



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

Michelle Borkin

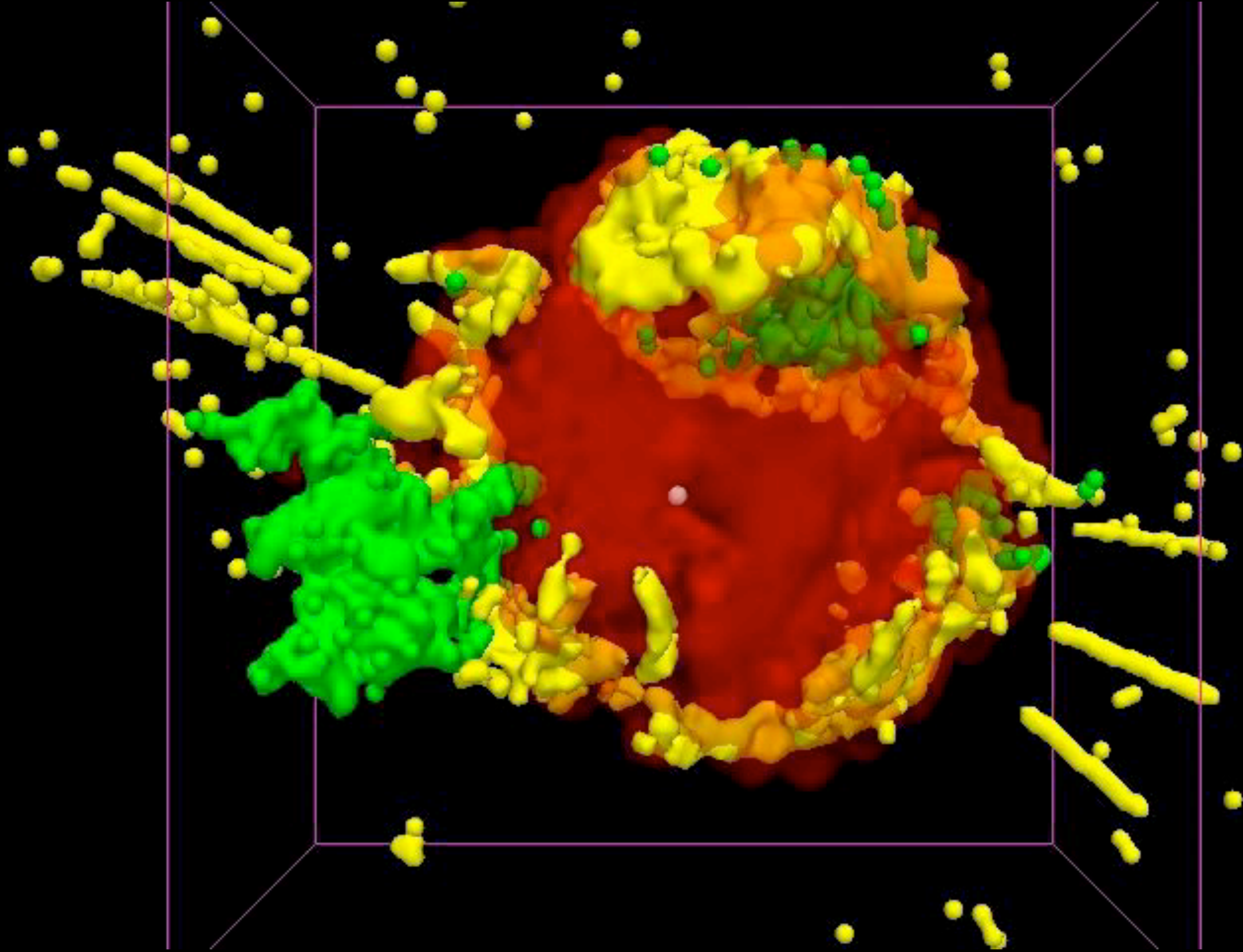
*(University of British Columbia & Harvard University)*

CPSC 547, UBC - September 24, 2014





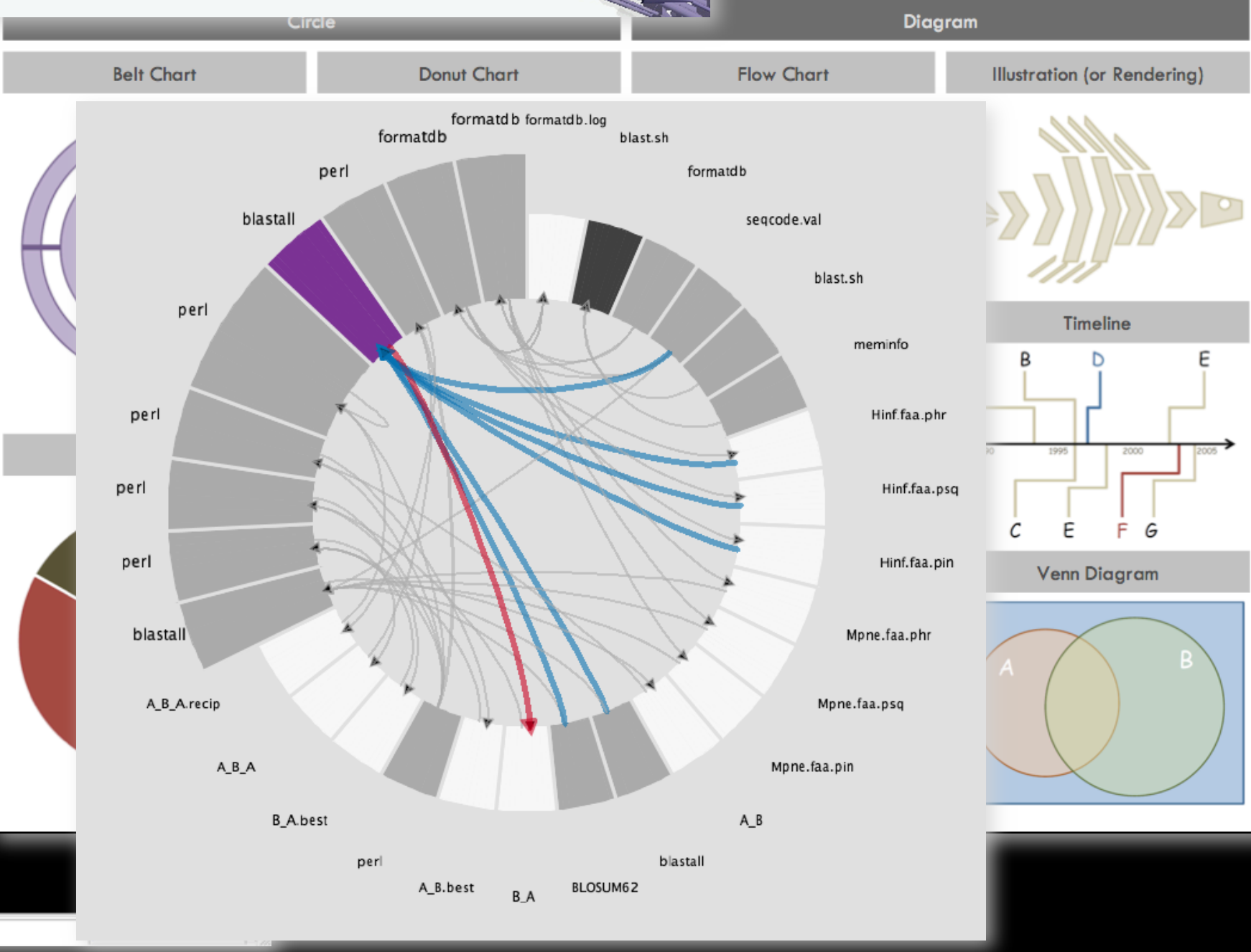
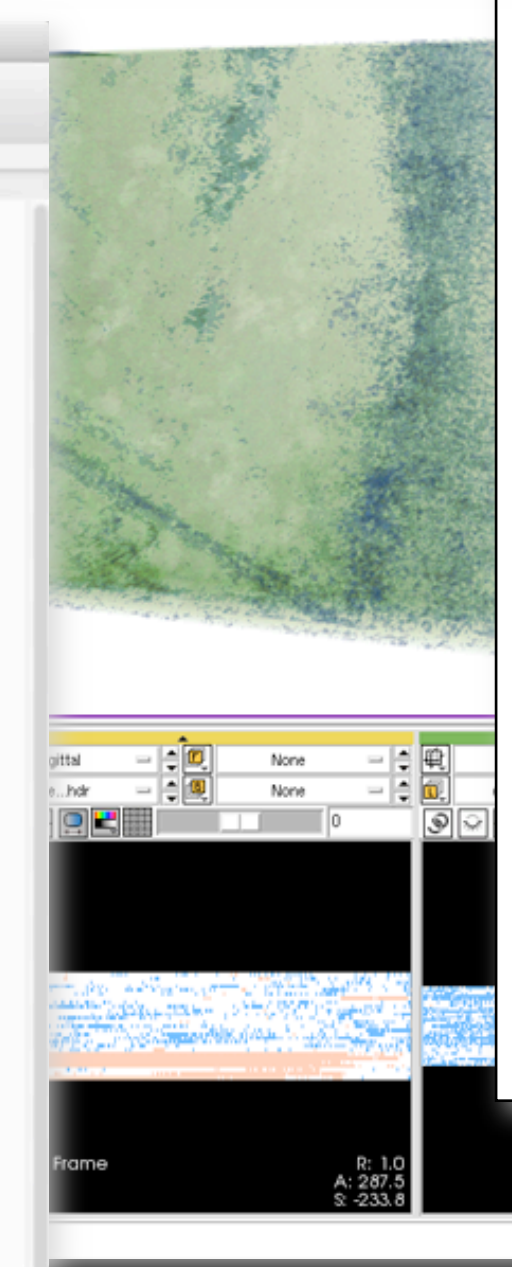
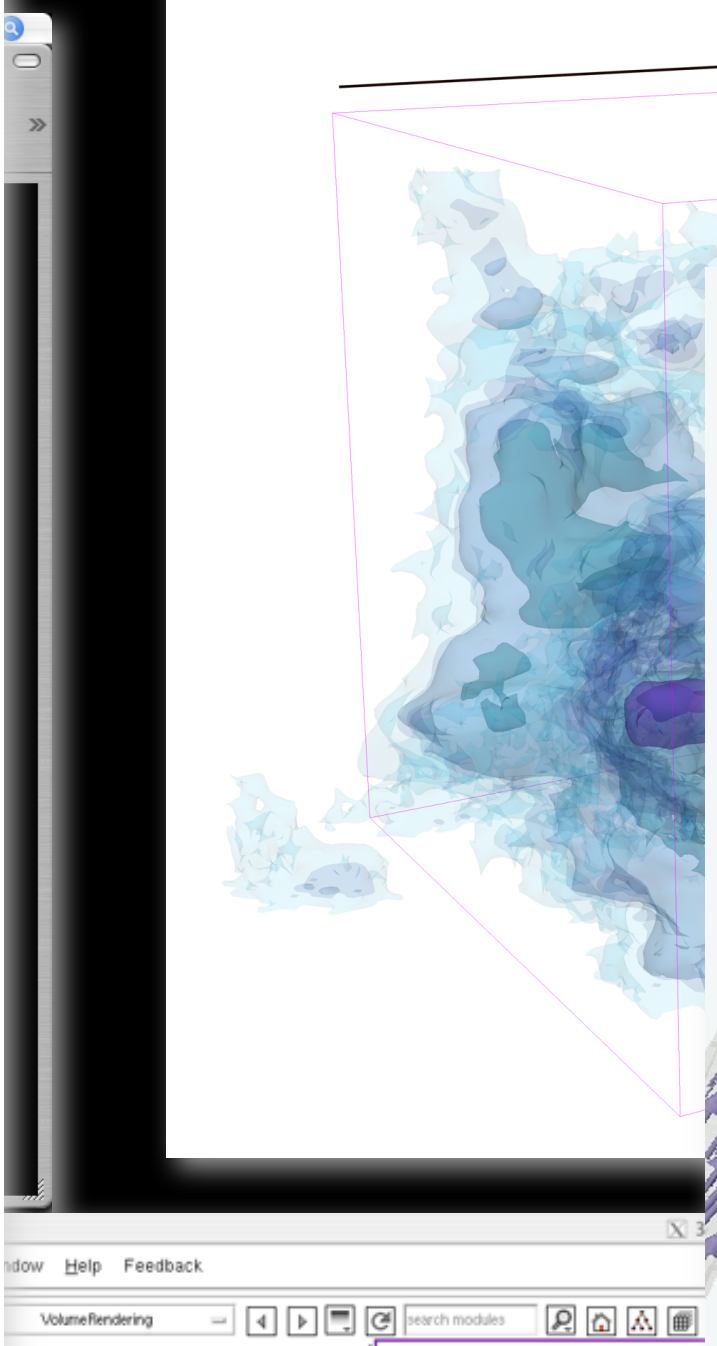




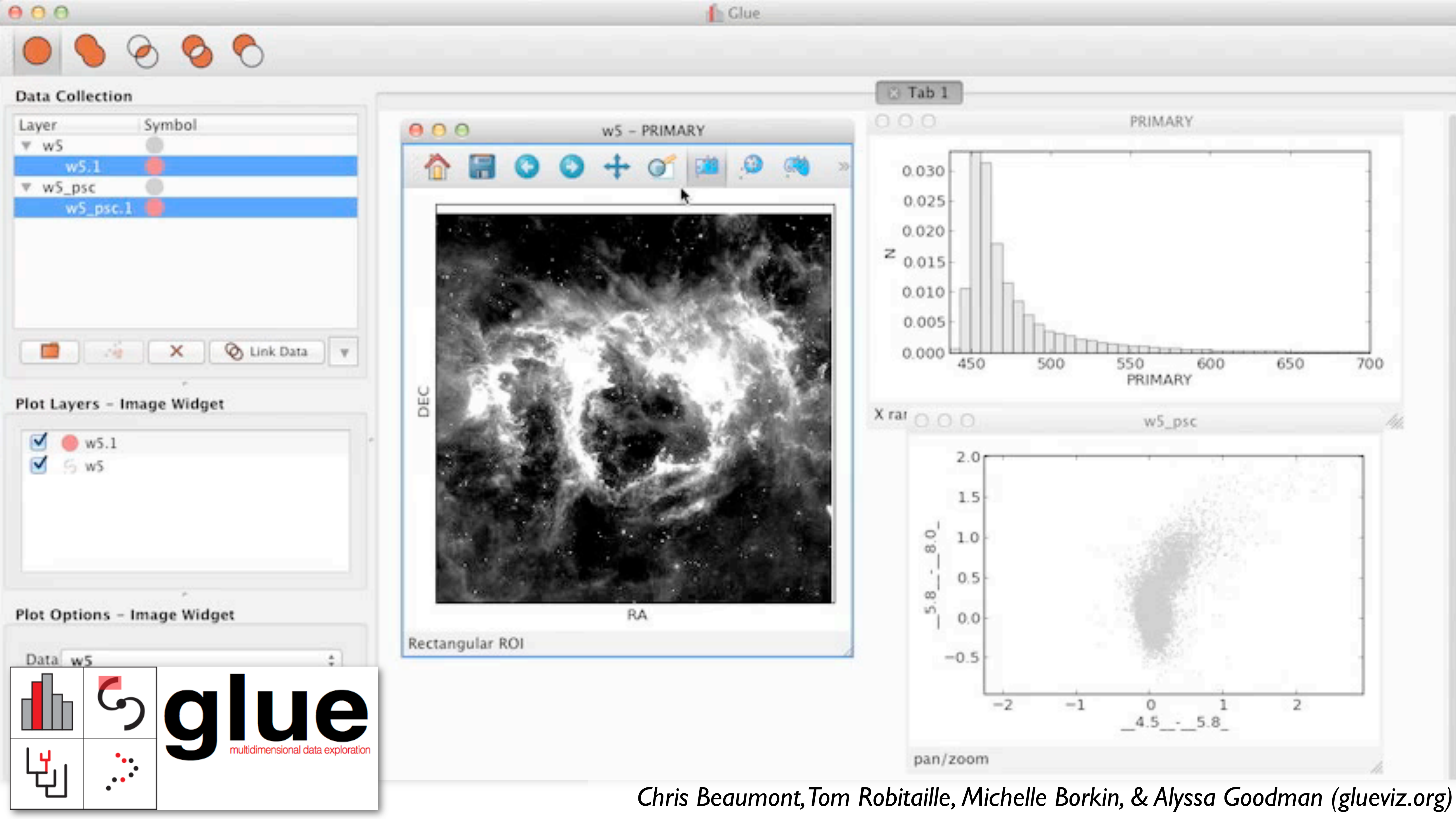




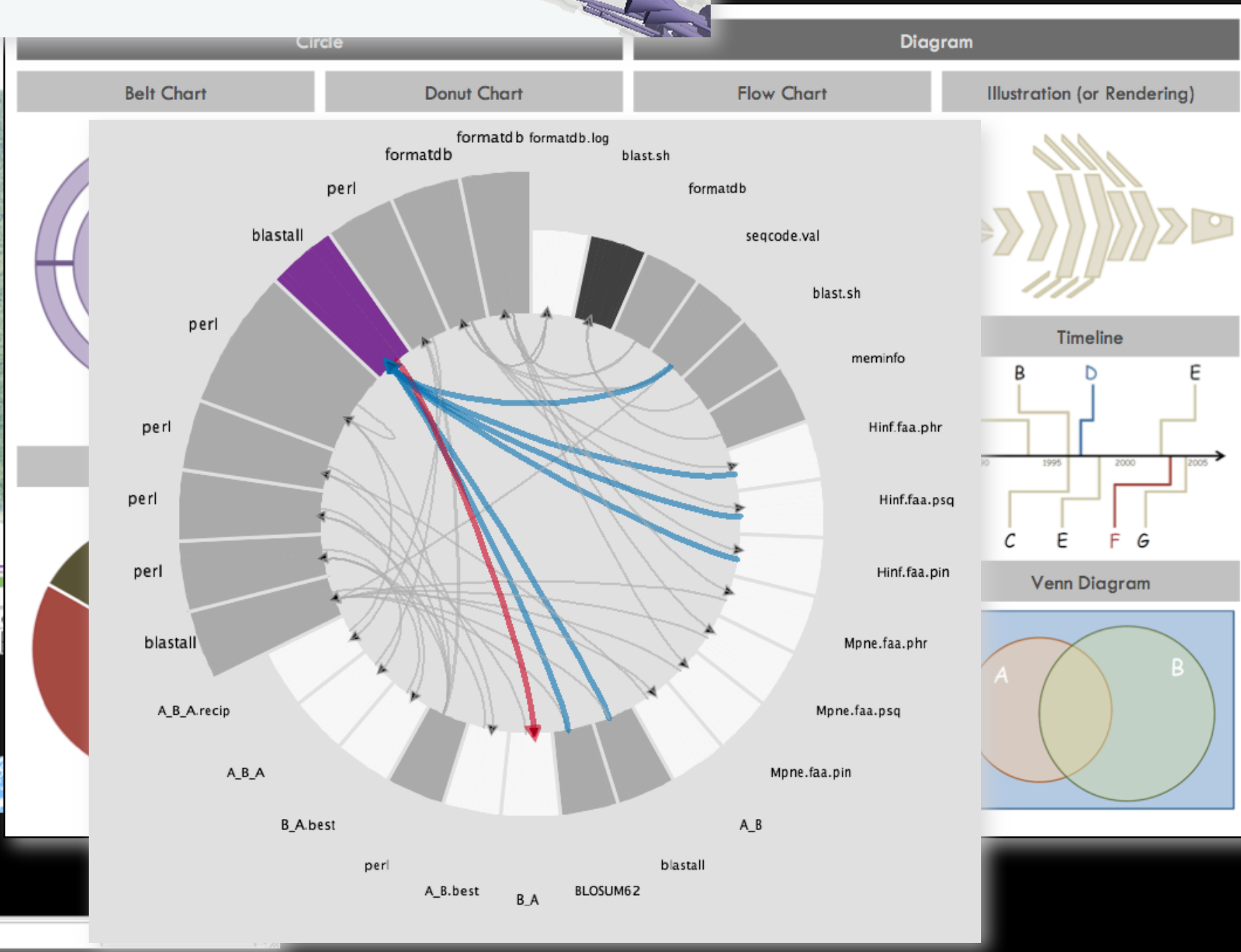
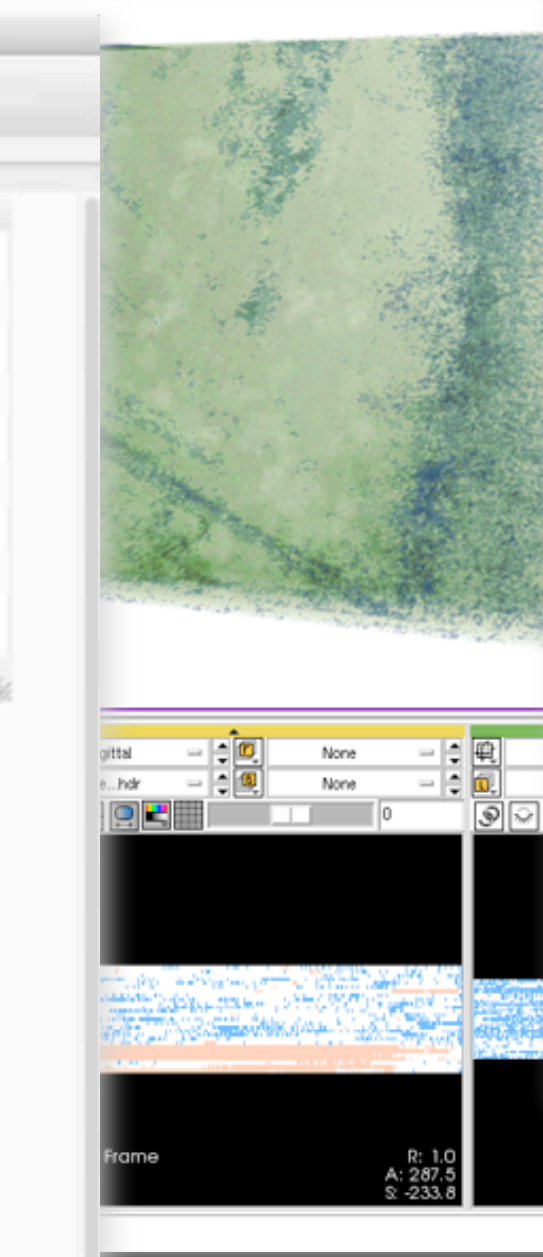
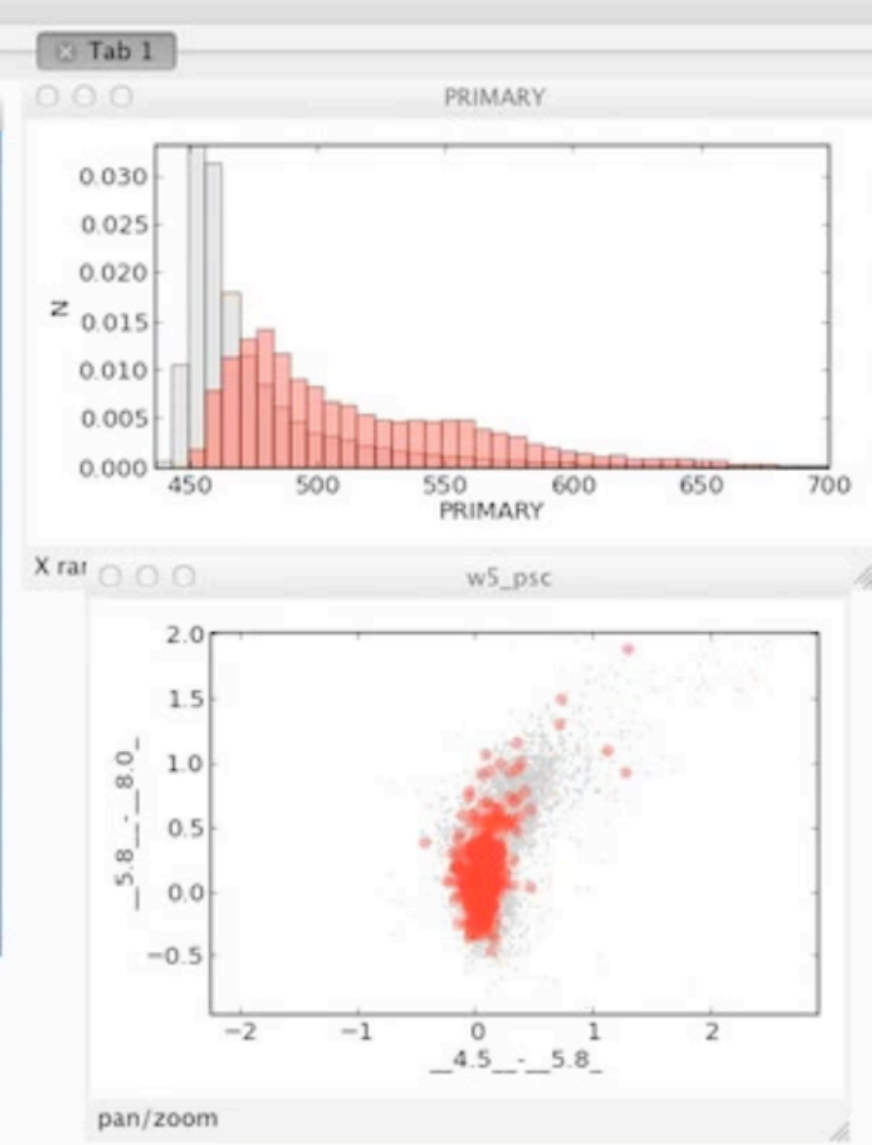
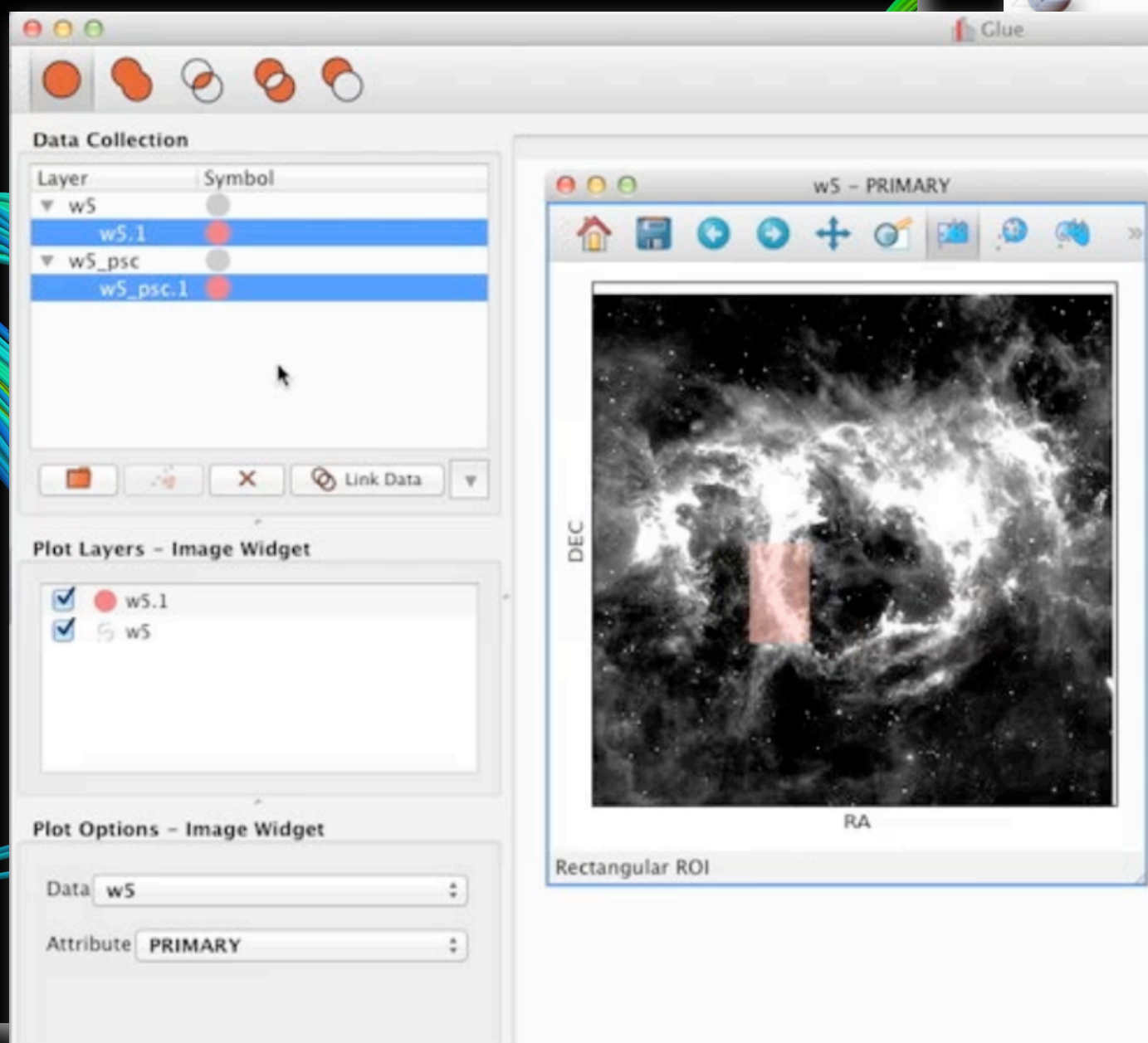
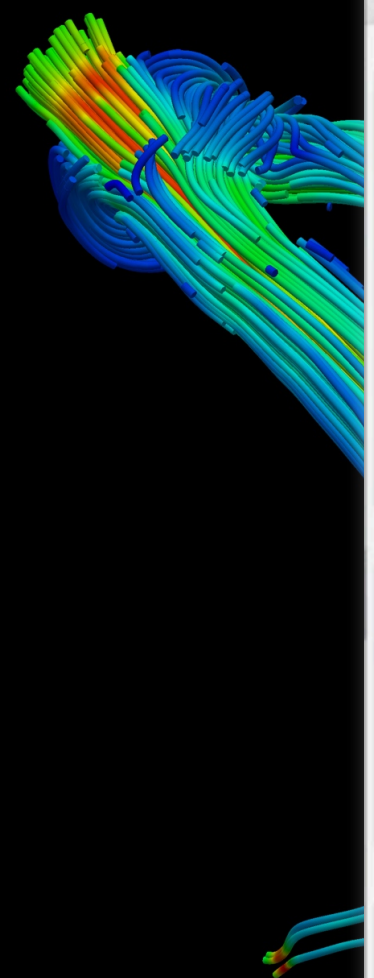
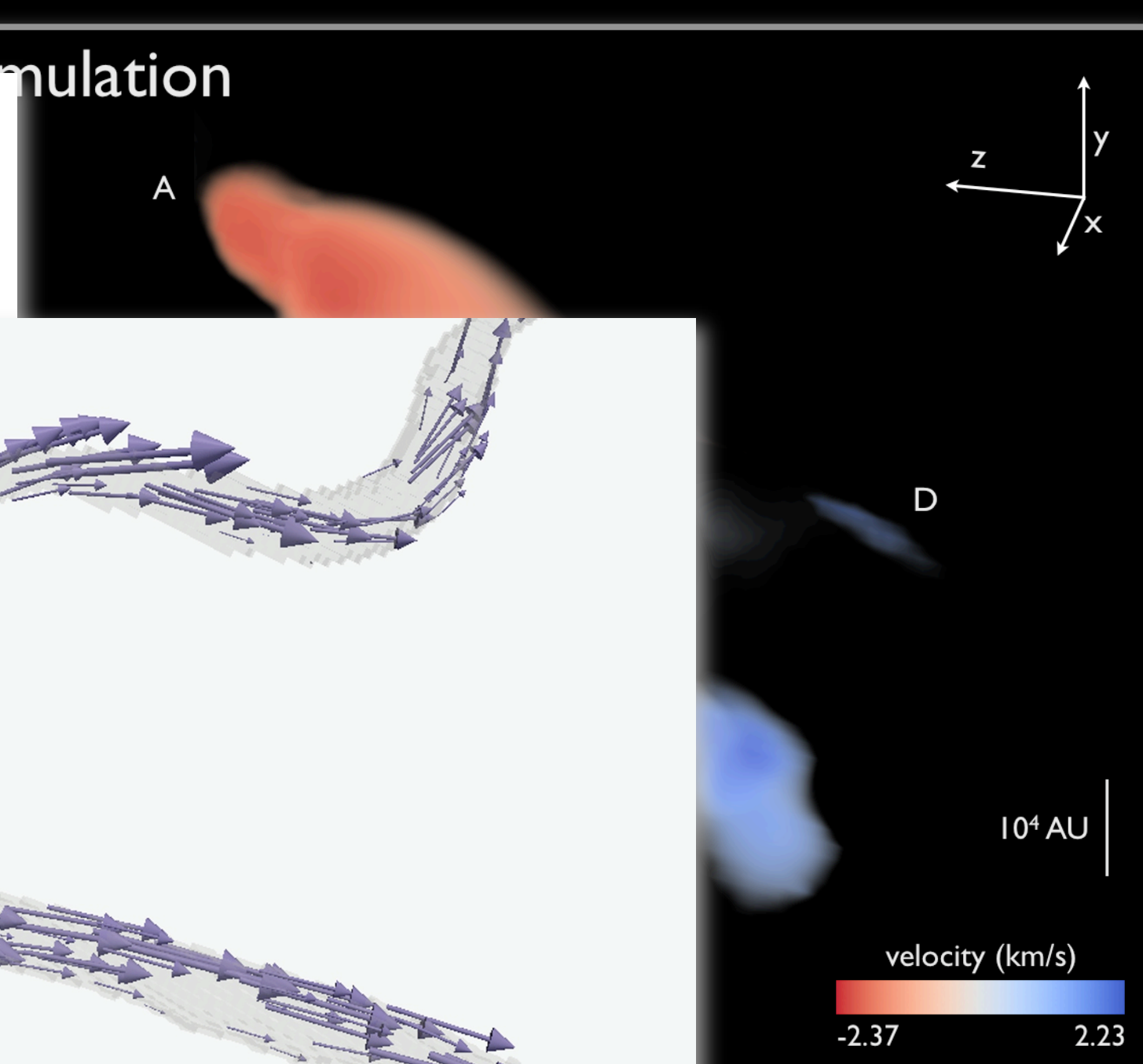
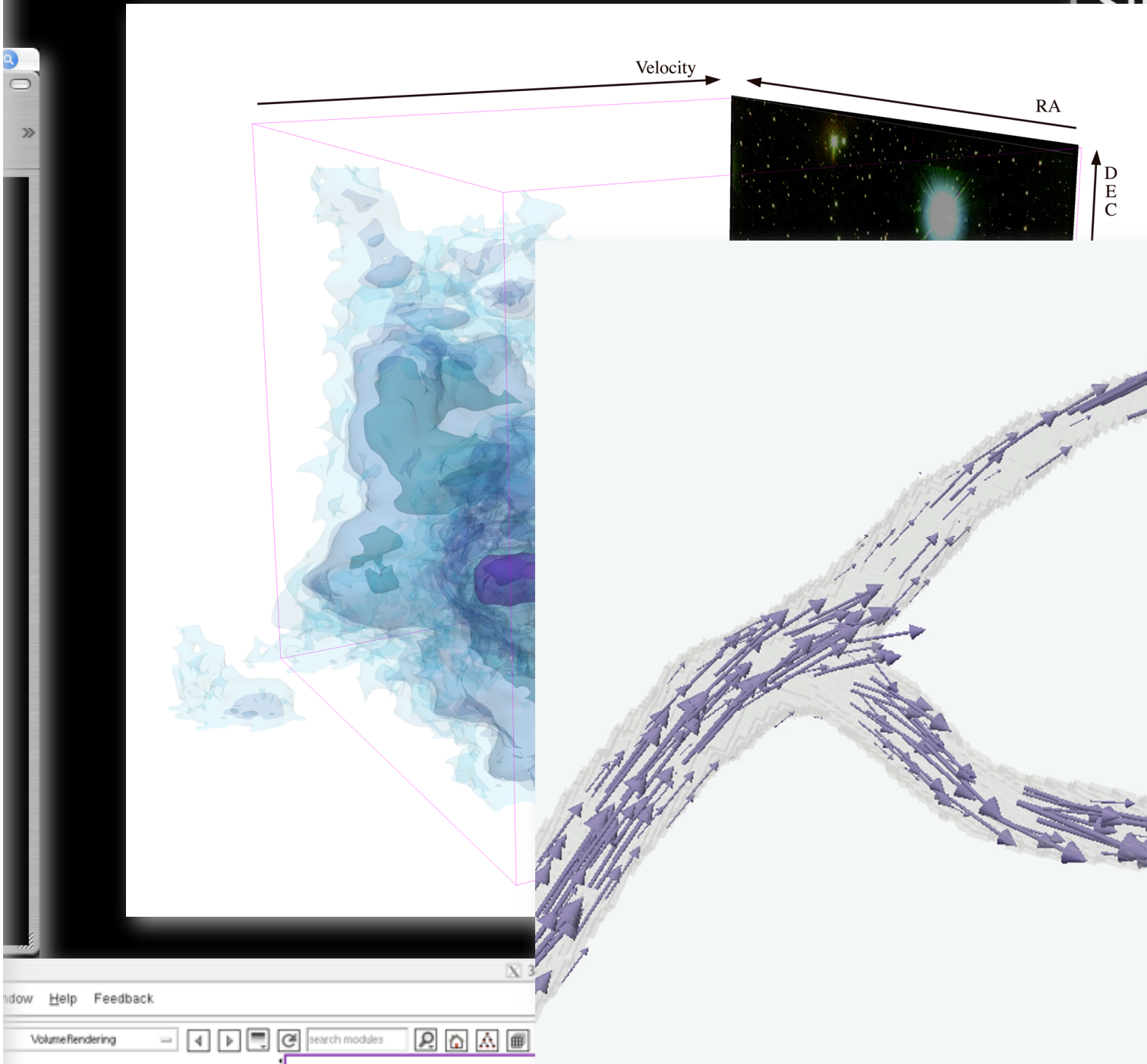
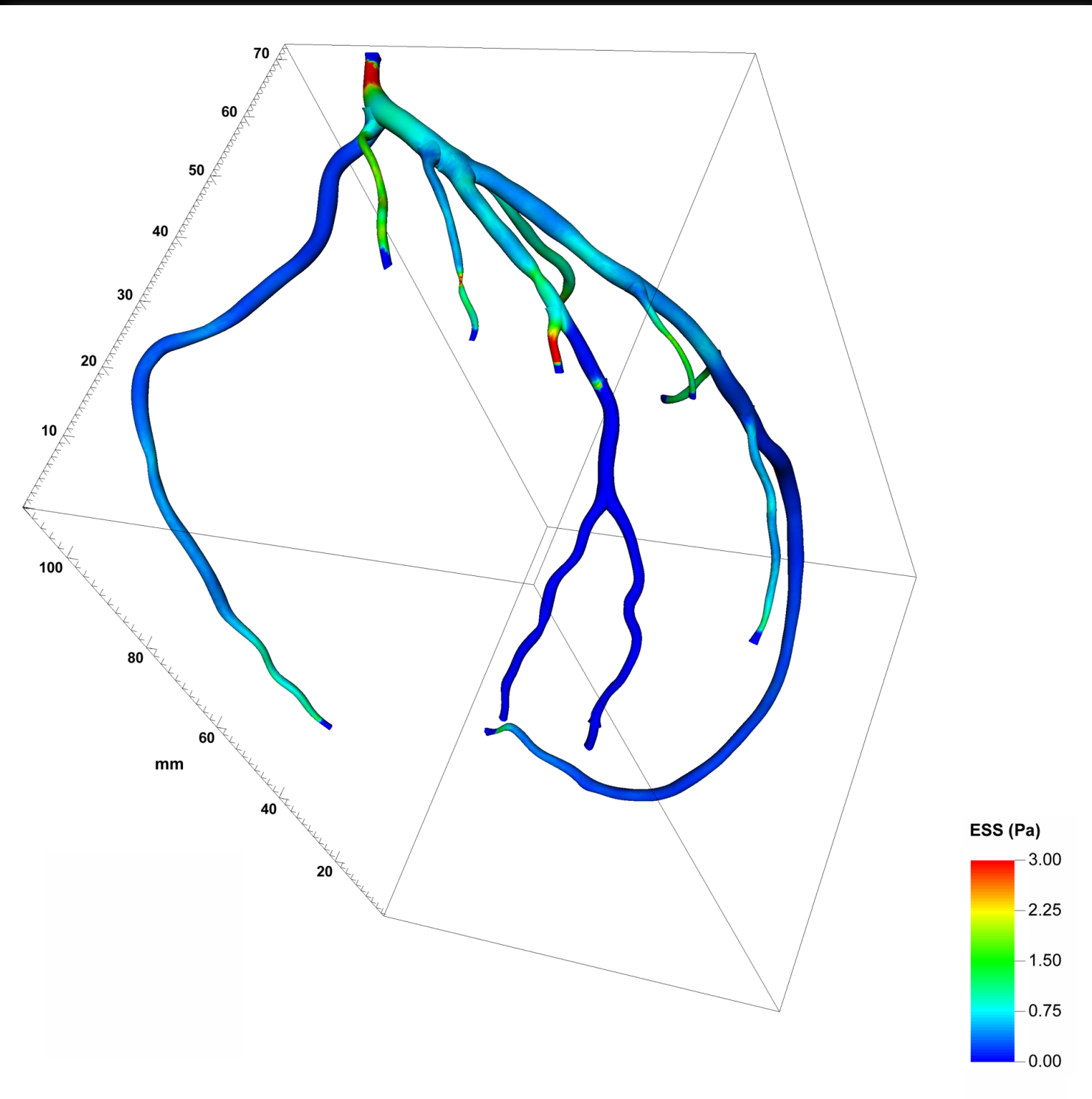
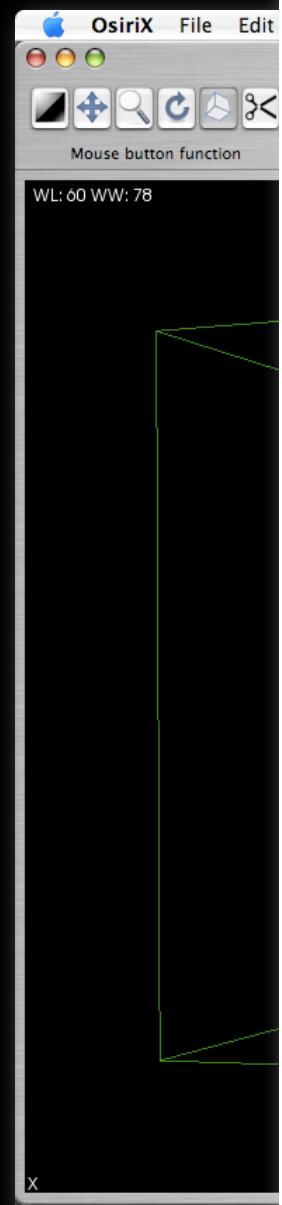








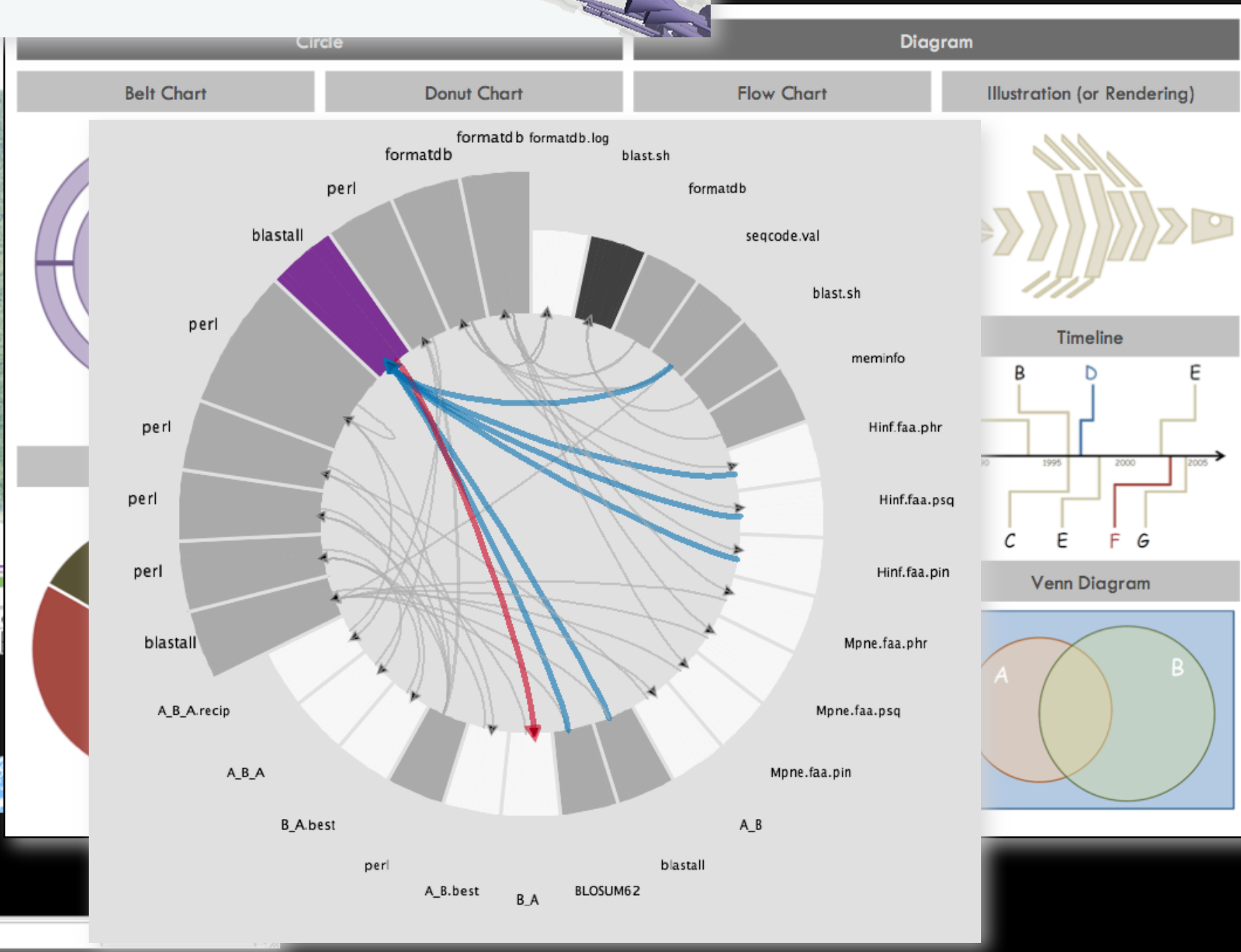
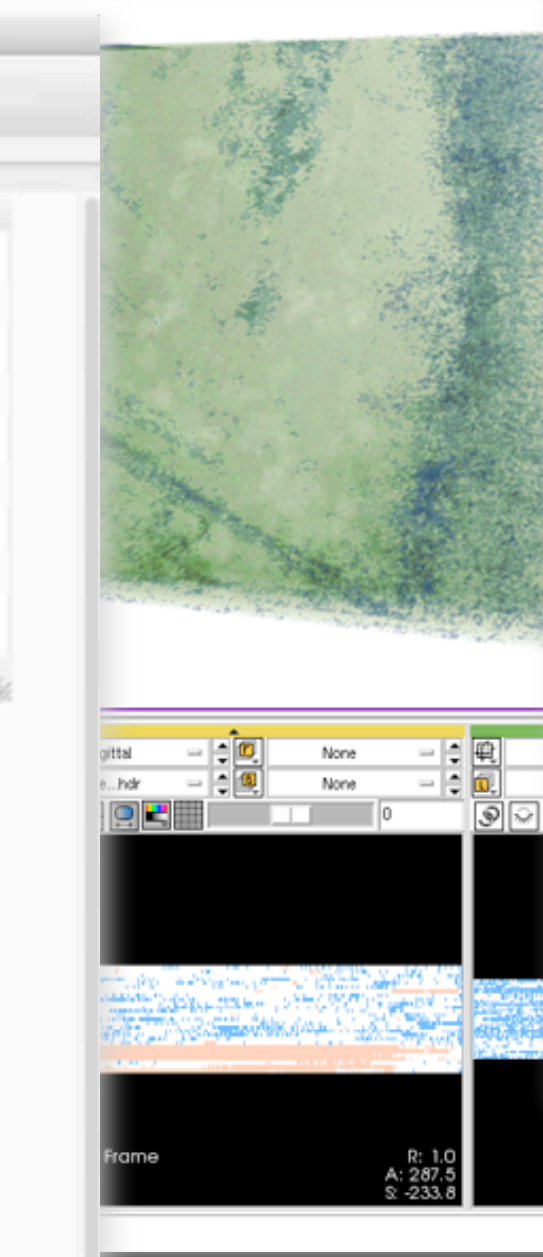
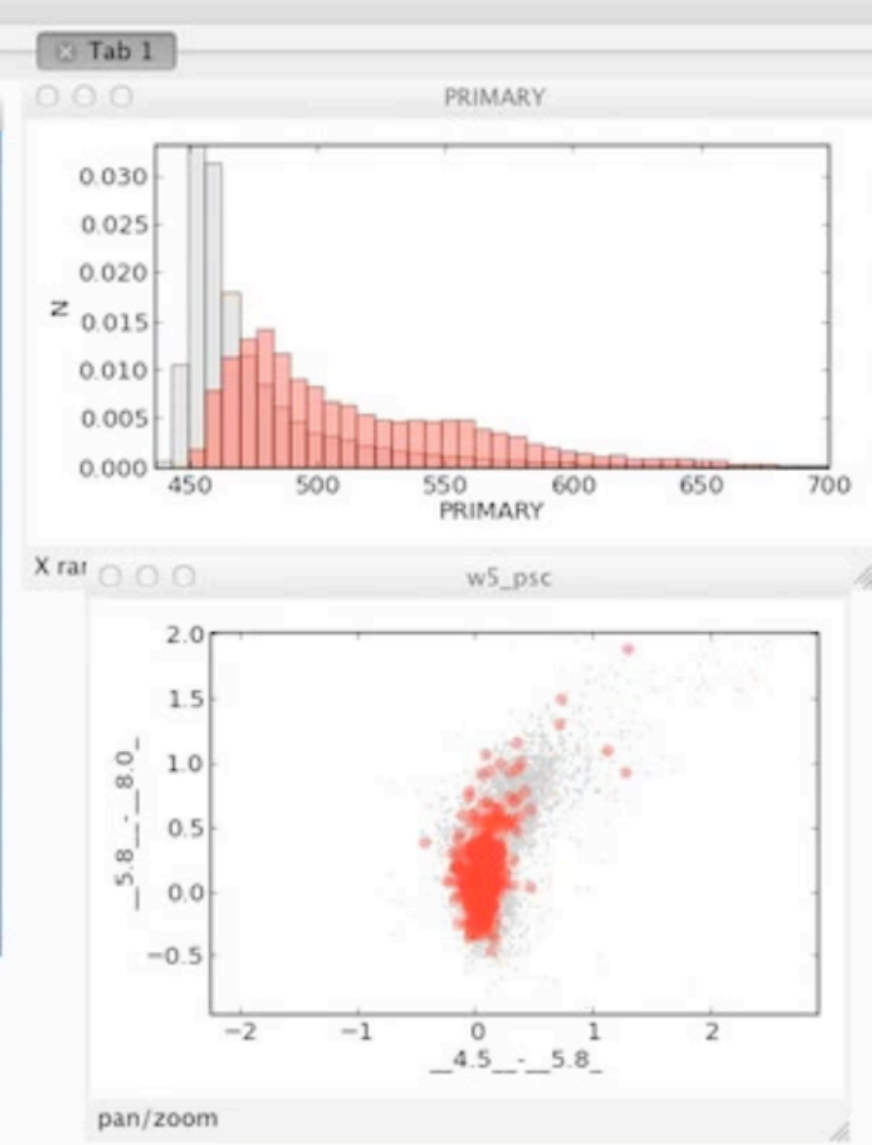
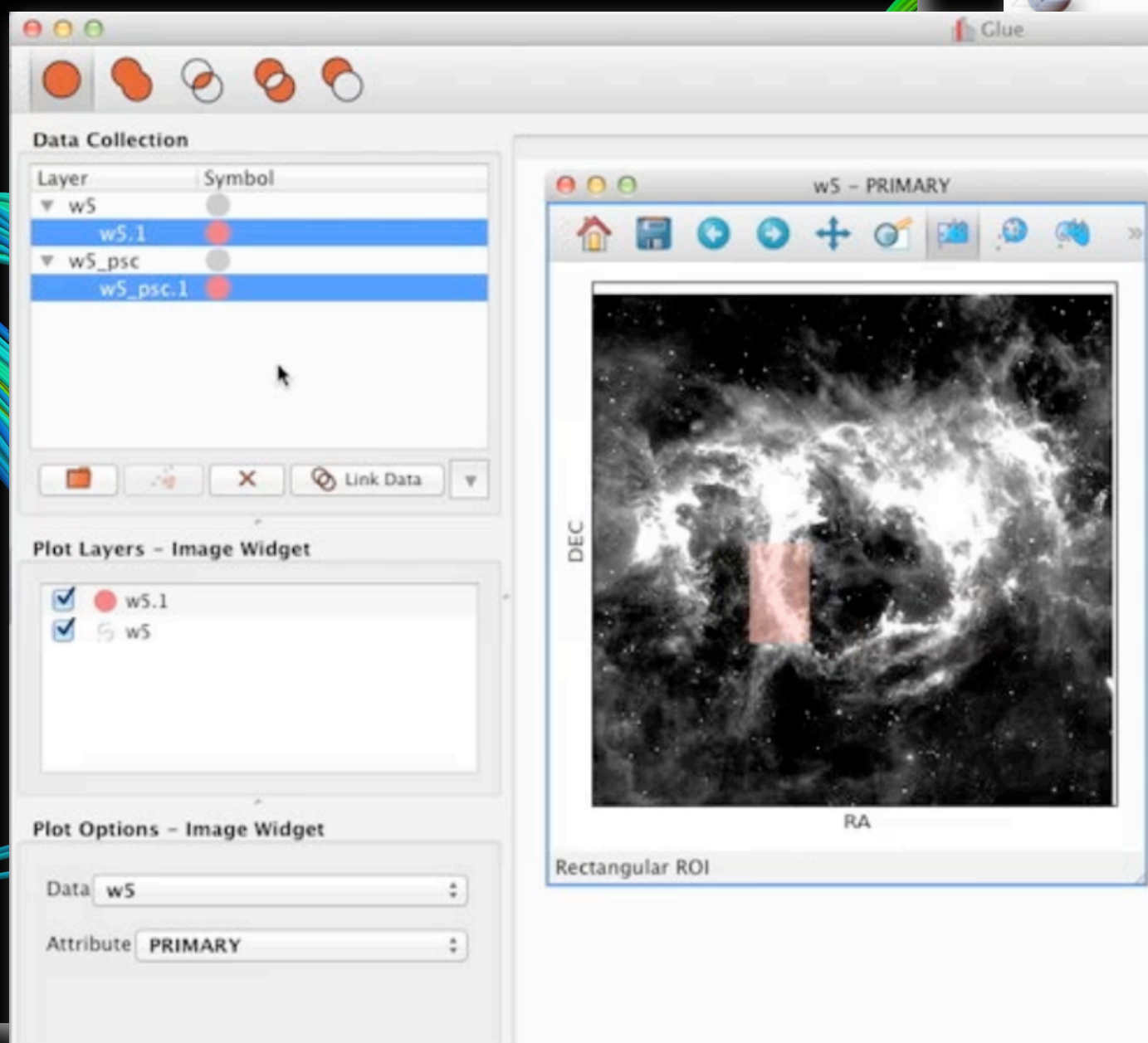
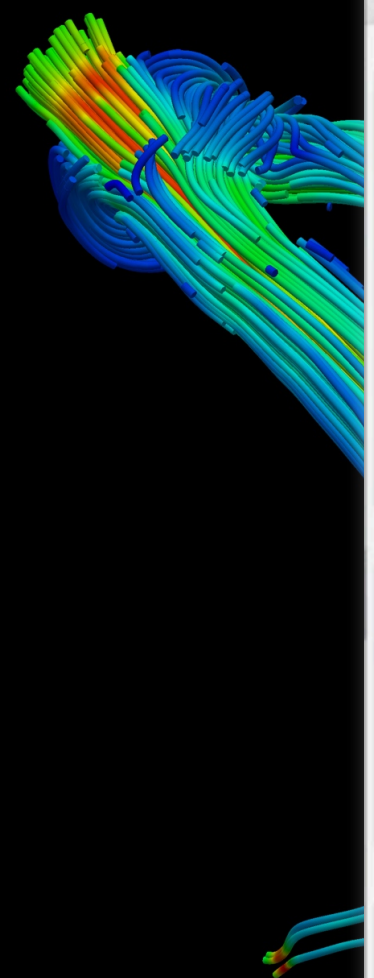
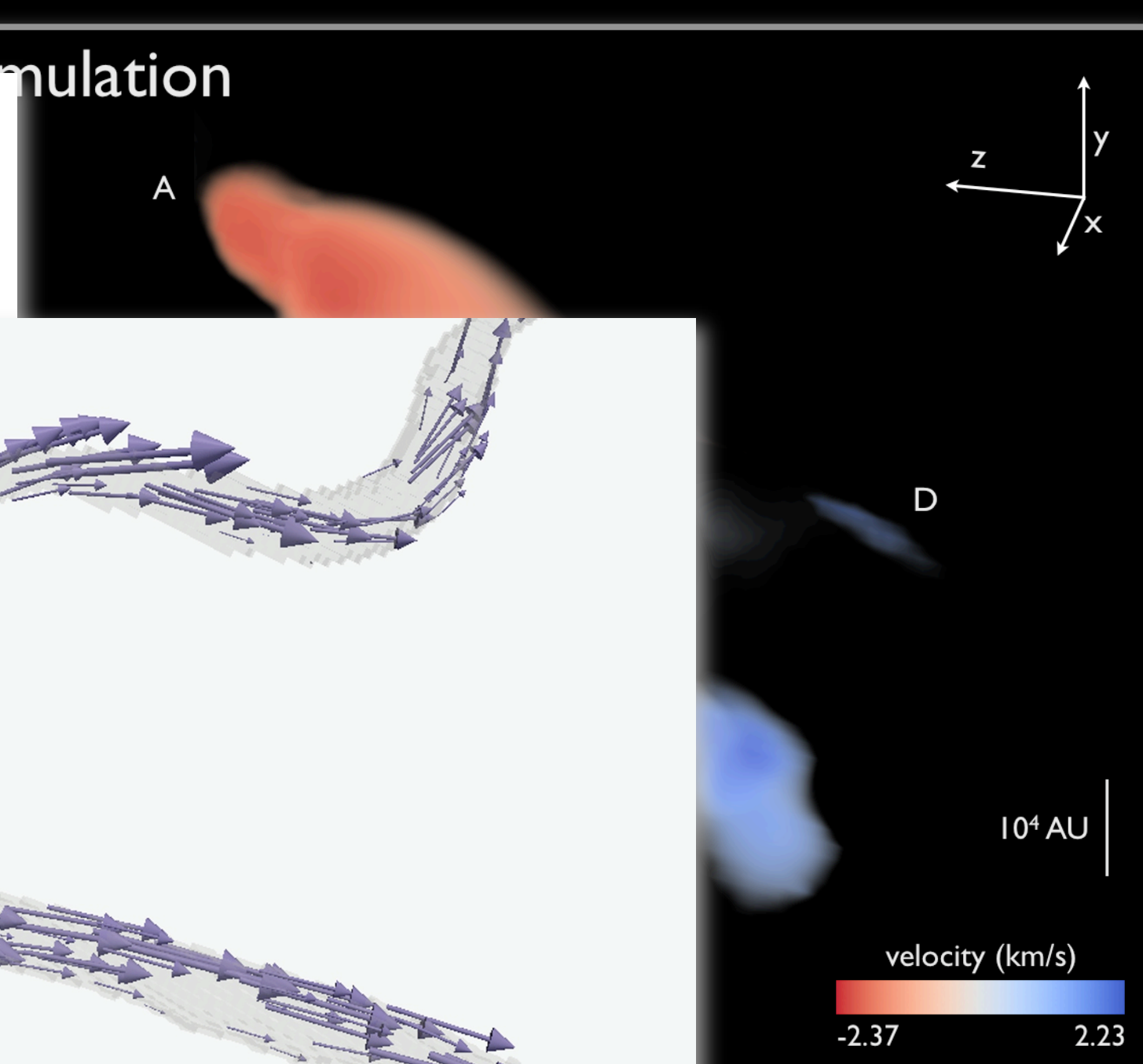
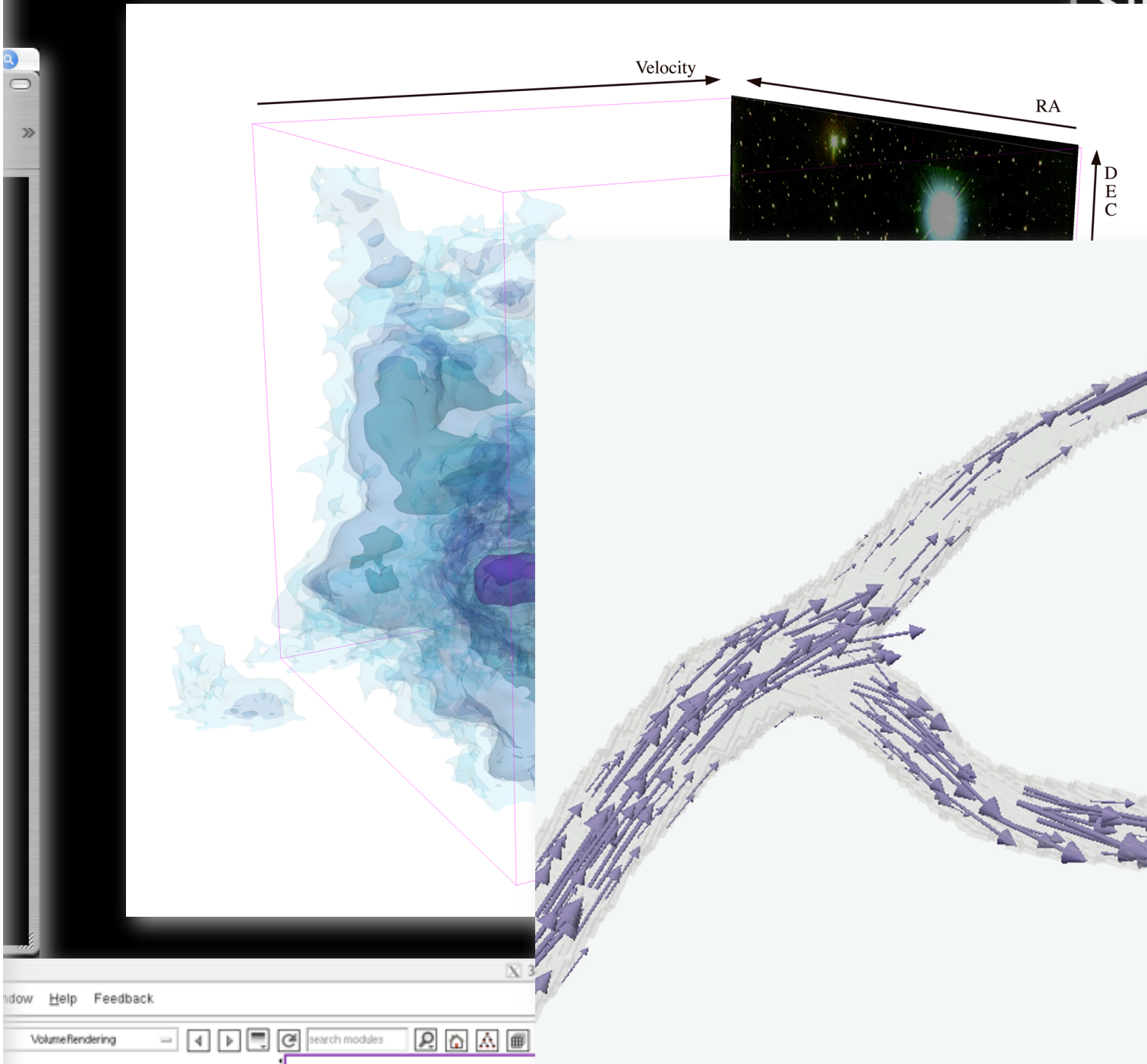
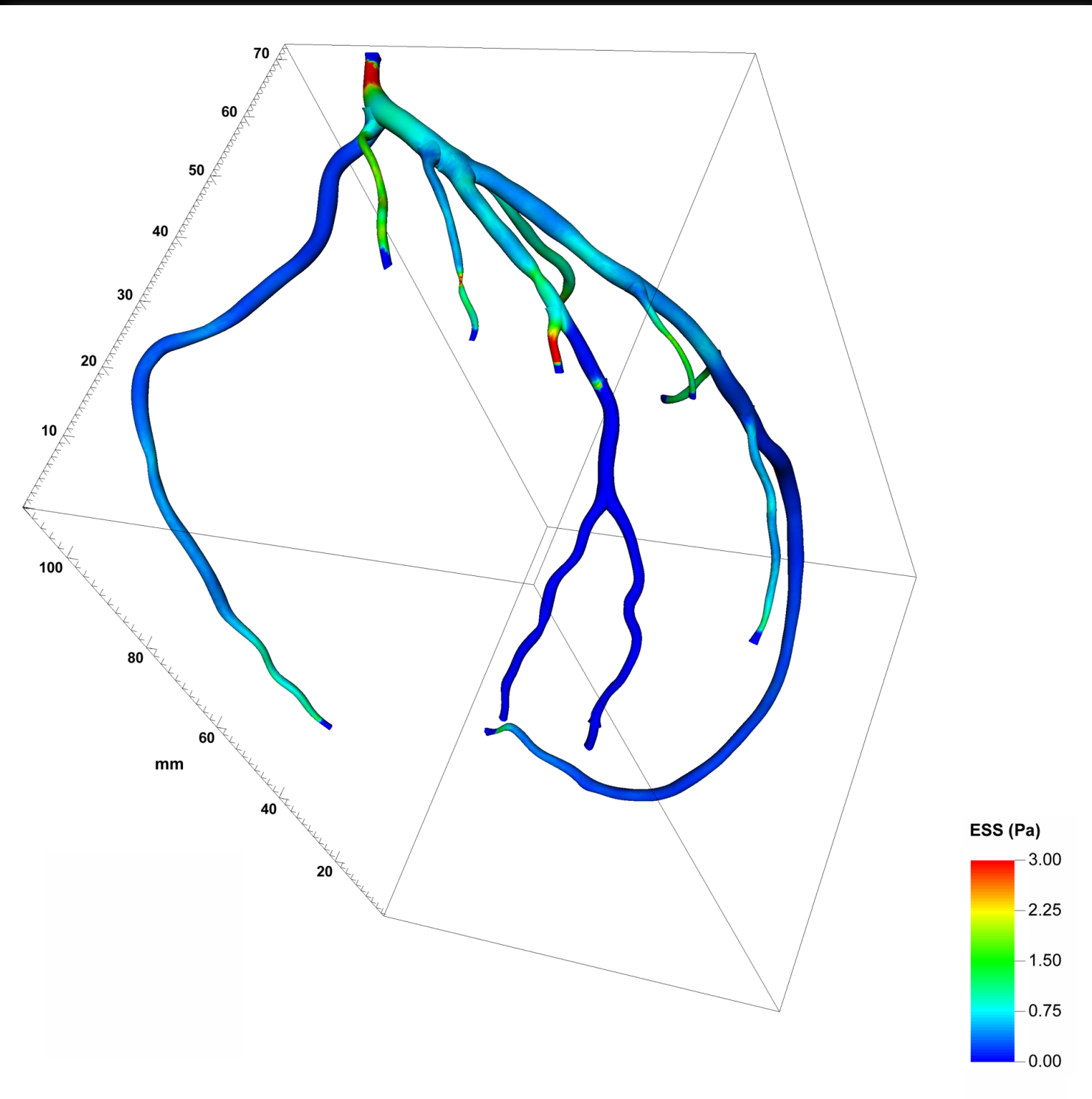
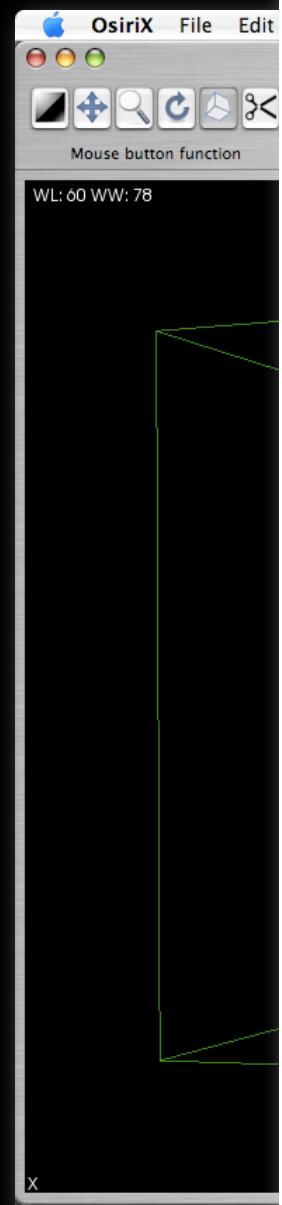




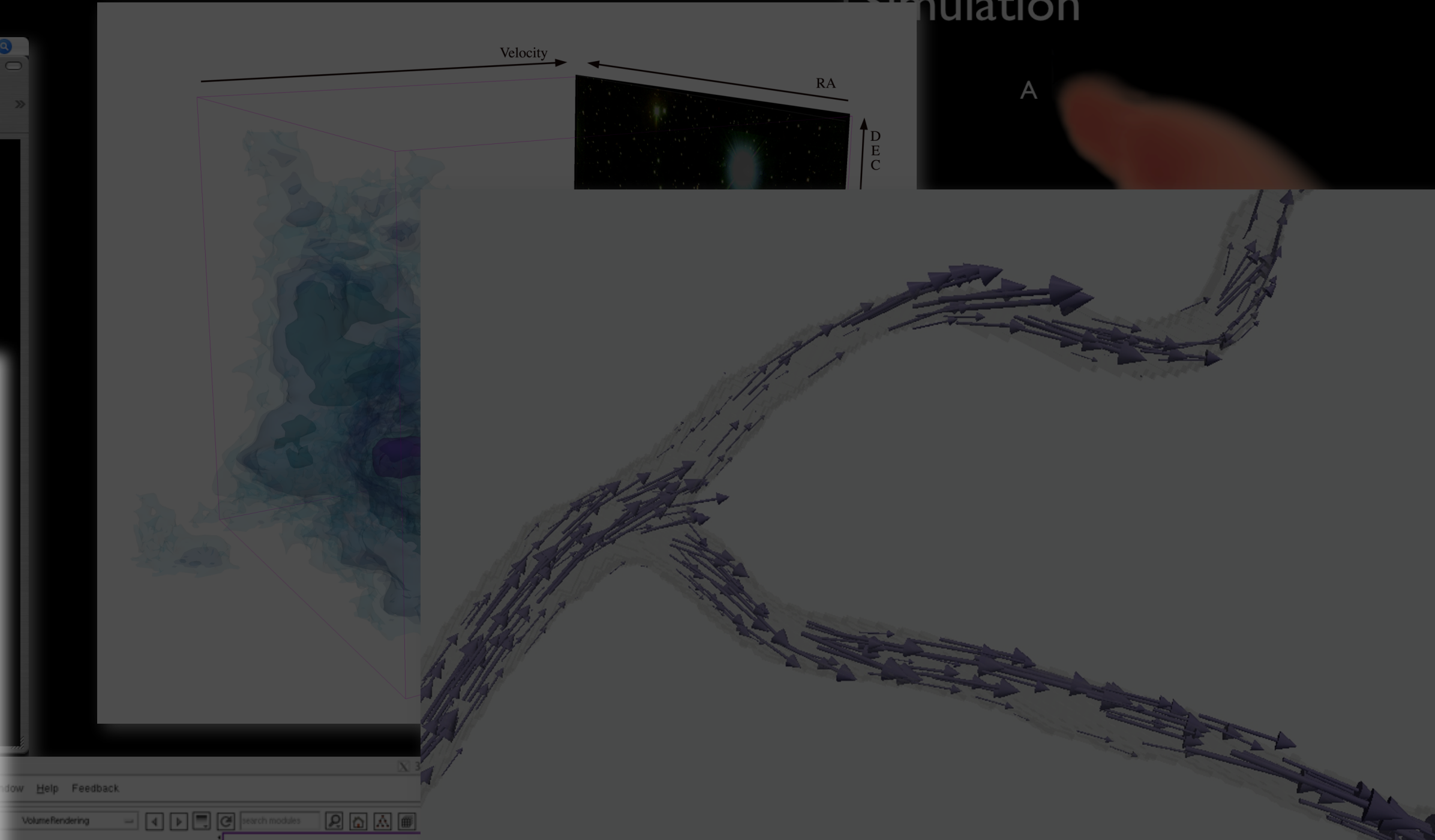
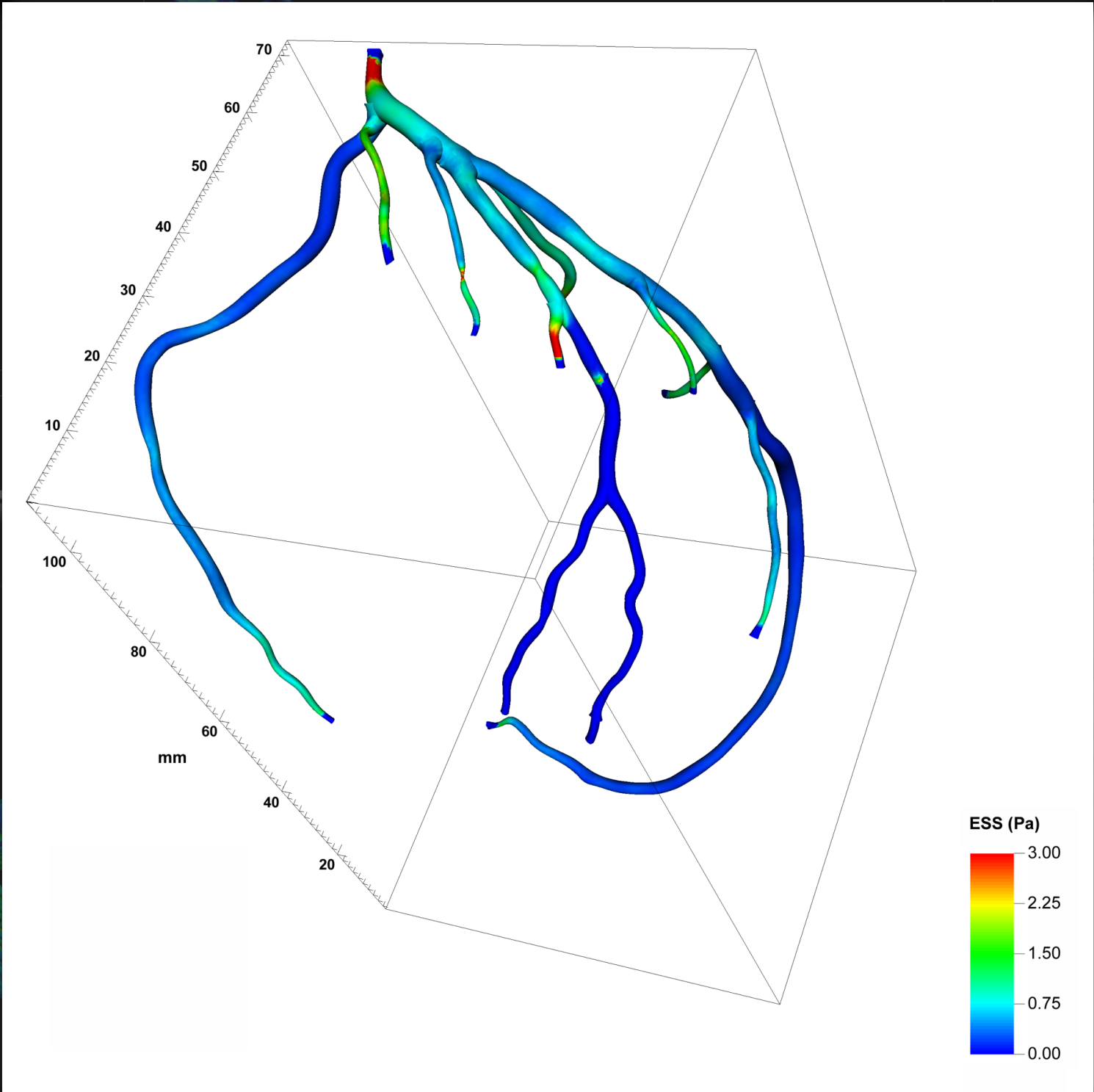
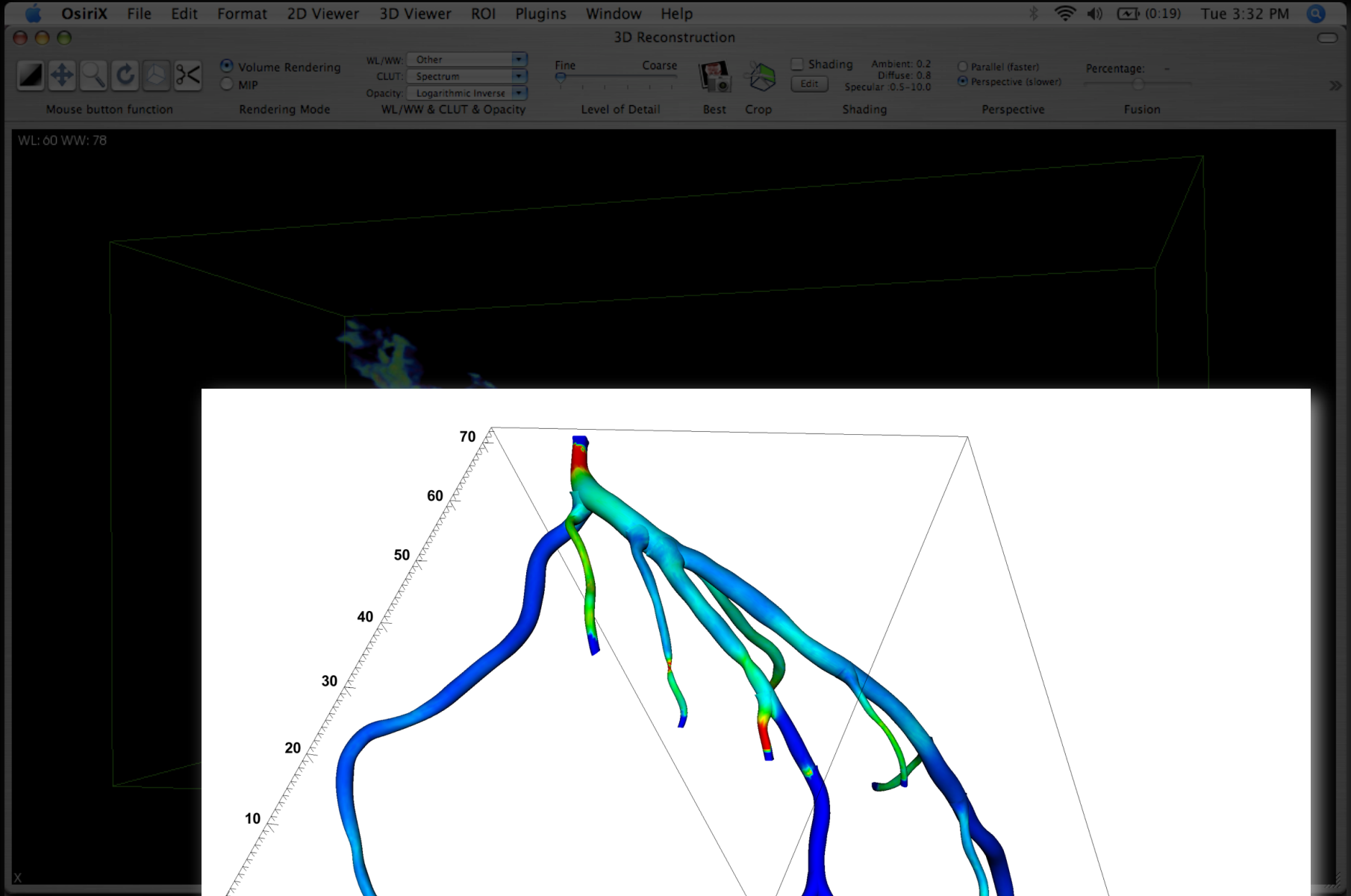




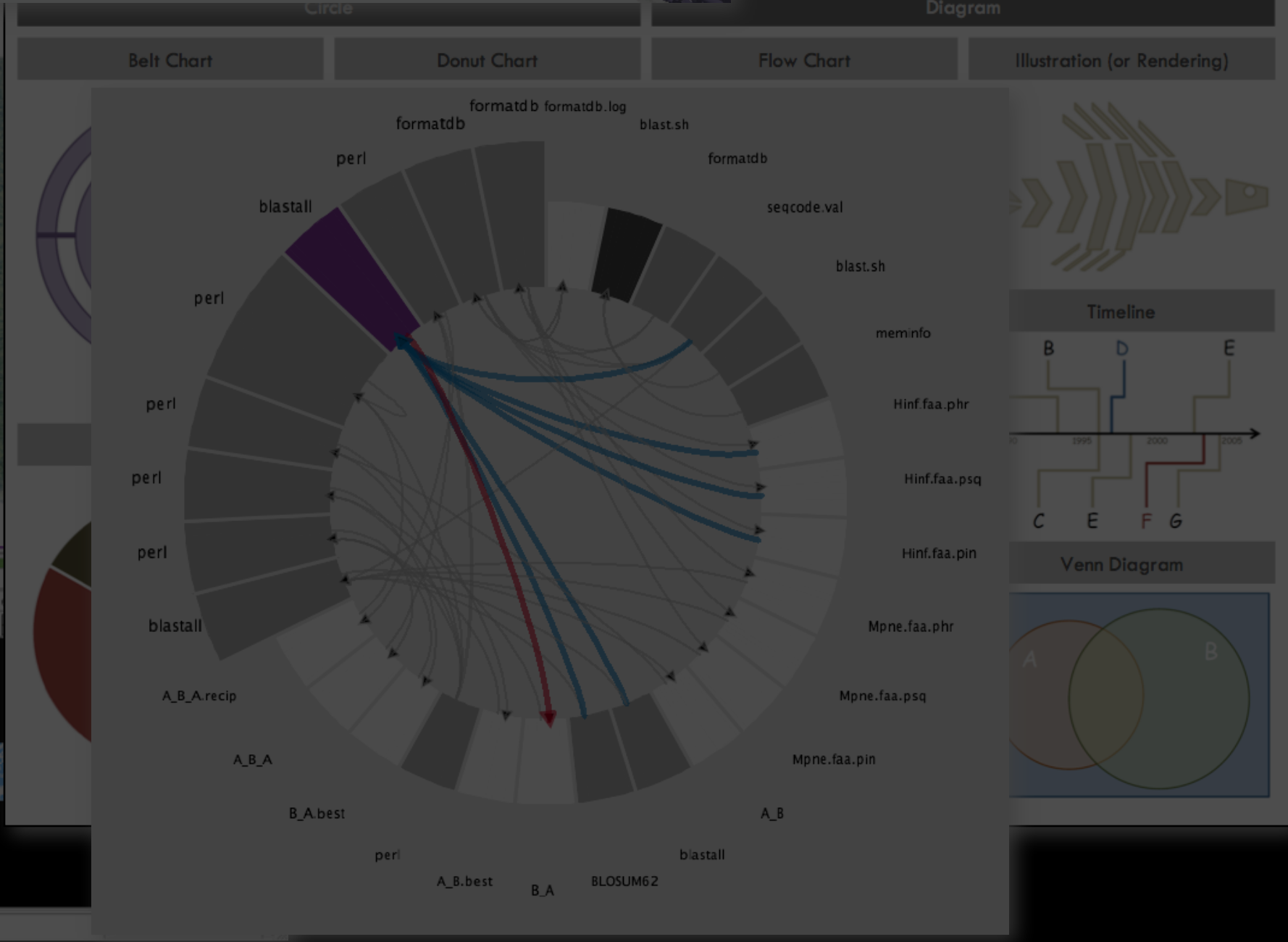
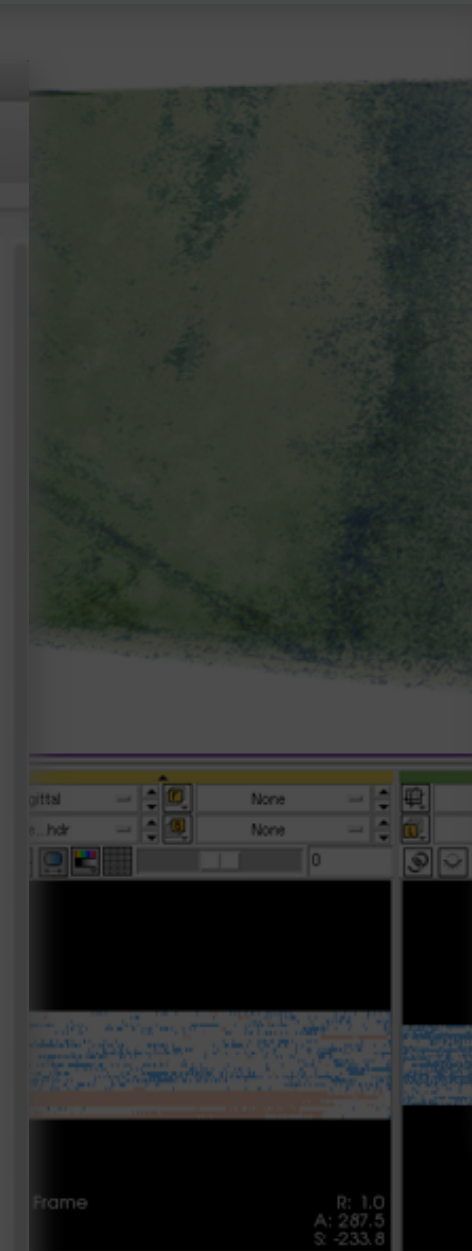
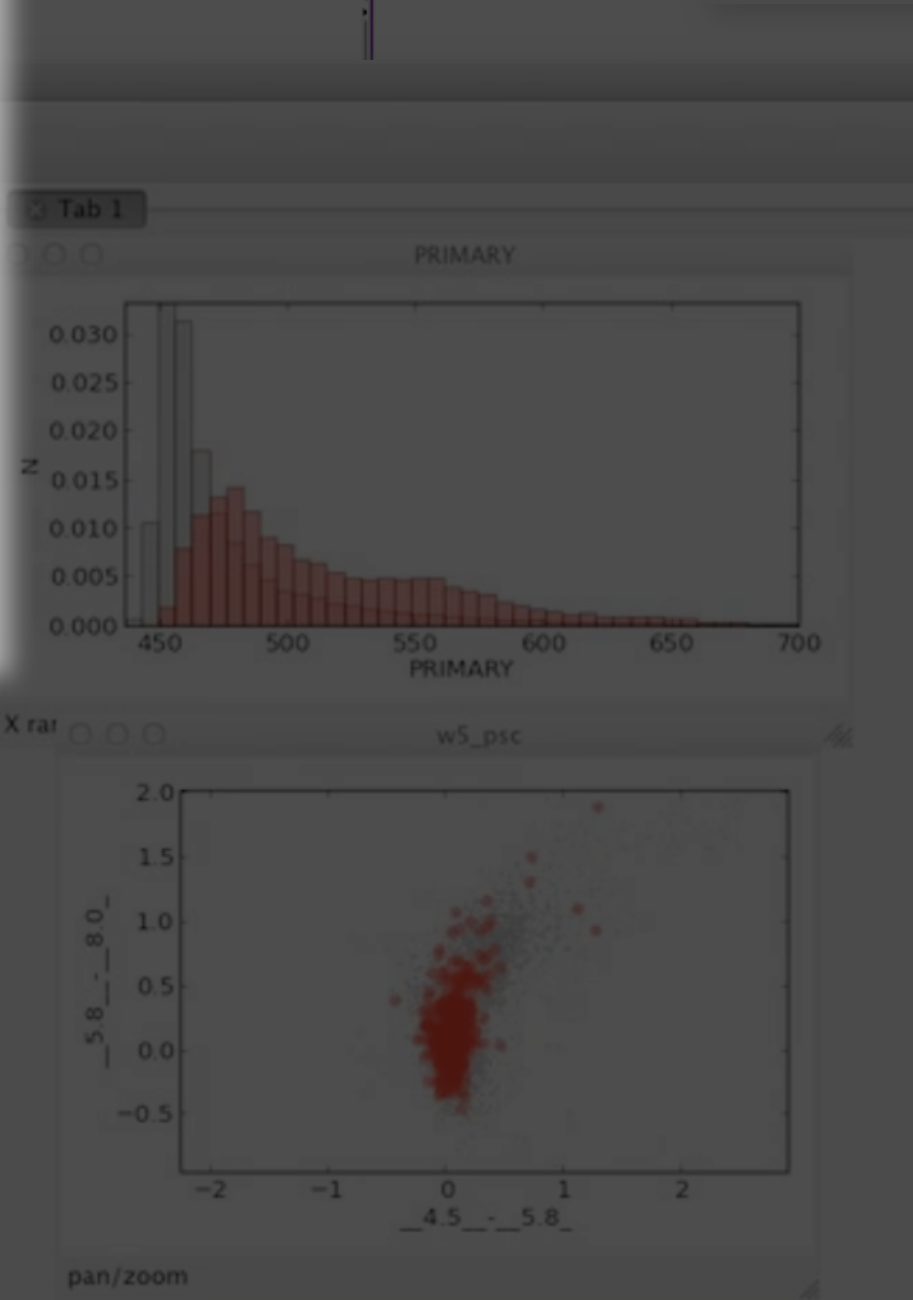
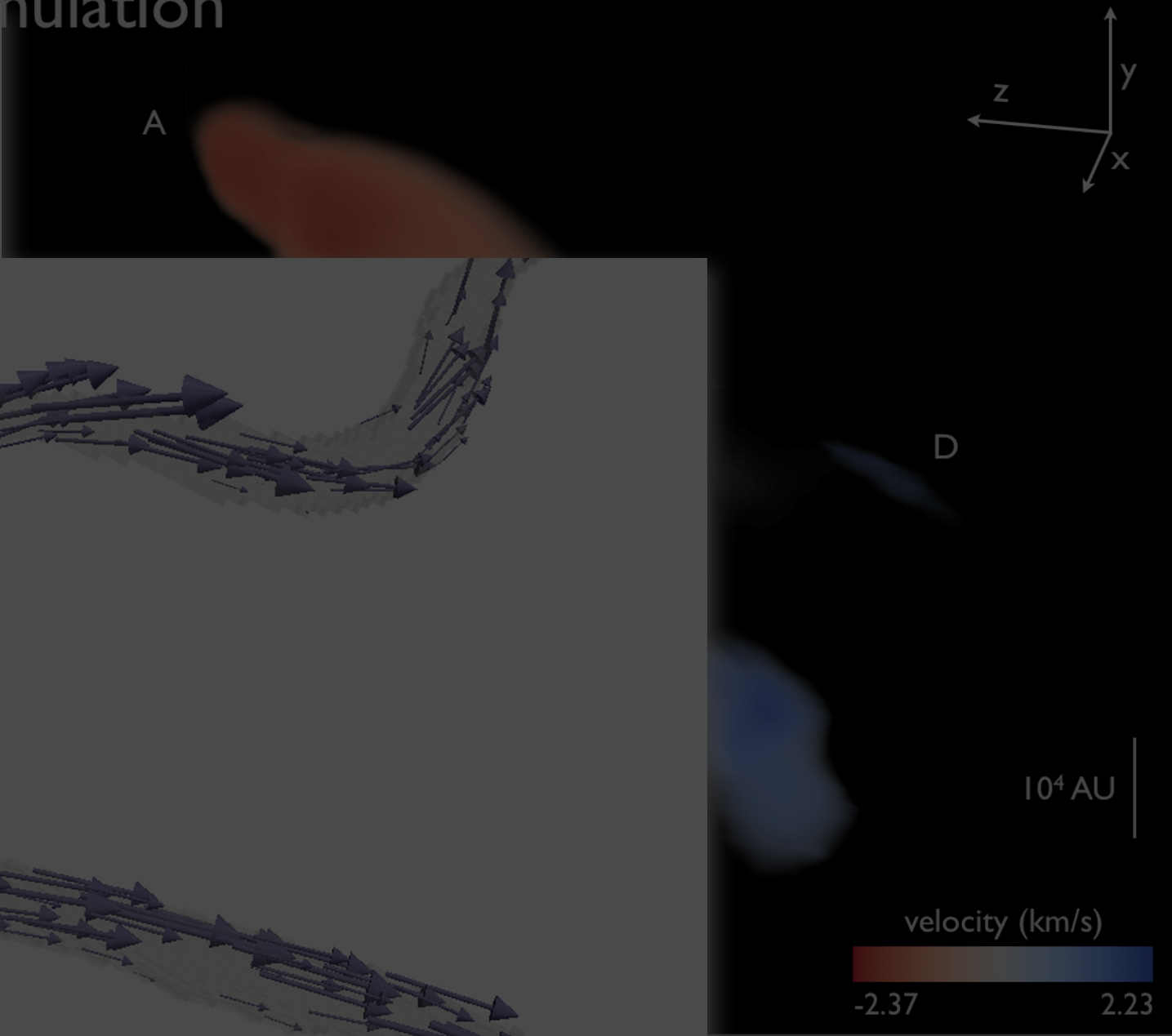




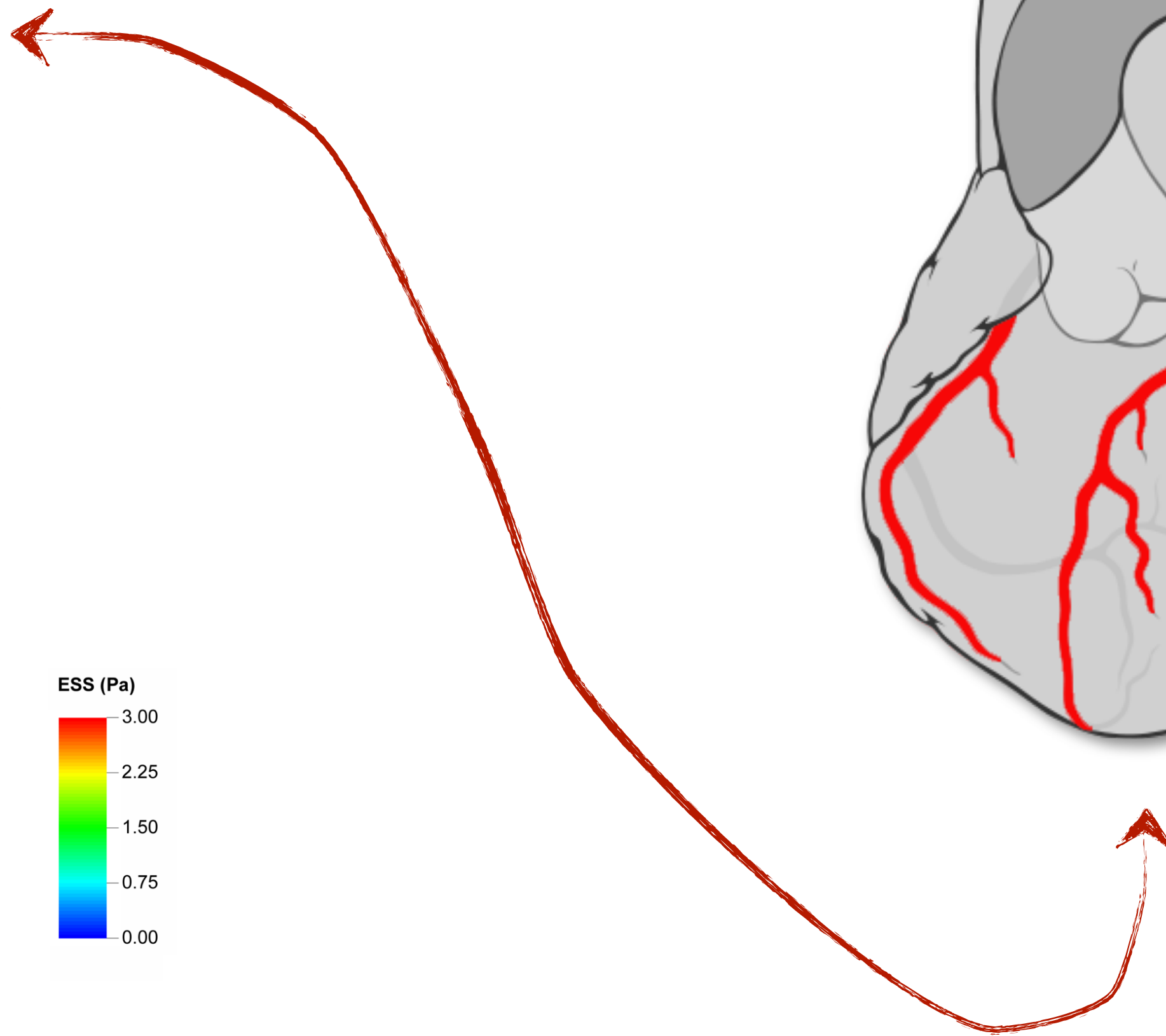
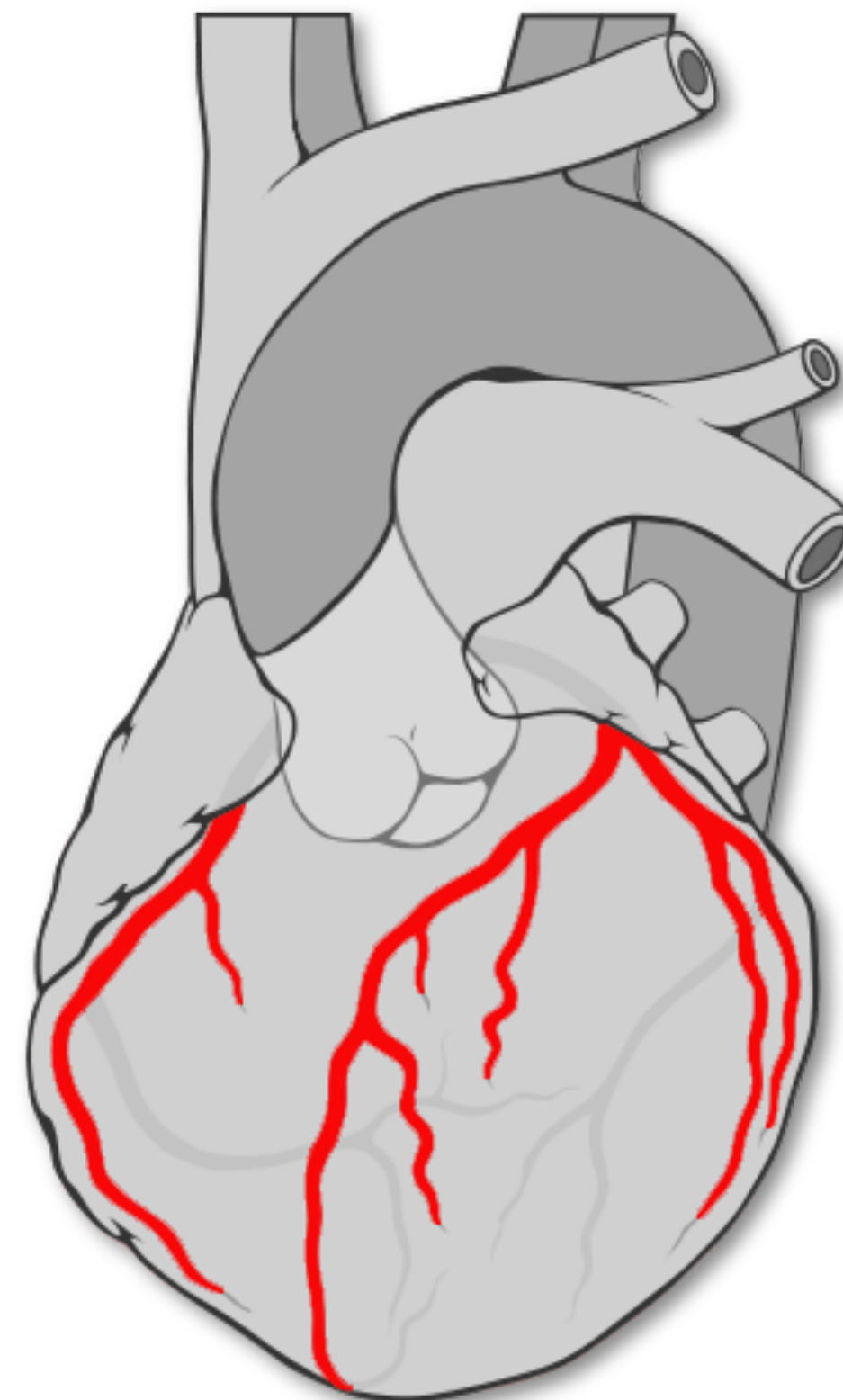
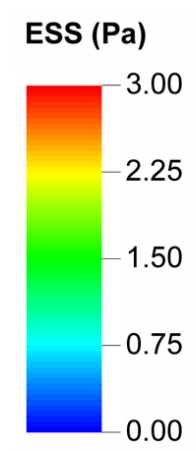
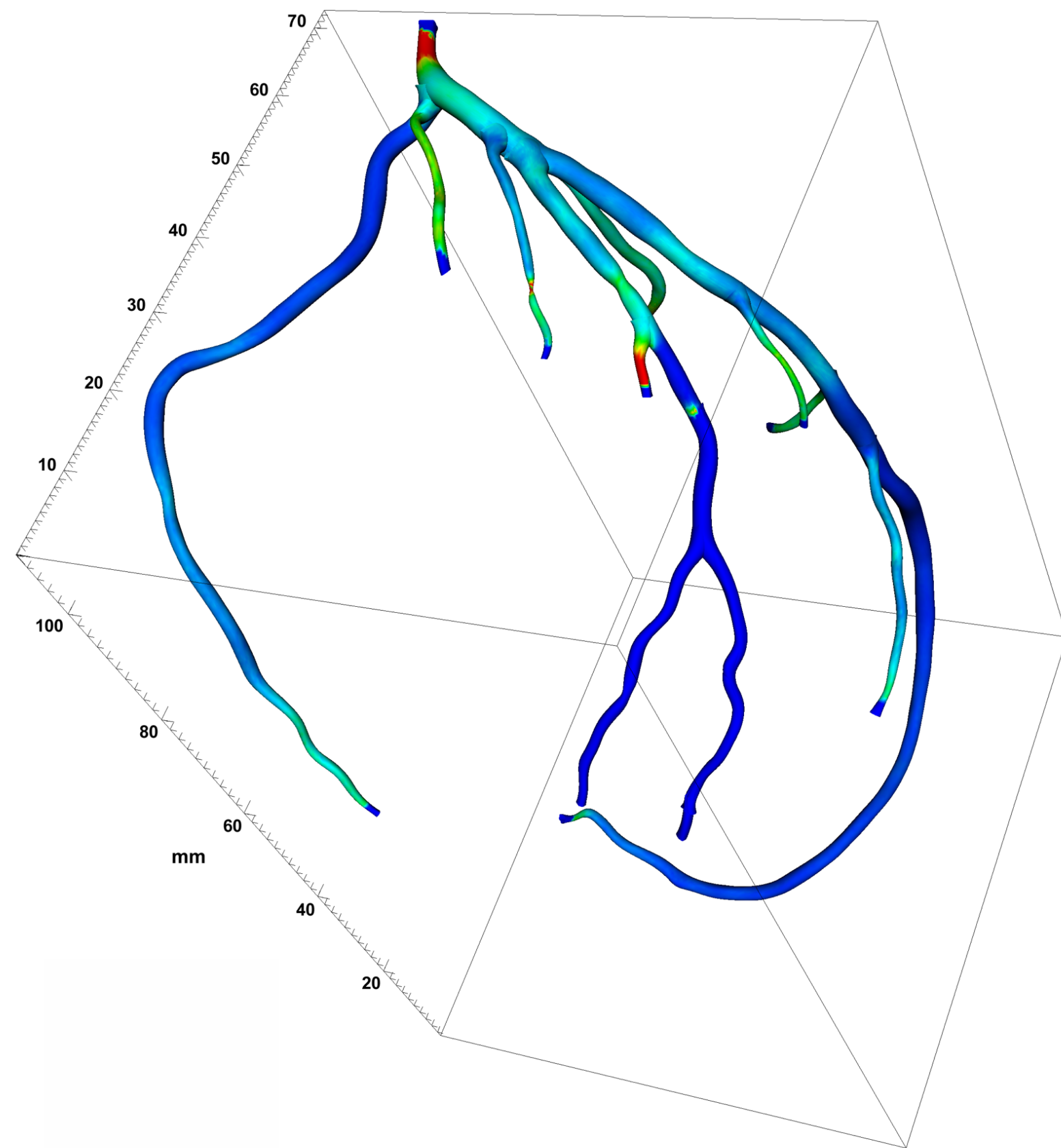




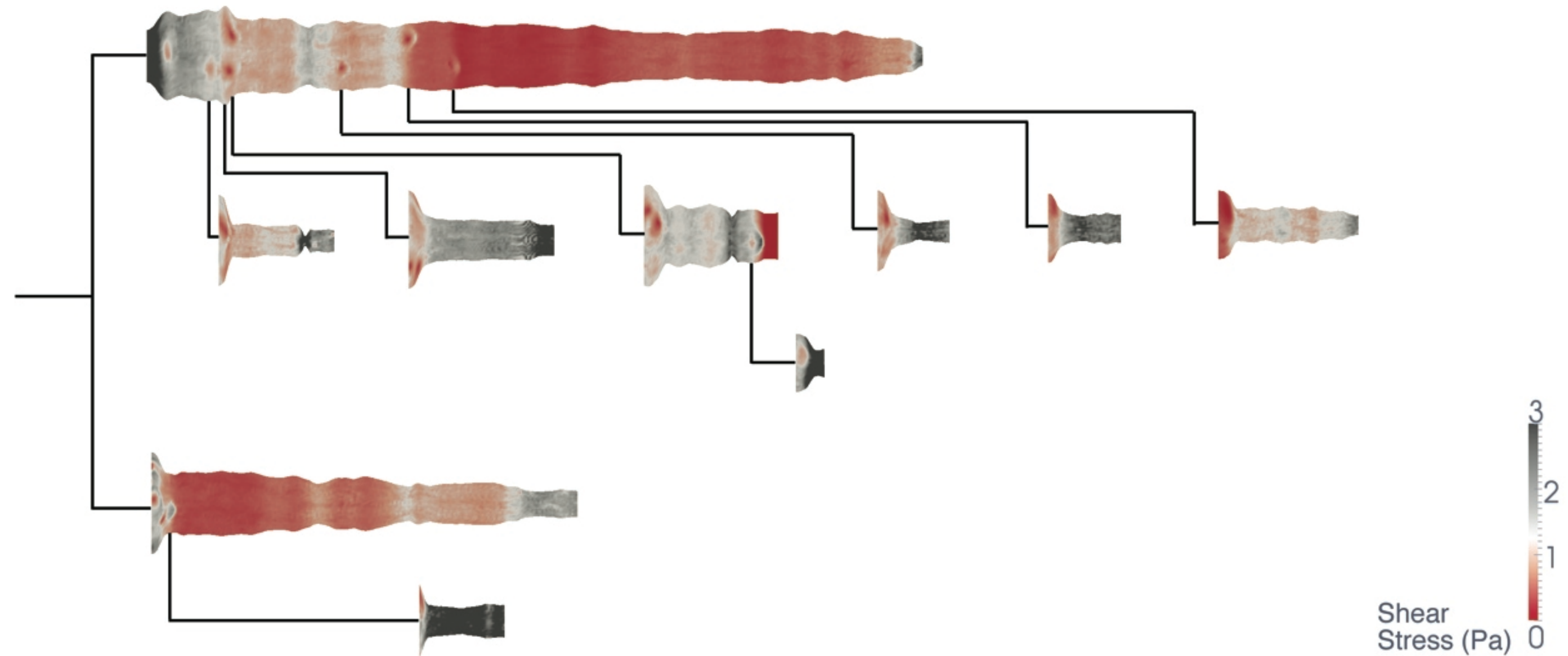
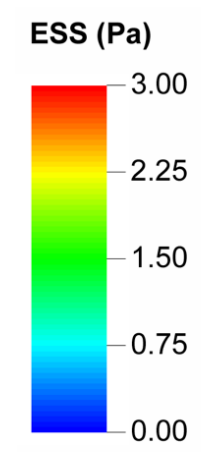
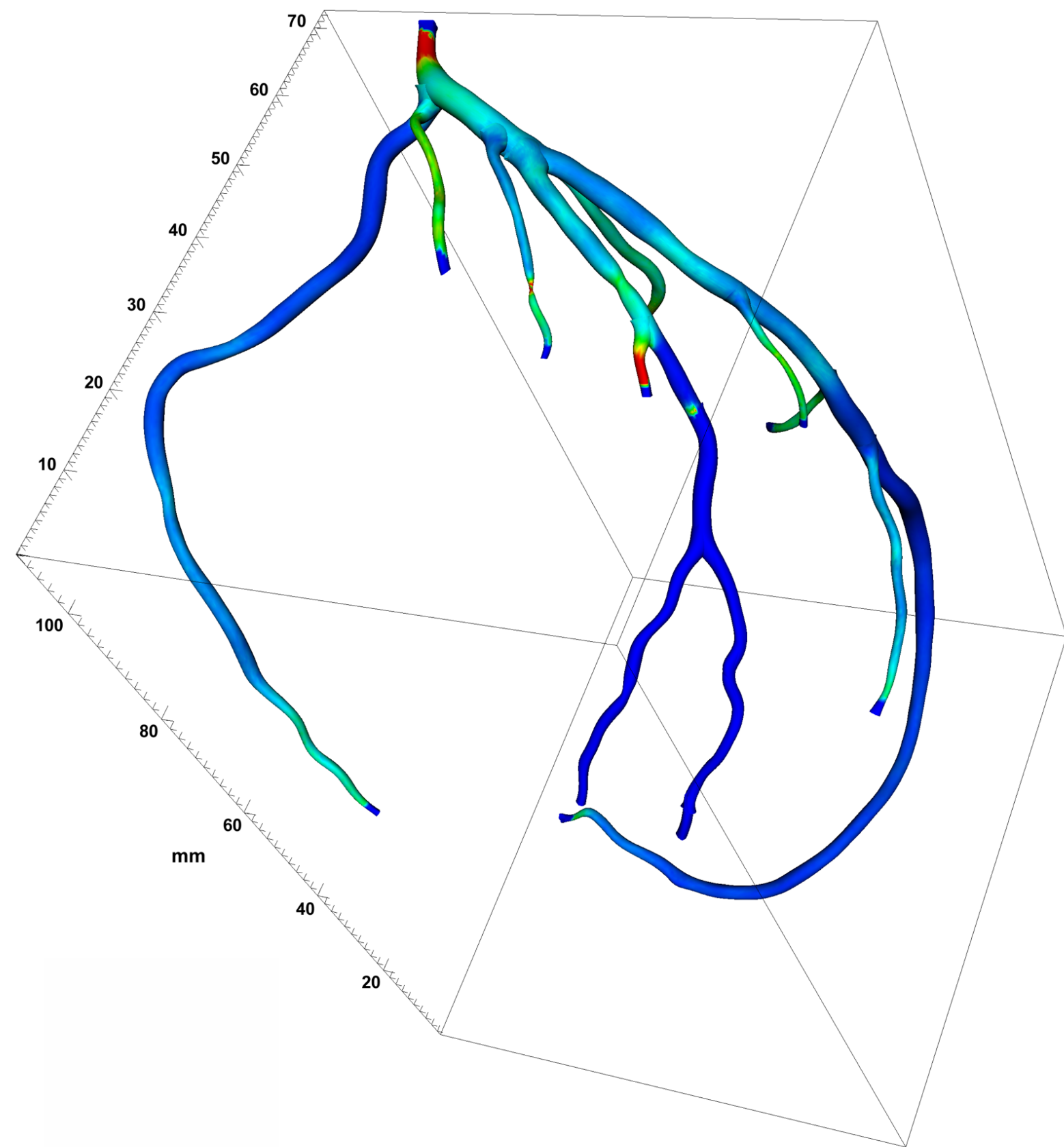
Simulation



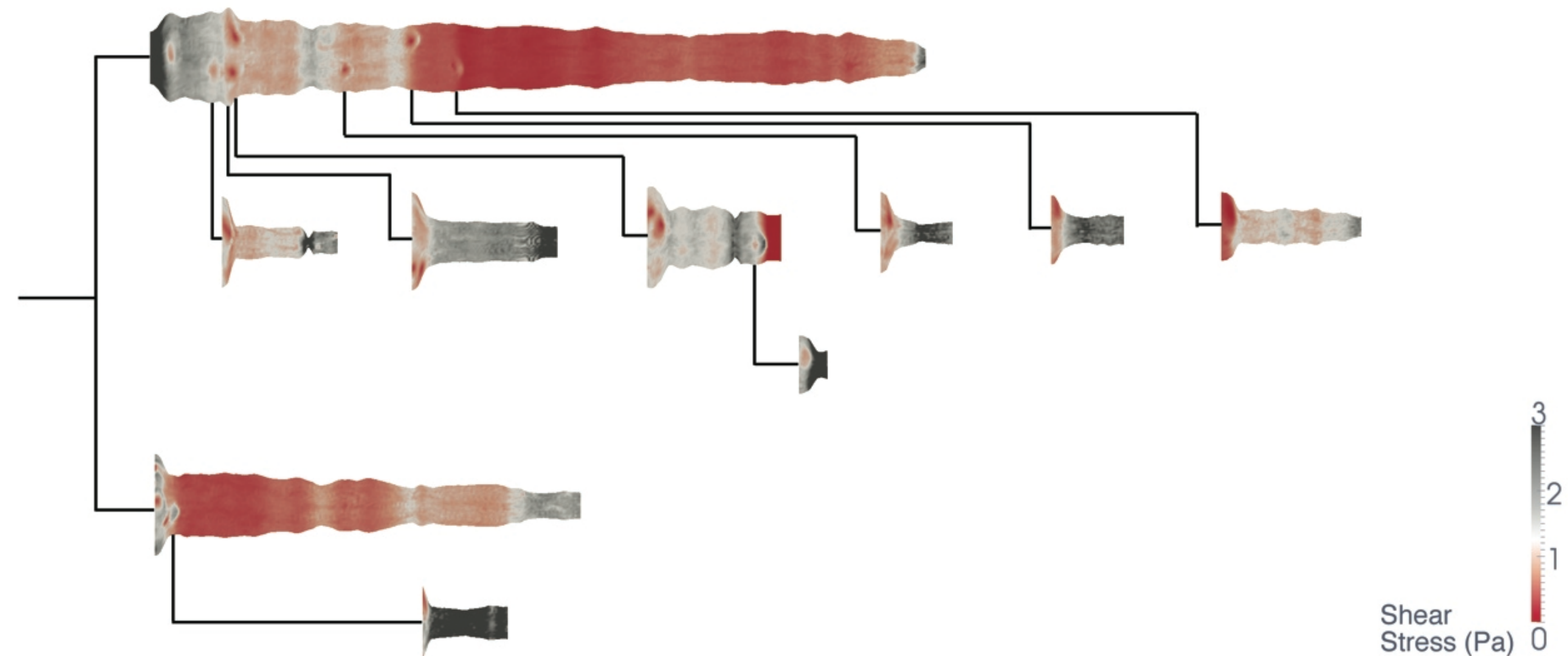
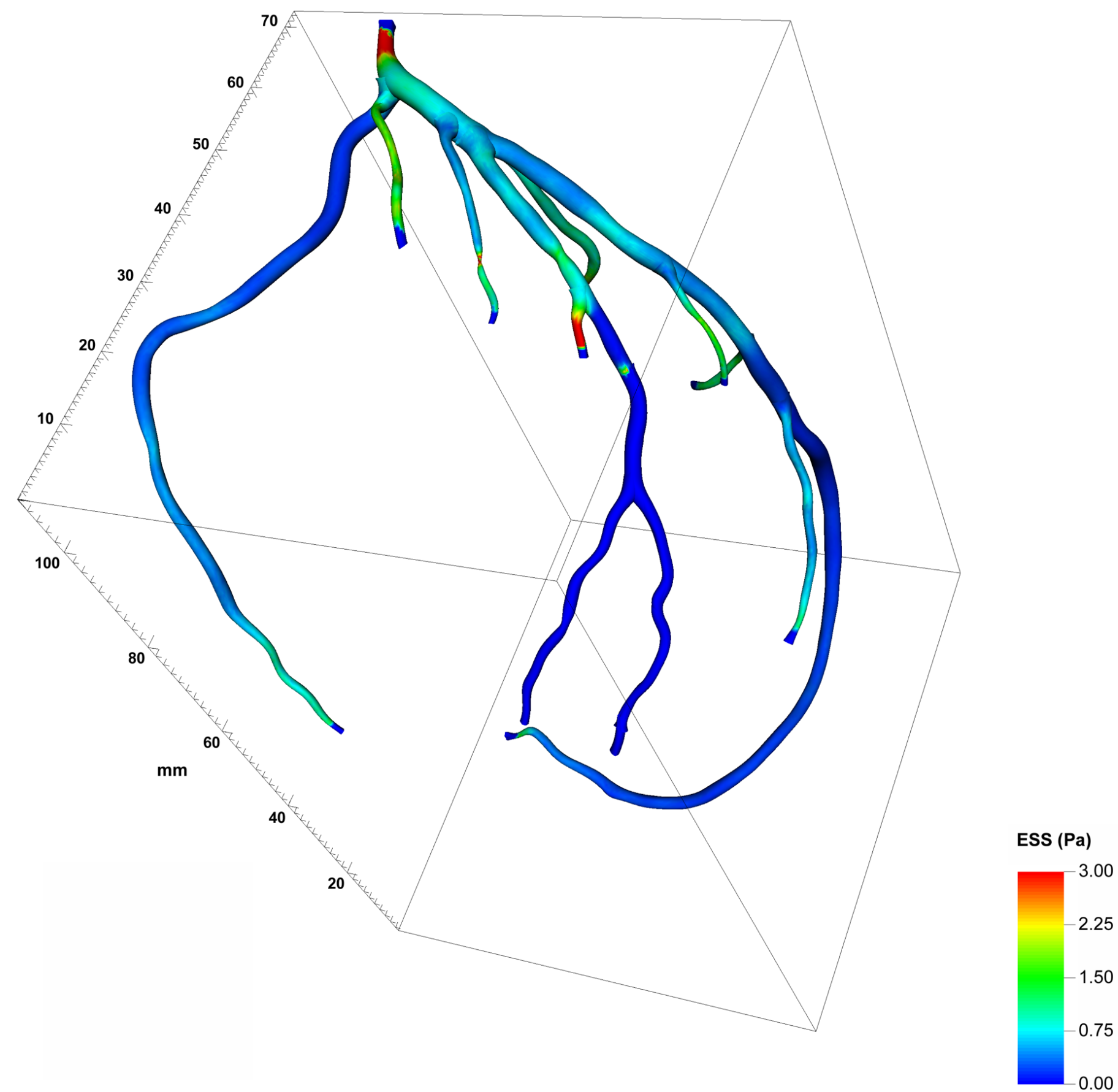












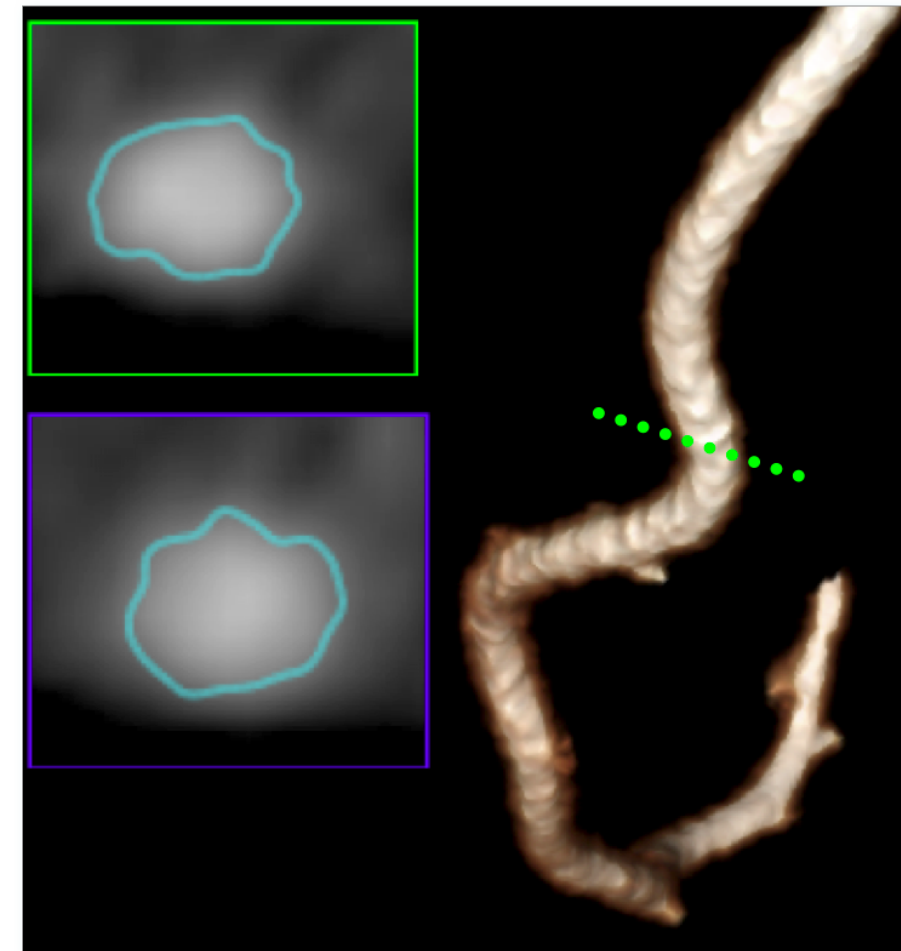
*Michelle Borkin, Krzysztof Gajos, Amanda Peters, Dimitris Mitsouras, Simone Melchionna,  
Frank Rybicki, Charles Feldman, & Hanspeter Pfister,  
“Evaluation of Artery Visualizations for Heart Disease Diagnosis” (IEEE TVCG / InfoVis 2011)*



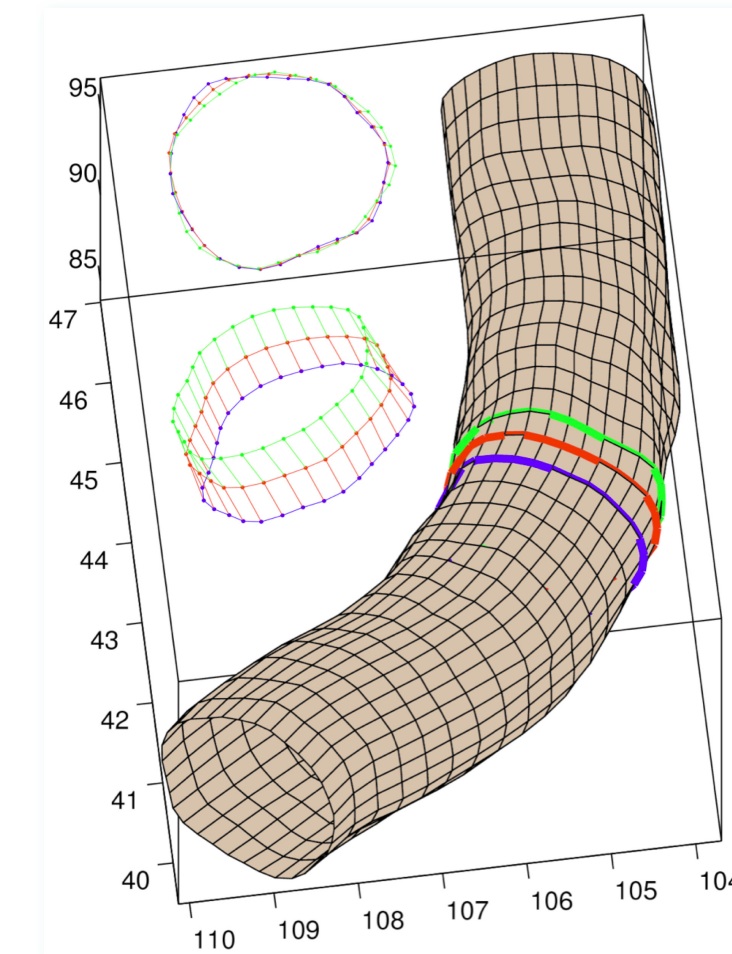
# NON-INVASIVE DIAGNOSIS



Obtain patient CT data



Segment arteries

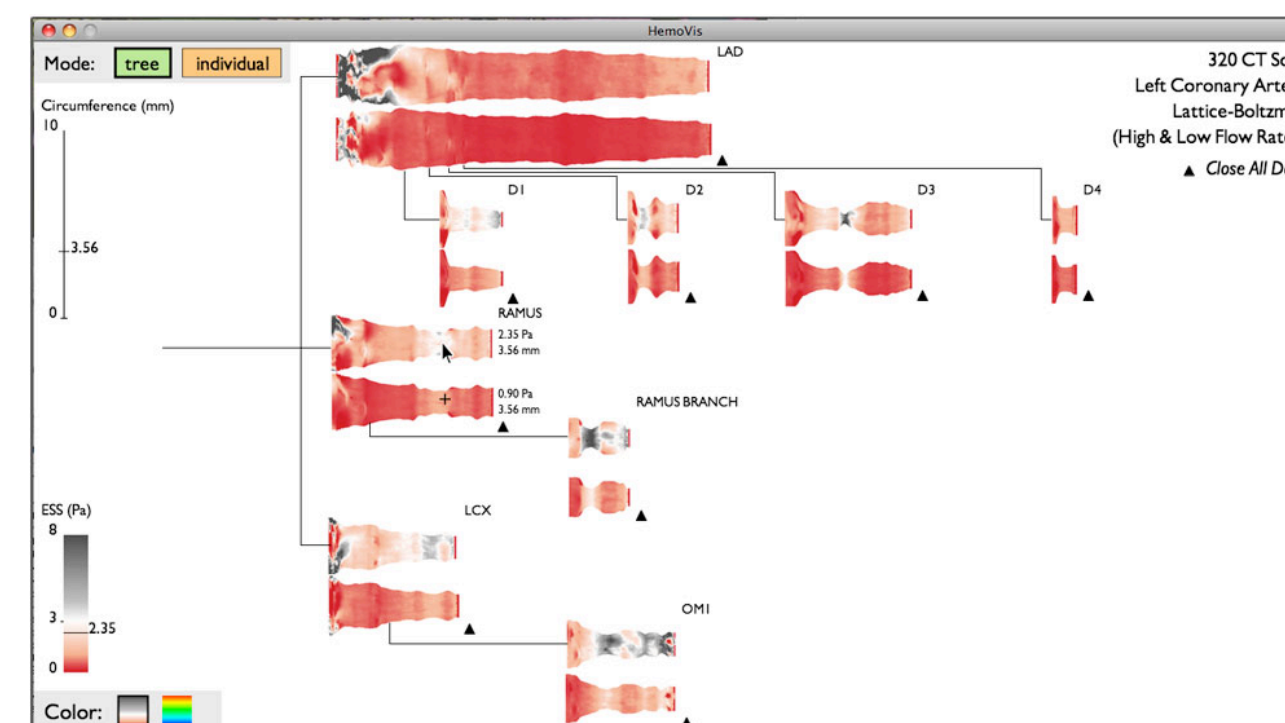


Generate patient geometries

Patient specific  
blood flow simulation



Visualize and  
analyze data

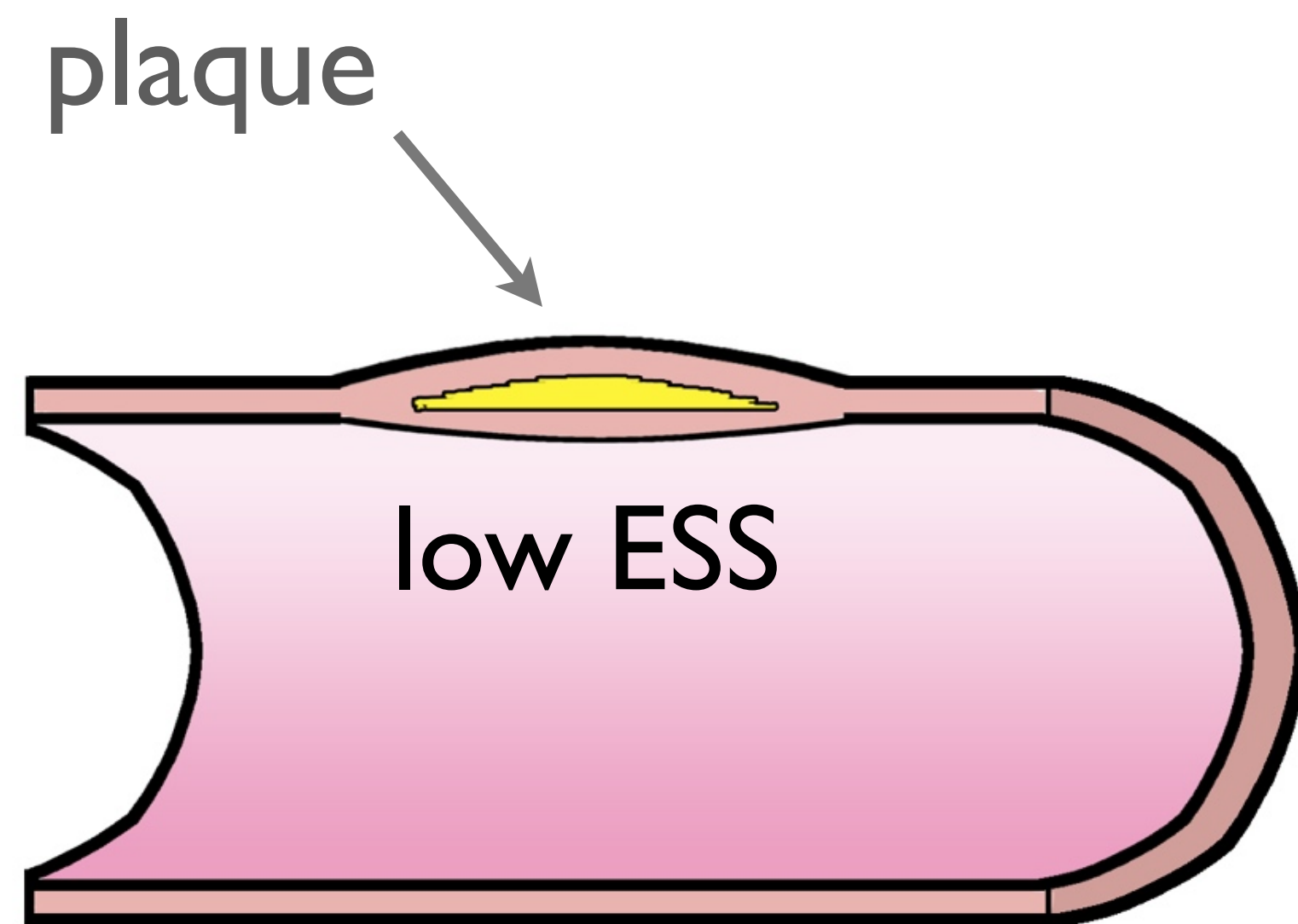


Clinical decision

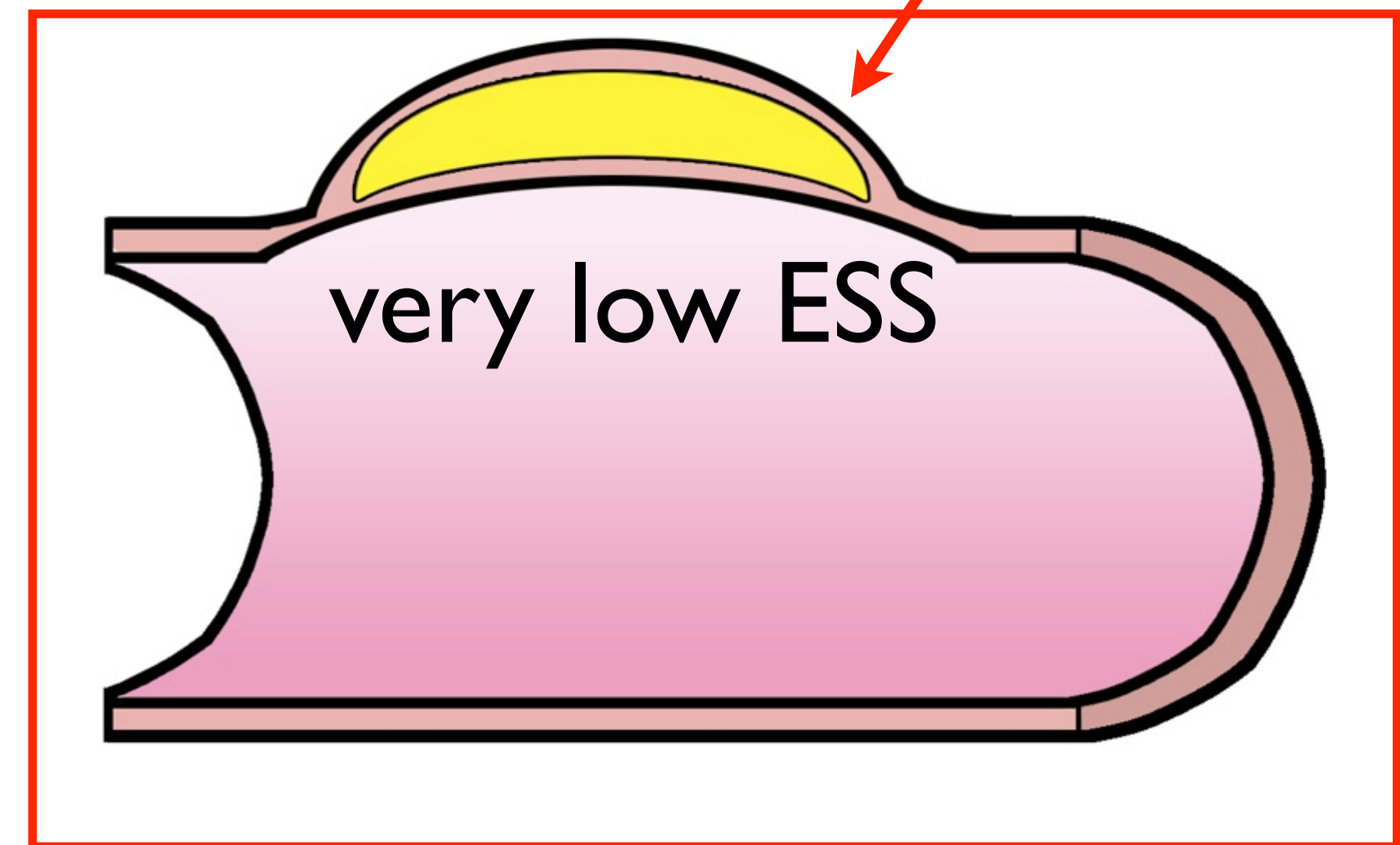




# DATA



*initial disease*

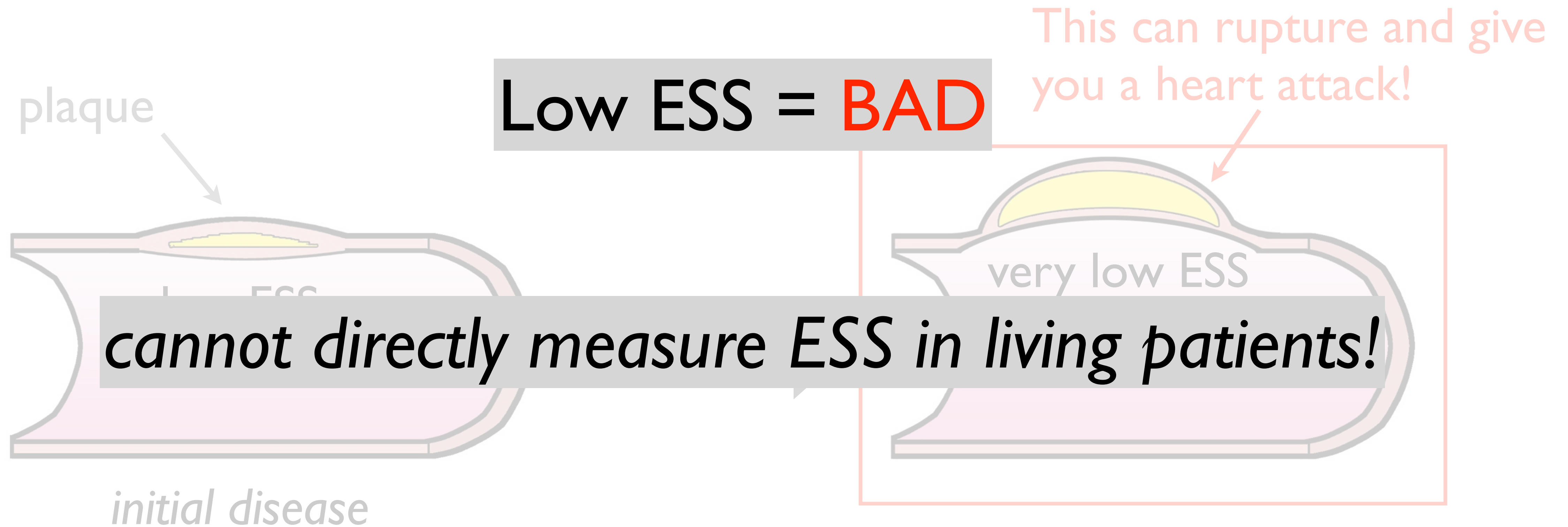


This can rupture and give you a heart attack!

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

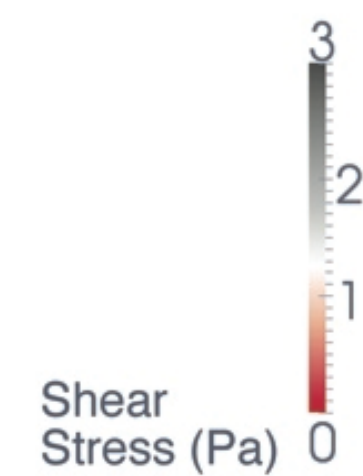
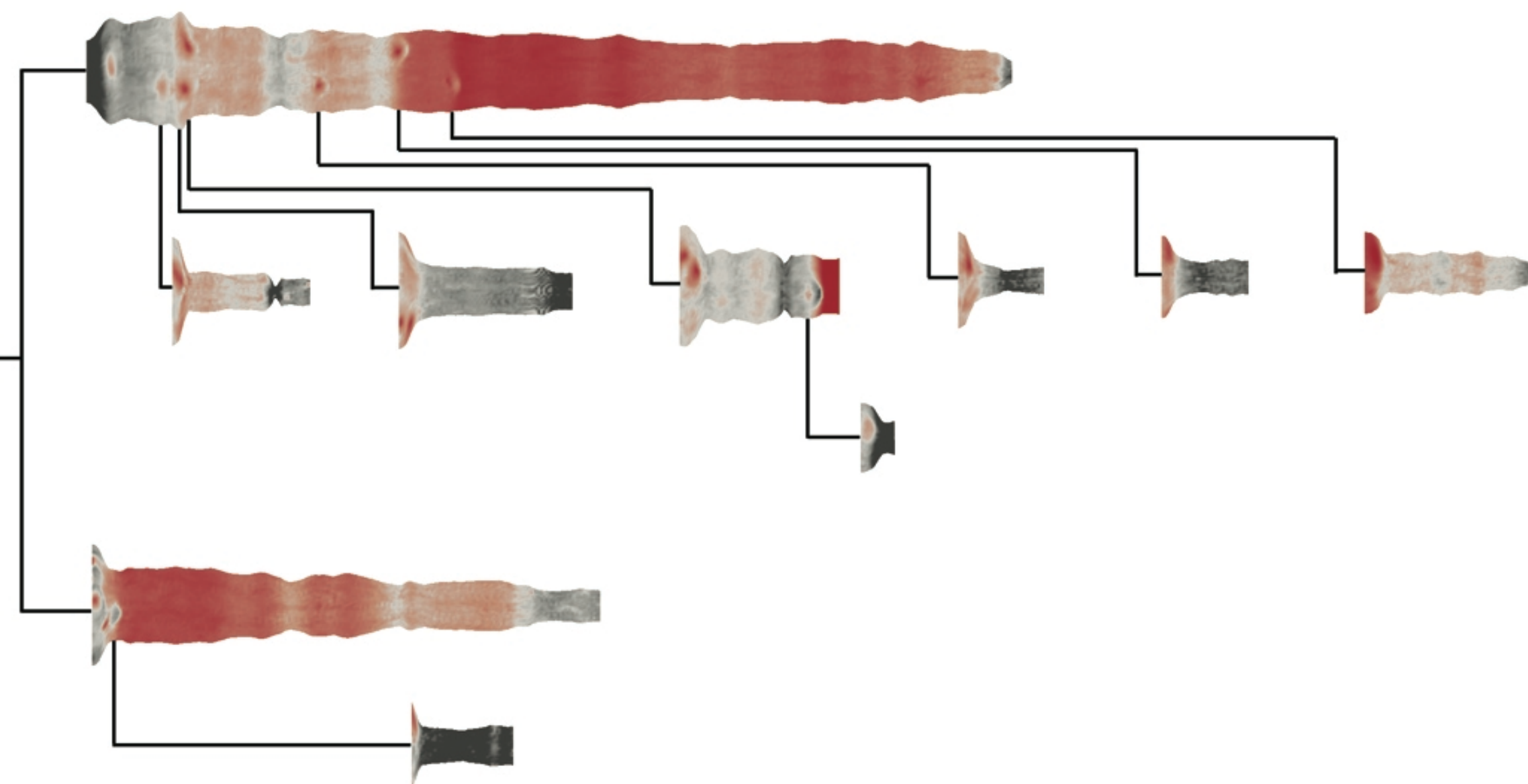
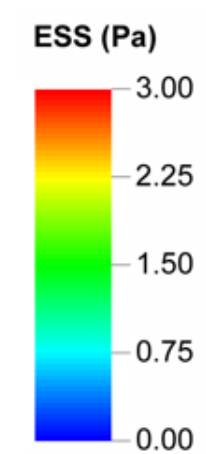
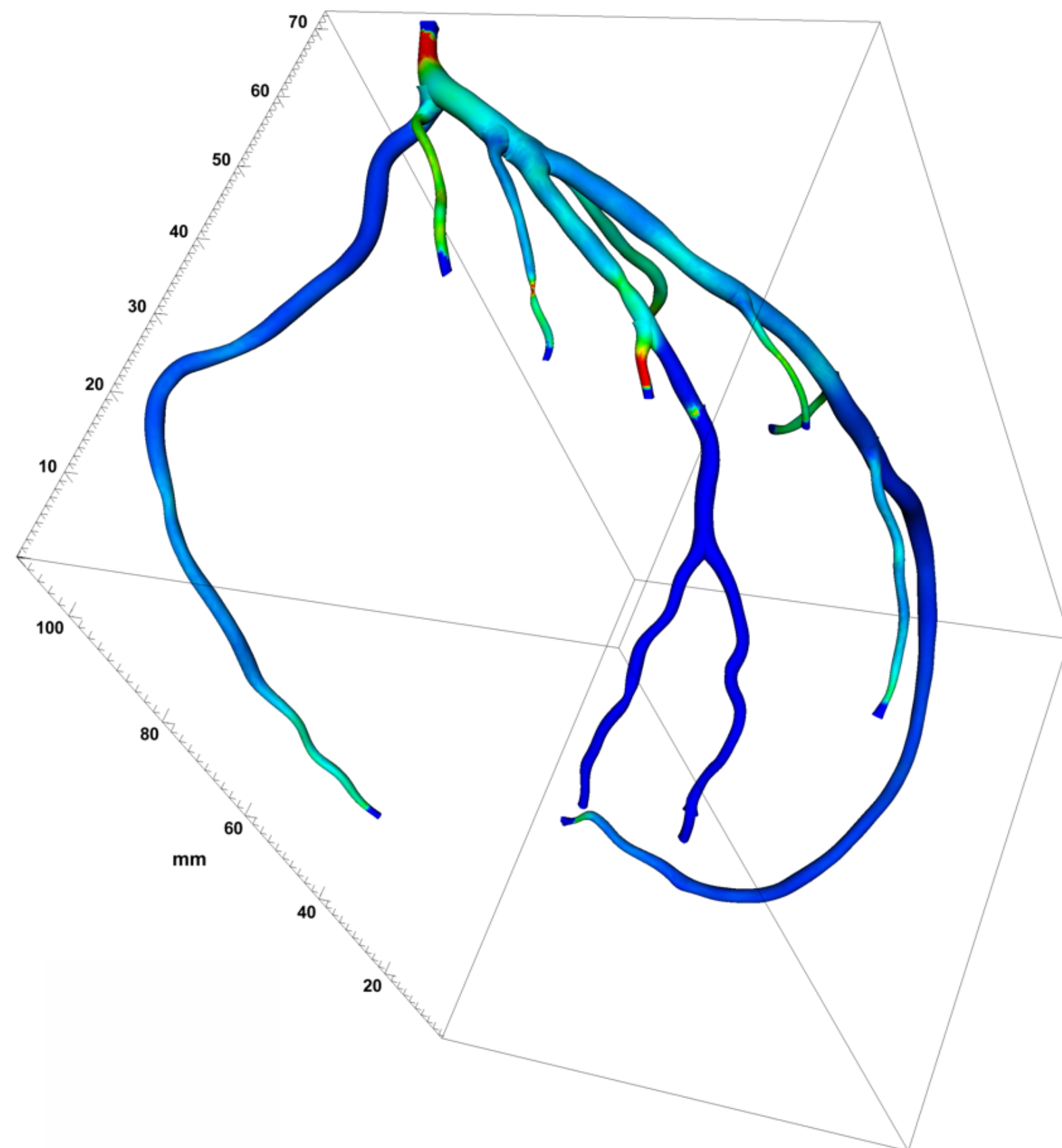


# DATA



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







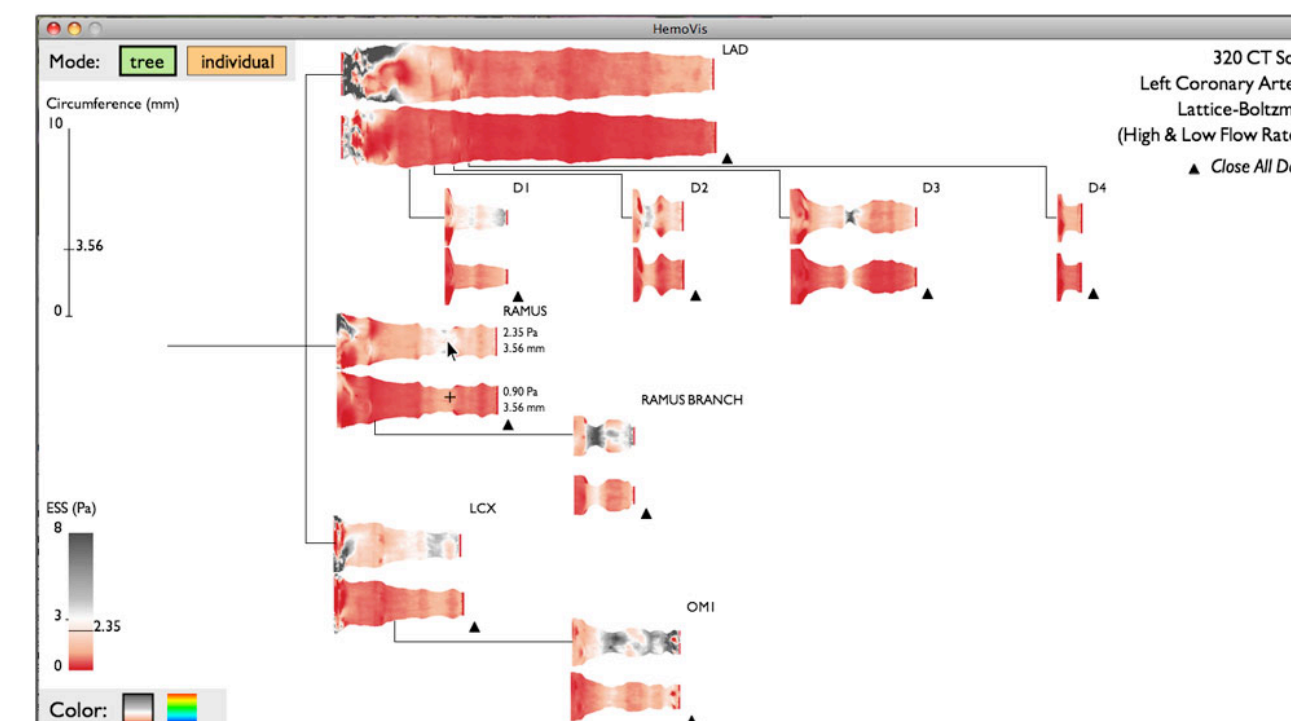
# FORMATIVE QUALITATIVE STUDY

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

Clinical decision



Visualize and analyze data





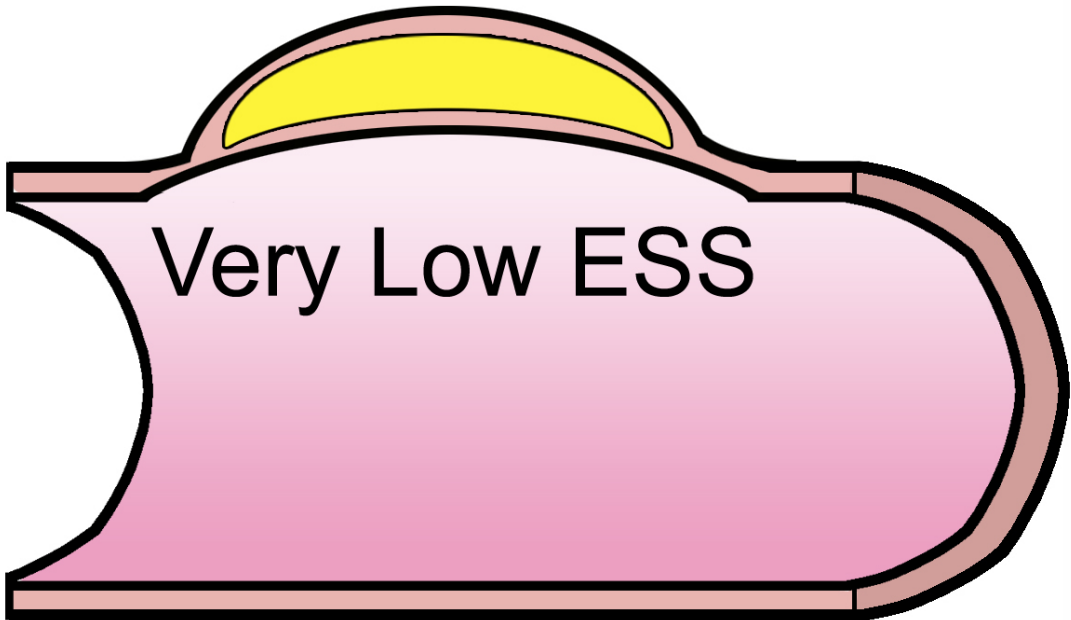
# TASK TAXONOMY

TASK	ABSTRACTION
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# TASK TAXONOMY

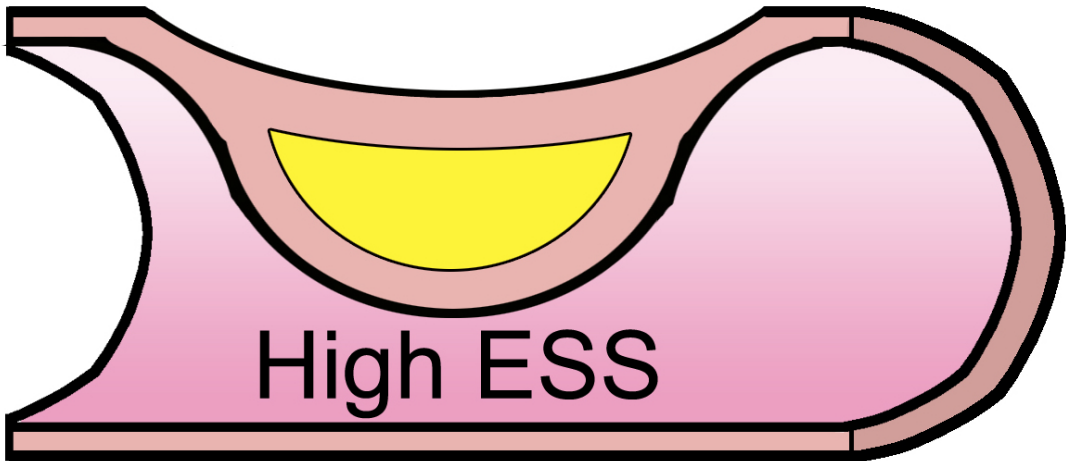
TASK	ABSTRACTION
“Identify regions of low ESS”	find extrema





# TASK TAXONOMY

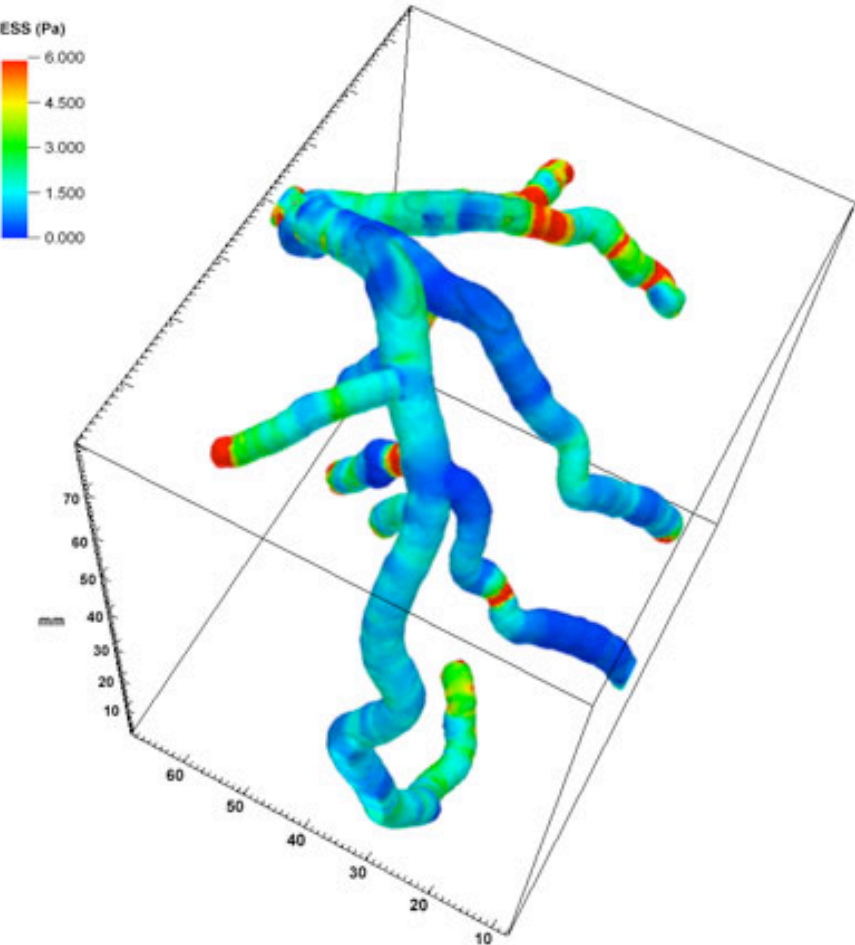
TASK	ABSTRACTION
“Identify regions of low ESS”	find extrema
“Identify stenosis or blockage”	find extrema





# TASK TAXONOMY

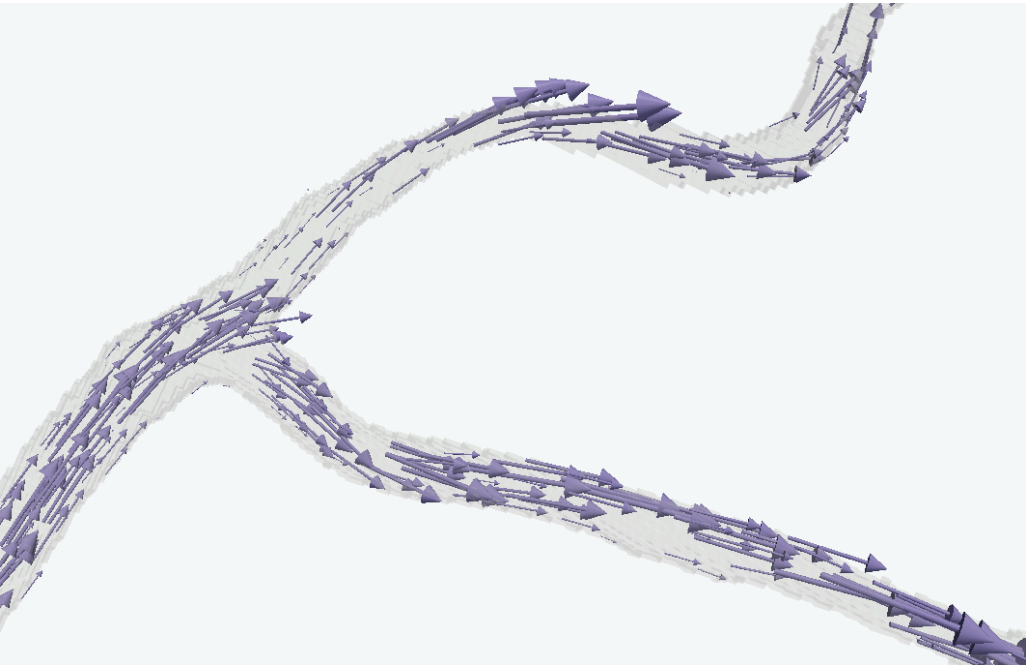
TASK	ABSTRACTION
“Identify regions of low ESS”	find extrema
“Identify stenosis or blockage”	find extrema
“View all ESS data for patterns”	cluster





# TASK TAXONOMY

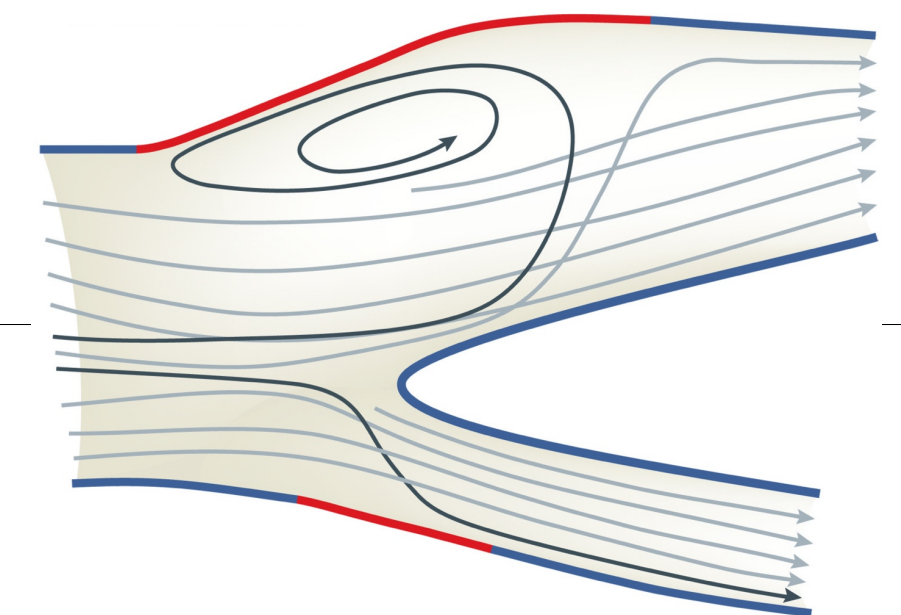
TASK	ABSTRACTION
“Identify regions of low ESS”	find extrema
“Identify stenosis or blockage”	find extrema
“View all ESS data for patterns”	cluster
“Study blood flow velocity patterns”	find anomalies





# TASK TAXONOMY

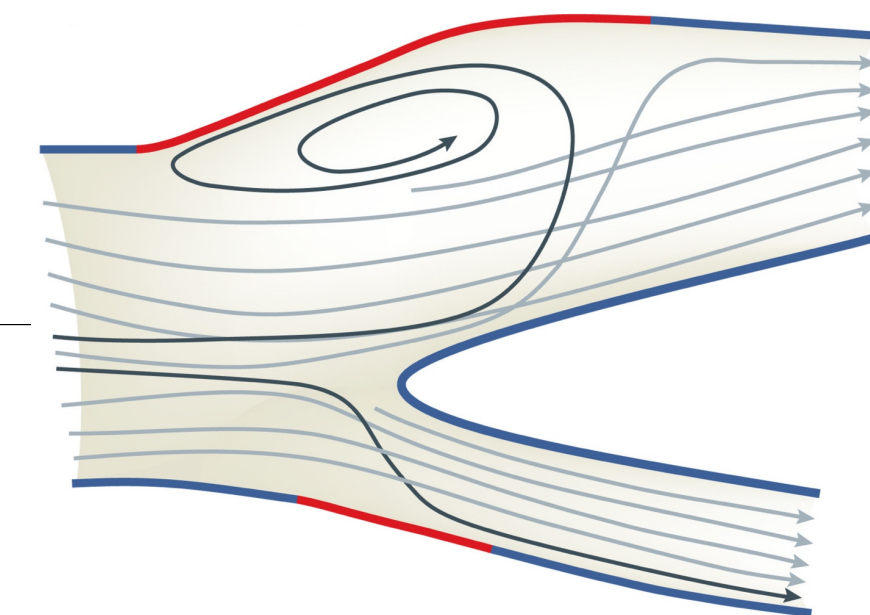
TASK	ABSTRACTION
“Identify regions of low ESS”	find extrema
“Identify stenosis or blockage”	find extrema
“View all ESS data for patterns”	cluster
“Study blood flow velocity patterns”	find anomalies
“Identify regions of blood recirculation”	find anomalies





# TASK TAXONOMY

TASK	ABSTRACTION
“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

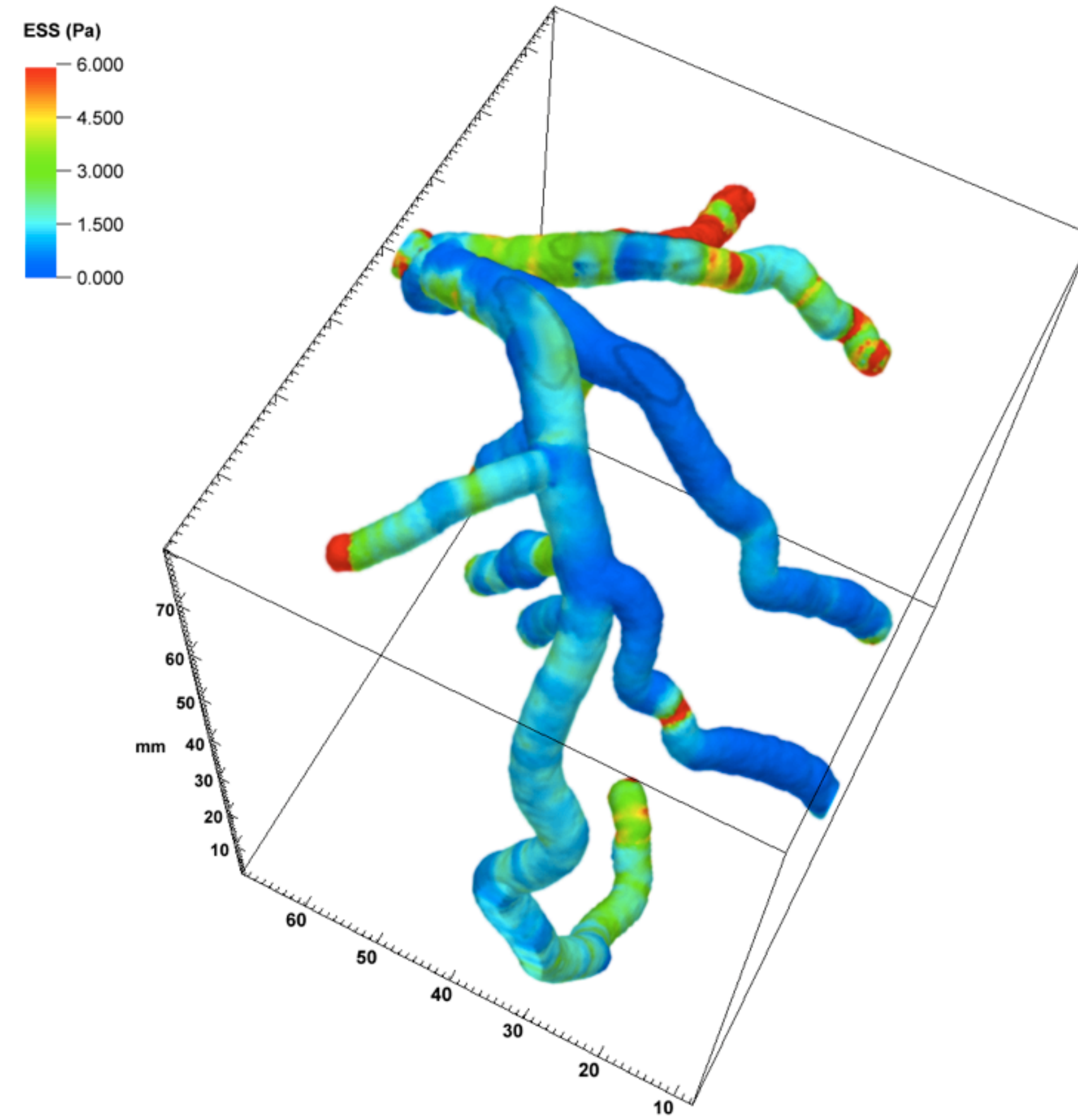
<b>TASK</b>	<b>ABSTRACTION</b>	<b><i>CLINICAL</i></b>	<b><i>RESEARCH</i></b>
“Identify regions of low ESS”	find extrema	X	X
“Identify stenosis or blockage”	find extrema	X	X
“View all ESS data for patterns”	cluster	X	X
“Study blood flow velocity patterns”	find anomalies		X
“Identify regions of blood recirculation”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



# TASK TAXONOMY

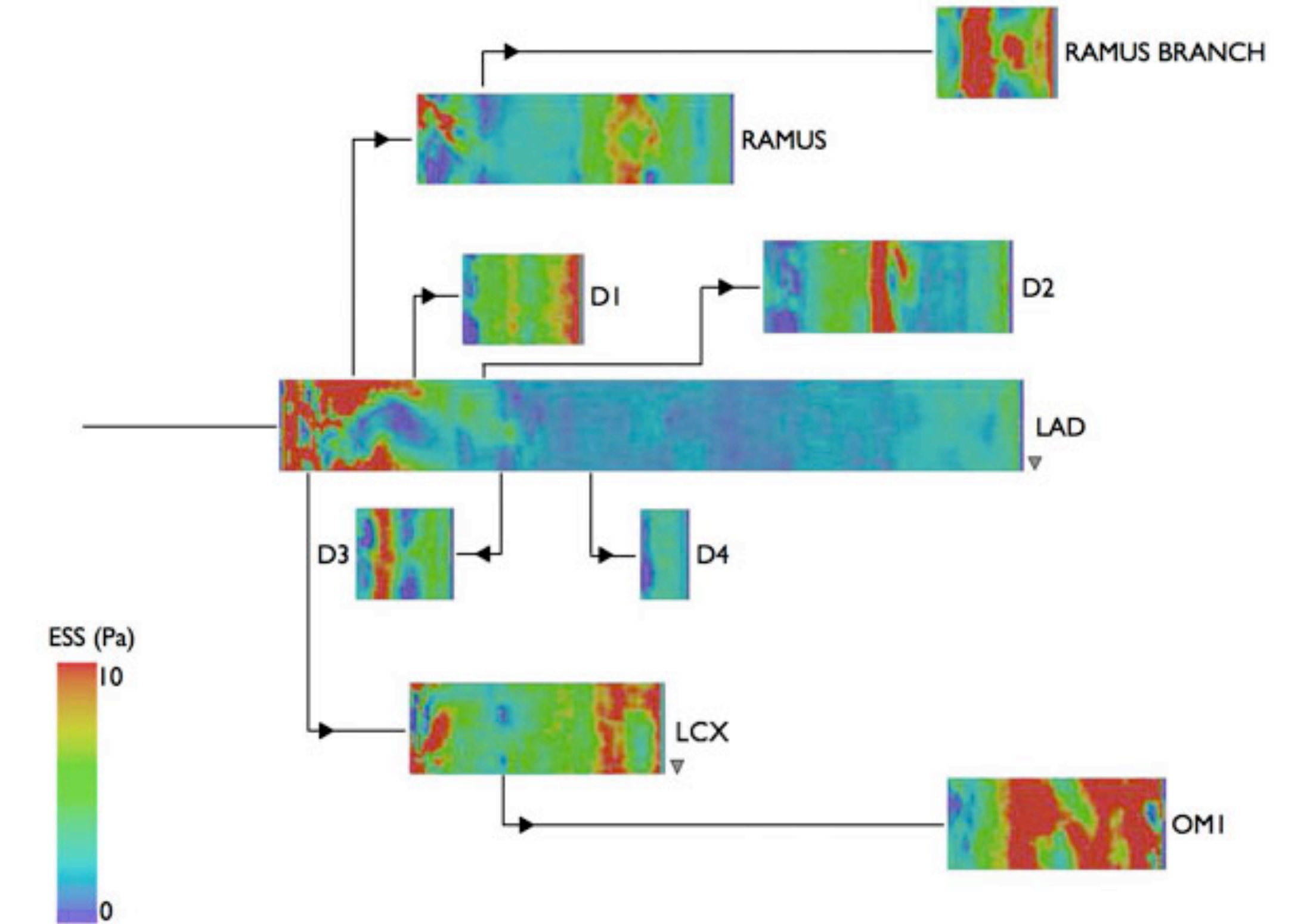
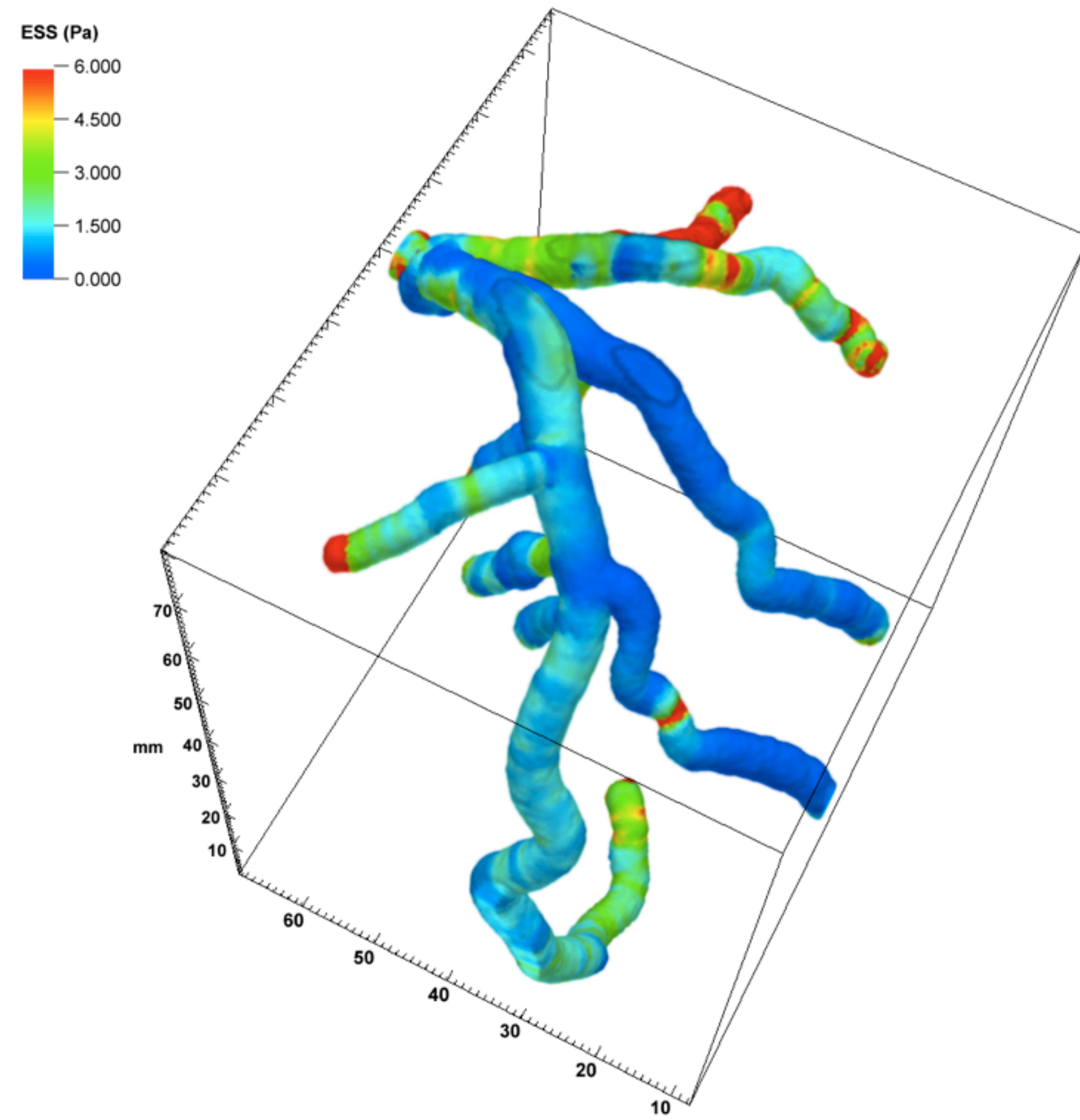
<b>TASK</b>	<b>ABSTRACTION</b>	<b><i>CLINICAL</i></b>	<b><i>RESEARCH</i></b>
“Identify regions of low ESS”	find extrema	X	X
“Identify stenosis or blockage”	find extrema	X	X
“View all ESS data for patterns”	cluster	X	X
“Study blood flow velocity patterns”	find anomalies		X
“Identify regions of blood recirculation”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

# 3D vs. 2D

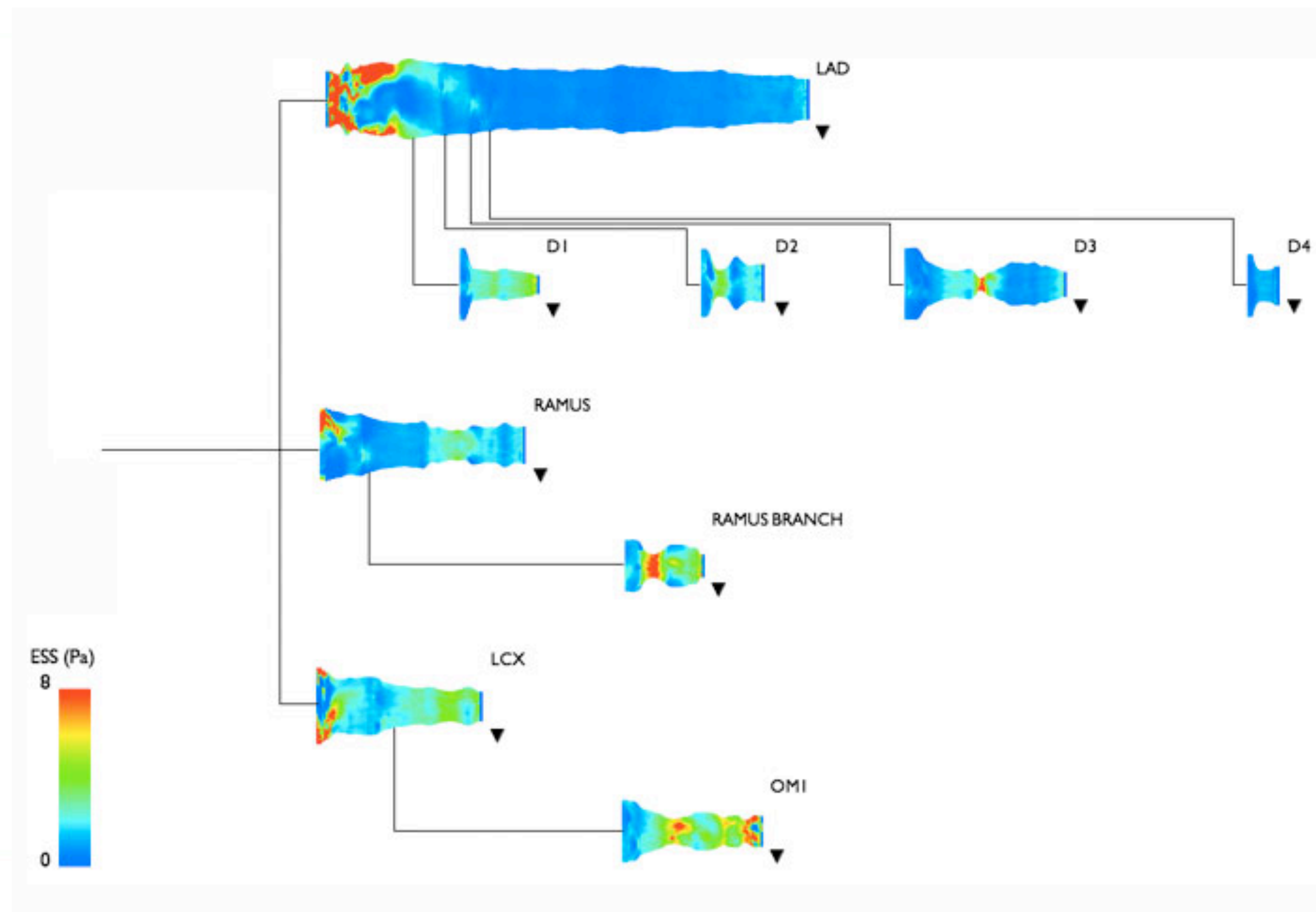
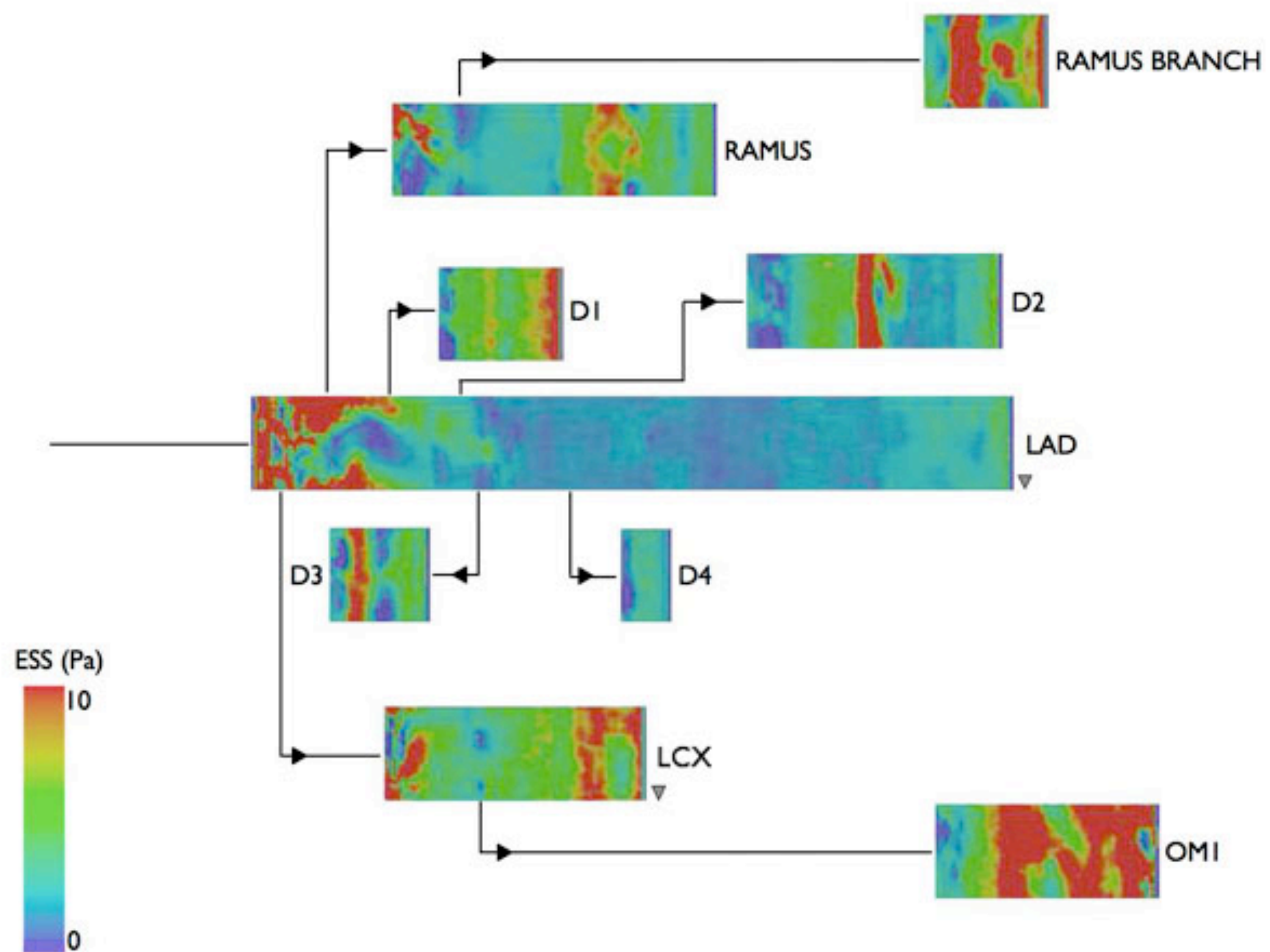




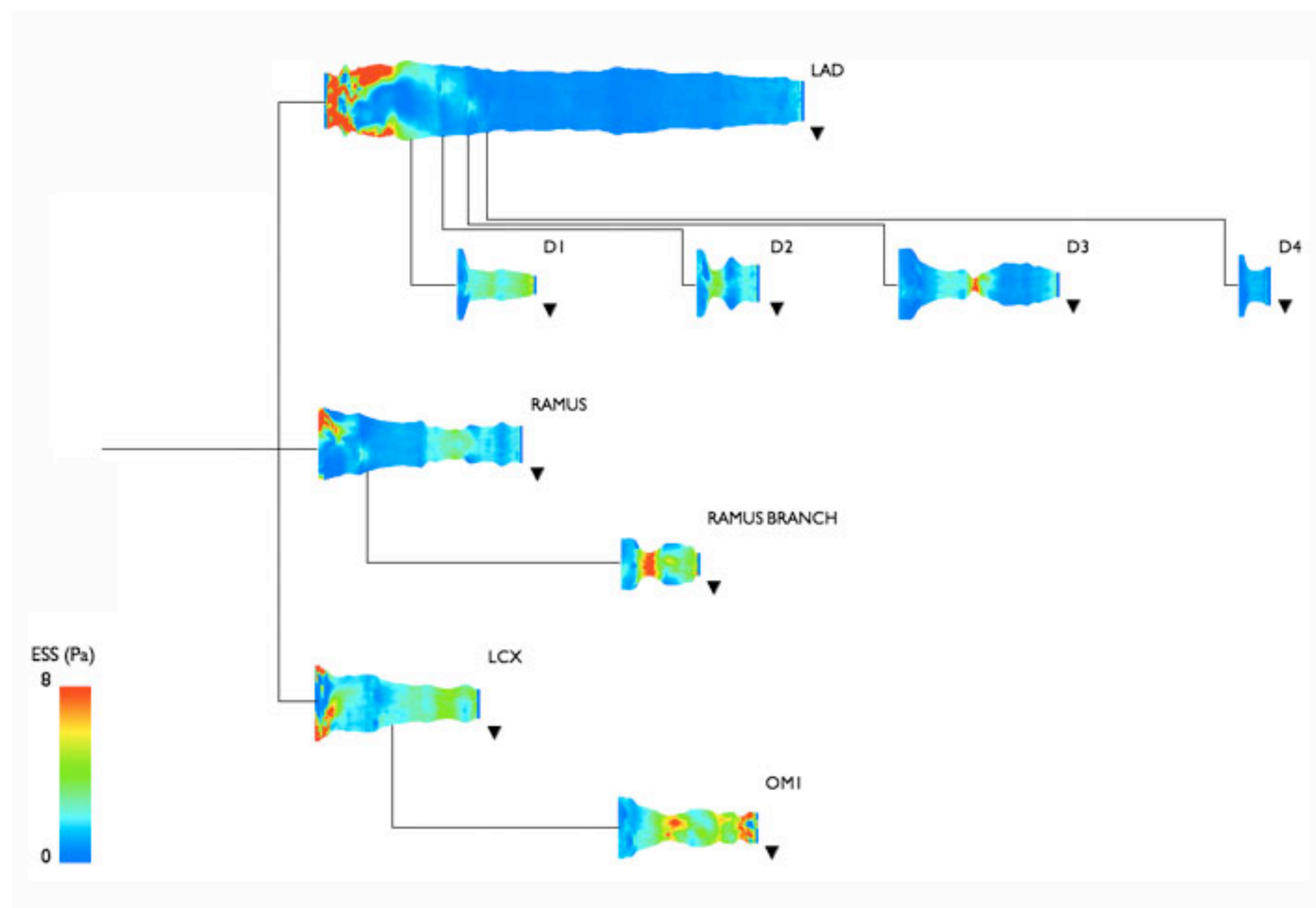
# 3D vs. 2D

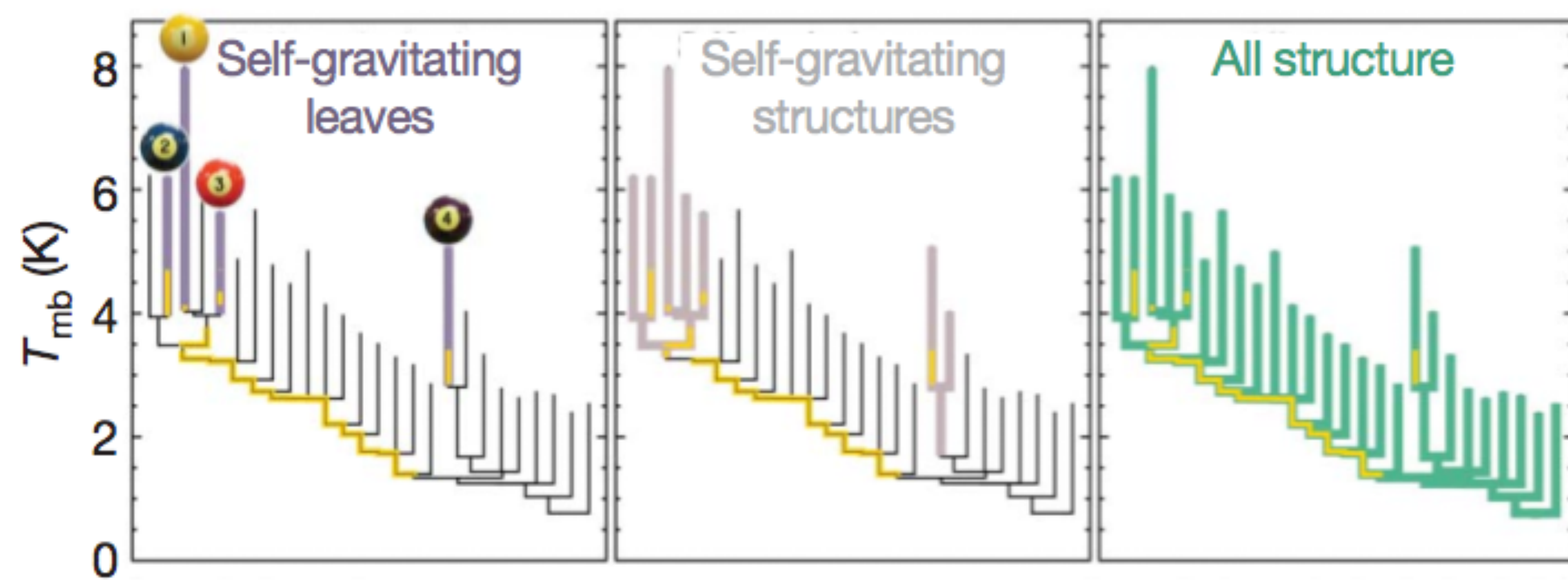
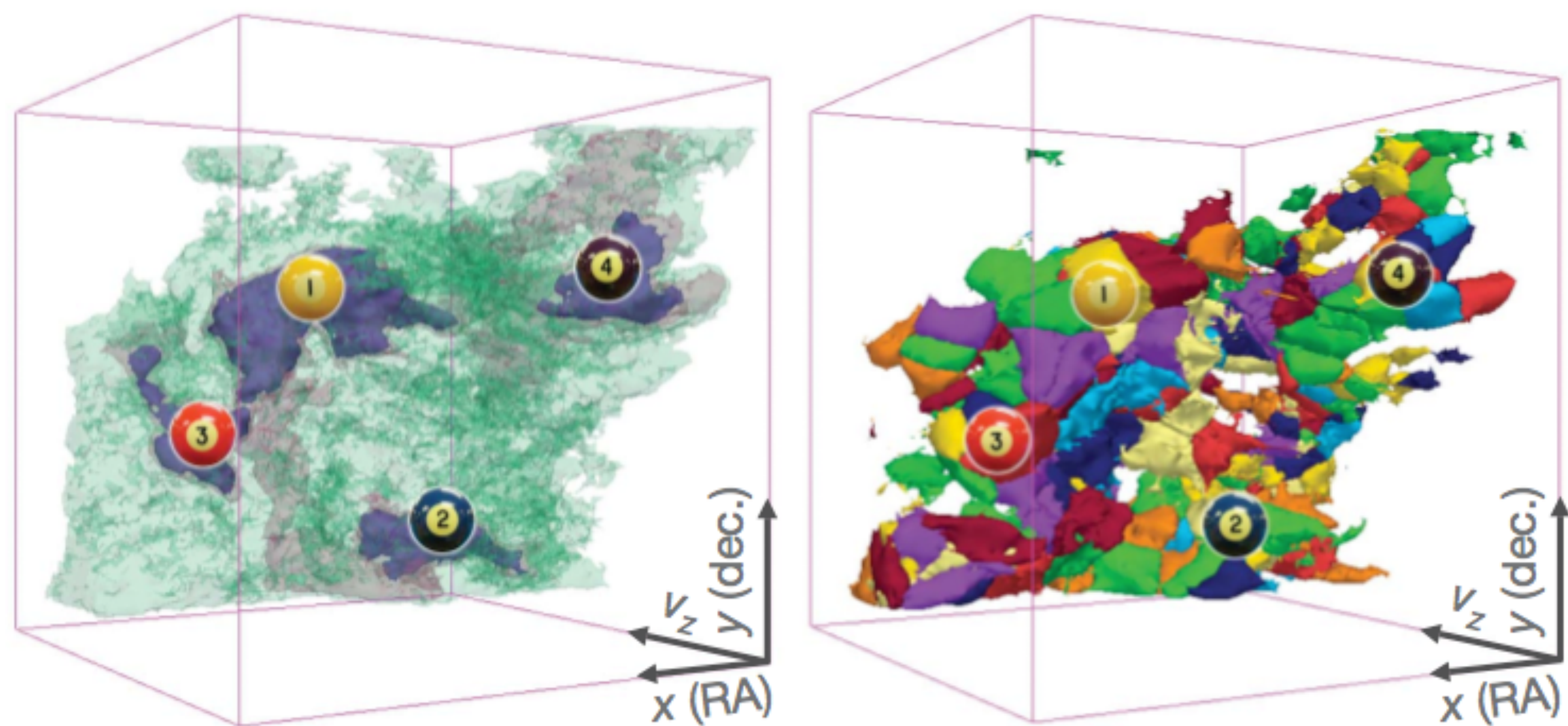


# LAYOUT AND PROJECTIONS

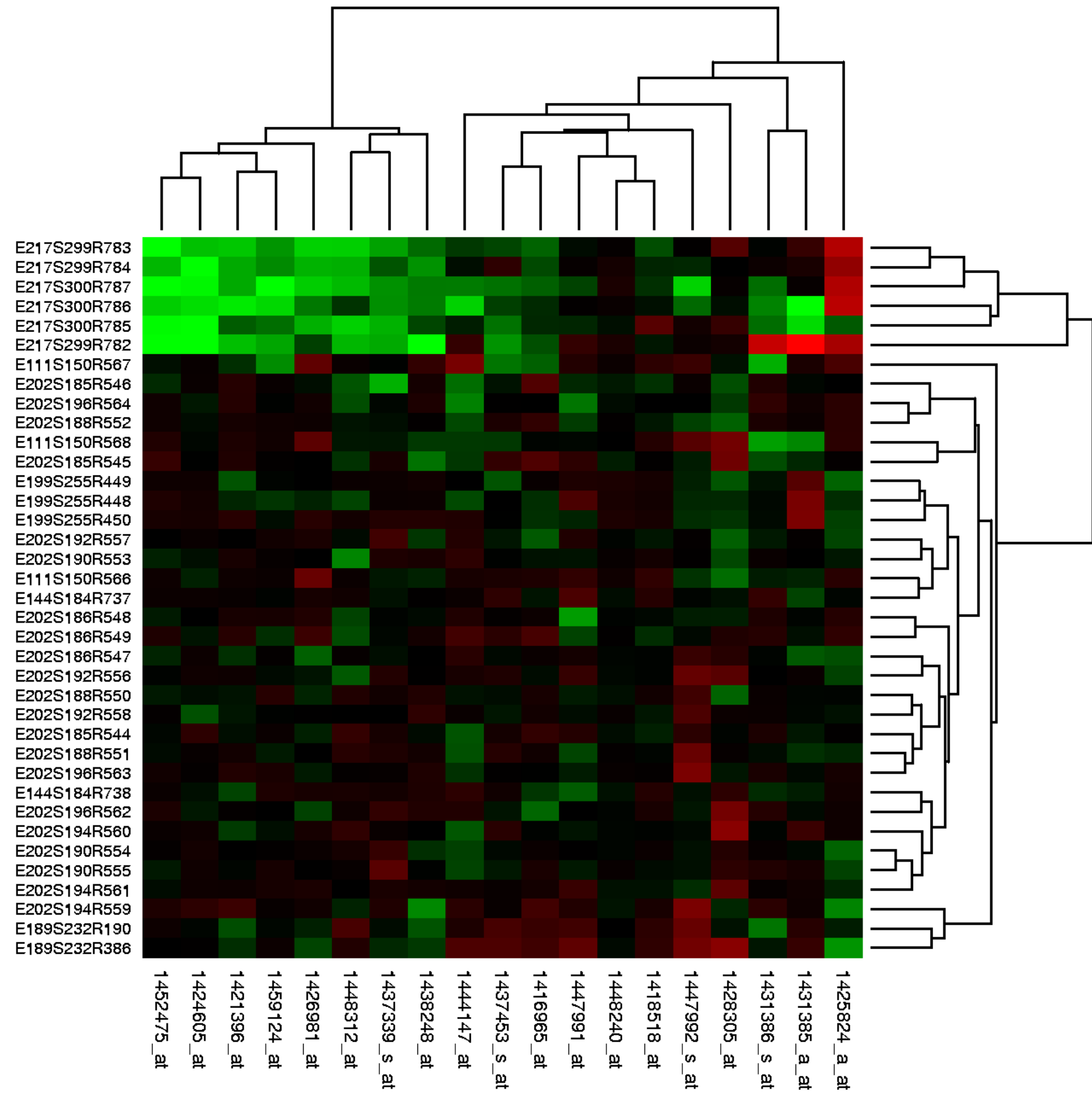


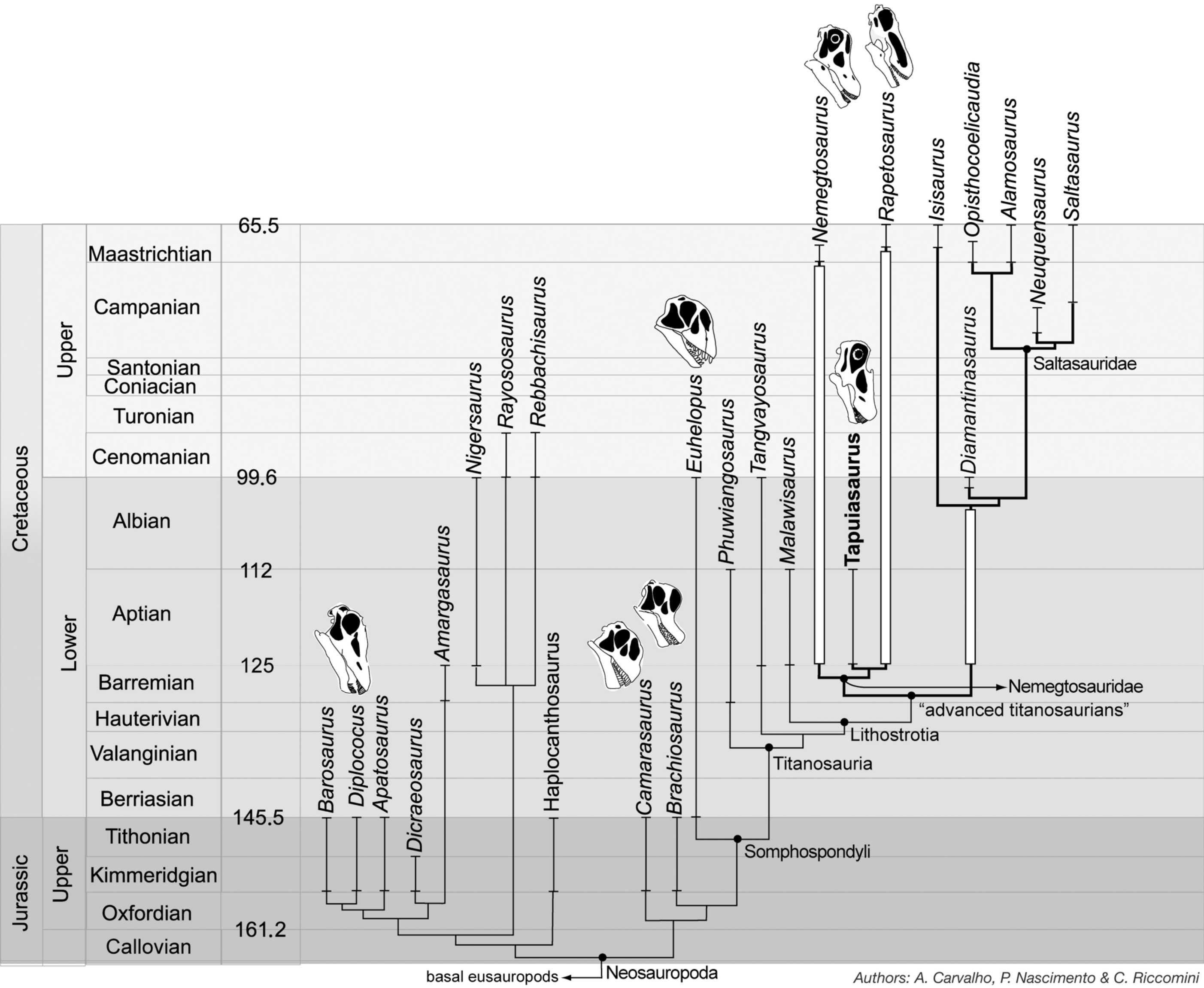






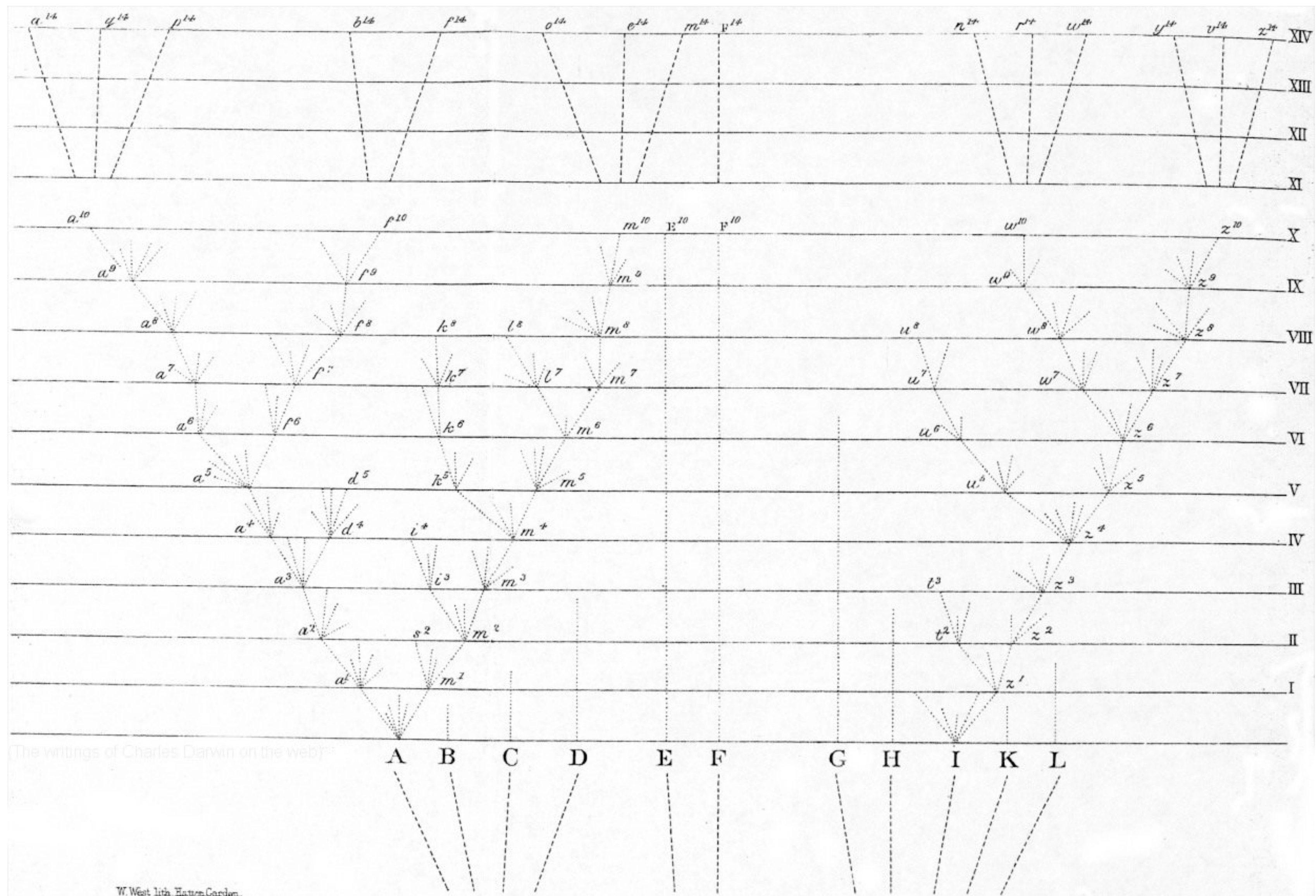




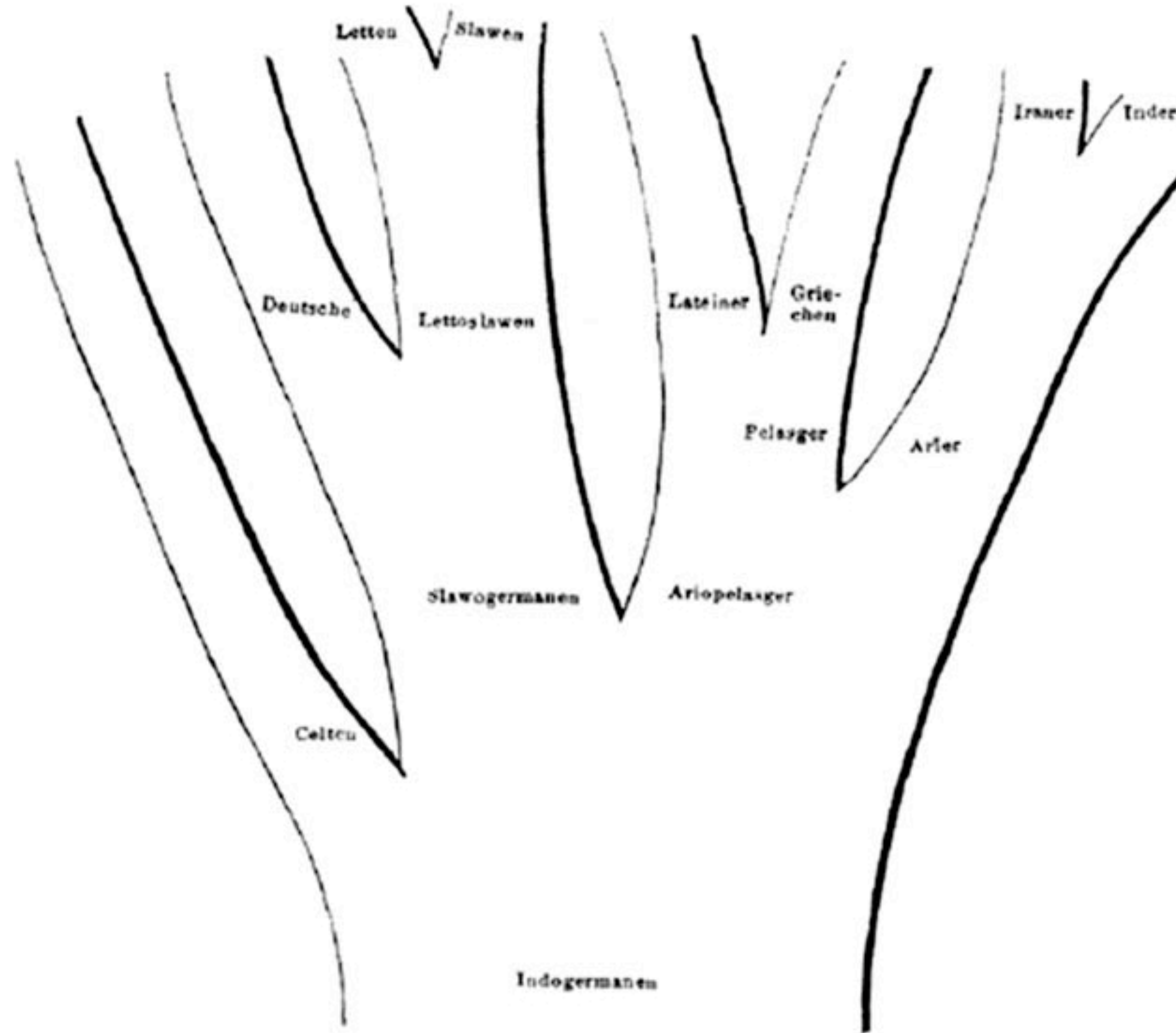


Authors: A. Carvalho, P. Nascimento & C. Riccomini



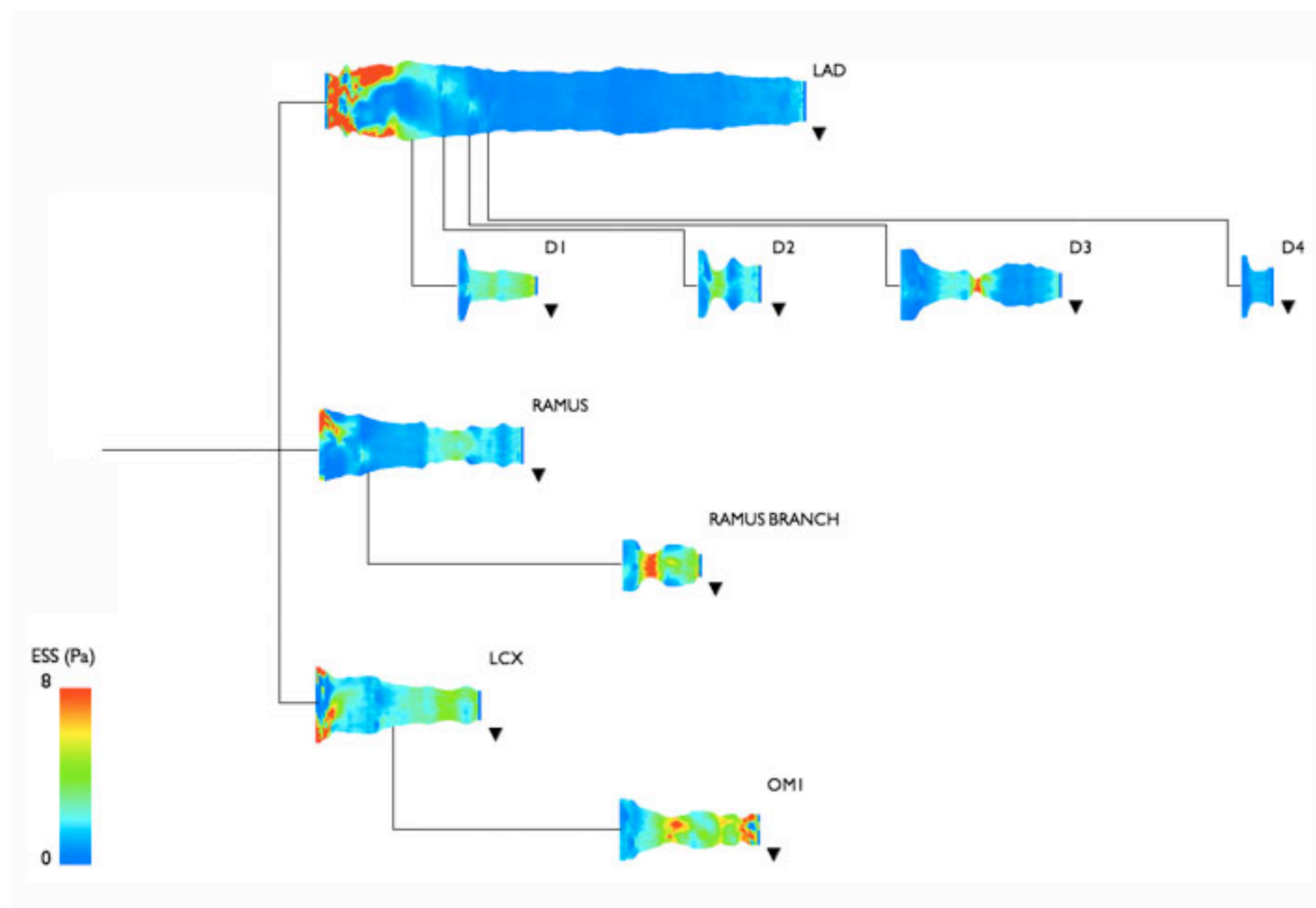


The writings of Charles Darwin on the web

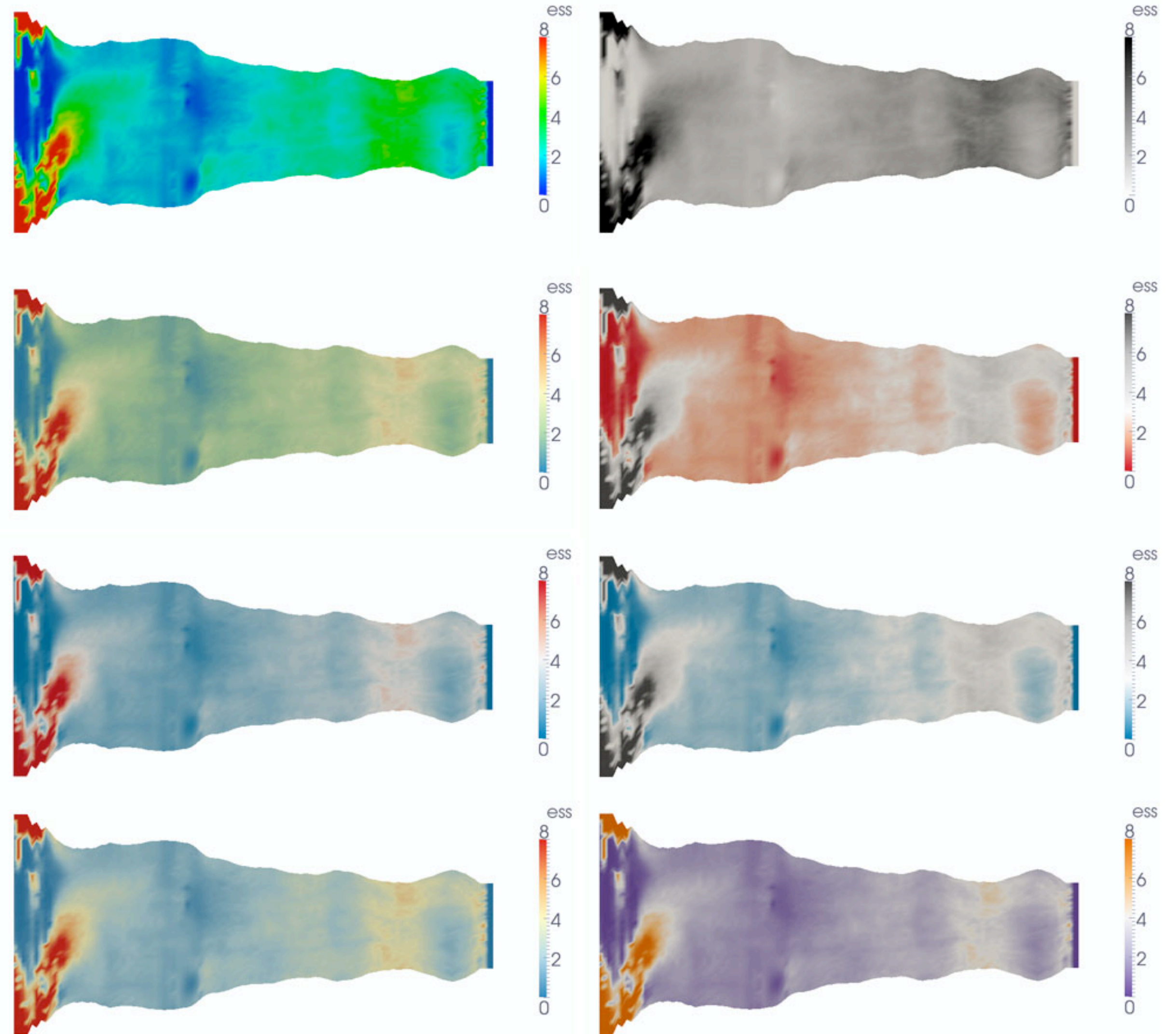
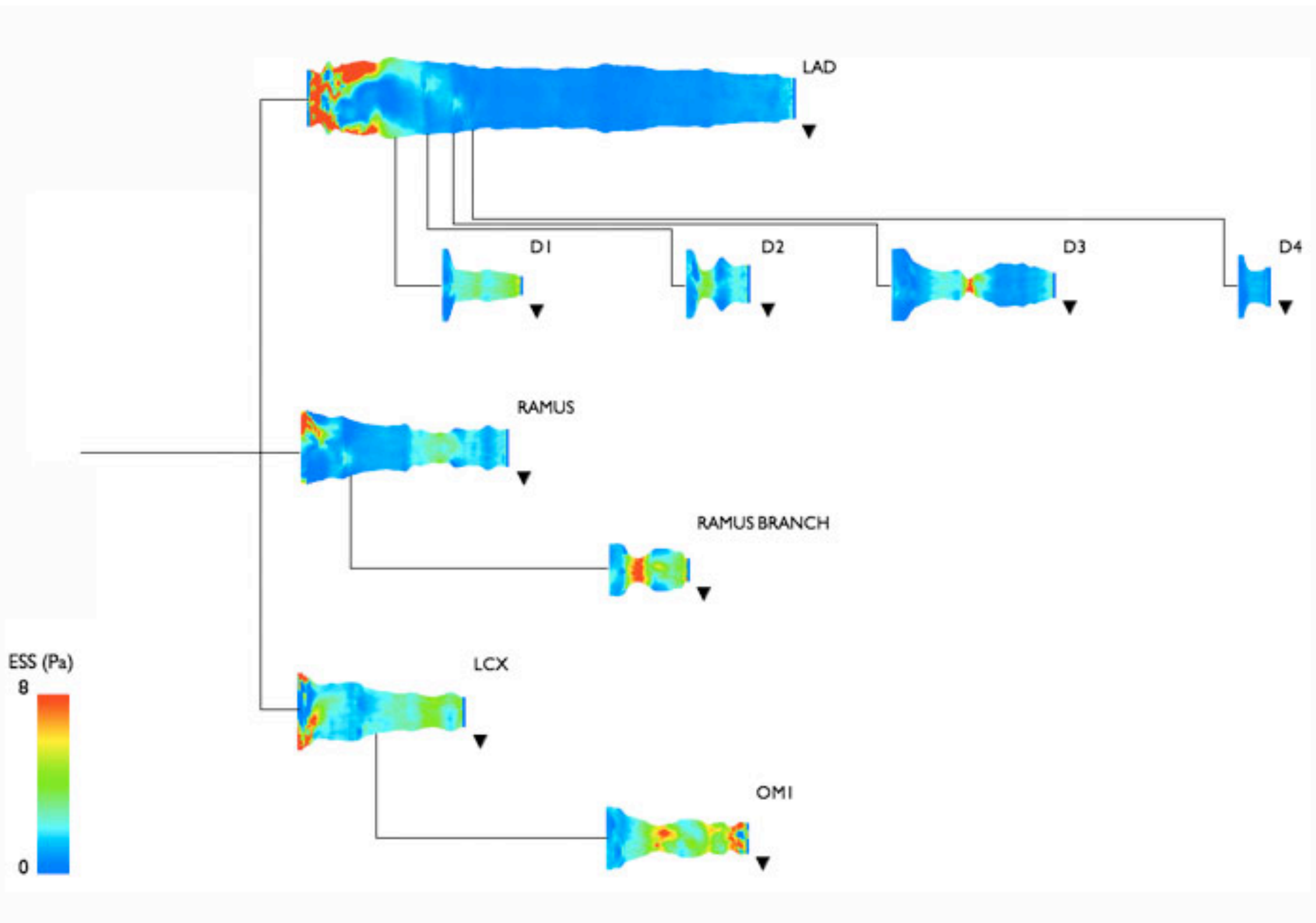


Sonneberg, den 15. Aug. 1853.



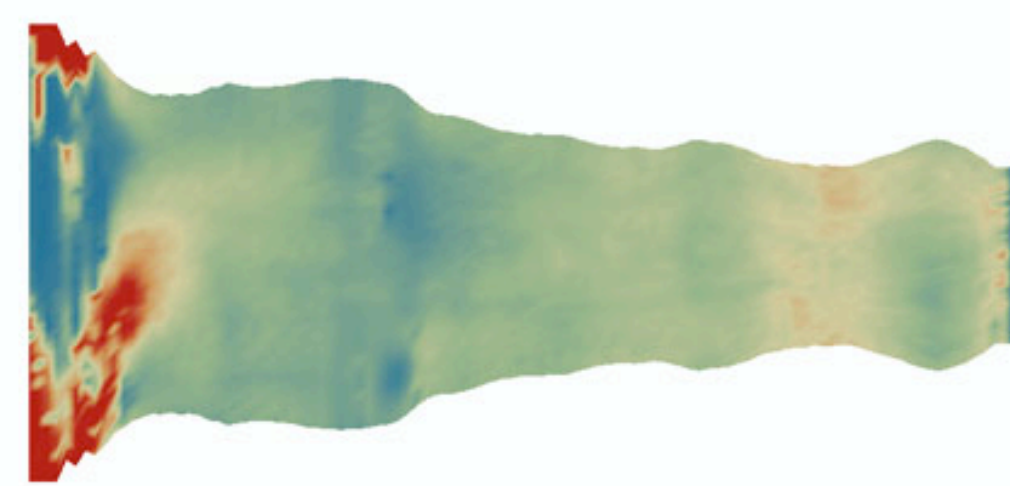
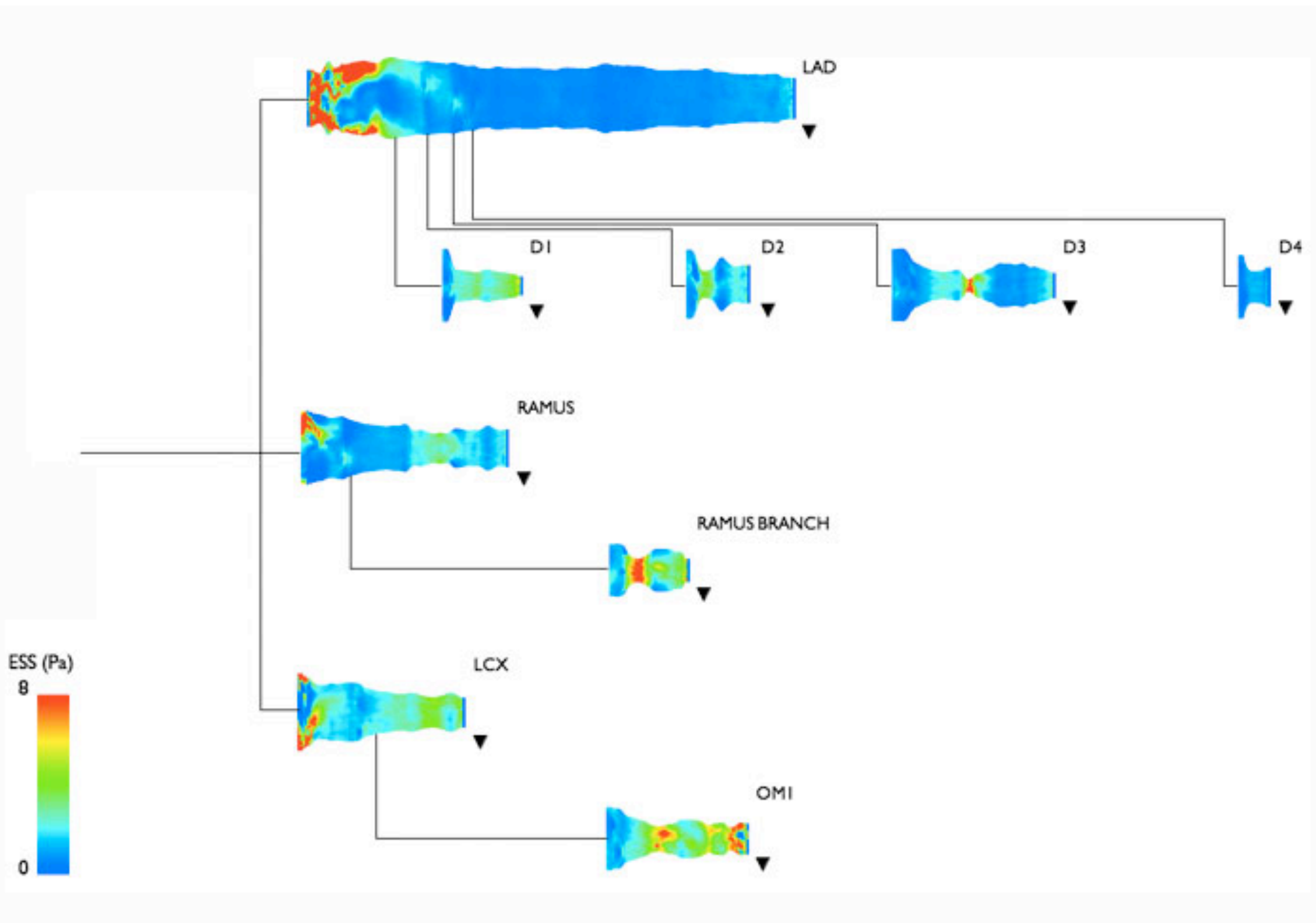


# COLOR

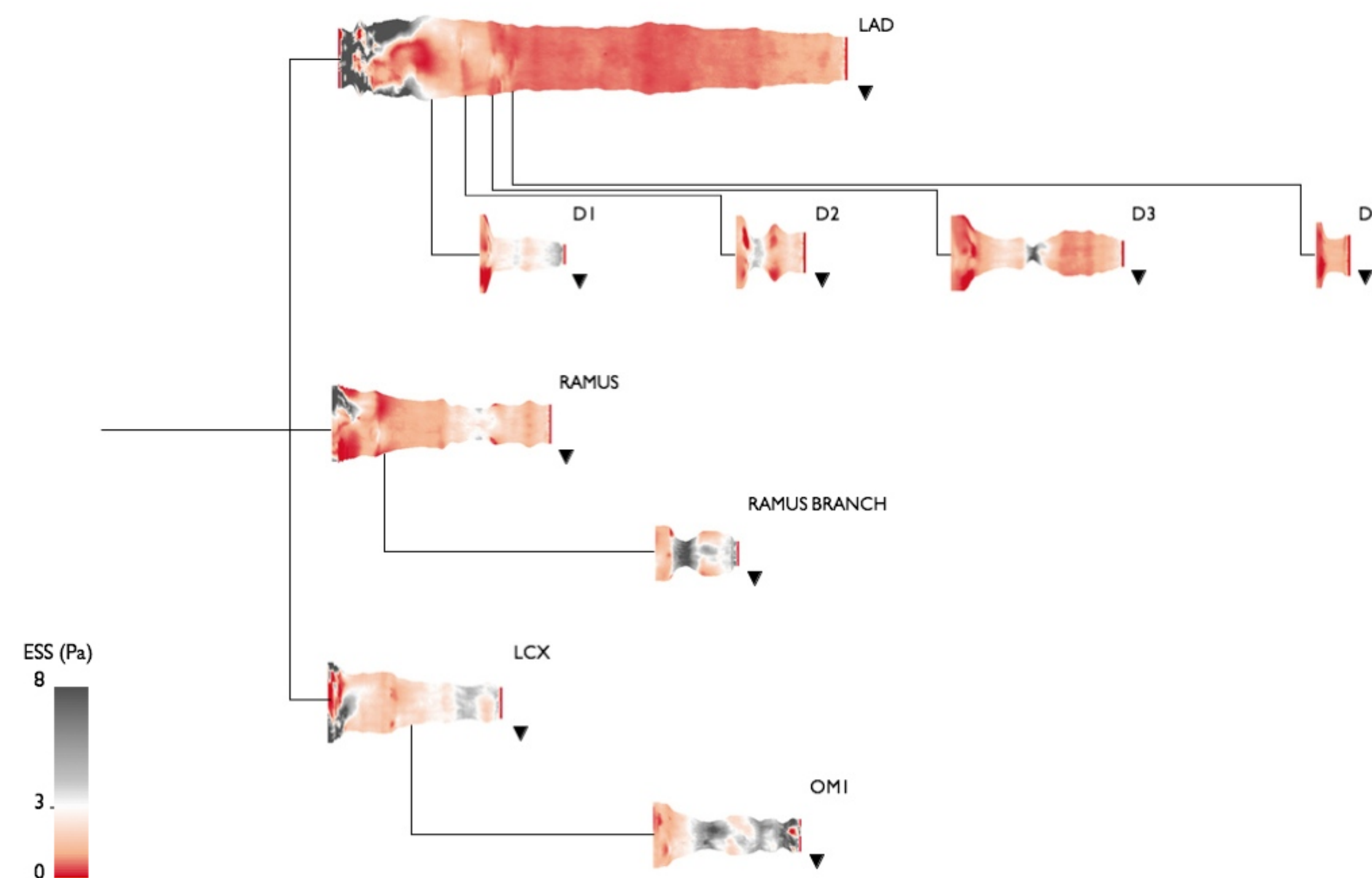
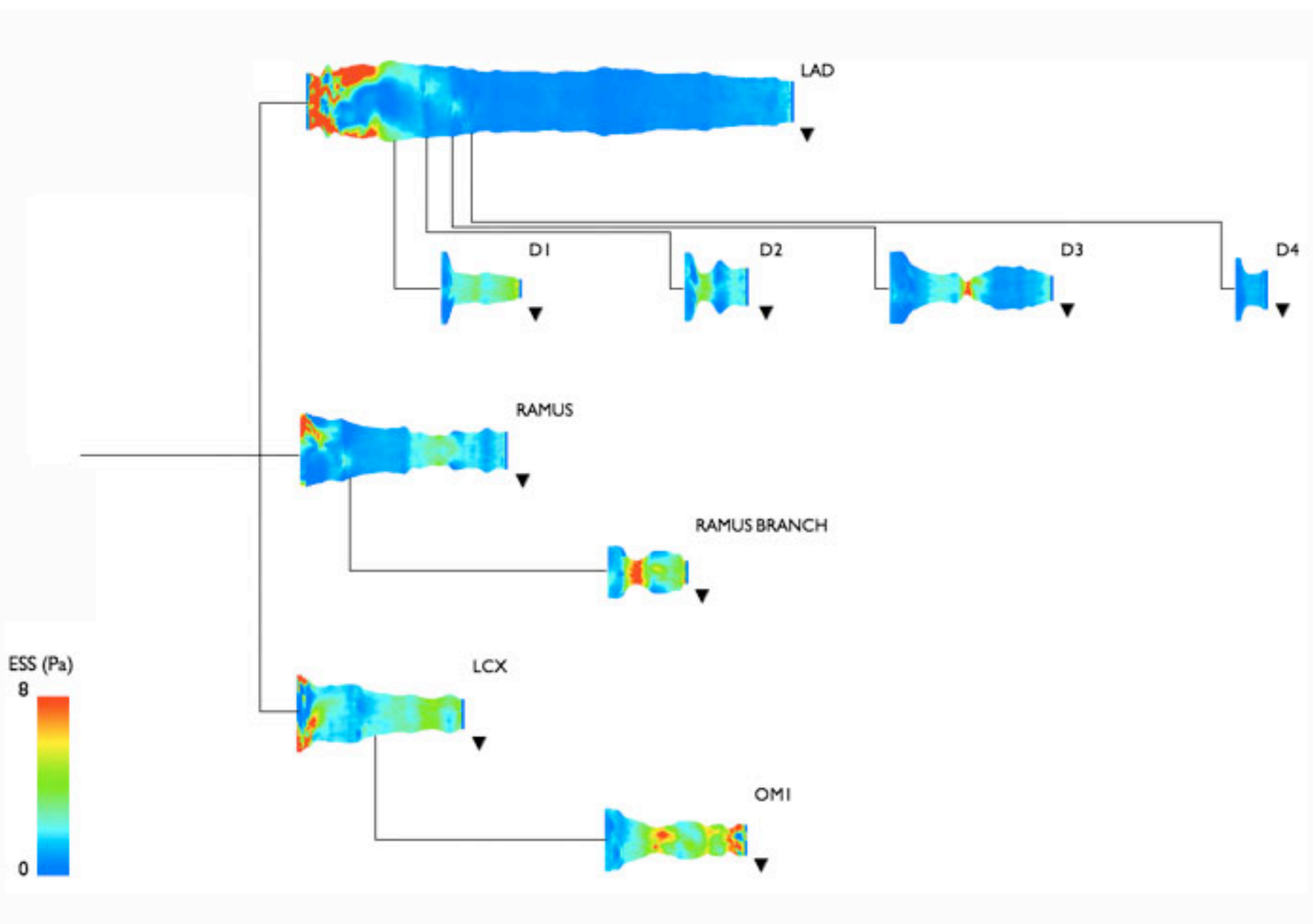




# COLOR



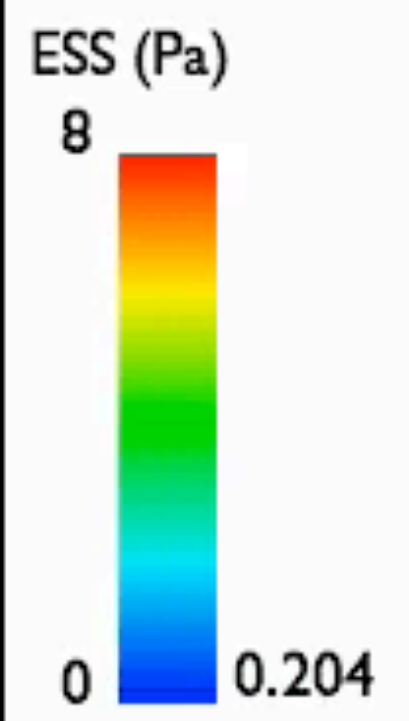
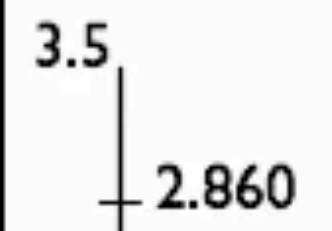
# COLOR



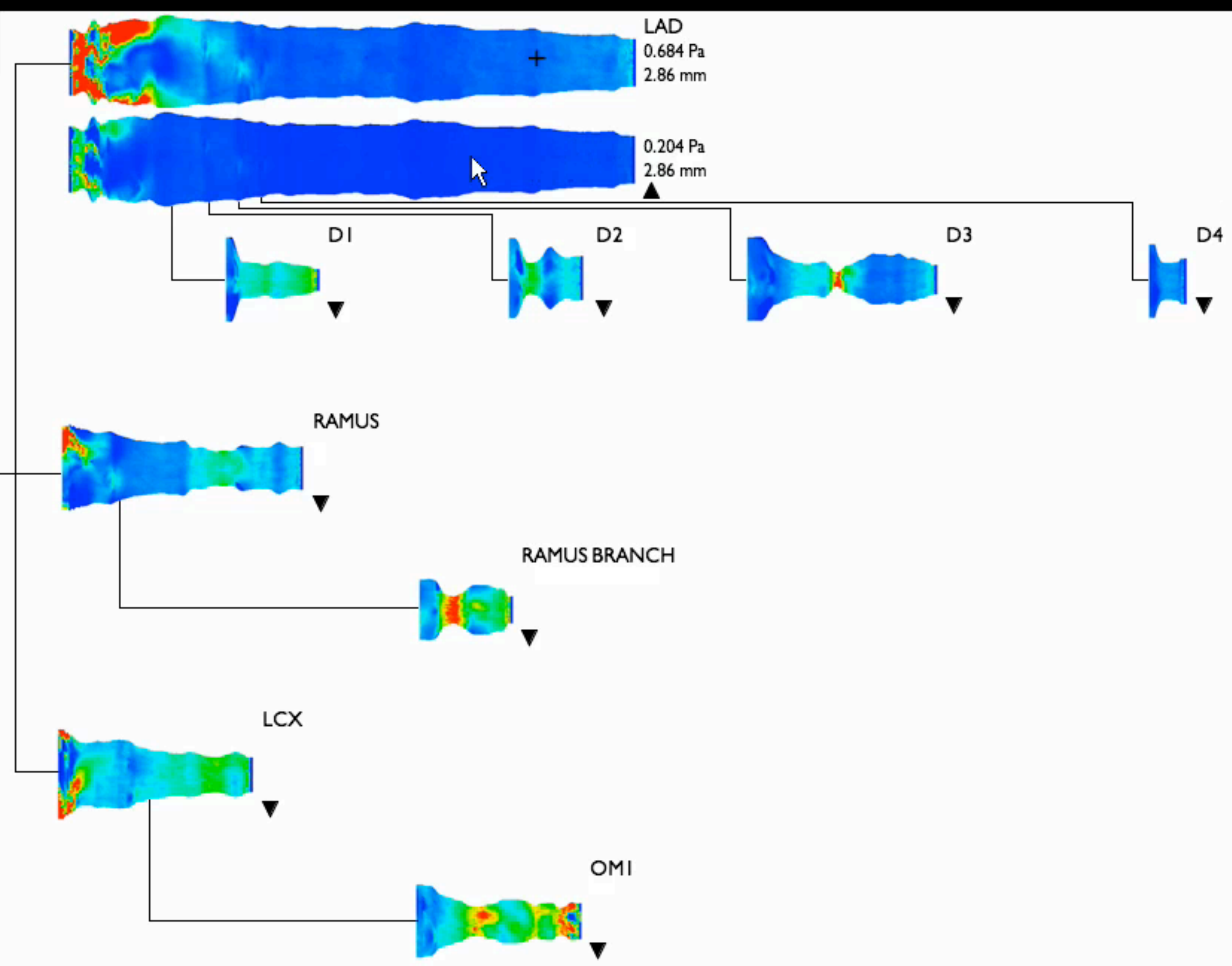


Mode: tree individual

Circumference (mm)



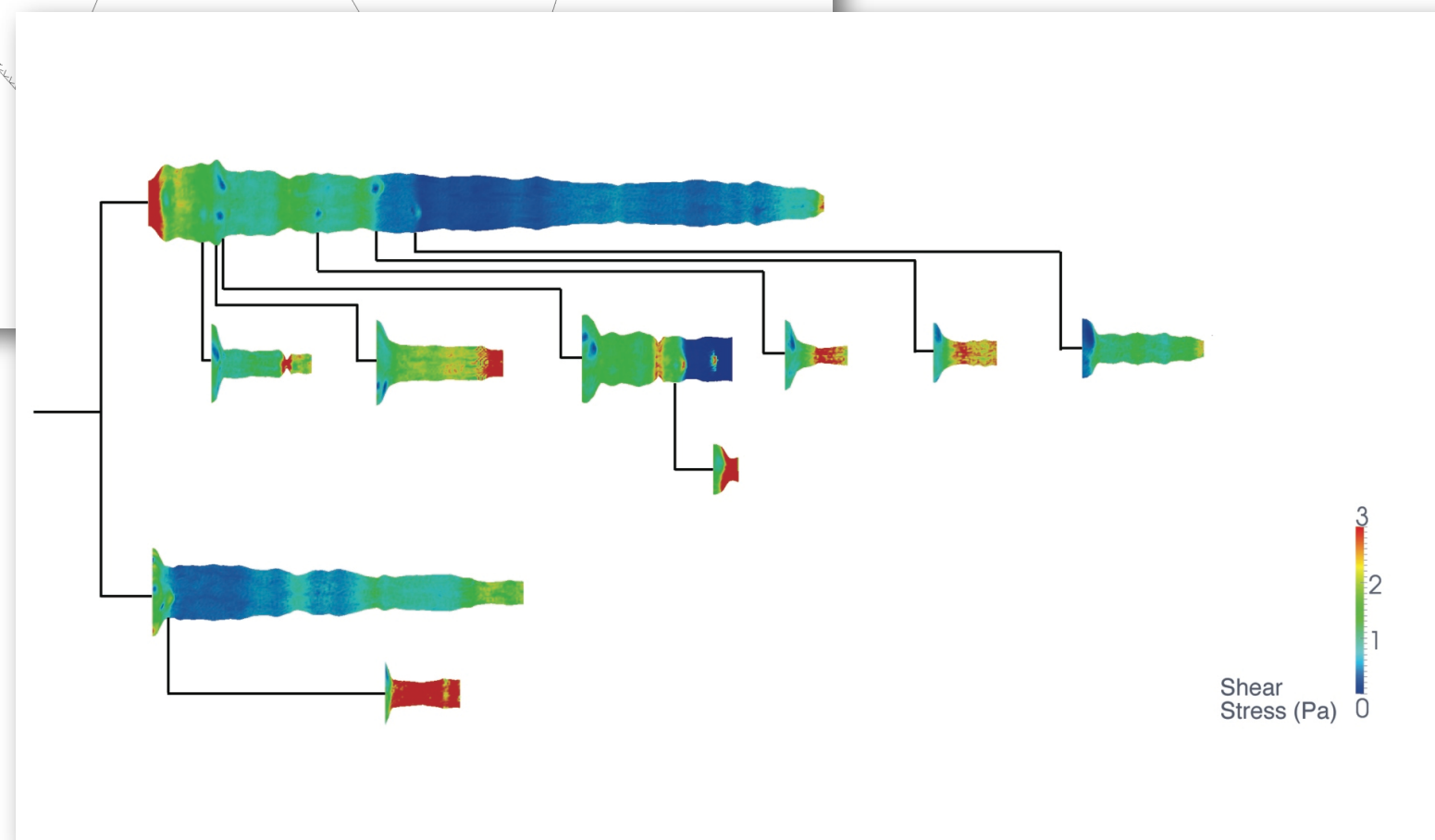
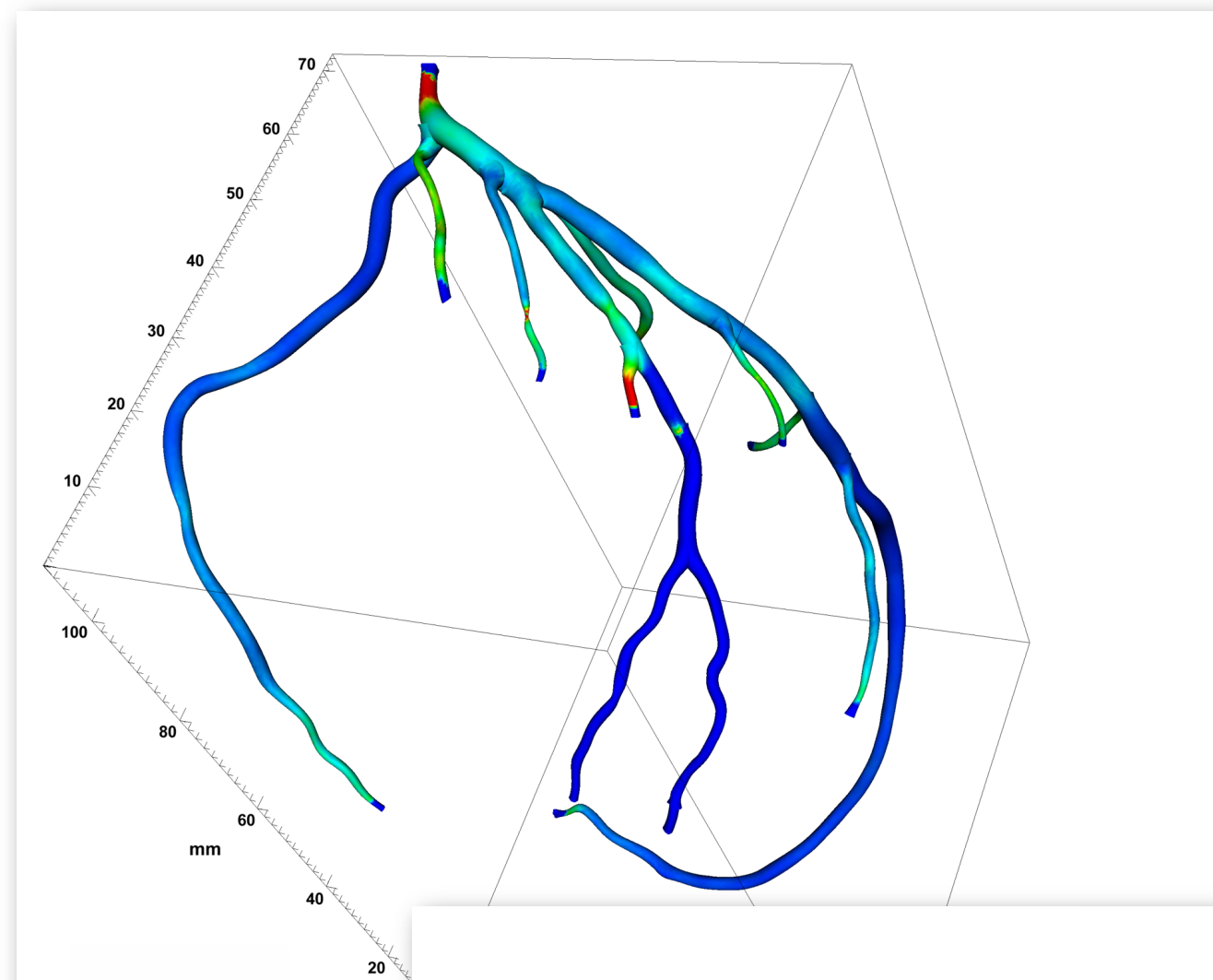
Color:



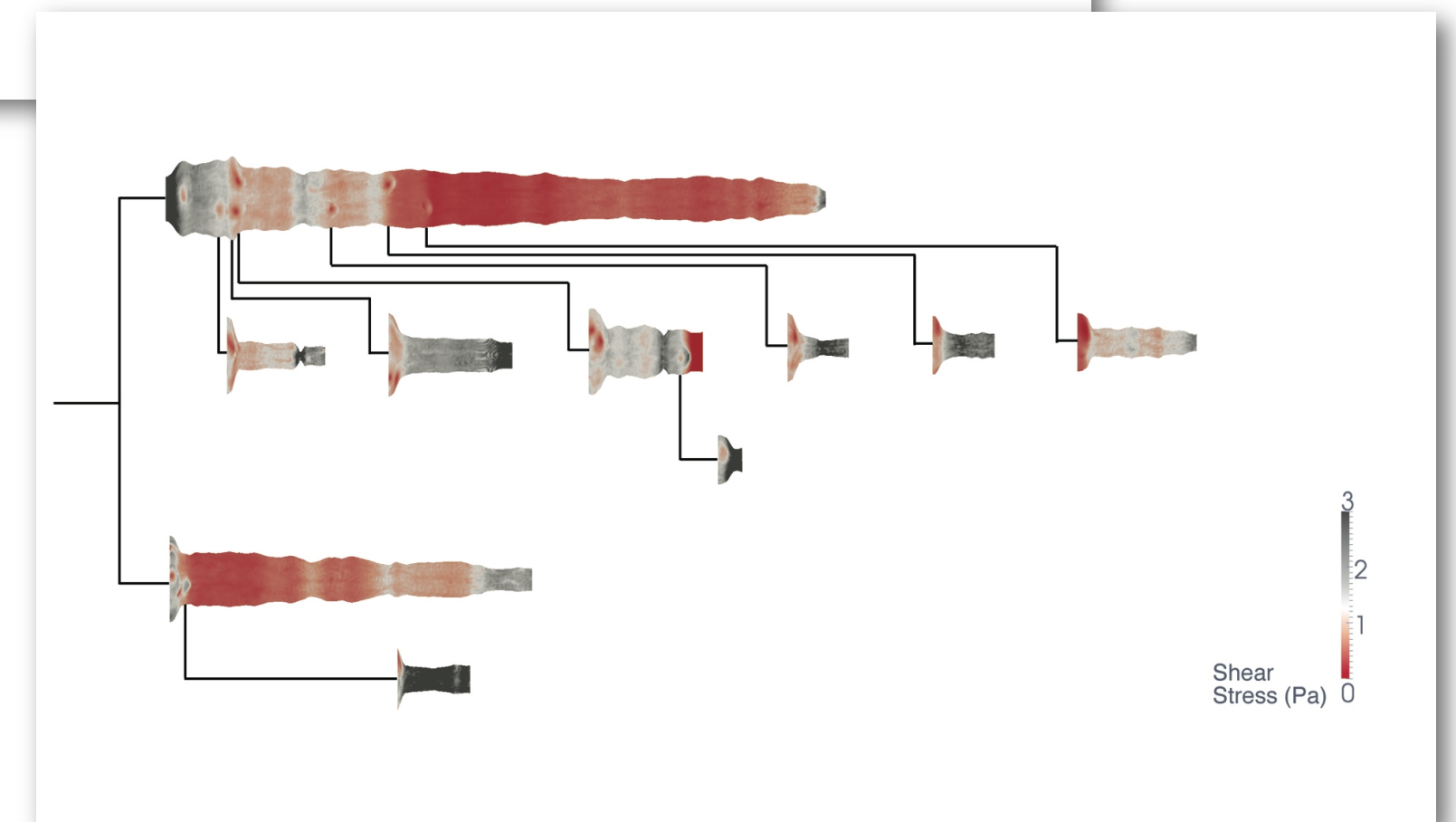
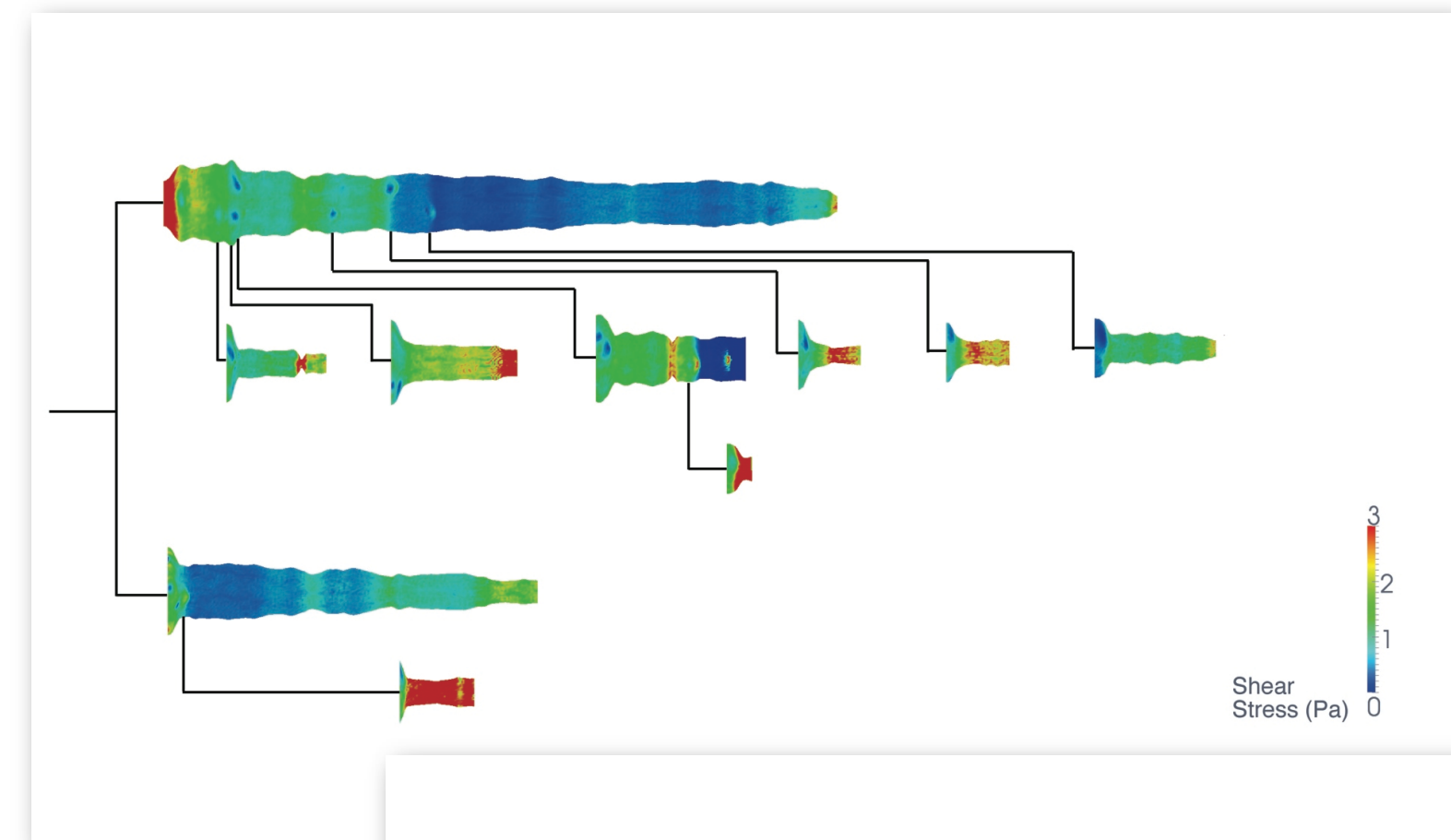
320 CT Scan  
Left Coronary Artery  
Lattice-Boltzman  
(High & Low Flow Rates)  
▼ *Open All Data*

# QUANTITATIVE STUDY: GOALS

3D vs. 2D



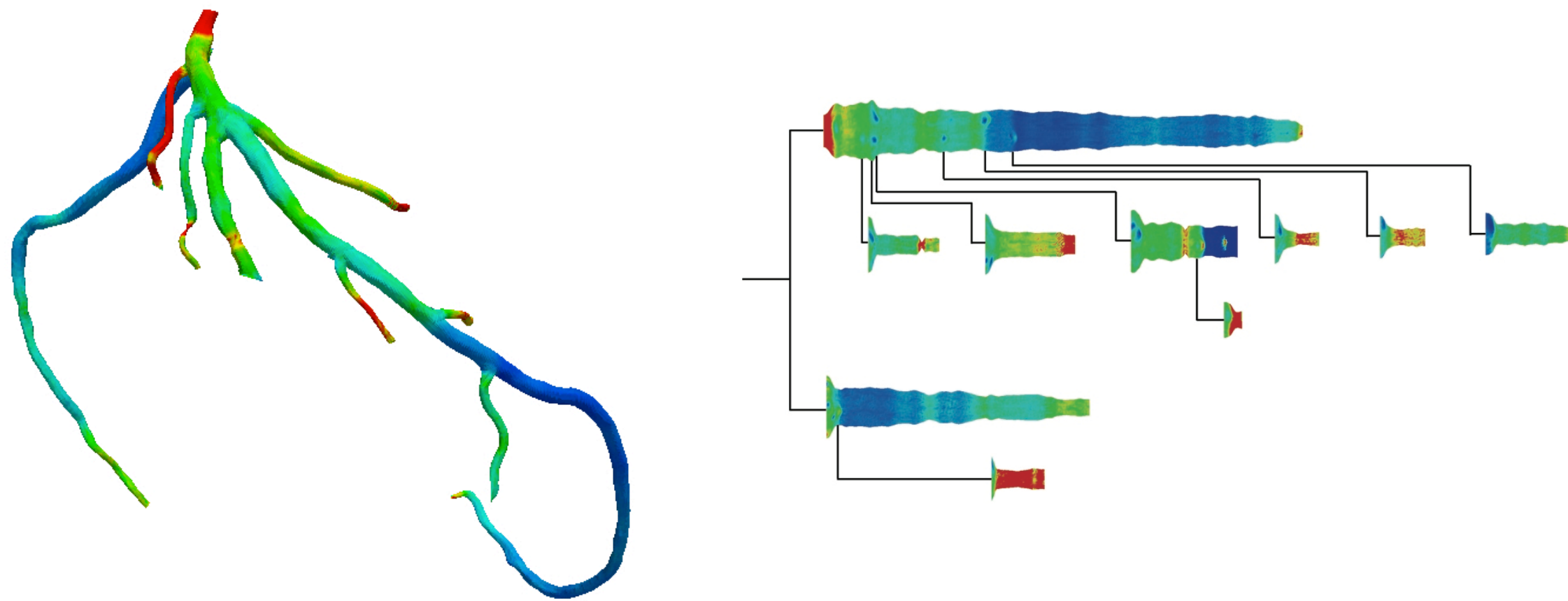
rainbow vs. diverging





# QUANTITATIVE STUDY

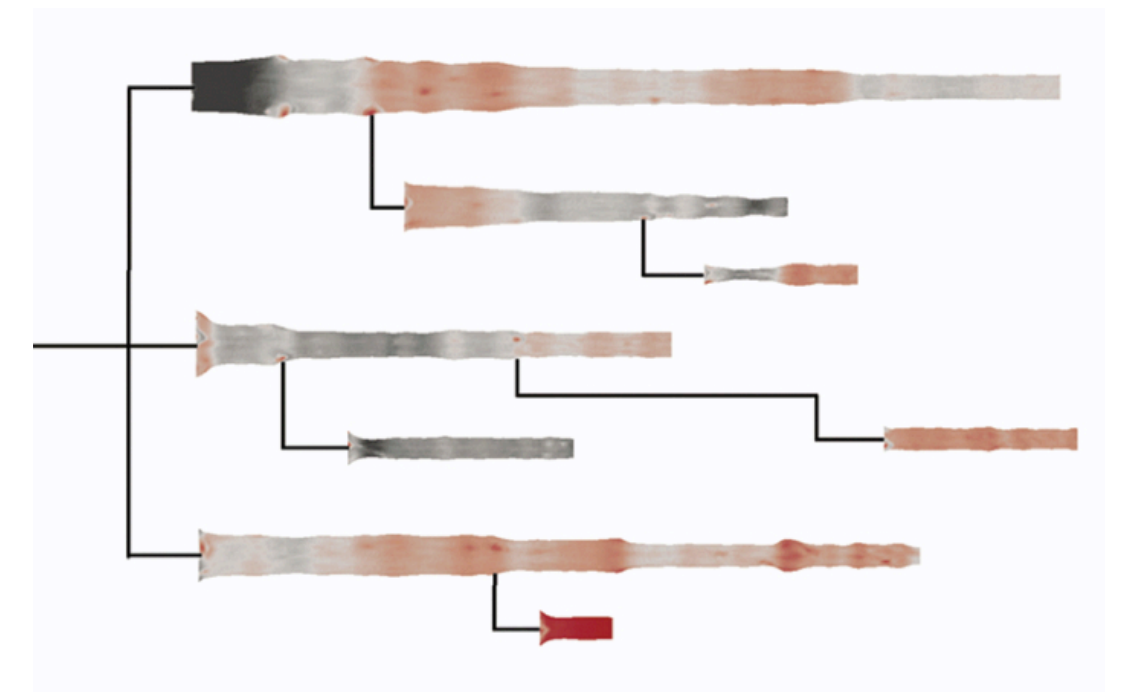
- 21 Harvard Medical students (12 women and 9 men)
- Mixed within-subject and between-subject design:
  - *within* = dimensionality of representation (2D or 3D)
  - *between* = color mapping (rainbow or diverging)



e.g., Participant A

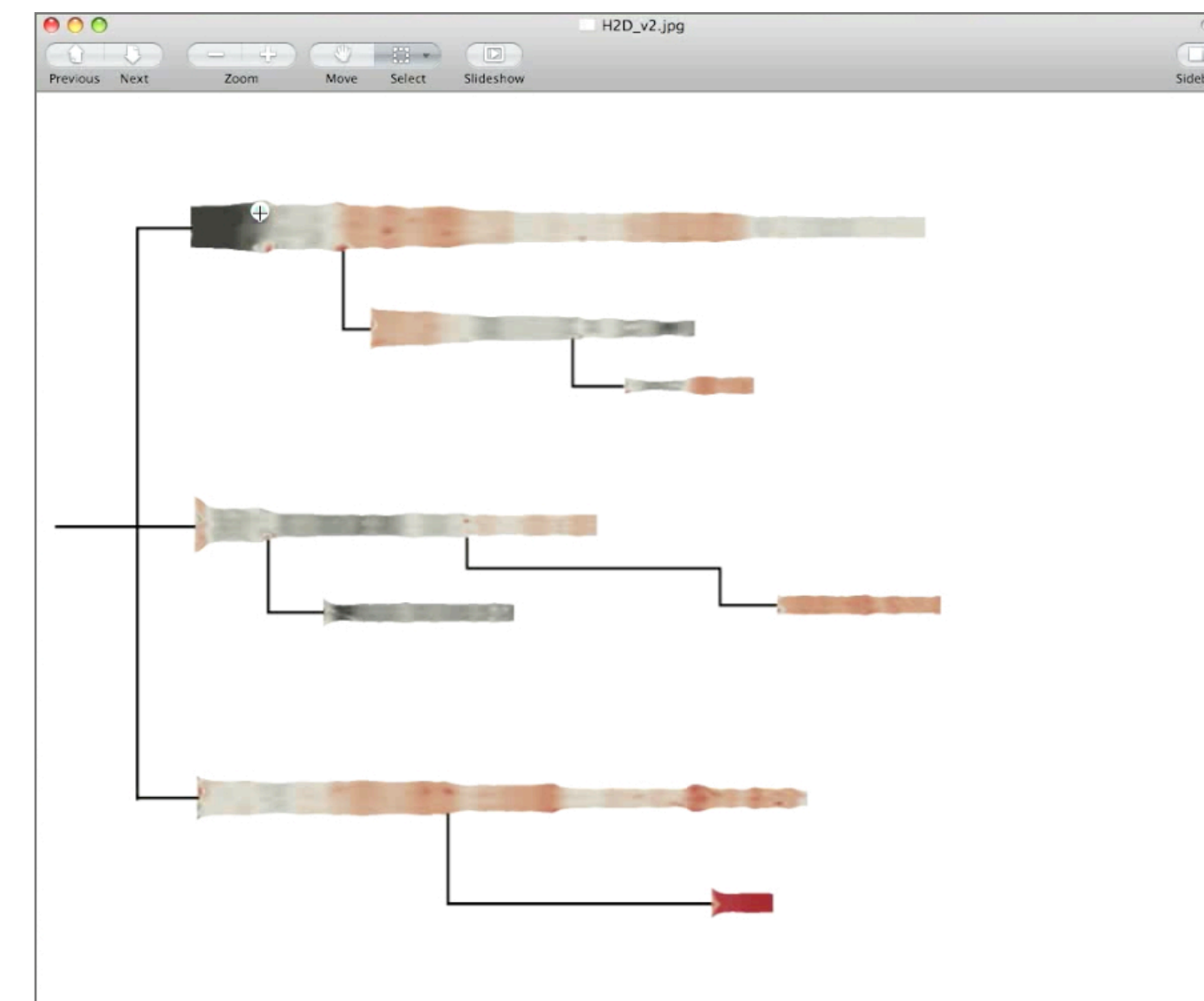
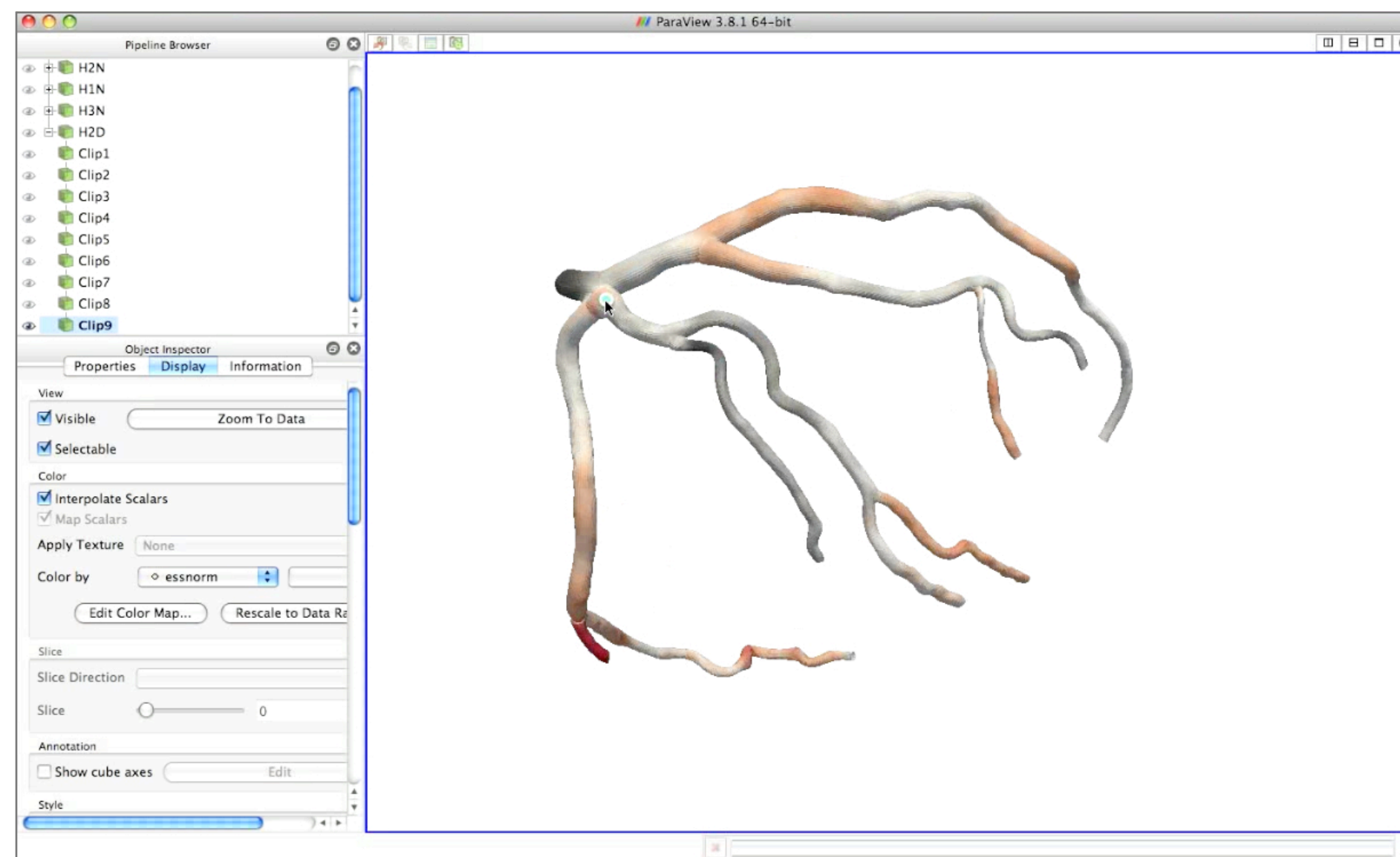


e.g., Participant B



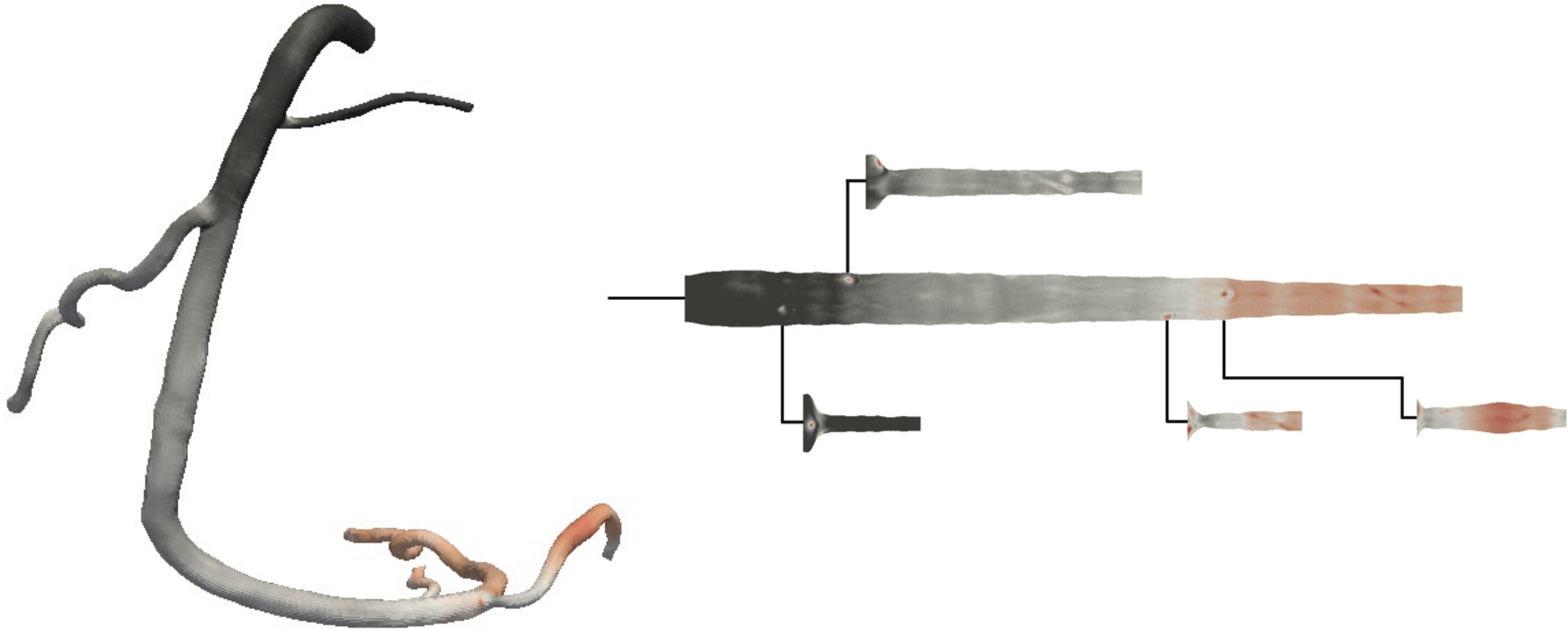
# QUANTITATIVE STUDY

- 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

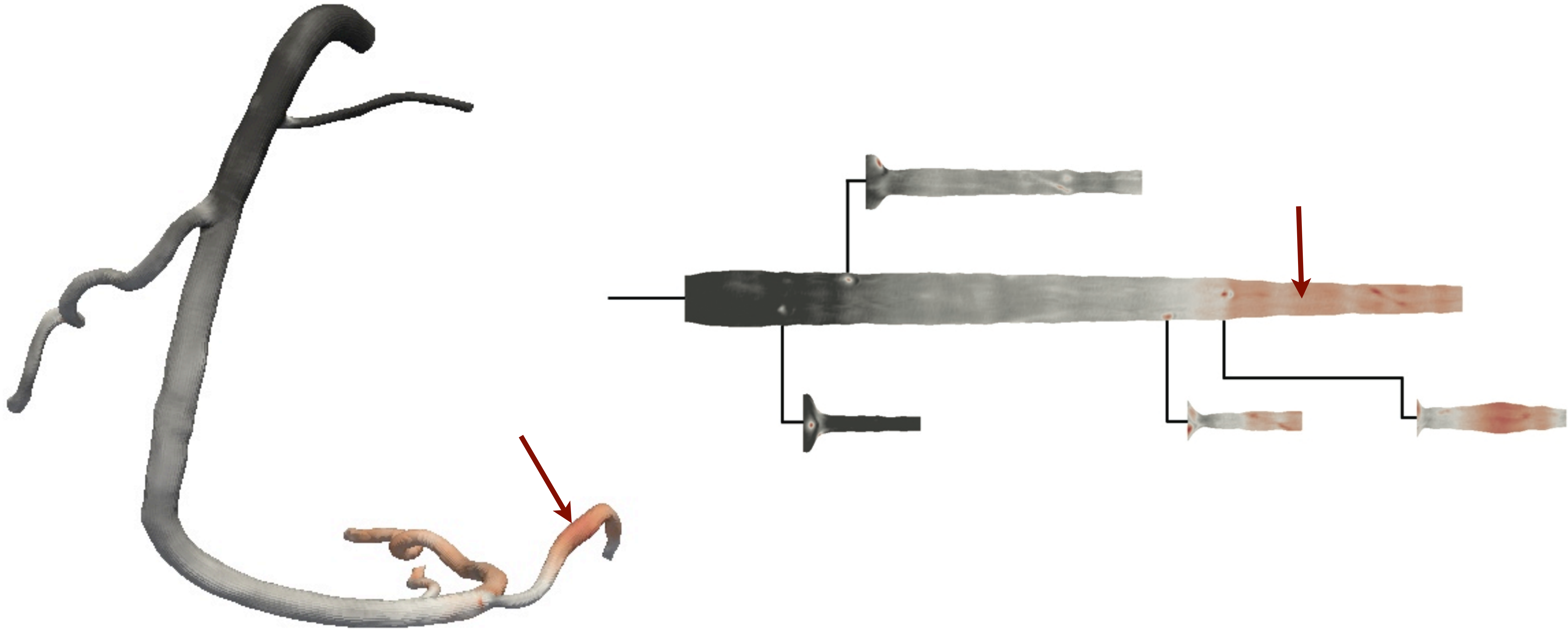




# QUANTITATIVE STUDY

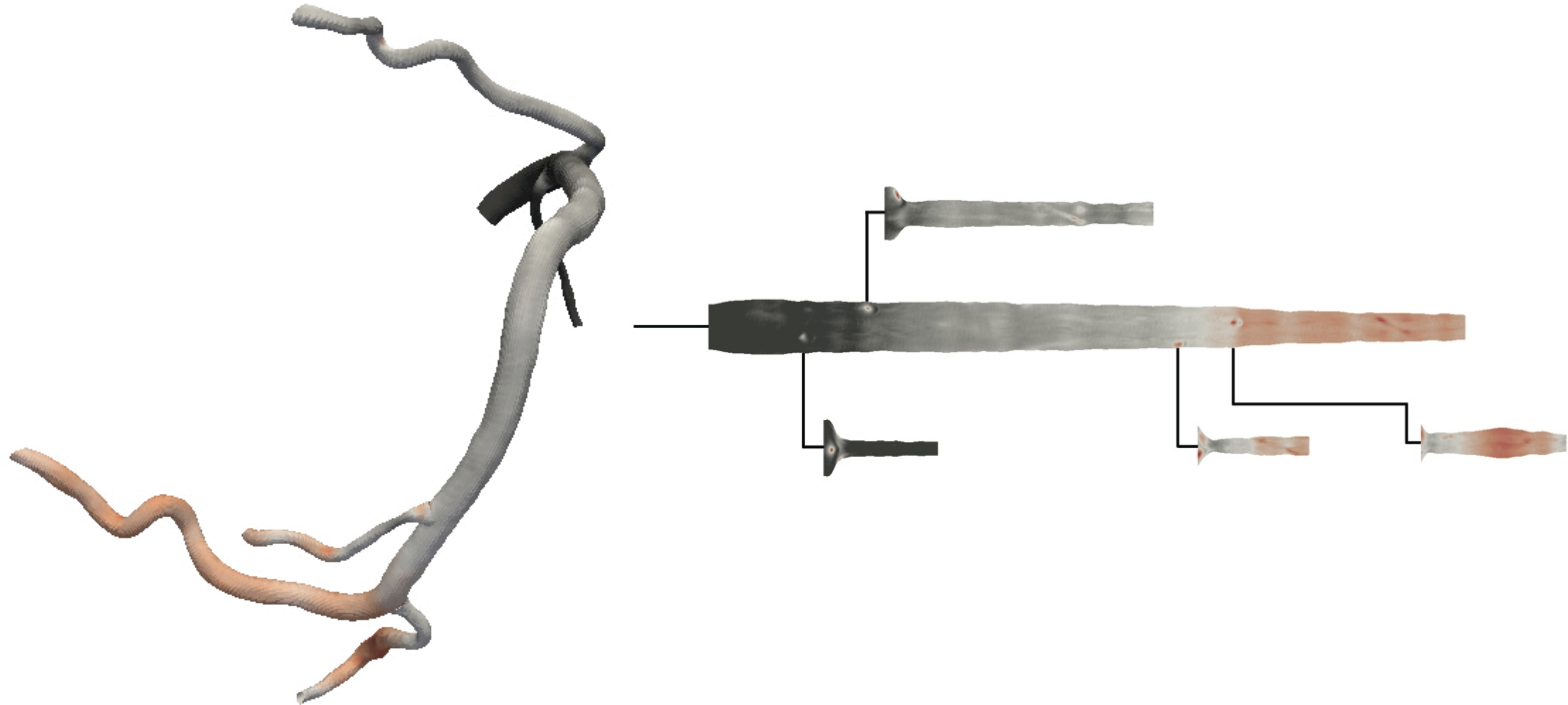


# QUANTITATIVE STUDY

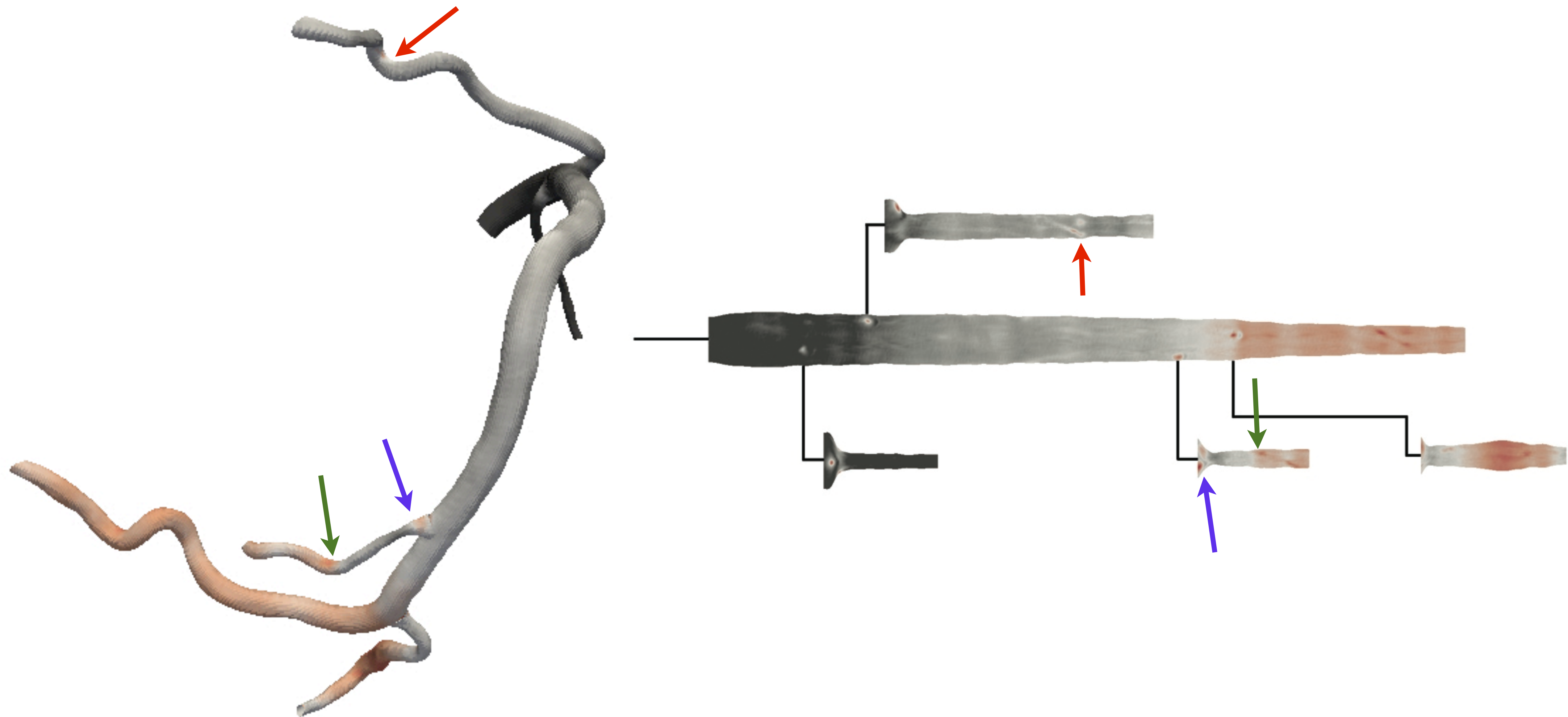




# QUANTITATIVE STUDY



# QUANTITATIVE STUDY



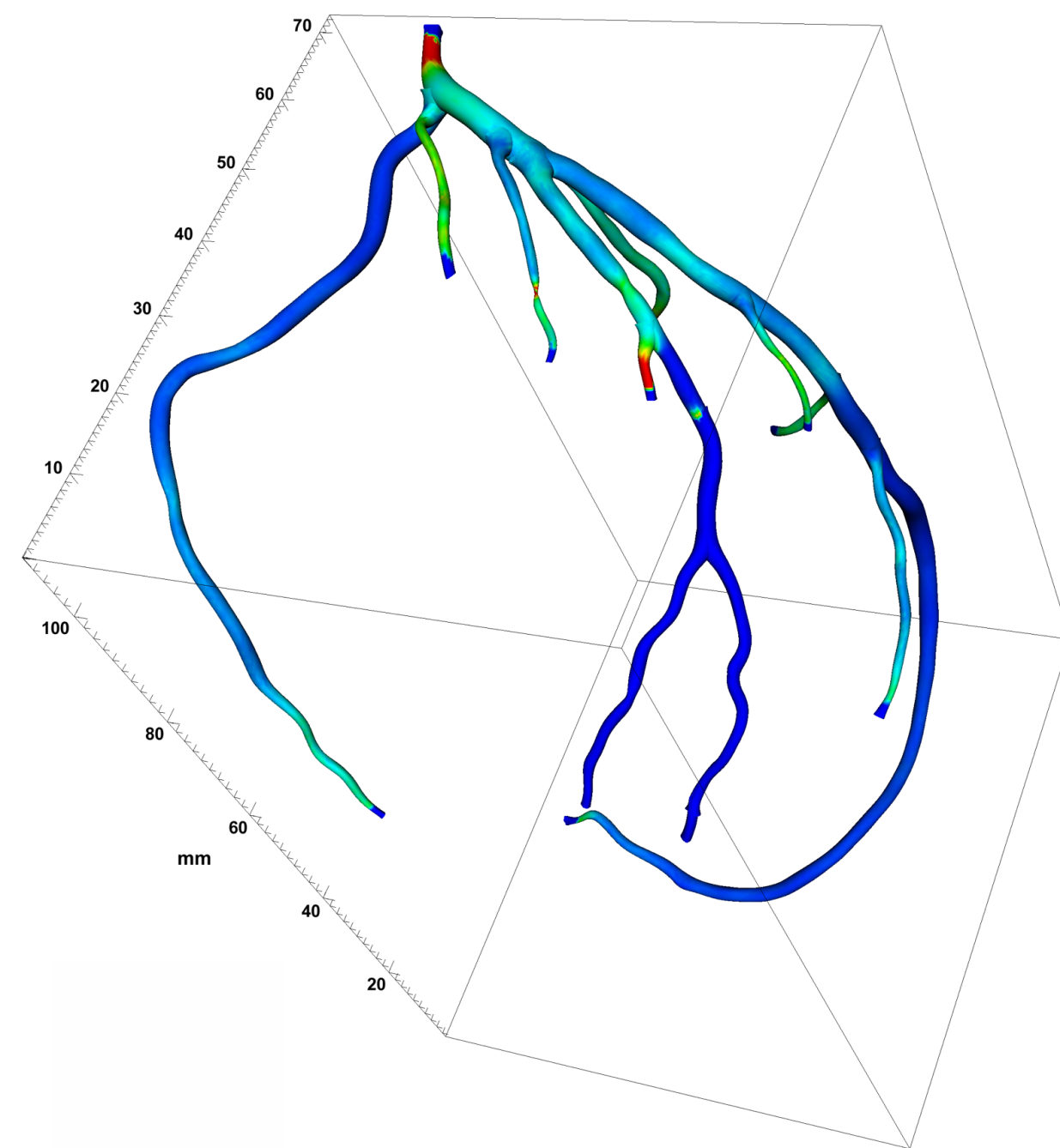


# RESULTS

# ACCURACY

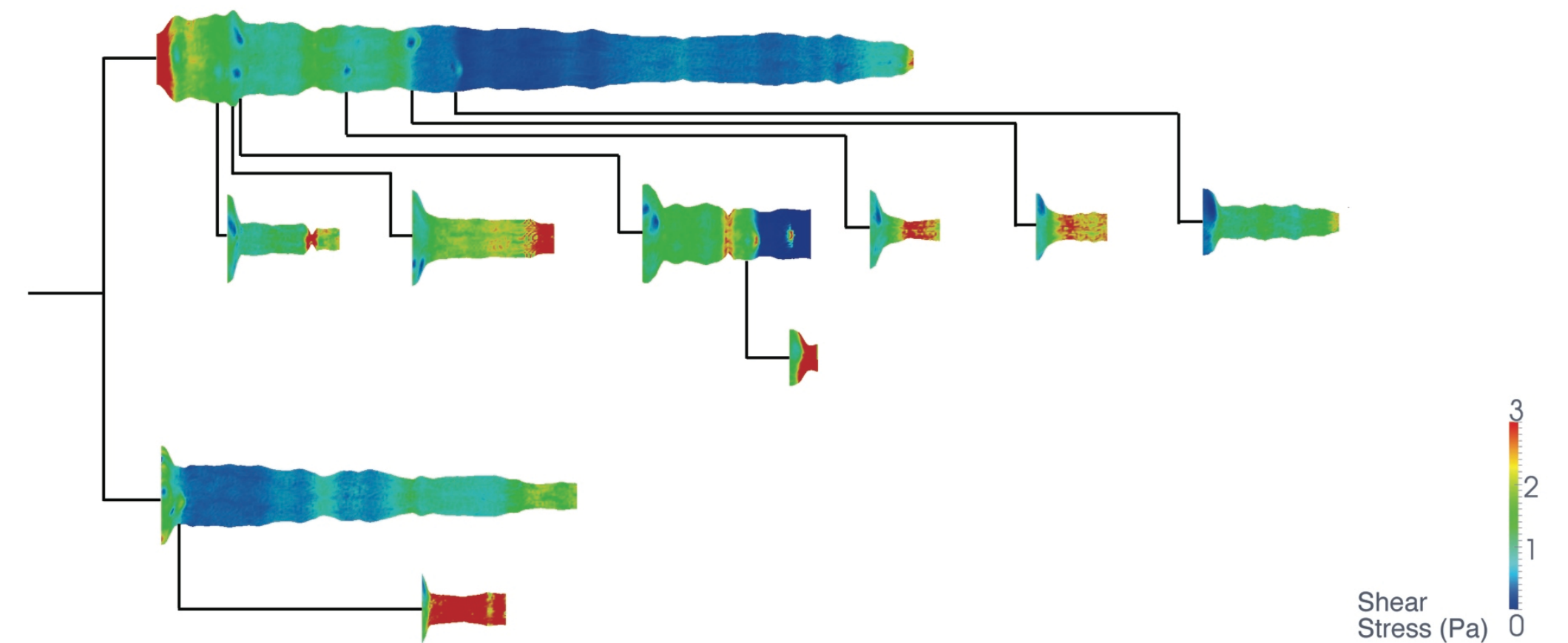
Strong effect of **dimensionality** on accuracy

39%



How many low ESS  
regions found?

62%



ESS (Pa)  
3.00  
2.25  
1.50  
0.75  
0.00

Shear  
Stress (Pa)  
3  
2  
1  
0



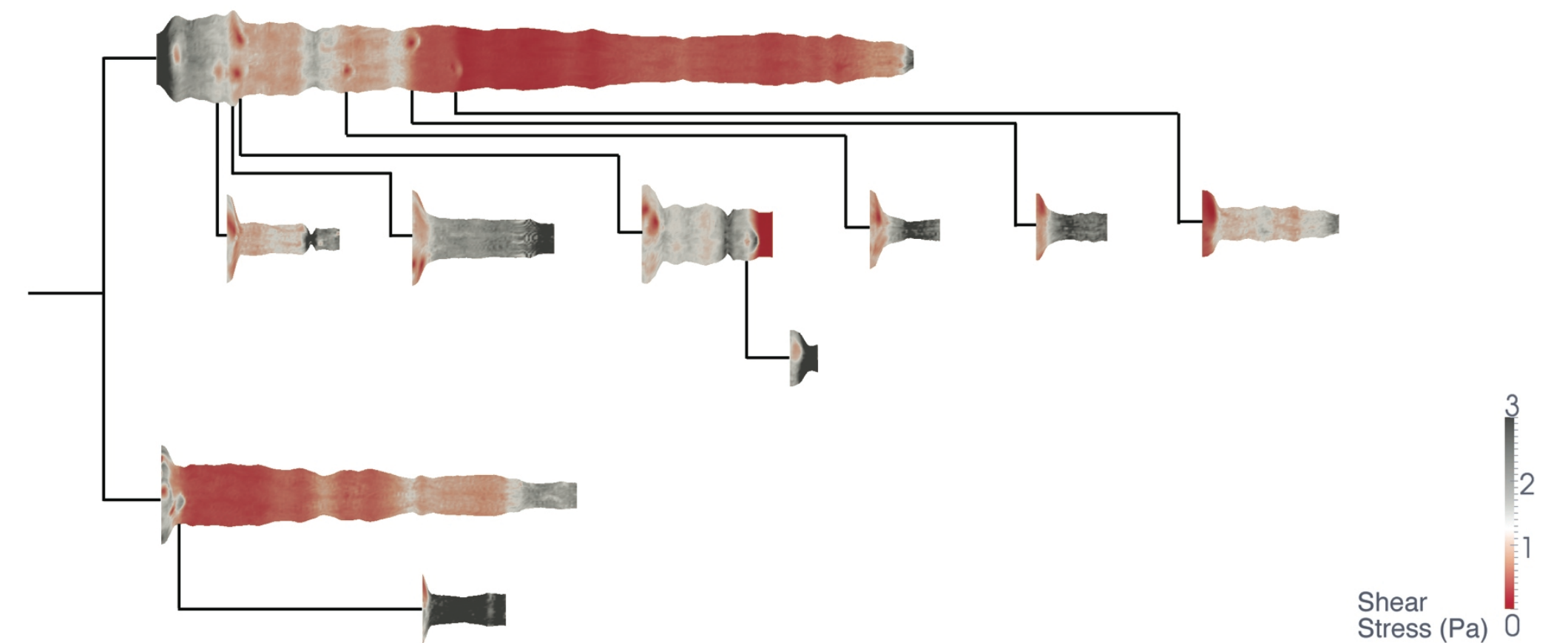
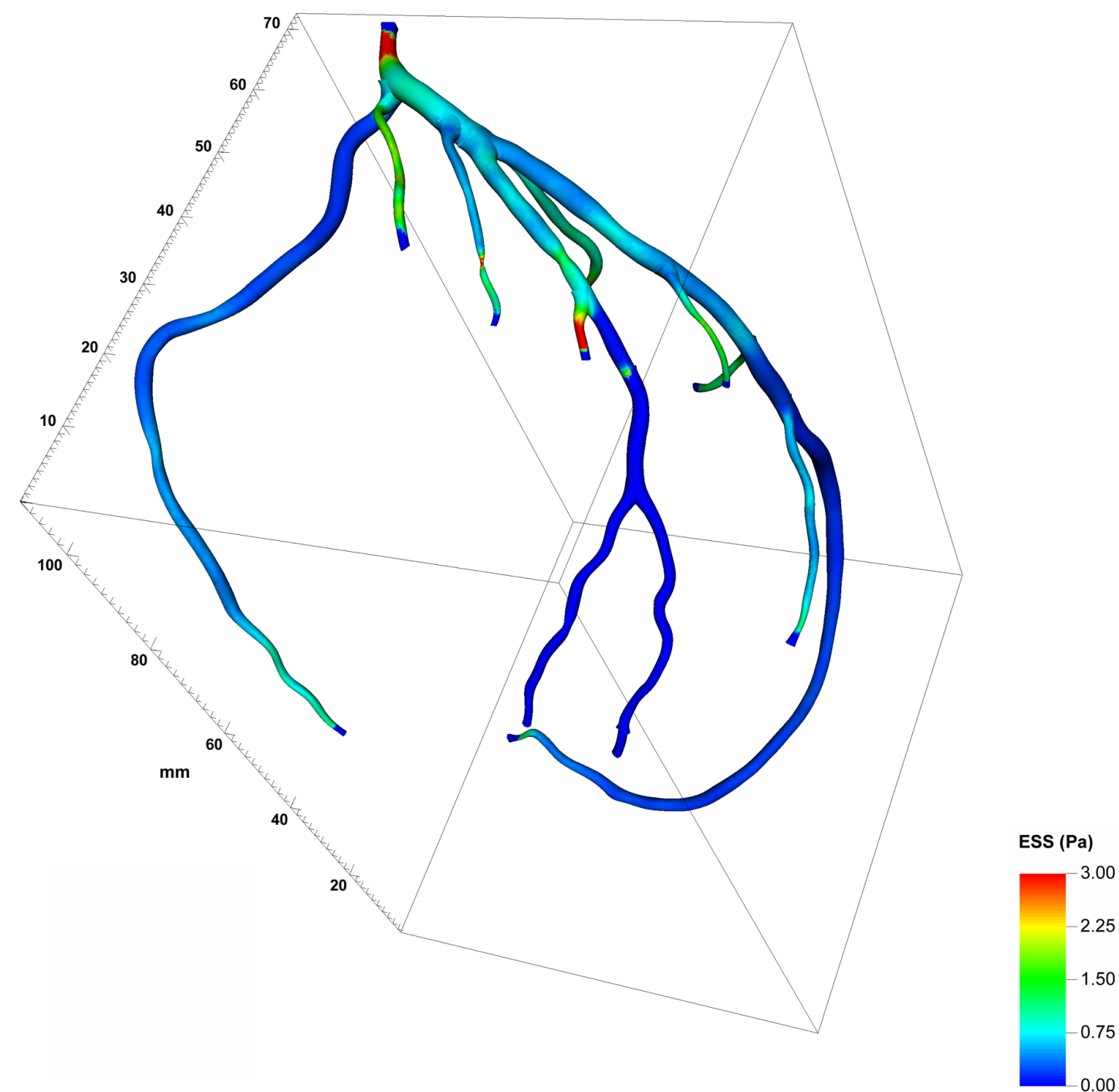
# ACCURACY

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

39%

How many low ESS  
regions found?

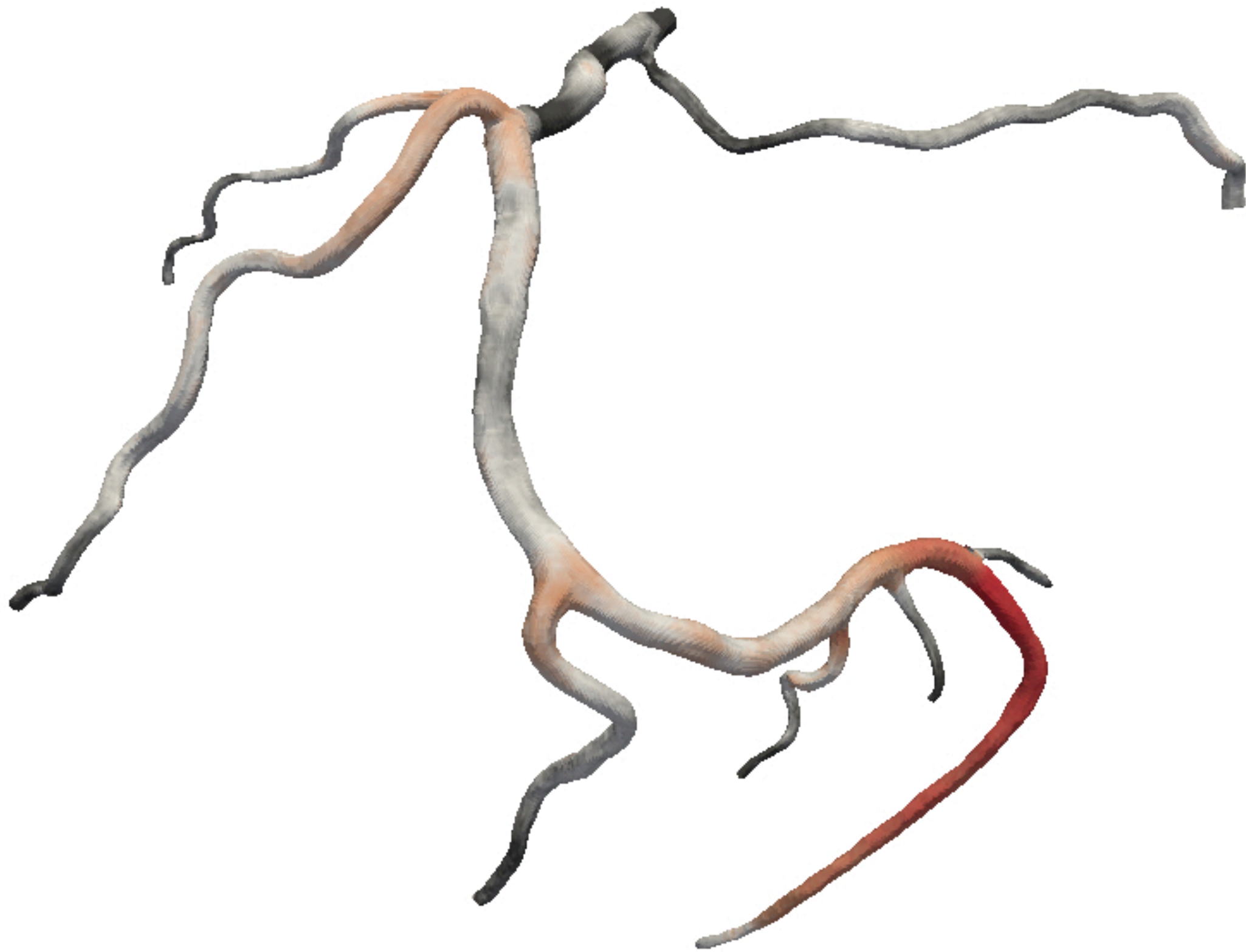
91%



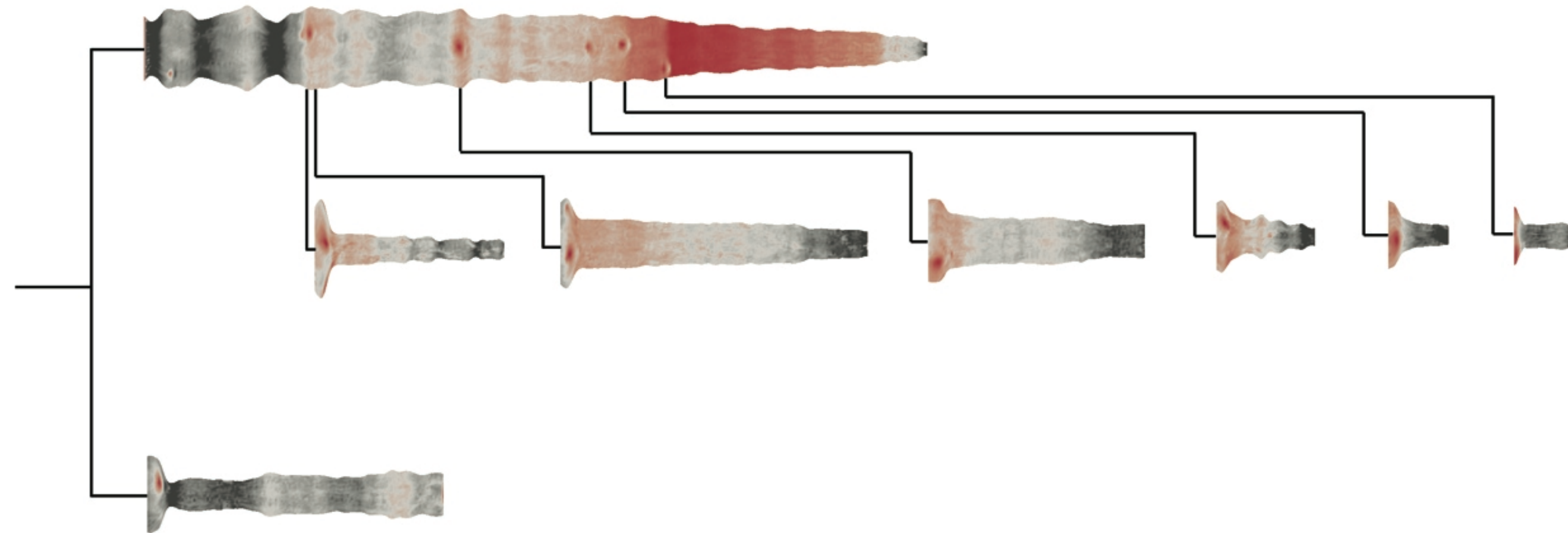
# EFFICIENCY

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

5.6 sec/region



2.4 sec/region

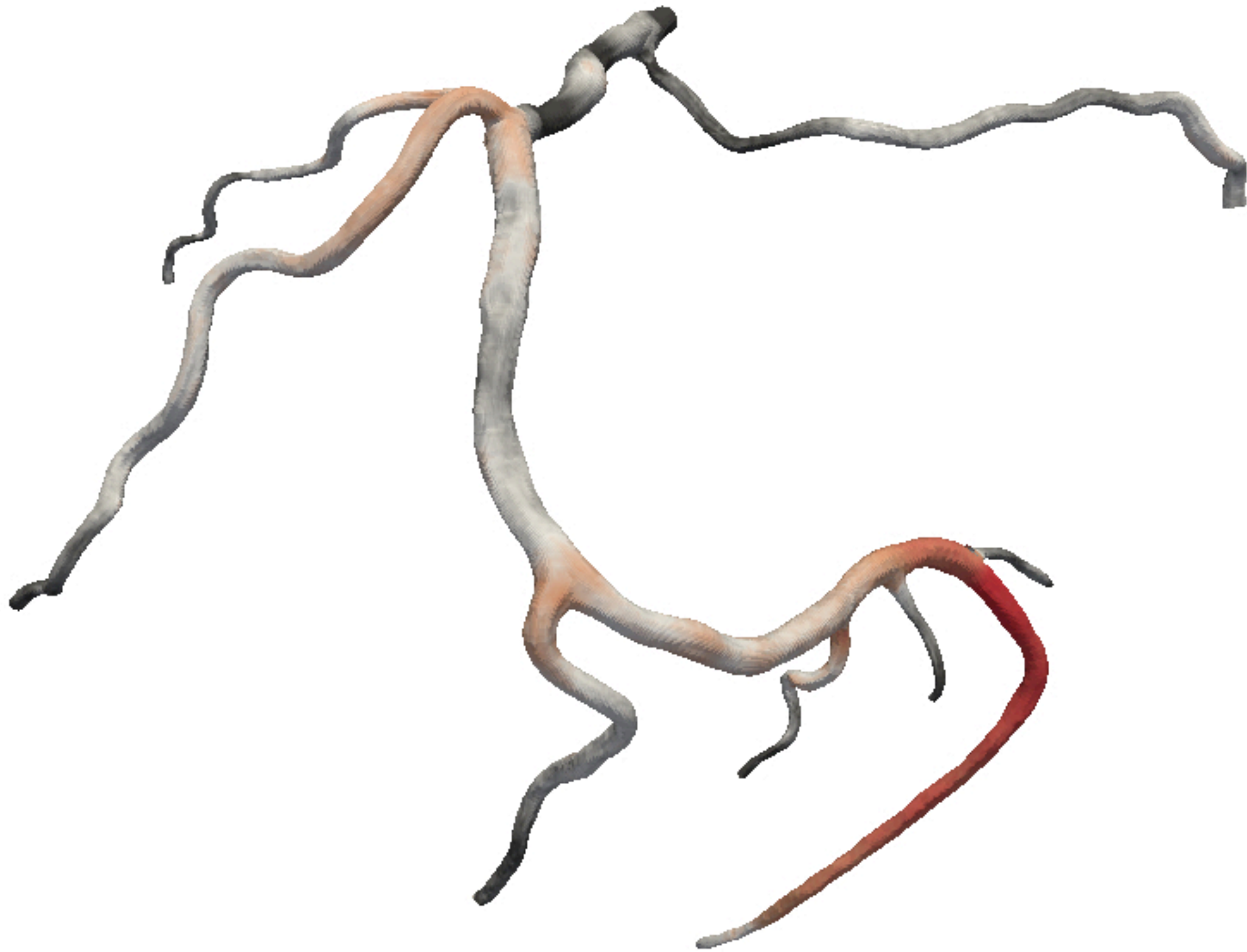




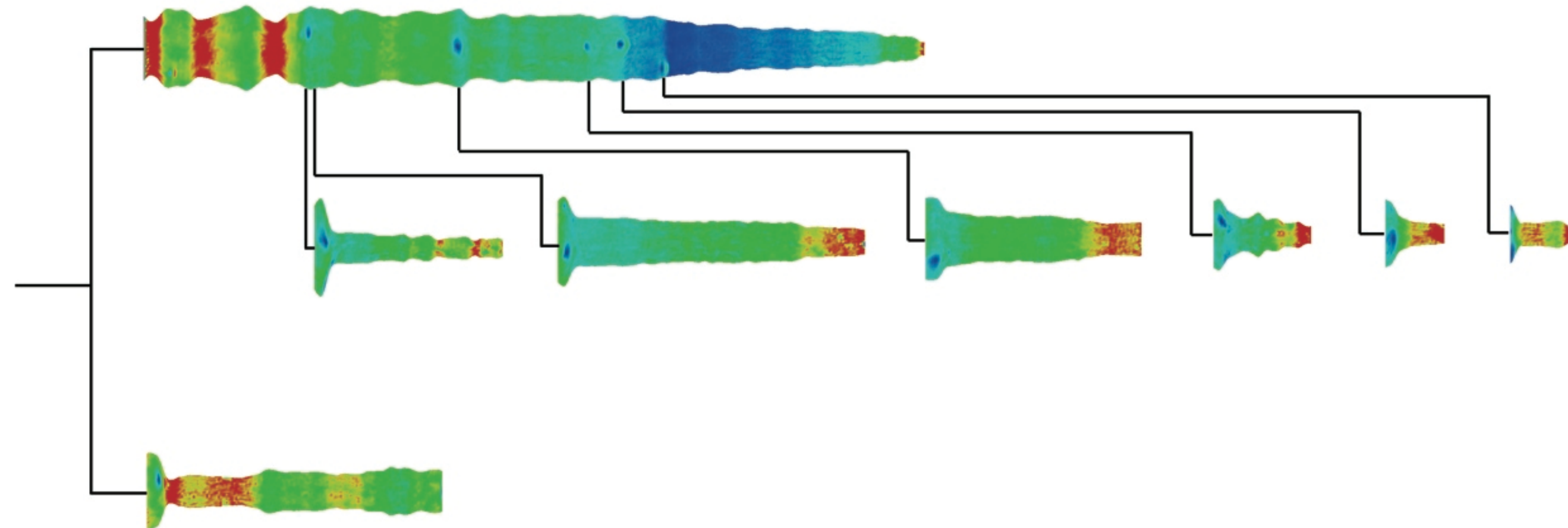
# EFFICIENCY

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

5.6 sec/region



2.6 sec/region

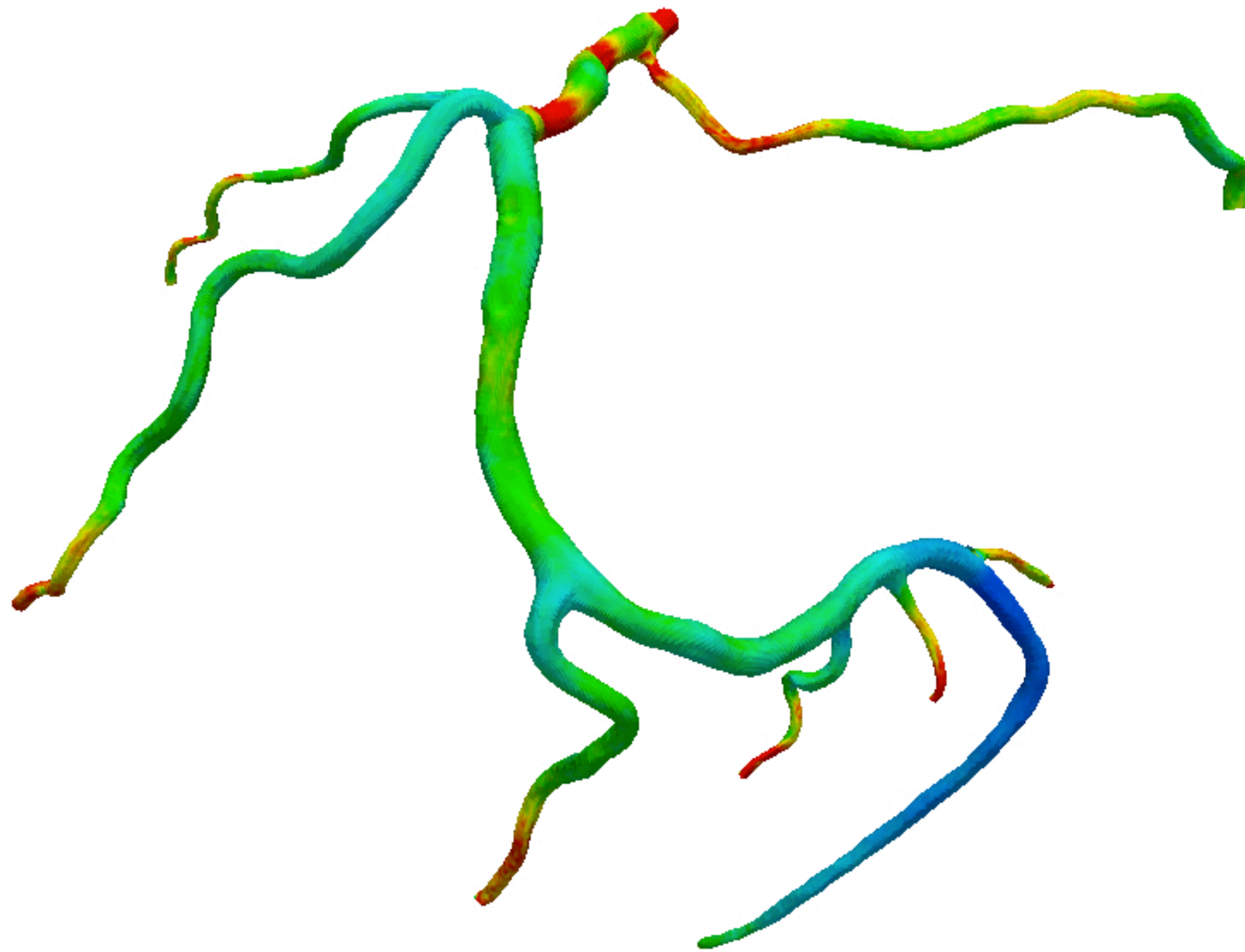


# EFFICIENCY

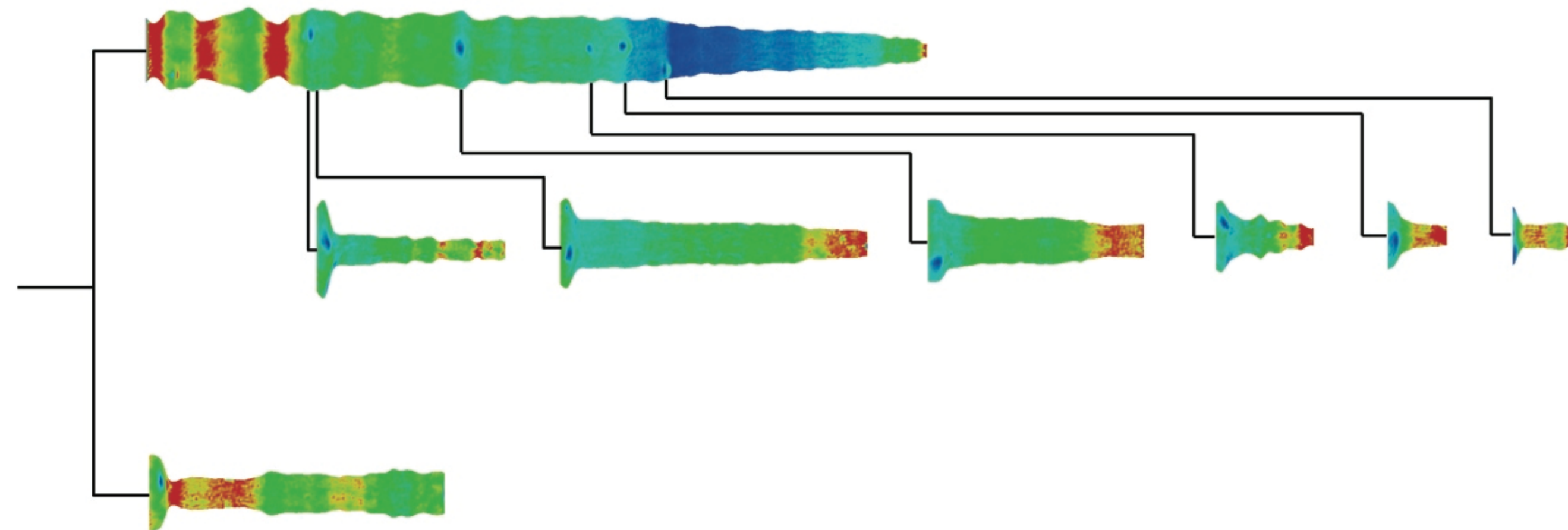
Participants more **efficient** in **2D**.

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

10.2 sec/region



2.6 sec/region

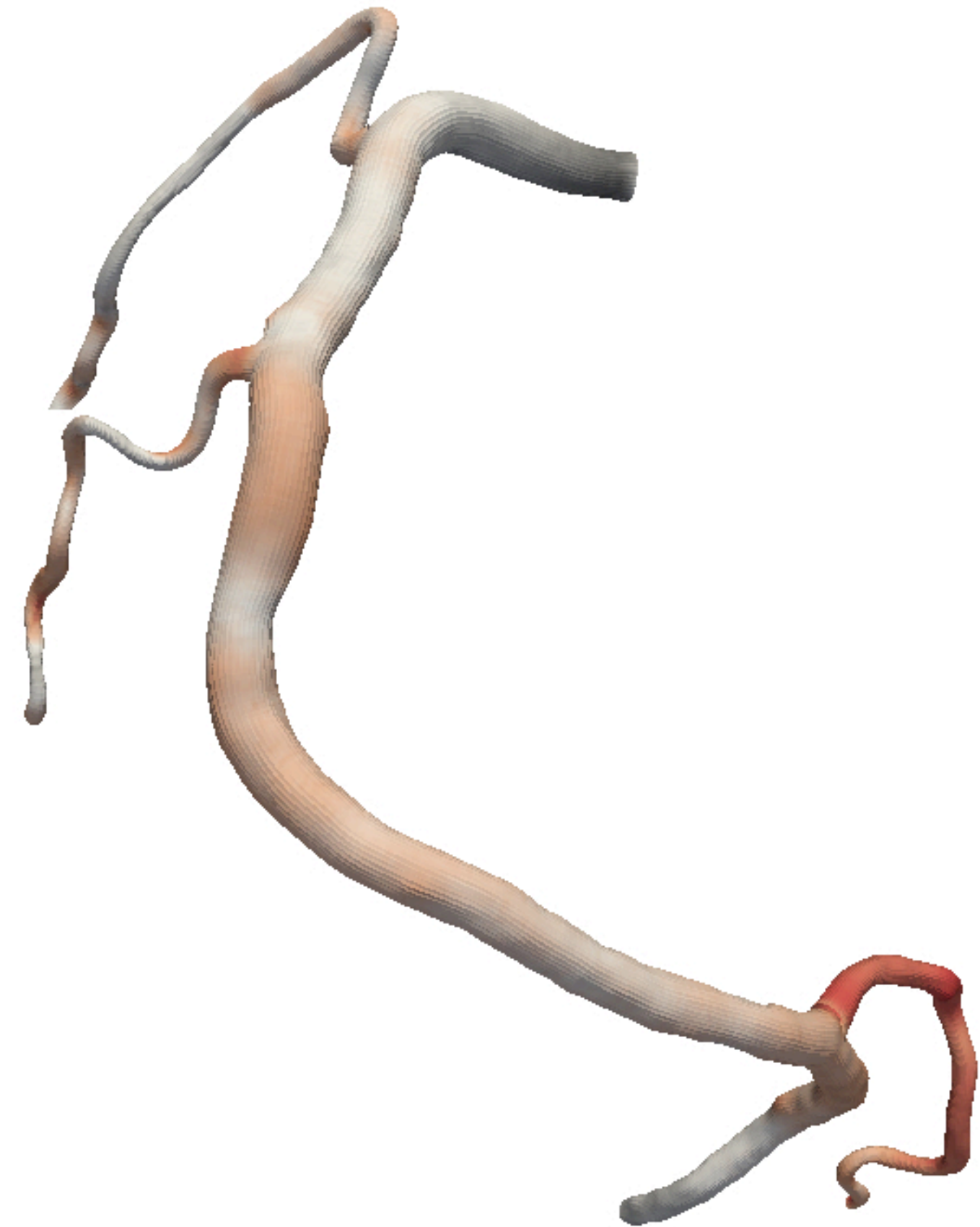
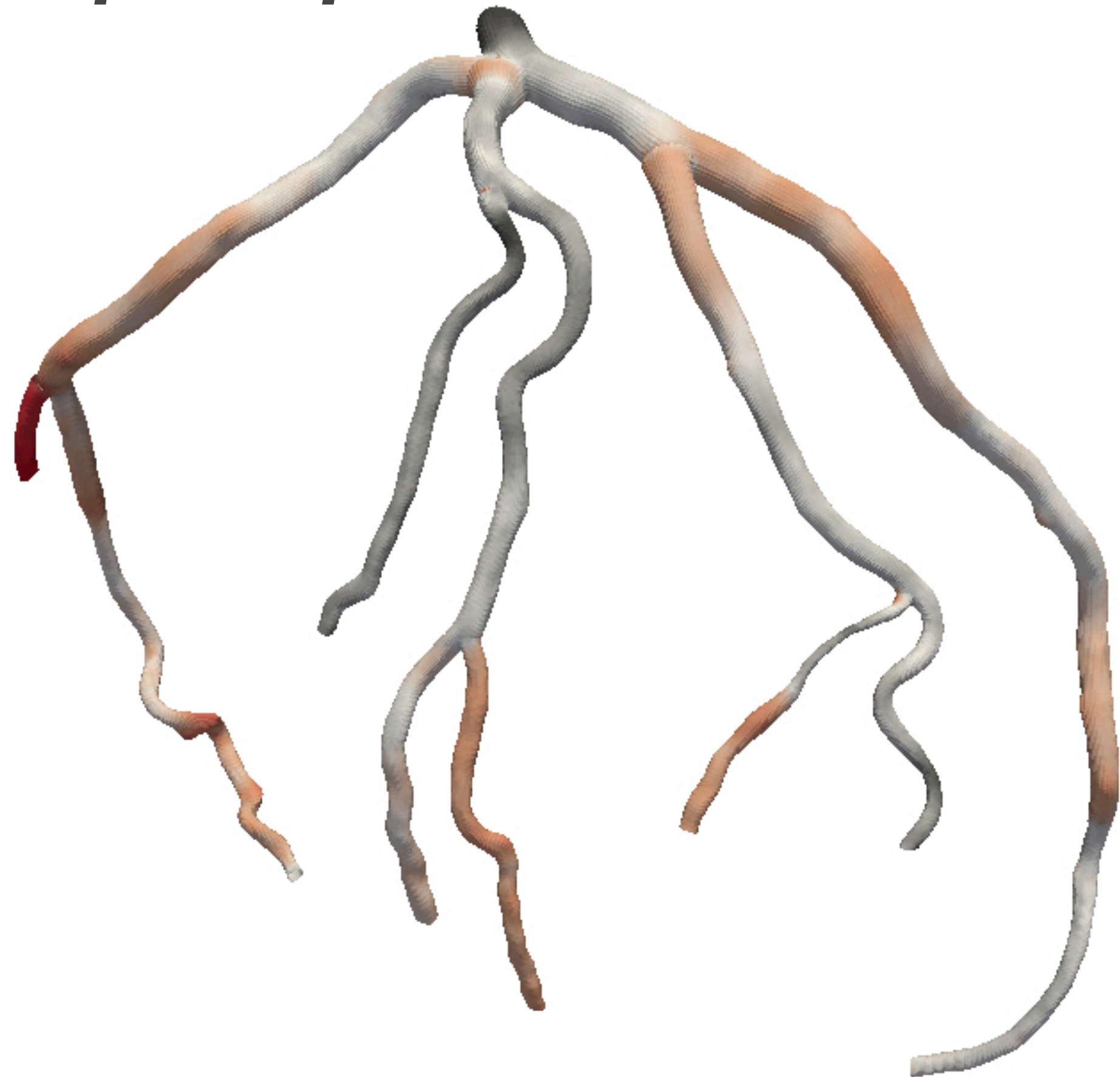




# COMPLEXITY

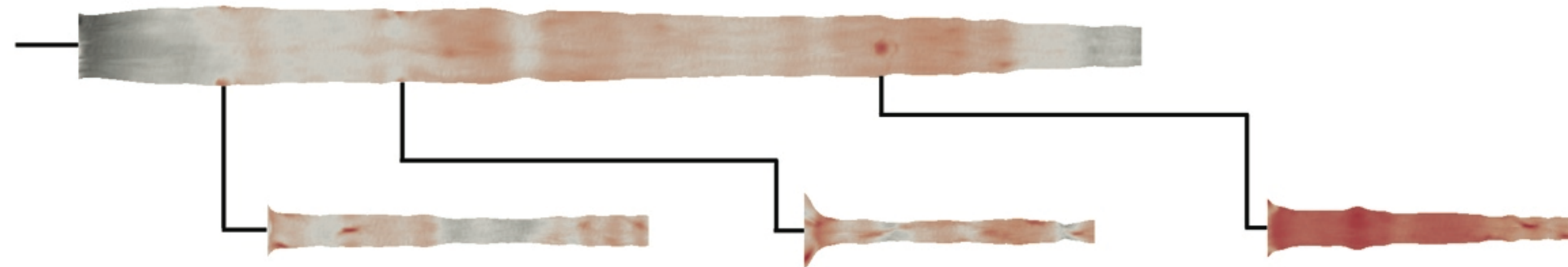
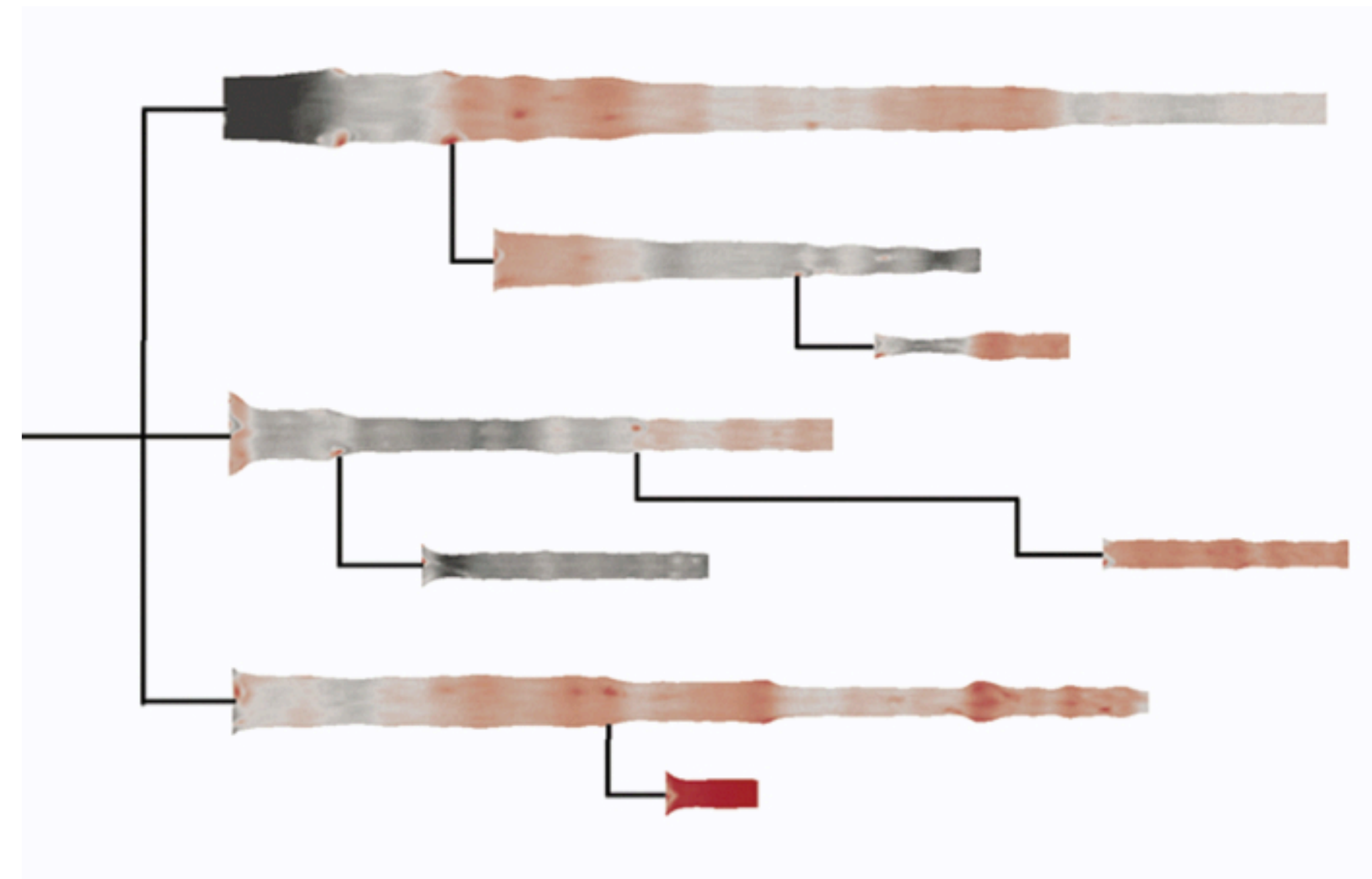
Accuracy decreases with increased data complexity in 3D

*participants less accurate*



# COMPLEXITY

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

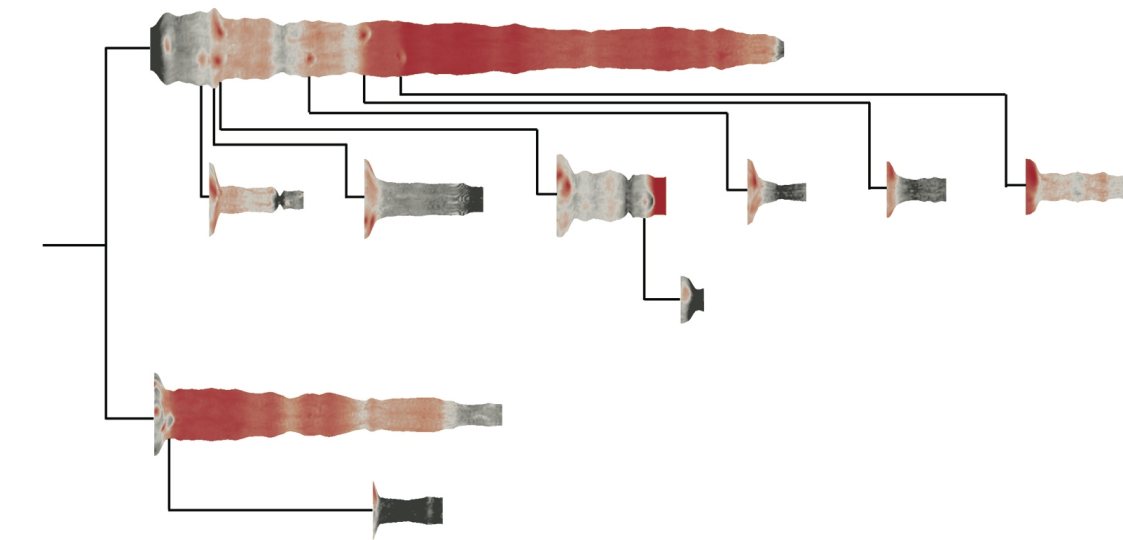




# FINDINGS SUMMARY

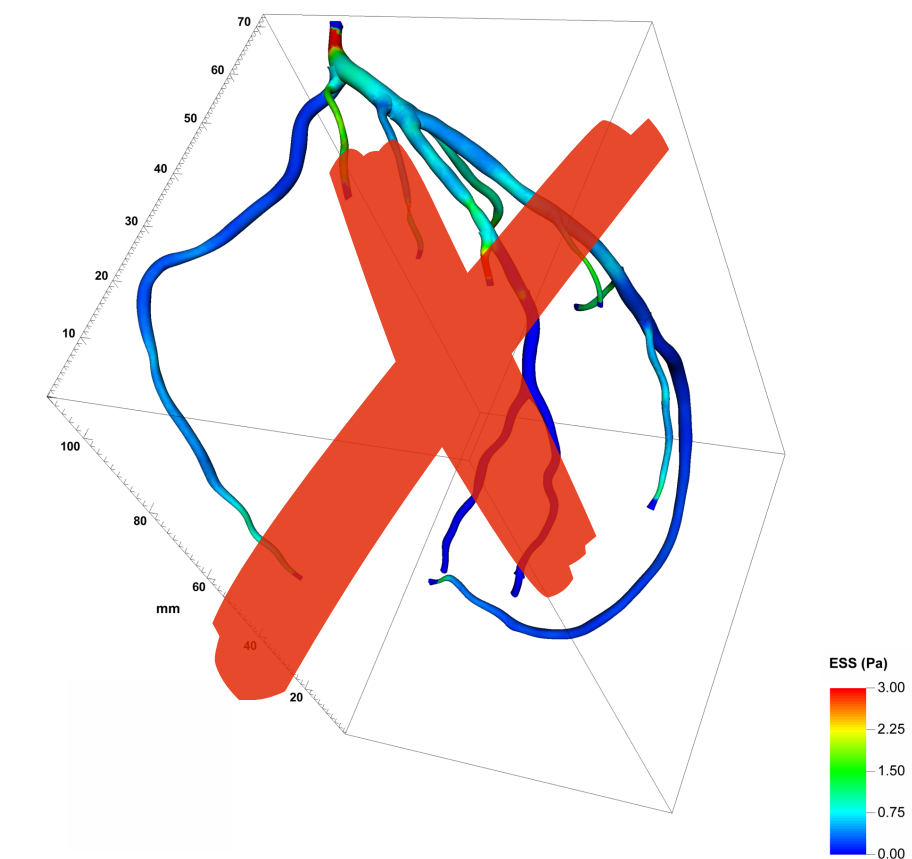
- Even for 3D spatial data, a **2D** representation is

- ▶ more **accurate** for spatial tasks
- ▶ more **efficient** for spatial tasks



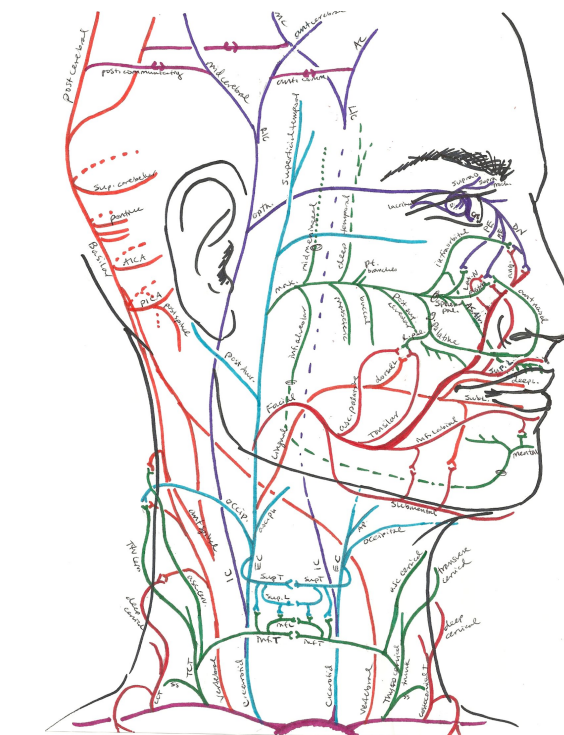
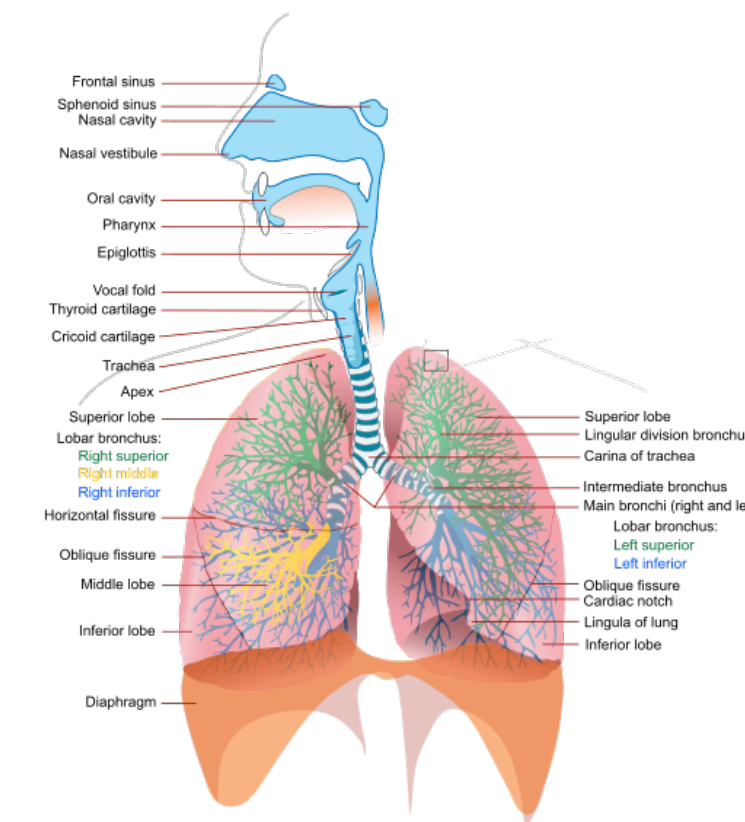
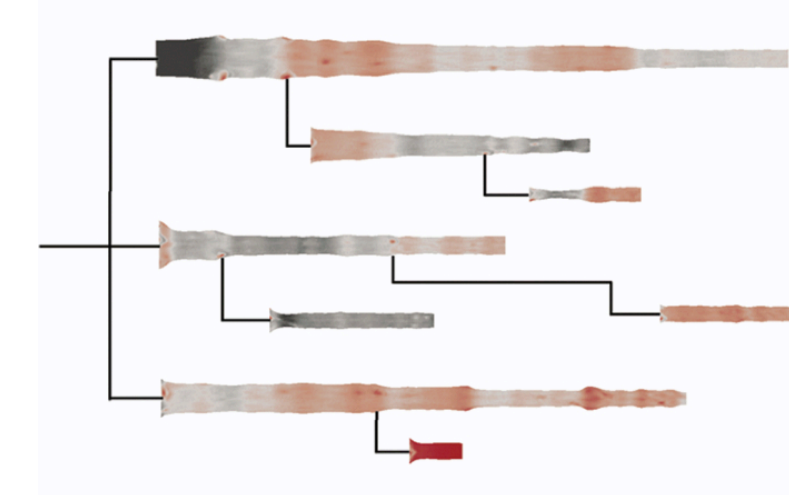
- Rainbow color map

- ▶ 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





MICHELLE BORKIN

<http://bit.ly/mborkin>



@michelle\_borkin

borkin@cs.ubc.ca

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