

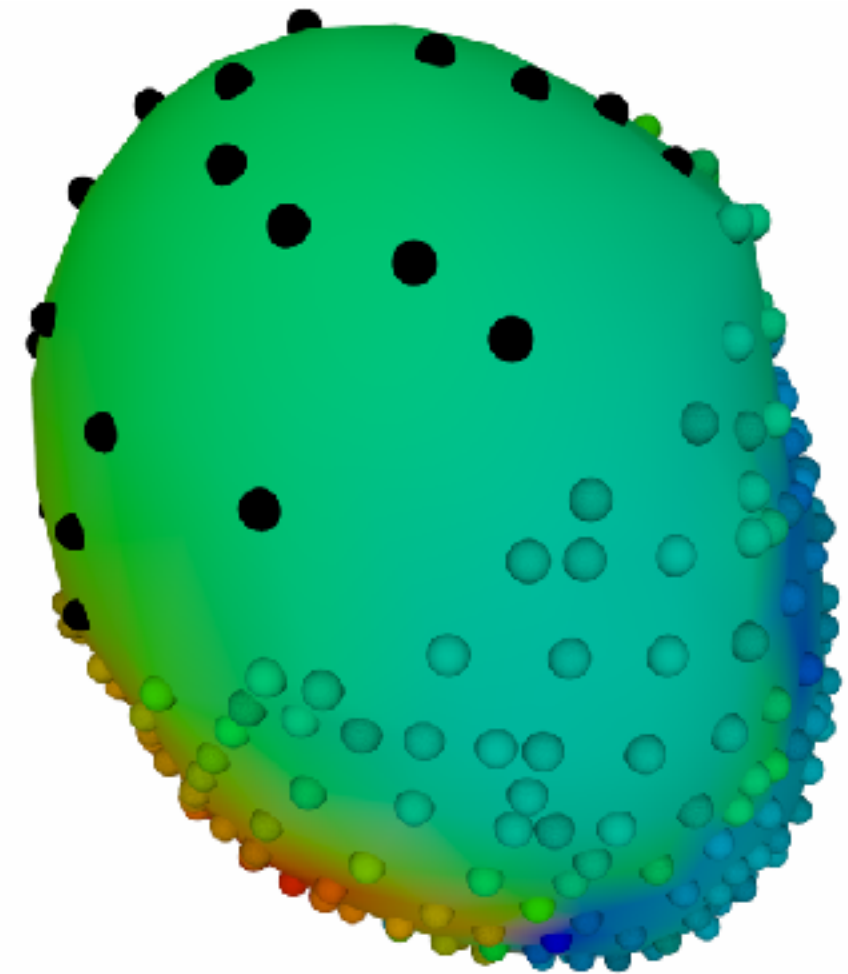
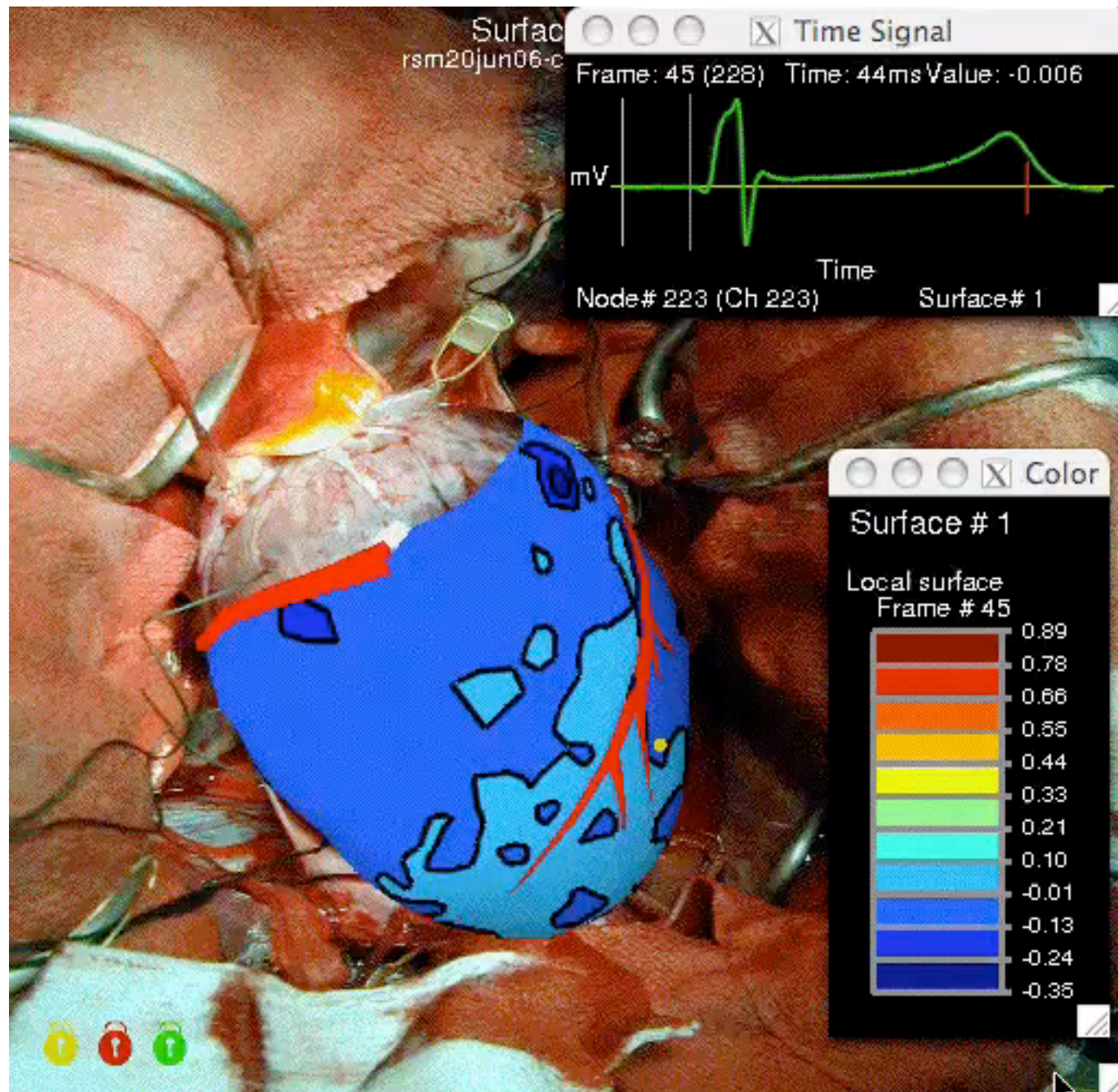
Correcting Undersampled Cardiac Sources in Equivalent Double Layer Forward Simulations

Jess D. Tate, Steffen Schuler, Olaf Dössel, Rob S. MacLeod, and Thom F. Oostendorp

Scientific Computing and Imaging Institute, University of Utah,
Salt Lake City, USA

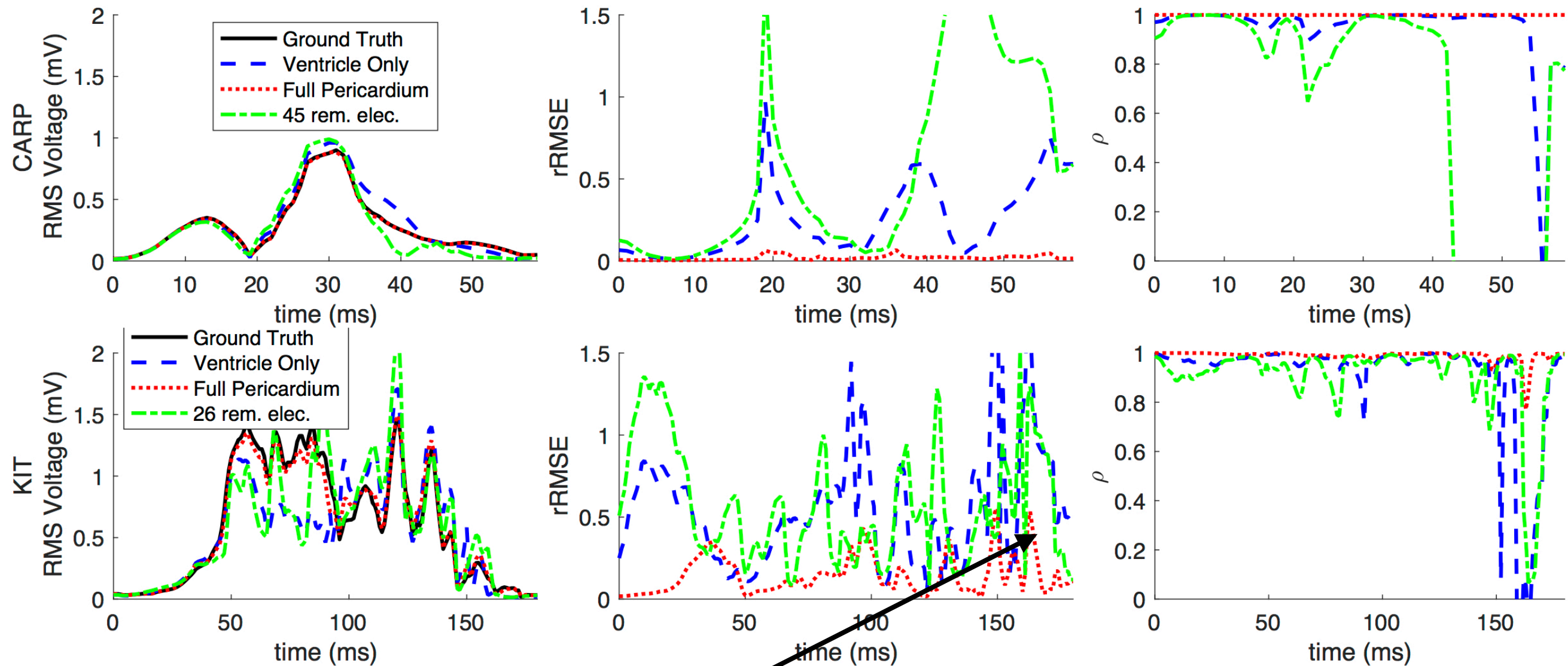
Institute of Biomed. Eng., KIT, Karlsruhe, Germany,
Donders Centre for Neuroscience, Radboud University,
Nijmegen, Netherlands

Atrial Sampling



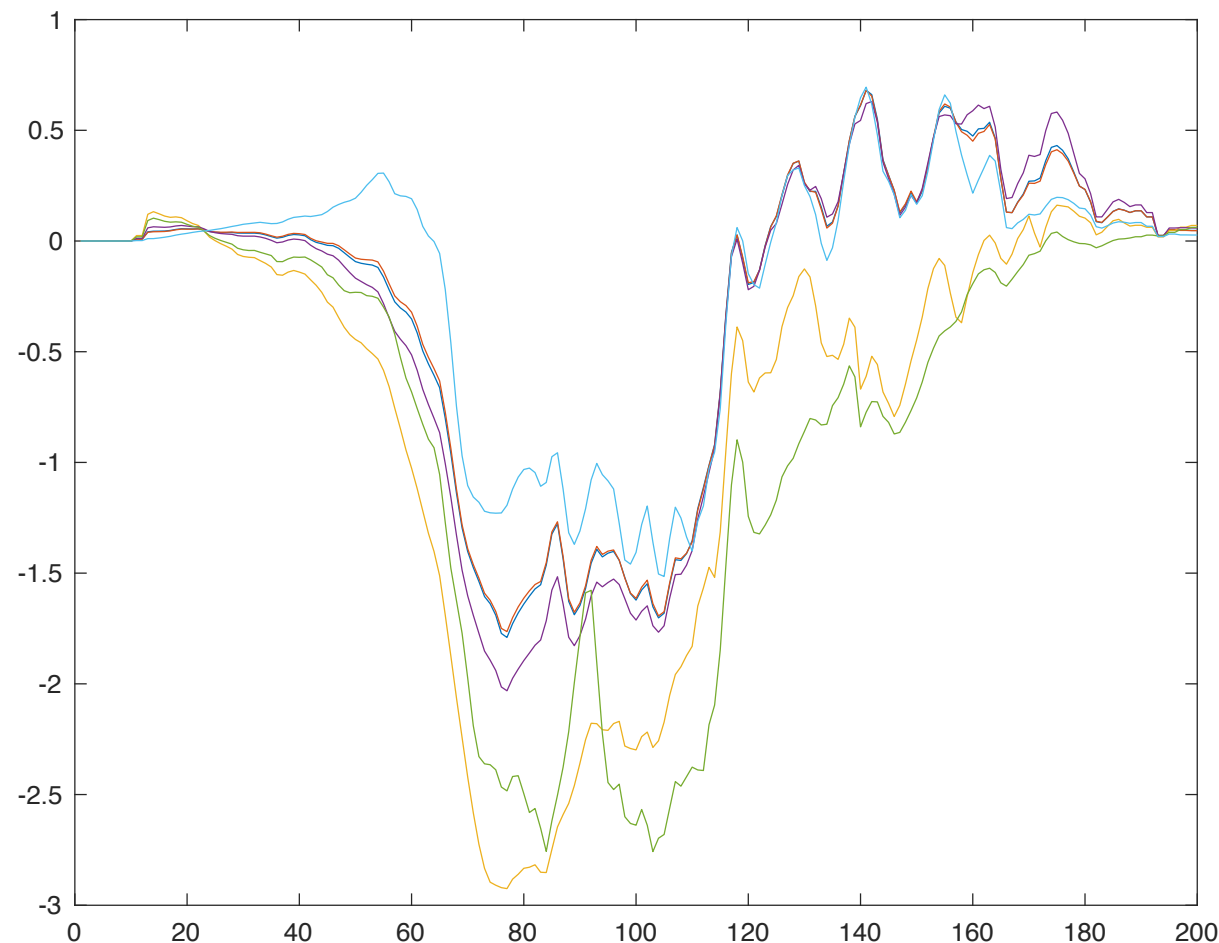
Tat, etal., Front. in Physiol, vol 9 p. 1304 , 2018

Effect of No Atrial Sampling

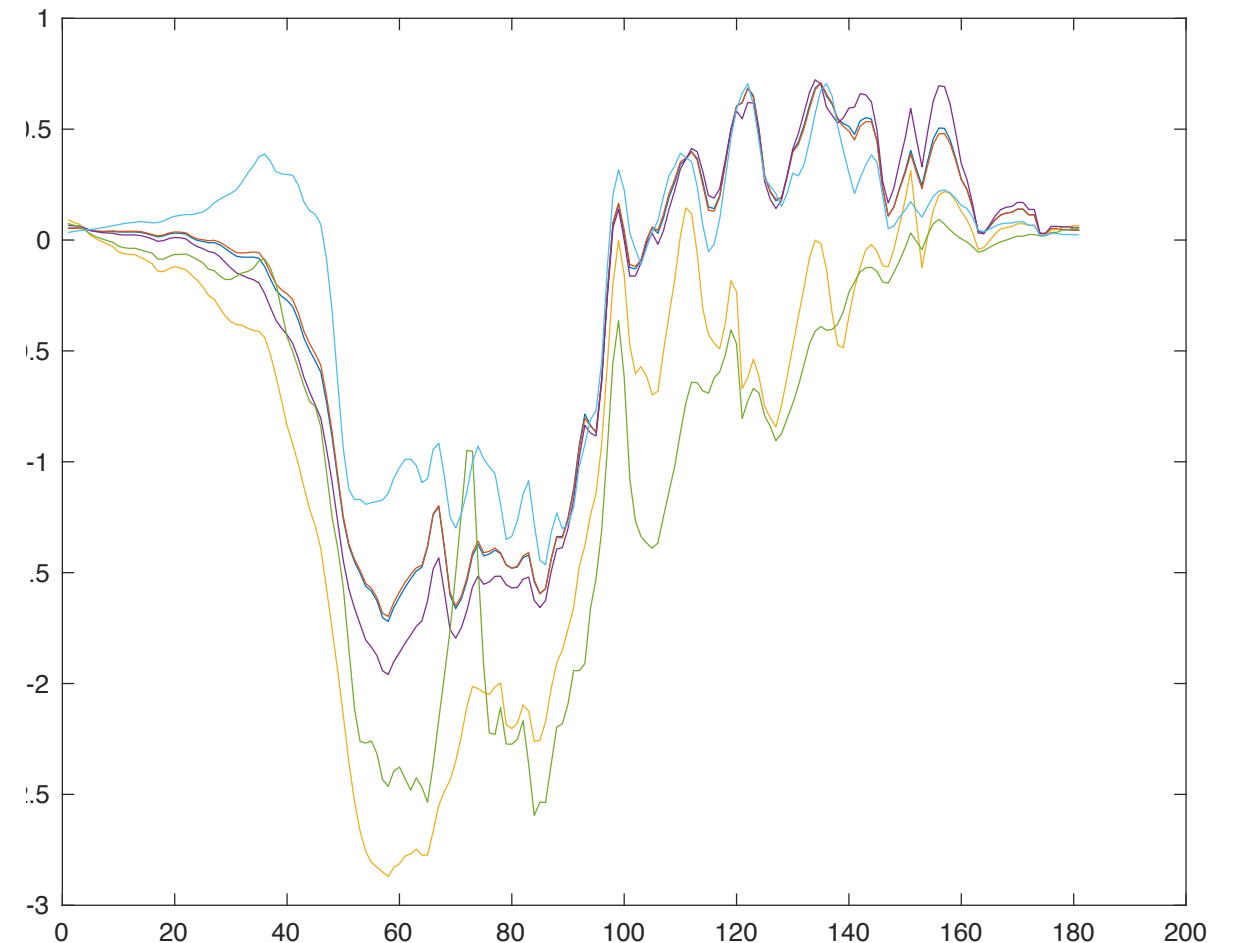


Higher Residual Error

Low Resolution Sources



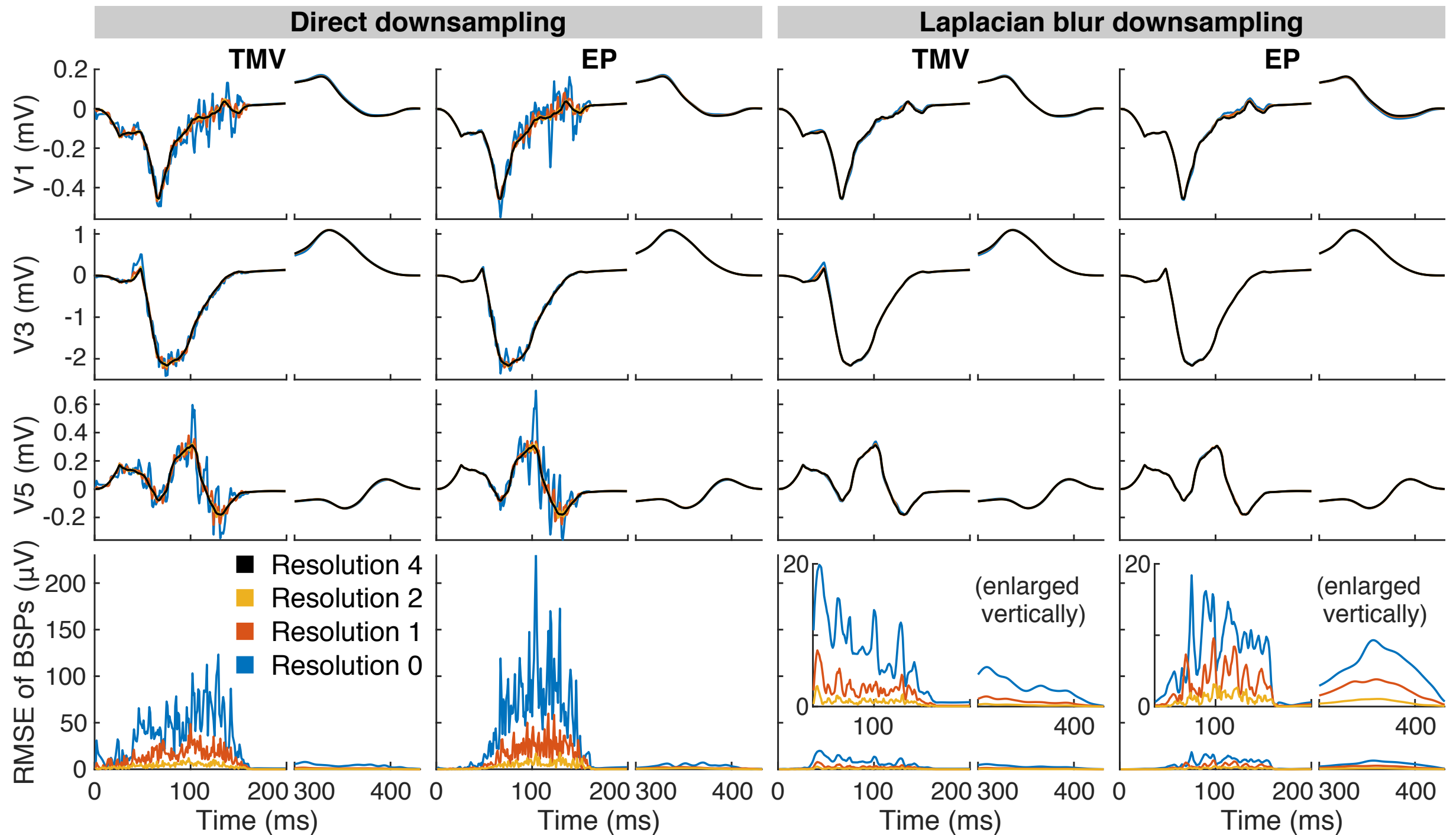
FEM



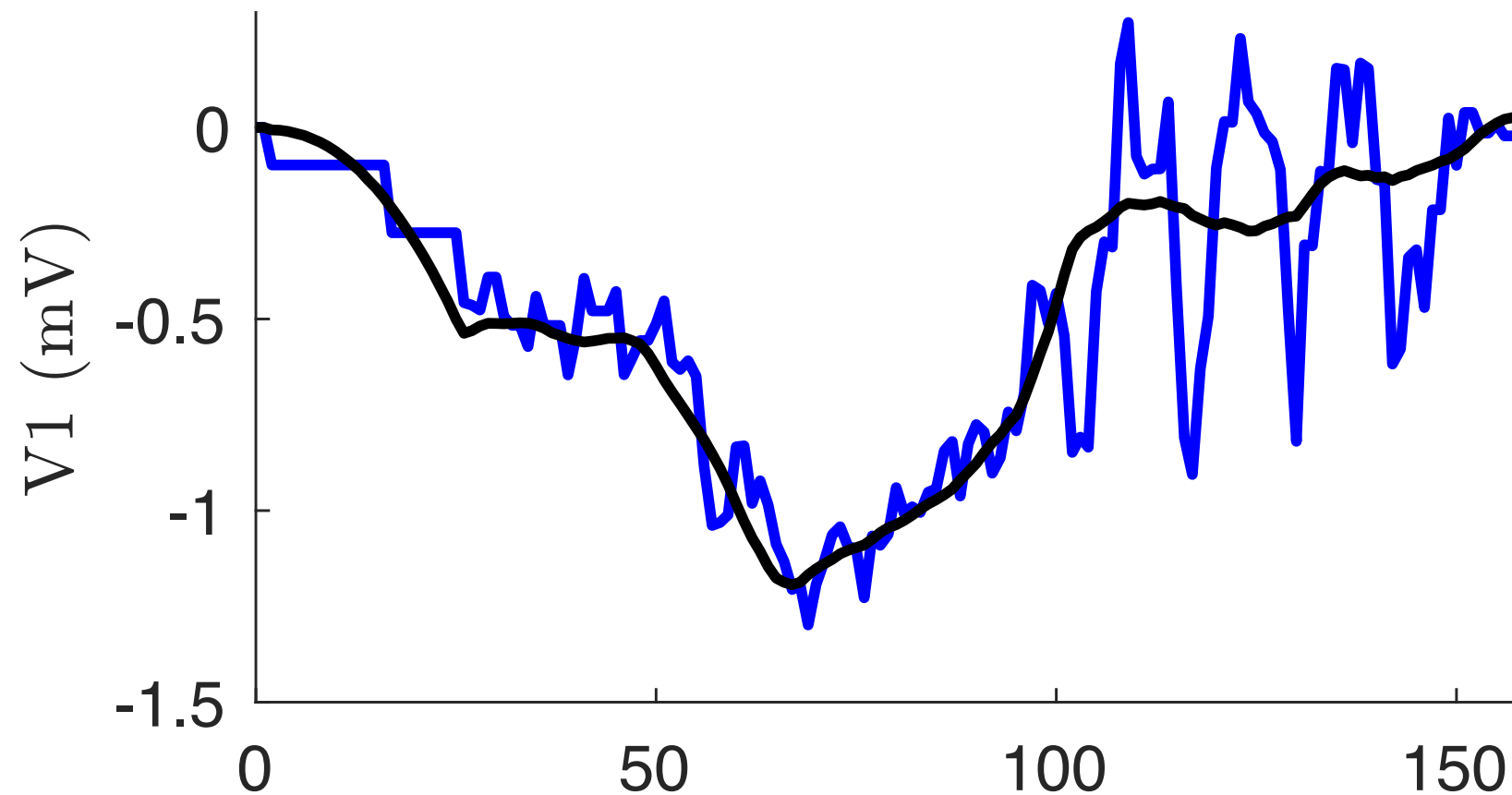
BEM

Reduced error with interpolation

Source Smoothing



Other Source Models?



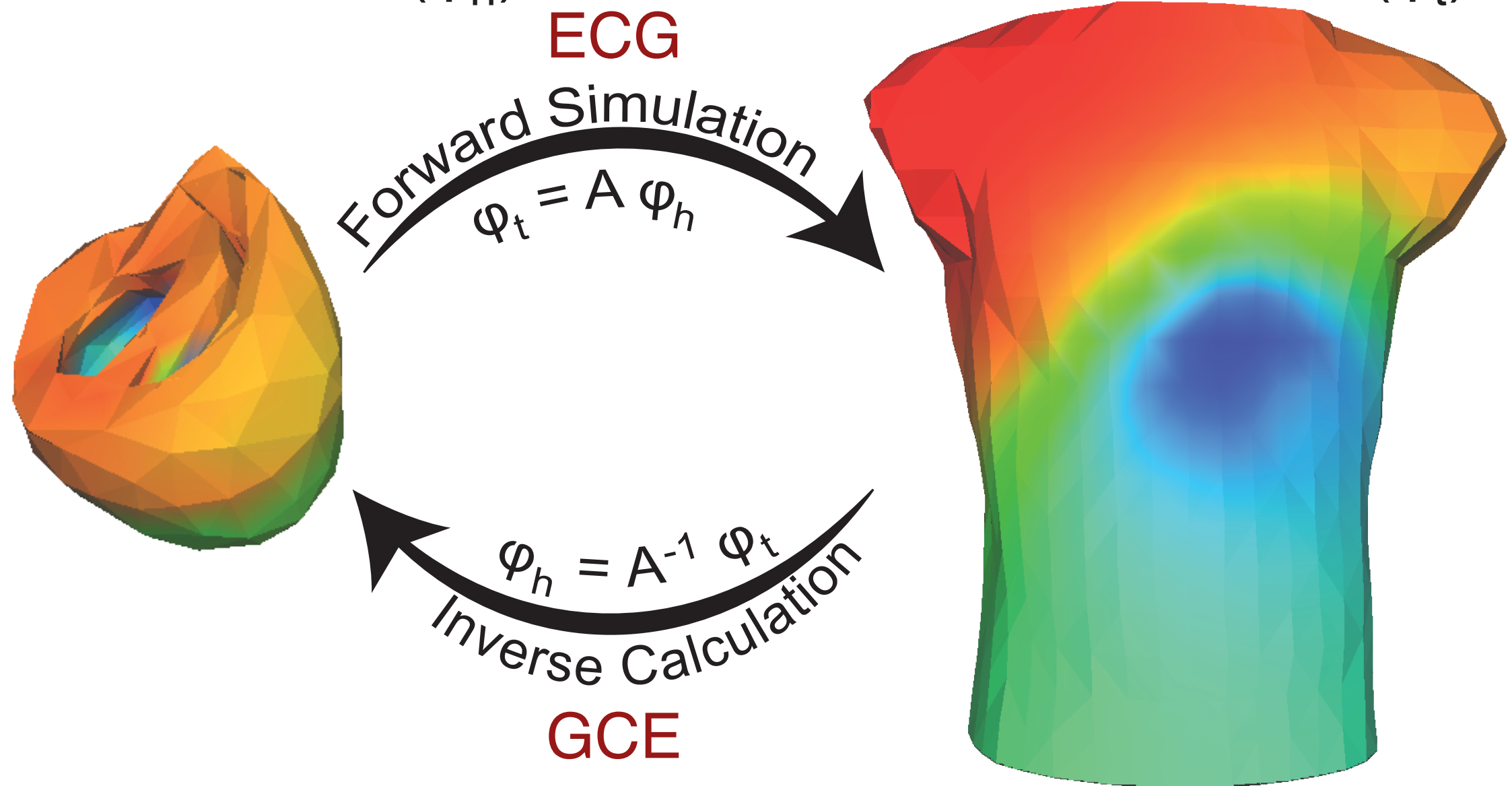
EDL

Can we reduce the error with interpolation?

ECG Imaging

Heart Potentials (φ_h)

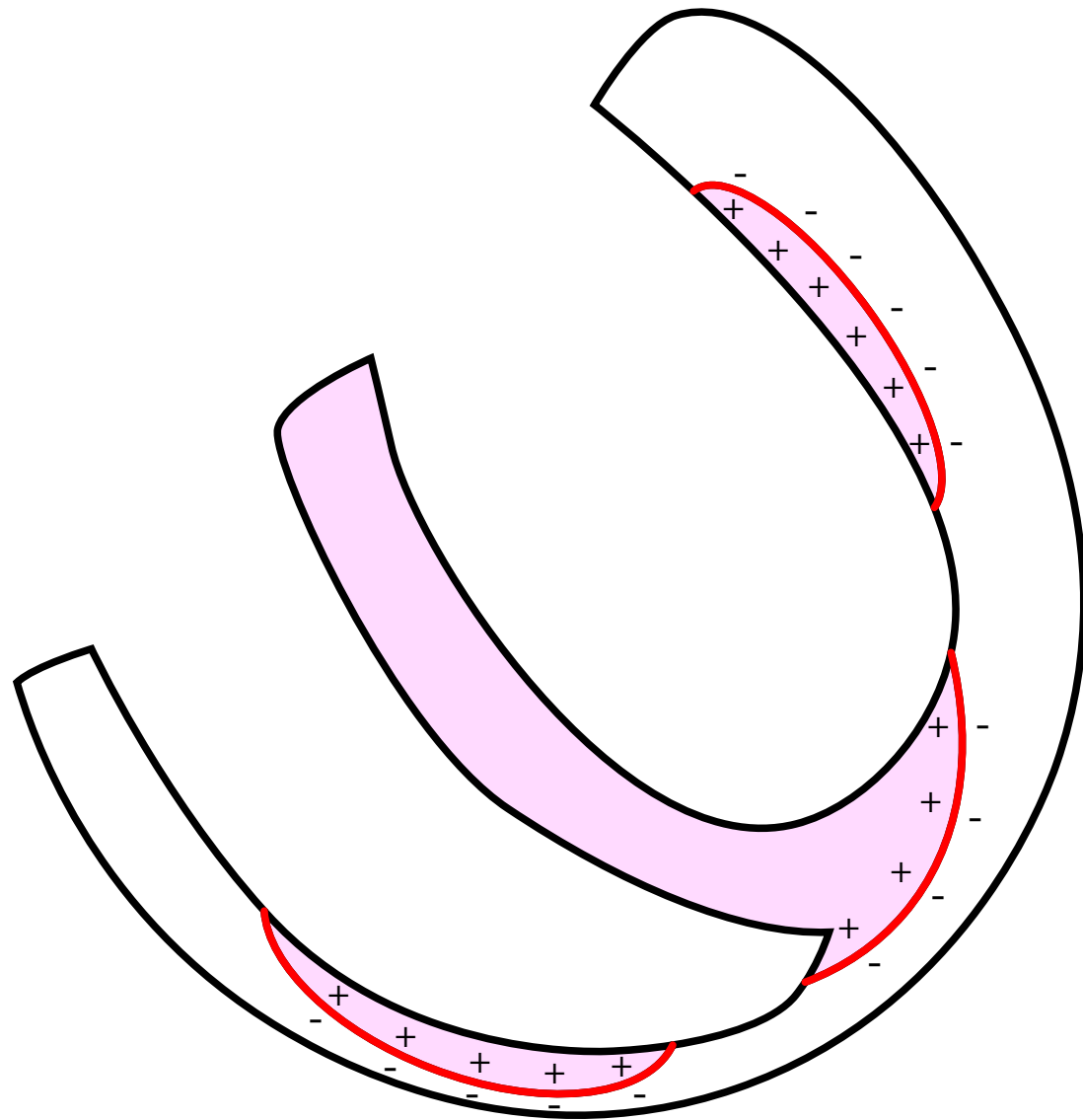
Torso Potentials (φ_t)



ECG Imaging Relies on Accurate Forward Models

Evaluate the effect of source sampling and interpolation strategies on EDL forward simulations

Uniform Dipole Layer



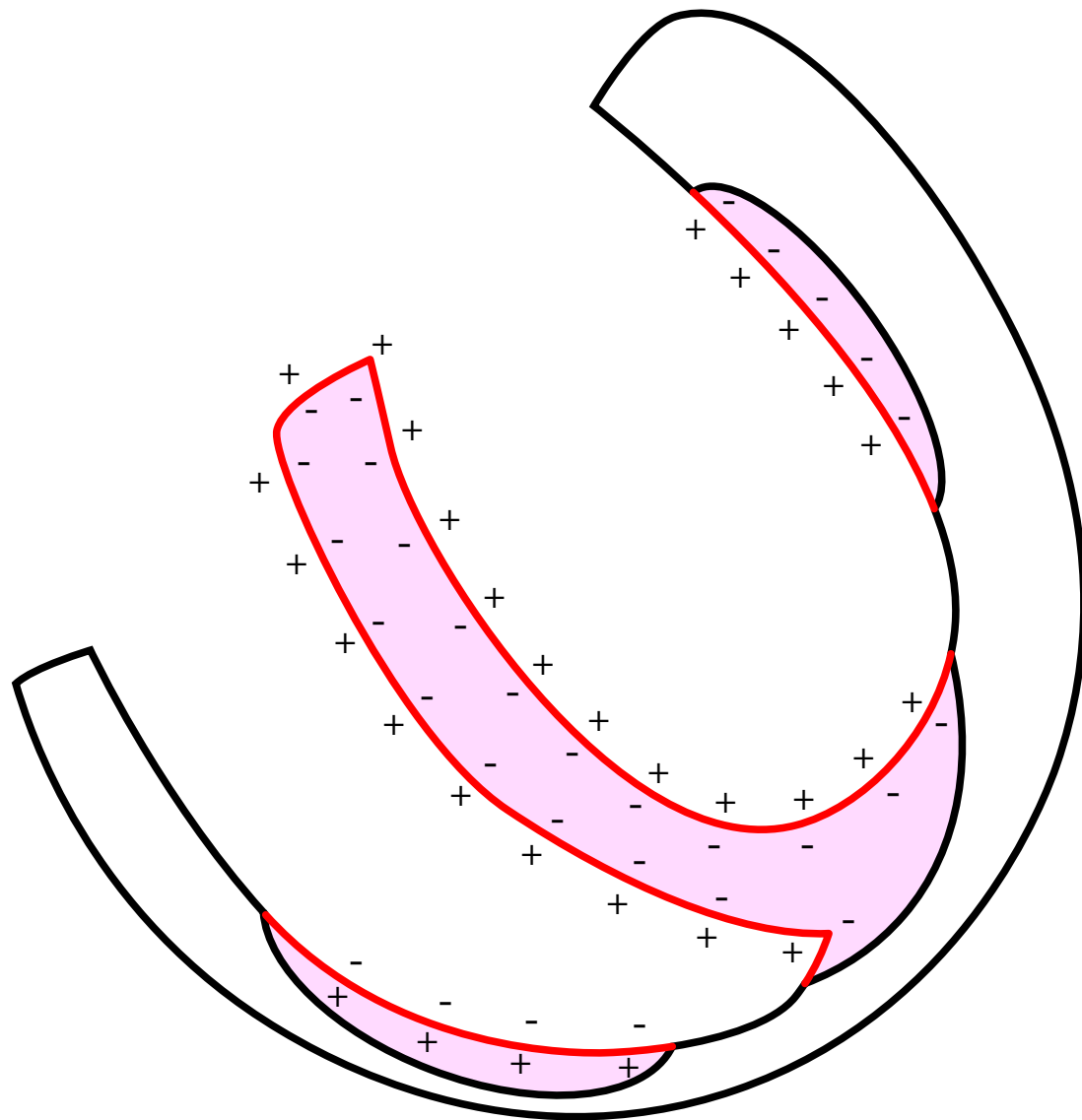
$$\varphi_{\infty}(\vec{r}') = \frac{1}{4\pi\sigma} \int_{S_d} \underbrace{\sigma_i \nabla \varphi_m(\vec{r})}_{\text{Dipole Layer Strength}} \underbrace{d\omega}_{\text{Solid Angle}}.$$

Dipole Layer
Strength

Solid Angle

van Oosterom, j. Electrocardiol., vol 35 suppl, pp 185-192, 2002

Equivalent Dipole Layer (EDL)



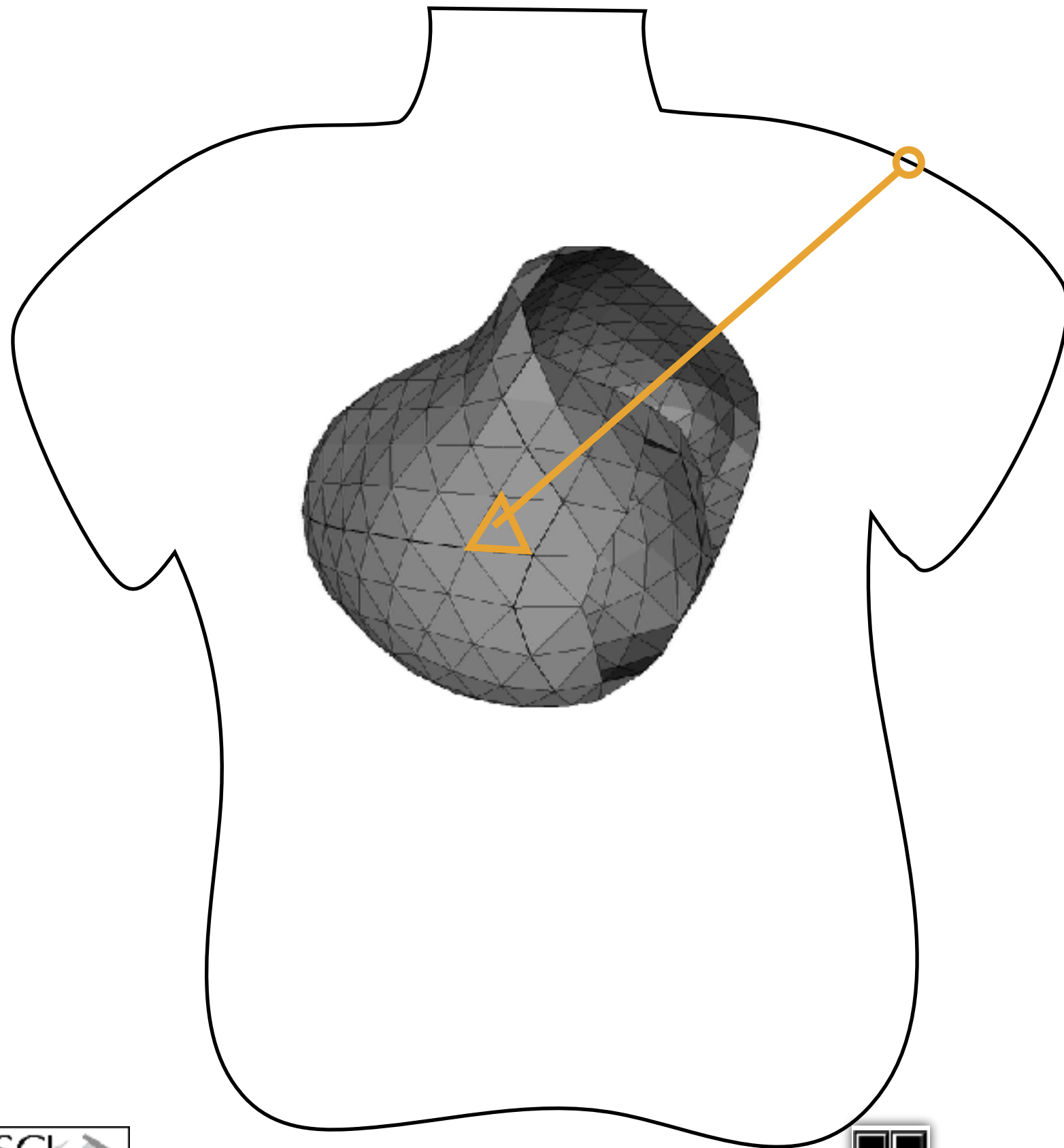
$$\varphi_{\infty}(\vec{r}') = \frac{1}{4\pi\sigma} \int_{S_d} \underbrace{\sigma_i \nabla \varphi_m(\vec{r})}_{\text{Dipole Layer Strength}} \underbrace{d\omega}_{\text{Solid Angle}}.$$

Dipole Layer
Strength

Solid Angle

van Oosterom, j. Electrocardiol., vol 35 suppl, pp 185-192, 2002

Calculating EDL

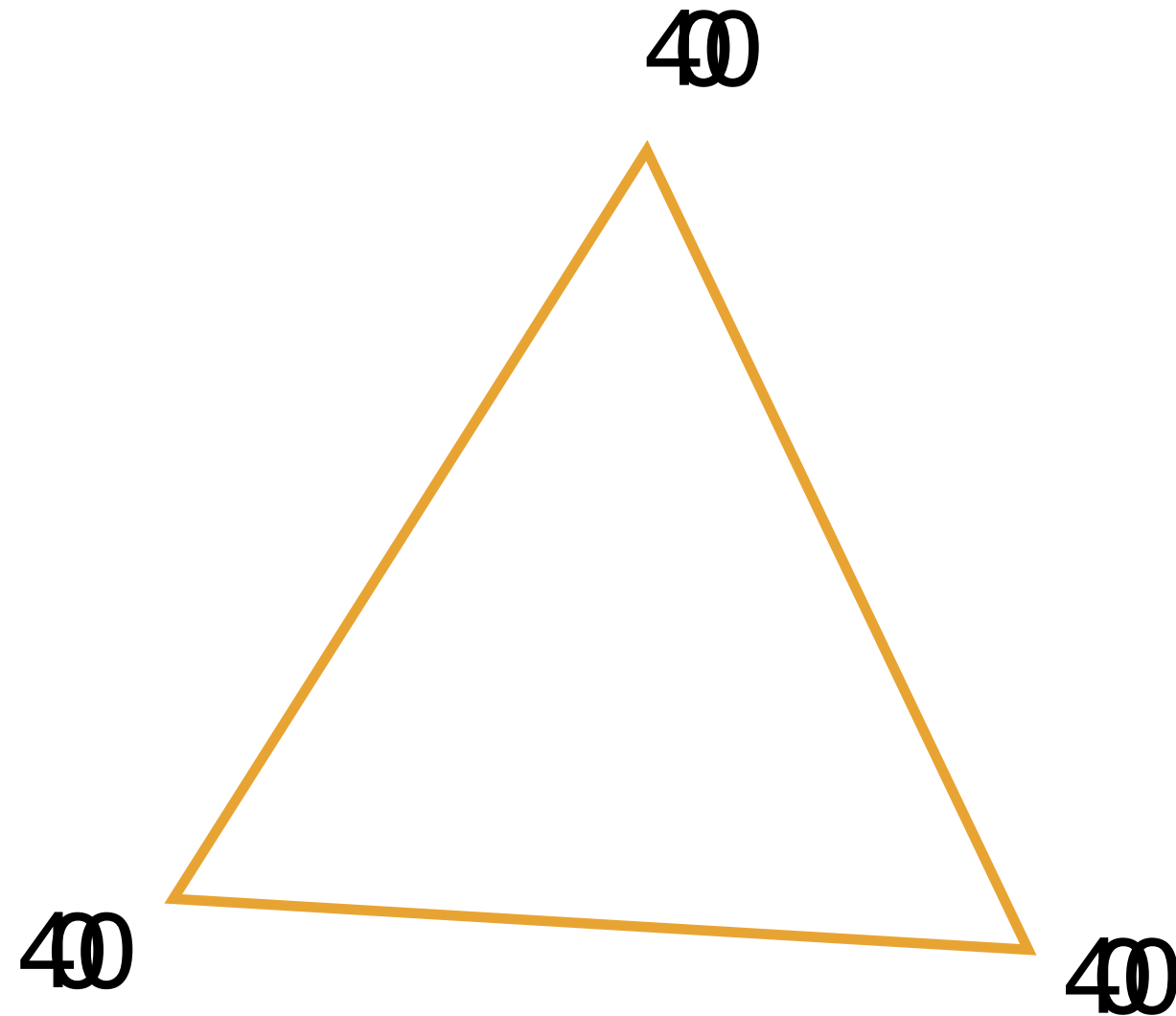


For each face:

Compute solid angle

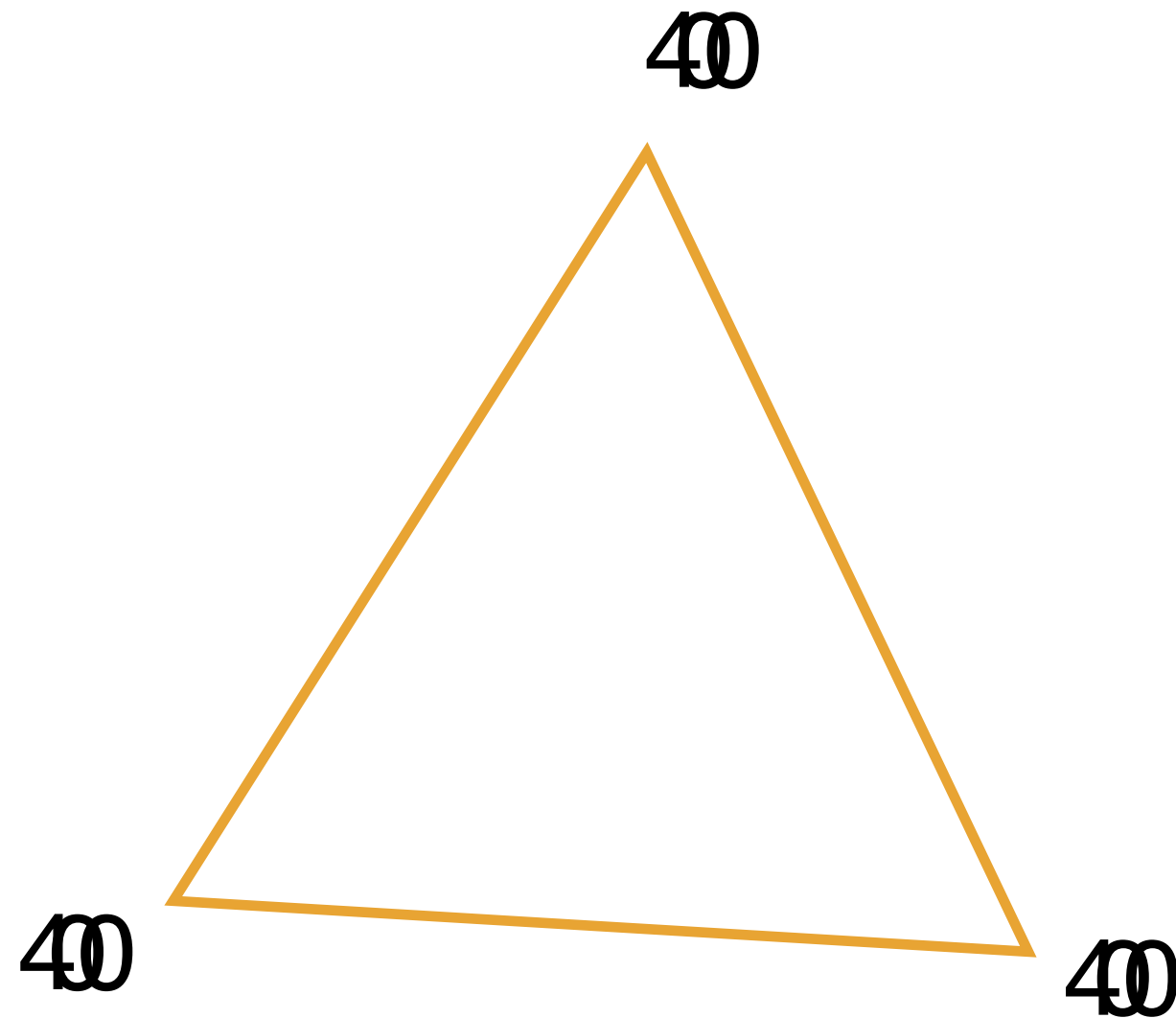
Apply dipole strength

Interpolating EDL



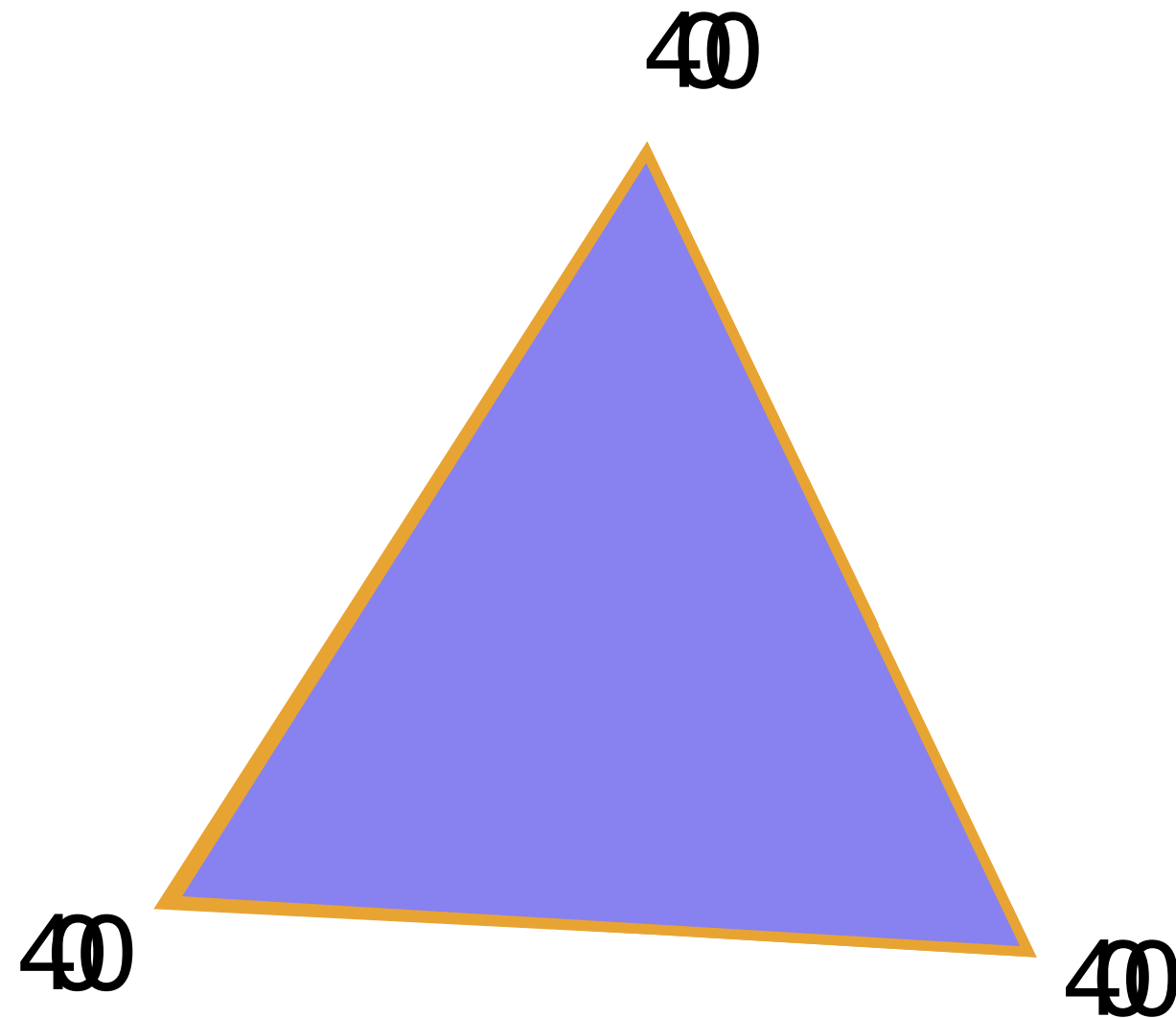
Constant (None)

Interpolating EDL



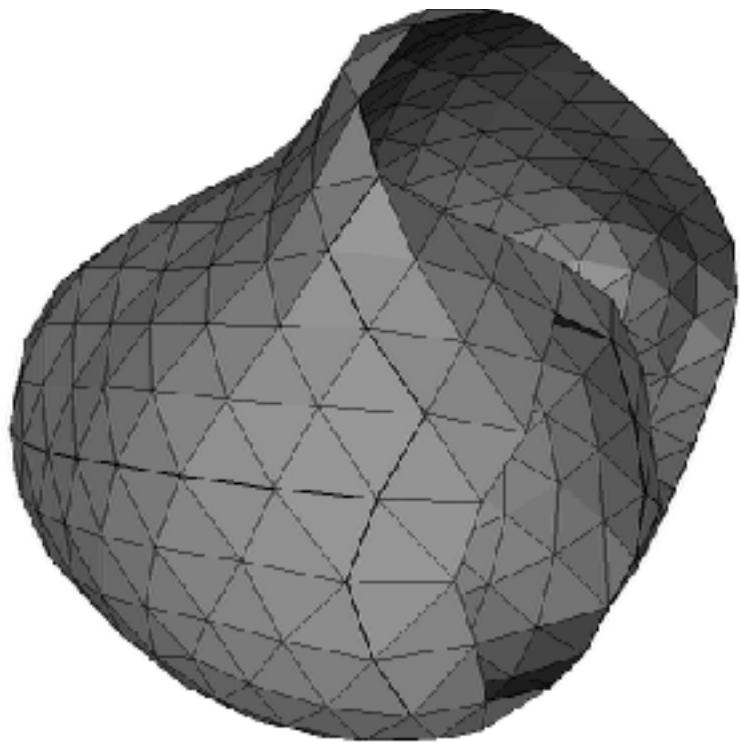
Triangle Weighting

Interpolating EDL

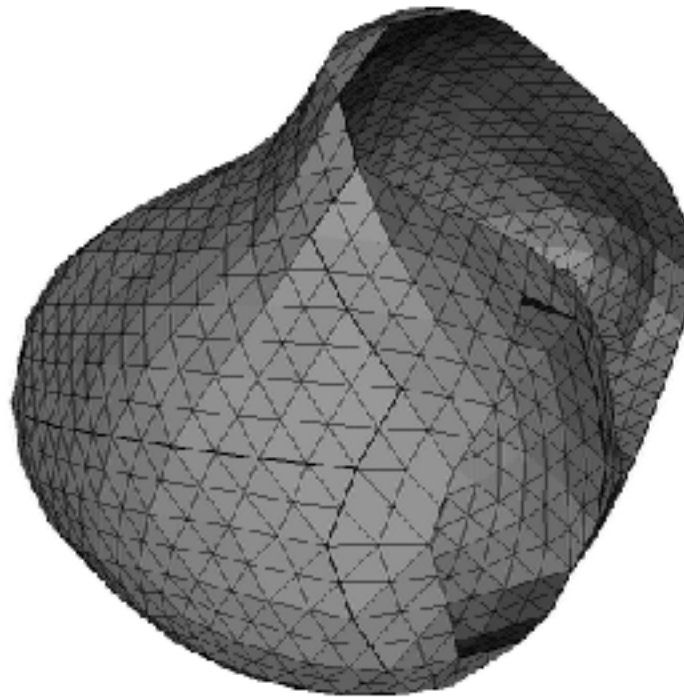


Triangle Splitting

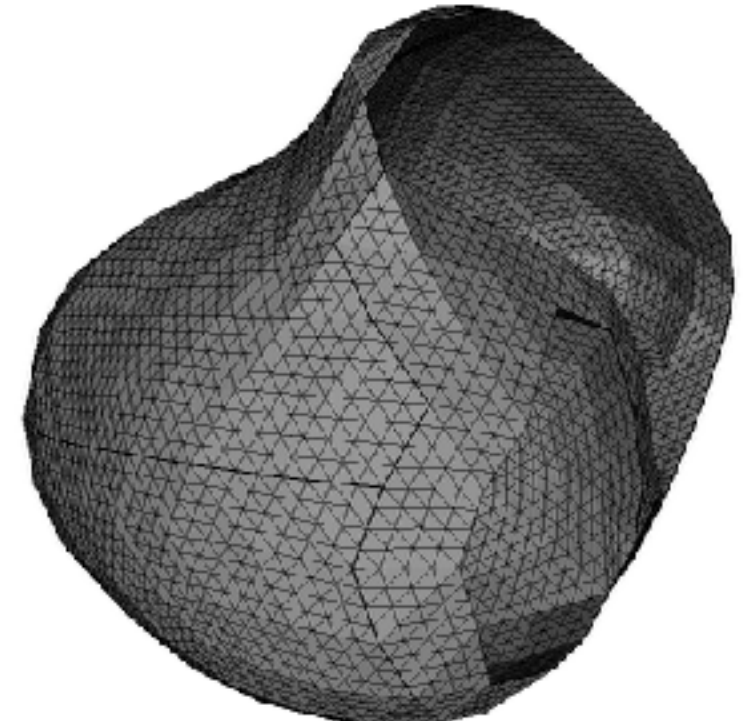
Sampling Resolutions



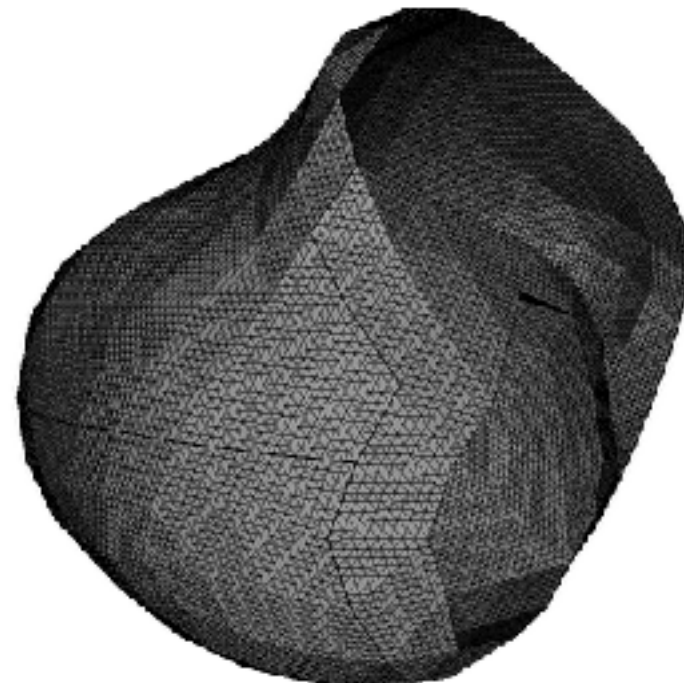
Res 0 (578 nodes)



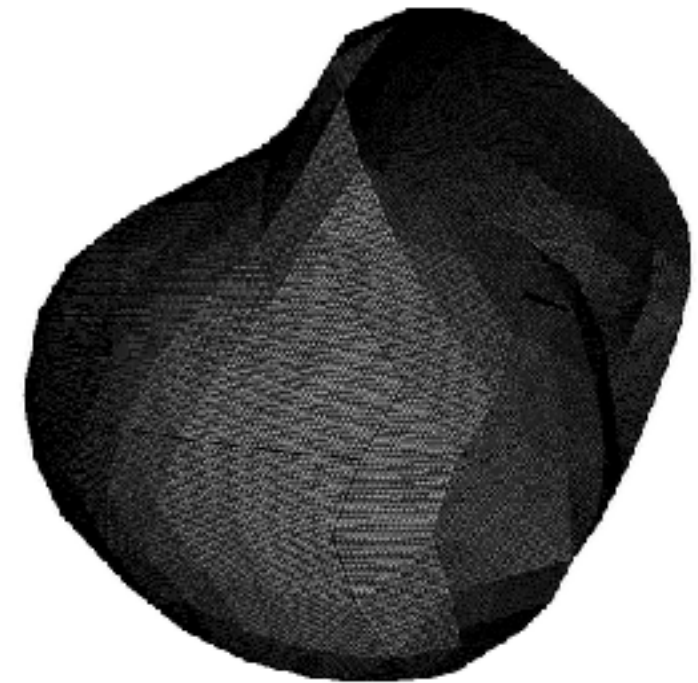
Res 1 (2,306)



Res 2 (9,218)



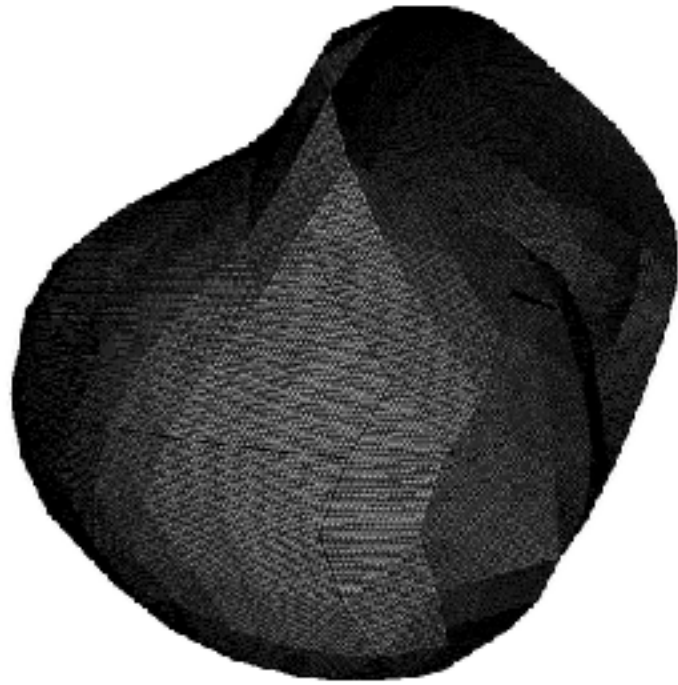
Res 3 (36,866)



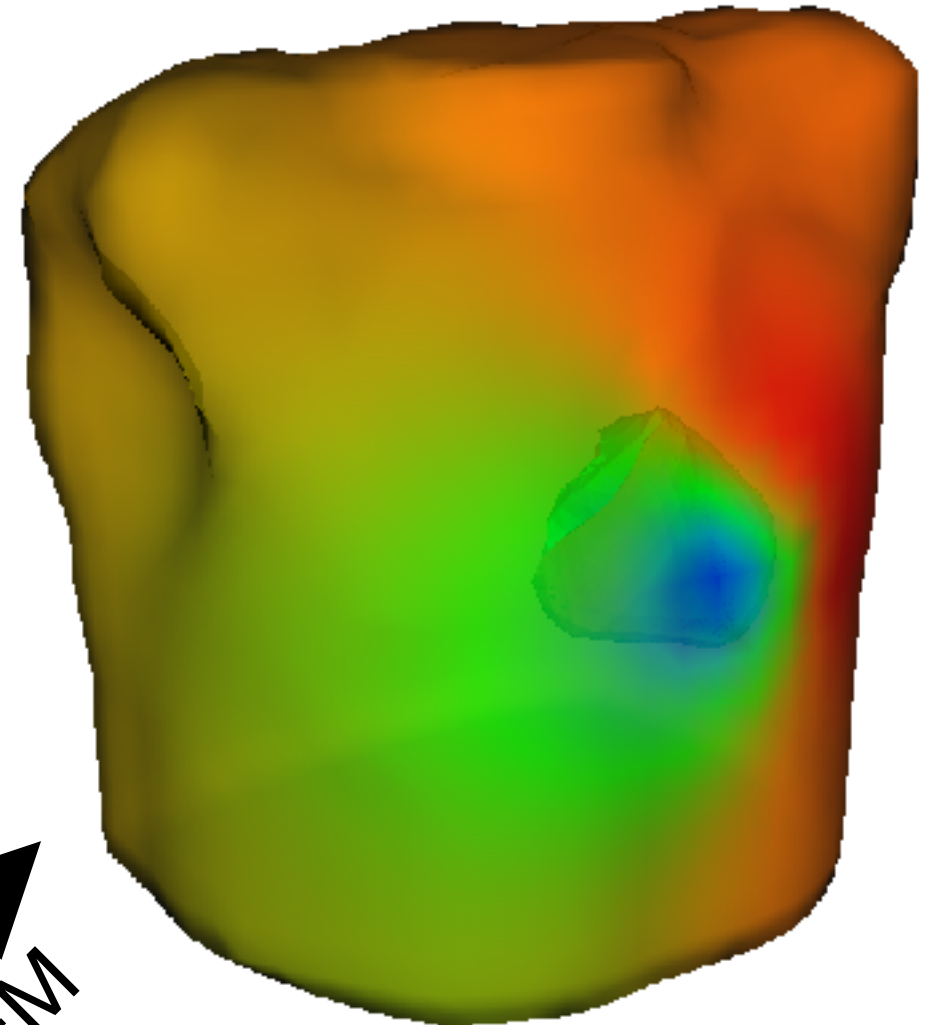
Res 4 (147,458)

Ground Truth

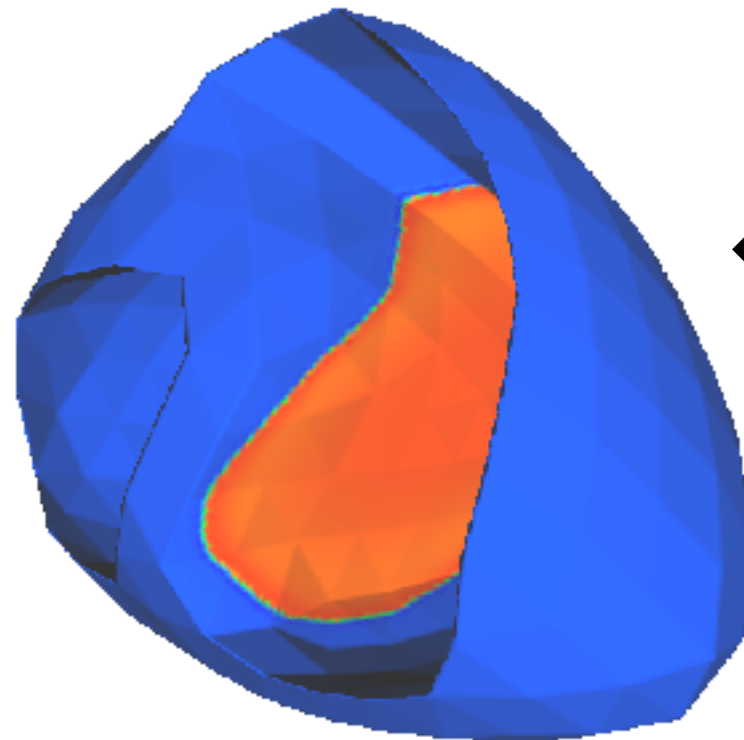
Res 4



BSPM

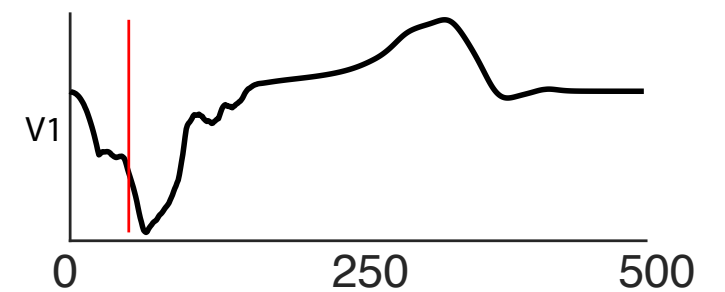


TMP



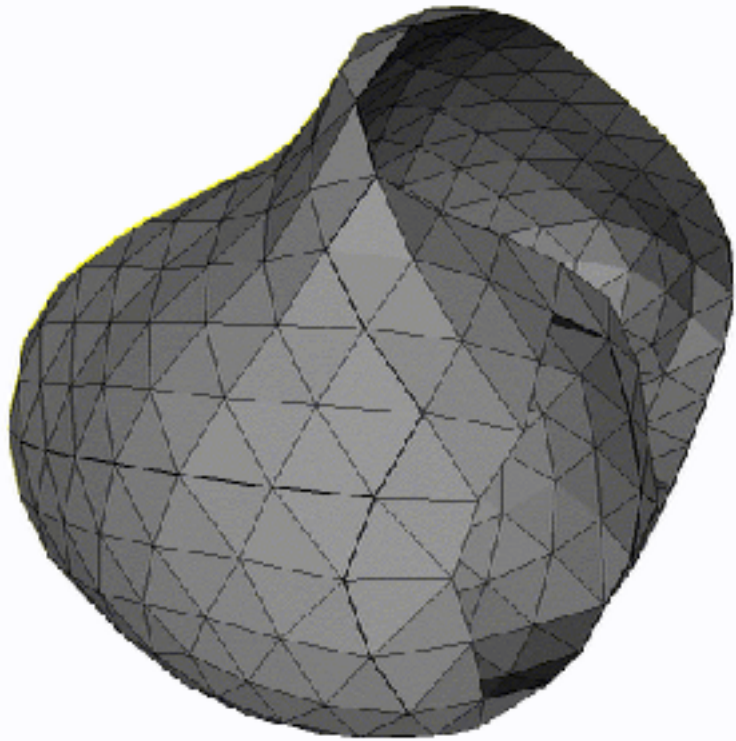
Bidomain
Simulation

BEM

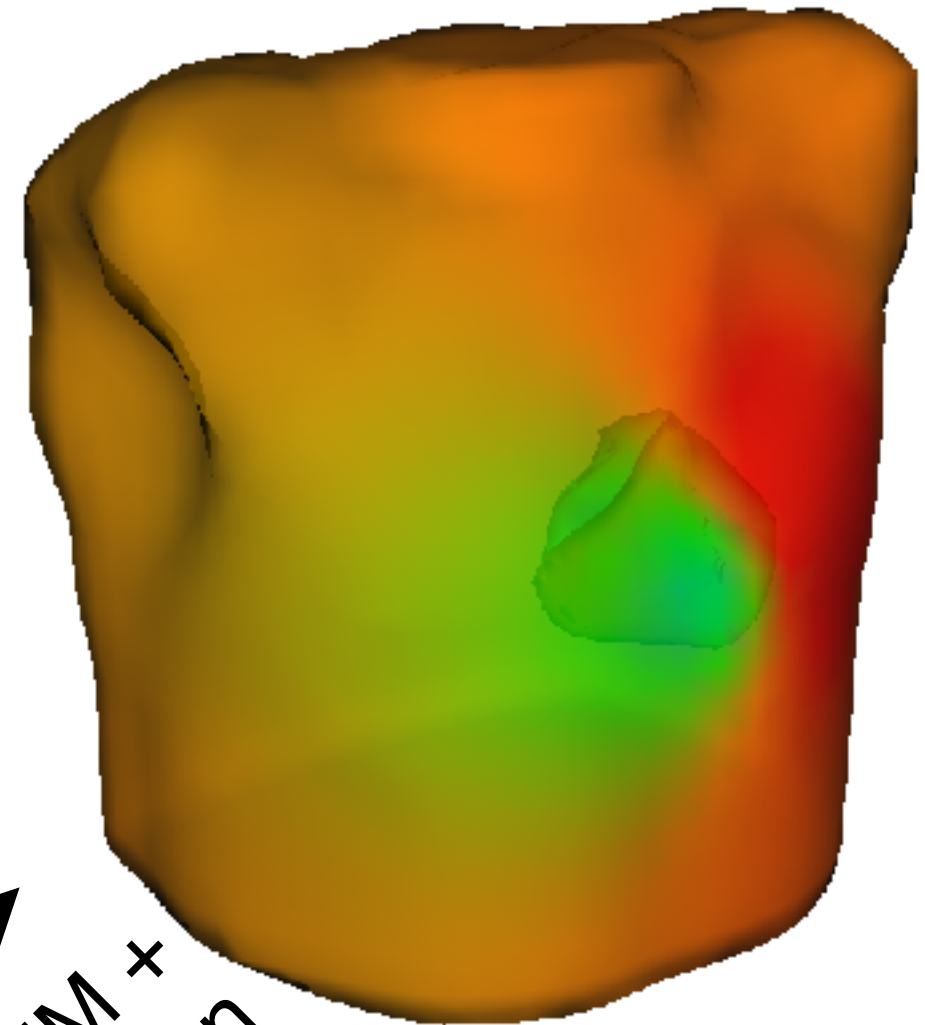


EDL Pipeline

Mesh

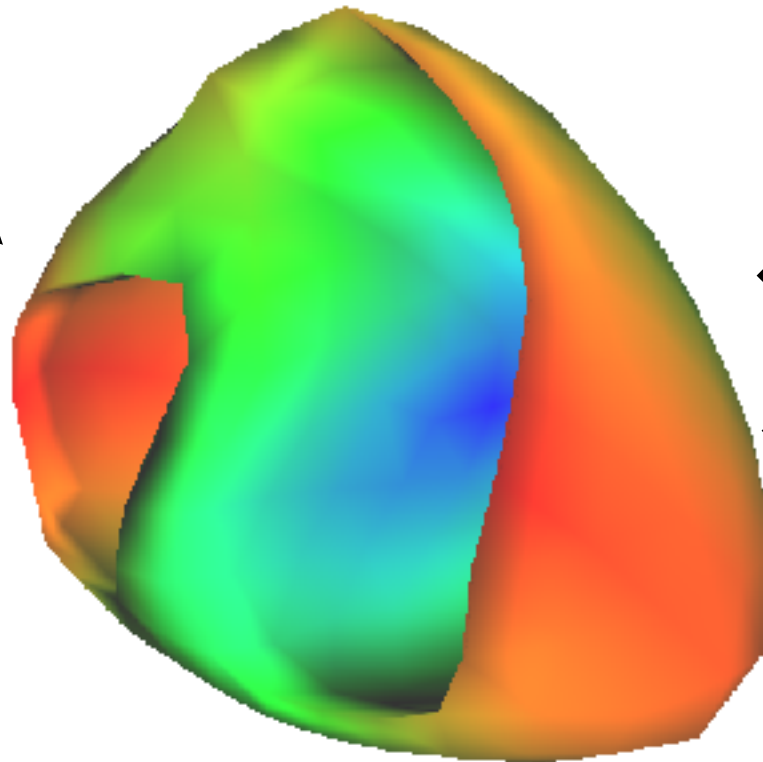


BSPM



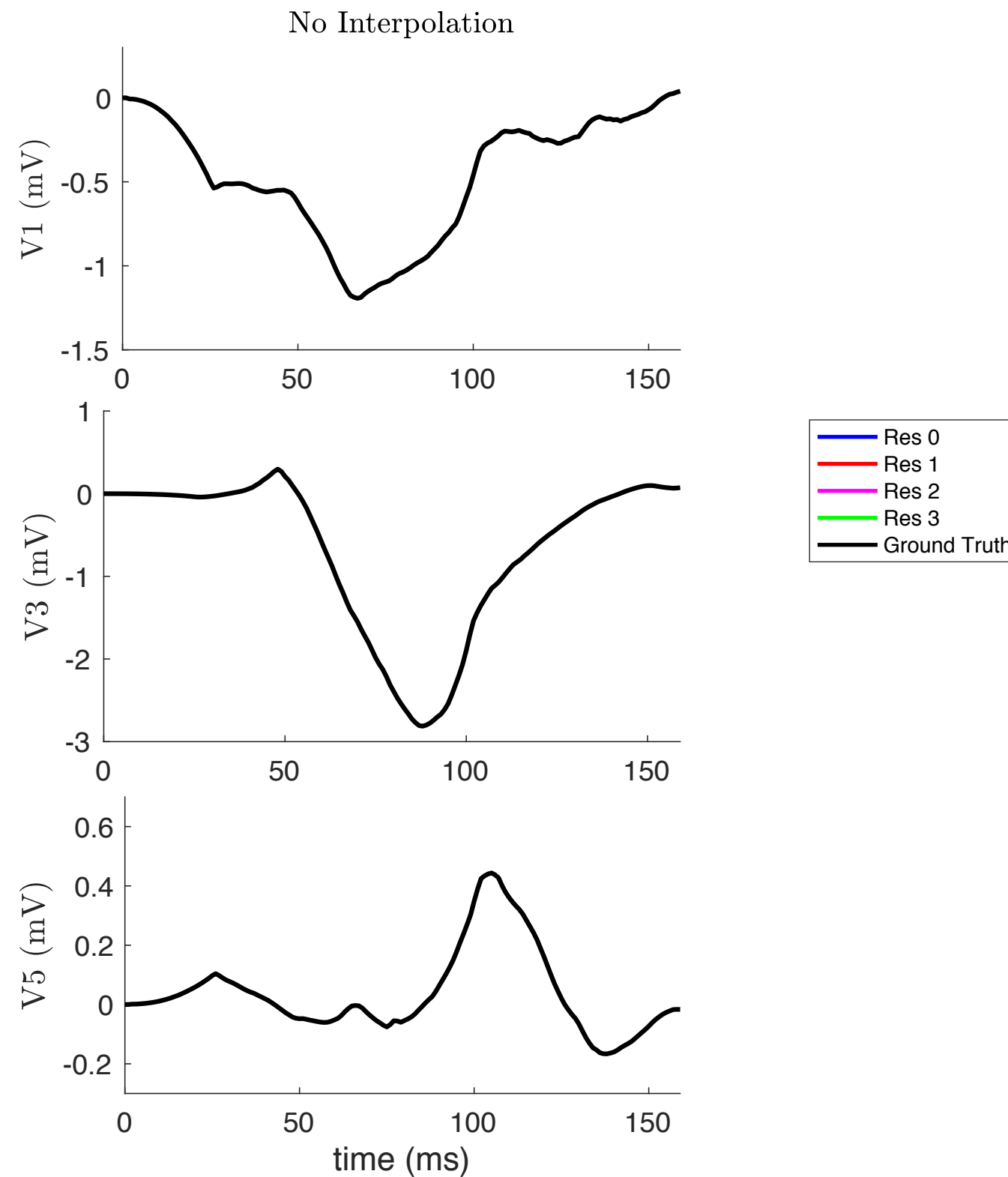
Activation Times

Mapping

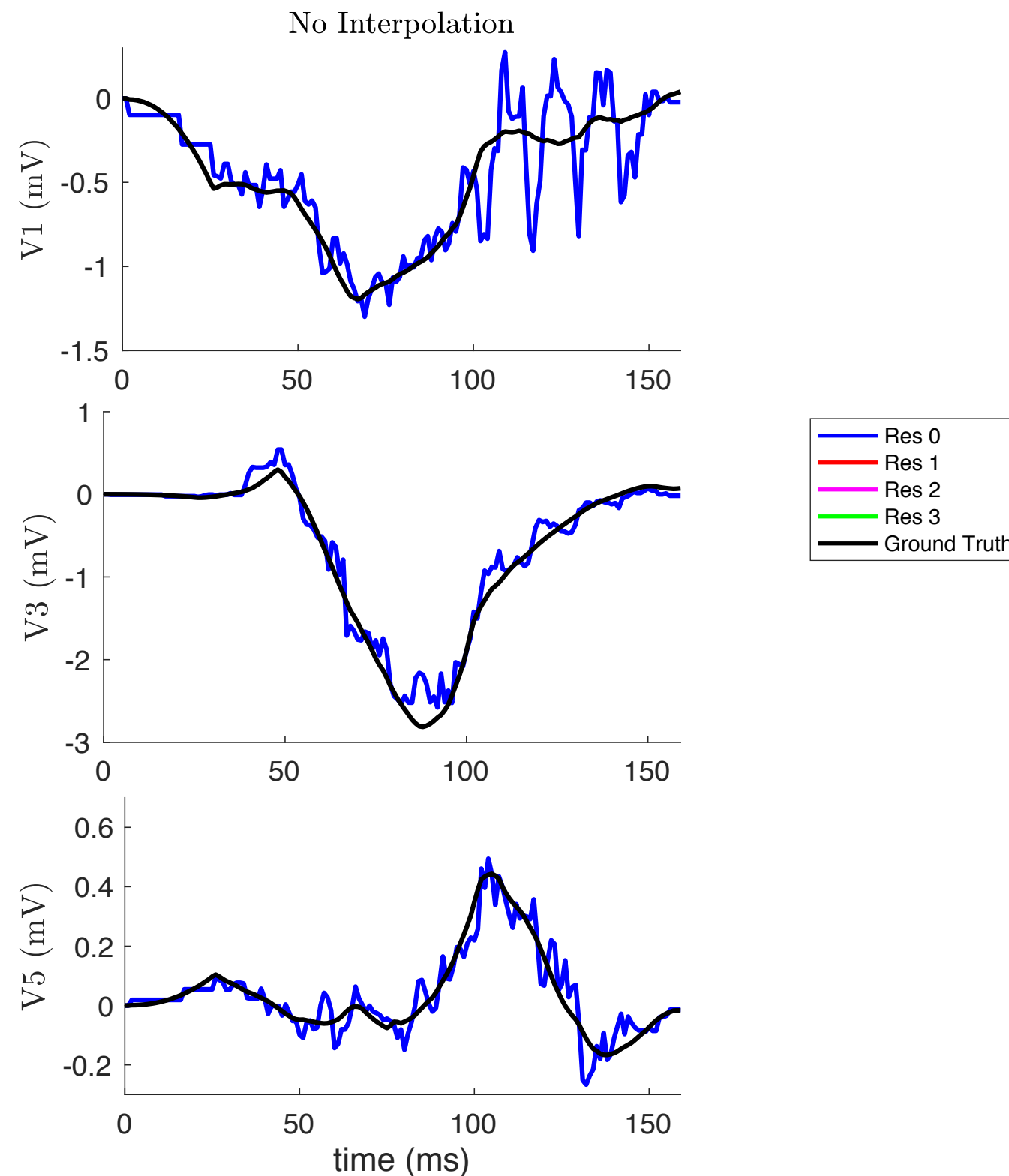


EDL BEM +
Interpolation

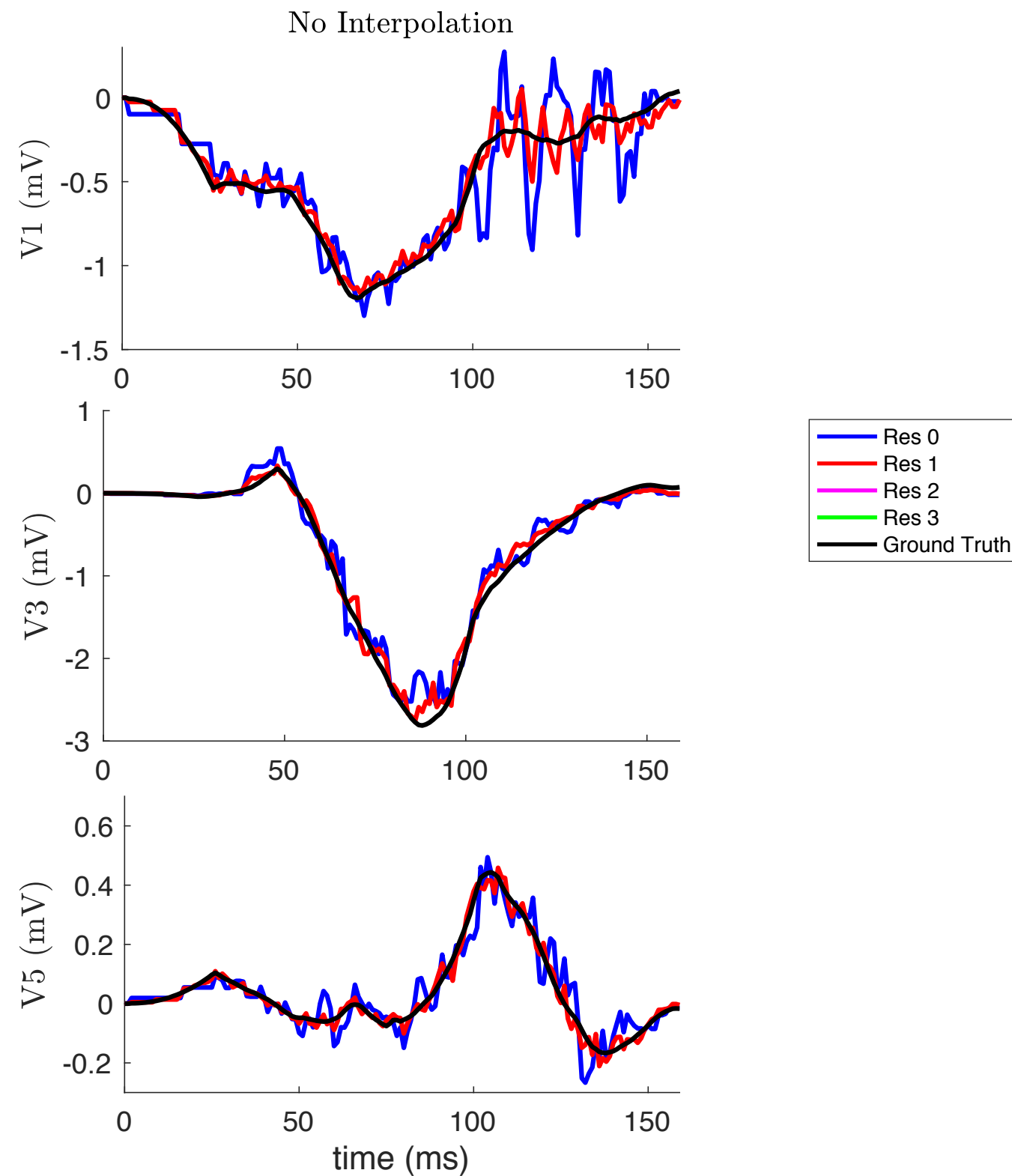
Effect of Undersampling



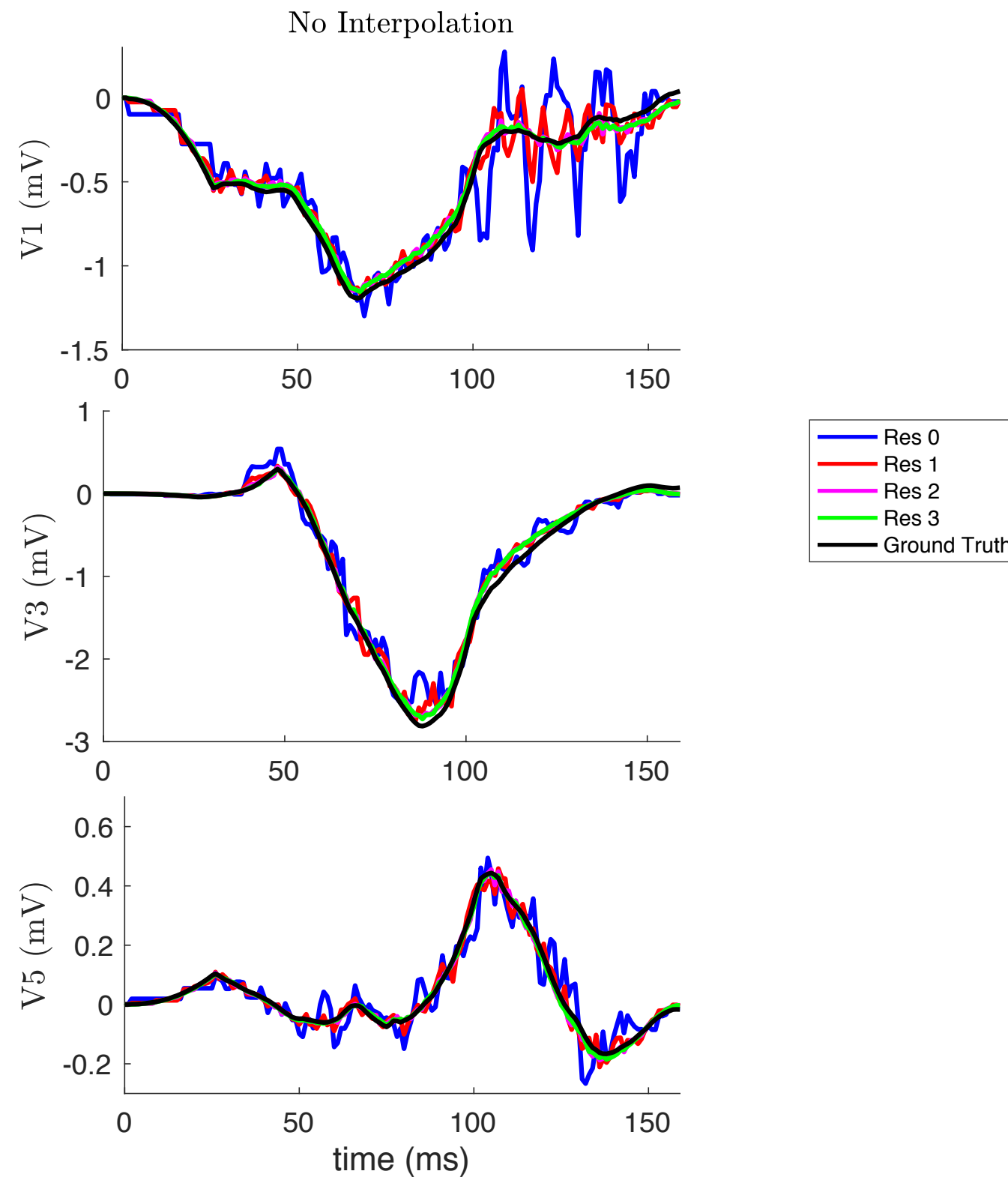
Effect of Undersampling



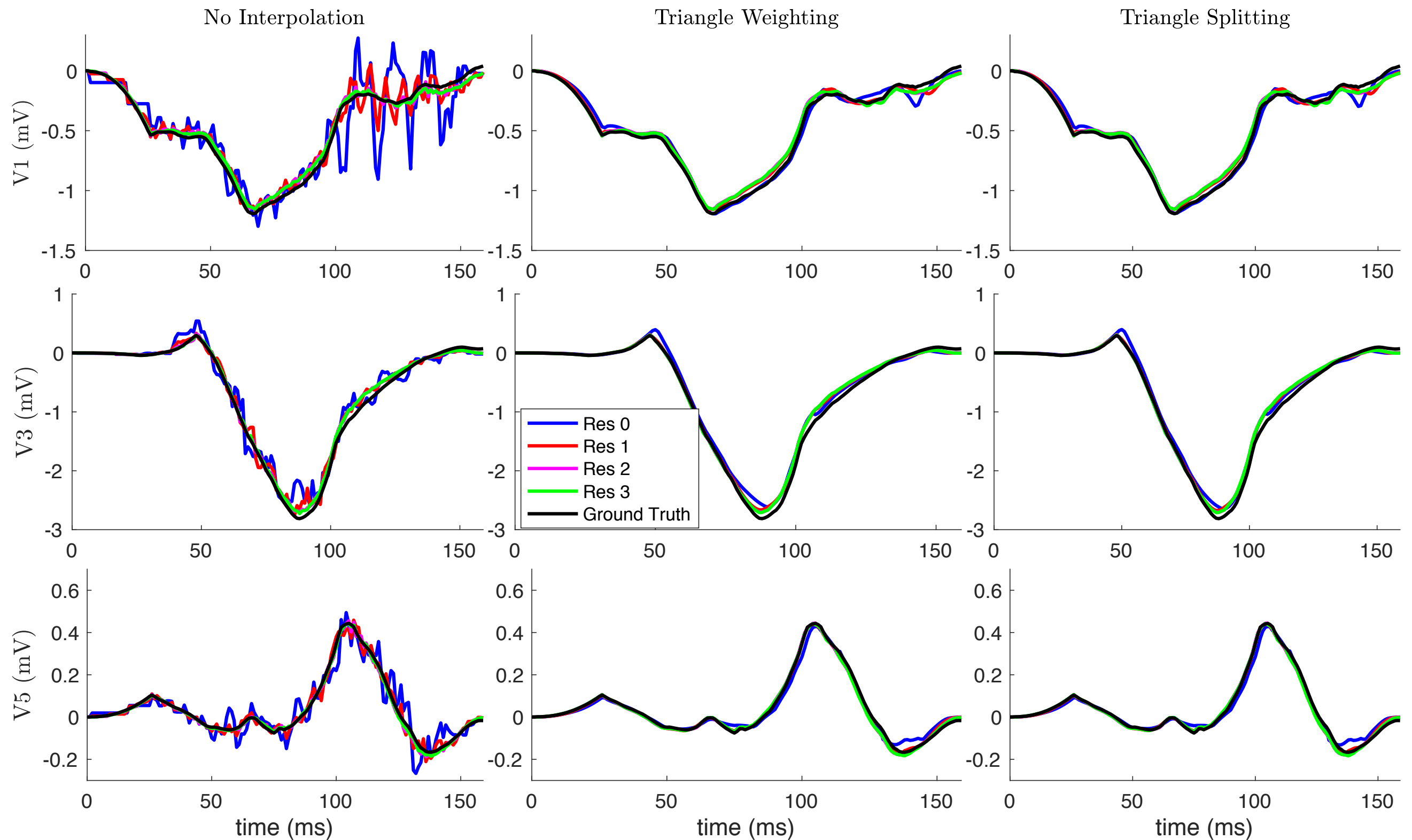
Effect of Undersampling



Effect of Undersampling

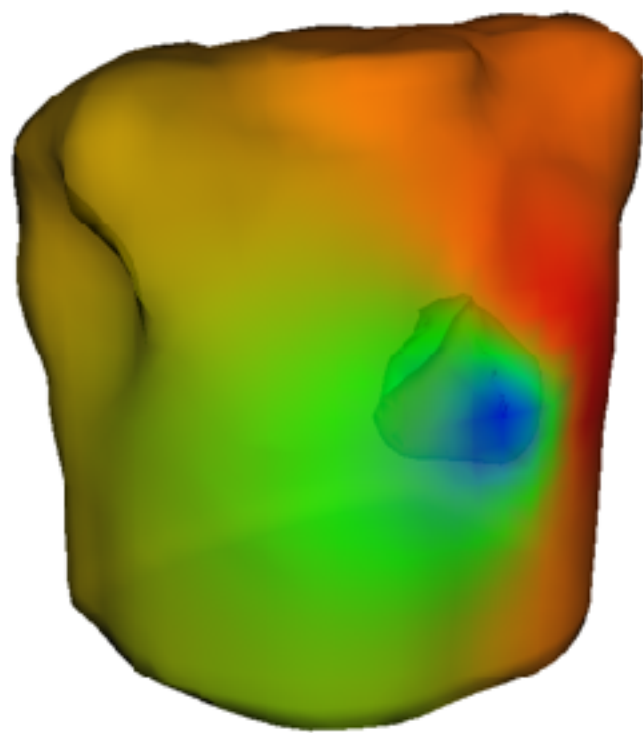


Effect of Interpolation

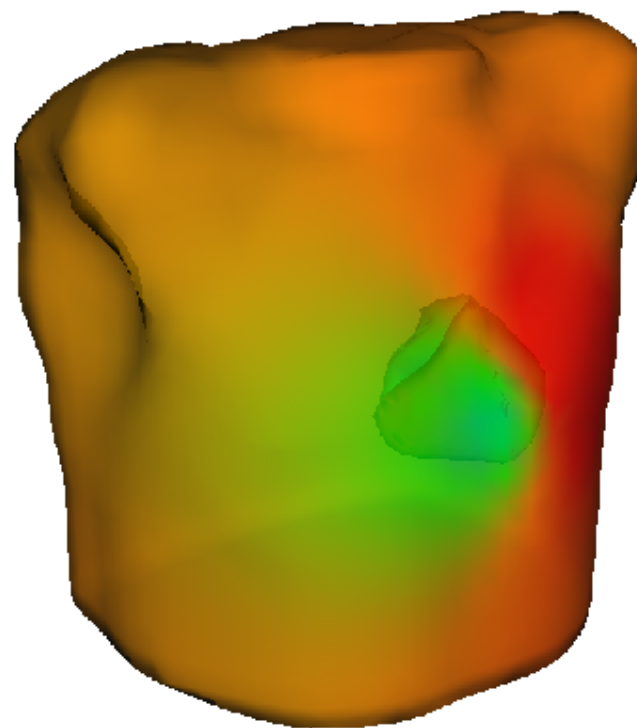


Spatial interpolation can eliminate temporal oscillations, even with low source resolution

Effect of Undersampling



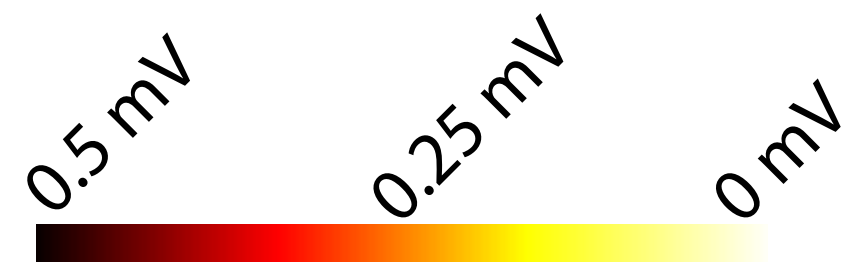
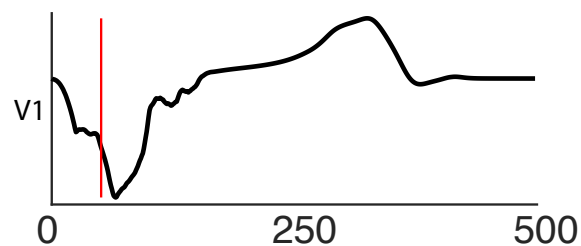
Ground Truth



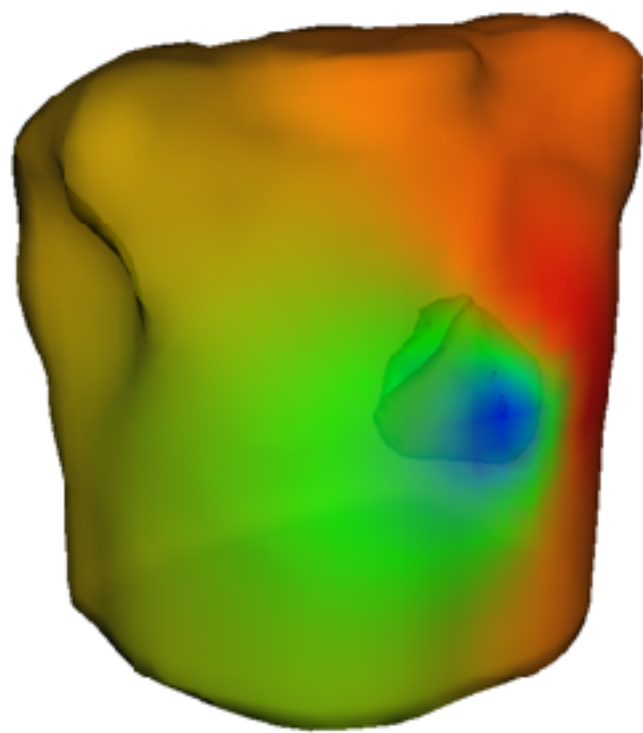
Res 0



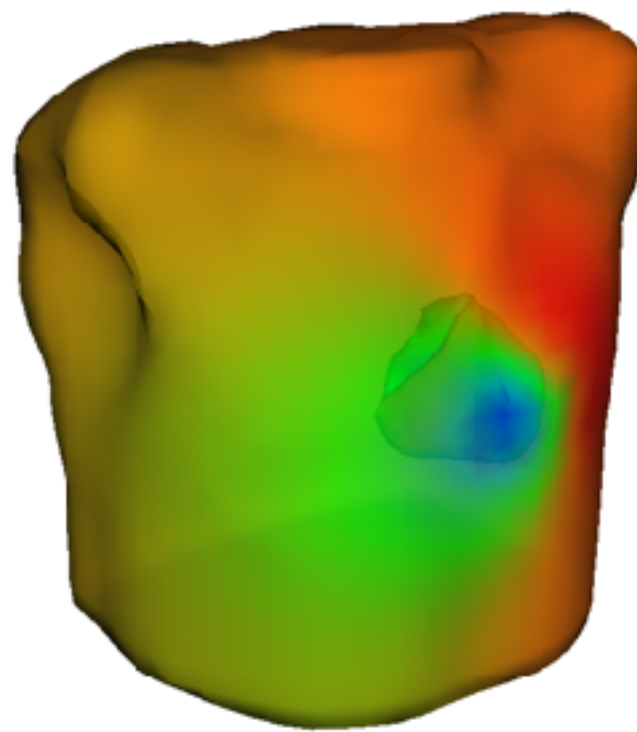
Difference



Effect of Undersampling



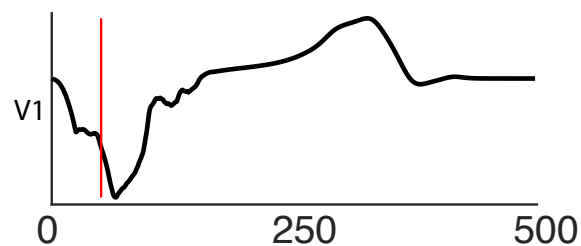
Ground Truth



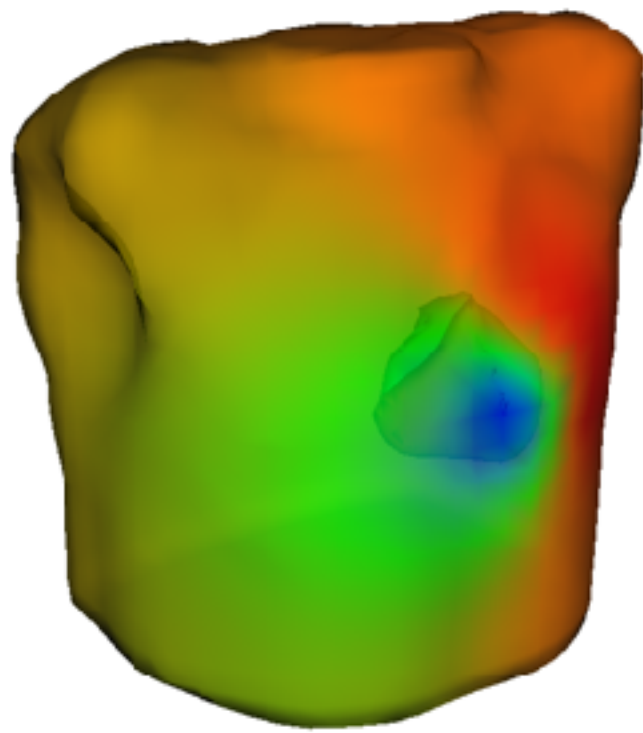
Res 1



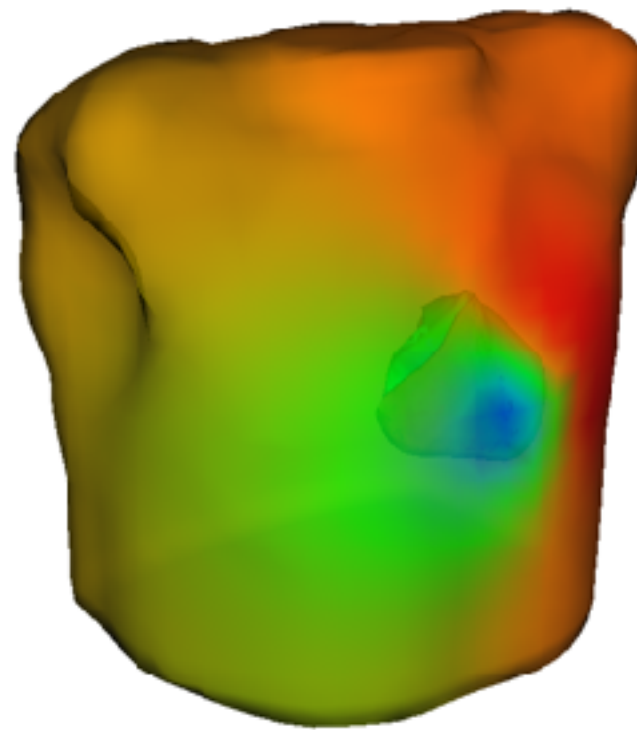
Difference



Effect of Undersampling



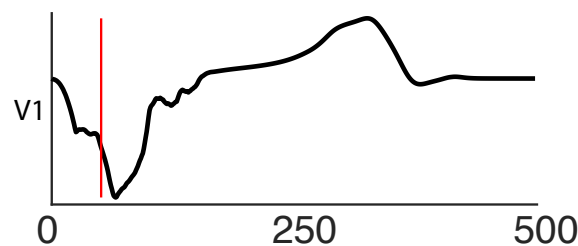
Ground Truth



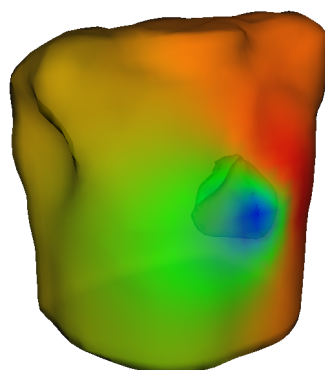
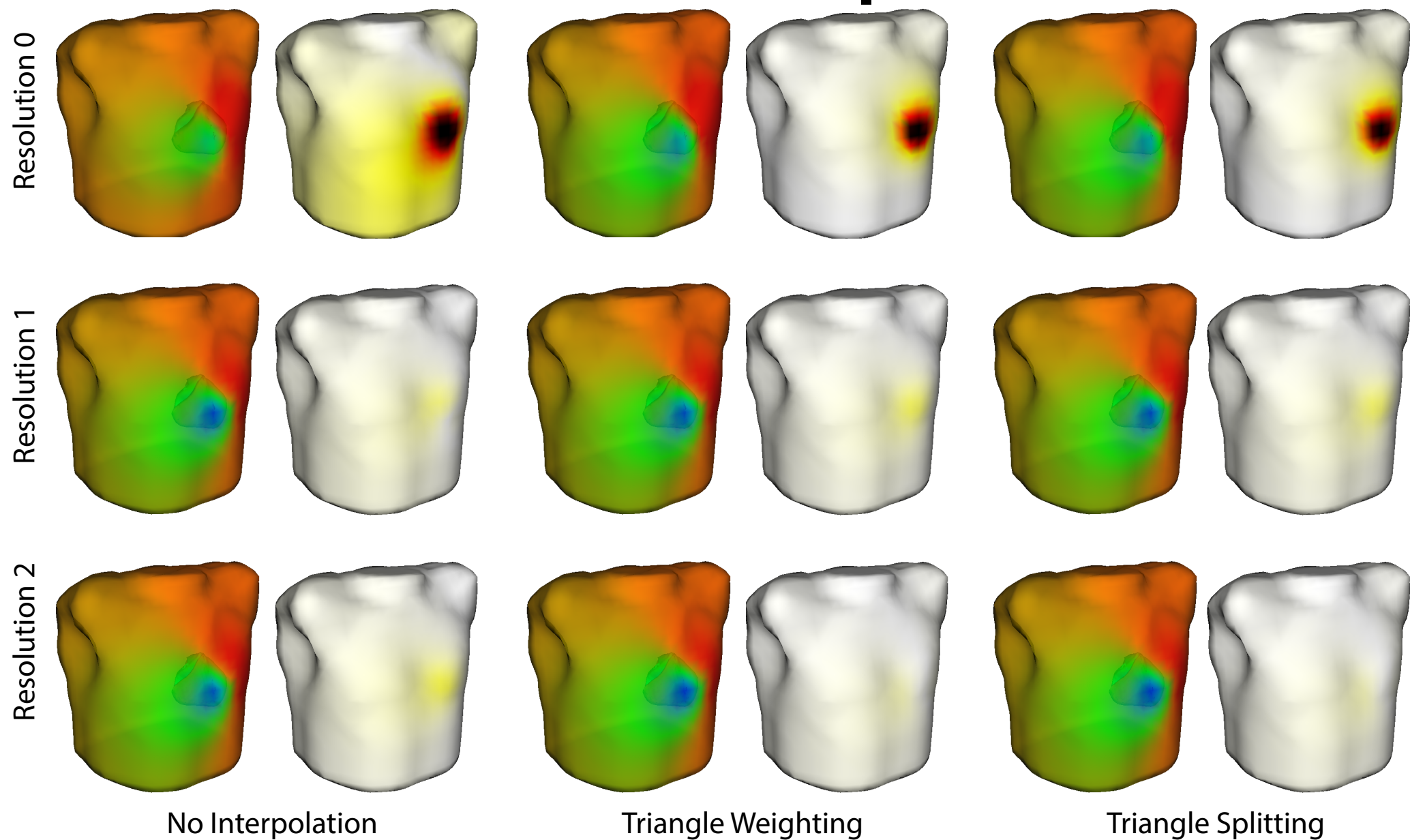
Res 2



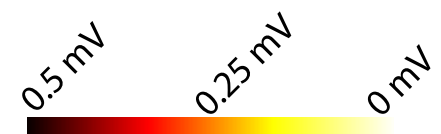
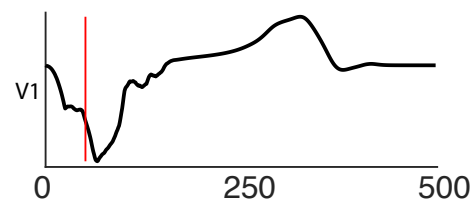
Difference



Effect of Interpolation

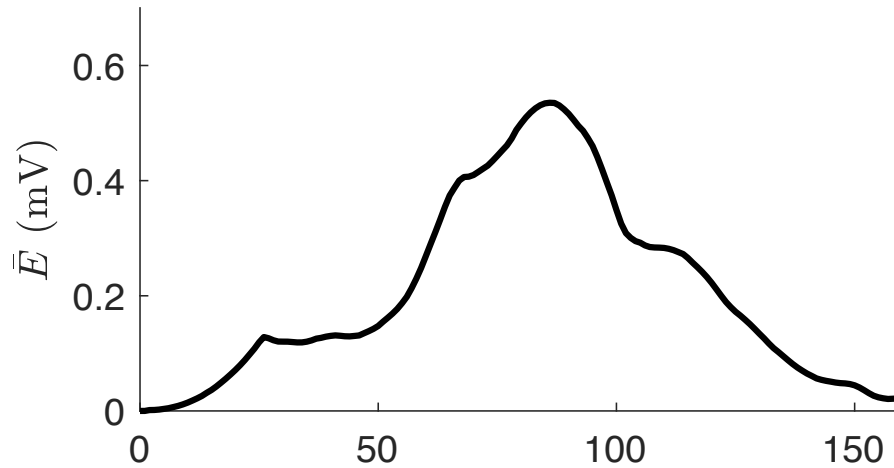


Ground Truth

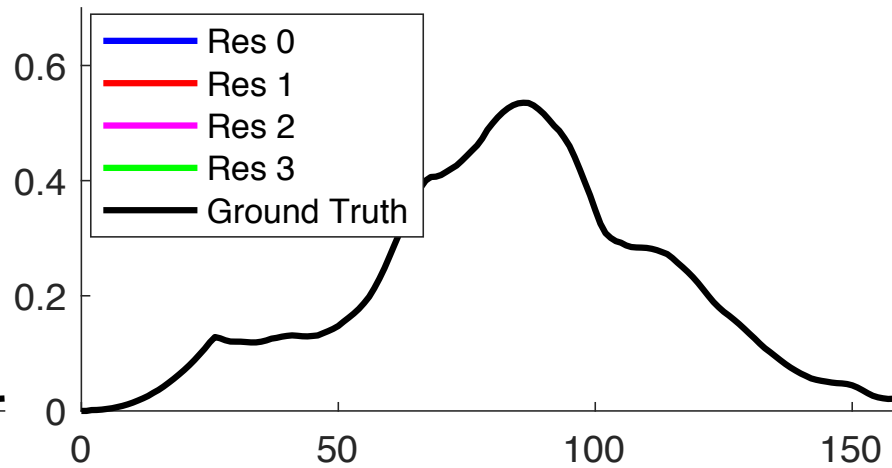


Metrics

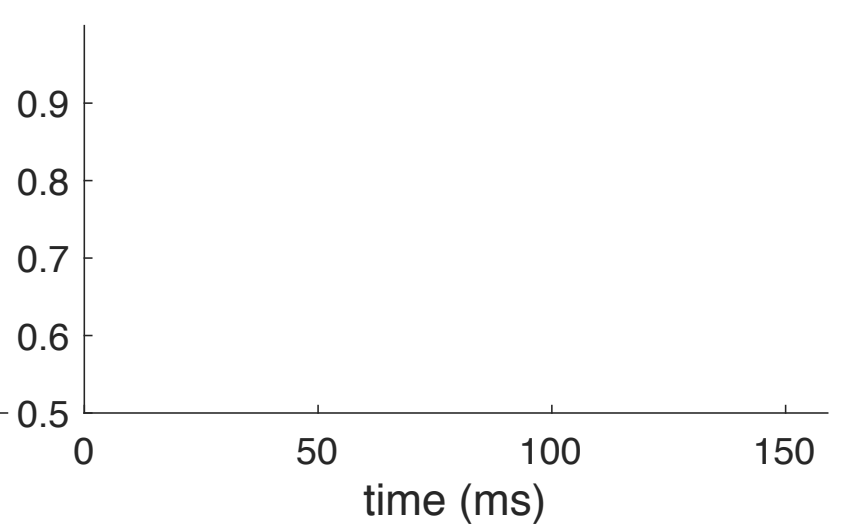
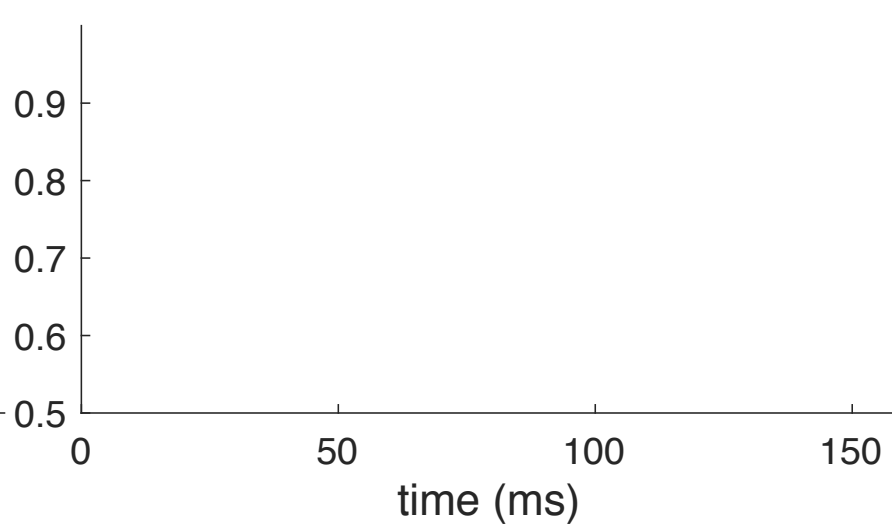
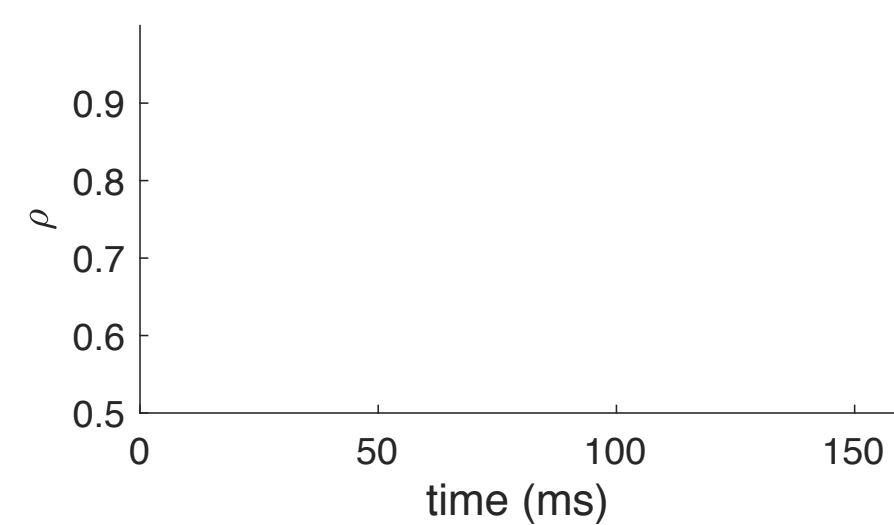
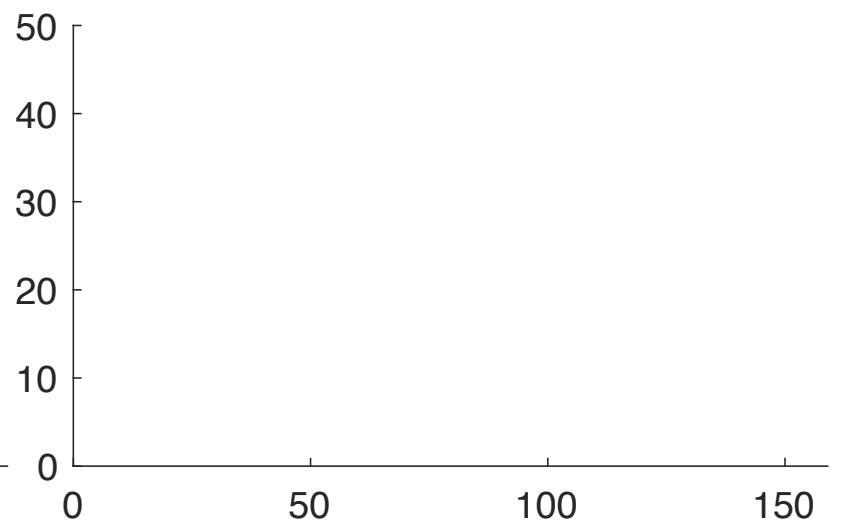
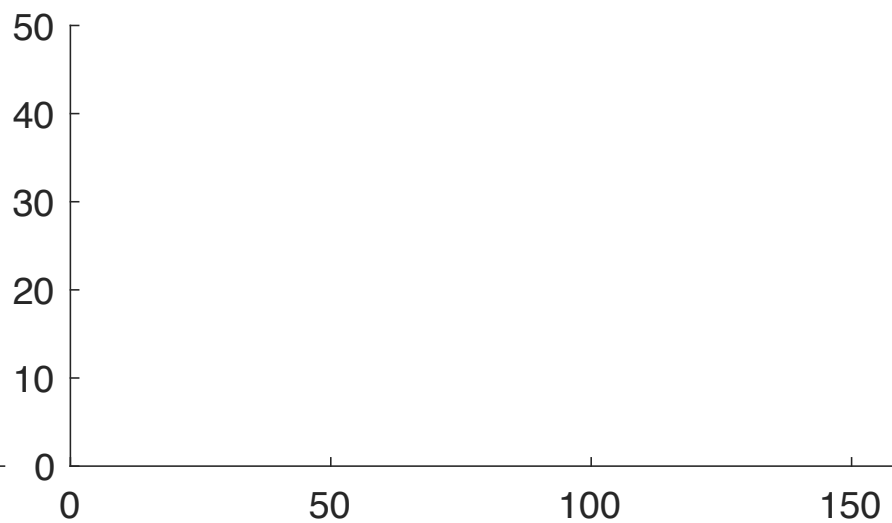
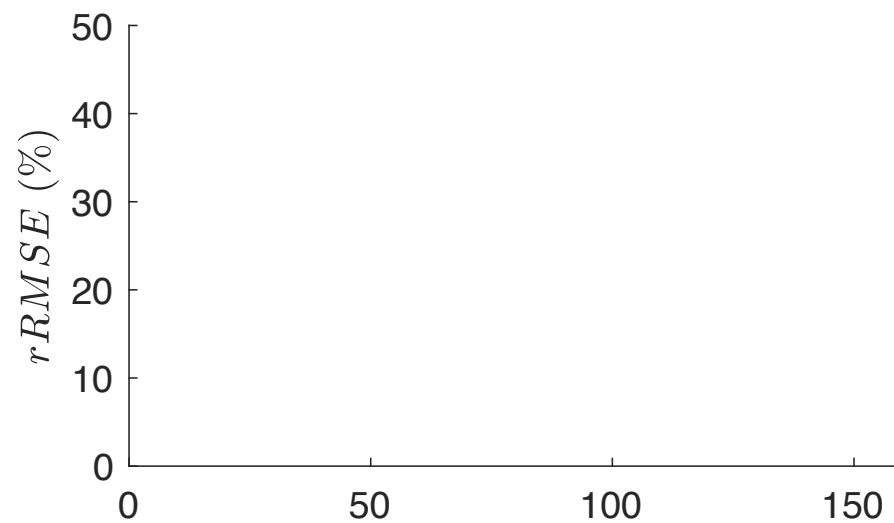
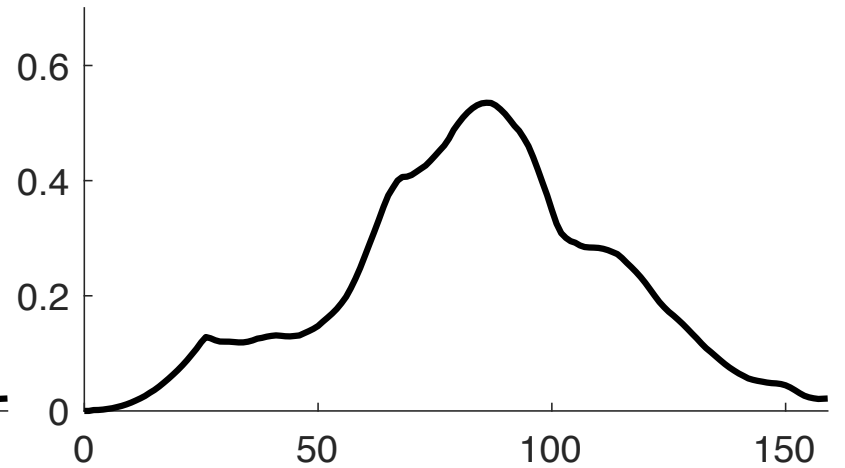
No Interpolation



Tringle Weighting



Tringle Splitting

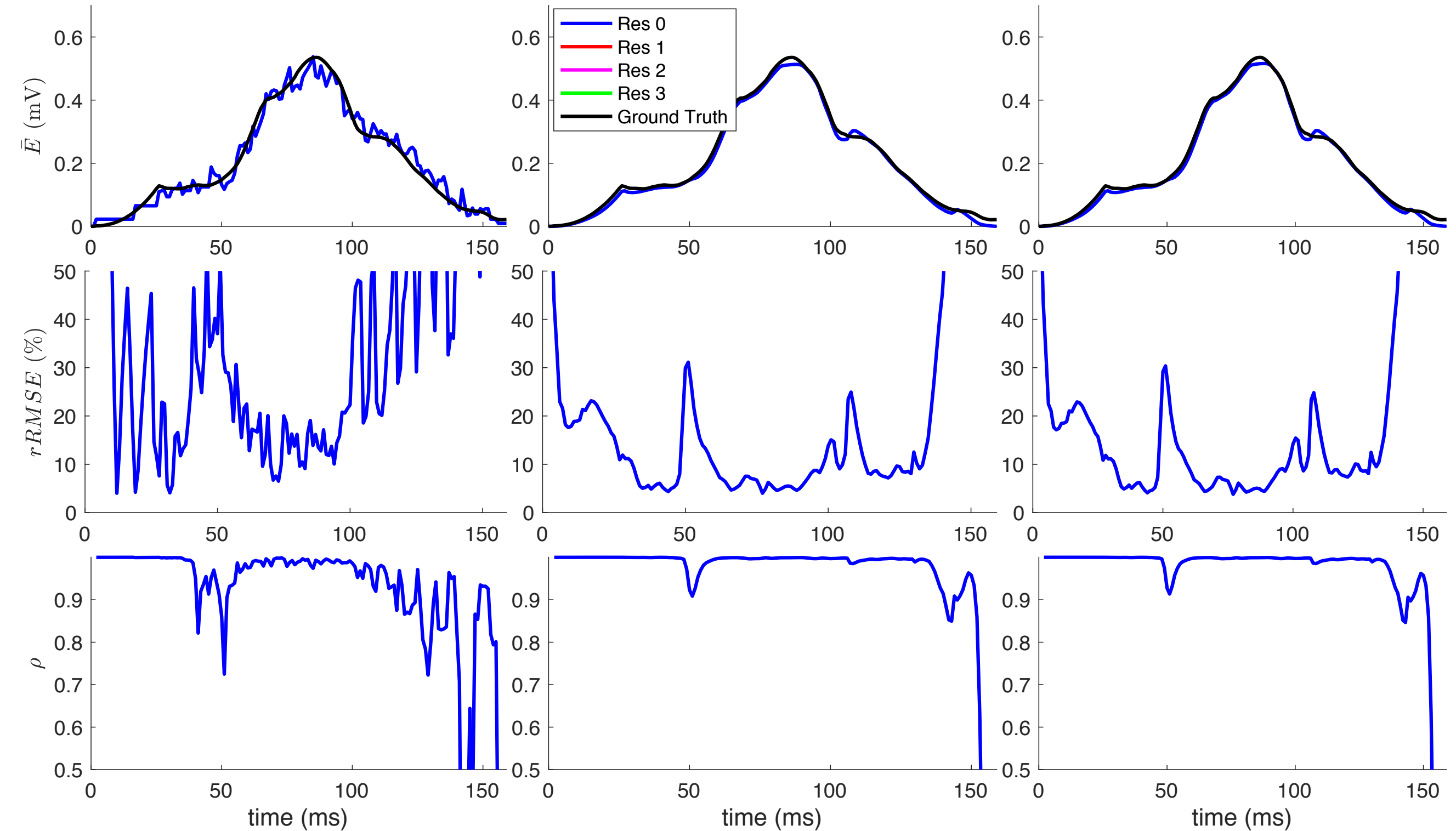


Metrics

No Interpolation

Tringle Weighting

Tringle Splitting

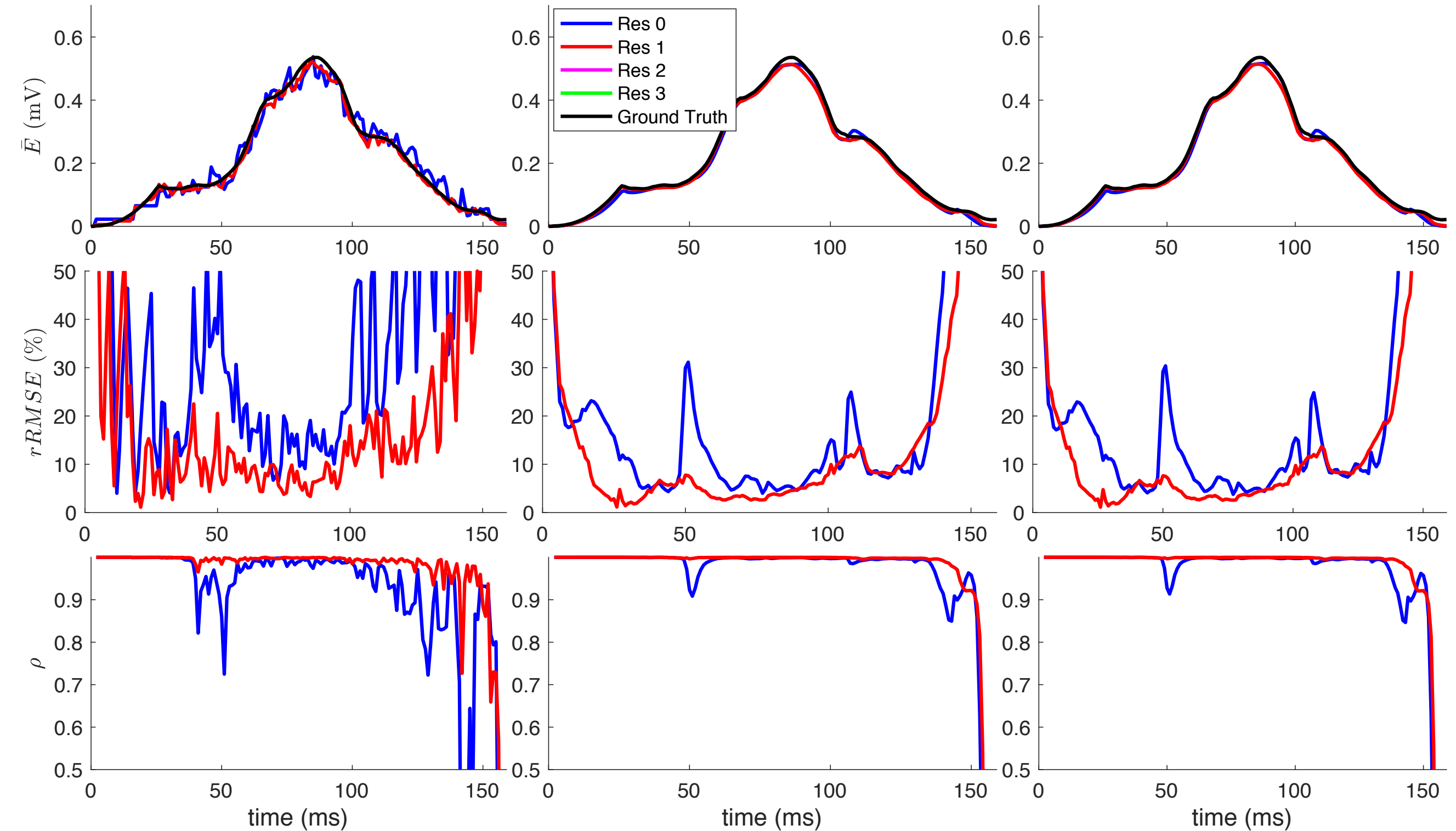


Metrics

No Interpolation

Tringle Weighting

Tringle Splitting

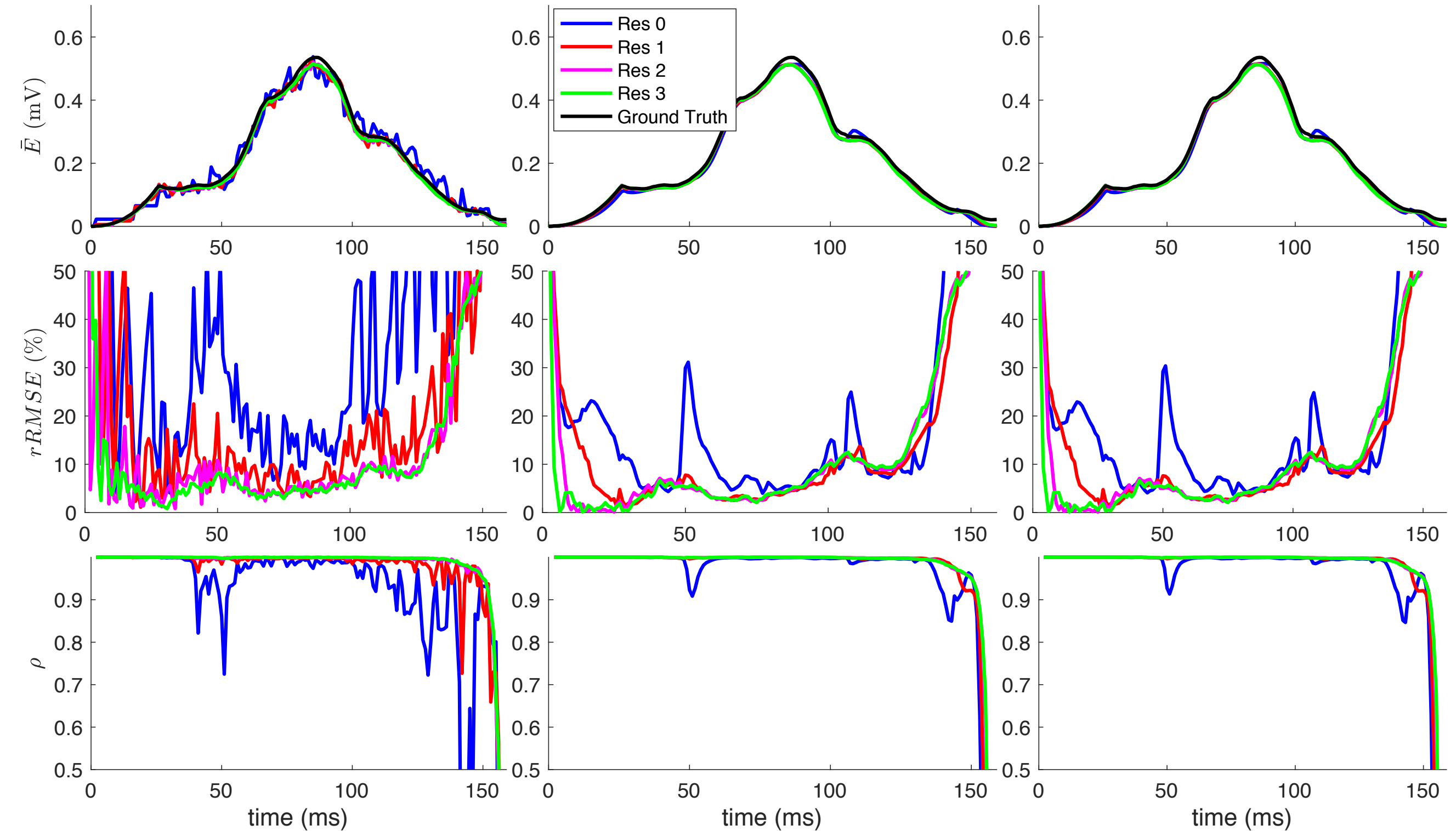


Metrics

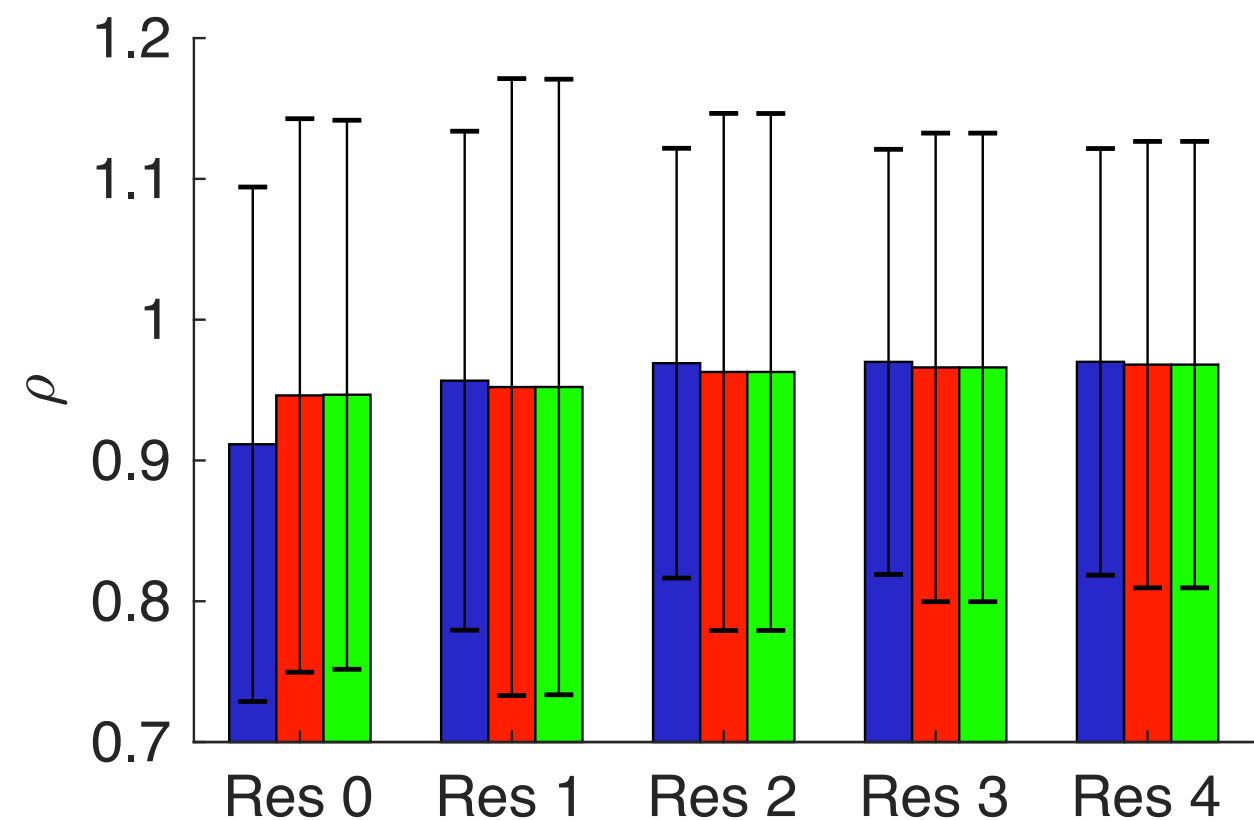
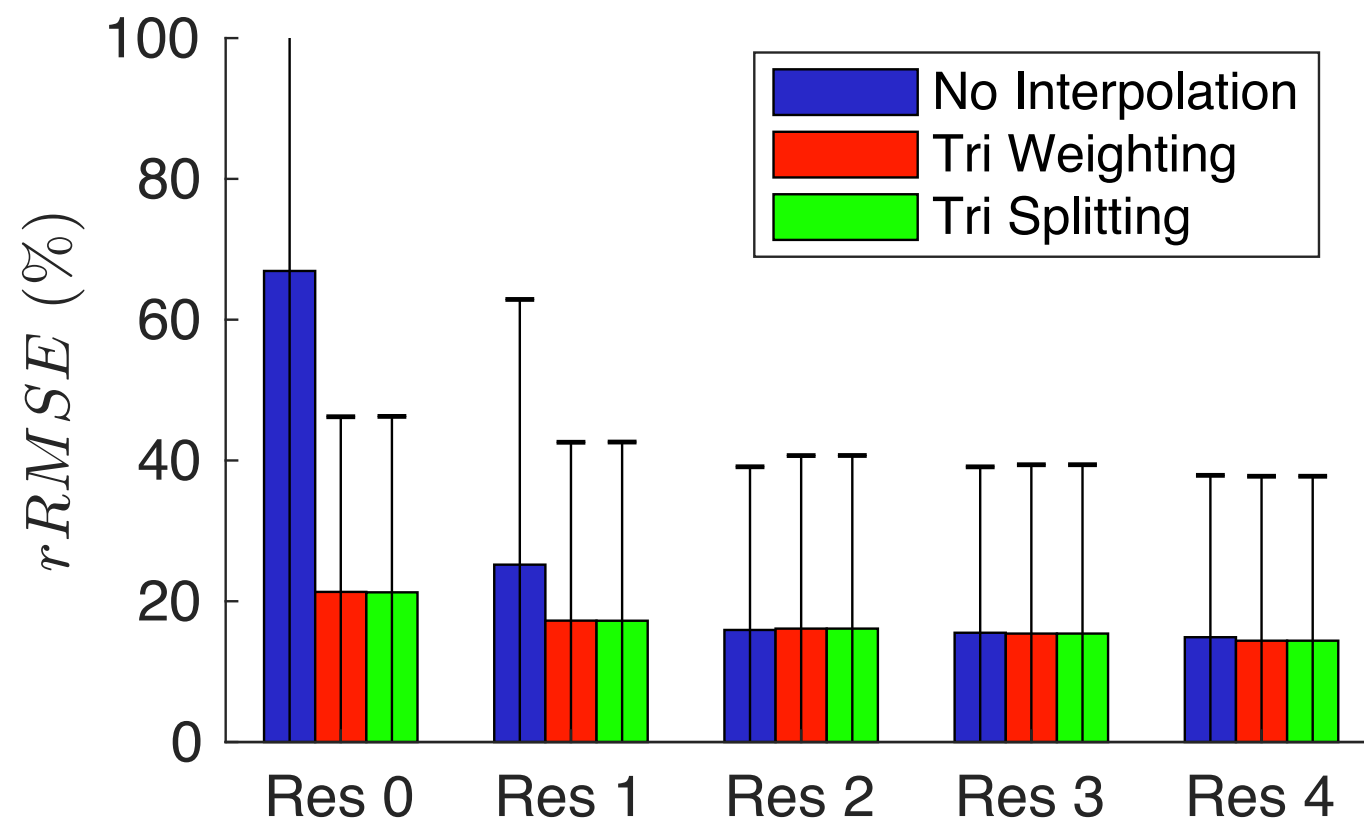
No Interpolation

Tringle Weighting

Tringle Splitting



Mean +/- Std Dev of Metrics



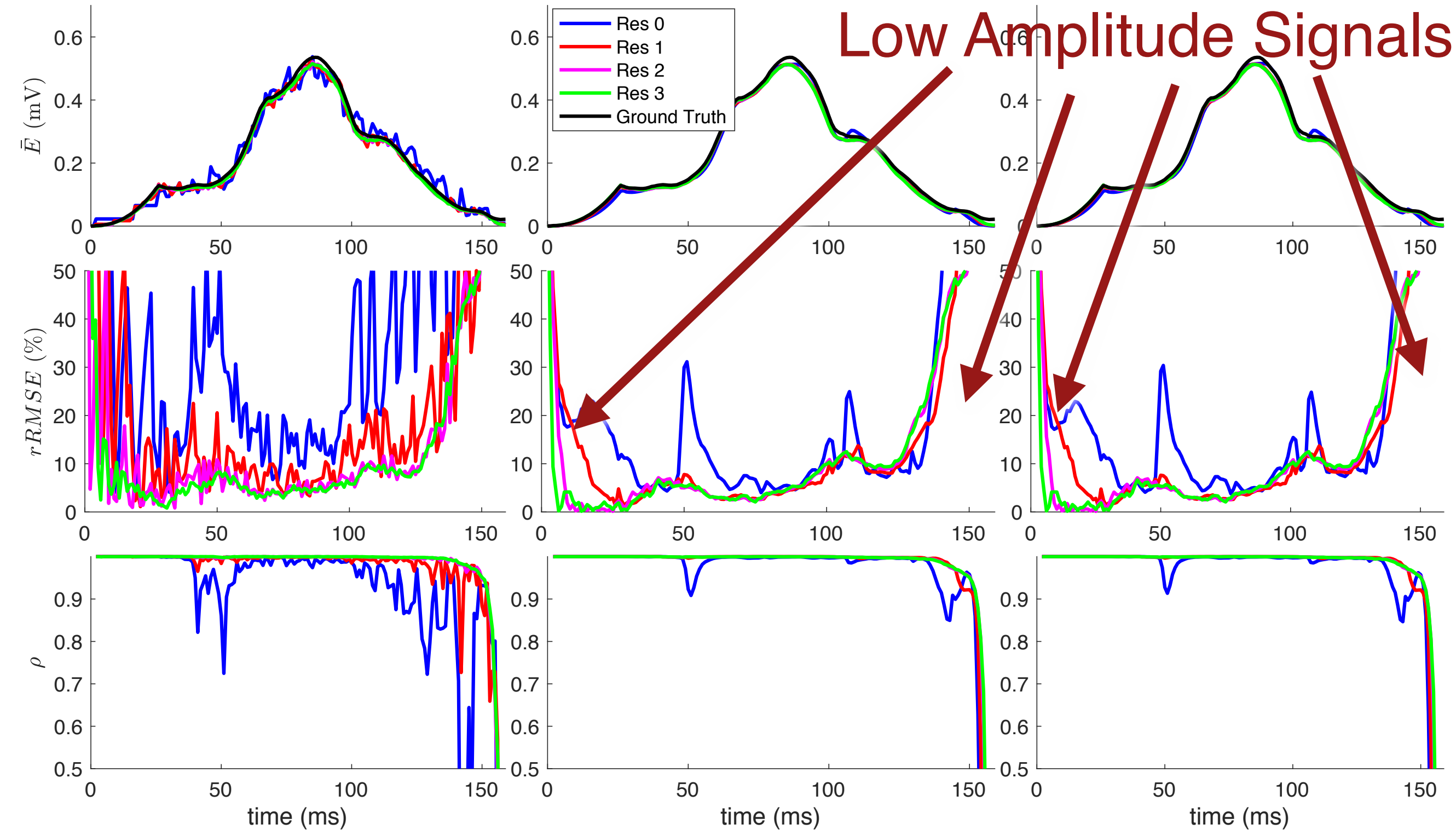
Metrics

No Interpolation

Tringle Weighting

Tringle Splitting

Low Amplitude Signals



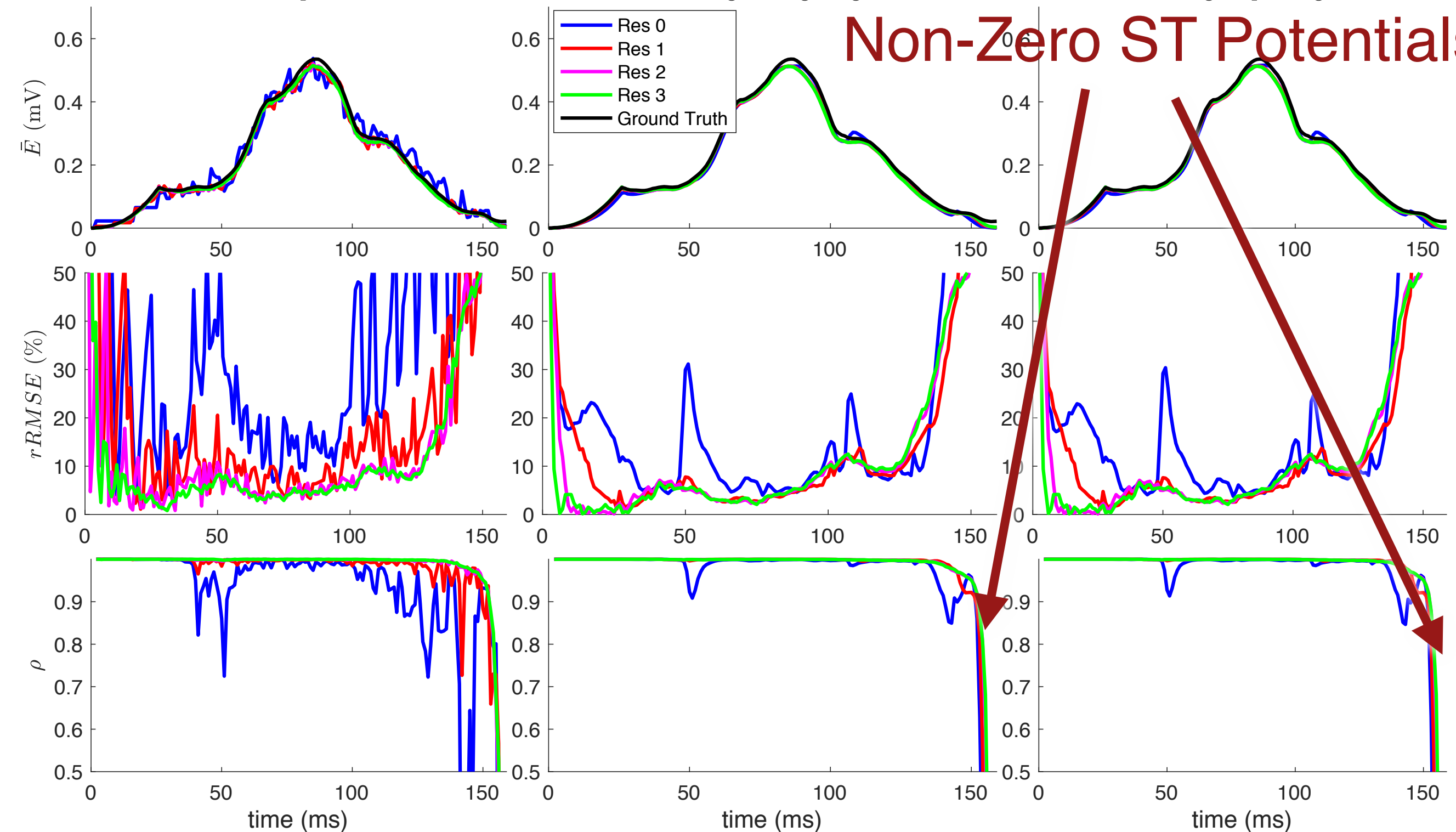
Metrics

No Interpolation

Tringle Weighting

Tringle Splitting

Non-Zero ST Potentials



Spatial interpolation can reduce temporal
and spatial error

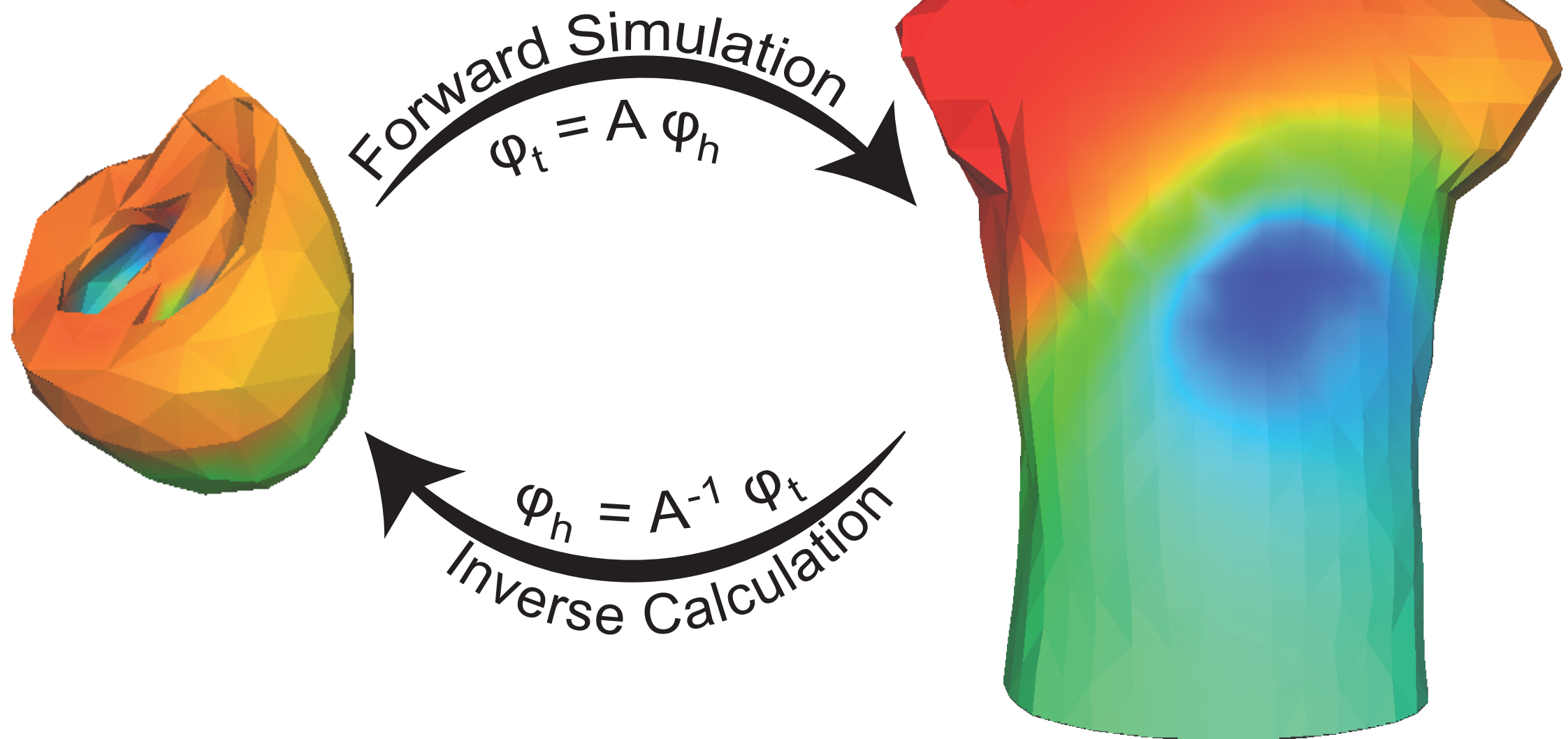
Triangle weighting and triangle splitting
performed similarly

EDL inverse is based on optimization
of the parameters

Improve ECGI (GCE)

Heart Potentials (φ_h)

Torso Potentials (φ_t)



With better source representation

Acknowledgements

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Rob MacLeod
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Steffen Schuler
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Dana Brooks

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