



# GeoSource 2.0

## Technical Manual



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# **GeoSource 2.0**

## Technical Manual

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# PREFACE

Welcome to GeoSource, the electrical source-imaging software from Electrical Geodesics, Inc. (EGI). As a complement to EGI's Net Station electroencephalography (EEG) acquisition, review, and analysis application, GeoSource uses inverse techniques to approximate the source data for any Net Station EEG file that does *not* contain bipolar channels.

The source data files generated by GeoSource are compatible with many of Net Station's Waveform Tools, which allows you to perform the same operations on the GeoSource source data files as you would on Net Station EEG files.



## Main Features

GeoSource allows you to:

- display source data in Chart, Grid, or Synoptic Plot views in the Net Station Viewer or on magnetic resonance image (MRI) slices in the GeoSource Viewer
- create source montages for viewing subsets of source data in Net Station Viewer
- create a GeoSource specification in the Waveform Tools
- export source data in a variety of formats: modified Net Station, modified simple binary, MATLAB .MAT, or tab-delimited text

This manual, the *GeoSource Technical Manual*, is intended for researchers and clinicians who are involved in the acquisition, processing, analysis, and modeling of EEG data.

The *GeoSource Technical Manual* assumes you have some familiarity with basic concepts in neuroscience, physics, and linear algebra.

Other Net Station manuals include:

- ***Net Station Viewer Technical Manual.*** This manual describes the features and functions of the Net Station Viewer, which is the component of Net Station that views and navigates EEG data.
- ***Net Station Waveform Tools Technical Manual.*** This manual describes the features and functions of the Net Station Waveform Tools, which are the components of Net Station that perform various operations on EEG data (primarily for basic ERP derivation).
- ***Net Station Viewer and Waveform Tools Tutorial.*** This manual instructs you in the use of the Net Station Viewer and the Waveform Tools by guiding you through the analysis of a sample data set. It is not intended to be a comprehensive guide to these components, but it is a good place to start when learning about the software.
- ***Net Station Acquisition Technical Manual.*** This manual describes features and functions of the Net Station Acquisition, which is the component of Net Station that acquires EEG in conjunction with the dense-array Geodesic Sensor Nets.
- ***Net Station File Formats Technical Manual.*** This manual documents the objects contained in a native Net Station file, the formats of the export files, and other files associated with Net Station.



Net Station logo

**Note:** You can find the PDF versions of these publications and other EGI documentation at [www.egi.com/membership-area](http://www.egi.com/membership-area).

These publications contain a good deal of background information on the EEG and ERP fields. However, they are not intended to represent a complete primer in these fields. To get the most out of these manuals, you should have some experience with EEG and ERP methods.

These manuals assume you are familiar with the hardware and software components of the Macintosh platform, which is the platform that Net Station runs on.

## About This Manual

This manual is supplied as a PDF file and in printed form. The hard copy version has been printed from the PDF file so the content of both will match.

The manual features a table of contents, list of figures, list of tables, and index, which are all hyperlinked in the PDF to the topics they reference in the publication.

## Manual Organization

The manual is divided into the following chapters:

- Chapter 1, "Introduction to GeoSource"
- Chapter 2, "GeoSource Menus and Windows"
- Chapter 3, "Getting Started"
- Chapter 4, "Source-Imaging Specifications"
- Chapter 5, "GeoSource File Organization"
- Appendix A, "Software Technical Support"
- Glossary

## Conventions and Typography

In general, a minimal amount of special fonts are used in this manual—*italics* for definitions or newly introduced terms, ***boldface italics*** for especially important concepts, and **boldface** for command paths (such as **File > Open**).

## Notes, Cautions, and Warnings

Notes, cautions, and warnings are used to convey additional information regarding this product.

**Note:** Notes indicate information that may be helpful in understanding product operation.



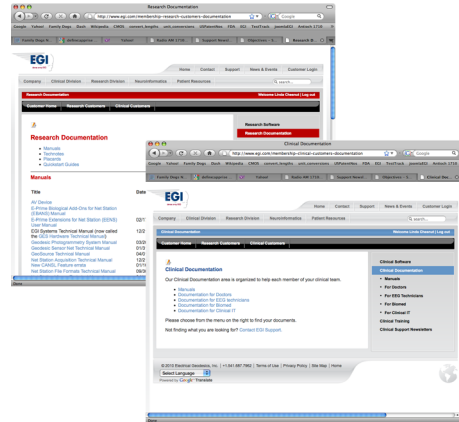
**CAUTION:** Cautions denote important information that, if unheeded, could result in injury or equipment damage or hinder the use of the product.



**WARNING:** Warnings denote important information that, if unheeded, could result in serious injury or death.

## Support, Repair, and Documentation

- For GeoSource support, see Appendix A.
- For online updates to this book, check EGI's documentation pages at [www.egi.com/membership-area](http://www.egi.com/membership-area).



Documentation webpages

# INTRODUCTION TO GEOSOURCE

The purpose of EGI's GeoSource software is to take the dense array (128 or 256 channel) electroencephalography (EEG) data measured on the scalp with the Geodesic Sensor Net (GSN) and recorded in a Net Station EEG file, and to use inverse techniques to estimate the source locations in the brain. The source data files that result from GeoSource's source estimation calculations are compatible with the following Waveform Tools:

- averaging
- baseline correction
- combine files
- difference wave
- file export
- filtering
- statistic extraction
- t-test
- wavelet

GeoSource should be used by trained personnel for EEG source calculation, review, and analysis. GeoSource does *not* perform a diagnostic function. It provides another data point that may help make inferences about brain function.



**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.

This chapter describes the software's official intended use and system requirements, and then introduces you to the general concepts involved in GeoSource.

## Intended Use

GeoSource is intended for use by a trained/qualified EEG technologist or physician on both adult and pediatric subjects of at least three years of age for the visualization of human brain function by fusing a variety of EEG information with rendered images of an idealized head model and an idealized MRI image.



**WARNING:** GeoSource has only been validated with 128- and 256-channel data. GeoSource should only be used if greater than or equal to 128 channels of EEG are used.

## System Requirements

GeoSource is available only in Net Station 4.3 or later, and is designed to run on Mac OS X 10.6. It has been specified to run on a PowerMac G5 or Mac Pro (Figure 1-1) that has at least a 2 GHz processor and at least 2 GB or more of random-access memory.



Courtesy of Apple

Figure 1-1. PowerMac G5

## 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 known surface measurements and propagation model, what are the source data? See Figure 1-2.

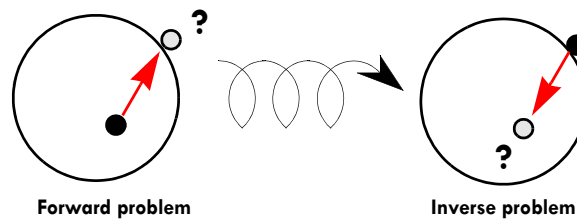


Figure 1-2. Generic forward and inverse problems

## EEG Forward and Inverse Problems

In GeoSource, you create specifications that combine the different components for solving the forward and the inverse problems as applied to source imaging. Those components are:

- **EEG sources.** Locations of possible generators.
- **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.

In GeoSource, source estimation is obtained by combining:

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

Source specifications can be used in the Net Station Viewer or with the Waveform Tools. For the former, you can apply a source-imaging specification to describe the source estimates during data review. For the latter, you can define a *GeoSource specification* (which contains a source-imaging specification and output options) and use the resulting tool for batch processing or scripting to generate source files.

The individual components of the forward and inverse models in GeoSource are described in Chapter 2, "GeoSource Menus and Windows."

## A Recommendation

GeoSource contains a selection of default source-imaging specifications based on the well-known LAURA, LORETA, and sLORETA source-imaging methods. GeoSource also allows you to create your own source-imaging specifications.

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 apply different source-imaging specifications to the same data for comparison, and to use GeoSource in conjunction with other EEG analysis techniques to determine if the solutions are consistent with the recorded data.

## Regulatory Compliance

### European Union (EU) Authorized Representative

**Contact:** Gerhard Frömel



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Medical Product Service GmbH  
Borngasse 20  
35619 Braunfels  
Germany

**Telephone:** 011 49 6442 962073  
**Fax:** 011 49 6442 962074  
**Email:** g.froemel@mps-gmbh.edu

## Symbols

Mark indicating that the product is CE compliant. The number 0297 is the EC reference number of the VDE Testing and Certification Institute, the notified body for Electrical Geodesics, Inc.



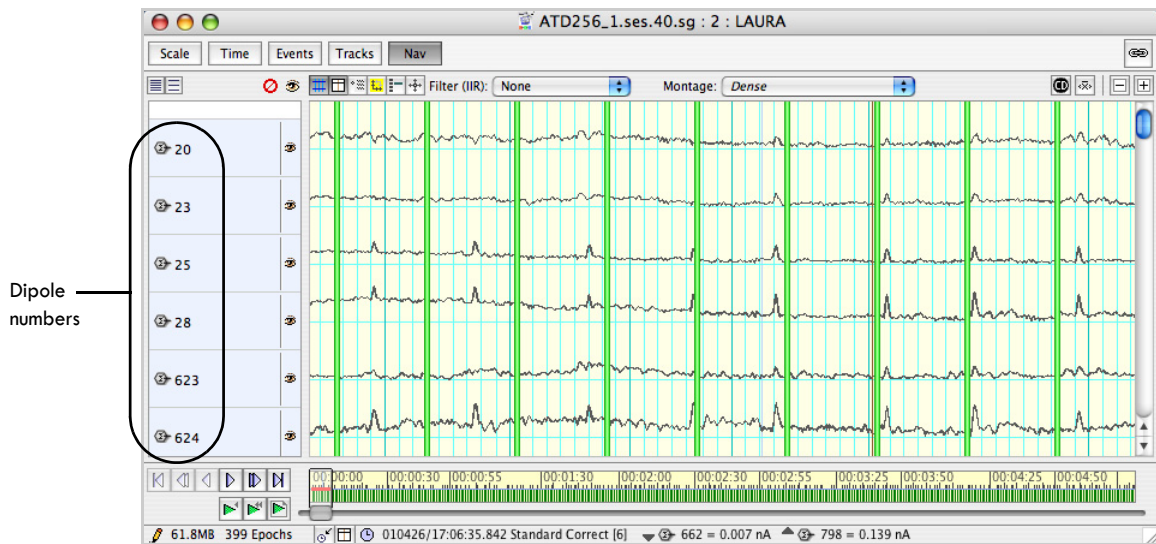


# GEOSOURCE MENUS AND WINDOWS

This chapter describes GeoSource's menus and windows, which are accessible from either the Net Station Viewer (page 21) or the GeoSource Viewer (page 39).

## Net Station Viewer

The Net Station Viewer displays source and EEG data nearly identically. The exceptions are that the source data can be displayed only in chart, grid, or synoptic plot views (see page 31), and the tiles to the left indicate the dipole numbers (not the channel numbers). For example, Figure 2-1 shows source data as continuous data in a chart view in the Net Station Viewer.



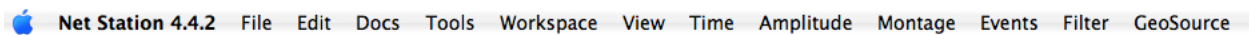
**Figure 2-1.** Net Station Viewer showing source data as continuous data in a chart view

The Net Station menu bar is visible when a Net Station Viewer is frontmost on the monitor screen.

The following section describes the GeoSource-specific features and functions in detail. For descriptions of common Net Station Viewer features, see the *Net Station Viewer Technical Manual*.

## Net Station Viewer Menus

Which menus and options are available onscreen from the Net Station Viewer menu bar (Figure 2-2) is determined by the space (source or scalp), view (chart, grid, etc.), category-viewing mode (as continuous data, etc.), and source-viewing mode (waveforms or MRI) of the currently open file or view (if not yet saved as a file). For details, see “What to Know Before Getting Started” on page 54.



**Figure 2-2.** Net Station Viewer menu bar

When viewing source data, the following Net Station Viewer menus enable GeoSource-specific functions.

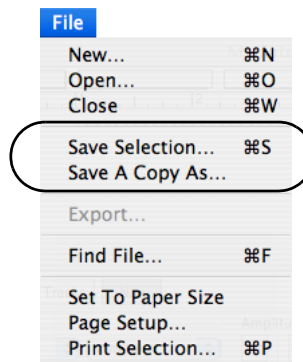
- **File.** Saves source data in a variety of formats.
- **Edit.** Selects source data.
- **Docs.** Maintains a list of all open files and minimizes selected files to the Dock.
- **Tools.** Creates a GeoSource specification.
- **Workspace.** Saves different combinations of view settings to open files with.
- **View.** Displays source data as continuous data, categories, or overlaid segments in chart, grid, or synoptic plot views. If the open file is in source space, the View menu can display source data as overlaid source components or the RMS of source components in a chart view.
- **Time.** Changes the time scale of the source data.
- **Amplitude.** Changes the amplitude of the source data.
- **Montage.** Applies a source montage to the source data.

- **Events.** Manages events in the source data.
- **Filter.** Unavailable.
- **GeoSource.** Opens the GeoSource Controls window (Figure 2-15) or the Source-Imaging Specification Editor window (Figure 2-16). The GeoSource Controls window allows you to apply GeoSource specifications and view the source data as waveforms or in the GeoSource Viewer. The Source-Imaging Specification Editor windows allows you to create or edit source-imaging specifications.

## File > Save

The File menu allows you to save a source data file or source data selection in a variety of formats.

- To save a source data file, choose **File > Save A Copy As.**
- To save a source data selection, highlight a selection of a file in the Net Station Viewer and choose **File > Save Selection** (Figure 2-3).



**Figure 2-3.** File menu

Choosing either command opens the File Save As or the Save Selection As dialog, which allows you to save your source data in a variety of file formats. See Figure 2-4.

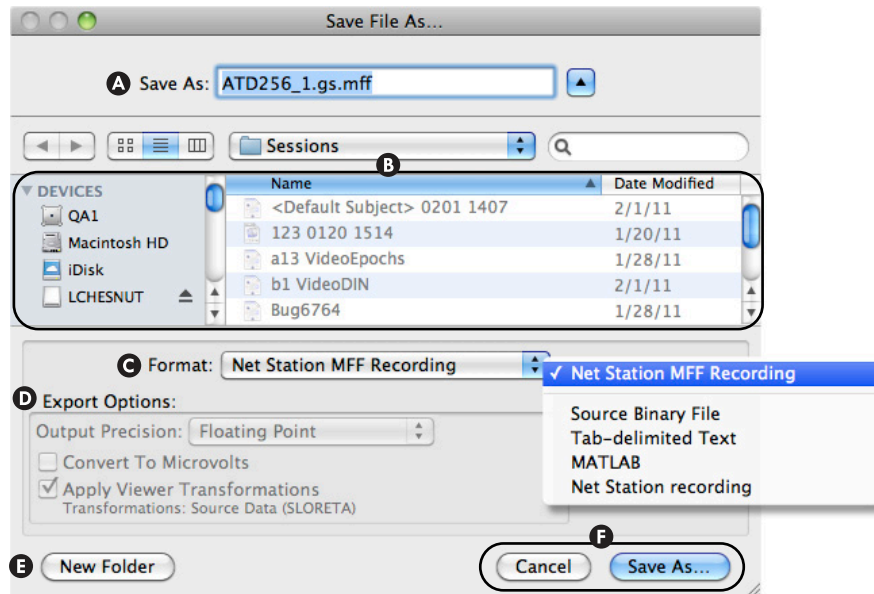


Figure 2-4. Save Selection As dialog

**Note:** If you are seeing a longer list of available formats than are shown in Figure 2-4, you have not yet converted the original Net Station EEG recording file into a GeoSource view (or file). Stop, and review the “What to Know Before Getting Started” section in Chapter 3. You must create a GeoSource view using a source-imaging specification before you can convert an original Net Station EEG recording file into a GeoSource file.

The following are brief descriptions of the items in Figure 2-4.

- A Save As.** Allows you to type in a name for the output file.
- B Where.** Allows you to select a destination for the output file. (Figure 2-4 shows the *Where* item expanded with the adjacent arrow.)
- C Format.** Allows you to select a format for the output file. Options are:
  - Net Station MFF Recording.** This format stores sample data in binary blocks and stores information about those samples in XML text files. For more information, request MFF documentation from EGI Support at [supportteam@egi.com](mailto:supportteam@egi.com).
  - Source Binary File.** This format is similar to a normal simple-binary file. For more information, see page 104.

**Tab-delimited Text.** This format represents each block of EEG data as text. It creates one text file per segment of EEG. For more information, see page 105.

**MATLAB (.mat).** This format is used in MATLAB programs. For more information, see page 105.

**Net Station Recording.** This format is similar to a Net Station EEG recording file. For more information, see page 104.

**D Export Options.** Allows you to specify the format of the exported data:

**Output Precision.** Only applicable for two formats: the Net Station Recording format and the Net Station MFF Recording format. Allows you to choose the data-type precision of the output file. Options are:

- *Floating Point.* This option produces more precise files, but the files export more slowly and they are larger than with the Integer option.
- *Integer.* This option creates smaller files (about half the size) that export faster, but the files produced are less precise than with the Floating Point option.

**Convert to Microvolts.** Never selectable; dimmed for all five output options, because it is not applicable. The units for the source waveforms are nanoamp meters.

**Apply Viewer Transformations.** Never selectable; defaults as appropriate. If this checkbox is selected (i.e., checked), the data are saved as source data. If unselected (i.e., unchecked), the data are saved as EEG scalp data.

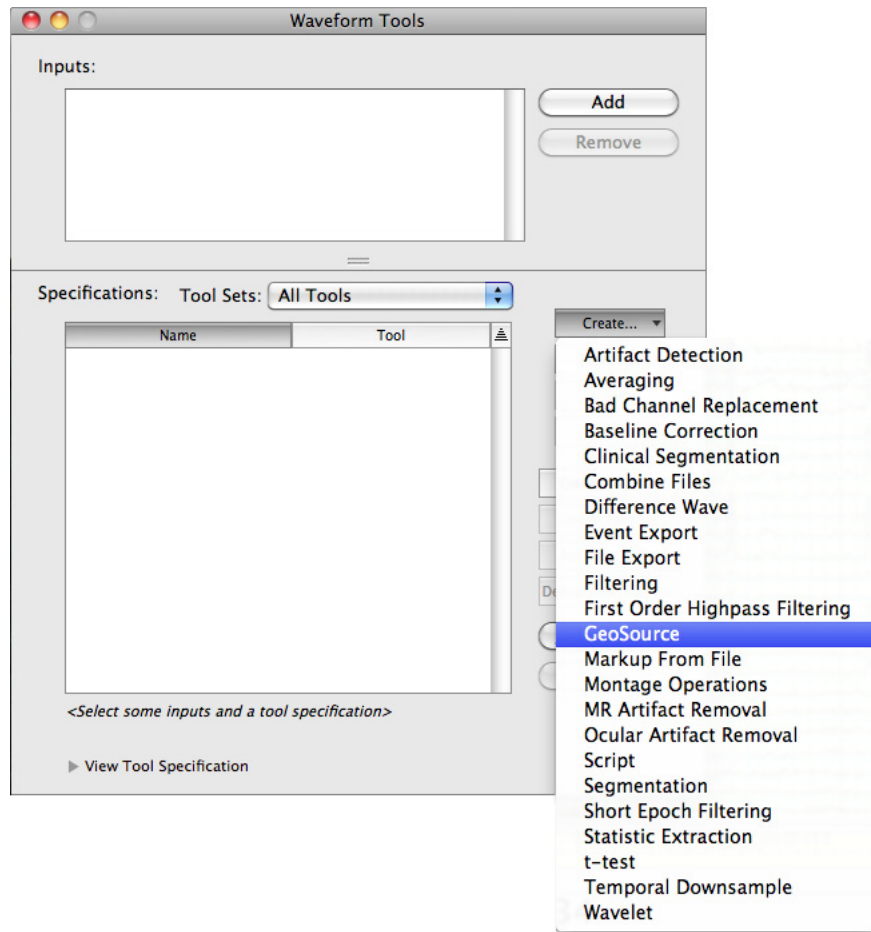
**E New Folder.** Allows you to create a new folder in which to place the file.

**F Cancel and Save As.** Whereas Save As saves a file while closing the dialog, Cancel closes the dialog without saving a file.

## Tools > Waveform Tools

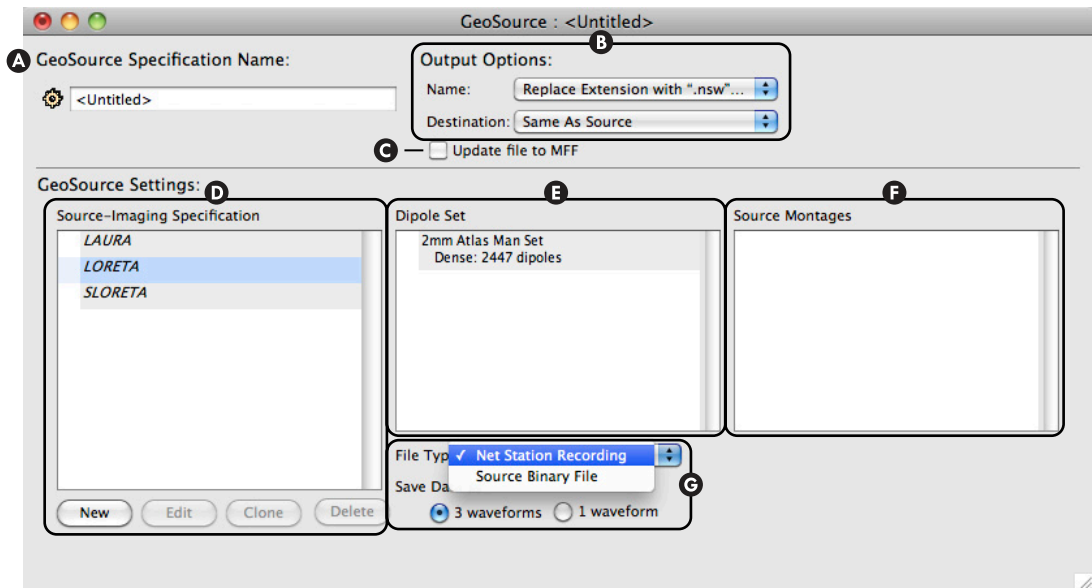
The GeoSource Specification Editor window (Figure 2-6) allows you to create a source-imaging tool that can be added to a script or used to process a batch of files. Different from a source-imaging specification (see Chapter 4, “Source-Imaging Specifications”), a GeoSource specification tool consists of EEG sources, source-imaging specification, and output format (Net Station recording or source binary).

To create a GeoSource specification tool, open the GeoSource Specification Editor window by choosing **Tools > Waveform Tools** and selecting GeoSource from the Create pop-up menu of the Waveform Tools window (Figure 2-5).



**Figure 2-5.** Waveform Tools window

Figure 2-6 shows the GeoSource Specification Editor window.



**Figure 2-6.** GeoSource Specification Editor window

The following are brief descriptions of the items in Figure 2-6.

- A GeoSource Specification Name.** Allows you to enter a name to identify a new GeoSource specification tool.
- B Output Options.** Allows you to add an extension to the files created by the new specification tool and to direct those files to a specific directory.
  - Name.* Allows you to select an extension (or a prompt for customizing the extension) for all files processed by the new specification tool.
  - Destination.* Specifies the destination for all files created by the new specification tool.
- C Update file to MFF.** Writes the output as an MFF file.
- D Source-Imaging Specification** (list and editing buttons). Allows you to select the source-imaging specification to use in solving the inverse problem. Click to the left of the desired specification name. A green dot will appear next to the selection. For more information about source-imaging specifications, see page 97.

The editing buttons allow you to apply the following functions to a selected default or user-defined specification.

**New.** Opens a blank Source-Imaging Specification Editor window (Figure 2-16) for creating a new user-defined specification.

**Edit.** Opens a filled-in Source-Imaging Specification Editor window (Figure 2-16) that contains the editable parameters of the user-defined specification that was selected in the Source Image Specification list.

**Clone.** Opens a filled-in Source-Imaging Specification Editor window (Figure 2-16) that contains the editable parameters of the default or user-defined specification that was selected in the Source Image Specification list. The Clone feature appends the word “copy” to the original name to ensure that the cloned specification is saved with a different name.

**Delete.** Opens a dialog confirming that you wish to delete the user-defined specification selected in the Source Image Specification list.

- E Dipole Set.** Allows you to select a dipole set for the named GeoSource specification tool. Click in the column left of the desired option. A green dot will appear next to the selection.

**Note:** You must select one item in the list, even if it is the only item listed.

**2 mm Atlas Man.** This set 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.

This set 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>.

- F Source Montages.** Allows you to select a source montage for the named GeoSource specification tool. Click in the column left of the desired option. A green dot will appear next to the selection.

**Note:** When the 2 mm Atlas Man set is selected and you choose to output the data as a Net Station EEG recording file or a Net Station MFF recording file, then you must select a source montage from the Source Montages list.



- Ⓒ **Data output options.** Allows you to specify the file type and source-waveform configuration of the output file.

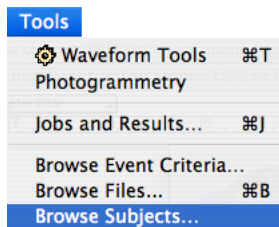
**File Type.** Sets the file as one of two types. Options are:

- *Net Station Recording.* This is similar to a Net Station EEG recording file. For more information, see page 104.
- *Source Binary File.* This is similar to a normal simple-binary file. For more information, see page 104.

**Save Data as.** Selecting either the Net Station Recording or the Source Binary File file type activates the Save Data as buttons, which allow you to save the data as *one waveform* collapsed per dipole location or as *three waveforms* overlaid per dipole location. For details and figures, see the as RMS of Source Components and as Overlaid Source Components viewing options on page 31.

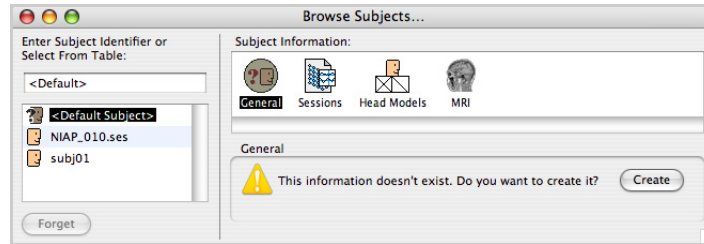
## Tools > Browse Subjects

The Browse Subjects window allows you to enter subject-specific information for a Net Station EEG file. To open the Browse Subjects window, choose **Tools > Browse Subjects** (Figure 2-7) from within the file.



**Figure 2-7.** Browse Subjects menu command

The Browse Subjects window contains General, Sessions, Head Models, and MRI panes (Figure 2-8). Choosing one of the icons in the Subject Information pane displays that icon's corresponding fields in the lower, right pane.



**Figure 2-8.** Browse Subjects window

If the information is not already available, the General pane enables you to enter data about the subject's age, date of birth, experiment ID, experiment name, subject's handedness, etc. Likewise, if session information is not already available, the Sessions pane enables you to select a particular session from a list of available session files.

The following sections describe the Head Models and MRI panes, which are designed to automatically use built-in default models for GeoSource operations.

## Head Models Pane

For clinical applications, the Head Models pane automatically uses built-in default models provided by Net Station for the subject's head model.

If Geodesic Photogrammetry System (GPS) coordinates are available for the subject, the GPS information is loaded into Net Station and the Head Models pane will list information about the GPS file, including the Geodesic Sensor Net model used and the date and time of the sensor registration. If multiple GPS sensor-registration files are available, Net Station uses the GPS file with the timestamp closest to that of the currently open Net Station EEG file.

If the subject has no GPS coordinates, Net Station uses a built-in default 3D coordinate set for the sensor layout specified in the Net Station EEG file.

## MRI Panes

The MRI panes contain two built-in MRI files:

- **MNI typical.hdr.** This is a *typical MRI* file from the Montreal Neurological Institute (hence, the MNI in the filename). This file is based on one subject's brain and represents that subject's specific anatomy, which closely matches the average MRI. This file is used to display the actual solutions, which are based on the *average MRI* file.
- **MNI average.hdr.** This is an *average MRI* file from the Montreal Neurological Institute. This file is based on the brains of approximately 300 subjects and represents the average of their collective anatomies. This file is the basis for the actual solutions that are displayed using the *typical MRI* file.

Both MRI files are approximations.

## View Menu

The View menu allows you to change the appearance of the data in Net Station Viewer. You can view source data as continuous data, categories, or overlaid segments in a chart, grid, or synoptic plot views (see Figure 2-9). For details about these features, see the *Net Station Viewer Technical Manual*.

In order for the RMS (root-mean-square; see Figure 2-10) and overlaid source components (see Figure 2-11) options to be available, your file must be in source space (i.e., source waveforms).

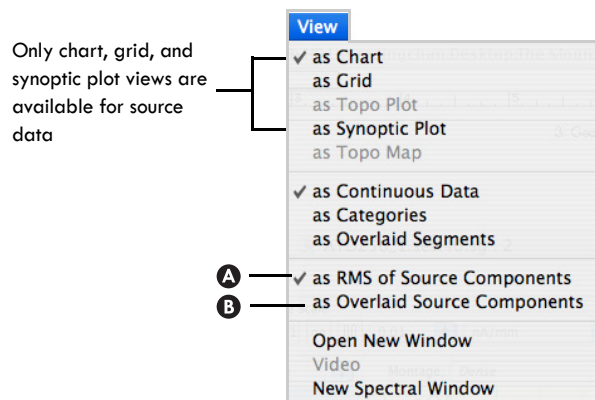
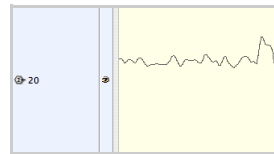


Figure 2-9. View menu

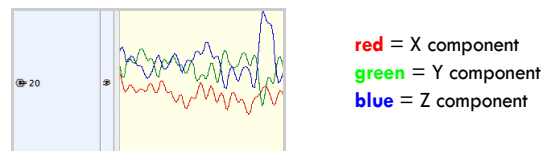
The following are brief descriptions of the items in Figure 2-9.

- A as RMS of Source Components.** Displays the source waveforms as collapsed into a single waveform (Figure 2-10).



**Figure 2-10.** As RMS of Source Components

- B as Overlaid Source Components.** Displays each dipole's three waveforms overlaid and color coded (the X component is red, the Y is green, and the Z is blue). See Figure 2-11.



**Figure 2-11.** As Overlaid Source Components

## Amplitude Menu

The Amplitude menu allows you to change the amplitude of the waveforms in the Net Station Viewer so that you can adjust the visibility of the waveforms. For example, if source waveforms appear flat, choosing a very small amplitude value from the Amplitude menu may reveal the true shape of the waveforms.

The Amplitude menu for source data is identical to that for scalp data, except it contains nanoamp meters rather than microvolts (Figure 2-12).

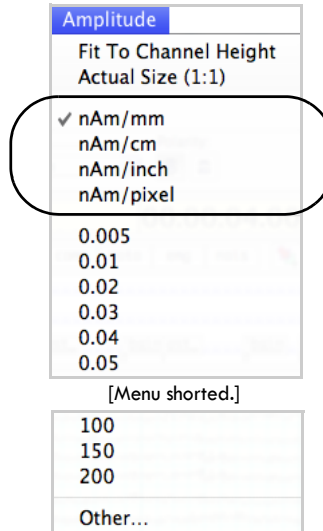


Figure 2-12. Amplitude menu

## Montage Menu

The Montage menu allows you to display a subset of dipoles that are of specific interest.

You can apply a montage to the source data in the Net Station Viewer one of two ways:

- From the menu bar, choose **Montage** > {source montage name}.
- From the data-display control strip, choose a source montage from the Montage pop-up menu (Figure 2-13).

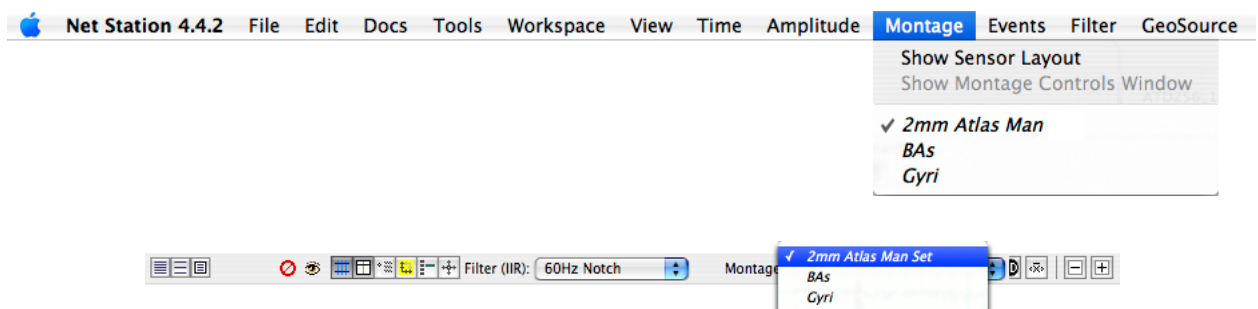


Figure 2-13. Montage menu (top) and Montage pop-up menu (bottom)

Source montages are created in the GeoSource Viewer. For details, see page 49.

## GeoSource > GeoSource Controls

The GeoSource menu provides access to the GeoSource Controls window (Figure 2-15) and the Source-Imaging Specification Editor window (Figure 2-16), which are two of the software's main windows. See Figure 2-14 for the items of the GeoSource menu.

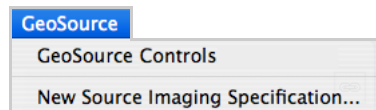


Figure 2-14. GeoSource menu

The GeoSource Controls window allows you to select a source-imaging specification at run (i.e., recording) time and to view it in the Net Station Viewer or the GeoSource Viewer. To open the GeoSource Controls window, choose **GeoSource > GeoSource Controls**.

Each GeoSource Controls window is unique to its corresponding Net Station EEG file. If you wish to view the source data of another Net Station EEG file, you must open a separate GeoSource Controls window from within that file. The name of the corresponding Net Station EEG file is displayed at the top of each GeoSource Controls window (see Figure 2-15).

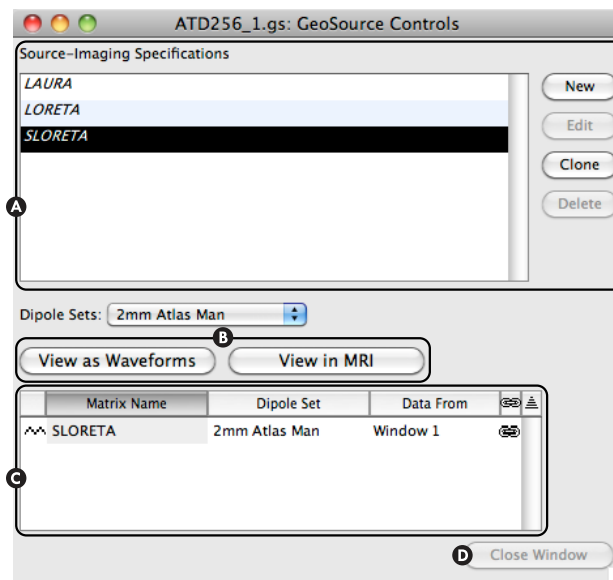


Figure 2-15. GeoSource Controls window

The following are brief descriptions of the items in Figure 2-15.

- A Source-Imaging Specifications** (list and editing buttons). Displays the available source-imaging specifications. Click a specification to select it. The editing buttons allow you to apply the following functions to a selected specification:



*New.* Opens a blank Source-Imaging Specification Editor window (Figure 2-16) for creating a new user-defined specification.




*Edit.* Opens a filled-in Source-Imaging Specification Editor window (Figure 2-16) that contains the editable parameters of the user-defined specification that was selected in the Source-Imaging Specification list.

*Clone.* Opens a filled-in Source-Imaging Specification Editor window (Figure 2-16) that contains the editable parameters of the default or user-defined specification that was selected in the Source-Imaging Specification list. The Clone feature appends the word “copy” to the original name to ensure that the cloned specification is saved with a different name.

*Delete.* Opens a dialog confirming that you wish to delete the user-defined specification selected in the Source-Imaging Specification list.

- B View as Waveforms and View in MRI** (for the source-viewing modes). Displays the source data either in the Net Station Viewer as waveforms (see page 21 and page 59) or in the GeoSource Viewer as dipole intensities overlaid on an MRI (see page 39 and page 60). The name of the source data file is automatically displayed in the View list.
- C View list.** Lists the currently open source data windows. This list can be sorted by column (window type, Matrix Name, Data From, or linked/unlinked) in either ascending or descending alphabetical or iconic order. Double-clicking in a specific row brings the selected window to the front.

*Ascending/descending order.* To the far right of the view list is the ascending/descending order toggle button, which shows the ascending () icon for ascending ordering and the descending () icon for descending ordering. Click it to change the direction of the ordering.

*Window-type column.* The window-type column has a blank header row icon () and has two icons in the rows below that indicate window type: waveform windows () and MRI windows () .

*Data From column.* The Data From column, which is applicable to source data displayed in both the GeoSource Viewer and the Net Station Viewer, identifies the EEG window supplying the data. If the data in the EEG windows are

displayed as continuous data or as categories, you can cycle through the available windows by clicking a file name in the Data From column.

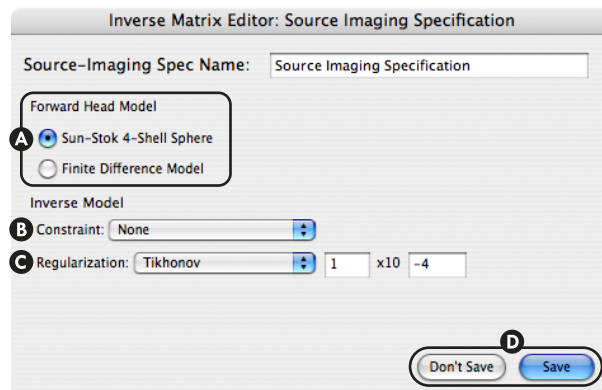
For example, whereas the same scalp data may be displayed in multiple windows, a 60-Hz notch filter may be applied in Window 1 and a 40-Hz highpass filter may be applied in Window 2. As a result, three EEG windows will be available in the Data From column:

- a recording file, which provides unprocessed data to the GeoSource Viewer for display on the 3D MRI slices;
- Window 1, which provides 60-Hz filtered data; and
- Window 2, which provides 40-Hz filtered data.

**D Close Window.** Closes any source data window selected in the View list.

## GeoSource > New Source-Imaging Specification

Choose **GeoSource > New Source-Imaging Specification** to open the Source-Imaging Specification Editor window (Figure 2-16), which allows you to create or edit a source-imaging specification. A source-imaging specification consists of the forward head model, inverse method, and various mathematical techniques.



**Figure 2-16.** Source-Imaging Specification Editor window

The following are brief descriptions of the items in Figure 2-16.

**A Forward Head Model.** Two models are available:

*Sun-Stok 4-Shell Sphere.* This is a spherical model that consists of four shells representing the cortex, cerebrospinal fluid, skull, and scalp.



**Finite Difference Model.** This is a head model that captures the typical geometry of the human head tissues, including the cortex, cerebrospinal fluid (CSF), skull, and scalp.

For more information about the forward head models, see Chapter 4, “Forward Algorithms for EEG” on page 97.

- B Constraint** (of the Inverse Model). The following schemes are available to constrain the source space before the source-imaging specification is applied to the Net Station EEG file. Options are:

**None.** Applies no constraint scheme.

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

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

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

If you choose the LAURA constraint, then additional parameters (Radius of Influence and Exponent) appear that pertain only to the LAURA solution. See Figure 2-17. You can use the default values for those parameters or refer to Grave de Peralta and Gonzalez Andino (2002) for more information.

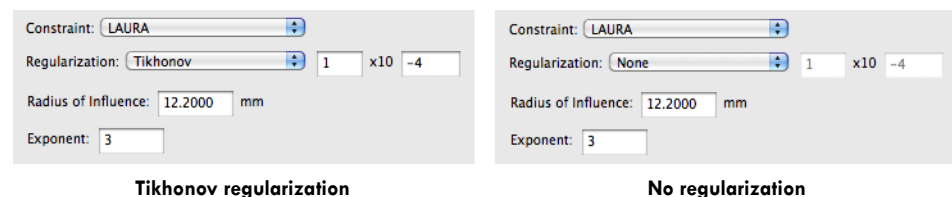


Figure 2-17. LAURA parameters

For more information about the constraint schemes, see Chapter 4, “Constraint Schemes” on page 100.

- C Regularization** (of the Inverse Model). A method that adds information to stabilize an *ill-posed* problem. Options are:

**None.** Applies no regularization method.

*Tikhonov.* Adds a small regularization parameter to all singular values, thus disproportionately increasing the small values.

For more information about regularization, see Chapter 4, “Regularization” on page 102.

- D Don't Save and Save.** Whereas Save saves all changes while closing the window, Don't Save closes the window without saving changes. New specifications that are saved automatically appear in the GeoSource Controls window (Figure 2-15) and the GeoSource Specification Editor window (Figure 2-6) that is opened from the Waveform Tools window.

## Default Source-Imaging Specifications

While you can define your own user-defined source-imaging specifications, GeoSource also provides three default source-imaging specifications for displaying source data. When you apply a default source-imaging specification to your scalp data, the following values are used to display the corresponding source data.

These values are available from the GeoSource Controls window and are based on values published in peer-reviewed scientific literature.

### *Default LAURA Source-Imaging Specification*

- Forward head model: Sun-Stok 4-shell sphere
- Inverse model:
  - Regularization: Tikhonov (1 x 10 and -4)
  - Constraint: LAURA
  - Radius of Influence: 12.2000 mm
  - Exponent: 3

### *Default LORETA Specification*

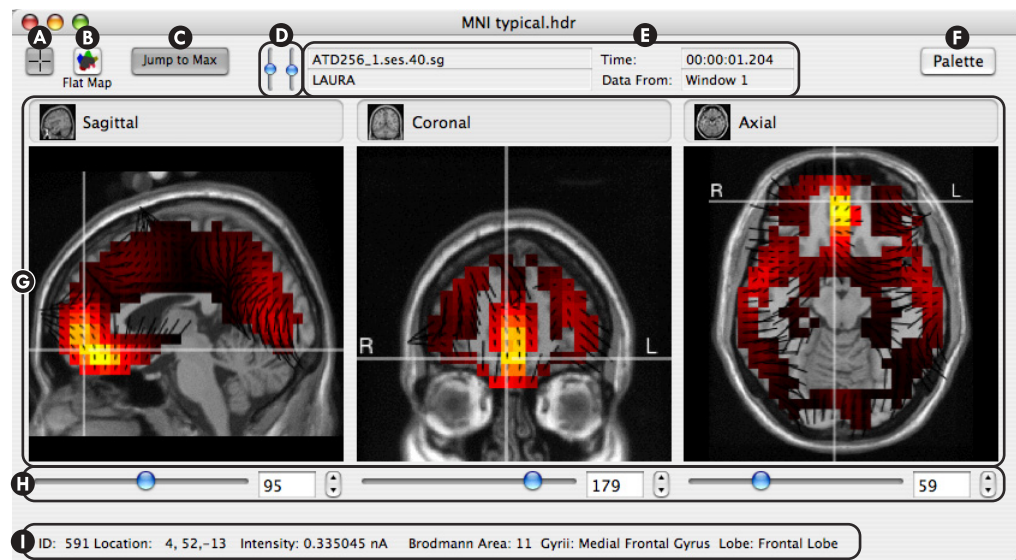
- Forward head model: Sun-Stok 4-shell sphere
- Inverse model:
  - Regularization: Tikhonov (1 x 10 and -3)
  - Constraint: LORETA

### Default sLORETA Specification

- Forward head model: Sun-Stok 4-shell sphere
- Inverse model:
  - Regularization: Tikhonov ( $1 \times 10$  and  $-2$ )
  - Constraint: sLORETA

## GeoSource Viewer

The GeoSource Viewer (Figure 2-18) displays source data as dipoles overlaid on 3D MRI slices. Separate from the Net Station Viewer, the GeoSource Viewer can be accessed only by clicking the **View in MRI** button in the GeoSource Controls window (see page 34).



**Figure 2-18.** GeoSource Viewer

The following are brief descriptions of the items in Figure 2-18.

- A Crosshairs.** When selected (darkened), this button displays the crosshairs overlaid on all three MRI panes. Clicking in an MRI pane selects that pane as the *focus pane*, which is indicated by a yellow crosshairs. As you navigate

through the focus pane, the other two panes will update accordingly. This button is selected by default. Click it to deselect it.

- B Flat Map.** This button opens the Flat Map window (see page 46).
- C Jump to Max.** When selected (darkened), this button ensures that each MRI pane is automatically centered on the dipole with the highest intensity value when it receives new time points as the EEG data are played in the Net Station Viewer. This button is selected by default. Click it to deselect it.

- D Sliders for brightness and contrast.** Adjusts the brightness and contrast in all three MRI panes.

*Brightness* (left slider). The left slider adds or subtracts values from each pixel to lighten or darken the images uniformly.

*Contrast* (right slider). The right slider changes the rate of change from black to white, or from white to black, in the images to emphasize or de-emphasize the differences in shading.

- E File information.** Displays information about the data file.

*Filename indicator.* Displays the filename for the scalp data.

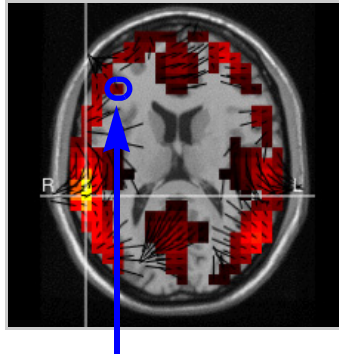
*Source specification indicator.* Displays the source-imaging specification used.

*Time indicator.* Displays the time under the Time Synch marker in the Net Station Viewer.

*Data From indicator.* Lists the EEG window providing the data to the GeoSource Viewer.

- F Palette.** When selected (darkened), this button opens the palette drawer. See the next section, which is titled “Palette Drawer”.

- Ⓒ **MRI panes.** Displays dipole intensities overlaid onto the sagittal, coronal, and axial MRI slices (see Figure 2-18). The dipoles are approximately represented by *voxels*, which are colored 3D volume pixels.



**Figure 2-19.** Dipoles in the MRI panes approximately represented by voxels

- Ⓕ **MRI slice sliders, text boxes, and arrow buttons.** If an MRI pane is selected, you can navigate to a specific *MRI slice* in that pane by moving the slider, entering the slice number in the text box, or by selecting the arrow buttons. You can also use the scroll wheel on your mouse. The other two MRI panes will update accordingly.

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

- Ⓖ **Dipole information area.** This area displays roll-over information about the dipole that is under the cursor in an MRI pane. The information includes dipole ID number, dipole location (in X, Y, and Z coordinates in MNI space), intensity in nanoamp meters, and Brodmann area, *gyrus* name, and lobe name (as defined by the Talairach Daemon).

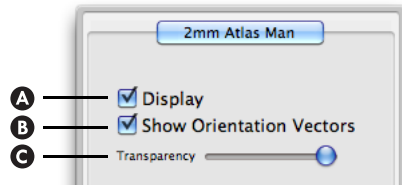
## Palette Drawer

The GeoSource Viewer displays the dipoles in colors that represent their intensities. The intensity values (including maximum and minimum) correspond to the datapoint beneath the Time Synch marker in the Net Station Viewer.

The palette drawer allows you to change the color palettes for the dipoles or to navigate directly to a specific dipole based on its dipole ID number or intensity value.

## General Palette Controls

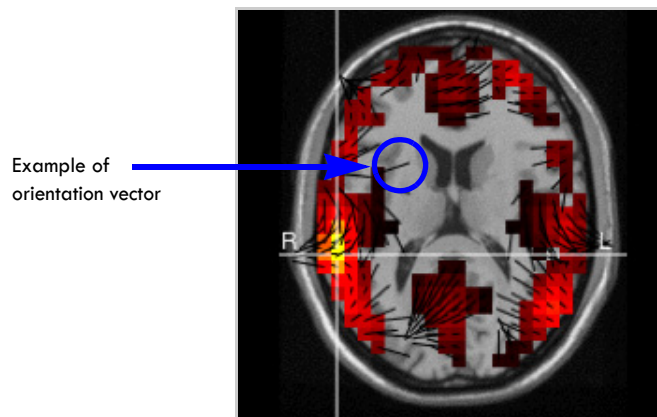
Figure 2-20 shows the top portion of the palette drawer. To show the palette drawer, click the **Palette** button on the GeoSource Viewer (see Figure 2-18).



**Figure 2-20.** General palette controls

The following are brief descriptions of the items in Figure 2-20.

- A Display.** When selected (checked), displays the dipoles that are overlaid onto the MRI slices; when unselected (unchecked), hides the dipoles.
- B Show Orientation Vector.** The Show Orientation Vector checkbox displays or hides the dipole orientation vectors in the MRI slices. The orientation vectors, which are represented by black lines (Figure 2-21), indicate the direction the dipole is pointing. They extend in the positive direction from the center of each voxel. (Check the checkbox to display; uncheck the checkbox to hide.)

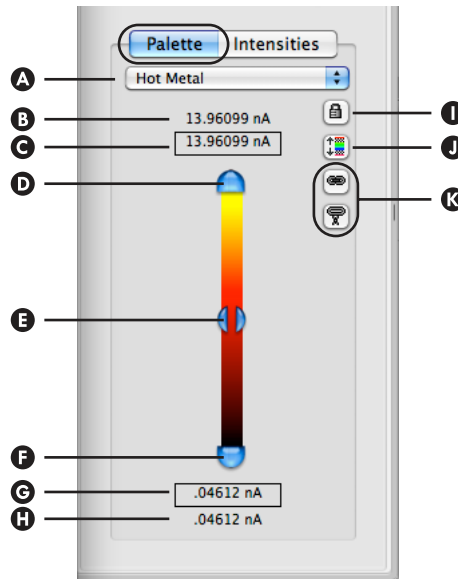


**Figure 2-21.** Orientation vectors

- C Transparency slider.** This slider increases or decreases the amount of light transmitted through the dipoles.

## Palette Pane

Click the **Palette** tab on the palette drawer to select the Palette pane (Figure 2-22).





**Figure 2-22.** Palette pane

The following are brief descriptions of the items in Figure 2-22.

- A Spectrum pop-up menu.** Allows the selection of a color spectrum. To view the available spectra, see the “Amplitude-Scale Palette” chapter in the *Net Station Viewer Technical Manual*.
- B Palette-maximum-slider label.** Initially, indicates the default palette maximum. You can, however, highlight this value and type a lesser value, which decreases the palette maximum and moves the palette-maximum slider (item D) downward.
- C Palette-maximum label.** Indicates the current palette maximum, which is a *setting* that is set by the palette-maximum slider (item D).
- D Palette-maximum slider.** When dragged downward, the palette maximum is reset to a lesser value, which is reflected in the palette-maximum label (item C).

- E Palette-range slider.** Marks the midpoint between the palette's maximum and minimum values. This slider is not draggable.
- F Palette-minimum slider.** When dragged upward, the palette minimum is reset to a greater value, which is reflected in the palette-minimum label (item G).
- G Palette-minimum label.** Indicates the current palette minimum, which is a *setting* that is set by the palette-minimum slider (item F).
- H Palette-minimum-slider label.** Initially, indicates the default palette minimum. You can, however, highlight this value and type a greater value, which increases the palette minimum and moves the palette-minimum slider (item F) upward.
- I Lock button.** This button, if selected (darkened), makes the palette-slider range equal to the data range for the data point under the Time Synch in the Net Station Viewer. This feature is useful if you want the data range to remain fixed while you navigate through the Net Station Viewer and view the dipoles of different time points in the GeoSource Viewer.
- J Accumulate button.** If this button is selected (darkened), the palette maximum and minimum values automatically update according to the new time points received as the EEG data are played in the Net Station Viewer. In other words, whenever a larger maximum or smaller minimum value appears, it becomes the new maximum or minimum value for the palette. If this button is unselected (not darkened), the palette will report the maximum and minimum values for only the current time point.
- K Palette-range link buttons.** Indicates whether the palette range (maximum and minimum) of the active window is independent of or linked to the palette range of another window.

**Master palette button** (  ). If this button is selected on the active window, the palette of the active window is setting the palette range for another window or windows.

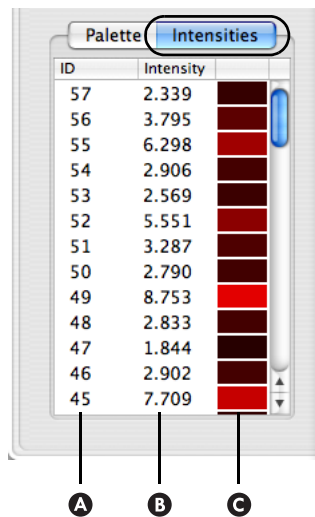
**Slave palette button** (  ). If this button is selected on the active window, the palette of the active window is having its palette range set by another window.

If neither link button is selected on the active window, there is no linking between the active window and other windows, which means that its palette range is independent of other windows.



## Intensities Pane

Click the **Intensities** tab on the palette drawer to select the Intensities pane (Figure 2-23). The Intensities pane lists the dipoles, organized by label or intensity. Clicking a label or an intensity in the Intensities pane automatically navigates the three MRI panes in the GeoSource Viewer to the selected dipole.



ID	Intensity	
57	2.339	
56	3.795	
55	6.298	
54	2.906	
53	2.569	
52	5.551	
51	3.287	
50	2.790	
49	8.753	
48	2.833	
47	1.844	
46	2.902	
45	7.709	

A B C

**Figure 2-23.** Intensities pane

The following are brief descriptions of the items in Figure 2-23.

- A ID column.** Lists the dipoles by ID number. Click the column title to sort the ID numbers in ascending or descending order.
- B Intensity column.** Lists the dipoles by intensity value. Click the column title to sort the intensity values in ascending or descending order.
- C Intensity color column.** Lists the dipoles by intensity color. Click the column to sort the intensity colors in ascending or descending order.

## Flat Map Window

The Flat Map window (Figure 2-24) projects the dipole information onto a smooth, two-dimensional representation of the cortical surface.

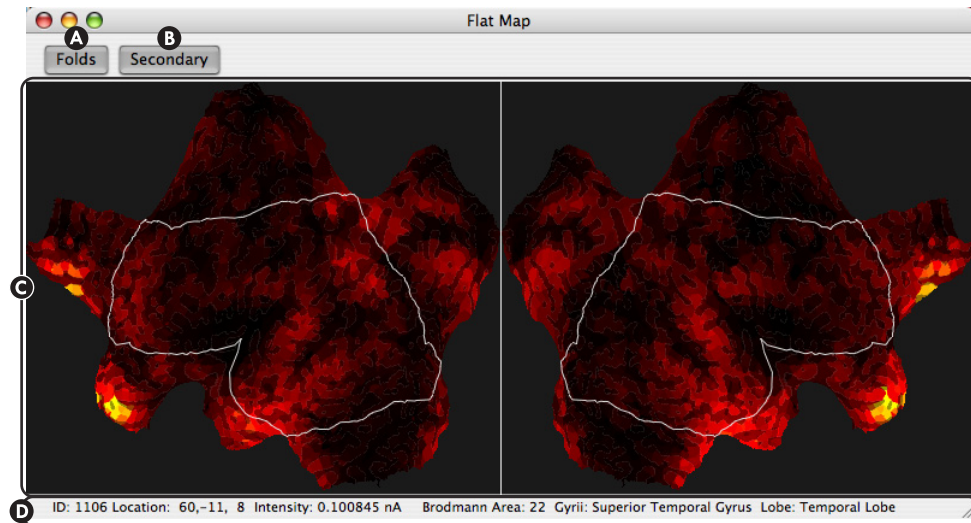


Figure 2-24. Flat Map window

The following are brief descriptions of the items in Figure 2-24.

- A Folds.** When selected (darkened), this button displays the borders of the cortical folds. This button is selected by default. Click it to deselect it.

**Note:** The folds are represented by transparent gray lines overlaid on the map, which may slightly mask some of the colors of the dipole activations. To see all of the colors of the dipole activations, deselect this feature.

- B Secondary.** The 3D-to-2D conversion of the dipoles results in a small number of overlapped dipoles. If this button is selected (darkened), the Flat Map window displays the *average intensity* of the overlapped dipoles. If this button is unselected (not darkened), the intensity of the topmost dipole is displayed.

- C Flat map.** Provides a two-dimensional representation of the left and right hemispheres of the cerebral cortex on which dipole activity is depicted. The thin white line indicates the approximate outlines of the lateral surface of each hemisphere.

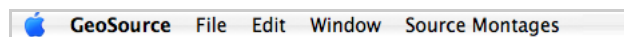
- D Dipole information area.** Displays roll-over information about the dipole that is under the cursor in the Flat Map window. The information includes dipole ID number, dipole location (in X, Y, and Z coordinates in MNI space), intensity in nanoamp meters, Brodmann area, *gyrus* name, and lobe name (as defined by the Talairach Daemon).

## GeoSource Menus

The GeoSource menu bar is visible when a GeoSource Viewer, which is for the MRI source-viewing mode, is frontmost on the monitor screen.

**Note:** Which viewer (Net Station or GeoSource), menus, and options are available onscreen is determined by the space (source or scalp), view (chart, grid, etc.), category-viewing mode (as continuous data, etc.), and source-viewing mode (waveforms or MRI) of the currently open file or view (if not yet saved as a file). For details, see “What to Know Before Getting Started” on page 54.

Figure 2-25 shows the GeoSource menu bar.



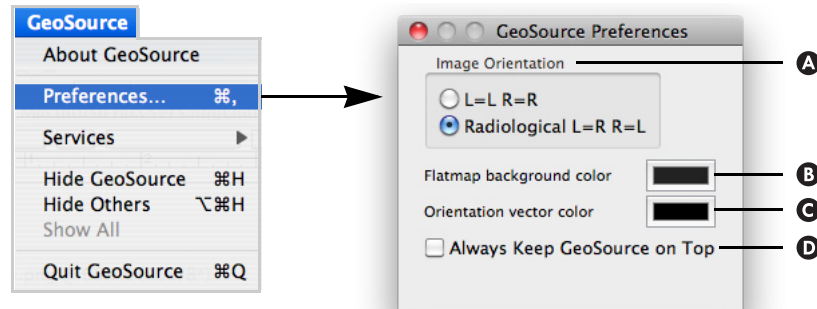
**Figure 2-25.** GeoSource menu bar

The following GeoSource menus enable these functions:

- **GeoSource menu.** Sets the GeoSource Viewer preferences.
- **File.** Opens and closes GeoSource files.
- **Edit.** Selects, copies, and pastes source data within and between files.
- **Window menu.** Zooms in on a GeoSource Viewer or brings all active GeoSource Viewers to the front.
- **Source Montages menu.** Creates or edits source montages, or applies source montages to the source data in the GeoSource Viewer.

## GeoSource > Preferences

The GeoSource menu allows you to set the orientation of the MRI panes by choosing **GeoSource > Preferences** (Figure 2-26).



**Figure 2-26.** GeoSource menu and GeoSource Preferences window

The following is a brief description of the items in Figure 2-26.

- A Image Orientation.** Allows you to view the dipoles on the MRI slices in one of two orientations (or views), as follows.
  - L = L and R = R.* Displays left on the left and right on the right.
  - Radiological | L=R R=L.* Displays left on the right and right on the left.
- B Flatmap background color.** Allows you to set the color that is displayed behind the flatmap. Black is the default.
- C Orientation vector color.** Allows you to set the color of the orientation vectors. Black is the default.
- D Always Keep GeoSource on Top.** When checked, allows you to set the GeoSource Viewer to display on top of all other open windows or dialogs.

## Window Menu

The Window menu (Figure 2-27) allows you to organize the viewing order of the GeoSource Viewer windows. You can also use the GeoSource icon in the Dock to easily distinguish between many open files by right clicking the GeoSource icon in the Dock and seeing a full description of each file.

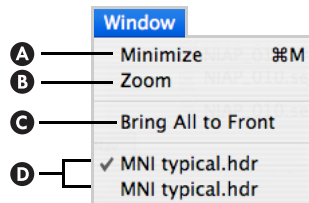


Figure 2-27. Window menu

The following are brief descriptions of the items in Figure 2-27.

- A Minimize.** Reduces the frontmost GeoSource Viewer to an icon and places it in the Dock to save screen space. (Clicking the yellow Minimize button in the top-left corner of the GeoSource Viewer achieves the same result.)
- B Zoom.** Enlarges the frontmost GeoSource Viewer to full screen size.
- C Bring All to Front.** Places all GeoSource Viewers in front of all other application windows.
- D Names of GeoSource viewers.** Brings the selected GeoSource Viewer to the front of all other windows.

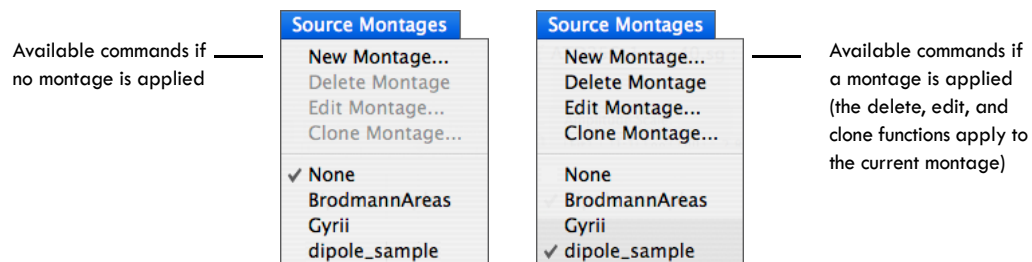
## Source Montages Menu

The Source Montages menu (Figure 2-28) allows you to apply, create, or edit a source montage (i.e., a subset of the dense dipole solution set, which is a region of interest).

The editing functions are available only for a currently applied source montage. You can delete, edit, or clone the source montage:

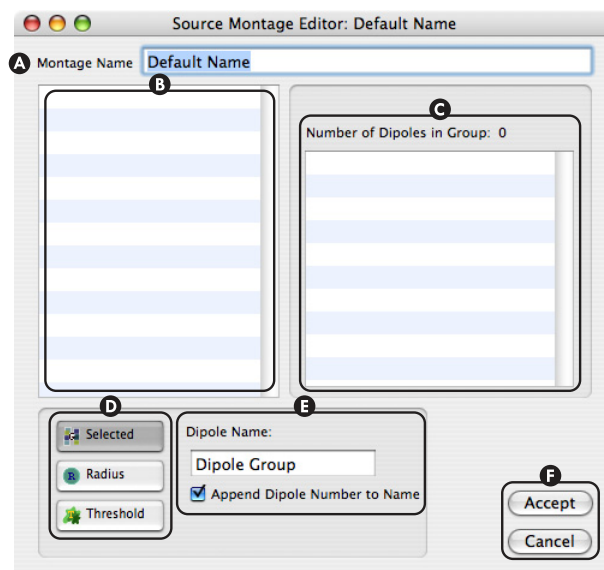
- If you choose **Delete Montage**, a confirmation dialog will appear.

- If you choose either **Edit Montage** or **Clone Montage**, you can rename the montage, rename dipole groups, or add or delete dipole groups from the selected montage, but you cannot change the radius distance or the threshold percentage values (see “4. Dipole-group creation buttons” on page 51). Note that cloned montages must be saved under a different name than the original.



**Figure 2-28.** Source Montages menu when a montage is not applied (left) and when it is (right)

Choosing **Source Montages > New Montage**, **Source Montages > Edit Montage**, or **Source Montages > Clone Montage** opens the Source Montage Editor window (Figure 2-29). The Source Montage Editor window allows you to populate source montages using a variety of dipole-group creation methods.



**Figure 2-29.** Source Montage Editor window

The following are brief descriptions of the items in Figure 2-29.

- A Montage Name.** Allows you to type in a name for the montage.
- B Names of dipole groups.** Lists the name and the icon for the dipole-group creation method of each *dipole group*, which is populated after you click a dipole-group creation button and click a voxel in an MRI pane of the GeoSource Viewer. *Note that a dipole group represents one dipole in a source montage.*
- C Members of selected dipole group.** Lists the number of dipoles, the icon and parameters of the dipole-group creation method, and the dipole ID numbers for each dipole group. This table is populated after you click a dipole-group creation button and click a voxel in an MRI pane of the GeoSource Viewer, or after you select an existing dipole group in the dipole-group names table.
- D Dipole-group creation options.** Click to select a dipole-group creation method. Options are:

**Selected.** Allows you to click or Shift-click individual voxels in the MRI panes to populate a dipole group.

**Radius.** Allows you to first specify a radius for a dipole group (Figure 2-30), and then click a voxel in the MRI panes. All voxels that fall within that radius from the selected voxel will populate the dipole group.

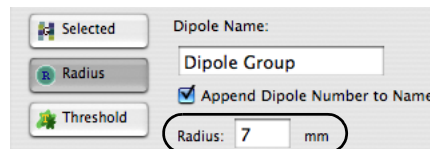


Figure 2-30. Radius parameters

**Threshold.** Allows you to first specify a percentage-of-peak value (Figure 2-31), and then click a voxel in the GeoSource Viewer. All adjacent voxels with intensities that fall within the specified percentage of the selected voxel's will populate the dipole group.

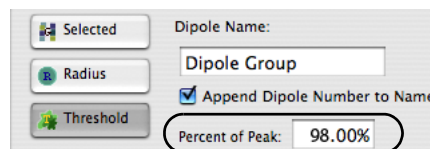


Figure 2-31. Threshold parameters

- **Dipole Name.** Allows you to type in a name for a dipole group whose voxels were individually selected or set by a radius or threshold setting. It is recommended that you assign a meaningful name that is indicative of a dipole group's anatomical location (such as amygdala) or indicative of the time point at which it occurred (such as P300).

*Append Dipole Number to Name.* When selected (checked), this checkbox automatically appends a dipole number to the name of the dipole group. The number appended is the number of the voxel that was first selected (clicked) to set the group.


- **Accept and Cancel.** Whereas Accept saves all changes while closing the window, Cancel closes the window without saving changes.



# GETTING STARTED

This chapter begins with what you need to know before getting started. With that understanding, the chapter then describes the basic tasks that are needed to apply a default source-imaging specification to a Net Station EEG scalp data file. Applying a source-imaging specification will allow you to:

- display source data in the Net Station Viewer or the GeoSource Viewer;
- view source data in the Net Station Viewer as the RMS (root-mean-square) of the source components or as overlaid source components; or
- navigate through source data in the Net Station Viewer and view the source data for the different time points in the GeoSource Viewer and the corresponding flat map in the Flat Map Window.

**Note:** GeoSource can be applied to any Net Station file that does *not* contain bipolar channels. Bipolar channels are not supported for source estimation. A warning dialog will appear if you mistakenly apply GeoSource to a file that does contain bipolar channels. If your file has the  icon next to the channel numbers, then it contains bipolar channels. Use another file.

The chapter goes on to describe the following user tasks:

- How to create a source montage in the GeoSource Viewer.
- How to edit, clone, or delete a source montage.
- How to create a source-imaging specification.
- How to edit, clone, or delete a source-imaging specification.
- How to create a GeoSource specification.

This chapter concludes with a list of basic user tips.

For descriptions of the GeoSource controls, see Chapter 2, “GeoSource Menus and Windows.” For explanations or definitions of unfamiliar terminology, see Chapter 4, “Source-Imaging Specifications” or the “Glossary.”

## What to Know Before Getting Started



Since Net Station can display GeoSource source waveforms, it is important that you know when you are using a Net-Station-formatted file (an EEG scalp data file) and when you are using a GeoSource-formatted file (a source data file). An EEG scalp data file can display data in various waveform, topographic, and synoptic plot views. A source data file can display either source waveforms in the Net Station Viewer (but only in the chart, grid, or synoptic plot views), or source MRI slices in the GeoSource Viewer.

One reason why you need to know when you are using what type of file is that some of the Net Station windows and dialogs display different fields and options depending upon whether a scalp data file or a source data file is currently open. Another reason for distinguishing your files is that the scalp data waveform files and the source data waveform files are both viewed with the Net Station Viewer. Therefore, as you put more files on the screen that may look similar, it becomes more important to ensure that you manage your files carefully.




## Scalp Data Files versus Source Data Files

Here are the distinguishing characteristics between scalp and source data files.

**Table 3-1.** Distinguishing characteristics between scalp data files and source data files

Distinguishing characteristics	Scalp data files		Source data files (including waveforms and MRI slices)	
file icon				
	Net Station MFF file icon		GeoSource file icon	
	Net Station windows and dialogs will display complete lists of fields and options.		Net Station windows and dialogs will display only those fields and options that pertain to GeoSource operations.	
file extension	File format	Default extension	File format	Default extension
	original Net Station session EEG MFF recording file	None, but Net Station does read original EEG recording files as having the .mff extension, since they are session files.	Net Station MFF Recording file	.mff
			Net Station Recording file	.ses
			Source Binary File	.swf
			Tab-delimited Text	.txt
			MATLAB	.mat

**Table 3-1.** Distinguishing characteristics between scalp data files and source data files

channel or dipole icon	single-channel icon 	bipolar-channel icon 	dipole icons 
listed montages	only defaults (including 10-20)		user-defined and two defaults (including Gyri)
amplitude scale (unit)	$\mu\text{V}$		nA
window title (before view saved)	filename : window #		filename : window # : name of source-imaging specification

## Creating a Source Data File

Note that once a set of parameters (source-imaging specification and source-viewing mode) is established for a GeoSource file, you cannot change those parameters for that saved file. You can, however, go back to the Net Station EEG scalp data file and save a series of GeoSource files from that original EEG data file with different sets of parameters.

**Note:** GeoSource will localize all scalp-recorded activity to dipoles distributed across the cortical gray 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.



**CAUTION:** The following steps are provided as a quick reference only. To avoid corrupting files or data, read all material in this manual **before** proceeding.

To convert a Net Station EEG scalp data file into a GeoSource source data file, do the following:

- 1 Open a scalp data file in Net Station.
- 2 Open the GeoSource Controls window by choosing **GeoSource > GeoSource Controls**.
- 3 Establish the desired GeoSource parameters for the file to be converted by:
  - a Choosing a source-imaging specification (default or user-defined). For details, see page 36 and page 88.
  - b Choosing a source-viewing mode (waveforms or MRI). For details, see page 35.

Note that by choosing one source-viewing mode or the other that a new source view of the EEG data is generated. What is displayed, however, is only a view. It is not yet a file.

- 4 Save the entire view or a selection of the view as a source data file (in waveform view) by:

- a Choosing **File > Save Selection** [or **Save A Copy As**].
- b Typing a new filename and extension into the Save As text box or leaving the default as is.


Note that you can customize the extensions (that is, not use the defaults) of Net Station and GeoSource files. Also note that the default file extensions change as you select a different format from the Format pop-up menu.

- c Using the Where pop-up menu to tell the software where to save the new file.
- d Choosing a file format from the Format pop-up menu. For details, see page 24.
- e Choosing an output option from the Output Precision pop-up menu. For details, see page 25.
- f Click **Save As**. Notice that the saved file now has the GeoSource file icon.

**Note:** Both the Convert to Microvolts and Apply Viewer Transformations checkboxes will default as appropriate and are never selectable.

## Displaying Source Data in the Net Station Viewer or the GeoSource Viewer

The configuration of the scalp data in the Net Station Viewer can affect how the source data are displayed in the Net Station Viewer and in the GeoSource Viewer. Therefore, before applying GeoSource to a Net Station EEG scalp data file:

- Regarding bipolar channels, make sure that the file does not contain them. Bipolar channels are not supported for source estimation. If your file has the  icon next to the channel numbers, then it contains bipolar channels. Use another file.
- Regarding display views, know that although GeoSource can be applied to any Net Station EEG scalp data file that does not contain bipolar channels, regardless of its view (chart, grid, topo plot, synoptic plot, or topo map) or

category-viewing mode (as continuous data, categories, or overlaid segments), the Net Station Viewer can display source data in only a chart, grid, or synoptic plot view.

**Note:** Be aware that scalp data that are displayed in a topo plot or topo map view will be displayed in a chart view when converted to source data.

- Regarding filters, know that any filter applied to scalp data in the Net Station Viewer will be applied in the conversion to source data. Furthermore, the Net Station Viewer IIR filter should be used for exploration purposes only. Finally, if you wish to source analyze filtered data, be sure to first filter your scalp file using the filtering Waveform Tool. For details about filters, see the *Net Station Viewer Technical Manual*.
- Regarding category-viewing modes, make sure that you select your mode carefully. The category-viewing mode selected in the Net Station Viewer for the scalp data affects the display of the source data in the GeoSource Viewer. Furthermore, if you change from viewing the scalp data file as categories to overlaid segments (or vice versa), the GeoSource Viewer will close and you will be required to regenerate the source data with your desired source-imaging specification. For details about the category-viewing modes, see the *Net Station Viewer Technical Manual*.
- Regarding optimum viewing (category-viewing mode and display views), typically, configuring the scalp data as overlaid segments in topo map view (potentials, full projection) works well, because it allows the user to view multiple conditions simultaneously in GeoSource and to more easily relate the source solution at a given time point to the scalp topography.

The following instructions describe how to use a default source-imaging specification to display source data in the Net Station Viewer (see page 21) or in the GeoSource Viewer (see page 39).

To display source data in both viewers, do the following:

- 1 Open the GeoSource Controls window by opening a Net Station EEG scalp data file, configuring the Net Station Viewer as described above, and choosing **GeoSource > GeoSource Controls** (Figure 3-1).

**Note:** This GeoSource Controls window provides source-imaging functions only for its corresponding Net Station EEG file. If you wish to view the source data of another Net Station EEG file, you must open a separate GeoSource Controls window from within that

file. The name of the corresponding Net Station EEG file is displayed at the top of each GeoSource Controls window (see page 34).

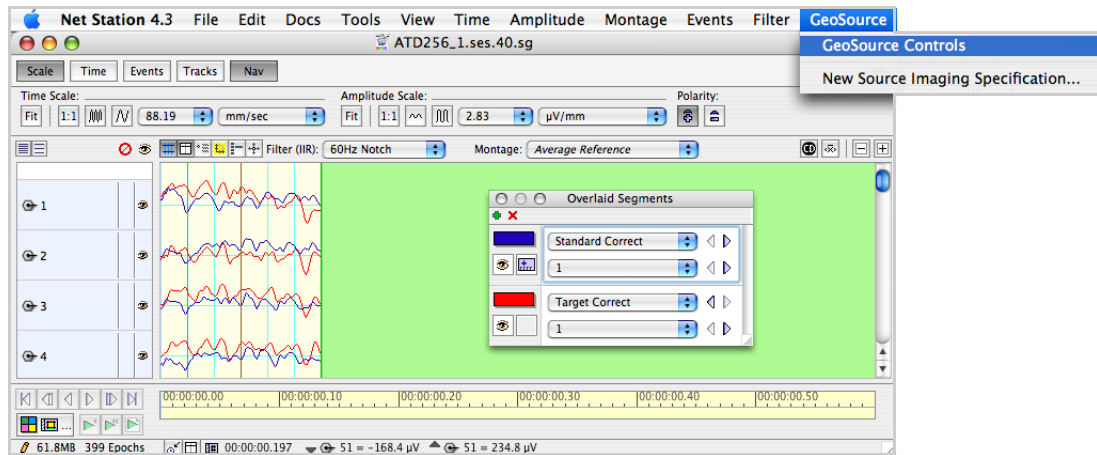


Figure 3-1. Opening the GeoSource Controls window

- 2 Click a default source-imaging specification to select it. See Figure 3-2.

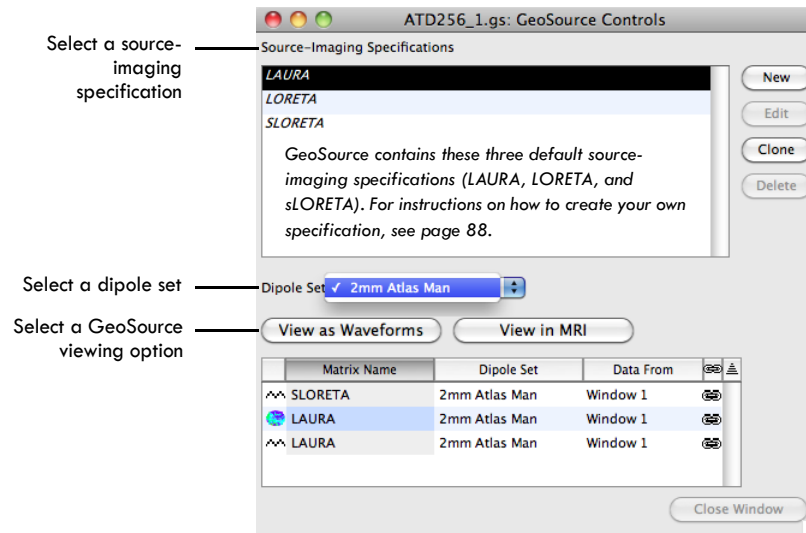
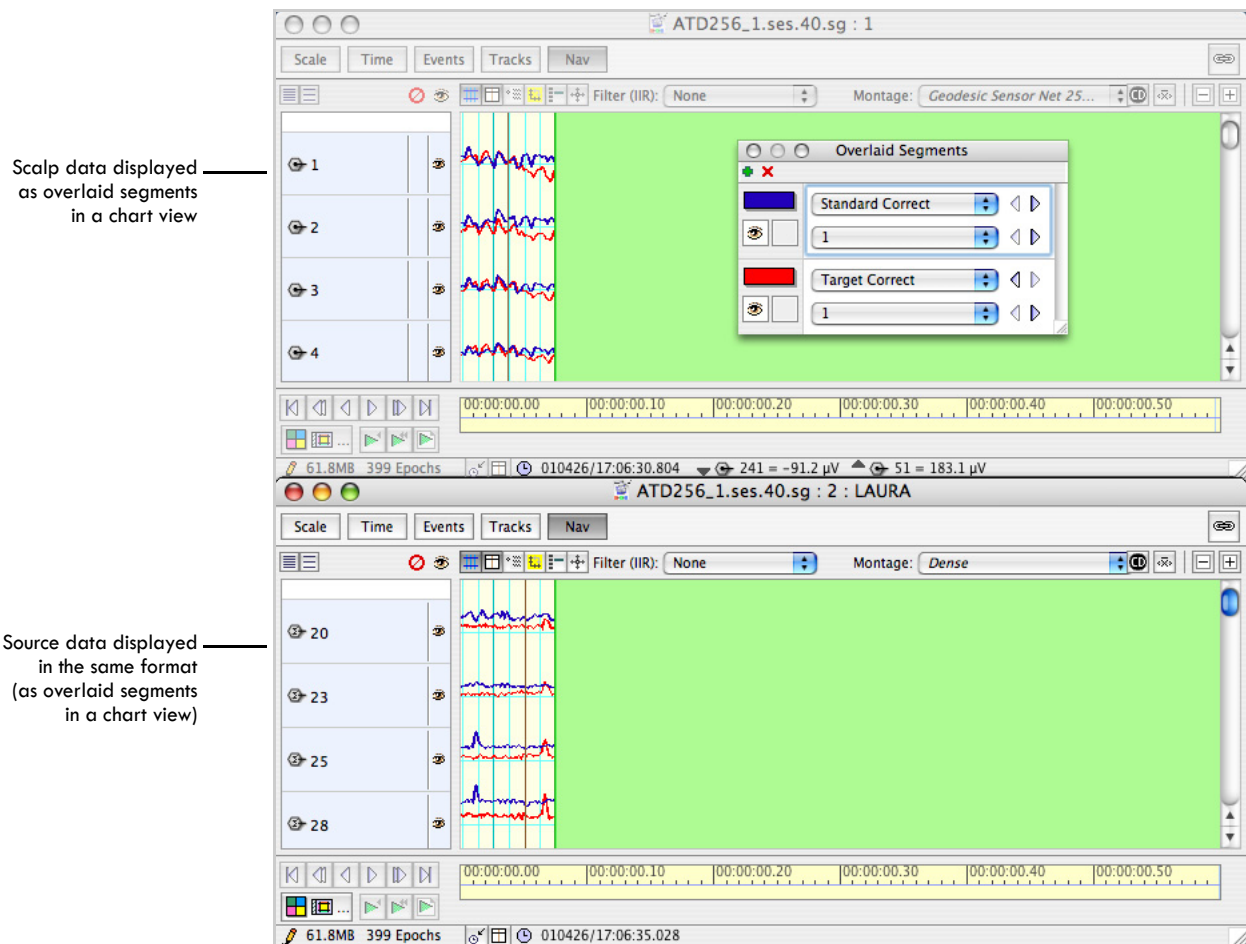


Figure 3-2. Selecting a default source-imaging specification and viewing option

- 3 Select a GeoSource viewing option in the GeoSource Controls window (Figure 3-2).

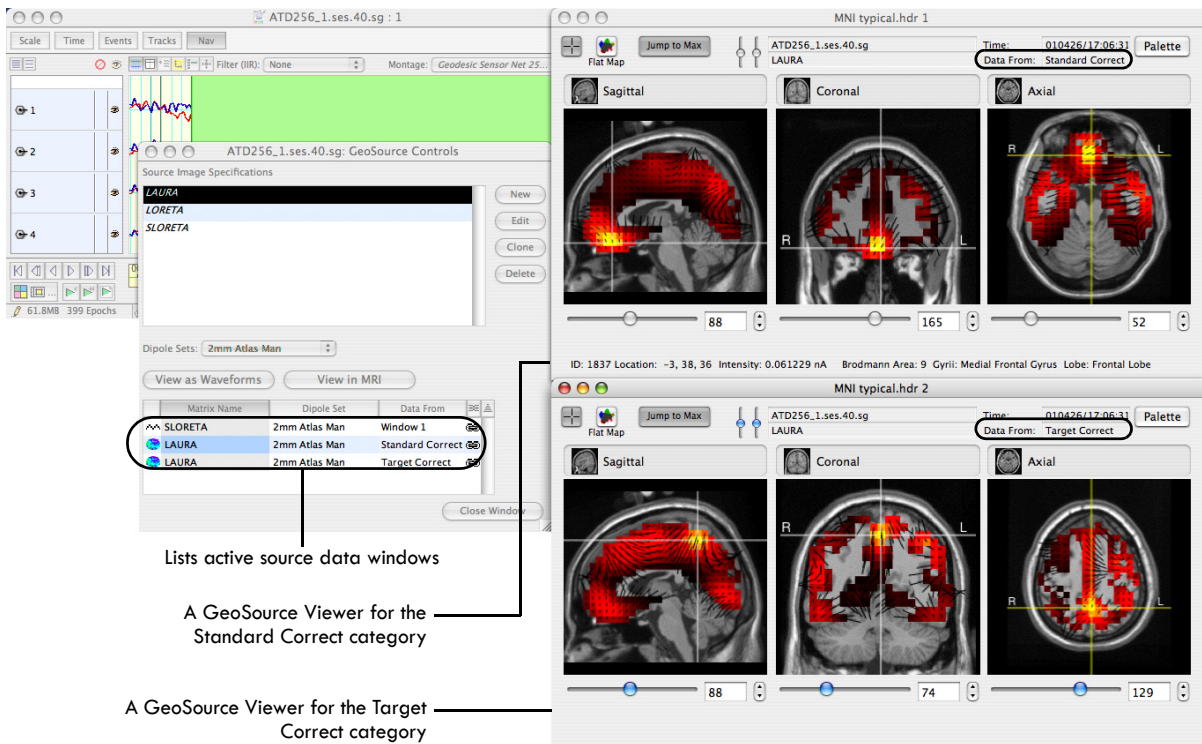
The viewing options are View as Waveforms and View in MRI:

- **View as Waveforms.** The resulting source waveforms will be displayed in a second Net Station Viewer window in a chart, grid, or synoptic plot view (Figure 3-3). If the scalp data are configured in a topo plot or topo map view, the source data will display in a chart view.



**Figure 3-3.** Scalp data (top) and source data (bottom) in the Net Station Viewer

- **View in MRI.** The resulting source data is displayed in the GeoSource Viewer projected onto MRI slices. If the scalp data are configured as overlaid segments in the Net Station Viewer, then the source data will display in a separate GeoSource Viewer for each category (Figure 3-4).



**Figure 3-4.** Source data in the GeoSource Viewer (right), along with scalp data in the Net Station Viewer (upper left) and the corresponding GeoSource Controls window (lower left)

Whether the source data are displayed in the Net Station Viewer (as waveforms) or in the GeoSource Viewer (as MRI slices), all active windows remain open on the desktop. This allows you to:

- Easily view the data from different perspectives—as scalp data, as source waveforms, or as dipoles in the GeoSource Viewer.
- Add more windows by choosing different source-imaging specifications in the GeoSource Controls window for side-by-side comparisons of the results.

**Note:** GeoSource labels these windows with the Net Station EEG filename and inverse method, and numbers them sequentially.

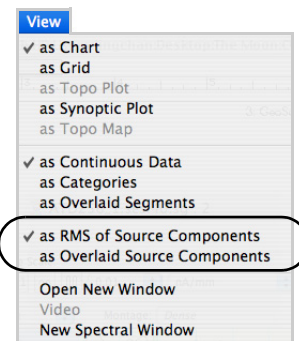


- Apply viewer transformations to a copy of the scalp data (created by choosing **View > Open New Window**), and view the effect on the source data in the GeoSource Viewer by cycling through the different EEG windows in the Data From column of the GeoSource Controls window (for more information, see page 35).

## Viewing Source Data as RMS or as Overlaid Components in the Net Station Viewer

Each dipole consists of three orthogonal orientations representing X, Y, and Z. In the Net Station Viewer, GeoSource allows you to view all three orientations for each dipole (as overlaid source components) or to view one collapsed waveform that represents the RMS of the three orientations combined (as RMS of source components). For details, see page 31.

**Note:** It is not possible to view all 2,447 dipole sources as waveforms in the Net Station Viewer. When a dense montage is selected, 47 representative dipoles are displayed. To display the waveforms of other dipoles (or dipole groups), you can create a user-defined source montage (see page 77).



To view the source waveforms in either representation, the Net Station Viewer must be in the chart or grid view. It can be in any of the category-viewing modes.

- 1 View GeoSource source waveforms in the Net Station Viewer. (If necessary, refer to steps 1 through 3 starting on page 56 in “Displaying Source Data in the Net Station Viewer or the GeoSource Viewer” to convert the scalp waveforms.)

- 2 With the source waveforms in the Net Station Viewer, choose **View > as RMS of Source Components** to view the component waveforms collapsed into a single waveform (Figure 3-5).

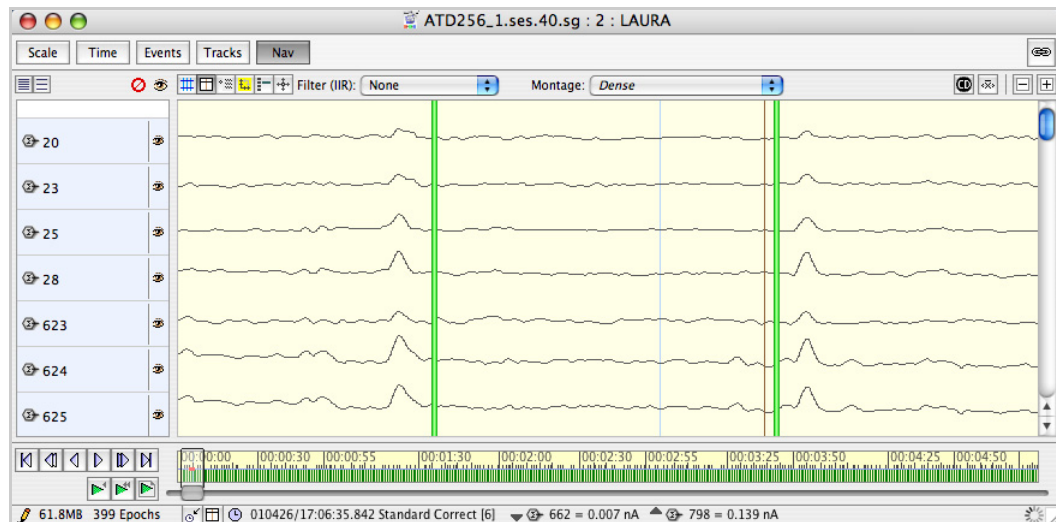


Figure 3-5. Source waveforms displayed as the RMS of the source components

- 3 With the source waveforms in the Net Station Viewer, choose **View > as Overlaid Source Components** to view the three orientations for each dipole (Figure 3-6).

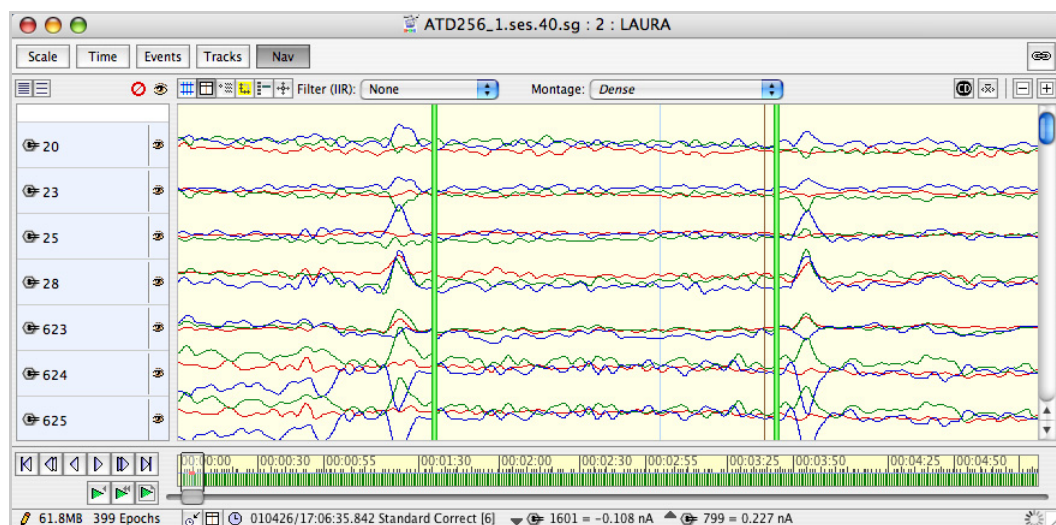


Figure 3-6. Source waveforms displayed as overlaid source components

Almost all the file export formats (Net Station MFF recording, Net Station recording, source binary, tab-delimited text, and MATLAB) save source data as all three source components. The one exception is the source binary format, which can save source data as either one or three components. If you save the source data to a Net Station recording file from the Net Station Viewer, make sure that the data are displayed in the desired configuration.

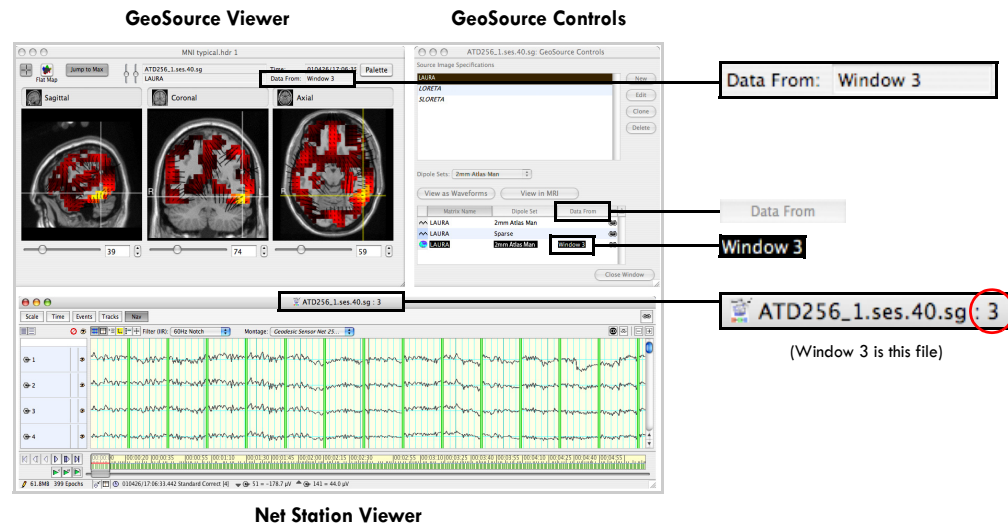
## Navigating through the GeoSource Viewer via the Net Station Viewer

Corresponding files in the Net Station Viewer (scalp data file) and the GeoSource Viewer (source data file) are automatically linked. However, whereas the Net Station Viewer contains data for an entire recording session or segment, the GeoSource Viewer does not. The GeoSource Viewer displays source data only for the time indicated by the Time Synch marker in the Net Station Viewer. Therefore, to navigate through the time of the source data in the GeoSource Viewer, you must navigate through the waveforms of the scalp data in the linked Net Station Viewer.

Because many scalp waveform data files may be open in the Net Station Viewer at the same time, make sure that you are navigating in the file that is actually providing the data to the GeoSource Viewer.

- The corresponding window designation will be displayed in the Data From text box in the GeoSource Viewer and in the Data From column of the GeoSource Controls window (Figure 3-7).
- If you are viewing data as categories in the Net Station Viewer, then simply progress to the next category to see it displayed in the GeoSource Viewer.
- If you are viewing data as overlaid segments, then the categories displayed in the Net Station Viewer will open in separate GeoSource Viewers, and the category name will be specified in the Data From text box.
- If you change the categories being viewed in the Net Station Viewer, then the corresponding GeoSource Viewer will be updated with the new category.

In this figure, to view the source data at different time points in the GeoSource Viewer, you must navigate in Net Station Viewer Window 3.



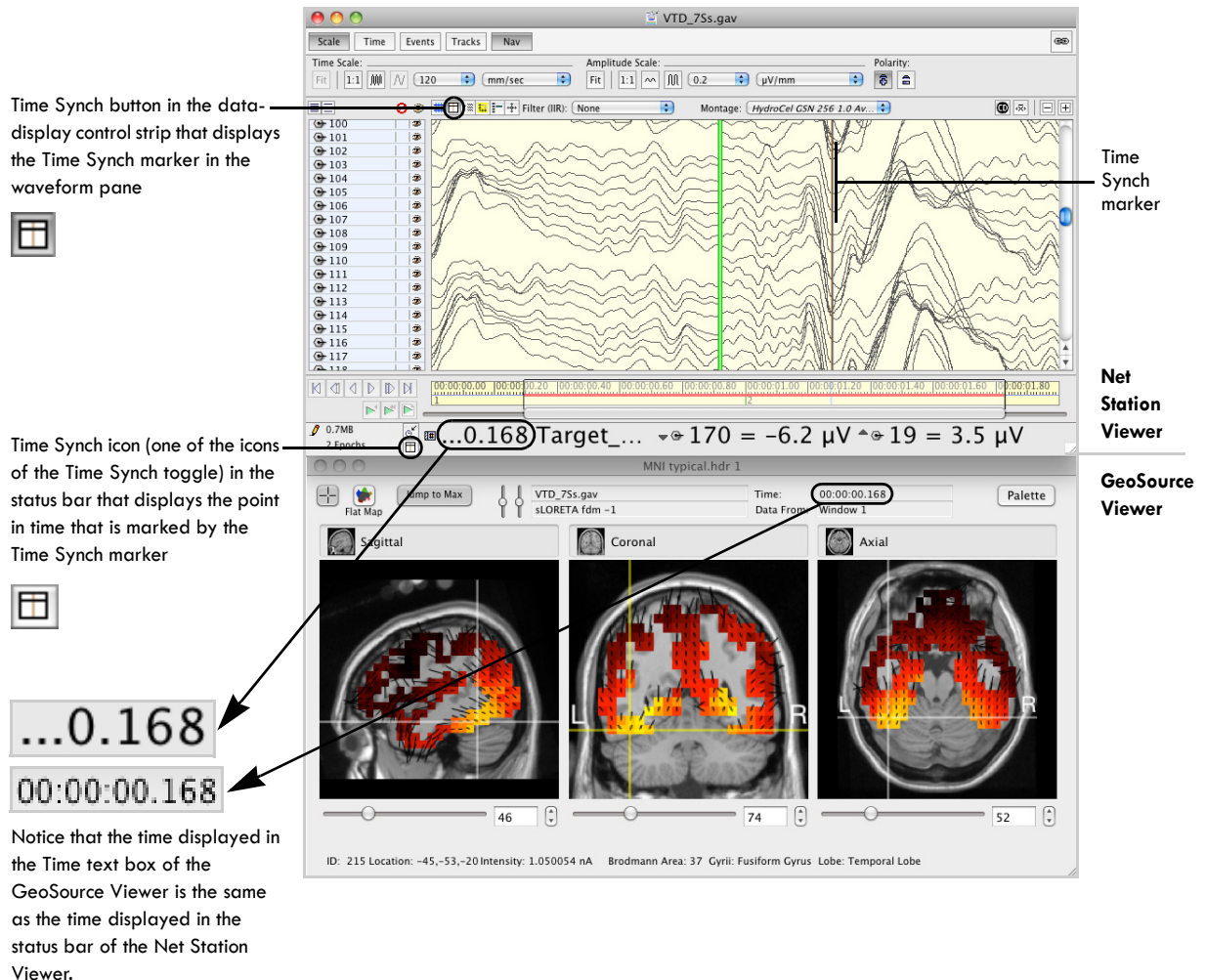
**Figure 3-7.** Navigating through the scalp waveforms in the Net Station Viewer that are supplying the data for the source MRI slices in the GeoSource Viewer

## Navigating Through Linked Files with Net Station in Chart View

To navigate through linked files in the Net Station Viewer, while in chart view, and the GeoSource Viewer, you must use the Time Sync button and do the following:

- 1 View the source data in the GeoSource Viewer. (If necessary, refer to steps 1 through 3 starting on page 56 in “Displaying Source Data in the Net Station Viewer or the GeoSource Viewer” to convert the scalp waveforms.)
- 2 Reveal the time synchronization information in the Net Station Viewer (Figure 3-8):
  - Select the **Time Sync** button in the data-display control strip to display the Time Sync marker (the vertical line) in the waveform pane.

- b Click the **Time Synch** toggle in the status bar until the Time Synch icon is displayed. The Time Synch icon displays the point in time that is marked by the Time Synch marker.



**Figure 3-8.** Navigating through linked files in the Net Station Viewer (chart view) and the GeoSource Viewer

- 3 Drag the **Time Synch** marker (in the Net Station Viewer) to the desired time point in the waveform pane (Figure 3-8). Note that the time displayed in the Time text box of the GeoSource Viewer changes accordingly (Figure 3-9).

- 4 Move to a different time point by dragging the Time Synch marker or using the navigation buttons. The GeoSource Viewer will update at each time point to show you the dipole activation in specific regions of the brain over time.

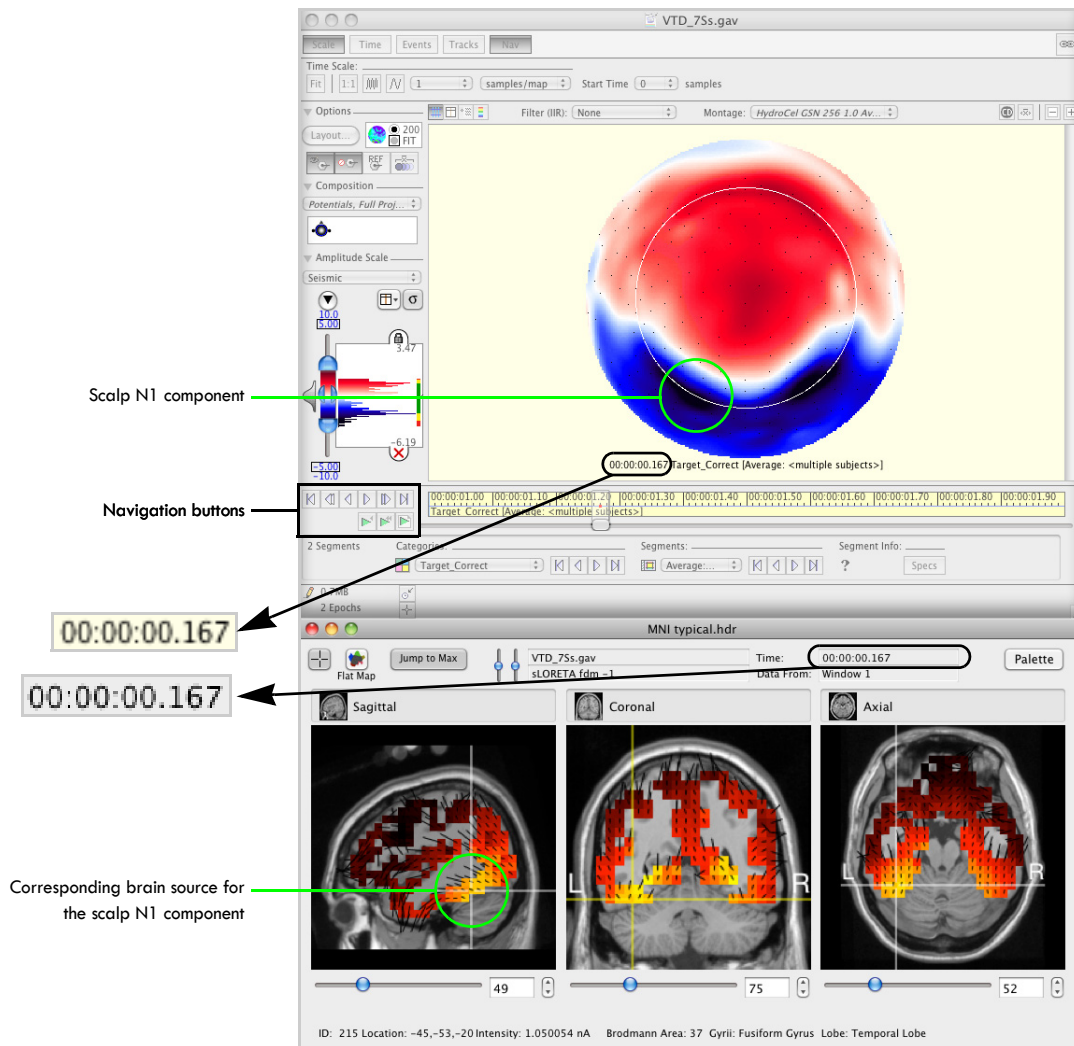
**Note:** If the GeoSource Viewer does not navigate in synch with the Net Station Viewer, double-check that you are navigating in the correct scalp waveform and that the link icon is present in the GeoSource Controls window.

## Navigating Through Linked Files with Net Station in Topo Map View

To navigate through linked files in the Net Station Viewer, while in topo map view, and the GeoSource Viewer, simply use the navigation buttons in the Net Station Viewer. See Figure 3-9.

The dipole activations will correspond to the time window displayed in the topo map view, and clicking the play button will initiate a movie of changing activations in specific brain regions over time.

**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 landmarks. Figure 3-9, for example, shows the source solution at 167 ms, the peak of the visual N1 component. The bilateral posterior negativities are likely generated by activity in the left and right fusiform gyrus, Brodmann Area 37. The MRI Viewer clearly shows high intensity activity in these regions. The orientation vectors, which point in the positive direction from the center of a dipole voxel, indicate that this dipolar activity is projecting surface-positive toward the front and top of the head, where the topo plot shows a broad positivity, and surface-negative on the left and right lateral inferior-posterior surface, where the topo plot shows focal negativities.



Corresponding files in the viewers are automatically linked so that moving the Time Synch marker in the Net Station Viewer will cause the GeoSource Viewer to move to the same time point, or that playing through the data in the Net Station Viewer will allow you to view the dipole activations developing over time in the GeoSource Viewer.

**Figure 3-9.** Navigating through linked files in the Net Station Viewer (topo map view) and the GeoSource Viewer



## Navigating to a Specific Dipole in the GeoSource Viewer Using the Palette Drawer

The ability to navigate directly to a specific dipole is useful if you wish to add it to or delete it from a source montage (described later on page 77) or just examine it and the surrounding dipoles more closely. The palette drawer of the GeoSource Viewer is designed specifically for this type of navigation—to allow you to find a dipole by its ID number or intensity value.

The palette drawer also allows you to define the color spectrum that represents the dipole intensities. Instructions on how to define the color spectrum are provided in the “Amplitude-Scale Palette” chapter in the *Net Station Viewer Technical Manual*.

This section describes how to navigate to a specific dipole and to view information about it in the GeoSource Viewer.

To navigate to a specific dipole using the palette drawer, do the following:

- 1 View the source data in the GeoSource Viewer. (If necessary, refer to steps 1 through 3 starting on page 56 in “Displaying Source Data in the Net Station Viewer or the GeoSource Viewer” to convert the scalp waveforms.)
- 2 Open the palette drawer by clicking the **Palette** button in the GeoSource Viewer (Figure 3-10).

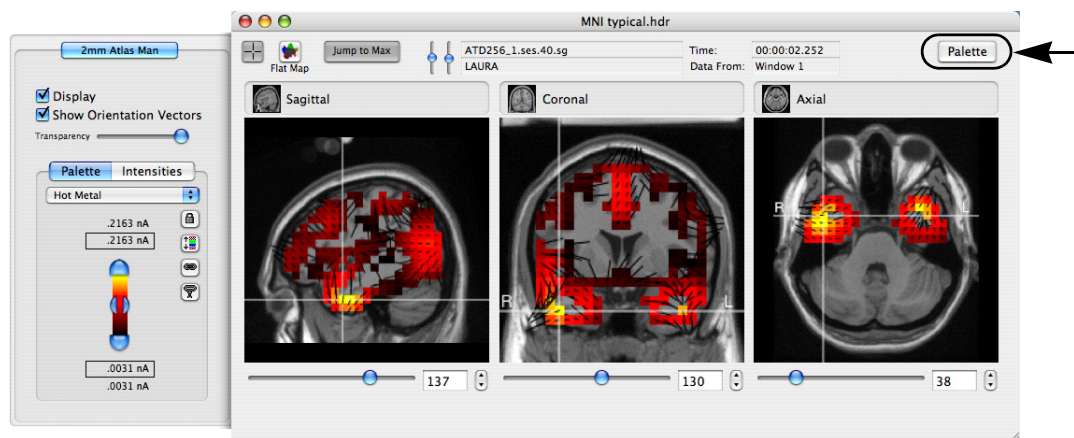


Figure 3-10. Opening the palette drawer



- 3 In the palette drawer, click the **Intensities** tab (Figure 3-11).

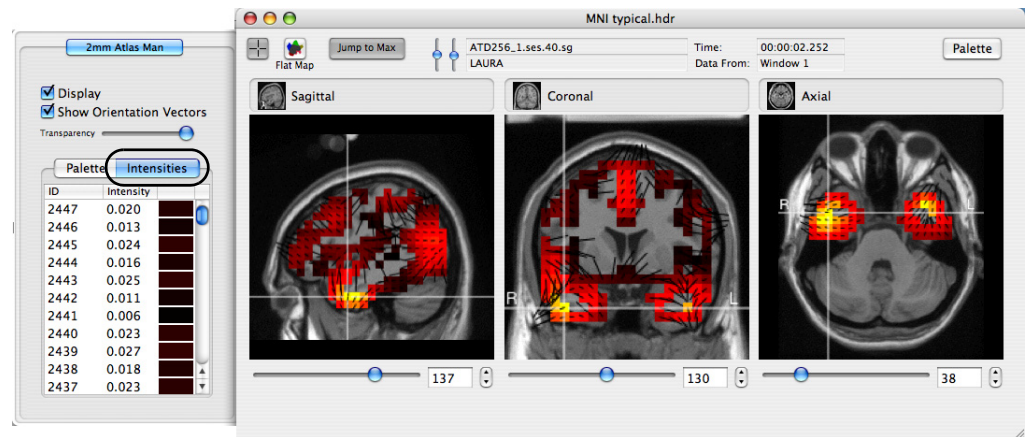


Figure 3-11. Viewing the palette intensities

- 4 The column titles in the palette drawer serve as toggles to sort the columns by ascending or descending order. Click a title (for example, the Intensities column title) once to change the direction of the order (ascending or descending), and click it again to change it back. The sorting order is indicated by the direction of the arrow next to the column title (Figure 3-12).

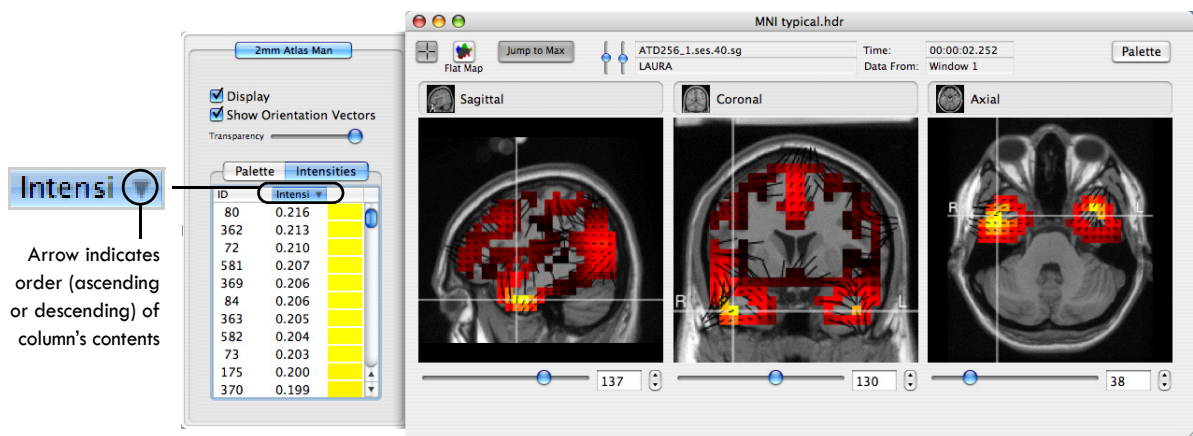
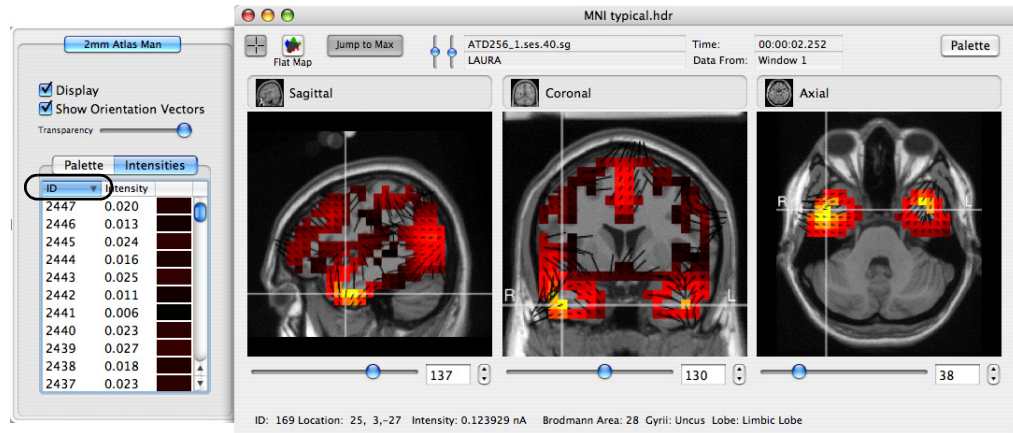


Figure 3-12. Sorting the dipoles by order of intensity

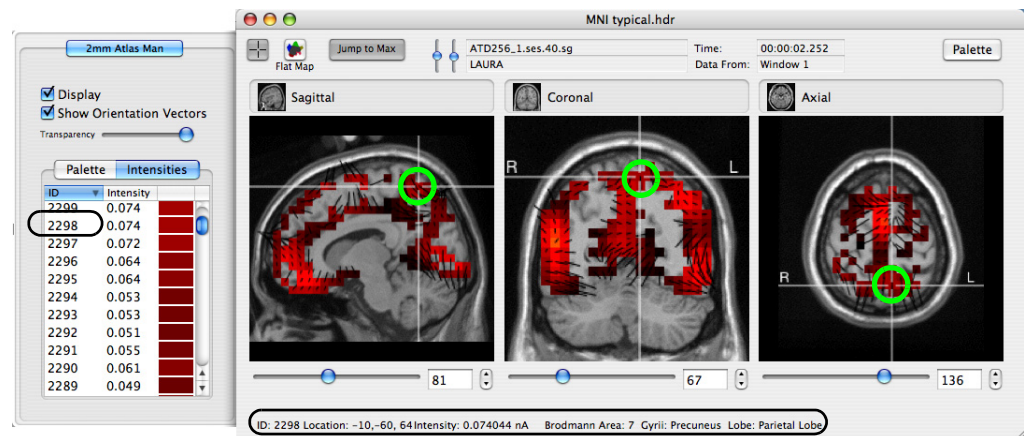
- Now, click the ID column's title once to change the direction of the sorting order (ascending or descending) of its contents, and click it again to change the order back (Figure 3-13).



**Figure 3-13.** Sorting the dipoles by order of ID number

- To navigate the three MRI panes in the GeoSource Viewer directly to a specific dipole, click one of the dipole numbers in the ID column of the Intensities pane of the palette drawer. To find a desired dipole that is not visible in the Intensities pane, drag the scroll bar that is on the right side of the palette drawer.
- Roll the cursor over a dipole in the MRI slices to display dipole information at the bottom of the GeoSource Viewer. The information includes the dipole's ID

number, location (X, Y, and Z coordinates in MNI space), intensity in nanoamp meters, Brodmann area, gyrus name, and lobe name (Figure 3-14).



**Figure 3-14.** Cursorsing over a specific dipole in the GeoSource Viewer and displaying information about it

## Navigating to a Specific Dipole in the GeoSource Viewer Using a Focus Pane

Another way to navigate through the GeoSource Viewer is to use a *focus pane*. This feature updates the other two MRI panes relative to the changes made in the focus pane. A focus pane is created by clicking one of the three MRI panes. The white crosshairs of the pane selected to be the focus pane will turn yellow.

To navigate when using a focus pane, do any of the following:

- **Point.** Click anywhere in the focus pane and all three MRI panes will automatically center their crosshairs relative to the clicked point.
- **Crosshairs.** Drag the crosshairs anywhere in the focus pane and all three MRI panes will automatically center their crosshairs relative to the dragged crosshairs.
- **MRI slice slider.** Drag the MRI slice slider beneath the focus pane and all three MRI panes will automatically center their crosshairs relative to the MRI slice under the slider.

- **MRI slice text box.** Type in an MRI slice number in the text box beneath the focus pane and all three MRI panes will automatically center their crosshairs relative to that slice number.
- **MRI slice arrow buttons.** Select the arrow buttons beneath the focus pane and all three MRI panes will automatically center their crosshairs relative to the selected slice.
- **Scroll wheel.** Roll the scroll wheel with the cursor over one of the panes (the crosshairs will turn yellow if they were white). All three MRI panes will automatically center their crosshairs relative to the scrolling point.

**Note:** The MRI slice sliders and text boxes are designed to navigate to a specific MRI slice, not to a specific dipole or dipole ID number.

**Note:** The MRI slice numbers correspond to the GeoSource grid, not Talairach or MNI space. To know the corresponding coordinate in MNI space, refer to the dipole information at the bottom of the GeoSource Viewer. To know the coordinate in Talairach space, convert the MNI coordinate to Talairach (e.g., MNI2TAL).

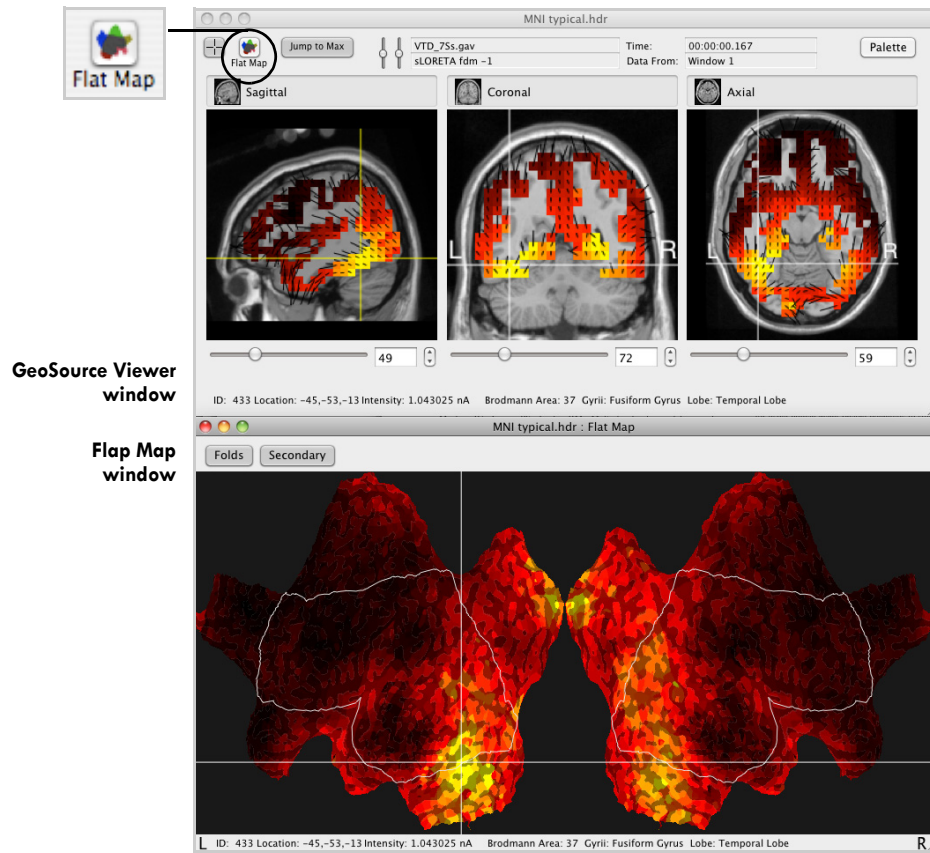
## Navigating in the Flat Map Window and the GeoSource Viewer

A flat map in the Flat Map window is useful for viewing dipole activations over the entire cortex, not just in the MRI slices currently displayed in the GeoSource Viewer. The Flat Map window and the GeoSource Viewer are linked, so navigating in one automatically causes the other to synchronize its view. The Flat Map window and the Net Station Viewer are also automatically linked so that when the Net Station Viewer is set to play through a scalp waveform file, the Flat Map window allows you to view dipole activations as they evolve over time.

To create a flat map of a file in the GeoSource Viewer, do the following:

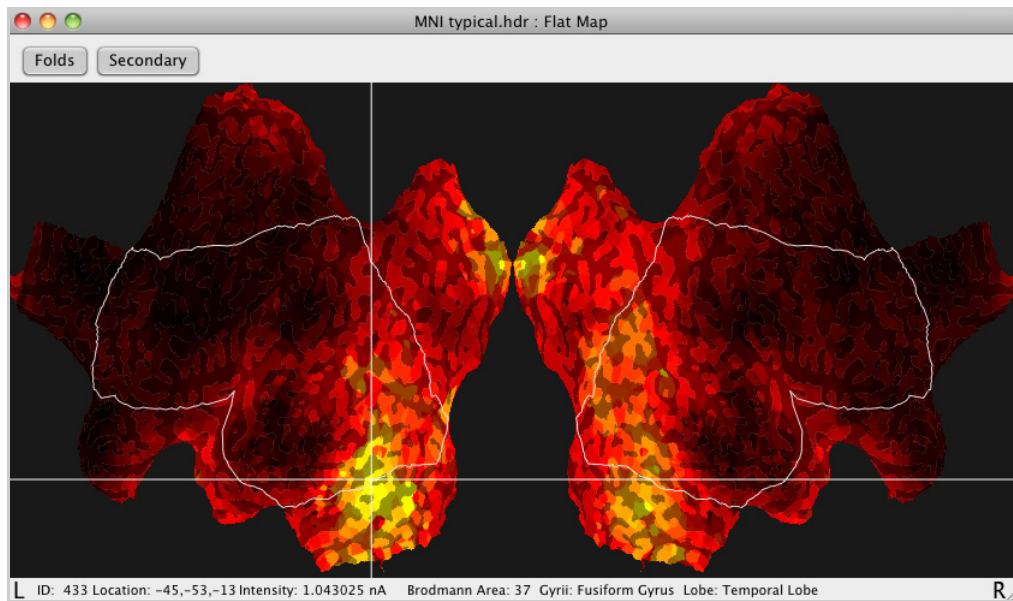
- 1 View the source data in the GeoSource Viewer. (If necessary, refer to steps 1 through 3 starting on page 56 in “Displaying Source Data in the Net Station Viewer or the GeoSource Viewer” to convert the scalp waveforms.)
- 2 Click the **Flat Map** button, which opens a second window that displays the dipole information projected onto a two-dimensional representation of the left and right hemispheres of the cerebral cortex. Like the GeoSource Viewer, at the

bottom of the Flat Map window is a dipole information area that displays the ID number, location (X, Y, and Z coordinates in MNI space), intensity in nanoamp meters, Brodmann area, gyrus name, and lobe name of the dipole currently under your cursor (Figure 3-15).



**Figure 3-15.** Clicking the Flat Map button for a two-dimensional cortical view of the dipoles

Figure 3-16 shows a larger view of the Flat Map window. To aid in orienting the user to the flat map, a thin white line roughly outlines the edge of the lateral surface of the brain. The regions outside this line correspond to the medial surfaces of each hemisphere (unwrapped and flattened). The Folds and Secondary buttons are both selected by default. These features are demonstrated in the following steps.

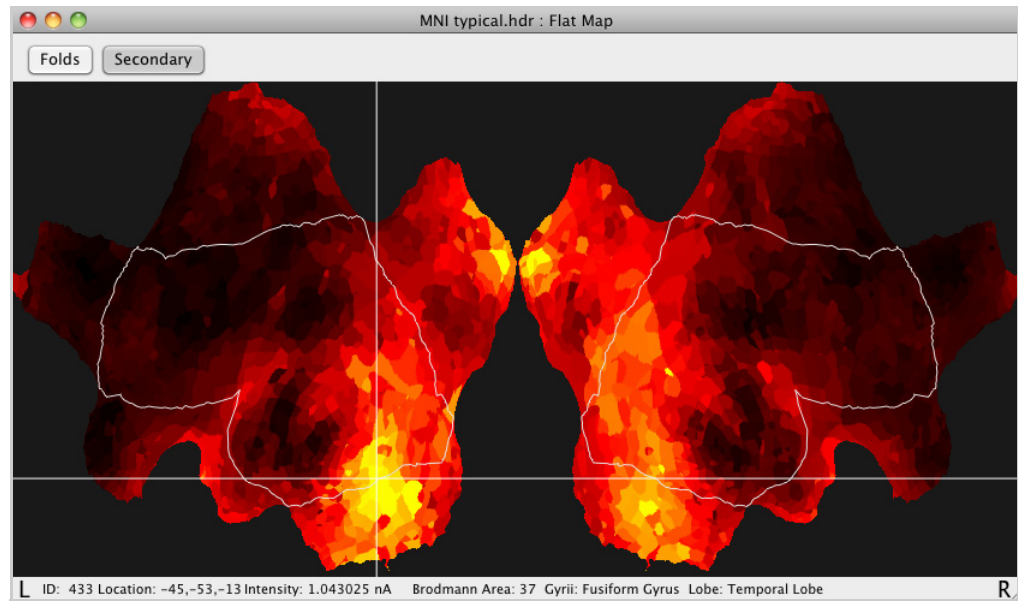


**Figure 3-16.** A flat map in the Flat Map window with both default settings (Folds and Secondary) selected

- 3 Click anywhere in the flat map of the Flat Map window, and the GeoSource Viewer will automatically navigate to that point in the MRI slices. See Figure 3-15. Vice versa—click anywhere in the MRI slices of the GeoSource Viewer, and the Flat Map window will automatically navigate to that point in the flat map.



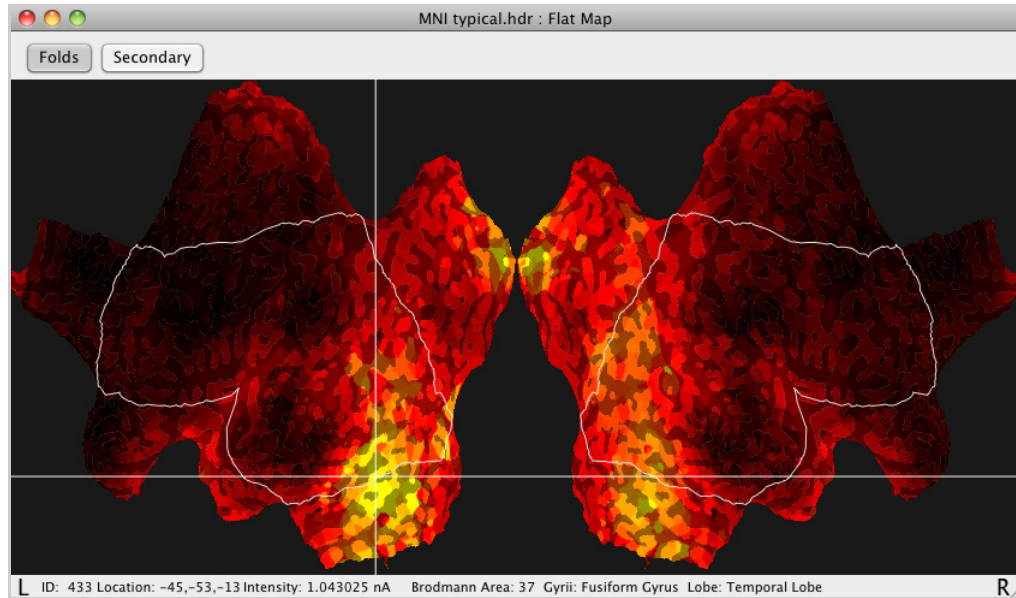
- 4 Click the **Folds** button to deselect it (Figure 3-17). Notice that the light gray mottling that represents the cortical folds disappears. Click the **Folds** button again to again display the cortical folds as shown in Figure 3-16.



**Figure 3-17.** A flat map that is not displaying the light gray mottling of the cortical folds because the Folds button is deselected

- 5 Click the **Secondary** button to deselect it. See Figure 3-18. Notice that the colors of some small regions of the flat map have changed. Because these small regions contain overlapped dipoles (as a result of the 3D-to-2D conversion of the dipoles), the Flat Map window uses different dipoles to represent them.
  - When the Secondary button is selected, the Flat Map window displays the *average intensity* of the overlapped dipoles.
  - When the Secondary button is deselected, the Flat Map window displays the intensity of the topmost dipole.

Click the **Secondary** button again to again display the average intensity of these small regions as shown in Figure 3-16.



**Figure 3-18.** A flat map that has changed the display of the overlapped dipoles from average intensity to topmost because the Secondary button is deselected

- 6 Arrange the Net Station Viewer with its scalp waveform, the GeoSource Viewer with its MRI slices, and the Flat Map window with its flat map on the desktop so that you can easily view all three.
- 7 In the scalp waveform file of the Net Station Viewer, open the navigation control strip, then click one of the navigation buttons (see Figure 3-9) to play through the file.

As the EEG scrolls temporally in the Net Station Viewer, the dipole activations will appear in the GeoSource Viewer and the Flat Map window, which are complementary viewing tools. When these two GeoSource views (MRI slices and flat map) and the Net Station view (such as the topo map or chart view) are viewed together, they can provide a comprehensive view of the estimated source activity.



## Built-in Source Montages

GeoSource provides two built-in source montages: BAs and Gyri. The BAs source montage groups individual dipoles into groups that correspond to Brodmann Areas. The Gyri source montage groups dipoles by the major brain gyri (e.g., fusiform gyrus).

GeoSource also allows you to create your own source montages made up of groups of dipoles specific to your own regions of interest. The following section (“Creating a Source Montage in the GeoSource Viewer”) steps you through the process.

## Creating a Source Montage in the GeoSource Viewer

A source montage allows you to highlight only the source data that is of interest. You can export this subset of data to another file using the **File > Save** commands (see page 23) or a GeoSource specification (see page 25).

If you save out individual subject average files as source waveform files using a source montage, you can then use these files in the Statistics Extraction tool to extract values for statistical analyses in time windows and brain regions of interest across conditions or subject groups.

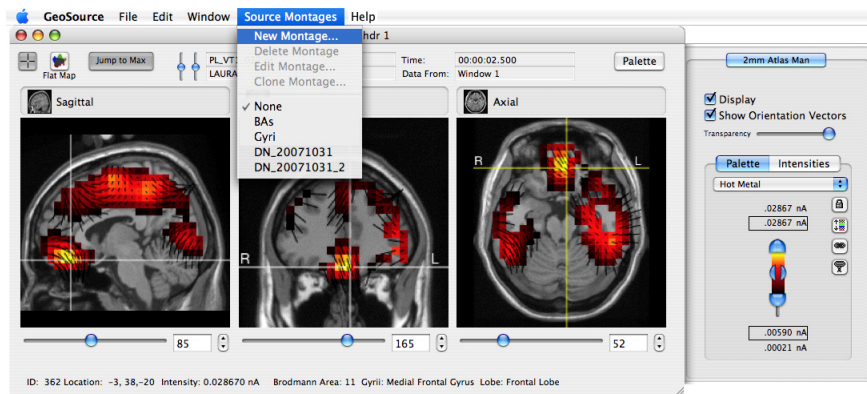
Source montages can be created only in the GeoSource Viewer. The dipoles in the GeoSource Viewer are approximately represented by *voxels*, which are colored 3D volume pixels. A dipole group represents one compound dipole in a source montage (computed as the mean intensity of the dipoles included in the group). See page 41 and page 51. Once created, source montages are available in either the GeoSource Viewer or the Net Station Viewer for any source data file.

To create a source montage, do the following:

- 1 View the source data at your time point of interest in the GeoSource Viewer. (If necessary, refer to steps 1 through 3 starting on page 56 in “Displaying Source Data in the Net Station Viewer or the GeoSource Viewer” to convert the scalp waveforms.)

**Note:** If desired, you can navigate to different time points of interest as you create different dipole groups within user-defined source montages.

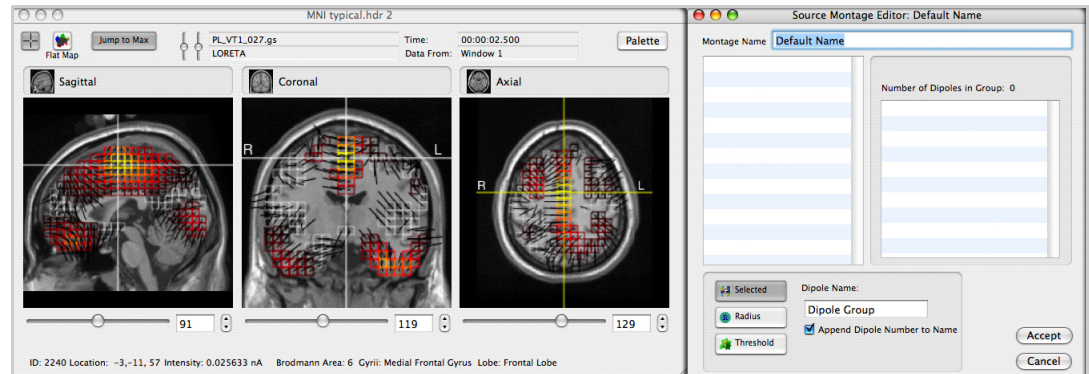
- 2 To make the spatially discrete areas of the MRI slices more obvious, you can reduce the number of low-intensity voxels that are showing. A good starting point is to reduce the palette maximum by approximately 20% to highlight the higher intensity voxels. To reduce the number of low-intensity voxels, raise the palette-minimum slider (see page 43).



**Figure 3-19.** Reducing the palette maximum to reduce the number of low-intensity voxels, and then opening the Source Montage Editor window

- 3 In the GeoSource Viewer, choose **Source Montages > New Montage** from the GeoSource menu bar (Figure 3-19).
- 4 After the Source Montage Editor window opens (see page 50), notice that the voxels in the MRI panes of the GeoSource Viewer are now empty so that they may be easily selected for a user-defined source montage. In the Source Montage Editor window, type in a name for this user-defined source montage and type in a name for the first (or only) dipole group to be included in the montage. See Figure 3-20.

The next few steps will step you through creating the one or more dipole groups for this source montage via the selected, radius, or threshold dipole-group creation methods.



**Figure 3-20.** Windows for creating a new source montage—the Source Montage Editor window (right) and the GeoSource Viewer (left)

- 5 If you want to include a dipole group that is defined using the selected dipole-group creation method, click the **Selected** button. Then, manually select voxels to populate the dipole group. Do so by clicking or Shift-clicking them in the MRI panes of the GeoSource Viewer. Clicking starts a new dipole group with the clicked voxel and Shift-clicking adds voxels to the current dipole group.

The dipole-group table updates to indicate the method (by method-specific icon), dipole-group name, dipole ID numbers, and the number of dipoles that are included in the current dipole group being created and added to the source montage. See Figure 3-21. When naming dipole groups, it is recommended that you assign meaningful names that are indicative of each group's anatomical location (such as amygdala or OFC for orbitofrontal cortex) or indicative of the time point at which each occurred (such as P300).

**Note:** The anatomical names of regions are visible at the bottom of the GeoSource Viewer window as you pass your cursor over the three MRI panes.

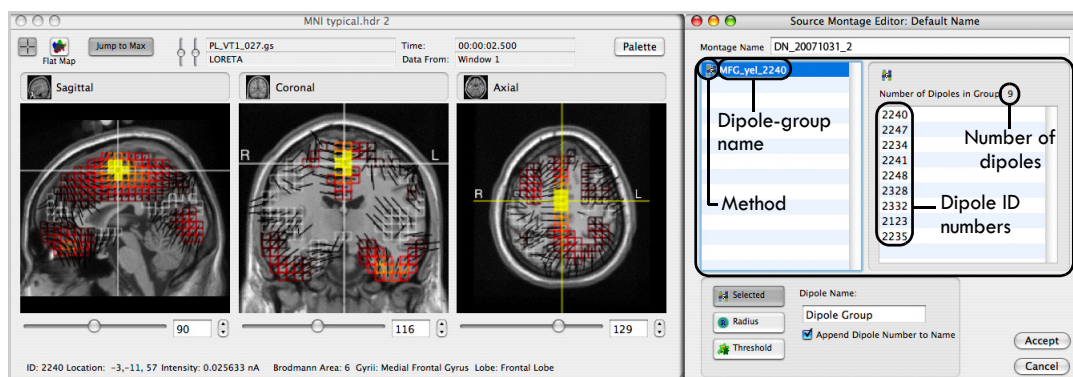
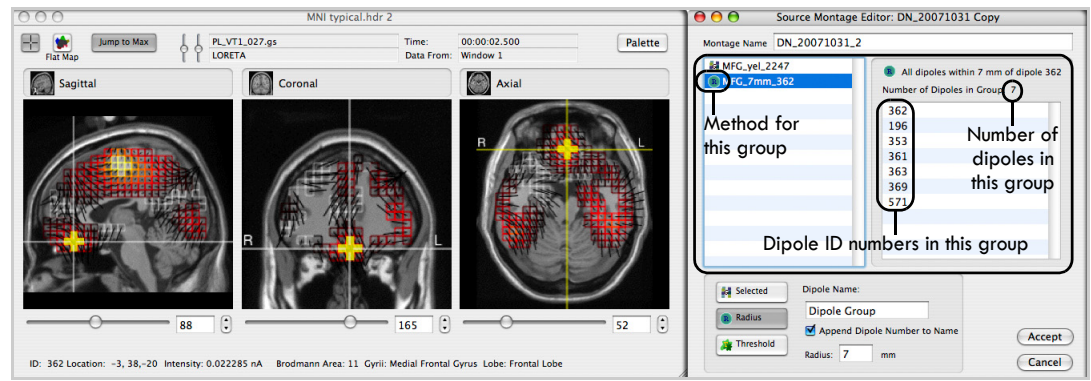


Figure 3-21. Using the selected method for creating a dipole group

- 6 If you want to include a dipole group that is defined using the radius dipole-group creation method:
  - a Click the **Radius** button.
  - b In the Radius text box, specify a distance from the voxel that will be selected in step c to include in the group.
  - c Click a voxel in the MRI panes of the GeoSource Viewer. All voxels that fall within the specified radius of the voxel selected will be added to the group.

The dipole-group table updates to indicate the method (by method-specific icon), dipole-group name, dipole ID numbers, and the number of dipoles that are included in the current dipole group being created and added to the source montage. See Figure 3-22. Again, when naming dipole groups, it is recommended that you assign meaningful names that are indicative of each group's anatomical location (such as amygdala or OFC for orbitofrontal cortex) or indicative of the time point at which each occurred (such as P300).

**Note:** The anatomical names of regions are visible at the bottom of the GeoSource Viewer window as you pass your cursor over the three MRI panes.



**Figure 3-22.** Using the radius method for creating a dipole group

**7** If you want to include a dipole group that is defined using the threshold dipole-group creation method:

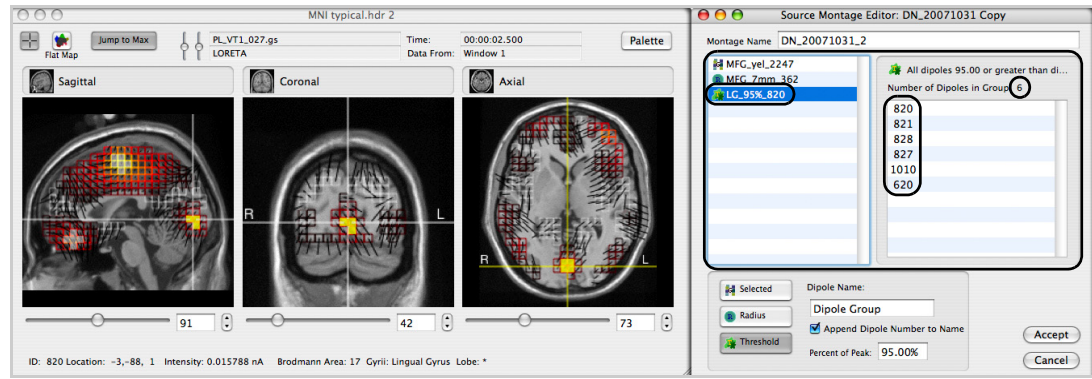
- a** Click the **Threshold** button.
- b** In the Percent of Peak text box, specify a percentage of the intensity of the voxel that will be selected in step c to be used for including adjacent voxels in the group.

**Note:** In lieu of a predetermined threshold, 80% is typically a good threshold to start with.

- c** Click a voxel in the MRI panes of the GeoSource Viewer. All adjacent voxels with intensities that fall within the specified percentage of the voxel selected will be added to the group.

The dipole-group table updates to indicate the method (by method-specific icon), dipole-group name, dipole ID numbers, and the number of dipoles that are included in the current dipole group being created and added to the source montage. See Figure 3-23. Again, when naming dipole groups, it is recommended that you assign meaningful names that are indicative of each group's anatomical location (such as amygdala or OFC for orbitofrontal cortex) or indicative of the time point at which each occurred (such as P300).

**Note:** The anatomical names of regions are visible at the bottom of the GeoSource Viewer window as you pass your cursor over the three MRI panes.

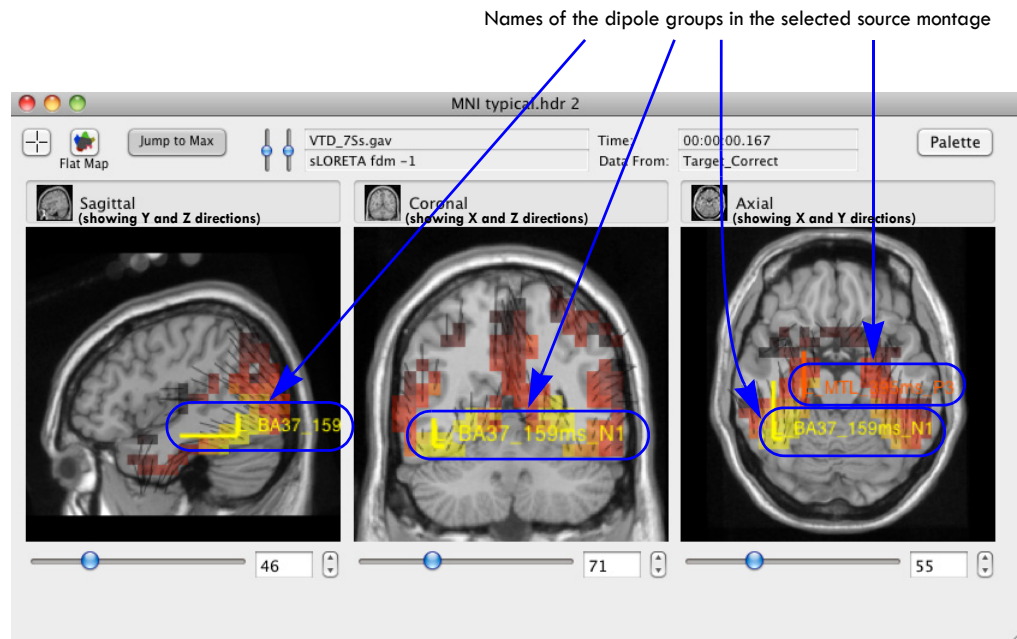


**Figure 3-23.** Using the threshold method for creating a dipole group

- 8 If you want to include more than one dipole group in your user-defined source montage, complete or repeat any one or more of the steps between step 5 and step 7 as often as is necessary.
- 9 Click the **Accept** button to save the dipole groups to your new user-defined source montage.
- 10 After a new source montage has been accepted (i.e., created), the GeoSource Viewer will automatically display it. To view all voxels again, choose **Source Montages > None**. To reapply a source montage to the GeoSource Viewer, choose **Source Montages > {montage name}**.

Only the voxels and the names of the dipole groups that are included in a source montage are highlighted in the MRI panes of the GeoSource Viewer when a source montage is selected. See Figure 3-24.

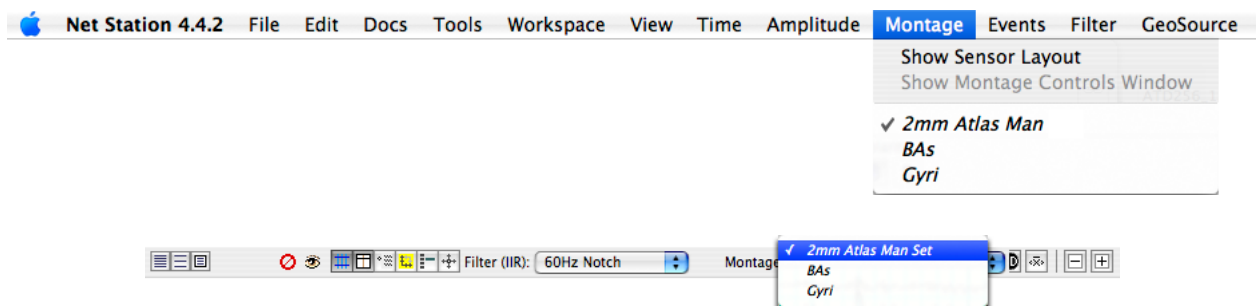
**OBSERVATIONS:** Notice that each dipole group of a source montage is displayed as a composite dipole with three vectors. Also notice that the length of each vector indicates the intensity of the corresponding dipole's orientation in the X, Y, and Z planes. The vectors point in the positive direction of the dipolar activity. In orthogonal slice views, only two of the three vectors are visible (Figure 3-24). For example, the coronal slice view shows vector orientation strengths in the X and Z directions. *To view the vectors more clearly, you may need to toggle off the crosshairs.*



**Figure 3-24.** Viewing only the dipoles of a selected user-defined source montage in the GeoSource Viewer (with crosshairs toggled off)

- 11 You can apply the same source montages that you have been using for the MRI slices in the GeoSource Viewer to other data files. To apply the source montages to other data files, such as a scalp data file viewed as a source waveform file in the Net Station Viewer, choose a source montage from the Montage menu or the Montage pop-up menu of the Net Station Viewer (Figure 3-25).

**Note:** Once you have applied and saved a source waveform file, the montage remains fixed. To view or save the data with a different montage, you must be actively viewing the source solution of a linked scalp data file.



**Figure 3-25.** Applying source montages using the montage menus in the Net Station Viewer



When you select a source montage in the Net Station Viewer, the waveforms that are displayed represent dipole groups and not individual dipoles. See Figure 3-26.



**Figure 3-26.** Applying a source montage to source waveforms in the Net Station Viewer

## Editing, Cloning, or Deleting a Source Montage

To edit, clone, or delete a source montage, you:

- must use the Source Montages menu in the GeoSource Viewer;
- can change only one source montage at a time;
- can edit and delete only the user-defined source montages;
- must clone built-in source montages (Brodmann Areas [BAs] and Gyri) before you can edit them; and
- must have the source montage to be changed currently open (that is, applied to source data in the GeoSource Viewer).

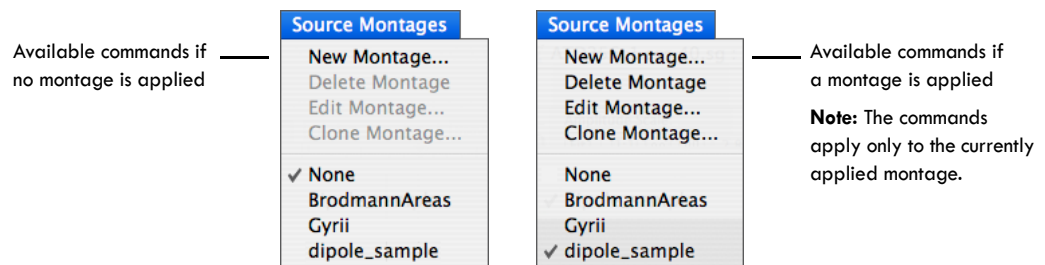
Edited or cloned source montages are immediately available in the Source Montages menu in the GeoSource Viewer and in the Montage menu and Montage pop-up menu in the Net Station Viewer. Deleted source montages are immediately removed from these same menus.

**Note:** User-defined source montages are saved in files in the GeoSource folder (Documents/Net Station User Data/GeoSource). To share user-defined source montages between users or computers, copy and paste the desired files in the corresponding folder on the desired computer.



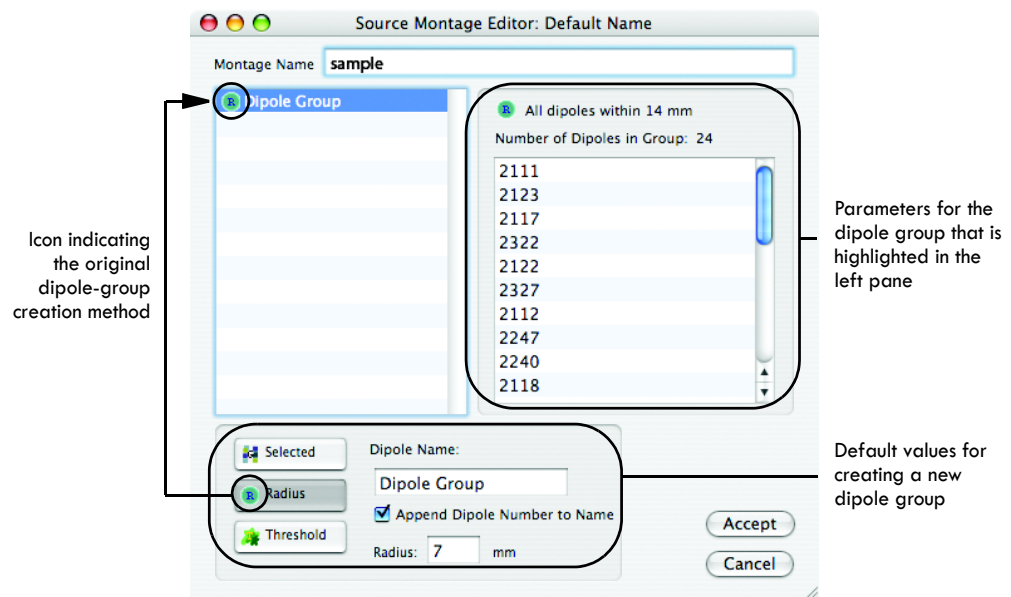
To edit, clone, or delete a source montage, do the following:

- 1 View or open a source data file in the GeoSource Viewer. Remember that source data in the GeoSource Viewer is in the form of MRI slices.
- 2 Apply the source montage that you wish to change by choosing **Source Montages > {montage name}**. Note that the edit, clone, or delete commands are not available if no source montage is applied to source data. See Figure 3-27.



**Figure 3-27.** Montage-editing commands are available only when a source montage is currently applied

- 3 Edit (step a), clone (step b), or delete (step c) the applied source montage. See Figure 3-28.



**Figure 3-28.** Dipole-group parameters in the Source Montage Editor window

- If you choose **Edit Montage** from the Source Montages menu, the Source Montage Editor window appears (Figure 3-28 above), and you can add dipoles or dipole groups (first bullet below), delete dipoles or dipole groups (second bullet below), or rename dipole groups (third bullet below) within the source montage.

**Note:** You cannot change the radius or threshold of dipole groups that were created with the Radius or Threshold dipole-group creation methods.

- You can **add** dipoles to only those groups that were created by the Selected dipole-group creation method. However, you can convert a Radius or Threshold dipole group to a Selected dipole group by first deleting one dipole in the group; then, you can add dipoles to that group.

To add dipoles to selected dipole groups, do the following:

- In the Source Montage Editor window, click a dipole group in the left pane to display its dipoles in the right pane.
- Shift-click dipoles in the MRI panes of the GeoSource Viewer. Shift-clicking adds voxels to the current dipole group.
- Repeat for other dipole groups in the source montage, if desired.
- If you are done with all changes, click the **Accept** button to save the changes. Otherwise, continue to the next bullet to make further changes to this source montage.

- You can **delete** dipole groups or individual dipoles from any dipole group, regardless of what dipole-group creation method was used to create it, but heed the following caution.



**CAUTION:** If you delete dipoles from dipole groups that were created with the Radius or Threshold dipole-group creation methods, they will no longer be Radius or Threshold dipole groups. They will functionally be Selected dipole groups. Their icon will change to show this changed status. Depending upon how you named these groups previously, make sure that you rename them to note their changed status; otherwise, you may make misassessments in future analyses.

To delete dipole groups, do the following:

- In the Source Montage Editor window, click a dipole group in the left pane.
- Press the **Delete** key. No confirmation dialog appears.
- Repeat for other dipole groups in the source montage, if desired.
- If you are done with all changes, click the **Accept** button to save the changes.

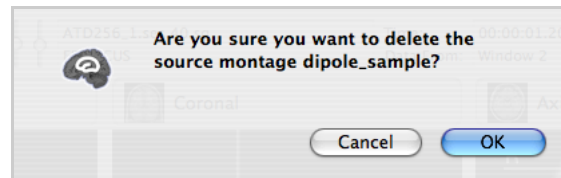
To delete dipoles from dipole groups, do the following:

- In the Source Montage Editor window, click a dipole group in the left pane to display its dipoles in the right pane.
  - Click or Shift-click one or more dipoles in the right pane.
- Note:** Before you press the Delete key in the next step, be aware that you will not get a confirmation dialog and the deletion is not reversible, unless you cancel all changes to the source montage by clicking Cancel.
- Press the **Delete** key. No confirmation dialog appears.
  - If you are deleting dipoles from a dipole group that was created with the Radius or Threshold dipole-group creation method, rename both the dipole group and the source montage so that you avoid making misassessments in future analyses due to using a dipole group that has been converted into a Selected dipole group.
  - Repeat for other dipole groups in the source montage, if desired.
  - If you are done with all changes, click the **Accept** button to save the changes. Otherwise, continue to the next bullet to make further changes to this source montage.
- You can **rename** dipole groups and the source montage.

To rename dipole groups and/or the source montage, do the following:

- To rename a dipole group, double-click a dipole group in the left pane and type your change.
  - To rename a source montage, click to insert an insertion point or double-click to select the entire name, then type your change.
  - Repeat for other dipole groups in the source montage, if desired.
  - If you are done with all changes, click the **Accept** button to save the changes. Otherwise, go back to the previous bullets to make further changes to this source montage.
- When you are completely done making editing changes in the source montage, click the **Accept** button to save all changes.
- b** If you choose **Clone Montage**, the Source Montage Editor window appears.
- To clone a source montage, do the following:
- Rename the clone of the original source montage to something unique.
  - If needed, edit the cloned source montage as described in step a.

- c If you choose **Delete Montage**, a confirmation dialog appears (Figure 3-29). Make sure that you do, in fact, want to delete the source montage.



**Figure 3-29.** Confirmation dialog for the Delete Montage command

## Creating a Source-Imaging Specification

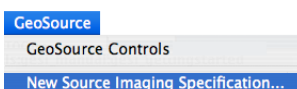
The Source-Imaging Specification Editor window (Figure 3-33) provides a variety of options to choose from. To use the window, the user must be familiar with the components of source-imaging specifications and how those components interact.

You will be able to perform the same tasks with your user-defined source-imaging specifications as you can with the default specifications.

Detailed descriptions of the components of source-imaging specifications are provided in Chapter 2, “GeoSource Menus and Windows,” and in Chapter 4, “Source-Imaging Specifications.”

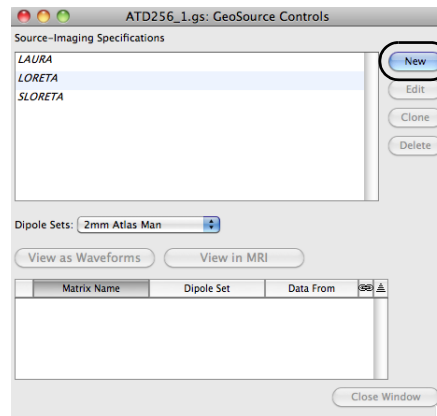
To create a source-imaging specification, do the following:

- 1 Open a scalp data file in Net Station.
- 2 Open the Source-Imaging Specification Editor window. You can do it one of three ways:
  - From the Net Station menu bar, choose **GeoSource > New Source-Imaging Specification** (Figure 3-30).



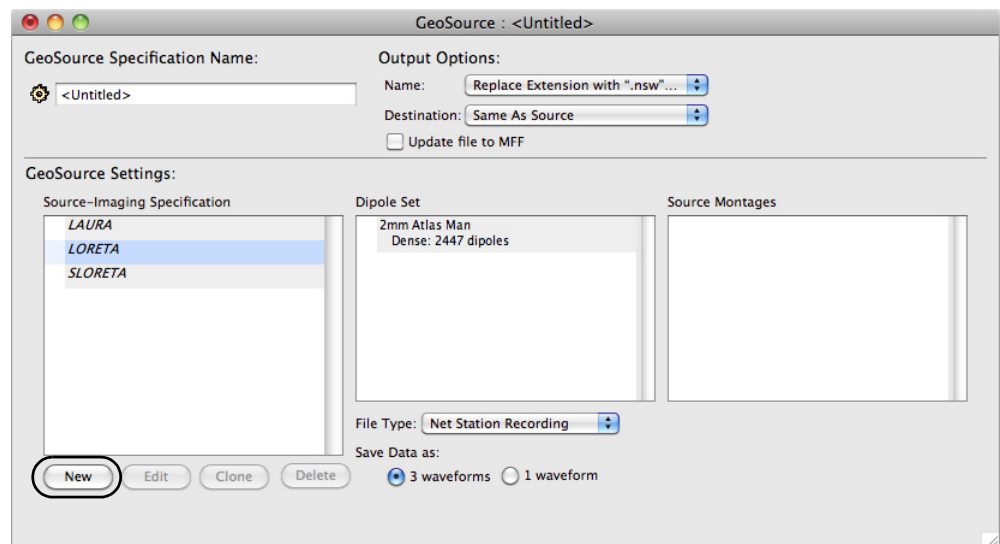
**Figure 3-30.** Using the GeoSource menu to open the Source-Imaging Specification Editor window

- From the Net Station menu bar, choose **GeoSource > GeoSource Controls**, and click the **New** button in the GeoSource Controls window (Figure 3-31).



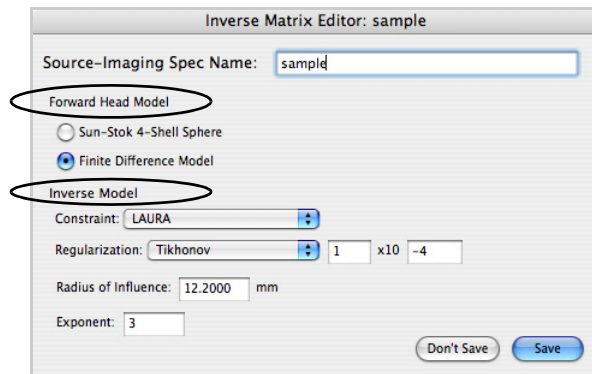
**Figure 3-31.** Using the GeoSource Controls window to open the Source-Imaging Specification Editor window

- From the Net Station menu bar, choose **Tools > Waveform Tools > Create > GeoSource**, and click the **New** button in the GeoSource Specification Editor window (which is not to be confused with the Source-Imaging Specification Editor window). See Figure 3-32.



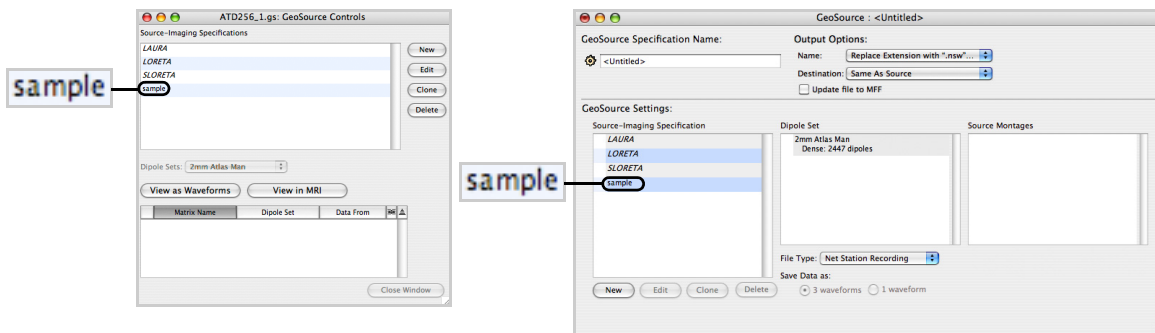
**Figure 3-32.** Using the GeoSource Specification Editor window to open the Source-Imaging Specification Editor window

- 3 In the Source-Imaging Specification Editor window that appears, specify the parameters of the forward head model and the inverse model, and click the **Save** button. See Figure 3-33.



**Figure 3-33.** Using the Source-Imaging Specification Editor window to specify the parameters for a new user-defined source-imaging specification

The new source-imaging specification automatically appears in the GeoSource Controls window and the GeoSource Specification Editor window. See Figure 3-34.



**Figure 3-34.** New source-imaging specifications automatically appear along with the default source-imaging specifications

## Editing, Cloning, or Deleting a Source-Imaging Specification

Your user-defined source-imaging specifications (see “Creating a Source-Imaging Specification” on page 88) can be edited, cloned, or deleted. The default source-imaging specifications can only be cloned.

To edit, clone, or delete a source-imaging specification, do the following:

- 1 Access the GeoSource Controls window or the GeoSource Specification Editor window.

To access the GeoSource Controls window, do the following:

- a Open a scalp data file in Net Station.
- b From the Net Station menu bar, choose **GeoSource > GeoSource Controls**.

To access the GeoSource Specification Editor window, do one of the following:

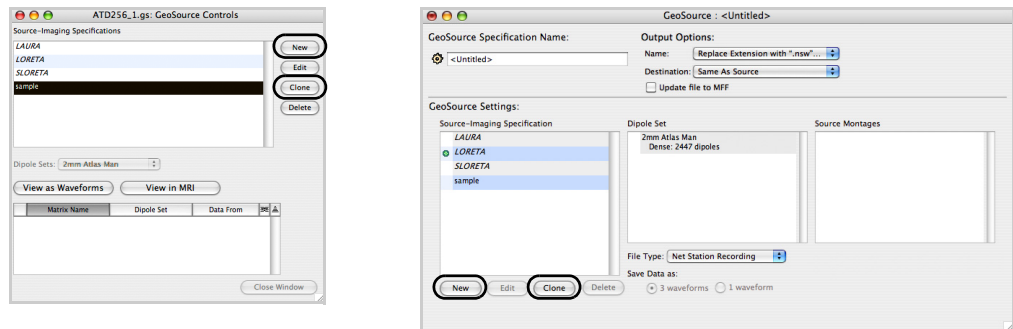
- If you do not already have Net Station open, double-click the application icon and, from the Net Station start-up window, choose **Waveform Tools > Create > GeoSource**.
- From the Net Station menu bar, choose **Tools > Waveform Tools > Create > GeoSource**.

- 2 Select a default or user-defined source-imaging specification from either the GeoSource Controls window or the GeoSource Specification Editor window.

To select a **default** source-imaging specification, do the following:

- a In either window, click a default source-imaging specification (LAURA, LORETA, or sLORETA) to select it.

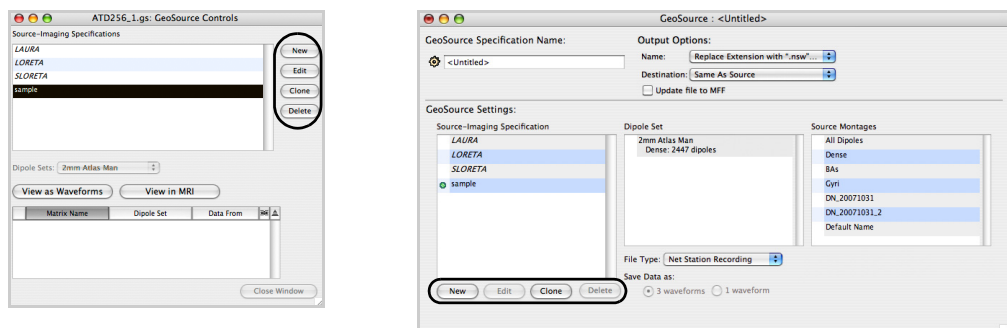
- b Notice that only the New and Clone buttons are active (Figure 3-35).



**Figure 3-35.** Default source-imaging specifications can only be cloned (they cannot be edited or deleted)

To select a **user-defined** source-imaging specification, do the following:

- a In either window, click a user-defined source-imaging specification to select it.
- b Notice that all four buttons (New, Edit, Clone, and Delete) are active (Figure 3-36).



**Figure 3-36.** User-defined source-imaging specifications can be edited, cloned, or deleted



- 3 To **edit** a user-defined source-imaging specification, do the following:

**Note:** Remember that you cannot edit a default source-imaging specification.

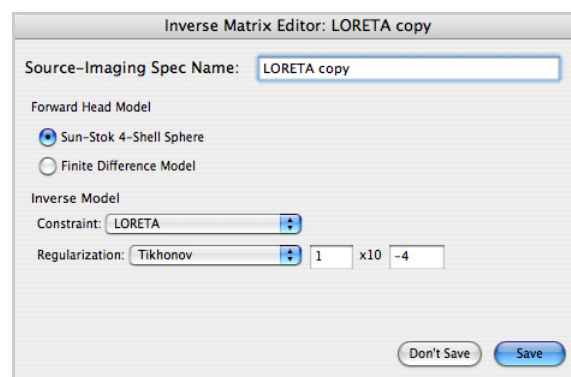
- a With a specification selected (step 2), click the **Edit** button. This opens the Source-Imaging Specification Editor window (Figure 3-37).
- b Edit the parameters as desired.
- c Click the **Save** button.

The edited source-imaging specification automatically appears in the GeoSource Controls window and the GeoSource Specification Editor window.

- 4 To **clone** a default or user-defined source-imaging specification, do the following:

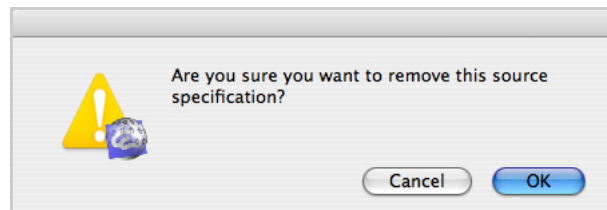
- a With a specification selected (step 2), click the **Clone** button. This opens the Source-Imaging Specification Editor window (Figure 3-37) with a copy of the selected source-imaging specification.
- b Assign a unique name to the clone (i.e, copy).
- c Edit the parameters, if desired.
- d Click the **Save** button.

The cloned source-imaging specification automatically appears in the GeoSource Controls window and the GeoSource Specification Editor window.



**Figure 3-37.** Source-Imaging Specification Editor window

- 5 To **delete** a user-defined source-imaging specification, do the following:
  - a With a specification selected (step 2), click the **Delete** button. A confirmation dialog appears (Figure 3-38).
  - b Make sure that you do, in fact, want to delete the source-imaging specification, then click **OK**.



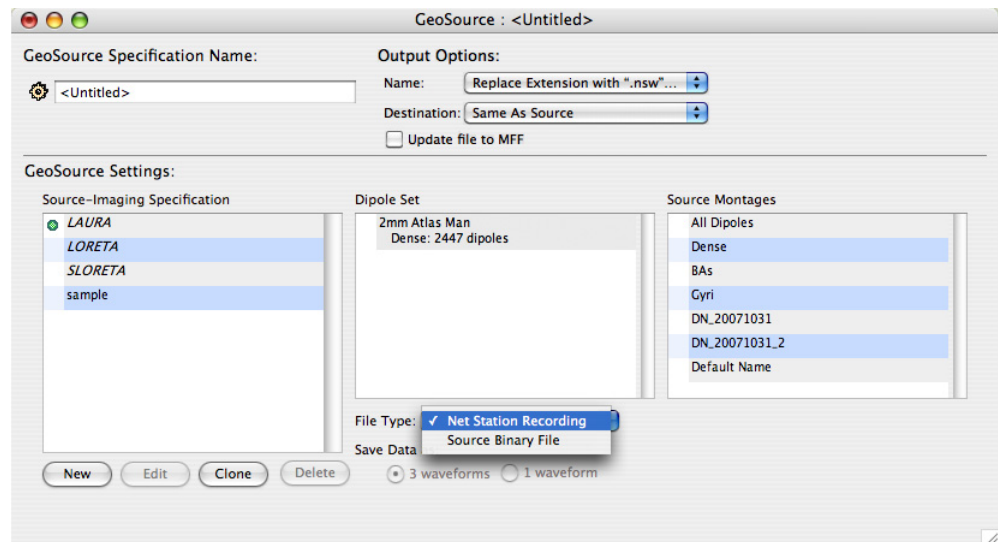
**Figure 3-38.** Confirmation dialog for deleting source-imaging specifications

## Creating a GeoSource Specification

GeoSource specifications consist of a source-imaging specification and output format (Net Station recording or source binary). They can be added to a script or used to process a batch of files.

To create a GeoSource specification, do the following:

- 1 Open the Waveform Tools window by one of two ways:
  - From the Net Station menu bar, choose **Tools > Waveform Tools**.
  - From the Net Station start-up window, choose **Waveform Tools**.
- 2 Open the GeoSource Specification Editor window (Figure 3-39) by choosing **Create > GeoSource**.



**Figure 3-39.** GeoSource Specification Editor window for creating new GeoSource specifications

- 3 To create a new GeoSource specification, do the following:
  - Specify the name and output options.
  - Select a source-imaging specification by clicking it. A green circle will appear next to it.
  - Select a source montage by clicking it. A green circle will appear next to it.
  - Choose a File Type.
  - If Source Binary File is selected as the file type, choose whether to save the data as one or three waveforms.
  - Click the red **Close** button in the upper-left corner of the window.

## User Tips

Following are some basic tips for using GeoSource:

- ***Organize your desktop.*** Many windows can be open while using GeoSource, so it is a good idea to standardize the way your desktop is arranged. For example, place the scalp waveforms being viewed in the Net Station Viewer in the same spot on your monitor screen every time.
- ***Refer to other EEG analysis tools.*** Use the GeoSource solutions in conjunction with other EEG tools, such as Net Station's chart, topo plot, and topo map views, or the results from other imaging modalities.

# SOURCE-IMAGING SPECIFICATIONS

A source-imaging specification contains the parameters for a forward algorithm for EEG, head conductivity and geometry settings, an inverse method, and applicable weighting, constraint, and regularization techniques. It estimates the source locations that are responsible for the EEG data measured on the scalp. All of these components are described in this chapter.

## Source-Imaging Specification Components

The source-imaging specification involves two main components:

- a head model
- an inverse method

## 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).

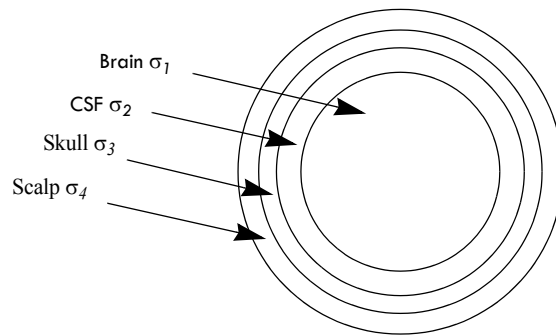
The resulting calculation is known as the forward matrix, which contains dipoles by EEG sensors (see Figure 4-2 on page 99). Note that because the number of sensors does not equal the number of dipoles, the forward matrix is *nonsquare*.

GeoSource's forward models for EEG are the Sun-Stok 4-shell sphere, a spherical head model (page 36, page 98, and page 122), and the finite difference model (FDM), a realistic head model (page 37, page 98, and page 114).

## Sun-Stok

As an *isotropic* model, the Sun-Stok consists of four shells that represent the brain, cerebrospinal fluid (CSF), skull, and scalp. The radii and their conductivity values are shown in Figure 4-1.

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



**Figure 4-1.** Sun-Stok shells

The geometry and conductivity values for the Sun-Stok model are listed in Table 4-1.

**Table 4-1.** Sun-Stok values

Shell	Radii (cm)	Radial conductivity (siemens per meter [S/m])	Tangential conductivity (siemens per meter [S/m])
Scalp ( $\sigma_4$ )	7.5	0.33	0.33
Skull ( $\sigma_3$ )	7.1	0.0042	0.0042
CSF ( $\sigma_2$ )	6.5	1	1
Brain ( $\sigma_1$ )	6.3	0.33	0.33

## Finite Difference Model (FDM)

A finite difference model (FDM) is a realistic 3D representation of the head. In GeoSource, the FDM is based on a realistic MRI (page 31 and page 39) and uses an isotropic model of tissue conductivities.

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

The conductivity values for the FDM model are listed in Table 4-2.

**Table 4-2.** FDM conductivity values (Ferre, et al., 2000)

Shell	Radii (cm)	Conductivity (siemens per meter [S/m])
Scalp ( $\sigma_4$ )	9.2	0.44
Skull ( $\sigma_3$ )	8.7	0.018
CSF ( $\sigma_2$ )	8.2	1.79
Brain ( $\sigma_1$ )	8.0	0.25

## EEG Sources

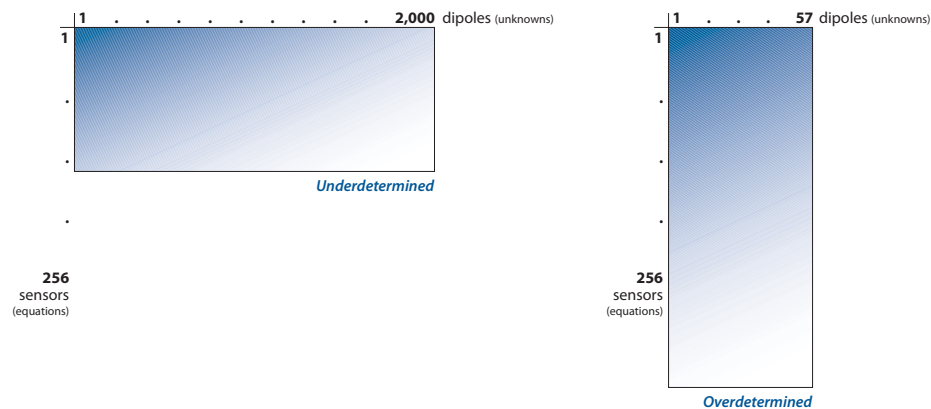
GeoSource offers a dense set of dipole locations. Sources in the FDM consist of 2,447 dipoles distributed throughout the gray matter. Each dipole is represented by a *triple regional source*, which consists of three dipoles in the X, Y, and Z orthogonal orientations.

This dipole set produces a nonsquare forward matrix (see page 97). When a nonsquare forward matrix is inverted using a pseudoinverse, the solution is either *underdetermined* or *overdetermined*.

## Underdetermined and Overdetermined Solutions

An *underdetermined solution* exists when there are more dipole sources than EEG sensors (in mathematical terminology, more *unknowns* than *equations*). See Figure 4-2. 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*).

**Figure 4-2.** Underdetermined (left) and overdetermined (right) solutions

## 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.

### 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.

## Constraint Schemes

Constraints can be applied to the inverse process to overcome the superficial bias of the MNLS technique. GeoSource offers three constraint schemes:

- LAURA
- LORETA
- sLORETA

### LAURA

LAURA (*local autoregressive average*) is a constraint that 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, and (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

LORETA (*low-resolution brain electromagnetic tomography*) 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

sLORETA (*standardized low-resolution brain electromagnetic tomography*) 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.

## Regularization

To account for noise in the data, *regularization* must be employed. Apart from explaining some of the variance in the data caused by noise, regularization also provides stability to the source solution, preventing small variations (assumed to be noise) in the data from leading to large variations in the distribution of activity in the solution.

GeoSource offers the Tikhonov regularization method.

## Suggested Reading

Following is a list of references for this chapter:

- 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.
- 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.

# GEOSOURCE FILE ORGANIZATION

**G**eoSource is an extension of Net Station. Consequently, some of the GeoSource application files reside inside of Net Station's folders, while others reside outside of them.

This chapter describes the GeoSource files and their file locations. These include *output*, *application*, and *related files*. For more information about Net Station file organization, see the *Net Station Acquisition Technical Manual*.

## Output Files

GeoSource outputs the following file formats:

- a Net Station MFF recording file
- a source binary file
- a tab-delimited text file
- a MATLAB .MAT file
- a modified Net Station recording file

**Note:** If you are seeing a longer list of available formats than are shown in the list above, you have not yet converted the original Net Station EEG recording file into a GeoSource view (or file). Stop, and review the “What to Know Before Getting Started” section in Chapter 3. You must create a GeoSource view using a source-imaging specification before you can convert an original Net Station EEG recording file into a GeoSource file.

You can save these files to any folder you choose.

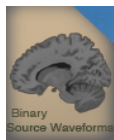
## Net Station MFF Recording



Net Station MFF  
Recording file icon

A file output from Net Station for GeoSource using the Net Station MFF Recording format option contains the source data in EGI's format for all data (EEG, wavelets, source data, T-Test, etc.). This file format contains the information for all selected dipoles, is not constrained by any size limit, and is fully integrated with Net Station. This format stores sample data in binary blocks and stores information about those samples in XML text files. For more information, request MFF documentation from EGI Support at [supportteam@egi.com](mailto:supportteam@egi.com).

## Source Binary



Source binary  
file icon

A file output from Net Station for GeoSource using the Source Binary File format option contains the source waveform data in a simple form that allows users to write applications for analyzing the data. This file format is similar in format to a normal simple binary file, which consists of a file header followed by data and events, but, whereas a normal simple binary file intersperses events throughout a file, this modified simple binary file stores events at the end of a file.

Capable of holding any kind of data, this simple binary file format is not limited to 2 GB in size, and consequently can easily accommodate large numbers of dipoles.

You can save a file in a sparse simple binary file format from the Net Station menus, depending on your current operation, by choosing **File > Save** or by choosing **Tools > Waveform Tools > Create > GeoSource** and, at the File Type pop-up menu, choosing **Binary File**.

When you save a dense simple binary source file by choosing **File > Save** from the Net Station menus, the resulting file contains only the active source montage of the dense solution set. When you save a dense simple binary source file by choosing **Tools > Waveform Tools > Create > GeoSource > File Type > Binary File**, the resulting file contains the entire dense solution set or the solution set for the selected montage.

## Tab-delimited Text

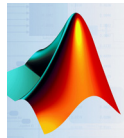


Text file icon

A file output from Net Station for GeoSource using the Tab-delimited Text format option contains the source data in a simple form that allows users to read the data into Excel or to write applications for analyzing the data. As a single, unsegmented block of source data that is saved with one level of precision and one type of unit (nanoamp meters), this format contains no metadata, events, or header. Because using this format is time-consuming and generates large files, we recommend exporting small files or selections of files to this format.

The tab-delimited text format is similar to the simple binary file format in terms of its file-size limits and export options.

## MATLAB .MAT



MATLAB icon

A file output from Net Station for GeoSource using the MATLAB .MAT format option contains the source data in a format suitable for MATLAB programming.

Net Station provides three output options for data being exported to the MATLAB .MAT format: nanoamp meters, no events, and double-point precision.

You can export to three arrays:

- individual arrays
- cell array
- 3D array

The MATLAB .MAT format is similar to the simple binary format in terms of its file-size limits and export options.

## Net Station Recording



A file output from Net Station for GeoSource using the Net Station Recording format option contains source data in a format similar to that of a Net Station EEG recording file, which is an object-oriented database consisting of elements, tracks, and epochs. Many waveform tool operations can be performed on these files (see page 17 for a list of tools). Note that you can open these files in the Net Station Viewer but you cannot transform the data back to scalp data.

You can save a file in the Net Station recording format from the Net Station menus, depending on your current operation, by choosing **File > Save** or by choosing **Tools > Waveform Tools > Create > GeoSource** and, at the File Type pop-up menu, choosing **Net Station Recording**. This file format can contain a source montage dense data set, because the entire dense solution set would exceed Net Station's 2-GB file-size limit. Each dipole location is represented by three waveforms—one for each orthogonal orientation (X, Y, and Z). The units are in nanoamp meters.

The file history information contains enough detail to reconstruct the file, if needed. To view this information—which includes the source-imaging specification parameters—open the file, choose **Edit > File Info**, and click the **History** tab.

## File Formats Manual

For more information about these file formats, refer the *Net Station File Formats Technical Manual*.

## GeoSource Application Files

The GeoSource application files consist of *EEG sources* and *source montages*. The application files reside in the GeoSource folder in the Net Station User Data folder and in the Net Station Application Program Package.



**CAUTION:** The Net Station Application Program Package is not intended for customer use. It should not be opened and none of its items moved, renamed, or deleted, or else Net Station may exhibit unexpected behavior, including data corruption.

## GeoSource-Related Files

GeoSource-related files are stand-alone files that are used in the software. GeoSource uses two kinds of files to approximate source data in the brain (*forward algorithms for EEG* and *average MRI files*). Both are stored in the Net Station Application Program Package.



**CAUTION:** The Net Station Application Program Package is not intended for customer use. It should not be opened and none of its items moved, renamed, or deleted, or else Net Station may exhibit unexpected behavior, including data corruption.

## GeoSource File Summary

Table 5-1 summarizes this chapter.

**Table 5-1.** GeoSource files and locations

Settings	Description	Storage location
Net Station MFF Recording file format	Derived source waveform data saved in a file format similar to that of a Net Station EEG recording file that differs by storing sample data in binary blocks and storing information about those samples in XML text files, which is designed for data accessibility from any language using any operating system and which allows extended continuous recordings to be compressed into a single file (without any additional steps needed to stitch separate files together).	<user-selected folder>
Source Binary File format	Derived source waveform data saved in a file format similar to that of a normal simple binary file, which contains a header followed by data and events; however, in a GeoSource simple binary file, the events are stored at the end of the file.	<user-selected folder>
Tab-delimited Text format	Derived source waveform data saved in a file format that contains no metadata, events, or header.	<user-selected folder>

**Table 5-1.** GeoSource files and locations

Settings	Description	Storage location
MATLAB .MAT format	Derived source waveform data saved in a file format that is designed for compatibility with MATLAB programs.	<user-selected folder>
Net Station Recording file format	Derived source waveform data saved in a file format similar to that of a Net Station EEG recording file, which is an object-oriented database.	<user-selected folder>
EEG sources	Set of assumed dipole locations that is used for determining the initial dipole locations in the cortex for the forward model.	User-defined sets: /Users/<username>/Documents/Net Station User Data/GeoSource Built-in sets: /Applications/Net Station/Net Station.app/GeoSource/ <b>Do not open this package.</b>
Source montage	User-created subset of a dense solution set that allows you to display only the dipoles of interest.	User-defined montages: /Users/<username>/Documents/Net Station User Data/GeoSource Built-in montages: /Applications/Net Station/Net Station.app/GeoSource/ <b>Do not open this package.</b>
Forward algorithm for EEG	Mathematical technique used to calculate the voltage at the sensors, when a dipole has a unit activation, for a given head volume geometry and conductivity, dipole locations, and sensor locations.	/Applications/Net Station/Net Station.app/GeoSource/ <b>Do not open this package.</b>
Average MRI	Used for 3D display of the derived source locations.	/Applications/Net Station/Net Station.app/GeoSource/ <b>Do not open this package.</b>



# SOFTWARE TECHNICAL SUPPORT

## Before Contacting EGI

Please check this manual's contents on page v or index on page 125 for coverage of your issue or question. You can also perform an electronic search using Find or Search in the PDF version of this manual, which is posted on the documentation page of the EGI website ([www.egi.com/membership-area](http://www.egi.com/membership-area)).

In addition, the Support page of the EGI website ([www.egi.com/support](http://www.egi.com/support)) may have the information you need.

If you need more help, EGI recommends the following:

- **Isolate the problem.** Try to repeat and define the problem.
- **Document the problem.** Carefully record the sequential details of the isolated problem.
- **Report the defined problem.** Contact EGI by web, email, phone, fax, or postal mail.

## Contacting EGI

<b>EGI Support web page</b>	<a href="http://www.egi.com/support">www.egi.com/support</a>
<b>Email support</b>	<a href="mailto:supportteam@egi.com">supportteam@egi.com</a>
<b>Sales information</b>	<a href="mailto:info@egi.com">info@egi.com</a>
<b>Telephone</b>	+541-687-7962
<b>Fax</b>	+541-687-7963
<b>Address</b>	Electrical Geodesics, Inc. 500 E 4th Avenue, Suite 200 Eugene, OR 97401 USA





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# GLOSSARY

**Note:** If a word is italicized in a definition, then that word (or a variant) is also defined in this glossary.

## A

***algorithm*** A set of instructions used to solve a problem or obtain a desired result. For example, the “shampoo algorithm” explains how to wash one's hair: wet hair, lather, rinse, repeat. Gaussian elimination is an algorithm for solving *linear* systems of equations.

***axon*** The usually long process of a nerve fiber that generally conducts impulses away from the body of the *neuron*.

## C

***cell body*** The portion of a *neuron* that contains the nucleus but does not incorporate the *dendrites* or *axon*. Also called “soma.”

***cerebral cortex*** The extensive outer layer of gray matter of the cerebral hemispheres, largely responsible for higher brain functions, including sensation, voluntary muscle movement, thought, reasoning, and memory.

***cerebrospinal fluid (CSF)*** The serumlike fluid that circulates through the ventricles of the brain, the cavity of the spinal cord, and the subarachnoid space, functioning in shock absorption.

***channel*** Each sensor of the *Geodesic Sensor Net* is cabled into the amplifier where its signal is converted into a stream of digital values. Each of these streams is the data of a channel.

***coefficient*** The number multiplied times a product of variables or powers of variables in a term. For example, 123 is the coefficient in the term  $123x^3y$ .

***coefficient matrix*** The matrix formed by the *coefficients* in a *linear* system of equations.

***column (of a matrix)*** A vertical set of numbers in a *matrix*.

***condition number*** The ratio of the largest to smallest *singular value* in the *singular value decomposition* of a *matrix*.

***conductivity*** A measure of the tendency of a material to transmit electrons; opposite of *impedance* or *resistance*.

***constraint scheme*** A scheme that imposes constraints on the *source space* by using prior anatomical or physiological information, often derived from other imaging modalities. In effect, this type of scheme places bounds on the norm. The *inverse method* is then applied to the reduced source space to yield a *solution set*. GeoSource offers three constraint schemes: *LAURA*, *LORETA*, and *sLORETA*.

***current*** Measured in amperes, this is the flow of electrons through a *conductor*. Also know as “electron flow.”

## D

***dendrite*** A branched protoplasmic extension of a *neuron* that conducts impulses from adjacent cells inward toward the *cell body*. A single nerve may possess many dendrites. Also called “dendron.”

***dense (sensor) array*** Any (sensor) system that supports a sufficient number of sensors to spatially *sample* a phenomenon adequately. For *EEG* recording, this generally means 64 or more *channels*. For source estimation, this means 128 or 256 channels.

***determinant*** The value computed from a *square matrix* of numbers by a rule of combining products of the matrix *elements* and that characterizes the solvability of simultaneous *linear equations*. Its absolute value can be interpreted as an area or volume.

***diagonal matrix*** A *square matrix* whose array contains constants on the diagonal and 0's everywhere else.

**dipolar** Of or relating to *dipole*.

**dipole** A pair of electric charges, of equal magnitude but opposite polarity, separated by a small distance. Each dipole has a location and orientation.

**dipole activation** The degree of power of the electrical *current* sent from the *dendrite* to the *cell body*.

**dipole location** The *cortical* section where the *dipole* is situated. The cortical section may be synonymous with the dipole.

**dipole orientation** The direction in which the *dipole* is pointing.

## E

**EEG** See *electroencephalography*.

**EEG sources** This *dipole set* bases the *dipole locations* on a *realistic* head shape (specifically, the average *magnetic resonance image* from the Montreal Neurological Institute), but uses a *spherical* shape to solve the *inverse EEG problem*. The dense set evenly spaces thousands of dipoles over the head shape.

**electrical field** A field or force that exists in the space between two different potentials or *voltages*. Also known as “electrostatic field.”

**electroencephalography** Science of recording and analyzing the electrical activity of the brain.

**element (of a matrix)** One of the entries in a *matrix*. The address of an element is given by listing the *row* number, then the *column* number.

**elementary row operation** The following methods used to transform *matrices*: trading two *rows*, multiplying a row by a nonzero *scalar*, or adding a scalar multiple of one row to another row.

## F

**FDM** See *finite difference model*.

**Finder** On Macintosh computers, the Finder is the program that keeps track of files and folders, and displays the desktop (the working area on the screen with disk icons, a Trash icon, and so on).

**finite difference model (FDM)** A 3D *realistic head model* based on finite differences, in which the basic calculation elements are nodes on a rectangular grid. The realistically shaped head model is obtained from 3D *magnetic resonance images*, and each cubic grid is allocated a specific *conductivity*, depending on the compartment in which it is located. In GeoSource, the conductivity values are fixed.

**fixed** Constant; not changing or moving.

**forward algorithm for EEG** For a given *head volume geometry and conductivity*, *dipole locations*, and sensor locations, this is the mathematical technique used to calculate the voltage at the *sensors* when the *dipole* has a unit activation. In the *Source-Imaging Specification Editor window*, GeoSource offers these choices: *finite difference model (FDM)* and *Sun-Stok 4-shell sphere*.

**forward EEG matrix** The *linear transformations* used to relate known *dipole locations and activations* to measured EEG locations and activations on the scalp. The *matrix* contains one *column* per *dipole*, one *row* per *sensor*, and one column topography for each unit dipole. The *elements* in this *matrix* result from the *forward algorithm for EEG*.

**forward EEG model** In GeoSource, this *model* is created by choosing a *forward algorithm for EEG* and a *head geometry and conductivity setting* and combining them with the EEG data (sensor locations). This is used to solve the *forward EEG problem*.

**forward EEG problem** Given known *dipole locations and activations* and *head volume geometry and conductivity* and sensor locations (from the EEG data), the goal is to estimate the EEG as it appears on the scalp. In GeoSource, this is solved using a *forward EEG model*.

**forward problem** Given known source data and propagation model, the goal is to estimate the surface measurements.

## G

**geodesic** The shortest distance between two points on the surface of a *sphere*. The *Geodesic Sensor Net* is a structure of elastomer lines in the approximation of a geodesic.

**Geodesic Sensor Net (GSN)** Electrical Geodesics Inc.'s *dense sensor array*.

**geometry** Surface shape.

**gray matter** See *cerebral cortex*.

**GSN** See *Geodesic Sensor Net*.

**gyrus** Any of the prominent, rounded, elevated convolutions on the surfaces of the cerebral hemispheres.

## H

**head geometry and conductivity setting** A scientifically and mathematically based method that represents a reconstruction of the shape and *conductivity* properties of a human head.

## I

**identity matrix** The simplest nontrivial *diagonal matrix*, defined such that  $IX = X$  for all *vectors*  $X$ . The identity matrix thus functions like the number "1," and its array consists of 1's on the diagonal and 0's everywhere else.

**ill-posed problem** First defined in 1902 by the mathematician Jacques Hadamard, an ill-posed problem fails to meet one or more of the following:

- For each set of data, there exists a solution.
- The solution is unique.
- The solution depends continuously on the data.

In other words, an ill-posed problem is one whose solution does not exist, is not unique, or is not stable under perturbations on the data. A matrix is ill posed if its *condition number* is large. Most inverse solutions are ill posed because they tend to be highly *underdetermined*. *Overdetermined* solutions can be ill posed as well, but they tend to be more stable overall.

**impedance** The alternating-current equivalent of *resistance*, impedance is the measurement of the resistance to the flow of electricity for a particular substance. Electrode/scalp impedances affect *waveform* susceptibility to environmental noise. The opposite of *conductivity*.

**inverse** Reversed in order, nature, or effect. For example, the inverse of 5 is 1/5.

**inverse EEG matrix** The *linear* transformations that relate the measured EEG locations and activations to the estimated *dipole locations and activations*. The *elements* in this matrix result from inverting the *forward EEG matrix*.

**inverse EEG model** Consists of an *inverse method* and *weighting, constraint, and/or regularization techniques*; this *model* is used to invert the *forward EEG model*. The inverse EEG model is defined in the *Source-Imaging Specification Editor window*, which can be accessed by choosing GeoSource menu > **New Source-Imaging Specification**.

**inverse EEG problem** Given known EEG locations/activations and *head geometry/conductivity*, the goal is to estimate the *dipole locations/activations*. In GeoSource, this is solved by using a *source-imaging specification* and applying the result to the EEG scalp data.

**inverse matrix** The *inverse* of a *nonsingular* and *square matrix*  $A$  is a matrix  $A^{-1}$  such that  $AA^{-1} = I$ , where  $I$  is the *identity matrix*. A square matrix  $A$  has an inverse if and only if the *determinant*  $|A| \neq 0$ .

**inverse method** Based on various assumptions about *dipole locations and activations*, this is a mathematical equation that produces a unique answer from the infinite number of possible answers to the *inverse EEG problem*. GeoSource uses the *minimum-norm least squares* (MNLS) technique when the solution is underdetermined.

**inverse problem** Given known surface measurements and propagation model, the goal is to derive the source data. This requires solving the *forward problem* first.

**isotropic** Identical *conductivity* in all directions; invariant with respect to direction.

## L

**LAURA** Stands for “local autoregressive average.” LAURA uses biophysical laws to constrain the minimum norm. This scheme derives a solution based on two factors: (1) the theory that the strength of a dipole decreases as the distance from the source increases, and (2) the local autoregressive average of coefficients that depend on the distance between solution points.



**least-squares fit** The *linear* fit that matches the pattern of a set of paired data as closely as possible. Out of all possible linear fits, the least-squares regression line is the one that has the smallest possible value for the sum of the squares of the residuals.

**linear** Like a line. A description of any graph or data that can be modeled by a linear polynomial. Opposite of *nonlinear*.

**linear equation** An equation that can be written in the form  $ax + b = 0$ , where  $a$  and  $b$  are constants.

**linear transformation** A change of variables where each variable is replaced by a function of the first degree in the new variable.

**LORETA** Stands for “low-resolution brain electromagnetic tomography,” which is a Laplacian weighted minimum-norm method. LORETA relies on physiological theories to add constraints to the depth weighting. This scheme selects the solution with the smoothest spatial distribution.

## M

**magnetic resonance image (MRI)** Magnetic resonance imaging uses computer imaging of atomic response to radio waves in a magnetic field to generate imagery of tissue.

**magnitude** In the case of EEG, the strength (i.e., the amount of current flow) of a source dipole as represented by the length of a vector. More generally, a property of relative size that is given as a scalar value having physical units.

**matrix** A rectangular array of items, with  $m$  number of rows and  $n$  number of columns, which is denoted as  $m \times n$ . Each item is called an *element* or “entry.”

**matrix rank** The number of linearly independent *rows* or *columns*.

**minimum-norm least squares (MNLS)** In a *linear* system of  $ax = b$ , this is the solution that yields the shortest *vector*  $x$  that achieves  $\min x ||ax - b||$ . This solution assumes that the 3D current distribution has minimum overall intensity. GeoSource uses MNLS.

**MNLS** See *minimum-norm least squares (MNLS)*.

**model (mathematical)** An equation or a system of equations representing real-world phenomena. Models also represent patterns found in graphs and/or data. Usually models are not exact matches of the objects or behavior they represent. A good model should capture the essential character of whatever is being modeled.

**montage** One of several methods of combining, selecting, or arranging data from multiple sensor locations, or the result of defining one of such methods. On a given montage, a combined *waveform* is a derivative of the waveforms at the sensors chosen to be combined. A selection of sensors results in the display of a subset of all the sensors originally used to make a recording.

**MRI** See *magnetic resonance image*.

## N

**neuron** Any of the impulse-conducting cells that constitute the brain, spinal column, and nerves, consisting of a nucleated *cell body* with one or more *dendrites* and a single *axon*. Also called “nerve cell.”

**noise** Any perturbation on the data that is not described by the applied *models*. In inverse solutions, a small amount of noise can create large errors, making the solution unstable and unreliable. GeoSource offers one method of mitigating noise: *Tikhonov*. In effect, this *regularization* method is based on assumptions about the smoothness of the norm.

**nonlinear** Not depictable graphically as a straight line; not changing by a constant amount for each unit of time, distance, or other independent *variable*. Opposite of *linear*.

**nonsingular matrix** A *matrix* that contains no *column* or *row* that is a variant of another column or row. If a nonsingular matrix is *square*, then it has an *inverse matrix*.

**nonsquare matrix** A *matrix* in which the number of *rows* does not equal the number of *columns*.

**nontrivial** A solution or example that is not *trivial*. Often, solutions or examples involving the number zero are considered trivial. Nonzero solutions or examples are considered nontrivial. For example, the equation  $x + 5y = 0$  has the trivial solution (0, 0). Nontrivial solutions include (5, -1) and (-2, 0.4)

## O

**oblique** Tilted at an angle; neither vertical nor horizontal.

**orthogonal** Relating to or composed of right angles.

**orthogonal matrix** Of or relating to a *matrix* whose *transpose* equals its *inverse*.

**overdetermined** The approach to solving the *inverse EEG problem* that contains fewer unknowns (the *dipole locations/activations* assumed in the *dipole set*) than knowns (the EEG locations/activations measured on the scalp).

**Overlaid Segments view** A viewing mode in the Net Station Viewer that allows you to view source waveforms as three overlaid waveforms per dipole location.

## P

**polarity** Intrinsic polar separation or orientation, especially of a physical property.

**pseudoinverse** An object similar to an *inverse matrix* that enables *rectangular matrices* to be *inverted*. A well-known example is the Moore-Penrose pseudoinverse, which multiplies the rectangular matrix by its *transpose* to make a *square matrix*, inverts the square matrix, and multiplies the inverted result by the *transpose* to return the matrix to its rectangular state.

## R

**radial** Radiating from or converging to a common center.

**realistic** Relating to the representation of an object as it is in reality. In GeoSource, a realistic head *model* is based on an average magnetic resonance image (*MRI*), rather than a *spherical* model. The computational capabilities required are greater, but so is the accuracy.

**rectangular matrix** A *matrix* that has a different number of *rows* than *columns* (denoted as an *m* x *n* matrix).

**reference** An electrical point that is treated as zero for purposes of amplifying electrical signals. The *Geodesic Sensor Net* has a reference electrode located at the vertex.

**regularization** Additional information about the solution that is introduced to an *ill-posed* problem, to stabilize the solution. GeoSource offers one type of regularization: *Tikhonov*.

**resistance** The opposition of a body or substance to *current* passing through it, resulting in a change of electrical energy into heat or another form of energy. Opposite of *conductivity*.

**RMS view** Stands for *root-mean-square* view. This is a viewing mode in the Net Station Viewer that allows you to view source waveforms as one collapsed waveform (with the RMS values of all three waveforms added together) per dipole location.

**root mean square (RMS)** A kind of average sometimes used in statistics and engineering, often abbreviated as RMS. To find the root mean square of a set of numbers, square all the numbers in the set and then find the arithmetic mean of the squares. Take the square root of the result.

**row (of a matrix)** A horizontal set of numbers in a *matrix*.

## S

**sample** When a continuous signal is measured by examining it at discrete moments in time, each measurement corresponds to a sample.

**scalar** A quantity, such as length, that is completely specified by its *magnitude*, and has no direction.

**sensor** A device that picks up a *signal* being generated by something in the real world.

**sensor layout** Descriptive information for a particular quantity and arrangement of *sensors*. Includes 2D and/or 3D coordinates specifying the locations of *sensors*, labels (names) of sensors, and connectivity. Such information is stored in a sensor layout file.

**shell** Any of the set of hypothetical *spherical* surfaces centered on an inner sphere (representing the brain in GeoSource).

**signal** A detectable, measurable quantity that can be expected to display periodicity or other forms of variation in time.

**singular matrix** A *matrix* that contains a *column* or *row* that is a variant of another column or row. A singular matrix has no true *inverse matrix*, but may be *inverted* using a *pseudoinverse*.

**singular value** The diagonal elements of a *diagonal matrix* in the *singular value decomposition* equation of  $A = U \Sigma V^T$ , where  $U$  and  $V$  are *orthogonal matrices*, and  $\Sigma$  is a *diagonal matrix*.

**singular value decomposition (SVD)** A powerful and widely used group of techniques dealing with sets of equations or *matrices* that are either singular or numerically very close to *singular*. SVD allows one to diagnose the problems in a given matrix and provides numerical answer as well. SVD decomposes a matrix into several component matrices, exposing many of the useful and interesting properties of the original matrix. Using the SVD, we can determine the *rank* of matrix, quantify the sensitivity of a *linear* system to numerical error, or obtain an optimal lower-rank approximation to the matrix. Every  $m \times n$  matrix has an SVD, which can be expressed as  $A = U \Sigma V^T$ , where  $U$  and  $V$  are *orthogonal matrices*, and  $\Sigma$  is a *diagonal matrix*.

**sLORETA** (*standardized low-resolution brain electromagnetic tomography*) Like LORETA, sLORETA 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.

**solution set** Any and all value(s) of the *variable(s)* that satisfies an equation, inequality, system of equations, or system of inequalities.

**source-imaging specification** In GeoSource, this is the group of settings to use when estimating source *waveforms* and *dipole activations*. A source-imaging specification consists of a *forward algorithm for EEG* (for the *forward EEG model*) and an *inverse EEG model*. Be aware that the term *source-imaging specification* is similar, but not identical, to terms such as *source-localization method*, *inverse solution*, and *source-analysis technique*.

**Source-Imaging Specification Editor window** This is the Net Station window where the *source-imaging specification* is defined. Accessible in a number of ways, primarily by choosing GeoSource menu > **New Source-Imaging Specification**.

**source montage** A subset of a *dense dipole solution set* that allows you to view only the *dipoles* of interest. In GeoSource, this is created in the GeoSource Viewer, and the montages can be applied in either the GeoSource Viewer or the Net Station Viewer.

**source space** The set of all possible outcomes of an experiment.

**sphere** A 3D solid consisting of all points equidistant from a given point. This point is the center of the sphere. All cross-sections of a sphere are circles.

**square matrix** A *matrix* that has the same number of *rows* as *columns* (that is,  $m = n$ ).

**Sun-Stok 4-Shell Sphere** A four-shell concentric structure, with different *conductivity* values for the brain, skull, *cerebrospinal fluid*, and scalp *spheres*. The Sun-Stok 4-shell sphere approximates the forward solution of the multishell model directly based on mathematical analysis of infinite sums of Legendre and associated Legendre polynomials. The weighting functions of these polynomials are fit using low-order polynomials, and closed-form expressions for the infinite sums are derived based on this polynomial representation. The resulting *algorithm* minimizes the amount of computer running time.

## T

**tangent** A line, curve, or surface meeting another line, curve, or surface at a common point and sharing a common tangent line or tangent plane at that point.

**tangential** Of, relating to, or moving along or in the direction of a *tangent*.

**Tikhonov regularization** A common and well-known *regularization* method that parameterizes a whole family of solutions by the weighting factor  $\lambda^2$ . This method multiplies each *singular value* by a constant, with the aim of increasing the small singular values such that when they are inverted, their effect on the stability of the solution is minimal. The effect of this regularization on large singular values should be negligible.

**transpose matrix** Created by taking the first *column* of a *matrix* A and using it as the first *row* of the transpose matrix A, taking the second column of matrix A and using it as the second row of the transpose matrix A, and so on. The transpose matrix is denoted as  $A^T$ .

**trivial** A solution or example that is ridiculously simple and of little interest. Often, solutions or examples involving the number 0 are considered trivial. Nonzero

solutions or examples are considered *nontrivial*. For example, the equation  $x + 5y = 0$  has the trivial solution  $x = 0, y = 0$ . Nontrivial solutions include  $x = 5, y = -1$  and  $x = -2, y = 0.4$ .

## U

**underdetermined** The approach to solving the *inverse EEG problem* that contains fewer knowns (the EEG locations/activations measured on the scalp) than unknowns (the *dipole locations/activations* assumed in the *dipole set*).

## V

**variable** A quantity that may increase or decrease; a quantity that admits an infinite number of values in the same expression; for example, in the equation  $x^2 - y^2 = R^2$ ,  $x$  and  $y$  are variables.

**vector** (1) A quantity, such as velocity, completely specified by a *magnitude* and a direction; (2) a one-dimensional array; or (3) an element of a *vector space*.

**vector space** A vector space  $V$  is a set that is closed under finite vector addition and scalar multiplication.

**vertex** The point on an EEG subject's scalp that is closest to the top of the head. In the International 10-20 system, Cz is the vertex electrode. In the Adult 128 GSN, electrode #129 is the vertex. The point on the scalp or skull located midway between the nasion and inion and centered between the periauricular points. Also the name of the *Geodesic Sensor Net* sensor that corresponds to this location and contains the reference electrode.

**volt/voltage** A measure of electrical force, or the tendency for electrons to move from one location to another. Voltages are measured with respect to a *reference*.

**voxel** Stands for "volume pixel," the smallest distinguishable box-shaped part of a 3D image.

## W

**waveform** Any graphical representation of a *signal*.

***weighting*** A *coefficient* assigned to elements of a distribution, to represent their relative importance. The objective of weighting is to correct for biases in the measurement method. The *inverse methods* in GeoSource are all based on variants of *minimum-norm least squares (MNLS)*, which favors shallow *dipole locations* over deeper sources. The weighting options offered include: per location and per orientation.

***well conditioned*** See *well posed*.

***well posed*** The following definition was first developed in 1902 by the mathematician Jacques Hadamard, who noticed that *inverse* formulations of boundary value problems (or their algebraic counterpart) were often *ill behaved*. He defined the conditions for well-posed and ill-posed problems. For a problem to be well posed in the Hadamard sense, it must meet the following criteria:

- For each set of data, there exists a solution.
- The solution is unique.
- The solution depends continuously on the data.



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