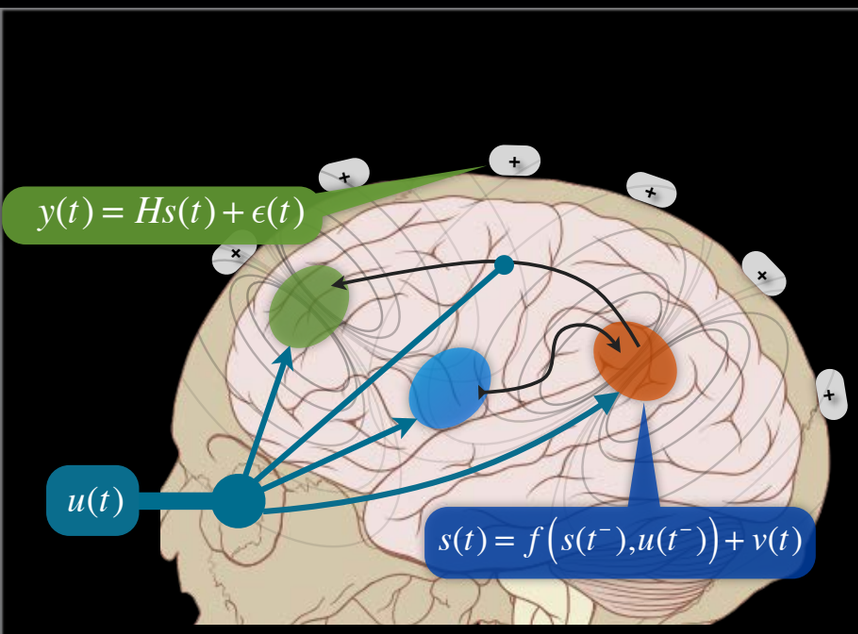
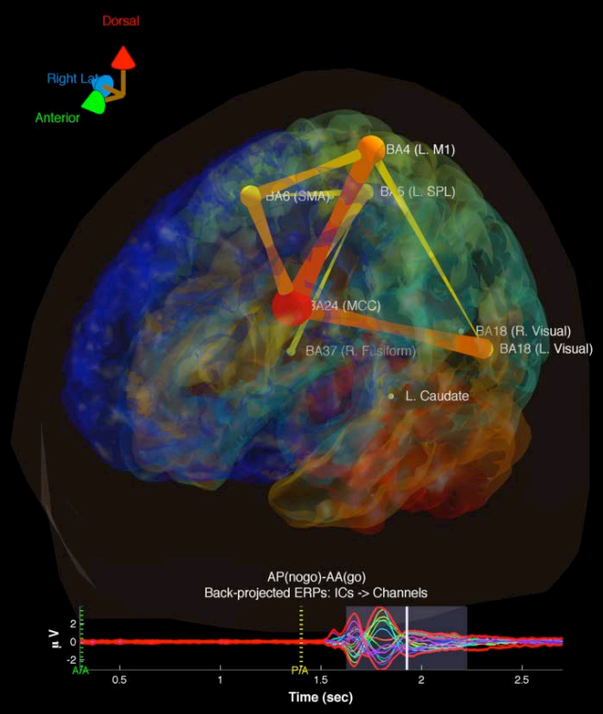
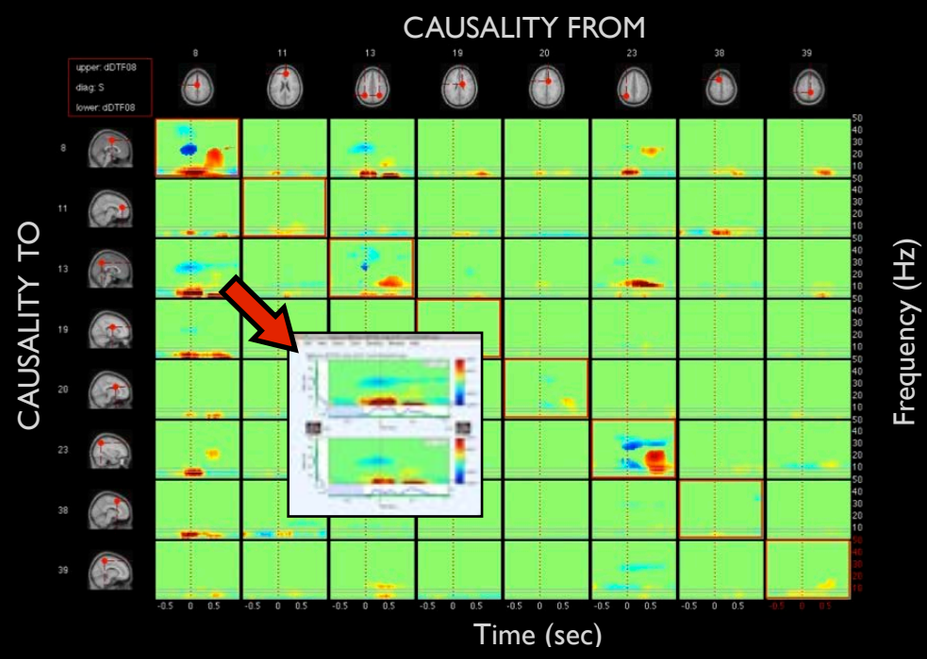
The Source Information Flow Toolbox

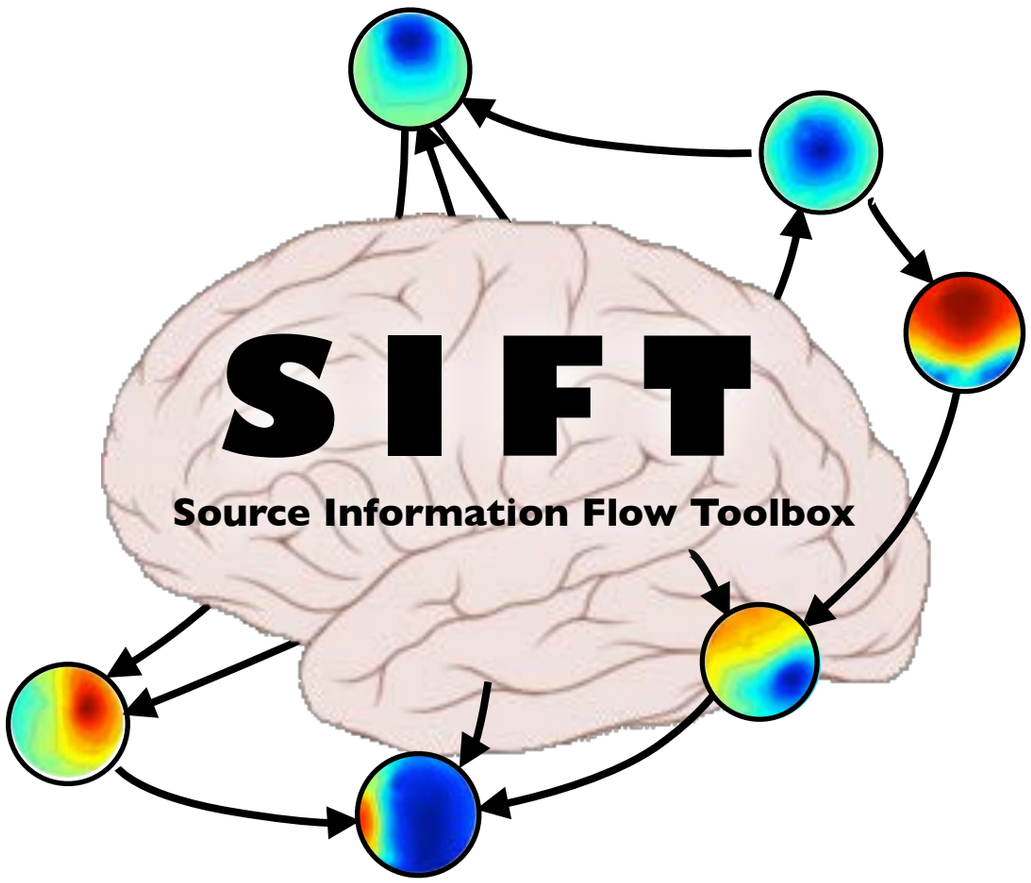




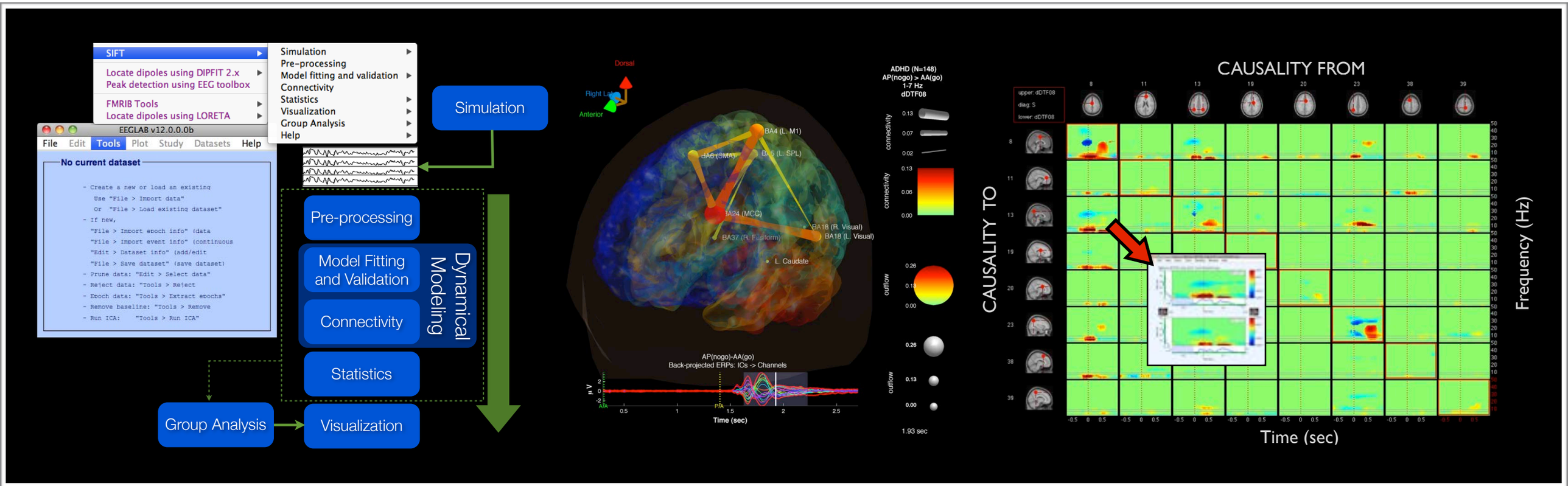


Tim Mullen, PhD

Mullen, T. (2014). "The Dynamic Brain: Modeling Neural Dynamics and Interactions From Human Electrophysiological Recordings." *UC San Diego*. ProQuest ID: Mullen_ucsd_0033D_14394. Merritt ID: ark:/13030/m5ht7b20.
Delorme, A., Mullen, T., et al, "EEGLAB, SIFT, NFT, BCILAB, and ERICA: New tools for advanced EEG/MEG processing." *Comp. Intel. and Neuro.*, vol 12, 2011



- A toolbox for (source-space) electrophysiological information flow and causality analysis (single- or multi-subject) integrated into the EEGLAB software environment.
- Modular architecture intended to support multiple modeling approaches
- Emphasis on vector autoregression and SSMs and time-frequency domain approaches
- Standard and novel interactive visualization methods for exploratory analysis of connectivity across time, frequency, and spatial location



SIFT Workshop Sessions

Theoretical Foundations I
Functional Connectivity Measures (PLV, PAC, Coherence)
Linear Dynamical Systems and the VAR model
Granger Causality and Effective Connectivity Measures
Scalp versus Source
Adapting to Time-Varying Dynamics
Practicum: Hands-On Walkthrough of SIFT

Saturday, Nov 10th
2:30-5:30pm
Track C
(INC Open Space)

Theoretical Foundations II
Model Validation
Multivariate vs. Bivariate
Imposing Constraints
Single-trial Estimation and State-Space Models
Statistical Testing
Practicum: Hands-On Simulation-based training

Sunday, Nov 11th
2:30-5:30pm
Track C
(INC Open Space)

The Source Information Flow Toolbox

Source Information Flow Toolbox (SIFT)

Swartz Center for Computational Neuroscience
Tim Mullen

- **Requirements**: EEGLAB, MATLAB 2008b+
- Some functions leverage: Signal Processing Toolbox, Statistics Toolbox

DOWNLOAD SIFT FROM THE EEGLAB EXTENSION MANAGER (File—>Manage EEGLAB Extensions—>Data Processing Extensions)

The Source Information Flow Toolbox

Swartz Center for Computational Neuroscience
Tim Mullen

SIFT ▶

Locate dipoles using DIPFIT 2.x ▶
Peak detection using EEG toolbox

FMRIB Tools ▶
Locate dipoles using LORETA ▶

- Simulation ▶
- Pre-processing
- Model fitting and validation ▶
- Connectivity
- Statistics ▶
- Visualization ▶
- Group Analysis ▶
- Help ▶

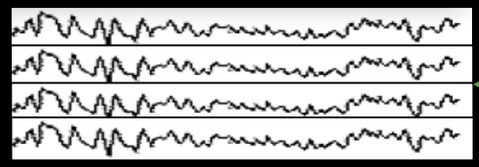
EEGLAB v12.0.0.0b

File Edit **Tools** Plot Study Datasets Help

No current dataset

```
- Create a new or load an existing
   Use "File > Import data"
   Or  "File > Load existing dataset"
- If new,
  "File > Import epoch info" (data
  "File > Import event info" (continuous
  "Edit > Dataset info" (add/edit
  "File > Save dataset" (save dataset)
- Prune data: "Edit > Select data"
- Reject data: "Tools > Reject
- Epoch data: "Tools > Extract epochs"
- Remove baseline: "Tools > Remove
- Run ICA:    "Tools > Run ICA"
```

Simulation



Pre-processing

Model Fitting and Validation

Connectivity

Dynamical Modeling

Statistics

Group Analysis

Visualization

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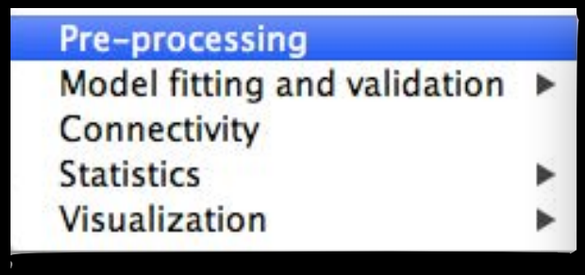
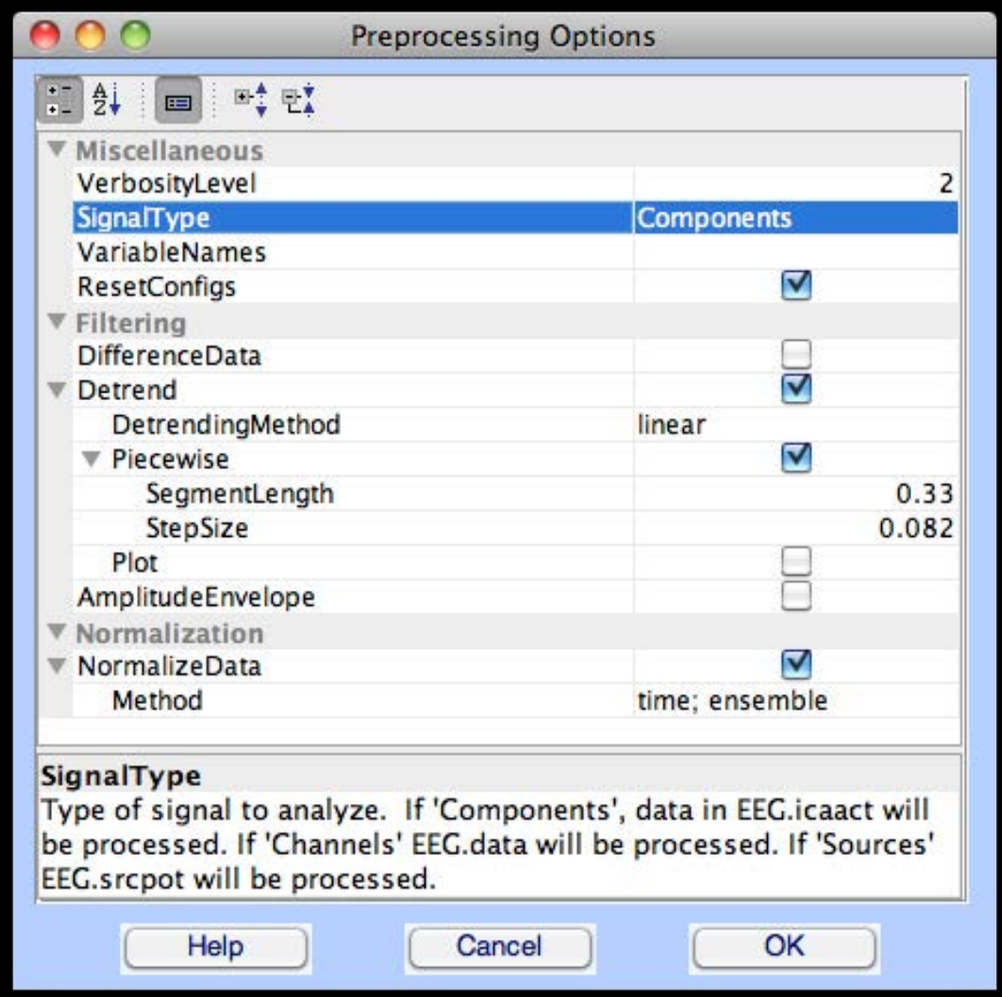
Preprocessing

Modeling

Statistics

Visualization





Source reconstruction
(performed externally using EEGLAB or other toolboxes)

Local Detrending or Filtering

Downsampling (EEGLAB)

Differencing

Normalization (temporal or ensemble)

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Preprocessing

Modeling

Model Fitting

Validation

Connectivity

Statistics

Visualization

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Preprocessing | **Modeling** | Statistics | Visualization

Model Fitting | Validation | Connectivity

Modeling Algorithm (1)	Linear	Nonlinear
Segmentation VAR (Sliding Window)		
Unconstrained		
Vieira-Morf	☑	
ARfit	☑	
Regularized		
Ridge Regression (L_2)	☑	
Group Lasso ($L_{1,2}$) ADMM, DAL	☑	
Sparse Bayesian Learning (L_p) TMSBL, BSBL	☑	

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Preprocessing | **Modeling** | Statistics | Visualization

Model Fitting | Validation | Connectivity

Modeling Algorithm (2)	Linear	Nonlinear
State-Space Modeling		
Linear Kalman Filtering	☑	
Dual Extended Kalman Filtering		☑
Sparsely Connected Components Analysis (SCSA)	☑	

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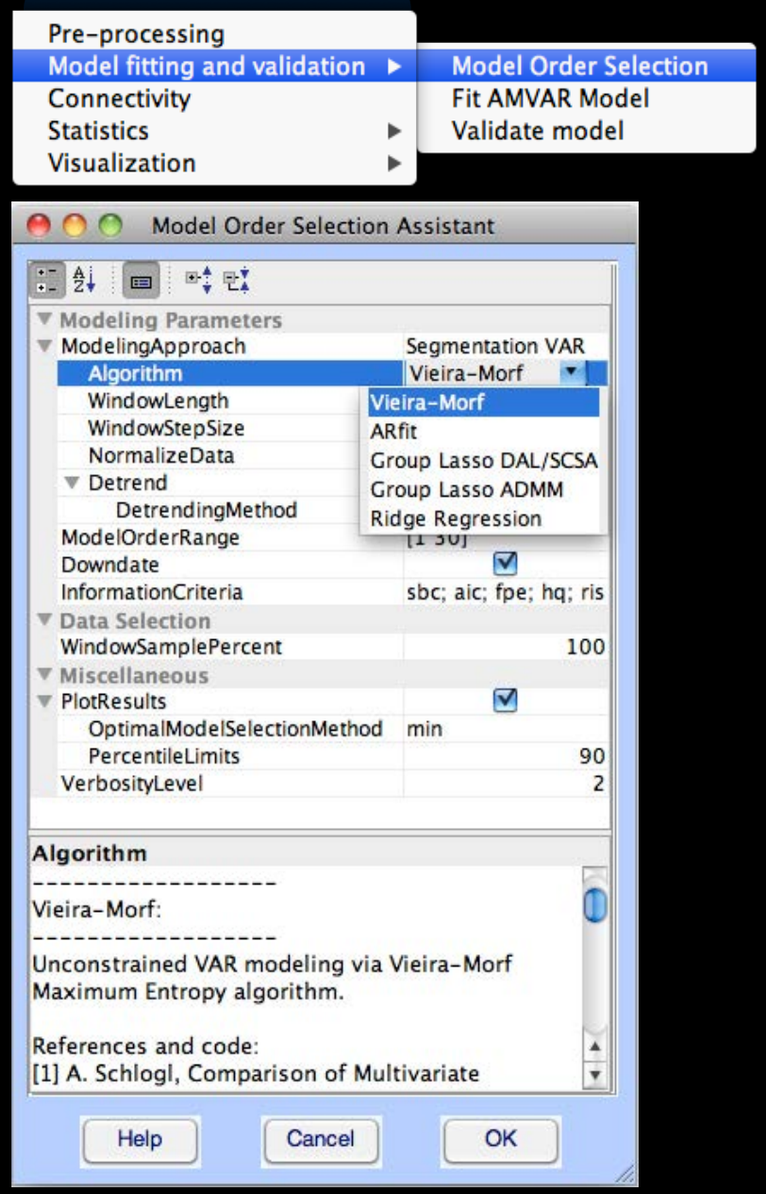
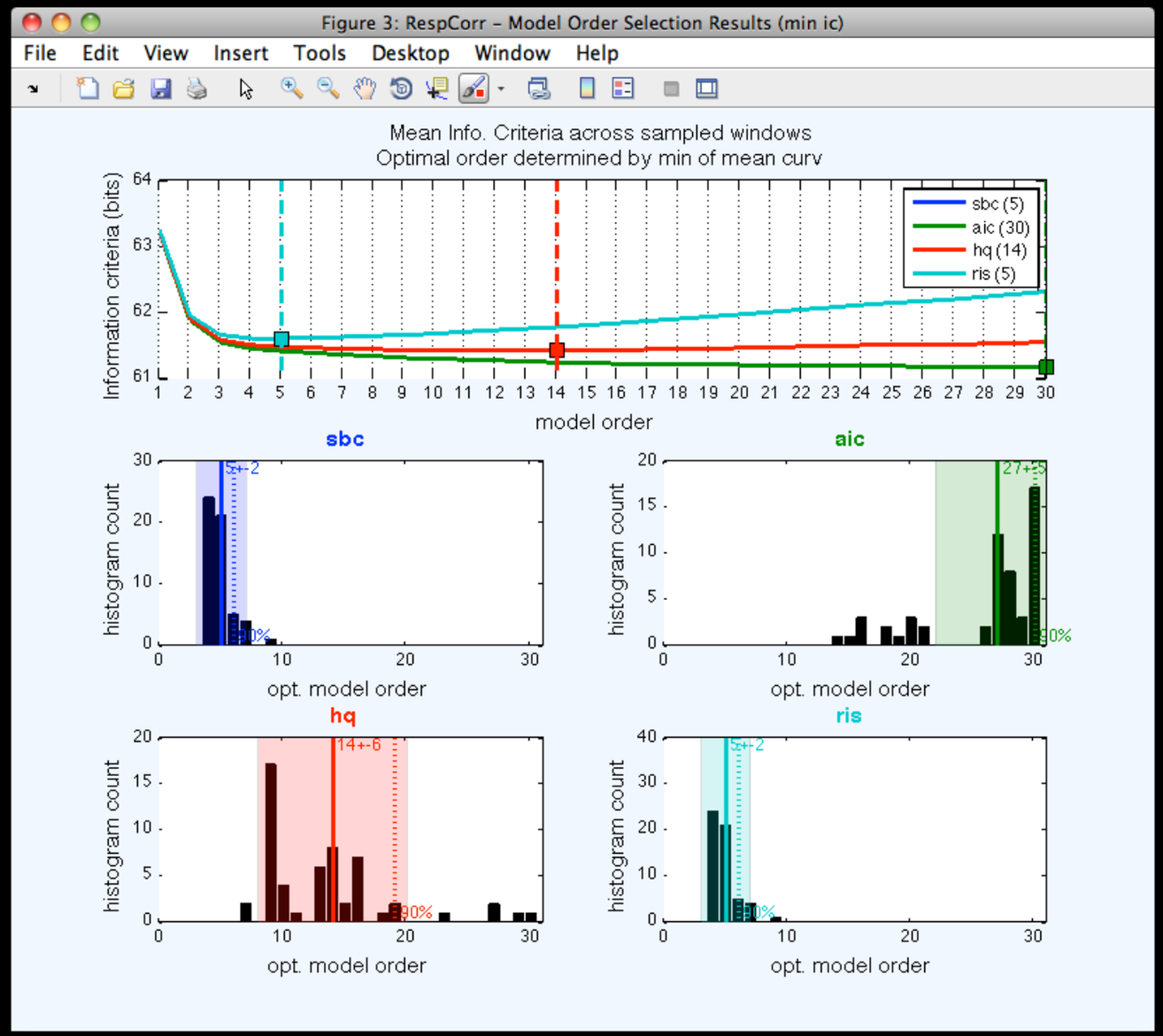
Preprocessing | **Modeling** | Statistics | Visualization

Model Fitting | Validation | Connectivity





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Preprocessing | **Modeling** | Statistics | Visualization

Model Fitting | **Validation** | Connectivity

VAR Model Validation

Residual 'Whiteness' Tests

- Multivariate portmanteau tests
- Residual autocorrelation probability test

Model Consistency

Model Stability

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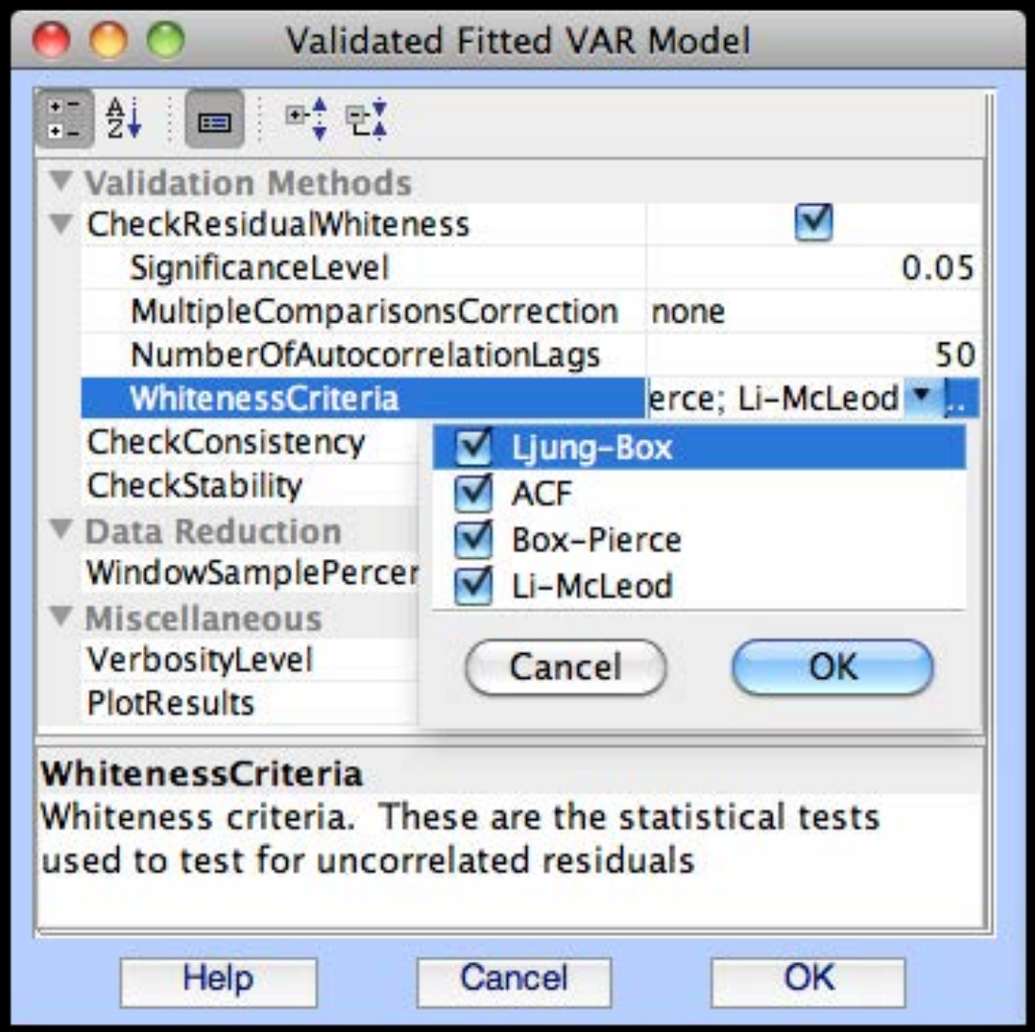
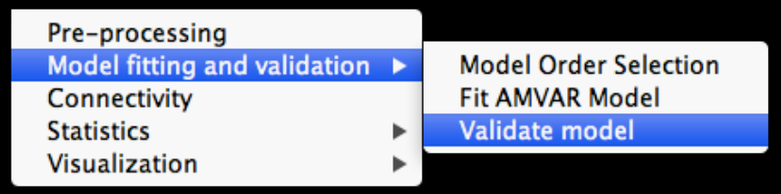
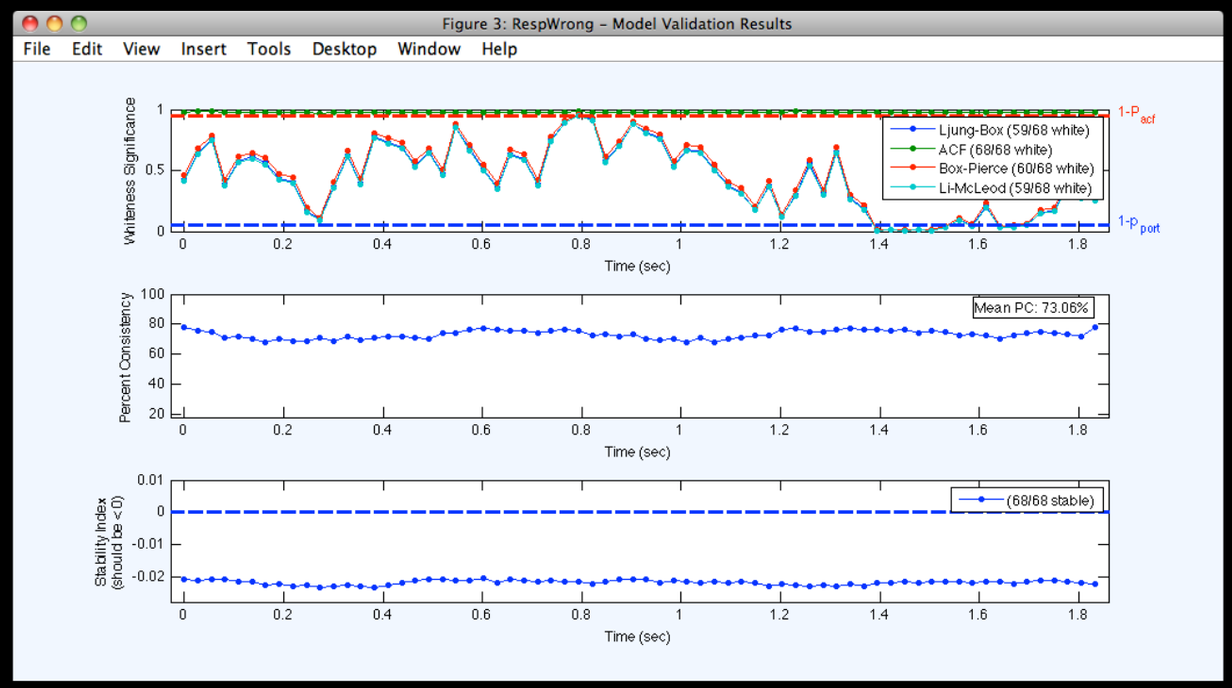
Preprocessing | **Modeling** | Statistics | Visualization

Model Fitting | **Validation** | Connectivity







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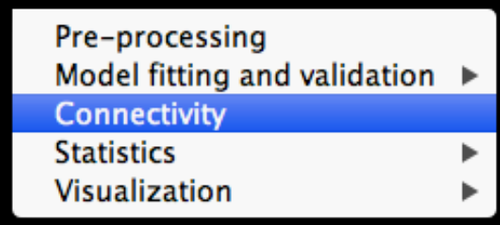
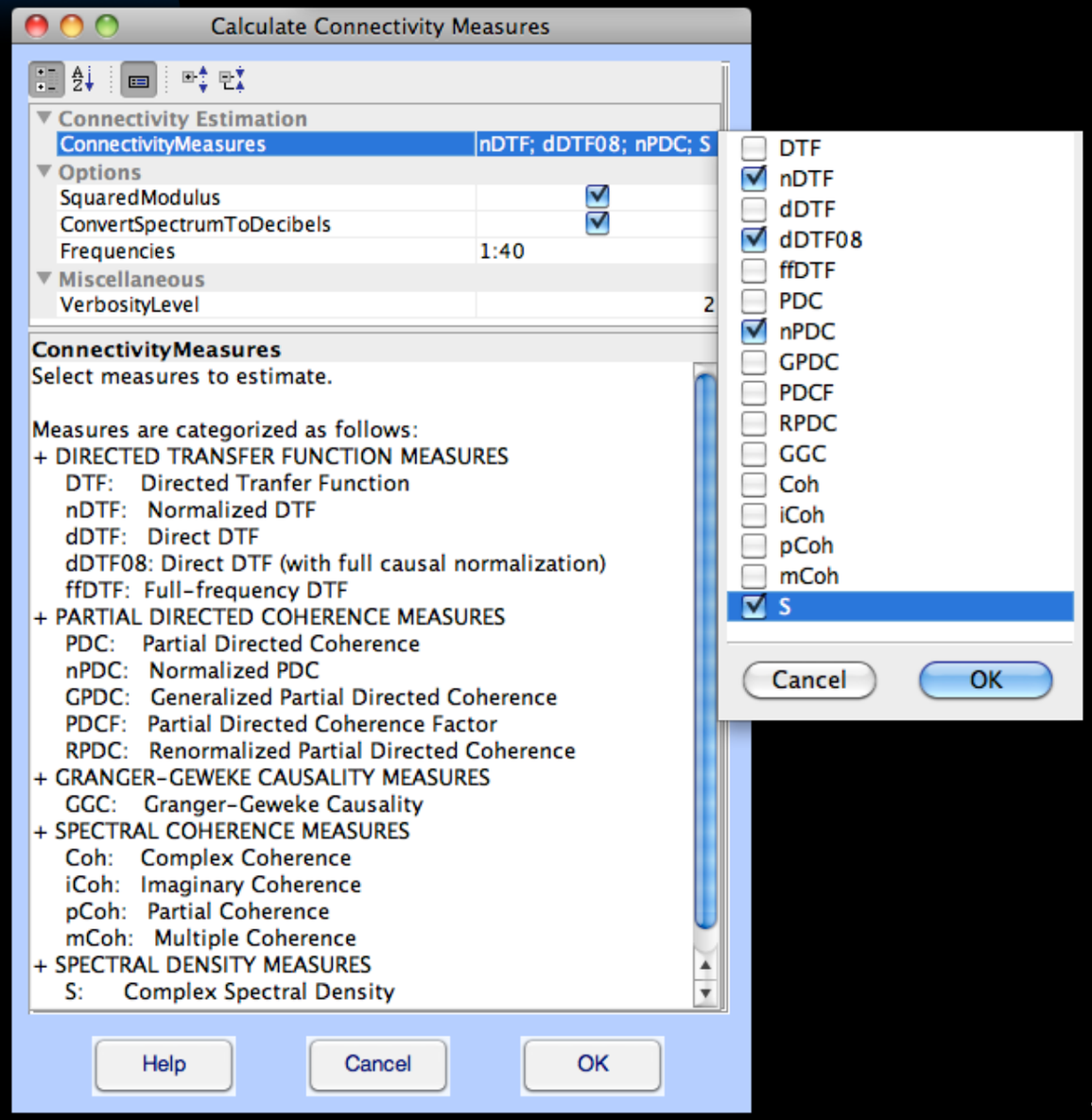
Preprocessing | **Modeling** | Statistics | Visualization

Model Fitting | Validation | Connectivity



VAR-based Measures

- Power spectrum (ERSP)
- Coherence (Coh), Partial Coherence (pCoh), Multiple Coherence (mCoh)
- Partial Directed Coherence (PDC)
- Generalized PDC (GPDC)
- Partial Directed Coherence Factor (PDCF)
- Renormalized PDC (rPDC)
- Directed Transfer Function (DTF)
- Direct Directed Transfer Function (dDTF)
- Bivariate Granger-Geweke Causality (GGC)
- Principal Oscillation Pattern Analysis (POP)



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Preprocessing | Modeling | **Statistics** | Visualization

Statistical Approach	Test	Parametric	Nonparam.
Asymptotic analytic estimates of confidence intervals. Applies to: PDC, nPDC, DTF, nDTF, rPDC	H_{null}, H_{base}, H_{AB}	☑	
Theiler phase randomization Applies to: all	H_{null}		☑
Bootstrap, Jacknife, Cross-Validation Applies to: all	H_{AB}, H_{base}		☑
Confidence intervals using Bayesian B-spline smoothing Applies to: all	H_{base}, H_{AB}	☑	☑

$H_{null}: \mathbf{C}_{ij} = 0$ $H_{base}: \mathbf{C}_{ij} = \mathbf{C}_{baseline}$ $H_{AB}: \mathbf{C}^{A}_{ij} = \mathbf{C}^{B}_{ij}$

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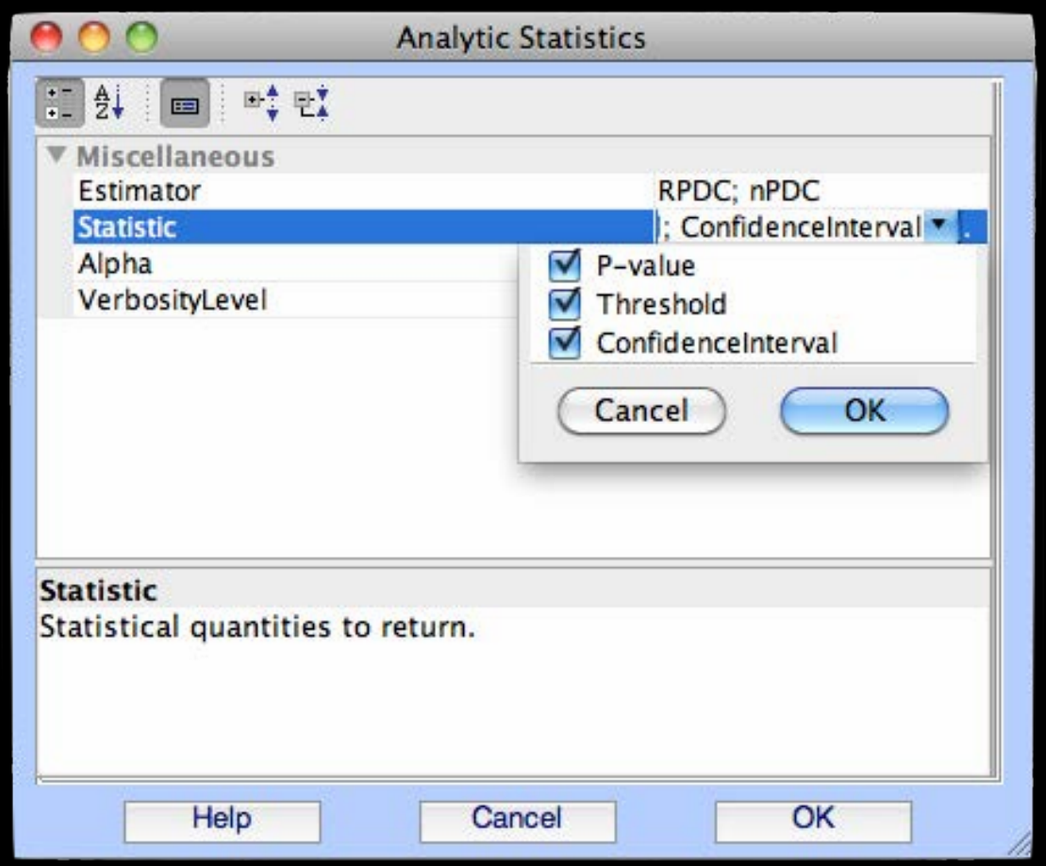
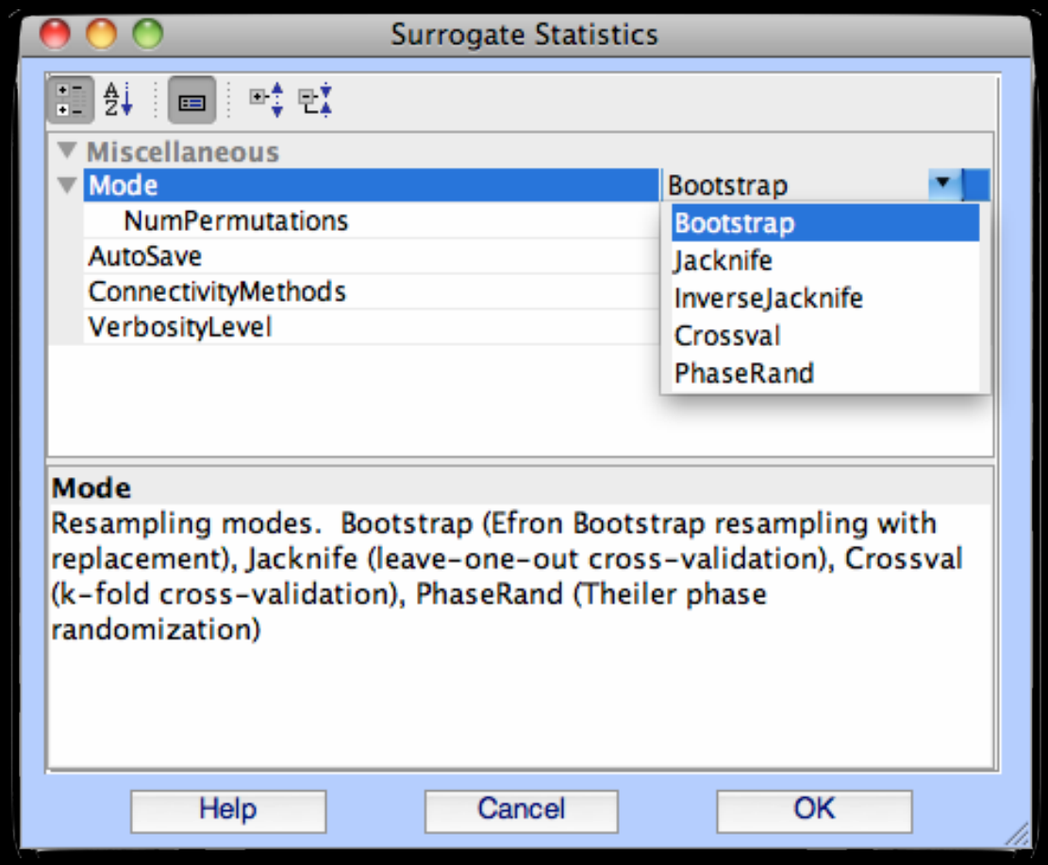
Preprocessing | Modeling | **Statistics** | Visualization

Parametric



Non-parametric



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Preprocessing | Modeling | Statistics | Visualization

Interactive Visualizers

- Interactive Time-Frequency Grid
- Interactive 3D Causal Brainmovie
- and others ...

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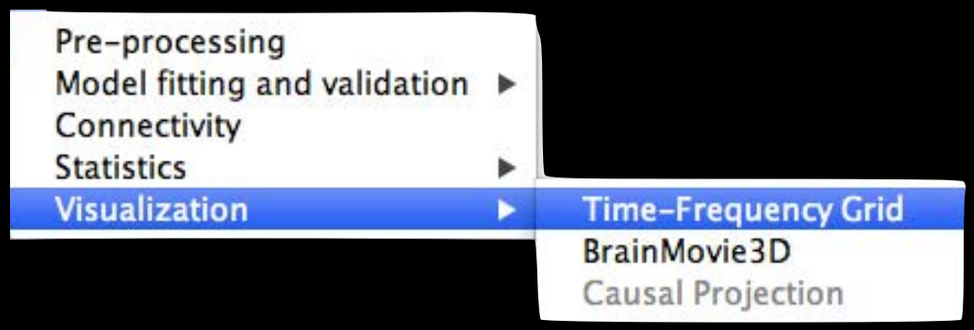
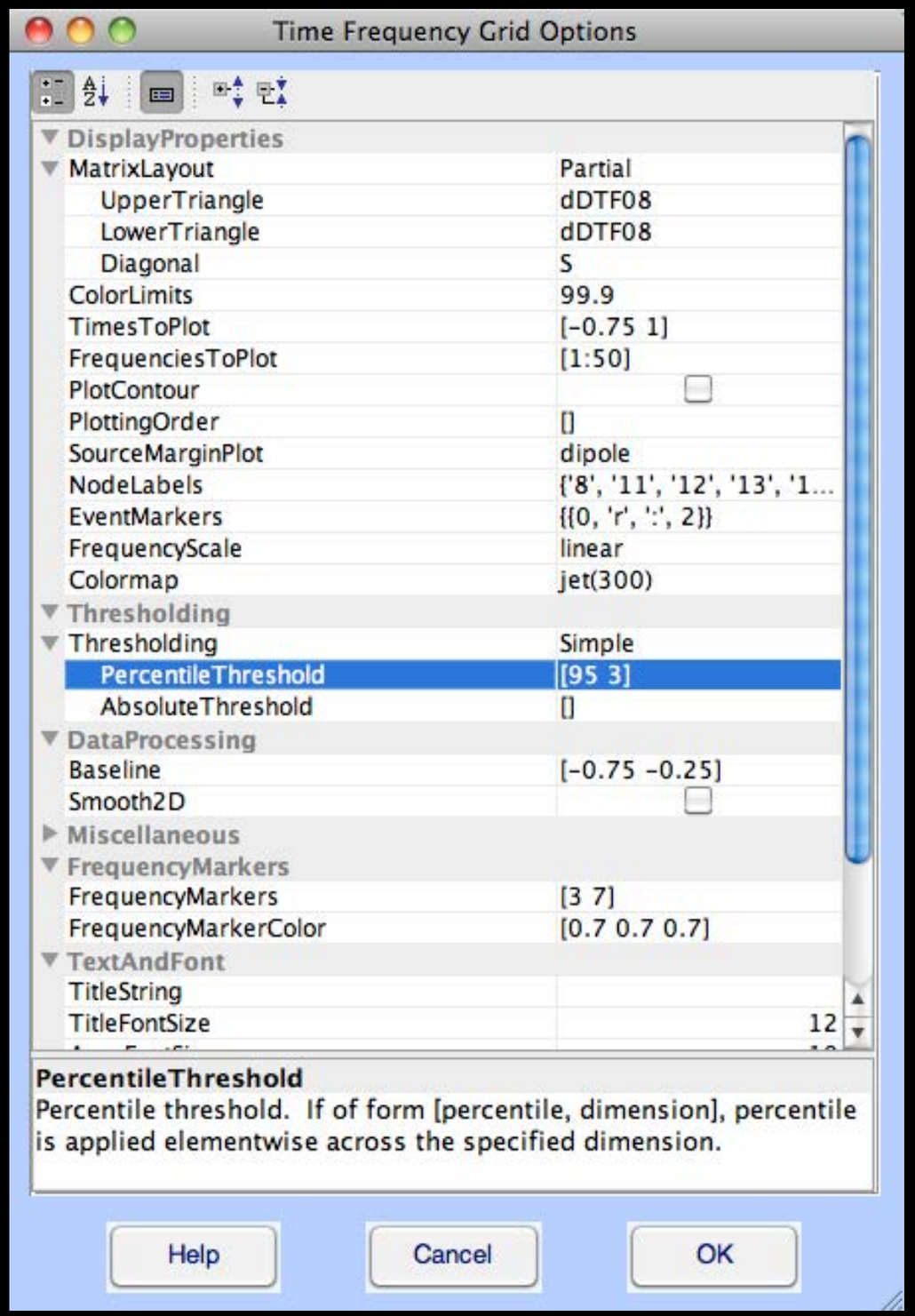
Interactive Time-Frequency Grid





Interactive Time-Frequency Grid

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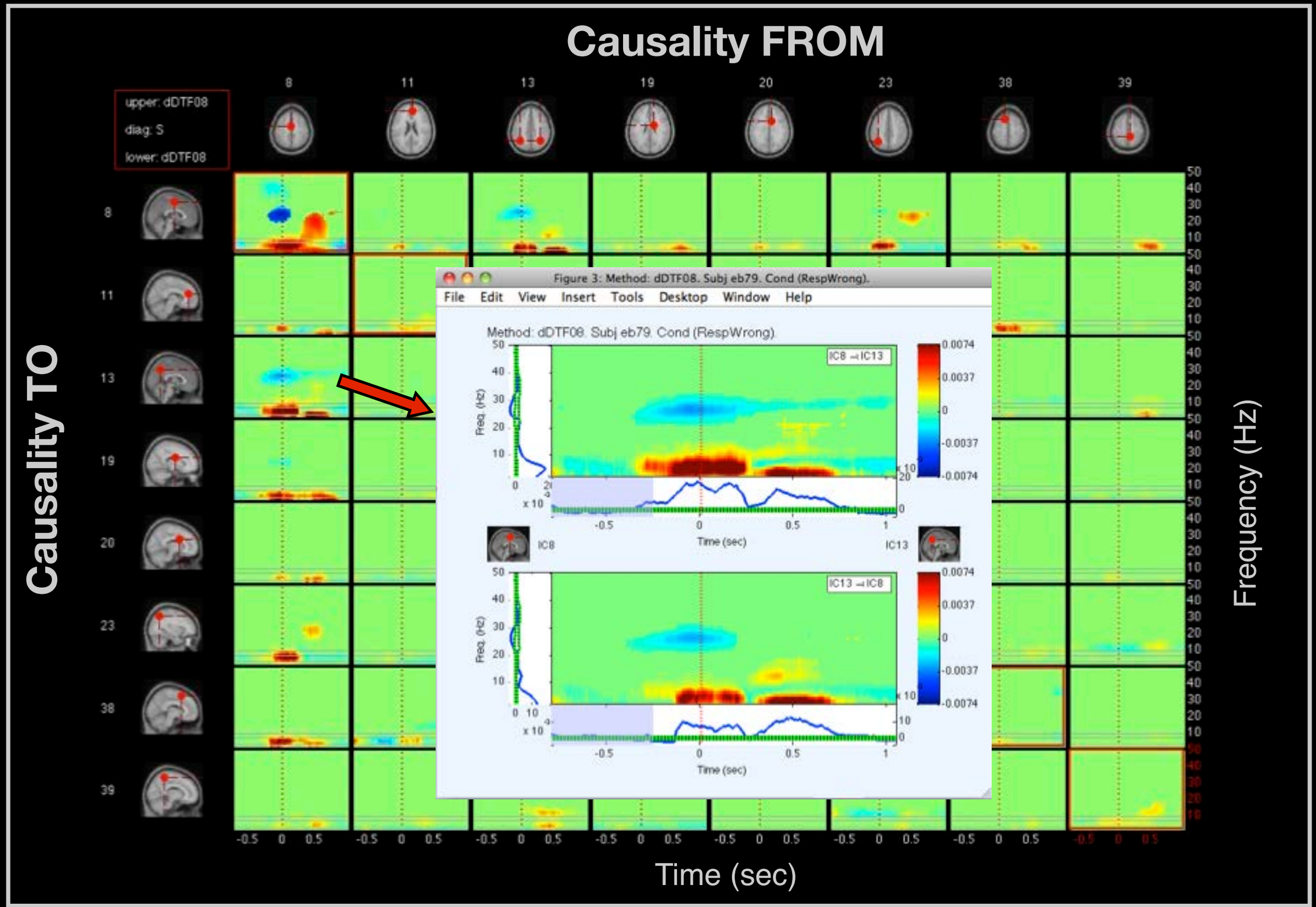

Interactive Causal BrainMovie3D

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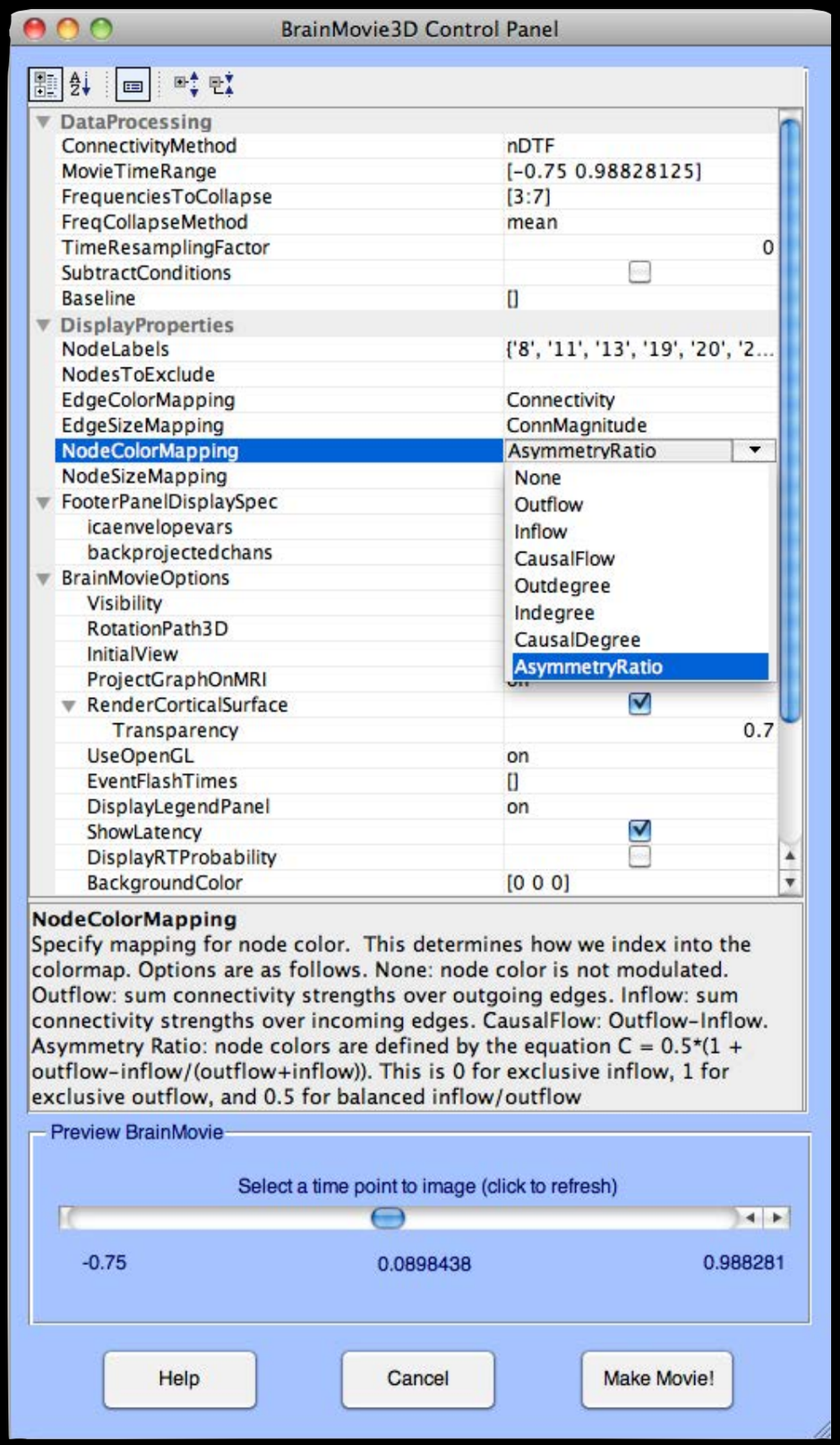

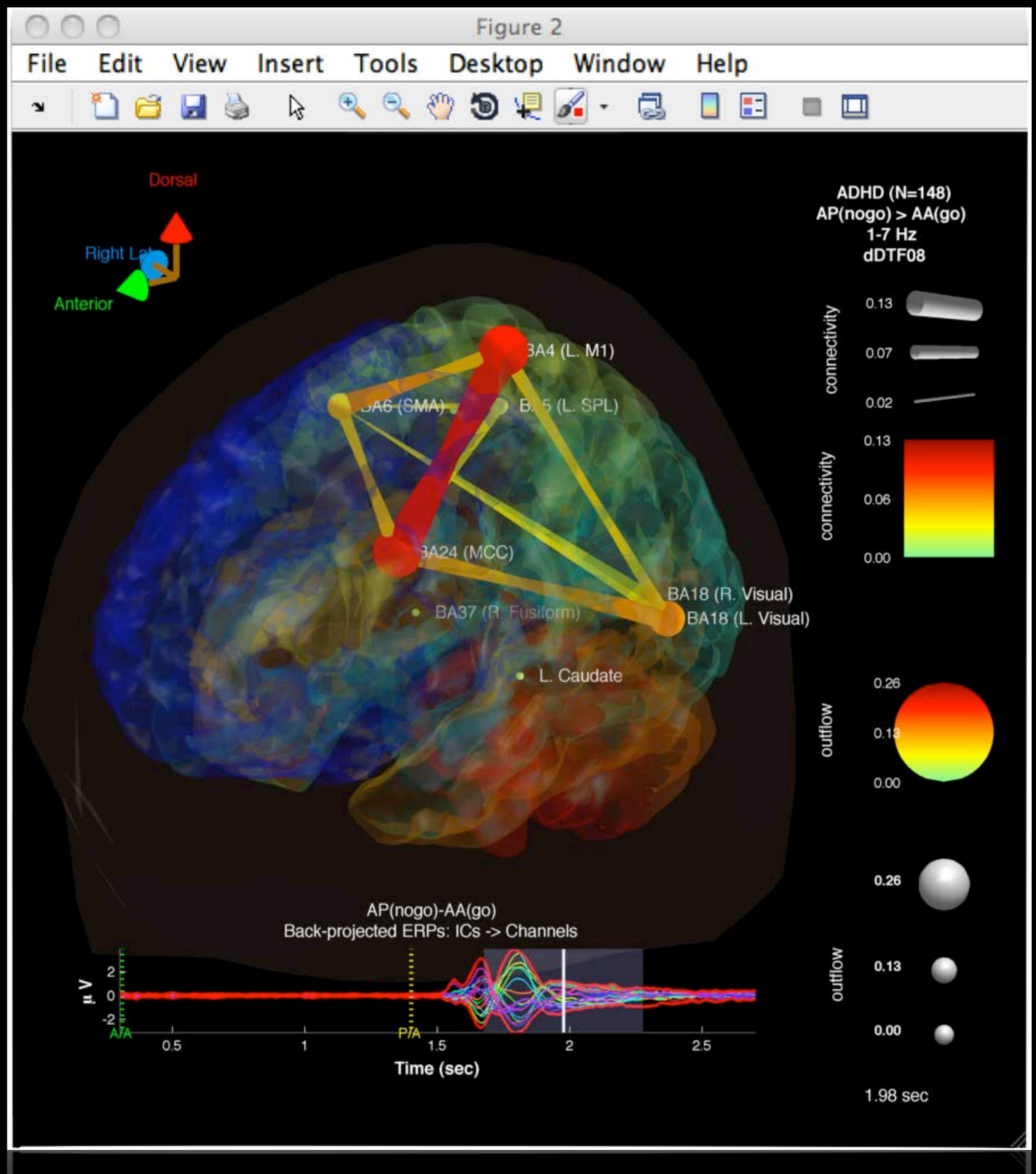

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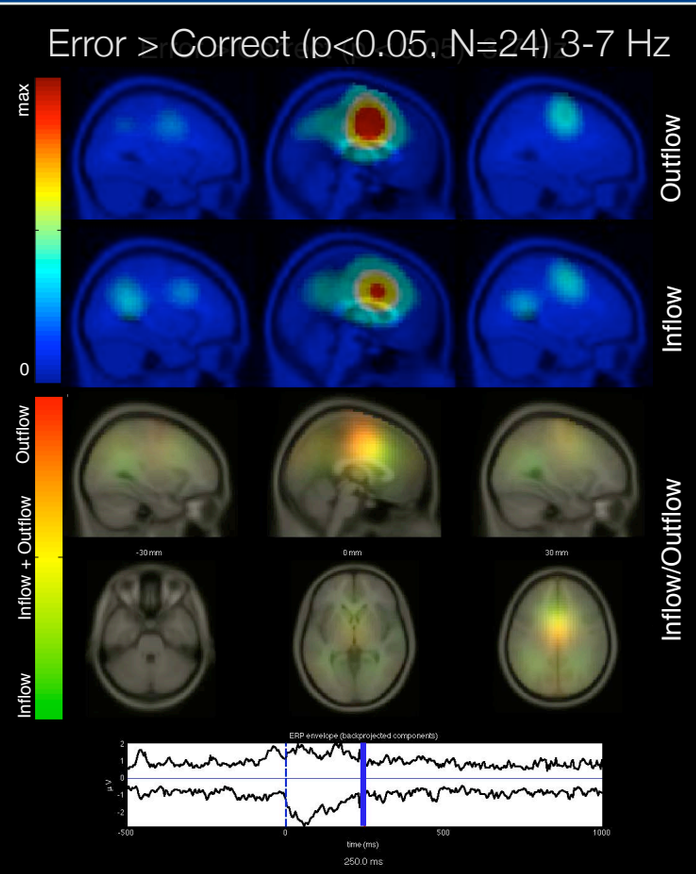
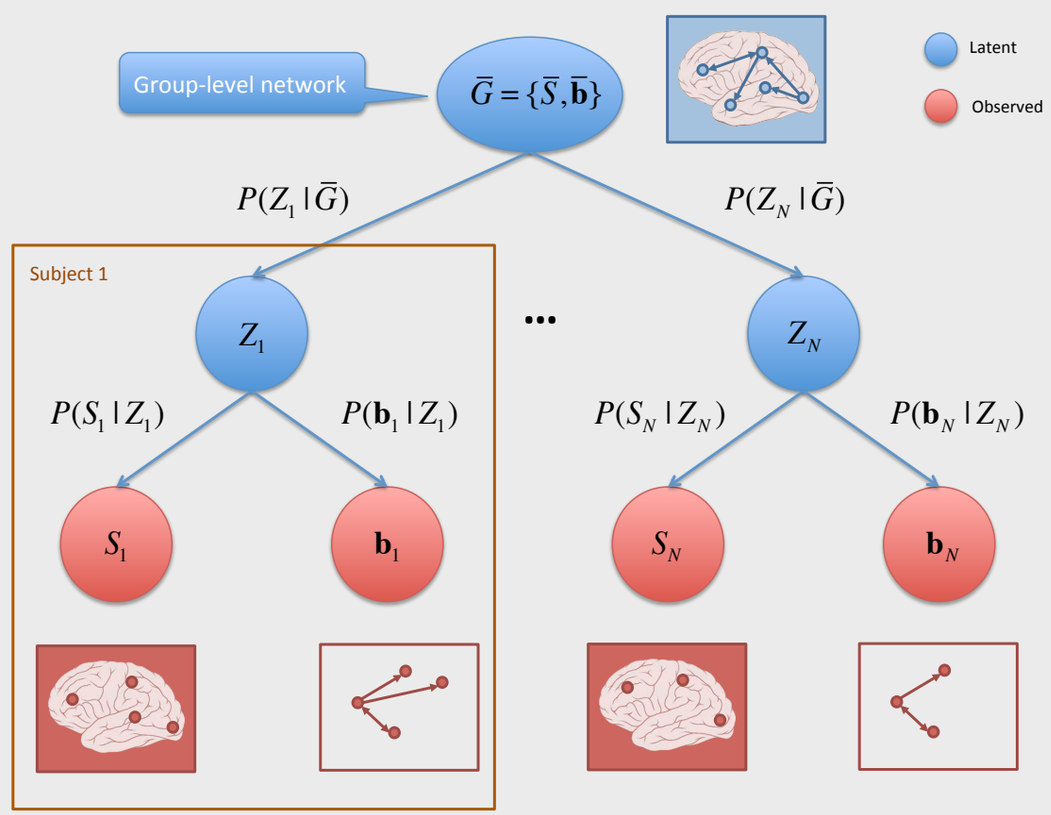
Group Analysis (beta)

Causal/Measure Projection



Mullen, et al, 2010, HBM, Barcelona
Bigdely-Shamlo, et al, 2013, *NeuroImage*

Bayesian Hierarchical Model

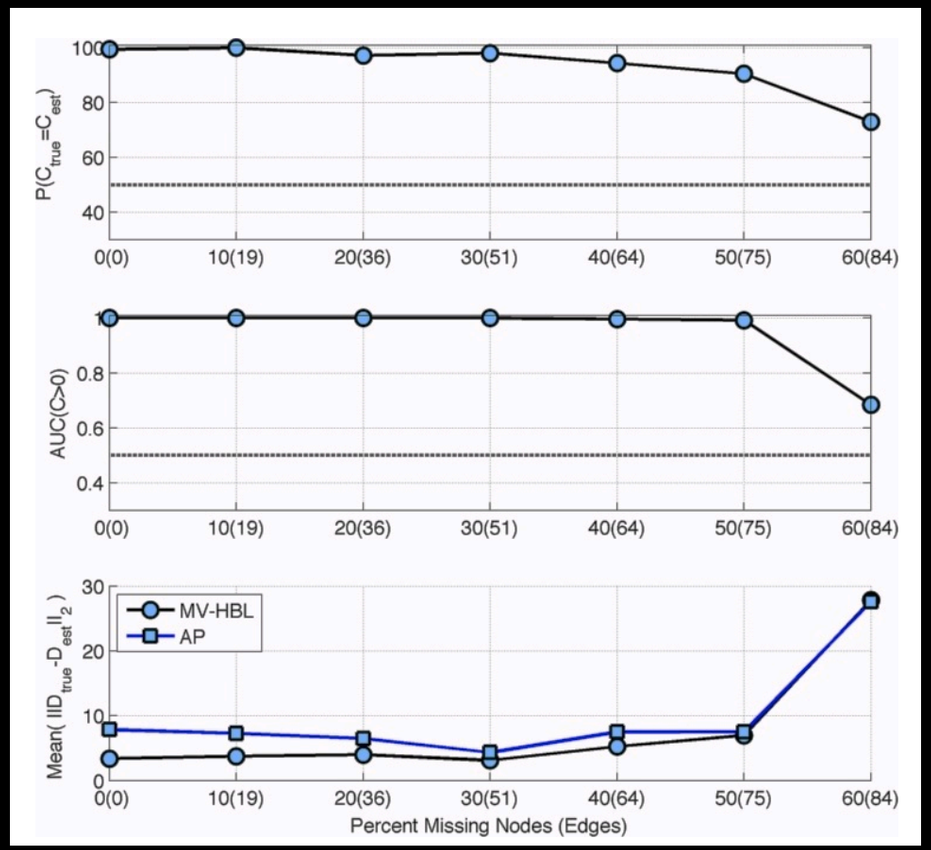


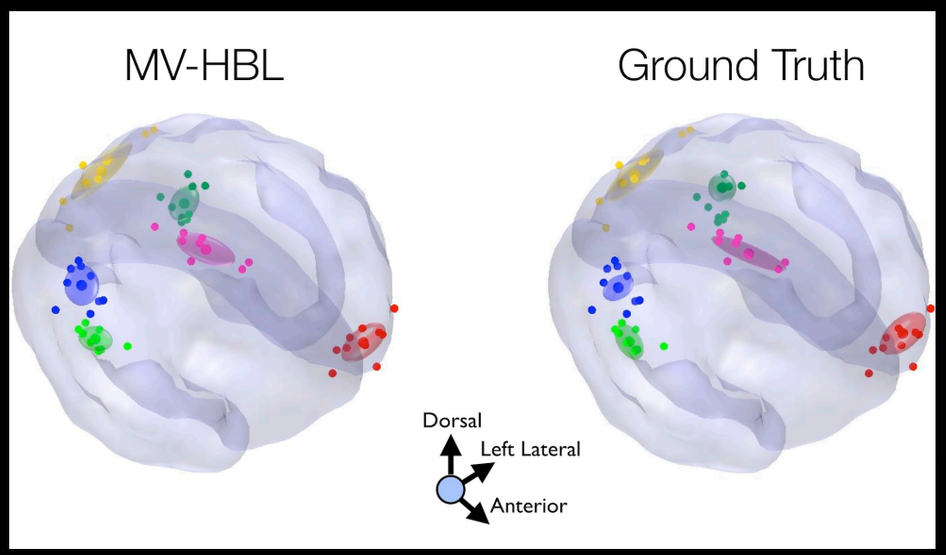
Thompson, Mullen, Makeig, 2011, ICONXI
Thompson, Mullen, Makeig, *in prep*

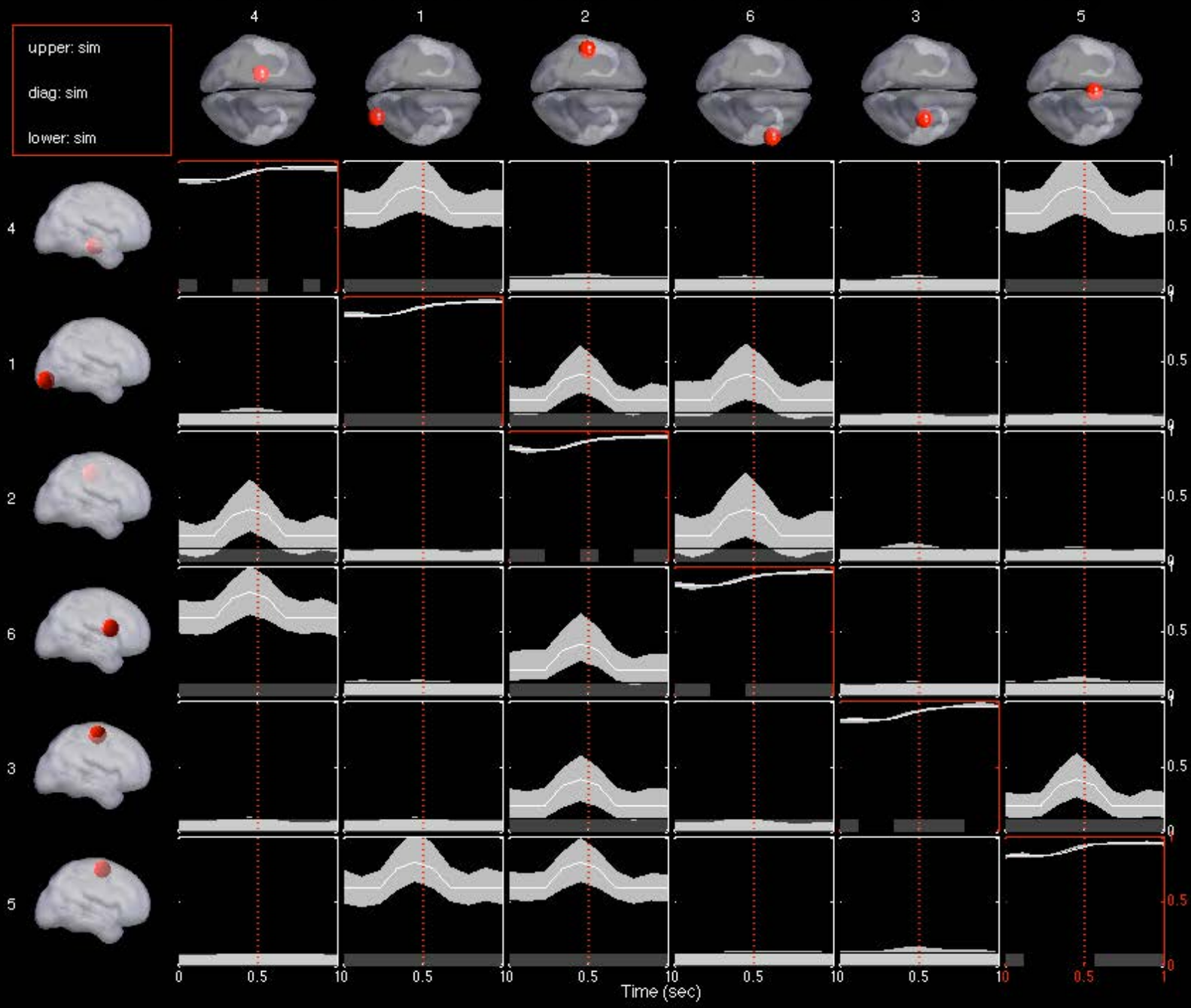
MV-HBL

Sim: 10 Subjects, 30% missing dipoles

Estimated 95% CI (gray) with Ground Truth Superimposed (white)







Est = True ($p < 0.05$)

Est. 95% CI

Mullen, T., 2014 “The Dynamic Brain”; Mullen & Thompson, in prep

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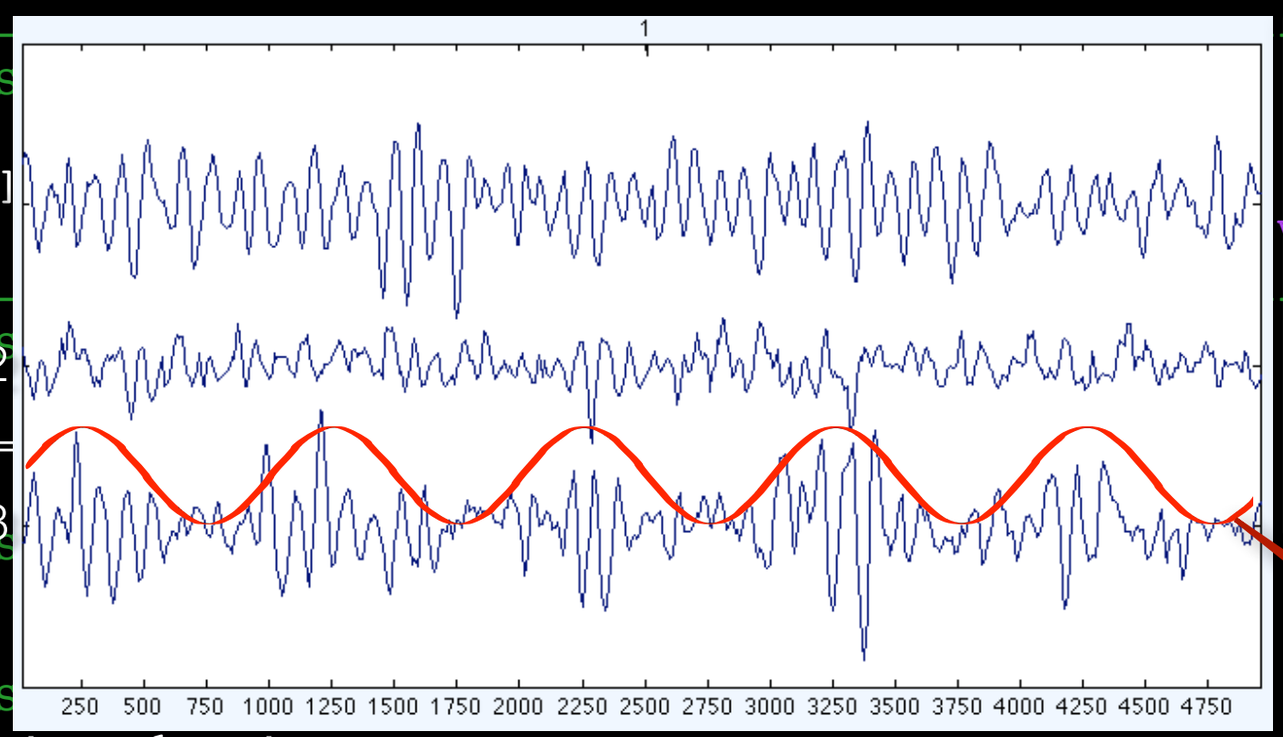
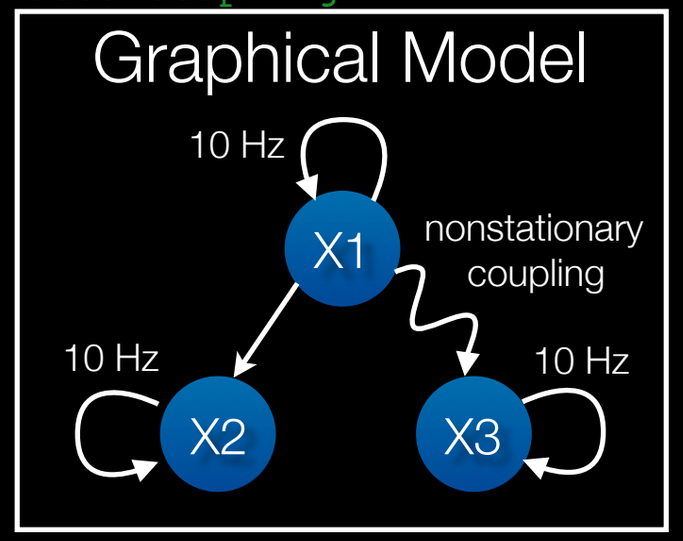
Simulation

Dynamical System Simulation Workbench

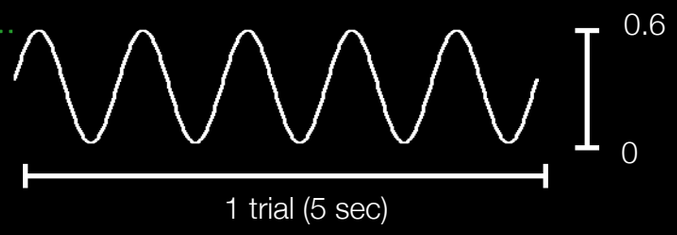
- Realistic source dynamics
  - Systems of linear stochastically-forced damped coupled oscillators
    - Support for arbitrary time-varying (non-stationary) coupling dynamics
    - Intuitive equation-based model definition
    - Support for generalized gaussian or hyperbolic secant innovations
- Realistic scalp EEG generation through forward head model
  - Convenient source definitions via cortical atlas (Mobilab Object)

```
% Example: Trivariate damped coupled oscillators with sinusoidally-modulated coupling
% ------------------------------------------------------------------------
% STEP 1: create prototype VAR structure

Fs = 100;                   % Sampling Rate (Hz)
Nl = 500;                   % length of each epoch (samples)
Nr = 100;                   % number of trials (realizations)
ndisc = 1000;               % number of startup samples to discard
ModelOrder = 2;             % model order
f0 = 10;                    % central oscillation frequency (Hz)

expr = {...
    ['x1(t) = ' sim_dampedOscillator(f0,9,Fs,1) '                                  + e1(t)'] ...
    ['x2(t) = ' sim_dampedOscillator(f0,2,Fs,2) ' + -0.1*x1(t-2)                   + e2(t)'] ...
    ['x3(t) = ' sim_dampedOscillator(f0,2,Fs,3) ' + {0.3*sin(2*pi*t/100)+0.3}*x1(t-2) + e3(t)'] ...
};

Aproto = sim_genVARModelFromEq(expr,ModelOrder);

% ------------------------------------------------------------------------
% STEP 2: create mixing matrix
A = [1 0 0
     0 1 0
     0 0 1];

% ------------------------------------------------------------------------
% STEP 3: create stationary VAR model
M = 3;
Mu = zeros(M,1);
sigma = 1;
E = sigma*eye(M);

% generate simulated data with laplacian (supergaussian) innovations
data = sim_tvarsim(Mu,A,E,[Nl Nr],ndisc,1,1,'gengauss');
```





Time-varying X1→X3 coupling
(1 Hz modulation)



Amplitude Modulation (PAC)

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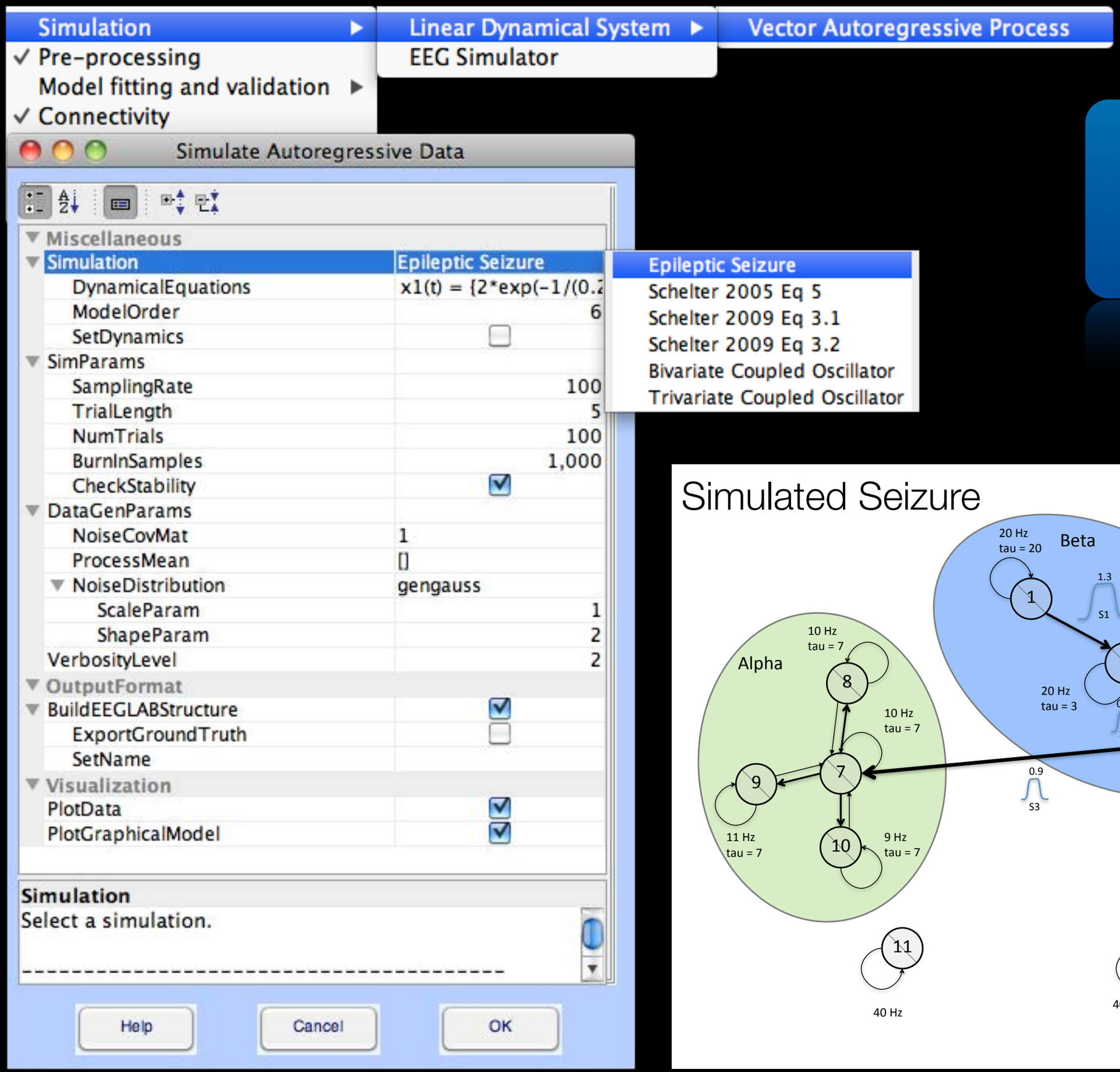

Simulation

Simulated Seizure

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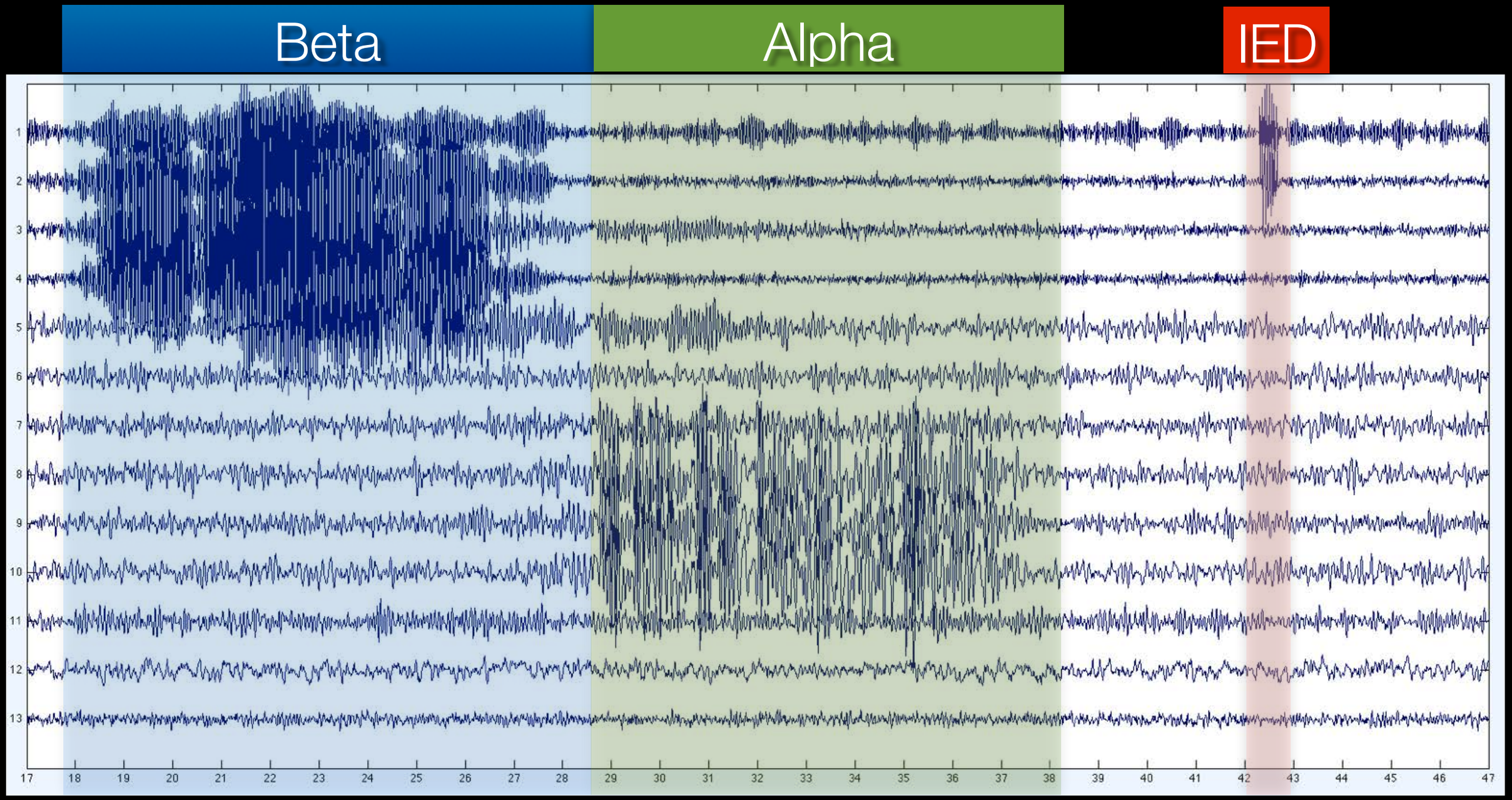
Simulated Seizure Sources



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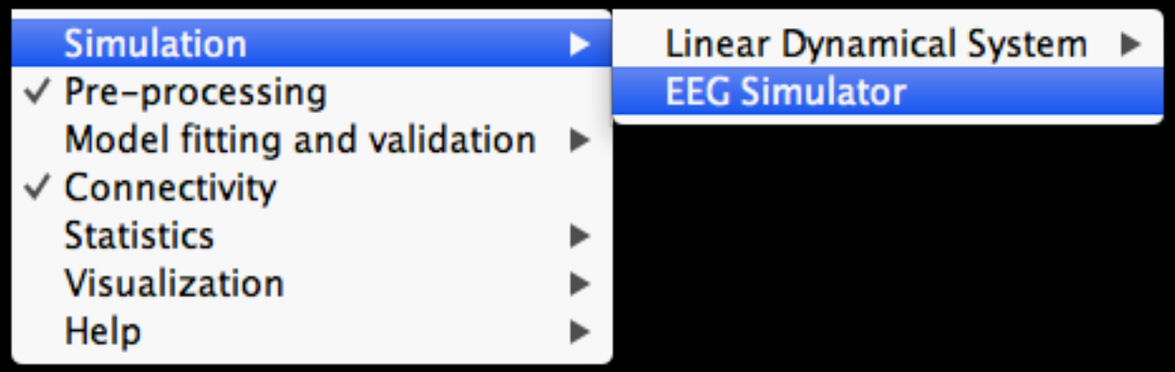
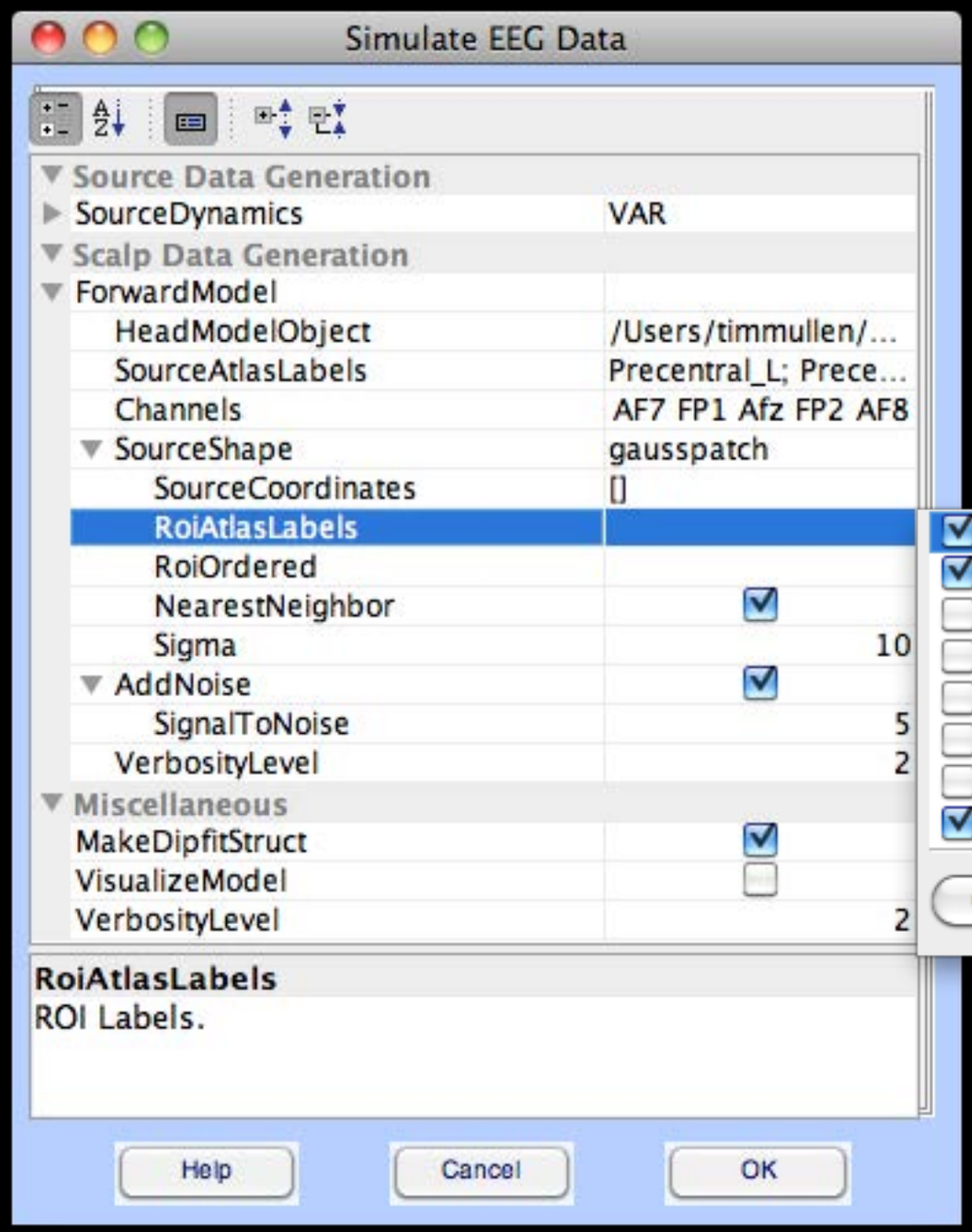
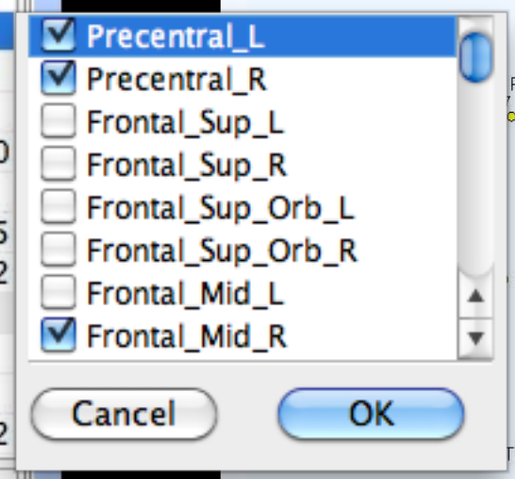
Simulation







Distribution and Educational Resources

Tim Mullen

sccn.ucsd.edu/wiki/SIFT

SIFT - SCCN

sccn.ucsd.edu/wiki/SIFT

Swartz Center for Computational Neuroscience

home
- SCCN web site
- EEGLAB Wiki
- DataSuite Wiki
- MoBI Lab Wiki
- SCCN Wiki Home

eeglab wiki pages
- EEGLAB web page
- EEGLAB Wiki
- EEGLAB Tutorial
- Online EEGLAB Workshop
- Download EEGLAB
- Revision history
- Help EEGLAB

scnn toolboxes
- EEGLAB
- NFT
- BCILAB
- SIFT
- DataSuite
- Producer
- MatRiver
- Enactor
- MoBILAB

wiki tools
- Sandbox
- Basic Wiki Syntax
- Wiki Help
- New Users
- Recent changes

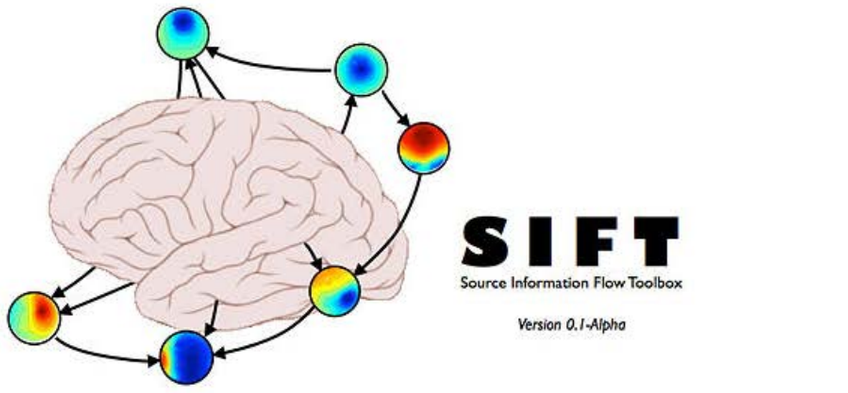
search

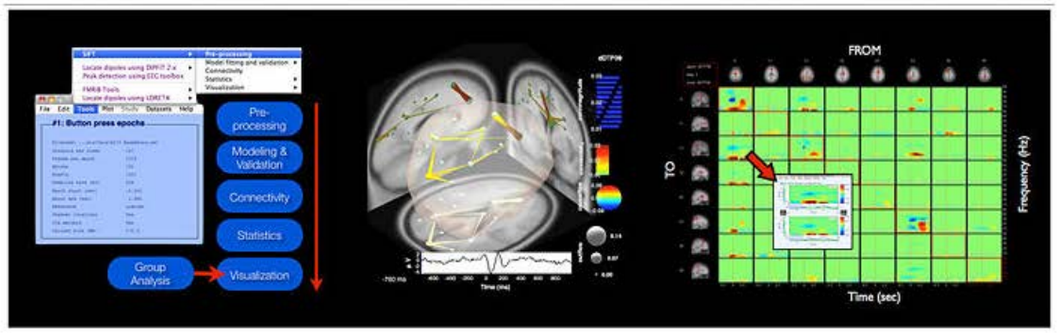
Go Search

advanced wiki tools
- What links here
- Related changes
- Upload file
- Special pages
- Printable version
- Permanent link

page discussion view source history

SIFT





Contents [hide]

Welcome to the repository for the Source Information Flow Toolbox (SIFT)

Developed and Maintained by: Tim Mullen (SCCN, INC, UCSD)
Web: http://www.antillipsi.net
Email: <Tim's first name> (at) sccn (dot) ucsd (dot) edu

SIFT is an EEGLAB-compatible toolbox for analysis and visualization of multivariate causality and information flow between sources of electrophysiological (EEG/ECoG/MEG) activity. It consists of a suite of command-line functions with an integrated Graphical User Interface for easy access to multiple features. There are currently four modules: data preprocessing, model fitting and connectivity estimation, statistical analysis, and visualization

SIFT Online Handbook and User Manual

A video-lecture on the (very) basic theory of application of SIFT to modeling distributed brain dynamics in EEG is available he

Table of Contents [hide]

Can also get from EEGLAB Plugin Manager or NITRC.org