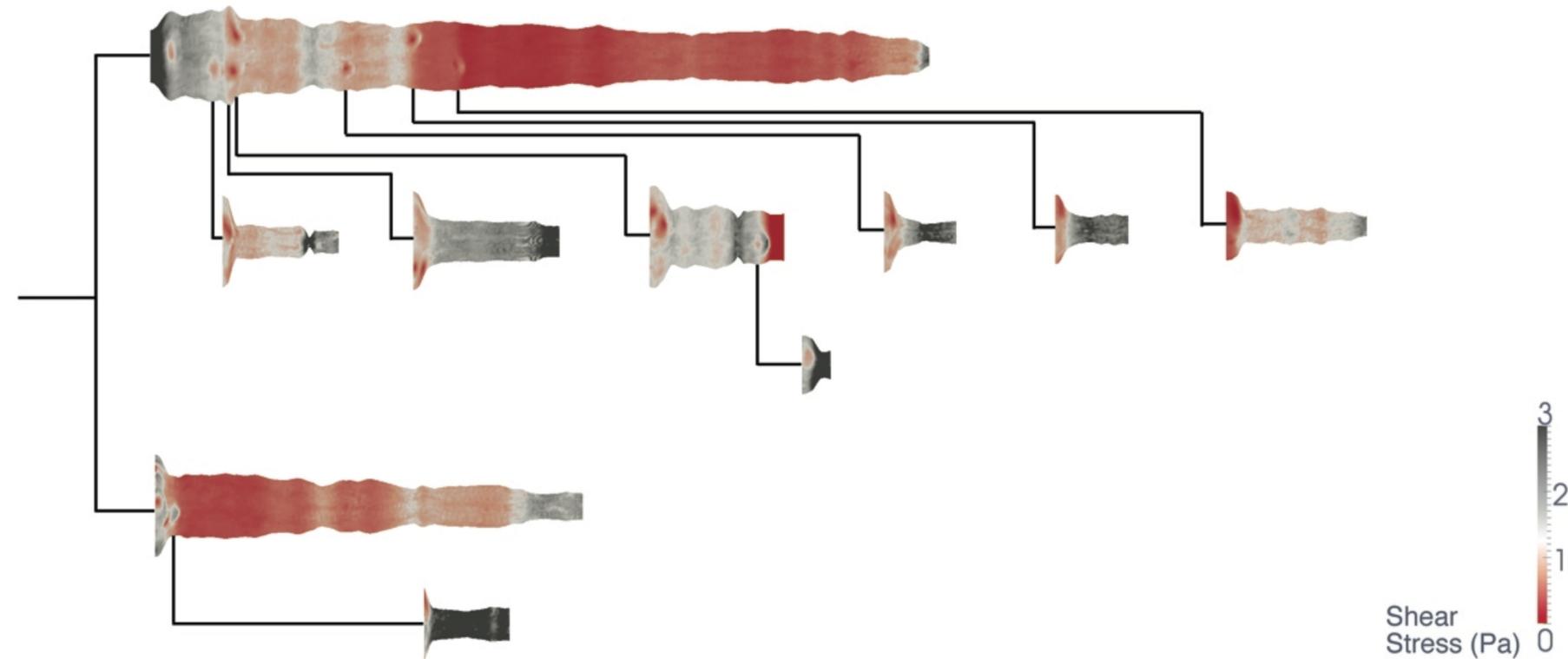
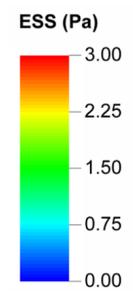
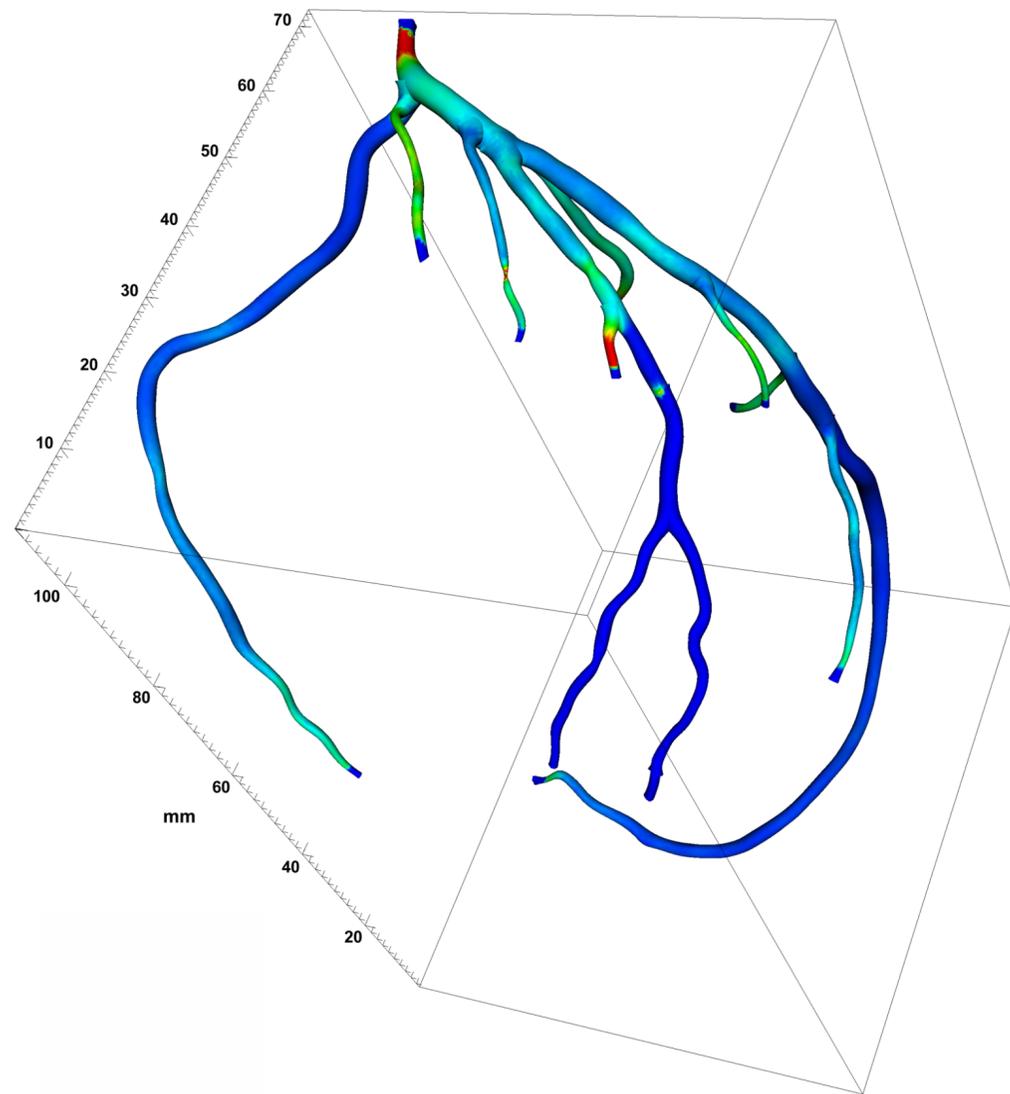


Plot Layers - Image Widget  
wS.1  
wS  
Plot Options - Image Widget  
Data: wS  
Attribute: PRIMARY







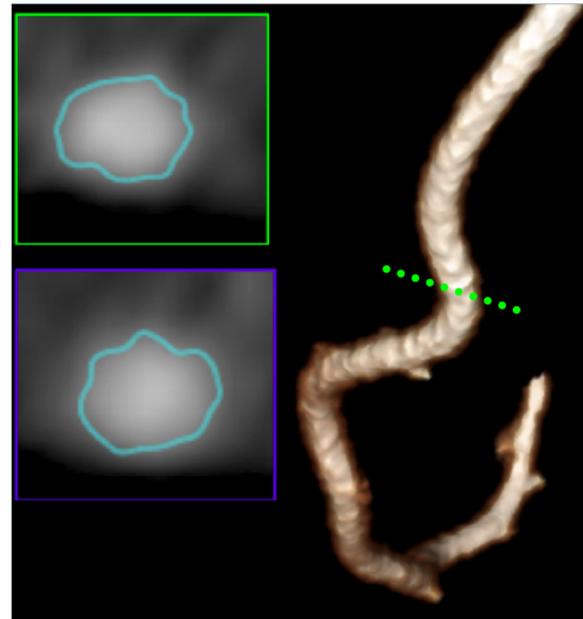


*Michelle Borkin, Krzysztof Gajos, Amanda Peters, Dimitris Mitsouras, Simone Melchionna, Frank Rybicki, Charles Feldman, & Hanspeter Pfister, "Evaluation of Artery Visualizations for Heart Disease Diagnosis" (IEEE TVCG / InfoVis 2011)*

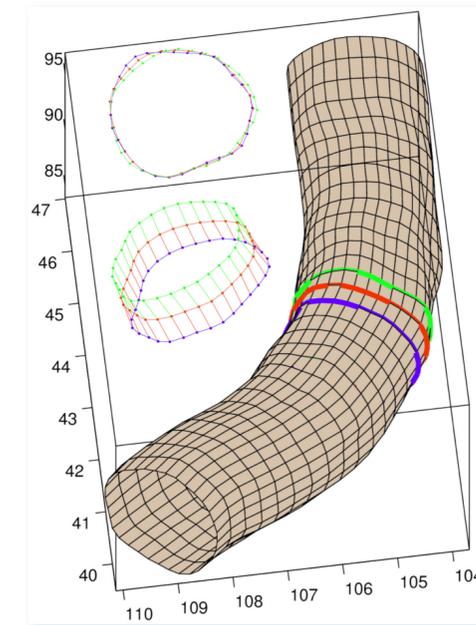
# NON-INVASIVE DIAGNOSIS



Obtain patient CT data



Segment arteries

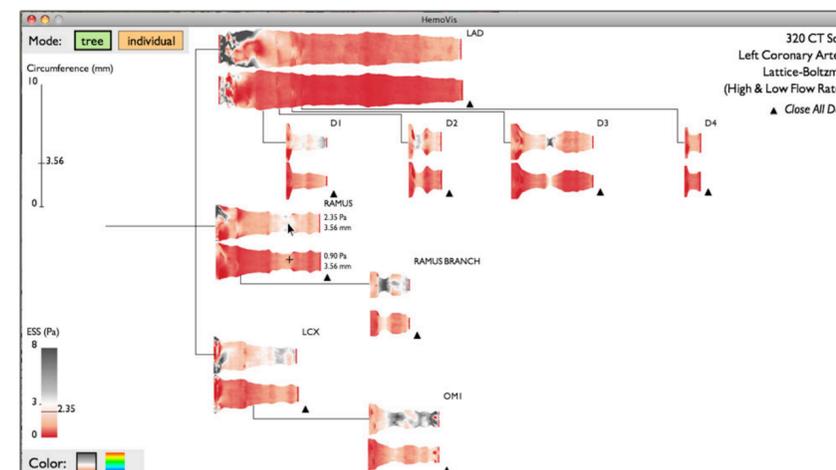


Generate patient geometries

Patient specific  
blood flow simulation



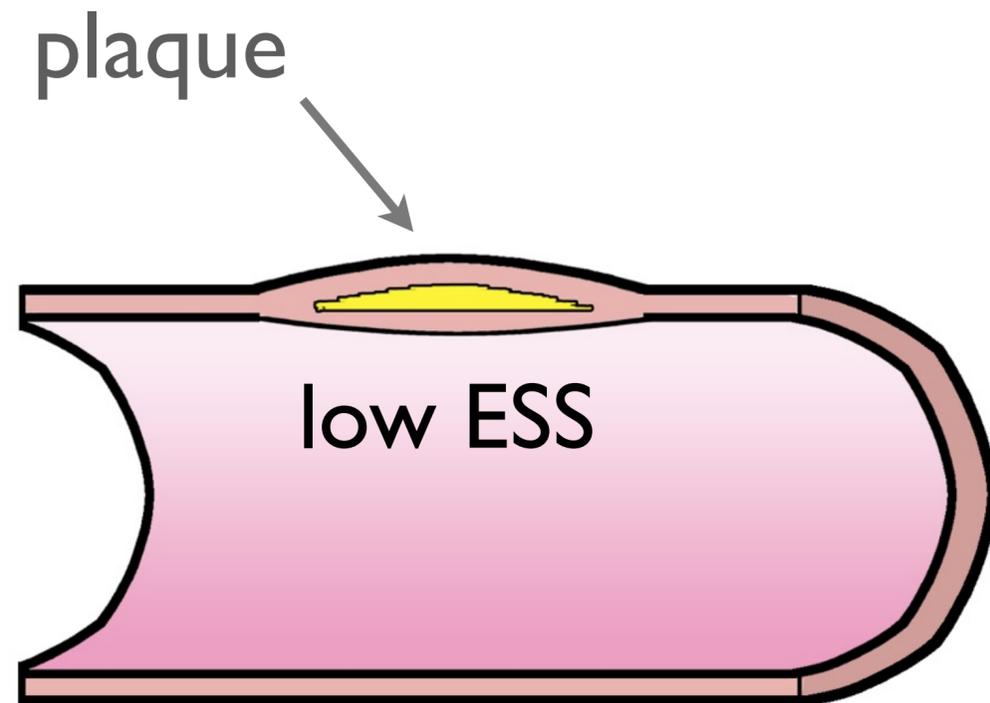
Visualize and  
analyze data



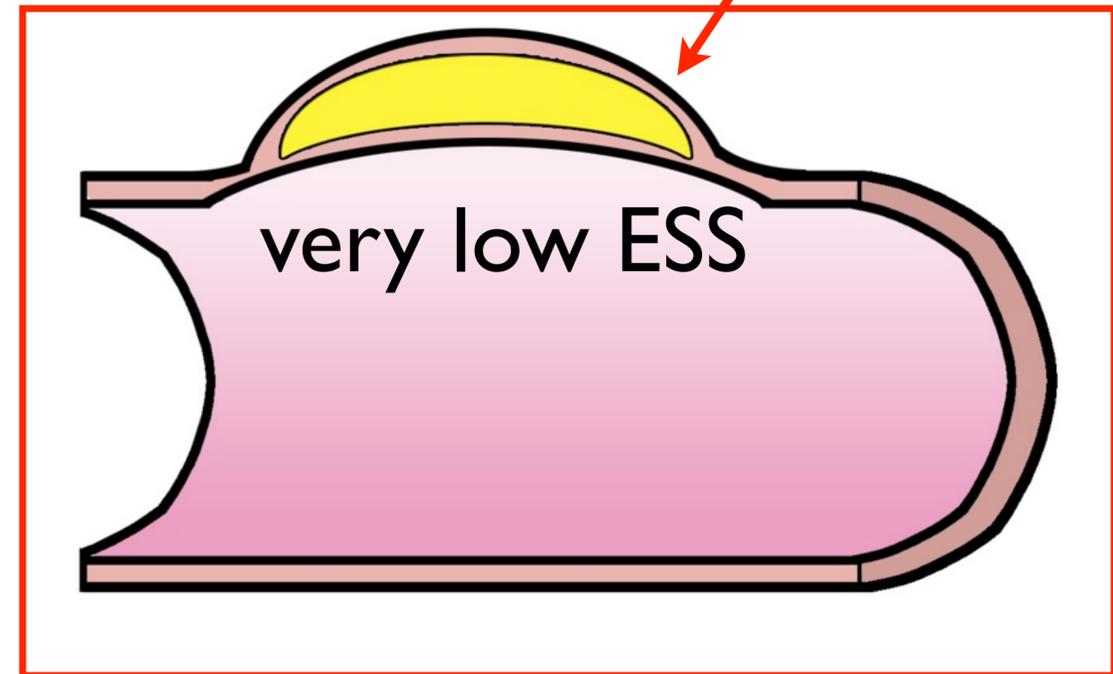
Clinical decision



# DATA

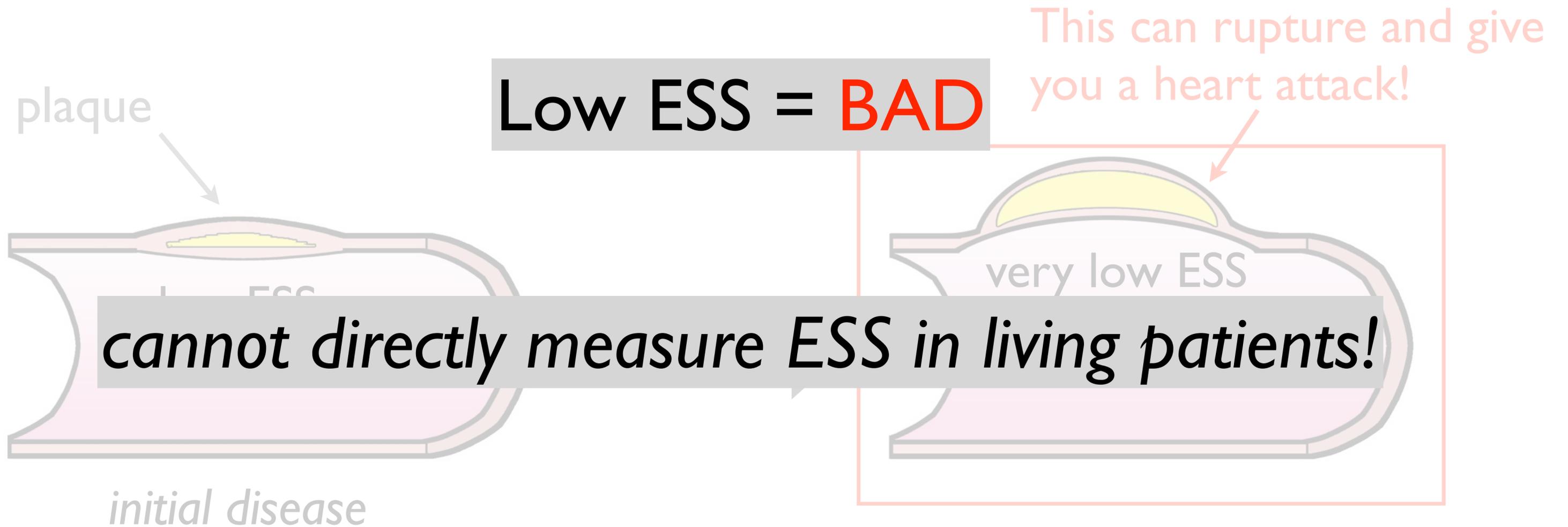


*initial disease*

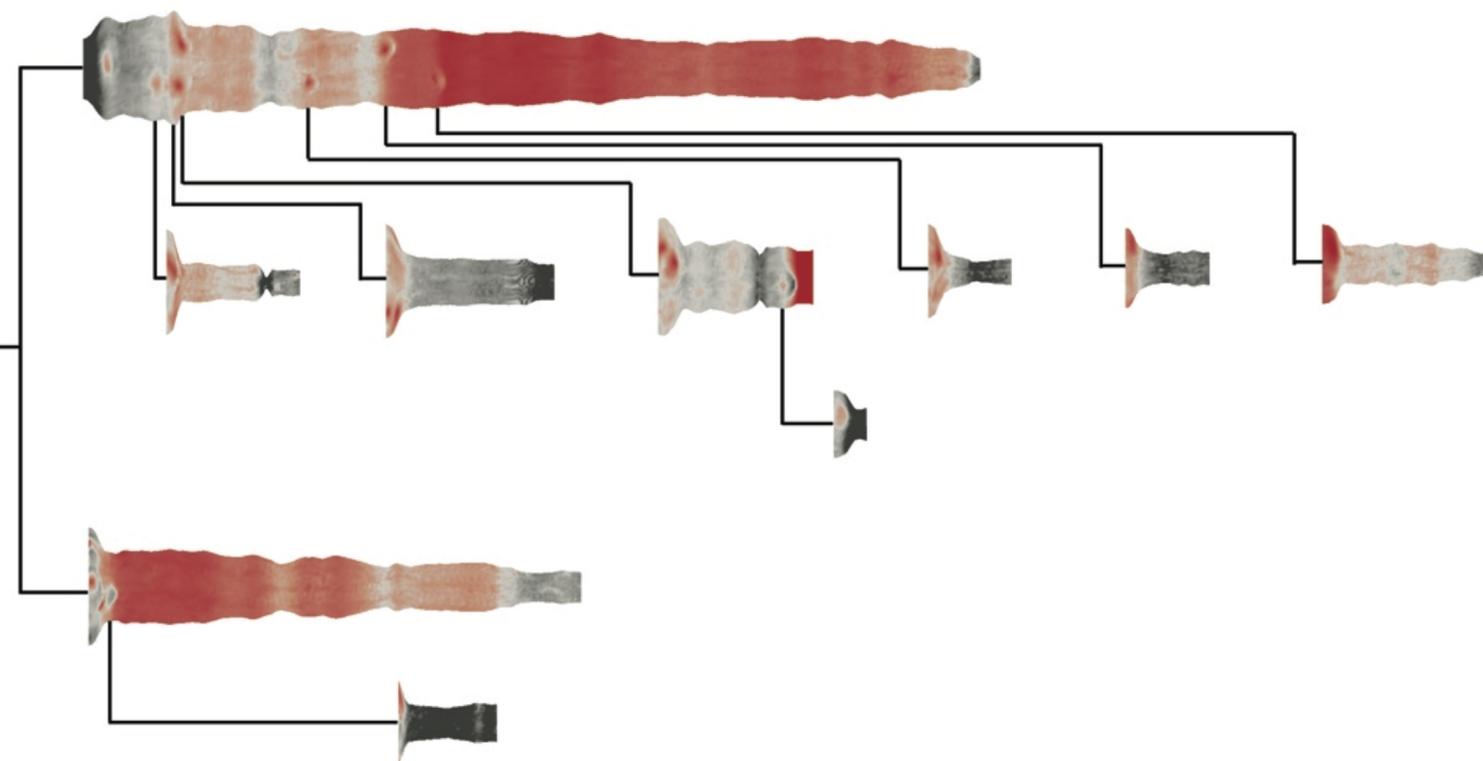
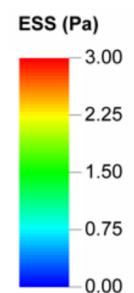
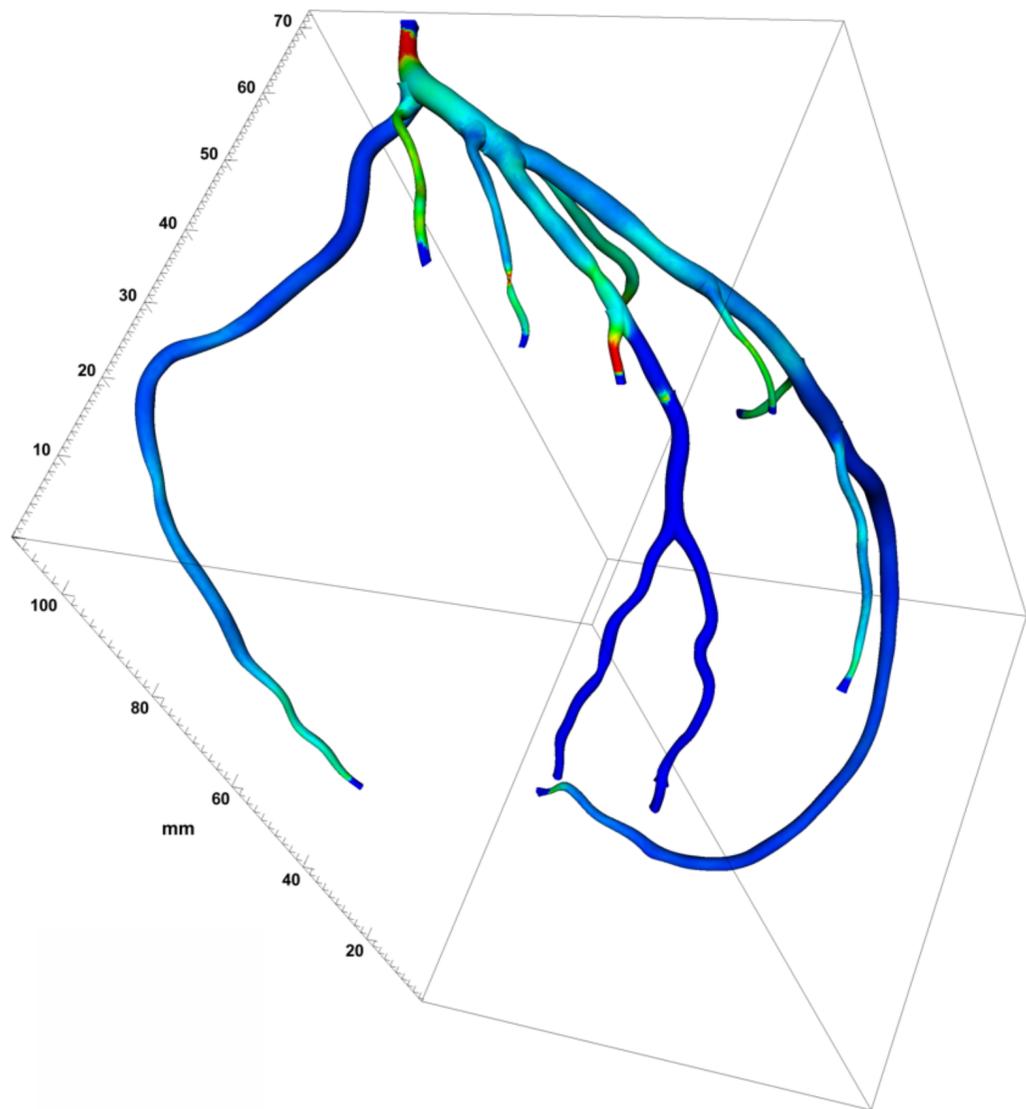


ESS = endothelial shear stress  
(i.e., frictional force from blood flow)

# DATA



ESS = endothelial shear stress  
(i.e., frictional force from blood flow)



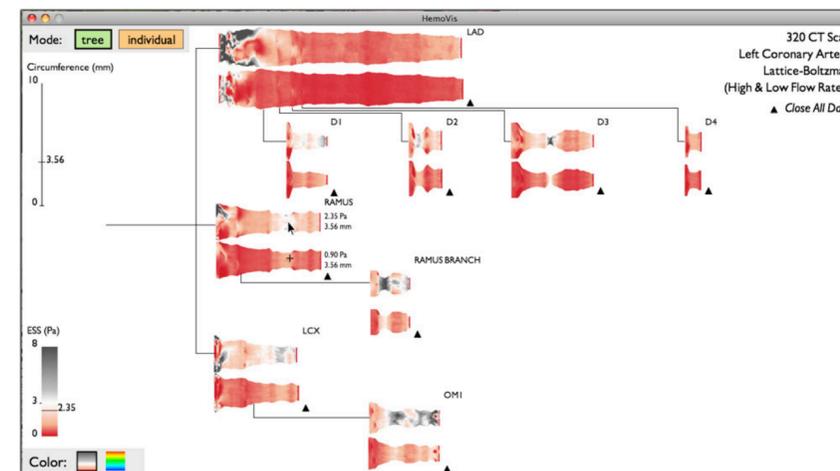
# FORMATIVE QUALITATIVE STUDY

- Semi-structured interviews
- 10 medical doctors and researchers
- Brigham & Women's Hospital (Boston, MA)

Clinical decision



Visualize and analyze data

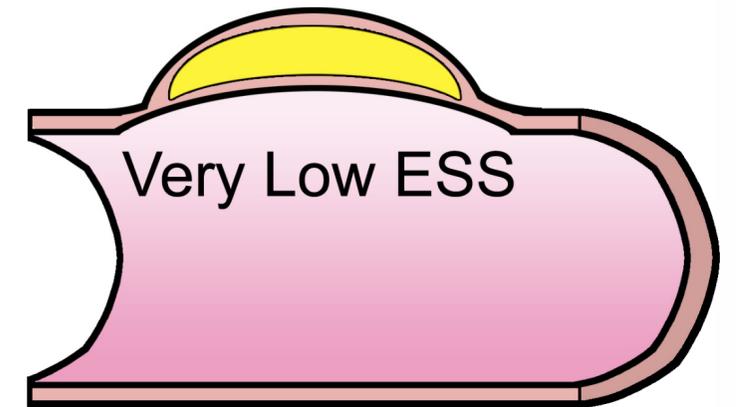


# TASK TAXONOMY

<b>TASK</b>	<b>ABSTRACTION</b>
-------------	--------------------

# TASK TAXONOMY

<b>TASK</b>	<b>ABSTRACTION</b>
“Identify regions of low ESS”	find extrema



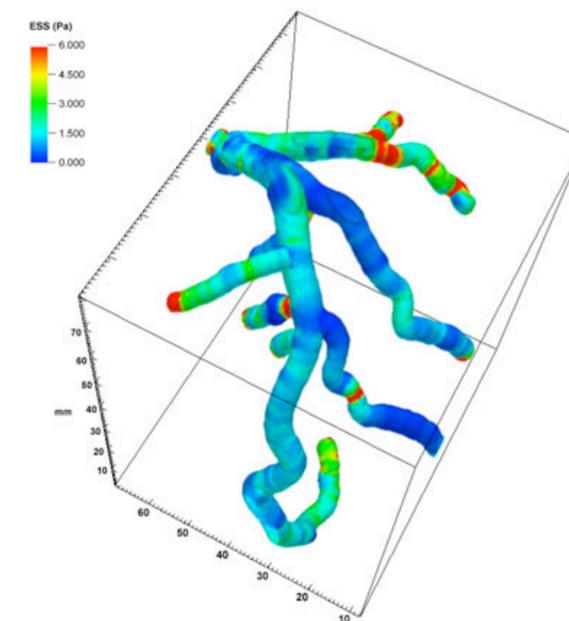
# TASK TAXONOMY

<b>TASK</b>	<b>ABSTRACTION</b>
“Identify regions of low ESS”	find extrema
“Identify stenosis or blockage”	find extrema



# TASK TAXONOMY

<b>TASK</b>	<b>ABSTRACTION</b>
“Identify regions of low ESS”	find extrema
“Identify stenosis or blockage”	find extrema
“View all ESS data for patterns”	cluster



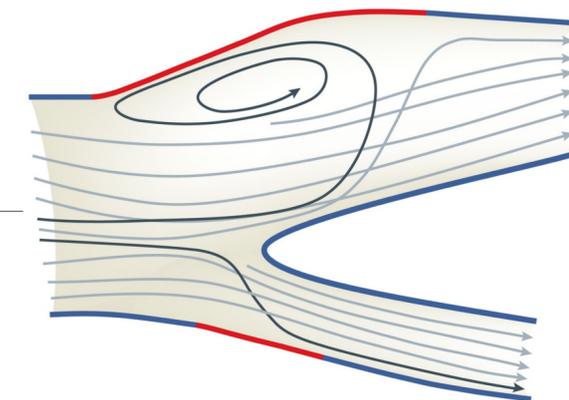
# TASK TAXONOMY

<b>TASK</b>	<b>ABSTRACTION</b>
“Identify regions of low ESS”	find extrema
“Identify stenosis or blockage”	find extrema
“View all ESS data for patterns”	cluster
“Study blood flow velocity patterns”	find anomalies



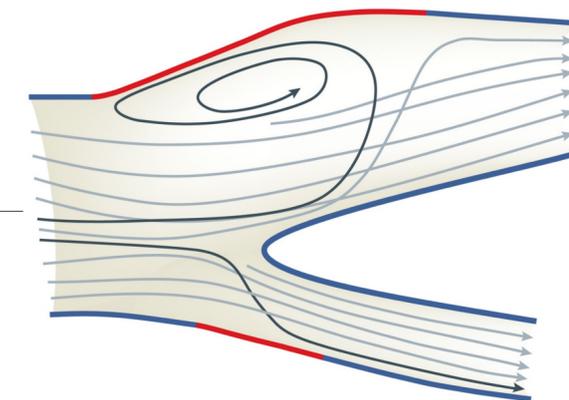
# TASK TAXONOMY

<b>TASK</b>	<b>ABSTRACTION</b>
“Identify regions of low ESS”	find extrema
“Identify stenosis or blockage”	find extrema
“View all ESS data for patterns”	cluster
“Study blood flow velocity patterns”	find anomalies
“Identify regions of blood recirculation”	find anomalies



# TASK TAXONOMY

<b>TASK</b>	<b>ABSTRACTION</b>
“Identify regions of low ESS”	find extrema
“Identify stenosis or blockage”	find extrema
“View all ESS data for patterns”	cluster
“Study blood flow velocity patterns”	find anomalies
“Identify regions of blood recirculation”	find anomalies
“Investigate other physical variables of blood flow”	find anomalies



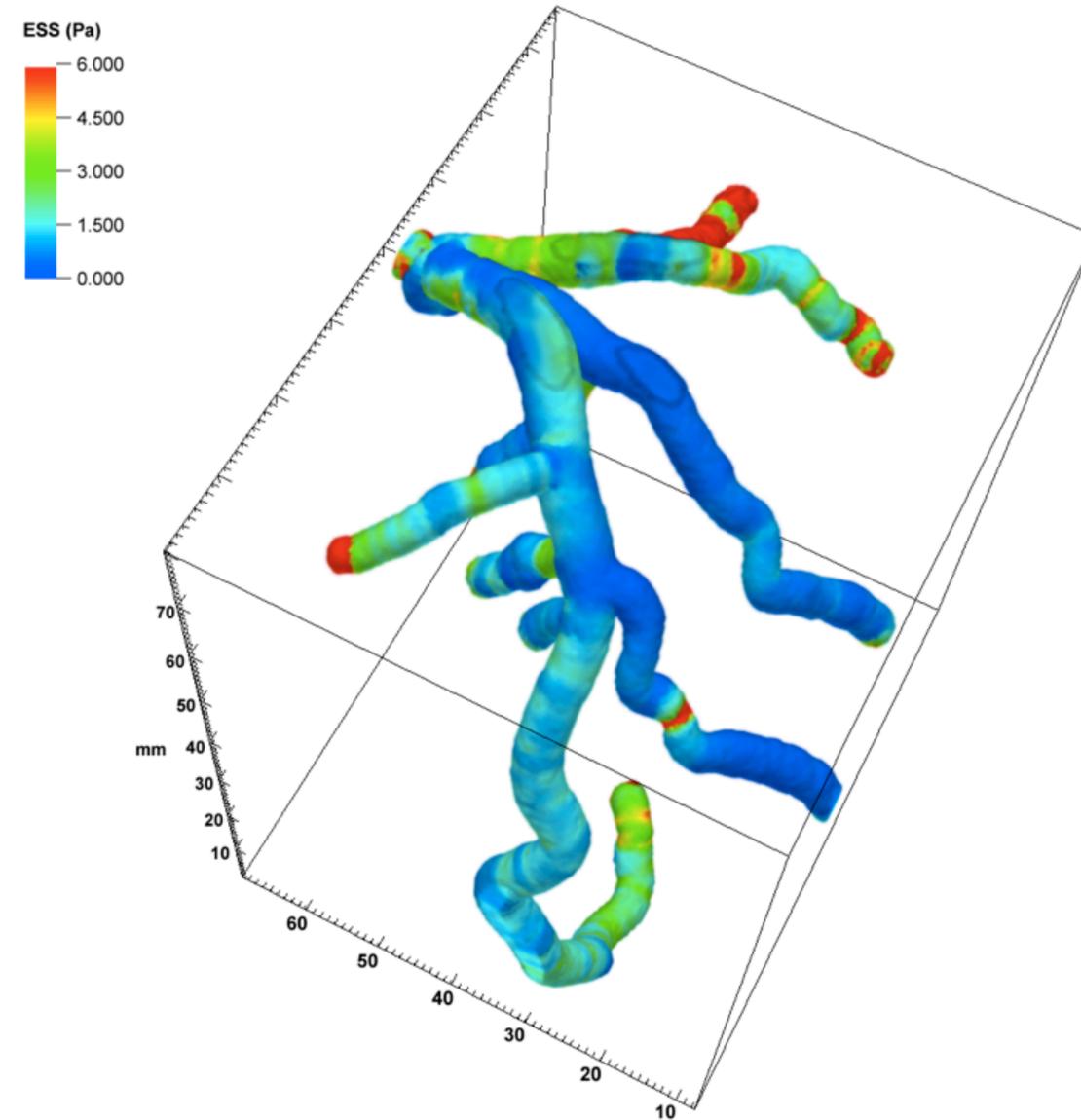
# TASK TAXONOMY

<b>TASK</b>	<b>ABSTRACTION</b>	<b>CLINICAL</b>	<b>RESEARCH</b>
“Identify regions of low ESS”	find extrema	X	X
“Identify stenosis or blockage”	find extrema	X	X
“View all ESS data for patterns”	cluster	X	X
“Study blood flow velocity patterns”	find anomalies		X
“Identify regions of blood recirculation”	find anomalies		X
“Investigate other physical variables of blood flow”	find anomalies		X

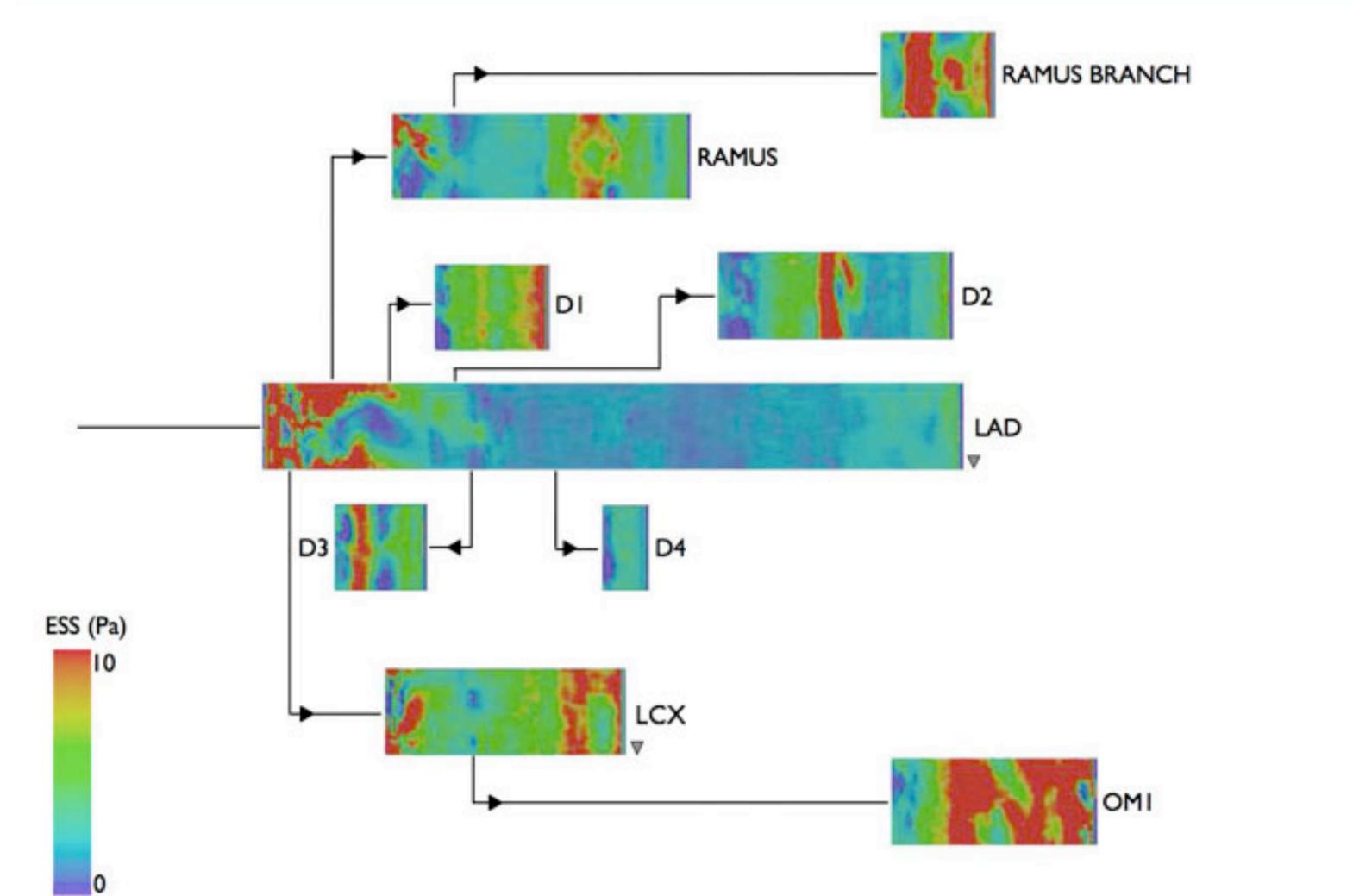
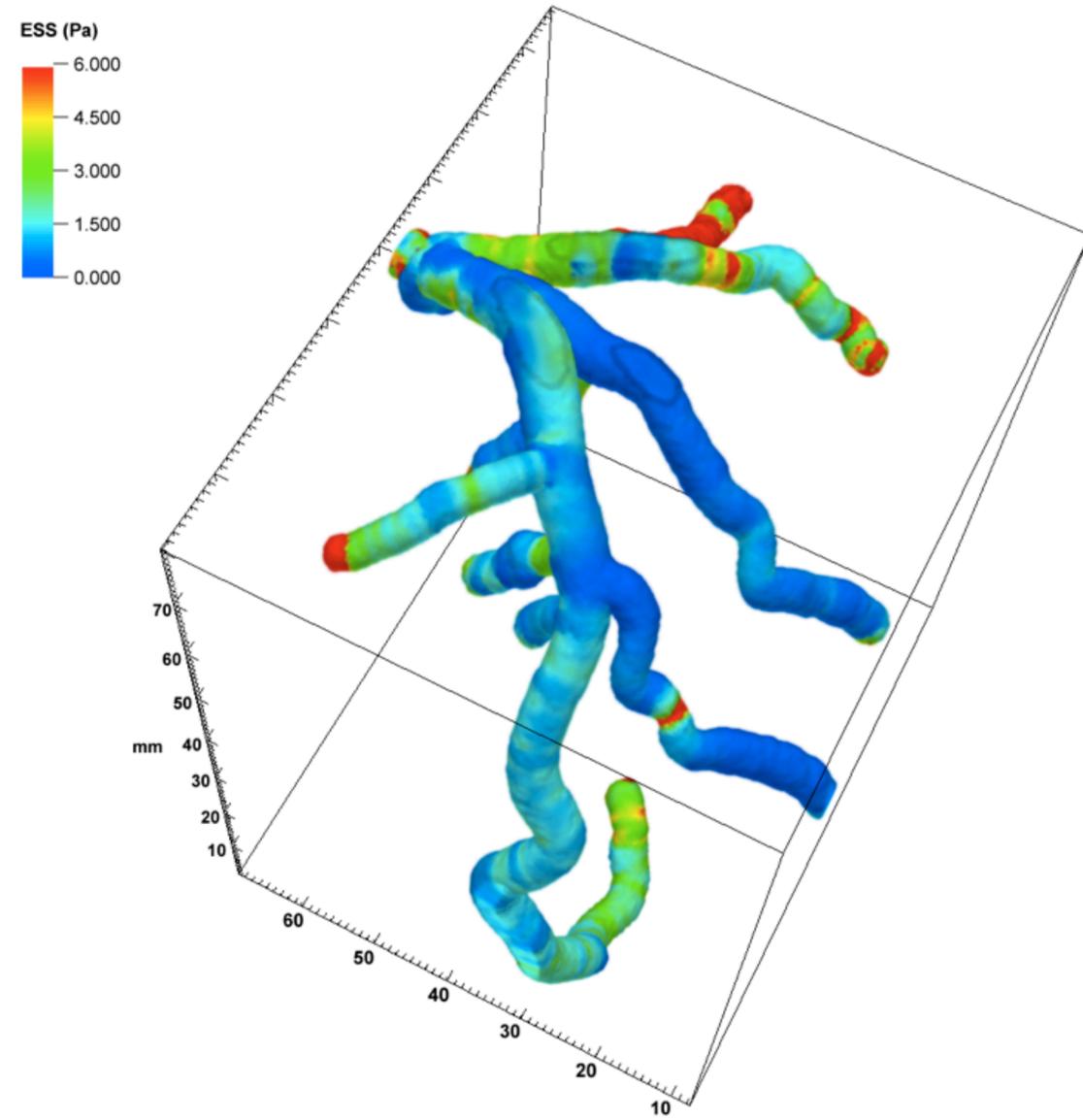
# TASK TAXONOMY

<b>TASK</b>	<b>ABSTRACTION</b>	<b>CLINICAL</b>	<b>RESEARCH</b>
“Identify regions of low ESS”	find extrema	X	X
“Identify stenosis or blockage”	find extrema	X	X
“View all ESS data for patterns”	cluster	X	X
“Study blood flow velocity patterns”	find anomalies		X
“Identify regions of blood recirculation”	find anomalies		X
“Investigate other physical variables of blood flow”	find anomalies		X

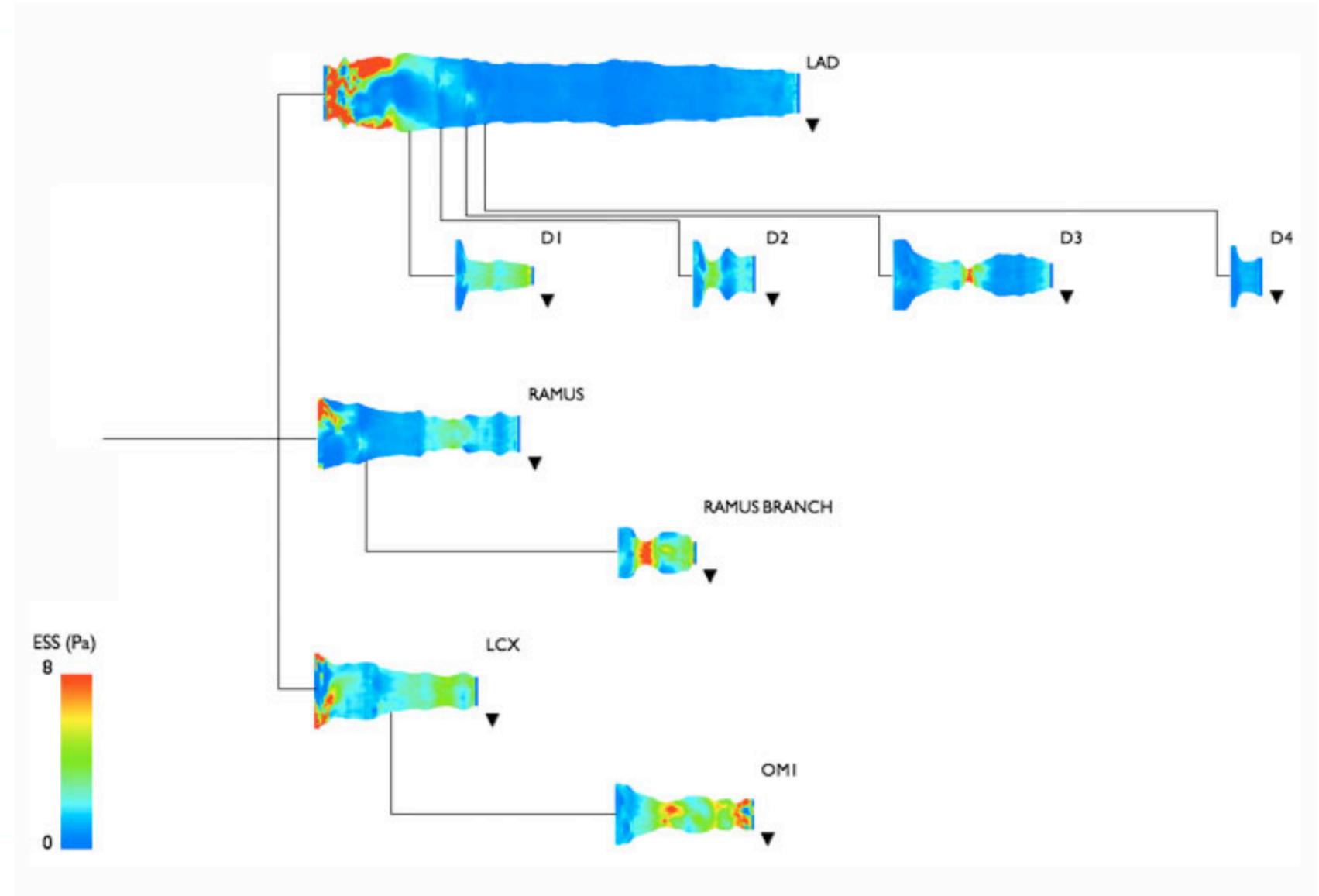
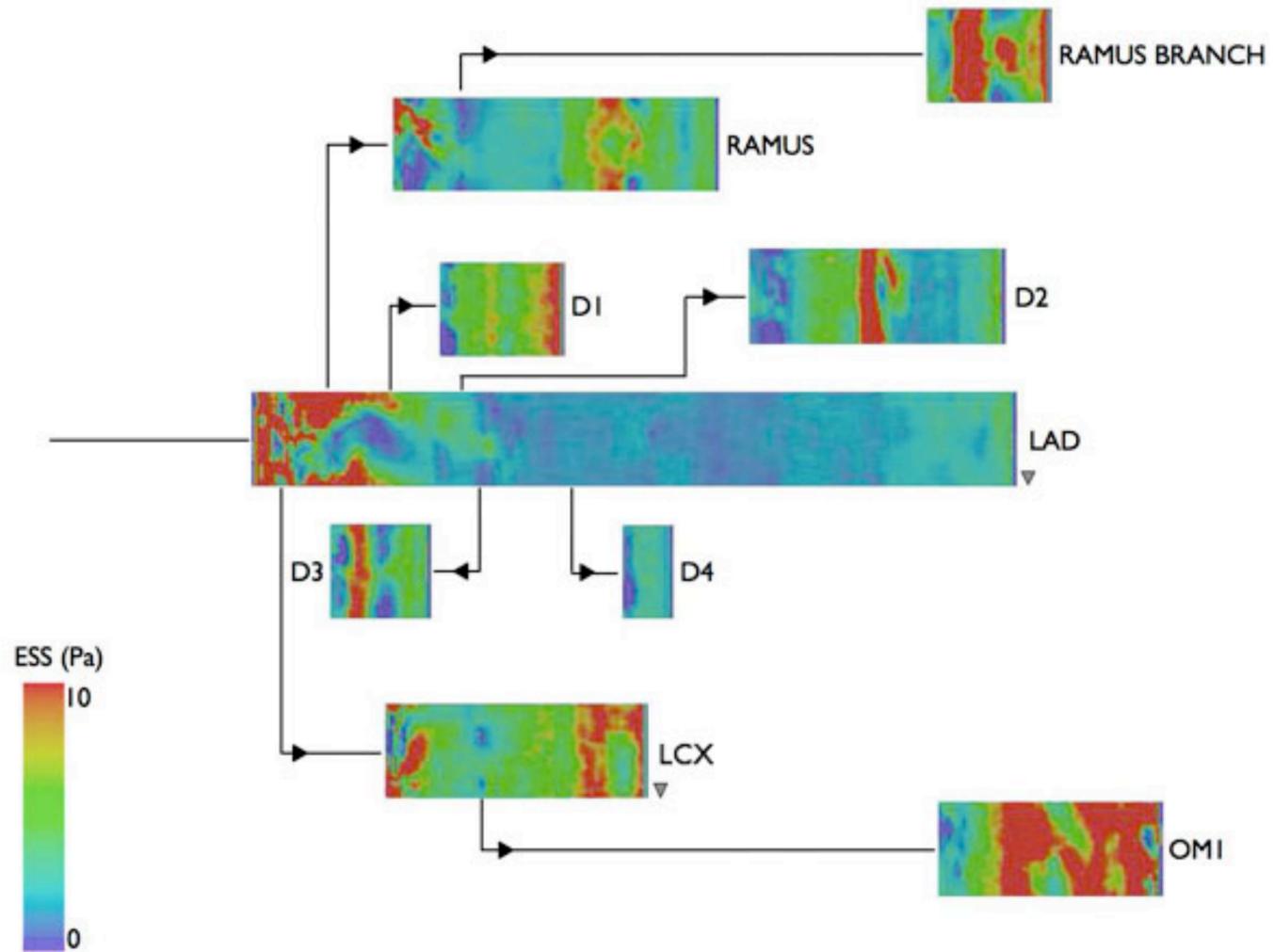
# 3D vs. 2D

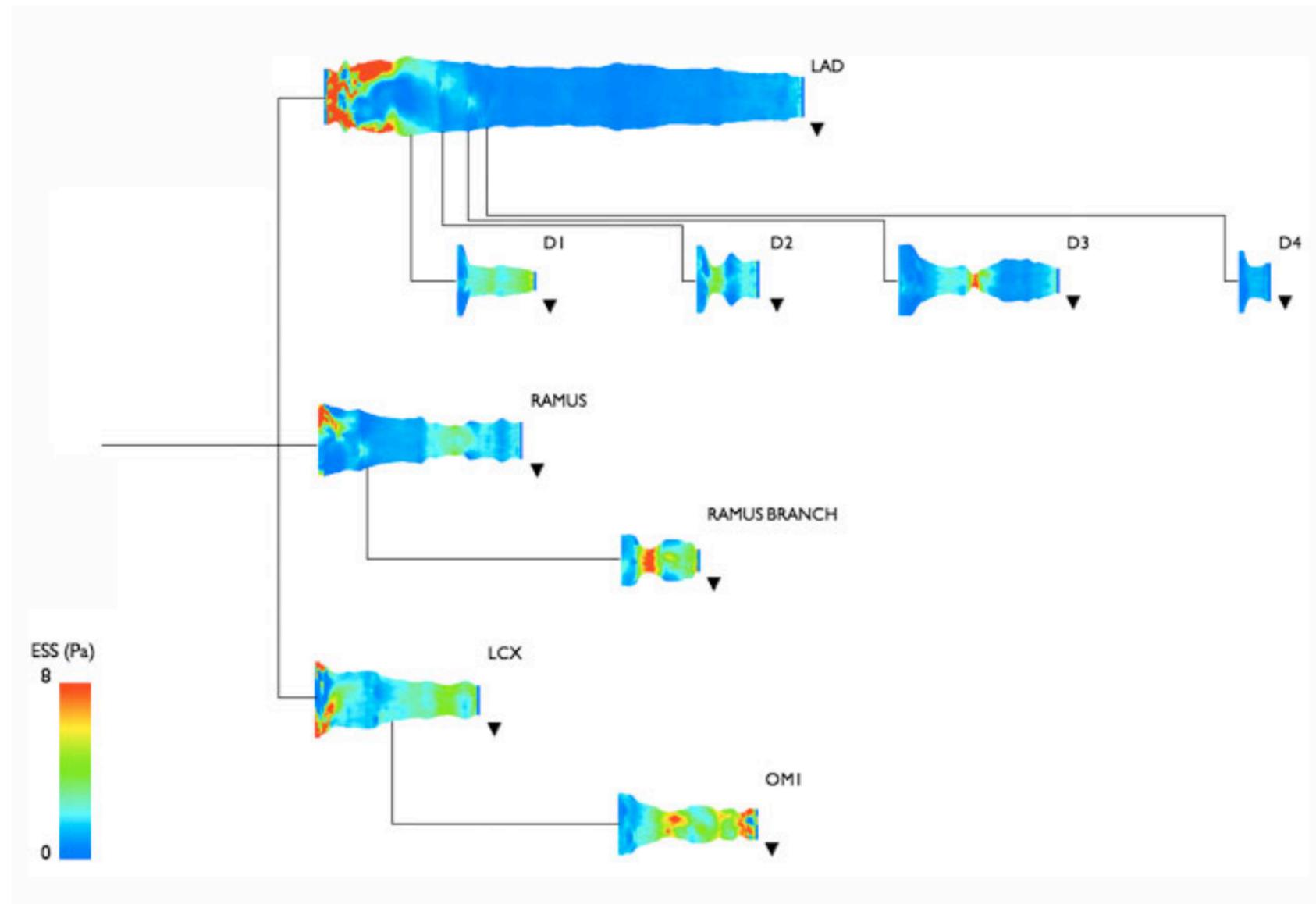


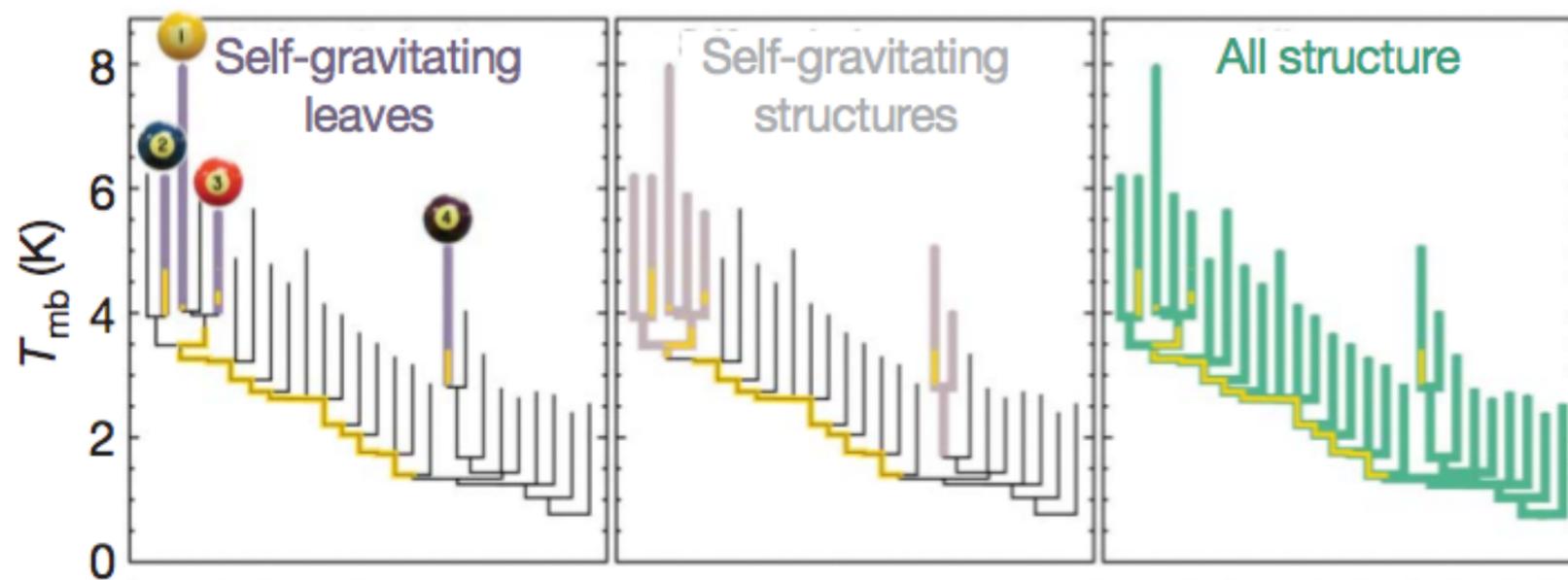
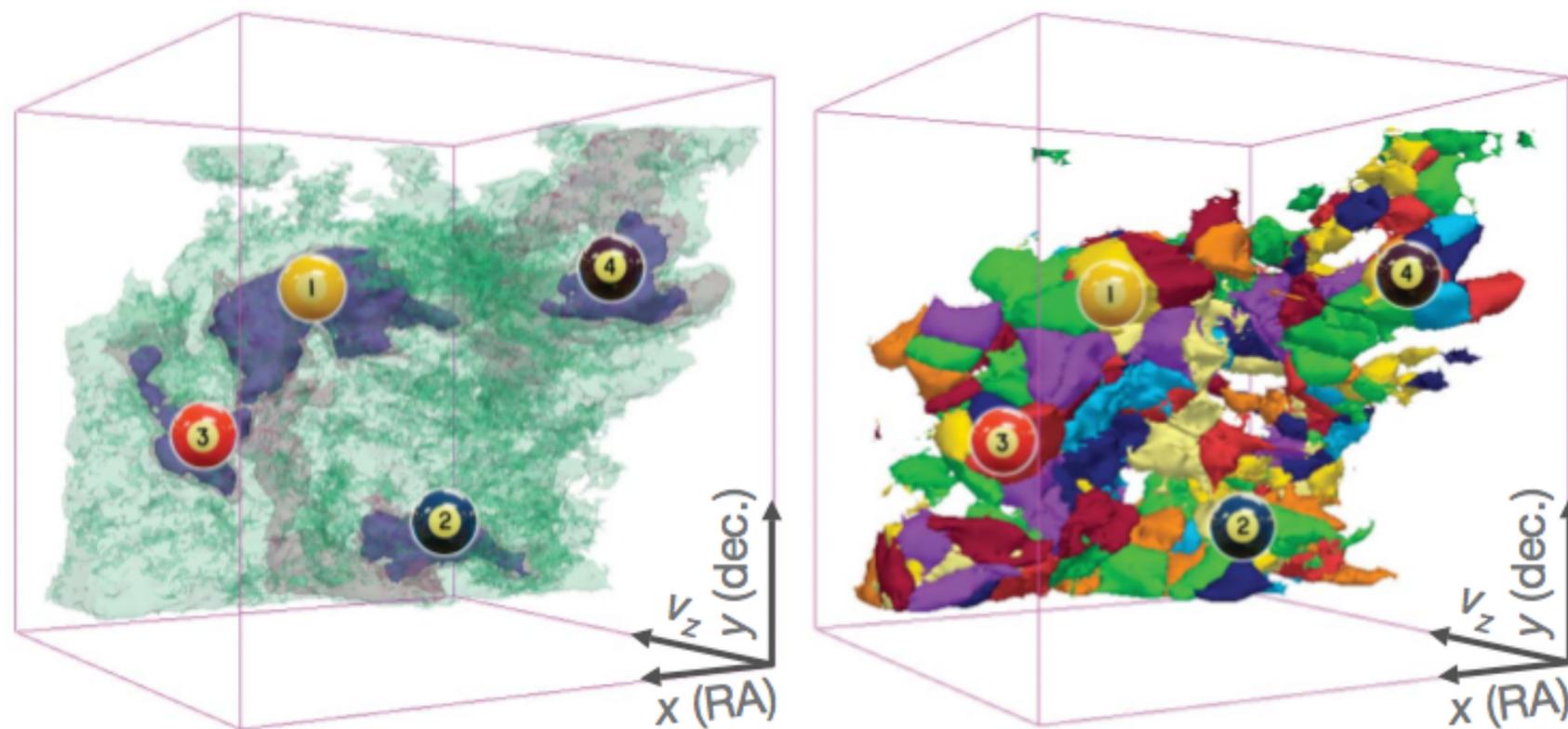
# 3D vs. 2D

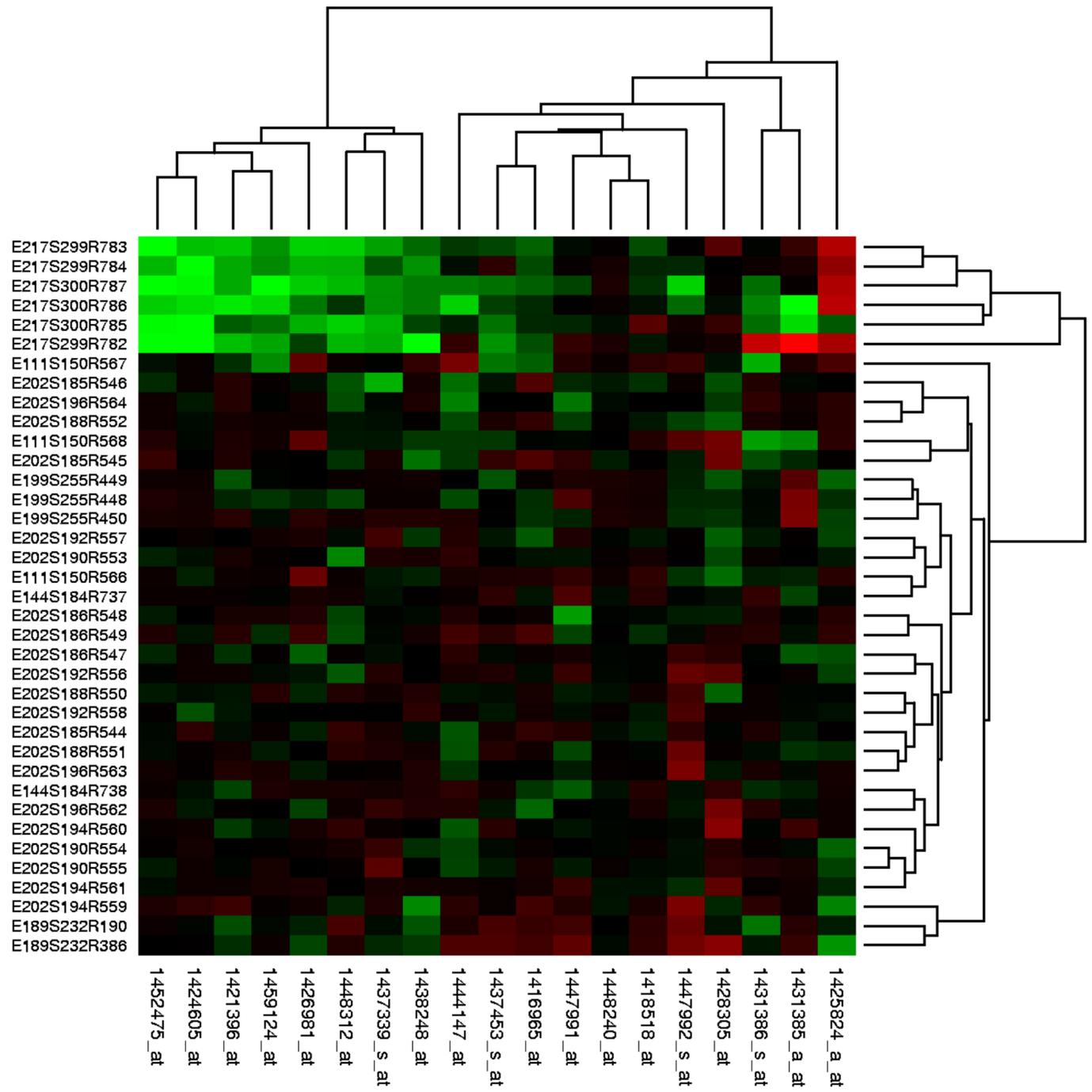


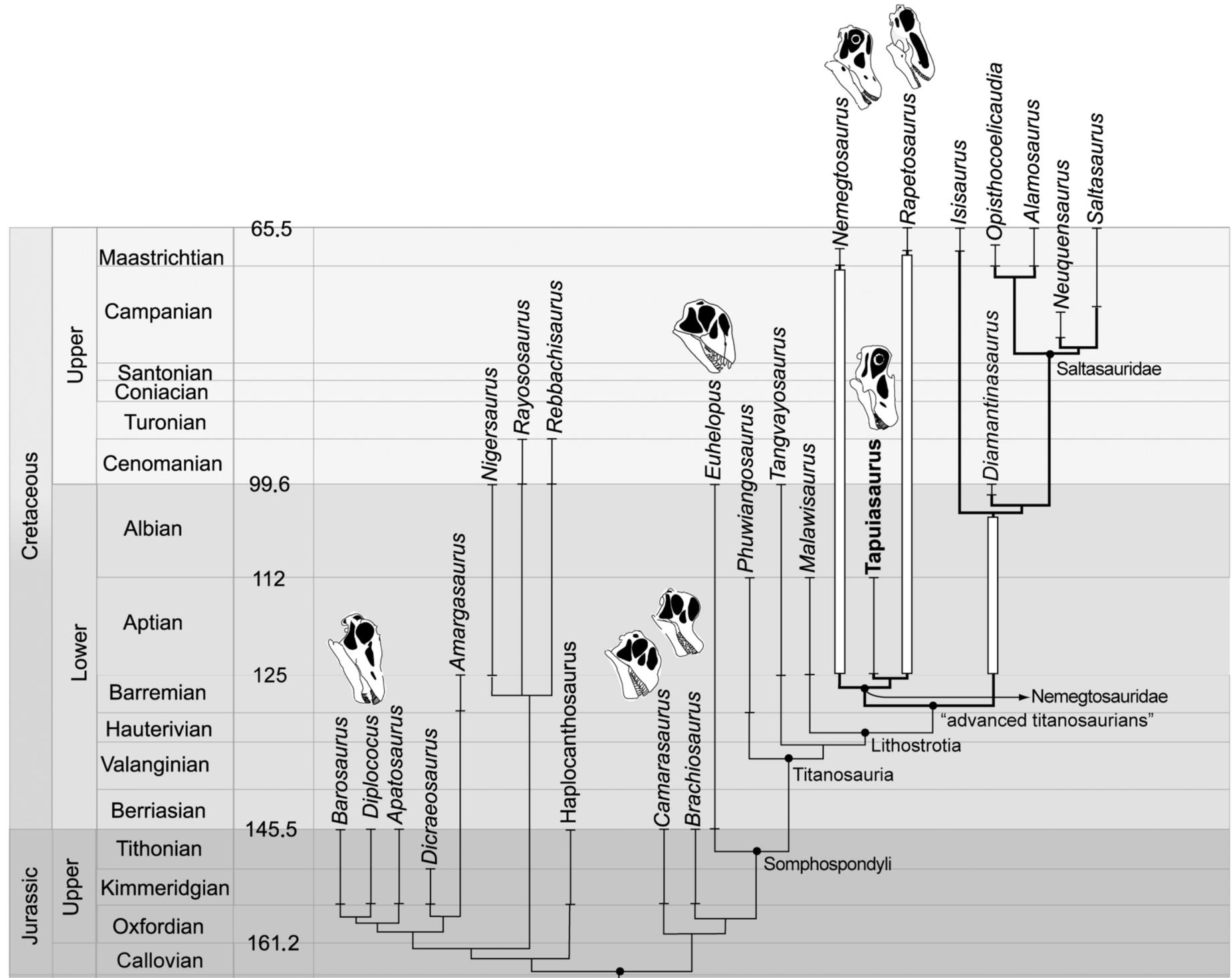
# LAYOUT AND PROJECTIONS





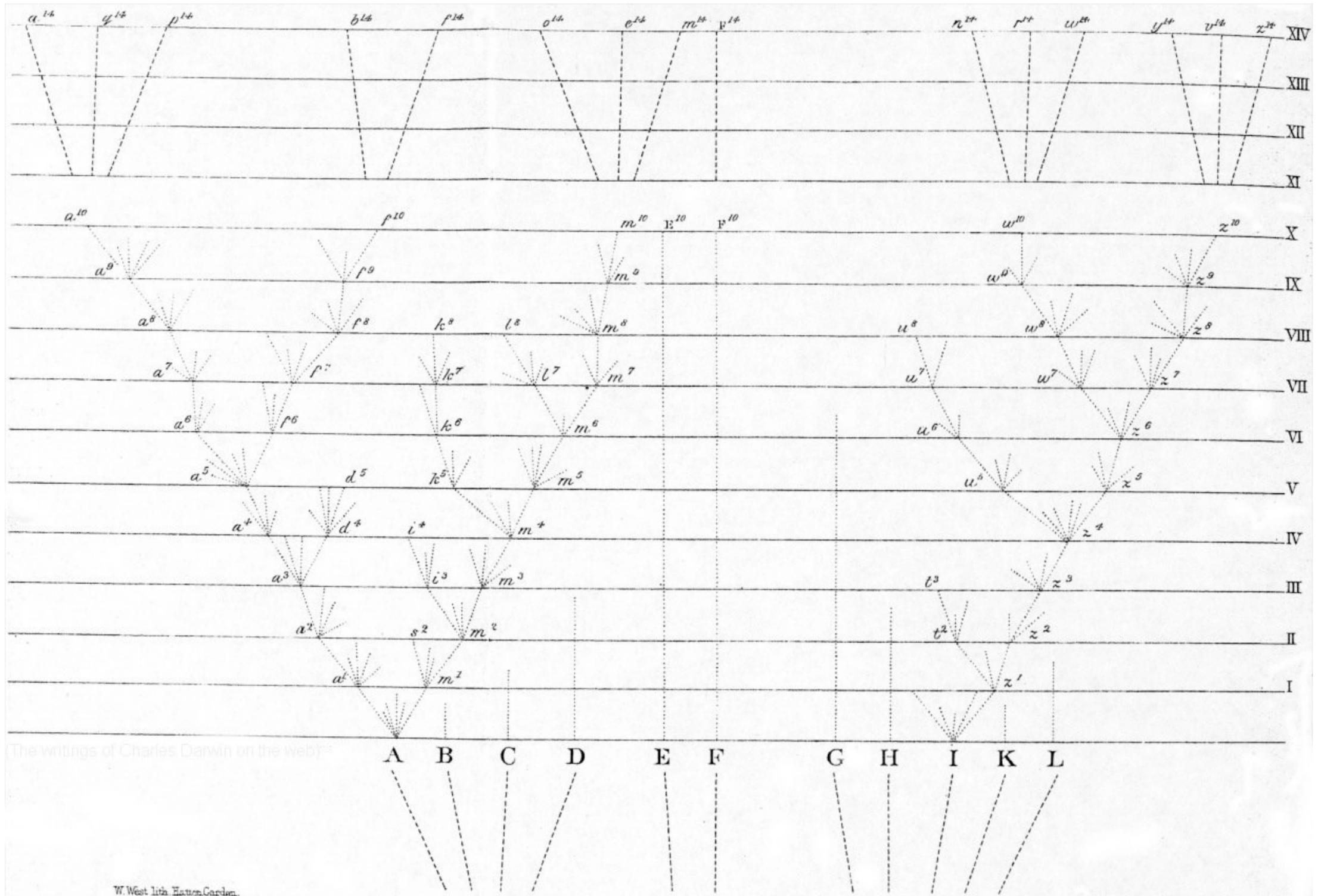




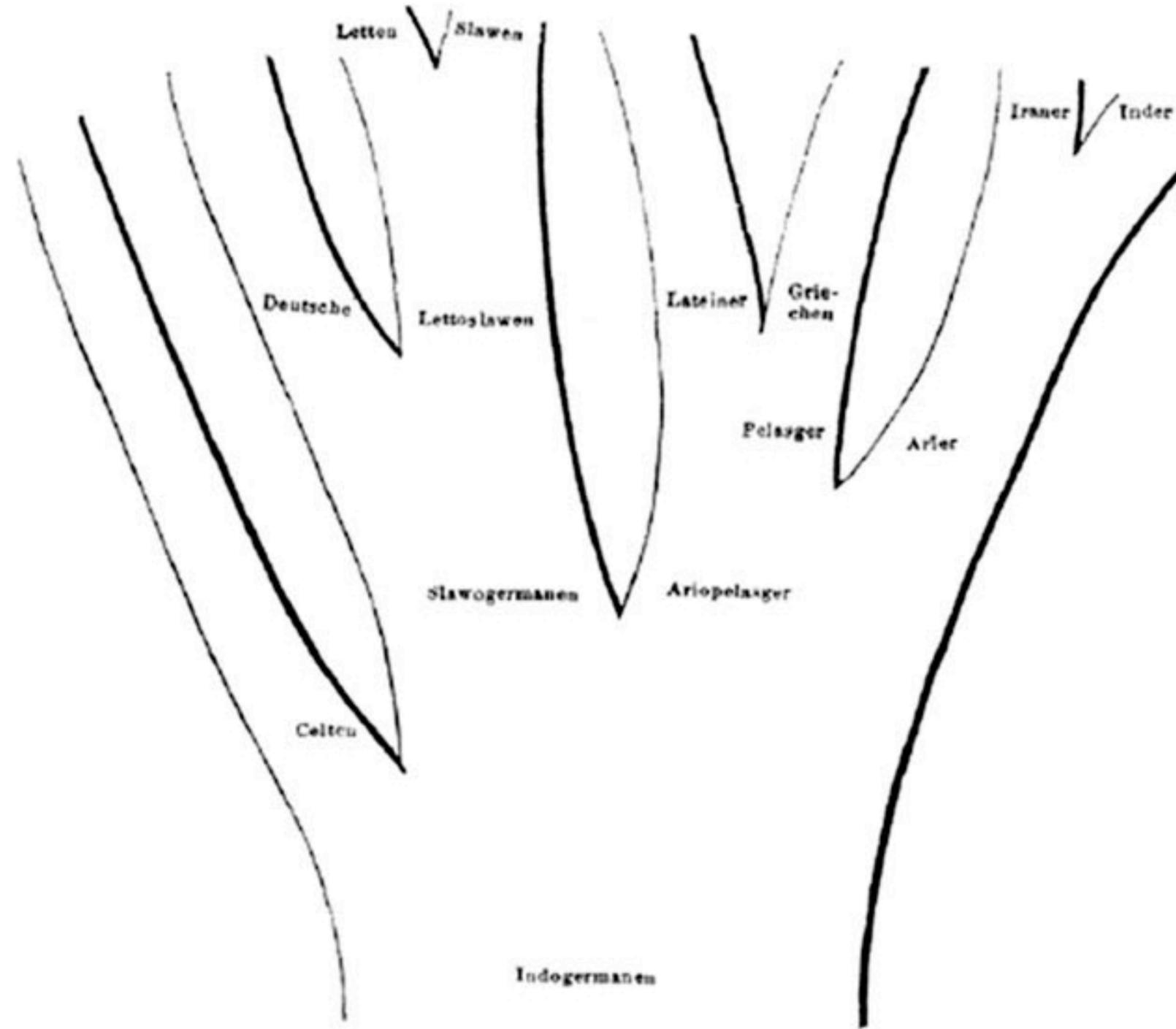


basal eusauropods ← Neosauropoda

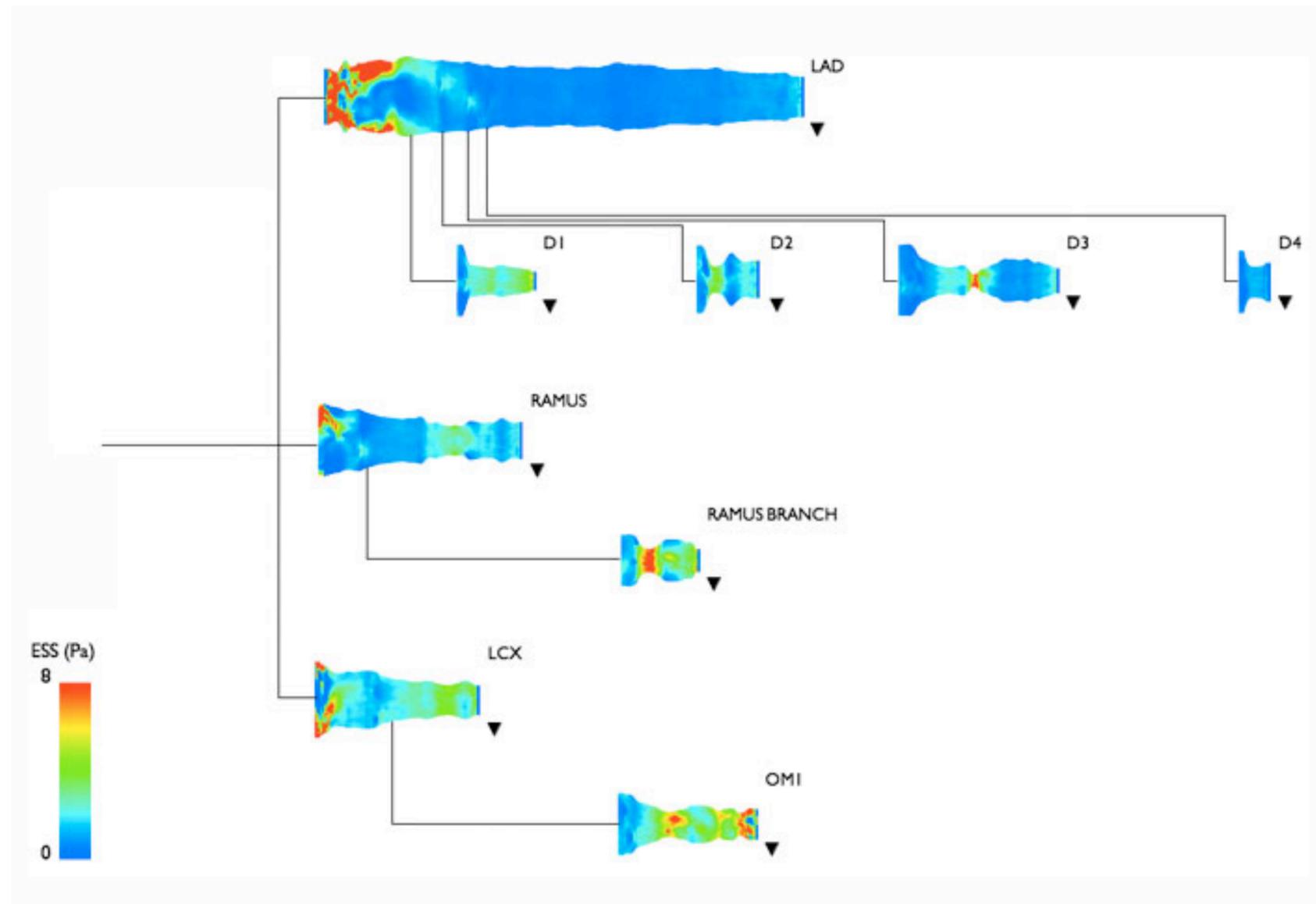
Authors: A. Carvalho, P. Nascimento & C. Riccomini



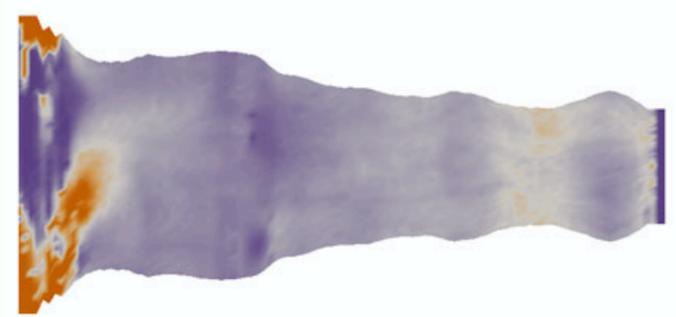
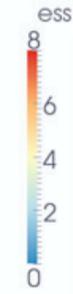
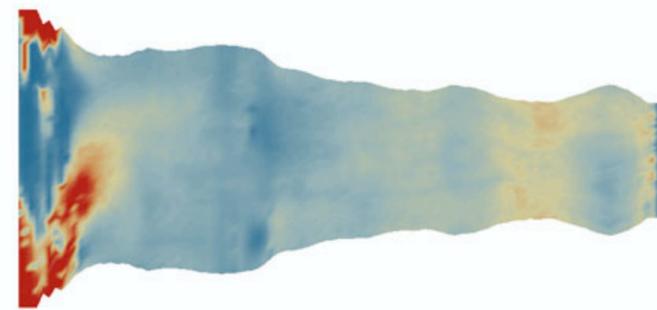
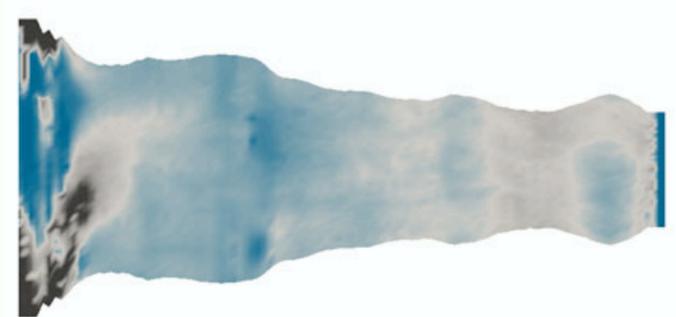
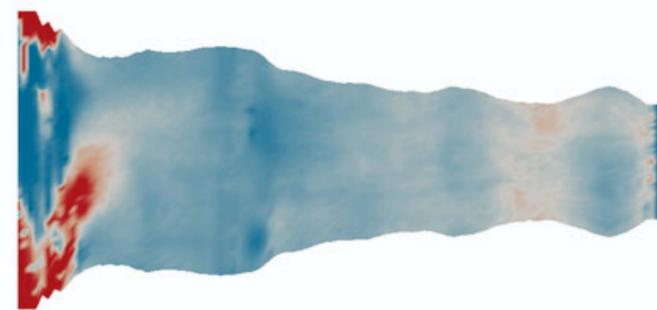
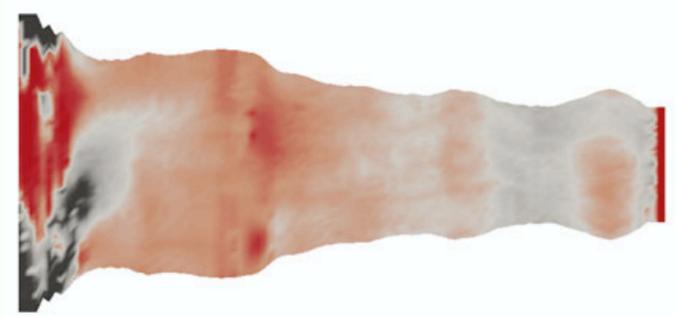
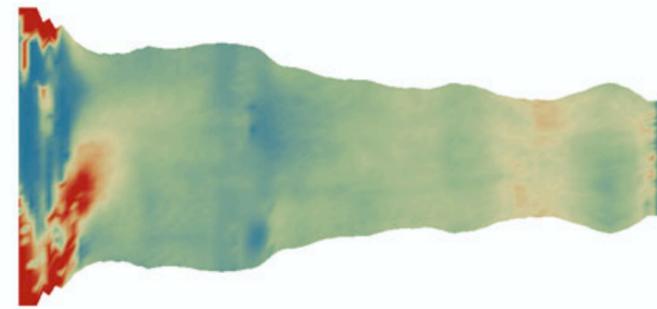
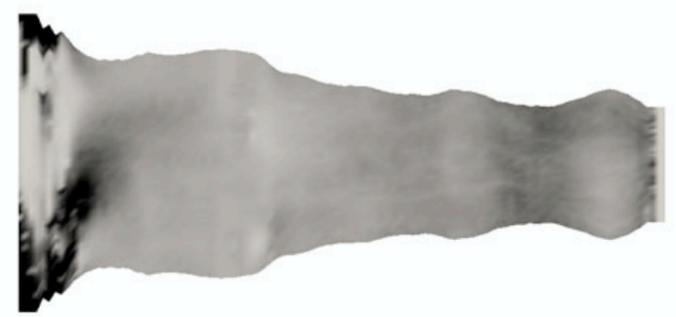
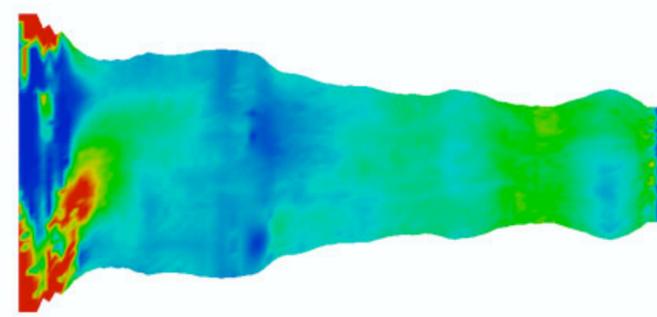
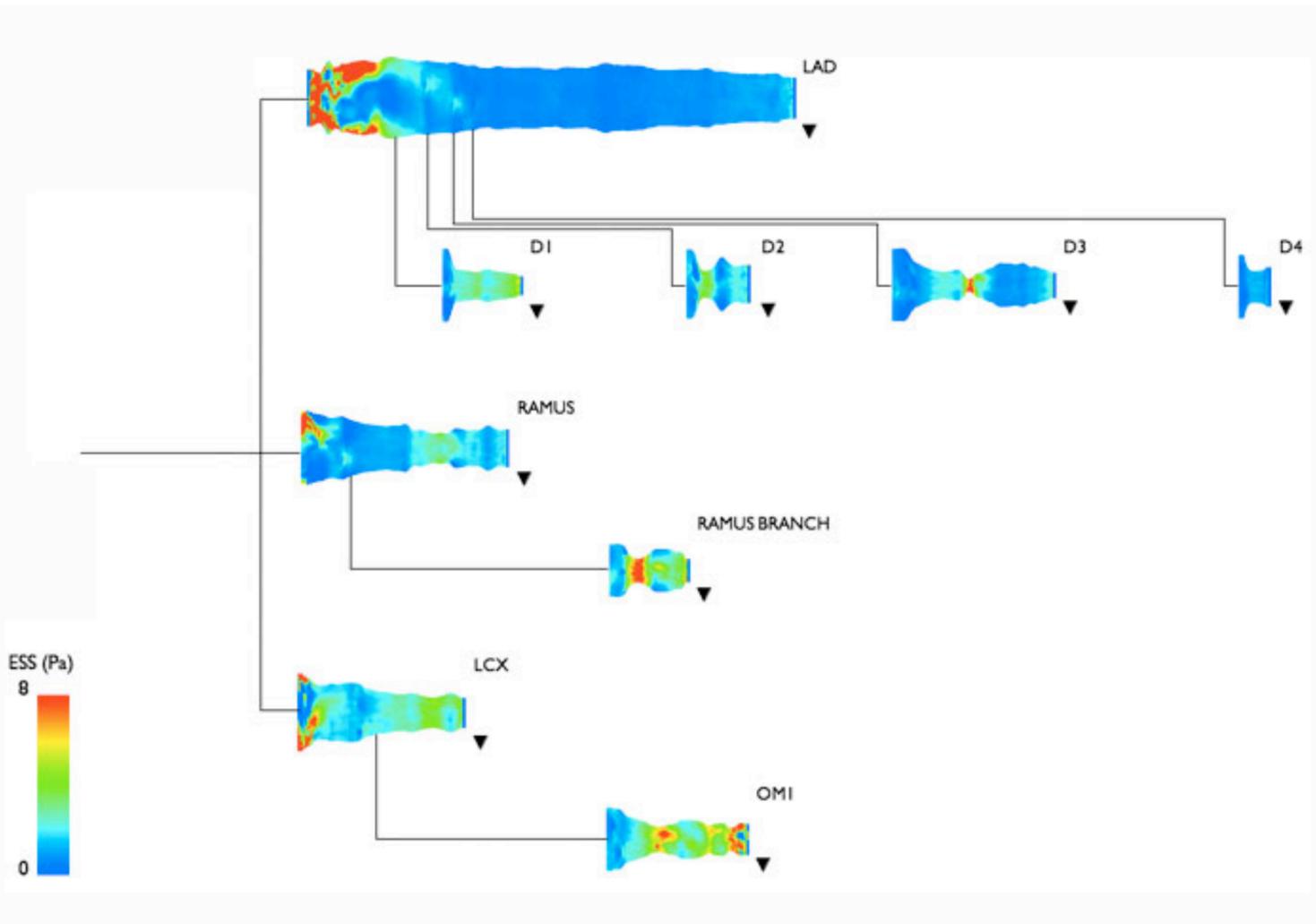
The writings of Charles Darwin on the web?



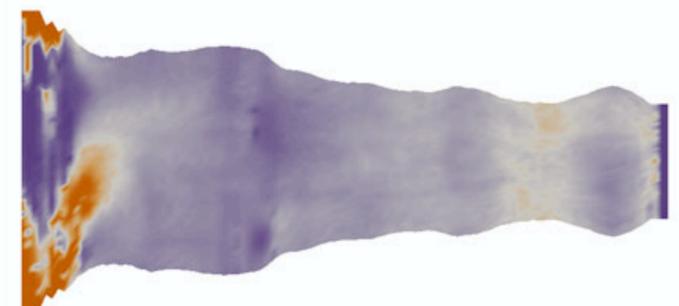
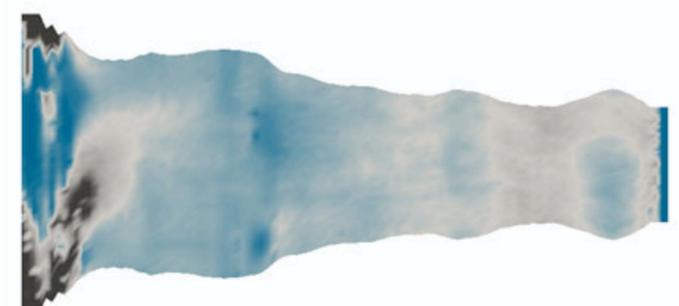
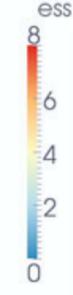
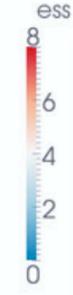
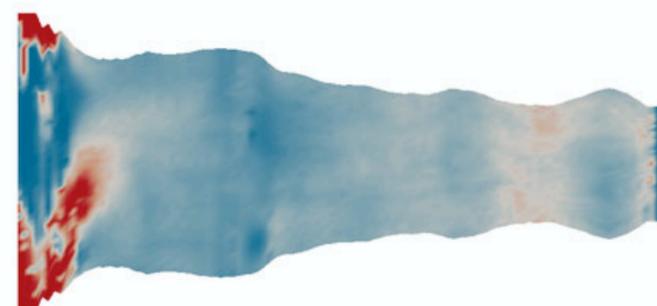
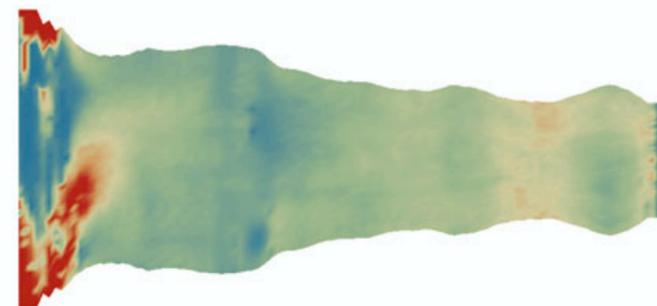
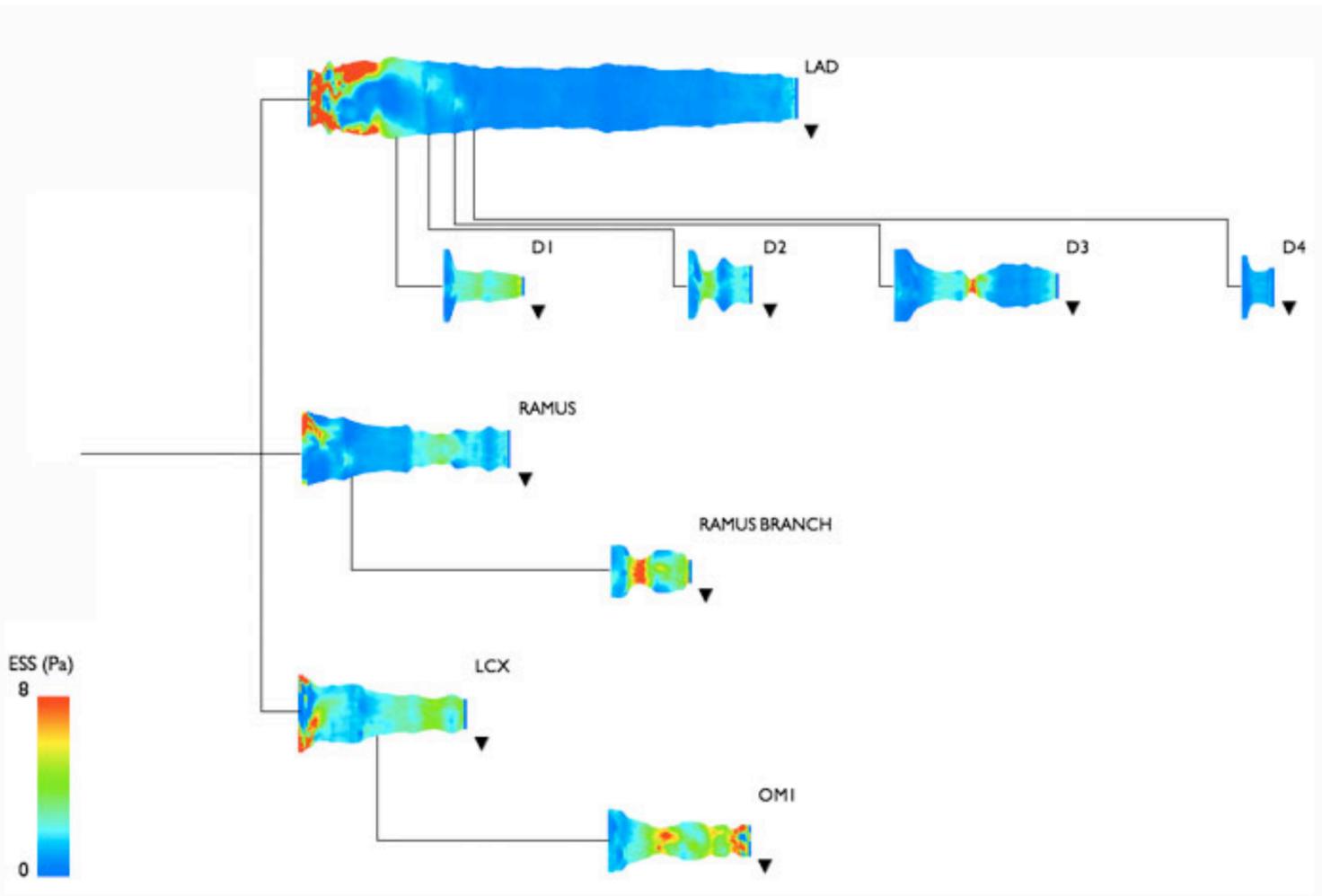
Sonneberg, den 15. Aug. 1853.



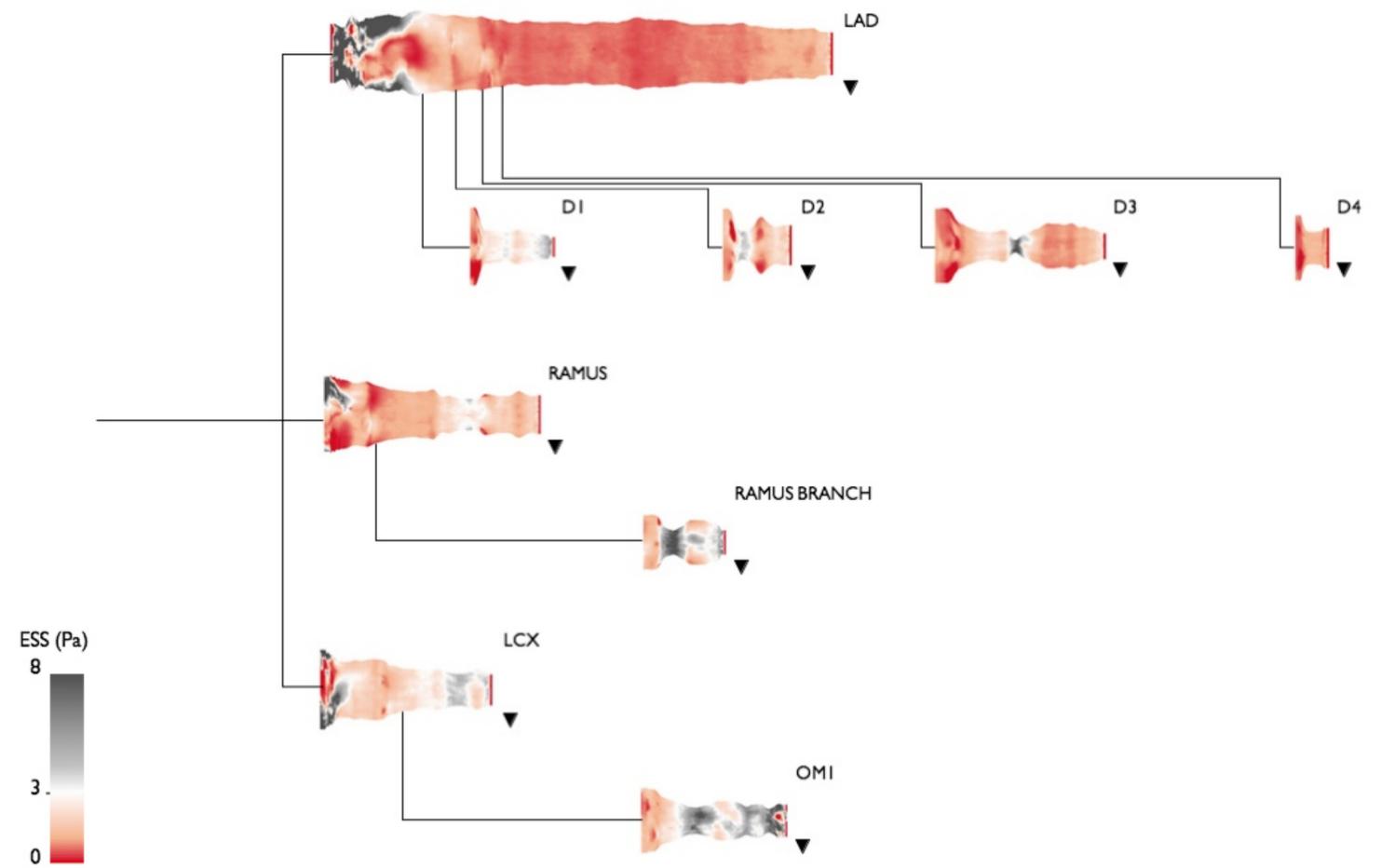
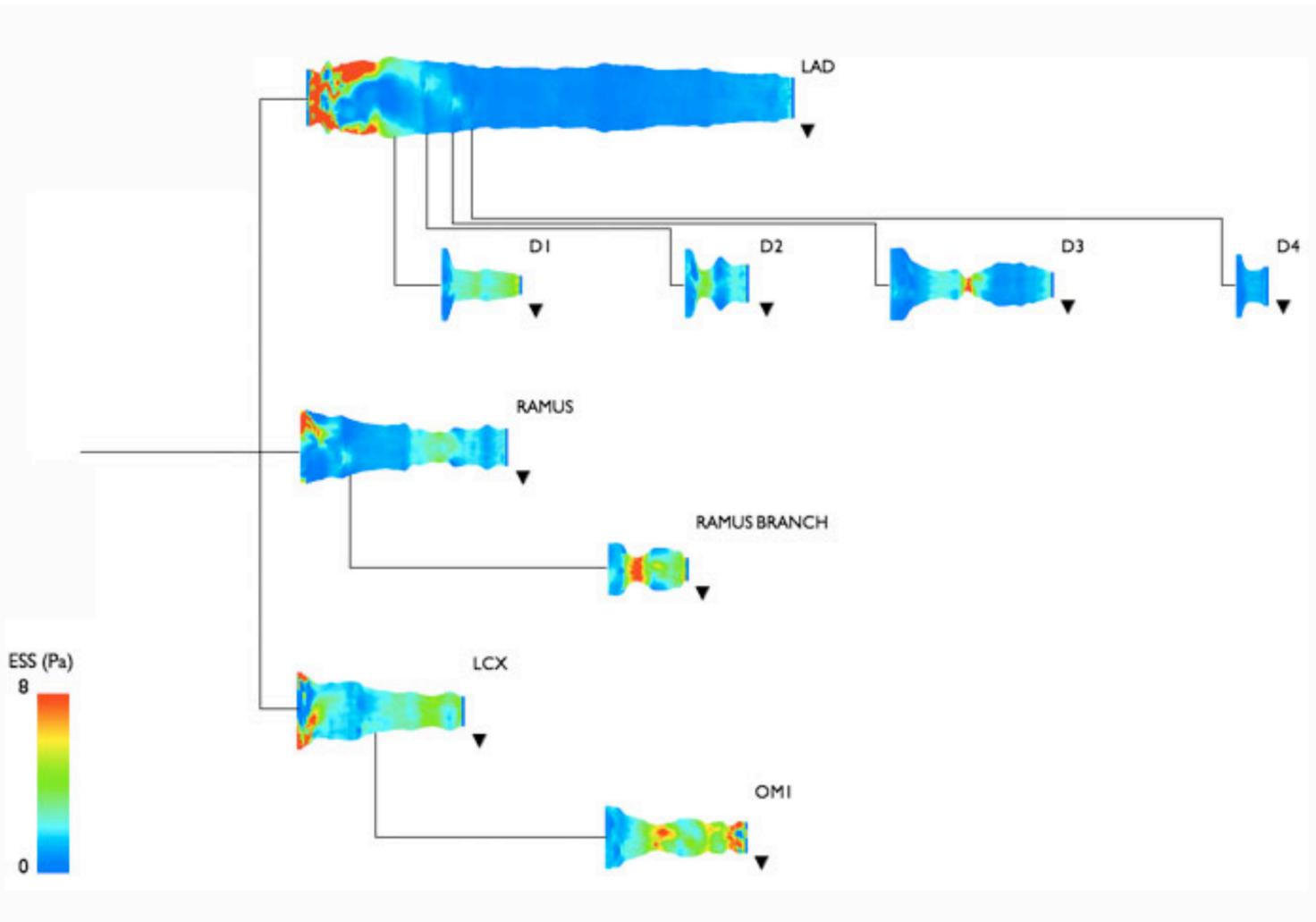
# COLOR



# COLOR



# COLOR



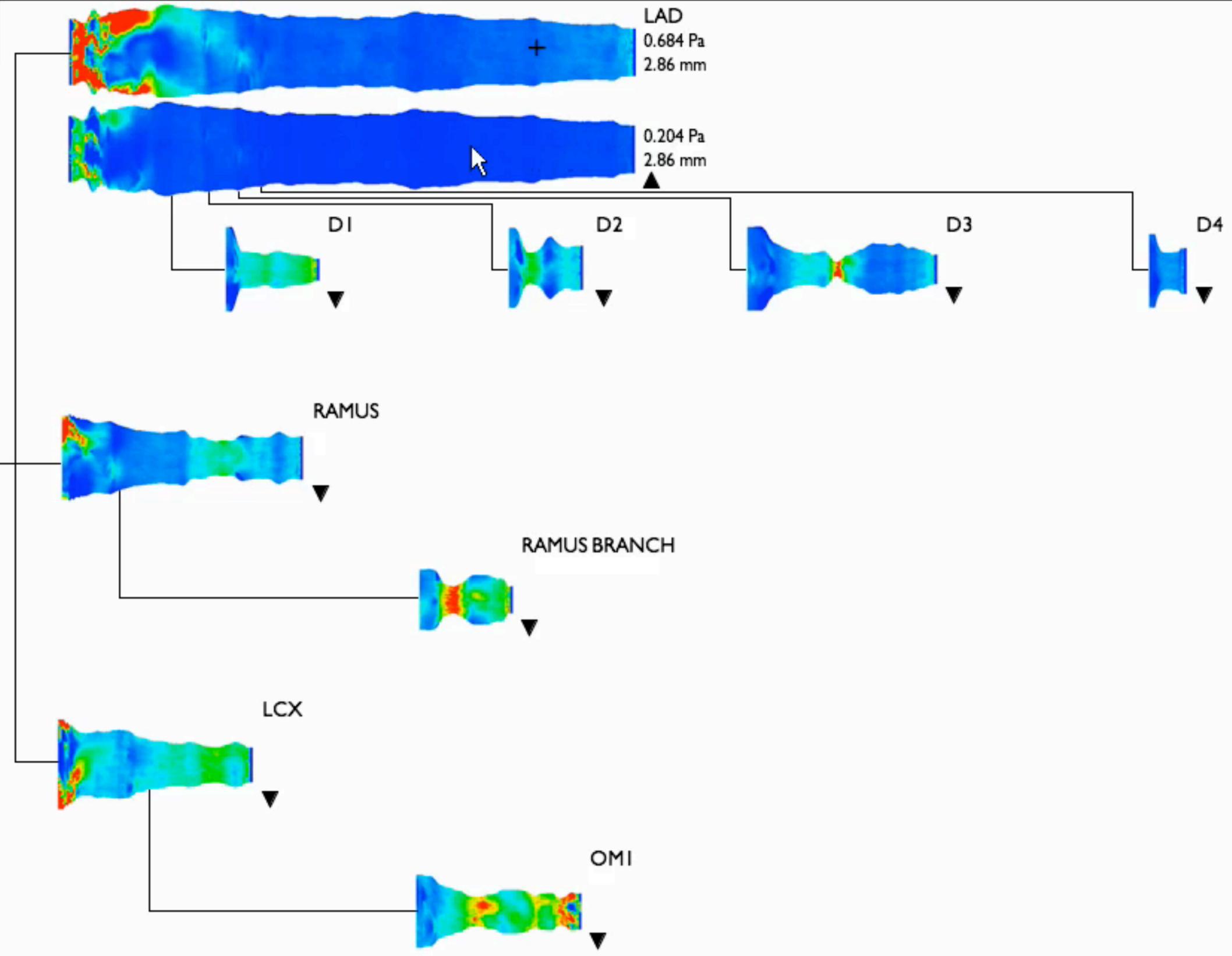
Mode: **tree** individual

Circumference (mm)

3.5  
2.860  
0

ESS (Pa)  
8  
0 0.204

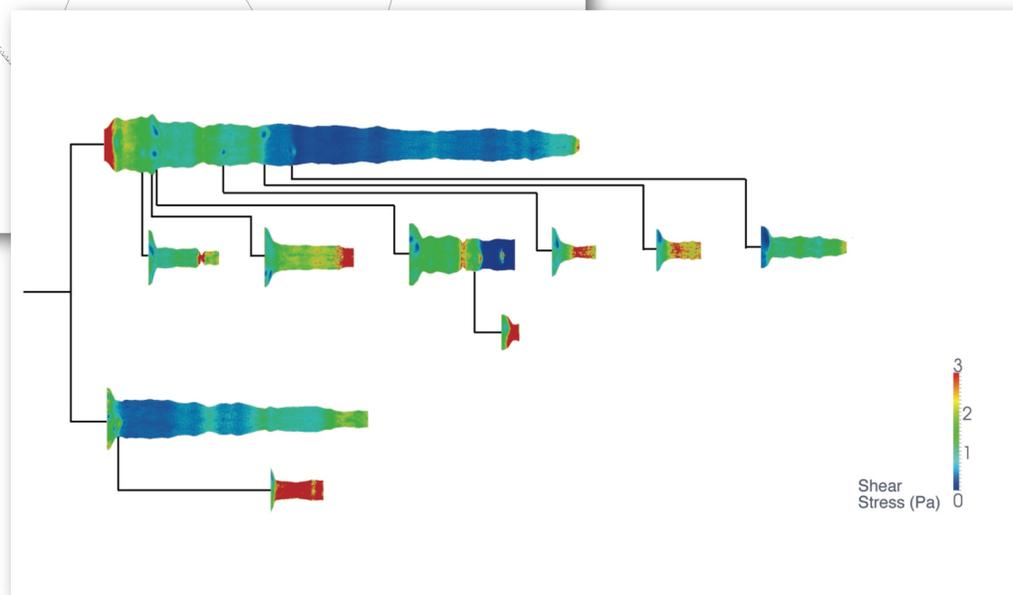
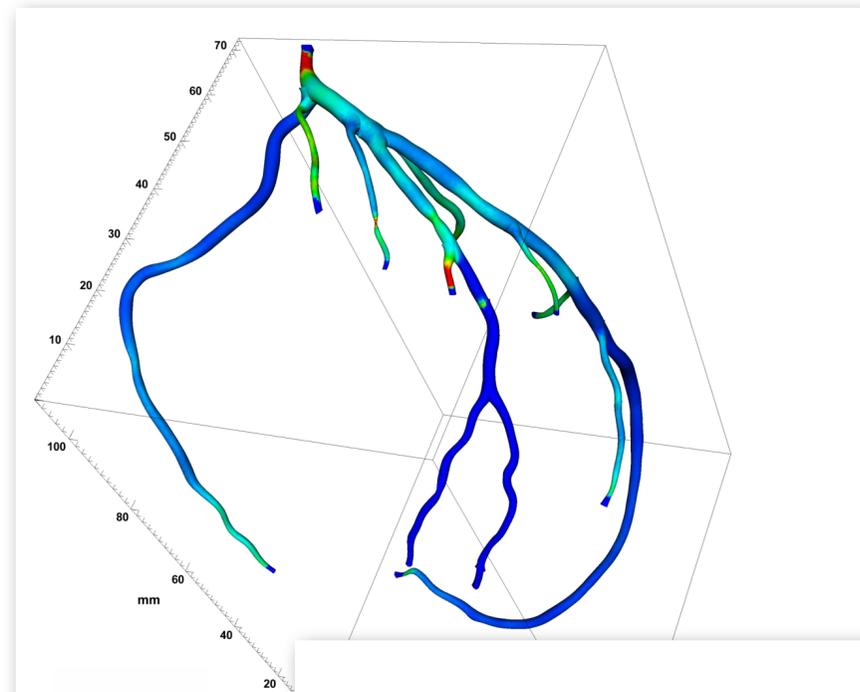
Color: 



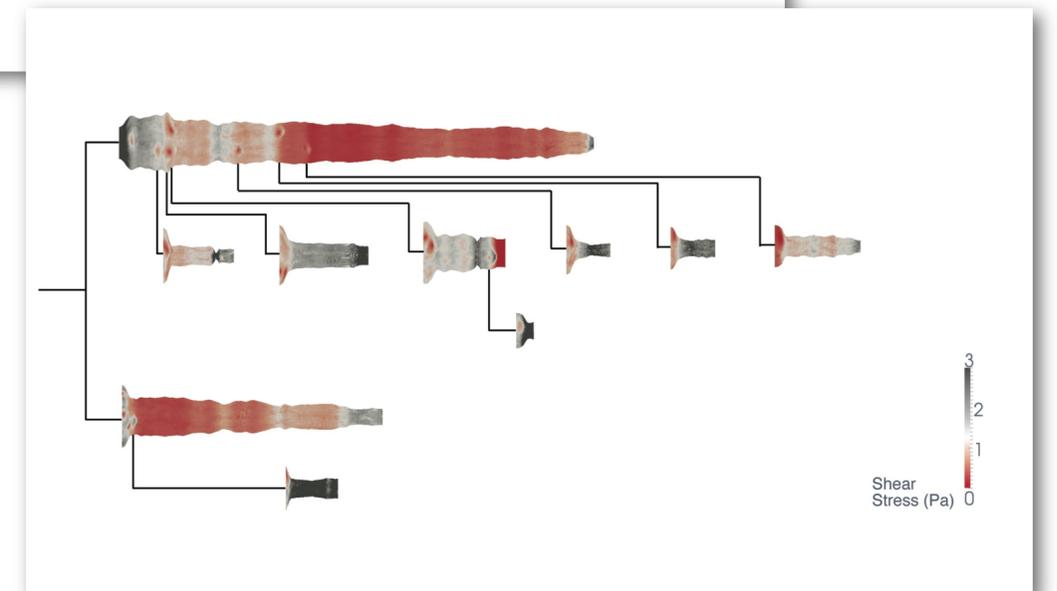
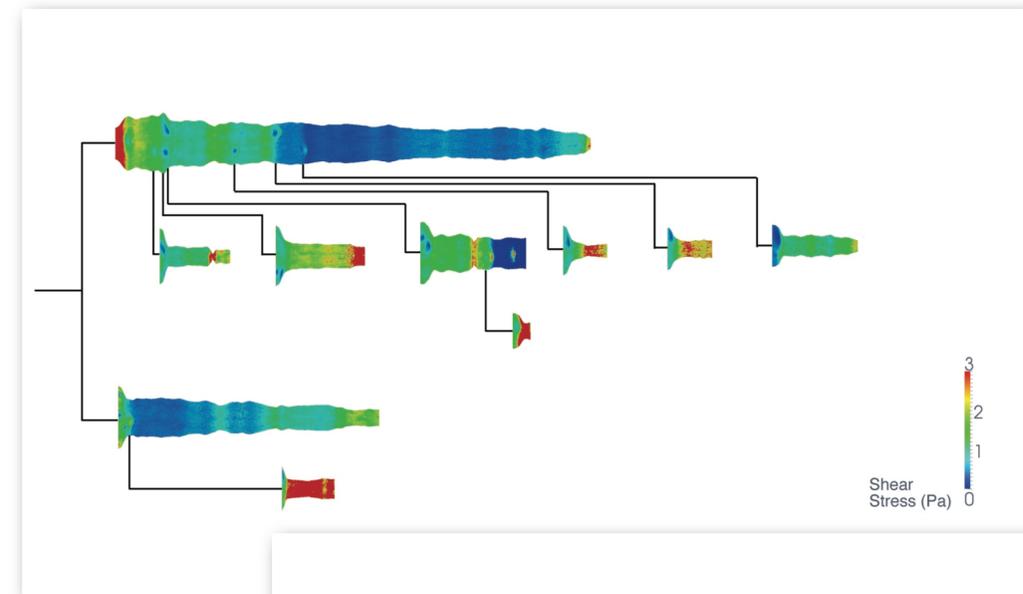
320 CT Scan  
Left Coronary Artery  
Lattice-Boltzman  
(High & Low Flow Rates)  
▼ *Open All Data*

# QUANTITATIVE STUDY: GOALS

3D vs. 2D

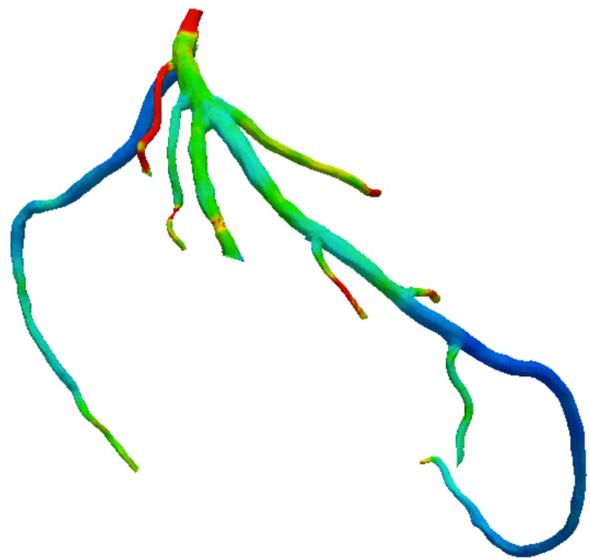


rainbow vs. diverging

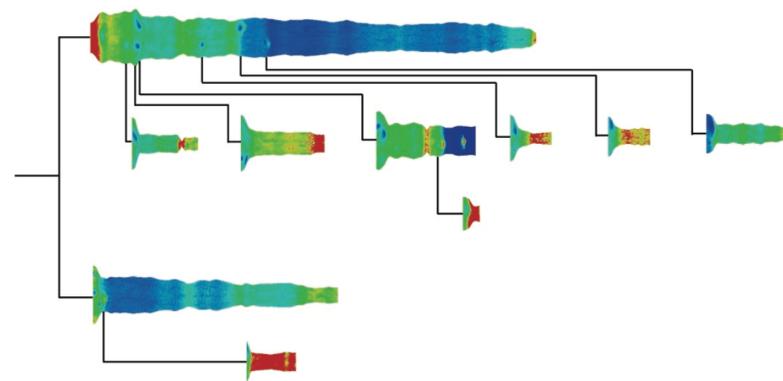


# QUANTITATIVE STUDY

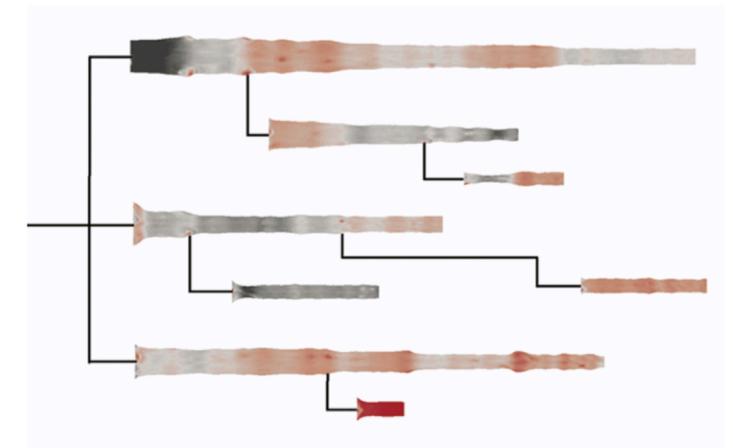
- 21 Harvard Medical students (12 women and 9 men)
- Mixed within-subject and between-subject design:
  - *within* = dimensionality of representation (2D or 3D)
  - *between* = color mapping (rainbow or diverging)



e.g., Participant A

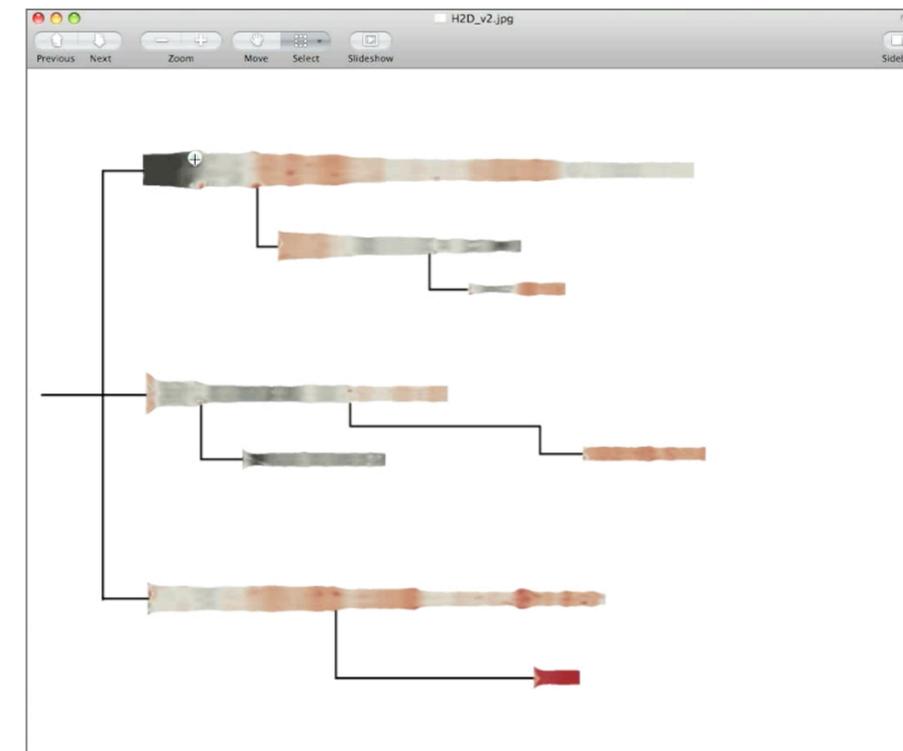
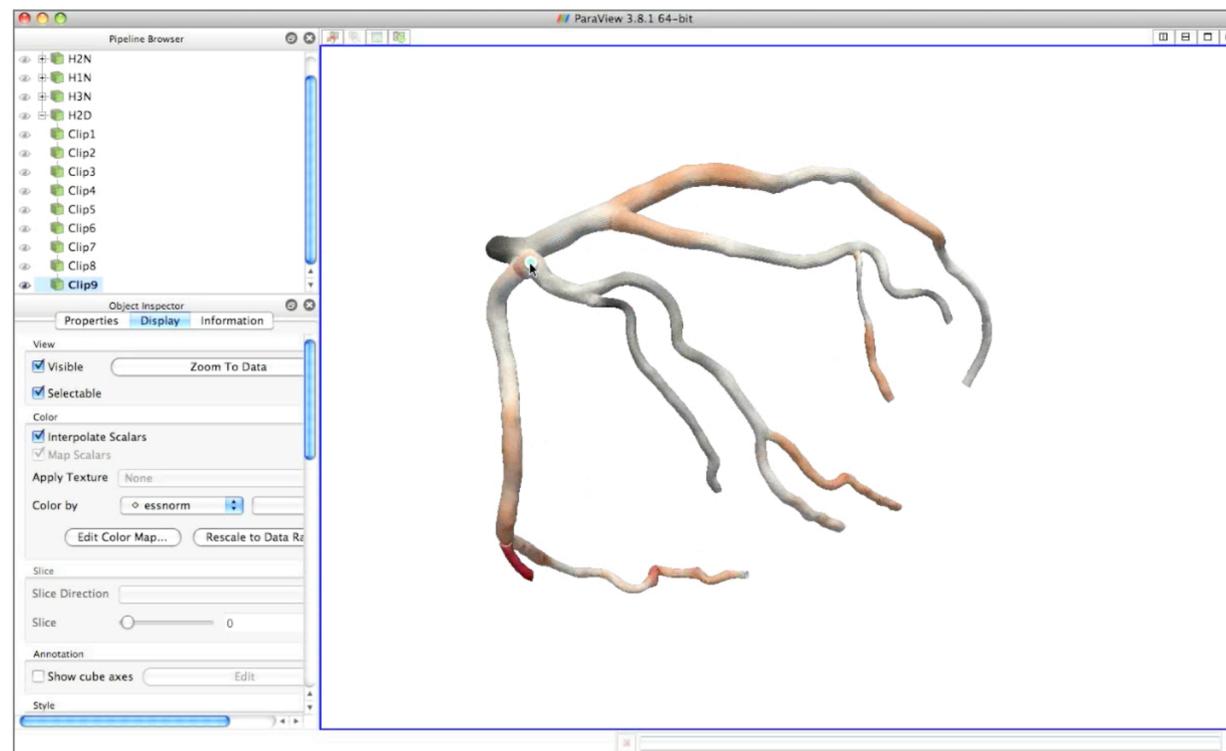


e.g., Participant B

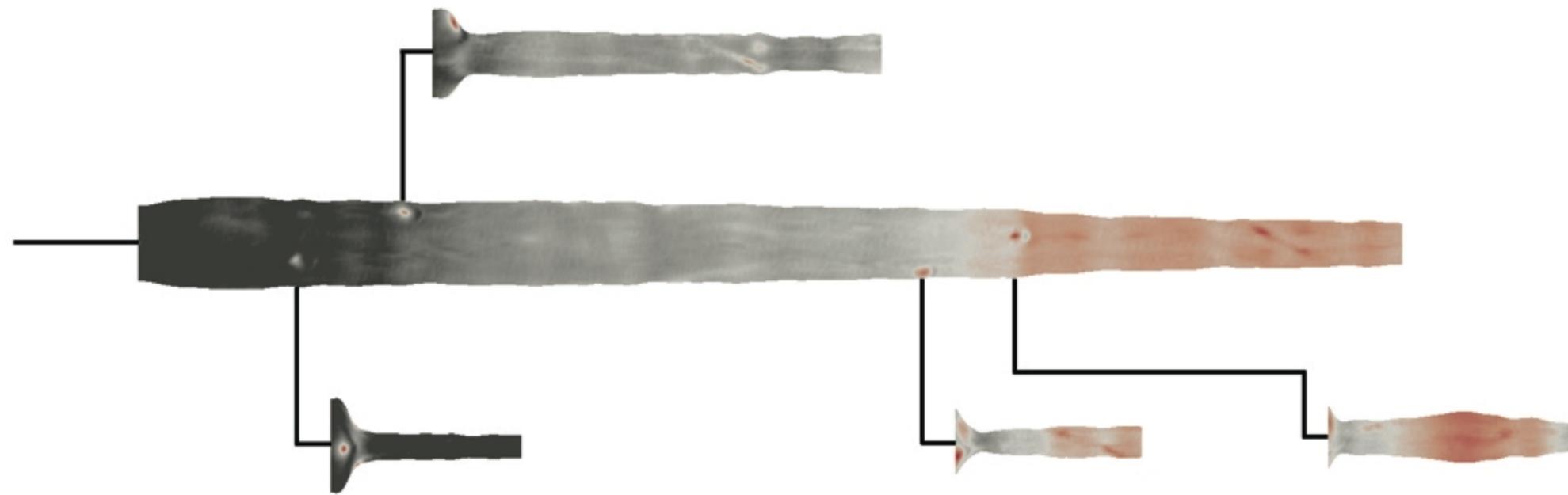
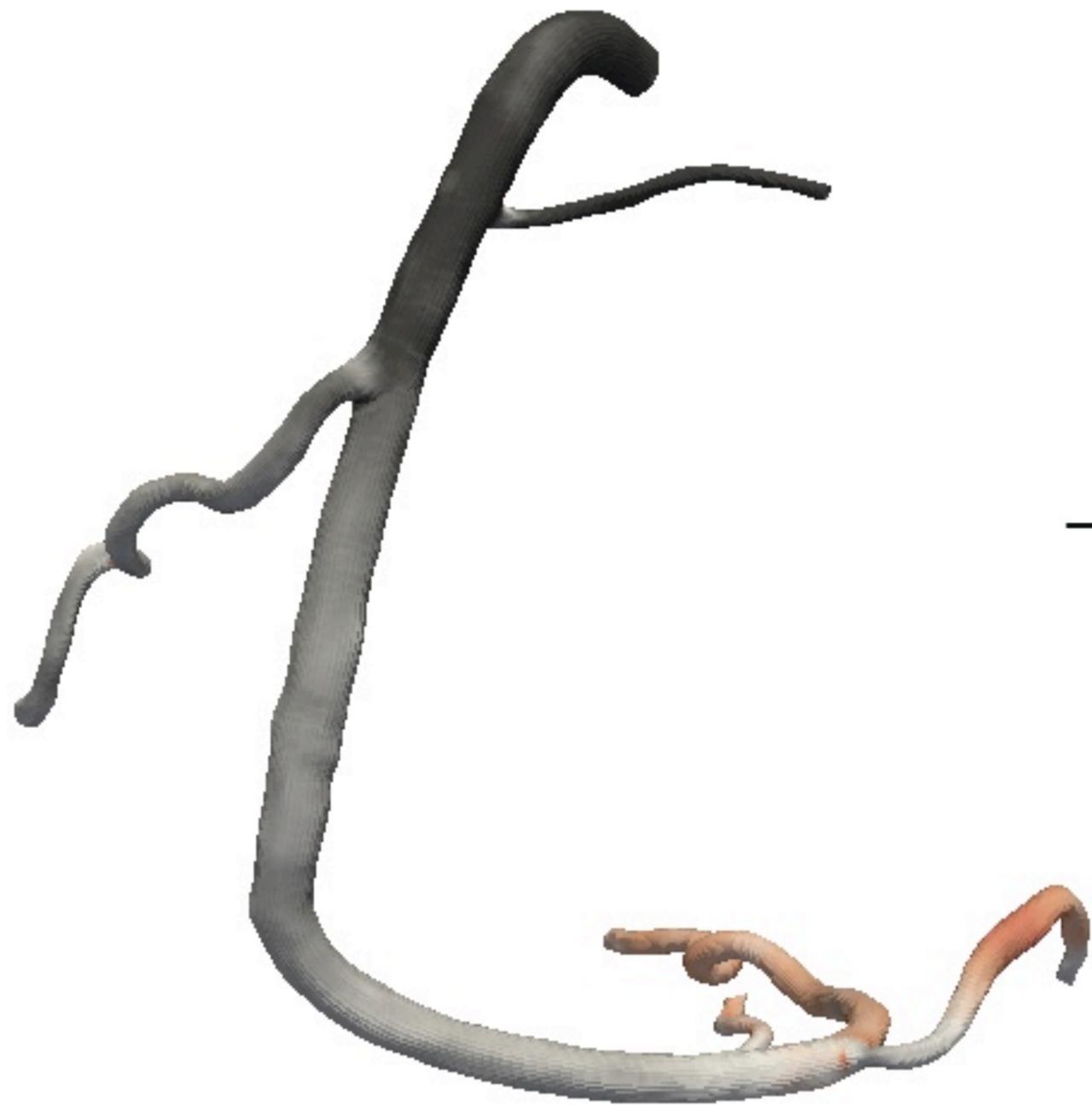


# QUANTITATIVE STUDY

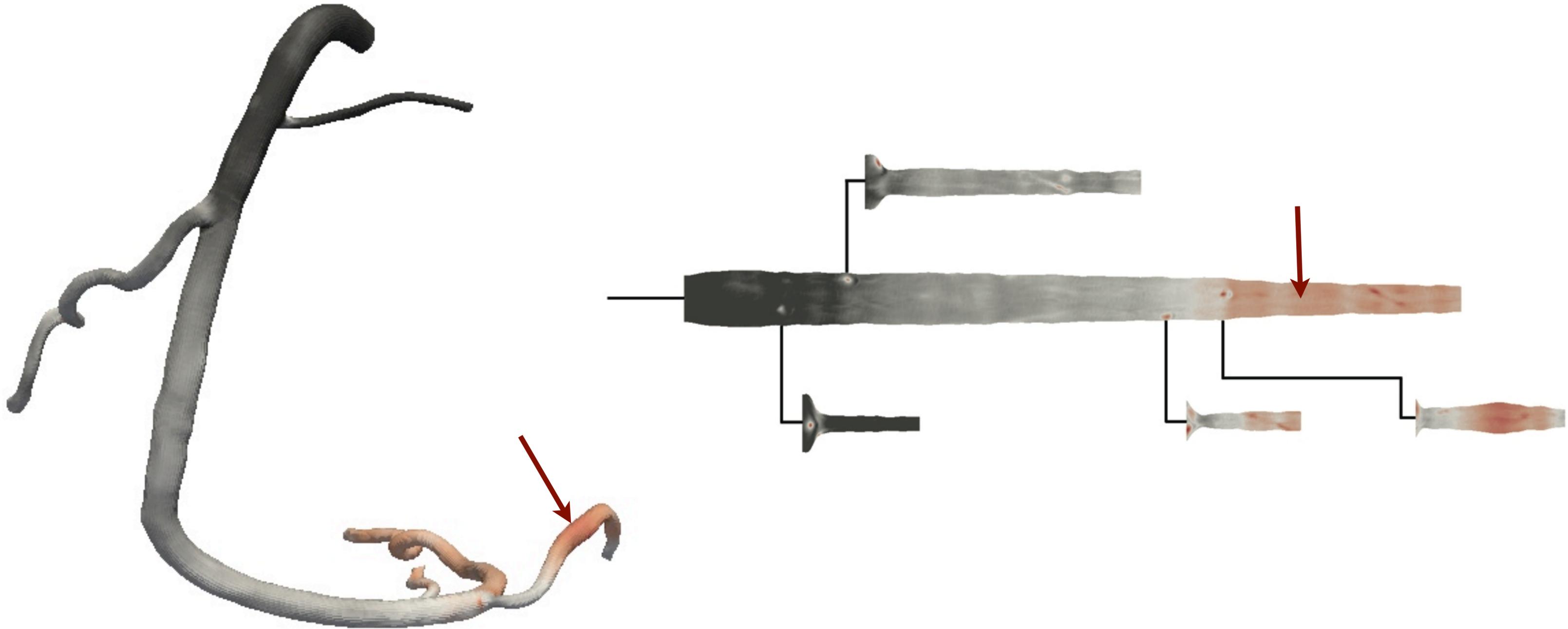
- Dependent measures:
  - fraction of low ESS regions identified
  - number of false positives (i.e., non-low ESS regions identified as low ESS)
  - time to complete a diagnosis



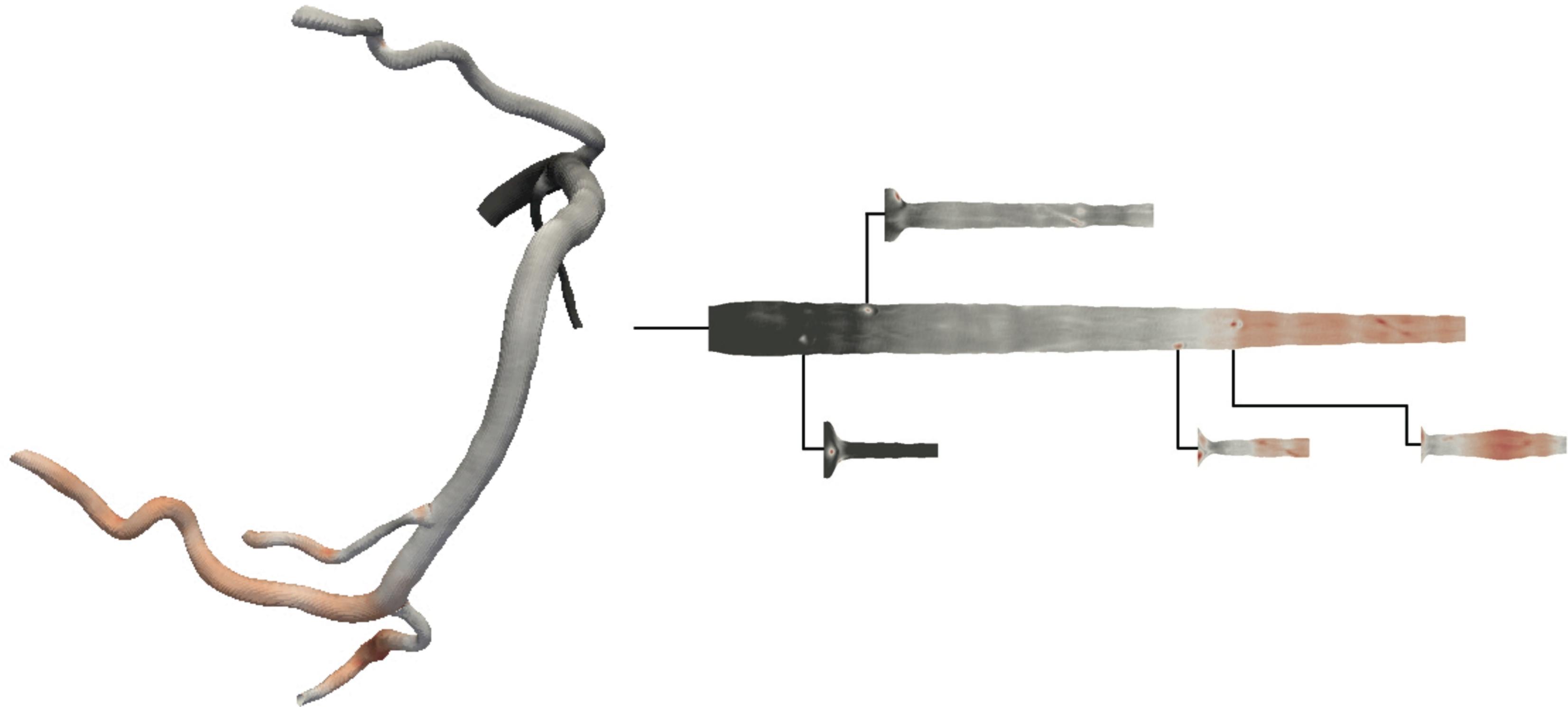
# QUANTITATIVE STUDY



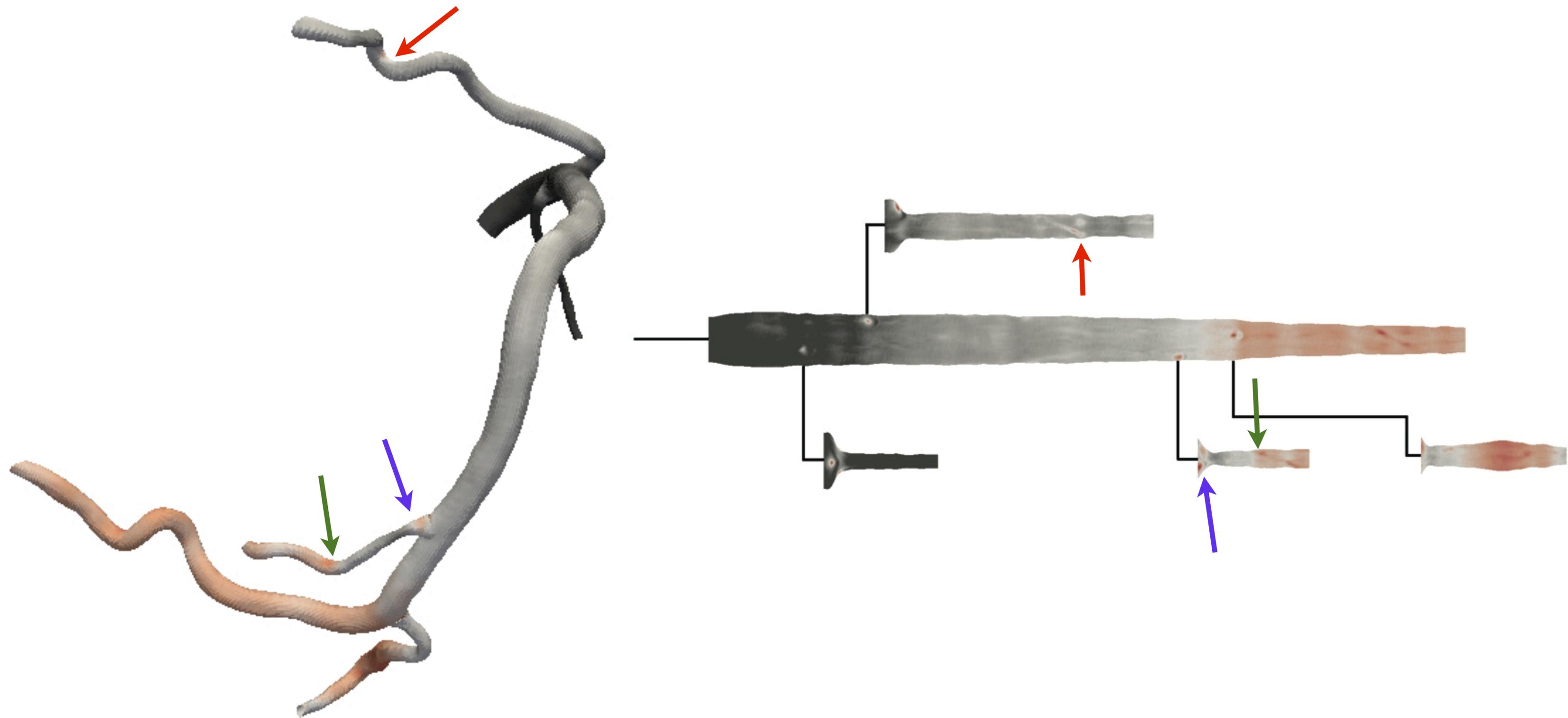
# QUANTITATIVE STUDY



# QUANTITATIVE STUDY



# QUANTITATIVE STUDY

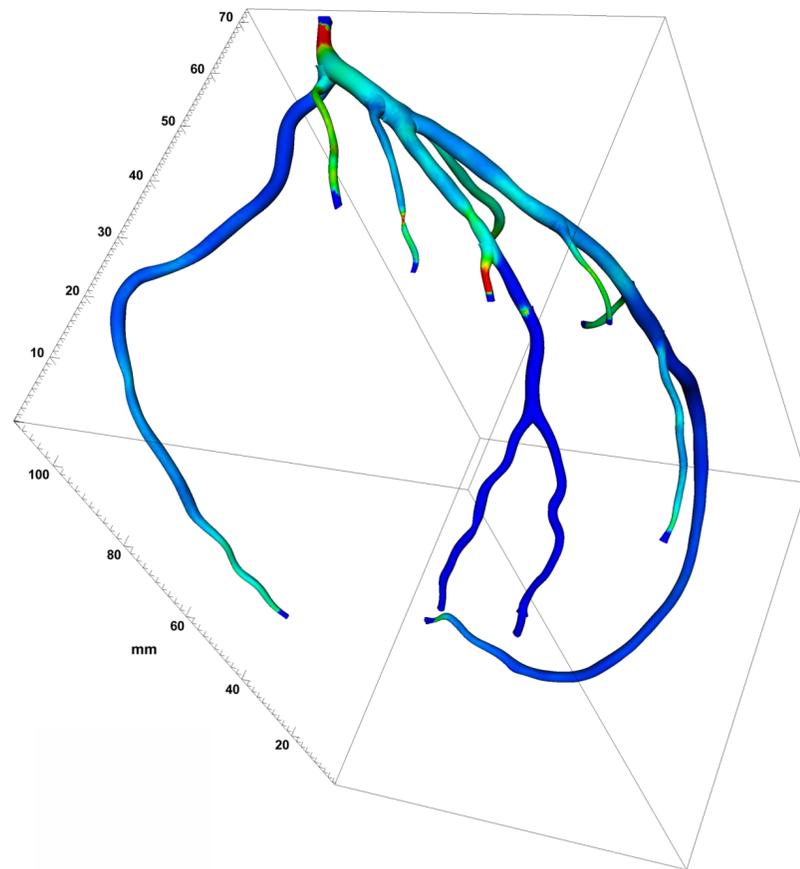


# RESULTS

# ACCURACY

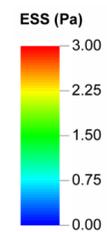
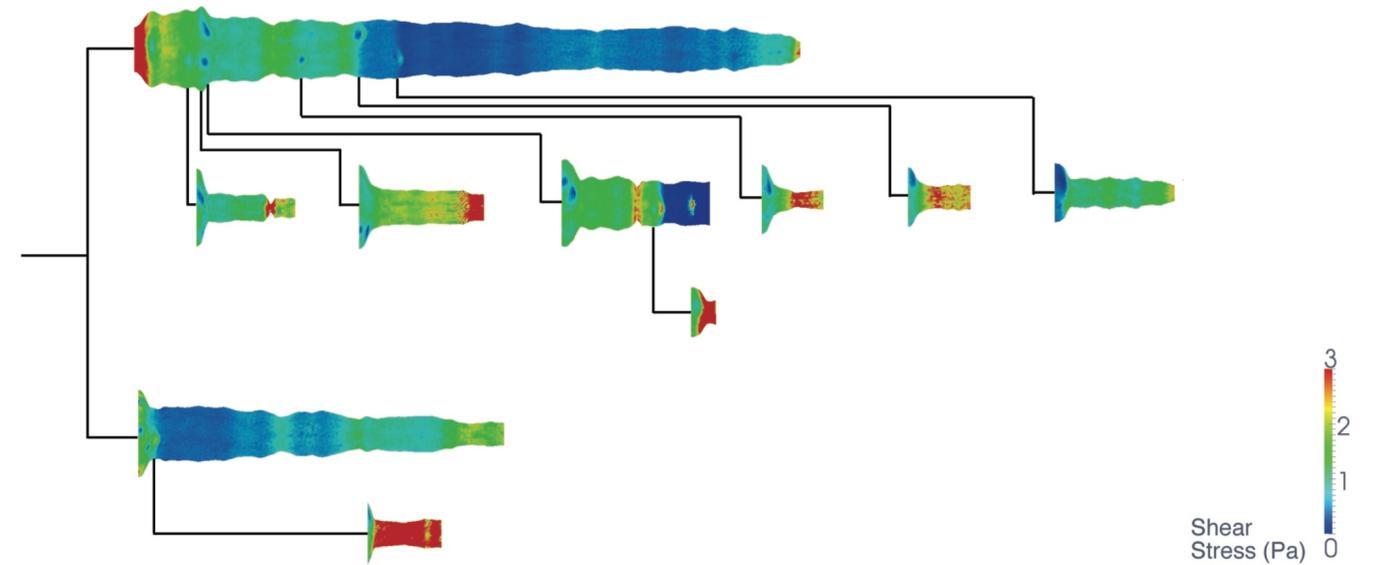
Strong effect of **dimensionality** on accuracy

39%



How many low ESS regions found?

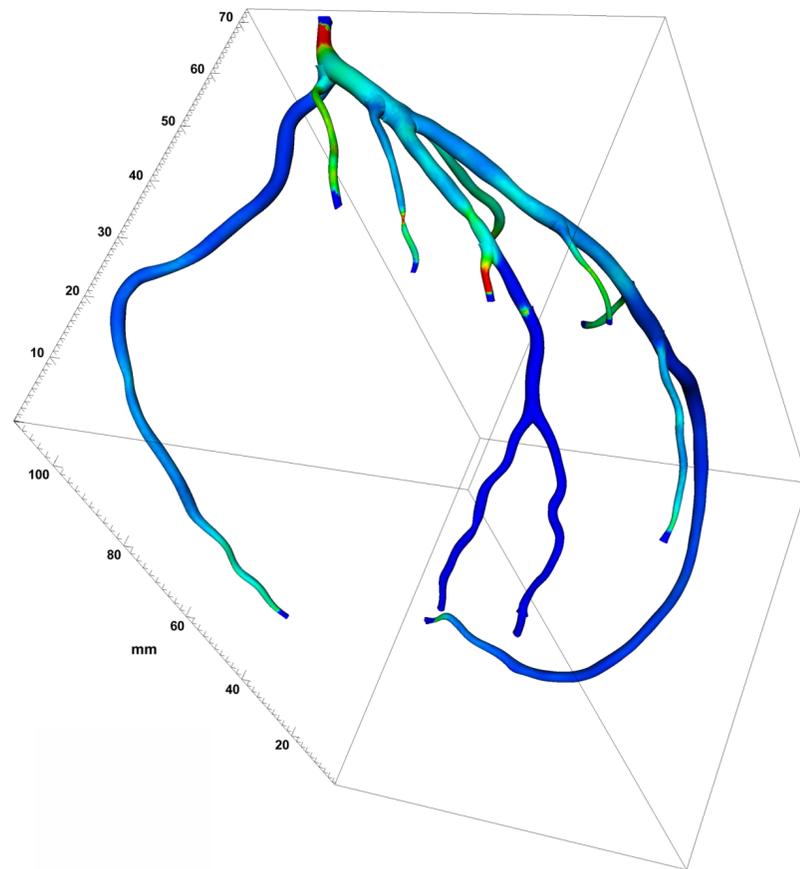
62%



# ACCURACY

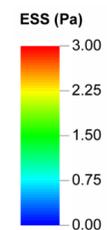
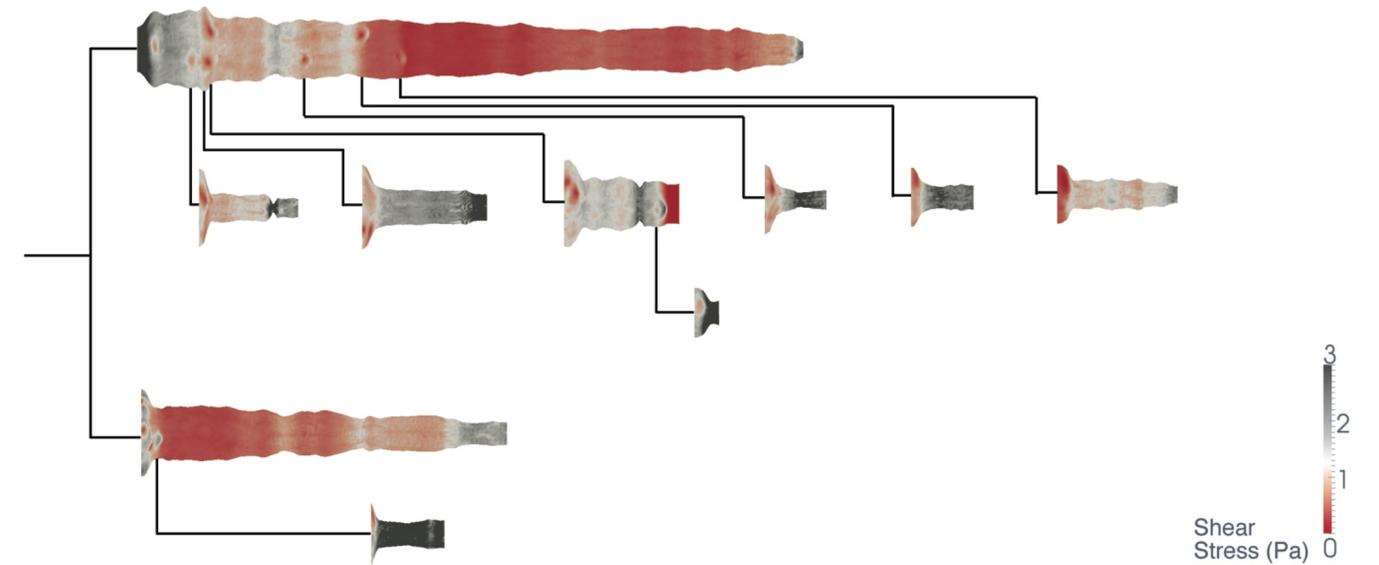
Strong effect of **dimensionality** on accuracy  
...as well as **color**

39%



How many low ESS  
regions found?

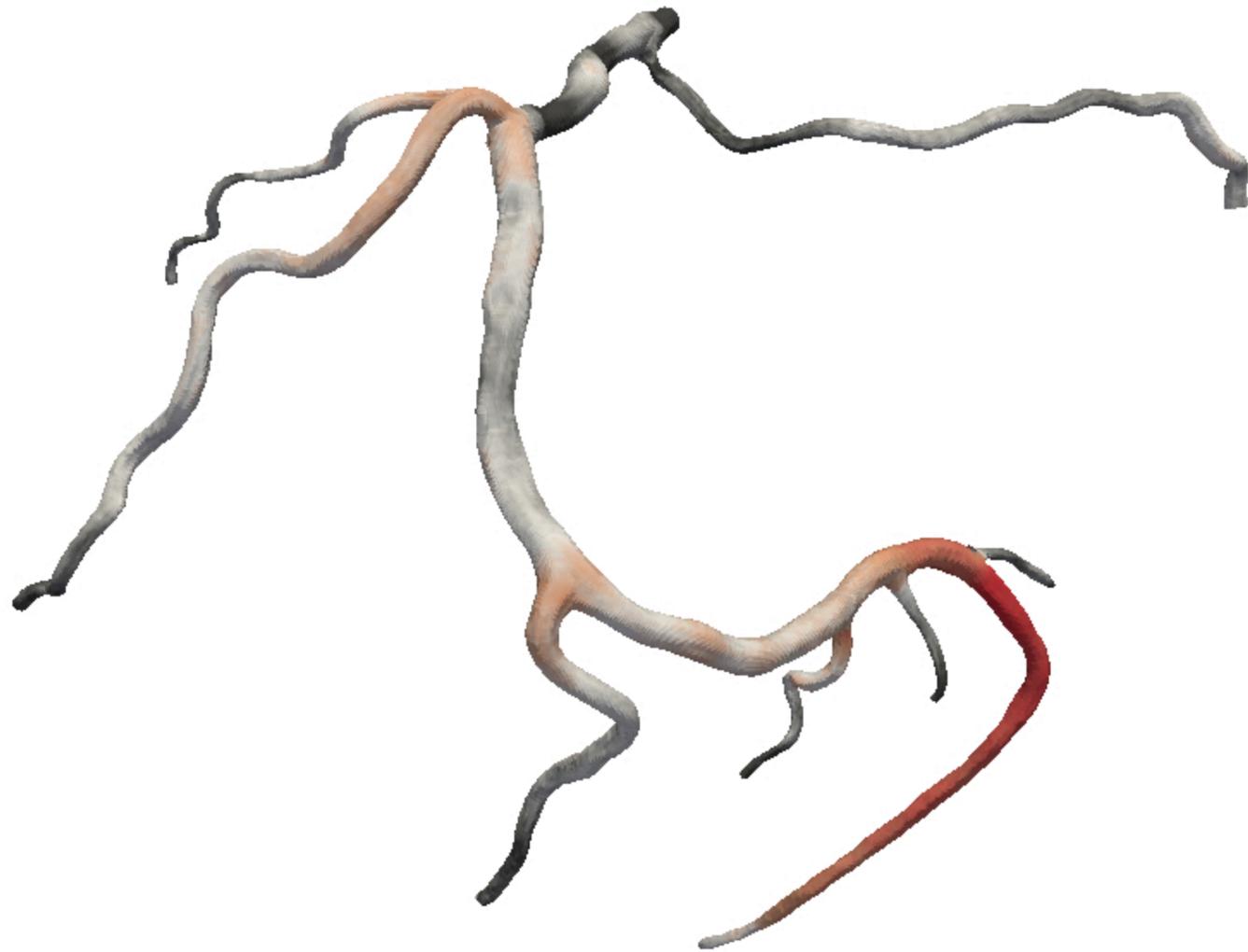
91%



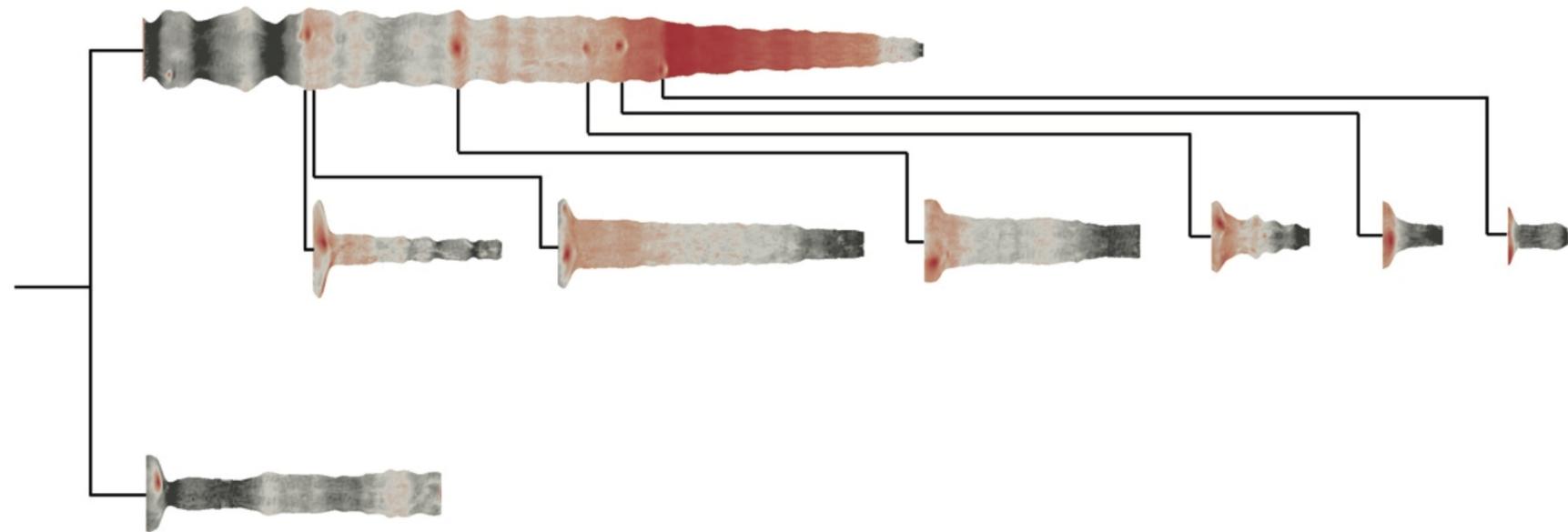
# EFFICIENCY

Participants more **efficient** in **2D**.

5.6 sec/region



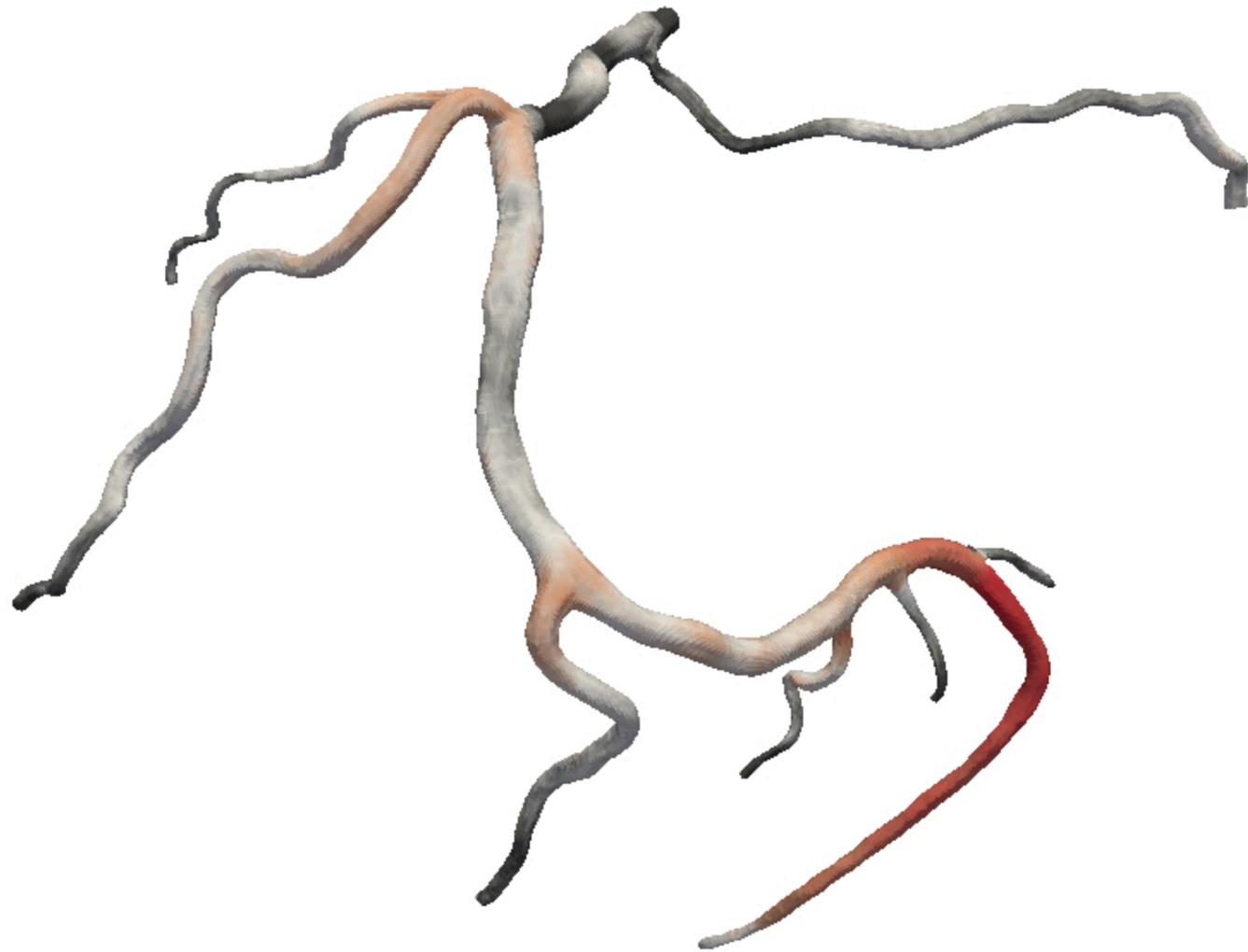
2.4 sec/region



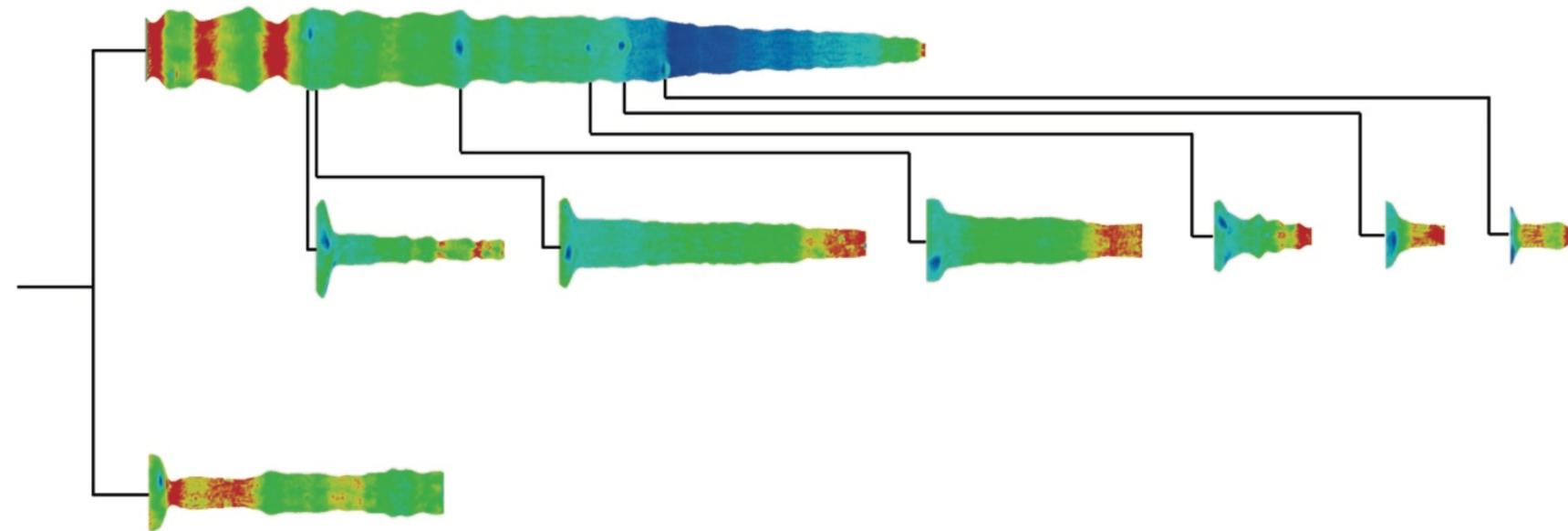
# EFFICIENCY

Participants more **efficient** in **2D**.

5.6 sec/region



2.6 sec/region

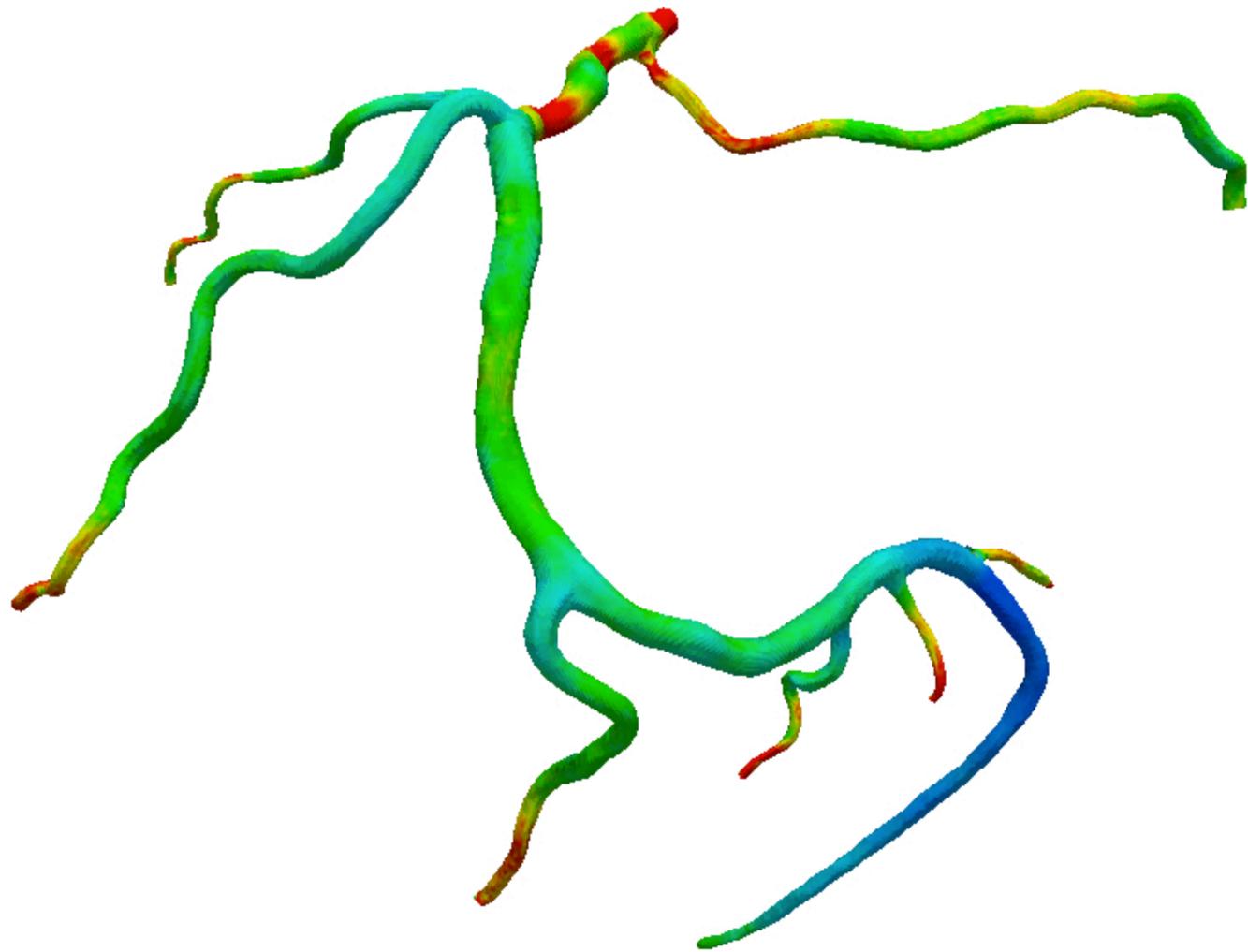


# EFFICIENCY

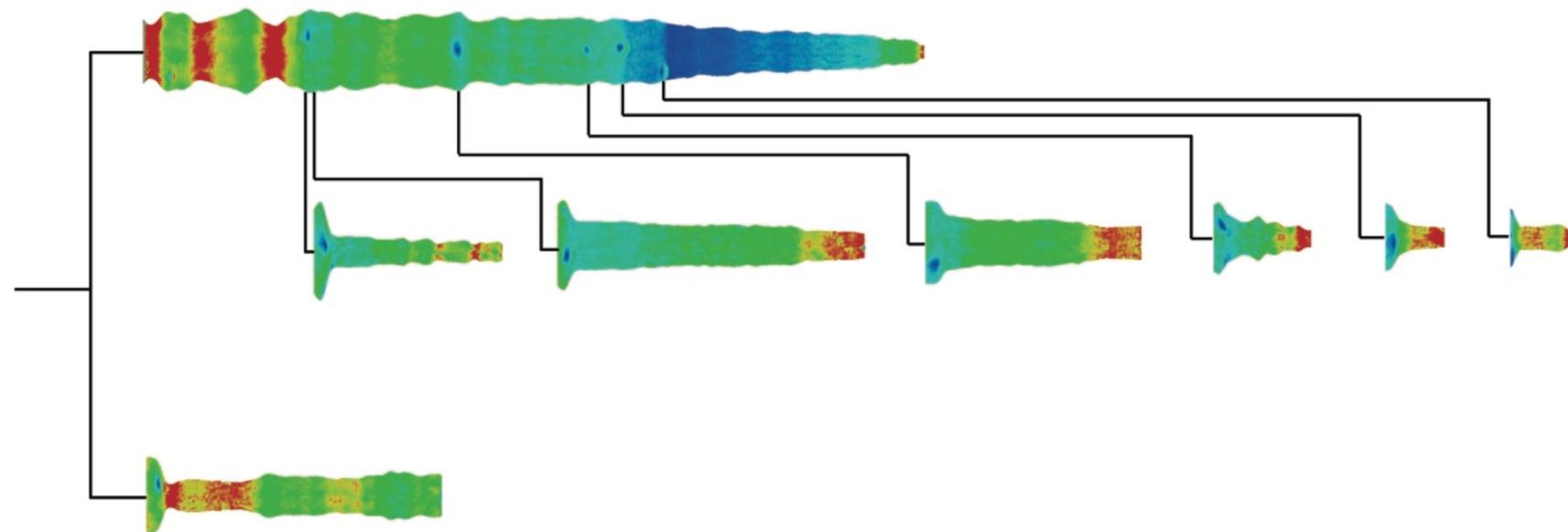
Participants more **efficient** in **2D**.

Rainbow color map has greater effect on efficiency in 3D.

10.2 sec/region



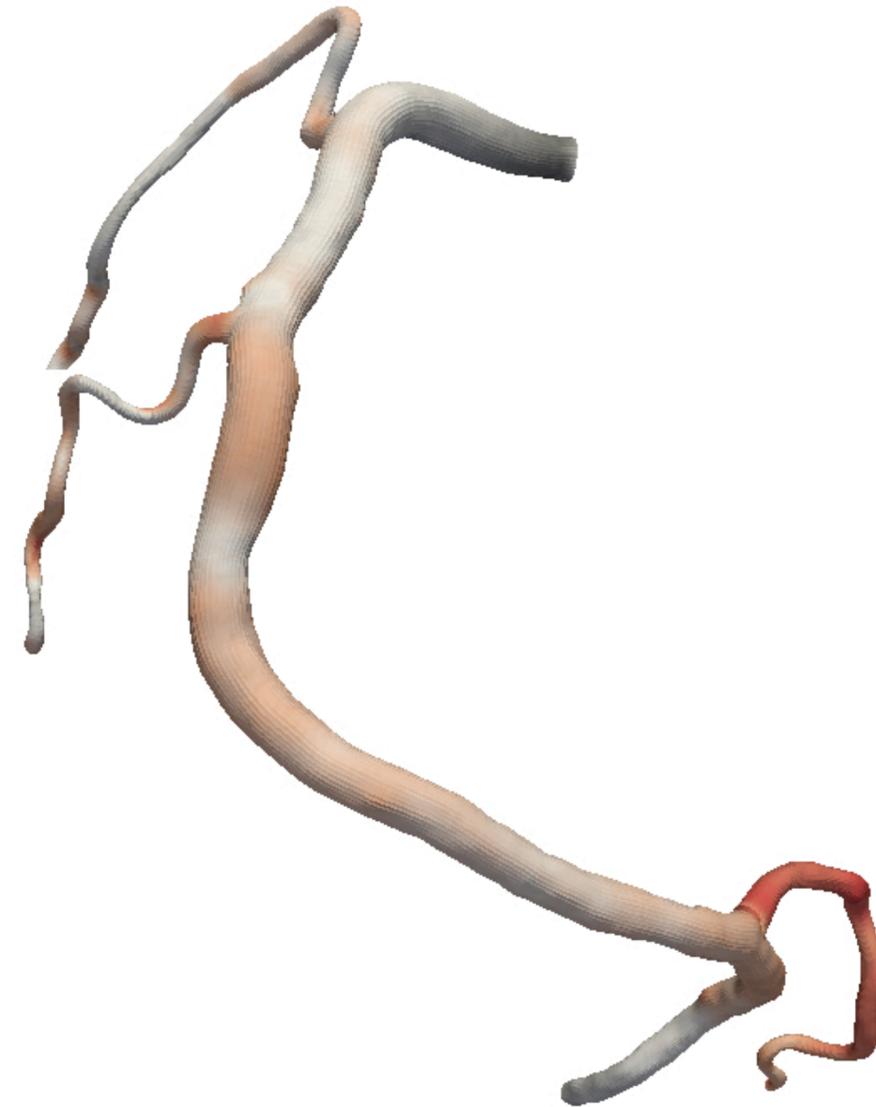
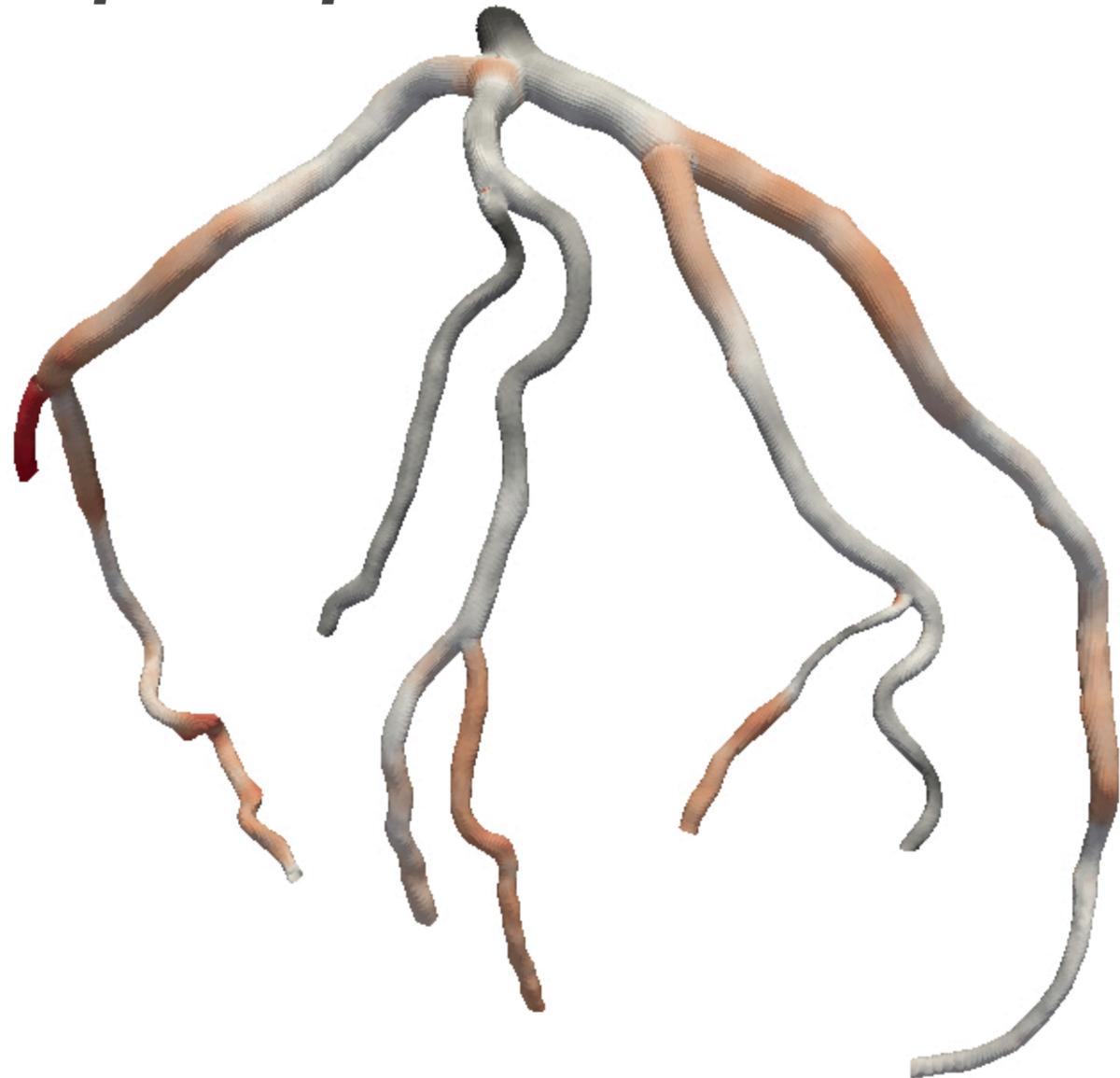
2.6 sec/region



# COMPLEXITY

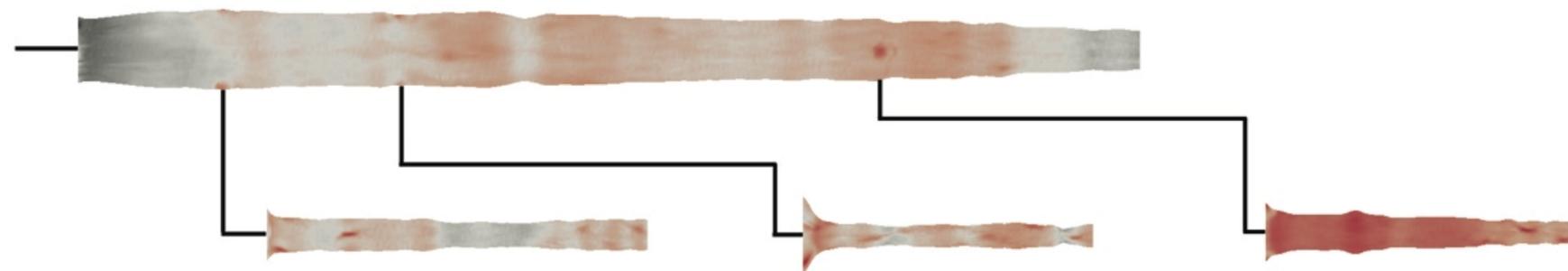
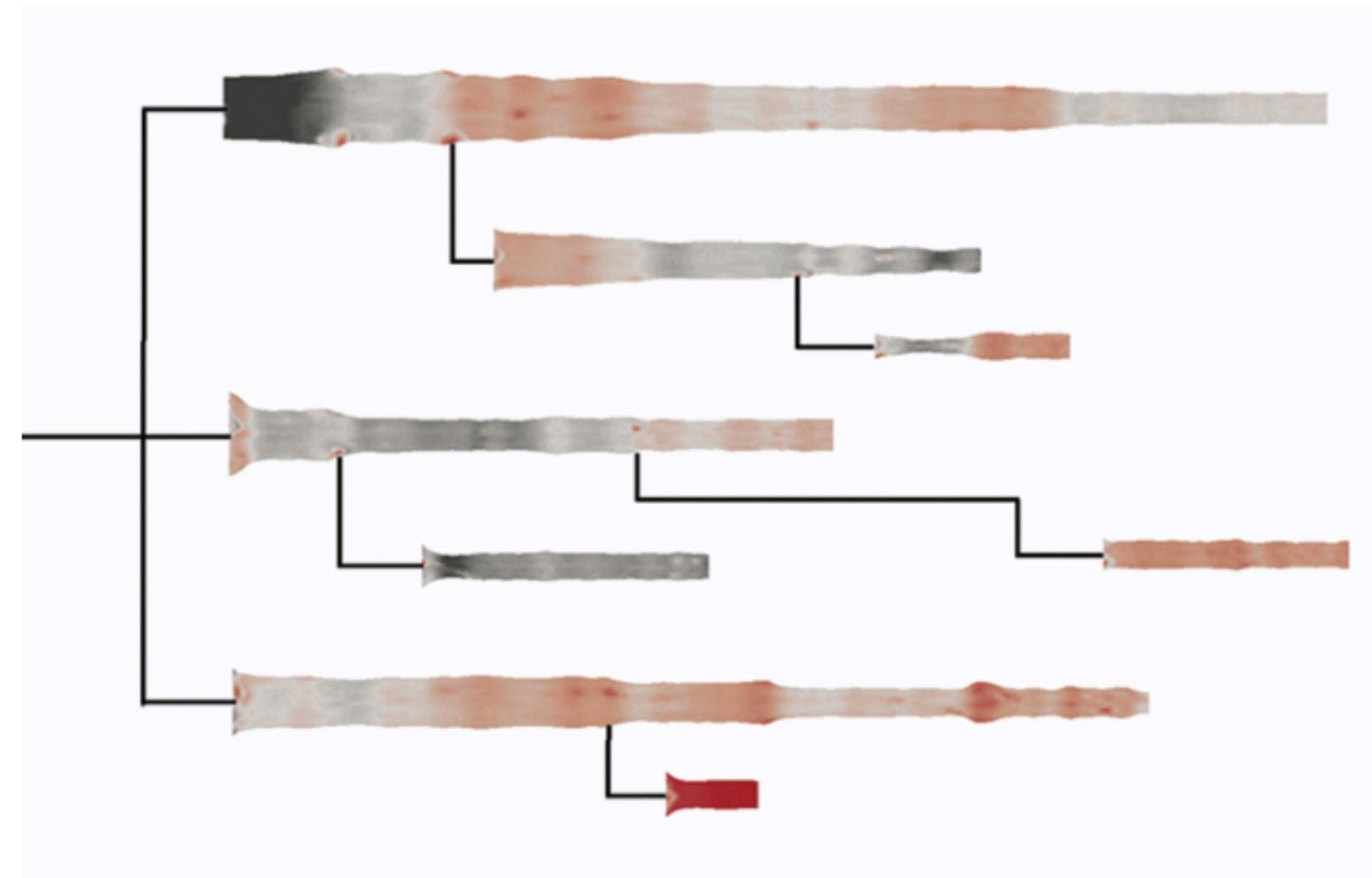
Accuracy decreases with increased data complexity in 3D

*participants less accurate*



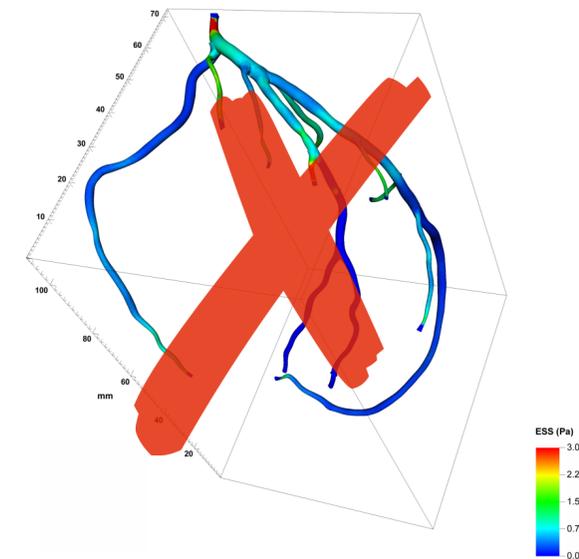
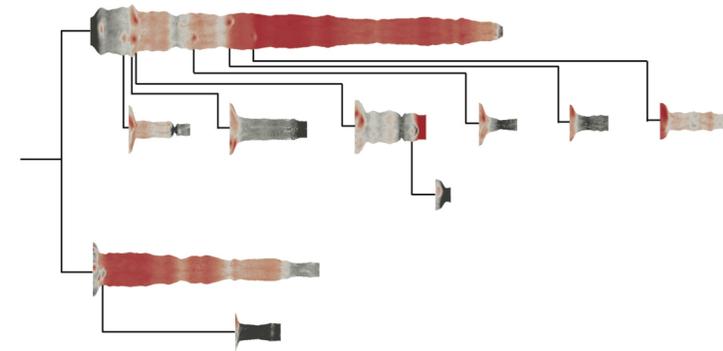
# COMPLEXITY

Accuracy decreases with increased data complexity in 3D  
*(not true in 2D!)*



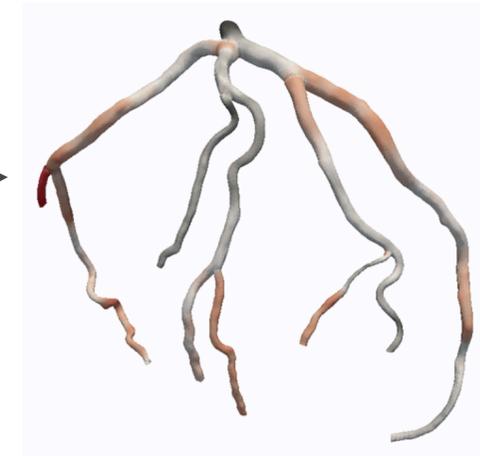
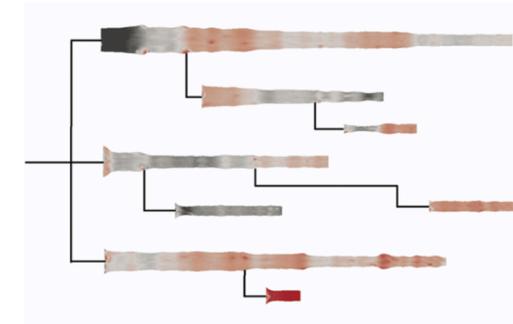
# FINDINGS SUMMARY

- Even for 3D spatial data, a **2D** representation is
  - ▶ more **accurate** for spatial tasks
  - ▶ more **efficient** for spatial tasks
- Rainbow color map
  - ▶ is **not accurate** and **not efficient**
  - ▶ has adverse effects even greater in 3D

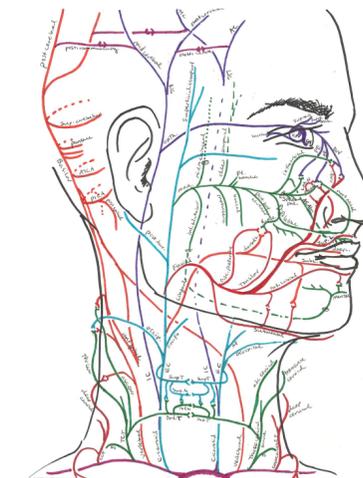
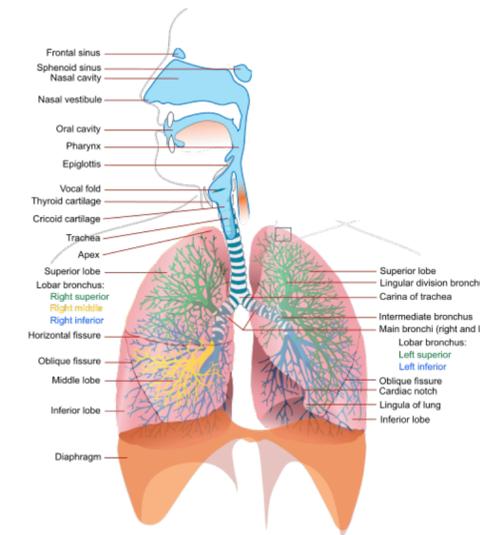


# FINAL REMARKS

- 3D representation is still essential for surgical planning



- 2D tree diagram applicable to other applications



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