UKF Tractography Tutorial

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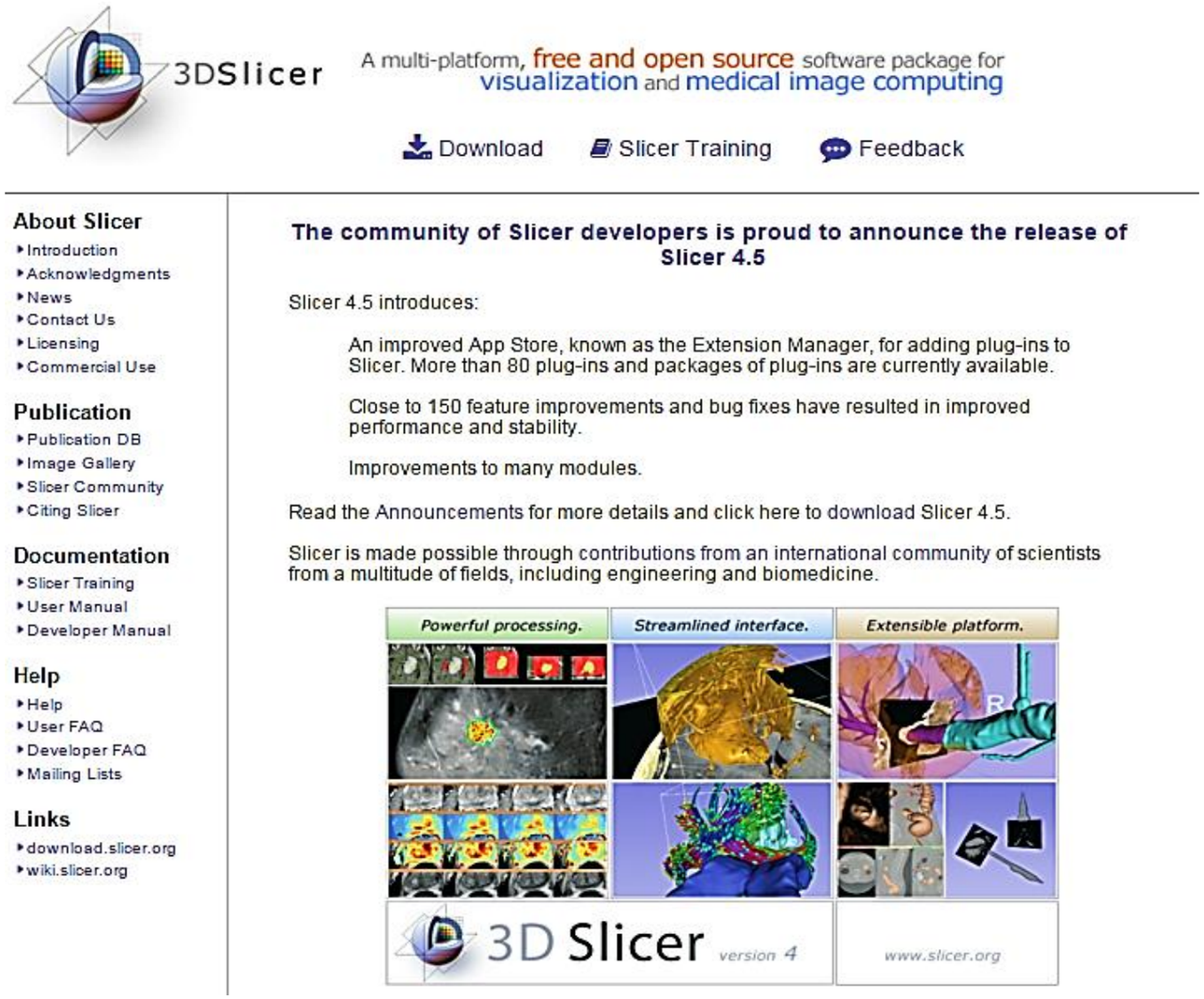
Harvard Medical School

3DSlicer

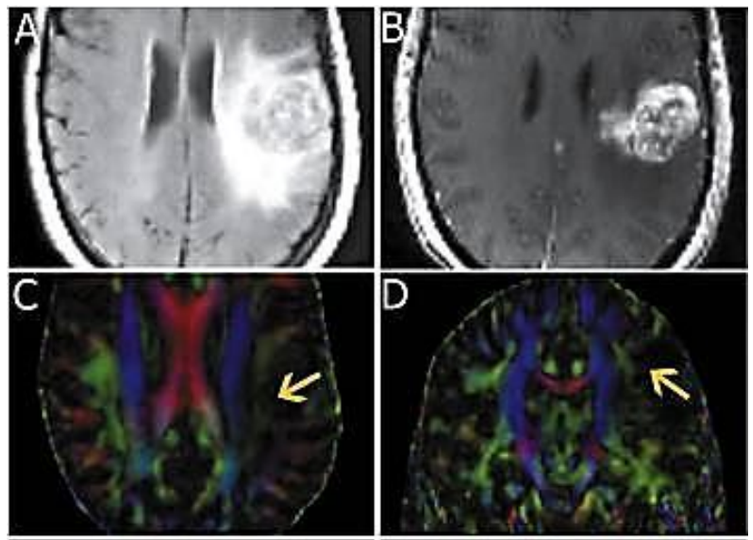
- The tutorial uses the 3DSlicer software (www.slicer.org)

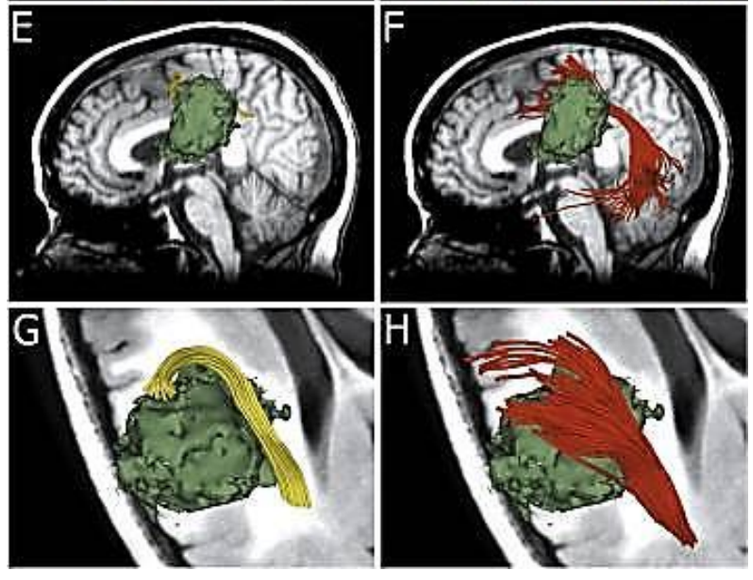


It is the responsibility of the user of 3DSlicer to comply with both the terms of the license and with the applicable laws, regulations and rules. Slicer is a tool for research, and is not FDA approved.

3DSlicer

- An end-user application for image analysis
- An open-source environment for software development
- A software platform that is both easy to use for clinical researchers and easy to extend for programmers





[Chen et al, 2015]

3D Slicer is a multi-institution effort supported by the National Institutes of Health.

UKF Installation

- 3D Slicer now supports plug-ins/extensions that are available for download from an extension server. Extensions allow end-users to selectively install features that are useful for them.

- UKF tractography can be installed on Slicer using “Extension Manager”.

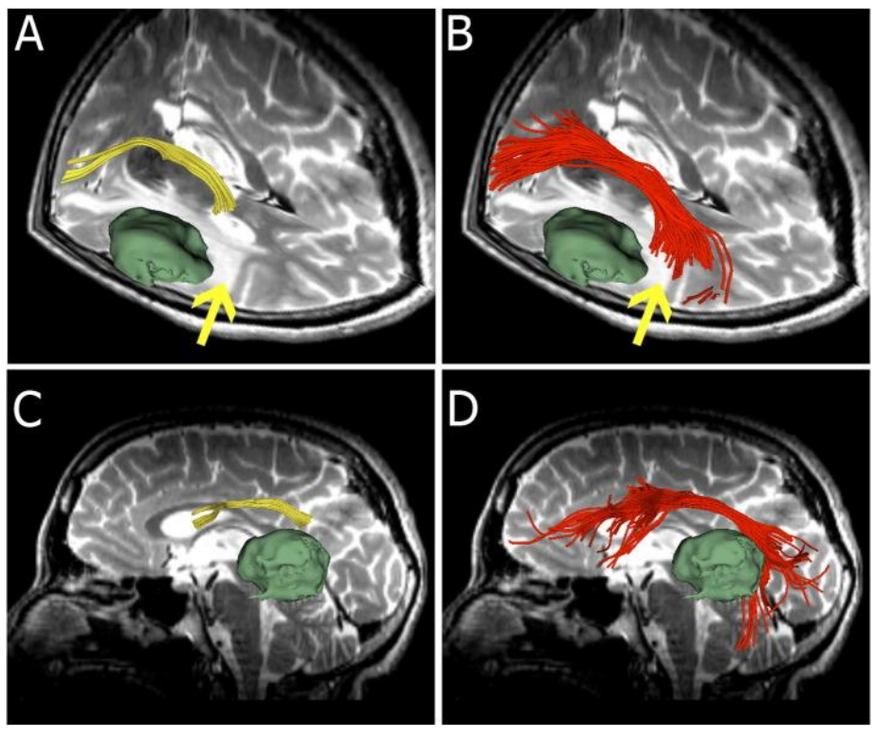
- Instructions: Extension Manager Wiki

UKF Tractography

- Unscented Kalman Filter tractography method:
  - Simultaneous model estimation and tractography
  - The diffusion model is fit to the data during tractography not before.

Why UKF

- UKF tractography may detect more fibers comparing to single-tensor streamline tractography (Slicer default method), especially in edematous areas.
- For example: The UKF two-tensor model traces a larger volume arcuate fasciculus in the setting of edema.



[Chen et al, 2015]

Unscented Kalman Filter Tractography

Inf Process Med Imaging. 2009;21:126-38.

Neural tractography using an unscented Kalman filter.

Malcolm JG[1], Shenton ME, Rathi Y.

Author information

[1]Psychiatry Neuroimaging Laboratory, Harvard Medical School, Boston, MA, USA. malcolm@bwh.harvard.edu

Abstract

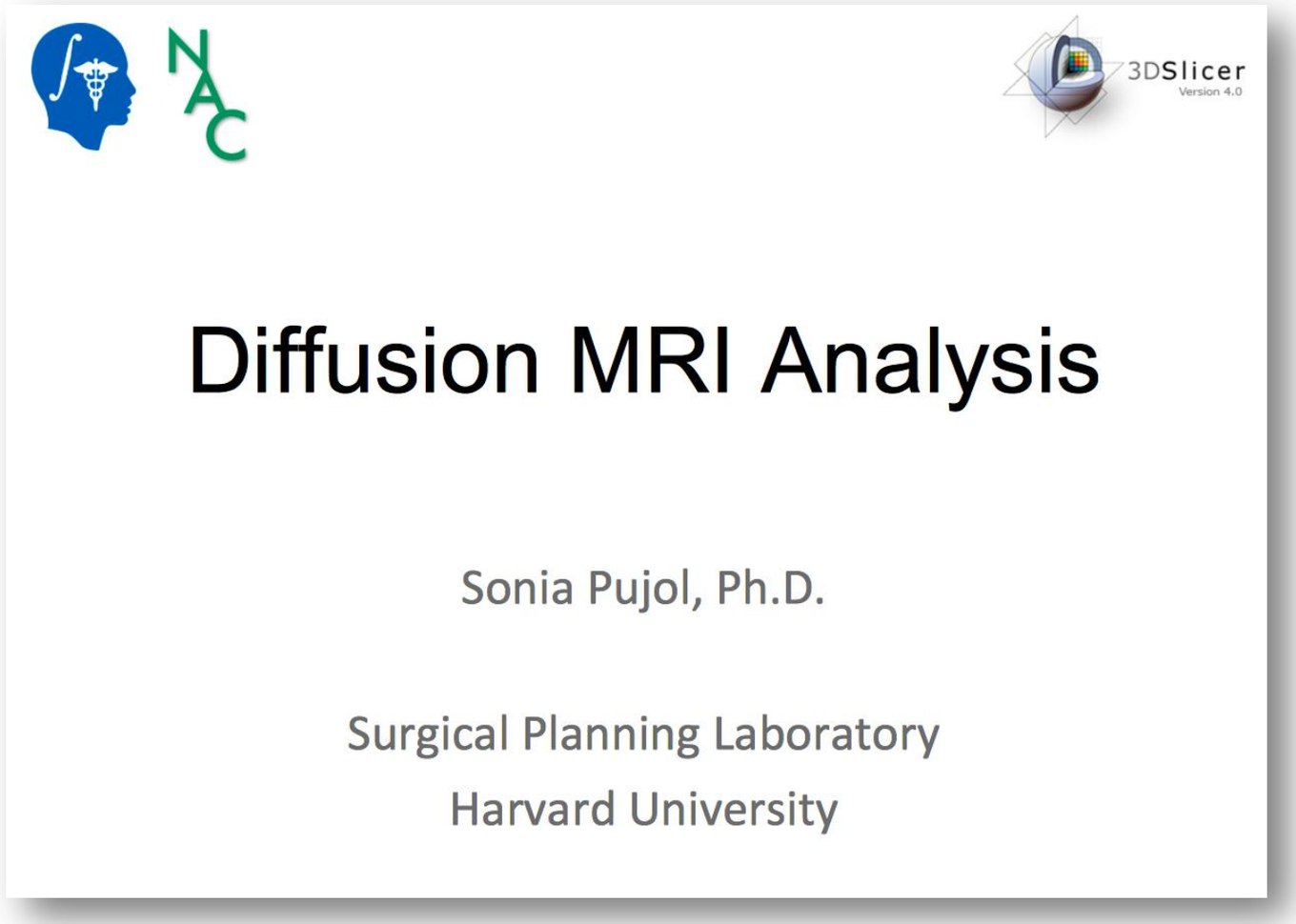
We describe a technique to simultaneously estimate a local neural fiber model and trace out its path. Existing techniques estimate the local fiber orientation at each voxel independently so there is no running knowledge of confidence in the estimated fiber model. We formulate fiber tracking as recursive estimation: at each step of tracing the fiber, the current estimate is guided by the previous. To do this we model the signal as a mixture of Gaussian tensors and perform tractography within a filter framework. Starting from a seed point, each fiber is traced to its termination using an unscented Kalman filter to simultaneously fit the local model and propagate in the most consistent direction. Despite the presence of noise and uncertainty, this provides a causal estimate of the local structure at each point along the fiber. Synthetic experiments demonstrate that this approach reduces signal reconstruction error and significantly improves the angular resolution at crossings and branchings. In vivo experiments confirm the ability to trace out fibers in areas known to contain such crossing and branching while providing inherent path regularization.

PMID: 19694258 [PubMed - indexed for MEDLINE] PMCID: PMC2768602 **Free PMC Article**

Neural Tractography Using an Unscented Kalman Filter
[Malcom et al., 2009]

Before getting started…

- take a look at: [Diffusion Tensor Imaging Tutorial]

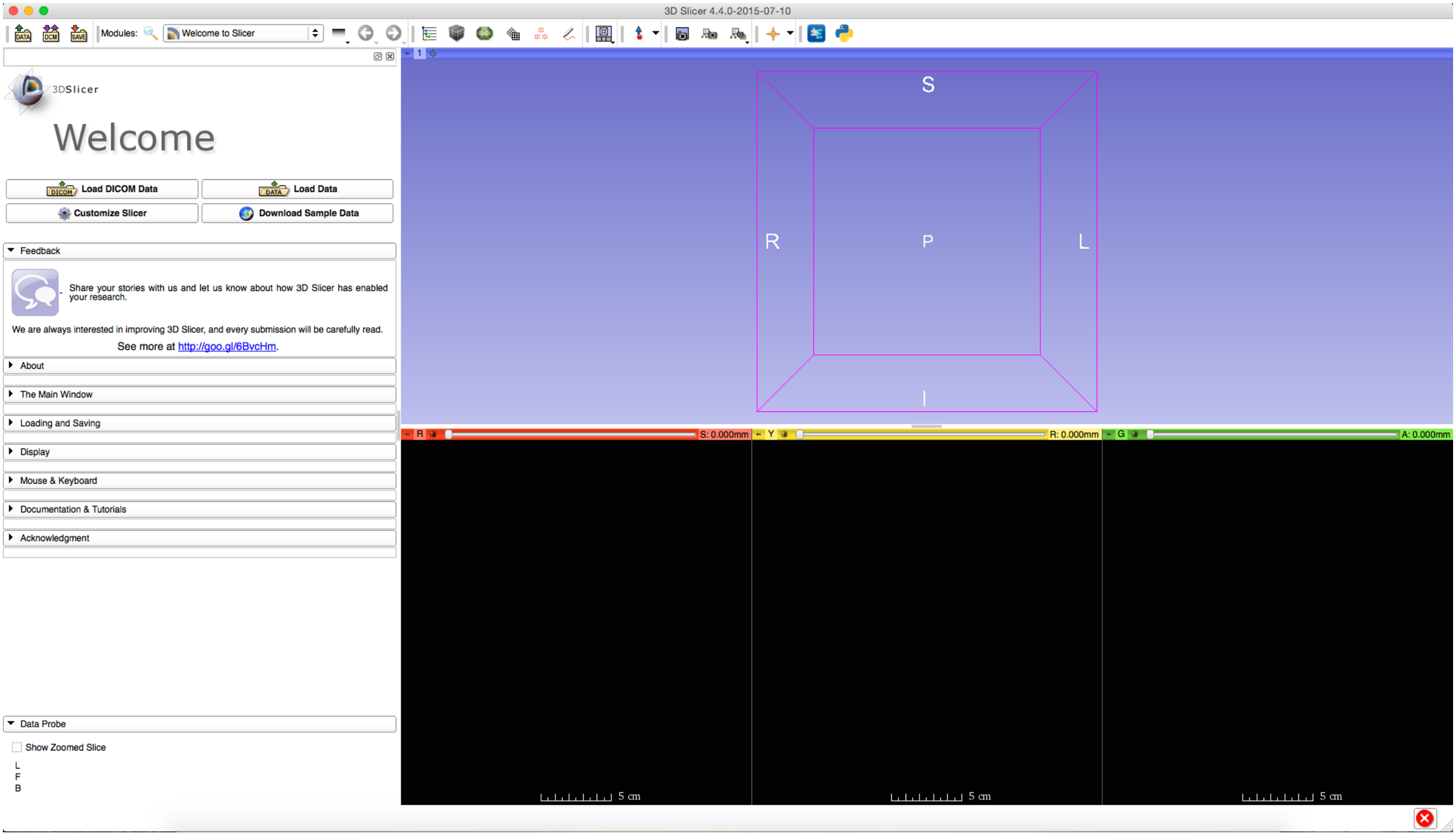


DWI Dataset

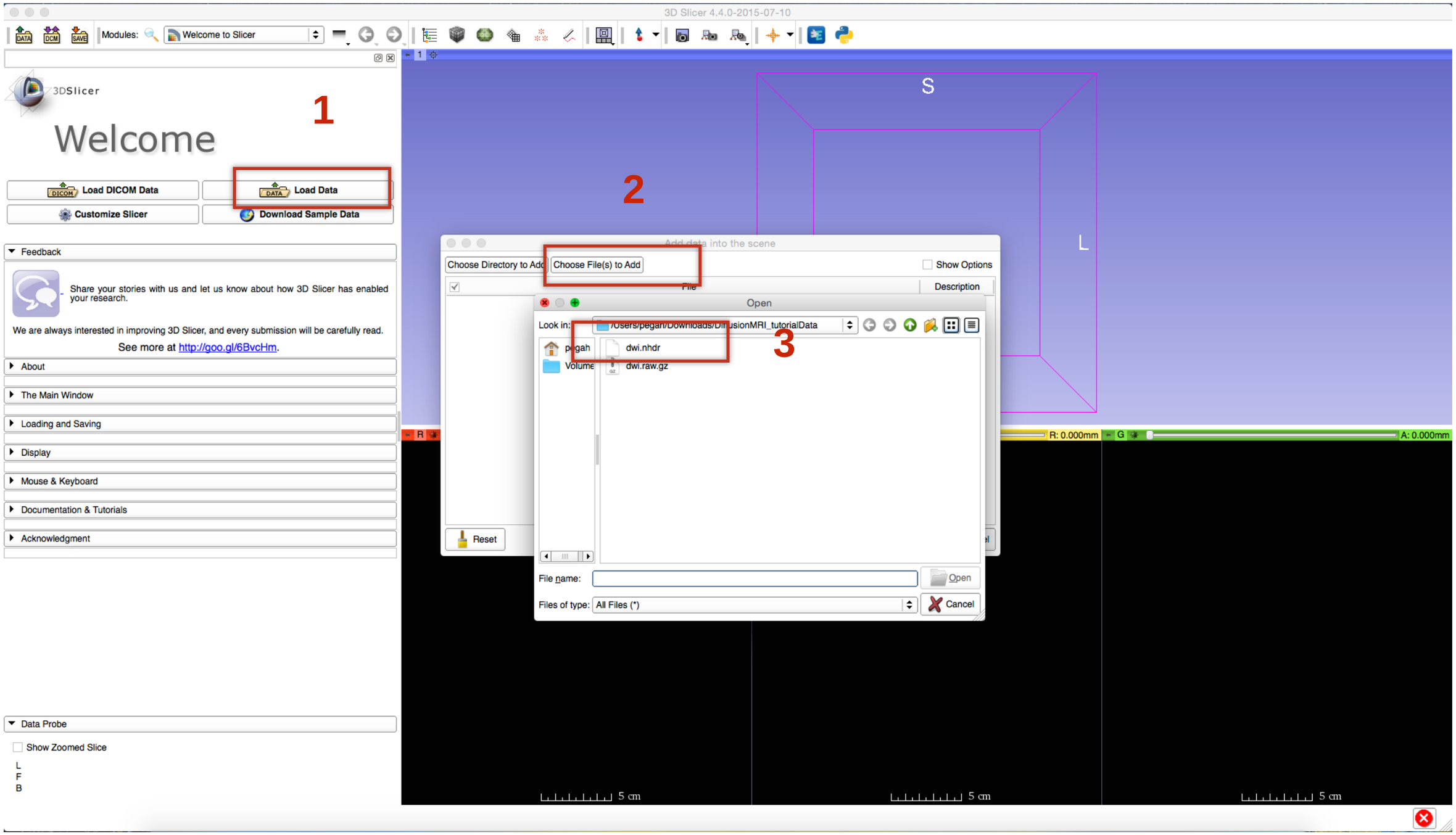
- Download the data at: DWI Dataset

- The Diffusion Weighted Imaging (DWI) dataset is composed of :
  - 1 volume acquired without diffusion-sensitizing gradient
  - 41 volumes acquired with 41 different diffusion-sensitizing gradient directions

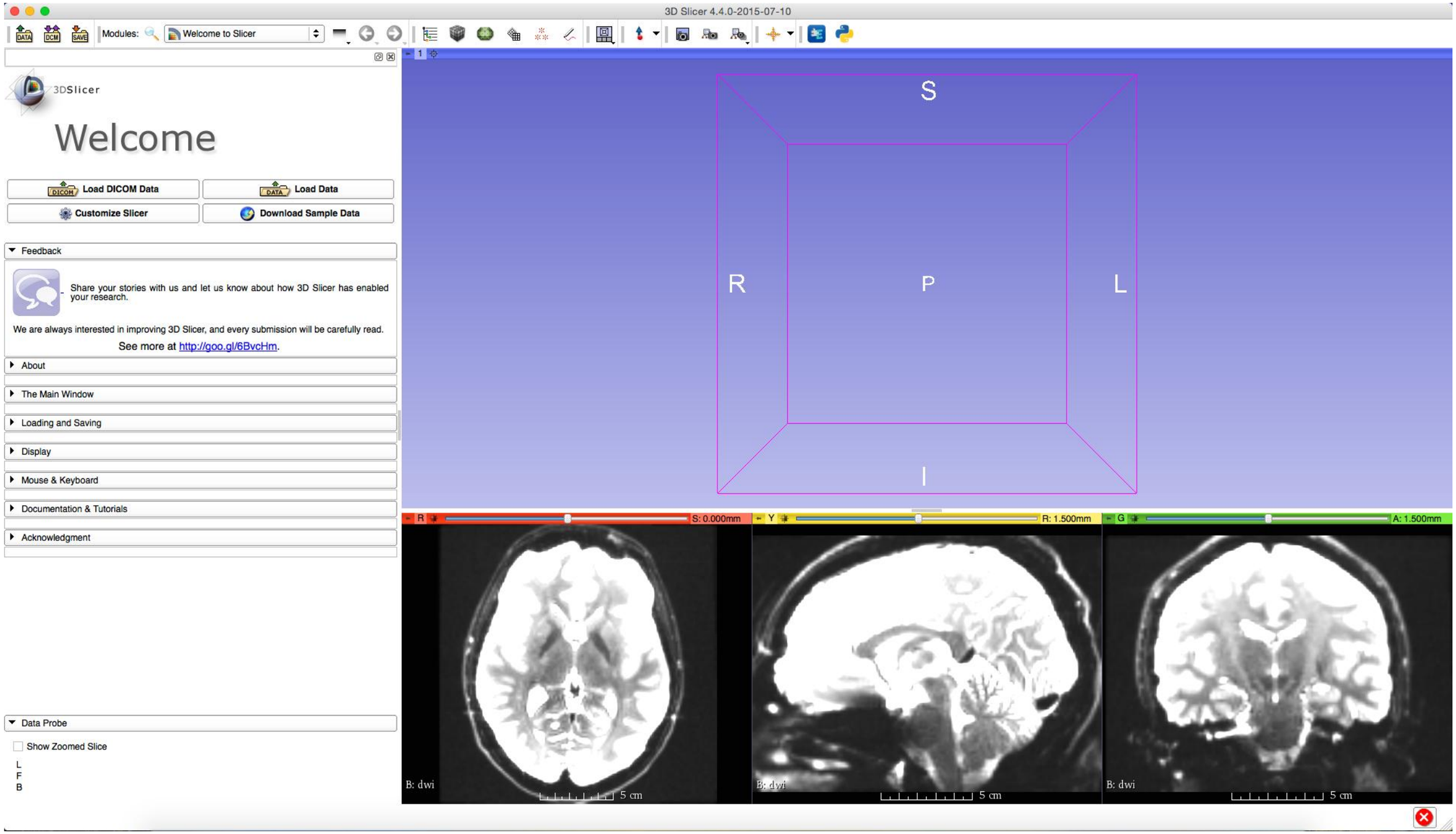
Start Slicer



Load the data



There you go…!


3D Slicer 4.4.0-2015-07-10
Modules:
Welcome to Slicer
3DSlicer
Welcome
Load DICOM Data
Load Data
Customize Slicer
Download Sample Data
Feedback
Share your stories with us and let us know about how 3D Slicer has enabled your research.
We are always interested in improving 3D Slicer, and every submission will be carefully read.
See more at http://goo.gl/6BvcHm.
About
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Display
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Documentation & Tutorials
Acknowledgment
Data Probe
Show Zoomed Slice
L
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B: dwi
5 cm
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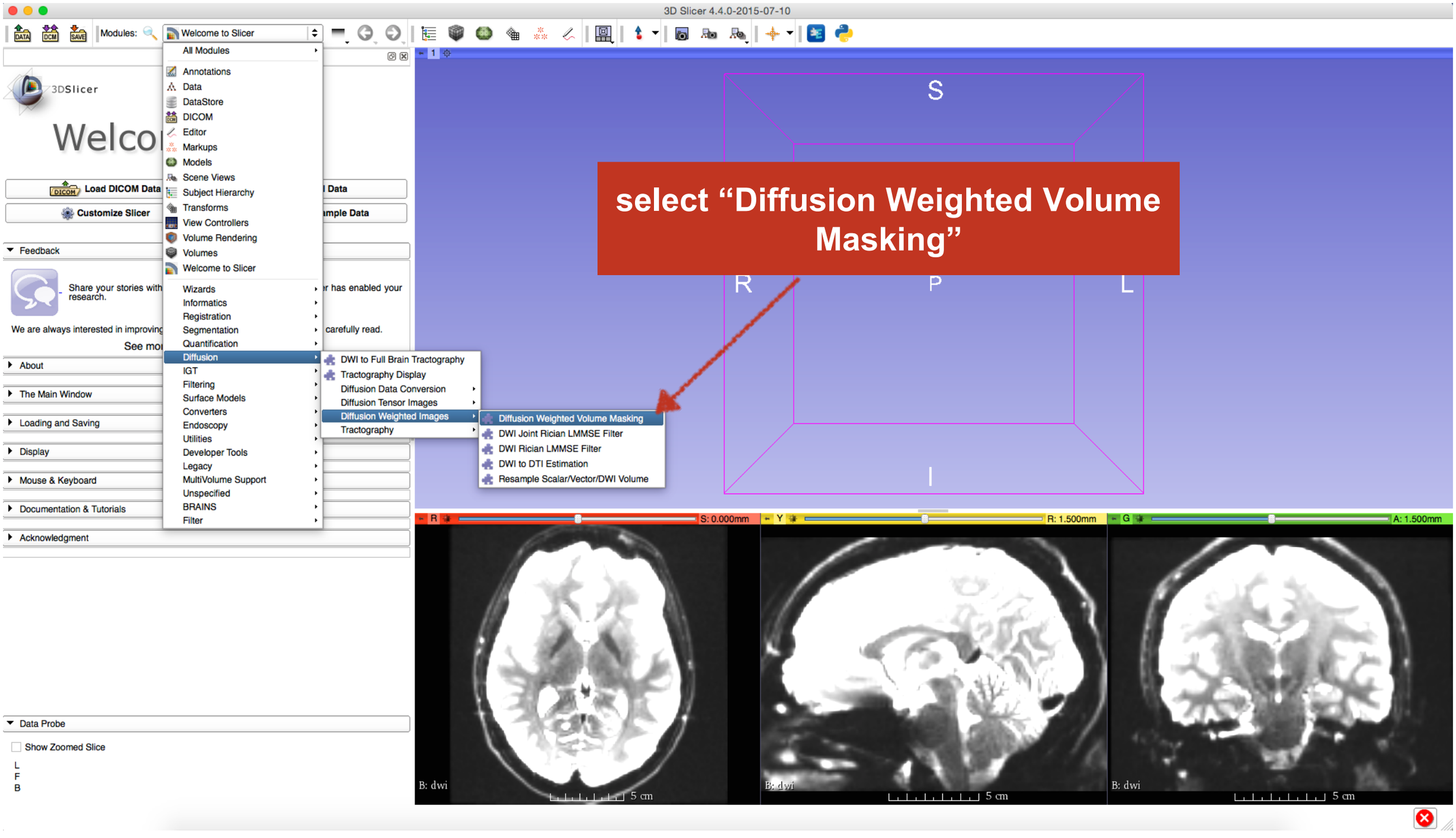
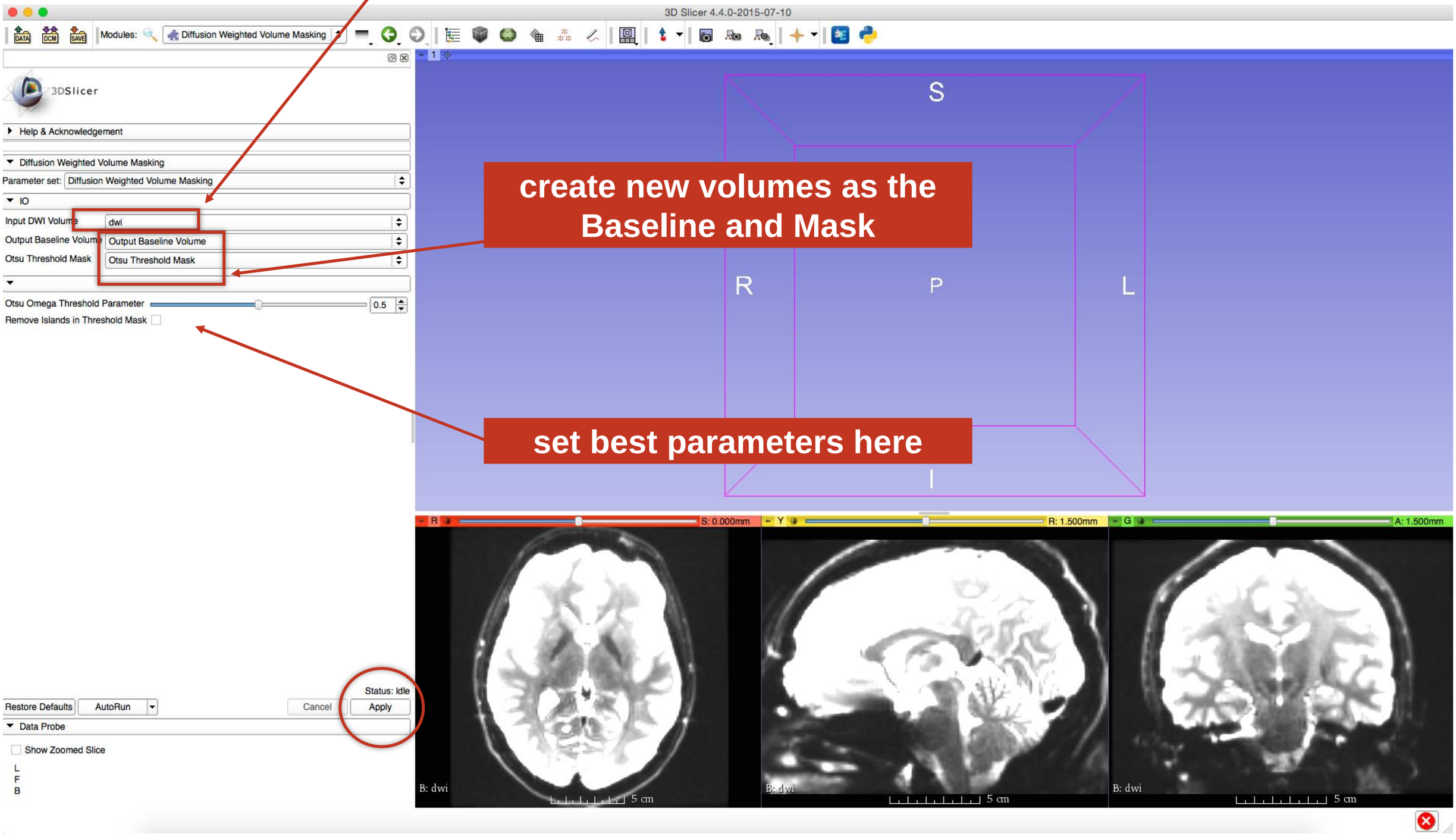
Main Steps

- Creating a brain mask
- Creating FA map
- Creating region of interest for tract seeding
- UKF tractography

Brain Mask Creation



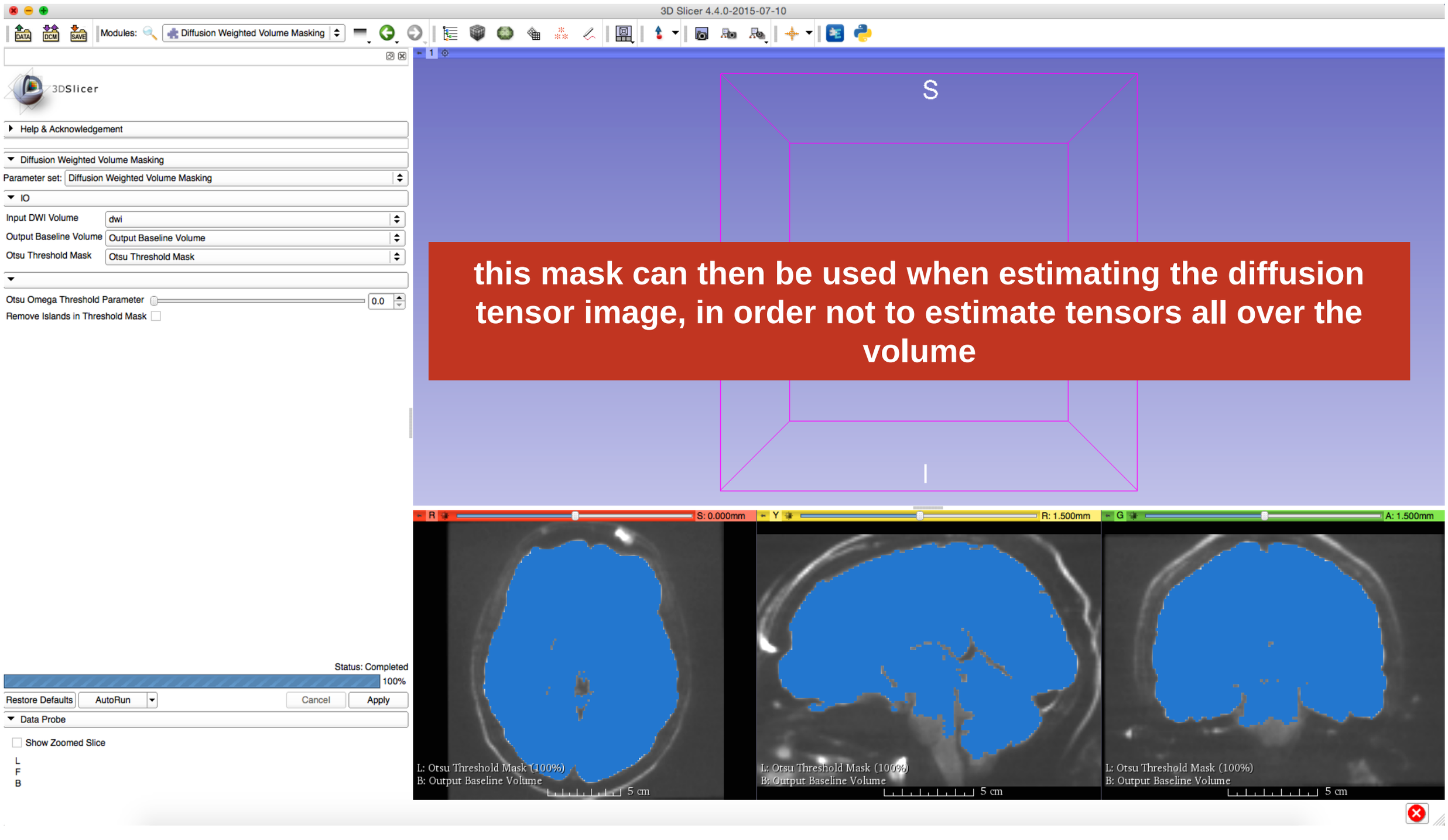
the input is the DWI volume you loaded



create new volumes as the Baseline and Mask

set best parameters here

the Otsu segmentation algorithm produces a mask



Tract Seeding

- For whole brain tractography with UKF, the Otsu threshold mask is used as the brain mask.

- To seed a specific tract of interest, label maps can be drawn on either:
  - DWI (output baseline volume)
  - FA map

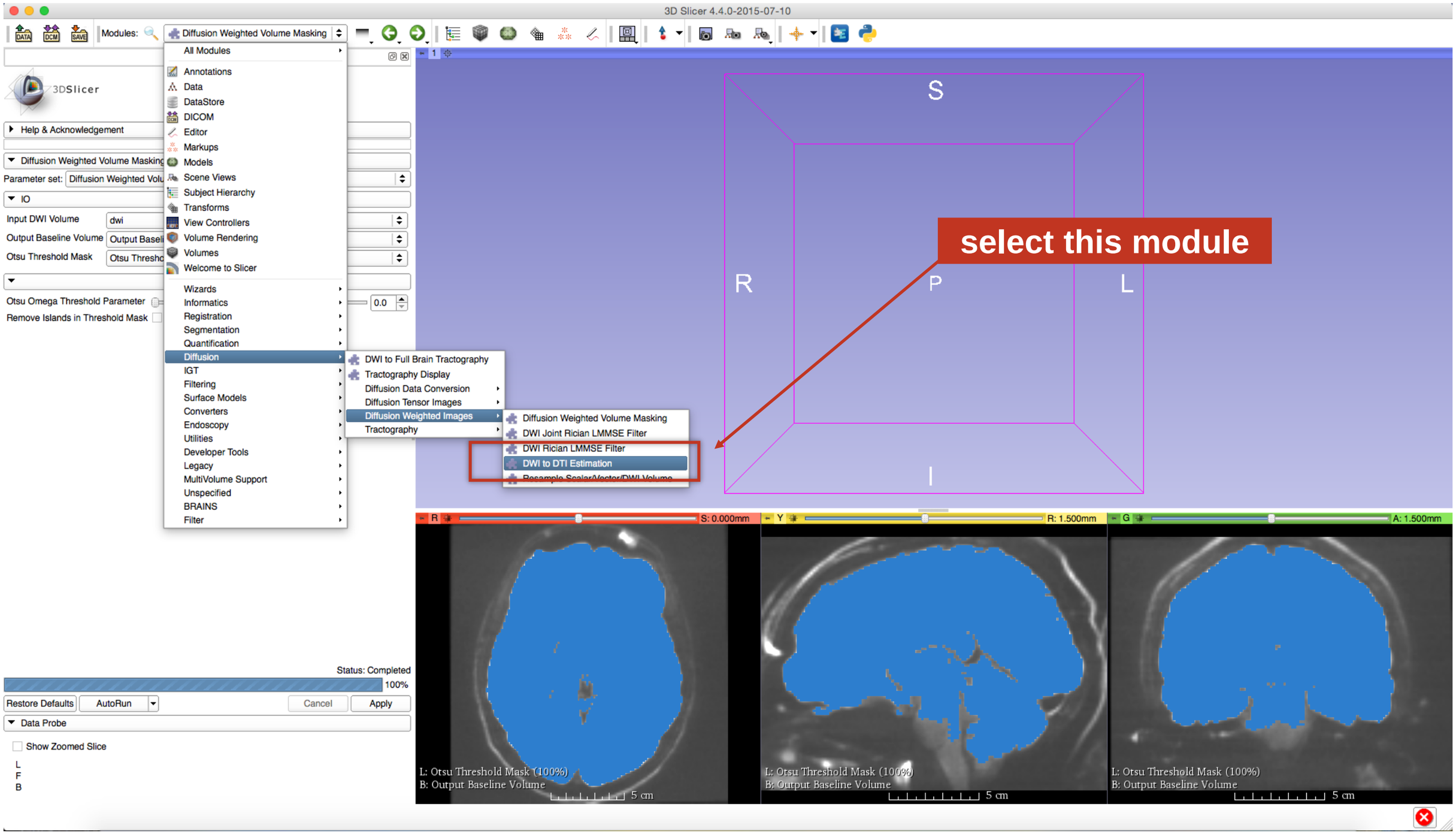
Tract Selection

- Note that FA maps can be more informative for selecting ROIs.

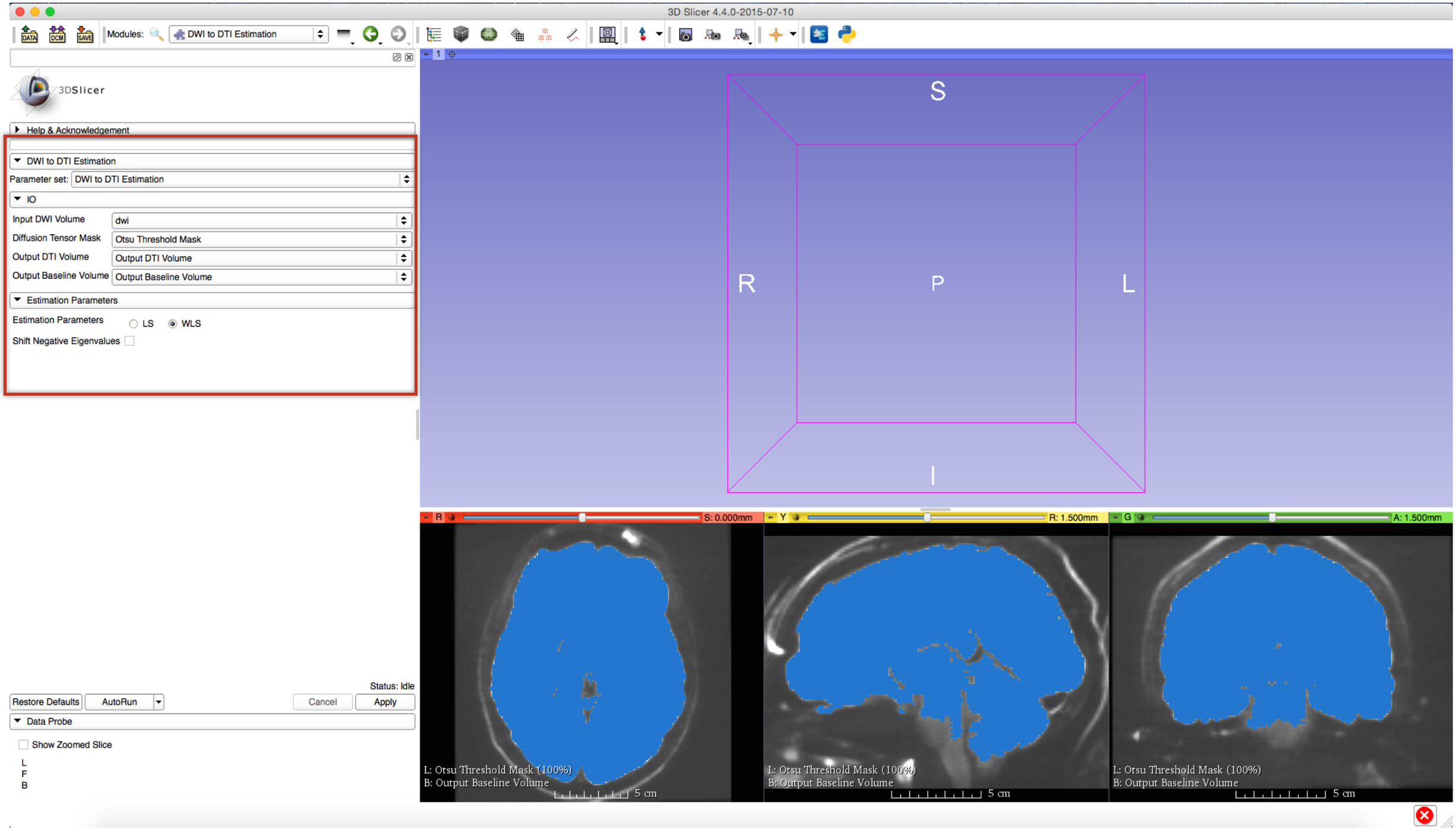
- For that purpose you should first estimate DTI and calculate FA map

- Although these maps are only used here for ROI selection and the model is again estimated from DWI for UKF tractography.

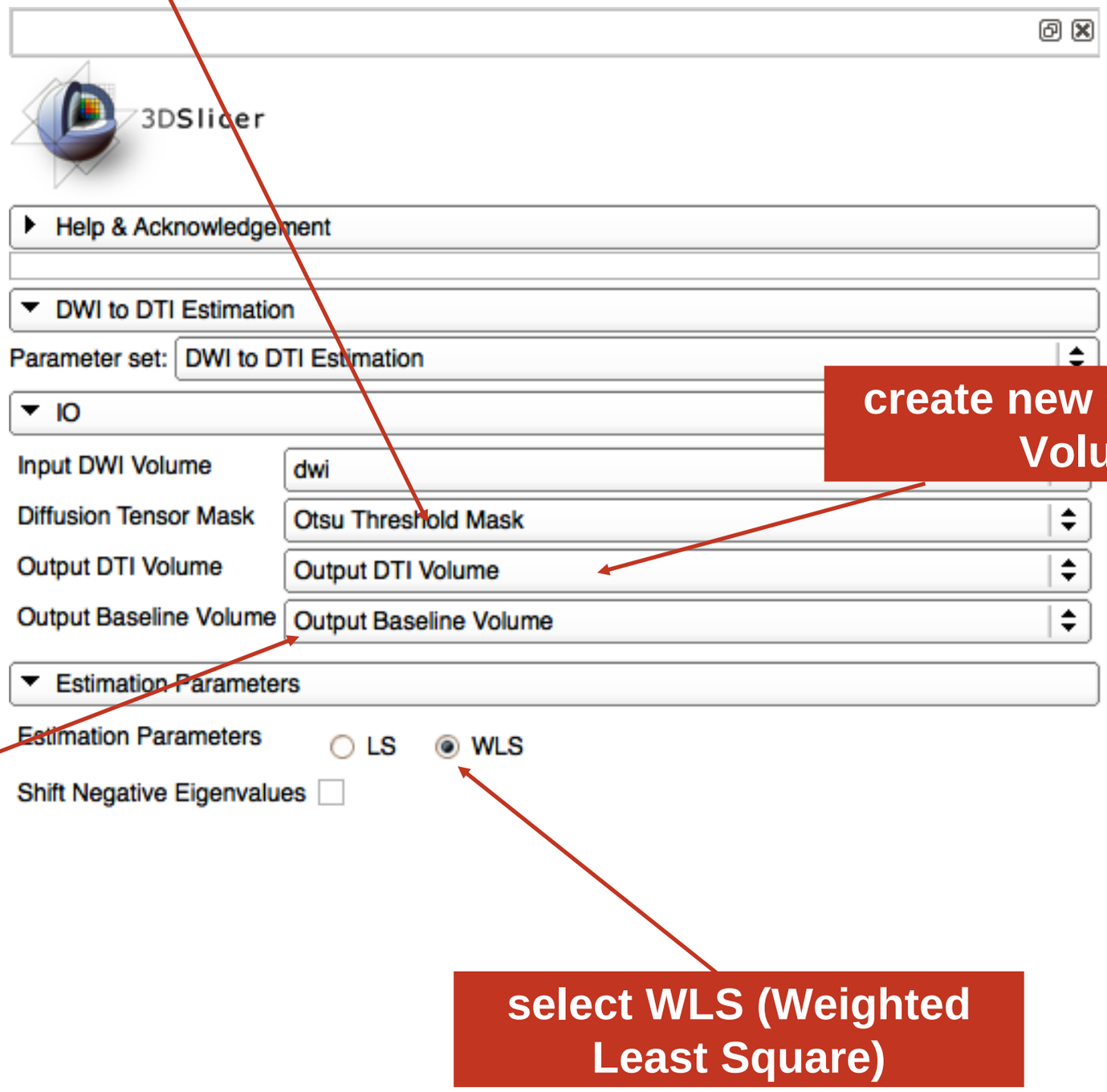
DWI to DTI Estimation



Set the Parameters



select Otsu Threshold Mask you already created



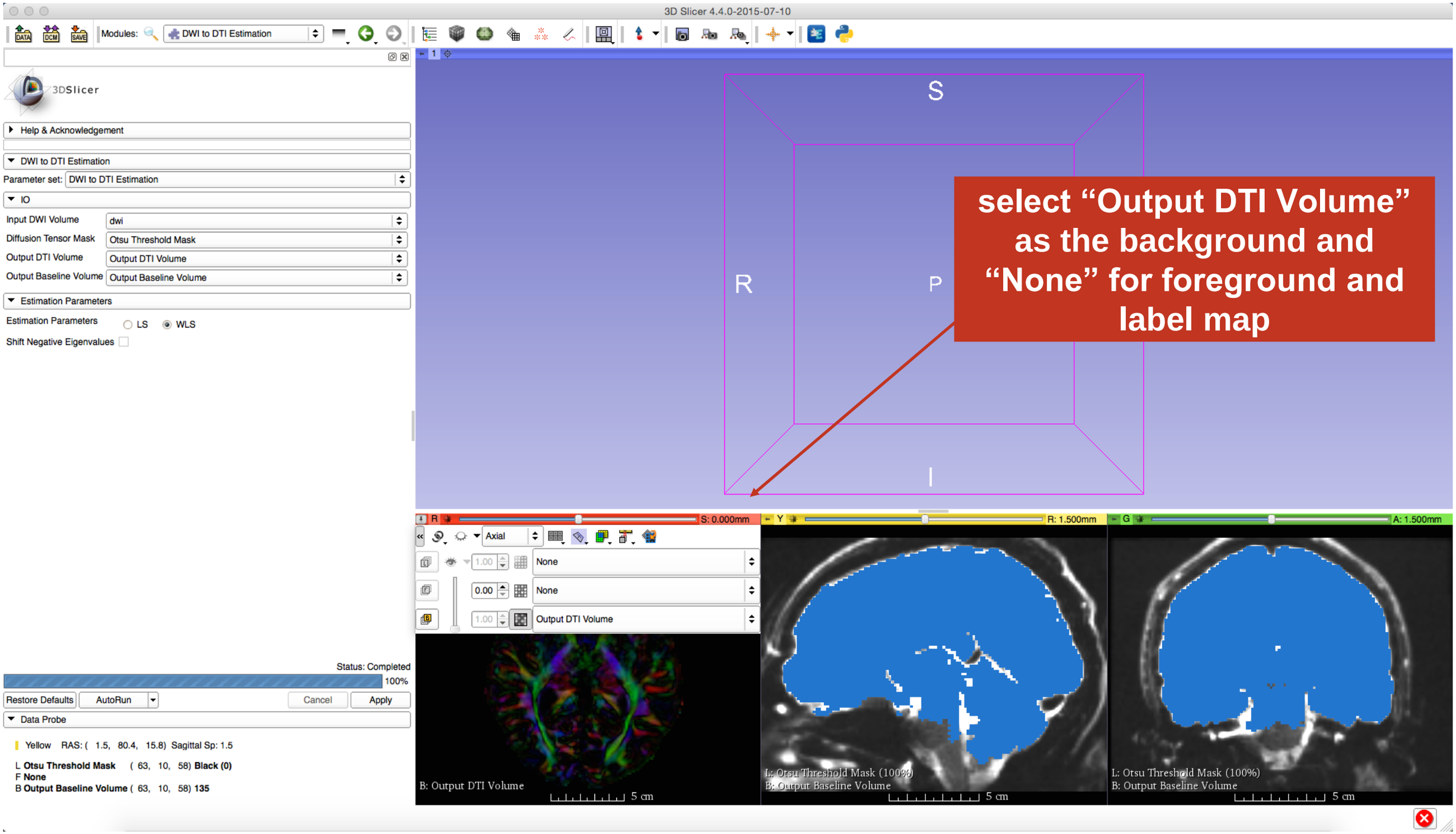
create new Output DTI Volume

select the “Output Baseline Volume” you already created

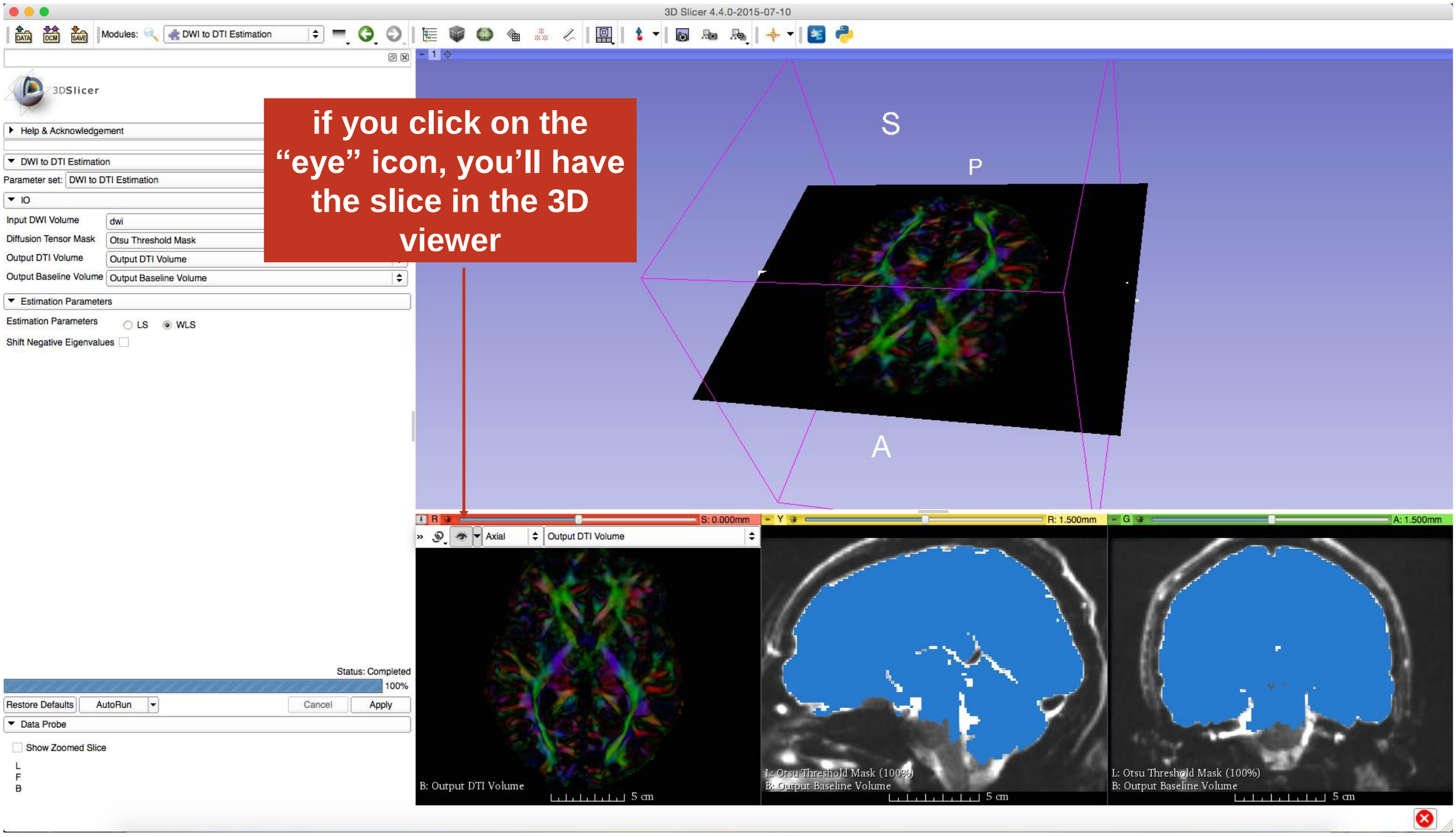
select WLS (Weighted Least Square)

Click Apply

Status: Completed! 100%

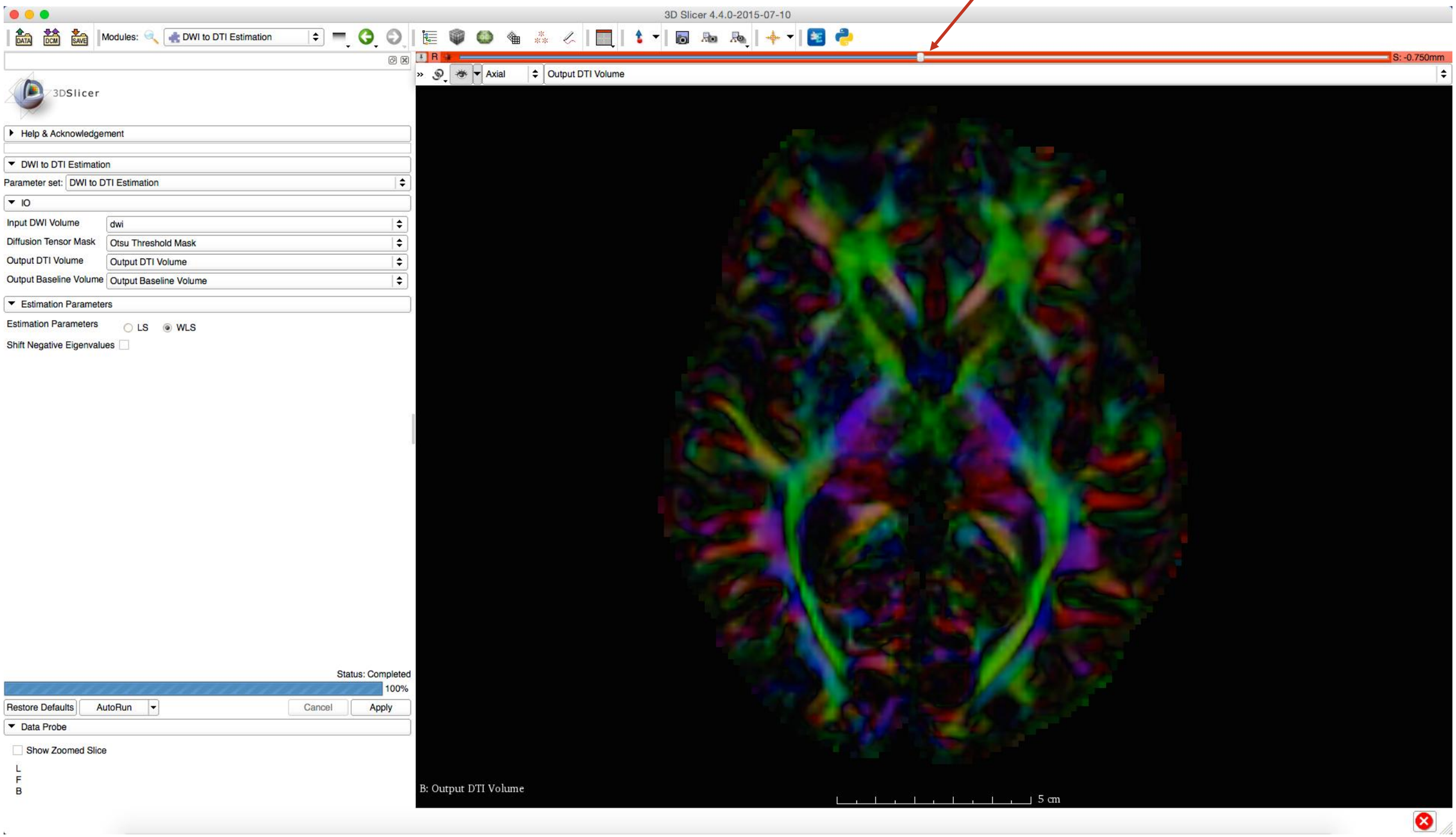


color-coded DTI volume

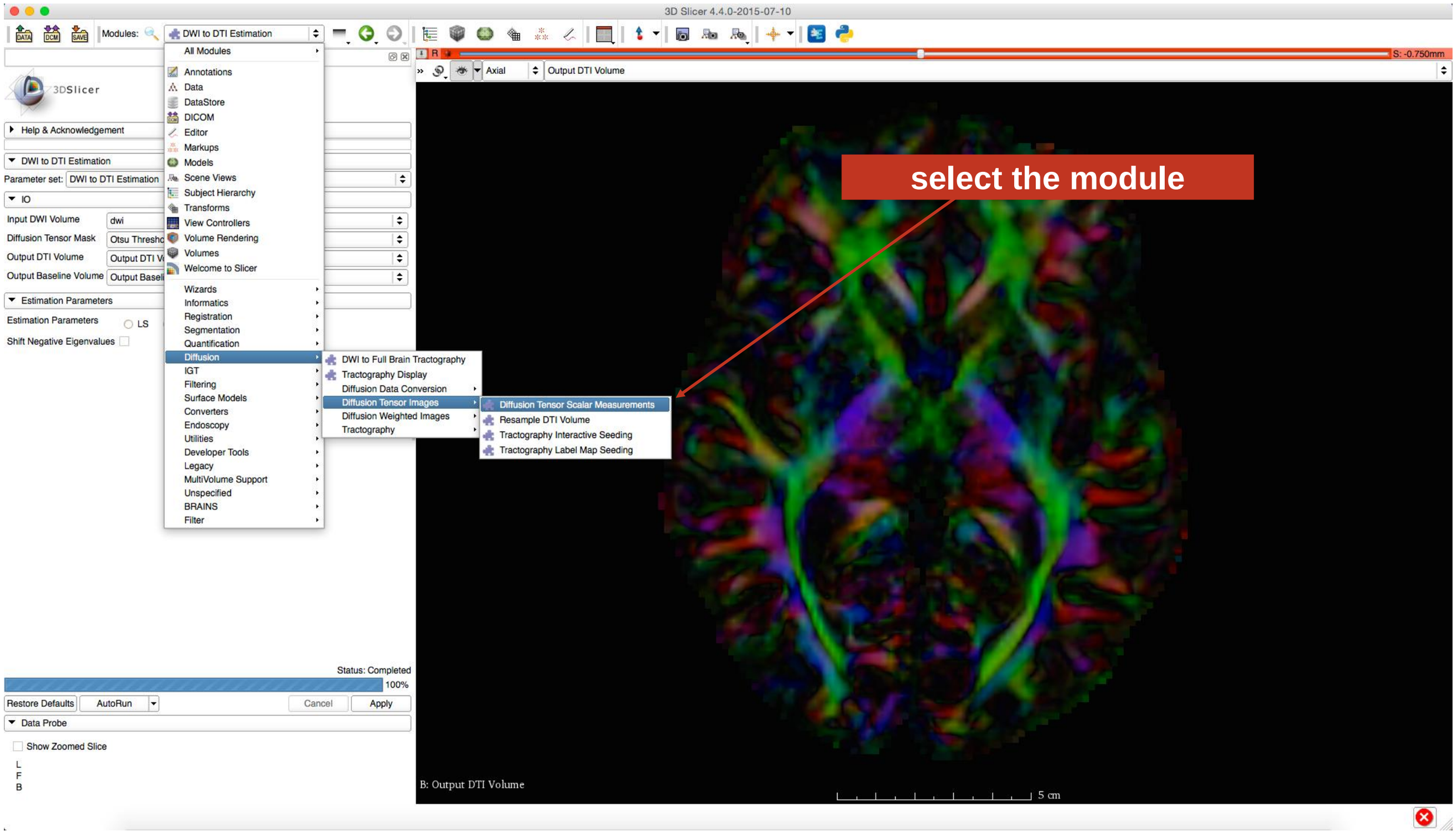


if you click on the "eye" icon, you'll have the slice in the 3D viewer

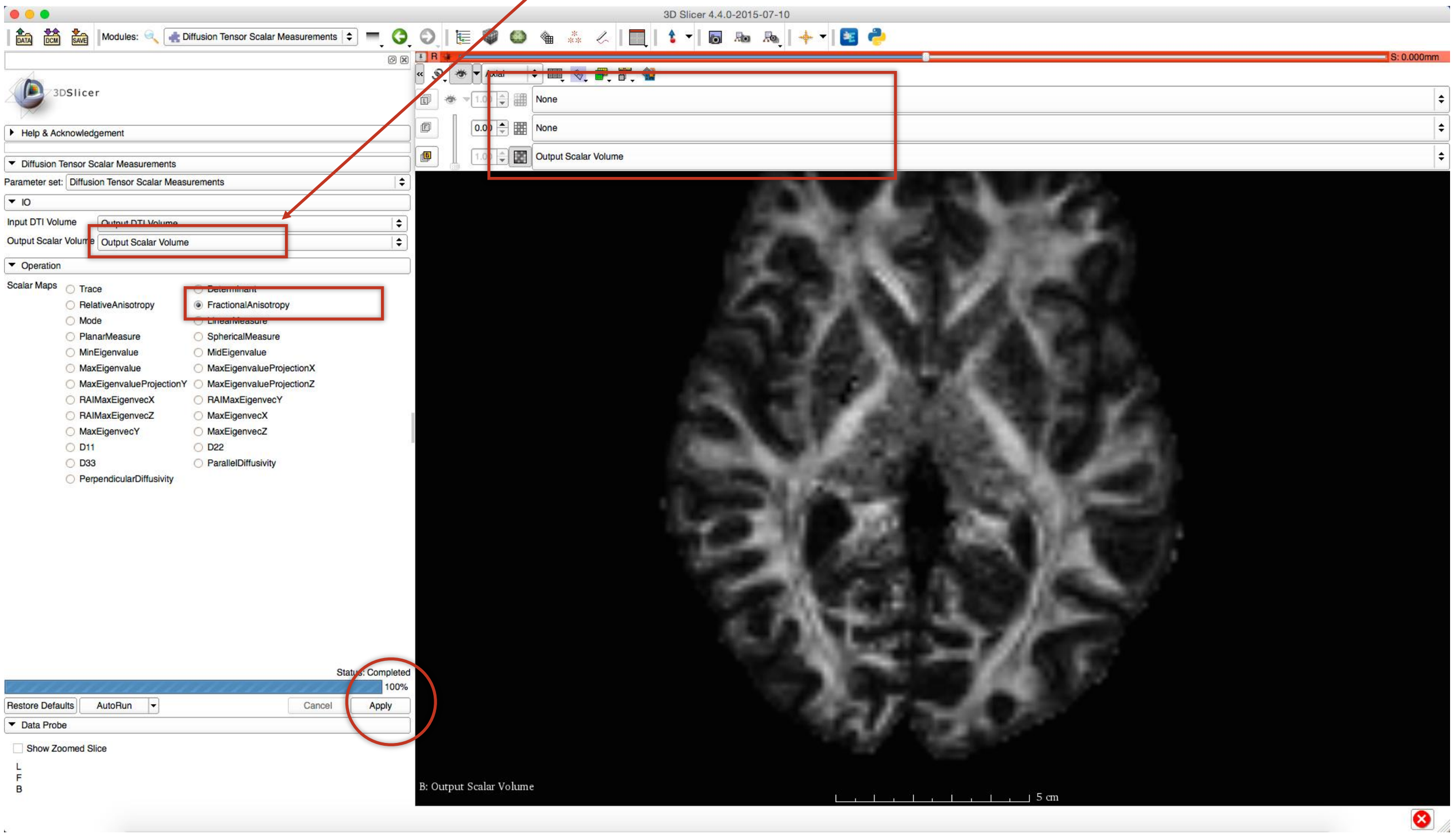
browse through the DTI volume here



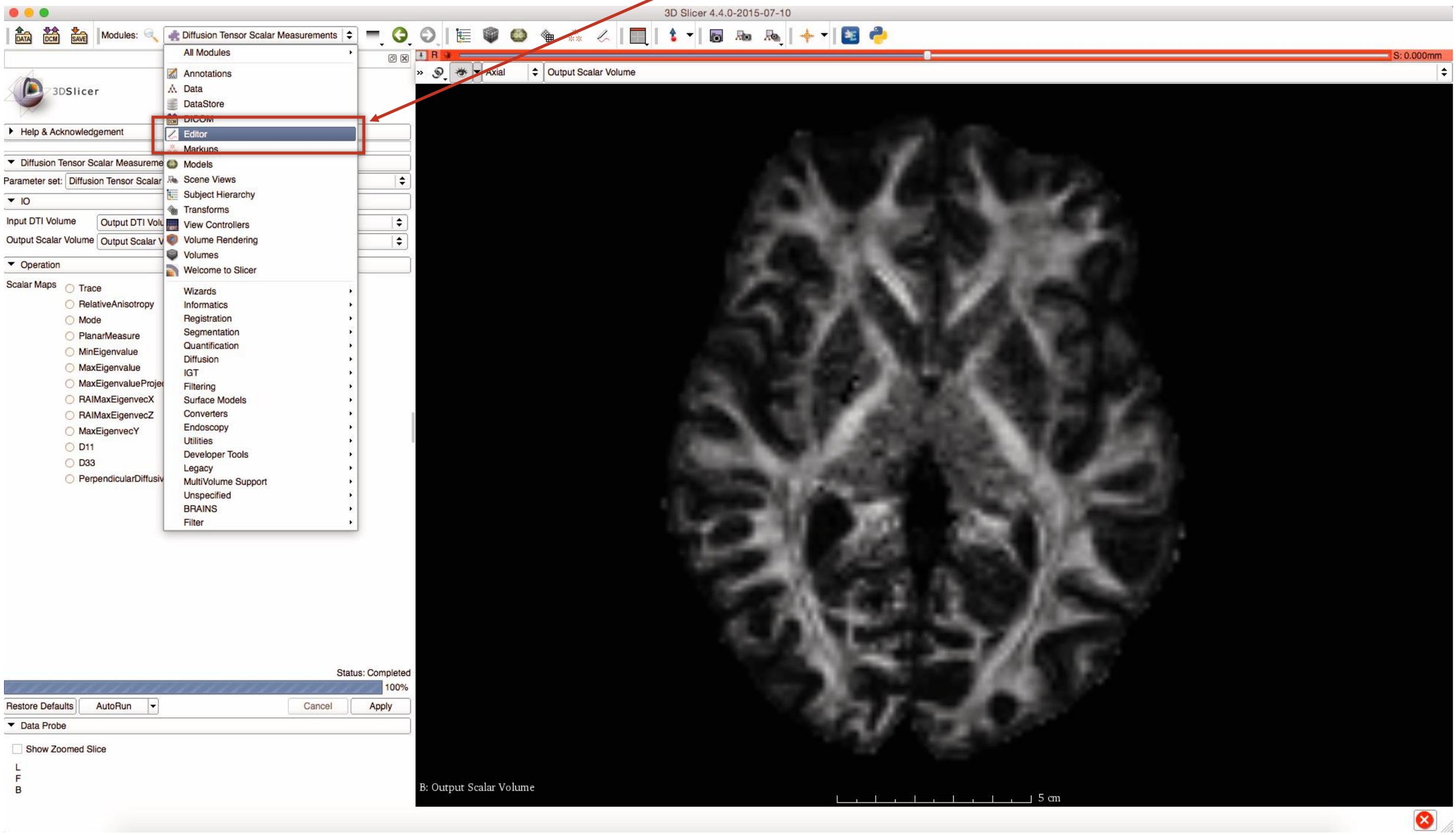
Diffusion Tensor Scalar Measurements; FA



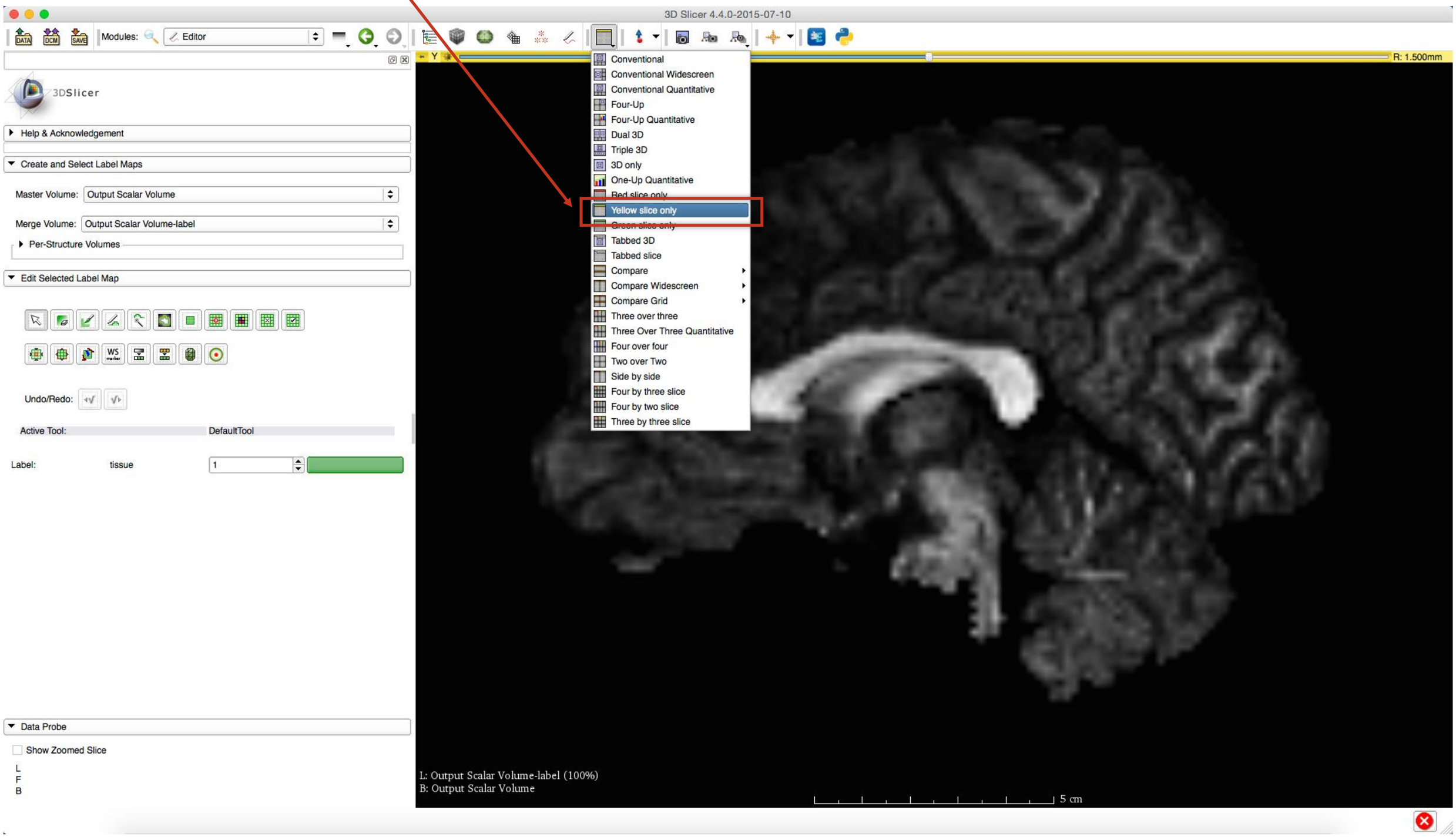
create new Output Scalar Volume (FA)



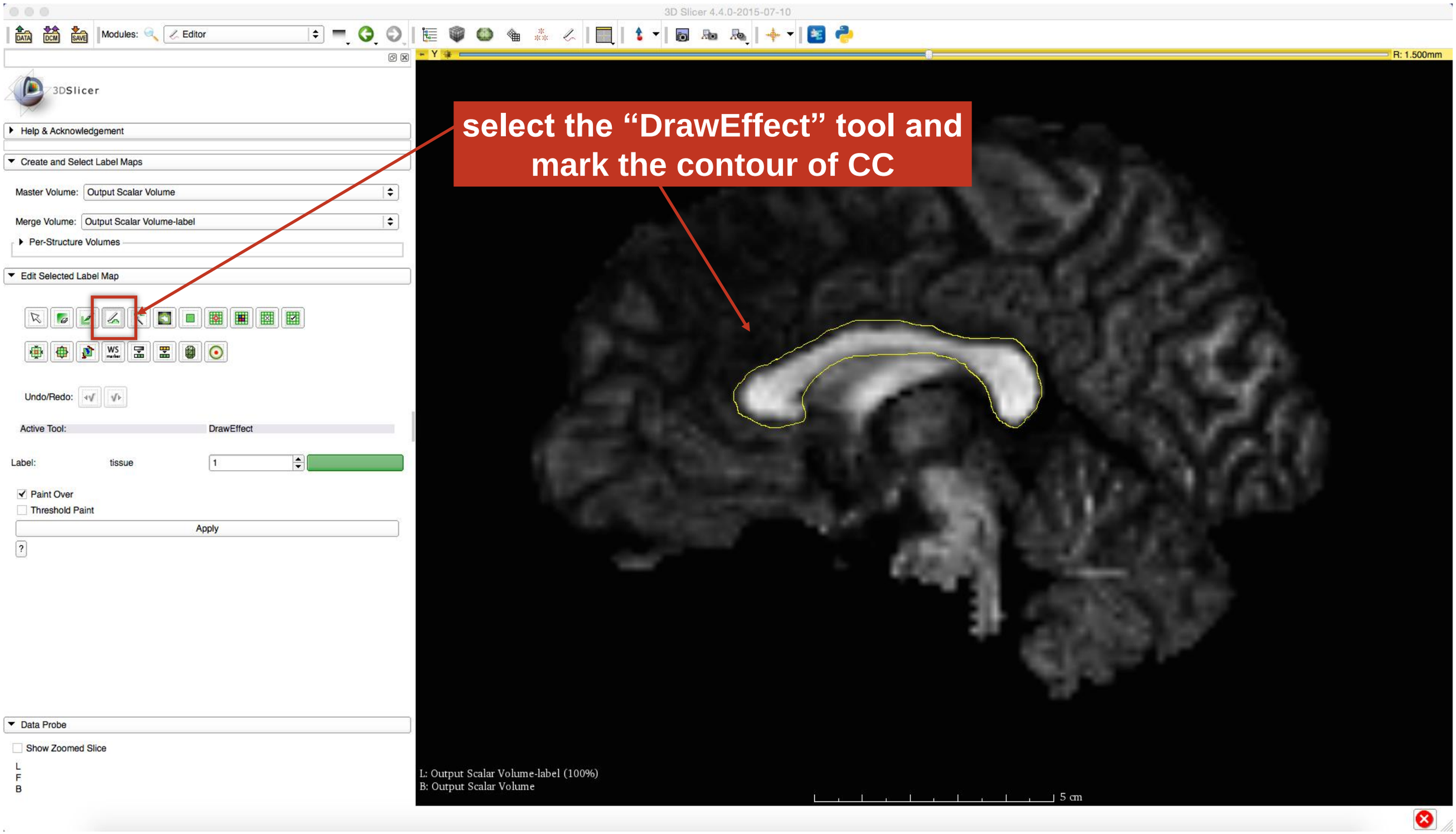
Select the Editor Module



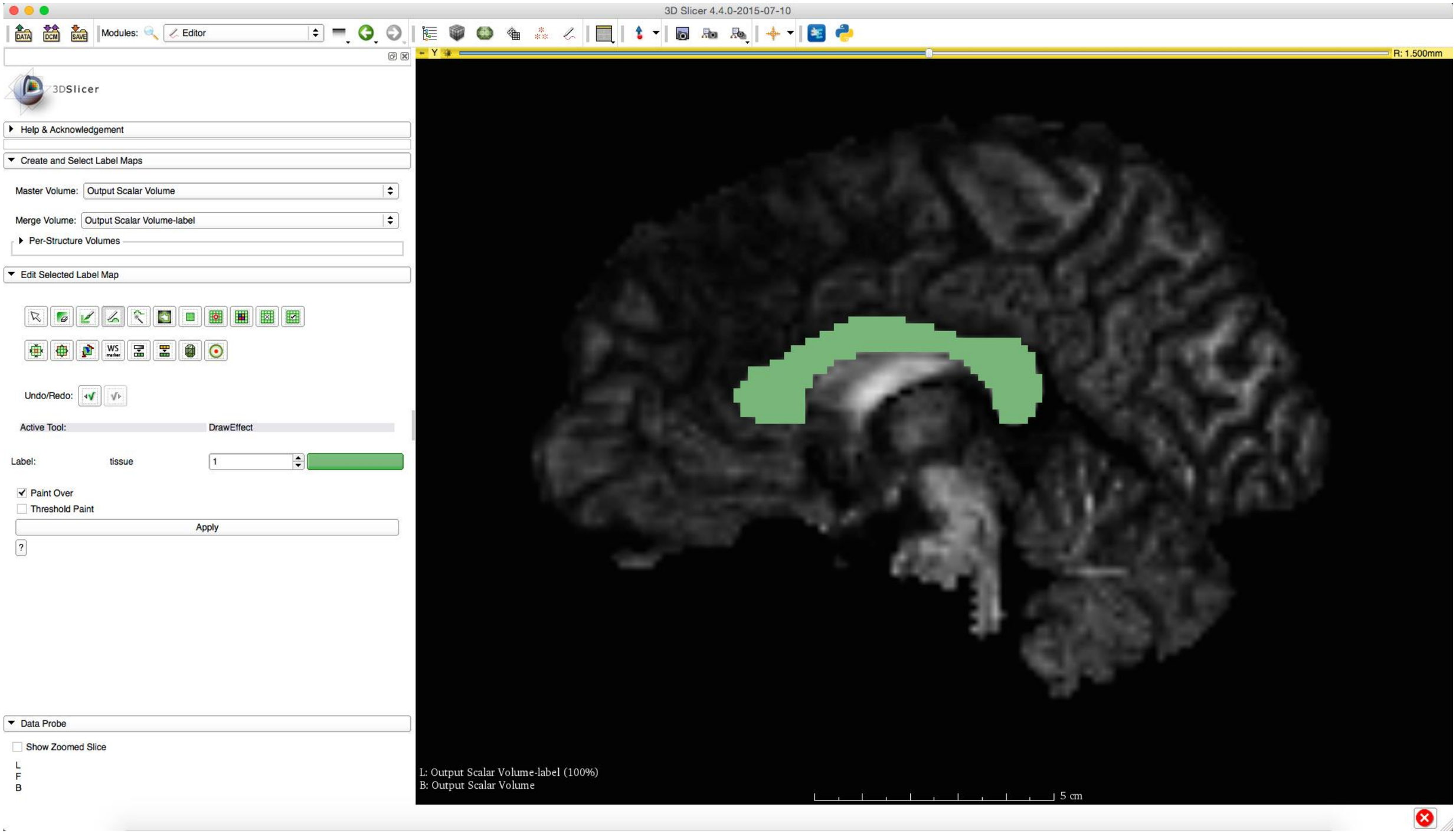
to be able to select ROI for CC as an example, select sagittal view (yellow slice only)



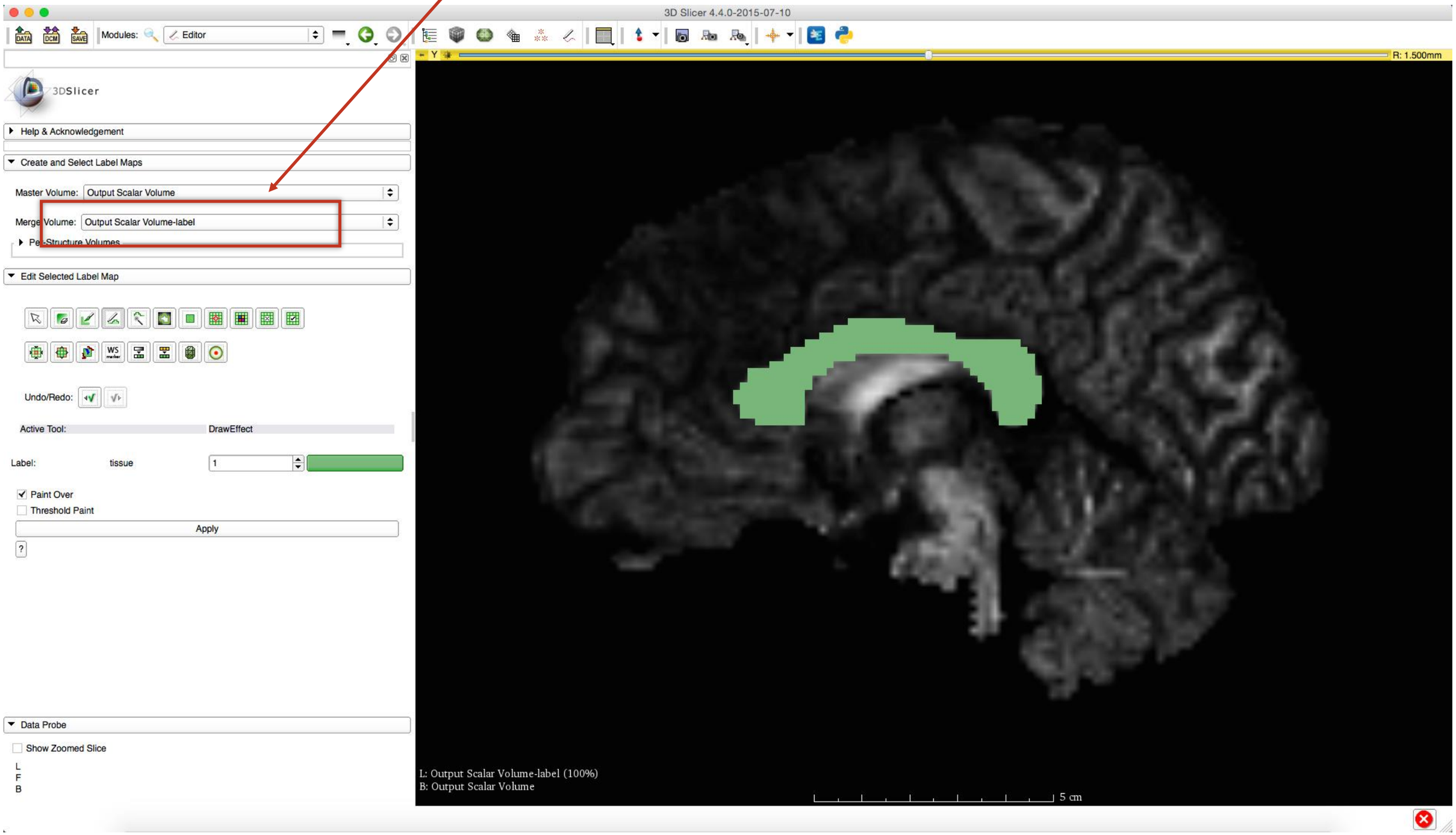
ROI Definiton



press enter
repeat this for 3 adjacent slices



label map containing the corpus callosum is created

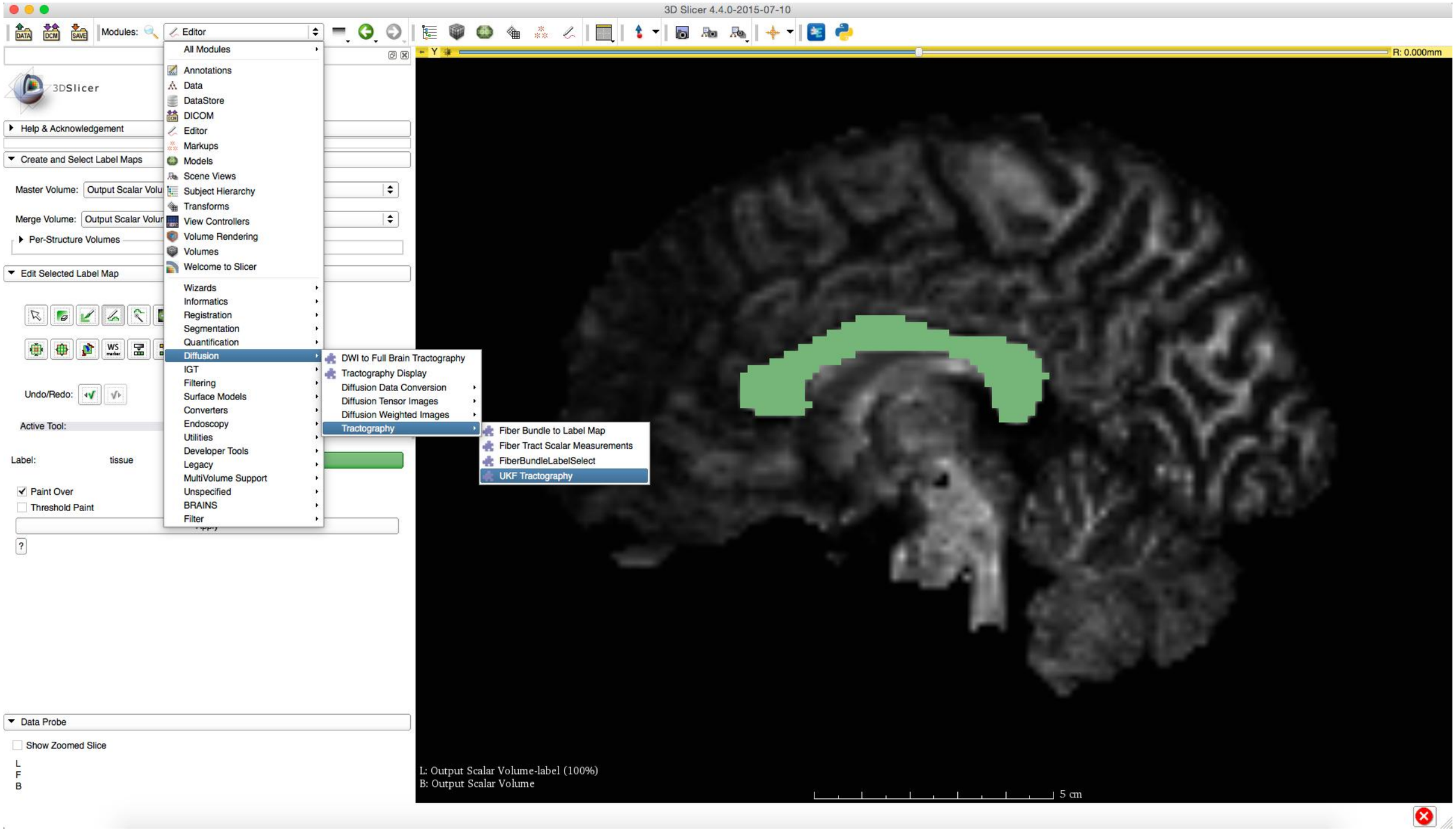


UKF Tractography

- The module can use different methods:
  - 1-Tensor tractography (single fiber model)
  - 2-Tensor tractography (crossing fiber model)
  - NODDI (estimates microstructural complexity of dendrites and axons)

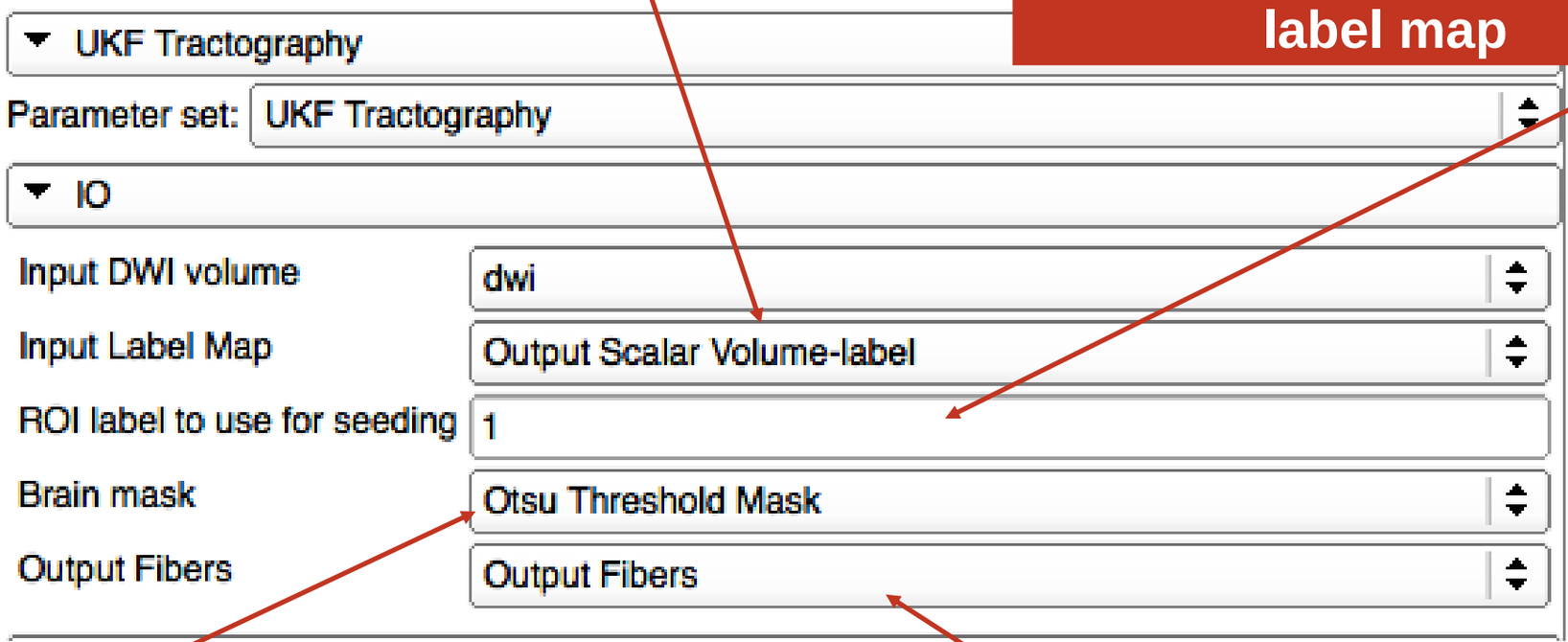
- The module can add a term for the free water model. This model tries to separate the signal from partial voluming with cerebrospinal fluid.

UKF Tractography Module



select the label map as seeds for tractography

select the number of the label map

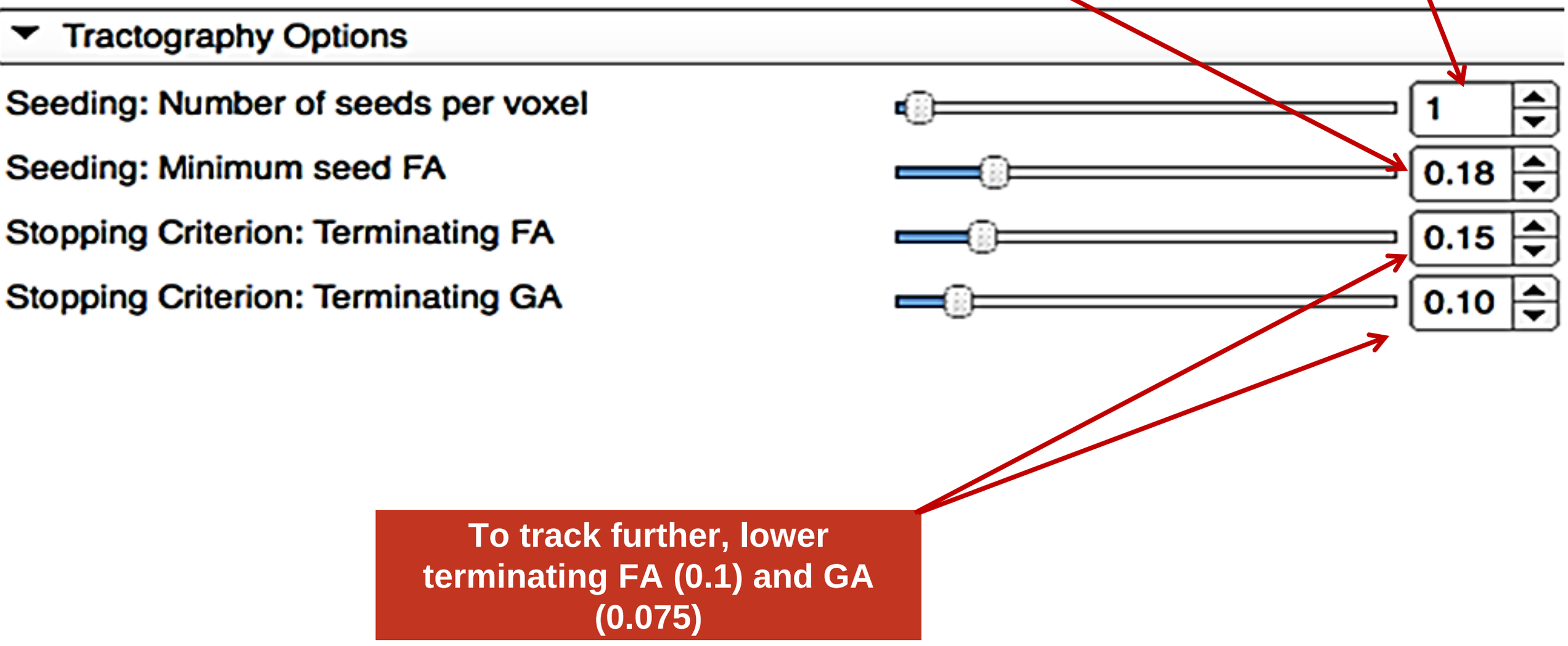


select the Otsu Mask to confine the tractography

create new FiberBundle

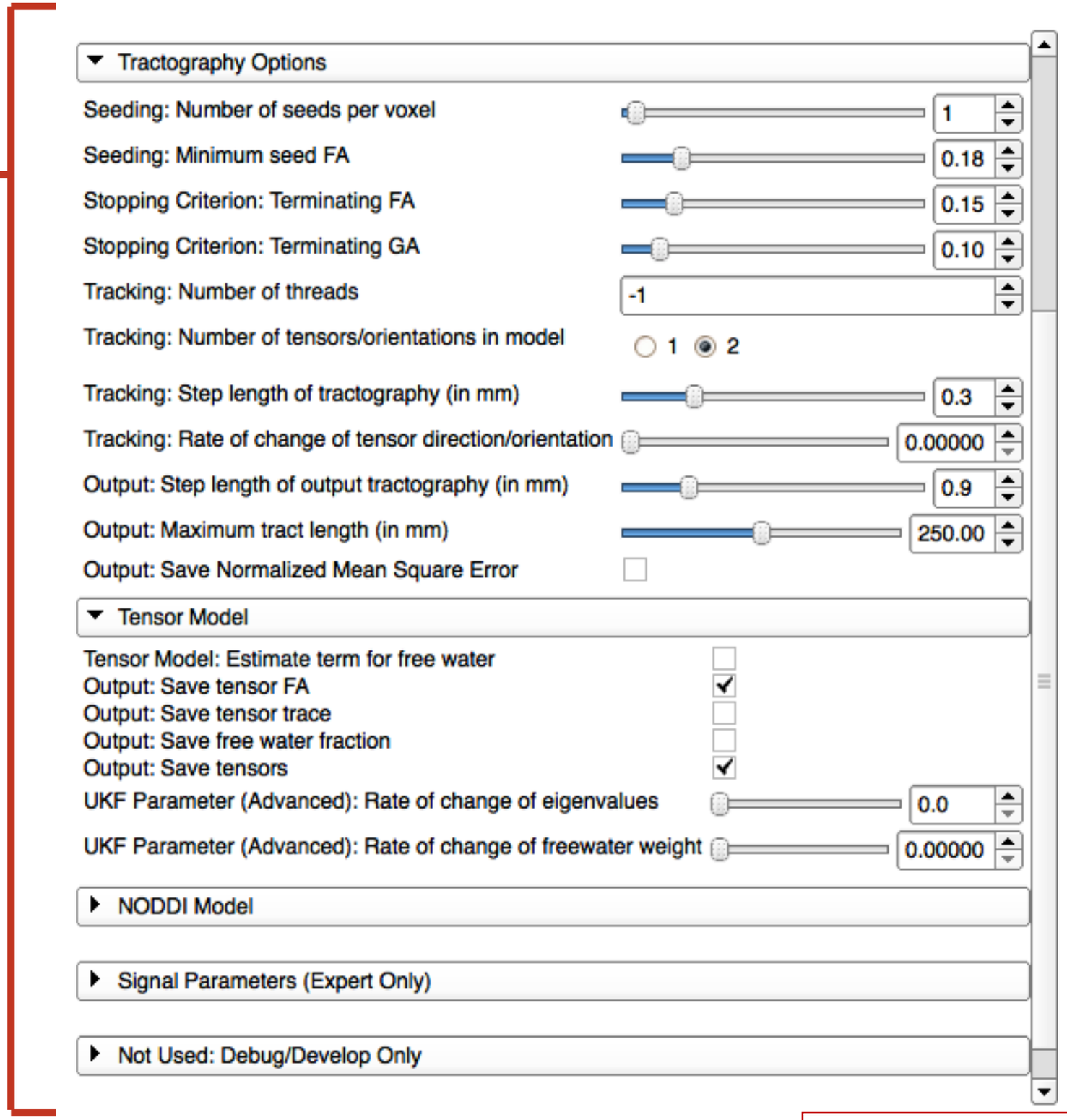
for bigger voxels, use higher number of seeds per voxel

To increase seeding sensitivity, lower seed FA (0.15)



To track further, lower terminating FA (0.1) and GA (0.075)

Set other parameters here:

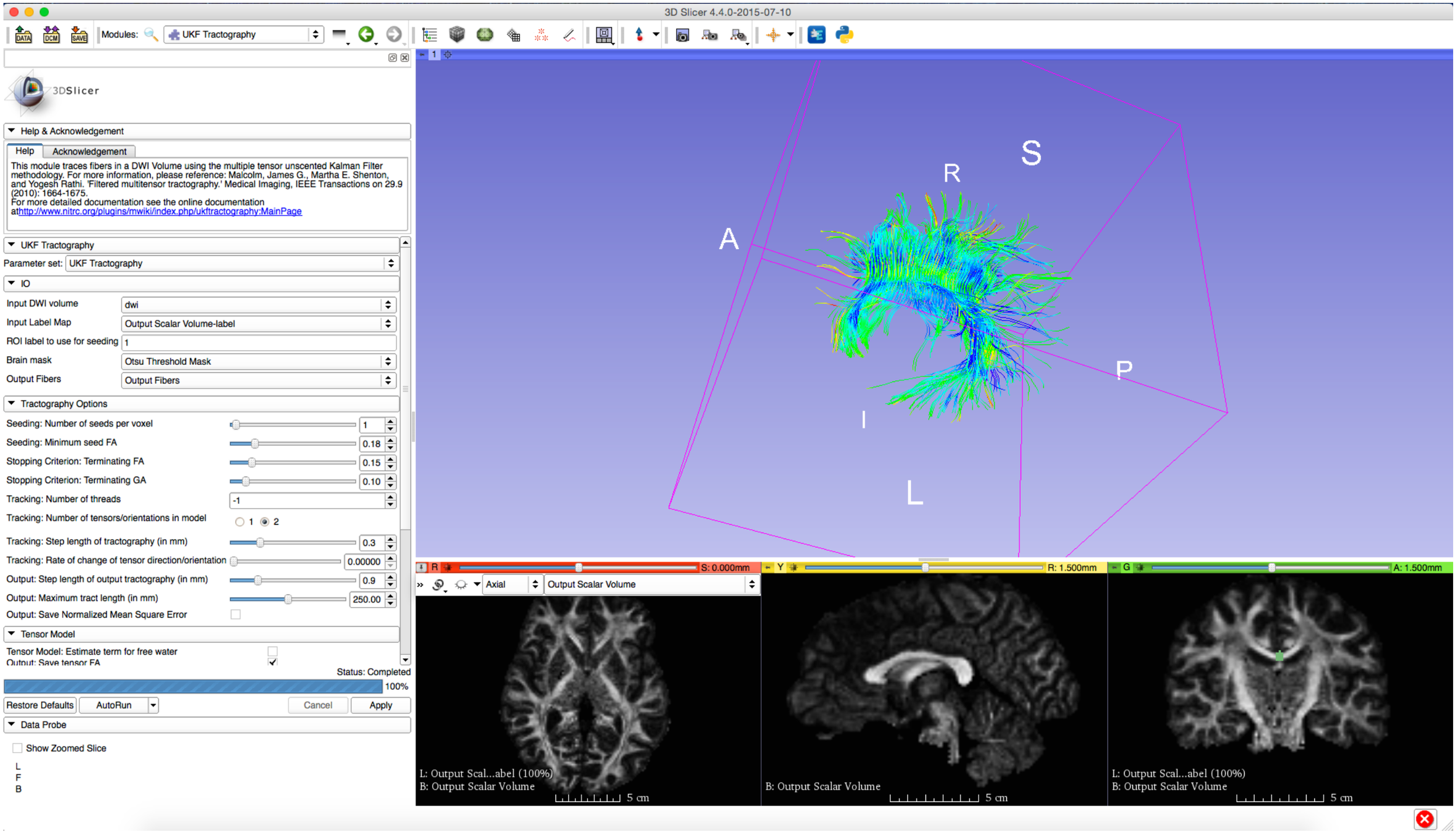


Click Apply

find out more details at:

[Documentation/Nightly/Modules/UKFTractography]

Corpus Callosum



Conclusion

- This tutorial, helps you to load diffusion data, run the tensor estimation, calculate scalar measurements, and define ROIs to finally be able to run UKF tractography.

- contact: yogesh@bwh.harvard.edu

Acknowledgments

- U01CA199459, Open Source Diffusion MRI Technology For Brain Cancer Research
- P41EB015898, National Center for Image Guided Therapy (NCIGT)
- P41EB015902, Neuroimage Analysis Center (NAC)