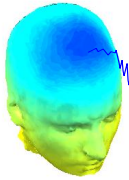


EEG Preprocessing

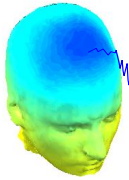
Importing data, rejecting data, and performing ICA decomposition

EEGLAB Workshop XXI

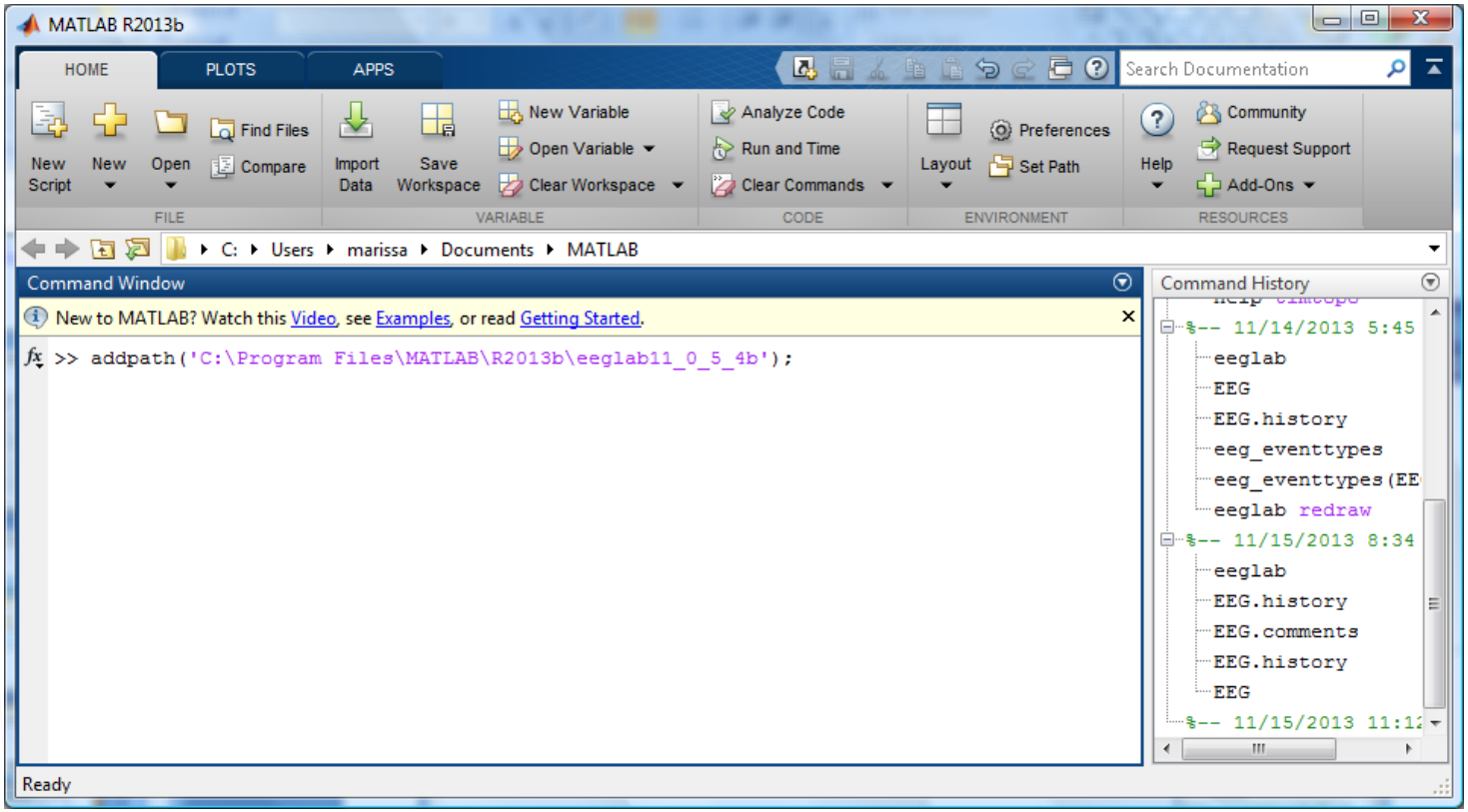
Santa Margherita Ligure, Italy

Day 1, 12:00-13:00

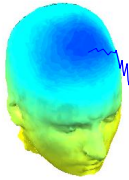
Installing EEGLAB and data folder



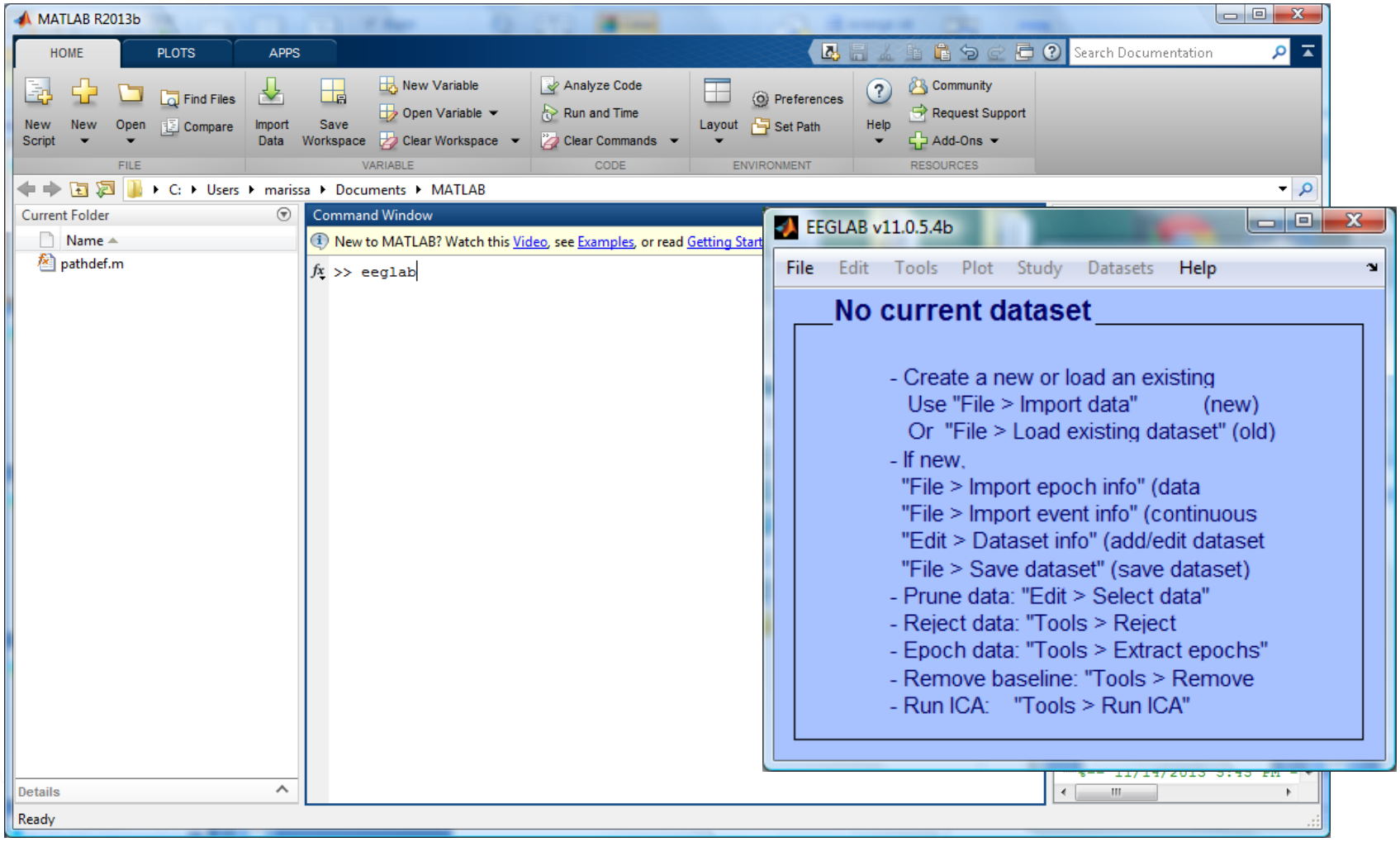
- Start Matlab
- Add the EEGLAB folder to your Matlab path:



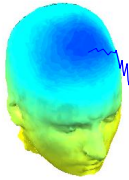
The EEGLAB Matlab software

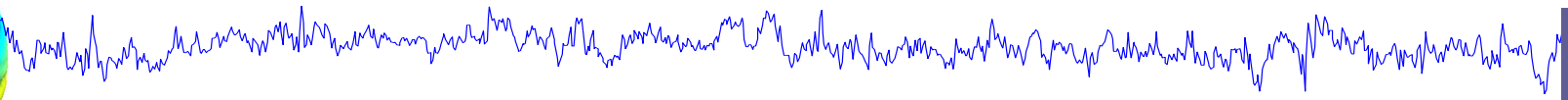


main graphic interface



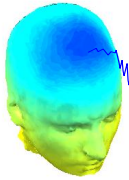
“Secrets” to a good ICA decomposition

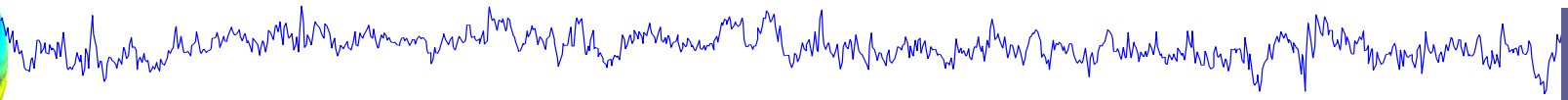




- Garbage in… garbage out (it’s not magic)
- Remove large, non-stereotyped artifacts
- Do you have enough data? (based mostly on time, not frames)
- High-pass filter to remove slow drifts (no low-pass filter needed)
- Remove bad channels

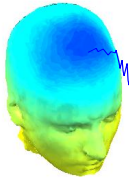
The Goal of Preprocessing





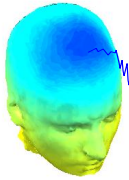
- Create a complete EEGLAB data set with
  - EEG
  - Channel Locations
  - Events
- Preprocess the EEG data to yield optimal ICA decompositions
  - Re-referencing
  - High Pass Filtering
  - Remove bad channels, noisy segments of data
- Run ICA decomposition

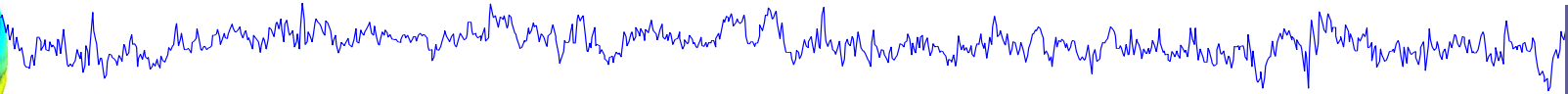
Many Preprocessing Variants



- Resources
  - EEGLAB wiki “Quick Tutorial on Rejection”
    - http://sccn.ucsd.edu/wiki/Quick_Rejection_Tutorial
  - Makoto’s Preprocessing Pipeline
    - http://sccn.ucsd.edu/wiki/Makoto%27s_preprocessing_pipeline
  - Bigdely-Shamlo et al (2015): PREP Pipeline
    - http://dx.doi.org/10.3389/fninf.2015.00016
  - EEGLAB Plugins
    - Kothe’s clean_rawdata plugin
    - Miyakoshi’s trimOutlier plugin

Pre-processing pipeline





Swartz Center for Computational Neuroscience

Collect high-density EEG data (>30 chan)

Import into EEGLAB

Import event markers and channel locations

Re-reference/ down-sample (if necessary)

High pass filter (~.5 – 1 Hz)

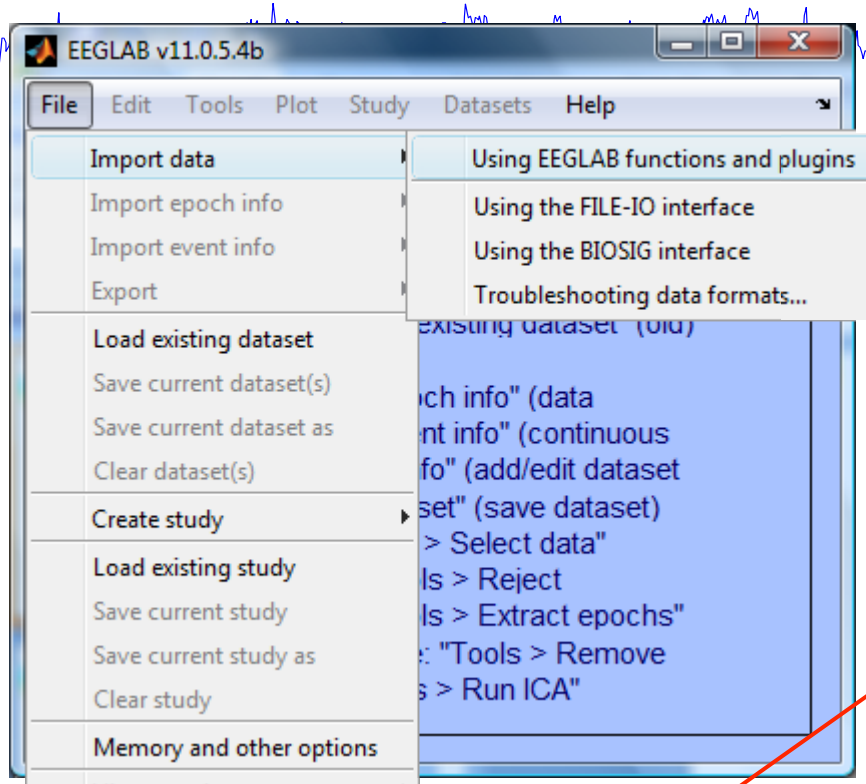
Examine raw data

Identify/reject bad channels

Reject large artifact time points

Run ICA

Importing a dataset

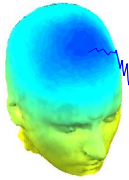


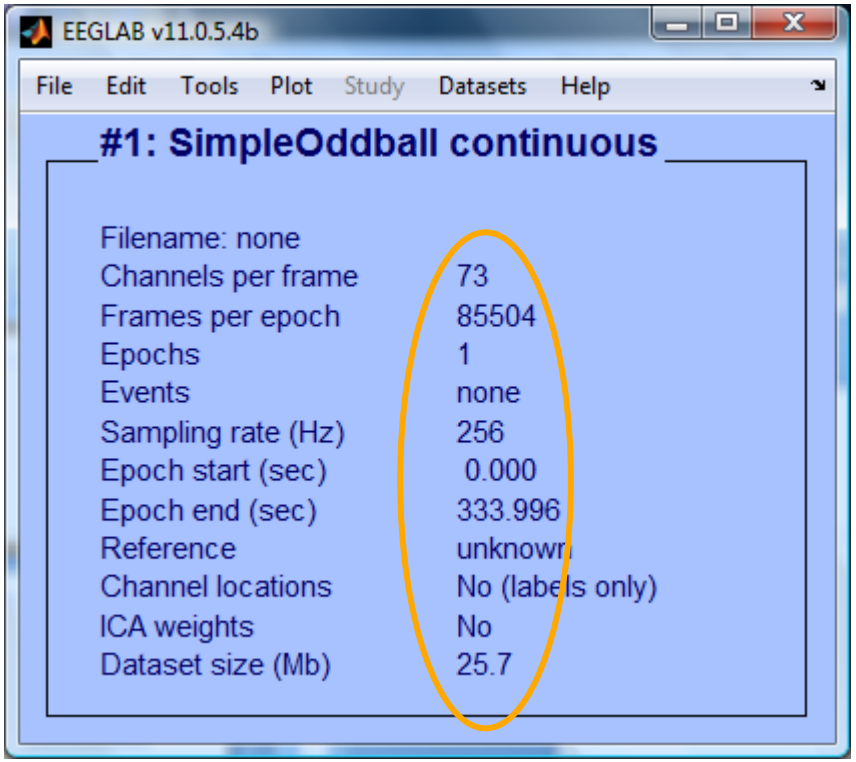
Tip for Biosemi users:

Use the 'BDF plugin' version

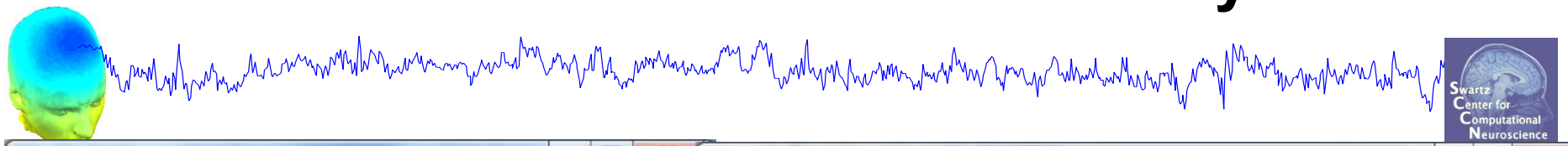
of the Biosemi BDF/EDF importer

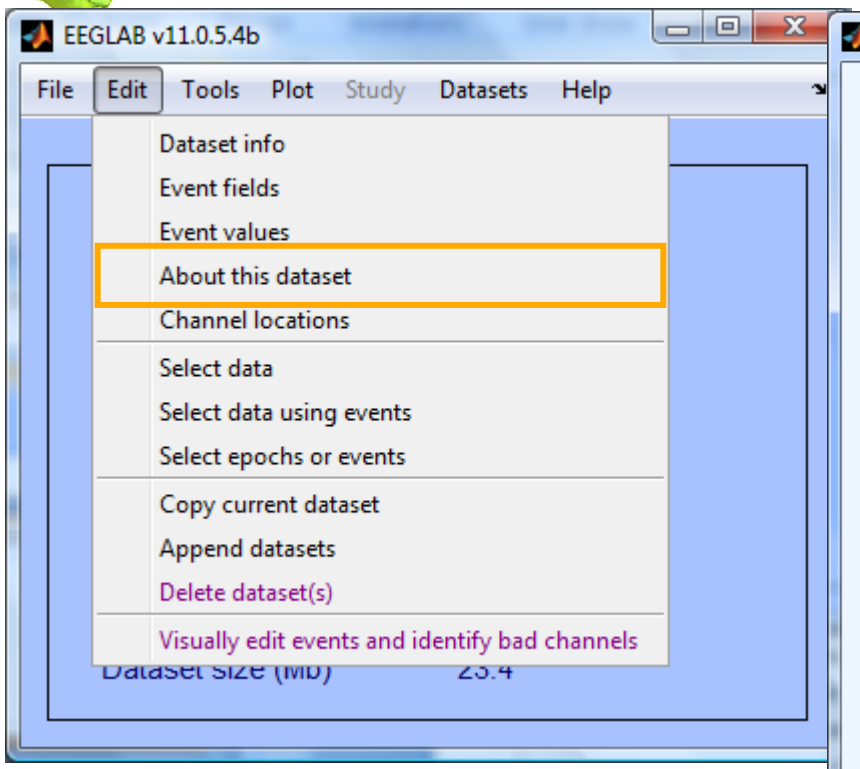
Imported EEG data

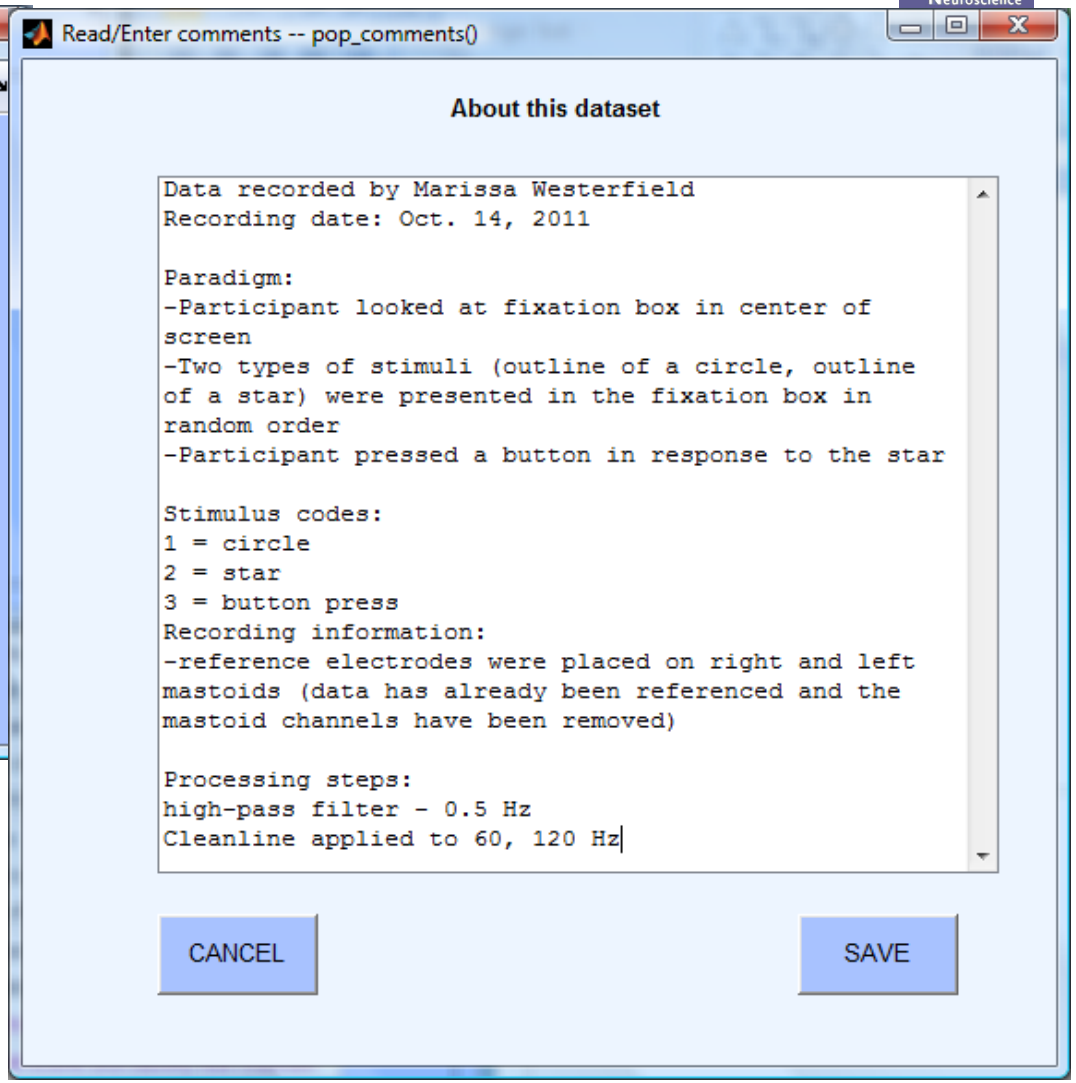




Comments and dataset history



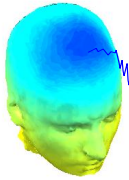


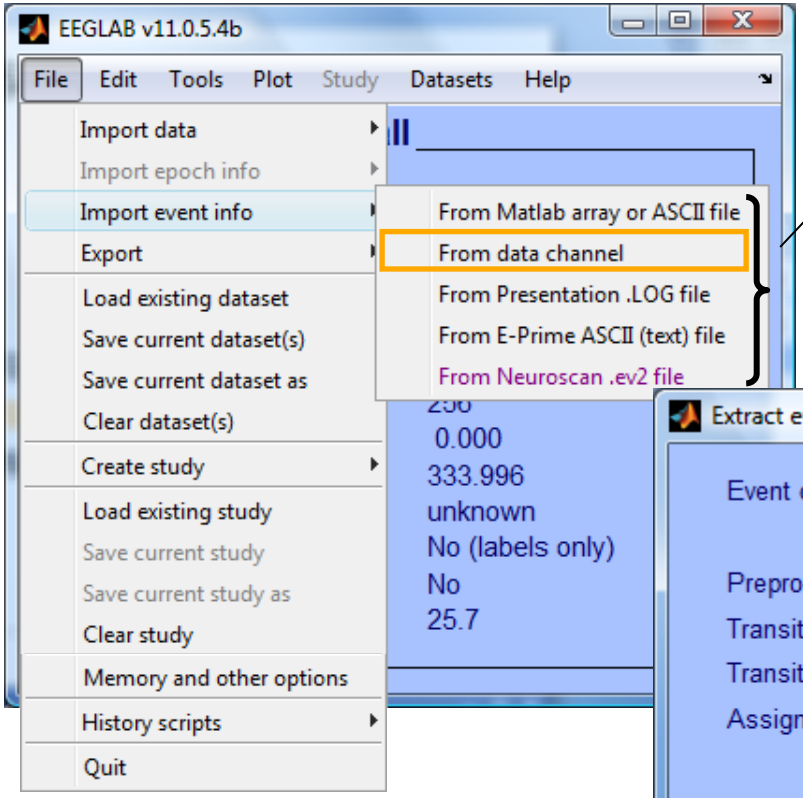


Also:
>> EEG.comments

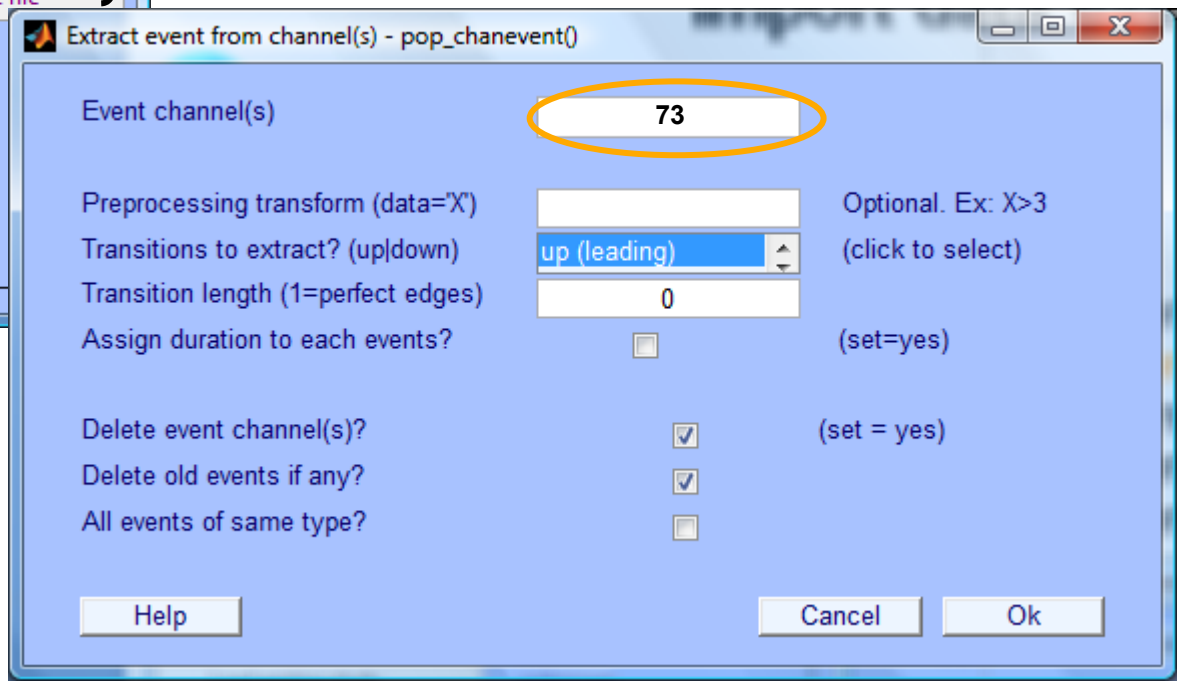
and
>> EEG.history

Import data events



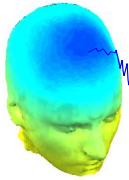


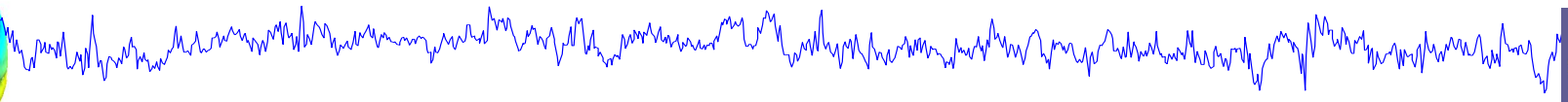
- Import events from Matlab array or ASCII file
- Import events from data channel
- Import from Presentation event file
- Import events from E-Prime event file
- Import events from Neuroscan event file

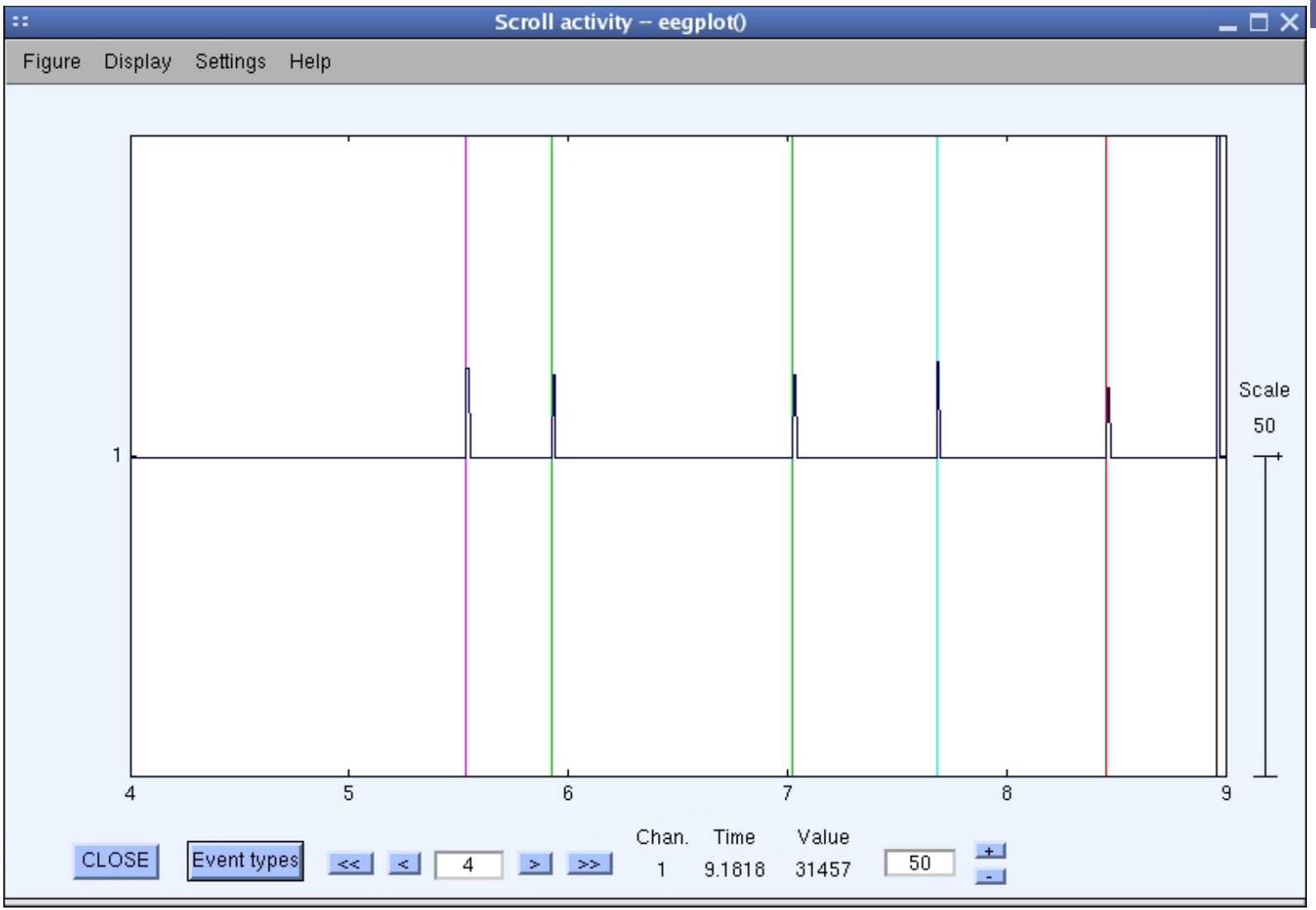


(Often imported automatically during data import)

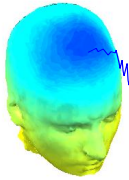
Appearance of an event channel in raw data

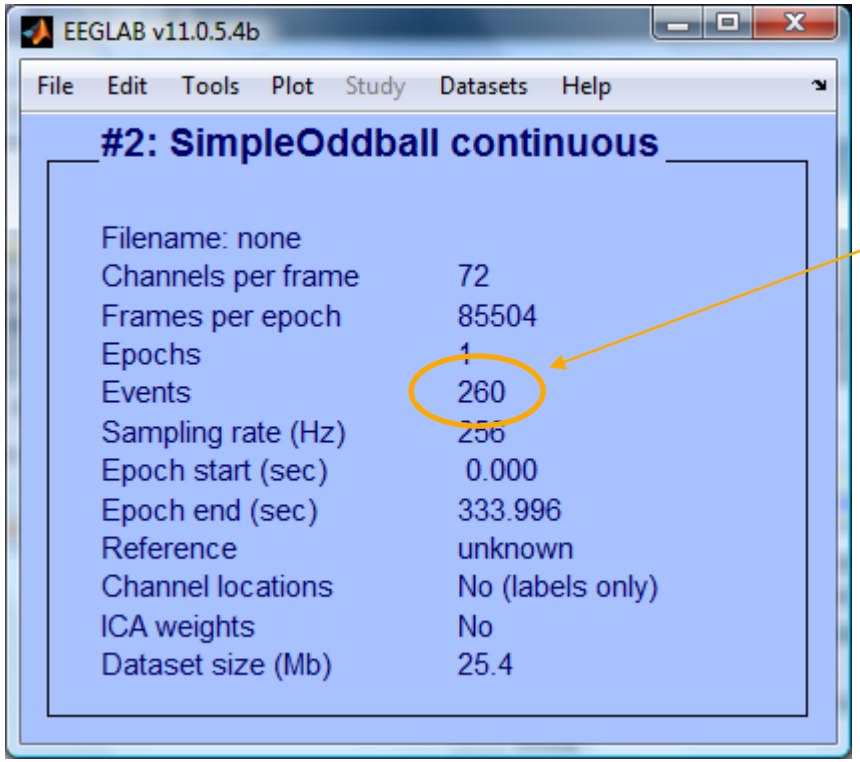






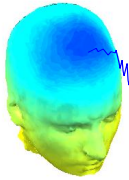
Imported data events

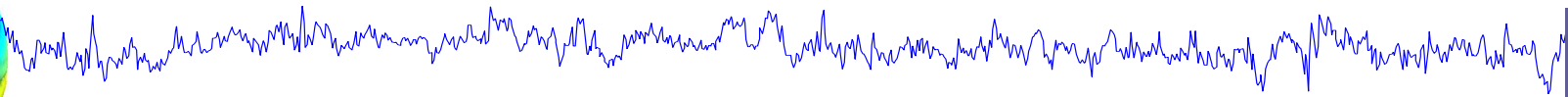




If event import was successful, you will see an appropriate number here

Sample data: basic P300 paradigm





File

SimpleOddball.set

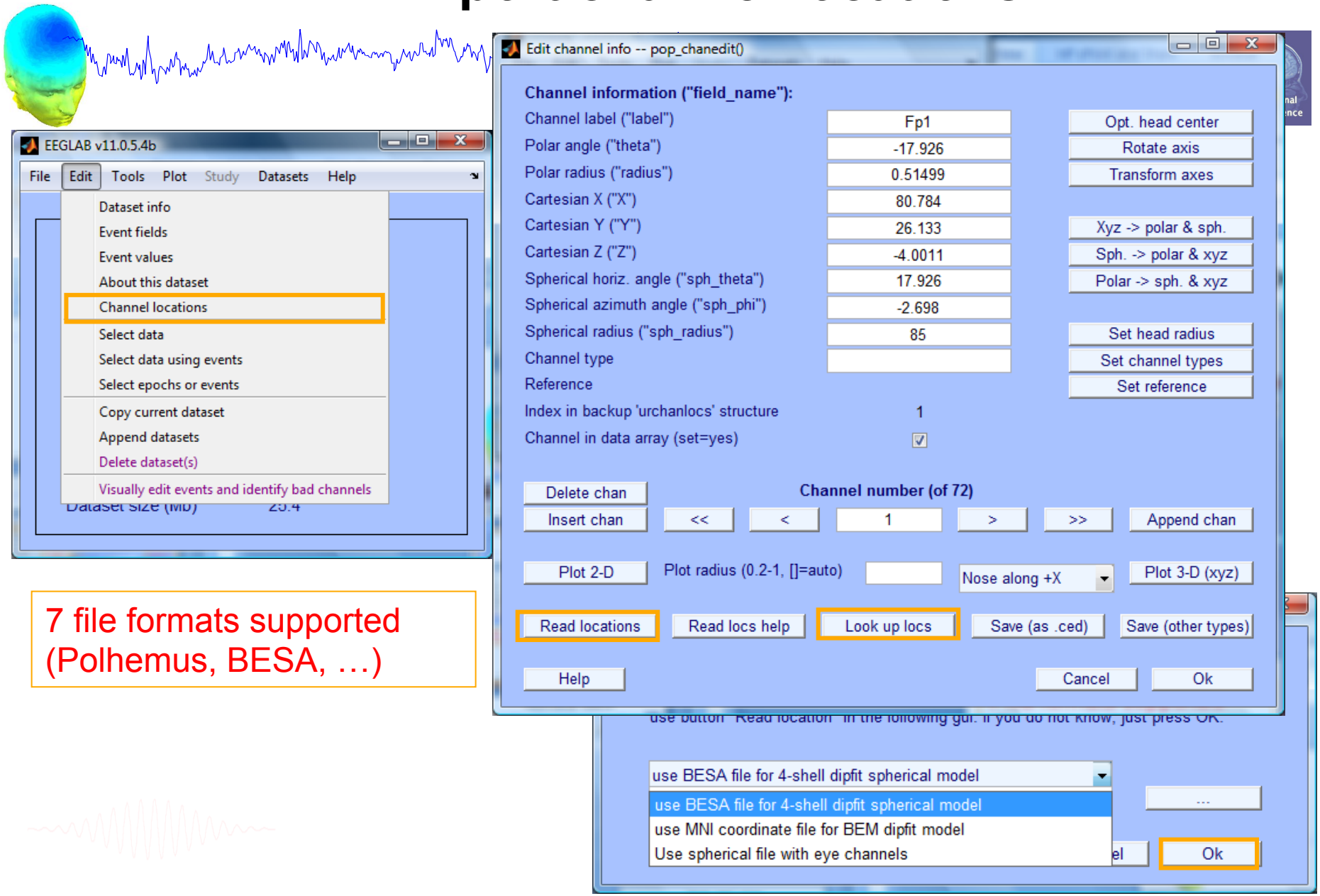
Data

68 channel EEG, 256 Hz sampling rate, Biosemi system, re-referenced during import to averaged left and right mastoid electrodes

Task

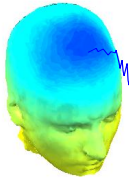
speeded button press response to star shape (no response to circle shape), 100 ms presentation duration, 200 trials

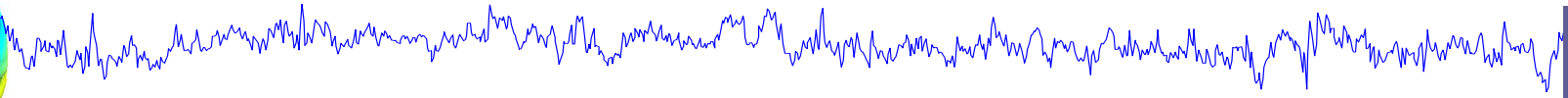
Import channel locations



7 file formats supported (Polhemus, BESA, …)

Import channel locations





Swartz Center for Computational Neuroscience

Edit channel info -- pop_chanedit()

Channel information ("field_name"):

Channel label ("label")	LEYE
Polar angle ("theta")	-45.1543
Polar radius ("radius")	0.54374
Cartesian X ("X")	0.79487
Cartesian Y ("Y")	0.79917
Cartesian Z ("Z")	-0.15585
Spherical horiz. angle ("sph_theta")	45.1543
Spherical azimuth angle ("sph_phi")	-7.8725
Spherical radius ("sph_radius")	1.1379
Channel type	EEG
Reference	
Index in backup 'urchanlocs' structure	
Channel in data array (set=yes)	☑

Opt. head center | Rotate axis | Transform axes | Xyz -> polar & sph. | Sph. -> polar & xyz | Polar -> sph. & xyz | Set head radius | Set channel types | Set reference

Delete chan | Insert chan | **Channel number (of 71)** | << | < | 1 | > | >> | Append chan

Plot 2-D | Plot radius (0.2-1, []=auto) | Nose along +X | Plot 3-D (xyz)

Read locations | Read locs help | Look up locs | Save (as .ced) | Save (other types)

Help | Cancel | Ok

Convert channel locations -- pop_chancenter()

Optimize center location ☑ **or specify center** 0 0 0

Channel indices to ignore for best-sphere matching

Browse

Help | Cancel | Ok

Force electrode location -- forcelocs()

X/Y value: 0 | Coordinate: X (rotate X-Z plane) | Electrode list: Cz | Pick

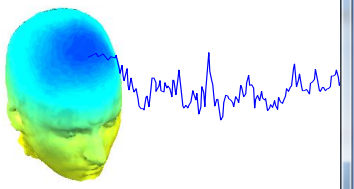
Help | Cancel | Ok

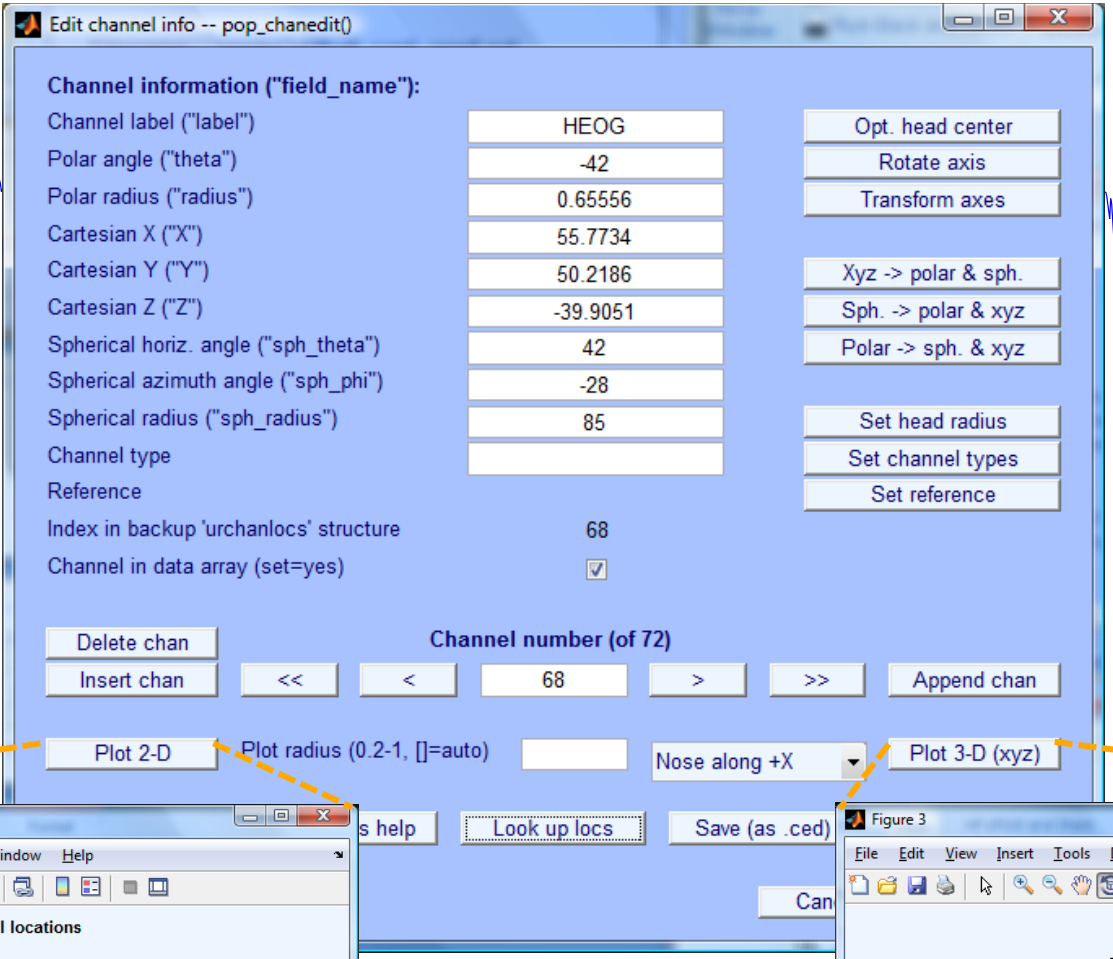
Set channel ...

Channel indices: 1:71

Type (e.g. EEG): EEG

Help | Cancel | Ok




Edit channel info -- pop_chanedit()
Channel information ("field_name"):
Channel label ("label")
HEOG
Polar angle ("theta")
-42
Polar radius ("radius")
0.65556
Cartesian X ("X")
55.7734
Cartesian Y ("Y")
50.2186
Cartesian Z ("Z")
-39.9051
Spherical horiz. angle ("sph_theta")
42
Spherical azimuth angle ("sph_phi")
-28
Spherical radius ("sph_radius")
85
Channel type
Reference
Index in backup 'urchanlocs' structure
68
Channel in data array (set=yes)
Opt. head center
Rotate axis
Transform axes
Xyz -> polar & sph.
Sph. -> polar & xyz
Polar -> sph. & xyz
Set head radius
Set channel types
Set reference
Delete chan
Insert chan
Channel number (of 72)
<<
<
68
>
>>
Append chan
Plot 2-D
Plot radius (0.2-1, []=auto)
Nose along +X
Plot 3-D (xyz)
s help
Look up locs
Save (as .ced)
Can

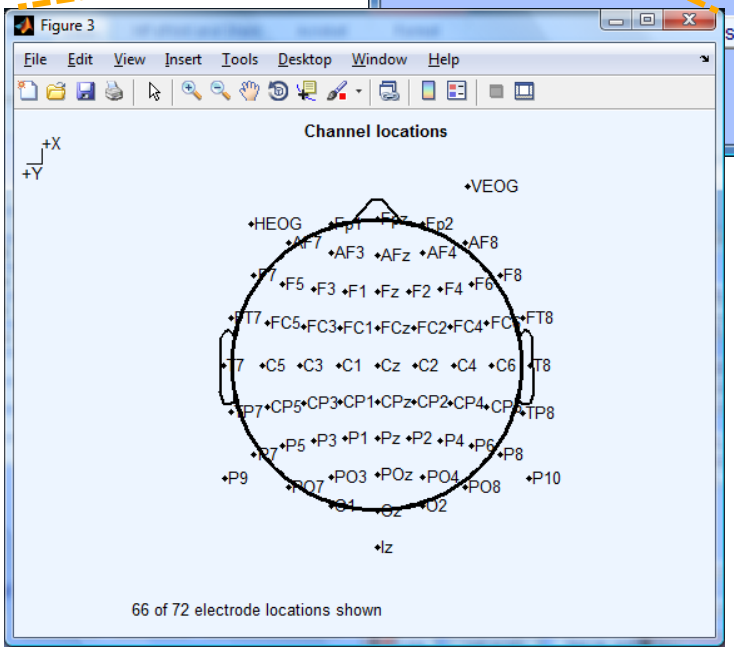


Figure 3
File Edit View Insert Tools Desktop Window Help
Channel locations
+X
+Y
66 of 72 electrode locations shown

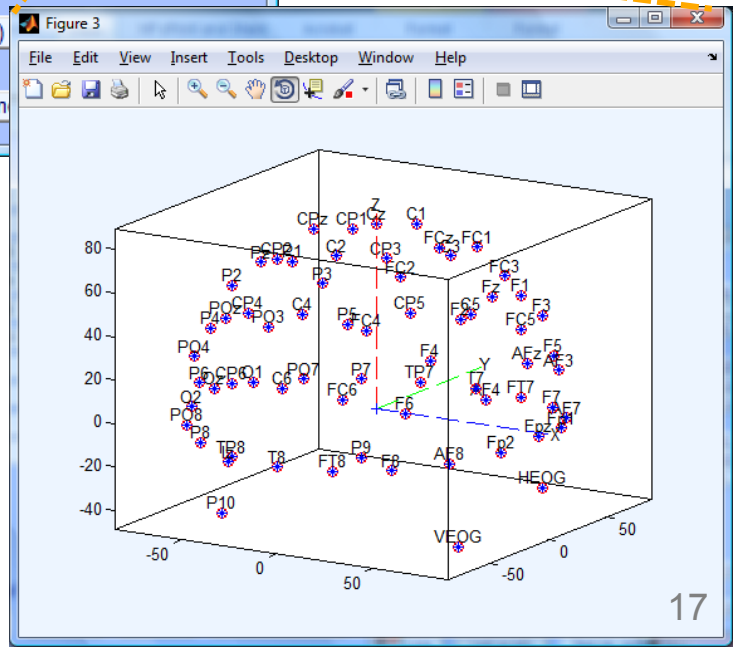
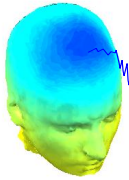
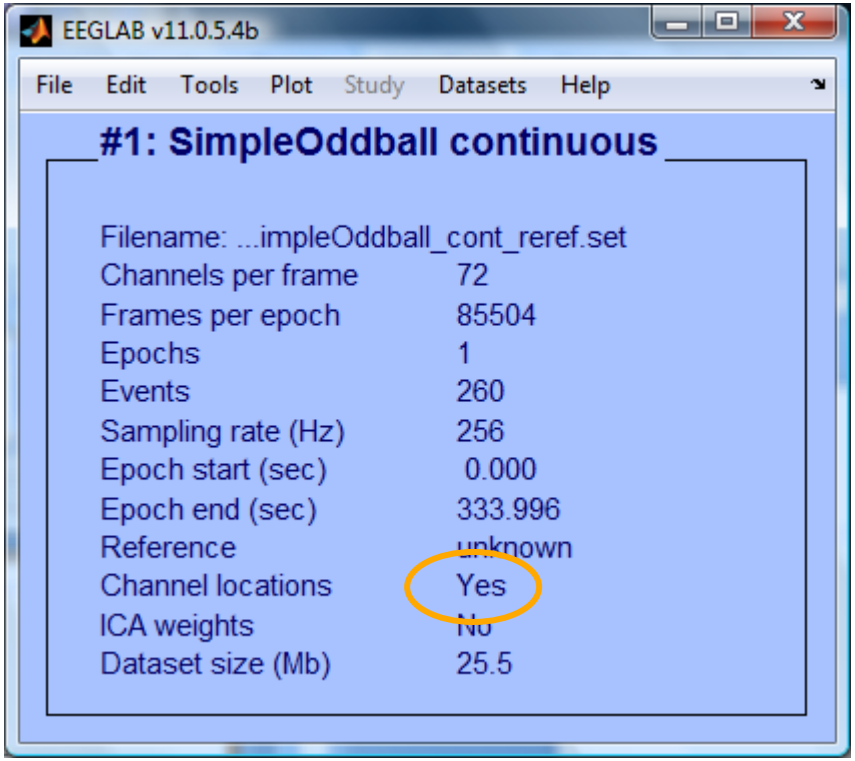


Figure 3
File Edit View Insert Tools Desktop Window Help

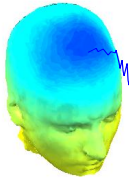

Swartz Center for Computational Neuroscience

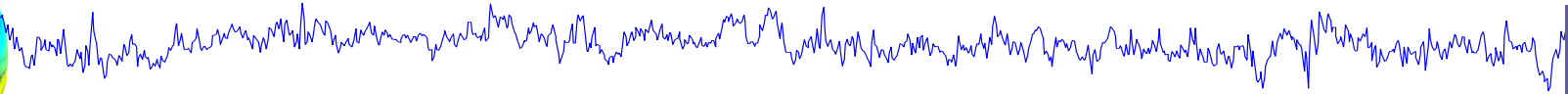
Imported channel locations





Pre-processing pipeline





Swartz Center for Computational Neuroscience

Collect high-density EEG data (>30 chan)

Import into EEGLAB

Import event markers and channel locations

Re-reference/ down-sample (if necessary)

High pass filter (~.5 – 1 Hz)

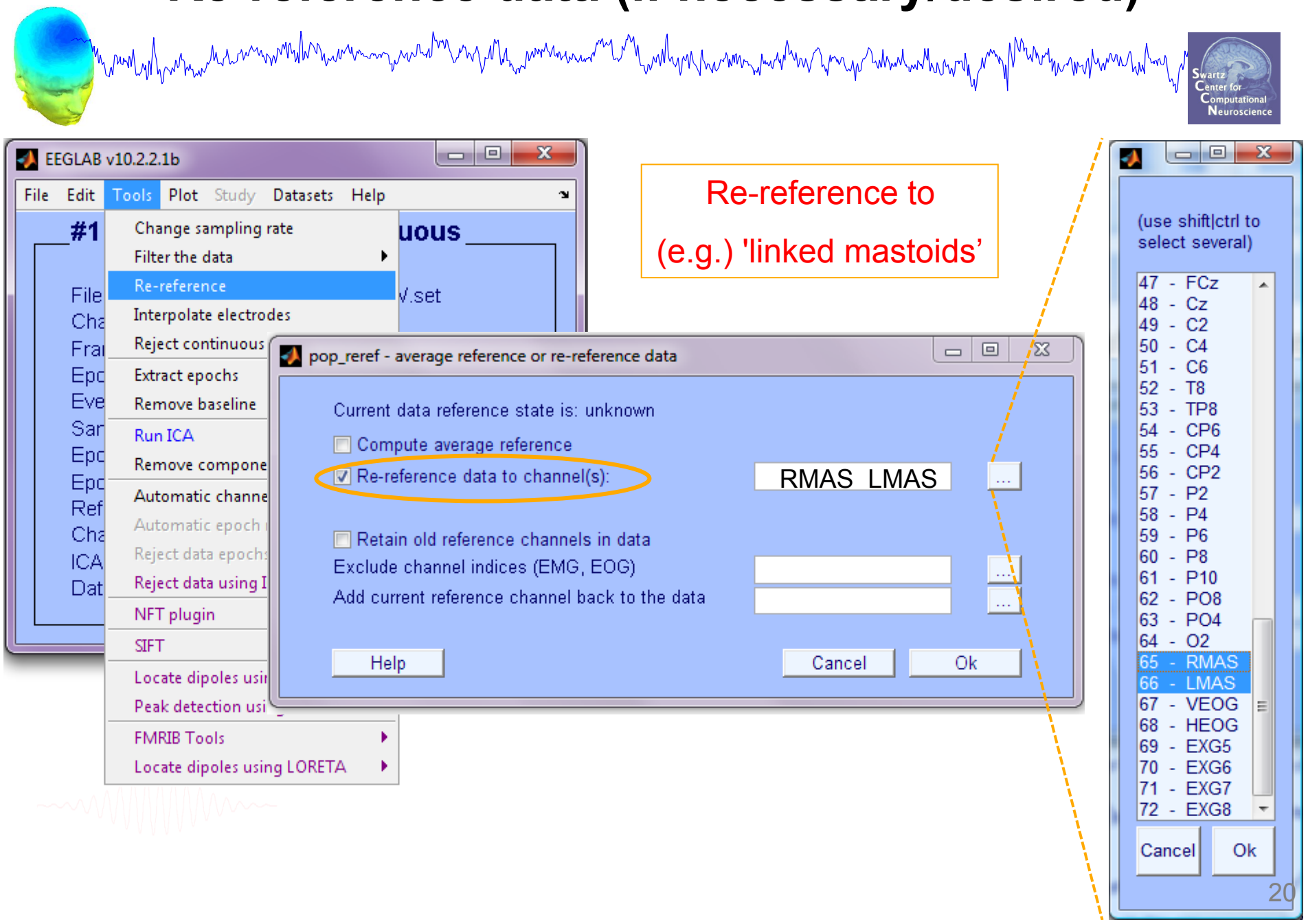
Remove line noise (if necessary)

Identify/reject bad channels

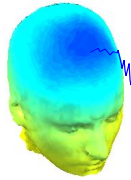
Reject large artifact time points

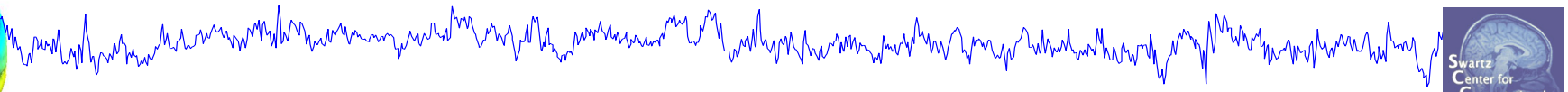
Run ICA

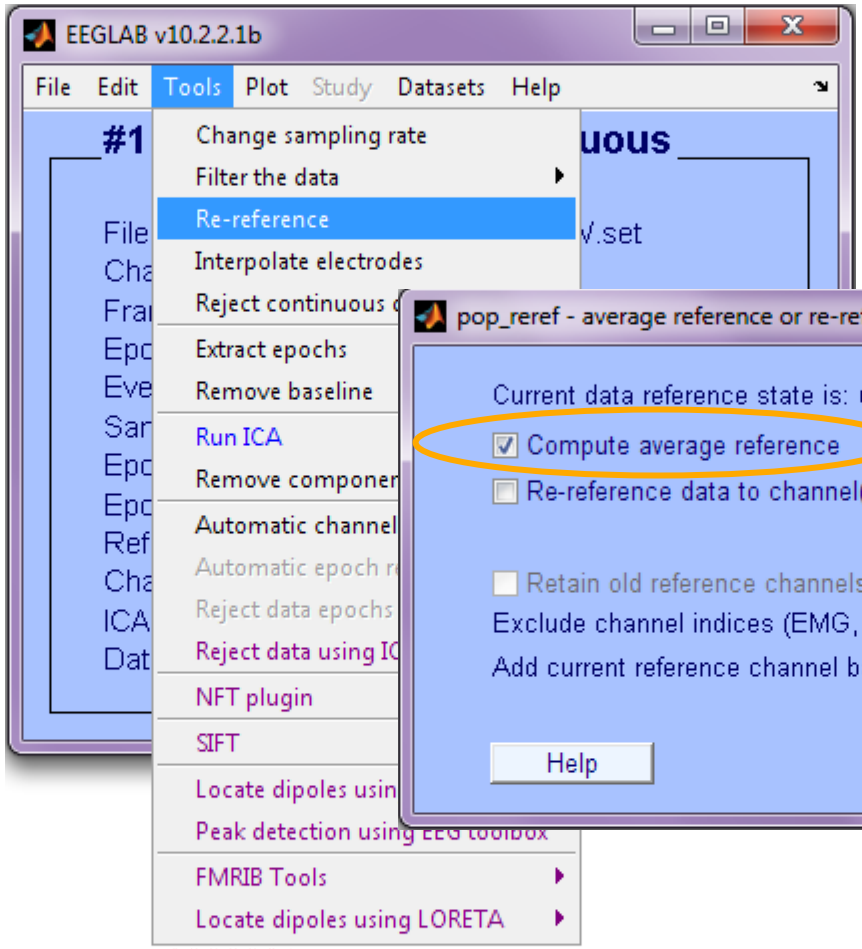
Re-reference data (if necessary/desired)

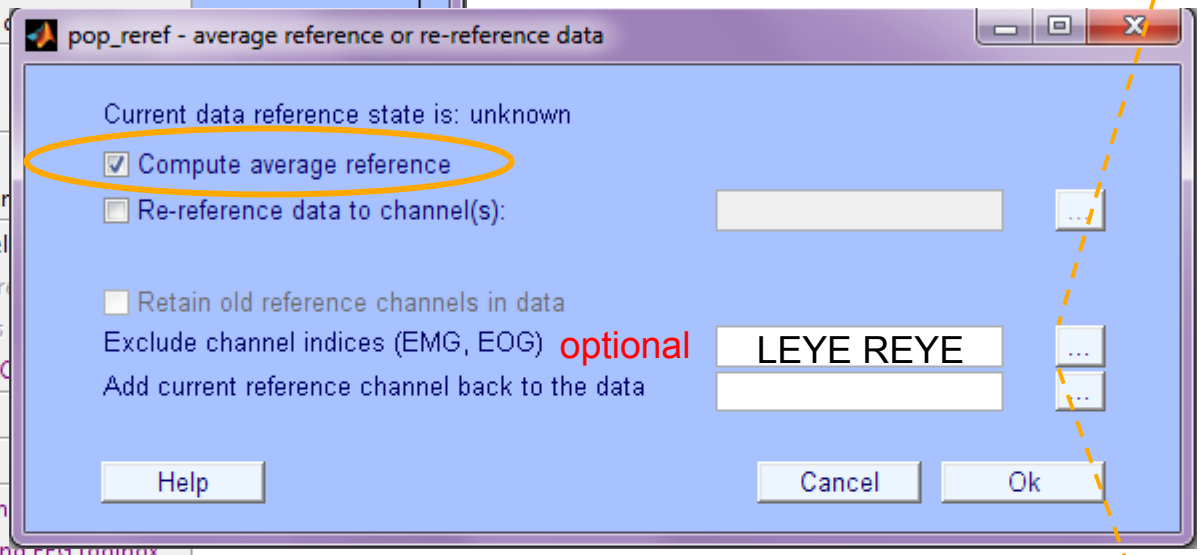


Re-reference data (if necessary/desired)





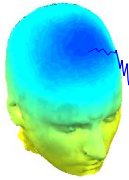


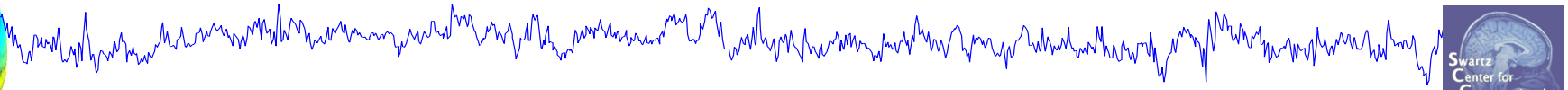


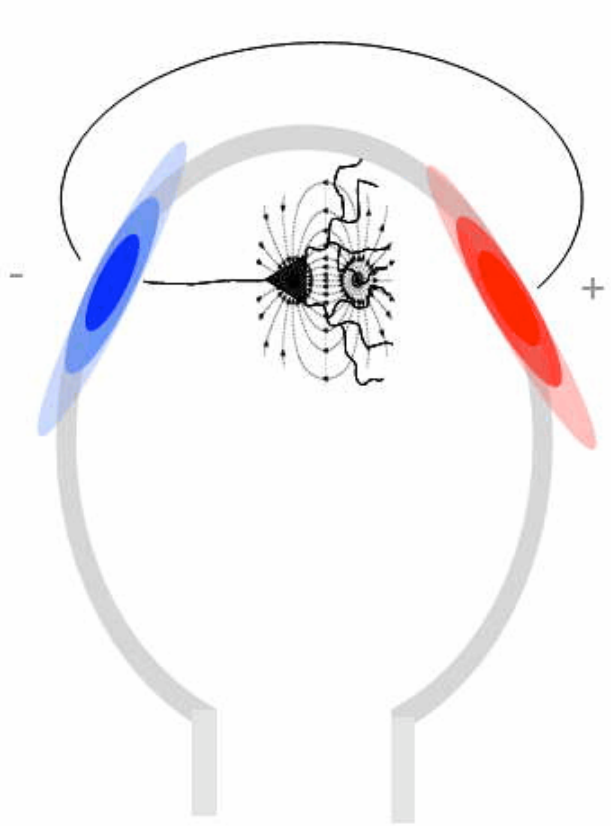
Or,

average reference

On Average Referencing





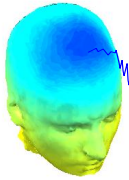


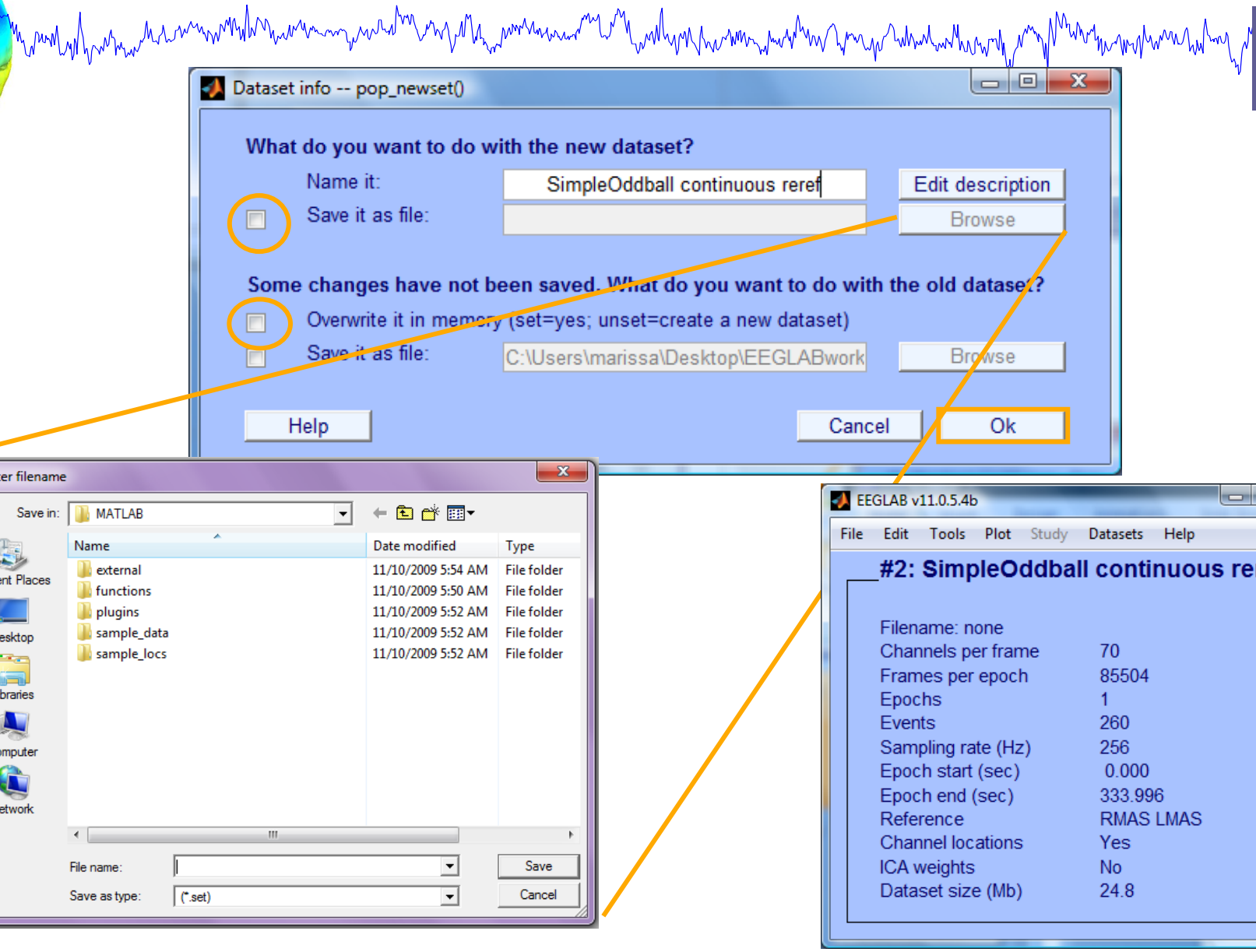
In theory, positive and negative current across entire head should balance—no net current source or sink: Average referencing enforces this.

In practice, depends on distribution of electrodes.

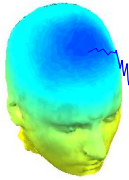
Average referencing reduces data rank by 1, so you must remove one channel (Cz often)

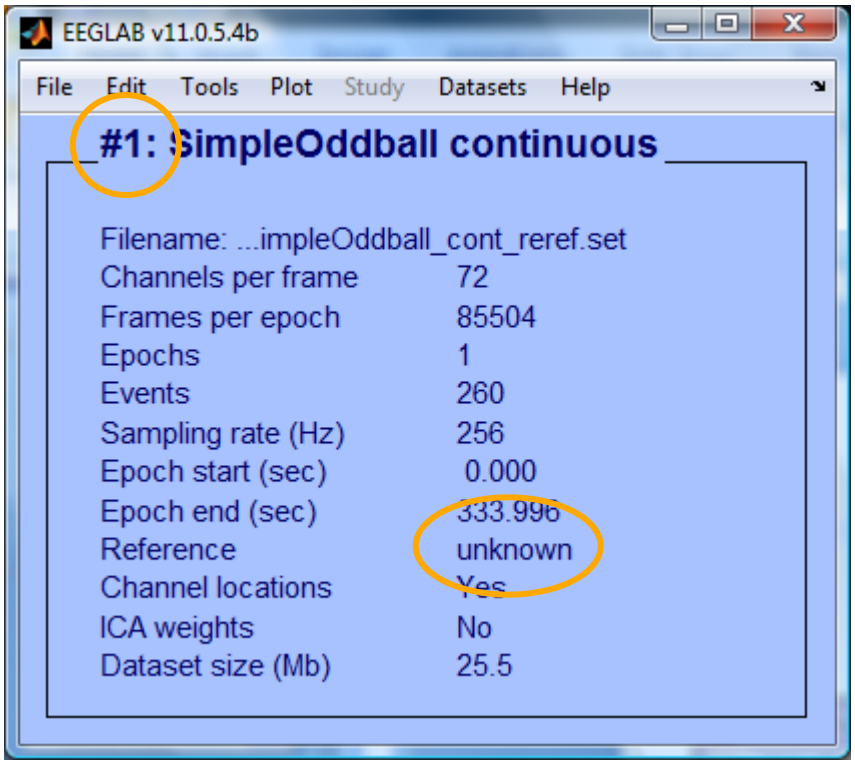
Save new dataset, keep old one

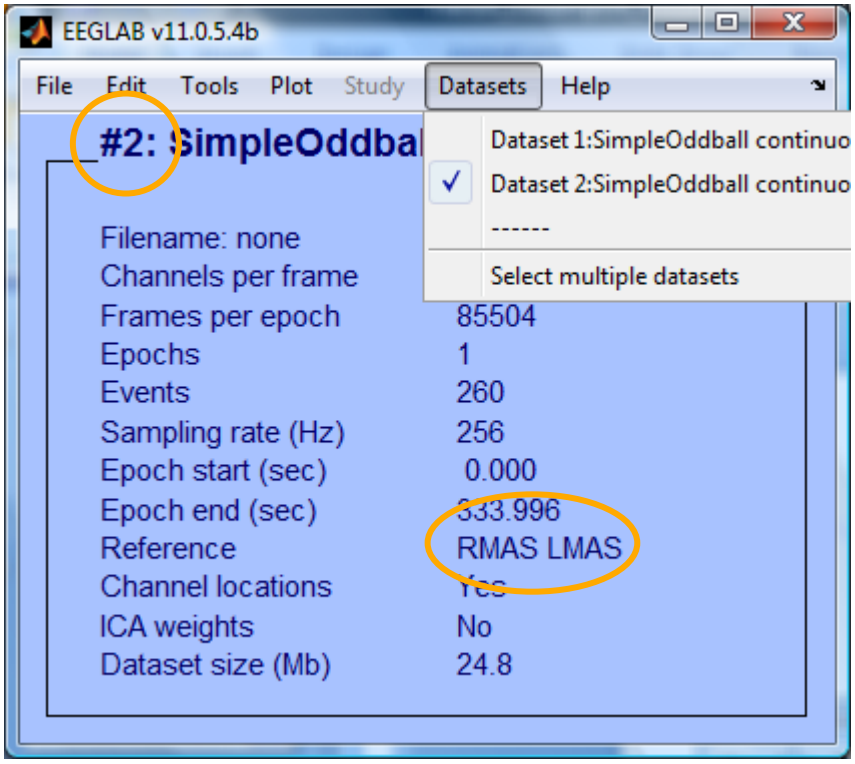




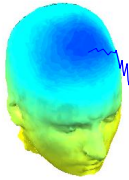
Multiple active datasets (ALLEEG)



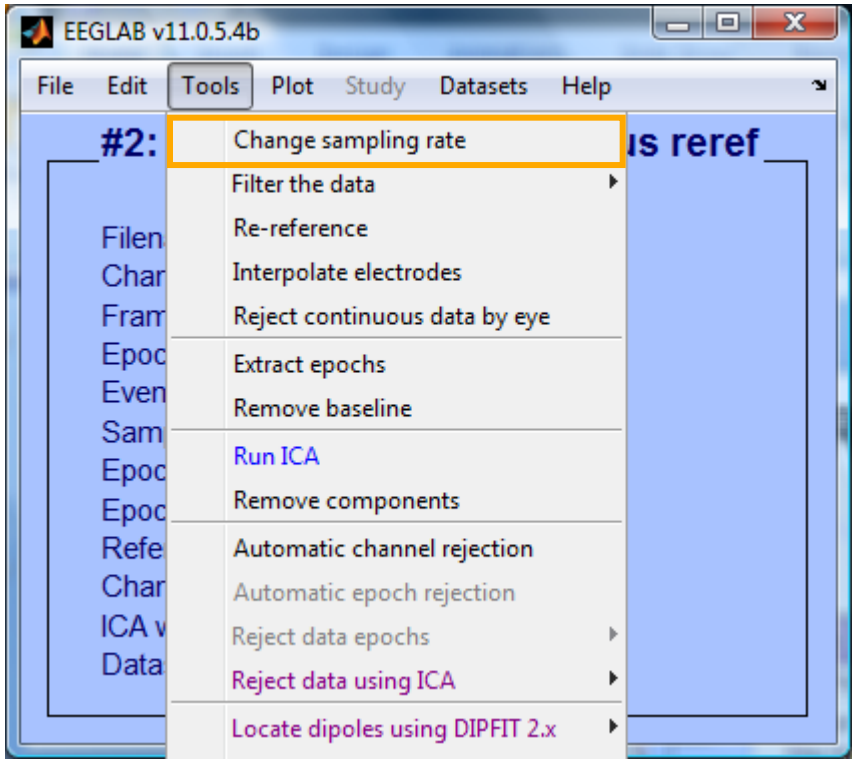


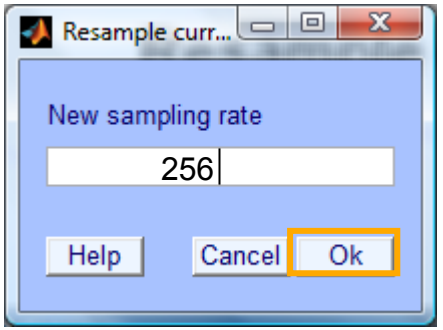


Resample data (if desired)

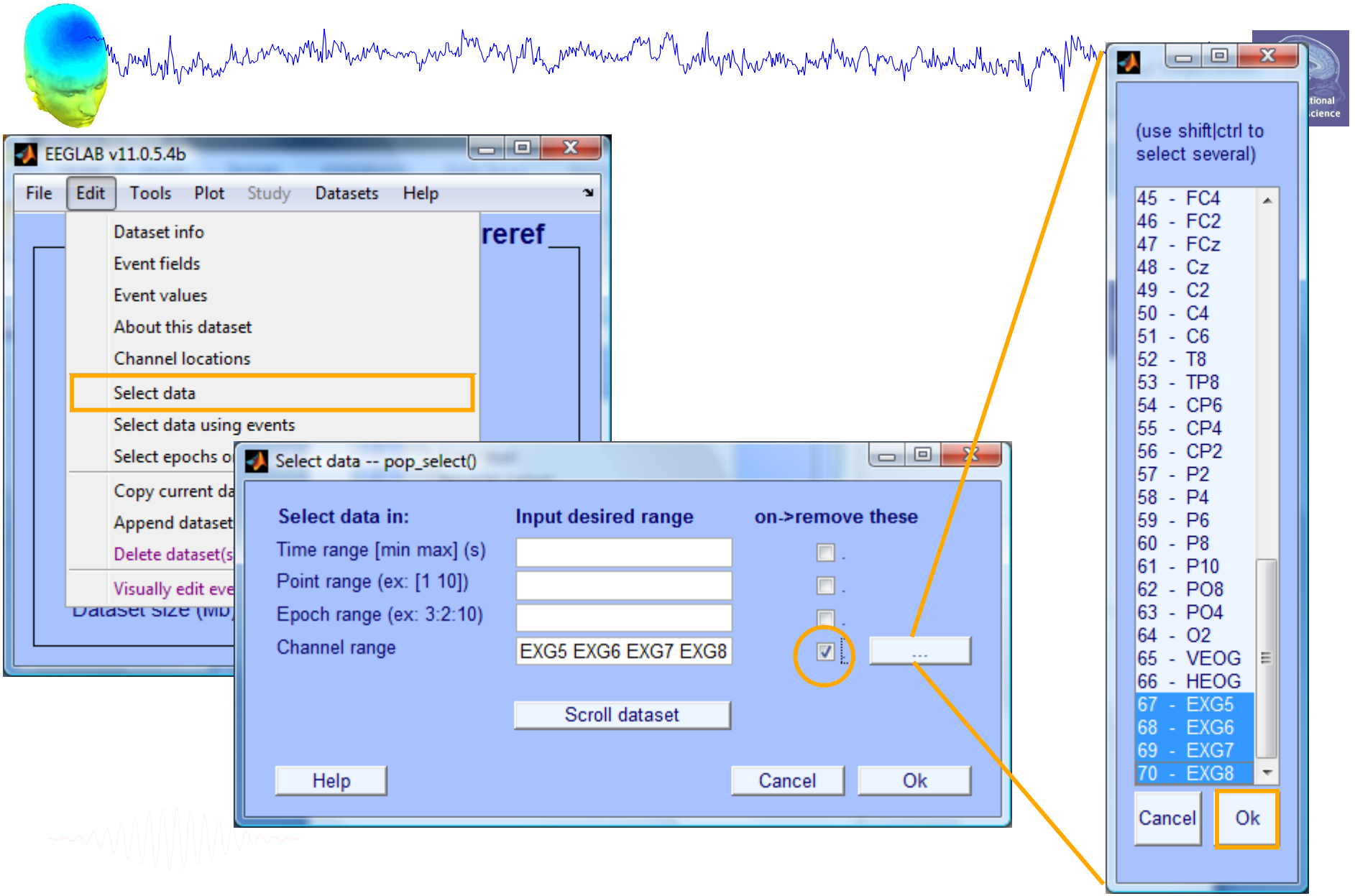


Reason: Reduce space, time. But keep nyquist and ICA data length requirements in mind…

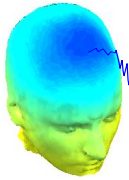


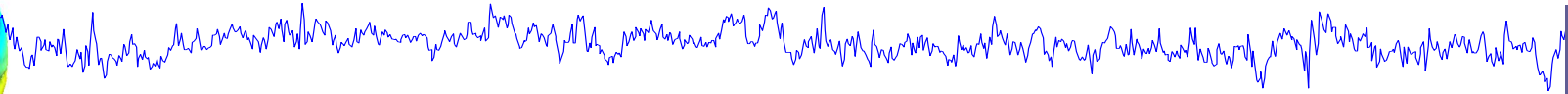


Remove unwanted channels



Pre-processing pipeline





Swartz Center for Computational Neuroscience

Collect high-density EEG data (>30 chan)

Import into EEGLAB

Import event markers and channel locations

Re-reference/ down-sample (if necessary)

STOP!

Save your continuous dataset here

(at least!)

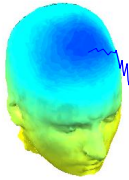
Remove line noise (if necessary)

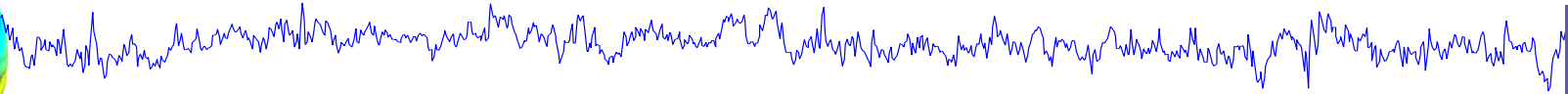
Identify/reject bad channels

Reject large artifact time points

Run ICA

Pre-processing pipeline





Swartz Center for Computational Neuroscience

Collect high-density EEG data (>30 chan)

Import into EEGLAB

Import event markers and channel locations

Re-reference/ down-sample (if necessary)

High pass filter (~.5 – 1 Hz)

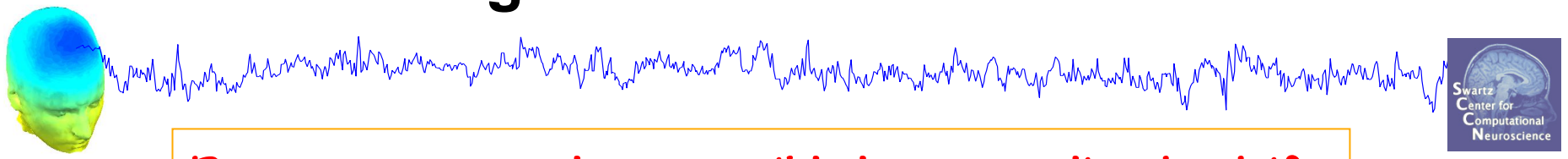
Remove line noise (if necessary)

Identify/reject bad channels

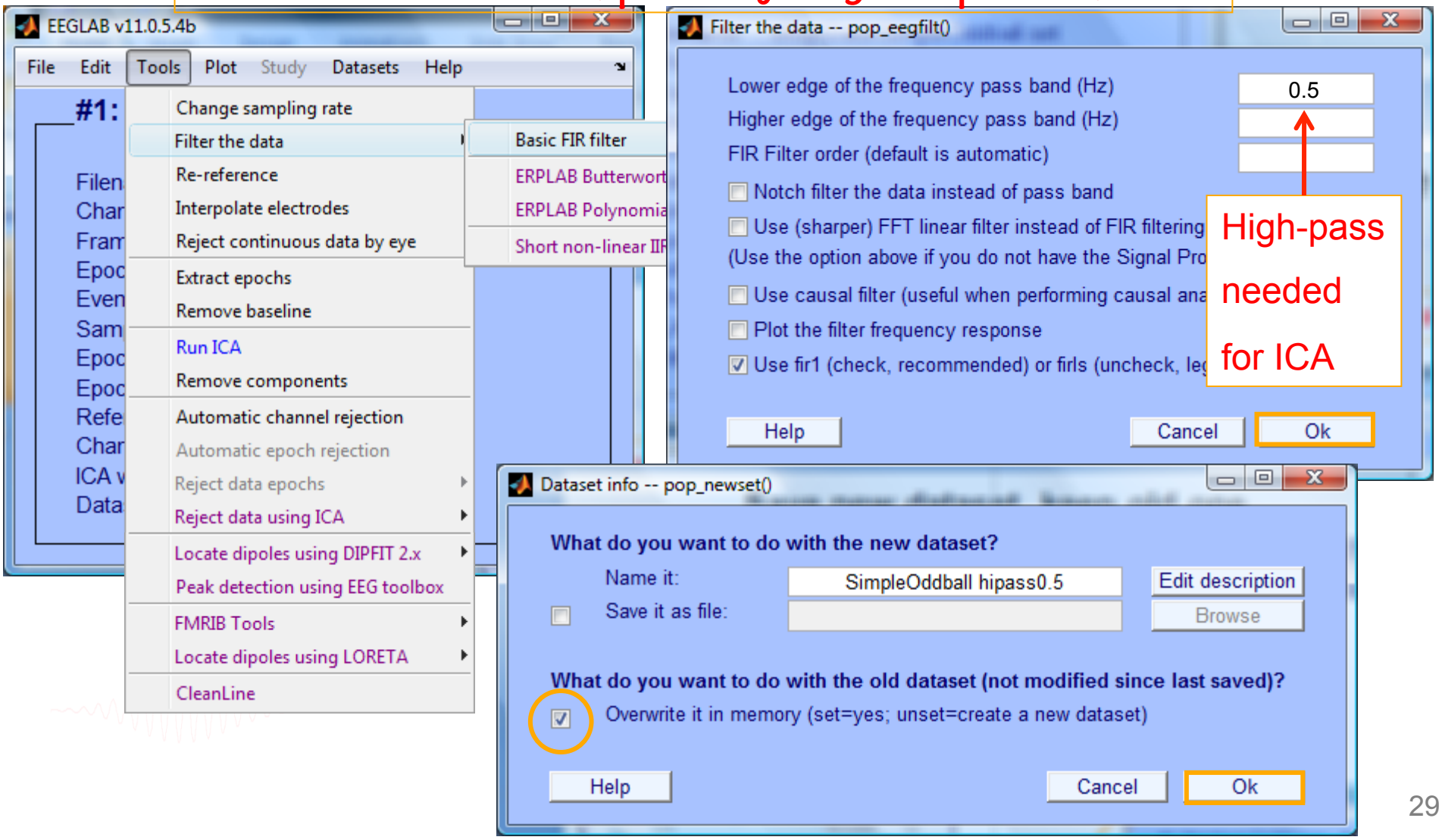
Reject large artifact time points

Run ICA

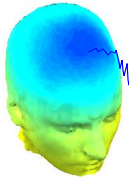
High-Pass Filter the data

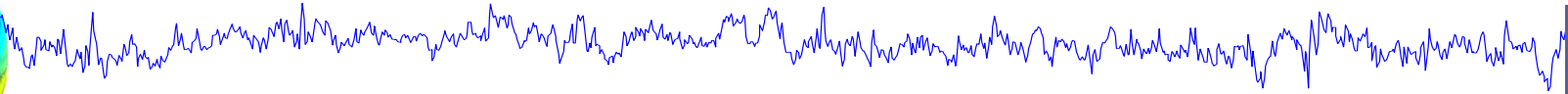


Reason: remove slow, possibly large amplitude, drift



Pre-processing pipeline





Swartz Center for Computational Neuroscience

Collect high-density EEG data (>30 chan)

Import into EEGLAB

Import event markers and channel locations

Re-reference/ down-sample (if necessary)

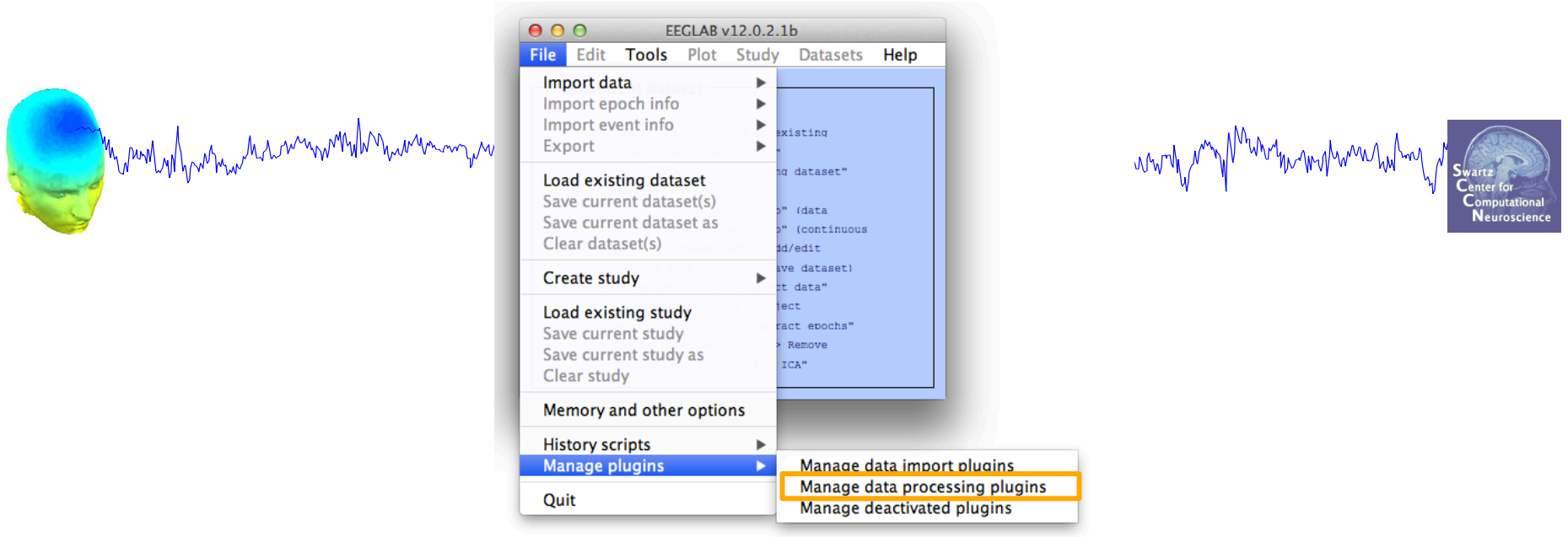
High pass filter (~.5 – 1 Hz)

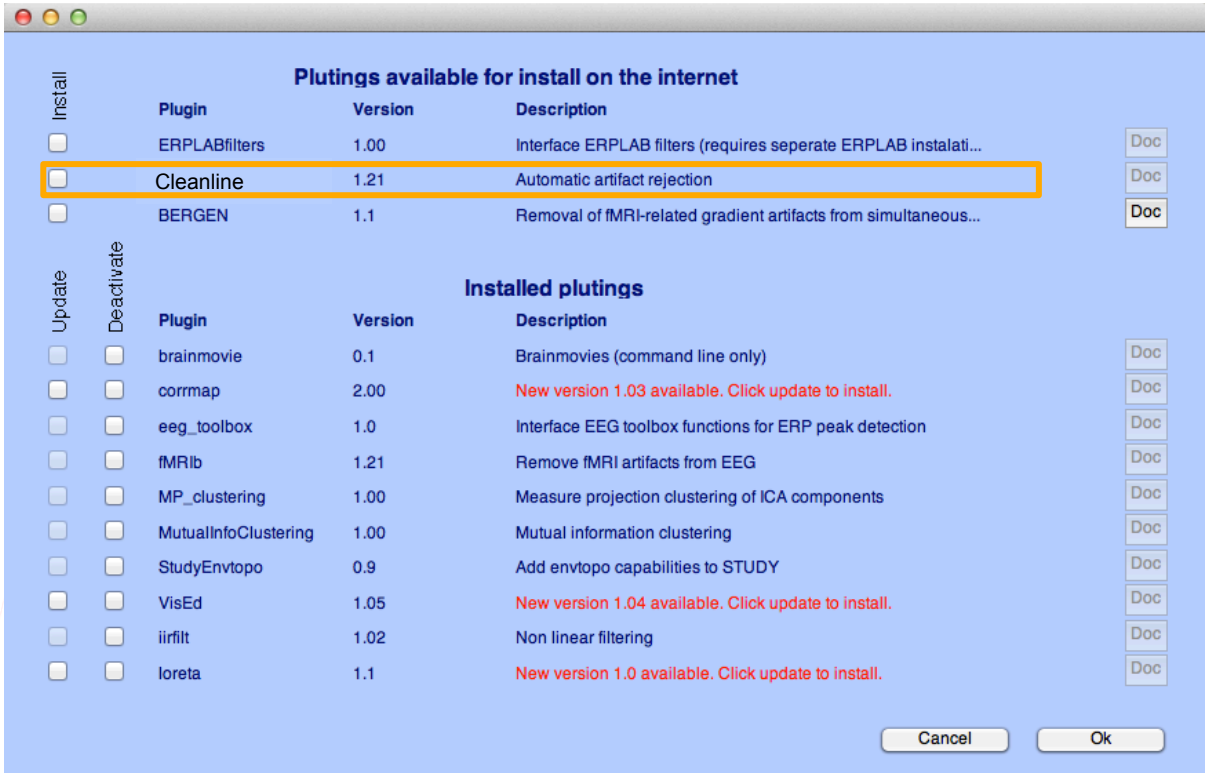
Remove line noise (if necessary)

Identify/reject bad channels

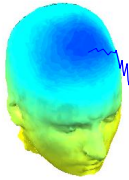
Reject large artifact time points

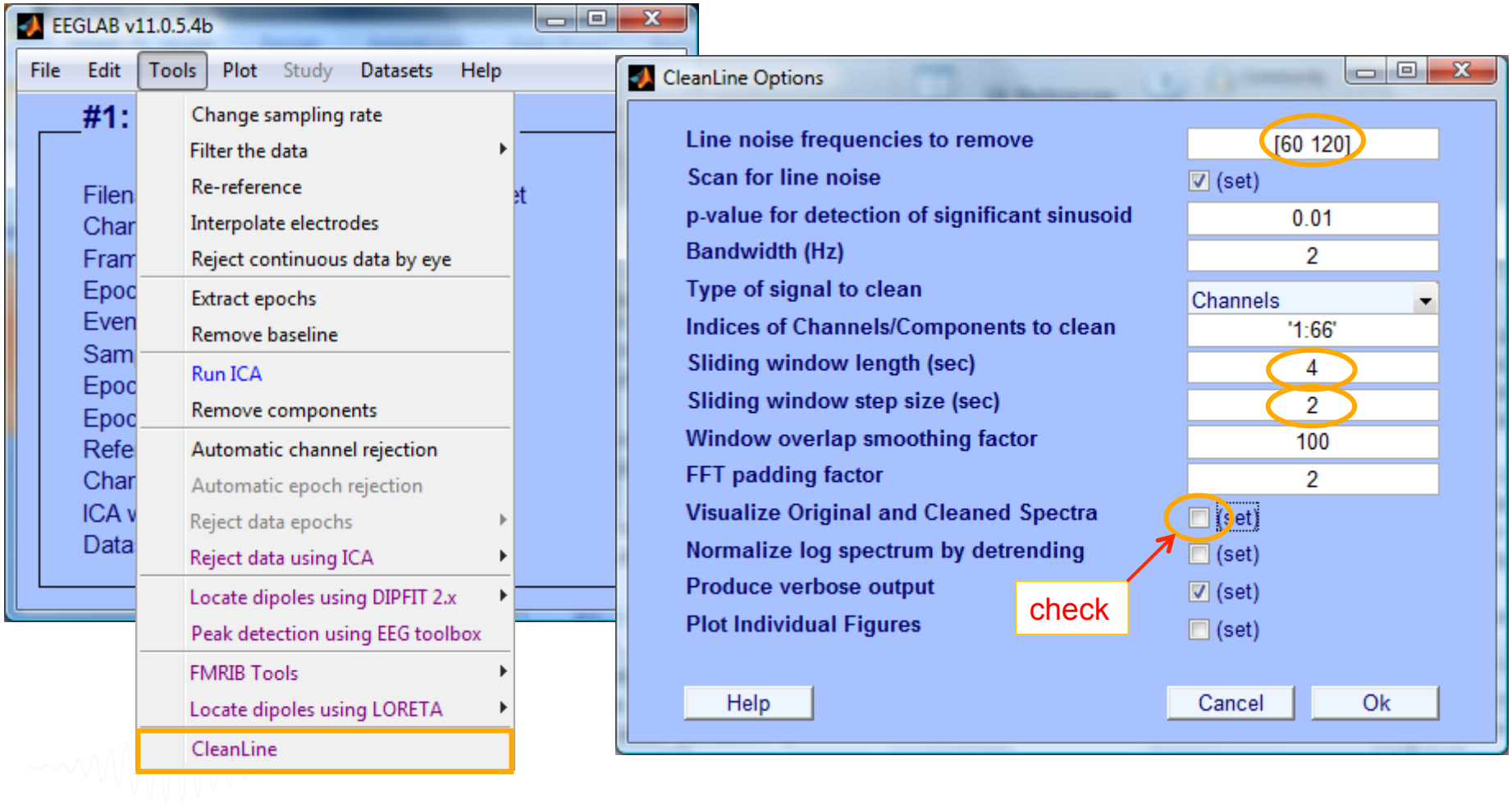
Run ICA


EEGLAB v12.0.2.1b
File Edit Tools Plot Study Datasets Help
Import data
Import epoch info
Import event info
Export
Load existing dataset
Save current dataset(s)
Save current dataset as
Clear dataset(s)
Create study
Load existing study
Save current study
Save current study as
Clear study
Memory and other options
History scripts
Manage plugins
Quit
Manage data import plugins
Manage data processing plugins
Manage deactivated plugins

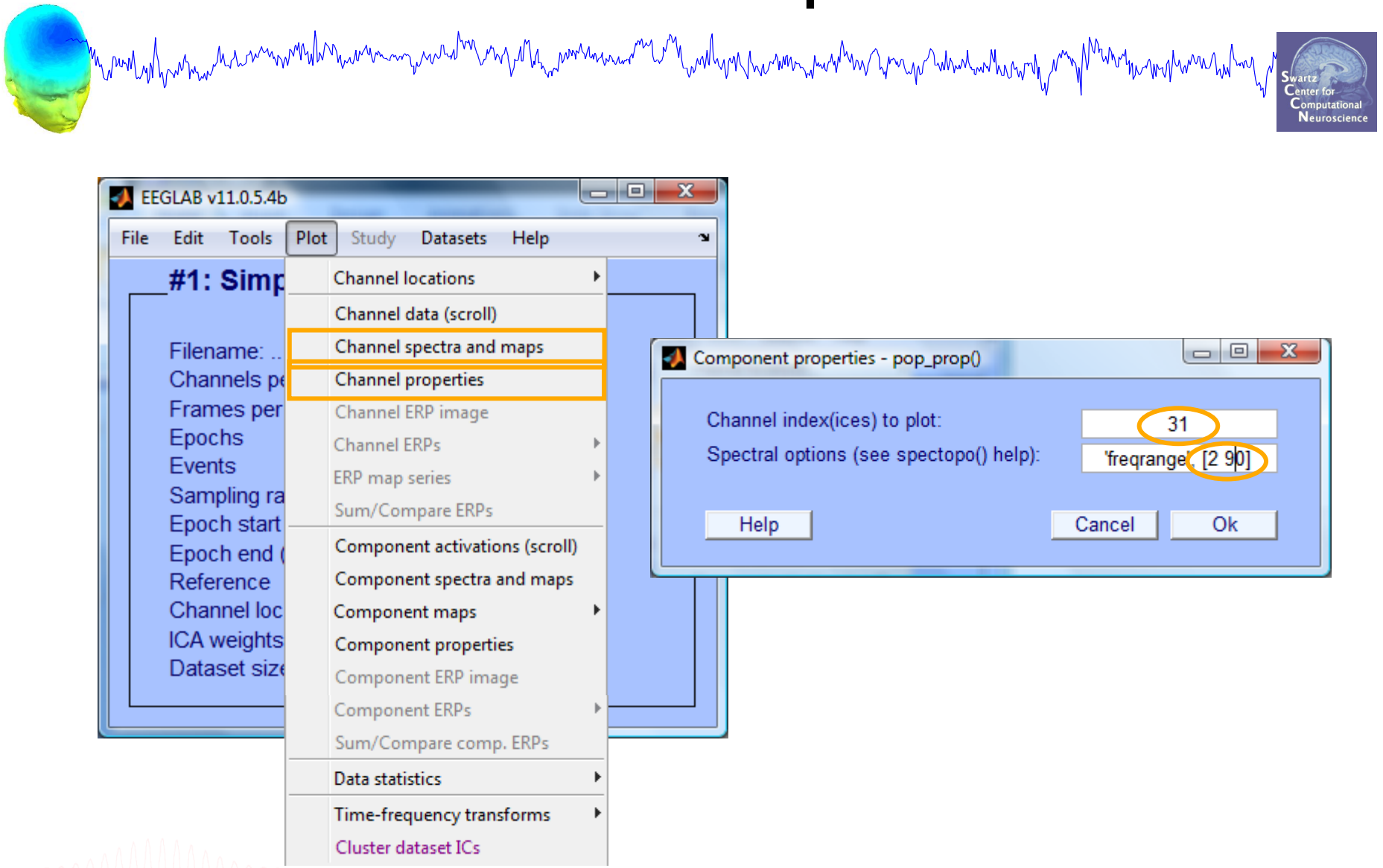

Plutings available for install on the internet
Install
Plugin
Version
Description
ERPLABfilters 1.00 Interface ERPLAB filters (requires seperate ERPLAB instalati... Doc
Cleanline 1.21 Automatic artifact rejection Doc
BERGEN 1.1 Removal of fMRI-related gradient artifacts from simultaneous... Doc
Update
Deactivate
Installed plutings
Plugin
Version
Description
brainmovie 0.1 Brainmovies (command line only) Doc
corrmap 2.00 New version 1.03 available. Click update to install. Doc
eeg_toolbox 1.0 Interface EEG toolbox functions for ERP peak detection Doc
fMRIb 1.21 Remove fMRI artifacts from EEG Doc
MP_clustering 1.00 Measure projection clustering of ICA components Doc
MutualInfoClustering 1.00 Mutual information clustering Doc
StudyEnvtopo 0.9 Add envtopo capabilities to STUDY Doc
VisEd 1.05 New version 1.04 available. Click update to install. Doc
iirfilt 1.02 Non linear filtering Doc
loreta 1.1 New version 1.0 available. Click update to install. Doc
Cancel
Ok

Remove line noise (Cleanline)

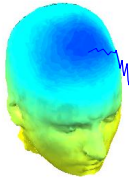


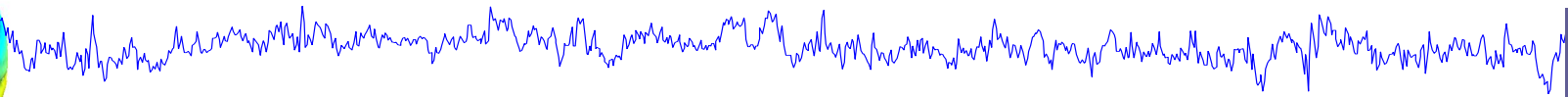


Plot channel spectra



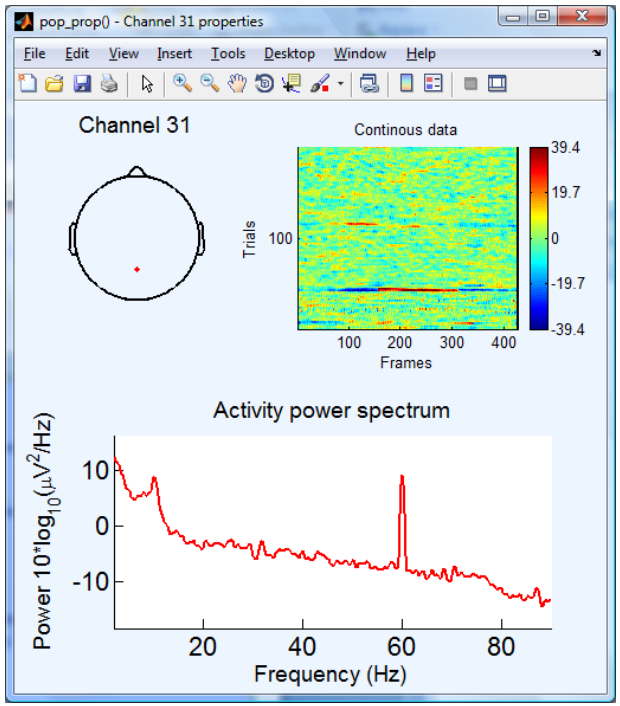
Filter comparisons



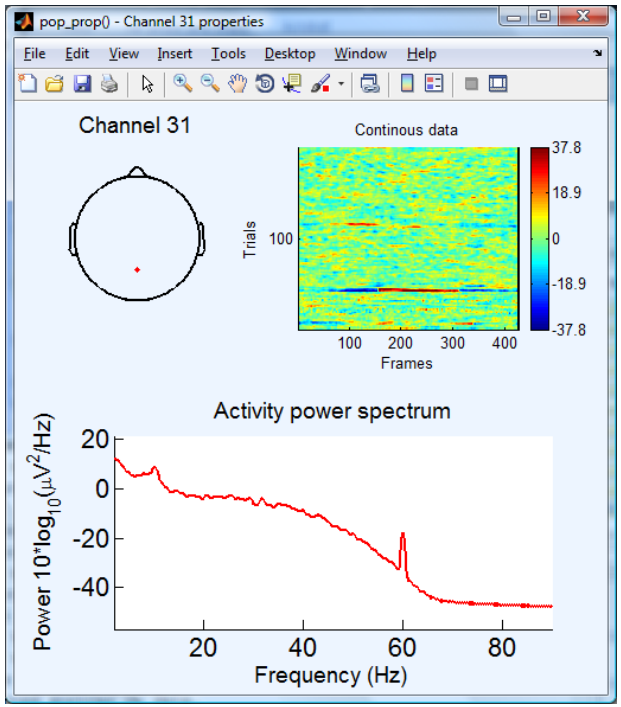


Swartz Center for Computational Neuroscience

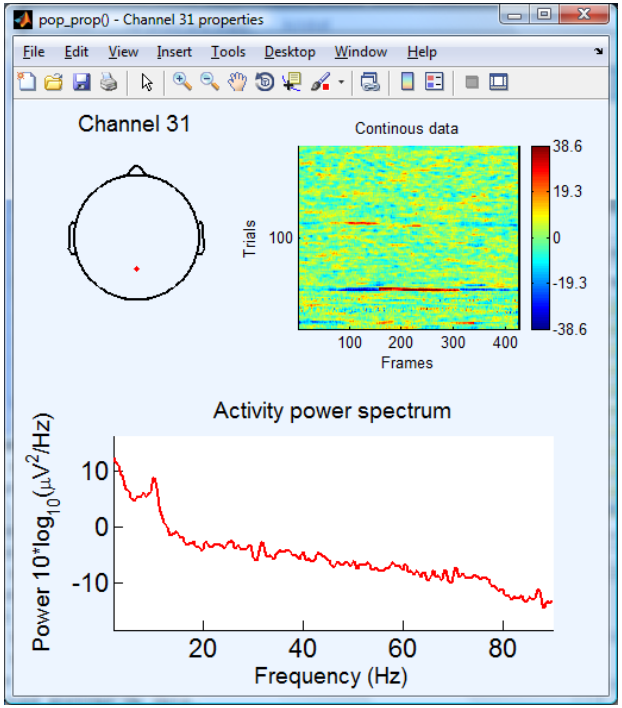
0.5 Hz high-pass filter



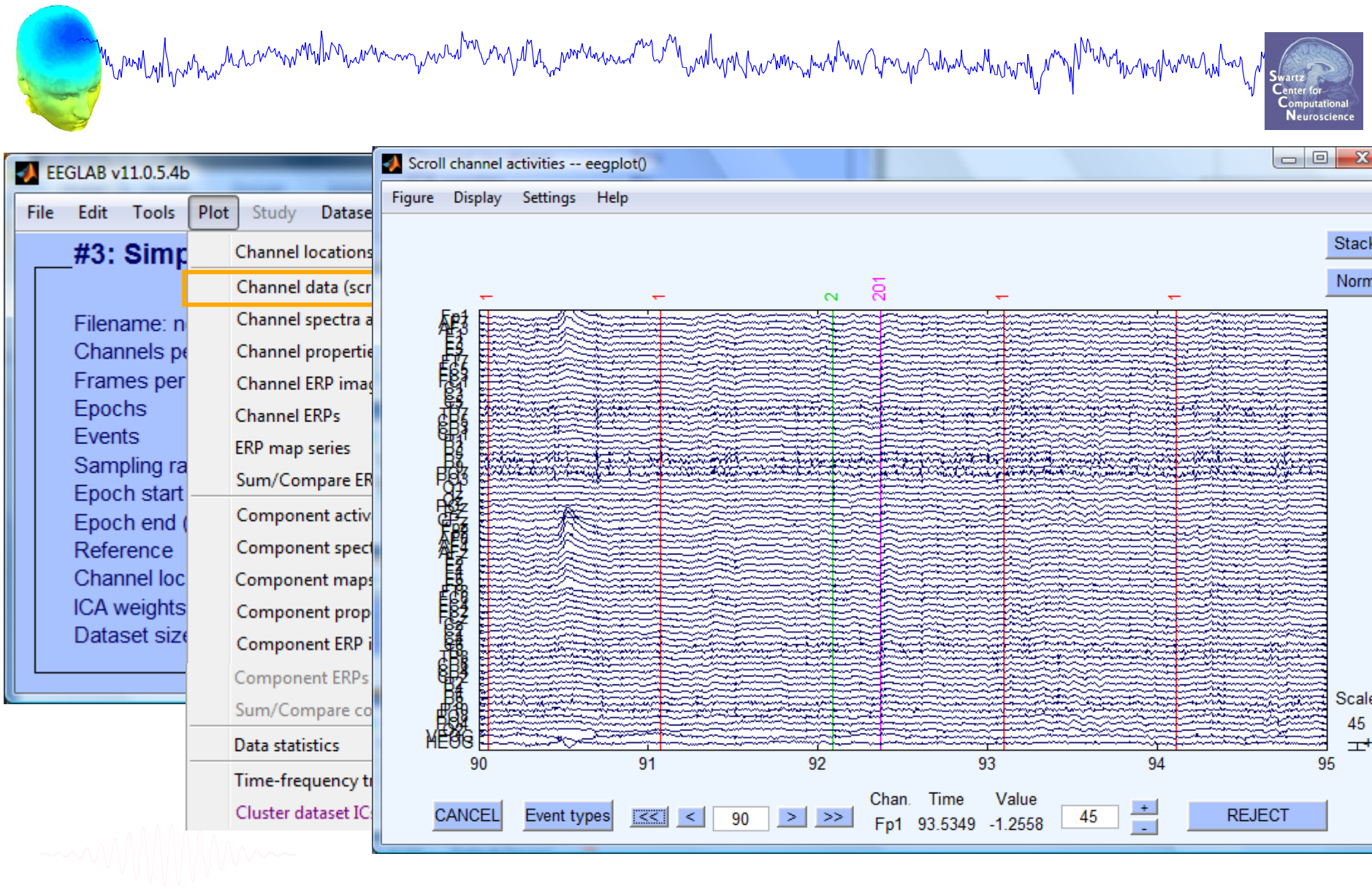
0.5 Hz high-pass filter
50 Hz low-pass filter



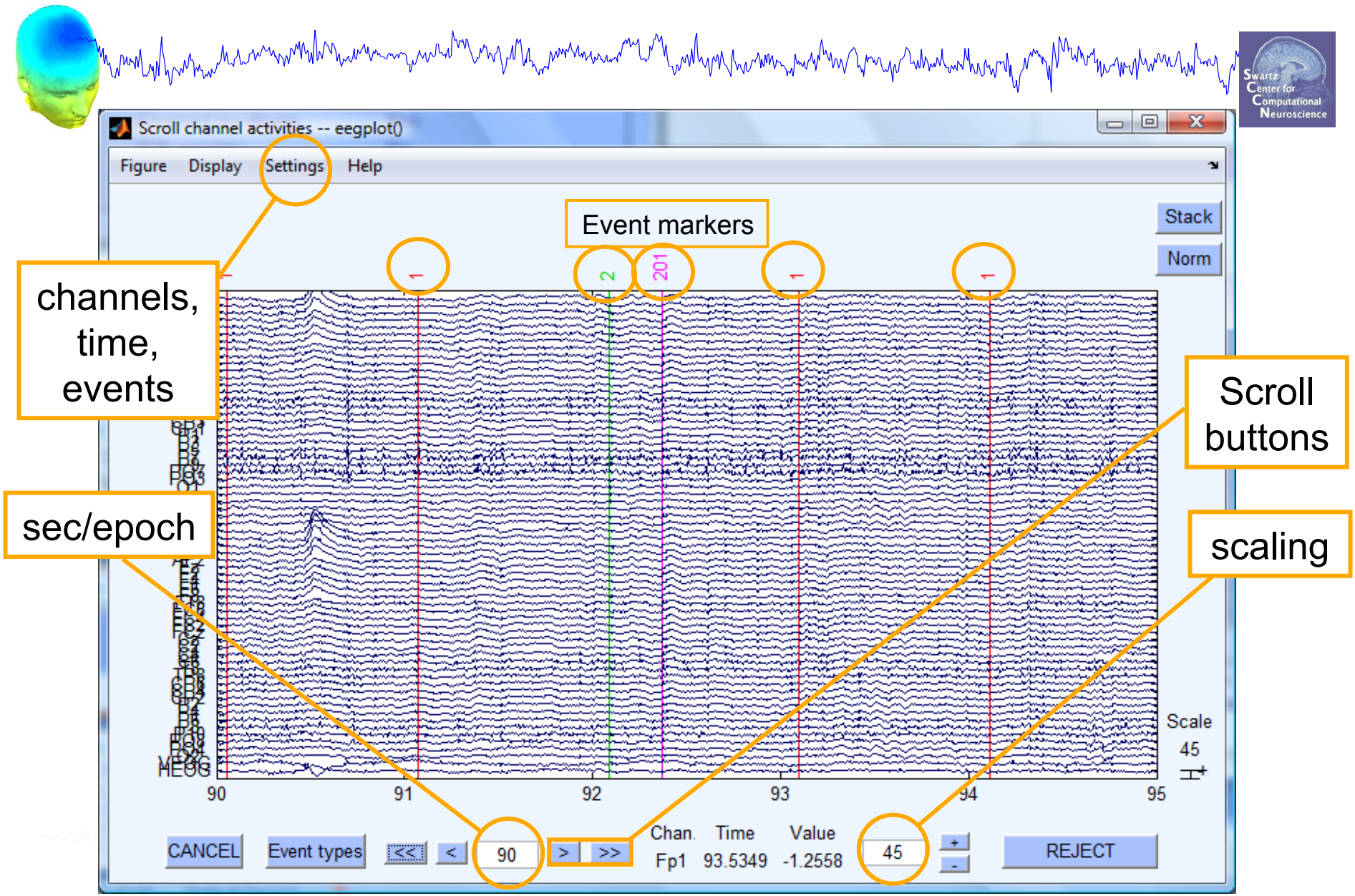
0.5 Hz high-pass filter
Cleanline



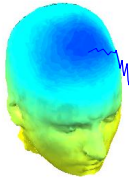
Scroll channel data

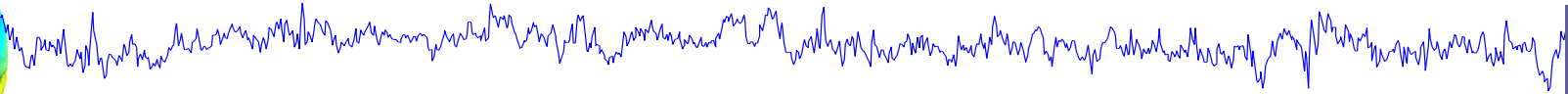


Scroll channel data



Pre-processing pipeline





Swartz Center for Computational Neuroscience

Collect high-density EEG data (>30 chan)

Import into EEGLAB

Import event markers and channel locations

Re-reference/ down-sample (if necessary)

High pass filter (~.5 – 1 Hz)

Remove line noise (if necessary)

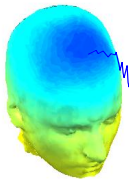
STOP!

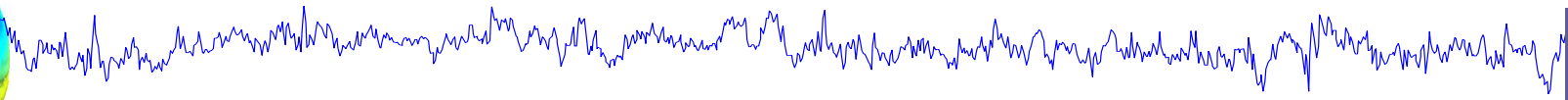
Save your dataset here; if you epoch before ICA you can import ICA weights to this dataset later

Identify/reject bad channels

time points

Run ICA

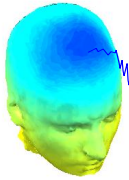


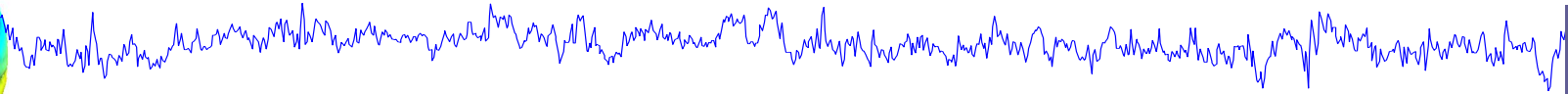


Data Cleaning for ICA

Variant 1: Continuous Data

Pre-processing pipeline





Swartz Center for Computational Neuroscience

Collect high-density EEG data (>30 chan)

Import into EEGLAB

Import event markers and channel locations

Re-reference/ down-sample (if necessary)

High pass filter (~.5 – 1 Hz)

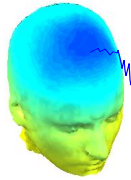
Remove line noise (if necessary)

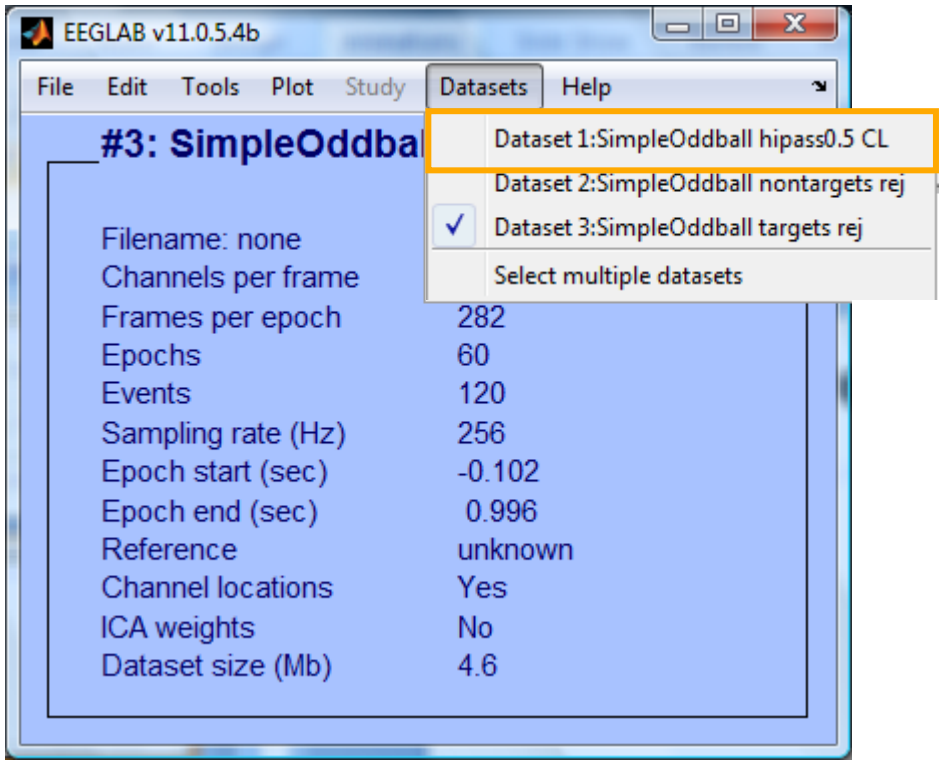
Identify/reject bad channels

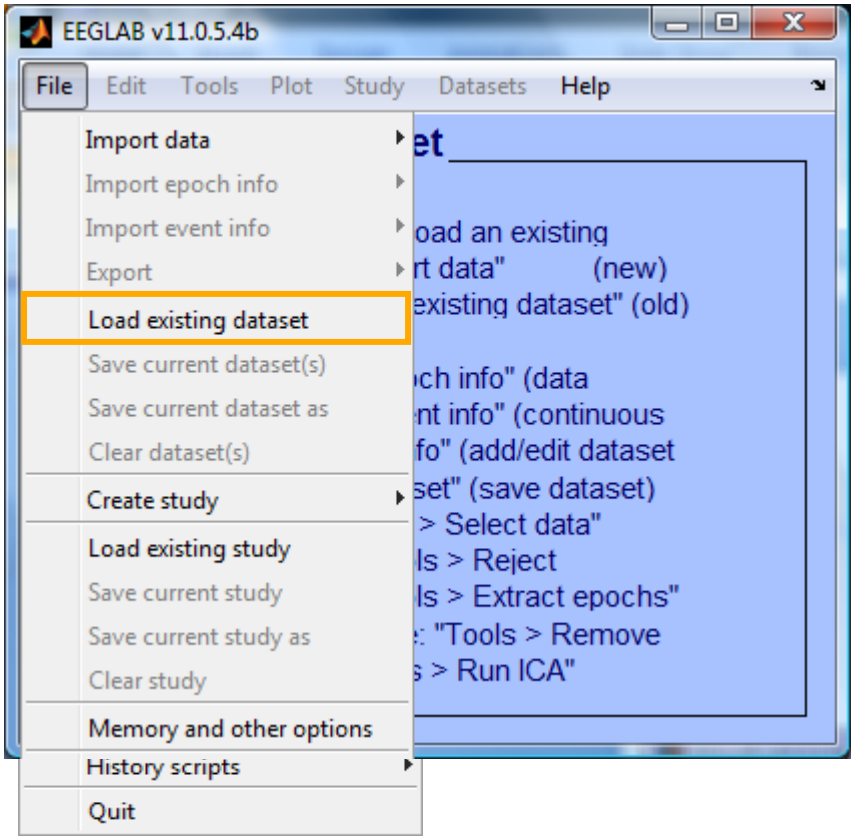
Reject large artifact time points

Run ICA

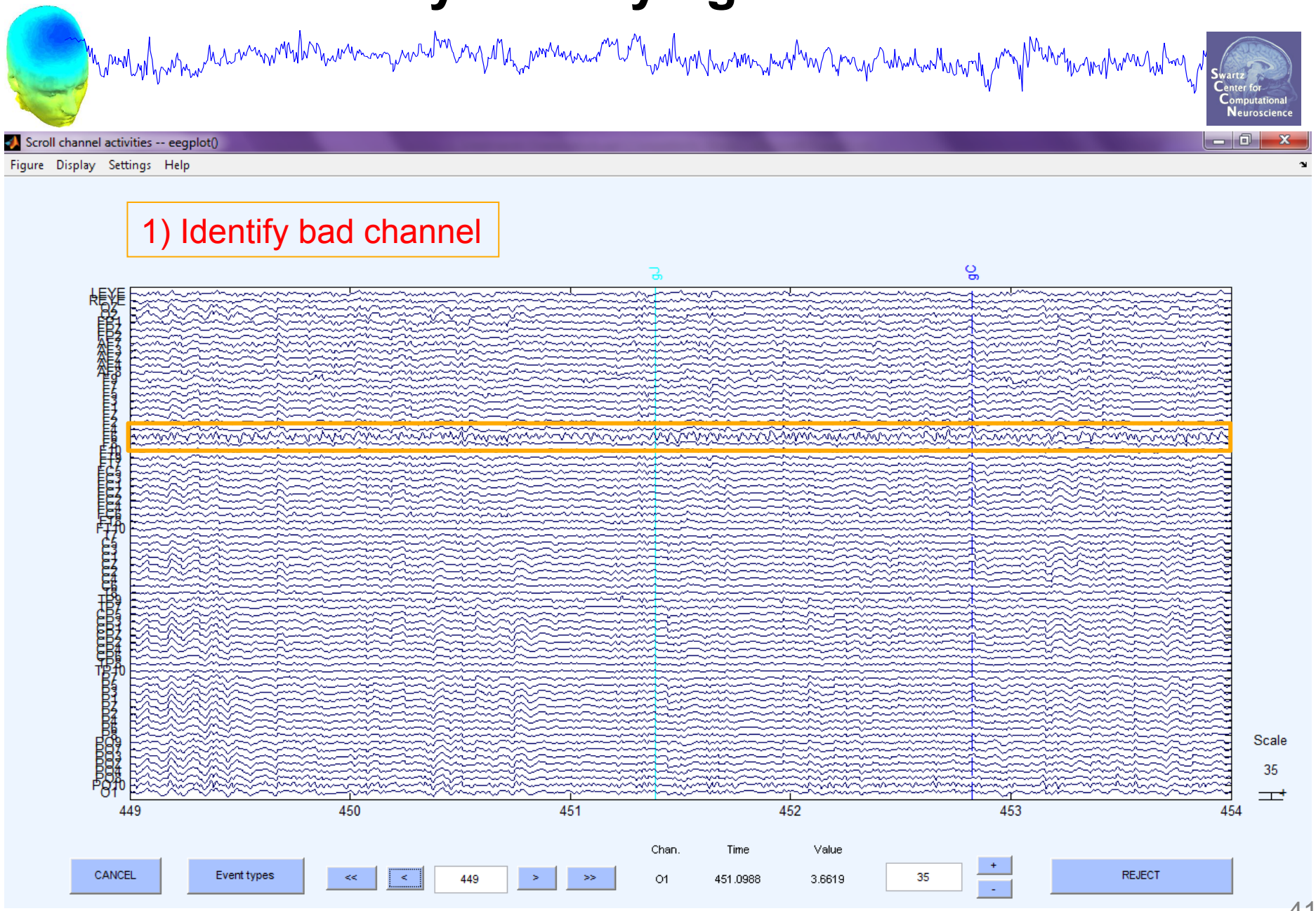
Retrieve or reload continuous EEG dataset



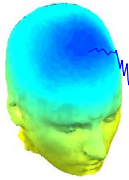


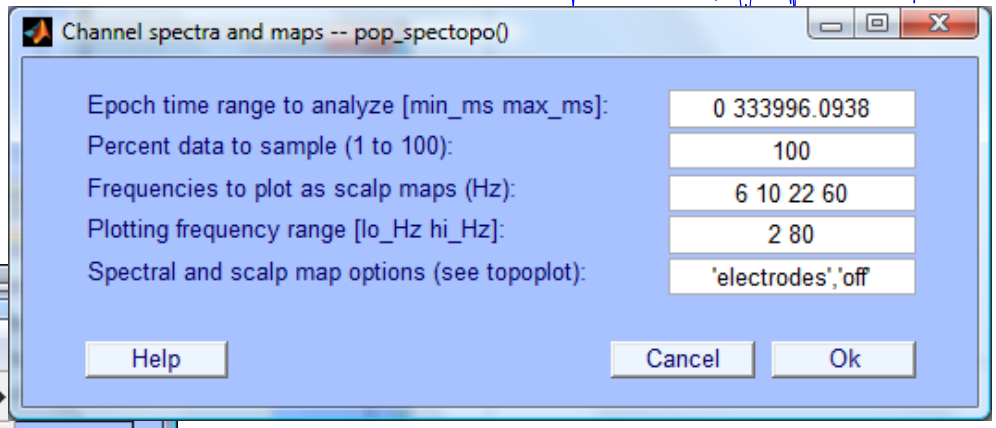


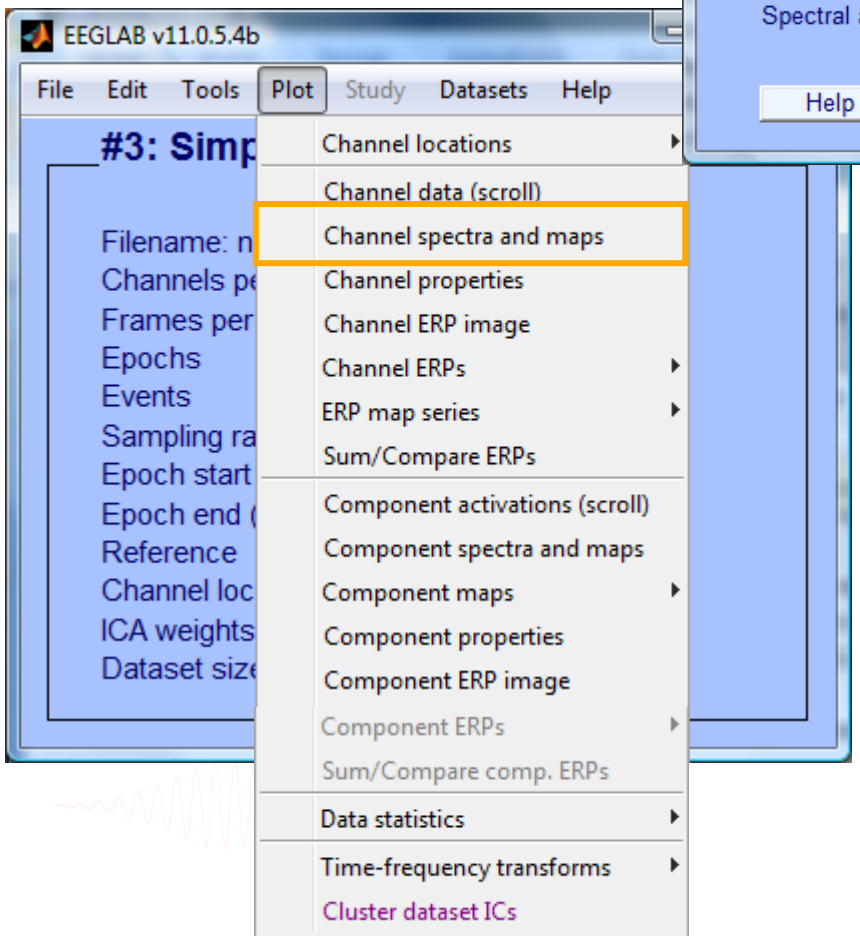
Manually identifying bad channels

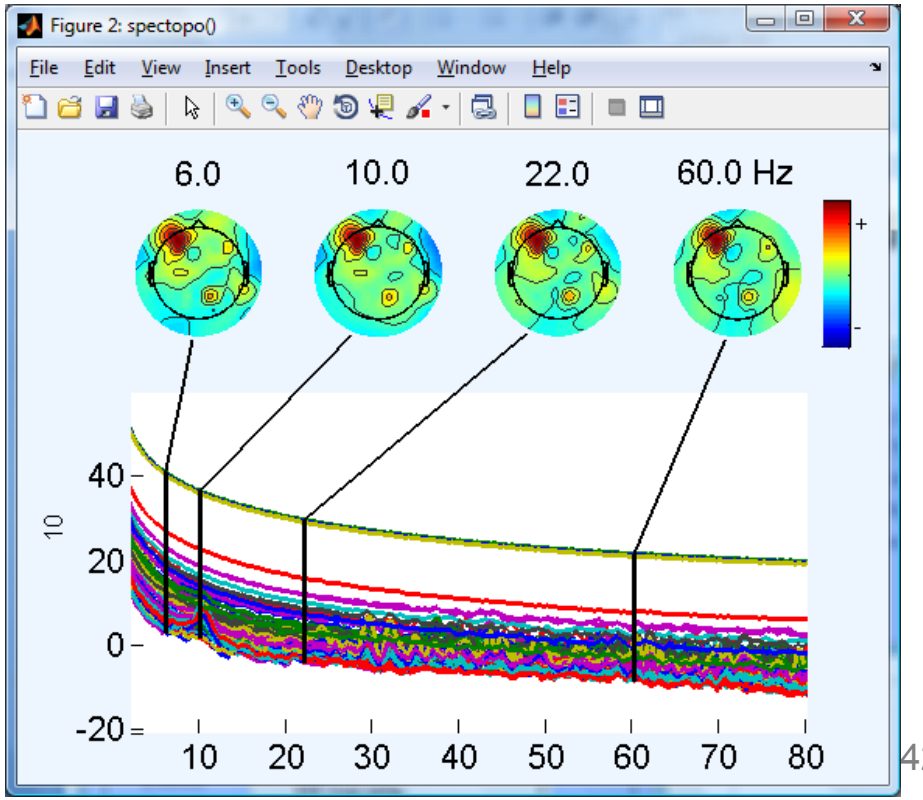


Manually identifying bad channels

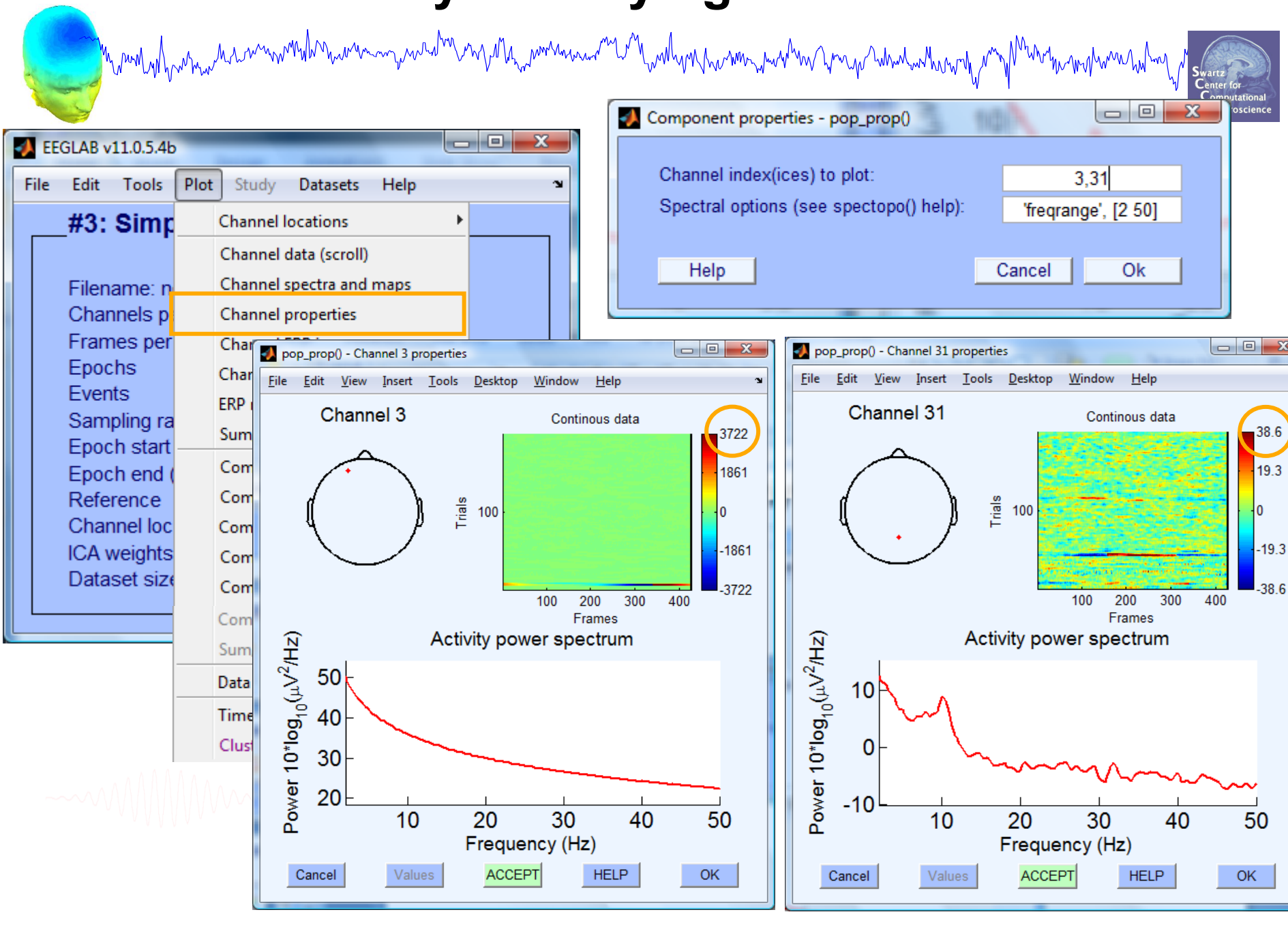




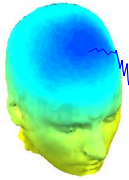


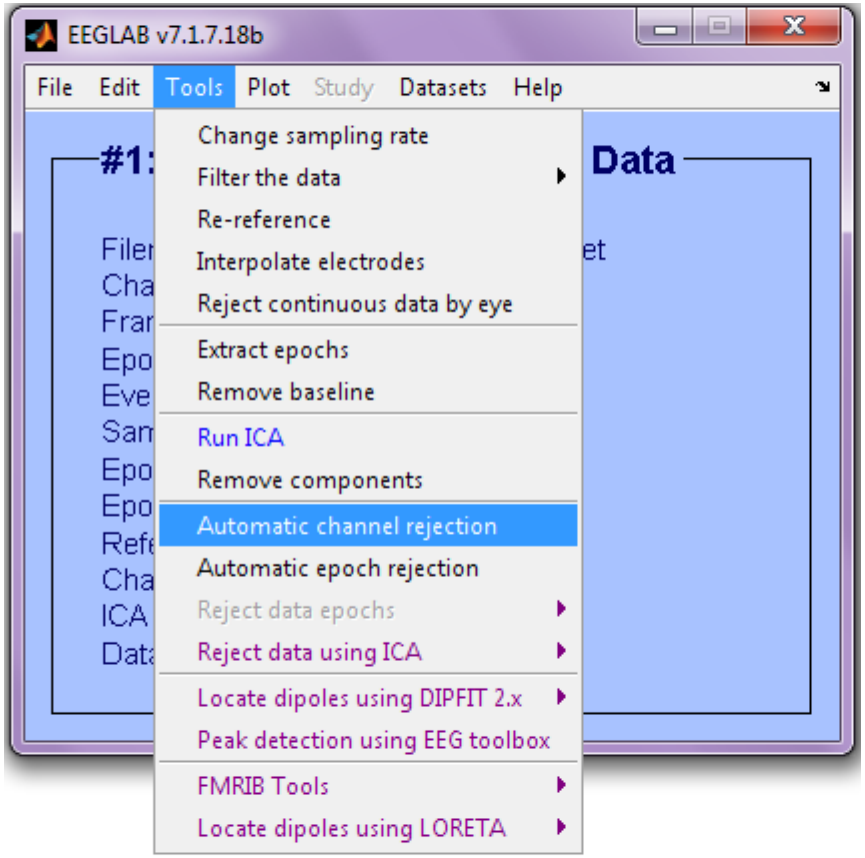


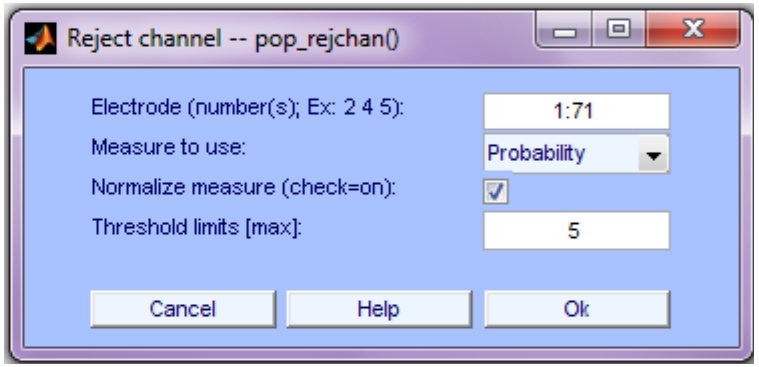
Manually identifying bad channels



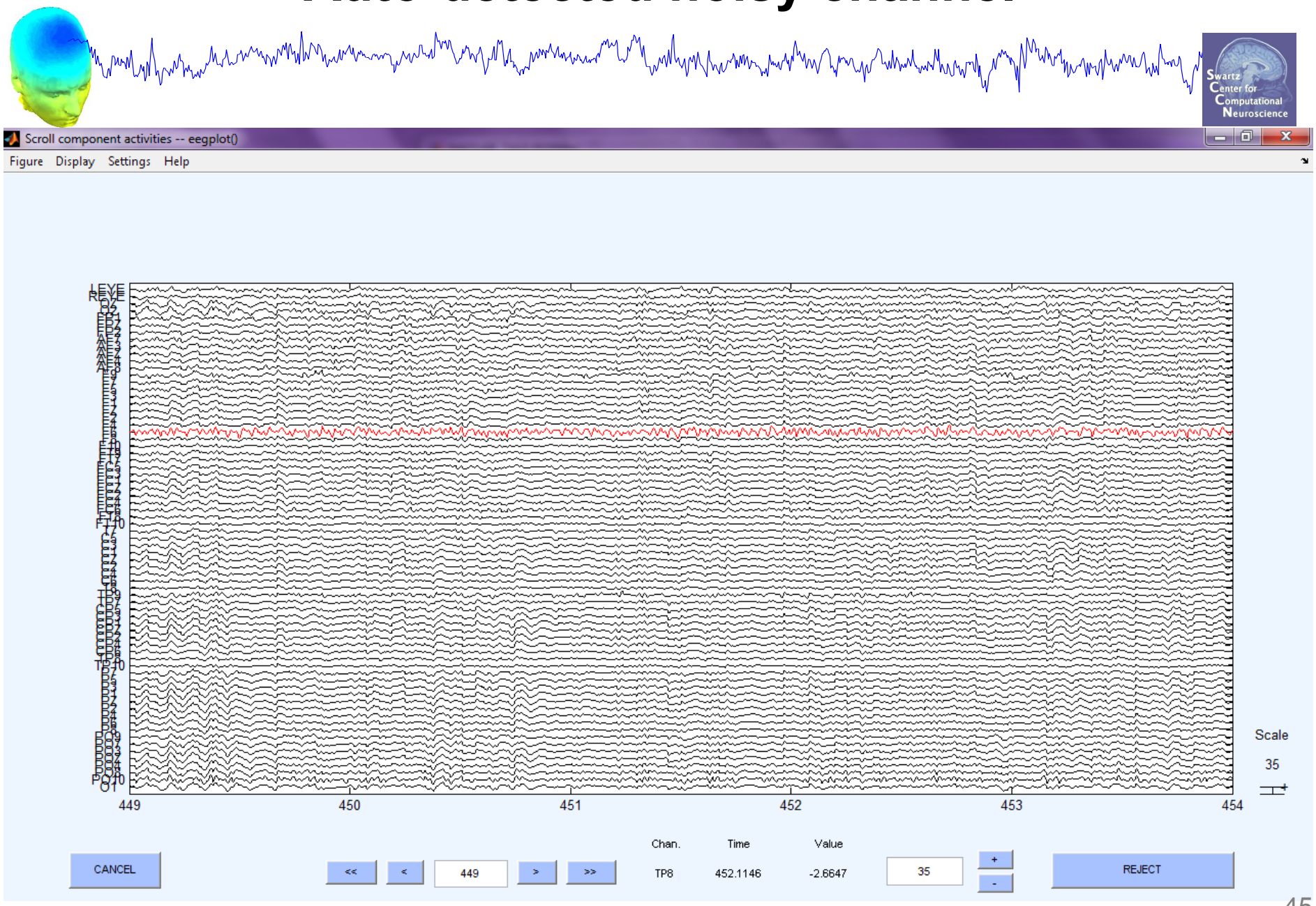
Auto-detection of noisy channels



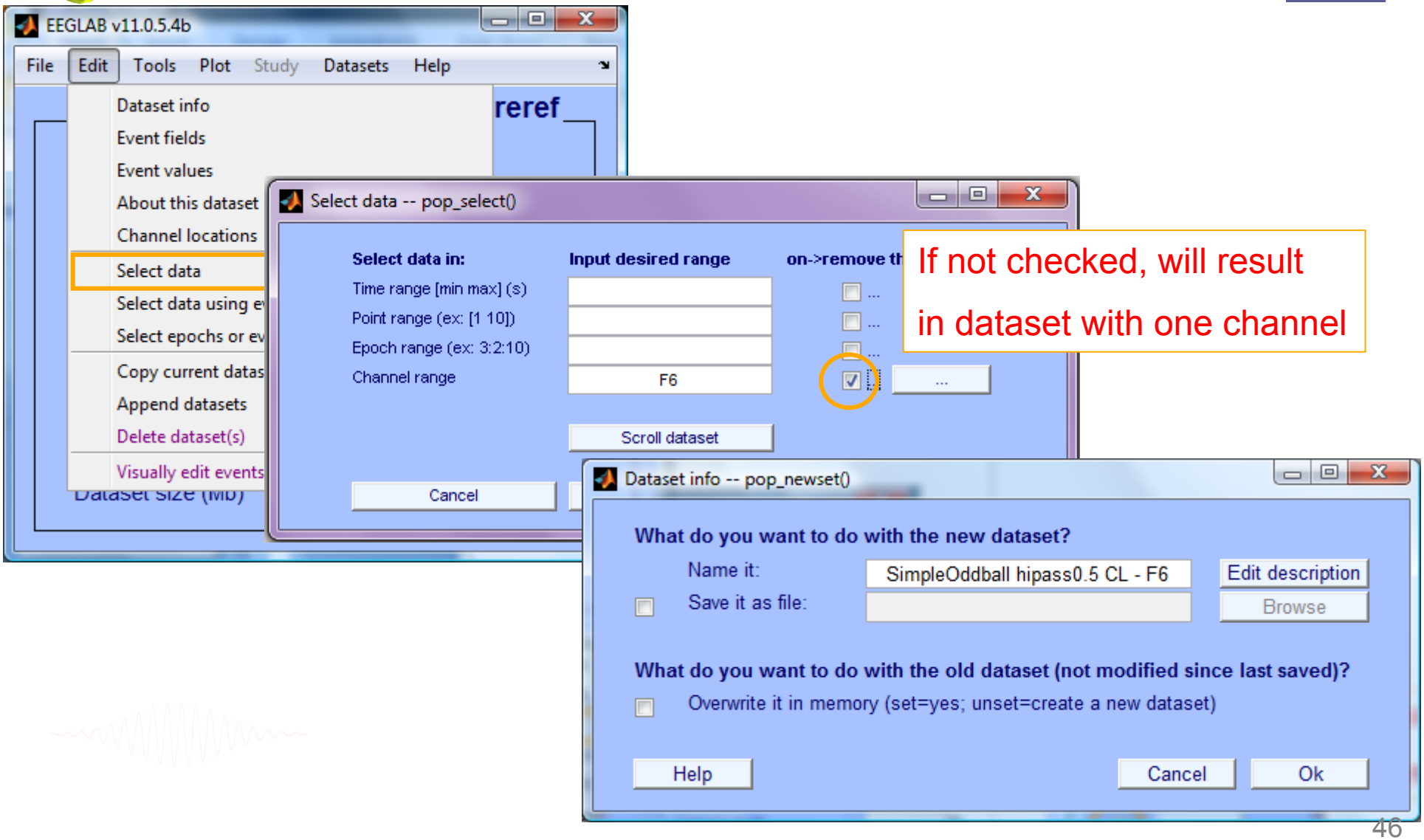




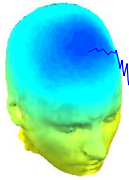
Auto-detected noisy channel

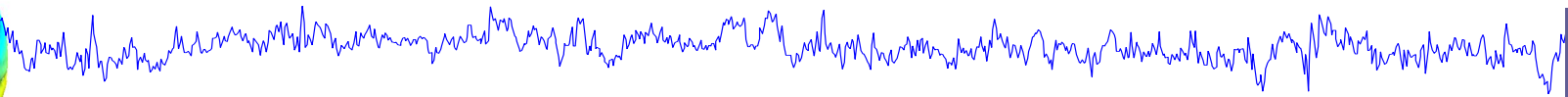


Removing channel(s)



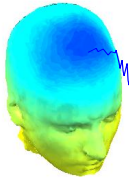
Removing channel(s)

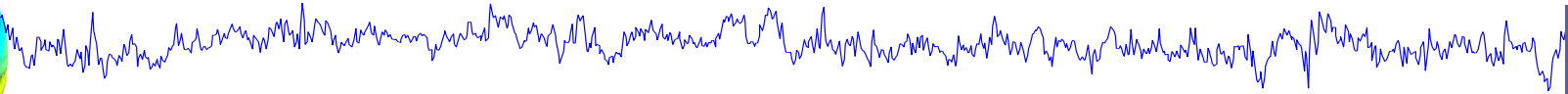




- You may want to interpolate bad channels rather than remove them altogether. Don't do this!
- The loss in dimensionality will affect the ICA decomposition
- Preferred solution:
  - **Delete** the bad channels before running ICA
  - STUDY tools will interpolate missing channels automatically

Pre-processing pipeline





Swartz Center for Computational Neuroscience

Collect high-density EEG data (>30 chan)

Import into EEGLAB

Import event markers and channel locations

Re-reference/ down-sample (if necessary)

High pass filter (~.5 – 1 Hz)

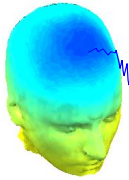
Remove line noise (if necessary)

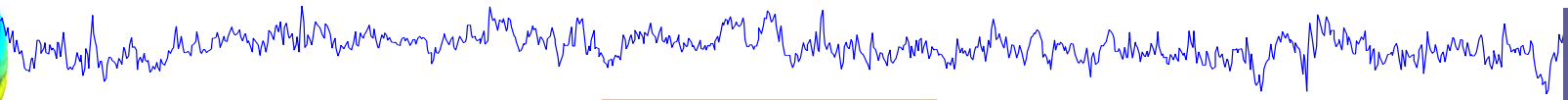
Identify/reject bad channels

Reject large artifact time points

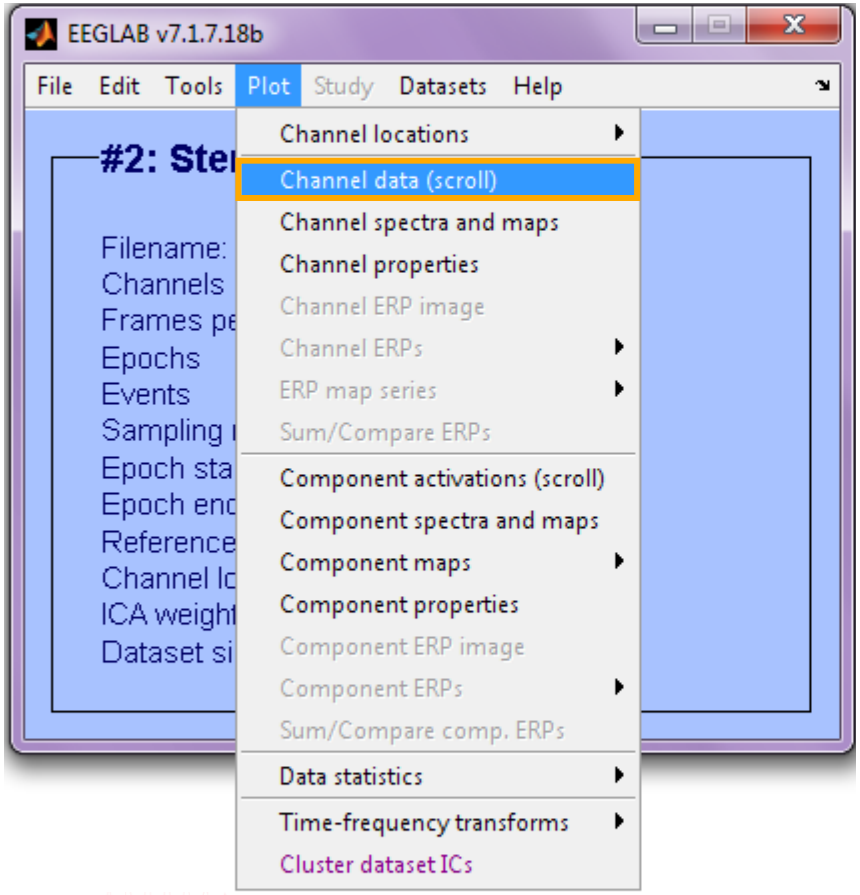
Run ICA

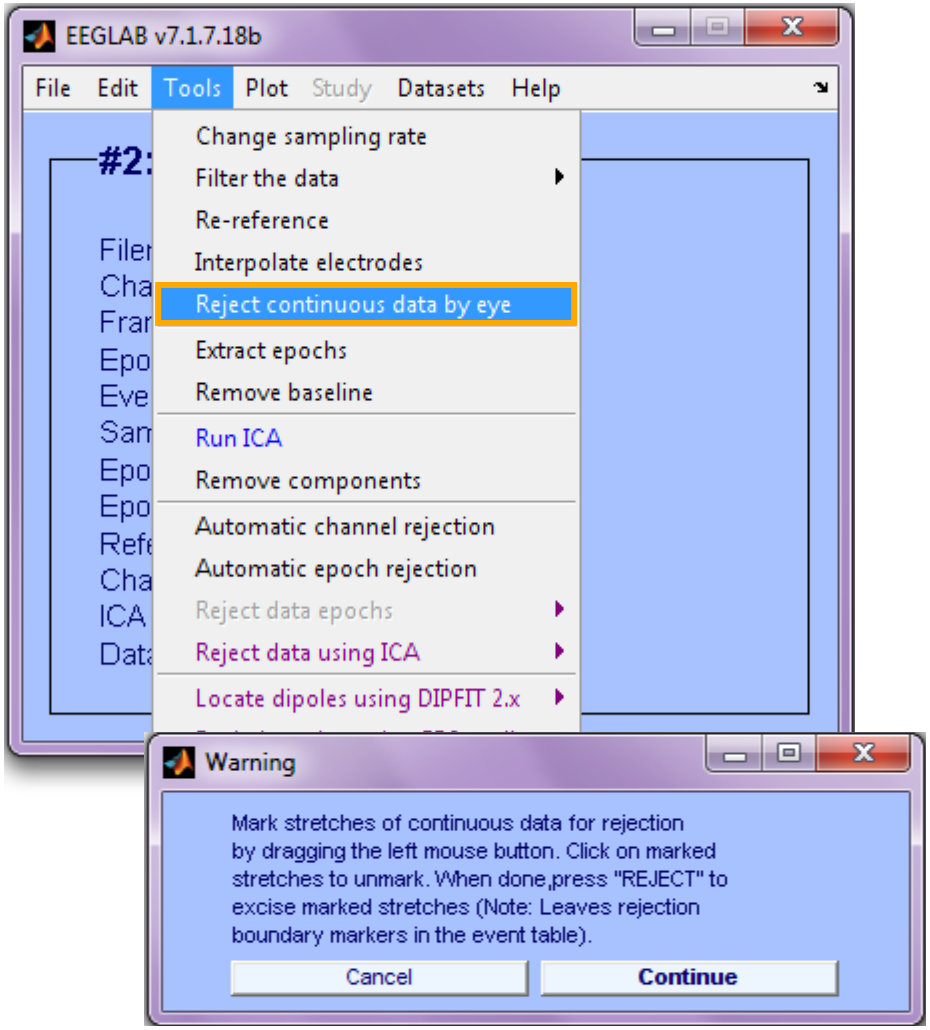
Reject continuous data



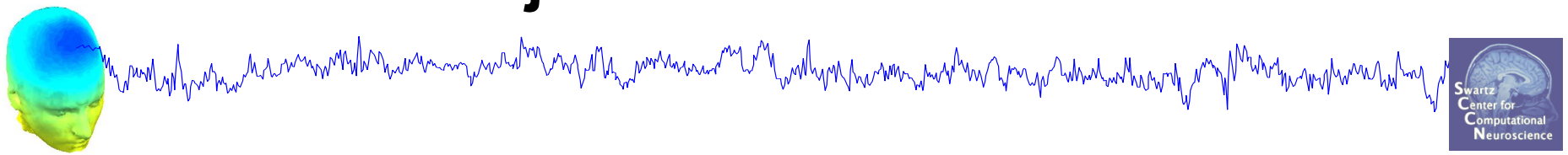


Equivalent





Reject continuous data



Scroll channel activities -- eegplot()

Figure Display Settings Help

Click and drag with mouse over noisy data to reject

536 537 538 539 540 541

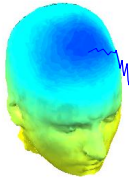
Scale 35

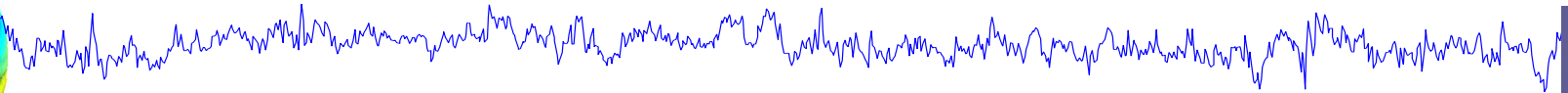
Chan. Time Value

FC6 539.9355 4.8773

CANCEL Event types << < 536 > >> 35 + - REJECT

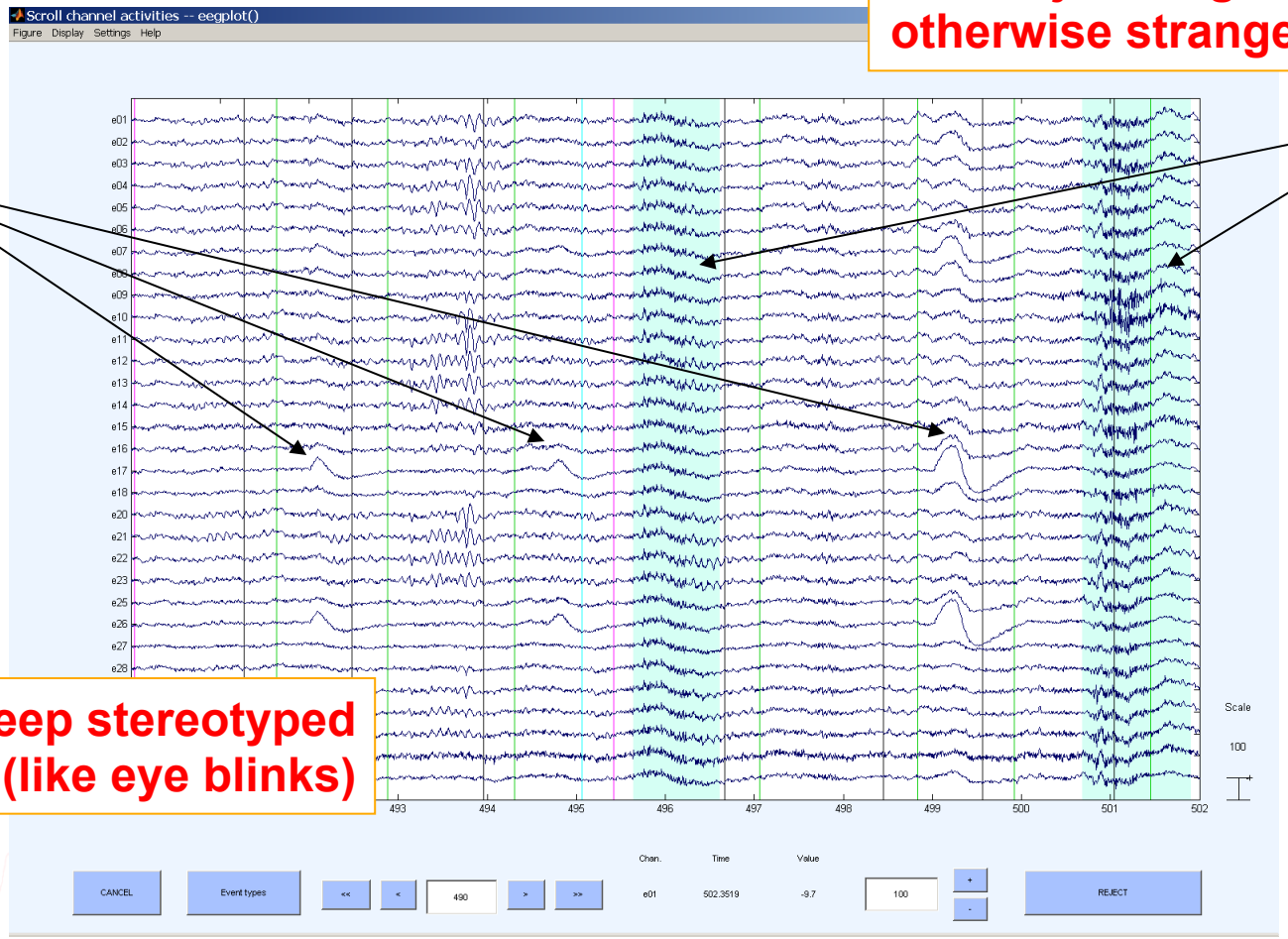
Rejecting data for ICA





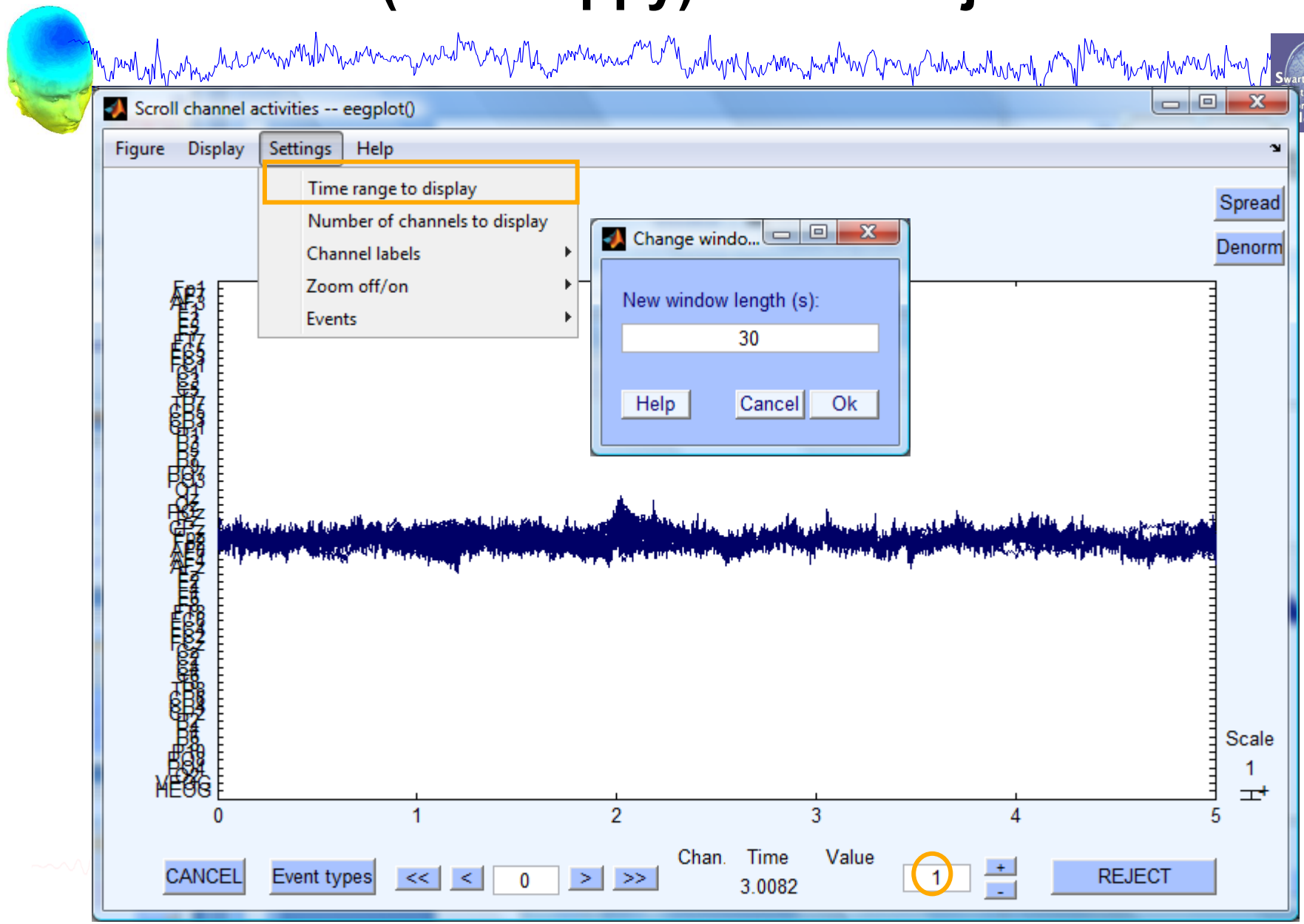
To prepare data for ICA:

Reject large muscle or otherwise strange events...

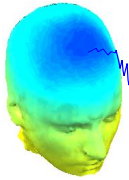


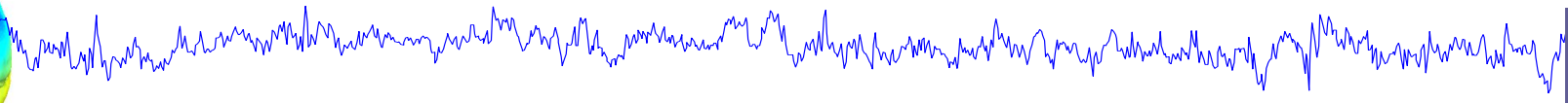
... but keep stereotyped artifacts (like eye blinks)

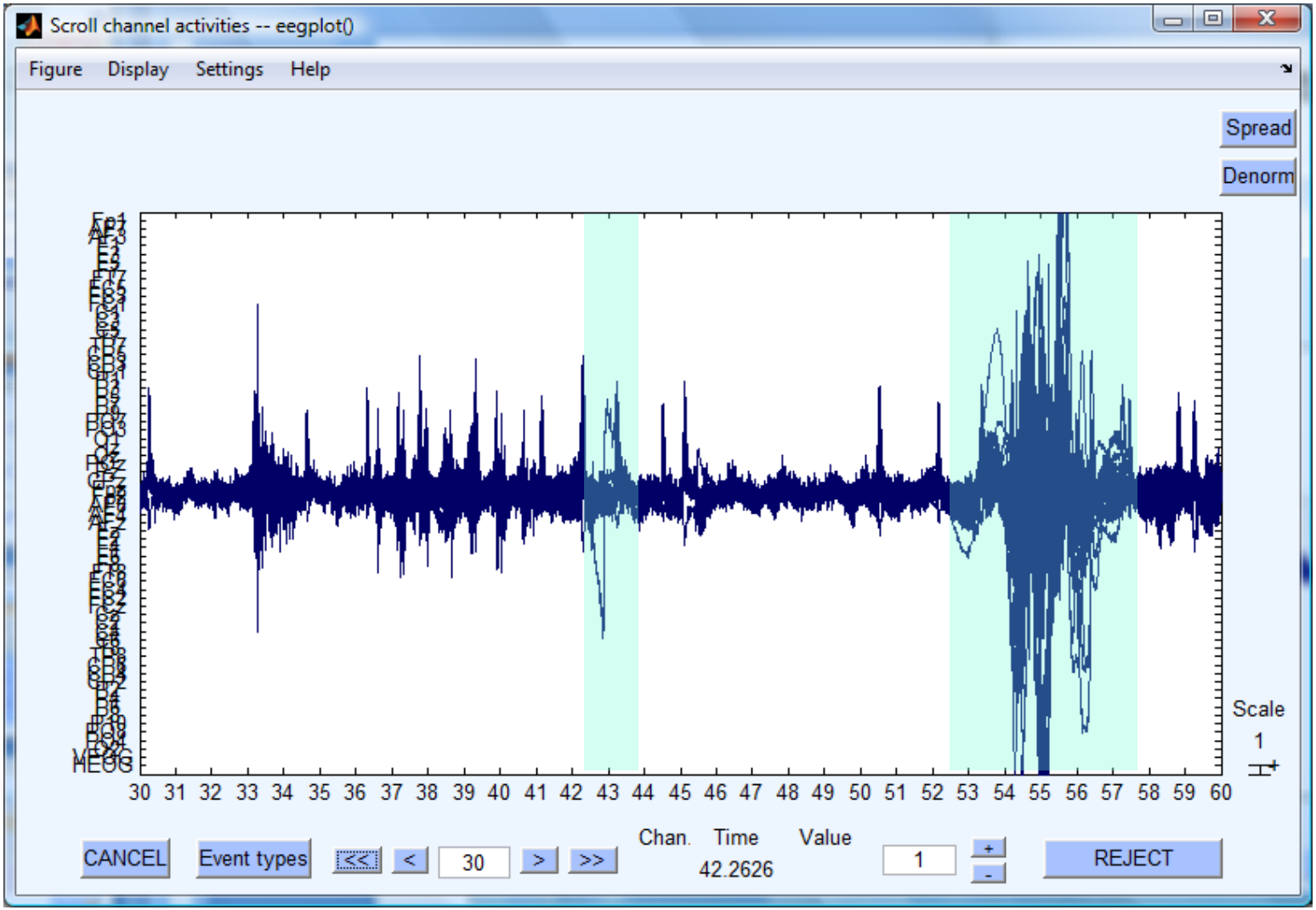
Fast (but sloppy) artifact rejection

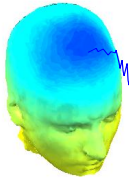


Fast (but sloppy) artifact rejection





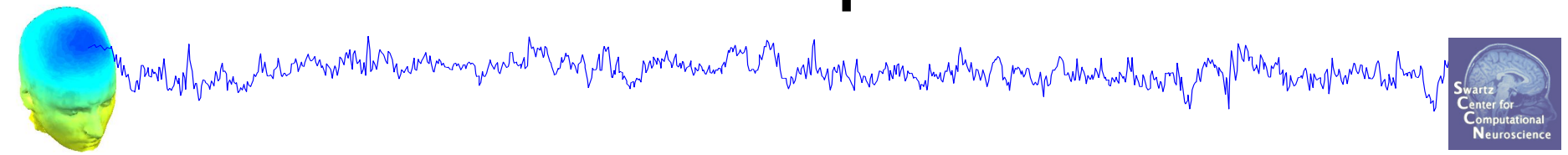


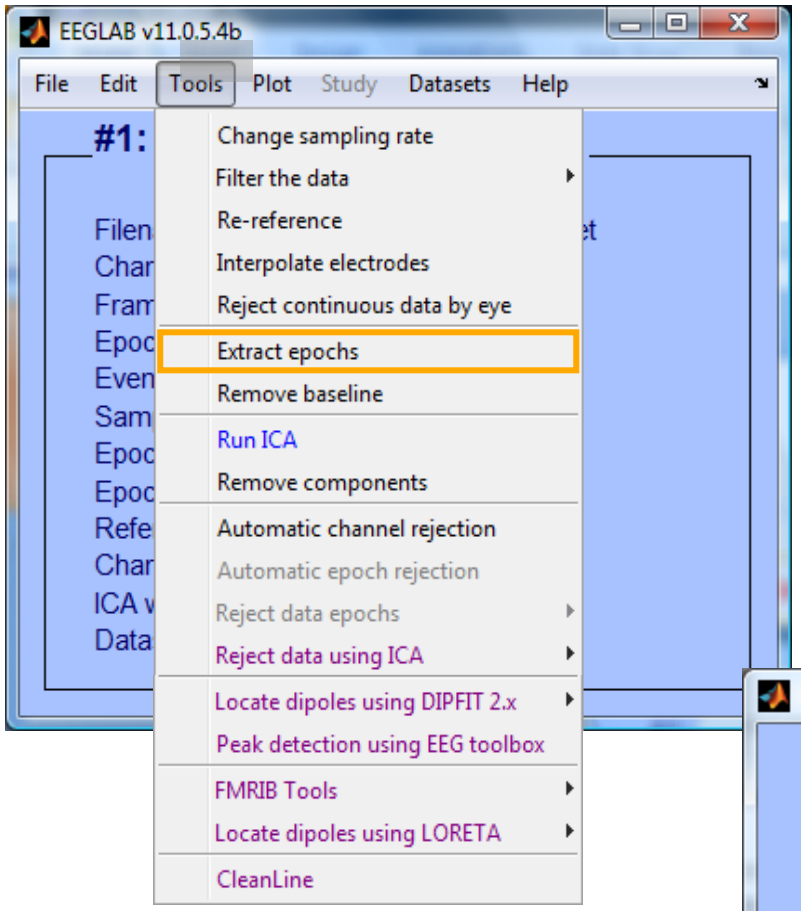


Data Cleaning for ICA

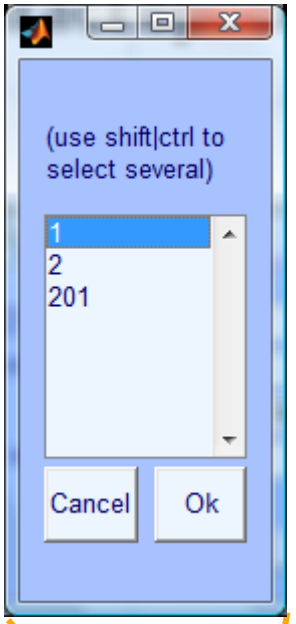
Variant 2: Epoched Data

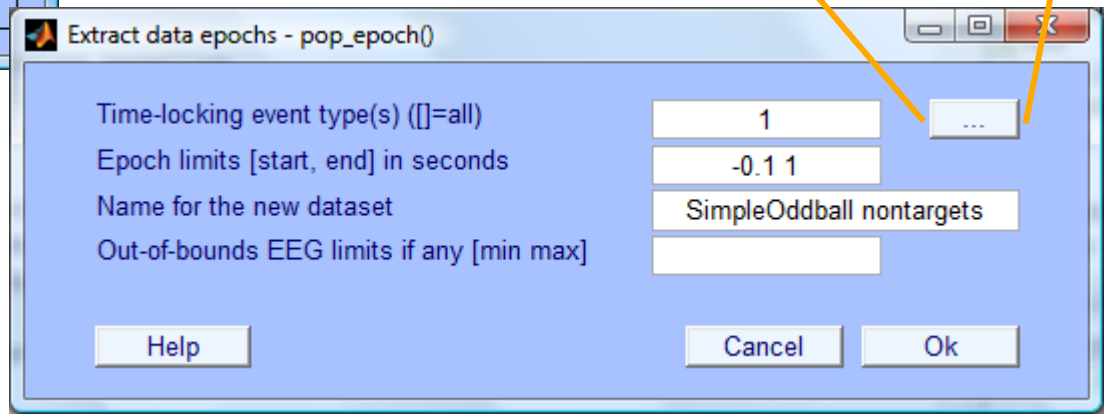
Extract epochs



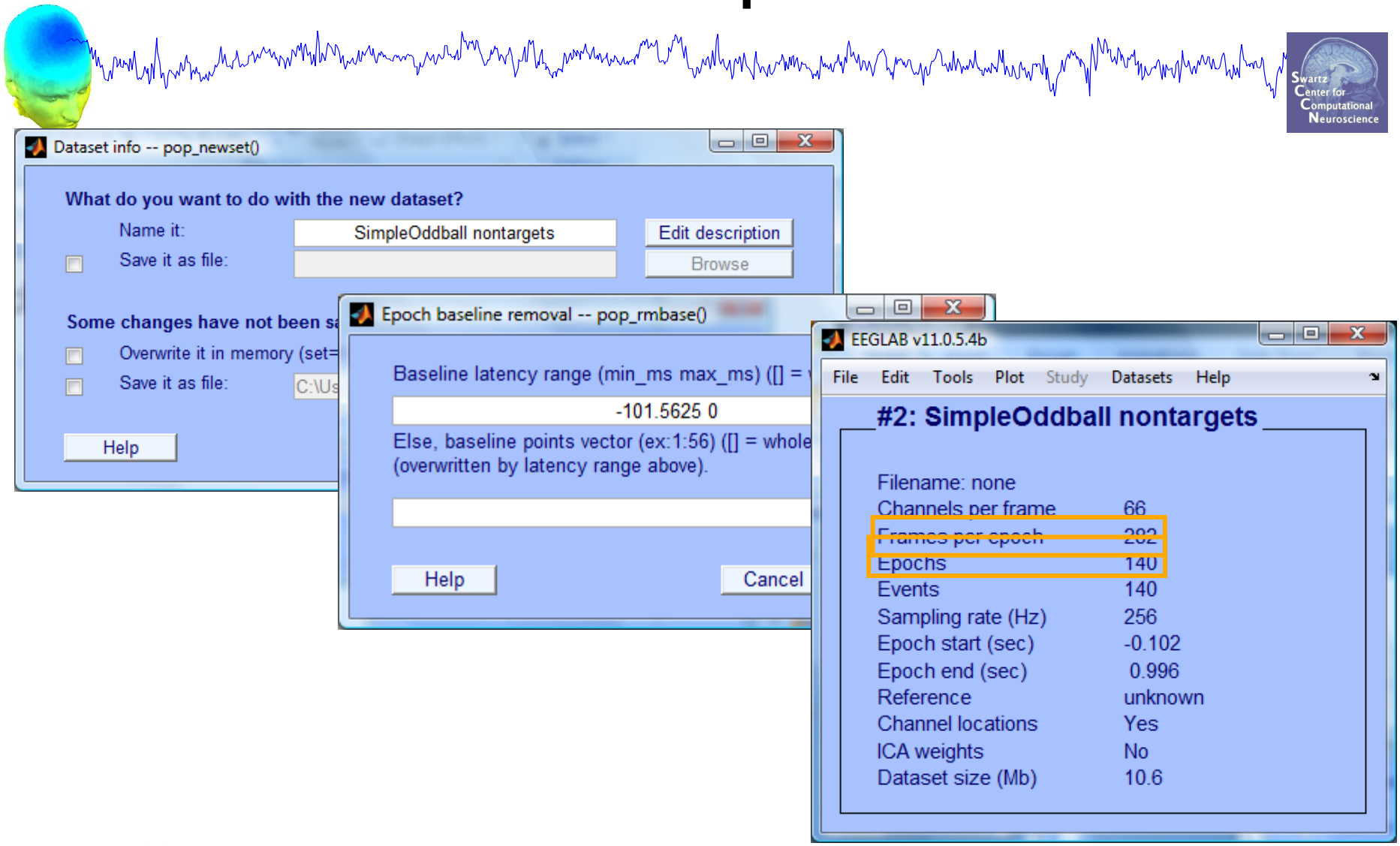



```
>> eeg_eventtypes(EEG)
   1        140
   2        60
   201      60
```

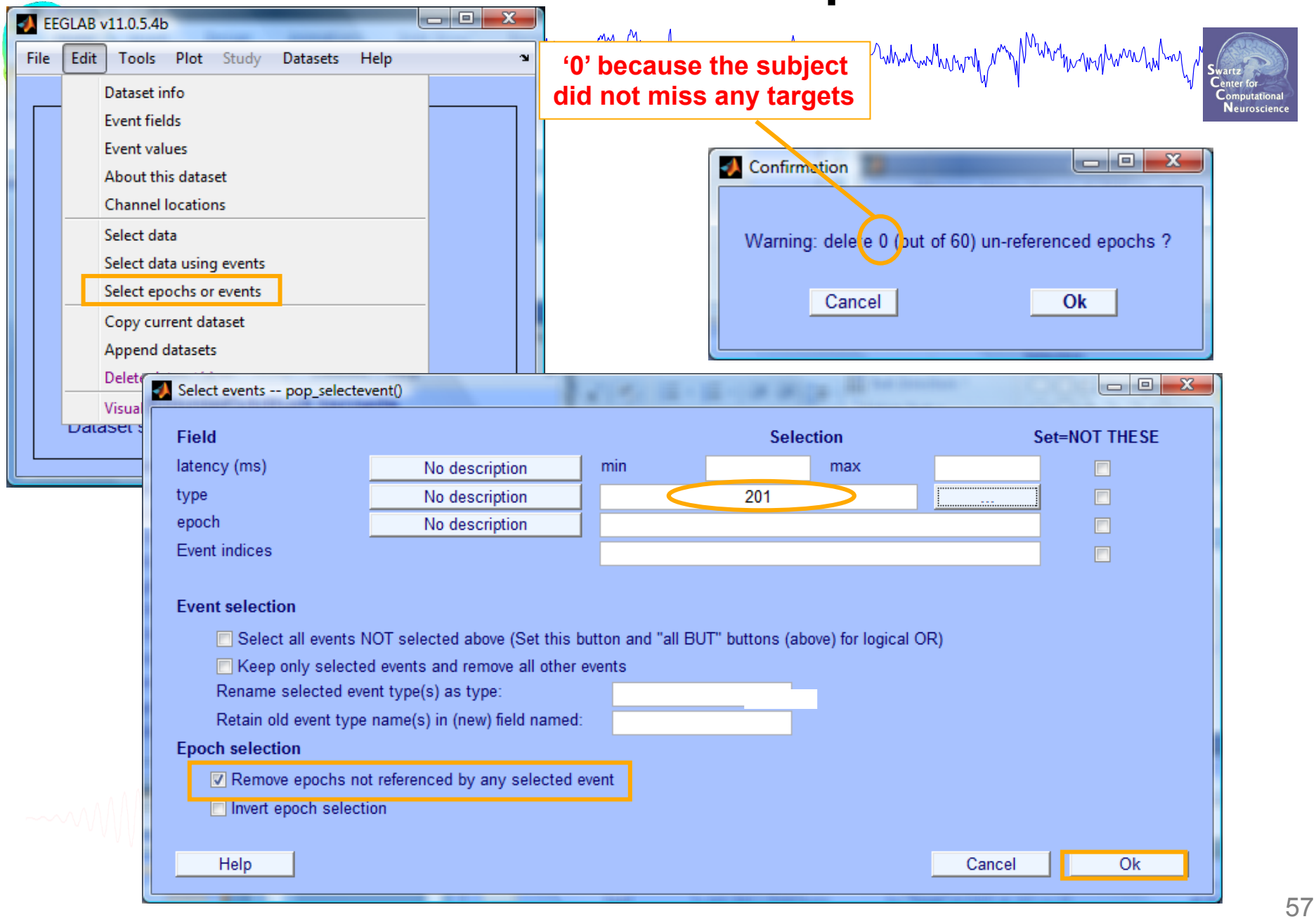


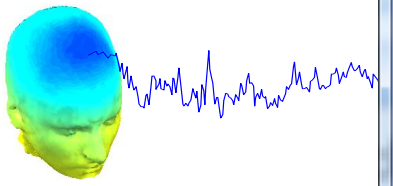


Extract epochs

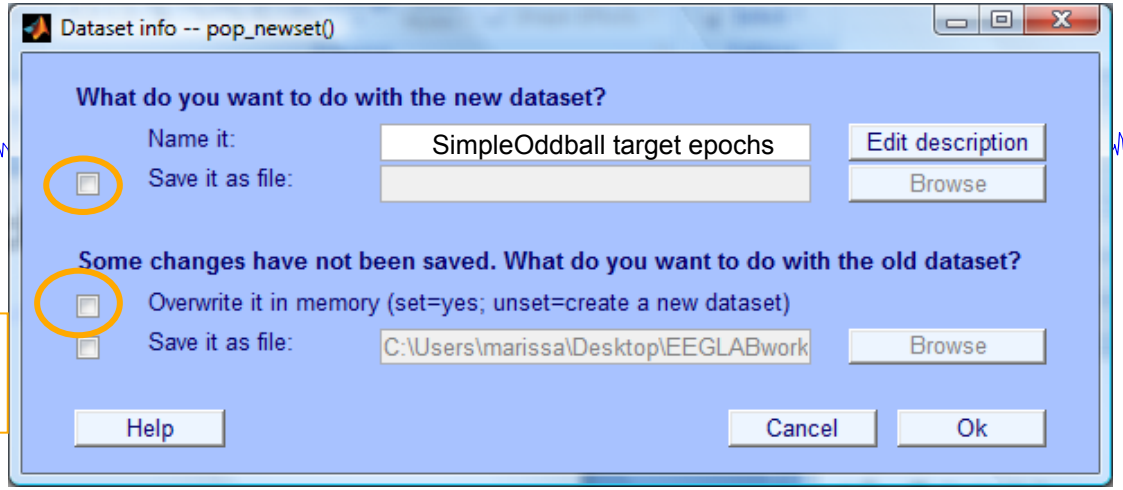


Select a subset of epochs

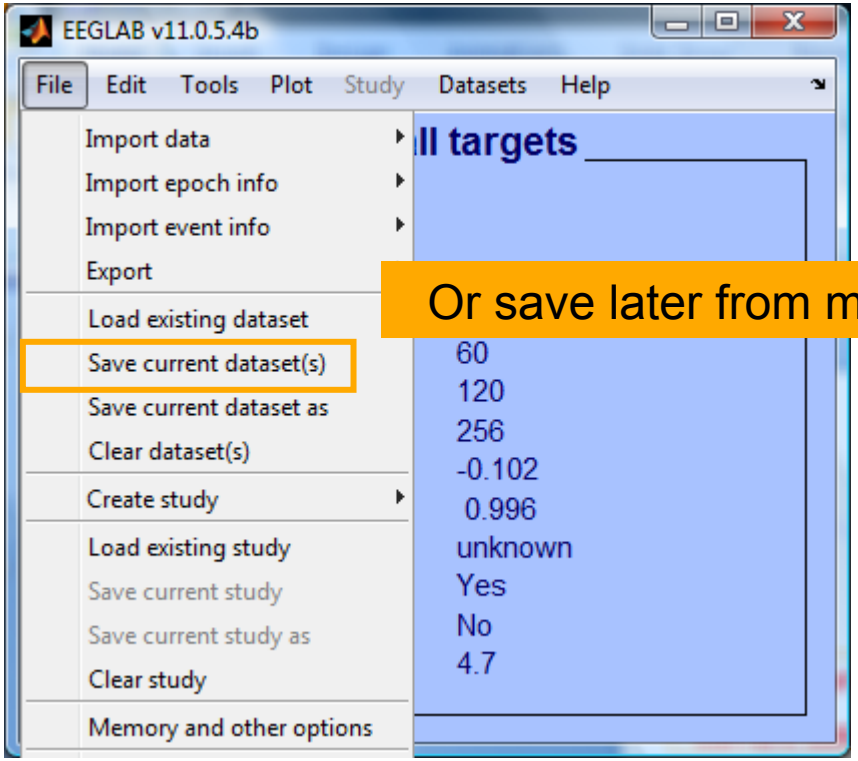




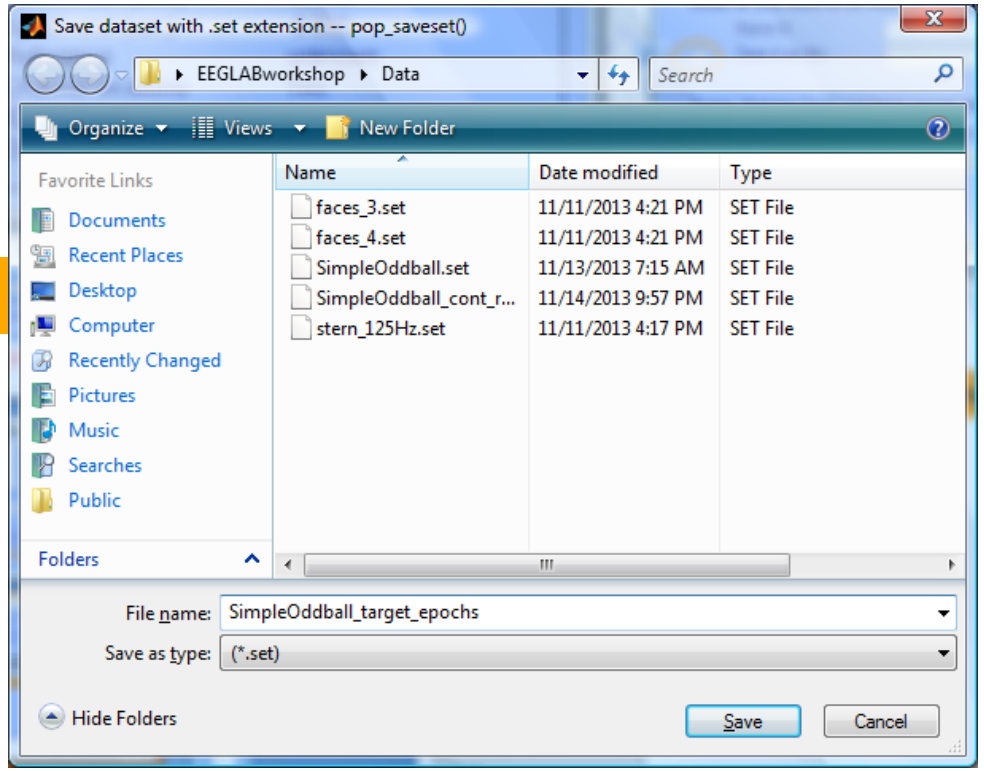
'Do not overwrite current dataset'



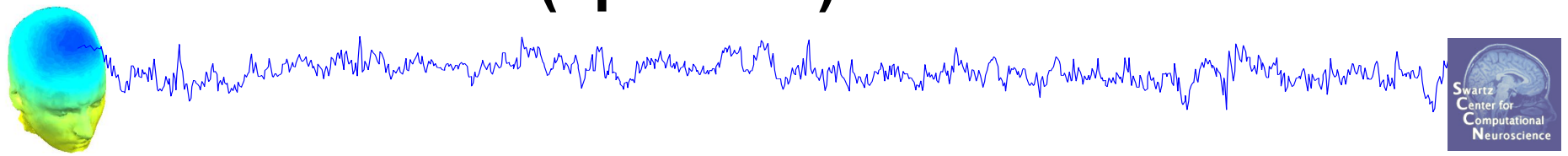
Save dataset (optional)

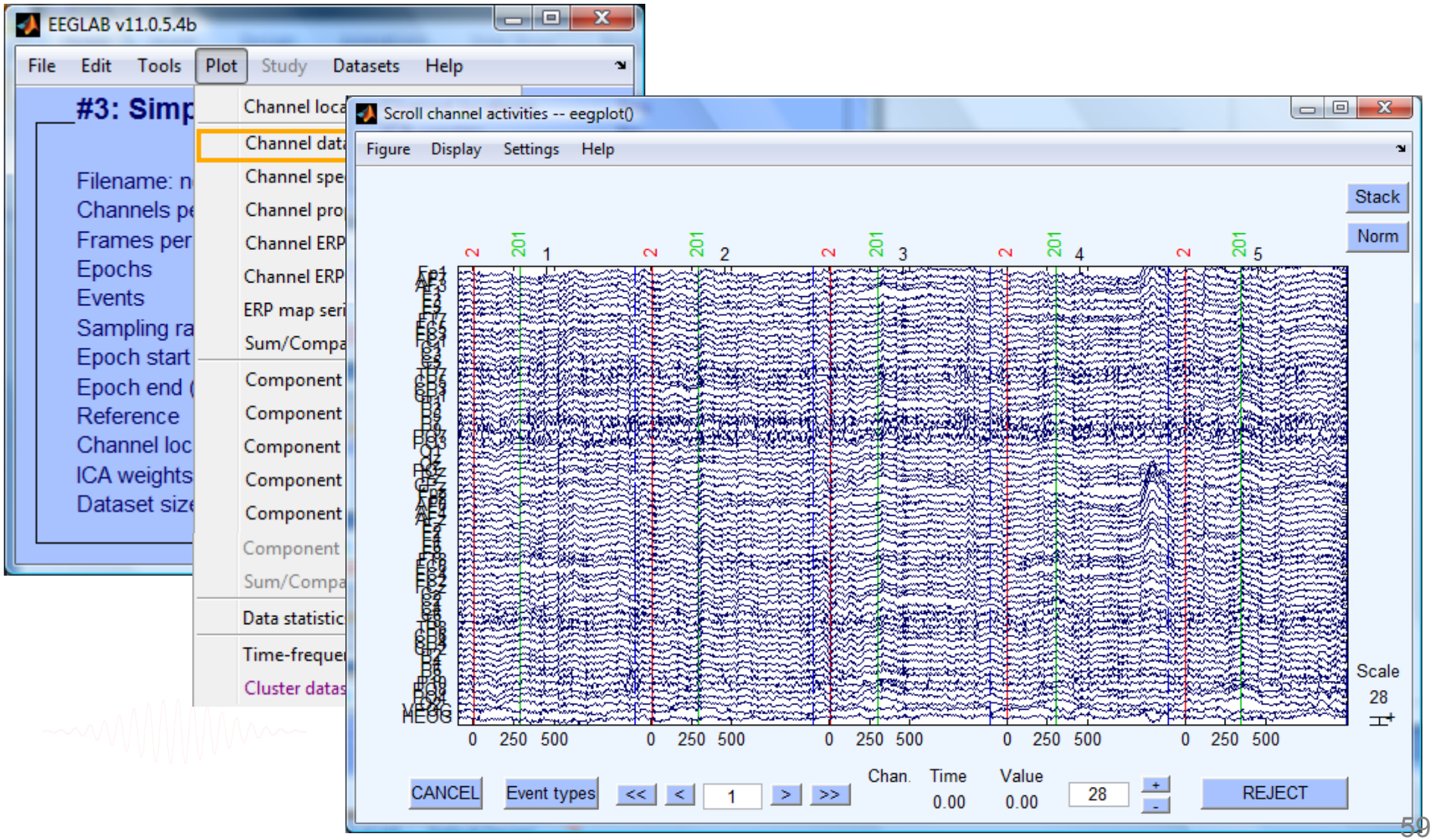


Or save later from menu



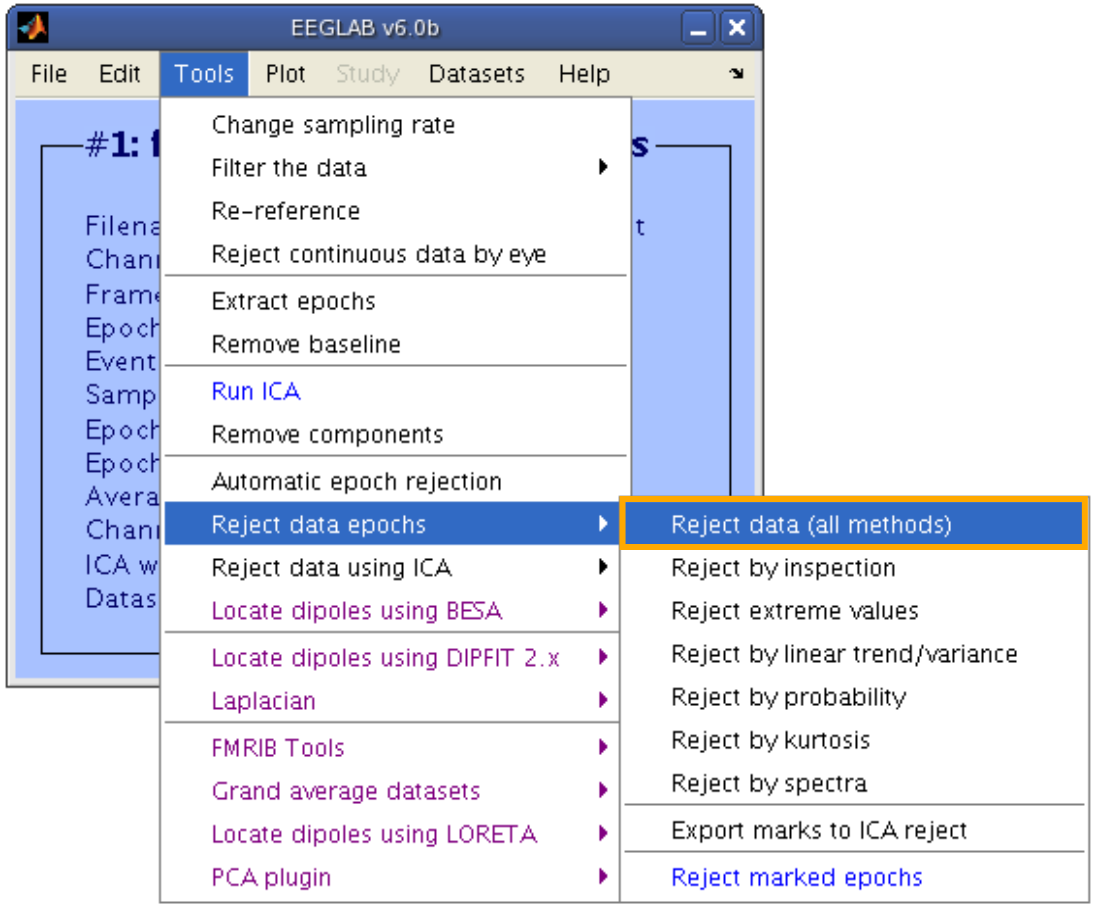
Scroll (epoched) channel data



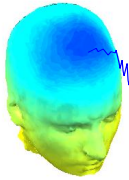


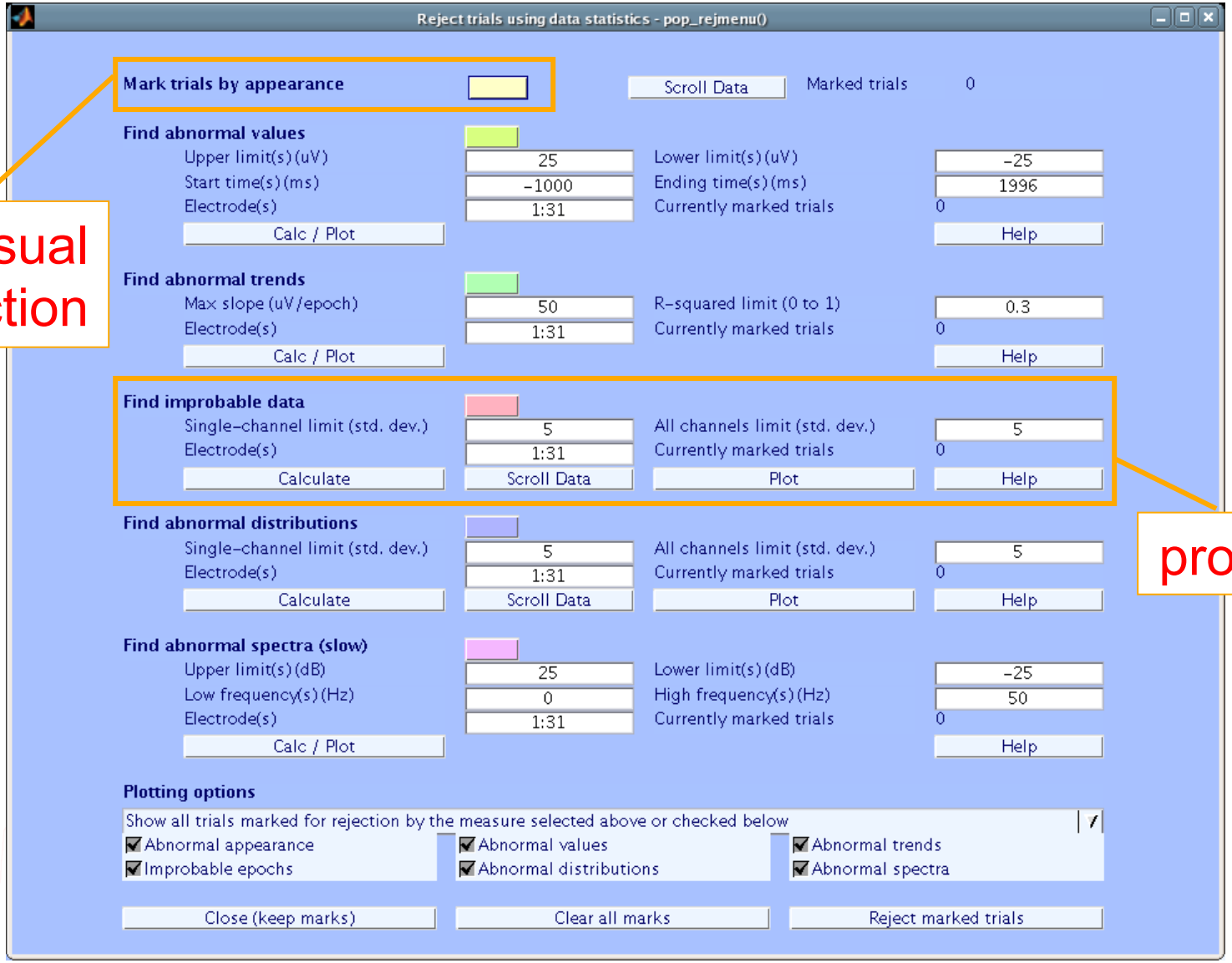
Reject epochs with artifact

Reject data epochs



Reject data epochs

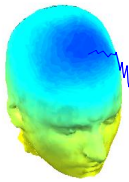


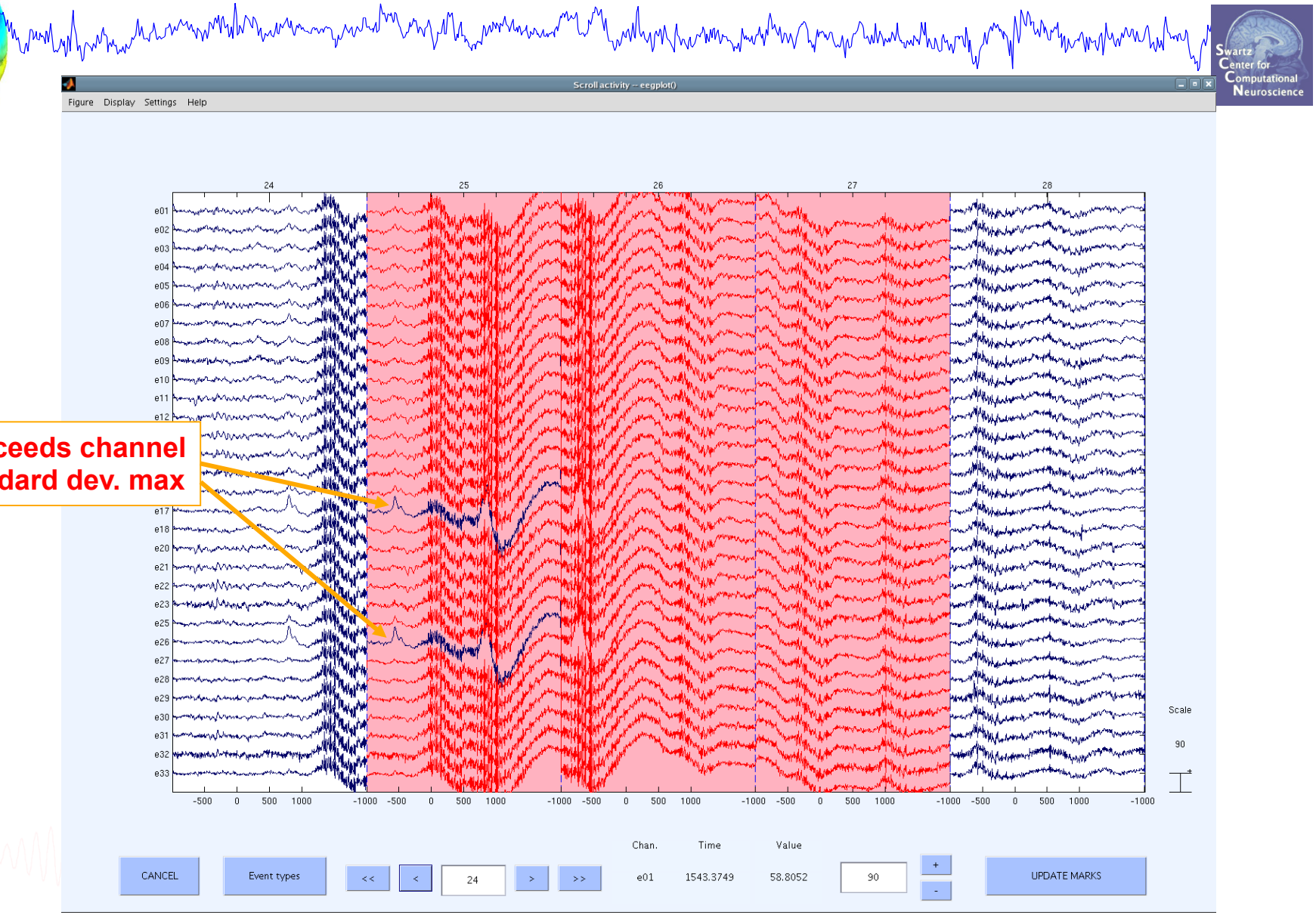


visual inspection

probability

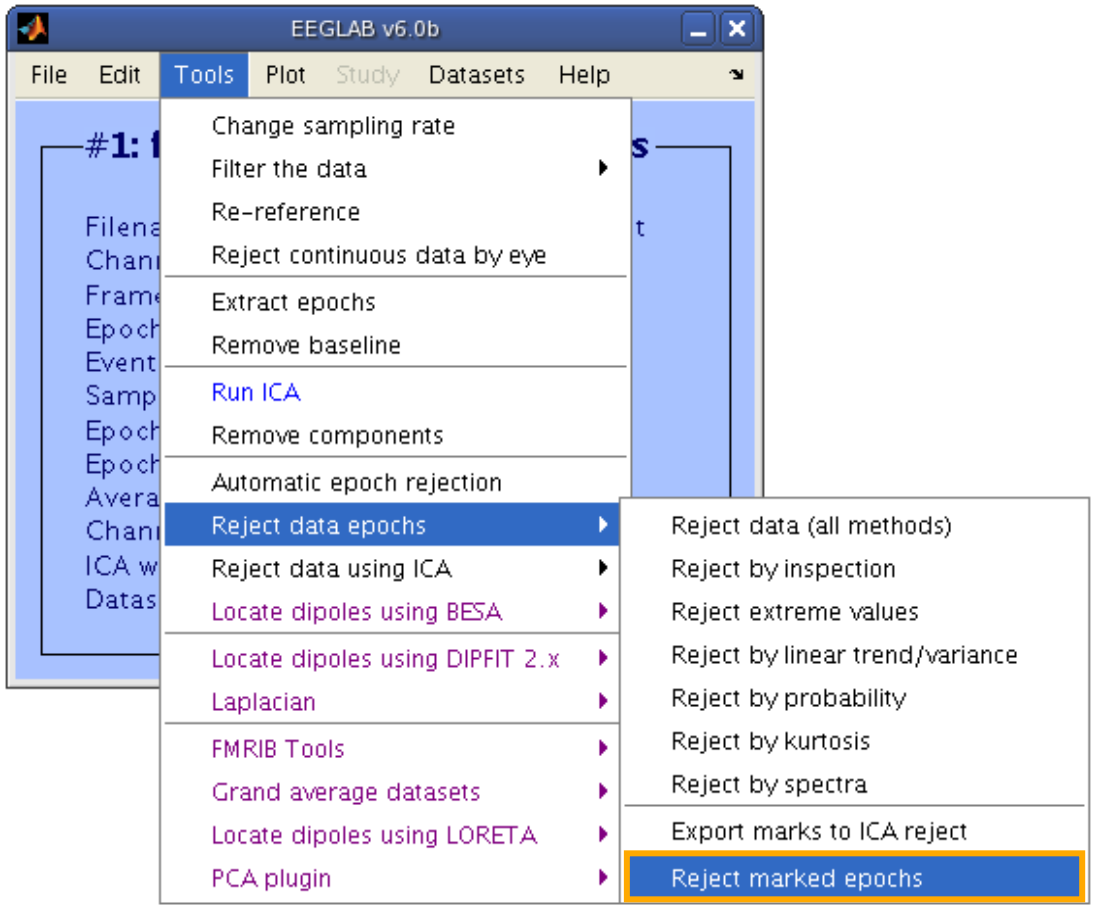
Reject data epochs



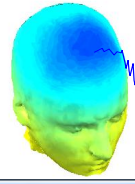


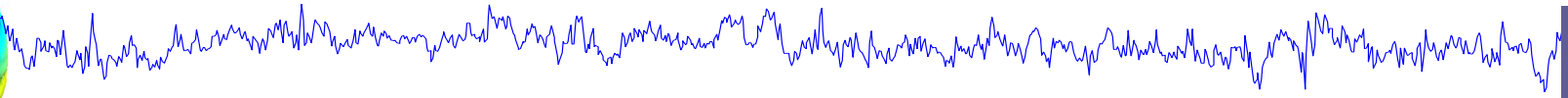
Exceeds channel standard dev. max

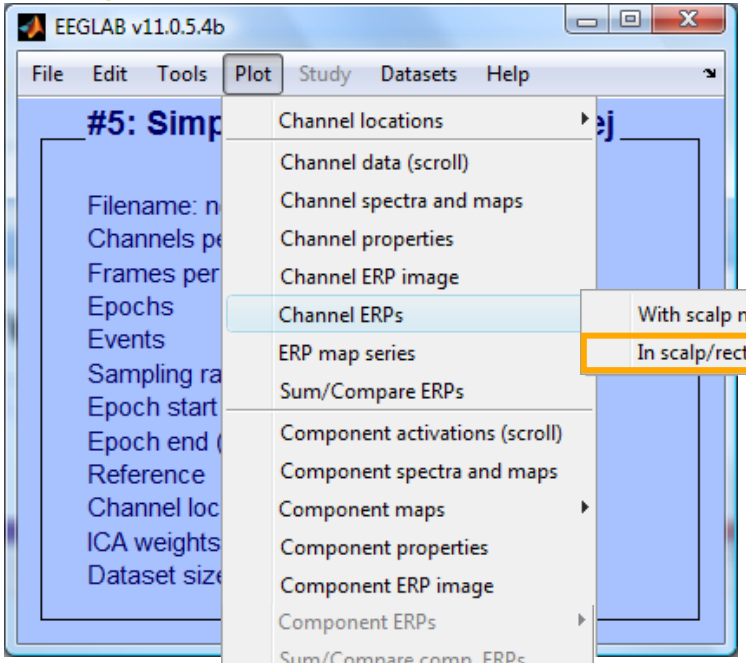
Reject data epochs

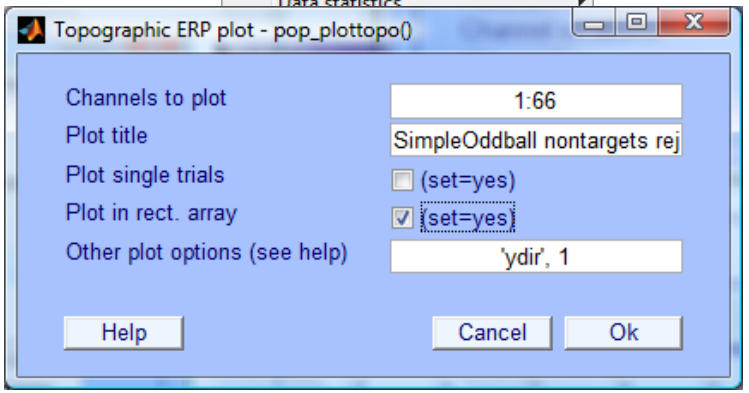


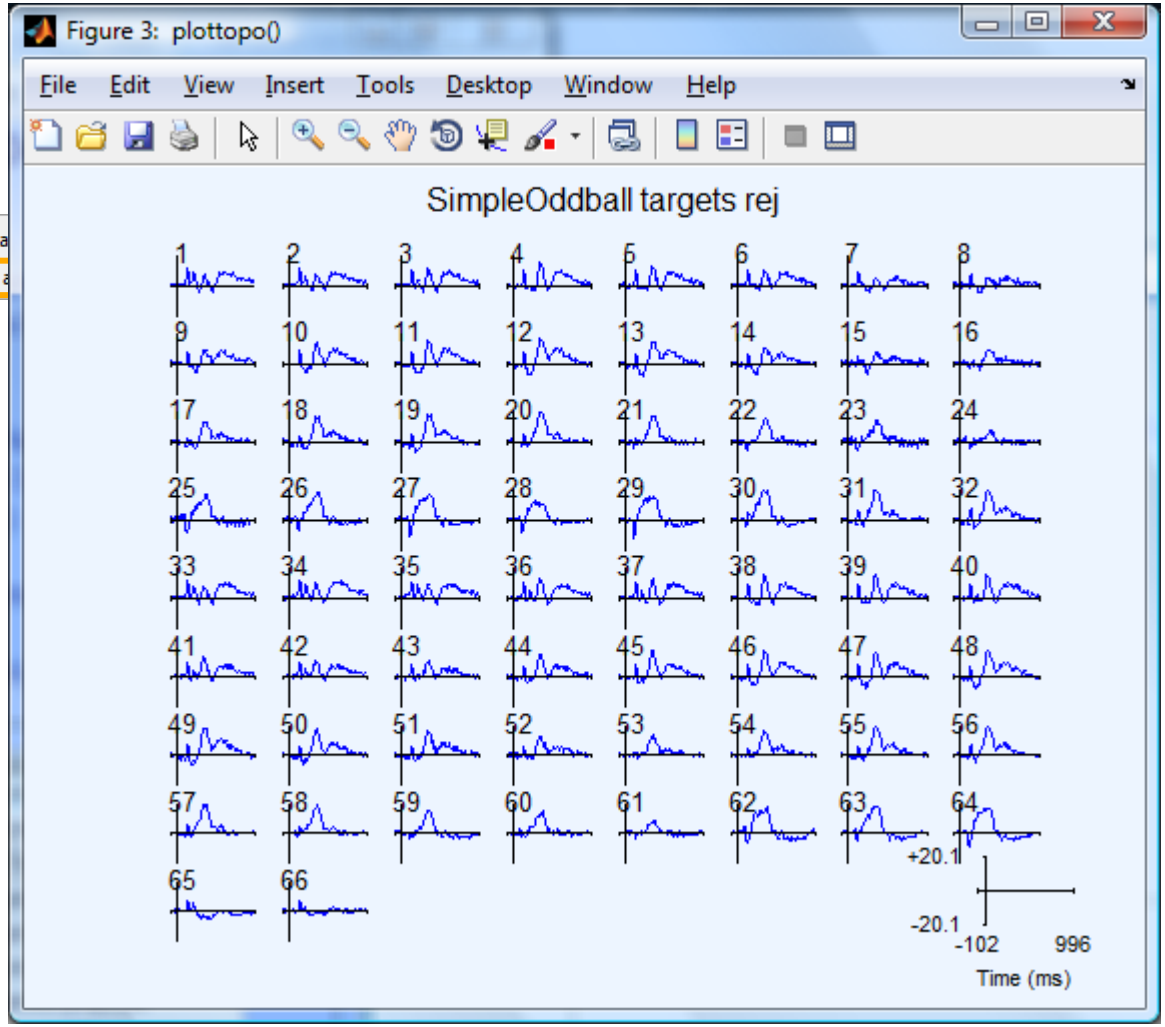
Visualize ERP in rectangular array



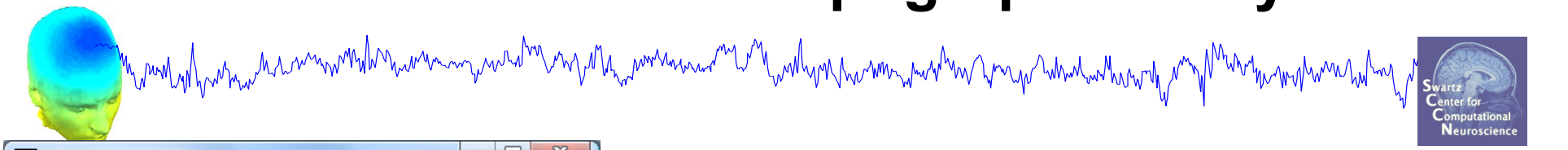


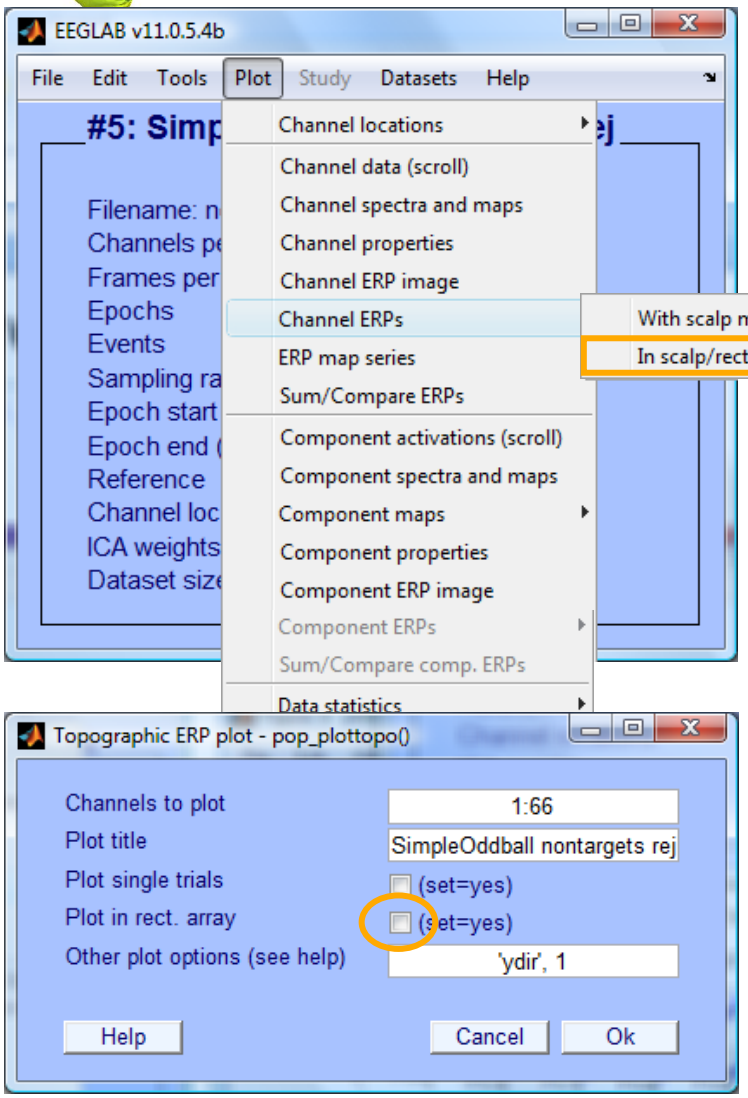


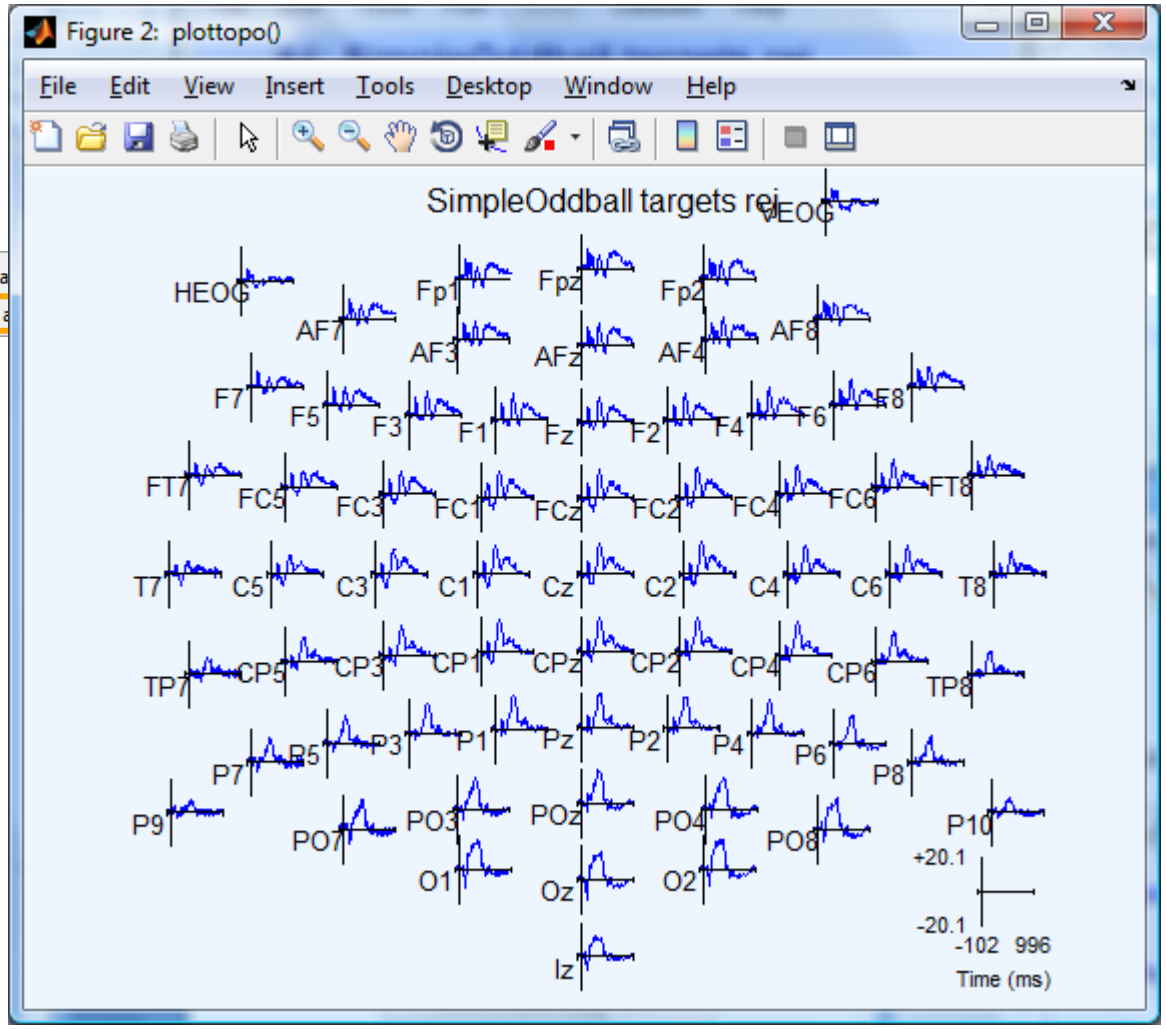




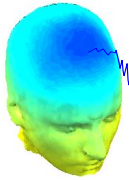
Visualize ERP in topographic array

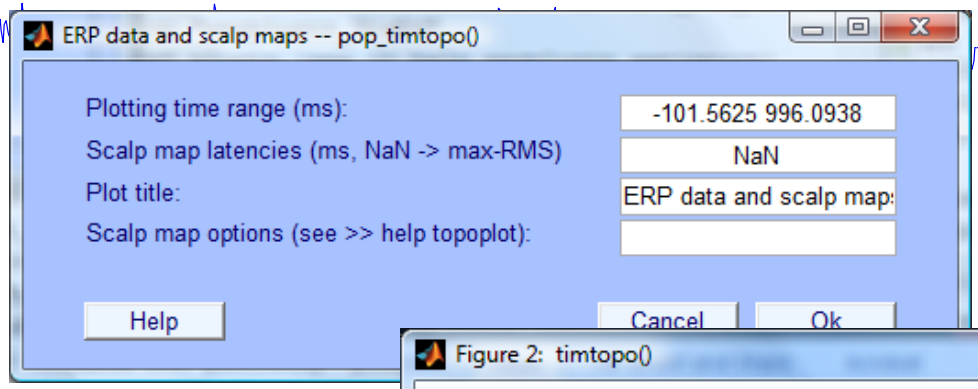


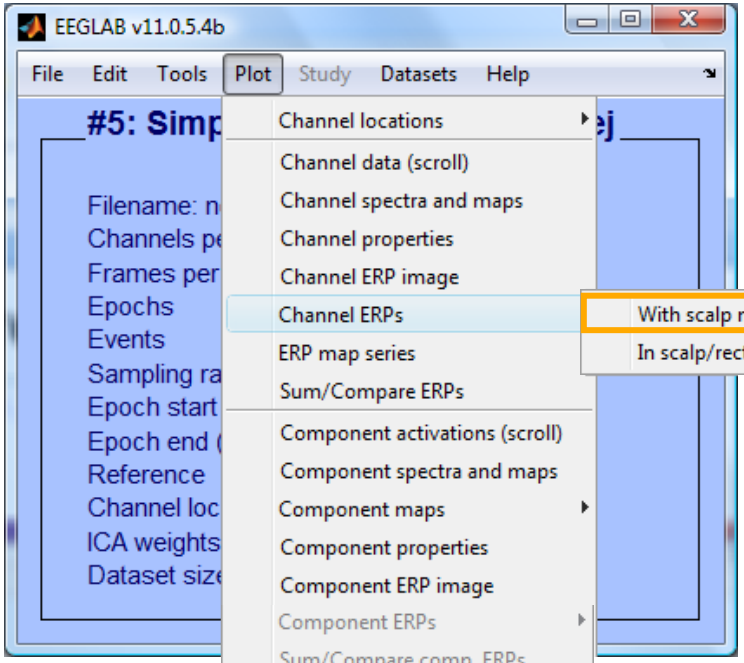


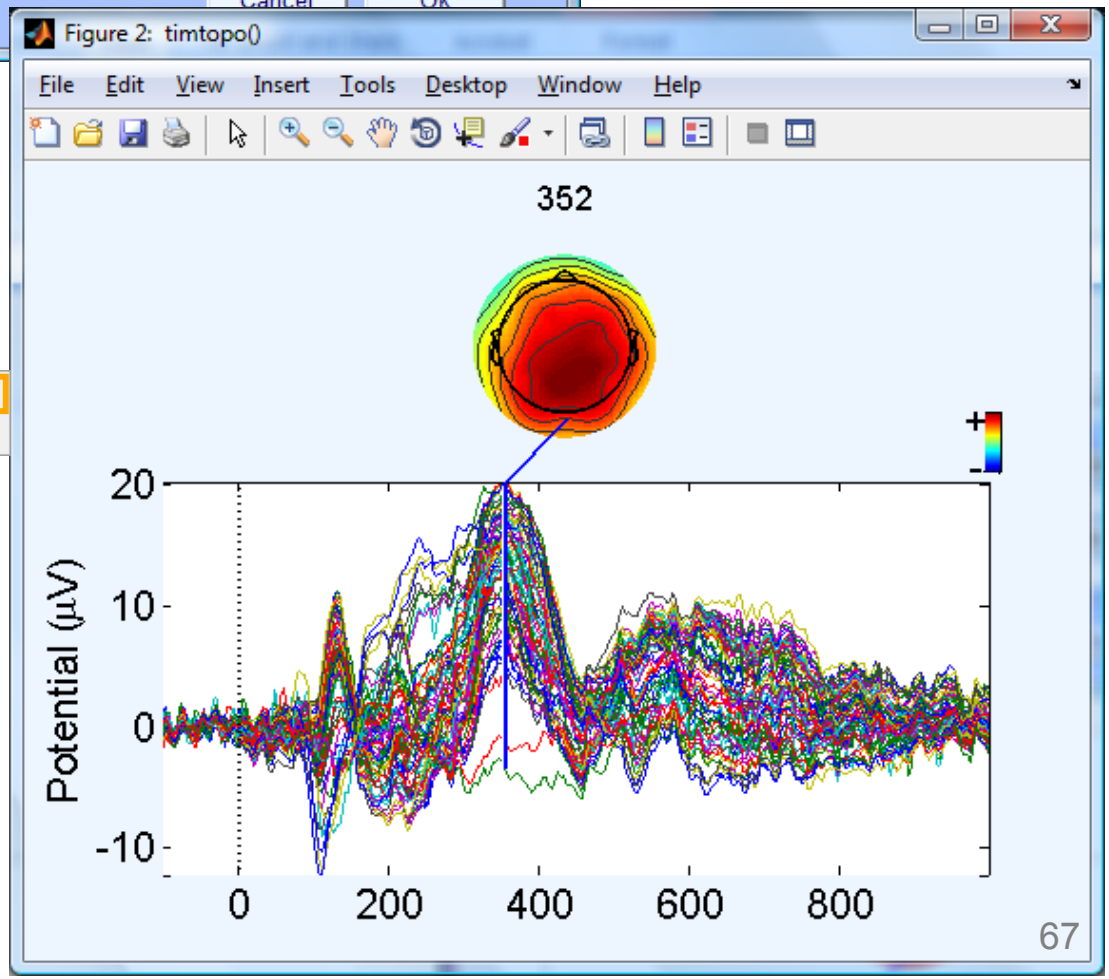


Visualize ERP scalp distribution

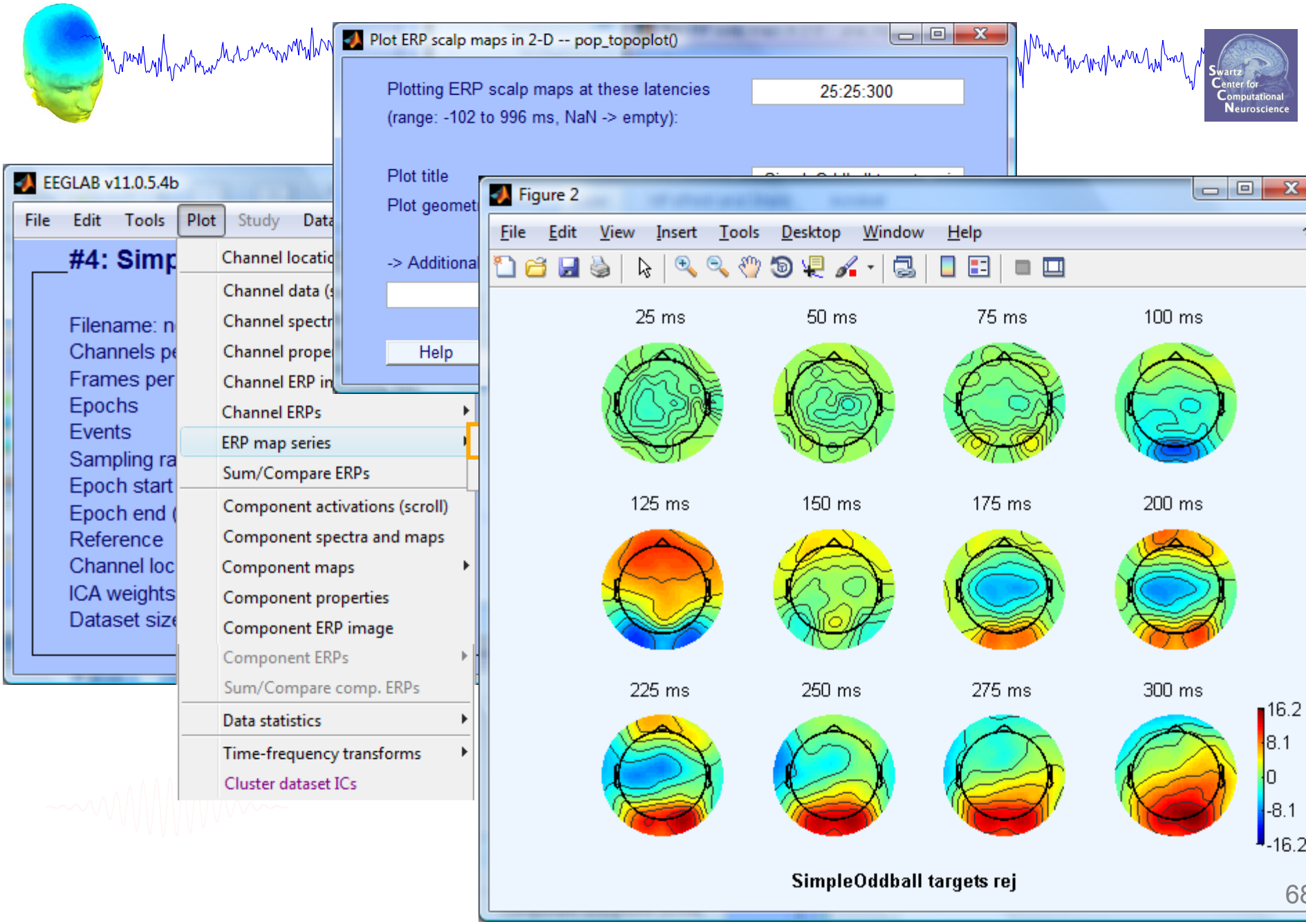




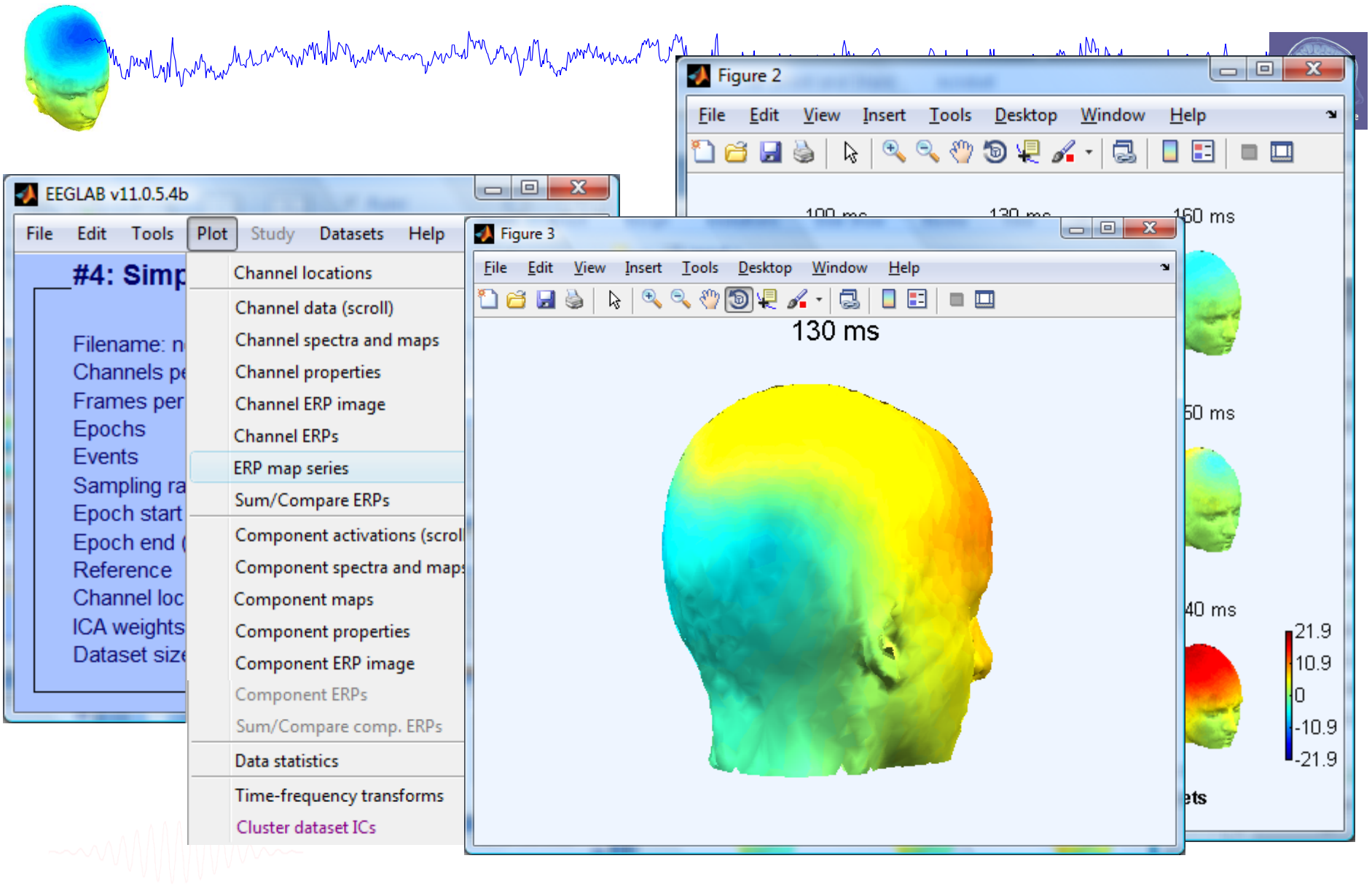




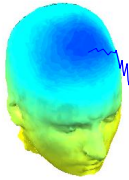
Visualize channel ERPs in 2D

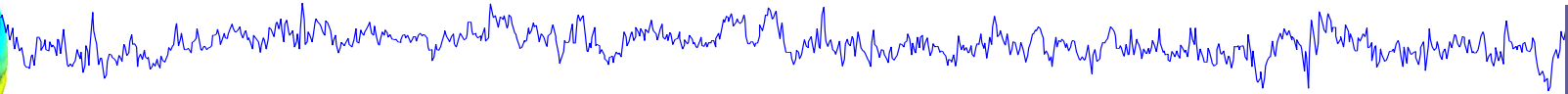


Visualize channel ERPs in 3D



Pre-processing pipeline





Swartz Center for Computational Neuroscience

Collect high-density EEG data (>30 chan)

Import into EEGLAB

Import event markers and channel locations

Re-reference/ down-sample (if necessary)

High pass filter (~.5 – 1 Hz)

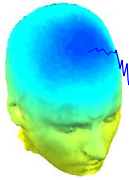
Remove line noise (if necessary)

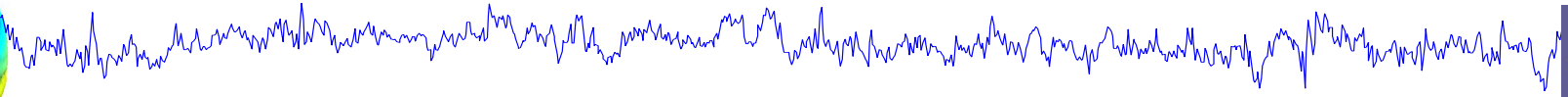
Identify/reject bad channels

Reject large artifact time points

Run ICA

Exercises





- Preprocess data of your choice or load a previously filtered dataset e.g. faces_4.set
- Identify bad channel(s) using auto-detection tool; plot channel properties of flagged channels
- Identify and remove non-task portions of continuous data; see if the previously flagged channels are still identified as bad
- Epoch on event of interest. Scroll the epoched data and perform visual rejection of epochs
- Explore the automated artifact rejection tools
- Run ICA