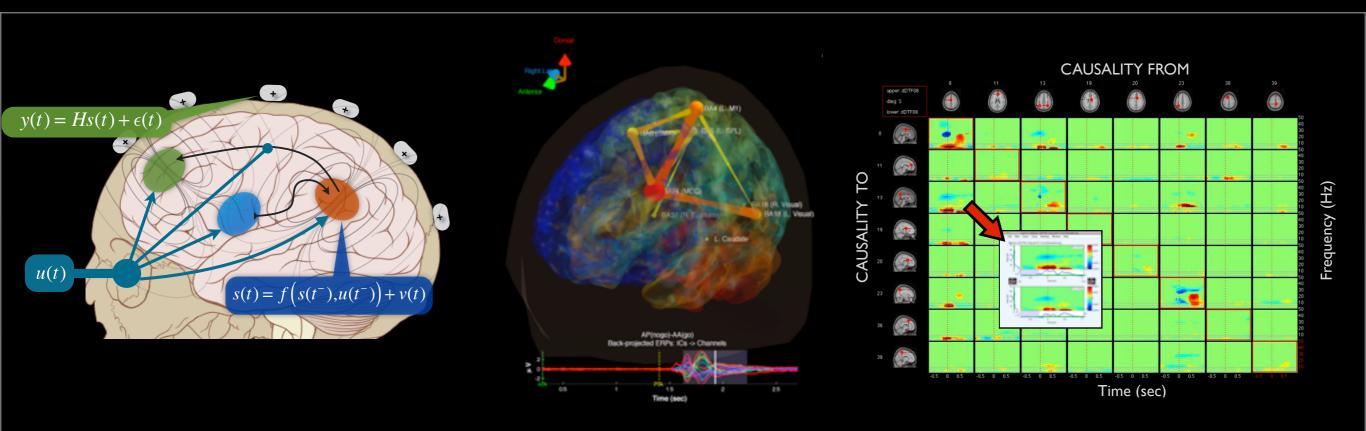
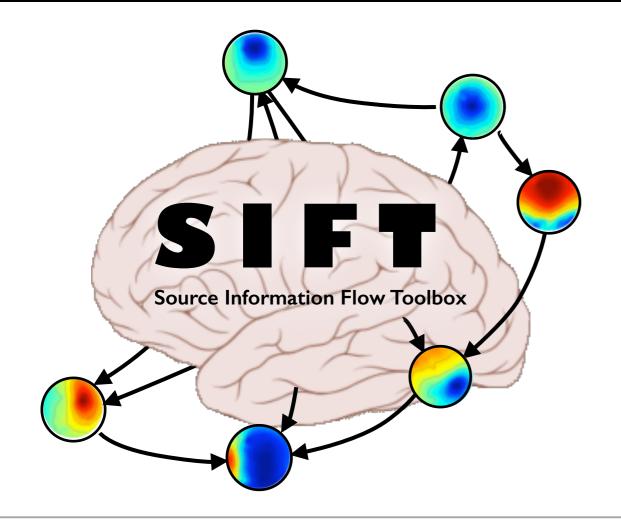
The Source Information Flow Toolbox

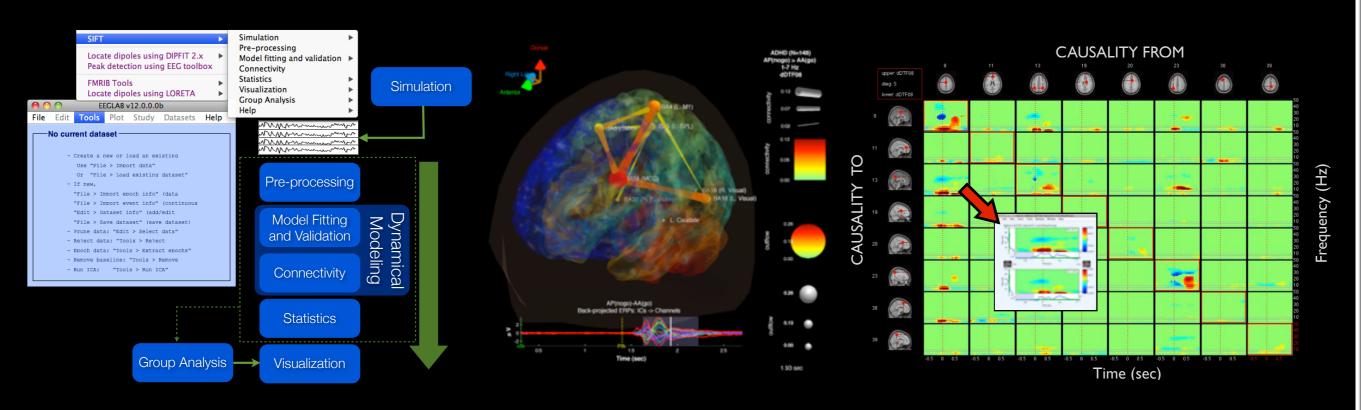


Tim Mullen, PhD

Swartz Center for Computational Neuroscience Institute for Neural Computation UC San Diego and Intheon Labs Mullen, T & Makeig, S., "The Source Information Flow Toolbox: An Electrophysiological Dynamical Modeling Toolbox for EEGLAB", in prep 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

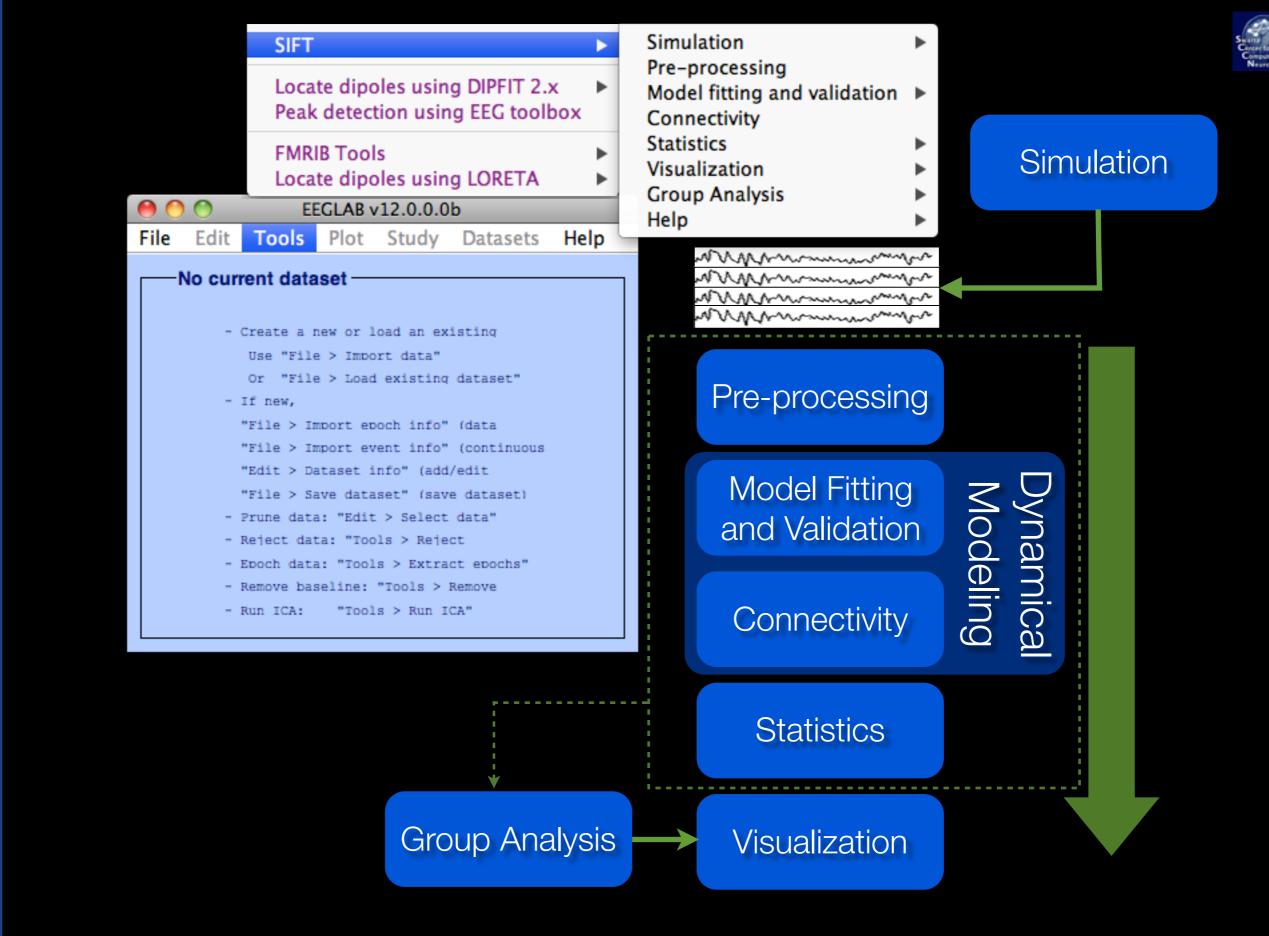


Source Information Flow Toolbox (SIFT)

Requirements: EEGLAB, MATLAB 2008a+

 Some functions leverage: Signal Processing Toolbox, Statistics Toolbox







Preprocessing

Modeling

Statistics

Visualization

Pre-processing	
Model fitting and validation	
Connectivity	
Statistics	•
Visualization	•

Source reconstruction

(performed externally using EEGLAB or other toolboxes)

Local Detrending or Filtering

Downsampling (EEGLAB)

Differencing

Normalization (temporal or ensemble)

	2
	Components
	linear
	0.33
	0.082
	time; ensemble
nels' EEG.data will b	', data in EEG.icaact will e processed. If 'Sources'
	ze. If 'Components

Cance

Help

OK





processing	Modeling	Statistics		Visualizat	ion
Model Fit	ting Validation Co	nnectivity			
Modeling Algorithm (1)			Linear	Nonlinear	
Segmentation VAR (Sliding Window)					
Unconstrained					
Vieira-Mo	Vieira-Morf				
ARfit					
Regularized					
Ridge Regression (L ₂)					
Group Lasso (L _{1,2}) ADMM, DAL					
	Bayesian Learning (L _p) SBL, BSBL				

ester für ompart altoral Neuroscience

processing	Modeling	Statistics		Visualization
Model Fitting Validation Connectivity				
Modeling Algorithm (2)			Linear	r Nonlinear
State-Space Modeling				
Linear Kalman Filtering				
Dual Extended Kalman Filtering				
Cubature Kalman Filtering				\checkmark
Sparsely Connected Components Analysis (SCSA)			\checkmark	

A

e forputational



Modeling

Statistics

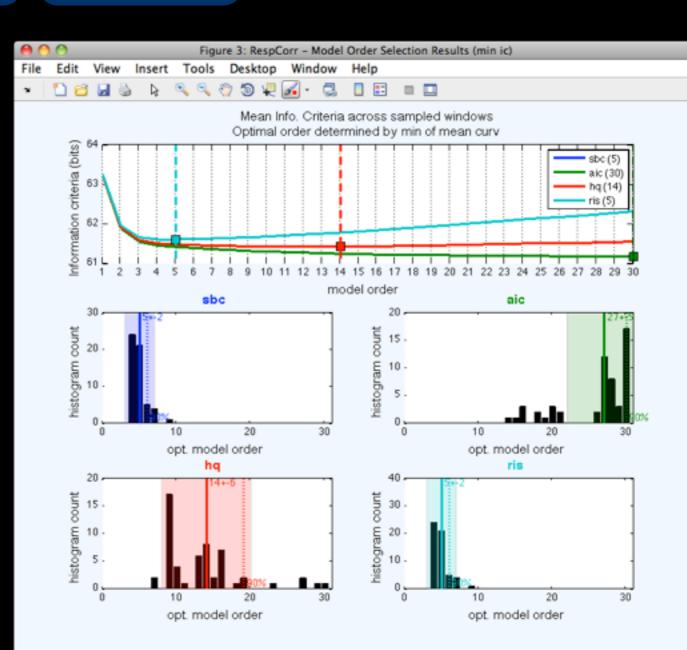
Visualization

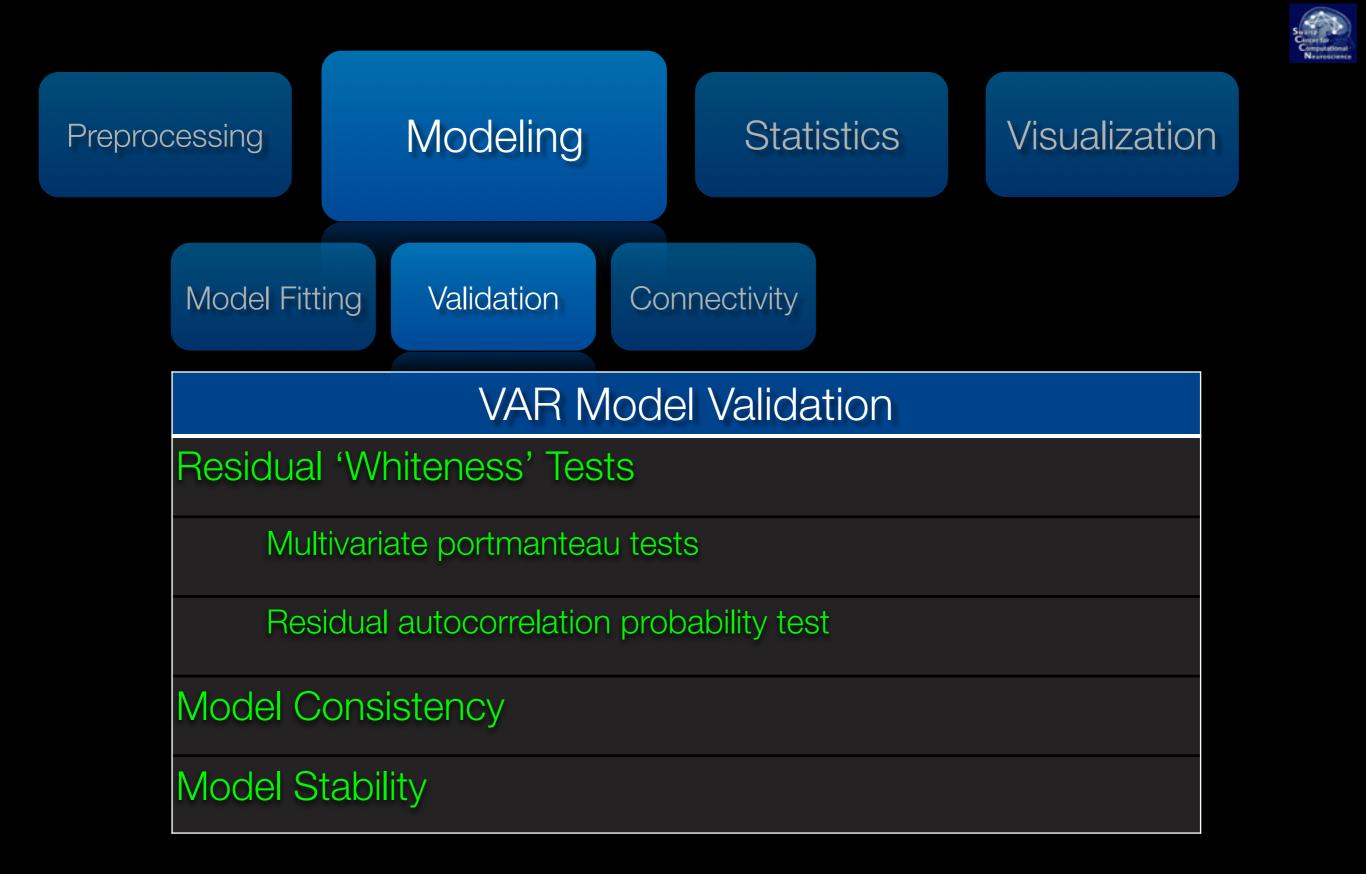
Model Fitting

Validation

Connectivity

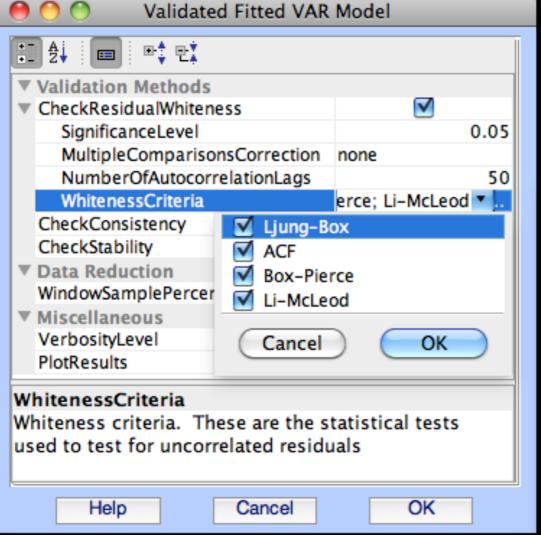
Pre-processing		
Model fitting and validation	on 🕨	Model Order Selectio
Connectivity		Fit AMVAR Model
Statistics		Validate model
		validate model
Visualization	•	
😝 🔿 🔿 Model Order Selec	stien A	colotant
Hodel Order Selec	LION A	ssistant
[24 💼 바라 반화		
▼ Modeling Parameters		
ModelingApproach	5	Segmentation VAR
Algorithm		Vieira-Morf
WindowLength	Vieir	ra-Morf
WindowStepSize	ARfit	1
NormalizeData	Grou	up Lasso DAL/SCSA
Tetrend		ID Lasso ADMM
DetrendingMethod		e Regression
ModelOrderRange		1 30
Downdate		
InformationCriteria	5	sbc; aic; fpe; hq; ris
▼ Data Selection		
WindowSamplePercent		100
▼ Miscellaneous		
OptimalModelSelectionMet	thod r	min
PercentileLimits		90
VerbosityLevel		2
Algorithm		
Algorithm		
Vieira-Morf:		
vieira-morr:		•
Unconstrained VAR modeling	uia Ma	aira-Morf
Maximum Entropy algorithm.		eira-Mort
Maximum Entropy algorithm.		
References and code:		\sim
[1] A. Schlogl, Comparison of	F Multis	ariate
Lin A. Schogi, Comparison of	march	ranate I
Help Cance	8	OK

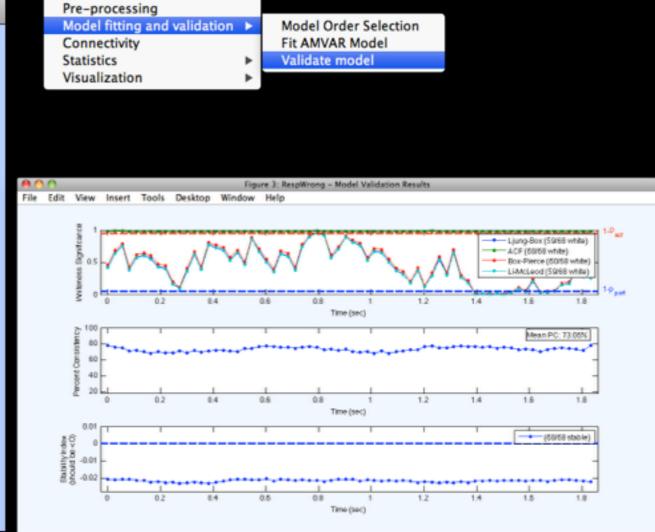


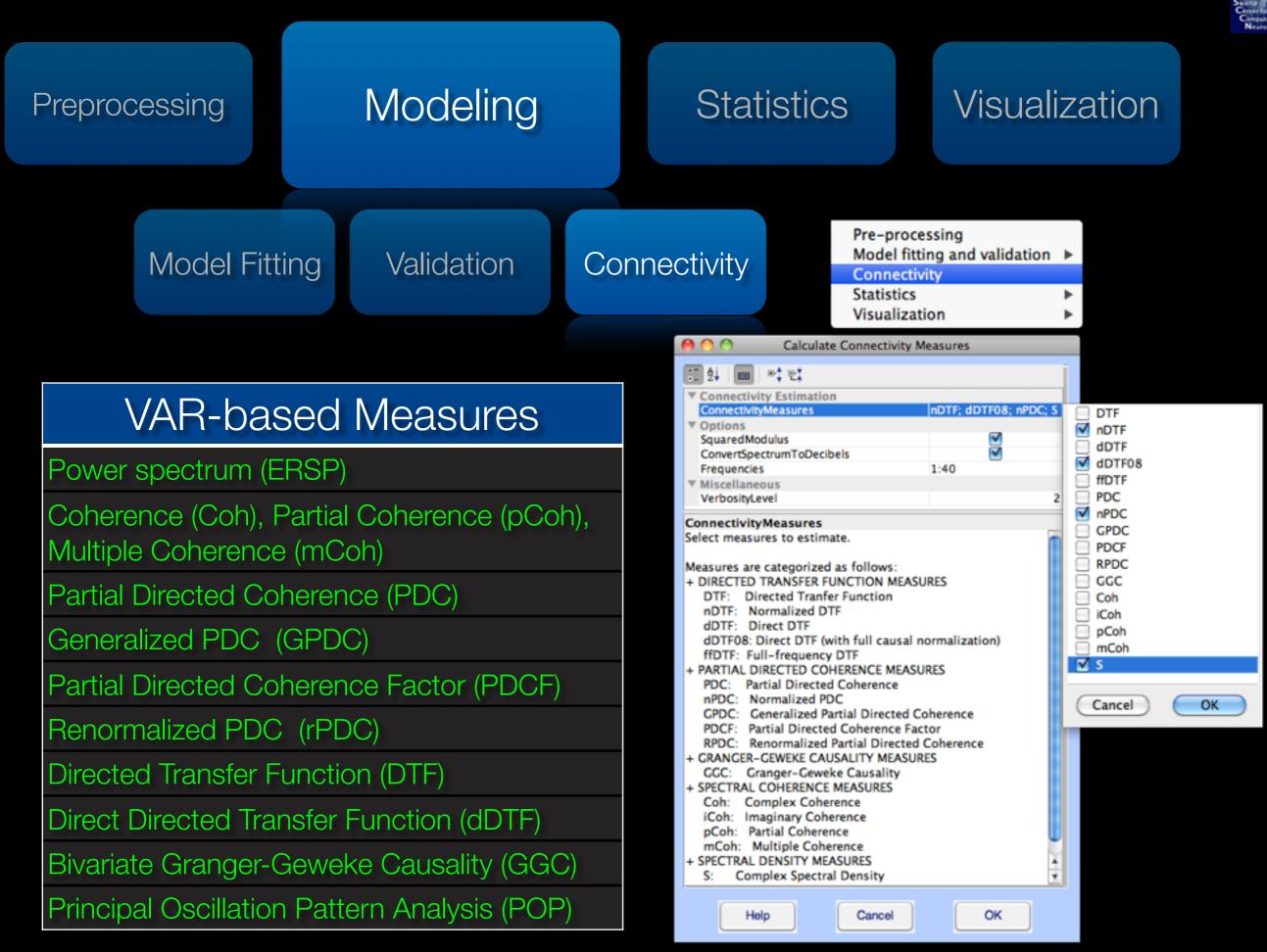




PreprocessingModelingStatisticsVisualizationModel FittingValidationConnectivity









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}		

$$H_{null}$$
 : $C_{ij} = 0$

ase:
$$C_{ij} = C_{baseline}$$

 $H_{\rm ba}$

$$H_{AB}$$
: $\mathbf{C}^{A}_{ij} = \mathbf{C}^{B}_{ij}$



Preprocessing

Modeling

Statistics

Visualization

Parametric

00	Analytic Statistics	
Miscellaneous Estimator Statistic Alpha VerbosityLevel	Analytic Statistics RPDC; nPDC ; ConfidenceInterval • P-value P-value ConfidenceInterval Cancel	
Statistic Statistical quantities to Help	o return.	

\varTheta 🕙 Surrogate	Statistics
11 24 📖 P1 P1	
▼ Miscellaneous ▼ Mode	Bootstrap
NumPermutations AutoSave ConnectivityMethods VerbosityLevel	Bootstrap Jacknife InverseJacknife Crossval PhaseRand
Mode Resampling modes. Bootstrap (Efr replacement), Jacknife (leave-one- (k-fold cross-validation), PhaseRat randomization)	out cross-validation), Crossval
Help Can	cel OK

Non-parametric



Modeling



Visualization

Interactive Visualizers

Interactive Time-Frequency Grid

Interactive 3D Causal Brainmovie

Causal Projection Movie

Directed Graphs and Graph Theoretic Analysis (Bioinformatics Toolbox Interface)

and more ...

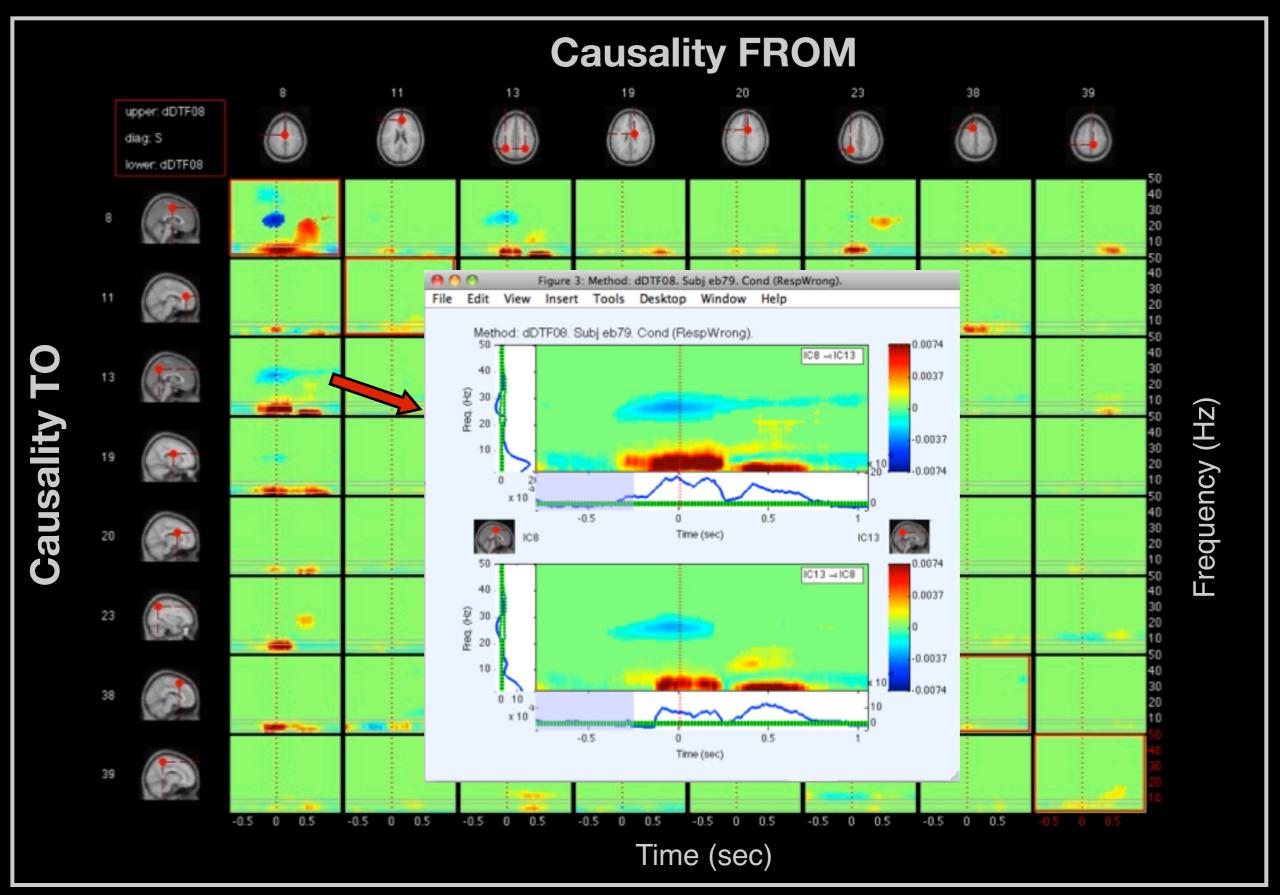


Interactive Time-Frequency Grid

Pre-processing Model fitting and validation Connectivity	۲	
Statistics	►	
Visualization	•	Time-Frequency Grid
		BrainMovie3D
		Causal Projection

DisplayProperties	
MatrixLayout	Partial
UpperTriangle	dDTF08
LowerTriangle	dDTF08
Diagonal	S
ColorLimits	99.9
TimesToPlot	[-0.75 1]
FrequenciesToPlot	[1:50]
PlotContour	
PlottingOrder	0
SourceMarginPlot	dipole
NodeLabels	{ '8' , '11' , '12' , '13' , '1
EventMarkers	{{0, 'r', ':', 2}}
FrequencyScale	linear
Colormap	jet(300)
7 Thresholding	
Thresholding	Simple
PercentileThreshold	[95 3]
AbsoluteThreshold	0
DataProcessing	
Baseline	[-0.75 -0.25]
Smooth2D	
Miscellaneous	
/ FrequencyMarkers	
FrequencyMarkers	[3 7]
FrequencyMarkerColor	[0.7 0.7 0.7]
TextAndFont	
TitleString	
TitleFontSize	12
ercentileThreshold	
ercentile threshold. If of form [p	arcantila dimensioni percentil
ercentile threshold. If of form (p	specified dimension.

Interactive Time-Frequency Grid

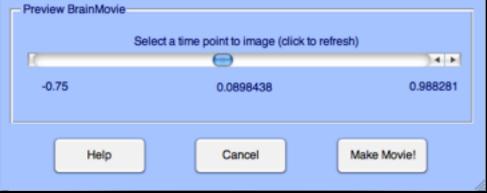


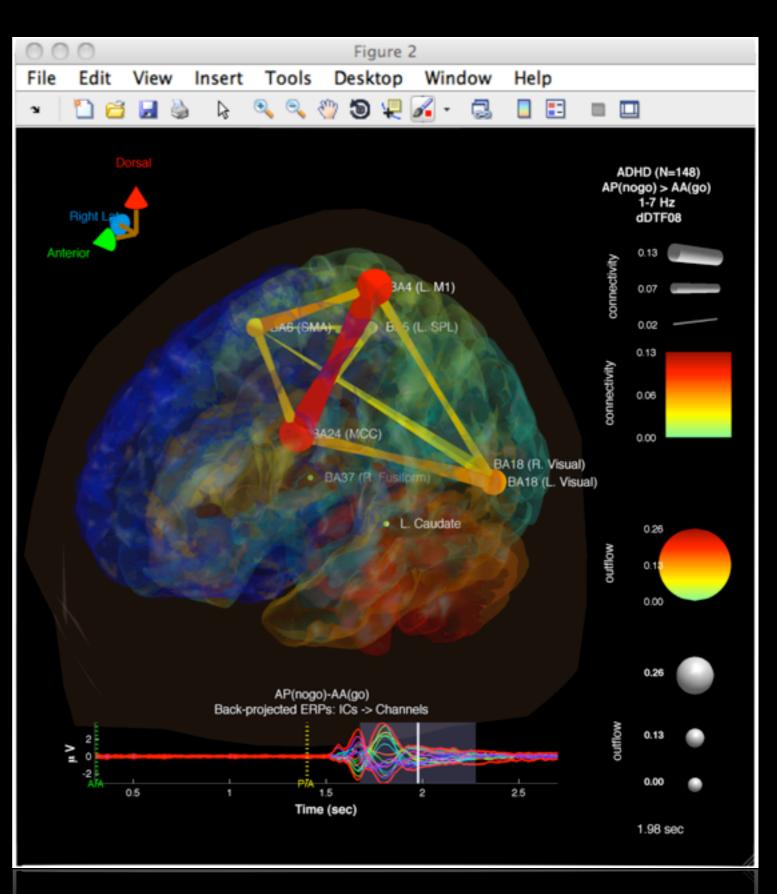
Interactive Causal BrainMovie3D

00	BrainMovie3D Control Panel	
22 1 💷 🖛 1		
▼ DataProcessing		1
ConnectivityMethod	d nDTF	
MovieTimeRange	[-0.75 0.98828125]	
FrequenciesToColl	apse [3:7]	
FreqCollapseMetho	od mean	
TimeResamplingFa	actor	0
SubtractConditions	i 🗌	
Baseline	0	
▼ DisplayProperties	5	
NodeLabels	('8', '11', '13', '19', '20	', '2
NodesToExclude		
EdgeColorMapping	g Connectivity	
EdgeSizeMapping	ConnMagnitude	
NodeColorMappin	g AsymmetryRatio	-
NodeSizeMapping	None	
FooterPanelDisplay	ySpec Outflow	
icaenvelopevars	s Inflow	
backprojectedc	hans CausalFlow	
BrainMovieOptions	Outdegree	
Visibility	Indegree	
RotationPath3D	CausalDegree	
InitialView	AsymmetryRatio	
ProjectGraphOr	IMKI Su	
RenderCorticalS	Surface 🗹	
Transparence	y .	0.7
UseOpenGL	on	
EventFlashTime	s ()	
DisplayLegendP	Panel on	
ShowLatency		
DisplayRTProba		4
BackgroundCold	or [0 0 0]	2

NodeColorMapping

Specify mapping for node color. This determines how we index into the colormap. Options are as follows. None: node color is not modulated. Outflow: sum connectivity strengths over outgoing edges. Inflow: sum connectivity strengths over incoming edges. CausalFlow: Outflow-Inflow. Asymmetry Ratio: node colors are defined by the equation C = 0.5*(1 + outflow-inflow/(outflow+inflow)). This is 0 for exclusive inflow, 1 for exclusive outflow, and 0.5 for balanced inflow/outflow



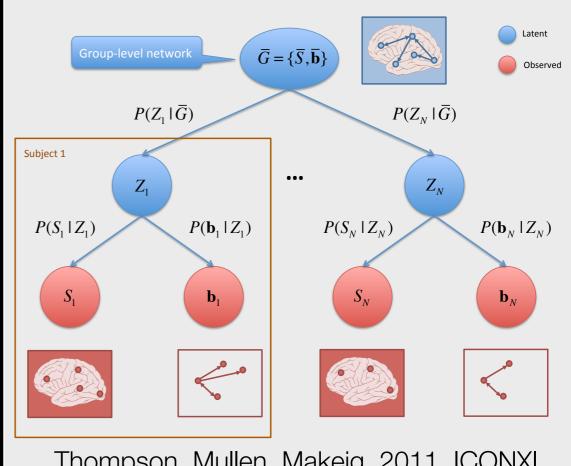




Group Analysis (beta)

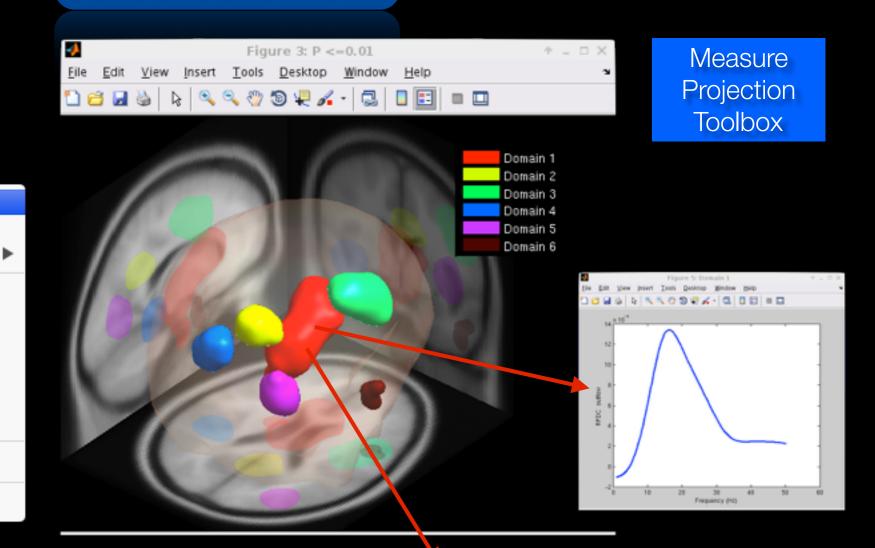
Causal/Measure Projection | Bayesian Hierarchical Model

Error > Correct (p<0.05, N=24) 3-7 Hz Outflow Inflow Inflow/Outflov Mullen, et al, 2010, HBM, Barcelona Bigdely-Shamlo, et al, 2013, Neurolmage



Thompson, Mullen, Makeig, 2011, ICONXI Thompson, Mullen, Makeig, 2012, *in prep*

Group Analysis (beta)



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

Causal Projection (MPT)

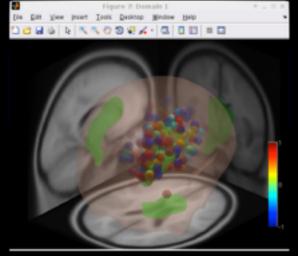
Project

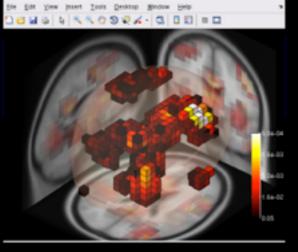
Create Domains Domains

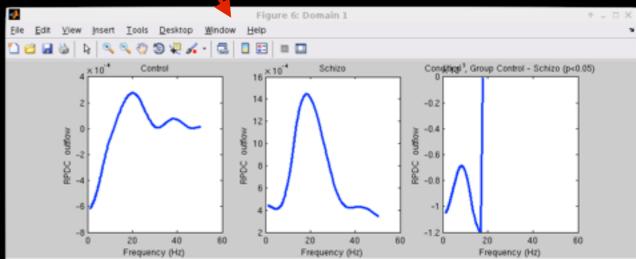
Show volume Show cortex Show colored by Significance Show colored by Measure Show colored by Domain Show volume as MRI

Options

About



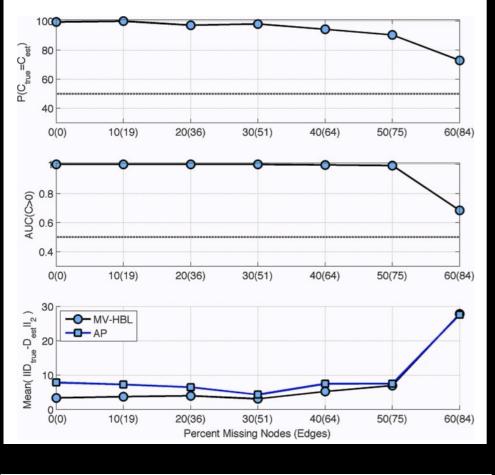


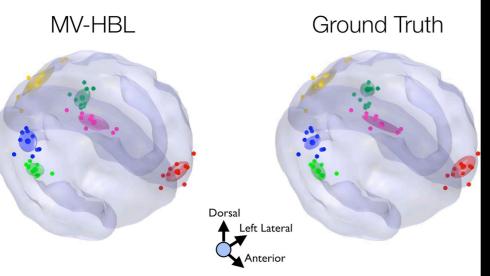


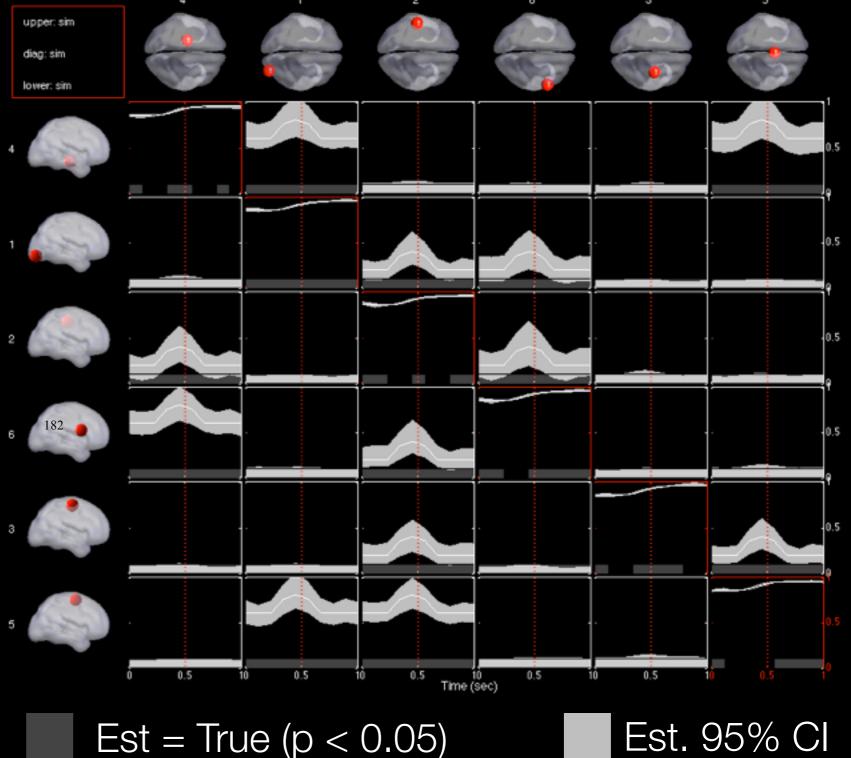
MV-HBL

Sim: 10 Subjects, 30% missing dipoles

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









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

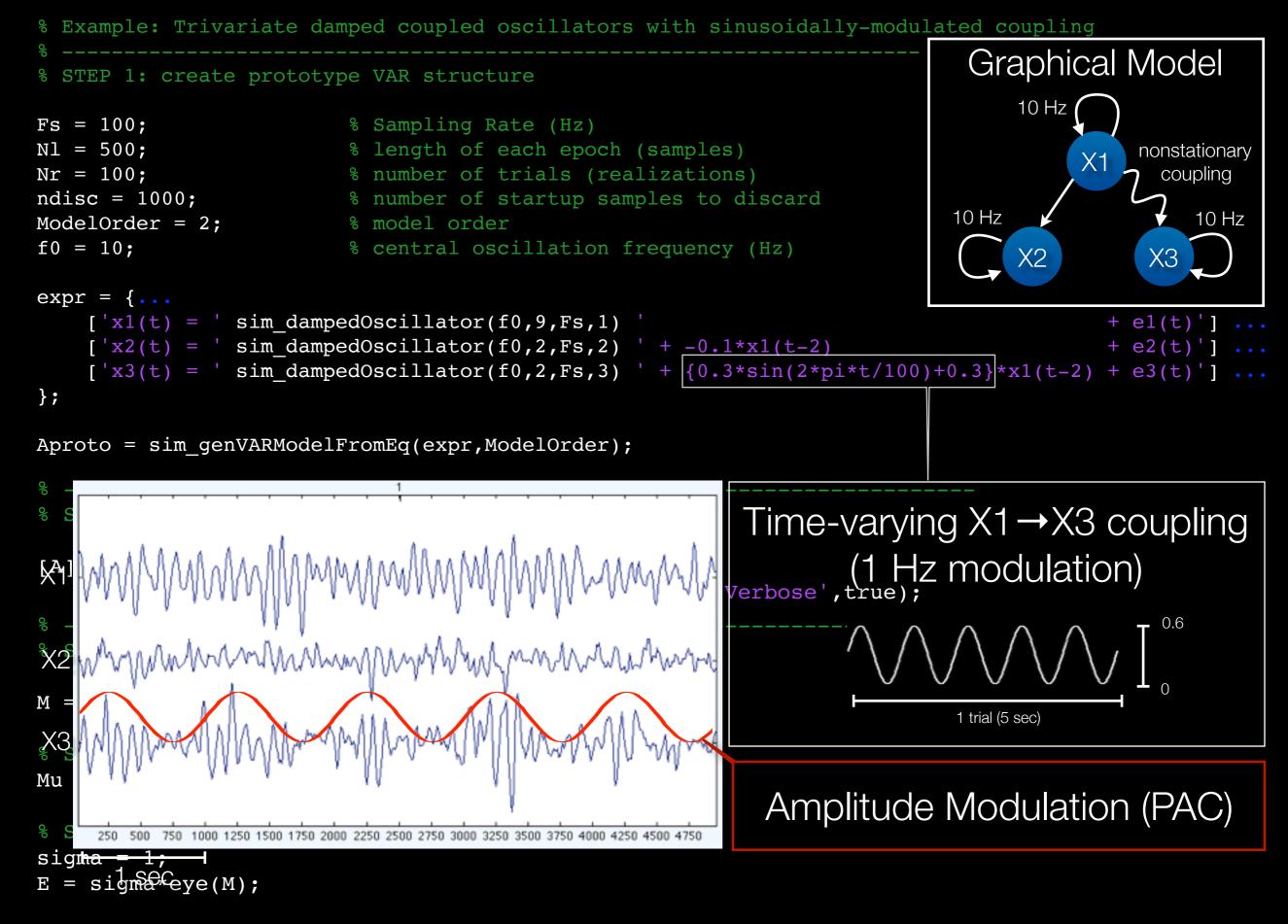
Support for generalized gaussian or hyperbolic secant innovations

Nonlinear Dynamical Systems

Rössler and Lorenz Systems

Realistic scalp EEG generation through forward head model

Convenient source definitions via cortical atlas (Mobilab Object)



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



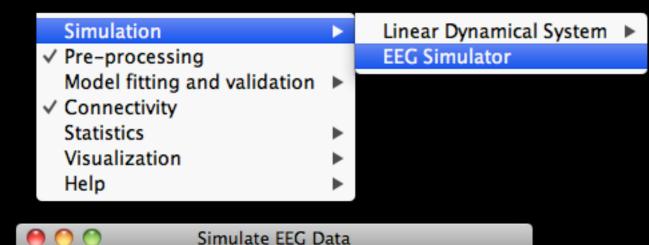
Simulation >	Linear Dynamical S	System Vector Autoregressive Process	Ca N
✓ Pre-processing	EEG Simulator		
Model fitting and validation			
✓ Connectivity			
	the Data		
🔴 🔿 🔿 Simulate Autoregress	sive Data		
		Simula	ation
Miscellaneous			
Simulation	Epileptic Seizure	Epileptic Seizure	
DynamicalEquations	$x1(t) = {2*exp(-1/(0.2))}$	Schelter 2005 Eq 5	
ModelOrder	6	Schelter 2009 Eq 3.1	
SetDynamics		Schelter 2009 Eq 3.2	
▼ SimParams		Bivariate Coupled Oscillator	
SamplingRate	100	Trivariate Coupled Oscillator	
TrialLength	5		
NumTrials	100		
BurninSamples	1,000		
CheckStability		Simulated Seizure	
▼ DataGenParams			
NoiseCovMat	1	tau = 20 HZ Beta	
ProcessMean	0	1.3	
NoiseDistribution ScaleBaram	gengauss		
ScaleParam	1		10 Hz
ShapeParam Verbosited evel	2	tau = 7 52	tau = 6
VerbosityLevel	2		5 Alpha
OutputFormat BuildEEGLABStructure			
ExportGroundTruth		tau = 7 52+53	
SetName			(6)
▼ Visualization			
PlotData	\checkmark	53 21 Hz	10 Hz
PlotGraphicalModel		tau = 3	
. loter up meal mouth		11 Hz (10) = 9 Hz (10) = 7 tau = 7	
Simulation			
Select a simulation.			12
	X		Γ
		40 Hz 40 Hz 40 Hz	
Help Cancel	ОК		



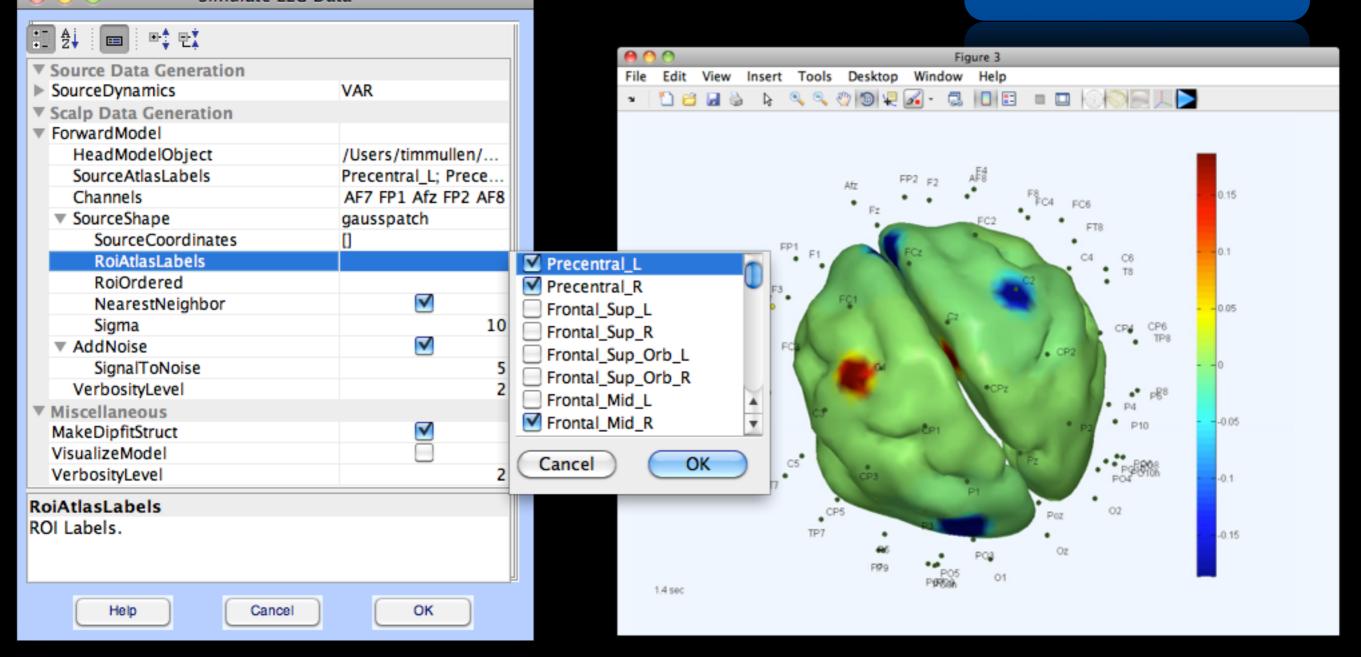
Simulated Seizure Sources

	Beta	Alpha	IED
1	and a state of the second s	viewerste vielen meine der für für für für der der der der der der der viewerste der verwerken der verwerken de	anarstaallifteraallifteraantearer aan ferraattalieraattalieraattalieraattalieraattalieraattalieraattalieraatta
		ine a density for the system consideration of the second present the second present of the present of the second beautiful as	
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5	friewowie werzen gegenten er en	A MANAGER AND	antrasponnialitation and an antraspondent and a state of the
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	or and the production of the second of the s		MMmANAMMANAMMANANANANANANANANANANANANANA
	are the contraction of the contr		
	an na falingar an asan kanakan kanan kanan kalan sa kanakasa kanakasa kalan kana kana kana kana kana kana ka		
17	I I	I I	39 40 41 42 43 44 45 46 4





Simulation



Distribution and Educational Resources



