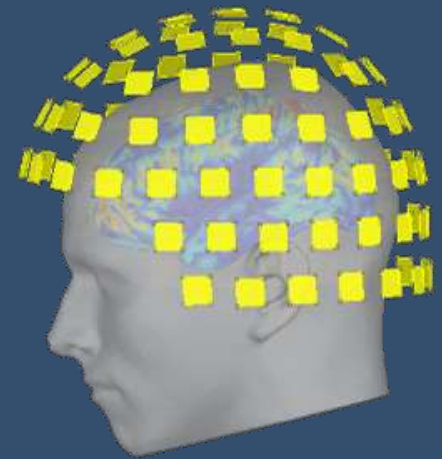


WIFI

Username : x-hbpvisitor

Password : nitfes96

MEG and EEG analysis with  
**Brainstorm**  
<http://neuroimage.usc.edu/brainstorm>



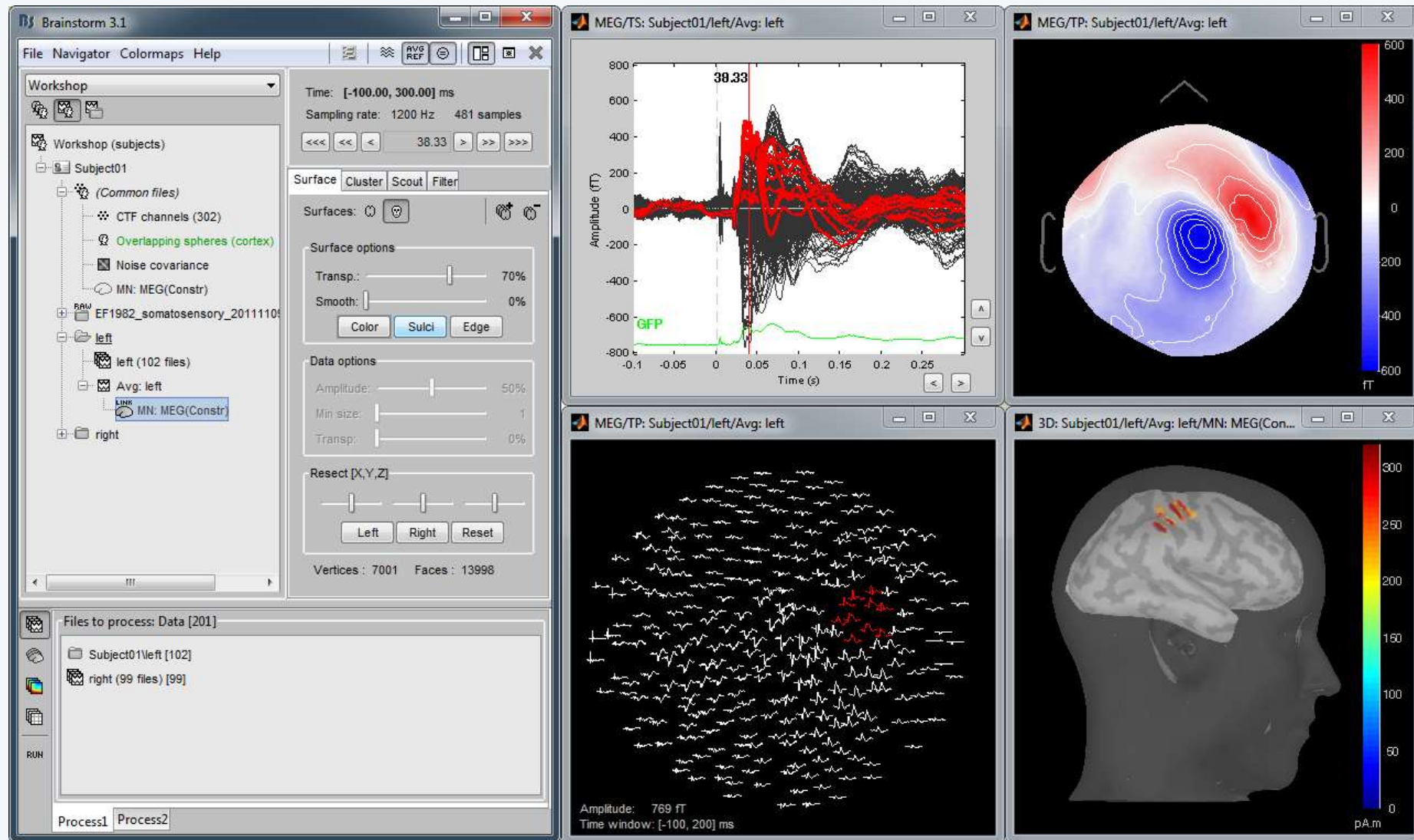
**Geneva, December 2015**

**Francois Tadel**

**Sylvain Baillet**

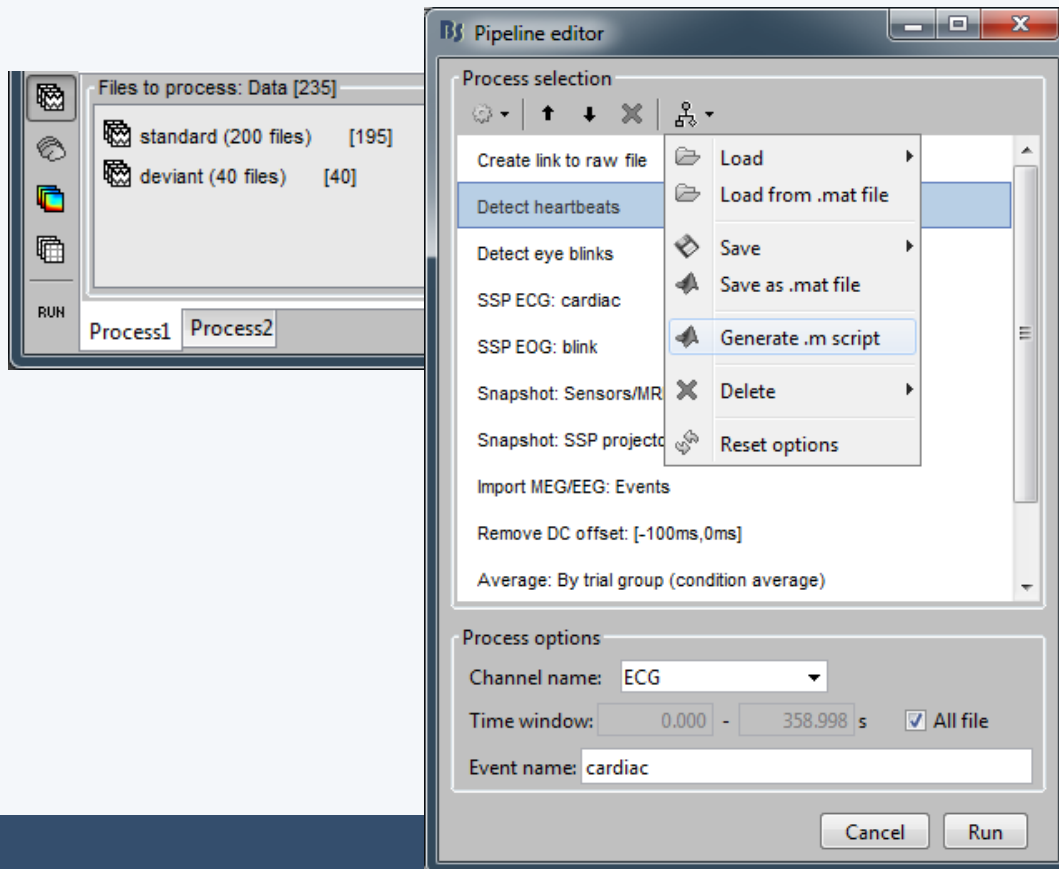
**Anne-Sophie Dubarry**

# Graphic interface



# Scripting environment

- Rapid selection of files and processes to apply
- Automatic generation of Matlab scripts
- Plug-in structure: easy to add custom processes



```
1 % Script generated by Brainstorm v3.1 (17-Dec-2010).
2 FileNamesA = {'Subject01\Left\data_average_101213_1558.mat', ...
3               'Subject01\Right\data_average_101213_1559.mat'};
4 FileNamesB = [];
5
6 % Process: Detect bad trials: Peak-to-peak MEGGRAD(0-2000)
7 sFiles = bst_process(...
8     'CallProcess', 'process_detectbad', ...
9     FileNamesA, FileNamesB, ...
10    'timewindow', [-0.0998, 0.3000], ...
11    'meggrad', {0, 2000}, 'ft/cm (x 0.04)', 1e-015), ...
12    'rejectmode', 2);
13
14 % Process: Remove baseline: [-100ms,-1ms]
15 sFiles = bst_process(...
16     'CallProcess', 'process_baseline', ...
17     sFiles, [], ...
18     'baseline', [-0.09983, -0.00056], ...
19     'overwrite', 1);
20
21 % Process: Band-pass filter: 1Hz - 80Hz
22 sFiles = bst_process(...
23     'CallProcess', 'process_bandpass', ...
24     sFiles, [], ...
25     'f1', 1, ...
26     'f2', 80, ...
27     'overwrite', 1);
28
29 % Process: Average by condition
30 sFiles = bst_process(...
31     'CallProcess', 'process_average', ...
32     sFiles, [], ...
33     'avgtype', 3, ...
34     'isstd', 0);
```

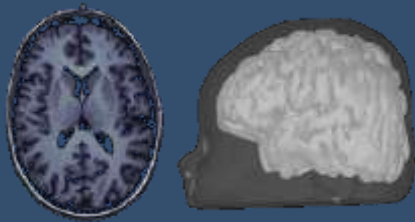
# Brainstorm is...

- A free and open-source application (GPL)
- Matlab & Java: Platform-independent
- Designed for Matlab environment
- Stand-alone version also available
- Interface-based: click, drag, drop
- No Matlab experience required
- Daily updates of the software
- Supports most common file formats

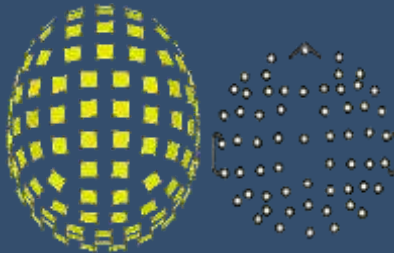


# Workflow

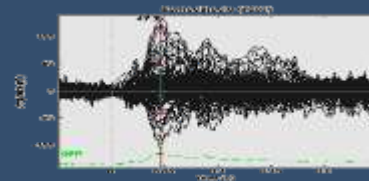
## Anatomy



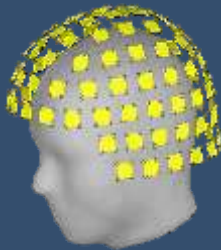
## Sensors



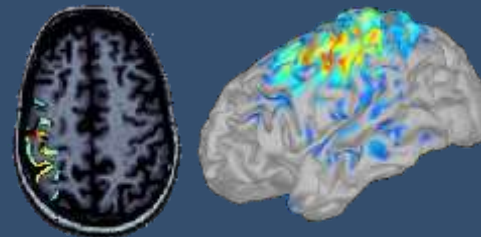
## EEG/MEG



## Co-registration

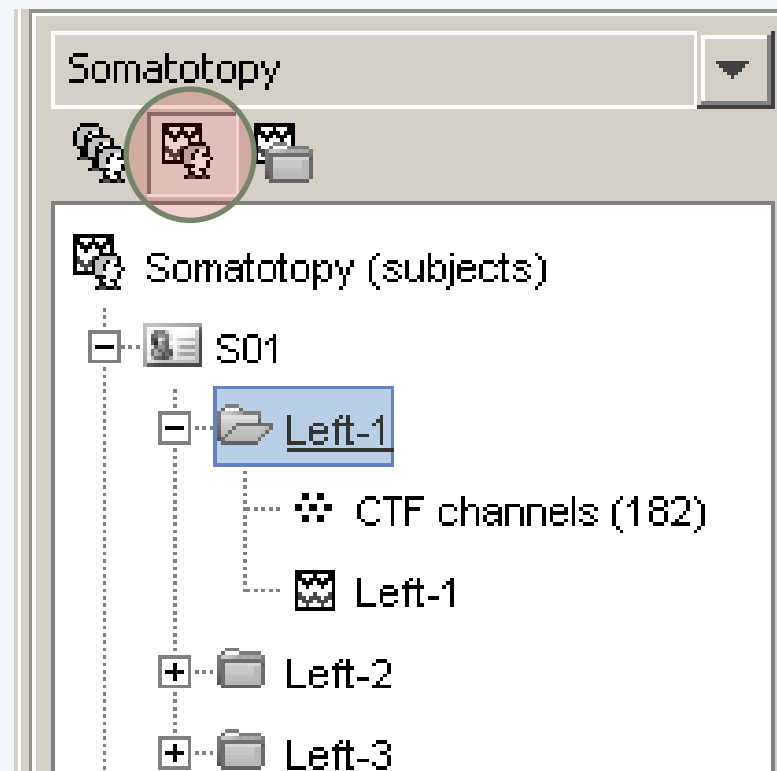
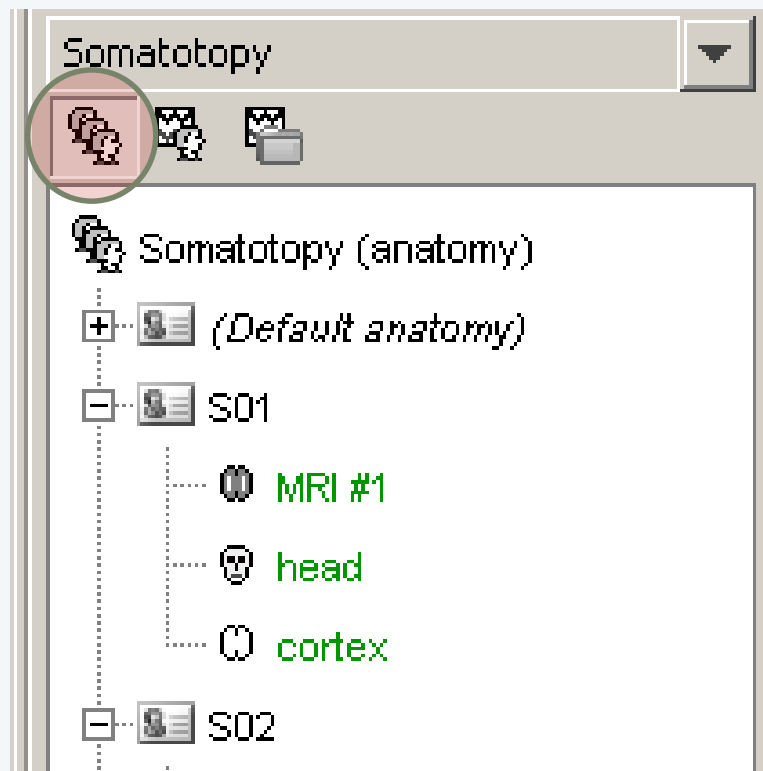


## Source estimation



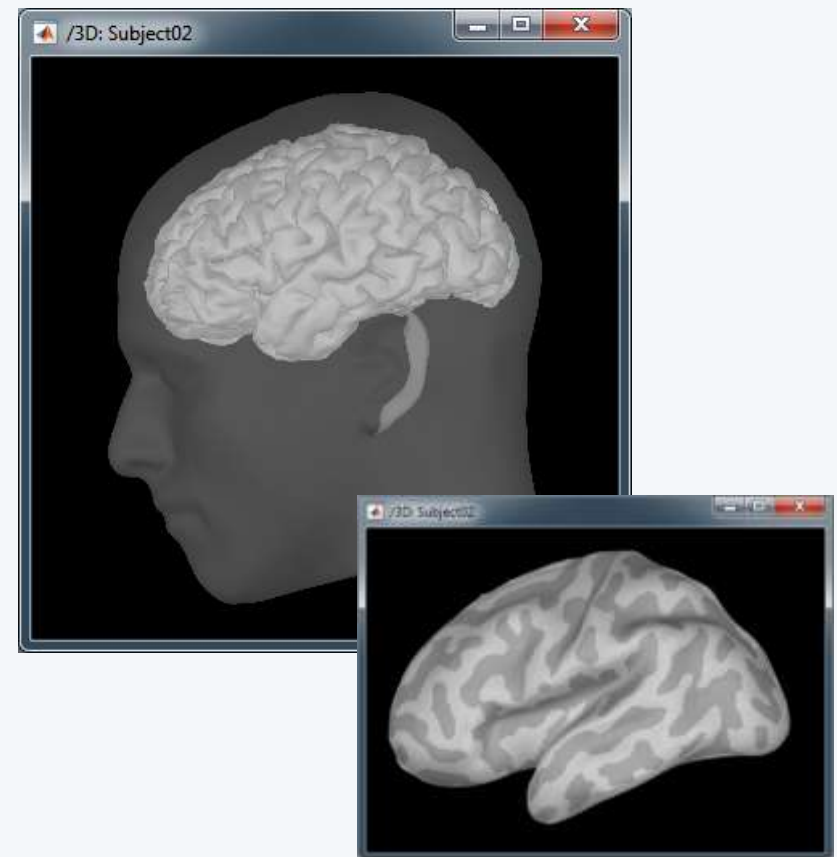
## Analysis

Averages  
Contrasts  
Group analysis  
Time-frequency  
Connectivity



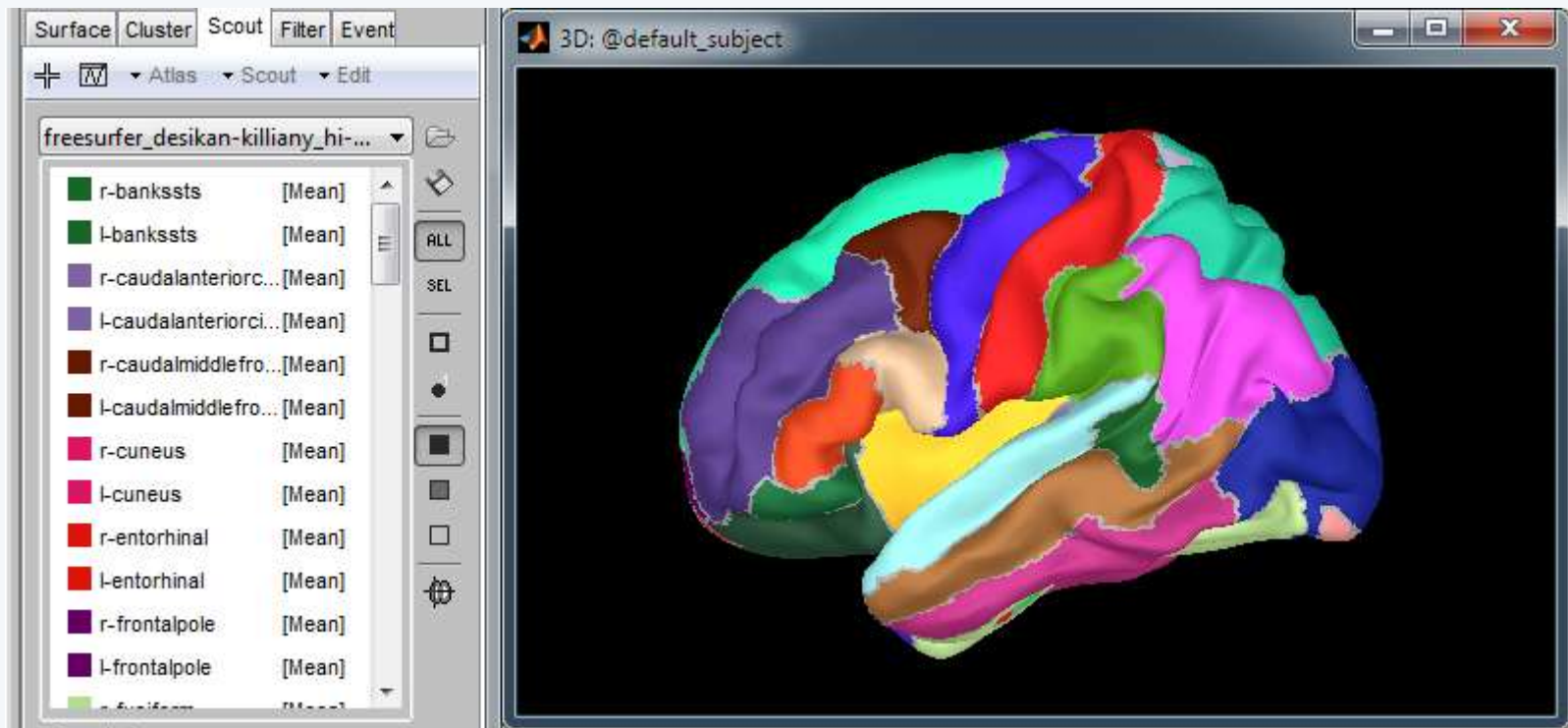
- Three levels:
  - Protocol
  - Subject
  - Condition
- Popup menus
- All files saved in Matlab .mat
- Same architecture on the disk

- One-click import of the T1 segmentation: FreeSurfer, BrainSuite, BrainVISA, CIVET



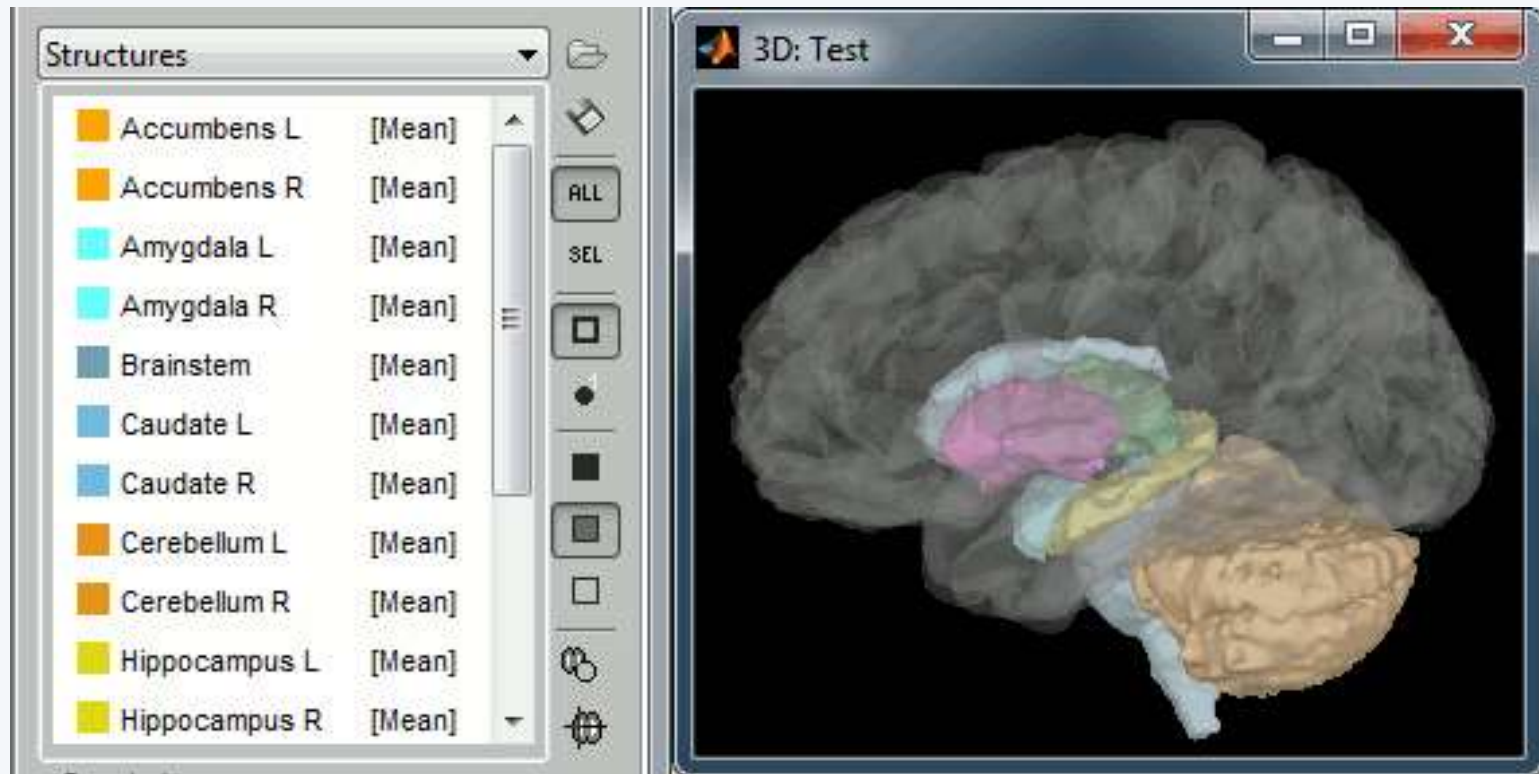


- Support for the surface-based atlases generated automatically by FreeSurfer and BrainSuite





- Support for the subcortical atlases generated automatically by FreeSurfer



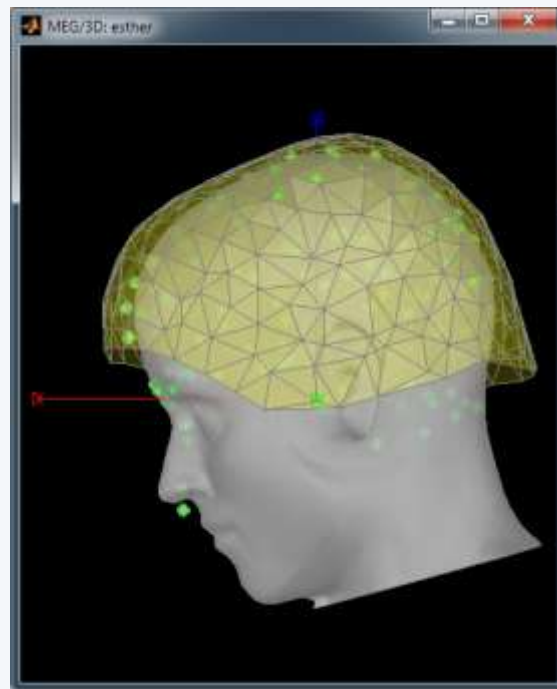
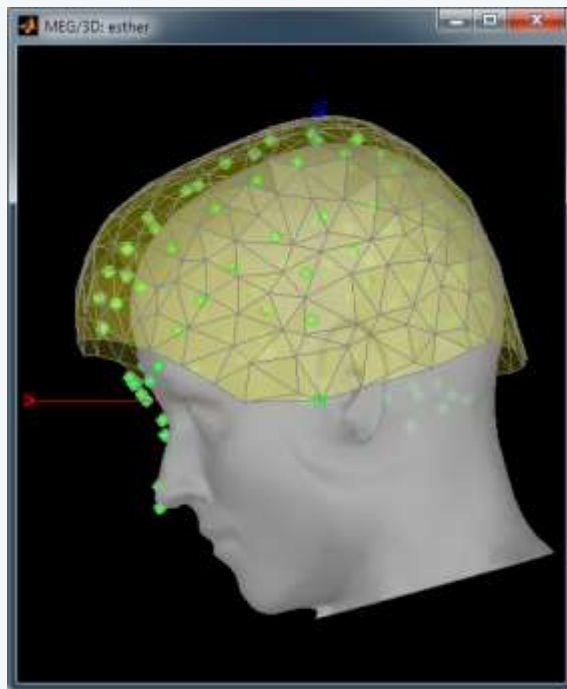
# Co-registration MEG / MRI (I)

- Basic estimation based on three points (NAS,LPA,RPA)
  - MRI: Marked in the volume with the MRI Viewer
  - MEG: Obtained with a tracking system (Polhemus)



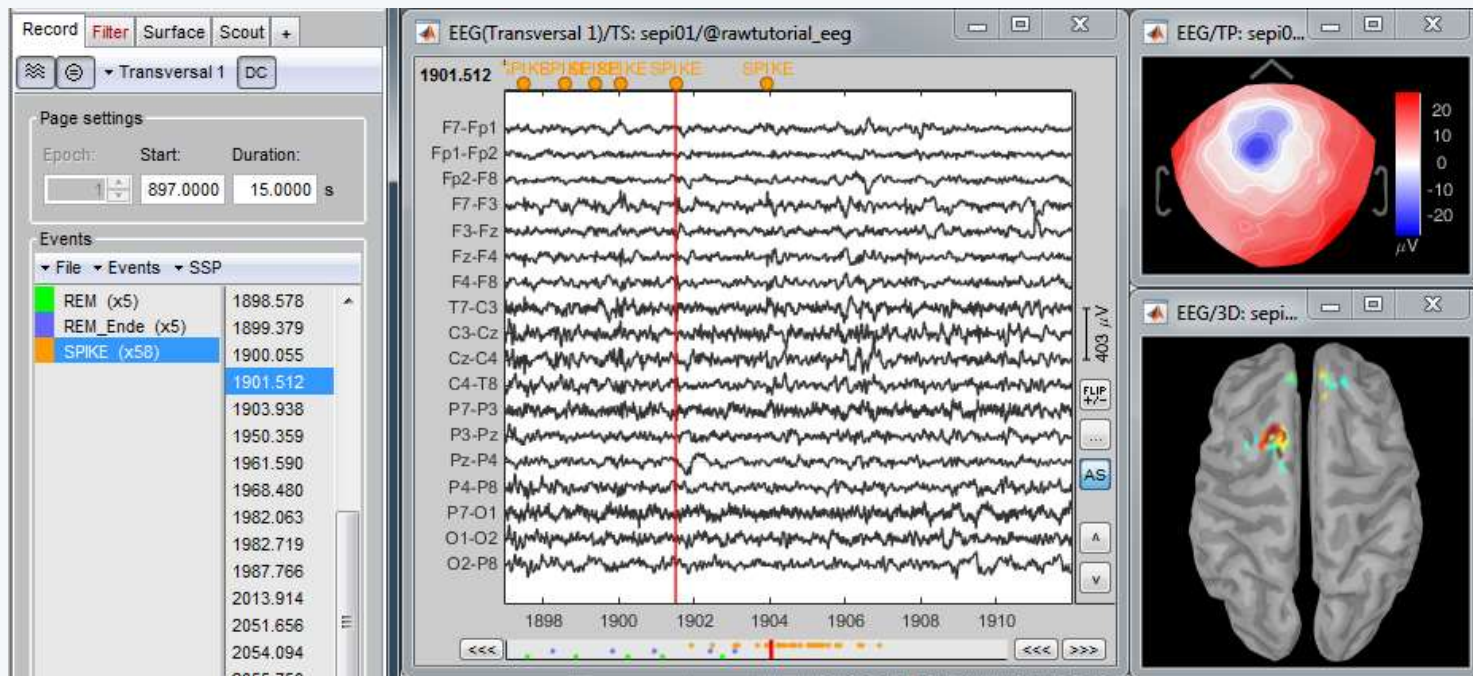
# Co-registration MEG / MRI (2)

- Automatic adjustment based on head shape:  
Fitting the Polhemus points with the MRI head surface
- Final registration must be checked manually
- Polhemus driver included in the software

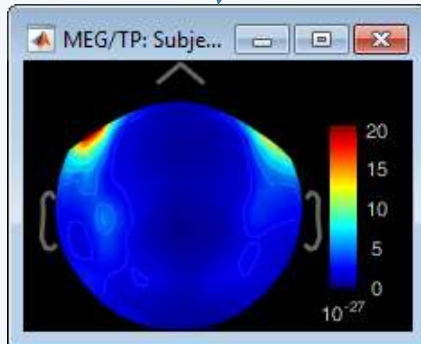
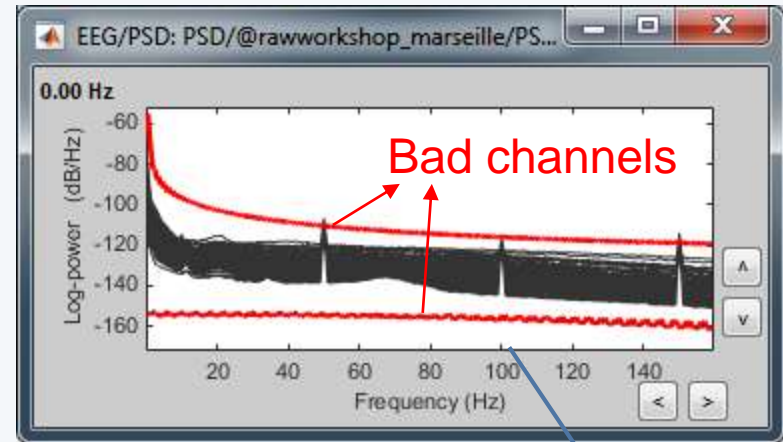
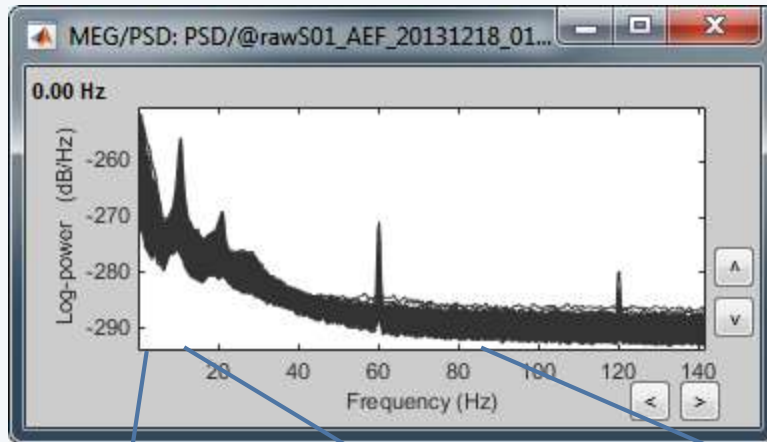


# Continuous recordings

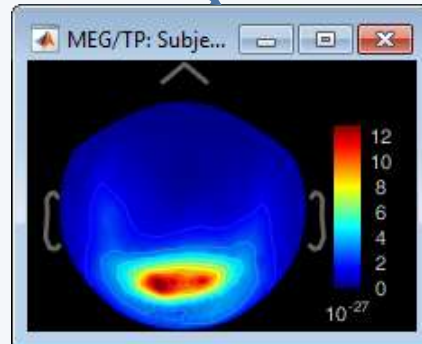
- Manual inspection of the recordings
- Identify noise sources, mark bad segments
- Check stimulus markers, add custom events
- Optimized workflow for clinicians (shortcuts, workspace...)



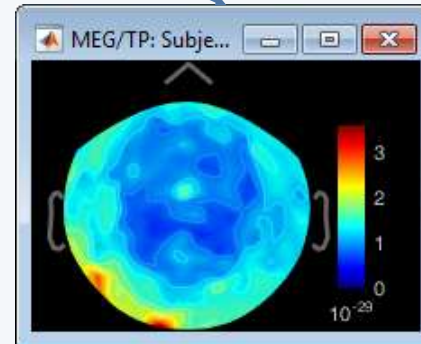




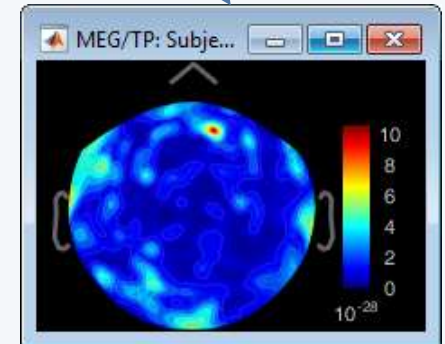
< 3Hz: Eyes



10Hz: Alpha



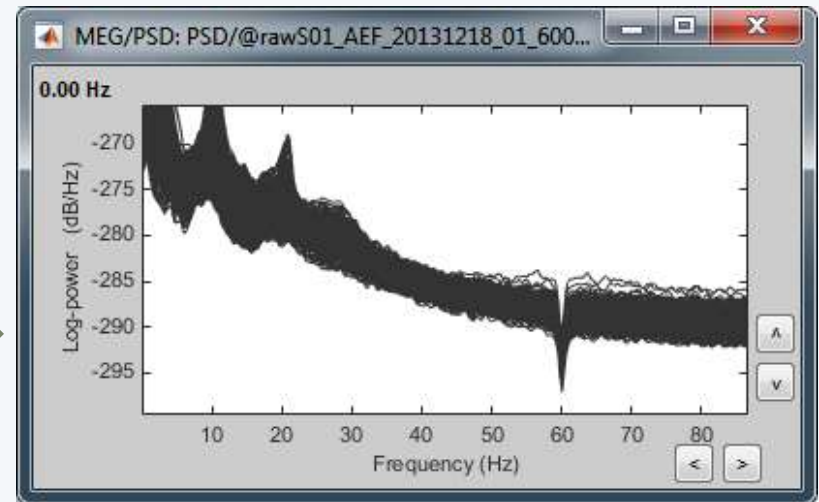
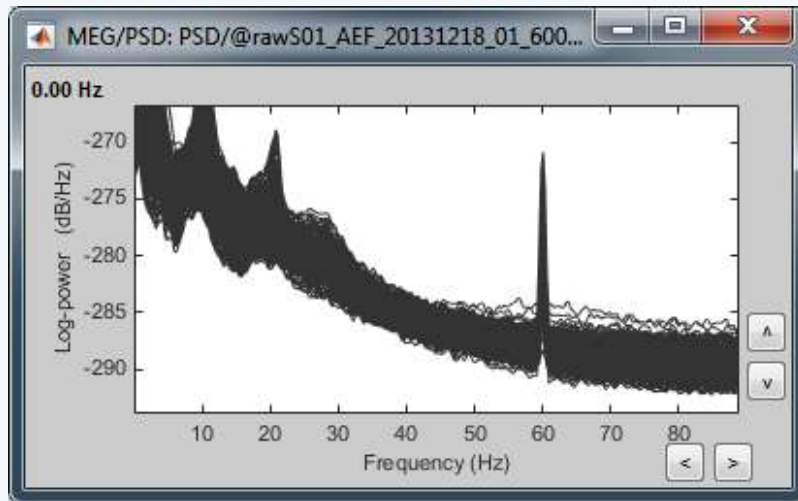
> 40Hz: Muscle



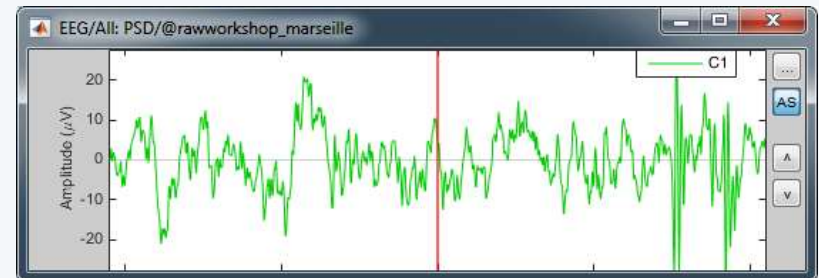
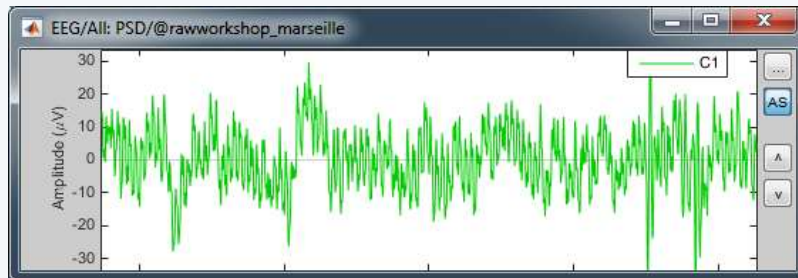
50/60Hz: Power

- Notch filter  
Removes 50Hz/60Hz power line noise (and harmonics)

PSD

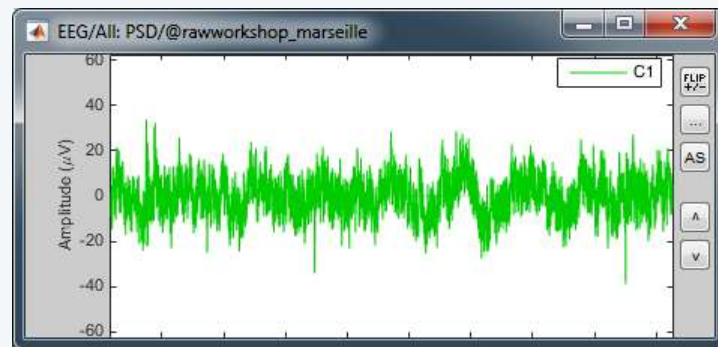
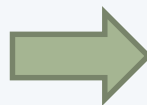
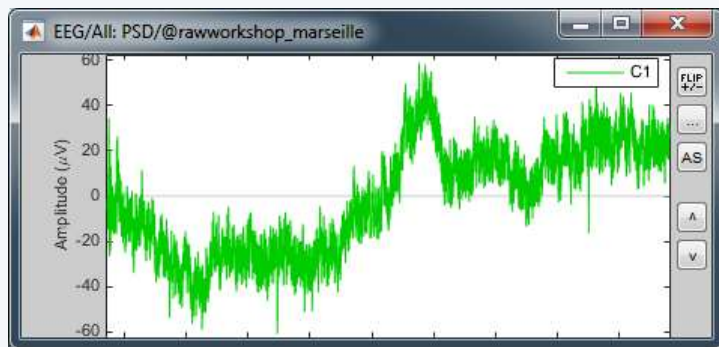


Signal

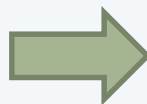
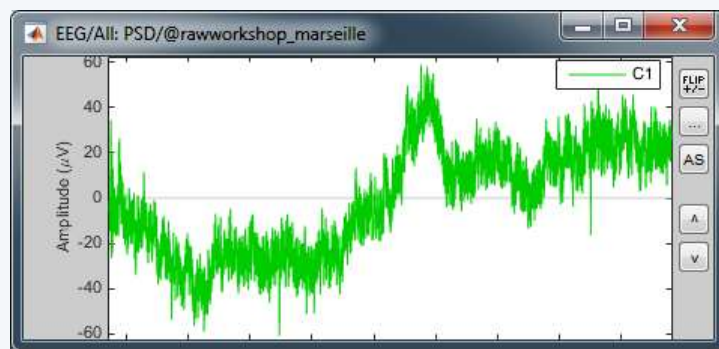




- High-pass filter: Removes slow components (eye movements, breathing, sensor drifts...)

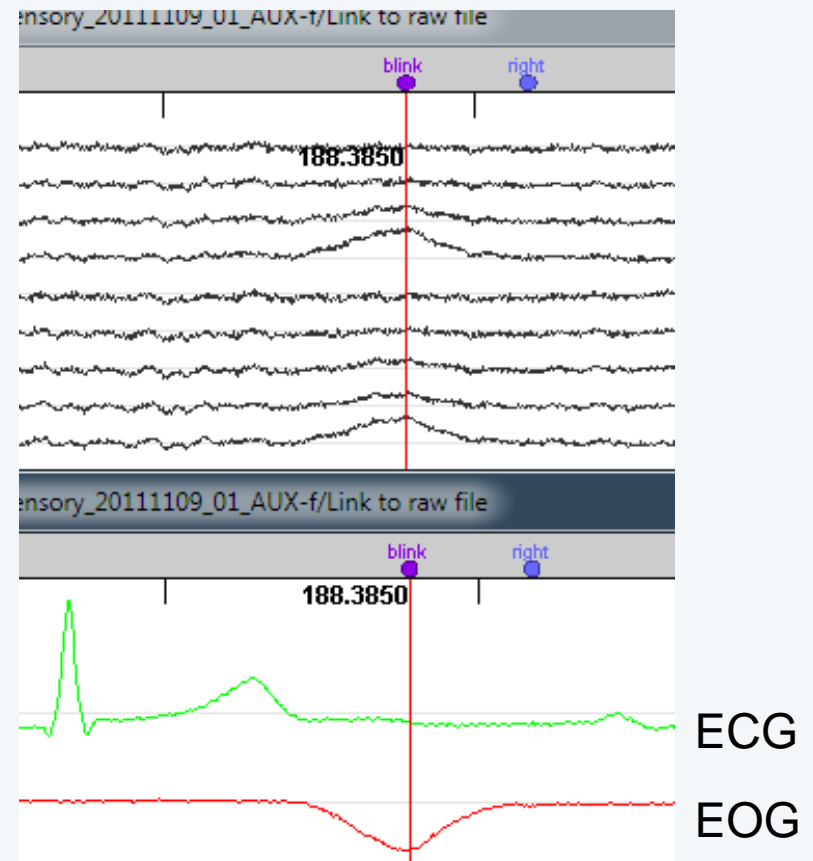
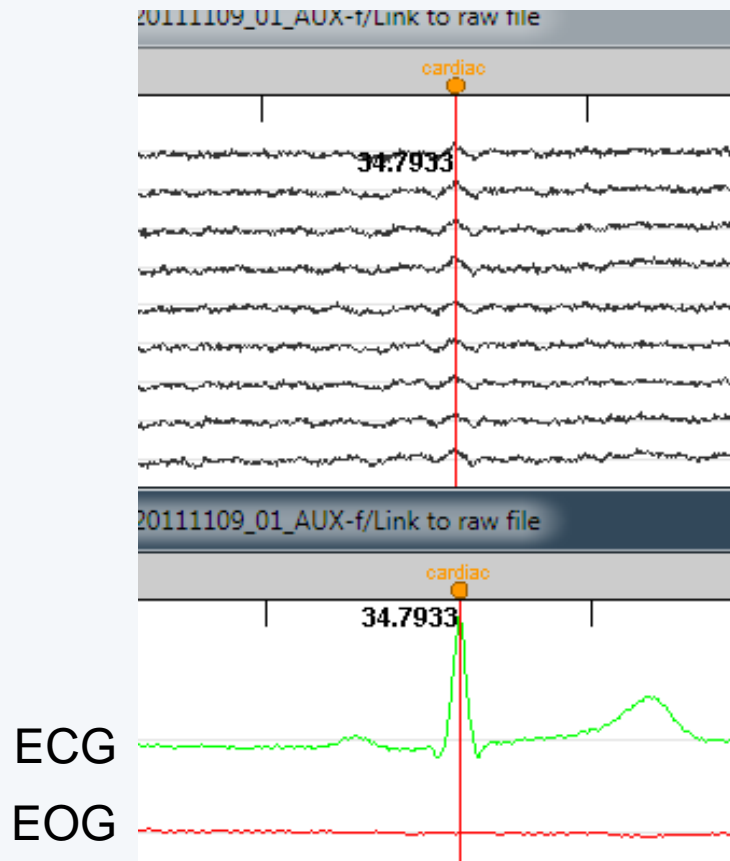


- Low-pass filter: Remove high-frequencies



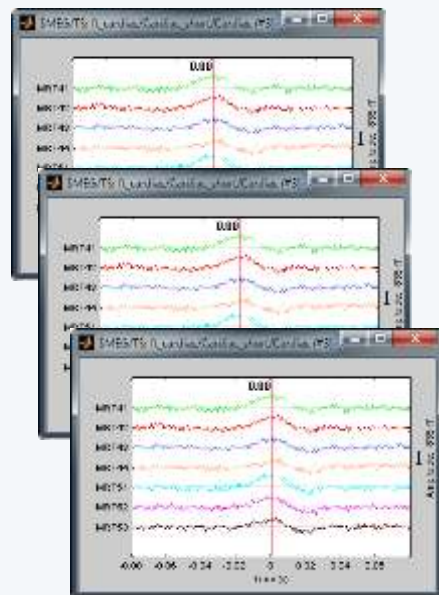
# Artifact correction

- Artifact detection and removal:
  - heartbeats, eye blinks, movements, ...

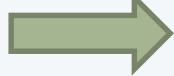


## Signal-Space Projection (SSP)

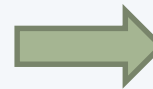
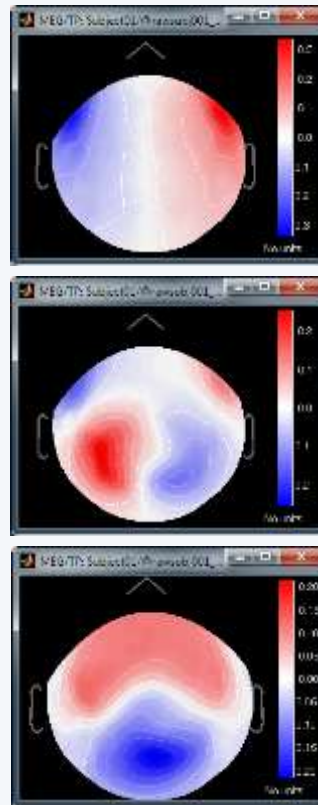
- Detect artifacts
- Concatenate epochs



PCA



Spatial components

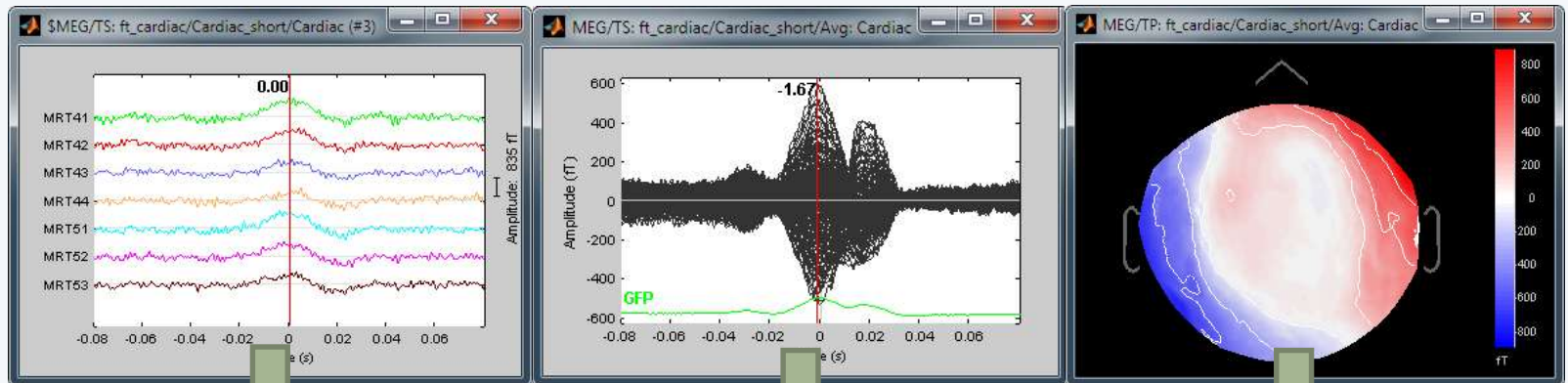


- Select components
- Compute projectors (linear operator)
- Apply to EEG/MEG

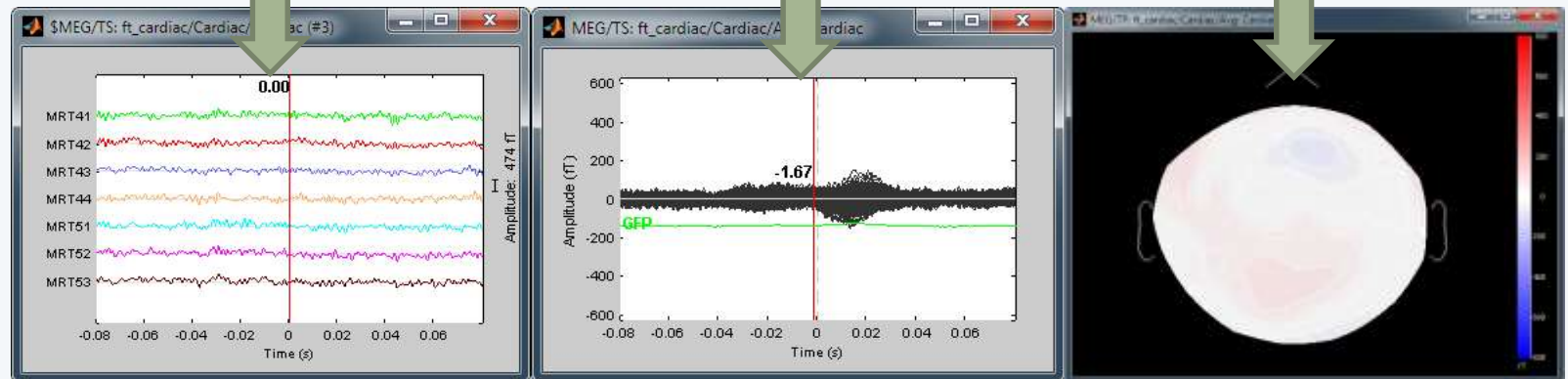
# Artifact correction

- Example: Cardiac artifact

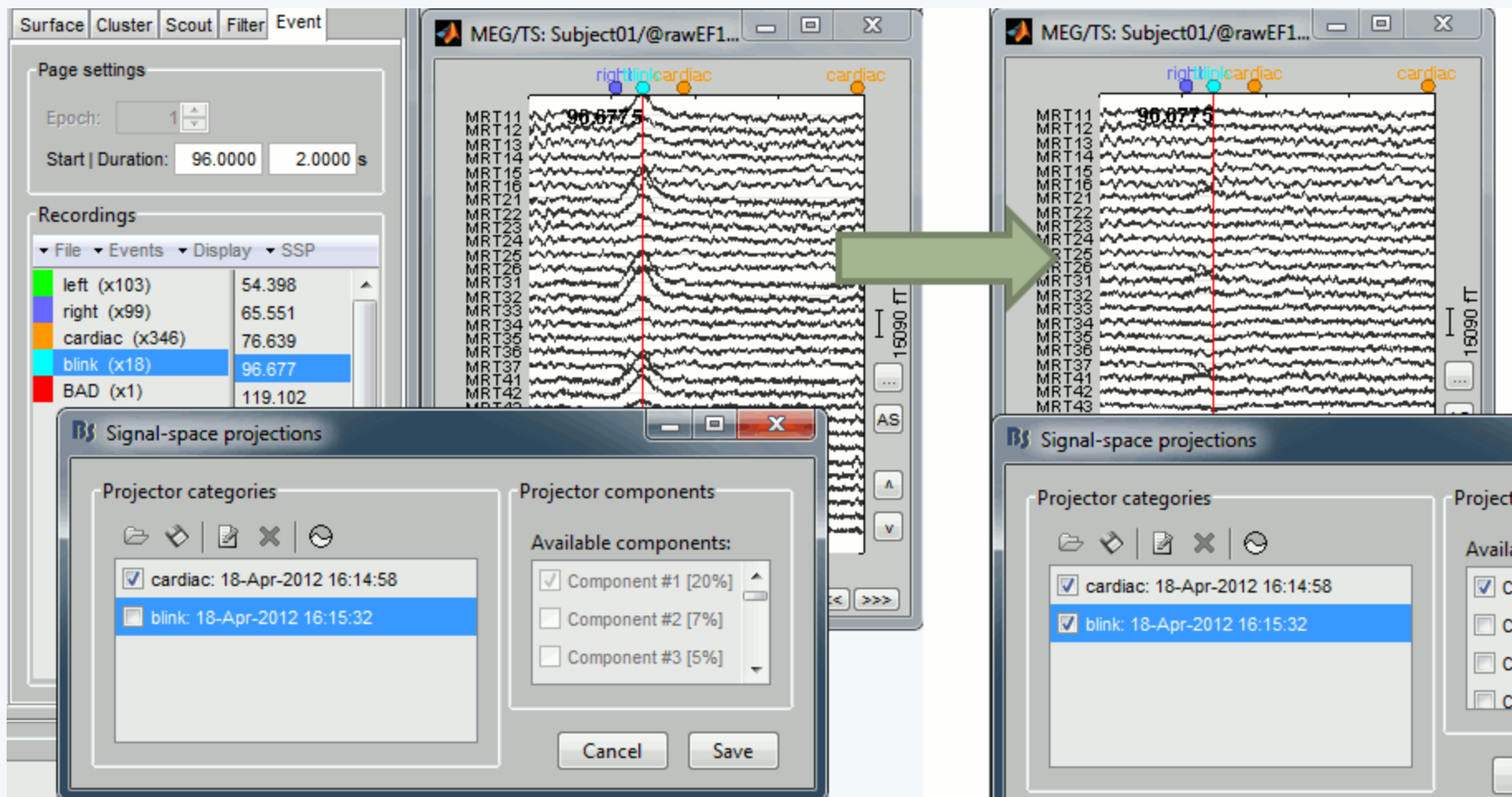
Original



SSP

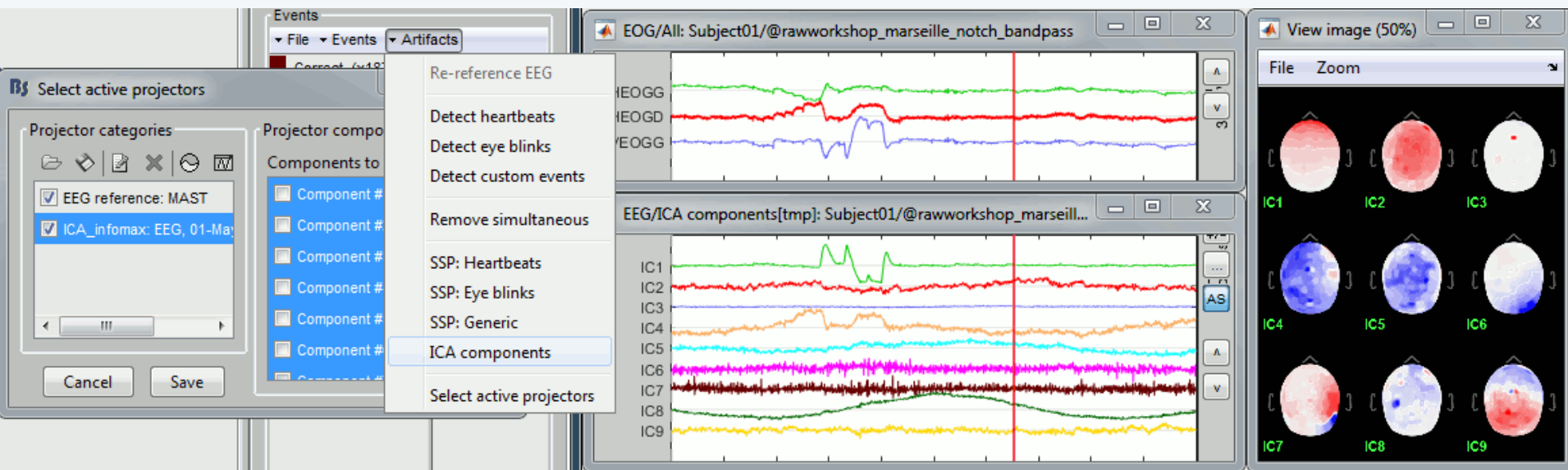


# Artifact correction



# Artifact correction

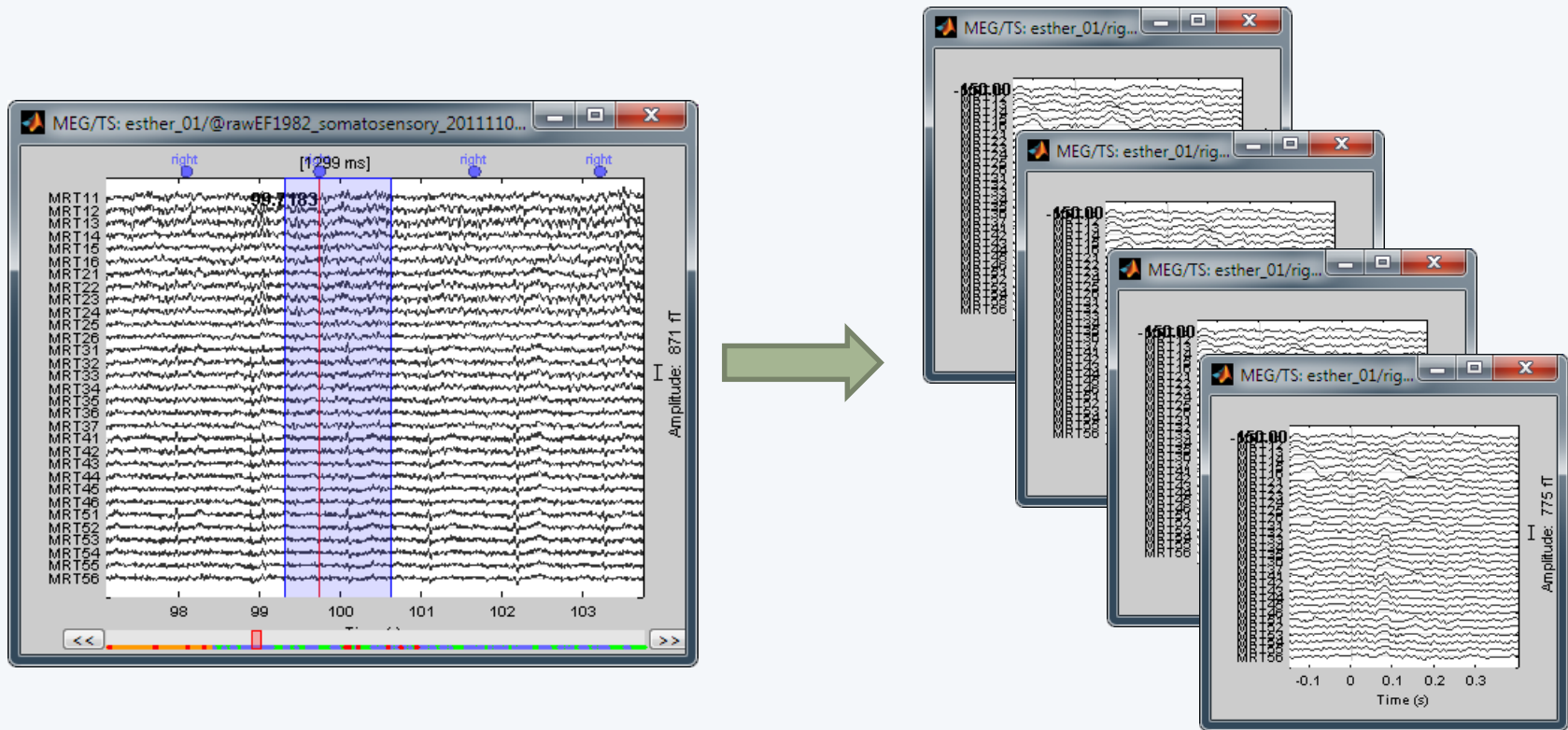
- Independent component analysis (ICA):
  - Popular in the EEG literature
  - Alternative to SSP for low number of sensors
  - Already implemented: Infomax and JADE (EEGLAB)





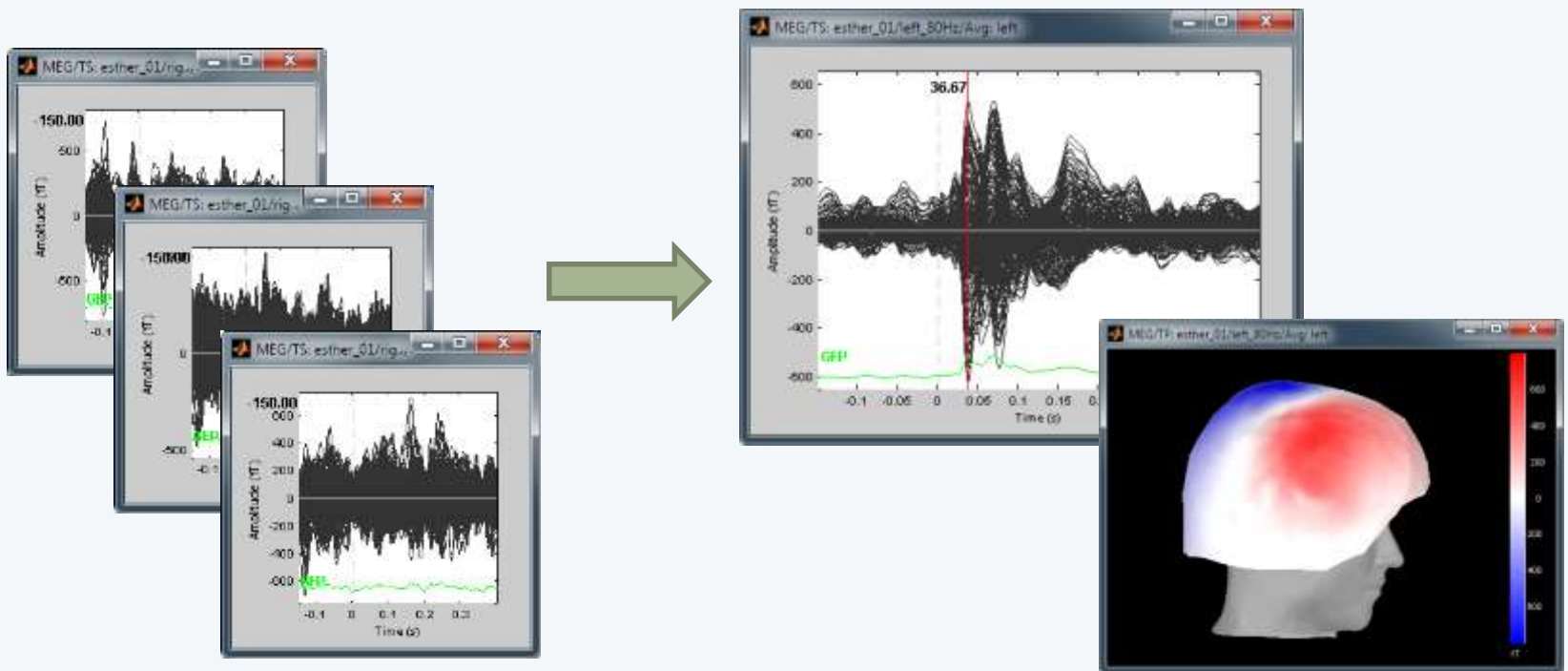
# Epoching

- Epoching: extraction of small blocks of recordings around an event of interest (stimulus, spike...)



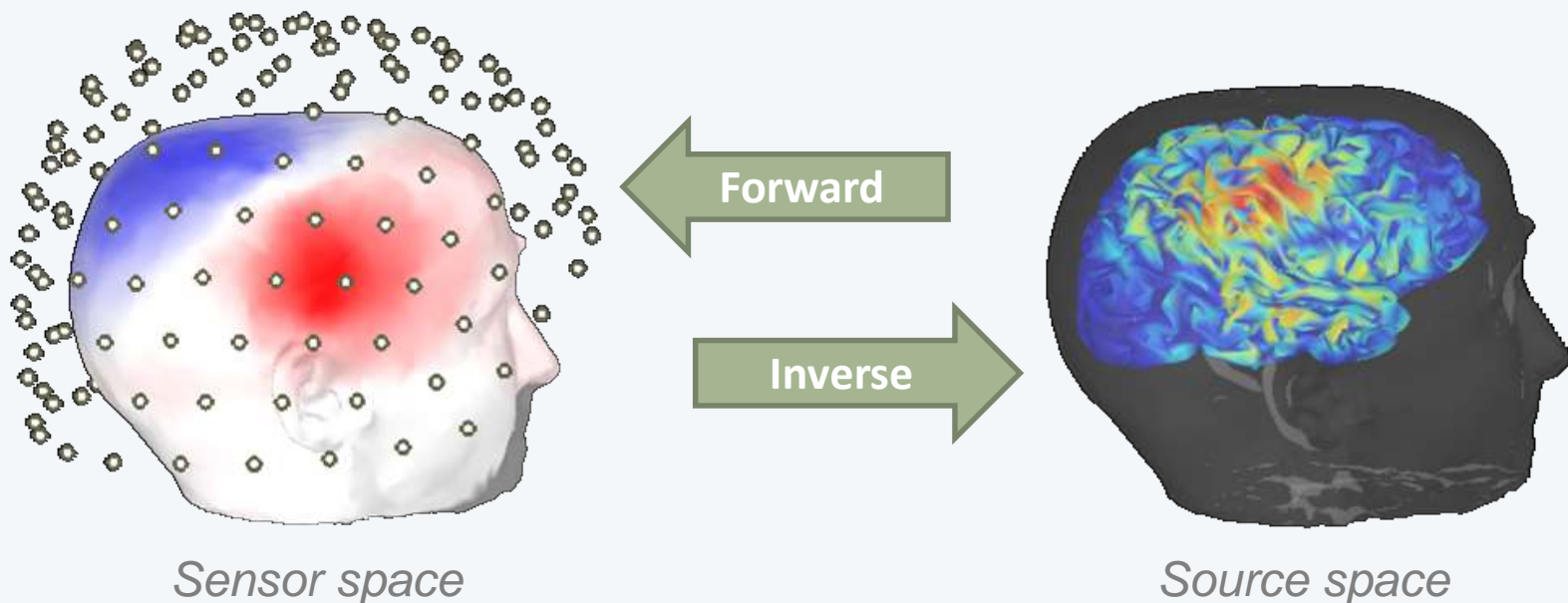
# Averaging

- Averaging all the trials: Reveals the features of the signals that are locked in time to a given event  
=> Event-related field (or potential) = Evoked response

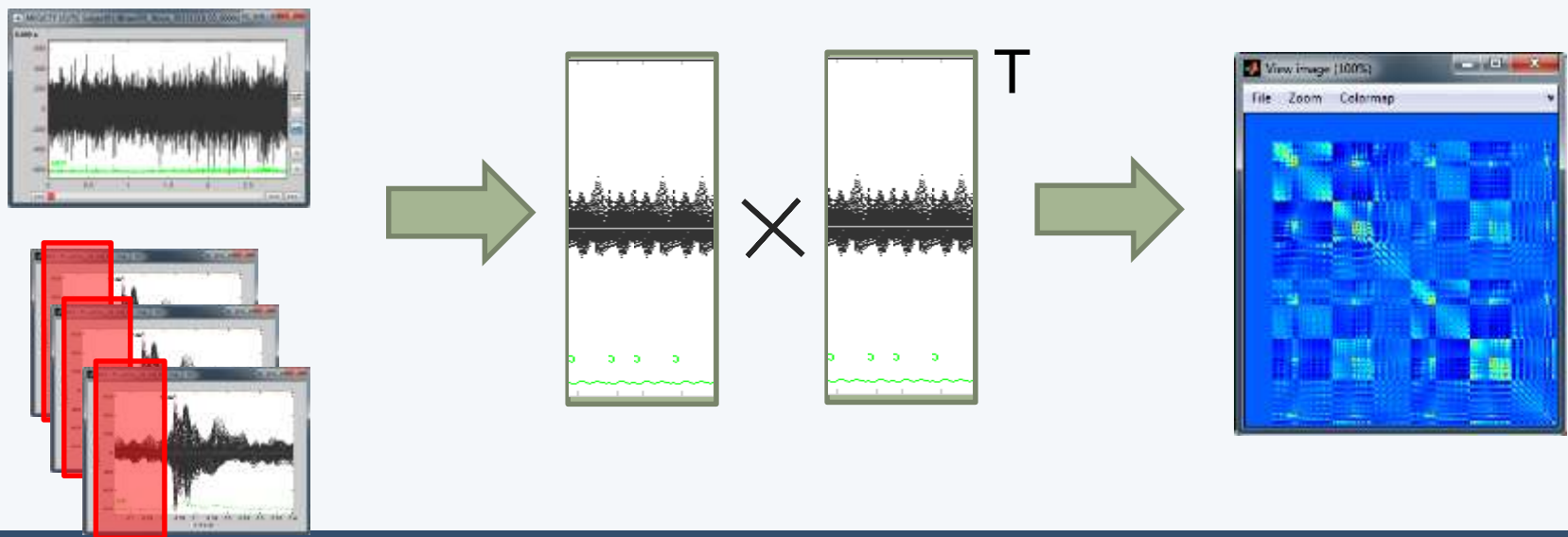


# Source estimation

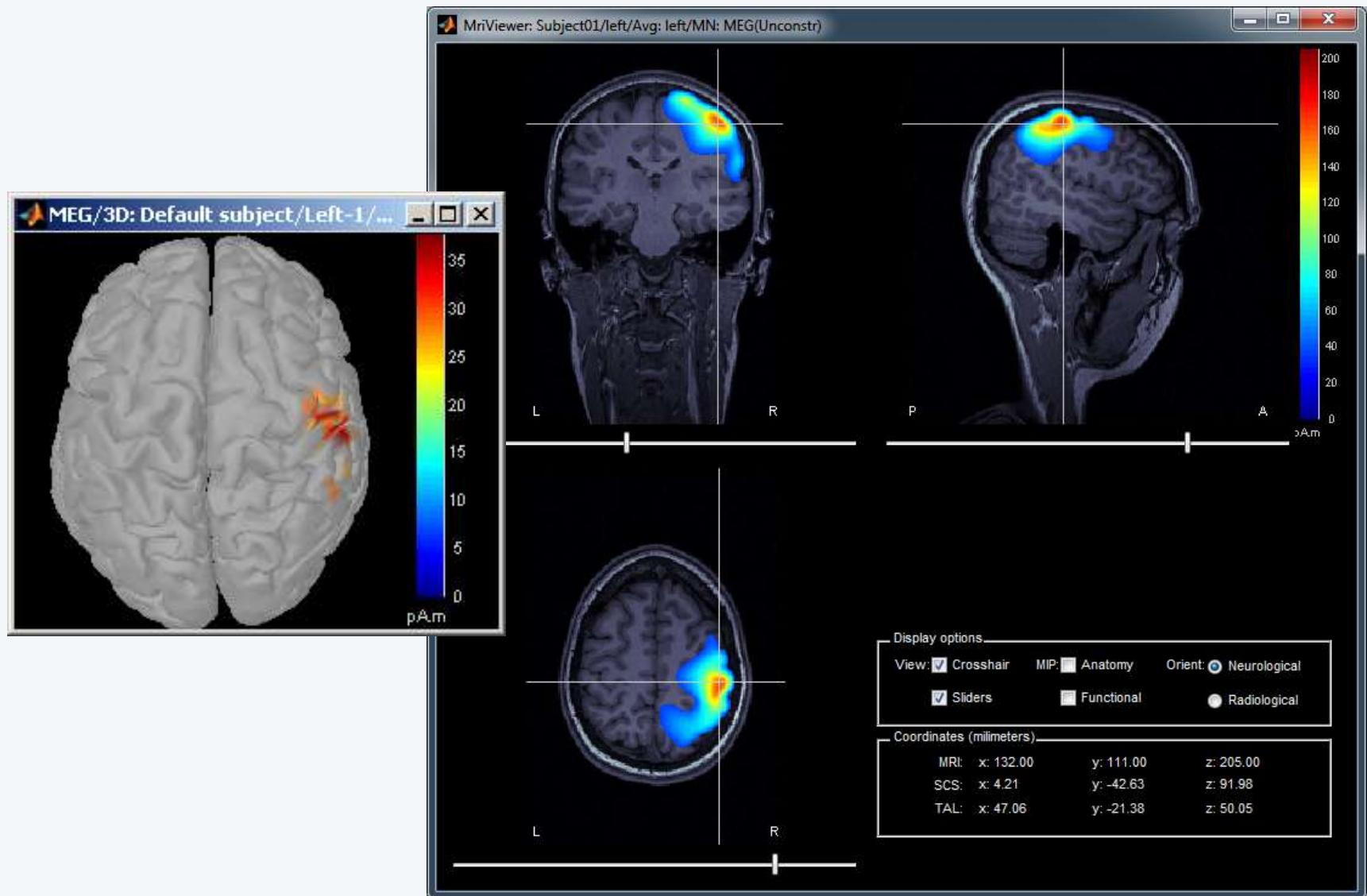
- Source space: Cortex surface or full head volume
- Forward model: Overlapping spheres (MEG)  
OpenMEEG BEM (EEG)
- Inverse model: Minimum norm estimates  
+ normalizations (dSPM, sLORETA)



- The MNE model requires an estimation of the level of noise of the sensors
- Noise covariance matrix = covariance of the segments that do not contain any “meaningful” data
- Empty room measures, pre-stim baseline, resting state



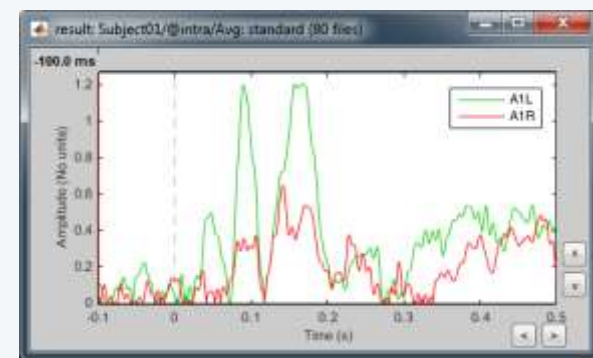
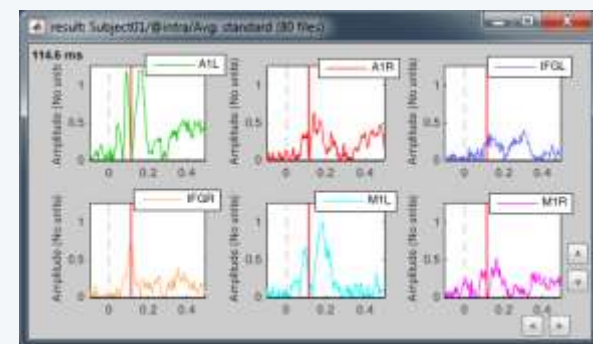
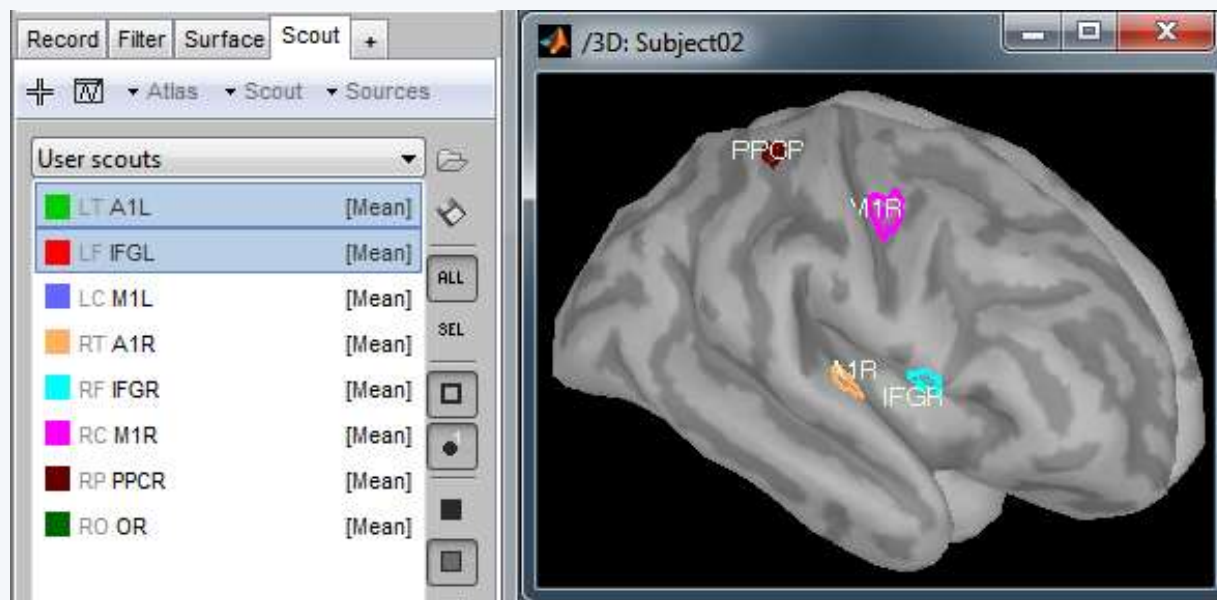
# Source activity





# Regions of interest

- Regions of interest at cortical level (scouts)
  - = Subset of a few dipoles in the brain
  - = Group of vertices of the cortex surface





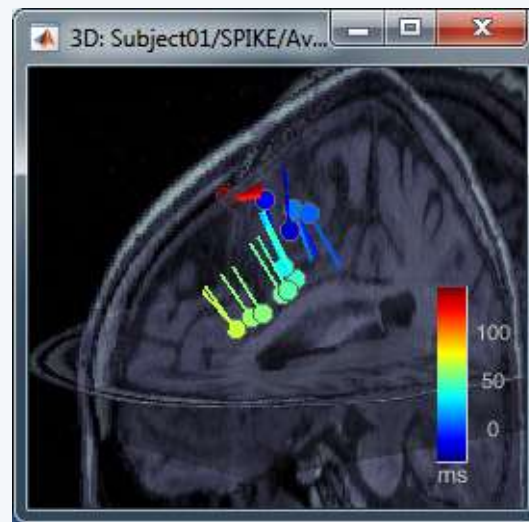
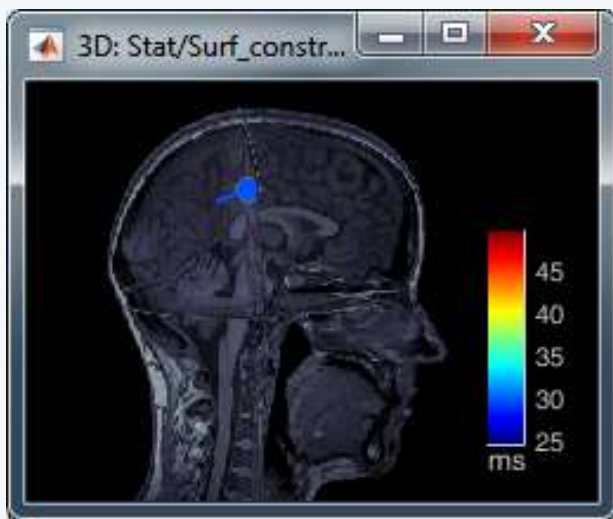
# Single dipoles

- Dipole scanning

Compute a distributed source model, then find the most significant dipole at each time sample.

- Dipole fitting (FieldTrip)

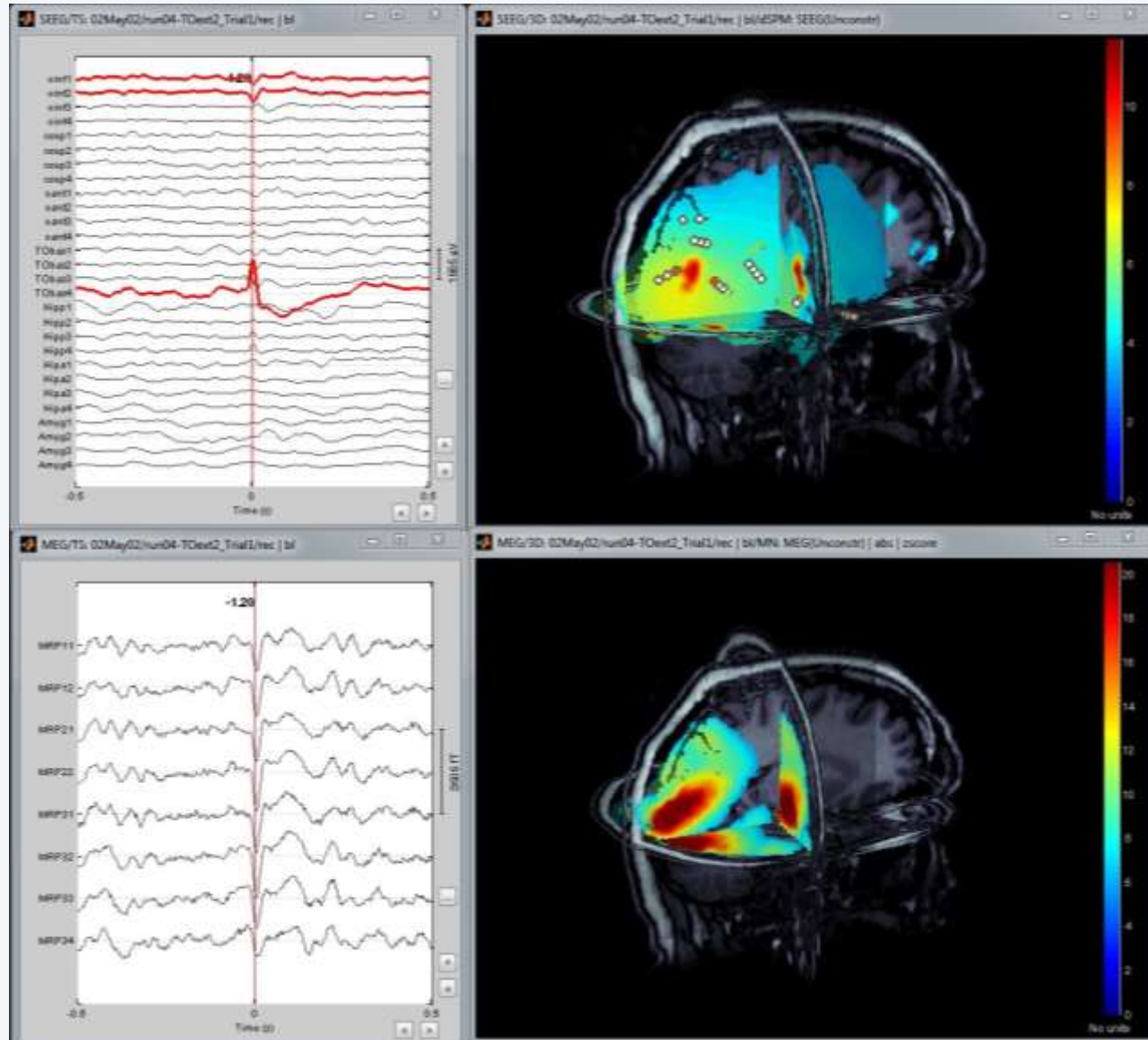
Non-linear search of the dipoles that minimizes the residuals (difference data explained by the dipole - recordings)



# Multi-modal imaging

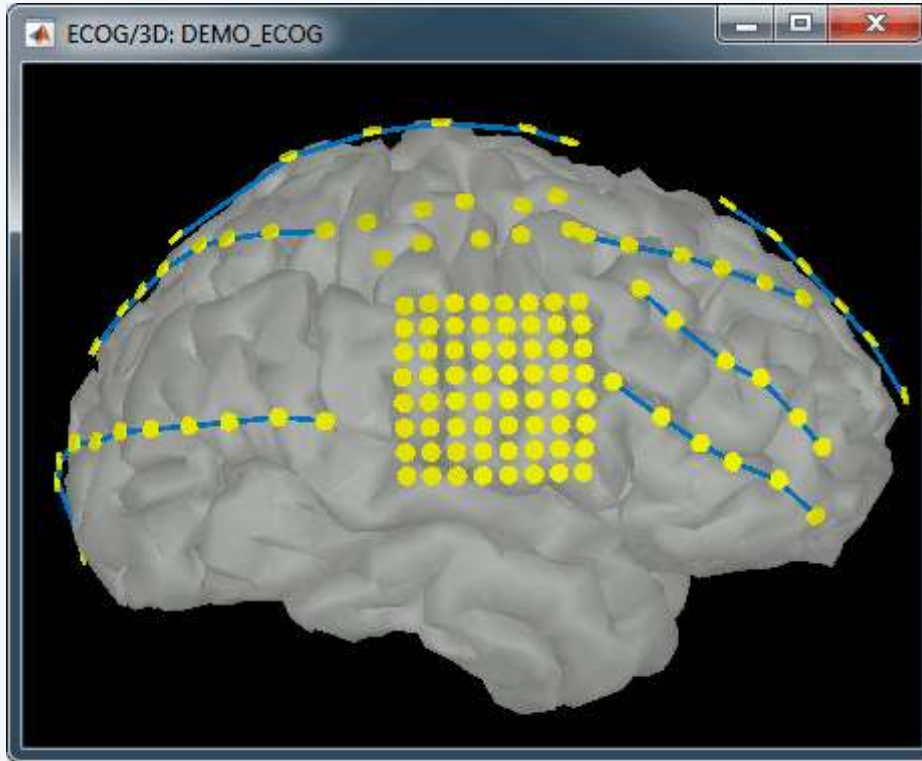
## Easy integration of:

- MEG
- EEG
- ECoG
- SEEG
- NIRS
- Animal LFP
- Eyetracker

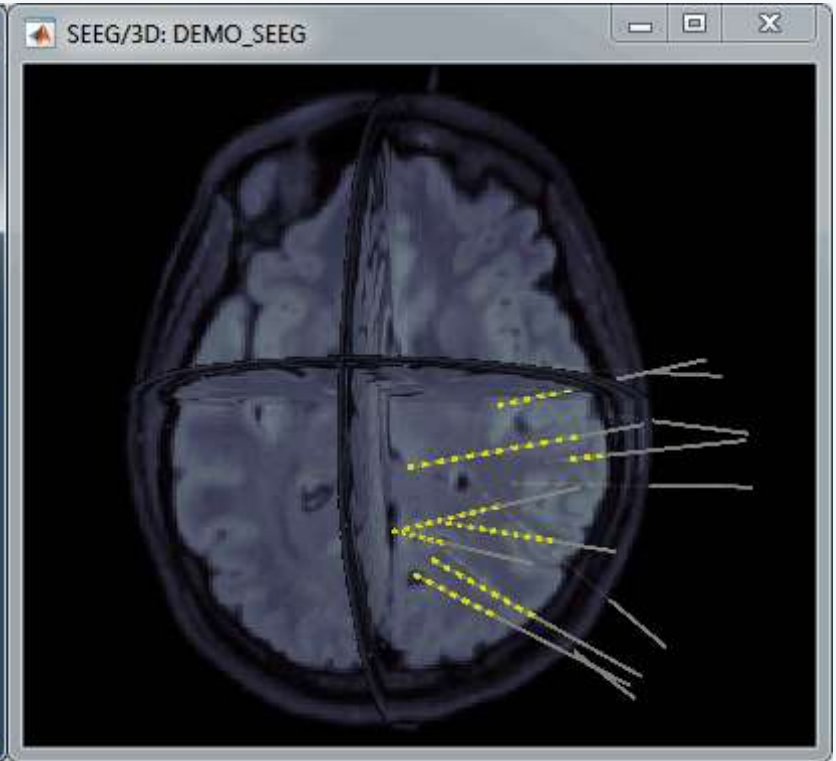


# Invasive recordings

## ECoG

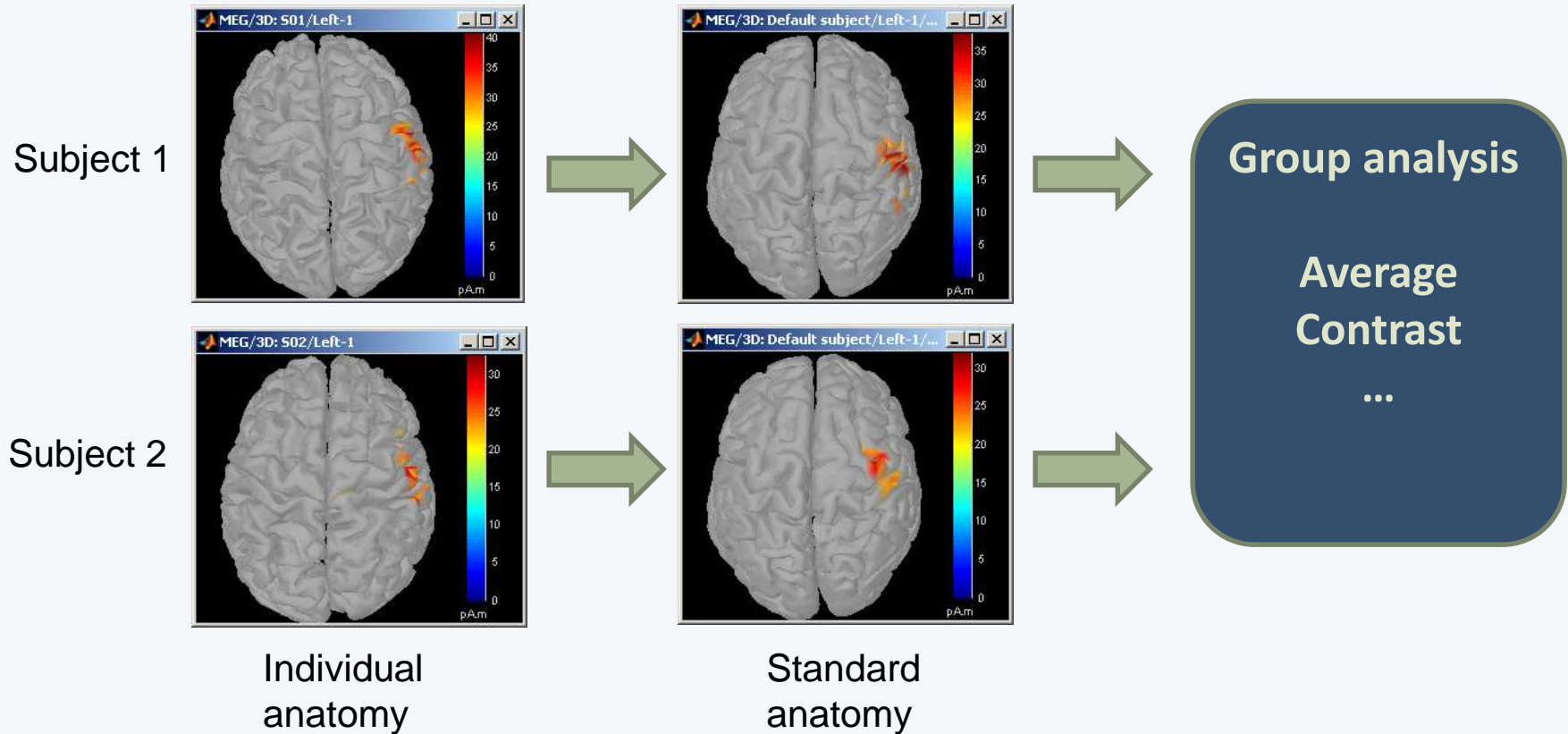


## Depth electrodes

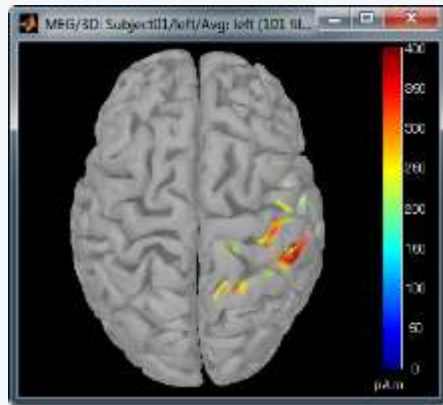


# Group analysis

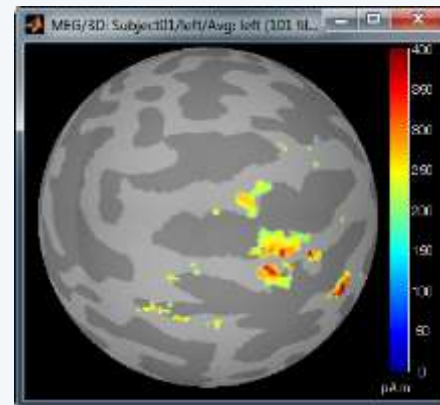
- Registration of individual brains on a template



Subject



*FreeSurfer  
registration*

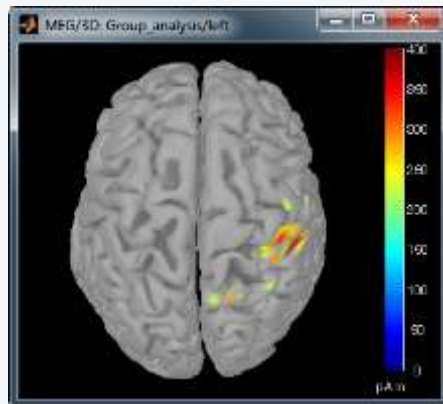


Subject anatomy  
Right hemisphere

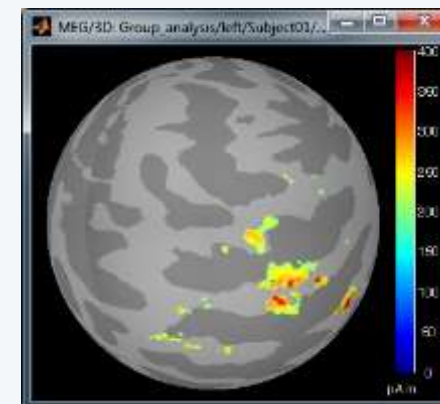


*Shepard interpolation*

Default anatomy



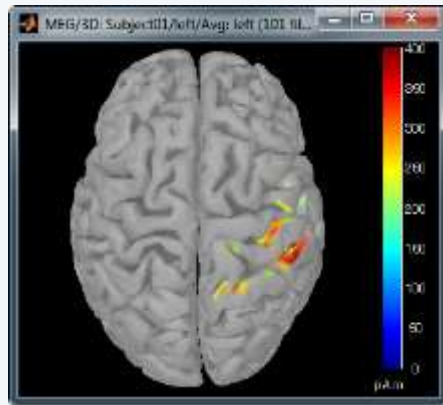
*FreeSurfer  
registration*



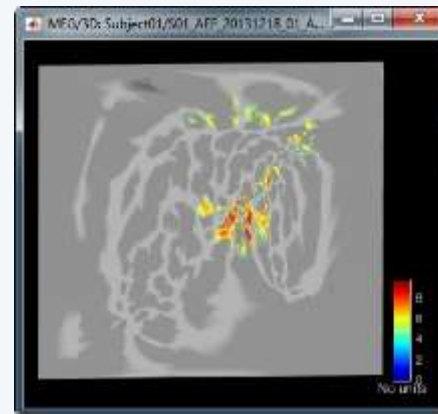
Template  
Right hemisphere



Subject



*BrainSuite  
registration*

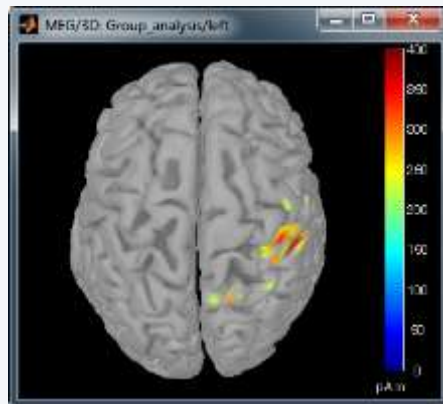


Subject anatomy  
Right hemisphere

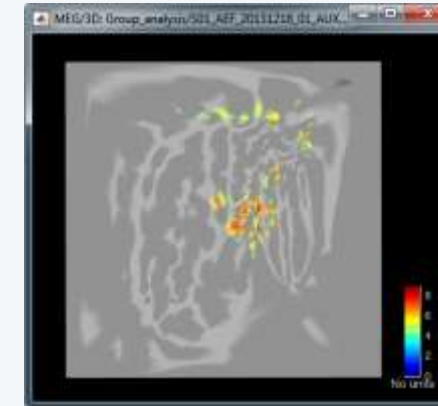


*Shepard interpolation*

Default anatomy



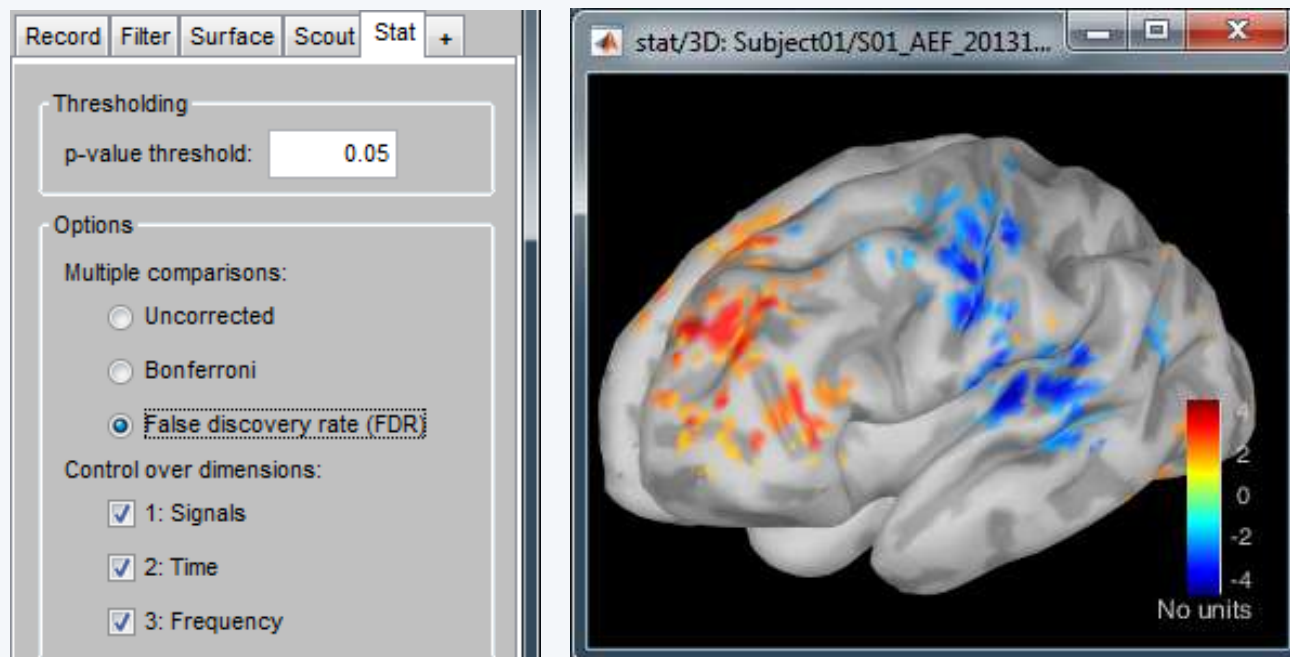
*BrainSuite  
registration*



Template  
Right hemisphere

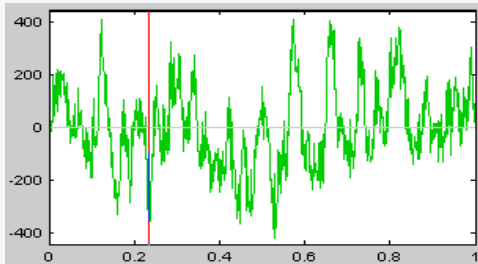


- Contrasts between subjects or conditions
- Parametric t-test
- Cluster-based non-parametric tests (with FieldTrip)
- Export to: **SPM**, R, Excel, SPSS, Matlab...

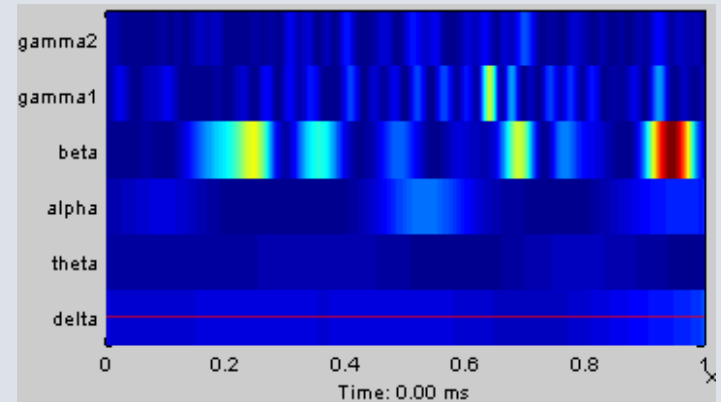
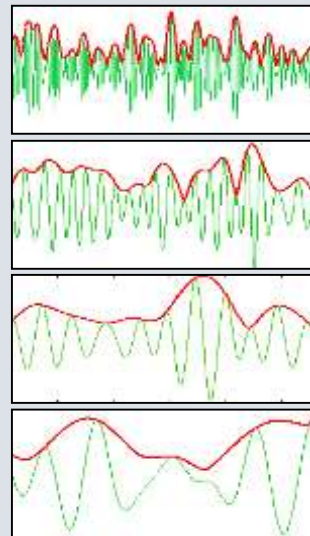
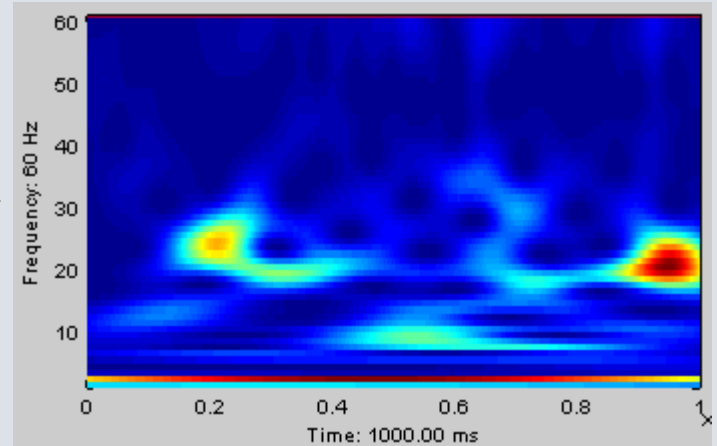
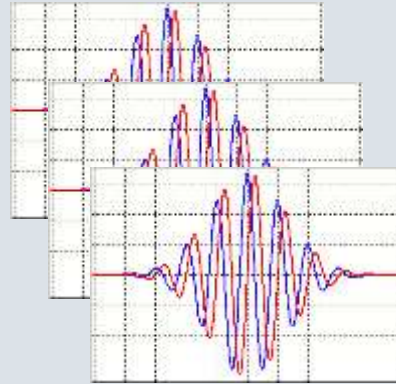


# Time-frequency

## Morlet wavelets

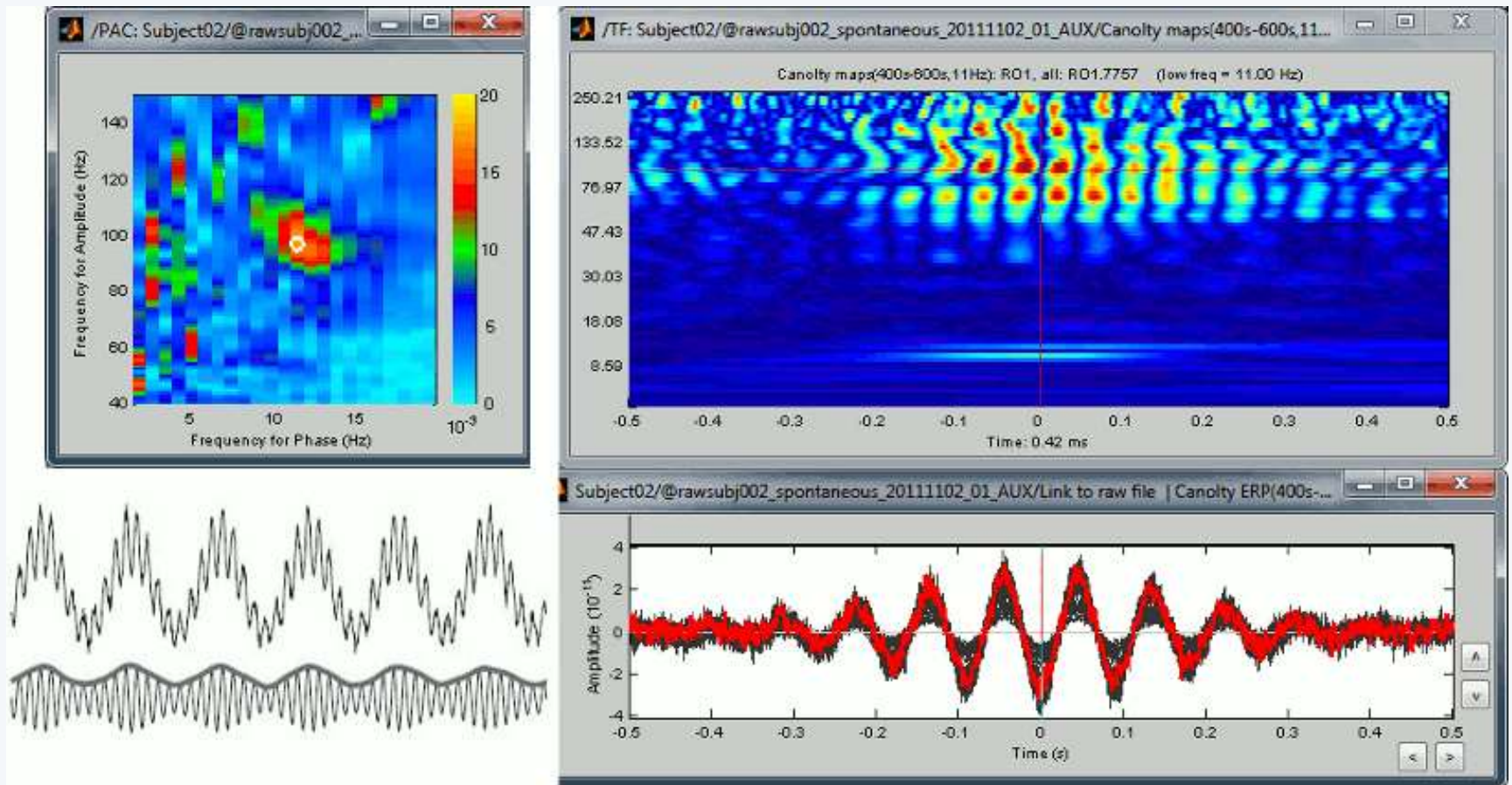


## Hilbert transform + band-pass filter



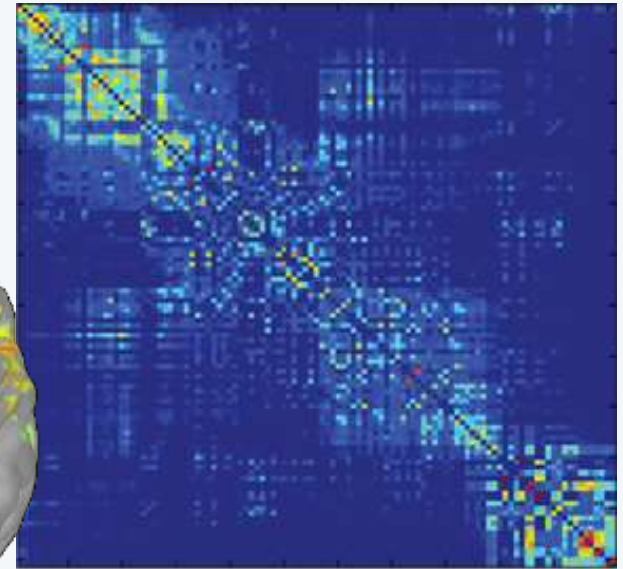
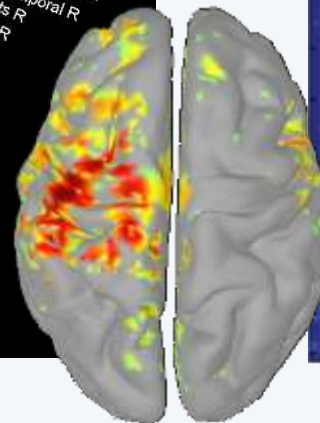
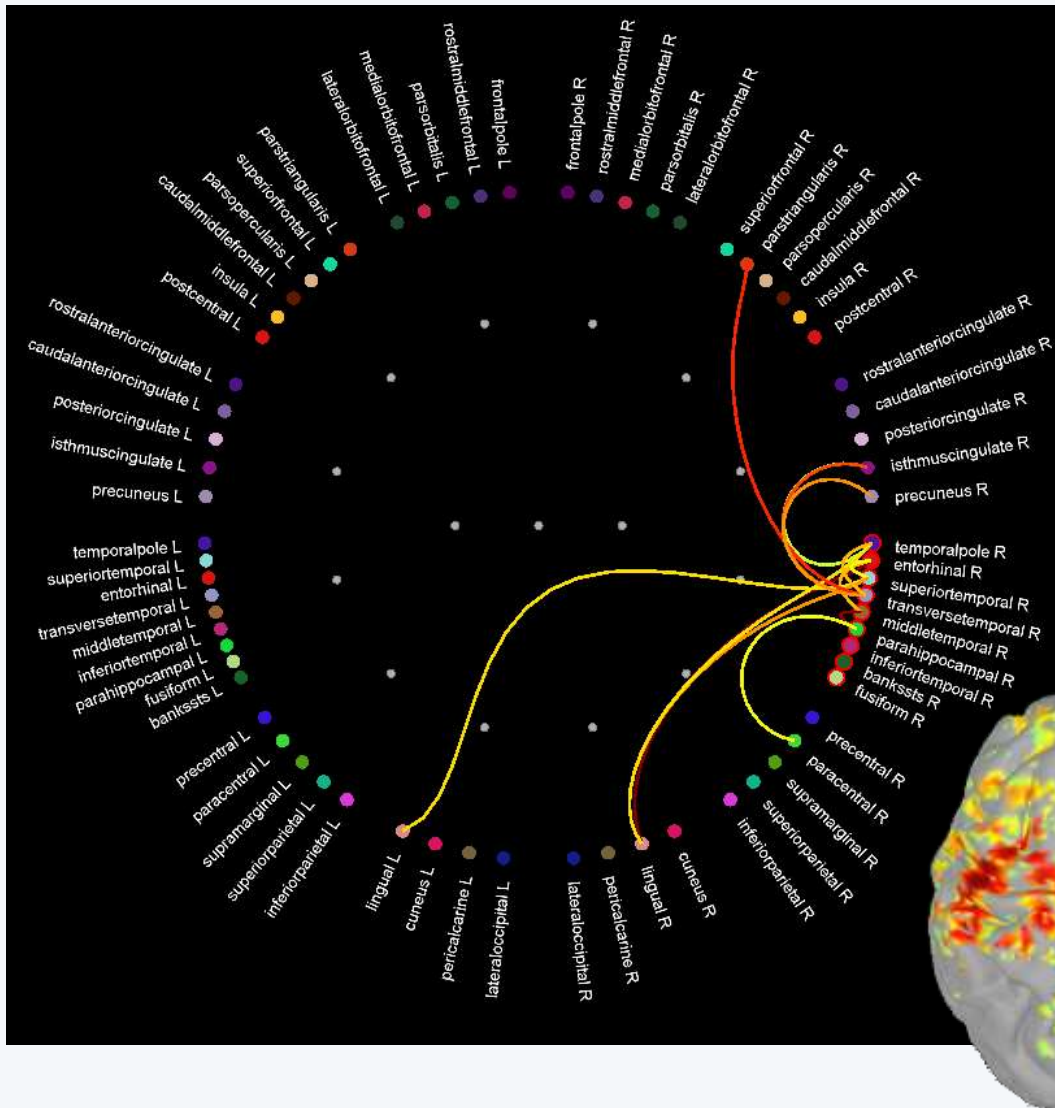
# Cross - frequency coupling

- Phase-amplitude coupling estimation



# Connectivity

- Correlation / Coherence
- Phase locking value
- Granger causality
- Sensor or source levels



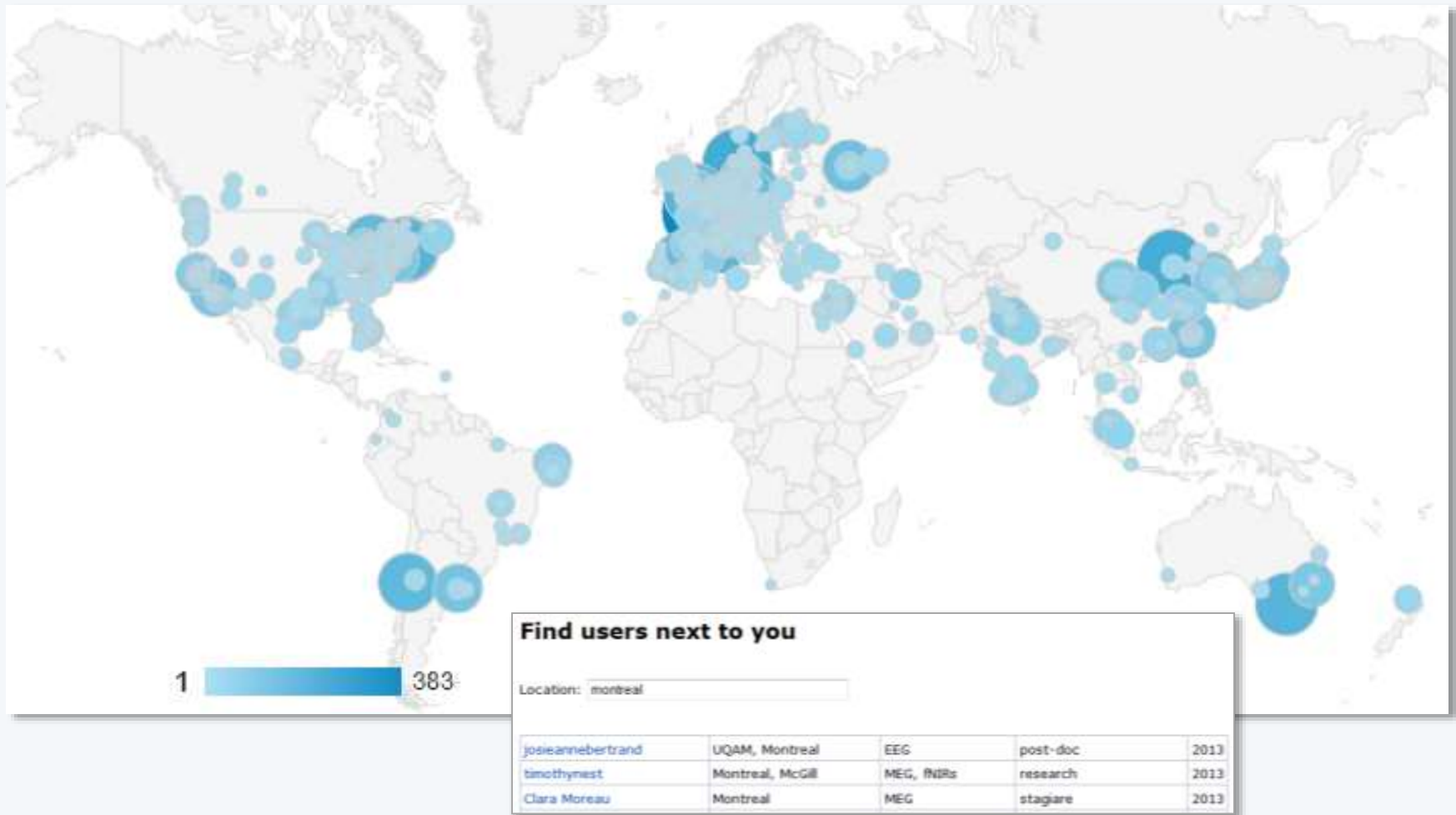
# Add your code to Brainstorm

- Direct manipulation of the files in Matlab
- Use the menu “Run Matlab command”
- Write a plugin:
  - Well documented API
  - Lots of example (170 functions written as plugins)
- Examples of recent external contributions:
  - MVPA decoding (Oliva, MIT)
  - Microstate segmentation (Cacioppo, UChicago)
  - Eyetracker/EEG synchronization (Uni Freiburg)



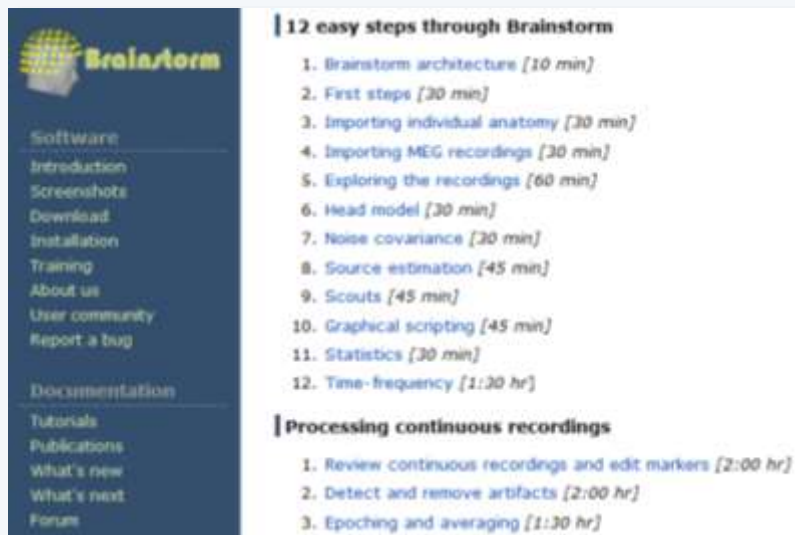
# User community

- 12,000 users from 70 countries registered on the website



# User support

- Online tutorials: 30-hour self-teaching program
- Active user forum: 200 posts/month
- Daily updates: 700 downloads/month



- Contact us for specific questions and requests:  
We will help you adding the features you need

# Contributors

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## Epilepsy recordings: Localization of frontal spikes

- Patient recorded at the Epilepsy Centre of the University Hospital in Freiburg, Germany
- Focal epilepsy with focal sensory, dyscognitive and secondarily generalized seizures since the age of eight years
- Histological analysis revealed a focal cortical dysplasia
- One hour of sleep recordings
- Neurofile NT EEG system, sampled at 256Hz
- 58 epileptic spikes marked by the epileptologists in Freiburg
- MRI processed with FreeSurfer 5.3