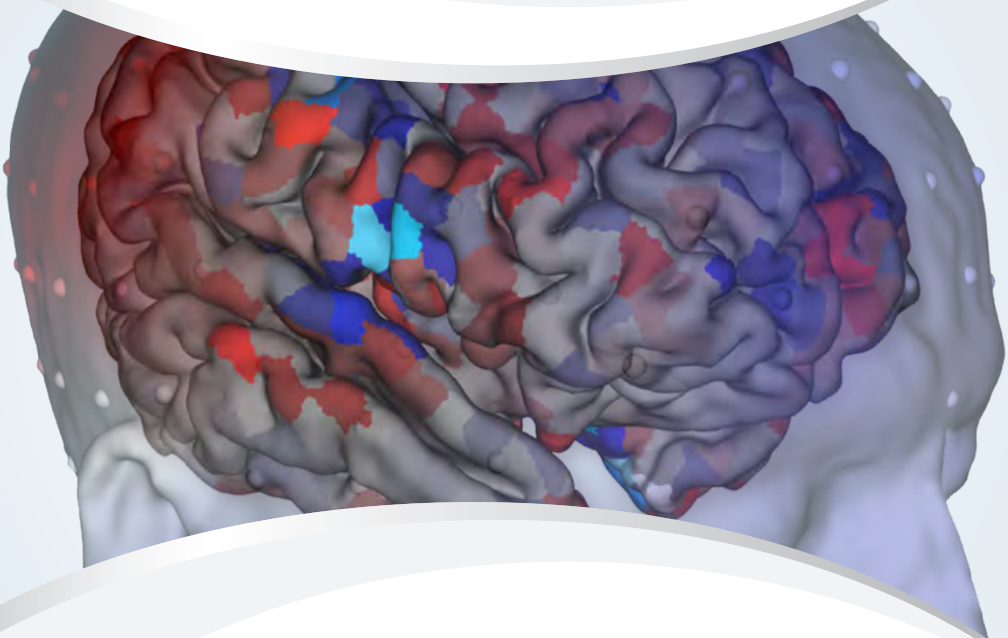

GeoSource 3 Research

Basic, Intermediate, and Advanced

Source Estimation Software

version 3.1

User Manual

For Research Use Only

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EC REP

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g.froemel@mps-gmbh.eu

NOT ALL EGI SYSTEM OR SOFTWARE PRODUCTS OR FEATURES ARE AVAILABLE FOR PURCHASE OR USE IN ALL COUNTRIES OR MARKETS. The sale of medical devices is strictly regulated by national laws. This manual is not an offer to sell a medical device in any country where its sale would be prohibited by national law. For the current regulatory clearance status of EGI products in your country, go to www.egi.com/company/certificationscompany.

RESEARCH USE ONLY in U.S.

The following EGI products, including variants, are sold for strictly research purposes and are not medical devices in the United States, including software that is not a "software as a medical device" (SaMD). As such, these products cannot be used for medical purposes such as the diagnosis, treatment, cure, mitigation, or prevention of diseases.

- Amp Server™ Pro SDK software
- Field Isolation Containment System (FICS) enclosure* for the amplifier (RESEARCH USE ONLY for EEG-fMRI)
- GeoScan™ 1.0 Sensor Digitization System
- Geodesic EEG System™ 400 MR series of systems (GES 400 MRs)
- GeoSource™ v3.0 to v3.1 Research software
- Geodesic Transcranial Electrical Neuromodulation™ 100 Research system (GTEN 100 Research system)
- Net Amps GTEN 100 amplifiers**

CE marked in Europe

The following EGI products, including variants, are CE marked in conformity with the European Medical Device Directive.

- *HydroCel* Geodesic Sensor Nets™ (GSNs)
- *MicroCel* Geodesic Sensor Nets™ (GSNs)
- Field Isolation Containment System (FICS) enclosure for the amplifier (for EEG-fMRI)
- Geodesic EEG System™ 400 series of systems (GES 400s)
- Geodesic EEG System™ 400 MR series of systems (GES 400 MRs)
- Geodesic Photogrammetry System™ (GPS)
- GeoSource™ 2.0 software (Available for clinical use in the U.S. as a SaMD.)
- Net Amps™ 400 series (NA 400s) amplifiers**

* Allowed for non-fMRI uses. For details, refer to the GES 400 series manual (8100400) and/or contact EGI Technical Support (Table P-2).

** Due to the resulting change in configuration, any EGI amplifier that is upgraded to a Net Amps GTEN 100 amplifier (as a part of a GTEN 100 system upgrade) loses its certification as a cleared medical device, and any system it operates within is also no longer certified.

GeoSource 3 Research

Basic, Intermediate, and Advanced

Source Estimation Software
version 3.1

User Manual

For Research Use Only

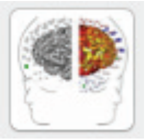
Key changes in this revision:

Preface: Clarified the key differences between Basic, Intermediate, and Advanced.
Section 1.1: Updated the intended use statement.
Section 2.1: Updated the system requirements.
Chapter 4: Clarified the differences between atlas head models and CAHMs and IHMs. Also, clarified the differences between the FDA-cleared **GeoSource 2.0** versus the **for-research-use-only** *GeoSource* ***3.1 Research***.
Chapter 7: Updated the MIP's head modeling to clarify the four stages.
Chapters 9 and 10: Updated for minor software changes.

Contents

Preface

Welcome to the *GeoSource™* ***3.1 Research*** (*Basic*, *Intermediate*, and *Advanced*) electrical source estimation software from Electrical Geodesics, Inc. (EGI). The GeoSource software extends the abilities of EGI's Net Station™ EEG acquisition, review, and analysis software to the imaging of electrical sources.



The source results from *GeoSource* ***3.1 Research*** are viewable in the Reciprocity™ Visualization Environment (RVE), which is accessed from within Net Station Review. The RVE is where you will explore the finite difference method (FDM) head models and view the forward projections of scalp voltage data from any region of the cortex.

For *GeoSource* ***3.1 Research*** *Intermediate* or *Advanced*, you will also use the Modal Image Pipeline™ (MIP) software module to create conformal atlas head models (CAHMs) and/or individual head models (IHMs).

WARNING: Source estimation refers to methods that are employed for estimating the current sources of scalp recorded EEG. There are two classes of methods: linear and nonlinear. Each class employs different approaches to source estimation, which is an ill-posed problem. In the nonlinear class are methods that employ equivalent dipoles, and in the linear class are methods that employ different constraints applied to a minimum norm solution. Because source estimation is an ill-posed problem, there are no unique answers. Therefore, estimates of current sources from scalp recorded EEG data, whether they are derived from linear or nonlinear techniques, are approximate, and should always be viewed in the context of the scalp data by a trained reviewer.

FDA-cleared GeoSource 2.0 versus _GeoSource 3.1 Research_

Every *GeoSource* ***3.1 Research**** license, **for research use only**, also includes a license for the clinically FDA-cleared **GeoSource 2.0**.

- **Be aware that any source waveforms created using *GeoSource 3.1 Research* are restricted to research use only.**
- **Note that a *source montage* in the FDA-cleared GeoSource 2.0 is the same as a *source collection* in *GeoSource 3.1 Research*.**

* *GeoSource* ***3.1 Research Intermediate*** includes *Basic and*
GeoSource ***3.1 Research Advanced*** includes *Intermediate* and *Basic*.

The three packages of *GeoSource* ***3.1 Research*** provide the following functionalities.

GeoSource ***3.1 Research Basic***:

Basic provides:

Six atlas head models
- three adult
- three pediatric

Three RVE views
- EEG Data Exploration
- Head Model Review
- Source Estimate Review (Triples)

3D topo maps viewable in the RVE

Custom source collections

Custom dipole source groups

Cannot use the MIP's outputs

- Uses inverse techniques to calculate estimations of source locations in the brain from dense array EEG data (up to 256 channels) that was measured on the scalp with EGI's HydroCel or MicroCel Geodesic Sensor Net™ (GSN) and recorded into a Net Station EEG .mff file.
- Extracts the current values needed for statistical analyses using the Statistic Extraction waveform tool from Net Station Tools.

GeoSource ***3.1 Research*** ***Intermediate***:

- Provides all the functionality of ***Basic***.
- Plus, warps conformal atlas head models (CAHMs) to digitized sensor positions.

Intermediate provides:

All of Basic's features, plus:

Uses the MIP's conformal atlas head model (CAHM) outputs

GeoSource ***3.1 Research*** ***Advanced***:

- Provides all the functionality of ***Basic*** and ***Intermediate***.
- Plus, utilizes individual head models (IHMs) that were created with imported MRI scans.

Advanced provides:

All of Intermediate's features, plus:

One additional RVE view

- Source Estimate Review (Oriented)

Uses both of the MIP's outputs

- conformal atlas head models (CAHMs)
- individual head models (IHMs)

EGI Knowledge Center

For articles that address various procedural and theory aspects of EEG source estimation, click the Training and Technical Support tab at www.egi.com.

- The **Type** tab provides articles by:
  - application advice (usage, best practices, workflows, etc.)
  - technical/troubleshooting/help advice
  - implementation theory of features and functions
  - theoretical background of dEEG, source estimation, and neuromodulation, etc.
- The **Products** tab provides articles by product group.
- The **Manuals** tab provides product manuals by product group.
- The **Video Tutorials** tab provides product and instruction videos.

Table P-1. Parts list for typical GES 400 series systems, including the GeoSource software
GES systems are expandable. Your system components will be specific to your purchased configuration.

<table>
<tr><th colspan="2">Part</th><th>Qty</th><th>Mfr</th><th>Mfr P/N</th><th>EGI P/N</th></tr>
<tr><td colspan="6">NOT ALL SYSTEM OR SOFTWARE FEATURES ARE AVAILABLE FOR PURCHASE OR USE IN ALL COUNTRIES OR MARKETS. Refer to www.egi.com/company/certificationscompany.</td></tr>
<tr><td colspan="6">For all safety and use conditions for using your EGI system, refer to the manuals and instructions that shipped with your system configuration.</td></tr>
<tr><td colspan="6">Core components—Software
Contains the Net Station Acquisition, Net Station Review, and Net Station Tools modules.</td></tr>
<tr><td colspan="2">Net Station (NS) 5.4</td><td>1</td><td>EGI</td><td></td><td>variant dependent</td></tr>
<tr><td colspan="2">HASP key</td><td>1</td><td>Safenet</td><td>YWRGC</td><td>variant dependent</td></tr>
<tr><td colspan="6">Core components—Amplifier
Contains Amp Server™, the software that controls, collects, and publishes data from the amplifier to NS.</td></tr>
<tr><td colspan="2">Net Amps 400
(NA 400)</td><td rowspan="4">1</td><td rowspan="4">EGI</td><td rowspan="4"></td><td>4608880 (256 chs)
4606168 (128 chs)
4606358 (64 chs)
4603285 (32 chs)</td></tr>
<tr><td colspan="2"><u>Not available in China</u>
Net Amps 405 (NA 405)
with D-sub connector to connect to HydroCel GSN G Nets</td><td>4603293 (32 chs)</td></tr>
<tr><td colspan="2">Net Amps 410
(NA 410)</td><td>4608884 (256 chs)
4606172 (128 chs)
4606362 (64 chs)
4603289 (32 chs)</td></tr>
<tr><td colspan="2">Net Amps GTEN 100 (NA GTEN 100) –
RESEARCH USE ONLY</td><td>4609000 (256 chs)</td></tr>
<tr><td colspan="6">Core components—Misc.</td></tr>
<tr><td colspan="2">Articulated Arm for GSNs</td><td>1</td><td>EGI</td><td></td><td>4605256 (256 chs)
4605128 (128 chs)</td></tr>
<tr><td colspan="2">Computer, monitor, keyboard, mouse:
iMac or laptop</td><td>1</td><td>Apple</td><td>current model</td><td>current model</td></tr>
<tr><td colspan="2">Ethernet switch</td><td>1</td><td>Black Box</td><td>LGB2008A-R2</td><td>6156366</td></tr>
<tr><td rowspan="2">Power supply
availability**</td><td>GES External Power Supply</td><td rowspan="2">1</td><td rowspan="2">EGI</td><td rowspan="2"></td><td>4603988</td></tr>
<tr><td>EGI External Power Supply 100</td><td>4603990</td></tr>
<tr><td colspan="2">Isolation transformer</td><td>1</td><td>Toroid</td><td>ISB-060M</td><td>6156331</td></tr>
<tr><td colspan="6">Accessory components—Sensor Array
Most Geodesic Sensor Nets (GSNs) have a modular Hypertronics connector.
HydroCel GSN G Nets, however, have a D-sub connector and connect only to the Net Amps 405 amplifier.</td></tr>
<tr><td colspan="2">HydroCel GSN</td><td>1 or more</td><td>EGI</td><td></td><td>variant dependent</td></tr>
<tr><td colspan="2">MicroCel GSN</td><td>1 or more</td><td>EGI</td><td></td><td>variant dependent</td></tr>
</table>

Part	Qty	Mfr	Mfr P/N	EGI P/N
Optional components				
Amp Server™ Pro SDK 2.0 – **RESEARCH USE ONLY**	1	EGI		4602003
AV Device Kit	1	EGI		4601418
AV Device DIN Adapter	1	EGI		4609786
Carts	1	EGI		4601100 (small) 4607100 (large)
EGI External Battery Pack	1	EGI		4605312
Field Isolation Containment System (FICS) *Allowed for non-fMRI uses** **RESEARCH USE ONLY for EEG-fMRI in the U.S.**	1	EGI		4609069 (256 chs) 4602986 (128 chs)
Clock sync *availability*** – GES Clock Sync I/O	1	EGI		4608295
Clock sync *availability*** – GES Clock Sync I/O				4608296
Geodesic Photogrammetry System (GPS)	1	EGI		4601900
GeoScan 1.0 – **RESEARCH USE ONLY**	1	EGI		4609761
GeoSource 2.0 – ***FDA-cleared for clinical use***	1	EGI		variant dependent
GeoSource 3.1 Research – **RESEARCH USE ONLY**	1	EGI		variant dependent
GSN Interface Cable (GSNIC)	1	EGI		4606256 (256 chs) 4606128 (128 chs)
Photic Stimulator	1	EGI		4609125
Physio16	1 or 2	EGI		4609271
Physio16 MR – **RESEARCH USE ONLY**	1 or 2	EGI		4609272
Response Pad	1	EGI		4608150
Documentation GSN user instructions (i.e., placards) differ per GSN variant—HydroCel or MicroCel and routine or LTM.				
AV Device Kit manual	1	EGI		S-MAN-200-AV-001
Computer, monitor, keyboard, mouse: iMac or laptop	For all safety and use conditions for using the computer that is shipped with your EGI system, refer to third-party manufacturer manuals at https://support.apple.com/country-selector/manuals.			
GeoScan 1.0 manual – **RESEARCH USE ONLY**	1	EGI		8100550
GeoSource 2.0 manual – ***FDA-cleared for clinical use***	1	EGI		8103101-52
GeoSource 3.1 Research manual – **RESEARCH USE ONLY**	1	EGI		8103101-53+
GES 400 manual	1	EGI		8100400
GES 400 MR manual – **RESEARCH USE ONLY**	1	EGI		8100401
GSN manual	1	EGI		8105171
GTEN 100 Research manual – **RESEARCH USE ONLY**	1	EGI		8102120
Net Station manual	1	EGI		8100050
Routine EEG placard	1	EGI		variant dependent
LTM EEG placard	1	EGI		variant dependent
Preterm Infant placard	1	EGI		variant dependent

** For details, refer to the GES 400 series manual (8100400) and/or contact EGI Technical Support (Table P-2).*

*** Changeover between equivalent component model/variants is due to parts availability.*

Typical GES System

The Net Station software operates within EGI's GES systems to acquire EEG data from a single Net Amps amplifier, to acquire EEG data from more than one amplifier, or to acquire simultaneous data from two different signal sources.

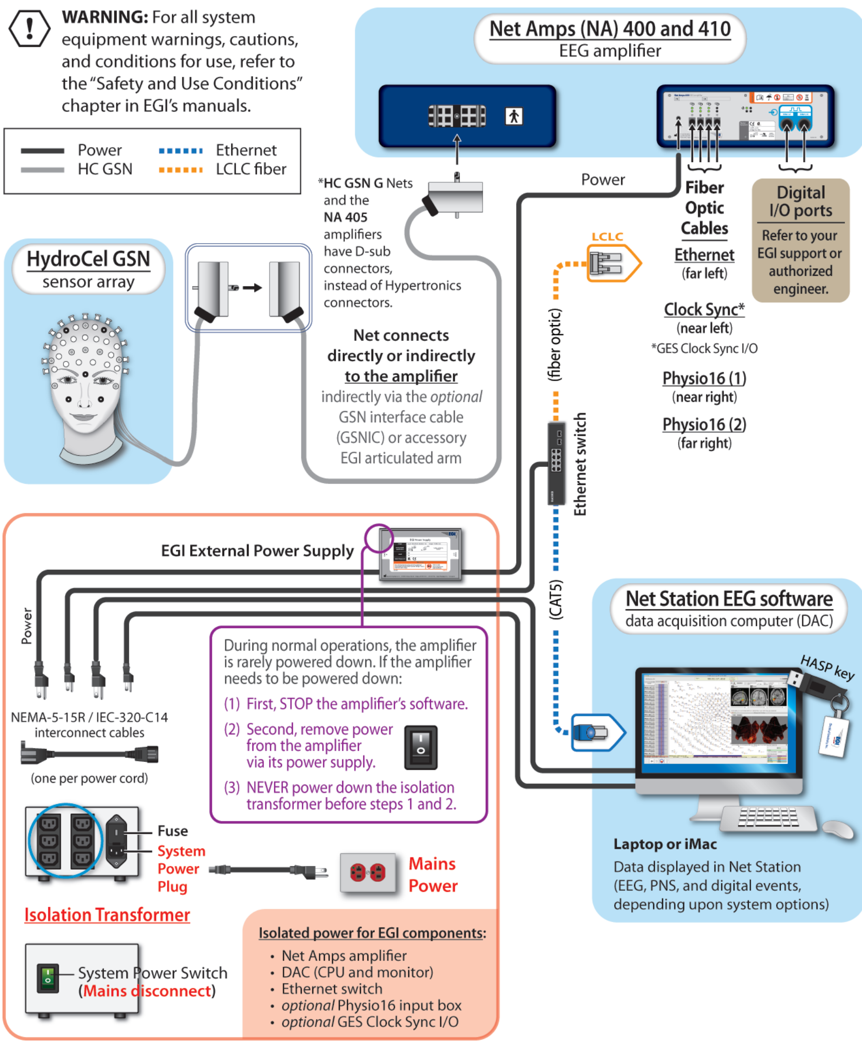


Figure P-1. Core components of a typical EEG-only GES system

About This Manual

This manual provides general information for safely and effectively using the GeoSource software to estimate electrical sources in EEG data and the MIP software module to create conformal atlas and individual head models. ***It assumes a working proficiency with EEG, head modeling, source localization, and computer systems.***

Note that the term *patient* is used to refer to subjects, participants, or patients.

An EGI support or authorized engineer will install and configure your EGI system, including all connections required for its operation. At the time of initial installation, the EGI support or authorized engineer will also train relevant staff in its operation. At any time you have additional questions or wish retraining, contact EGI Technical Support (Table P-2).

Typographic conventions:

- *Italics* are used for definitions or newly introduced terms.
- ***Boldface italics*** are used for important concepts or for special emphasis.
- **Boldface** is used for command paths (for example, **File > Open**).

Warnings, Cautions, and Notes

The following are used to convey important information:

WARNING: Warnings provide important information that, if unheeded, could result in serious physical injury, death, or equipment damage.

CAUTION: Cautions provide important information that, if unheeded, could hinder the use of a product, feature, or procedure, or result in physical injury or equipment failure.

Note: Notes provide clarifying information about a product, feature, or procedure.

Support, Repairs, and Documentation

Electronic copies of EGI's user manuals and instructions are available for download at www.egi.com/knowledge-center or from the Training and Technical Support tab at www.egi.com.

If you have a question, please:

- For *urgent issues during acquisition*, contact EGI immediately.
- For *nonurgent issues*, do the following before contacting EGI:
  - **Isolate the problem.**
    Try to repeat and define the problem.
  - **Document the problem.**
    Carefully record the sequential details of the problem.
  - **Report the defined problem.**
    Contact EGI.

Table P-2. EGI contact information

EGI Technical Support web page	www.egi.com/knowledge-center
Email Technical Support	supportteam@egi.com
Email Sales	orderdesk@egi.com
Telephone	+1.541.687.7962
Fax	+1.541.687.7963
Address	Electrical Geodesics, Inc. (EGI) 500 E 4th Avenue, Suite 200 Eugene, OR 97401 USA

1. Safety and Use Conditions

For all safety and use conditions for using your EGI system, refer to the manuals and instructions that shipped with your system configuration.

Do not operate your GES system, including the GeoSource and/or MIP software, ***until you are fully trained and understand*** all warnings, cautions, and conditions for use provided in EGI's manuals for the components of your GES system. If you have any questions, contact EGI Technical Support (Table P-2).

WARNING: All EGI system components must be installed and configured by an EGI support or authorized engineer. Deviating from the supported configuration or running the system with non-EGI-approved components attached can cause hazards or unexpected performance.

Note that the information in this manual is subject to change, without notice. The manufacturer declines responsibility for the safety, reliability, and performance of EGI system components if not used in compliance with EGI documentation.

1.1 Intended Use

As an optional component of the GES 400 family of EEG devices, the *GeoSource* ***3.1 Research*** software is intended to:

- Visualize human brain function via imaging the electrical sources in EEG data with rendered images of an idealized head model and an idealized MRI image.

- Be used with the Modal Image Pipeline (MIP) software module that creates conformal atlas head models (CAHMs) and individual head models (IHMs).
- Be used with adults, children, and infants.
- Be used by a trained clinician or doctor.
- Provide data that may be used by a trained clinician or doctor to aid in the diagnosis of epilepsy and other related neurological disorders.
- Be used with no restrictions on patient population that may be treated.
- Be used with no contraindications for use.
- Regarding Geodesic Sensor Nets (GSNs), these accessory devices are not recommended with non-intact skin.

For research use only. ***Rx only.*** ***For indoor use only.***

1.2 Features

GeoSource ***3.1 Research*** is available in three packages:

- **Basic** — provides six built-in atlas head models (three adult, two pediatric, and one infant)
- **Intermediate** — creates conformal atlas head models (CAHMs) using digitized sensor positions to conform/warp an atlas head model to individual head geometry
- **Advanced** — creates individual head models (IHMs) using imported MRI scans

Each license provides features depending upon the package purchased and includes:

- High-resolution, dense array EEG with up to 256 channels
- Fast, step-by-step head model building
- More realistic head models with seven characterized tissue types

- More realistic electrical conductivity modeling using the finite difference method (FDM)
- LORETA, sLORETA, and LAURA constraint methods
- FDM head models built from 1 mm resolution MRI data
- ***Intermediate*** and ***Advanced*** provide a GPU-accelerated computer for generating lead field matrices (LFMs)

1.3 Safety Warnings

1.3.1 Computer and OS X

CAUTION: Before upgrading your EGI system (computer, operating system, or EGI software), confirm compatibility with EGI Technical Support (Table P-2).

1.3.2 Reviewing and Manipulating EEG Data

CAUTION: Vary file names within the first 22 characters. When exporting data to text files, Net Station truncates file names longer than 22 characters. If truncated file names are identical, they may overwrite each other

2. Software

EGI protects its software from unauthorized use by encoding the licensing data in a HASP key (similar to a USB flash drive). All authorized EGI software users have a HASP key that plugs into one of the USB ports of any EGI Mac OS system computer to allow access to the purchased applications licensed to that HASP key.

2.1 System Requirements
for *GeoSource* ***3.1 Research***

Table 2-1. Software compatibilities

GeoSource	Net Station	Mac OS
3.1 Research *Intermediate* and *Advanced*, include MIP and OsiriX MD	**5.4**	**10.12.4**
		10.11.6
3.0 Research *Intermediate* and *Advanced*, include MIP and OsiriX MD	**5.3.0.x**	**10.11.5**
FDA-cleared **2.0**	**5.3 and later**	**corresponding**
	5.2	**10.10.5**
FDA-cleared **2.0**	**4.5.7**	**10.6.8**

To create conformal atlas head models (CAHMs) or individual head models (IHMs), the Modal Image Pipeline™ (MIP) will require 3D sensor position files from either of EGI's sensor registration products:

- Geodesic Photogrammetry System™ (GPS)
- GeoScan™ sensor digitization system

The computer that runs *GeoSource* ***3.1 Research*** and the MIP can be the same as the computer that is running Net Station 5.4 Review. However, a GPU-accelerated computer is required to generate lead field matrices for CAHMs or IHMs.

Table 2-2. Hardware requirements

EGI Mac Computer running: *GeoSource* ***3.1 Research*** Net Station 5.4 MIP (with OsiriX MD)	**GPU-accelerated Unix Computer generating:** Lead field matrices (LFMs)
• Mac OS X 10.11.6 or 10.12.4 • Intel Core 2 Duo processor (2 GHz minimum) • 16 GB RAM (minimum)	Silicon Mechanics 4U Tower with: • Two GPUs – EVGA GeForce GTX 1080 TI 6 GB • Two Intel Xeon 8 Core processors [2.1 GHz (minimum) and 64 GB RAM (minimum)]

2.2 Installation

If the GeoSource and/or MIP software is purchased with a new system, it comes installed on the EGI system computer. If you need to download software purchased separately from a system or you need to reinstall the software, contact EGI Technical Support (Table P-2).

3. Source Estimation

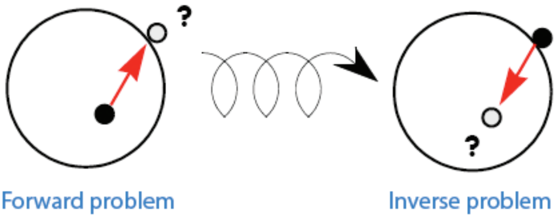
With a range of specification settings, GeoSource allows you to easily visualize and explore source activations represented in MRI and waveform views. These comparative source estimations allow you to draw educated conclusions.

The solutions provided by GeoSource are *approximations* of the locations of sources that are responsible for generating the EEG that is recorded at the scalp. It is a good idea to use GeoSource solutions from different source-imaging specifications in conjunction with other EEG tools and the results from other imaging modalities to determine if the solutions are consistent with the recorded data.

3.1 Parameters of Source Imaging Settings

3.1.1 Generic Forward and Inverse Problems

Source imaging involves solving a *forward problem* and an *inverse problem*.



In simple terms, the generic *forward problem* is:

> Given known source locations and propagation model, what are the surface measurements?

The solution is then "flipped over" to solve the generic *inverse problem*, which is:

> Given a known topography on the scalp, what is the contribution of each dipole necessary to produce the topography?

3.1.2 EEG Forward and Inverse Problems

With GeoSource, you create source imaging specifications that combine the following components for solving the inverse problems based on defined forward solutions.

- **EEG sources (or source locations).** Locations of possible current generators that might produce a dipole.
- **Forward head models.** Models that describe the propagation of current through a conductive medium (i.e., the head).
- **Inverse models.** Models that produce a unique answer from the infinite number of possible answers to the inverse problem.

GeoSource estimates sources by combining:

- a source-imaging specification, which contains forward and inverse models; and
- EEG scalp data from a Net Station file.

3.1.3 Forward Algorithms for EEG

For a given set of source (i.e., dipole) locations, the geometry of the conductive media (i.e., shape of the brain, cerebrospinal fluid (CSF), skull, and scalp), the conductivity of each media, and the location of EEG sensors on the scalp, we can calculate the voltage potential recorded by the EEG sensors for each source. This calculation is known as the lead-field calculation and may be performed using different assumptions (such as spheres for geometry).

The resulting calculation is known as the forward matrix, which contains dipoles by EEG sensors. Note that because the number of sensors does not equal the number of dipoles, the forward matrix is nonsquare.

In other words, the forward matrix models the electrophysics resulting from a dipole at a cortical location and the potential field that it generates throughout the head volume.

GeoSource's forward models for EEG are the:

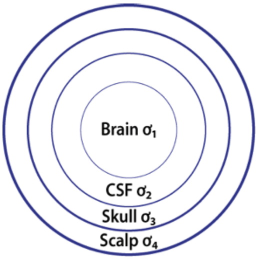
- **Sun-Stok 4-shell sphere:** A spherical head model used with atlas head models.
- **finite difference model (FDM):** A realistic head model used with conformal atlas head models (CAHMs) and individual head models (IHMs).

3.1.3.1 **Spherical**—Atlases Head Models only

As an *isotropic* model, the spherical model consists of four shells that represent the brain, cerebrospinal fluid (CSF), skull, and scalp.

Remember that ***isotropic models*** *have identical conductivity in all directions.*

Following are the geometry and their conductivity values:

Shell	**Radii** (cm)	**Radial conductivity** (siemens per meter [S/m])	**Tangential conductivity** (siemens per meter [S/m])	**Spherical Shells**
Scalp (σ_4)	7.5	0.33	0.33	
Skull (σ_3)	7.1	0.0042	0.0042	
CSF (σ_2)	6.5	1	1	
Brain (σ_1)	6.3	0.33	0.33	

3.1.3.2 Finite Difference Method (FDM)—CAHMs and IHMs

A finite difference method (FDM) is a realistic 3D representation of the head. In GeoSource, the FDM is based on a realistic MRI and uses an *isotropic* model of tissue conductivities.

*Remember that **isotropic models** have identical conductivity in all directions.*

Shell	**Radii** (cm)	**Conductivity** (siemens per meter [S/m])
Brain (σ_1)	8.0	0.35 (WM)
		0.25 (GM)
CSF (σ_2)	8.2	1.79
Skull (σ_3)	8.7	0.010 (age 2+)
		0.036 (age 0-2)
Scalp (σ_4)	9.2	0.33
Eyeballs		1.55

Conductivity values for the FDM model (Ferre, et al., 2000)

3.1.4 Dipoles

In each forward head model, the cortex is tessellated into small units to define source locations. Each source location is defined as a possible current generator that could produce a dipole. Each dipole location has a location and an orientation.

For IHMs, dipole locations are defined as patches of cortex. Each dipole is oriented in one direction, perpendicular (normal) to the cortical surface.

For atlases, dipole locations are defined as 3D voxels. Each dipole consists of three orthogonal orientations representing X, Y, and Z.

Within the RVE, GeoSource allows you to view each dipole location (cortical patch or 3D voxel) and the orientations associated with each dipole in a 3D head model.

When viewing source waveforms, GeoSource allows you to view all three orientations for each dipole (as overlaid source waveform components) or as one collapsed waveform that represents the RMS (root mean square) of the three orientations combined (as RMS of source waveform components).

3.1.5 EEG Sources (or Source Locations)

GeoSource offers a dense set of dipole locations.

Depending upon the atlas, the sources in the FDM consist of 958 to 2,447 dipoles distributed throughout the gray matter.

Atlas	Number of Dipoles
2 mm Atlas Man	2,447
0-2 year male	958
2-9 year male	1,463
9-18 year female	1,745
32 year male	1,732
40 year male	1,721
45 year female	1,720
Oriented example	2,384

Remember that:

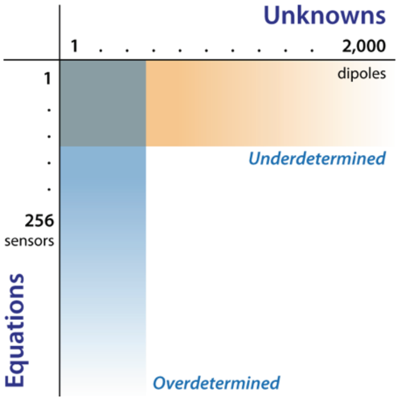
- Each dipole (EEG source

or source location) is a cortical location of a current generator that is capable of producing a dipole.

- Atlas head models display dipoles as 3D voxels, whereas individual head models display dipoles as cortical patches. See section 3.1.4.

This dipole set produces a *nonsquare forward matrix*. When a nonsquare forward matrix is inverted using a pseudoinverse, the solution is either *underdetermined* or *overdetermined*.

3.1.5.1 Underdetermined and Overdetermined Solutions



An *underdetermined solution* exists when there are more dipole sources than EEG sensors (in mathematical terminology, more unknowns than equations). MNLS is used by GeoSource when the solution is underdetermined.

An *overdetermined solution* exists when there are more EEG sensors than dipole sources (more equations than unknowns).

3.1.6 Minimum Norm Least Squares (MNLS)

Least squares is a mathematical process that finds the best-fitting curve to a set of points by minimizing the sum of the squares of the offsets of the points from the curve. The result is an infinite number of possible least-squares solutions. *Minimum norm* captures a unique solution by choosing the one that uses the least amount of energy.

3.1.6.1 Weighting

The MNLS technique, used by GeoSource when the solution is underdetermined, produces a unique solution because only one combination of sources can simultaneously explain the data and be of lowest overall intensity. Weaker and more localized solutions are favored because less activity is required to explain the measured data and, consequently, deeper sources are often “incorrectly” projected on the surface, which means that the MNLS technique has a superficial bias.

3.1.7 Methods (constraint schemes)

GeoSource provides three source-imaging specification methods for solving the inverse problem to overcome the superficial bias of the MNLS technique.

LAURA (*local autoregressive average*)**.** The LAURA method is based on biophysical laws. According to electromagnetic theory, the strength of the source falls off with the inverse of the cubic distance for vector fields and with the inverse of the squared distance for potential fields.

LAURA constrains a solution based on two factors:

(1) The theory that the strength of a dipole decreases as the distance from the source increases.

(2) The local autoregressive average of coefficients that depend on the distance between solution points.

The *weighting* is based on the mean of norms of all three sources (X, Y, and Z) at each dipole location.

The *constraint* is based on the closest neighbors for each location, and the falloff is proportional to the inverse of the distance cubed.

For further information, please reference:

- Grave de Peralta Menendez, R., Gonzalez Andino, S.L., Lantz, G., Michel, C.M., & Landis, T. (2001). Noninvasive localization of electromagnetic epileptic activity. I. Method descriptions and simulations. *Brain Topogr*, 14, 131–137.
- Grave de Peralta, R., & Gonzalez, Andino, S. (2002). Comparison of algorithms for the localization of focal sources: Evaluation with simulated data and analysis of experimental data. *International Journal of Bioelectromagnetism*, online journal.
- Grave de Peralta, R., Murray, M.M., Michel, C.M., Martuzzi, R., & Gonzalez, Andino S. (2004a). Electrical neuroimaging based on biophysical constraints. *Neuroimage*, 21:527–39.

LORETA (*low-resolution brain electromagnetic tomography*)**.** The LORETA method assumes that physiological properties act as *constraints* to the depth weighting in the minimum norm algorithm. Specifically, this scheme assumes that the activity in neurons in neighboring patches of cortex is related and selects the solution with the smoothest spatial distribution by minimizing the Laplacian of the weighted sources, which is a measure of spatial roughness. This results in a rather “blurred” solution. The *weighting* is based on the norm of all three sources (X, Y, and Z) at each dipole location.

For further information, please reference:

- Pascual-Marqui, R.D. (1999). Review of methods for solving the EEG inverse problem. *International Journal of Bioelectromagnetism*, 1: 75-86.
- Pascual-Marqui, R.D., Michel, C.M., & Lehmann, D. (1994). Low resolution electromagnetic tomography: a new method for localizing electrical activity in the brain. *International Journal of Psychophysiology*, 18: 49-65.

sLORETA (*standardized low-resolution brain electromagnetic tomography*)**.** The sLORETA method also assumes that physiological properties act as constraints to the depth weighting in the minimum norm algorithm. The difference between sLORETA and LORETA, however, is that sLORETA selects the solution that standardizes the source current density such that there is equal sensitivity for deep and superficial sources.

For further information, please reference:

- Pascual-Marqui, R.D. (2002). Standardized low resolution brain electromagnetic tomography (sLORETA): technical details. *Methods & Findings in Experimental & Clinical Pharmacology*, 24D:5-12.

3.1.8 Suggested Reading

- Ferre, T.C., Eriksen, K.J., and Tucker, D.M. (2000). Regional head tissue conductivity estimation for improved EEG analysis. *IEEE Transactions on Biomedical Engineering*, 47(12), 1584–1592.
- Gorodnitsky, I.F., George, J.S., & Rao, B.D. (1995). Neuromagnetic source imaging with FOCUSS: A recursive weighted minimum norm algorithm. *Electroencephalography and Clinical Neurophysiology*, 95, 231–251.
- Grave de Peralta, R., & Gonzalez Andino, S. (2002). Comparison of algorithms for the localization of focal sources: Evaluation with simulated data and analysis of experimental data. *International Journal of Bioelectromagnetism*, online journal.
- Lemieux, L., McBride, A., & Hand, J.W. (1996). Calculation of electrical potentials on the surface of a realistic head model by finite differences. *Physics in Medicine and Biology*, 41, 1079–1091.
- Michel, C.M, Murray, M.M., Lantz, G., Gonzalez, S., Spinelli, L., & Grave de Peralta, R. (2004). EEG source imaging. *Clinical Neurophysiology*, 115(10), 2195– 2222.
- Neumaier, A. (1998). Solving ill-conditioned and singular linear systems: A tutorial on regularization. *SIAM Review*, 40, 636–666.
- Pascual-Marqui, R.D. (1991). Review of methods for solving the EEG inverse problem. *International Journal of Bioelectromagnetism*, 1, 75–86.
- Song, J., Morgan, K., Turovets, S., Li, K., Davey, C., Govyadinov, P., . . . Tucker, D. M. (2103). Anatomically accurate head models and their derivatives for dense array EEG source localization. *Functional Neurology, Rehabilitation, and Ergonomics, 3*, 275-293.
- Sun, M. (1997). An efficient algorithm for computing multishell spherical volume conductor models in EEG dipole source localization. *IEEE Transactions on Biomedical Engineering*, 44(12), 1243–1252.

3.2 Available GeoSource Parameters

Whether you are viewing GeoSource data using the GeoSource specification tool, Waveform viewer, MRI viewer, or RVE viewer, the *method*, *regularization*, *computation model*, and *head model* parameters apply.

For details about the GeoSource specification tool, see chapter 5.

For details about the Waveform, MRI, and RVE viewers, see chapter 4.

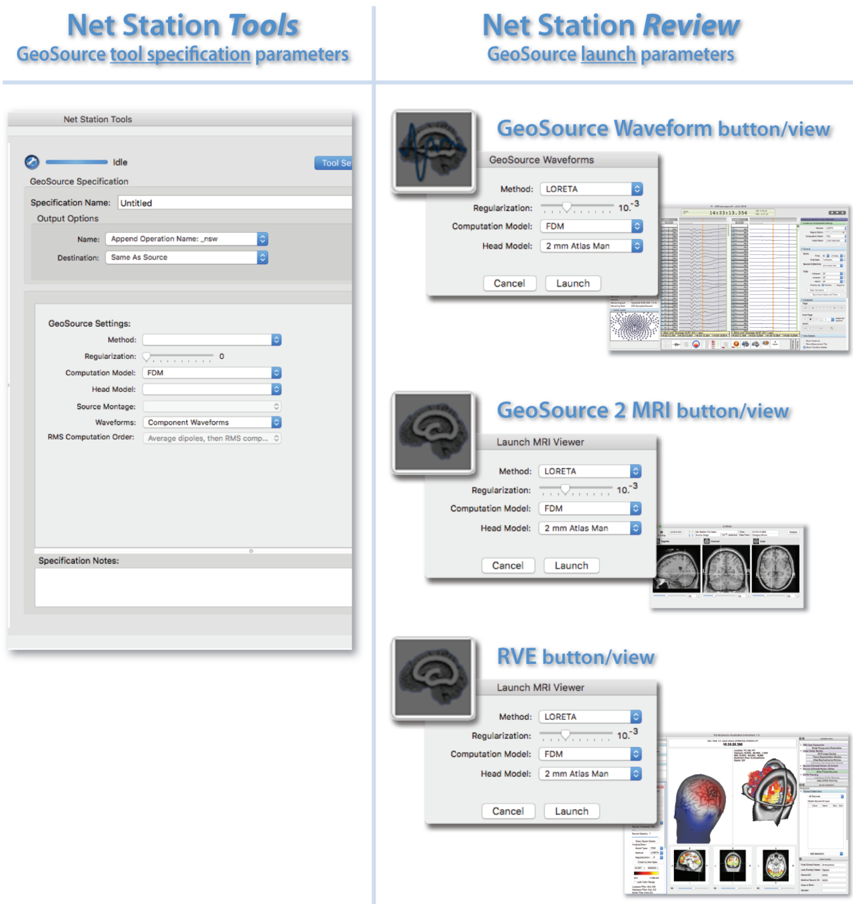


Figure 3-1. General GeoSource parameters via Net Station *Tools* and Net Station *Review*

3.2.1 Method

GeoSource provides three source-imaging specification methods for constraining the inverse problem: LAURA, LORETA, and sLORETA.

LAURA (*local autoregressive average*)**.** The LAURA method is based on the 26 closest neighbors for each location.

LORETA (*low-resolution brain electromagnetic tomography*)**.** The LORETA method selects the solution with the smoothest spatial distribution.

sLORETA (*standardized low-resolution brain electromagnetic tomography*)**.** For IHMs, the sLORETA method standardizes the source current density such that there is equal sensitivity for deep and superficial sources.

3.2.2 Regularization

GeoSource allows for the broadening of information to stabilize an *ill-posed* problem. By stabilizing the solution, small variations in the data are prevented from leading to large variations in the distribution of activity in the source solution. This forces additional *smoothness* to the constraints on the final source estimation and reduces the effects of noise.

Whereas values of 0 to 10^{-9} are available to regularize the inverse model, values of 10^{-2} to 10^{-4} are suitable for most data.

3.2.3 Computation Model

GeoSource provides two forward-head computation models to define the geometry of the head tissues: spherical and FDM.

Spherical. For atlas head models, the spherical model consists of four shells representing the cortex, cerebrospinal fluid (CSF), skull, and scalp.

Finite Difference Model (FDM). For CAHMs and IHMS, the FDM model captures the typical geometry of the human head tissues, including the cortex, cerebrospinal fluid (CSF), skull, and scalp.

3.2.4 Built-in Atlas Head Models

GeoSource ***3.1 Research*** provides six built-in, 1 mm resolution atlas head models that were built from MR and CT scans of average brains using the FDM.

Because the FDA-cleared GeoSource 2.0 product is included with purchases of the *GeoSource* ***3.1 Research*** product, you also have access to the FDA-cleared 2 mm Atlas Man head model for continued use for those who wish it.

FDA-cleared **GeoSource 2.0 versus** *GeoSource* ***3.1 Research***

Every *GeoSource* ***3.1 Research**** license, **for research use only**, also includes a license for the clinically FDA-cleared **GeoSource 2.0**.

- **Be aware that any source waveforms created using *GeoSource 3.1 Research* are restricted to research use only.**
- **Note that a *source montage* in the FDA-cleared GeoSource 2.0 is the same as a *source collection* in *GeoSource 3.1 Research*.**

* *GeoSource* ***3.1 Research Intermediate*** includes *Basic and*
GeoSource ***3.1 Research Advanced*** includes *Intermediate* and *Basic*.

Each atlas head model has a defined dipole set.

RESEARCH USE ONLY. For the **research-use-only** *GeoSource* ***3.1 Research***, the six built-in atlas head models were developed from the skull and scalp of one individual and the averaged brain of many individuals (based on MNI average brains).

The same brain was used for all three adult atlases and age-appropriate brains were used for the infant/pediatric atlases. (For the 0-2 year atlas, the brain came from the University of North Carolina, instead of MNI.)

After the brains were put into the individual skull and scalp anatomy, to get the average head shape for each atlas, the skull and scalp were warped to the HydroCel GSN average point cloud for each age group.

Atlas	Number of Dipoles
2 mm Atlas Man	2,447
0-2 year male	958
2-9 year male	1,463
9-18 year female	1,745
32 year male	1,732
40 year male	1,721
45 year female	1,720
Oriented example	2,384

For a full description of the creation details for the six age- and gender-specific FDM atlas head models of *GeoSource **3.1 Research***, refer to:

Song, J., Morgan, K., Turovets, S., Li, K., Davey, C., Govyadinov, P., . . . Tucker, D. M. (2103). Anatomically accurate head models and their derivatives for dense array EEG source localization. *Functional Neurology, Rehabilitation, and Ergonomics, 3*, 275-293.

FDA cleared for clinical use. For the FDA-cleared GeoSource 2.0, the 2 mm Atlas Man head model has a dipole set that contains 2,447 dipoles distributed across general regions of the cortex. Each dipole is represented as a triple regional source made up of three dipoles in the X, Y, and Z orientations.

The set for the 2 mm Atlas Man head model represents the Montreal Neurological Institute's (MNI) average MRI specification of brain tissue, which is derived from the average of 305 subjects. This average MRI specification is well represented in scientific literature for use with functional brain imaging data, such as fMRI, and was created to be representative of a generalized population (239 M, 66 F, age 23.4 +/- 4.1). Information about the average MRI and its use in the scientific literature can be viewed at: http://imaging.mrc-cbu.cam.ac.uk/imaging/MniTalairach.

3.2.5 Source Collections

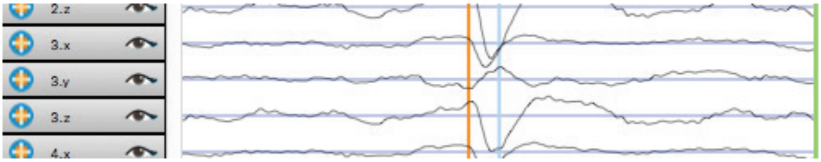
GeoSource ***3.1 Research*** provides six built-in source collections in the form of its six atlases. The power of *GeoSource* ***3.1 Research***, however, is in creating custom source collections from custom head models. Using conformal atlas head models (CAHMs) with *GeoSource* ***3.1 Research*** *Intermediate* or using CAHMs or individual head models (IHMs) with *GeoSource* ***3.1 Research*** *Advanced* in the Reciprocity Visualization Environment (RVE), you can create more accurate source collections within your scalp EEG data.

3.2.6 Waveforms

For individual head models (IHMs), source waveforms represent current density information for one-directional, oriented dipoles.

For atlases, including conformal atlas head models (CAHMs), GeoSource provides two ways to view current density information using source waveforms: component and RMS.

Component Waveforms. The component option displays source waveforms as three separate waveforms—one for each dipole in a separately labeled track, such as 1x, 1y, 1z, 2x, 2y, 2z, etc.



RMS Waveform. The RMS option displays source waveforms collapsed into a single waveform.

3.2.7 RMS Computation Order—*GeoSource Tool only*

GeoSource provides options for the RMS Computation Order setting only if the Waveforms setting is set to RMS Waveform. The available options are: ‘Average dipoles, then RMS components’ and ‘RMS components, then average dipoles’.

Average dipoles, then RMS components. To take orientation into account, this option takes the mean of each vector orientation (i.e., the mean of all Xs, the mean of all Ys, and the mean of all Zs), and then takes the RMS at the end.

RMS components, then average dipoles. To take the magnitude of each dipole triple into account, this option takes the RMS of the vector strengths of each dipole triple first, and then takes the average across the group.

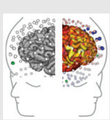
4. 3D Visualization

While working with the *GeoSource* ***3.1 Research*** software (*Basic*, *Intermediate*, or *Advanced*), you will work seamlessly between the Reciprocity Visualization Environment (RVE) and Net Station 5.4 Review.

The RVE provides you with vivid visualizations and 3D source localizations of your EEG scalp data. See Table 4-1.

> ***FDA-cleared* GeoSource 2.0 versus *GeoSource 3.1 Research***
>
> **RESEARCH USE ONLY. Be aware that any source waveforms created using *GeoSource 3.1 Research* are restricted to research use only.**
>
> **Note that a *source montage* in the FDA-cleared GeoSource 2.0 is the same as a *source collection* in *GeoSource 3.1 Research*.**

Table 4-1. General functionalities of EGI's interoperable software applications

EGI Software	Function
Net Station 5.4 *Acquisition*, *Review*, and *Tools*	• Acquires, reviews, and exports EEG data. • Saves EEG data to MFF files. • Provides the link between EEG data and 3D head models in the RVE.
GeoSource ***3.1 Research*** *Basic*, *Intermediate*, or *Advanced*	• Estimates electrical sources. • Displays source estimations in the RVE.
Reciprocity Visualization Environment (RVE) 	• With or without *GeoSource* ***3.1 Research***: shows 3D topo maps. • With any level of *GeoSource* ***3.1 Research***: shows 3D advanced visualization of your EEG data. • With *Basic* or *Intermediate* *GeoSource* ***3.1 Research***: displays 2D MRI slices of the corresponding cortical source estimations. • Displays source intensities with 3D topo maps and 3D head models of your EEG data

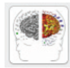
EGI Software	Function
RVE *cont'd*	generated from a variety of views, including: • With any level of *GeoSource* ***3.1 Research***: scalp topography • With *Basic* and *Intermediate*: atlas triples dipoles • With *Advanced*: individual oriented dipoles
Modal Image Pipeline (MIP) *used only with GeoSource* ***3.1 Research*** *Intermediate or Advanced*	• Creates conformal atlas head models (CAHM). • Creates individual head models (IHMs).

What you see in the RVE depends upon what type of data you are viewing. See Table 4-2.

Table 4-2. RVE functionality, depending upon other licensed software

Net Station 5.4 Review, GeoSource (FDA-cleared 2.0 and ***3.1 Research***), **and MIP**	**Reciprocity Visualization Environment (RVE)**
Net Station 5.4 *Review* *with GeoSource* ***2.0***   The RVE is not available when using GeoSource **2.0**. GeoSource 2.0 files open only with the MRI Viewer from Net Station Review, which provides access to: • 2 mm Atlas Man head model • 2D MR slice view with highlighted sources • all GeoSource 2.0 features	
Net Station 5.4 *Review* *with no version of GeoSource*  *Review* provides access to the RVE, even when no version of GeoSource is licensed.	With no licensed version of GeoSource, the RVE provides only 3D topo maps for review.

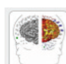
<table>
<tr><th>Net Station 5.4 Review,
GeoSource (FDA-cleared 2.0 and 3.1 Research),
and MIP</th><th>Reciprocity Visualization Environment (RVE)</th></tr>
<tr><td><u>Net Station 5.4 Review</u>

with GeoSource 3.1 Research Basic 

Review provides access to the RVE, while GeoSource 3.1 Research Basic provides access to the following in the RVE:

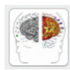
• Three views:
– EEG Data Exploration
– Head Model Review
– Source Estimate Review (Triples)
• Six atlas head models:
– Three adult atlases
– Three pediatric atlases
• MRI slices
• Cannot use MIP outputs.</td><td>With GeoSource 3.1 Research Basic,
the RVE provides:

• 3D topo maps
• Triples dipole sources
• Custom source collections
• Custom dipole source groups</td></tr>
<tr><td colspan="2">Modal Image Pipeline (MIP)
For GeoSource 3.1 Research Intermediate, the MIP creates Conformal Atlas Head Models (CAHMs).</td></tr>
<tr><td><u>Net Station 5.4 Review</u>

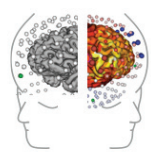
with GeoSource 3.1 Research Intermediate 

• Includes all of Basic's features, plus:
• Uses the MIP's Conformal Atlas Head Model (CAHM) outputs</td><td>With GeoSource 3.1 Research Intermediate,
the RVE provides:

• 3D topo maps
• Triples dipole sources
• Custom source collections
• Custom dipole source groups</td></tr>
</table>

<table>
<tr><th>Net Station 5.4 Review,
GeoSource (FDA-cleared 2.0 and 3.1 Research),
and MIP</th><th>Reciprocity Visualization Environment (RVE)</th></tr>
<tr><td colspan="2">Modal Image Pipeline (MIP)
For GeoSource 3.1 Research Advanced, the MIP creates Conformal Atlas Head Models (CAHMs) and Individual Head Models (IHMs).</td></tr>
<tr><td><u>Net Station 5.4 Review</u>
with GeoSource 3.1 Research Advanced 
• Includes all of Intermediate's features, plus:
• Provides one additional view
– Source Estimate Review (Oriented)
• Uses both of the MIP's outputs:
– Conformal Atlas Head Models (CAHMs)
– Individual Head Models (IHM)</td><td>With GeoSource 3.1 Research Advanced,
the RVE provides:
• 3D topo maps
• Oriented dipole sources
• Custom source collections
• Custom dipole source groups</td></tr>
</table>

4.1 RVE Viewer

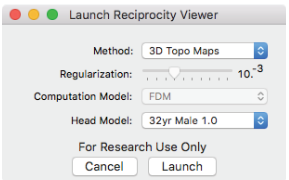
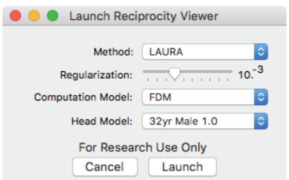
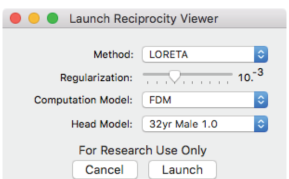
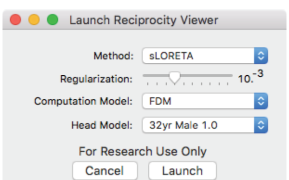


Depending upon what you want to do with your data, you will launch the RVE Viewer either from inside **Net Station Review** or from **Finder > Applications > EGI > Net Station 5**. Select the RVE icon from either place.

Opening the RVE from Finder > Applications allows you to open any head model directly into the Reciprocity Viewer.

4.1.1 Launched from Net Station Review

Table 4-3. Reciprocity's available launching options from Net Station Review

<table>
<tr><th>Methods</th><th>Regularization Values</th><th>Computational Models</th><th>Head Models</th></tr>
<tr><td>3D Topo Maps

</td><td>Not applicable</td><td>Not applicable</td><td>Built-in atlases:
• three adult
• three pediatric</td></tr>
<tr><td>LAURA*

</td><td>$10 – 10^{-9}$
(10^{-3} is the default.)</td><td>Spherical / FDM
(FDM is the default.)</td><td>Built-in atlases:
• three adult
• three pediatric</td></tr>
<tr><td>LORETA*

</td><td>$10 – 10^{-9}$
(10^{-3} is the default.)</td><td>Spherical / FDM
(FDM is the default.)</td><td>Built-in atlases:
• three adult
• three pediatric</td></tr>
<tr><td>sLORETA**

</td><td>$10 – 10^{-9}$
(10^{-2} is the default.)</td><td>Spherical / FDM
(FDM is the default.)</td><td>Built-in atlases:
• three adult
• three pediatric</td></tr>
</table>

*Also appropriate for conformal atlas head models (CAHMs).
**Also appropriate for individual head models (IHMs).

4.1.1.1 Chart View as Display Controller of the RVE

While you are exploring your source EEG data, be aware that the display of EEG data in the RVE is controlled by the settings made in the Chart view of Net Station Review.

If, however, you switch views between montages that use different references (for example, HydroCel GSN 256 1.0 to an Average Reference), the RVE will re-reference the scalp (electrode) EEG data.

If, however, you switch between montages that do not include the same number of channels (for example, a 10-10 montage to a 10-20 montage), the RVE will display the maximum number of sensors in the Net and EEG data (that is, 256, 128, 64, or 32) on the 3D head model.

4.1.2 Launched From Finder > Applications

Accessing the RVE as a standalone application provides the features for visualizing CAHMs and IHMs in *GeoSource* ***3.1 Research*** *Intermediate* or *Advanced* and/or creating neuromodulation protocols with GTEN Planning.

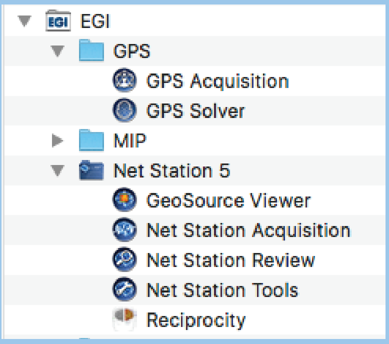
For details about the *Geodesic Transcranial Electrical Neuromodulation™* ***(GTEN™) 100 Research*** system, refer to the ***GTEN 100 Research*** manual (8102120).

When launched as a standalone application, the Reciprocity Viewer provides most of the features as when launched from Net Station Review, except for source localization—there are no GeoSource settings for method, regularization, computation model, or head model when launched from Finder.

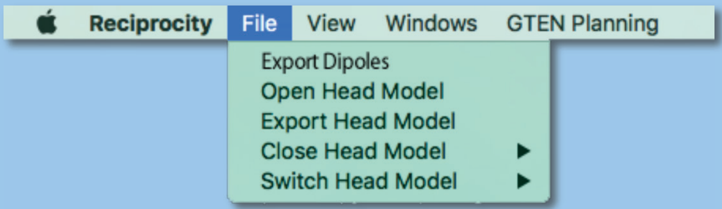
Note that source localization with all of Reciprocity's 3D source estimation and visualization features requires that you access your EEG data from Net Station Review.

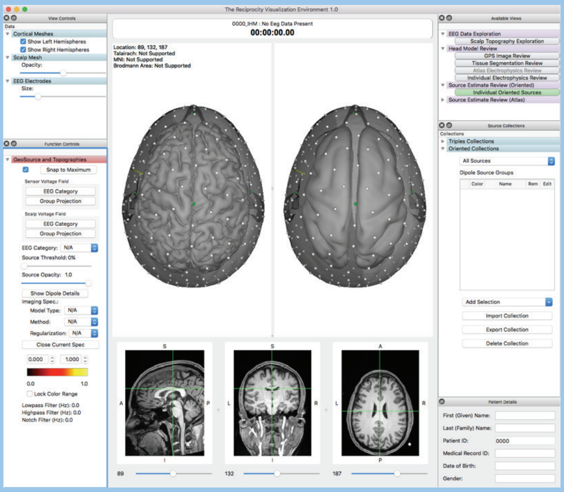
To launch the RVE and visualize a head model:

❶ Launch the RVE from **Applications > EGI > Net Station 5 > Reciprocity**.



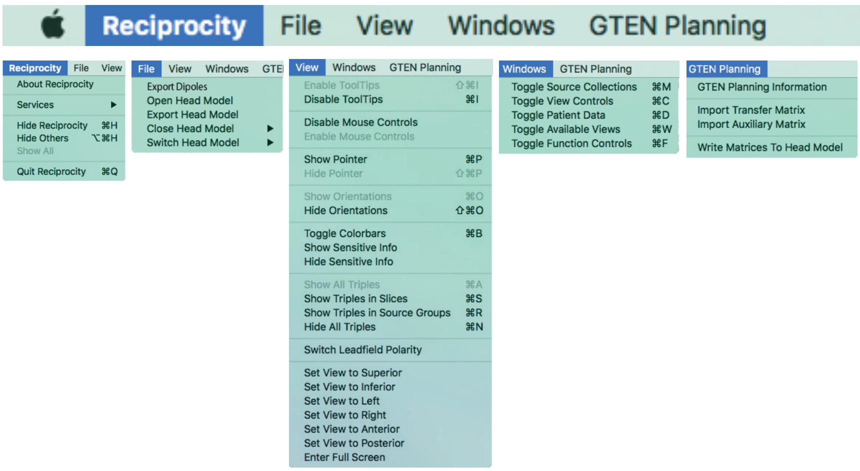
❷ Open a head model by clicking **File > Open Head Model**.





4.2 RVE's Menus

Standard menus operate as expected. Reciprocity-specific menus are described here.



Reciprocity. *About* gives you the version number of your copy of the RVE and *Quit* allows you to quit the application (or, you can click the red close button).

File. Use these menu options to open, export, close, or switch between opened head models. Also export dipoles.

When the RVE is launched from the Finder, remember that you have no source localization features for a file in the RVE. If you need to use the source localization features, you must launch the RVE from within Net Station Review. See section 4.1.

View. Use these menu options to set views to a particular angle of the head, toggle color bars, etc.

For additional controls that create source collections, view GeoSource and topographic data, and increase the visibility of areas of interest in head models, see sections 4.3.2, 4.3.4, 4.3.5, and 4.3.6.

Windows. Use these menu options to show/hide the five panes of the RVE window.

GTEN Planning. The GTEN Planning menu is described in the ***GTEN 100 Research*** manual (8102120).

4.3 RVE's Window, Features, and Controls

Not all features are available in all versions of the software. If you have any questions, contact EGI Technical Support (Table P-2).

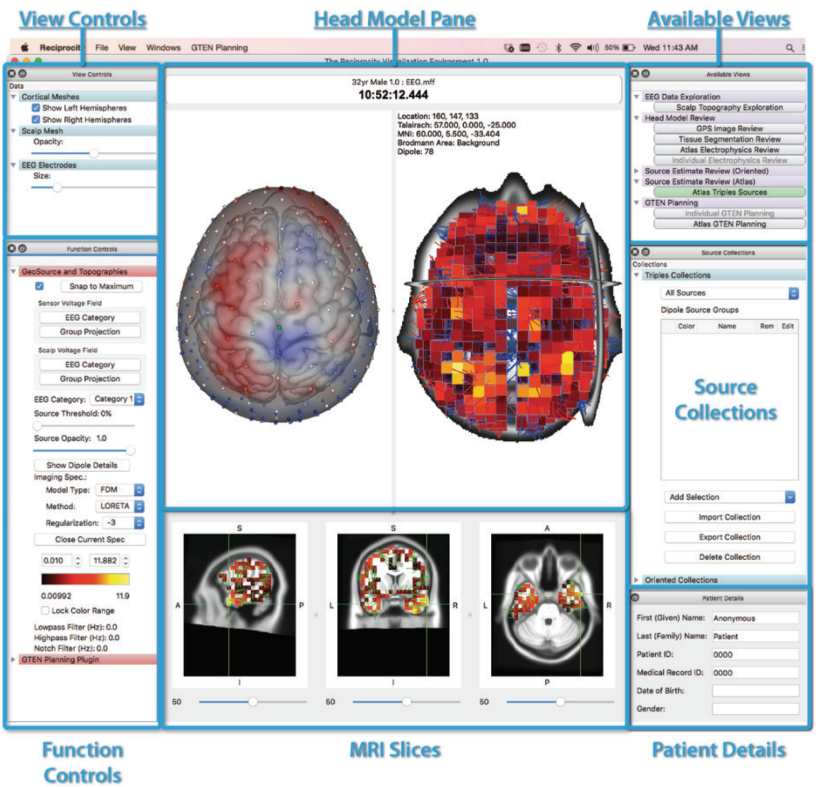


Figure 4-1. Features and controls of the RVE window

4.3.1 Available Views

Depending upon which version of GeoSource you have a license for (the FDA-cleared GeoSource 2.0 or the Basic, Intermediate, or Advanced level of *GeoSource* ***3.1 Research***), different views will be available to you in the RVE.

After the RVE opens, either from Net Station Review or Finder > Applications, the RVE provides a selection of views to facilitate your further research or clinical research work.

Remember that EEG data displayed in the RVE is controlled by the settings made in the Chart view of Net Station Review. See section 4.1.1.1.

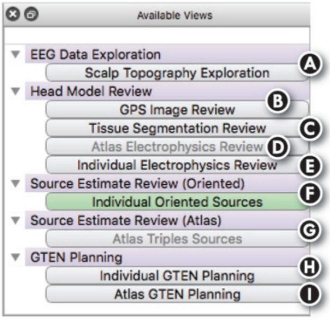


Table 4-4. Available views

Callout	View	Description
A	**EEG Data Exploration**	*Scalp Topography Exploration*. This is the 3D topo map view that is selected as a Method from Net Station Review.
B	**Head Model Review** Aside from any *GeoSource* ***3.1 Research*** or *GTEN* ***100 Research*** uses, these views are useful for verifying electrical head models.	*GPS Image Review*. This view shows how well EEG sensor positions are registered to CAHMs and IHMs.
C		*Tissue Segmentation Review*. This view shows how well tissue classifications are characterized.
D		*Atlas Electrophysics Review*. This view shows the forward leadfield projections of triples dipoles for built-in atlases and CAHMs.
E		*Individual Electrophysics Review*. This view shows the forward leadfield projections of oriented dipoles for IHMs.
F	**Source Estimate Review (Oriented)**	*Individual Oriented Dipoles*. This is a *GeoSource* ***3.1 Research Advanced*** view for IHMs.

Callout	View	Description
G	**Source Estimate Review (Atlas)**	*Atlas Triples Dipoles*. This is a *GeoSource **3.1 Research*** view for any atlas-based head model.
H	**GTEN Planning**	*Individual GTEN Planning. Present with licensed optional software*. Used to create modulation protocols with individual head models (IHMs).
I		*Atlas GTEN Planning. Present with licensed optional software*. Used to create modulation protocols with atlas and conformal atlas head models (CAHMs).

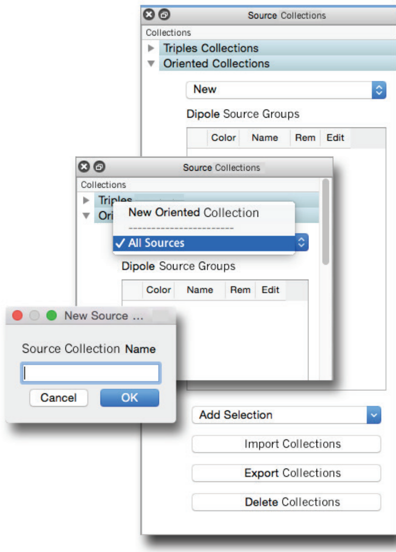
4.3.1.1 Default Settings for Available Views

The Available View buttons work as follows for all atlas and individual head models:

- Click a view button *once* to display data in that view, starting with that view's default settings.
- Click the same view button *again* to reset that view to its default settings, at any time during your exploration.
- Click another view's button, and that view will display the data with its default settings.
- **Zoom exception.** All view settings reset to default, except for the zoom setting. Even if you are changing from one view to another, the zoom setting will remain as it was set in the previous view.

4.3.2 Source Collections

You can create customized triples or oriented source collections within the RVE to display specific dipoles or dipole groups.



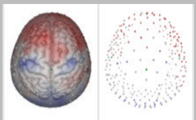
Remember that:

GeoSource 2.0	**=**	**GeoSource *3.1 Research***
source montage	=	source collections
ROIs	=	dipole source groups

In addition to creating dipole source groups from the Source Collections pane, you can select dipoles (voxels) manually.

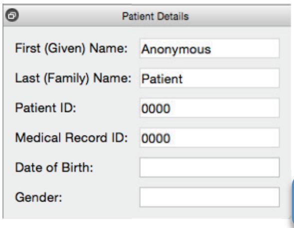
Table 4-5. Selecting dipoles (voxels)

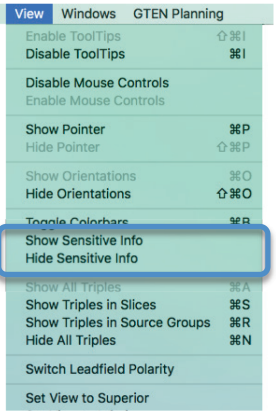
Method	**Keystrokes**	**Descriptions**
2D MRI Slices — *Basic* and *Intermediate* **For use with:** • **Atlas and Conformal Atlas Head Models (CAHMs)** • **Triples Dipole Source Groups** • **Triples Source Collections** 		
Individual	**Shift + click**	Selects individual dipoles to populate a dipole source group.
Radius	**Shift + click + drag**	Selects a group of dipoles within a drawn radius.

Method	Keystrokes	Descriptions
Threshold	**Cmd (⌘) + click**	Selects the first dipole and then displays a dialog box to enter a threshold value for the automatic selection of additional dipoles that are connected to the first dipole. For example, a threshold of 50 entered for a dipole of 10 µA fills the dipole source group with dipoles that are within ± 50% (5-15 µA).
Dynamic Threshold	**Cmd (⌘) + click + drag**	Selects the first dipole and then displays mouseover text of the threshold percentage value based upon the additional dipoles you select by dragging.
3D Head Models — *Advanced* **For use with:** • Individual Head Models (IHMs) • Oriented Source Groups • Oriented Source Collections		
Patch	**Cmd (⌘) + click**	Selects patches of dipoles to populate a dipole source group.

4.3.3 Patient Details

The Patient Details pane in Reciprocity is linked to the Show/Hide Sensitive Info button in Net Station Review.





You can change the display (show or hide) from Review or from Reciprocity by clicking **View > Show [or Hide] Sensitive Info**.

4.3.4 **Function Controls**—GeoSource and Topographies

Following are the function controls that appear when viewing GeoSource and topographic data.

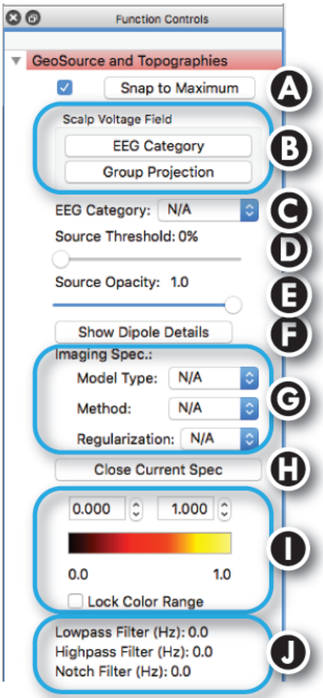
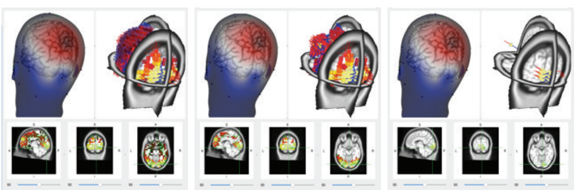
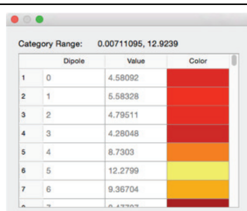
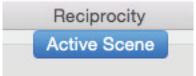


Table 4-6. Function controls for GeoSource and Topography views

Callout	Control	Description
A	**Snap to Maximum**	Centers the crosshairs to the location of the maximum (or highest) dipole intensity. **Checkbox**. When checked, the crosshairs will automatically snap to the location with the highest dipole intensity as you continue to move through the data. **Button**. When the checkbox is unchecked, the button is still available to selectively snap the crosshairs to the highest dipole intensity.
B	**Scalp Voltage Field**	Provides buttons to view scalp voltage data as scalp EEG categories or dipole source group projections.

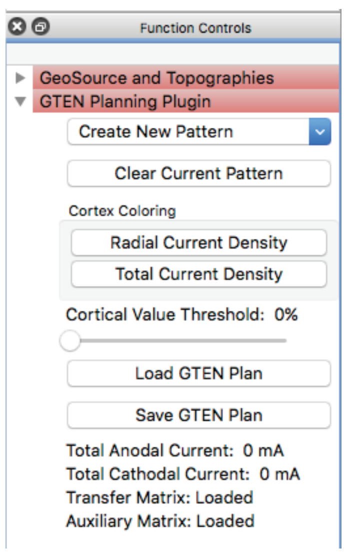
Callout	Control	Description
C	**EEG Category**	Shows the category currently being displayed, which is the category selected in Net Station Review and linked to the RVE. If multiple categories (as with overlaid segments) are being displayed in Net Station Review, use this selector to choose which category is displayed in the RVE.
D	**Source Threshold**	Displays more or fewer of the source results based on a percentage of threshold values for dipole intensity. Depending upon the selected threshold: • A **higher** percentage displays a wider range of dipole intensities, including all of the highest values (and colors) and gradually fewer of the lower values (and colors). • A **lower** percentage displays a narrower range of dipole intensities, including far fewer or none of the lower value intensities, but still showing most or all the highest valued dipole intensities.  threshold **0%** threshold **16%** threshold **68%**
E	**Source Opacity**	Adjusts the transparency of the displayed source data.
F	**Show Dipole Details**	For a category range, lists all dipoles and their values and colors. This dialog can be sorted and used to navigate (jump) to specific locations.  Any view, except 3D topo maps, will show dipole details.

Callout	Control	Description
G	**Imaging Spec**	Shows the *Model Type*, *Method*, and *Regularization* a file was launched with. To see a head model with other imaging specifications, go back into Net Station Review, click the **RVE** button again, and launch another RVE window for the same head model, but with different imaging specification parameters. The second RVE *scene* will show the same head model with different parameters that are linked to the same EEG data in Review. With multiple RVE windows open for the same head model (with different parameters), the Imaging Spec fields become active so that you can change the parameters for the *active head model* (that is, the *Active Scene*).  Note that only two head models can be open at the same time and only four windows associated with each head model can be open.
H	**Close Current Spec**	When multiple head models and imaging specifications are loaded into the RVE, this button closes the active imaging specification. When only one head model and imaging specification is open, this button closes the RVE completely. Note that two head models can be open at the same time, and each head model can have up to four imaging specifications open with it. To switch between multiple open head models, click **File > Switch Head Model**.

Callout	Control	Description
I	**Intensity color controls**	**Minimum and Maximum pickers**. Upon first displaying a file, these pickers display the default minimum (right picker) and default maximum (left picker) intensities. You can adjust these as desired. **Intensities color bar**. Graphically shows the intensities shown by the pickers. **Lock Color Range**. When checked, the minimum and maximum, as well as the spectrum palette, are locked, regardless of the time point changing. When unchecked, the minimum and maximum values will update as the current time point changes in the data.
	You can use these controls to make spatially discrete areas more obvious: • Reduce the maximum picker value by 20% to highlight the higher intensity voxels. • Reduce the number of low-intensity voxels that are showing by raising the minimum picker value.	
J	**Filters**	Shows the values of the lowpass, highpass, and notch filters as set in the file.

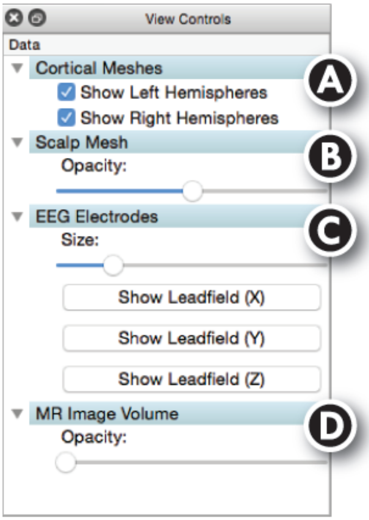
4.3.5 Function Controls—GTEN Planning Plugin

The Function Controls of the GTEN Planning Plugin are described in the ***GTEN 100 Research*** manual (8102120).



4.3.6 View Controls

The View controls increase the visibility of areas of interest in head models.



Not all view controls appear for all types of head models.

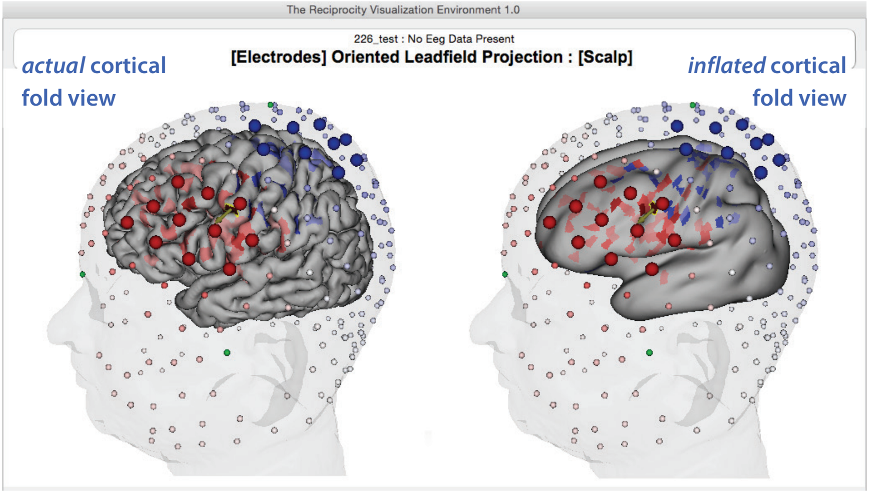
Table 4-7. View controls (*some are not available for all views*)

Callout	Control	Description
A	**Cortical Meshes**	Shows/hides the left and/or right hemispheres.
B	**Scalp Mesh**	Indicates the head surface. **Opacity slider**. Adjusts the transparency of the scalp mesh.
C	**EEG Electrodes**	Indicates the location of the EEG sensors across the head surface. **Size slider**. Adjusts the size of the displayed EEG sensors. **Show Leadfields (X, Y, and Z)**. For *triples* dipoles with three vectors (X, Y, and Z), these buttons change the leadfield projection to the stated direction (X, Y, or Z) and displays only this projection.
D	**MR Image Volume**	Indicates dipole intensities. **Opacity slider**. Adjusts the transparency of the segmentation overlay that is on top of the MRI slices.

4.3.7 Head Model Pane

Depending upon whether you are creating source data files with *GeoSource* ***3.1 Research*** or creating modulation protocols with GTEN 100 Research, the 3D head model pane is used to display EEG data and source results or to create dipole source groups and source collections.

The left 3D head model is an *actual* cortical fold view and the right 3D head model is an *inflated* cortical fold view.



To navigate within the 3D images, refer to the keyboard shortcuts given in section 4.4.

4.3.8 MRI Slices

The MRI slices of the RVE visualize the brain in one of two ways:

- **MRI brain**, when viewing individual head models (IHMs) with oriented dipoles, or
- **voxelated brain**, when viewing atlas head models, including conformal atlas head models (CAHMs) with triples dipoles.

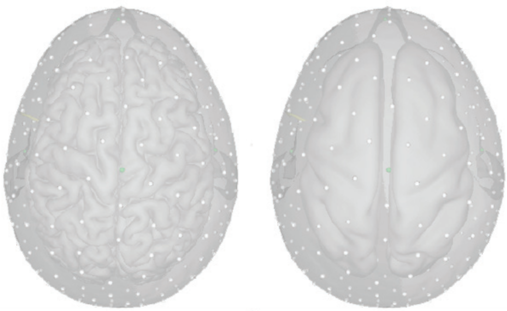
For details about voxels and dipoles, see section 3.1.

4.3.8.1 **MRI Brain** – showing oriented dipoles

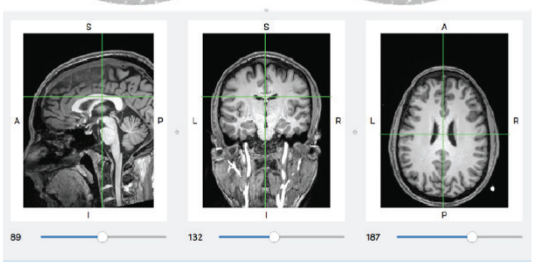
For individual head models (IHMs), the MRI slice panes display individual head geometry, such as tissue segmentation and cortical surface.

For IHMs, dipoles are oriented, which means they are one-directional and oriented perpendicular to the cortical surface.

corresponding 3D head model
showing oriented dipoles over
***actual* cortical folds on the left and**
***inflated* cortical folds on the right**



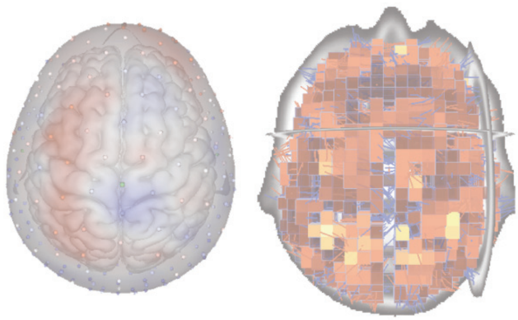
MRI brain slices
showing head geometry



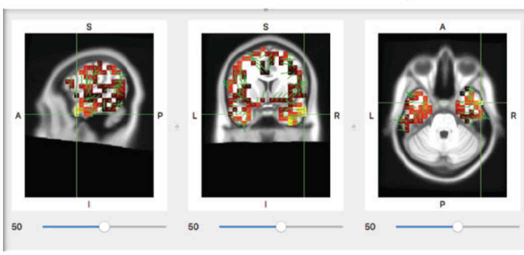
4.3.8.2 **Voxelated Brain** – showing triples dipoles

For atlas head models, including CAHMs, the MRI slice panes display dipole intensities overlaid onto sagittal, coronal, and axial MRI slices.

For atlases, dipoles are approximately represented by voxels, which are colored 3D volume pixels. Specifically, a single, colored dipole cube represents 7 voxels cubed. As a basic volume unit in the MRI slices, a dipole of 7 voxels x 7 voxels x 7 voxels is resampled in .egia files as 1 mm x 1 mm x 1mm.



corresponding 3D head model
showing a topo map over *actual* cortical folds on the left and showing all dipoles over *inflated* cortical folds on the right



voxelated brain MRI slices
showing triples dipoles

The **slice sliders** navigate to a specific slice in the corresponding pane (sagittal, coronal, or axial). As they do, the other two slice panes will update accordingly.

The grid numbers used in GeoSource do not correspond to Talairach Daemon or MNI coordinates.

4.4 3D Image and 2D Slice Shortcuts

The keyboard shortcut mappings available for *GeoSource* ***3.1 Research*** in the RVE allow you to easily rotate, zoom, move, and navigate 3D images and 2D MRI slices.

Table 4-8. 3D image and 2D slice keyboard shortcuts for *GeoSource* ***3.1 Research*** in the RVE

Mode	Function	Keys
2D slice	**Zoom**	Right-click + drag
	Move	Shift + right-click + drag
	MRI slice navigation	Left-click + drag
	Brightness	Cmd (⌘) + right-click + drag ⇔
	Contrast	Cmd (⌘) + right-click + drag ⇕
3D image	**Zoom**	Right-click + drag
	Move	Shift + right-click + drag
	Rotate	Left-click + drag

5. GeoSource Tools and Source Results

Whereas both the RVE and the GeoSource tool perform source estimation on EEG data:

- You can only *visualize* source results in the RVE.

  Note that you must have opened the RVE from Net Station Review to be linked to the EEG data file.

- You create source data files containing source waveform results with GeoSource tools from within Net Station Tools. These files have "_nsw" appended to their names.

  With these files, you can:

  - View source waveform results in Net Station Review using the GeoSource Waveform viewer.
  - Use the Statistic Extraction tool to extract the current values you need to perform statistical analysis.

  For details, refer to Appendix C, "Net Station's Tools," of the Net Station 5 manual (8100050).

The GeoSource tool may be specified differently for different evaluations, such as clinical research, interictal, or classic ERP. Even for the same evaluation, the tool may be specified with different parameters to better explore the data.

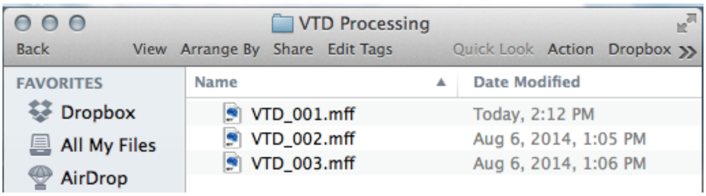
GeoSource will localize all scalp-recorded activity to dipoles distributed across the cortical grey matter. It is, therefore, important for the scalp data to be as artifact free as possible. This is accomplished through careful data acquisition followed by postprocessing to identify and correct/remove artifact-contaminated trials and channels.

Common workflows (clinical research, interictal, classic ERP, etc.) containing different tools and settings are available from EGI Technical Support (Table P-2).

To specify a GeoSource specification tool, do the following:

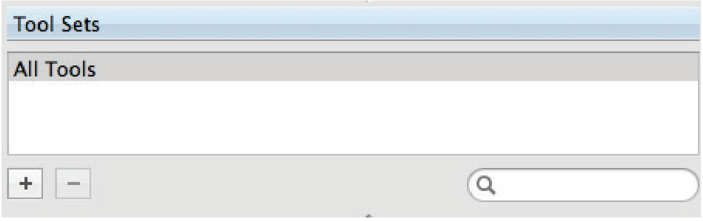
1. Know where your session data files are.

   In this example, the three session data files are titled VTD_00X and the folder they are in is titled VTD Processing.



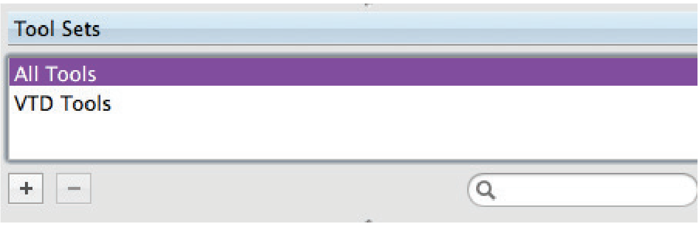
2. Open the **Net Station Tools** module of Net Station 5.

3. Tool sets are optional but, if desired, click **+** (**plus**) to make a new tool set.

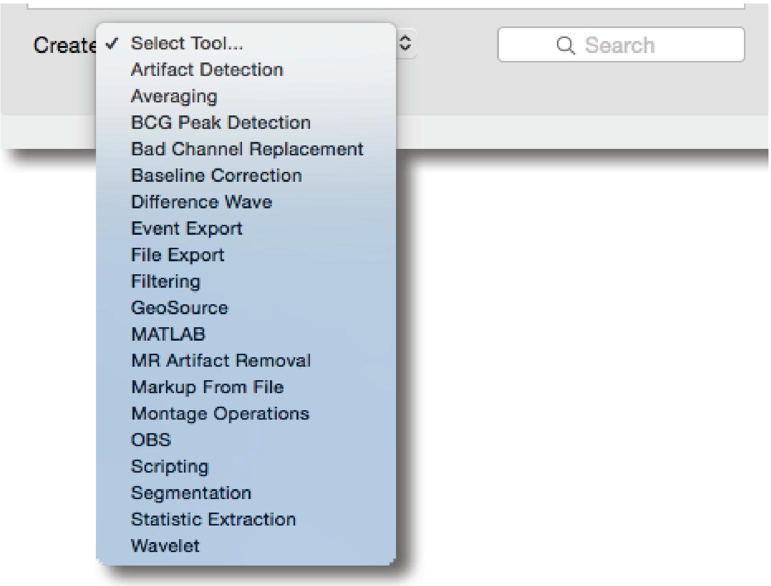


4. If you created a new tool set, name it.

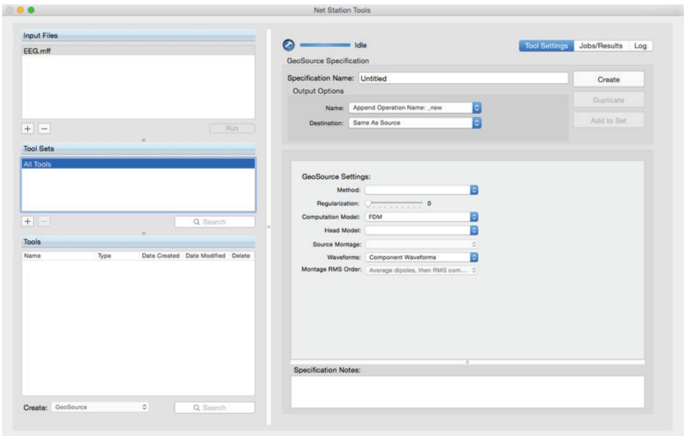
   In this example, change the untitled tool set to VTD Tools.



5. Beside Create, select **GeoSource** as the tool to be specified.

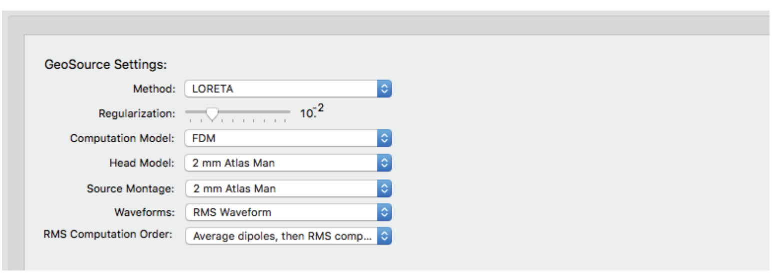


6. A new GeoSource specification with default settings appears on the right. Type a **name** for this new specification (that is, this new tool) into the Specification Name field.



7. Under GeoSource Settings, set the fields as follows:

- **Method**: LORETA
- **Regularization**: 10^{-2}
- **Computation Model**: FDM
- **Head Model**: 2 mm Atlas Man
- **Source Montage**: 2 mm Atlas Man
- **Waveforms**: RMS Waveform
- **RMS Computation Order**: Average dipoles, then RMS components



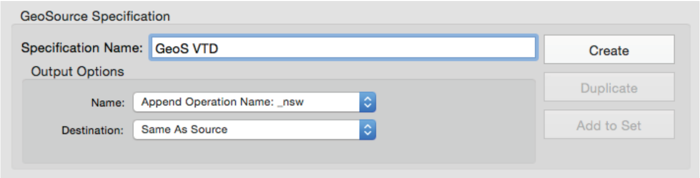
RMS Computation Order*—atlases only*

GeoSource provides the following options for the RMS Computation Order setting, when the Waveforms setting is set to RMS Waveform.

Average dipoles, then RMS components. To take orientation into account, this option takes the mean of each vector orientation (i.e., the mean of all Xs, the mean of all Ys, and the mean of all Zs), and then takes the RMS at the end.

RMS components, then average dipoles. To take the magnitude of each dipole triple into account, this option takes the RMS of the vector strengths of each dipole triple first, and then takes the average across the group.

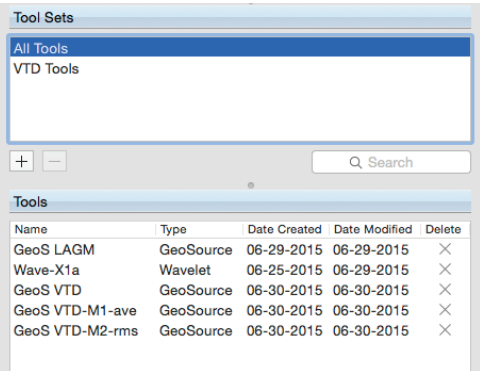
8. For this example, leave the Destination output **Same As Source** and click **Create**. This creates a tool that outputs files with automatically appended names (for GeoSource specification tools, "_nsw"), saved to the source file's location.



The GeoSource *tool* outputs source waveform files.

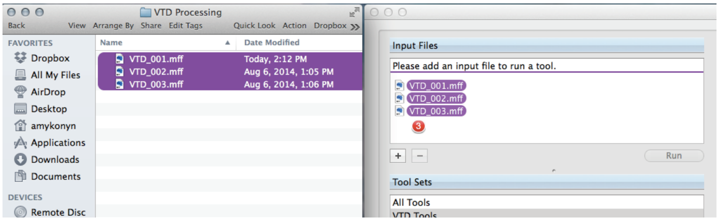
9. Notice that your new GeoSource tool appears in the Tools pane below the Tool Sets pane.

   As shown in the image, when estimating sources, you would normally explore your data with various versions of the GeoSource Tool to verify results.



10. Drag your **session files** to the Input Files pane.

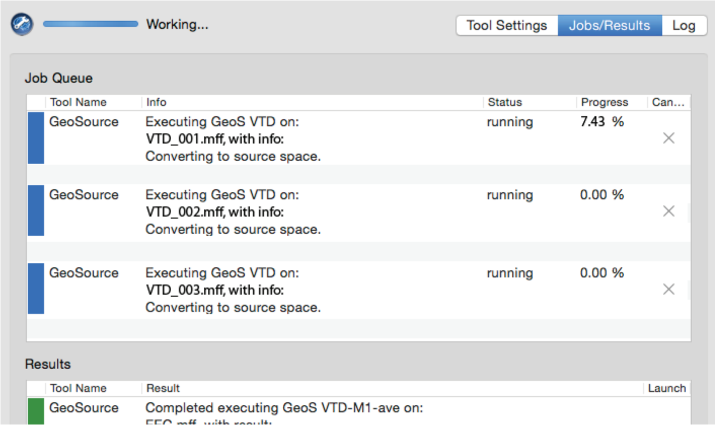
    Note that tools have been run successfully on up to 30 input files.



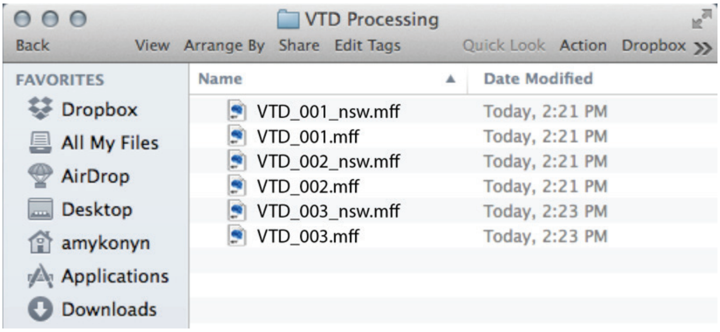
11. If not done already, select (highlight) your **new GeoSource tool** in the Tools pane.

    Confirm you have selected the correct tool and that the specification settings are correct.

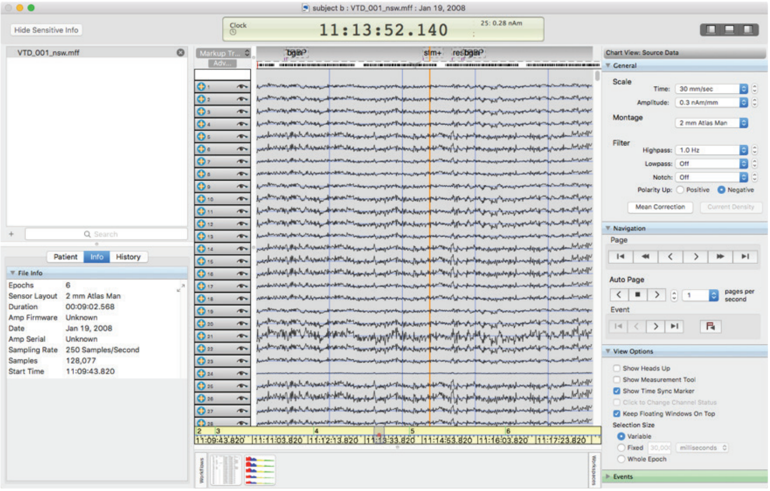
12. Click **Run** to process the files. Net Station will display the Job Queue and begin executing the selected tool.



13. New _nsw.mff source data files will appear in the processing folder, which, in this case, also contains the .mff EEG data files.



14. Double-click your **new source data files** to open them in Net Station Review. Confirm the quality of the source results.



6. Defining Source Collections

You will define dipole source groups from which to build your source collections. This chapter uses an *oriented* source collection as an example.

When a source collection is created, only the voxels and the names of the dipole source groups that are included in the source collection are highlighted in the MRI panes of the RVE.

Remember that a source montage in GeoSource 2.0 is the same as a source collection in *GeoSource* ***3.1 Research***.

TRIPLES SOURCE COLLECTIONS (used with atlas and conformal atlas head models (CAHMs))**:** Notice that each dipole source group of a source collection is displayed as a composite dipole with three vectors. Also notice that the length of each vector indicates the intensity of the corresponding dipole's orientation in the X, Y, and Z planes. The vectors point in the positive direction of the dipolar activity. In orthogonal slice views, only two of the three vectors are visible. For example, the coronal slice view shows vector orientation strengths in the X and Z directions.

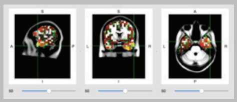
ORIENTED SOURCE COLLECTIONS (used with individual head models (IHMs)**:** Dipoles of source groups and source collections are oriented perpendicular to the cortical surface.

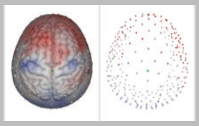
OBSERVATIONS: Observe the relationship between the source solution and the scalp topography. Look for brain regions and orientations that would volume conduct to produce your major scalp topographic features.

6.1 Manually Selecting Dipoles for Dipole Source Groups

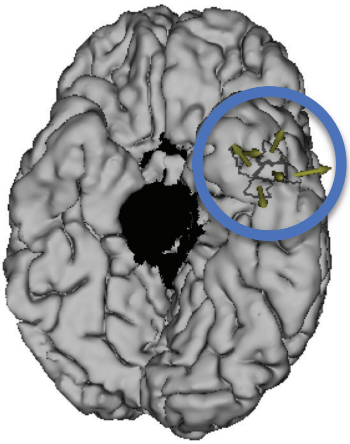
In *GeoSource* ***3.1 Research's*** 2D MRI Viewer, do the following to manually select dipoles for dipole source groups.

Table 6-1. Selecting dipoles (voxels) for dipole source groups

Method	Keystrokes	Descriptions
2D MRI Slices — *Basic* and *Intermediate* **For use with:** • Atlas and Conformal Atlas Head Models (CAHMs) • Triples Dipole Source Groups • Triples Source Collections		
Individual	**Shift + click**	Selects individual dipoles to populate a dipole source group.
Radius	**Shift + click + drag**	Selects a group of dipoles within a drawn radius.
Threshold	**Cmd (⌘) + click**	Selects the first dipole and then displays a dialog box to enter a threshold value for the automatic selection of additional dipoles that are connected to the first dipole. For example, a threshold of 50 entered for a dipole of 10 µA fills the dipole source group with dipoles that are within ± 50% (5-15 µA).
Dynamic Threshold	**Cmd (⌘) + click + drag**	Selects the first dipole and then displays mouseover text of the threshold percentage value based upon the additional dipoles you select by dragging.

Method	Keystrokes	Descriptions
3D Head Models — *Advanced* For use with: • Individual Head Models (IHMs) • Oriented Source Groups • Oriented Source Collections 		
Patch	**Cmd (⌘) + click**	Selects patches of dipoles to populate a dipole source group.

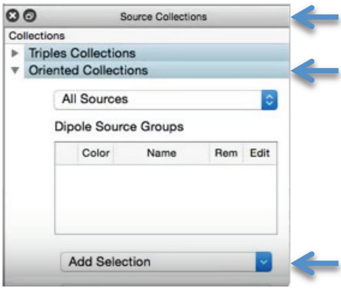
6.2 Defining Dipole Source Groups and Source Collections



❶ Select the relevant cortical surface dipole source(es). You can select one or more dipole sources.

1. **Click** once to select a dipole source.
2. **Cmd+click** to select multiple dipole sources.

   Selected dipole sources are outlined with a darker gray and display their directional dipole arrows.



❷ Add these dipole source groups to a new group:

1. Expand the **Source Collections** pane.
2. Expand the **Oriented Collections** pane.

3. From the Add Selection drop-down box, select **Add As New Group**.

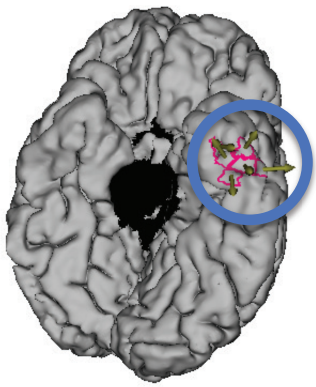
4. In the following pop-up dialogs:

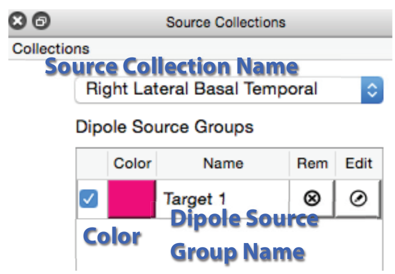
   a) Enter a unique **source collection name**.

   b) Enter a unique **source group name**.

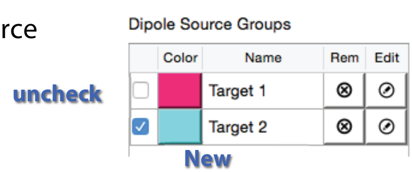
   c) Select a unique source group **color**.

5. After these selections, both the cortical surface image and the Source Collections pane will update with your parameters.





6. To add additional dipole source groups, first, deselect (*uncheck*) all active groups.



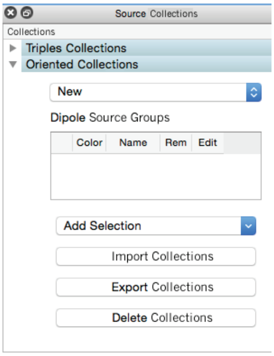
7. To add an individual dipole to an existing dipole source group:

   a) Click a **dipole**.

   b) From the Add Selection drop-down box, select **Add To Existing Group**.

c) Select a **Dipole Source Group**. The new dipole will take on the color of the assigned dipole source group.

8. If desired, click **Export Collection**.



7. Head Modeling with MIP

The Modal Image Pipeline™ (MIP) software from Electrical Geodesics, Inc. (EGI) is a separate application that is included with your *GeoSource* ***3.1 Research*** *Intermediate* or *Advanced* license. The MIP creates realistic conformal atlas head models (CAHMs) for *Intermediate* and *Advanced*, and creates individual head models (IHMs) for *Advanced*.

When taken into *GeoSource* ***3.1 Research***, these more accurate head models improve the estimations of source locations from scalp EEG data. Among other uses, these more accurate head models are useful for deriving neuromodulation plans with GTEN 100 Research.

For details, refer to the GTEN 100 Research manual (8102120).

7.1 Identical Subject/Patient IDs

In order to complete any head modeling and/or GTEN workflow, the subject/patient ID must be *identical in all files* used in the workflow. When it is not identical, the software will stop you with a warning message to correct the mismatch.

Table 7-1. File types used to create head models or GTEN workflows

Files	CAHMs	IHMs	GTEN
EEG (.mff)	✔	✔	
Sensor coordinates (.gpsr or .sfp)	✔	✔	
MR images (.egia)		✔	
Head model (.gsrc)			✔
GTEN Planning (.mcb)			✔

7.2 Processing

The MIP software, to create conformal atlas and individual head models, uses a patented method that identifies seven different tissue types from MRI images:

- white matter (WM)
- grey matter (GM)
- cerebrospinal fluid (CSF)
- skull
- scalp
- eyeballs
- air

Based on the finite difference method (FDM) and using GPU-accelerated computing, the MIP software creates conformal atlas head models (CAHMs) in about 30 minutes and individual head models (IHMs) in about 90 minutes.

These more accurate head models can then be taken into *GeoSource* ***3.1 Research*** (Intermediate and Advanced) for the estimation of source locations and into GTEN 100 Research for the creation of neuromodulation plans.

Table 7-2. Required inputs to generate head models

Head model	MIP inputs	GeoSource version
Conformal Atlas Head Models (CAHMs)	GPS .gpsr files **or** GeoScan .sfp files	*GeoSource* ***3.1 Research*** *Intermediate* and *Advanced*
Individual Head Models (IHMs)	MRI* files **plus** .sfp, .gpsr, or averaged**	*GeoSource* ***3.1 Research*** *Advanced*

* For individual head models (IHMs), you will also use OsiriX MD to prepare your MRI files for entry into the MIP.

** An individual solved sensor position file (.sfp or .gpsr) is not required for the IHM workflow. You can use one of the built-in averaged sensor position files. However, be aware that these averaged files are not ideal for IHMs.

7.2.1 Four Fundamental Stages

The CAHM and IHM head models are created in four fundamental stages. The first three stages are processed by the MIP software on your EGI Mac system computer. The last stage, generating the LFM, is processed on your EGI GPU-accelerated computer.

Perform for IHMs, but not for CAHMs.

Stage 1—Tissue segmentation. The MIP's algorithm first identifies the seven different tissue types directly from MRI scans. To estimate the skull tissue, which is not identifiable in the MRI data, an atlas skull is warped to the MRI identified tissue.

This processing produces an *anatomy.egia* file.

For CAHMs, stages 1 and 2 are calculated within the atlas head models; therefore, the creation of CAHMs starts with "stage 3."

Perform for IHMs, but not for CAHMs.

Stage 2—Cortical surface extraction. The MIP software then creates 2,400 or 4,800 dipoles (triples for CAHMs and oriented for IHMs) on a tessellated cortical surface.

This stage produces a *geometry.egig* file.

For CAHMs, stages 1 and 2 are calculated within the atlas head models; therefore, the creation of CAHMs starts with "stage 3."

Stage 3—Sensor registration. The 3D sensor positions contained in either GeoScan's .sfp files or GPS's .gpsr files are used differently for CAHMs and IHMs.

Perform for both CAHMs and IHMs.

For CAHMs, the 3D sensor positions are used to warp a given atlas to an individual's inferred geometry, which is based on the positions of EEG sensors that are completely covering the head.

For IHMs, the 3D sensor positions are registered to the scalp model that was derived from an individual's MRI.

At the end of this stage, which is processed within the MIP, conductivity values are assigned to each tissue type before creating the bundled zip file that you will take into the GPU-accelerated computer to generate the LFM.

For both CAHMs and IHMs, this stage must be completed.

Stage 4—Lead field matrix (LFM) generation. Using a GPU-accelerated computer, this last stage generates the lead field matrix (LFM) that relates how current from a given brain location (dipole) is propagated to the scalp and is recorded as voltage potentials at each EEG sensor position.

Perform for both CAHMs and IHMs.

For both CAHMs and IHMs, this stage must be completed.

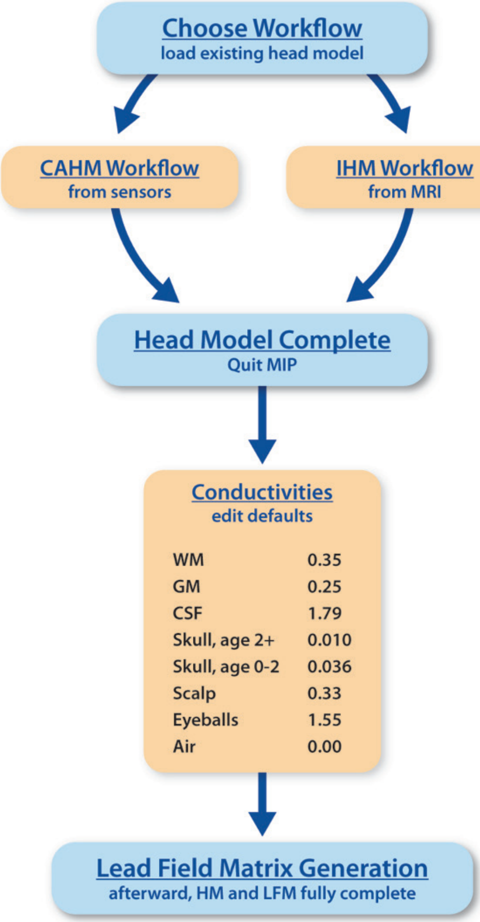


Figure 7-1. MIP workflows for CAHMs and IHMs

7.2.2 Information Generated by MIP

The MIP software creates the following information for *GeoSource **3.1 Research*** (Intermediate and Advanced).

• **MRI volume**	for visualization
• **Dipole locations**	for visualization and calculating source intensities
• **Surface meshes of the cerebral cortex**	one for each hemisphere for visualization in the Reciprocity Visualization Environment (RVE)
• **Inflated surface meshes of the cerebral cortex** (*only IHMs*)	one for each hemisphere for visualization in the RVE
• **Surface mesh of the scalp**	for visualization in the RVE
• **Lookup tables for the Talairach transformation**	to allow navigation in both native and Talairach coordinates
• **Lead field matrix (LFM)**	for calculating the source intensities

7.2.3 How MIP Generates Information

Through tissue segmentation, cortical surface extraction, and sensor orientation, a processed version of an MRI is created where every voxel is assigned a tissue type with known conductivities.

Table 7-3. Default conductivities for the seven segmented tissue types

Tissue Type	Default Conductivities (S/m)
White matter (WM)	0.35
Grey matter (GM)	0.25
Cerebrospinal fluid (CSF)	1.79

Tissue Type		Default Conductivities (S/m)
Skull	age 2+	0.010
	age 0-2	0.036
Scalp		0.33
Eyeballs		1.55
Air		0.00

This processing produces an *anatomy.egia* file.

7.3 MIP's Two Workflows

The MIP software will guide users step-by-step through the tissue segmentation, cortical surface extraction, and sensor registration stages of the MIP's workflows for generating CAHMs and IHMs. These stages are processed on your Mac computer. Stage 4 uses the GPU-accelerated computer to generate LFMs.

7.3.1 Conformal Atlas Head Model (CAHM)

A conformal atlas head model (CAHM) is created with an atlas when no MRI scan exists for a subject. This head model uses one of the pre-packaged, built-in atlases (i.e., generalized head models) that are based on generalized age and gender.

Since stages 1 and 2 (tissue segmentation and cortical surface extraction) are already

Built-in Atlas Head Models

Male pediatric atlas:	0 to 2 years
Male pediatric atlas:	2 to 9 years
Female pediatric atlas:	9 to 18 years
Male adult atlas:	32 years
Male adult atlas:	40 years
Female adult atlas:	45 years

The MIP software will automatically suggest the closest match to the subject's data, but you can change this selection as needed.

determined from the atlas head models, users need to complete only stages 3 and 4 (sensor registration and lead field generation).

After a built-in atlas head model that is closest to the subject's age and gender is selected, it is warped by the subject's 3D sensor positions (from either a GeoScan **.sfp** file or a GPS **.gpsr** file), which acts as a geometrical target.

For CAHMs, dipoles have three orthogonal orientations.

7.3.2 Individual Head Model (IHM)

An individual head model (IHM) can be created where an MRI scan exists for a subject. For IHMs, users will need to complete all four stages (tissue segmentation, cortical surface extraction, sensor registration, and lead field generation).

For IHMs, dipoles are oriented perpendicular to the cortical surface.

Higher Quality MRI Images

Be aware that higher quality MRI images will:

- **Determine the quality of the IHMs created by the MIP.**
- **Require less manual editing during MIP processing.**

To ensure that your MRI images are optimized for head modeling, see Appendix A (*MRI Scanning Guidelines*) and/or contact EGI Technical Support (Table P-2).

8. Creating CAHMs

Creating conformal atlas head models (CAHMs) takes only about 30 minutes, and the MIP steps you through the process. See Figure 8-1. You can complete stage 3 (sensor registration) on the same computer that is running Net Station Review. This workflow accepts solved sensor files (.sfp files from GeoScan or .gpsr files from GPS), but not averaged sensor position or other file formats.

After you complete this processing, you will generate the lead field using the GPU-accelerated computer (see chapter 10).

Remember that, for CAHMs, the tissue segmentation (stage 1) and cortical surface extraction (stage 2) are calculated within the atlas head models and not while creating the CAHMs. Therefore, creating CAHMs starts with stage 3.

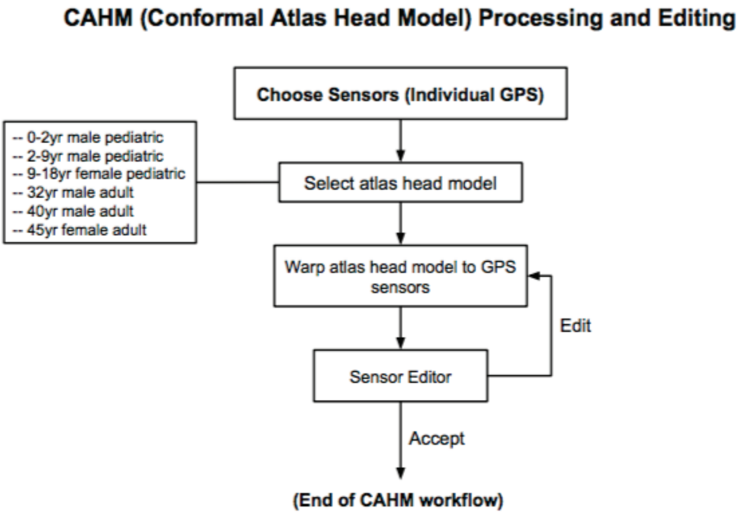
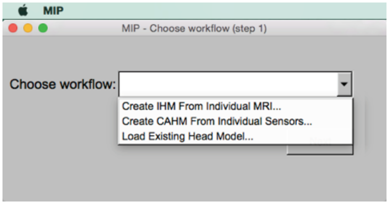


Figure 8-1. Stage 3 of the CAHM workflow (*stages 1 and 2 are calculated within the atlas*)

To complete stage 3 of the CAHM workflow, do the following:

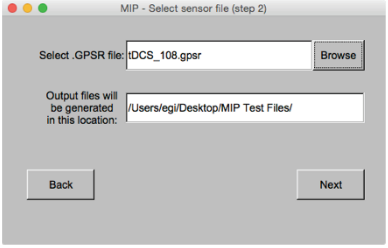
❶ Launch **MIP** from Finder/Applications/EGI/MIP/.

❷ Select **Create CAHM From Individual Sensors**, for a CAHM head model, requiring an .sfp or .gpsr file.



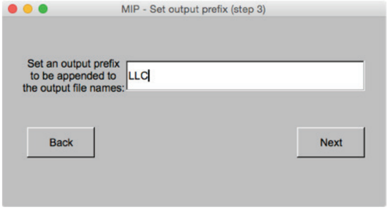
Note that the Load Existing Head Model option is used for reviewing a completed heac model or resuming the processing of an incomplete head model.

❸ **Browse** to select the .sfp or .gpsr file to use in creating the head model.

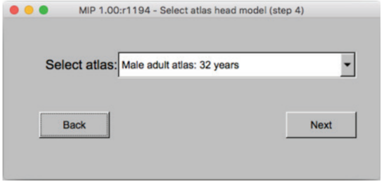


❹ Type a prefix to append to the output file.

This is required.



❺ One of the six built-in atlas head models will be preselected based on the closest age and gender to that in the .sfp or .gpsr file. You can, however, reselect another.



Male pediatric atlas – 0 to 2 years
Male pediatric atlas – 2 to 9 years
Female pediatric atlas – 9 to 18 years

Male adult atlas – 32 years
Male adult atlas – 40 years
Female adult atlas – 45 years

This atlas will warp to the sensor locations and give a more accurate head geometry for all of the tissues in the resulting head model.

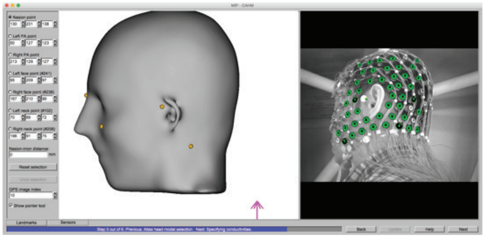
❻ Wait for the MIP to open the GPS sensor registration window.

This will take some minutes.

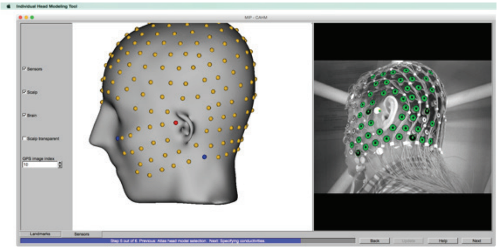
❼ Adjust landmark points and ensure the sensors on the 3D head model (left pane) are placed ***exactly*** as in the net application photos (right pane).

1. Click **Landmarks**.

2. Manually adjust the **seven points**, if necessary.



Landmarks screen



Sensors screen

Navigate in the 3D and 2D panes by:

- Using the keyboard shortcut mappings (see section 4.4).
- Selecting a camera in the GPS camera view field.

Purpose of landmark points:

Landmark points are what you use to adjust the individual sensors.

When you move landmark points:

- **all sensors will move around the head; although**
- **sensors closer to a moved landmark point will move relatively farther than sensors further away from the landmark point.**

You cannot move the individual sensors themselves.

How landmark points adjust individual sensors:

1. Click the **radio button** of one of the seven landmarks, then either:
   a) shift+click to place and/or move the selected landmark, or
   b) use the X, Y, or Z number fields to move the selected landmark's location.
2. When satisfied with sensor positions, click **Update.**

Also:

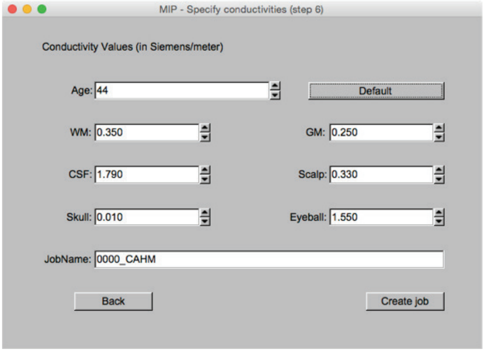
- Landmark points that contain electrodes provide their corresponding sensor number. For instance, the left neck landmark point is identified as sensor #102.
- To return a mark to its default position, click the **Reset selection** button.
- To undo the last action, click the **Undo selection** button.

3. When satisfied with your changes, click **Update**.
4. Next, verify the sensors and adjust the landmarks, if needed.
   a) Click **Sensors**.
   b) Review all sensors in more than one camera image.
      - Ensure there are no sensors *on* the ears.
      - Look carefully to ensure there are no sensors tucked in behind the ears.
   c) If adjustments are needed, click **Landmarks**.
   d) Make landmark adjustments.
   e) When satisfied with your changes, click **Update**.

Continue working between the Landmarks and Sensors windows until the sensors on the 3D head model the ***exactly match*** the sensors in the 2D net application photos. Remember to click Update to save changes.

❽ When satisfied with changes, click **Next** to specify conductivities.

❾ The default conductivity values that appear are based on the most up-to-date values suggested by literature and EGI's own work.



You may change any of the defaults, if desired. Before doing so, however, you should have the knowledge to do so prudently. To revert back to the MIP's default values (at any time before clicking Create Job), click **Default**.

❿ Click **Create job**.

When complete, your working directory will contain:

- Folder with the 3D sensor positions file (.sfp or .gpsr)
- Folder with the prefix you assigned in step ❹ containing:
    - anatomy.egia
    - geometry.egig
    - JobName.zip
- Folder named "internal_data"

Now, go to chapter 10, for lead field generation.

9. Creating IHMs

Creating individual head models (IHMs) takes only about 90 minutes, and the MIP steps you through the process. See Figure 9-1. You can complete the anatomical processing portion on the same computer that is running Net Station Review. This workflow accepts .egia MRI scan files and solved sensor position files (.sfp files from GeoScan or .gpsr files from GPS).

Note that an individual solved sensor position file (.sfp or .gpsr) is not required for the IHM workflow. You can use one of the built-in averaged sensor position files. However, be aware that these averaged files are not ideal for IHMs.

After you complete this processing, you will generate the lead field matrix using the GPU-accelerated computer (chapter 10).

Higher Quality MRI Images

Be aware that higher quality MRI images will:

- **Determine the quality of the IHMs created by the MIP.**
- **Require less manual editing during MIP processing.**

To ensure that your MRI images are optimized for head modeling, see Appendix A (*MRI Scanning Guidelines*) and/or contact EGI Technical Support (Table P-2).

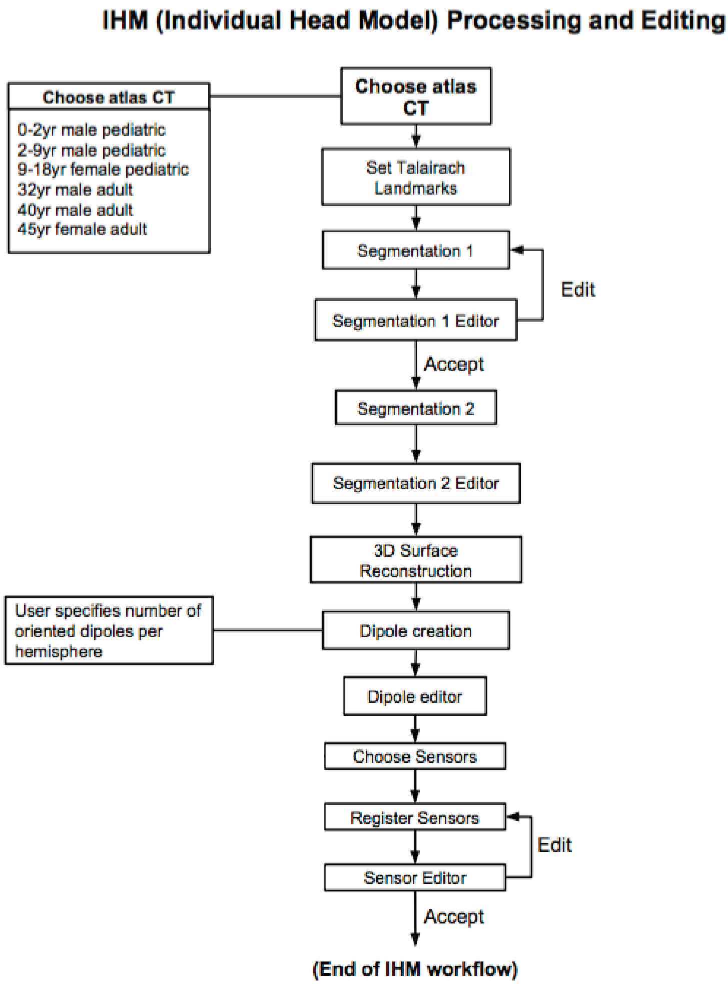


Figure 9-1. Stages 1 – 3 of the IHM workflow

9.1 Preparing MRI Files with OsiriX MD

Before you create an individual head model with the MIP software, you need to format your MRI files and locate them in a specific directory.

You format your files by running them through OsiriX MD, which was included with your MIP purchase.

You locate your files in a *working directory,* which is a folder that you establish for all of the input data files the MIP software will need. This is also the folder where the MIP's generated output files will be saved.

Note that once you start processing, you cannot change the location for the output files.

Where the MIP and OsiriX MD applications are installed on your local hard drive:

- **MIP software**
  Location: ***Applications/EGI/MIP***
- **OsiriX MD software**
  Location: ***Users/<username>/Library/Applications Support/OsiriX MD***
- **OsiriX MD plug-ins**
  Accessed from within the open application.

If the GeoSource and/or MIP software is purchased with a new system, it comes installed on the EGI system computer. If you need to download software purchased separately from a system or you need to reinstall the software, contact EGI Technical Support (Table P-1).

❶ Create a folder to be your working directory for the following:

- 3D sensor positions file (.sfp or .gpsr)
- MRI scan files (.egia)

❷ Ensure that you are using a supported version of OsiriX MD to convert your MR images. Using an unsupported version will cause the resulting .egia file to be suspended with a warning message.

If you have any questions, contact EGI Technical Support (Table P-2).

❸ Convert the MR images to the necessary **.egia** format.

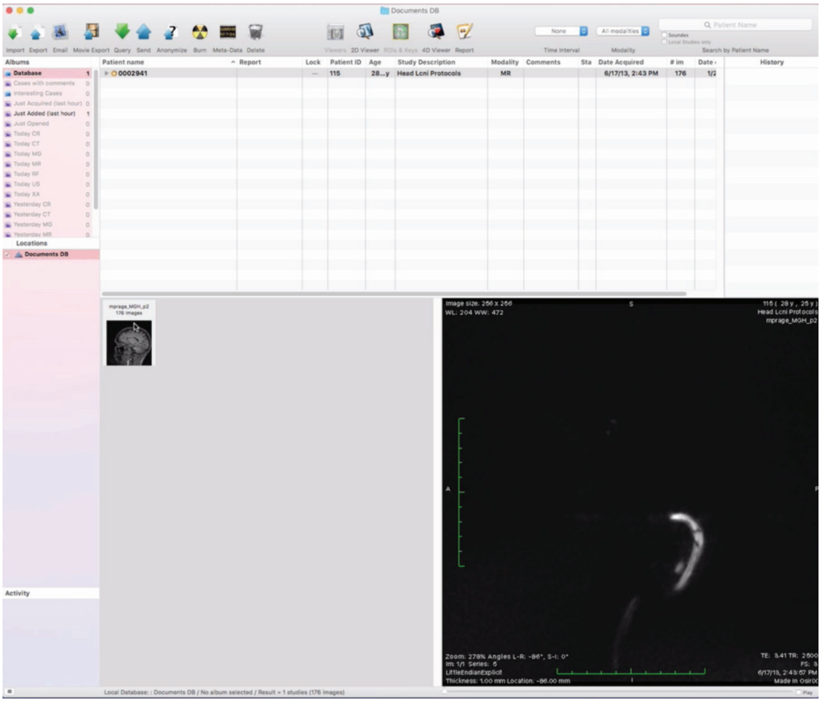
1. Load the MR file(s) into OsiriX MD by dragging the archive of raw MR data onto the OsiriX MD icon in the Mac's Dock.

2. Wait for the MR data to automatically load into OsiriX MD.

❹ When the OsiriX MD window opens:

- Notice the series of thumbnails.
- T1 MPRAGE (or equivalent) image files are required, and one's with the most head coverage are highly recommended.

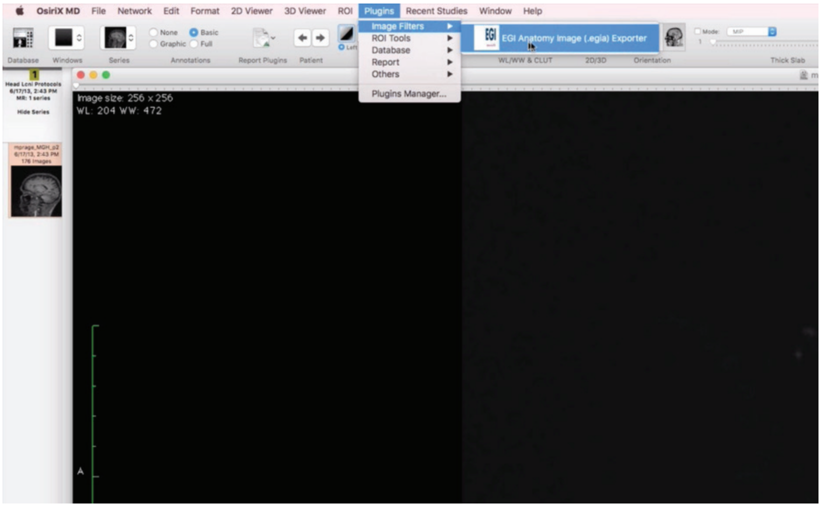
  For structural imaging requirements, see Appendix A. If you have any questions, contact EGI Technical Support (Table P-2).
- Double-click to select that thumbnail.



❺ After the MR image loads, click the **MR image** to unlock and make all features in the OsiriX MD window available.

If needed, this will also allow you to verify the patient information appended to the file.

❻ From the menu bar, click **Plugins** > **Image Filters** > **EGI Anatomy XML Exporter**.



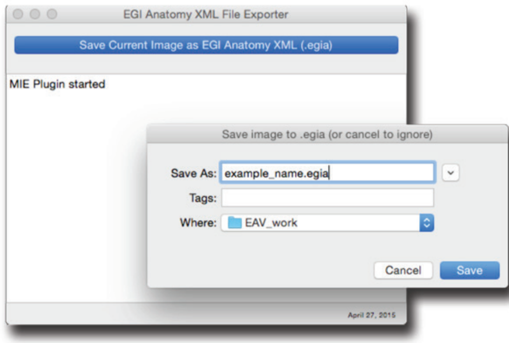
❼ From this plug-in, export the anatomy files in the **.egia** format to your working directory:

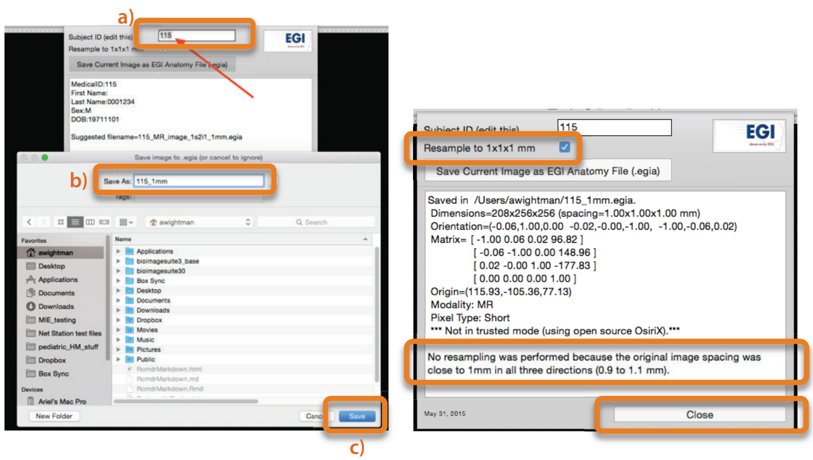
1. With or without editing the Subject ID.

   Remember that the subject ID must be identical in all files (.mff, .sfp or .gpsr, .egia, .gsrc, and, if later using GTEN 100 Research, .mcb) used in the workflow.

2. Typing an appropriate file name.

3. And clicking **Save**.





❽ Ensure that you are saving the .egia file to your working directory.

❾ Ensure that the **Resample to 1x1x1 mm** field is checked.

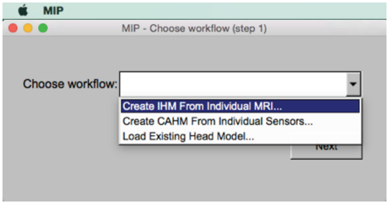
❿ Click **Close** to quit OsiriX MD.

9.2 Setup Before Stage 1

Before beginning with stage 1 (tissue segmentation), you need to set up the MRI scan and atlas CT files.

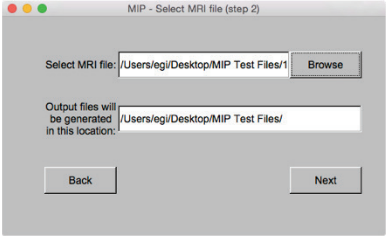
❶ Launch **MIP** from Finder/Applications/EGI/MIP/.

❷ Select **Create IHM From Individual MRI**, for a IHM head model, requiring a .egia file.



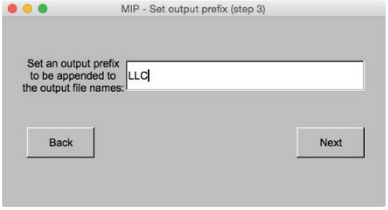
Note that the Load Existing Head Model option is used for reviewing a completed head model or resuming the processing of an incomplete head model.

❸ **Browse** to select the .egia MRI scan file to use in creating the head model.

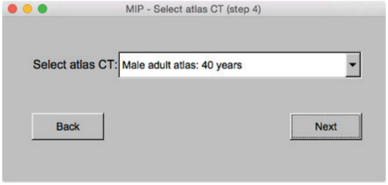


❹ Type a prefix to append to the output file.

This is required.



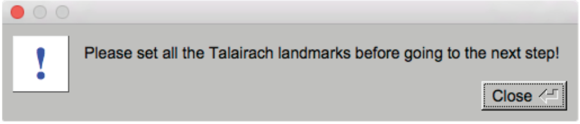
❺ One of the six built-in atlas CT head models will be preselected based on the closest age and gender to that in the **.egia** file. You can, however, reselect another.



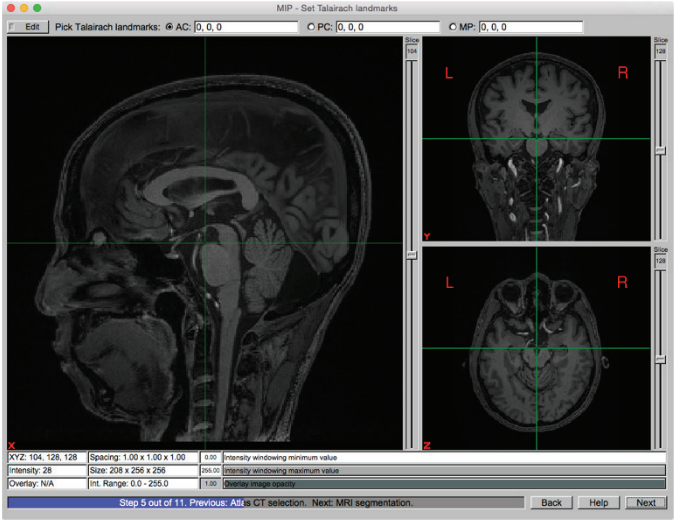
Male pediatric atlas – 0 to 2 years
Male pediatric atlas – 2 to 9 years
Female pediatric atlas – 9 to 18 years
Male adult atlas – 32 years
Male adult atlas – 40 years
Female adult atlas – 45 years

This CT atlas will warp to your MRI scan and give more accurate bone structure to your head model.

The Set Talairach Landmarks window will appear next. You will be required to set the Talairach landmarks before continuing.



❻ With the Set Talairach Landmarks window, you will perform a Talairach transformation on the MR data by providing the software with three needed anatomical points.



CAUTION: Carefully mark the Talairach landmarks. This early step will significantly affect all later processing.

1. Click **Edit**. This activates the editing tools.

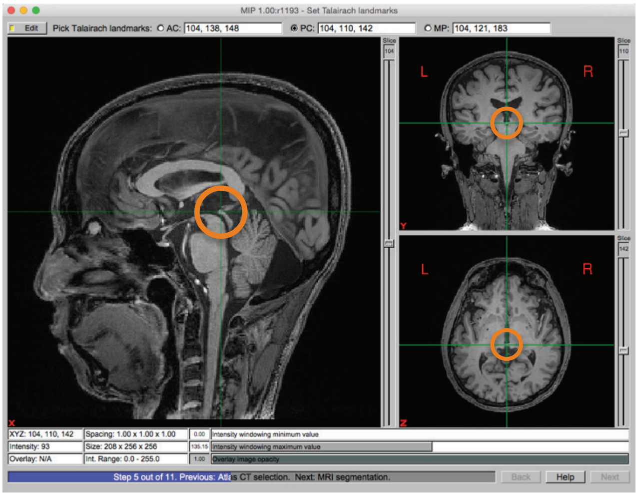
2. Click the **AC** button and then click the **anterior commissure (AC)**.

   You want to mark the tiny peak of the teardrop that hangs down under the lateral ventricle and corpus callosum.

   Note that visibility will depend upon the quality of the MRI slices.

3. Click the **PC** button and then click the **posterior commissure (PC)**.

   You want to mark the upper leftmost tip of the tube-like cylinder that sits on top of the pons and left of the hindbrain.



4. Click the **MP** button and then click the point that sits equidistant between the AC and PC and occupies the hemispheric divide.

5. When done with edits, *unclick* **Edit** (to exit the editing mode), and then click **Next** (to accept and process changes made thus far).

6. In the panes of the Transformed Image tab, review how the MR image has realigned to the Talairach landmarks compared to the original image.

   If there are no changes, click **Next**.

   If there are changes under either tab (Original image or Transformed image):

   a) Click **Edit** (to enter editing mode).

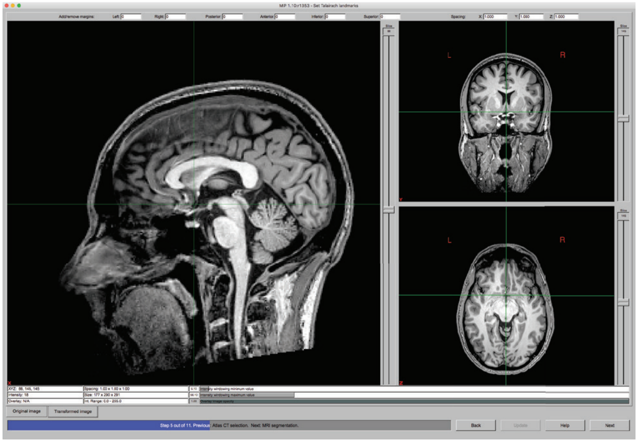
   b) Make changes.

   c) Click **Update**.

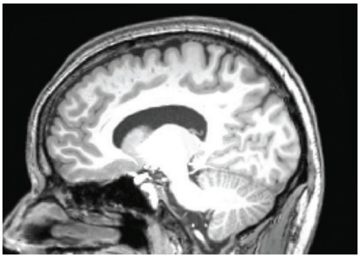
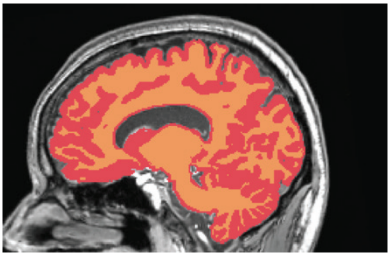
   d) Deselect **Edit** (to exit editing mode).

   e) Click **Next**.

Notice that the MR image is tilted slightly forward after realignment.



7. Wait until the MIP completes its processing and color overlays are showing on the MRI images.

The processing results in a *tissue overlay* being applied to each slice of the MRI. After stage 1 (tissue segmentation), every voxel in the MRI images will be designated as one of the seven tissue types.

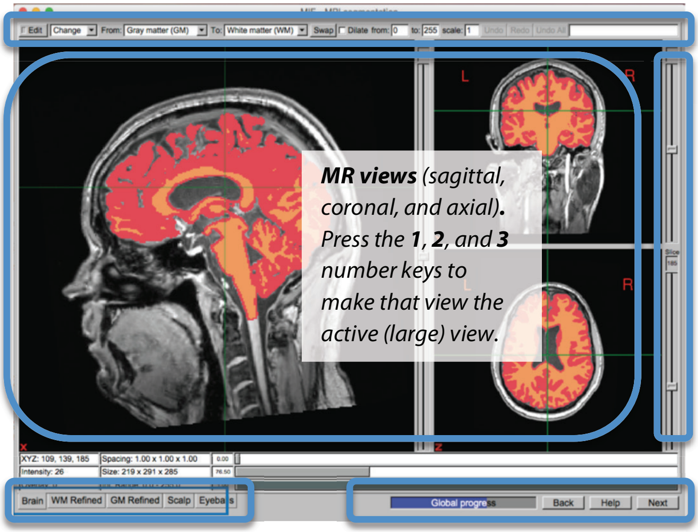
The quality of MR images affects the MIP's processing of the seven tissue types. High-quality MR images are interpreted fairly precisely. Lower quality MR images will require some correction. Stage 1 (tissue segmentation) is the user's opportunity to review and edit, if needed, this processing of the MR images.

9.3 Stage 1—Tissue Segmentation

The segmentation stage will step you through the brain, WM (white matter), GM (grey matter), scalp, and eyeball tissues. You will have opportunities along the way to double-check your work before proceeding.

❶ Get familiar with your viewing options:

Edit bar. *Activates and controls editing.*



Slider bars. *Navigate through the slices of each MR view.*

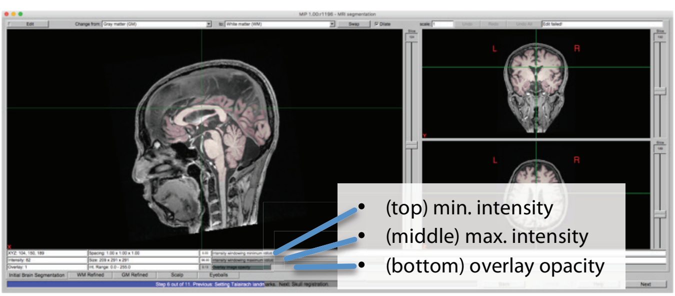
Use the ↑ and ↓ arrows to navigate one slice at a time.

Segmentation bar. *Work left to right (brain to eyeballs) to carry changes forward.*

Status, Back, Help, and Next

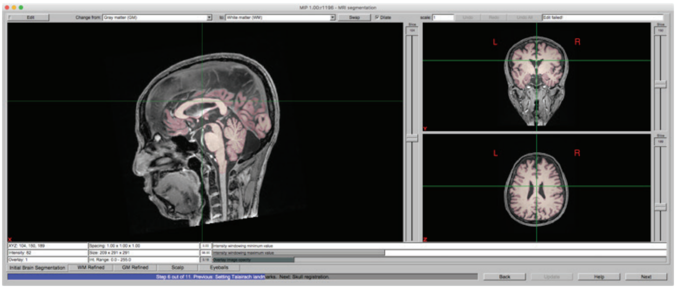
Intensity sliders

- **Top slider** controls the *minimum intensity threshold*.
- **Middle slider** controls the *maximum intensity threshold*.

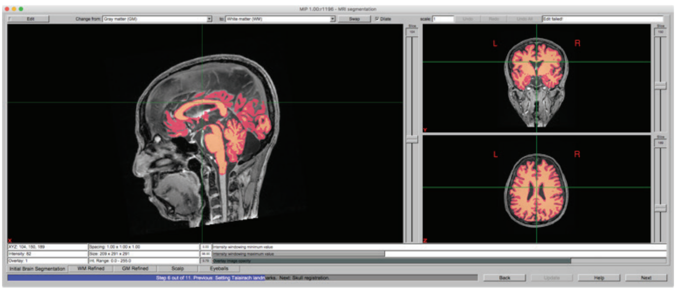


Example of slices with a *minimum intensity* of 0.00 (top slider) and a *maximum intensity* of 96.90 (middle slider).

Overlay Opacity slider *(bottom slider)*

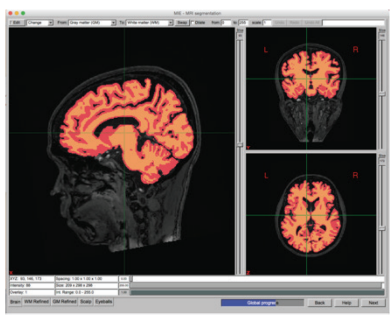


Example of slices with an overlay opacity of 0.18.



Example of slices with an overlay opacity of 0.79.

❷ Review **Initial Brain Segmentation** and make edits, if needed.



The MIP will open at the first module (Initial Brain Segmentation). See *Brain* activated in the bottom bar.

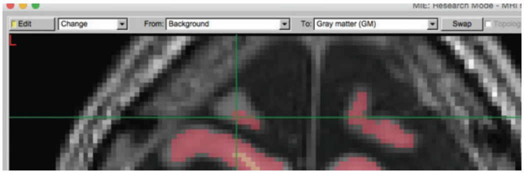
To review and edit:

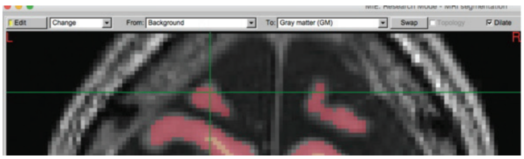
1. Click **Edit**.

2. Specify any changes to be made in the fields of the upper bar.

   Click **Change**, then change the **From** and **To** to reclassify inaccurate tissue labeling or segmentation, if necessary.

The following example changes Background (From) to Grey matter (To), while editing the frontal lobe. Clicking and dragging fills GM into the areas that the tissue mask missed.





3. Whether you made edits or not:

   - **To accept tissue edits and move to the next tissue type:** *unclick* **Edit**, click **Update**, and click **Yes**.

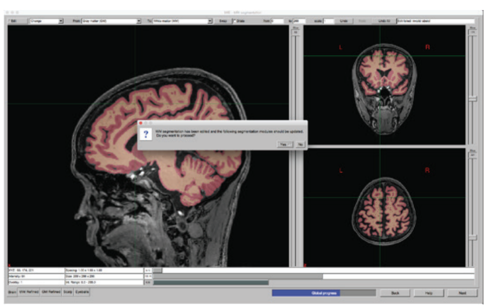
   - **To reject edits:** *unclick* **Edit**, then click **Undo All**.

   - **If you accidently clicked Next:** and inadvertently moved to the next tissue module, click **Back** and wait for the file to reload.

   - **If you made no edits:** simply select the next tissue module's tab. You do not need to click Update.

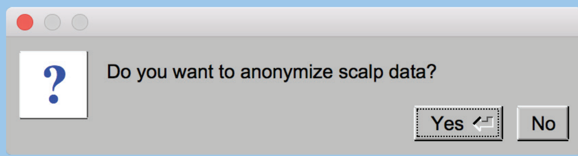
   - **To accept edits for ALL tissue types:** *unclick* **Edit**, click **Next**, and click **Yes**.

     Clicking Next and Yes saves all edits/changes to the file so that they apply to all stages of processing.

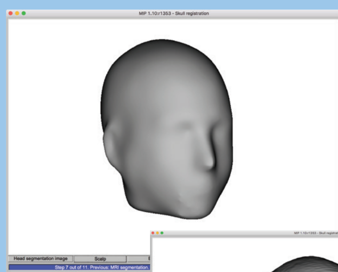


Anonymizing Scalp Data

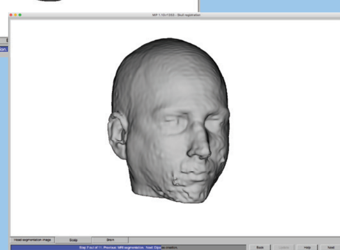
The first time you click Next, a prompt will appear asking if you want to *anonymize* the scalp data. This is your opportunity to de-identify the patient/subject by removing identifying facial features.



Clicking Yes will smooth (anonymize) the scalp data to remove identifying facial features.

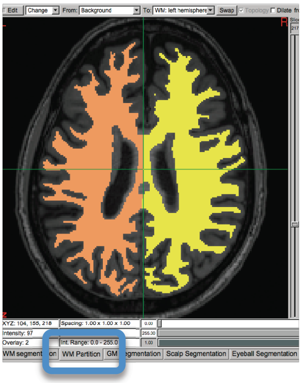


Clicking No will not smooth (anonymize) the scalp data, so will retain identifying facial features.

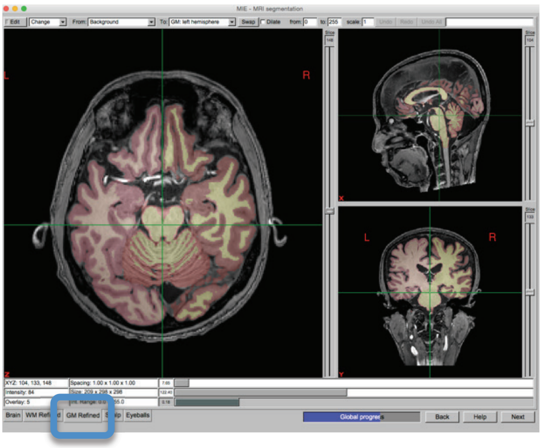


❸ Click the **WM** tab to review WM segmentation and make edits, if needed.

You will rarely, if ever, need to edit the properly proportioned right and left hemispheres. If you do, make sure that you *unclick* **Edit** and click **Update** to process the changes before proceeding.



❹ Click the **GM** tab to review GM segmentation and make edits, if needed.

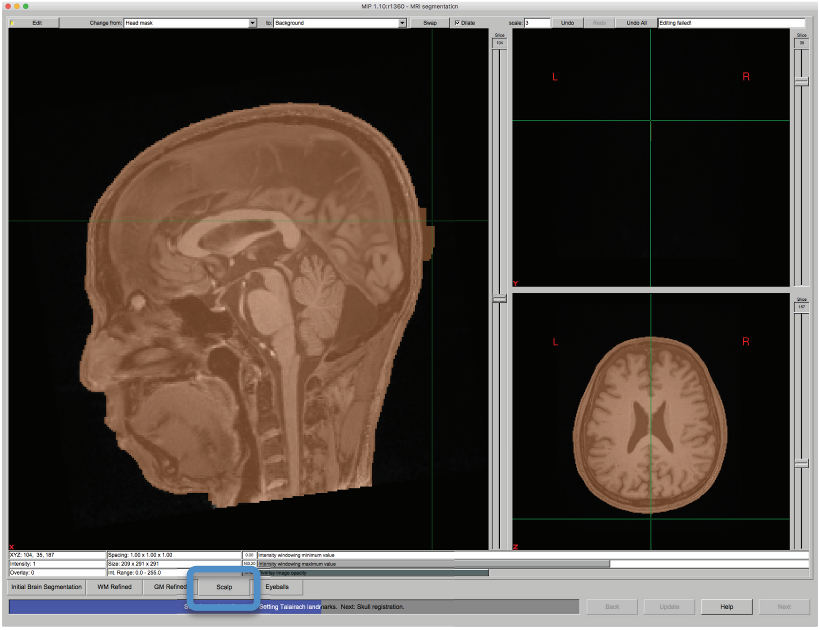


Similarly to the white matter, you will rarely, if ever, need to edit the grey matter. You should, however, review how the various tissues separate between the hemispheres. If you need to make any edits, make sure that you *unclick* **Edit** and click **Update** to process the changes before proceeding.

❺ Click the **Scalp** tab to review Scalp segmentation and make edits, if needed.

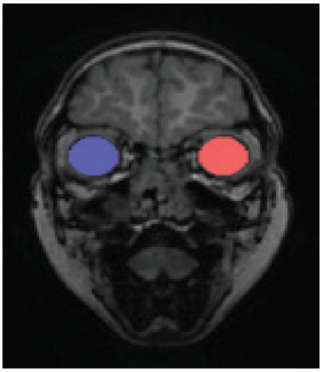
1. Make changes in one view and double-check them in the other two views. Always verify in all three views (sagittal, coronal, and axial).
2. Delete spacers and scalp artifacts.
3. Also clean up any bumps or ridges left behind after deleting spacers and scalp artifacts.

4. When done with edits, *unclick* **Edit** and click **Update**.



❻ Click the **Eyeball** tab to review Eyeball segmentation and make edits, if needed.

To correctly place the eye tissue, you must position and size the eyeballs.



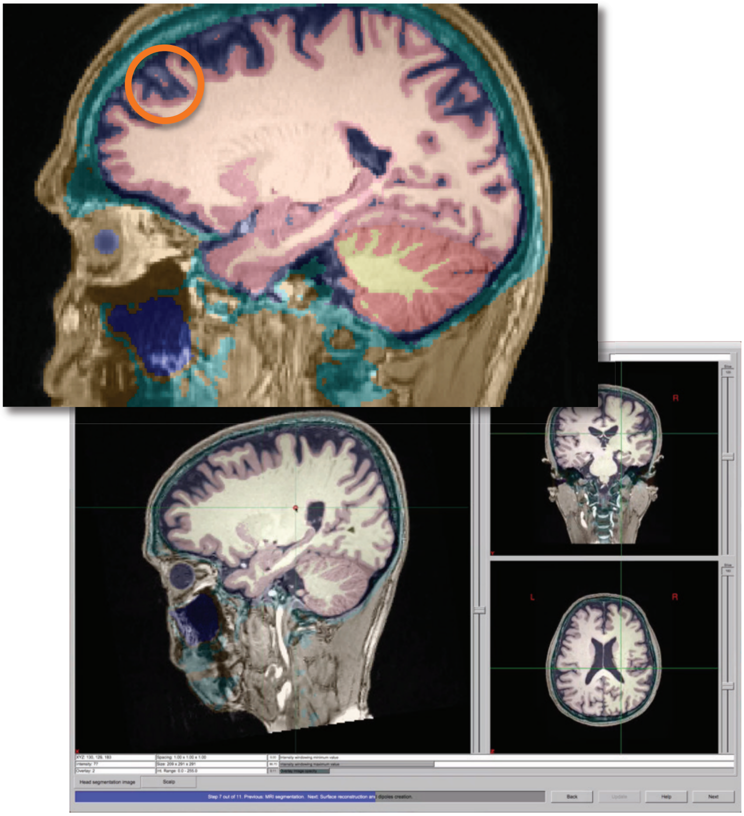
1. Locate the center of the eyeballs in *all three views*: sagittal, coronal, and axial. *The center can be incorrect in one view, despite looking correct in another.*
2. Resize the radius of the eyeballs such that they fill the ocular cavities completely.
3. When done with edits, *unclick* **Edit** and click **Update**.

❼ Before continuing with stage 2 (cortical surface extraction), verify the tissue types reviewed and/or edited thus far in the skull registration process.

Use the intensity and overlay opacity sliders, along with the crosshairs to move through the slices.

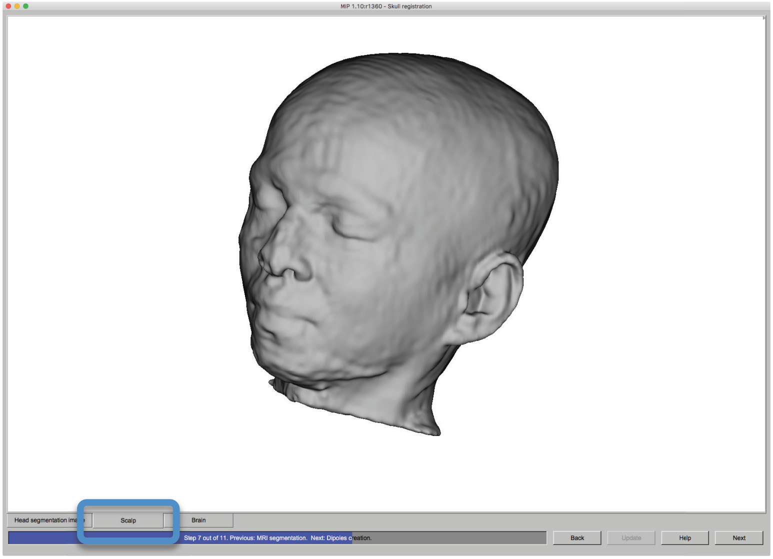
1. The viewer looks at soft tissues first. Review the reconstructed grey and white matter for possible additional edits.

   For example, in this image the grey matter seems incomplete. Therefore, return to GM segmentation to verify this area.



2. Click the **Scalp** tab to review the scalp reconstruction.

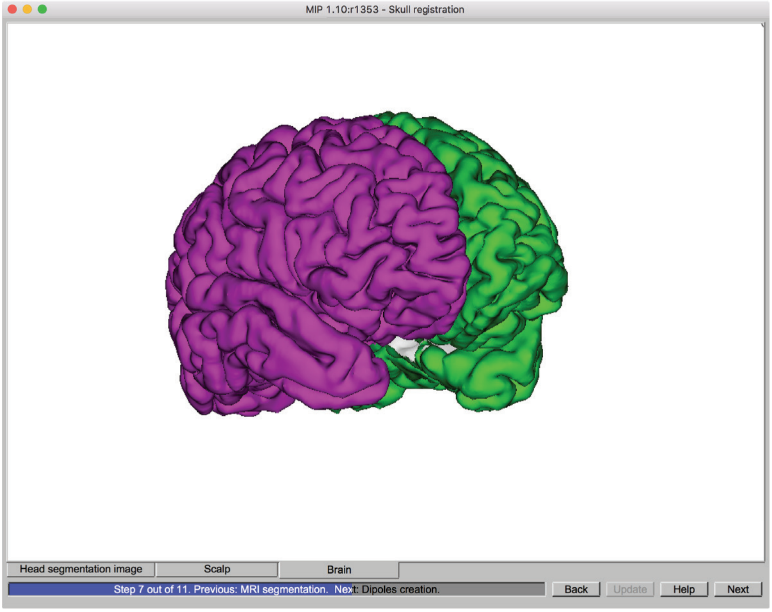
   If you find anything that requires verification or editing, click the **Back** button to return to the scalp mesh.



3. If you found nothing to go back to verify or edit, then click **Next** and **Yes**.

4. Click the **Brain** tab to preview the 3D brain.

   If you find anything that requires verification or editing, click the **Back** button to return to the scalp mesh.



5. If you found nothing to go back to verify or edit, then click **Next** and **Yes**.

   The software has now completed the skull registration.

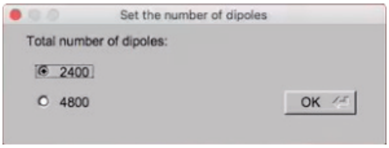
   In the next stage you will be reconstructing the cortical surface and creating the dipoles.

9.4 Stage 2—Cortical Surface Extraction

Stage 2 carries on from where skull registration left off—it creates dipoles on a reconstructed cortical surface.

The MIP's masks will automatically remove most unnecessary dipoles. In this section, however, you will verify and, if necessary, edit some dipoles. More or less editing may be required for the different tissue types, depending upon the quality of the MRI images.

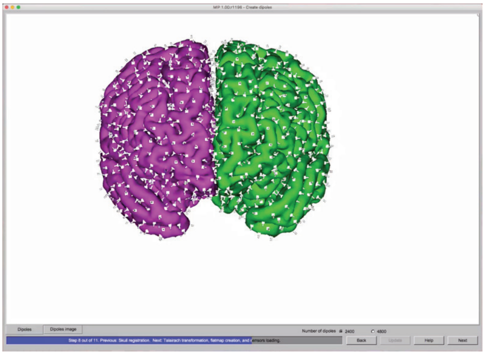
❶ After the software has created the surface reconstruction, set the number of dipoles (2,400 or 4,800) to be created for your head model.



Note that you have two trade-offs:

- More dipoles add more precision for small sources, whereas fewer dipoles may be sufficient for larger sources.
- More dipoles provide higher resolution, whereas fewer dipoles calculate quicker.

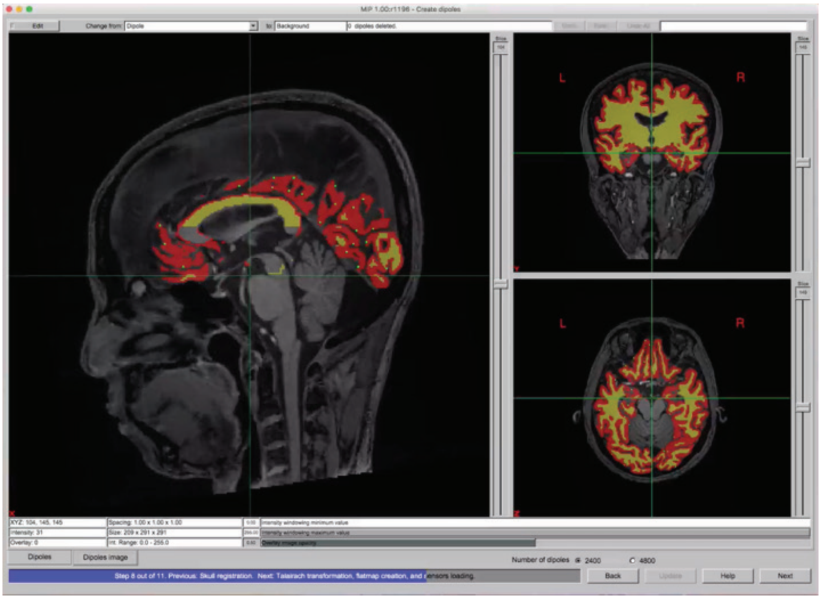
❷ A 3D model opens showing all of the dipoles created. The dipole arrows show their orientation to the cortical surface.



Note that the bottom blue status bar says the MIP is at step 8 of 11 and that the window now provides the Dipoles and Dipoles Image buttons.

❸ If you change your mind about the number of dipoles you want, click the desired radio button and click **Update**.

❹ Click **Dipoles image** to see the MRI slices.



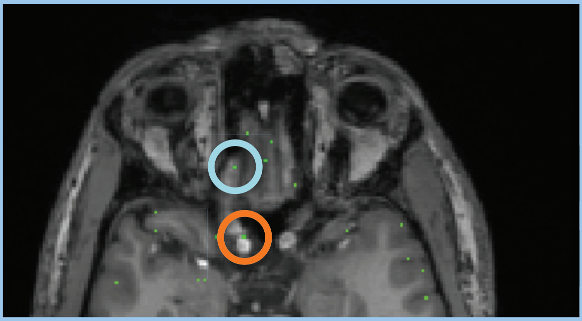
❺ Use the intensity and opacity sliders to evaluate the dipoles:

- Verify dipoles in ***each slice***.
- Verify that all dipoles are in the cortical grey matter.
- Verify that all dipoles are properly categorized.

- Verify dipoles in ***each view*** (sagittal, coronal, and axial) to ensure that all dipoles are verified.

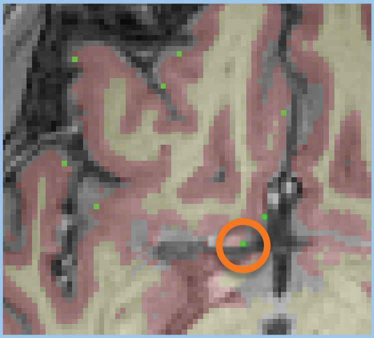
Examples of erroneous dipoles that need deleting:

Optic nerves. It is common for erroneous dipoles to be found on the optic nerves in the hemispheric divide (posterior to the eyes). Delete most of these, except those that are anterior enough to be relevant.

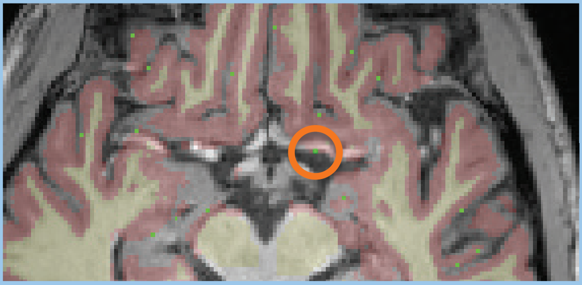


Do not delete.

Delete



Delete



Delete

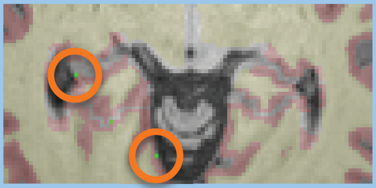
Rhombencephalon (hindbrain). Look for dipoles that border where the spine seems to merge with the brain. The hindbrain and midbrain should not display dipoles. The cerebellum is less critical. An isolated patch of GM showing a dipole should be deleted. However, do not delete a dipole from a section of GM, if, for example, it extends rostrally from the cerebrum. If unsure, do not delete.

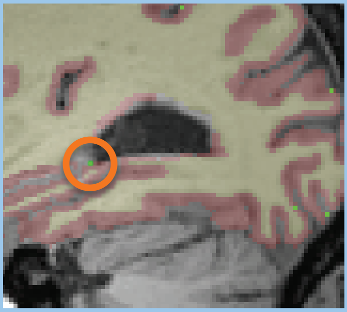
No dipoles should be in the optic nerve area.

Delete

If a dipole is isolated in a patch of GM, delete the dipole. Verify by navigating up through slices.

Ventricles. Verify that the mask automatically removed all dipoles from the ventricle area in all views (sagittal, coronal, and axial).

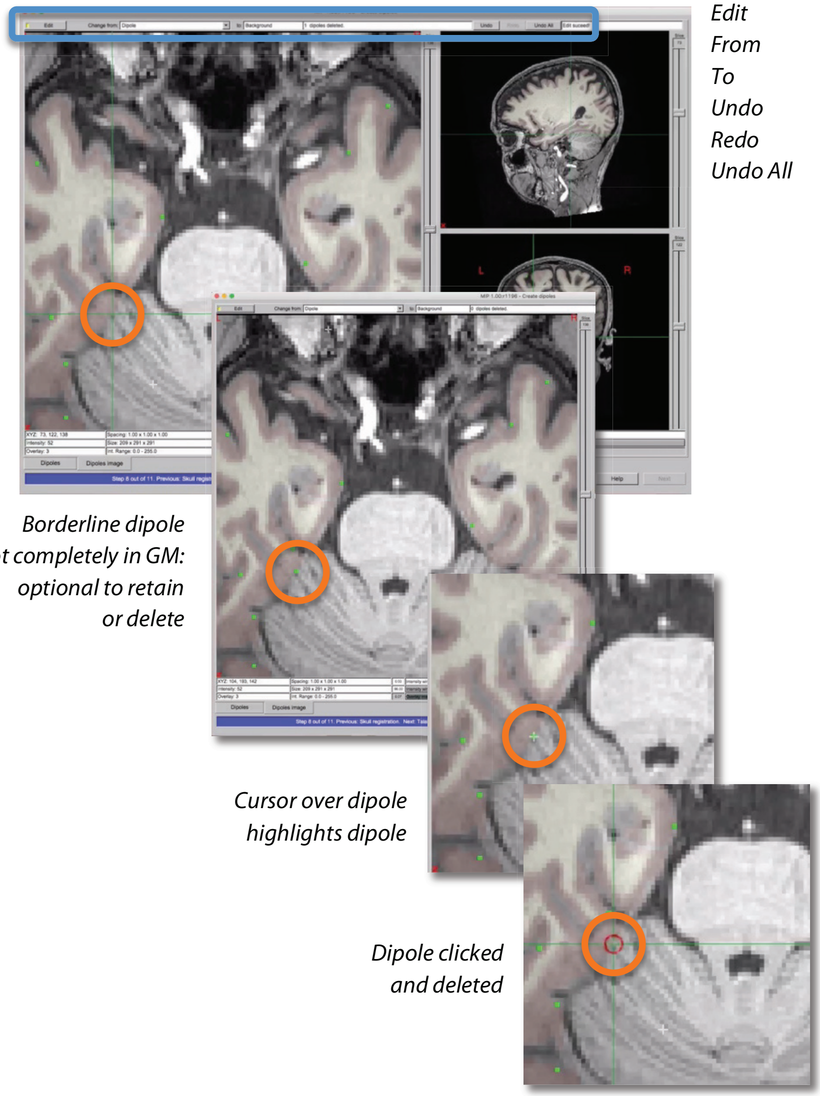




❻ To delete dipoles that are misplaced:

1. Click **Edit**.
2. Set From to **Dipole** and To to **Background**.
3. Click the **dipole**.

<u>Button bar</u>:
Edit
From
To
Undo
Redo
Undo All



Borderline dipole not completely in GM: optional to retain or delete

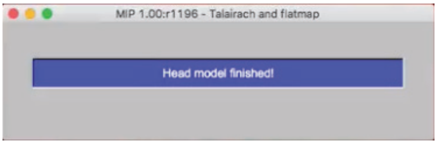
Cursor over dipole highlights dipole

Dipole clicked and deleted

❼ When done with all edits:

1. Unclick **Edit**.
2. Click **Next**.

The software will now complete the dipole creation.

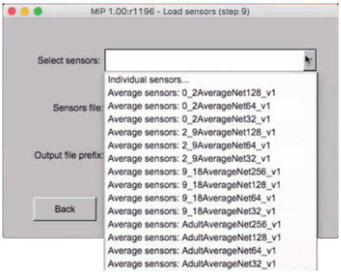


In the next stage, you will be transforming the Talairach landmark coordinates and loading the sensors.

9.5 Stage 3—Sensor Registration

Stage 3 carries on from where dipole creation left off—after transforming the Talairach, it will load the sensors and specify the conductivities. The goal of this stage is to verify the placement of sensors on the 3D head model (in the left pane) against the 2D photos (in the right pane).

❶ When the head modeling from the previous stage is complete, you are automatically presented with a dialog for selecting your sensor positions file.

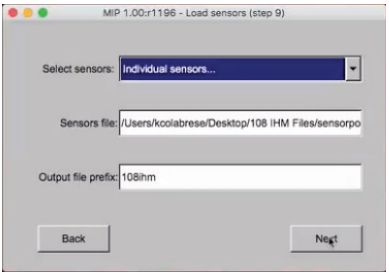


1. Select **Individual Sensors** in the Select sensors field. Or, if preferred, select a built-in averaged sensor position file.

   Note that an individual solved sensor position file (.sfp or .gpsr) is not required for the IHM workflow. You can use one of the built-in averaged sensor position files. However, be aware that these averaged files are not ideal for IHMs.

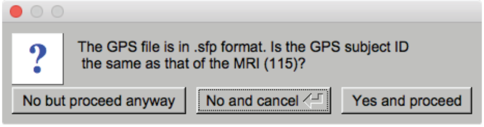
2. If you selected Individual Sensors, browse to select your **.sfp** or **.gpsr** file.

3. The path to that file will autofill in the **Sensors file** field.



4. In most cases, retain the autofilled **Output file prefix**; this is the working directory you specified earlier. However, if you are registering another net to an existing head model, you will want to specify a separate directory.

5. You will be prompted to proceed or not, depending upon whether you can confirm that the subject ID in the .sfp GPS file is the same (or not) as that in the MRI file.



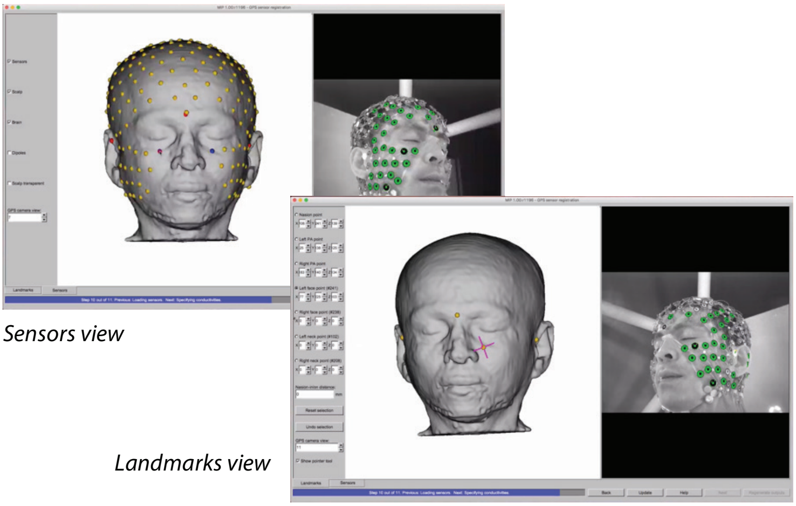
   Select the **option** that applies.

   Note that the software cannot confirm the subject ID inside the .sfp file.

   Remember that the subject ID must be identical in all files (.mff, .sfp or .gpsr, .egia, .gsrc, and, if later using GTEN 100 Research, .mcb) used in the workflow.

❷ Wait for the GPS sensor registration window to open. It opens with the Landmarks view active.

You will work between this window's two views (*Landmarks* and *Sensors*) to manually place the landmark points, and then ensure that the sensors on the 3D head model (left pane) are placed exactly as in the net application photos (right pane).



Sensors view

Landmarks view

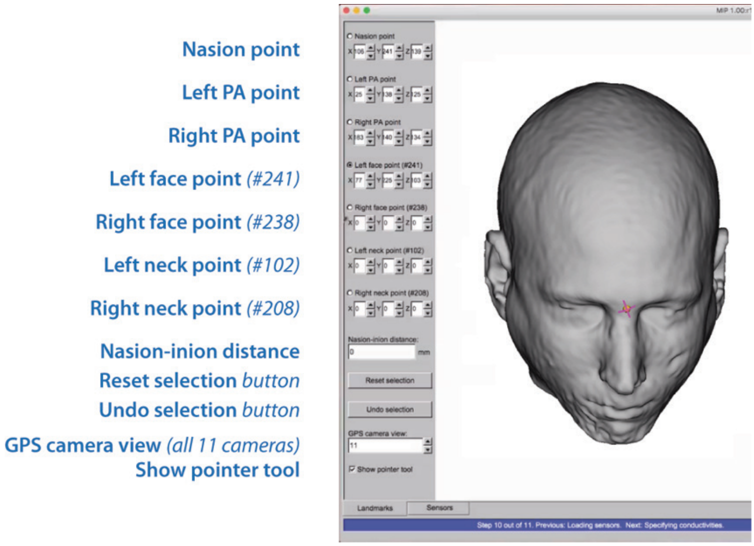
Navigation in the 3D and 2D panes:

- Using the keyboard shortcut mappings (see section 4.4).
- Selecting a camera in the **GPS camera view** field.

❸ First, manually place the seven landmark points on the head model:

1. Click **Landmarks**, if it is not already the active view.

2. Place each of the seven landmark points (*nasion, left PA, right PA, left face, right face, left neck,* and *right neck*) on the head model as they appear in the 2D net application photos. You can either:



- Click the **radio button** of one of the seven landmarks, then either:
  - shift+click to place and/or move the selected landmark, or
  - use the X, Y, or Z number fields to move the selected landmark's location.

  Notice that landmarks that contain electrodes provide their corresponding sensor number.
- Click the **Reset selection** button to return a mark to its default position.
- Click the **Undo selection** button to undo the last action.

3. When satisfied with your changes, click **Update**.

❹ Next, verify the sensors and adjust them, if needed.

You cannot move individual sensors. You will adjust the sensors across the head via the seven landmark points. When you move these landmark points, all sensors will move around the head.

1. Click **Sensors**.
2. Review all sensors in more than one camera image.
   - Ensure there are no sensors *on* the ears.
   - Look carefully to ensure there are no sensors tucked in behind the ears that are not actually there.
3. If adjustments are needed, click **Landmarks**.
4. Make landmark adjustments. You can:
   - Click the **radio button** of one of the seven landmarks, then either:
     - shift+click to place and/or move the selected landmark, or
     - use the X, Y, or Z number fields to move the selected landmark's location.

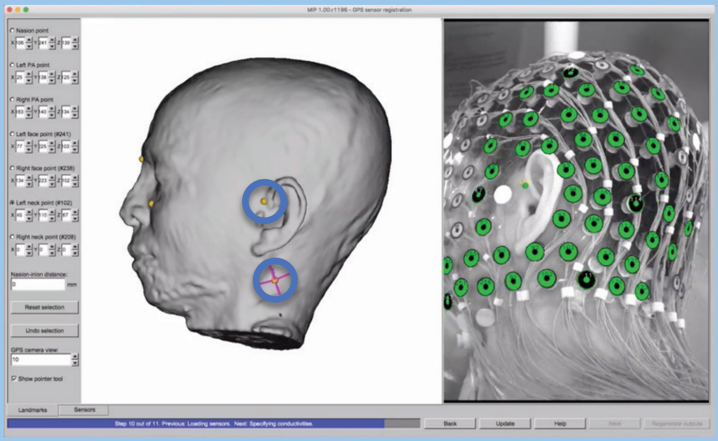
   Notice that landmarks that contain electrodes provide their corresponding sensor number.
5. When satisfied with your changes, click **Update**.
6. Click **Sensors** and verify the affects of the landmark adjustments on the sensor positions.
7. Repeat steps 3 through 6 until the sensors in the 3D head model ***exactly match*** the sensors in the 2D net application photos.
8. Enter the nasion-inion distance, if you have it. If you do not, the software will use the Cz from the atlas CT scan.
9. When satisfied with changes, click **Next**.

   The Specify Conductivities dialog will appear next.

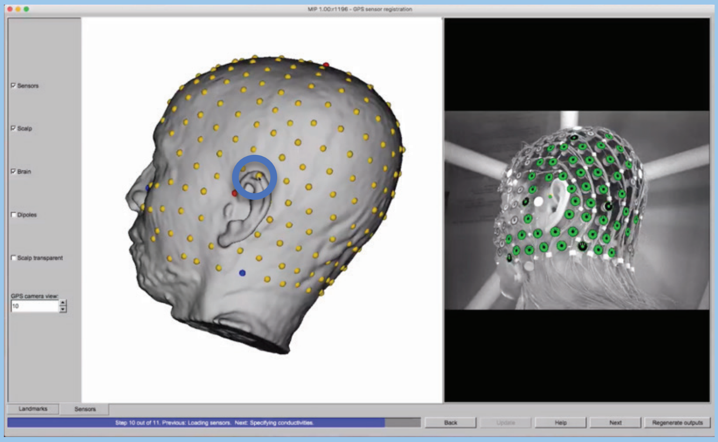
Example:

After clicking **Landmarks**, making adjustments, then clicking **Sensors** to review, we see that adjustments have resulted in a sensor appearing on the ear, even though most other sensors are better positioned. By going back into Landmarks and making another adjustment to the closest landmark points (and updating the file), we can remove the sensor from the ear.

Always verify each adjustment before moving on.

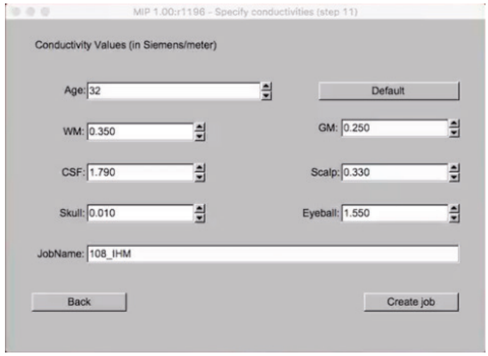


The above landmarks affect the below misplaced sensor on the ear.



❺ Wait for the specify conductivities dialog to appear.

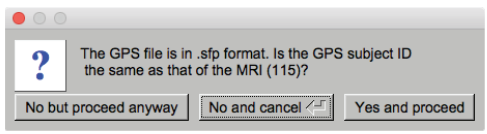
1. Unless you have specific conductivity values, retain the default values.



2. Enter your working directory name in the **Job Name** field.
3. Click **Create Job**.

   This will create a bundled zip file containing the components of your head model.

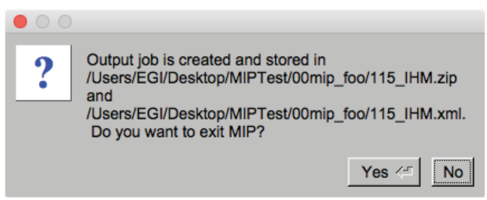
4. You will be prompted to proceed or not, depending upon whether you can confirm that the subject ID in the .sfp GPS file is the same (or not) as that in the MRI file.



   Note that the software cannot confirm the subject ID inside the .sfp file.

   Select the **option** that applies.

5. Click **Yes** to quit MIP.



Now, go to chapter 10, for lead field matrix generation.

10. Stage 4—Generating the LFM

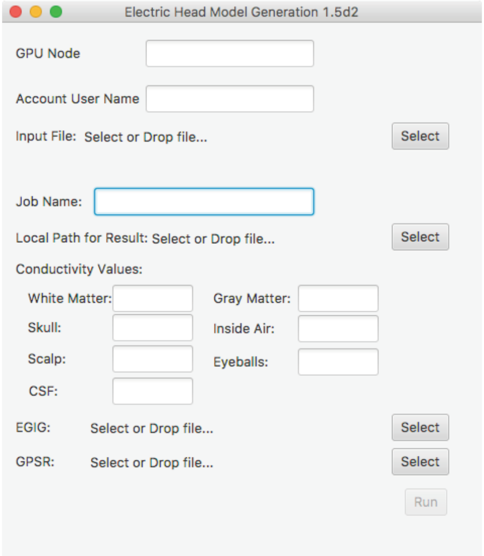
You will generate your lead field matrix (LFM) for all CAHMs and IHMs using the EGI GPU-accelerated computer, not the EGI Mac computer.

You will need the following files:

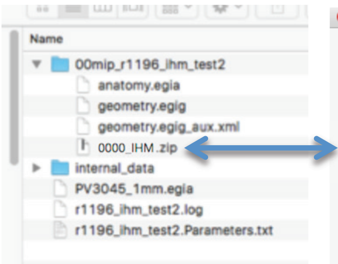
- The .zip or .xml file of a completed CAHM or IHM.
- Optionally, a .gpsr file for the completed CAHM or IHM.

❶ Double-click the **JAR** icon to launch the Electric Head Model Generator.

❷ Wait for the Electric Head Model Generation dialog to open.



❸ Click **Select** or **drag and drop** the .zip file of the completed head model from your working directory into the **Input File** field of the Electric Head Model Generation dialog.

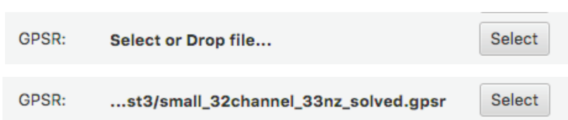


Fields automatically populated:

- Subject Name
- Model Type
- Local Path for Result
- Conductivity Values
- EGIG

*Clicking **Select** allows you to change related fields.

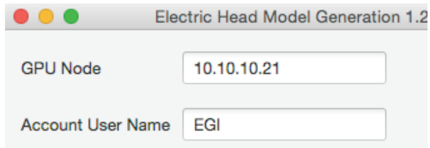
❹ If you used a .gpsr file of the completed head model, click **Select** or **drag and drop** the .gpsr file from your working directory into the **GPSR** field of the Electric Head Model Generation dialog.



This field can be left blank, however, if no .gpsr file was used.

*If you completed your head model using an .sfp sensor position file, you will **not** use that file here, because .sfp files do not contain photos. Therefore, leave this field blank.*

❺ Enter the **name** or **IP address** of the GPU computer being used into the GPU Node field.



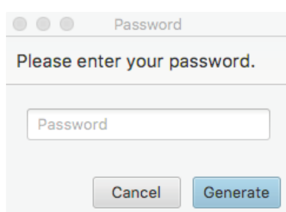
❻ Enter the **name** for the user account in the Account User Name field.

❼ Notice that all required fields are now filled.

❽ If needed, click **Select** to change associated fields.

❾ With required fields filled in correctly, click **Run**.

❿ Enter your EGI account **password** and click **Generate**.



LFM processing will take about 25 – 45 minutes, depending upon the channel count used with the head model.

When processing is complete, the output will be a .gsrc file, which can be opened in the RVE for use with the GTEN 100 Research system for neuromodulation planning.

Your working directory now contains the following files:

- .gsrc completed head model bundle, including:
  - LFM output
  - egia anatomy file
  - .egig geometry file
- .zip file, including LFM inputs
- .sfp or .gpsr sensor position file

Appendix A:
MRI Scanning Guidelines

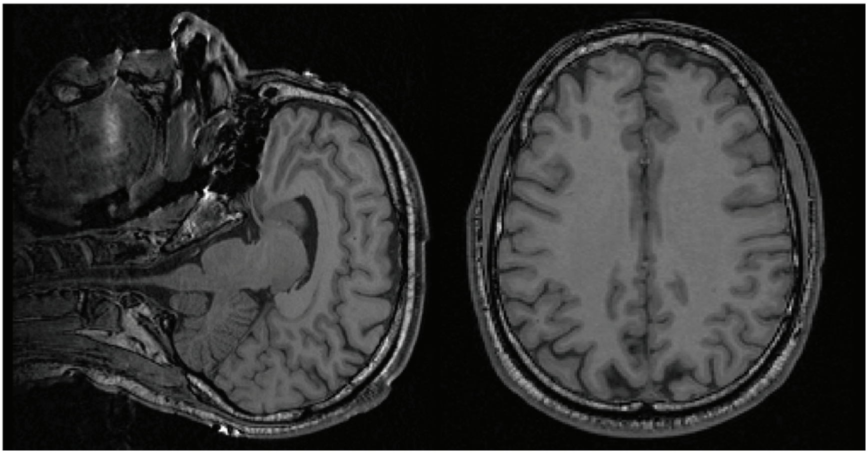
For the generation of individual head models (IHMs), EGI:

- Requires T1 MPRAGE (or equivalent) image files.
- Highly recommends image files with the most head coverage.

Following are EGI's guidelines for suitably scanning the anatomical structures that are needed for the creation of electrical head models.

Image Requirements

Adhere to the following image requirements to ensure the proper generation of your electrical head models.



Good image: good tissue contrast, whole head coverage, low noise, and minimal distortion

Good tissue contrast:

The gray and white matter should be easily distinguished.

If the contrast resolution is poor, the segmenting software may confuse the tissue types.

We recommend a T1 scan using a sequence similar to Siemen's MPRAGE (or GE's SPGR) with a 1X1X1 mm resolution.
(The scanning direction is not important.)

Whole head scan (not just whole brain):

The structural T1 scan should cover the entire head and extend about 4 cm below the chin.

The cheek and upper neck regions need to be included in the MRI scans to coincide with the EEG electrodes in those same areas that will be registered when generating the head model.

Low Noise:

The T1 should:

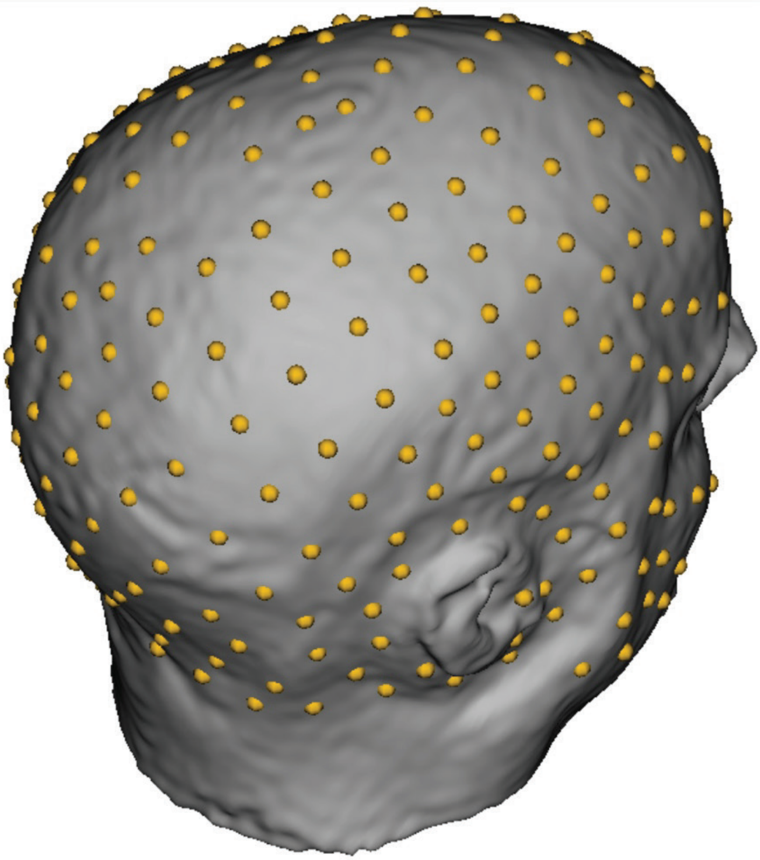
- look crisp
- be an accurate description of the subject's head geometry
- be low in noise
- be low in distortion
- show all identifiable anatomical features (nose, mouth, eyes, forehead)

Minimal Scalp Distortion:

Nothing should be used during scanning that will distort the scalp surface. The scanned head surface must match the head surface during EEG acquisition.

The subject should:

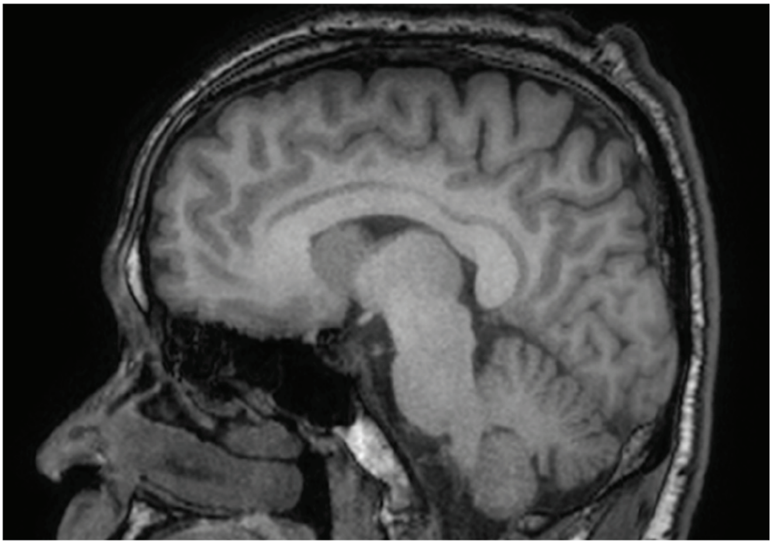
- ***not*** wear headphones, but instead use ear plugs
- ***not*** wear the EEG sensor net
- ***not*** have excessive padding around the head
- ***not*** be positioned such that the scalp is squished, stretched, wrinkled, or otherwise distorted



Poor image: wearing head phones depressed the skin and scalp around the ears

Examples of Poor Imaging

Poor Coverage

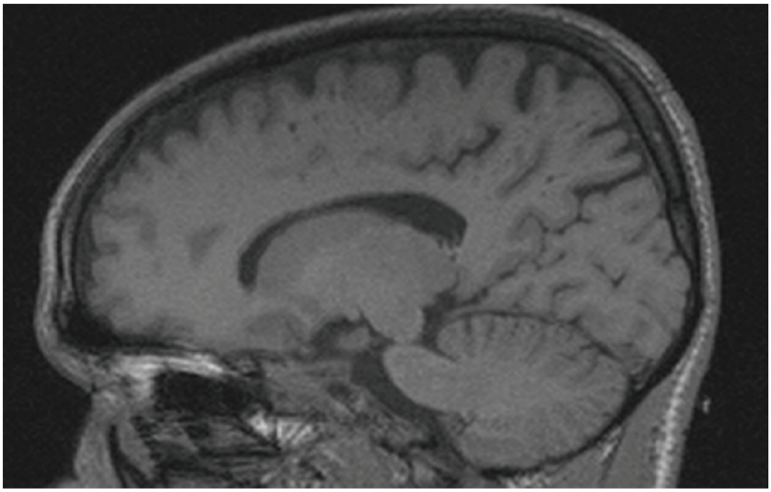


Poor image: The jaw and neck region is missing and the crown of the scalp is distorted.

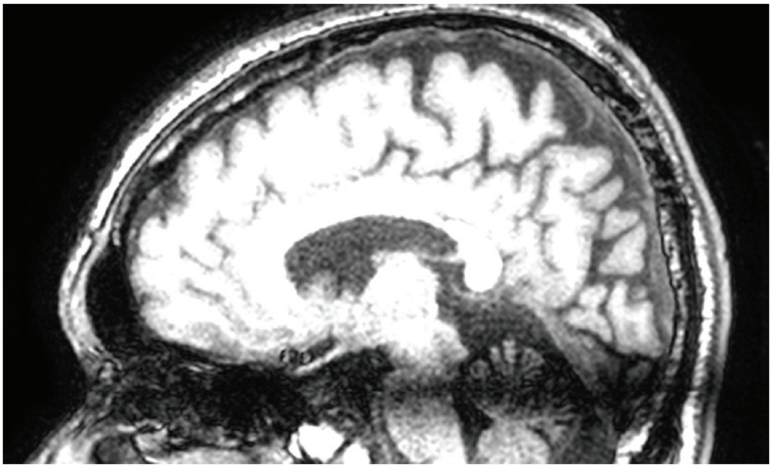
In the above image, there are two conditions that prevent it from being usable for accurately registering all of the EEG sensors that are required for generating an electrical head model.

1. The cheek and face sensors are missing.
2. The crown of the scalp is distorted.

Poor Contrast



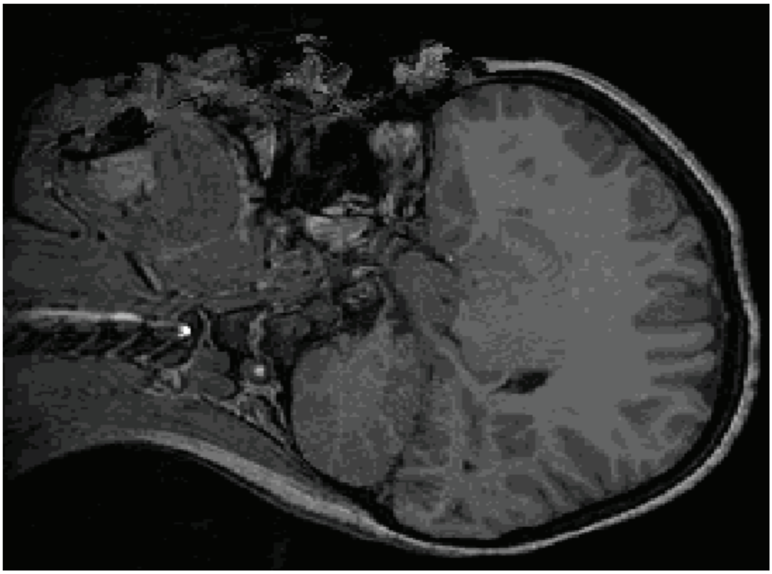
Poor image: The contrast is too low to clearly distinguish tissues.



Poor image: The contrast is too high to clearly distinguish tissues.

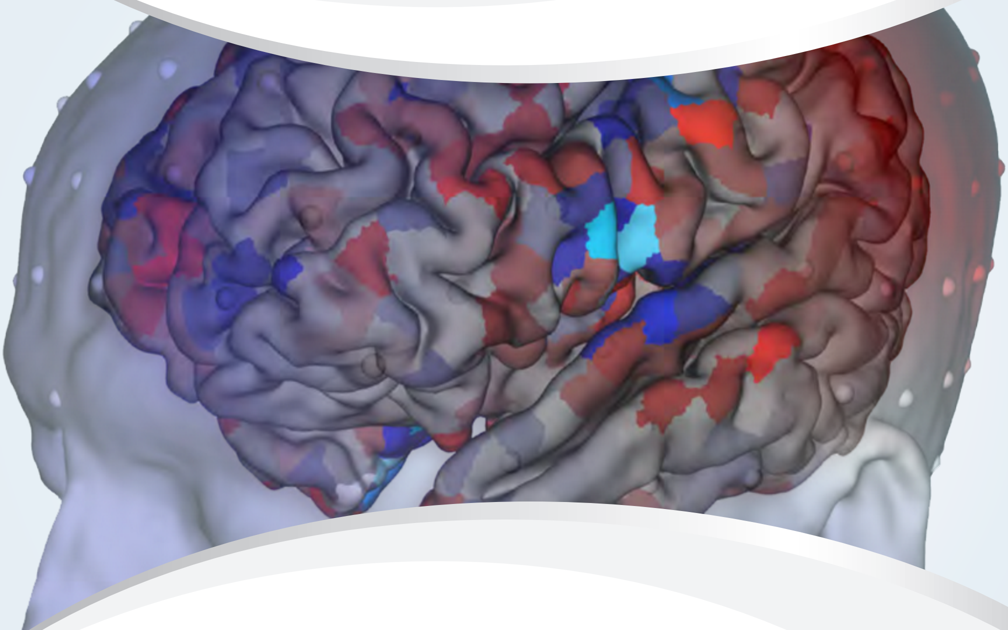
In the above images, the blacks and whites are either too dark in the low contract image or too bright in the high contrast image in order to easily differentiate white matter from gray matter.

Poor Distortion



Poor image: Facial features (nose, eyes, mouth, teeth, chin, and forehead) are missing.

Along with the inclusion of the cheeks, jaw, and neck, all anatomical features must be intact for the MRI to be useful in generating an electrical head model.



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