

Study of EEG-based Functional Networks

eLORETA Tutorial

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eLORETA Installation

How to install the LORETA KEY software, version >2017

Prerequisites:

- 1. Windows 7 or higher (will not work correctly with WindowsXP or lower).**
- 2. The user must be logged into windows as an administrator with full rights as Administrator.**
- 3. The user must be familiar with the use of “Windows File Explorer”.**

Download:

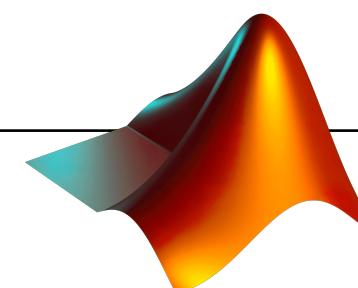
- 1. Download the loreta key self-extracting file (“LoretaKey.exe”) to your computer.
Suggested locations: hard disk drive “C” or “D”, or to the “Desktop”.**
- 2. Open the program “Windows File Explorer”, and navigate to the location of “LoretaKey.exe”.**

|

EEG Input

- EEG signal in the txt format.

```
load(filename) %filename of the mat file containing EEG signal (Nsamples x Nchannels)  
dlmwrite([filename,'.txt'],seg,'delimiter','\t','precision',3)
```

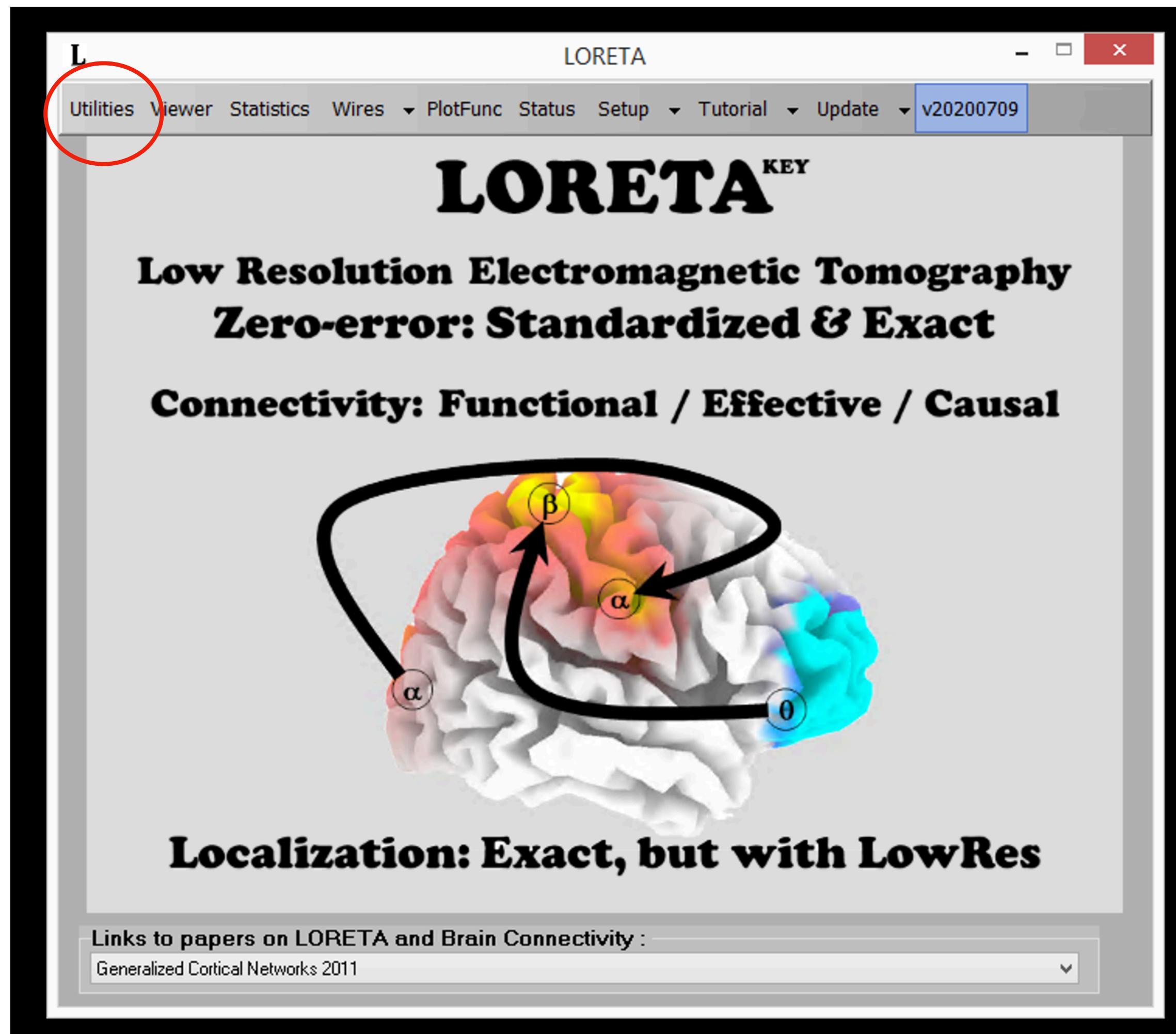


EEG channels

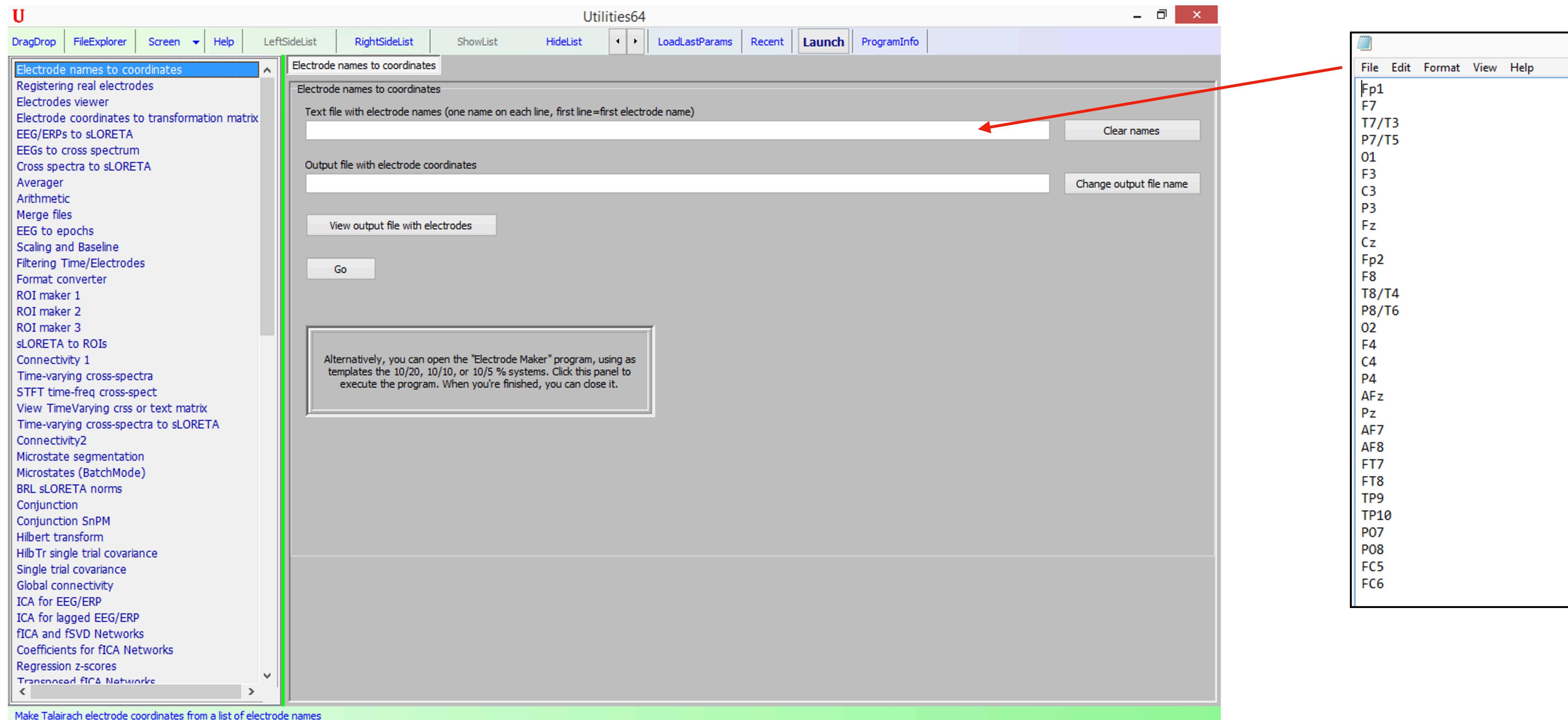
12.9	12.8	9.65	10	15.4
15	15.2	11.4	3.58	0.498
5.74	11.6	14	9.2	4.25
21.4	26.6	30.7	34.6	34.8
7.05	-0.542	-9.26	-11.6	-6.36
2.91	-0.334	-6.07	-12.2	-10.9
8	-16.6	-19.7	-23.4	-26.9
5	-15	-17.3	-13.1	-8.96
1.34	-2.49	-12.7	-16.6	-12.5
16.2	21.6	18.6	15.8	12.7
0.797	-1.31	-4.37	-0.51	7.17
4.37	-2.78	-5.89	-8.2	-7.75
5.47	-3.66	-8.77	-8	-6.63
5	-21.1	-18.9	-19.2	-20.4
8.44	8.71	10.3	14.7	14.3
24.4	22.5	17.5	16.3	22.9
7.86	-3.48	-16.2	-14.6	-4.15
12.8	13.2	7.61	1.43	-1.9
1.72	-4.15	-11.3	-8.85	-7.26
2.35	-0.377	-0.284	-2.57	-5.06
2.6	-1.08	-9.87	-15.4	-16
5.16	-3.91	-9.95	-11.3	-2.6
3.82	-4.87	-7.95	-9.53	-18.4
11.6	11	12.2	10.2	14.3
9.55	-3.84	-16.1	-18.1	-17.1
2.24	-9.36	-14.2	-15.3	-11.5
2.49	-0.24	-5.71	-11.7	-15.1
3	-13.3	-11.2	-2.49	5.71

Samples

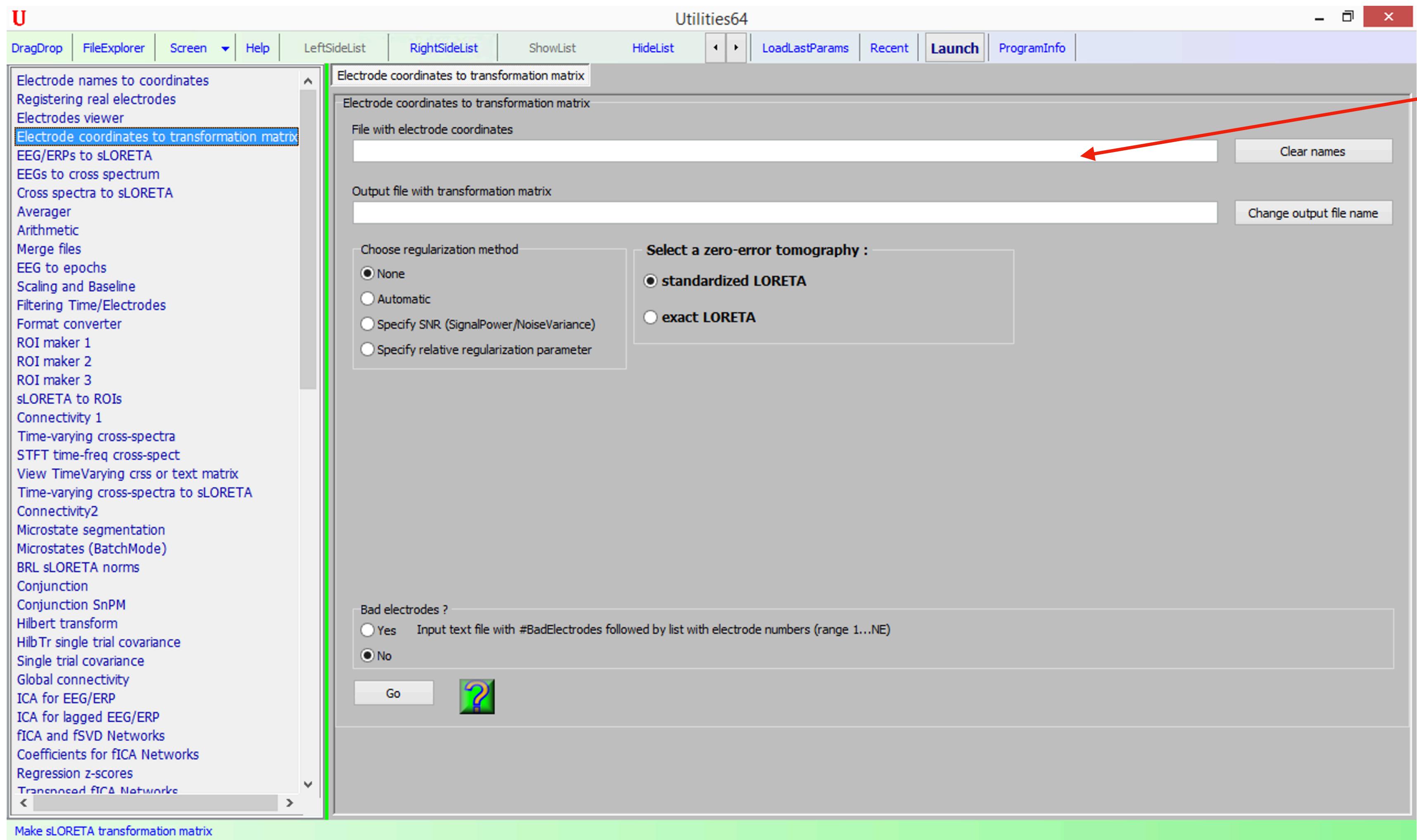
Functional Connectivity Estimation



• Identification of the EEG electrodes coordinates

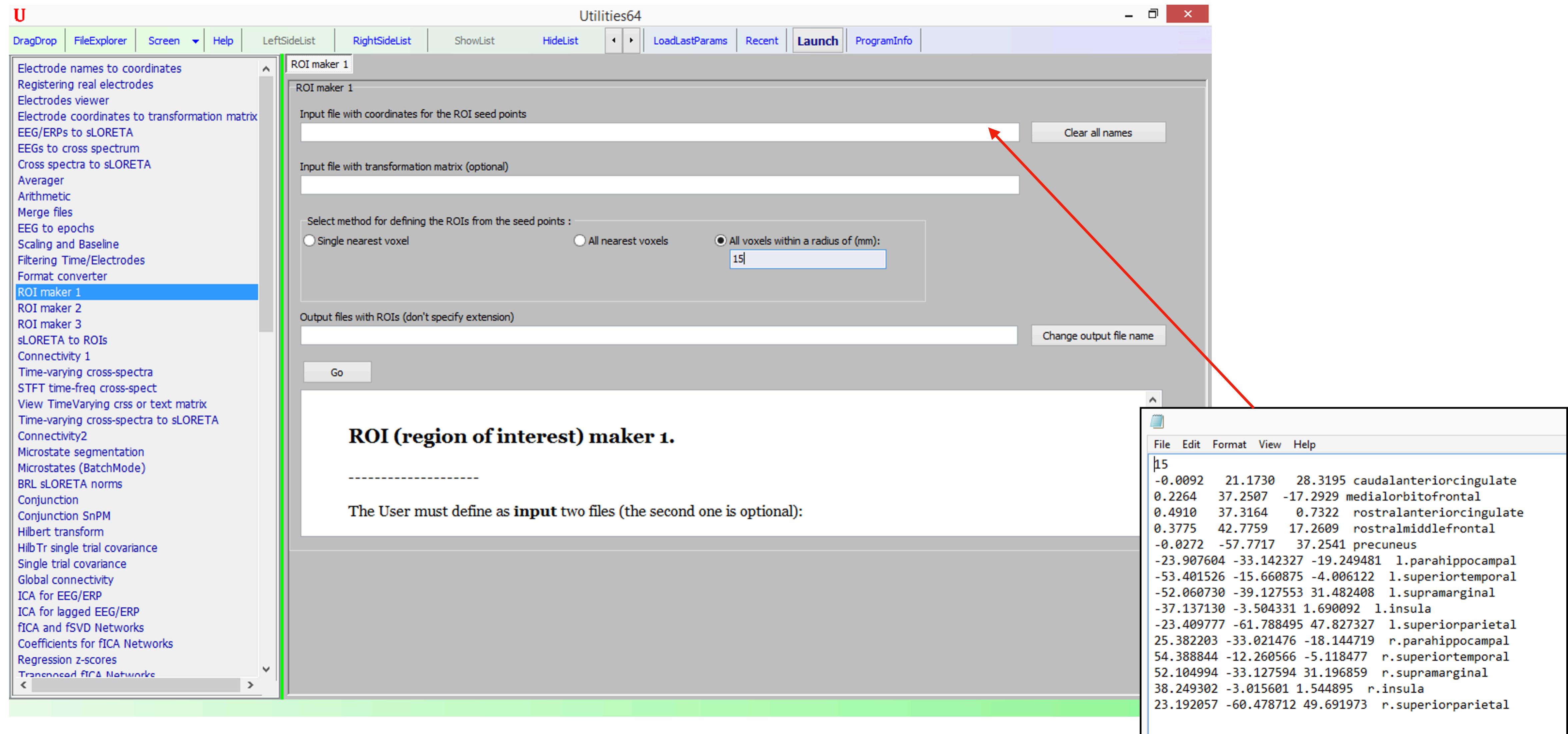


- Computation of the transformation matrix

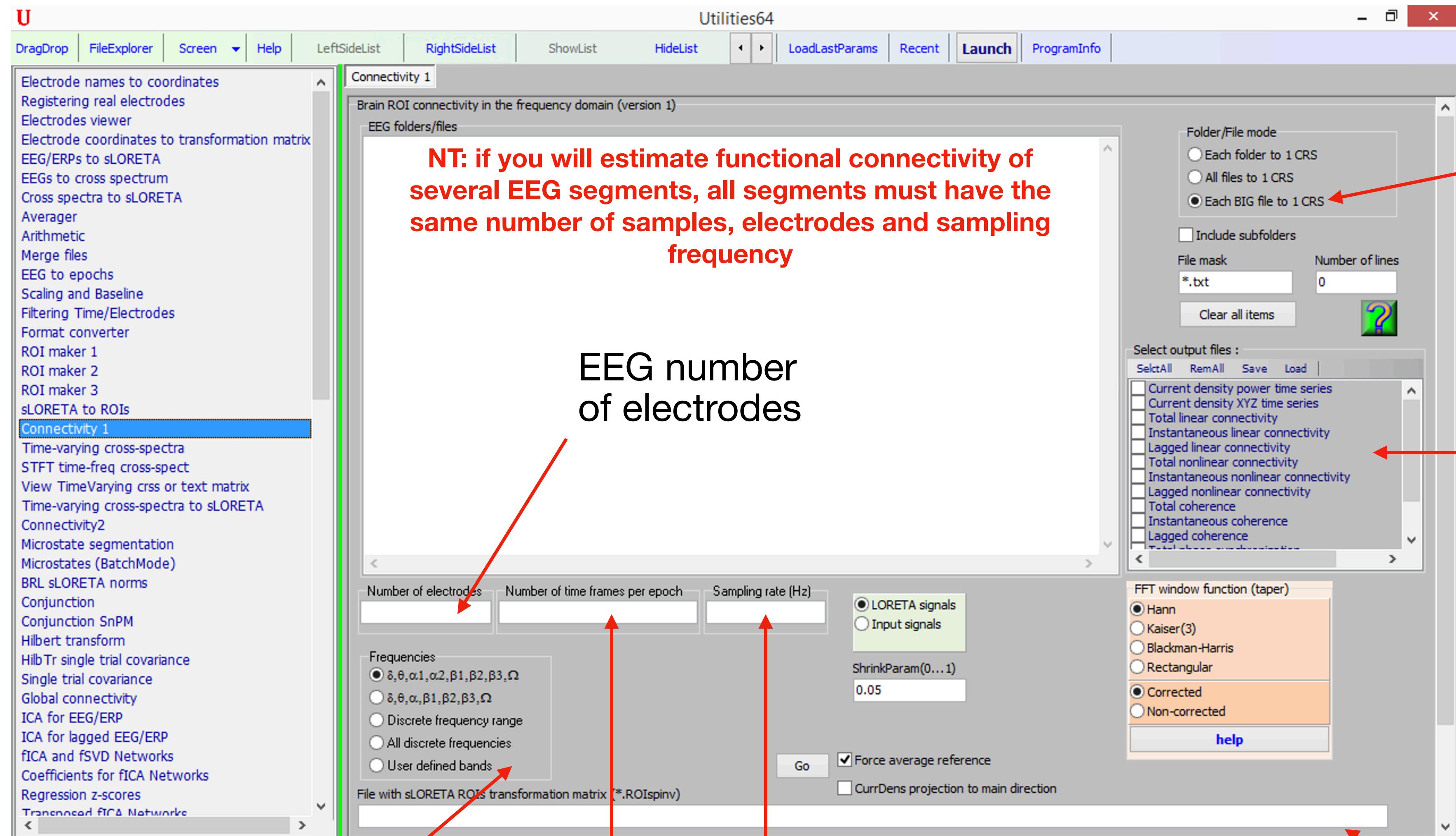


Output of the previous step

• Regions of interest



• Estimation of the functional connectivity



Frequency
bands

EEG
number of
samples

EEG sampling rate

9

Each EEG in txt
format will be
used to estimate
functional
connectivity

Type of
metrics

Output of the
previous step

NT: if you will estimate functional connectivity of
several EEG segments, all segments must have the
same number of samples, electrodes and sampling
frequency

- Outputs (e.g. linear lagged connectivity metric)

Global Linear Connectivity

FreqHz	TotConn	InstConn	LagConn	LagConnTr	JiriHerm
3.750	7.01609192E+0001	6.45986404E+0001	5.56227922E+0000	2.27375496E-0002	3.54074
7.250	7.73558578E+0001	7.22356567E+0001	5.12019777E+0000	1.70914605E-0001	2.31295
9.250	7.49072647E+0001	7.08060532E+0001	4.10121393E+0000	7.54067898E-0002	2.05456
11.250	7.84071808E+0001	7.31402283E+0001	5.26694679E+0000	1.89253390E-0001	2.08648
15.250	7.42767487E+0001	7.17637482E+0001	2.51300359E+0000	2.44371090E-0002	2.98971
19.750	7.44122543E+0001	7.03906174E+0001	4.02163982E+0000	6.98847398E-0002	2.21750
25.750	6.82785873E+0001	6.45450439E+0001	3.73354530E+0000	2.95096915E-0002	3.36339
15.750	6.63802414E+0001	6.50413589E+0001	1.33887708E+0000	8.35987926E-0003	3.43293

Global Nonlinear Connectivity

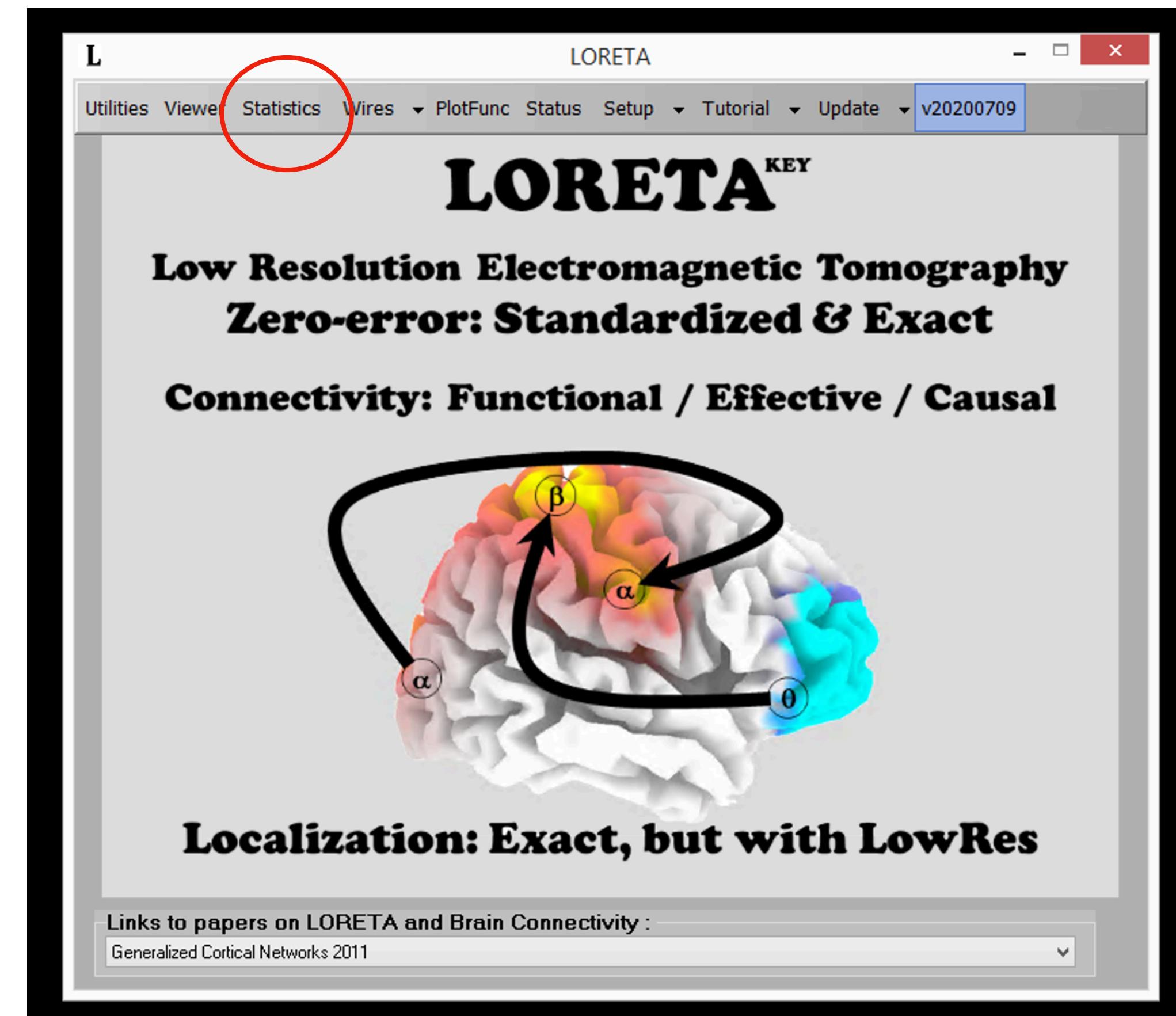
FreqHz	TotConn	InstConn	LagConn	LagConnTr	JiriHerm
3.750	7.99776764E+0001	7.05001297E+0001	9.47754288E+0000	3.77016924E-0002	4.51684
7.250	9.65526123E+0001	8.69519348E+0001	9.60067463E+0000	2.00585857E-0001	2.88871
9.250	8.82023849E+0001	8.22863846E+0001	5.91599512E+0000	1.08481519E-0001	1.98531
11.250	9.21470490E+0001	8.45559235E+0001	7.59112167E+0000	2.22552299E-0001	2.28670
15.250	8.19917221E+0001	7.64176025E+0001	5.57411623E+0000	2.88658217E-0002	4.15635
19.750	8.87290649E+0001	8.14815445E+0001	7.24752426E+0000	8.62169340E-0002	2.62736
25.750	7.52567902E+0001	6.82749405E+0001	6.98185349E+0000	2.42424347E-0002	5.28354
15.750	6.67919540E+0001	6.39262009E+0001	2.86575174E+0000	7.97627587E-0003	5.39558

Linear lagged connectivity

v2_seg6_00_02_pos_A_ss1-RollinLagConn-crss - Notepad																		
File	Edit	Format	View	Help														
<code>6661999 = Ignore first line (new format code)</code>																		
<code>File name: C:\Users\cber\Desktop\Elodie's Work\Projects\tDCSProject\Code\LORETA\eLORETA_Dataset\N1\v2_seg6_00_02_pos_A_ss1-ROIinLagConn-crss.txt</code>																		
<code>1 = Number of time frames in Time X Frequency decomposition</code>																		
<code>1 = Number of EEG files</code>																		
<code>15 = Number Electrodes</code>																		
<code>512 = Number of time frames in EEG files</code>																		
<code>512 = Number of time frames in EEG files power of 2</code>																		
<code>8 = Number of matrices</code>																		
<code>1 = Band type (1=Classical1; 2=Classical2; 3=DiscreteFreqs; 4>AllDiscreteFreqs; 5=UserDefinedBands)</code>																		
<code>2.560000E+0002 = Sampling rate Hz</code>																		
<code>-1.000000E+0002 = Freq1 Hz</code>																		
<code>-1.000000E+0002 = Freq2 Hz</code>																		
<code>5.000000E-0001 = Frequency resolution Hz</code>																		
<code>0.000000E+0000 1.734410E-0002 4.983628E-0002 1.041009E-0001 2.875109E-0002 9.762289E-0002 1.862788E-0001 1.444596E-0001 7.219578E-0002 2.466349E</code>																		
<code>1.734410E-0002 0.000000E+0000 1.148468E-0001 1.480680E-0001 7.770351E-0002 5.281580E-0002 8.133495E-0002 1.370559E-0001 6.006715E-0002 7.054657E</code>																		
<code>4.983628E-0002 1.148468E-0001 0.000000E+0000 2.307392E-0002 7.591797E-0002 4.593500E-0002 1.196794E-0001 7.116984E-0002 3.860955E-0002 3.479529E</code>																		
<code>1.041009E-0001 1.480680E-0001 2.307392E-0002 0.000000E+0000 1.512768E-0001 1.177284E-0001 1.150601E-0001 2.158976E-0001 5.786743E-0002 5.487221E</code>																		
<code>2.875109E-0002 7.770351E-0002 7.591797E-0002 1.512768E-0001 0.000000E+0000 9.502095E-0002 1.506303E-0001 1.169983E-0001 1.522771E-0001 1.372532E</code>																		
<code>9.762289E-0002 5.281580E-0002 4.593500E-0002 1.196794E-0001 7.116984E-0002 3.860955E-0002 4.679356E-0001 7.789156E-0002 9.069025E</code>																		
<code>1.862788E-0001 8.133495E-0002 1.196794E-0001 1.150601E-0001 2.158976E-0001 1.69983E-0001 4.679356E-0001 3.467619E-0001 0.000000E+0000 3.467619E-0001 5.172979E-0002 2.491937E</code>																		
<code>1.444596E-0001 1.370559E-0001 7.116984E-0002 2.158976E-0001 1.69983E-0001 4.679356E-0001 3.467619E-0001 0.000000E+0000 1.691501E-0001 0.000000E+0000 1.280618E</code>																		
<code>7.219578E-0002 2.466349E-0002 4.679356E-0001 7.789156E-0002 5.172979E-0001 2.491937E-0001 7.000913E-0002 1.280618E-0002 0.000000E+0000 8.844873E-0002 9.458629E-0002 2.609331E</code>																		
<code>1.299415E-0002 8.258239E-0002 3.928395E-0002 3.591885E-0002 4.088722E-0002 2.412233E-0002 9.312642E-0002 6.569710E-0002 5.180811E-0002 3</code>																		

Statistical Comparison Between Networks

- E.g., if you want to compare connectivity changes between two distinct groups.



- Statistical comparison of connectivity between 2 groups using non-parametric randomization techniques with correction for multiple testing ($n>6$)

Chose the directory for results

Networks belonging to the group 1

Networks belonging to the group 2

Note that you have to have the same of number of networks for different groups

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- Outputs

Setup

File Edit Format View Help

ERP= FALSE
sLORETA= FALSE
sLORETA-XYZ= FALSE
Cross-spectrum= FALSE
Measures of dependence= TRUE
text data= FALSE
Number of header lines to skip = 0
Ridge param type (1:user,2:gcve,3:aic,4:bic,5:gcvec,6:aicc,7:bicc= 6
Set columns to 0 mean= FALSE
Set rows to 0 mean= FALSE
Set matrix to 0 mean= FALSE

Average reference= FALSE
No re-referencing= FALSE
Number of electrodes= 1
Number of time frames= 1

No normalization= TRUE
TimeFrame/Frequency-wise normalization= FALSE
Subject-wise normalization= FALSE
Electrode/Voxel-wise normalization (relative power type)= FALSE
Spatial maximum normalization = FALSE

Paired groups, test A=B: FALSE
Paired groups, test A=B: FALSE
Paired groups, test A+B=0 (i.e. A=-B): FALSE
Independent groups, test A=B: TRUE
Single group: FALSE
Descriptive: FALSE
All TF/Frq pairs: FALSE
zero mean: FALSE
Value for mean test = 0
Power for zero mean test = 1
outlier test: FALSE
z-transform: FALSE
robust z-transform: FALSE
Paired groups, test (A-A2)=(B-B2): FALSE

T-test values

Threshold and Extremes Ps

The figure shows two Notepad windows. The top window, titled 'test_N3 - Notepad', displays a grid of numerical values representing t-statistics. The bottom window, titled 'test_N3-Thresholds&ExtremePs - Notepad', displays effect size thresholds and corresponding p-values. A red arrow points from the value '-4.729' in the bottom window to the value '-4.729' in the top window.

test_N3 - Notepad

```
t-statistics
8 = Number of matrices
15 = Number of regions of interest (ROIs)

0.000000E+0000 -1.858590E+0000 -3.037053E+0000 -2.541035E+0000 -7.651428E-0002 -1.062794E+0000 -2.271698E+0000 -1.173550E+0000 -2.581041E+0000 -1.812720E
-1.858590E+0000 0.000000E+0000 -2.482308E+0000 -1.234445E+0000 -1.619644E+0000 -7.966330E-0001 -1.625702E+0000 -9.174783E-0001 -1.433292E+0000 -2.126241E
-3.037053E+0000 -2.482308E+0000 0.000000E+0000 -1.920127E+0000 -1.775808E+0000 -1.064346E+0000 -1.772205E+0000 -1.549542E+0000 -1.885445E+0000 -2.768474E
-2.541035E+0000 -1.234445E+0000 -1.920127E+0000 0.000000E+0000 -2.309720E+0000 -1.692447E+0000 -5.548338E-0001 -2.117221E+0000 -7.939923E-0001 -2.487891E
-7.651428E-0002 -1.619644E+0000 -1.775808E+0000 -2.309720E+0000 0.000000E+0000 -5.991768E-0001 -1.492890E+0000 -9.848879E-0001 -1.719774E+0000 -1.498781E
-1.062794E+0000 -7.966330E-0001 -1.064346E+0000 -1.692447E+0000 -5.991768E-0001 0.000000E+0000 -1.651366E+0000 -1.586593E+0000 -1.921520E+0000 -8.269397E
-2.271698E+0000 -1.625702E+0000 -1.772205E+0000 -5.548338E-0001 -1.492890E+0000 -1.651366E+0000 0.000000E+0000 -1.966856E+0000 -1.543376E+0000 -2.123353E
-1.173550E+0000 -9.174783E-0001 -1.549542E+0000 -2.117221E+0000 -9.848879E-0001 -1.586593E+0000 -1.966856E+0000 0.000000E+0000 -2.155169E+0000 -1.412355E
-2.581041E+0000 -1.433292E+0000 -8.8245E+0000 -7.939923E-0001 -1.719774E+0000 -1.921520E+0000 -1.543376E+0000 -2.155169E+0000 0.000000E+0000 -2.356408E
-1.812720E+0000 -2.126241E+0000 -2.768474E+0000 -2.487891E+0000 -1.498781E-0001 -8.269397E-0001 -2.123353E+0000 -1.412355E+0000 -2.356408E+0000 0.000000E
-1.636423E+0000 -1.175824E+0000 -1.127574E+0000 -1.013200E+0000 -1.415075E+0000 -4.964257E-0001 -1.018106E+0000 -2.048112E+0000 -1.359522E+0000 -1.612771E
-2.157282E+0000 -1.143381E+0000 -1.402830E+0000 -1.010615E+0000 -2.158899E+0000 -5.527260E-0001 -1.154448E+0000 -1.892118E+0000 -1.085403E+0000 -2.515244E
-1.706139E+0000 -1.568852E+0000 -1.567924E+0000 -1.272118E+0000 -1.195278E+0000 2.145830E-0001 -9.420485E-0001 -1.256668E+0000 -1.322798E+0000 -1.769889E
-2.016327E+0000 -1.110324E+0000 -1.389260E+0000 -8.904269E-0001 -2.173535E+0000 -1.114284E+0000 -1.266031E+0000 -2.291023E+0000 -9.534665E-0001 -2.374357E
-1.825234E+0000 -8.587080E-0001 -1.018025E+0000 -7.691271E-0001 -8.827933E-0001 -5.807697E-0002 -4.289255E-0001 -1.063622E+0000 -9.793494E-0001 -1.974908E

0.000000E+0000 -1.676780E+0000 -2.203030E+0000 -2.121245E+0000 -1.103556E+0000 -1.032471E+0000 -2.069551E+0000 -1.545944E+0000 -1.942593E+0000 -1.573600E
-1.676780E+0000 0.000000E+0000 -9.427816E-0001 -3.204981E-0001 -2.392875E+0000 -9.825112E-0001 -9.877236E-0001 -1.567878E+0000 -1.256817E+0000 -1.887555E
-2.203030E+0000 -9.427816E-0001 0.000000E+0000
-2.121245E+0000 -3.204981E-0001 -5.644716E+0000
-1.103556E+0000 -2.392875E+0000 -1.602287E+0000
-1.032471E+0000 -9.825112E-0001 -4.181734E+0000
-2.069551E+0000 -9.877236E-0001 4.467497E+0000
-1.545944E+0000 -1.567878E+0000 -4.534342E+0000
-1.942593E+0000 -1.256817E+0000 2.081609E+0000
-1.573600E+0000 -1.887555E+0000 -8.890525E+0000
-8.114391E-0001 -3.265078E-0001 -9.878434E+0000
-4.574609E-0001 1.100936E+0000 -1.103803E+0000
-8.610137E-0001 7.377858E-0001 -3.916710E+0000
-7.655775E-0001 1.393989E+0000 2.573901E+0000
-3.391200E-0001 -1.318979E+0000 -1.560203E+0000
0.000000E+0000 -9.908193E-0001 -1.959010E+0000
```

test_N3-Thresholds&ExtremePs - Notepad

```
Effect size thresholds for t-stats:
small = 0.800
medium = 2.000
large = 3.200
Corresponding to Cohen's d values: small=0.2 medium=0.5 large=0.8
EffSize for SignTest (P>0.5, P:proportion>0) (low med hi): 0.05 0.15 0.25
-----
One-Tailed (A>B): t(0.01) t(0.05) t(0.10) ExtremeP
One-Tailed (A<B): -5.733 -4.751 -4.335 0.94620
Two-Tailed (A<>B): 6.271 -4.729 -4.289 0.18340
0.391200E-0001 -1.318979E+0000 -1.560203E+0000
0.000000E+0000 -9.908193E-0001 -1.959010E+0000
```

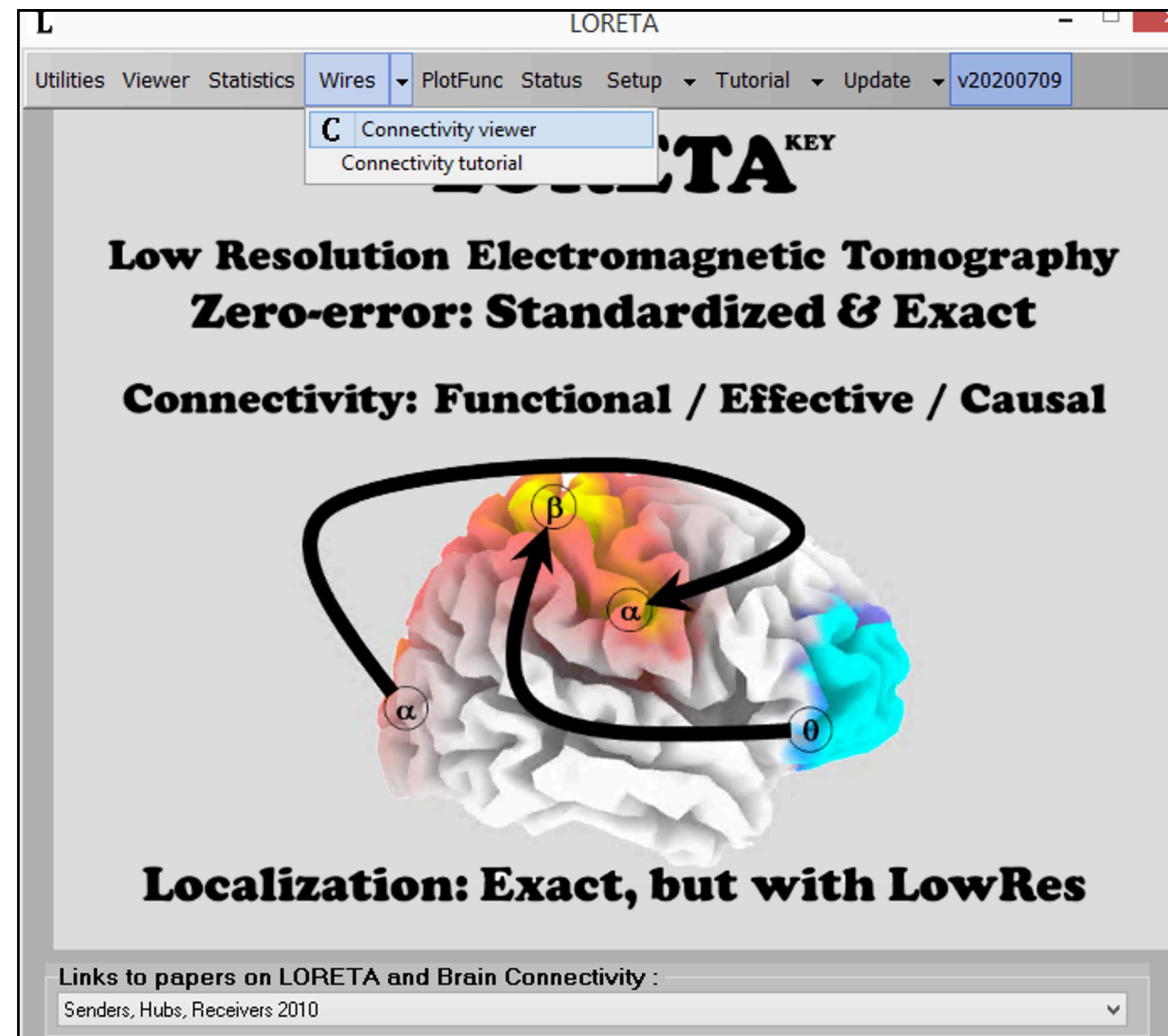
Exceedence proportion tests:

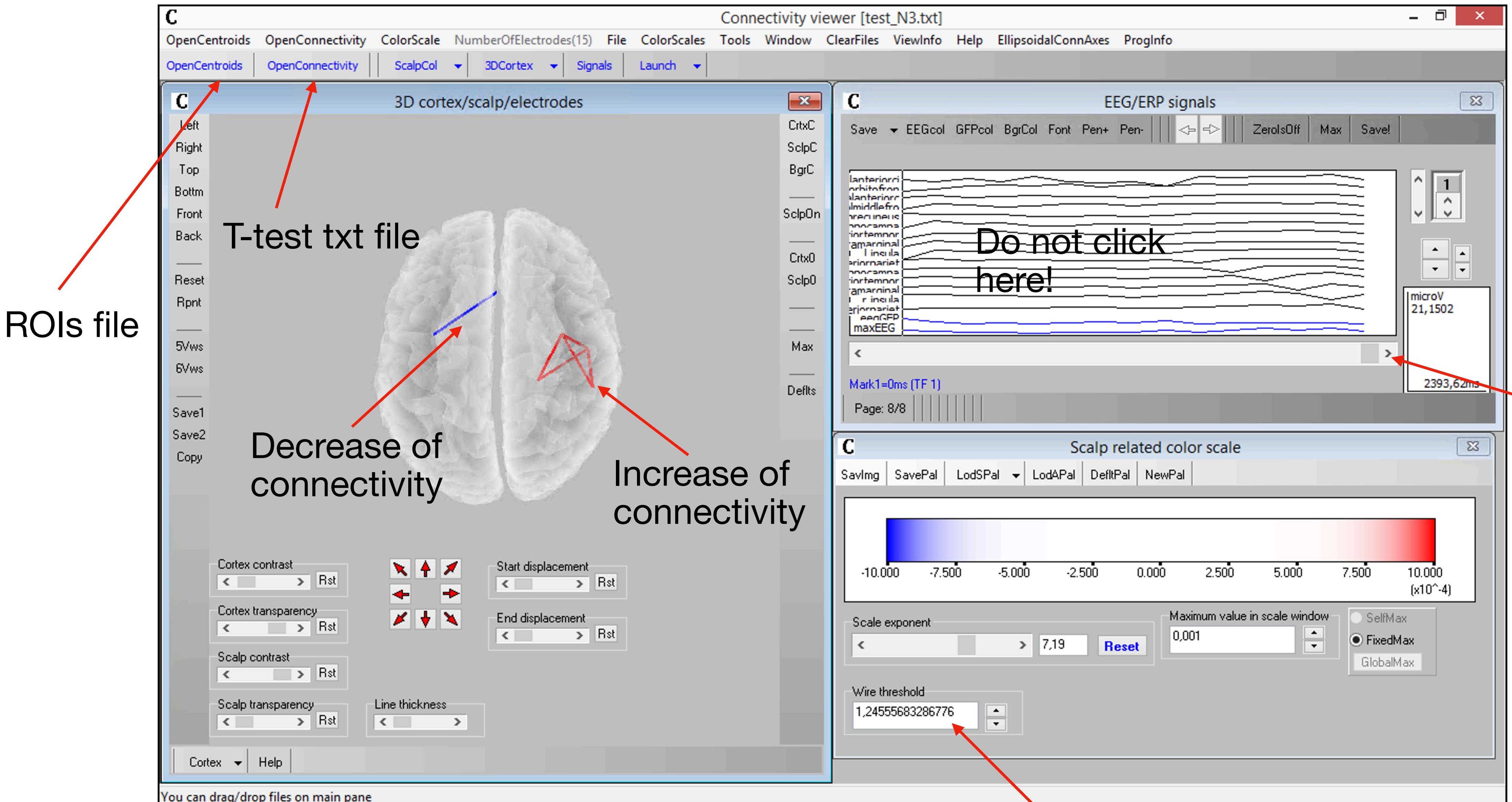
Thrsh(1Tailed>0)	Prob(1Tailed>0)	Thrsh(1Tailed<0)	Prob(1Tailed<0)	Thrsh(2Tailed)	Prob(2Tailed)
0.214216	0.503000	-0.391183	0.403000	0.391183	0.531000
0.428433	0.518800	-0.782367	0.298000	0.782367	0.525400
0.642649	0.551200	-1.173550	0.225400	1.173550	0.562400
0.856865	0.666800	-1.564734	0.138600	1.564734	0.406200
1.071082	0.781000	-1.955917	0.109000	1.955917	0.315000
1.285298	0.873000	-2.347100	0.101200	2.347100	0.260400
1.499514	0.897600	-2.738284	0.088200	2.738284	0.211200
1.713731	0.924000	-3.129467	0.092800	3.129467	0.208200
1.927947	0.921000	-3.520651	0.186400	3.520651	0.373800
2.142163	0.946000	-3.911834	0.183400	3.911834	0.354200

Corrected Threshold

Corrected Threshold

Results Visualization





Insert the corrected threshold value

Each increment will give you the results for each frequency band selected