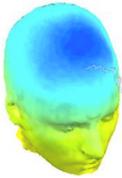


EEGLAB overview

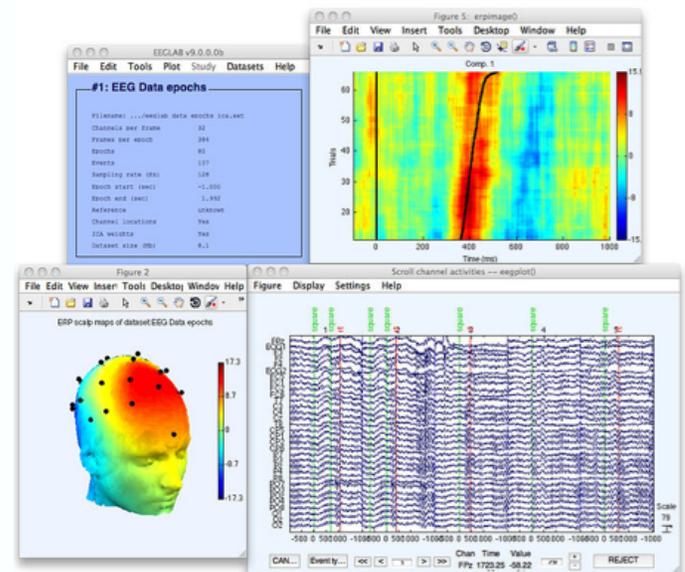


- Collection of over 300 functions (70000 lines of code)
- About 70 000 download over the past 8 years
- About 3500 users on the discussion list and 8500 on the diffusion list
- NIH funding since 2003

<http://sccn.ucsd.edu/eeglab>

<http://sccn.ucsd.edu/wiki/eeglab>

<http://sccn.ucsd.edu/wiki/Workshop>



EEGLAB standard processing pipeline



Single subject

1. Import binary data, events and channel location
2. Edit, Re-reference, Resample, High pass filter data
3. Reject artifacts in continuous data by visual inspection
4. Extract epochs from data & reject artifactual epochs
5. Visualize data measures
6. Perform ICA decomposition
 - Perform source localization of components
 - Analyze components contribution to ERP
 - Analyze components contribution to spectrum

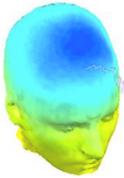
Multi-subjects

1. Build study and STUDY design
2. Pre-compute measures
3. Cluster components
4. Analyze clusters



Advanced analysis using scripting and EEGLAB command line functions

The EEGLAB Matlab software



The screenshot displays the EEGLAB Matlab software interface. On the left is a terminal window titled "EEGLAB Shell - Konsole" with a menu bar "Session Edit View Bookmarks Settings Help". The terminal shows the command `matlab -nodesktop` being executed, resulting in the MATLAB startup screen for version 6.5.0.180913a, released on June 18, 2002. The terminal also shows the command `>> eeglab` being entered. On the right is a help window titled "EEGLAB" with a menu bar "File Edit Tools Plot Datasets Help". The help window displays the message "No current dataset" and lists several actions that can be performed:

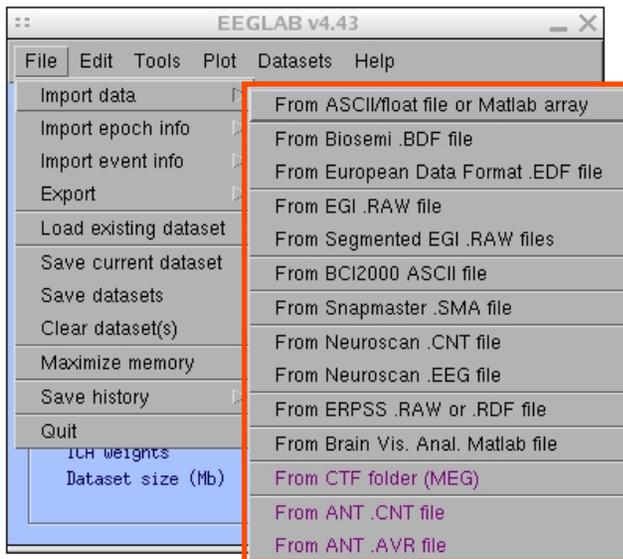
- Create a new or load an existing dataset:
 - Use `"/File/Import data"` (new)
 - Or `"/File/Load existing dataset"` (old)
- If new,
 - `"/File/Import epoch info"` (data epochs), else
 - `"/File/Import event info"` (continuous data)
 - `"/Edit/Dataset info"` (add/edit dataset info)
 - `"/File/Save dataset"`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



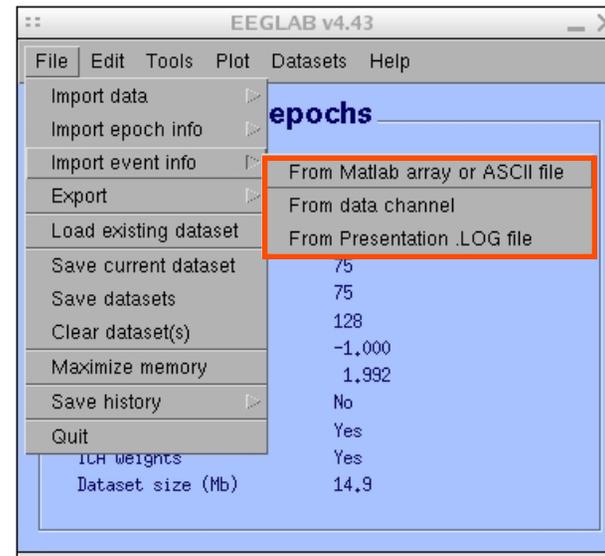
1. Importing data



Import/load data



Import events



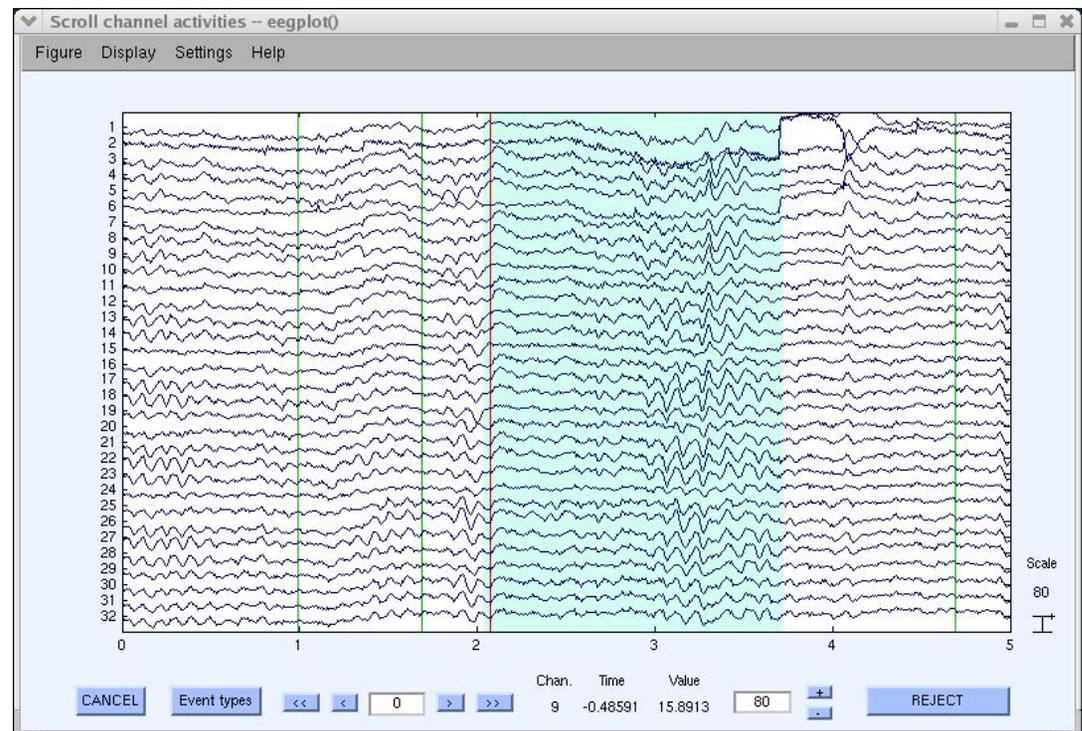
1. Importing data



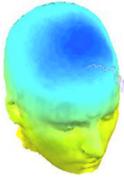
Data info



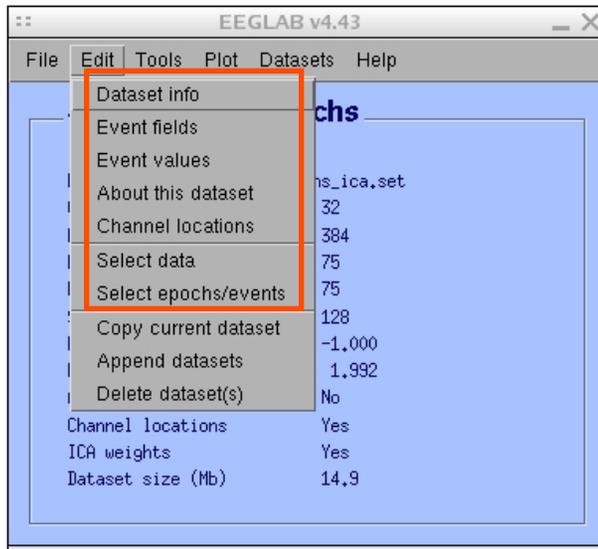
Scrolling data



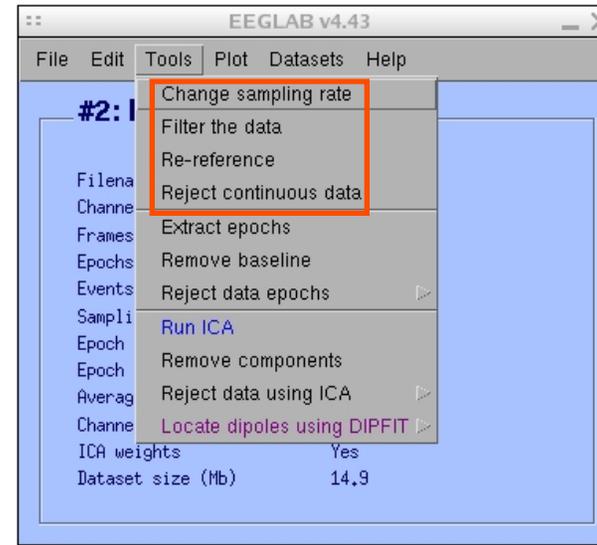
2. Edit, Re-reference, Resample, High pass filter data



Edit/select data



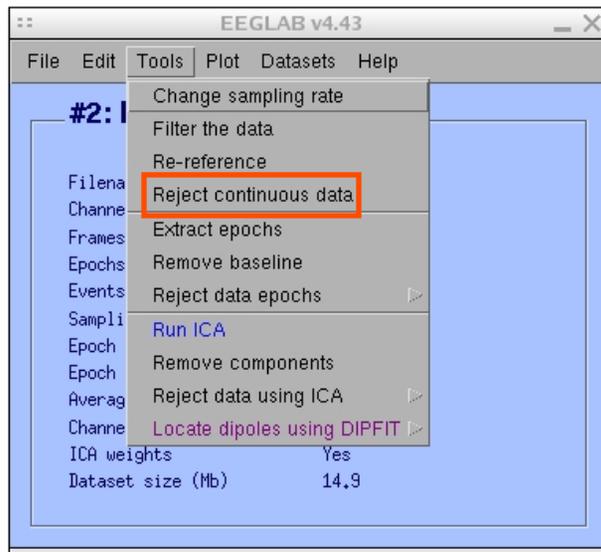
Preprocessing data



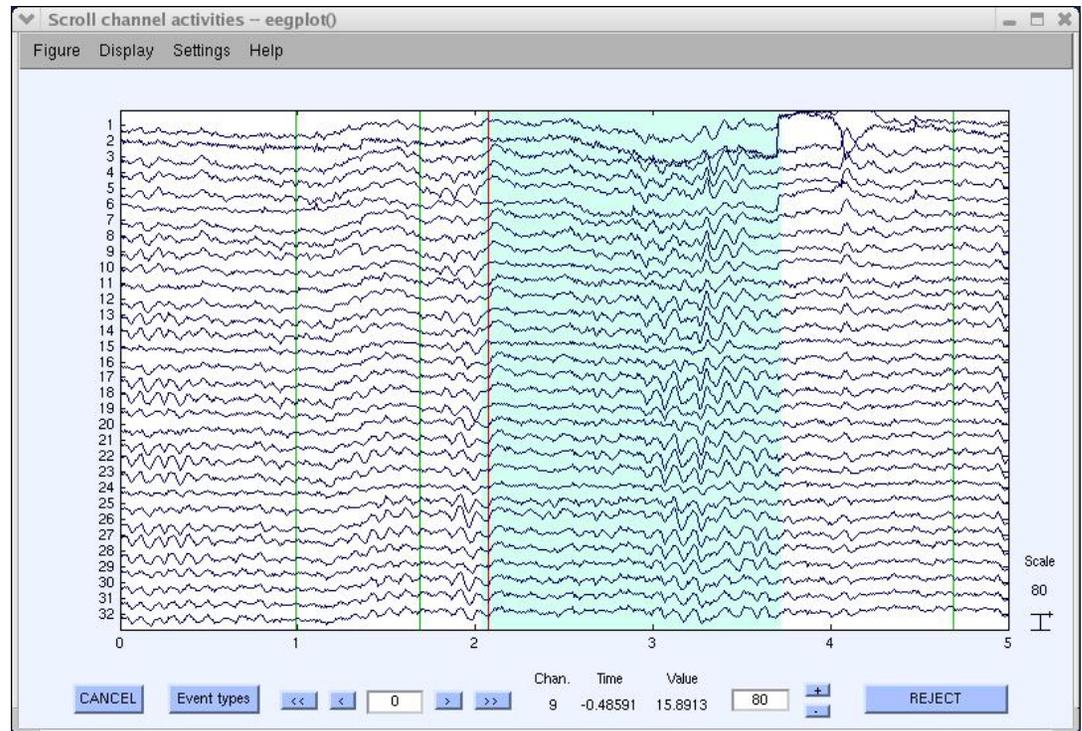
3. Reject artifacts in continuous data by visual inspection



Data info



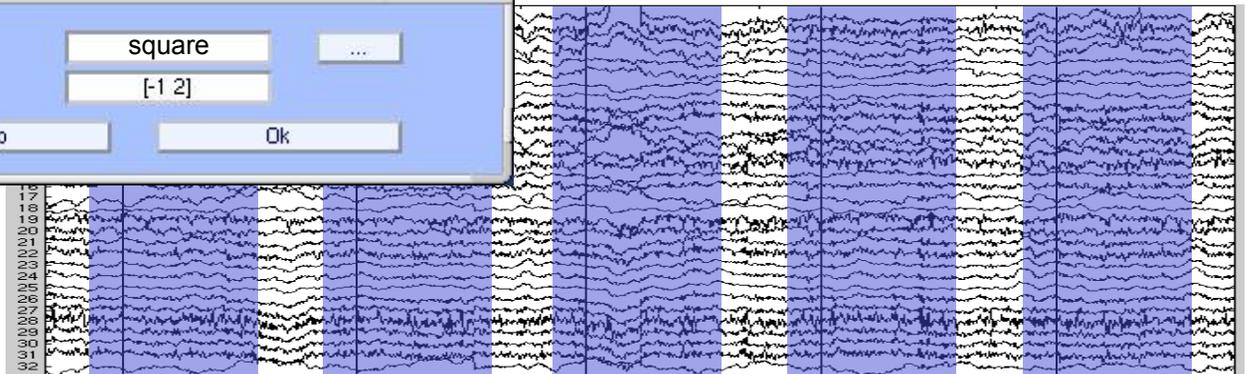
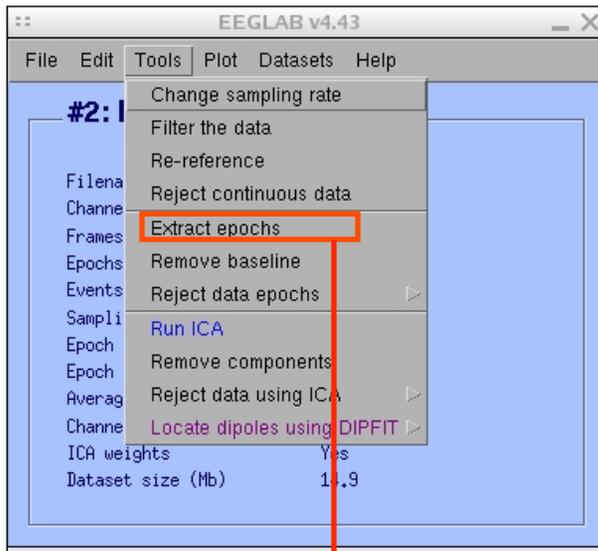
Reject portions of continuous data



4. Extract epochs from data & reject artifactual epochs



Preprocessing data



4. Extract epochs from data & reject artifactual epochs



EEGLAB v4.51

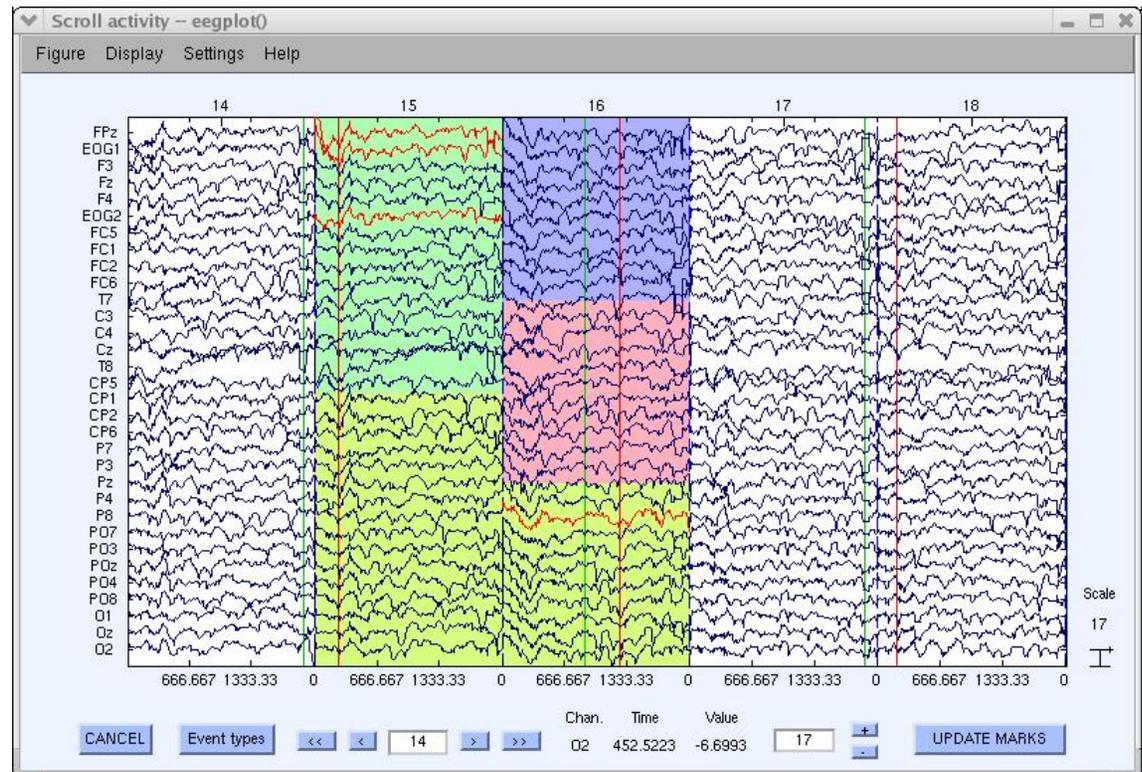
File Edit Tools Plot Datasets Help

#2: I... out chann...

- Change sampling rate
- Filter the data
- Re-reference
- Reject continuous data
- Extract epochs
- Remove baseline
- Reject data epochs
- Reject data (all methods)
- Reject by inspection
- Reject extreme values
- Reject flat line data
- Reject by probability
- Reject by kurtosis
- Reject by spectra
- Export marks to ICA reject
- Reject marked epochs

- Run ICA
- Remove components
- Reject data using ICA
- Locate dipoles using BESA
- Locate dipoles using DIPFIT
- Laplacian
- Cluster component
- Filter the data (IIR)

Different color = different rejection methods

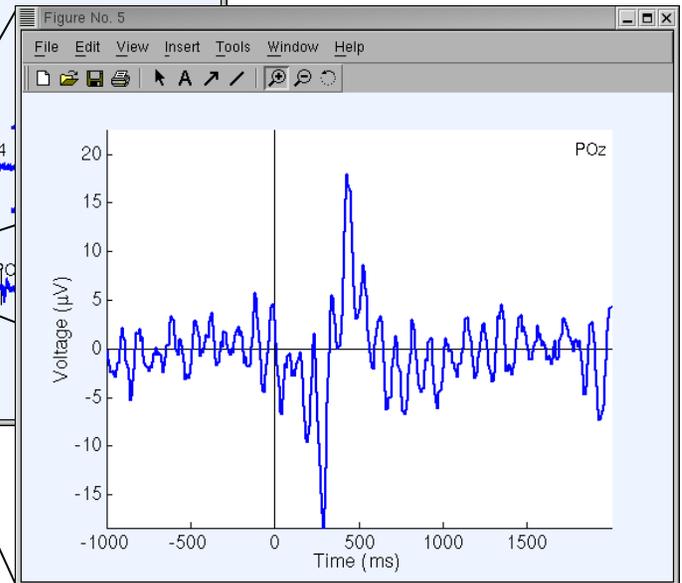
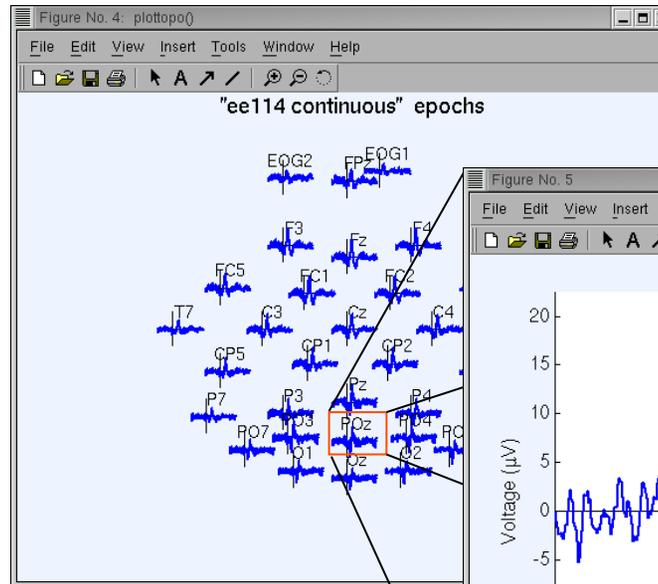


5. Visualize data measures



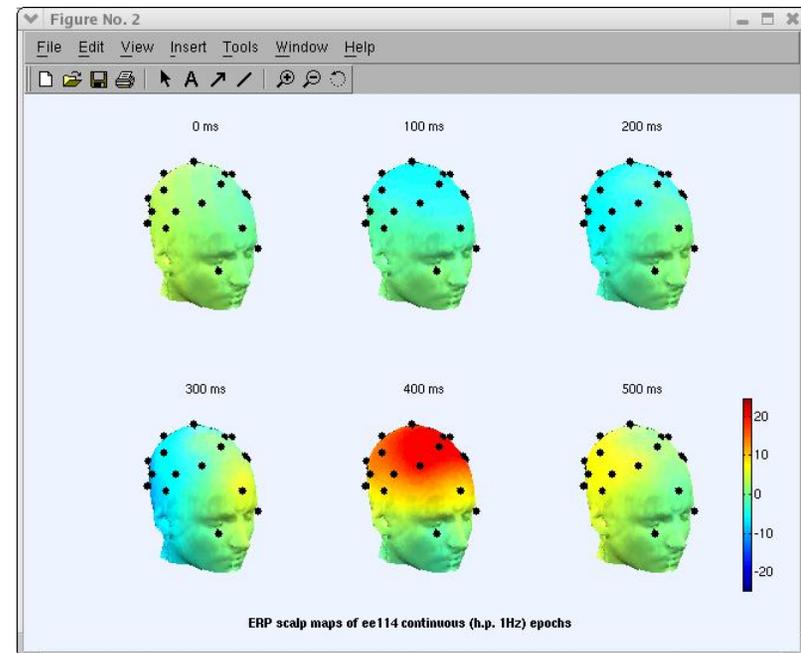
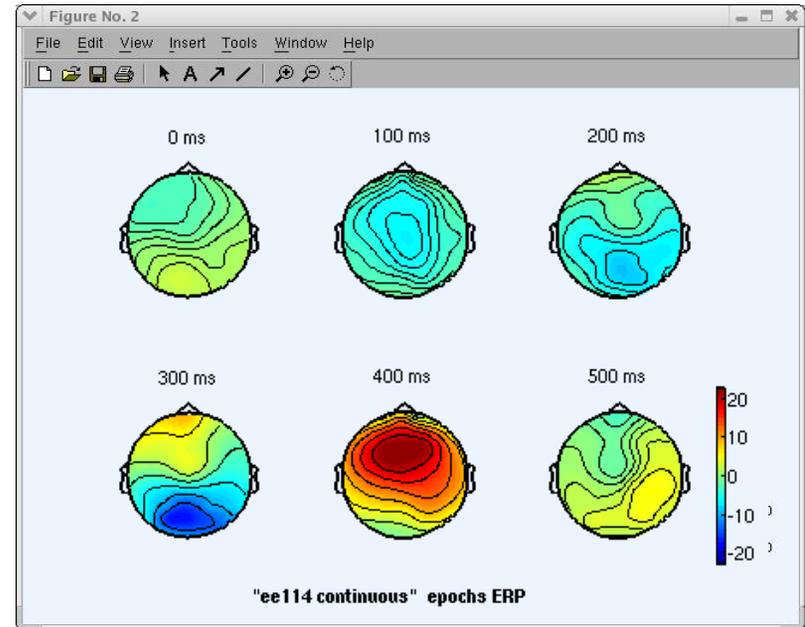
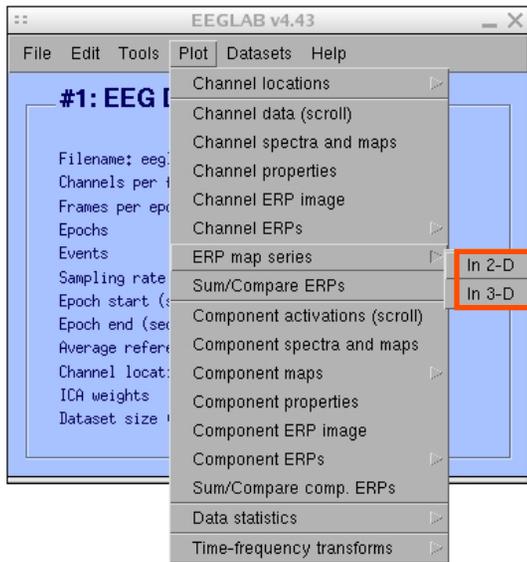
Plot ERP

- Channel locations
- Channel data (scroll)
- Channel spectra and maps
- Channel properties
- Channel ERP image
- Channel ERPs
 - With scalp maps
 - In scalp array**
 - In rect. array
- ERP map series
- Sum/Compare ERPs
- Component activations (scroll)
- Component spectra and maps
- Component maps
- Component properties
- Component ERP image
- Component ERPs
- Sum/Compare comp. ERPs
- Data statistics
- Time-frequency transforms



5. Visualize data measures

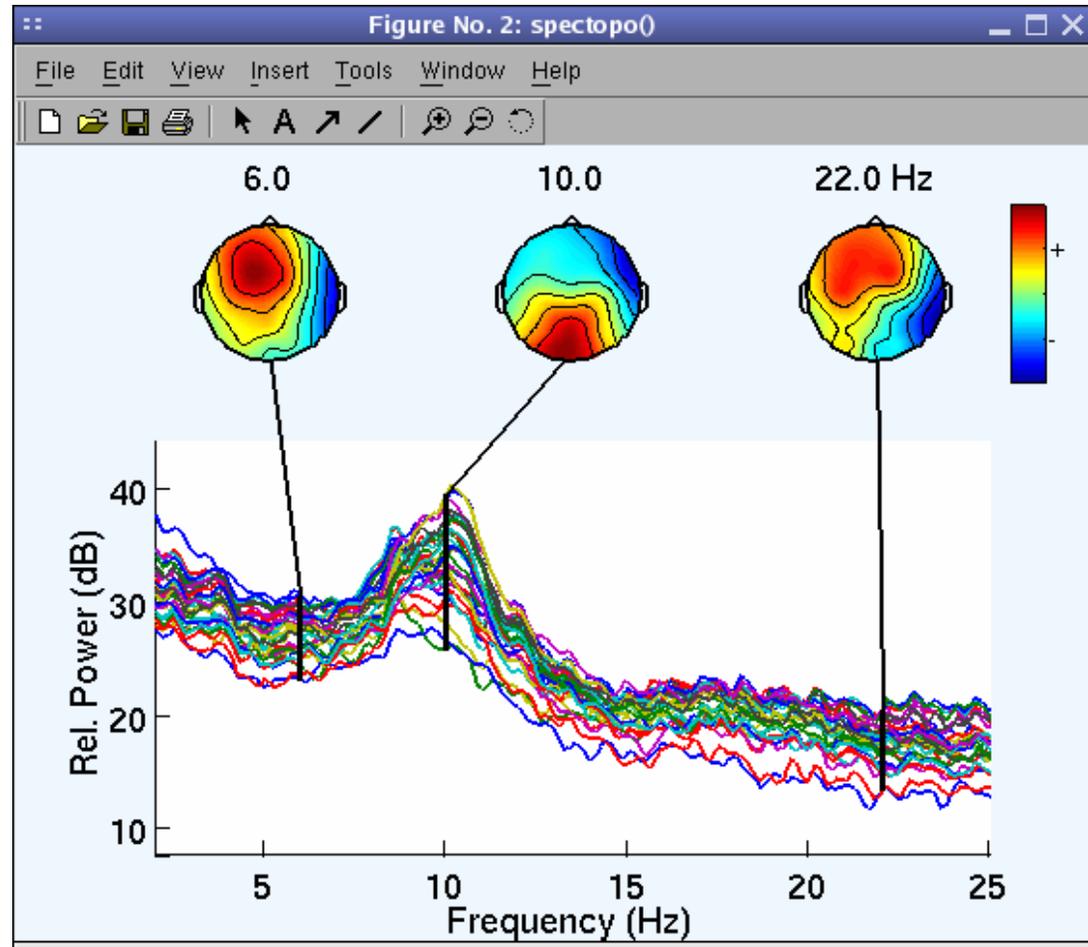
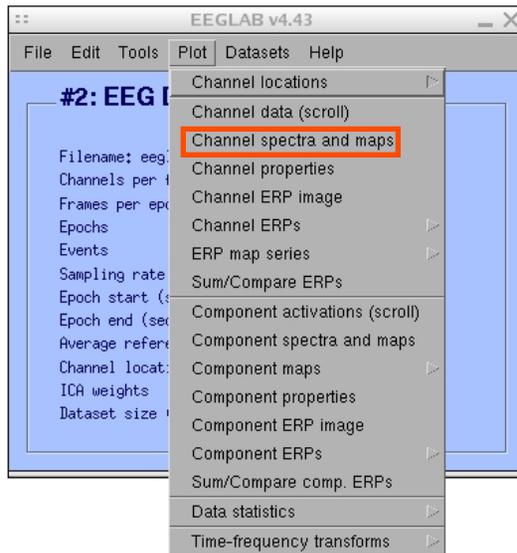
Plot ERP
map series



5. Visualize data measures



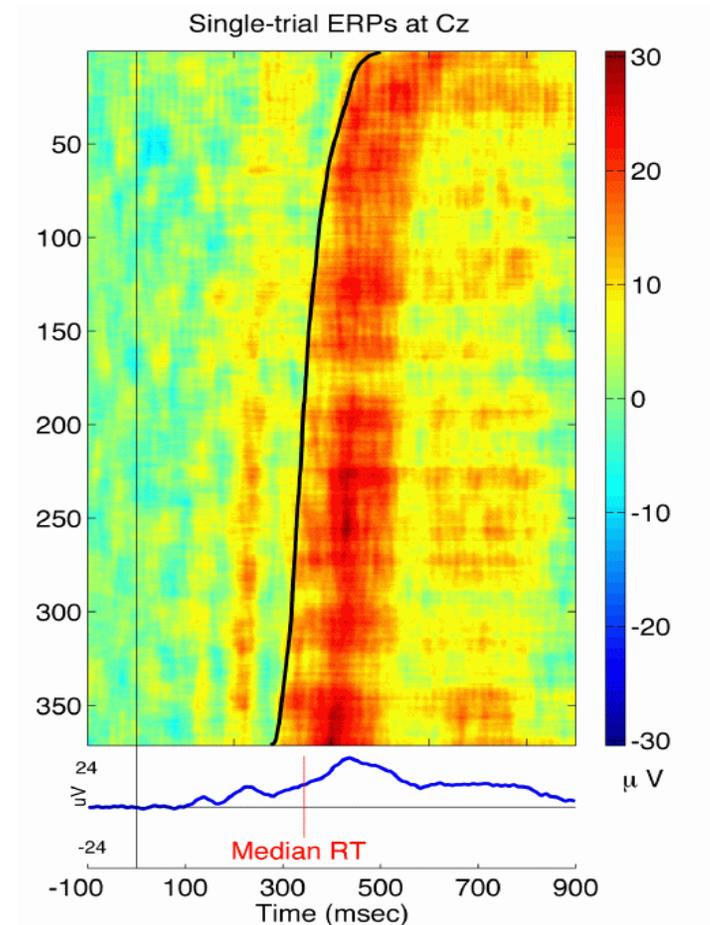
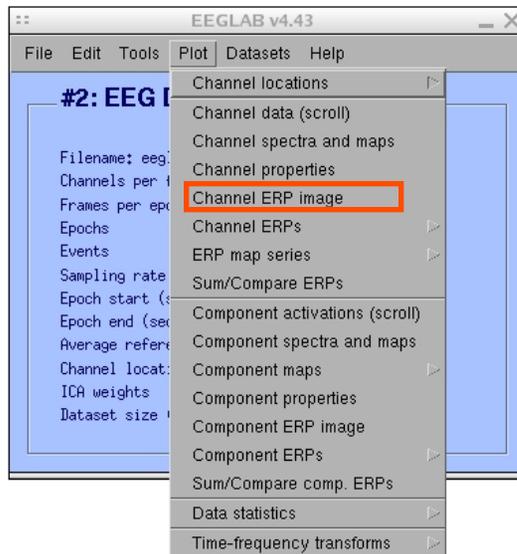
Plot data
spectrum and
maps



5. Visualize data measures



Plot channel ERP image



EEGLAB standard processing pipeline



Single subject

1. Import binary data, events and channel location
2. Edit, Re-reference, Resample, High pass filter data
3. Reject artifacts in continuous data by visual inspection
4. Extract epochs from data & reject artifactual epochs
5. Visualize data measures
6. Perform ICA decomposition
 - Perform source localization of components
 - Analyze components contribution to ERP
 - Analyze components contribution to spectrum

Multi-subjects

1. Build study
2. Pre-compute measures
3. Cluster components
4. Analyze clusters



Advanced analysis using scripting and EEGLAB command line functions

6. Perform ICA decomposition



EEGLAB v4.43

File Edit Tools Plot Datasets Help

#2: I

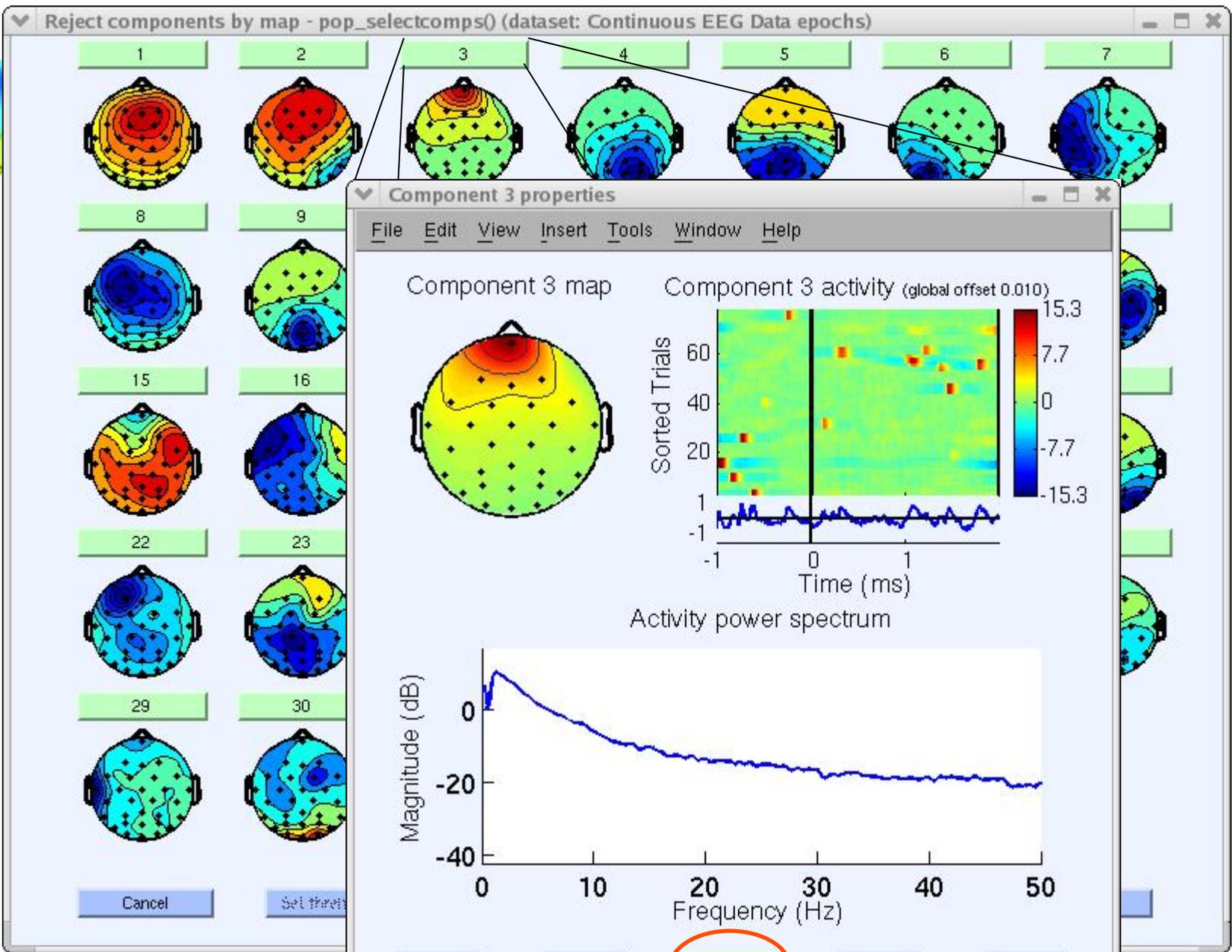
- Change sampling rate
- Filter the data
- Re-reference
- Reject continuous data
- Extract epochs
- Remove baseline
- Reject data epochs
- Run ICA**
- Remove components
- Reject data using ICA
- Locate dipoles using DIPFIT

File name: ...
Channel names: ...
Frames: ...
Epochs: ...
Events: ...
Sampling rate: ...
Epoch duration: ...
Epoch start: ...
Average: ...
Channel weights: Yes
Dataset size (Mb): 14.9

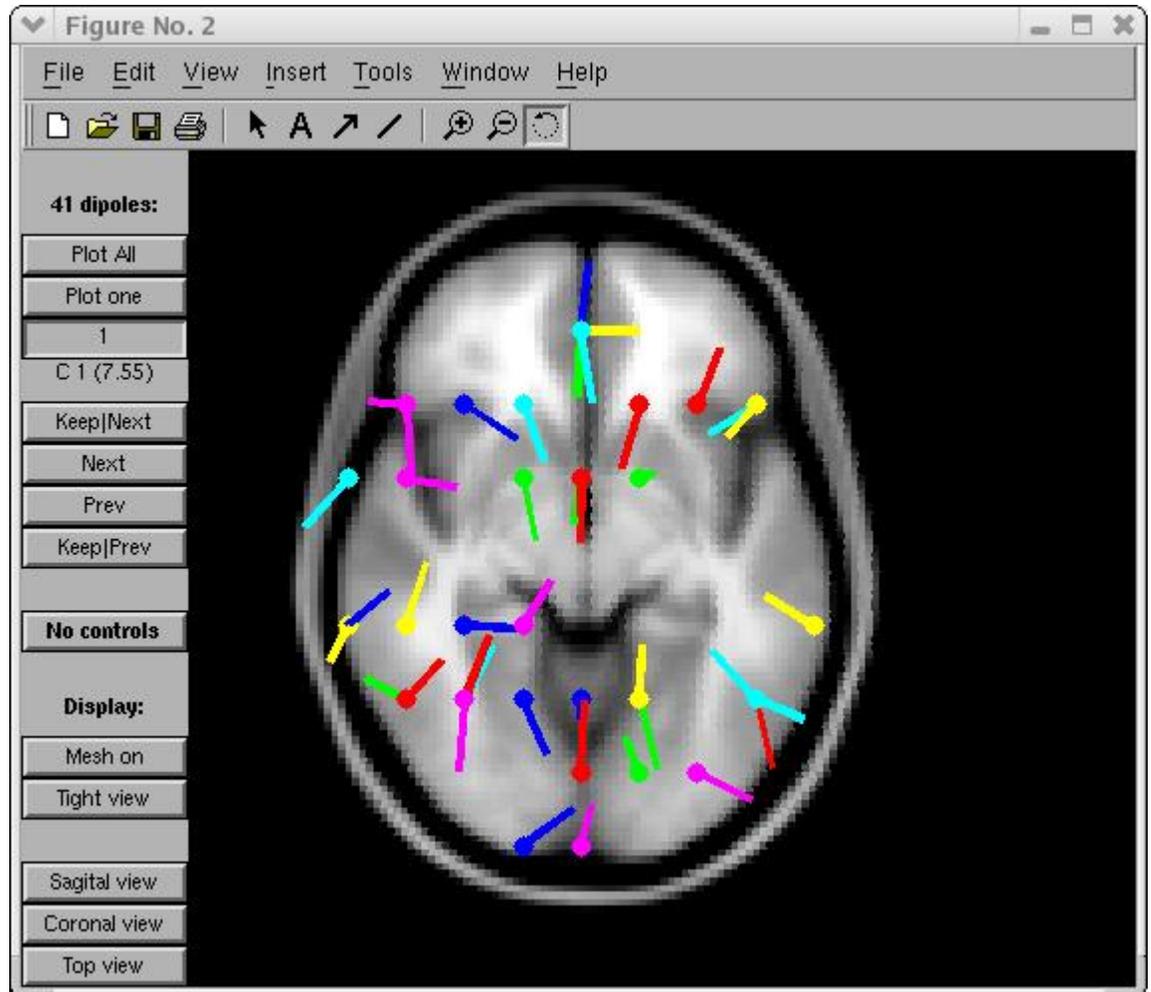
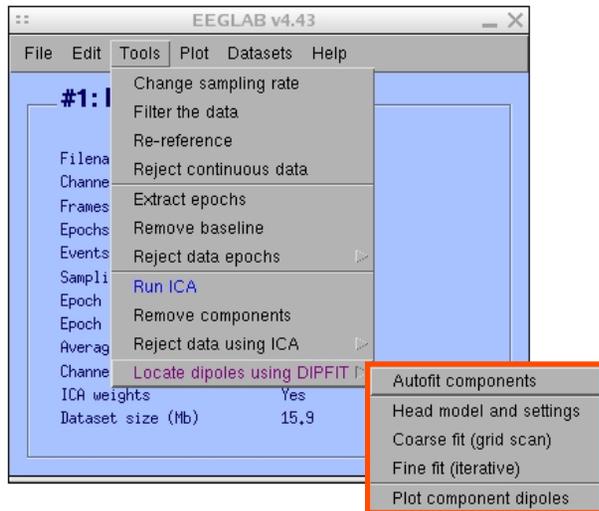
Run ICA decomposition - pop_runica()

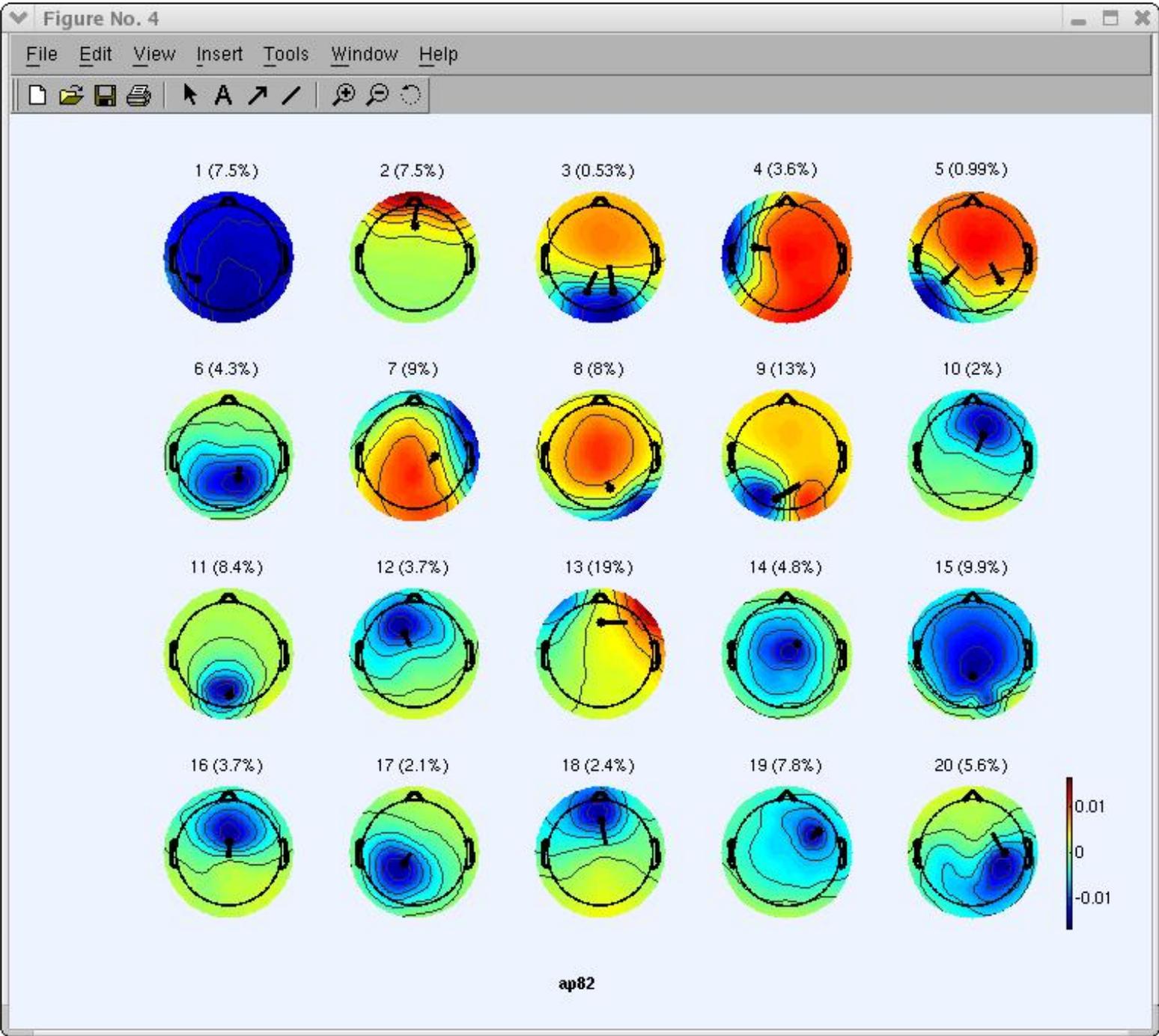
ICA algorithm to use [runica | binica | jader | sobi | acsobi]

Commandline options (See algorithm help messages)

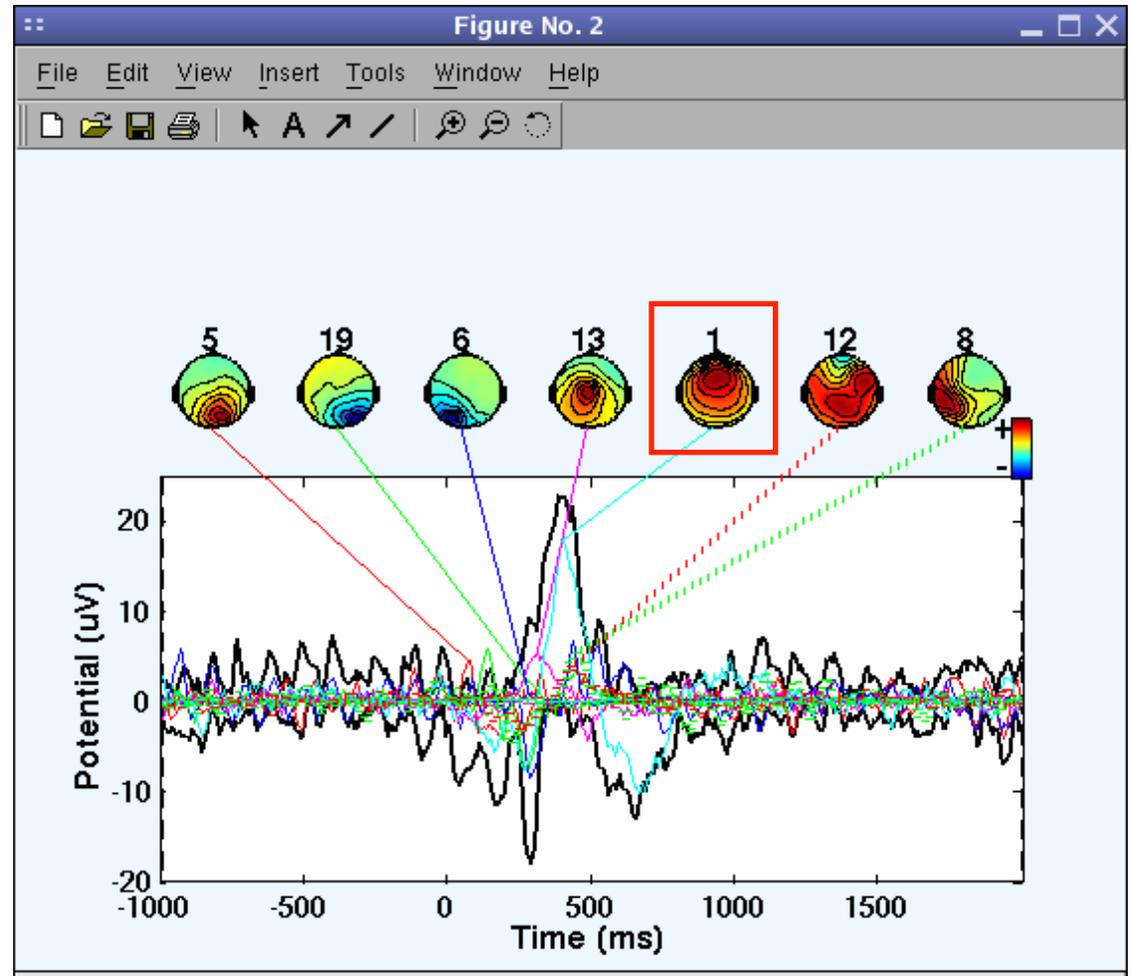
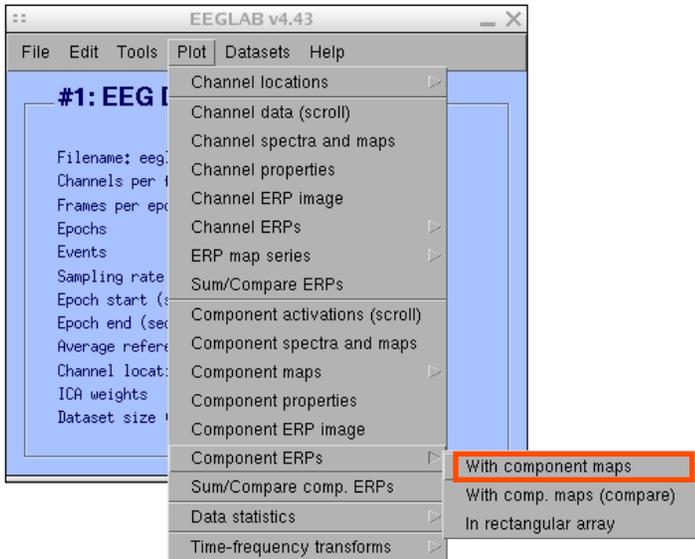


Localizing components



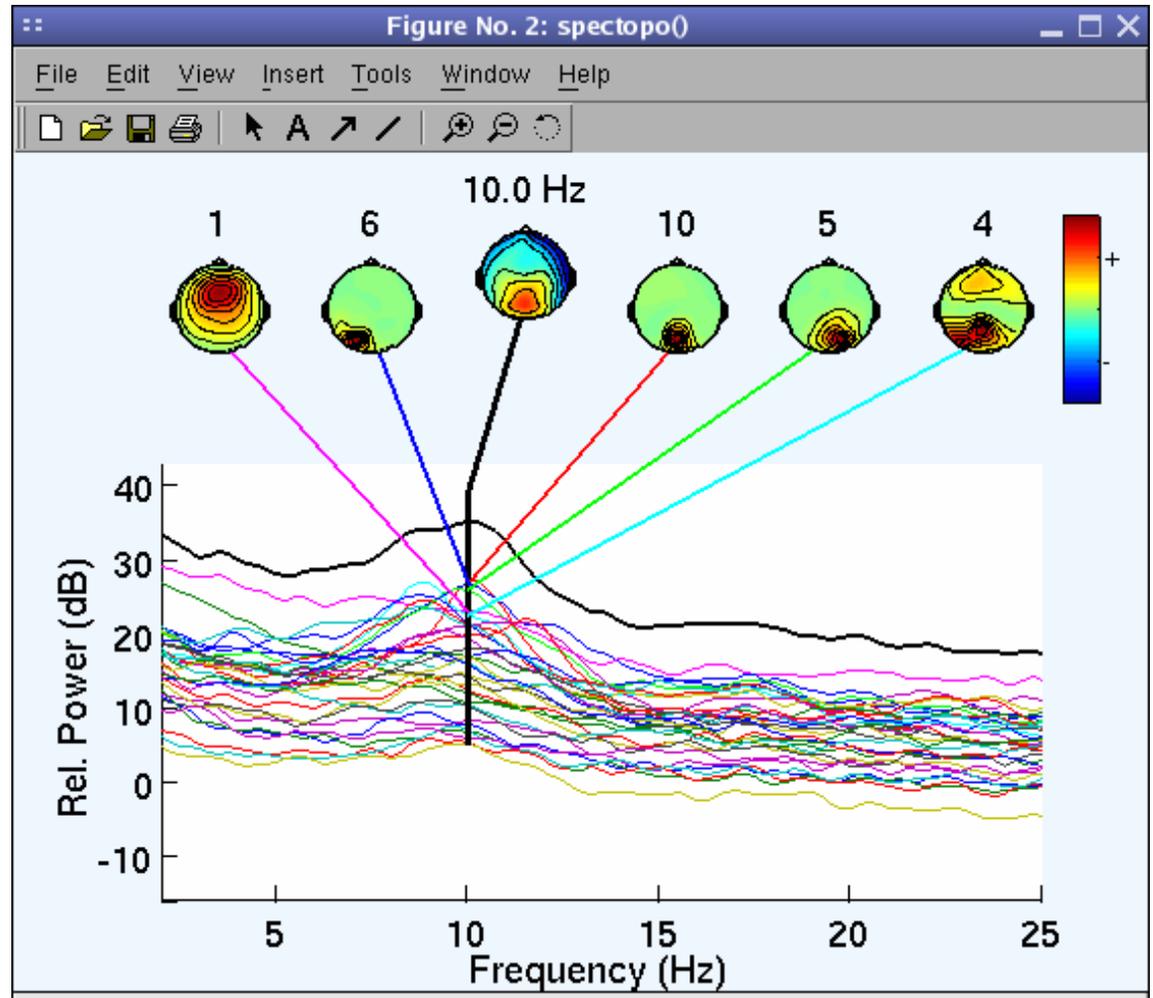
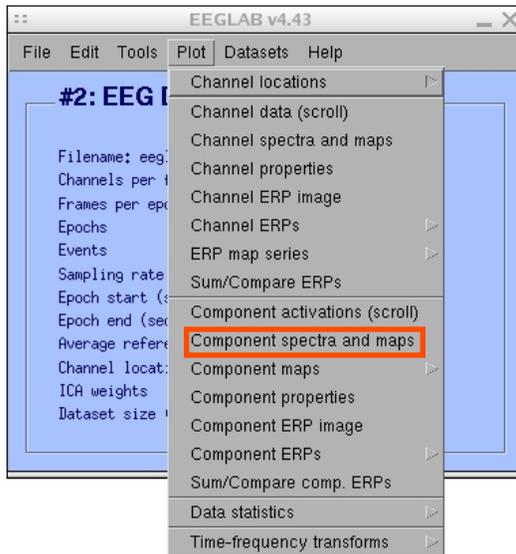


Component contribution to the ERP

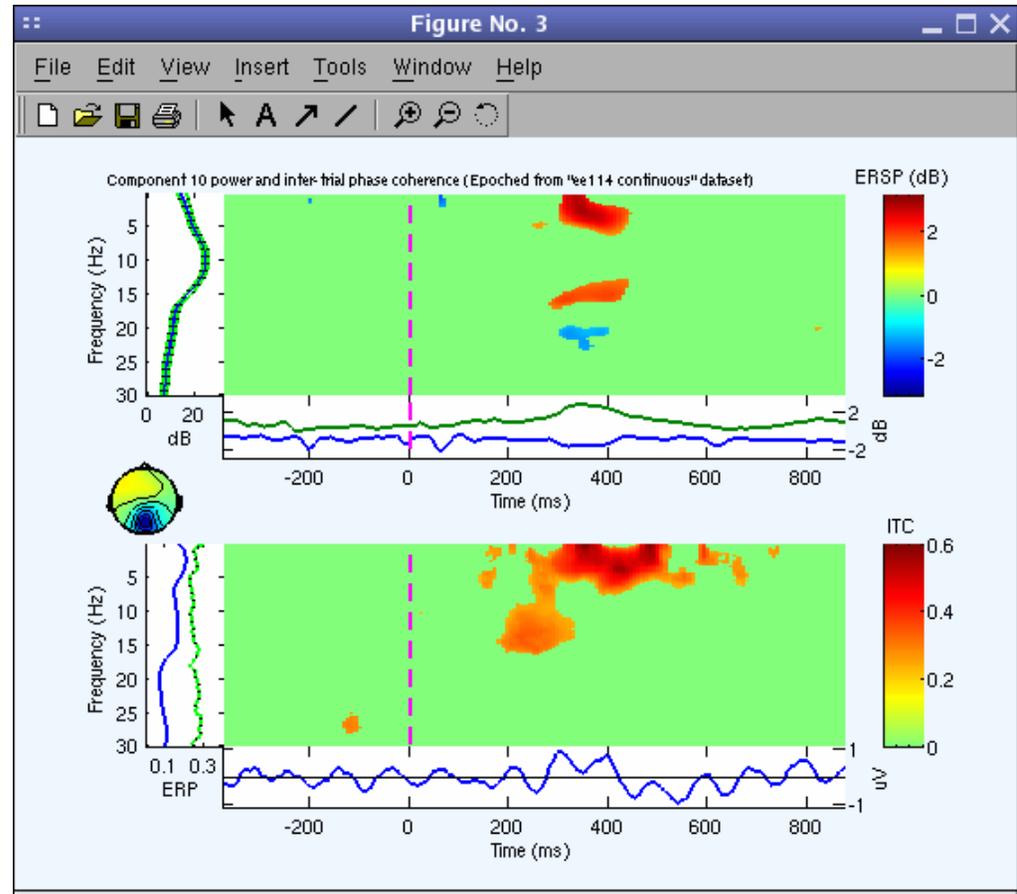
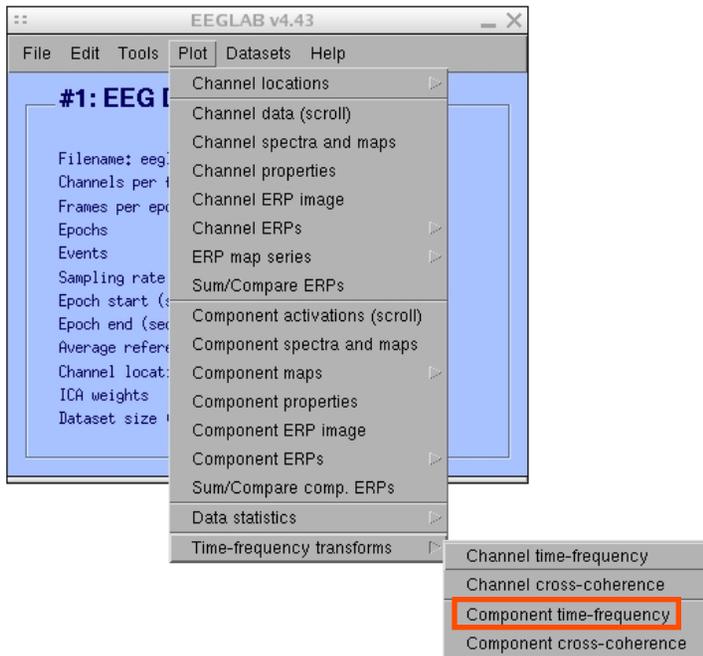




Component contribution to the EEG spectrum



Component time-frequency



EEGLAB standard processing pipeline



Single subject

1. Import binary data, events and channel location
2. Edit, Re-reference, Resample, High pass filter data
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4. Extract epochs from data & reject artifactual epochs
5. Visualize data measures
6. Perform ICA decomposition
 - Perform source localization of components
 - Analyze components contribution to ERP
 - Analyze components contribution to spectrum

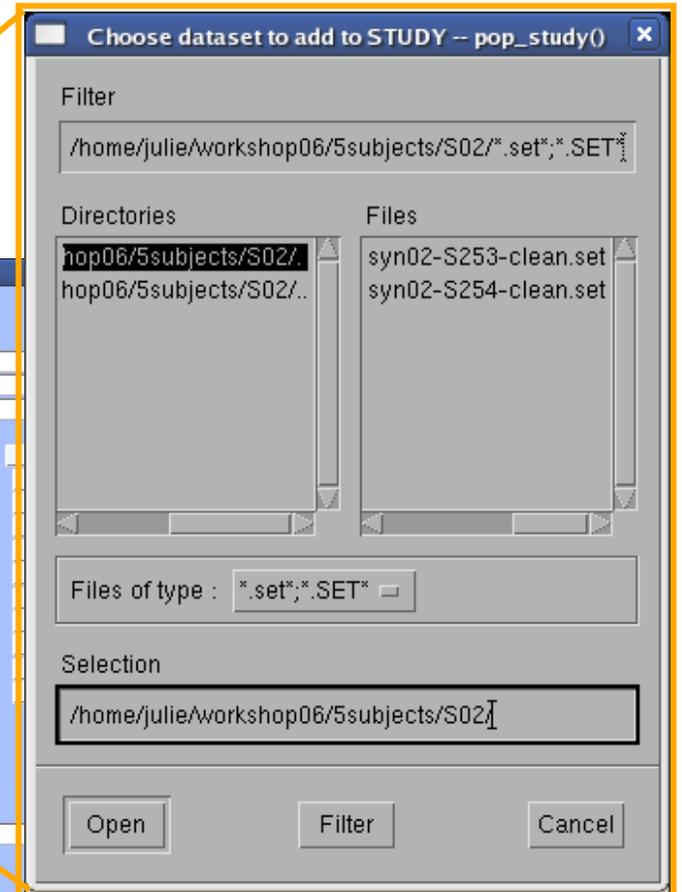
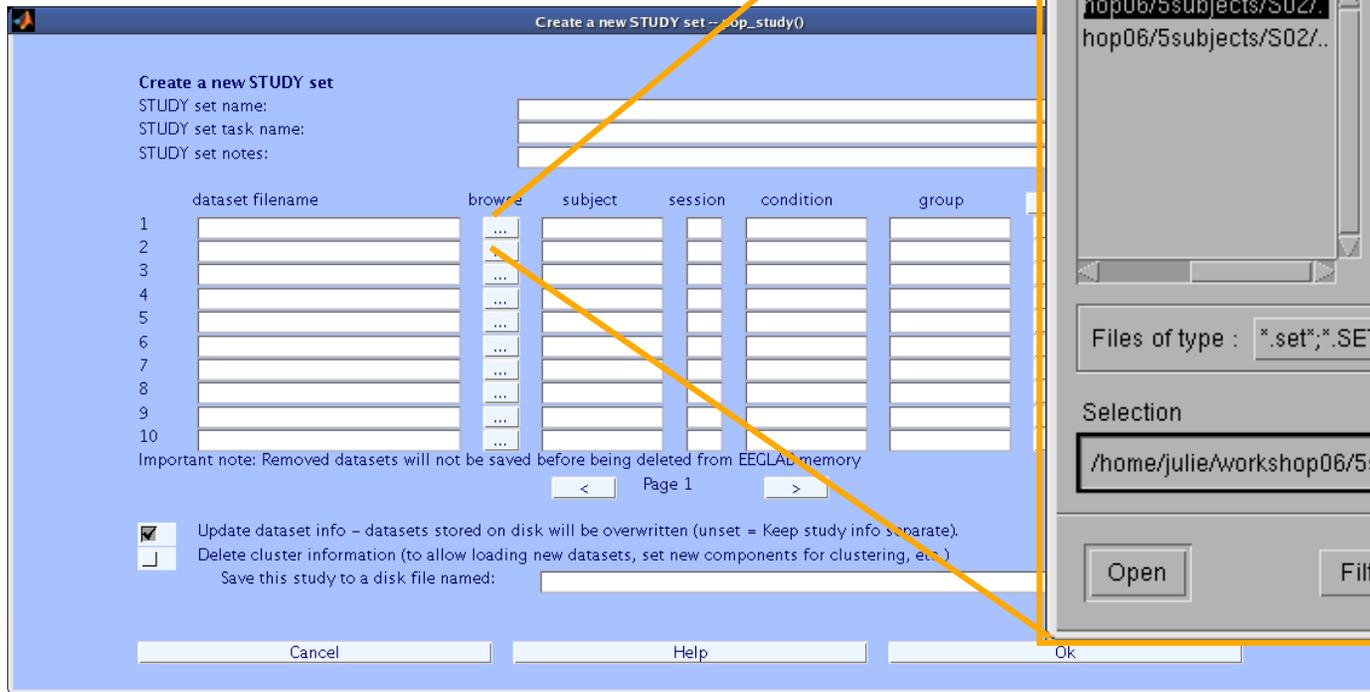
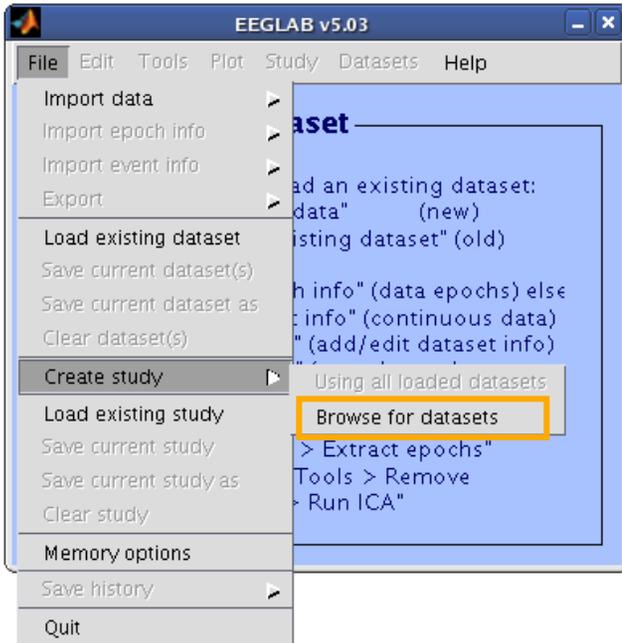
Multi-subjects

1. Build study and STUDY design
2. Pre-compute measures
3. Cluster components
4. Analyze clusters



Advanced analysis using scripting and EEGLAB command line functions

1. Build a STUDY



EEGLAB v9.0.0.0b

File Edit Tools Plot **Study** Datasets Help

STUDY set:

- Study filename: ...s/data
- Study task name
- Nb of subjects
- Nb of conditions
- Nb of sessions
- Nb of groups
- Epoch consistency
- Channels per frame 61
- Channel locations yes
- Clusters 1
- Status Pre-clustered
- Total size (Mb) 8.2

Edit study info
Select/Edit study design(s)
 Precompute channel measures
 Plot channel measures
 Precompute component measures
 Measure Product clustering ▶
 PCA clustering (original) ▶
 Edit/plot clusters

Edit STUDY design



Select STUDY design

STUDY.design 1

Add design
Rename design
Delete design

Subjects

S05
S08

Select all subjects

Independent variable 1

None
condition
description
duration
type

Ind. var. 1 values

non-synonyms
synonyms

Combine selected values
Unpaired statistics

Independent variable 2

None
condition
description
duration
type

Ind. var. 2 values

Combine selected values
Unpaired statistics

Use only specific datasets/trials

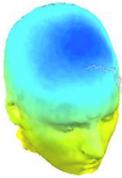
Delete all datafiles associated with this STUDY design

Save the STUDY

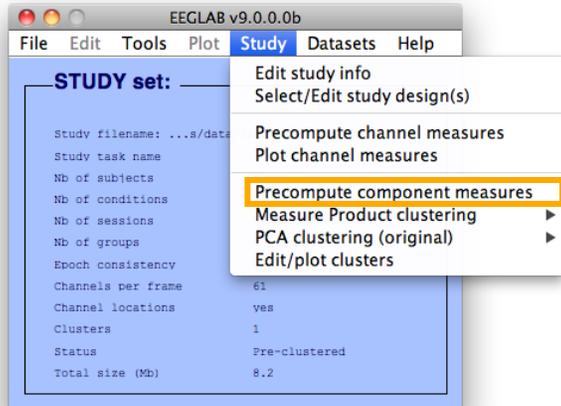
Cancel Ok



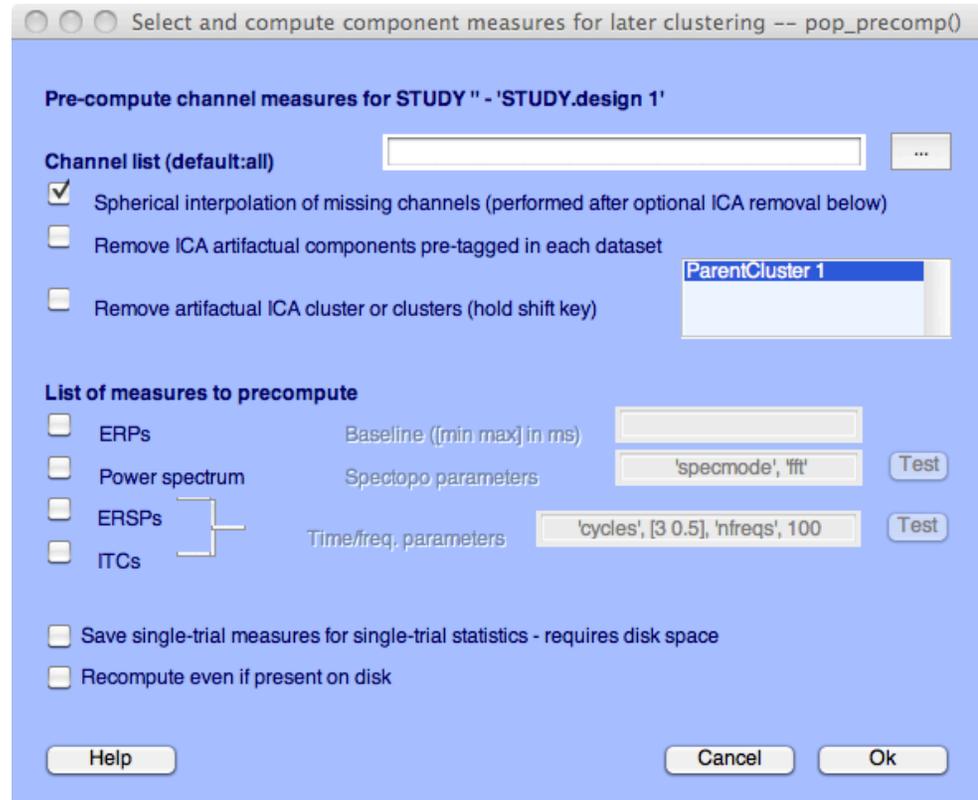
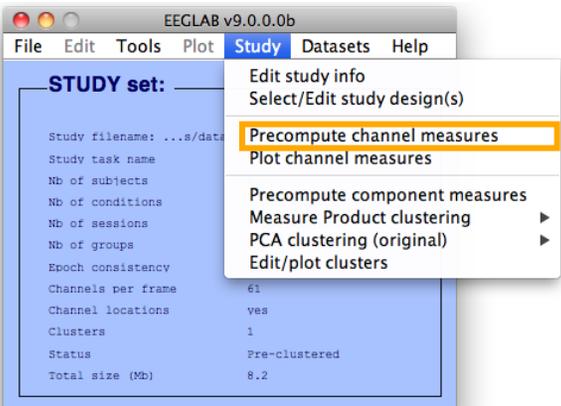
2. Pre-compute measures



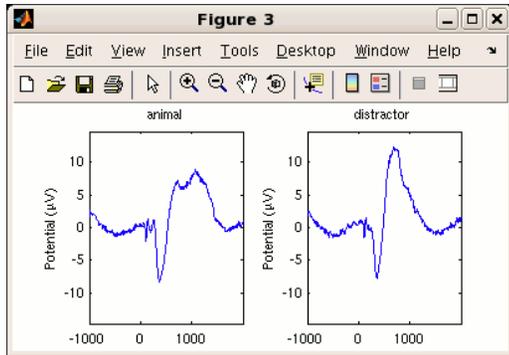
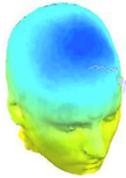
Components



Channels



Channel plotting



View and edit current channels -- pop_chanplot()

Study "

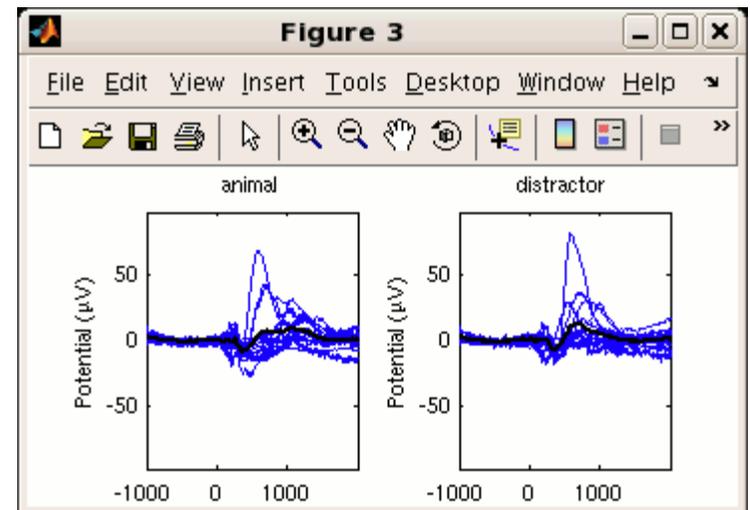
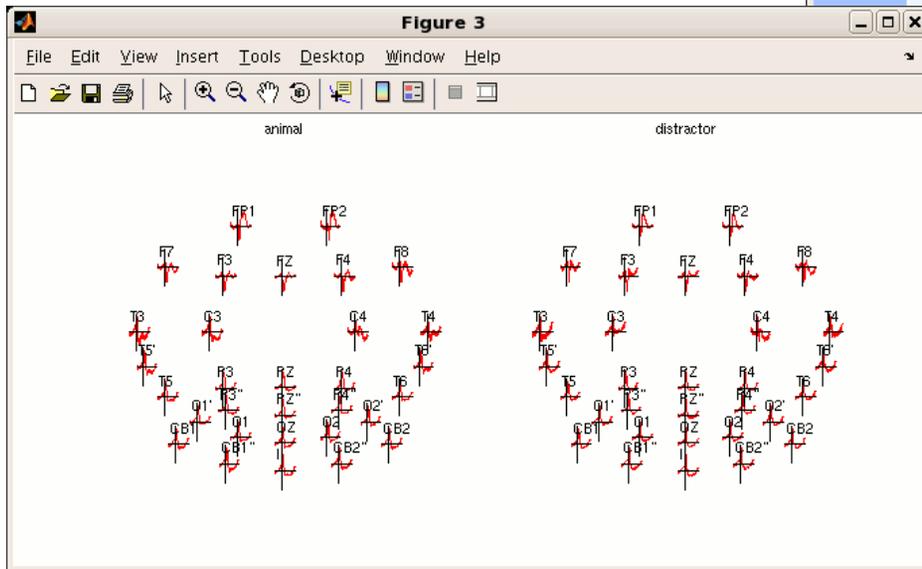
Select channel to plot

- All FP1
- All FP2
- All F3
- All F4
- All C3
- All C4
- All P2

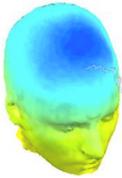
Select subject(s) to plot

- All subjects
- cba FP1
- clm FP1
- ega FP1
- fsa FP1
- gro FP1
- hsh FP1

Save STUDY set to disk



3. Cluster components



EEGLAB v6.0b

File Edit Tools Plot **Study** Datasets Help

STUDY set: At

Study filename:
Study task name
Nb of subjects
Nb of conditions
Nb of sessions
Nb of groups
Epoch consistency: yes
Channels per frame: 31
Channel locations: yes
Clusters: 1
Status: Pre-clustered
Total size (Mb): 32.4

- Edit study info
- Precompute channel measures
- Plot channel measures
- Precompute component measures
- Build preclustering array**
- Cluster components
- Edit/plot clusters

Select and compute component measures for later clustering -- pop_preclust()

Build pre-clustering matrix for STUDY 'Attention'
Select the cluster to refine during sub-clustering (any existing sub-hierarchy will be overwritten)

ParentCluster 1 (181 ICs)

(note: only measures that have been precomputed may be used)

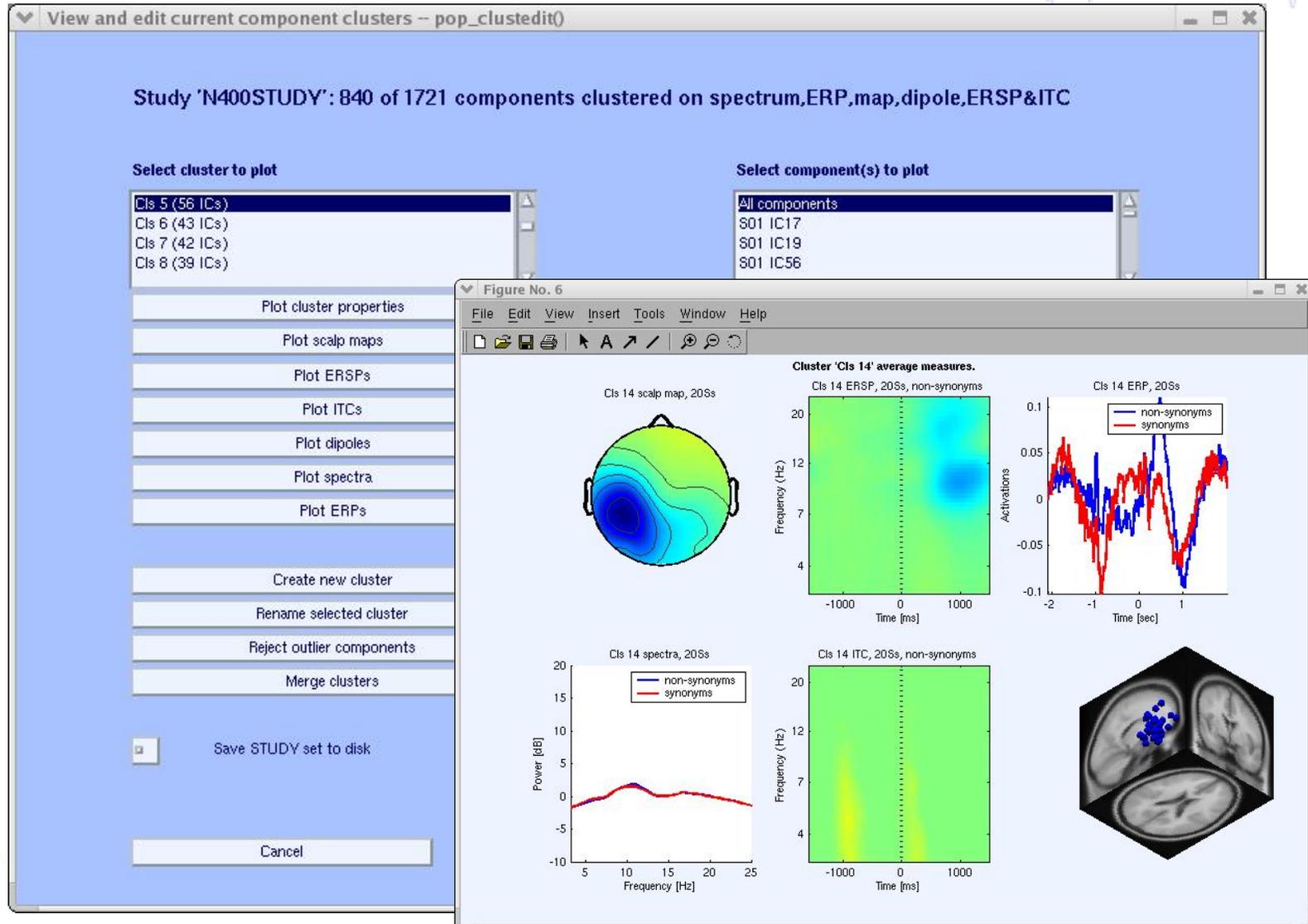
Load	Dims.	Norm.	Rel. Wt.	
<input checked="" type="checkbox"/> spectra	10	<input checked="" type="checkbox"/>	1	Freq. range [Hz] 3 25
<input checked="" type="checkbox"/> ERPs	10	<input checked="" type="checkbox"/>	1	Time range [ms] 0 600
<input checked="" type="checkbox"/> dipoles	3	<input checked="" type="checkbox"/>	10	
<input type="checkbox"/> scalp maps	10	<input checked="" type="checkbox"/>	1	Use channel values <input checked="" type="checkbox"/> Absolute values
<input checked="" type="checkbox"/> ERSPs	20	<input checked="" type="checkbox"/>	1	Time range [ms] 0 1500 Freq. range [Hz] 3 45
<input checked="" type="checkbox"/> ITCs	10	<input checked="" type="checkbox"/>	1	Time range [ms] 0 600 Freq. range [Hz] 2 30
<input type="checkbox"/> Final dimensions	10			

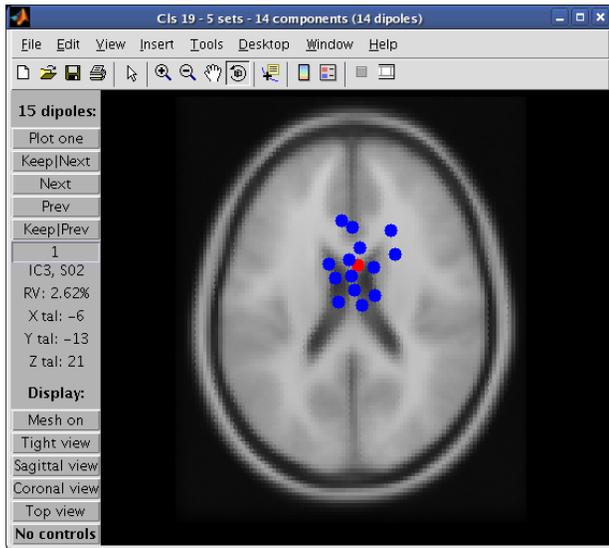
Save STUDY to file /home/julie/WorkshopSD2007/STUDY/attention.study

Cancel Help Ok



4. Analyze clusters

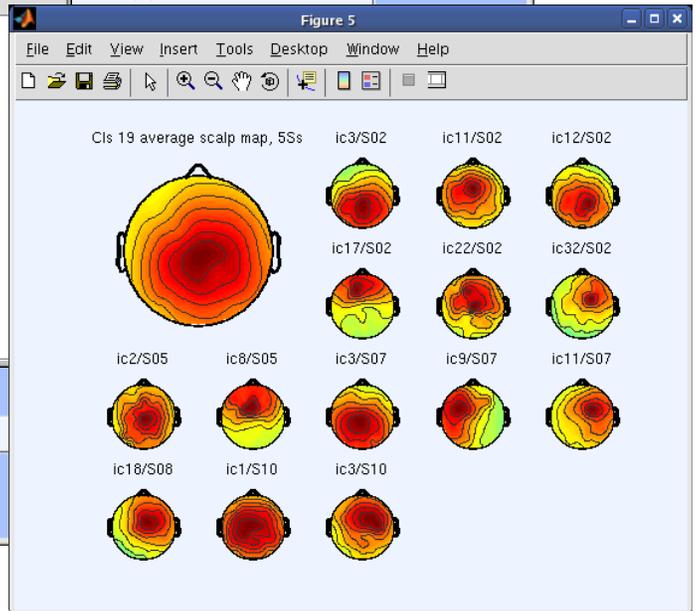
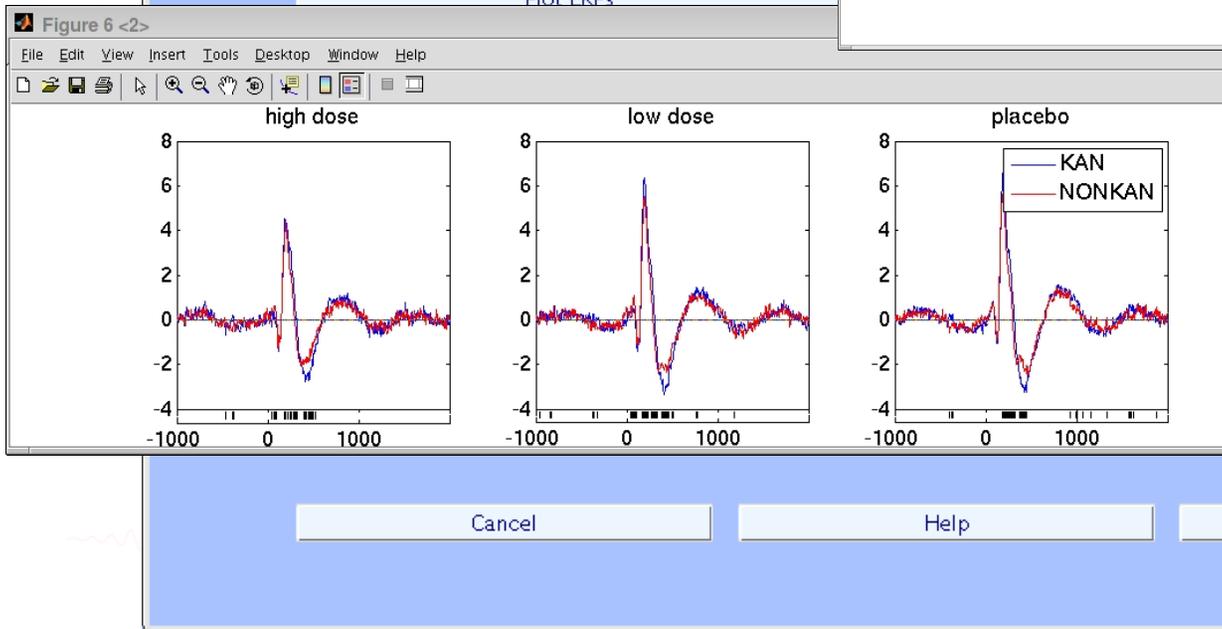
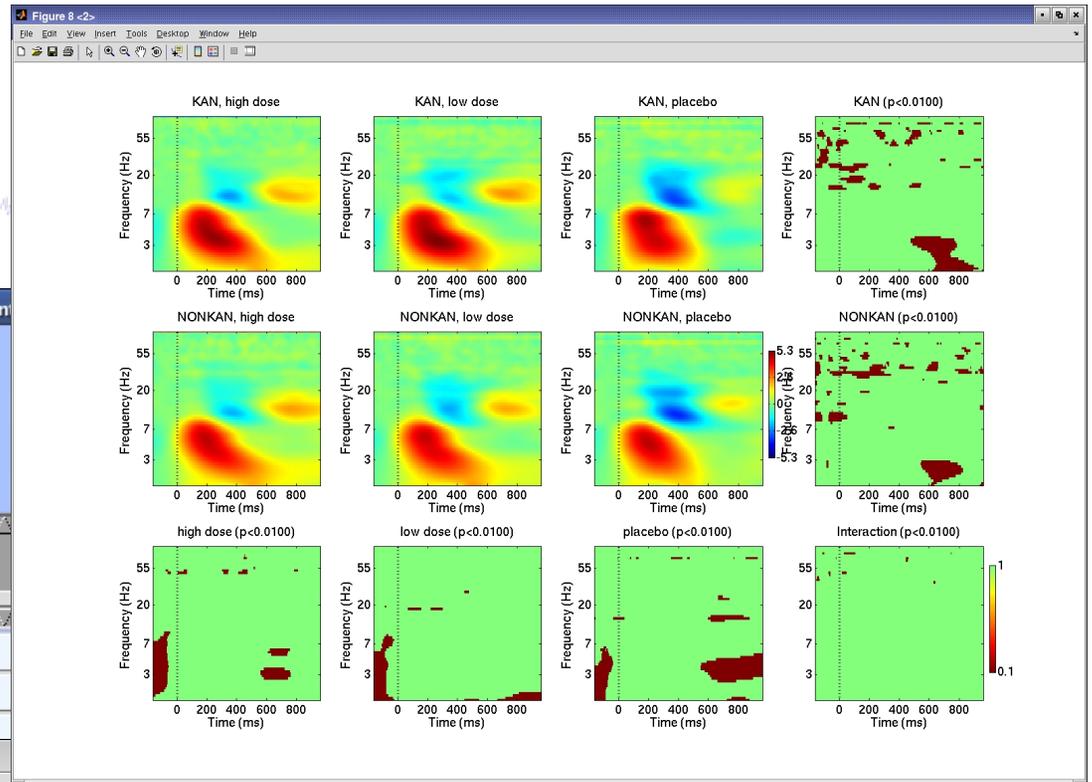




View and edit current
 dipoles clustered

Cls 17 (S02)
 Cls 18 (14 ICs)
 Cls 19 (14 ICs)
 Outliers Cls 17 20 (1 ICs)

Plot scalp maps
 Plot dipoles
 Plot FRPs



EEGLAB standard processing pipeline



Single subject

1. Import binary data, events and channel location
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 - Analyze components contribution to ERP
 - Analyze components contribution to spectrum

Multi-subjects

1. Build study and design
2. Pre-compute measures
3. Cluster components
4. Analyze clusters



Advanced analysis using scripting and EEGLAB command line functions

EEG structure

EEG =

```
setname:'Epoched from "ee114 continuous"  
filename:'ee114squareepochs.set'  
filepath:'/home/arno/ee114/'  
pnts:384  
nbchan:32  
trials:80  
srate:128  
xmin :-1  
xmax:1.9922  
data:[32x384x80 double]  
icawinv:[32x32 double]  
icasphere:[32x32 double]  
icaweights:[32x32 double]  
icaact:[32x384x80 double]  
event:[1x157 struct]  
epoch:[1x80 struct]  
chanlocs:[1x32 struct]  
comments:[8x150 char]  
averef:'no'  
rt:[]  
eventdescription:{1x5 cell}  
epochdescription:{}  
specdata:[]  
specicaact:[]  
reject:[1x1 struct]  
stats:[1x1 struct]  
splinefile:[]  
ref:'common'  
history:[7x138 char]  
urevent:[1x154 struct]  
times:[1x384 double]
```

Number of data points per trial

Number of channels

Number of trials

Sampling rate

Time limits

Data

ICA scalp maps

ICA activity

Epoch/event information

Channel location

3 levels of functions



Administrative functions: handle EEG and ALLEEG structures

`eeglab()`, `eeg_checkset()`, `pop_delset()`, ...

Pop functions: interactive functions using EEG structure

`pop_erpimage()`, `pop_topoplot()`, `pop_envtopo()`, ...

Signal processing functions: perform signal processing

`erpimage()`, `topoplot()`, `envtopo()`, ...



Command line tools

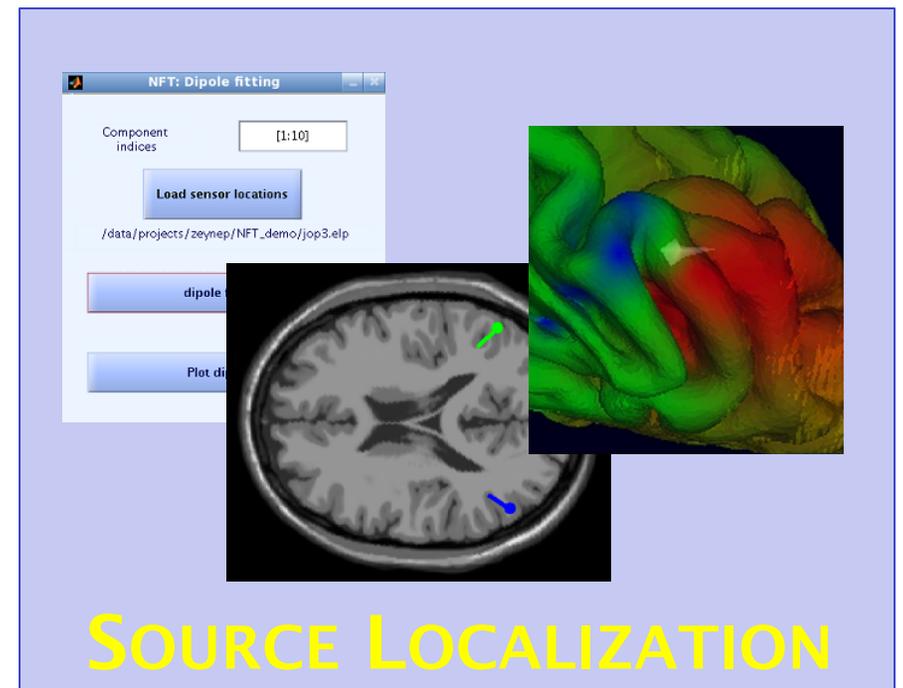
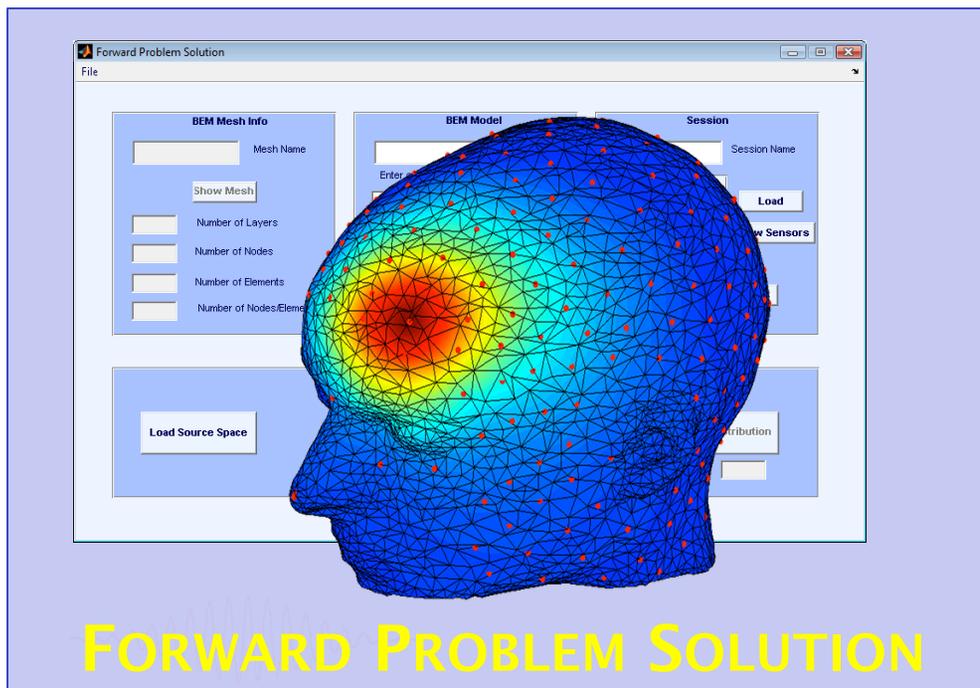
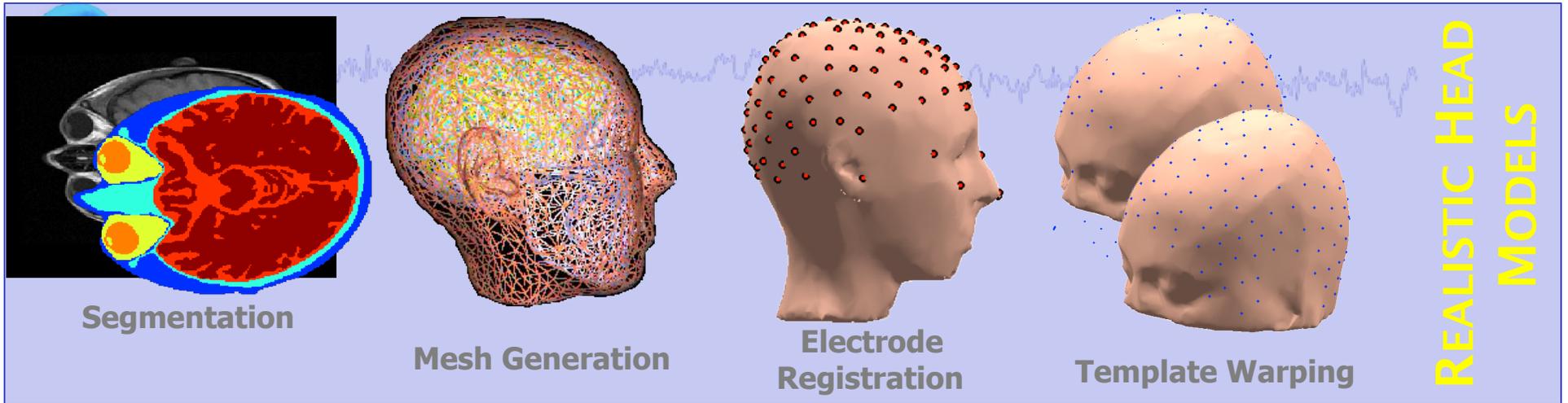


(“eegh” Menus write both dataset and global history)

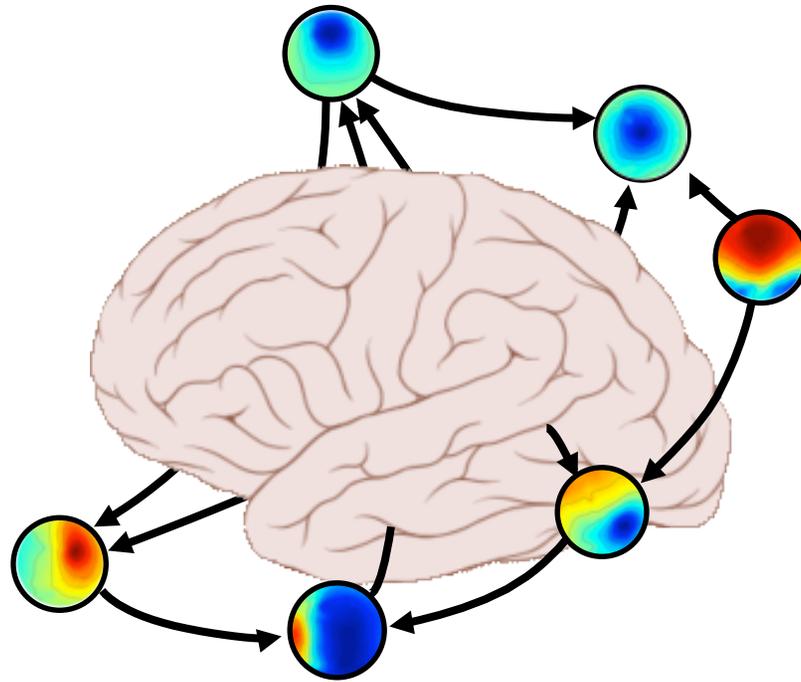
- Automated processing on groups of subjects (possibly on several processors).
- Richer options for plotting and processing functions (time-frequency decompositions, ...)
- Custom processing...



NFT: Neuroelectromagnetic Forward Head Modeling Toolbox



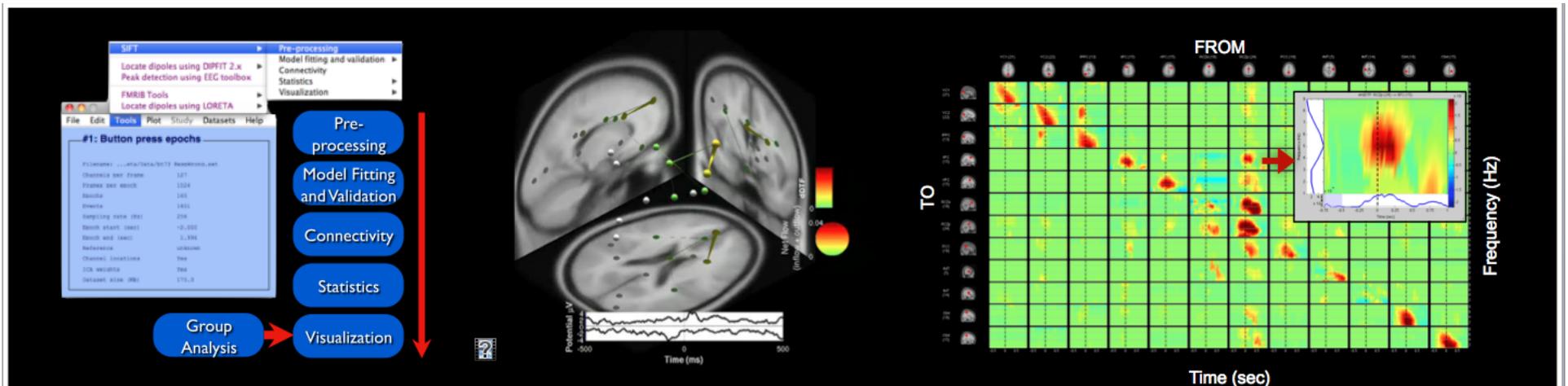
<http://sccn.ucsd.edu/nft>



SIFT

Source Information Flow Toolbox

"It makes you cool"



BCILAB - C. Kothe

The screenshot displays the BCILAB 0.9 software interface. The main window shows the 'Review/edit approach' menu with 'Train new model...' selected. A 'Figure 2: Common Spatial P...' window is open, showing six topographic maps of the head and corresponding line plots for Spec-CSP patterns 1 through 6. The plots show power spectra over time (0 to 40). A 'Train a model' dialog box is also visible, showing configuration parameters for the selected approach, including calibration data source, loss/performance metric, cross-validation folds, and spacing around test trials.

Approach properties

- Signal Processing
 - SignalProcessing
 - FilterOrdering
 - Resampling
 - SamplingRate
 - ChannelSelection
 - Rereferencing
 - ICA
 - SurfaceLaplacian
 - FIRFilter
 - Projection
 - IIRFilter
 - Standardization
 - SparseReconstruction
 - EpochExtraction
 - TimeWindow
 - EventTypes
 - BaselineRemoval
 - WindowSelection
 - SpectralTransform
 - SpectralSelection
 - FrequencySpecification
 - Feature Extraction
 - FeatureExtraction
 - PatternPairs
 - ParameterP
 - ParameterQ
 - SpectralPrior
 - MaxIterations
 - PluginFunctions
 - FeatureAdaptor

ICA
Annotate the Signal with a spatial ICA) (flt_ica).

Figure 2: Common Spatial P...

Spec-CSP Pattern 1, Spec-CSP Pattern 2, Spec-CSP Pattern 3, Spec-CSP Pattern 6, Spec-CSP Pattern 5, Spec-CSP Pattern 4

Train a model

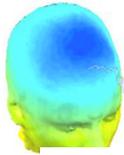
Selected approach: lastapproach ("Spectrally Weighted C...")
Calibration data source: lastdata ("imag.vhdr")
Loss/Performance Metric: Automatically chosen
Cross-validation folds: 5
Spacing around test trials: 5

Performance estimates:
Cross-validation folds: 10
Spacing around test trials: 5

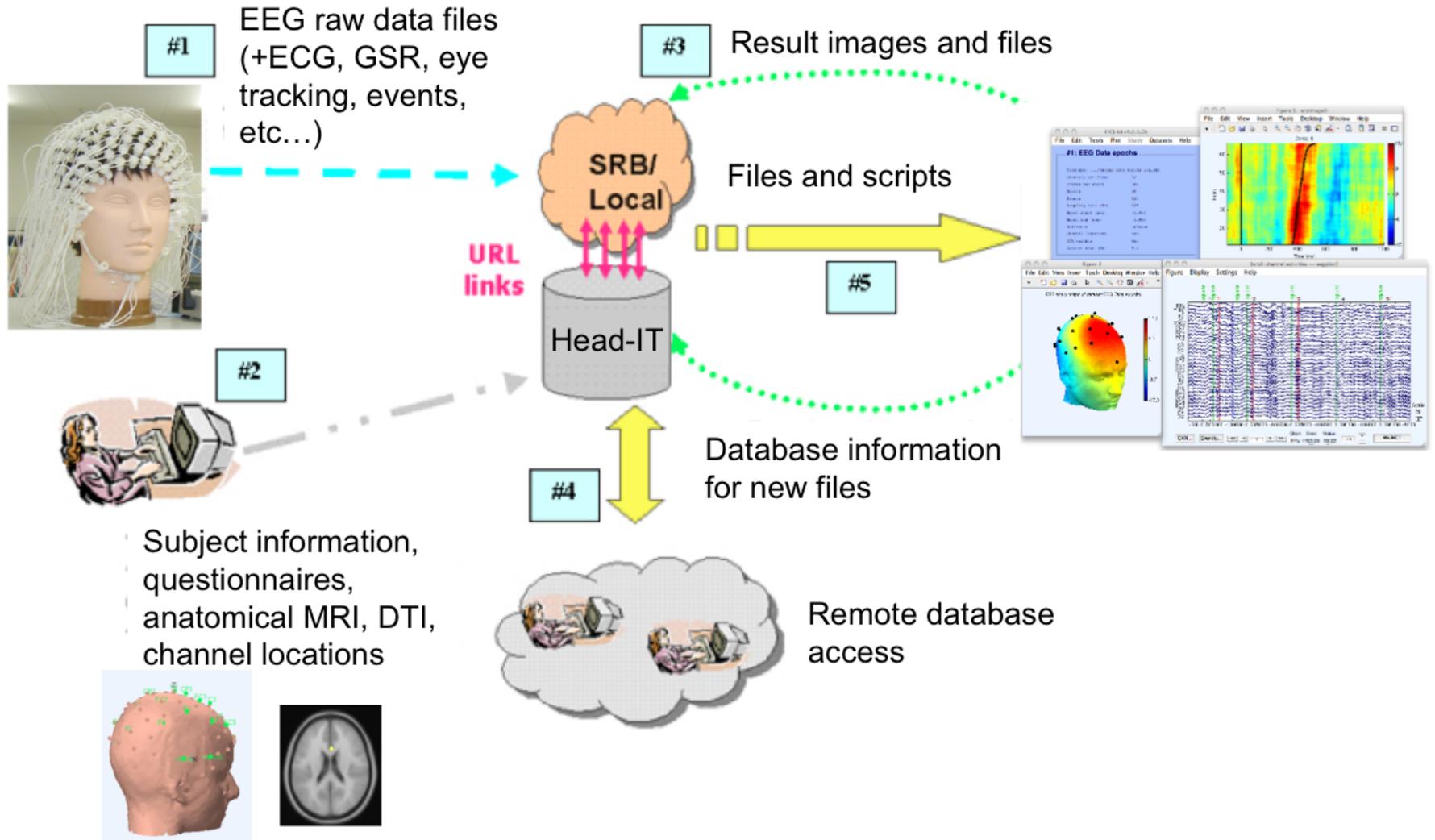
Cluster:
Node pool: (use current config)

Save as:
Save as: lastmodel
Save as: laststats

```
on, 'ZO', 0, 'Fl', 1, 'Err', 2,  
'n-SlackShrink', 1, '1-Sla  
'poly', 1, 'rbf', 2, 'sigmoic  
SubsetHeuristic', 1, 'FixedI  
1, 'l2', 2);  
ling, 'slack', 1, 'margin', 2
```



EEG database: HEAD-IT framework



Pros/Cons of Matlab based open source



- Pros

- Easy to program, highly modular and extendable
- Not dependent on any platform (64-bit)
- Large community of users (latest development in signal processing research)
- Cannot imagine more powerful scripting capabilities

- Cons

- Matlab required for which you have to pay
- Large memory requirements
- Matlab bugs, possible version differences, cross-platform compatibility problems

EEGLAB Workshop Program Session I



Thursday, Nov. 18

8:00 - 8:30 am Check-in open (park early!)

8:30 – 10:00 am - Mining event-related brain dynamics I (Scott Makeig)

10:00 – 10:30 am - EEGLAB and Workshop overview (Arnaud Delorme)

Break (10:30-11:00)

11:00 am – 12:00 pm - Time-frequency decomposition (Arnaud Delorme)

12:00 pm – 12:30 pm - Independent component analysis (ICA) theory I (Jason Palmer)

12:30-1:30 Lunch on your own on campus

1:30 pm – 2:00 pm - ICA theory II (Jason Palmer)

2:00 – 3:00 pm - Data import and channel analysis (Klaus Gramann)

Break (3:00-3:30)

3:30– 4:30 pm - Evaluating ICA components (Julie Onton)

4:30– 5:30 pm - Basic scripting using EEGLAB “history” and the EEG structure (Julie Onton)

5:30 – 6:30 pm - Free time to explore EEGLAB using tutorial data and/or your own data

Friday, Nov 19

8:30 – 9:15 pm - Using bootstrap statistics (David Groppe)

9:15 – 10:30 am - The new 'STUDY.design' facility and multi-subject plotting (Arnaud Delorme)

Break (10:30-11:00)

11:00 – 11:45 am – Forward and inverse source modeling (Zeynep Akalin Acar)

11:45 – 12:30 am – Using the DIPFIT toolbox (Julie Onton)

12:30-3:00 Networking excursion: Picnic lunch and short hike in scenic Torrey Pines Reserve

4:00 – 4:30 am - STUDY component clustering (Arnaud Delorme)

4:30 – 5:30 pm - Advanced uses of 'STUDY.design' statistics (Arnaud Delorme)

5:30 – 6:30 pm - Free time to work on tutorial projects and/or own data

Saturday, Nov 20

8:30 – 9:30 am – Mining event-related dynamics II (Scott Makeig)

9:30 – 10:00 pm – Building EEGLAB plug-ins (Arnaud Delorme)

10:00 – 10:30 am - Small groups work on tutorial projects

Break (10:30-11:00)

11:00 – 11:45 am - Continued work on tutorial projects

11:45 – 12:30 am – Group project presentations and General Discussion (all)

12:30-1:30 Lunch on campus

EEGLAB Workshop Program Session II



Saturday, Nov 20

1:30 – 2:30 pm – Comparing EEG dynamics across subjects using the Measure Projection toolbox (Nima Bigdely Shamlo)

2:30 – 3:00 pm - Modeling effective connectivity by measuring source EEG information flow: theory (Tim Mullen)

Break (3:00-3:30)

3:30 – 5:00 pm - Modeling effective connectivity by measuring EEG information flow: practicum (Tim Mullen)

5:00 – 6:30 pm - Free time to work on tutorial projects and/or own data

Sunday, Nov 21

8:30 – 9:30 am – The NFT head modeling toolbox: overview (Zeynep Akalin Acar)

9:30 – 10:30 am – The NFT head modeling toolbox: practicum (Zeynep Akalin)

Break (10:30-11:00)

11:30 – 12:00 pm - Imaging human agency with Mobile brain/body imaging (MoBI) (Scott Makeig)

12:00 – 12:30 pm - The ERICA software environment for real-time, interactive experimental control and analysis (Andrey Vankov)

12:30-1:30 Lunch on campus

1:00 – 2:10 pm - MoBI Lab demos (Dev Sarma, Grace Leslie, Nima Bigdely-Shamlo)

2:10 – 2:30 pm - HeadIT: A resource for human electrophysiological data and tools (Jeff Grethe)

2:30 – 3:00 pm - EEG classification and cross-validation using the BCILAB toolbox: overview (Christian Kothe)

Break (3:00-3:30)

3:30 – 5:00 pm - EEG classification and cross-validation using the BCILAB toolbox: practicum (Christian Kothe)

5:00 – 6:30 pm - Free time to work on tutorial projects and/or own data

Monday, Nov 22

8:30 – 9:15 am - New directions in electrophysiology: Mobile brain monitoring by wearable/wireless EEG (Tzyy Ping Jung)

9:15 – 9:30 am - Mobile brain monitoring demo using 15-channel wireless dry electrode cap (TP Jung)

10:00 – 10:30 am - Small groups work on tutorial projects

Break (10:30-11:00)

11:00 am – 12:00 pm -- Continued work on tutorial projects

12:00 am – 12:30 pm -- Project results presentation and general discussion (all)

12:30 pm - Workshop close

EEGLAB articles



Delorme, A., Makeig, S. (2004) EEGLAB: an open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. *Journal of Neuroscience Methods*, 134(1), 9-21.

Makeig, S., Debener, S., Onton, J., Delorme, A. (2004) Mining event related dynamics. *Trends in cognitive Neuroscience*, 8(5), 204-210.

Delorme, A., Kothe, C., Bigdely, N., Vankov, A., Oostenveld, R., Makeig, S. Matlab Tools for BCI Research? In "human-computer interaction and brain-computer interfaces". Editors : Tan, D. and Nijholt, A. To appear in 2010. Springer Publishing.

Delorme, A., Mullen, T., Kothe, C., Bigdely-Shamlo, N., Akalin, Z., Vankov, A., Makeig, S. EEGLAB, MPT, NetSIFT, NFT, BCILAB, and ERICA: New tools for advanced EEG/MEG processing. *Computational Intelligence*, accepted.

Delorme, A., Makeig, S. Open Source Programming for Interpreted Language: Graphic Interface and Macro Bridging Interface. IEEE International Conference on Signal Image Technology and Internet Based Systems. In press.

