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Using a spectral element method to model atrial excitation

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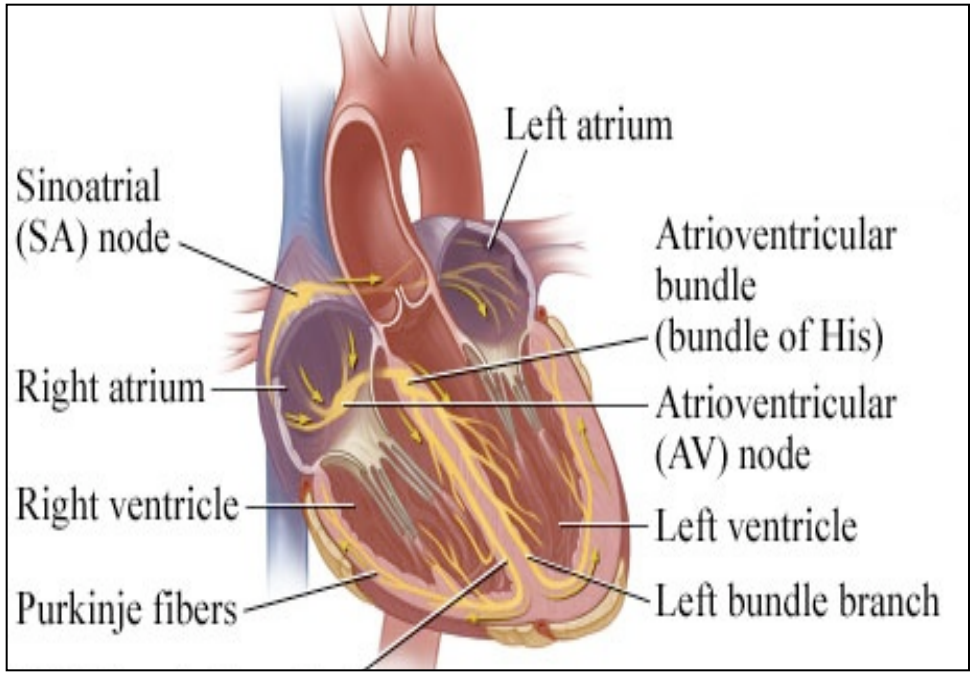
14/03/13

British Heart Foundation

Biological Background: Cardiac Excitation

Propagating action potentials: Co-ordinated contraction of the heart muscles.



Heart's Conduction Pathway [1]

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Clinical relevance: Cardiac Arrhythmias

Cardiac Arrhythmia: Abnormal excitation of cardiac tissue

Possible causes:

- Abnormal trigger, e.g. cells which are not in the SAN
- Structural damage creating a disorganised wave front of electrical activity

Types of Cardiac Arrhythmias:

1. Ventricular fibrillation – can result in sudden cardiac arrest and death
2. Atrial fibrillation (AF)

- Most common type of Arrhythmia
- Development of serious complications, e.g. stroke
- It affects over 10% of people over 75[1]

1. http://www.nhs.uk/conditions/Atrial-fibrillation/Pages/Introduction.aspx

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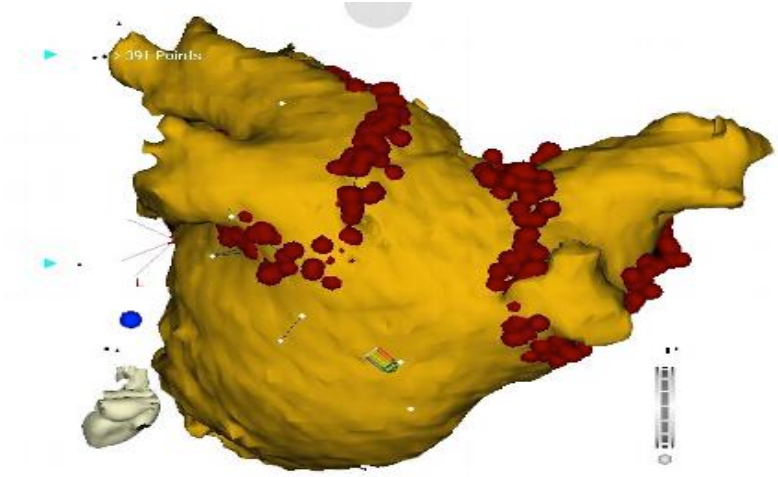
Clinical relevance: Treatment of Atrial Fibrillation

Use of Radiofrequency (RF) ablation:

- Done via catheter which is inserted from the femoral artery
- Application of Radio frequency energy to tissue so that it can no longer be electrically excited

Paroxysmal atrial fibrillation :

- Pulmonary veins- triggers of atrial fibrillation
- Pulmonary vein isolation- ablation around the two pairs of pulmonary veins.



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Clinical relevance: Treatment of Atrial Fibrillation

Use of Radiofrequency (RF) ablation:

- Done via catheter which is inserted from the femoral artery
- Application of Radio frequency energy to tissue so that it can no longer be electrically excited

Persistent Atrial Fibrillation- common factors:

- Structural changes, e.g. fibrosis, hypertrophy
- Electrical remodelling, e.g. shortening of the refractory period

Atrial Ablation Strategies: Pulmonary Vein Isolation is not sufficient, additional ablation required

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Clinical relevance: Persistent Atrial ablation strategies

Persistent Atrial ablation strategies- combination of

- Anatomical location- e.g. PVI isolation
- Simple vs. complex electrograms

Limitation of strategies of AF ablation:

- Difficulty in determining optimal ablation locations
- More ablation carried out than necessary
- Loss of contraction
- Atrial ablation has a success rate of less than 40% for Persistent AF [1]

1 Cheema, A. et al. (2006). Long-term single procedure efficacy of catheter ablation of atrial fibrillation. Journal of Interventional Cardiac Electrophysiology

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Clinical relevance: Persistent Atrial ablation strategies

IDEA:

NUMERICAL MODELLING CAN HELP INFORM ABLATION STRATEGIES

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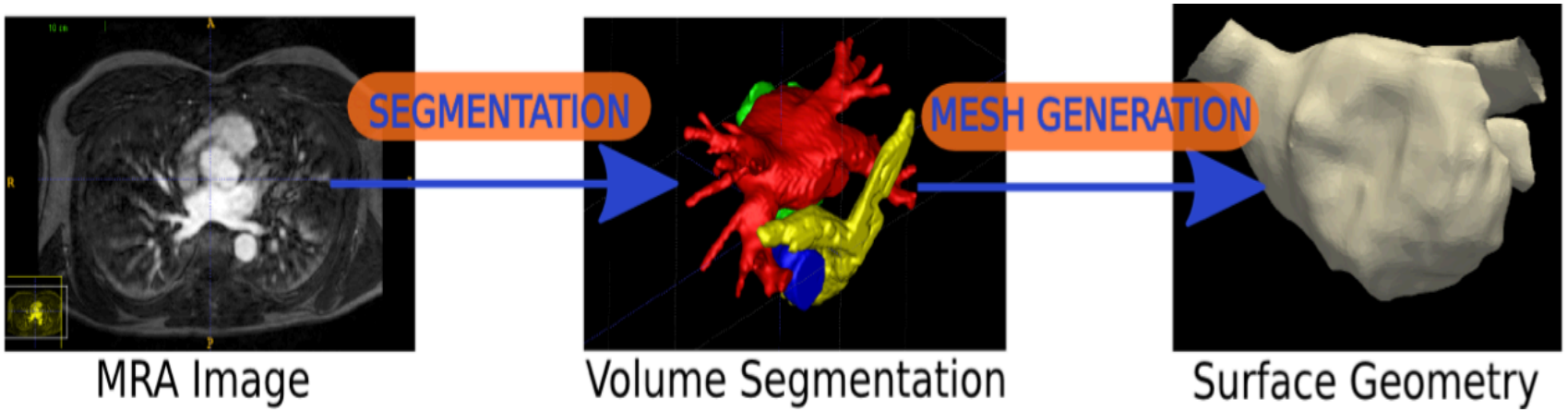
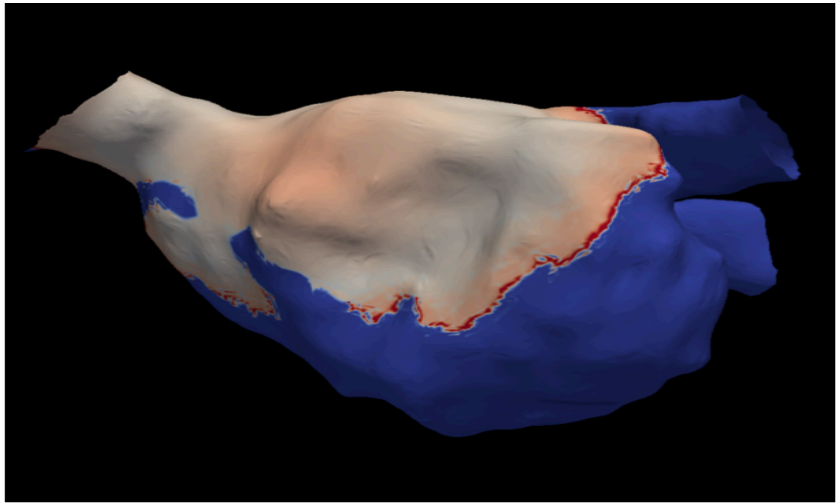
Background: Generation of patient specific geometry



Stimulate atrial model using electrophysiological model, e.g. Courtemanche



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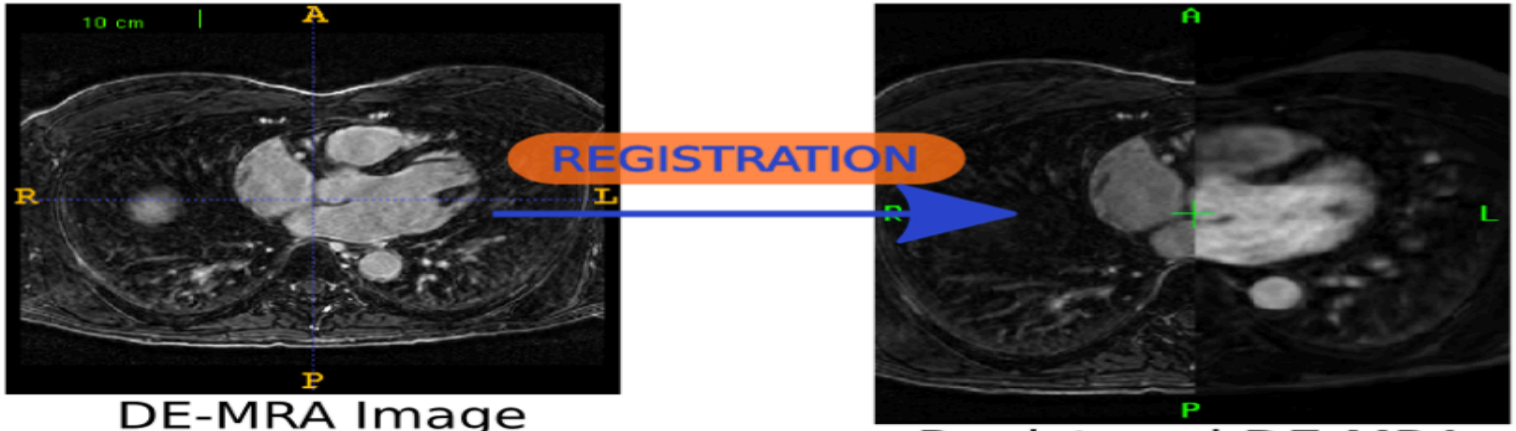
Validation of model: 1. Generation of patient specific geometry

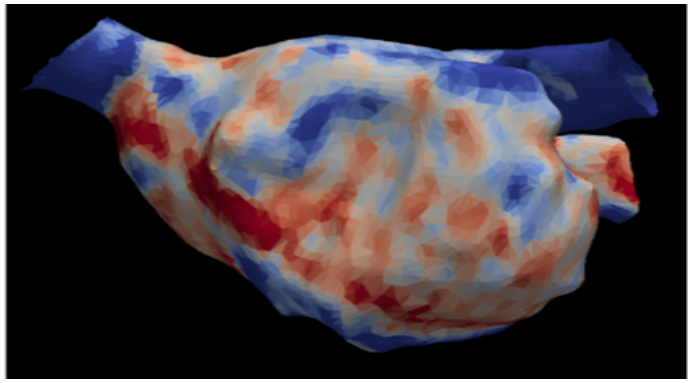
Register the de-MRA (contrasted) image onto the MRA geometry



DE-MRA Image

Registered DE-MRA

Project intensity onto Surface Geometry



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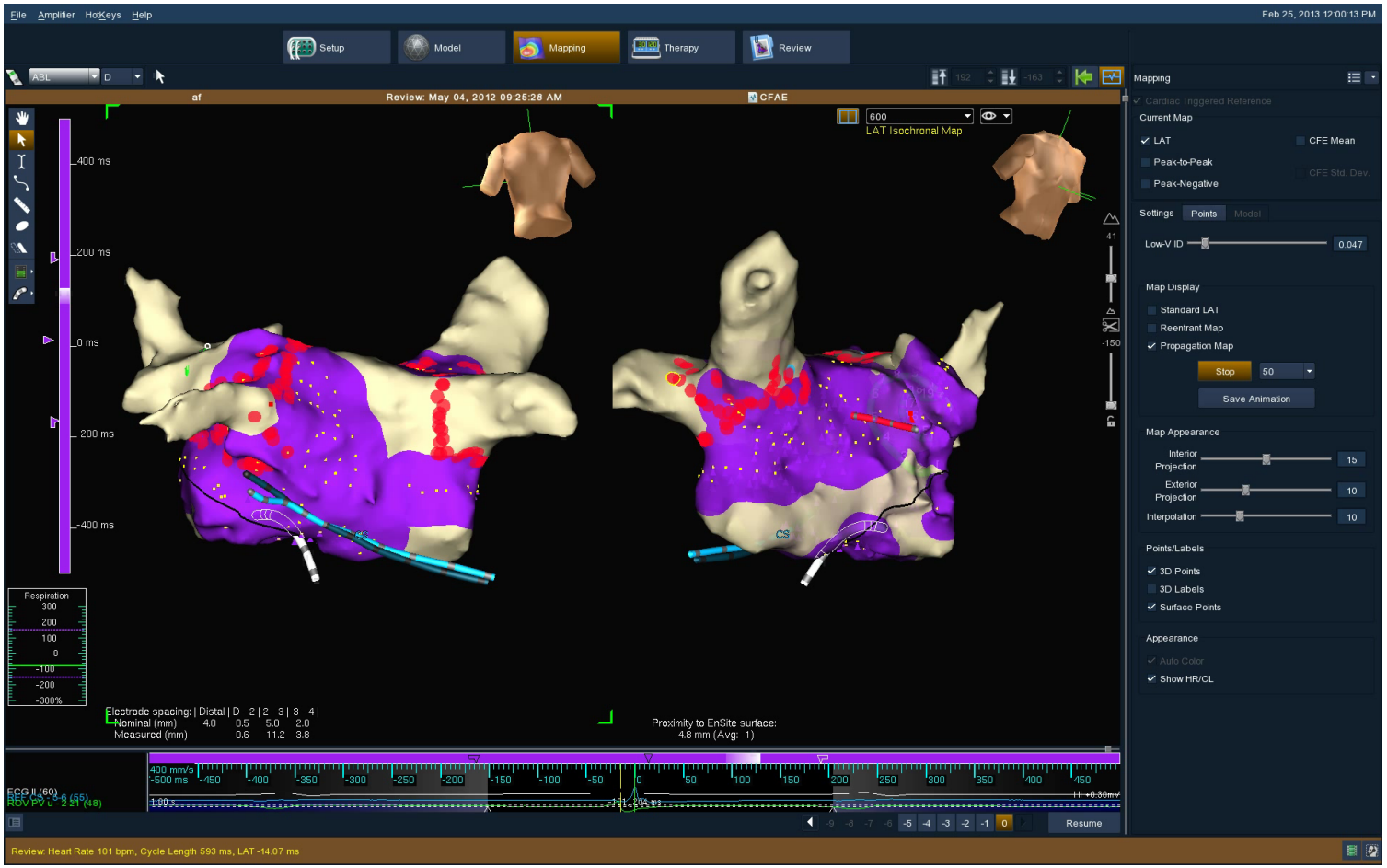
Atrial Excitation in the Clinical Software



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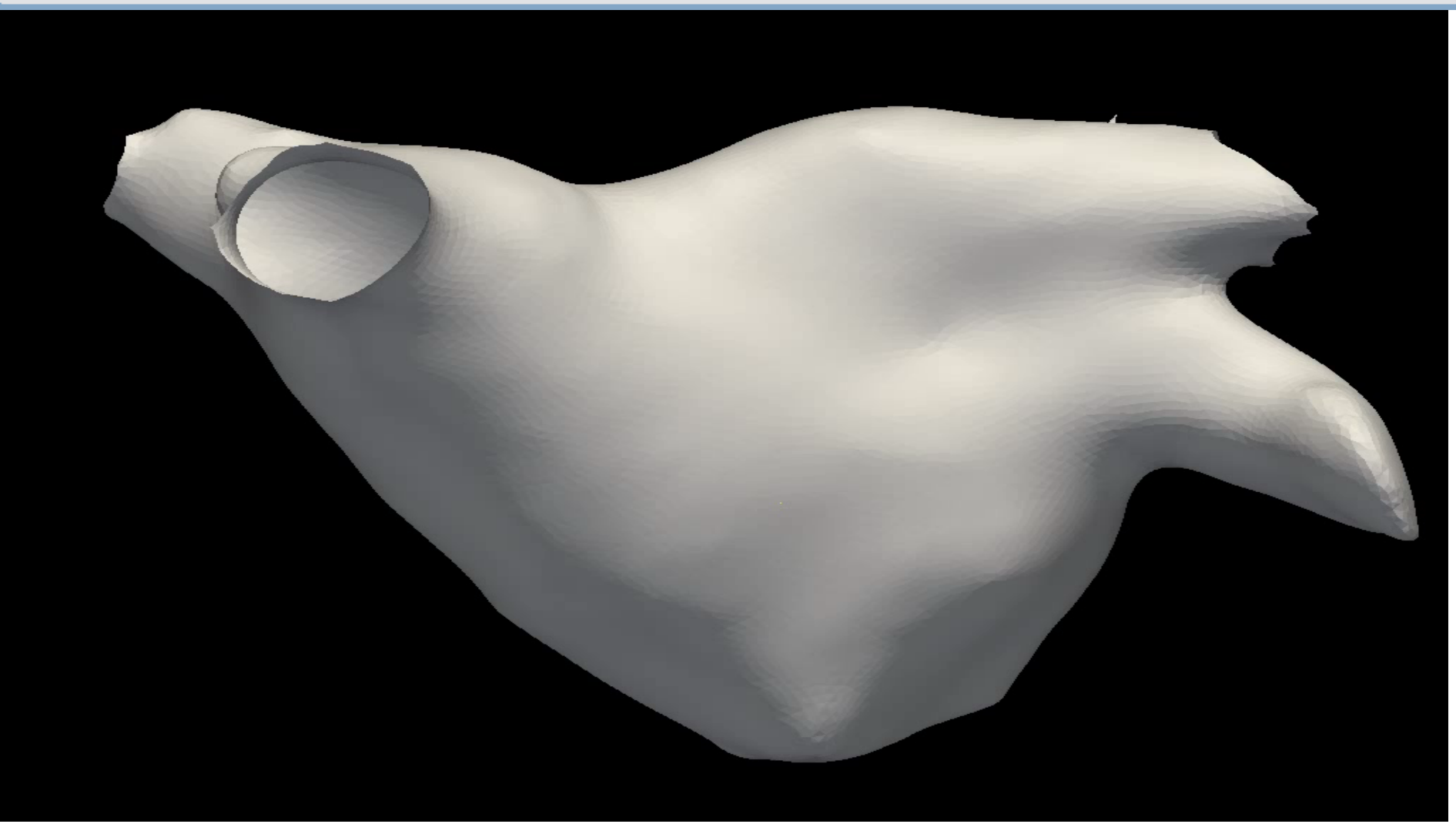
Isotropic excitation in Nektar ++ : 15,000 elements



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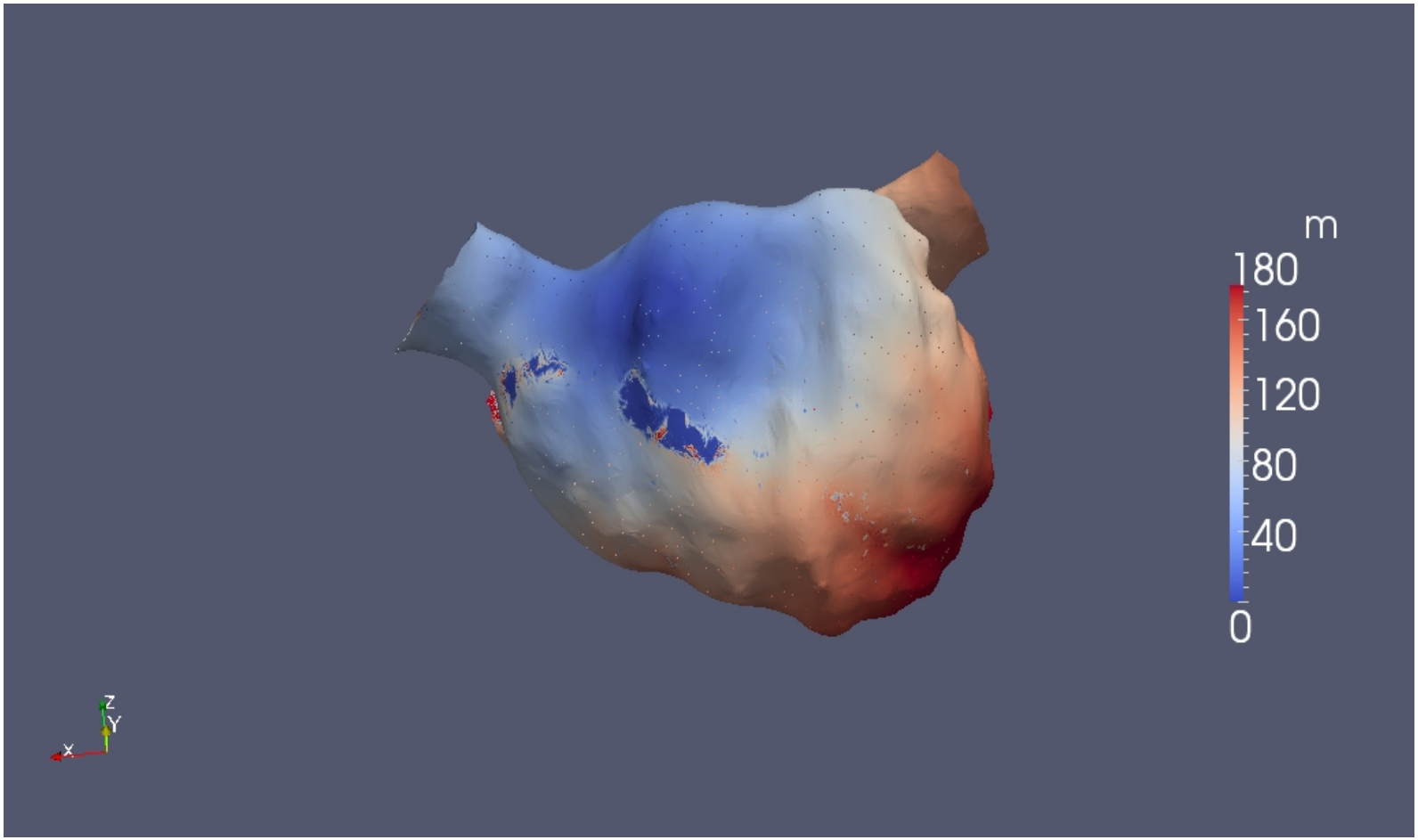
Post processing using Nektar++ Utility



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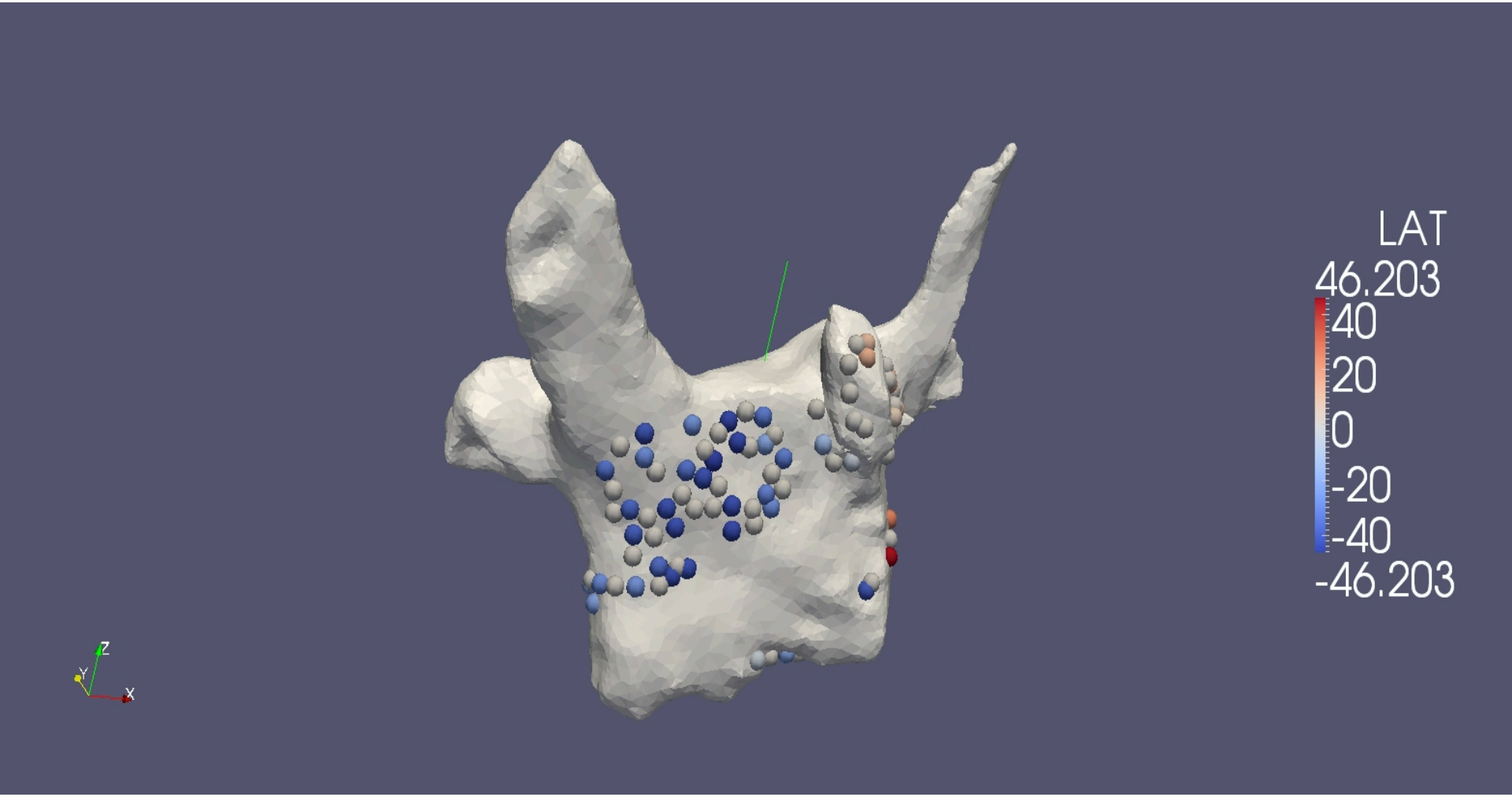
Clinical Geometry



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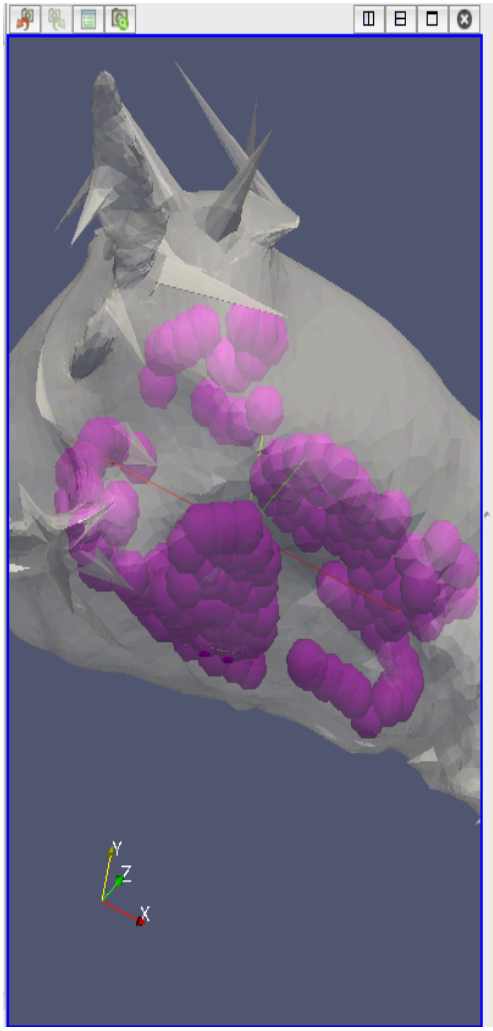
Probed Electrogram Points



Showing: surf_morphed-points_electrogram.vtk Attribute: Point Data Precision: 6

	Points			Point ID
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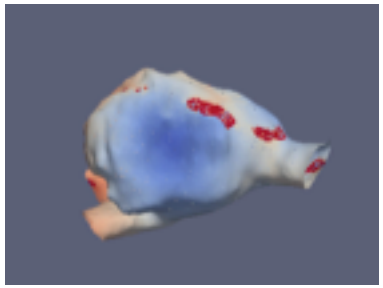
1	-27.3366	-0.601281	23.6112	1
2	-28.987	-0.296735	21.7173	2
3	-31.4464	0.63156	21.5156	3
4	-38.2876	-0.549939	22.2442	4
5	-39.3095	0.263665	26.793	5
6	-38.7877	-0.0636689	28.8153	6
7	-37.7082	0.484554	30.0643	7
8	-36.3428	1.58811	30.9748	8
9	-31.9217	3.32453	33.0176	9
10	-30.0239	3.56585	32.8008	10
11	-28.0956	4.63528	30.6498	11
12	-28.8383	3.82336	27.9544	12
13	-29.9026	3.44991	25.1588	13
14	-31.3505	3.85168	24.3744	14
15	-37.1312	2.71126	25.5272	15
16	-37.9972	1.47279	26.8786	16
17	-37.4314	1.09682	29.3402	17



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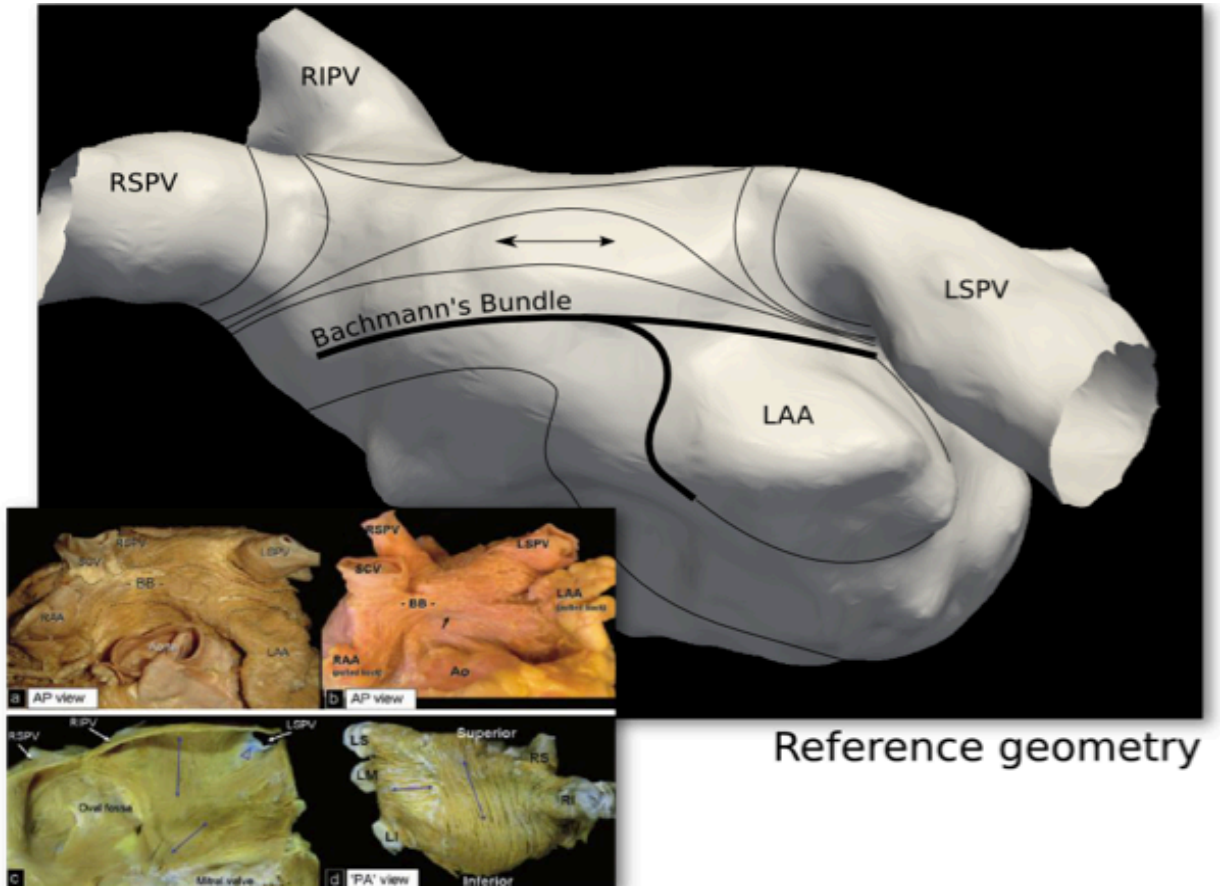
Validation of model: 2 . Reference geometry-fibre orientation

Fibre orientation required to more accurately model anisotropy of action potential propagation.



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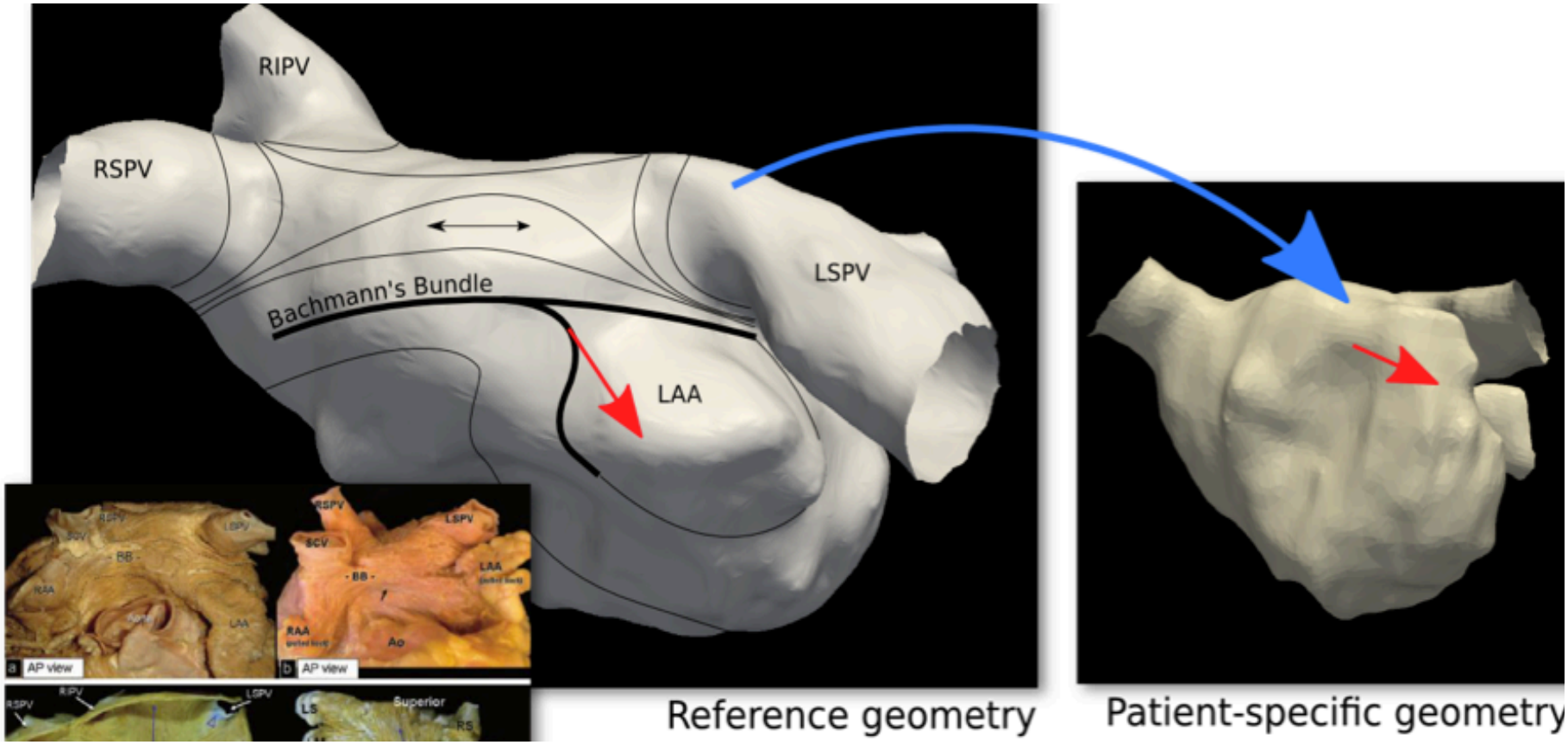
Validation of model: 3. Map fibre orientation onto patient specific geometry

Map landmark points on reference geometry onto patient specific geometry



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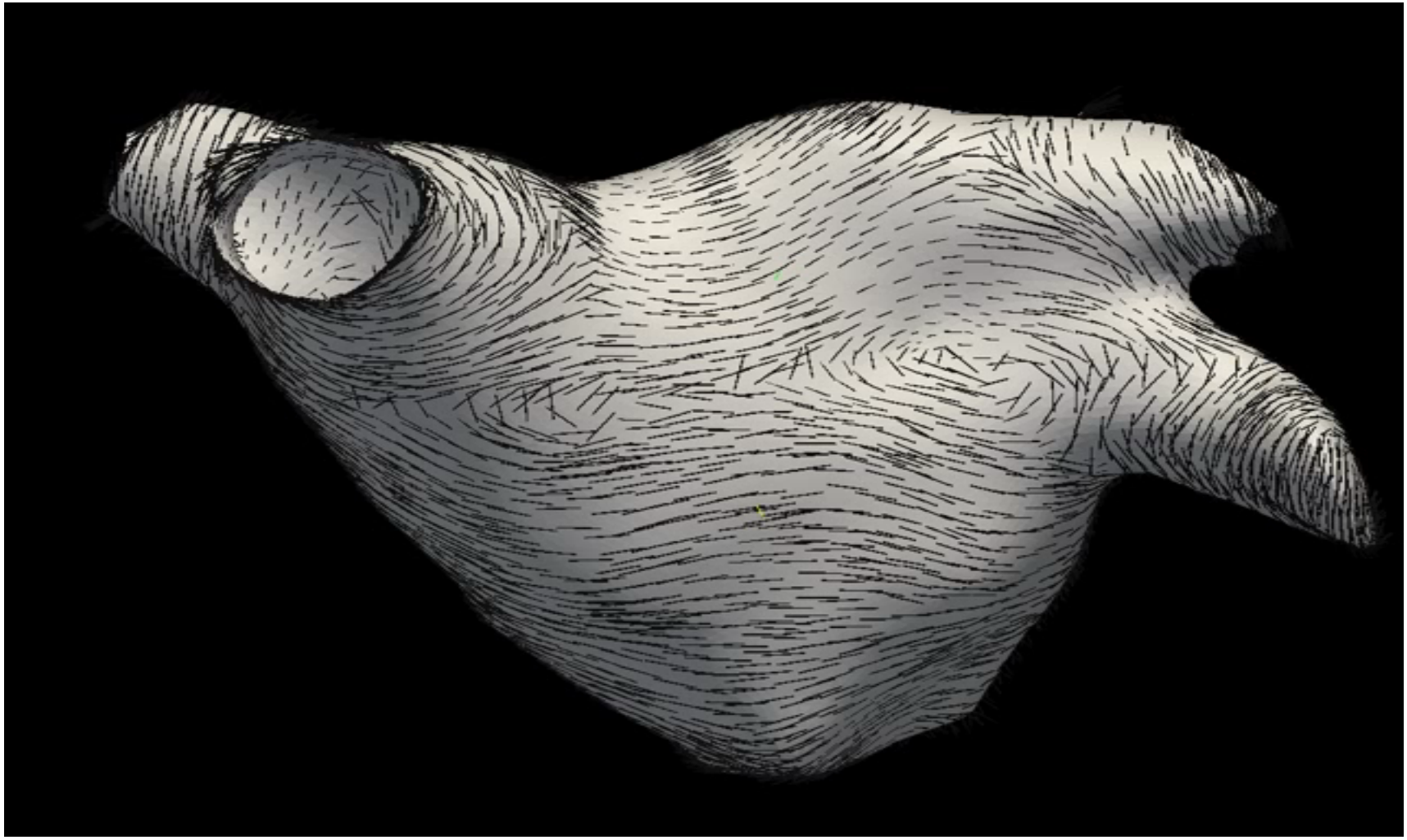
Anisotropy with Fibre Direction in Nektar ++



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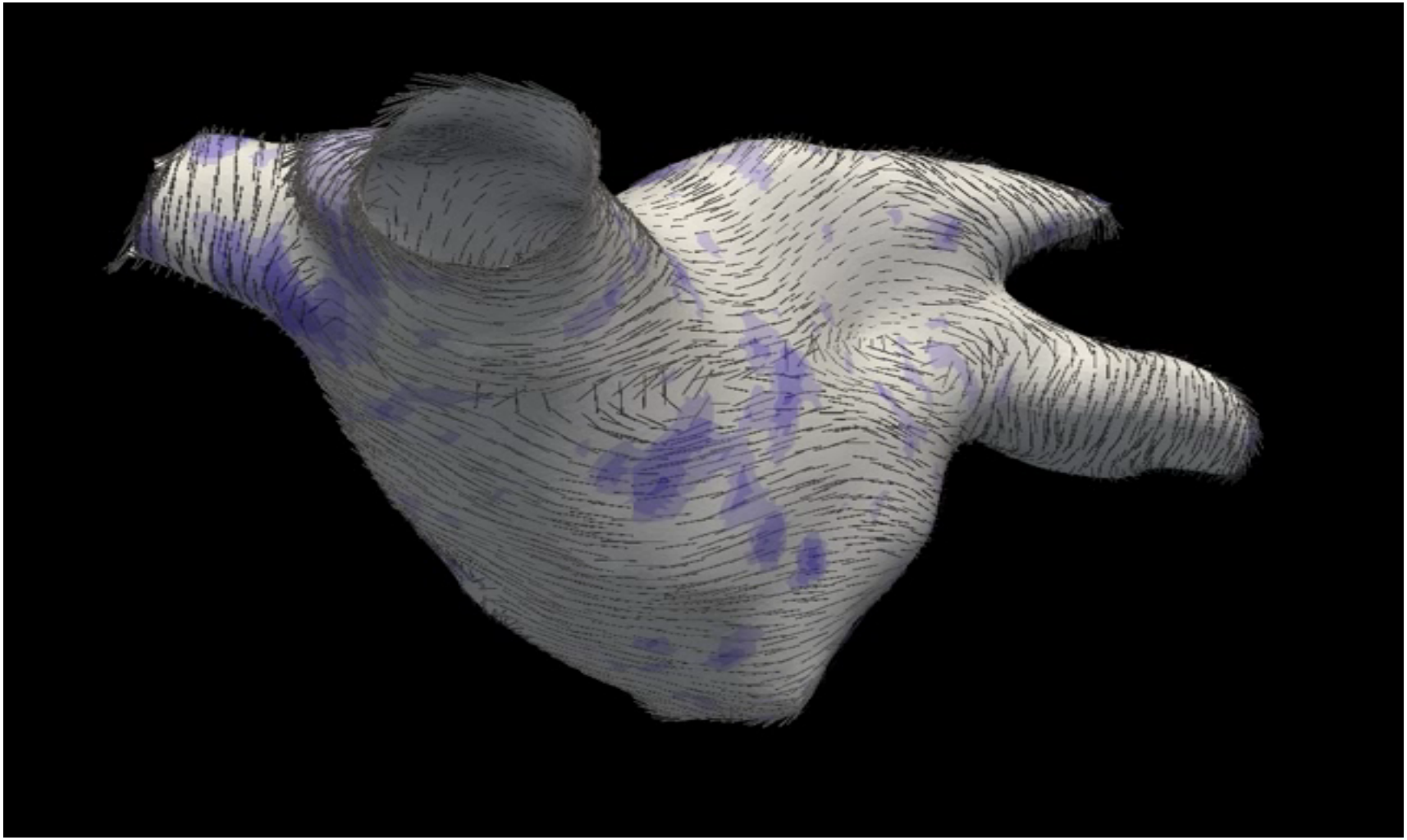
Anisotropy with Fibre Direction in Nektar ++



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Modelling Atrial Wall Thickness

Circulation
Arrhythmia and Electrophysiology
JOURNAL OF THE AMERICAN HEART ASSOCIATION

American Heart Association
Learn and Live

An Image-Based Model of Atrial Muscular Architecture : Effects of Structural Anisotropy on Electrical Activation

Jichao Zhao, Timothy D. Butters, Henggui Zhang, Andrew J. Pullan, Ian J. LeGrice, Gregory B. Sands and Bruce H. Smaill

Circ Arrhythm Electrophysiol 2012;5;361-370; originally published online March 14, 2012;

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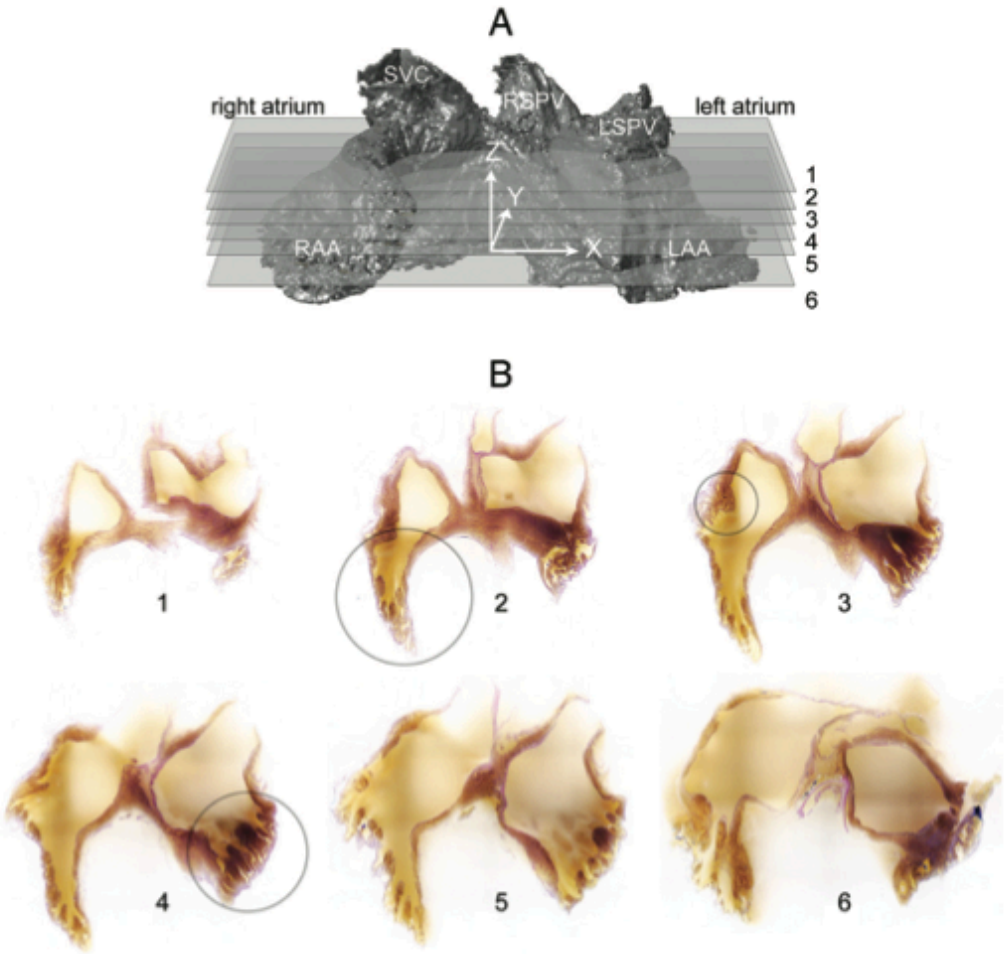
Atrial Architecture



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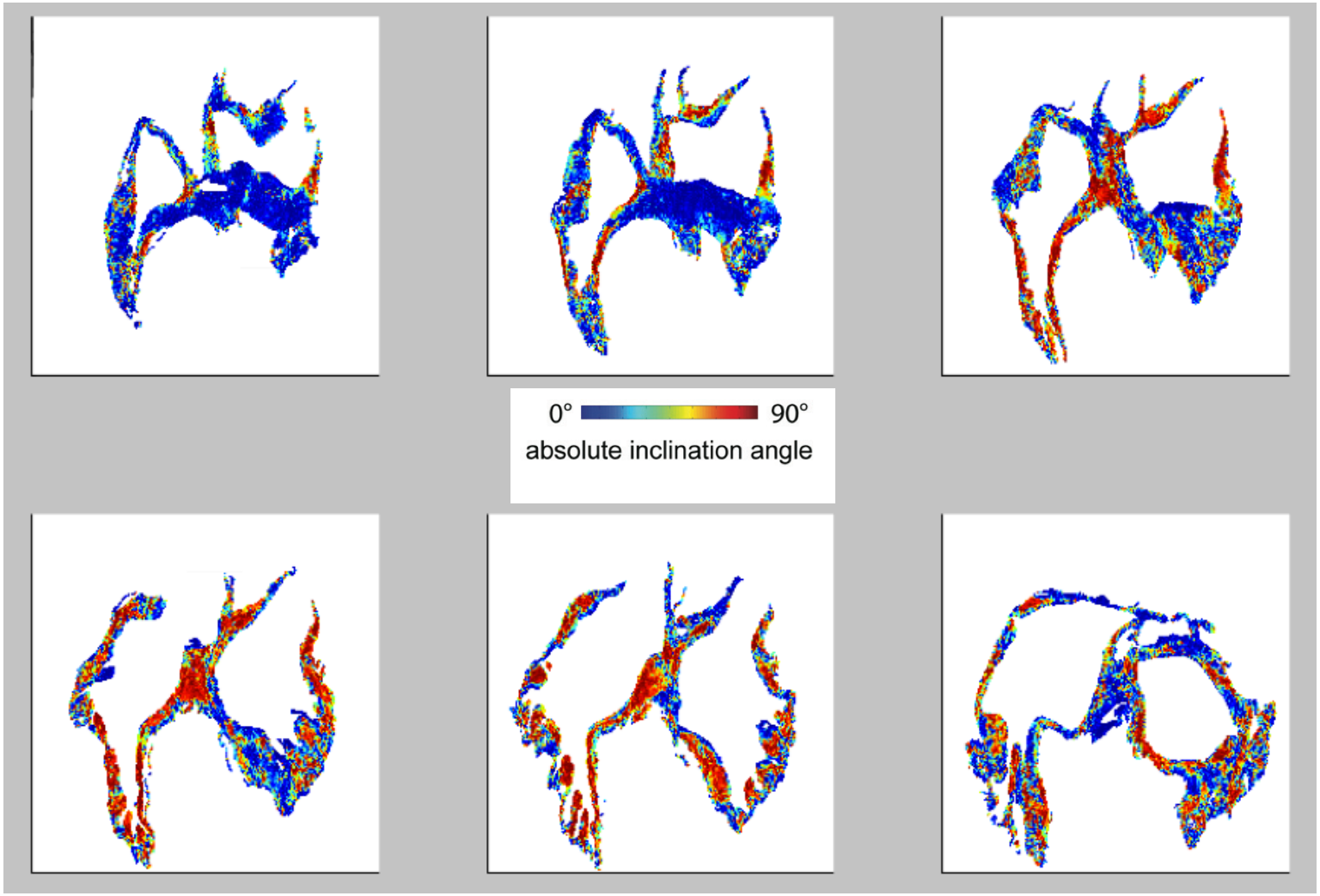
Slice Fibre Directions



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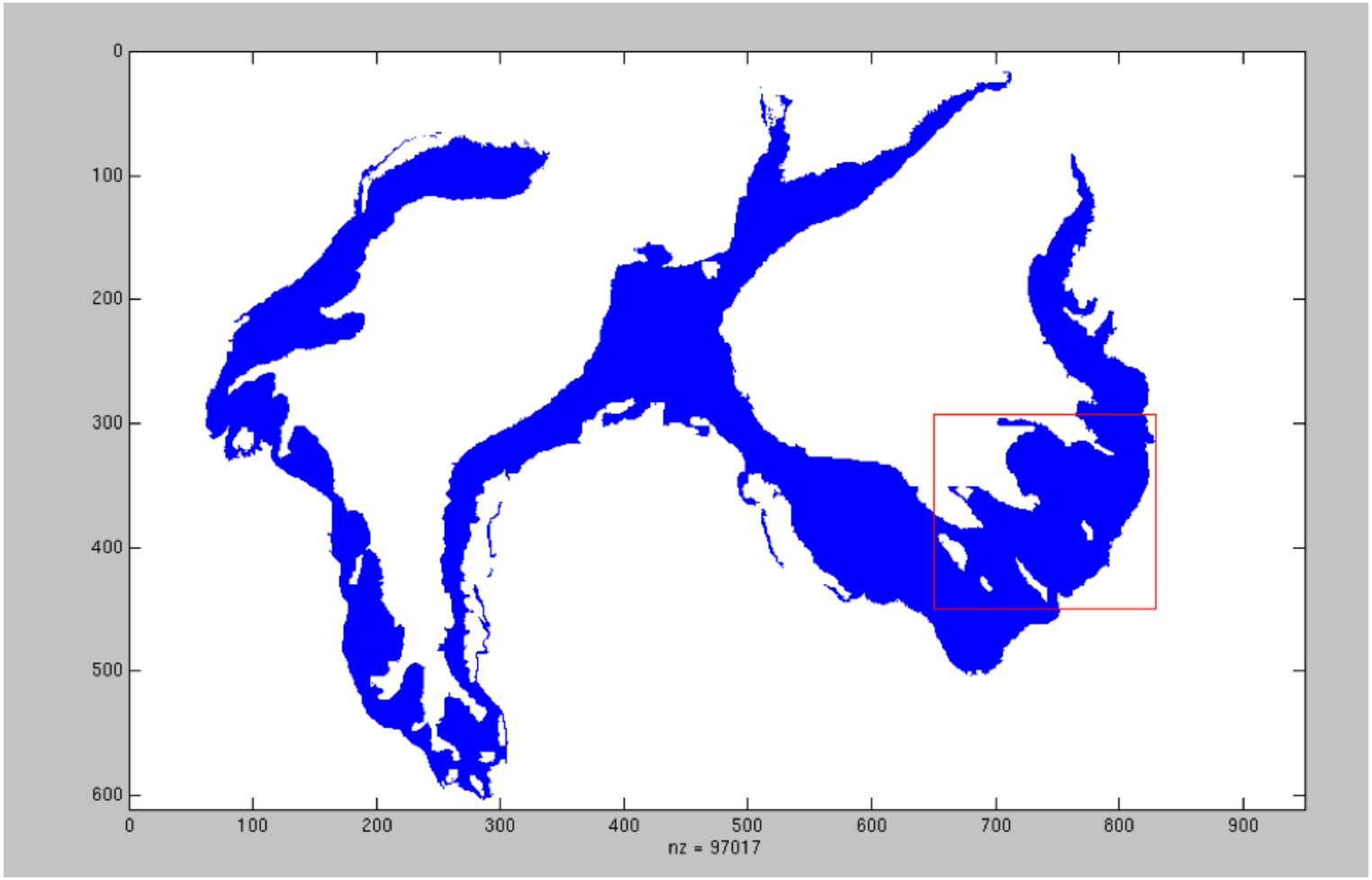
Choosing an Example Domain



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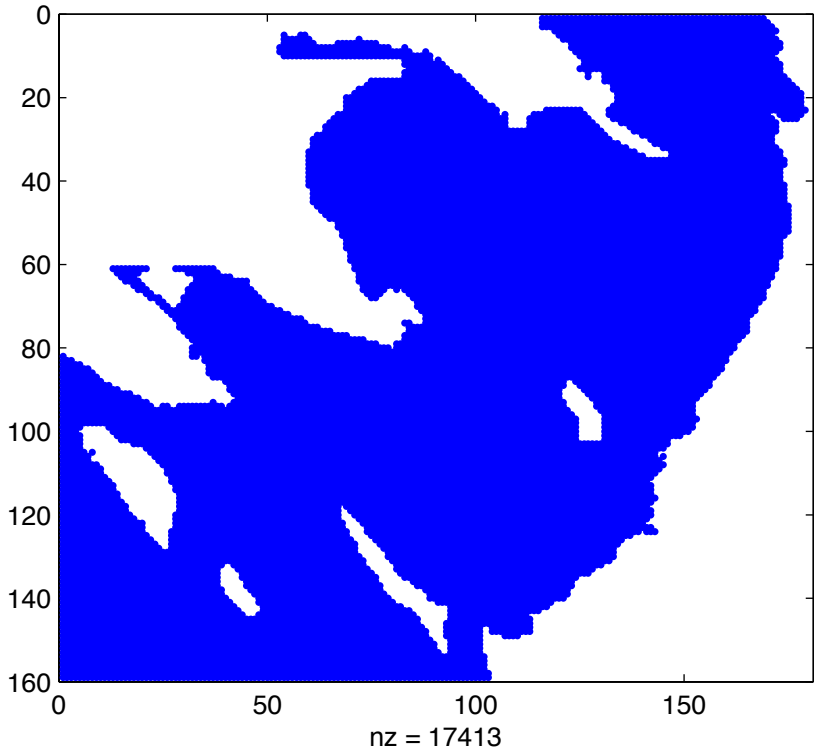
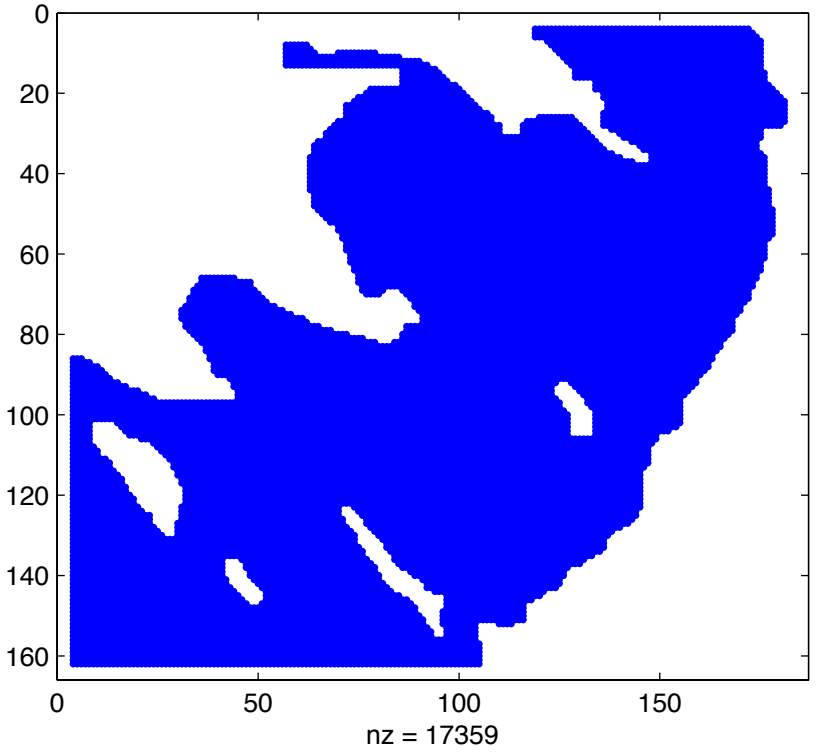
Smoothing the data



Raw Data



Smoothed Data

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Example Simulation