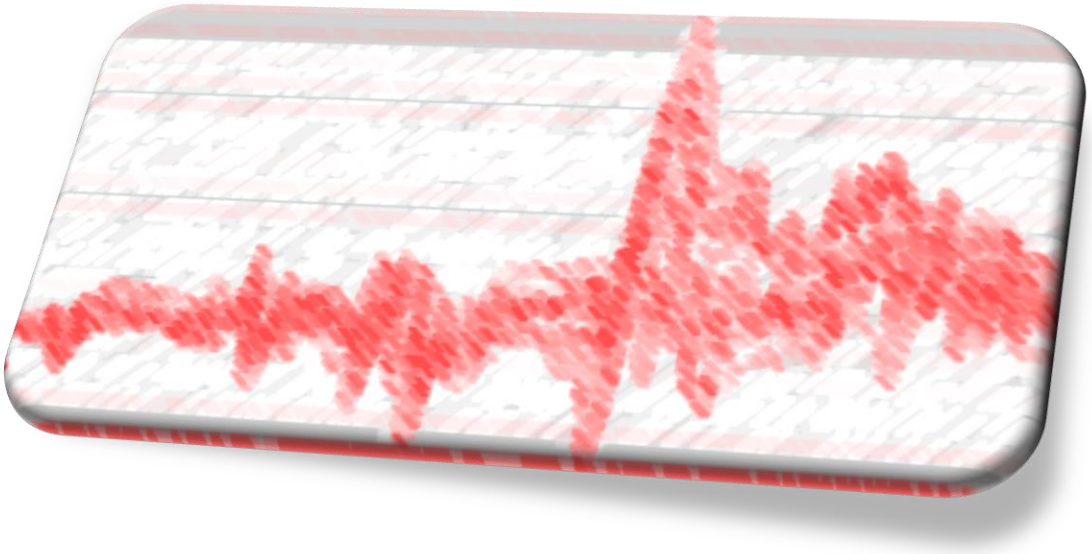
fnirSoft

A Quick Start Guide



fnirSoft

Please refer to fnirSoft in your publications with the following:

Ayaz, H. (2010). "*Functional Near Infrared Spectroscopy based Brain Computer Interface".* PhD Thesis, Drexel University, Philadelphia, PA.

Table of Contents

1. Introduction

fnirSoft (fS) is a stand-alone software package designed to process, analyze and visualize functional near infrared (fNIR) spectroscopy signals through a graphical user interface and/or scripting (for automation). This section provides an introduction to the fNIR technology and discusses Modified Beer Lambert Law (MBLL) that is integral to the analysis of fNIR spectroscopy signals. The next chapter provides step-by-step guide for using fS. For information about fnirSoft programming and command line options, please refer to fnirSoft Scripting Manual.

1.1.Functional Near Infrared Spectroscopy

fNIR is an optical brain monitoring technology that monitors changes in hemodynamic response within cortex [1-3] and has been used to assess cognitive and motor task related brain activity [4-11] . fNIR technology uses specific wavelengths of light, introduced at the scalp, to enable the noninvasive measurement of changes in the relative ratios of deoxygenated hemoglobin (deoxy-Hb) and oxygenated hemoglobin (oxy-Hb) in the capillary beds during brain activity. This technology allows the design of portable, safe, affordable, noninvasive, and minimally intrusive monitoring systems.

Our focus here is analysis of continuous-wave fNIR signals collected by the fNIR Devices. The system is composed of two parts: a hardware box and a flexible sensor pad that is placed over the forehead of subjects. With a fixed source-detector separation of 2.5 cm, this configuration generates a total of 16 measurement locations (optodes) with at least two wavelengths each. The sensor pad as shown in Figure 1 below. The hardware box is connected to a computer via a standard universal serial bus (USB) cable for data acquisition and control via Cognitive Optical Brain Imaging (COBI) Studio [6]. The system records two wavelengths and dark current for each 16 optodes, totaling 48 measurements for each sampling period. The sampling rate of the latest generation systems are up to 10Hz.

Figure 1. fNIR sensor pad (fNIRDevices.com)

1.2.Modified Beer Lambert Law

For a medium that contains chromophores (light absorbing molecules) and no scattering, the Beer-Lambert Law states that the ratio of incident and response (detected) light intensity is proportional to the concentration of the chromophore in the unit length of the medium:

$$\log(\frac{I_0}{I}) = \alpha cL \quad (1)$$

where I_0 is incident light intensity and I is the detected light intensity. c is the concentration of the chromophore. L is the distance from where light enters the tissue to where it leaves the tissue. Finally, α is the absorption coefficient of the chromophore.

However, tissue is a highly scattering medium and L does not reflect the true path length. Scattering significantly prolongs the path length of light. To account for that, the modified Beer-Lambert law can be used:

$$\log(\frac{I_0}{I}) = \alpha cLB + G \quad (2)$$

where I_0, I, c, α and L are the same as in the previous equation. B is an experimentally determined correction factor for L. G is constant attenuation factor related to optical properties and geometry of the tissue. If measurements are made of the changes in attenuation, the Modified Beer Lambert Law can be rearranged as follows:

$$\Delta c = \frac{\Delta OD}{\alpha LB} \quad (3)$$

where $OD = \log(\frac{I_0}{I})$ (4)

To calculate changes in the concentrations of the chromophores, we need to compare two measurements: one from the subject in a "rest" state as a baseline, and one during the presentation of the stimulus or "test" condition. This comparison can be expressed as follows:

$$\begin{aligned} \Delta OD &= \log(\frac{I_0}{I_{test}}) - \log(\frac{I_0}{I_{rest}}) \\ &= \log(I_{rest}) - \log(I_{test}) \\ &= \log(\frac{I_{rest}}{I_{test}}) \end{aligned} \quad (5)$$

where I_{rest} is the measured reflected light intensity in the baseline condition, and I_{test} is the reflected light intensity during the presentation of the stimulus.

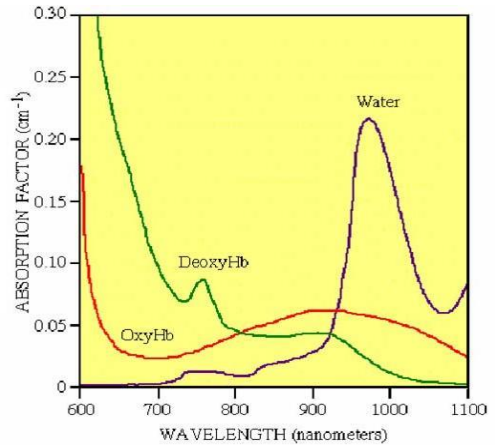
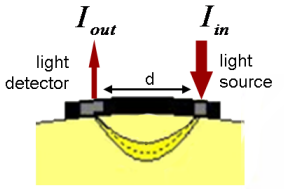


Figure 2 Absorption factors of 3 main chromophores in tissue

Brain tissues have three significant chromophores: water, oxy-hemoglobin (oxy-Hb) and deoxy-hemoglobin (deoxy-Hb). In functional brain imaging applications, the main interest is to monitor oxy-Hb and deoxy-Hb concentration changes. Within the 700-900nm range, also called as 'optical window', tissue is relatively transparent because all significant chromophore absorption factors are low. The dominant chromophores in the optical window are oxy-Hb and deoxy-Hb, and their concentration changes can be calculated using Equation 3. Absorption factors of the three main chromophores with respect to wavelength are given in Figure 2. Within the optical window, there is an isosbestic point where the absorption spectra of oxy-Hb and deoxy-Hb cross. Measurements by choosing two wavelengths, one below and one above this isosbestic point, could reveal the individual effects of oxy-Hb and deoxy-Hb.



$$OD_\lambda = \log\left(\frac{I_{in}}{I_{out}}\right) \approx \varepsilon_\lambda . c . d . DPF + G \qquad (6)$$

Having the same I_{in} at two different instances

$$\Delta OD_\lambda = \log\left(\frac{I_{rest}}{I_{test}}\right) = \varepsilon_\lambda^{HB} . \Delta c^{HB} . d . DPF + \varepsilon_\lambda^{HBO_2} . \Delta c^{HBO_2} . d . DPF \qquad (7)$$

Measuring at two different wavelengths

$$\begin{bmatrix} \Delta OD_{\lambda 1} \\ \Delta OD_{\lambda 2} \end{bmatrix} = \underbrace{\begin{bmatrix} \varepsilon_{\lambda 1}^{HB} . d . DPF & \varepsilon_{\lambda 1}^{HBO_2} . d . DPF \\ \varepsilon_{\lambda 2}^{HB} . d . DPF & \varepsilon_{\lambda 2}^{HBO_2} . d . DPF \end{bmatrix}}_{F} \begin{bmatrix} \Delta c^{HB} \\ \Delta c^{HBO_2} \end{bmatrix}$$

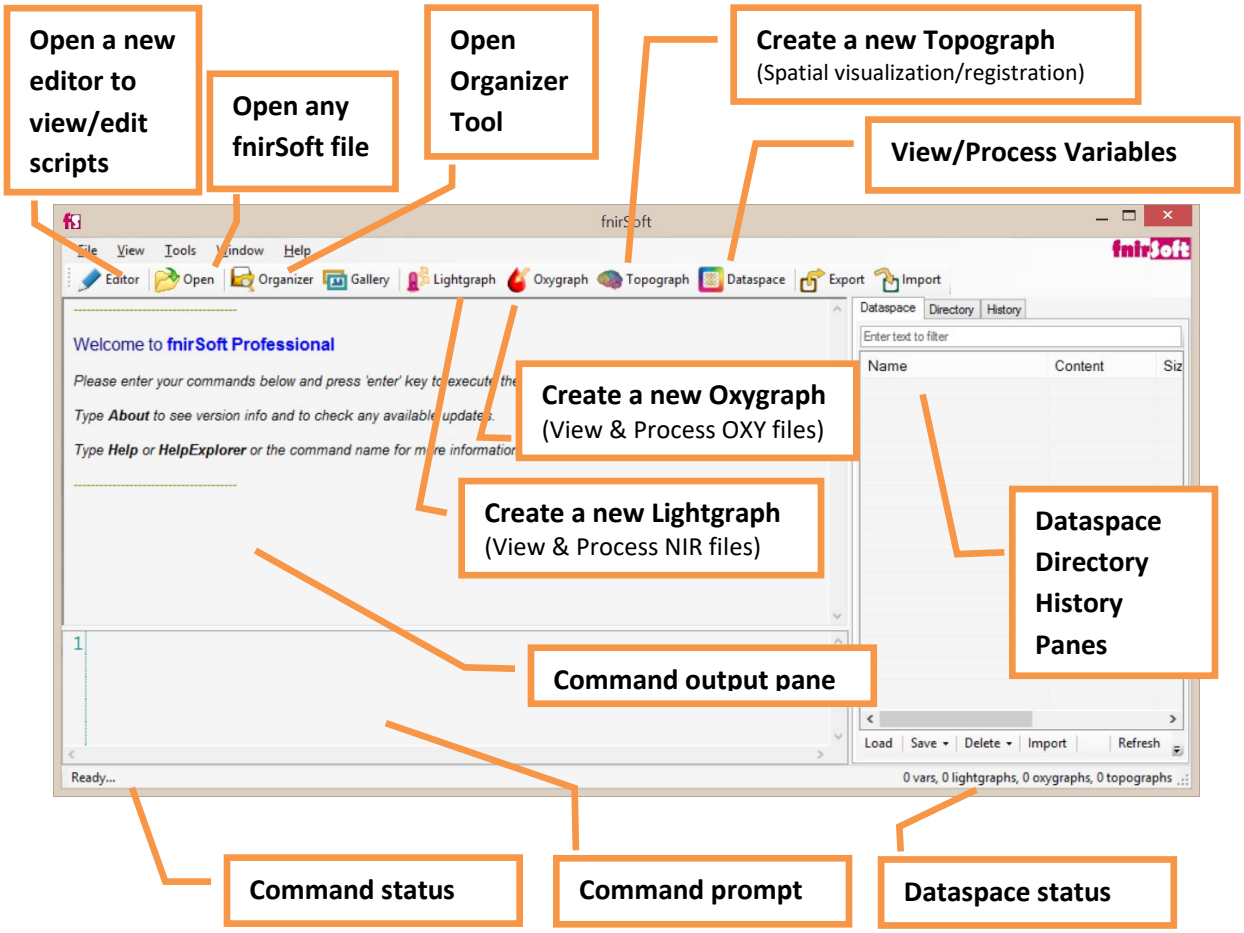
Can be solved for Concentrations for non-singular F matrix

2. Quick Start

This section provides a step-by-step tutorial for basic tasks required for data analysis. Each step is illustrated by screen captures. For information about fnirSoft programming and command line options, please refer to fnirSoft Scripting Manual (2018).

2.1.Overview

Below is the main window of fnirSoft with common user elements and tools identified.



fnirSoft includes a scripting engine, so commands written to the "command prompt" at the bottom of the window are executed by pressing "Enter" on your keyboard. The command prompt can also evaluate algebraic expressions. For more information about syntax, see the fnirSoft Scripting Manual. The rest of this chapter will detail basic steps in fNIR signal processing with graphical user interface elements.

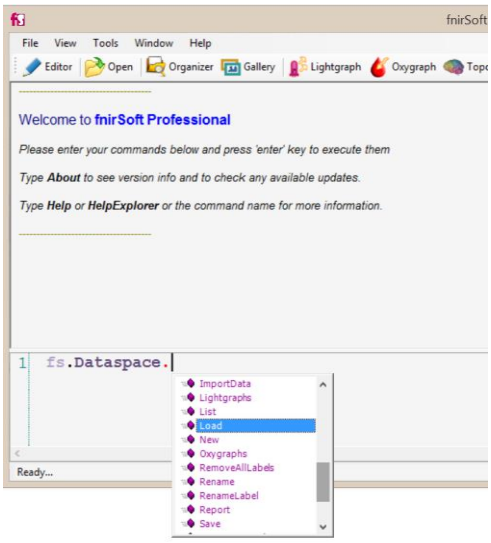
TIP

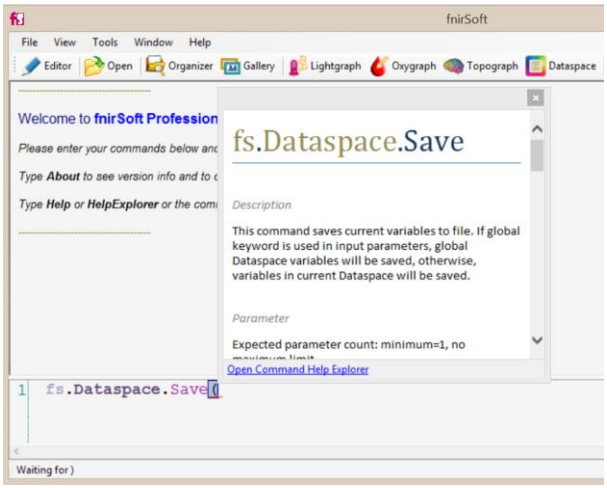
Type "2 +3" (without quotes) at the command prompt and press enter. You should see the result 5 at the output pane.

TIP

Intellisense is available at command prompt and editor. Try typing fs following by '.' (dot) character to show intellisense dropdown menu. As you continue typing, options are updated. Hover your mouse to see information about the item in a tooltip.

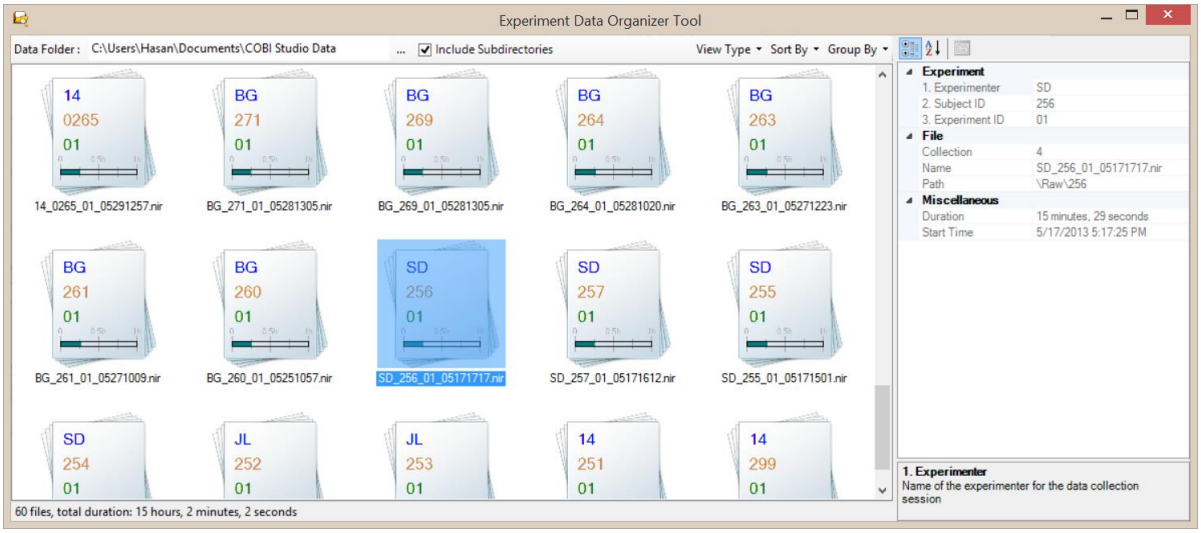
Context help windows appear for functions when you type a valid function name followed by '(' open-parenthesis character. This pop-up windows shows information about the command, its parameters and sample usage. For more information, click "Open Command Help Explorer" link.



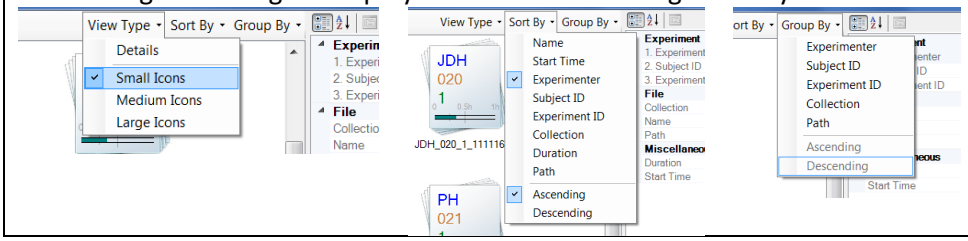


TIP

Use **Organizer Tool** to keep track of your experiment data files. Organizer Tool visualizes summary information about your data, allows you to sort, view, group, and access all your files.

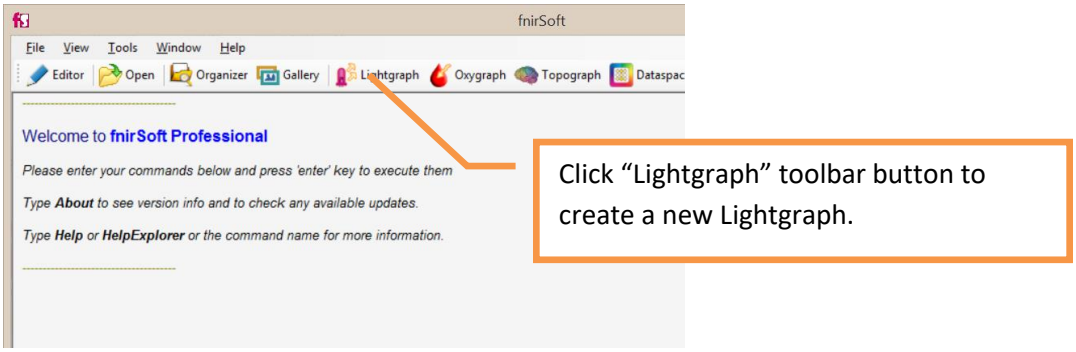


Change View Type (Details list or icons), change Sorting (by experiment features) bot ascending or descending and change Group By to show all data categorized by selected features.

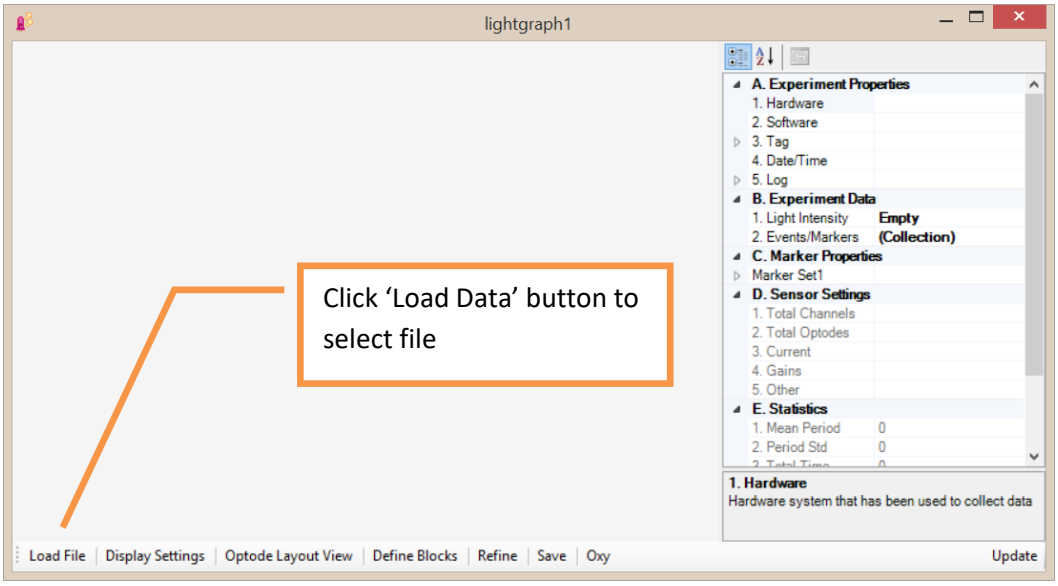


2.2.Loading Raw Light Intensity (*.nir) Files

1. Click on the 'Lightgraph' at the toolbar of main window. This will open a new Lightgraph window.

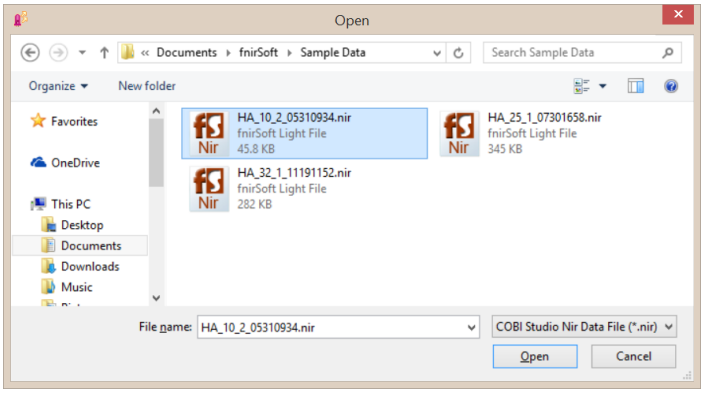


2. In the Lightgraph window, click on the 'Load Data' Button at the lower left corner of the window.

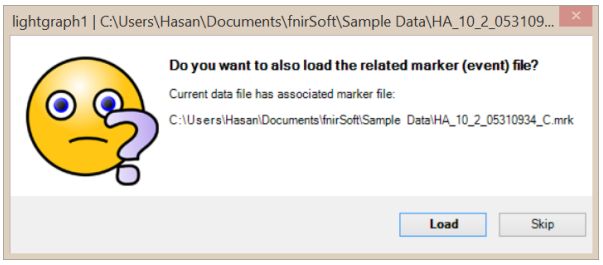


3. A file selection window will appear. COBI data files (*.nir) are filtered and shown by default. Lightgraph tool only recognizes also recognizes event marker (*.mrk) files and also the

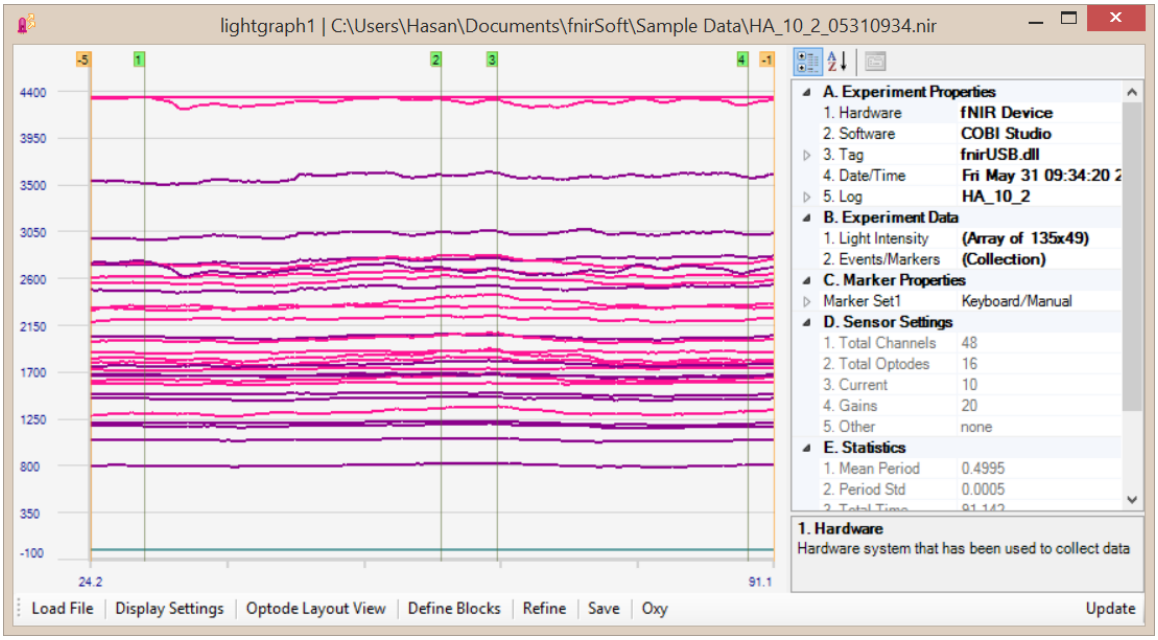
associated experiment log (*.log) files. Marker and log files can be automatically loaded with the main NIR file (see next step). Just select one NIR file and click open button.



4. If the selected file is part of an experiment saved by COBI, it might be accompanied by one or more marker files for time and event information. If 'Skip' button is clicked, these files will be ignored. Click 'Load' to also load the associated marker files with the data file.



5. Measurements from all channels in the selected file will be displayed in the graph. If a marker file was loaded, vertical lines corresponding to the markers will be displayed as well. The '*Properties*' pane on the right-hand side provides information about the current data file.



6. The data can be also displayed in 2-by-8 format (in the sensor's optode layout). This view shows data for each optode and channel individually, in an arrangement corresponding to the actual arrangement of the sensors used. To select this view, right click on the graph and select *Optode Layout View*. This will open the following window.

TIP

Each graph can be enlarged by

- double-clicking on the graph

  or

- right-click and selecting 'Enlarge' from the context menu of the graph.

Note: Performing the same operation will bring back the 2-by-8 view.

TIP

If you resize the window, the graphs will be automatically refreshed, and this can also be manually initiated by one of the following:

- Click on Update button (lower right-hand side corner)

  or

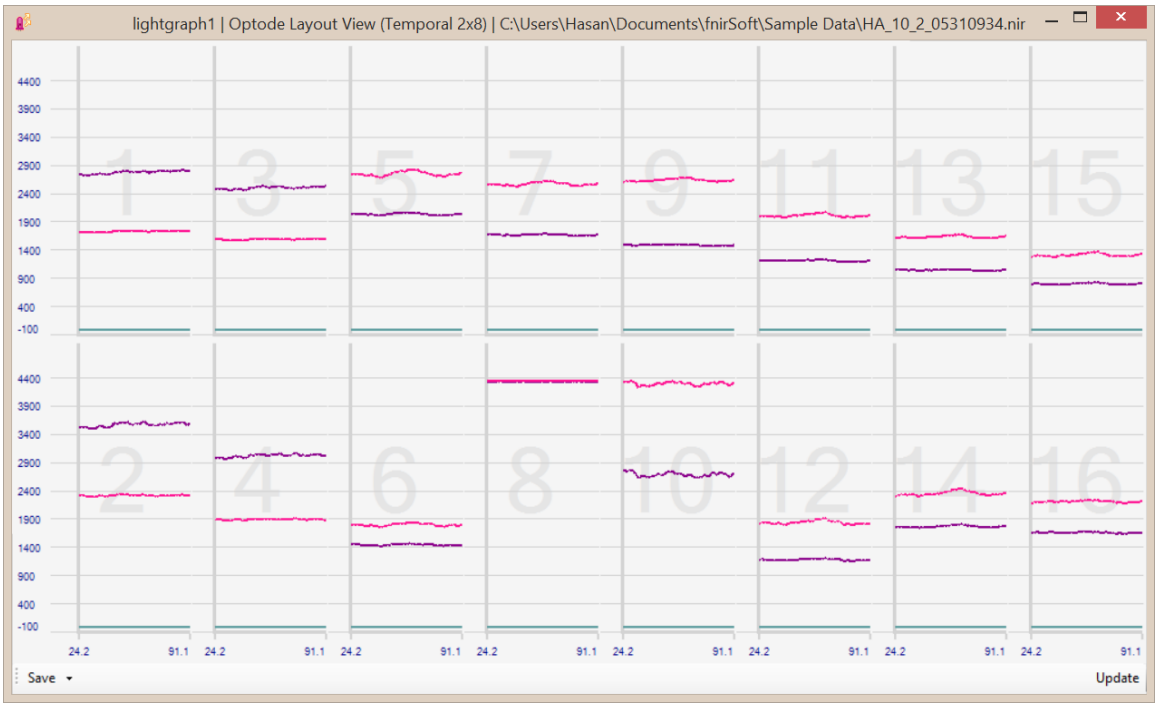
- Right-click and select 'Update' from the context menu

  or

- Left-click on the graph

TIP
Left or right click on a graph will highlight the graph (with red borders).
Use CTRL+click to unselect or multi-select.

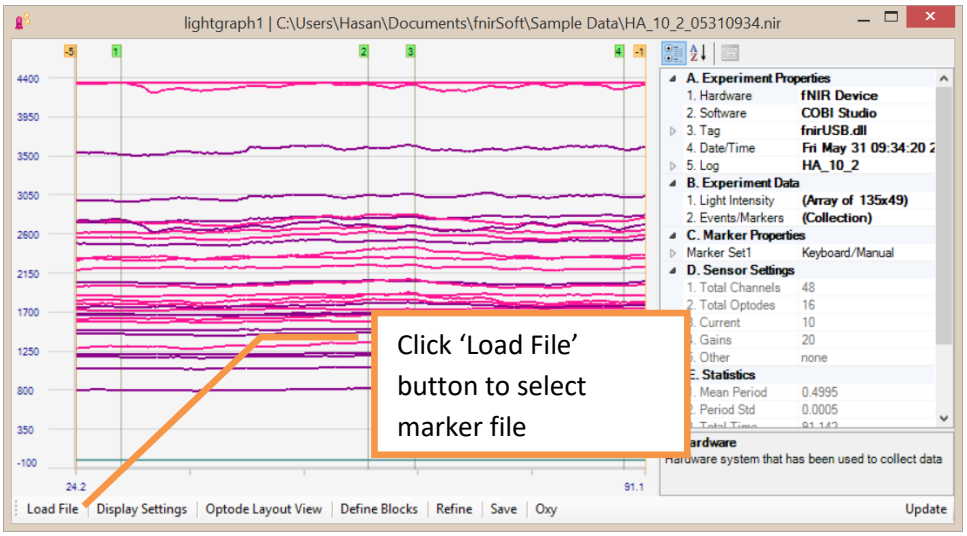
7. When there are many markers, they can occlude the graphs. To hide marker information, right click on any graph and select *Toggle Marker Visibility*. This will update all graphs.



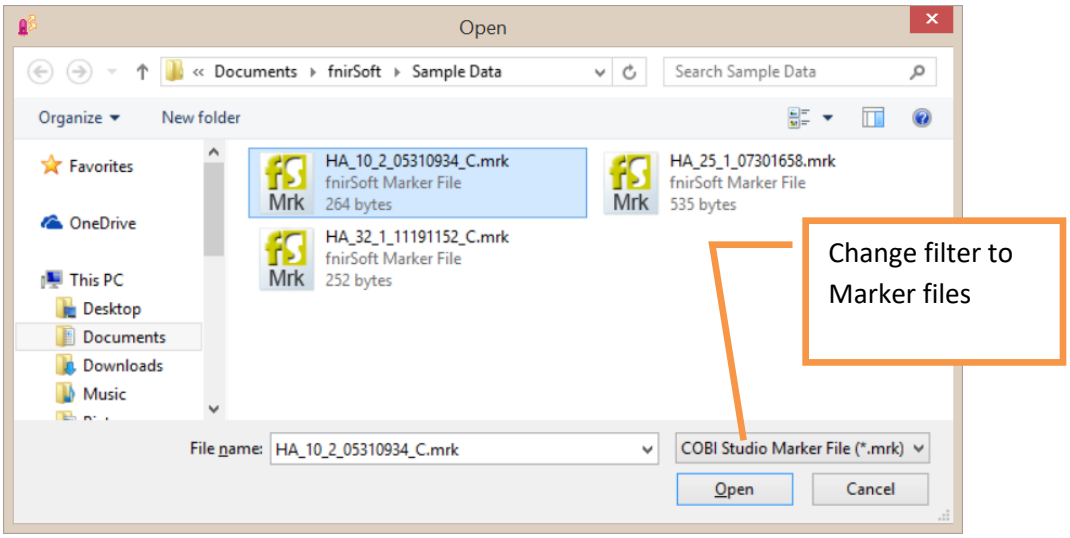
2.3.Loading Event Marker (*.mrk) Files

Marker files that are associated with fNIR data files are automatically recognized and will be loaded with the respective fNIR data file if using default settings. However, if data were not recorded in the 'Experiment mode' of COBI, marker files are not associated with the data file. In this case, 'Load File' button can be used to select a marker file to load.

1. Click the 'Load File' button at the bottom of the main graph window.



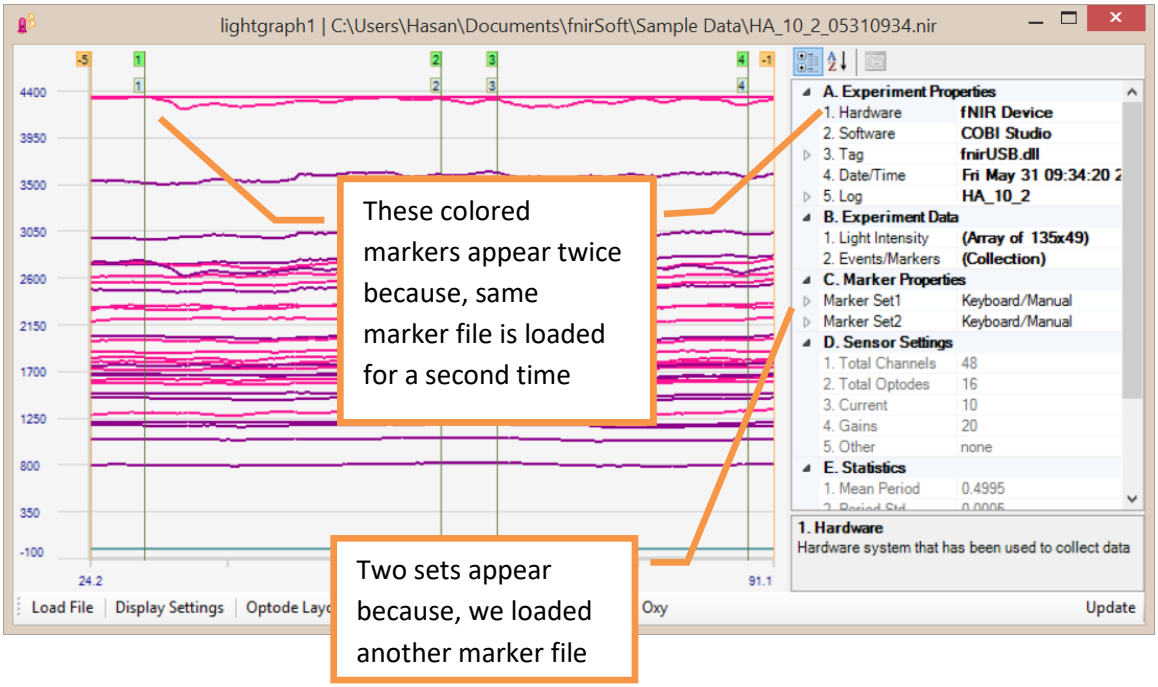
2. Select the marker file to load.



Once a file is selected and loaded, all markers are displayed on graph immediately. Note that each NIR file by default has the -1 (end of recording), -2 (start of baseline),-3 (end of baseline),-4 (baseline values ready) and -5 (record button is pressed) markers and these are shown in orange

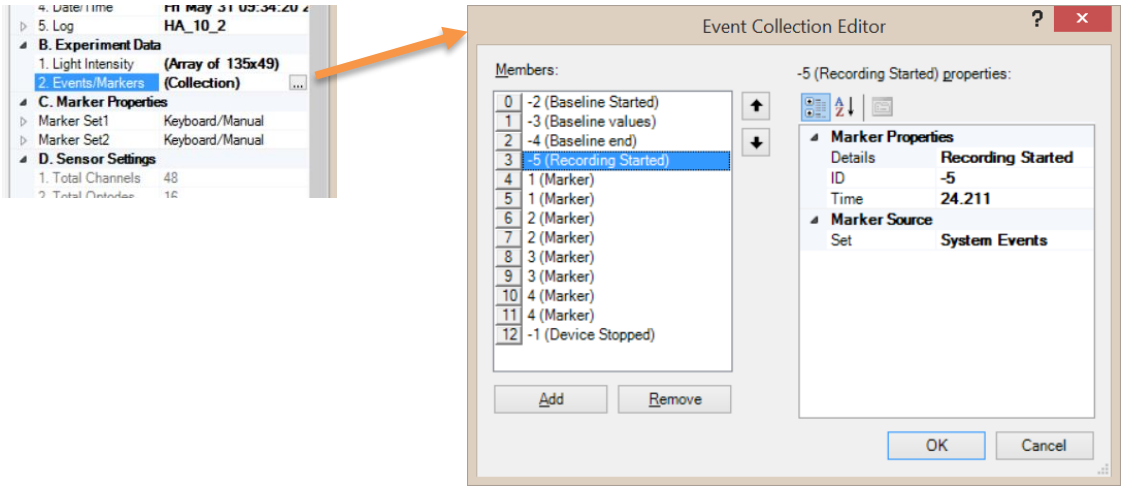
color. Other markers groups have different color. All markers loaded from the same file will have the same color.

Note here that, same marker file is loaded again, and that's why all such markers appear double below. Also,



TIP

You can view a list of all loaded markers click on the "Events/Markers" item in the properties pane (right-hand side) within "Experiment Data" group. A small button ("…") will appear next to it, click on the button to see the collection as below:



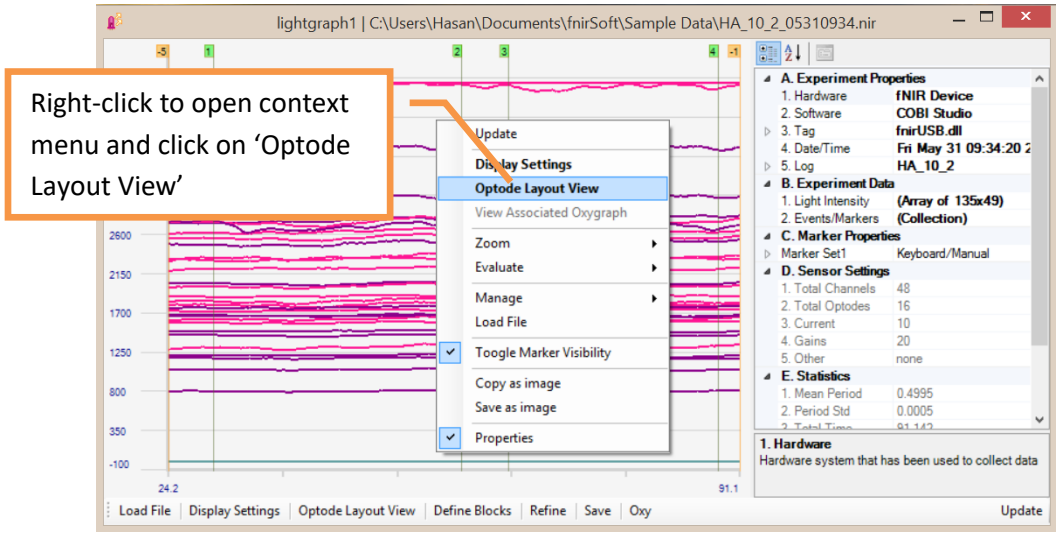
2.4.Preprocessing Raw Light Intensity Data

The necessary steps for preprocessing may change depending on the current data and experiment protocol. Also, if oxy files are used light intensity preprocessing would be skipped entirely, but not recommended. If the data is noisy, it is advised to apply a linear phase, low pass filter that attenuates high frequency components of the signal. Furthermore, certain channels, or time periods may need to be excluded due motion artifact, saturation or noise. fnirSoft can be used to design and apply window-based finite impulse response (FIR) filters.

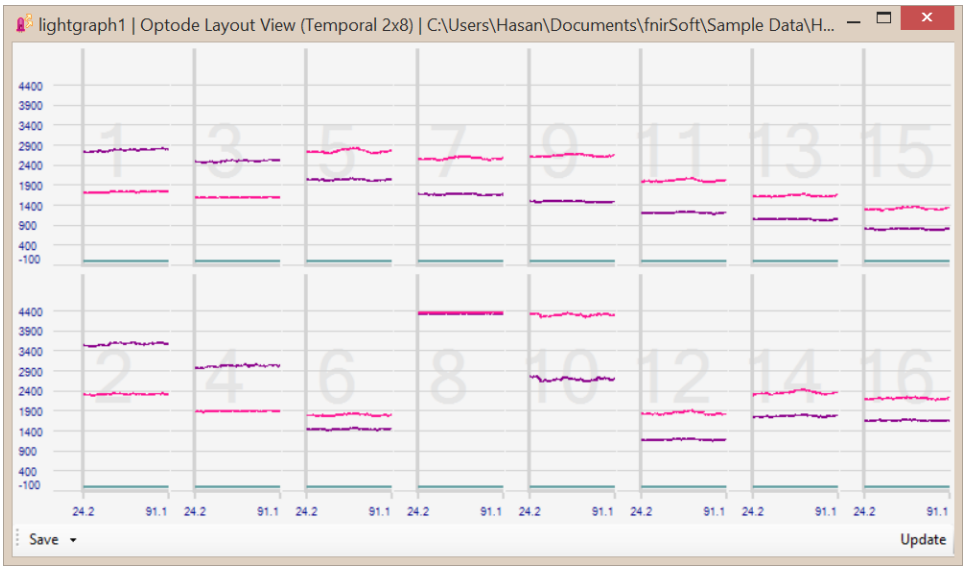
2.4.1. Rejecting Optodes/Channels

To exclude all data from an optode, first, go to "Optode Layout View" window and reject or accept the selected optode from the "Evaluate" option at the context-menu (by right-click).

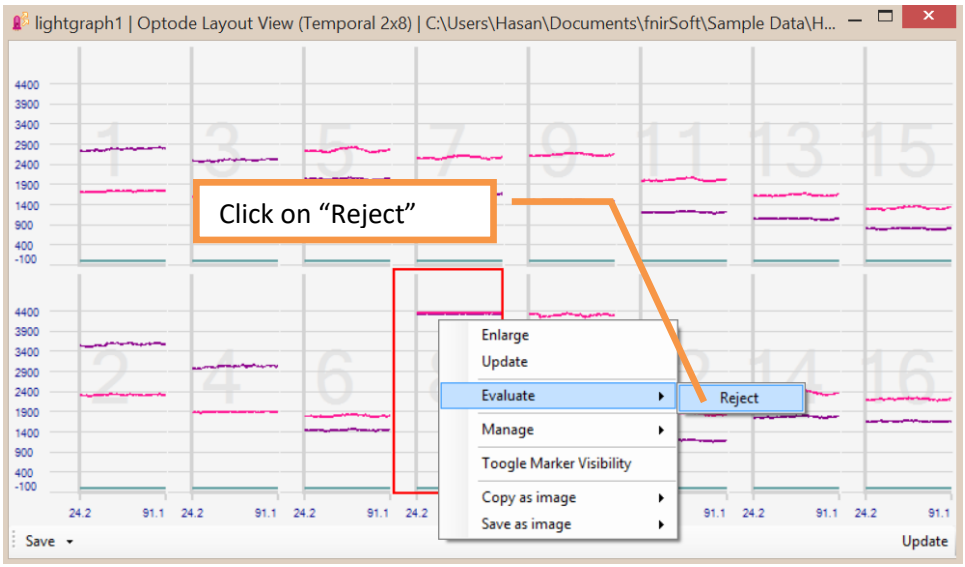
1. Right-click on the Lightgraph, and select "Optode Layout View" from the context menu.



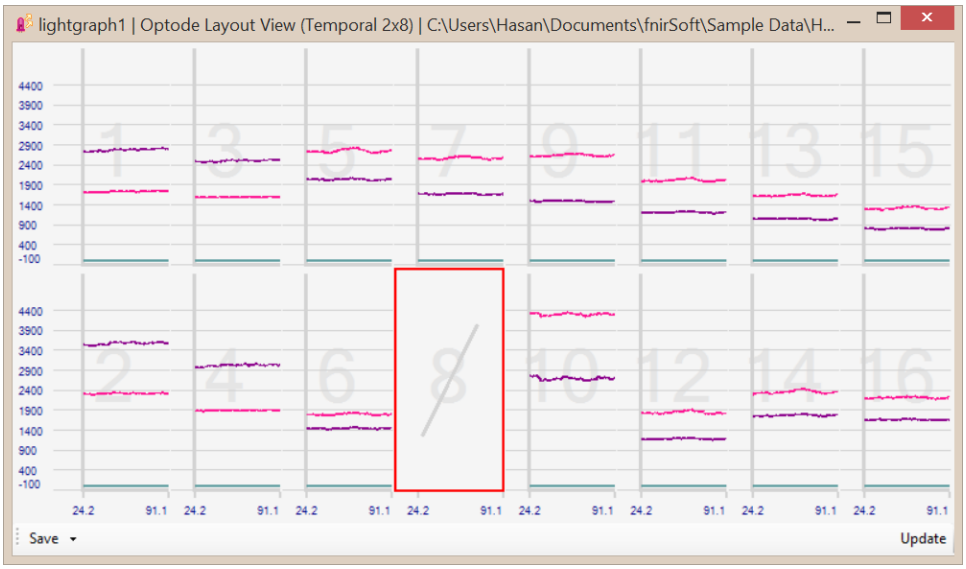
2. A new window will appear as shown below. In this "Optode Layout View", you can toggle hide/view markers (by right clicking graphs and selecting *Toggle Marker Visibility*).



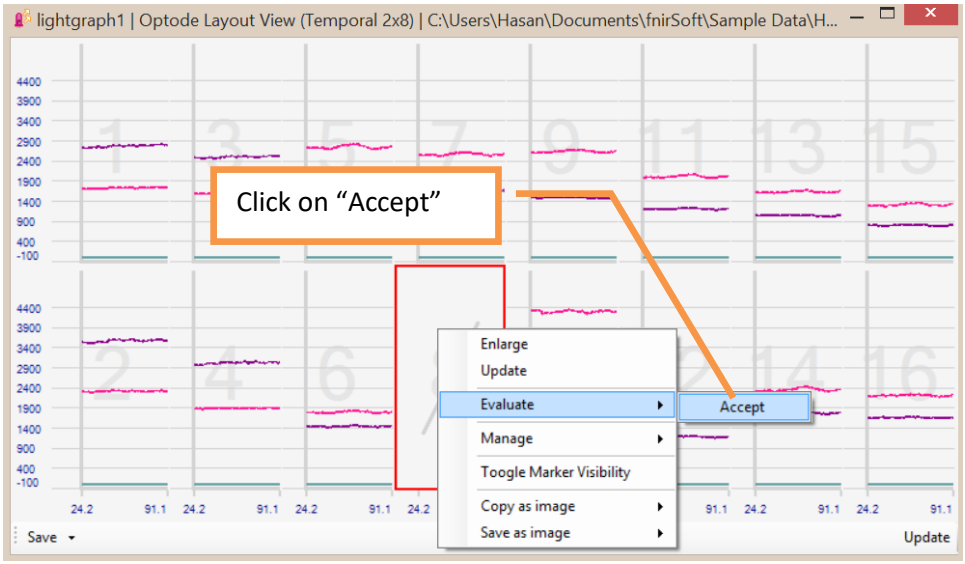
3. In the Optode Layout View, right-click on the graph of the optode you want to reject, and at the context menu, select *Evaluate > Reject*. Note that optode numbers are written at the lower left corner of each graph.



4. Once rejected, the optode graph is changed to "null" display as shown below for optode 8:



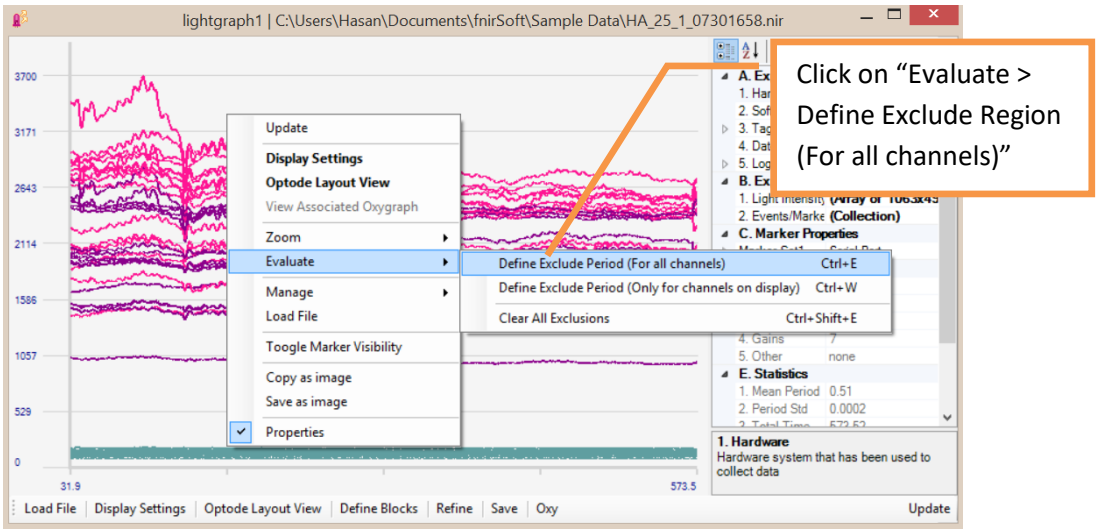
5. To reverse this action, simply right-click on the graph of the rejected optode and *select Evaluate > Accept* from the context menu. The graph will be updated to show the optode data instead of the "null" display.



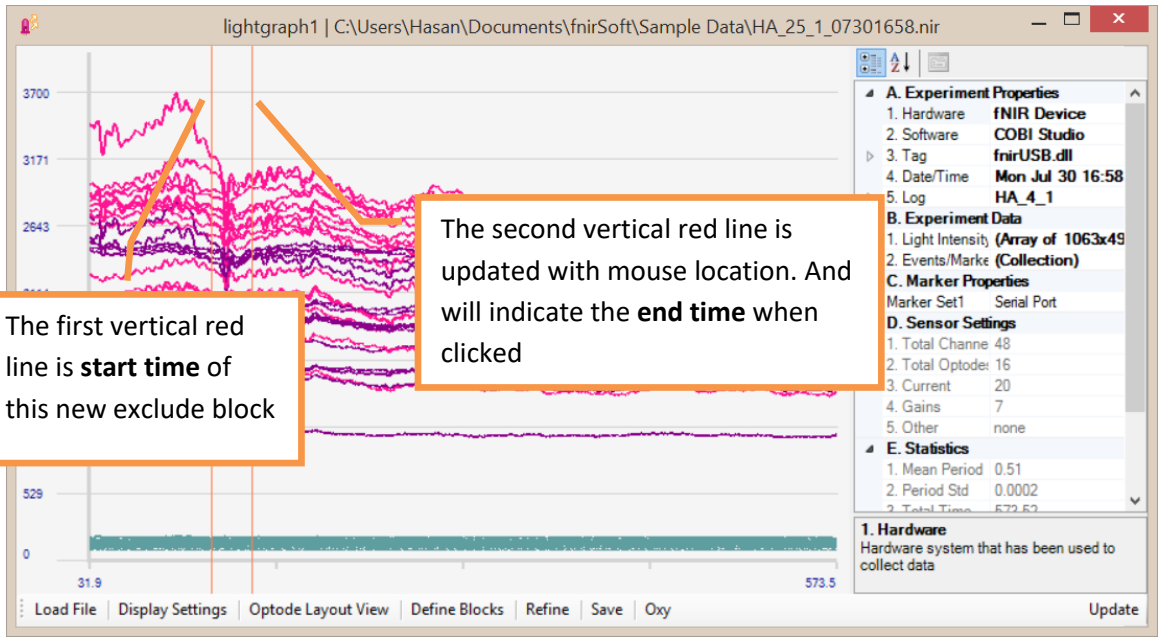
2.4.2. Defining Exclude Regions

The previous section described how to reject all data for an optode. It is also possible to reject certain time periods within an optode.

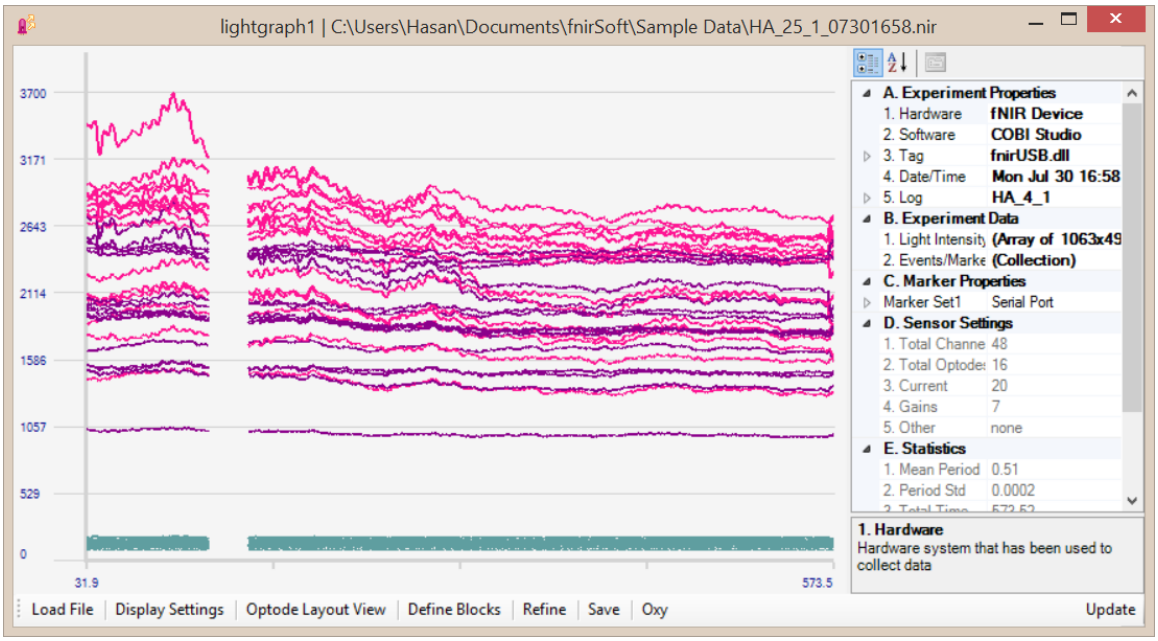
1. Right-click on the Lightgraph and from context menu, click on *Evaluate > Define Exclude Period (For all Channels)*. NOTE: For clarity, the following figure is shown with markers hidden (markers can be hidden either through "Display Settings" or right-click context menu.)



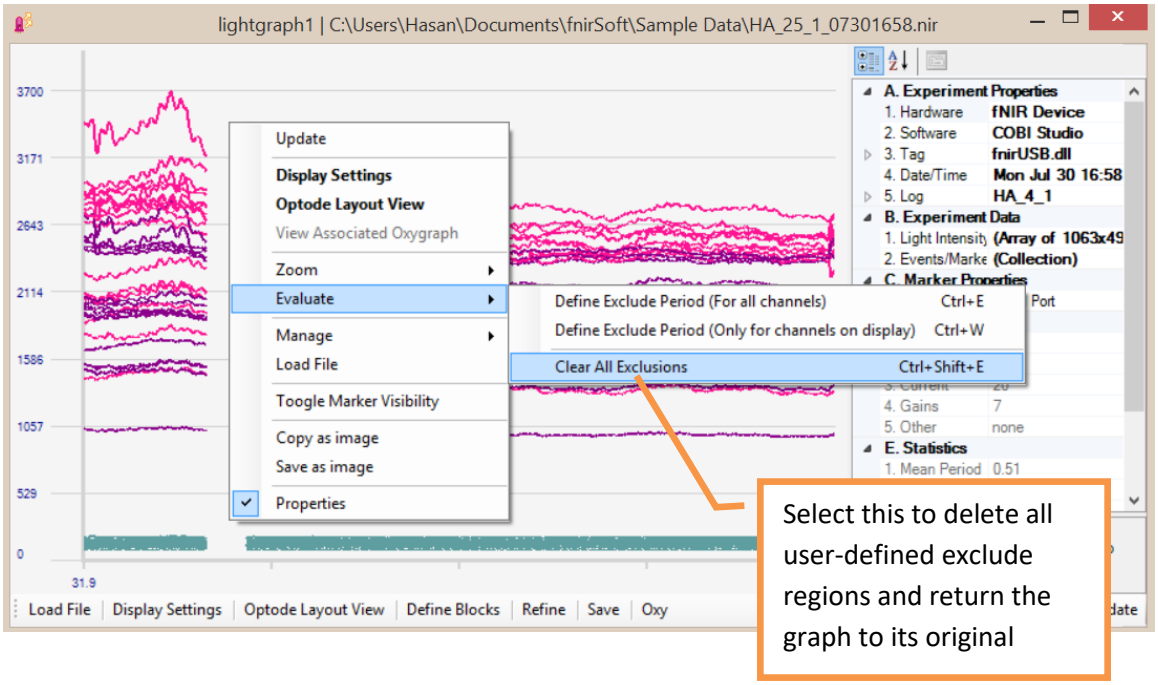
2. Once "Define Exclude Region" is selected, two mouse left-clicks are required to identify **start** and **end** times for the exclude region. After the first click, a vertical red line will appear at the location under the mouse pointer. The next click will identify the end time and finalize the procedure.



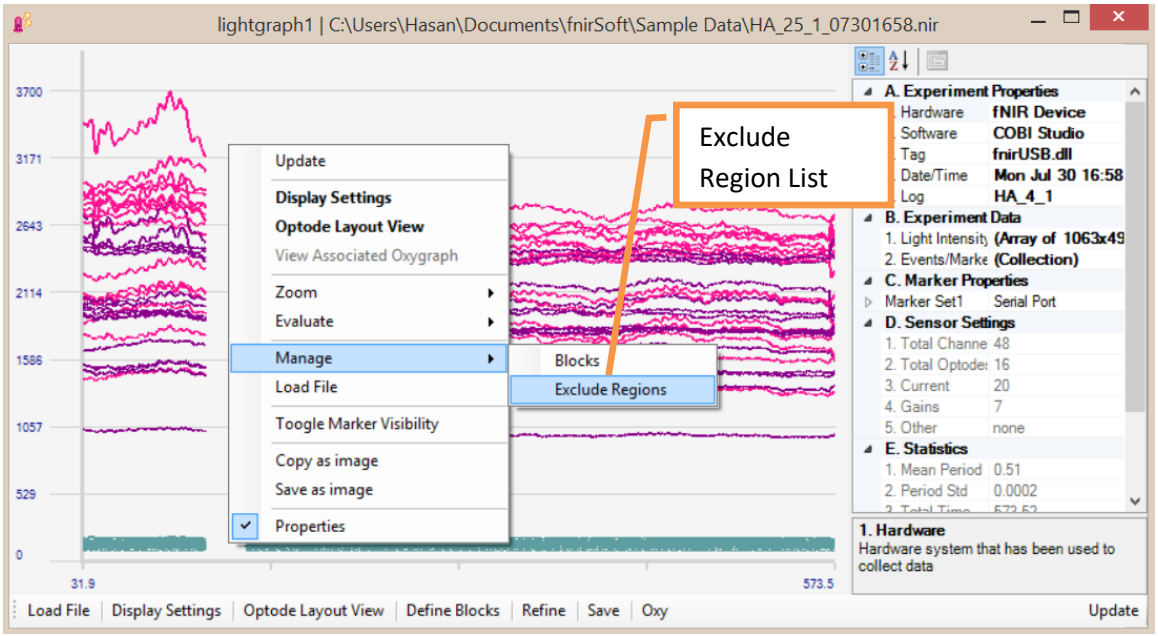
3. Once the start and end times are selected, the graph is immediately updated to exclude the selected region. NOTE: Selecting exclude regions do not delete/remove data. This is just masking the data.



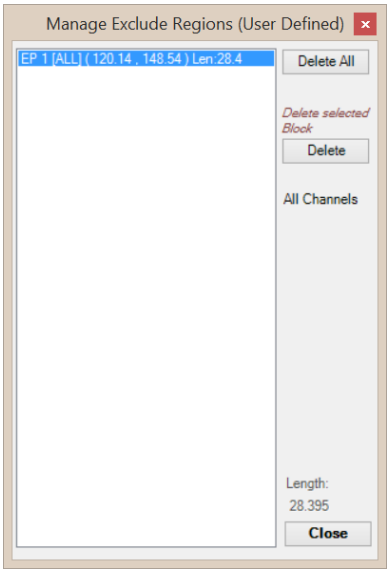
4. All exclude regions can be deleted by right-clicking the Lightgraph and selecting *Evaluate > Clear All Exclude Regions* in the context menu. Selecting this is option will update the graph immediately and all user-defined exclude-regions will be deleted.



5. You can view a list of all defined exclude blocks by right-clicking the Lightgraph and selecting *Manage > Exclude Regions* in the context menu.

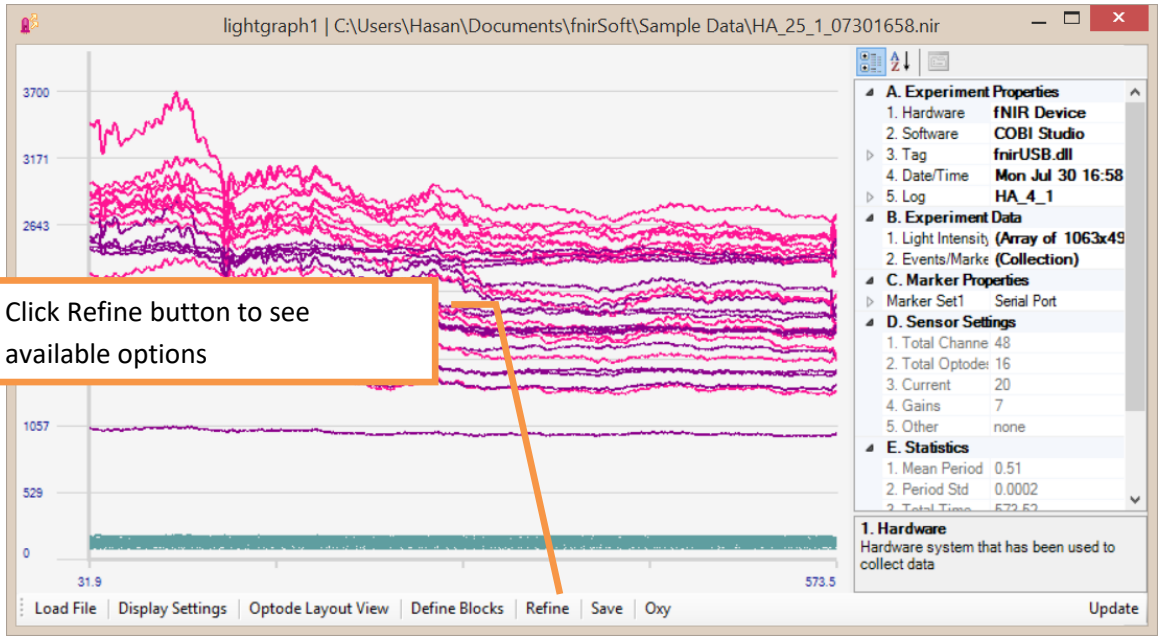


6. This will display the list of all exclude regions. Any or all of them can be deleted.



2.4.3. Applying Low-pass Filter

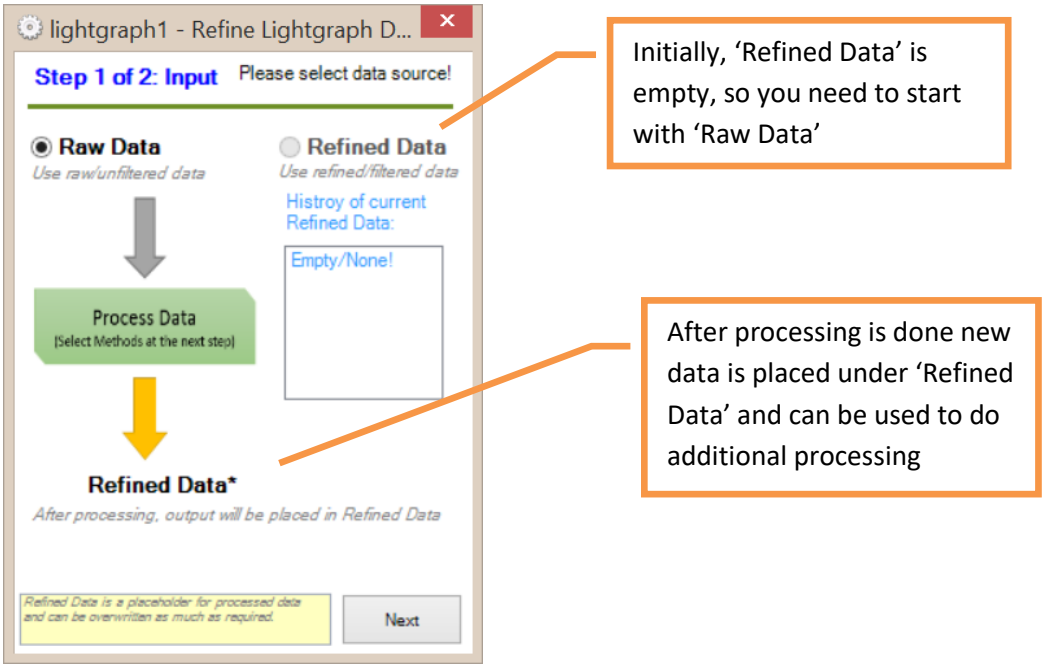
1) To apply a low-pass filter to the noisy data, first, click on the Refine button at the toolbar.



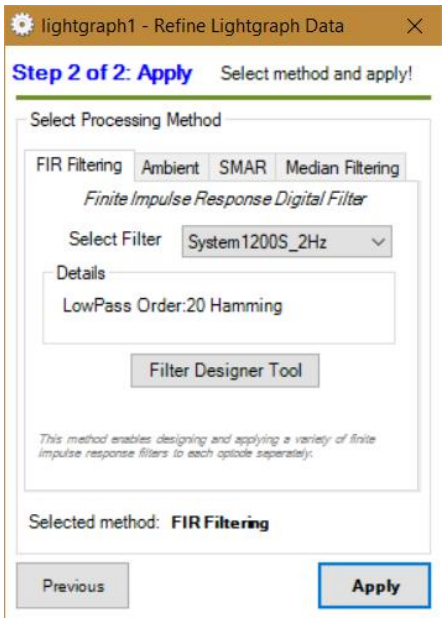
2) A popup windows will appear that displays the first step: selection of input. Either 'Raw Data' or 'Refined Data' can be selected as input for processing.

[Note: At first, only 'Raw Data' is available and 'Refined Data' is empty (as there's no processing done). After processing, output data is placed in 'Refined Data'.]

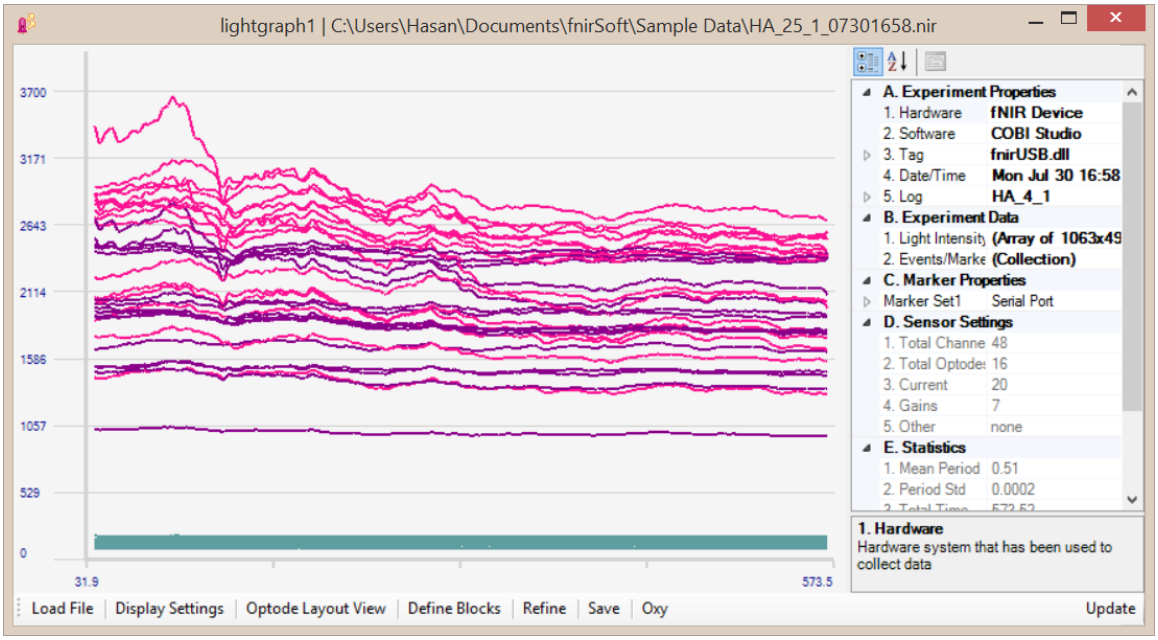
Just keep default selections and click Next button to go to step 2.



3) Finally at 'Step 2', method to be applied is selected. By default FIR Filtering tab and also "System1200S_2Hz" filter is selected. This default filter is a low pass FIR filter with an order of 20. Just keep default selections and click Next button to apply the filter.



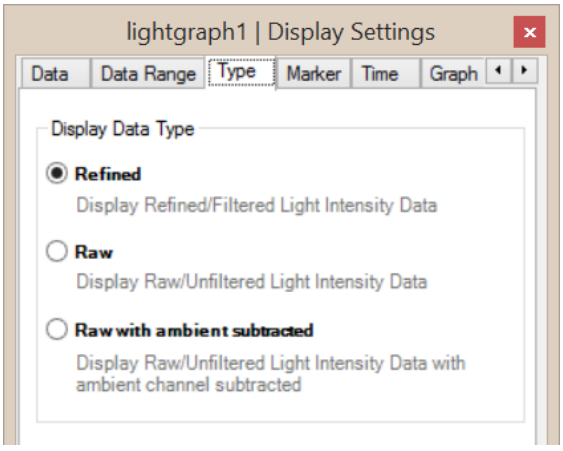
4) The filter will be applied and the graph will be updated immediately, as shown below:



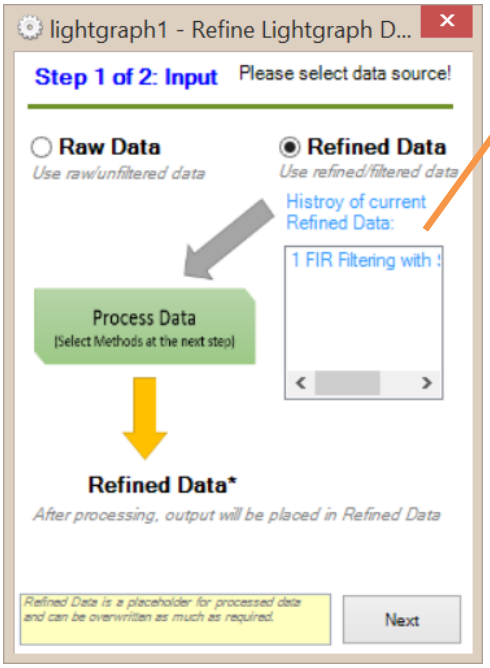
5) Filtered data do not replace original (raw/unfiltered) data. Both are accessible with functions to be exported or used for oxygenation calculation.

TIP

To return to viewing raw/unfiltered data, right-click on the graph and select "Display Settings". In the pop-up dialog, under the "Type" tab, select the "**Raw**" option and click the "**Update**" button.



6) Also, now that a filter applied, 'Refine Data' is available again. Click on 'Refine' button on Lightgraph that will step 1 again as below. This time, 'Refine Data' is available and can be clicked. And, the history list shows it contains 'FIR' filtered version of 'raw data'. If more than one operation is performed, they will be listed here.



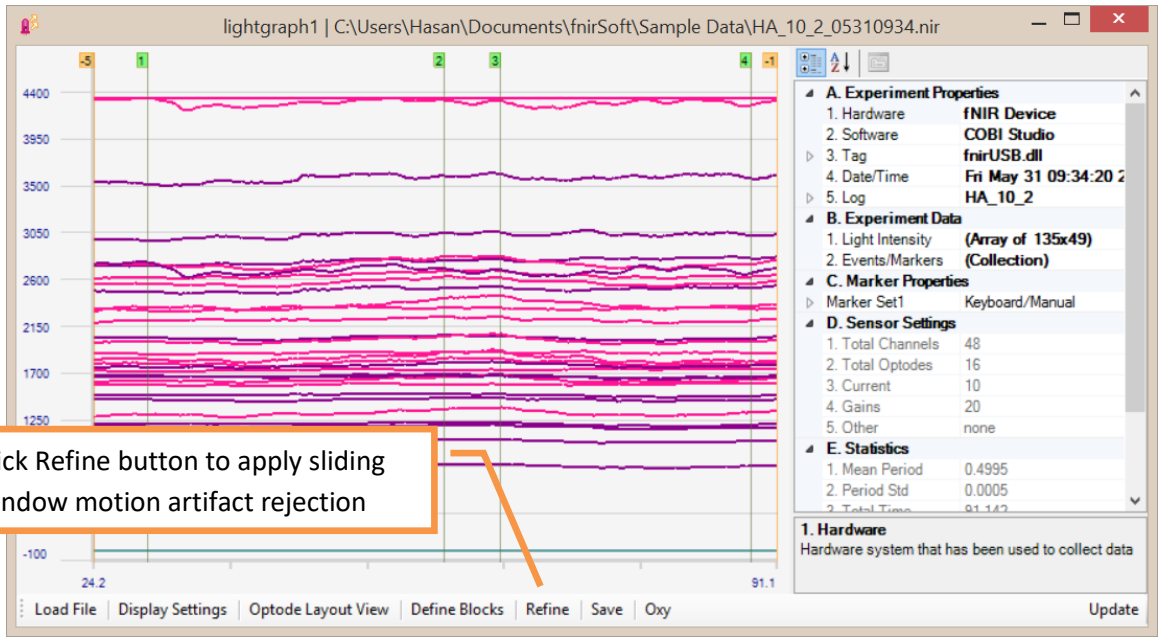
History list of '*Refined Data*' contains FIR filtering.

This contains more than one item if '*Refined Data*' is selected again for another processing.

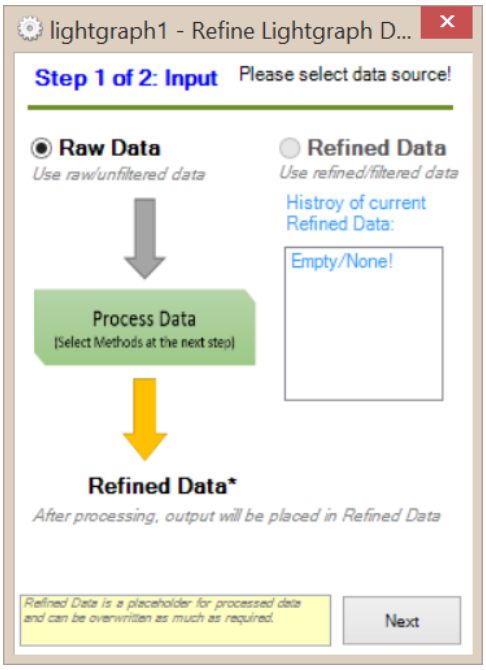
NOTE: When '*Raw data*' is selected, any previous value in '*Refined data*' is deleted and new processed data is loaded.

2.4.4. Applying Motion Artifact Rejection (SMAR)

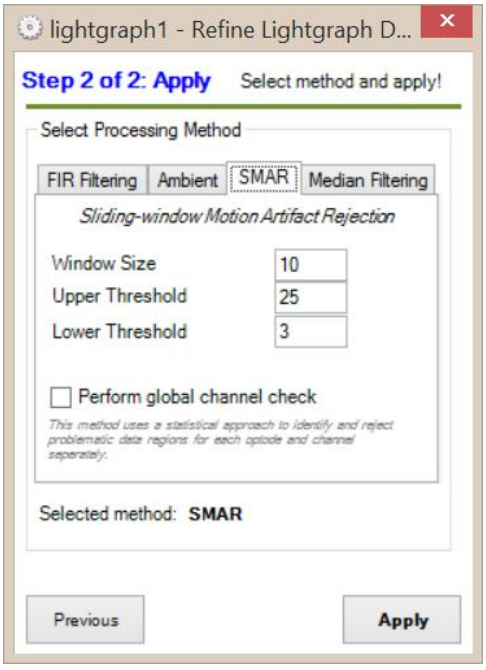
1) Motion artifacts and saturation can be detected automatically by a Sliding-window Motion Artifact Rejection (SMAR) algorithm. See Ayaz et. al. [12] for more information about the algorithm. To apply, click "Refine" button at the toolbar.



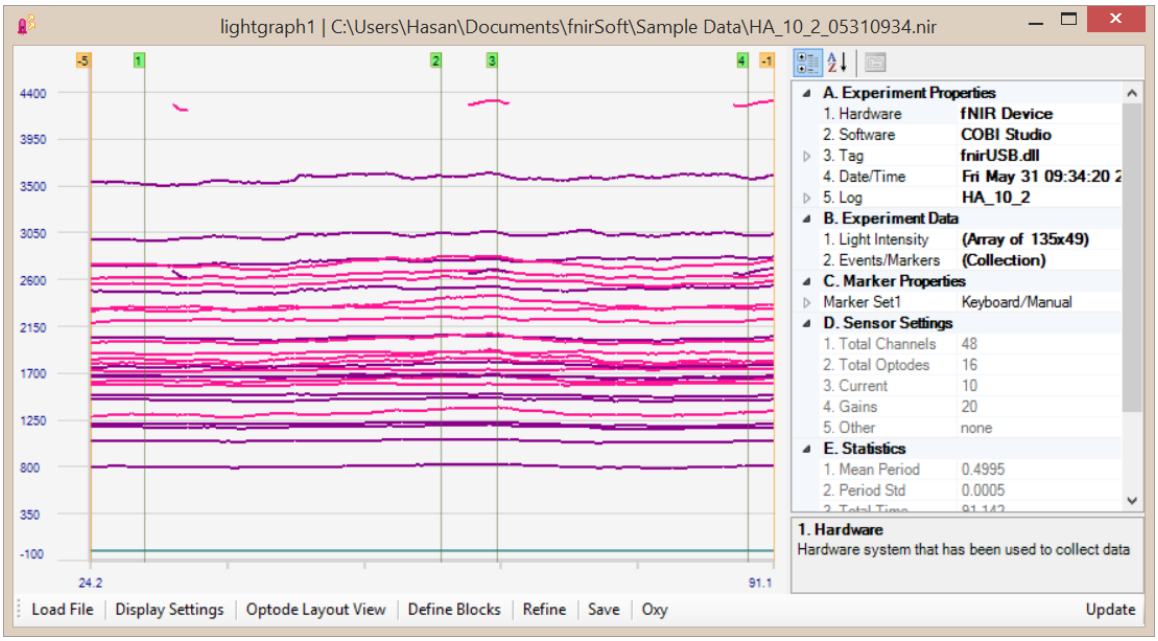
2) Refine window will appear, as below. Just click next to proceed.



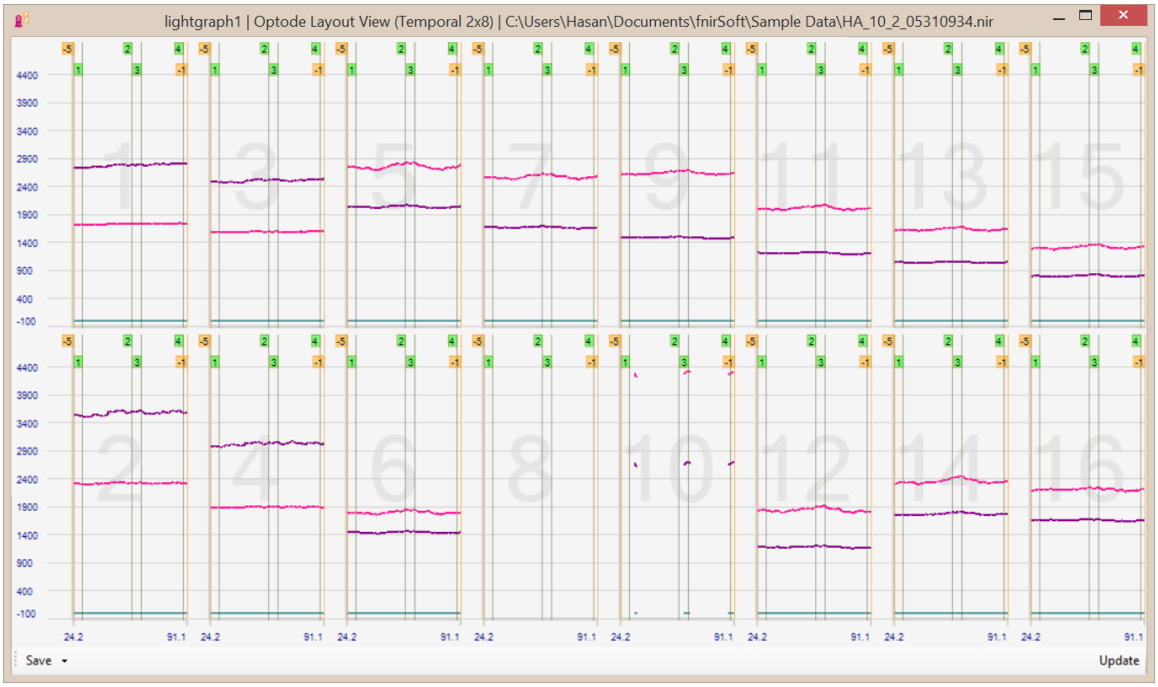
3) Click on 'SMAR' tab to select this method. Configuration options are within this tab and allow changing algorithm parameters. Just keep default settings. Click the "Apply" button to accept current parameters and apply the algorithm.



4) Segments identified as motion artifacts and saturated channels will be excluded automatically. Compare the following graph with the one in step 1 above. Also, see the command output pane (at the main window) for a brief report. The graph will be updated immediately.

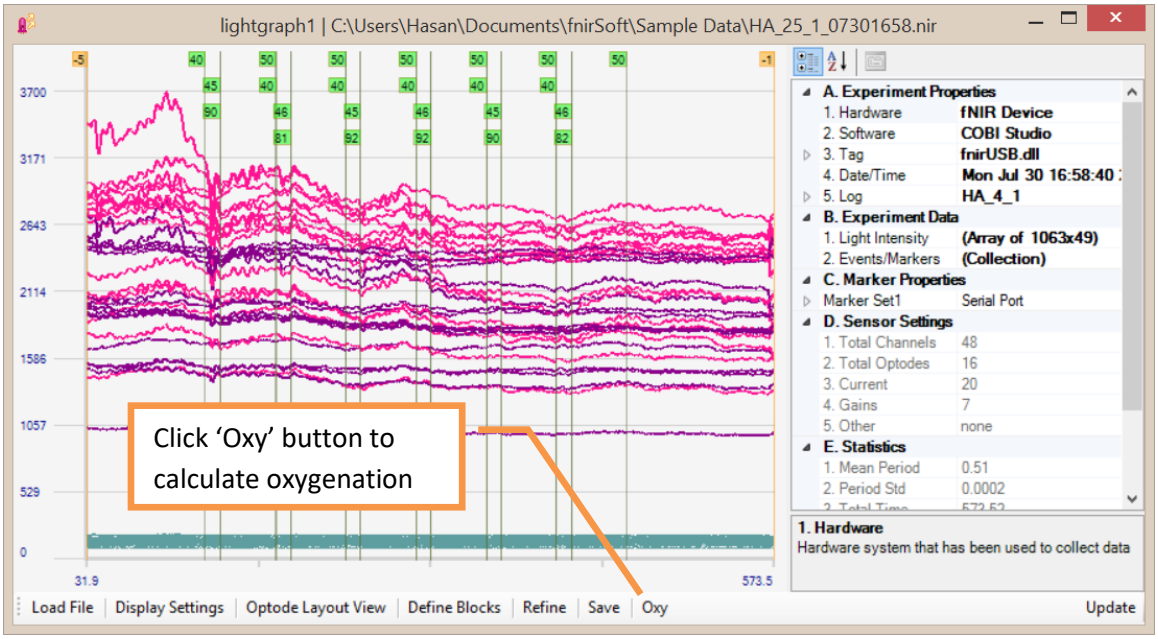


5) Rejected regions can be seen easier at 'Optode Layout View'. As shown below, optodes 8 and 10 were rejected.

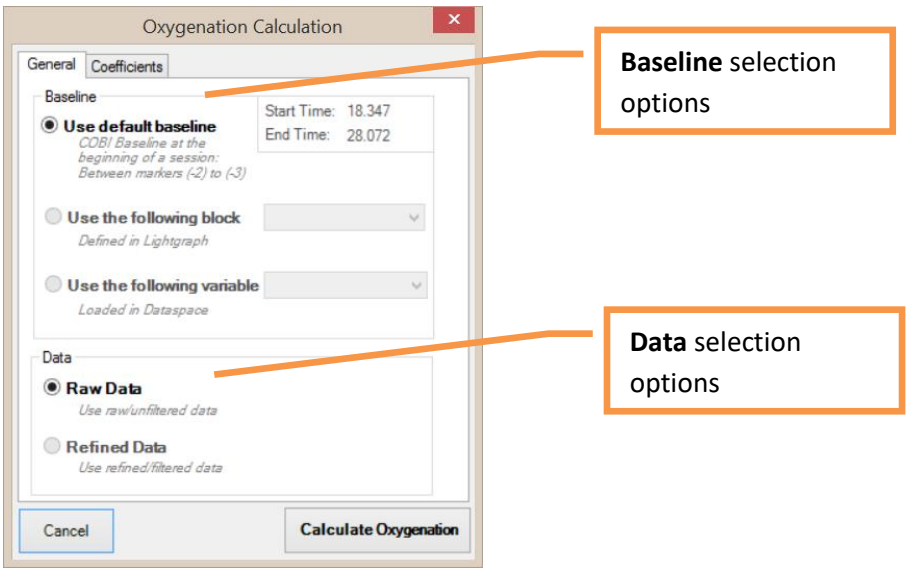


2.5.Calculating Oxygenation (MBLL)

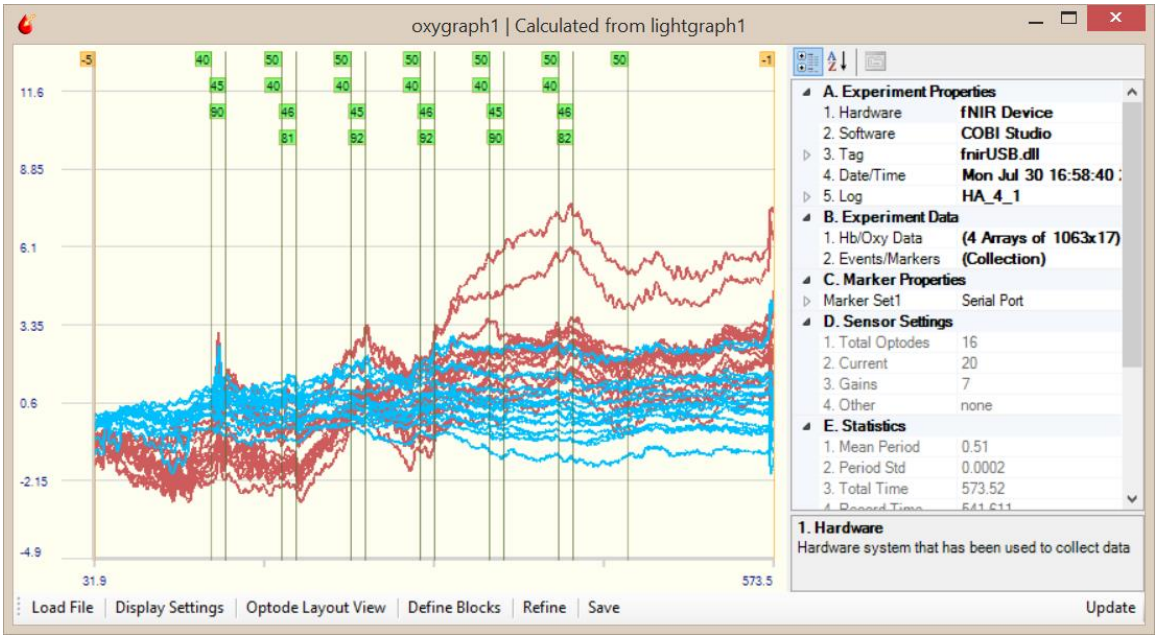
1) fnirSoft calculates oxygenation by applying the Modified Beer Lambert Law (MBLL) described in the previous chapter. To start the process, click the "Oxy" button on the toolbar.



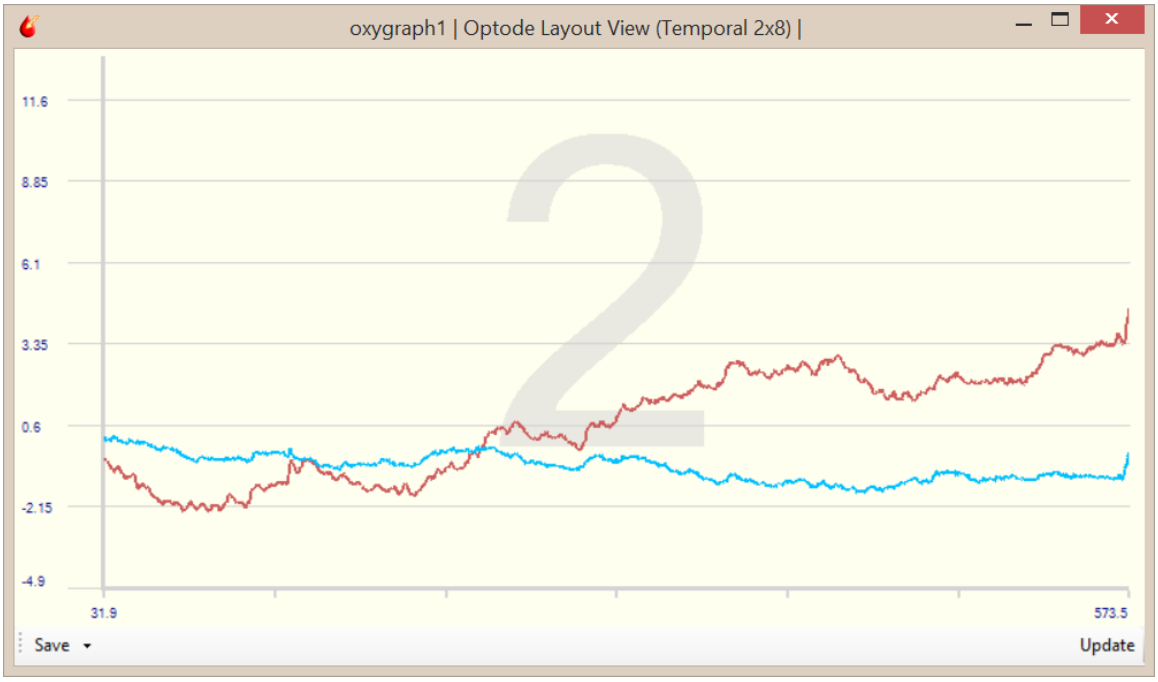
2) The following parameter window will appear. Under the General tab, there two main selections: **Baseline** and **Data** to enable use of different baselines (reference point), and specify filtered or unfiltered data. The Coefficients tab allows modifying the absorption spectrum coefficients of oxy-Hb and deoxy-Hb of MBLL. The "**Refined Data**" option will be disabled if no processing has been applied to the current data. The default baseline is the "**COBI Baseline**". Click the "Calculate Oxygenation" button to accept current settings and continue.



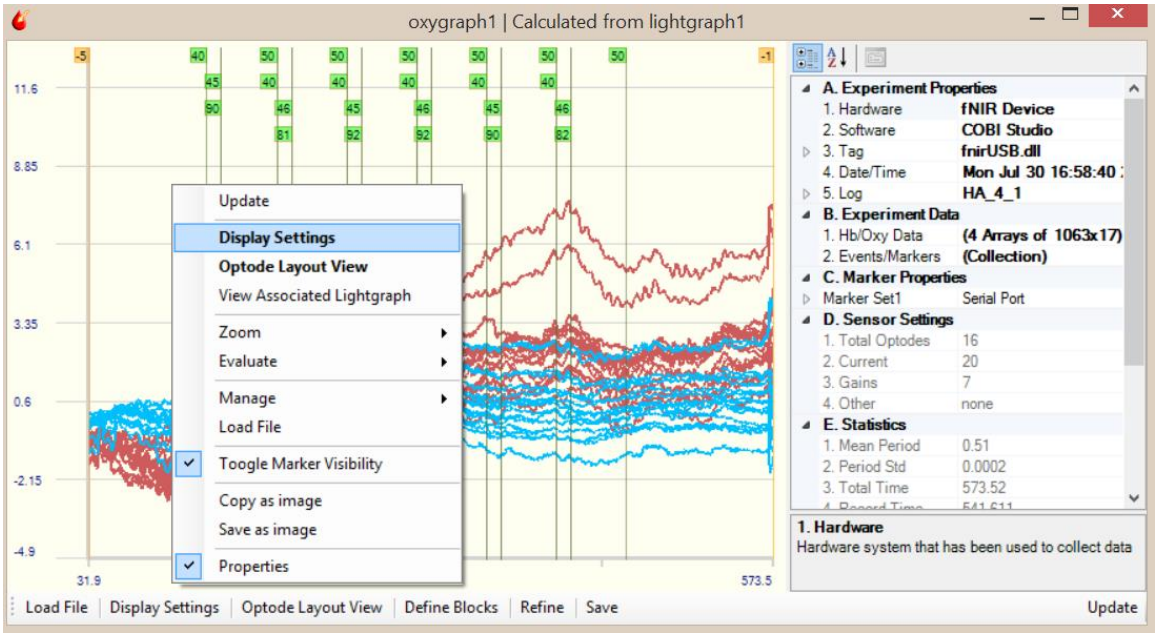
3) Once oxygenation data is calculated, a new Oxygraph window will appear as below.
By default, all markers and exclude regions are transferred. The graphs displays HbR (deoxy-hemoglobin), HbO (oxy-hemoglobin), HbT (total-hemoglobin) and Oxy (difference between oxy- and deoxy-hemoglobin).

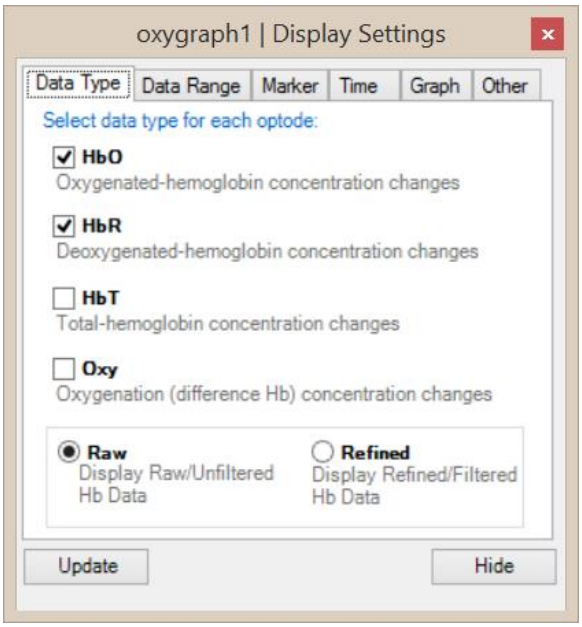


4) Oxygraph has options and menu items similar to Lightgraph, for example, Optode Layout View. Open Optode Layout View in Oxygraph and double-click on optode two to see it in full-window as below.

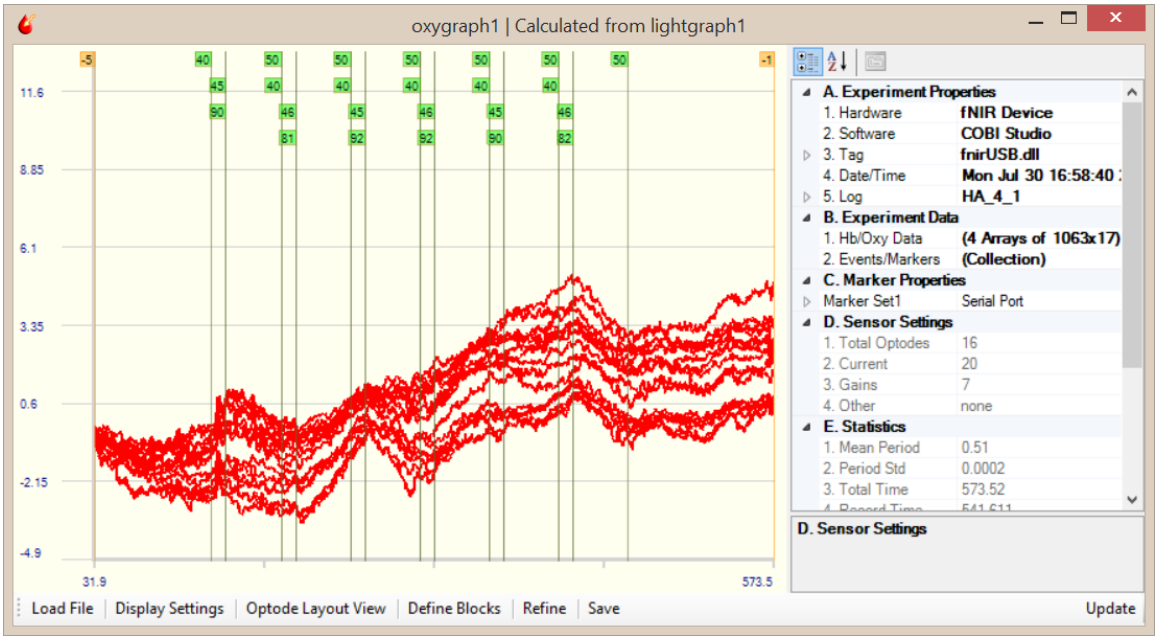


5) Also, Oxygraph, by default displays oxygenated-Hemoglobin (HbO) and deoxygenated-hemoglobin (HbR) data. To change display options, right click on the main window of Oxygraph and select “Display Settings” from the context menu. A new dialog box will appear as shown below.





6) Uncheck oxygenated-hemoglobin (HbO) and deoxygenated-hemoglobin (HbR) click on Oxy (difference in hemoglobin). Click “Update” to refresh the graphs as shown below.

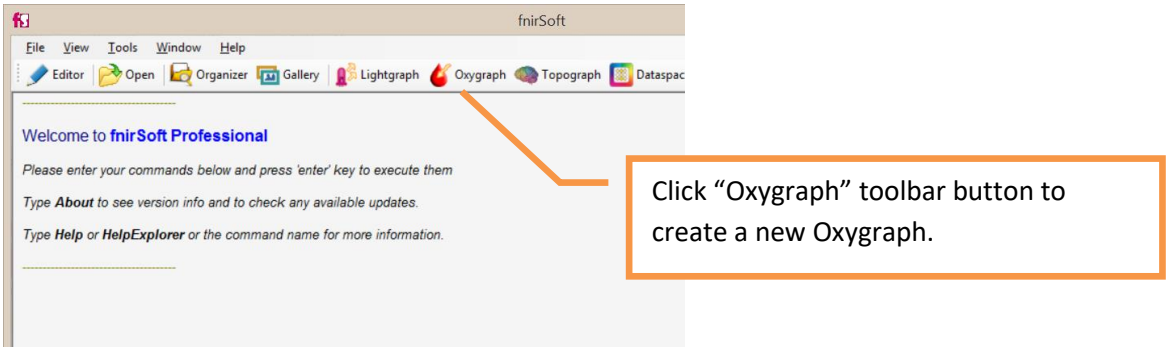


7) You can apply various filters using filters using Refine tool available on the toolbar. To save and/or export data and apply block analysis, see the next chapter.

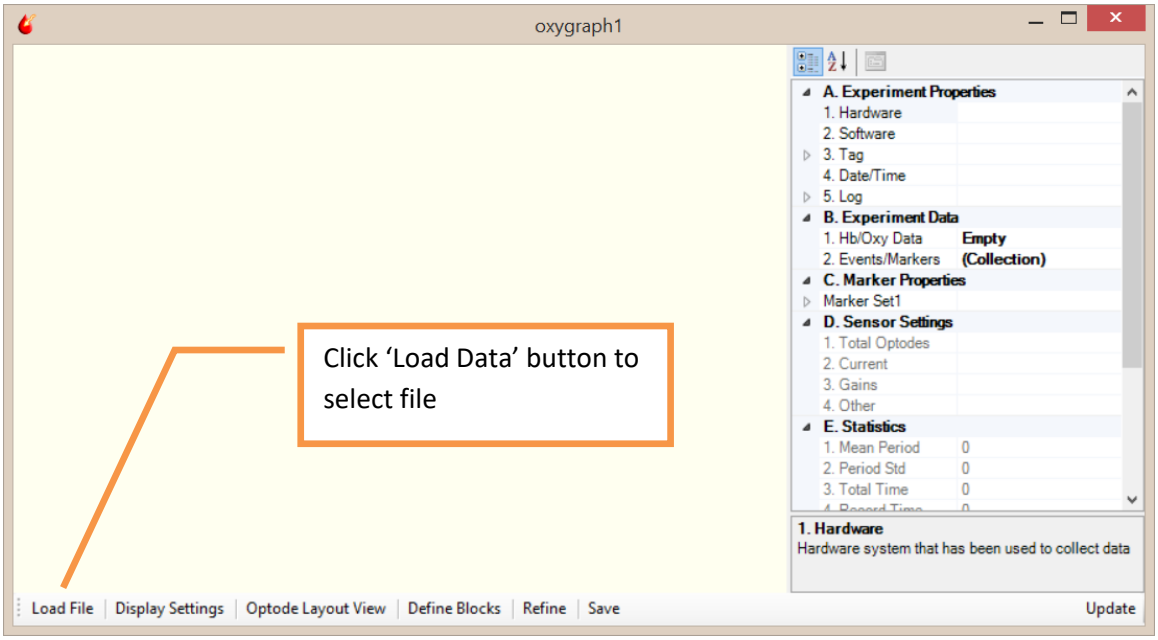
2.6.Loading Oxygenation/Hemoglobin (*.oxy) Files

An experiment data saved from COBI Studio includes oxy file in addition to nir, mrk and log files. Oxy file contains hemoglobin concentration changes and can be completely recalculated from nir file by using the default (COBI) baseline. If oxy file is used (as shown in this section), light intensity preprocessing steps would be skipped (in Lightgraph). See previous section for information on loading nir file and then calculating oxygenation data.

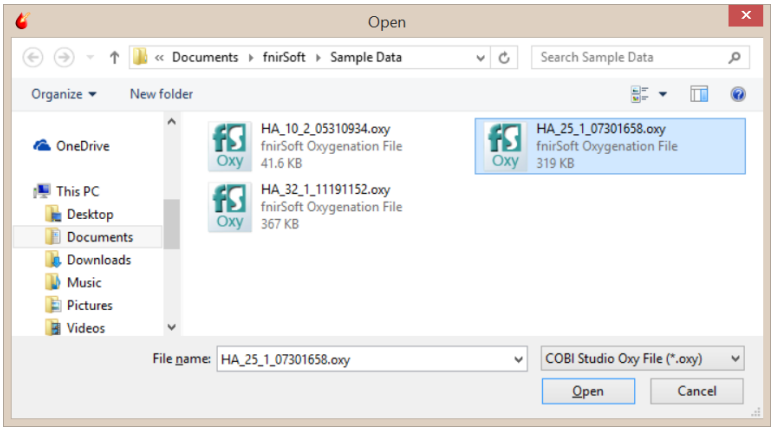
1. Click on the 'Oxygraph' at the toolbar of main window. This will open a new Oxygraph window.



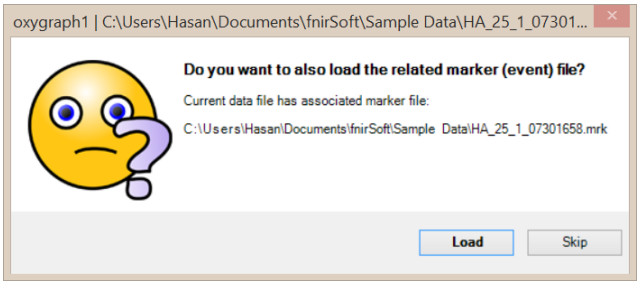
2. In the Oxygraph window, click on the 'Load Data' Button at the lower left corner of the window.



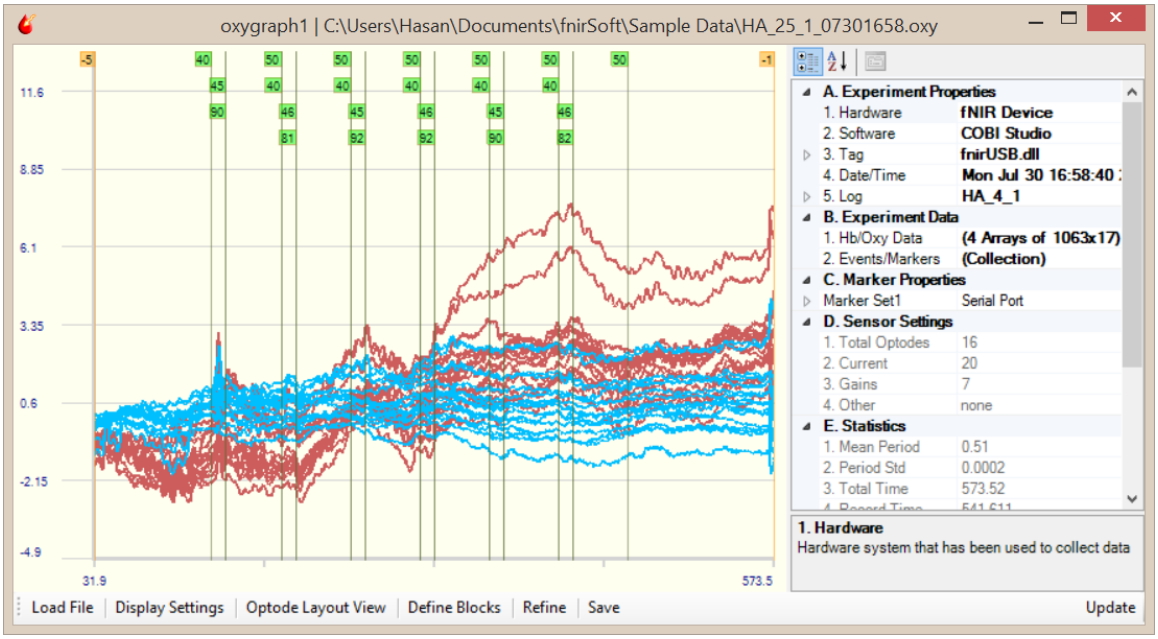
3. A file selection window will appear. COBI Oxy data files (*.oxy) are filtered and shown by default. Oxygraph tool only recognizes also recognizes event marker (*.mrk) files and also the associated experiment log (*.log) files. Marker and log files can be automatically loaded with the main NIR file (see next step). Just select one NIR file and click open button.



4. If the selected file is part of an experiment saved by COBI, it might be accompanied by a marker file for time and event information. Click 'Yes' to also load the associated marker file with the data file.



5. Measurements from all optodes in the selected file will be displayed in the graph. If a marker file was loaded, vertical lines corresponding to the markers will be displayed as well. The '*Properties*' pane on the right hand side provides information about the current data file. **NOTE**: This graph is identical to the calculated-oxygenation from raw light intensity (see the graph in 2.5 step 4).



6. You can apply various filters using filters using Refine tool available on the toolbar. To save and/or export data and apply block analysis, see the next section.

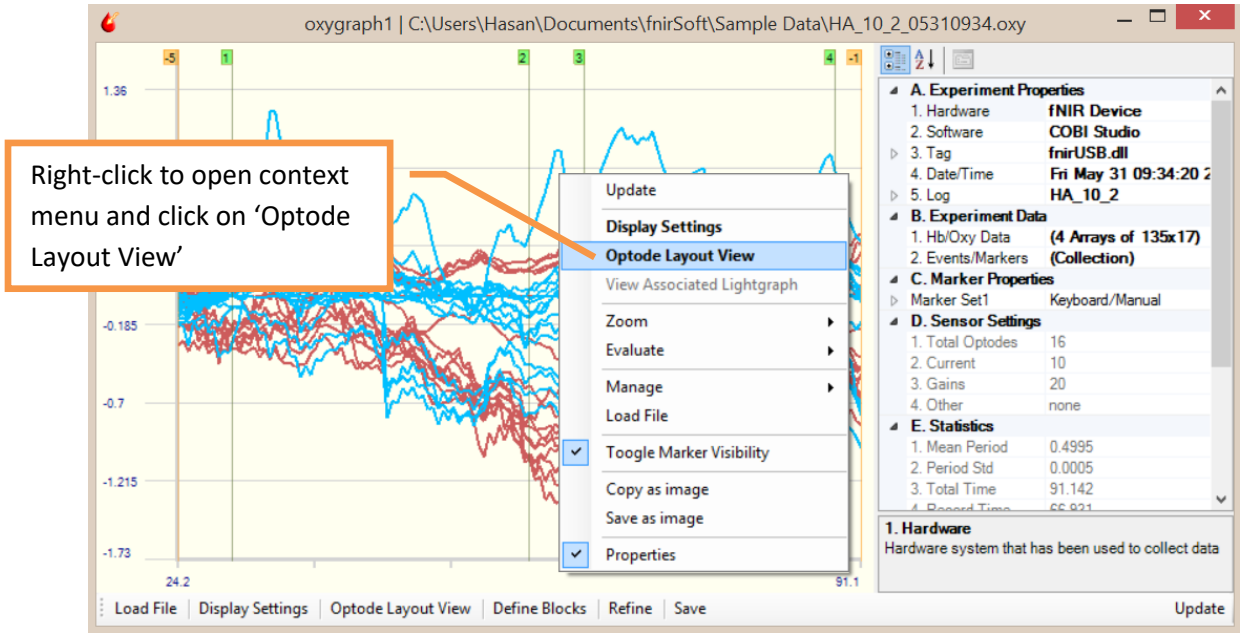
2.7.Preprocessing Raw Hemoglobin Data

The necessary steps for preprocessing may change depending on the current data and experiment protocol. Also, if oxy files are used from raw files, light intensity preprocessing have been skipped entirely, but not recommended. If the data is noisy, it is advised to apply a linear phase, low pass filter that attenuates high frequency components of the signal. Furthermore, certain channels, or time periods may need to be excluded due motion artifact, saturation or noise. fnirSoft can be used to design and apply window-based finite impulse response (FIR) filters.

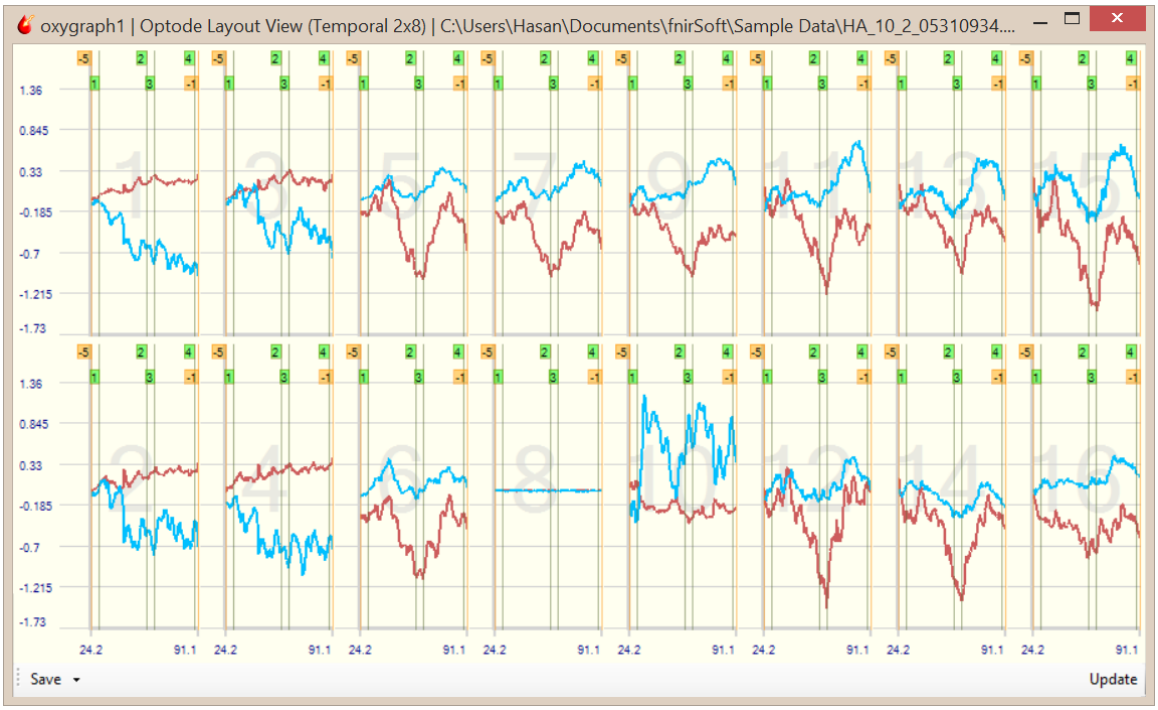
2.7.1. Rejecting Optodes

To exclude all data from an optode, first, go to "Optode Layout View" window and reject or accept the selected optode from the "Evaluate" option at the context-menu (by right-click).

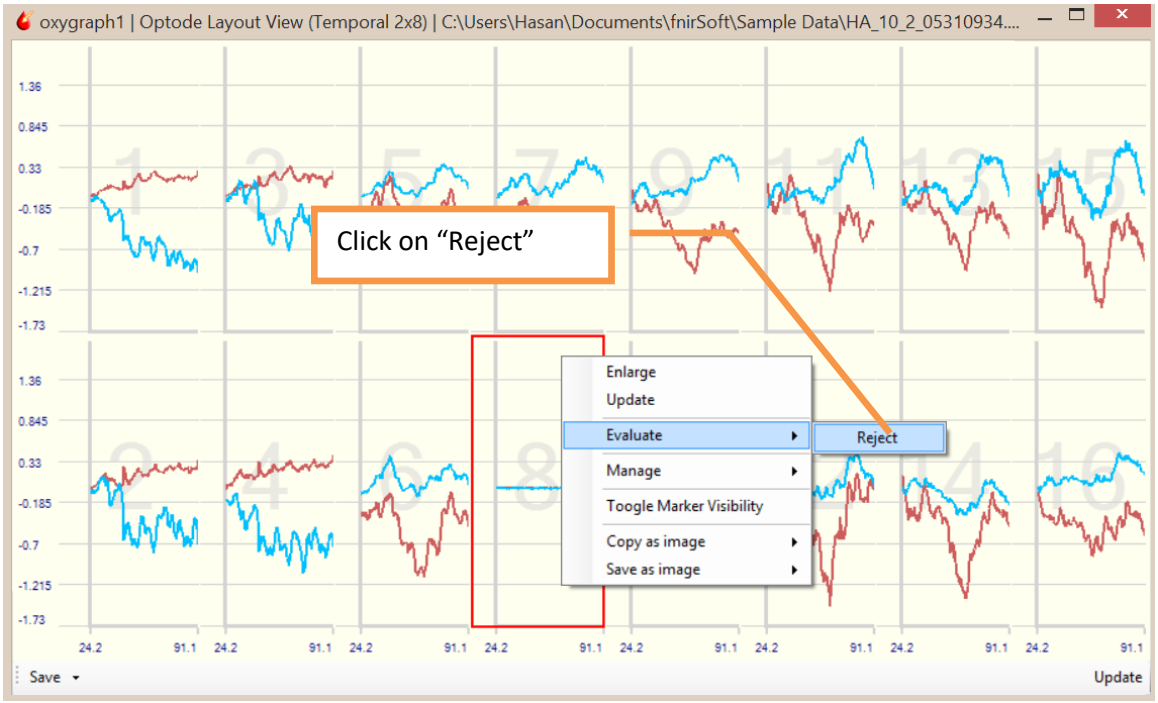
1. Right-click on the Oxygraph, and select "Optode Layout View" from the context menu.



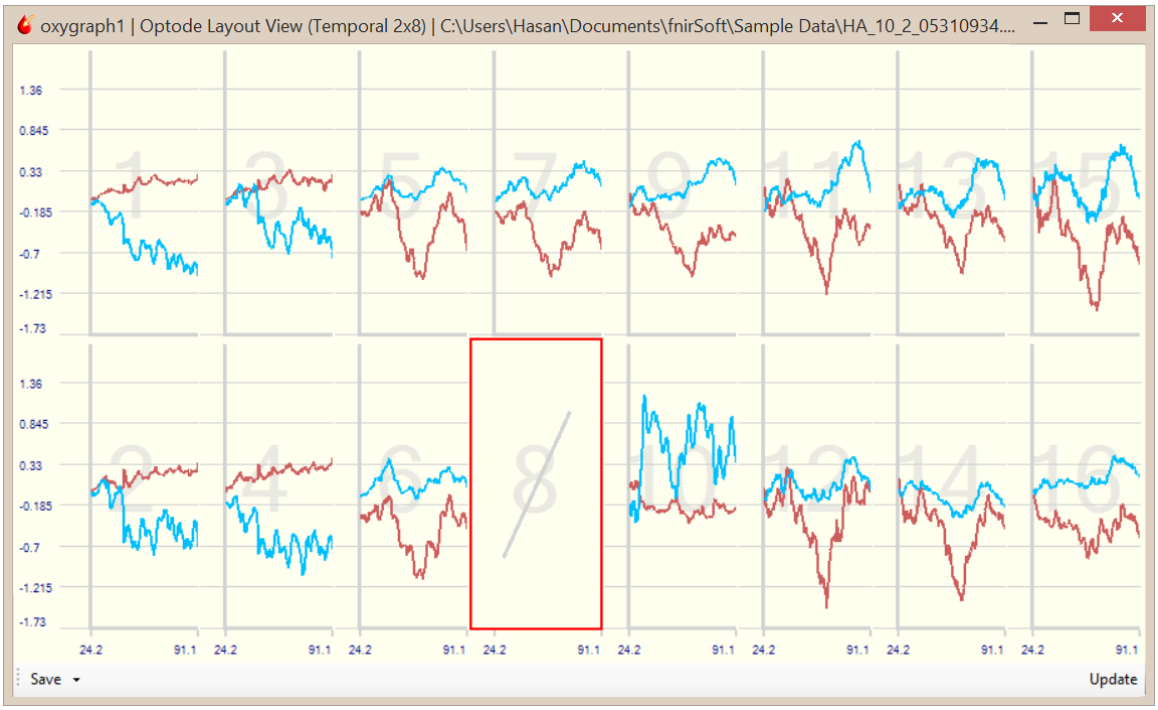
2. A new window will appear as shown below. In this "Optode Layout View", you can toggle hide/view markers (by right clicking graphs and selecting Toggle Marker Visibility).



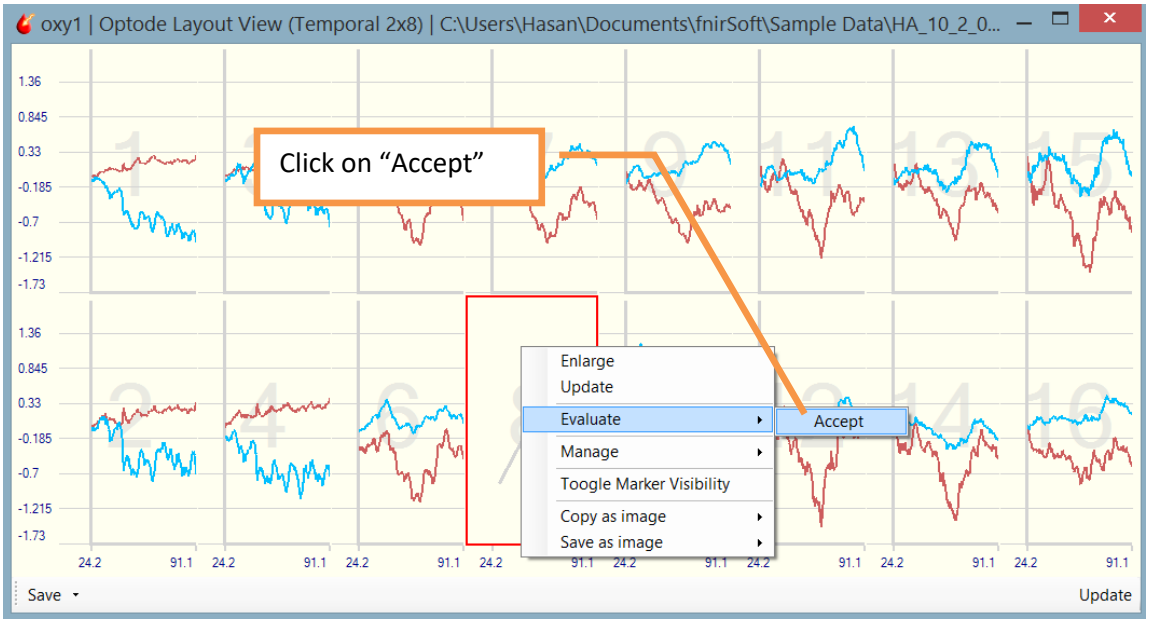
3. In the Optode Layout View, right-click on the graph of the optode you want to reject, and at the context menu, select *Evaluate* > *Reject*. Note that optode numbers are written at the lower left corner of each graph.



4. Once rejected, the optode graph is changed to “null” display as shown below for optode 8:



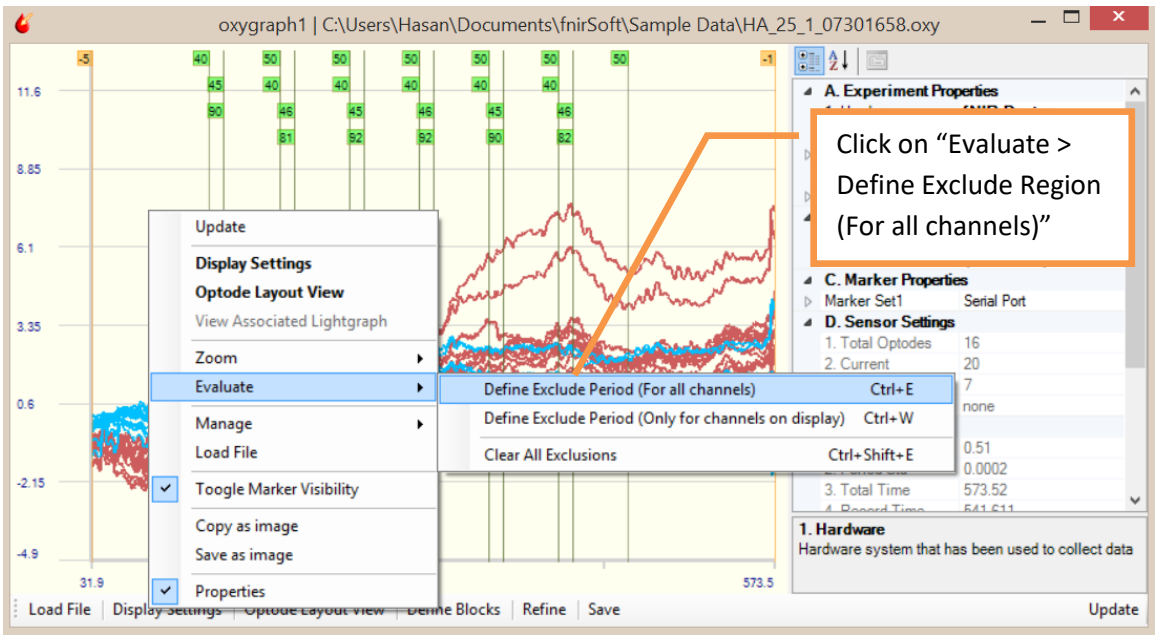
5. To reverse this action, simply right-click on the graph of the rejected optode and *select Evaluate > Accept* from the context menu. The graph will be updated to show the optode data instead of the “null” display.



2.7.2. Defining Exclude Regions

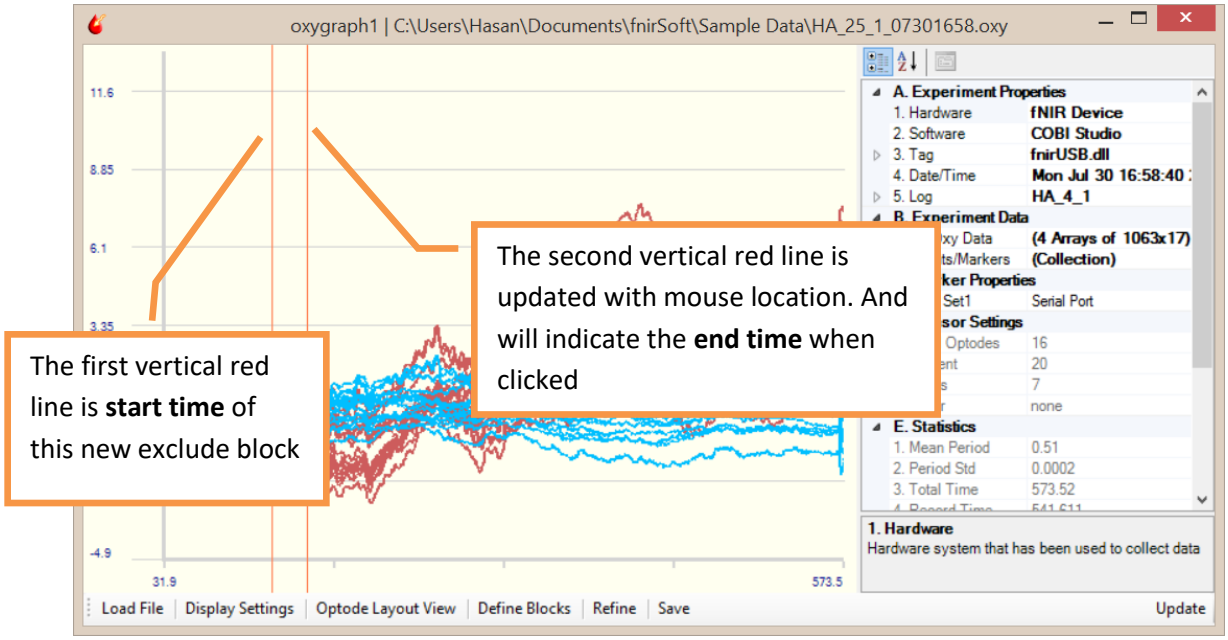
The previous section described how to reject all data for an optode. It is also possible to reject certain time periods within an optode.

7. Right-click on the Oxygraph and from context menu, click on *Evaluate > Define Exclude Period (For all Channels)*. NOTE: For clarity, the following figure is shown with markers hidden (markers can be hidden either through "Display Settings" or right-click context menu.

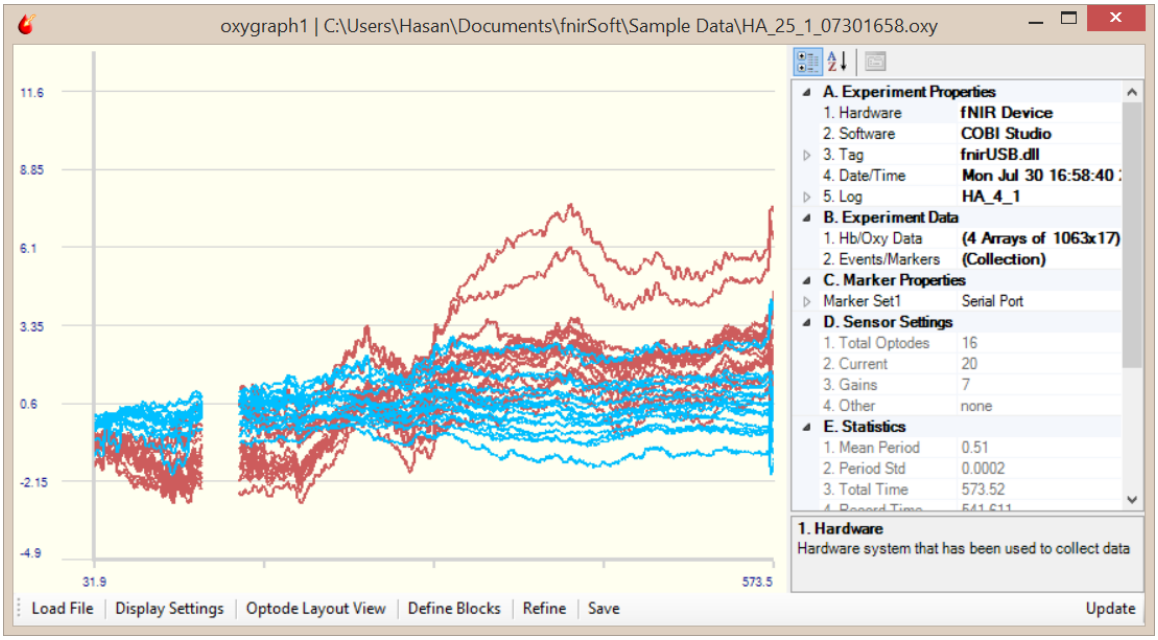


8. Once "Define Exclude Region" is selected, two mouse left-clicks are required to identify **start** and **end** times for the exclude region. After the first click, a vertical red line will appear at the

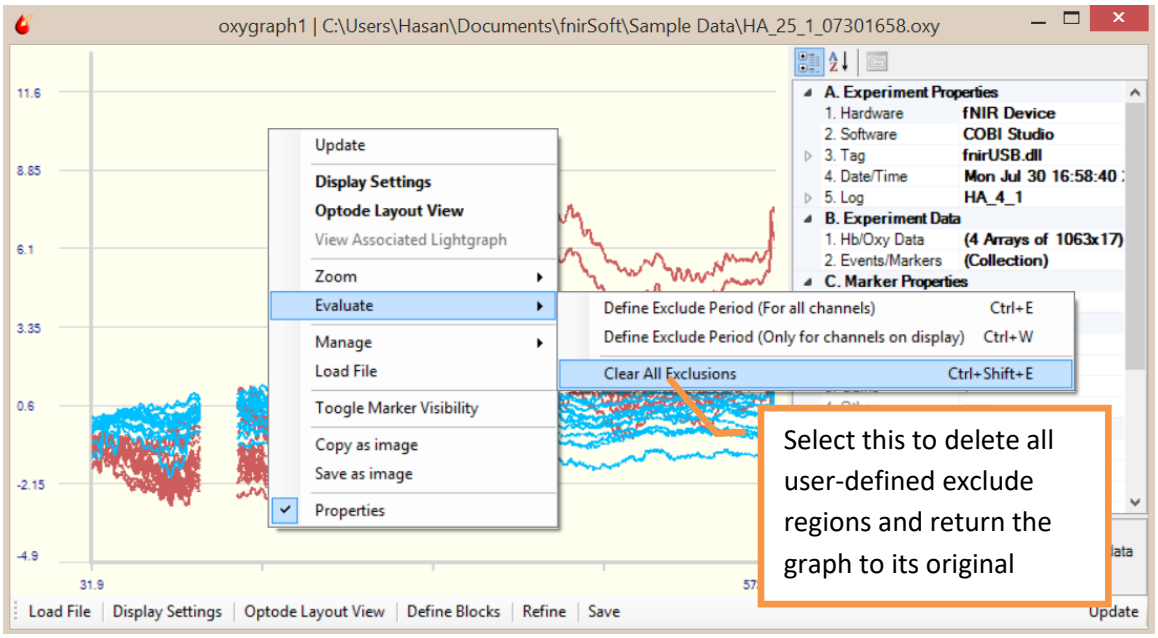
location under the mouse pointer. The next click will identify the end time and finalize the procedure.



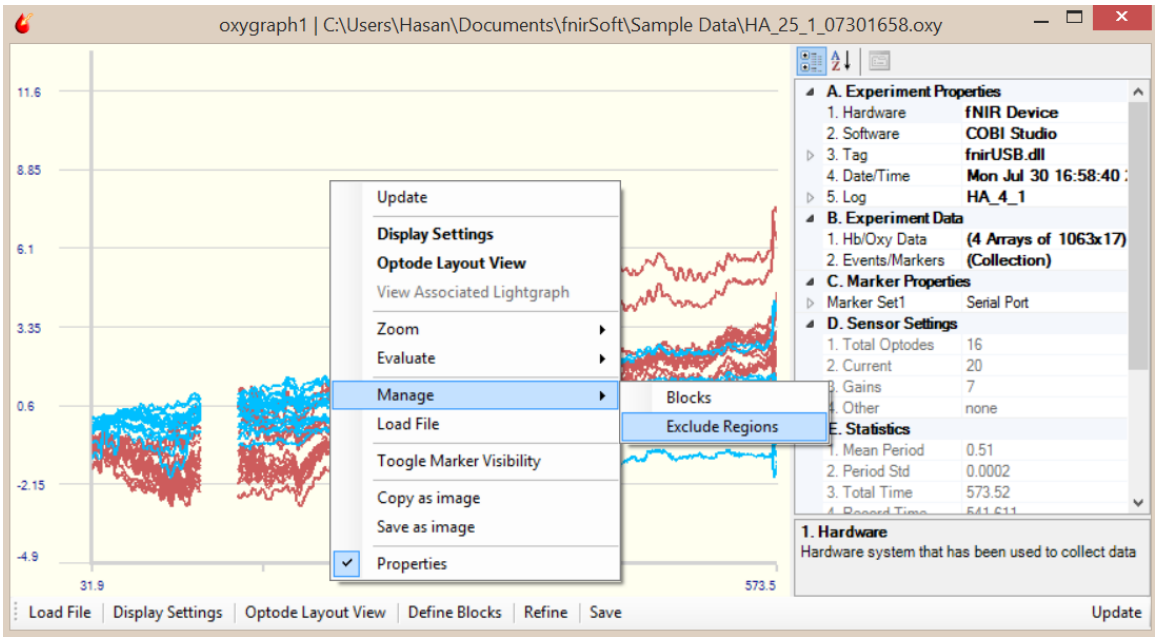
9. Once the start and end times are selected, the graph is immediately updated to exclude the selected region. NOTE: Selecting exclude regions do not delete/remove data. This is just masking the data.



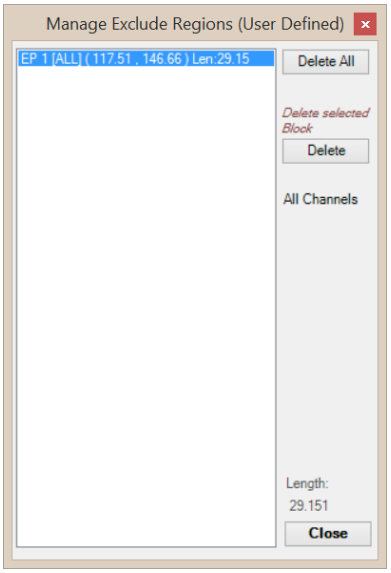
10. All exclude regions can be deleted by right-clicking the Oxygraph and selecting *Evaluate > Clear All Exclude Regions* in the context menu. Selecting this is option will update the graph immediately and all user-defined exclude-regions will be deleted.



11. You can view a list of all defined exclude blocks by right-clicking the Oxygraph and selecting *Manage > Exclude Regions* in the context menu.

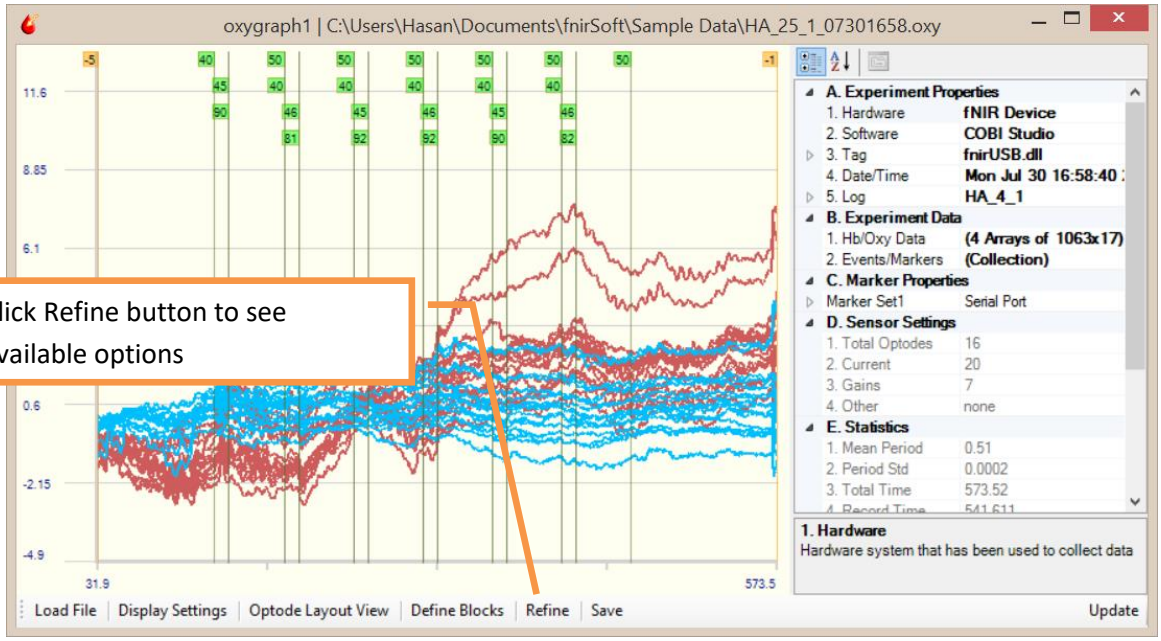


12. This will display the list of all exclude regions. Any or all of them can be deleted.



2.7.3. Applying Low-pass Filter

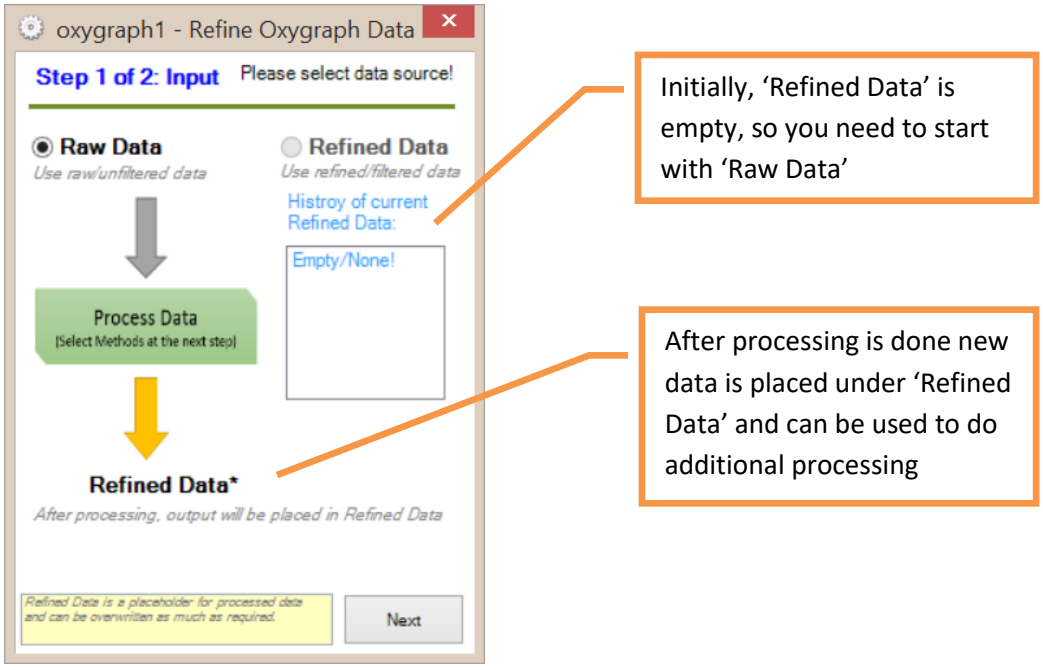
1) To apply a low-pass filter to the noisy data, first, click on the Refine button at the toolbar.



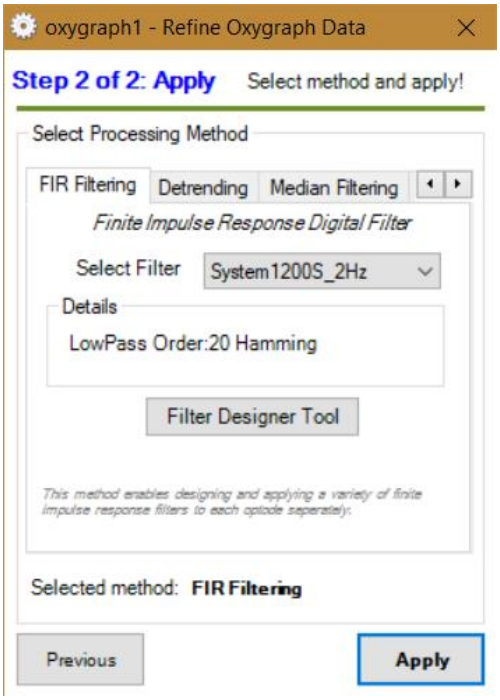
2) A popup windows will appear that displays the first step: selection of input. Either 'Raw Data' or 'Refined Data' can be selected as input for processing.

[Note: At first, only 'Raw Data' is available and 'Refined Data' is empty (as there's no processing done). After processing, output data is placed in 'Refined Data'.]

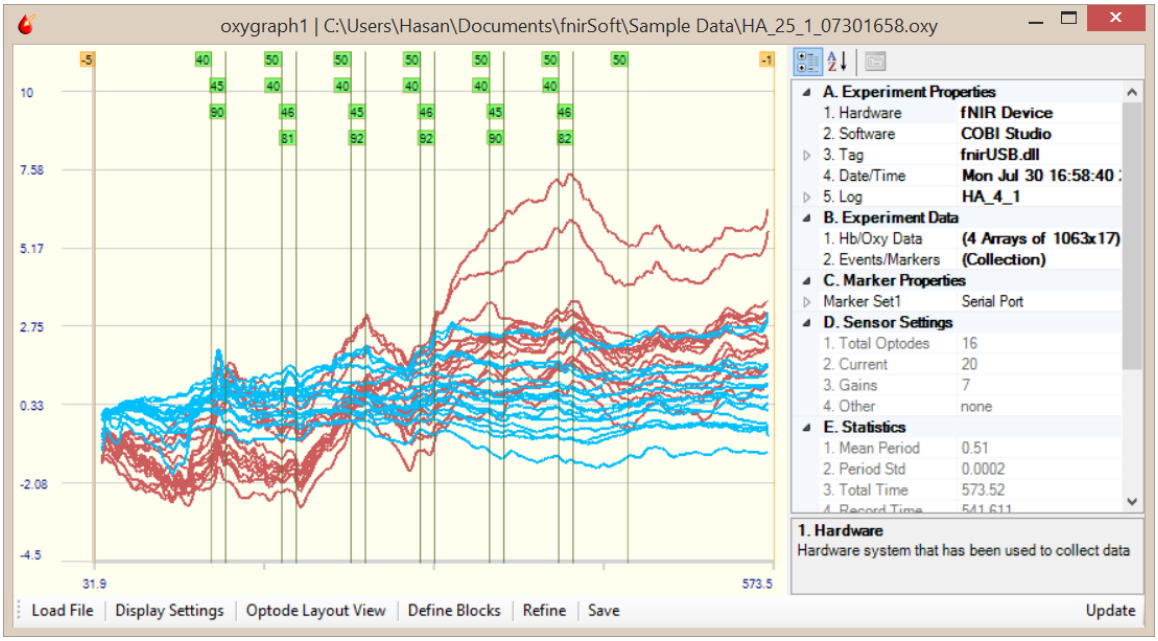
Just keep default selections and click Next button to go to step 2.



3) Finally at 'Step 2', method to be applied is selected. By default FIR Filtering tab and also '*System1200S_2Hz*' filter is selected. This default filter is a low pass FIR filter with an order of 20. Just keep default selections and click Next button to apply the filter. (Note that available processing methods are different in Oxygraph then in Lightgraph).



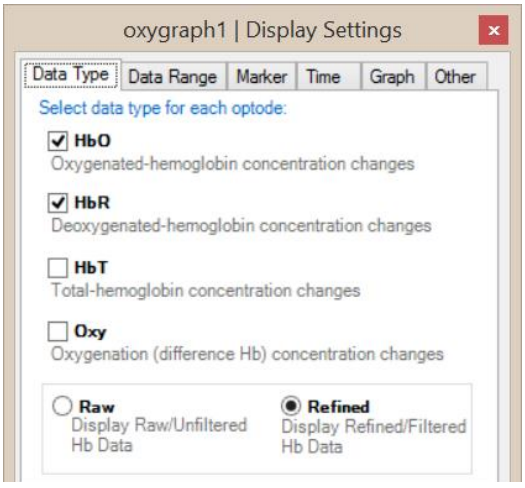
4) The filter will be applied, and the graph will be updated immediately, as shown below:



5) Filtered data do not replace original (raw/unfiltered) data. Both are accessible with functions to be exported or used for oxygenation calculation.

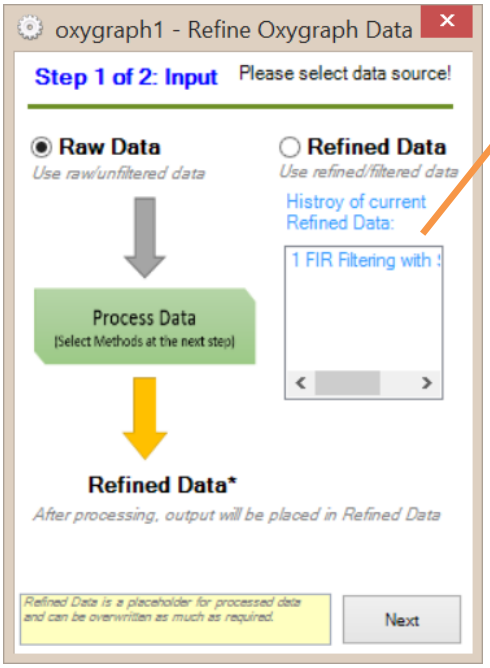
TIP

To return to viewing raw/unfiltered data, right-click on the graph and select "Display Settings". In the pop-up dialog, under the "Data Type" tab, select the "**Raw**" option and click the "**Update**" button.



6) Also, now that a filter applied, 'Refine Data' is available again. Click on 'Refine' button on Oxygraph that will step 1 again as below. This time, 'Refine Data' is available and can be clicked.

And, the history list shows it contains 'FIR' filtered version of 'raw data'. If more than one operations are performed, they will be listed here.



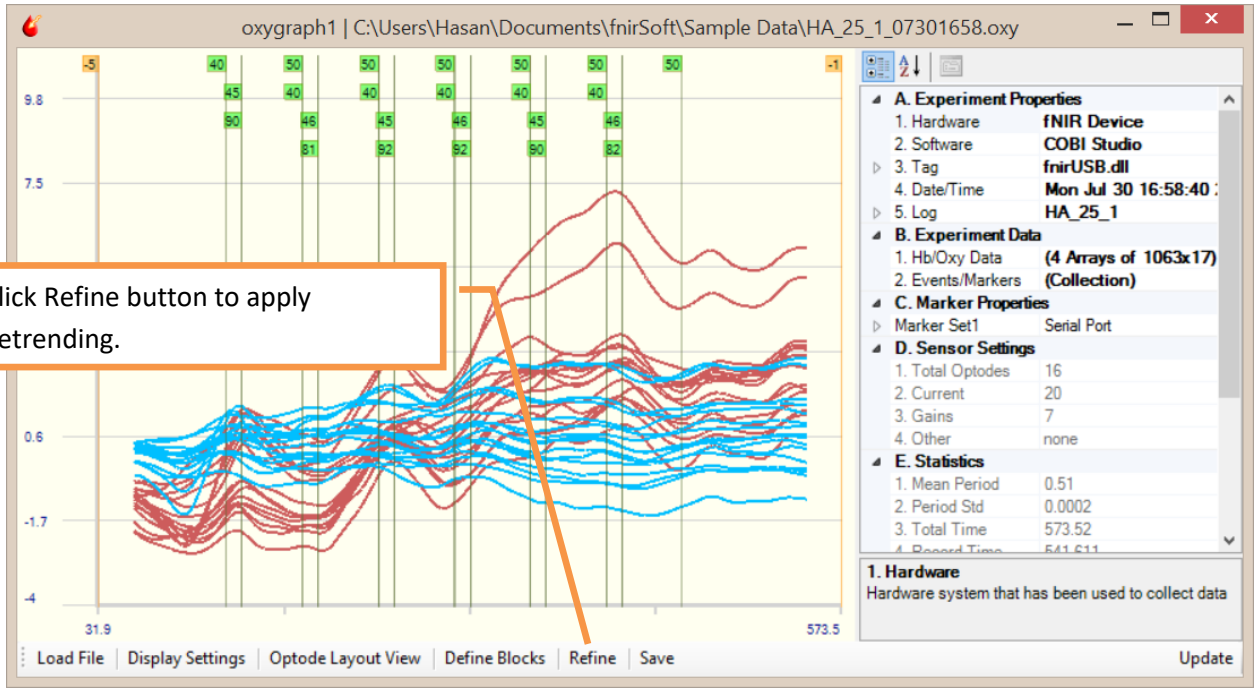
History list of '*Refined Data*' contains FIR filtering.

This contains more than one item if '*Refined Data*' is selected again for another processing.

NOTE: When '*Raw data*' is selected, any previous value in '*Refined data*' is deleted and new processed data is loaded.

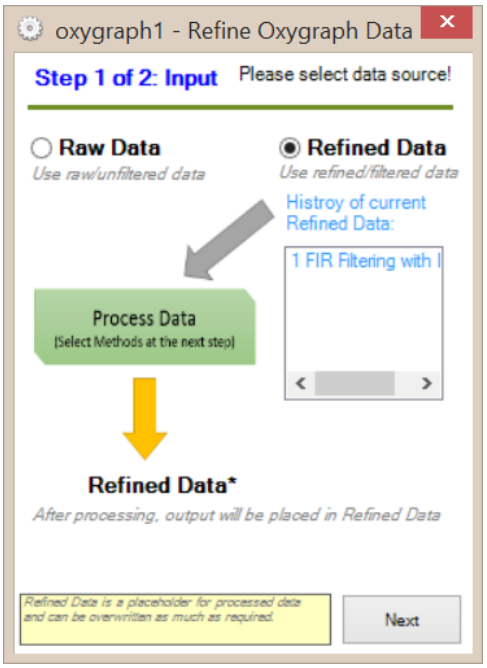
2.7.4. Applying Detrending

1) Signal drifts global trends can be automatically removed by linear detrending. See Ayaz et. al. [7] for more information about the algorithm. To apply, click "Refine" button at the toolbar. In this example, FIR filtered data (as described in previous section but using another filter of size 100, and cutoff 0.03 created in filter designer tool) is used. Detrending will applied to refined data (filtered data).

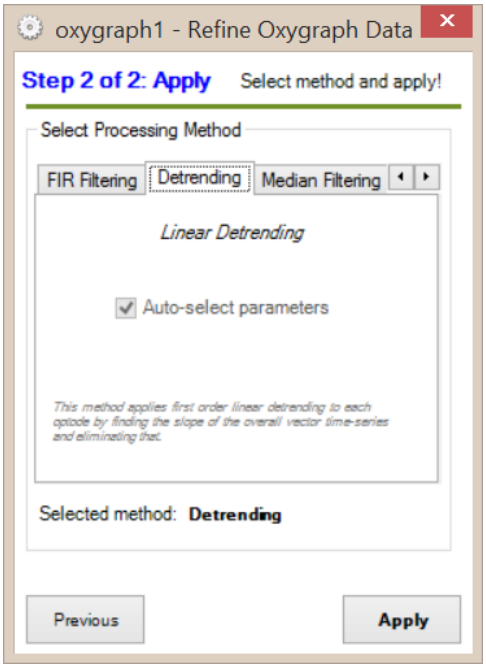


2) Refine window will appear, as below. Select 'Refined Data' and click next to proceed.

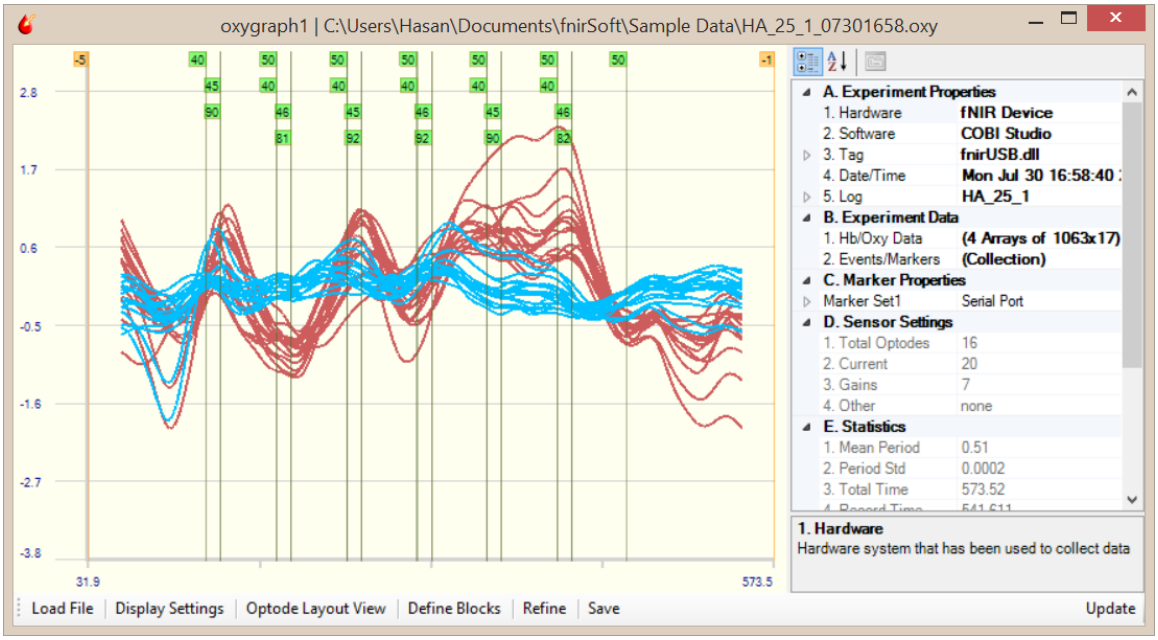
Note that if FIR filtered was not applied, 'Refined Data' option here will be disabled as there won't be any processed data.



3) Click on 'Detrending' tab to select this method. Configuration options are within this tab and allow changing algorithm parameters. Just keep default settings. Click the "Apply" button to accept current parameters and apply the algorithm.



4) Detrending will be applied to each optode separately, and global trend will be removed automatically. Compare the following graph with the one in step 1 above. Also, see the command output pane (at the main window) for a brief report. The graph will be updated immediately.

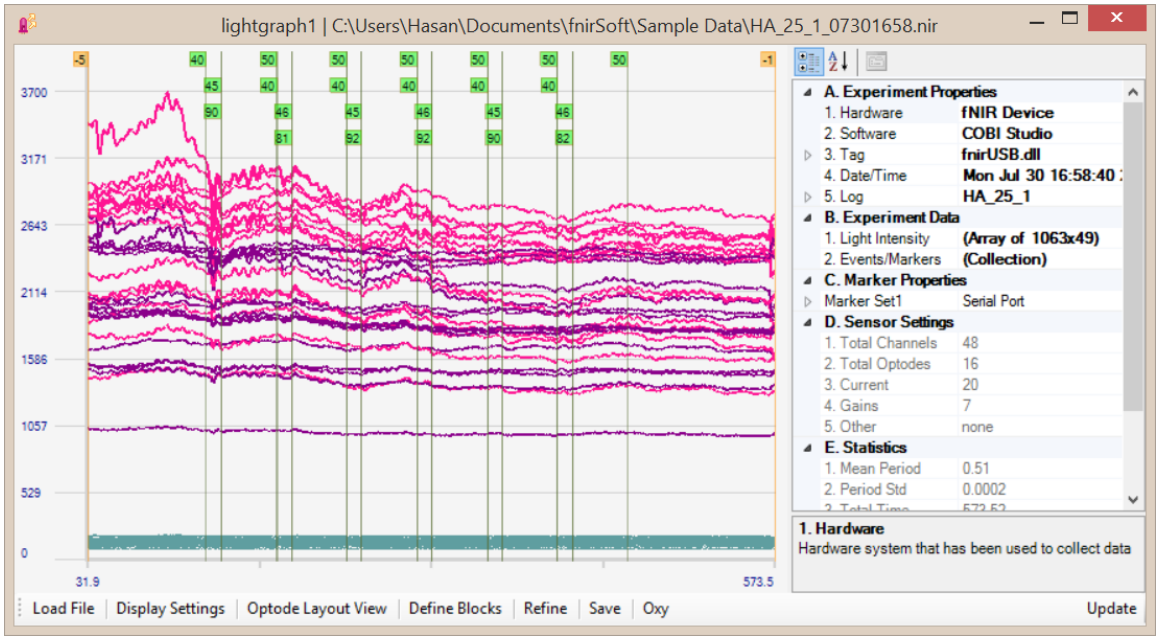


3. Block Analysis

This section describes the most common analysis approach. Here, a "block" refers to an epoch/segment of data, defined by a start time and end time; and contains all channels (i.e. with full-forehead sensor: 48 for raw data blocks and 16 for oxygenation data blocks).

Block analysis allows comparing data periods that corresponds to different task conditions or stimuli effects (pre/post events), etc. For example, blocks before and after events can be compared across trials, within subjects or across groups. The remainder of this section describes various ways to define blocks using the "Define Blocks" tool, available in both Lightgraph and Oxygraph windows. Once blocks are defined, block data or block times (start/end) can be saved to Dataspace and further processing or can be exported to text or other output files using the Export Tool.

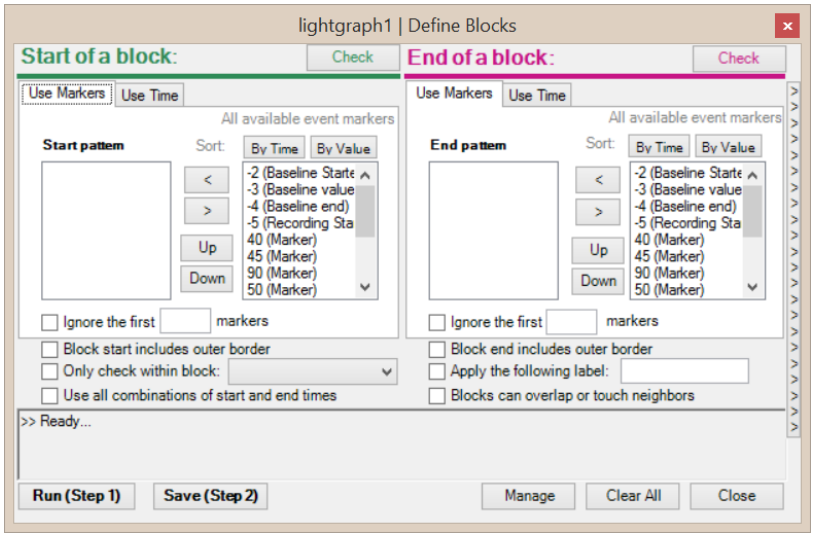
1) The following data file and event file are loaded for the reminder of the section:



2) There are two main colored markers (vertical lines) available: Green colored markers were recorded from serial port in this case (as indicated on the right-hand side properties pane) are 40, 45, 46, 50, 81, 82, 90 and 92, each appearing various times. Orange colored markers are system events and includes -5 (Recording Started) and -1 (Device Stopped). Actually there are additional system markers such as -2 for baseline start and -4 for baseline end. However, these markers are not active and visible as they all are earlier then marker -5 that indicates start of recording.

3.1.Defining Blocks

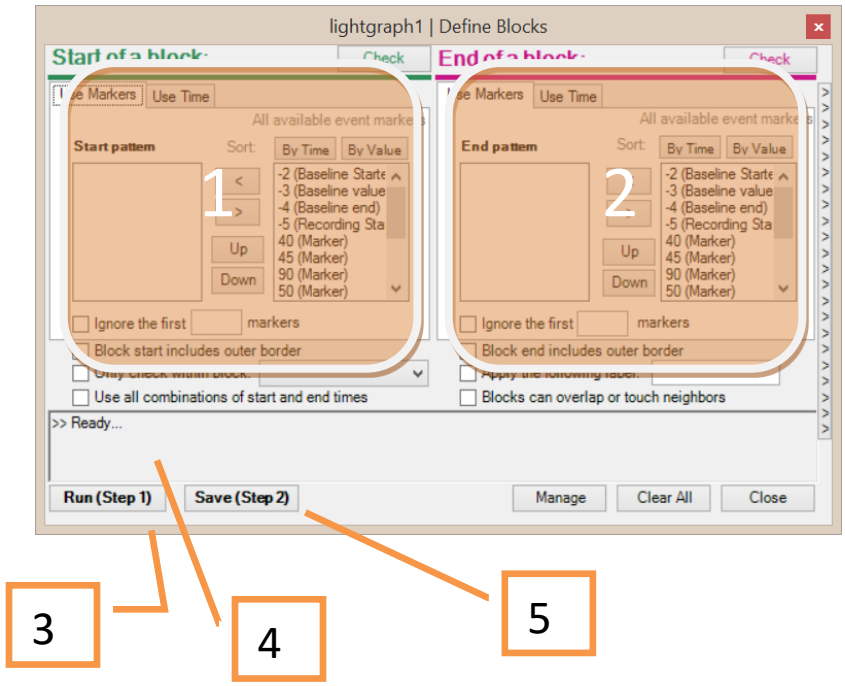
The "Define Blocks" tool is available in both the Lightgraph and Oxygraph windows by clicking the "Define Blocks" button on the toolbar. The following window will appear, allowing you to define blocks separately by using marker(s), absolute time or relative time.



There are 5 steps in creating blocks. Multiple blocks or a single block can be created with each run. The steps are as follows; details of each step are provided in the next sections.

1) Define "**Start of a block**"
2) Define "**End of a block**"
3) **Run** current settings
4) **See the report** at the output pane.
5) **Save** the new found blocks to current list

TIP
To see current list of blocks, click **manage** button. A new window with list of blocks will appear.

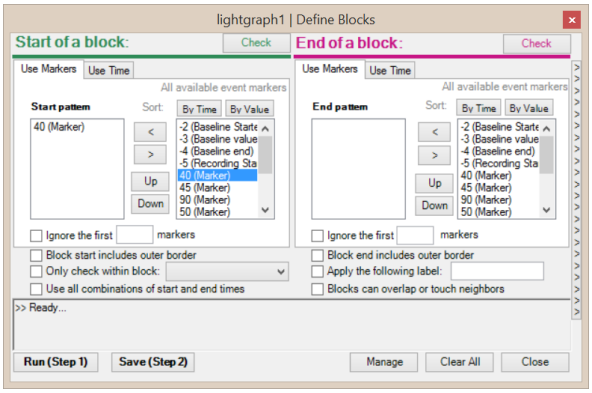


3.1.1. Defining Blocks using Markers

1) In this section, we will create two types of blocks: one type is between markers ‘40’ and ‘45’, and another between the ‘45’ marker and the ‘50’ marker.

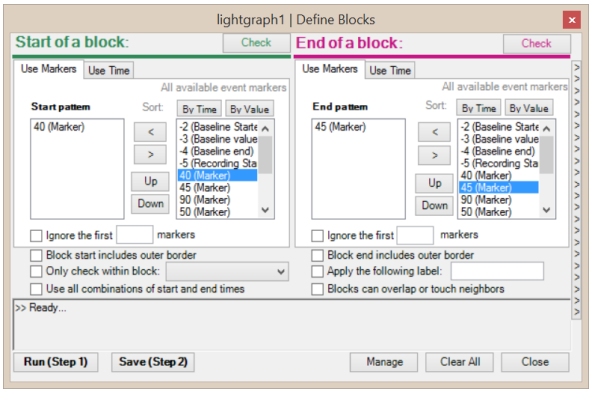
2) Both “Start of a block” and “End of a block” sections has two lists: one empty and the other one with all available marker types as source. Transfer any type and number of markers from these lists on the right to the left to create a pattern that specifies start and end of blocks.

3) For the first type:
   a. Load ‘HA_25_1_07301658.nir’ sample file and accept to load its associated marker file to a Lightgraph window. Open ‘Define Blocks’ tool. On the “Start of a block” side: On the right list, click to select the ‘40 (Marker)’ item and then the ‘<’ button to transfer it to the left-most list.

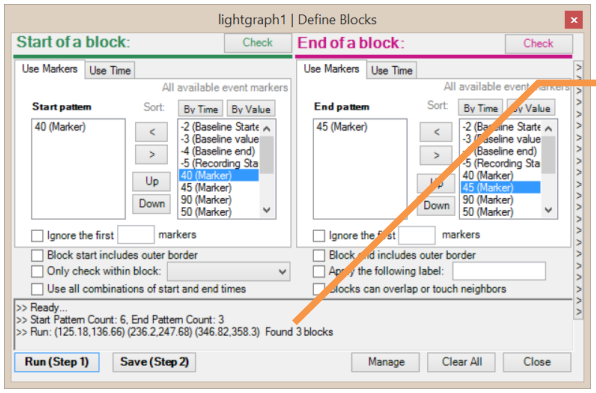


TIP
Double-clicking on list items transfer them to the next list.

   b. On the “End of a block” side: On the right list, click on the ‘45 (Marker)’ and then the ‘<’ button to transfer it to the left-most list. The window should appear as follows:

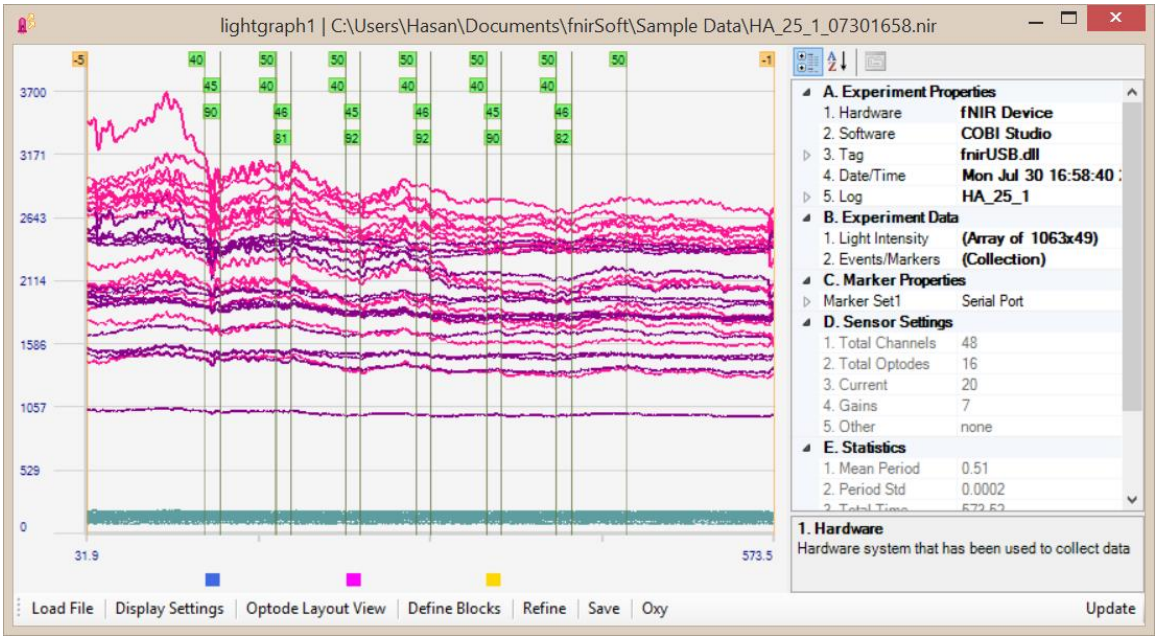


   c. Now that we have identified the start and end of the block, click the ‘Run (Step 1)’ button at the bottom of the window. fnirSoft will search the data for all blocks that can be defined as beginning and ending marker patterns. All found blocks will be listed in the text box just above the buttons, as indicated below:



Indicates how many blocks have been found with the current settings. *Start and end times for each found block are within parentheses.*

d. Click the "Save (Step 2)" button at the bottom of the window to save the blocks. In this example, three blocks were found. On the Lightgraph window, the blocks will be shown by a colored (in this case blue, pink and yellow) bars drawn between the start and end times, just below the X axis.



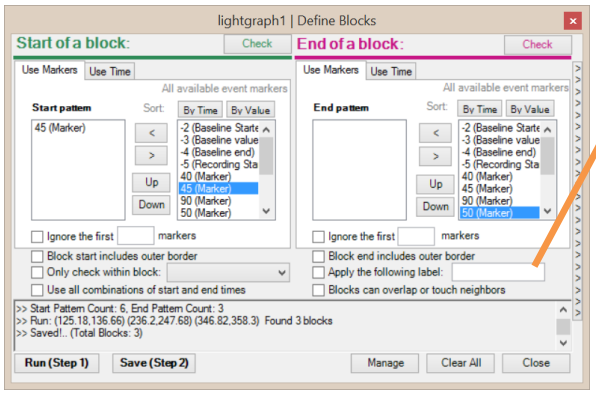
TIP

You can apply labels (that are simply strings) to tag blocks you have created. To do that, add any string (separate by comma for multiple labels) to "Apply following label" field in the define blocks dialog (see next item for more info).

If you use # within the label, block index numbers will be added to the label. For example, with "sample#" temple, and if 3 blocks are created, they will have "sample1", "sample2" and "sample3".

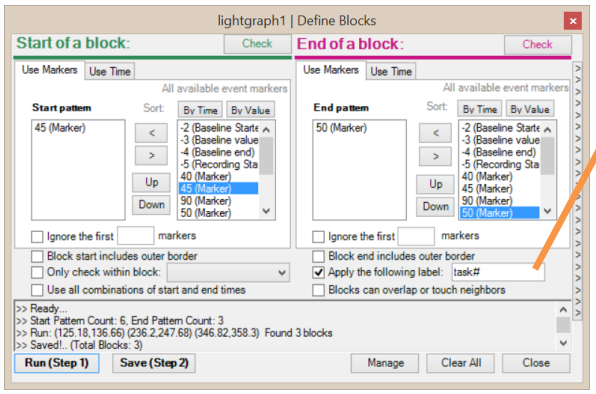
4) For the second type:

a. At the “Start of a block” side: On the right list, click on ‘45 (Marker)’ and ‘<’ button to transfer it to the left-most list.



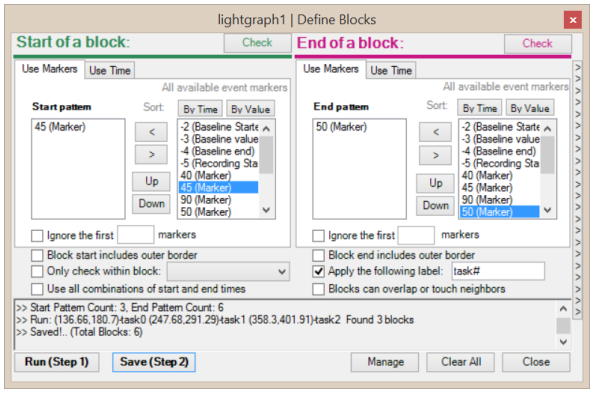
Any text entered here will be used as label when new blocks are identified using ‘Run’ button and then saved using ‘Save’ button.

b. At the “end of a block” side: On the right list, click on ‘50 (Marker)’ and ‘<’ button to transfer it to the left-most list. Also, type ‘task#’ next to the

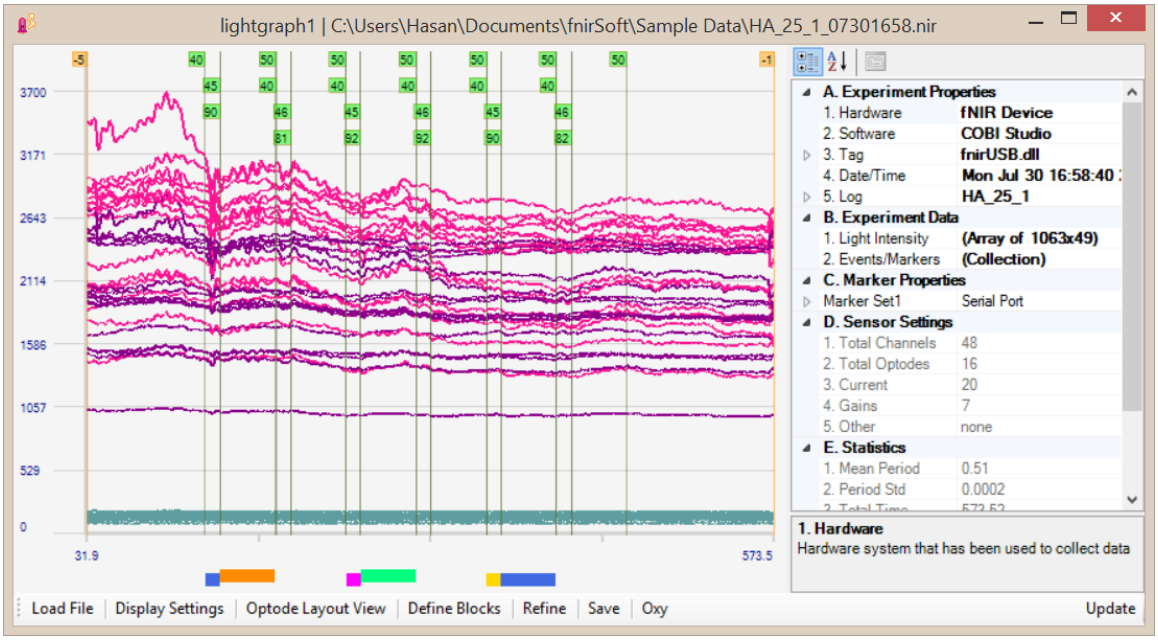


Enter ‘task#’ here to label each new block. The ‘#’ sign will be replaced by the block index value.

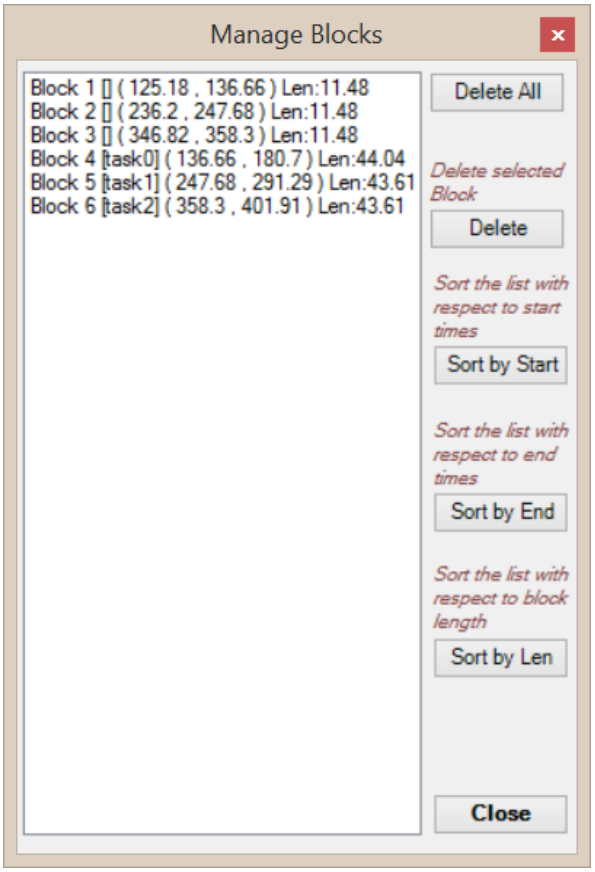
c. Click ‘Run’ button. This will use current settings to identify any available blocks. The output pane indicates 3 new block found.



d. Click ‘Save’ button to add this new block to the available blocks list. The Lightgraph window will be updated immediately to show the all 6 blocks (3 short blocks from first execution, and 3 long blocks from second execution).



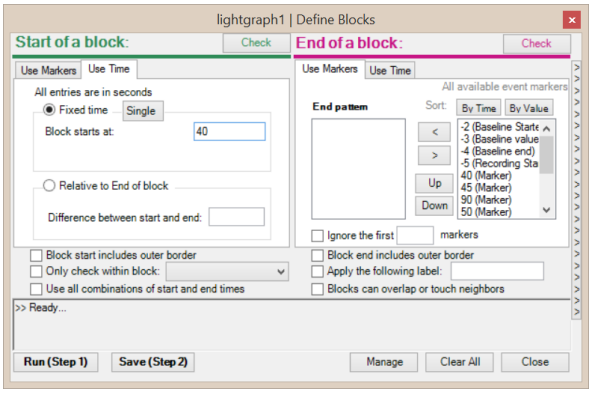
5) All currently available blocks can be listed by right clicking on the graph, and from the context-menu, selecting *Manage > Blocks*. Here, it displays all 6 blocks in order of creation. They can be sorted in order of their start or end times. Any one of them can be deleted and the whole list can be re-sorted. Note that the last three blocks contain a label (task0, task1 and task2).



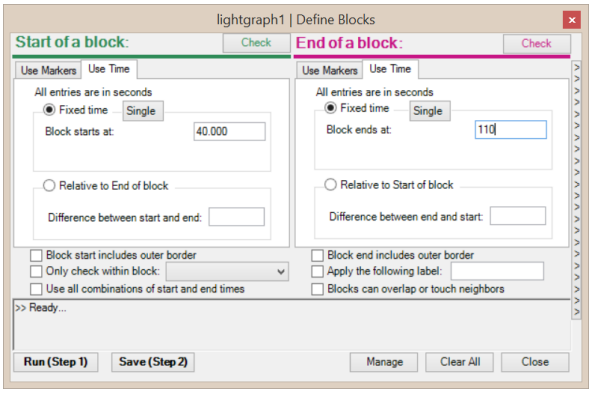
3.1.2. Define Blocks using Time

1) In this section, we will create two blocks, the first one with start and end times as 40 sec and 110 sec. And the second block, with 460 sec and 570 sec.

2) For the first block:
   a. Load 'HA_25_1_07301658.nir' sample file and accept to load its associated marker file to a Lightgraph window. Open 'Define Blocks' tool. At the "start of a block" side: click on "Use Time" Tab. Under fixed time, enter 40 for 'block starts at' field.

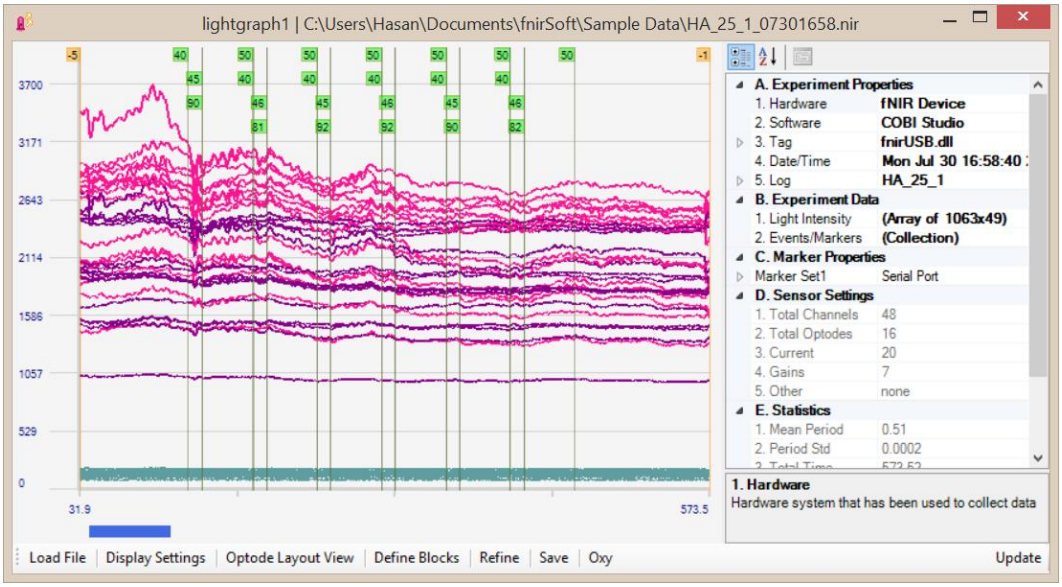


   b. At the "End of block" side, click on "Use Time" tab and enter 110 at the within fixed time group, for "block ends at" as shown below.



   c. Click "Run (Step 1)" button to apply these settings to identify blocks. Pane will indicate that it found 1 block.

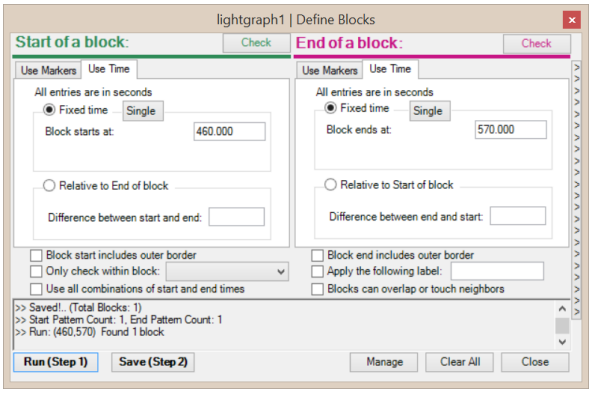
   d. Click on "Save (Step 2)" button to add this block to current block list. The Lightgraph window will be updated immediately to visualize the block.



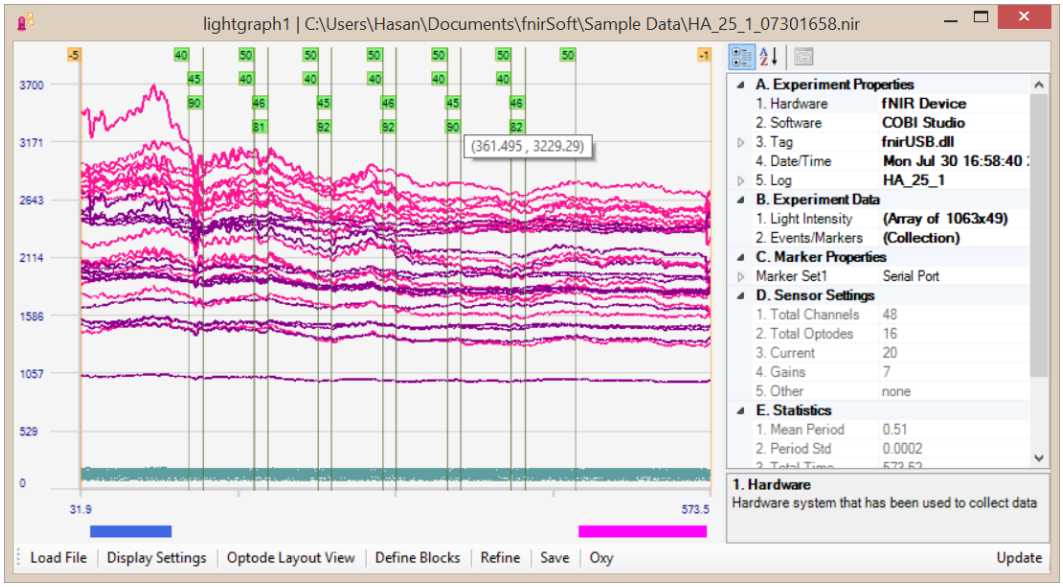
3) For the second block:
   a. At the “start of a block” side: under “Use Time” Tab. Under fixed time group, enter 460 for ‘block starts at’ field.

   b. At the “end of a block” side: under “Use Time” Tab. Under fixed time group, enter 570 for ‘block ends at’ field.

   c. Click “Run (Step 1)” button to apply these settings to identify blocks. Pane will indicate that it found 1 new block.



   d. Click “Save (Step 2)” button to add this new block to current block list.

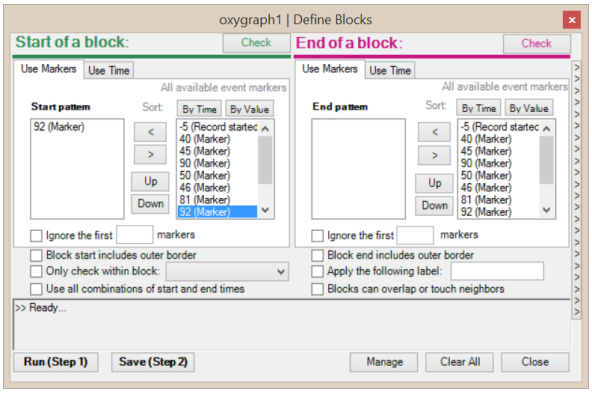


4) All blocks can be removed by the “Clear All” button at the “Define Blocks” tool window. Or, by right-clicking the graph and from the context menu, selecting, *Manage>Blocks* and “Delete All” at the new window.

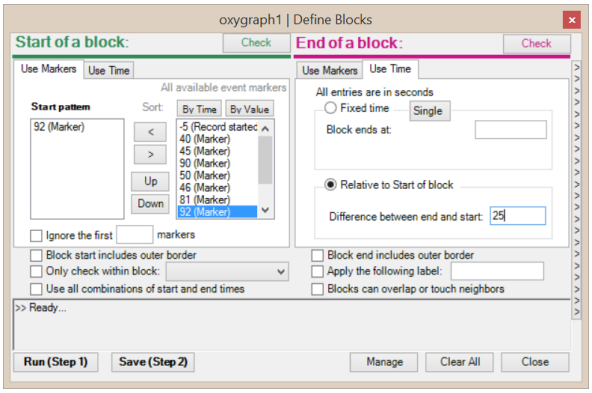
3.1.3. Defining Blocks using Markers and Time

1) In this section, we will create two blocks that start with marker ‘92’ and ends 25 seconds after that.

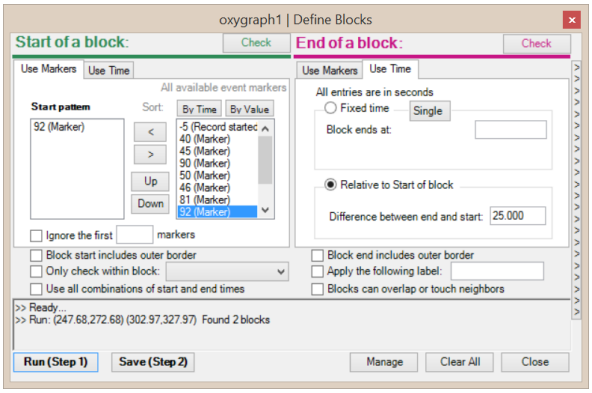
2) Load ‘HA_25_1_07301658.oxy’ sample file and accept to load its associated marker file to an Oxygraph window. Open ‘Define Blocks’ tool. At the “Start of a block” side, at the “Use Marker” tab, add only one marker ‘92’ to the list as shown below.



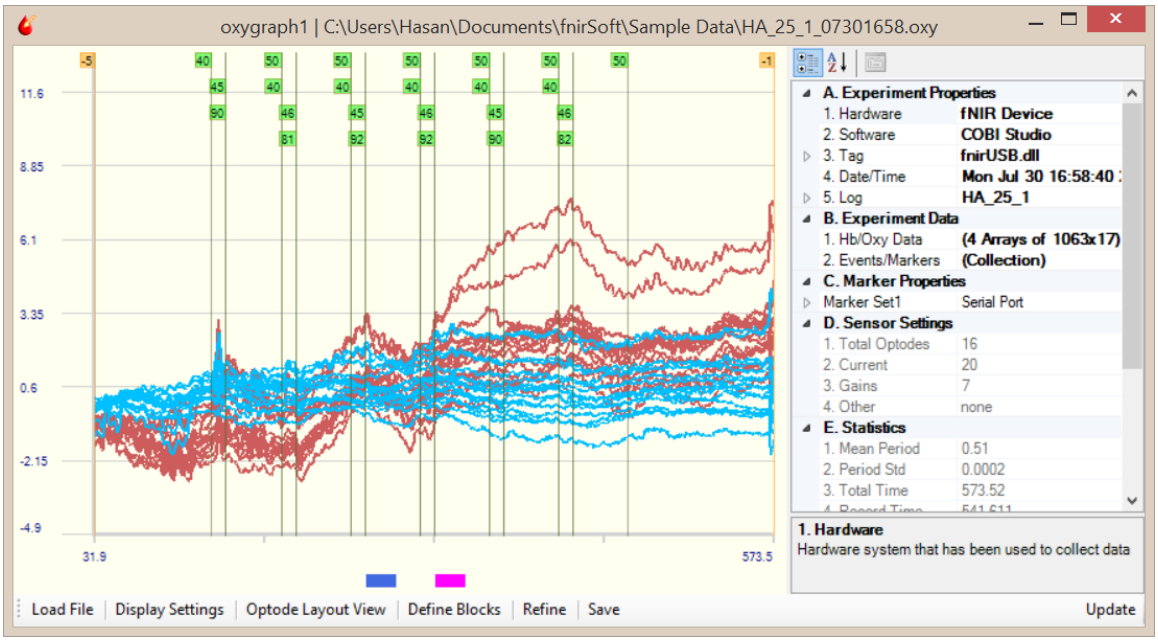
3) At the “End of a block” side, click on “Use Time” tab, within “Relative to Start of block” group, enter 25 for ‘difference between end and start’ field.



4) Click on “Run (Step 1)” button to use these settings to identify blocks. Output pane will indicate 2 blocks are found and their start & end times.



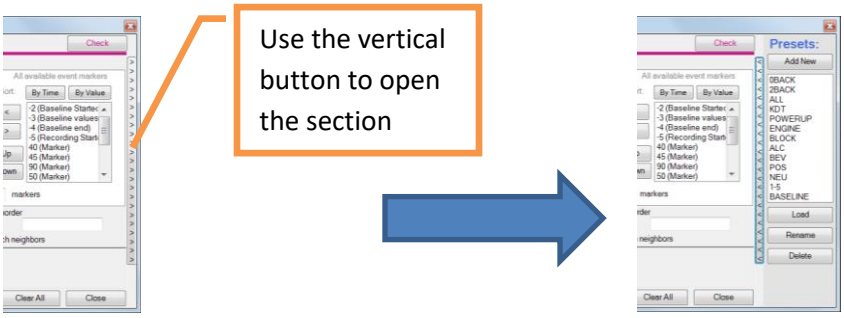
5) Click “Save (Step 2)” button to add these blocks to current blocks list. The graph will be updated immediately to visualize them. The two blocks are have identical length and start with a marker ‘92’.



TIP

Use **Presets** in 'Define Blocks' window to store and re-enter all patterns later at one step.

1) To do that, first open the 'Preset' section on the 'Define Blocks' window:



2) Use 'Add New' button at the top to store all current settings (start and end pattern, labels, etc.) by entering a new string as name for that preset. It will be added to the list.
3) To recall (enter the information), just click on one of the presets. All of its settings will be applied to the current window. Note that, if current data file does not contain some of the markers, each will generate a warning message.

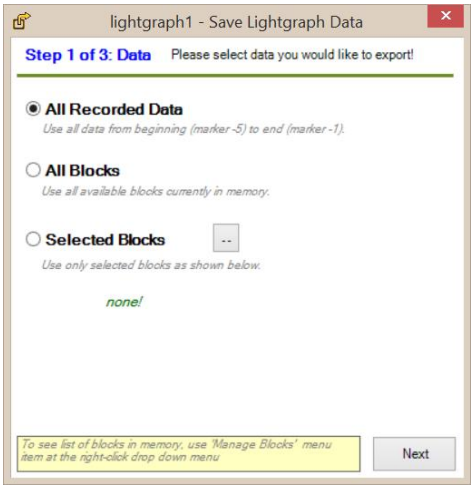
3.2.Using Blocks

This section describes how to utilize the data or time information in defined blocks. In a typical experimental data analysis, block data from many task conditions and subjects are acquired after pre-processing steps are applied (refined data), and next, feature extraction or data reduction is applied to each and aggregate list from all conditions or subjects are formed. All these steps can be done in Dataspace tool which will be described in the next chapter. This section describes procedures to save block data to Dataspace or to external files. Also, data in Dataspace can be saved to external files and can also be processed through scripting.

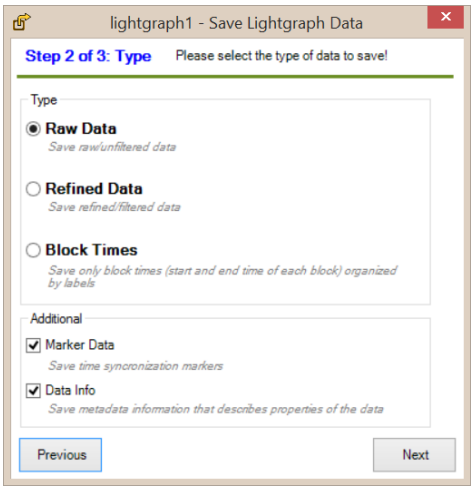
This section uses the raw data in Lightgraph for illustration, but the same interface and options are available for the Oxygraph.

3.2.1. Saving Blocks as Variables in Dataspace

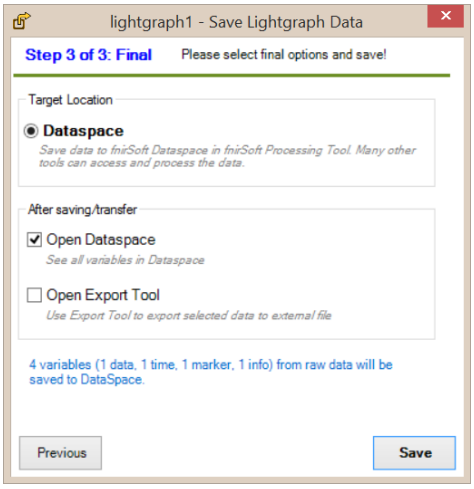
1) Load 'HA_25_1_07301658.nir' sample file to a Lightgraph. Click the "Save" button on the toolbar. A popup dialog appears and first step is to identify what to save. Select "All Recorded Data", this option saves all data as a single block from marker (-5) to marker (-1).



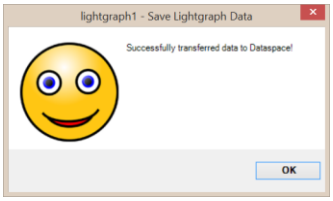
2) In step 2, select type of data to be save. By default, raw data (unfiltered) original data loaded from file is selected. If processing is applied, refined data is also available. Block times option just saves start and end times for blocks.



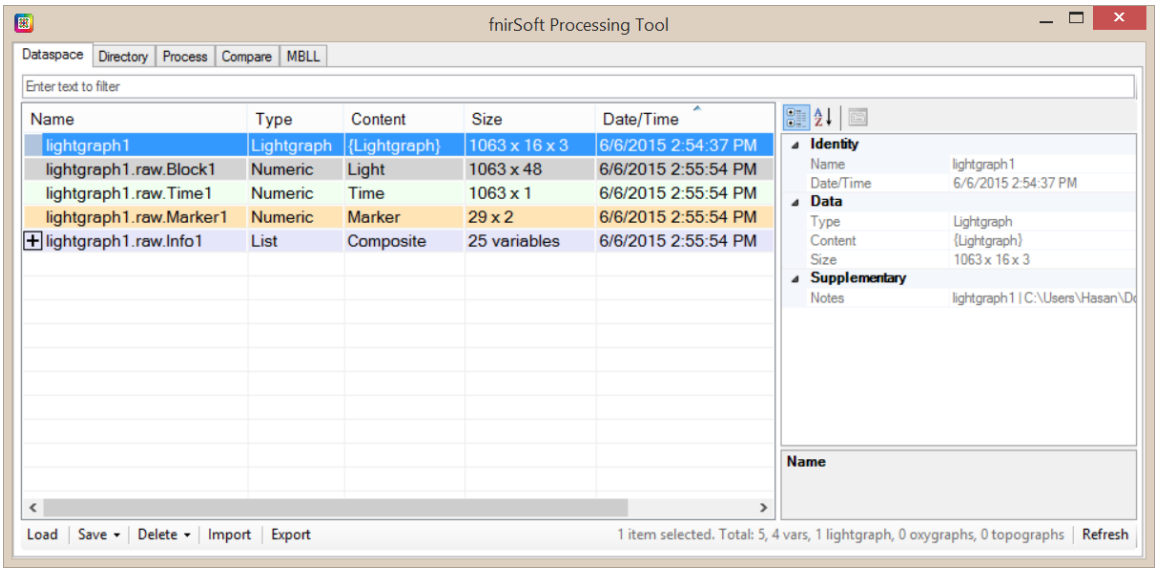
3) Finally, in step 3, outcome is previewed (how many blocks will be generated) and if any post-saving actions should be triggered such as opening Dataspace window. Keep default options and hit 'Save' button to actually save the data to Dataspace.



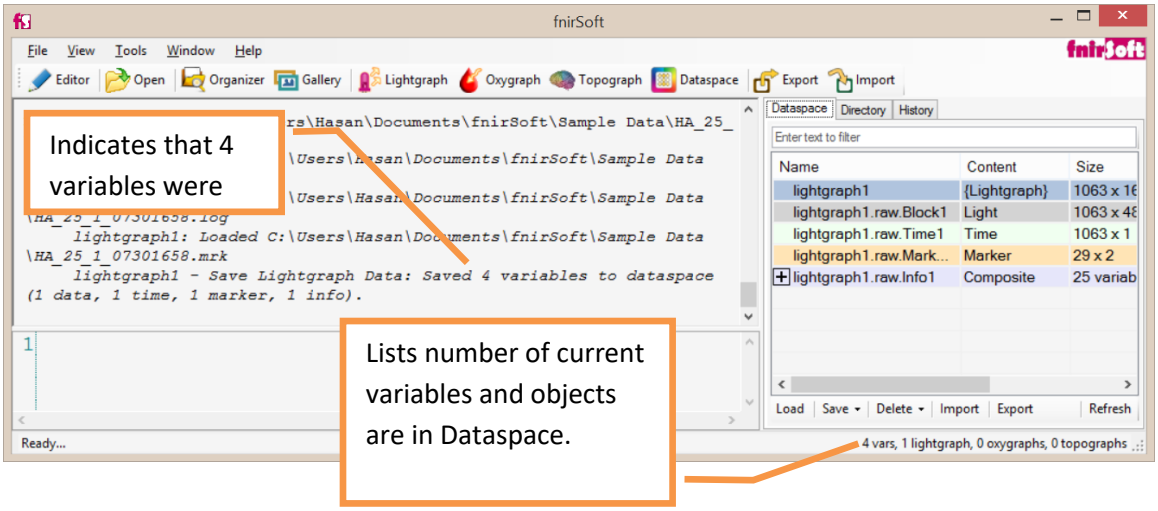
4) A success message is displayed as below. After, pressing “Ok” the messagebox and the previous dialog is closed.



5) Dataspace window appears and lists the two blocks as shown below. Note that Lightgraph object is also listed (as first item) in the list. The following four items are the new variables that were just created with types of ‘Light intensity’, ‘Time’, ‘Marker’ and ‘Composite’ (metadata information about the variable).

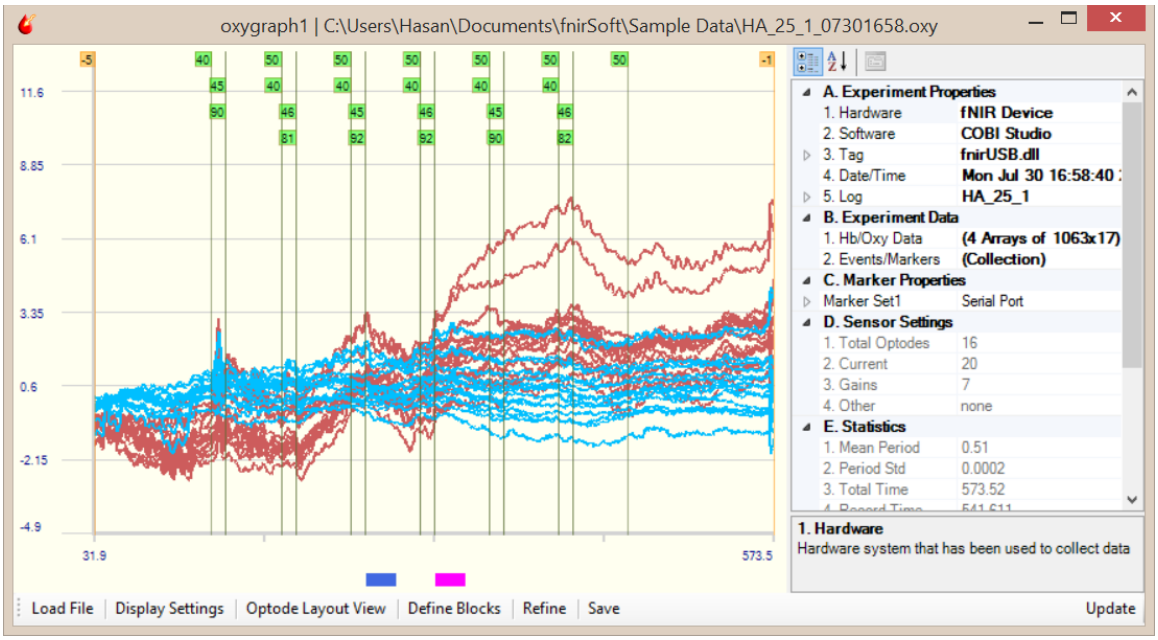


6) Also, on the main window a brief report about the operation is printed in command output pane.

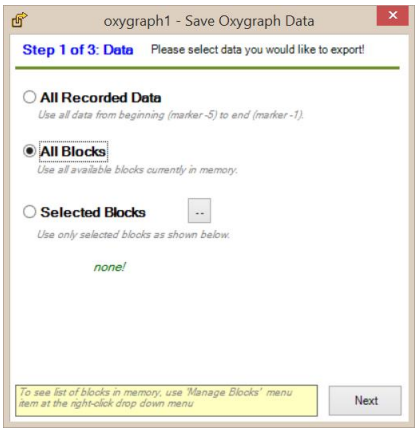


3.2.2. Exporting Blocks directly to a Matlab™ File

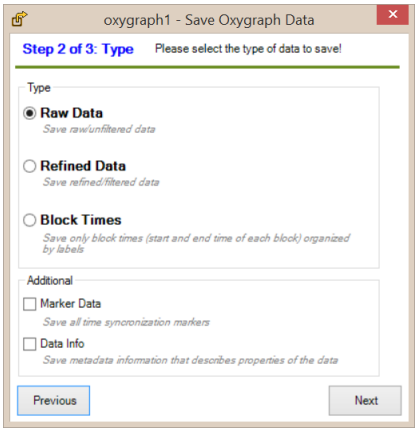
1) Follow section 3.1.3 to generate two blocks in Oxygraph as shown below.



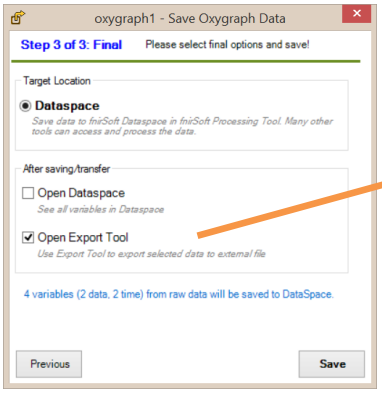
2) Click the “Save” button in the toolbar and select “All Blocks” in step 1.



3) Click next and select “Raw data”.

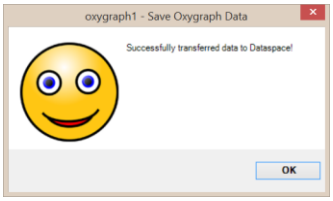


4) At step 3, check “Open Export Tool” option, this will upload saved blocks (from Dataspace) directly to Export Tool.

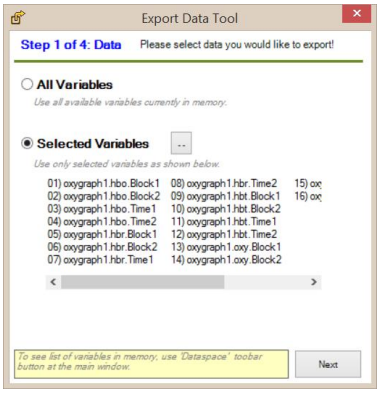


This option loads currently saved blocks to Export Tool for exporting as different file formats.

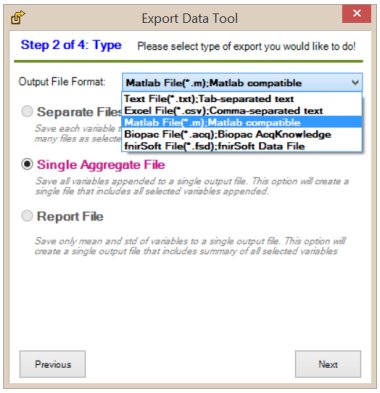
5) A success message will be shown as below, just click “Ok” to continue.



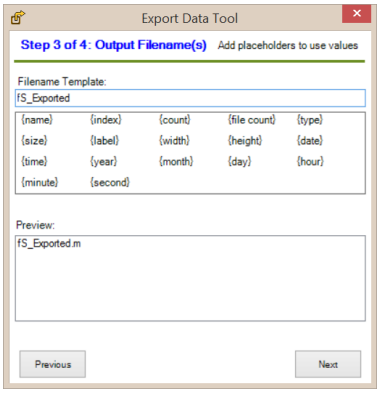
6) A new dialog, Export Tool with all block data will appear as below. Click ’Next’ to continue.



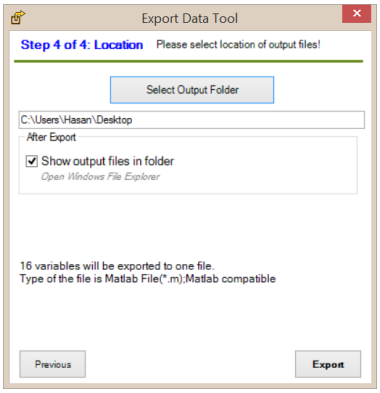
7) In Step 2, select the type of output file format. Select “Matlab’ from the drop down menu. This will automatically enable “single aggregate file’ option. This way, all blocks will be saved to a single output file.



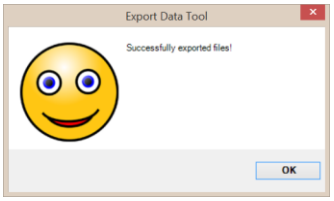
8) At Step 3, output file names are set. Various properties of block variables such as name, index, count, current date or time, etc can be used in output names. Click on the properties to add them to the name template or just type them with curly parenthesis. A preview list of output filenames is displayed at the lower part of the window. In this example a single file will be generated 'fs_Exported.m". Click next to continue.



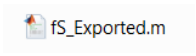
9) At step 4, output folder can be changed. The default folder is shown and also a brief summary of operation number of input block variables, number and type of output file is listed. Click "Export" button perform the operation.



10) A confirmation Messagebox will appear to indicate success. Also, main window command output pane will show a summary report line about the operation.

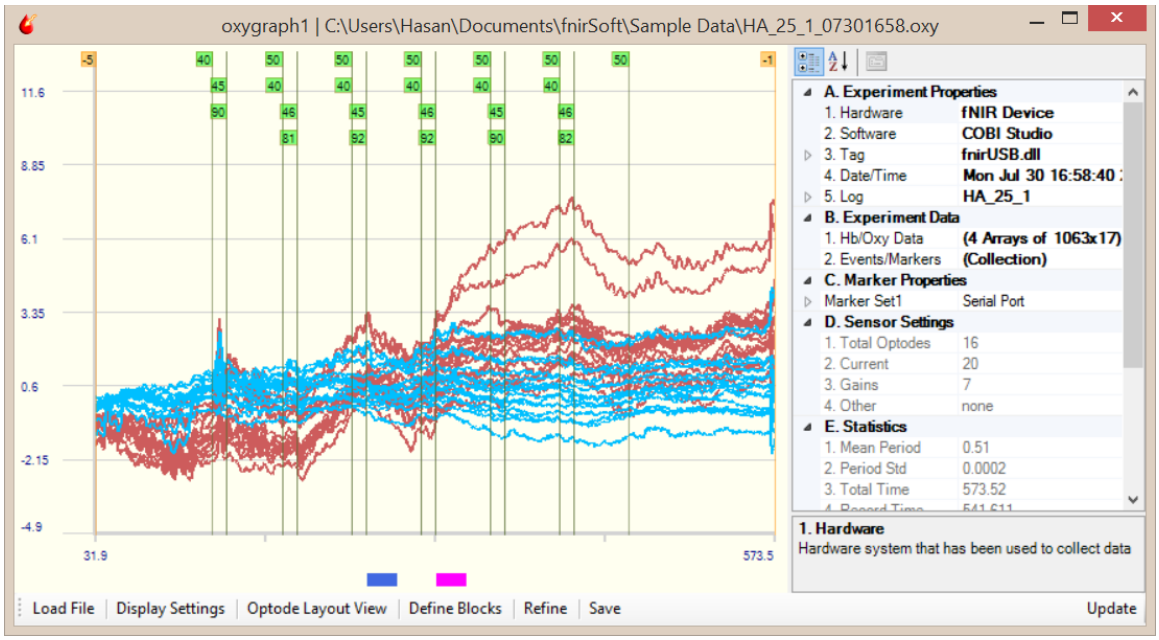


From windows explorer, the output file can be used:

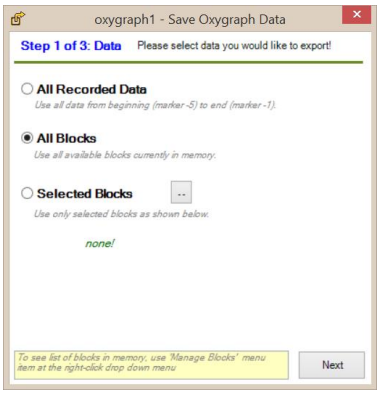


3.2.3. Exporting Blocks directly to a Text File

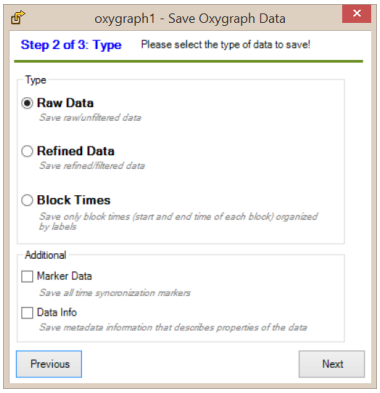
1) Follow section 3.1.3 to generate two blocks in Oxygraph as shown below.



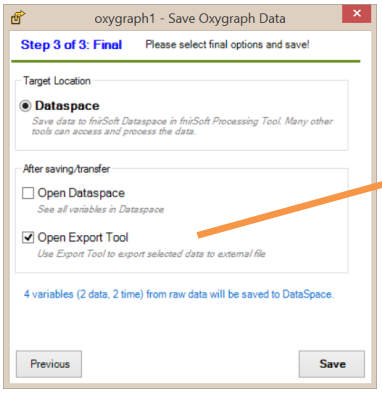
2) Click the "Save" button in the toolbar and select "All Blocks" in step 1.



3) Click next and select "Raw data".

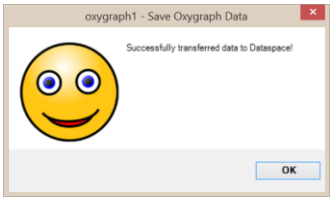


4) At step 3, check "Open Export Tool" option, this will upload saved blocks (from Dataspace) directly to Export Tool.

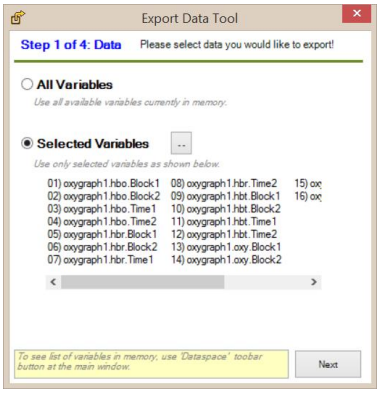


This option loads currently saved blocks to Export Tool for exporting as different file formats.

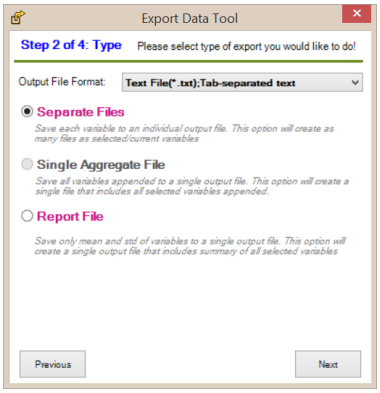
5) A success message will be shown as below, just click “Ok” to continue.



6) A new dialog, Export Tool with all block data will appear as below. Click ’Next’ to continue.

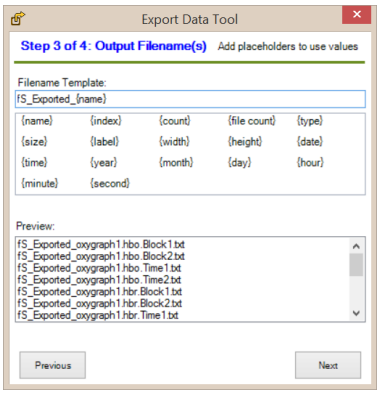


7) In Step 2, select the type of output file format. Select ‘Text file’ from the drop down menu. This will by default enable “Separate files’ option. This way, each blocks will be saved to a separate output file and the number of output files is the same as the number of input blocks.

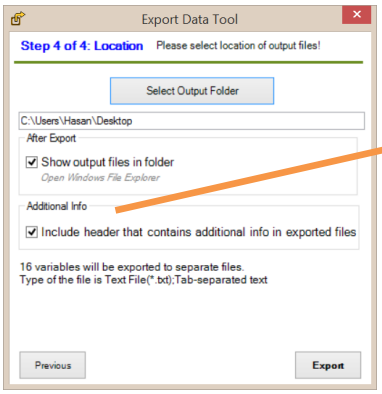


8) At Step 3, output file names are set. Various properties of block variables such as name, index, count, current date or time, etc can be used in output names. Click on the properties to add them to the name template or just type them with curly parenthesis. By default ‘{name}’ is

added so filename template is 'fS_Exported_{name}'. With this template, when processing each block, name of that block is used to create its respective output file. A preview list of all output filenames is displayed at the lower part of the window. Click next to continue.



9) At step 4, output folder can be changed. The default folder is shown and also a brief summary of operation number of input block variables, number and type of output file is listed. Click "Export" button perform the operation.



This option includes header (extra rows at the beginning of each file) that contains additional information about the data.

10) Files will be created at the selected folder and main window command output pane will show a summary report line about the operation.

From explorer, the output files can be used:

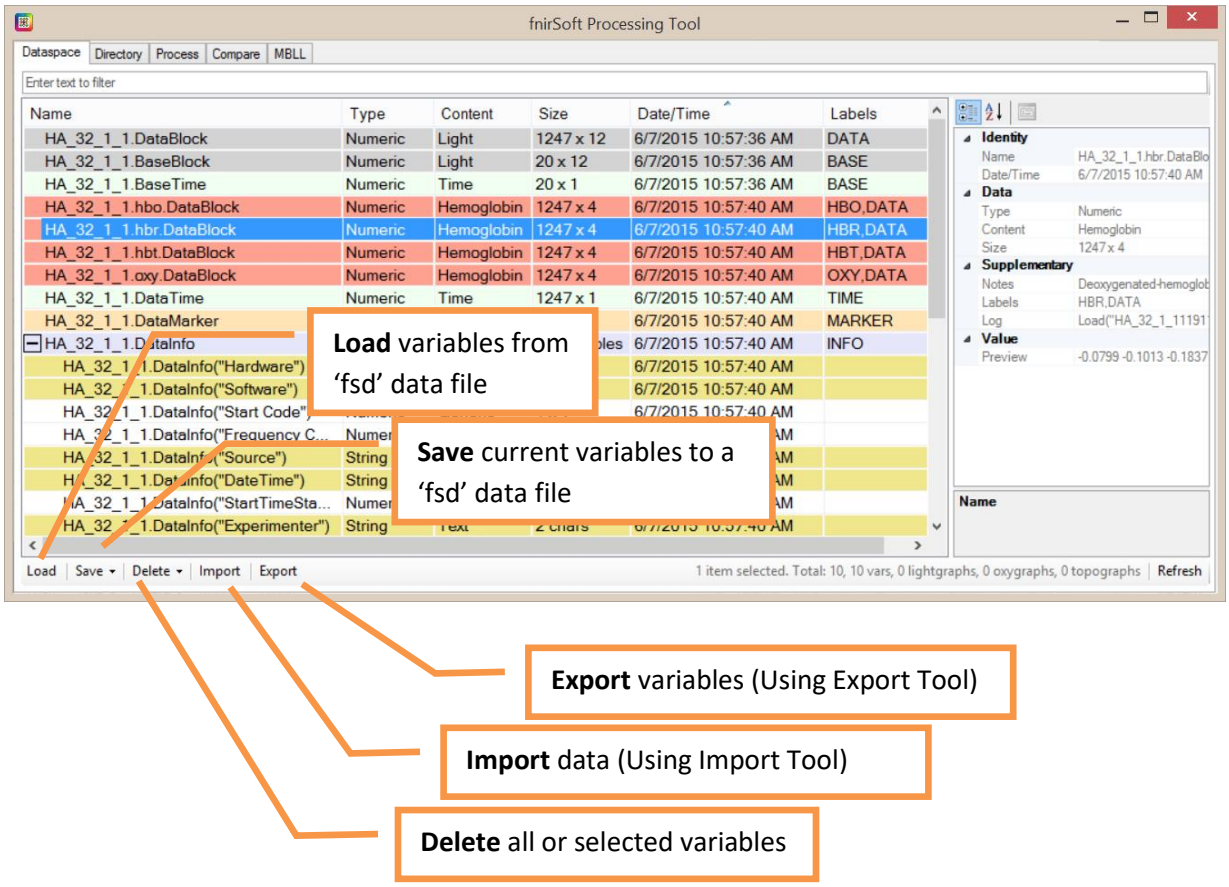
fS_Exported_oxygraph1.hbo.Block1.txt
fS_Exported_oxygraph1.hbo.Block2.txt
fS_Exported_oxygraph1.hbo.Time1.txt
fS_Exported_oxygraph1.hbo.Time2.txt
fS_Exported_oxygraph1.hbr.Block1.txt
fS_Exported_oxygraph1.hbr.Block2.txt
fS_Exported_oxygraph1.hbr.Time1.txt
fS_Exported_oxygraph1.hbr.Time2.txt
fS_Exported_oxygraph1.hbt.Block1.txt
fS_Exported_oxygraph1.hbt.Block2.txt
fS_Exported_oxygraph1.hbt.Time1.txt
fS_Exported_oxygraph1.hbt.Time2.txt
fS_Exported_oxygraph1.oxy.Block1.txt
fS_Exported_oxygraph1.oxy.Block2.txt
fS_Exported_oxygraph1.oxy.Time1.txt
fS_Exported_oxygraph1.oxy.Time2.txt

4. Dataspace

fnirSoft global memory is called Dataspace. All data variables (numeric, string, lists) and all objects (Lightgraph, Oxygraph, Topograph) are created and stored in Dataspace. Processing Tool allows applying various functions/processing methods through user interface. All these functions are also available as commands through fnirSoft scripting.

4.1.Saving and loading fnirSoft data (*.fsd) files

fnirSoft data variables can be saved to and re-loaded from 'fsd' files. Once a data file is saved or loaded, a brief report is included in the command output pane at the main window. fnirSoft Processing Tool, variable tab options are explained below.

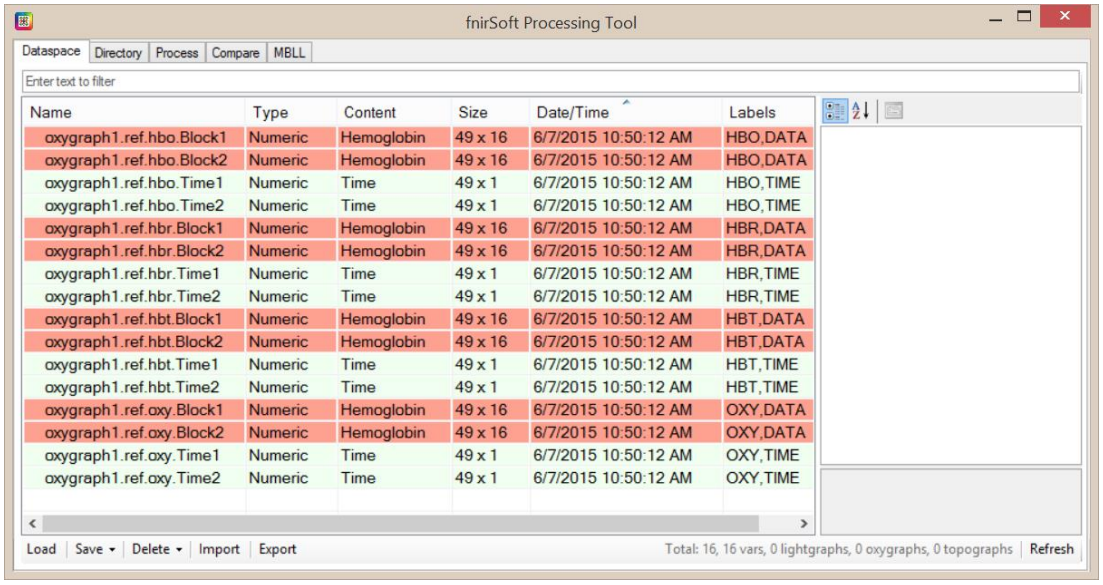


To select variables click on them, to select multiple variables, keep ctrl button (on the keyboard) pressed and click (with mouse) on the variables listed.

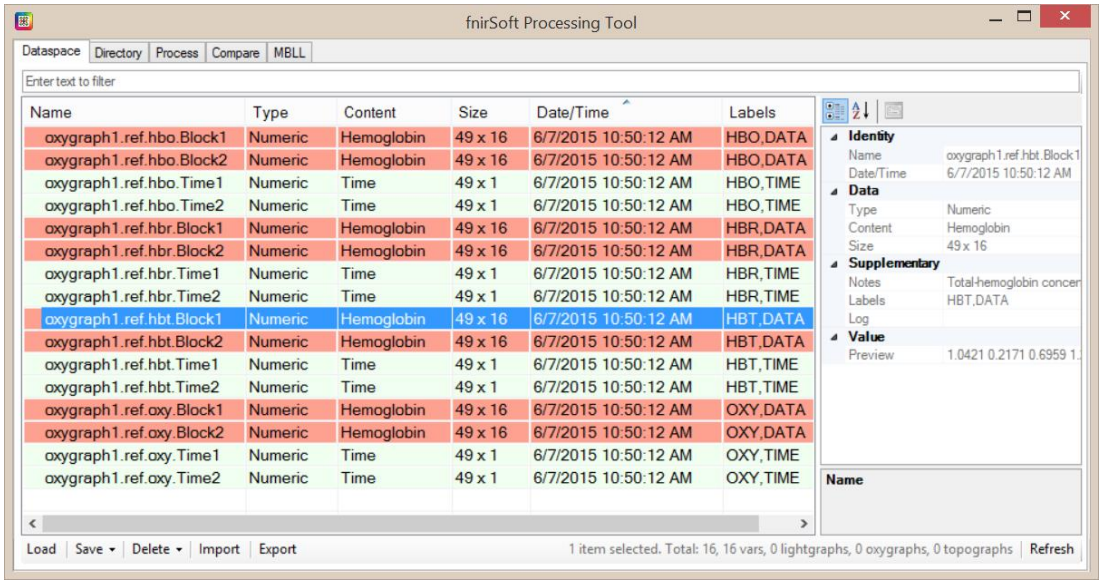
Note: When saving or clearing variables, all variables (which are either numeric, string or list) in the Dataspace list are saved or cleared except objects (which are either Lightgraph, Oxygraph or Topograph) as indicated in the 'Type' column. Objects can be deleted by right-clicking and selecting *Delete* from the context menu.

4.2.Viewing a variable

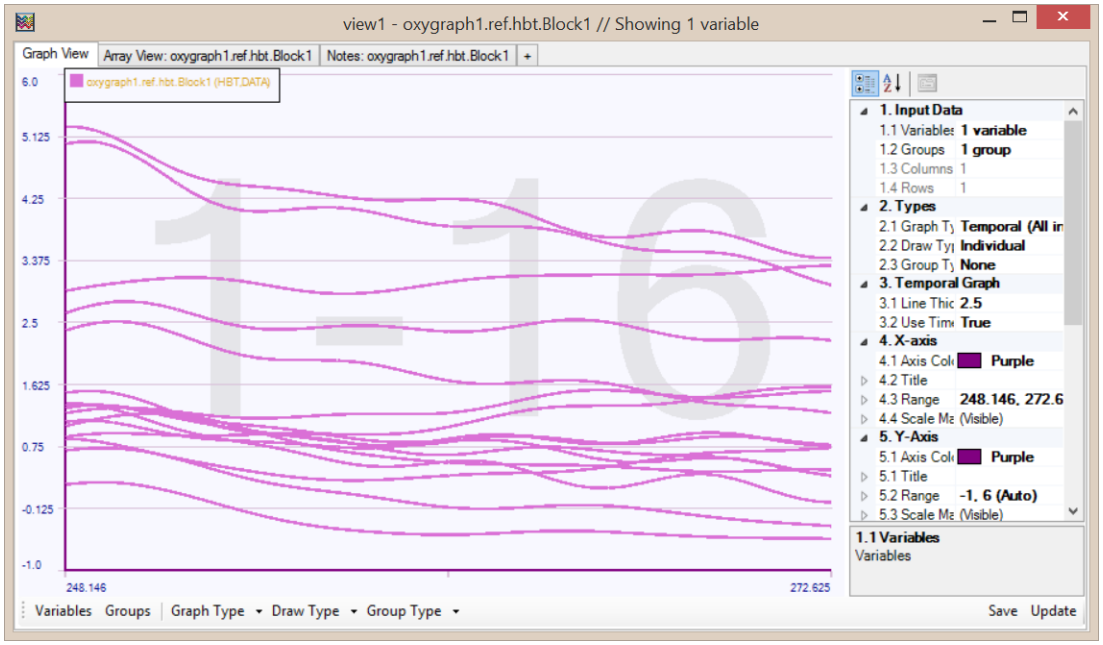
1) All available variables are listed in “Dataspace” tab of *fnirSoft Processing Tool*. This list can be re-sorted by clicking on any column header. *fnirSoft Processing Tool* can be accessed from the main window by clicking on the “Dataspace” toolbar button. Load data_3.2.2_refined.fsd file as below.



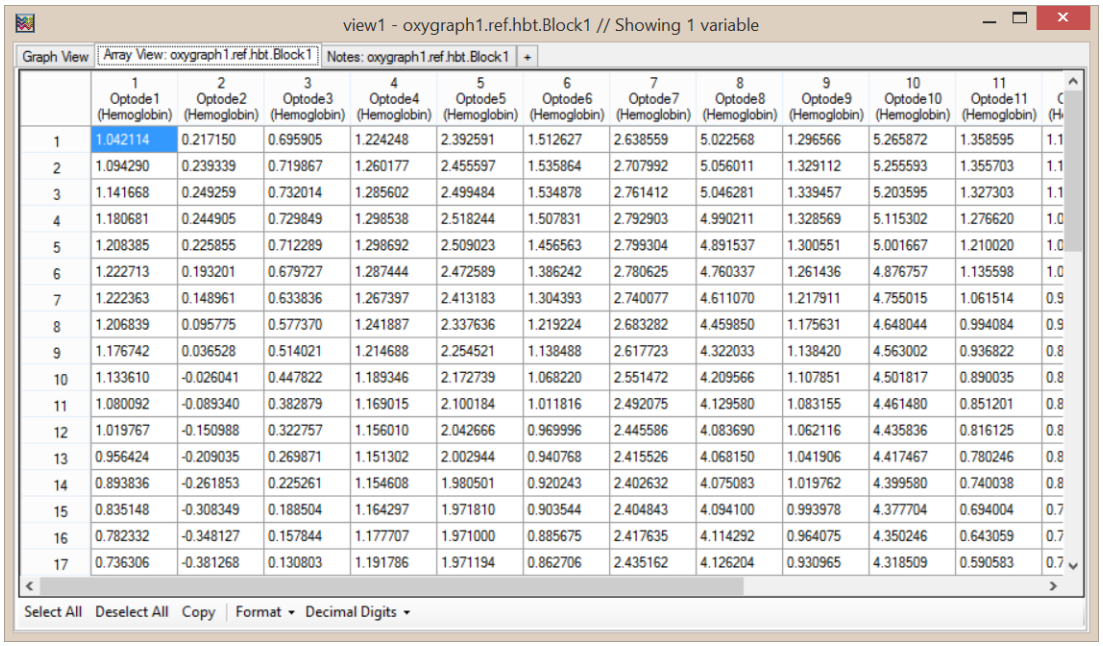
2) Any selected (by clicking with left mouse button) variable will be highlighted.



3) Double click on a variable to open detail-view for that variable. Alternatively, right click on any variable in the list and click on ‘view’. Detail-view allows viewing variable in graph or array formats. A new window that displays all channels of the selected variable will appear. Graph view is shown by default.

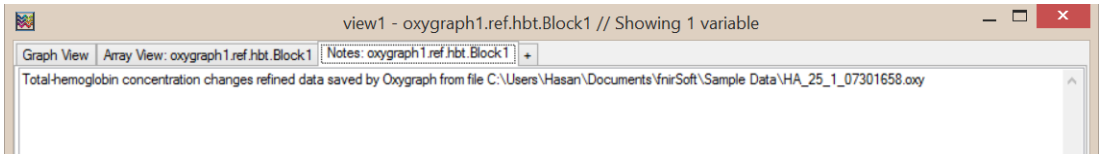


4) Click on 'Array View' tab at the top. Contents of the variable are shown in a grid with rows and columns. All cells of the data can be viewed. Note that, each column caption contains optode number and content type of the data in that column.



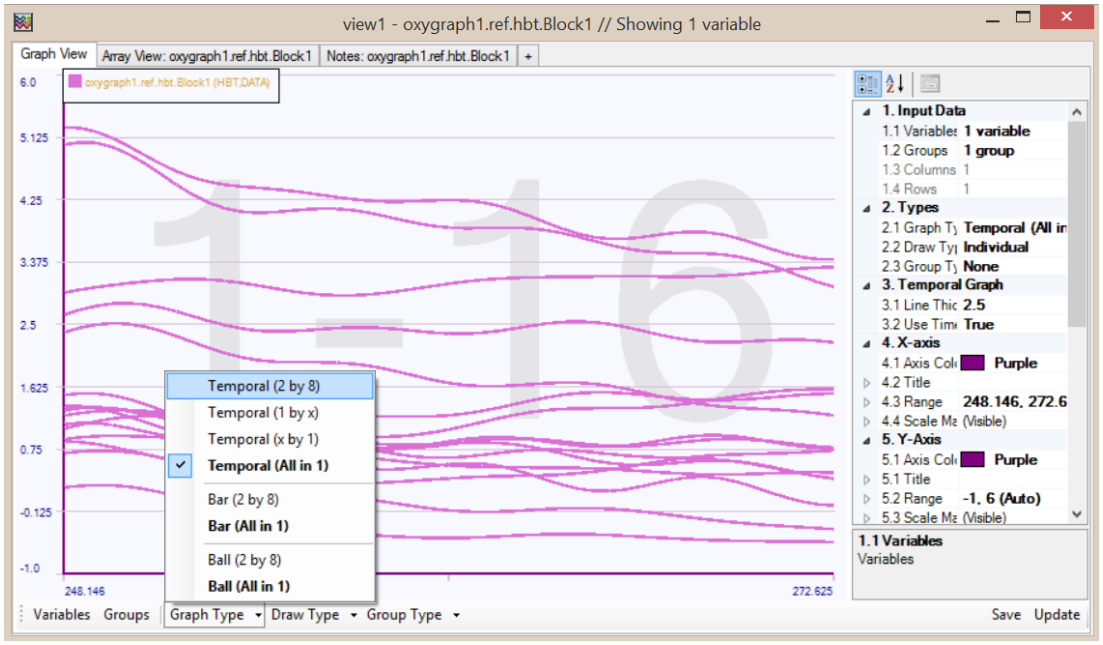
	1 Optode1 (Hemoglobin)	2 Optode2 (Hemoglobin)	3 Optode3 (Hemoglobin)	4 Optode4 (Hemoglobin)	5 Optode5 (Hemoglobin)	6 Optode6 (Hemoglobin)	7 Optode7 (Hemoglobin)	8 Optode8 (Hemoglobin)	9 Optode9 (Hemoglobin)	10 Optode10 (Hemoglobin)	11 Optode11 (Hemoglobin)
1	1.042114	0.217150	0.695905	1.224248	2.392591	1.512627	2.638559	5.022568	1.296566	5.265872	1.358595
2	1.094290	0.239339	0.719867	1.260177	2.455597	1.535864	2.707992	5.056011	1.329112	5.255593	1.355703
3	1.141668	0.249259	0.732014	1.285602	2.499484	1.534878	2.761412	5.046281	1.339457	5.203595	1.327303
4	1.180681	0.244905	0.729849	1.298538	2.518244	1.507831	2.792903	4.990211	1.328569	5.115302	1.276620
5	1.208385	0.225855	0.712289	1.298692	2.509023	1.456563	2.799304	4.891537	1.300551	5.001667	1.210020
6	1.222713	0.193201	0.679727	1.287444	2.472589	1.386242	2.780625	4.760337	1.261436	4.876757	1.135598
7	1.222363	0.148961	0.633836	1.267397	2.413183	1.304393	2.740077	4.611070	1.217911	4.755015	1.061514
8	1.206839	0.095775	0.577370	1.241887	2.337636	1.219224	2.683282	4.459850	1.175631	4.648044	0.994084
9	1.176742	0.036528	0.514021	1.214688	2.254521	1.138488	2.617723	4.322033	1.138420	4.563002	0.936822
10	1.133610	-0.026041	0.447822	1.189346	2.172739	1.068220	2.551472	4.209566	1.107851	4.501817	0.890035
11	1.080092	-0.089340	0.382879	1.169015	2.100184	1.011816	2.492075	4.129580	1.083155	4.461480	0.851201
12	1.019767	-0.150988	0.322757	1.156010	2.042666	0.969996	2.445586	4.083690	1.062116	4.435836	0.816125
13	0.956424	-0.209035	0.269871	1.151302	2.002944	0.940768	2.415526	4.068150	1.041906	4.417467	0.780246
14	0.893836	-0.261853	0.225261	1.154608	1.980501	0.920243	2.402632	4.075083	1.019762	4.399580	0.740038
15	0.835148	-0.308349	0.188504	1.164297	1.971810	0.903544	2.404843	4.094100	0.993978	4.377704	0.694004
16	0.782332	-0.348127	0.157844	1.177707	1.971000	0.885675	2.417635	4.114292	0.964075	4.350246	0.643059
17	0.736306	-0.381268	0.130803	1.191786	1.971194	0.862706	2.435162	4.126204	0.930965	4.318509	0.590583

5) Click on Notes tab. This tab displays a string text that is metadata of the variable. You can view or edit descriptive information about the variable here. Any changes can be saved by using the 'save' button at the lower left corner.

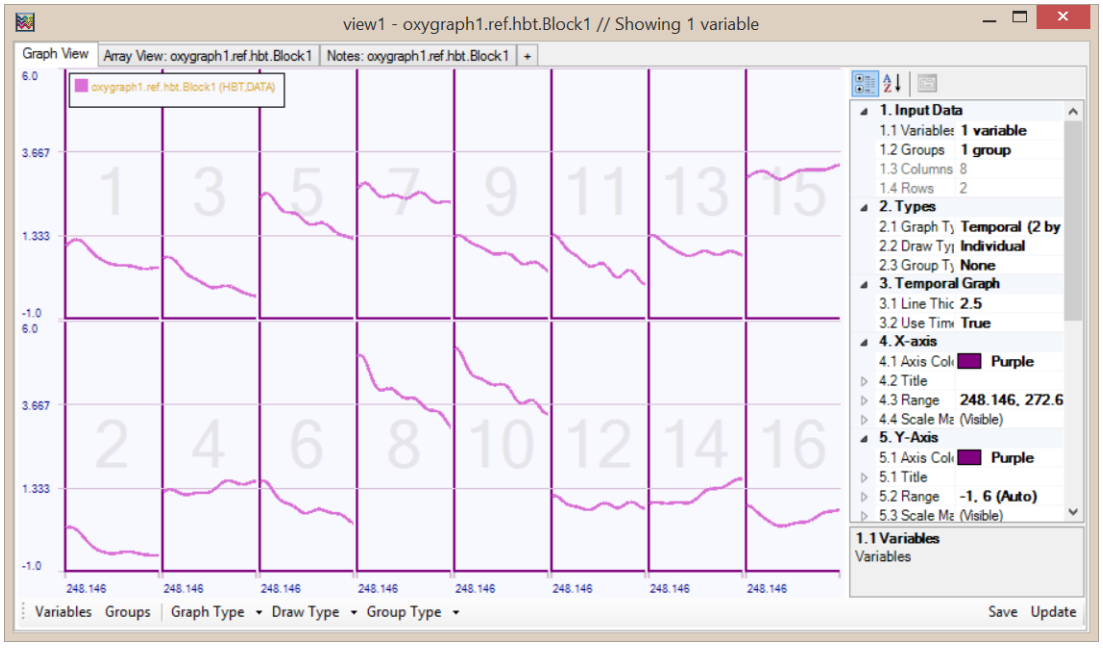


4.2.1. Single variable temporal graph

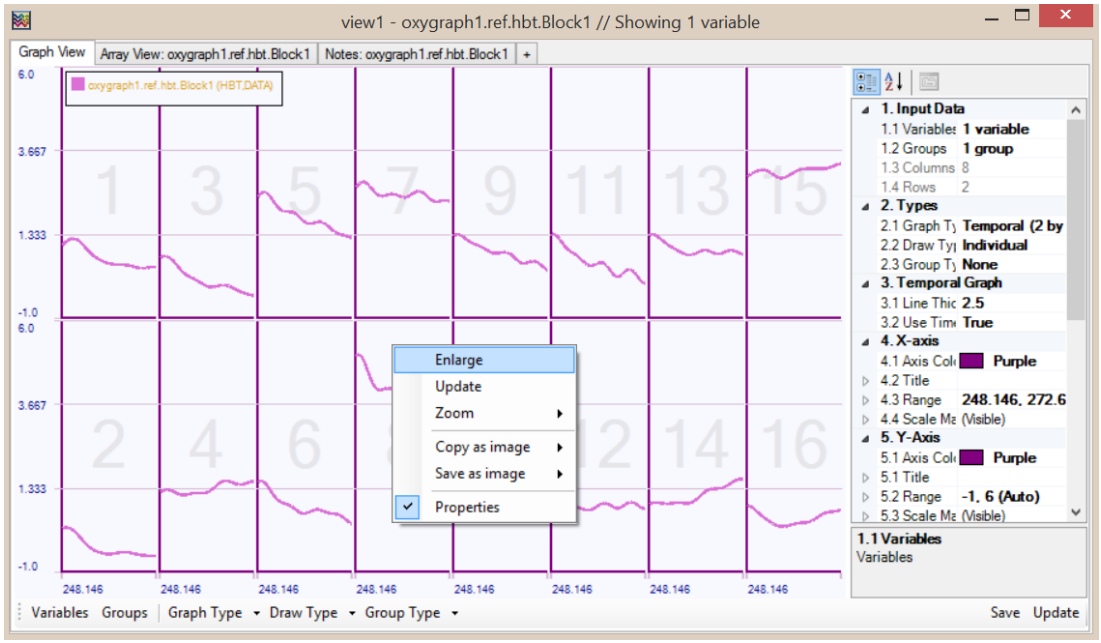
6) Click on “Graph View” tab to go back to the graph view. By default all channels are shown in a single graph, this is called Temporal (All in 1) type graph. In this example, our variable has 16 columns, and is a variable collected with 16 optode sensor. We can change the graph type to sensor optode layout format using the graph type toolbar button at the bottom of the screen. The dropdown menu from the button will list compatible options with the currently loaded data as shown below.



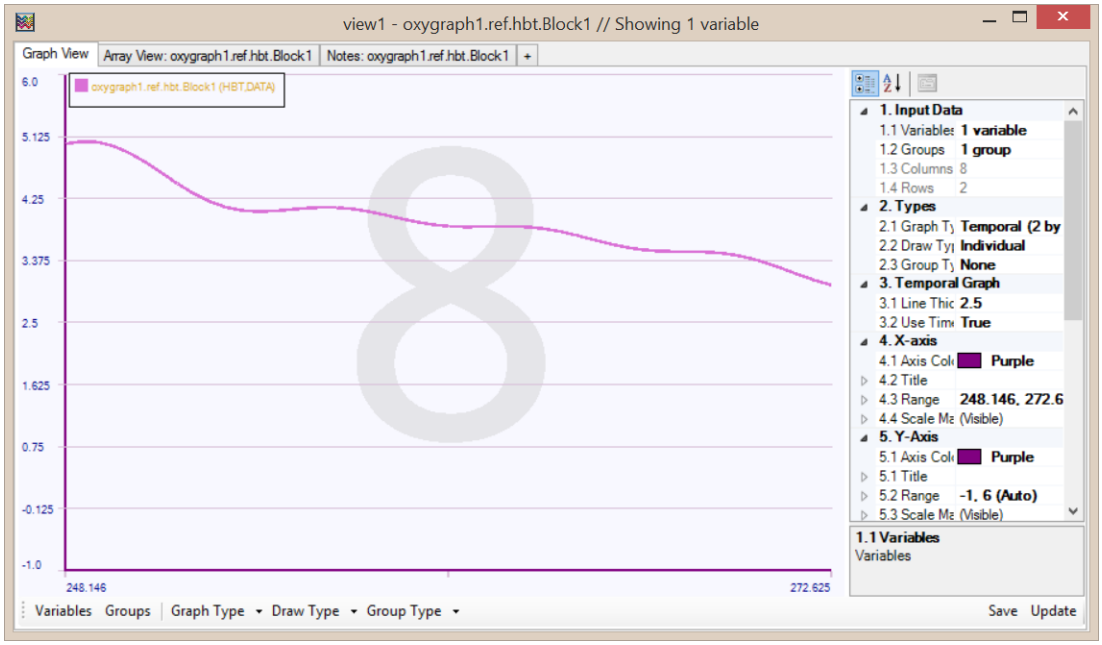
7) Select ‘Temporal-(2 by 8)’ as graph type. The window will be updated immediately and individual optodes will be displayed in separate graphs.



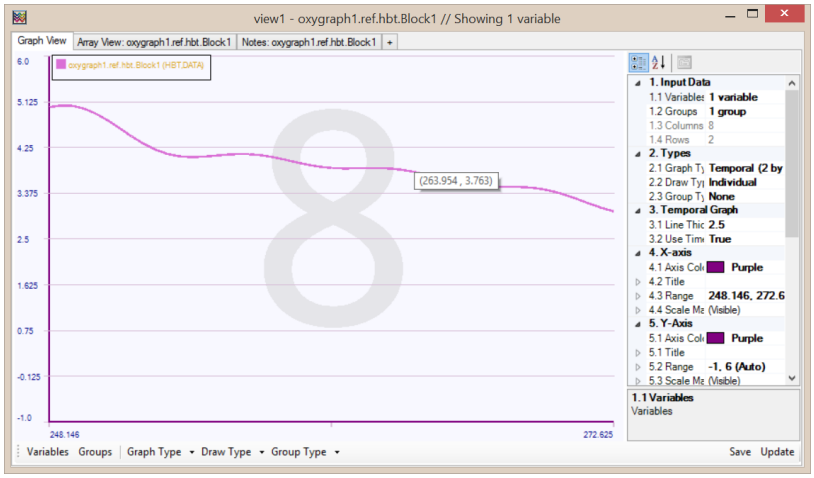
8) Right-click on one of the graphs and context menu will appear as below.



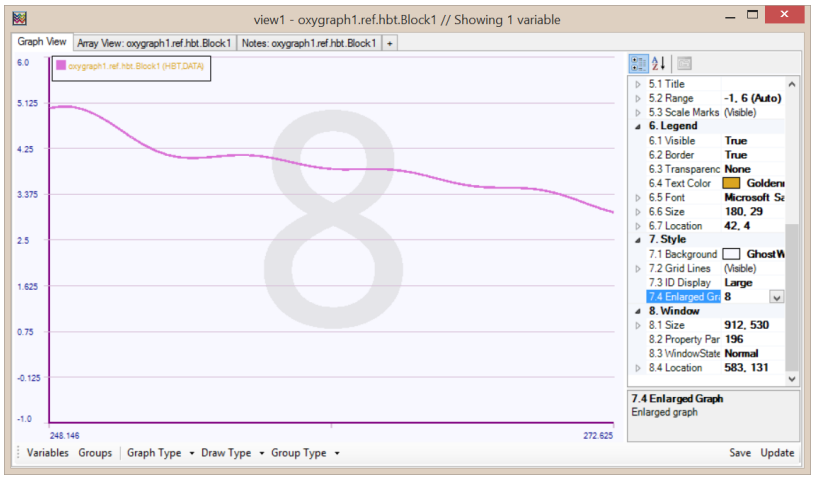
9) Select 'Enlarge' from the right-click context menu (alternatively double-click on the graph). This make the graph to the size of the window and enables viewing in more detail.



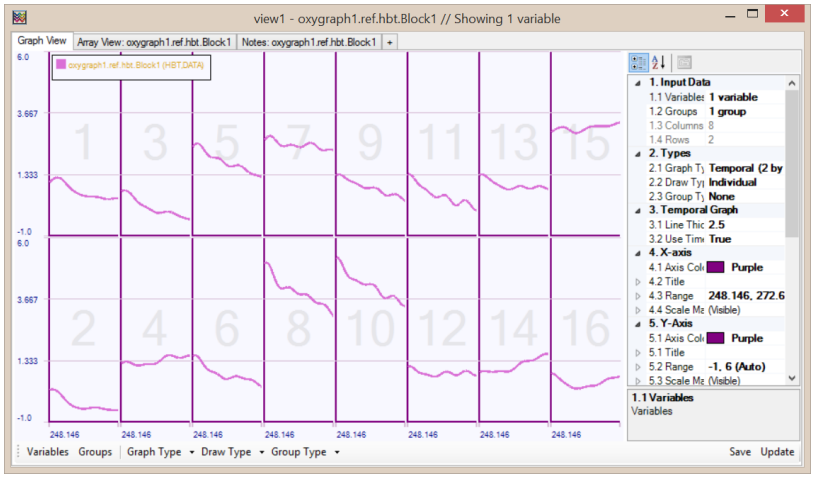
10) Similar to Lightgraph and Oxygraph windows, single-click on the graph displays a tip-window that shows x and y coordinate (time and signal value) at the clicked location.



11) Enlarged graph can be changed from right hand side properties pane, within Style>Enlarged Graph item

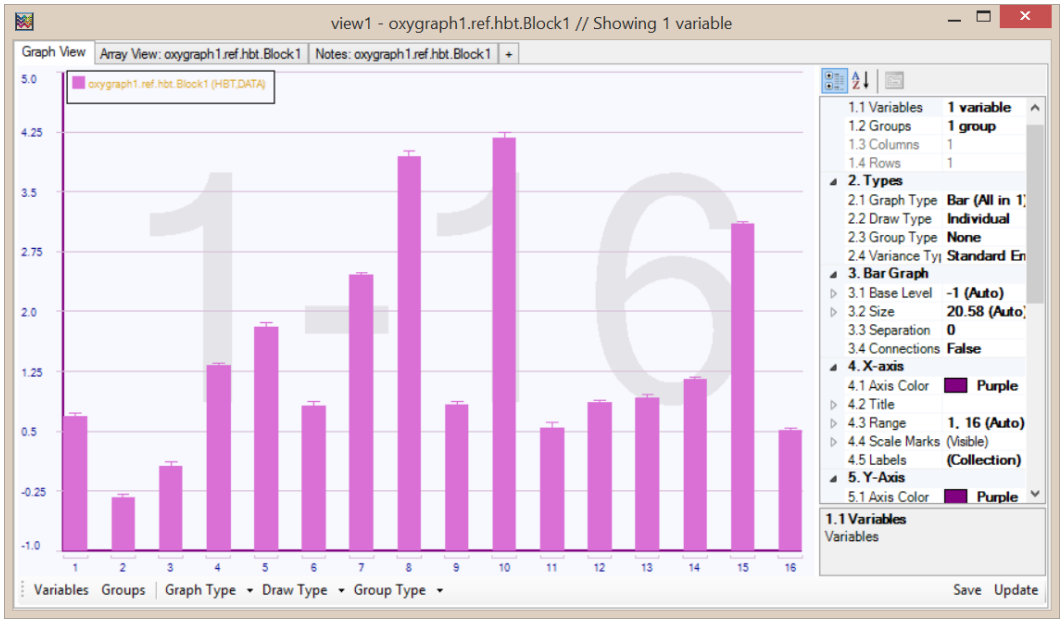


12) To go back, right-click and select ‘Enlarge’ from context-menu again (Or double-click on the graph).

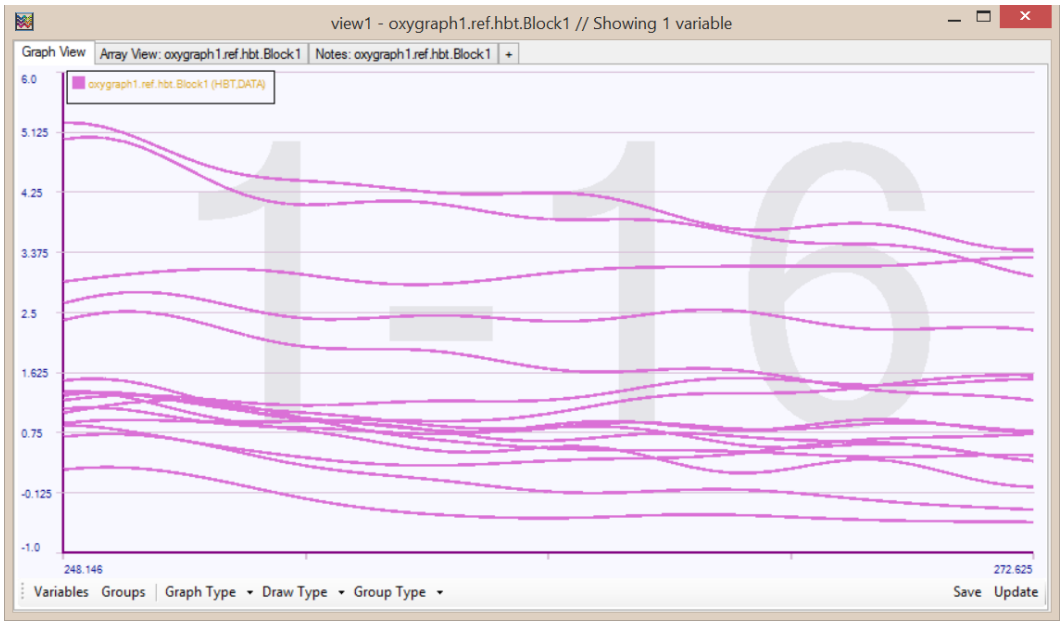


4.2.2. Single variable bar graph

13) Select “Bar- All in 1” at the “Graph Type” button at the toolbar. In this case, all 16 optodes are shown as rectangular bars at the length of their mean and standard deviation/error is shown at the tip of the bars.

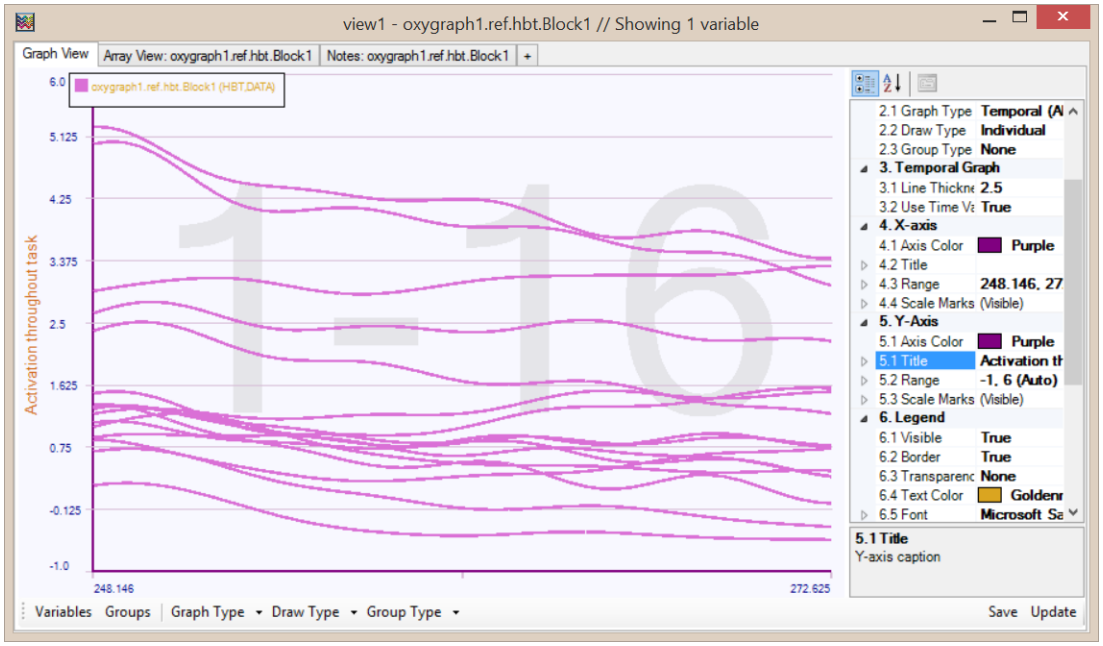


14) Select “*Temporal (All in 1)”* graph type from the toolbar to go back to original view. Right click on the graph and select “*Properties*” from the context menu to hide the right-hand side properties pane. The properties pane allows modifying various parameters to further customize the graph view, such as from background panel color to removing grid lines to arranging axis ranges but can be hidden to extent graph display area.

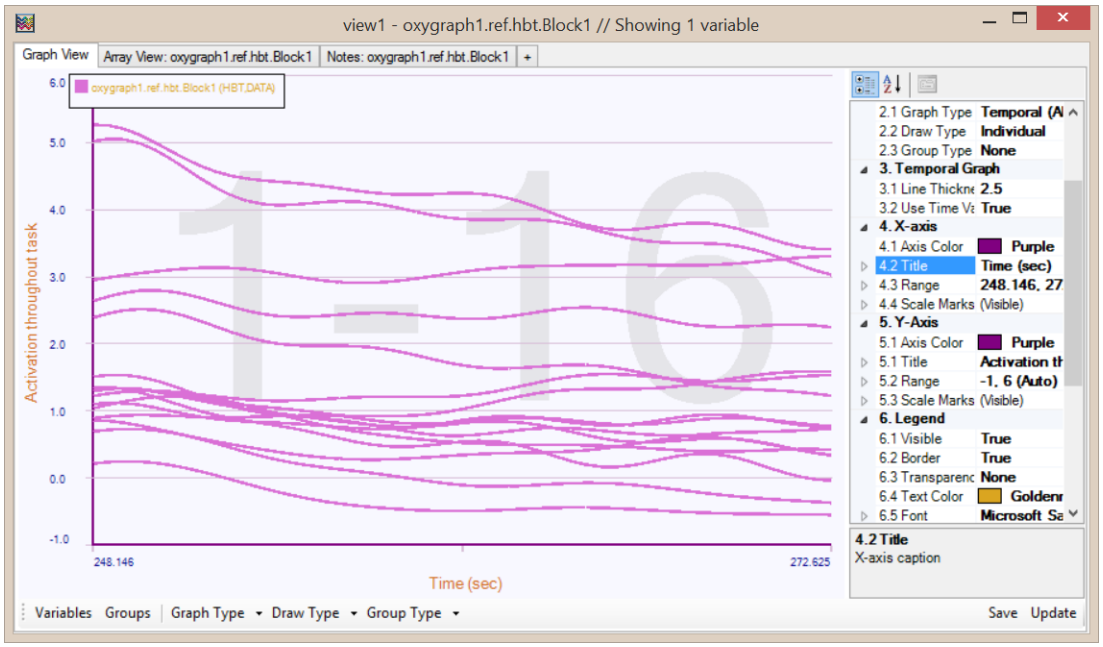


4.2.3. Editing axis titles for graphs

15) Display properties pane again by right-click and selecting properties from dropdown menu. At the right-hand side properties pane, under “Y-Axis”, for “Axis title” field, enter “Activation throughout task” and hit enter. The text will be displayed as y-axis title.

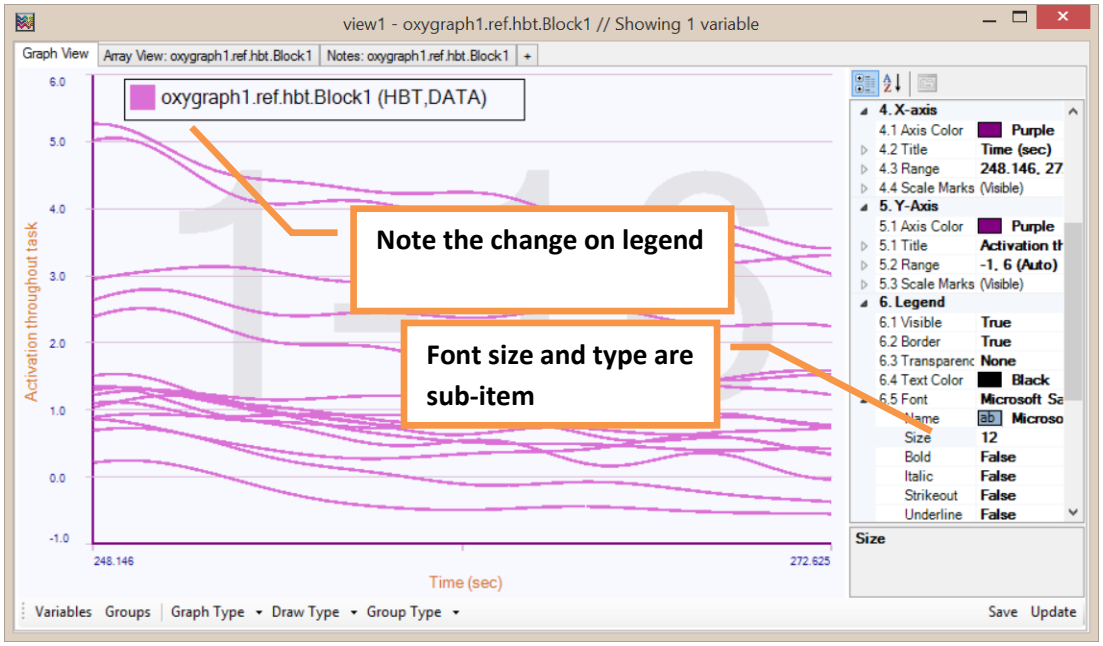


16) Similarly, enter “Time (sec)” for Axis title under “X-axis” group. Both titles will be displayed as below.

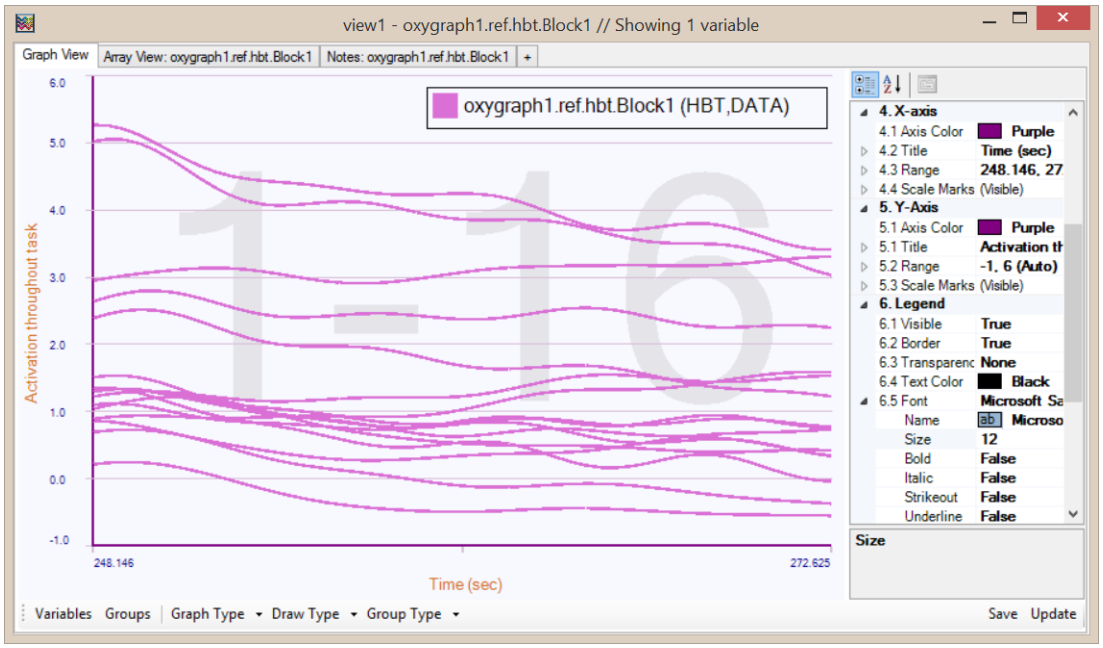


4.2.4. Editing and moving legend display

17) This font type/size/color and place of legend can be modified for best fit to the current graph. At properties pane, under legend section, change text color to black and font size to 12 as shown below. The legend box might need to be re-sized to display all (enlarged) text by placing the mouse cursor at the border of the legend box.

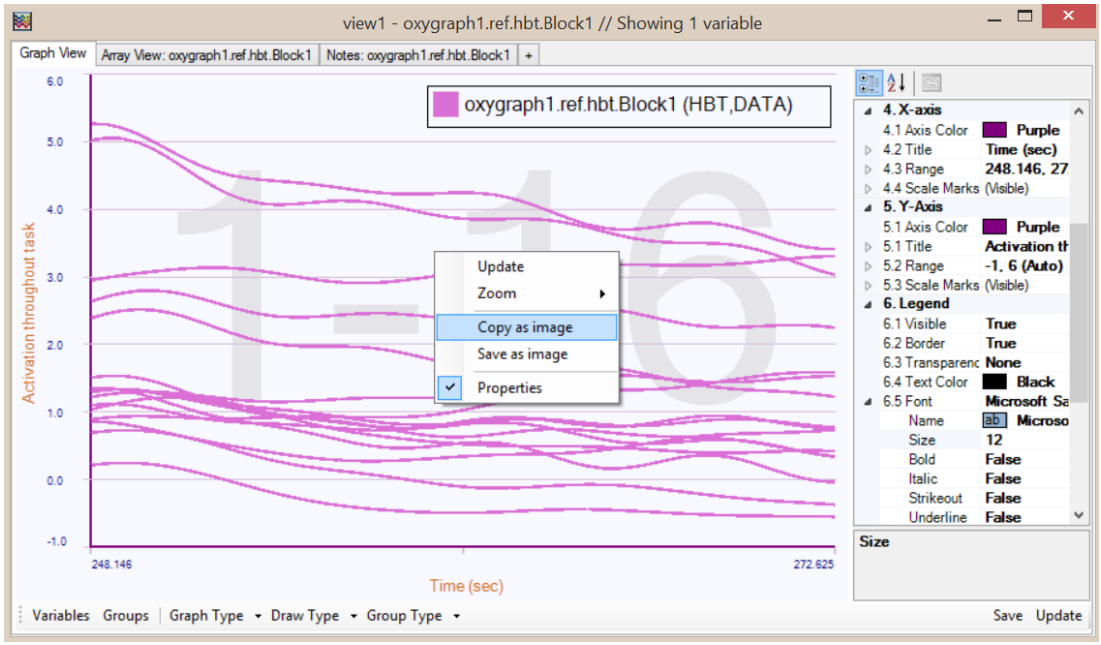


18) Move the legend box by clicking inside legend and keeping the left mouse window while moving cursor. Once you reach the desired location, release the left mouse button.



4.2.5. Saving graphs as image or copying to clipboard

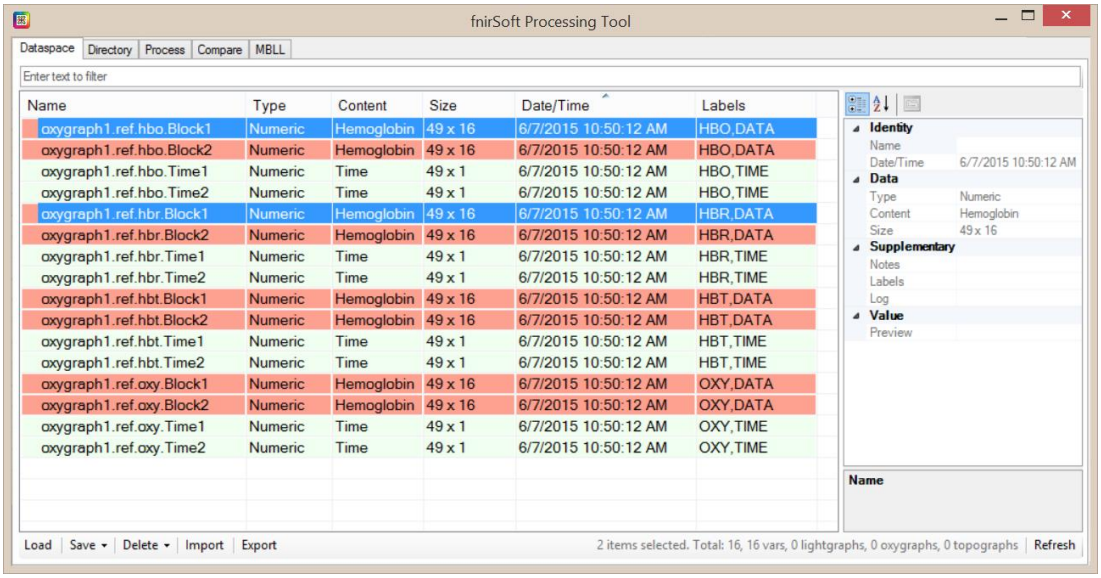
19) At any time, graph can be saved as an image or copied to clipboard to be pasted into other applications (such as Microsoft Word, Powerpoint, etc) when preparing report. When more than one graph is visible (such as temporal 2by8 view), single graph or all can be saved/copied.



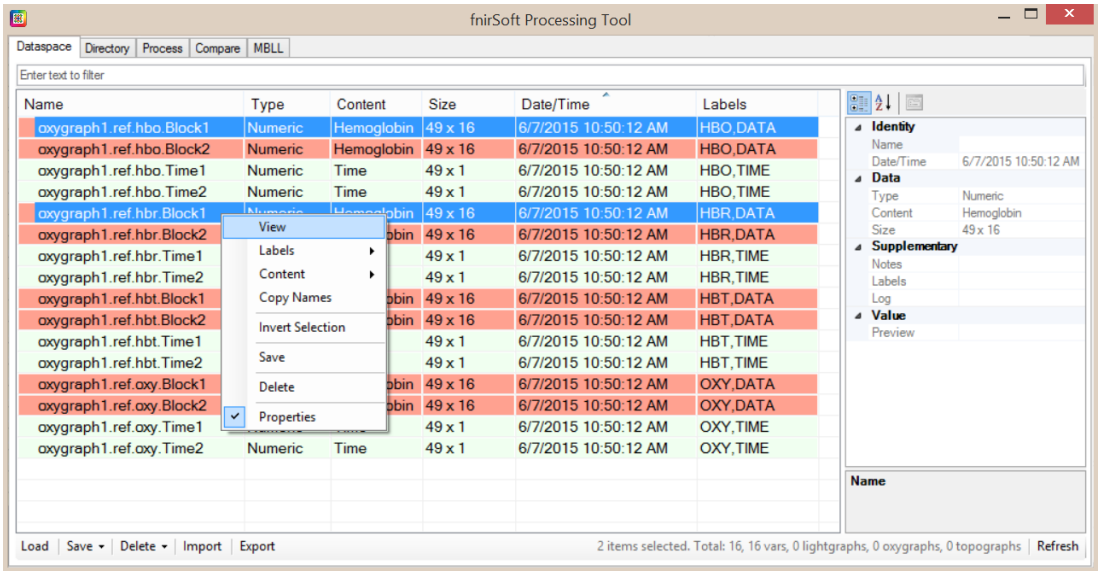
4.3.Viewing multiple variables

1) The Detail-view window described in previous section can also display two or more variables simultaneously in one window other than opening two separate windows for each. This is usually needed for comparison of variables such as different conditions of an experiment or different groups from a study.

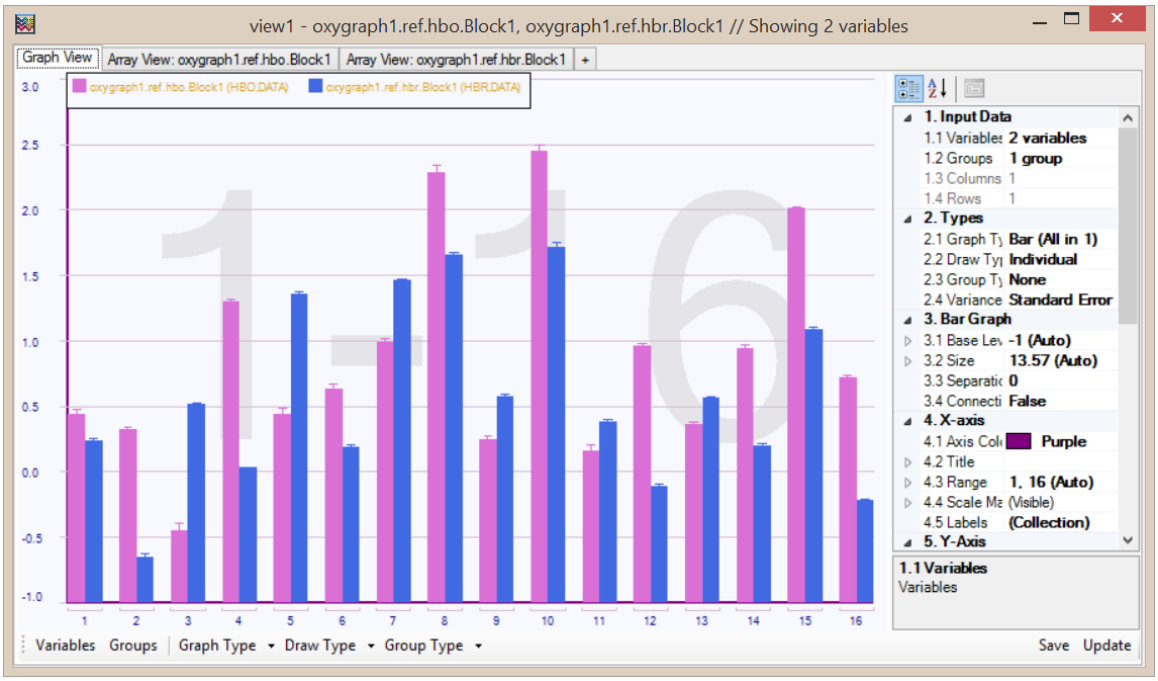
2) Load sample file 'data_3.2.2_refined.fsd' file as below. And, select two (or more can be selected) at "Dataspace" tab of "fnirSoft Processing Tool" open them together in variable View Tool. To do that, keep 'ctrl' button (at the keyboard) and click on variables to select more variables. In the figure below, two variables (oxygraph1.ref.hbo.Block1 and oxygraph1.ref.hbr.Block1) are selected.



3) Right-click on one of the selected variables and click on "View" from the context-menu.

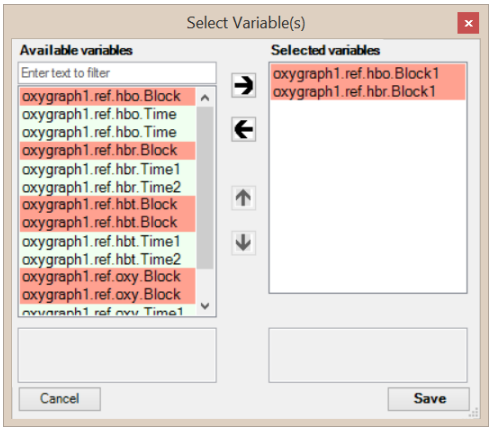


4) Comparison of means of all optodes (columns) are shown with bar graph type by default. Error bars at the tip are Standard Error of the Mean (SEM) by default.

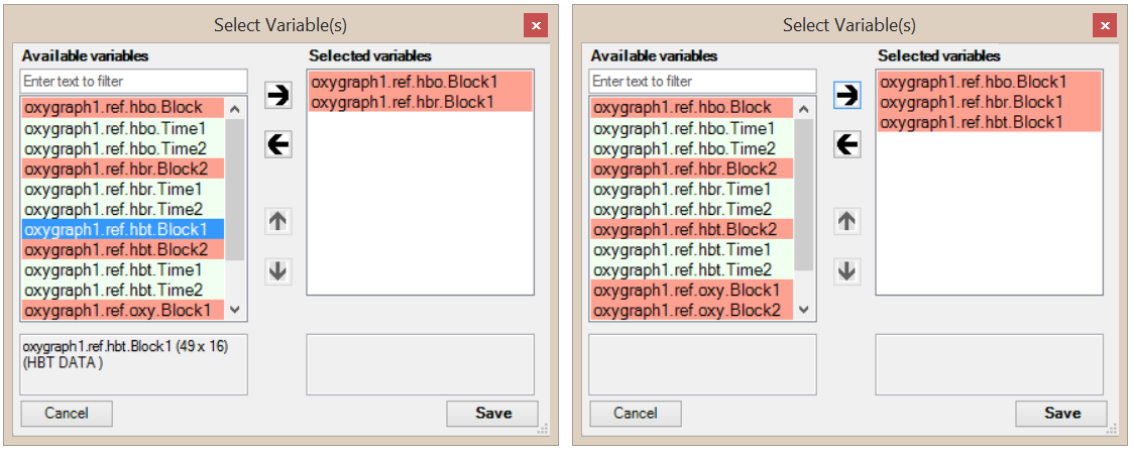


4.3.1. Add/remove variables to the current view

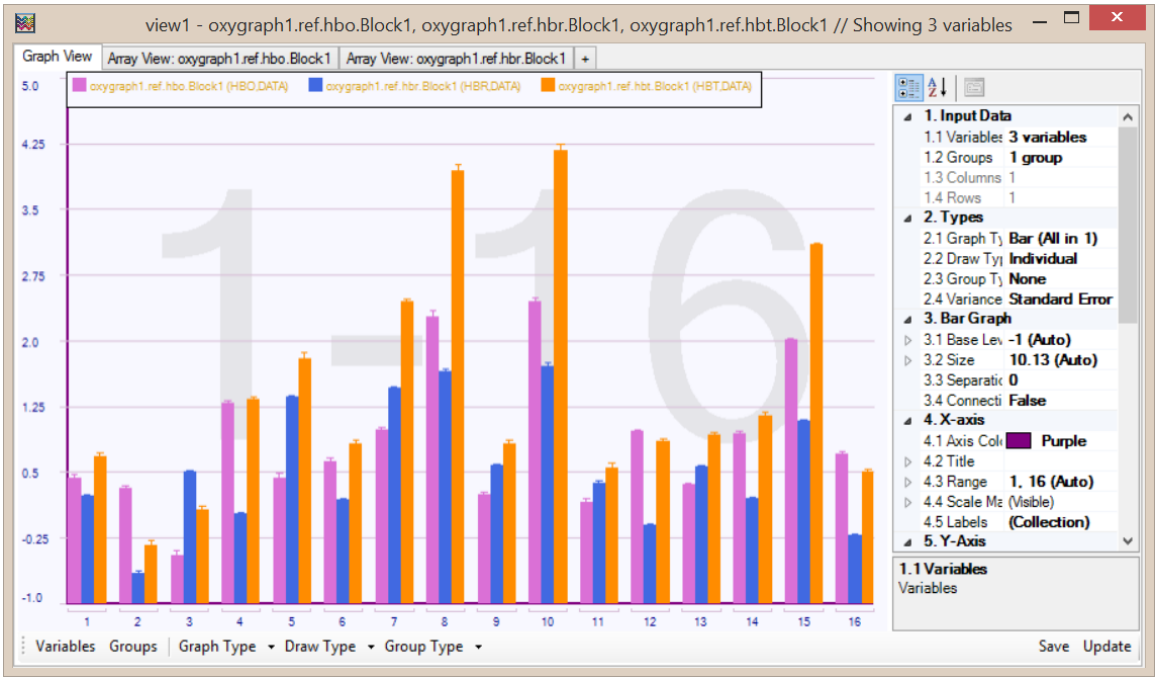
5) To add or remove more variables, click on the “Variables” button at the bottom toolbar. This will show “Select Variables” window as below. On the left hand side, all available variables are listed and on right-hand side, those already selected (loaded) to the current detail-view window are listed. You can move variables from one to the other and select “Save” to commit the changes to update the graph.



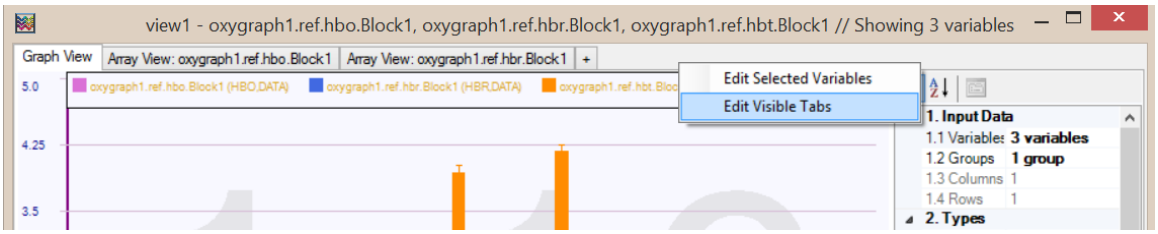
6) From the left list locate ‘oxygraph1.ref.hbt.Block1’ variable and move it to the right-hand side by double-clicking or highlighting and using right-arrow button. See the tip at the end of this section for filtering the list by name.



7) Click “Save” button to accept changes. The dialog will close and the graph will be updated. Also, note the title that lists all variable names.

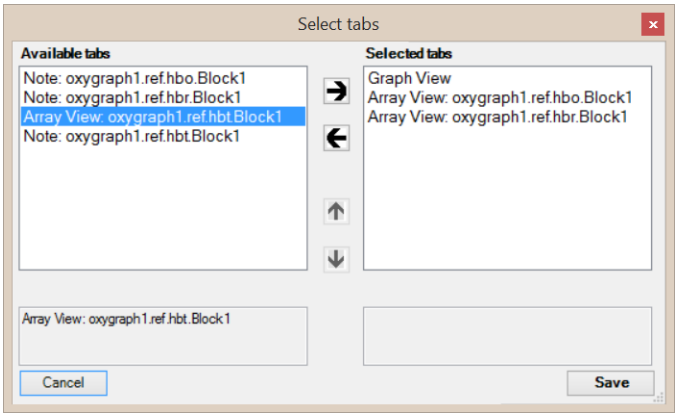


8) It is also possible to add/remove tabs on the detail-view window for different views. In this example, other than graph view, array view of two variables are listed because they were loaded together initially. To add/remove tab, click on the small “+” tab button or, right click on the tab name and select “edit visible tabs”.

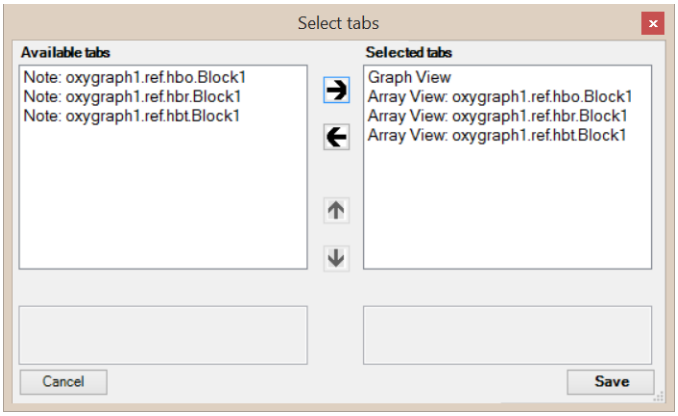


4.3.2. Add/remove tabs to the current view

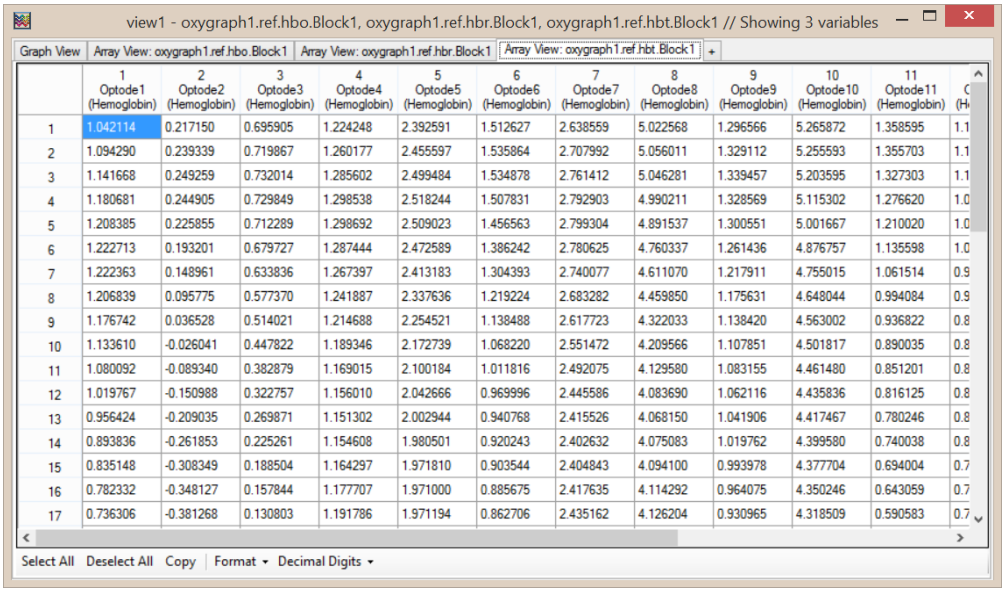
9) Similar to “Select variables” window, a “Select tabs” window will appear as below. Available but invisible tabs are listed on the left and already visible tabs are listed on the right-hand side.



10) Select “Array View: oxygraph1.ref.hbt.Block1” and move it to the right-hand side list: either by double-clicking on it, or by highlighting it with single click and using “right-arrow” button.



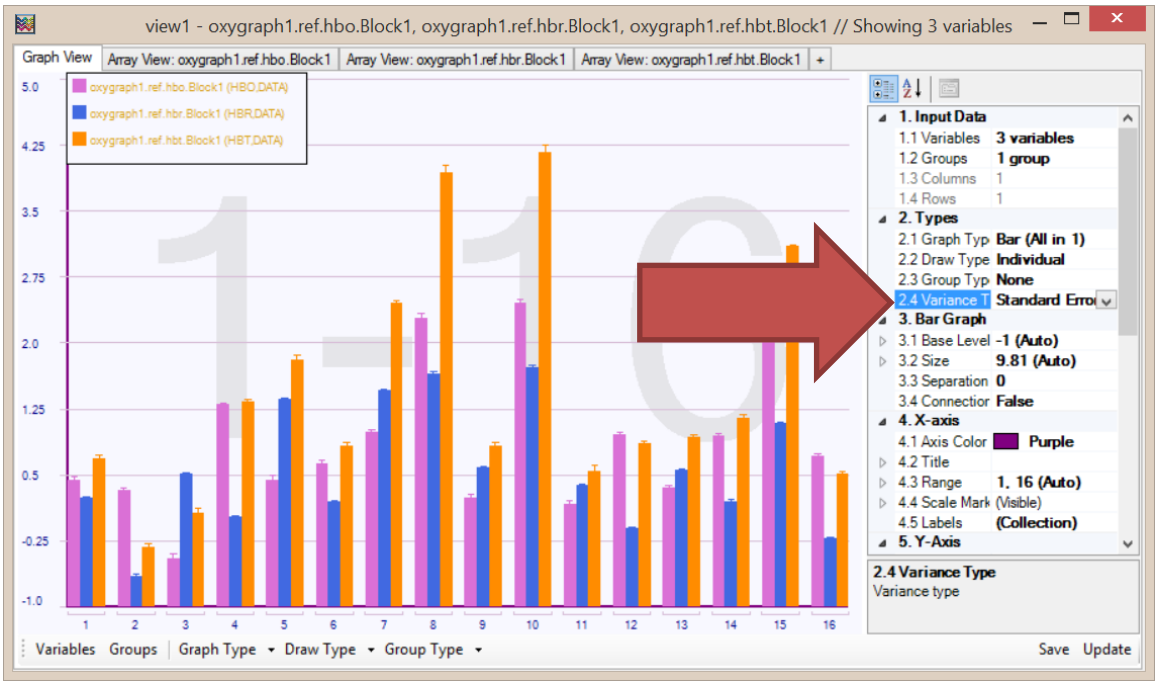
11) Click “Save” to accept changes and close the dialog. The detail-view window will be updated to include the new tab. Click on the new tab to display contents as below.



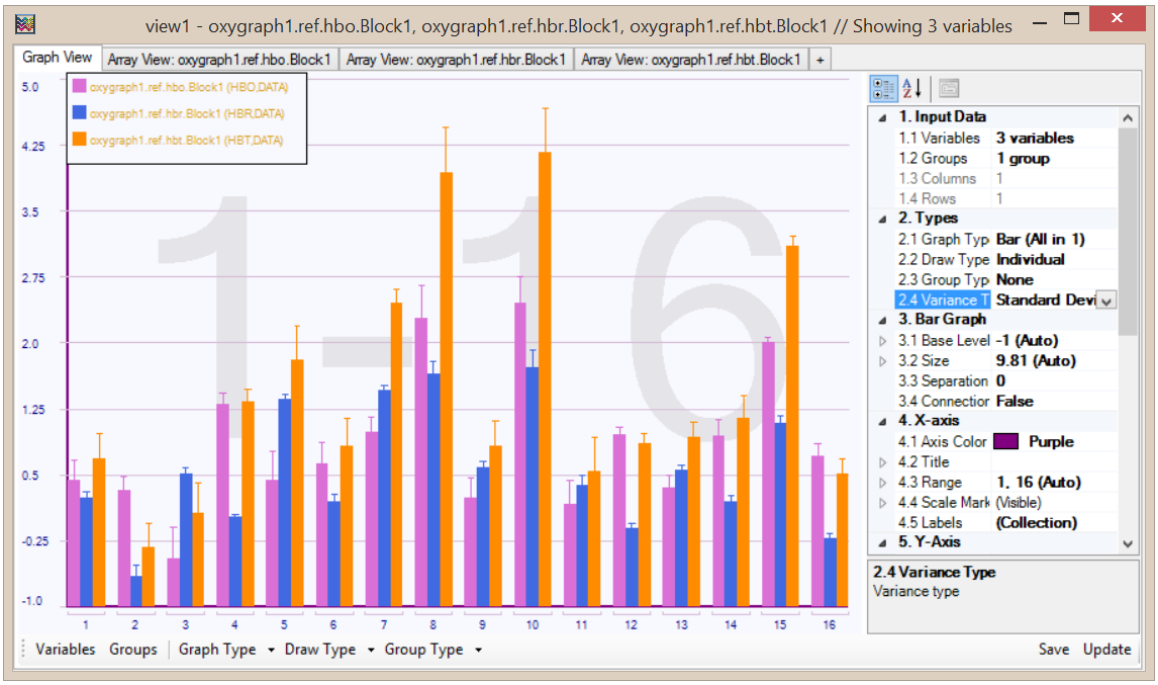
	1 Optode1 (Hemoglobin)	2 Optode2 (Hemoglobin)	3 Optode3 (Hemoglobin)	4 Optode4 (Hemoglobin)	5 Optode5 (Hemoglobin)	6 Optode6 (Hemoglobin)	7 Optode7 (Hemoglobin)	8 Optode8 (Hemoglobin)	9 Optode9 (Hemoglobin)	10 Optode10 (Hemoglobin)	11 Optode11 (Hemoglobin)
1	1.042114	0.217150	0.695905	1.224248	2.392591	1.512627	2.638559	5.022568	1.296566	5.265872	1.358595
2	1.094290	0.239339	0.719867	1.260177	2.455597	1.535864	2.707992	5.056011	1.329112	5.255593	1.355703
3	1.141668	0.249259	0.732014	1.285602	2.499484	1.534878	2.761412	5.046281	1.339457	5.203595	1.327303
4	1.180681	0.244905	0.729849	1.298538	2.518244	1.507831	2.792903	4.990211	1.328569	5.115302	1.276620
5	1.208385	0.225855	0.712289	1.298692	2.509023	1.456563	2.799304	4.891537	1.300551	5.001667	1.210020
6	1.222713	0.193201	0.679727	1.287444	2.472589	1.386242	2.780625	4.760337	1.261436	4.876757	1.135598
7	1.222363	0.148961	0.633836	1.267397	2.413183	1.304393	2.740077	4.611070	1.217911	4.755015	1.061514
8	1.206839	0.095775	0.577370	1.241887	2.337636	1.219224	2.683282	4.459850	1.175631	4.648044	0.994084
9	1.176742	0.036528	0.514021	1.214688	2.254521	1.138488	2.617723	4.322033	1.138420	4.563002	0.936822
10	1.133610	-0.026041	0.447822	1.189346	2.172739	1.068220	2.551472	4.209566	1.107851	4.501817	0.890035
11	1.080092	-0.089340	0.382879	1.169015	2.100184	1.011816	2.492075	4.129580	1.083155	4.461480	0.851201
12	1.019767	-0.150988	0.322757	1.156010	2.042666	0.969996	2.445586	4.083690	1.062116	4.435836	0.816125
13	0.956424	-0.209035	0.269871	1.151302	2.002944	0.940768	2.415526	4.068150	1.041906	4.417467	0.780246
14	0.893836	-0.261853	0.225261	1.154608	1.980501	0.920243	2.402632	4.075083	1.019762	4.399580	0.740038
15	0.835148	-0.308349	0.188504	1.164297	1.971810	0.903544	2.404843	4.094100	0.993978	4.377704	0.694004
16	0.782332	-0.348127	0.157844	1.177707	1.971000	0.885675	2.417635	4.114292	0.964075	4.350246	0.643059
17	0.736306	-0.381268	0.130803	1.191786	1.971194	0.862706	2.435162	4.126204	0.930965	4.318509	0.590583

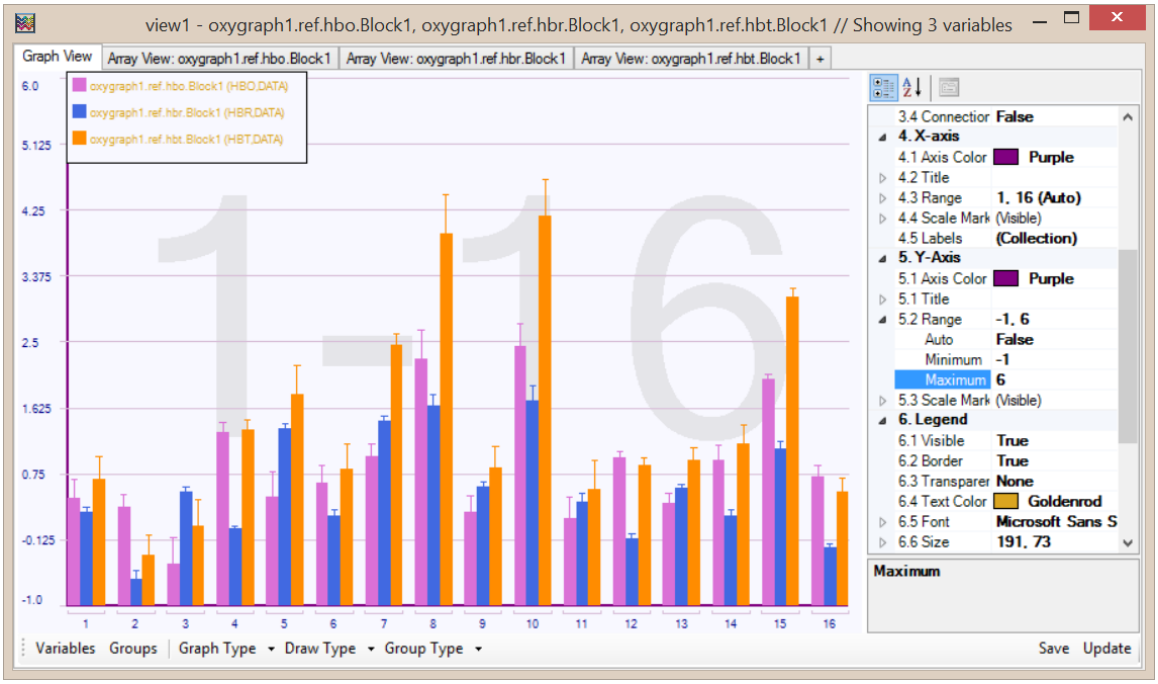
4.3.3. Multi-variable bar graph

12) Open “Graph View” tab to see the graph from all variables. To edit graph properties such as range, error bar type, etc, use Properties Pane. If it is closed, can be opened again, by right clicking on the graph and selecting on “Properties” from the dropdown context-menu.

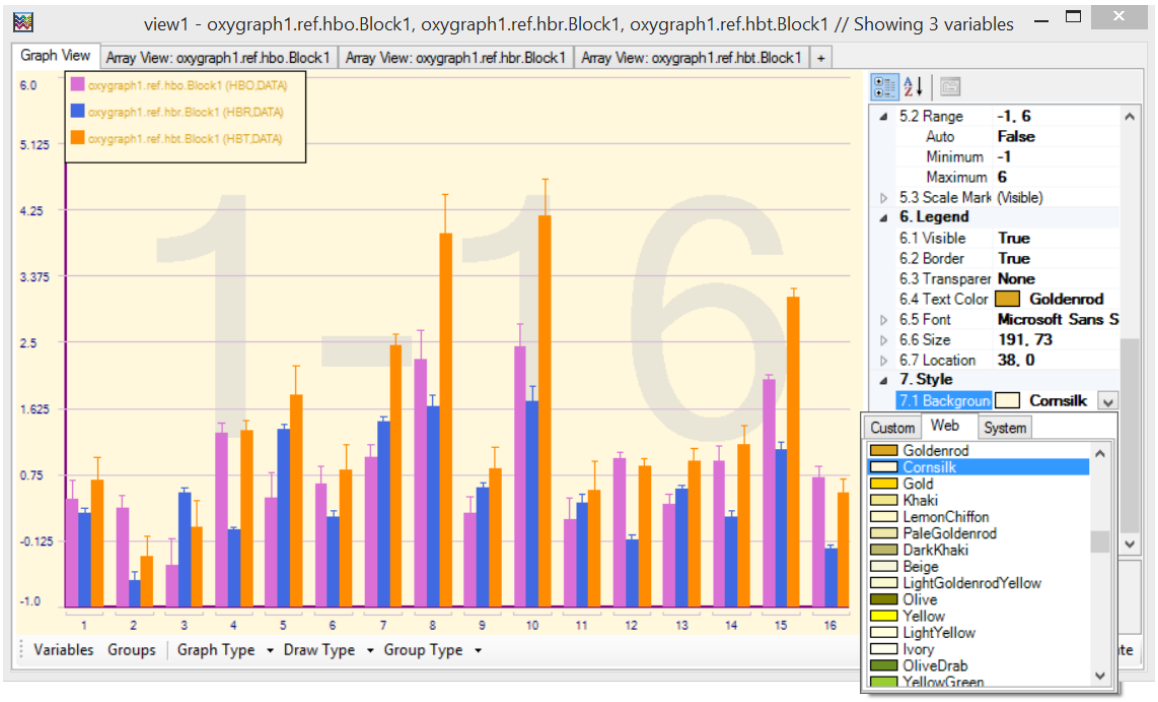


13) Change the error bars to “standard deviation” at item “2.4 Variance Type” and Y-axis range maximum to 6 at item “5.2 Range”

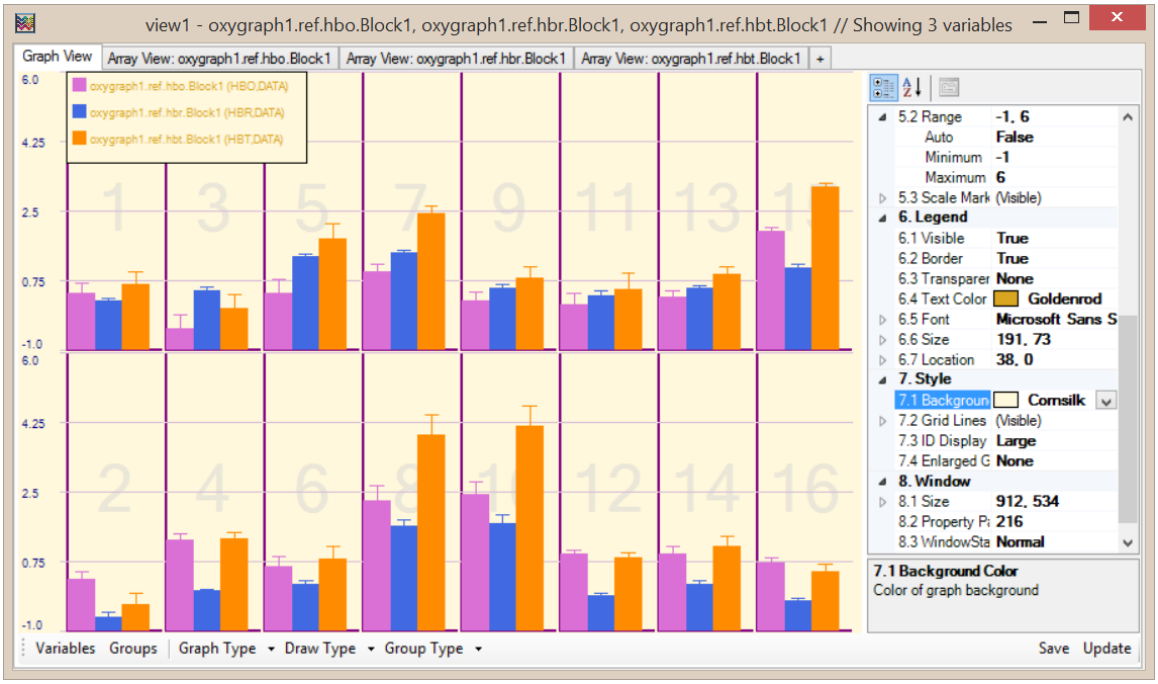




14) Next, change background color to 'Beige' at item "7.1 Background Color".

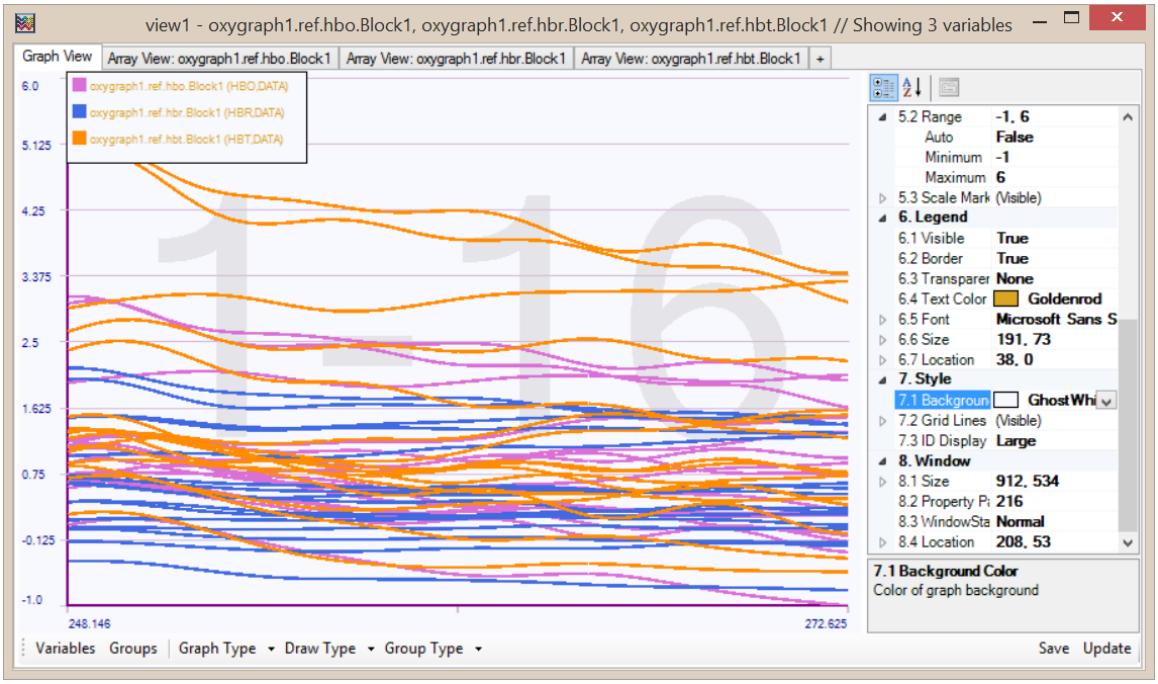


15) Change Graph Type to 'Bar (2 by 8)' to see each optode data (from all variables) in separate sub-graphs. And hide properties by right-clicking on the graph and unselecting Properties from the context menu. The color legend is still available as small squares at the top left corner and can be moved by clicking & dragging.

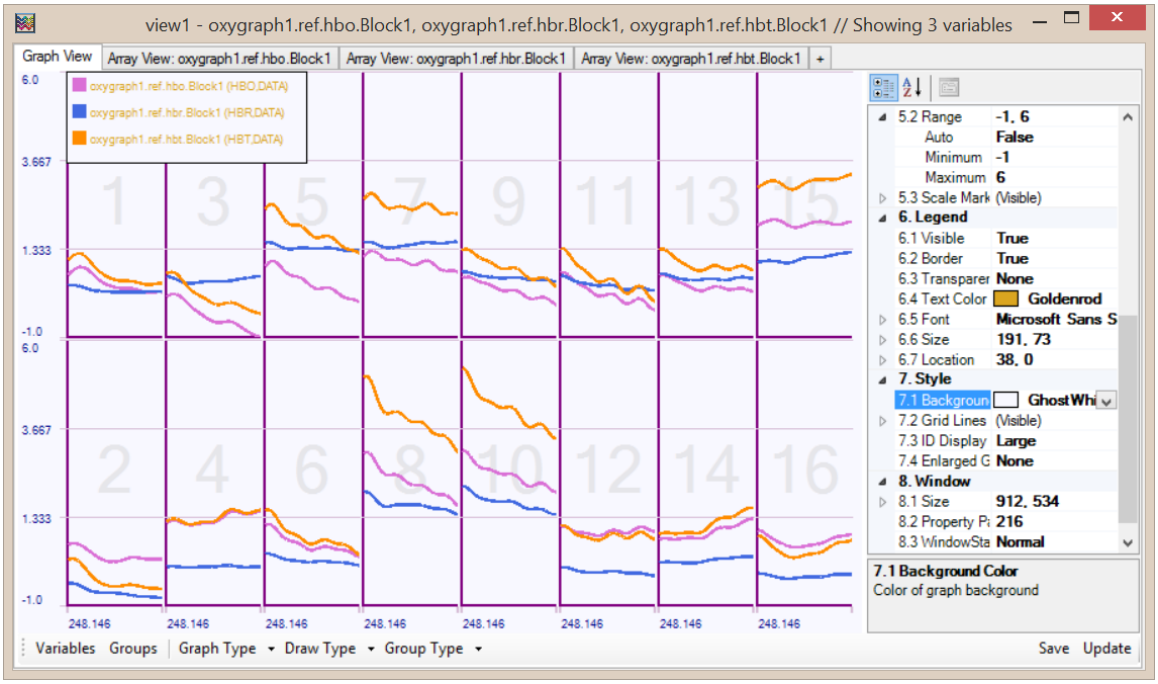


4.3.4. Multi-variable temporal graph

16) Change Graph Type to “Temporal All in 1” to see all optodes from all variables in a single time series graph. Also change background color back to “GhostWhite”.

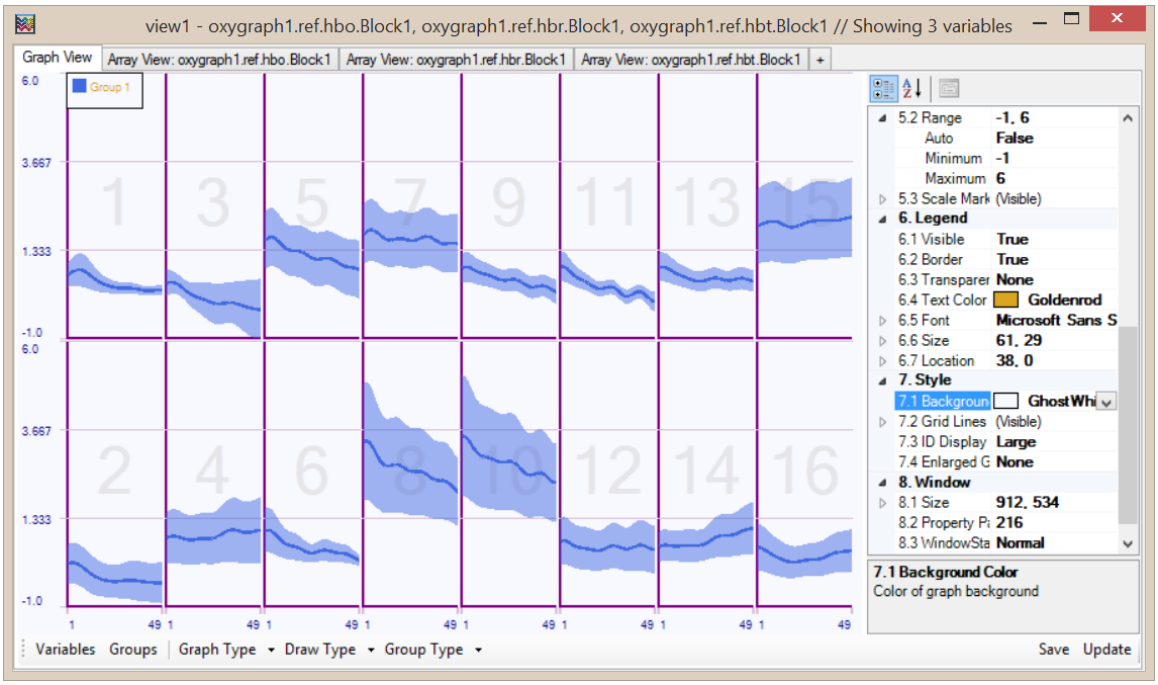


17) The above type of graph can be hard to evaluate with many number of optodes and variables. Instead, each optode can be graphed separately. From the bottom toolbar, change graph type to “Temporal 2 by 8”.



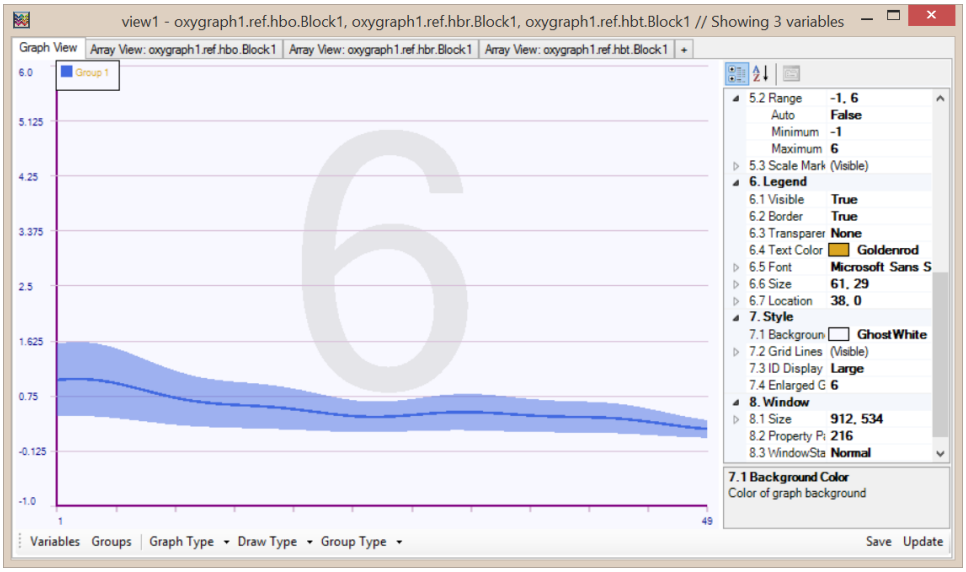
4.3.5. Multi-variable aggregate temporal graph

18) In this case, there are three time-traces in each optode graph (one for each variable). Another useful option is to draw aggregate (average time-series). To do that, change “Draw Type” at the bottom toolbar to “Aggregate”.



19) With the aggregate draw type, an average time-series (in blue) and also error (plus and minus) to this average is also drawn as a shaded area. The error area, similar to error bar, can be standard error, standard deviation or 95% confidence interval. Also note that the legend is changed when the draw type was changed.

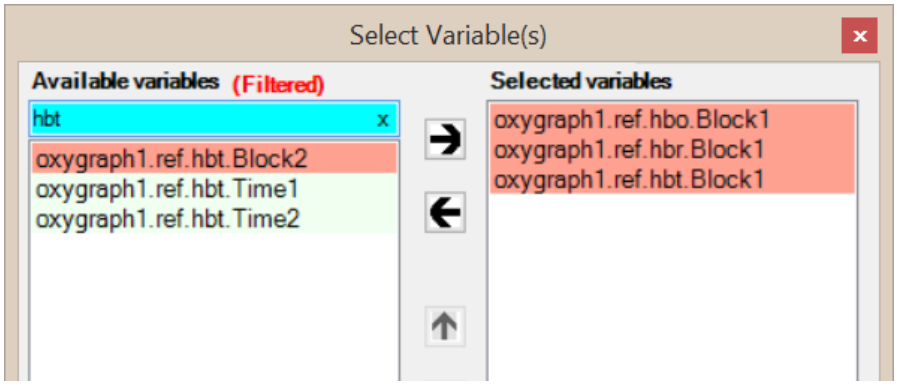
20) It is possible enlarge one of the optode graphs to cover all window by double-clicking or selecting view from right-click-context menu.



TIP

Use name filtering in “Select Variables” window:

When there are large number of variables are loaded in Dataspace, finding specific variable can be challenging in “Select Variable(s)” window. Use “filter by name” to list only variables that contain a specific string in their names as shown below.



TIP

Data and Time variable coupling/association is by name.

Data variables contain only optode (for hemoglobin data) or channel (for light intensity data). The time information is kept in a separate variable that has only one column but has the same number of rows as the data variable.

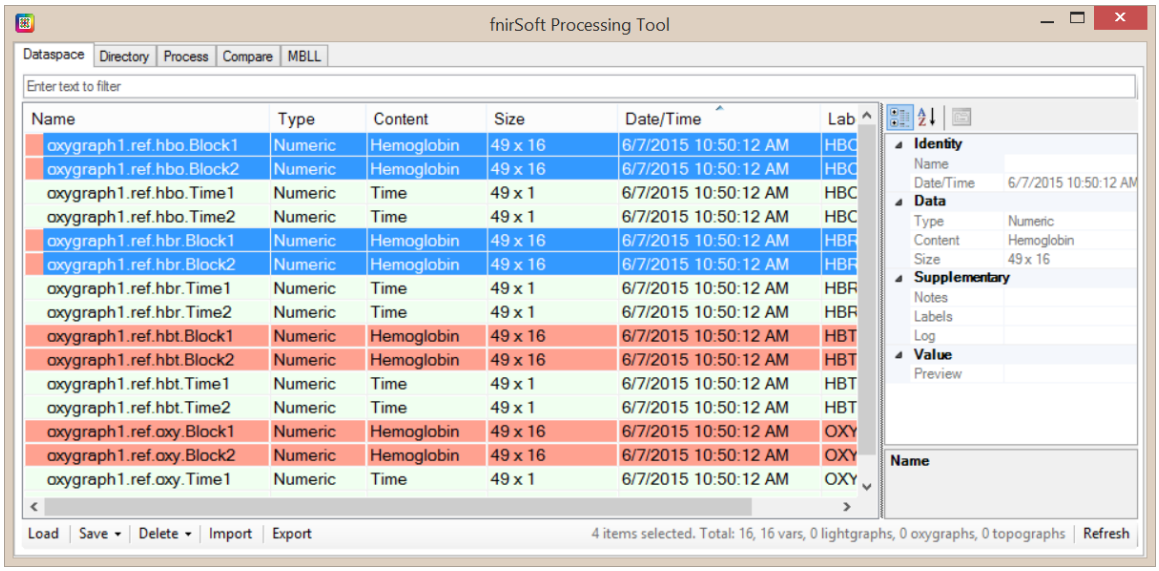
Name association: The time variable for any time variable is found by the following:

1. Start with the name of data variable (i.e . "oxy1.hbo.Block1")
2. Replace the term "Block" with "Time" (i.e. "oxy1.hbo.Time1")
3. If there are any variable with the above string, use that as time variable.

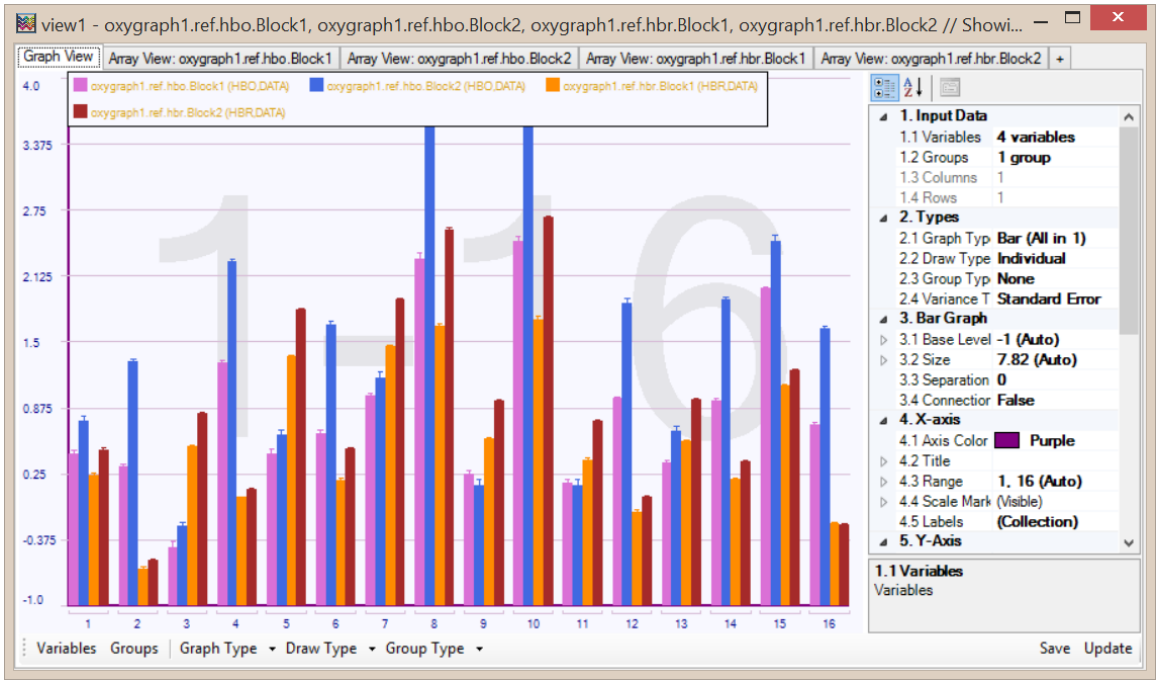
- The keywords are "**Block**", "**Time**", "**Marker**" are special within names, fnirSoft replaces them in name templates to find associated variables.

4.3.6. Multi-variable aggregate & grouped temporal graph

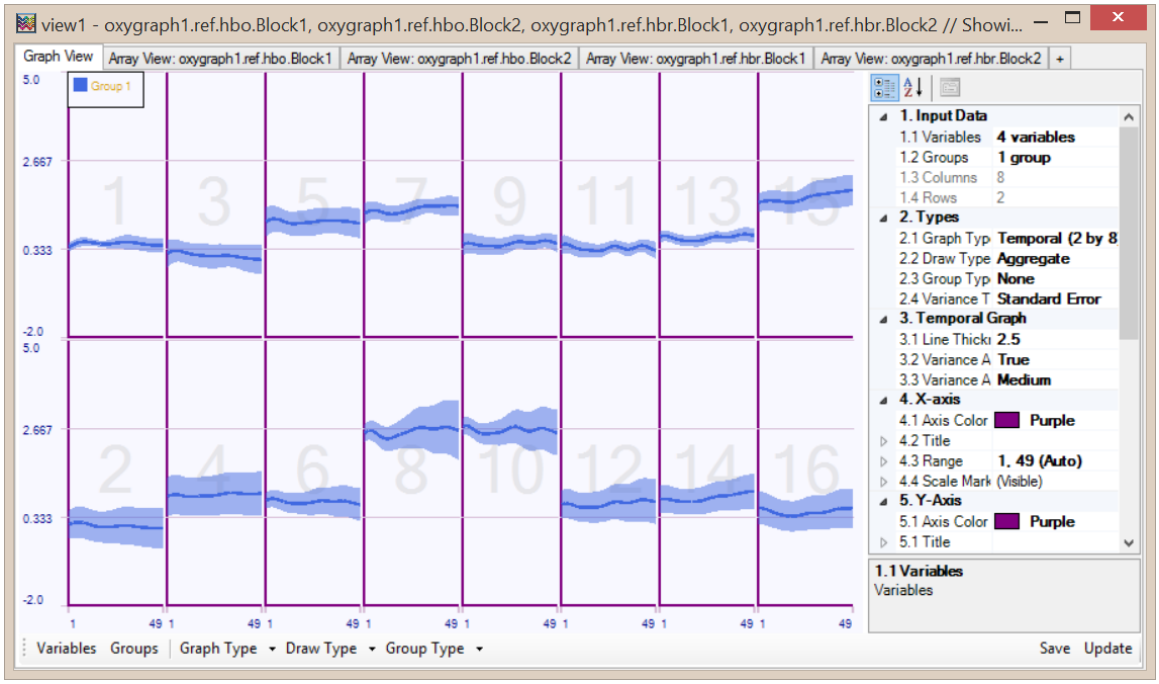
21. From Dataspace, select the following 4 variables: (oxygraph1.ref.hbo.Block1 oxygraph1.ref.hbo.Block2 oxygraph1.ref.hbr.Block1 oxygraph1.ref.hbr.Block2).



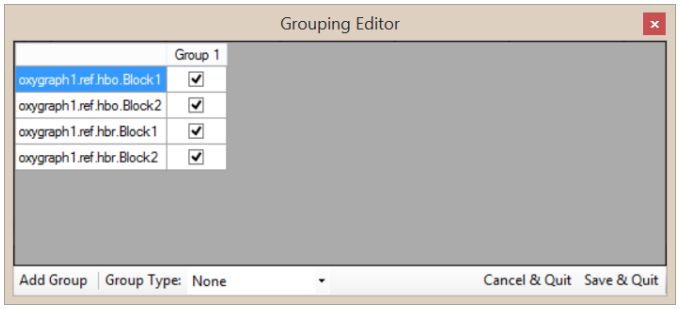
22. Next, right-click and select "view" to open them in view tool.



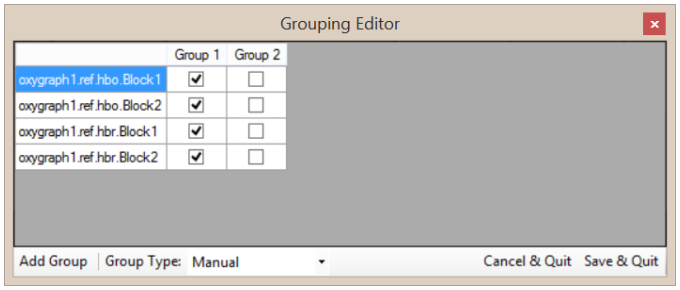
23. Change Graph Type to “Temporal 2x8” and Draw Type to “Aggregate”.



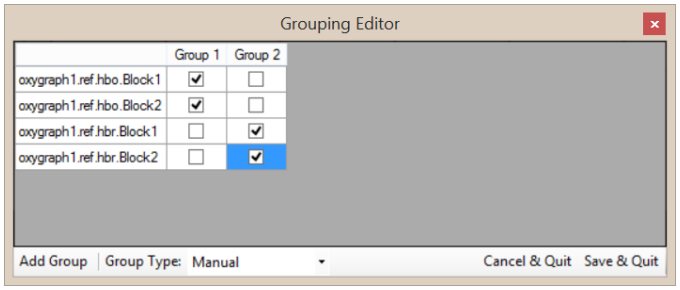
24. Click “Groups” button on the bottom toolbar. The Grouping Editor will be shown with only one group that all variables are in.



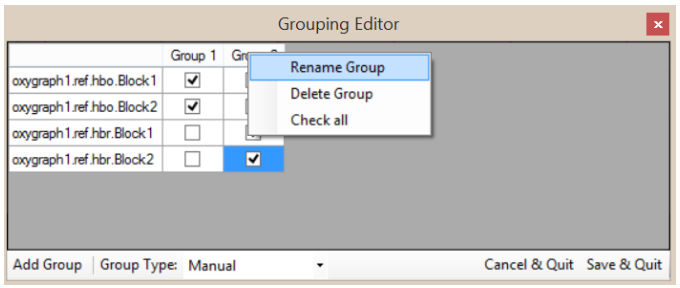
25. Click on “Add Group” button at the bottom toolbar to add a new group.

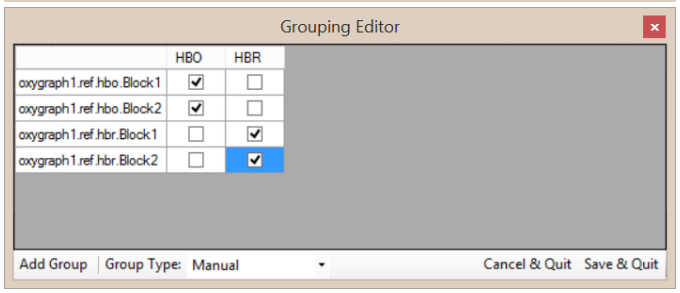


26. Next, to move ‘oxygraph1.ref.hbr.Block1’ and ‘oxygraph1.ref.hbr.Block2’ variables, click on the checkboxes under the Group 2 column. Note that, group type is now changed to ‘manual’.

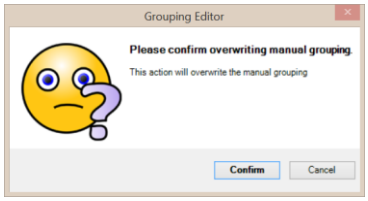


27. It is possible to rename the groups. Right click on the column headers that say “Group 1” and “Group 2” to enter HBO and HBR respectively.

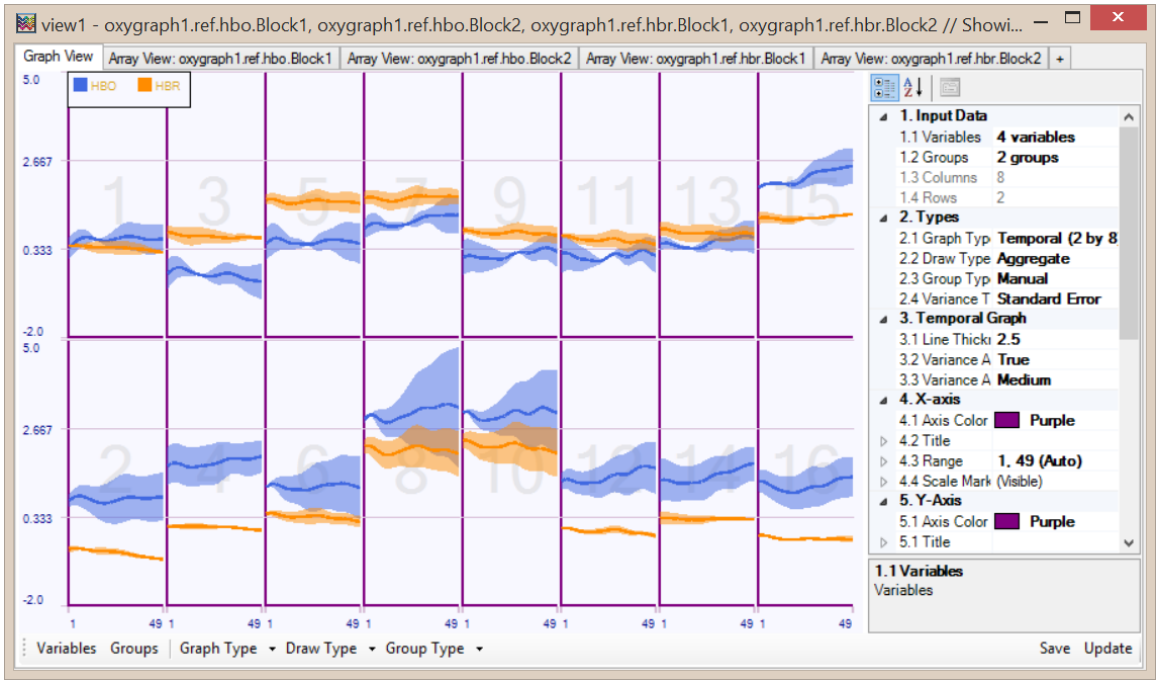




28. Click “save and quit” button the lower right corner. Accept manual changing of the groups to this will return to the graph view.

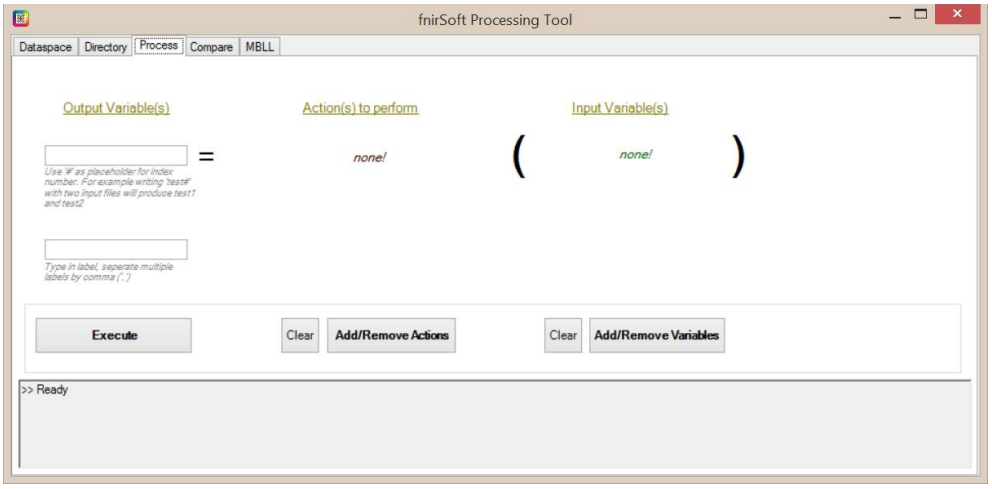


29. Graph view will be updated to show the two groups time-traces (each are product of multiple variables). Note also that, the legend displays the names of the groups with color coding.



5. Processing Tool

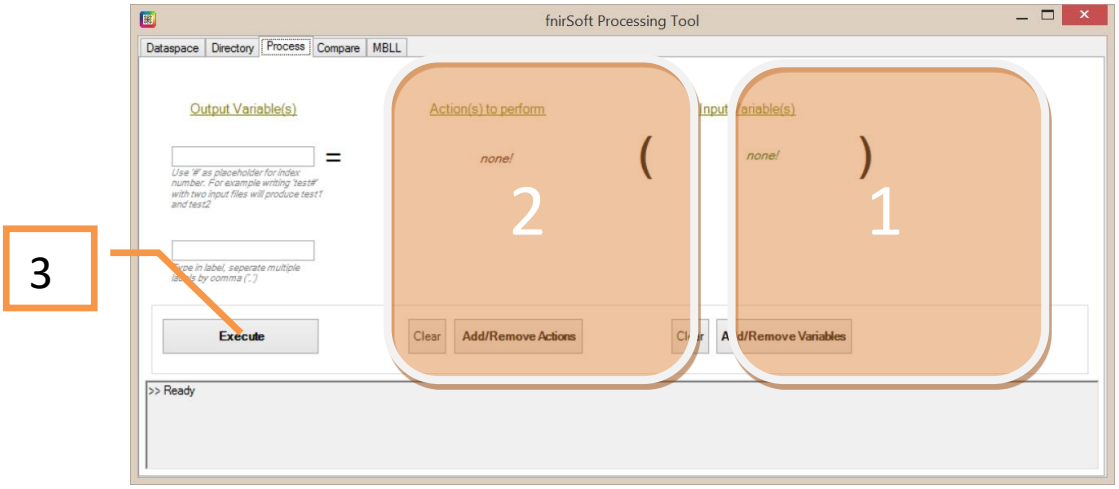
Processing tools provides a quick and visual interface to apply various predefined action(s) to the selected input variables. See the previous chapter on Dataspace to get more information on variables. Processing tool is available at the "Process" tab next to "Dataspace" tab. To open, click on "Dataspace" toolbar button of the main window. The following window will appear.



There are 3 steps needed to perform an operation:

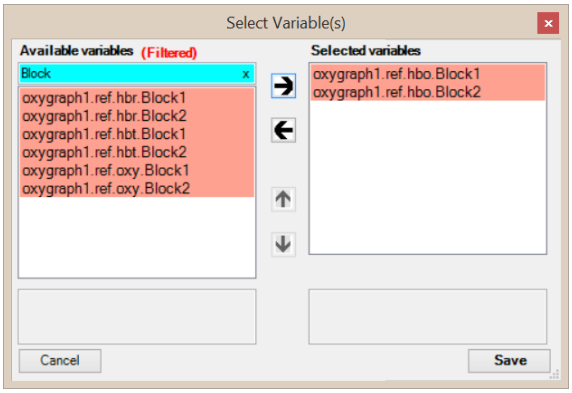
1) Select **input variable(s)**
2) Select **action(s)** to perform
3) **Execute**

The outcome will be displayed at the output pane at the bottom of the window. And, new variable(s) will be added to the current variables' list.

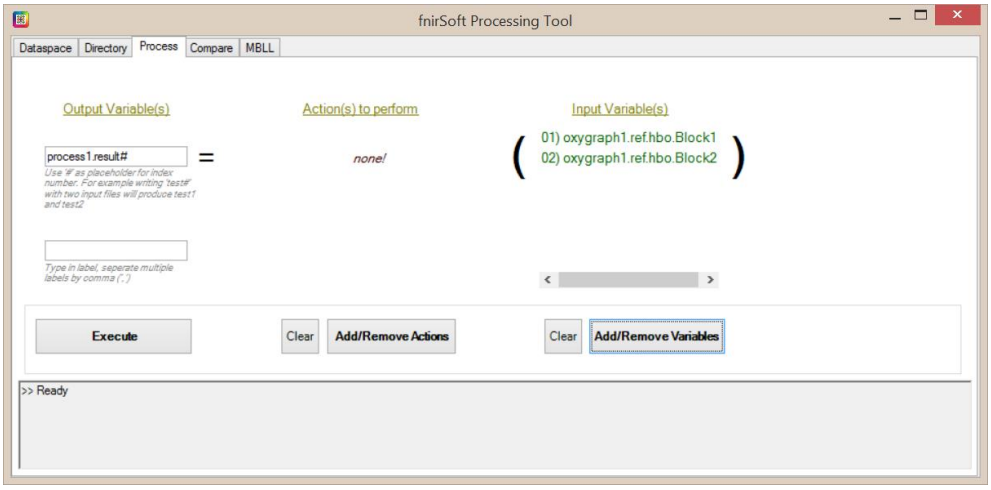


5.1.Select input variables

1. Click on “Add/Remove Variables” button, a new window will appear that lists all available variables. On the left hand side, all available variables are listed and on right-hand side, those already selected (loaded) to the current detail-view window are listed. You can move variables from one to the other and select “Save” to commit the changes to update the graph. Use “filter by name” to list only variables that contain a specific string in their names as shown below that filters by “Block”, so only data variables are listed and not time variables (that has 1 column)



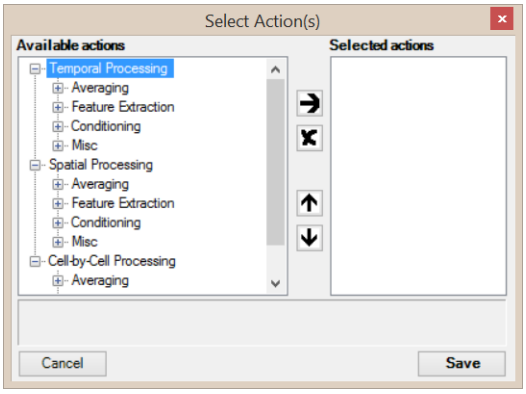
2. Select one or more variables of interest and click ‘right-arrow’ button to move them to the list on the right hand side. Selected variables’ name and size is also shown at the bottom of the list. Click “Save” button to accept the selected list and close the window. The “Process” screen will change to indicate selected variables. Also, a name template will be added to the output variable name section.



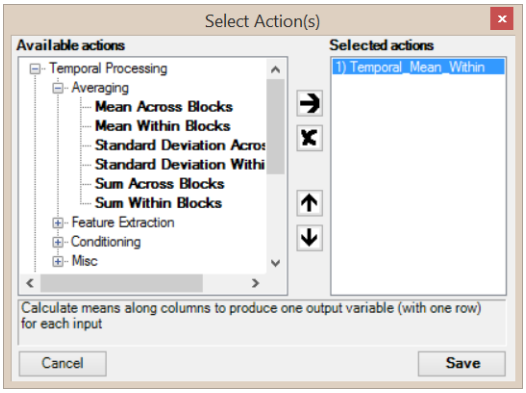
5.2.Select actions

1) Click “Add/Remove Actions” button to display all available actions as shown below. The list on the left is categorized by processing type (Temporal/Spatial/Cell by Cell). Temporal processing operation is performed across rows. So, for Temporal Mean, the result variable has the same number of columns with the input and only one row that is the mean values. Spatial processing

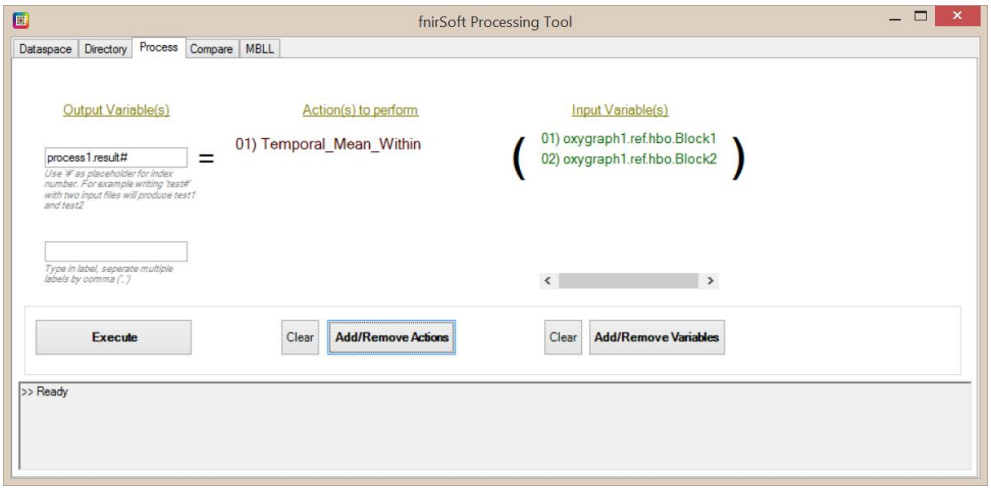
is performed across columns, so for Spatial Mean, the resultant variable has same number of rows with input variable but one column that contains mean values.



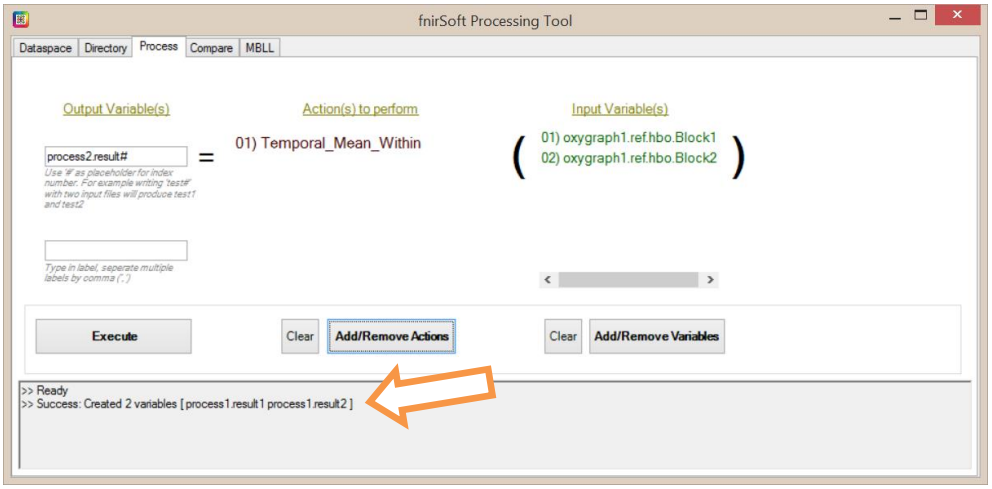
2) Select *Temporal Processing > Averaging > Mean Within Blocks* and click right arrow button.

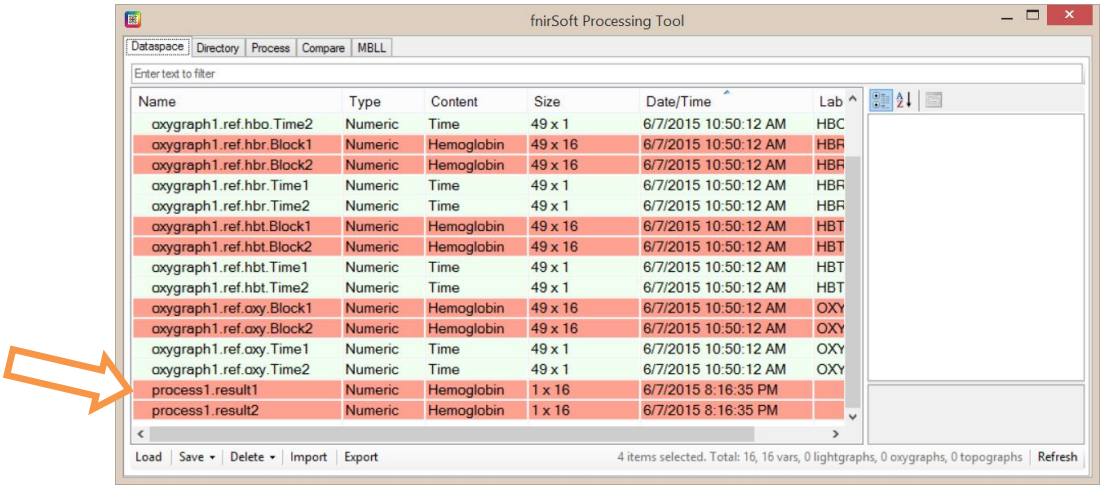


3) Click “Save” button to accept changes and close the window. Note that “Process” tab is updated immediately with selected settings and output variable name is automatically entered. This can be changed if necessary.



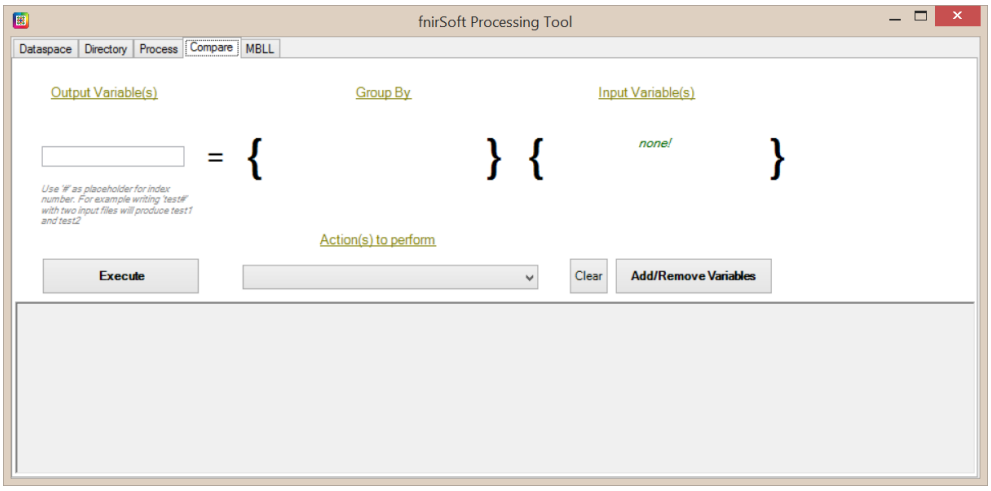
4) Finally, click on Execute button to perform the actions on the selected variables. The outcome will be posted at the bottom pane as shown below. For the selected operations, temporal means of the two input variables are created as new variables with names 'process1.result1' and 'process1.result2'. These are single row (1x16) variables and each cell in the row is the mean of the corresponding column of the corresponding input variable.





5.3.Statistical comparison and tests

Statistical comparison methods can be applied at the “Compare” tab of “fnirSoft Processing Tool” window as shown below.

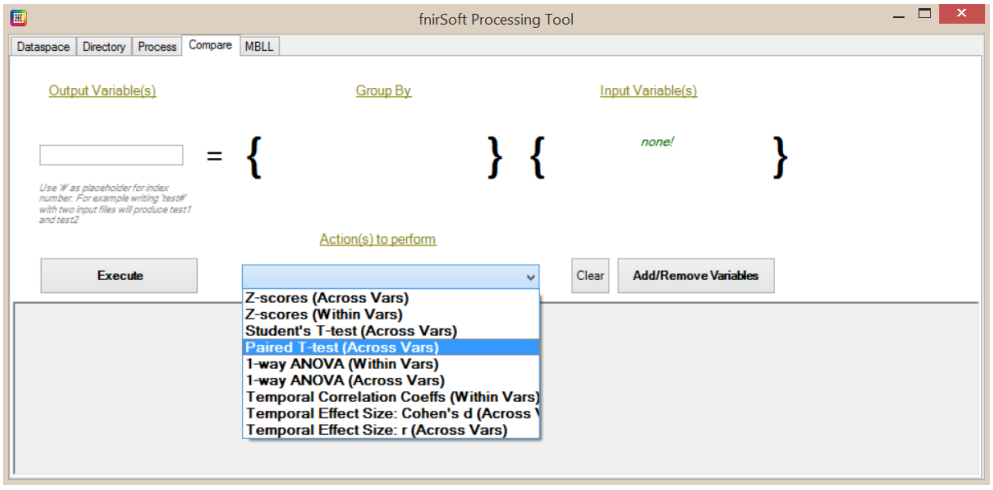


Similar to Process Tool, there are 3 steps:

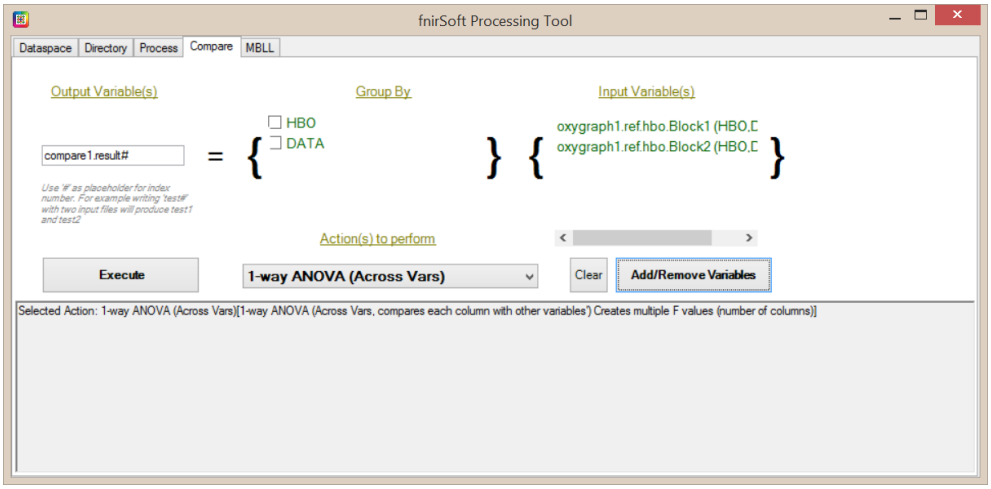
1) Select **input variable(s)**
2) Select **action** to perform
3) **Execute**

The outcome will be displayed at the output pane at the bottom of the window. And new variable(s) will be added to the current variables list.

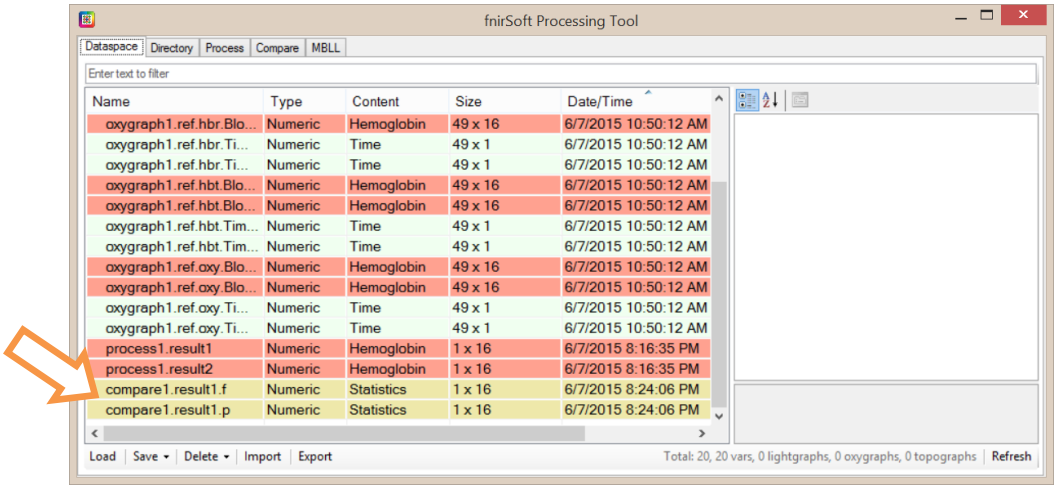
Selection of ‘input variables’ are same using the variable selection window interface. However, “Actions to perform” are selected from a drop-down menu as shown below.



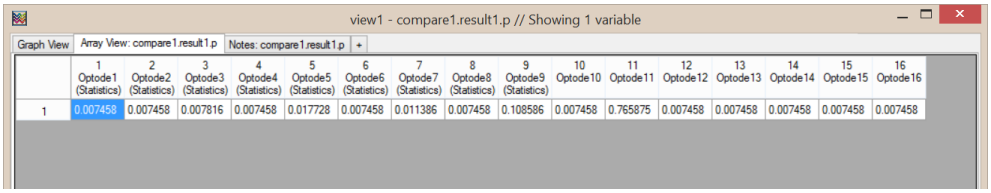
Once the input variable and the action to perform are selected, output variable names are automatically filled. Also, description of selected action is added to the pane at the bottom of the screen.



Finally, clicking "Execute" button performed the analysis and creates new variables depending on the analysis type. In this case, for ANOVA, two new variables are created: one for F and the other for p values.

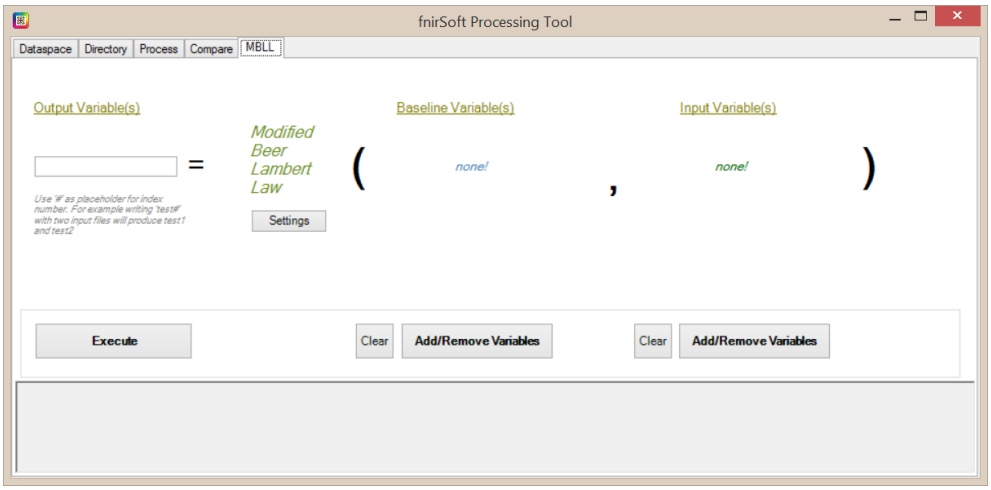


As any other variable, clicking on one of the statistics type variables will open them in View Tool. And at the 'Array View' tab, individual values can be observed.



5.4.Using MBLL to calculate oxygenation from variables

Programmatic oxygenation calculation from variables can be performed at the “MBLL” tab of “fnirSoft Processing Tool” window as shown below. This tool provides more flexibility and additional features for oxygenation calculation.

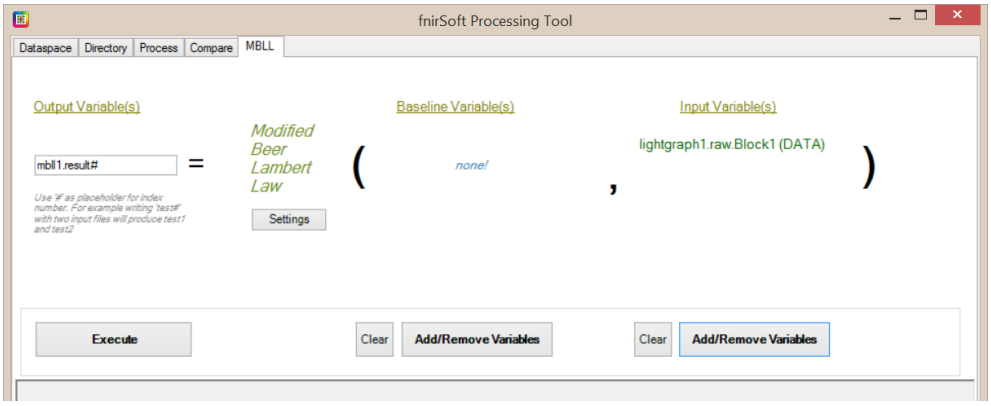


Similar to Process Tool, there are 3 steps:

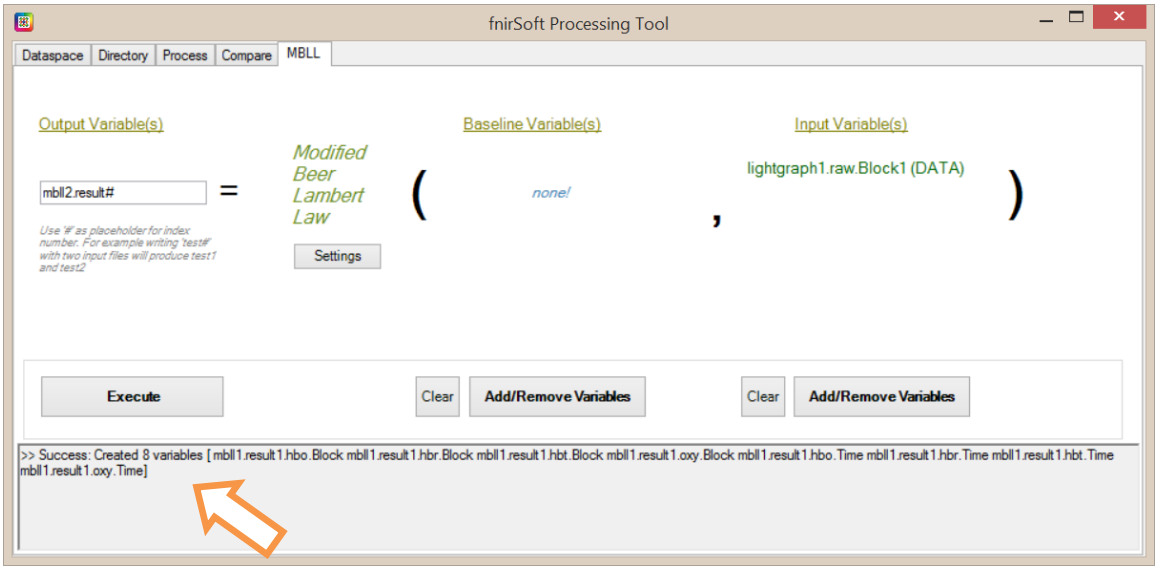
1) Select **input variable(s)**
2) Select **baseline variable(s)** (optional)
3) **Execute**

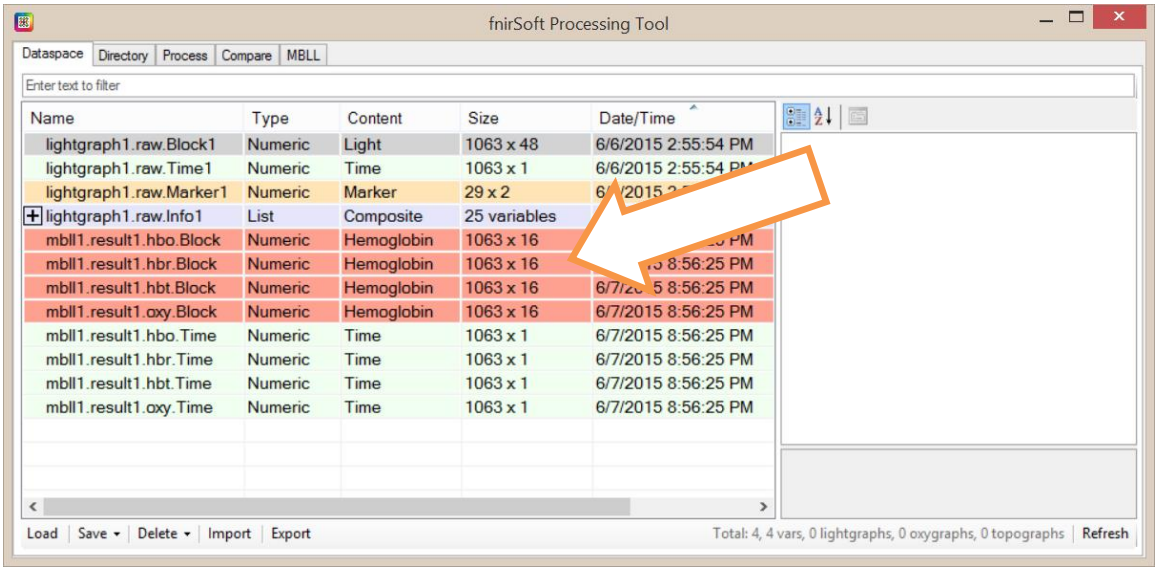
All input variables should be light intensity content type. Any number of input variables can be used. If no baseline variable is provided, first 20 rows of each input variable will be used for that variable as a baseline. Otherwise, same number of baseline variables needs to be selected so, through one to one matching, first baseline variable will be used for first input variable, etc. If only one baseline variable is selected or at the MBLL settings dialog, ‘use single baseline’ is enabled, all input baseline variables will be averaged and the same baseline will be used for each input variable.

Once the input variable is selected, output variable names are automatically filled.



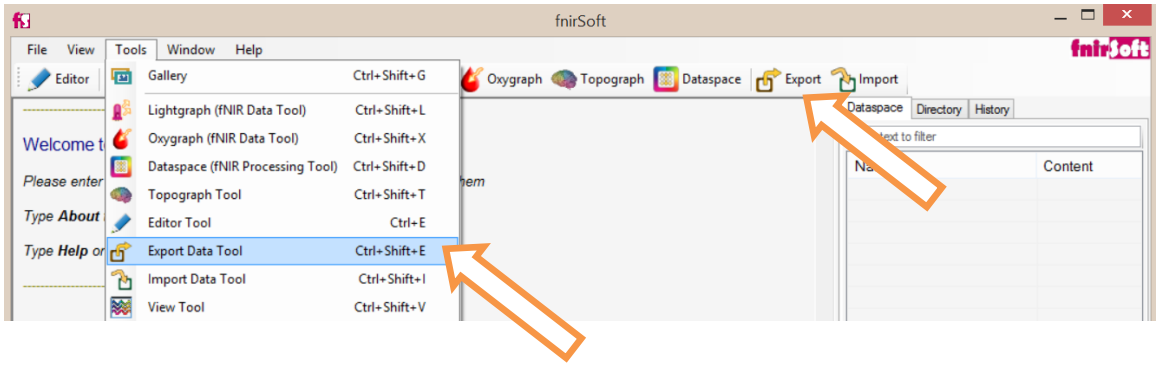
When, ‘Execute’ is clicked, all variables (names by default starts with mbll as they are created by mbll tool) are calculated. Also, time variables are generated for each corresponding data variable.



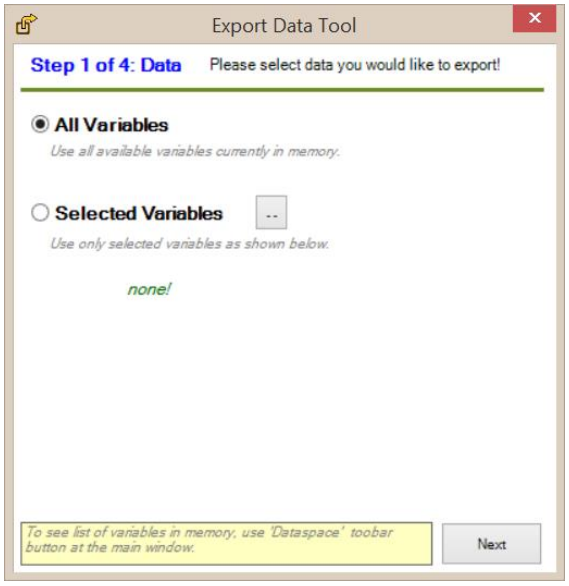


6. Export Data Tool

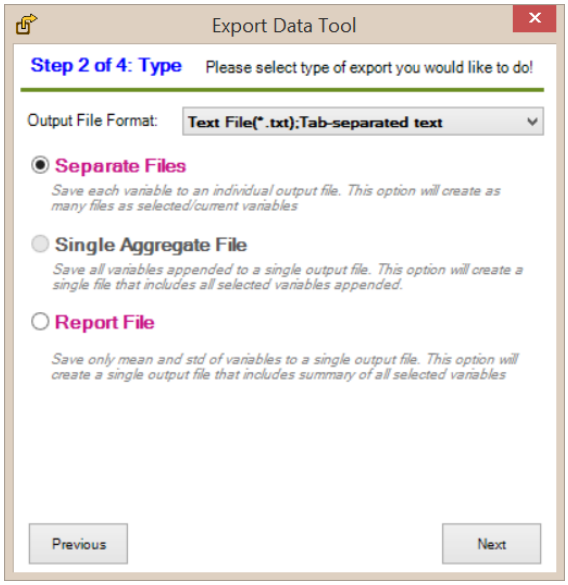
1. The Export Data Tool can save variables in Dataspace to output file formats in various format for other applications to use. The Export Data tool is accessible from Main window, toolbar button, "Tools" dropdown menu item, or fnirSoft Processing Tool, variable tab, export button.



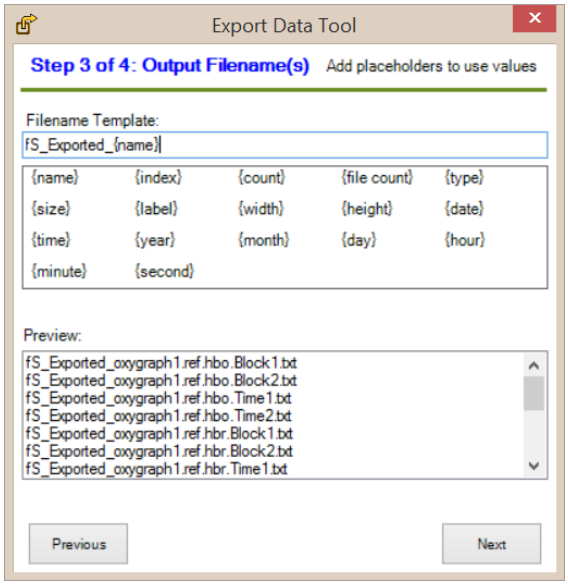
2. The wizard style dialog, provides 4 steps where all variables or selected ones can be saved in various formats and styles. The first step includes selection of all variables or selection of a subset of variables for export.



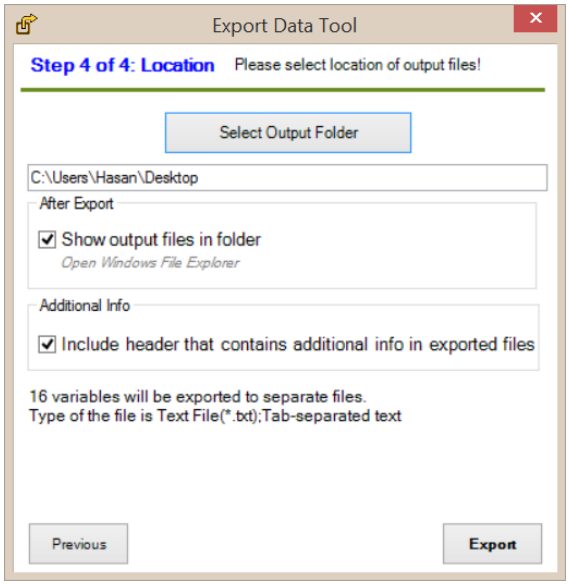
3. Next, one of the available file formats is selected: tab-separated text file, comma separated Excel file and Matlab file format, Biopac Acknowledge or fnirSoft data file format. Also, exported variables can be saved into separate files (one file for each variable) or all of them into a single output file (one file for all variables). Also, a report file can be generated. The report option generates a summary file for each input variable by saving mean and standard deviation of all optodes (columns) of each variables.



4. The next step is to name the output files. Name template is applied to each output file generated and if it includes placeholders (special keywords in between curly parenthesis) as listed below on screen, appropriate values are replaced. For example, "{name}" placeholder is replaced by the variable name. A preview of output filenames based on current input variables and name template is listed at the bottom of the screen.



5. At the last step, the output folder is selected by using the "Select Output Folder" button. Also, summary of overall action (number of input, type of output files, etc.) are presented for final confirmation. Hit Export button to perform the action.

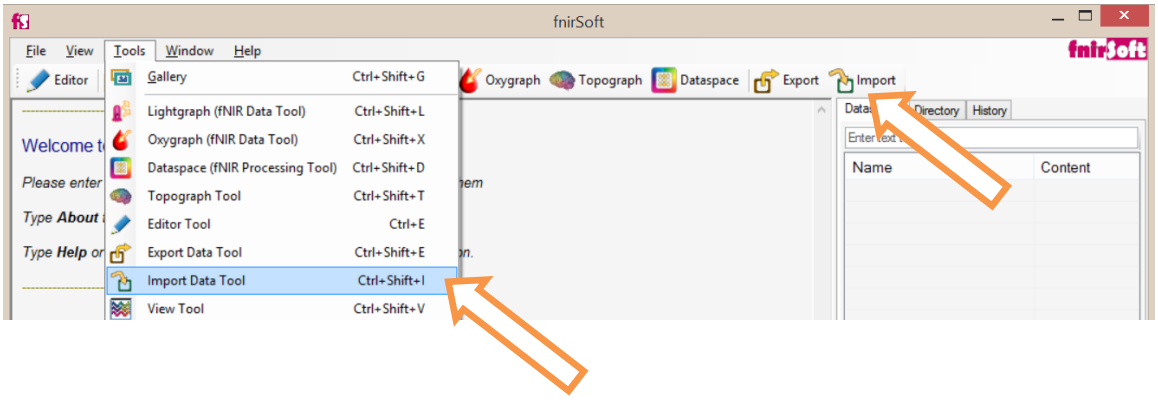


Below is a representative output file (plain text with tab separated columns) that contains header rows that includes description of the data and individual column content type and descriptive captions.

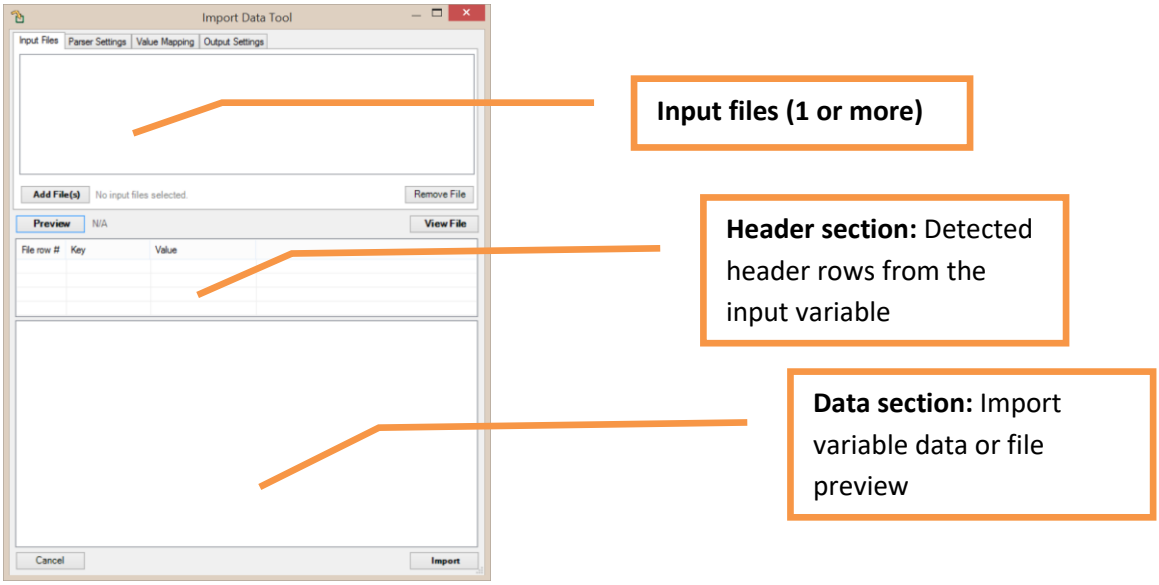
fnirSoft:	Exported Text File															
Version:	4															
ExportDat	6/7/2015 23:46															
VariableInfo																
Name:	oxygraph1.ref.hbo.Block1															
Size:	49 x 16															
Type:	Numeric															
Content:	Hemoglobin															
Date:	6/7/2015 10:50															
Notes:	Oxygenated-hemoglobin concentration changes refined data saved by Oxygraph from file C:\															5_1_07301658.oxy
Labels:	HBO	DATA														
VariableData																
Hemoglob	Hemoglob	Hemoglob	Hemoglob	Hemoglob	Hemoglob	Hemoglob	Hemogl		Hemoglob	Hemoglob	Hemoglob	Hemoglob	Hemoglob	Hemoglob	Hemoglobin	
Optode1	Optode2	Optode3	Optode4	Optode5	Optode6	Optode7	Optode8	Opto 9	Optode10	Optode11	Optode12	Optode13	Optode14	Optode15	Optode16	
0.654976	0.619831	0.	188677	0.891127	1.13215	1.128692	3.013687	0.566331	3.106394	0.719753	1.078529	0.632966	0.750965	1.960423	1.003706	
0.703441	0.640601	0.	219211	0.945265	1.151786	1.189305	3.04343	0.593639	3.102431	0.725675	1.094304	0.649117	0.769801	1.990398	0.992387	
0.750071	0.652797	0.1	1308	0.987399	1.154202	1.238813	3.046335	0.605892	3.072513	0.712898	1.092623	0.653251	0.779216	2.015963	0.969483	
0.792075	0.655658	0.1	084	1.012618	1.137738	1.272618	3.019714	0.603653	3.019797	0.683378	1.075912	0.645749	0.780447	2.03816	0.937862	
0.826712	0.64926	0.153527	1.					89591	2.951034	0.641488	1.049072	0.628503	0.776027	2.058231	0.901256	
0.85163	0.634418	0.143287	1.24					67653	2.87505	0.592901	1.018017	0.604387	0.768913	2.076647	0.863093	
0.86496	0.612343	0.120412	1.23277					42249	2.801077	0.543467	0.988503	0.576585	0.761935	2.093008	0.826035	
0.865495	0.58442	0.086164	1.212942	0.920968	0.933984	1.231366	2.703951	0.517069	2.736703	0.497783	0.964532	0.547903	0.75733	2.10594	0.791599	
0.853048	0.552047	0.042823	1.191344	0.864446	0.874744	1.190195	2.619394	0.494632	2.686659	0.458382	0.947941	0.520216	0.756234	2.113307	0.759997	
0.828303	0.516432	-0.0068	1.170869	0.805792	0.822807	1.146944	2.547171	0.47589	2.652264	0.425568	0.938454	0.494437	0.758945	2.113169	0.730739	
0.792957	0.478663	-0.05957	1.154095	0.750967	0.780997	1.107064	2.494155	0.460249	2.631547	0.39754	0.933845	0.470501	0.764849	2.10439	0.703043	
0.749584	0.439752	-0.11238	1.142935	0.704594	0.750083	1.075121	2.461723	0.446086	2.620312	0.371364	0.931097	0.447748	0.772835	2.087031	0.676305	
0.701059	0.400579	-0.16293	1.138145	0.669308	0.728819	1.053834	2.44785	0.431477	2.61338	0.343836	0.927366	0.425241	0.781578	2.062512	0.650509	
0.650372	0.362085	-0.20972	1.139441	0.645326	0.714234	1.043847	2.447753	0.414496	2.605861	0.312474	0.920334	0.402058	0.78951	2.033155	0.625986	
0.600452	0.325303	-0.25231	1.145616	0.630643	0.702542	1.04362	2.454797	0.39398	2.59429	0.276285	0.909089	0.377653	0.795313	2.001805	0.603438	
0.553521	0.291133	-0.2912	1.154723	0.621366	0.689608	1.049734	2.461783	0.369745	2.577194	0.236015	0.894175	0.352032	0.798129	1.971621	0.583803	

7. Import Data Tool

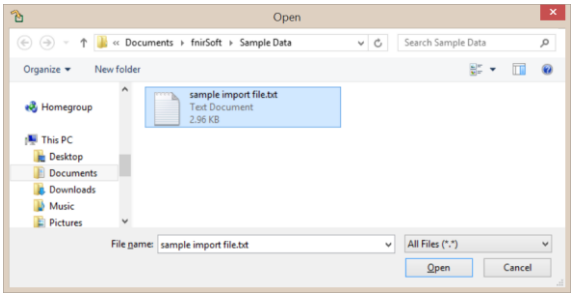
1) fnirSoft can import data from text files. This section describes Import Data Tool that parses text files with customizable formatting guideline and extract data to be stored as variables in Dataspace (See Dataspace chapter for more information on variables). To start the procedure, select “Import Data Tool” under Tools dropdown menu item, or from toolbar button.



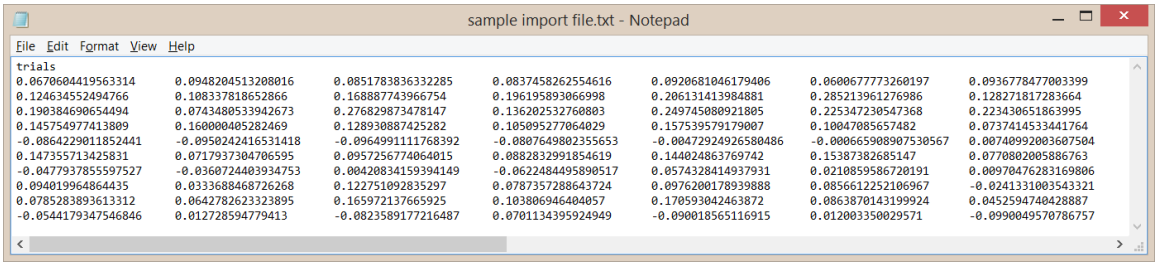
2) The Import Data Tool will appear empty as below. From the “Add File” button, select as many text files to import as required.



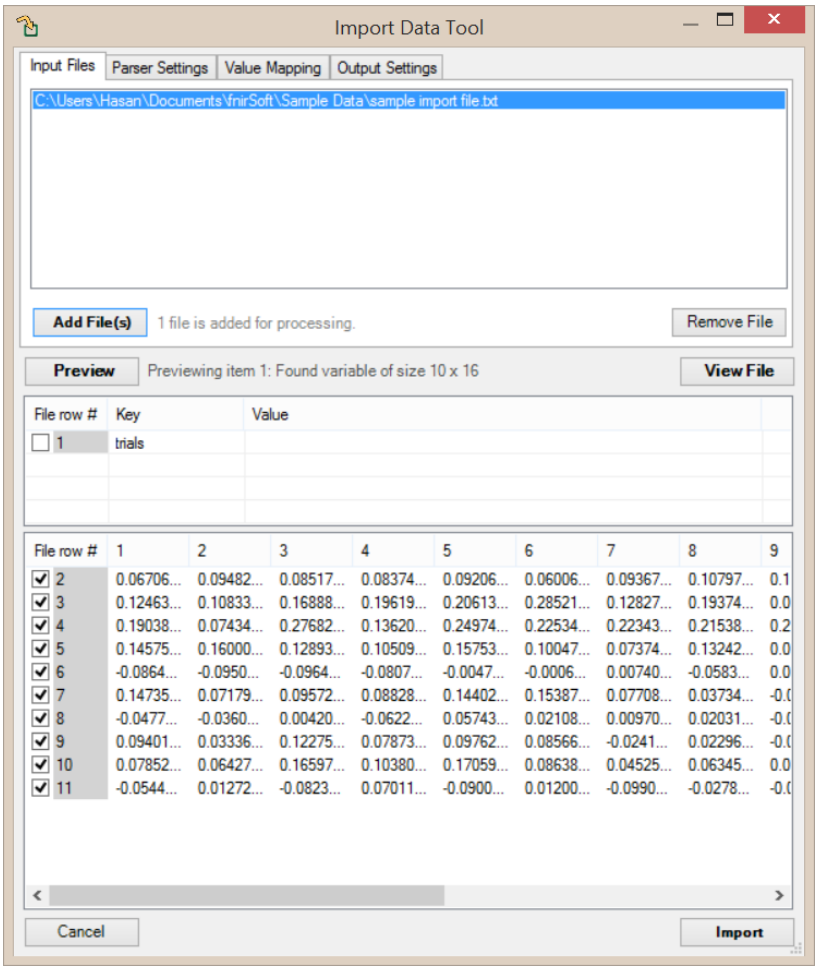
3) From the “Add File(s)” dialog, select the text file to be imported. Alternatively, one or more text files can also be drag-dropped (with mouse cursor) to this list to be added automatically.



4) A sample text file (provided in sample data folder) contents are shown in the Notepad as follows



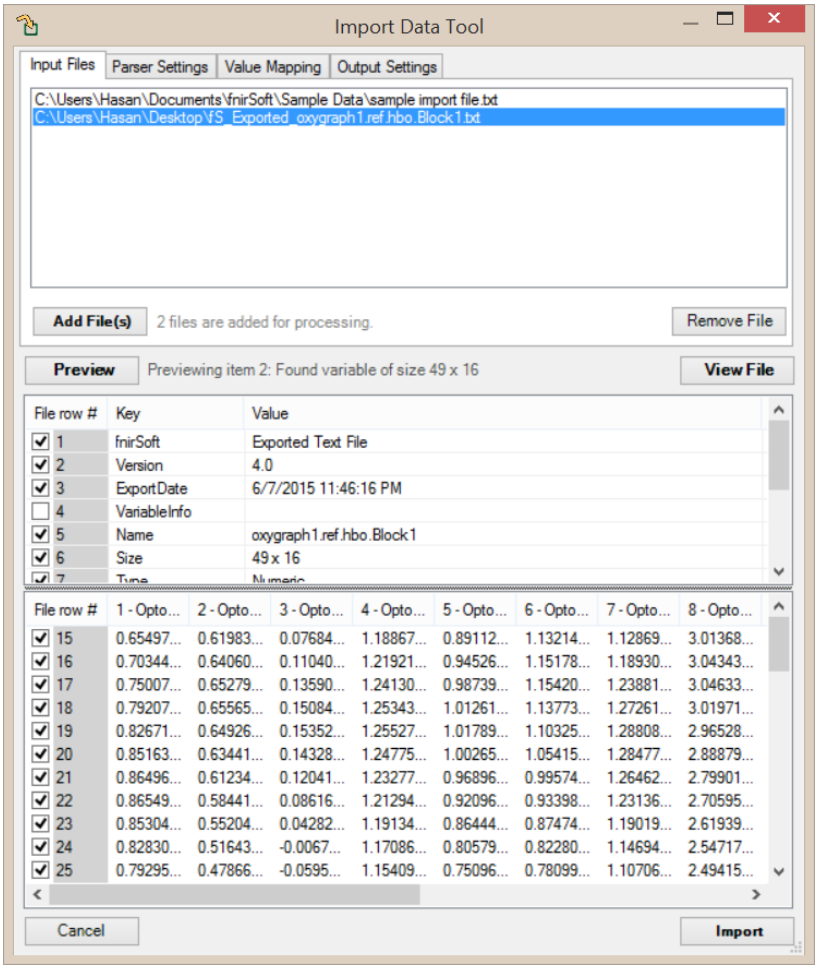
5) Once the file is added to Import data dialog, it will appear in the file list. And, if the file is selected, the import function with current parser settings can be previewed at the Data section (bottom pane of the dialog).



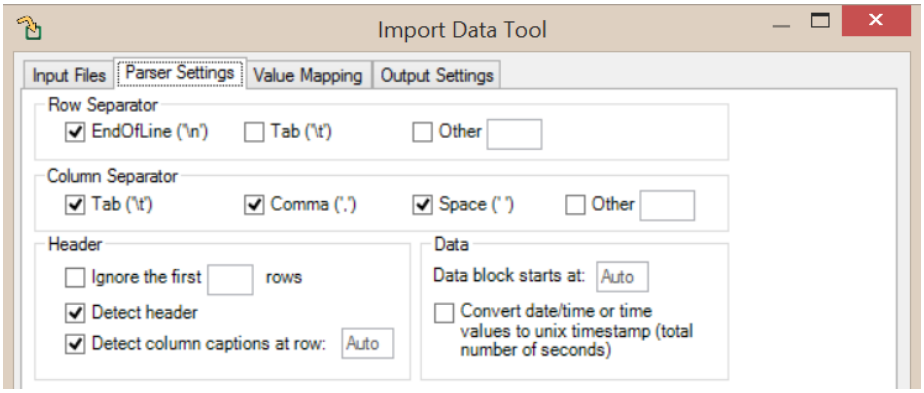
6) The first section contains the first row of the file (see above file contents above) as it is automatically detected header text and not data. To remove it from importing, simply remove the check at the beginning of the row. Any row can be removed from import by clearing the respective checkbox.

When the any row checkbox is cleared (customization), this is noted by adding selected row count in parenthesis at in the input files tab, next to the filename.

7) Another input file can be added at any time. For example, the following is the output of exporter described at the end of previous chapter. All the headers rows are listed in header section and data section column captions are named after the information found in the file.

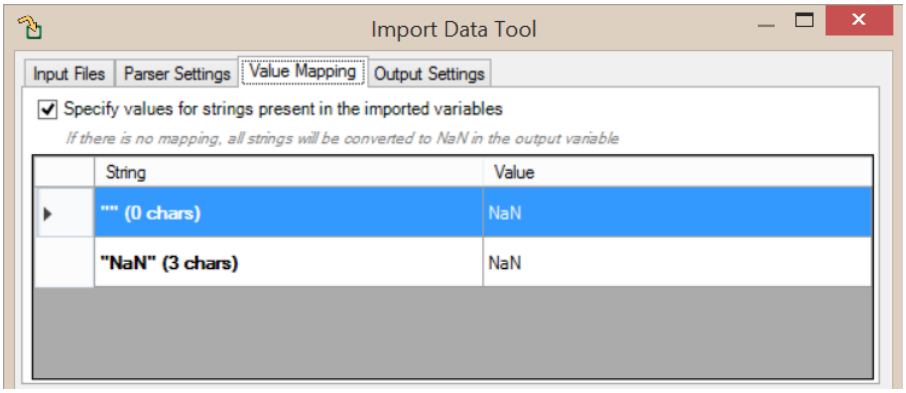


8) The 'Parser Settings' tab can be used reconfigure the parsing of the input files

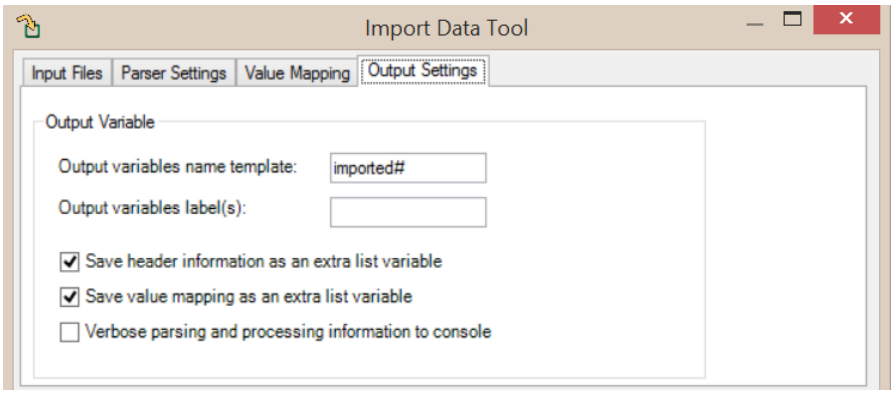


9) The 'Value mapping' tab can be used to convert various strings within the data (like keys, condition descriptions, etc.) to numeric values. By default empty cell values and "NaN" string

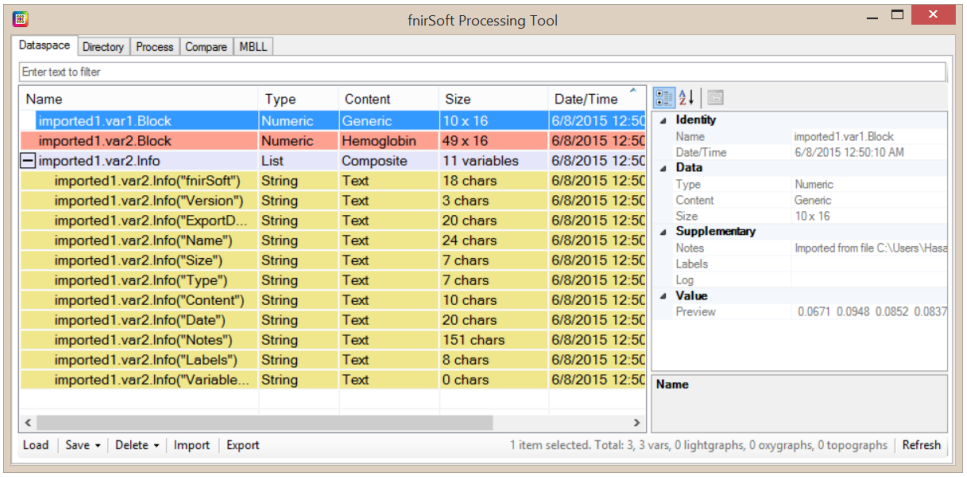
values are converted to NaN value. Any other string found in the files will be automatically added to the list.



10) The “Output settings” tab, contains the controls for naming the output variable (that will be saved in Dataspace). Also, labels can be added to the output variable. Any value mapping used can be saved as a separate list file. By default output data variable name template is “imported#”. The ‘#’ sign is a placeholder for the count number.



11) Click “Import” button to add this 10x16 and 49x16 variables to the Dataspace. Their names start with ‘import’ since they are generated by import tool and includes ‘var1’ for the first variable and ‘var2’ for the second variable that is count number (1, 2, etc.) of the input file list. The third variable is the header values for the second variable in a list.

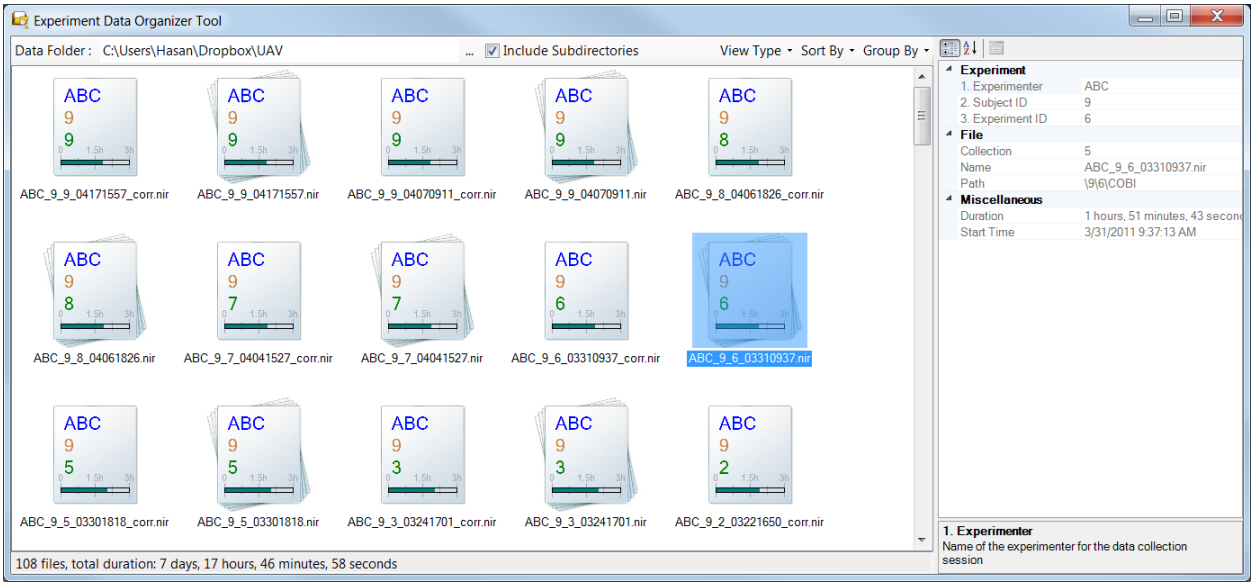


8. Organizer Tool

A typical experimental study contains many recording sessions from multiple participants. Each experiment might contain multiple files (such as nir, mrk, log) and multiple iterations.

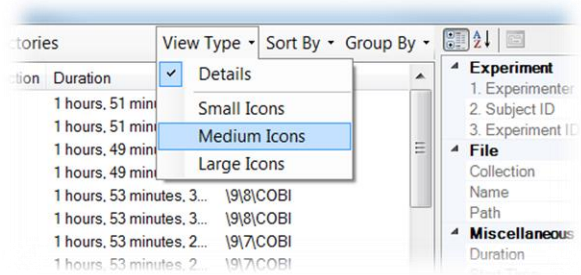
The Organizer tool helps coordinating data files each might reside in many different folders or sub-folders. And, Organizer tool catalogs them, lists & visualizes data contents and enables users to sort according to various criteria and finally access file content with one click.

The following window displays a typical Organizer window that lists a folder and all of its sub-folders by searching *.nir files. Also the number of associated files (such as mrk, oxy, log) are counted and visualized in the icon as number of compiled sheets that are slightly rotated. The data acquisition length in each file is also visualized in a horizontal bar by looking at the maximum recording length. In the example below it is 3 hours and half full bar indicates 1 and half hours of data collection on COBI Studio.

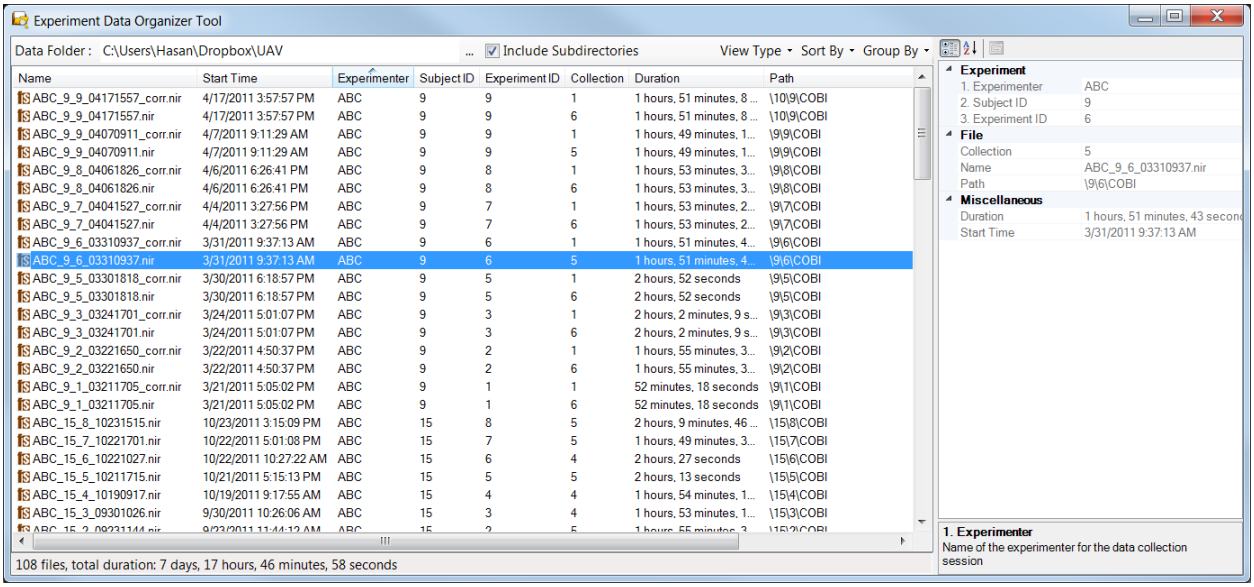


The total number of files and total duration is listed at the lower left corner of the window. The right hand side pane lists properties of selected item.

The view type can be changed from top right down button: available options are small, medium or large icon display, or details list as shown below.

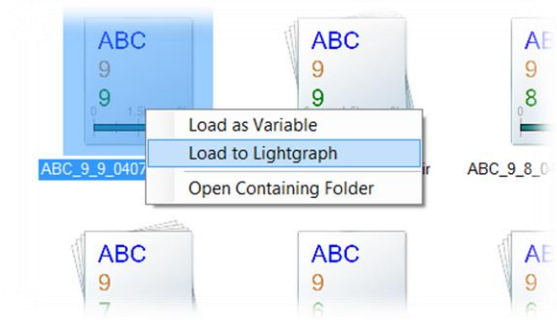


The Details view type is list and each experiment data file group is shown is a separate row. Sorting of rows can be changed by clicking on the headers (such as Start Time, Experimenter, Subject ID, Experiment ID, Duration, Path) or from the “Sort By” dropdown button menu.

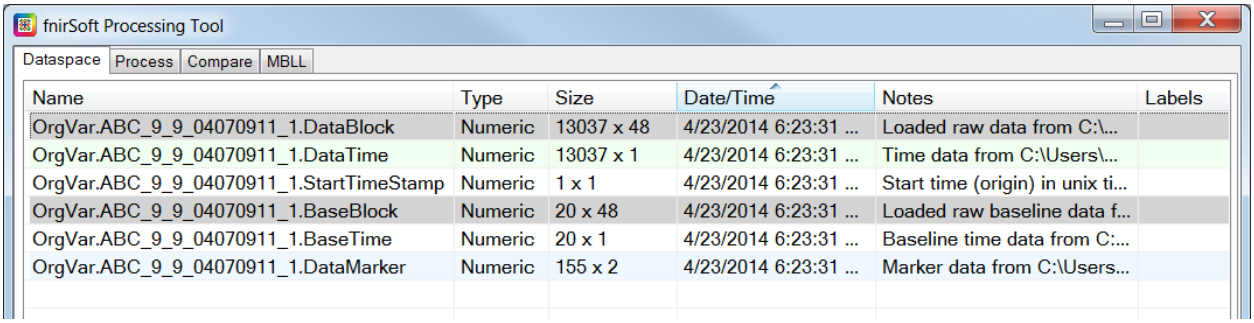


To load any of them to a Lightgraph, simply double click on the row or icon.

Right-click on a row or an icon to display loading options.

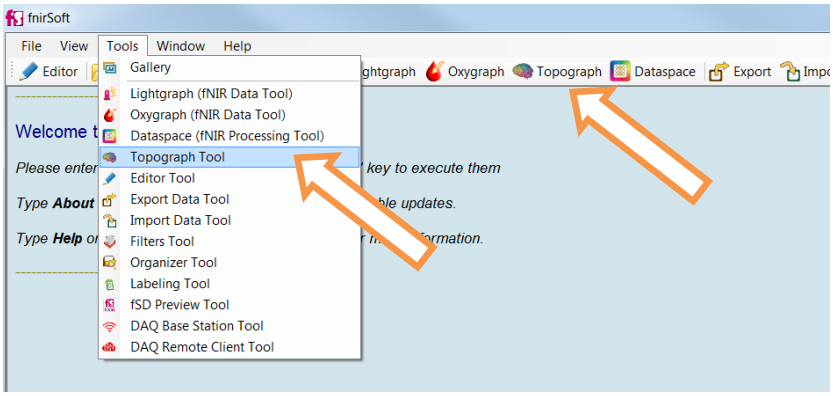


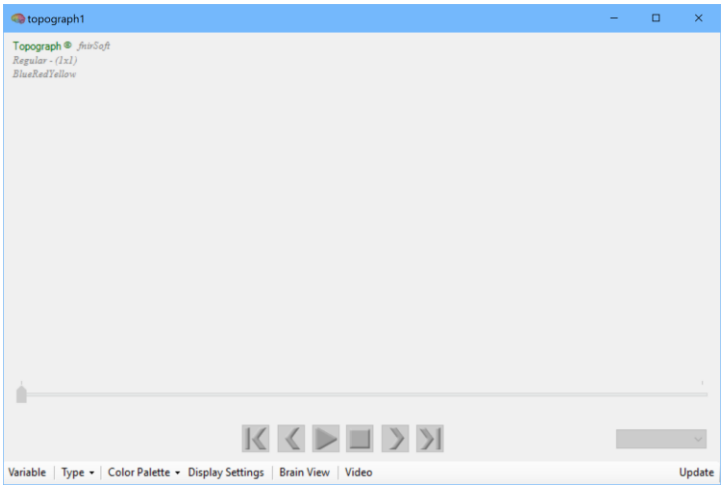
If “Load as Variable” is selected, the data file is loaded to Dataspace with variable names that start with “OrgVar”.

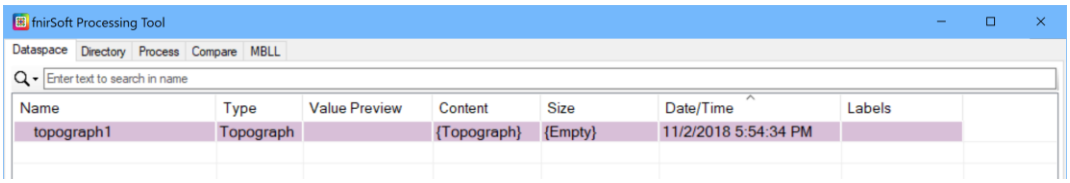


9. Topograph Tool

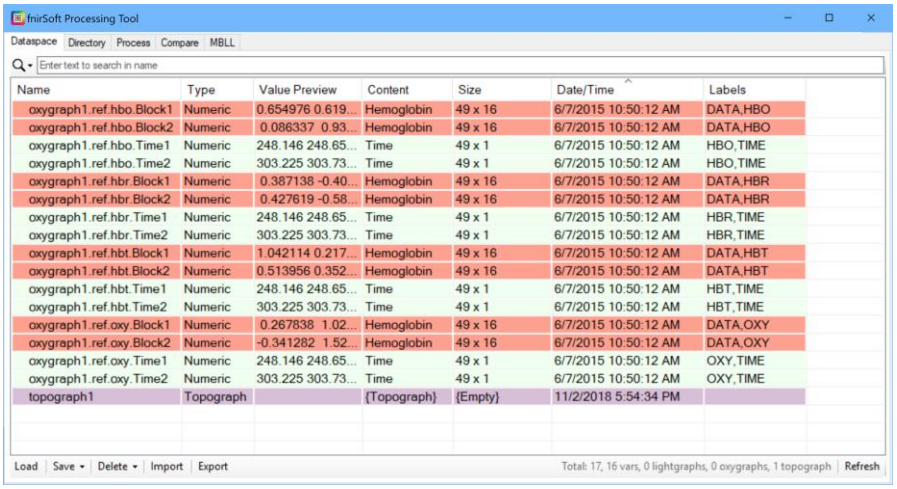
1) Click on Topograph button at the main window toolbar or from Tools drop-down menu. This will create a new window which is a Topograph object named ‘topograph1’. The new object is created in the Dataspace and can be accessed or deleted from the Dataspace window.



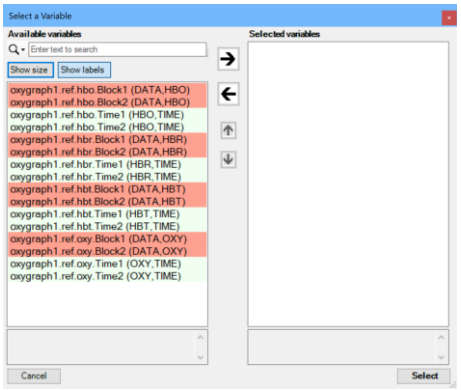




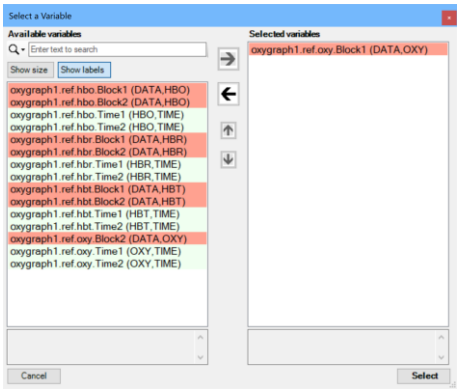
2) First load sample fsd file “data_3.2.2_refined.fsd” to use as variable.



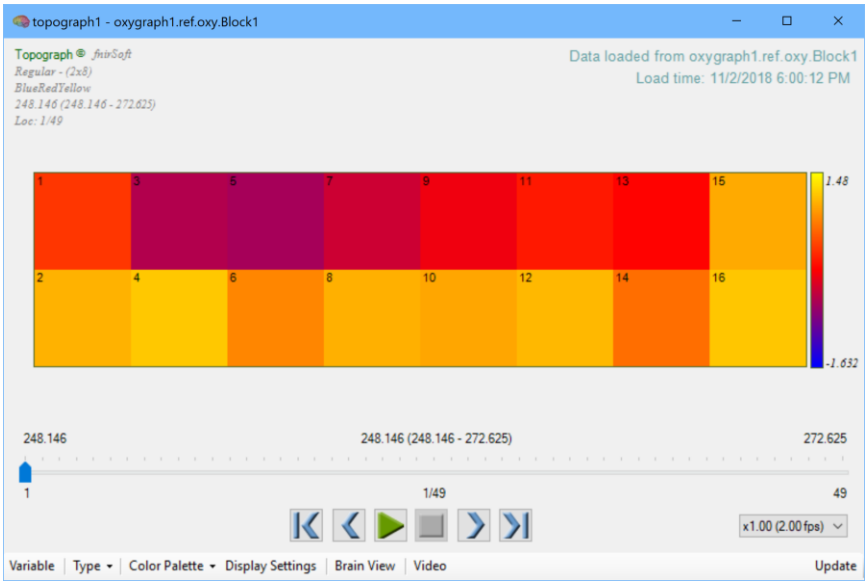
3) The new Topograph object (topograph1) is empty. To load a variable, click on variables button at the toolbar. Select variables window will appears as below. On the left-hand side, all available variables are listed and on right-hand side, those already selected (loaded) to the current detail-view window are listed. You can move a variable from one to the other and select “Save” to commit the changes to update the graph.



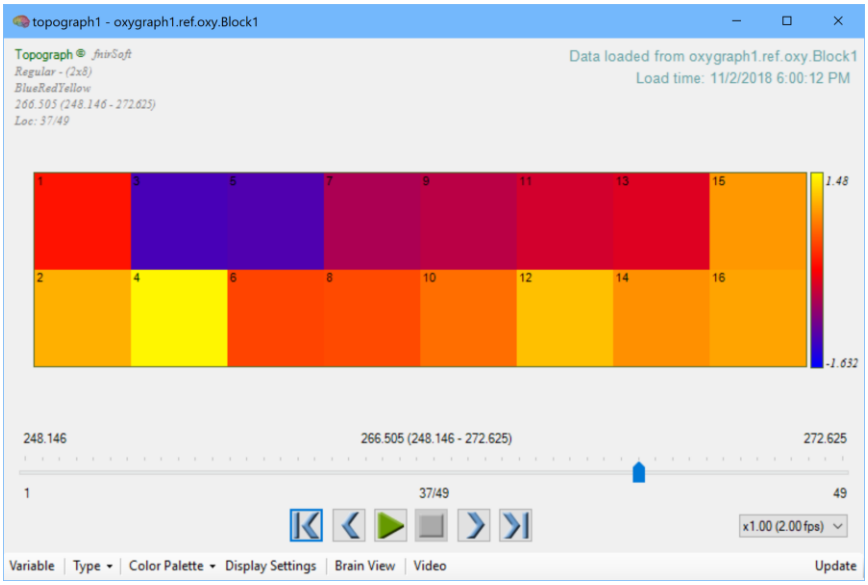
4) Select oxygraph1.ref.oxy.Block1 from the list on the left and transfer it to the selected variables list on the right by clicking on the right arrow button.



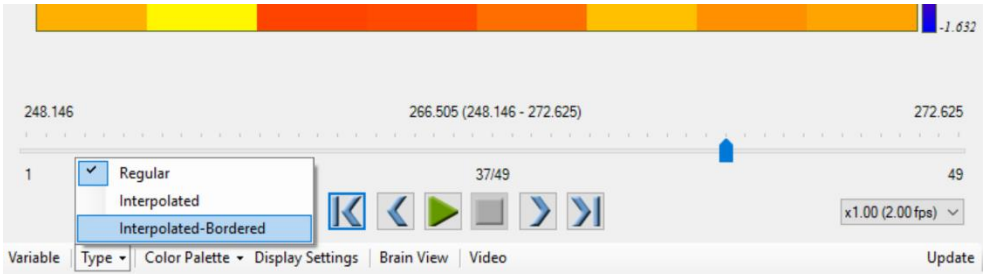
5) Click ‘Select’ button to use the selected variable and close this window. The Topograph window will be updated immediately to show the current variable’s all optodes together in color code by value.



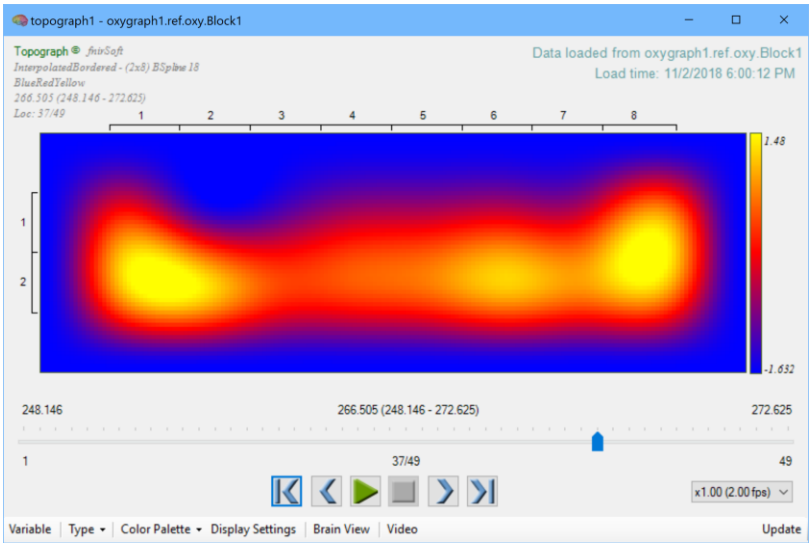
6) Since the variable contains more than one row, temporal progression of spatial changes can be visualized. (Similar to a video with each row being a different frame). Click play button to start. You can drag the slider to the desired location.



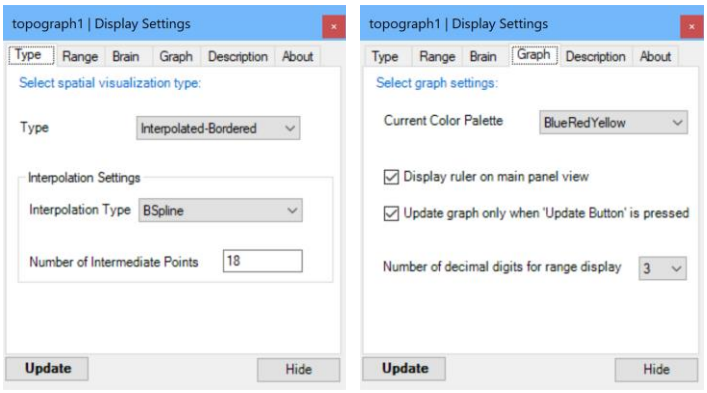
7) Change the view type from regular to “Interpolated-Bordered” for visualization.



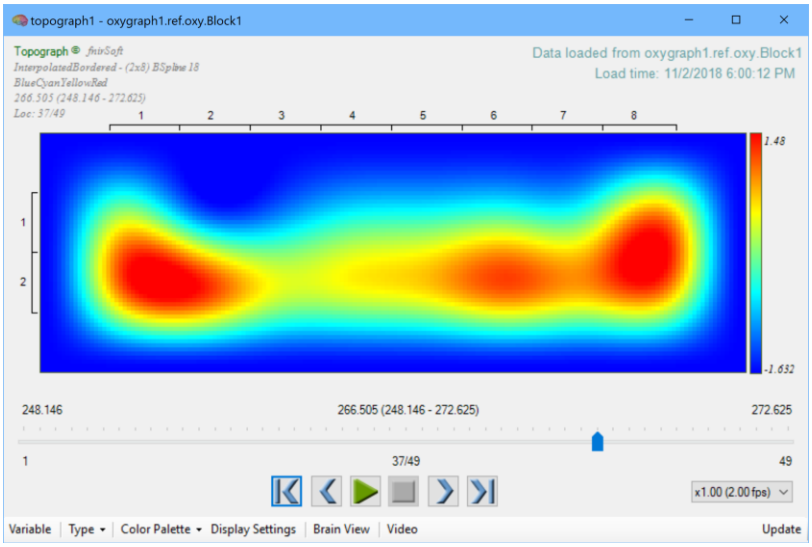
8) The graph will change immediately to reflect the changes.



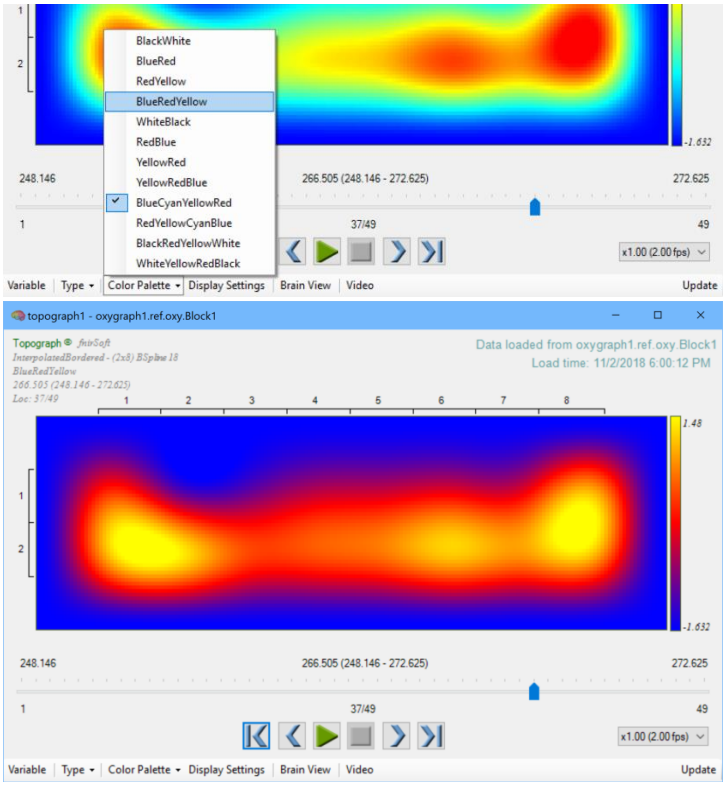
9) Interpolation type, range and other properties can be changes by right-clicking on the graph and selecting “Display Settings”. A new dialog box will appear as shown below.



10) At the ‘Graph’ tab, select “BlueCyanYellowRed” from as the color pallet and click ‘Update’. The graph will be updated as follows.

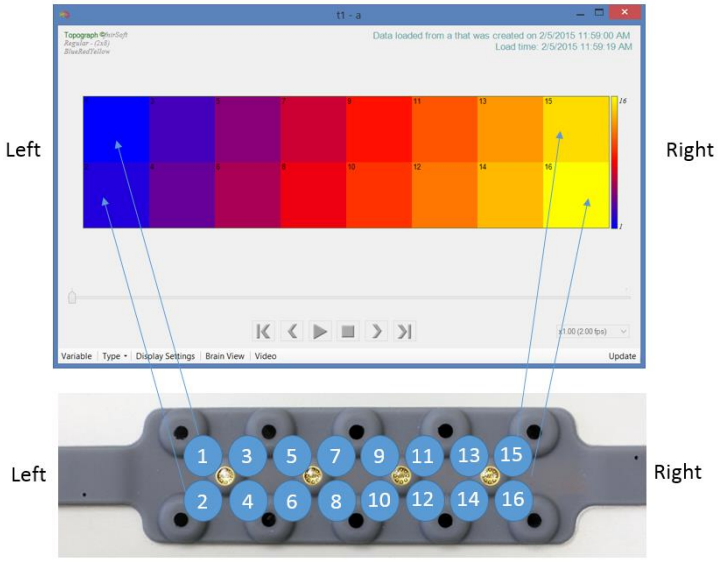


11) Change the color pallet back to “BlueRedYellow from the display settings.



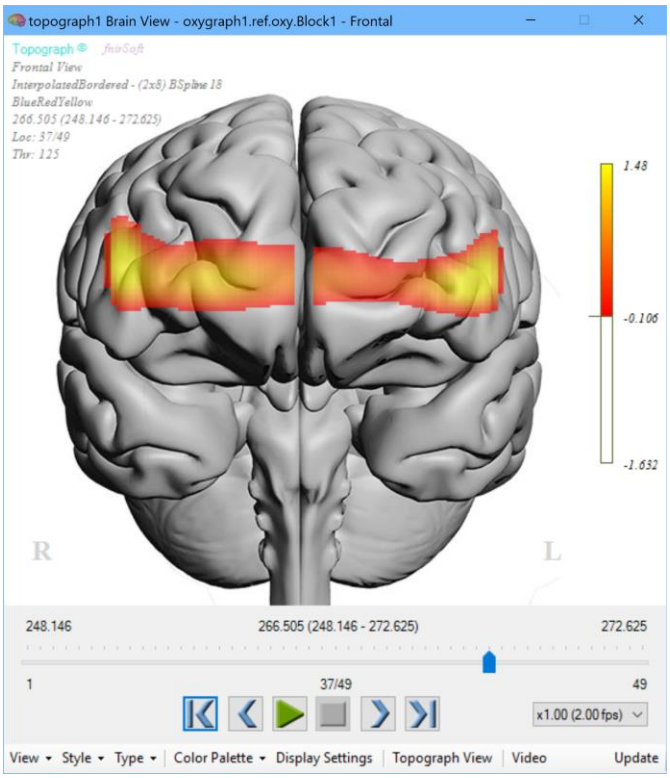
TIP

Note that, in topograph main window, left side contains subjects left side optodes (1,2, etc.) and right hand-side contains subjects right-hand side optodes (16, 15, etc.)

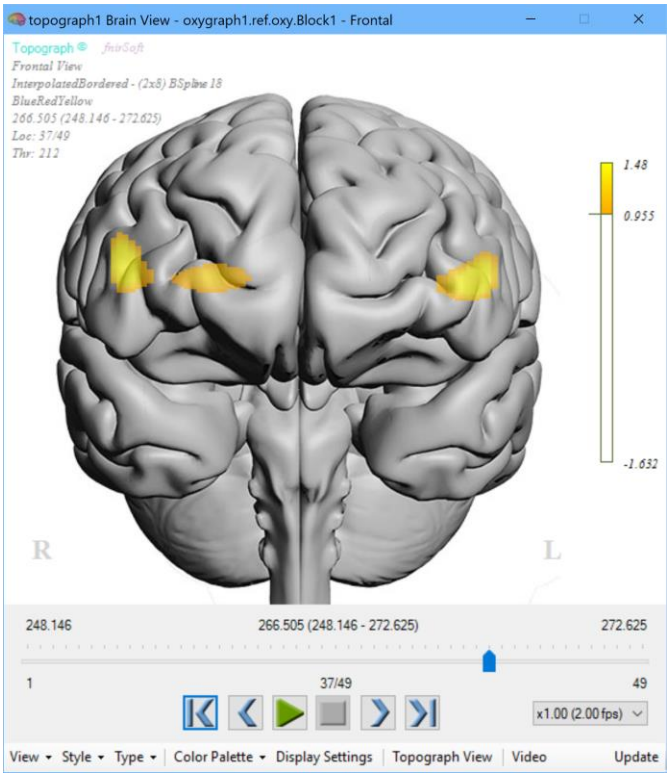


9.1.Visualize activations on brain surface image

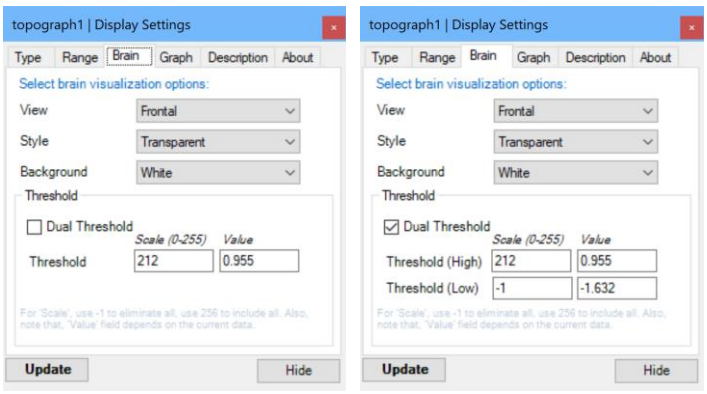
12) Click “Brain View” from the bottom toolbar. A new visualization window will appear that registers the data to a brain surface image. See Ayaz et. al. (2006) for details.



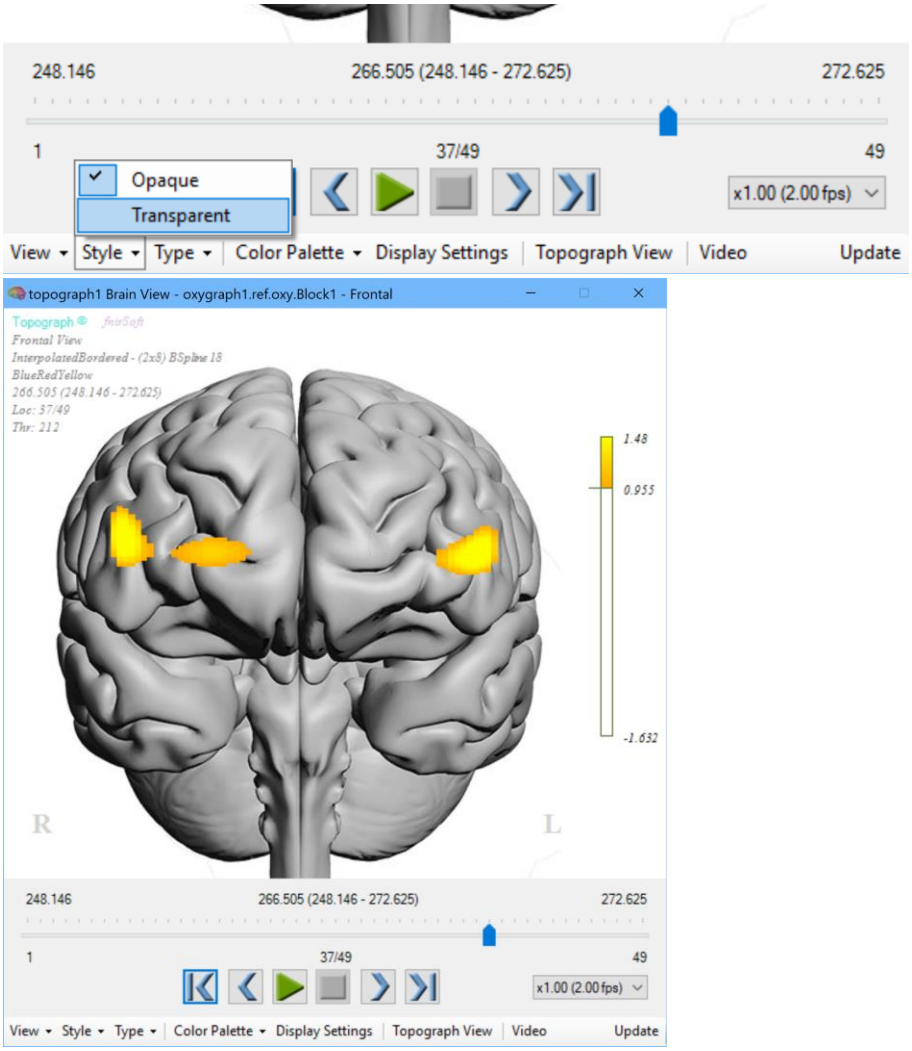
13) On the color legend, you can adjust the threshold value based on your context (e.g. statistical significance, etc.). To change the threshold level, move your mouse pointer to the threshold point at the center of the color legend (the last visible color part, the middle value is the threshold) click and hold, while moving it up or down. As you move it up, the color bar will shrink, and the threshold value will change.



14) It is also possible to enter specific values from 'Display Settings' and at Brain tab. You can specify threshold value as a scale (between 0 to 255), or as value based on your current data range. Note that is also possible to specify dual threshold, one for upper and one for lower part of data range.

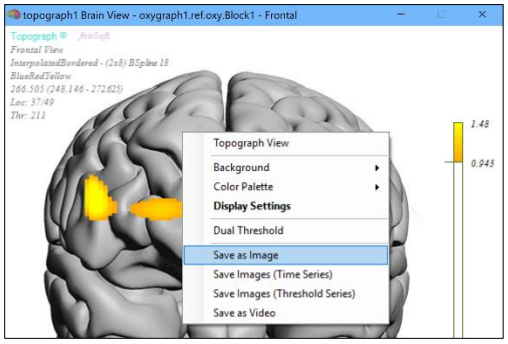


15) To increase the visibility, activation rendering can be changed from *Transparent* to *Opaque* for clear image. To do this, at the top menu, select *Style > Opaque*



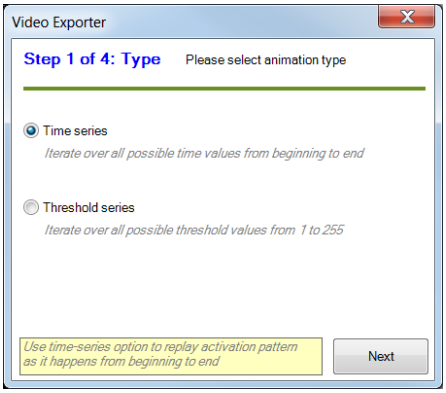
9.2.Save activations as image

16) The current view can be saved as image. Right click on the brain surface and select “Save as Image” from the context menu. Current image can be saved or series (by time or threshold) can be used to scan from beginning to end to generate multiple image files all at once. Or a video file can be generated.

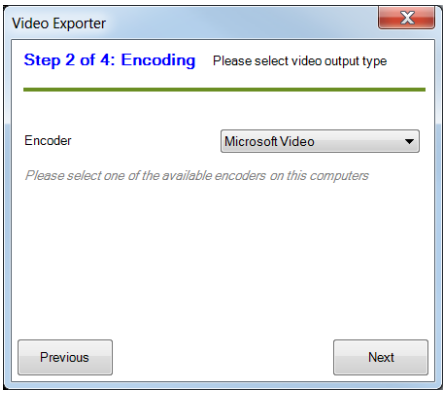


9.3.Save activations as video

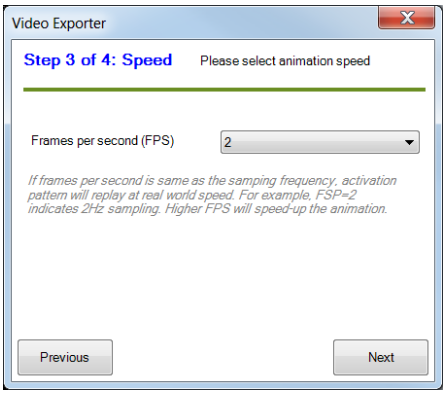
17) Next, select save as video option. A wizard will appear with 4 steps. The first step identifies the type. Time-series is the default option and it will generate a video that spans across time (from beginning to end) including all frames. The other option, threshold series, spans across different threshold values on the same (current) frame.



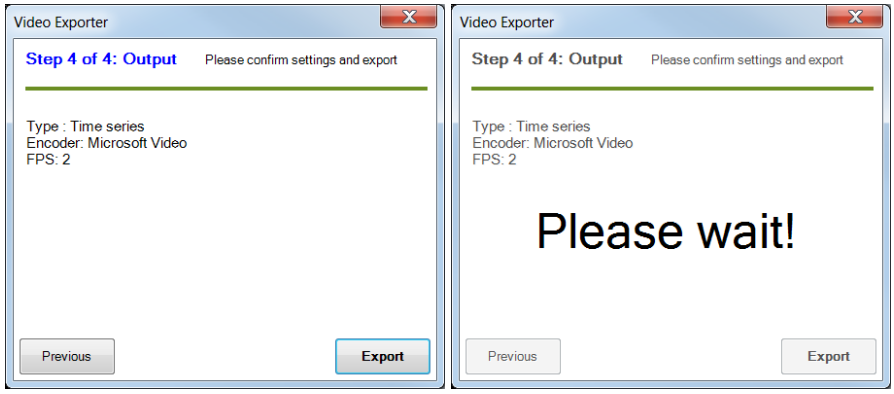
18) In the second step, select the video encoder. Keep the default.



19) In the third step, select frames per second (fps) of the output video. This indicates how fast the video will play. For a signal that was collected at 2Hz, selecting 2 fps will result in real-time speed. And, selecting 4 fps will result in twice as fast playing and selecting 10 fps will indicate 5 times as fast as real speed.

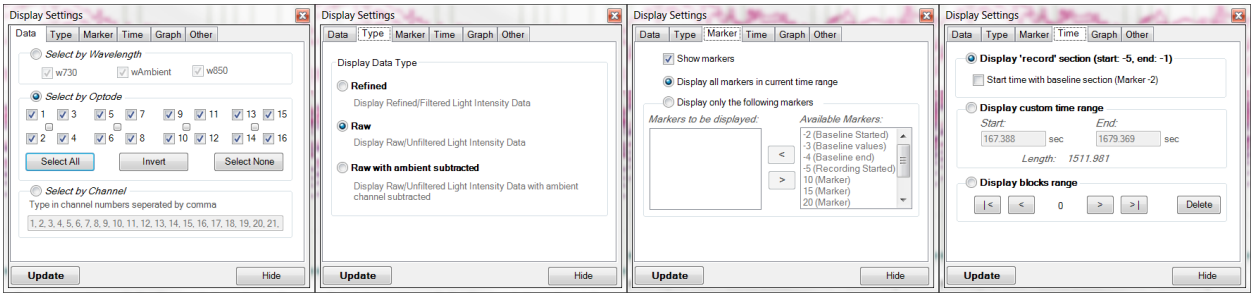


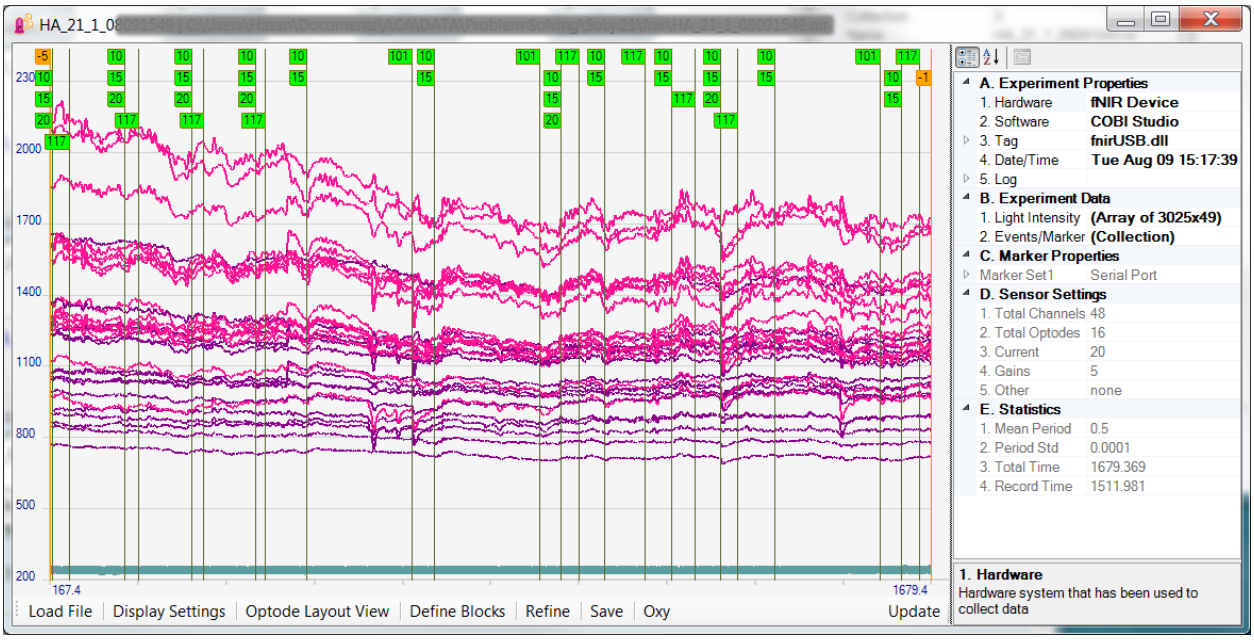
20) At the last step, confirm the settings and click “export” button to select the output filename. Once operation starts, “please wait” message will appear. Depending on the data and computer hardware, this might take couple seconds or couple of minutes or more. Please wait until output report arrives.

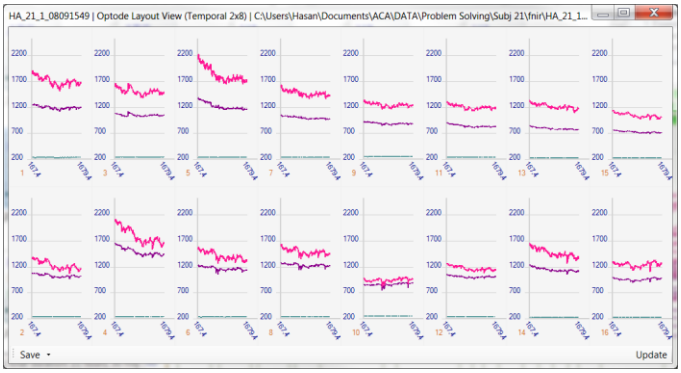


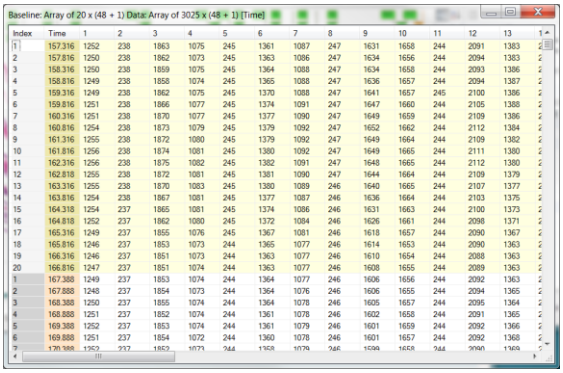
10. Lightgraph Tool

This tool enables visualizing, refining, processing and analyzing light intensity measurements that are recorded by COBI Studio to '*.nir' files. The tool includes many settings to visualize specific group of channels or optodes. Also, display time synchronized markers, custom time range settings are included. And, block analysis and various signal refinement options are available. Below are representative screens.



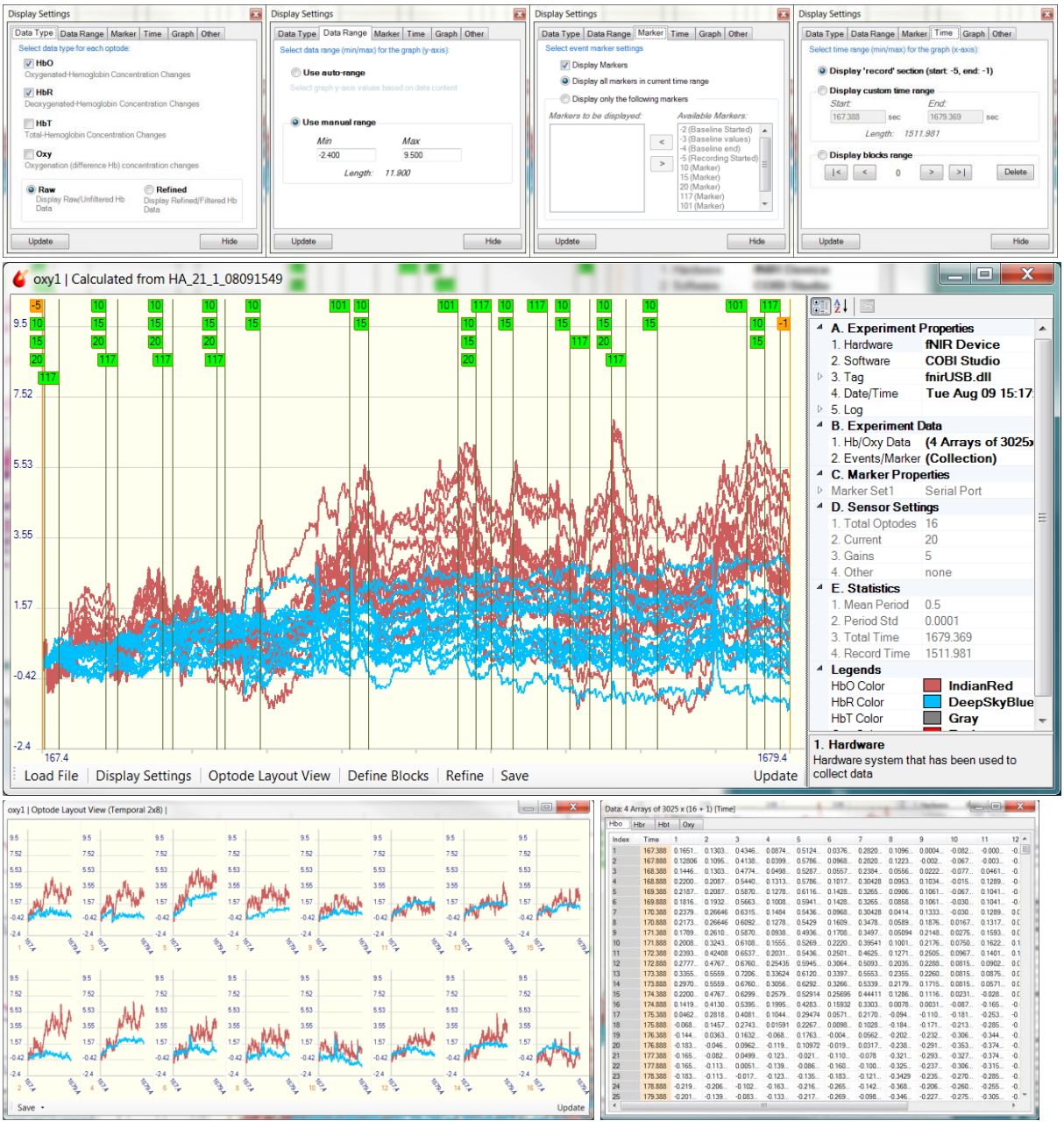






11. Oxygraph Tool

This tool enables visualizing, refining, processing and analyzing oxygenation/hemoglobin measurements that are recorded by COBI Studio to '*.oxy' files. Note that, earlier versions of COBI Studio save the oxy files as "filename.nir.oxy" that is "oxy" extension append to the nir filename. And some computers are set hide file extensions so nir file (filename.nir) would be display as "filename" and oxy file (filename.nir.oxy) would be displayed "filename.nir". The tool includes many settings to visualize specific group of optodes. And, display time synchronized markers, custom time range settings options are included. Also, block analysis and various signal refinement options are available. Below are representative screens.



12. Define Block Automation

This tool can be used in Lightgraph and Oxygraph to define multiple types of blocks at once. This is especially very useful as once the block configuration of an experiment is defined, this can be applied to many subjects easily using the 'Define Block Automation' tool.

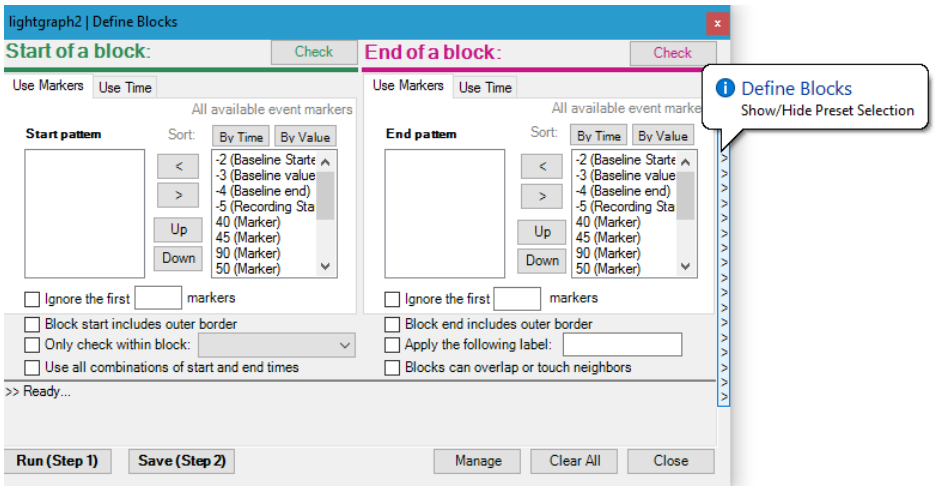
Define Block Automations actually a list of presets that each defines one type of block. A preset, actually contains the 'start pattern', 'end pattern' and other settings such as 'label' that is used at the Define Block dialog. When a preset is executed zero or many blocks can be created at once. When an automation is executed, many presets can be executed at once.

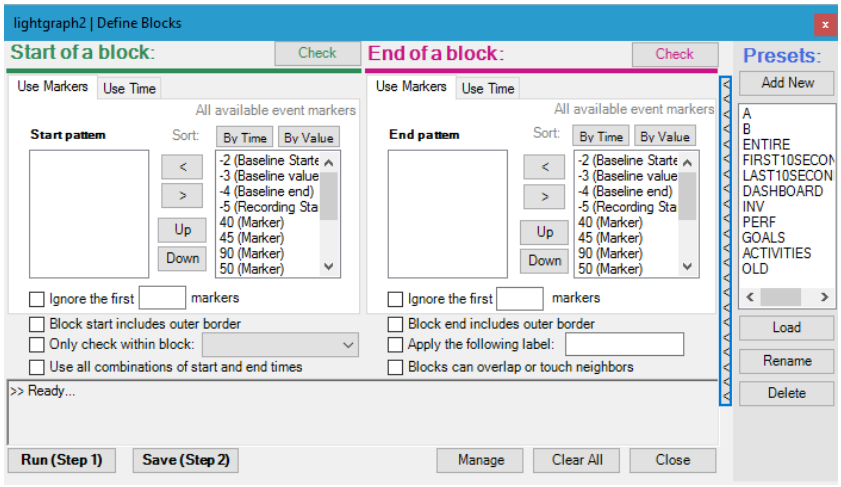
12.1 Define Preset

A new preset can be created at the 'Define Block Automation' dialog or 'Define Block' dialog. For information about 'Define Block' dialog see section 3.1.

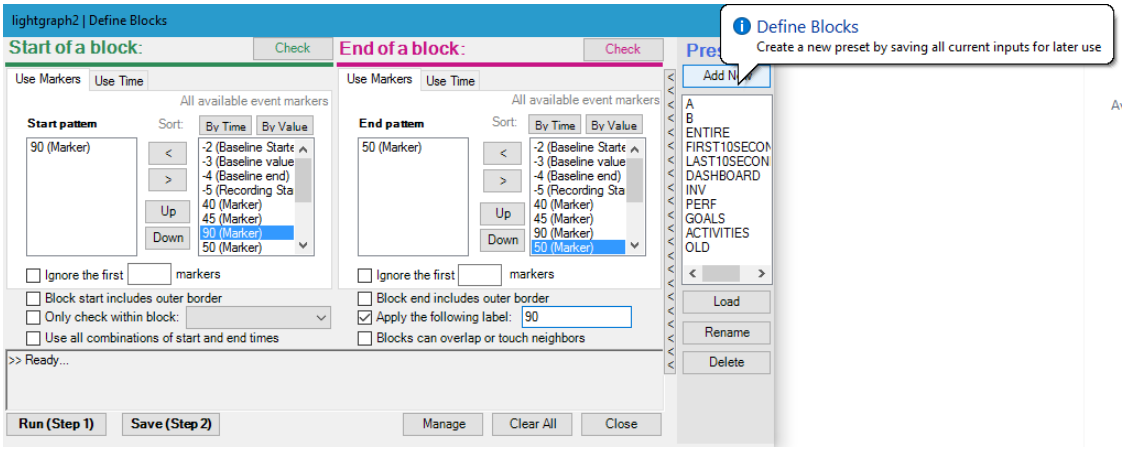
12.1.1. Using 'Define Block' dialog

1. Expand the dialog by pressing the vertical button at the right-hand side of the dialog.

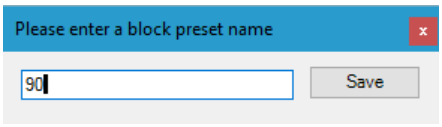




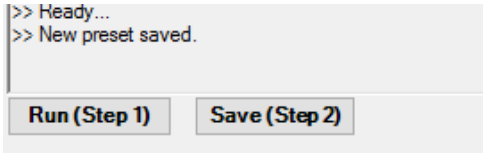
2. The preset list is displayed. Clicking any preset will attempt load the preset to the 'Define Block' dialog. (i.e. update all the input sections of the dialog with respect to the preset settings.). Note that if preset is not compatible with the current data (in Lightgraph or Oxygraph) not all settings of the preset could be loaded. This is not the case for Define Block Automation Tool as it is independent of the data for display.
3. Enter settings on the 'Define Block' dialog, (start pattern, end pattern, label, etc.) that you wish to use for preset.
4. Click on the 'Add New' button at the right top.



5. A popup dialog will appear asking you to enter a new name for the preset.



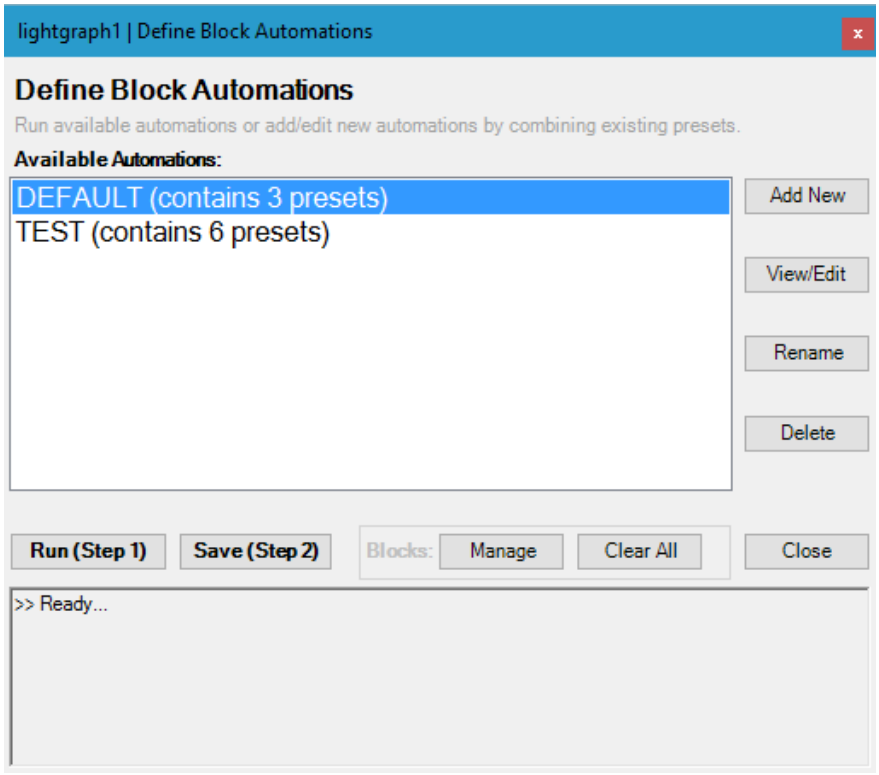
6. Asdasd



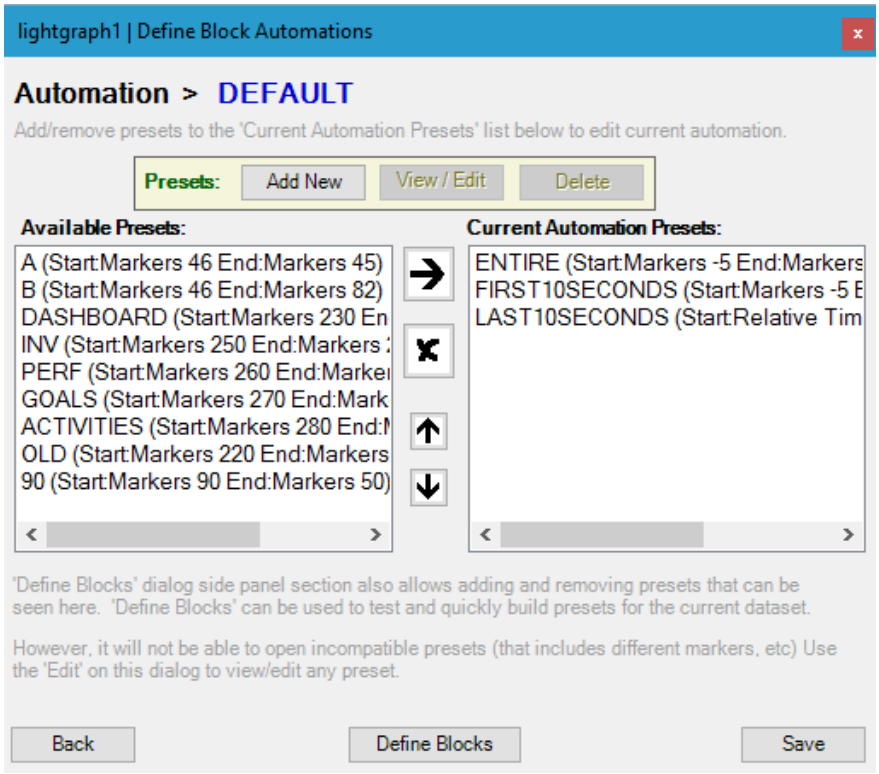
12.1.2. Using Automation dialog

A new preset can be created directly at the Automation Dialog.

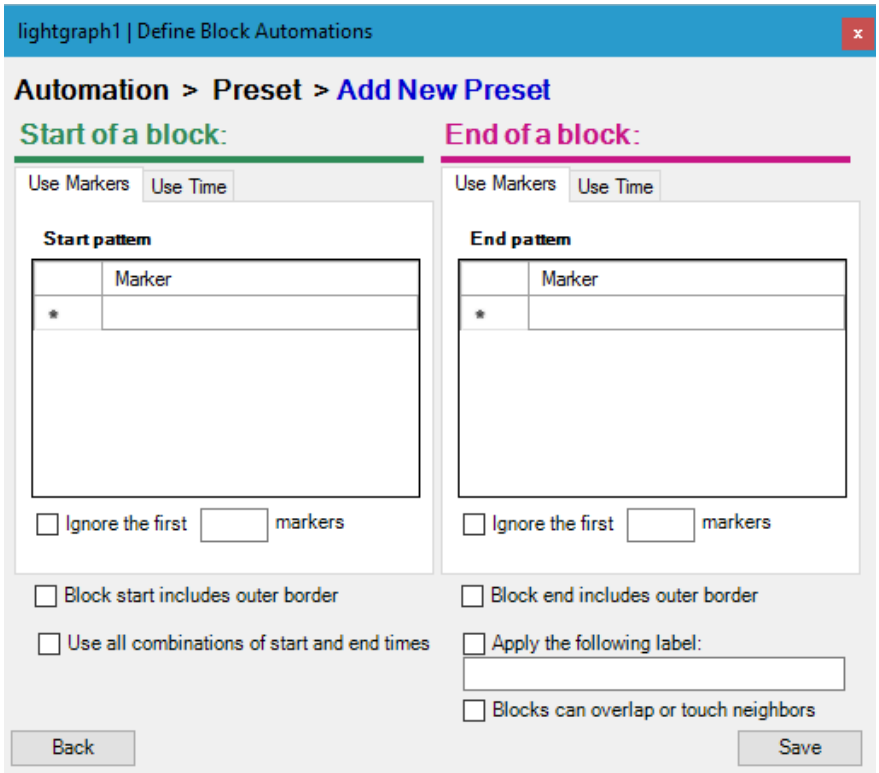
1. Open the Automation dialog using the 'Automation' button at the bottom toolbar of Lightgraph or Oxygraph.
2. On the Automation dialog, select 'Default' automation item from the list and click View/Edit button on the right-hand side of the window.



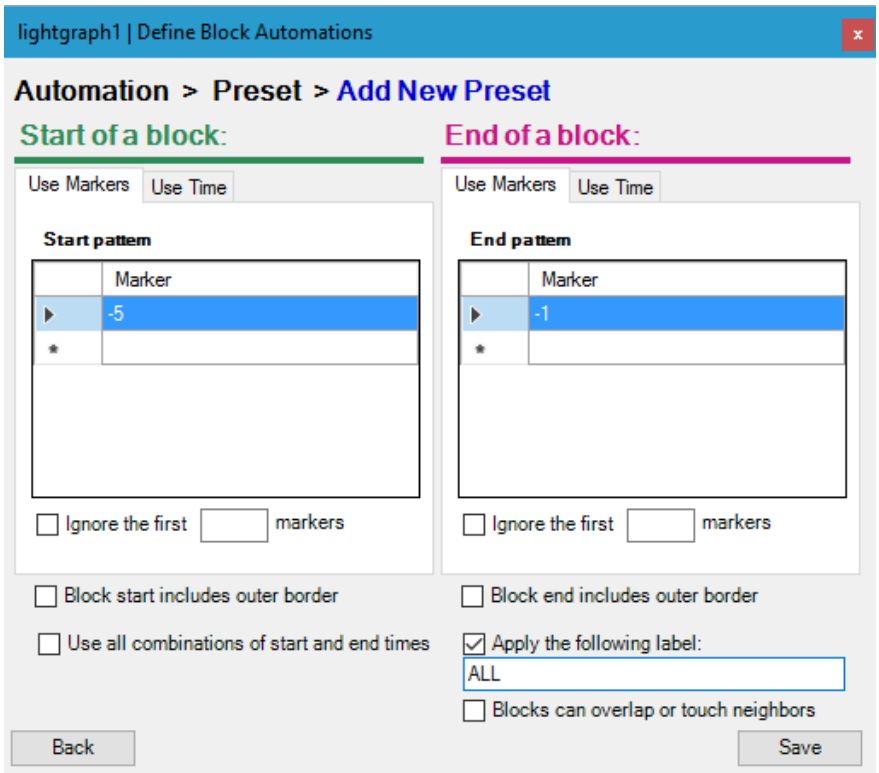
3. At this screen, you can modify the automation list items (the right-hand side list) by moving available presets from the left. Also, using the 'Add New' button, you can create new presets. Click 'Add New'



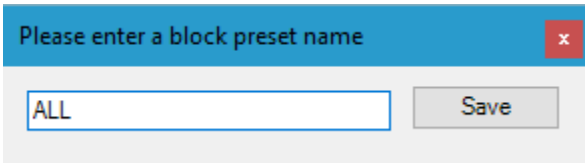
4. Preset editor will open with all empty settings.



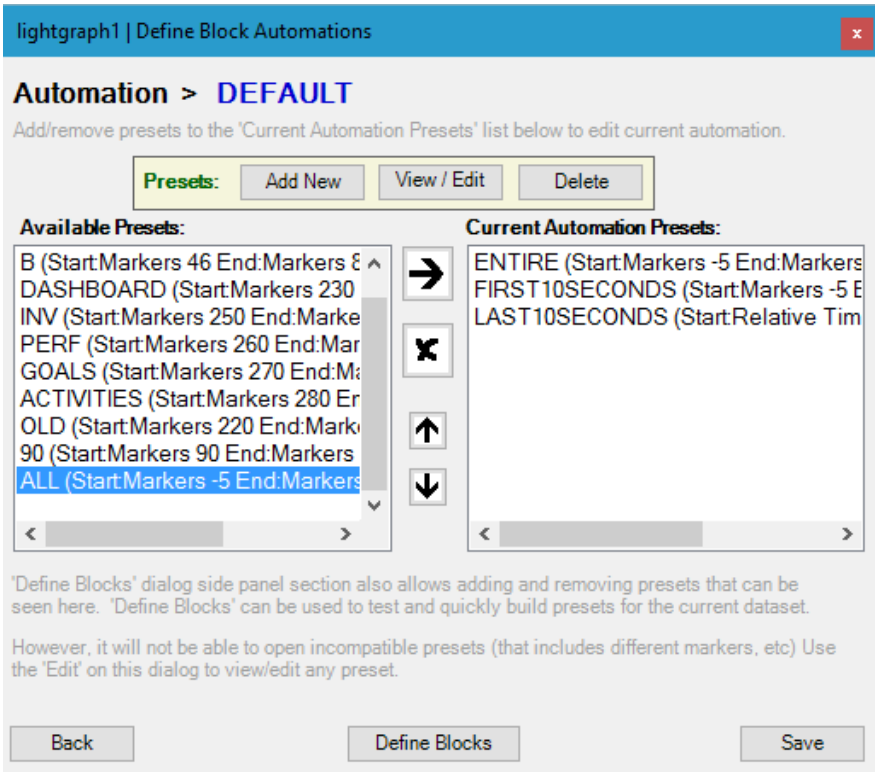
5. To create a new preset, enter '-5' for start of a block, '-1' for end of a block and 'ALL' for label as follows.



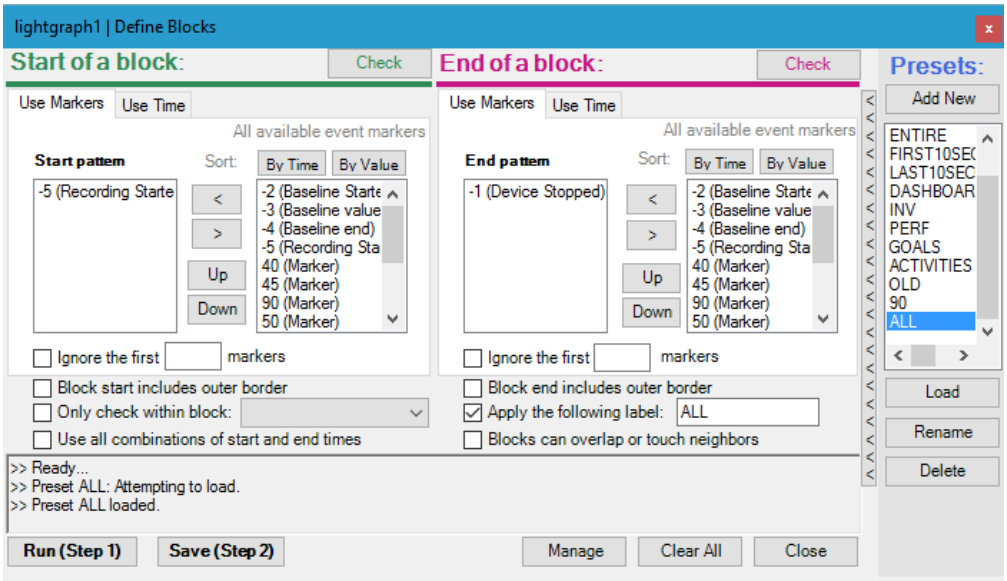
6. Click Save to record this new preset. A popup will appear. Enter 'ALL' as a name for this new preset.



7. Click save and you will be back to the preset list. The new preset is now should be available in the left-hand side list.



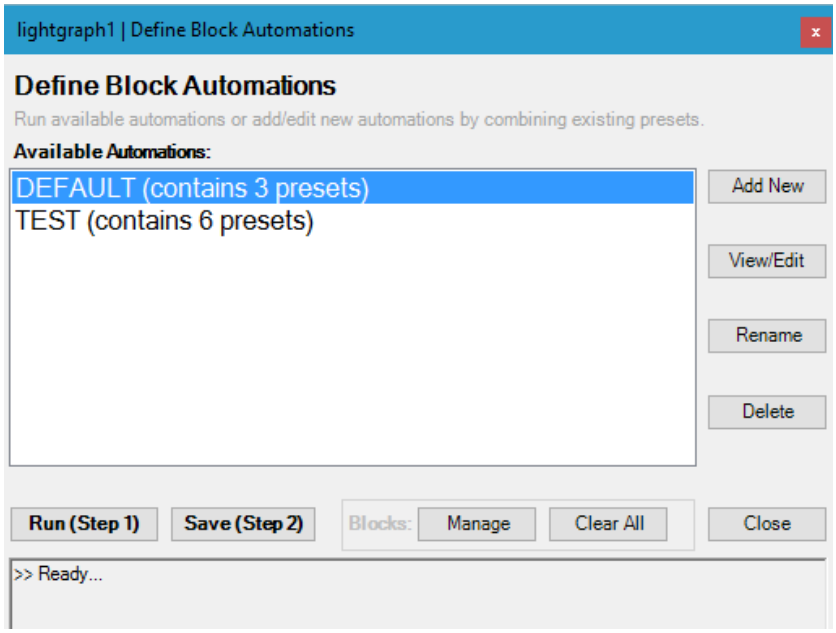
8. Same preset is also availablbe Define Block dialog preset list.



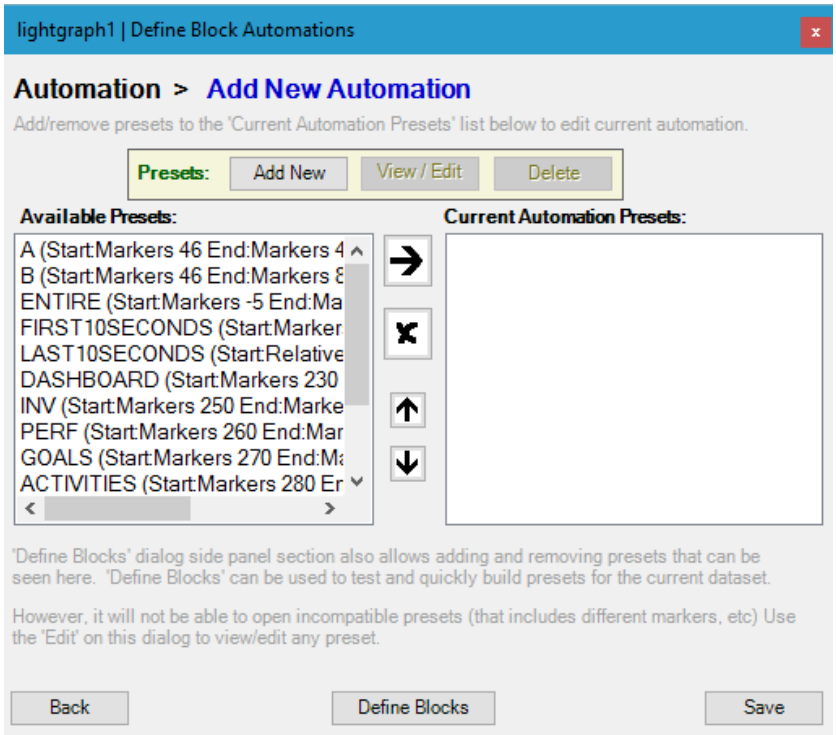
12.2 Define Automation

An automation is essentially a list of presets. Different presets can be listed together to create different automation.

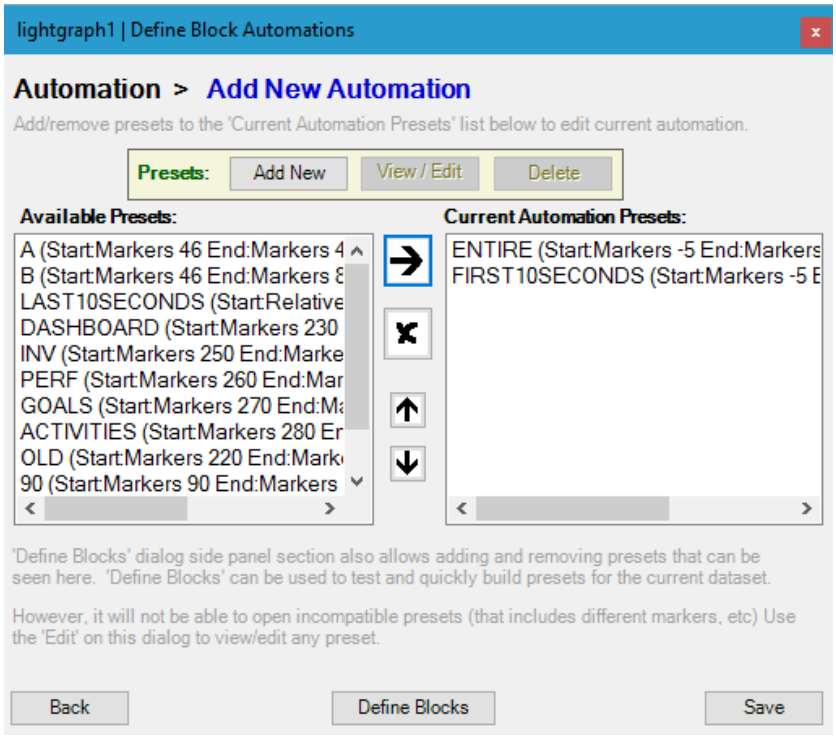
1. Open the Automation dialog using the 'Automation' button at the bottom toolbar of Lightgraph or Oxygraph.



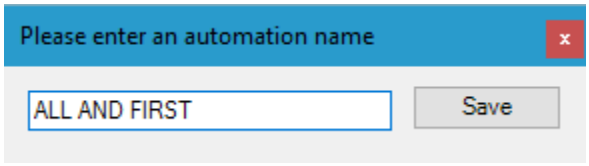
2. On the Automation dialog, click on the 'Add New' button at the right-top.



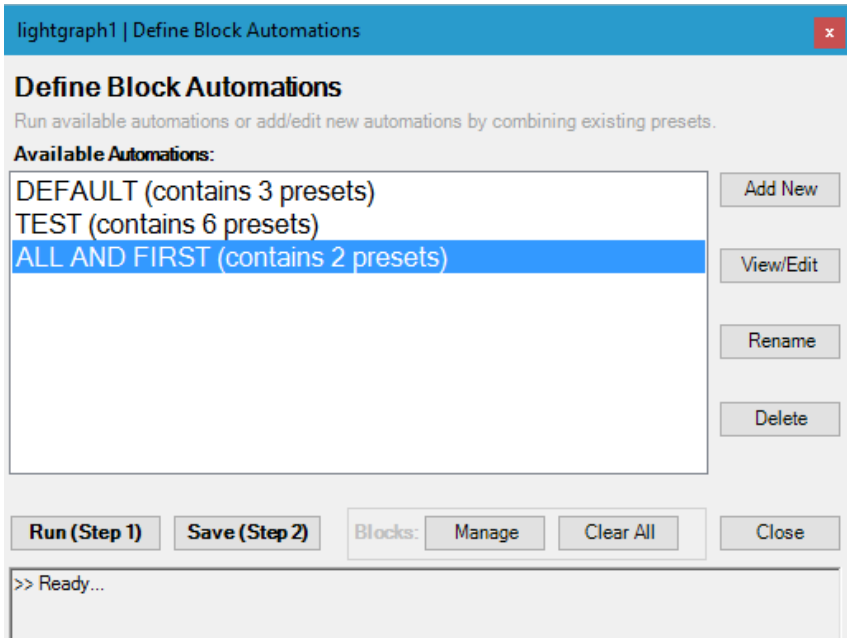
3. A blank automation list will appear. From the available presets list (left-hand side) select ‘ENTIRE’ and ‘FIRST10SECONDS’ to the current automation list (right hand side)



4. Click ‘Save’ at the lower right hand side of the dialog and enter ‘All and First’ for name



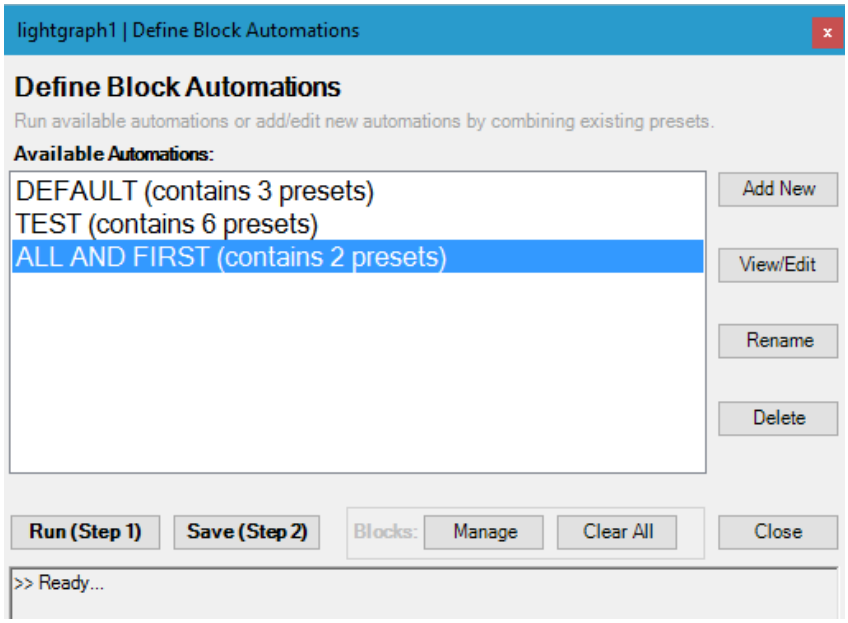
5. Click ‘Save’ and the Automation is not listed on the Automations list.



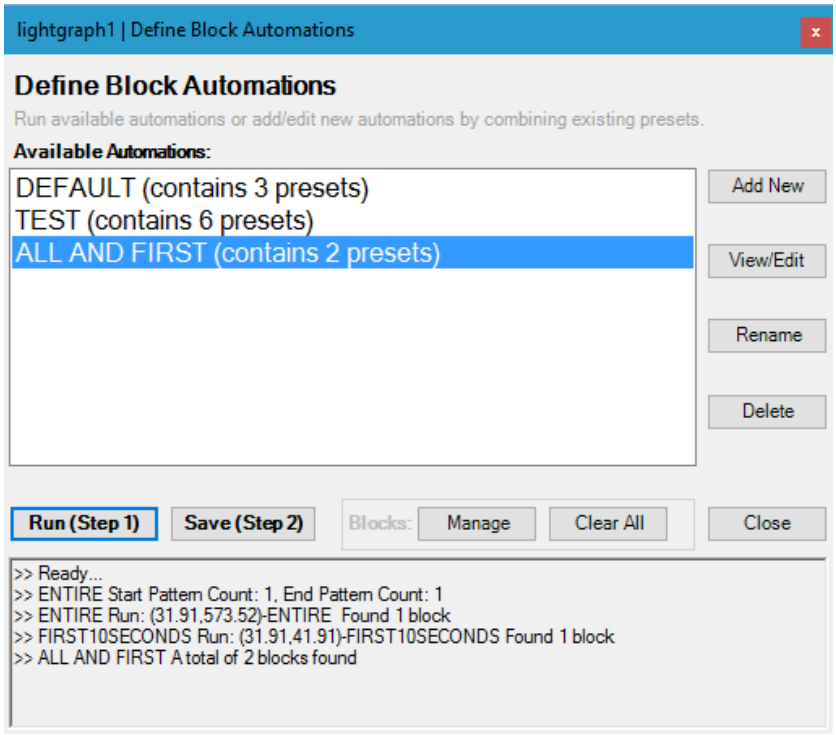
12.3 Using Automation

Automations can be executed on Lightgraph and Oxygraph tools, similar to running Define Block operation: Step 1: run (and see output) and Step 2: save (if you like the output).

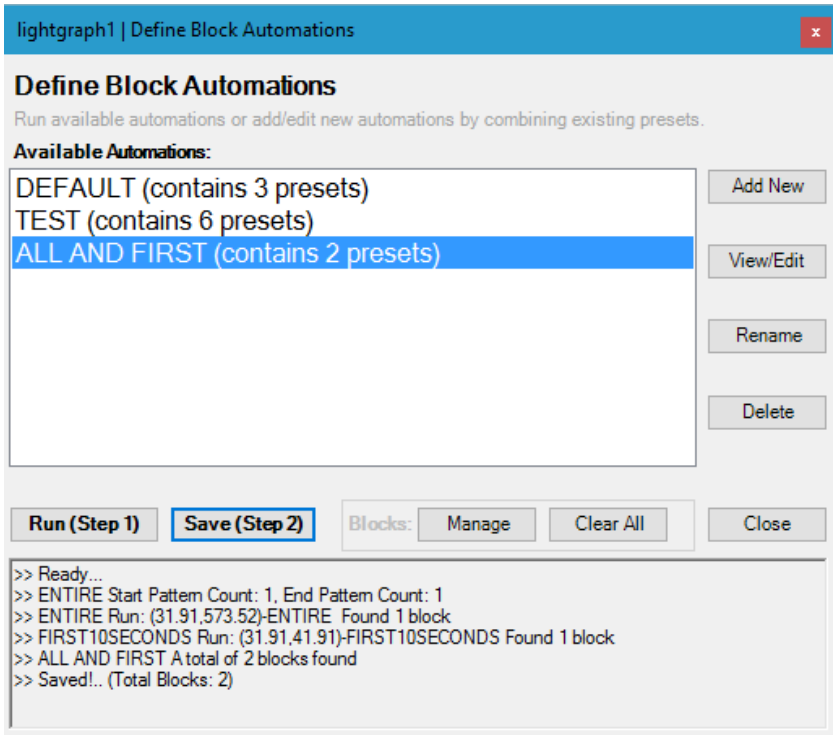
1. Open the Automation dialog using the 'Automation' button at the bottom toolbar of Lightgraph or Oxygraph.



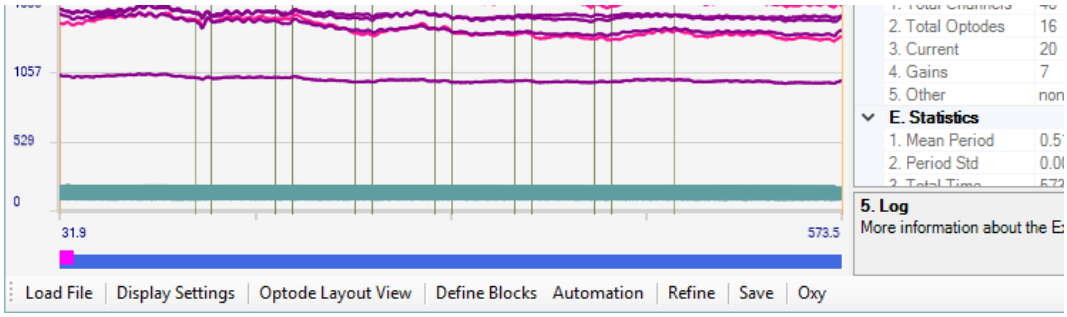
2. Select 'ALL AND FIRST' that was created in the previous section. Click 'Run (Step 1). It says 2 blocks were found.



3. Click ‘Save (Step 2)’ to accept these and save them to the Lightgraph (or Oxygraph). At the bottom output pane, ‘Saved’ message will appear.



4. At the Lightgraph (or Oxygraph), blocks will appear immediately.



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