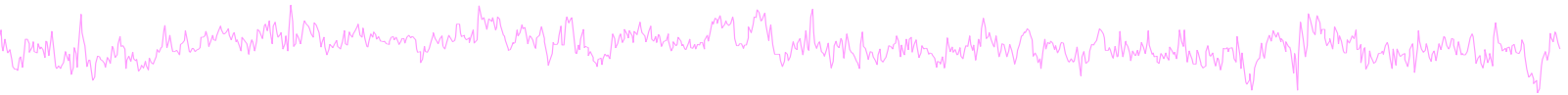
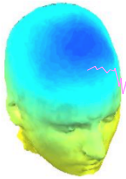


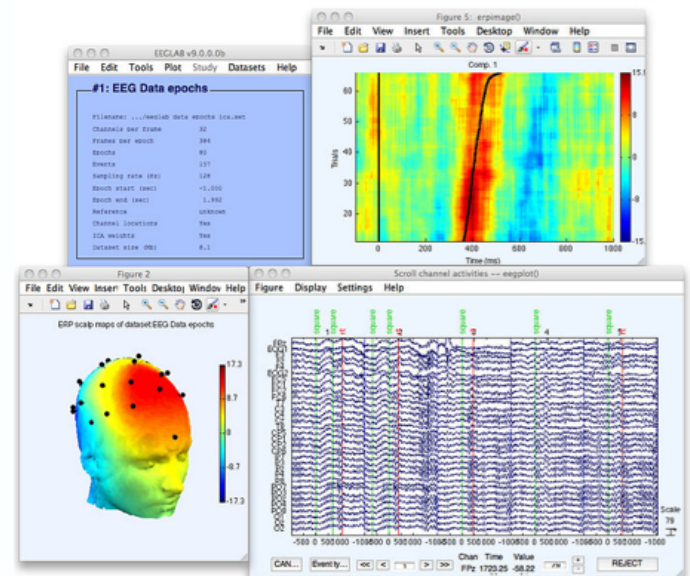
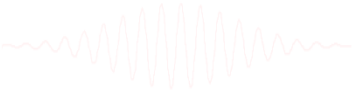
EEGLAB overview



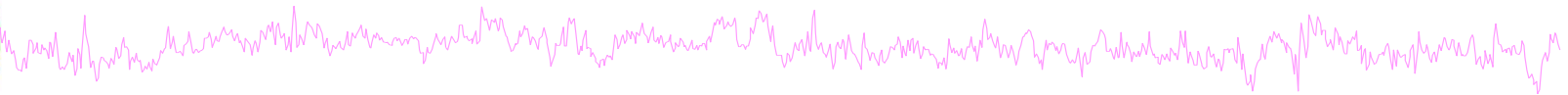
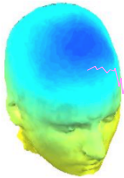
- Collection of about 600 functions (70 000 lines of code)
- About 100 000 download over the past 10 years
- 6 500 users on the discussion list and 10 500 on the diffusion list
- NIH funding since 2003

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

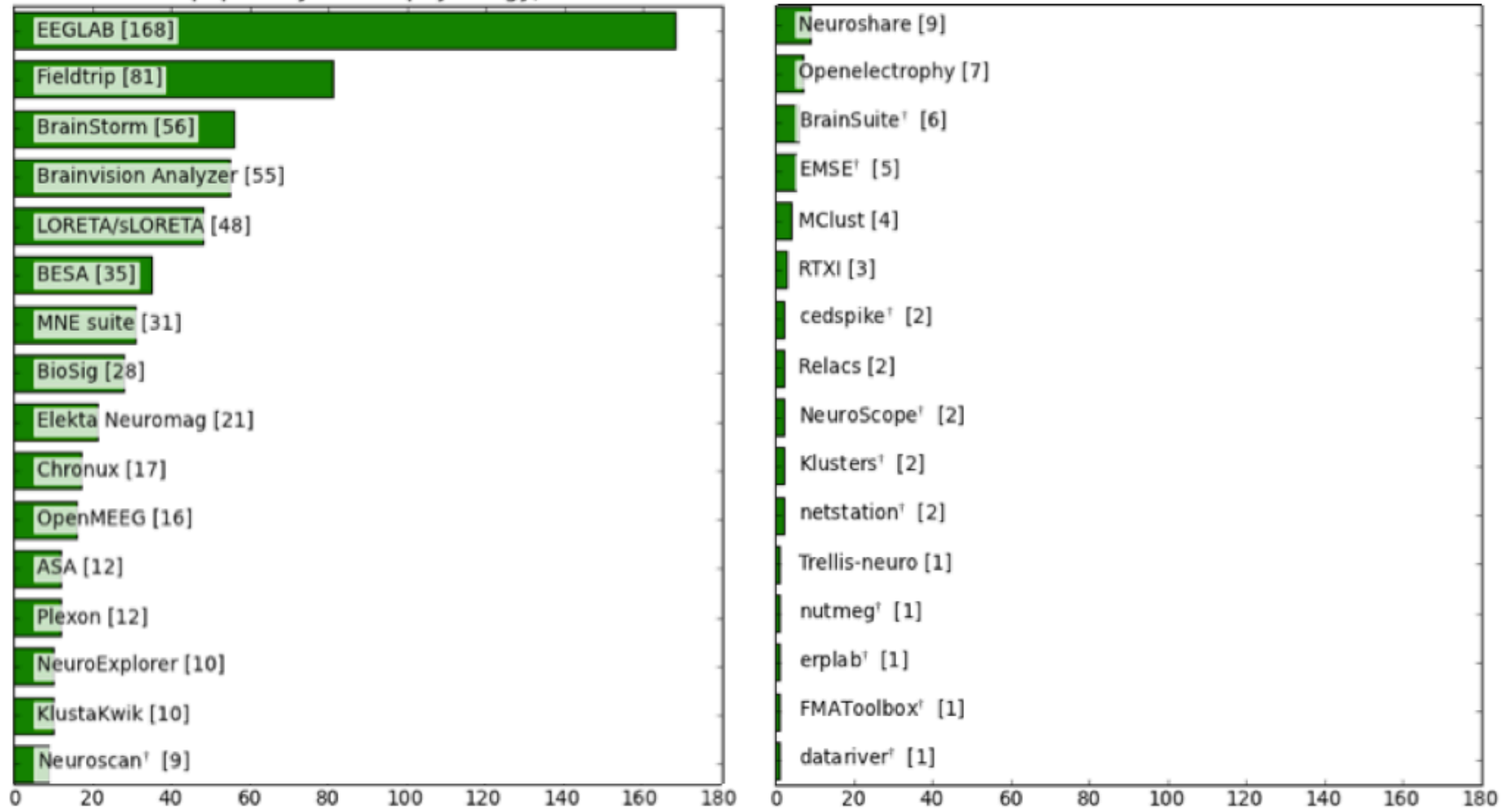
<http://sccn.ucsd.edu/wiki/eeglab>



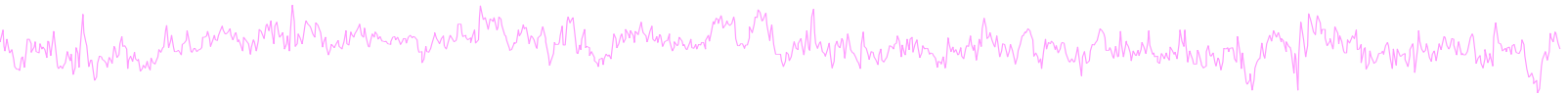
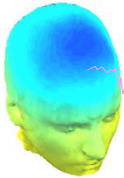
Hanke & Helcencko, 2011, Frontier in Neuroinformatics



Software popularity: Electrophysiology, MEG/EEG



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

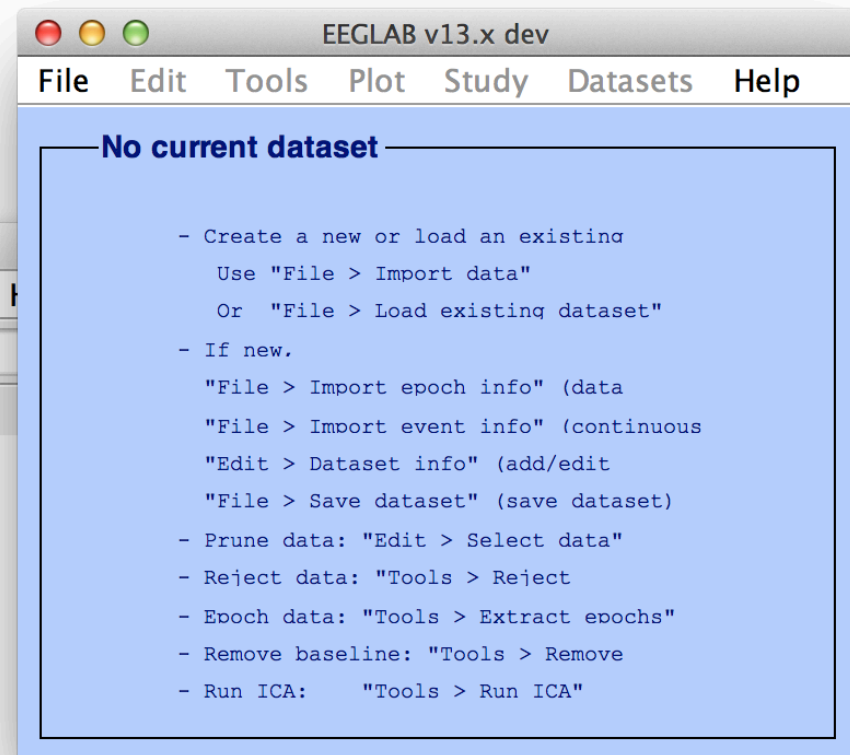
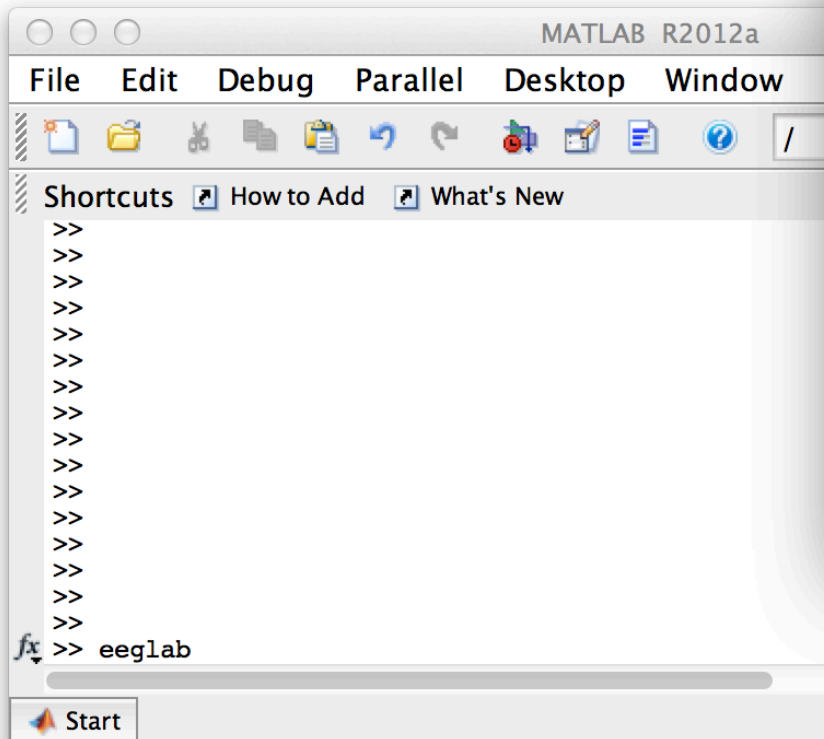
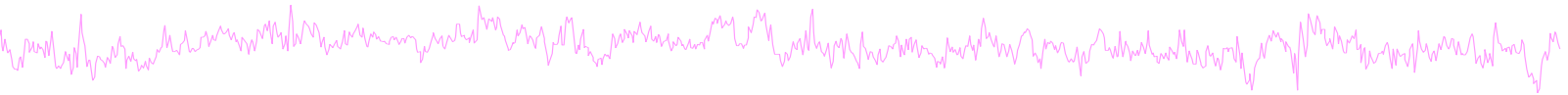
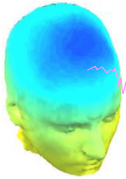
Multi-subjects

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

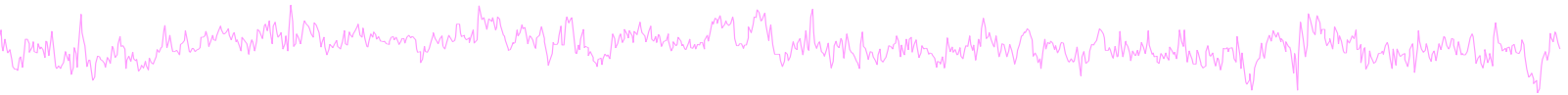
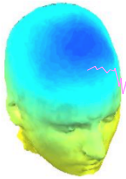


Advanced analysis using scripting and EEGLAB command line functions

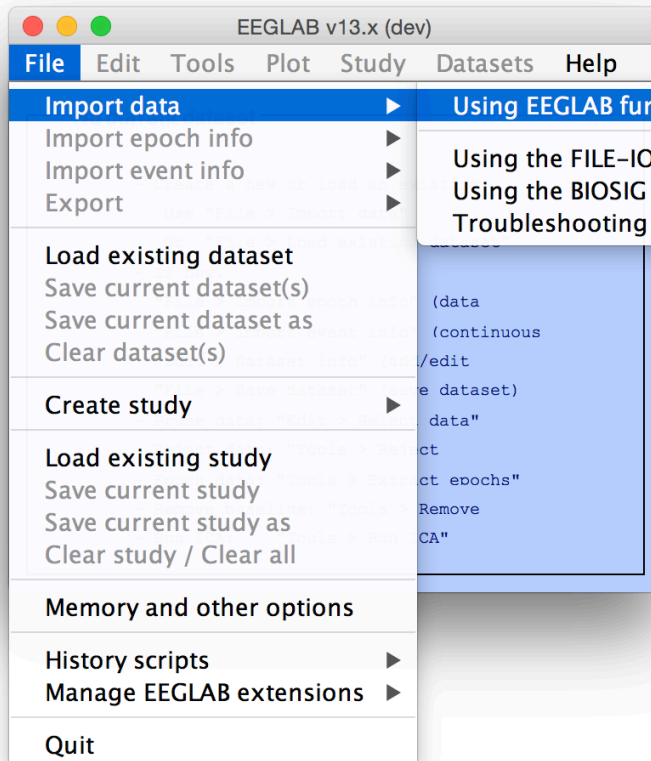
The EEGLAB Matlab software



1. Importing data



Import/load data



From ASCII/float file or Matlab array

From Netstation binary simple file
From EGI Net Station .MFF file
From Multiple seg. Netstation files
From Netstation Matlab files

From BCI2000 ASCII file

From Snapmaster .SMA file

From Neuroscan .CNT file
From Neuroscan .EEG file

From Biosemi BDF file (BIOSIG toolbox)
From EDF/EDF+/GDF files (BIOSIG toolbox)
From Biosemi BDF and EDF files (BDF plugin)

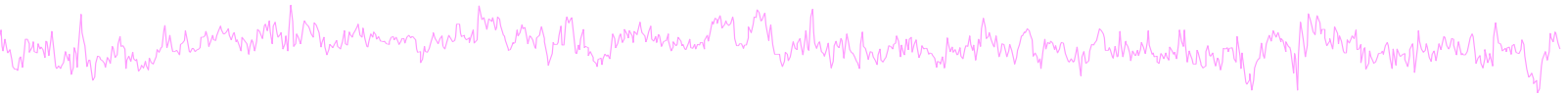
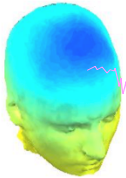
From a NeurOne file (.ses)

From BIOPAC MATLAB files

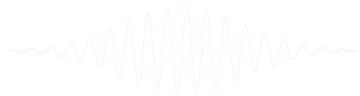
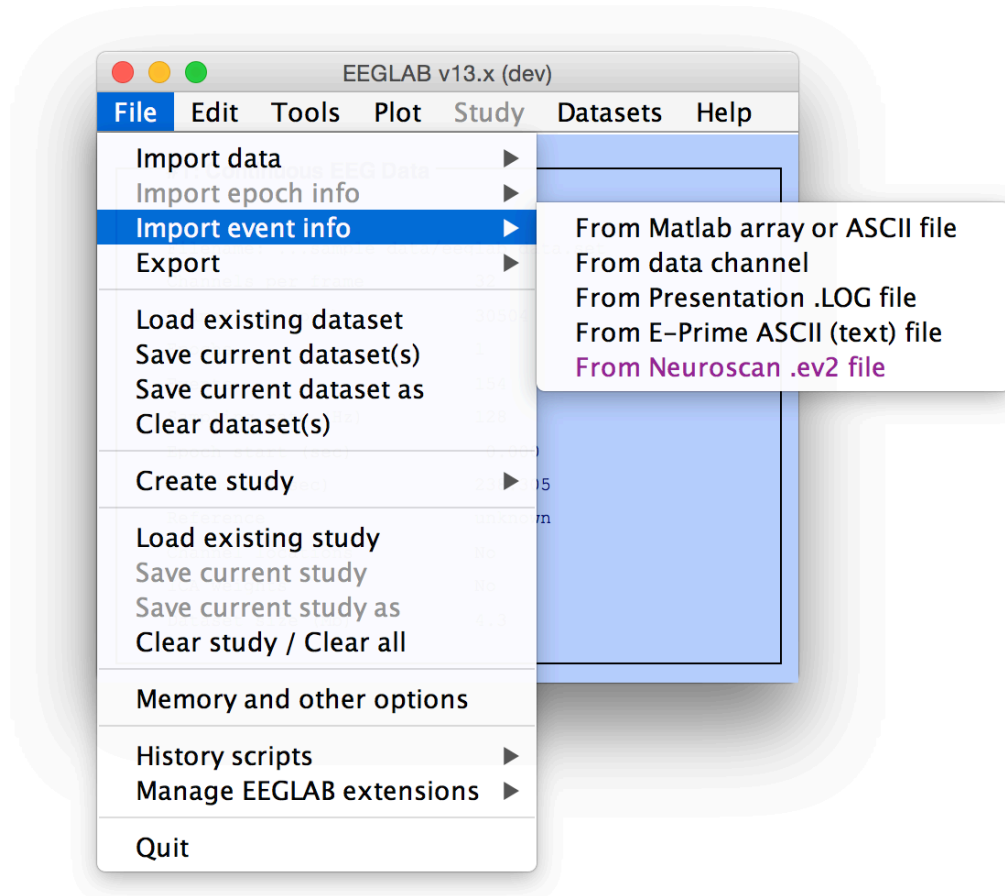
From Brain Vis. Rec. .vhdr file
From Brain Vis. Anal. Matlab file

From ERPSS .RAW or .RDF file
From EGI .MFF file

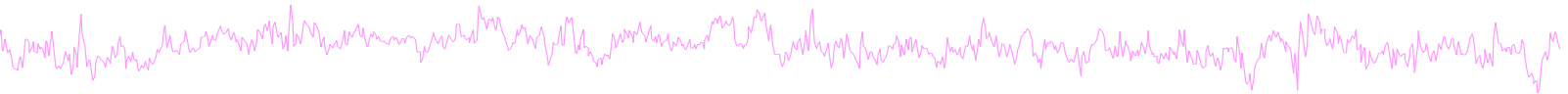
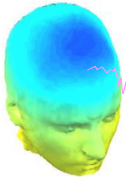
1. Importing data



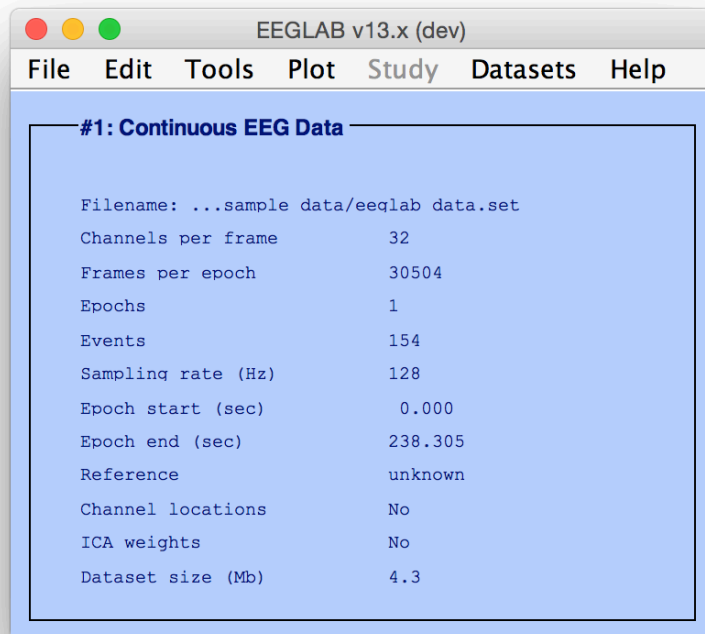
Import events



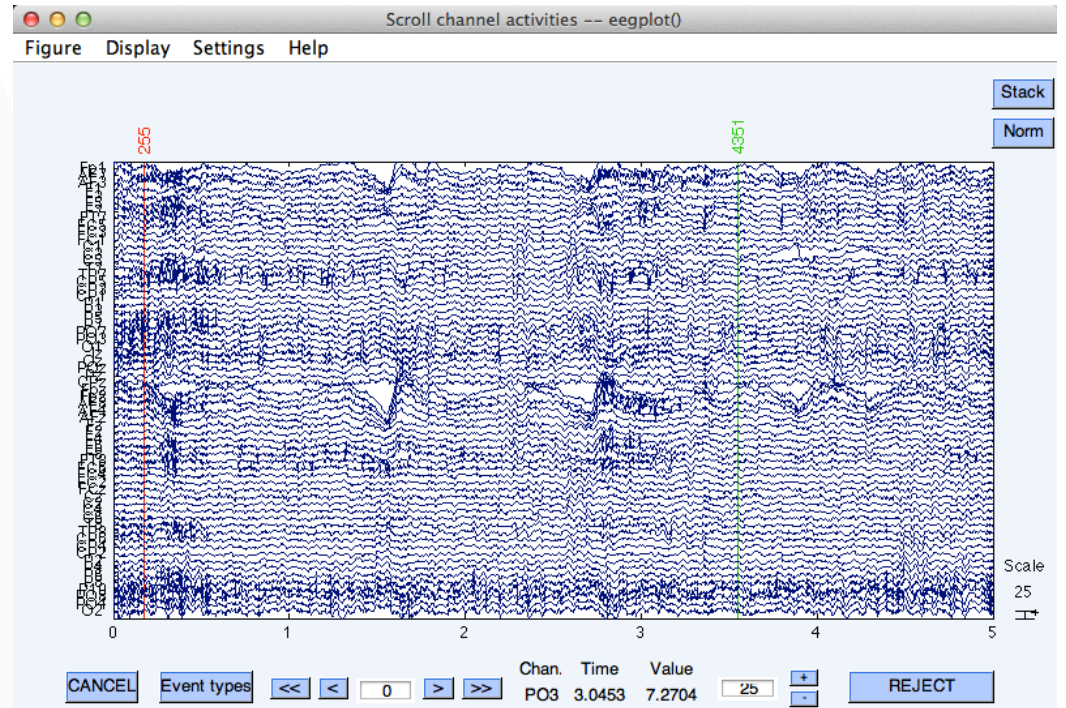
1. Importing data



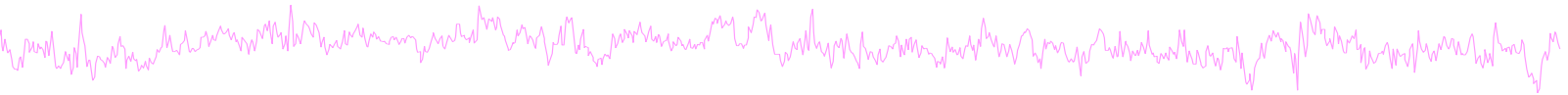
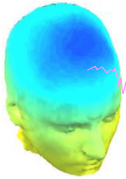
Data info



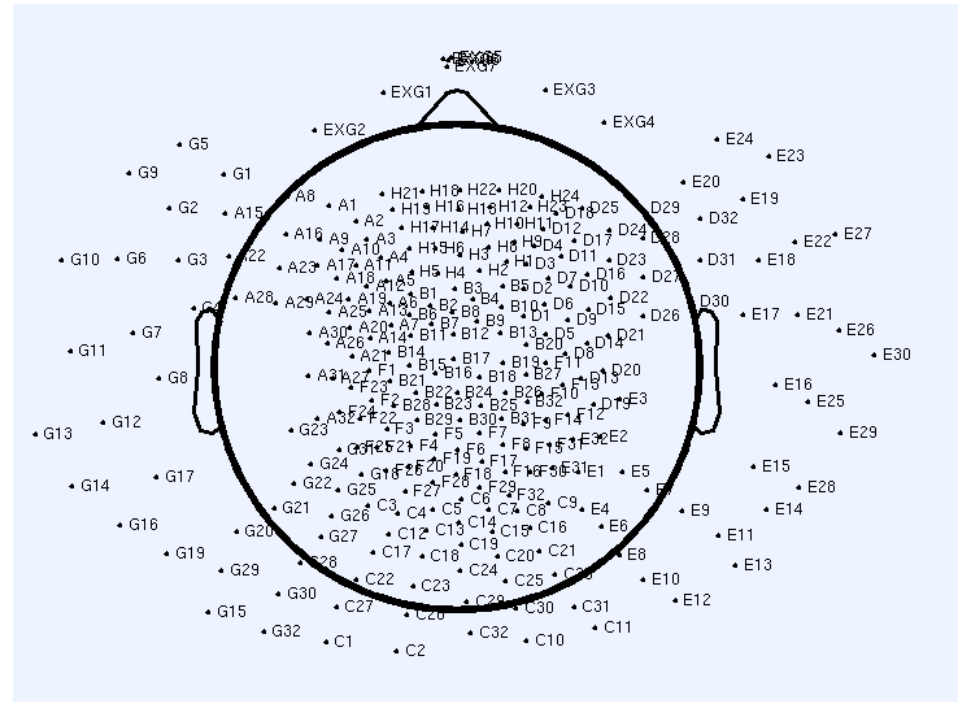
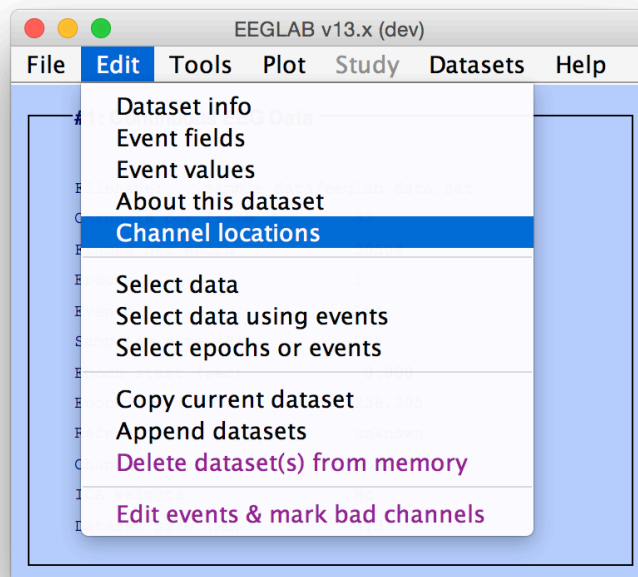
Scrolling data



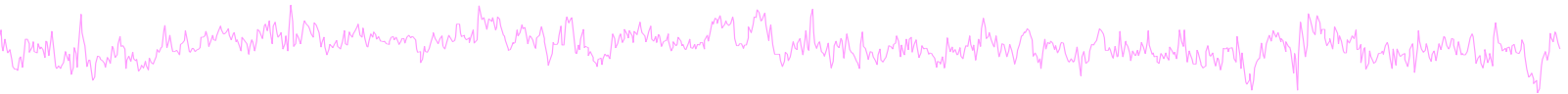
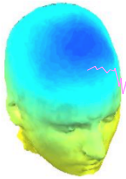
1. Importing channel location



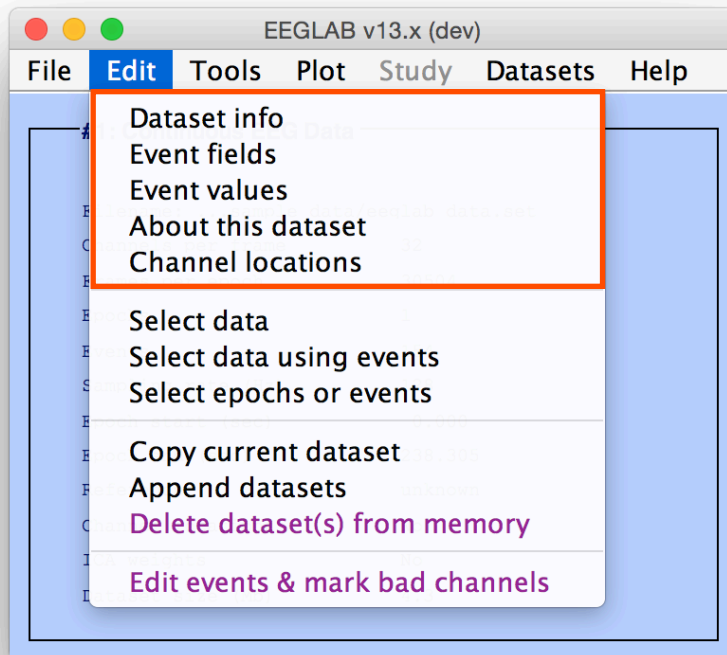
Import channel location



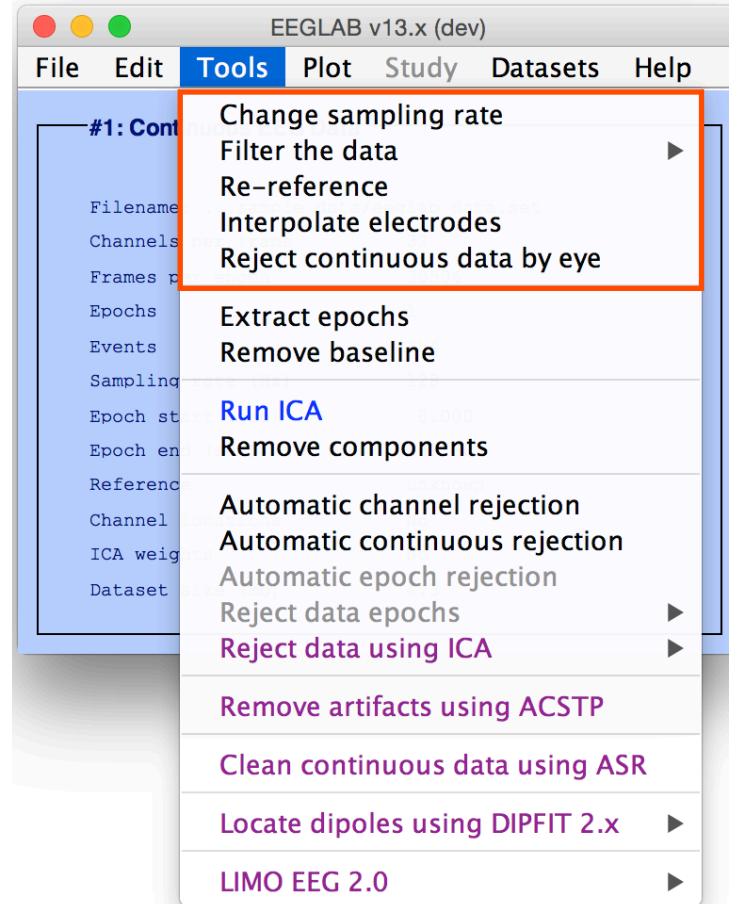
2. Edit, Re-reference, Resample, High pass filter data



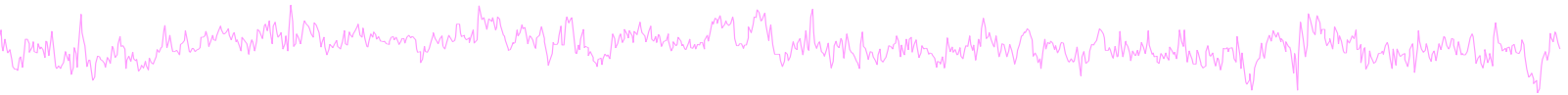
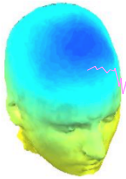
Edit/select data



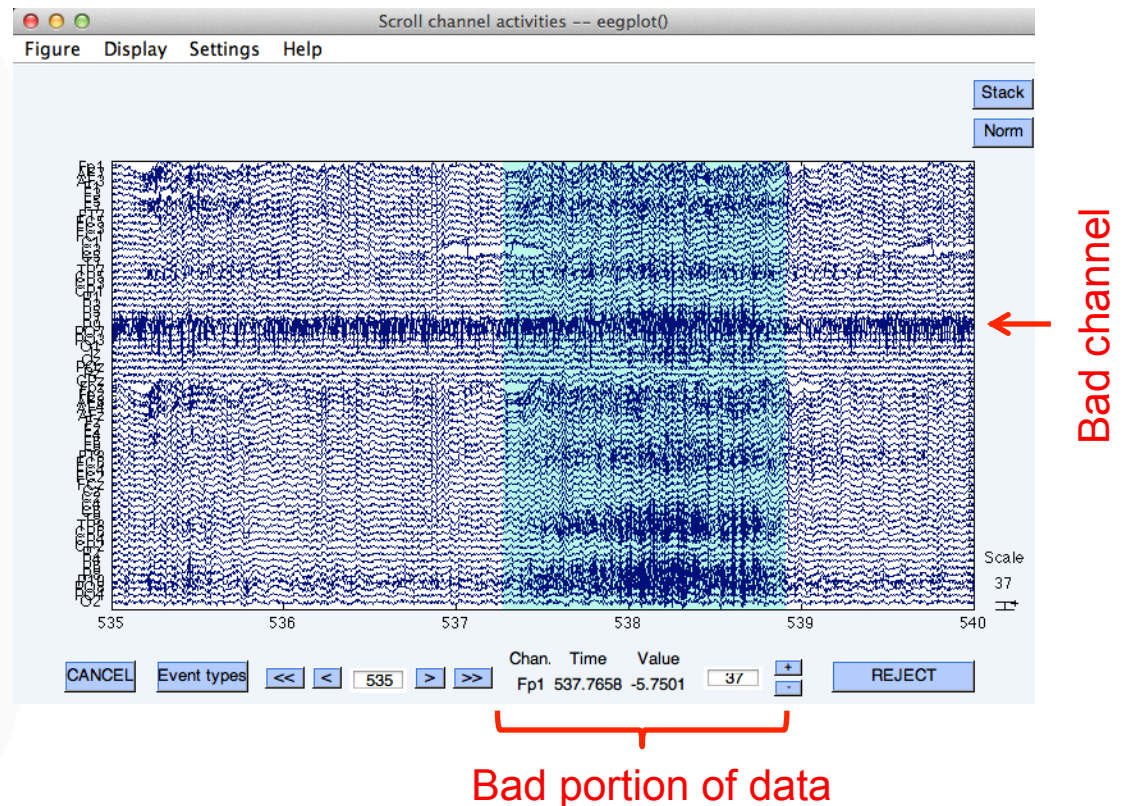
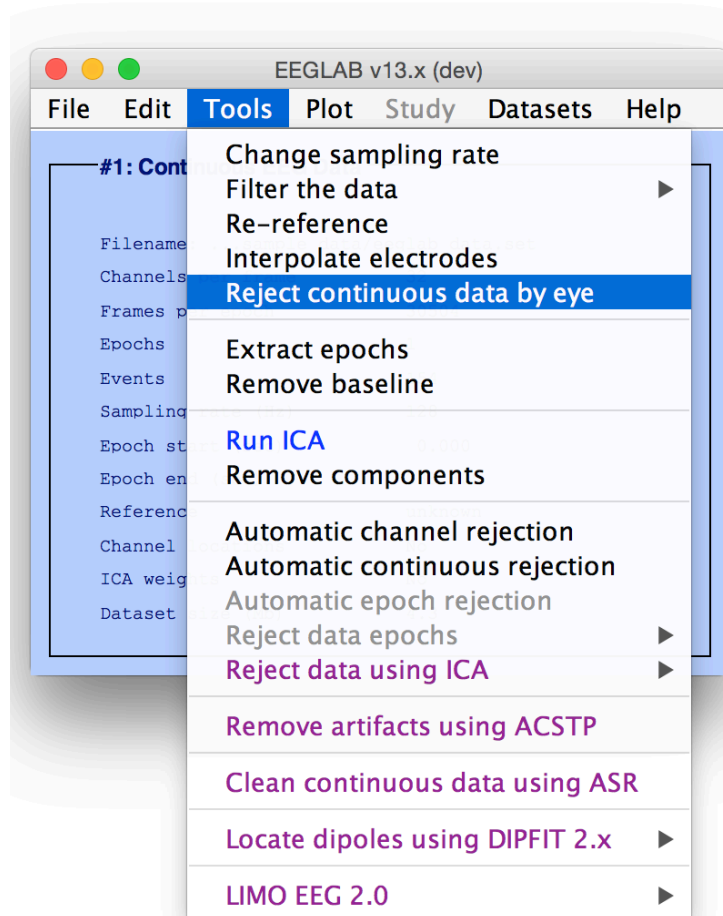
Preprocessing data



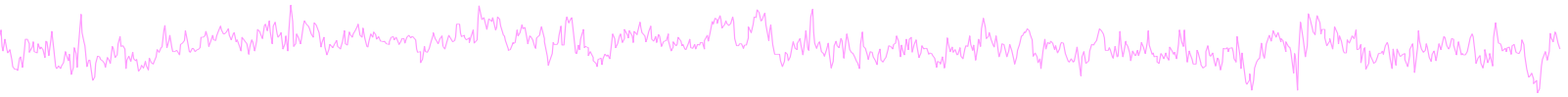
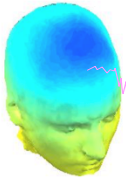
3. Reject artifacts in continuous data by visual inspection



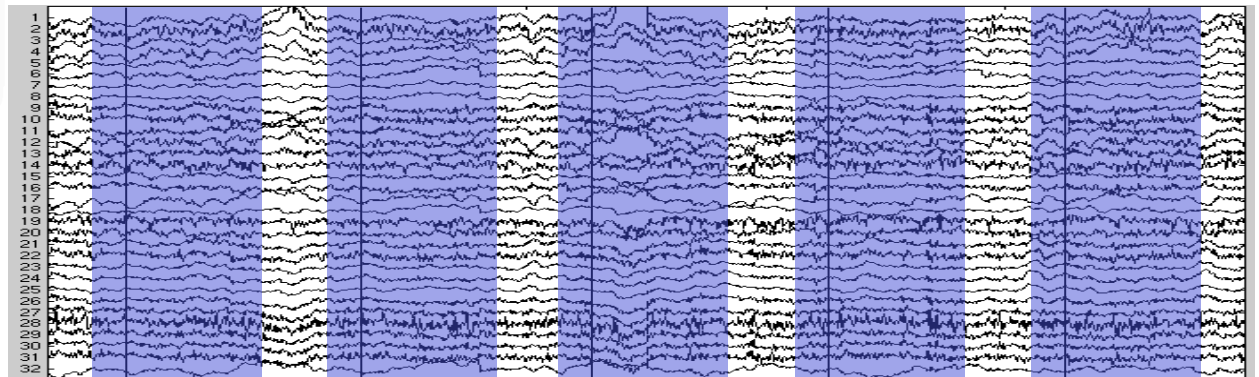
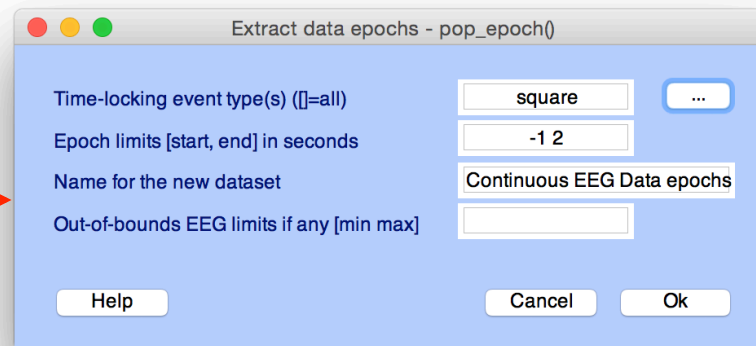
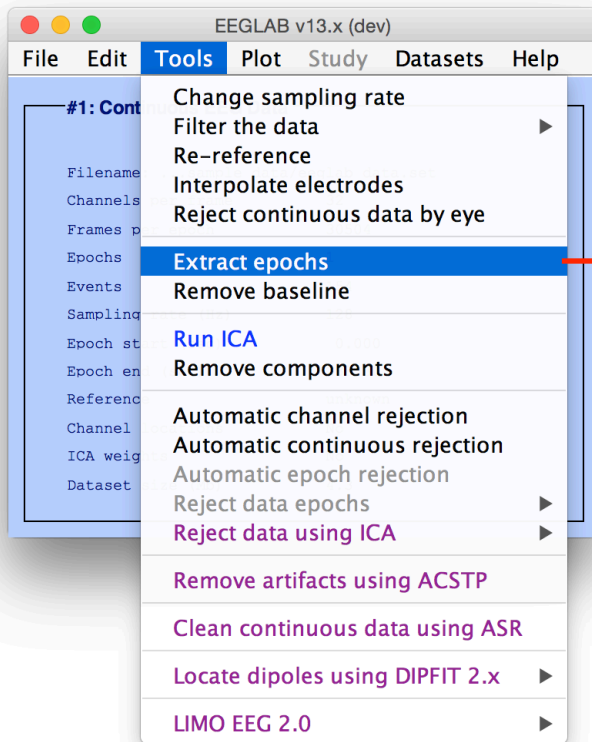
Reject portions of continuous data



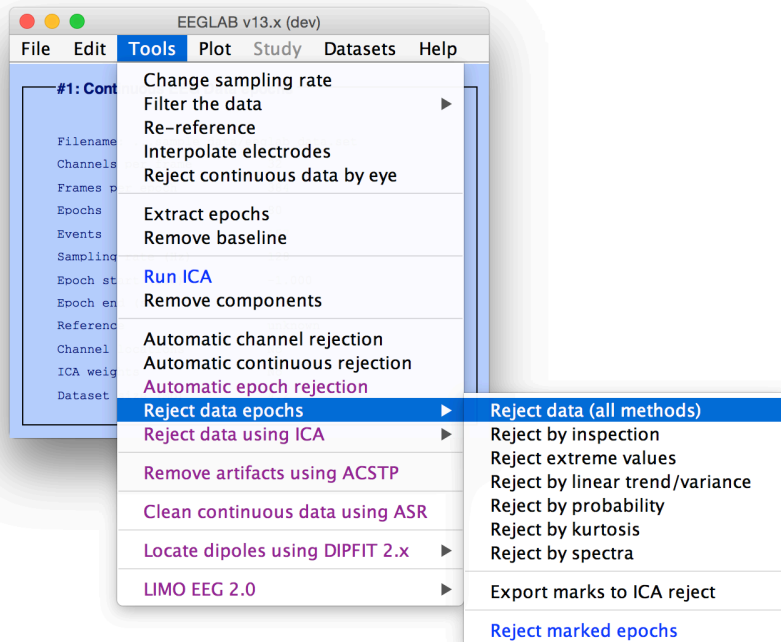
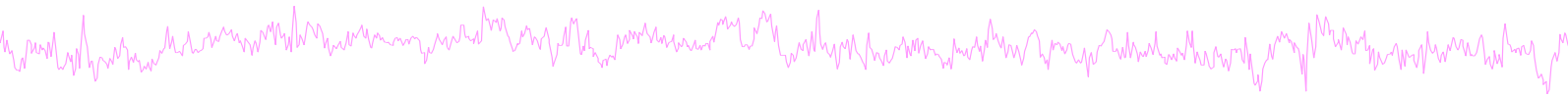
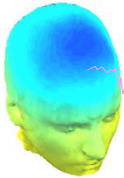
4. Extract epochs from data & reject artifactual epochs



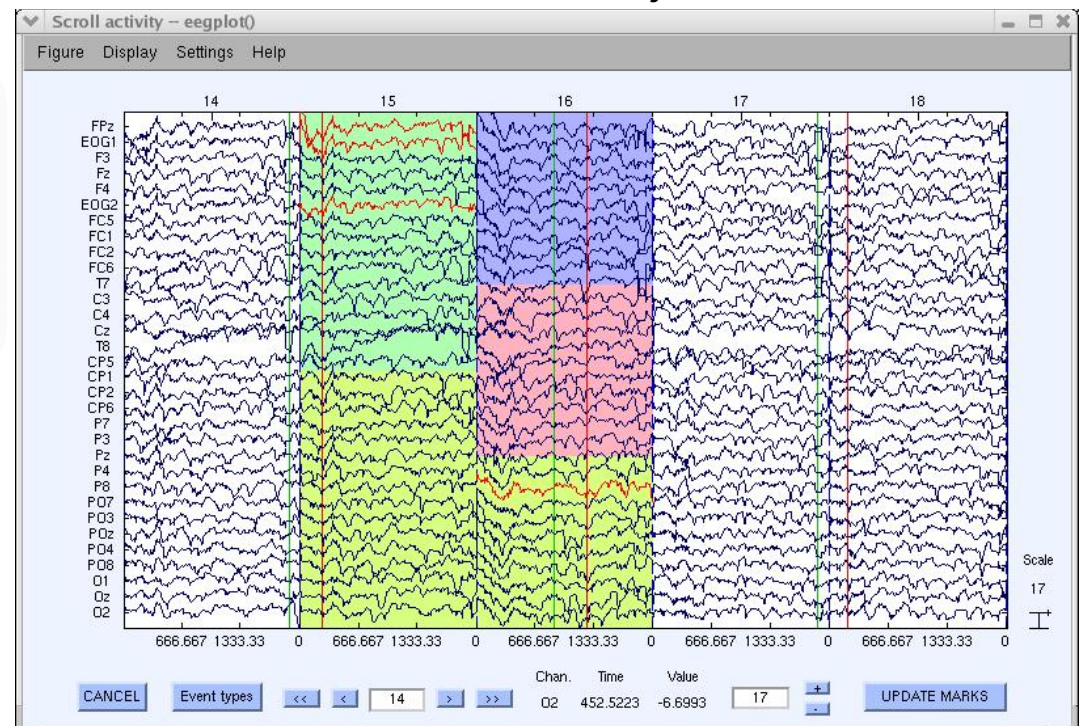
Preprocessing data



4. Extract epochs from data & reject artifactual epochs



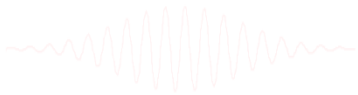
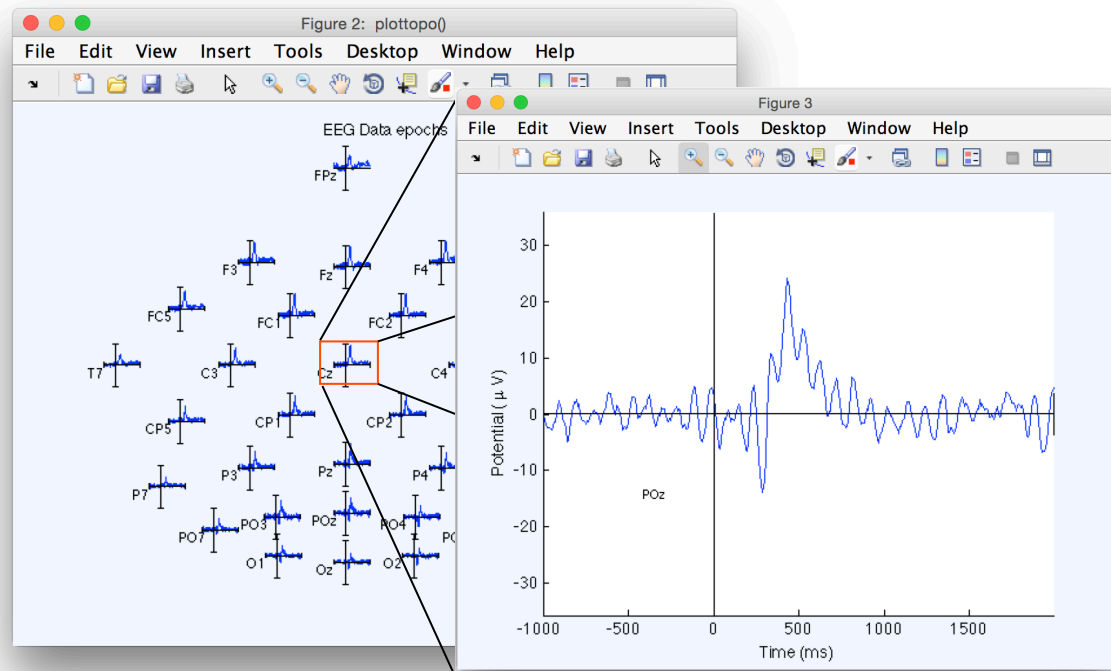
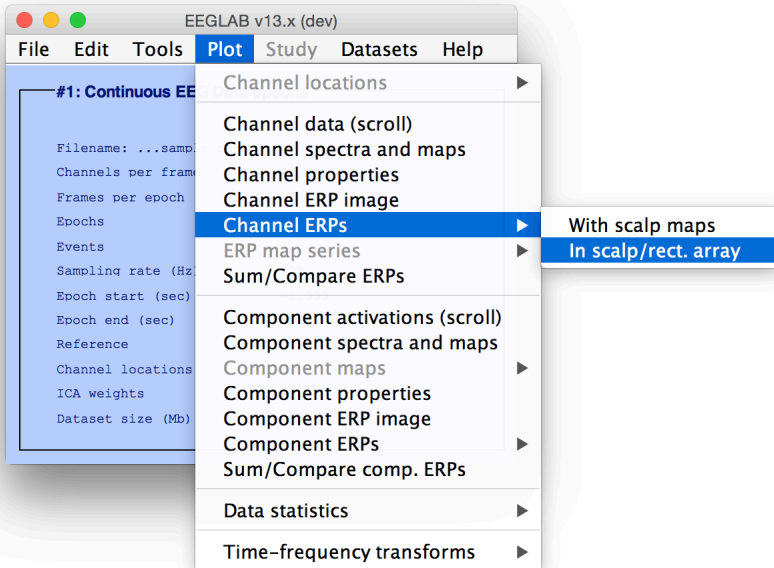
Different color = different rejection methods



5. Visualize data measures

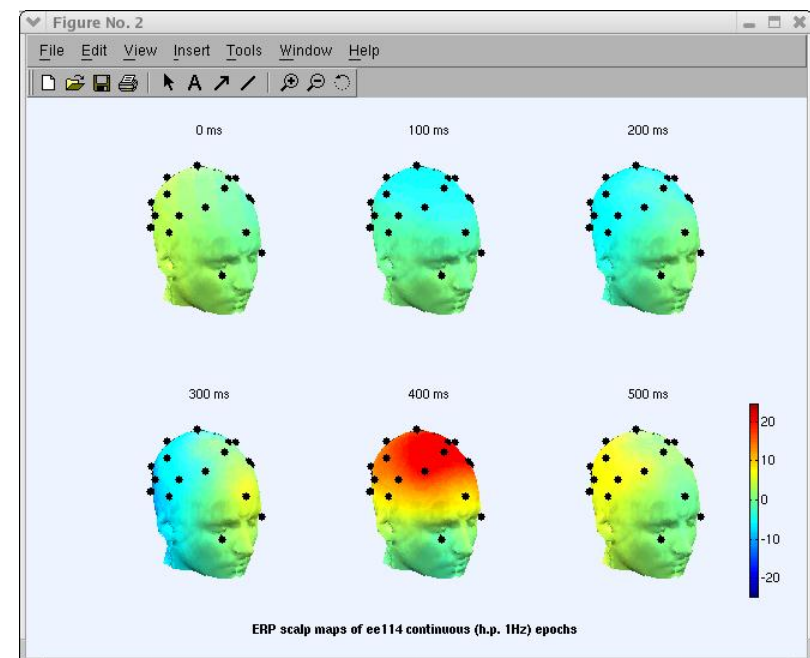
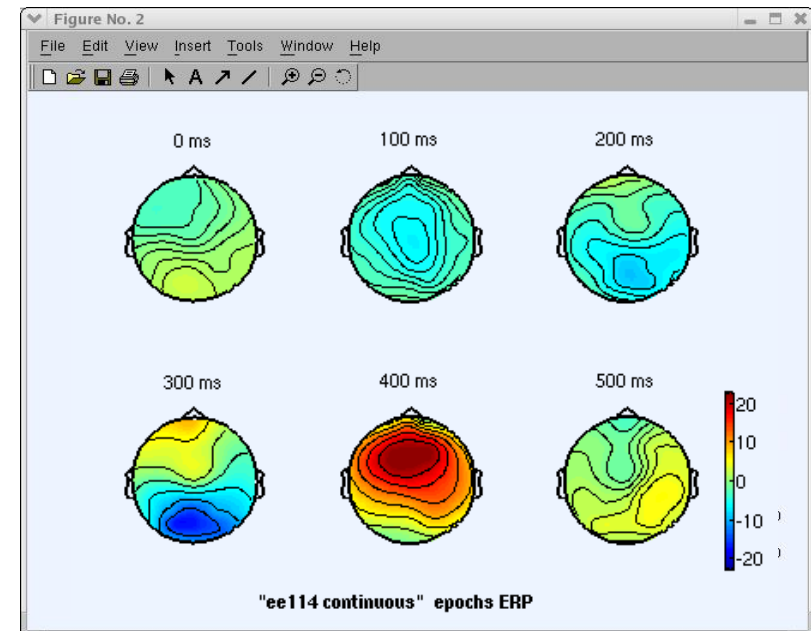
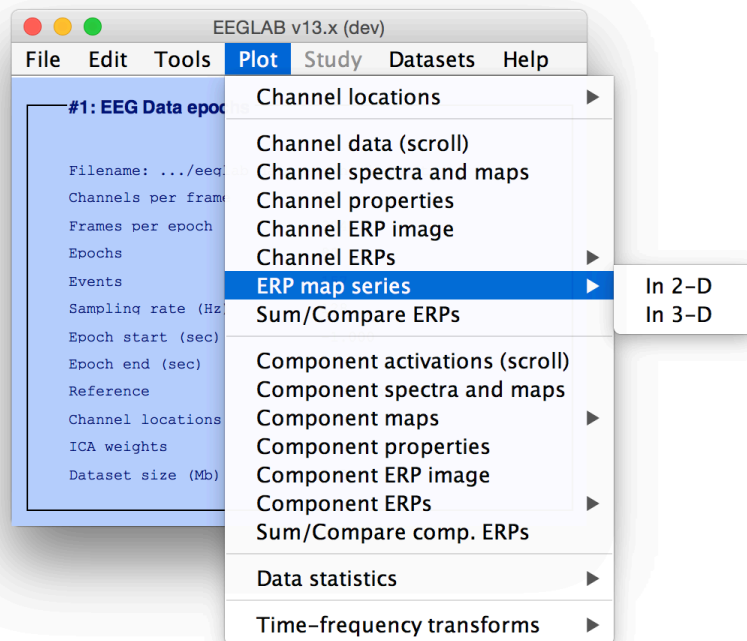


Plot ERP

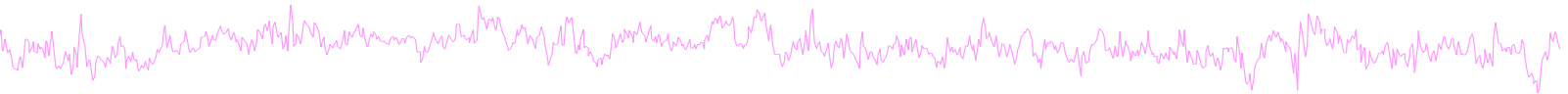
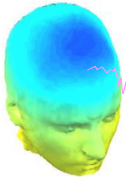


5. Visualize data measures

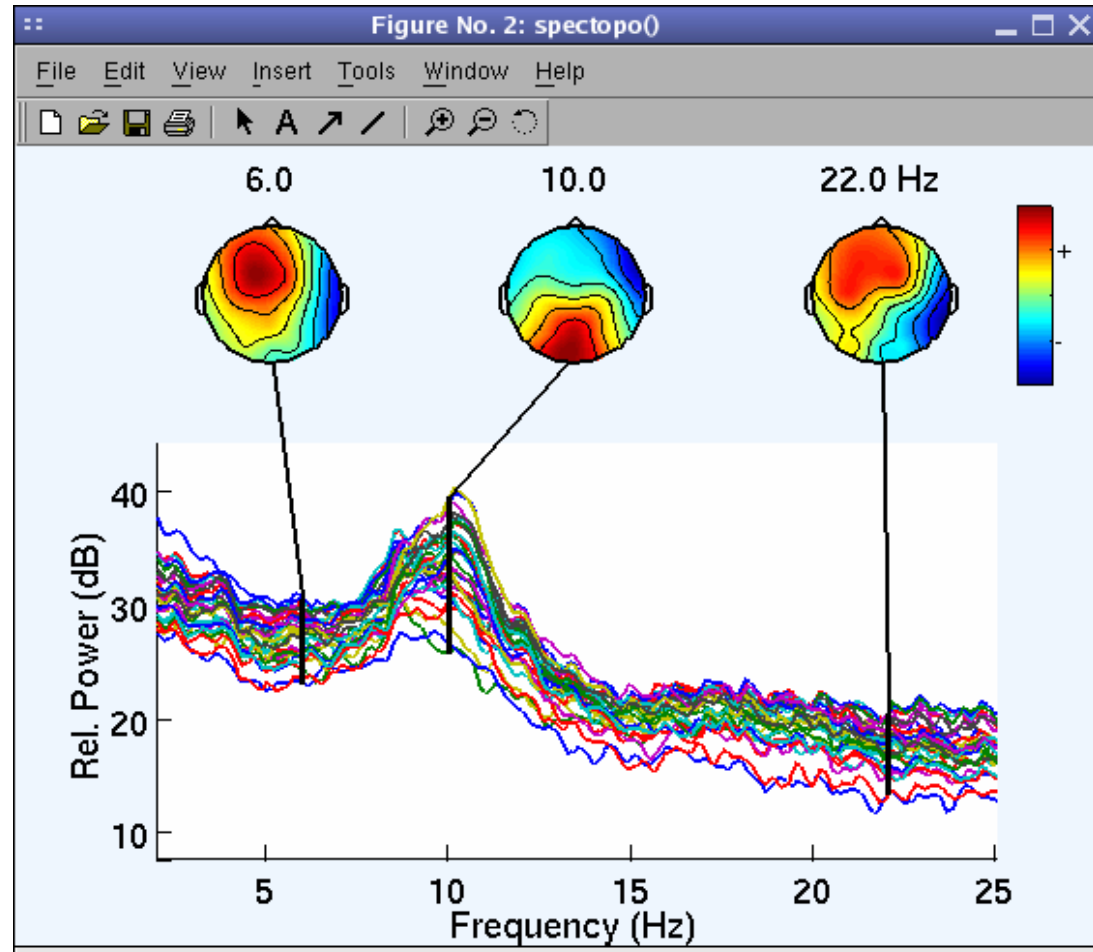
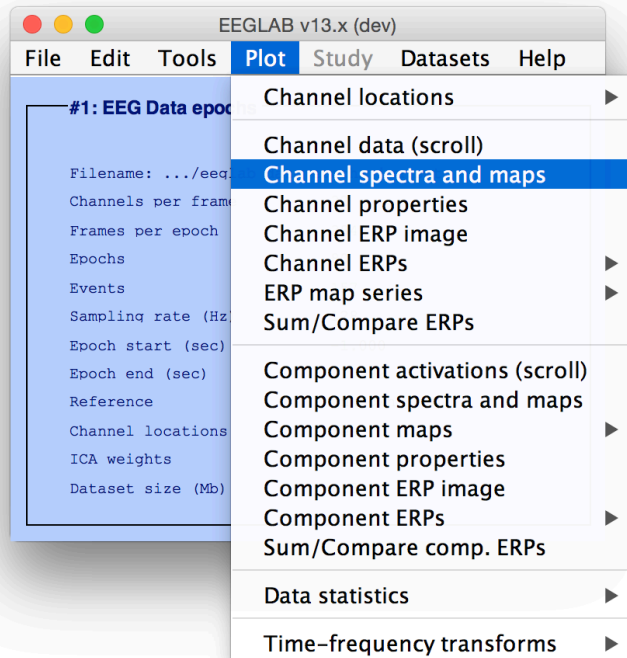
Plot ERP
map series



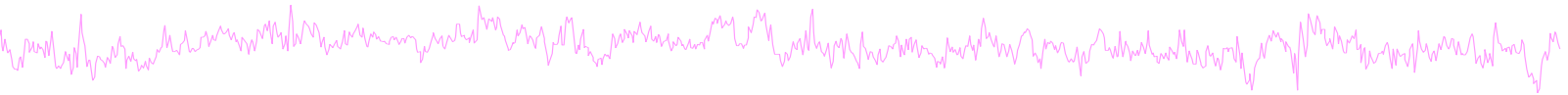
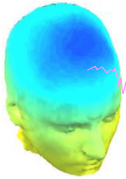
5. Visualize data measures



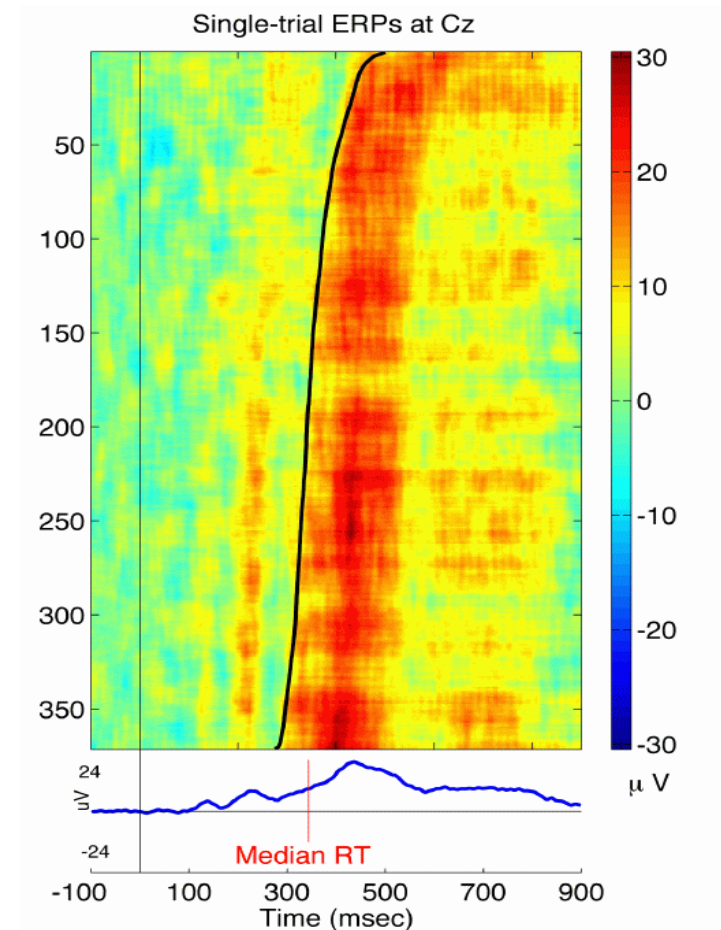
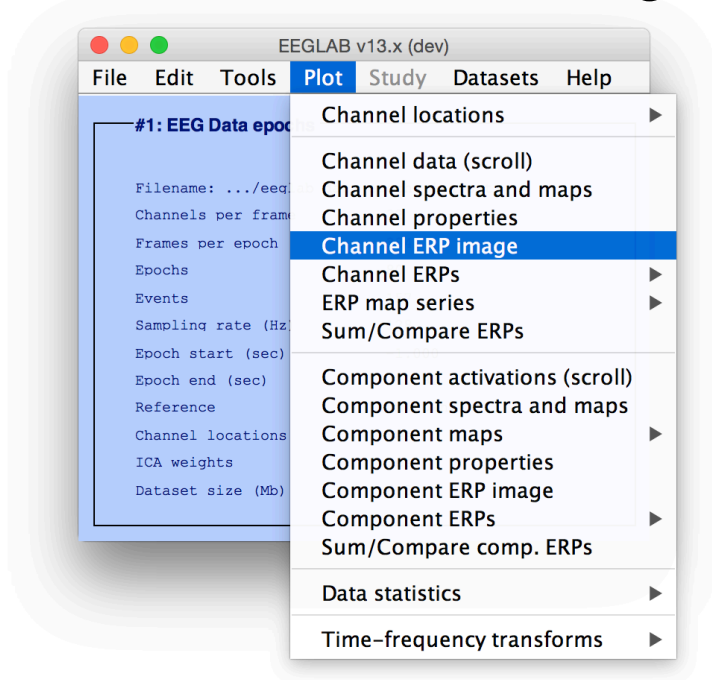
Plot data
spectrum and
maps



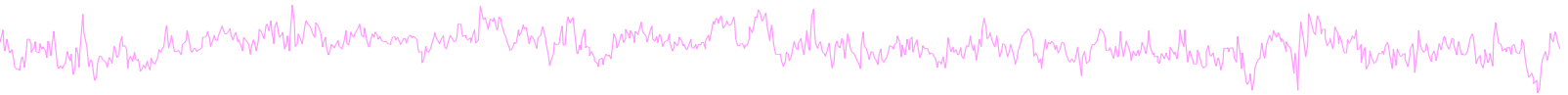
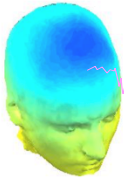
5. Visualize data measures



Plot channel ERPimage



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

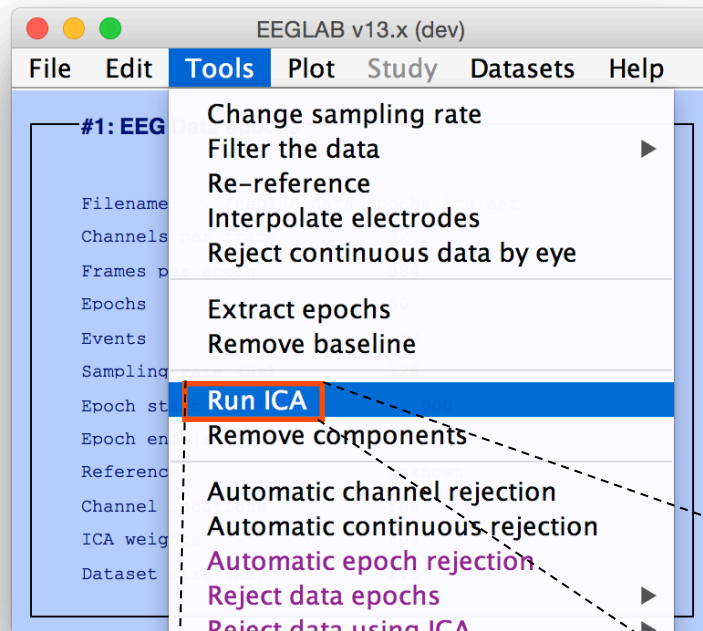
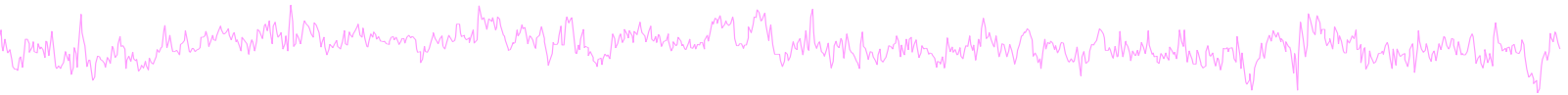
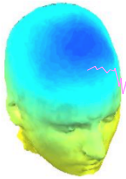
Multi-subjects

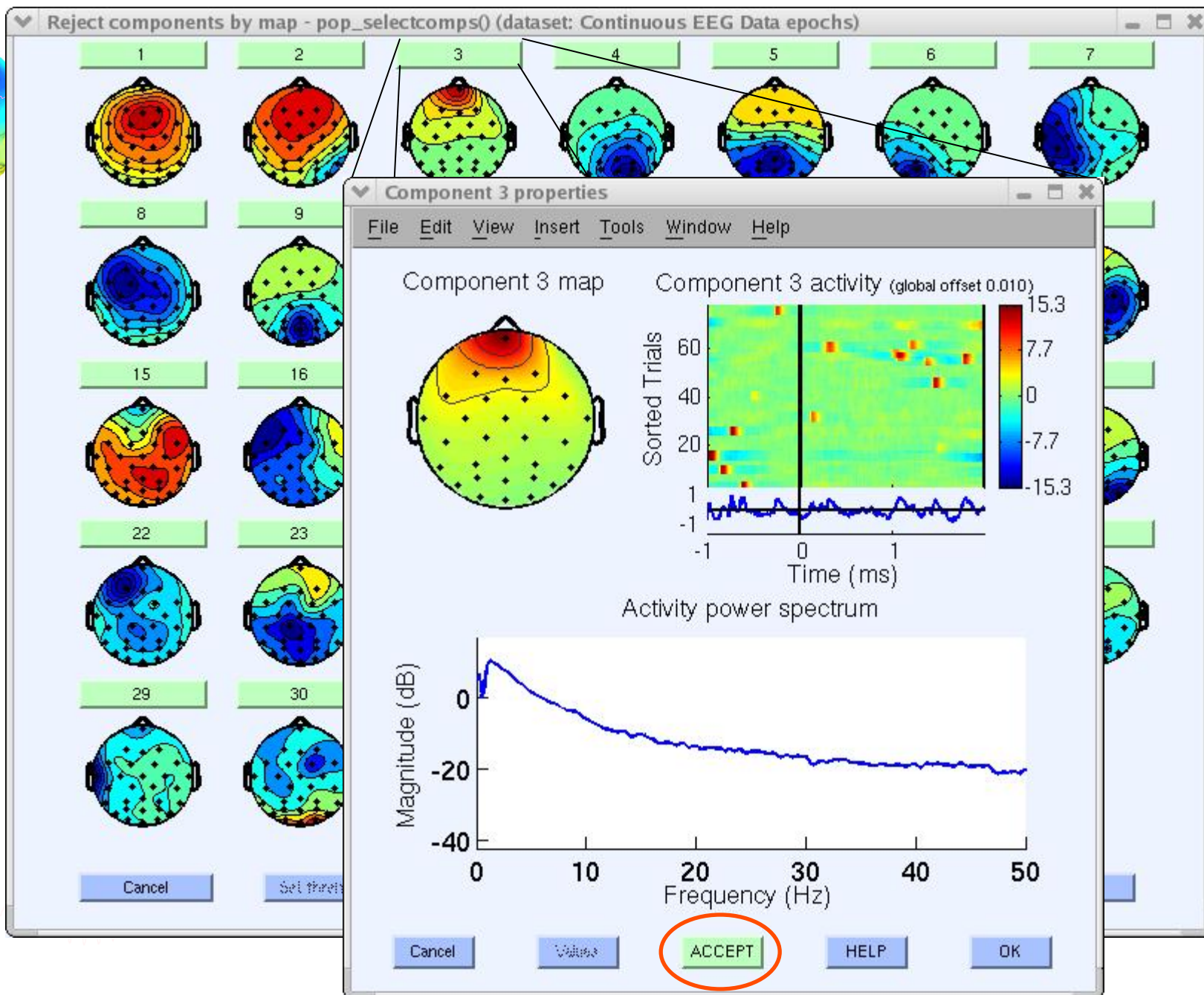
1. Build study
2. Pre-compute measures
3. Cluster components
4. Analyze clusters



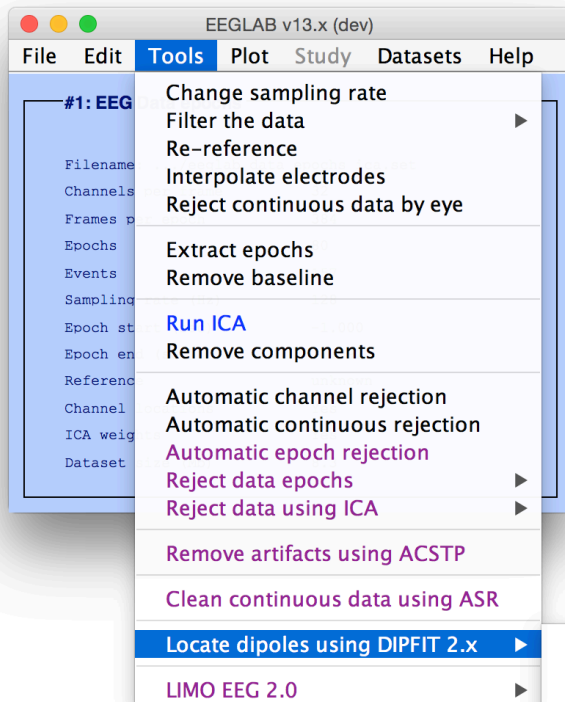
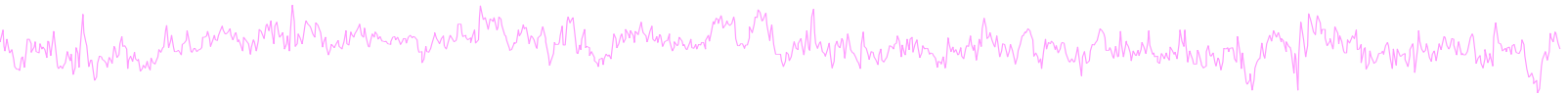
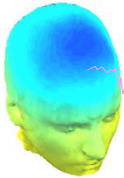
Advanced analysis using scripting and EEGLAB command line functions

6. Perform ICA decomposition





Localizing components



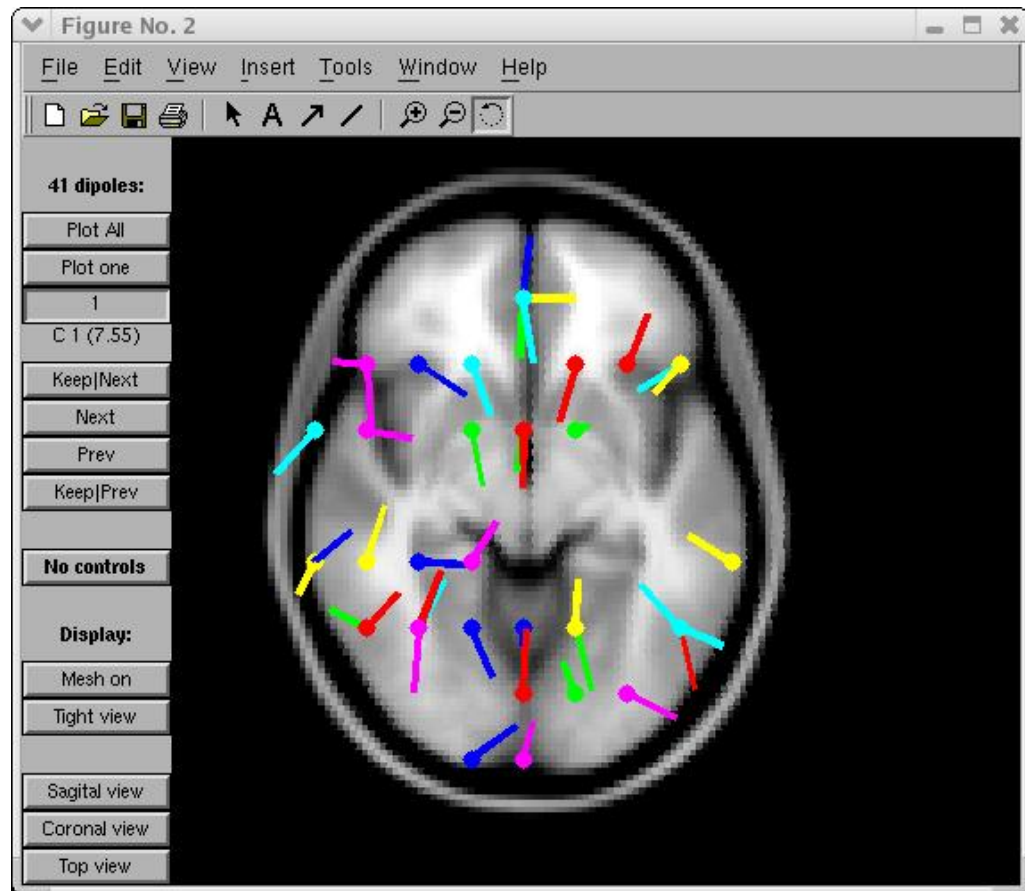
Head model and settings

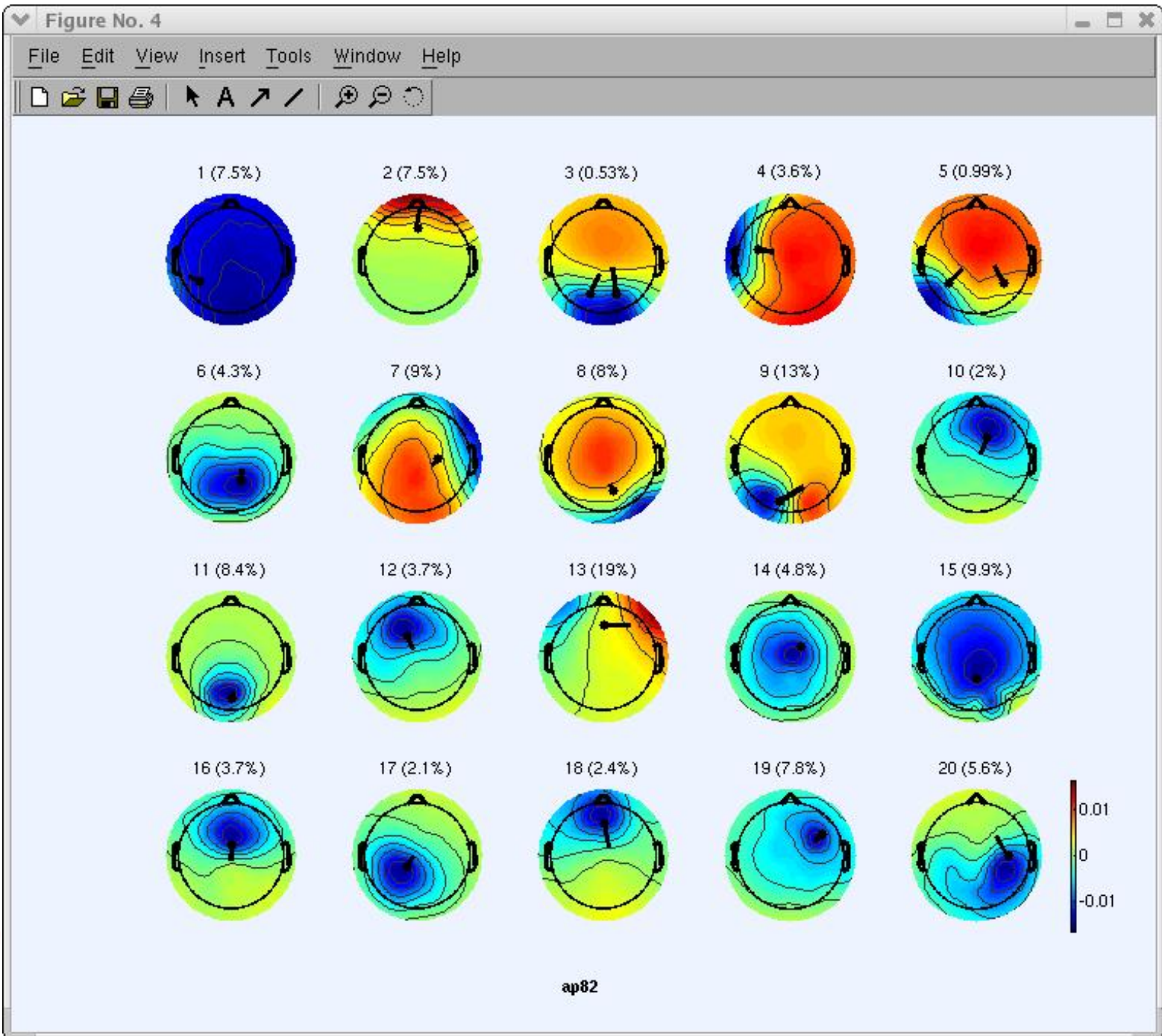
Coarse fit (grid scan)

Fine fit (iterative)

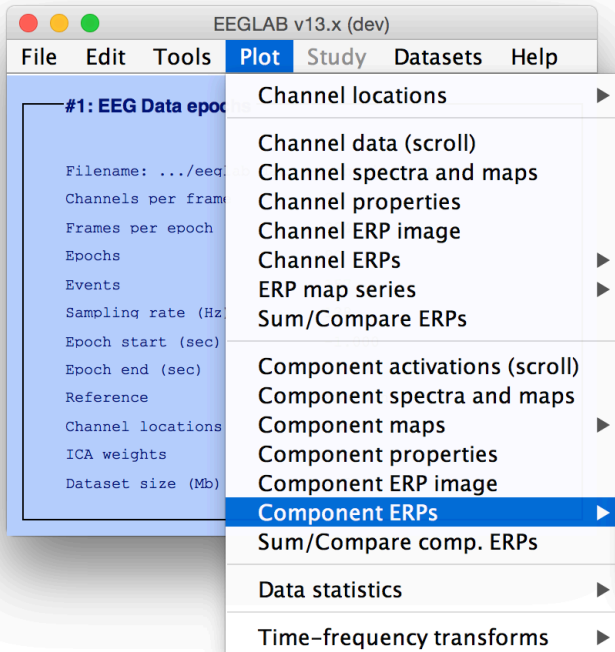
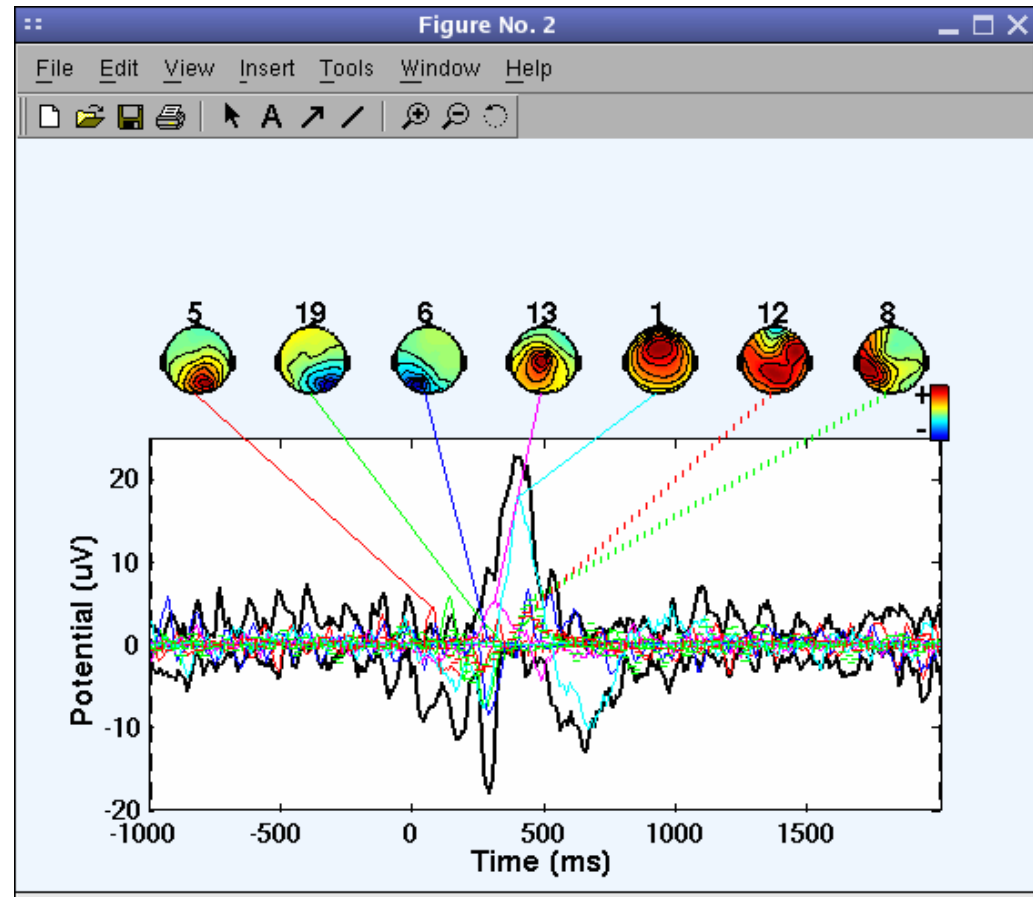
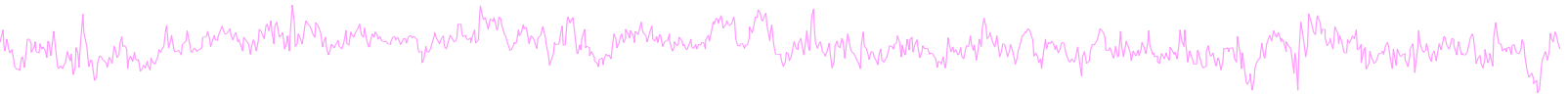
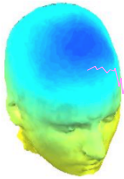
Autofit (coarse fit, fine fit & plot)

Plot component dipoles

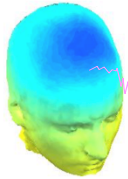




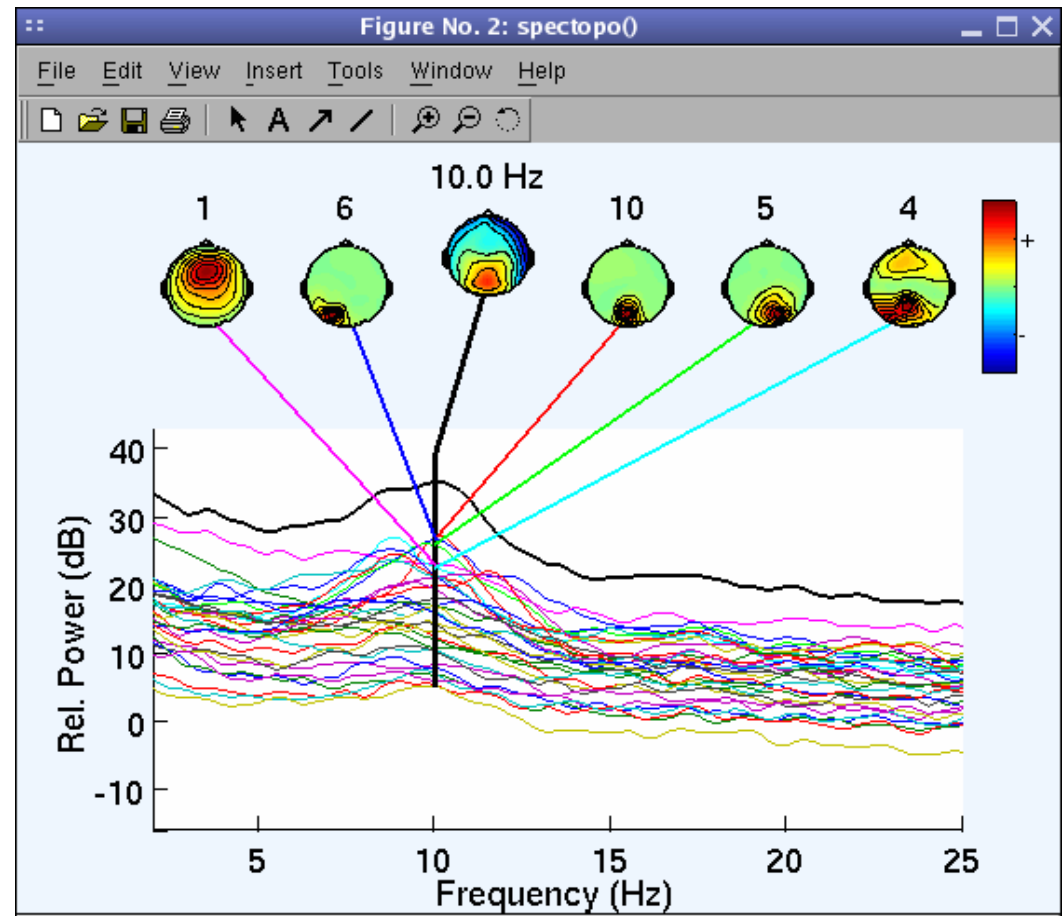
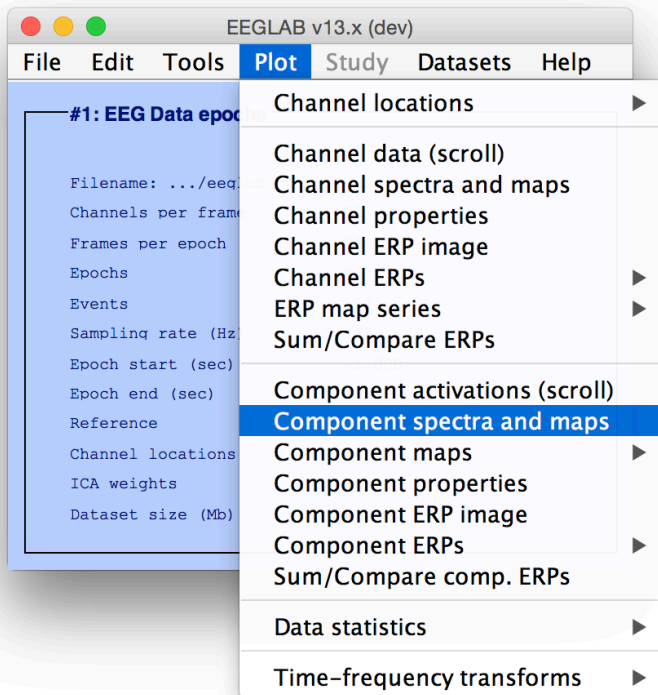
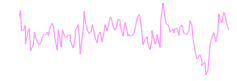
Component contribution to the ERP



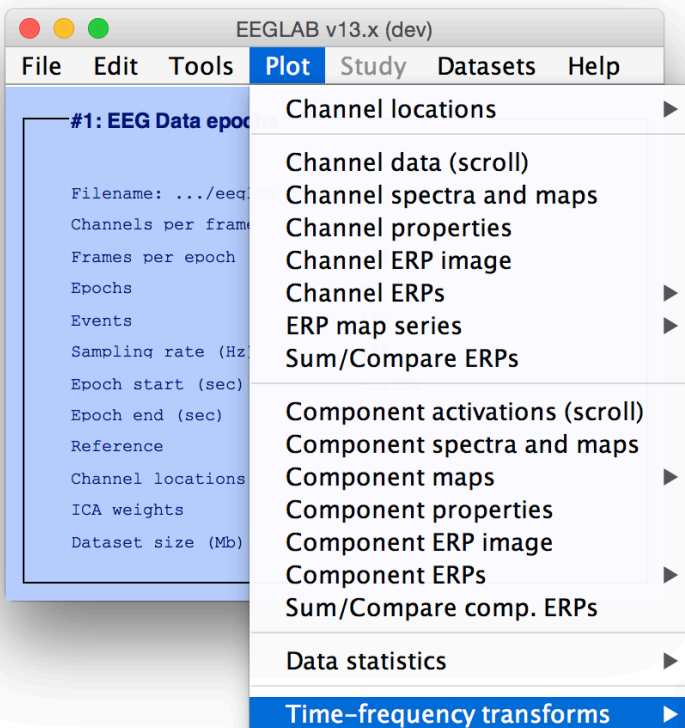
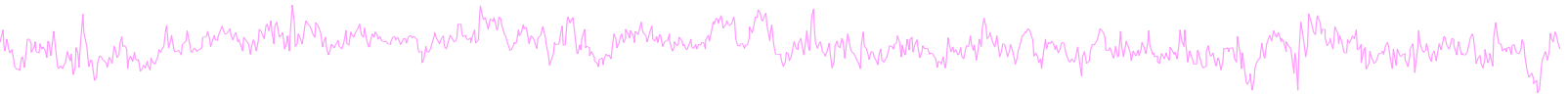
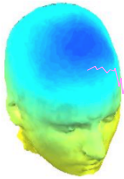
With component maps
With comp. maps (compare)
In rectangular array



Component contribution to the EEG spectrum

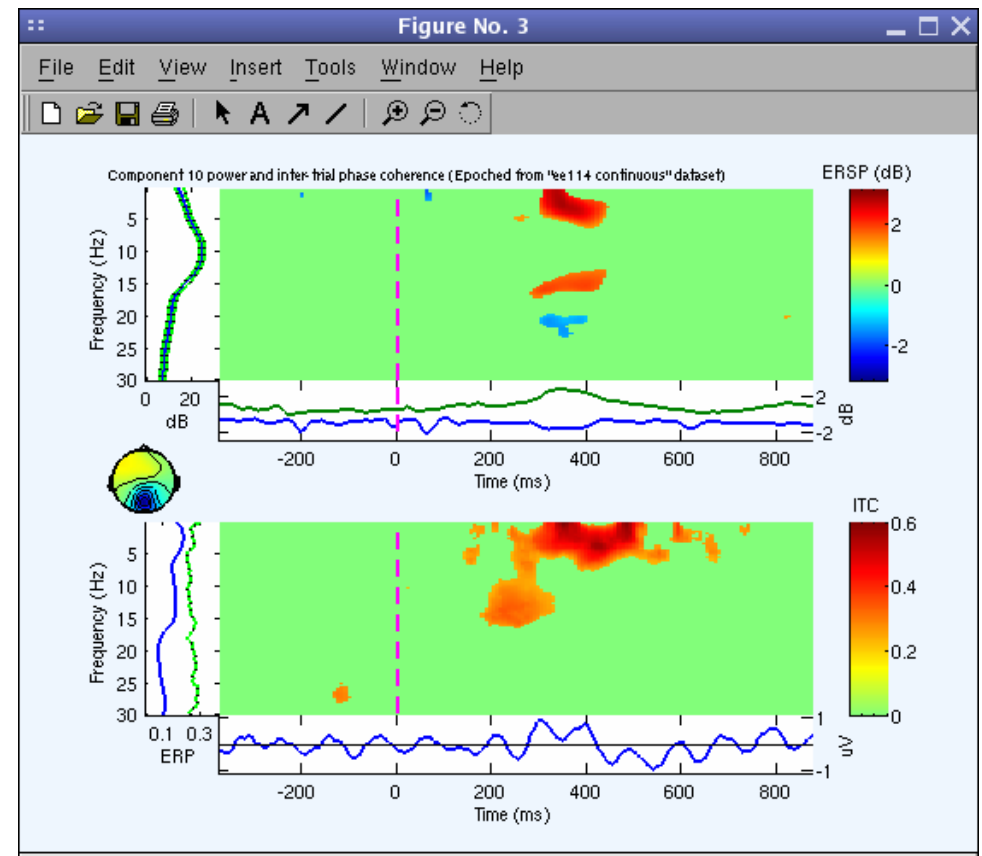


Component time-frequency

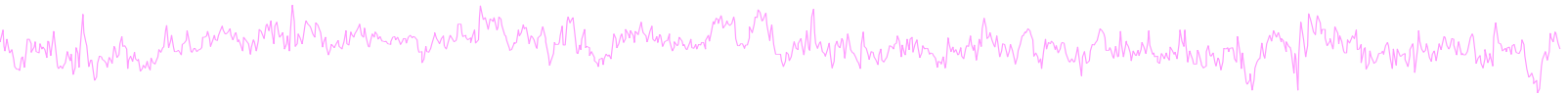
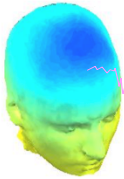


Channel time-frequency
Channel cross-coherence

Component time-frequency
Component cross-coherence



EEGLAB standard processing pipeline



Single subject

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 - Analyze components contribution to spectrum

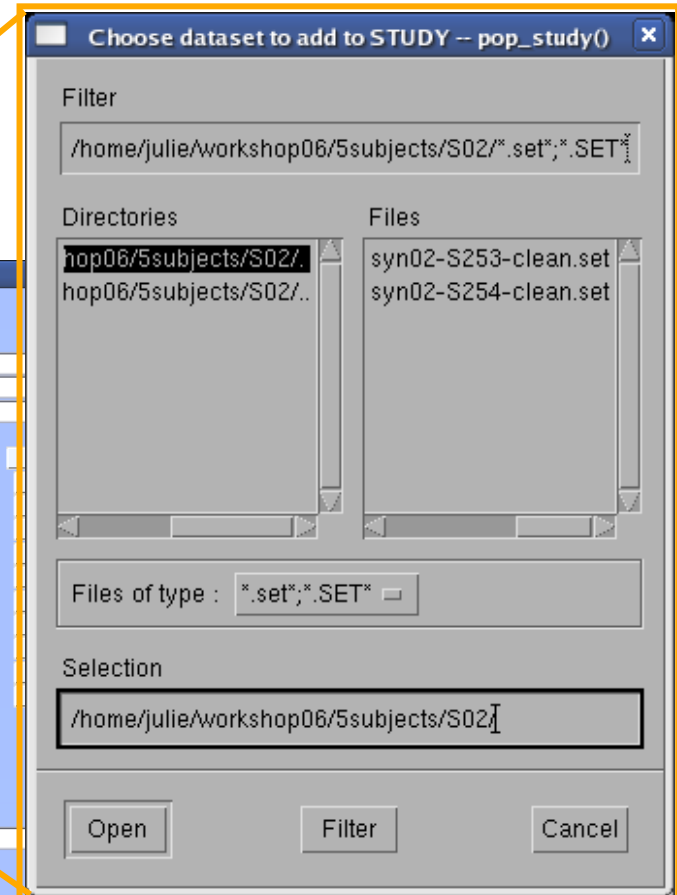
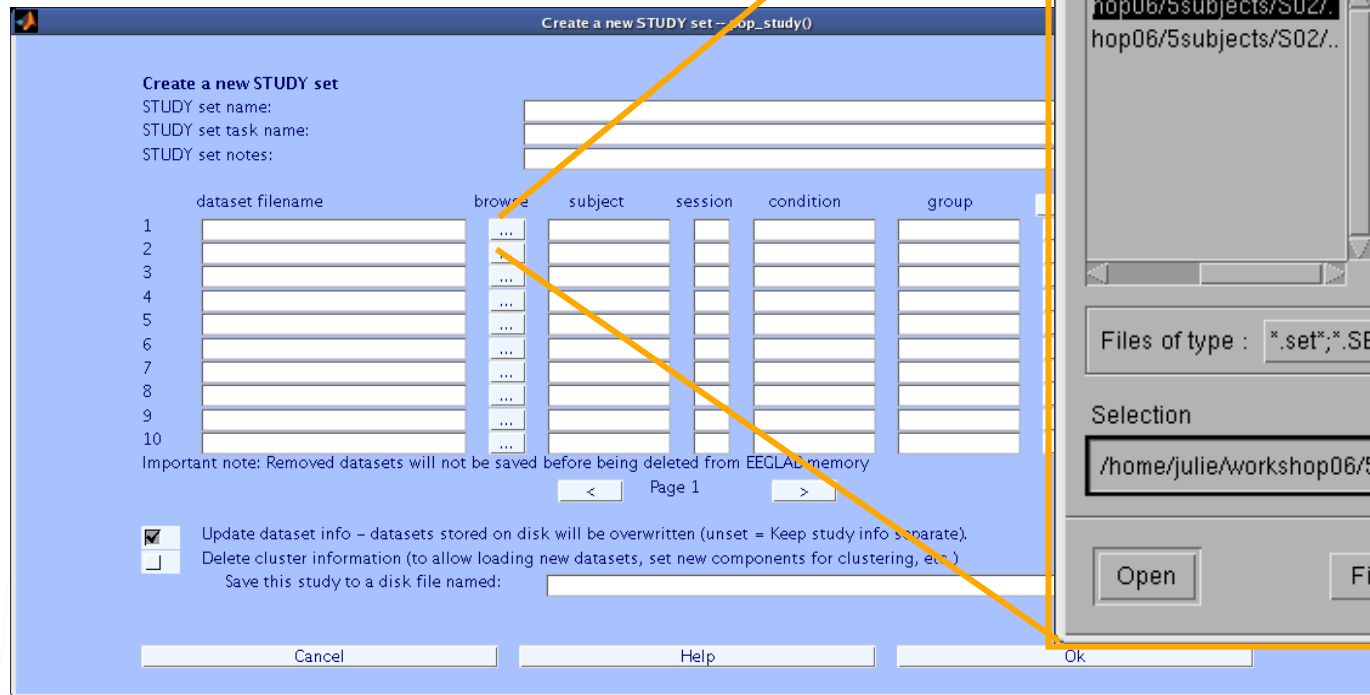
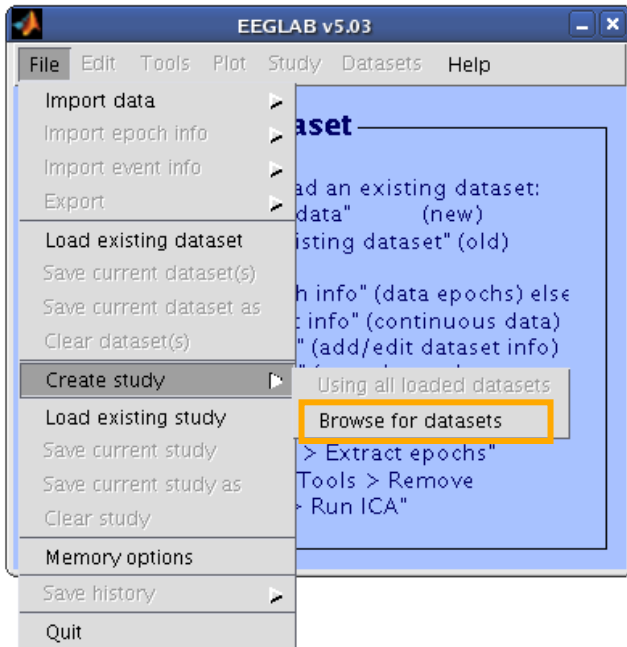
Multi-subjects

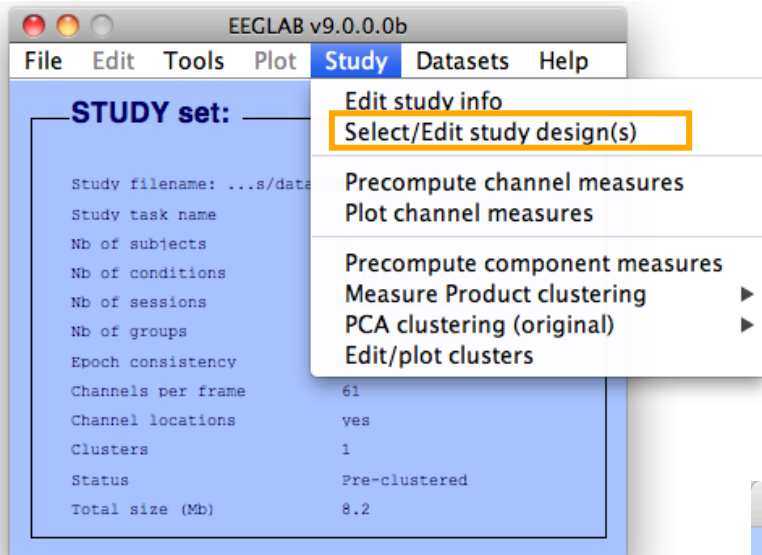
1. Build study and STUDY design
2. Pre-compute measures
3. Cluster components
4. Analyze clusters



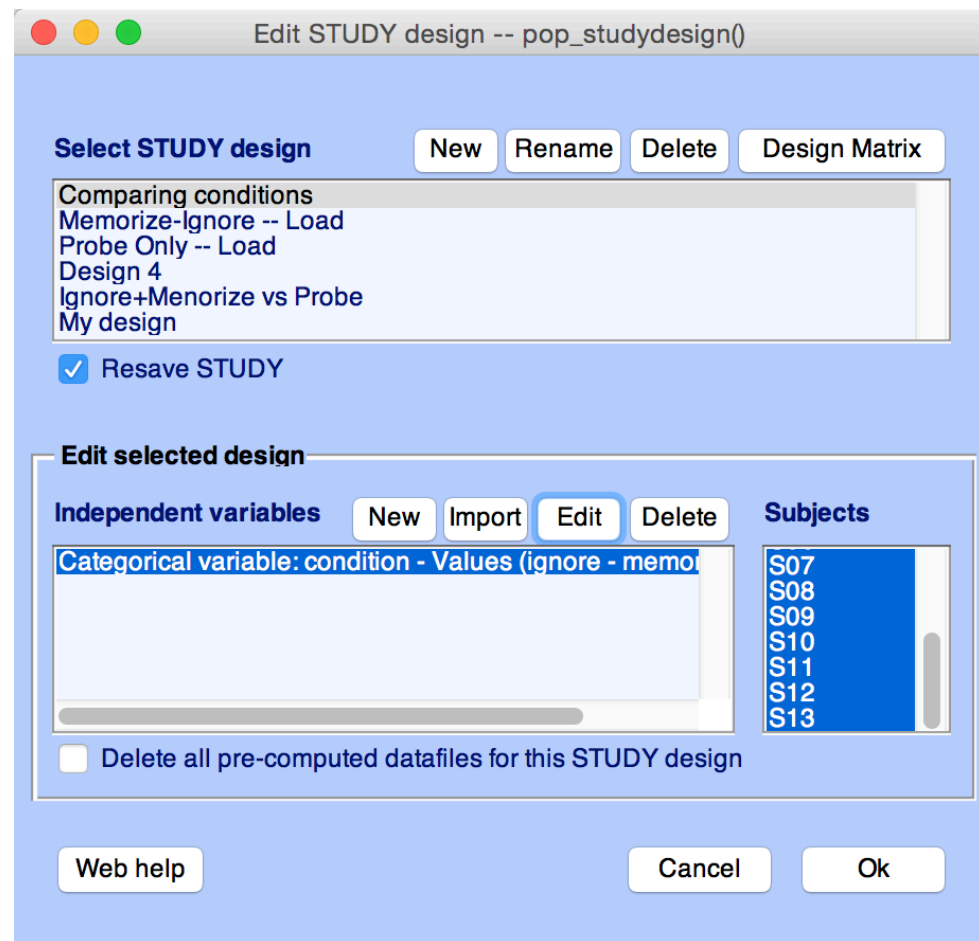
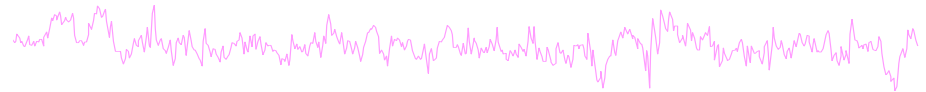
Advanced analysis using scripting and EEGLAB command line functions

1. Build a STUDY

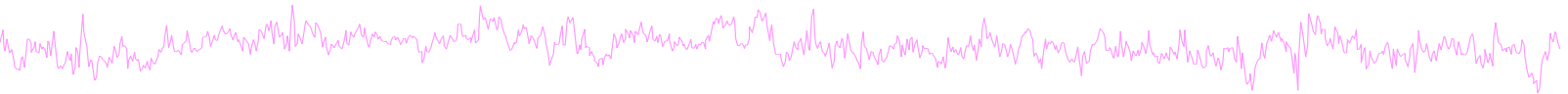
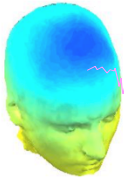




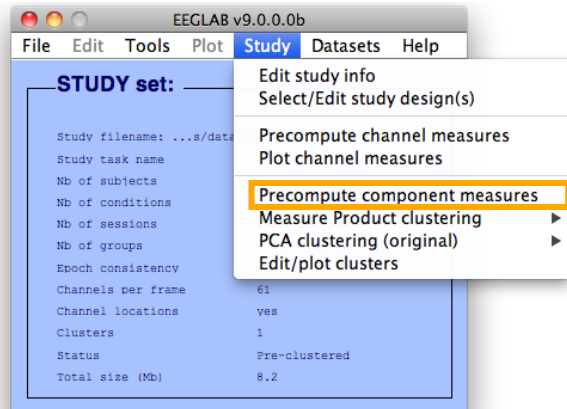
Edit STUDY design



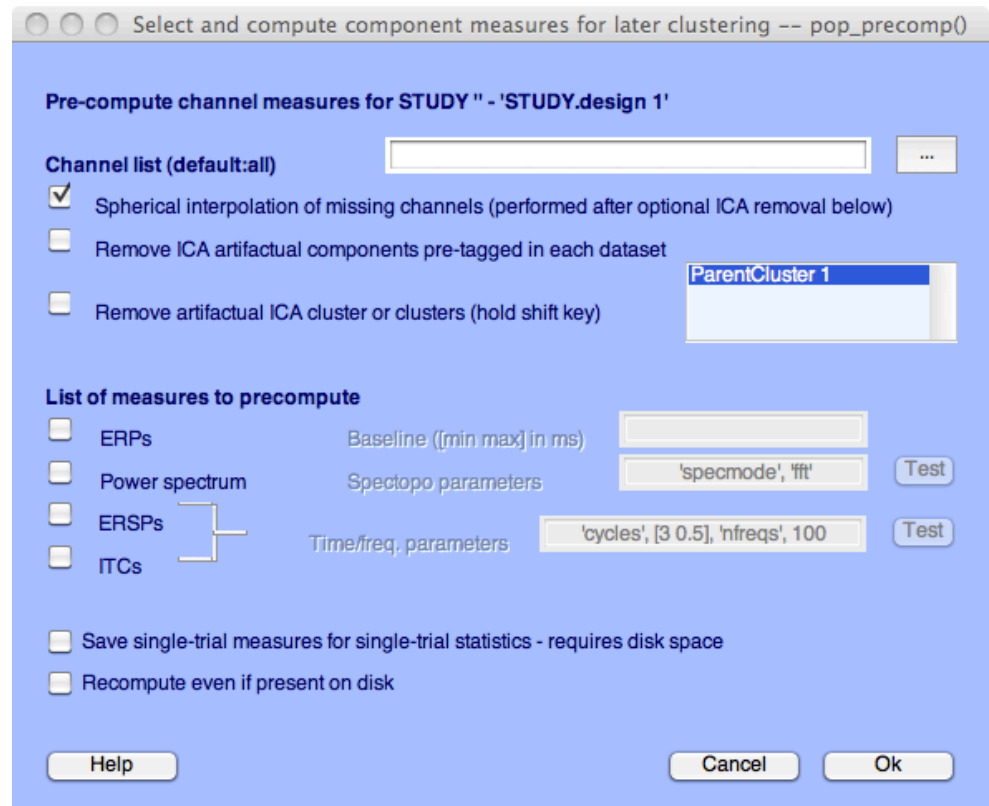
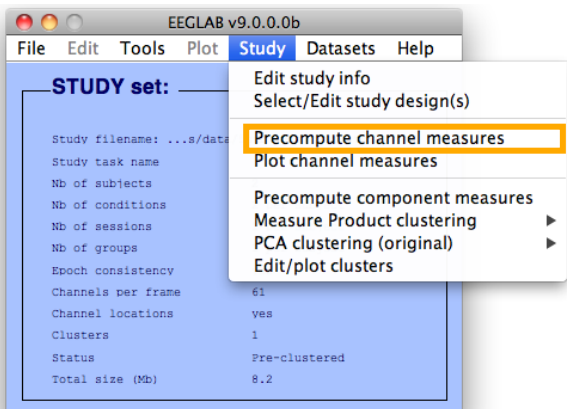
2. Pre-compute measures

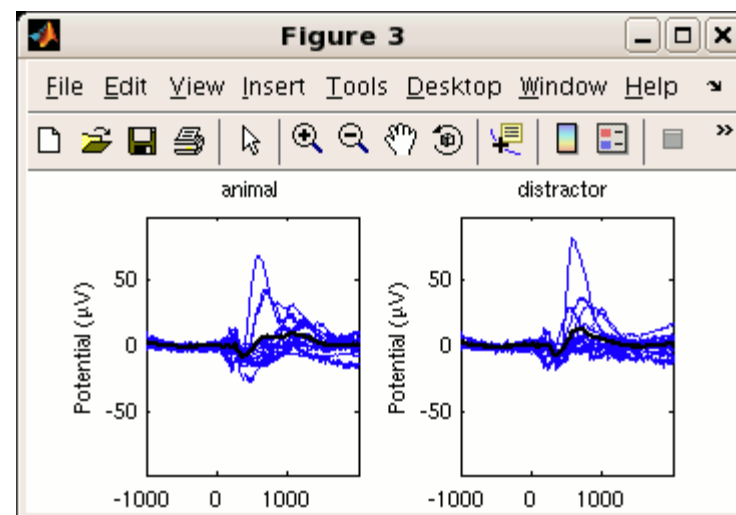
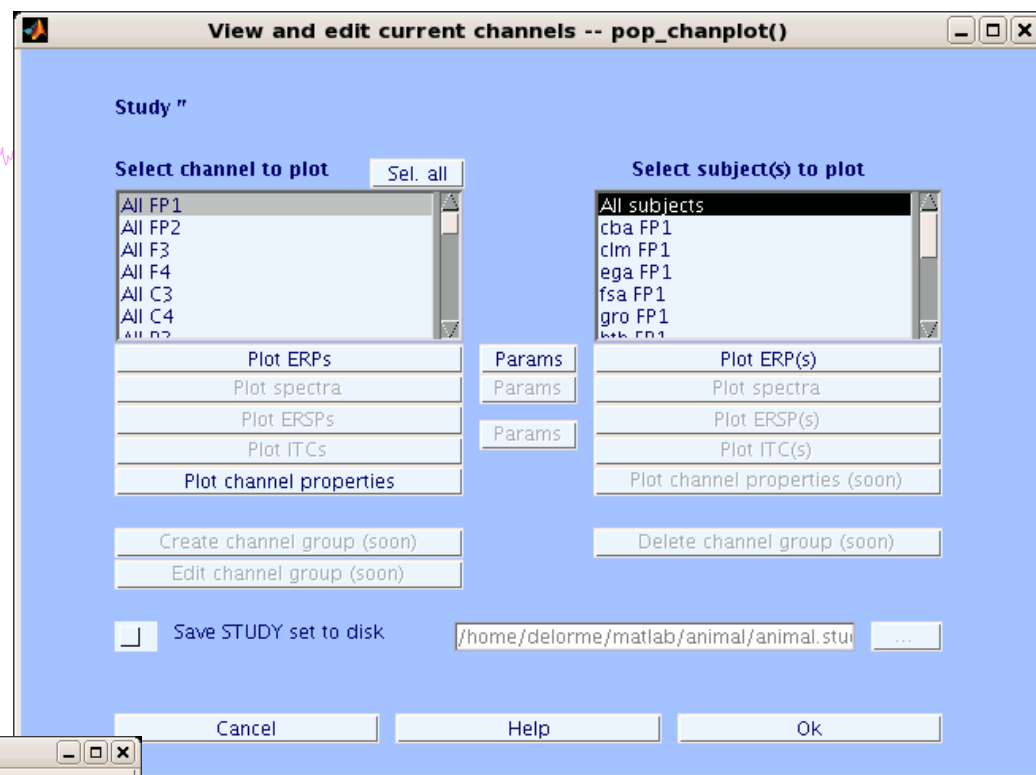
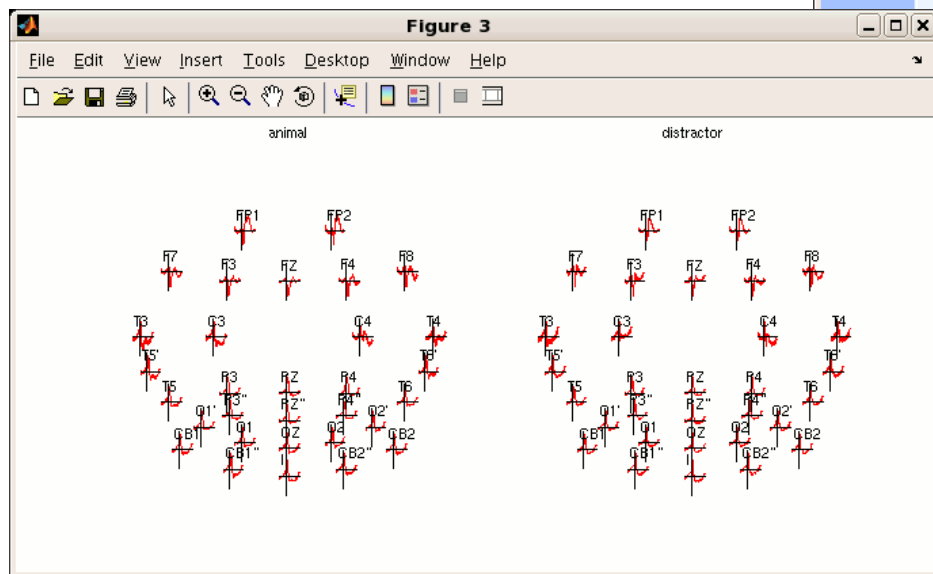
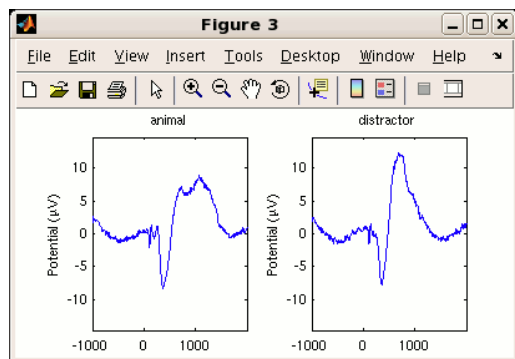


Components

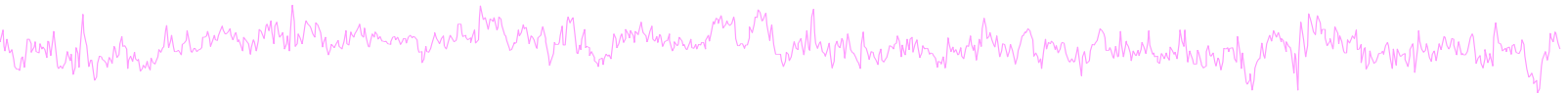
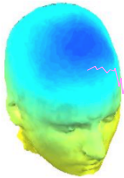


Channels





3. Cluster components



EEGLAB v6.0b

File Edit Tools Plot Study Datasets Help

STUDY set: Attention

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)

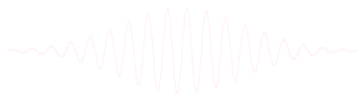
Load	Dims.	Norm.	Rel. Wt.	
☒ spectra	10	☒	1	Freq. range [Hz] 3 25
☒ ERPs	10	☒	1	Time range [ms] 0 600
☒ dipoles	3	☒	10	
☐ scalp maps	10	☒	1	Use channel values
☒ ERSPs	20	☒	1	Time range [ms] 0 1500
☒ ITCs	10	☒	1	Time range [ms] 0 600
☐ Final dimensions	10			

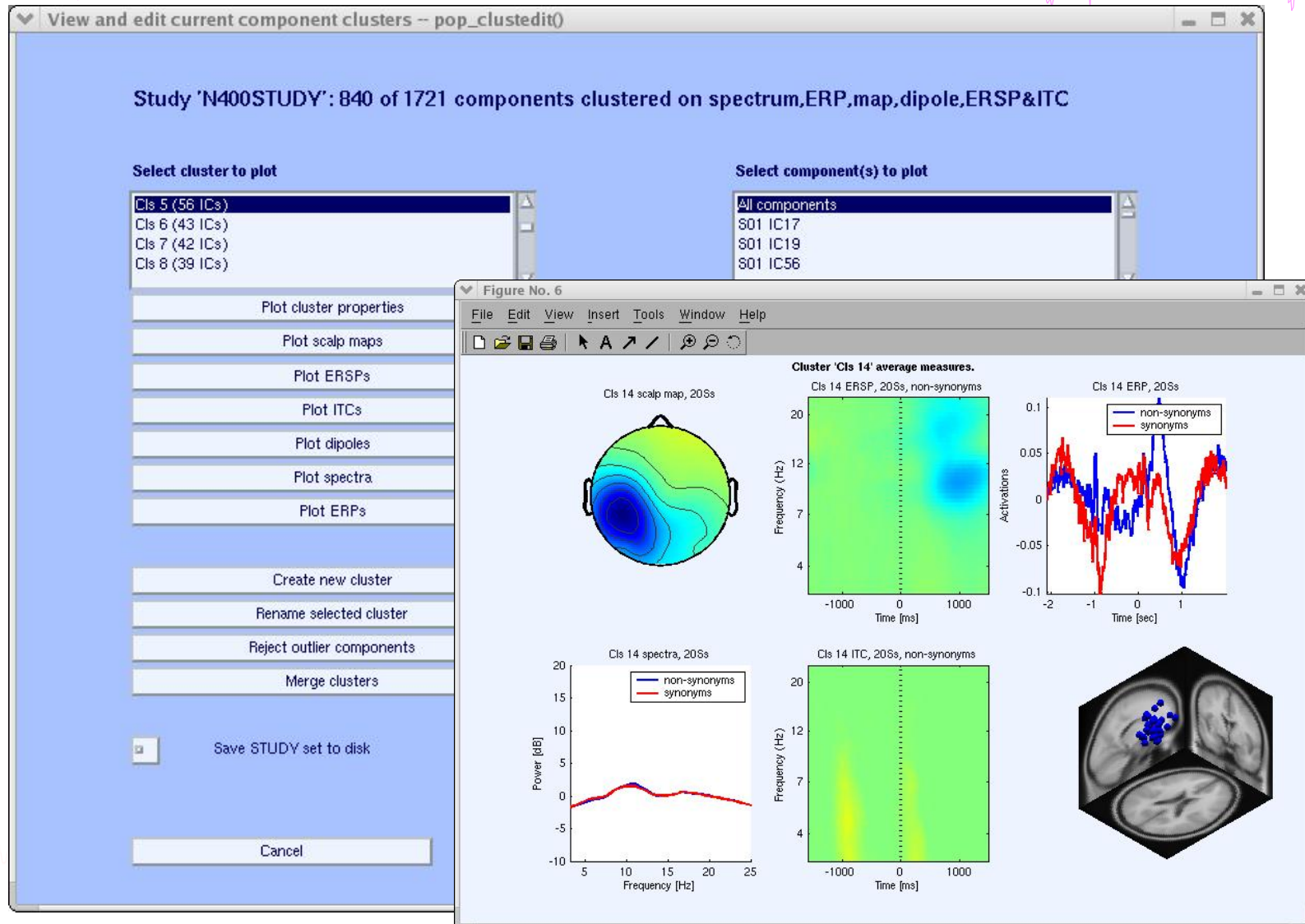
☒ Absolute values

Freq. range [Hz] 3 45
Freq. range [Hz] 2 30

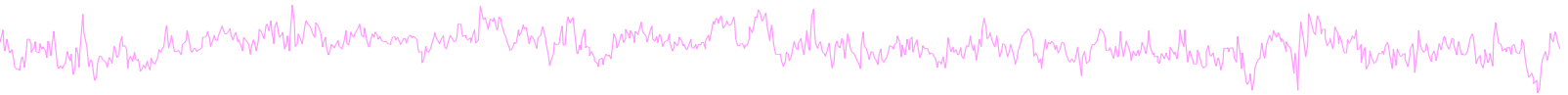
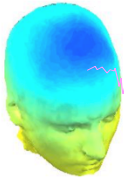
☐ Save STUDY to file /home/julie/WorkshopSD2007/STUDY/attention.study ...

Cancel Help Ok





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 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

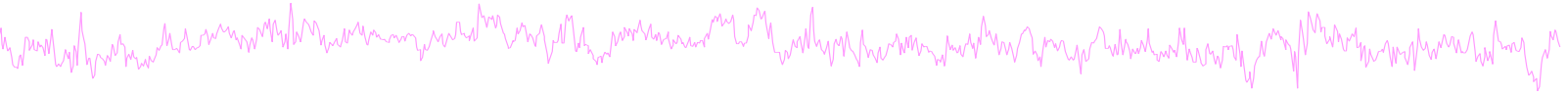
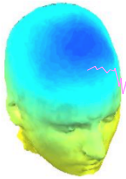
ICA scalp maps

ICA activity

Epoch/event
information

Channel location

3 levels of functions



Administrative functions: handle EEG and ALLEEG structures

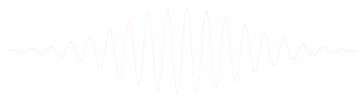
`eeglab()`, `eeg_checkset()`, `pop_delset()`, ...

Pop functions: interactive functions using EEG structure

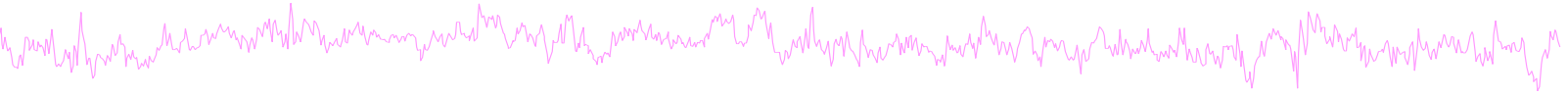
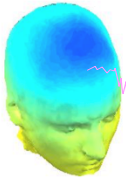
`pop_erpimage()`, `pop_topoplot()`, `pop_envtopo()`, ...

Signal processing functions: perform signal processing

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

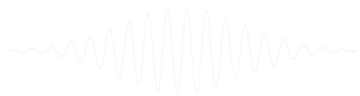


Command line tools



(“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...



EEGLAB Scripting

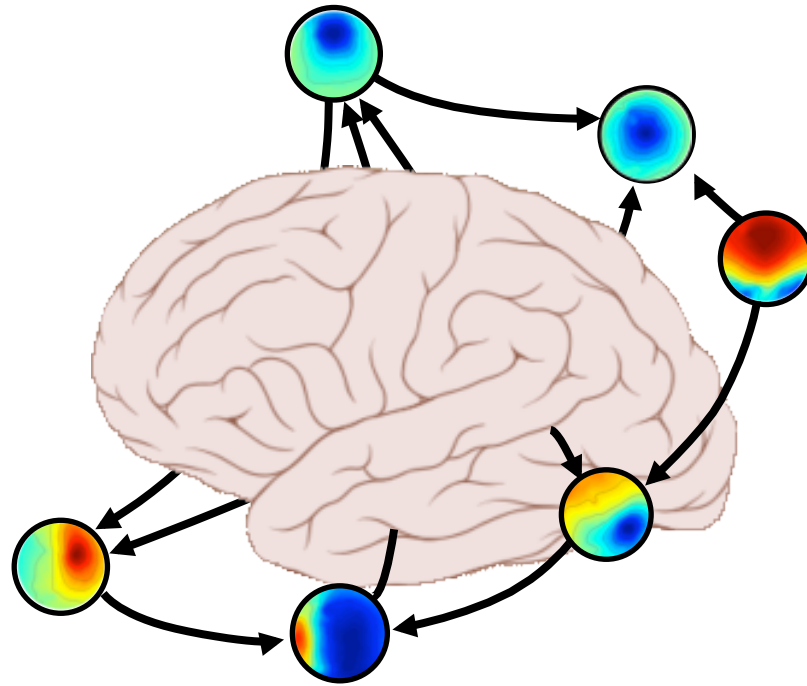
```
% Create Stern STUDY
[ALLEEG EEG CURRENTSET ALLCOM] = eeglab;
pop_editoptions( 'option_storedisk', 1);
subjects = {'S01' 'S02' 'S03' 'S04' 'S05' 'S06' 'S07' 'S08' 'S09' 'S10' 'S11' 'S12'};
filepath = '/Users/arno/temp/STUDY'; % XXXXX Change path here XXXXX
if ~exist(filepath), error('You need to change the path to the STUDY'); end;
commands = {}; % initialize STUDY dataset list

% Loop through all of the subjects in the study to create the dataset
for loopnum = 1:length(subjects) %for each subject
    IgnoreFile = fullfile(filepath, subjects{loopnum}, 'Ignore.set');
    MemorizeFile = fullfile(filepath, subjects{loopnum}, 'Memorize.set');
    ProbeFile = fullfile(filepath, subjects{loopnum}, 'Probe.set');
    commands = {commands{:} ...
        {'index' 3*loopnum-2 'load' IgnoreFile 'subject' subjects{loopnum} 'condition' 'Ignore'} ...
        {'index' 3*loopnum-1 'load' MemorizeFile 'subject' subjects{loopnum} 'condition' 'Memorize'} ...
        {'index' 3*loopnum 'load' ProbeFile 'subject' subjects{loopnum} 'condition' 'Probe'}};
end;
% Uncomment the line below to select ICA components with less than 15% residual variance
% commands = {commands{:} {'dipselect', 0.15}};
[STUDY, ALLEEG] = std_editset(STUDY, ALLEEG, 'name', 'Sternberg', 'commands', commands, 'updatedat', 'on');

% Update workspace variables and redraw EEGLAB
CURRENTSTUDY = 1; EEG = ALLEEG; CURRENTSET = [1:length(EEG)];
[STUDY, ALLEEG] = std_checkset(STUDY, ALLEEG);
eeglab redraw

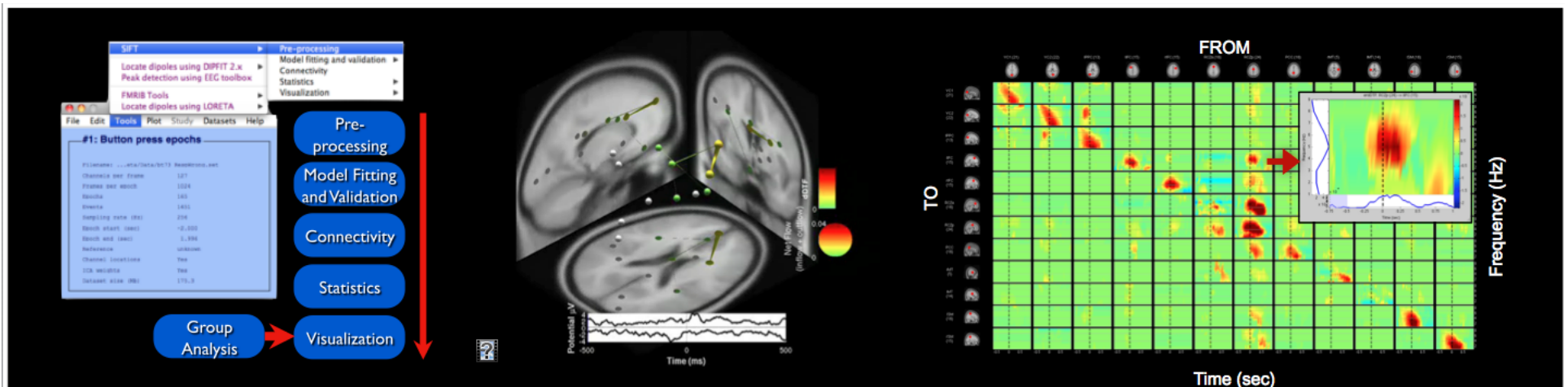
[STUDY ALLEEG] = std_precomp(STUDY, ALLEEG, {}, 'rmicacomp', 'on', 'interp', 'on', 'recompute', 'on', 'erp', 'on');
STUDY = pop_erpparams(STUDY, 'topotime', [200 300] );
[STUDY erpdata] = std_erpplot(STUDY, ALLEEG, 'channels', {'LEYE' 'REYE' 'OZ' 'O2' 'FP1' 'FPZ' 'FP2' 'AF7' ...
    'AF3' 'AFZ' 'AF4' 'AF8' 'F9' 'F7' 'F5' 'F3' 'F1' 'FZ' 'F2' 'F4' 'F6' 'F8' 'F10' 'FT9' ...
    'FT7' 'FC5' 'FC3' 'FC1' 'FCZ' 'FC2' 'FC4' 'FC6' 'FT8' 'FT10' 'T7' 'C5' 'C3' 'C1' 'CZ' ...
    'C2' 'C4' 'C6' 'T8' 'TP9' 'TP7' 'CP5' 'CP3' 'CP1' 'CPZ' 'CP2' 'CP4' 'CP6' 'TP8' 'TP10' ...
    'P7' 'P5' 'P3' 'P1' 'PZ' 'P2' 'P4' 'P6' 'P8' 'PO9' 'PO7' 'PO3' 'POZ' 'PO4' 'PO8' 'PO10' 'O1'});

dlmwrite('erpfile.txt', squeeze(erpdata{1}), 'delimiter', '\t', 'precision', 2);
dlmwrite('erpfile.txt', squeeze(erpdata{2}), '-append', 'roffset', 1, 'delimiter', '\t', 'precision', 2);
dlmwrite('erpfile.txt', squeeze(erpdata{2}), '-append', 'roffset', 1, 'delimiter', '\t', 'precision', 2);
```

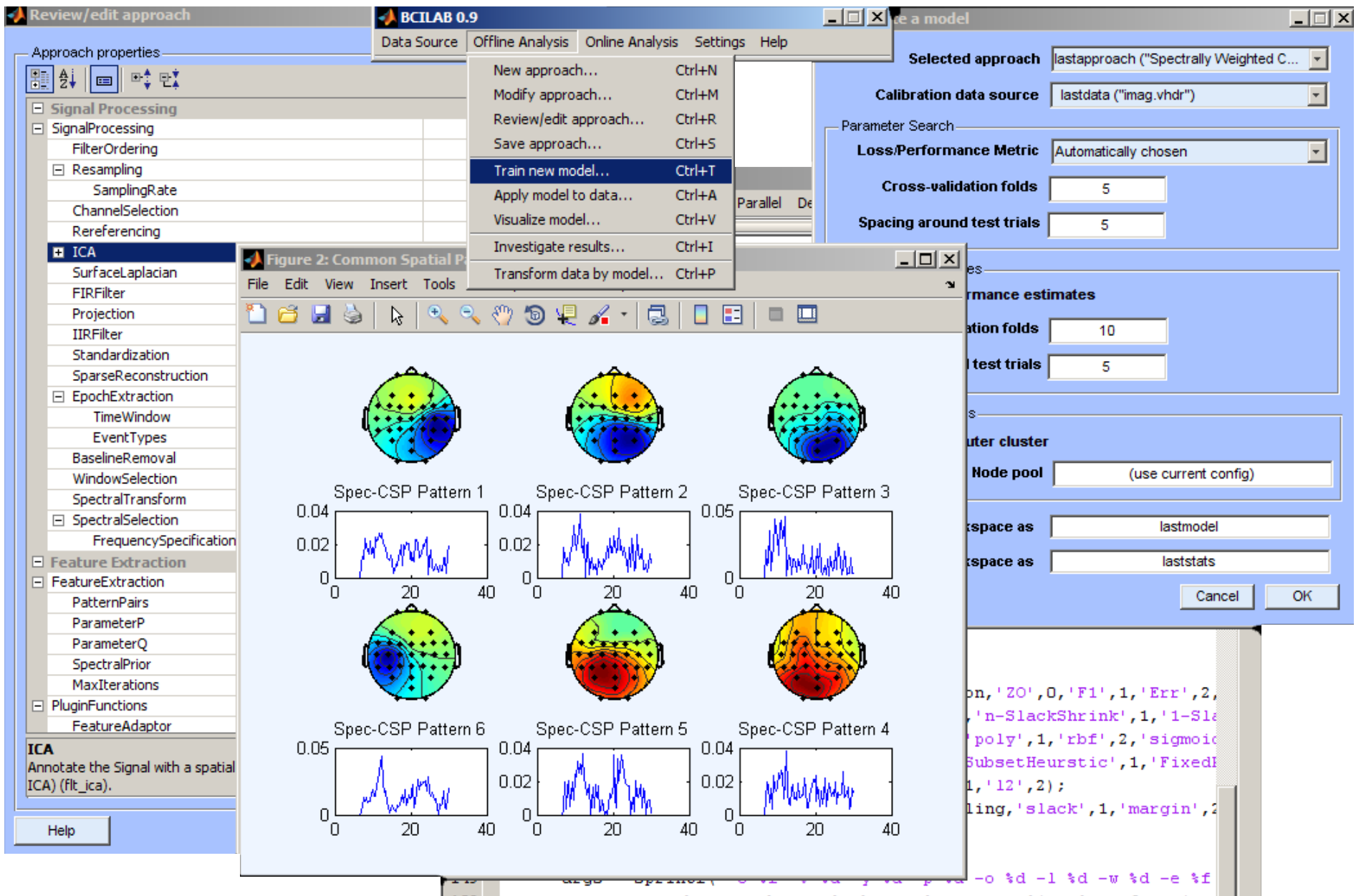


SIFT

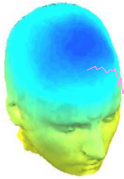
Source Information Flow Toolbox



BCILAB - C. Kothe

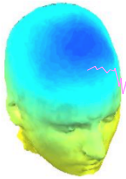


Pros/Cons of Matlab based open source



- Pros
 - Easy to program, highly modular and extendable
 - Not dependent on any platform (64-bit) and highly optimized
 - Large community of users (latest development in signal processing research)
 - Powerful scripting capabilities
- Cons
 - Matlab required for which you have to pay
 - Large memory requirements
 - Matlab bugs, possible version differences, cross-platform compatibility problems
 - Poor graphical interface

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., Mullen, T., Kothe, C., Bigdely-Shamlo, N., Akalin, Z., Vankov, A., Makeig, S. (2011) EEGLAB, MPT, NetSIFT, NFT, BCILAB, and ERICA: New tools for advanced EEG/MEG processing. *Computational Intelligence*, article ID 130714.

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

Delorme, A., Makeig, S. (2009) Open Source Programming for Interpreted Language: Graphic Interface and Macro Bridging Interface. 2009 Fifth International Conference on Signal-Image Technology & Internet-Based Systems (SITIS, indexed in IEEE), Nov. 29 2009-Dec. 4 2009, 430-434.

Delorme, A., Palmer, J., Onton, J., Oostenveld, R., Makeig, S. (2012) Independent EEG sources are dipolar. *PLoS One*, 7(2).

Delorme, A., Miyakoshi, M., Jung, T.P., Makeig, S. (2014) Grand average ERP-image plotting and statistics: A method for comparing variability in event-related single-trial EEG activities across subjects and conditions. *J Neurosci Methods*. 2014 Oct 22. pii: S0165-0270(14)00363-X. doi: 10.1016/j.jneumeth.2014.10.003