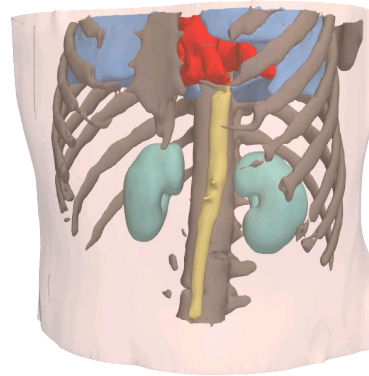
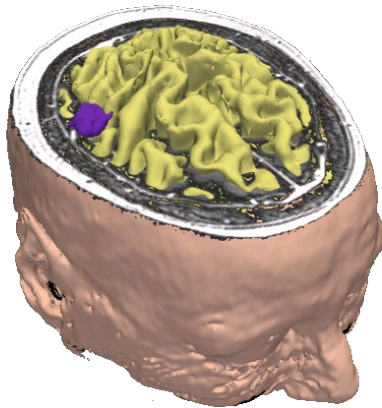




EMSegmenter Tutorial (Advanced Mode)



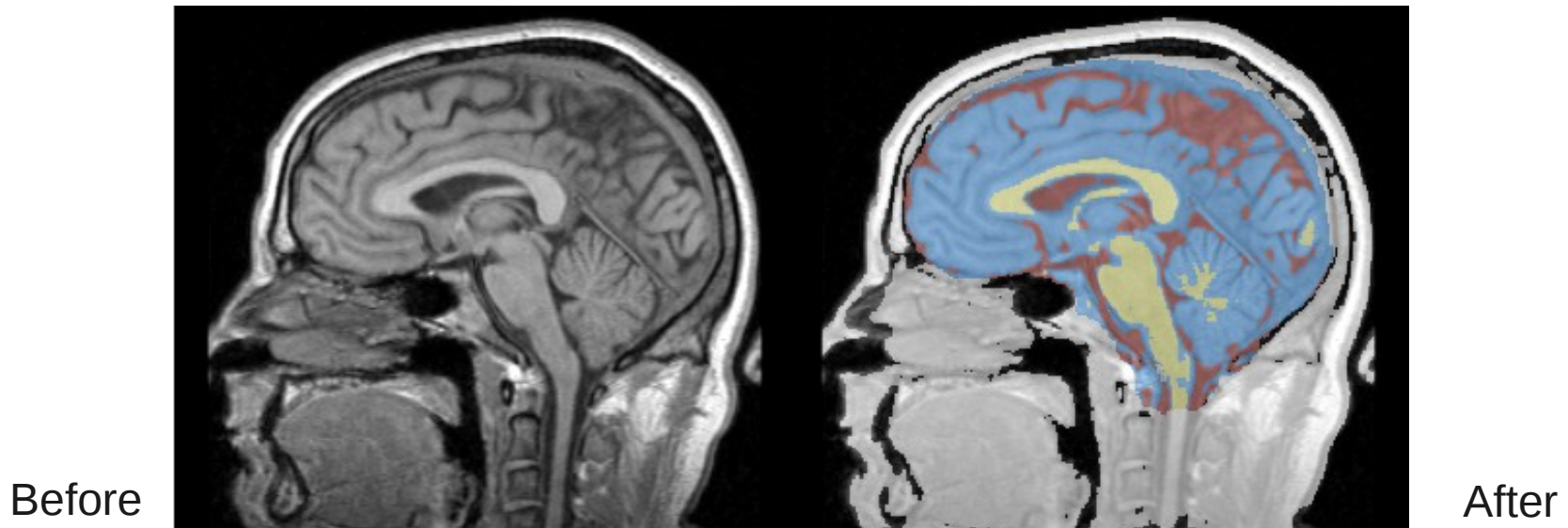
Dominique Belhachemi

Section of Biomedical Image Analysis
Department of Radiology
University of Pennsylvania

Overview

The goal of this tutorial is to apply the EMSegmenter to MRI brain scans. We will segment the clinical T1 scan shown below into **grey matter**, **white matter**, and **cerebrospinal fluid**.

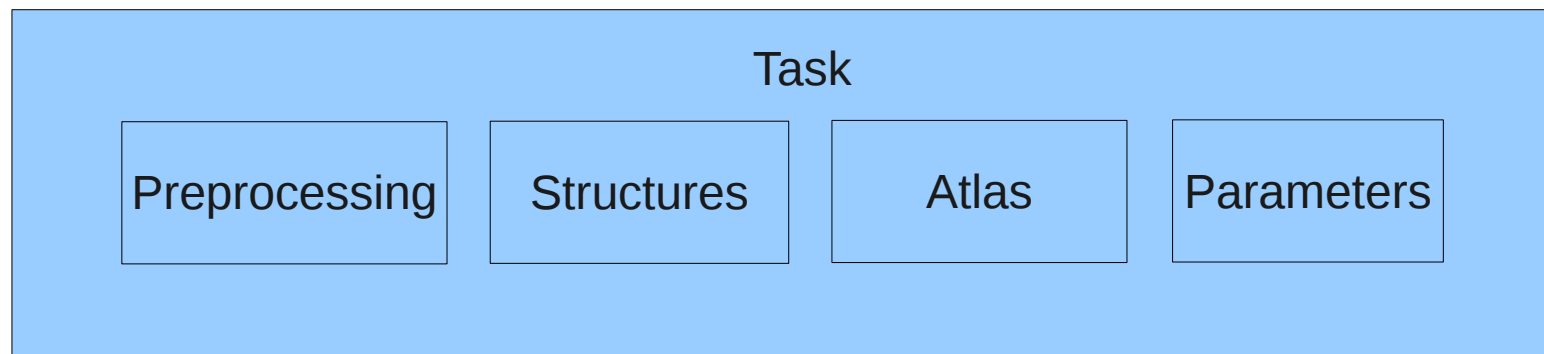
The tutorial is based on Slicer 3.6.2 .





Overview

We will segment the MRI scans by specifying a 'Task' for the EMSegmenter. The task captures the setting of the EMSegmenter for generating the automatic segmentation of the subject scan. A task specifies the pre-processing of the scan, such as the type of atlas to image registration. It also specifies the structures to be segmented and the atlas specifying the structures. Furthermore, the task specifies the parameters related to the optimization algorithm (EM).





Overview

The tutorial leads you through the steps necessary for creating a new task:

- Step 1: Define task name and type of pre-processing
- Step 2: Define Input Channel
- Step 3: Define the Anatomical Tree
- Step 4: Assign an atlas to each node in the tree
- Step 5: Defining the Atlas to Image Registration
- Step 6: Further Specify pre-processing
- Step 7: Specifying the Intensity Distribution
- Step 8: Define EM Specific Parameters
- Step 9: Specify the Region of Interest and complete the Segmentation



Define Task

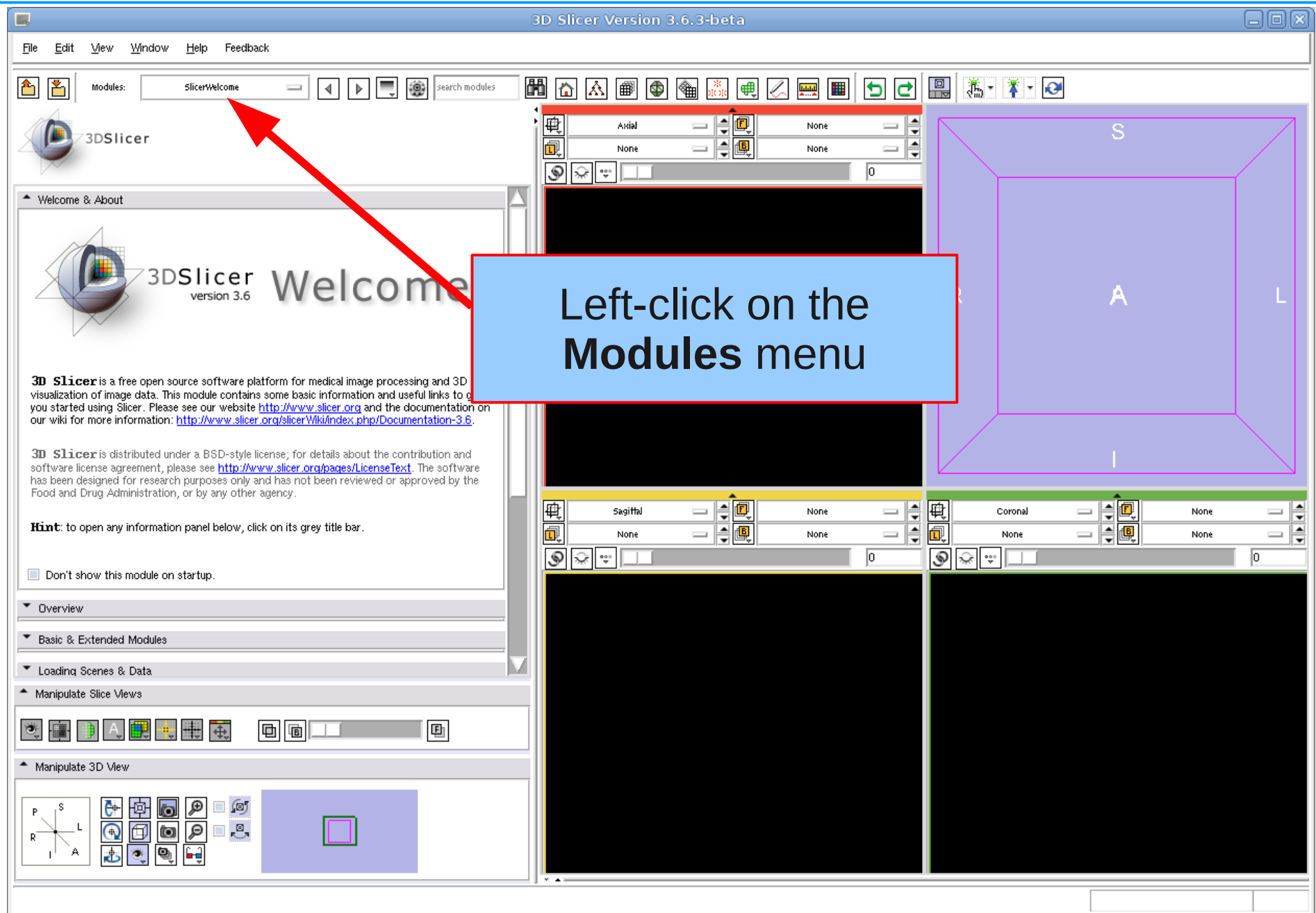
Step 1:

Define task name and type of pre-processing

The name should be a brief description of the segmentation scenario that the task addresses, such as 'T1 Brain Tissue Segmentation'. Each pre-processing type defines a sequence of approaches for modifying the scan before segmenting the scan into the structures of interest. For example, the pre-processing “MRI Human Brain” consists of image inhomogeneity correction and atlas registration. For further details please see <http://www.slicer.org/slicerWiki/index.php/EMSegmenter-Tasks>

EMSegmenter (Advanced mode)

3DSlicer





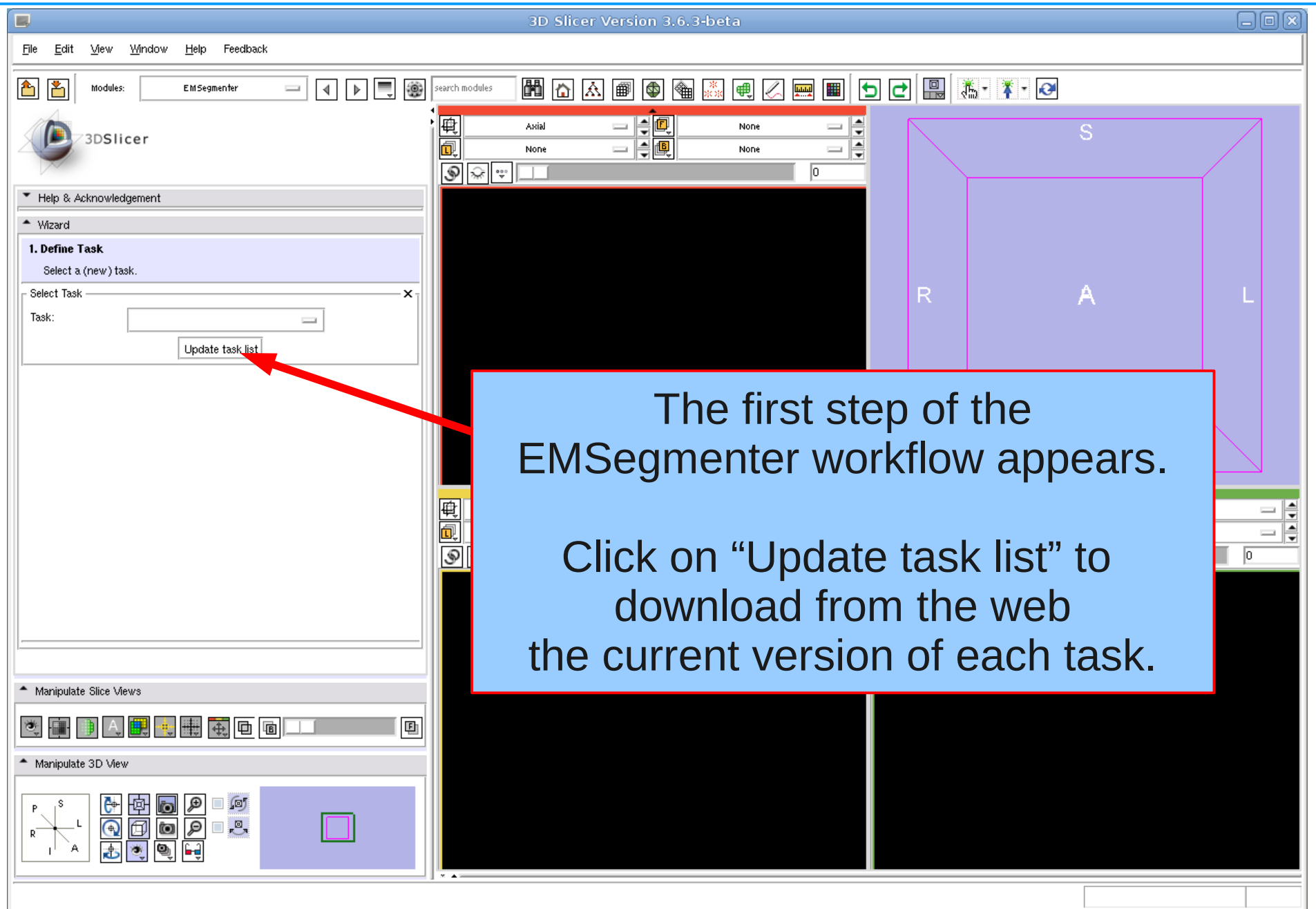
Select EMSegmenter Module

The screenshot displays the 3D Slicer 3.6.3-beta interface. On the left, the 'Modules' panel is open, showing a tree view of available modules. The 'Segmentation' module is selected, and its sub-menu is expanded, highlighting the 'EMSegmenter' module. A red arrow points from a blue callout box to the 'EMSegmenter' option. The main window shows three orthogonal views: Axial, Sagittal, and Coronal. The Axial view displays a purple rectangular region with labels 'S', 'R', 'A', and 'L'. The Sagittal and Coronal views are currently empty. The bottom status bar indicates the 'EMSegmenter' module is active.

**Select Segmentation
→ EMSegmenter**

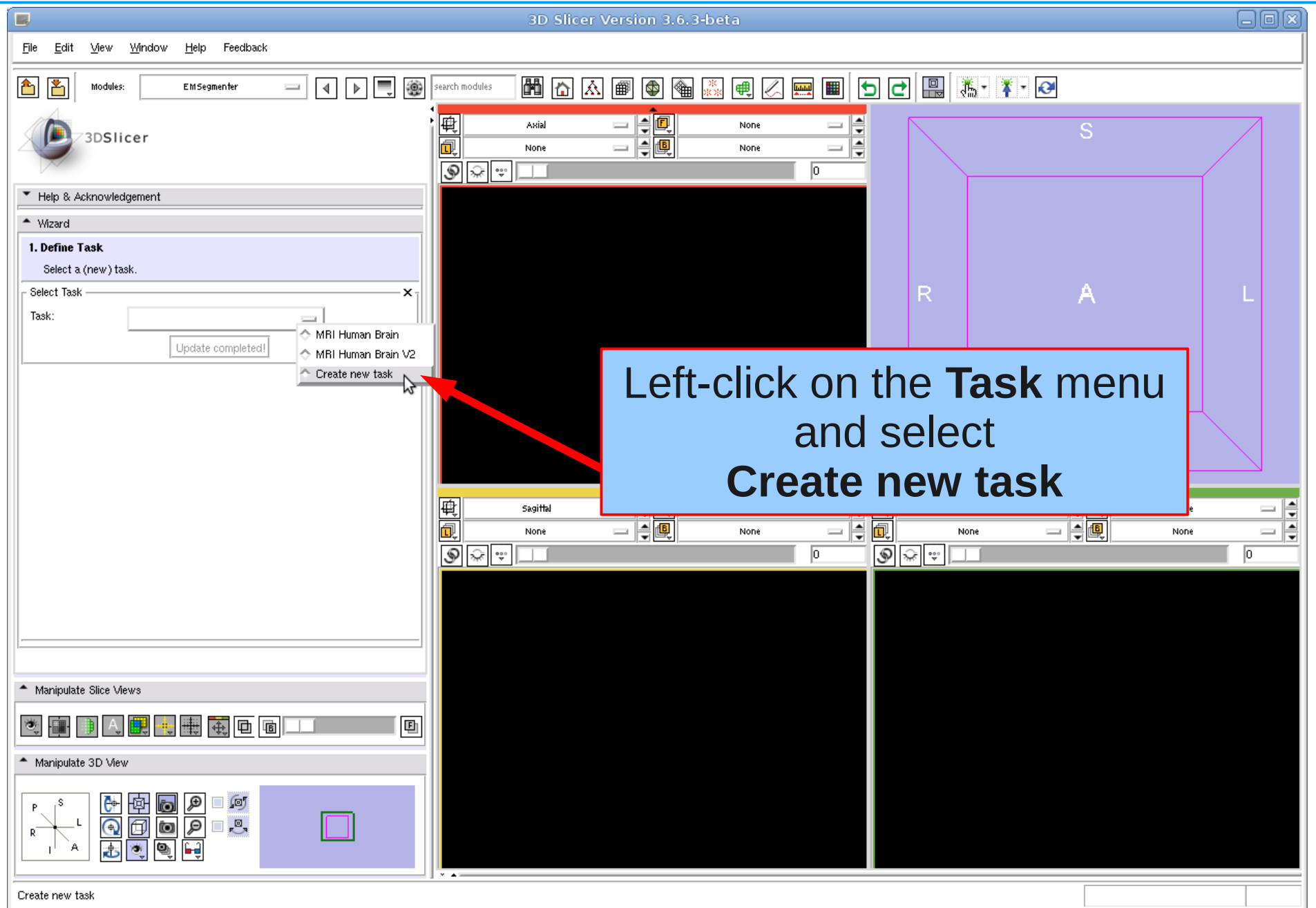


Update Task List



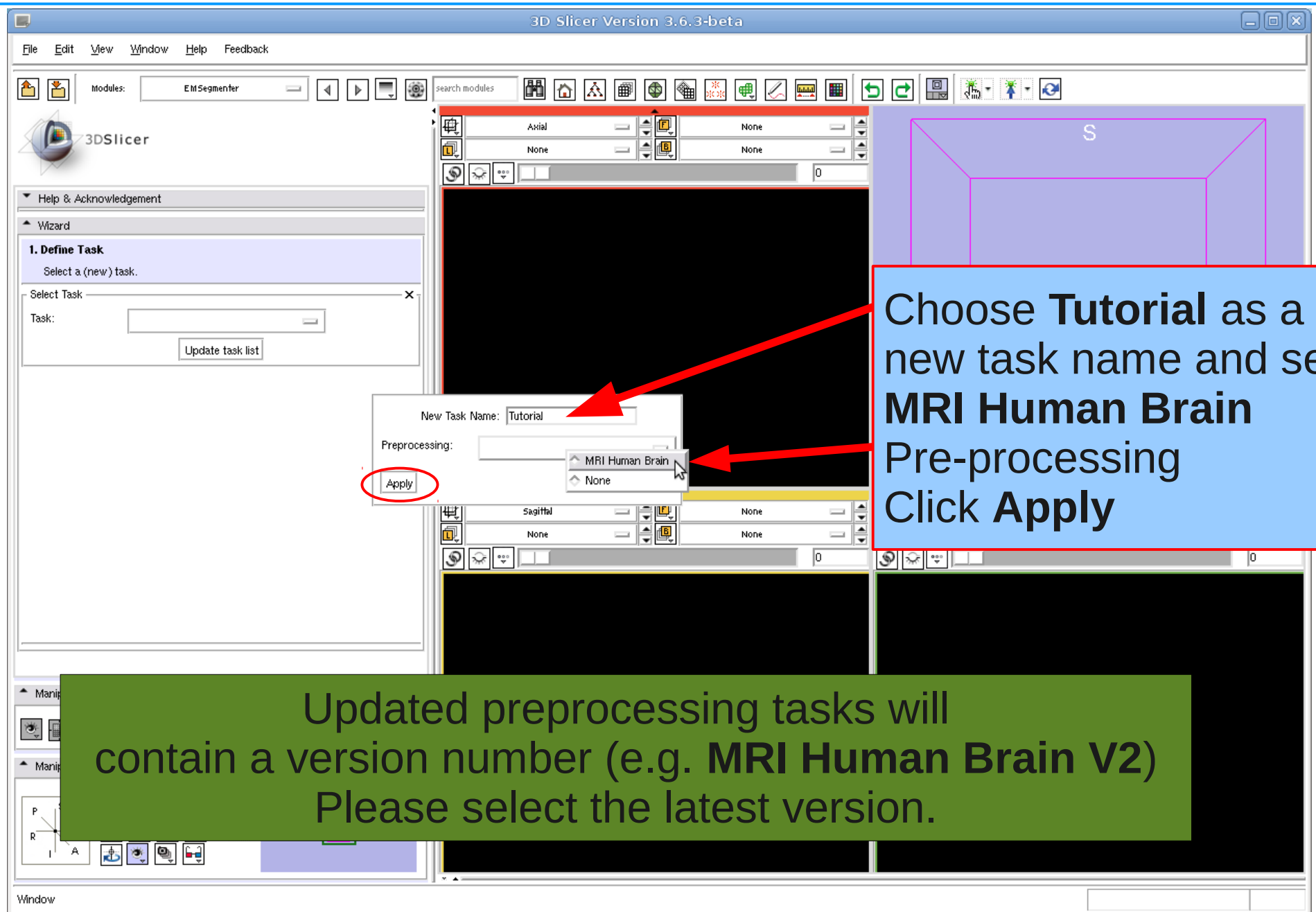


Create New Task





Create New Task



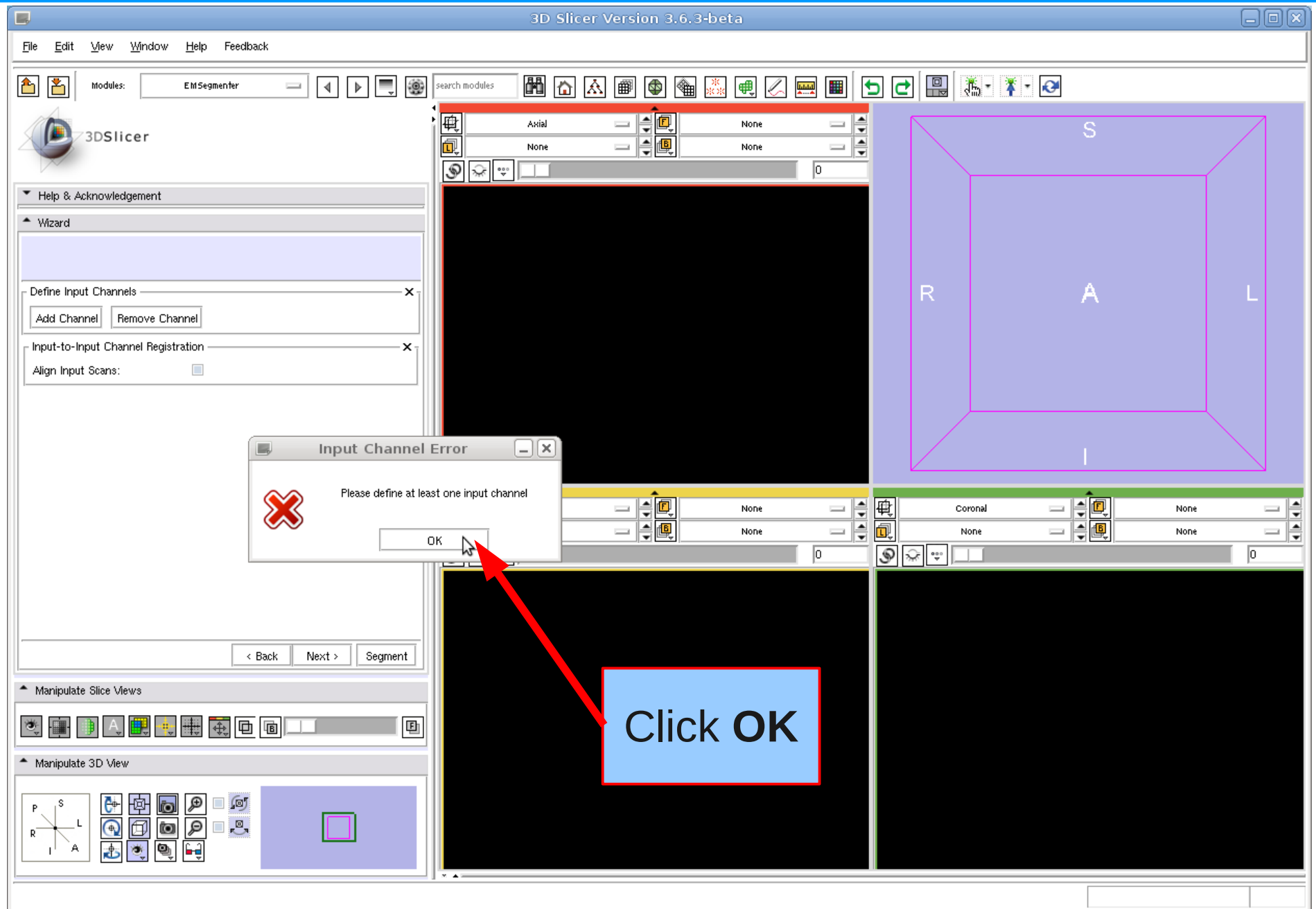


Define Input Channel

Step 2: Define Input Channel

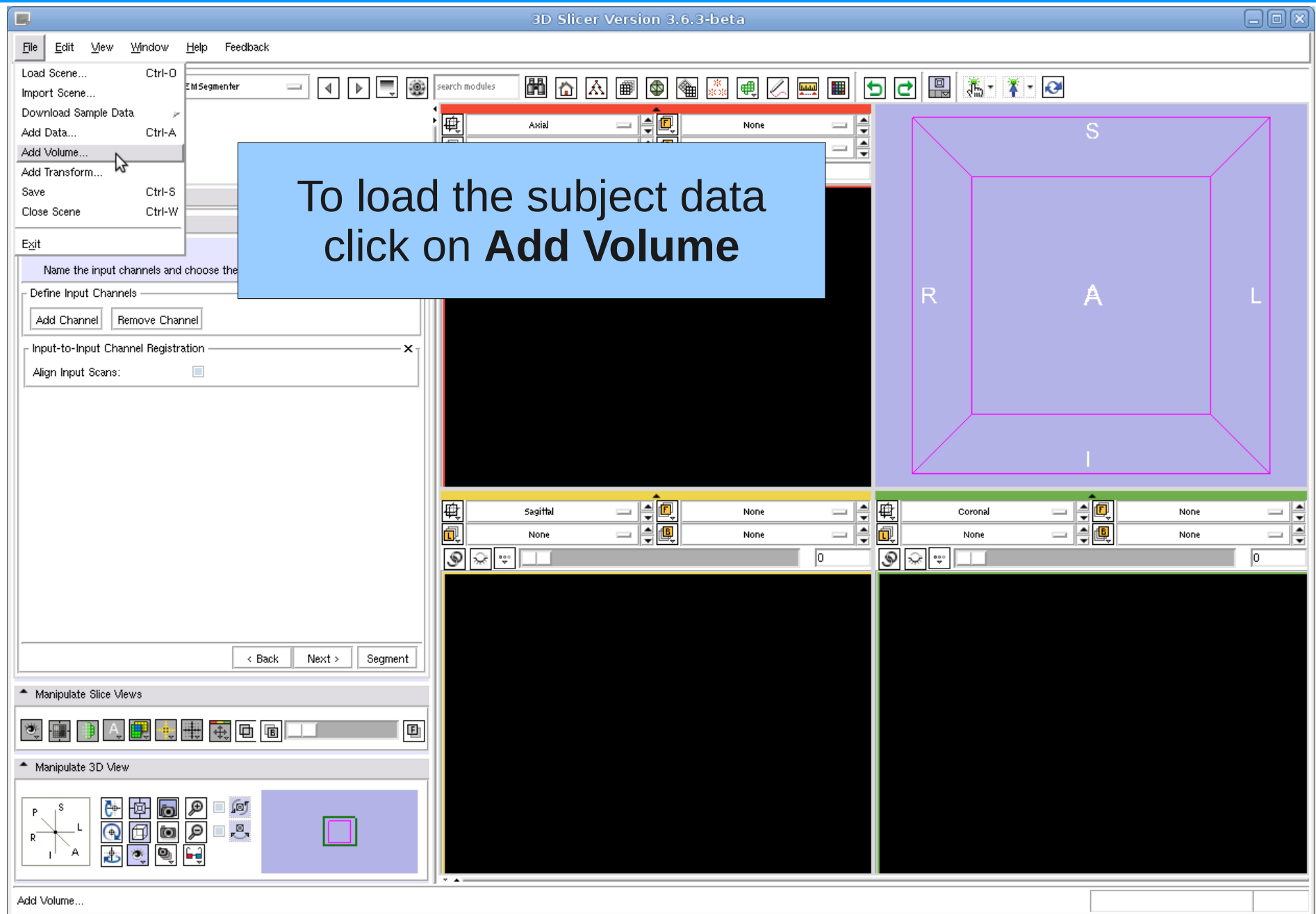
The EMSegmenter is equipped for multi-channel segmentations. For this tutorial, we want to perform single channel T1 segmentation. We now specify the task accordingly by loading in a T1 scan and creating a single input channel.

Define Input Channels



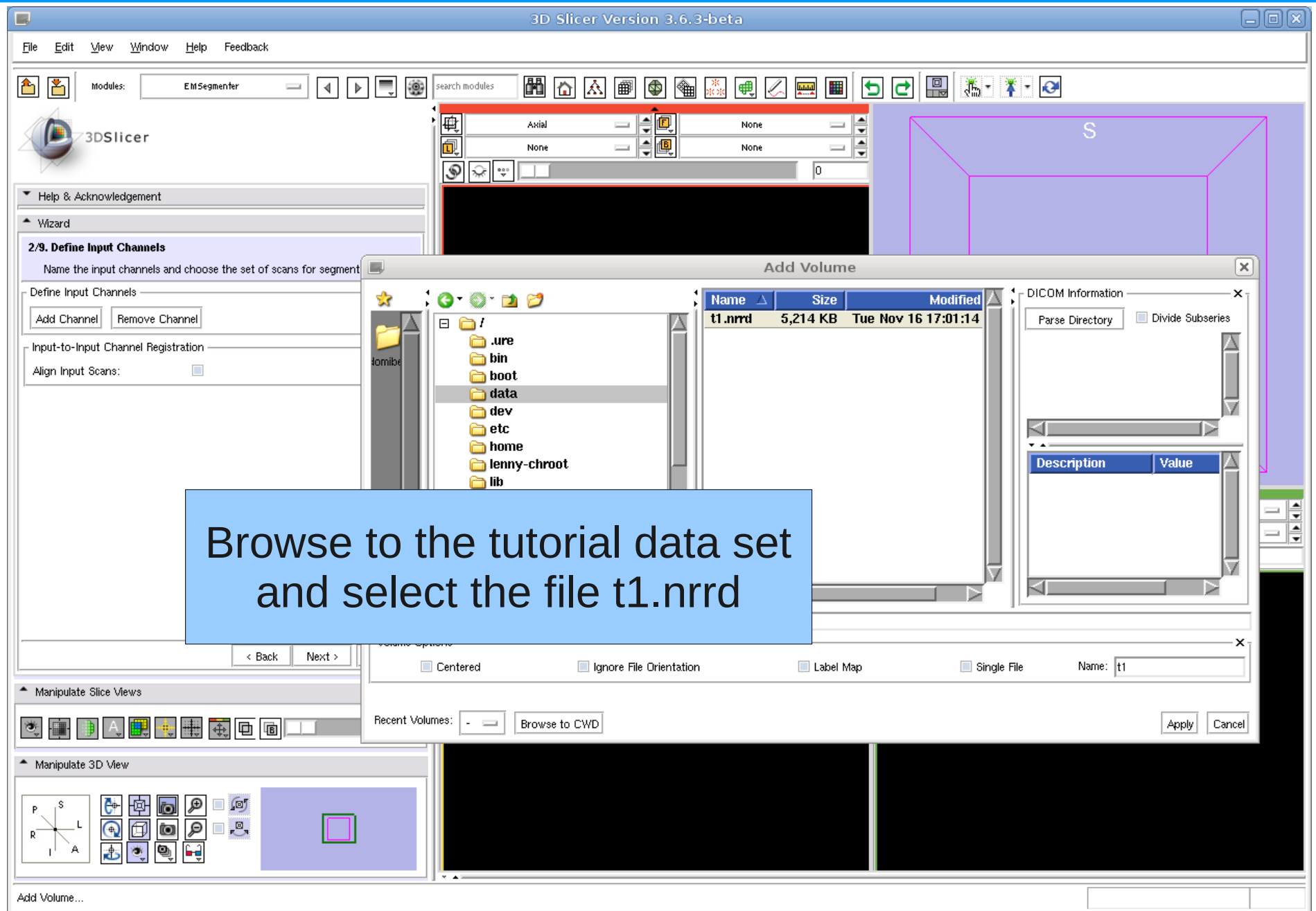


Add Subject Data



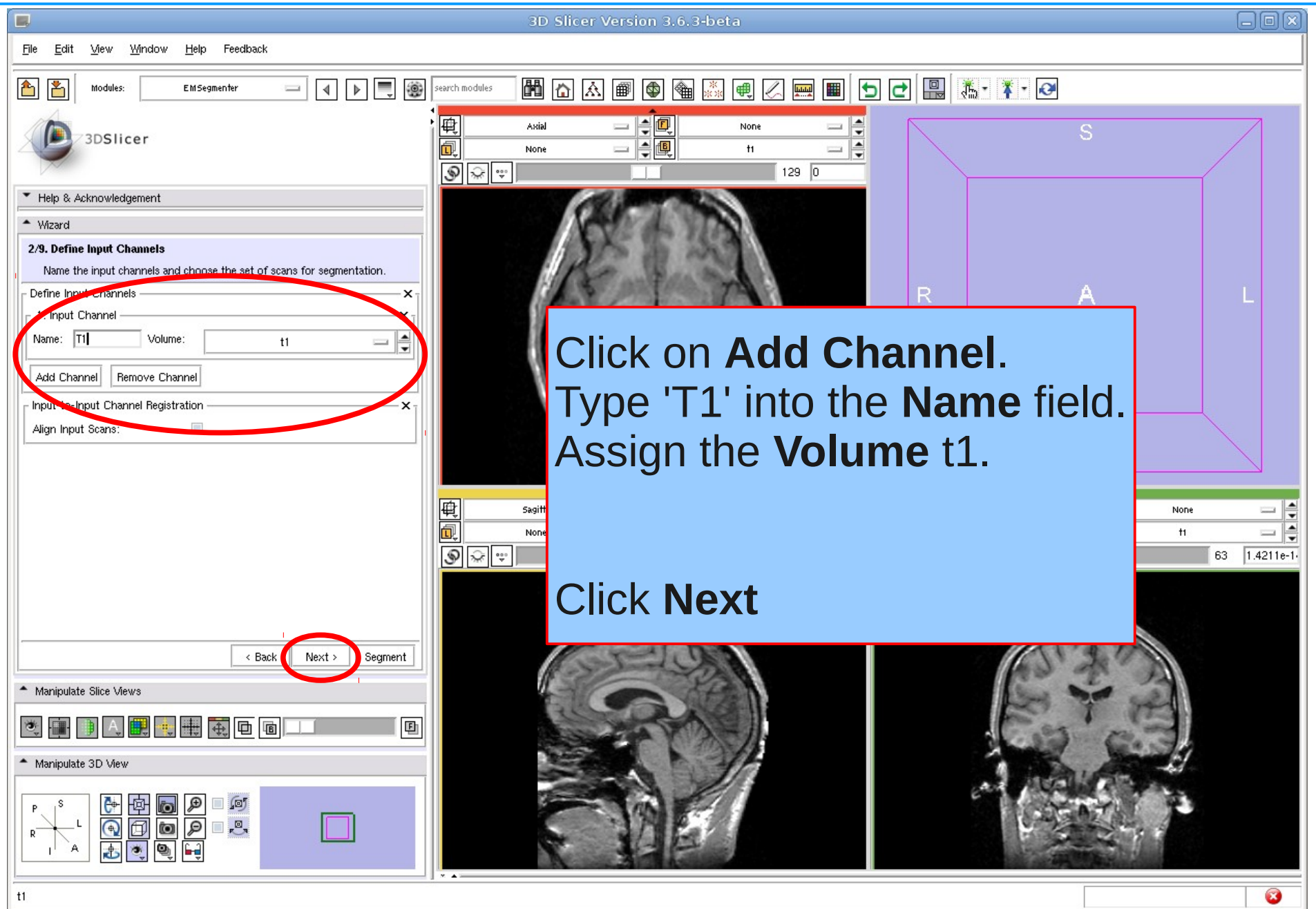


Load Subject Data





Define Input Channel



Define Input Channel





Define Anatomical Tree

Step 3: Define the Anatomical Tree

In this step we are defining the anatomical structures we want to segment and store the information in a tree data structure. Each node represents an anatomical structure. Additionally, a label and color can be assigned to each node, which are used when generating the segmentation map.



Define Anatomical Tree

3D Slicer Version 3.6.3-beta

File Edit View Window Help Feedback

Modules: EMSegmenter

search modules

3DSlicer

Help & Acknowledgement

Wizard

3/9. Define Anatomical Tree
Define a hierarchy of structures.

Anatomical Tree

Root

Add sub-class
Delete sub-class

Node Attributes

Name: Root
Label: 1000 Color: [Black]

Select colormap: L...s

Entry	Name	Color
0	Black	[Black]
1	jake	[Blue]
2	Peach	[Orange]
3	Brain	[Purple]

Manipulate Slice Views

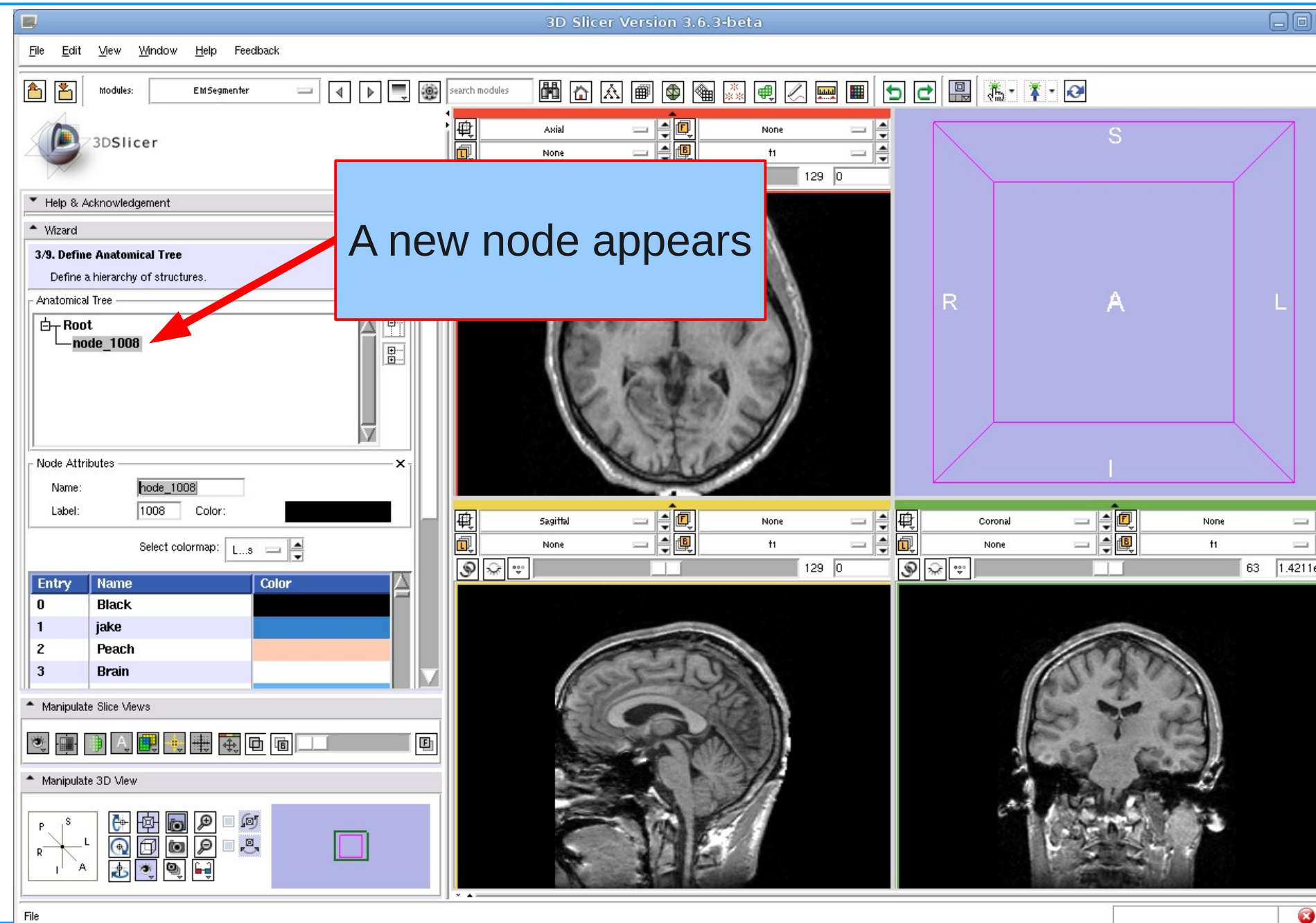
Manipulate 3D View

Right-click on **Root**, and select **Add sub-class**

3D Slicer interface showing MRI slices (Axial, Sagittal, Coronal) and a 3D view of a brain model. The 3D view shows a purple box representing the brain volume, with axes labeled R (Right), L (Left), S (Superior), and I (Inferior).

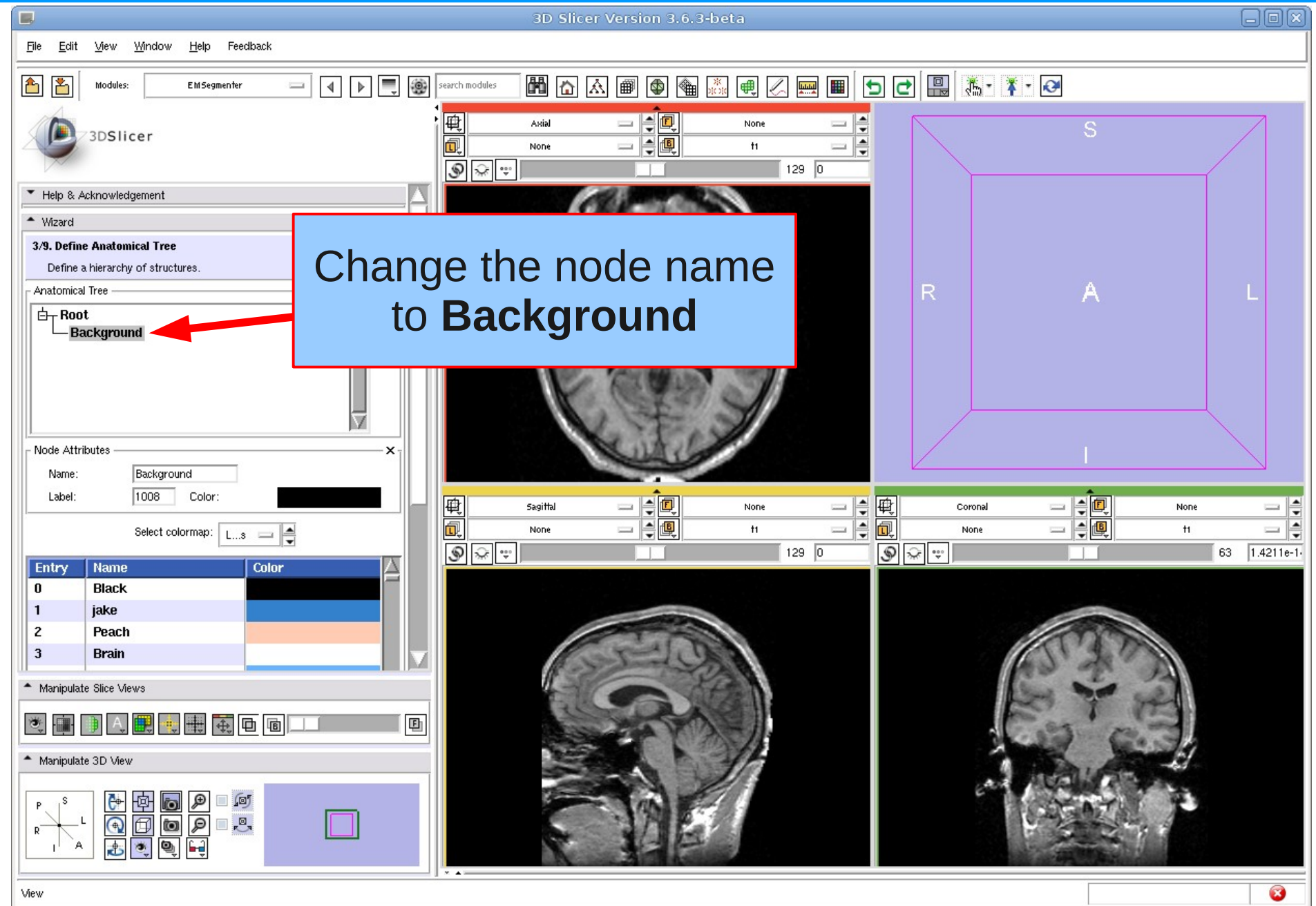


Define Anatomical Tree

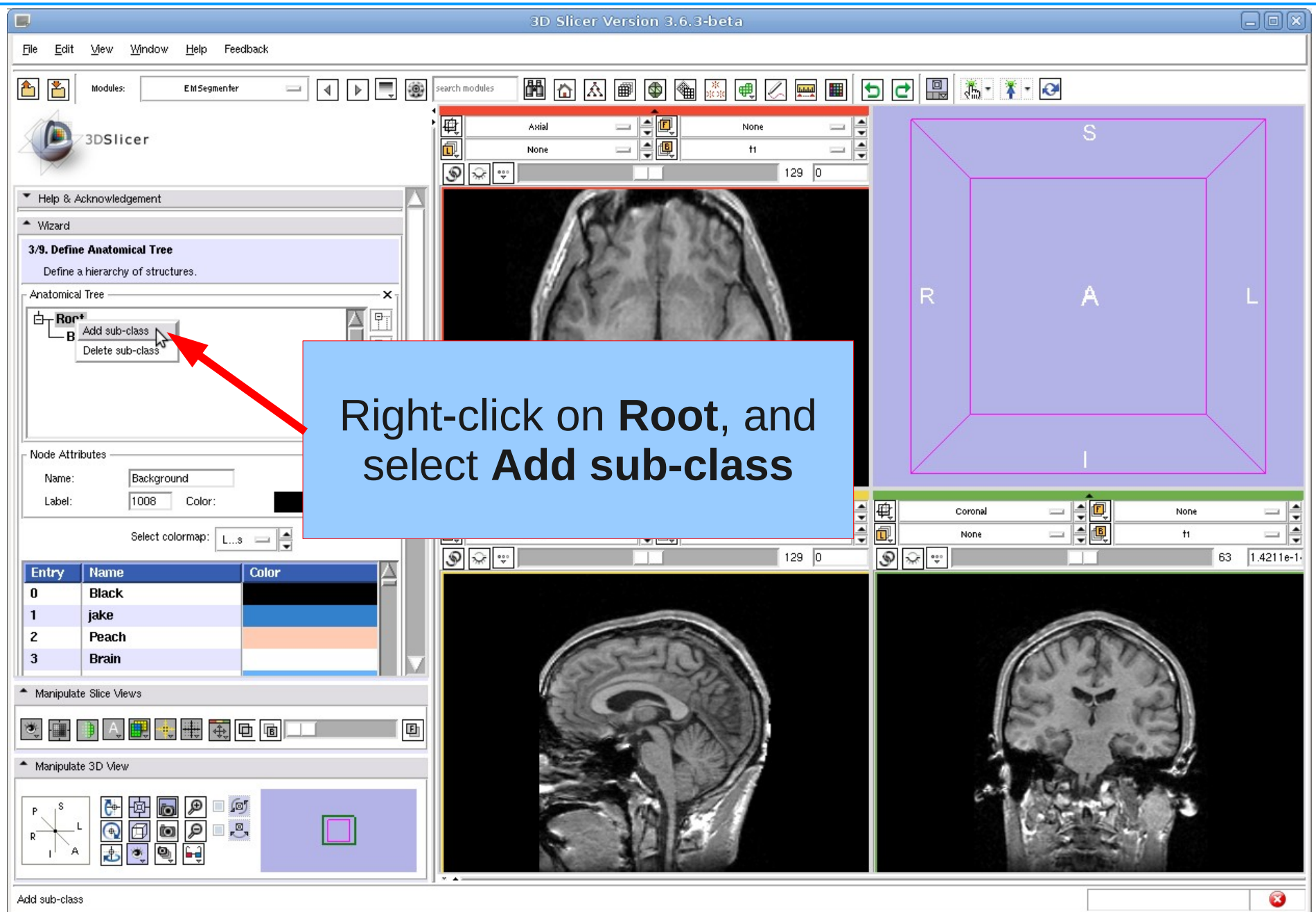




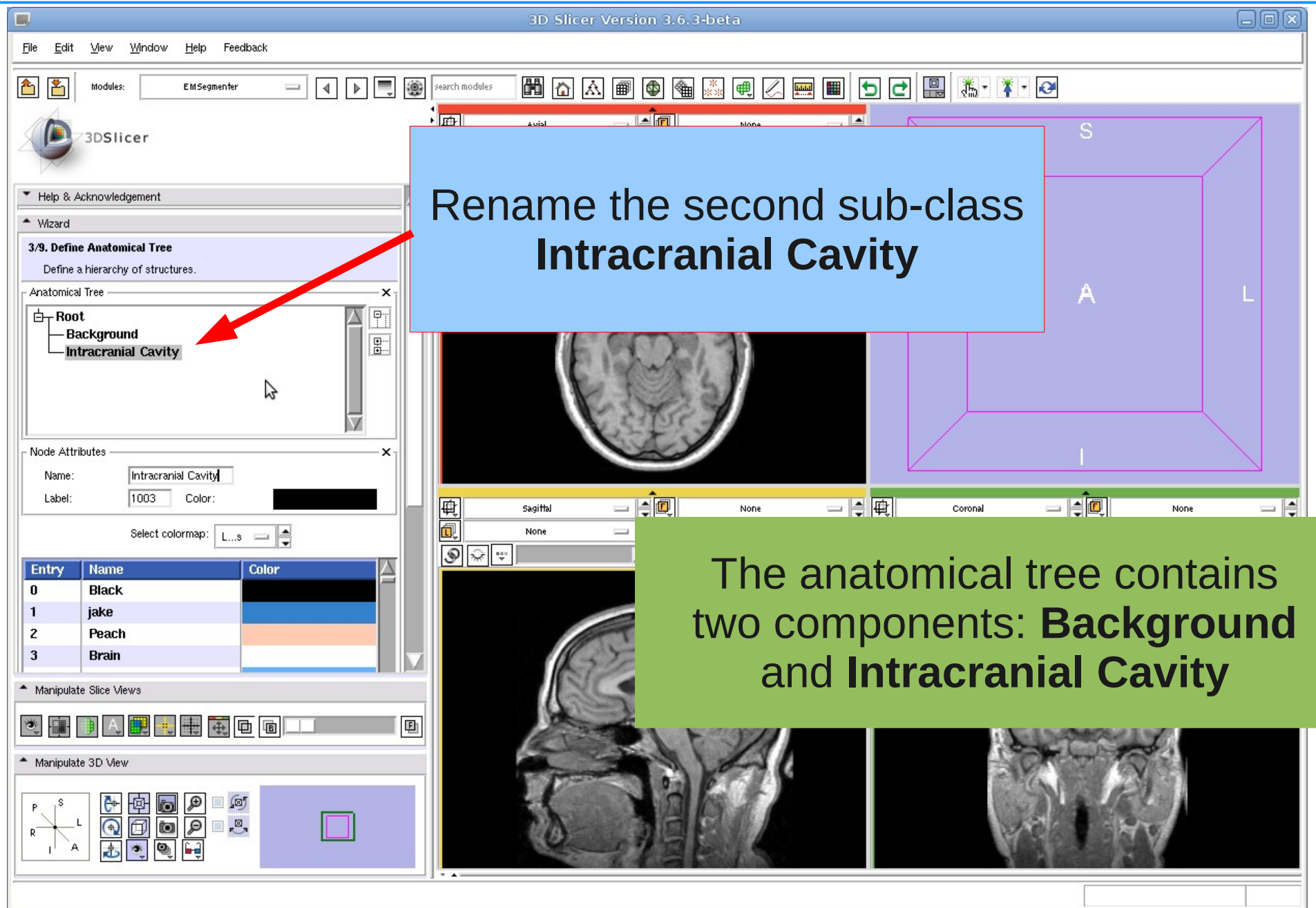
Define Anatomical Tree



Define Anatomical Tree



Define Anatomical Tree



3D Slicer Version 3.6.3-beta

File Edit View Window Help Feedback

Modules: EMSegmenter

search modules

3DSlicer

Help & Acknowledgement

Wizard

3/9. Define Anatomical Tree

Define a hierarchy of structures.

Anatomical Tree

- Root
 - Background
 - Intracranial Cavity

Node Attributes

Name: Intracranial Cavity

Label: 1003 Color: Black

Select colormap: L...s

Entry	Name	Color
0	Black	Black
1	jake	Blue
2	Peach	Orange
3	Brain	White

Manipulate Slice Views

Manipulate 3D View

Sagittal None Coronal None

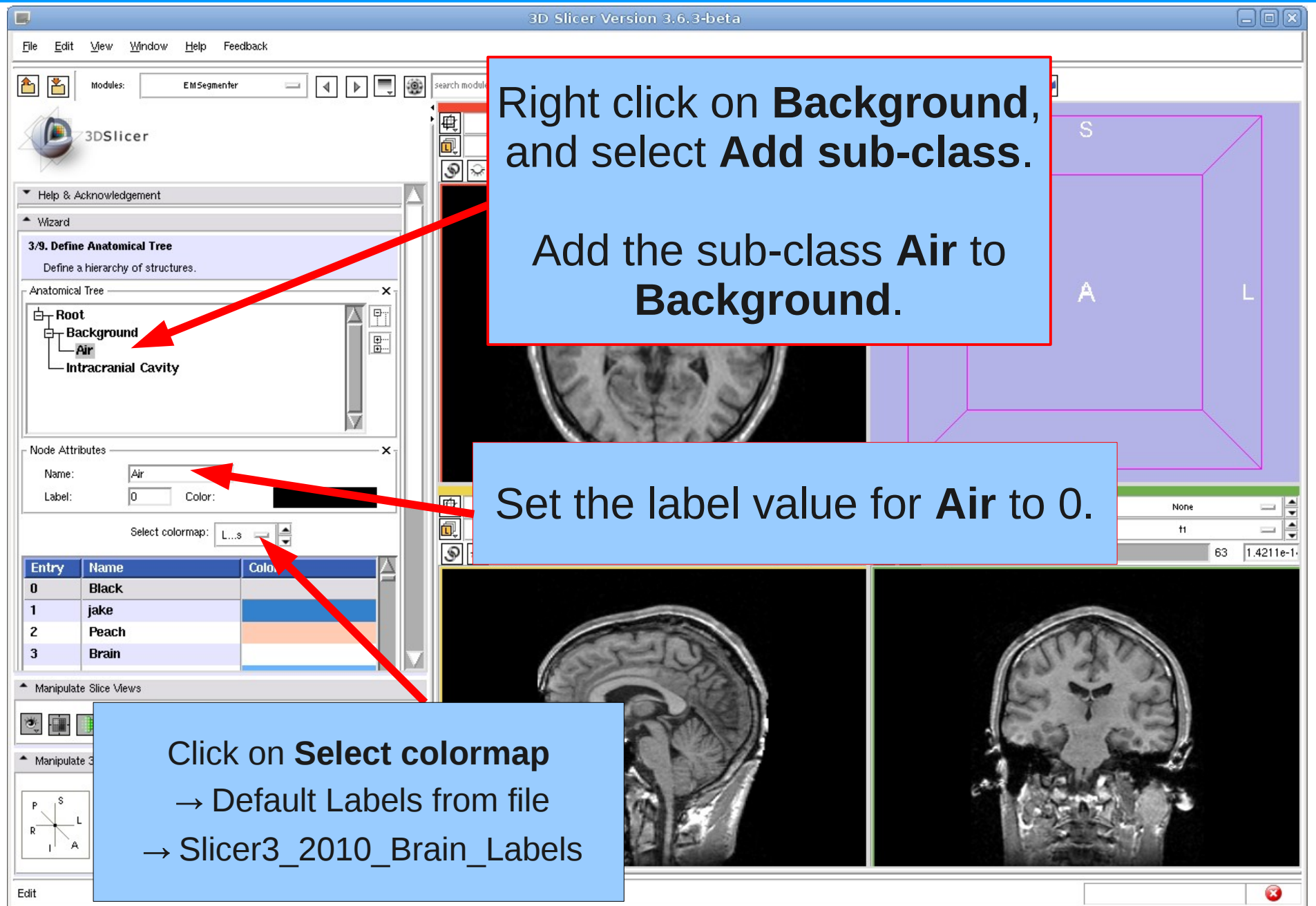
S I A L

R I A

Rename the second sub-class
Intracranial Cavity

The anatomical tree contains
two components: **Background**
and **Intracranial Cavity**

Define Anatomical Tree



3D Slicer Version 3.6.3-beta

File Edit View Window Help Feedback

Modules: EM Segmenter

3DSlicer

Help & Acknowledgement

Wizard

3/9. Define Anatomical Tree

Define a hierarchy of structures.

Anatomical Tree

- Root
 - Background
 - Air
 - Intracranial Cavity

Node Attributes

Name: Air

Label: 0 Color: [black]

Select colormap: L...s

Entry	Name	Color
0	Black	[black]
1	jake	[blue]
2	Peach	[orange]
3	Brain	[white]

Manipulate Slice Views

Manipulate 3D View

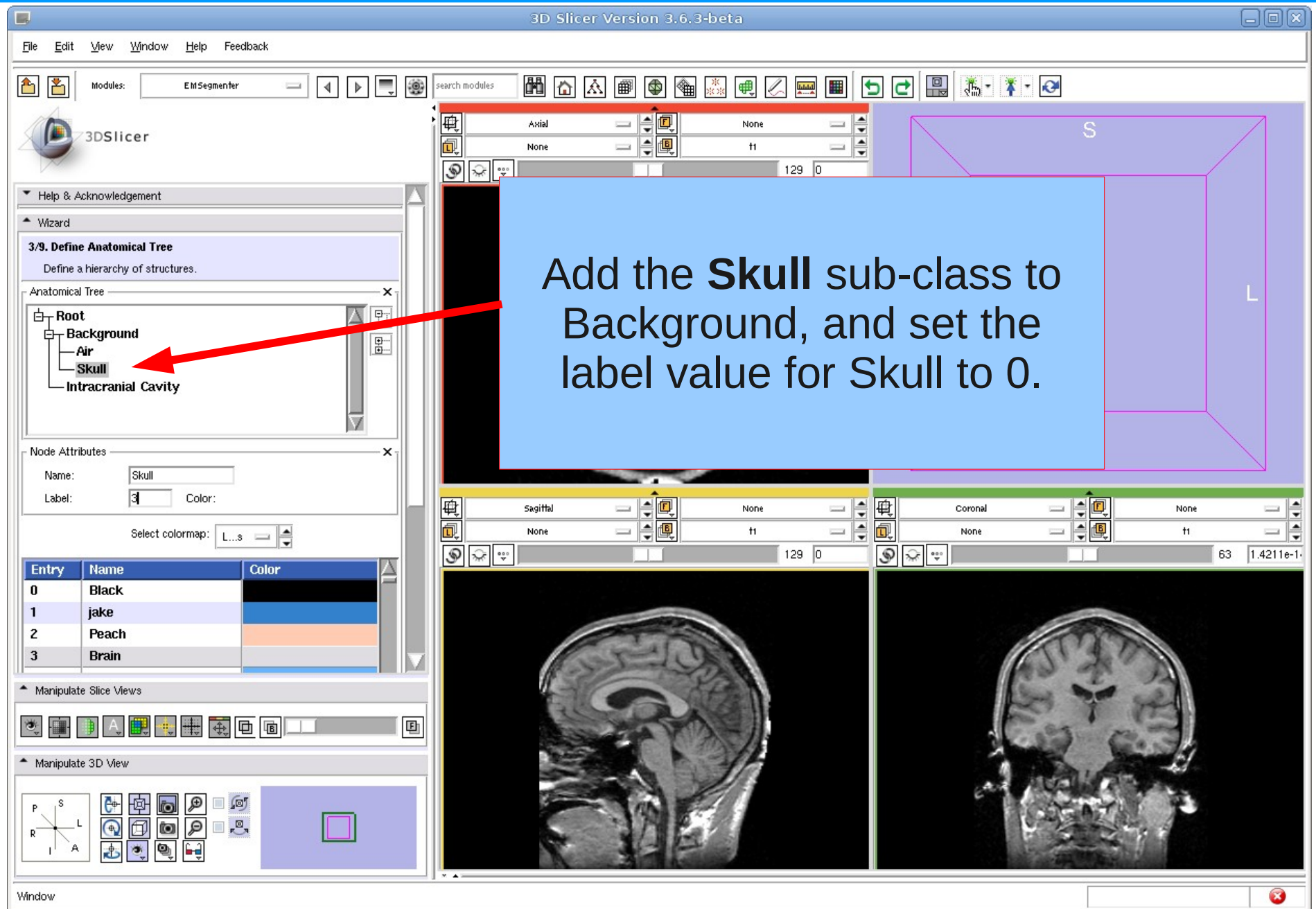
Click on **Select colormap**
 → Default Labels from file
 → Slicer3_2010_Brain_Labels

Right click on **Background**, and select **Add sub-class**.
 Add the sub-class **Air** to **Background**.

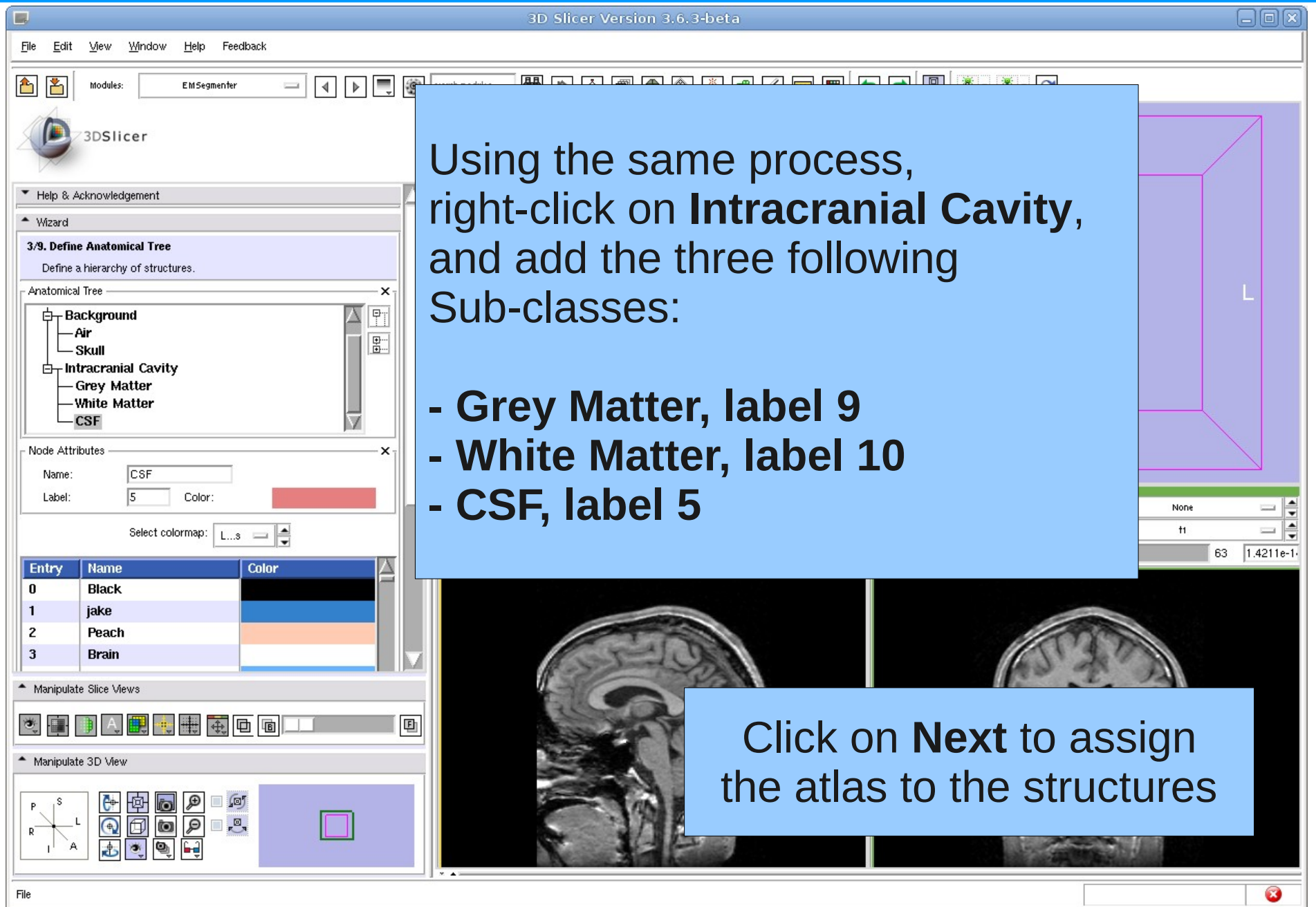
Set the label value for **Air** to 0.



Define Anatomical Tree



Define Anatomical Tree



3D Slicer Version 3.6.3-beta

File Edit View Window Help Feedback

Modules: EM Segmenter

3DSlicer

Help & Acknowledgement

Wizard

3/9. Define Anatomical Tree
Define a hierarchy of structures.

Anatomical Tree

- Background
 - Air
 - Skull
 - Intracranial Cavity
 - Grey Matter
 - White Matter
 - CSF

Node Attributes

Name: CSF
Label: 5 Color:

Select colormap: L...s

Entry	Name	Color
0	Black	
1	jake	
2	Peach	
3	Brain	

Manipulate Slice Views

Manipulate 3D View

File

Using the same process, right-click on **Intracranial Cavity**, and add the three following Sub-classes:

- Grey Matter, label 9
- White Matter, label 10
- CSF, label 5

Click on **Next** to assign the atlas to the structures



Define Atlas

Step 4: Assign an atlas to each node in the tree

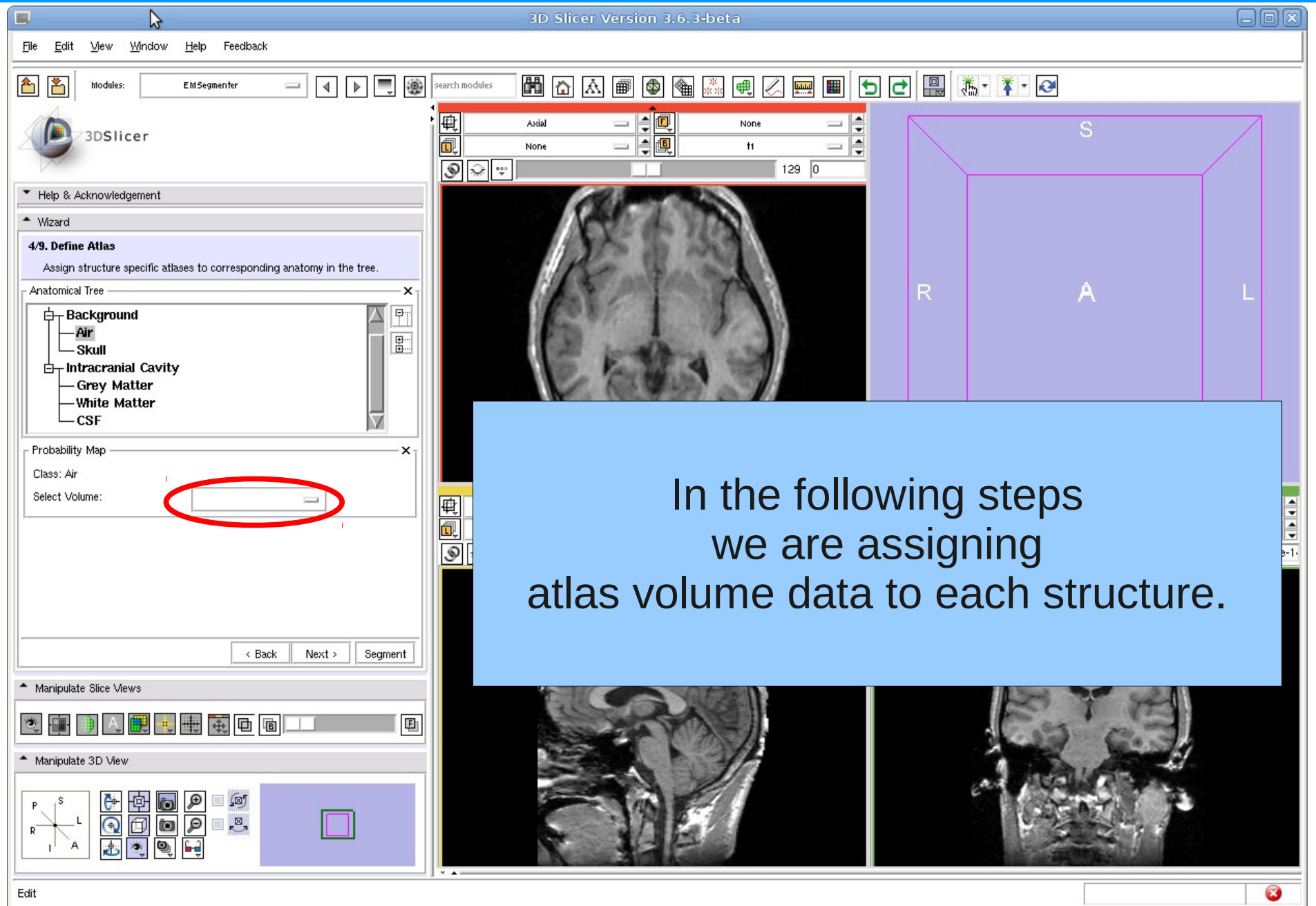
We now further characterize each anatomical structure by specifying the atlas associated with that structure. For the EMSegmenter, the atlas defines the spatial distribution of the structure of interest, which is the frequency the structure appeared at each image location in a given set of scans.

For further information on generating these atlas please read:

L. Zöllei, M. Shenton, W.M. Wells III, K.M. Pohl. "The Impact of Atlas Formation Methods on Atlas-Guided Brain Segmentation, Statistical Registration." In Pair-wise and Group-wise Alignment and Atlas Formation Workshop at MICCAI 2007: Tenth International Conference on Medical Image Computing and Computer-Assisted Intervention, pp. 39 - 46, 2007.

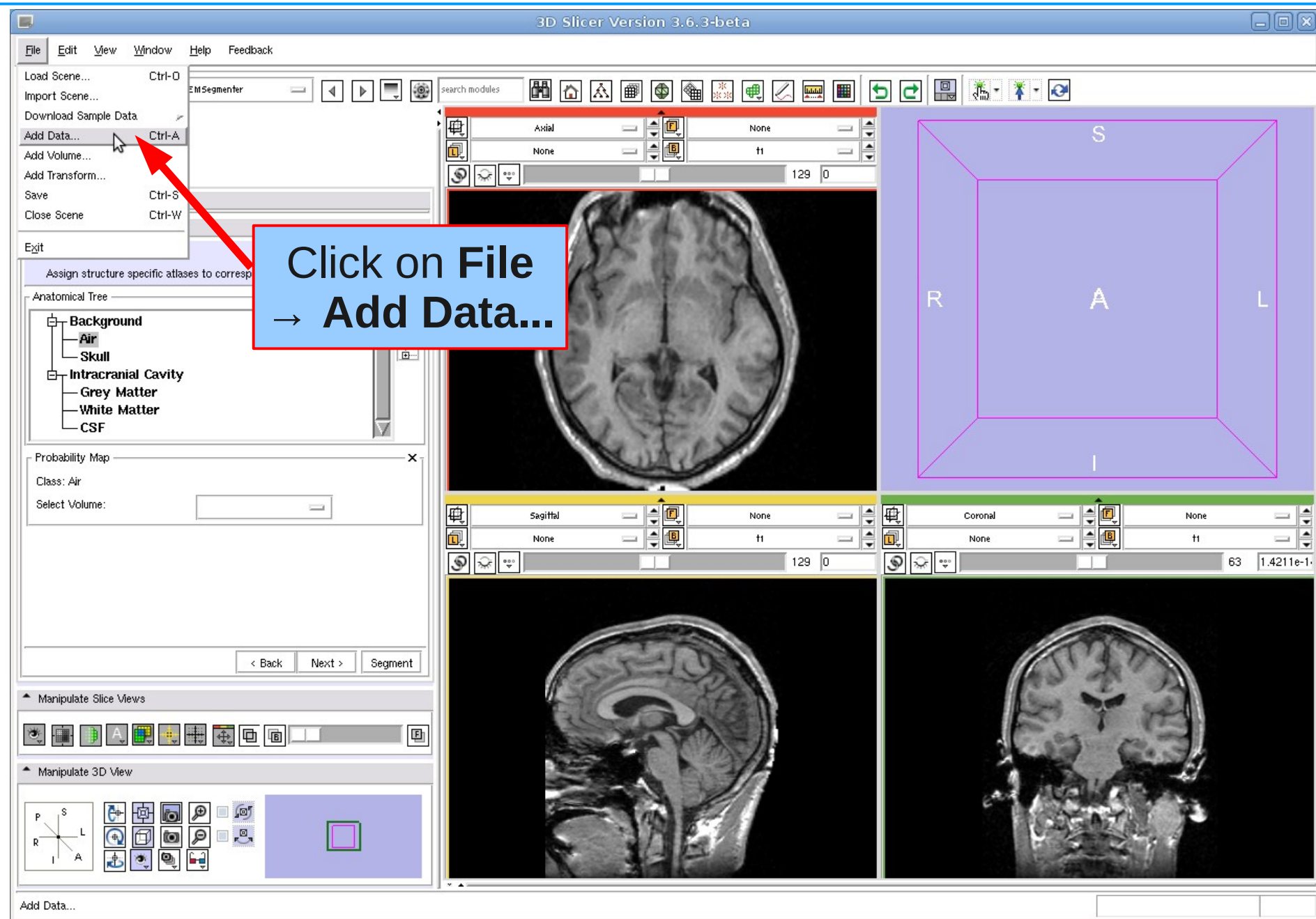
<https://www.rad.upenn.edu/sbia/Kilian.Pohl/publications/zollei-miccai-2007.pdf>

Define Atlas

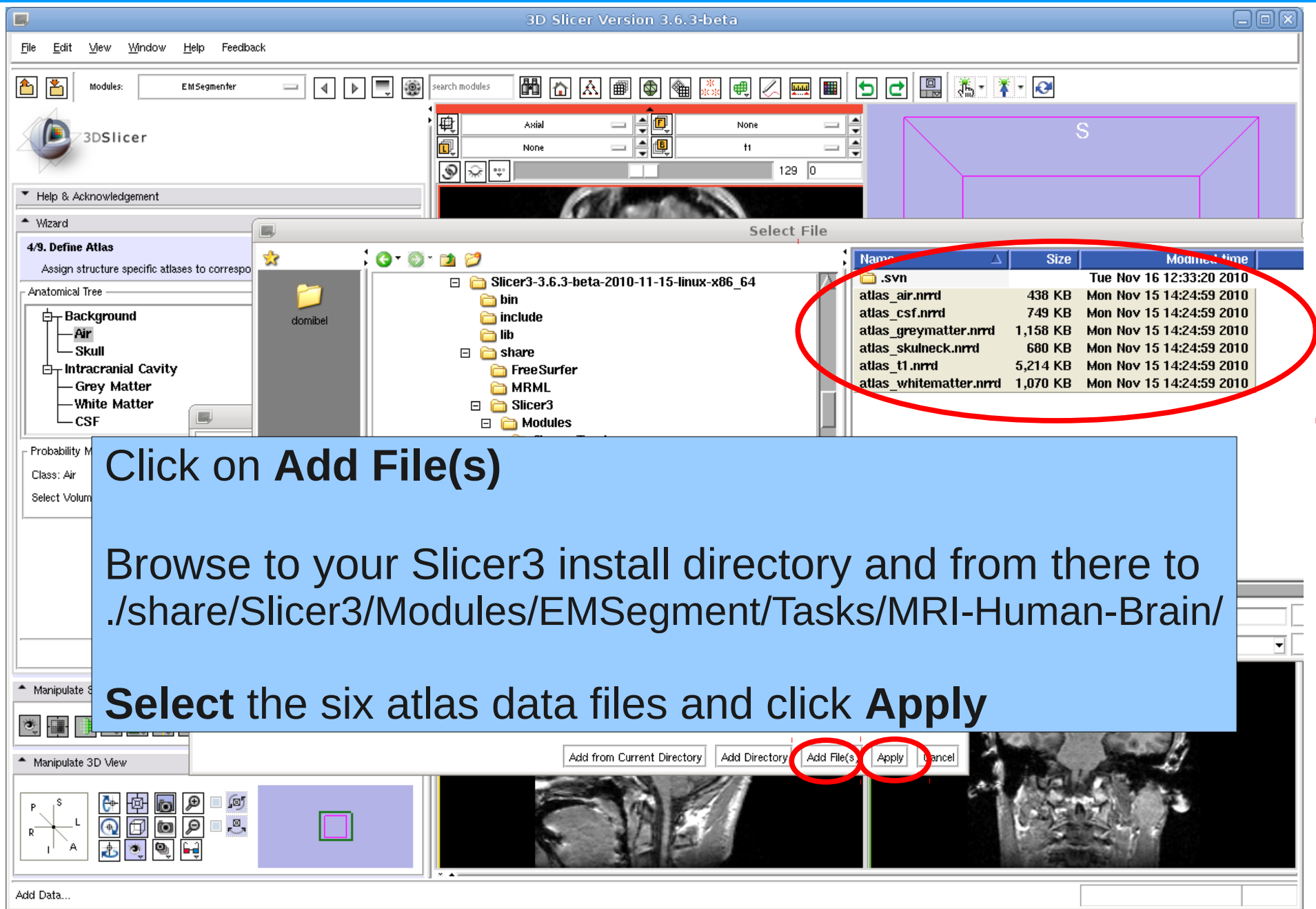




Load Atlas Data



Load Atlas Data



3D Slicer Version 3.6.3-beta

File Edit View Window Help Feedback

Modules: EMSegmenter

search modules

3DSlicer

Help & Acknowledgement

Wizard

4/9. Define Atlas

Assign structure specific atlases to correspo

Anatomical Tree

- Background
 - Air
 - Skull
- Intracranial Cavity
 - Grey Matter
 - White Matter
 - CSF

Probability M

Class: Air

Select Volum

Manipulate S

Manipulate 3D View

Add from Current Directory Add Directory Add File(s) Apply Cancel

Add Data...

Select File

Name	Size	Modified time
.svn		Tue Nov 16 12:33:20 2010
atlas_air.nrrd	438 KB	Mon Nov 15 14:24:59 2010
atlas_csf.nrrd	749 KB	Mon Nov 15 14:24:59 2010
atlas_greymatter.nrrd	1,158 KB	Mon Nov 15 14:24:59 2010
atlas_skulneck.nrrd	680 KB	Mon Nov 15 14:24:59 2010
atlas_t1.nrrd	5,214 KB	Mon Nov 15 14:24:59 2010
atlas_whitematter.nrrd	1,070 KB	Mon Nov 15 14:24:59 2010

Click on Add File(s)

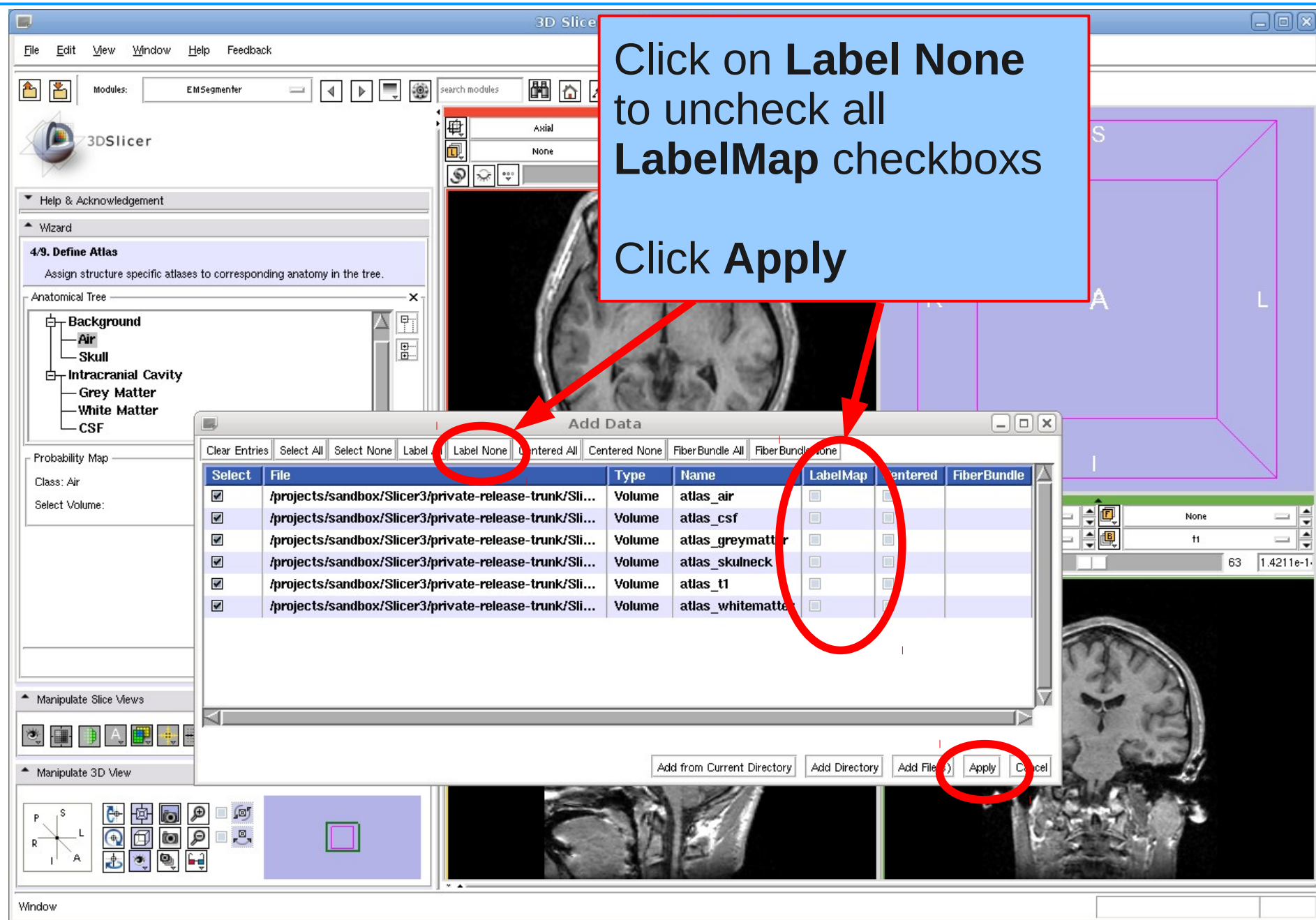
Browse to your Slicer3 install directory and from there to
./share/Slicer3/Modules/EMSegment/Tasks/MRI-Human-Brain/

Select the six atlas data files and click Apply

Load Atlas Data

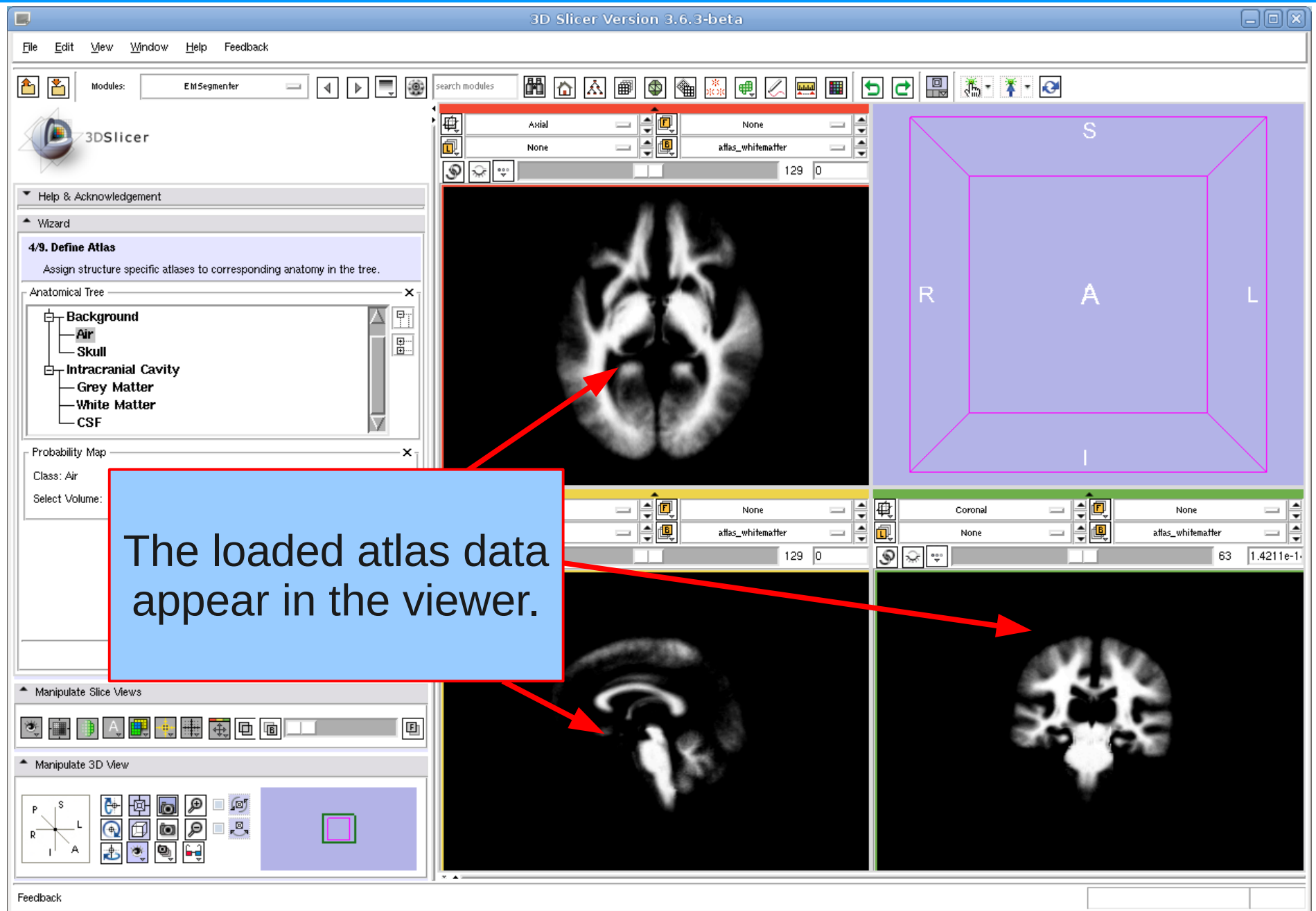
Click on **Label None**
to uncheck all
LabelMap checkboxes

Click **Apply**

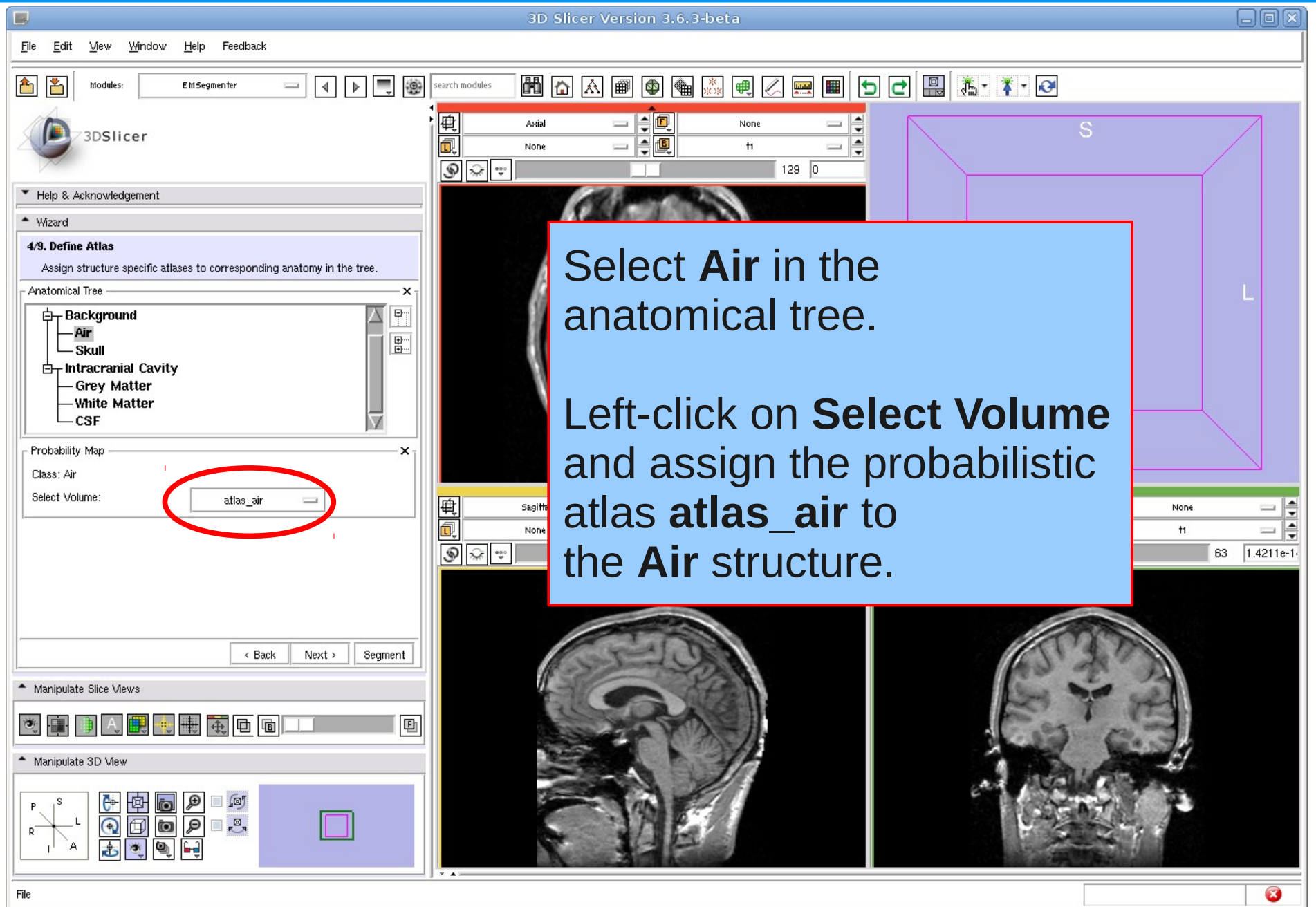




Load Atlas Data



Define Atlas



3D Slicer Version 3.6.3-beta

File Edit View Window Help Feedback

Modules: EMSegmenter

search modules

4/9. Define Atlas

Assign structure specific atlases to corresponding anatomy in the tree.

Anatomical Tree

- Background
 - Air**
 - Skull
- Intracranial Cavity
 - Grey Matter
 - White Matter
 - CSF

Probability Map

Class: Air

Select Volume: **atlas_air**

< Back Next > Segment

Manipulate Slice Views

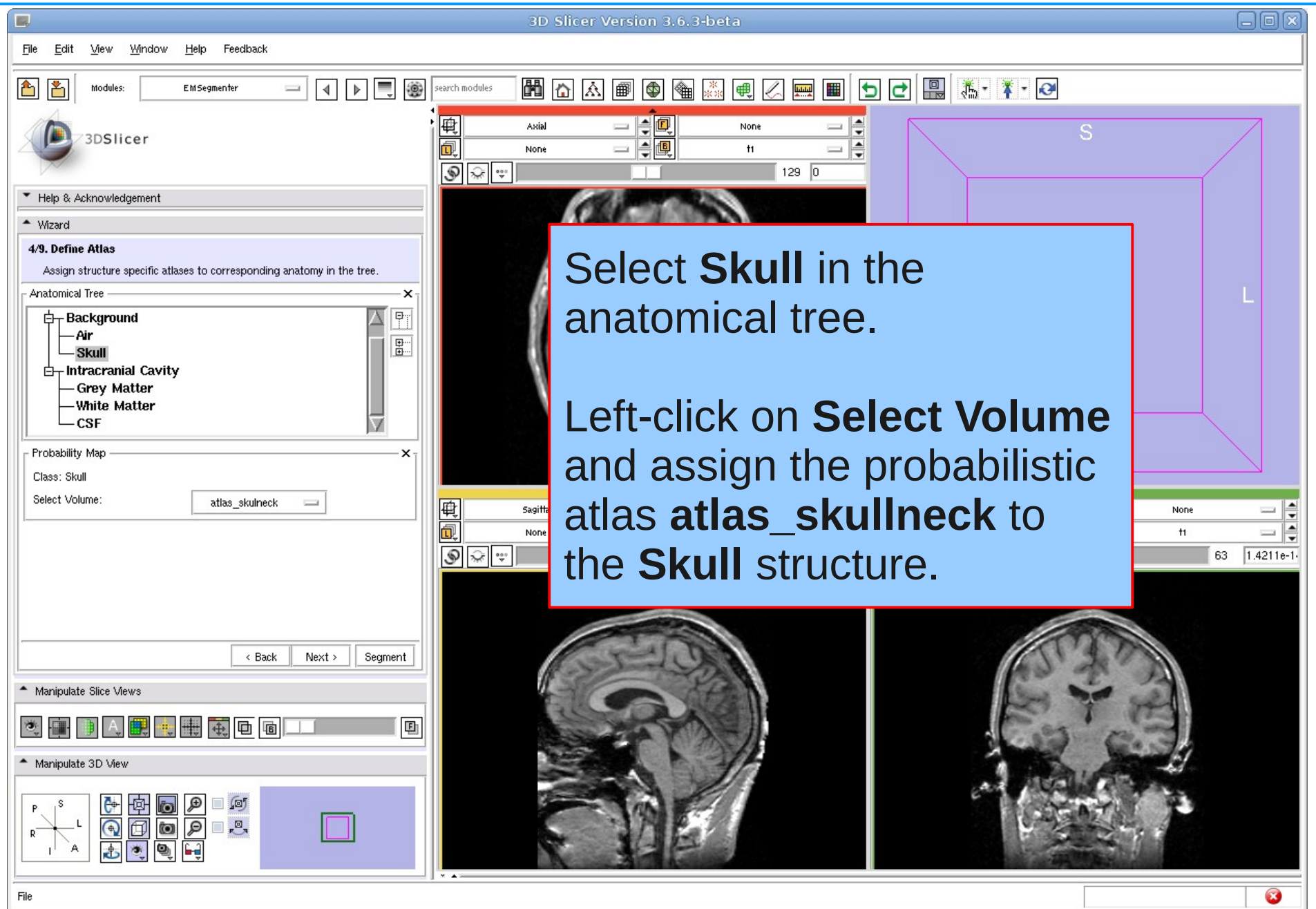
Manipulate 3D View

File

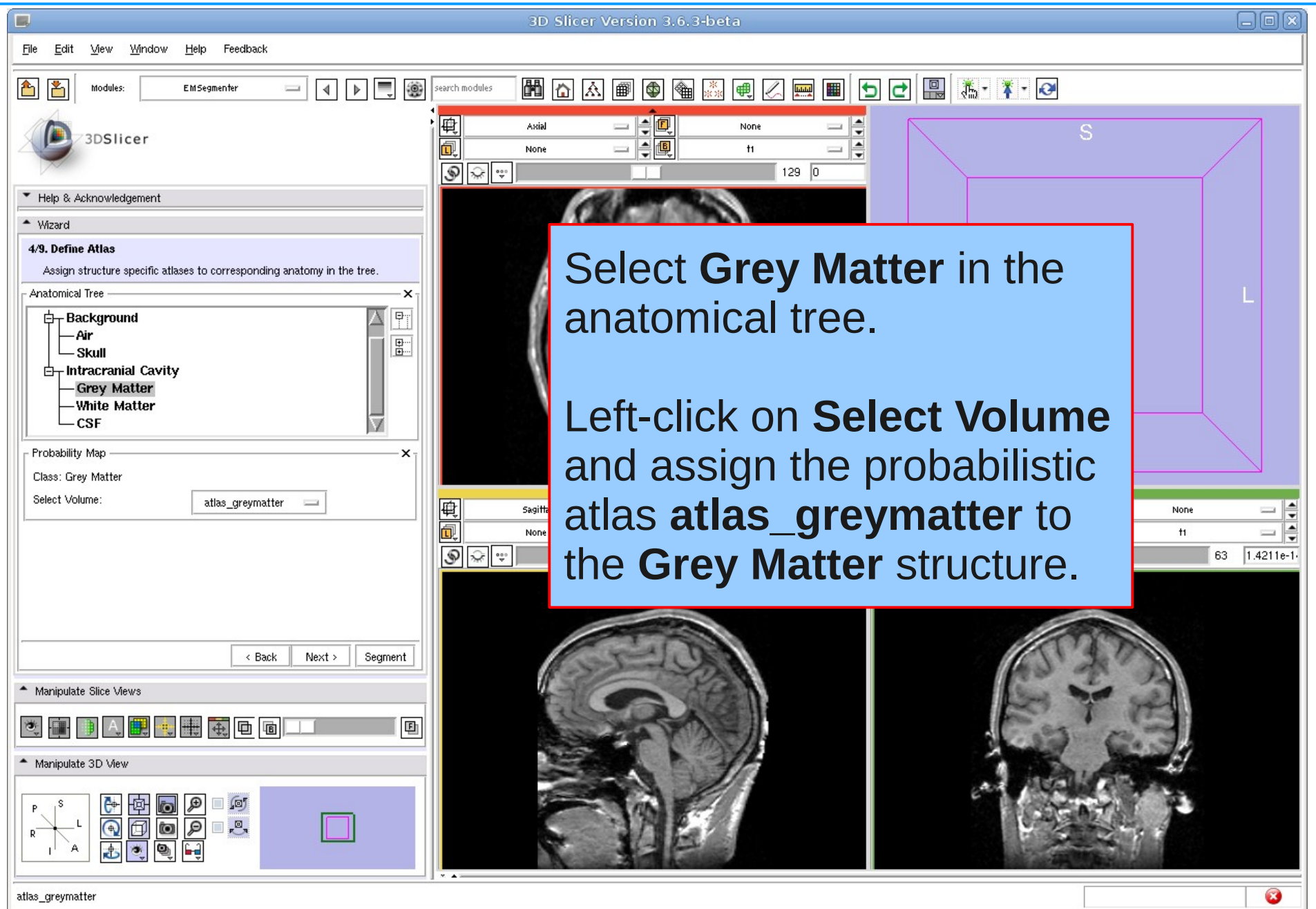
Select **Air** in the anatomical tree.

Left-click on **Select Volume** and assign the probabilistic atlas **atlas_air** to the **Air** structure.

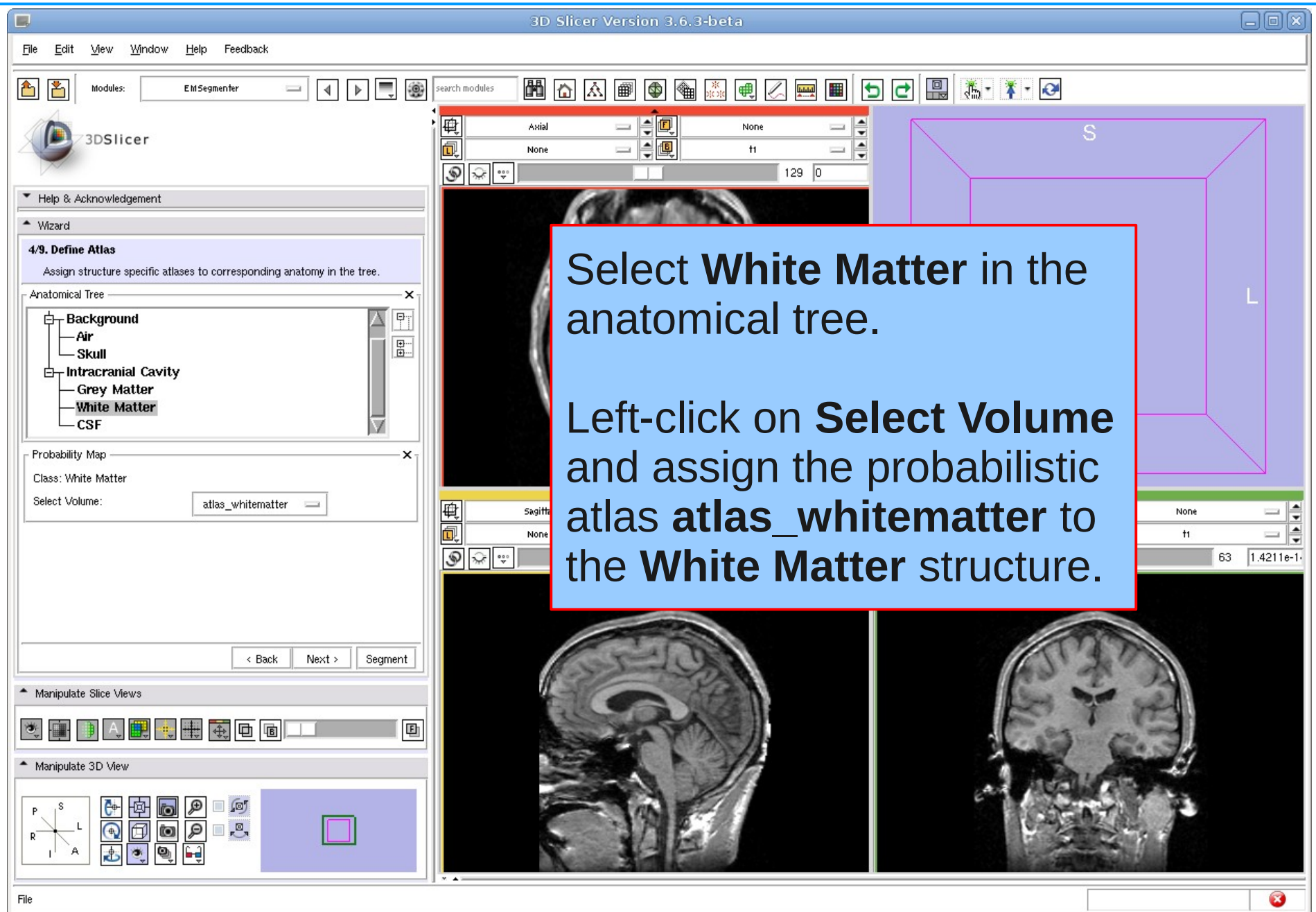
Define Atlas



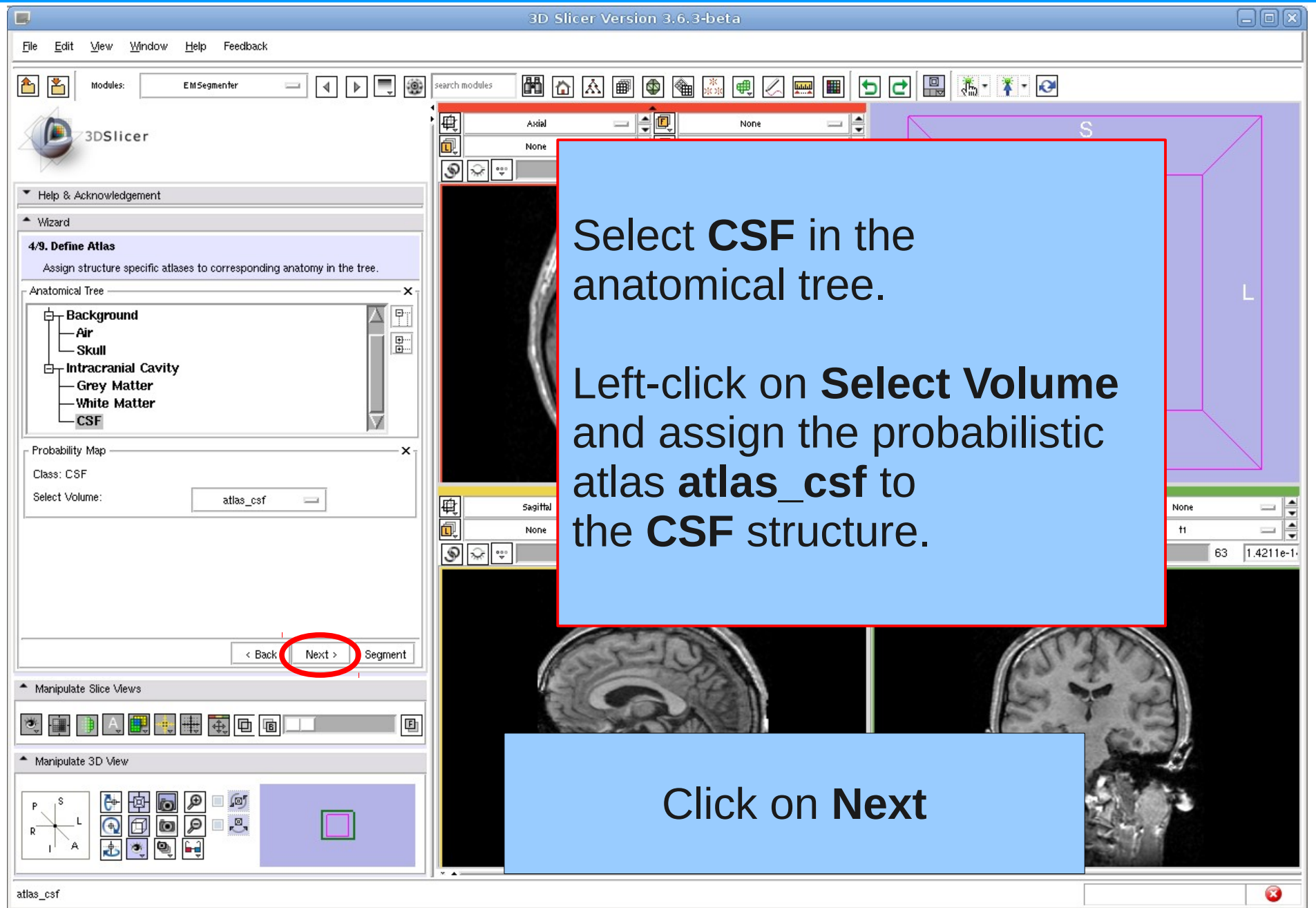
Define Atlas



Define Atlas



Define Atlas



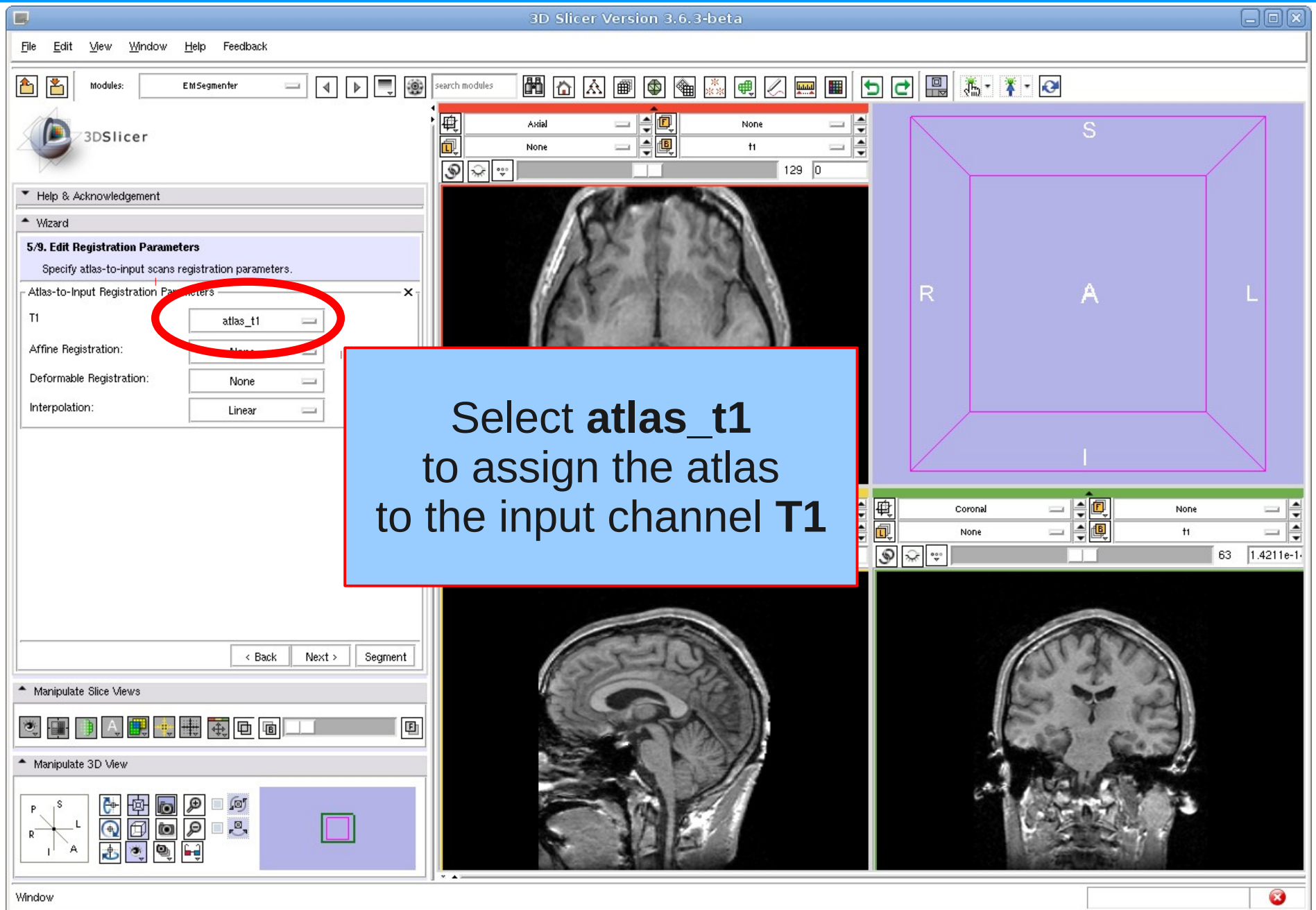


Edit Registration Parameters

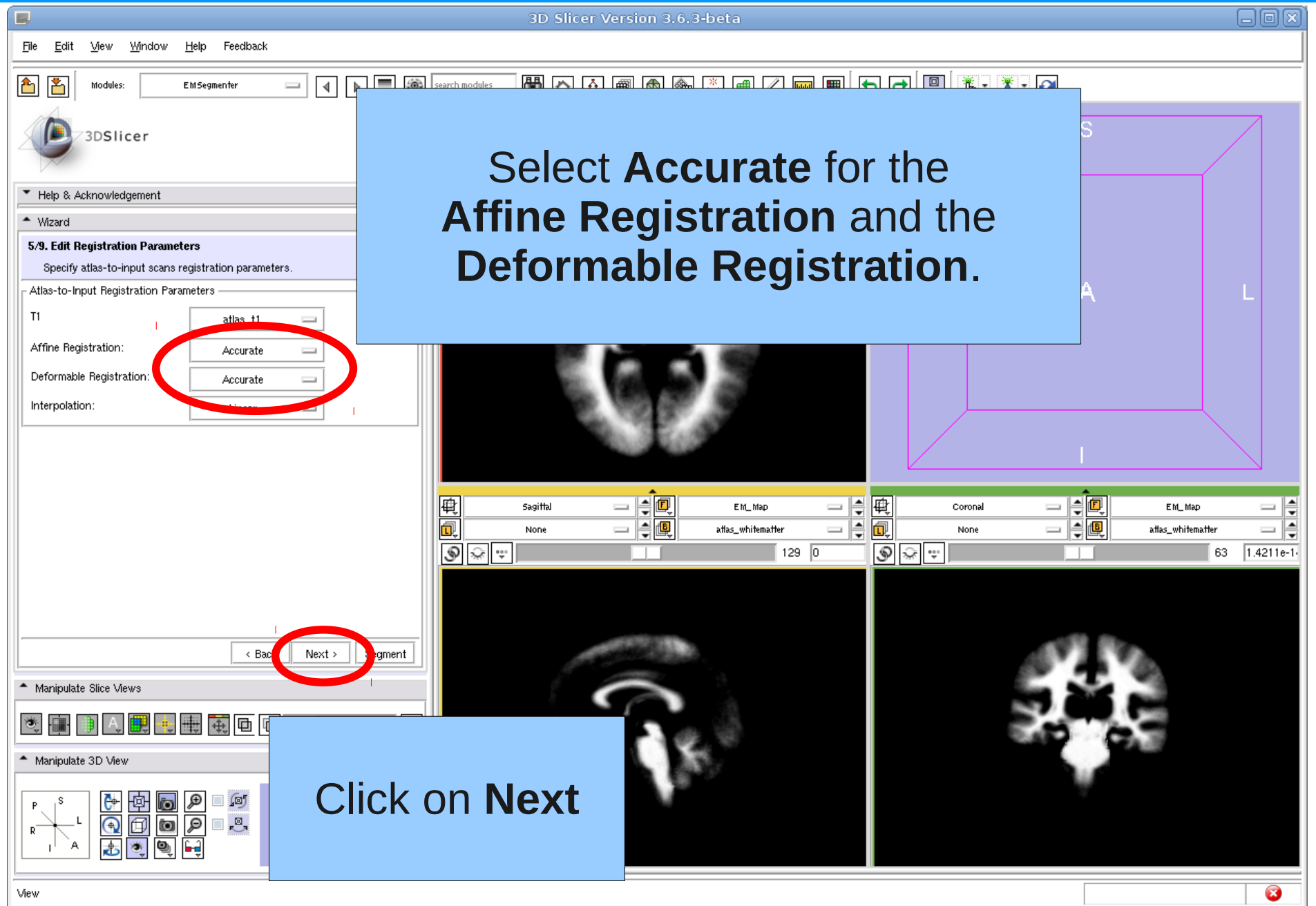
Step 5: Defining the Atlas to Image Registration

In general, the currently defined atlas has to be aligned to the subject scan. To do so, we define in this step the template, which in this case is a T1 scan, that the atlas is currently aligned to as well as the type of registration we would like to perform

Edit Registration Parameters



Edit Registration Parameters





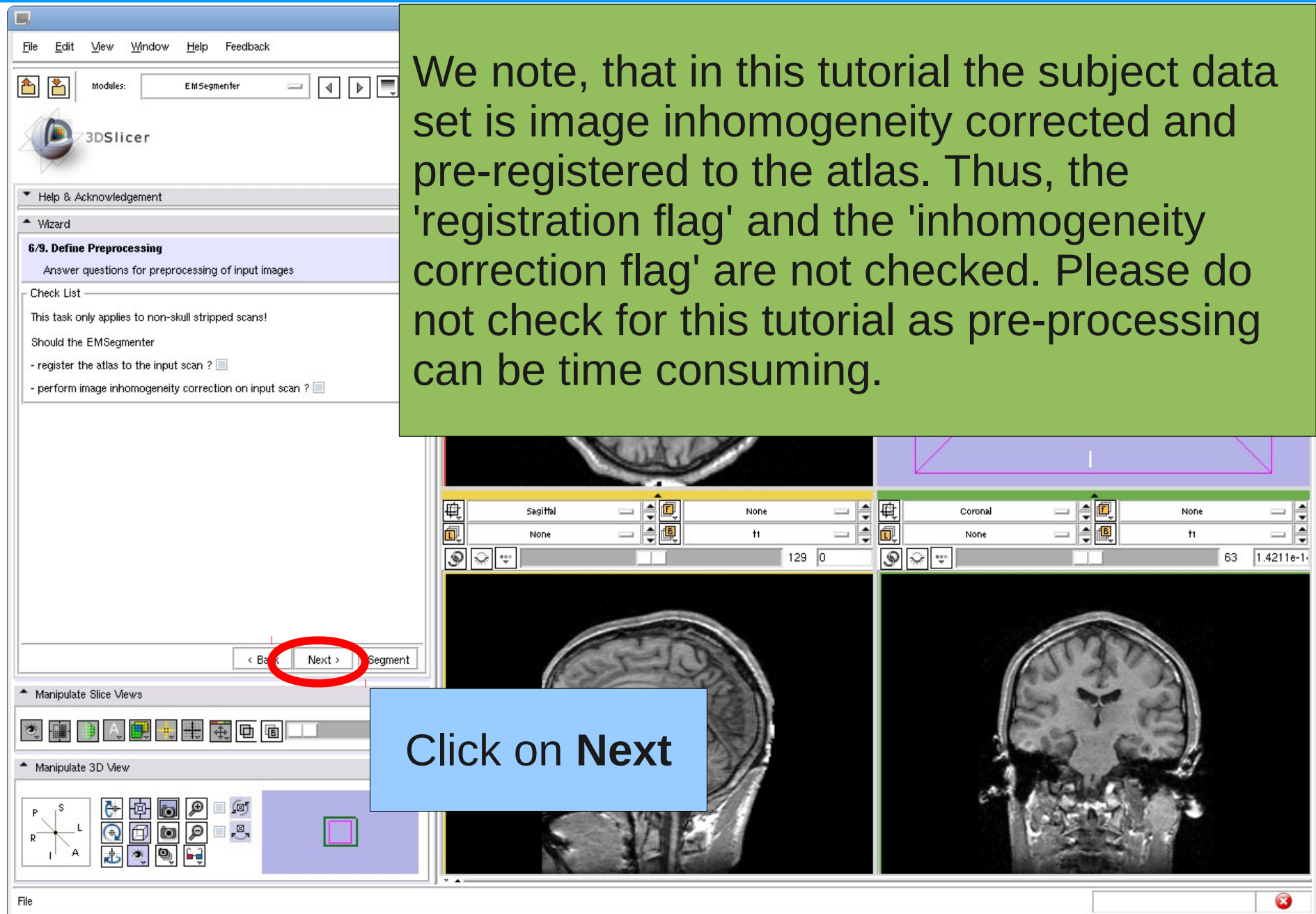
Define Preprocessing

Step 6: Further Specify Preprocessing

In the first step, we defined the type of preprocessing we wanted to perform. We now further specify the pre-processing by answering a set of questions further specifying the type of data we attend to segment. For example, in this tutorial we assume that the subject scan is already aligned to the atlas so that we skip the atlas to image registration during preprocessing.

Define Preprocessing

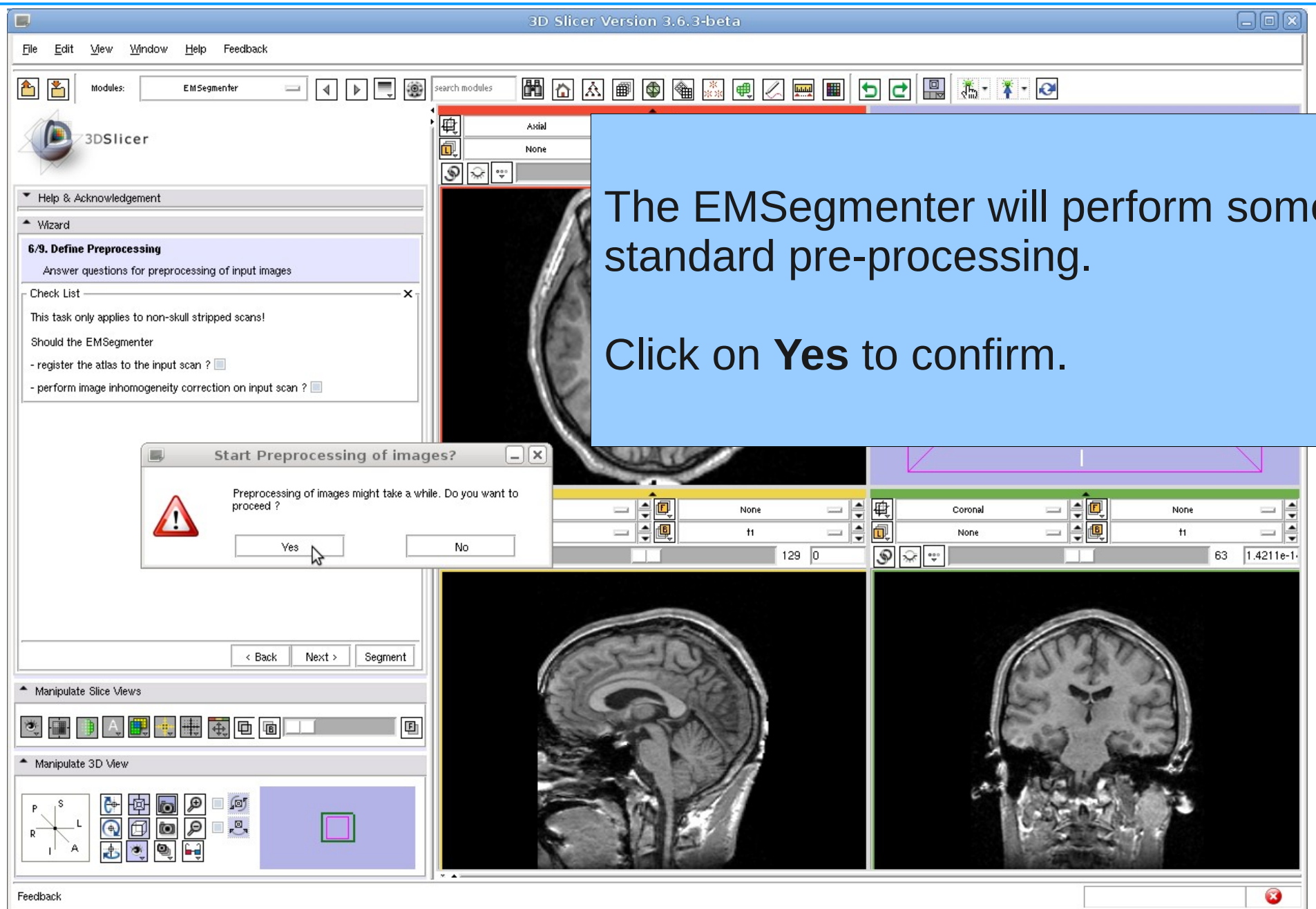
We note, that in this tutorial the subject data set is image inhomogeneity corrected and pre-registered to the atlas. Thus, the 'registration flag' and the 'inhomogeneity correction flag' are not checked. Please do not check for this tutorial as pre-processing can be time consuming.



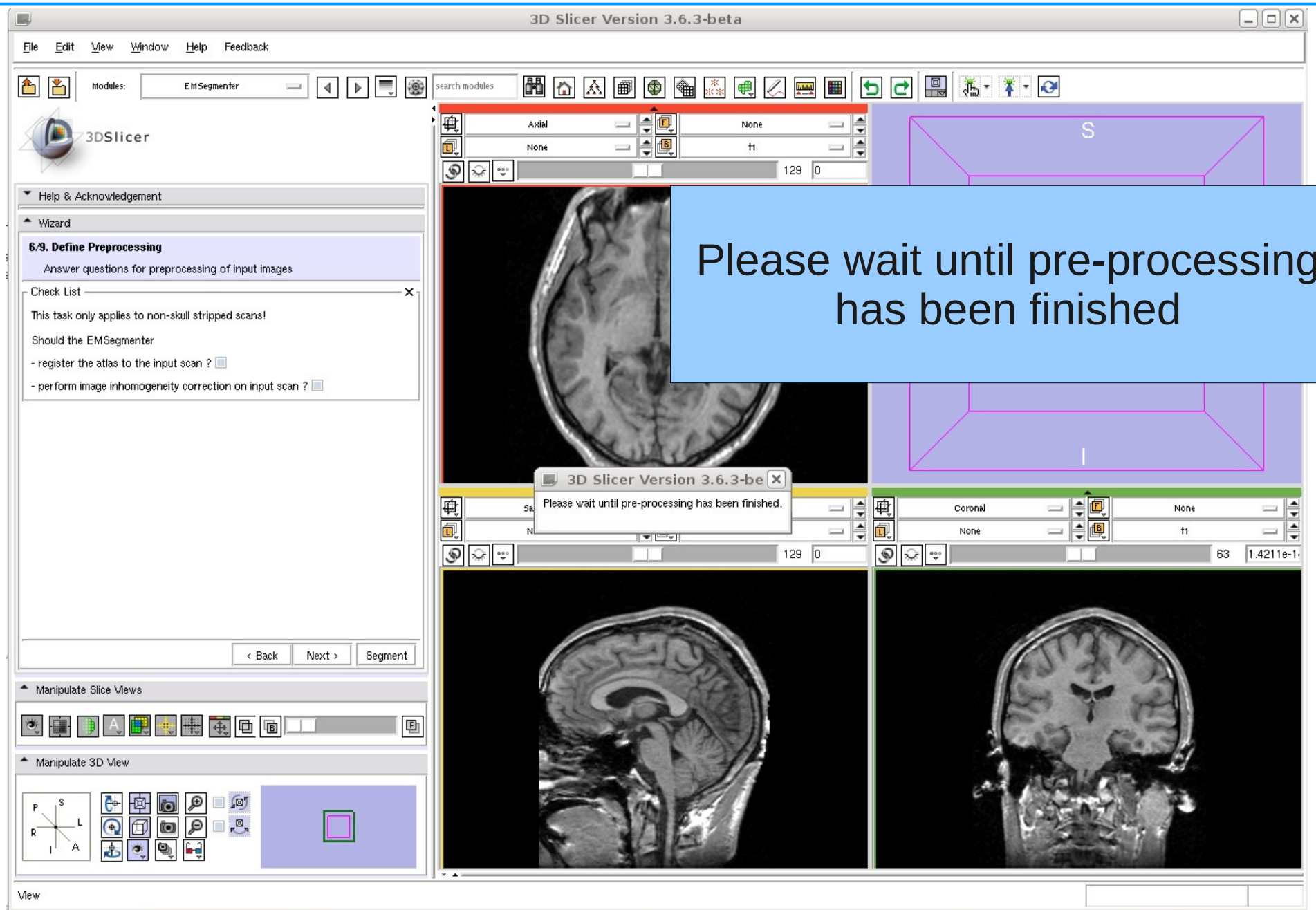
Define Preprocessing

The EMSegmenter will perform some standard pre-processing.

Click on **Yes** to confirm.



Define Preprocessing





Specify Intensity Distribution

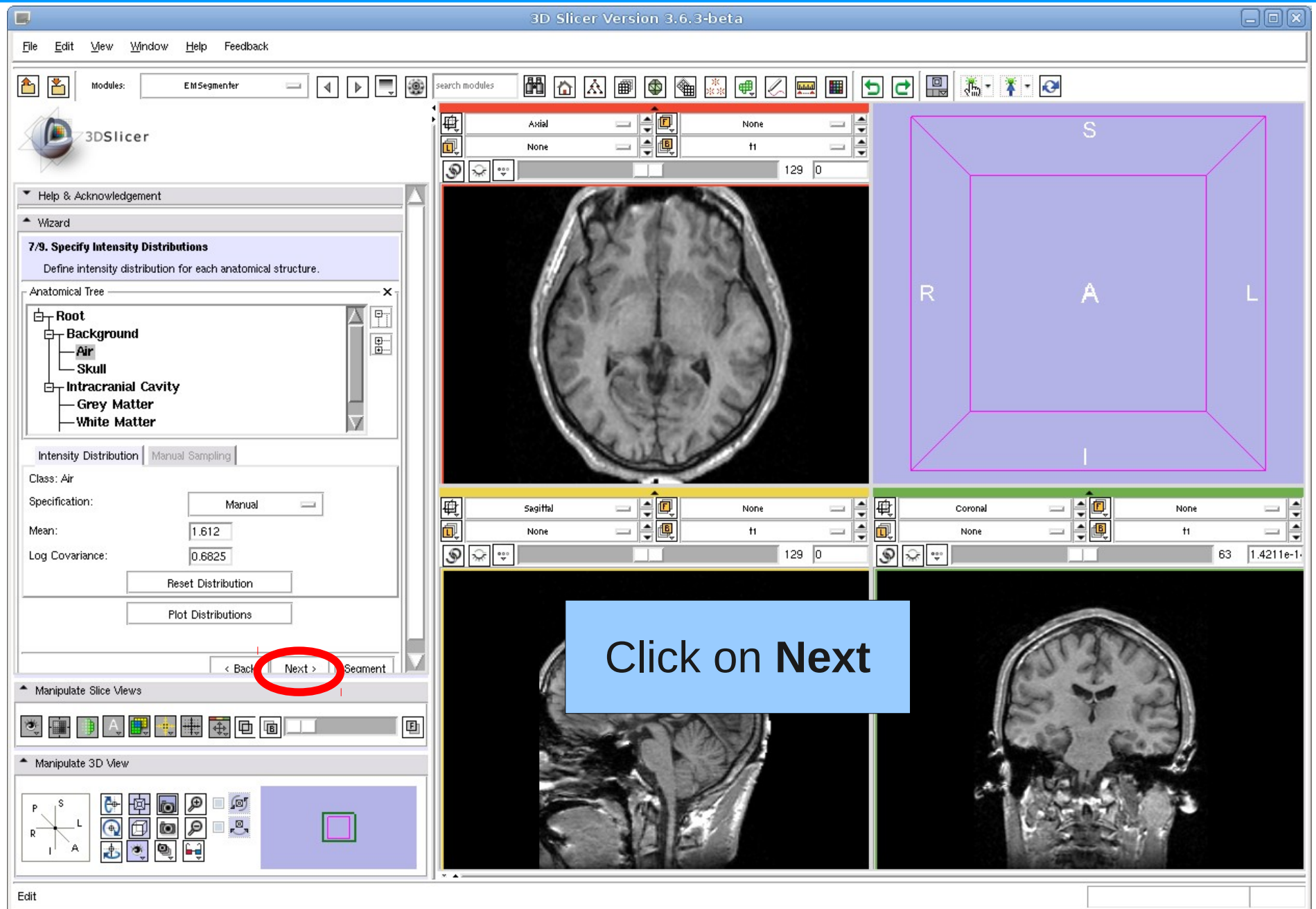
Step 7: Specifying the Intensity Distribution

In this step, users further specify each anatomical structure by defining the intensity distribution that is typical for the structure in the input scan.

In this tutorial the step can be skipped as the intensity distributions have been calculated during the pre-processing.



Specify Intensity Distribution





Edit Node-based Parameters

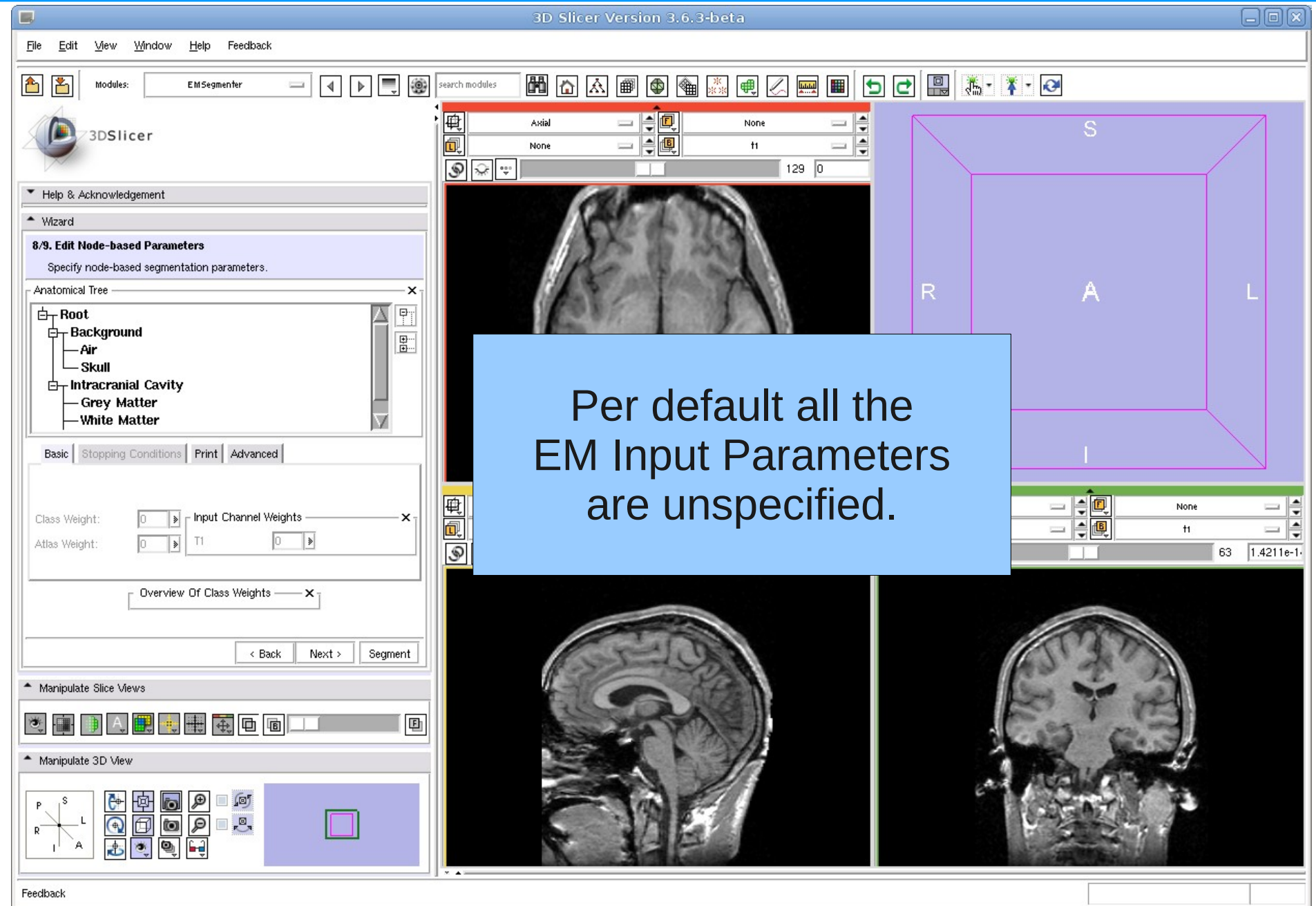
Step 8: Define EM Specific Parameters

The EMSegmenter segments the input scans of Step 1 into the structure of interest of Step 2 by using an optimization algorithm called the Expectation Maximization Algorithm. This algorithm has specific parameters that influence the segmentation. In this tutorial we will specify:

- **class weights**, which define the relative importance of structure over other structure. This is useful if a structure is too dominant in the automatic segmentation. By lowering the weight, the structure will be less present in the corresponding automatic segmentation.
- **atlas weight**, which define the importance of the atlas (of Step 3) over the image data defined in Step 1. One might want to lower the weight if the intensity distributions clearly define each structure to be segmented.
- **Input Channel weight**, which defines the importance between the different input channels for the structure of interest. Since we only defined one input channel, this parameter should simply be set to 1.
- **Alpha**, which defines the smoothness of the segmentation. The alpha value has to be between 0 and 1. An alpha value of 1 produces fairly smooth segmentations while an alpha value of 0 generally results in noisy segmentations.



Edit Node-based Parameters





Edit Node-based Parameters

3D Slicer Version 3.6.3-beta

File Edit View Window Help Feedback

Modules: EM Segmenter

search modules

3DSlicer

Wizard

8/9. Edit Node-based Parameters

Specify node-based segmentation parameters.

Anatomical Tree

- Background
 - Air
 - Skull
- Intracranial Cavity
 - Grey Matter
 - White Matter
 - CSF

Basic Stopping Conditions Print Advanced

Class: Background

Class Weight: 0.15 Input Channel Weights: T1 1

Atlas Weight: 1 Alpha: 0.99

Overview Of Class Weights

Class	Weight
Background	0.15
Intracranial Cavity	0

< Back Next > Segment

Manipulate Slice Views

Manipulate 3D View

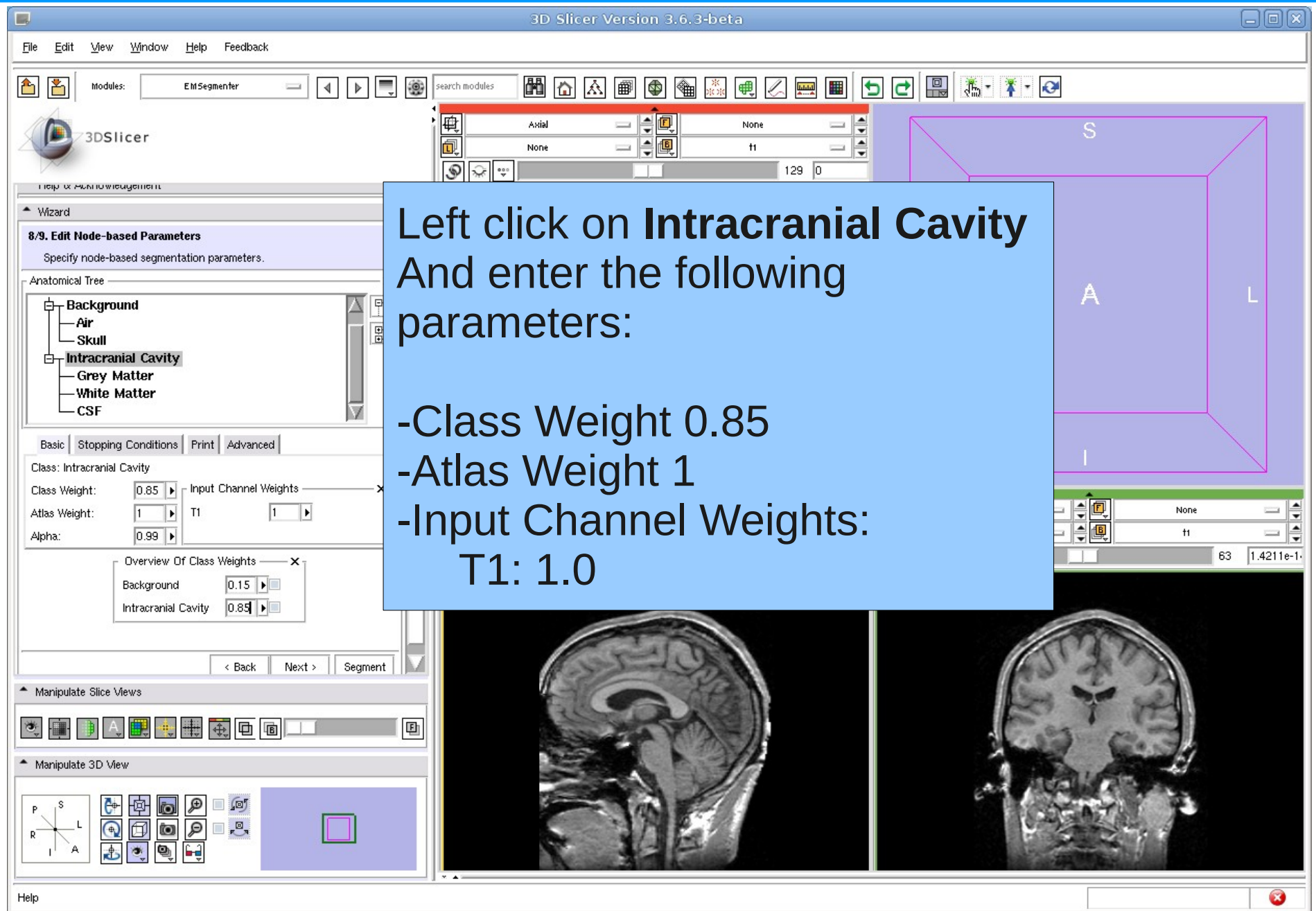
Help

Left click on **Background** and Enter the following parameters:

- Class Weight 0.15
- Atlas Weight 1

We only defined one input channel, please set
Input Channel Weights:
T1: 1.0

Edit Node-based Parameters



3D Slicer Version 3.6.3-beta

File Edit View Window Help Feedback

Modules: EM Segmenter

search modules

3DSlicer

Wizard

8/9. Edit Node-based Parameters

Specify node-based segmentation parameters.

Anatomical Tree

- Background
 - Air
 - Skull
- Intracranial Cavity
 - Grey Matter
 - White Matter
 - CSF

Basic Stopping Conditions Print Advanced

Class: Intracranial Cavity

Class Weight: 0.85 Input Channel Weights

Atlas Weight: 1 T1 1

Alpha: 0.99

Overview Of Class Weights

Class	Weight
Background	0.15
Intracranial Cavity	0.85

< Back Next > Segment

Manipulate Slice Views

Manipulate 3D View

Help

Left click on **Intracranial Cavity**
And enter the following parameters:

- Class Weight 0.85
- Atlas Weight 1
- Input Channel Weights:
T1: 1.0



Edit Node-based Parameters

3D Slicer Version 3.6.3-beta

File Edit View Window Help Feedback

Modules: EM Segmenter

3DSlicer

Wizard

8/9. Edit Node-based Parameters

Specify node-based segmentation parameters.

Anatomical Tree

- Background
 - Air
 - Skull
- Intracranial Cavity
 - Grey Matter
 - White Matter
 - CSF

Basic | Stopping Conditions | Print | Advanced

Class: Skull

Class Weight: 0.3 | Input Channel Weights: T1 1

Atlas Weight: 1

Overview Of Class Weights

Air	0.7
Skull	0.3

< Back | Next > | Segment

Manipulate Slice Views

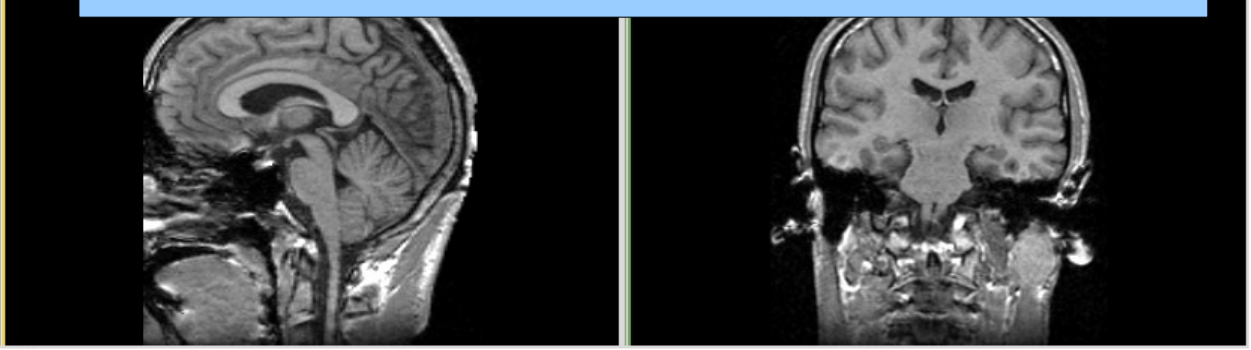
Manipulate 3D View

Help

Enter the following parameters for Air and Skull

Air: Class Weight: 0.7
Atlas Weight: 1.0
Input Channel Weight: 1.0

Skull: Class Weight: 0.3
Atlas Weight: 1.0
Input Channel Weight: 1.0





Edit Node-based Parameters

3D Slicer Version 3.6.3-beta

File Edit View Window Help Feedback

Modules: EMSegmenter

3DSlicer

Wizard

8/9. Edit Node-based Parameters

Specify node-based segmentation parameters.

Anatomical Tree

- Background
 - Air
 - Skull
- Intracranial Cavity
 - Grey Matter
 - White Matter
 - CSF

Basic Stopping Conditions Print Advanced

Class: Grey Matter

Class Weight: 0.45 Input Channel Weights: T1 1

Atlas Weight: 0.01

Overview Of Class Weights

Grey Matter	0.45
White Matter	0.3
CSF	0.25

< Back Next > Segment

Manipulate Slice Views

Manipulate 3D View

Window

Enter the following parameters for GM, WM, and CSF

GM: Class Weight: 0.45
Atlas Weight: 0.01
Input Channel Weight: 1.0

WM: Class Weight: 0.3
Atlas Weight: 0.7
Input Channel Weight: 1.0

CSF: Class Weight: 0.25
Atlas Weight: 0.01
Input Channel Weight: 1.0

Click on Next



Run Segmentation

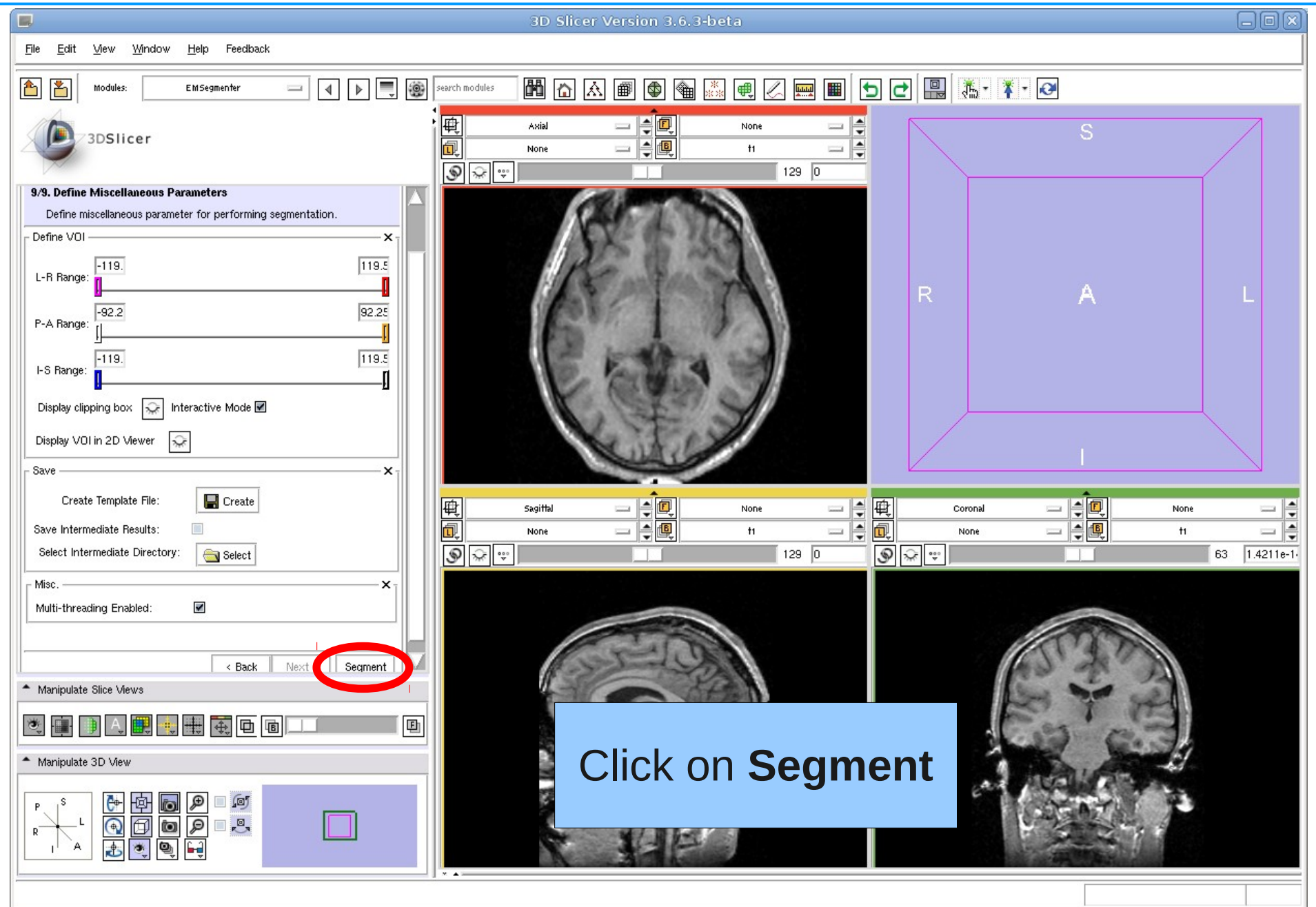
Step 9: Specify the Region of Interest and complete the Segmentation

This is the last step of the EMSegmenter wizard.

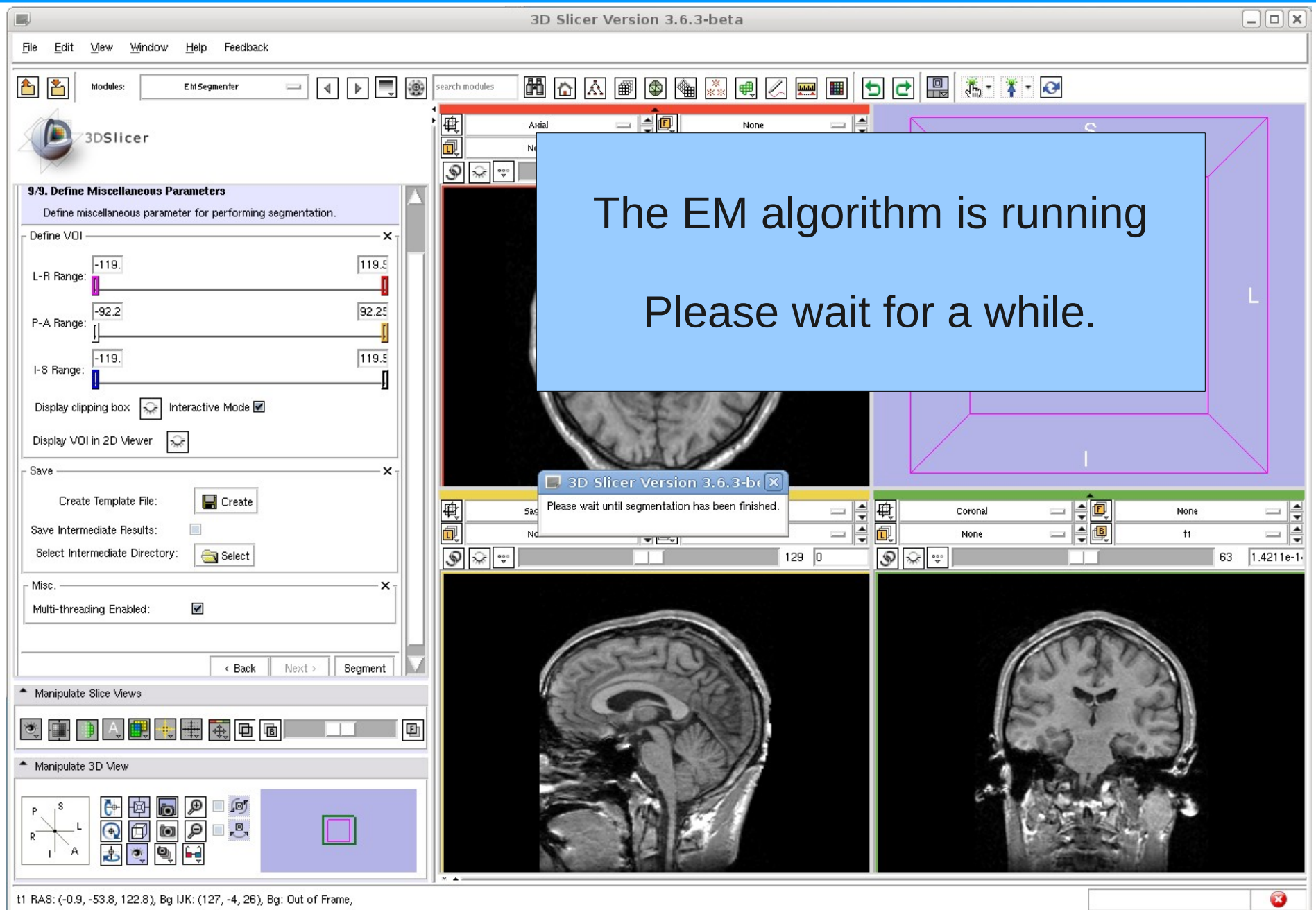
The Volume Of Interested (VOI) can be specified, and one can start the EM algorithm, which will segment the input channels by taking all the information entered in the previous steps into account .



Run Segmentation

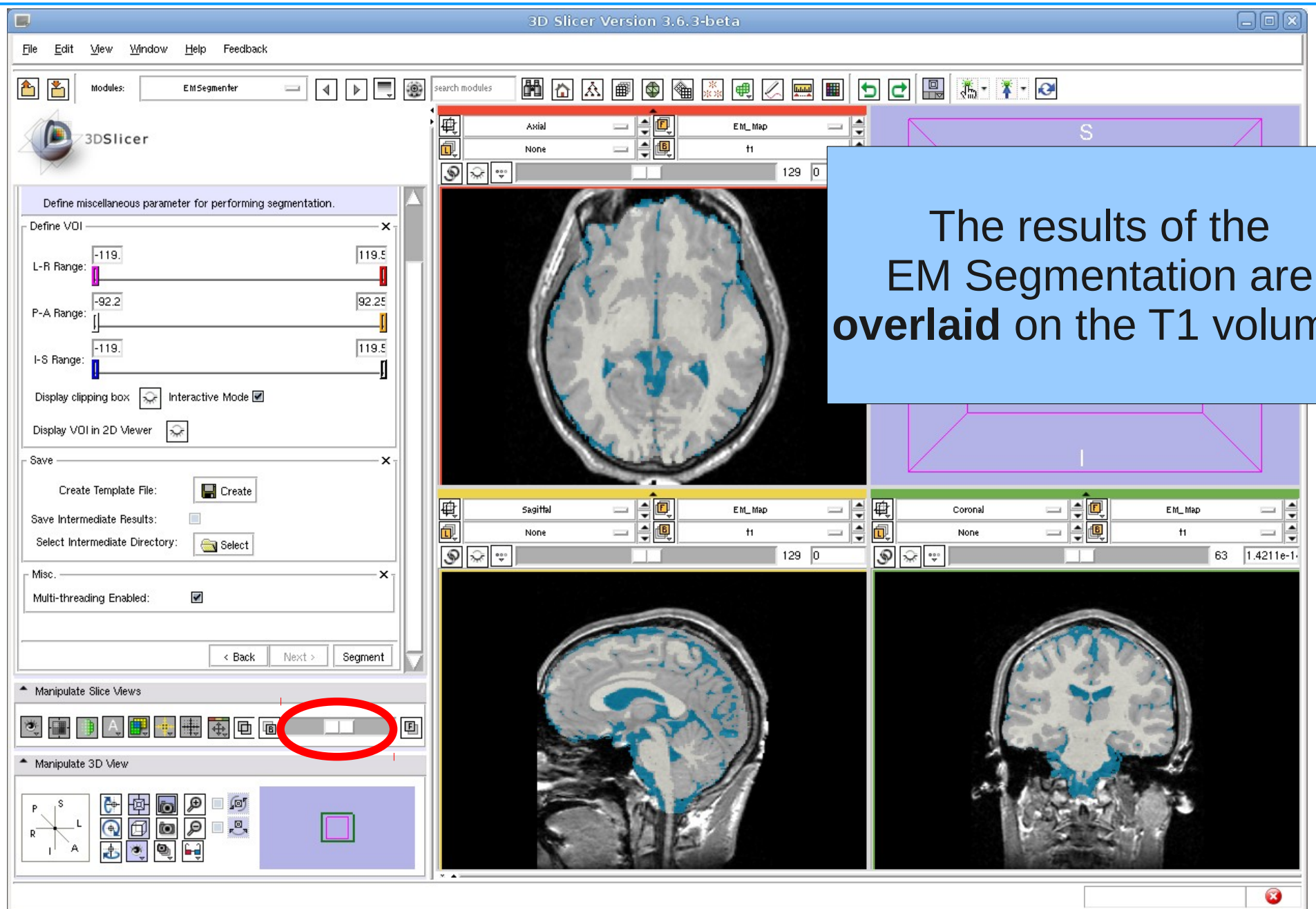


Run Segmentation





Results: Run Segmentation





Consecutive adjustment

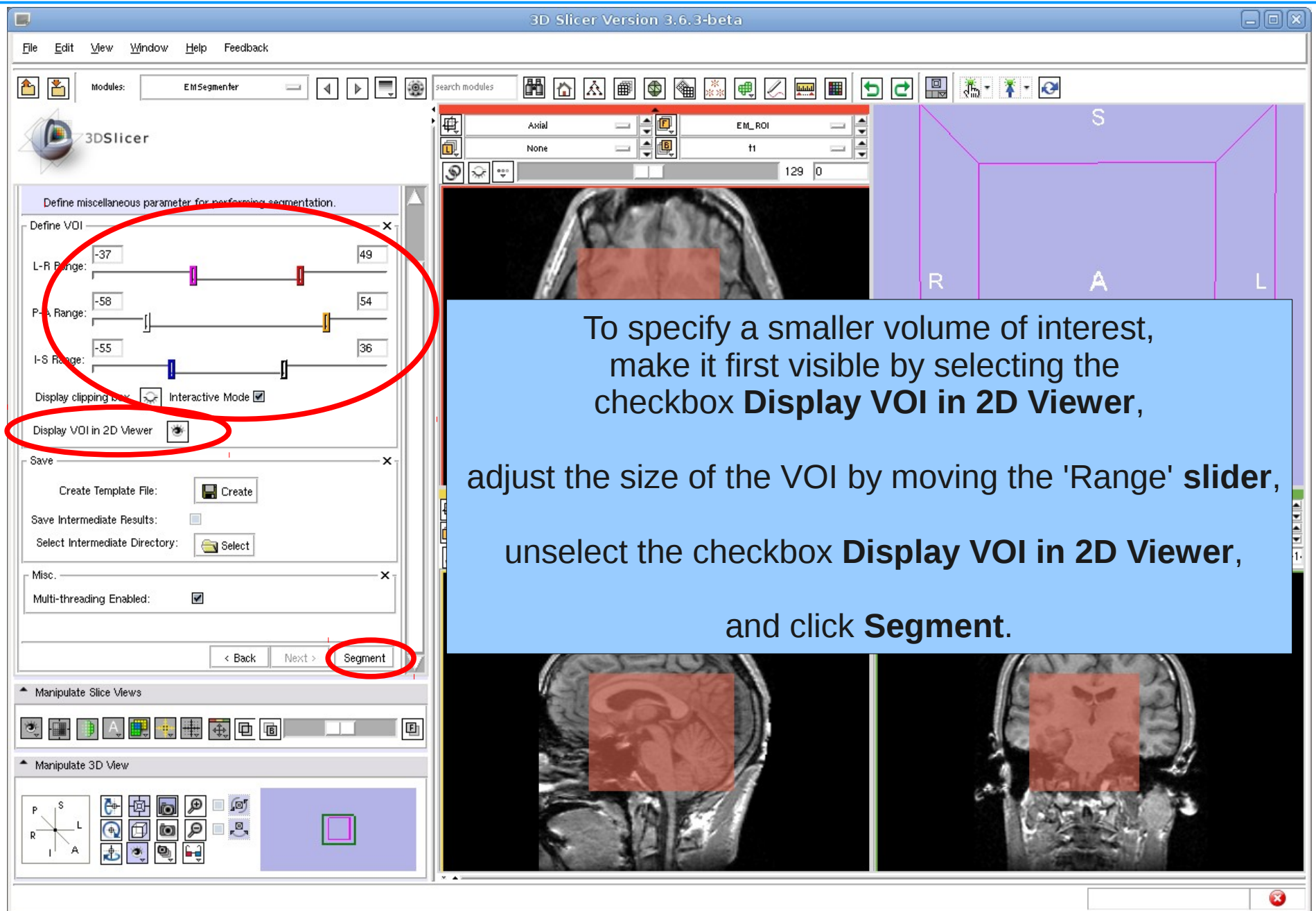
As previously mentioned, one might want to adjust the parameters of Step 8 in order to improve the segmentation. We now adjust three parameters and show the impact on the segmentation. The following slides illustrate

- how to specify a volume of interest and
- how to adjust segmentation parameters

the refine the segmentation result.



Volume Of Interest (VOI)





Result: Volume Of Interest (VOI)

3D Slicer Version 3.6.3-beta

File Edit View Window Help Feedback

Modules: EMSegmenter

search modules

Define miscellaneous parameter for performing segmentation.

Define VOI

L-R Range: -37 49

P-A Range: -58 54

I-S Range: -55 36

Display clipping box ☐ Interactive Mode ☒

Display VOI in 2D Viewer ☒

Save

Create Template File:

Save Intermediate Results: ☐

Select Intermediate Directory:

Misc.

Multi-threading Enabled: ☒

< Back Next > Segment

Manipulate Slice Views

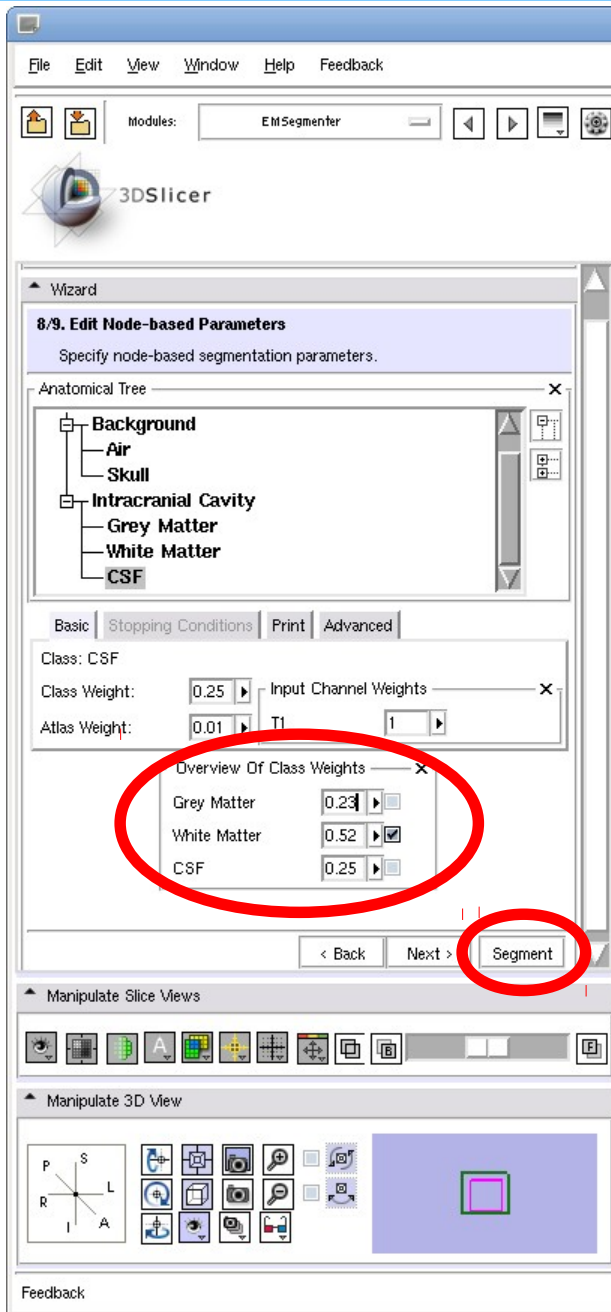
Manipulate 3D View

Only the VOI has been segmented.

Note that a smaller VOI leads to a faster segmentation.

For the next adjustment click on **Back**

Adjusting Parameters



3D Slicer Version 3.6.3-beta

File Edit View Window Help Feedback

Modules: EM Segmenter

3DSlicer

Wizard

8/9. Edit Node-based Parameters

Specify node-based segmentation parameters.

Anatomical Tree

- Background
 - Air
 - Skull
- Intracranial Cavity
 - Grey Matter
 - White Matter
 - CSF

Basic | Stopping Conditions | Print | Advanced

Class: CSF

Class Weight: 0.25 | Input Channel Weights: X

Atlas Weight: 0.01 | T1: 1

Overview Of Class Weights: X

Class	Weight	Selected
Grey Matter	0.23	<input type="checkbox"/>
White Matter	0.52	<input checked="" type="checkbox"/>
CSF	0.25	<input type="checkbox"/>

< Back | Next > | **Segment**

Manipulate Slice Views

Manipulate 3D View

Feedback

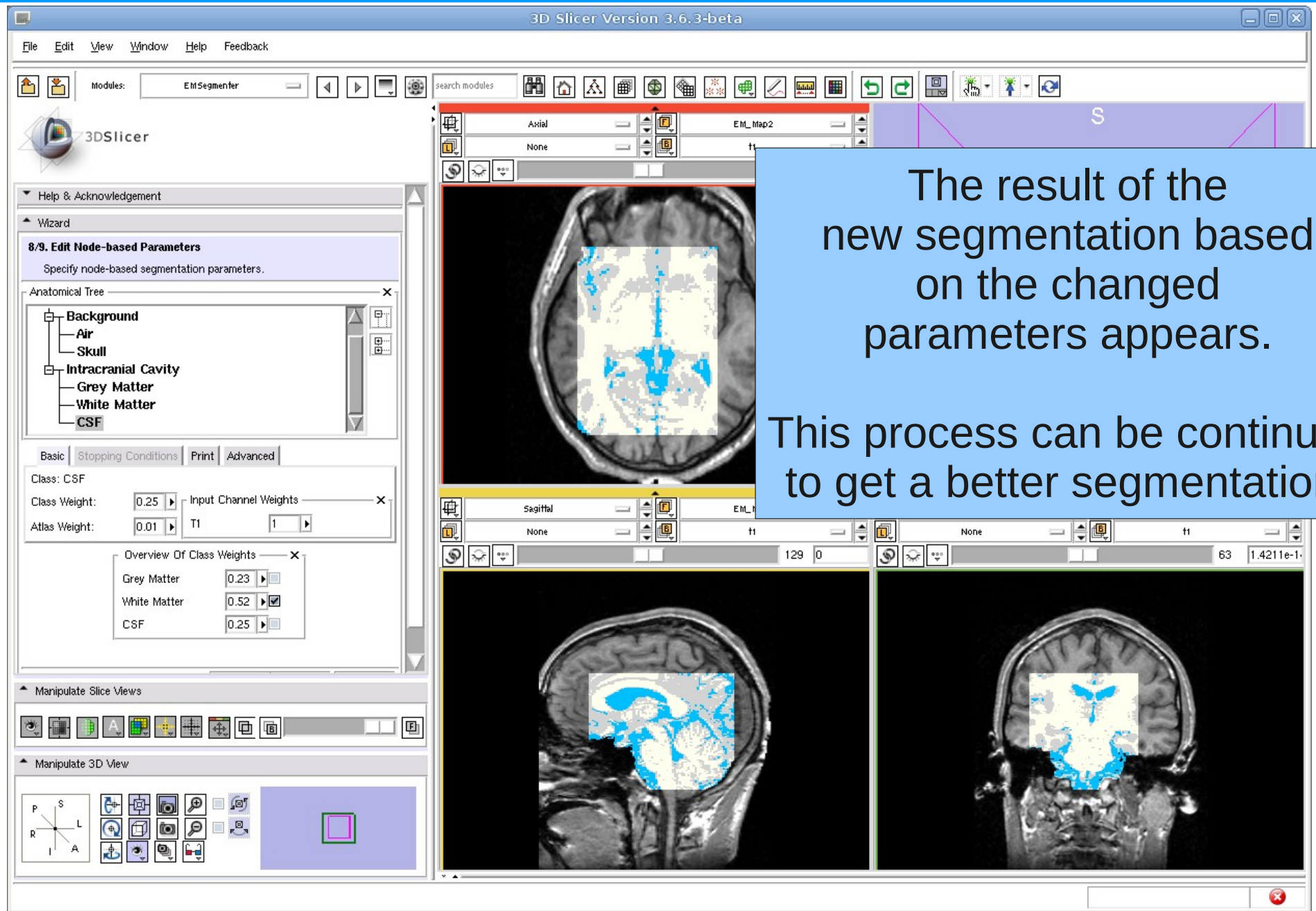
Step 8/9. Edit Node-based Parameters:

We want to change the class weight for grey matter and automatically update the class weight for white matter.

To do so,
select the checkbox next to white matter and
change the class weight for grey matter.

Click on **Segment**.

Result: Adjusting Parameters



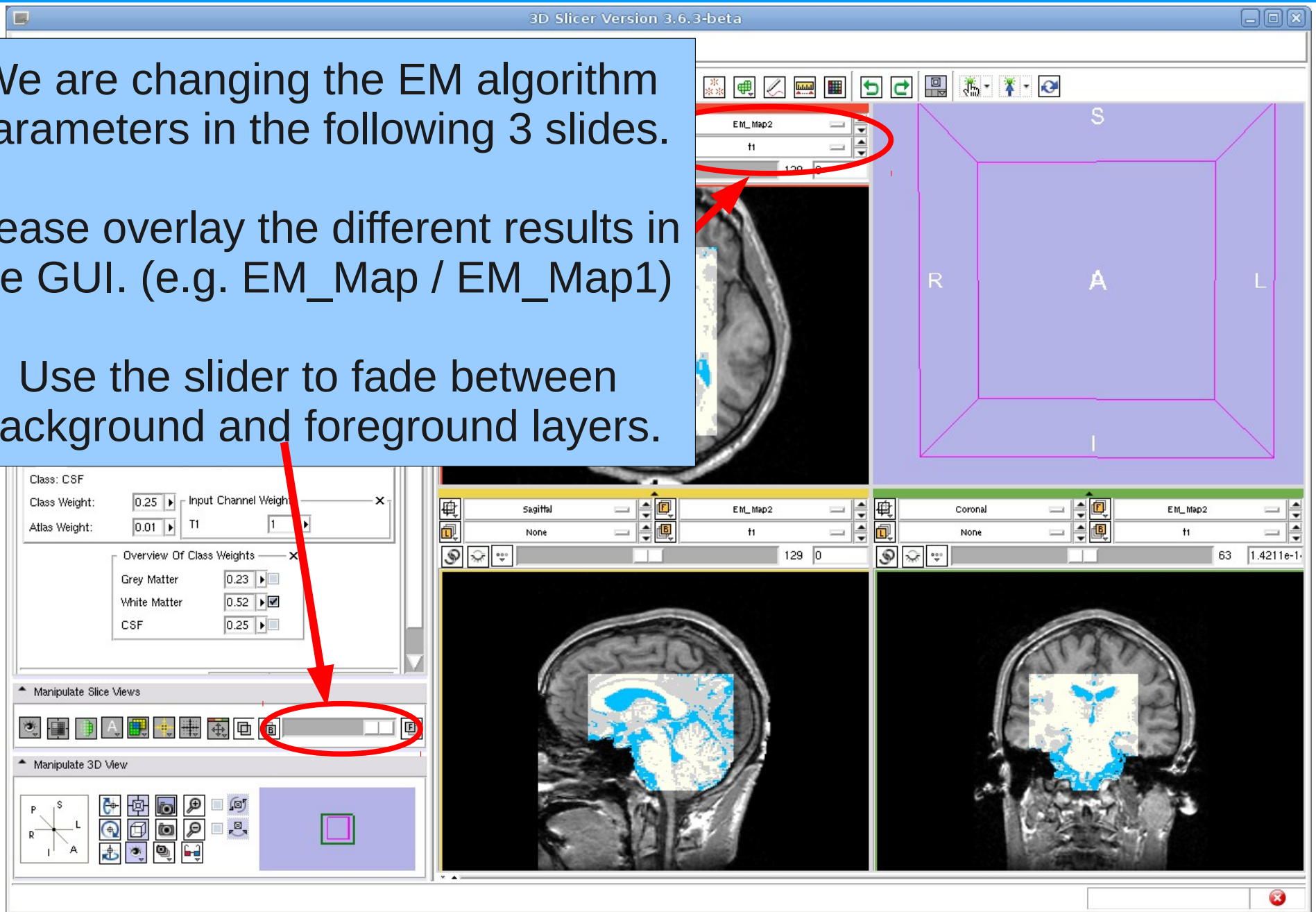


Compare Results

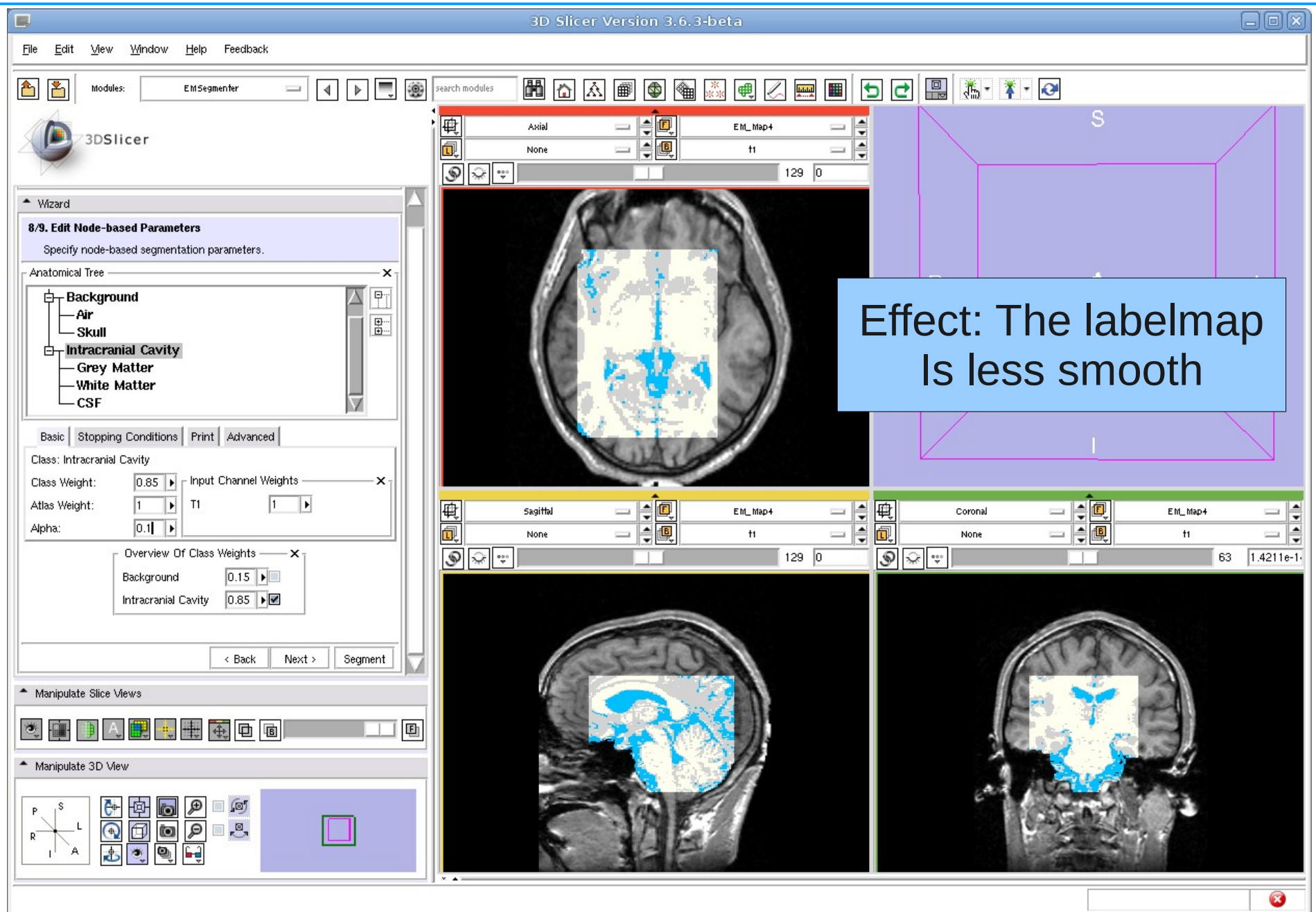
We are changing the EM algorithm parameters in the following 3 slides.

Please overlay the different results in the GUI. (e.g. EM_Map / EM_Map1)

Use the slider to fade between background and foreground layers.

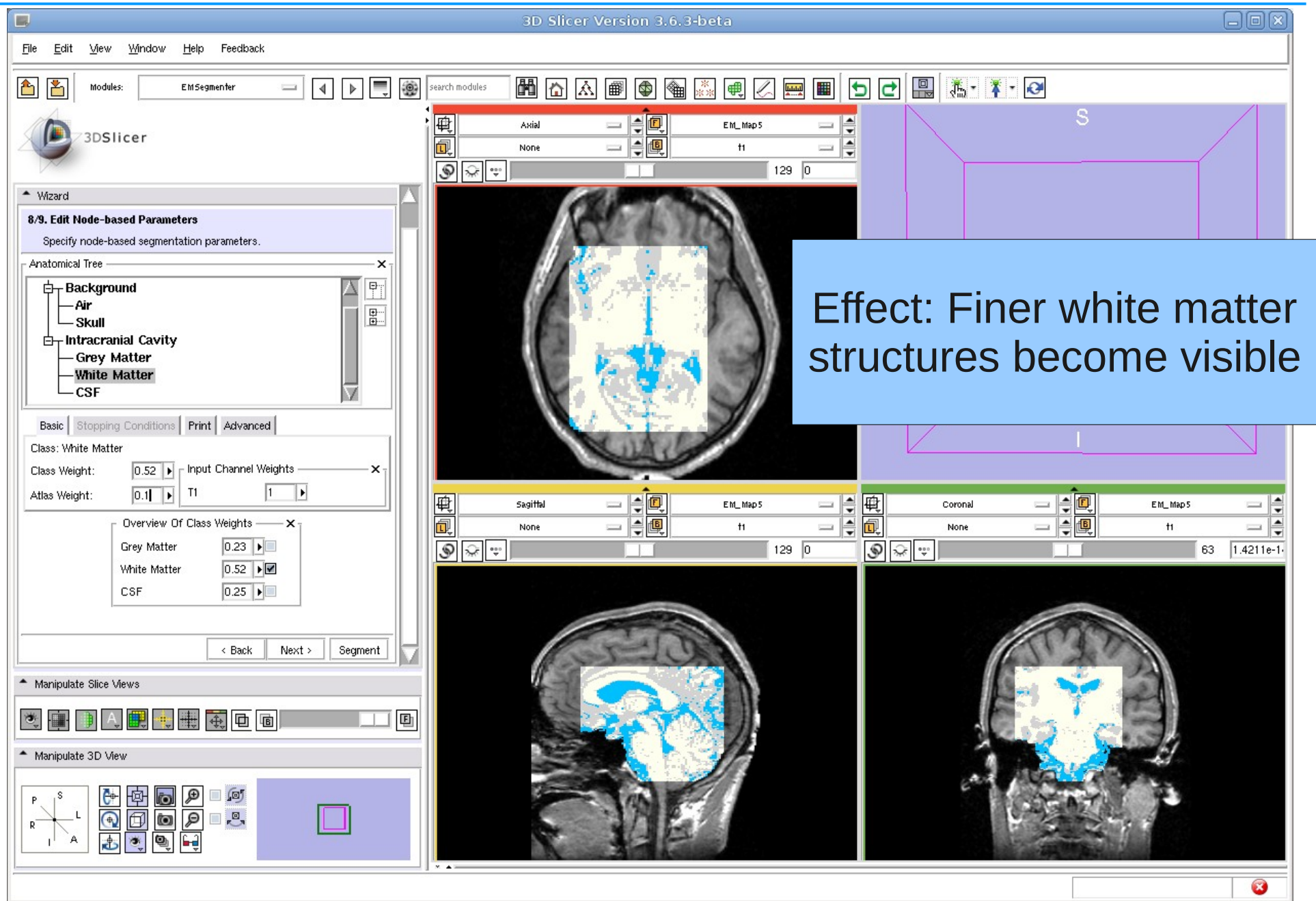


Low ICC alpha value



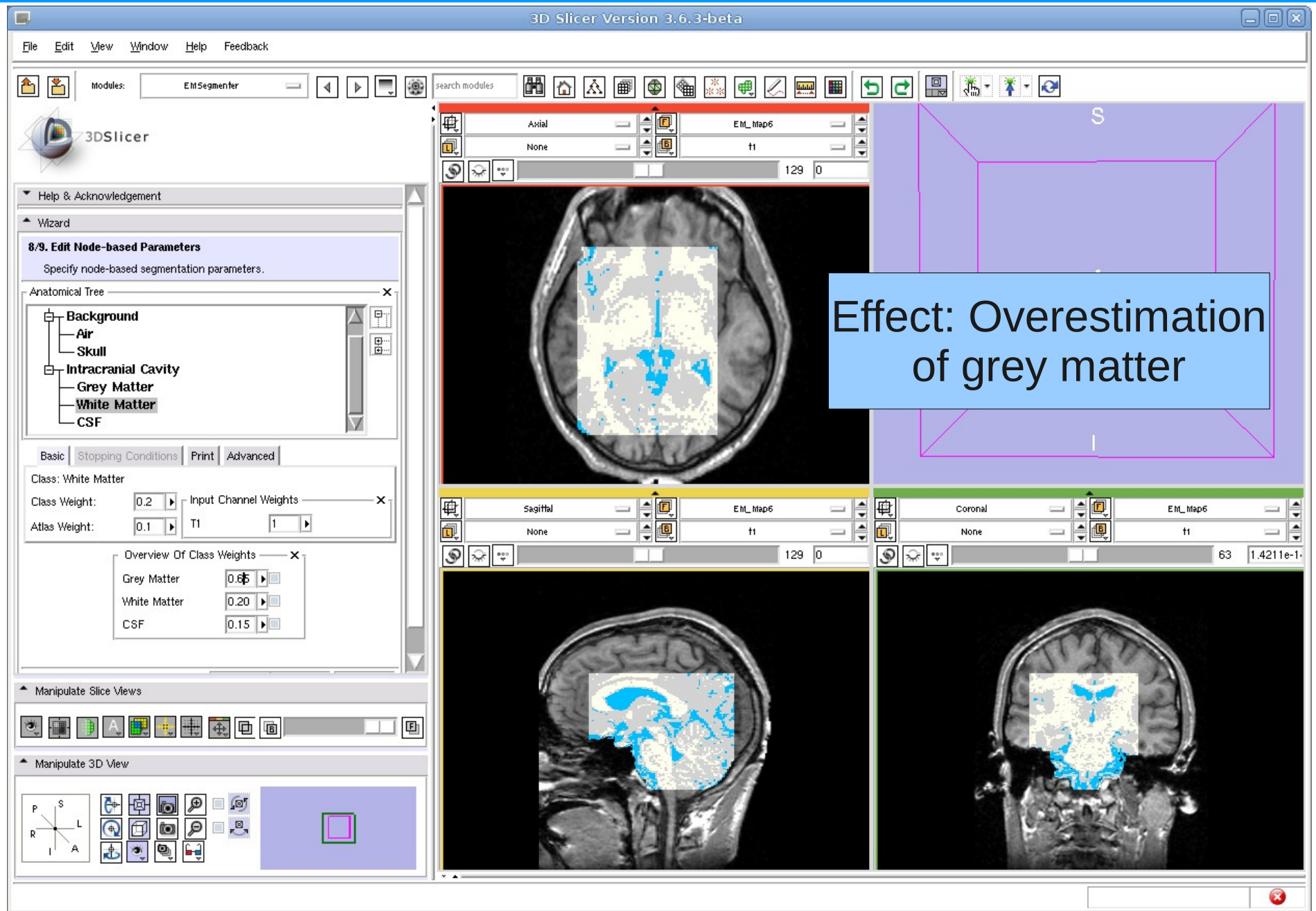


Low white matter atlas weight





High grey matter class weight





Further Info & Acknowledgments

EMSegmenter Wiki Page:

<http://www.slicer.org/slicerWiki/index.php/EMSegmenter-Overview>

The EMSegmenter technology behind was reported in:

K.M. Pohl et. A hierarchical algorithm for MR brain image parcellation. IEEE Transactions on Medical Imaging, 26(9), pp 1201-1212, 2007.

We thank the following institutions for their support:

