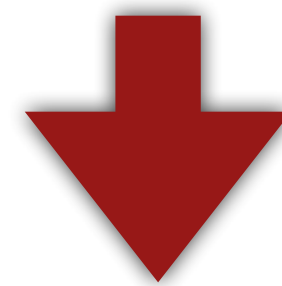
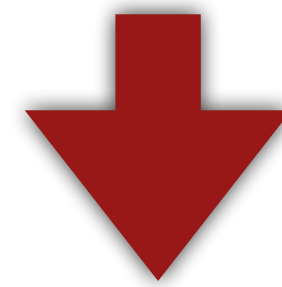


# Cardiac Bioelectricity Case Studies

Jess Tate & Jake Bergquist

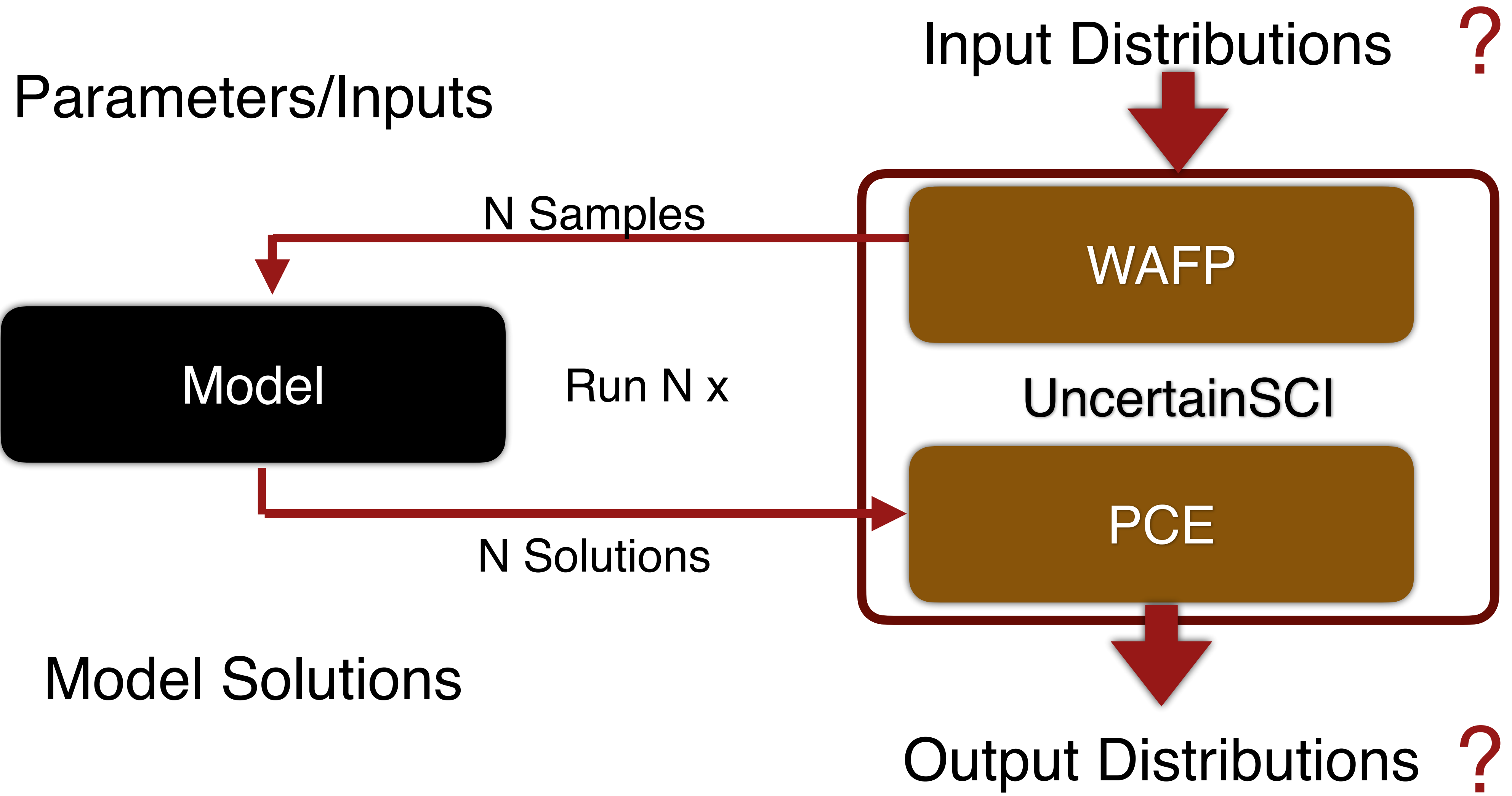
# Forward Modeling

Parameters/Inputs ?



Model Solutions ?

# UncertainSCI



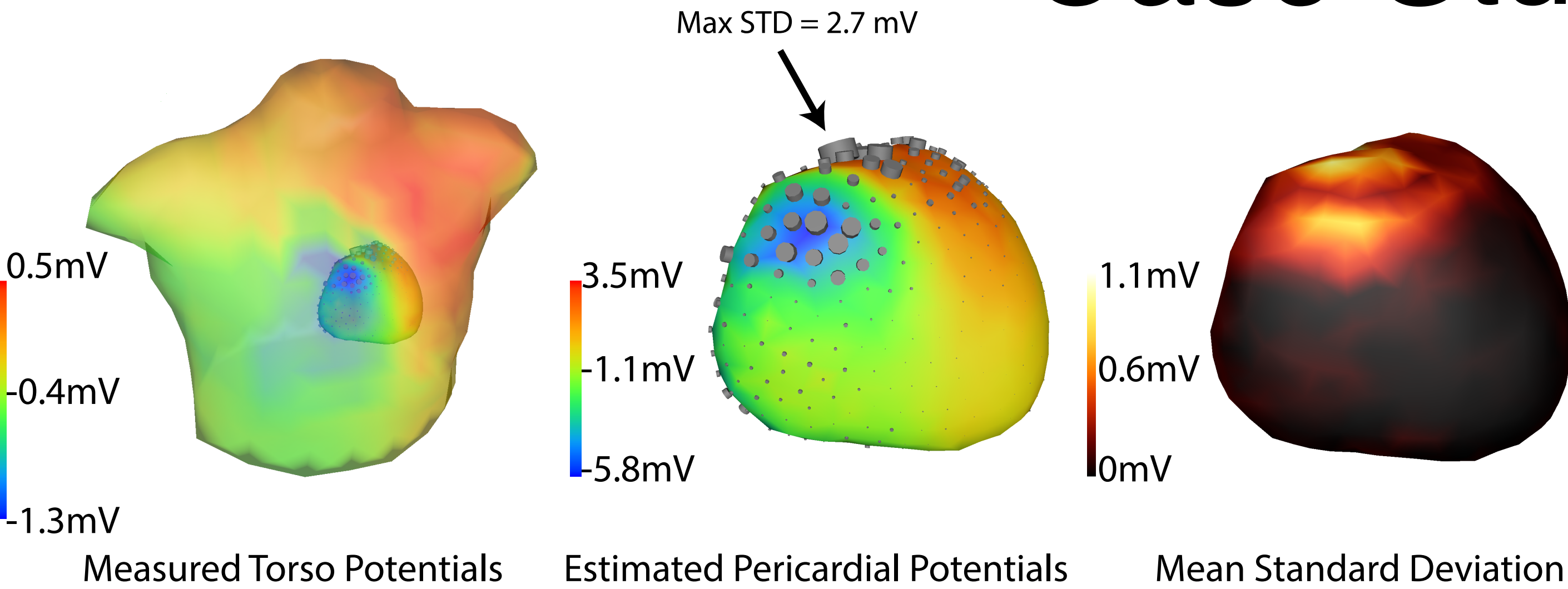
# Knowing Input Uncertainty

## Analysing/Visualizing UQ Results

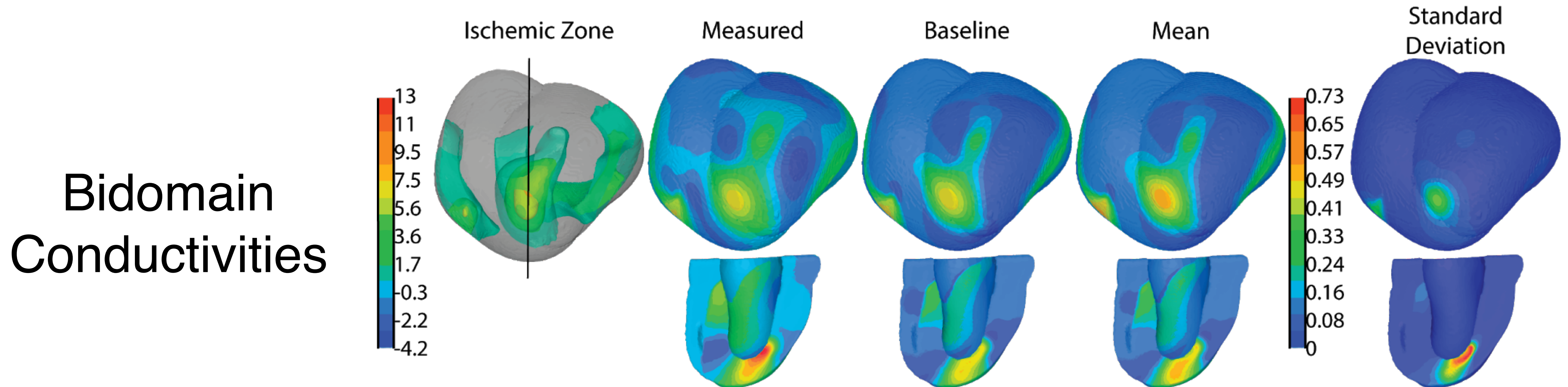
# Active Areas of Research

Intuition, Literature, Data

# Case Studies



## Segmentation Shape in ECGI

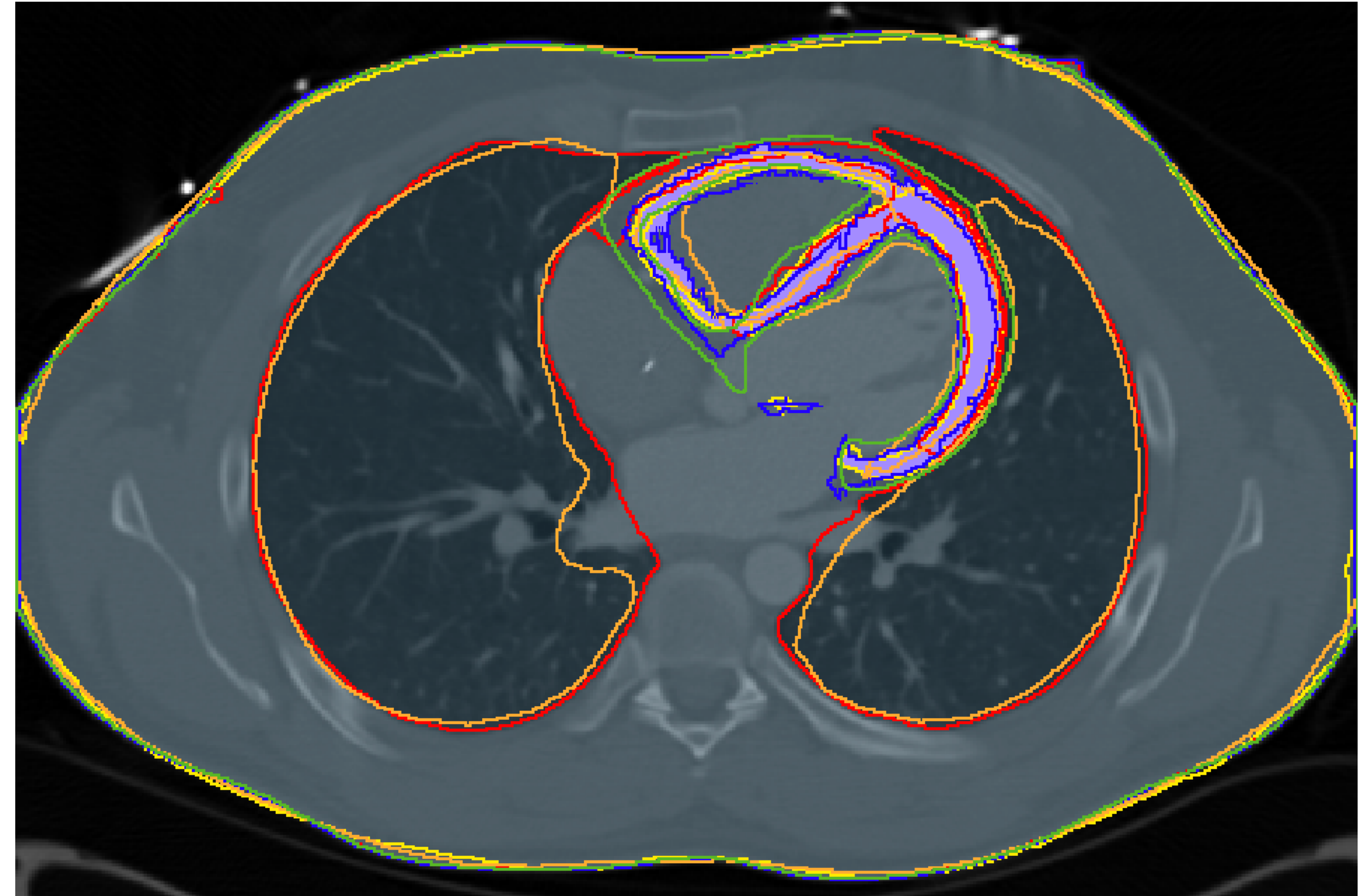
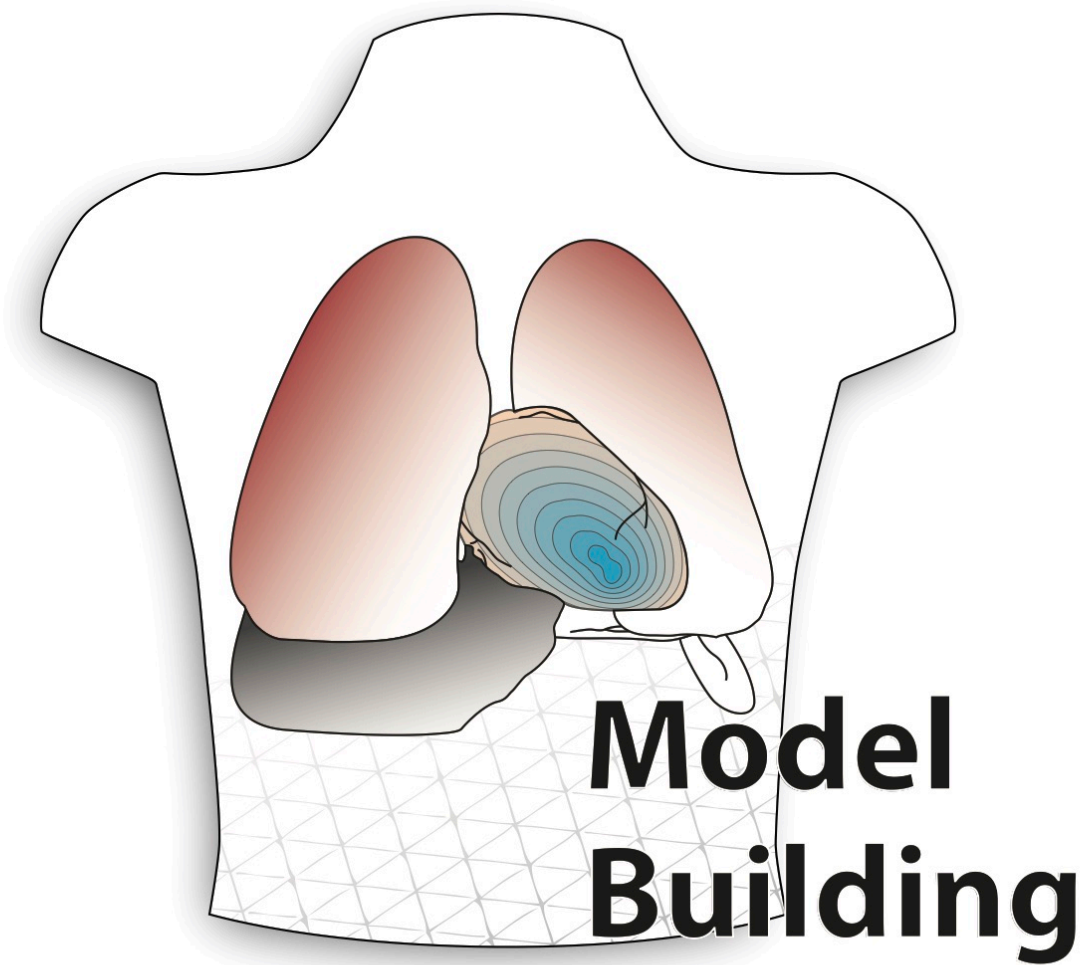


# Segmentation Shape UQ in ECGI

FMIH 2021: Tate etal.

# CEI: Modeling Error Workgroup

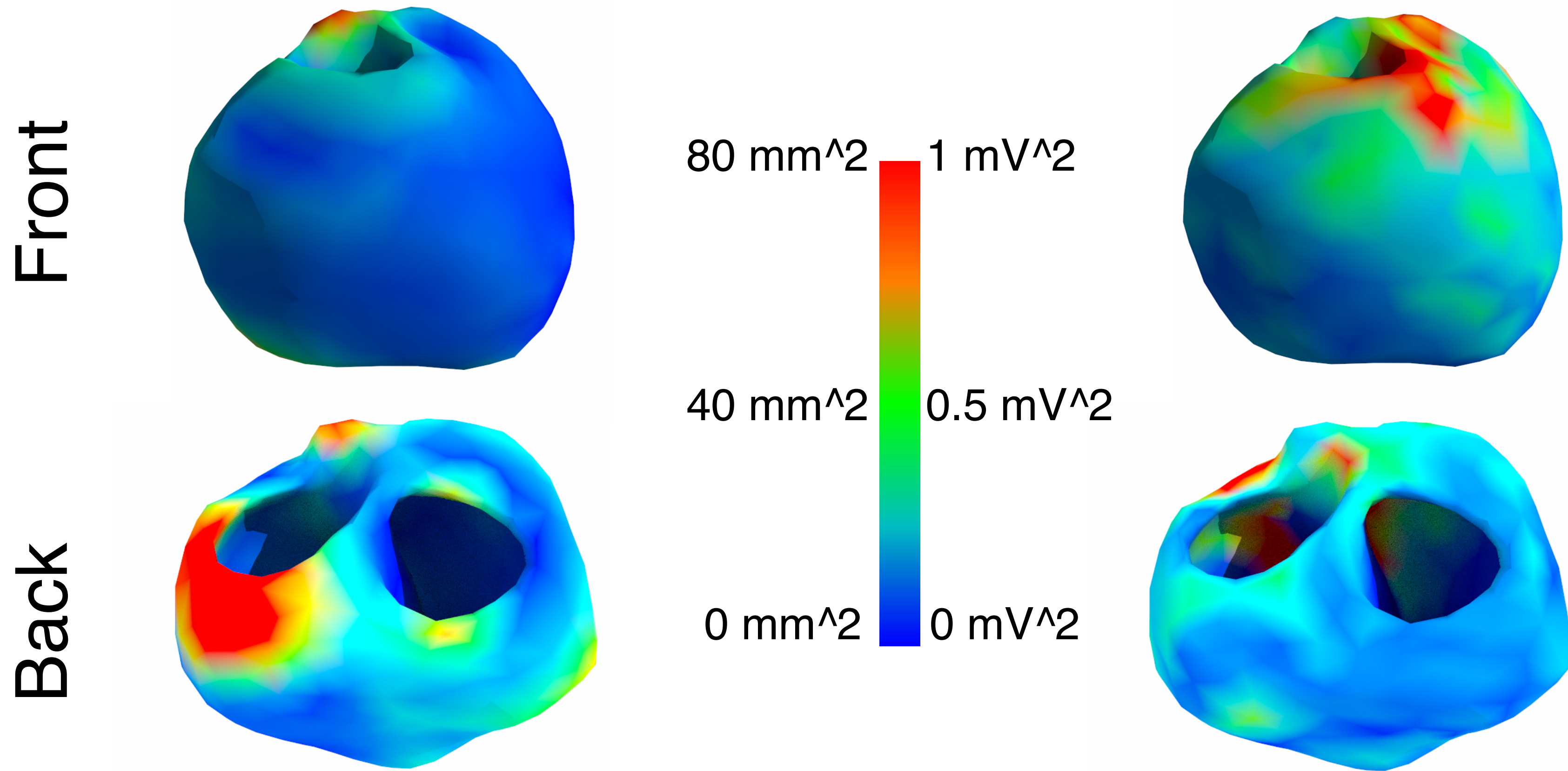
(Consortium for ECG Imaging)



Quantify the effects of error



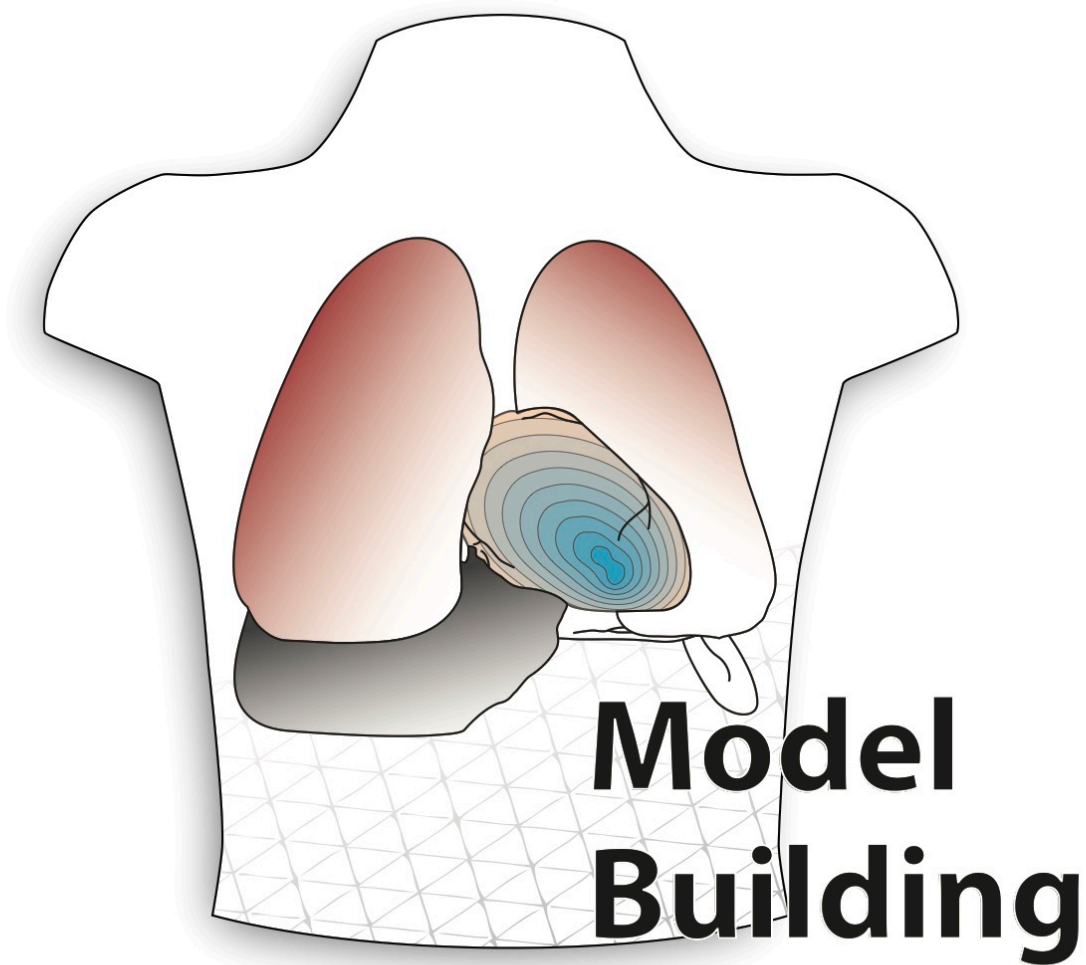
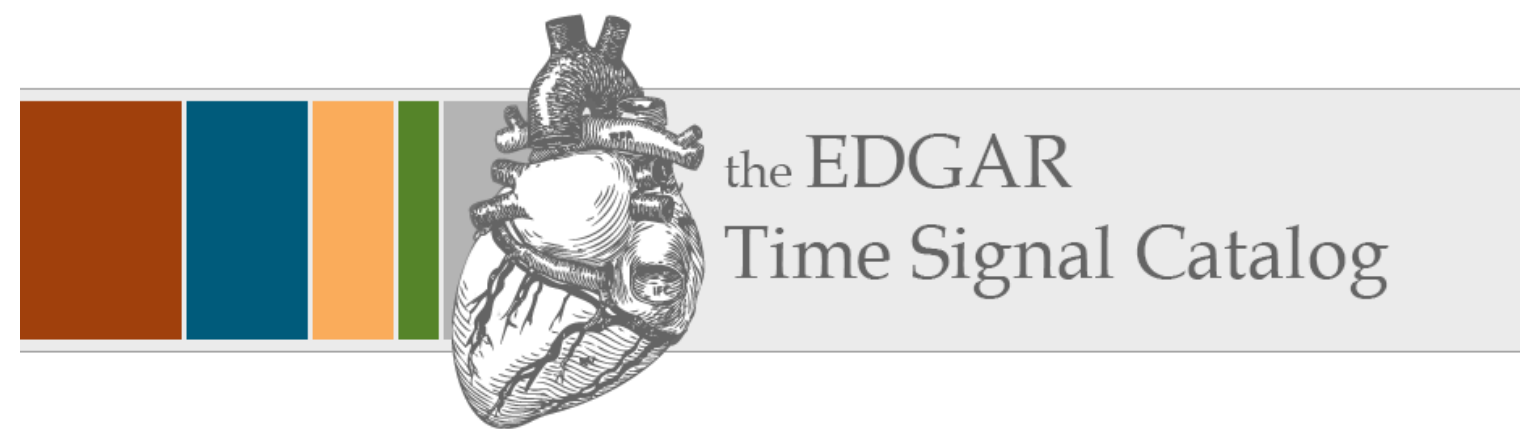
# Variance of Solutions and Meshes



Mesh Variance

Solution Variance

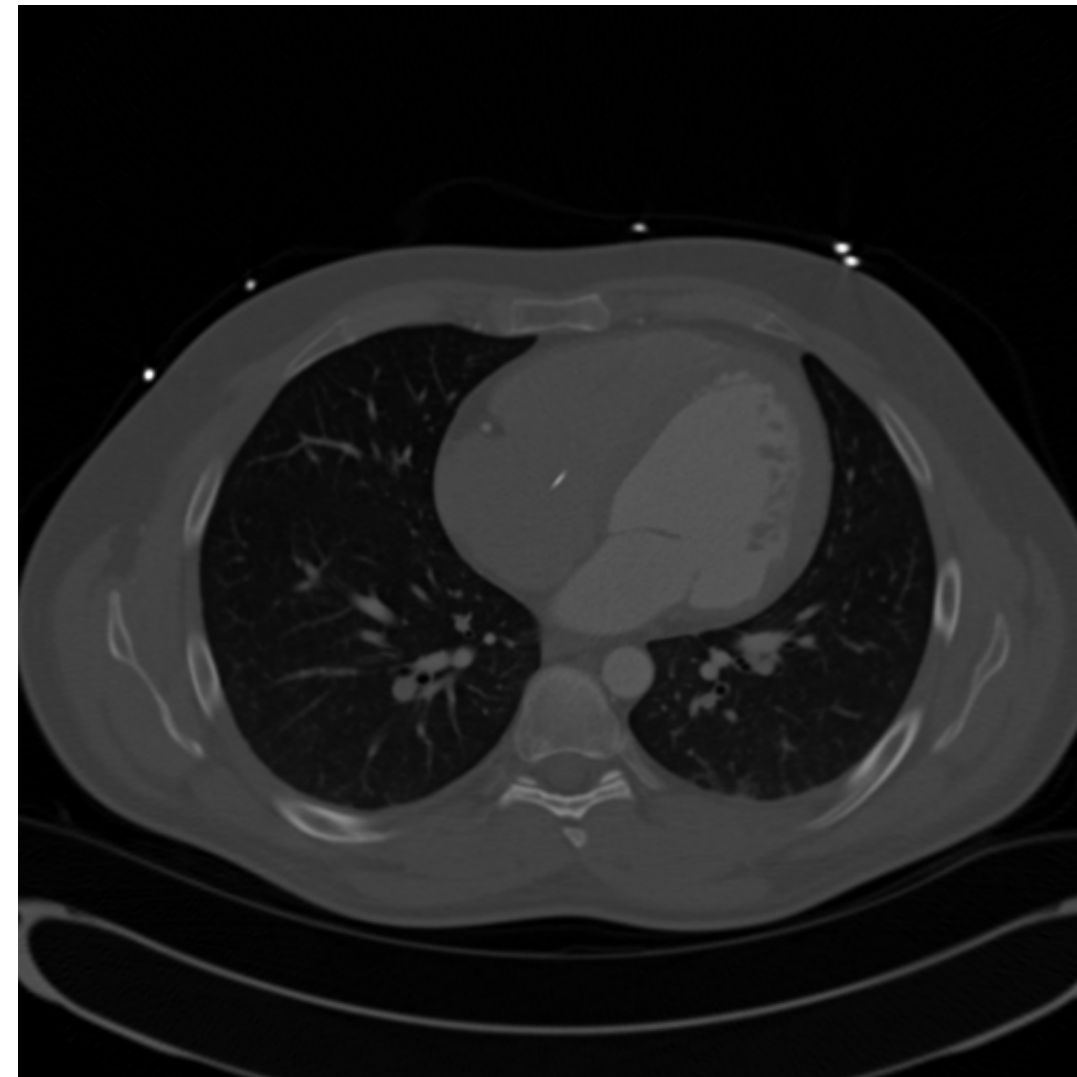
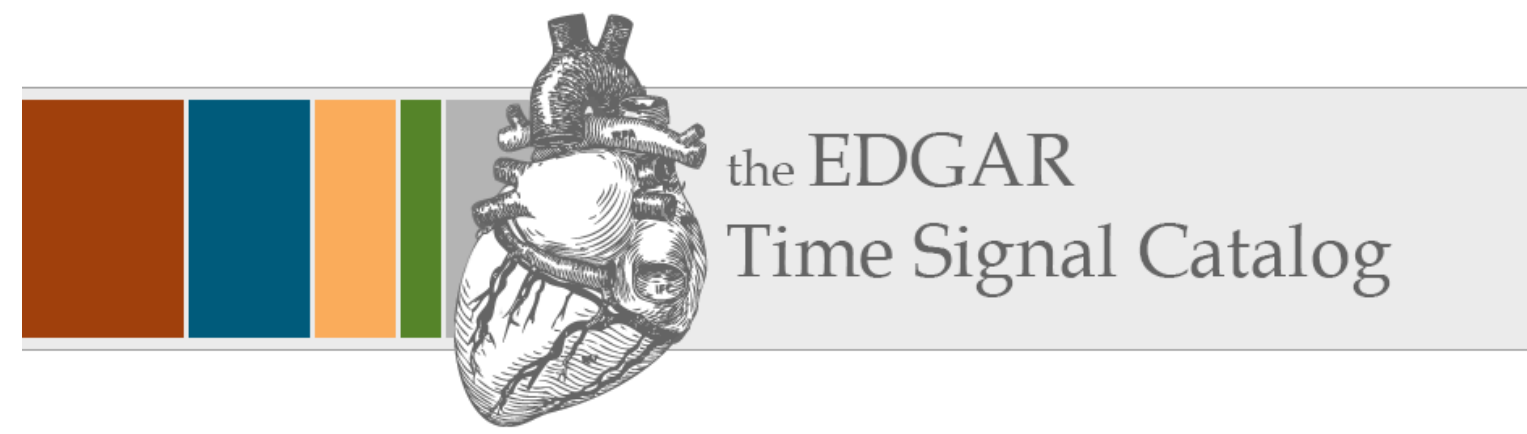
# Data Collection



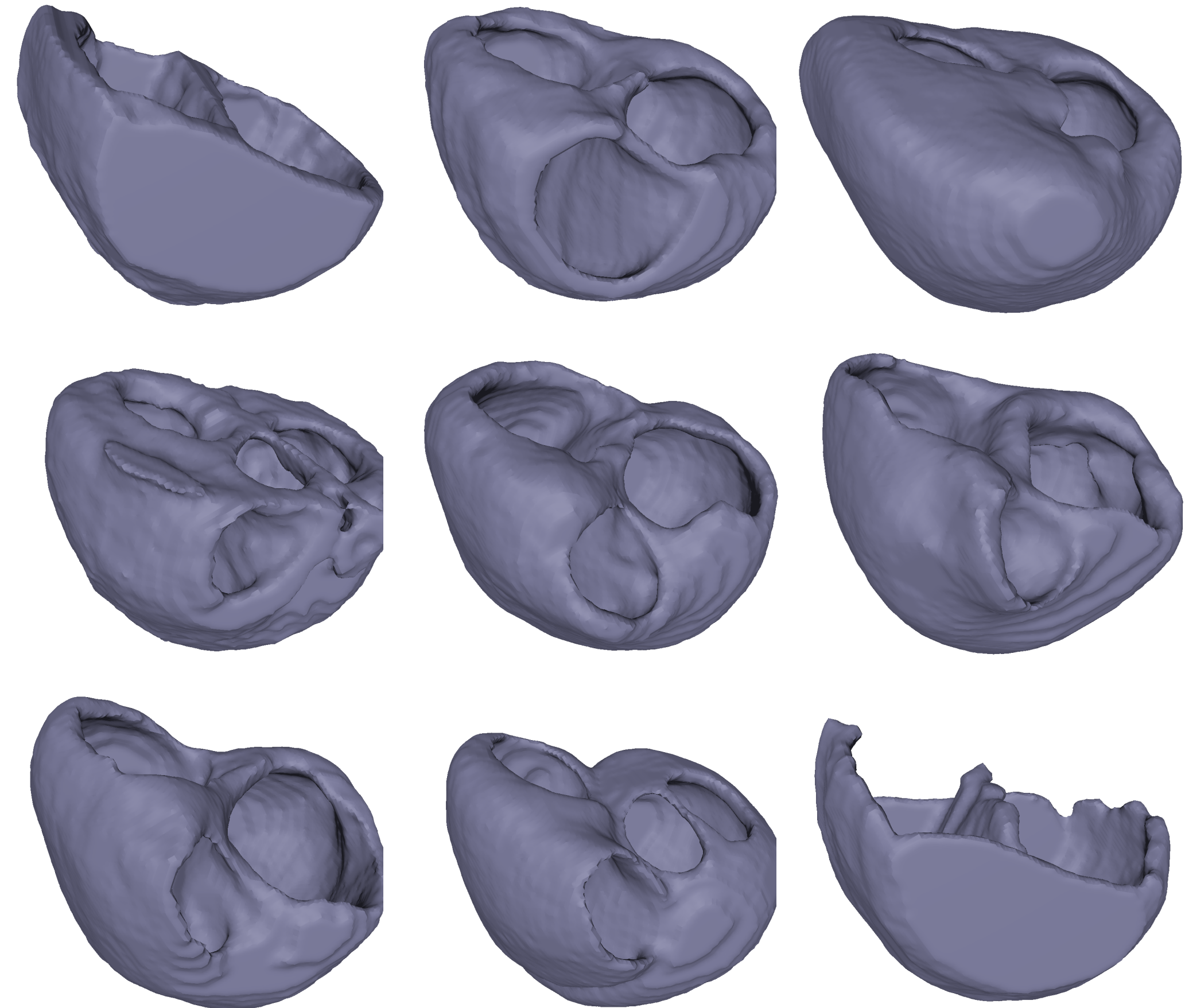
Patient Data Located on EDGAR

Segmentations Supplied by Members  
of the CEI working group

# Segmentations

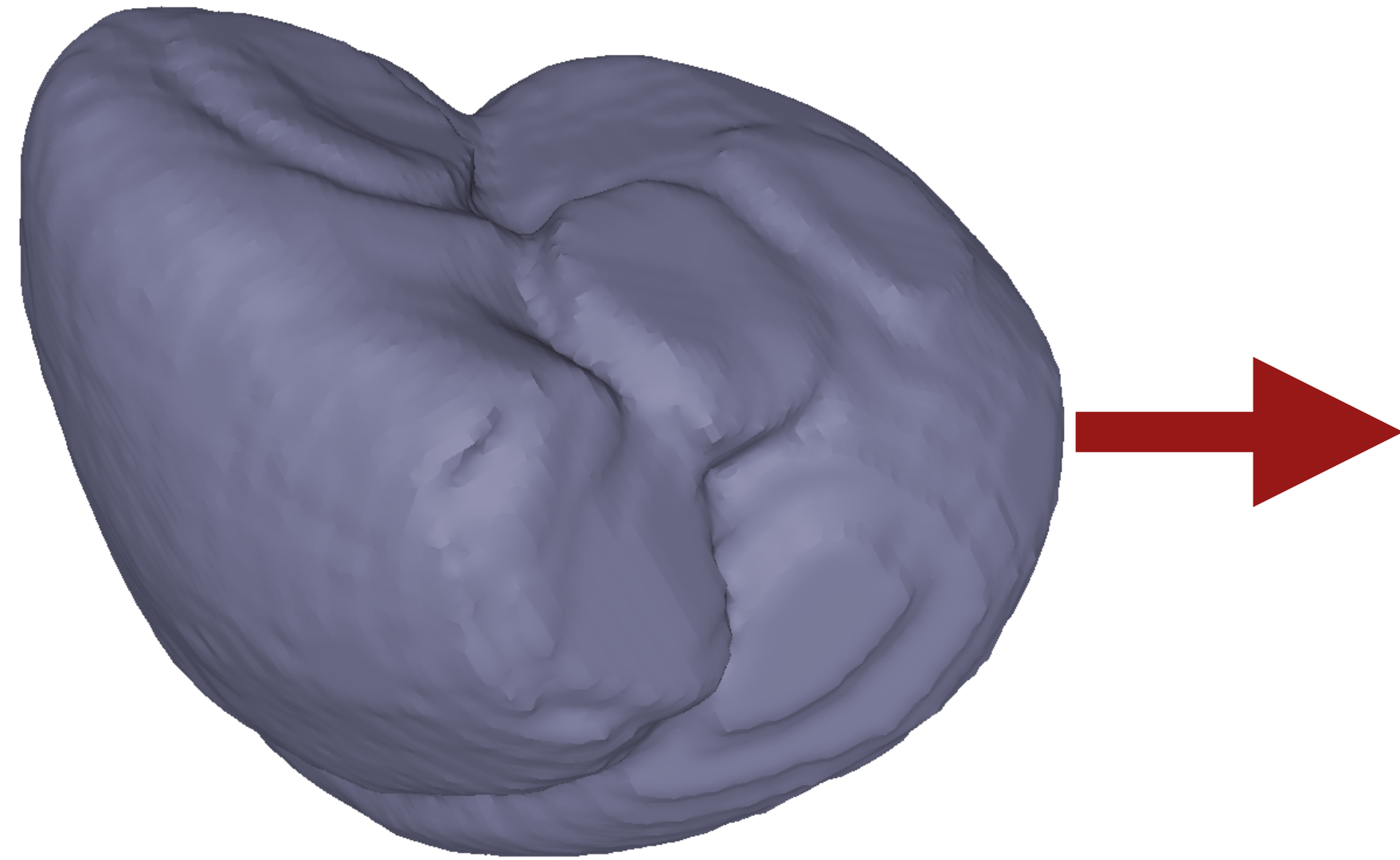


CT scan

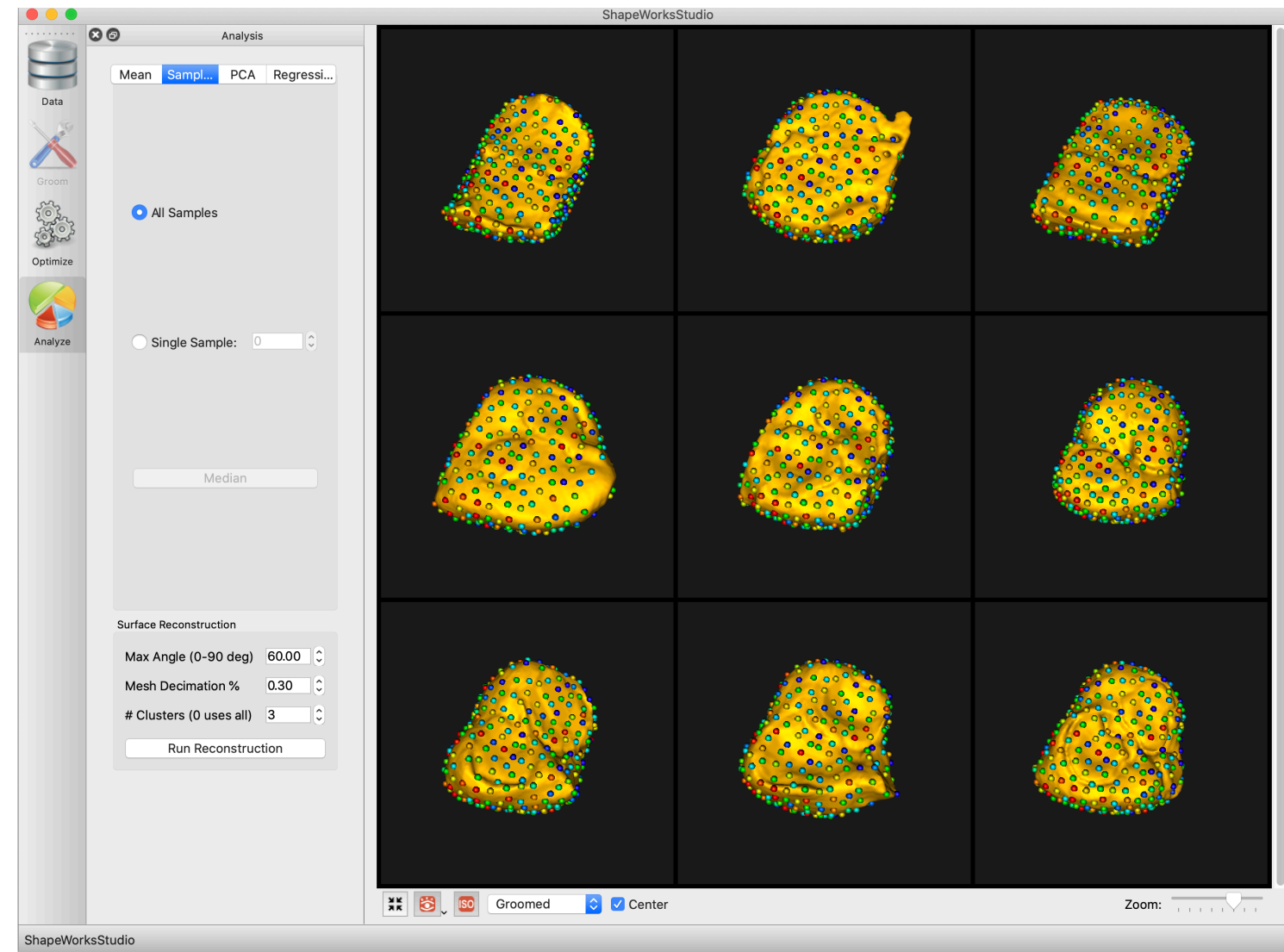


Nine Segmentations

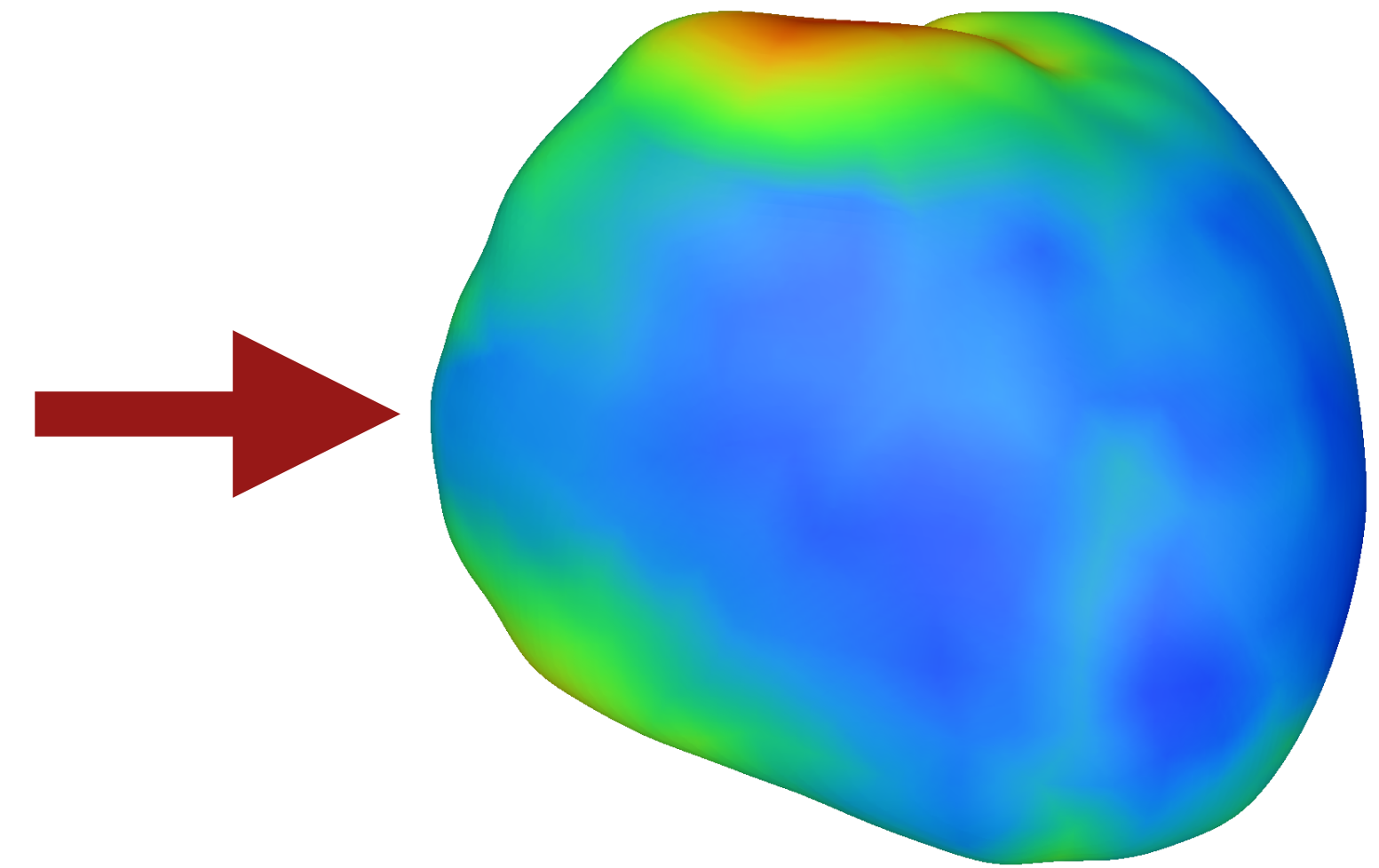
# Pipeline



User  
Segmentations

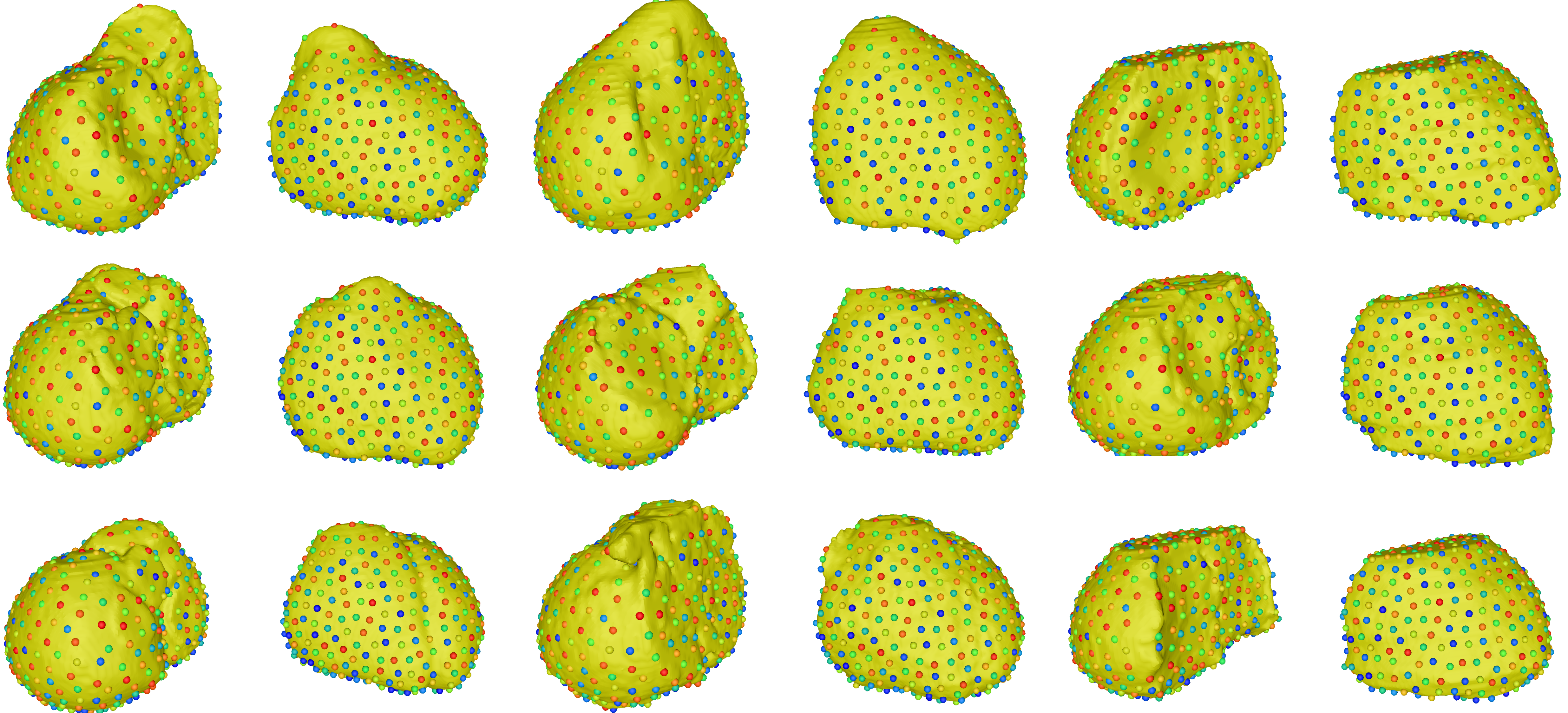


ShapeWorks  
Correspondence



Statistics  
and PCA

# Epicardial Correspondence



Back

Front

Back

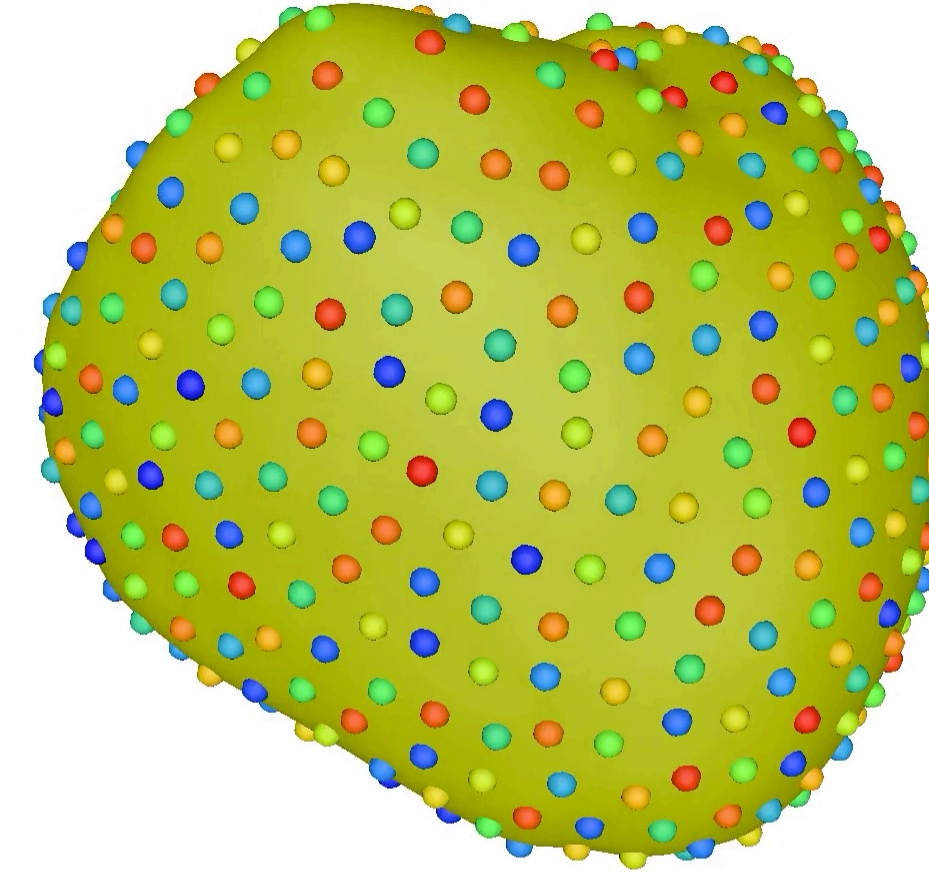
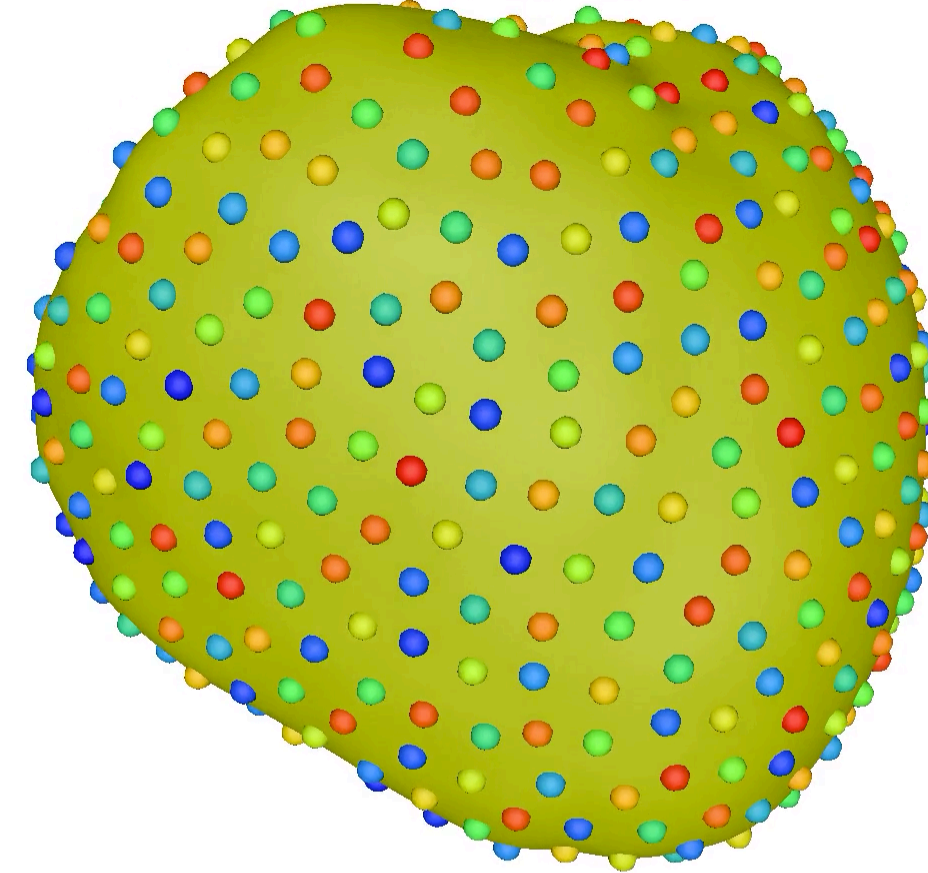
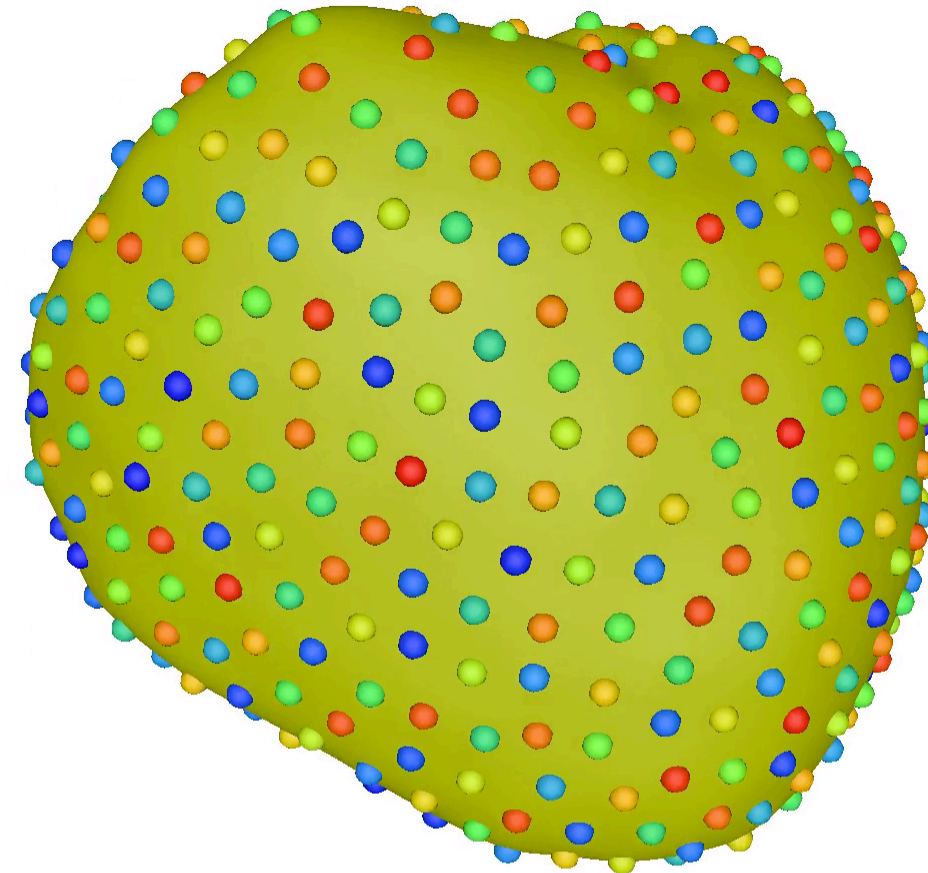
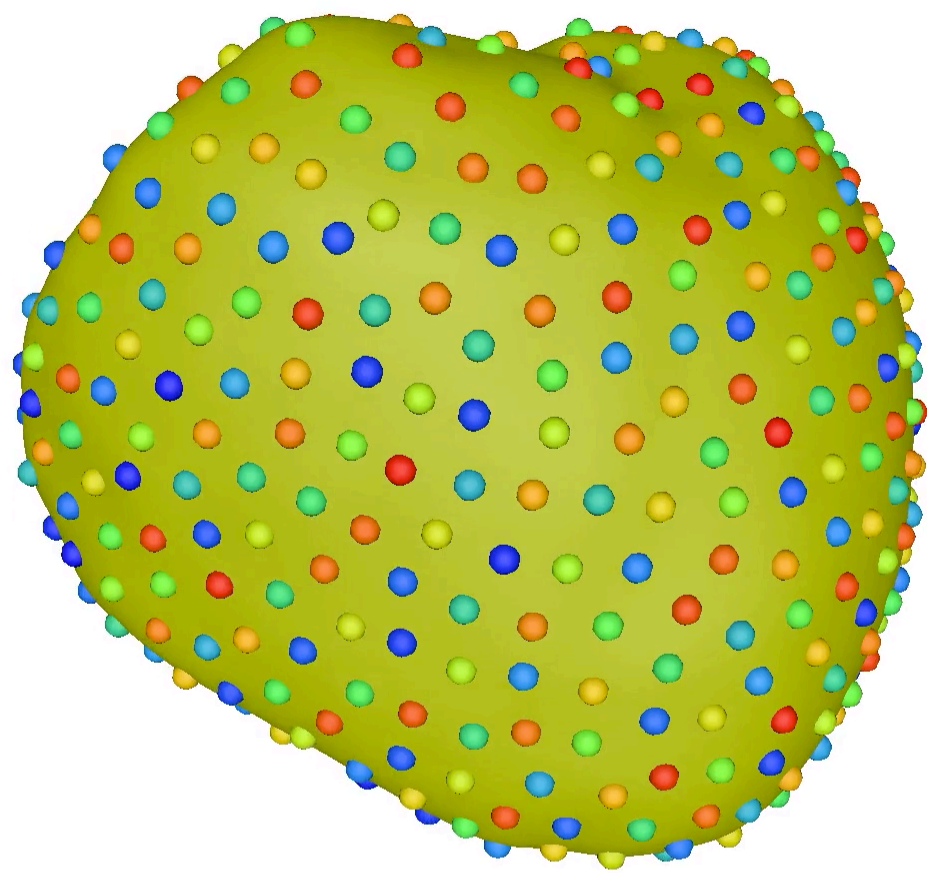
Front

Back

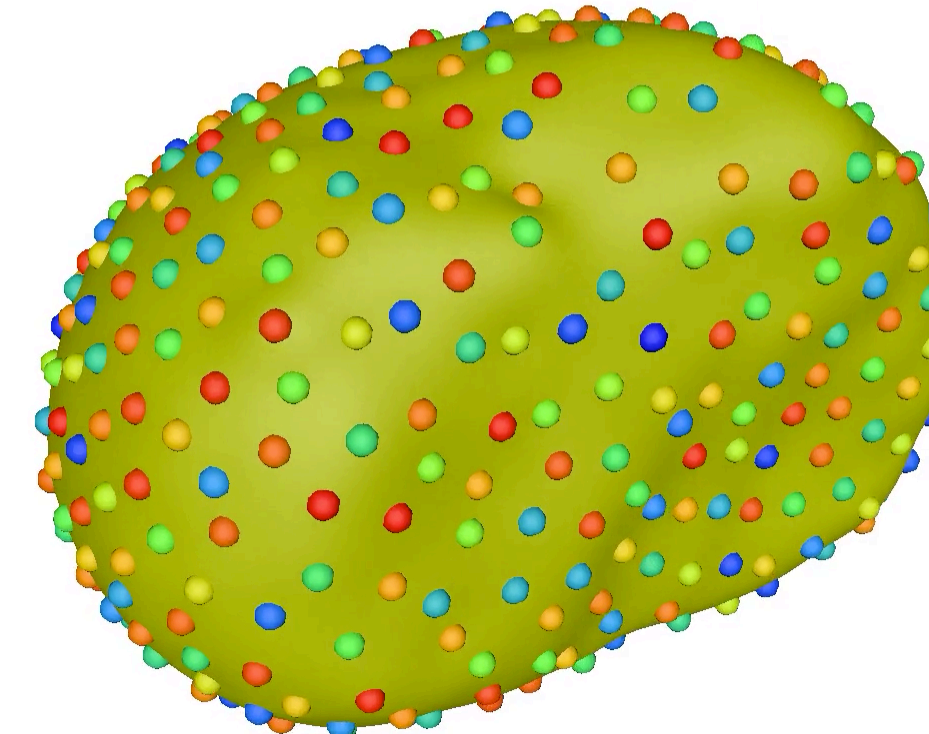
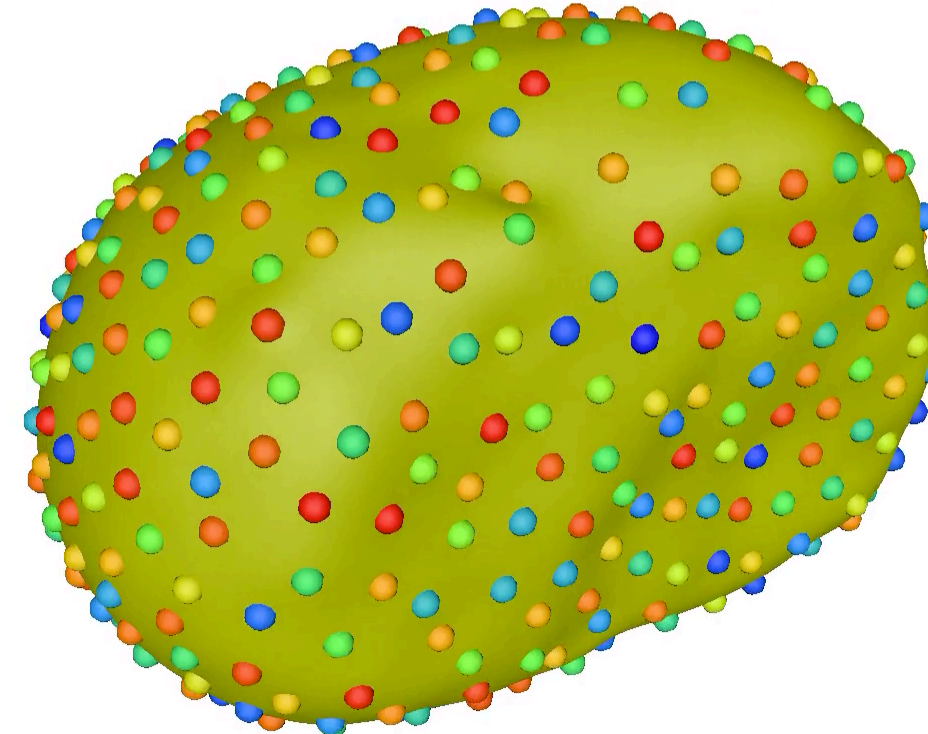
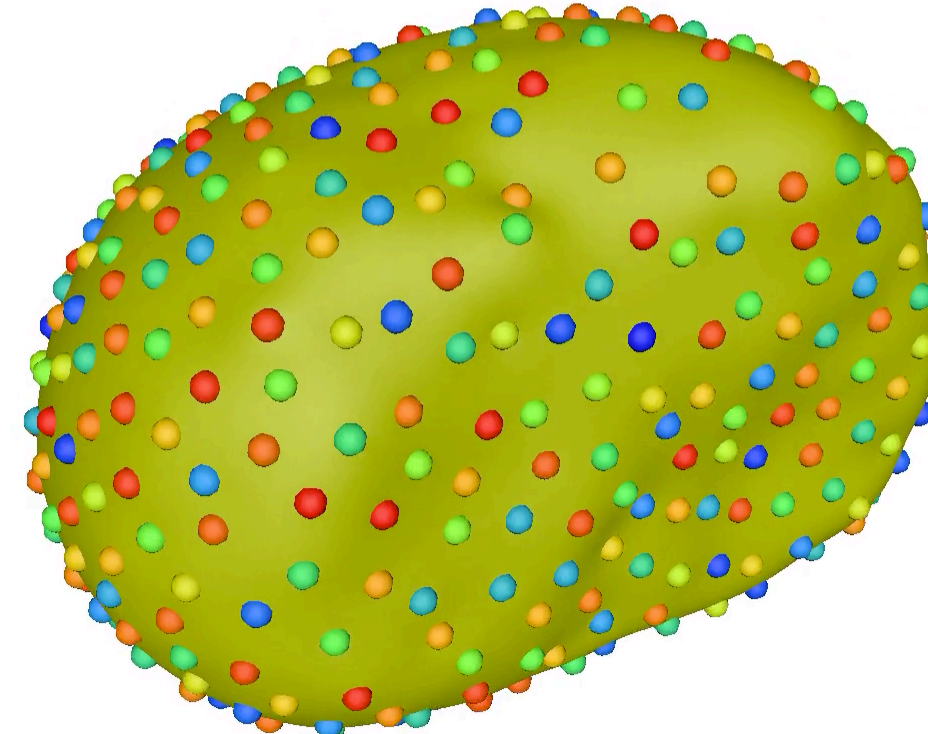
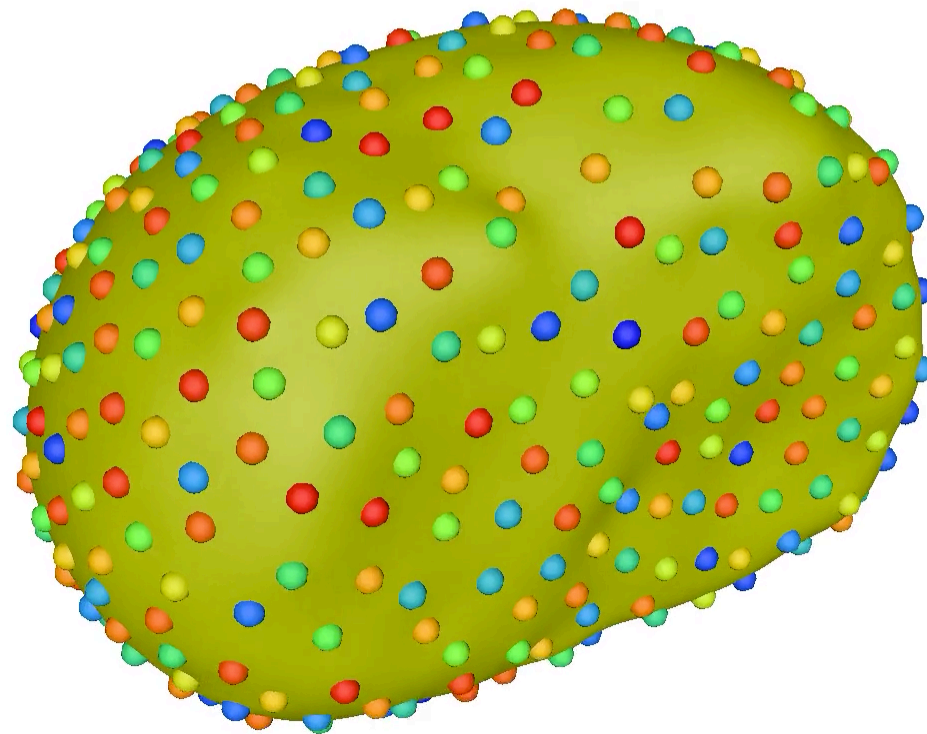
Front

# Epicardium PCA

Front



Back



Axis 0

Axis 1

Axis 2

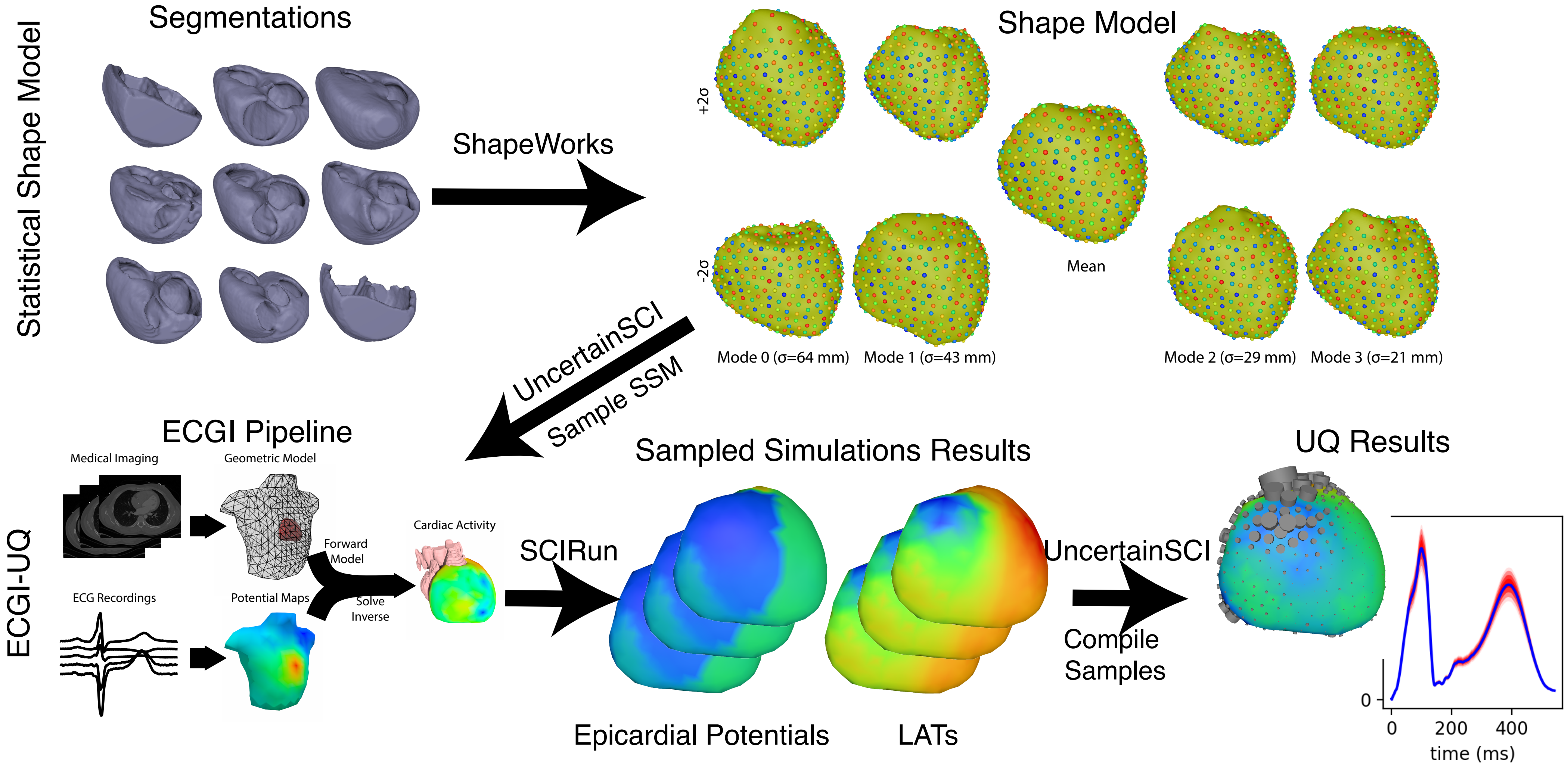
Axis 3

# Shape Model

PC Axes (Shape Modes)

Distributions on Axes (Uniform)

# Segmentation Shape UQ Pipeline



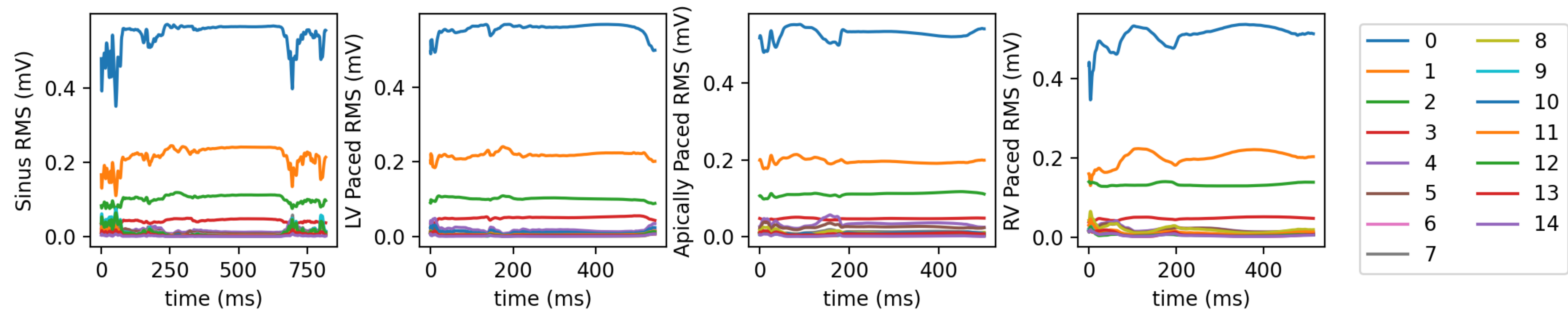
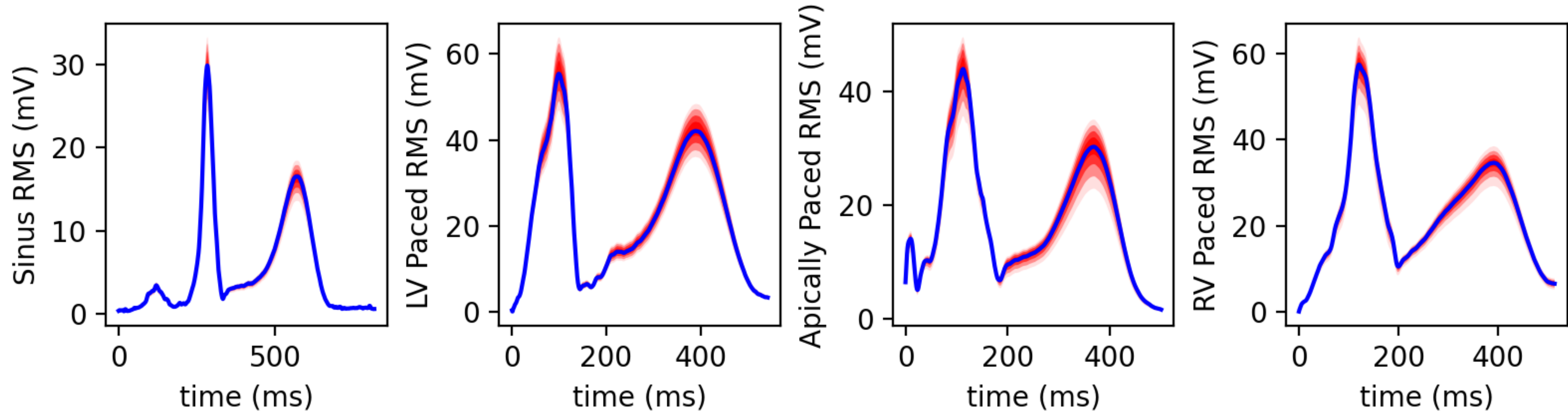


# Analyzing/Visualizing UQ Results

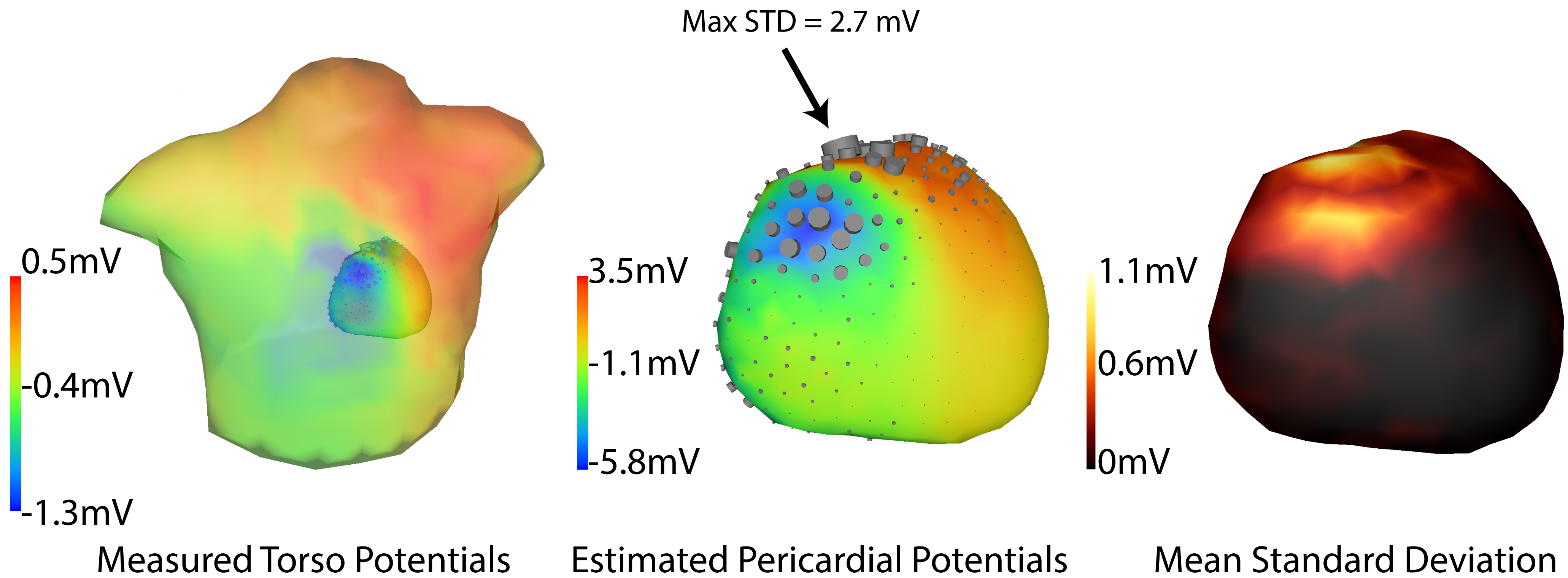
Potentials - 3D Spatial and temporal

Local Activation Times (LAT) - non-linear

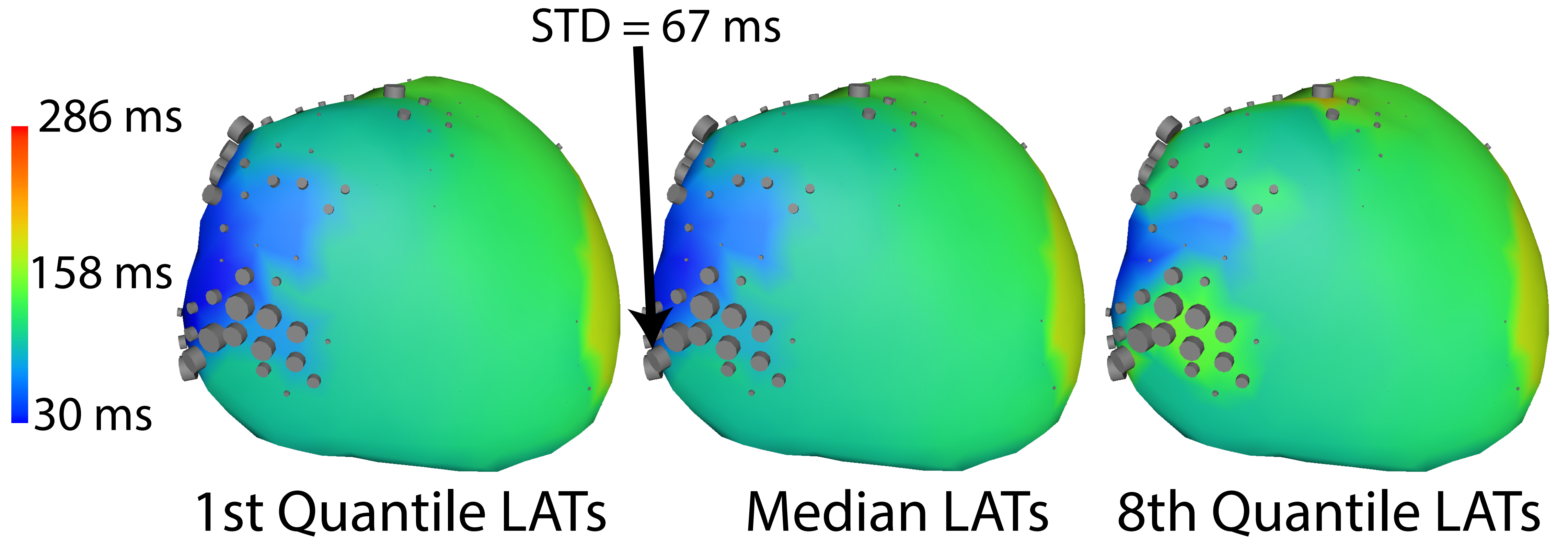
# Temporal RMS



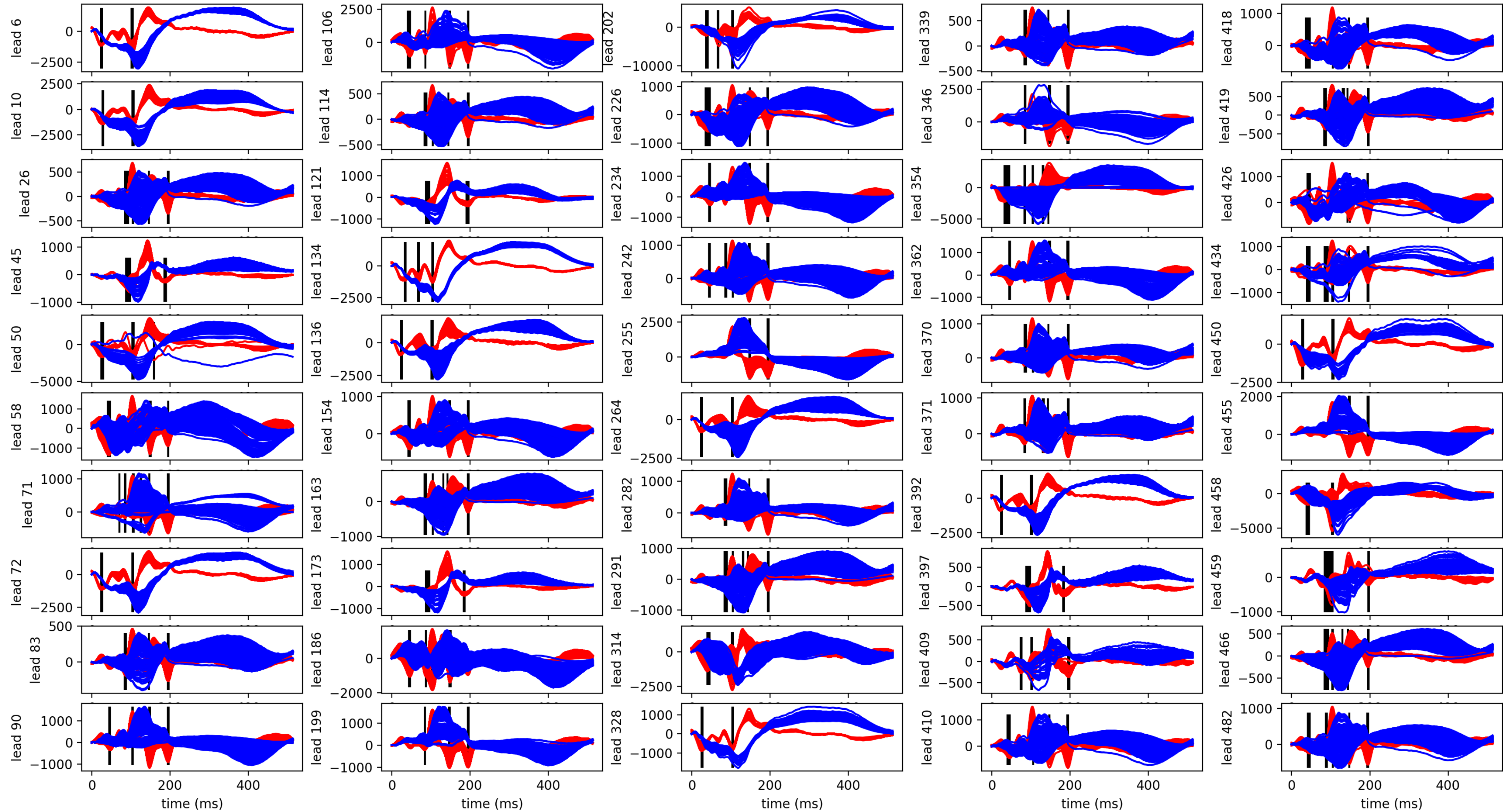
# Potential Distribution

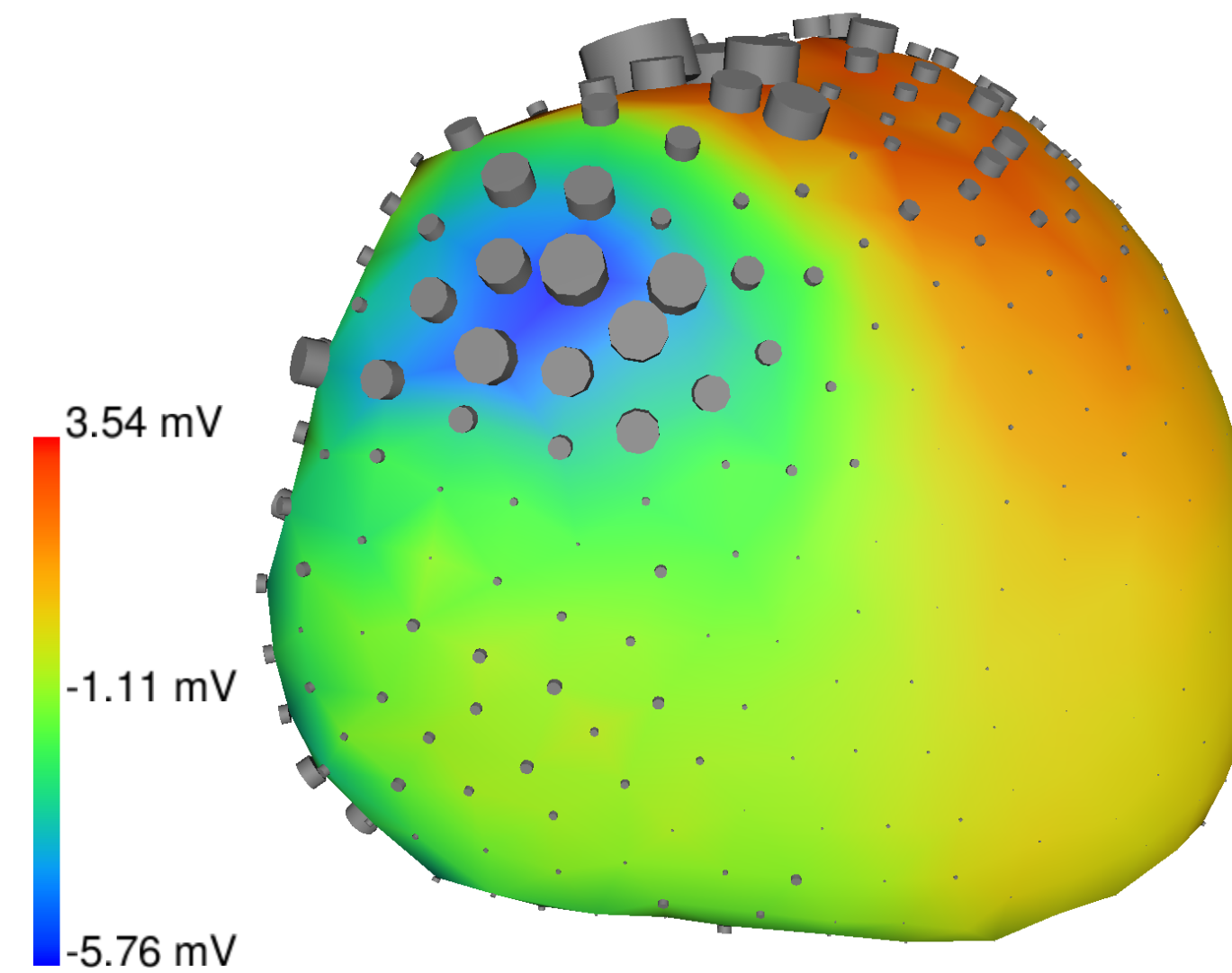
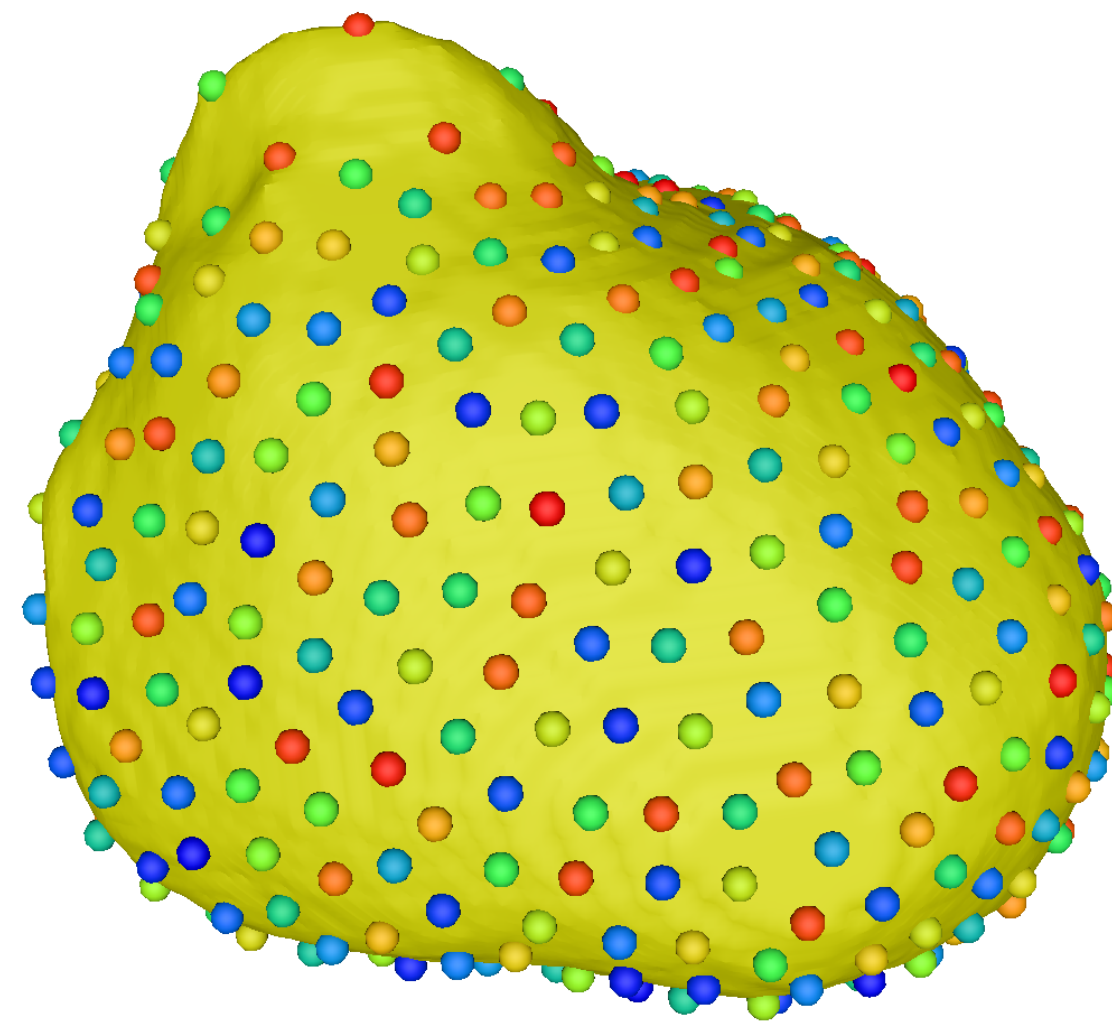


# Local Activation Times



# High Variability LATs





# Strategies for input characterization and visualization

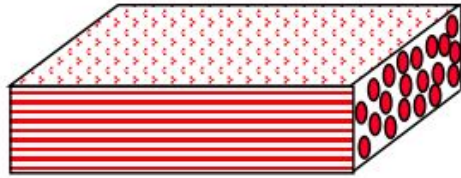
# Conductivity UQ in Static Bidomain

Cinc 2021 Presentations: Jake Bergquist, Lindsay Rupp

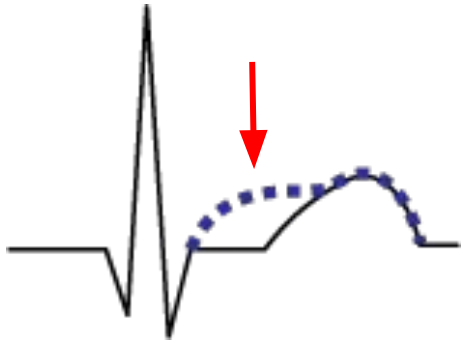
## Passive Bidomain



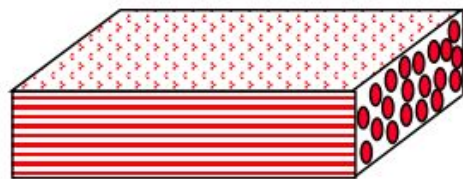
## Passive Bidomain



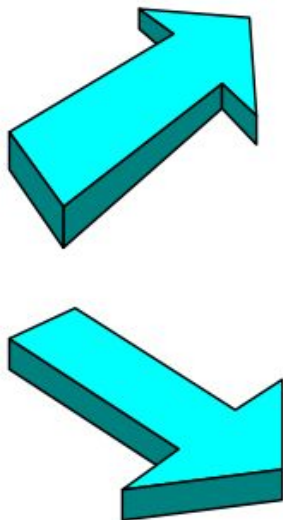
Tissue



## Passive Bidomain



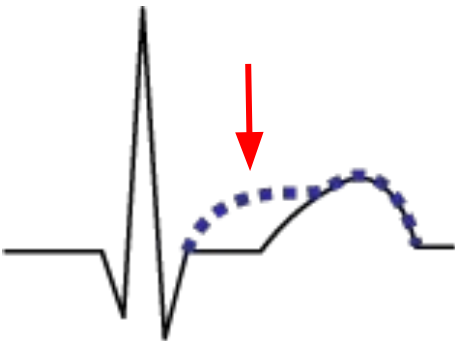
Tissue



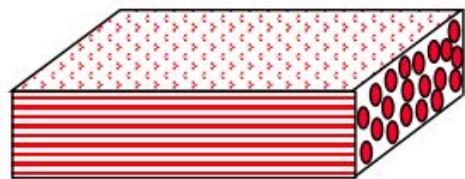
Continuum 1: Extracellular space  
(Interstitial space)



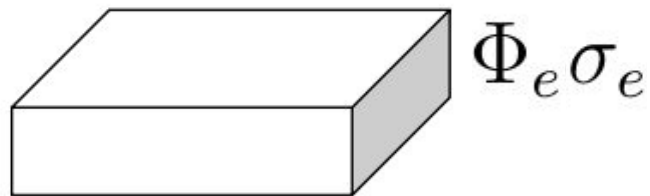
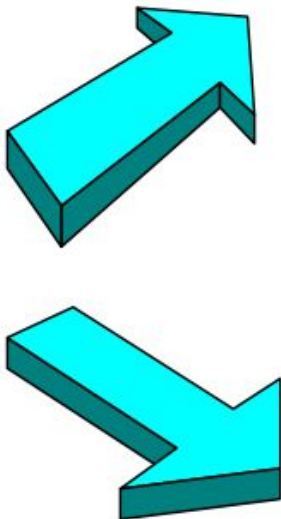
Continuum 2: Intracellular space



# Passive Bidomain



Tissue



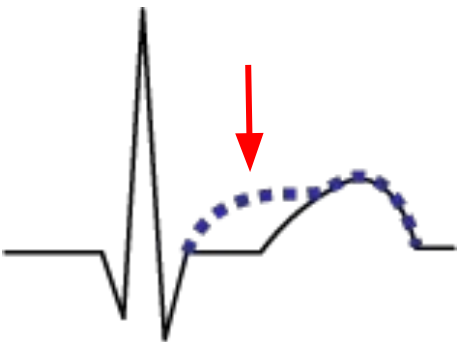
$$\Phi_e \sigma_e$$

Continuum 1: Extracellular space  
(Interstitial space)



$$\Phi_i \sigma_i$$

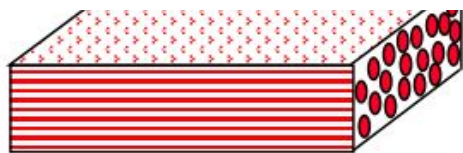
Continuum 2: Intracellular space



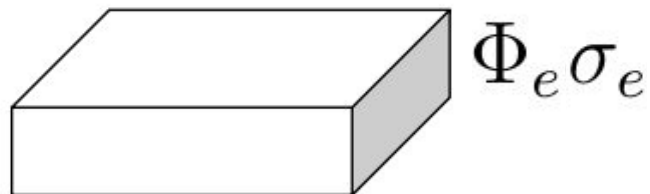
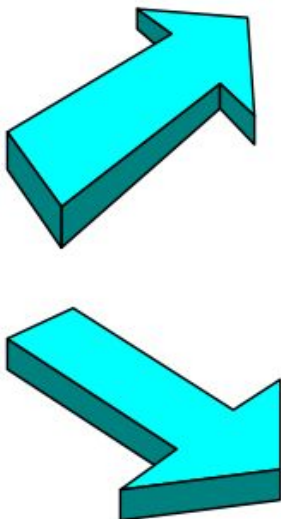
## Passive Bidomain

$$\sigma_b = \sigma_i + \sigma_e$$

$$\Phi_m = \Phi_i - \Phi_e$$



Tissue



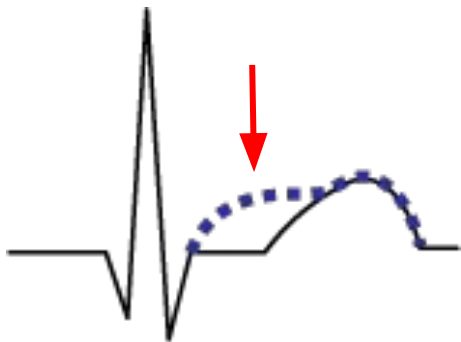
$$\Phi_e \sigma_e$$

Continuum 1: Extracellular space  
(Interstitial space)



$$\Phi_i \sigma_i$$

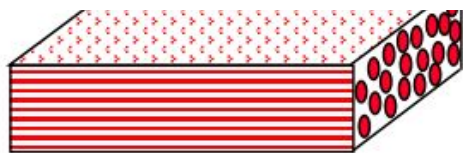
Continuum 2: Intracellular space



## Passive Bidomain

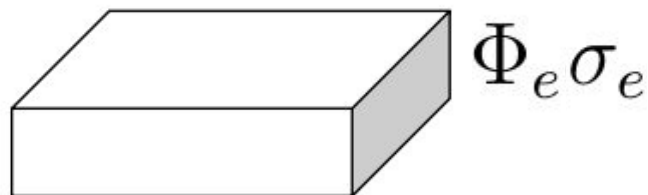
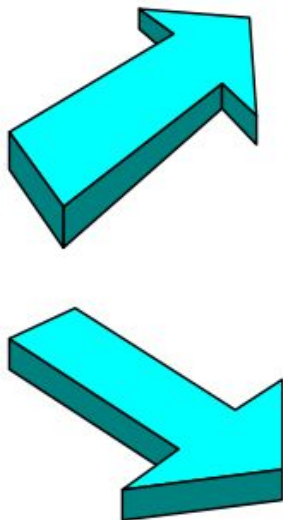
$$\sigma_b = \sigma_i + \sigma_e$$

$$\Phi_m = \Phi_i - \Phi_e$$



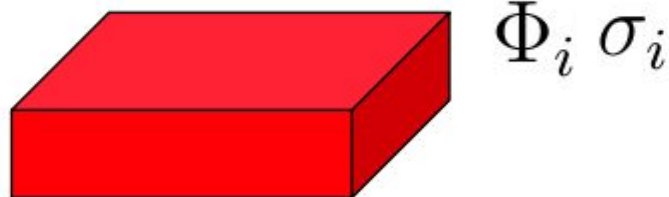
Tissue

$$-\nabla \cdot \sigma_b \nabla \Phi_e = \nabla \cdot \sigma_i \nabla \Phi_m$$



$$\Phi_e \sigma_e$$

Continuum 1: Extracellular space  
(Interstitial space)



$$\Phi_i \sigma_i$$

Continuum 2: Intracellular space

$$-\nabla \cdot \sigma_b \nabla \Phi_e = \nabla \cdot \sigma_i \nabla \Phi_m$$

$$-\nabla \cdot \sigma_b \nabla \Phi_e = \nabla \cdot \sigma_i \nabla \Phi_m$$



unknown



Known

$$-\nabla \cdot \sigma_b \nabla \Phi_e = \nabla \cdot \sigma_i \nabla \Phi_m$$

$$\sigma_b = \sigma_i + \sigma_e$$

Conductivity	Healthy Tissue	Ischemic Tissue
$\sigma_{iL}$	1	1/10
$\sigma_{eL}$	1	1/2
$\sigma_{iT}$	1/10	1/1000
$\sigma_{eT}$	1/3	1/4
$\sigma_{iB}$	0	0
$\sigma_{eB}$	3	3

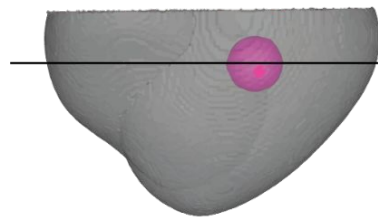


$$-\nabla \cdot \sigma_b \nabla \Phi_e = \nabla \cdot \sigma_i \nabla \Phi_m$$

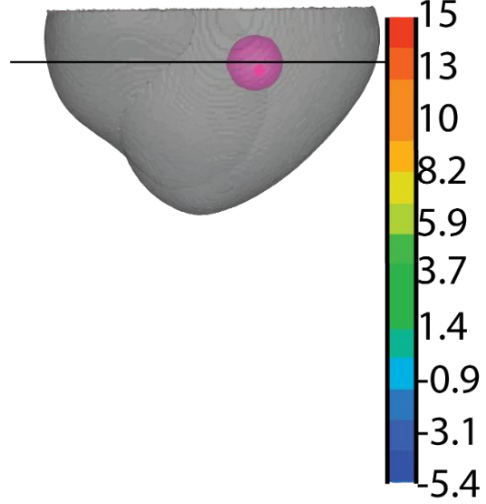
$$\sigma_b = \sigma_i + \sigma_e$$

Conductivity	Healthy Tissue	Ischemic Tissue
$\sigma_{iL}$	1	1/10
$\sigma_{eL}$	1	1/2
$\sigma_{iT}$	1/10	1/1000
$\sigma_{eT}$	1/3	1/4
$\sigma_{iB}$	0	0
$\sigma_{eB}$	3	3

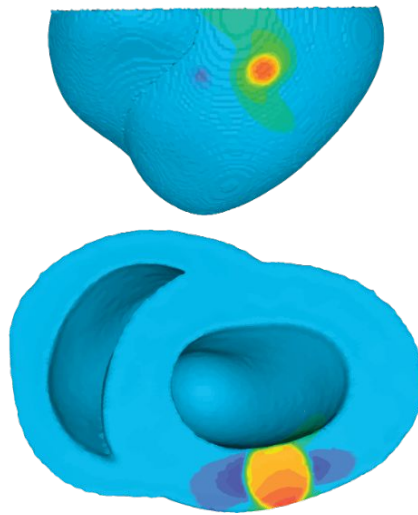
Ischemic Zone



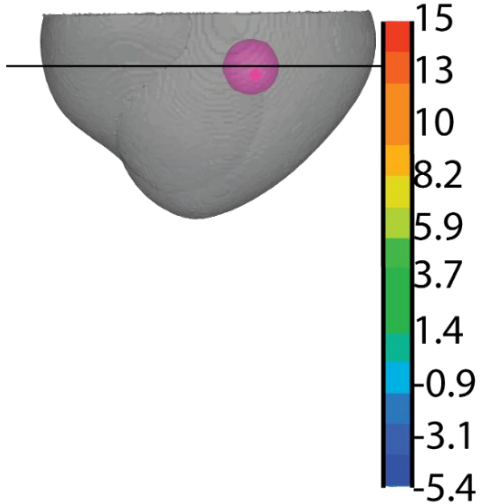
Ischemic Zone



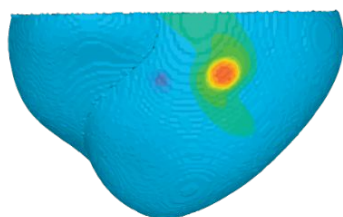
Baseline



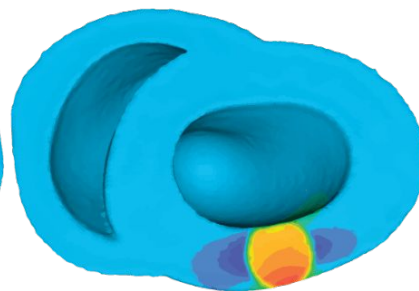
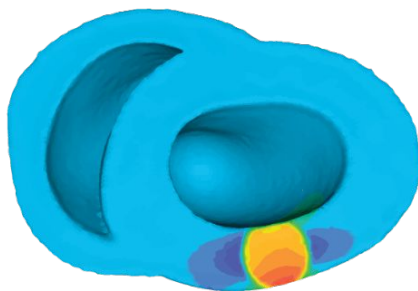
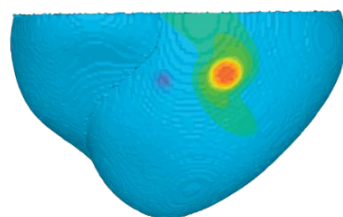
Ischemic Zone



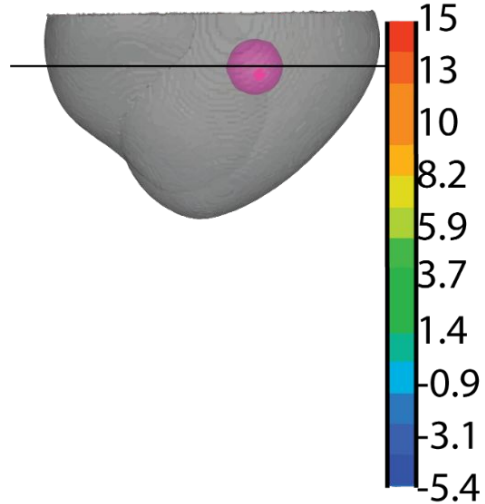
Baseline



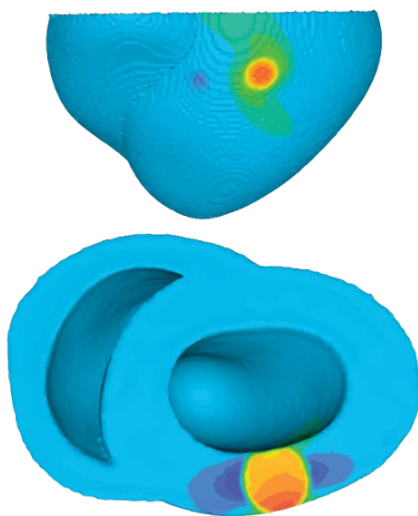
Mean



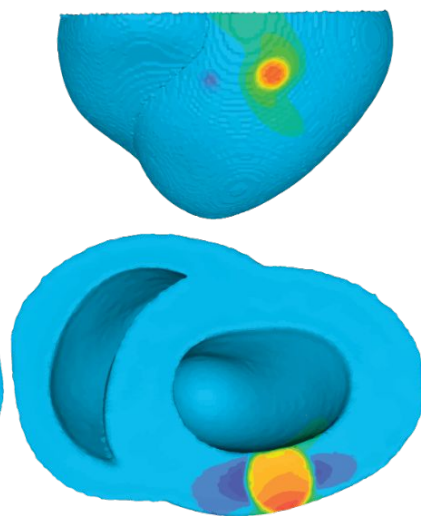
Ischemic Zone



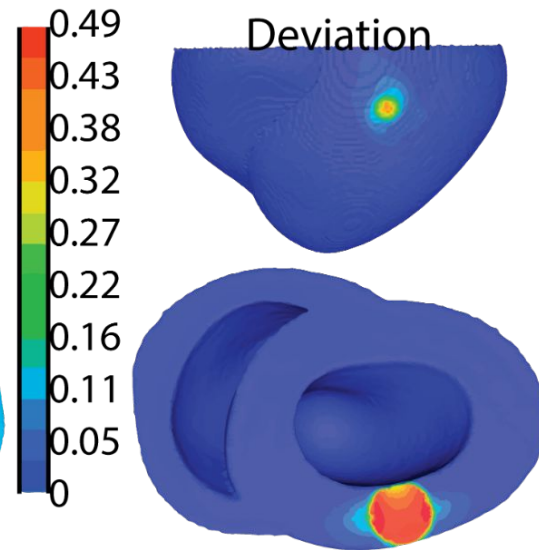
Baseline



Mean

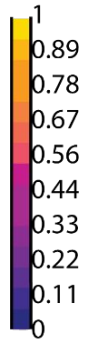


Standard Deviation



## Total Sensitivities

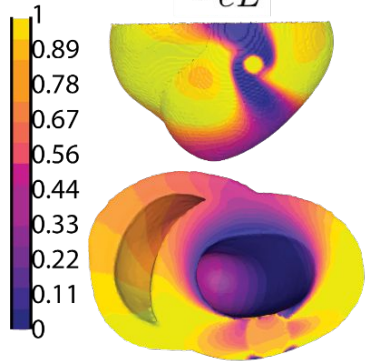
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# Total Sensitivities

---

$\sigma_{eL}$

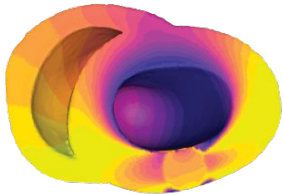
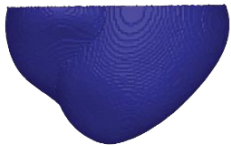
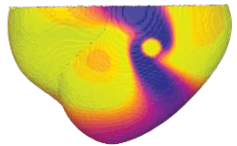
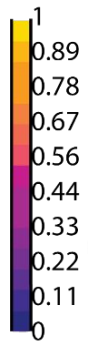


# Total Sensitivities

---

$\sigma_{eL}$

$\sigma_{eT}$



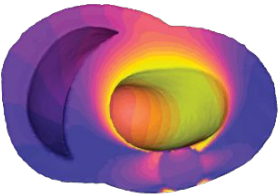
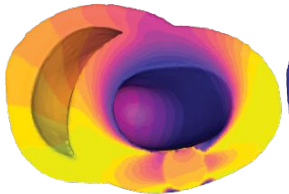
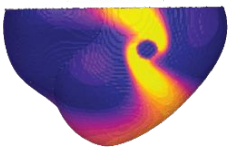
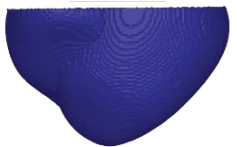
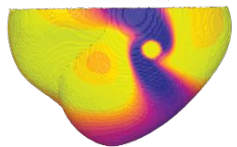
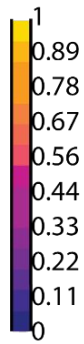


# Total Sensitivities

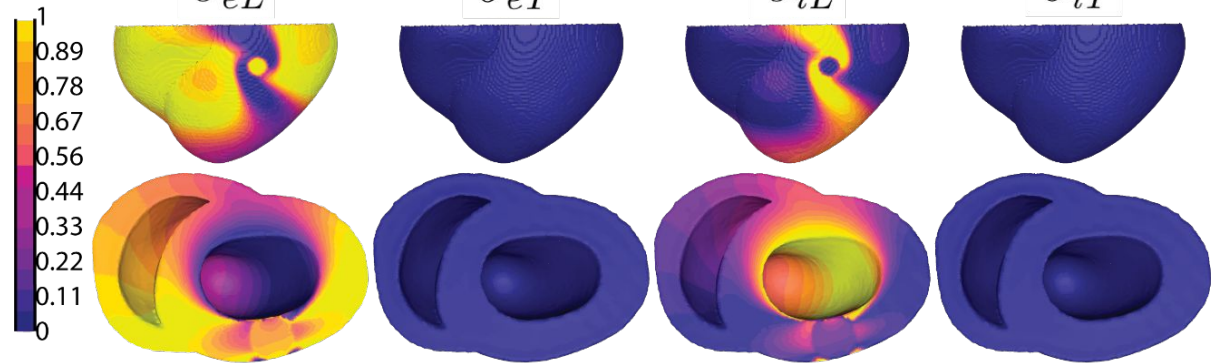
$\sigma_{eL}$

$\sigma_{eT}$

$\sigma_{iL}$



Total Sensitivities



Total Sensitivities

$\sigma_{eL}$

$\sigma_{eT}$

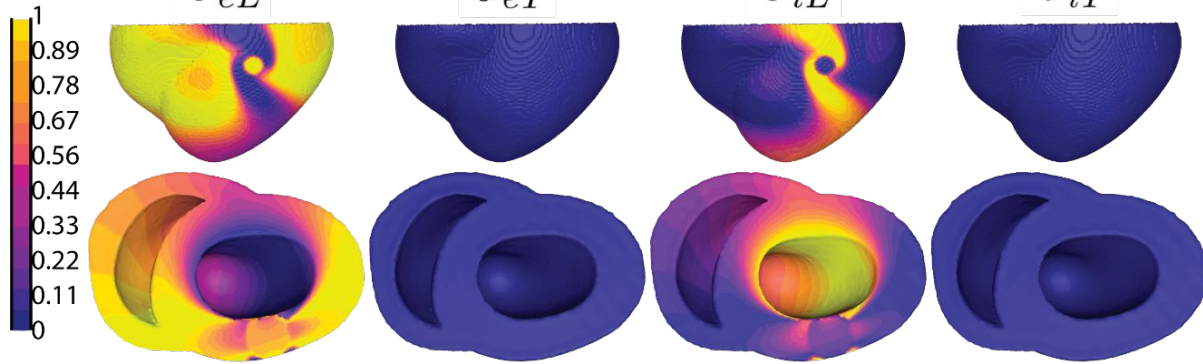
$\sigma_{iL}$

$\sigma_{iT}$

Standard Deviations

$\sigma_{eL}$

$\sigma_{iL}$



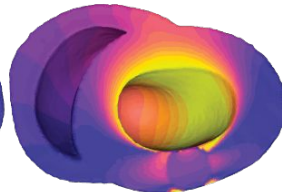
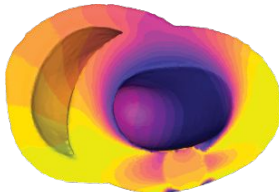
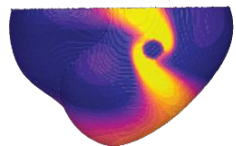
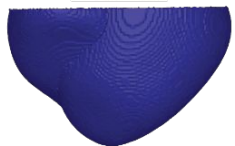
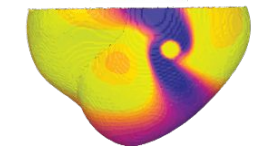
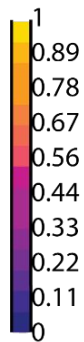
Total Sensitivities

$\sigma_{eL}$

$\sigma_{eT}$

$\sigma_{iL}$

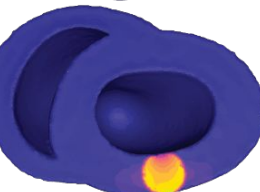
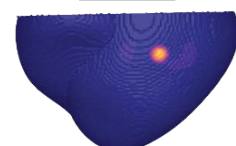
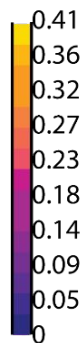
$\sigma_{iT}$



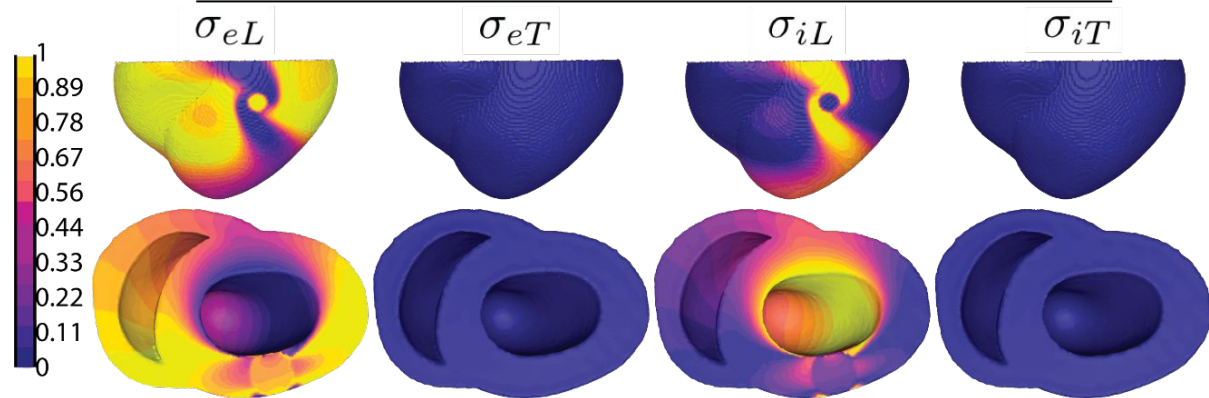
Standard Deviations

$\sigma_{eL}$

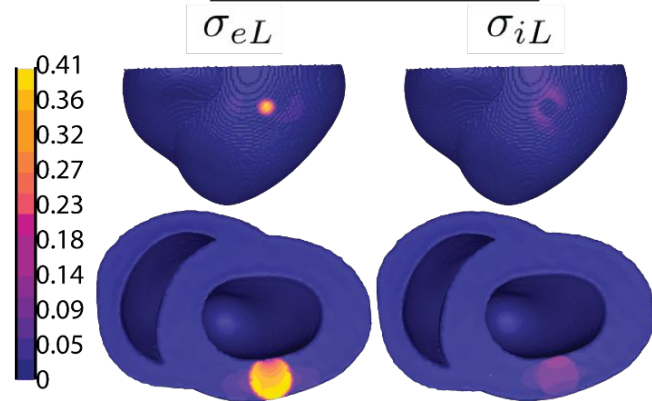
$\sigma_{iL}$



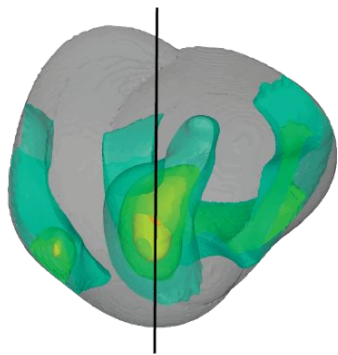
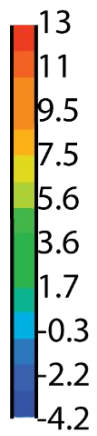
Total Sensitivities



Standard Deviations

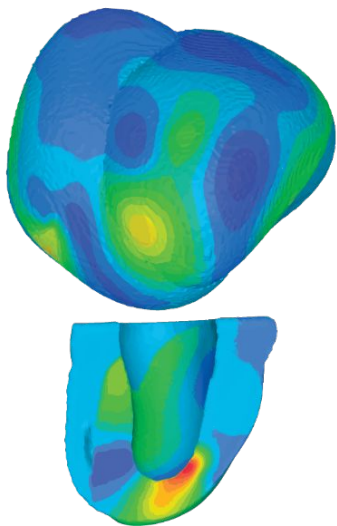
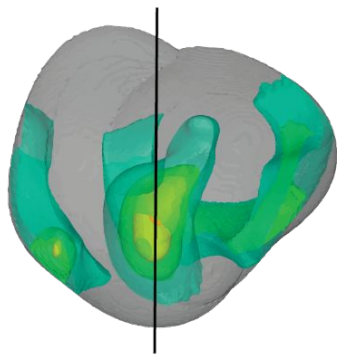
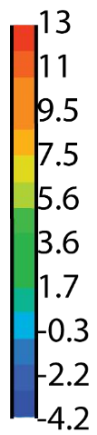


# Ischemic Zone



Ischemic Zone

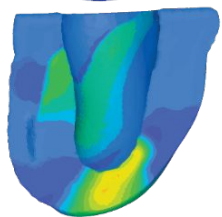
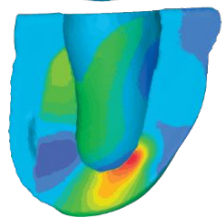
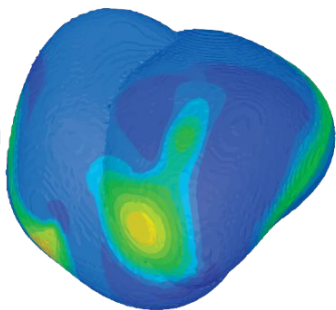
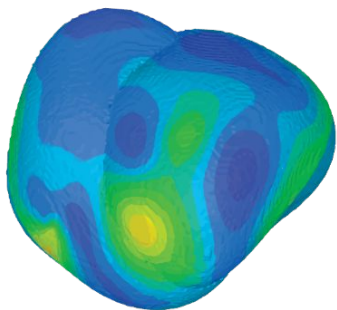
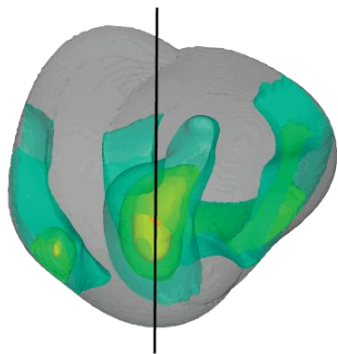
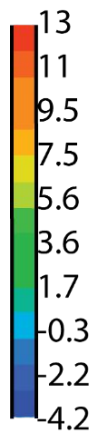
Measured



Ischemic Zone

Measured

Baseline



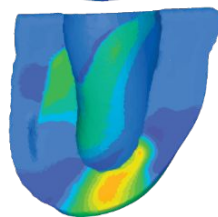
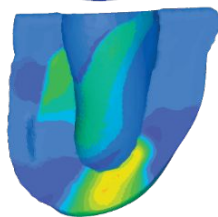
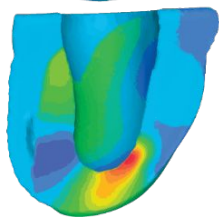
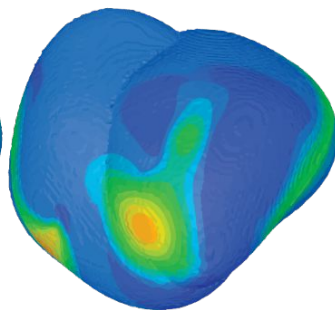
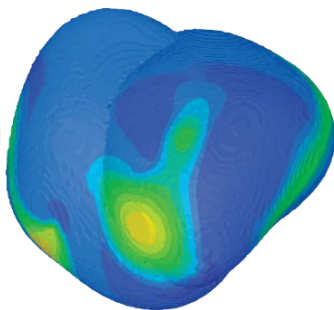
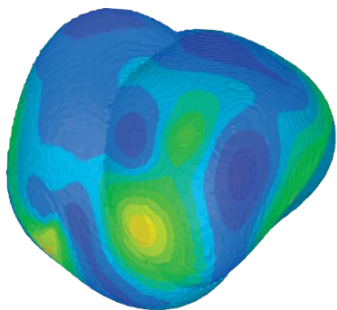
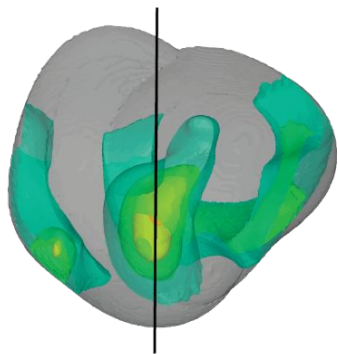
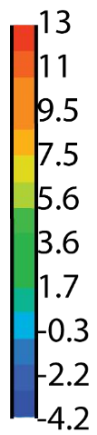


Ischemic Zone

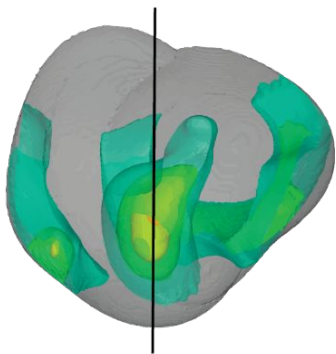
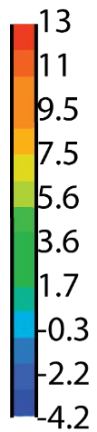
Measured

Baseline

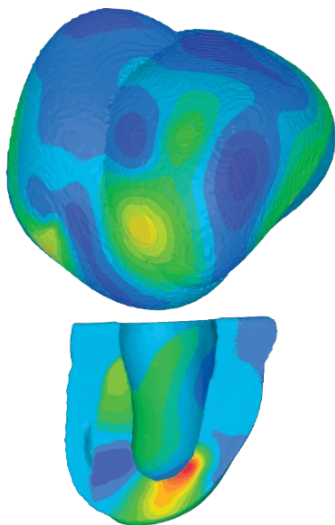
Mean



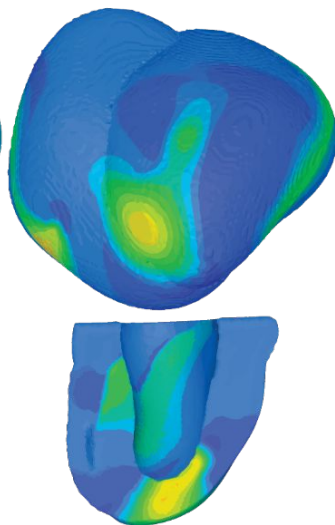
Ischemic Zone



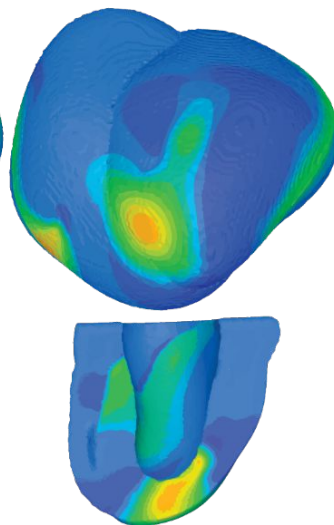
Measured



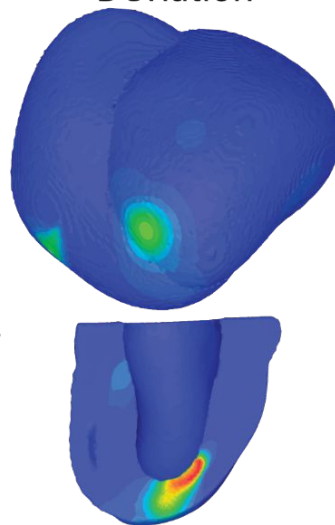
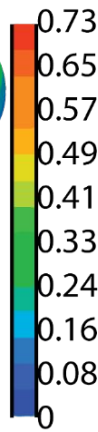
Baseline



Mean



Standard Deviation



Total Sensitivities

$\sigma_{eL}$

$\sigma_{eT}$

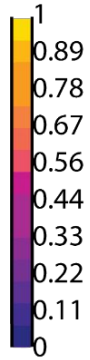
$\sigma_{iL}$

$\sigma_{iT}$

Standard Deviations

$\sigma_{eL}$

$\sigma_{iL}$



Total Sensitivities

$\sigma_{eL}$

$\sigma_{eT}$

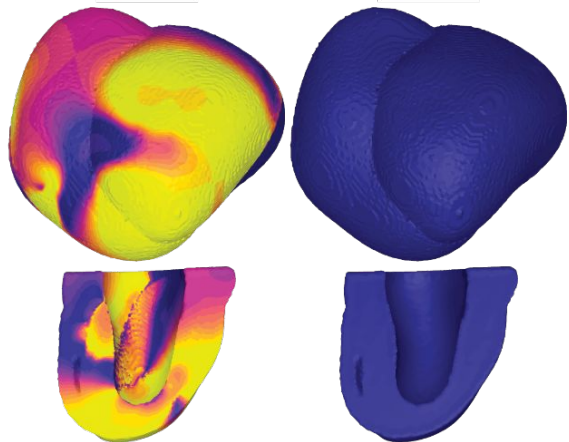
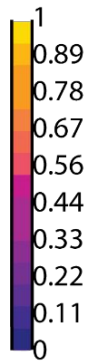
$\sigma_{iL}$

$\sigma_{iT}$

Standard Deviations

$\sigma_{eL}$

$\sigma_{iL}$



Total Sensitivities

$\sigma_{eL}$

$\sigma_{eT}$

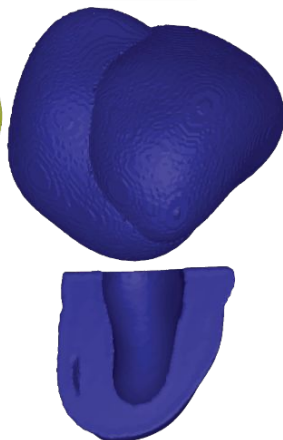
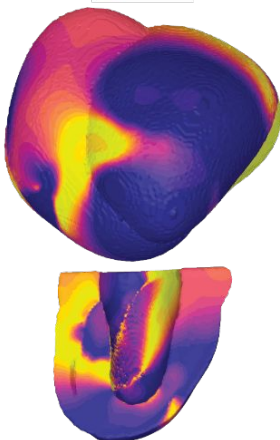
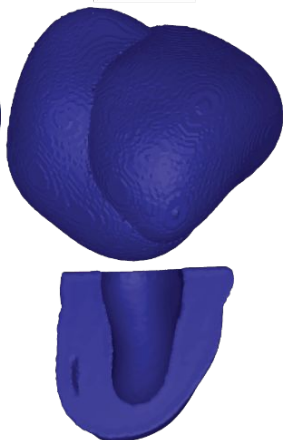
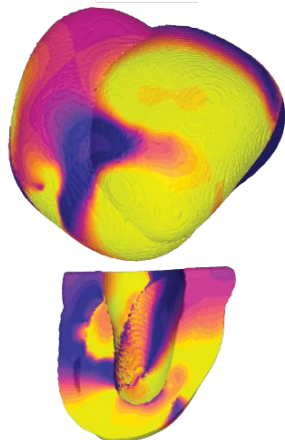
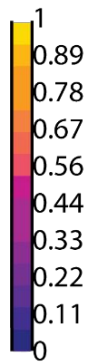
$\sigma_{iL}$

$\sigma_{iT}$

Standard Deviations

$\sigma_{eL}$

$\sigma_{iL}$



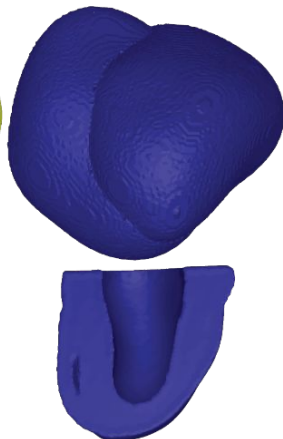
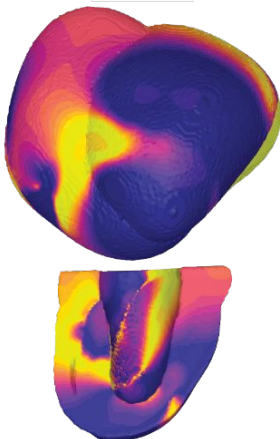
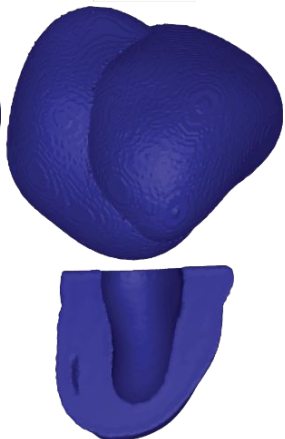
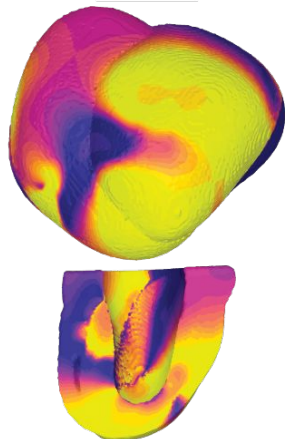
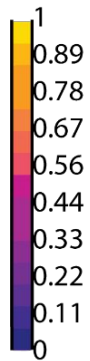
Total Sensitivities

$\sigma_{eL}$

$\sigma_{eT}$

$\sigma_{iL}$

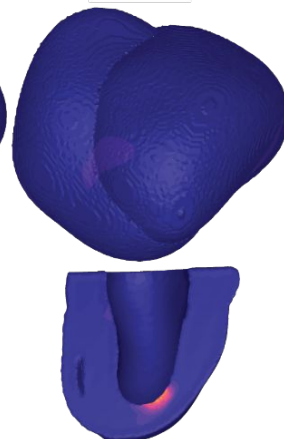
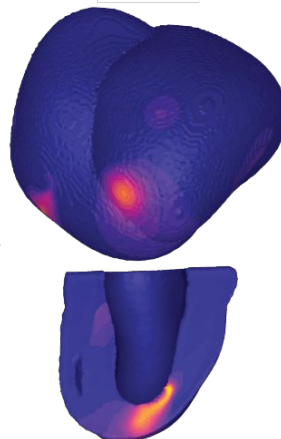
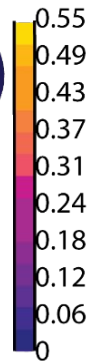
$\sigma_{iT}$



Standard Deviations

$\sigma_{eL}$

$\sigma_{iL}$



# UncertainSCI

