DDMT

Instruction manual

Version: 11 April 2023

Contents

Visualisation controls by type:

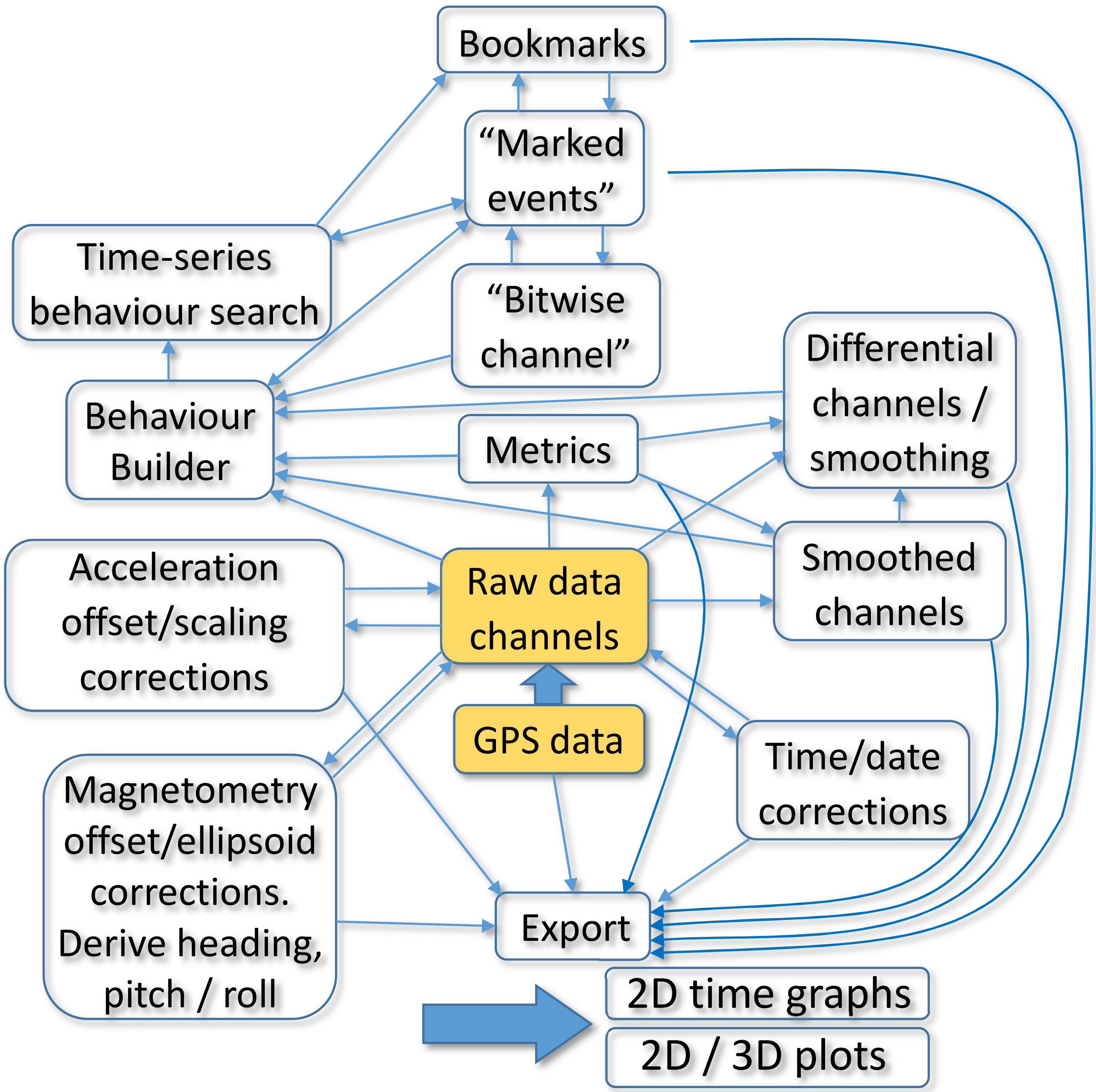
Get the latest version of DDMT and user manual

Please note that this user manual is primarily for use with data from Wildbyte Technologies Ltd *Daily Diaries*. The software package, this instruction manual, and other supporting files, can all be downloaded from Github at the following link: https://github.com/DDMT-Software/DDMT

It has taken a lot of time to develop the analysis algorithms and visualisations to maximise efficiency and ease of use. Many controls/aspects may appear complex initially. If there are errors within the code, or this user manual is not clear on any aspect, or perhaps any ideas for future improvements, please contact the author at ddmt_software@outlook.com for assistance.

DDMT Overview

Daily Diary Multiple Trace (DDMT) allows you to graphically display, and through application of filters through various mechanisms, to analyse complex animal behaviours using accelerometry, magnetometry, temperature, pressure, GPS etc.). This has largely been developed at Swansea University within the Swansea Lab for Animal Movement, headed by Professor Rory Wilson.

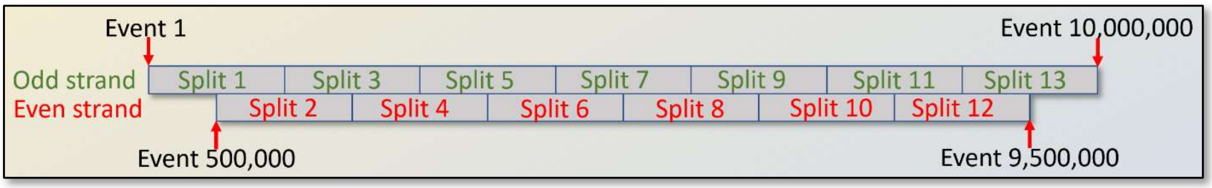


- Offsets corrections (acceleration / magnetometry) semi-auto/guided
- Time corrections (manual)
- Smoothed channels derived from primary raw data channels (user can select level of smoothing)
- Metrics created from both raw and smoothed channel data
- Smoothed channels of metrics can also be created (user can select level of smoothing)
- Differentials can be created from any channels / all (user can selectively control level of smoothing if required)
- All resulting channel data made available to the visualisation, search functions, and available for immediate export
- Any changes to level of smoothing or differential stepping has a ripple effect through the system to update visualisations

Some keywords

Event In this software / manual, an ***Event*** is a data point in time where one or more sensor values exist within a large data array. For a logger capturing data at perhaps 40 Hz, this is the equivalent to 40 ***Events*** per second. Described as ***Events*** as every single data point consists of many parameters/sensor measurements which could describe a single action/behaviour.

Split A subset of the data file. The data that is currently in memory. The split size is chosen by the user prior to loading any data. DDMT may adjust this value slightly to align it with internal data structures. The split size is then fixed for that session. Example below shows a data file containing 10,000,000 events, while the user has chosen to load a split size of ~1,000,000 events.



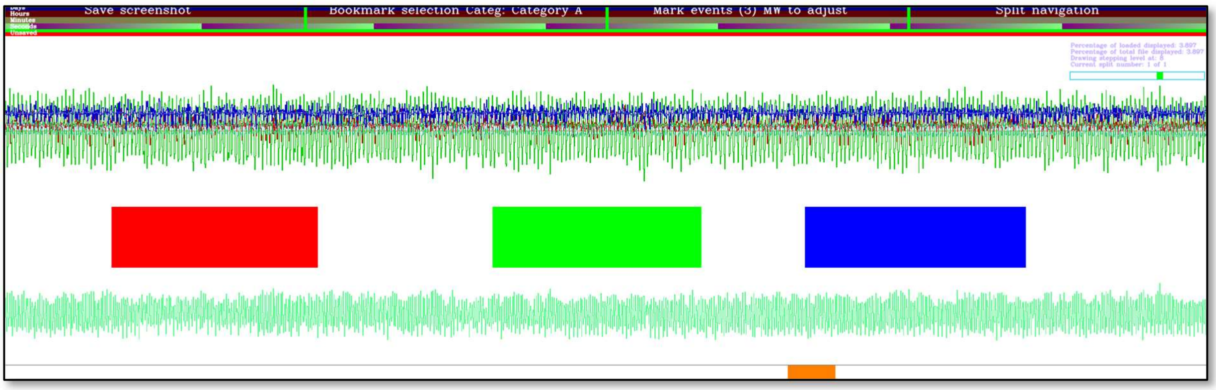
Marked Event is where an ***Event*** (a data point) has been marked with an integer value between 1 and 9 (inclusive) either as the result of a search function, or manually marked by the user. ***Marked Events*** are persistent for a session throughout the whole file i.e., moving to another split and returning, any ***Marked*** Events will still be present/in-view. The purpose of ***Marked Events*** is to:

i. highlight data to be saved
ii. to be used as part of a Boolean search function
iii. or simply as a visual indicator of the meaning of a part of the data
iv. to be used as a filter for displayed data on the 3D visualisation system
v. to be used as a filter for the Dead Reckoning algorithm, built into the 3D visualisation system

Marked Events from a given session can be exported as a file and reloaded at a later session; see ***Exporting Global Marked Events***

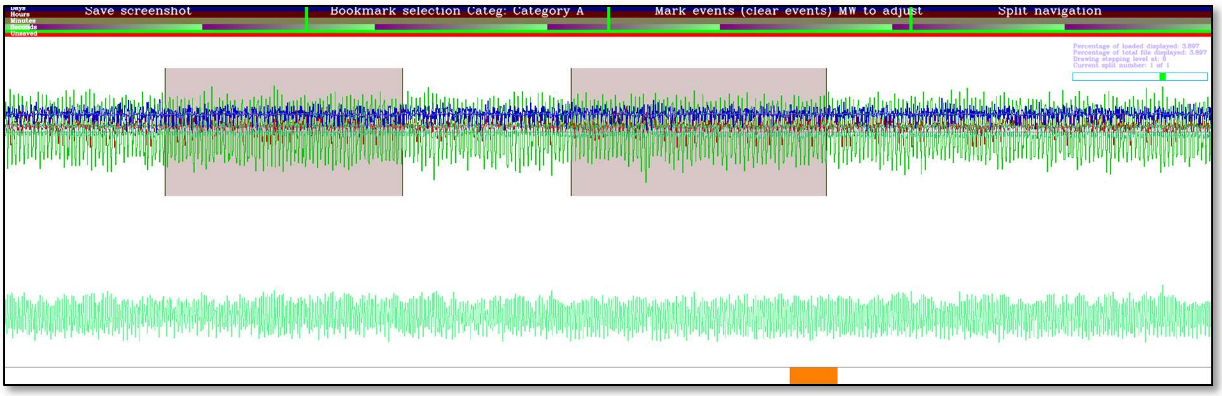
An ***Event*** can only be marked with a single ***Marked Event*** value (1-9). If it is marked again, the old ***Marked Event*** value will be replaced with the new value

Marked Events are discussed in later chapters where relevant



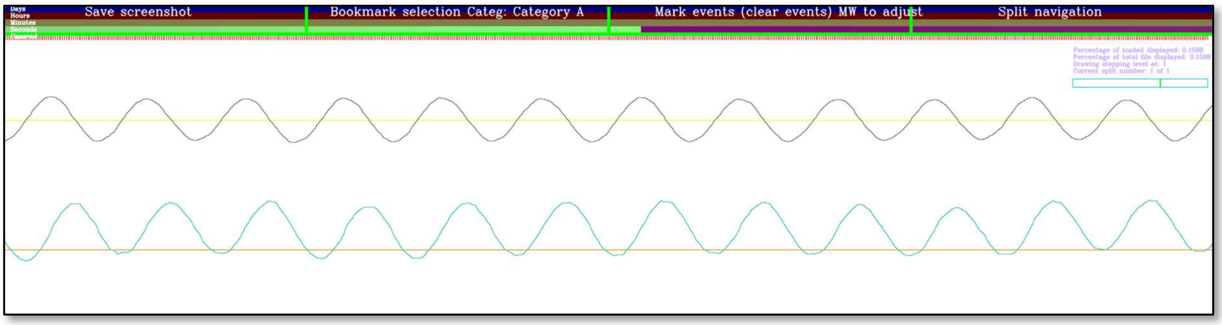
Marked events shown as highlighted regions in red, green, and blue (Marked Events values 1,2, and 3)

Bookmark is a highlighted section of multiple events that has been noted either as the result of a search function, or manually noted by the user. ***Bookmarks*** can be assigned any 1 of 14 different "categories"; categories initially named Category A to Category N, the names of which can be updated by the user to give better meaning. ***Bookmarks*** from a given session can be exported as a file and reloaded at a later session. Unlike ***Marked Events***, ***Bookmarks*** can overlap, although, on the display this will not be immediately apparent. ***Bookmarks*** can be used to export multiple sections of data as a single file, filtered by category if required, with numerous statistics associated with every ***Bookmark***. ***Bookmarks*** can be used to generate a single file containing comprehensive statistics of multiple sections of data across many channels / metrics. ***Bookmarks*** are discussed in-depth in Chapter 6.



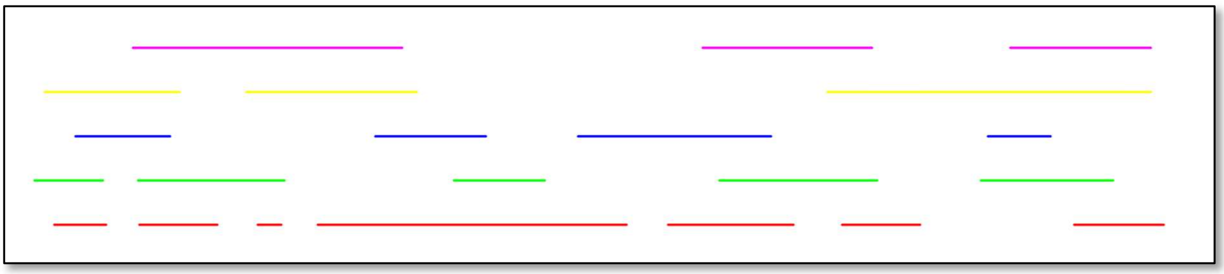
Example of 2 bookmarks

Differential is a simply the rate of change of a channel of data. In the figure below, the bottom trace is **Acceleration Y** (smoothed), while the top trace is the differential of this, calculated, per point *n*, as ($x_{n+y/2} - x_{n-y/2}$) where *x* is the value at point *n* and *y* is *stepping difference* or the number of points over which to measure the rate of change i.e. for point *n*, the differential is calculated using half the stepping distance before/after



Example of a differential

Bitwise Layers are multiple bits of information ('1' or '0') packed into a single channel named ***Bitwise***. This layered information may already be embedded within a file if converted using the DDMT data converter. Layers within the ***Bitwise*** channel can be set '1' by copying (or merging) ***Marked Events*** across to it or cleared to '0'. Single or multiple ***Layers*** may be searched using the ***Behaviour Builder*** search engine to generate ***Marked Events*** / ***Bookmarks*** to export data. Bitwise layers are discussed in more depth within Chapter 5. The ***2D graphing window*** displays the layers vertically separated. Example below shows the first 5 layers, red through to pink (with their binary values 1, 2, 4, 8, and 16 respectively):



Quick DDMT controls

Find below a selection of controls for use on the ***2D graphing windows***.

These controls are always a combination of keyboard buttons Shift, Ctrl, Alt, and mouse Left, Right, and Centre buttons, including the mouse wheel

What you want to do	How to do it
Bring up data point values overlay and probe values at specific time points	Click middle mouse wheel button Left and Right mouse click for "left / right white lines" to get data point values/ move mouse around to update overlay
Move "left / right white lines" to probe sensor/metrics at data points	Move mouse while holding down Left or Right click on ***2D graphing window***
Zoom into specific area within the data	Place left / right white lines around data of interest and then with Ctrl, Shift & Alt held down together, Left click
Zoom out to view all data	Use Left / Right mouse click to drag the orange bar along the bottom of the drawing out
Zoom out a little	Use mouse wheel (stroke down) in the centre of the ***2D graphing window*** to zoom in or out a little
Scroll through data	When zoomed in to some data within the split, hold down Alt + L click, and drag mouse left / right across the vertical centre of the ***2D graphing window*** to drag the bottom orange bar
Jump quickly through data	When 'Jump by half screen?' is ticked on the display options tab, by holding down Ctrl and clicking Left / Right on the ***2D graphing window***, the data position will jump by half a screen to the side
Move position of the values overlay	Hold down Shift & Left mouse button to move
Highlight (yellow) parameter(s) on the values overlay	Hold down Ctrl & Alt and move mouse over first (parameters description) column in the values overlay. Items will change colour to green. Left mouse click to toggle highlight to yellow
Toggle display of "zoomed in" window of drawing	Ctrl, Shift & Alt held down together, then Right mouse click
Move zoomed window	Hold down shift and use Right mouse click to move
Adjust zoom level of zoom panel	Left Alt and mouse wheel
Moving to the next split	Left and right click simultaneously in the fourth panel across the top of the drawing; labelled "Split navigation"
Bookmarking data	Left / Right click to set start / stop of the data section to Bookmark, then Left + Right click in the second panel across the top to generate the Bookmark's markers

0. First run of DDMT

Minimum specification PC/laptop to run DDMT

An Intel i5 (or AMD equivalent) with 16 GB of RAM at a minimum to comfortably use DDMT. This will cover the use of the 2D, 3D and all required metrics used within the code. By default, the 'split size' (below Figure 0.1), is ~1,000,000 data points (the amount of data loaded into memory of the full file. This 'split size' can be altered at the start, prior to the first 'Load data' is pressed. If, during the use of DDMT, and error message appears stating that an array could not be generated due to memory constraints, please restart DDMT, and lower the 'split size' and retry. Upgrading user memory to 32 GB will resolve such an issue. An advanced graphics card is not a general requirement for DDMT, but something moderate may help.

When running DDMT, the user is first presented with the control panel shown in Figure 0.1.

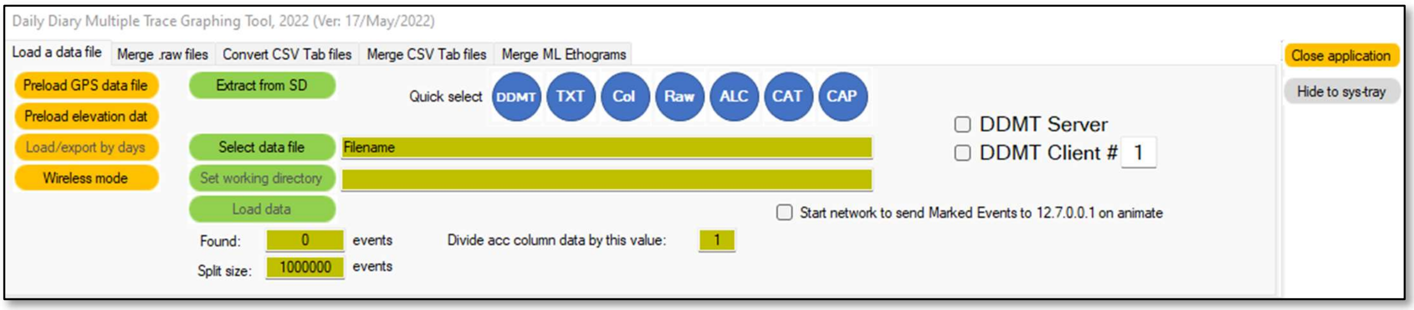


Figure 0.1 *Initial control panel – setting the graphics window dimensions*

Note that a great many laptops will default to a non-standard scaling of the screen. For instance, a laptop having a full HD resolution of 1920x1080, might then be rescaled by Windows to 125%, or even 150%, and so a window having dimensions 1900x600 would be "blown up" to nearly 3000x1500. A great deal of the window content will be off the edge of the display as a result. To resolve this, right-click on Windows' Desktop, select ***Display settings***, and change the ***Scale and layout*** to 100%. It might not be necessary to alter the ***Display resolution***; Figure 0.2.

The ***2D graphing windows*** can be resized manually by the user by grabbing the window corners as usual in Windows.

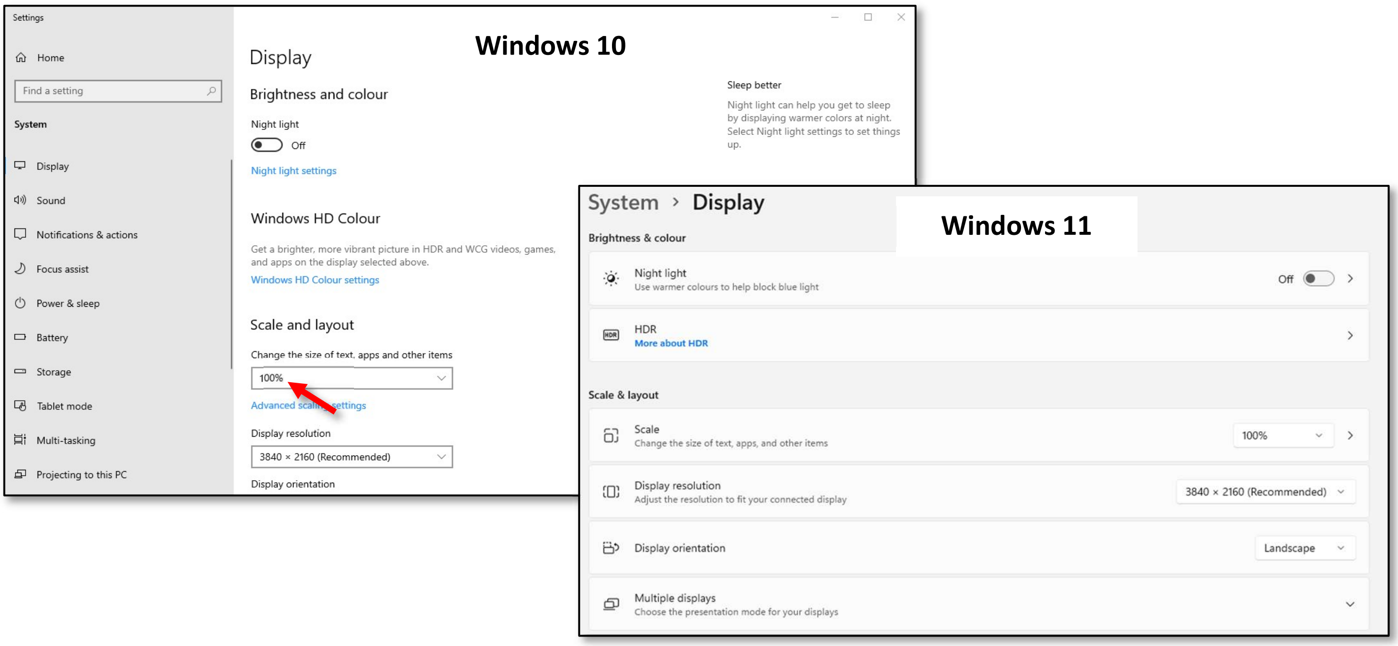


Figure 0.2 *Adjusting Windows Desktop Display to 100% scaling*

If, either on a PC or laptop, after loading a data file into DDMT, you don't see any of the windows on your screen, it may be because at some earlier time you had a second external monitor connected, and Windows has created the graphics windows for DDMT on that screen space (that no longer exists!). Hovering the mouse over DDMT on the taskbar, one might see greyed windows such as:

***Figure 0.3** Multiple windows grouped by Windows on the Taskbar*

To bring the windows onto the current display, hover the mouse over each of the grey windows one at a time, right-click the mouse, left click **Move**, and tap one of the keyboard cursor keys. This will lock the window to the mouse pointer. You can now move the mouse and bring the window into view. Repeat for all.

For more information on this issue (not just related to DDMT), see "Method 2" on this Microsoft link:

https://support.microsoft.com/en-us/topic/some-programs-are-displayed-off-the-screen-b2a915b7-4705-c455-febf-8ddb6e7f0ae4

A common error:

Should you experience the following error (or similar) when you run DDMT for the first time:

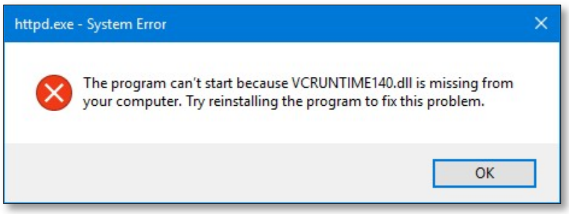


***Figure 0.4** Possible error with primary executable*

Please install the file named ***vcredistx64.exe*** contained within the DDMT zip file, to install the runtime libraries required for DDMT to function. Note that a restart of your computer may be required to complete this installation.

This is also available from Microsoft directly at:

https://www.microsoft.com/en-us/download/details.aspx?id=52685

Use of commas and dots as decimal points for numbers in text boxes

If, within your country, you typically use a comma as a decimal point, then please use this same format in the text boxes, else you might experience some strange behaviour, such as a value of 0.1 becoming 0.0 i.e., within the Behaviour Builder:

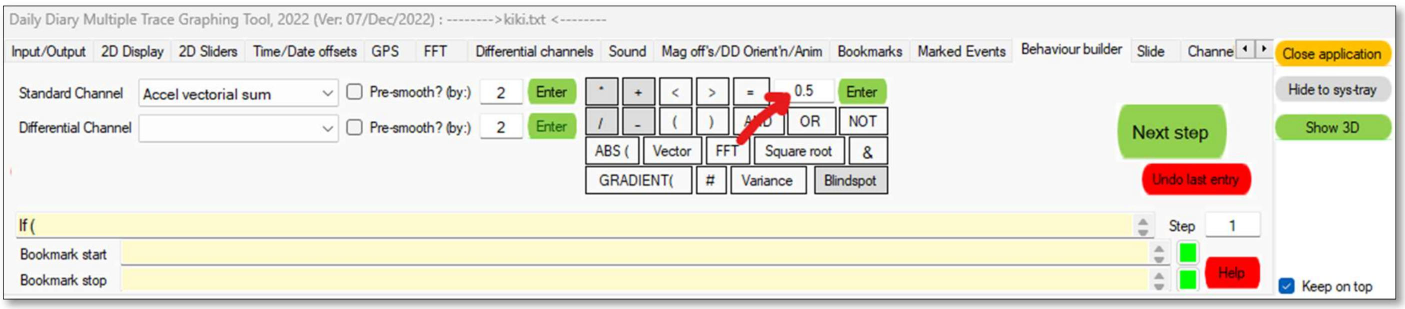


***Figure 0.5** Use of commas/dots as a decimal point*

1. Importing and Exporting Data with DDMT

Extracting Daily Diary data from an SD card

With the current Daily Diary firmware, it is necessary to use Daily Diary Multiple Trace software (hereafter **DDMT**) to first extract the collected data from the MicroSD card.

When DDMT is first opened, the user is presented with the control panel shown in Figure 1.1. To begin, click the button labelled ***Extract from SD card***. This will initially present a small box, into which the name of the file that will be created with the Daily Diary data to be extracted should be entered. After ***Set extract filename*** is clicked, the user will then be asked to provide first the location of the SD card using a browser box, and second, the destination directory for the new file containing the Daily Diary data. DDMT will then proceed to extract the data off the SD card and store it within 1 or more 2 GB files within the user's selected destination folder.

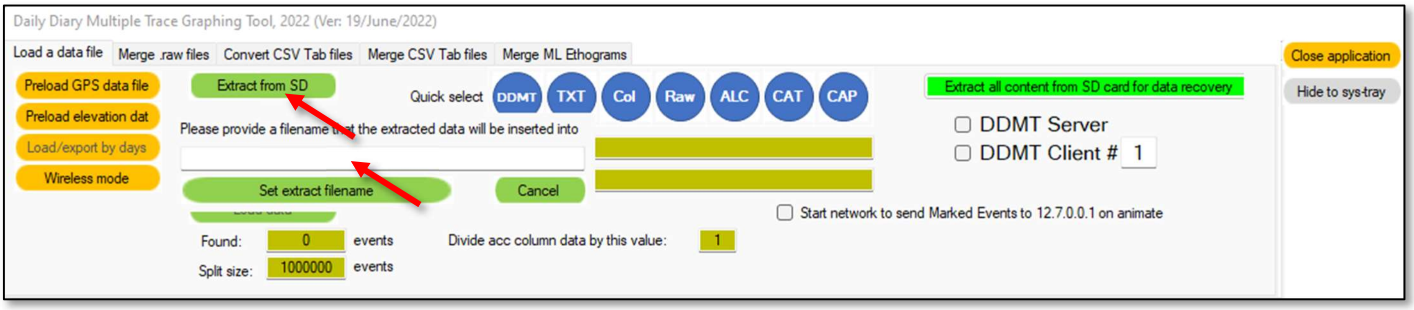


Figure 1.1 *Initial control panel for data extraction from MicroSD cards (from a Daily Diary logging session)*

Once DDMT informs the user that the data has been extracted, the user is then free to select and load this data file by clicking ***Select data file***.

Loading data files into the software

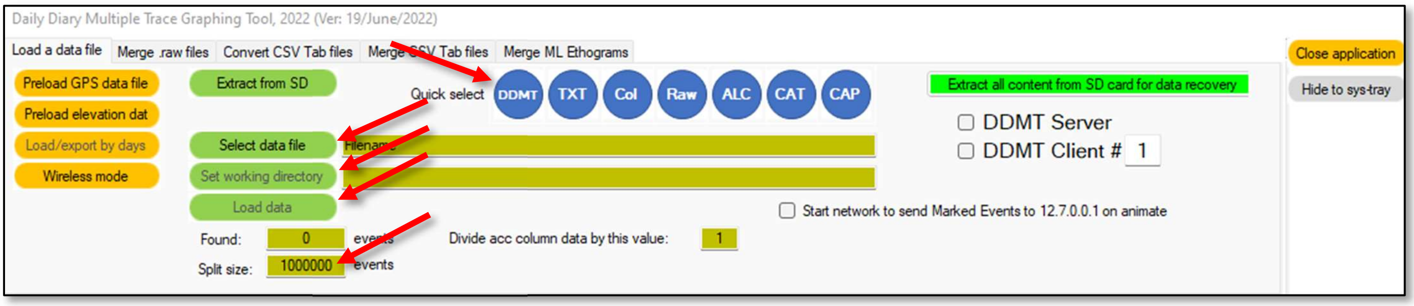


Figure 1.2 *Click* ***Select data file*** *to locate the data to load into the application, followed by* ***Set working directory*** *(if required; Desktop is the default), and finally* ***Load data*** *to load some, or all, of the data into memory*

There are several different file types that can be loaded into the software.

TXT	(extension **.txt*) data file created by the Daily Diary, binary format (not human readable)
RAW	(extension **.raw*) created within the software, binary format (not human readable)
COL	(extension **.txt*) tri-axial acceleration data from other devices, ascii format, tab delimited
DDMT	(extension **.ddmt*) various data channels (acc, mag, etc.) from other devices, binary format

Additionally, the user can pre-load other data structures before loading sensor data.

Preload GPS data file preload (before selecting your primary data file) a GPS data file into memory; ascii/CSV format. Please see Chapter 8 regarding the required data format for this file.

Select data file a browser window will appear giving access to your files; the user can manually select the data type from the above types (*.txt, *.raw, *.txt, *.ddmt, or other legacy type). Alternatively, select the file type using the "Quick Select" blue buttons as indicated in Figure 1.2. Select the text file you would like to load directly from your PC/laptop/storage device.

The application will read through the file and determine how many 'events' (data points) are recorded in the file (40 Hz = 40 'events' (data points) per second; each "***event"*** will contain multiple sensor values, and timing information – not that if no timing information is included within the data file, DDMT will construction for you). The total number of events and the number of events to load will be displayed in the ***Found*** and ***Load*** boxes respectively.

Set working directory to indicate where to store the outputs, e.g., data files or screenshots, from the software. The user's ***Desktop*** is selected by default.

Note, some versions of Windows (or in-built policies / anti-virus) do not allow DDMT to write files to the user's Desktop, the default Working Directory. If you find no file found on export (even if DDMT reports 'file written', please select an alternative Working Directory i.e., an alternative drive or an external drive, or perhaps the 'downloads' directory

Load data to display your first 'split' of data, Figure 1.3. A split is defined as either all of the data if the user is able to load all in one go, or a subset of the whole. A series of windows will now appear. The window named ***drawing*** will contain a series of graphs. ***Drawing 2*** is simply a second window to display the same, or other, data – think of it as more "floor space".

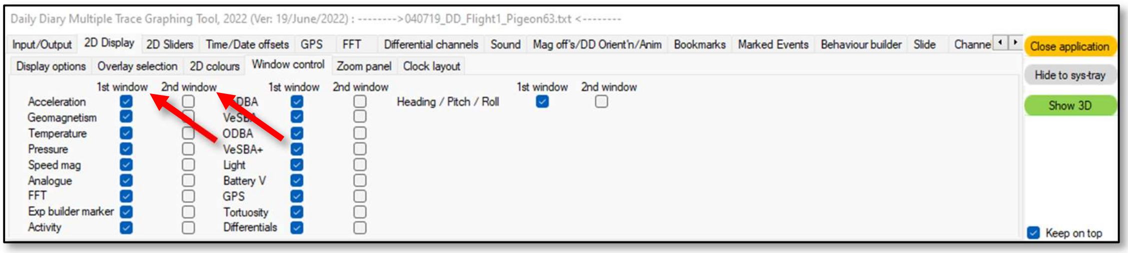


Figure 1.3 *Graphing data on the second 2D window*

If there is a problem extracting the data via the extract button, then there is now a button that will extract all data from the SD card:

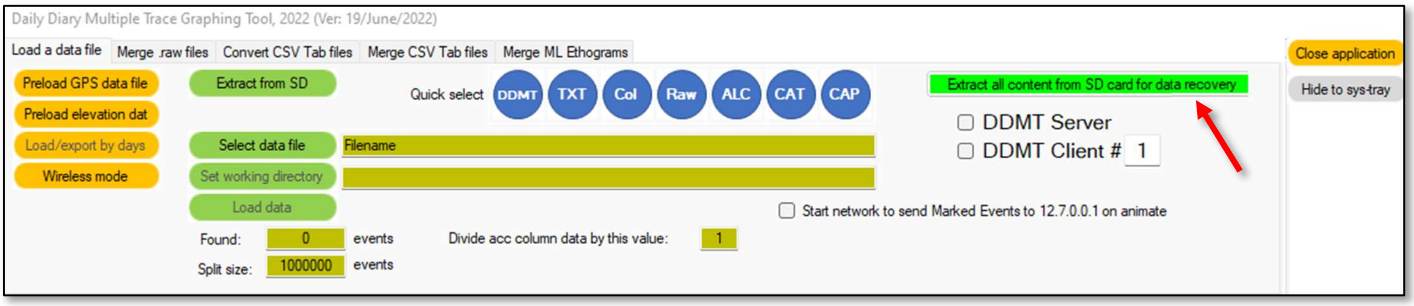


Figure 1.4 *'Emergency' extract of all data from the SD card to file*

Clicking this button will ask for the location of the SD card, and where to place the resulting data file(s). Once this is done, the user should attempt to open the files, and if there is still an issue, contact ddmt_software@outlook.com and request assistance.

To load a data file into DDMT:

1. ***Select data file***
2. Change the file type to that required (*.*txt*, *.*raw*, *.*ddmt* etc.)
3. Set ***Working directory*** if the default (User's Desktop) is not preferred
4. Adjust the ***Split size*** from 1,000,000 events to something larger (keep < 3,000,000 else the software will lag)
5. Click ***Load data***

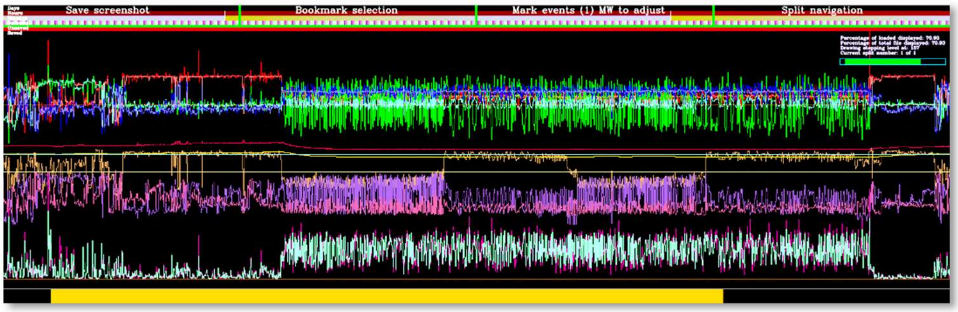


Figure 1.5 *Main graphs window (2D)*

By default, the top red/green/blue graphs represent acceleration X/Y/Z, the middle red and yellow represent pressure and temperature respectively, the lower brown/purple/pink represent magnetometer X/Y/Z, and finally at the bottom is VeDBA (a measure of Vectorial Dynamic Body Acceleration) in pink and VeDBA smoothed over the top in pale green. The temperature and pressure vertical scales and positions will automatically adjust depending on the data to be displayed to maintain a relatively central position.

Close application *to* close the software at any point; located on the right-hand side of the control panel. This performs an orderly shutdown of the application.

Hide to Sys-tray *will minimise the main control panel to the system tray. This is useful when it is set to "stay on top" but is required to be temporarily out of the way.*

The Column file format for importing triaxial accelerometery into DDMT

Triaxial accelerometery data can be loaded into DDMT from any source. Simply create a file containing your 3 acceleration channels in the order X, Y, and Z. The delimiter must be "tab", and there should be no header row (it will be assumed that the columns are in X --> Y --> Z order). The file should have a file extension *.txt*.

As an example, here is some data in Excel; Figure 1.4.

	A	B	C
1	0.292606	0.206278	0.47943
2	0.079364	0.657229	0.454833
3	0.813417	0.255477	0.695476
4	0.949998	0.48214	0.002423
5	0.709955	0.763539	0.554591
6	0.94285	0.582487	0.788854
7	0.963425	0.489661	0.151246
8	0.652498	0.059643	0.71832
9	0.686657	0.667858	0.41335
10	0.637207	0.961429	0.513011
11	0.479828	0.84392	0.202608

Figure 1.6 *Triaxial accelerometery. No header row present*

Select ***File*** -> ***Save As***, browse to the destination folder, and change the file type to "Text (Tab delimited) (*. Txt)".

File name:	Book1.txt
Save as type:	Text (Tab delimited) (*.txt)

Figure 1.7 *Export the data as file-type "Text (Tab delimited) (*. Txt)"*

Previously, it was required that the extension *.txt* be adjusted to *.col*. This is no longer the case; it must now remain as *.txt*. Selecting ***Col*** as the file type on the initial control panel instructs DDMT of the incoming file format (*tab delimited, tri-axial only*).

Setting up a DDMT Server / multiple DDMT clients

This option allows the user to simply slide through the data within the current *split* and have other instances of DDMT running and they copy. The purpose of this is to synchronise by data point (not by time) datasets from multiple loggers. For instance, a dataset might contain two files from loggers affixed to the head and body of a particular animal. Time-drift aside, this feature allows the user to scroll through the data on the primary instance and have the other datasets 'keep up' / show the same data point range.

To use this feature, you must first tick the ***DDMT Server*** box, and then load one dataset into memory, so that the data can be seen on the 2D graphing window.

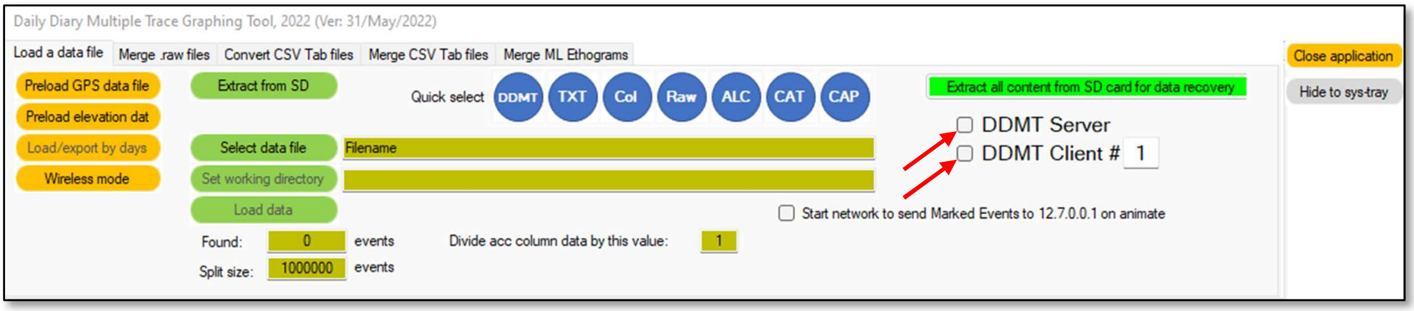


Figure 1.8 *Synchronising multiple instances of DDMT. Step 1 – initialise the DDMT Server*

Once the user can see the first split of data in the 2D graphing window, it is then that the app named "*DDMT multi-client*" should be run.

DDMT multi-client When this is run, a console window will appear, and a question is posed:

"How many clients of DDMT (not including primary)?"

If the user has just 2 files (head/body perhaps), then the user should type '1' and hit "enter". This will look for that first instance of DDMT and link to it. The console window that opens should state a successful connection.

Figure 1.9 *Establishing a connection between the arbitration app and the first instance of DDMT (Server)*

Now, as the user has stated '1' client, they should next run another session of DDMT and click "DDMT Client #" and leave the value in the adjacent box as 1. This value is the identifier for each client, and must be different for each client, and sequential, starting from value 1. So, if 3 clients were to be used (in addition to the DDMT Server), then these must be numbered 1, 2, and 3.

Once the DDMT Client box has been ticked and the client number set (default 1), then the user should load the data file for that client. It's best to load the same number of events in all sessions of DDMT.

Now, in the 2D graphing window of the "DDMT Server", and changes to the extremes (the orange bar at the bottom) will be instantly reflected in the DDMT Clients.

In later versions of DDMT, it is hoped to achieve more than just synchronising the extremes of the current split i.e., more interaction within the 3D between the multiple clients.

The data file, broken down by split number

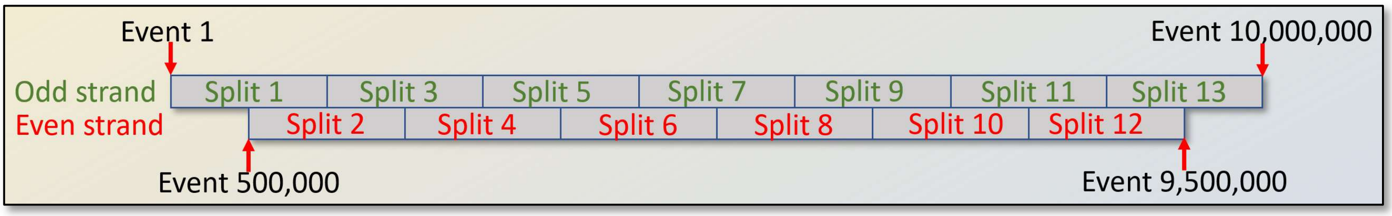


Figure 1.10 *Data file "split" structure*

Some definitions:

"Event"	A single instance in time containing all sensor values i.e., "data point"
"Split"	A slice of the whole data file

Number of splits for a data file = (((data points)/(split size)) x 2 - 1)

In the above example, there are a total of 10,000,000 events (data points) contained within the file. In this case, the user loaded the default number of events for a "split" as 1,000,000 events. The *odd* splits span the total file, while the *even* splits are offset at the midway points of the *odd* splits, allowing the user some continuity as they work through the data.

Exporting data / calibration data

Data can be exported in two main formats, either as a raw format which can be loaded back into DDMT for further visualisation/algorithmic searches, or as tab delimited columns, which cannot be reloaded into DDMT, but can be transferred for analysis in other software packages. Below is the ***File output/Save*** tab and an explanation of each export option.

The export data function DDMT has now grown to allow a high level of control over what channels are output to file.

The user can change the default filename from "Filename", to which are several characters that define the type of export, followed by a numerical suffix that is incremented after the execution of each save to help generate unique filenames.

By ticking ***Omit headers***, when exporting ASCII data i.e., human readable format, headers will be removed from the first row.

The data to be exported is determined by how the user selects the range. There is a control in the centre that allows the user to switch between 3 types of data selection:

1. ***Save data in current split***

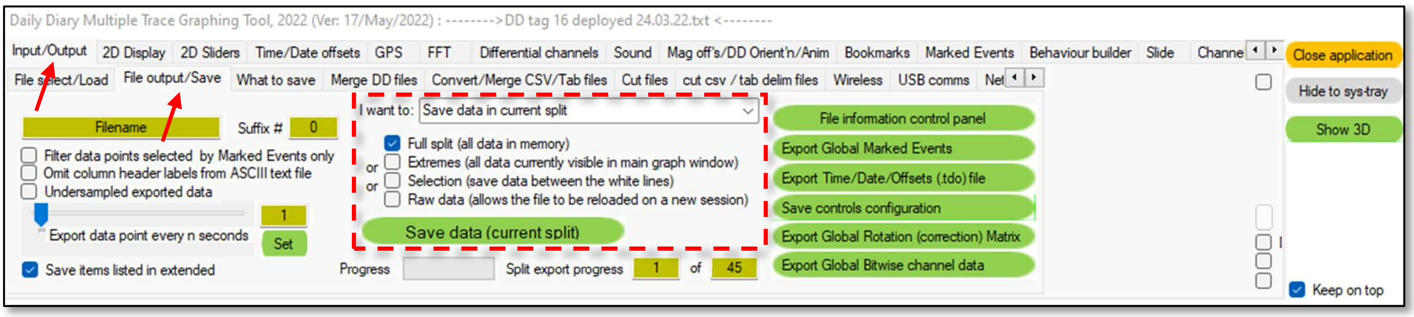


Figure 1.11 *Save data in current split*

This allows the user to export data from the current split, quickly and simply, as either ASCII for reading into another application such as Excel, MatLab, or R, or as a binary format, *.raw*, that can be reread into DDMT during another session.

Full split will export all the data from the current split you have open

Extremes will export all the data-points currently on display in the ***2D graphing window***.

Selection will export all the data-points between the left and right white lines (left/right mouse buttons)

Raw data creates a file that can be reloaded into DDMT (discussed a few pages down)

2. ***Save data from one (total) event number to another*** (total event number, <u>not</u> the local split event number) i.e., from any event within one split to any event number within another split

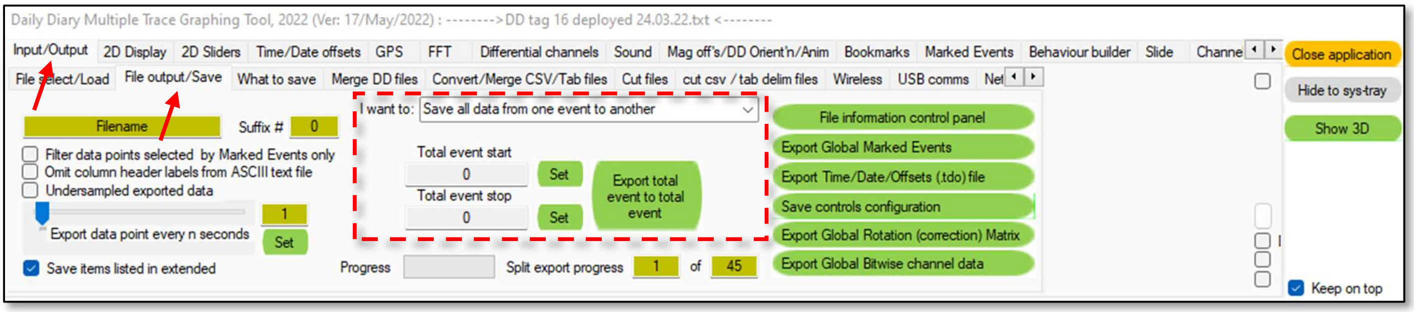


Figure 1.12 *Save data from one event to another.*

DDMT will move through the splits and export all data between the start and end points. The user must place the left white line at the start and end points and click **Set** to define these, and then click the button labelled "Export total event to total event". Note that one the previous save option there was 'I want to…' with a tickbox for *Raw*, one can export from one total event to another total event in the *.raw* format, even if the total event values span across multiple split boundaries. This will however result in multiple *.raw* files. These are numbered in export sequence and may be merged (discussed below).

3. ***Save data as per the split list provided***

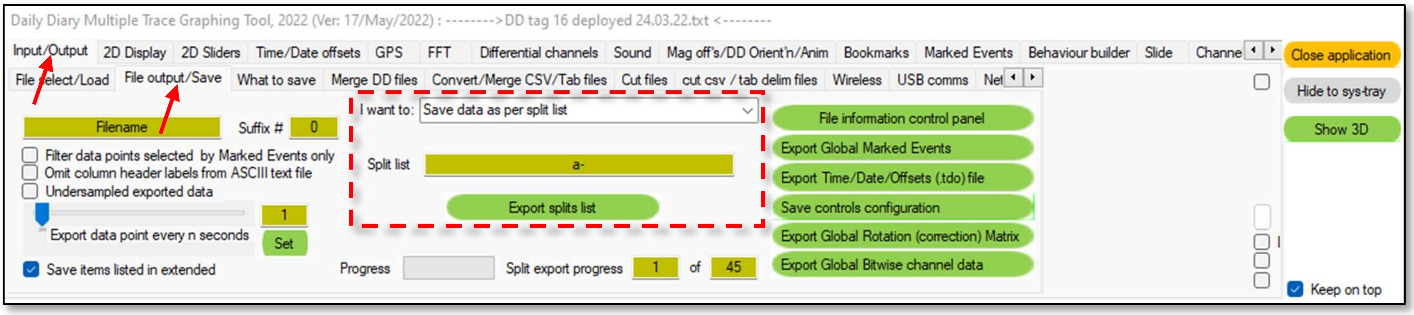


Figure 1.13 *Save data by split number as dictated by the list default "a-"*

Export splits list Specific splits can be selected for export using the syntax illustrated in the examples below. Note that while letters below are given in uppercase, these commands are not case sensitive, i.e. E4-10 and e4-10 generate the same outputs.

E4-10 *even*-numbered splits only, from 4 to 10 inclusive, i.e., splits 4, 6, 8 and 10 are exported

O3-10 *odd*-numbered splits only, from 3 to 10 inclusive, i.e., splits 3, 5, 7 and 9 are exported

E- all *even*-numbered splits in the data file

O- all *odd*-numbered splits in the data file

- all *odd*-numbered splits in the data file

3 split 3 only

3-	all splits from split 3 to the end of the data file, both *odd*- and *even*-numbered
-7	splits 1 to 7 inclusive, both *odd*- and *even*-numbered
E-7	*even*-numbered splits from 1 to 7, i.e., splits 2, 4 and 6 are exported
O-8	*odd*-numbered splits from 1 to 8, i.e., splits 1, 3, 5 and 7 are exported

Additional syntax

C or ***c***	signifies the current split, i.e., the data split currently loaded in DDMT
+	used with the current split command above and followed by a number exports the current split and the specified number of following splits (inclusive)
c-	exports all *odd* or all *even* splits (depending on whether the current split is *odd* or *even*) from the current split to the end. Note if exporting *even* splits, it will miss the last section of data which is contained in the *odd* splits only which are staggered by half a split
ec-	exports all *even* splits from the current split to the end of the data file. If the current split is *odd* it will not be included
oc-	exports all *odd* splits from the current split to the end of the data file. If the current split is *even* it will not be included
ec-9	exports all *even* splits from the current split to split 9. If the current split is 3 then splits 4, 6 and 8 are exported
c	exports the current split
c+2	the current split and the next 2 splits; the system will look to see if the current split is on the *odd* or *even* strand and export the current split and the number of splits listed
ec+3	forces DDMT to *even* strand. If the current split is *odd*, it will be skipped and only the next 3 *even* splits are exported
e-c	all *even* splits from the start of the data file (i.e. 2 onwards) to the current split (or the one before the current if the current split is *odd*)
-c	either all *even* or all *odd* splits until the current split. Whether *odd* or even splits are exported is determined by whether the current split is *odd* or *even*
3-c	here, the current split has the priority of the strand. If the current split is *even*, split 3 is excluded, but 4, 6, 8, etc. to the current split will export
E3-c	here, the *even* strand is forced so that 4, 6, 8, etc. to the current split are exported (unless the current split is *odd*, in which case, it will be the split before the current)

The user can also choose to export alternating splits, where DDMT saves data from all splits (therefore alternating between odd and even splits) but excludes the first and last 25% of data in each individual split. This exports all data without overlap and avoids zero values in the smoothed channels at split boundaries. ***This function cannot be combined with other search strings***.

a-	all splits from start to finish, dropping the first and last 25% of each split. This command is the default option
a-7	from the start of the data file to the end of split 7, dropping the first and last 25% of each split
a3-7	from split 3 to split, dropping the first and last 25% of each split
a7-	from split 7 to the final split, dropping the first and last 25% of each split

The first split defined here will include the first 25% of data and the final defined split will include the last 25% of data, so no data is lost from the beginning or end of the total data file. In the example below, the split size is 1,000,000.

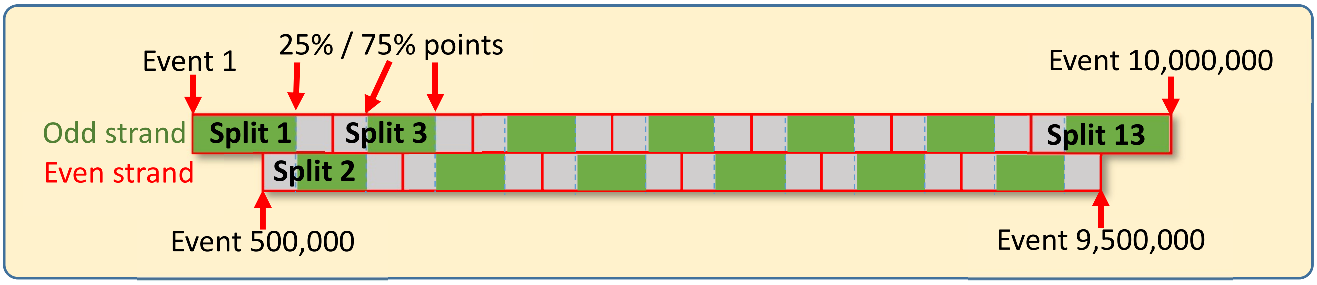


__Figure 1.14__ Using the "a" prefix will make the export function switch (alternate) between the odd and even strand at the 25% / 75% points to ensure that it doesn't export the left and right extremes of each split where smoothed data is zero (due to the centred window averaging function)

What to save (tab)

When exporting as tabulated data (***Raw data*** unticked), this determines which sensors and metrics are exported. The ***General / Primary channels*** tab contains the timing and raw sensor data, while ***Additional / metrics channels*** displays all Daily Diary channels; dead reckoning coordinate data can also be exported (see chapter 10).

If ***Save items listed in extended*** is unticked, none of the selections within ***What to save*** will be exported, regardless of their being selected or not; a quick way of omitting multiple selections.

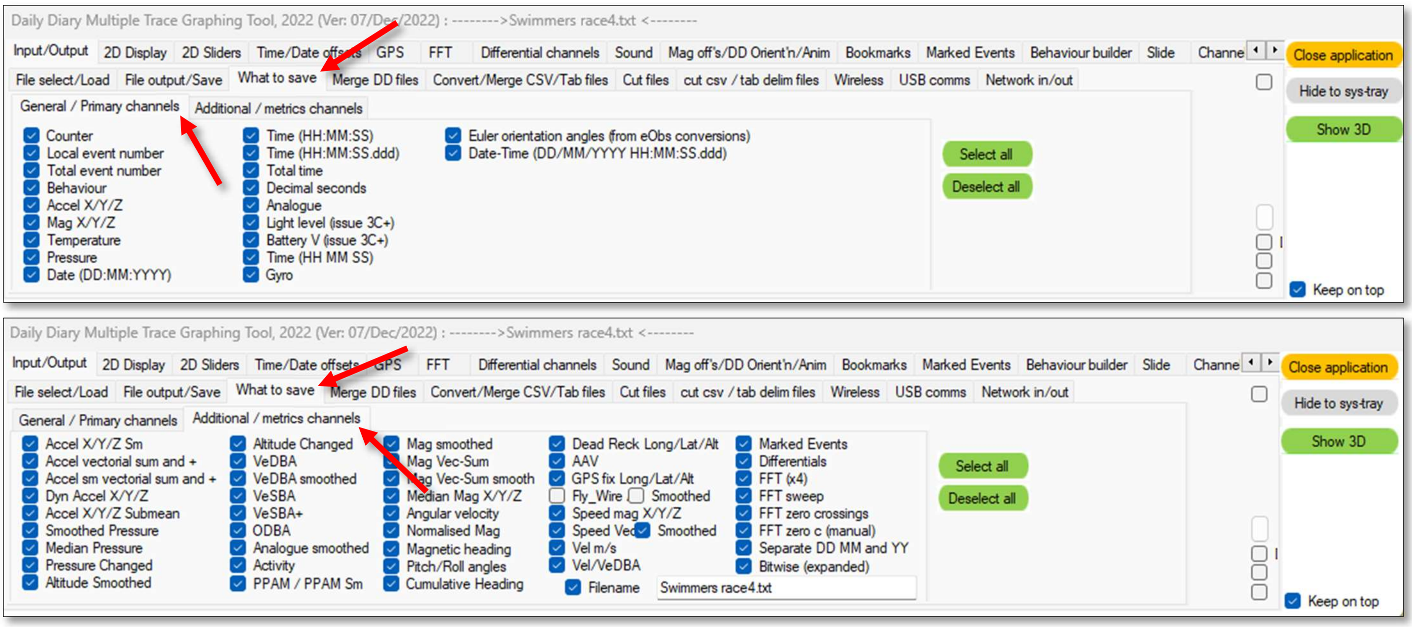


__Figure 1.15__ What to save General / Primary channels / Save items listed in Additional / metrics channels sub-tabs on the control panel

Raw (binary) data files

Sections of data can be exported in *.raw* format (binary files, as opposed to ASCII – human readable) and reloaded into the software later. This might be useful where the user is cutting out useful sections of the data, and thus discarding useless / unwanted data. Note that *.raw* data files can be merged into a single large *.raw* file. Merged *.raw* files can be partially loaded into memory, so (within reason), there is no upper limit to the size of the merged file. This is discussed further on.

Note that the ***Export splits list*** function outlined in the previous section can also be used to export *.raw* files, simply select the ***Raw data*** checkbox on the ***File output/Save*** sub-tab.

Please ensure that any time corrections and magnetometer / accelerometer corrections have been applied to the data prior to exporting as *.raw* files, as these correction functions are disabled when loading in *.raw* files.

Exporting using the Under-sampling checkbox to "thin" the data

Exported data may be 'thinned' by selecting the ***Under-sample exported data*** checkbox on the ***Input / Output File output / Save*** sub-tab. The degree of under-sampling is determined using the ***Export data point every n seconds*** slider, or by entering a value in the box and clicking ***Set***. Allowed values are "every 0.1 s", "every 0.2 s", "every 0.5 s", or every second from 1 to 297. To sample at sub-second levels, it is easier to enter 0.1, 0.2, or 0.5 into the box and clicking ***Set***, but one can use the slider, moving it to the left, and then left-clicking in the space just to the right of the slider to jog it up to 0.2 or 0.5.

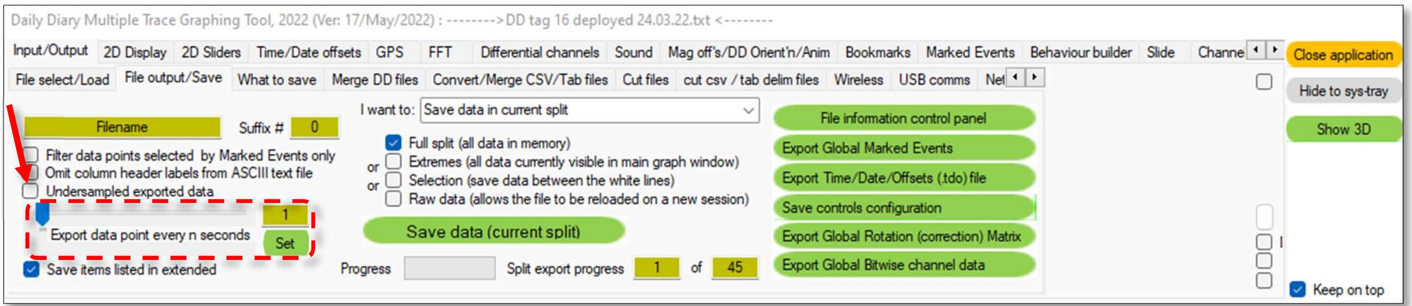


Figure 1.16 File output/Save sub-tab with under-sampling controls indicated

Exporting data by Marked Events

Marked Events are literally just that, they are ***events*** that have been given a marker (value 1-9) either manually by the user, by converting ***Bookmarks*** to ***Marked Events*** or through the result of the Behaviour Builder/Time series Search functions. Manually marking data is discussed in Chapter 10.

It is also possible to export ***Marked Events*** as defined by behaviour builder (see Chapter 10) by selecting the ***Export behaviour builder marked events only*** checkbox in the ***Input / Output File output/Save*** sub-tab. In doing so, behaviours, or simply sections of identified data, will export along with the ***Marked Event*** value. Possibly useful for further analysis in other software packages such as R, or MatLab.

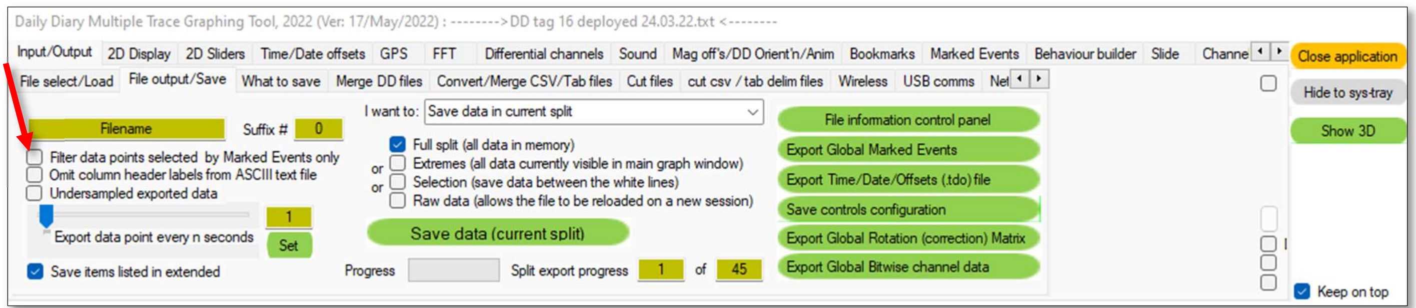


Figure 1.17 File output/Save sub-tab with export marked events option indicated

Merging raw files

Exported *.raw* files (perhaps with each containing data of a specific behaviour or time period) can be merged into a single contiguous file, and then reloaded into DDMT, as long as they are from the same original *.txt* file.

On the ***Merge files*** sub-tab:

1. select files with the ***Merge multiple .raw files*** button. This will open a window allowing you to choose the files you wish to merge. The selected files will then be listed in the box below (*All files to be merged must reside within the same directory)* in the order that they will be merged. If the order is reversed, perhaps, within the Windows file dialog, select the *Date modified* column header, to reverse the file order.
2. Next use the ***Set working directory*** button to determine where the new merged file should be saved.
3. Finally, select the ***Merge the files*** button.

A dialogue box stating the name of the new file will appear when the software has finished merging the files.

The software will indicate if the selected files are standard *.raw* files, or if they are bookmarked *.raw* files.

Standard *.raw* files are simply selections of the data saved in *.raw* format, while bookmarked *.raw* files are exported through a separate process using the functions within the ***Bookmarks*** tab. Bookmarked *.raw* files and standard *.raw* files cannot be merged as one, as they use a different internal structure. A bookmarked *.raw* file can be converted to a standard *.raw* file simply by loading it and then using the standard ***Save*** function with the ***Raw data*** checkbox selected from the list on the ***File output / Save*** tab, thus stripping off the ***Bookmark*** information.

The file merging function will not affect any data currently in memory. Merged standard *.raw* files will result in a standard *.raw* file, while merged bookmarked *.raw* files will result in a larger bookmarked *.raw* file, with all the bookmarks from the two files in their expected positions. Merging multiple *.raw* files can take some time as two are merged, to a single file, and the resulting file is then merged with the next, and so on; a reciprocal type of process.

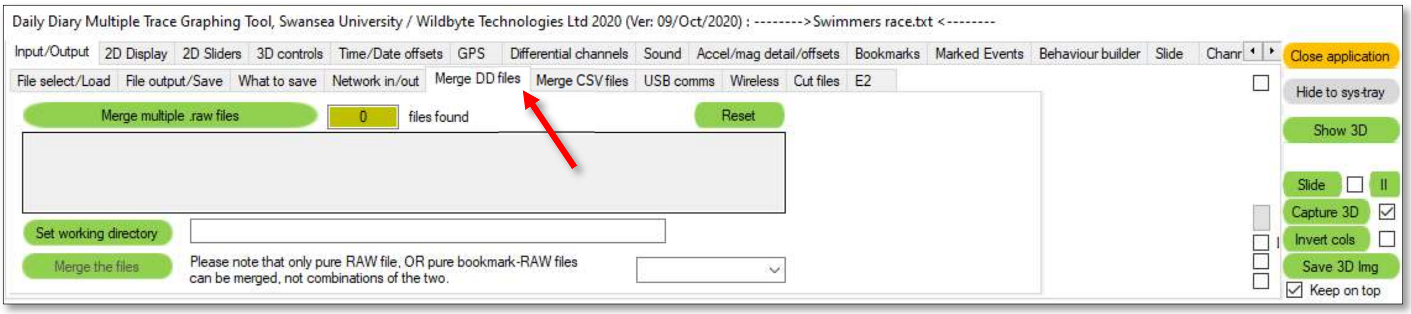


Figure 1.18 ***Merge DD files*** *tab on the control panel*

Note that merged *.raw* files maintain their timing data (both date and time) so there will be "time jumps" (when viewed on the ***Values overlay***) as the user left-/right-clicks through the data.

Merged files can subsequently be merged with other merged files, creating super-sized merged .raw files!

Note that with more recent software updates, merged *.raw* files can now be partially loaded, as is the case with all other standard data files within DDMT.

Converting .csv -> tab / tab -> .csv, Merging csv / tab delimited files / ML Ethograms

When exporting data from DDMT, often is the case that this results in many long files of either tab delimited, or csv files. The majority of the export functions work on a per-split basis with the export/save data function and so, if the user requires that the final result is a single file of human-readable data, these multiple files will need to be merged.

Files may be merged using the tab ***Convert / Merge CSV/Tab files*** (includes the tab-delimited format).

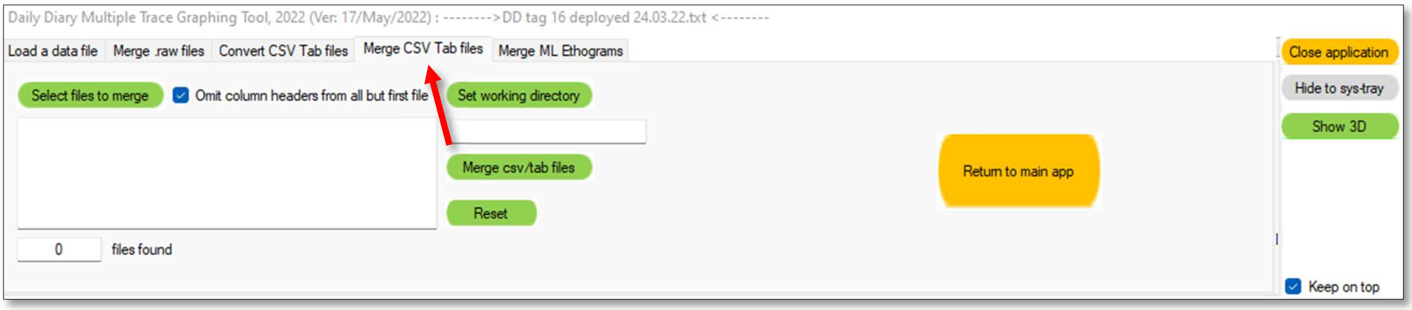


*Figure 1.19 **Merge CSV/Tab files** tab on the control panel*

Clicking ***Select files to merge*** opens a browser dialog. Hold down ***ctrl*** to select multiple files and click ***Open*** to apply these file names into the box below the button. Note that the files are added into the box in the order that they will be merged, starting with the first at the top. To change the order of the files added, use Windows Explorer column header controls to order them such that the first file is at the top of the file selection dialog prior to clicking ***Open***. Within the Windows file dialog, there is a drop-down box at the bottom to switch between csv and tab (txt) formats.

Set the working directory, where the merged files will come together in a new file, appropriately labelled, and click ***Merge csv/tab files***. While it is merging the files, a small counter at the bottom left will increment as it steps through the list of files.

A tickbox labelled ***Omit columns headers from all but first file*** should ordinarily be ticked so that only the top of the resulting file has a header, while all of the merged data flows together from the separate files.

The ***Reset*** button clears the list of files from the files list box.

Note that, for the merging function, it is assumed that all files will contain the same number of columns; the function simply reads each line of data, and immediately exports these into the final file. *Note that it also does not re-order columns from multiple files to match that of the other selected files.*

Click the orange ***Return to main app*** to reveal the main controls.

*Figure 1.20 **Merge csv/tab files** tab on the control panel*

Additionally, one can click the ***Convert csv -> tab / tab -> csv*** button that allows the user to select a file to convert between data formats. The tab content will change due to an update, showing the control in the figure below. The resulting file from this will have the alternate suffix, appropriate to its new file-type. This feature can also be used to convert from files utilising a semi-colon as a delimiter to a tab file, but not back to a semi-colon format i.e. convert from a "comma (csv) /semi-colon (also known as csv)" --> "tab (generally a .txt)", or, "tab" --> "comma (csv)". Click the orange ***Return to main app*** to reveal the main controls.

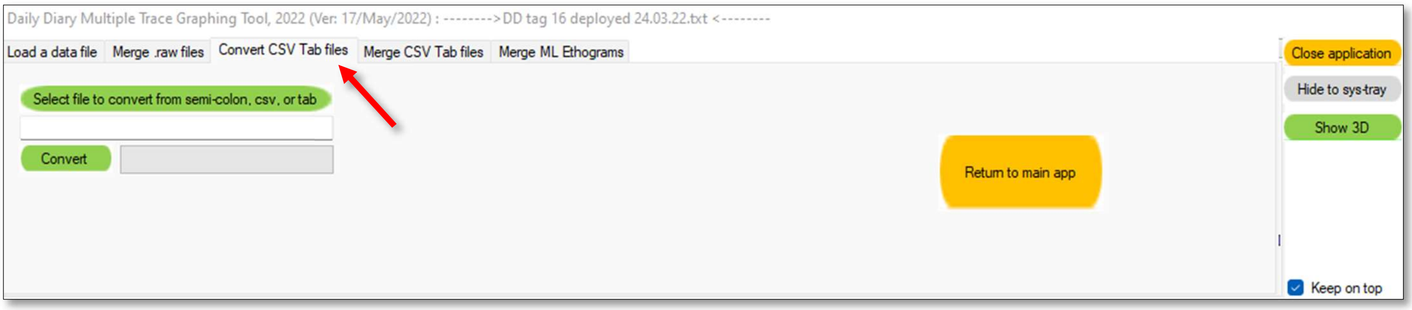


__Figure 1.21 Merge csv/tab files__ tab on the control panel

Alternatively, the button labelled ***Merge multiple ML ethograms*** (machine learning, ML) reads in multiple ethograms, of the particular type shown in figure 1.17, where total data point in the file start/stop are listed, as opposed to time values. This assumes that all the header colouring/category names are identical, sorts all the entries chronologically, and removes any duplicates. It then outputs a single merged ethogram file that can be loaded into DDMT. The ***999*** within the first column of every entry tells the ***Bookmark*** system upon load of this file type that it's an "ML" type of ethogram (where machine learning has been used to identify behaviours and noted the start/stop data point values in this file).

	A	B	C	D	E
1	type	code	Red (0-255)	Green (0-255)	Blue (0-255)
2	Cont Walk	1	255	0	0
3	Foraging	2	0	255	0
4	NULL	3	0	0	0
5	Other	4	255	255	0
6	Resting	5	255	0	255
7	Rooting	6	0	255	255
8	Running	7	255	128	0
9	Standing	8	0	0	225
10	Trotting	9	128	0	180
11	Vigilance	10	225	225	225
12	B	11	128	80	128
13	C	12	128	50	80
14	D	13	110	70	20
15	E	14	255	64	64
16					
17	NA	start	stop	behavior	
18	999	126491399	126491412	3	
19	999	126491413	126494922	2	
20	999	126494923	126494973	4	
21	999	126494974	126495049	1	
22	999	126495050	126495072	4	

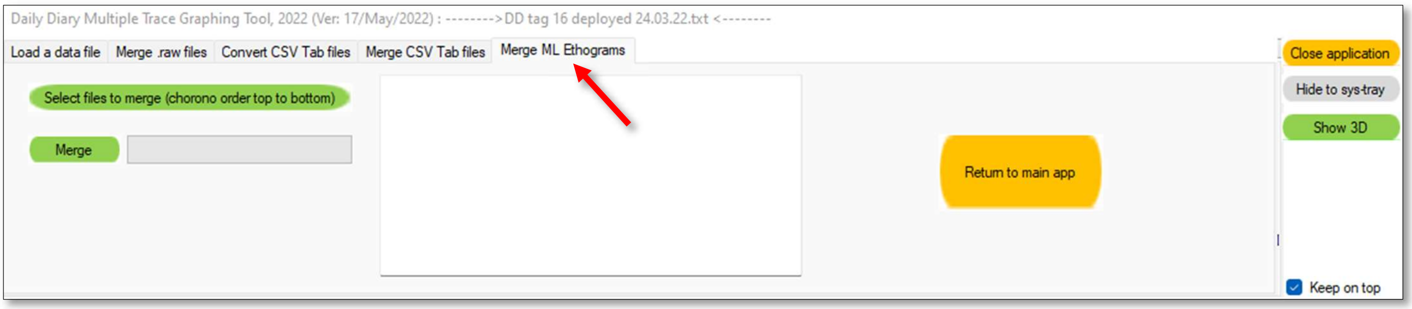


__Figure 1.22 Merge csv/tab files__ tab on the control panel

2. Main graphs (2D) windows

Time indicator bars at the top and bottom of the main drawing windows

Graphically, data from these tags can be difficult to understand at times, more so when one cannot easily discern the time scale of changing events. The coloured bars at the top of the screen give an indication of evolving time from the Daily Diary data (Figure 2.1).

Figure 2.1 *Top indicator bars on the **drawing** window*

The coloured bars, as indicated above, represent Days, Hours, Minutes, Seconds, and whether sections of data have been saved or not. The red bar level with the white ***Unsaved*** label to the left of the ***drawing*** window indicates nothing so far has been saved; the green line below (which intersects the red line above it) shows this section of data has been exported/saved. The ***Incremental hours per day*** bar changes colour from black to bright red with increasing hour value, returning to black at midnight, while the ***Incremental minutes per hour*** bar changes from green to mauve through the hour, and underneath likewise for ***Incremental seconds per minute*** (Figure 2.1).

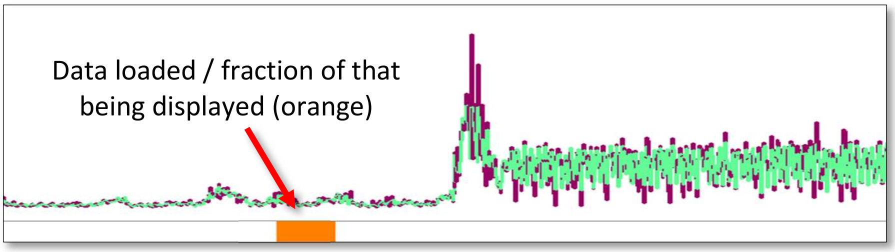


Figure 2.2 *Bottom indicator bar on **drawing** window*

The orange bar at the bottom of the screen represents the fraction of the current split on display (a full width bar represents the full split). To zoom in on a section of the data, simply left-click to define the left ***Extreme***, and right-click to define the right ***Extreme*** on this orange bar, which will rescale accordingly in size. The position of the bar corresponds to the position of the data currently in-view as part of the currently loaded split.

Percentages of displayed data as a function of that loaded and the whole dataset are displayed in the top right corner. The percentage of data loaded from the current split and total file are given, as well as the drawing stepping level and current split number. The green bar here represents how much data has been loaded in the current split as a fraction of the full dataset. These values can be removed from view by deselecting ***Display percentage visuals on 2D graph window*** under ***Display / Display options***. The above bar indicator will make more sense once the user has explored the data a little.

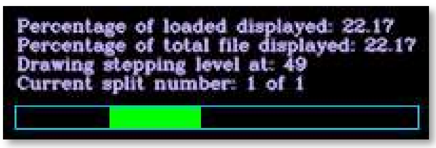
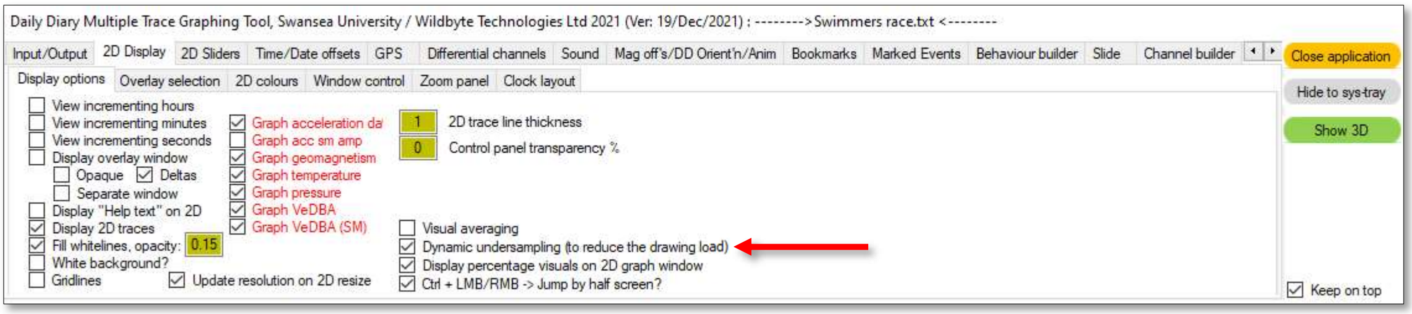
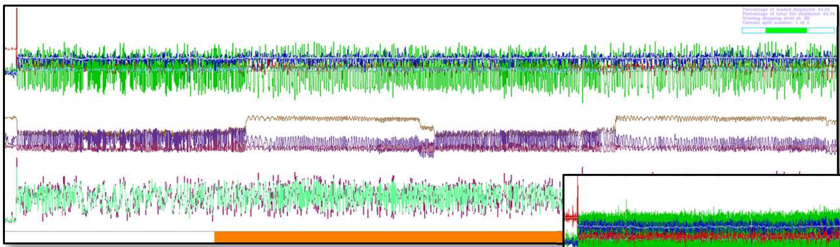


Figure 2.3 *Percentage loaded/displayed indicators*

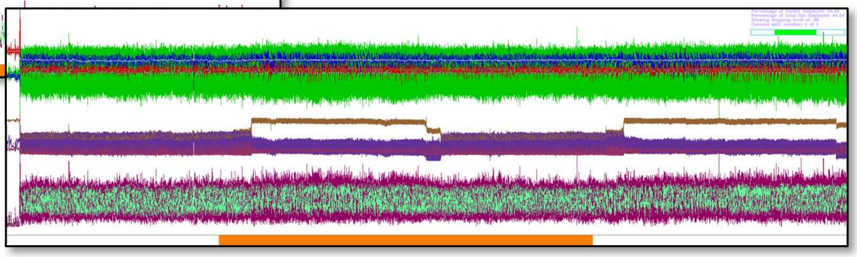
Displaying data in “under-sampled mode” for improved application performance

The data drawn in the two ***Drawing windows*** is under-sampled, by default, to improve application performance. Most display monitors these days are typically a minimum of 2k pixels across (full HD) or 4k pixels across (4k UHD), and so, if there are 1,000,000 events / data points in the current split and the user has zoomed out enough to display all 1,000,000 of these for several different channels of data, this would cause a severe performance problem. What the application does is to look at how many events it has to display, and divides this down by the horizontal resolution of the display, and uses this value as the “stepping” value through the data. This under-sampling can be disabled on the ***Display*** tab by deselecting “Dynamic undersampling”:





Left: Under-sampled data view; software more responsive, but key some peaks may not be displayed



Right: Non-under-sampled data view; software is less responsive, but key peaks will more likely stand out

Figure 2.4 *Under-sampled vs non under-sampled drawing modes on the two* ***drawing windows***

The tickbox labelled ***Update resolution on 2D resize*** forces a display resolution within the above 2D graphing window, so that more data might be displayed. If this box is not checked, then everything, including all text, will be resized up/down with any adjustment to the window dimensions.

If the 2D is being viewed within the 3D window (more recent update to DDMT), then this under-sampling does still occur and, as with the above 2D, can be disabled to show all of the data, but is less of an issue within the 3D, as it’s a mor effective drawing solution/system. At some point, the old (above) 2D output will be disabled/removed. For further details, please see the start of the 3D part of this user manual at Chapter 11.

Displaying data in “Visual averaging mode”

The alternate drawing mode is ***Visual Averaging***. To use this drawing mode, select ***Visual averaging enable***. When displaying averaged data, a slider, ***Degree of averaging***, will be available to set the degree of smoothing of the currently visible channel data**.** This defines a centred sliding average window width that visually smooths the data set; <u>Note that this does not in any way affect any exported data; it is a visual effect only</u>.

Two 2D graphing windows

When considering multiple data channels, it can be helpful to use two graphing windows. By default, selected data channels are displayed in the main graphing window, titled ***drawing***. An additional graphing window, ***drawing2***, is blank by default but can be useful for showing more channels at larger amplitudes across two screens. To adjust these settings, select the tab labelled ***Window control***, a sub-tab of ***Display***. This allows the user to set which data channels are displayed in each of the two ***drawing windows***. Note that the two windows represent the same time-period and adjusting the data on view in one graphing window automatically updates the other to match. Figure 2.5 shows an example where the second graphing window has been used to display the differential channels (see chapter 4) corresponding to Acceleration X, Y and Z.

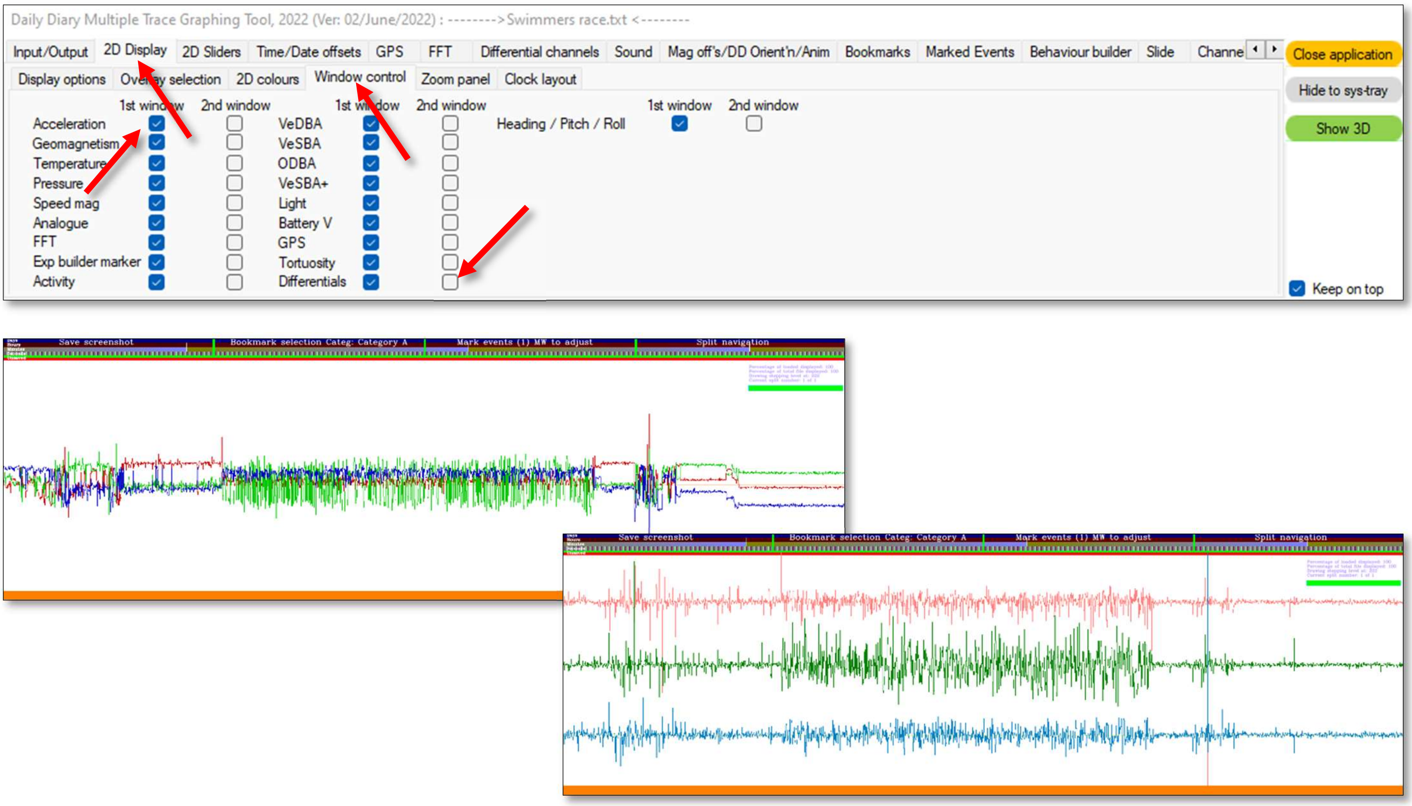


__Figure 2.5__ The settings on the above control panel are set to show acceleration (X, Y, and Z) on __drawing__ and the differentials of these on __drawing2__

Navigating through a large dataset

To move to another split, simultaneously left and right mouse-click on the fourth box along the top of the drawing (***Left + Right mouse / Left CTRL + Left mouse Navigate through data***).

Figure 2.6 *Bringing up the split navigation menu*

A sub-box will then appear in the centre of the drawing; if this doesn't appear, hold down the left and right mouse-click on the fourth box again for a couple of seconds, and then release. The top row of the sub-box represents the full set of data, while in the bottom row, each unit represents half of each of the two top units it touches (Figure 3.6). These units are "splits" of data. The splits are alternately numbered, with odd numbers on top and even numbers on the bottom. The number of splits present in the file is determined by the number of events loaded when the file is first opened (refer to Chapter 1 – Exporting Data).

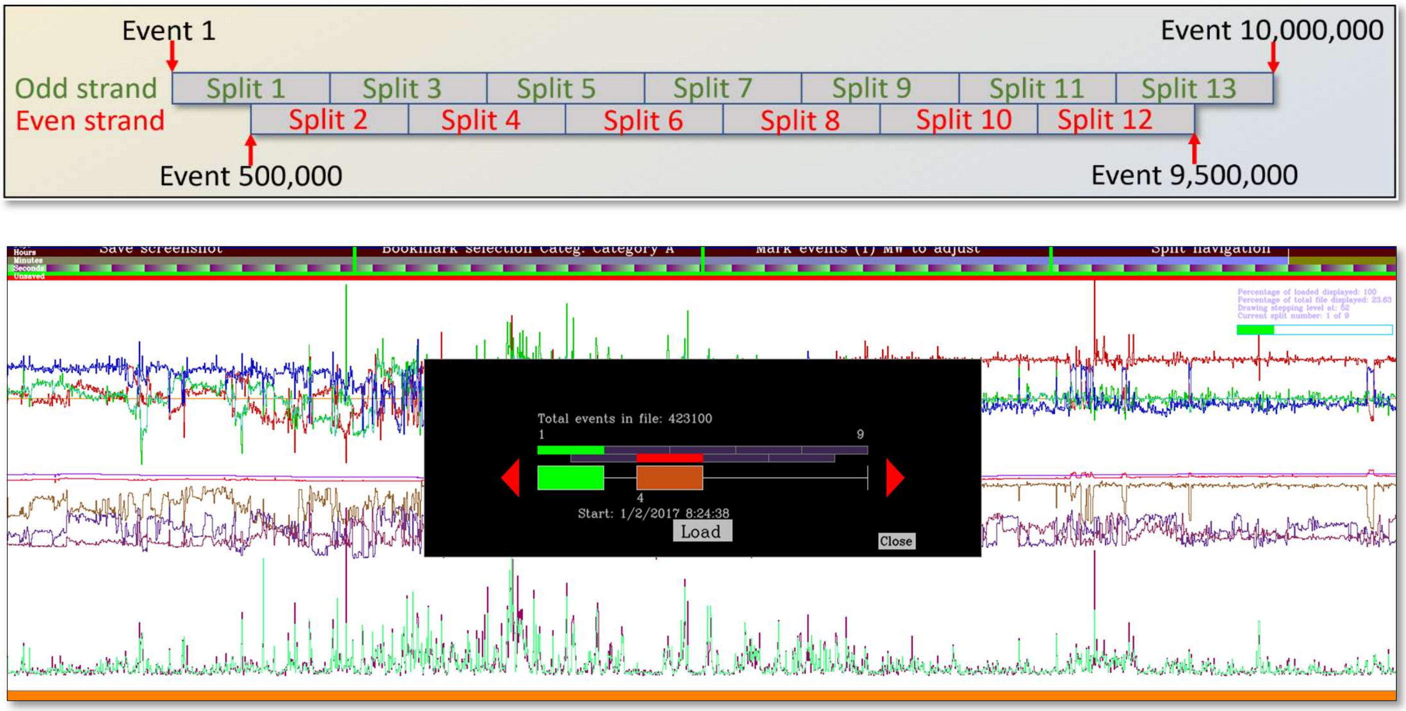


Figure 2.7 *The split navigation menu*

The currently loaded split is coloured green. To select a new split to load, left mouse click and drag the orange block along the panel until you reach the split you would like to load. The start time and date of the split at the position of the orange box selected is given below the bar for reference. Alternatively, especially for files containing many splits, the two red arrows either side of the navigation menu can be used to increment/decrement the split number. Click ***Load*** to load and process this split for display.

Generating custom colour schemes for 2D graphed data

The default colour scheme of the graphing windows can be modified for ease of access for users with colour blindness. All data channel colours can be customised fully. The third sub-tab of the ***Display*** tab is ***2D colours***. The controls shown on this tab enable the user to select a variable from the drop-down menu (*Acc. X*, for example), and adjust the red/green/blue colour sliders to adjust its final colour. The rectangle beneath represents the resulting colour mix. New colour schemes can be saved as a .csv file and loaded again later or reset to the default using the green button commands under the drop-down menu.

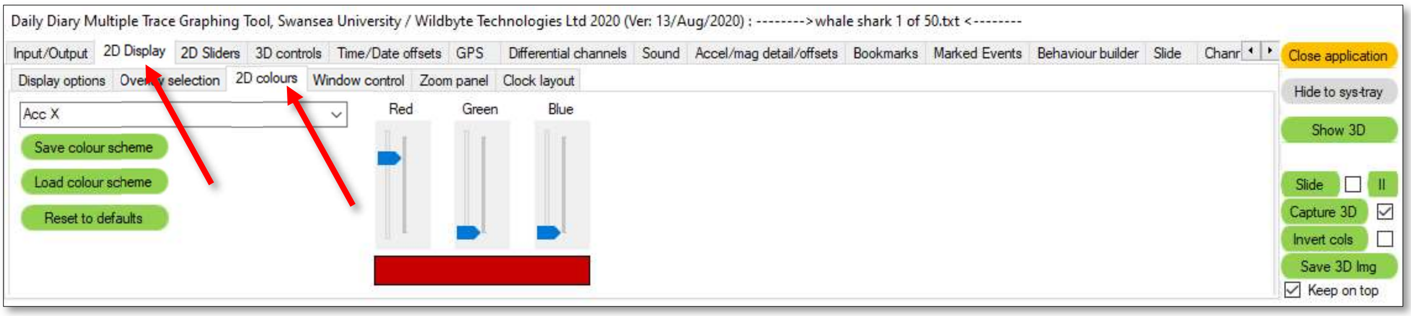


Figure 2.8 *Adjusting the colour of traces and indicators within the mian drawing*

Figure 2.9 shows the effect of adjusting the Acceleration X/Y/Z colour balance from the standard red/green/blue. This can also be useful for screenshots, especially when captured using a white background.

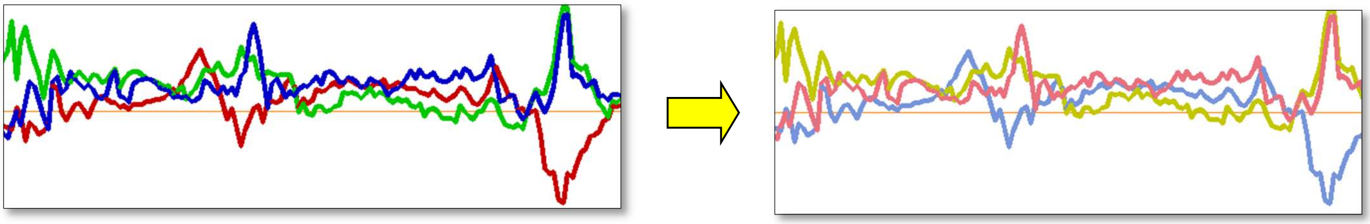


Figure 2.9 *Colours for Acceleration X/Y/Z adjusted from standard red/green/blue*

Horizontal guidelines

On the ***2D main windows***, by holding down **Ctrl** and **Alt**, and then left or right mouse clicking, one can produce 2 horizontal lines (different colours). These are merely for comparing the heights of data points on the display. They are also used for defining the vertical height of the ***Bookmarks*** and ***Marked Events*** bands.

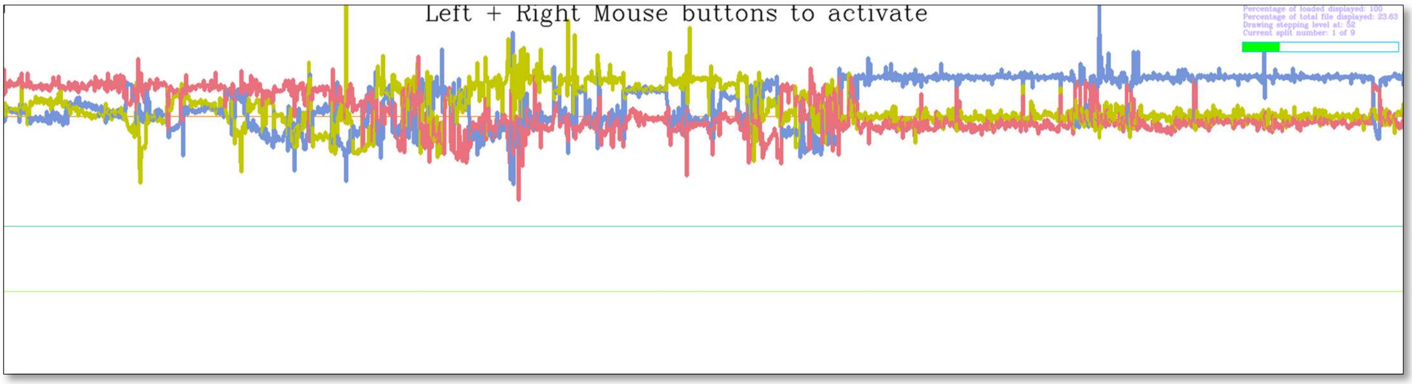


Figure 2.10 *Horizontal lines for data comparison / levelling*

It is also possible to add more horizontal lines that have the only purpose of data level comparison.

- To add a new horizontal line, hold down the **Alt** key; a coloured band will appear on the left and right sides of the ***2D graphing windows***.
- Right-clicking in the left side band will generate a new horizontal line that can be adjusted up/down at any time (while holding down the **Alt** key and right-clicking the mouse).
- Holding down **Alt** and right clicking in the left band again will create another, and another etc. horizontal band.
- Move the mouse outside of the left blue band to finalise the location of the current horizontal line.
- Holding down the **Alt** key and right-clicking in the band on the right side of the window will clear all these supplemental horizontal lines.

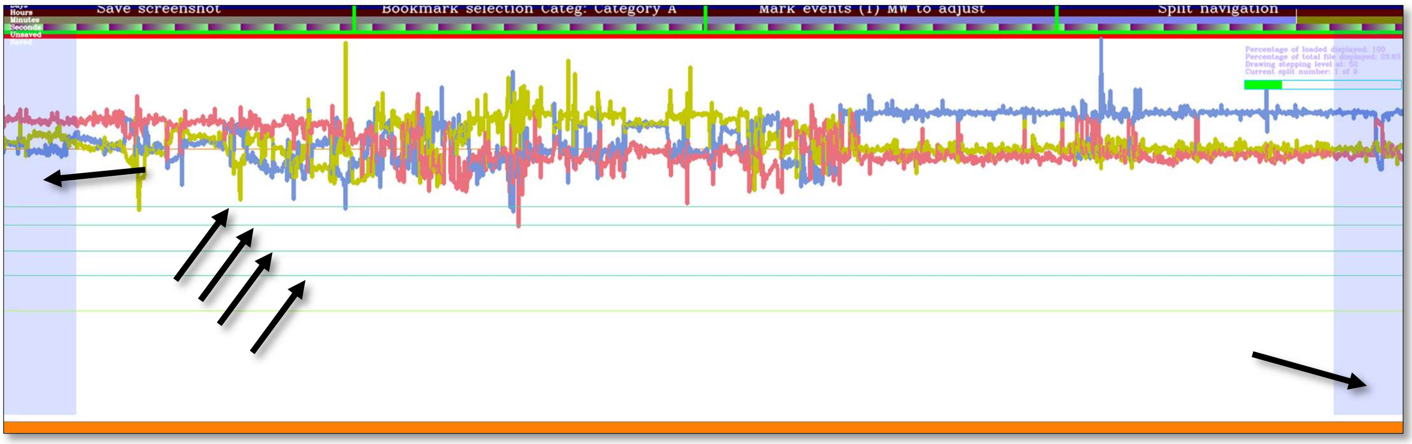


Figure 2.11 *Additional horizontal lines for data comparison*

Values overlay

To view, in real-time (of adjust the position of the left/right white lines), numerical values from the data displayed in DDMT, select the ***Display*** tab, and ***Display options*** sub-tab on the control panel, the default tab after first loading a data file. Using this tab, you can control a lot of what is displayed on the ***2D graphing window***.

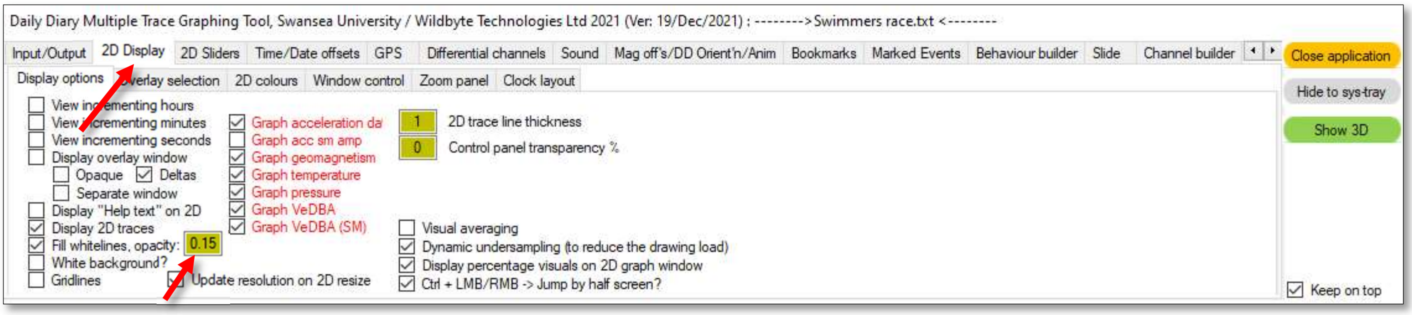


Figure 2.12 Display/Display options tab

On the left side of the window, you will see a tick box named ***Display overlay window***; check this tickbox and a list of names and values should appear on the drawing. An alternative, quicker, method to bring the overlay window up is to depress the mouse-wheel button. To move the overlay window, hold down shift on your keyboard and drag the overlay to where you would like it using a left mouse click. Additionally, by selecting ***Opaque*** under ***Display overlay window*** on the control panel, the overlay is put on a dark background for ease of viewing. If using the mouse wheel to bring up the overlay window, it appears on a dark background by default. The overlay can also be displayed in an external window by selecting the ***Separate window*** tick-box in the ***Display options*** tab, under ***Display overlay window***.

Left and right click respectively on the drawing to select two vertical parameters to compare data from, example in Figure 2.13. The event data along the left and right vertical white lines will be displayed in the left- and right-hand column on the overlay. Additionally, a third column will be displayed; these delta values are the difference of the left and right column. This column can be removed from the overlay by deselecting ***Deltas.***

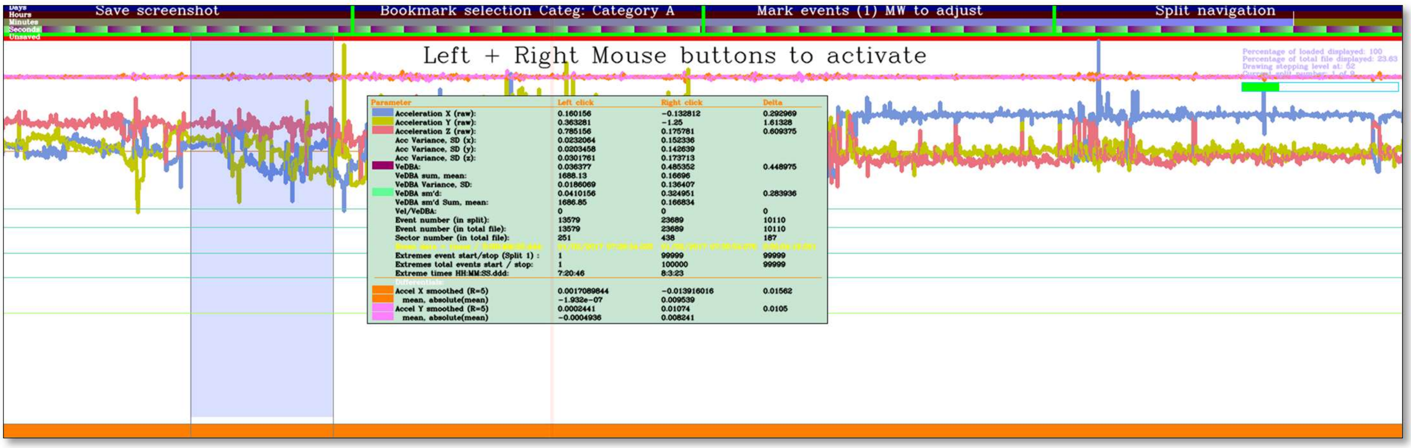


Figure 2.13 *Main drawing with the opaque overlay and left and right mouse line position parameters*

Variance and Standard Deviation for the acceleration (raw acceleration, not smoothed), VeDBA, and VeDBA sum/ VeDBA mean etc. relate to the data between the left and right white lines. These values therefore will change when the left or right white lines are adjusted in position.

Highlighting variables

Variables of interest on the overlay window can be highlighted for ease of viewing. Items in the list can have their display colour toggled from white to yellow for viewing contrast. This can be done by holding down ***Ctrl + Alt*** and running the mouse over the left side of the overlay on the parameter labels and left-clicking on one of the parameter names; the parameter name will increase in size and turn green (grey when background set to white), and toggle yellow (red when background set to white) or white with a left mouse click. The ***Event times*** parameter is yellow and cannot be unhighlighted (Figure 2.14).

Note that all highlights will be removed upon adding/removing any items to the overlay.

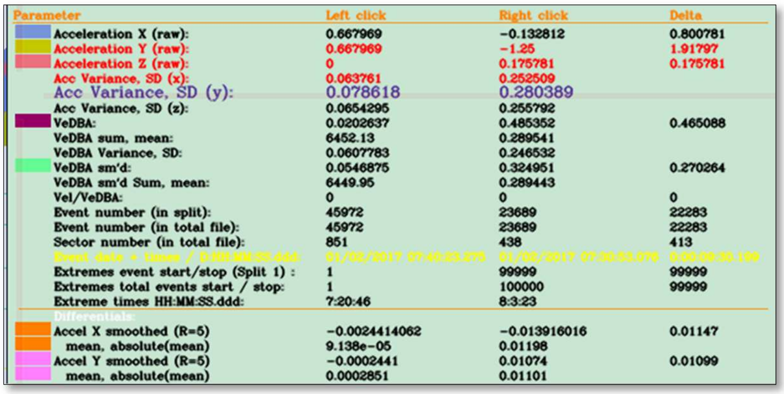


__Figure 2.14__ Highlight items on the overlay

Adding items to the values overlay

Variables which are not of interest can be removed from the overlay window list entirely. The parameters displayed on the overlay are customisable, check or uncheck your choices using the list on the ***Display/Overlay selection*** sub-tab (Figure 2.15).

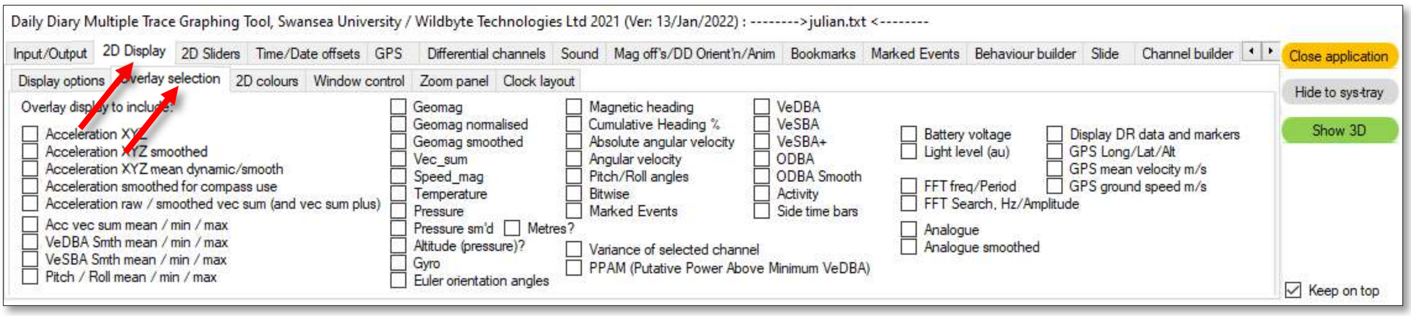


__Figure 2.15__ Overlay display options

The items related to FFT are for debugging purposes only.

Other display options

The ***2D Display / Display options*** tab (Figure 2.14) has some additional functions that allow the user to customise their view in the main graphing windows.

The ***View incrementing hours / minutes / seconds*** tick-boxes can be selected to create a shaded area behind the data to illustrate the changing time. These synchronise with the top indicator bars. In the example below, ***Seconds*** has been ticked and each incremental unit of shading from black to green represents one minute (Figure 2.16).

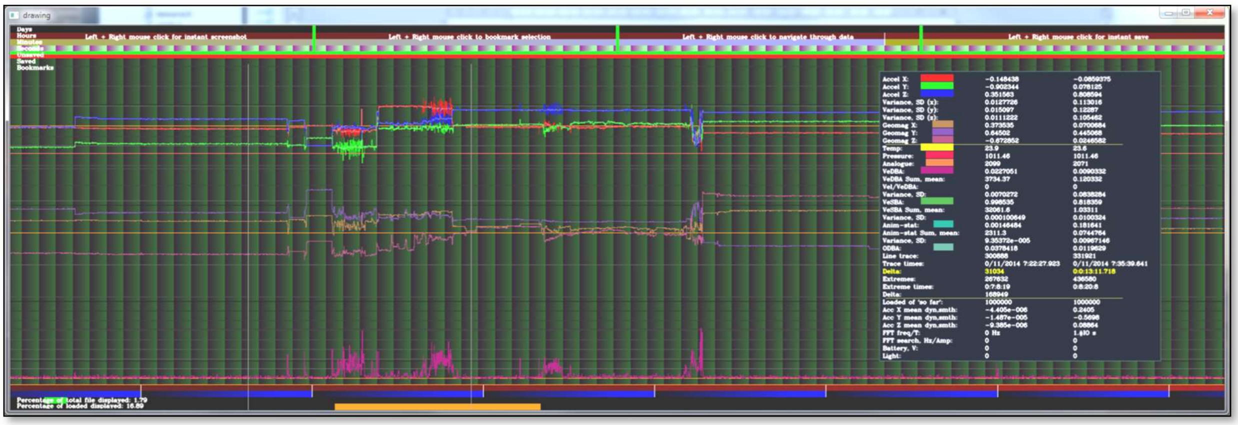


Figure 2.16 *Background time progression indications of seconds, minutes, or hours*

Display "Help text" on 2D brings up text in the top left corner of the drawing that describes various mouse/key combinations to navigate through the data (Figure 2.17).

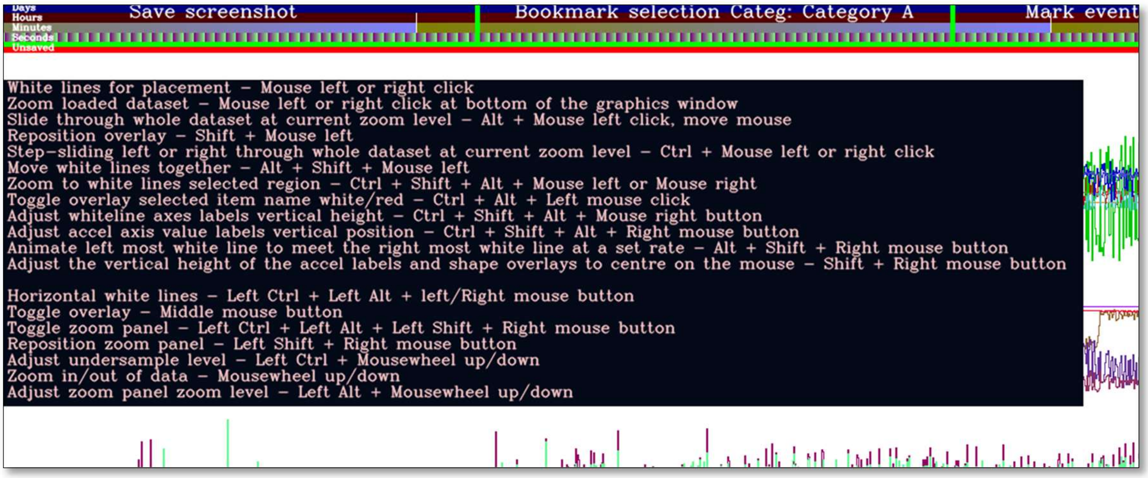


Figure 2.17 *Displaying the controls help text*

Display 2D traces is ticked by default and tells the application to draw the graphs. If unticked, the graphs are not drawn, and the drawing will appear blank. This is useful when in 3D mode as it lessens the load on the CPU, allowing it to devote more power to the 3D environment. Note that the neighbouring column allows the user to remove specific data channels (acceleration, geomagnetism, etc) from the drawing (see red text) or add in a measure of activity over a customisable time-period.

Fill white-lines, opacity (range 0 to 1.0) changes the opacity of the shaded area between the two white lines. This value is 0.15 by default but can be adjusted in the adjacent text box (Figure 2.12).

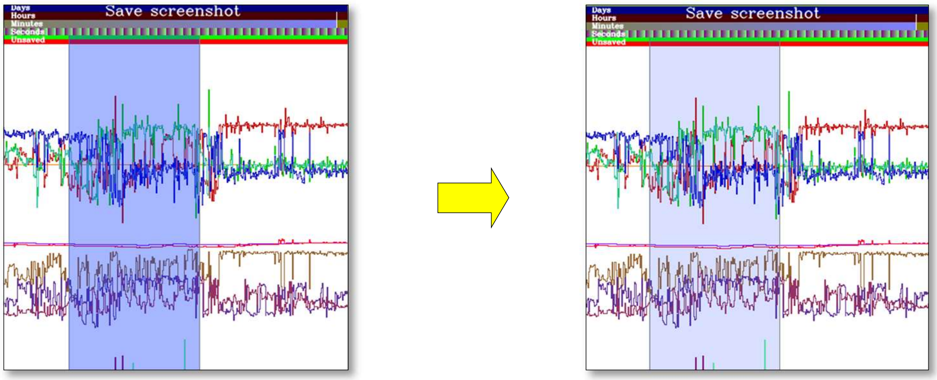


Figure 2.18 *Adjusting the opacity of the rectangular fill between the left/right white lines*

White background? changes the background colour of the drawing window from black to white.

Gridlines redirects to ***2D Sliders/Gridlines*** (discussed earlier in this chapter).

2D trace line thickness increases the line thickness of the graphed data on the 2D graphing window. This is often useful when using screenshots from DDMT in presentations.

Control panel transparency, % allows the user to change the transparency of the above control panel; particularly useful when a small-screened laptop is in use. The maximum is limited to 60% so there will always be 'some' visibility.

If the limits of accelerometery or magnetometry are required, this can be enabled by heading to the ***Accel/mag detail/offsets*** tab, then ***Accel/Mag trace limits*** sub-tab. Once the ***View max/min limits*** box is ticked any data between the white lines (left and right click) will be scanned to determine the maximum and minimum values for the acceleration and magnetism channels (Figure 2.19).

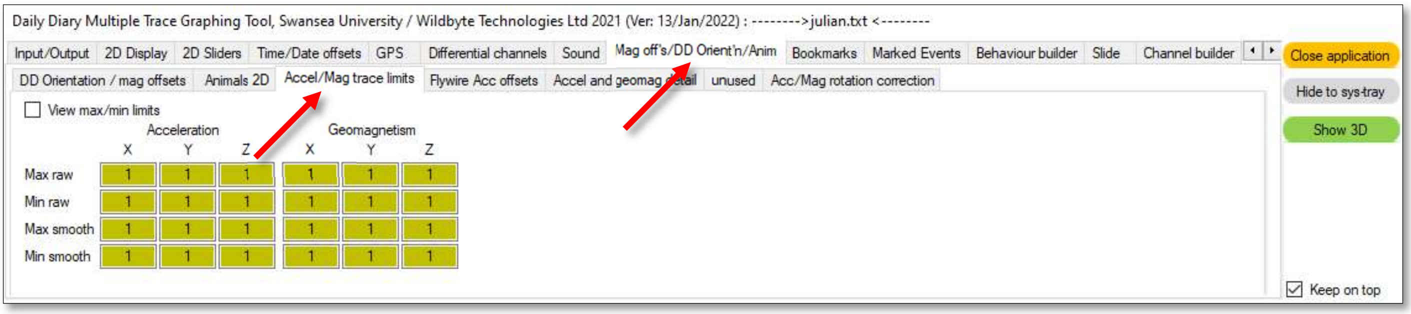


Figure 2.19 *Determining maximum and minimum acceleration and magnetism values between the white lines*

Adjustments to the visual vertical amplitude / offsets / controls of 2D graphs

By selecting the ***2D Sliders*** tab, you are presented with a tab ***Slider controls grouped by purpose*** which represents the various sensor channels from the Daily Diary. A control on this tab allows the user to switch between the different sensors and alter the visual amplitude and vertical offset of graphed data within the drawing window, along with controlling the level of smoothing for these channels. The area highlighted in Figure 2.20 will switch by action of the user's selection of the combo on the left side to show the relevant controls.

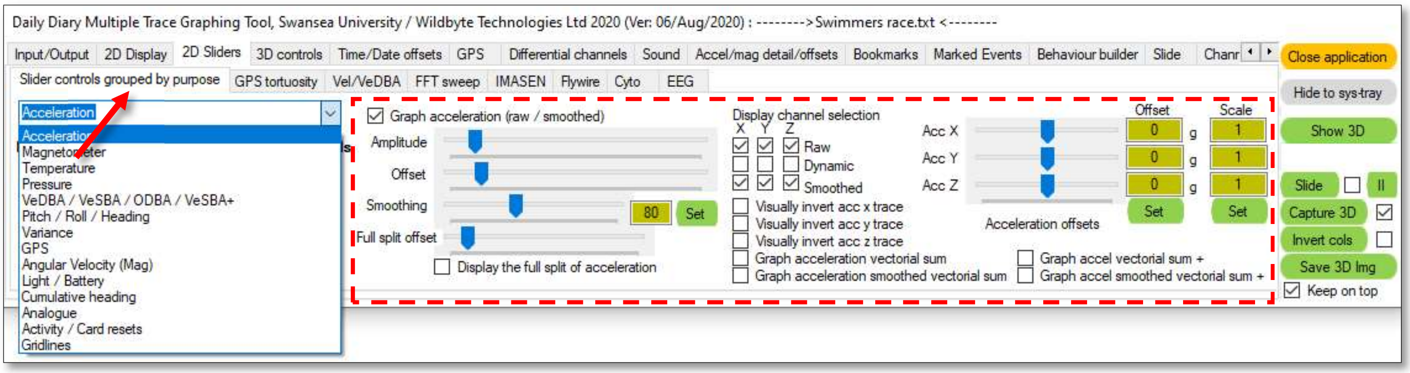


Figure 2.20 Controls list for the various sensors and other metrics

The 18 sets of controls represent ***Acceleration, Magnetometry, Temperature, Pressure, VeDBA / VeSBA, ODBA, VeSBA+, Pitch / Roll / Heading, Vairance, GPS, Angular Velocity (Mag), Light / Battery, Cumulative Heading, Analogue, Activity / Card resets, Gridlines, Bitwise, PPAM, Gyro, Euler Orientation Angles,*** and ***Behavioural Cascade***.

A discussion of each of the first 15 (of 18) sets of controls is discussed below, but ***Gyro, and Euler OA*** are for future compatibility, and ***Behavioural Cascade*** is a work in progress.

➔ *Acceleration controls*

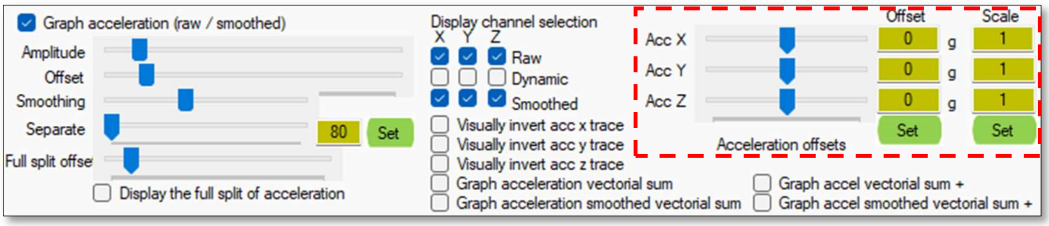


Figure 2.21 *Acceleration controls*

Display the full split of acceleration (Checkbox)

Switches on a display of the full split's acceleration, along with markers to show the section of data currently being viewed at zoom. This is shown close to the bottom with the two yellow arrows within Figure 2.22.

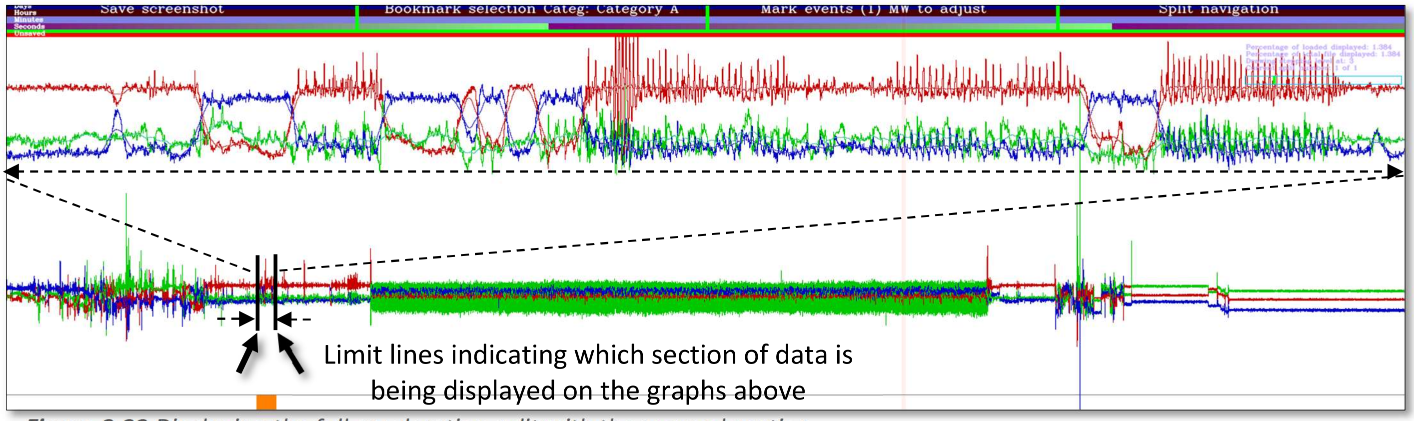


Figure 2.22 *Displaying the full acceleration split with the zoomed portion*

Amplitude, and Offset adjusts the amplitude and offset of the 2D graphed acceleration data

Smoothing adjusts the centre averaged smoothing window of the acceleration data

Separate separates the smoothed, raw, and dynamic acceleration channels vertically

Full Split Offset adjusts the vertical offset of the optional Full split (selectable below)

Graph acceleration (raw / smoothed)
enables/disables the display of the acceleration traces. Fine control of which axes are displayed is achieved through the checkboxes in the centre

Graph acc sm amp enables/disables the display of the smoothed acceleration amplitude
(This is the square root of the sum of the squares of the smoothed accel X/Y/Z traces. At rest, this would be 1.0 g)

Visually invert acc x/y/z traces
visually invert the vertical trace of the acceleration traces

Graph acceleration (smoothed) vectorial sum
display the graph of $sqrt(Acc_x^2 + Acc_y^2 + Accz_z^2)$

Graph accel (smoothed) vectorial sum +
display the graph of $1 - sqrt(Acc_x^2 + Acc_y^2 + Accz_z^2) + 1$

The controls in the area highlighted in a dashed red box, offsets, and scale, are discussed at length in Chapter 3.

➔ *Magnetometry controls*

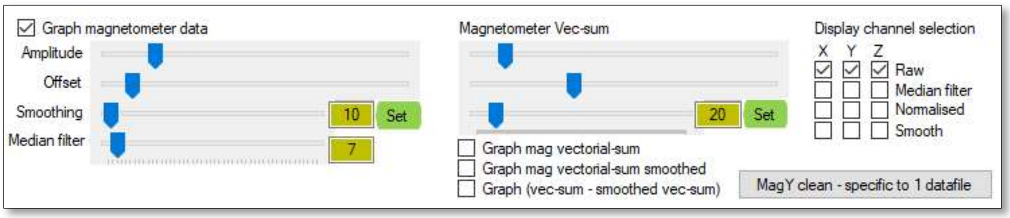


Figure 2.23 *Magnetometry controls*

Amplitude, and Offset	adjusts the amplitude and offset of the 2D graphed magnetometry (also mag vec-sum) data
Smoothing	adjusts the centre averaged smoothing window of the magnetometry data
Graph magnetometry	enables/disables the display of the magnetometry traces. Fine control of which axes are displayed is achieved through the checkboxes on the right side
Graph mag (smoothed) vectorial sum	display the graph of $sqrt(Mag_x^2 + Mag_y^2 + Magz_z^2)$
Graph (vec-sum - smoothed vec-sum)	display the graph of $sqrt((Mag_x^2 – MagSm_x^2) + (Mag_y^2 – MagSm_y^2) + (Mag_z^2 – MagSm_z^2))$

Normalised channels are simply the individual X, Y, and Z mag channels divided by the magnitude of the XYZ vector

➔ *Temperature controls*

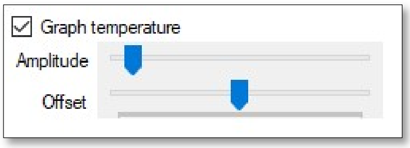


Figure 2.24 *Temperature controls*

Graph temperature	enables/disables the display of the temperature traces
Amplitude	slider adjusts the amplitude of the graphed temperature data
Offset	slider adjusts the vertical offset of the graphed temperature data

➔ *Pressure controls*

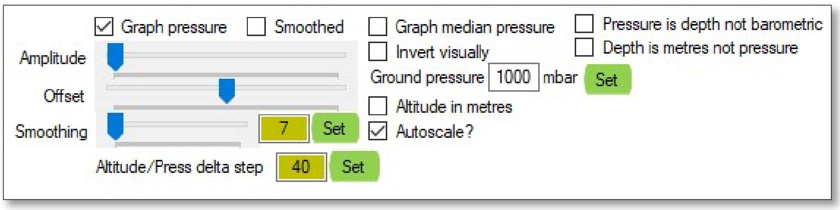


Figure 2.25 *Pressure controls*

Amplitude	adjusts the amplitude of the graphed pressure data
Offset	adjusts the vertical offset of the graphed pressure data
Smoothing	adjusts the centre averaged smoothing window of the pressure data
Median pressure	enables/disables display of the median filtered pressure data
Smooth pressure	enables/disables display of the smoothed pressure data (the smoothing value is individually set on the ***Channel Smoothing*** tab)
Pressure	enables/disables display of the pressure data
Invert visually	enables/disables inversion of any of the above pressure data, to see dives more clearly.
Altitude, metres	adds an altitude channel to the ***drawing*** window (default colour is light blue)
Ground pressure	used to set the air pressure at sea level to enable the calculation of altitude directly from barometric pressure sensor readings
Altitude/Press delta step	is used to adjust the altitude and pressure stepping rate

➔ *Metrics – VeDBA, VeSBA, ODBA, and VeSBA+ controls*

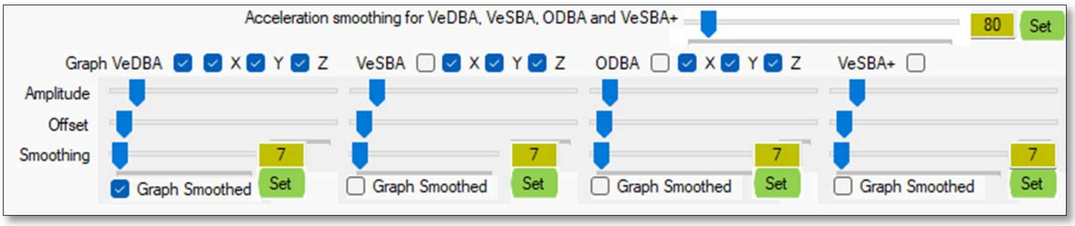


Figure 2.26 *Metrics controls*

Amplitude	adjusts the amplitude of the graphed metrics data
Offset	adjusts the vertical offset of the graphed metrics data
Smoothing	adjusts the centre averaged smoothing window of the metrics data after they are calculated i.e. VeDBA smoothed, VeSBA smoothed etc.

4 different graphs are controlled here: VeDBA, VeSBA, ODBA, and VeSBA+. These are 4 metrics derived from the 3 raw acceleration channels, and smoothed acceleration – note this is its own level of smoothed acceleration (top slider in Figure 3.27), not the level of acceleration defined on the acceleration controls panel. There is only the one level of smoothing of the raw acceleration channels for all 4 of these metrics.

There are also optional X, Y, and Z tickboxes to allow the first 3 metrics constitute of either 2 or 3 channels. Note that deselecting more than 2 channels will invoke the auto selection of the other7 unticked channel.

VeDBA (vector of the dynamic body acceleration):

$$VeDBA = \sqrt{((AccX - AccX_{sm})^2 + (AccY - AccY_{sm})^2 + (AccZ - AccZ_{sm})^2)}$$

VeSBA (vector of the static body acceleration):

$$VeSBA = \sqrt{((AccX_{sm})^2 + (AccY_{sm})^2 + (AccZ_{sm})^2)}$$

ODBA (Overall dynamic body acceleration):

$$VeDBA = \sqrt{(AccX - AccX\_sm\ )\hat{}2} + \sqrt{(AccY - AccY_{sm})^2} + \sqrt{(AccZ - AccZ_{sm})^2}$$

VeSBA+ (vector of the static body acceleration):

$$VeSBA+ = (VeSBA \geq 1)\ ?\ VeSBA : 2 - VeSBA$$

i.e. if VeSBA is ≥ 1 then VeSBA+ = VeSBA, else VeSBA+ = 2 - VeSBA

All 8 channels (the 4 basic metrics, and their smoothed counterparts) are then available in the ***Behaviour Builder*** function, and as axes on the different types of 3D visualisations.

Each of the 4 primary graphs can be toggled on/off on the 2D drawing display by ticking the ***Graph VeDBA***, ***Graph VeSBA*** etc. tickboxes, while their smoothed channels can also be displayed by ticking the ***Graph Smoothed*** tickboxes at the bottom of each of the 4 sets of controls.

➔ *Metrics – Pitch / Roll / Heading controls*

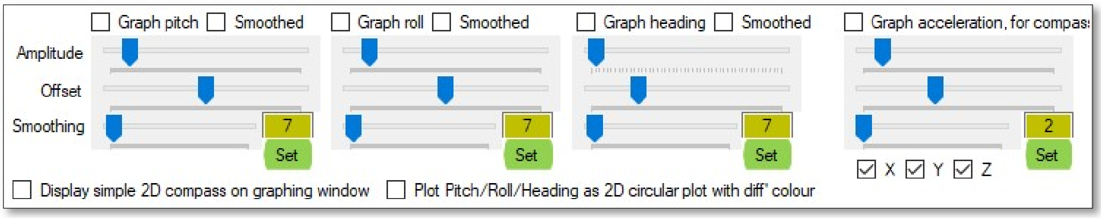


Figure 2.27 *Metrics controls*

With both triaxial acceleration and triaxial magnetometry channels present, it is possible to calculate heading, pitch, and roll (HPR) of the logger. When the logging device is tilted with respect to the ground, HPR will be miscalculated if this tilt were not considered. Therefore, the acceleration channels are utilised in a well known algorithm known as the ***Tilt compensated compass*** whereby the pitch and roll of the logger are determined, and the magnetometry channels are rotated back to the horizontal plane, providing a non-skewed measure of HPR. This is discussed later in Chapter 8.

Amplitude	adjusts the amplitude of the graphed pitch, roll, or heading data
Offset	adjusts the vertical offset of the graphed pitch, roll, or heading data
Smoothing	adjusts the centre averaged smoothing window of the pitch, roll, or heading data after they are calculated i.e. pitch, roll, or heading smoothed, pitch, roll, or heading smoothed

The first 3 sets of controls relate to pitch, roll, and heading respectively. Each can be post-smoothed, and either the raw channel, or its smoothed counterpart can be graphed individually.

The 4th set of controls allows the user to view the acceleration used by the tilt-compensated compass algorithm. This is to allow the user to ensure the acceleration channels are not being under/over smoothed, and to view the degree of “roughness” of the trace. The third slider on this 4th set of controls, ***Smoothing***, defines the level of smoothing of the raw acceleration channels. It is the smoothed acceleration channel that is then passed onto the ***Tilt compensated compass*** algorithm where pitch, roll, and heading are derived. The 3 tickboxes for X, Y, and Z are simply to allow the user to switch on/off whichever channels are of interest on the ***2D graphing window***.

Display simple 2D compass on graphing window (tickbox)

This displays a simple compass that displays the heading (both raw and mean) at the event selected with the left white line – note that heading is already derived from both smoothed acceleration and smoothed magnetometry channels:

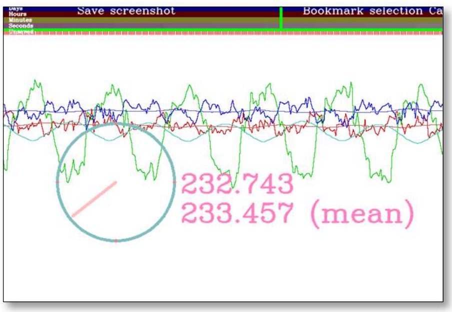


Figure 2.28 *Simple compass overlay showing heading as defined at the left white line*

Note - By first turning off the values overlay with the middle mouse button, one can hold down left shift and left mouse click to drag this small compass around the ***2D graphing window.***

Plot Pitch/Roll/Heading as 2D circular plot with diff' colour (tickbox)

This switches the plots on the ***2D graphing window*** from linear plots of these 3 metrics, to the cosine of. Also, the colour is switched when either positive or negative for pitch and roll, and when either 0-180, >180 with heading.

➔ *Metric – Variance controls*

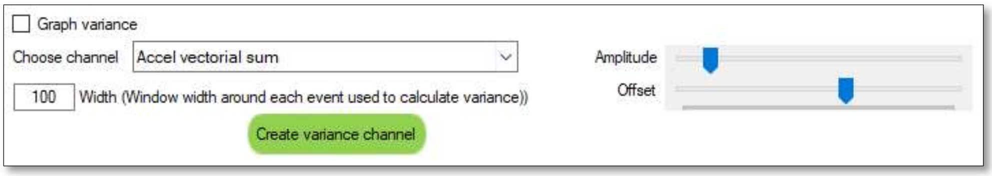


Figure 2.29 *Variance controls*

For variance to be used as a channel in the Behaviour Builder, one first needs to determine the limits of variance of a particular channel of interest. What these controls allow is for the creation of a channel named Variance of any data channel in the list. This Variance channel is calculated based on a centred window, with each point being the variance of a window of data around it. The user can choose the data channel and the window width, finally clicking ***Create variance channel*** to create that channel.

Amplitude adjusts the amplitude of the graphed variance data
Offset adjusts the vertical offset of the graphed variance data

This does not create a channel that can be used anywhere else. It is merely to allow the user to investigate likely limits by observing values present on the display over. The user will need to enable Variance on the values overlay by opting it on the ***2D Display / Overlay selection*** tab:

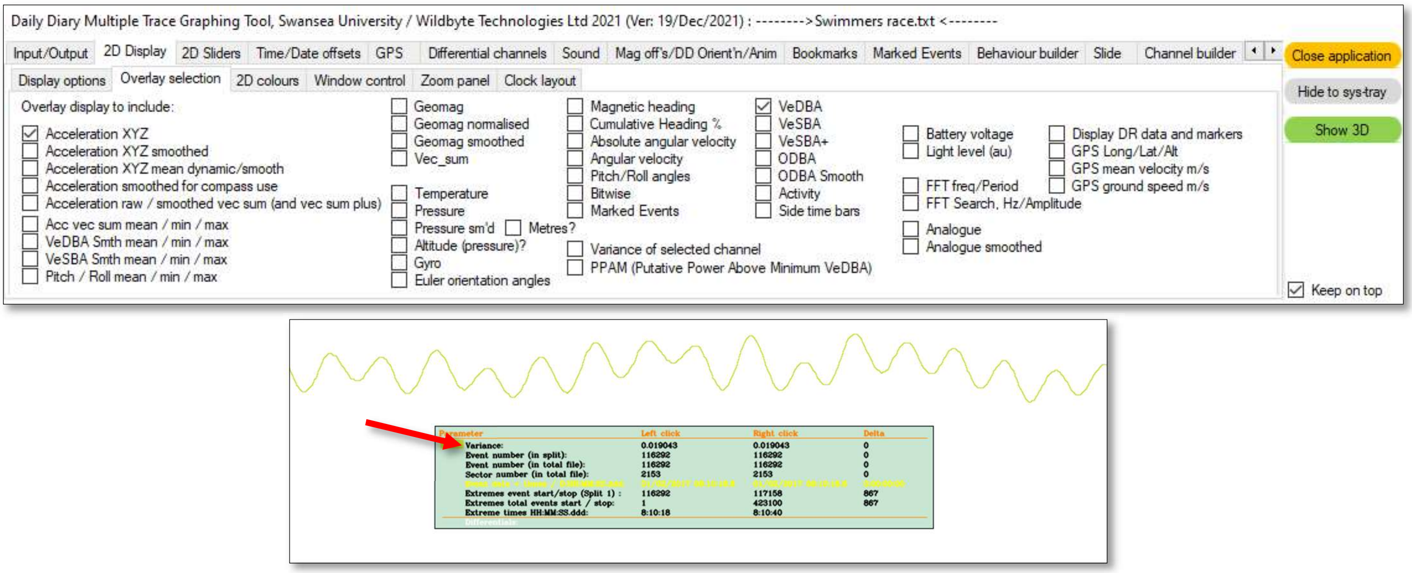


Figure 2.30 *Variance on the Values Overlay*

➔ *GPS controls*

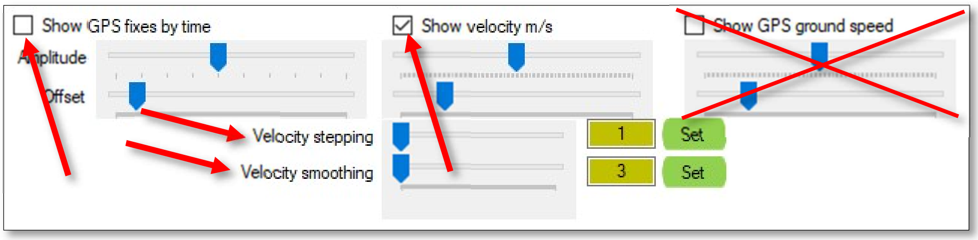


Figure 2.31 *GPS fixes and velocity controls*

For GPS, markers can be shown on the ***2D graphing window*** showing where a GPS fix synchronises with a time point in the logger's data.

Amplitude	adjusts the amplitude of the graphed variance data
Offset	adjusts the vertical offset of the graphed variance data
Velocity stepping	adjusts the GPS-GPS counter for determining velocity
Velocity smoothing	adjusts the centred average smoothing of the resulting velocity graph

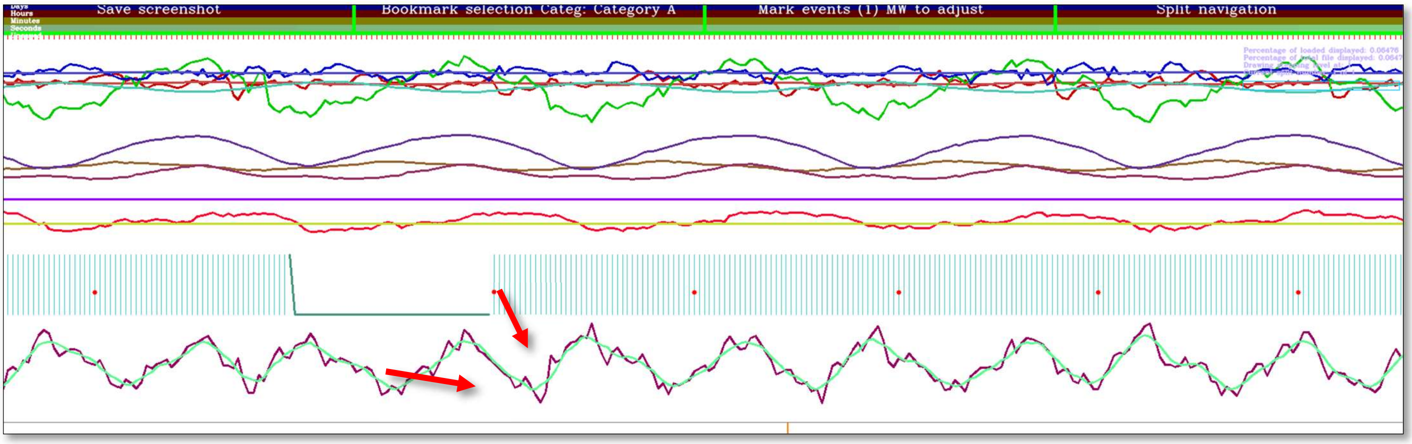


Figure 2.32 Visualising where GPS synchronises with the logger's data

Where a vertical blue line exists, a GPS fix exists in memory with that date and time (to the integer second) value. There are multiple blue lines per GPS fix as acceleration loggers typically log at > 1 Hz. The red dot that precedes each stretch of vertical blue lines represents the first point for a given GPS fix i.e. once per second at 1 Hz GPS.

Secondly, ***Show velocity m/s*** can be ticked to overlay a graph, Figure 2.33.

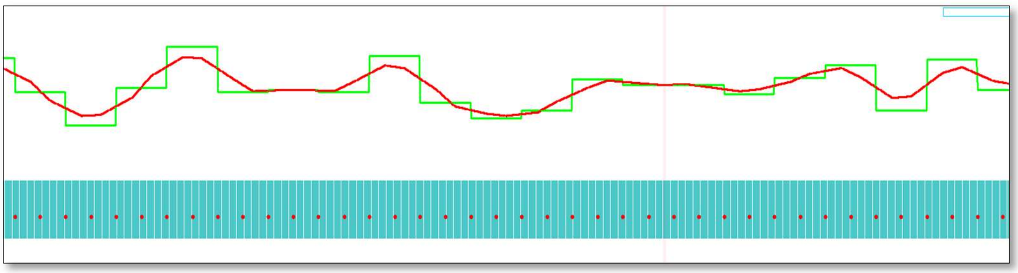


Figure 2.33 Visualising GPS velocity (m/s) and mean velocity

Show GPS ground speed is not yet implemented

➔ *Metrics - Angular /Absolute angular velocity controls*

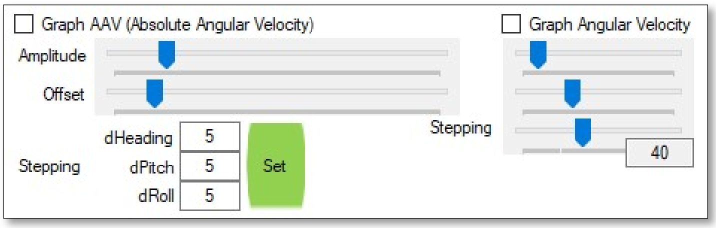


Figure 2.34 Absolute angular velocity controls

Absolute angular velocity is a metric that combines rate of change of 3 channels, heading, pitch, and roll. The rate of change is separately adjustable for each of the 3, each calculated centred around each event.

For example, if *dHeading*, *dPitch*, and *dRoll*, were 3, 5, and 7 respectively, then when the channel is created, event 1000 would be calculated based on the difference of data at events 999 and 1001 for *dHeading*, 998 and 1002 for *dPitch*, and 997 and 1003 for *dRoll*.

The metric is calculated as:

$$AAV = \sqrt{(dHeading_1 - dHeading_2)^2 + (dPitch_1 - dPitch_2)^2 + (dRoll_1 - dRoll_2)^2}$$

The value is stored in degrees.

Angular velocity is a metric that determines the rate of change across the sphere of heading vs pitch. This sphere is the same sphere also described as the ***Orientation sphere***, discussed in the 3D visualisation section later in this manual.

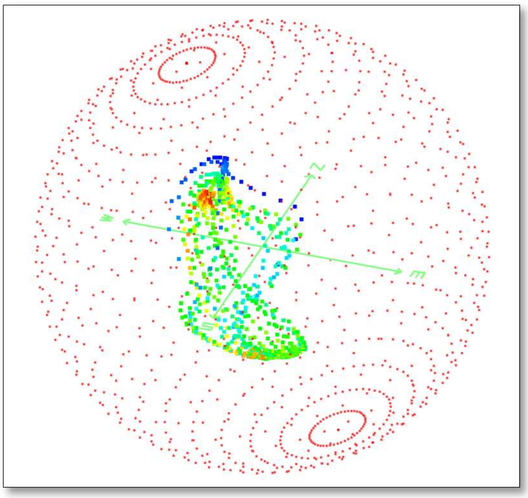


Figure 2.35 Angular velocity controls

A point is located on this surface based first on its heading value, to determine the position around the “equator”, and then rotated vertically up (down) for pitch positive (negative).

The value is stored in degrees. For this alternative angular velocity measure, the user can also adjust the stepping using its 3rd slider. Note that this calculation is based on the data point at the current event and the events *n* steps behind i.e. not a “centred measure”.

For both controls,

Amplitude	adjusts the amplitude of the graphed angular velocity data
Offset	adjusts the vertical offset of the graphed angular velocity data

➔ *Light / Battery*

Figure 2.36 Battery and light level controls

These controls simply allow the viewing of battery voltage and light level (the square Daily Diary with connectors).

Amplitude	adjusts the amplitude of the graphed battery voltage / light level data
Offset	adjusts the vertical offset of the graphed battery voltage / light level data

➔ *Metric - Cumulative heading*

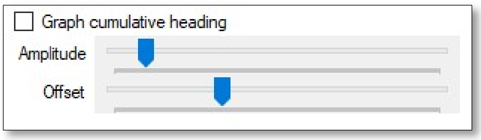


Figure 2.37 Cumulative heading controls

Cumulative heading is still under development.

Amplitude	adjusts the amplitude of the graphed cumulative heading data
Offset	adjusts the vertical offset of the graphed cumulative heading data

➔ *Analogue*

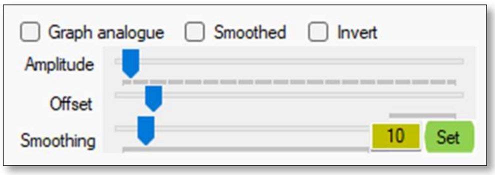


Figure 2.38 Analogue controls

Analogue data, available with some types of loggers.

Amplitude	adjusts the amplitude of the graphed analogue data
Offset	adjusts the vertical offset of the graphed analogue data
Smoothing	adjusts the centre averaged smoothing window of the analogue channel
Invert	visually invert the trace

➔ *Activity / SD card resets*

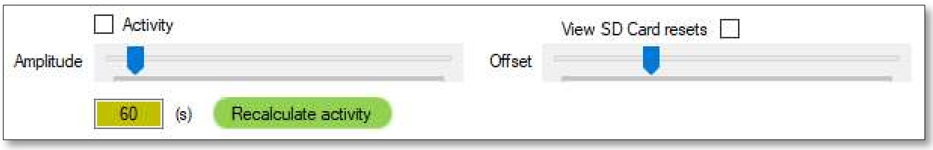


Figure 2.39 Activity / SD card resets controls

Activity is simply the sum of VeDBA per unit time. The user can define the number of seconds over which this is calculated.

The SD card reset line colour is by default green, and when a reset has occurred where power was momentarily lost to the SD card and the logger had paused collecting data (but the real-time clock had continued to increment), there will be a vertical red line. At this point, the user will notice a time jump/step where the logger resumed collecting/storing data to the SD card.

Amplitude adjusts the amplitude of the graphed activity data
Offset adjusts the vertical offset of the graphed SD card reset data

➔ *Gridlines (for acceleration, geomagnetism, and metrics)*

The main graphing windows can show graduated lines, customiseable by the user on the ***2D Sliders / Gridlines*** sub-tab.

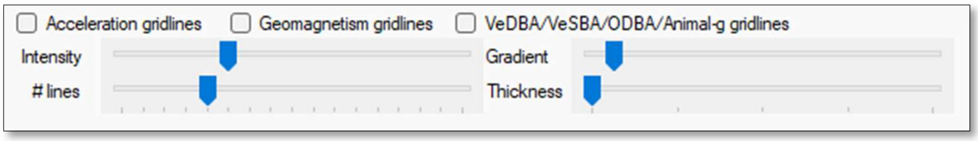


Figure 2.40 *The* ***Gridlines*** *menu*

Intensity adjusts the intensity of the gridlines displayed around the Acceleration, Geomagnetism, and VeDBA traces

 # lines adjusts the number of positive and negative gridlines visible on the graph. For Acceleration and Geomagnetism traces, the gridlines are +/- 1, +/-2, +/-3 g or gauss etc. For the VeDBA trace, the gridlines are spaced positively at 0.2, 0.4, 0.6 etc

Gradient determines how quickly the intensity of the gridlines falls within increasing absolute range value

Thickness determines how thick the drawn lines are. This is useful in presentations etc. to help illustrate the amplitude of your dataset at various time points

Acceleration gridlines shows acceleration gridlines when selected
Geomagnetism gridlines shows geomagnetism when selected
VeDBA/VeSBA/ODBA/ Animal-g gridlines shows metric gridlines when selected

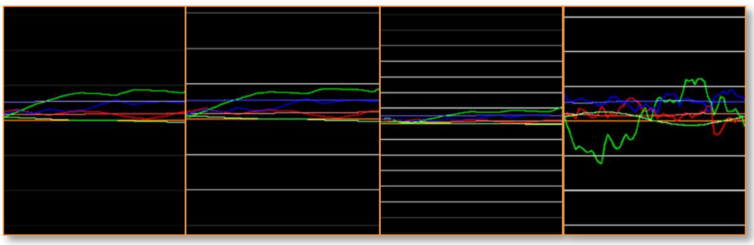


Figure 2.41 *The effects of dim, bright, gradient, and flat gridlines for the accelerometery trace*

If the gridlines do not display even when the checkboxes outlined above on the ***Gridlines*** sub-tab are selected, ensure that the separate ***Gridlines*** checkbox on the ***Display/Display options*** sub-tab has also been selected.

➔ ***Bitwise***

The main graphing windows can show the ***Bitwise*** channel split up into multiple layers. The channel is 64 bits wide, meaning it could potentially hold 64 layers of '1' or '0' per data point, but currently only 16 bits are used. ***Marked Events*** (the presense of) can be copied into any one of the first 16 ***Layers*** of the ***Bitwise*** channel. This channel is global, and so moving to another split and returning will preserve any data within the 16 ***Layers***. See chapter 5 ***Marked Events and Bitwise Layers*** for details.

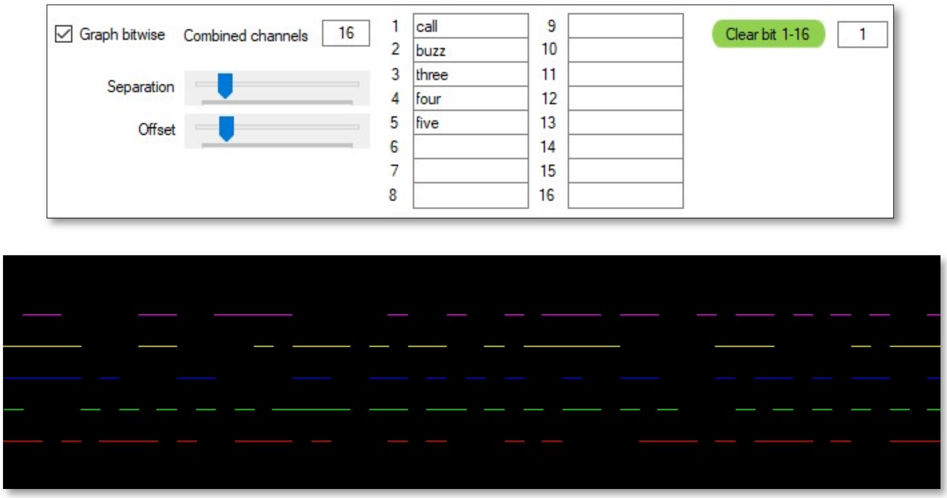


Figure 2.42 **Bitwise** *channel controls*

Offset	adjusts the vertical offset of the different bits of the ***Bitwise*** channel
Separation	adjusts the relative separatiuon of the different bits of the ***Bitwise*** channel
Combined channels	limits how many channels (from #1) are displayed on the ***2D graphing window***
Clear bit 1-16	(button) will clear (globally / all splits) the chosen bit number, unless the selected bit number is parts of a data file (some data file types have ***Bitwise*** channels embedded within them and therefore cannot be overwritten by clearing, or by copying ***Marked Events*** to them
Labels	On the ***2D graphing windows***, if ***Bitwise*** is selected on the ***Overlay selection*** tab, then any bits where the left or right mouse clicks, relevant labels will be displayed on the overlay

Figure 2.43 **Bitwise** *channels on the overlay. Notice that the left and right click labels are different as they highlight different bits on the graph (left = 1 (red)+2 (green)+3(blue)+5(pink), right = 2(green)+5(pink)*

The Zoom panel – a quick localised zoom of the data currently in-view

There is a zoom panel available within the graphing window for closer inspection of data. To toggle this panel, hold ***Ctrl***, ***Shift***, and ***Alt*** together and right click the mouse. Move the zoom panel across the graphing window by holding down the ***Shift*** key and dragging with a **right** mouse click. Use the ***Alt*** key and mouse wheel to adjust the data width (the zoom level) displayed in the zoom panel.

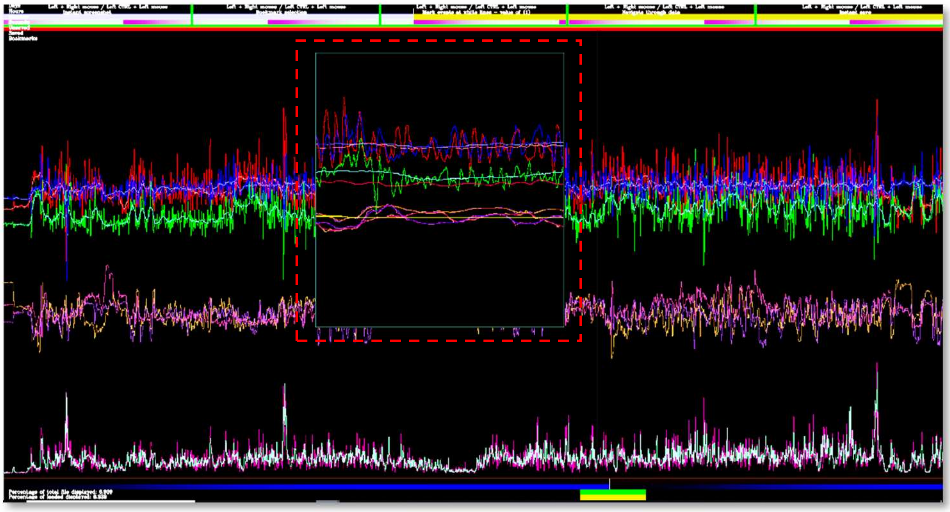


Figure 2.44 *Main graphing window with zoom panel enabled*

Currently only acceleration (+smoothed), magnetometry (+smoothed), temperature, and pressure can be displayed on the zoom panel. The controls can be found in Figure 2.45 below. These are primarily offsets for the individual data channels, along with a data width slider (also adjustable with key and mouse combination as described above).

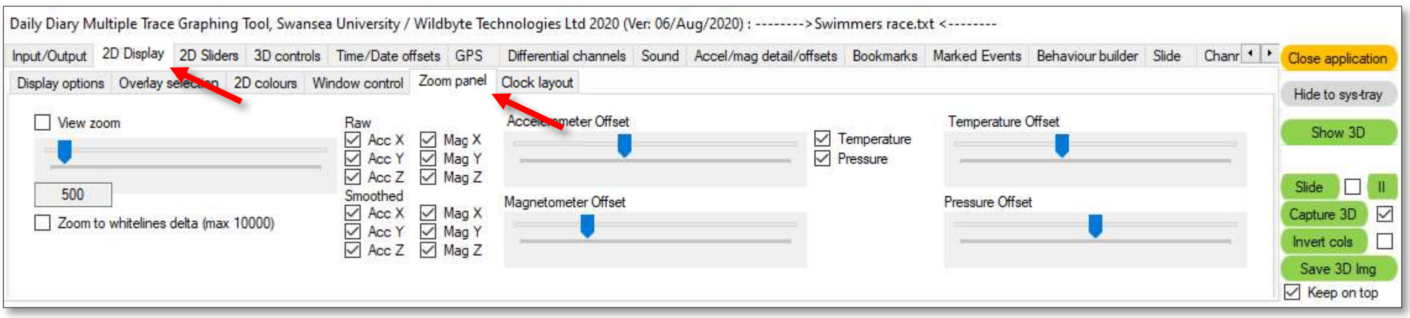


Figure 2.45 *The zoom panel controls*

Animal image overlay to show animal orientation with respect to surge/sway/heave

To gain a better understanding of animal orientation from the data, the programme allows the user to place three animal drawings down the left and right white lines symbolising the surge, sway and heave acceleration axes. These are automatically oriented as a function of the smoothed acceleration data channels. By using the smoothed channels, we are effectively obtaining the static acceleration as most dynamic acceleration spikes are smoothed out.

Under the ***Accel/mag detail/offsets/Animals 2D*** tab you will find the controls for the animal drawings. To make them appear the ***X***, ***Y***, ***Z*** check boxes on the left of the coloured squares need to be ticked.

The axis labels can be renamed from their default "Surge", "Sway", and "Heave". These labels depend on the orientation of the tag on the animal, so is left to the user to determine the appropriate labelling. Similarly, the check boxes to the right of the coloured squares invert the images, which can also be useful depending on the position of the tag on the animal. The ***Axes offsets*** (coloured boxes, see Figure 2.46) allow the images to be rotated into the correct resting orientation.

By default, both animal images and angle values are displayed. The angle is a simple *arcsine* function of the value from each of the accelerometer traces (if smoothed, normally within the range -1 to +1; values greater than this are clipped at these limits). This feature is particularly useful for talks/demonstrations.

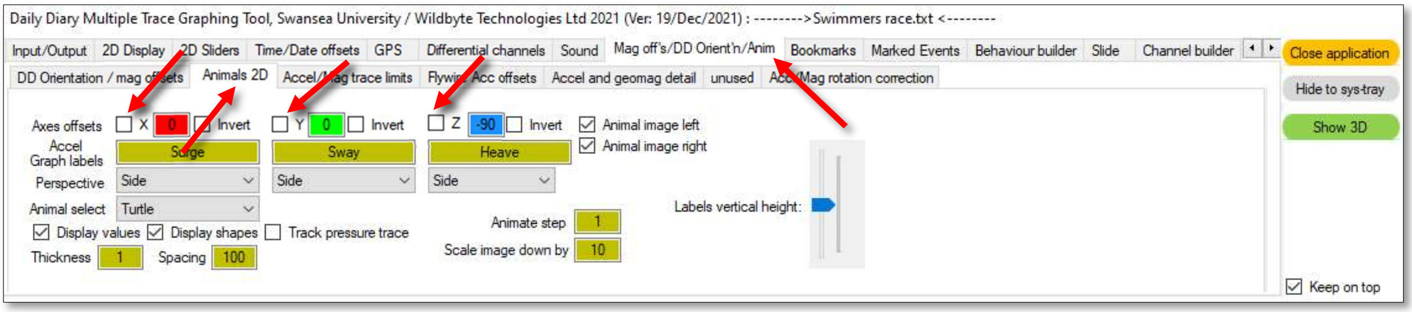


__Figure 2.46__ Accel/mag detail/offsets/Animals 2D tab

The animal images can be adjusted in size by altering the ***Scale down factor*** (default value of 10). Larger values shrink the size of the animal images, while smaller values increase their size. When the ***Scale down factor*** is changed, the image sizes will be updated as soon as the mouse moves over the graphic window. The vertical spacing between the images can also be adjusted; necessary if the images are made significantly larger (default spacing of 100 pixels).

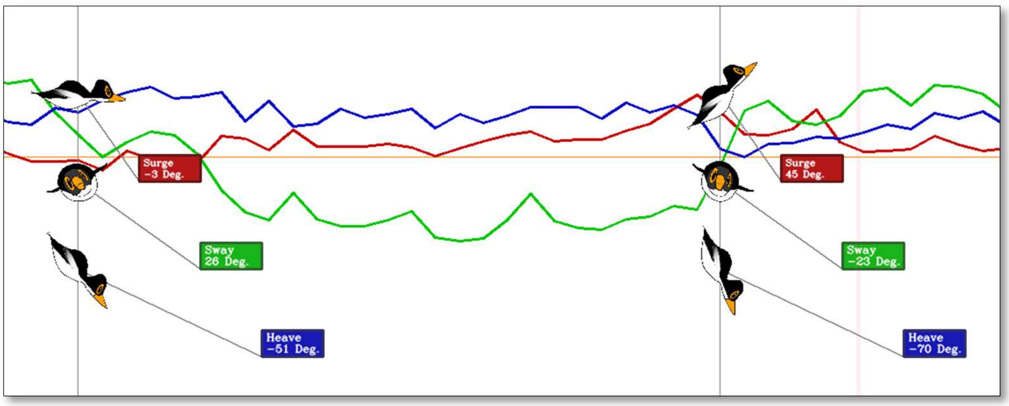


__Figure 2.47__ Accel/mag detail/offsets/Animals 2D tab, set

Depending on the size of the graphic window, the user might find that one of the animal traces falls below the bottom of the screen. To raise the animals' centres up the screen, hold down ***Shift*** and hold down the right mouse button. Mouse movement then determines the vertical position of these images.

Slide function for animation

For discussions/presentations, it is sometimes useful to have the animal and the white line move across the screen with changes to animal posture automatically animated as it progresses. To do this, select start and stop positions with left and right mouse clicks to set the extremes. Then hold down ***Shift*** and ***Alt*** and click the right mouse button in the graphic area. The left white line will now move to the right towards the right white line until they meet and stop. The animal image(s) will automatically assume the orientation determined by the smoothed acceleration channels as the white line travels from left to right. By default, the white line will step one "event" at a time. For a large amount of data points between the two white lines means this might take some time and so an ***Animate step*** variable is provided within the window, allowing it to jump *X* events with every frame update (default value of 1).

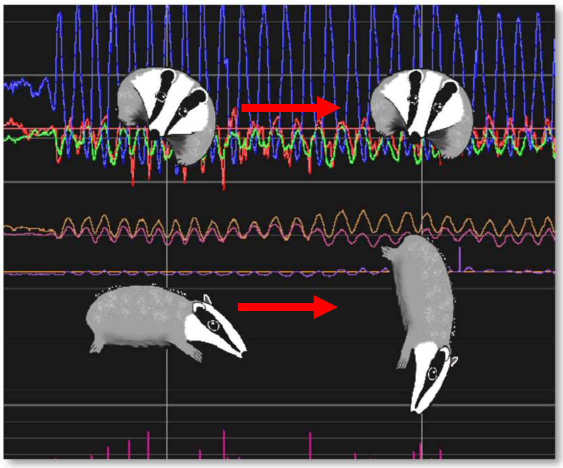


Figure 2.48 *Animate function automatically drags the left white line over to meet the right white line, causing the images to rotate according to the smoothed acceleration data at each step*

Additionally, if pressure data is a good variable for the animal such as with condors (changes in barometric pressure during circling), or turtles (depth sensor pressure), the animation can also be made to track vertically up and down along the pressure trace by ticking the ***Track pressure trace*** check box.

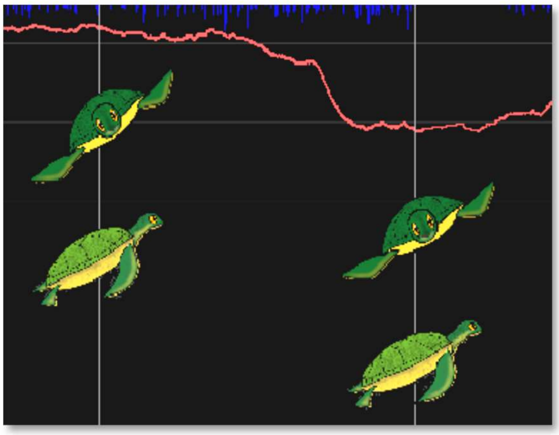


Figure 2.49 *Track pressure trace function with the animation*

3. Time / date, and acceleration / geomagnetism data corrections

Daily Diary on-board Real Time Clock – Setting the start time for your dataset

As discussed in the ***System Overview,*** the Daily Diary unit possesses an on-board Real-Time Clock (RTC). When data is stored to the logger's memory, a time stamp, or partial stamp, is stored with that single event, to aid in providing the best timing accuracy knowledge. There are several factors to consider when managing time data in DDMT.

The ***Input/output*** tab will show the start and finish times of the entire dataset in ***Days*** : ***Hours*** : ***Minutes*** : ***Seconds*** (Figure 2.1). Note that as the Daily Diary doesn't have a link to actual time i.e. GMT, this is a relative value. The user could have perhaps set the clock within the command string on the memory card, such that upon power up, it assumes a specific time value. Alternatively, DDMT allows the user to input an offset to the time and date attributes to correct the timing aspect of the data. Note that for some data files, this information will either not be displayed, or could be incorrect.

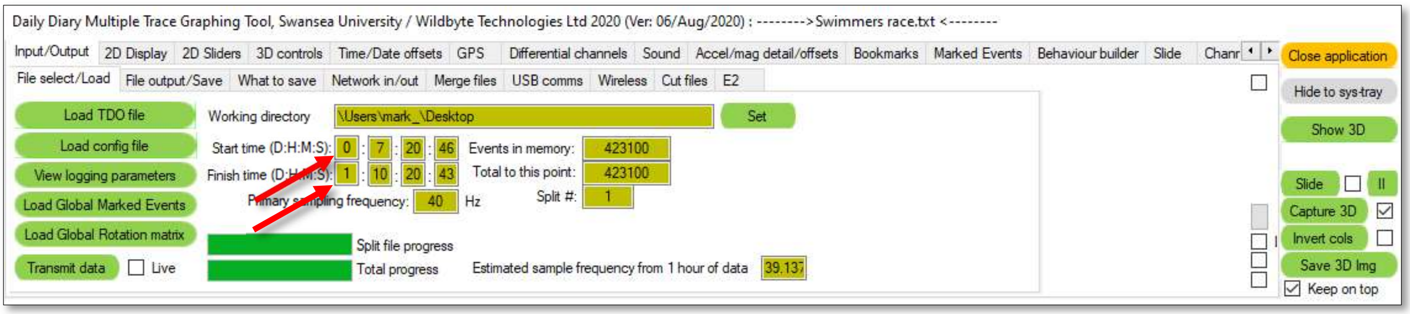


Figure 3.1 *The start and finish times of the source text file (DD:HH:MM:SS)*

To manually set the correct time for your data click on the ***Time / Date offsets*** tab along the top of the control panel. The ***Daily Diary settings*** tab will automatically open and display the screen in Figure 2.2. Knowing your deployment details is crucial to set the correct time and date for your data. Select an event that began at a known time to the second (usually this is the time the Daily Diary was turned on or the start time of device calibration), ensuring that the left white line (displayed when left cursor is clicked on the main graph window) matches this event exactly. Set the date by entering the day / month / year in the top three boxes on the right-hand side of the window (circled). When the correct date is entered, press the bright green ***Set start date on Daily Diary data*** button on the left-hand side to apply date corrections to the whole file. Next, enter the time of the selected event in the three green boxes under the date using hour / minute / second format. When the correct time has been entered, press the bright green ***Set time for DD data set from white line*** button to the left-hand side. Make sure the time is correct, as once set the time cannot be changed. If set incorrectly, the user will need to close and reopen the source text file.

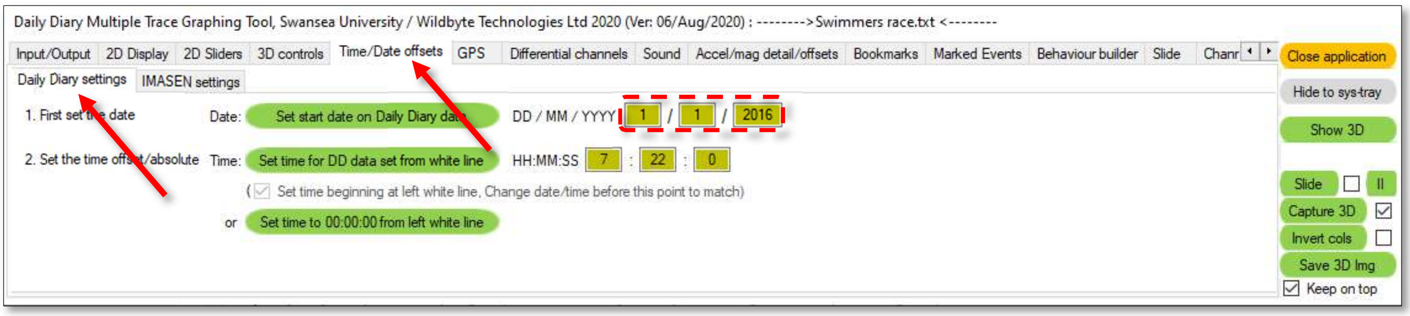


Figure 3.2 *The screen displayed when opening the Time/Date offsets tab*

Decimal seconds are created by the software when the data file is first analysed / loaded into memory. For 40 Hz data, there will be approximately 40 events per second with the same "seconds" value and so a decimal value is assigned to every data point with the same time / date (to the second). Note that due to the data being collected asynchronously i.e. not "by the RTC", for 40 Hz sampling, there might be 39 events in one second, and 41 events in the next, so bear this in mind when looking at the decimal seconds value; it's just to provide time-ordering of sequential events.

Magnetometry hard/soft iron corrections

In order to perform the magnetometer correction, the user must first enable the 3D side of the software by clicking ***Show 3D*** on the right side of the control panel. Next find the button labelled ***Initiate magnetometer correction algorithm***

Figure 3.3 *Initiating magnetometer correction algorithm on the 3D window*

Upon clicking this, the following will be shown.

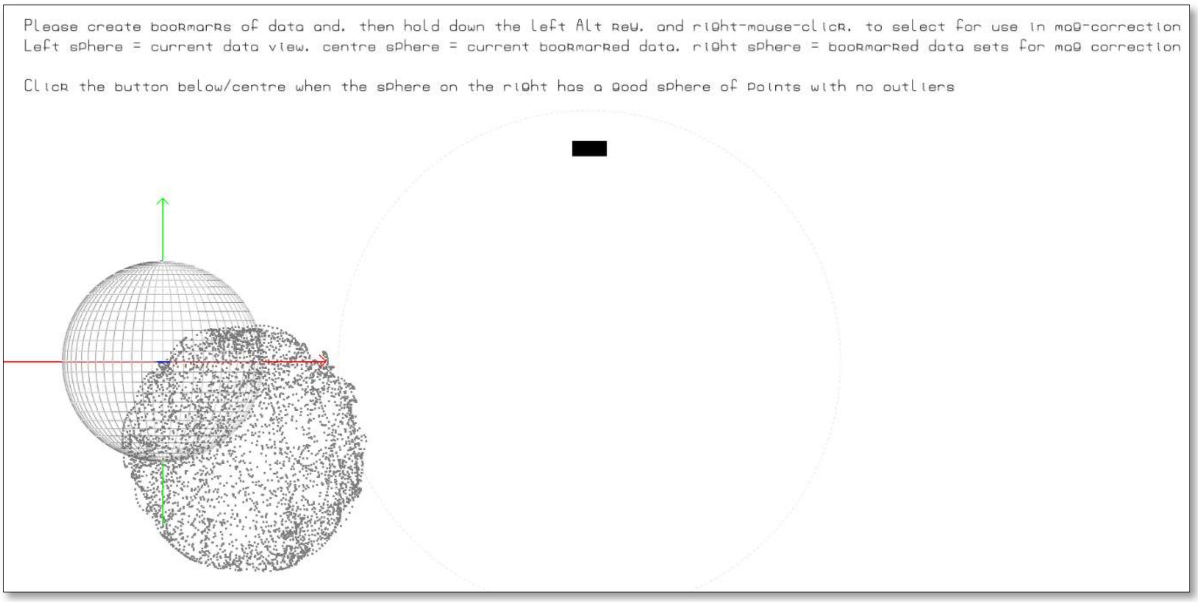


Figure 3.4 *First stage of magnetometer offset/ellipsoid correction; selecting data by bookmarks*

The data shown in the grey sphere above represents all the data currently on view in the ***2D graphing window***. Zooming in on the ***2D graphing window*** will change the data contained in the above sphere to the left. The aim here is to find magnetometry data that roughly forms either a sphere or an ellipsoid, with no outliers, as is not the case in the data shown above. By zooming in on some data in the ***2D graphing window*** that shows a sphere with no outliers, the user can then bookmark this data on the ***2D graphing window***, as in Figure 3.5 below.

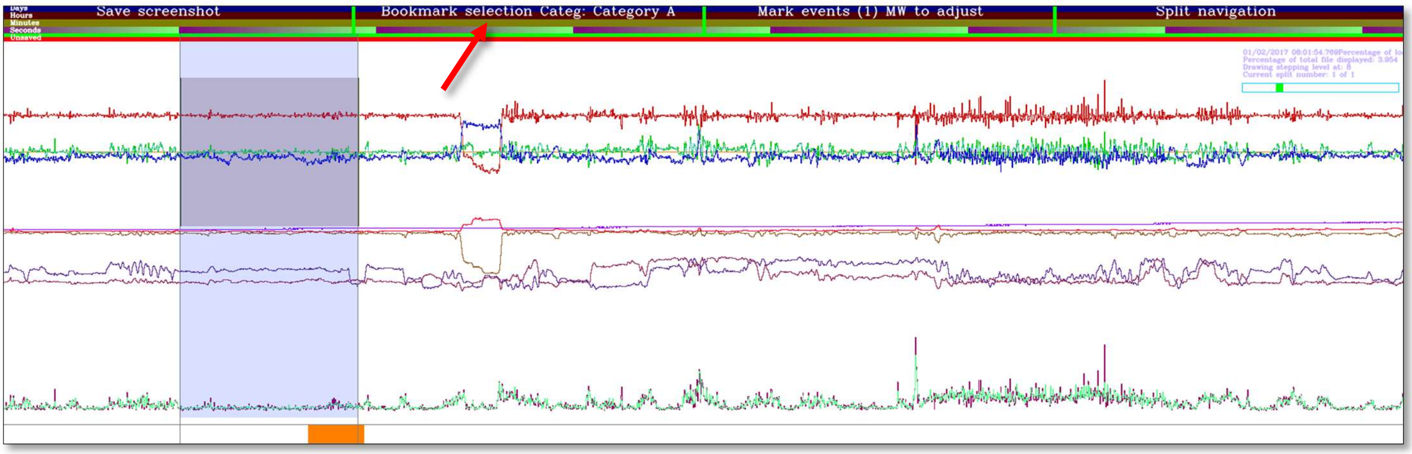


Figure 3.5 *Bookmark data by left and right clicking on "Bookmark selection" at the top of the* ***2D graphing window****, with a section of bookmarked data shown in grey*

Note that on the 3D window, there is a large, dashed circle in the centre region of the screen that can be used to drag/roll the sphere of data around (rotation) with the left mouse button.

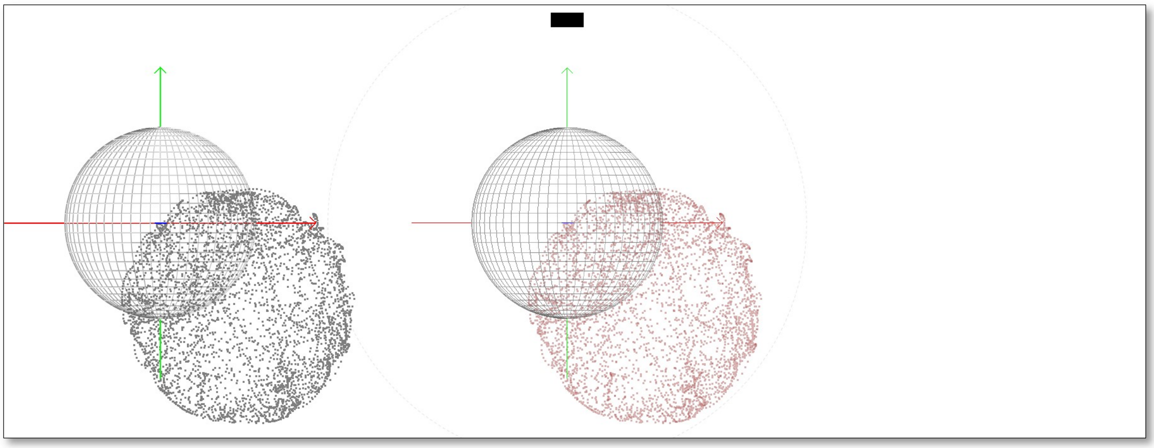


Figure 3.6 *Second stage* *of magnetometer offset/ellipsoid correction; in the left image, a new sphere is now shown, the result of the bookmark that has been created on the left side of the* ***2D graphing window*** *in the image on the right*

The next step is to create one or more bookmarks that encompass data that define near-spherical data. The bookmarks must exist in the current split. Any data contained in bookmarks (in the current split) will add to the second (centre) sphere. When enough data is present in the centre sphere, and no outliers are visible (checked by left clicking in the dashed circle and rotating the spheres of data), then begin "selecting" the bookmarks that will be used for the magnetometer correction, by holding down the ***Alt*** key and **right-clicking** on the bookmarks required to create the sphere of data. As each bookmark is "selected" for inclusion in the magnetometer correction, they will slowly add to the third sphere on the right side; see Figure 3.7.

When in this data selection mode part of the magnetometer correction, the yellow label that appears when the mouse moves over a bookmark on the ***2D graphing window*** will have a new line stating whether that bookmark is "selected" or "not selected" into the 3rd (right side) sphere as part of the magnetometer correction routine:

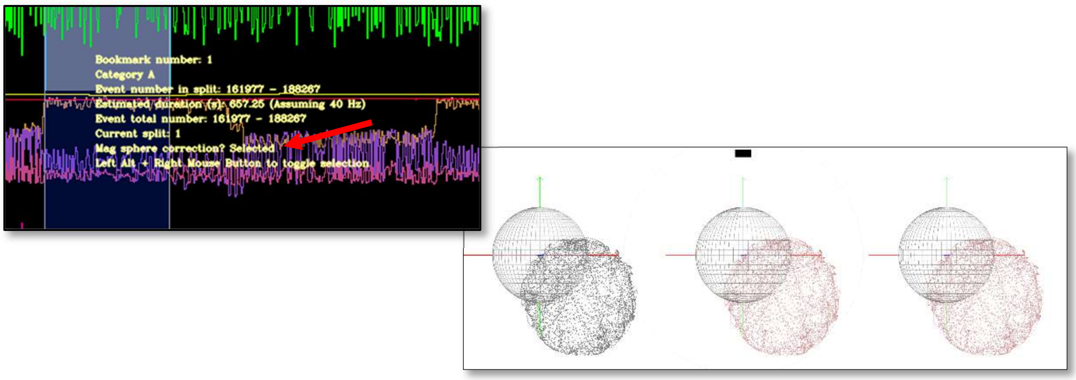


Figure 3.7 *Third stage* *of magnetometer offset/ellipsoid correction; in the left image, the bookmark has been "selected" for inclusion in the magnetometer correction algorithm, resulting in the data being used to form the 3rd sphere on the right-side image*

When the 3rd sphere on the right side has enough data forming a sphere or ellipsoid, click the rectangular button centre-top of the 3D window to progress to the next stage.

The 3D environment will now show two spheres on either side of a central square with white and purple cross hairs. The left side sphere represents the data that was in the 3rd sphere on the right side in the previous stage of the correction algorithm. X/Y/Z offsets in the data have now been subtracted from all data, centring the data on the origin. By right-clicking within the centre square, DDMT will run through all possible ellipsoid corrections. As it does this, the square will slowly fill with colour as shown in Figure 3.8 below. Please beware, the more data selected for the correction process, the longer this will take. The darkest blue areas mark the best fit (most spherical) correction, while the darkest red areas highlight the worst selections. The purple cross hairs will automatically move to the best fit area found by the software once it has finished looking at the data presented to it.

Alternatively, the user can move the white cross hairs to a point of their choosing using ***Shift*** and dragging with a left mouse click. Click the orange button above the square when finished to apply the correction. A text box will appear on screen at the end of this process to verify the magnetic correction is complete.

Note that, with good data selection, the ellipsoidal correction now incorporates the ability to also solve for scalene effects – where an ellipsoid is squashed perpendicular to the long axis. In this video (https://www.youtube.com/watch?v=Hu-dWmhpvLk), pseudo random data, at random orientations, is generated, and immediately corrected back to a sphere (the right side shows the XY, and the XZ perspectives of the corrected ellipsoid).

Note that orange help text appears in the 3D environment throughout the magnetometer correction process to advise/guide the user through the process.

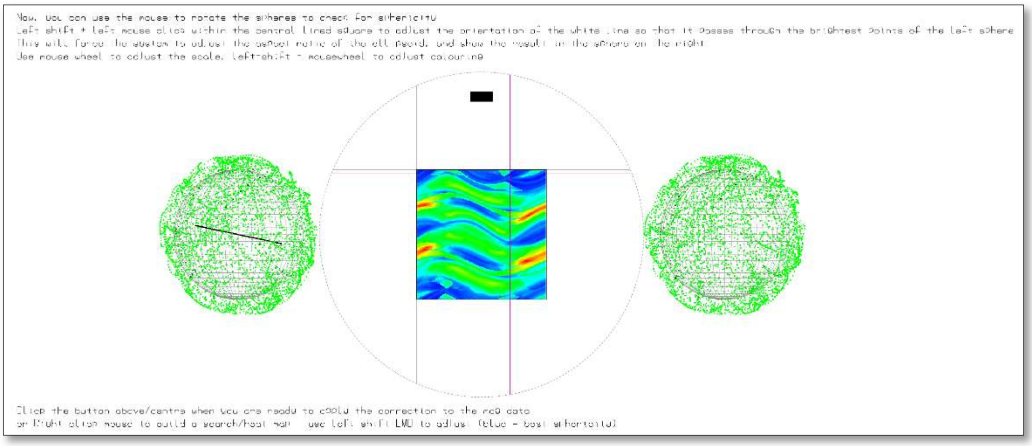


Figure 3.8 *The software generates a 'heat map' to aid the user in finding the most spherical magnetometer correction, and auto-selects the best result (most spherical point). Note that the above uncorrected data (left sphere) is already actually quite spherical, closely matching its own corrected sphere on the (right side), so not the best example…*

An update to this magnetometer correction algorithm now allows the user to intervene and manually adjust the magnetometer data offsets. This is particularly useful when the mag' data is noisy or creates an incomplete sphere.

To use this enhanced correction, the user should still try to bookmark data that defines a sphere, or a part thereof such as below:

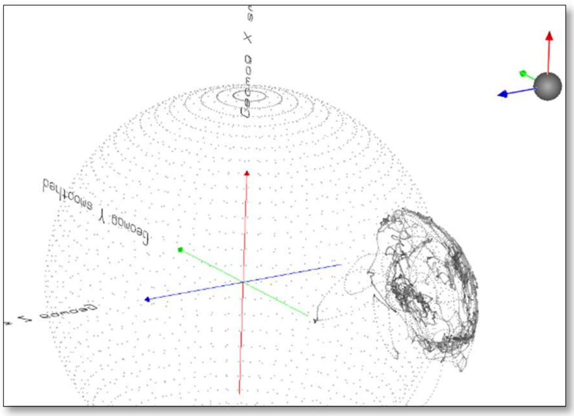


Figure 3.9 *Less than half a sphere of mag data selected for the magnetometer correction algorithm*

Once the above data is chosen, a bookmark should be created around this data, and the magnetometer correction algorithm initiated, and that bookmark selected using left-alt and right-click, as below:

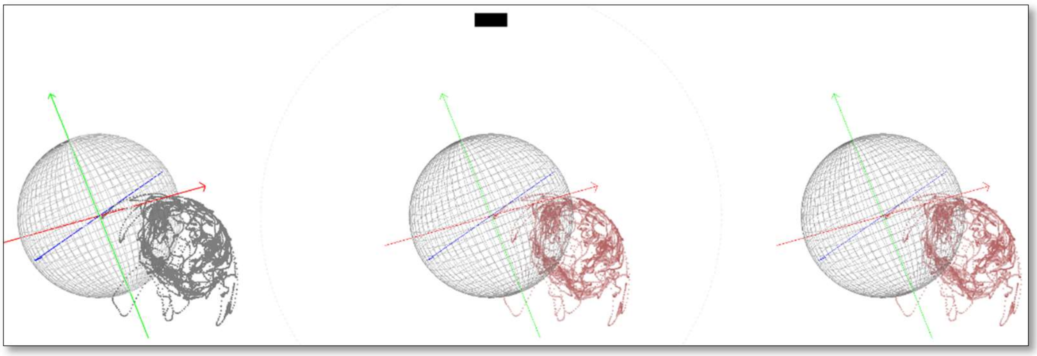


__Figure 3.10__ The above data highlighted as a bookmark, and 'selected' for inclusion within the magnetometer correction algorithm

Clicking the button above the spheres then progresses the algorithm to the ellipsoid correction stage, after having attempted to correct the offsets, below:

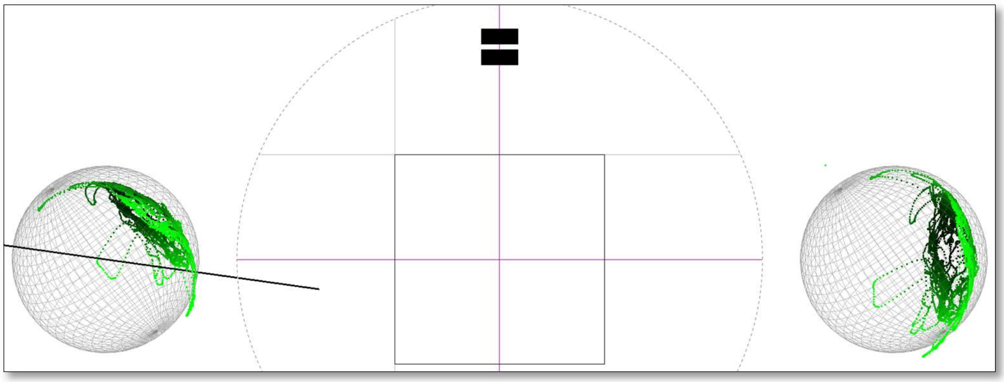


__Figure 3.11__ The ellipsoid correction stage of the magnetometer correction algorithm

Now, there are two buttons to choose from; written instructions are provided on-screen above the buttons. The top button accepts the ellipsoid correction (after using the controls for this stage (described earlier in this chapter). As we've used less than half a sphere of data, it's clear that the offsets here are incorrect. Clicking the lower button of the two takes us to the manual offset correction (correction):

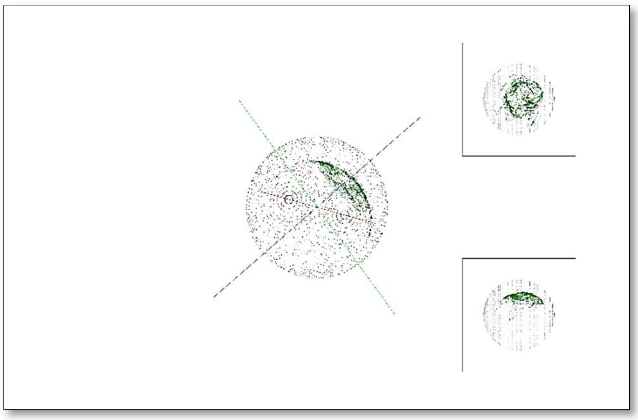


__Figure 3.12__ The manual offset correction (of the offset-corrected data!)

Here, the user is presented with a rotatable sphere of the user-selected magnetometer data, and the X-Y perspective (top), and X-Z perspective (bottom) images.

- The user can use the mouse-wheel to scale up/down the data of all 3 views
- If the user holds down ***Ctrl*** and adjusts the mouse-wheel, the sphere (main) and those within the two perspective views to size up/down to better fit the data. The idea is that the user should try to adjust the sphere to substitute that which 'should' be present if a full magnetometer sphere were present, and not just a partial fit
- The user can also hold down the ***Shift*** key and move the mouse within either of the perspective regions to adjust the position of the sphere to 'complete the sphere' of the data that is already present.

The user should rotate the main view around many times until the data sits 'on' the synthetic sphere, as in the figure below.

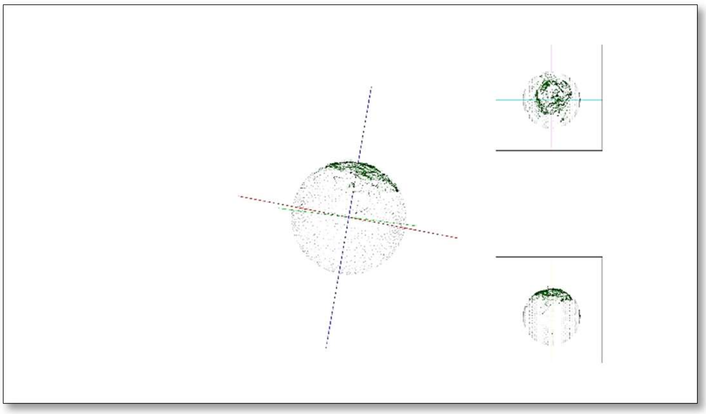


Figure 3.13 *The manually adjusted synthetic sphere with the user data sitting on the outside*

At this point, clicking on the button at the top would have the algorithm accept the new offsets, and then offer the user the choice to correct for any ellipsoid issues in the data. For this dataset, the user should decline as there is no complete sphere present, and the correction algorithm would terminate (complete) with just offsets defined. If there was a near sphere of data present, the user should opt to go the ellipsoid correction route (click 'Yes'), and they would be returned to the image shown in Figure 3.11. It would then be possible to adjust the right-viewed corrected data to a sphere. The user should then click the top button. After this is done, the user should then click the top (of two) buttons as before to complete the correction algorithm.

Applied magnetometer offsets values can be viewed (and set manually) here on the ***Mag off's'DD Orient'n/Anim*** tab. Also, if the ellipsoid correction settings are known, then these can be entered manually.

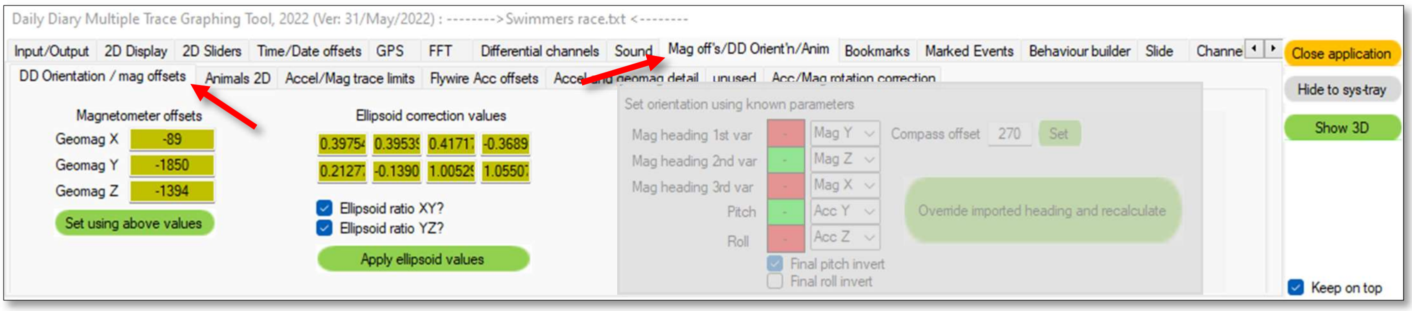


Figure 3.14 *Geomag offsets and ellipsoid correction settings*

The right-side content on this tab is greyed out as this is not applicable to Geomag offsets etc., instead, related to the definition of the data logger orientation relative to the ground, and the forward-facing side of the data logger.

As an extended, fine adjustment to the magnetometer offset corrections, it is worth collecting data in the following way.

1. Place your logger in the orientation that it will be mounted on the animal, with the magnetometer centred on the pivot point of the graphed compass below, with the logger facing approximately north

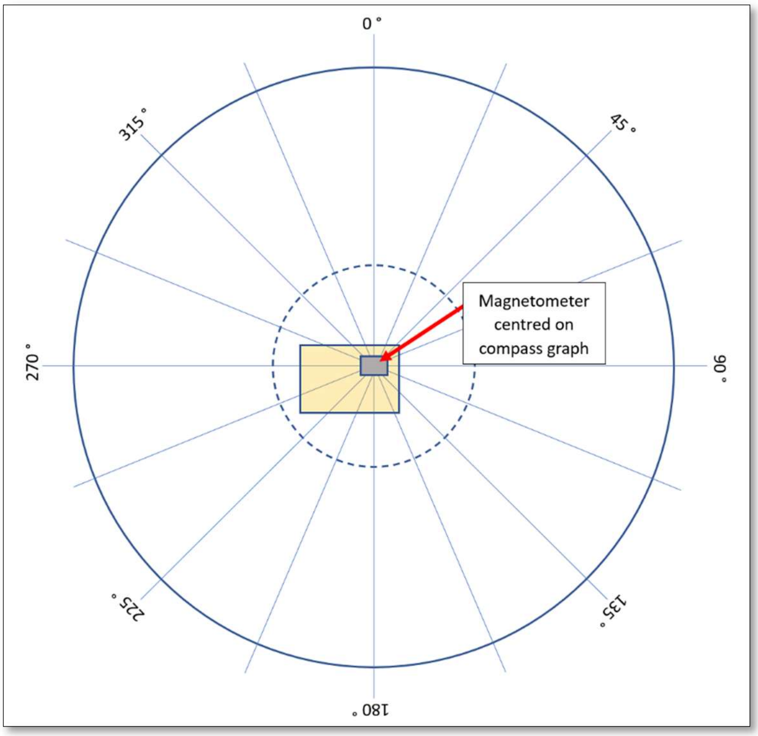


Figure 3.15 *Additional tweaks to the magnetometer offsets*

2. With the logger continuously collecting data, collect about 20 seconds of data, and then rotate to the next compass point, 22.5 degrees on. Finer divisions may help, but a minimum of 22.5 degrees is recommended. Continue all the way around back to north, completing 16 divisions (the final repeating the first at north).
3. Now, once the logger has been deployed and retrieved, perform the usual magnetometer offset/ellipsoid corrections described above.
4. Set the device orientation so that the heading channel is correctly calculated

5. This final step is the new addition:
   a. Create a 3D dot plot
   b. Channel 1 – *Time*
   c. Channel 2 – Compass Heading 3D
   d. Channel 3 – Pitch
   e. Enable *Radius by Channel 3* (Pitch)
   f. Enable *Compass split*
   g. *Adjust the rotation of the visual by right-clicking on the 'Ortho-Viewer' (floats to the top right of this visual) twice, such that the Z axis is coming out of the screen and the compass data can be viewed as below*
   h. Adjust *Compass split* to the number of divisions (16 below)
   i. Now, carefully adjust the 3 buttons in the 5th column to tweak the magnetometer offsets
      The clusters of data at the *n* divisions (16 below) will adjust around. With some care, it might be possible to adjust them to evenly distribute around the circumference
   j. Hold ***Ctrl*** and adjust the mousewheel on the *Compass split* button to rotate the compass divisions CW / ACW

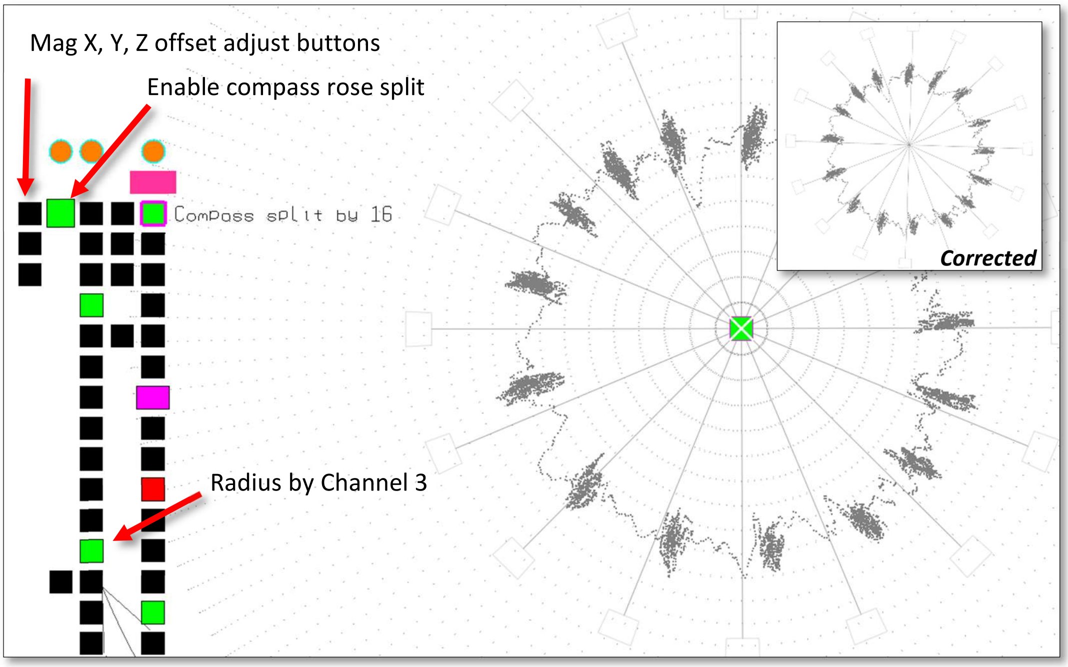


Figure 3.16 *Additional tweaks to the magnetometer offsets*

Alternatively, a button has been added to the 2D graphs (when no visualisation is selected) on the left side that allows direct adjustment of the magnetometer offsets:

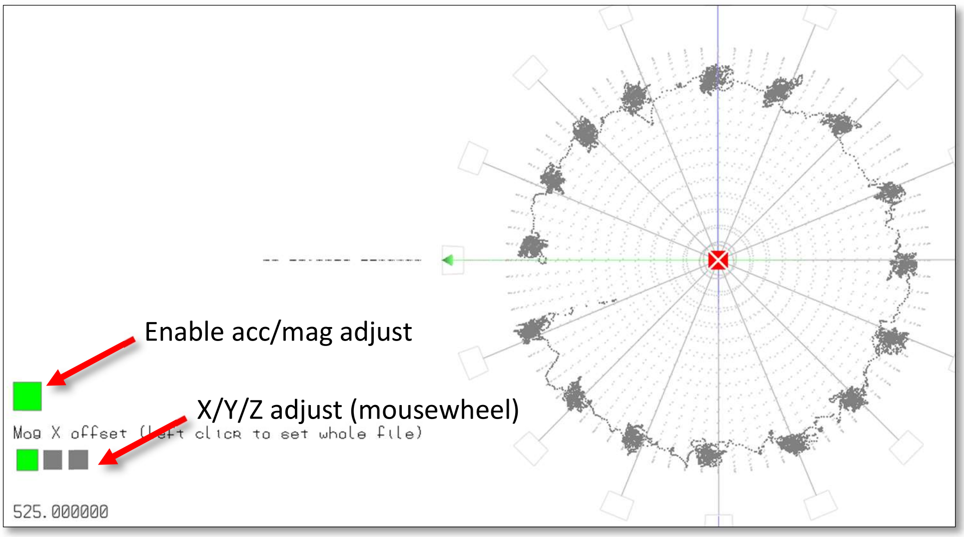


Figure 3.17 *Alternative controls for adjustment of acceleration and magnetometer offsets / scale*

And one final means to view the changes in the magnetometry heading, there are now controls on the Rose-plot that allow multiple line divisions, and compass offset. It is recommended that the user increase the number of rose-plot bins to around 200+ in order for the data to be nicely spread across the compass for this to be useful in adjusting the magnetometer offsets.

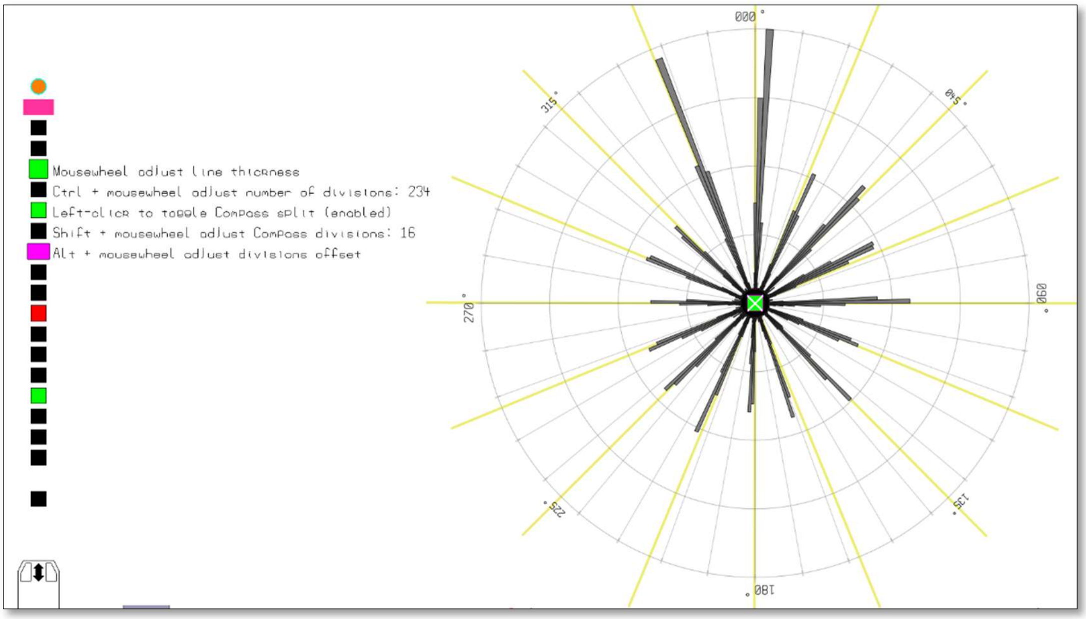


Figure 3.18 Use the rose-plot with the compass data to view the spread, and also the actual compass values

If the user has a dead-reckoned path open as a visual, then this will dynamically update.

Once the user has completed their adjustments to the offsets, click the 4th button down on the menu's 5th column *Apply offset adjustments*, and the primary magnetometer offsets on the ***Mag off's/DD Orient'n/Anim*** tab will update, and this visual's offset adjustments will reset to zero. The current split will also reload to ensure that all calculations, including any user-defined differentials are properly recalculated.

The user is now advised to save / update their Time / Date / Offsets (.tdo) file with these refinements.

Acceleration offsets and scaling controls

The acceleration offsets are corrected manually by the user by navigating to the ***2D Sliders / Slider controls grouped by purpose*** tab and then the scrolling through to ***Acceleration*** as in Figure 3.18. Click ***Show 3D*** to open the 3D visualisation window and either click the button near the top labelled "***Create smoothed accel sphere***" or right-click in the centre of the 3D area and create a new XYZ plot (Acceleration by default). If the data you see does not present a suitable sphere of data, move around the split, or progress to a latter/earlier split, ideally one that has ~1 *g* acceleration covering roughly the whole surface of the sphere. Or, if the possibility exists, collect some data like that shown in Figure 3.18 below where the logger is placed on its (approximate 6 faces for some short period of time).

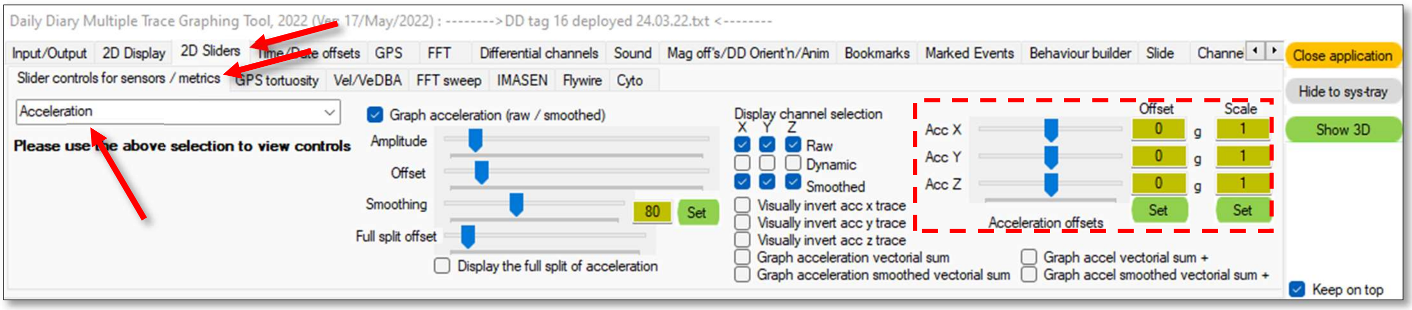


Figure 3.19 The acceleration offsets and scaling control panel

The aim here is to adjust the sliders so that the sphere is centred in all 3 (X, Y, and Z) axes, unlike in the image below in Figure 3.19. To make the offset more visible you can increase the line intensity of your sphere / data, and either manually rotate it on the X axis to 90 degrees – see the 3D visualisation chapter(s) later in this manual, or right-click on the little widget to the upper-right to cycle through various orthogonal views. Note, holding down ***Ctrl*** and right clicking the mouse makes the transition to the next orthogonal view faster.

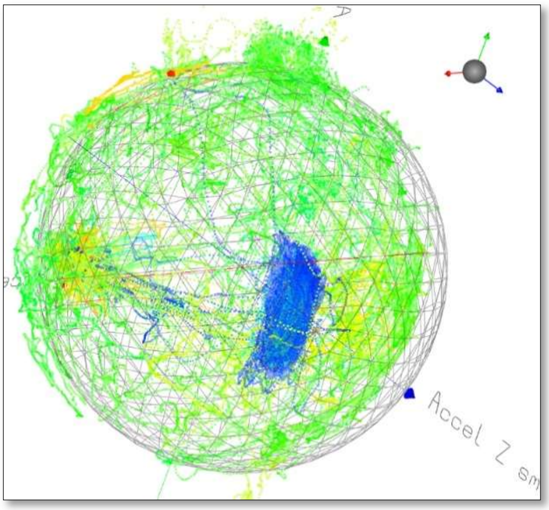


Figure 3.20 *The sliders allow the data points to be repositioned so that they sit on the sphere*

Once the sphere has been centred in X and Y, pull the sphere down so that the X axis is into/out of the "screen" and the Y axis is vertical on-screen, or right-click on the widget one or more times to cycle through various orthogonal orientations, such that the Z axis is pointing either up or down the screen. Then adjust the Z axis offset to centre the data on the origin.

Alternatively, as mentioned above in the magnetometer correction discussion, acceleration offsets can be made by enabling the 2D traces (within the 3D) and selecting the offsets / scaling control on the left side. The mousewheel is used to switch between acceleration and magnetometer controls.

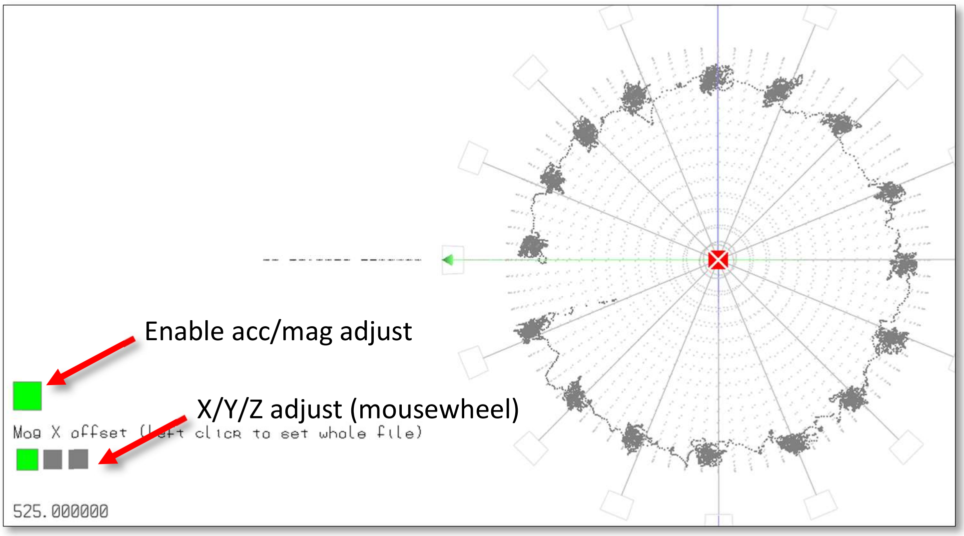


Figure 3.21*Alternative controls for adjustment of acceleration and magnetometer offsets / scale*

Once the sphere is centred (offset corrected), it is then time to consider acceleration axes scaling, where each axis is expected to be a minimum/maximum of 1 g at some point on the sphere when the logger is stationary. To do this, it is advised to collect some data using the logger in question (acceleration offsets do not change for a particular logger, they are the result of changes that occur during the PCB manufacture. By holding the logger while it is collecting data with each "face" of the logger pointing vertically up from the floor, and then "very gently"/slowly wobble it slightly around/across in small circles to ensure that a near zero degree offset from the vertical point is captured (for each of the 6x faces). We capture something like that in Figure 3.17.

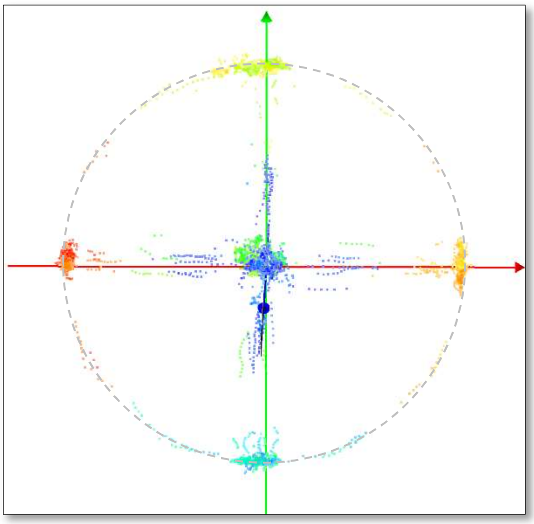


Figure 3.22 *6x clusters of acceleration data for use in correcting the acceleration scaling (applicable to correcting offsets also)*

Now enter decimal values such as 0.95, or 1.05 etc. to each of the 3 axes scaling boxes shown in Figure 3.15 so that these small clusters of data sit on the 1 g sphere above – the sphere has a dashed ring drawn over the top to highlight the location of the digital 1 g sphere.

Note that the 3D viewer now includes a small ortho-view model at the top right of the screen. Right-clicking on this, will switch/rotate the currently selected visual through different rotations i.e., X-Y, X-Z etc. The ortho-viewer can also be left-clicked and dragged anywhere on the screen, and resized with the mouse-wheel:

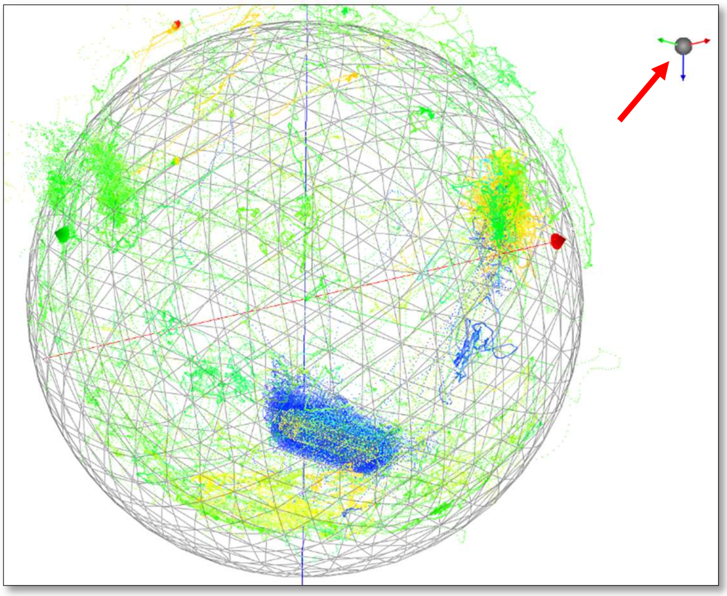


Figure 3.23 *The ortho-viewer that helps illustrate the orientation of the current visualisation*

TDO (time, date, acceleration/magnetometer offset) files

These time adjustments and acceleration/magnetometry correction settings can then be exported as a *.tdo* (time-date-offset) configuration file that can be reloaded at a later date. As well as saving the time correction, this can facilitate data sharing and aid users working with previously collected data, and synchronisation with GPS data. See Figure 3.2 of this chapter for correcting the time and date for your data in DDMT. Please note that the *.tdo* file also holds the device orientation information discussed later in the 3D visualisation section, an important aspect relating to the calculation of heading, pitch, and roll metrics.

To export the *.tdo* corrections file, simply click the green button labelled ***Export Time/Date/Offsets (.tdo) file*** on the ***Input/Output / File output/Save*** tab. Note that if no magnetometry ellipsoid correction has been performed an error message will alert the user that this must be done before saving a *.tdo* file.

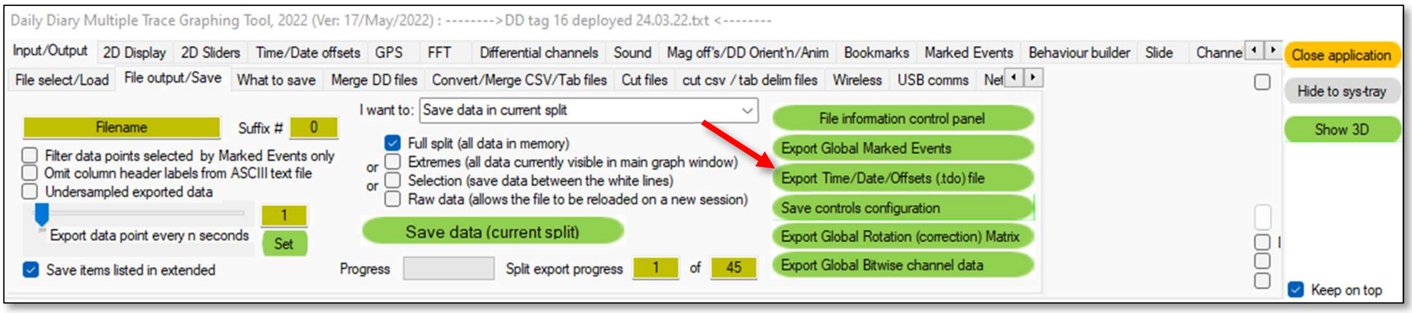


Figure 3.24 The ***File output/Save*** sub-tab with the ***Export Time/Date/Offsets (.tdo) file*** button indicated.

The next time the file is used, the previously exported *.tdo* file can be reloaded at the start of the session using the ***Load TDO file*** function on the ***Input/Output / File select/Load*** sub-tab.

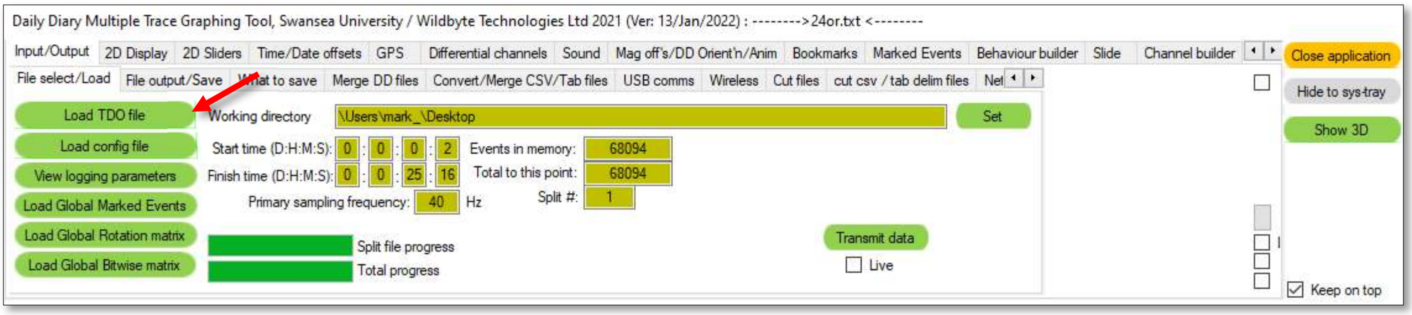


Figure 3.25 The ***File select/Load*** tab on the control panel

On the ***Input/Output*** / ***File output/Save*** tab, there is a button labelled ***File information control panel.*** Clicking this reveals a small window where useful information pertinent to the data file can be stored, for inclusion within the .tdo file. Note that “line feeds” are converted to full-stops for the ease of storing the contained comments as a single string of text.

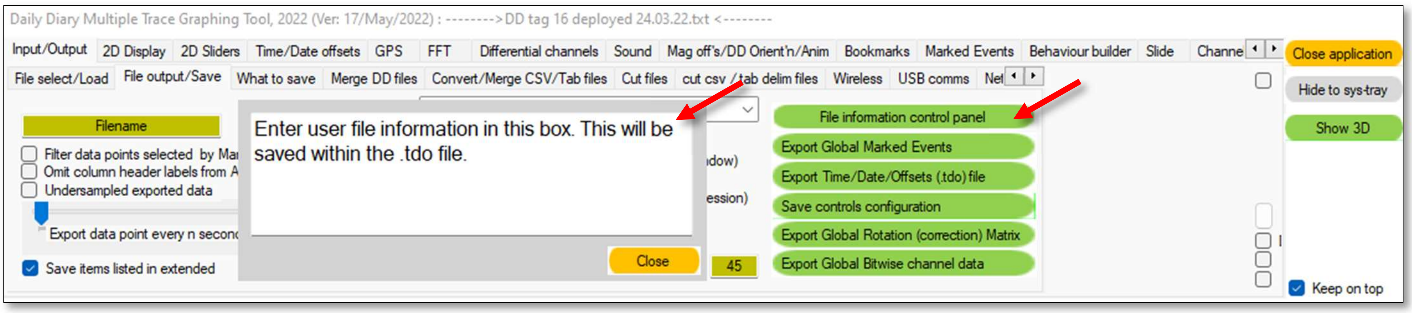


Figure 3.26 File information control panel – text entered here will be stored within the .tdo file

Additionally, as discussed earlier in this chapter, the ***All magnetometer offsets*** (advanced offset correction to cope with drift over long periods of time) are also stored within the .tdo file.

Overall, the *.tdo* file contains:

- Acceleration offset correction
- Acceleration scale correction
- Magnetometry offset correction
- Magnetometry spherical/ellipsoid correction
- Time / date correction
- Device orientation settings (to enable correct calculation of heading/pitch/roll – discussed later)
- User text containing any useful information to be remembered
- ***All magnetometer offsets***

Further optional data adjustments

Rotation correction

When attaching tags to animals or objects, there is always a chance that the attachment may shift its central position to some different angle. By looking at the data in either 3D or possibly in the ***2D graphing window***, this can be determined when the tag is in a resting state. Data can be sectioned and manually rotated on any or all the 3 rotational axes.

To rotationally correct data (both acceleration and magnetometry at the same time), on the 3D window, create a ***Rotational Correction*** visual. The *X*, *Y*, and *Z* axes are locked to either *Acceleration* or *Acceleration Smoothed*. This initially will appear the same as that for a simple XYZ plot (2nd visual type). To the left of the visual, you'll see the X, Y, and Z Euler correction values.

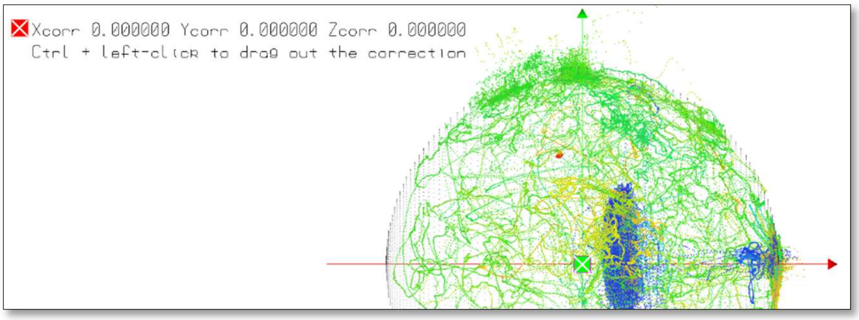


Figure 3.27 *Rotation correction visual*

From here on, all corrections are controlled via the use of the mouse, left-click, ***Ctrl***, and the visual's menu system.

To generate a correction, simply hold down the ***Ctrl*** and left-click the mouse and drag out the required correction. In the figure below, the original data is shown in colour, while the "ghost-correction" is in grey, slightly offset vertically down. The correction values are shown to the left. Left-clicking and dragging the mouse will rotate both the original and the ghost-copy together for visual confirmation of correction. The red arrows in Figure 3.27 show the rotation of the data in colour and grey.

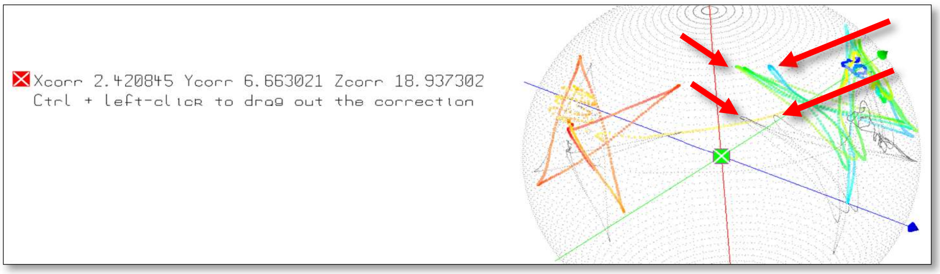


Figure 3.28 *Original data, with a ghost-copy of the data rotated vertically down (grey)*

When the ghost-correction is correctly positioned, the next step is to save this correction by clicking ***Store this correction*** (indicated below). The relevant controls for the rotation correction lie in the 3rd column (from the right) of the menu structure as follows:

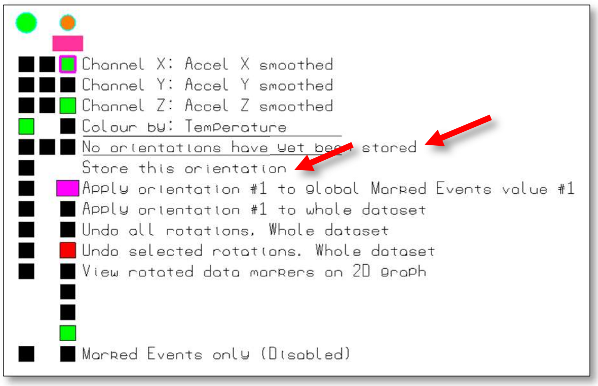


Figure 3.29 *Relevant rotation correction controls on the left side (3rd column) buttons*

The 3 Euler values will then appear at the button above this, currently showing ***No orientations have yet been stored***.

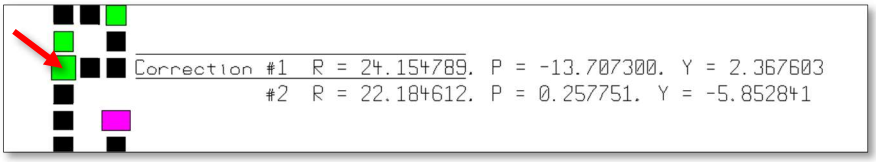


Figure 3.30*Stored corrections (2x)*

After storing corrections, they will appear in the above list. While mouse-hovering over this button, the mouse wheel can be used to select different corrections.

There are now two options. One can either apply the currently select correction values to the entire data set (all splits), or, to all data points of ***Marked Events*** of a value between 1 and 9 (all splits). In Figure 3.24, this is set to ***Marked Events value #1***, but this can easily be adjusted to any value, 1-9, with the mouse wheel. The main idea here is that one can setup many (up to 9 maximum) different bands of ***Marked Events*** throughout the file, and then apply the correction once to each ***Marked Event*** value. Once the rotations have been applied, the ***Marked Events*** can all be cleared down, as the rotation corrections, for each/every event (data point) within the whole file, are stored separately.

Rotations can be undone as a whole, or individual corrections, #1, #2, #3 etc. can be undone.

One can also view which data has been corrected by clicking on the button labelled ***View rotated data markers on 2D graph***, and rotated data will show indicators on the ***2D graphing window***.

To know which data has already been rotated, and with which Marked Event value, DDMT colours the rotated sections with the same colour scheme as is allocated to the ***Marked Events*** system.

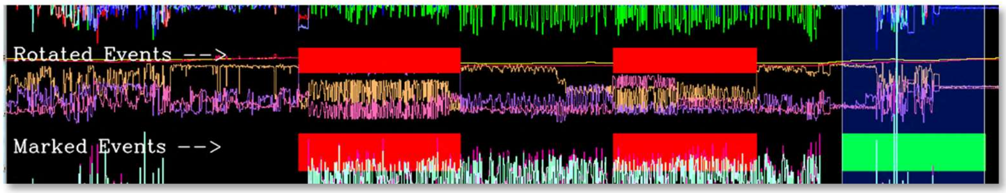


Figure 3.31 *Rotation data has been applied to the two sections (red), while some other data has Marked Events value 2 (green)*

To export the "global rotation correction matrix", click on the button ***Export Global Rotation (correction) Matrix*** button on the ***Input/Output / File Output/Save*** tab.

All rotation information for the entire file is stored in a single array. 2 rotations cannot be applied to an event twice i.e., if a data point(s) correction is not quite correct, then that correction must first be removed and an improved correction applied.

This rotation matrix can be exported and reimported later i.e., overlaid onto the primary data file (DDMT never makes any changes to the original data file, so it is necessary to load the *.tdo* file for time/date corrections, and acceleration/magnetometry corrections). It must be done in that specific order – magnetometry corrections (offsets/ellipsoidal), and *then* the rotation correction matrix can be loaded from a previously exported session.

To import this correction matrix, click on the button ***Load Global Rotation Matrix*** on the ***Input/Output / File select/Load*** tab.

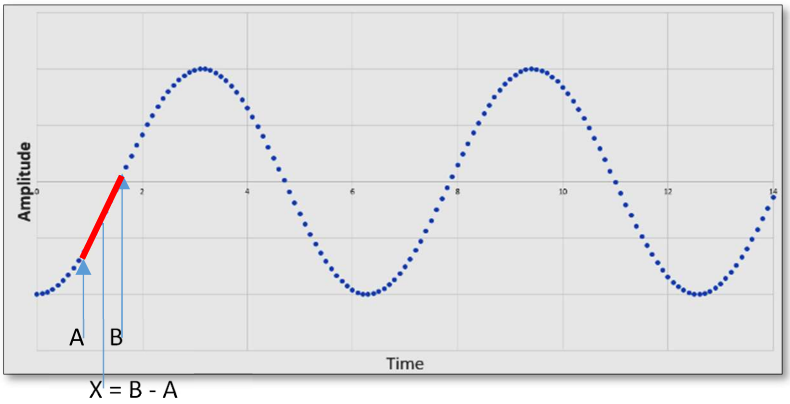
Rotation corrections

4. Differential Channels

Differential channels offer a method of extracting rate of change of various channels. Differential channels stepping ranges, per channel, are user-defined. This is particularly useful when using Behaviour Builder (Chapter 12). Differential channel settings are found on the ***Differential channels*** tab.

Differential channel creation

The full list of variables for which differential channels can be created is listed under ***Available channels.*** Select the channel(s) of interest and specify the range using ***Differential calculated over range*** value.



The differential algorithm runs through each point calculating B-A, centred around the point with a separation of *Range* n (difference of X_B and X_A), default 5. If n = 5 then B will be 2 events after the current point, and A will be 2 events before. The same channel can be added to the differentials list many times, each with a different *Range* value. In this way, we obtain the gradient (red line) for the point X

Figure 4.1 Differential channel *calculation*

Once you have selected the channel(s) of interest and set the range, click the adjacent green ***Add*** button. The selected channels will now be displayed in the next box ***Channels selected for processing***. Click the green ***Process channels*** button under this box. The channels will now be displayed in the third and final box on the ***Differential channels*** window and on the 2D graphing window.

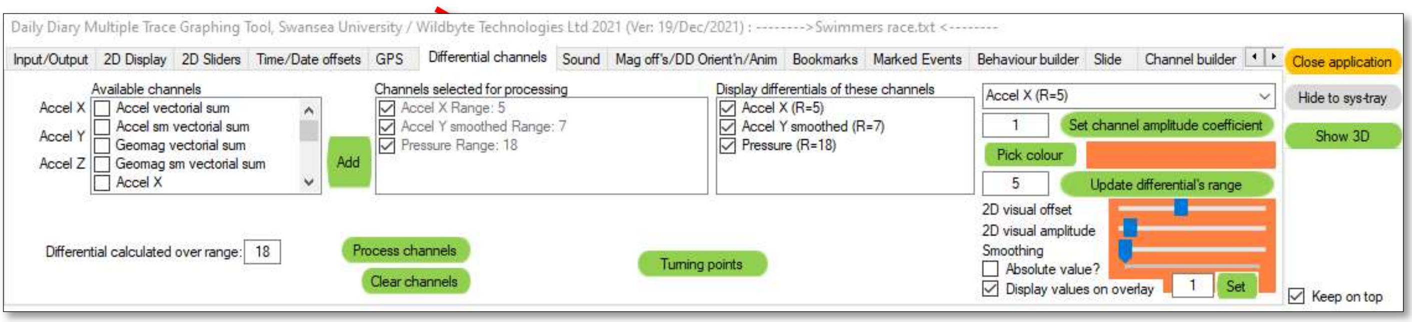


Figure 4.2 Differential channels *with Accel X,Y,Z selected and processed with Range values of 5 events (+/- 2 from each event)*

Note that ***Set channel amplitude coefficient*** allows some small or large differential waveforms to be displayed on the ***2D graphing windows*** with appropriate scaling; if the waveform is too large, perhaps enter a value of 0.1, or even 0.01 here and click the ***Set amplitude*** button. This is a visual / cosmetic change and does not affect the data itself in any way. The ***2D visual offset*** and ***amplitude*** sliders are also just visual / cosmetic adjustments to allow the user to individually adjust the vertical and scale of each of the differentials on the display so that multiple waveforms may be separated vertically.

Smoothing does, however, affect the channels of differential data. When the value is 1 then no smoothing is applied. Each differential channel has its own individual level of smoothing.

A differential channel's ***Range*** can be altered by manually entering a value in the box on the right side and clicking ***Update differential's range*** button.

Note that the default colour for a differential channel is grey and if processing multiple differential channels at once all will appear in the same colour on the same location of the 2D graphing window. Select individual channels using the drop-down menu on the right-hand side of the ***Differential channels*** sub-tab. Use ***Pick colour*** to update the channel colour and adjust its offset, amplitude and smoothing using the sliders underneath, shown in the same colour as that selected for the differential channel currently selected. When selected, the ***Absolute value?*** checkbox will display the magnitude of the differential channel values without regard to its sign (no negative values given).

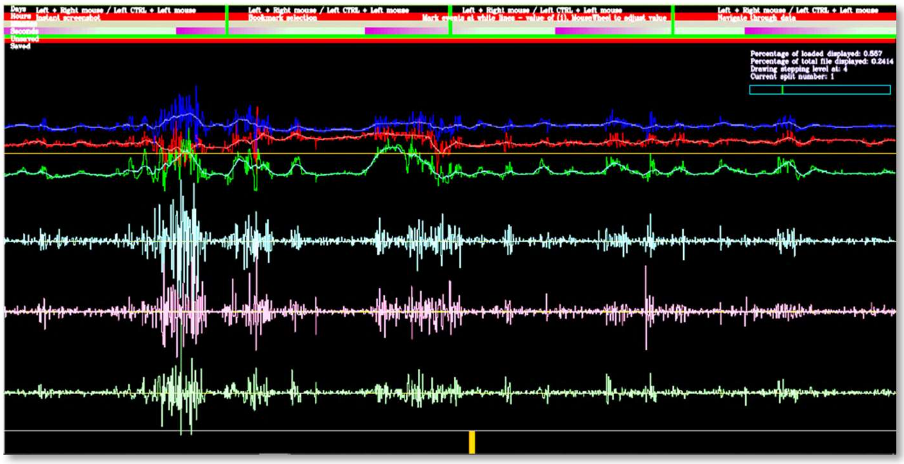


Figure 4.3 *Acceleration channels with corresponding differential channels after colour and offset adjustments*

Displaying the differential events values on the values overlay

The ***Display values on overlay*** checkbox on the ***Differential channels*** sub-tab is selected by default, so unless unchecked the newly created differential channels will be added to the bottom of the display overlay. The overlay will update when colours are customised and include the range (stepping) over which the channels were calculated. Note that the same channel can be processed multiple times at different stepping ranges to explore which is most useful for detecting patterns of interest.

Note that the overlay now includes the *mean* and *absolute(mean)* of the values between the left/right white lines on the 2D graphing window.

Parameter	Left click	Right click	Delta
Acceleration X (raw):	0.373291	−0.161621	0.534912
Acceleration Y (raw):	−0.671631	0.359375	1.03101
Acceleration Z (raw):	0.634521	0.822021	0.1875
Acc Variance, SD (x):	0.0433757	0.208268	
Acc Variance, SD (y):	0.765566	0.874966	
Acc Variance, SD (z):	0.0422289	0.205497	
Event number (in split):	222566	222598	32
Event number (in total file):	222566	222598	32
Event date + times / D:HH:MM:SS.ddd:	01/02/2017 08:55:29.512	01/02/2017 08:55:30.333	0:00:00:00.821
Extremes event start/stop (Split 1) :	221688	223248	1561
Extremes total events start / stop:	1	423100	1561
Extreme times HH:MM:SS.ddd:	8:55:7	8:55:46	
Differentials:			
Accel X (R=5)	0.078125	0.171875	0.09375
mean, absolute(mean)	−0.05904	0.1821	
Accel Y (R=5)	0.1445	−0.2734	0.418
mean, absolute(mean)	0.1468	0.3343	
Accel Z (R=5)	−0.05859	0.3672	0.4258
mean, absolute(mean)	0.009233	0.1882	
Accel Z (R=10)	−0.4219	0.3984	0.8203
mean, absolute(mean)	−0.03078	0.3321	

Figure 4.4 *Differential channels automatically added to the display overlay*

Turning point finder

All channels in DDMT can be passed through the ***Differential channels*** generator, therefore, it is relatively straightforward to isolate turning points in data by honing in on the differential values around zero.

Built into the ***Differential channels*** algorithm, one can click the ***Turning points*** button; Figure 4.5.

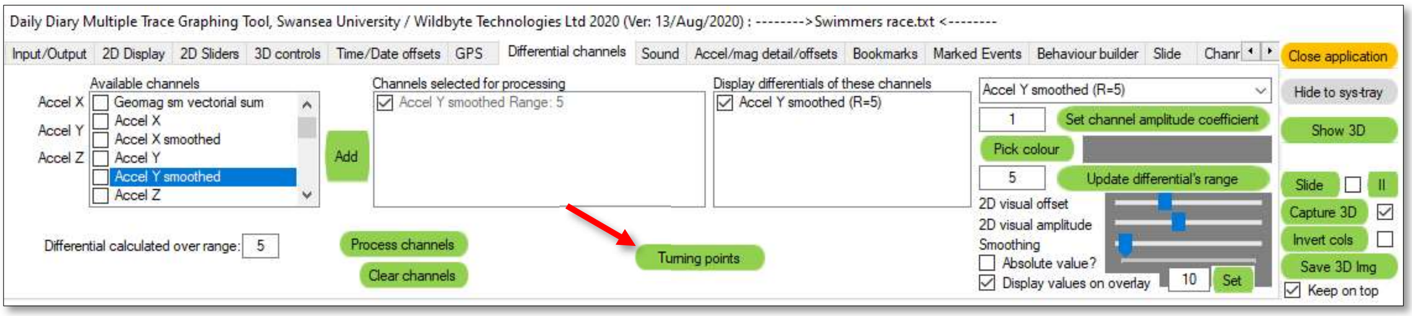


*Figure 4.5 Differential channels **Turning points***

This reveals the ***Turning points*** controls panel; Figure 4.6

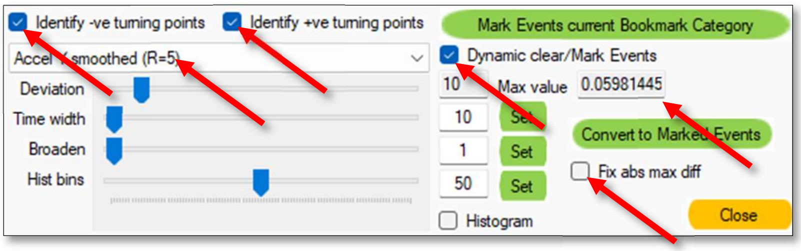


***Figure 4.6 Turning points** controls*

Options are present to select either peaks (+ve turning points) or dips (-ve turning points). Tick ***Dynamic clear/Mark Events*** so that as a region of data is highlighted on the ***2D graphing window*** with the left/right white lines, this region is dynamically assessed for peaks/dips.

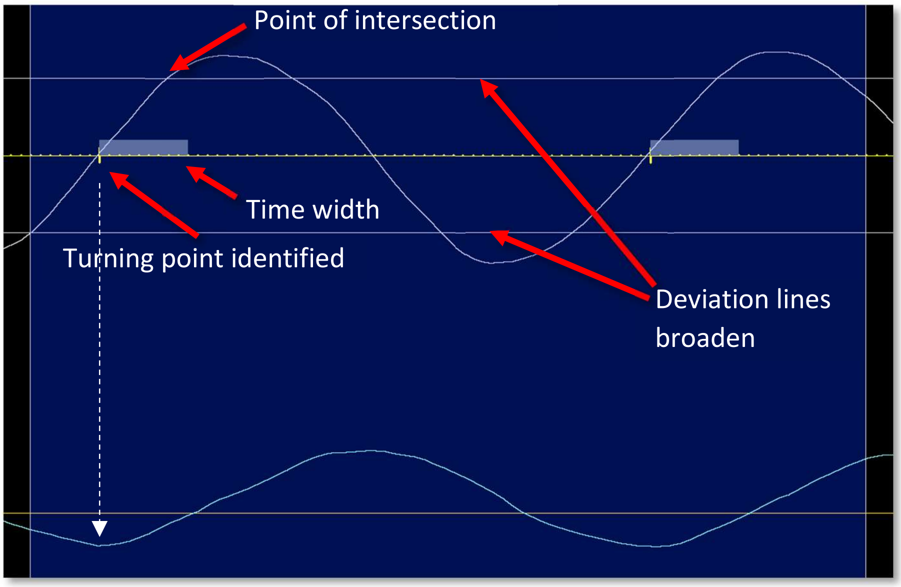


***Figure 4.7 Turning points** deviation lines*

As the ***Deviation*** slider is adjusted up, the ***Deviation*** lines widen. The grey patch after the turning point is the ***Time width*** which can be expanded with the ***Time width*** slider. If the ***Differential*** line intersects with the ***Deviation*** line before reaching beyond the ***Time width*** ends, the turning point will exist (small vertical line; yellow for a dip, purple for a peak).

The ***Broaden*** slider adjusts the single line indicator at the turning point to multiple points; Figure 4.8.

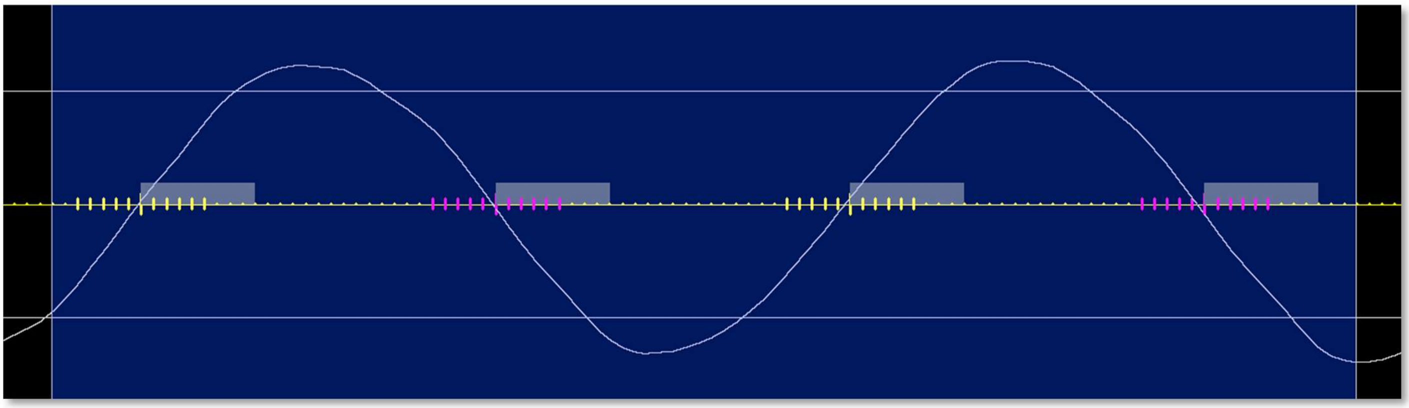


Figure 4.8 Turning points *and broadening*

Here, in Figure 4.8, we've also selected the positive turning points (purple). The turning points only exist temporarily. To convert them to ***Marked Events***, click ***Convert to Marked Events.***

Here, Figure 4.9, these markers have been converted to ***Marked Events***; value 1 (red) for dips, and value 2 (green) for peaks.

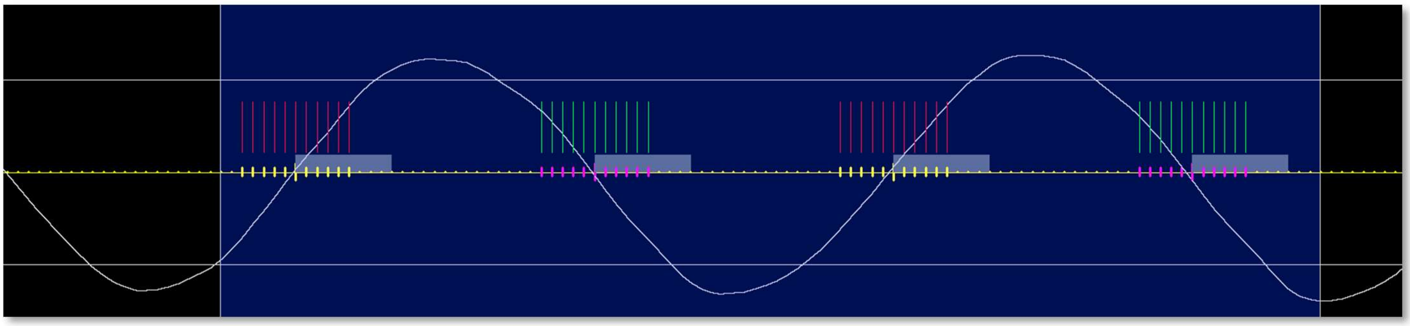


Figure 4.9 *Converting* ***Turning points*** *to* ***Marked Events***

For a selected section of data, there will be a maximum *absolute differential value* (for the selected differential channel). Deviation operates as a percentage of this maximum, and so, zooming out to include more data, will likely find a greater *absolute differential value* and therefore alter the response of the algorithm. To mitigate this issue, while the user still has the selected data in-view, select the tickbox ***Fix abs max diff*** and the ***Max value*** will remain unchanged when adjusting the zoom (Figure 4.6).

When a lot of turning points are available, a histogram is available by ticking ***Histogram***.

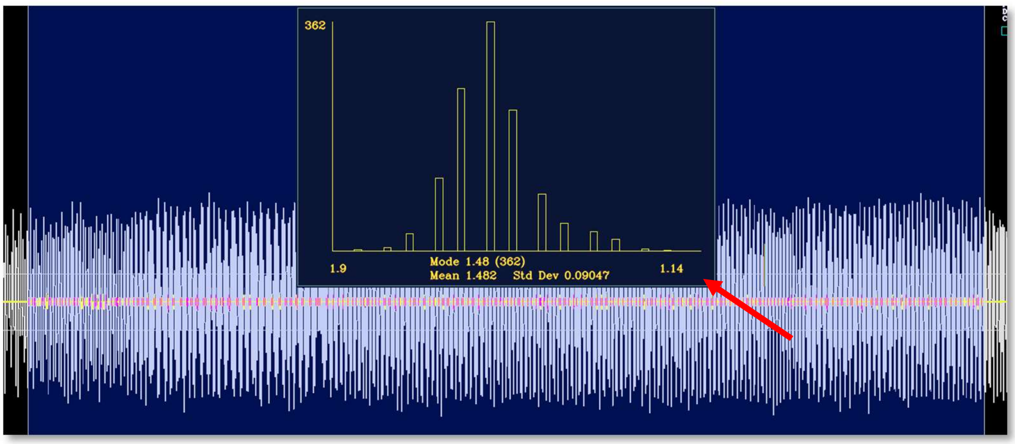


Figure 4.10 *Histogram of* ***Turning points*** *showing the peak-peak period Mode, Mean, and Standard Deviation*

The histogram is one of timing and illustrates the peak-peak and dip-dip period data for all identified turning points for the selected differential. Figure 4.10 identifies the Mode and Mean around 1.4-1.5. Zooming in on one of the oscillations gives a little over 1.4 seconds.

__Figure 4.11__ A quick check on the period of an oscillation to compare against that of the histogram in Figure 4.10

With these turning points converted to ***Marked Events***, these data can either be saved directly, or used in conjunction with new expressions in the ***Behaviour Builder*** to generate ***Bookmarks*** etc. to export data of interest.

5. Marked Events and Bitwise Layers

A ***Marked Event*** is where an ***Event*** has been marked with a value between 1 and 9 (inclusive) either as the result of search function, or manually marked by the user. The purpose of ***Marked Events*** is to:

i. highlight data to be saved (Marked Events can be used as a filter in the export process)
ii. to be used as part of a Boolean search function
iii. or simply as a visual indicator of the meaning of a part of the data

Marked Events from a given session can be exported as a file and reloaded at a later session.

An ***Event*** can only be marked with a single ***Marked Event*** value (1-9). If it is marked again, the old ***Marked Event*** value will be replaced with the new value.

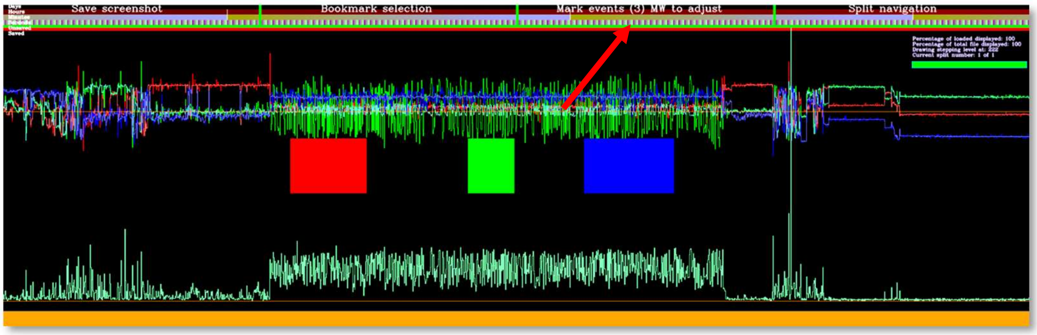


***Figure 5.1 Marked Events** shown as highlighted regions in red, green, and blue (Marked Events values 1,2, and 3)*

Marked Events may be created either manually by the user by placing the left and right white lines on the ***2D graphing window*** as above and then left and right clicking simultaneously on the area marked in Figure 5.1 labelled "Mark events". Also, hovering the mouse over this area and rolling the mouse wheel will change the ***Marked Events*** value between 0 and 9. If the value is set to 0 then the region selected will have any current ***Marked Events*** cleared, while a value between 1 and 9 will set that area to that value, overwriting any previous values present.

A new method of marking events (***dynamic marking***) has recently been added. By hovering the mouse over the 3rd portion of the top banner on the ***2D graphing window***, a new message appears informing the user that holding down the ***Ctrl*** and clicking the middle mouse button toggles on/off dynamic marking events on the window. The first **MMB** click enables this feature and then *left clicked* (+optional dragging the mouse left/right across other data points – slowly) events will be marked with the current ***Marked Events*** value if < 9, else a value of 1 (red) will be selected. Right clicking in the same way will mark events with the current ***Marked Events*** value +1 i.e., if 8 is showing, it'll set the ***Marked Events*** value to 9.

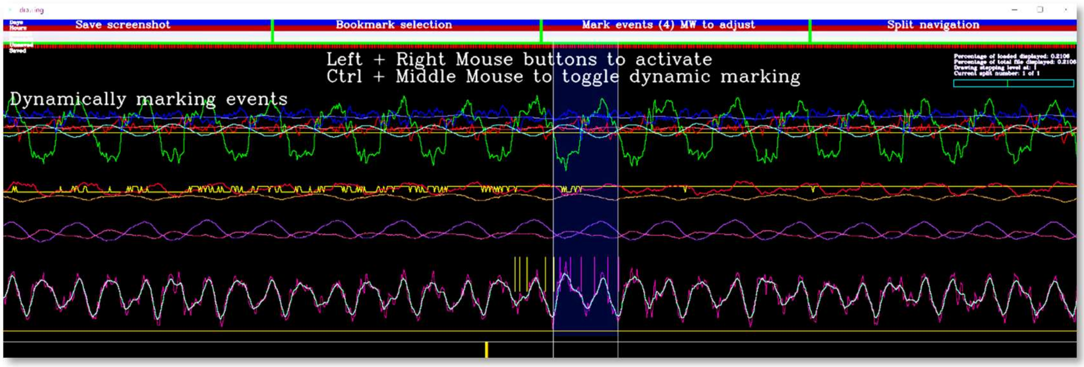


***Figure 5.2 Marked Events** via 'Dynamic marking' (with the mouse left/right buttons)*

Marked Events are persistent for the whole session, while moving through various splits, as is the case with ***Bookmarks*** (discussed in the next chapter).

For more ***Marked Events*** controls, click on the ***Marked events controls*** button on the ***Behavioural Builder*** tab.

Here the colours for the ***Marked Events*** 1-9 can be individually set, ***Marked Events*** between the white lines, or throughout the entire data file can be cleared etc. "Bands" of Marked Events of an event width below a minimum threshold can also be deleted.

The vertical height of the ***Marked Events*** bands can also be set by using the two horizontal lines created by holding down ***Alt*** and **Ctrl** and left or right clicking on the ***2D graphing window*** defining the vertical spacing of the bands and clicking ***Set visual height of Marked Events*** to set it.

Finally, ***Marked Events*** that are close together, and of the same value, can be merged by clicking ***Merge Marked Events with proximity*** i.e., any events with a gap of no ***Marked Events*** less than / equal to the proximity value with be filled in with the same ***Marked Event*** value. This aids in cleaning up results from noisy behaviour that is being investigated using the ***Behaviour Builder***.

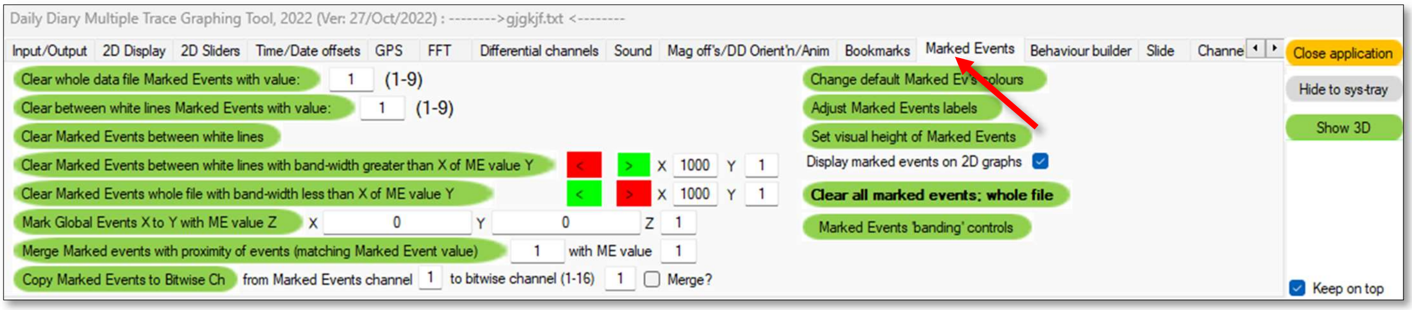


*Figure 5.2 **Marked Events** control panel*

Clicking on ***Change default Marked Ev's colours*** button shows a new panel. Here, the first 9 buttons can be used to adjust the colours for the 9 ***Marked Events*** colours; the remaining buttons are present for future expansion.

*Figure 5.3 **Marked Events** colours control panel*

Equally, clicking on ***Adjust Marked Events labels*** button, shows a panel that allows the naming of the different ***Marked Events*** values.

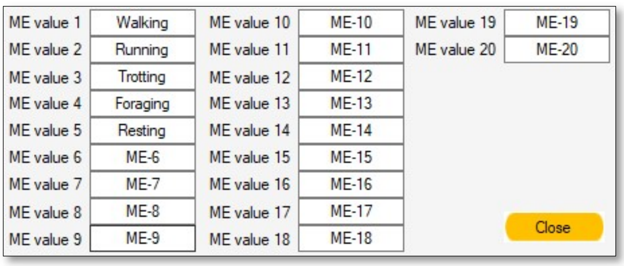


*Figure 5.4 **Marked Events** labels control panel*

In Figure 5.4, these have been marked as "Walking", "Running" etc. These serve no purpose other than general reference for the user. Some files that have annotations for the data will import labels with the data into these boxes. Again, boxes 10 through to 20 are present for future expansion.

Marked Events Banding

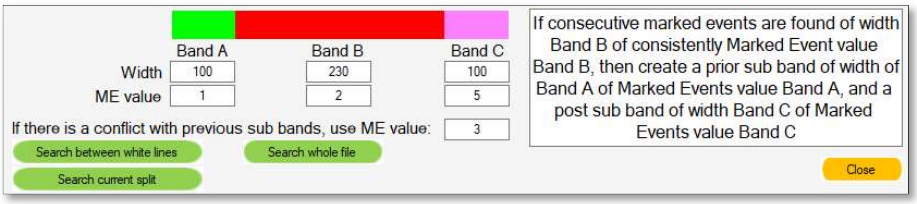


Figure 5.5 Marked Events "Banding" control panel

With "Banding", bands of continuous ***Marked Events*** of a minimum width **B** (1000 events in the example above) will have two bands of ***Marked Events*** appended to the left and right of width 100 and 100, and of ***ME*** value 2 and 5 respectively. If there is a sidebands *conflict* between the right side of one banding hit and the left of the next, then the *conflict* will be coloured according to the *conflict* colour: in the above example it's value 3 (dark blue).

A worked example:

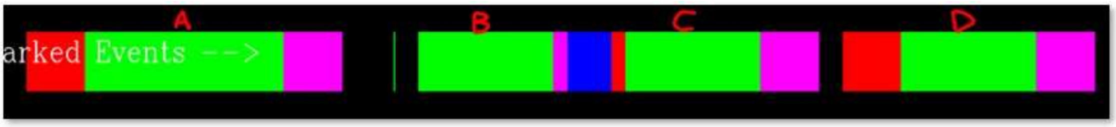


Figure 5.6 Marked Events "Banding" example

- **Example A -->** Band B width is the search parameter. If a band of at least 230 points consecutive marked events is value 2, then it will generate 100 marked events value 2 to the left, and 100 marked events value 5 to the right. However, the width of search band is >> 230 and so it places the pink (ME=5) 100 point wide after the end of Band A.
- **Example B -->** Same parameters as panel above, but this time, there are some marked events of value 2 in the way of the left side of the 230 (these 'conflict' with what would have been the 'left side of ME=1'), so it opts to not overwrite this and only places the 100 wide ME=5 band to the right side. But, as there is another band (C) close, there is an overlap, so the overlapping points are coloured blue (ME=3, the conflict value entered into the control panel). So, where a conflict occurs because of a few data points having the same ME value as that of the main wideband, it's best to tell the Marked Events tab to remove Marked Events of small size first so that these 'small patches' of Marked Events are first deleted (or merged with other by proximity' to make larger bands).
- **Example C -->** This obviously has the same clash from **B**
- **Example D -->** This has no clash and has the left and right sides extended with ME=1 and ME=5

The vertical height/position of the coloured banding on the ***2D graphing window*** for ***Marked Events*** can be adjusted by holding **left ctrl** and **left alt**, and then left / right clicking to define the vertical position of two reference lines. Clicking the button labelled ***Set visual height of Marked Events*** then sets the vertical limits for this feature.

Marked Events were initially the output/result from the ***Behaviour Builder*** function, discussed later in Chapter 10 (***Behaviour Builder***). They can now also be used as part of the ***Behaviour Builder*** search functions themselves i.e., the results of one or more searches can be used as a variable of subsequent searches.

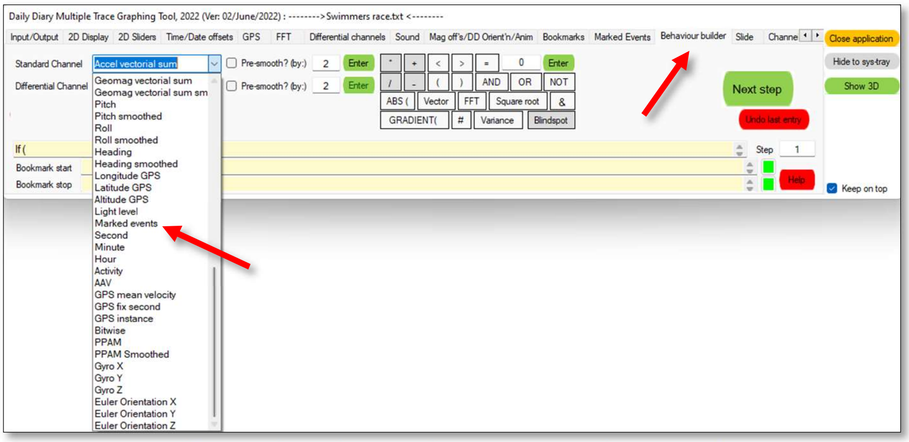


*Figure 5.7 **Marked Events** is one of the variables that can be used for Boolean search expressions i.e. Marked Events > 0, or Marked Events = 3*

Marked Events can also be used as a filter for the visualisations. Ordinarily, a visualisation is constructed from the data viewed in the ***2D graphing window***. Figure 6.3 shows some data in a ***2D graphing window*** and the result in a 3D dot plot. The data on the right side has ***Marked Events*** value 1, red, while the left side has a value of 0.

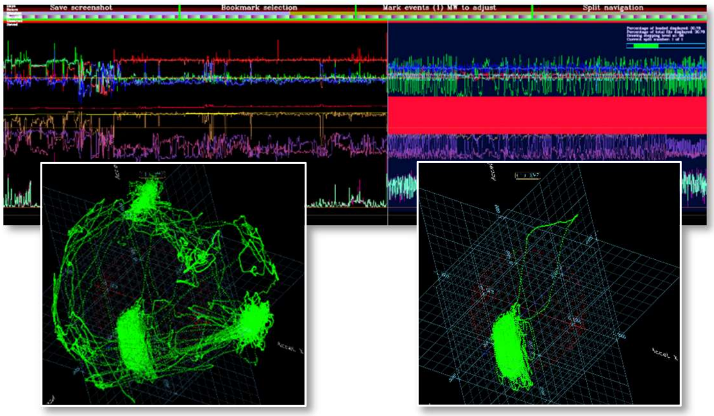


*Figure 5.8 **Marked Events** used as a filter to only include specific events in the 3D visualisations*

Continuing with the 3D visualisation side, ***Marked Events*** play and important role in the Dead Reckoning visual, allowing up to 9 different coefficients of movement or stationary behaviours (see Chapter 11).

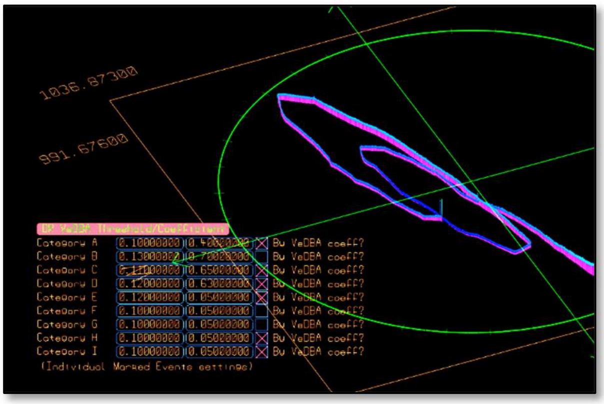


*Figure 5.9 **Marked Events** used as different threshold/coefficients for various behaviours in the Dead Reckoning the 3D visualisations. This allows for fine tuning the path*

Marked events can also be used to as a filter on the export/save function.

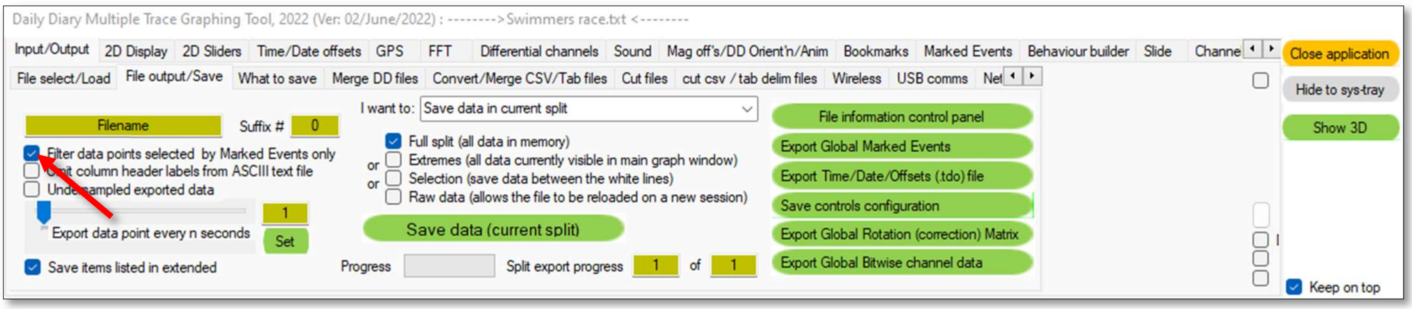


*Figure 5.10 **Marked Events** used as a filter to only include specific events in the 3D visualisations*

By selecting the tickbox above, only events that have ***Marked Events*** associated will be exported.

The ***Marked Events*** channel (global / whole file markings) can be exported as a *.me* file (a binary file) that can be reloaded during another session of DDMT. To export this data channel, click on the ***Export Global Marked Events*** button.

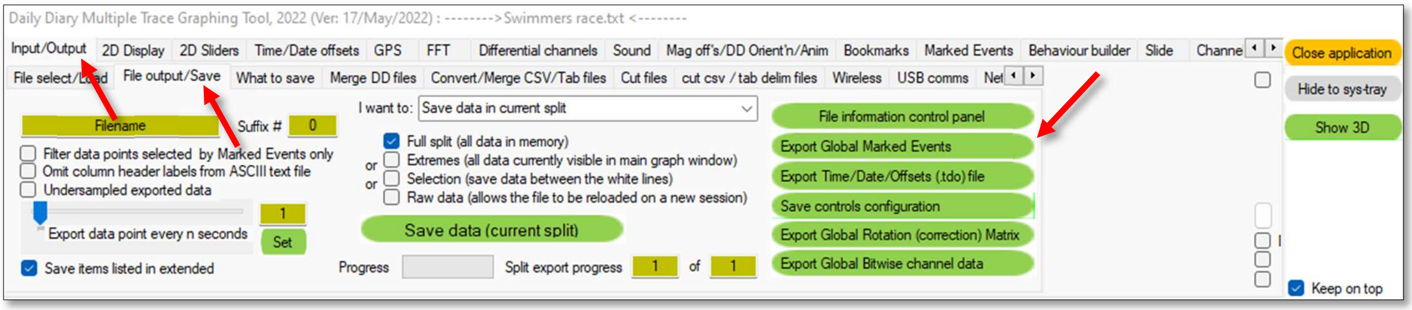


Figure 5.11 *Export **Global Marked Events** data channel*

Note that this will also export a *.csv* file containing the same data, but in a human-readable format, including information such as the ***Marked Events*** labels (1-9), and their percentage content for the entire file:

	A	B	C
1	Number of data points:	423100	
2	Marked Event labels		
3	1	ME-1	8.58%
4	2	ME-2	0%
5	3	ME-3	0%
6	4	ME-4	14.17%
7	5	ME-5	44.18%
8	6	ME-6	0%
9	7	ME-7	0%
10	8	ME-8	0%
11	9	ME-9	0%
12	Marked events below		
13	1	0	
14	2	0	
15	3	0	
16	4	0	

Figure 5.12 *Export **Global Marked Events** button also exports a human readable breakdown of the **Marked Event** content*

To re-import this data channel during another session, or to clear current ***Global Marked Events***, click ***Load Global Marked Events***.

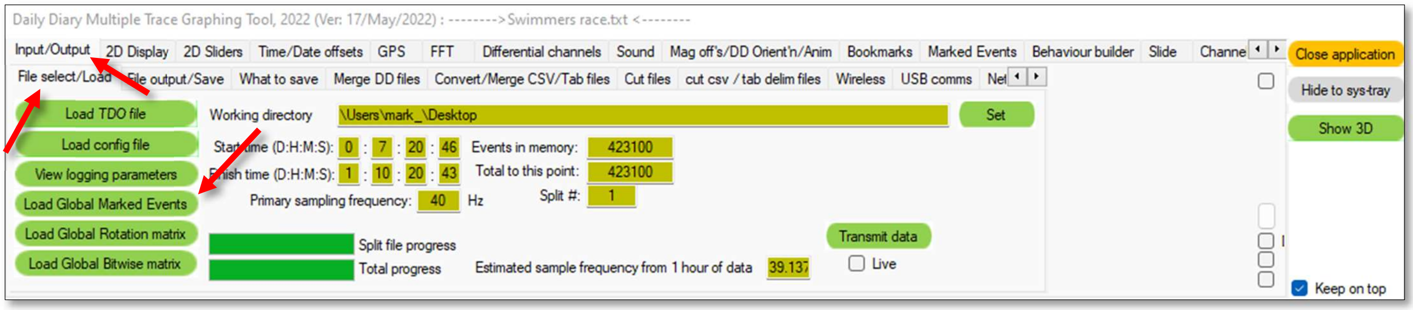


Figure 5.13 *Import **Global Marked Events** data channel*

If data was exported for further analysis in ***R***, results can be imported back into DDMT via this ***Global Marked Events*** channel (integer values 0-9 only) using the following script, which generates a binary format file, compatible with that exported by DDMT itself (**.gme*) kindly provided by Dr Richard Gunner (rgunner@ab.mpg.de) :

```
#####Supplied values required within the function input#####
#TNE = TOTAL number of events in DDMT source file - A single value
#ME = Marked events calculated in R - A column/vector of values. Any value between 0-9!
#TEN = Total event number that the marked events correspond to - A column/vector of values (same number as ME)
#filename = Change file name to what ever you want.
####
#You need to set your working directory first to where you want the output file
#e.g., setwd("C:/Users/Richard/Desktop")
#The function out puts a global marked events file in the directory you set prior to carrying out the function
```

```
Global.ME <- function(TNE = NULL, ME = NULL, TEN = NULL, filename = "testbin"){

  if(is.null(TNE)) stop("TOTAL number of events is NULL: Supply the TOTAL number of events in the DDMT source file - A single value")
  if(is.null(ME)) stop("Marked events is NULL: Supply the marked events to loaded into DDMT - A column/vector of values")
  if(is.null(TEN)) stop("Total event number is NULL: Supply the total event numbers that the marked events correspond to - A column/vector of values (same
number as ME)")
  if(TNE < length(ME)) stop("Supplied marked events is greater than the TOTAL number of events")
  if(max(TEN, na.rm = TRUE) > TNE) stop("Supplied Total event number is larger than the TOTAL number of events in the DDMT source file")
  if(length(TEN) != length(ME)) stop("Supplied Total event number should match length of the the supplied marked events")
  if(any(duplicated(TEN) == TRUE)) stop("There are duplicated total event numbers")

  myfile <- file(paste0(getwd(),"/", filename , ".gme"), "wb") # Create and open the connection with the .gme file using your set working directory
  TNE <- as.integer(TNE)
  ME = ifelse(is.na(ME)== TRUE, 0, ME) #Replace NA values with zeros

  #First 4 bits, zeroes
  x<-as.integer(0)
  writeBin(x, myfile, size = 4)
  writeBin(TNE, myfile, size = 4) # Add size of file as 4 byte value

  #Fill in the 'gaps' if data analysed in R is a subset or under-sampled version of the DDMT source file
  #E.g., If supplied TEN is not the same as increment (by one) values from one to TNE
  TNE = as.integer(rep(1:TNE))
  TEN = as.integer(TEN)
  suppressWarnings(if(any(as.logical(TEN == TNE) == FALSE)) { cat("ooo, we have a mismatch in event number from original source file - No probs brahh, I got ya
back!")
    #Paste the marked event value at the indexed location of TNE, when TNE = TEN
    ME <- ifelse(TNE %in% TEN, ME[match(TNE, TEN)], 0)
  })

  x <- as.integer(ME) # Set the "marked.events" column as integer (cannot write decimal numeric in 1 byte)
  writeBin(x, myfile, size = 1) # Write the marked event data must be 1 byte integers (size = 1)
  close(myfile) # Close the connection
}

#Example
setwd("C:/Users/Richard/Desktop")
Global.ME(TNE = 34805106, ME = df$Marked.event, TEN = df$Total.Event.no., filename = "Global.marked.events")
```

Bitwise layers

Bitwise Layers is a feature that allows for the storage of multiple ***Marked Events*** by copying or merging them across to 1 of 16 different bits within the ***Bitwise*** channel.

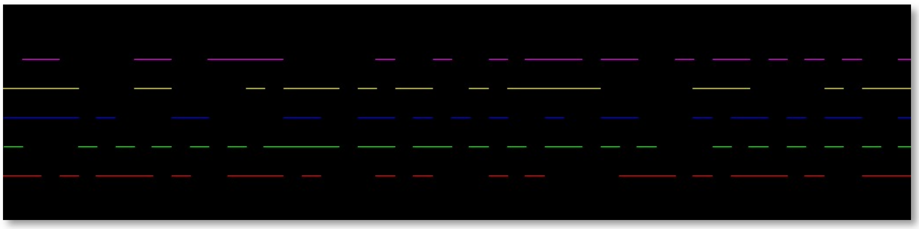


Figure 5.14 ***Bitwise Layers*** *on the* ***2D graphing window***

If the primary DDMT source file comes from a conversion app, it may contain a ***Bitwise*** channel with embedded info ('1's and '0's)

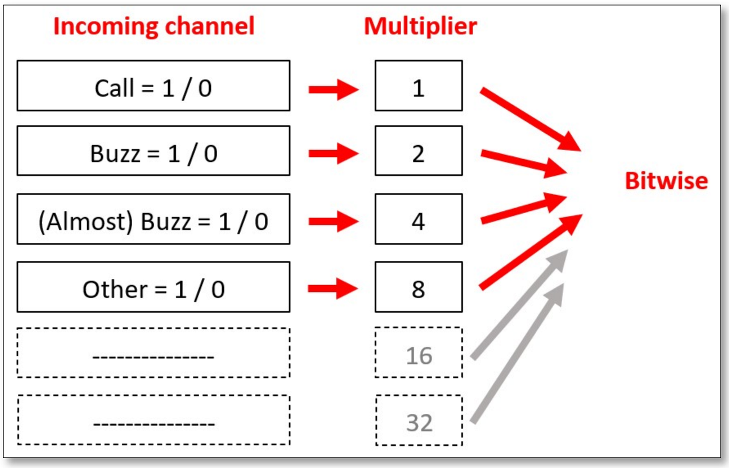


Figure 5.15 *5 Creation of the* ***Bitwise Layers*** *using an external app to merge multiple channels into one. Each channel is multiplied by a power of 2 (from 0-15) so that when they combine, no information is lost/merged*

Slider controls are available on the ***2D sliders*** tab that allow the vertical offset on the ***2D graphing window*** and their relative vertical separation from each other.

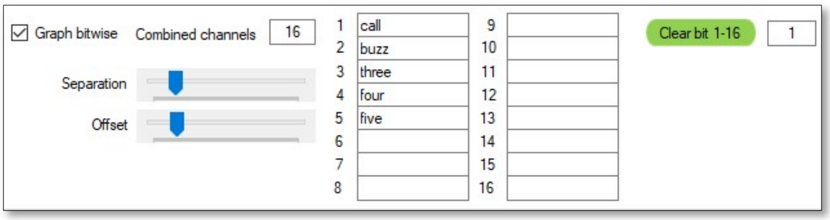


Figure 5.16 *Controls for the* ***Bitwise*** *channel on the* ***2D graphing window***

The ***Combined channels*** box limits how many channels are graphed on the 2D window.

The 16x text boxes are labels for the ***Display overlay*** on the 2d window. They are also filled (to the number of channels) if the primary DDMT source file has embedded ***Bitwise*** channel data, from the column headers.

The ***Clear bit 1-16*** button will clear down and ***Layers*** in the ***Bitwise*** channel, although any channels embedded within the source file will not be cleared; they're locked out from any change.

The ***Bitwise*** channel's ***Layers*** can be used as part of an expression in the ***Behaviour Builder***. For instance, in the figure below, the Bitwise has been selected as part of the expression.

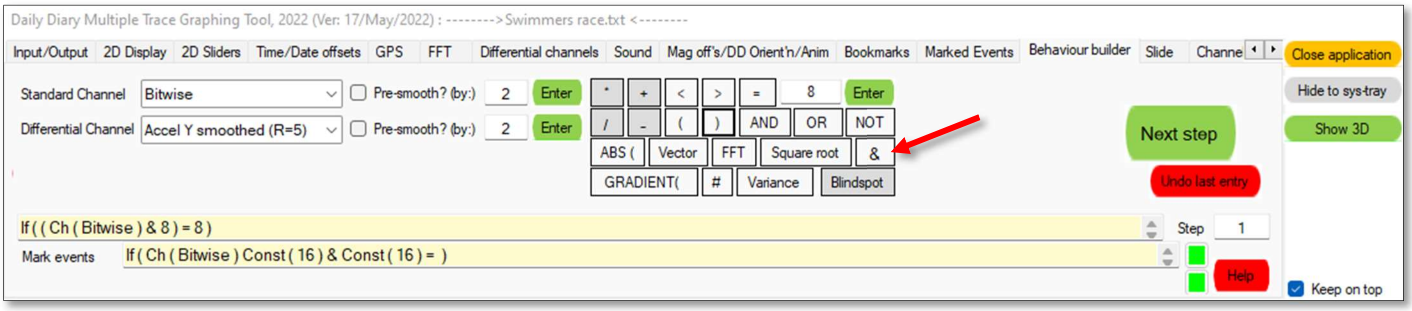


*Figure 5.17 The **Bitwise** channel requires the use of the ampersand '&' to mask out specific bits within the channel*

An example expression using the ***Bitwise*** channel might be:

If ((Ch (Bitwise) & 8) = 8) then Mark Events

would ***Mark Events*** for any data point that had a '1' in the 4th ***Layer*** of the ***Bitwise*** channel (as 2^3 = 8, while counting in powers from 0), while

If ((Ch (Bitwise) & 10) = 10) then Mark Events

would ***Mark Events*** for any data point that had a '1' in the 2nd and 4th ***Layers***. Using this expression would also mark any data points that had other layers. The "& 10) = 10" acts as a mask, ignoring the presence or absence of other ***Layers*** within the ***Bitwise*** channel.

Note that the ampersand is equated to the value of the power of $2^{(Layer-1)}$, not the Layer value i.e., to filter out the 4th ***Layer***, one would equate to 2^3 = 8. Layer values 1-16 would therefore be equated to 1, 2, 4, 8, 16, 32, 64, 128 (for layers 1-8), and 256, 512, 1024, 2048, 4096, 8192, 16384, 32768 (for layers 9-16) respectively.

Such an expression, using the ***Bitwise*** channel, could be combined with other channels such as:

If (((Ch (Bitwise) & 24) = 24) AND (Ch (Pressure sm) < 984.23)) then Mark Events

Note that the two parts of the expression are both enclosed in their own bracket structure, and a logical ***AND*** separating them. This level of bracketing is required for the breakdown/translation (by DDMT) of the expression.

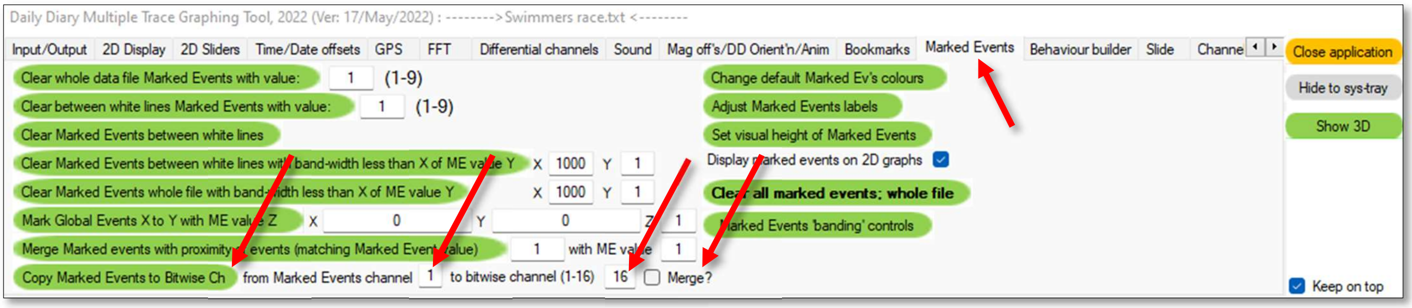


*Figure 5.18 Controls for copying/merging **Marked Events** into a **Layer** in the **Bitwise** channel*

The presence of ***Marked Events*** of a particular value can be copied across into any ***Layer*** within the ***Bitwise*** channel. In the above (Figure 5.10), clicking ***Copy MEs to Bitwise*** would copy (overwrite the entire ***Layer***) from the ***Marked Events*** channel values of 1, into ***Layer*** 16 (2^{15} = 32768 / e.g. ***If ((Ch (Bitwise) & 32768) = 32768) then Mark Events***). "Globally" (across the entire data file) ***Marked Events*** of value 1 will be entered into ***Bitwise Layer*** 16. If a Marked Event is '0' or any other value, then the ***Bitwise Layer*** bit will be set to '0'.

If ***Merge*** was ticked prior to clicking the ***Copy MEs to Bitwise*** button, then only data points within the ***Bitwise Layer*** where a ***Marked Event*** was =1 would be set to '1' in the ***Layer***.

The global (across all ***Splits***) ***Bitwise*** channel (containing all 16 ***Layers***) can be exported to a file (.gbw) by clicking ***Export Global Bitwise channel data*** button on the ***Input/Output / File output/Save*** tab:

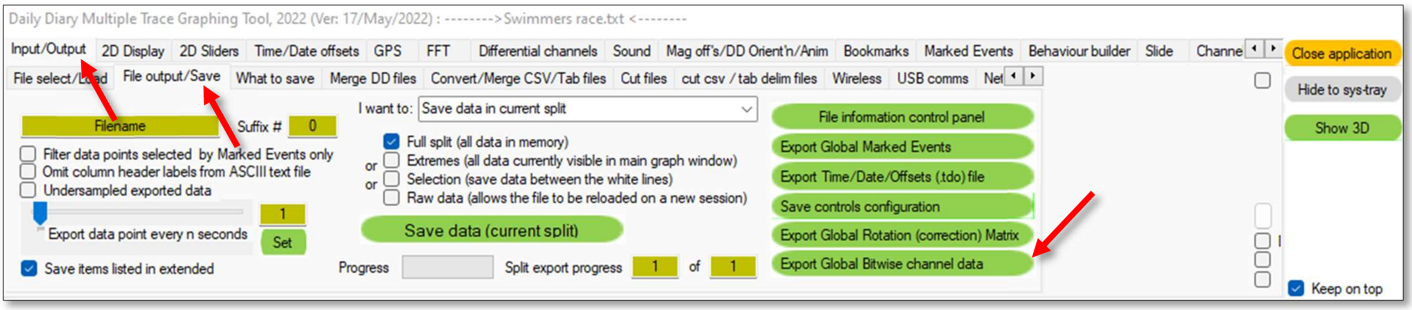


Figure 5.19 ***Export Global Bitwise channel data*** *button on the* ***File output/Save*** *tab*

While a file containing the global ***Bitwise*** channel data (from a previous session with this primary DDMT source file) can be reimported by clicking the ***Load Global Bitwise matrix*** button on the ***File select/Load*** tab.

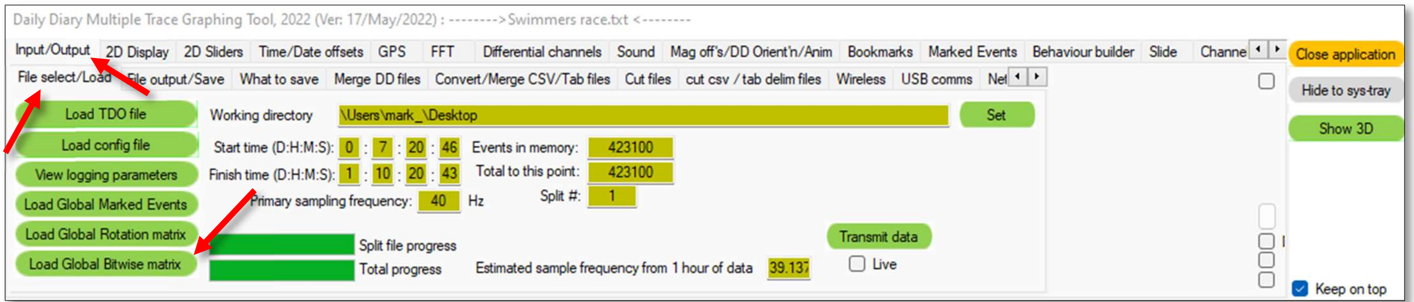


Figure 5.20 Load Global Bitwise matrix *on the* ***File select/Load***

The presence of '1's within a particular ***Layer*** can be viewed, along with the ***Layer***'s label, by ticking the ***Bitwise*** checkbox on the ***Overlay selection*** tab. The ***Layer***'s labels will be displayed for both the left and right white mouse lines:

Figure 5.21 *Labels are displayed on the* ***Overlay*** *for any layers containing a '1' at the position of the left/right white lines*

The ***Bitwise*** channel information can be exported by selecting the ***Bitwise*** check box on the ***What to save / Additional*** tab. Every data point will then show all 16 ***Bitwise*** channels, with the channel labels as defined on the 2D ***Bitwise*** controls tab, with the data either being a ‘1’ (present), or a ‘0’ (not present).

1	Event no.	Bitwise 1 Call	Bitwise 2 Buzz	Bitwise 3 Three	Bitwise 4 Five	Bitwise 5	Bitwise 6	Bitwise 7	Bitwis
454	165972	1	0	1	1	0	0	0	
455	165973	1	0	1	1	0	0	0	
456	165974	1	0	1	1	0	0	0	
457	165975	1	0	1	1	0	0	0	
458	165976	1	0	1	1	0	0	0	
459	165977	1	0	1	1	0	0	0	
460	165978	1	0	1	1	0	0	0	
461	165979	1	0	1	1	0	0	0	
462	165980	1	0	1	1	0	0	0	
463	165981	1	0	1	1	0	0	0	
464	165982	1	0	1	1	0	0	0	
465	165983	1	0	1	1	0	0	0	
466	165984	0	1	1	0	0	0	0	
467	165985	0	1	1	0	0	0	0	
468	165986	0	1	1	0	0	0	0	
469	165987	0	1	1	0	0	0	0	
470	165988	0	1	1	0	0	0	0	
471	165989	0	1	1	0	0	0	0	
472	165990	0	1	1	0	0	0	0	
473	165991	0	1	1	0	0	0	0	

Figure 5.22 *Exported* ***Bitwise*** *channel data showing the presence ‘1’ or absence ‘0’ of data in each bit layer*

6. Bookmarks

Manually creating bookmarks on the *2D graphing windows*

Bookmarks highlight user-defined sections of data which can be saved and reloaded later. Bookmarks can be created manually by placing the two white lines either side of the data, and then simultaneously left and right mouse-clicking in the second box along at the top of the main graphing window where it is labelled ***Bookmark Selection***. The selected data are then highlighted with two blue lines denoting the start and end points and the bookmarked area showing a grey background. Collections of bookmarks can be saved to file (***.bmk***) and reloaded during a later session. As the cursor is moved over a bookmark in the ***drawing*** window, event limits, category, and bookmark number are displayed beside the cursor in yellow (Figure 7.1). This can be switched off by deselecting the tick box labelled ***Show bookmark tags*** on the ***Bookmarks*** tab. Multiple bookmarks may be created throughout the entire data file, within any / all of the splits. Moving from one split to another will refresh the data view and reveal any bookmarks previously created within that split.

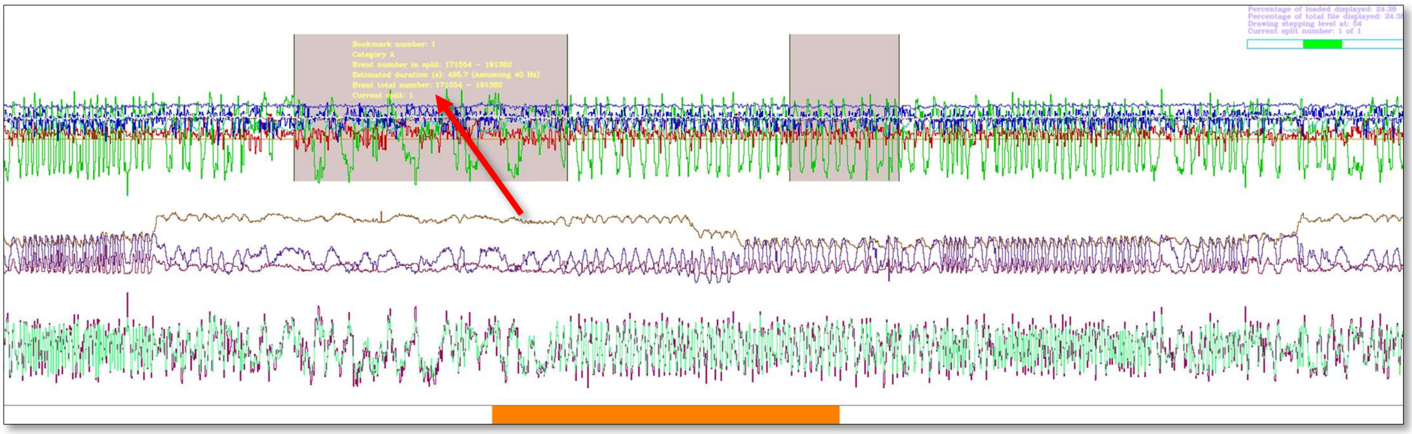


Figure 6.1 *Selecting data and bookmarking; bookmark information is displayed on each bookmark as the cursor moves over it showing start/stop event numbers, category name, bookmark time width (s), and split#.*

Categories

After selecting the ***Bookmarks*** tab, a drop-down box will show the bookmarks that have been created this session numbered/ordered chronololgically (not necessarily the order in which the bookmarks are created). Note that ***Bookmarks*** "inherit" the currently selected category. Once a bookmark is selected, its category can be changed to any one of 14 different labelled categories, allowing sections of data to be reclassified. To change the currently selected category, use the second drop-down menu in the centre of the ***Bookmarks*** tab and then click the adjacent green ***Set*** button.

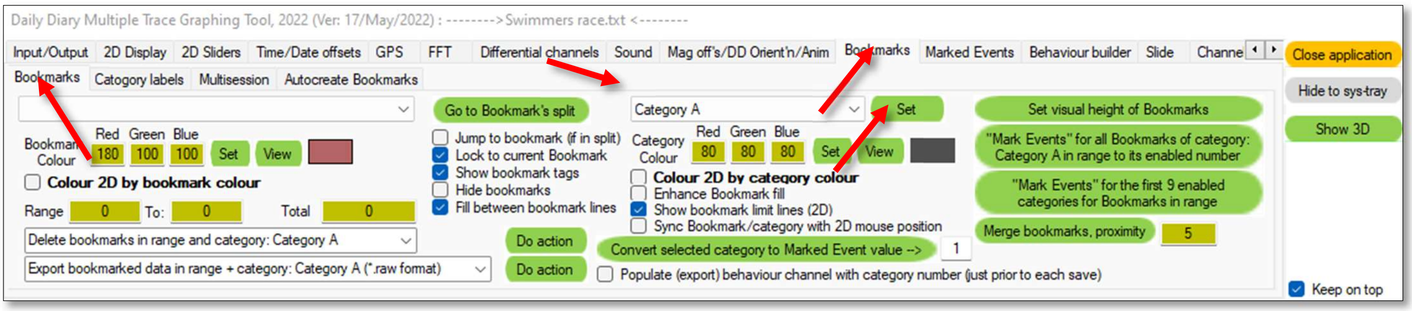


Figure 6.2 *The drop-down box for selecting categories is indicated by the red arrow.*

Renaming categories

Category names can be changed to anything from the default ***Category X***. Category names will also be stored within the exported *.bmk* file. To rename categories, navigate to the ***Bookmarks/Category labels*** sub-tab. Click on the text box corresponding to the category you would like to rename and type the new name in its place. Click the ***Update categories using list*** button to save the new labels.

Note that the checkboxes on this tab allow each category to be added or removed from both the 2D and 3D graphing environments. By default, each category label is enabled in both 2D and 3D.

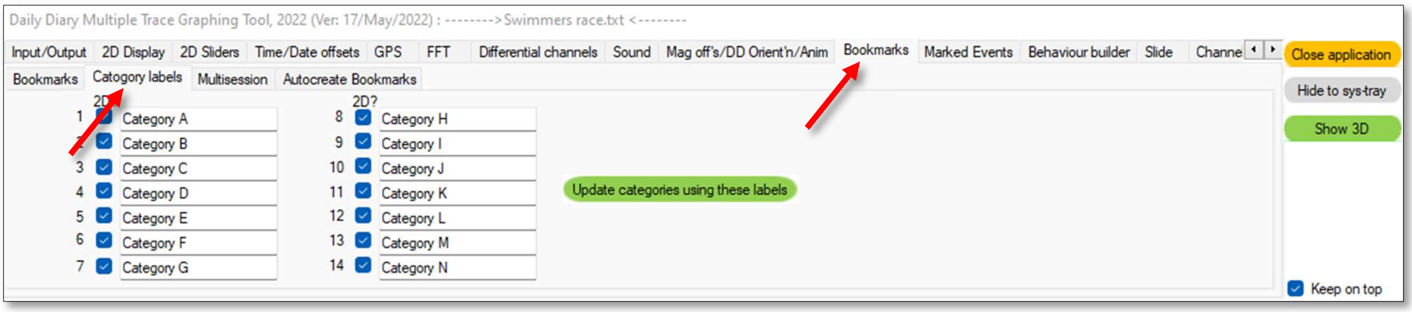


Figure 6.3 *Setting new category labels*

Adjusting the vertical height of the bookmark bands

By default, the vertical height of the bookmark bands is from the top to the bottom of the ***2D graphing windows***, but this can be changed to suit the data on display by holding down ***Ctrl*** and ***Alt*** and using the left and right mouse buttons to place the two horizontal lines and clicking ***Set visual height of bookmarks***. The placing of these defines the top and bottom limits of the bookmarks.

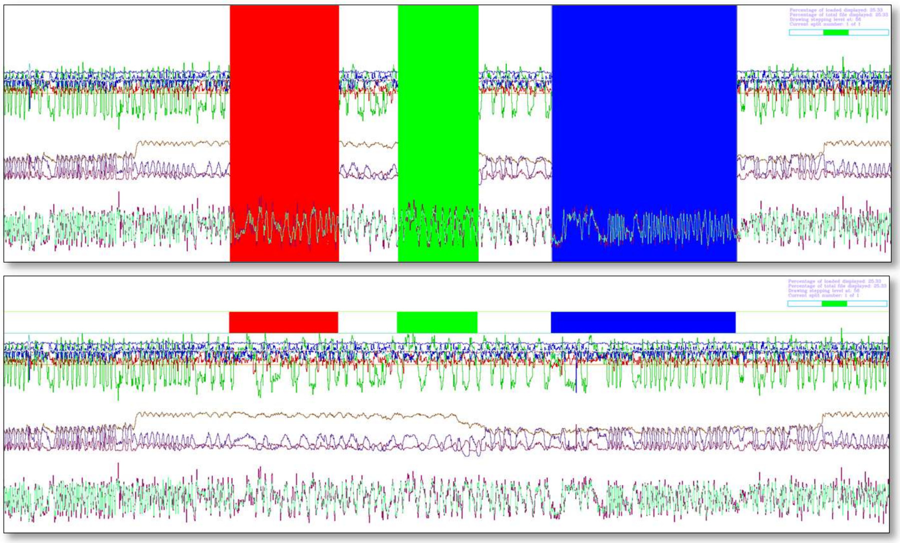


Figure 6.4 *Adjusting the top/bottom height limits of the bookmark bands*

Save/load *.bmk* files

Load bookmarks loads previously saved bookmarks into the original data file from which they were exported. ***Save bookmarks (.bmk + .txt)*** saves the current bookmarks in your DDMT file as both text and .bmk files. The .bmk files enable you to reload previously defined bookmarks into DDMT again during future sessions, while the text files can be used for inspection or analysis in other programmes such as Excel and R.

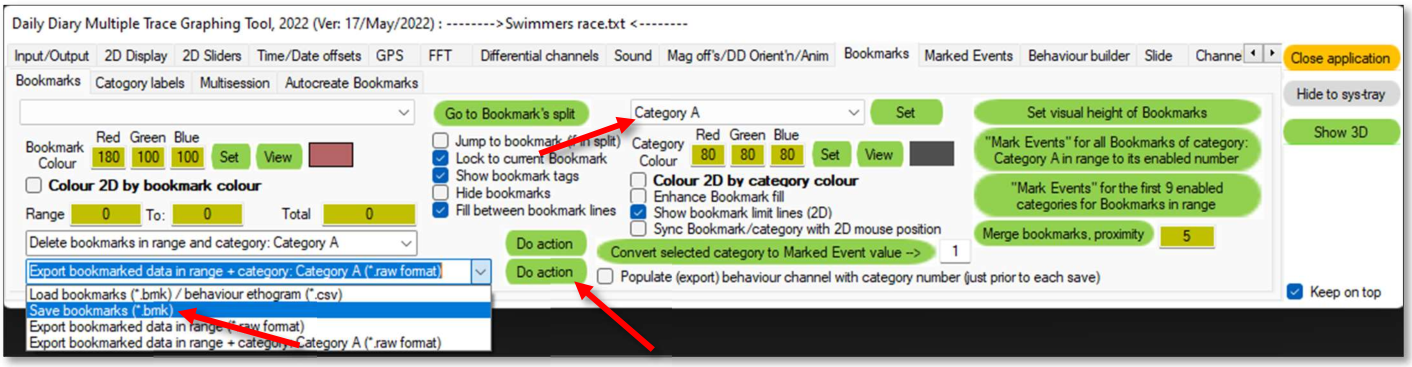


Figure 6.5 Saving and loading .bmk files

Export .raw files

Export bookmaks in range (raw) exports all the data from bookmark **X** to bookmark **Y**, where **X** and **Y** are the values in the two textboxes above this button, as a single .raw file that can be reloaded into DDMT. Note that the bookmark markers will be maintained, showing the separate sections of data. ***Export in range and category (raw)*** exports all bookmarked data that matches the category selected in the drop down menu (as indicated in Figure 6.5).

Convert Bookmarks to Marked Events

Use the ***Mark events for selected bookmark of category X in range to its enabled number*** button to quickly mark all events in all bookmarks of the currently selected category. When working with multiple categories, ***Mark events for enabled categories 1-9 between bookmarks*** can be used to mark all events in all bookmarks, with each category represented by a separate colour. If the user wishes to convert bookmarks of 10-14, then at least 5 earlier categories must be disabled, leaving 9 remaining.

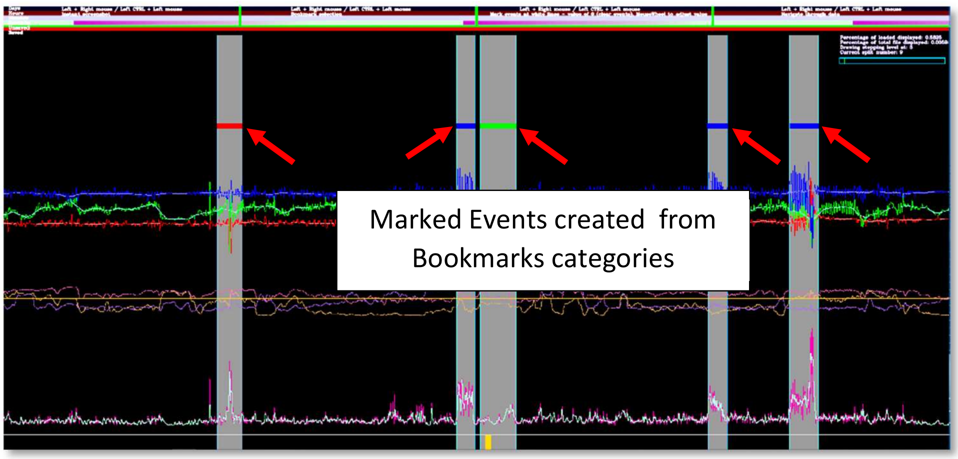


Figure 6.6 Marking events where each bookmark category has a distinct colour

Delete bookmarks

The delete functions are listed in the second column of the ***Bookmarks / Bookmarks*** tab. ***Delete all bookmarks*** deletes all bookmarks currently in file while ***Delete current*** only deletes the currently selected bookmark. Alternatively, the user can delete specific bookmarks by their size, range or category. ***Delete bookmarks < size*** deletes bookmarks below a certain number of events, which can be set in the adjacent box. ***Delete bookmarks in range*** deletes bookmarks **X** to **Y** in the yellow ***Range*** boxes. ***Delete bookmarks in range / category*** deletes bookmarks which are included in the currently set ***Range*** and match the set cateogory in the adjacent drop-down list.

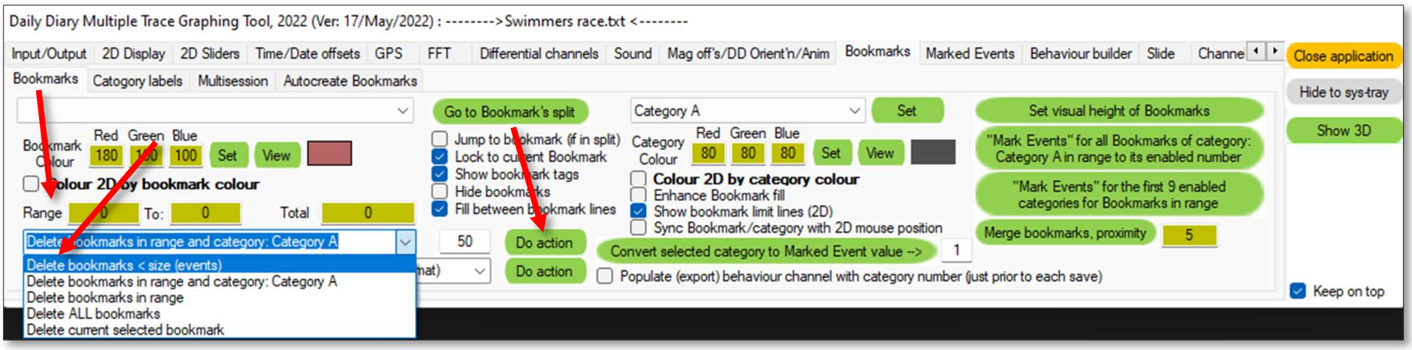


Figure 6.7 *Deleting bookmarks in range and category*

Additional bookmark options

Merge bookmarks, proximity merges two bookmarks in close proxmity to create one larger boomark. Proximity is defined as being the number of events between the end of one bookmark, and the start of the next

Colour 2D by bookmark colour each bookmark can have its own individually assigned colour with RGB value 0-255. Enter these colour values in the boxes and click Set to assign these values

Colour 2D by category colour colours the bookmark to colours set for that category, which can be customised by adjusting the values in the ***Category Colour*** boxes, then using ***Set*** and ***View*** (separately for each category using the categories drop-down menu)

Lock

Jump to bookmark enables navigation to whichever bookmark is selected in the bookmark drop-down menu (if within the currently loaded split). This zooms in on the bookmark

Sync bookmark and category with mouse

when selected will update bookmark and category drop-down lists to match any bookmark that the mouse moves over in the 2D graphing windows

Enhance banding improves the contrast of the bookmarks on the black background

Fill between bookmark lines controls whether the area between the bookmark limits is shaded or not

Go to bookmark's split navigates to the split containing the bookmark currently selected in the bookmark drop-down menu

Populate behaviour channel adds bookmark behaviour categories as a column in exported *.txt* file data (ASCII format) per event

Show bookmark tags turns the information about the bookmark visible in yellow writing on and off

Show bookmark limit lines (2D) toggles the visibilty of the bookmarks start/stop boundary lines on / off

Hide bookmarks allows all bookmarks to be hidden from the 2D "Main graphs" window

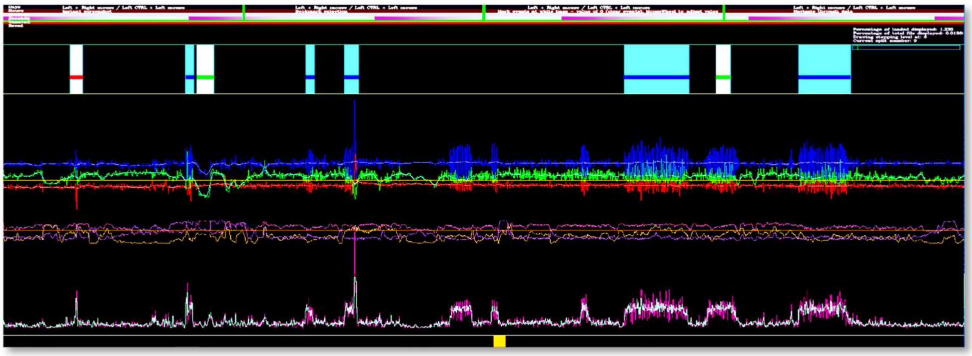


Figure 6.8 *Bookmarks with marked events, adjusted visual heights and custom colours by category*

Behaviour ethogram files

Behaviour ethogram files can be created and loaded into DDMT to create bookmarks based on lists of behaviours where behavioural observations have been conducted. Lists of observations should include the date, time and duration of the behaviour in seconds and behaviour category as a value. DDMT will then search for a match based on the start time and date, note the duration as width (seconds), and create bookmarks (by category per line) where appropriate.

Behaviour ethogram files only work when the format matches that shown in Figure 6.8 i.e. *DD/MM/YYYY* and *HH:MM:SS*, as DDMT looks to specific cell positions for the information it requires to create bookmarks. The cells shown in grey in Figure 6.8 should be copied exactly in the new file, in terms of both cell content and position. The ***Red / Green / Blue*** value columns (C-E) can be any value from 0-255 to allow custom colours for each category. The ***type*** column (A) allows category labels to be named, which are applied adopted by the category name lists in DDMT.

If using ***R*** to create this list, when you use *write.table*, ensure you add command *command = I.e.. write.table(df, “xxx”, quotes= FALSE)* else the date and time column data will have quotes (Excel won’t show these) and DDMT may refuse to load the data.

Two different formats exist to the user for creating ethograms.

Either ***Date, Start, Duration,*** and ***Behaviour*** (with ***Events width*** set to zero)

date	start	duration	behavior	decimal	events width
01/02/2017	08:42:11	55	1	0.15	0
01/02/2017	08:42:21	177	2	0.85	0

Figure 6.9 *Bookmarks with marked events, adjusted visual heights and custom colours by category*

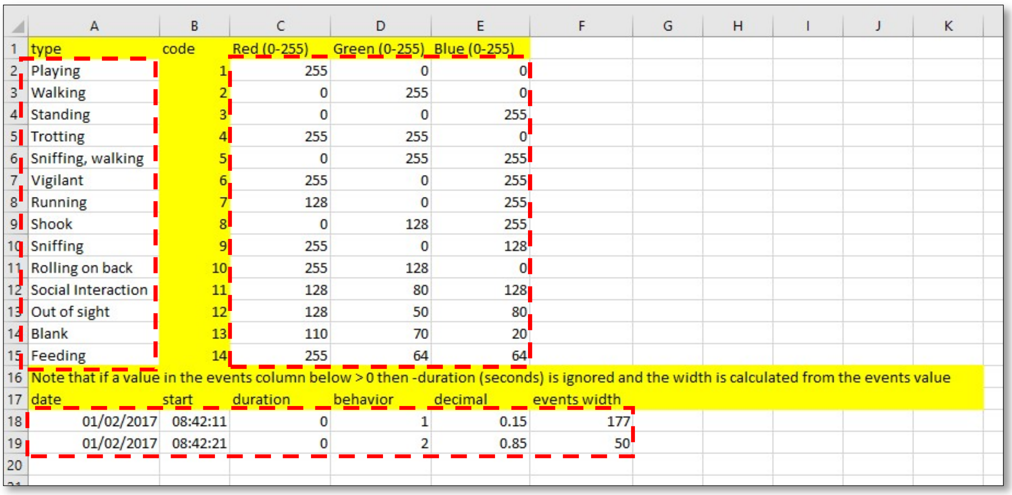
This will create ***Bookmarks*** to the second with duration in seconds (events width must be zero for the software to recognise this is the format required). Decimal seconds will be used as best it can. In Figure 6.9, the start times would be taken as being 08:42:11.15, and 08::42:21.85. The duration values can also be decimalised, with carry-over from the start time’s decimal value i.e. 08:42:21.55 with duration of 2.5 seconds, would result in the bookmark stop being set at 08:42:24.05 seconds.

Or, ***Date, Start, Behaviour, Decimal,*** and ***Events width*** (with ***Events width*** being >0, the software recognises that the ***Duration*** channel is to be ignored and that the width of the ***Bookmark*** will be in ***events*** not seconds.

date	start	duration	behavior	decimal	events width
01/02/2017	08:42:11	55	1	0.15	55
01/02/2017	08:42:21	177	2	0.85	177

Figure 6.10 *Bookmarks with marked events, adjusted visual heights and custom colours by category*

Here, decimal seconds is considered. The ***Bookmarks*** *in the above data will start at approximately 08:42:11.15 and 08:42:21.85s and will be 55 and 177 events wide respectively.*



	A	B	C	D	E	F
1	type	code	Red (0-255)	Green (0-255)	Blue (0-255)	
2	Playing	1	255	0	0	
3	Walking	2	0	255	0	
4	Standing	3	0	0	255	
5	Trotting	4	255	255	0	
6	Sniffing, walking	5	0	255	255	
7	Vigilant	6	255	0	255	
8	Running	7	128	0	255	
9	Shook	8	0	128	255	
10	Sniffing	9	255	0	128	
11	Rolling on back	10	255	128	0	
12	Social Interaction	11	128	80	128	
13	Out of sight	12	128	50	80	
14	Blank	13	110	70	20	
15	Feeding	14	255	64	64	
16	Note that if a value in the events column below > 0 then -duration (seconds) is ignored and the width is calculated from the events value					
17	date	start	duration	behavior	decimal	events width
18	01/02/2017	08:42:11	0	1	0.15	177
19	01/02/2017	08:42:21	0	2	0.85	50
20						

Figure 6.11 *Behaviour ethogram file format, cells in yellow must be included exactly as shown. Do not delete/alter them*

As an example, after loading the main daily diary text file and setting the time and date (either manually or using a *.tdo* file), use the ***Load bookmarks*** function on the ***Bookmarks*** tab (Figure 6.12).

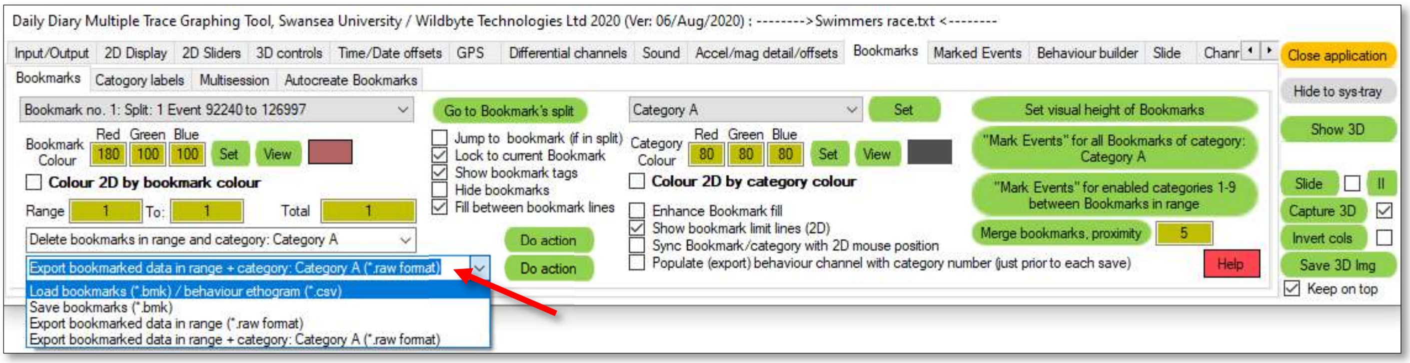


Figure 6.12 *Select the first in the list and click* ***Do action*** *to load the ethogram*

A window will open allowing the user to select the relevant file. Change ***Files of Type:*** to ***Behaviour ethogram files (.csv)*** and select your file (Figure 6.13). After loading the behaviour ethogram file, a pop-up window will confirm the number of successful bookmarks loaded and the number which have failed to load, if applicable. This is when it may be helpful to use the ***Console***.

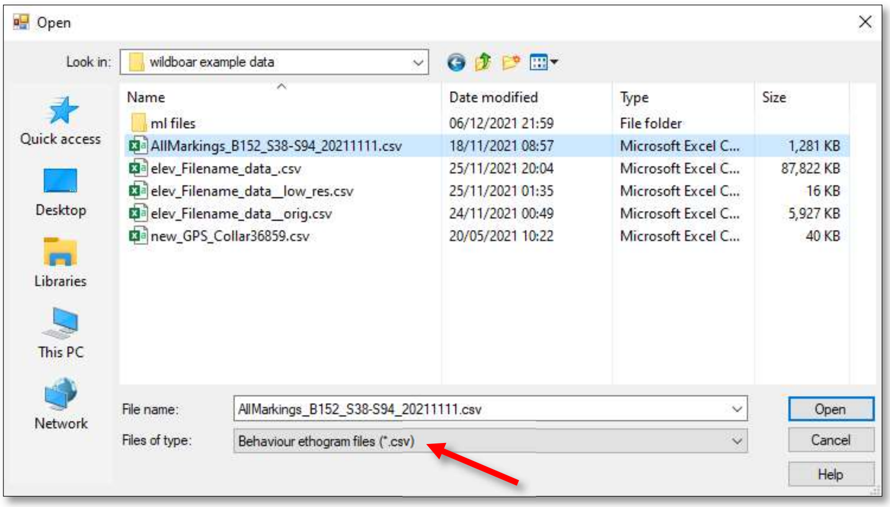


Figure 6.13 *Select your file, ensuring you have selected the correct file type*

DDMT will search for a time match for each ethogram line, add the duration in seconds and create a bookmark at that point for the noted behaviour category. The blue bookmark limit lines will not appear and the ***Colour 2D by category colour*** will be enabled by default. The bookmarks will fill the entire screen height initially, but the visual height can be manually adjusted as outlined above, ***Adjusting the vertical height of the bookmark bands***. All bookmarks will be automatically added to the bookmark drop-down menu on the ***Bookmarks*** tab, including split and event numbers.

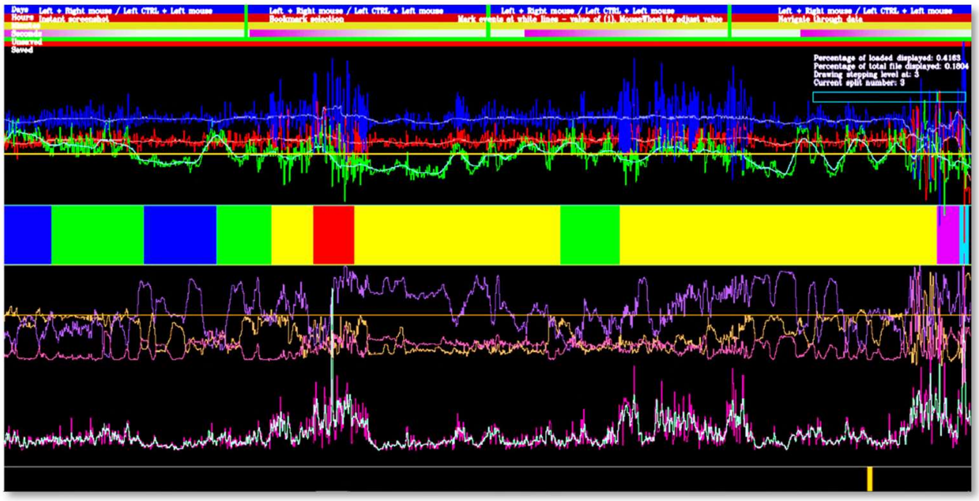


Figure 6.14 *Bookmarks created by a behaviour ethogram file, with visual height of the bookmarks adjusted to a central band*

Note that Behavioural ethogram files do not need to cover the whole span of time; gaps in the timeline are allowed i.e., gaps in behaviours are allowed.

An additional format of ethogram is possible, where behaviours have been identified by an external algorithm, perhaps machine learning for example. In this format, on 4 pieces of information are required for the time entries. The first column <u>must</u> be ***999***, the second and third columns represent the ***total event number start/stop*** respectively within the full file, and the last column is the behaviour identifier (category 1-14) as with the other ethogram formats. Again, gaps in the timeline are allowed.

	A	B	C	D	E
1	type	code	Red (0-255)	Green (0-255)	Blue (0-255)
2	Cont Walk	1	255	0	0
3	Foraging	2	0	255	0
4	NULL	3	0	0	0
5	Other	4	255	255	0
6	Resting	5	255	0	255
7	Rooting	6	0	255	255
8	Running	7	255	128	0
9	Standing	8	0	0	225
10	Trotting	9	128	0	180
11	Vigilance	10	225	225	225
12	B	11	128	80	128
13	C	12	128	50	80
14	D	13	110	70	20
15	E	14	255	64	64
16					
17	NA	start	stop	behavior	
18	999	126491399	126491412	3	
19	999	126491413	126494922	2	
20	999	126494923	126494973	4	
21	999	126494974	126495049	1	
22	999	126495050	126495072	4	

Figure 6.15 *Machine Learning (ML) ethogram format*

Multisession (*data export*) of bookmarked data

A ***Bookmark Multisession*** is a file containing ASCII data from one or more ***Bookmarks***. The columns contained within this file (partially named Master data file) are primarily dictated by the selection criteria in the ***Input / Output / What to save*** tab. Accompanying this Master data file is a Header file with a single entry per ***Bookmark*** of data in the Master data file that denotes where each ***Bookmark***'s data starts and how many lines of (events) it has, along with other statistical information per ***Bookmark***. This ***Multisession*** function is a quick way of exporting data that is of relevance/interest, perhaps containing only one type of behaviour, for analysis in another software package.

Multisession is controlled from the ***Bookmarks / Multisession*** tab where the user can select the parameters of interest (of each Bookmark) to be exported in the Header file in the blue box, Figure 6.16. These parameters include maximum and minimum values, means, medians, standard deviations, variances, and ranges, as well as event times and dates. The ***Header summaries only (no master data file)*** checkbox controls whether an optional Master file is exported along with summaries i.e., sometimes it is not required to generate the Master data file, only the summary Header file.

To begin the multisession, click ***Initiate BM multisession (text/column)***. A pop-up window will appear with the message "Bookmark Multi-session initialised." Clicking ***OK*** will bring up a second pop-up window stating, "Stop BM Multi-session to re-show Close application button." Notice that on the DDMT ***Graphing Tool***, the orange ***Close application*** button is no longer visible, and the ***Initialise BM multisession (text/column)*** button now reads ***Stop BM multisession***.

Create bookmarks as normal. Use ***Save bookmarks in range to multisession*** or ***Save bookmarks in range + categ to multisession*** to export only bookmarks that have the currently selected Category and in the numbered range shown in the two boxes on the primary ***Bookmarks*** tab. Remember to click ***Stop BM multisession*** when finished, after file export is complete.

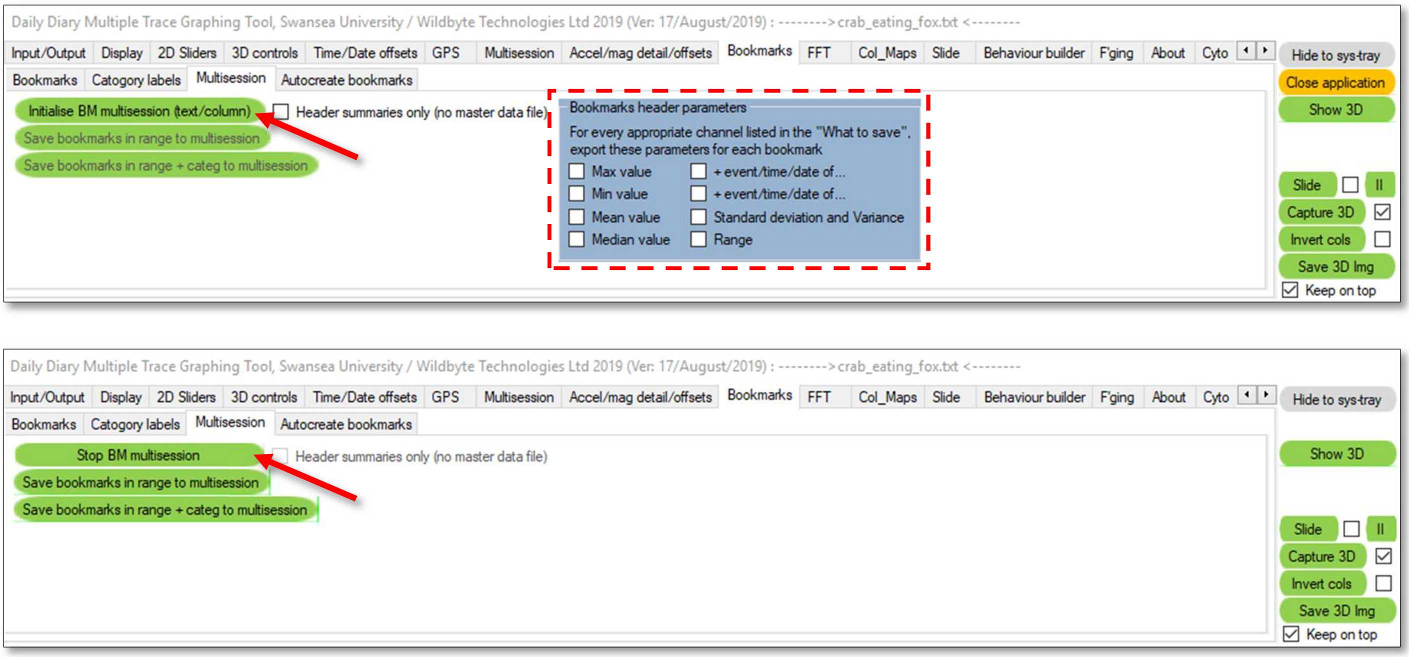


Figure 6.16 ***Bookmarks/Multisession*** tab before and after initialising the session

Auto-create bookmarks

Bookmarks can be created automatically for regular time periods throughout the whole file on the ***Bookmarks/Autocreate bookmarks*** tab. The ***Minutes per bookmark*** drop-down menu allows the user to select a 1-60 minute time period. Place the left white limit line (left mouse click) at the desired start point and click ***Create bookmarks from left white line of this length*** to create bookmarks for the specified time period from this start point to the end of the file (bookmarks created across splits in larger files). Alternatively, use ***Autocreate bookmarks in split for Marked Events 1-9***.

Note that the time the first bookmark begins at the next boundary of "*seconds = 0*" from where the left white line has been placed (this was just algorithmically more simple to program!).

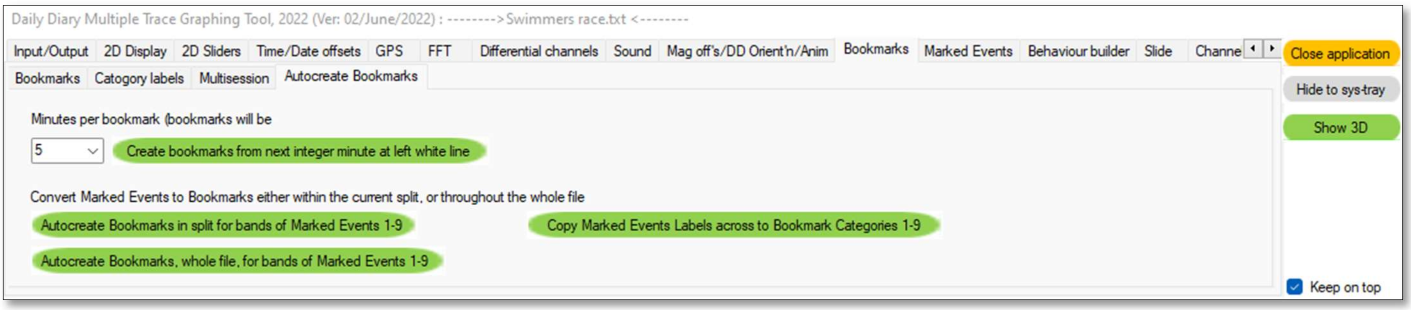


Figure 6.17 ***Autocreate bookmarks*** tab

There is the additional button to copy the text from the Marked Events labels tab across to the Bookmarks labels tab, to save some typing.

Auto-create bookmarks in split for Marked Events

The user may have bands of ***Marked events*** within the split, or even perhaps in other splits, and might prefer to have these as ***Bookmarks*** in order to take advantage of the ***Multisession*** function that provide summary statistics of the data contained within each ***Bookmark***. By clicking ***Autocreate bookmarks in split for Marked Events 1-9*** (for only ***Marked events*** within the currently loaded ***Split***), or ***Autocreate bookmarks, whole file, for Marked Events 1-9***, contiguous banks of ***Marked Events*** (contiguous being every event and of the same ***Marked event*** value) a ***Bookmark*** will be generated around them.

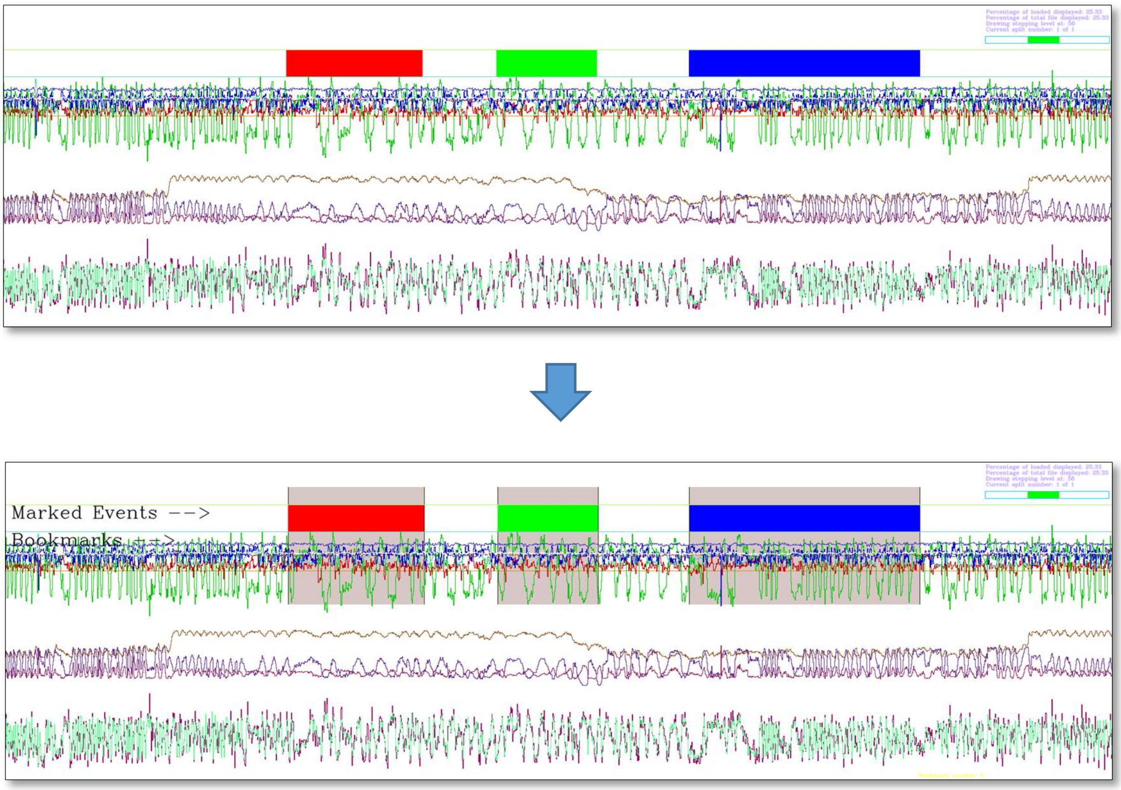


Figure 6.18 ***Autocreate bookmarks*** *by converting* ***Marked Events*** *to* ***Bookmarks***

7. Tilt-Compensated Compass / setting device orientation

The magnetometer and accelerometer on the Daily Diary can be combined to create a tilt-compensated compass. This means the accelerometer corrects the magnetic compass heading when the Daily Diary is tilted from the horizontal such that, when turning in a circle, from a plan-view, the magnetometer data would generate a circle as opposed to an ellipse. Circular magnetic data allows the generation of heading, while an ellipse would be a distortion of this.

Knowing the actual orientation of the Daily Diary relative to the ground can be helpful, but not essential, in informing DDMT which axis should be used to calculate pitch and roll respectively, and which axes are the most important to determine compass heading.

To correctly determine magnetic heading, your data must first be offset-corrected, achieved by following the steps outlined in chapter 3. This brings the bulk of the magnetic data to sit around the 0,0,0 origin.

Once the magnetic offsets have been corrected, click the ***Show 3D*** button on the right side of the control panel and right-click in the view and select ***Device Orientation*** near the bottom of the list (inset). This will then show a simplified image of the ground, and a forward pointing light-green triangle. The data logger hovering above here can be switched between the Square (as below), the Elongated, the Thumb, or the Alice.

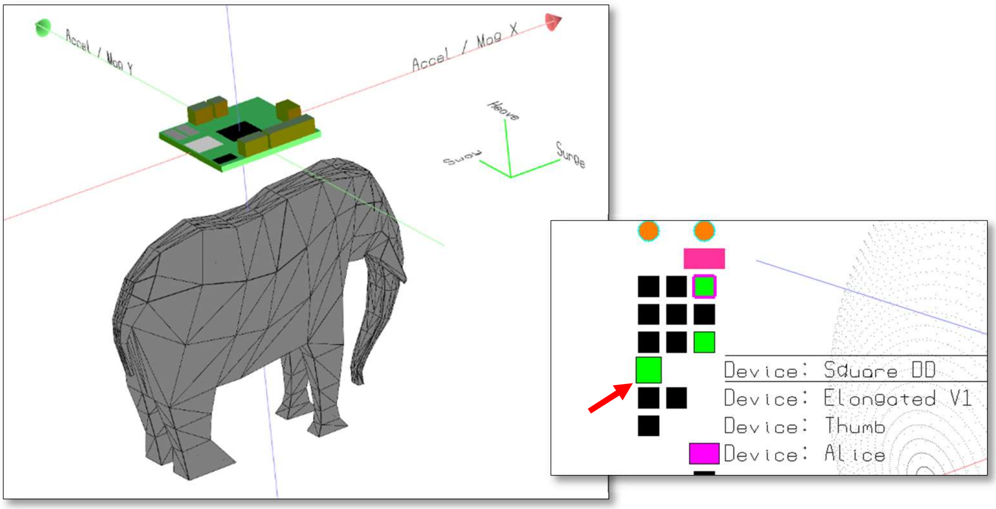


Figure 7.1 *Setting Daily Diary orientation, device selection*

The 5th button down in the third menu column allows the user to flick with the mouse wheel through all 24 possible orientations (perpendicular to the ground). The visual of the selected logger will orient itself accordingly. The user must left click this button to confirm the selection.

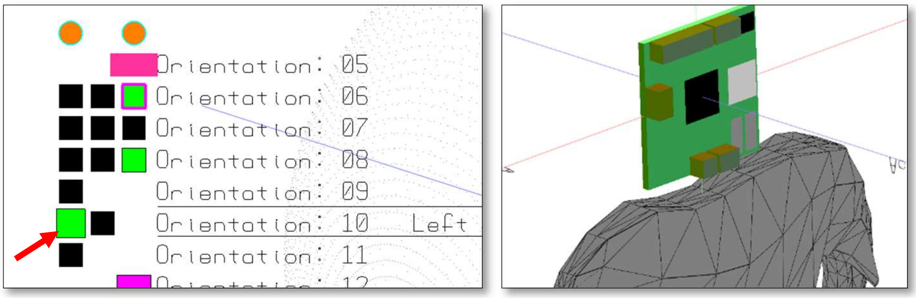


Figure 7.2 *Logger orientation selection*

Once confirmed, the magnetometer axes adjustments and pitch/roll accelerometer axes selections will be input into the DD Orientation tab interface, and heading, pitch, and roll etc. will all be calculated based on this preference.

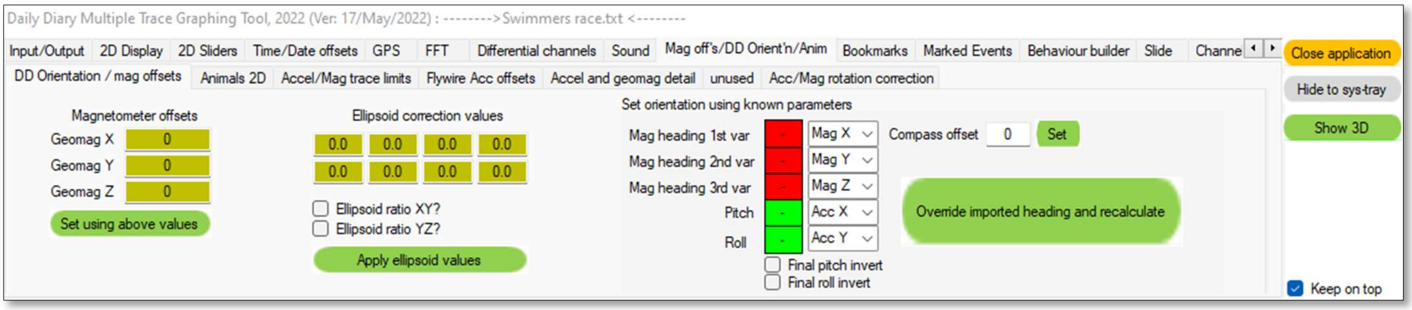


Figure 7.3 Manual orientation controls. The settings are automatically set through the 3D Device Orientation visual but can also be used to set the parameters required for other manufacturer's device's data streams.

The ellipsoid correction values are for manual entry should they be obtained from another data file and the use of the magnetometer offset correction algorithm.

Any visualisations using heading, pitch, or roll, including the 2D graphs will update after they've been recalculated.

To save your magnetic heading data, click on the ***Input/Output*** and go to ***File output/Save***. Ensure ***Magnetic heading*** is selected o the ***What to save/Additional / metrics channels*** sub-tab.

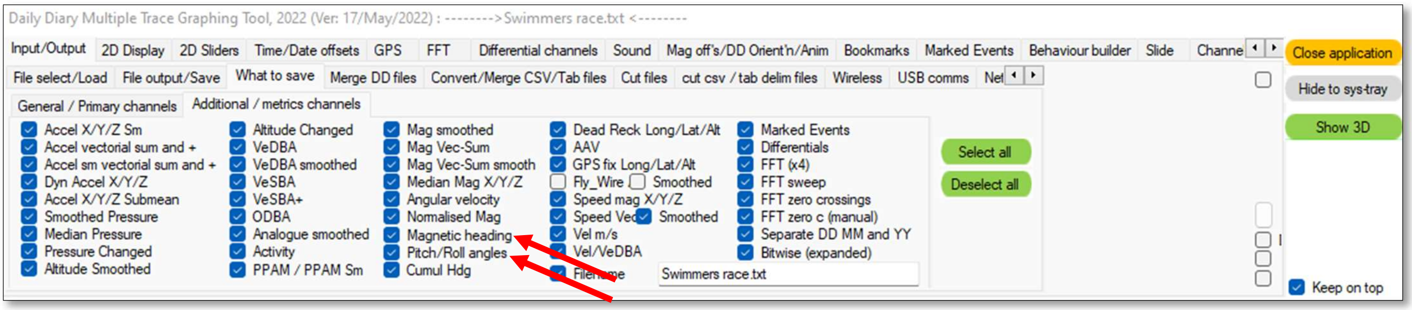


*Figure 7.4 Ensure **Magnetic heading** is selected under **What to save***

Setting the device orientation manually by defining *Heave, Surge,* and *Sway*

Alternatively, to visually setting the logger orientation, one can observe the heave, surge, and sway in the 2D graph acceleration traces.

In the 2D graphs below, a motion test is performed with a logger where it is gently pitched up, and down, and then rolled left, and right, at all 4 compass points, before finally being held level, and spun around 360 degrees (see YouTube video: https://www.youtube.com/watch?v=uDzJ6SQEeoQ).

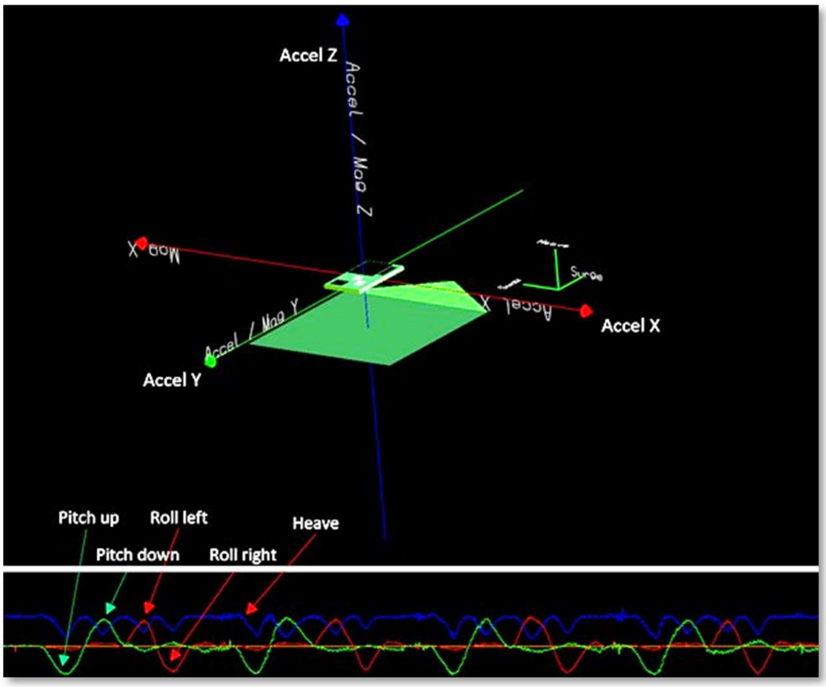


Figure 7.5 *Observing acceleration traces to identify Heave, Surge, and Sway*

It is best to start by setting Heave as, in the above, this is obviously, Z acceleration (blue), at 1 g.

From here, you have 4 possible combinations; surge is +ve or -ve on one of the two remaining axes, and the same for sway.

The next step would be to define *Surge* as, perhaps with a dive behaviour acceleration (not pitch) data increases or decreases on the trace, when the animal pitches down. If the animal were to pitch up, but the accel trace goes negative, then a negative acceleration axis should be selected. In the above, surge is green (Accel Y), and so, for surge, select Accel -Y as it goes negative for positive pitch and vice versa. Sway can now only be one possible value, in this case Accel -X, as +ve Accel X is not possible due to the previous 2 selections.

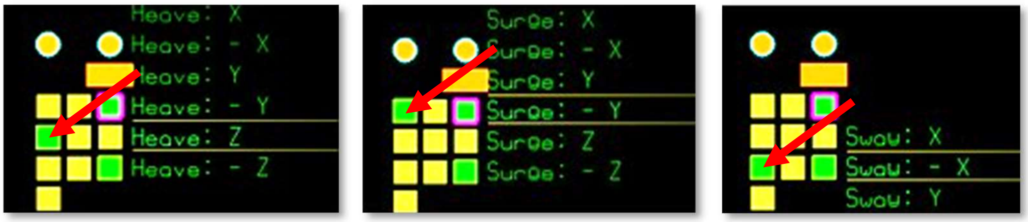


Figure 7.6 *Setting the Heave, Surge, and Sway axes via the menu structure*

Once *Heave*, *Surge*, and *Sway* have been selected and define a possible orientation, the ortho' lines all green (at the right side of Figure 7.5 will turn green, and the device orientation selection, as shown in Figure 7.2 and the visual orientation of the logger will switch to that defined by these parameters. Left clicking on the device orientation button (5th down) then causes the magnetometer and pitch/roll parameters to be correctly set on the DD Orientation tab (Figure 7.3).

Pitch and Roll

Pitch and Roll are determined from the acceleration data, but first, the orientation axes must be set as shown in preceeding pages. Ideally, pitch and roll should be determined from static Daily Diary data but dynamic acceleration can be dealt with using the ***Acc smoothing for compass*** on the ***2D Sliders/Channel smoothing*** tab to take the *mean* orientation. The level of smoothing here is independent of any other acceleration smoothing in the software. The smoothed acceleration channels for compass heading can be viewed on the ***drawing*** window by selecting ***Graph acceleration, for compass***.

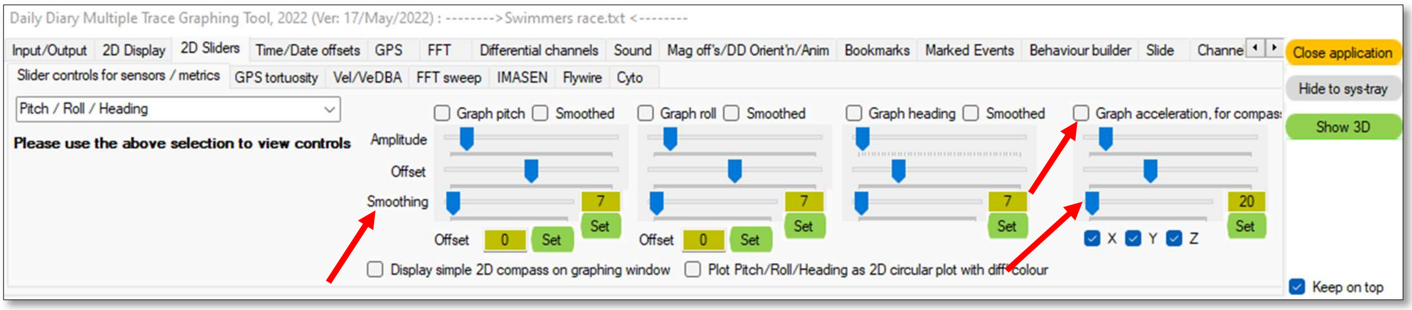


Figure 7.7 *Set the acceleration smoothing level to remove dynamic acceleration from the signal*

8. Importing GPS Data (Pre-Loaded / the first file to be loaded before main data file)

GPS data files containing parameters ***Date***, ***Time***, ***Latitude***, ***Longitude***, and ***Altitude*** can be imported into DDMT by saving any GPS data as a .csv file, i.e. comma-delimited, with the column headers as shown in Figure 8.1. Note all other columns will simply be ignored during the import process. If altitude data is not included, ensure there is still an altitude column with zero values or the file will not load correctly.

The ***Date*** column must be in DD/MM/YYYY format, whilst the ***Time*** column must be in a 24-hour clock with formatting as HH:MM:SS. ***Latitude*** and ***Longitude*** will be assumed to be in decimal degrees, and ***Altitude*** in metres. The ordering of the columns is equally important as the header row is not read.

	A	B	C	D	E	F	
1	Date	Time	Latitude	Longitude	Altitude	Speed	Co
2	31/10/2014	16:05:42	54.58593	-5.94168	36.52	720	
3	31/10/2014	16:07:41	54.58593	-5.94168	36.52	2196	
4	31/10/2014	16:11:36	54.58591	-5.9419	13.55	1296	
5	31/10/2014	16:13:53	54.58599	-5.94227	20.57	3312	
6	31/10/2014	16:16:01	54.58576	-5.94168	84.01	1800	
7	31/10/2014	16:17:44	54.58604	-5.94221	63.82	468	
8	31/10/2014	16:19:19	54.58596	-5.9421	43.73	1044	
9	31/10/2014	16:20:51	54.58575	-5.94092	18.54	828	
10	31/10/2014	16:22:20	54.58578	-5.94121	50.45	1620	

Figure 8.1 *Format required of GPS data to be imported*

To import a GPS .csv file (this can be imported prior to selecting / loading the main data file) click ***Preload GPS data file*** at the top left of the ***Input / Output*** tab. Once the GPS data has been imported, the user is then free to select a Daily Diary data file and load the first split**.**

Figure 8.2 Preload GPS data file *button must be selected before clicking* ***Select data file***

Alternatively, on the ***Input / Output*** tab, there is a button ***Load GPS data*** that allows GPS data to be loaded into the currently loaded acceleration (etc.) data file.

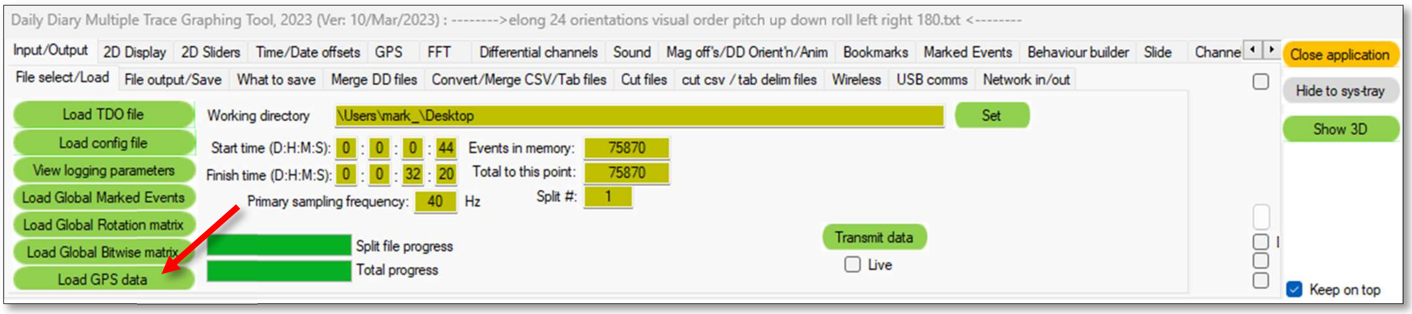


Figure 8.3 *Button to load GPS data after the primary data file has already been loaded*

GPS data can be exported along with all other channel data, by selecting it on the ***What to save*** tab. It can also be used to influence/correct the dead reckoning track within the 3D visualisation side of the software.

Syncing GPS data to Daily Diary data

By synchronising the GPS with DD data sets, DD data becomes a great deal more powerful due to the ability to couple environmental attributes with behaviours. GPS data will be assumed to have the correct time and date information. To set or correct the Daily Diary data time and date, refer to Chapter 3.

Before synchronising GPS data to Daily Diary (DD) logger data, it is important to ensure that any date/time corrections are performed on the DD data, as the sync function looks for matches in both date and time information. The maximum time resolution DDMT performs is 1 Hz so GPS data must be prefiltered to 1 Hz prior to presenting it to DDMT.

Synchronisation will occur from either the start of the Daily Diary dataset, or, from the event number where time/date corrections have been applied, if at all.

To sync the two data sets, click the ***Sync GPS file to DD*** button on the ***GPS*** tab. DDMT may be non-responsive for a few seconds or more, depending on how much data it has to assess - please be patient with large datasets. A red banner on the ***GPS*** tab will state ***Synching GPS*** (red) and switch to ***Sync complete*** (green) when finished.

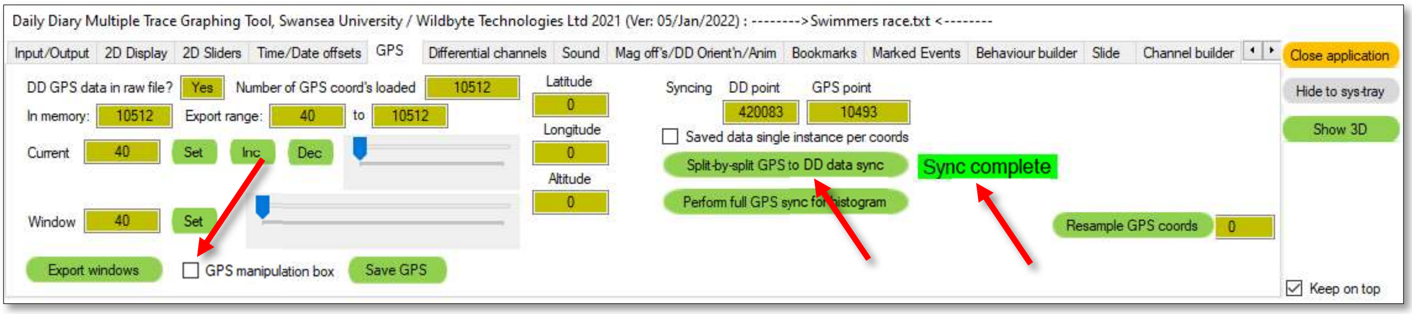


*Figure 8.4 **Sync GPS file to DD** on the **GPS** tab*

To show the synchronicity of the DD and GPS data sets, close the ***GPS manipulation box*** (untick if selected) and enable the 2D graphic view of the GPS fixes by ticking the ***Show GPS*** checkbox on the ***2D Sliders/GPS*** sub-tab (Figure 9.4). This is also where the amplitude and offset of the GPS trace can be adjusted on the ***drawing*** window. It is also possible to add a velocity graph (measured in metres per second, m/s) calculated from GPS fixes and adjust its amplitude and offset.

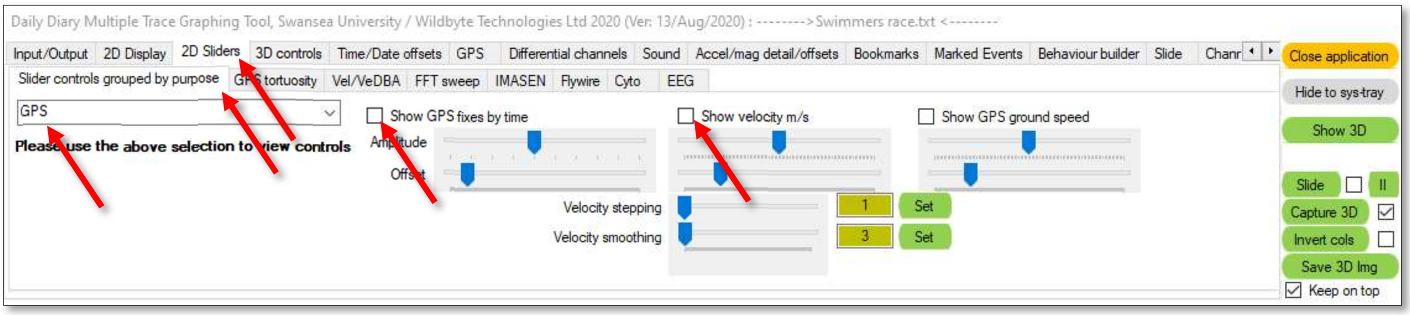


*Figure 8.5 **Show GPS** and **Show velocity m/s** settings*

Additionally, if ***Perform full GPS sync for histogram*** is selected, then, after a short time, depending on how much GPS data there is present in the system, the split navigator window will show where, within the whole data file, the GPS data exists. It's represented as a histogram:

Figure 8.6 The 'Full GPS sync' shown (yellow) as a histogram on the 'split navigator' control panel

Once the general GPS synchronisation is complete, the ***2D drawing*** window will now show a vertical blue line for every DD data point and GPS fix with the same time and data attributes. 1 Hz is the maximum frequency for syncing data, therefore with Daily Diary data at 40 Hz, there will be 40 blue lines for every GPS fix match.

The first blue Daily Diary event fix synchronised to a GPS fix will also have a small red dot (the other blue lines are considered in-sync due to sub-second sampling frequency).

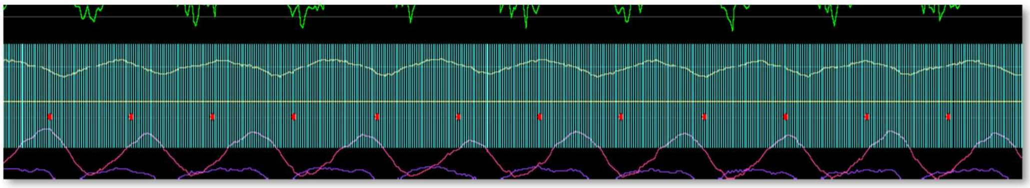


Figure 8.7 *Blue lines indicating a DD to GPS fix match*

Figure 8.8 shows us DD to GPS fix matches in blue, with a red/blue base line where a DD to GPS fix match did not occur.

Figure 8.8 *Blue lines indicating a DD to GPS fix match while blue dots indicate a lack of a fix match*

Once the data has been successfully synchronised, ***GPS Long/Lat/Alt*** and ***GPS mean velocity m/s*** for events that have a GPS fix match can be seen in the ***Overlay*** on the ***Display/Overlay selection*** sub-tab.

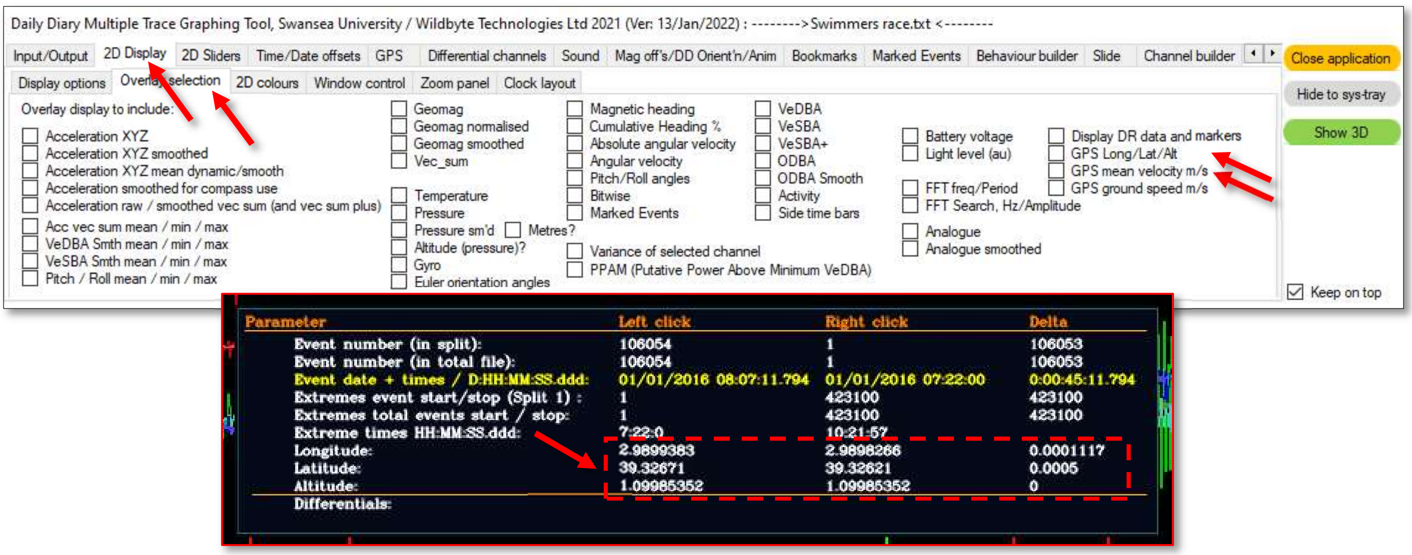


Figure 8.9 *Enabling GPS information on the* ***Overlay***

The values will then appear at the bottom of the ***Overlay***, for data points that have a DD to GPS fix match. GPS parameters are selected for export by default on the ***Input/Output/What to save/Additional / metrics channels*** sub-tab.

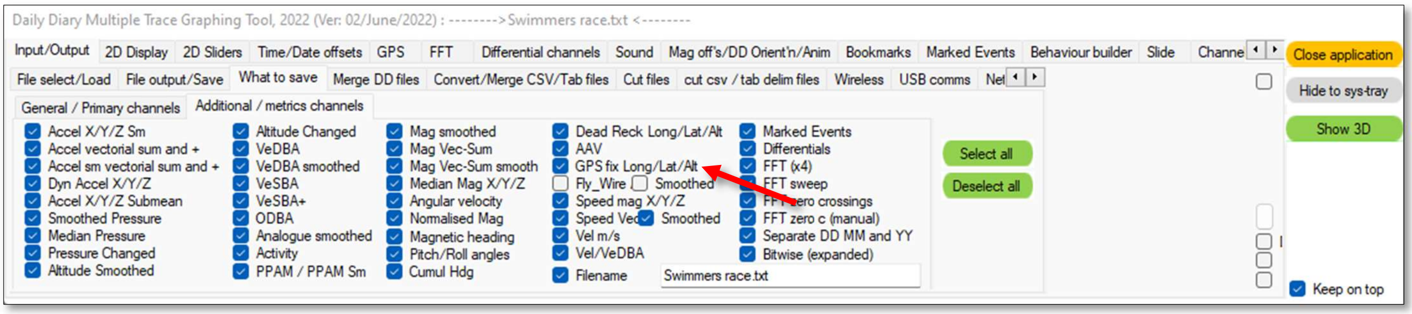


Figure 8.10 *Exporting the DD to GPS fix match GPS coordinates*

GPS straight-line interpolation

It is possible to fill in gaps between GPS points to provide a second-by-second fix, simply derived by straight-line interpolation (in both latitude and longitude) between two consecutive GPS fixes. This should be used with care as it does not consider heading or potential changes in velocity but fills data gaps, at a rate of 1 GPS fix per second. Click ***Linear interpolation / resample GPS coords*** on the ***GPS*** tab, and then click the ***Sync GPS file to DD*** once again to account for the newly generated interpolated fixes.

Figure 8.11 *Using the* ***Resample GPS coords*** *function to fill in missing GPS coordinates by linearly interpolating GPS longitude/latitude values*

Bracketing

With the DD and GPS datasets synchronised, the software can slide through the data, centring on GPS points one after another with a user-defined window width of events around that point. To do this, open the ***GPS*** tab.

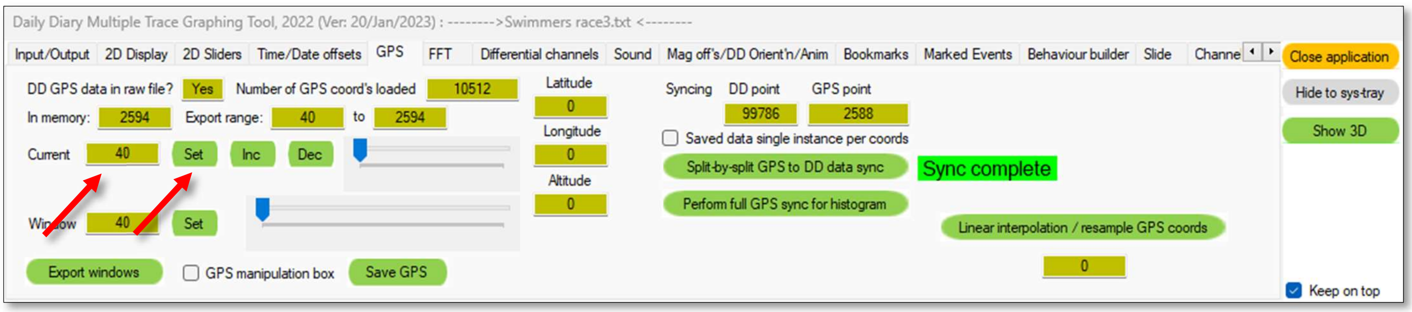


Figure 8.12 *GPS data bracketing controls*

Current is the currently displayed GPS point with a window of 1000 events around the point (+/- 500 points, limited at either extreme of the data set). To enable this function, simply click ***Set*** (adjacent to ***Current***'s value-box, as indicated above). The ***2D***

Drawing Window will immediately lock down and display only 1000 events with this GPS data point centred. Clicking the green ***Inc*** or ***Dec*** buttons will move the window forward or backward to the next GPS fix match. Slider bars are also provided to the right of the GPS point window width buttons. As each GPS point is shifted into position, the ***Longitude***, ***Latitude*** and ***Altitude*** value boxes will automatically update. The centred points are the red dots described earlier in this GPS section, which denote the first event to have a time/date match, between the Daily Diary and GPS data sets.

In memory tells the user how many GPS points are in memory (within the currently loaded split of the full dataset) and the ***Export range*** allows the user to specify which points will be used in the data export process described below. If all the Daily Diary data has been loaded as a single split, then this will be from 1 to *n*. The ***Current*** slider and ***Inc***/***Dec*** buttons will be confined to the allowed range.

The ***Export windows*** function makes the software cycle through all the in-memory GPS points (within the user specified ***Export range*** and export all the windows of Daily Diary data surrounding them as a single file; the data channels exported is as per the ***What to save*** tab tick-boxes. Please note that this can create enormous files! If you consider having 10,000 GPS data points each having a Daily Diary data window of 1,000 events – it'll create a single file (with a single line break between each window) of 1,000 x 10,000 events, of *n* channels of data.

10. Behaviour Builder

Behaviour builder is a Boolean conditional search function, used to find data that fits user-specified criteria. This can be in the form of a single statement that will generate ***Marked Events*** if true, or a double statement that, when found true, will create a new ***Bookmark***. The strength of this utility lies both in the quality of the data, and in the user's ability to identify essential criteria.

Figure 9.1 *The initial behaviour builder tab*

Some examples below of Behaviour Builder expressions (notice the brackets around the inequalities before and after the ***AND*** function – required (also for OR and NOT) to ensure correct parsing of these types of double-barrelled expressions):

- *If ((SM(Acc X, 50) > 0.5) AND (Temperature < 28)) then Mark Events*
- *If ((VeDBA Smoothed > 0.5) AND (ABS (Acc X Smoothed) < 0.1)) then Mark Events*
- *If ((Temperature < 25) AND (GPS Lat < 4.231) AND (GPS Long > 52.514) AND (GPS Long < 53.154)) then Mark Events*

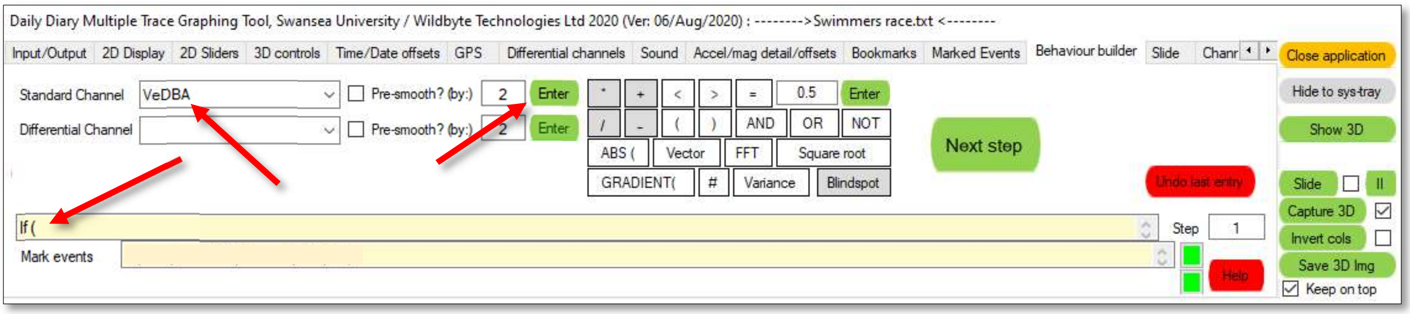
Note that, if at any time during the creation of an expression is made, then there is a red button to ***Undo last entry***. Or, if the user wants to simply restart the whole expression, they can simply click ***Next step*** and click ***If (*** to restart the expression, or ***(Reset)*** to clear the expression entry box.

Using Behaviour Builder to create marked events

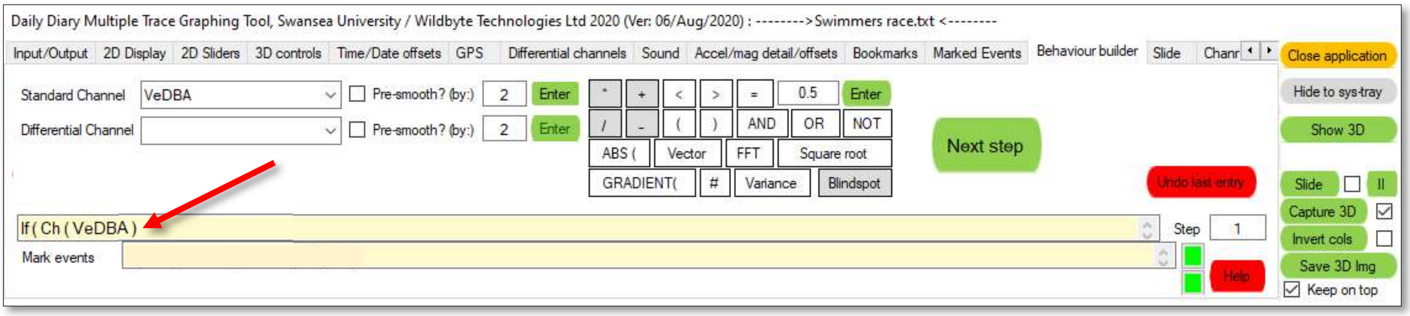
To build our first expression, perform the following:

1. Click ***If (*** button

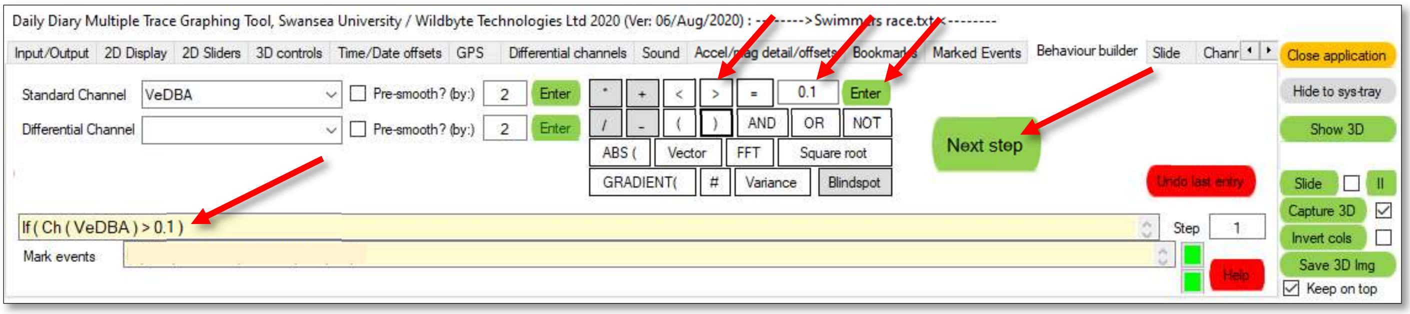
   The view will now change to allow us to enter our expression



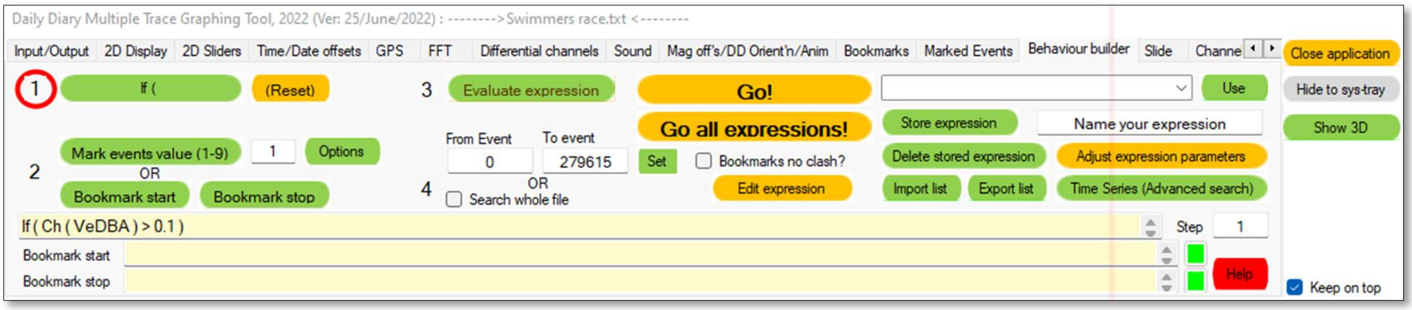
2. Now click the drop-down box indicated in Figure 10.3 and change it to VeDBA and click ***Enter*** to its right



3. Now click **>**, enter 0.1 into the values box and click its ***Enter*** button, followed by ***)***

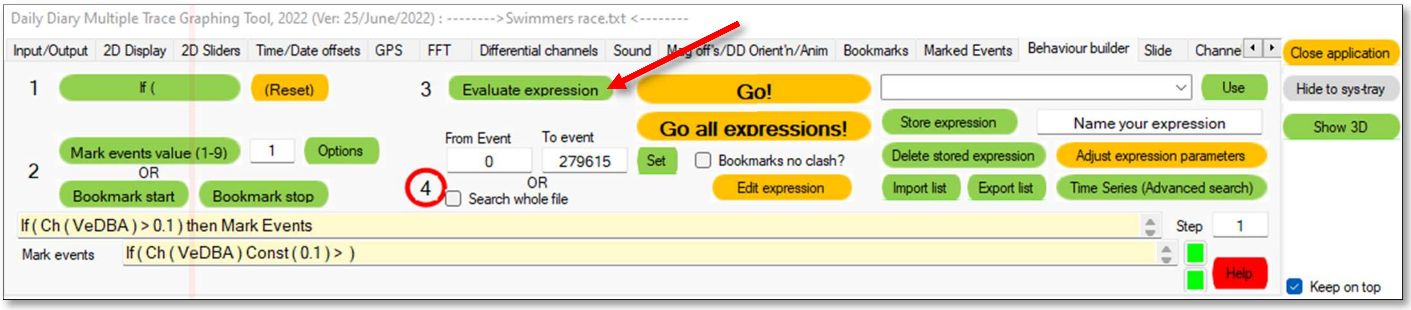


4. Now click ***Next step*** button, and the previous view will be returned

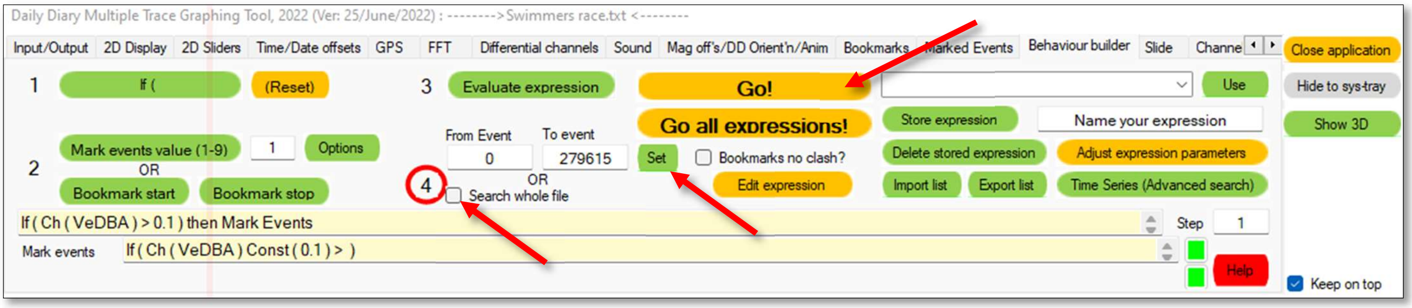


5. Now there is the choice of defining either a single expression that will evaluate single events as true or false, or double expressions that will define the start and stop of a ***Bookmark***. In this first example, click ***Mark events value (1-9)*** to generate ***Marked Events***

6. Now we need to tell the algorithm that we've completed the expression and request it convert it to Reverse Polish Notation (RPN), a format more easily parsed rapidly by a search algorithm. Click ***Evaluate expression*** and the translated expression appears in the lower box as ***If (Ch (VeDBA) Const (0.1) >)*** (RPN)



7. Next, define what data we want to evaluate, so place white lines using the left/right mouse buttons on the ***2D graphing window***, and click ***Set***, or click ***Search whole file***. Note - if ***Search whole file*** is ticked, this will override the start/stop event markers in the two boxes.



8. Finally, click ***Go!*** Because a value of 1 was in the box adjacent to the button labelled ***Mark Events value (1-9)***, this will place a ***Marked Event*** value of 1 on any event where the VeDBA is less than 0.1 *g*. By default, ***Marked Events*** value 1 is red. The colour scheme can be adjusted on the ***Marked Events*** tab.

Here, some data with low (< 0.1 g) has been "Marked" as value 1 (red):

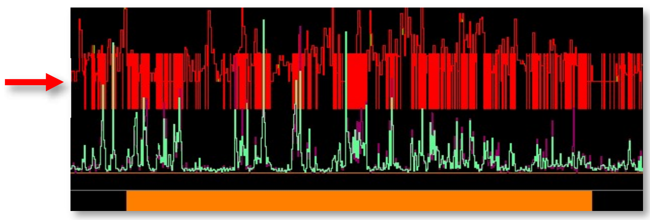


***Figure 9.2 Marked events** on events where VeDBA < 0.1 g*

This expression can be stored in a list by clicking ***Store expression***. Before storing, a name can be entered into the box to the right of this button "Name your expression"

Figure 9.3 *Storing this first expression*

Multiple expressions of this ***Marked Event*** type can be stored in the list. There are also buttons for exporting and importing these expressions lists ***Export list*** and ***Import list***. Expressions can also be deleted from the list by clicking ***Delete stored expression***.

To recall an expression from the list, select it from the drop-down box, and click ***Use***, and its expression and RPN conversion will be loaded into the two boxes at the bottom.

The alternative to the single ***Marked Event*** expression, as discussed briefly above, is to create two expressions that define the start and stop points for a bookmark. To use this feature, instead of clicking ***Mark events value (1-9)*** button (step 5 above), click either ***Bookmark start*** or ***Bookmark stop***. Below, Figure 10.5, are two expressions using the start/stop pair, in RPN.

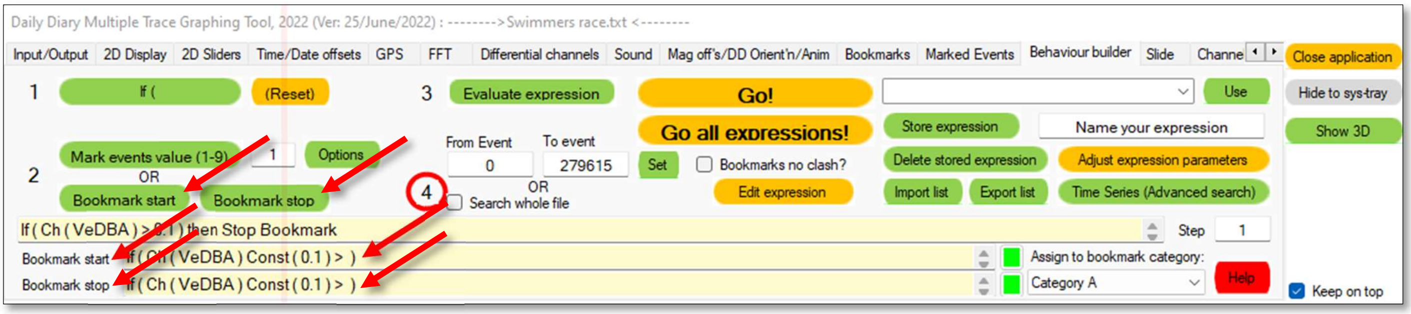


Figure 9.4 *Creating an expression pair that will define the start/stop for a* ***Bookmark***

Clicking the ***Go!*** button results in multiple bookmarks where the two expressions are found true. Figure 10.6 illustrates this. Note, the start of the bookmark is where VeDBA < 0.1 *g*, and the stop if where VeDBA > 0.1 *g*.

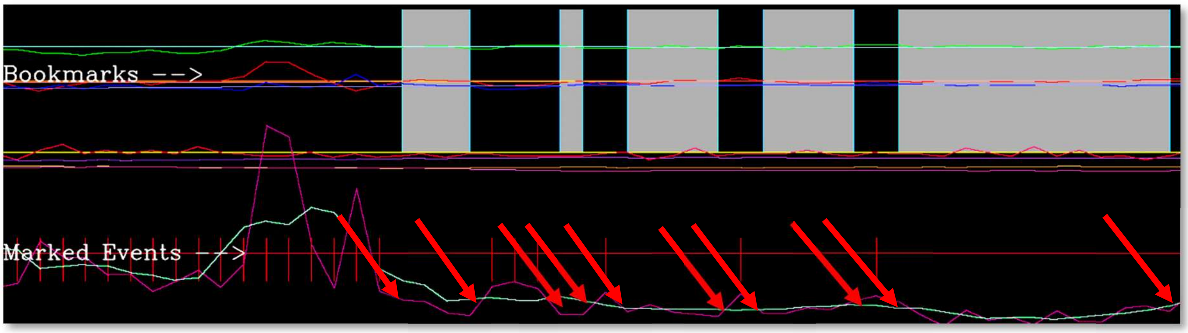


Figure 9.5 *Creating an expression pair that will define the start/stop for a* ***Bookmark***

Searching multiple stored Behaviour Builder expressions through a large file

If the user has multiple stored expressions in the Behaviour Builder, and the whole data file is not loaded i.e., the split is less than the full size of the file, then ticking ***Search whole*** file, and clicking ***Go all expressions!*** will tell the Behaviour Builder algorithm to run through the list, one expression at a time, and apply it to the whole data file. As it increments through each expression, the ***Behaviour Builder Category*** and the ***Marked Events*** category will increment (***Marked Events*** for single expressions, and ***Bookmark Categories*** for double ***Bookmark Start/Stop*** double expressions).

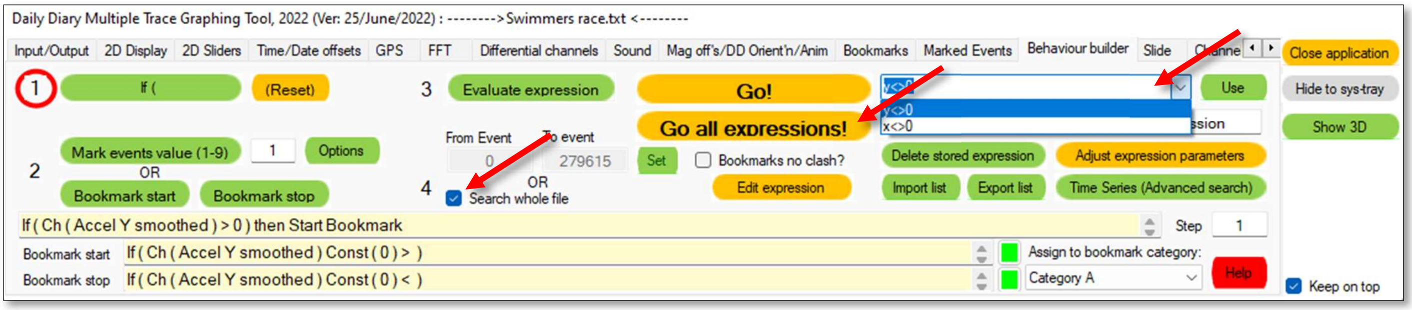


Figure 9.6 *Searching the whole file for multiple expressions using the **Go all expressions!** button*

Behaviour builder pre-smoothing

Channels may be pre-smoothed on-the-fly if required by ticking the ***Pre-smooth? (by:)*** checkbox and entering a value in the adjacent box (the averaging window) before clicking the ***Enter*** button to add that data channel to the expression. See Figure 10.7 for an example where ***Accel X*** is used in an expression with no pre-smoothing and then the behaviour is instead added with a pre-smoothing function *If (SM(Acc X, 25)…* telling the software to smooth with a centred averaging window of 25 events.

Figure 9.7 ***Marked events*** *with and without pre-smoothing*

Behaviour Builder function - Variance

Variance of any channel can be used as part of an expression. An example might be:

If (Variance(Accel X smoothed | 1000)> 2.5) then Mark Events

By starting a ***Behaviour Builder*** expression with ***If (***, clicking the ***Variance*** button will show its controls; Figure 9.8.

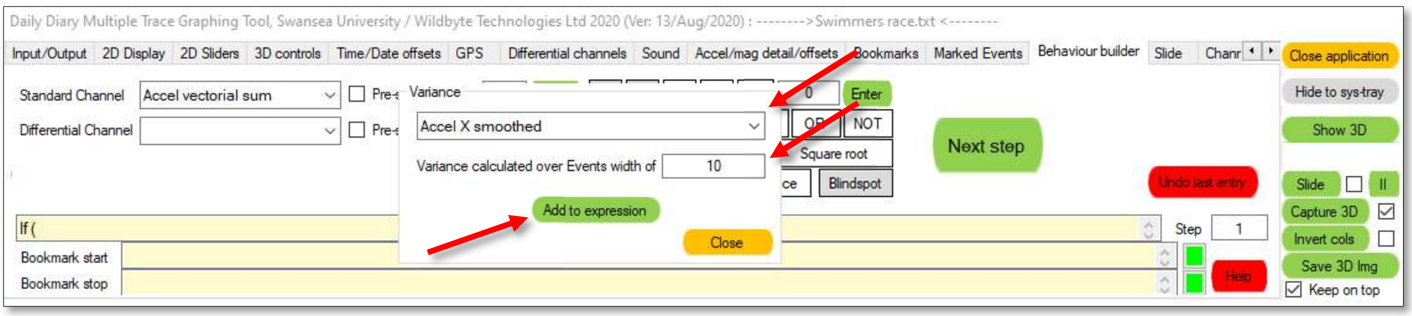


Figure 9.8 ***Marked events*** *with and without pre-smoothing*

Variance parameters, such as over how wide a window to use (per event), and the resulting variance value, can both be predetermined by generating a Variance channel as discussed in Chapter 2 (Metric – Variance controls / Figure 2.28), and looking at the Variance values on the ***Values Overlay.*** This is the sole purpose of the Variance channel discussed there, to determine values required for the ***Behaviour Builder***.

Gradient function

The ***Gradient*** function allows one to determine the gradient across *X* number of any points, for any channel listed (***Standard Channels*** only, not ***Differential Channels***). To use this, select the ***Gradient*** button, then select a channel and click the green ***Enter*** button to push the channel into the behaviour box. Click the ***#*** button to add in a vertical line separator. Next, enter a value for the number of events over which to determine the gradient into the numeric box and click the green ***Enter*** button, then close the bracket with the ***)*** button. The user can then add an inequality (**<** or **>**) and another value. The ***Gradient*** function can be used for both ***Marked Events*** or ***Bookmarks***. Note that the gradient is calculated at point *n* such that it is "*Gradient value(n + step) – Gradient value(n)*".

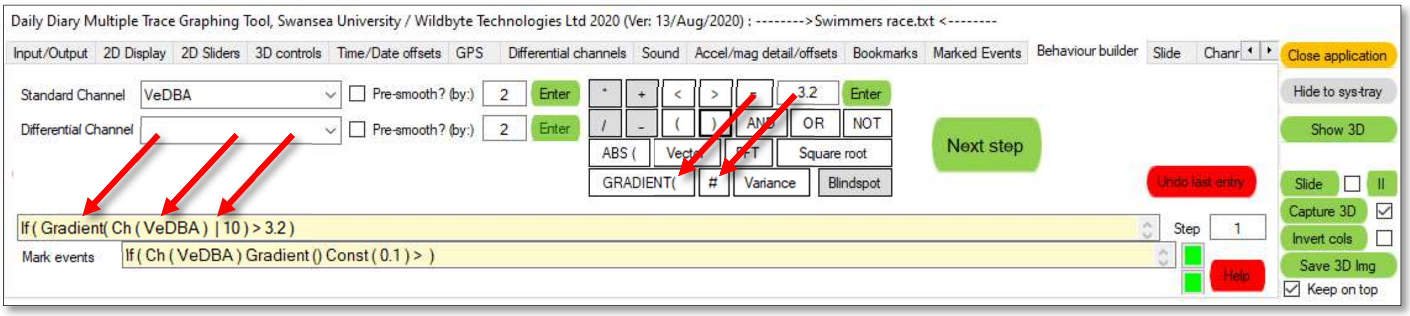


Figure 9.9** Entering a function using **Gradient(

An example expression using the ***Gradient*** would be:

If (Gradient(Ch (Mag Z) | 10) > 0.22) then mark events

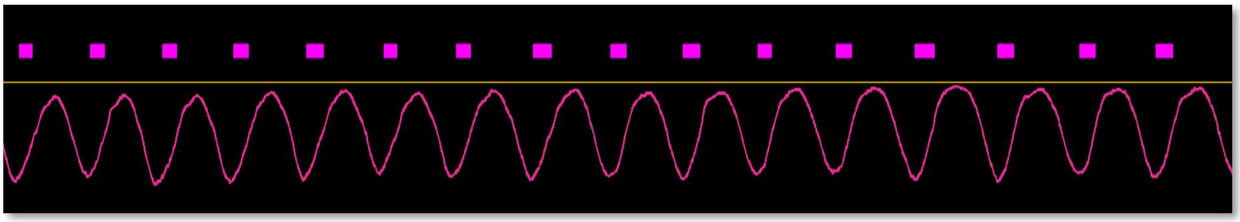


***Figure 9.10 Gradient** function with marked events used to pick out the positive gradients*

Figure 9.10 shows how the ***Gradient*** function can be used to pick out the positive-going slopes in an oscillatory signal. Here, we get more than one marked event per slope.

Blindspot

The ***Blindspot*** function can be added to the end of an expression so that DDMT stops looking for any match of the behaviour for a defined number of events after it finds one; essentially stepping over *n* events. Knowing the approximate period of the signal above, it is possible to set the ***Blindspot*** range so that there is only one ***Marked Event*** per region of ***Events***. This is useful for functions such as ***Gradient*** that might generate multiple ***Marked Events*** where only one is required.

If (Gradient(Ch(Mag Z) | 10) > 0.22) Blindspot(30) then mark events

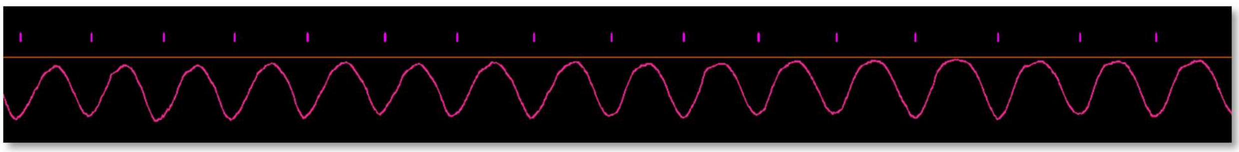


Figure 9.11 Gradient** function with* marked events *used to pick out the positive gradients including **Blindspot

The positive slope of the waveform in Figure 9.10 is approximately 30 events, so setting the ***Blindspot*** to 30 events ensures that the next marked event will occur at the next trough. Using the ***Blindspot*** function, this allows a single marker per oscillation of the waveform. Data exported with the checkbox ***Export behaviour builder marked events only*** on the ***Input/Output / File output/Save*** tab will also, by default, export the timing of single events.

Differential channels in the Behaviour Builder

Below the ***Standard Channel*** selection on the Behaviour Builder control panel, other user generated channels can be found such as the ***Differential channels***. These are used in the same way as ***Standard Channels***; any differential channels that are created by the user will appear in this list. Pre-smoothing is also available for these channels. Note that differentials can also be smoothed as part of their construction; see Chapter 4.

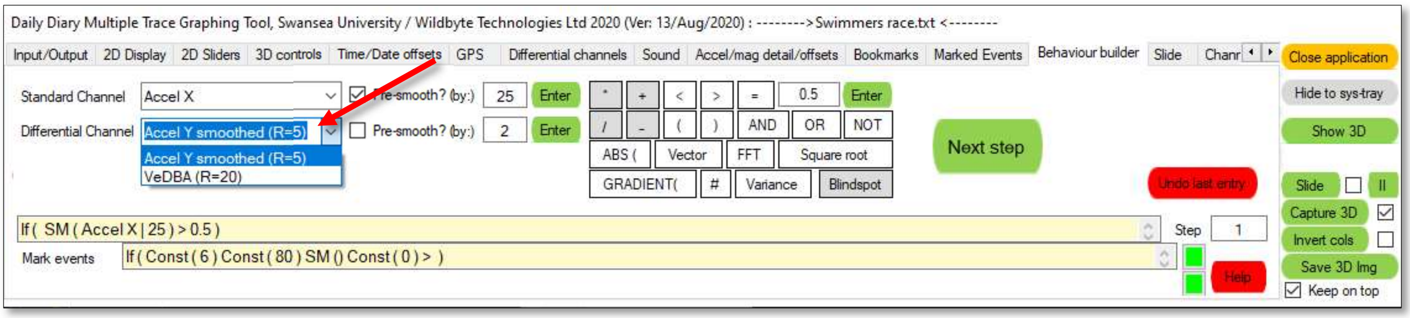


__Figure 9.12 Marked events__ with and without pre-smoothing

Categories

When bookmarking data via the ***Behaviour Builder***, ***Bookmarks*** will be assigned to a category. The currently selected category will be assigned to each bookmark that is created.

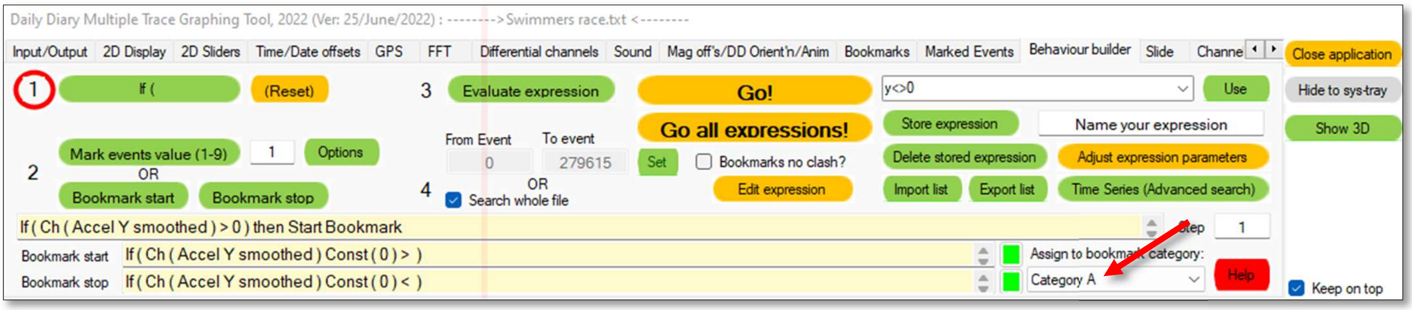


Figure 9.13 *Assigning categories to **Bookmarks** generated by the **Behaviour Builder***

When category names are updated on the ***Bookmarks*** tab, this down-down list of categories will also be updated. Default category names are *Category A*, *Category B…*

Summary

In summary, the basic **Behaviour Builder** evaluates all ***Events*** within the selected range of events, or the whole file, for the currently selected expression and, either marks it as a ***Marked Event*** or as a start/stop marker to generate a ***Bookmark***.

Other functions available are *******, ***/***, ***+***, ***-***, Absolute (***ABS***), ***=***, inequalities **<** and **>**, logical expressions ***AND***, ***OR***, and ***NOT***, ***Square root***, and some special functions including ***Gradient*** and ***Vector***

Time series – Advanced Behaviour Builder

A series of Behaviour Builder expressions can be linked in time to define a multi-step behaviour. This works by defining multiple individual Behavioural Builder expressions, that stipulate levels of VeDBA, or the rate of change of Accel Y for instance. These are then placed in a time series, as a list of elements in a sequence, each having a defined number of events over which its condition must be true, a rule that defines when the next successive element can begin with its own search, and a specified range for flexibility. This flexibility value means that each element is not fixed rigidly in time, rather they can adjust automatically to the natural variability of animal movement data.

The expressions passed to the Time series part of the ***Behaviour Builder*** must be of the ***Marked Events*** type, not the ***Bookmark Start/Stop*** type.

To use this, first create some equations and store them so they appear within the drop-down boxes shown in Figure 9.14.

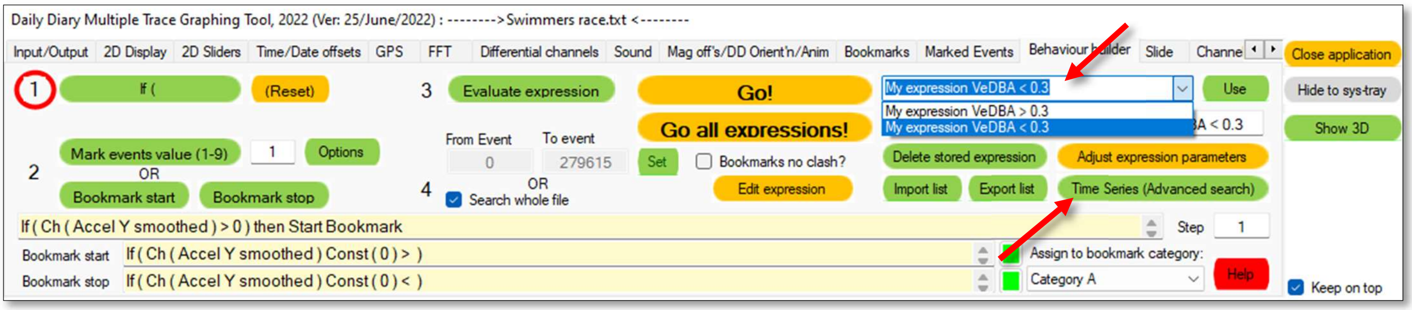


Figure 9.14 *Creating and storing behaviours for use within the time series behavioural identification algorithm*

Now click the button labelled ***Time Series (Advanced search)*** to open the time series control panel which will have these same expressions listed (Figure 9.15).

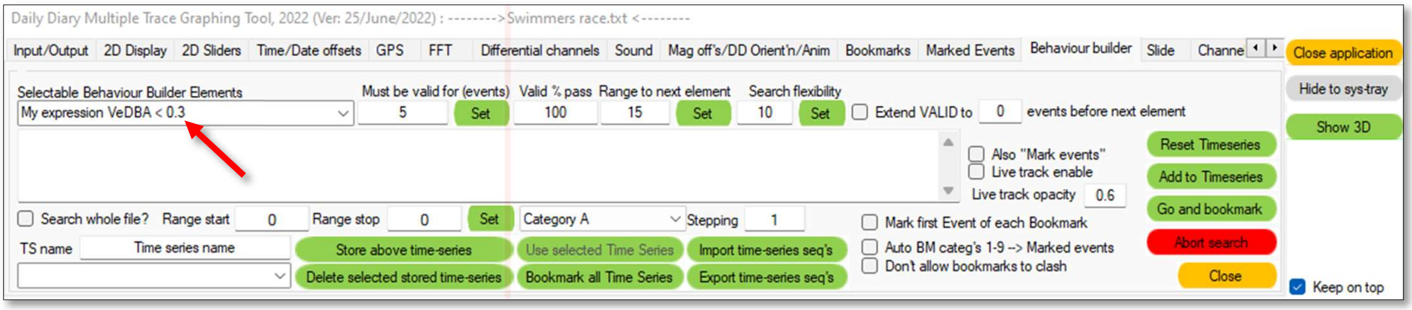


Figure 9.15 *Time series control panel; using expressions previously defined and saved within the Behavioural Builder*

The aim of this part of the algorithm is to allow previously defined expressions to be placed along a time line at points of "interest", enveloping a behaviour i.e. a series of changes in the data that express a known pattern(s) or movement(s).

First example of Time series Behaviour builder

Our first simple case below is an oscillation in the smoothed Acceleration Y channel. We wish to identify all the sections where the data is > 0. The horizontal orange line defines where Y = 0.

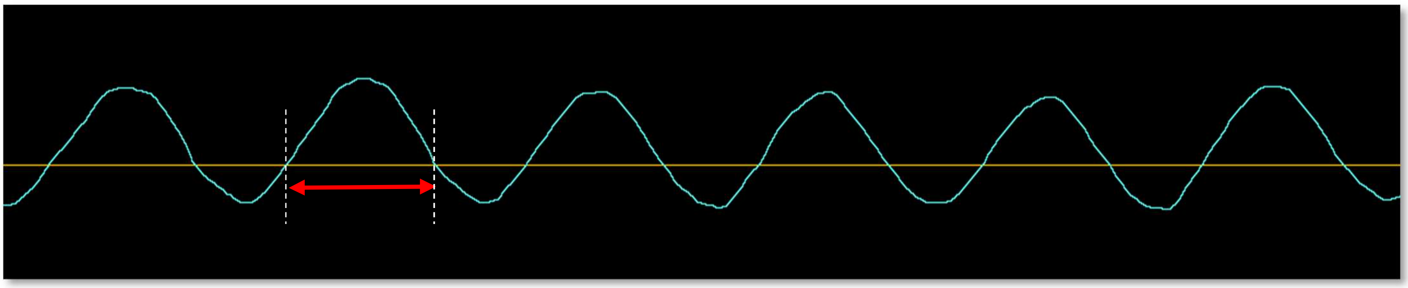


Figure 9.16 *Acceleration Y smoothed; horizontal orange line is Y = 0*

In the ***Behaviour Builder***, we create two expressions; the first defines AccYsm > 0 and the second AccYsm < 0, Figure 9.17.

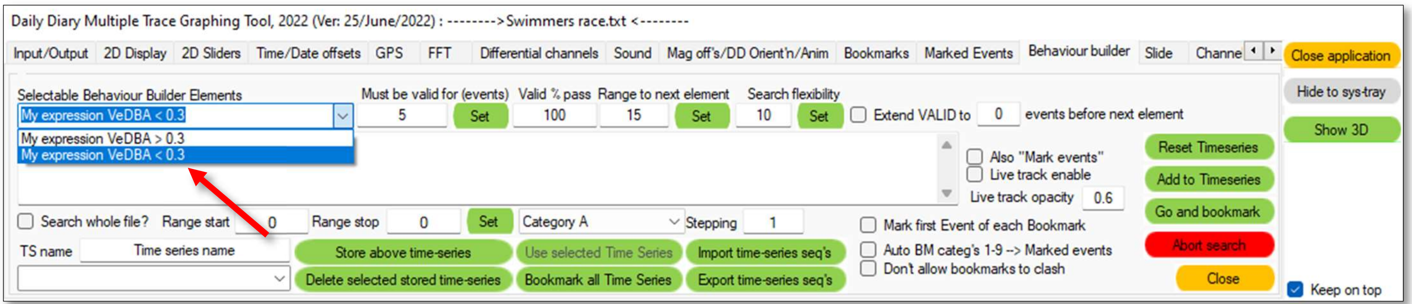


Figure 9.17 *Two* ***Behaviour Builder*** *expressions*

To identify a full-width peak as in Figure 9.16, we need to identify the crossings. There are several ways, perhaps better than what we'll do here, but the following method will illustrate the simplicity of this advanced search.

What we're going to do is add an expression, which has several parameters associated.

Must be valid (events)

Number of consecutive events that expression *n* is valid (true) for

Valid % pass (0-100%)

% of the above consecutive events that must be valid for expression *n* to be valid (true)

Range to next element (events)

Number of events from expression *n* to expression *n+1 (this value must be greater or equal to 'must be valid')*

Search flexibility (events)

Number of events within which expression *n+1* can be searched for / found to be valid i.e. expression *n+1* must exist within the flexibility region of expression *n* else expression *n+1* will be found invalid

To begin, we select our first expression AccYsm > 0, change ***Must be valid*** to 1, and ***Search flexibility*** to 100 (for this particular dataset) and click ***Add to Timeseries***. This first ***Element*** will be added to the central behaviour definition box.

Next, we select our second expression AccYsm < 0, and then just click ***Add totTimeseries***; the ***Range to next element*** and ***Search flexibility*** parameters will be ignored for the 2nd ***Element*** as there is no 3rd ***Element*** to which they will be applied. See Figure 9.17.

Expressions may be used more than once in a behaviour definition.

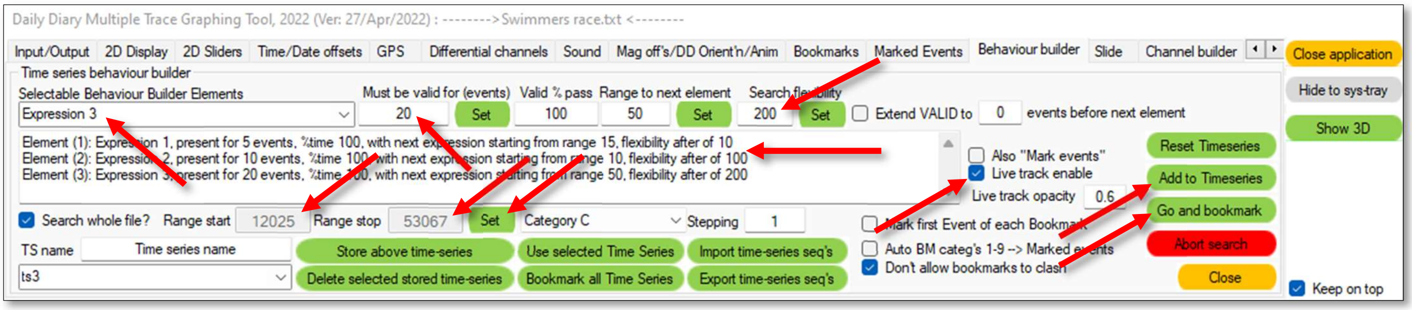


*Figure 9.18 Element parameters when added to the **Behaviour definition***

Highlight a region covering the data to search with the mouse's left/right white lines, and click ***Set*** and those start/stop ***Event*** values will be entered into the ***Range start*** and ***Range stop*** boxes.

Now, to use this ***Behaviour***, we must first store it and tell the software we wish to use it. First assign a name to the ***Behaviour***; in Figure 10.17, we called this ***peaks***. Clicking ***Store above time-series*** adds this ***Behaviour*** to a buffer. Finally, click ***Use selected Time Series*** and the data within the search range just defined will be validated for the defined ***Elements***. Clicking ***Live track enable*** tells the software to validate the ***Behaviour*** for wherever the user moves the ***Elements***.

Live tracking is a feature that allows the user to "test" a section of data and perfect the ***Behaviour*** definition.

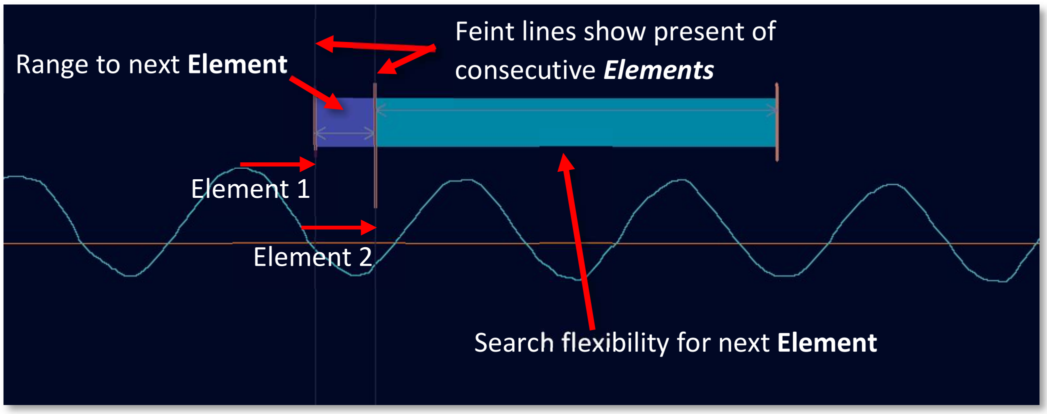


*Figure 9.19 Layout of **Elements** on the **Live tracking** graphic*

Once ***Live track enable*** is ticked, the user can hold down **left ctrl** and **left shift** and **left-click** the mouse and drag the graphic shown in Figure 9.19 through the data.

By default, when ***Live tracking*** is enabled, all ***Elements*** will move to sit under last invalid ***Element***. Once the first ***Element*** finds a point where it is valid, its ***Element*** line will turn green and the subsequent ***Element*** (in our example here, ***Element 2***) will move to the start of the ***Search flexibility*** region (i.e., the end of the previous ***Element's Range to next element*** point. In Figure 9.20, the second ***Element*** moved to the start of the ***Search flexibility point*** of the first ***Element***, and then searched for the first point where it too is valid i.e., AccYsm < 0. Once it was valid, the system determined that all (2) ***Elements*** were valid and so the (entire) ***Behaviour*** was valid and placed a horizontal green line spanning the first to last ***Elements***. Now, if a search (as opposed to ***Live tracking –*** a test feature) were performed, a ***Bookmark*** would have been created here. This merely shows you that your valid, range, flexibility etc. all represent possible search criteria.

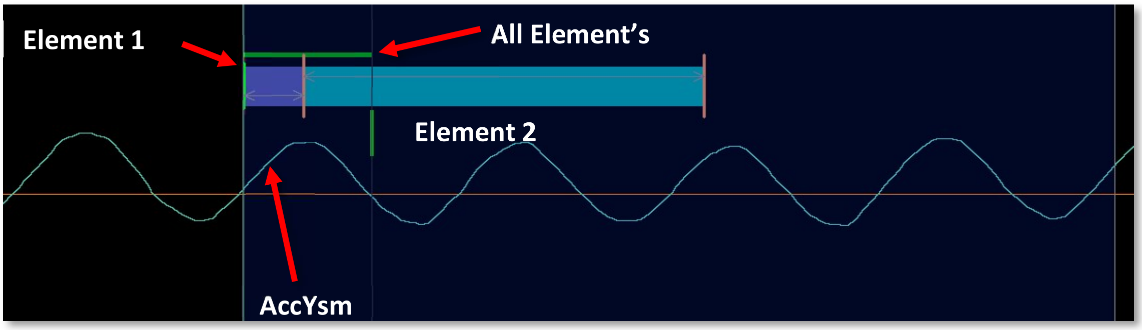


Figure 9.20 Elements *1 and 2 valid. Horizontal green band along the top spans the full distance between the first and last* ***Elements*** *that will define the width of the* ***Bookmark*** *that will be created in a search*

To test the actual search function of the Time series, click ***Go and bookmark***. There will be a pause while DDMT validates the ***Elements*** for every ***Event*** (data point) currently in memory. The search is then performed immediately after.

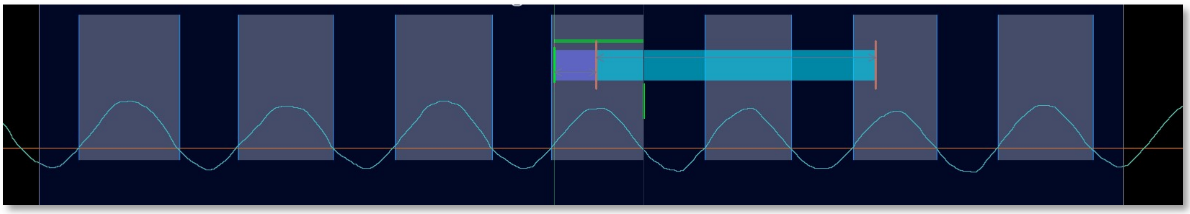


Figure 9.21 Bookmarks *created in the defined search range*

Second example of Time series Behaviour builder

As another example, here is some pressure data from a diving animal. The pressure has been inverted such that greater pressures are at the bottom of the graph.

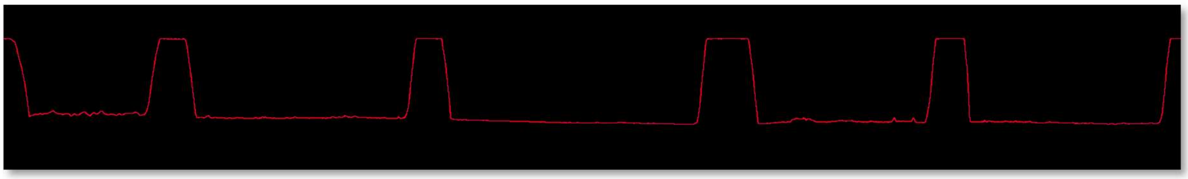


Figure 9.22 *Second data example of diving behaviour*

Here, we would like to ***Bookmark*** each of the dives, and subsequently use the power of the ***Bookmarking*** functionality of DDMT to export all the stats of each individual dive.

First, we define expressions for the low pressure and high pressure.

If (Ch (Pressure) > 0.15) then mark events

If (Ch (Pressure) < 0.15) then mark events

We measure the number of ***Events*** to span the dive here as ~64,000 events. So we'll set the ***Search flexibility*** of the first ***Element*** to 100,000 events.

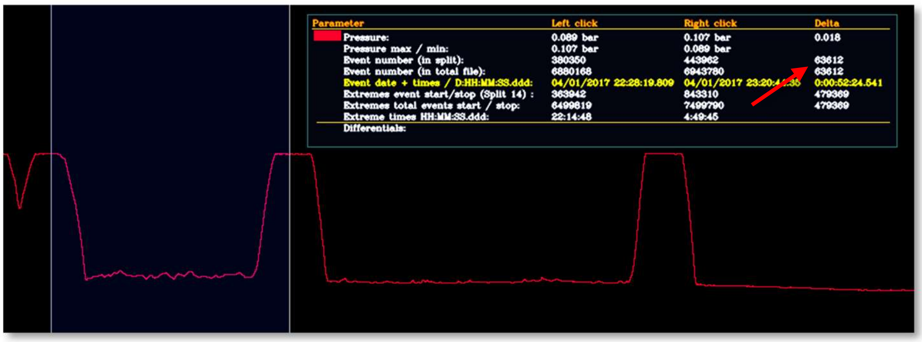


__Figure 9.23__ The span of one of the dives is approximately 64,000 events, and so the first __Element__'s __Search flexibility__ needs to be at least this for the 2nd __Element__ to fit

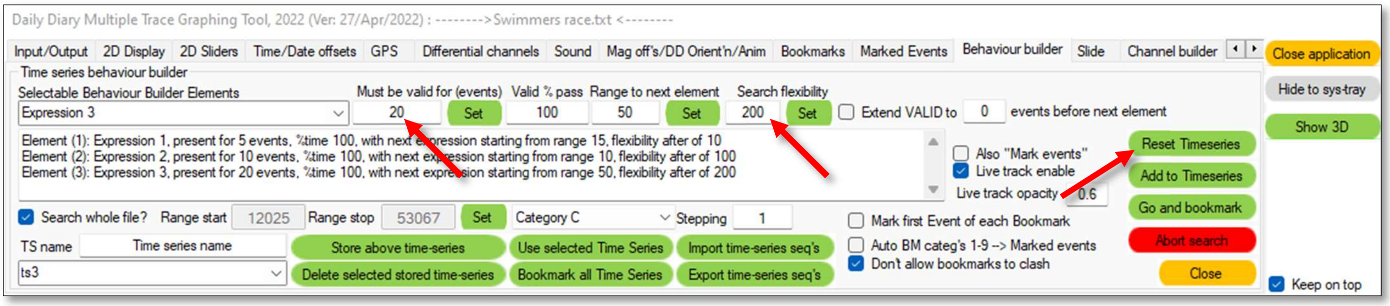


__Figure 9.24__ The two __Elements__ with __Must be valid__ values of 50 to negate a hit on any small fluctuations i.e., ensure it is a real dive

Saving these two ***Elements*** as "Dives", setting the data range to cover a few of these dives, clicking ***Use selected Time Series*** ("Dives"), and clicking ***Live track enable*** we get Figure 9.25.

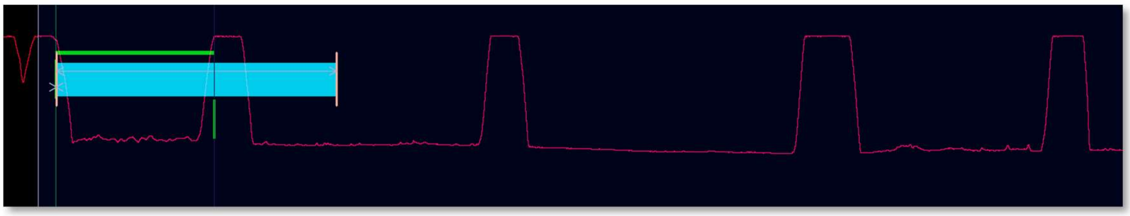


__Figure 9.25__ The two __Elements__ both pass and so the overall __Behaviour__ is valid – horizontal green line

Moving the live tracker further along, the longer dives are too wide for the flexibility. To save resetting the ***Behaviour*** by clicking ***Reset Timeseries***, we can dynamically adjust the ***Search flexibility*** by moving mouse over the first ***Element***'s vertical bar – a label will appear showing the flex, range, and valid values; Figure 9.26.

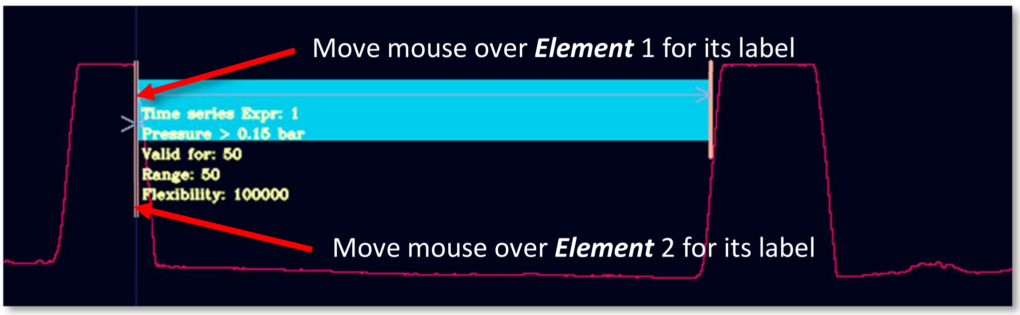


__Figure 9.26 Element__ values labels. In the above, the __flex__ value is not large enough for it to span the gap between the dive down and surface aspects of the "behaviour"

When the ***Element***'s label is visible, changes made as:

Shift + Ctrl + Alt	Mousewheel to adjust ***Range to next element***
Shift + Alt	Mousewheel to adjust ***Search flexibility***
Shift + Ctrl	Mousewheel to adjust ***Must be valid for***

With each change, the ***Live tracker*** will dynamically check the validity of all ***Elements*** both visually on the ***2D graphing window***, and also numerically on the ***Behaviour definition*** window.

Note that the mouse-wheel only adjusts these values by +/- 1, so if these values are drastically different from that required, one would need to reset the time series expression window by clicking the ***Reset*** button and redefining from ***Element 1***.

Adjusting these values only affects the ***Live track*** behaviour i.e., the ***Valid***, ***Flex***, and ***Range*** values in the ***Behaviour*** definition window (where the *n* elements are listed along with their individual parameter values). The updated time-series definition must first be saved with the ***Store above time-series*** button, before clicking the ***Go and bookmark*** button before it can be used in a search. The ***Live track*** function allows the user to make adjustments and determine optimal limits for behaviour definition(s).

Time series definitions can be exported by clicking ***Export time-series seq's*** which will create a .csv file. Opening this will reveal a simple format that allows the user to combine multiple exports for the purpose of creating a library of time-series definitions. Within the .csv file, the first line contains a value defining the number of time-series definitions within the file. If multiple files are combined, simply count the number of lines (time series definitions) and enter this number at the top line to tell the software how many it should expect within the file.

Extend VALID to *n* events before next element

If ***Extend VALID to n events before next element*** is ticked prior to clicking the ***Add to Timeseries*** button, this will require that ***Element n*** is valid from after its initial ***Valid*** window to the start of where the next ***Element*** is valid minus *n* ***events.*** Note that the ***Must be valid for*** events has its own ***Valid % pass*** validation i.e. 80% pass rate, while the ***Extend VALID to n events before next element*** is validated separately from this i.e. 80% pass rate. Do not tick this and add it with the final ***Element*** in a ***Behaviour*** definition.

Additional Time series functionality

- Ticking ***Also "Mark events"*** will generate ***Marked Events*** throughout any ***Bookmarks*** created during a search.
- To search an entire data file (all splits), tick the box ***Search whole file ?*** and the search algorithm will search from ***Split*** 1 to ***Split*** 2.
- If a search is taking a long time to complete for a ***Split***, click ***Abort search*** to step out of the search algorithm

Bookmark all Time Series button

If the user had 3 time-series stored as TS1, TS2, and TS3, in that order, then clicking the button labelled ***Bookmark all Time Series*** with ***Search whole file***, and ***Don't allow bookmarks to clash*** selected, would have it process all splits for TS1 with the currently selected bookmark category. Then, it would increment the bookmark category, and process all splits for TS2, and so on. This might be useful if the user has lots of files and multiple TS to process Note that, due to the ***Don't allow bookmarks to clash*** selected, the stored time series' must be ordered such that the first ones (top of list) have the priority over those further down the list.

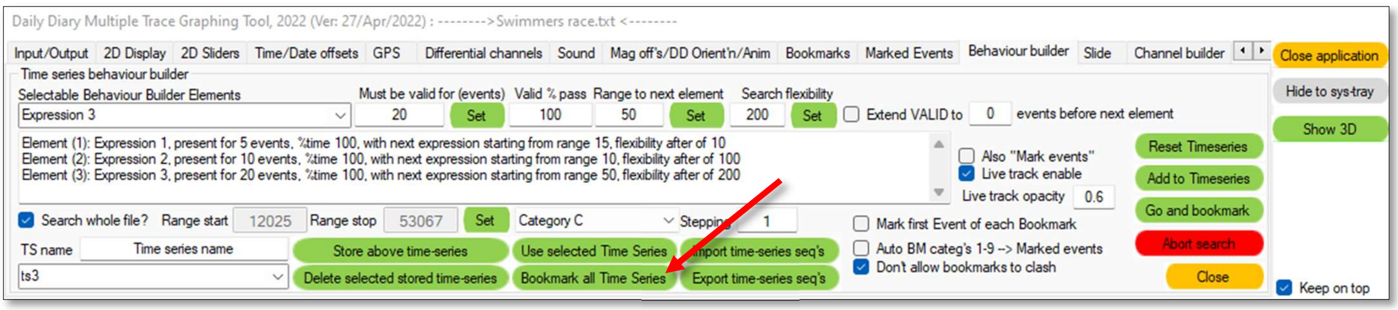


Figure 9.27 Element *values labels. In the above, the* ***flex*** *value is not large enough for it to span the gap between the dive down and surface aspects*

Finally, there is now the option to have the time series algorithm run through all ‘stored’ time series definitions, throughout the entire file. For example, in the figure below, there are 3 stored time series definitions “Time series 1”, “Time series 2”, and “Time series 3”. The currently selected category is ***Category A***. If the user were to select ***Search whole file?***, and then click ***Bookmark all Time Series***, then DDMT would return to the start of the file, loading split #1, and search split by split to the end of the file, creating bookmarks of category A. It would then load up the second time series definition, increment to ***Category B***, and search the entire file again, and finally, increment to ***Category C***, and perform one more full-file search. Depending on the complexity of the time series definition, and the size of the data file, this could take some time.

11. 3D Data Visualisation

Enable 3D, and syncing with changes in data view on 2D graph window

To view data in 3D, simply click the ***Show 3D*** button as indicated. The control panel will be extended with the new window appearing beneath.

Moving the mouse over the new area will show a row of buttons in the top left corner.

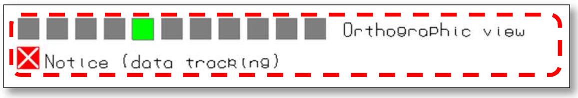


Figure 10.1 *Initial 3D display; 9 buttons listed below*

These buttons, from left to right are (more will be added over time):

1. ***Toggle 3D full window*** – full view will extend the 3D window vertically up to cover the control panel. Moving the mouse out of the window, or to a border will force the control panel to reappear.
2. ***Toggle colour*** – provides a choice between five colour schemes, with orange as the default.

   Additionally, ***Ctrl*** + left click switches to a precision cursor, rather than the standard Windows cursor, and ***Ctrl + MW*** adjusts the size of this cursor (while on this button)

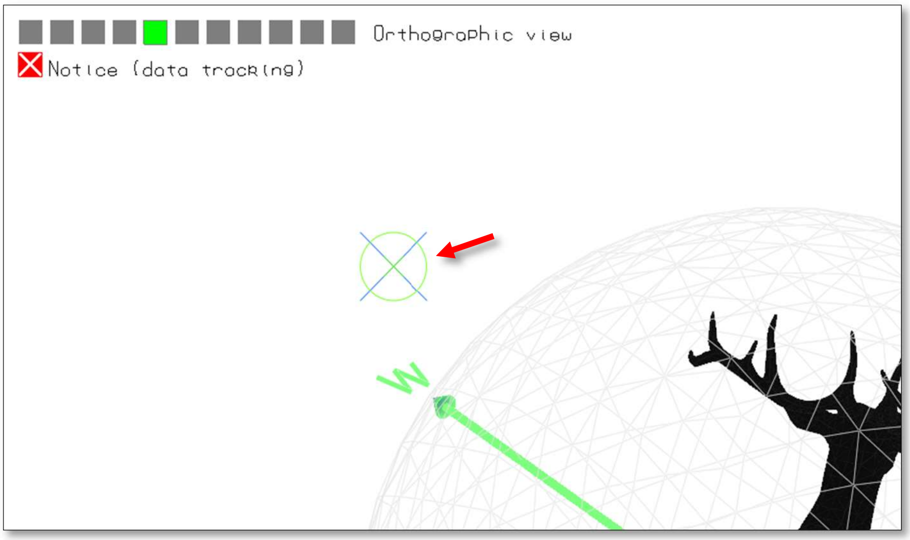


Figure 10.2 *Custom cursor for pin-point accurate selection*

3. ***Colour map Generator*** – discussed later.
4. ***Show 3D help*** brings up help text outlining the mouse controls.

```
Right-click on background to obtain vis-menu
Right-click on Data (reset orientation) button for 3 sub-buttons
Right-click on top sub-button for more menu items
To autorotate a vis, left Alt and slow-drag the vis
To cancel an autorotate, right-click on its centre
To move a visual colourbar around, left Ctrl and drag it
To move a manual-entry values box, left Shift and drag it
Hover mouse over a button to show a graphic of its mouse interactions
(some buttons are a combination of left, right, and/or mousewheel)
To unhook from a vis, left-click then right-click on backdrop
Unhook from current vis to interact with the colourbar generator
Visuals can be rotation-linked by setting them to the same vis channel
(bottom menu button to enable, mousewheel to select channel)
Hold down left Alt to rotate plan-view with dead-reckoning visualisations
Hold down CTRL and SHIFT and rotate mouse wheel to adjust vis axes font size
```

Figure 10.3 *Mouse controls in the 3D window*

5. ***Toggle background*** alters between honeycomb/patchwork/no background. When a background is present, the mouse-wheel, while situated over this button, can be used to modulate the contrast of the background colour.

   Additionally, when the background is non-white, then holding down either ***Ctrl***, ***Shift***, or ***Alt***, and adjusting the mouse wheel will increase the red/green/blue component of the background colour. There will, by default, be a gradient present, such that the bottom of the screen will have a stronger colour than the top. This gradient can be adjusted to level by holding down ***Ctrl + Shift*** and adjusting the mouse wheel to suit:

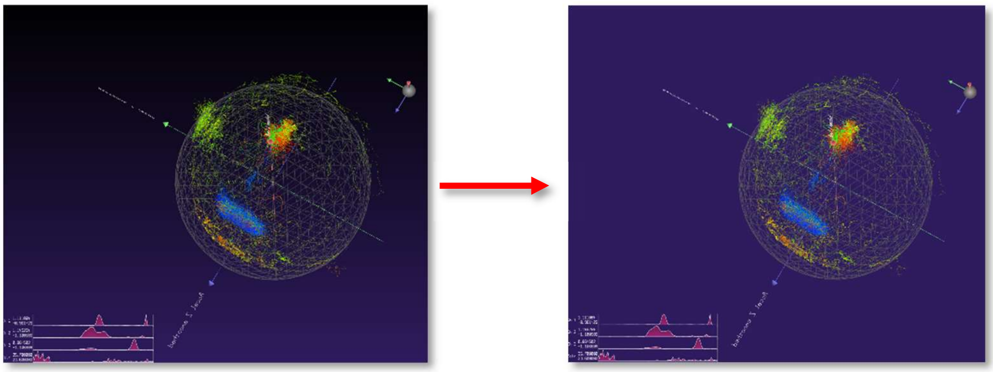


Figure 10.4 *Adjusting the background from black to something with more colour (using Ctrl / Shift / Alt + MW for the red/green/blue components, and Ctrl + Shift + MW for the gradient)*

6. ***Capture screen*** – once clicked, will cause the 3D window to be captured to memory once the mouse is moved off the window area; it waits for the mouse to leave so that the visualisation's menu is removed before capture. If the mouse wheel is rolled on this button, the button label changes to show that it will invert the colours of the image (so a black background will become white etc.).

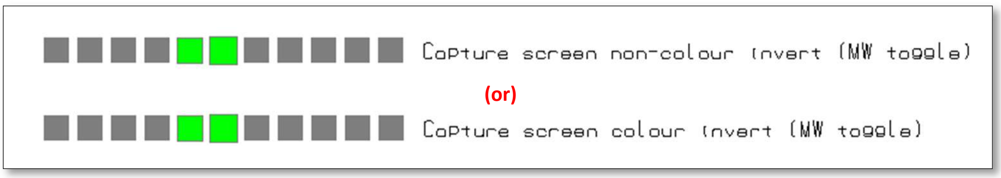


Figure 10.5 *Create screen captures of the 3D window and save them to the working directory (without/with colours invert)*

7. ***Initiate magnetometer correction algorithm*** – this will take the user through correcting the magnetometer data. This is outlined in Chapter 4 and written instructions are available on screen.

8. ***Show Marked Events Pie Charts*** – shows one, two (current 2D data in-view, and current split), or three (all Marked Events (whole file) pie charts of unmarked and marked data by ***Marked Event*** value. Note that the whole file pie chart requires a manual update by the user to have it calculate the %age spread around the disc by holding down ***Ctrl*** and left-clicking this button. The numerical display on the right-side will also show ***Marked Events*** stats for the full data pie.

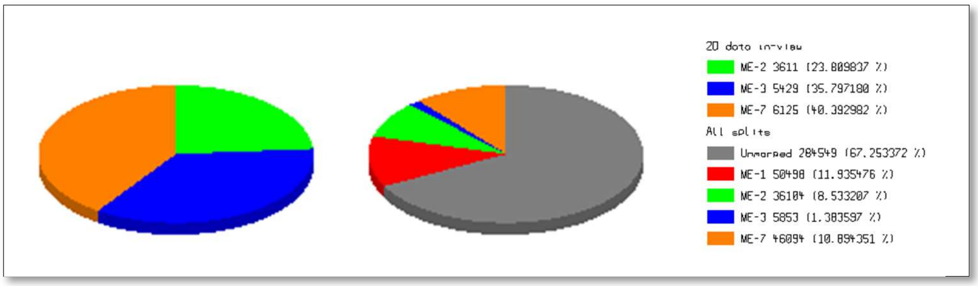


Figure 10.6 *Pie charts to show* ***Marked Event*** *usage throughout the current split and full data file*

9. ***Create Smoothed Accel sphere*** – brings a spherical acceleration plot onto the screen. This sphere corresponds to the data currently on view in the ***2D graphing window***.
10. ***Create Smoothed Mag sphere*** – brings a spherical magnetometry plot onto the screen. This sphere also corresponds to the data currently on view in the ***2D graphing window***.

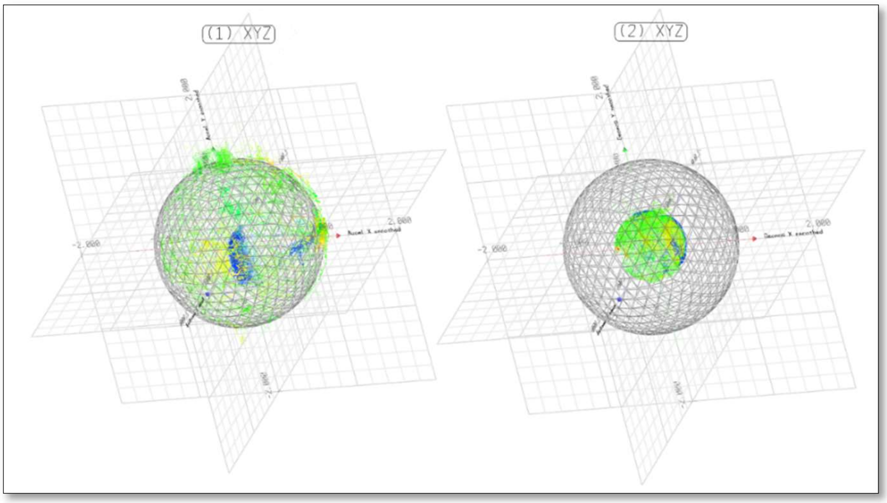


Figure 10.7 *Smoothed Acceleration (left) and Magnetometry (right) spheres*

11. ***Toggle 2D graphs*** – enables the display of a reproduction of what is shown within the 2D graphing window. Eventually, the 2D graphing window will be removed altogether, but for now, this (2D within the 3D) will run in parallel during testing/optimisation (it's significantly faster within the 3D). The benefit of being able to display the 2D within the 3D window is that on laptops that may be limited to a single screen (no external monitor connected), both the 2D graphs and any visualisations may be viewed simultaneously.

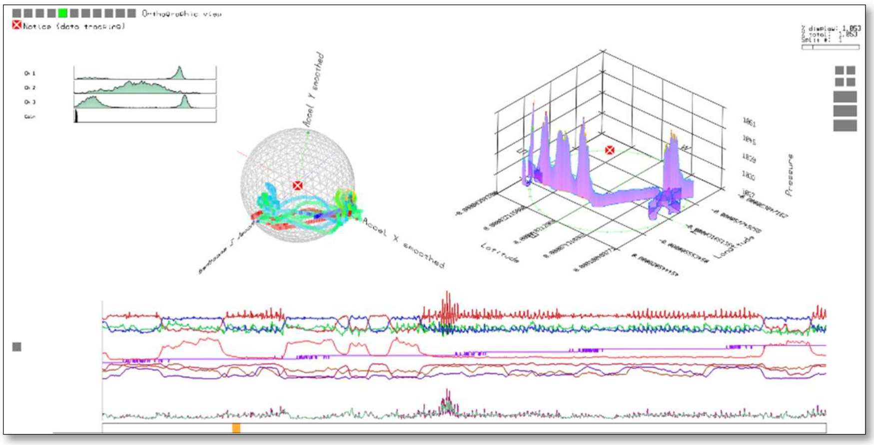


Figure 10.8 *2D graphs viewed within the 3D*

2D data visualisation (within the 3D window)

The new 2D (within the 3D) tries to reflect all the same controls as used within the old 2D. These controls can be viewed within the following video. Please note that the writer of this user manual is not responsible for adverts / links at these external video sites: https://www.youtube.com/watch?v=wBkPinDwc7o&t=59s&ab_channel=SecretsfromtheBatCave

To enable the 2D graphs, toggle them on by left-clicking ***Toggle 2D graphs***:

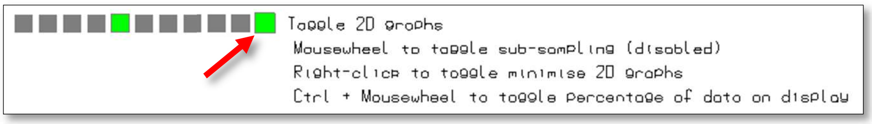


Figure 10.9 *2D graphs viewed data range*

To interact with the 2D graphs, first dissociate from any visualisations by holding **Ctrl** and **right-clicking** (any selected centre flag will toggle from green to red to reflect this).

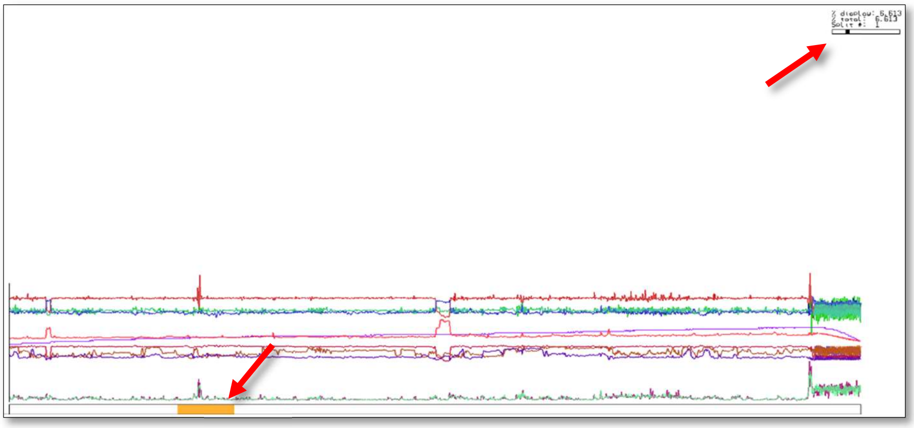


Figure 10.9 *2D graphs viewed data range*

In the above figure, the gadget at the top right shows the data currently in view within the entire data file, while the orange bar at the bottom shows how much data of that currently loaded into memory is being displayed. In this case, the entire file is loaded into memory and so they reflect each other.

By default, the bar at the bottom is orange to indicate that the data in-view is being subsampled for speed. Zooming in on the data will eventually hit a point where the visual system will switch off the under-sampling, and this orange bar will turn red (to indicate under-sampling disabled). Under-sampling can be manually disabled by adjusting the mouse-wheel on the

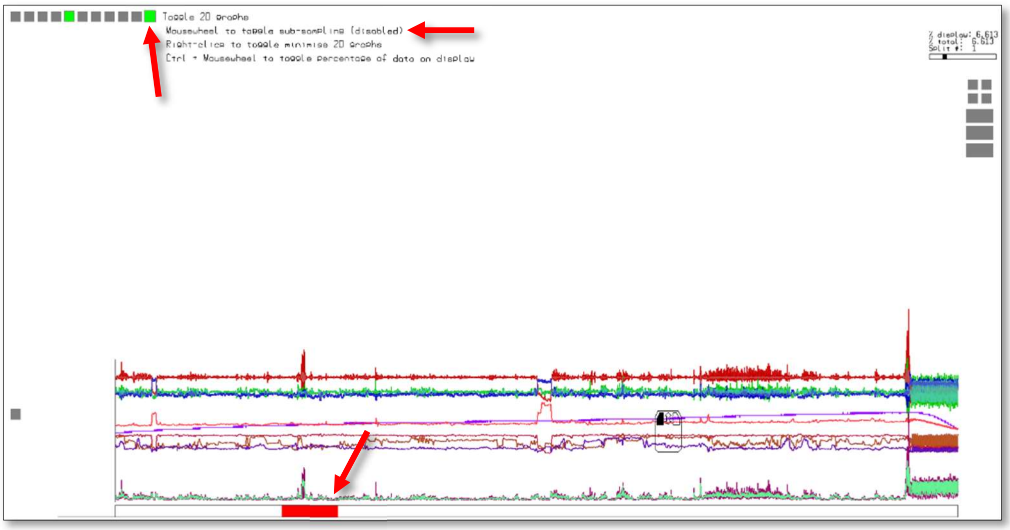


Figure 10.10 *Roll the mousewheel on the **Toggle 2D graphs** button to disable under-sampling (sub-sampling)*

Right clicking the ***Toggle 2D graphs*** button toggles the 2D graphs to 1/3rd of their height, giving more *floor space* for 3D visualisations.

Holding ***Ctrl*** and adjusting the mousewheel on the ***Toggle 2D graphs*** button will toggle the presence of the *Percentage of data* widget at the top right of the display.

Left- or Right-clicking on the bottom bar will set the zoom level of the currently loaded data. Holding down the ***Alt*** key and left clicking will slide the bottom bar to '*slide'* through the data at the current zoom level.

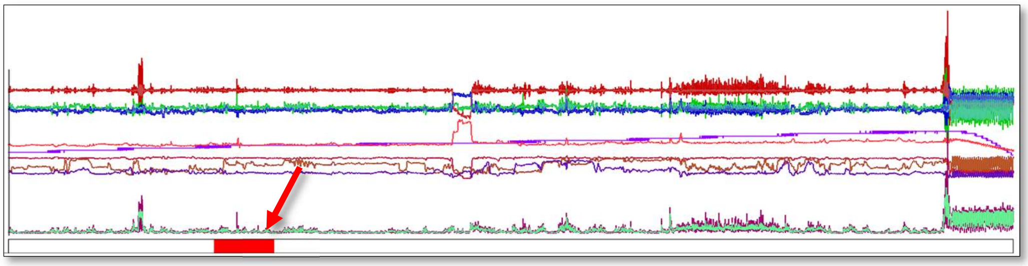


Figure 10.11 *Hold the* ***Alt*** *key to drag this bar left/right through the data*

Left- or right clicking on the 2D display will position the left or right *white lines* line markers.

2D graphs control panel

The 2D graphs control panel at the top right allow adjustment of ***Marked Events***, ***Bookmarks***, and ***White lines*** vertical heights, values overlay controls, split navigation etc.

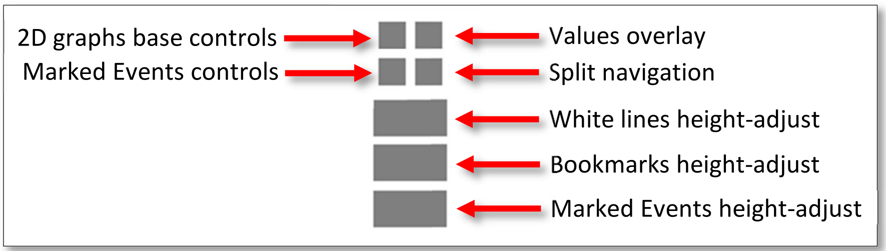


Figure 10.12 *2D graphs control panel*

2D graphs base controls Mousewheel adjusts 2D graphs line thickness
Ctrl + mousewheel toggles between "lines" and "dots", and "lines + dots"

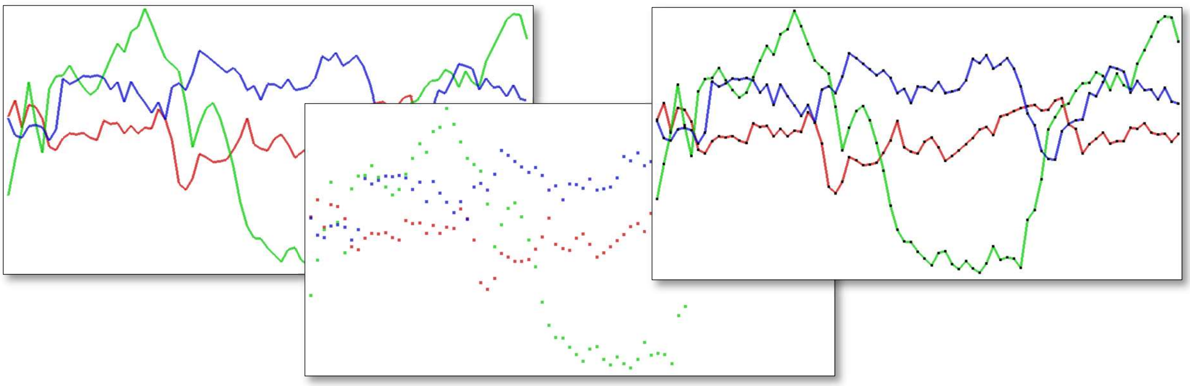


Figure 10.13 *Switching between 'lines', 'dots' and 'lines + dots' using* ***Ctrl*** *+* ***MW*** *on the 2D graphs base controls button*

Left click to toggle enable of 2D graphs position adjustment

When enabled:

***Ctrl* + left-click** adjusts Left edge of the 2D graphs

***Ctrl* + *Shift* + left-click** adjusts width of 2D graphs display

This way, the 2D graphs *footprint* can be minimised on limited sized displays:

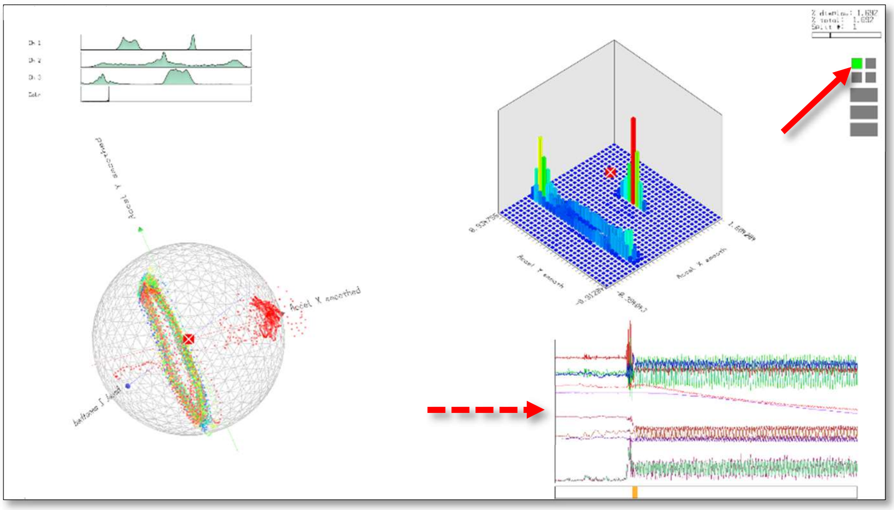


Figure 10.14 *2D graphs control panel*

Marked Events controls

Ctrl + left-click will mark events with the current **Marked Events** value

Adjust mousewheel to adjust this value from 0 (clear) to 9

Right-click toggles view of **Marked Events** on the display

Values overlay

Left-click toggles the values overlay:

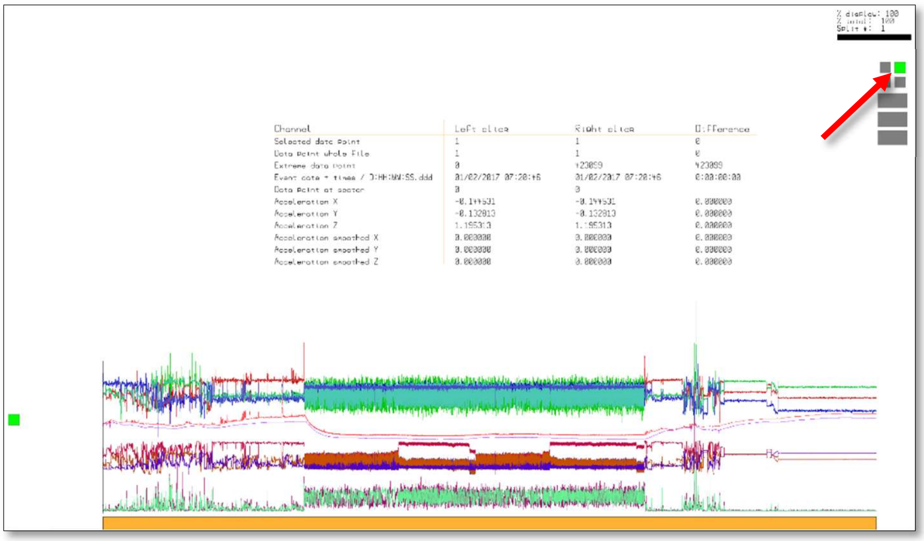


Figure 10.15 *2D graphs* ***Values overlay***

Hold ***Shift*** and left-click/drag the values overlay to the desired position

Mousewheel on this button to adjust the scale of this overlay – adjusts font size
Right-click to toggle values overlay selection:

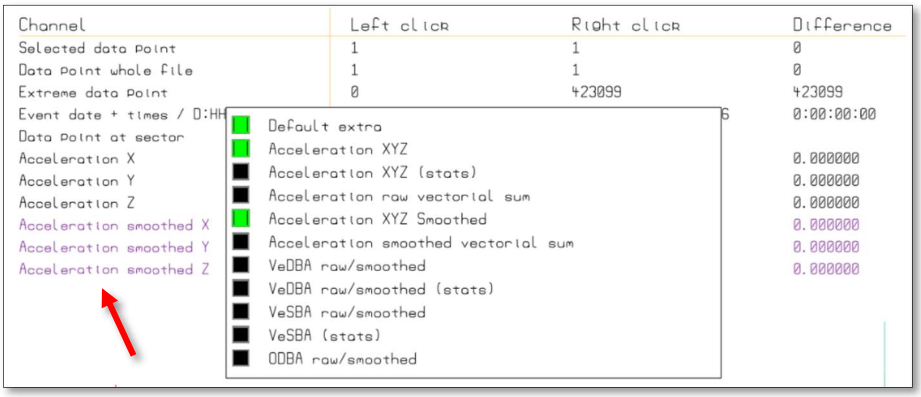


Figure 10.16 *2D graphs* ***Values overlay channel select***

Mousewheel up/down to slide through all possible selections
Left-click on a black square to enable the highlight for that selection

Split navigation

Click this to view the split navigation controls

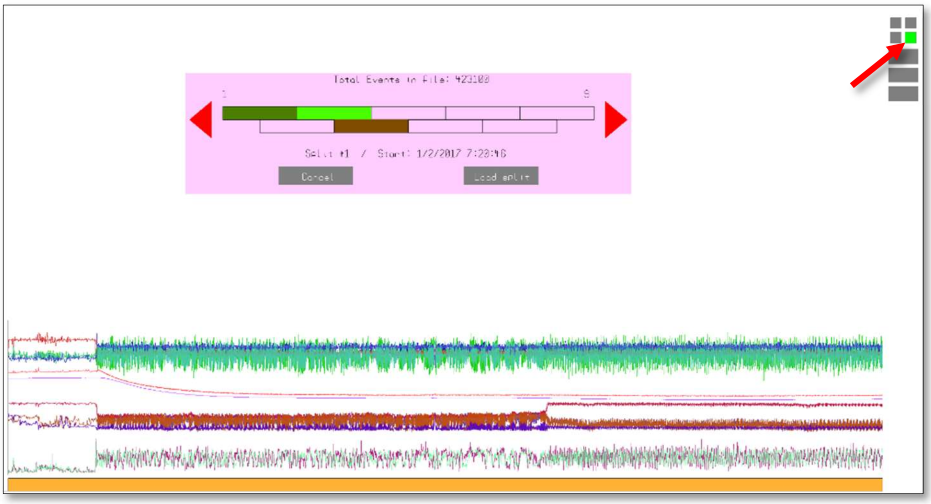


Figure 10.17 *2D graphs* ***Split navigation control***

Bright green – current split
Dark green – selected split to go to if ***Load split*** clicked
Brown selection – split below the mouse cursor (left click to select split)

White lines height-adjust

When this button is enabled (green), a bar will appear on the right side of the screen. Left or right-clicking near it will set the top or bottom range respectively, setting the 'vertical height' of the *white lines* marker lines/area.

Adjusting the mousewheel on this button alters the opacity of the band between the white line markers; see inset below.

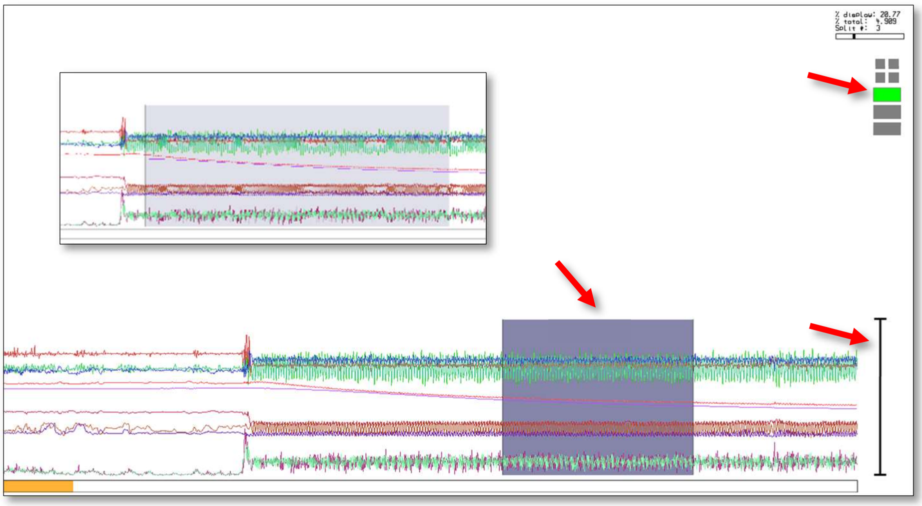


Figure 10.18 *2D graphs* ***White lines height-adjust***

Toggle between 2D and 3D control interfaces. Selecting this button below will enable or disable the 2D, thereby disassociating from any selected 3D visual, or, is toggled off, enable the first generated 3D visual.

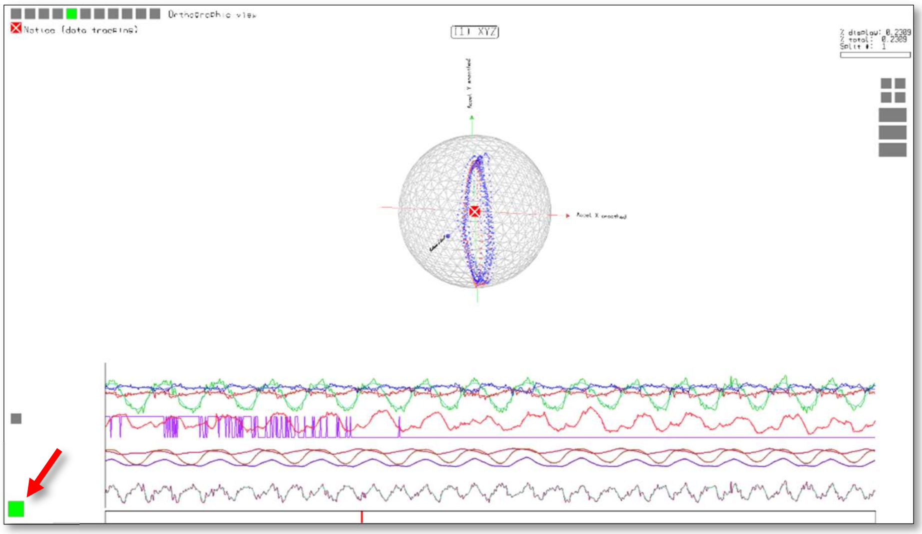


Figure 10.19 *Toggle between 2D and 3D interface controls*

Bookmarks height-adjust

When this button is enabled (green), a bar will appear on the right side of the screen. Left or right-clicking near it will set the top or bottom range respectively, setting the 'vertical height' of the ***Bookmarks*** bands.

Adjusting the mousewheel on this button alters the currently selected 'category' (14 possible categories). The category will be shown at the top of the 3D viewing area (when hovering the mouse cursor over this button).

Right-click this button to generate a book (of the currently selected category) between the current position of the *white lines*.

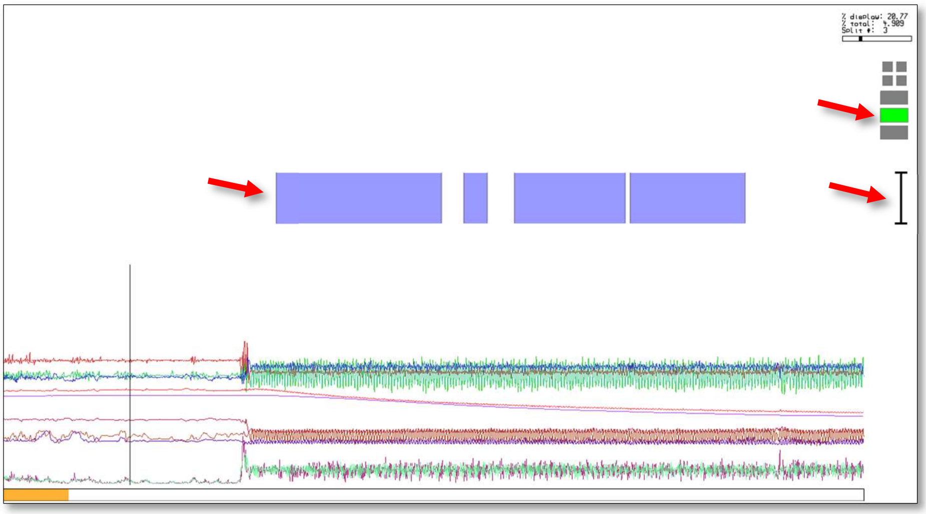


*Figure 10.20 2D graphs **Bookmarks height-adjust***

Marked Events height-adjust

When this button is enabled (green), a bar will appear on the right side of the screen. Left or right-clicking near it will set the top or bottom range respectively, setting the 'vertical height' of the ***Marked Events*** bands.

Adjusting the mousewheel on this button alters the current ***Marked Events*** value that will be applied to data. This value can be from 0 (clear ***Marked Events*** value), up to 9.

Right-clicking on this button will generate ***Marked Events*** for all data points (inclusively) between the current positions of the *white lines*, using the current ***Marked Events*** value.

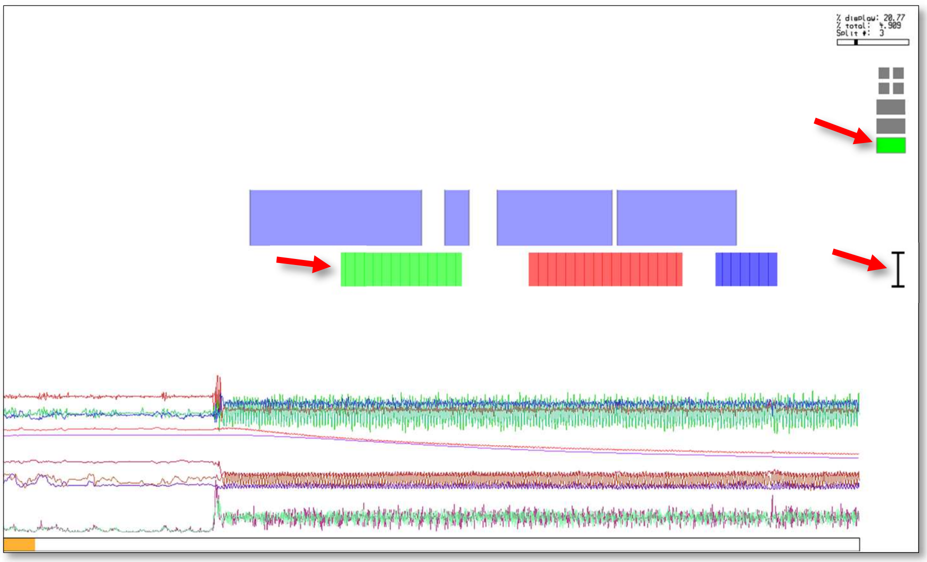


*Figure 10.21 2D graphs **Marked Events height-adjust***

Controlling presence and position of data channels with the ***Channel button***

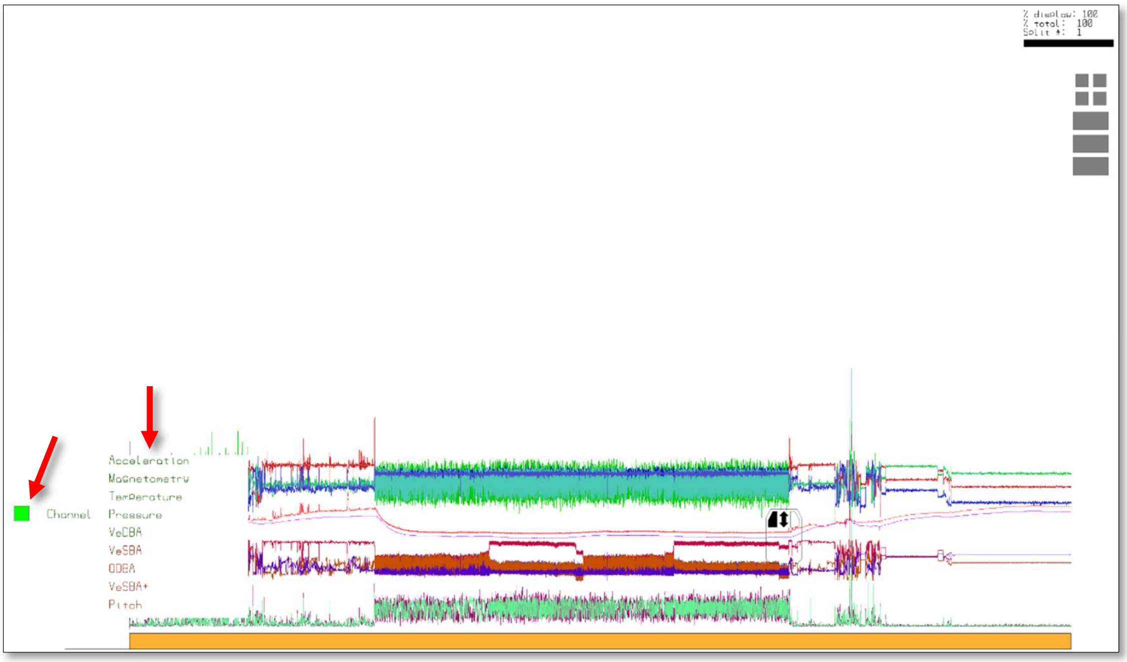


Figure 10.22 *2D graphs* ***Channel button***

Hovering the mouse over this button reveals a list of available channels. Channels will be shaded green if enabled (data graphed), or red/orange is disabled.

- Use the mousewheel to scroll down the list.
- Hold ***Ctrl*** and left-click to toggle a channel to enabled

Left-clicking the ***Channel button*** shows controls:

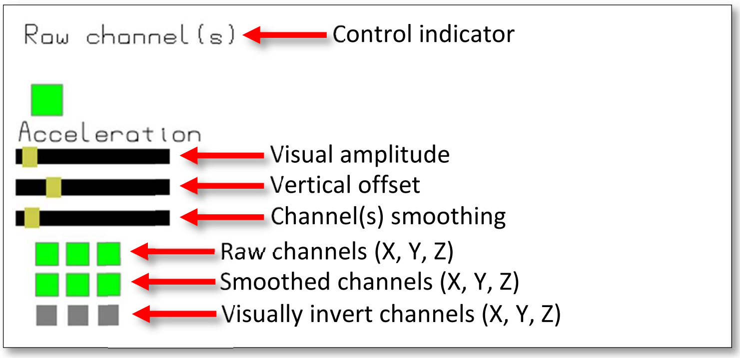


Figure 10.23 *2D graphs* ***Channel button*** controls

As the mouse moves over any of the sliders or button, the ***Control indicator*** above the ***Control button*** shows the control's purpose.

For most channels, a smoothed channel tick box(es) is available, while for some, there is also an additional visual invert option. Where multiple sub-channels are available for a single channel, such as for acceleration or geomagnetism, channels may be enabled, disabled, and visually inverted separately. This may be helpful when attempting to interpret the meaning of the data.

For some channels that result in angular data, the invert buttons become an option to plot the cosine of the data, as opposed to 0-360. This 'gets around' the issue of graphs jumping vertically when passing through 359<-->0. Example channels are ***Pitch***, ***Roll***, and ***Heading***.

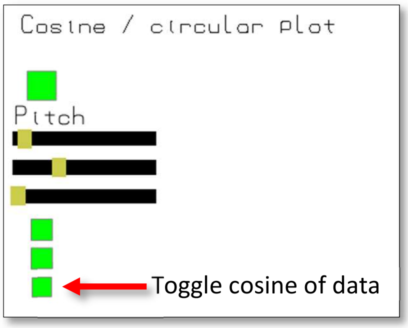
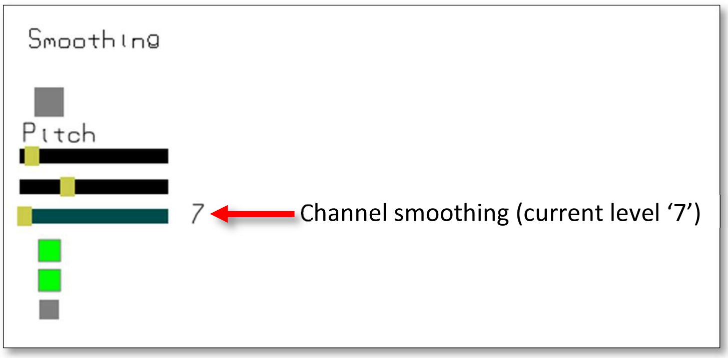


Figure 10.24 *2D graphs Toggle channel to be displayed as the cosine of the data i.e. a 'circular function' to mitigate issues with 359<-->0 transitions*

Channel smoothing



Ctrl + left-click to adjust, right-click to apply

Or

Ctrl + ***Alt*** + left-click to dynamically adjust

Figure 10.25 *2D graphs* ***Smoothing channel controls***

With the 3rd slider (available for most channels), the user must hold down the ***Ctrl*** key and left-click to drag the bar to the required position. When the desired smoothing position is met, right-click on the slider to apply the level of smoothing. The smoothed sub-channel of this channel will be smoothed to this level, and the level of smoothing value will also be adjusted at the ***2D sliders*** controls on the main control panel's controls for the selected channel. Alternatively, the user can hold down ***Ctrl*** + ***Alt*** and left-click / drag the slider to the required position and the smoothing will adjust dynamically, without the need to right-click. Obviously, this can get a little unresponsive with exceptionally large levels of smoothing.

Additional control to allow the easy adjustment of the accelerometer and magnetometer offsets (and scale – acc only). Note that for accelerometer scale, and magnetometer offsets, this requires the left click of the control button and a reload of the split to effect the change.

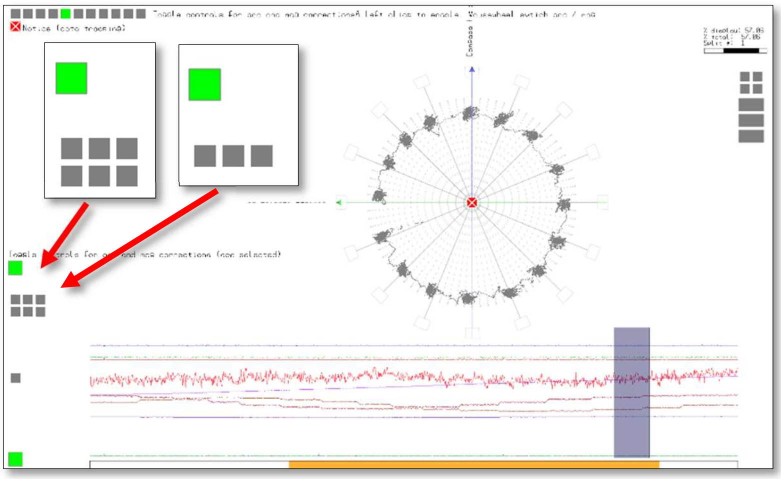


Figure 10.26 *2D graphs* controls to adjust accelerometer and magnetometer offsets (+ scale – acc only)

Creating a visualisation

Ctrl + Right-clicking on the 3D window will show a menu from which one of many visualisation types can be selected:

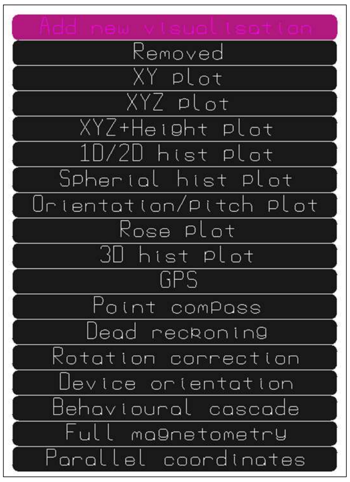


Figure 10.27 *Visualisation selection menu*

To 'dissociate' from a visualisation, again, hold down ***Ctrl*** and right-click. The currently selected visualisation's centre indicator will switch from green to red to confirm. <u>To interact with the controls of the 2D graphs (within the 3D arena), no visualisation may be selected</u>. This is to stop overlap of potential mouse/keyboard controls between the two systems.

XY plot Plot of two variables, X vs Y.

XYZ plot Plot of three variables, X vs Y vs Z.

XYZ+Height plot Plot of acceleration or geomagnetism, normalised, and then modulated by a 4th channel such as pressure or temperature.

1D/2D hist plot Generates either a 1D or 2D (if a second axis is selected) histogram of channel data.

Spherical hist plot A spherical histogram plot of data, using either acceleration or geomagnetism to determine from where the point data is collated from.

Orientation/pitch plot Plot (O-sphere) of data points generated by heading being the circumference, with pitch (up to +/- 90 degrees) varying the point between the two poles.

Rose plot Display a rose plot of the data, i.e. a histogram of heading, segmented to 5 degrees resolution.

3D hist plot Generates a 3D histogram from 3 selected channels.

GPS Plots the GPS track currently loaded into memory.

Point compass Creates a red arrow with a compass that aligns itself to the currently calculated heading value according to the position of the left white line in the ***2D graphing window***. Tilting according to pitch is also included.

Dead reckoning #1 Dead-reckoning algorithm whereby a track is generated according to levels of VeDBA above a user-determined threshold, and pressure for the 3rd dimension

Rotation correction This allows all, or portions of, the whole data set to be rotationally corrected for issues such as collar roll etc.

Device orientation This enables the user to automatically set the magnetometer and accelerometer axes for the correct generation of pitch, roll, and heading angles (for Wildbyte Technologies Ltd *Daily Diaries* only)

Behavioural cascade This visualisation is still in development

Full magnetometry This visualisation allows all magnetometry data to be loaded into DDMT (in a sub-sampled format to reduce memory load). The data is then split up chronologically, which can be individually (manually) corrected for offset drift/magnetic anomalies over time. Once this visualisation is executed, with the user's assistance, all magnetometry data is corrected at the points (int time) selected by the user, and interpolated correction-to-correction throughout the entire file. This allows for drift in any/all magnetic axes over long periods of time. The use of this function is discussed briefly in chapter X and in-depth later in this chapter 3.

Parallel coordinates This visualisation is still in development, but does begin with tri-axial acceleration and magnetometry in-view

Visualisation controls (common)

Some visualisations allow the user to grab the visualisation with the left mouse-button and rotate it around. Some visualisations, such as the 1D/2D histogram, GPS, Dead reckoning, etc., contain data that do not make sense when fully inverted by rotation and therefore use a different rotation algorithm, rotation and tilt i.e., the mouse can be used to rotate around the vertical (Y) axis and pitch the visual up/down. Holding down the left Alt key lets the user rotate the visual on the Z axis (the axis coming out of the screen). Note that a visualisation must be selected to rotate it. Select a visualisation by clicking the centre square with a white cross (green when selected, red when deselected).

Hold down Ctrl and right click anywhere in the background to deselect the currently selected visualisation.
***Ctrl* + Right click** to bring up the visualisation selection menu once again.
***Ctrl* + Left click** to select (on the centre square) an existing visualisation.

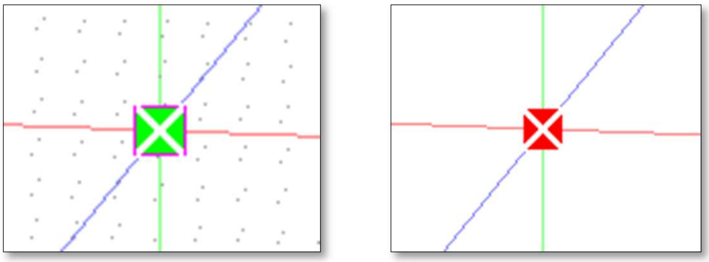


Figure 10.28 *Centre square when deselected (left) and selected (right)*

The white cross indicates that the data currently being displayed on the 3D visualisation will automatically update when the user moves to a different section of data on the ***2D graphing window***, be it sliding through the current split, or changing to a different split altogether. A notice will appear at the top left of the viewing area to inform the user that data tracking is enabled (as opposed to the data in visualisation being locked). Moving the mouse over this red square will expand the notice information to provide a more complete explanation.

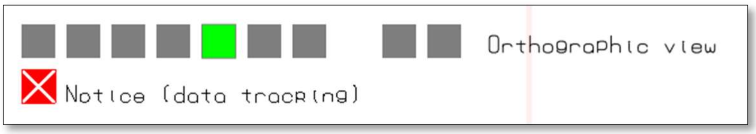


Figure 10.29 *Data tracking notice*

Position a visual by either left clicking and dragging the centre square, or simply hold down shift and left click somewhere to force the currently selected visual to relocate to the current mouse position. Right-clicking again on the background area will show the ***Add new visualisation*** menu, and at the same time, release the currently selected visualisation.

When the mouse pointer enters the 3D area, if any visualisation is selected, a menu of buttons will be visible that apply to that selected. Moving the mouse over the buttons will provide a written description of the button's action.

The top two buttons (Hold, and Reset), and the buttons highlighted in red below are identical for all visualisations, while for the remaining buttons, if present, will vary in function with visualisation type.

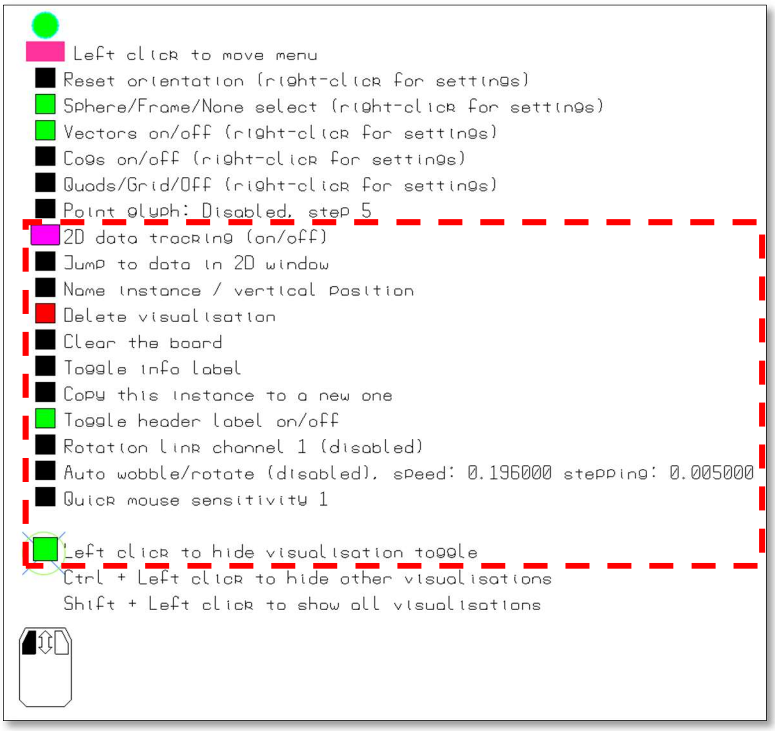


Figure 10.30 *Visualisation menu controls*

The top button in the menu (coloured pink to make it more visible) can be used to relocate the menu (left click / drag) within the 3D window, as it often gets in the way. The second button down has 3 mouse-interactions, as indicated by the mouse image at the bottom (left, right, and mouse-wheel).

The left mouse button will reset the rotational orientation of the visualisation, the mouse-wheel (MW) will adjust the font size of the text (sometimes useful on larger screens), while the right mouse button will produce another column of buttons. More on this later. The circular button at the top of the menu structure toggles all button labels below it, else the button name will appear when the mouse passes over it.

Some visualisations will have an associated “ortho-viewer” appear than can be dragged into any location on the 3D area, which best shows the 3D orientation of the current visualisation. Right clicking on this also cycles the rotation of the visualisation through several set orientations, including X-Y, and X-Z etc.

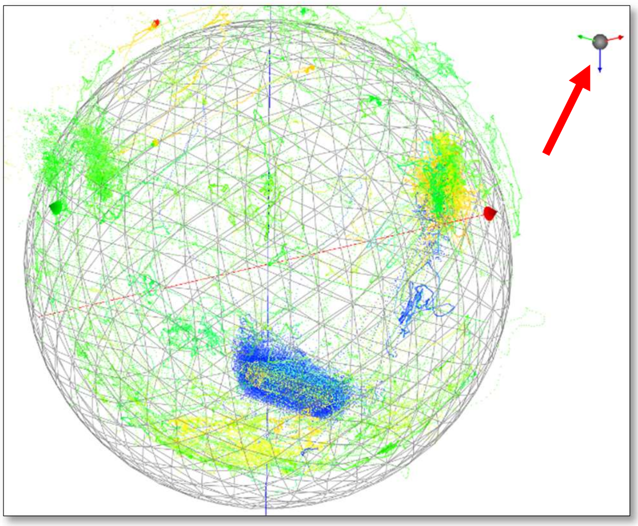


Figure 10.31 *Ortho-viewer for visualisation orientation, and also for auto-switching the rotation through one of a number of preset orientations*

The other buttons, highlighted with the dashed red line, have a variety of useful function as described below, and are common to all visualisations.

Data tracking

When a visualisation is created, this is enabled by default (pink to emphasize it is enabled). When data tracking is enabled, any change to the viewed data in the 2D viewing area (or perhaps changes in smoothing level of various data channels) will update this data-tracking enabled visual. The visual doesn't need to be selected at the time for it to be updated by a change in the viewing on the 2D window. When data tracking is disabled, the visual is data-frozen; moving to another split will not update the visual with the newly loaded data channels.

Jump to data in 2D window

If the currently viewed split contains the data of the selected visual, then the 2D window will jump to / zoom in on the data used to create it. Only to be used when ***Data tracking*** is enabled for the visualisation in use

Name visualisation instance

This lets the user set the name of the instance (visual).

Delete visualisation

Does what it says on the tin. Note there is currently no confirmation so do not accidentally click it. Coloured red to emphasize its use/importance.

Clear the board

This will scale and position all the currently generated visuals to the top of the screen.

Toggle info label

Moving the mouse over the centre square of a visual will show a small info label detailing the split origin of the visual, its start/stop data points, visual type etc. Enabling the info label will make this show permanently, for this selected visual.

Copy this instance to a new one

Will simply create a copy. Useful if you wish to perhaps show the same data sets, coloured by two different properties such as temperature, and pressure.

Toggle visual label

This will toggle the presence of the name of the visual above it. The mouse-wheel can be used to adjust the vertical position of the name label.

Rotation link / channel

All visualisations can be linked via a rotation "channel" (1-9). When enabled, any other visualisations that are enabled (and on the same rotation "channel") will rotate at the same time. Note that clicking the orientation reset button will also orientation-reset any other rotational linked visuals. – useful if the user would like to match rotation orientations. Two or more visualisations do not need to begin with the same rotation offset, one might be rotated by 40 degrees in the X axis, and 27 degrees in the Z axis, but will still move the same relative amount indicated by the user's mouse

Auto wobble / rotate

Will cause the visualisation to rotate / wobble. The mouse wheel will increase the speed of this wobble until it becomes a rotation. Holding down Ctrl and adjusting with the mouse wheel changes the stepping. The combination of speed and stepping both affect the degree of speed of rotation and apparent randomness of rotation

Quick mouse sensitivity

Allows the mouse scroll wheel to make changes to menu parameters more quickly by setting the wheel sensitivity to values, 1, 10, 100, 1000, or 10000 (and then back to 1) by left clicking this button. Note that some controls such as scaling of visuals auto-limit the sensitivity to something small as 10000 on scaling would be pointless

Visualisation(s) hide/show toggle

Allows the current visualisation to be toggled to hide from view. When the mouse is in the 3D area, the centre green/red patch will be visible to select it and to toggle it back to view

Other options are allow the hiding of all other visualisations bar this one, or, to show all other visualisations that were hidden, using either Ctrl or Shift, respectively

Second column buttons

Right click on the ***Data reset orientation*** button at the top of the menu (2nd button down) to show a further 3 (or 4) buttons to the left of it (2nd column controls). The reset button will be outlined in purple to emphasize that these new buttons relate to the reset button as can be seen below (just below the orange rectangular "menu relocation" button):

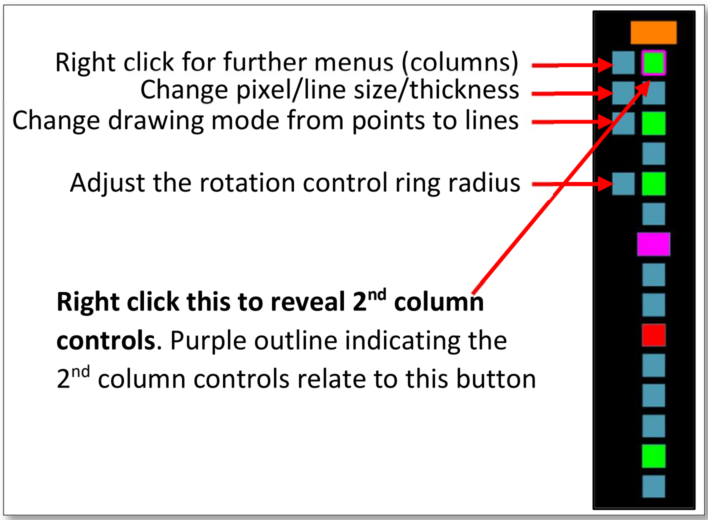


Figure 10.32 *First extended menu*

The second button from the top (2nd column from right) will adjust (mouse wheel) the point or line thickness (depending on drawing type) of the data in the visualisation.

The third button toggles the drawing mode between points and a continuous joined line (toggle mode with the mouse wheel).

The top button is right click only, providing access to the remainder of the controls (3rd, and 4th column for some visuals only). For each visual, the button-content is visualisation-type dependent. Additional round buttons are visible above each column of controls to allow all button labels to be simultaneously displayed (as in Figure 11.14 below). Some visualisations will have 3, 4, or perhaps 5 columns of controls in total, depending on the complexity of the visualisation type.

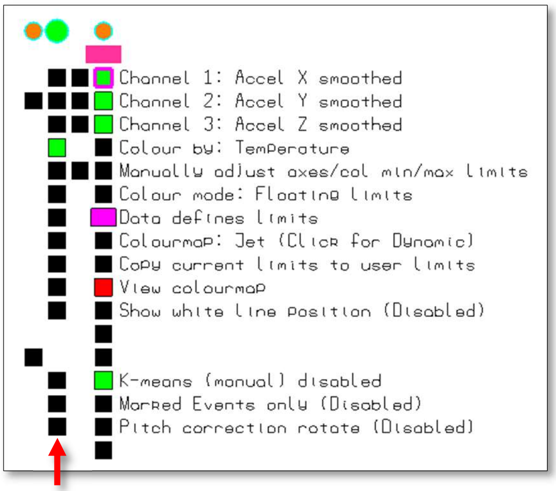


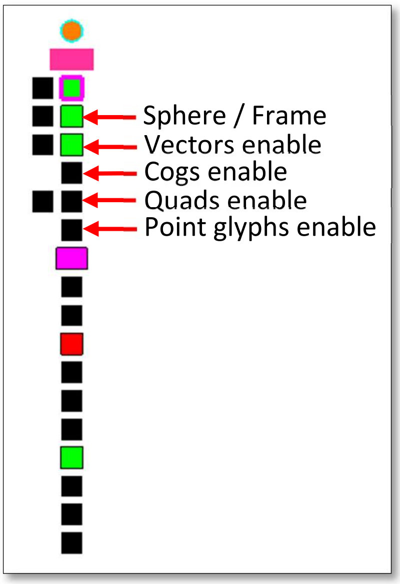
Figure 10.33 *Second extended menu*

Third column buttons

The 3rd column of buttons (from the right) above allows (for this visualisation) selection of channels for the various axes and colour schemes of the visualisations, and then more complex adjustments depending on the visualisation type.

First column additional buttons (vary with visualisation)

Several of the visualisations have some other common controls, with buttons placed in the 1st (RHS) column. Right-click provides further controls (for that function) on the 2nd column:



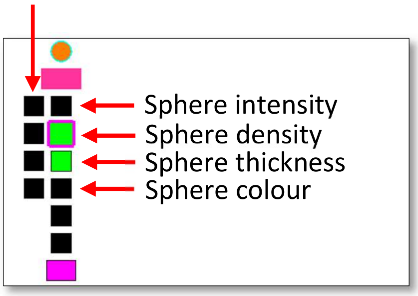


Figure 10.34 *Customisable visualisation options. Several of the buttons in the first column can be right clicked to reveal controls in the 2nd column that apply to that control*

Sphere/Frame

This will place a sphere of points, or a sphere of lines, or a box frame around the visual; left mouse-click cycles from one mode to the next. Right mouse-click will shift the above purple box to over the *Sphere* button and the 3 or 4 buttons in the 2nd column will then be attributes for sphere (*Intensity, Density, dot/line thickness, and colour*). The user can use the mouse-wheel to adjust these attributes.

Vectors

This button places the X, Y, and Z vectors onto the graphic along with labels indicating which channel data is responsible for each axis. Right mouse-click will shift the above purple box to over the *Vectors* button and the three buttons in the 2nd column will then be attributes for vectors (*line thickness, invert colours, and vectors magnitude*) -use the mouse-wheel to adjust these attributes.

Cogs

This button places 3 orthogonal intersecting cogs over the visual. Right mouse-click will shift the above purple box to over the *Cogs* button and the three buttons in the 2nd column will then be attributes for cogs (*opacity, divisions, and cog thickness*) -use the mouse-wheel to adjust these attributes.

Quads

This button will place 3 orthogonal quad planes on the visual; left mouse button cycles between simple planes, and gridlines with numbered scales. Right mouse-click will shift the above purple box to over the *Quads* button and the three buttons in the 2nd column will then be attributes for quads (*opacity, colour, and size*) -use the mouse-wheel to adjust these attributes.

Point glyph

This button will place small glyphs placed at every X points of data. Their size is fixed, but the value of X can be adjusted with the mouse-wheel. The point glyph will assume the colour of the data point it sits over.

Visualisation controls – by visualisation "type"

XY plot (2D)

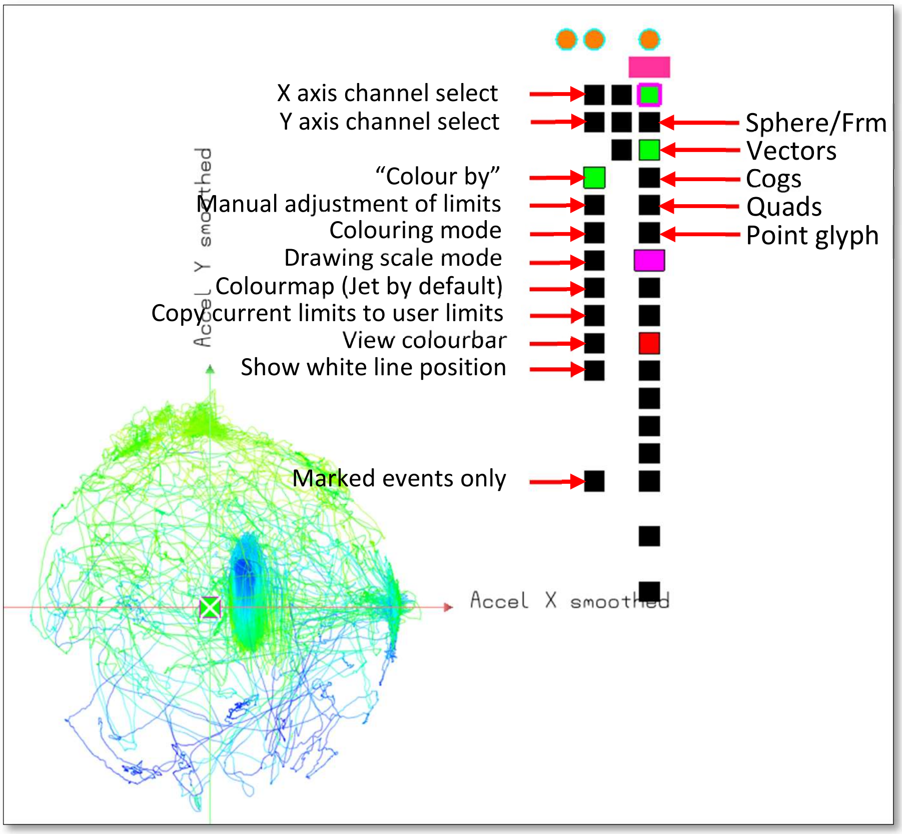


Figure 10.35 *XY plot data selection and visualisation options*

Channel 1 select

Use the mouse-wheel to select the appropriate data channel for the first axis

Channel 2 select

Use the mouse-wheel to select the appropriate data channel for the second axis

Colour by select

Use the mouse-wheel to select the appropriate data channel to colour the data points

Left-clicking this button switches from colouring by channel data, to a single colour; use the mouse-wheel to adjust the actual colour mono-colour to any colour within the *Jet* colour-scheme

Manual adjustment of limits

This manifests a control panel whereby the user can adjust the channels' limits of the above grid scale. Note that it is the halfway points that will be defined.

There is also a small box, visible only when data is scaling to 'user limits' (see ***Drawing scale mode*** below), ticking this will double the values within the XYZ min/max user limits boxes. Alternatively, rolling the mouse-wheel while hovering over this tickbox will adjust up/down the values by 5%, thus scaling the data in view by this amount.

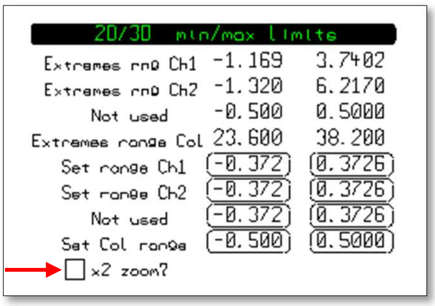


Figure 10.36 *Control panel allowing channels limits to be defined*

Hold down the shift key and mouse click and drag the above window around to better position it for viewing the values. The top few rows of data indicate the currently selected channels' min/max values. Click on any of the ringed values to set the limits for the halfway +/- values for each axis. A numeric touchpad will appear. Enter the required value and then click anywhere else on the viewing area to accept this value and the graphic will update (if ***Drawing scale mode*** is set to ***Axes: User limits***). For example, to double the size of the drawing set the min/max values for the two axes to +/- 0.5, rather than the default +/- 1.0. As the data, in the above graphic, is approximately +/- 1.0, it will double the size of the sphere. Note that this values panel is used in other visuals so some of the rows are "Not used". In the above example, the graphic is coloured by ***Temperature***, and the values in the panel are min 23.6 C and max 38.2 C, which, by the "Jet" colour scheme, is blue through to red
Click the ***Manual adjustments of limits*** button again to hide this values panel

Colouring mode

When ***Colour by select*** is using channel data to colour the data points, it can either use the colour limits as defined by the user in the above ***Manual adjustment of limits*** for the min/max colour values, or use floating limits i.e., scale the colour to the min/max values in the currently selected data

Drawing scale mode

There are 3 drawing scale modes to display the data:

1. Auto-normalise/centralise on the origin
2. By the user-defined limits through the ***Manual adjustment of limits*** control above
3. (Default) Data defines the limits; centre 0.0,0.0, with grid max at +/- 2.0. **Some data channels such as barometric pressure will be 'off the screen' at ~1000 mbar, so switching to user-defined limits (and setting the min/max limits to fit those 'large' channels) or to auto-normalise will be necessary.**

Colourmap

Select the colourmap to use via the mouse-wheel (only Jet available by default). Left mouse-click to switch to dynamic colouring. The graphic will update in real-time while adjusting the colourmap in the colourmap generator app (3rd button from the left on the top left of the viewing area)

Copy current limits to user limits

This copies the values for the X and Y min/max extremes to the ***Set range Ch1/2*** user limits boxes:

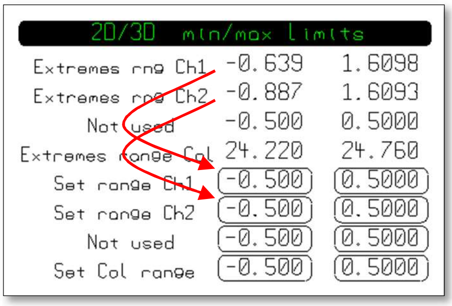


Figure 10.37 *Min/max limits control panel*

By copying the 'current data limits' to the range limits, and setting the ***Drawing scale mode*** to ***user-defined*** (detailed just above), one can use data channels such as barometric pressure on one of the axes without that axis displaying 'off-screen'

View colourbar

This toggles the view of the colourbar, showing the ***colour by*** channel name, and min/max limits currently being applied

Show white line position

Left clicking on the ***2D graphing window*** will show a small white square on the visualisation at that selected data point. If the plot is filtered by ***Marked Events,*** then the white square will position itself either at the start of the plot (first data point with a ***Marked Event***) or at the last ***Marked Event*** before the currently selected data point (if itself is not ***Marked***). Left clicking and moving the mouse through the data allows the user to see the chronological position of the data point

Marked events only

By default, this is disabled (value 0). Use the mouse-wheel to cycle this through values 1-9 (or to ALL – any value of Marked Event other than zero) in order to filter by data that has been marked with events values 1-9 either manually, or via the Behaviour Builder function. This allows only data of interest to be included/displayed on this visual

Special cases with using the XY plot

For the two channels available, Channel 1 additionally has ***Time*** as a possible channel towards the bottom of the list. This allows the user to plot Channel 2 on the vertical axis versus ***Time*** on the horizontal, similar to that seen on the ***2D graphing window***. Axes numerical limits are currently not displayed on the axes themselves, and so if required, the limits box must be displayed for now.

It should be noted, as mentioned earlier, some channels will potentially have large negative or positive values. By default, the axes are scaled for data that has values around +/- 1 i.e., acceleration data. To have the axes

normalise / fit nicely within the visual widget, change the ***Drawing scale mode*** to auto-normalise (discussed above).

When the ***Vectors*** are enabled as below, the axes labels can be toggled on/off by holding down shift and rolling the mouse-wheel on the vectors enable button. Additionally, when channel 2 is enabled, the axes can be switched from centralised to bottom left, shown below, by holding down ctrl and again rolling the mouse-wheel on the vectors enable button. Their colours also switch to black (white when background is black). This is possible on this visual widget (Plot XY) only, not the Plot XYZ.

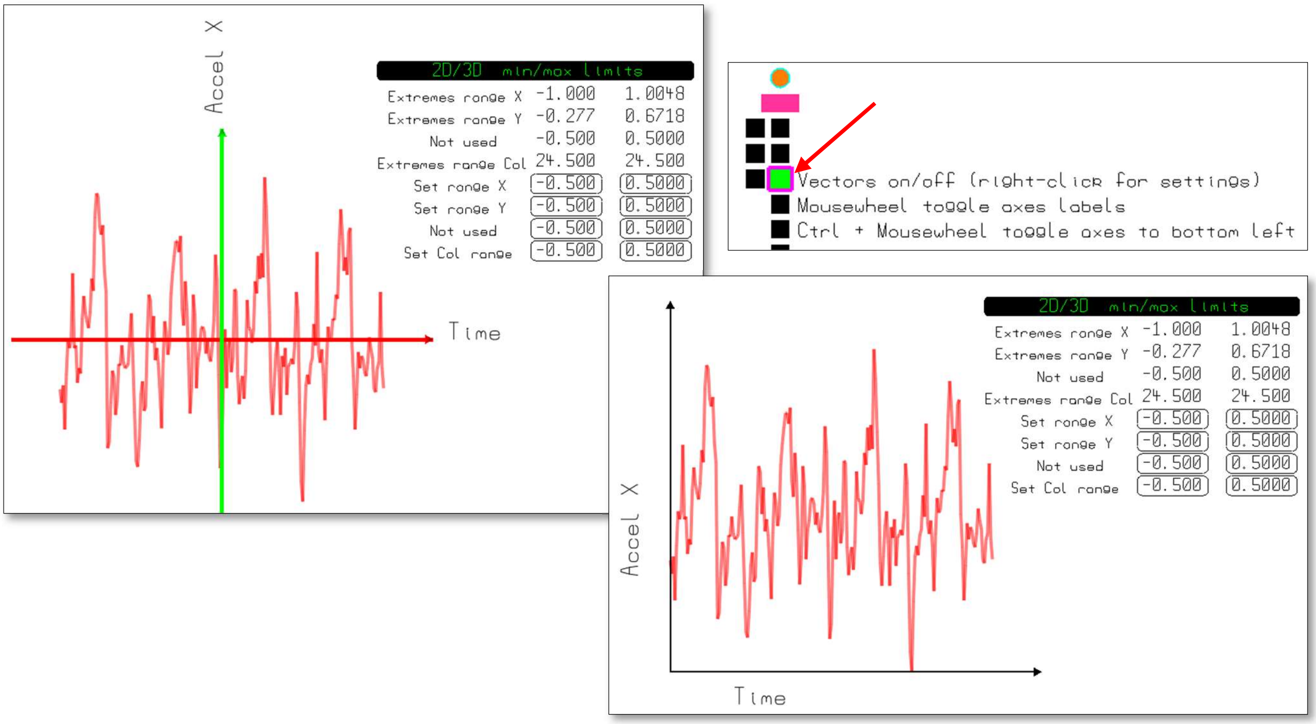


Figure 10.38 *Axes vectors adjustments*

Channel 2 can also be disabled by left clicking it, making this plot a single axis (*Channel 1* vs *Time*) only. The horizontal axis will therefore become ***Time*** by default, with Channel 1 being displayed on the vertical, with the ability to adjust the horizontal and/or vertical scaling on the 4th button, 2nd column menu control. Vectors switching to the bottom left in this single channel mode will be added at some point.

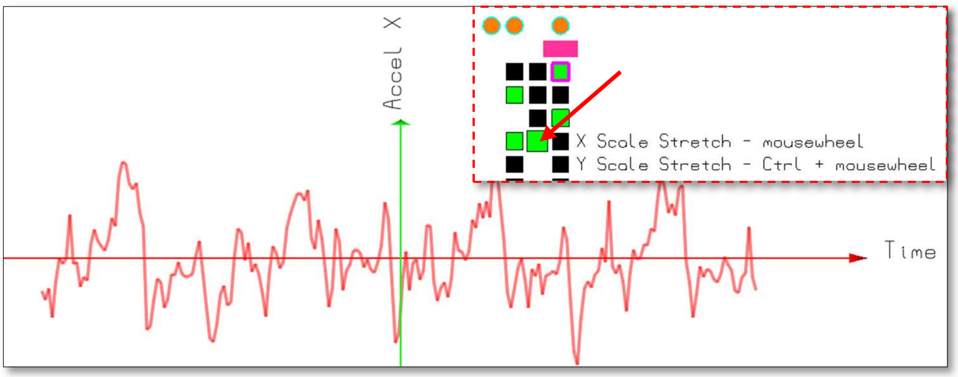


Figure 10.39 *Single channel plot on the vertical axis, vs the default of time on the horizontal*

When data has ***Marked Events*** associated (figure below), these can be used to filter what's displayed on the plot. For the same dataset displayed above in Figure 11.20, we can mark sections of these events with values 5, 1, 2, 3, and again 1 (pink, red, green, blue, and red):

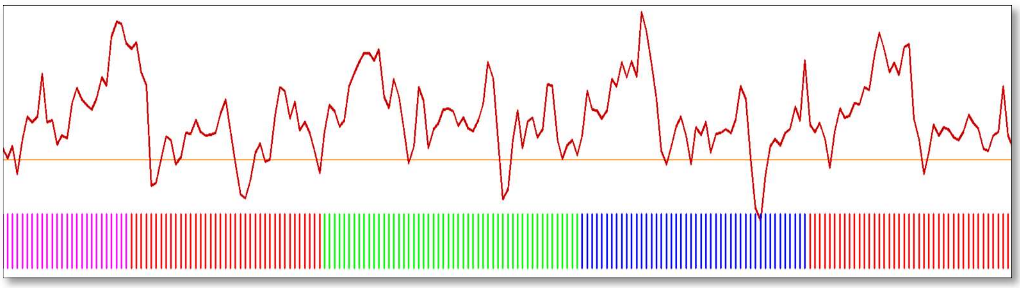


Figure 10.40 *A section of data split and marked with different* ***Marked Events*** *values (5, 1, 2, 3, 1)*

Using the ***Marked Events*** button, we can select (to filter) either *disabled (this filter will not be used)*, any value 1-9, or *all*. In the case of value '1', this merges the 2nd and 5th sections of data into one, while the other 3 sections can be displayed independently, figure below. Note that ***Marked Events*** is also listed in the ***Colour by*** as a channel and is used in the figure below.

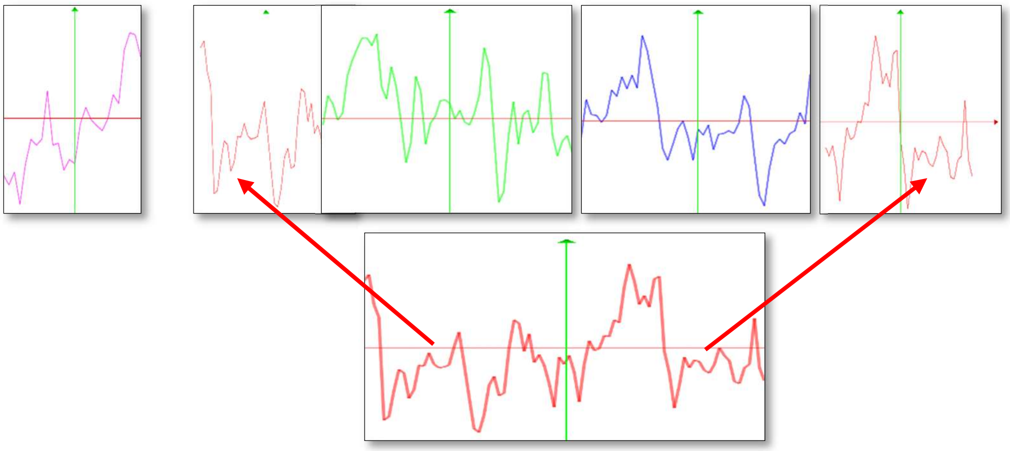


Figure 10.41 The above sections of data are filtered and merged from the data in figure 11.19. Note that they're scaling varies from one section to the other as they're individually normalised

If the ***Marked Events*** selection on this plot is set to *all*, and the ***Colour by*** is set to ***Marked Events*** then the resulting plot will be the same as viewed in the ***2D graphing window***.

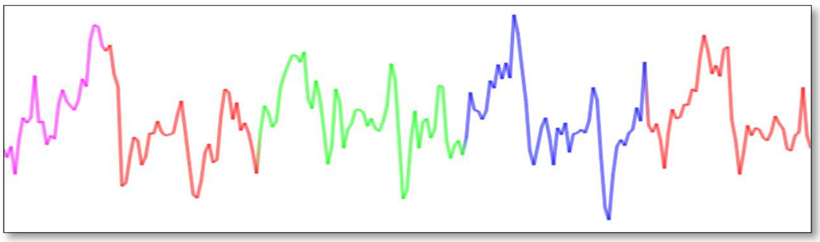


Figure 10.42 *A single trace of data plotted on the 3D area, filtered and coloured by the data points'* ***Marked Events*** *values*

XYZ plot (3D)

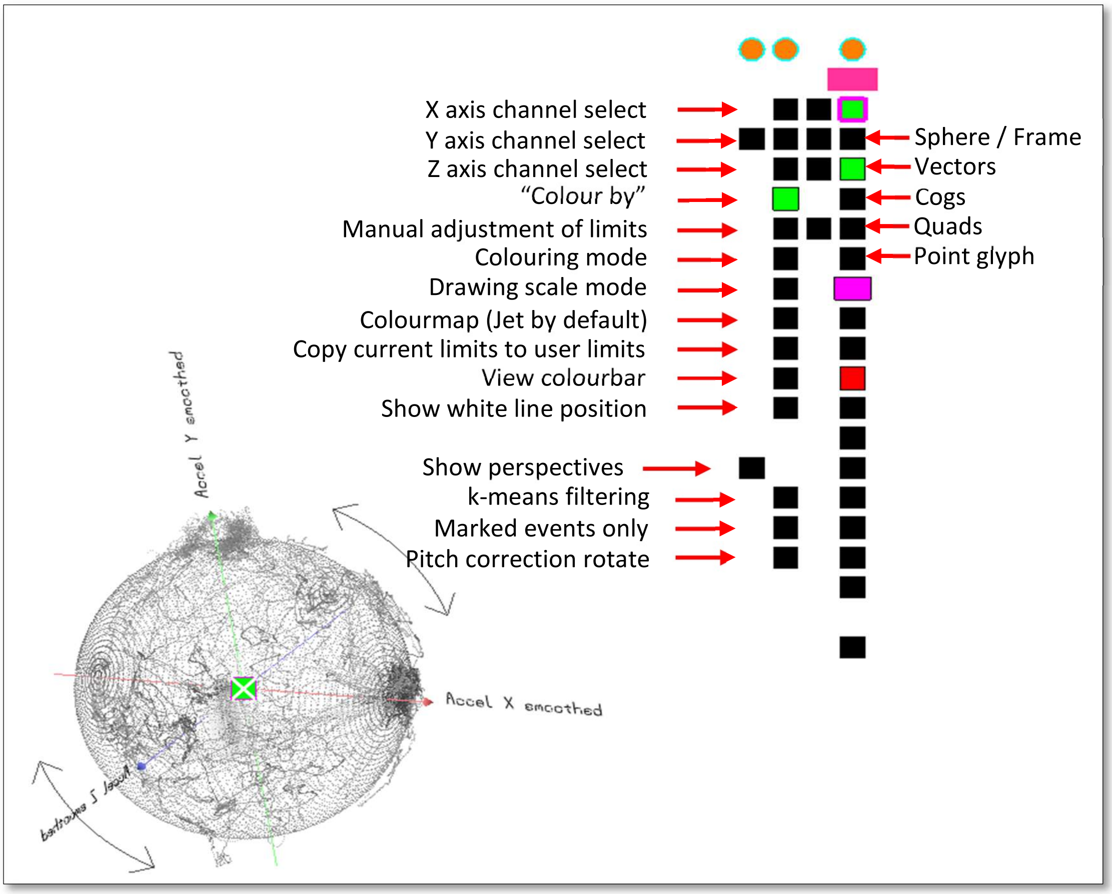


__Figure 10.43__ XYZ plot data selection and visualisation options

Channel 1 select

Use the mouse-wheel to select the appropriate data channel for the first axis

Channel 2 select

Use the mouse-wheel to select the appropriate data channel for the second axis

Channel 3 select

Use the mouse-wheel to select the appropriate data channel for the third axis

Colour by select

Use the mouse-wheel to select the appropriate data channel to colour the data points.
Left-clicking this button switches from colouring by channel data, to a single colour; use the mouse-wheel to adjust the actual colour mono-colour to any colour within the *Jet* colour-scheme

Manual adjustment of limits

This manifests a control panel whereby the user can adjust the X/Y limits of the above grid scale. Note that it is the halfway points that will be defined.
There is also a small box, visible only when data is scaling to 'user limits' (see ***Drawing scale mode*** below), ticking this will double the values within the XYZ min/max user limits boxes. Alternatively, rolling the mouse-wheel while hovering over this tickbox will adjust up/down the values by 5%, thus scaling the data in view by this amount.

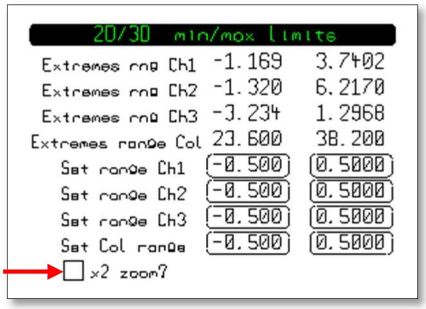


__Figure 10.44__ Control panel allowing channel limits to be defined

Hold down the shift key and left mouse click to drag the above window around to better position it for viewing the values. The top few rows of data indicate the currently selected channels' min/max values. Click on any of the ringed values to set the limits for the halfway +/- values for each axis. A numeric touchpad will appear (figure below). Enter the required value and then left-click anywhere else on the viewing area to accept this value, and the graphic will update (if ***Drawing scale mode*** is set to ***Axes: User limits***).

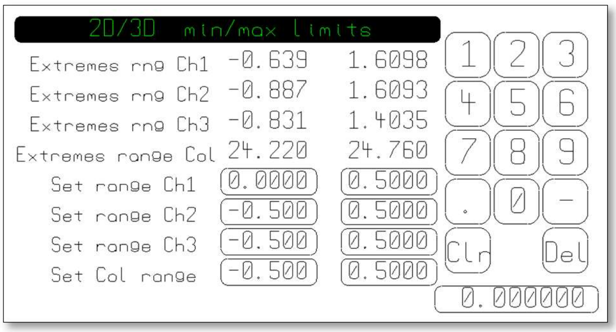


Figure 10.45 *Numeric keypad to adjust a value within one of the circled range boxes*

For example, to double the size of the data in the image below (with the ***Drawing scale mode*** (discussed below) set to 'User limits'), set the min/max values for the three axes to +/- 0.5, rather than the default +/- 1.0.

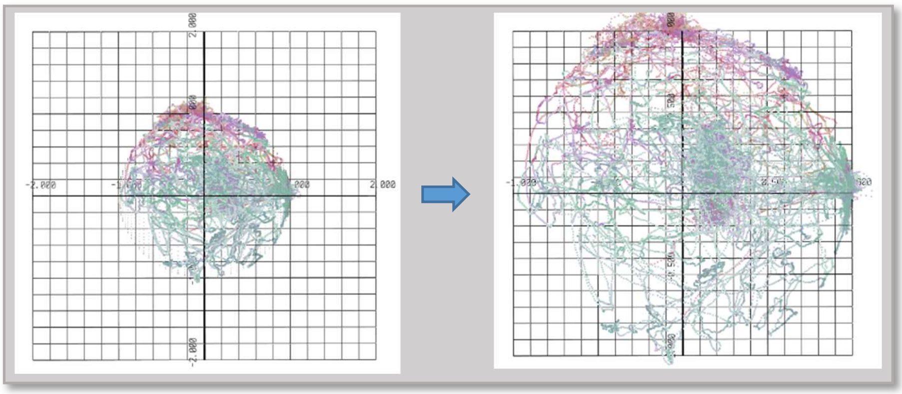


Figure 10.46 *Changing the Range Limits from (-/+1.0) to (-/+0.5) for the 3 axes doubles the scale of the data (when **Drawing scale mode** is set to 'User limits'*

The same method of range can be applied to the colouring. The *Extremes range Col* boxes give the min and max values from the channel setting the colour (when colouring is set to colour by channel data (and not *mono*) such that the data will be coloured by the full colour map currently selected (*Jet* by default)

Colouring mode

When ***Colour by*** is selected to use channel data to colour the data points, it can either use the colour limits as defined by the user in the above ***Manual adjustment of limits*** (mentioned above) for the min/max colour values, or use floating limits i.e. scale the colour to the current min/max values in the data channel currently selected to colour by

Drawing scale mode

There are 3 drawing scale modes to display the data:

1. Auto-normalise/centralise on the origin – each axis will adjust and centralise on its own axis
2. Axis scaling set the user-defined limits through the ***Manual adjustment of limits*** control above
3. Data defines the limits; centre 0.0,0.0, with grid max at +/- 2.0. Data will draw beyond this and may/may not appear within the bounds of the drawing area

Colourmap

Select the colourmap to use via the mouse-wheel (only Jet available by default). Left mouse-click to switch to dynamic colouring. The graphic will update in real-time while adjusting the colourmap in the colourmap generator app (3rd button from the left on the top left of the viewing area)

Copy current limits to user limits

This copies the values for the X, Y, Z, and Colour min/max extremes to the ***Set range 1/2/3/Col*** user limits boxes:

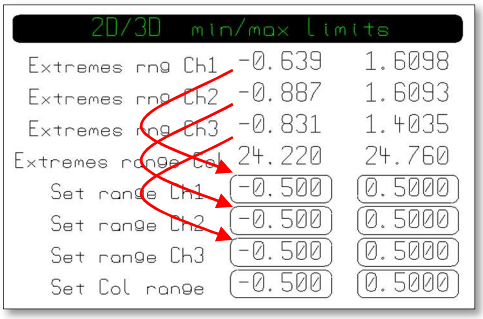


Figure 10.47 *Control panel allowing channel limits to be defined or copied from current extremes*

View colourbar

This toggles the view of the colourbar, showing the ***colour by*** channel name, and min/max limits currently being applied. The colourbar can be moved around the screen by holding down Ctrl and left clicking /dragging with the mouse

Marked events only

By default, this is disabled (value 0). Use the mouse-wheel to cycle this through values 1-9 in order to filter by data that has been marked with events values 1-9 either manually, or via the Behaviour Builder function on the 2D graphing window. If there is no data on the plot, then it is likely that there is no data with the same values of Marked Events selected on this button via the mouse wheel

Special cases with using the XYZ plot

Channel 1 has ***Time*** as a possible channel towards the bottom of the list. This allows the user to plot Channel 2 on the vertical axis versus ***Time***, similar to that seen on the ***2D graphing window***. Axes numerical limits are currently not displayed on the axes themselves, but can be displayed by enabling the quads/grid option.

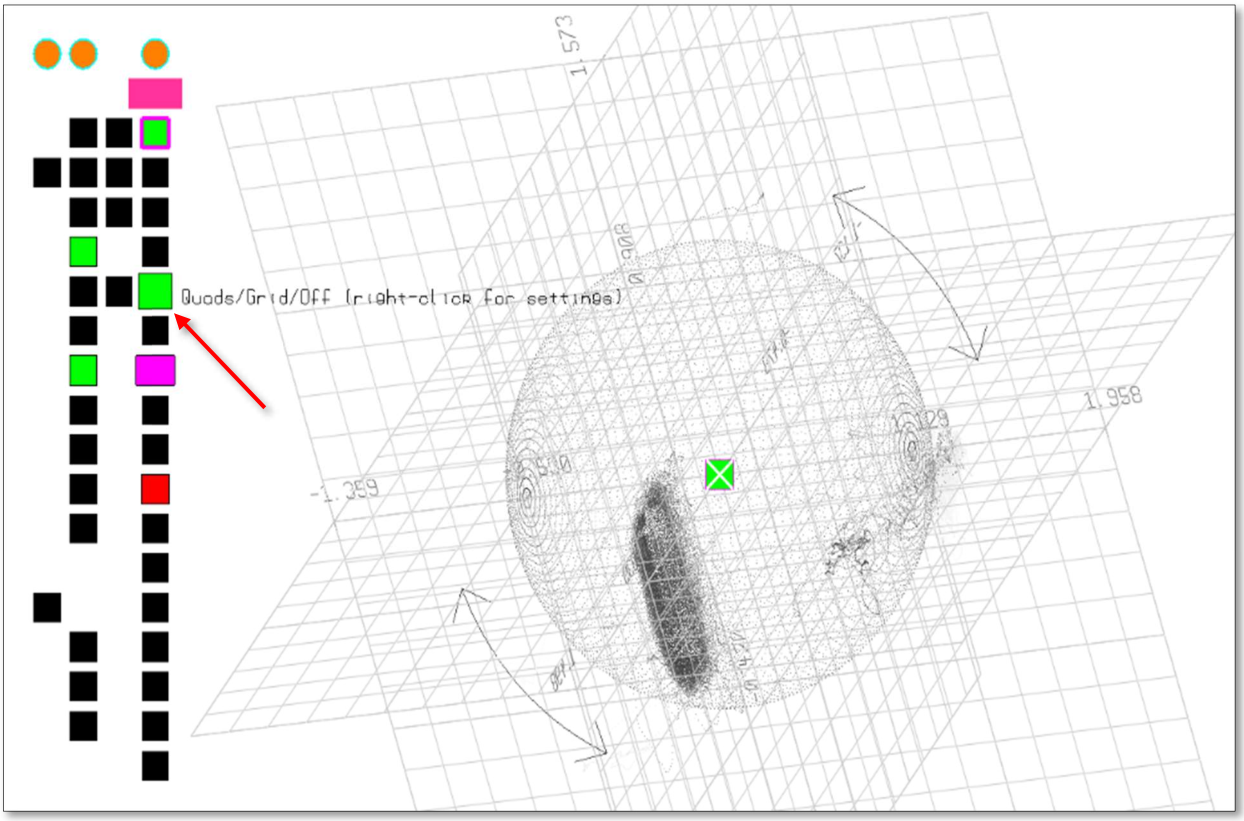


Figure 10.48 *Enable the quads grid option to have numerical limits displayed on a 3D grid through/around the data*

Right-clicking on the "Quads/Grid" button reveals 3x buttons on the second column (from the right), one of which is not used. Via the mouse wheel, the two controls enable adjustment of the font size for the numerics on the grid structure, and adjustment of the intensity of the grid structure's lines.

It should be noted, as mentioned earlier, some channels (temperature, pressure etc.) will potentially have large negative or positive values. By default, the axes are scaled for data that has values in the region of +/- 1 i.e., acceleration / magnetometry data. To have the axes normalise / fit nicely within the visual widget, change the ***Drawing scale mode*** to auto-normalise (discussed above).

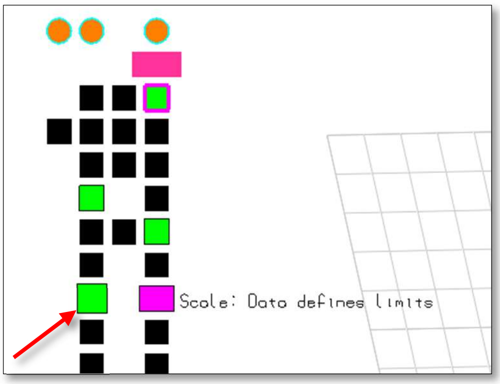
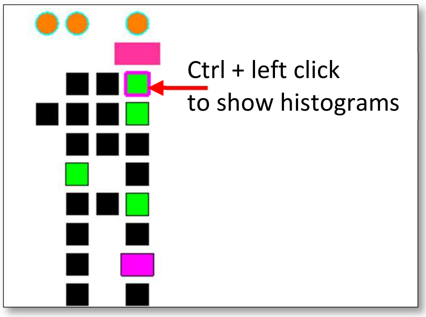


Figure 10.49 *Adjust the scale (left-click mouse) to suit the scale of data in view*

When the ***Vectors*** are enabled as below, the axes labels can be toggled on/off by holding down shift and rolling the mouse-wheel on the vectors enable button. Additionally, when channel 2 is enabled, the axes can be switched from centralised to bottom left

This 3D plot by default shows a histogram of the 3 axes and the colour data. To toggle this off, simply hold down Ctrl and left-click on the orientation reset button:



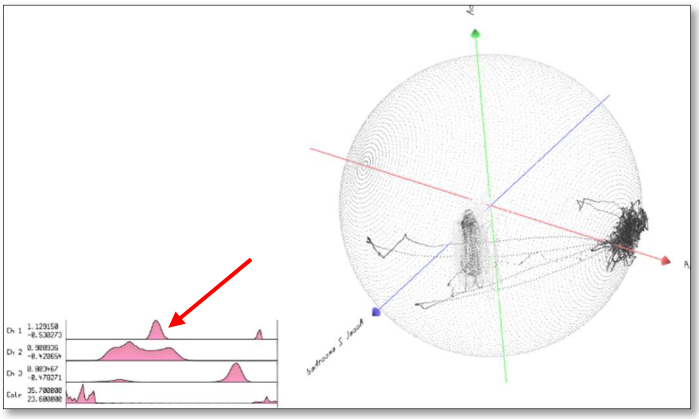


Figure 10.50 *Tri-channel histogram allows user to view where on the scale the majority of data resides*

Channel 1 has *Time* as one of its possibilities (towards the bottom of the list), which allows the user to plot two other channels along an axis. In the image below, Channels *GeomagY_smoothed* and *GeomagZ_smoothed* are plotted vs *time*:

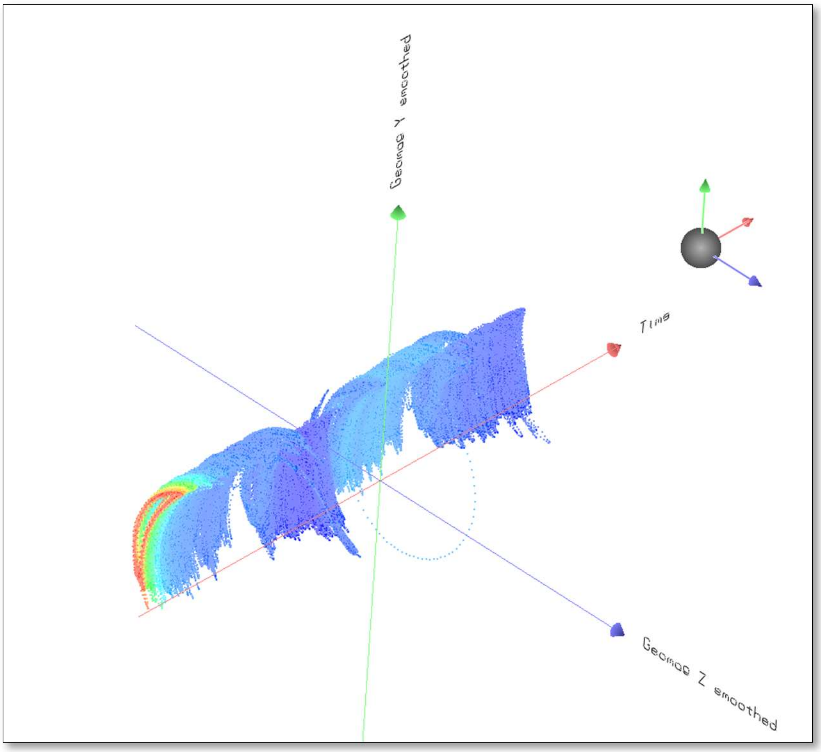


Figure 10.51 *Channels GeomagY_smoothed and GeomagZ_smoothed plotted vs time*

If channel 1 is set to *Time*, and channel 2 is set to Compass 3D, then channel 3 is disabled by default initially. This plot therefore shows change in heading over time. See example below:

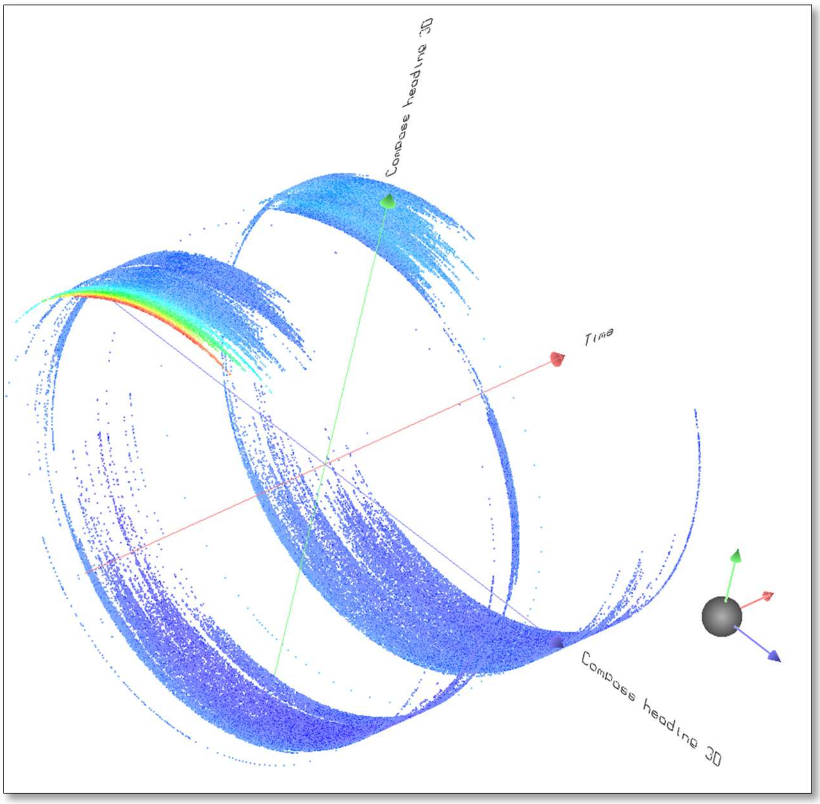


Figure 10.52 *Channel 1 is set to time, channel 2 is set to Compass 3D (channel 3 therefore is used with channel 2).*

A twist on this is that when channel 2 is set to *Compass 3D*, then a new button will appear halfway down the 3rd column named *Radius by channel 3*. This allows the third channel selection to modulate the radius of the compass' heading data. In the image below, the radius is modulated by temperature. Left clicking toggles this radius modulation on/off.

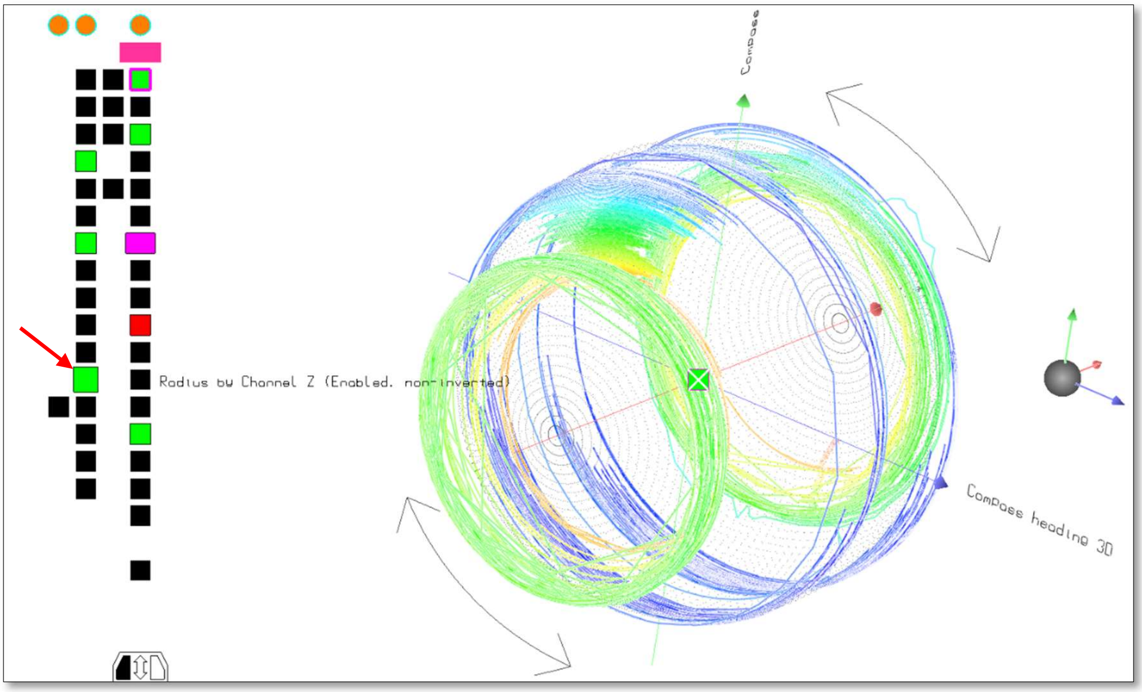


Figure 10.53 *Channel 1 is set to time, channel 2 is set to Compass 3D, while channel 3 modulates the radius of the heading data*

If any differential channels have been defined, then these are added to the bottom of the list of all 3 channels.

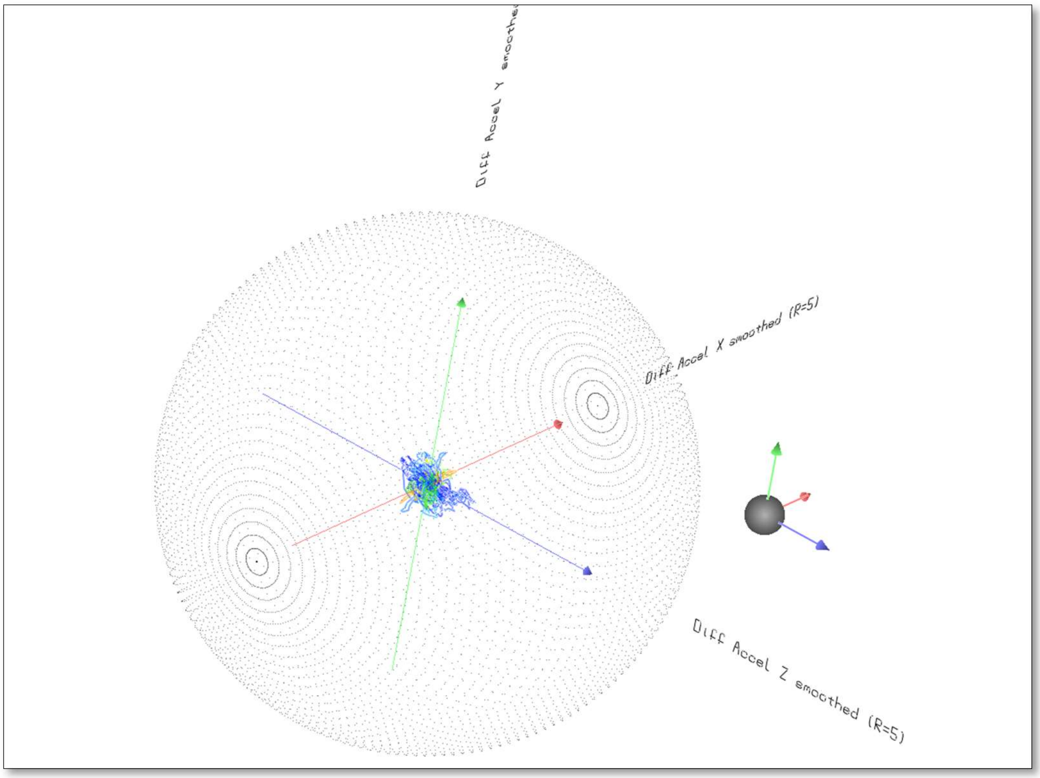


Figure 10.54 *Plotting differential channels against each other*

K-means clustering to identify clusters of data points

Data points on this 3D plot can be separated into clusters using the standard k-means clustering algorithm.

In the image below, the k-means button, and the button to its left ***Add nodes*** have both been enabled. This results in the perspective boxes to the right appearing (X-Y, X-Z, and Z-Y; horizontal-vertical in each case). Additionally, a small black square (white if the background is black) and crossing lines appears on each of the 3 perspectives, and on the main display.

Holding down the ***Shift*** button and moving the mouse within the 3 perspective boxes relocates this small square within the confines of the 3 boxes. By holding down / releasing ***Shift***, while moving between the 3 boxes, one can locate this on a cluster. Clicking the left mouse button puts a marker at that location. What this is achieving is adding a starting position for one of ***X*** nodes for the k-means clustering algorithm. The user should add as many starting nodes as they believe are required to complete the clustering process. As nodes are added, the k-means clustering algorithm runs through the data and allocates datapoints to clusters. The final node (cluster) centres of may not be exactly where the user has defined the starting position, but that is the nature of the algorithm.

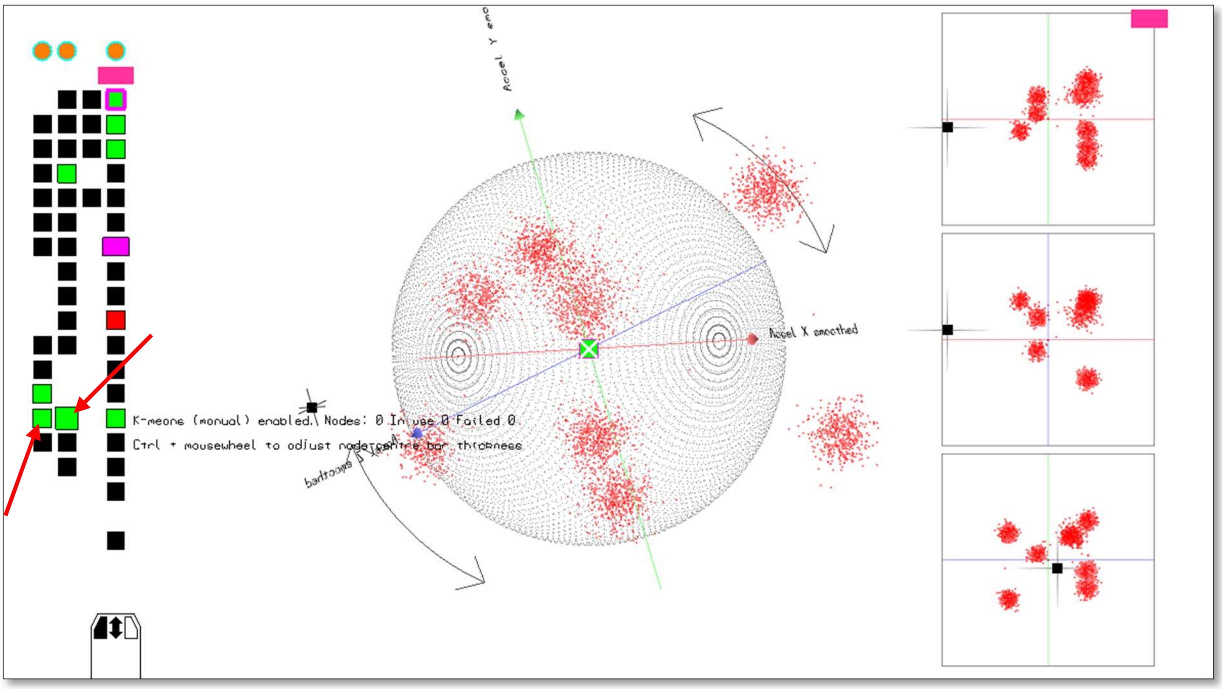


Figure 10.55 *Enabling k-means clustering, and the **Add nodes** button to its left*

During the k-means clustering algorithm execution, it's always possible that some nodes may end up with no data points within them. In the image above, it states the number of nodes, the number *in use*, and the number *failed*. *Failed* nodes are those that contain no data points, while *in use* implies those nodes have 1 or more data points.

In the image below, 9 clusters have had manual nodes allocated to them, and the ***Add nodes*** button toggled off. The perspective boxes to the right continue to show the 9 manual markers, while the main display shows the resulting final node centres, with coloured lines pointing to them, with the data of each cluster coloured by the node colour.

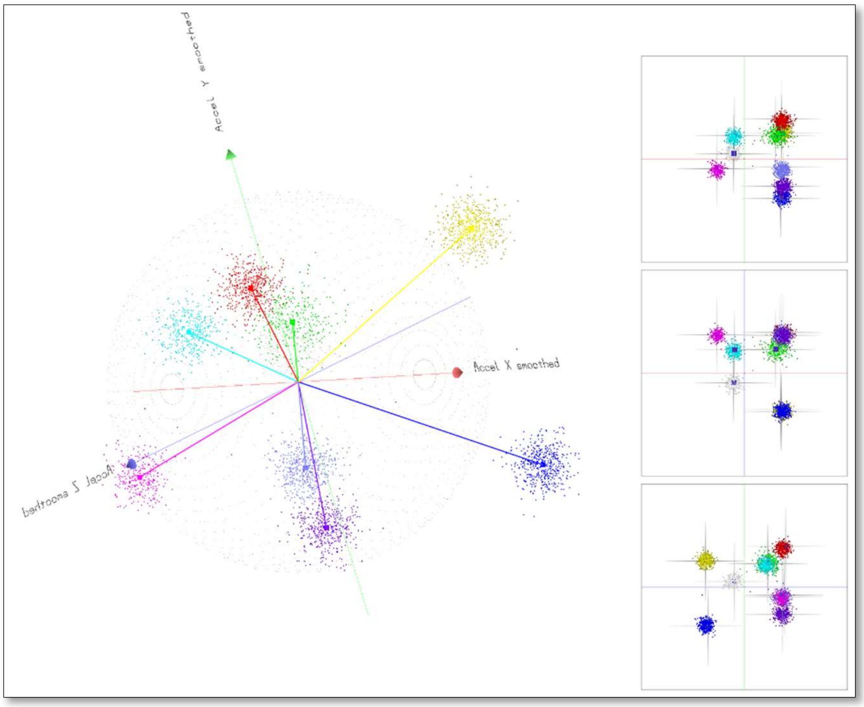


Figure 10.56 *9 clusters with nodes initially manually assigned*

Now that the clusters/nodes have been identified and marked, the data points in each can have Marked Events applied to either a single cluster with a specific Marked Event value, or the first 9 can be marked with the same Marked Event value (1-9).

The third option (left click only), if the first line of text states *Convert first 9 nodes to Marked events*, results in:

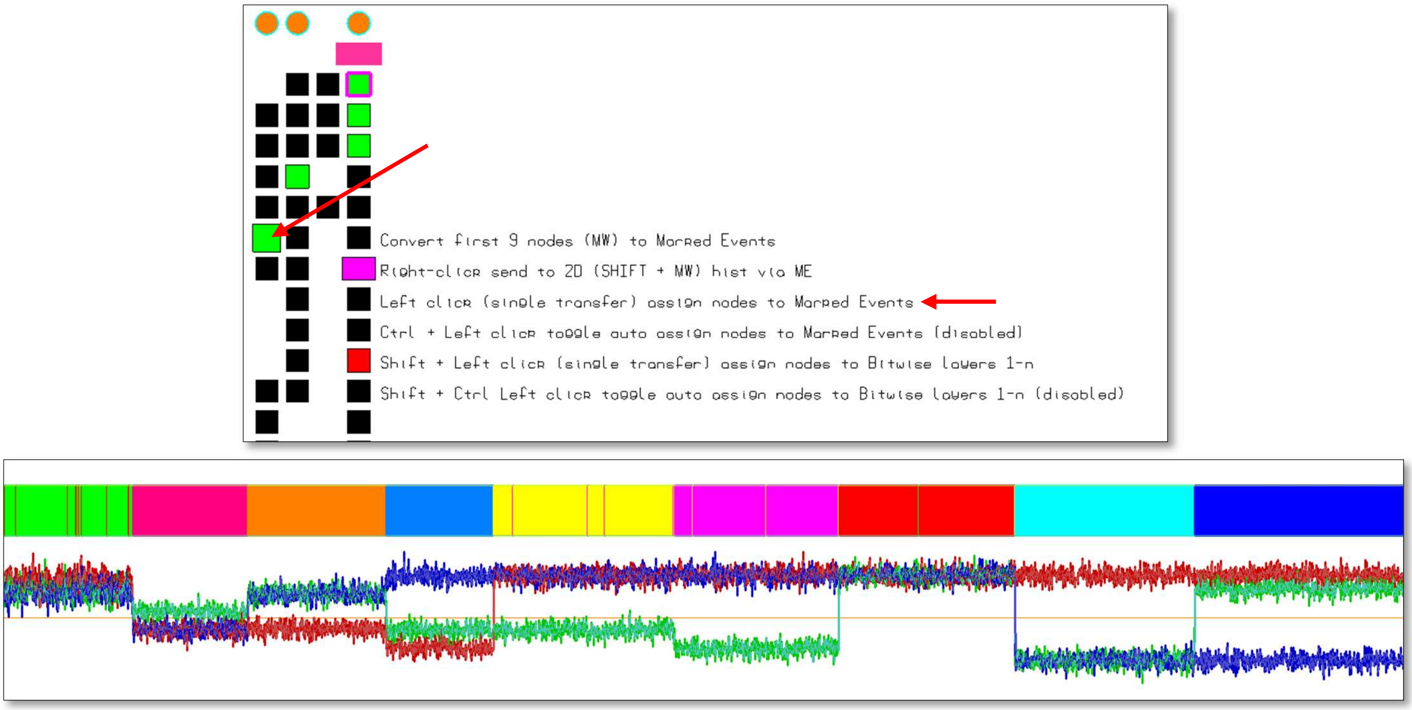


Figure 10.57 *The data within the first 9 clusters (in this case, all clusters) have the Marked Event value for their cluster value*

If, however, the mouse-wheel is adjusted on this button (with/without the Ctrl key), then a particular node's data points can be assigned to a particular Marked Event value by left-clicking on the button. In the case below, the data points in cluster #2 will be assigned Marked Events value 3:

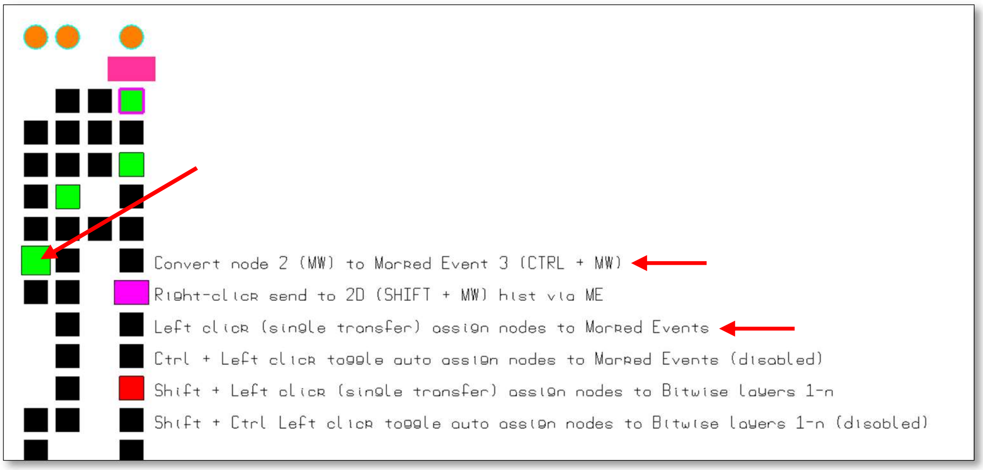


Figure 10.58 *Enable assignment of the data points of a particular cluster a particular Marked Event value (adjustable)*

The fifth option (***Shift*** + Left click) works in a similar way, but instead, it assigns clusters to Bitwise layers:

Figure 10.59 *The data within the first 9 clusters (in this case, all clusters) have the Bitwise value for their cluster value. Note, the user will need to enable the view of Bitwise layers on its control panel under the 2D sliders tab*

As discussed in chapters 2 and 5, Marked Events can be used as filters for further analysis in both the Behaviour Builder and during data export, while Bitwise channels can be used as filters within the Behaviour Builder. Both can be simply used as indicators on the 2D graph window of behavioural *state*.

If this button is ***Ctrl*** + left-clicked (when this function is enabled, it'll state (*enabled*) on this line), then the Marked Events within the current split are cleared, and events within view on the 2D graphing window will have Marked Events assigned, as per the cluster number they reside in.

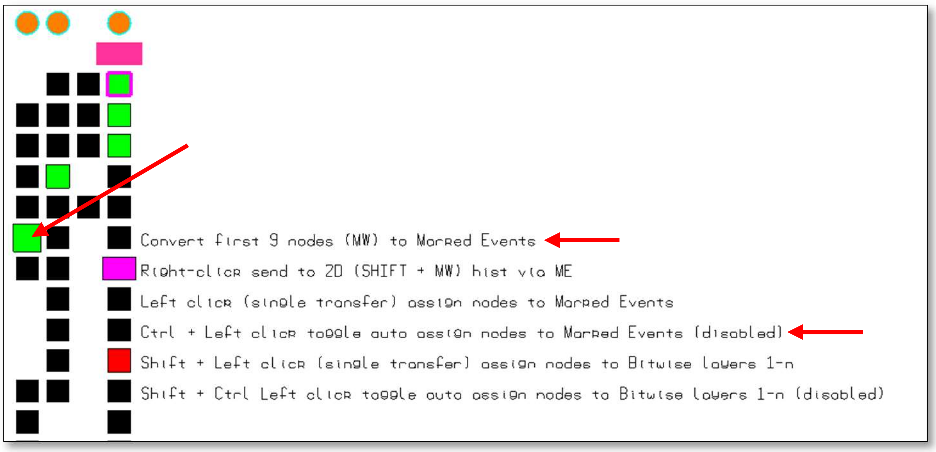


Figure 10.60 *The data within the first 9 clusters (in this case, all clusters) have the Bitwise value for their cluster value. Note, the user will need to enable*

If the ***Shift*** + ***Ctrl*** keys were held and the button left-clicked, then instead of dynamic Marked Events, the result would be dynamic Bitwise layers:

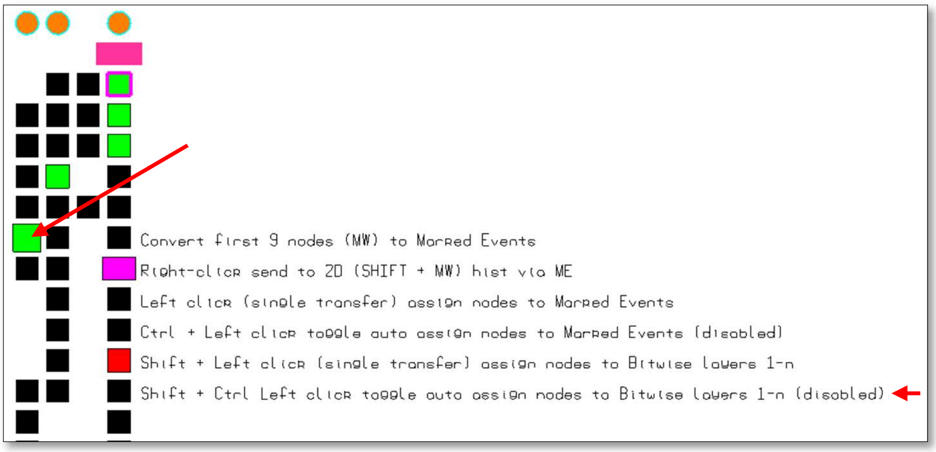


Figure 10.61 *The data within the first 9 clusters (in this case, all clusters) have the Bitwise value for their cluster value. Note, the user will need to*

In both cases (holding down ***Ctrl*** or ***Shift***, for Marked Events or Bitwise layers respectively), the same applies to adjustments of the extremes (zooming in/out / adjusting the orange bar at the bottom of the 2D graphing window). This will update the data assignment to clusters and will also therefore result in a clearing of the Marked Events / Bitwise layers for the entire current split, and reassignment of Marked Events / Bitwise layers data as per the current cluster numbers. It's effectively a dynamic update to the Marked Events / Bitwise layers within the current split.

Regarding the issue of cluster number, there is a button that when enabled, the selected cluster (by adjustment of the mouse wheel) will be coloured, while all other clusters will be a dull grey. This allows the cluster number to be more easily identified.

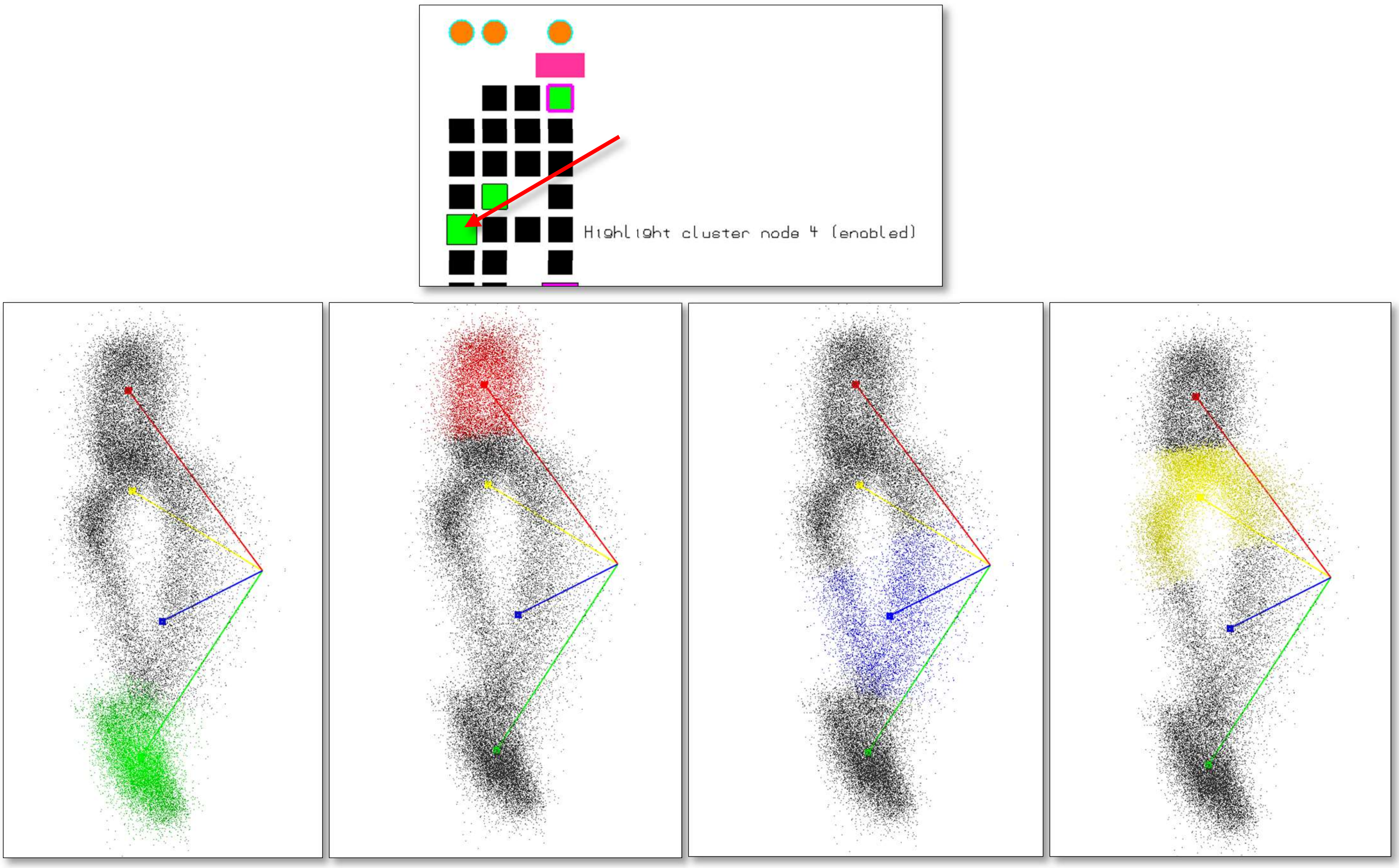


Figure 10.62 *Enabling 'Highlight cluster' allows cluster number to be easily identified*

XYZ + Height plot

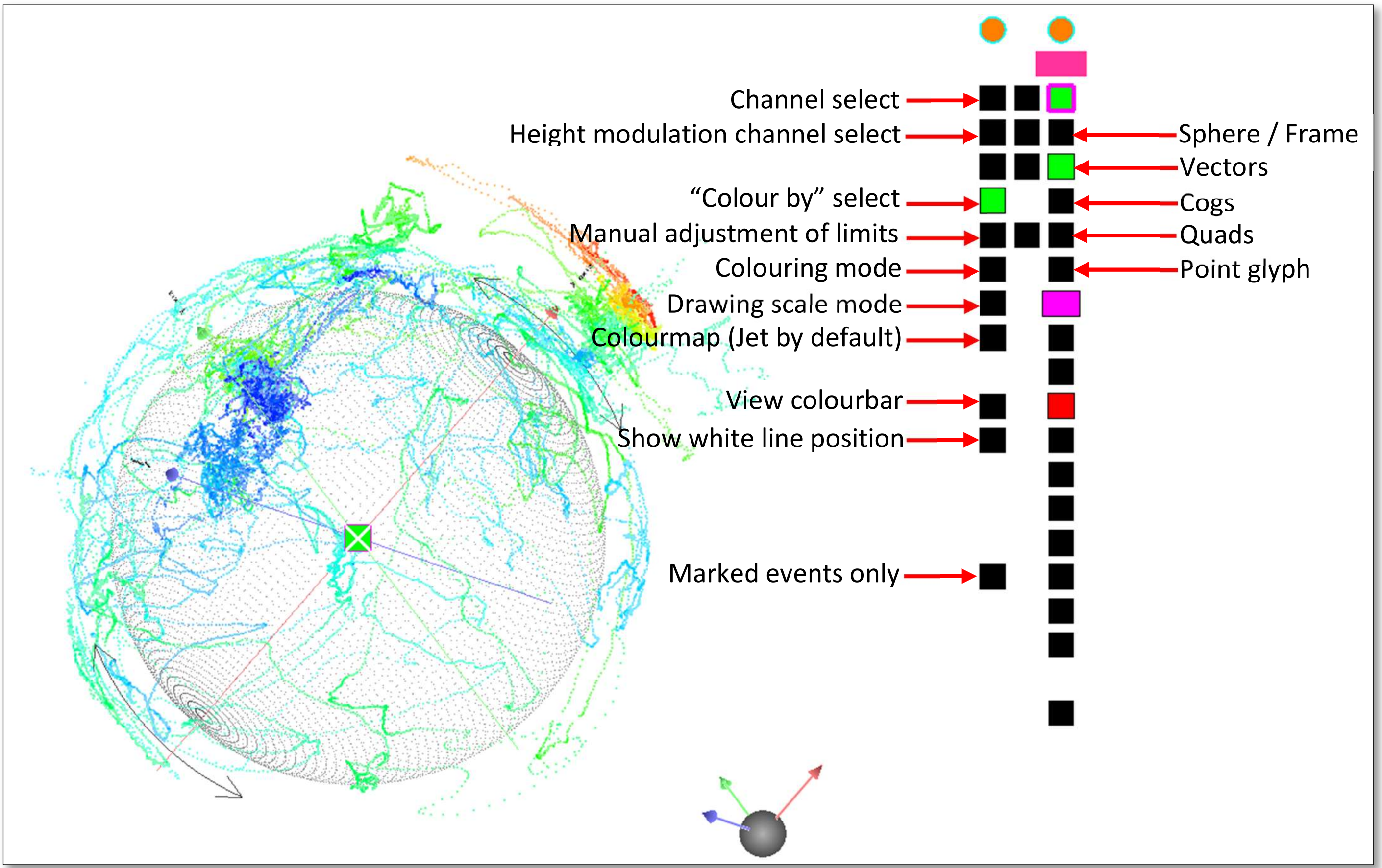


Figure 10.63 *XYZ plot data selection and visualisation options*

Channel select

Use the mouse-wheel to select the appropriate data channel for the x axis.

Height modulation channel select

Use the mouse-wheel to select the appropriate data channel for the y axis

Colour by select

Use the mouse-wheel to select the appropriate data channel to colour the data points. Left-clicking this button switches from colouring by channel data, to a single colour; use the mouse-wheel to adjust the actual colour

Manual adjustment of limits

This manifests a control panel whereby the user can adjust the height channel limit.
Hold down the shift key and mouse click and drag the above window around to better position it for viewing the values. Clicking on the height min/max ringed values and a numeric touchpad will appear. Enter the required value and then click anyway else on the viewing area to accept this value, and the graphic will update (if ***Drawing scale mode*** is set to ***Axes: User limits***). If the ***Drawing scale mode*** is set to floating limits, the height modulation will auto-scale to the min/max data values in the height modulation channel selected. Click the ***Manual adjustments of limits*** button again to hide this values panel

Colouring mode

When ***Colour by select*** is using channel data to colour the data points, it can either use the colour limits as defined by the user in the above ***Manual adjustment of limits*** for the min/max colour values, or use floating limits i.e., scale the colour to the min/max values in the currently selected data

Drawing scale mode

There are 2 drawing scale modes to display the data:

1. Through using user-defined limits defined on the ***Manual adjustment of limits*** controls above
2. Through floating limits whereby the min/max values within the height modulation channel selected will be used to normalise this effect

Colourmap

Select the colourmap to use via the mouse-wheel (only Jet available by default). Left mouse-click to switch to dynamic colouring. The graphic will update in real-time while adjusting the colourmap in the colourmap generator app (3rd button from the left on the top left of the viewing area)

Copy current limits to user limits

This copies the values for the X, Y, and Z min/max extremes to the ***Set range X/Y/Z*** user limits boxes

View colourbar

This toggles the view of the colourbar, showing the ***colour by*** channel name, and min/max limits currently being applied

Marked events only

By default, this is disabled (value 0). Use the mouse-wheel to cycle this through values 1-9 in order to filter by data that has been marked with events values 1-9 either manually, or via the Behaviour Builder facility

Show white line position

When enabled, left clicking on the 2D graphing window will show a small square in the 3D plot, highlighting the position of that data point. When the background is set to 'white background', the square will be black, else it will be white

1D/2D Histogram

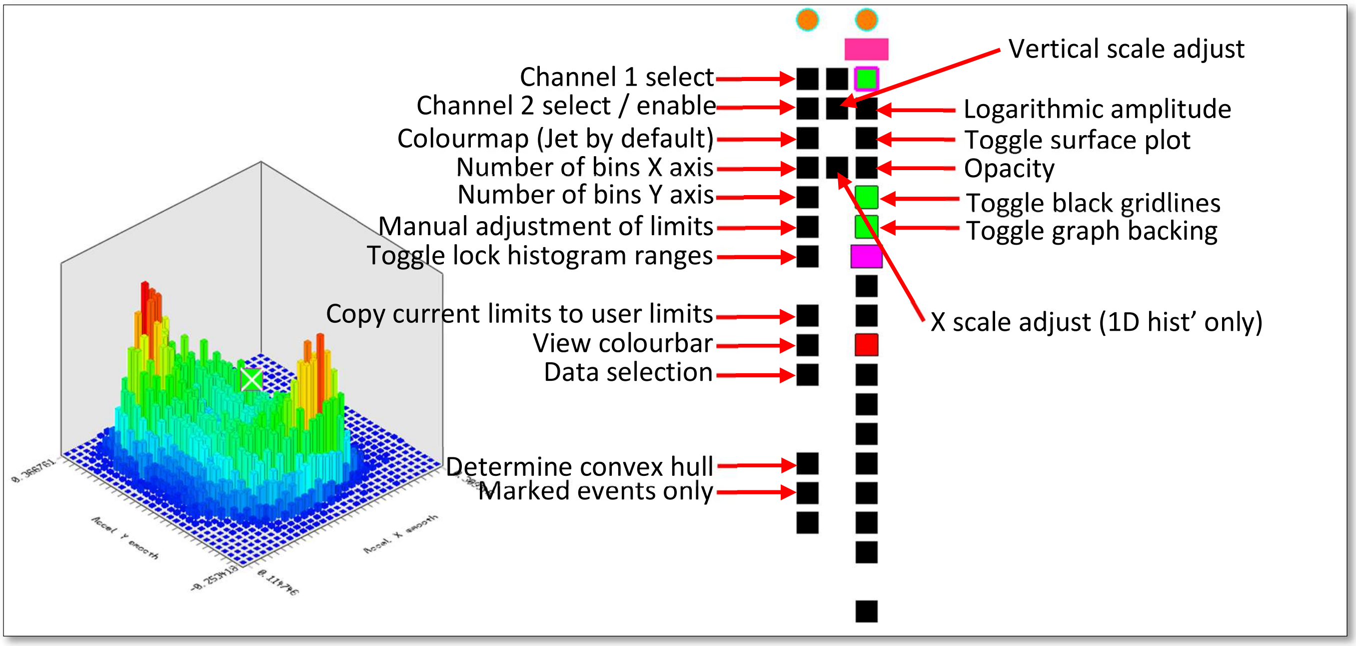


Figure 10.64 Histogram channel selection and visualisation options

Vertical scale adjust

Adjust the vertical height of the histogram

Logarithmic amplitude

Rescale the vertical height of the histogram logarithmically

Toggle surface plot

Toggle between different drawing modes, including blocks, surface plot, discs etc.

Opacity

Alter the opacity of the graphic

Toggle black gridlines

Outline the blocks with black lines

Toggle graph backing

Toggles the presence of the backing of the graphic (discussed below)

X scale adjust (1D histogram only)

Stretch out the 1D histogram

Channel 1 select

Use the mouse-wheel to select the appropriate data channel for the horizontal axis

Channel 2 select / enable

Use the mouse-wheel to select the appropriate data channel for the vertical axis; left mouse-click to toggle between 1D and 2D histogram i.e. disable channel 2

Colourmap

Select the colourmap to use via the mouse-wheel (only Jet available by default). Left mouse-click to switch to dynamic colouring. The graphic will update in real-time while adjusting the colourmap in the colourmap generator app (3rd button from the left on the top left of the viewing area)

Number of bins X axis

Use the mouse-wheel to adjust the number of bins for the X axis

Number of bins Y axis

Use the mouse-wheel to adjust the number of bins for the Y axis

Manual adjustment of limits

This manifests a control panel whereby the user can adjust the 2 channel limits of the histogram. Hold down the shift key and mouse click/drag the above window around to better position it for viewing the values. Click on any of the ringed values to set the limits for the halfway +/- values for each axis. A numeric touchpad will appear. Enter the required value and then click anyway else on the viewing area to accept this value, and the graphic will update (if "Lock histogram ranges" is enabled). Click the ***Manual adjustments of limits*** button again to hide this values panel

Toggle lock histogram ranges

Linked with the above button; when enabled, the X (and Y if 2D) axes are limited to those min/max values set by the user

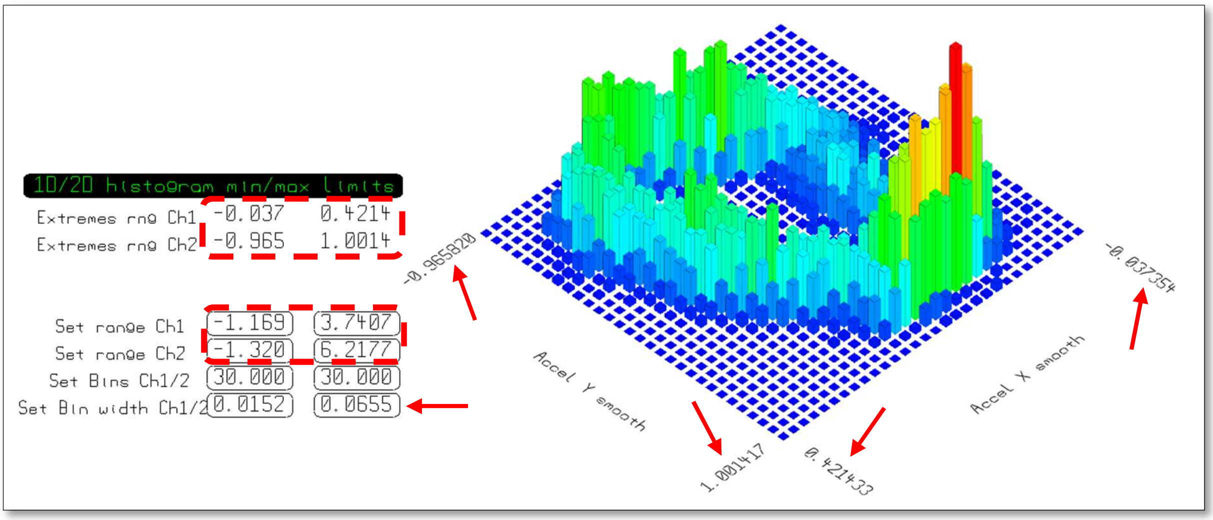


Figure 10.65 *Different drawing modes of the histogram data*

In the above figure, ***Toggle lock histogram ranges*** has not been enabled and so the **X**, **Y** ranges (by 'Set range Ch1 (/ 2)') are not being used, but instead, the graph is auto-ranging based on the current data limits available (by 'Extremes rng Ch1 (/ 2)').

Additionally, if ***Toggle lock histogram ranges*** is selected, then the values for 'Set Bin width Ch1 (/ 2)' become active. When active, a change to values within (for **X** or **Y**) 'Set range Ch1' or 'Set range Ch2' min / max limits will update the values within the 'Set Bin width Ch1 (/ 2)' boxes. Alternatively, if a change is made to the 'Set Bin width Ch1 (/2)' boxes, then the max range values for Ch1 or Ch2 will update based on the min channel values, and the number of bins for those channels.

Copy current limits to user limits

This copies the values for the channel 1, 2, min/max extremes to the ***Set range 1/2*** user limits boxes. This is usually a good place to begin before manually entering min / max values, and before enabling ***Toggle lock histogram ranges***, as, if the manual min / max values are off, there may be no data displayed on the graph.

View colourbar

This toggles the view of the colourbar, showing the ***colour by*** channel name, and min/max limits currently being applied

Data selection

This is a multifunction button that enables the user to select cells within the 2D histogram grid. The user can cycle through the different modes with the mouse wheel (*Line division, Island division, Cell selection*)

Marked events only

By default, this is disabled (value 0). Use the mouse-wheel to cycle this through values 1-9 to filter by data that has been marked with events values 1-9 either manually, or via the Behaviour Builder

Drawing mode (via Toggle surface plot button)

There are several different drawing modes to choose from with this plot. Left-clicking on the ***Toggle surface plot*** cycles through these.

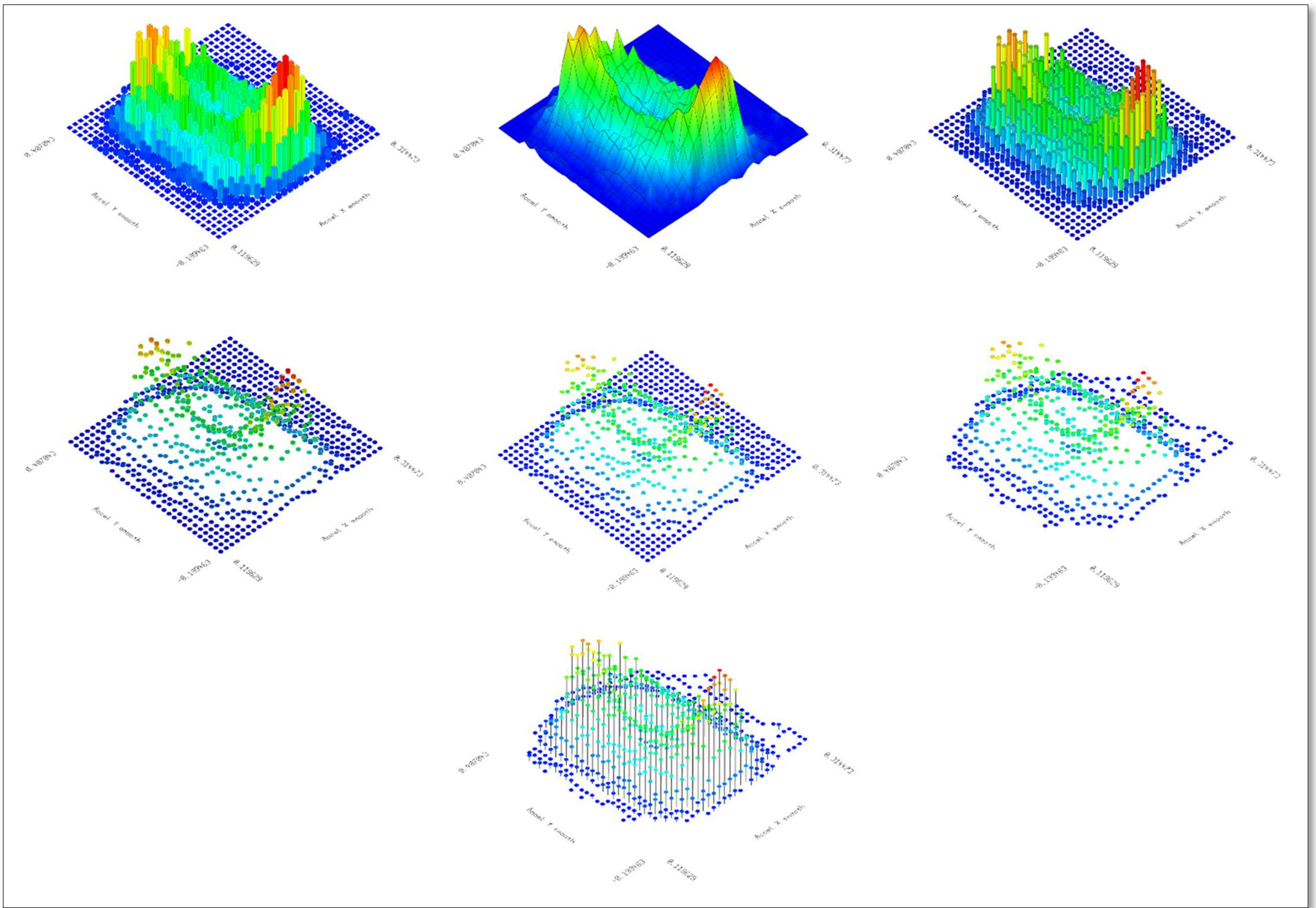


Figure 10.66 *Different drawing modes of the histogram data*

For modes that display columns/discs, the can be adjusted with the mousewheel on this button between 10 and 100%, while the circularity can be alternated between a disc and hexagon by holding down ***Ctrl*** and rolling the mouse wheel:

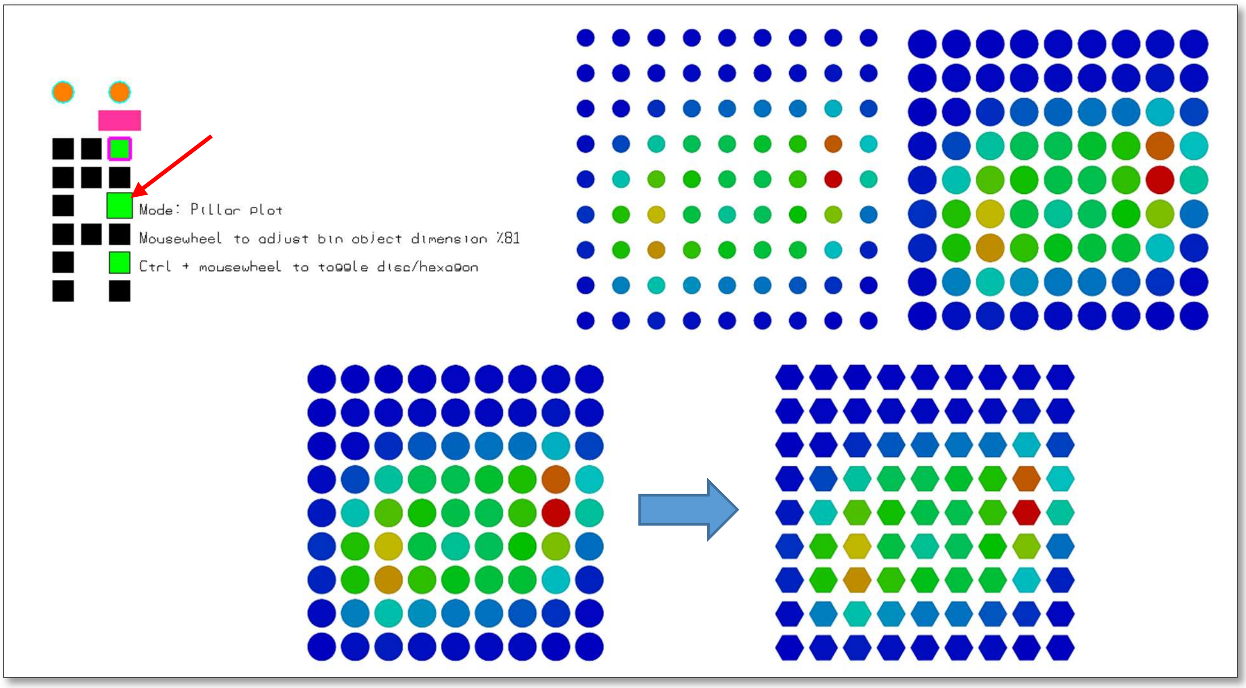


Figure 10.67 *Adjusting the cross section / circularity of the modes supporting column/disc plot modes*

A “backing” can be applied to the graphic by clicking the ***Toggle graph backing***:

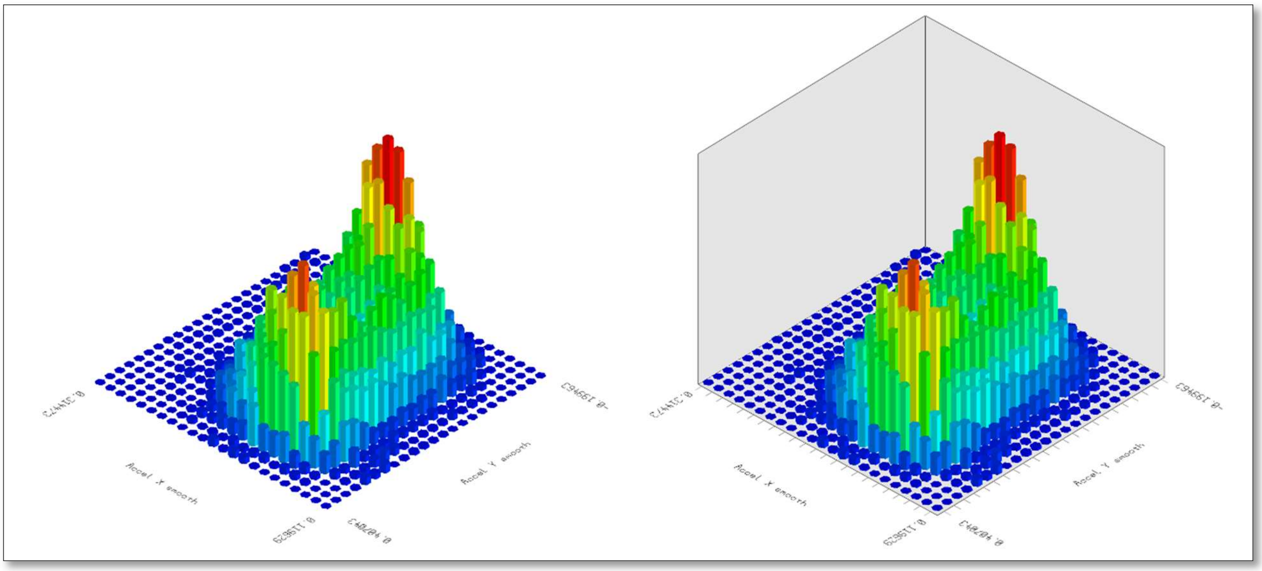


Figure 10.68 *Add a ‘backing’ to the graphic with the* ***Toggle graph backing*** *control*

Adjust the vertical scale of the plot with the mouse wheel on the ***Vertical scale adjust button***:

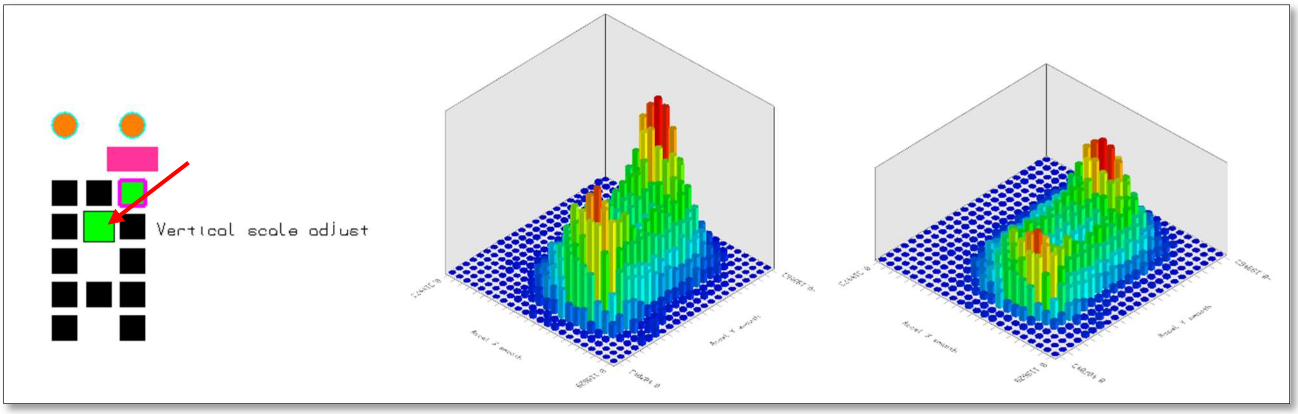


Figure 10.69 *Adjust vertical dimension with the* ***Vertical scale adjust*** *control*

Data selection, use of

Line division **This selection is currently unfinalized**, but the idea is that the two menu buttons below ***Data selection*** allow the line shown below to be moved around the edge. The data constituting the histogram being split in two, will then be able to be converted to Marked Events of two different values.

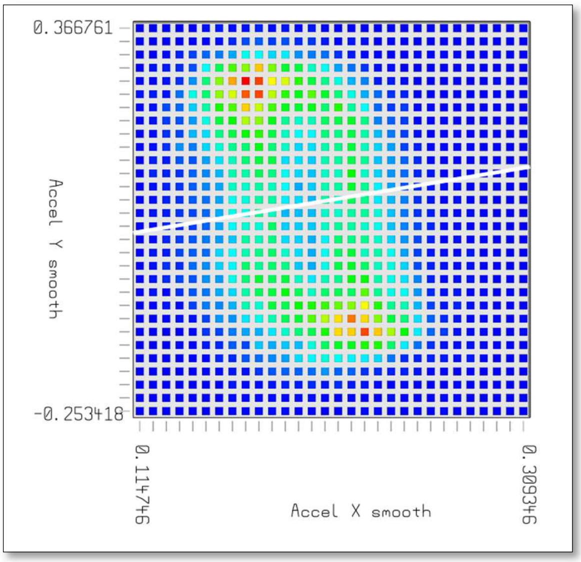


Figure 11.70 *Line division mode will allow the split across the histogram into two subsections*

Island division This selection is used to separate data based on peak/regions

Adjustment of the water level (0-100%) helps to separate peaks into 'islands'. If a cells, above the 'water level' is not adjacent, either horizontally, vertically, or diagonally, to another cell, then it is deemed independent of that cell/'island'.

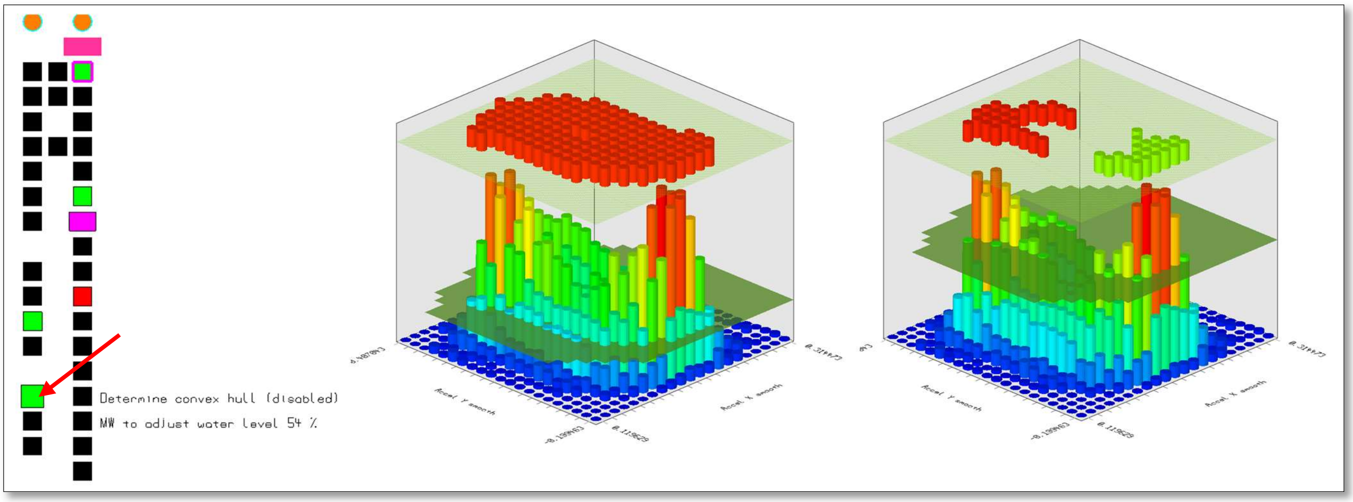


Figure 10.71 *Adjustment of the 'water level' allows 'islands' to form*

At this point, *island selection* is possible by hovering over this button and rolling the mouse wheel – the selected *island* will turn grey. Holding down the **Ctrl** key and rolling the mouse wheel adjusts the ***Marked Events*** value that the data within the selected island will be given.

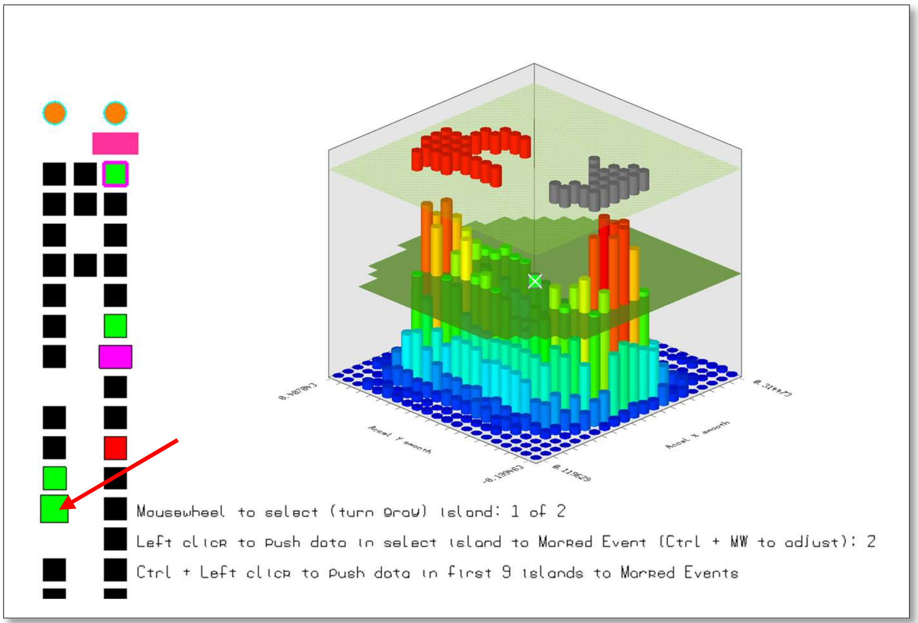


Figure 10.72 *Island selection, and adjustment of destination* ***Marked Events*** *value*

Alternatively, holding down the **Ctrl** button and left clicking the mouse will assign data points within the first 9 *islands* a ***Marked Event*** value equivalent to their *island* assignment number.

Cell selection This selection allows the user to select/deselect cells within the grid. The user can then adjust which ***Marked Events*** value that any data within these selected cells will be assigned.

In the image below, cells have been selected by holding down the ***Alt*** key and left clicking / wiping over cells (***Alt*** key and right click to deselect a cell). Left clicking on the button indicated below will mark (with ***Marked Events***) all data within the selected cells.

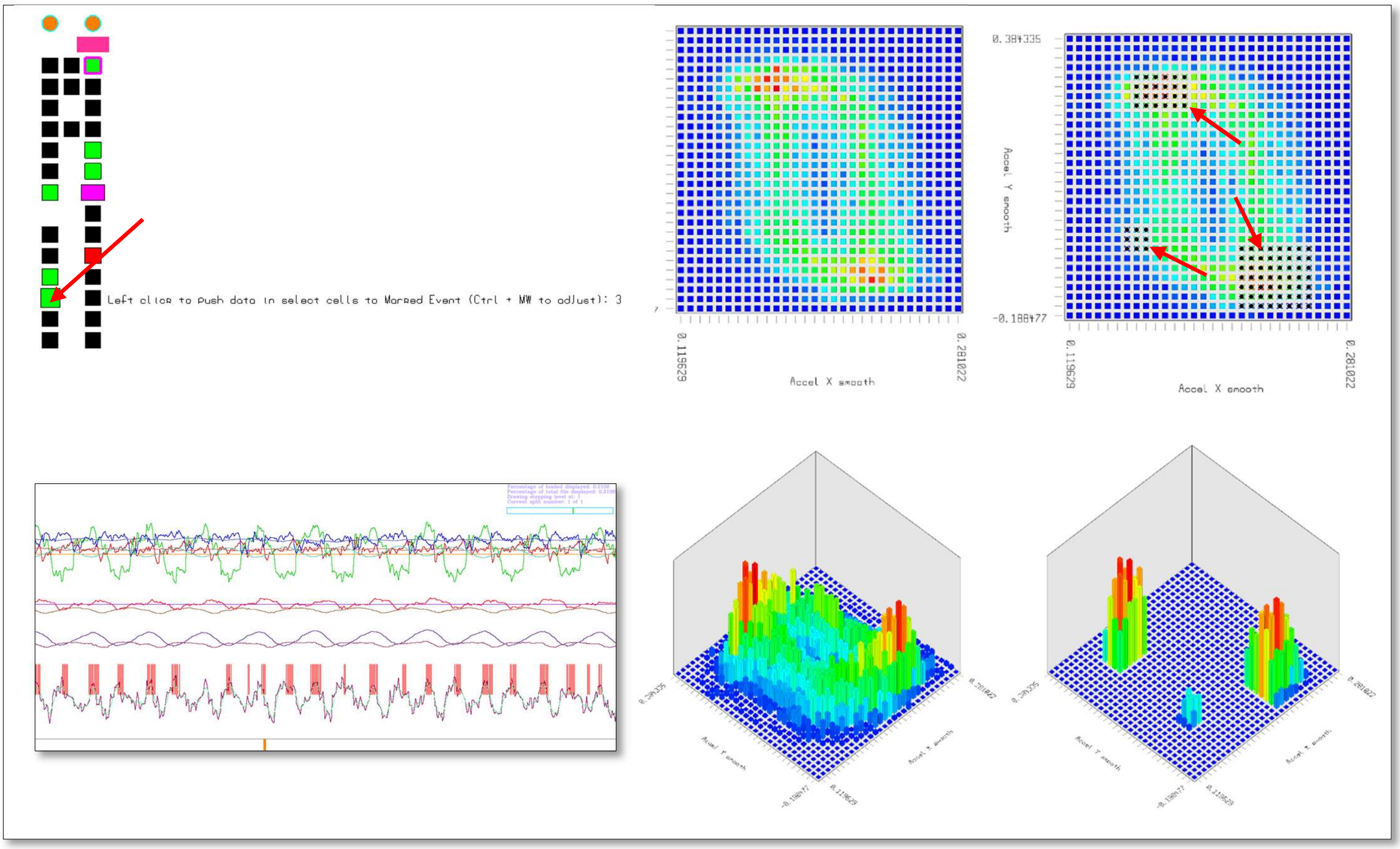
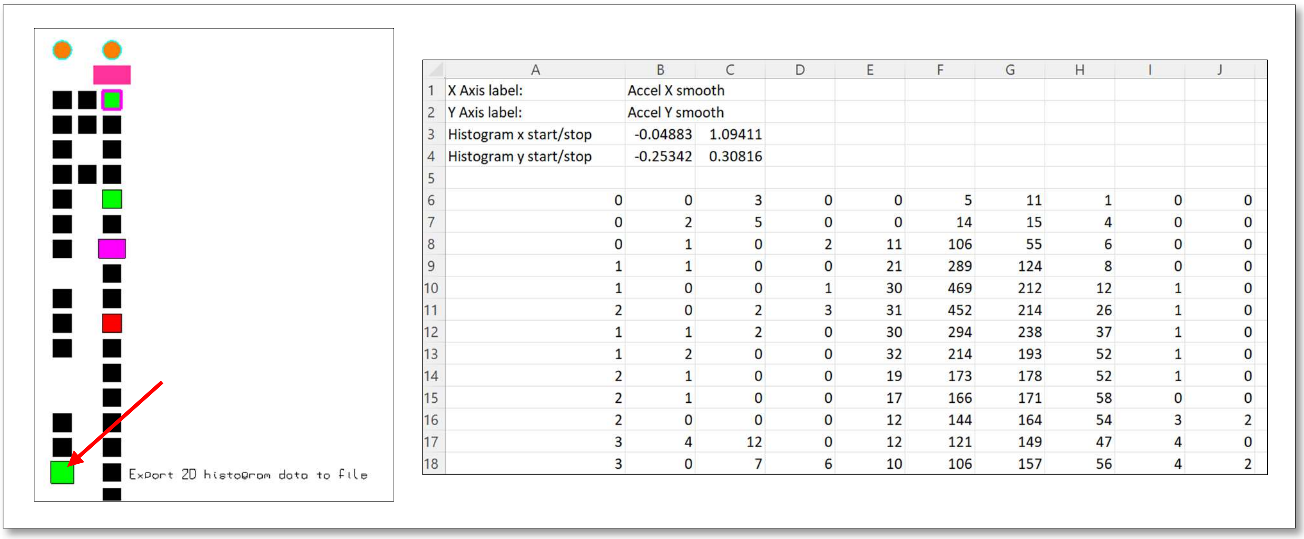


Figure 10.73 *Cell selection, before/after, with the histogram axes range-locked to maintain the aspect ratio. The data for the histogram*

Note that the 2D histogram data can be exported by clicking this button



	A	B	C	D	E	F	G	H	I	J
1	X Axis label:	Accel X smooth								
2	Y Axis label:	Accel Y smooth								
3	Histogram x start/stop	-0.04883	1.09411							
4	Histogram y start/stop	-0.25342	0.30816							
5										
6	0	0	3	0	0	5	11	1	0	0
7	0	2	5	0	0	14	15	4	0	0
8	0	1	0	2	11	106	55	6	0	0
9	1	1	0	0	21	289	124	8	0	0
10	1	0	0	1	30	469	212	12	1	0
11	2	0	2	3	31	452	214	26	1	0
12	1	1	2	0	30	294	238	37	1	0
13	1	2	0	0	32	214	193	52	1	0
14	2	1	0	0	19	173	178	52	1	0
15	2	1	0	0	17	166	171	58	0	0
16	2	0	0	0	12	144	164	54	3	2
17	3	4	12	0	12	121	149	47	4	0
18	3	0	7	6	10	106	157	56	4	2

Figure 10.74 *Exporting the 2D histogram bin data to a .csv file*

Switching to 1D histogram and filtering data by bins selection

By left-clicking on the Channel 2 selection, the visualisation toggles to a 1D histogram where data is comprised of that within Channel 1 only. Left-click this again to toggle back to 2D.

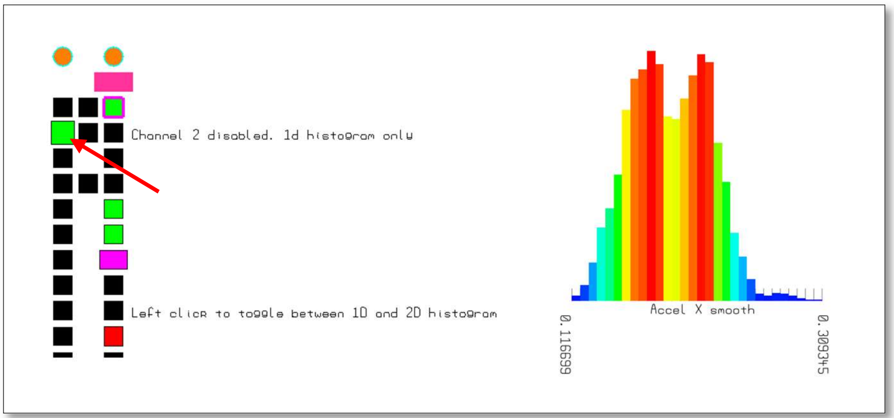


Figure 10.75 *Switching between 2D and 1D histogram*

When in 1D, there is an alternative data selection method – in 2D there is the water level/island method, and the manual cell selection. Left clicking on the ***Bins select*** button reveals a simple 1D grid. The user can hold down the ***Alt*** key and either left-click to select (and drag for speed), or ***Alt*** key and right-click to deselect (and drag for speed).

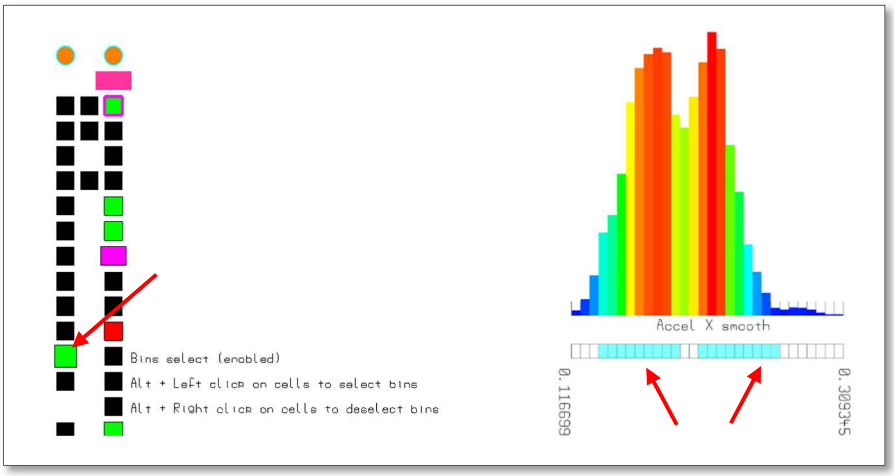


Figure 10.76 *Bin selection using the* ***Bins select*** *button and holding down the Alt key and left/right-clicking on the bins (blue)*

The data within the selected bins can now be marked with a user-selected ***Marked Events*** value (1-9) by clicking the button below this:

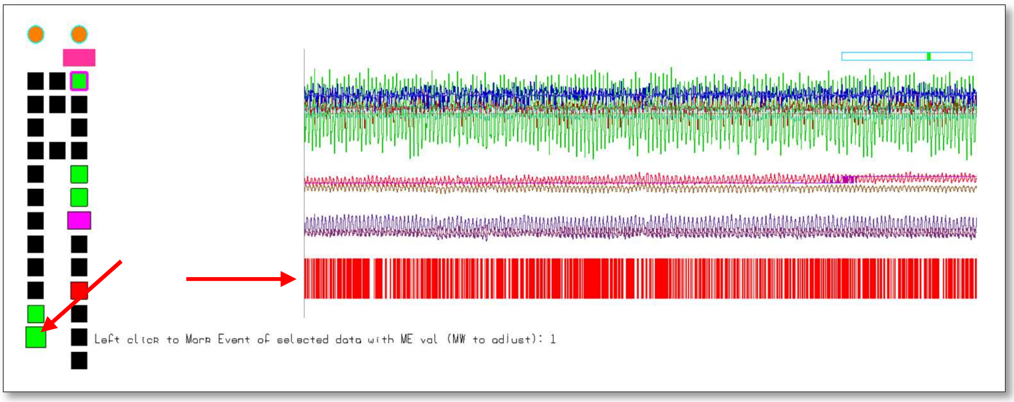


Figure 10.77 *Marking data with a* ***Marked Events*** *value of 1 (adjustable with the mousewheel) for any data within the bins selected in the previous figure*

Cumulative frequency graph of 1D histogram

Left-clicking on this button below will overlay a cumulative frequency graph with 5% and 95% points marked.

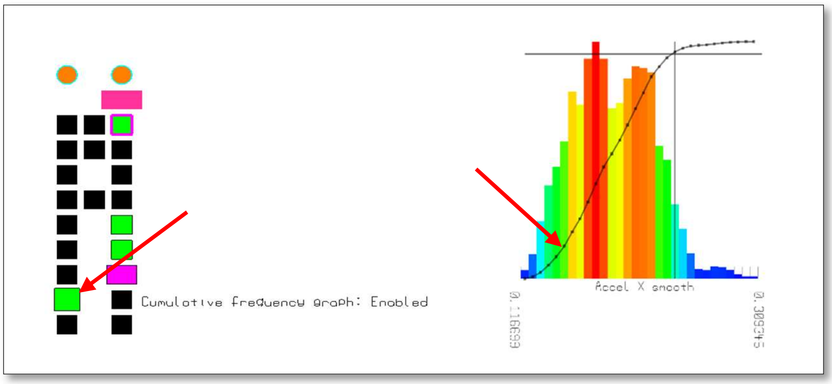


Figure 10.78 *Enabling the cumulative frequency graph*

Finally, the data within the 1D histogram and the cumulative frequency graph can be exported as a .csv file by clicking this button:

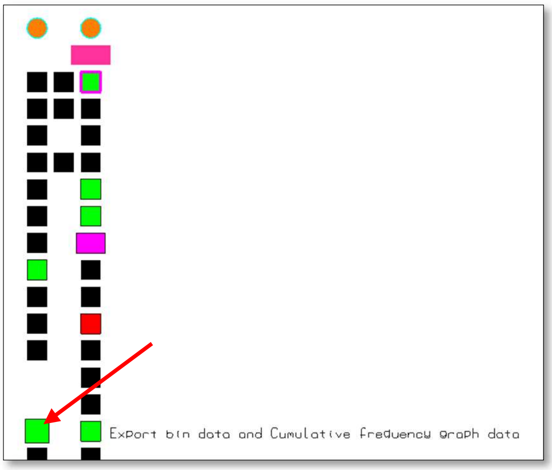


Figure 10.79 *Exporting the 1D histogram data and the cumulative frequency graph*

Filtering data by Marked Event Value

All data in the Extremes is used to generate the 1D or 2D histograms (as is the case for all visualisations). A filter, however, can be applied in the form of ***Marked Events***.

In the figure below, all data is being displayed on the 2D histogram, then filtered by ***Marked Events*** value 1, then ***Marked Events*** value 2, and finally ***Marked Events*** value 'all' (any ***Marked Events*** > 0):

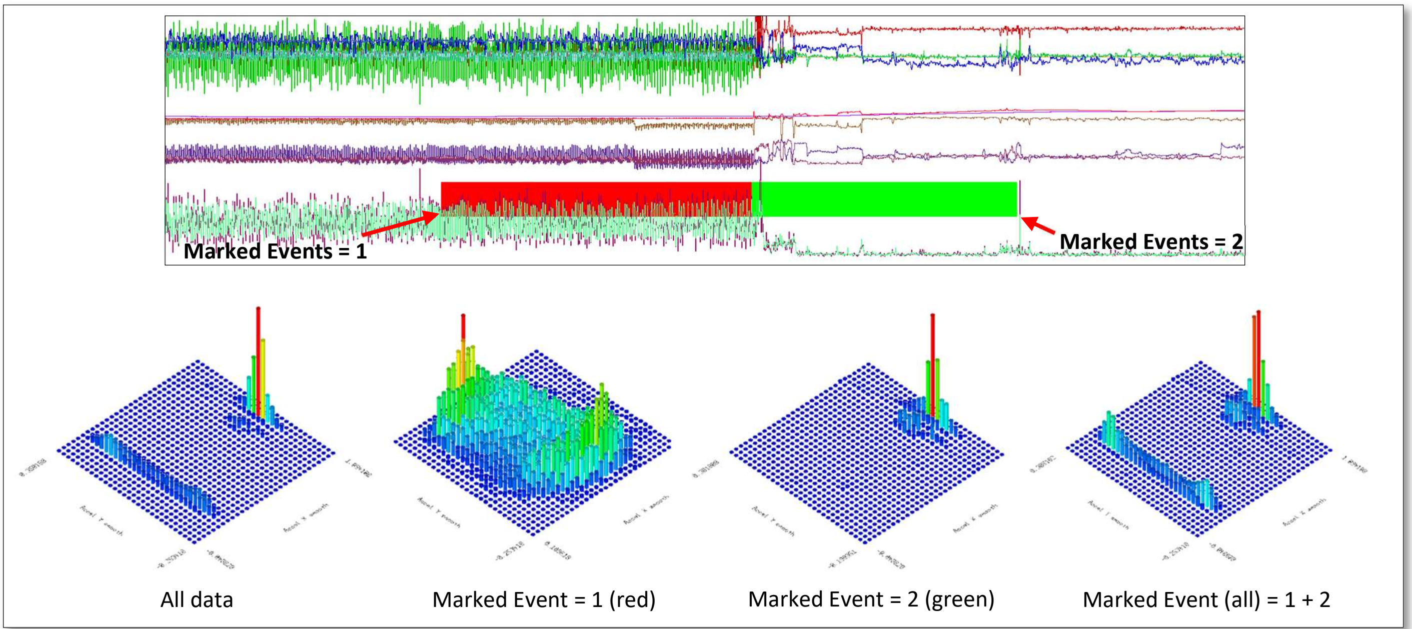


Figure 10.80 *Filtering data using* ***Marked Events*** *(this applies to the 1D histogram also*

Spherical Histogram

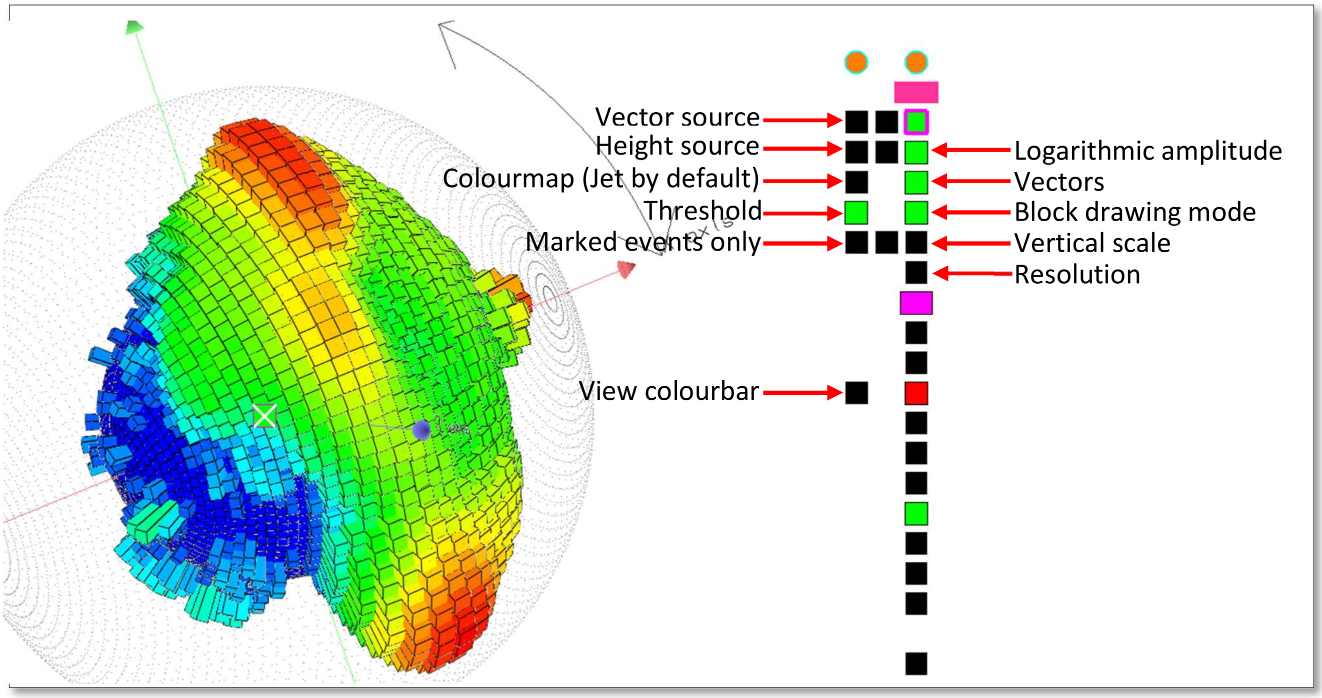


Figure 10.81 *Spherical histogram data selection and visualisation options*

Logarithmic amplitude

Rescale the vertical height of the histogram logarithmically

Vectors

This button places the X, Y, and Z vectors onto the graphic along with labels indicating which channel data is responsible for each axis. Right mouse-click will shift the above purple box to over the ***Vectors*** button and the three buttons in the 2nd column will then be attributes for vectors (line thickness, invert colours, and vectors magnitude) -use the mouse-wheel to adjust these attributes

Block drawing mode

Left mouse button switches through various drawing modes including “spikes”, coloured blocks, with/without outline etc.

Vertical scale

Determines the height to which the spikes/blocks rise from the central sphere of patches

Resolution

This determines the number of patches (n-1) around the mid-point of the X axis. Any change to the resolution must be followed by a left-click of the mouse on this button to have the algorithm recalculate/reattribute the source vector to each patch and determine the height

Vector source

This is the data channel used to determine which patch each event falls into. Any change to the vector source needs to be followed by the ***Resolution*** button to action it – see above ***Resolution***

Height source

All data points that fall into a patch, as determined by the vector source, contribute to the height as dictated by the ***Height source***

Colourmap

Select the colourmap to use via the mouse-wheel (only Jet available by default). Left mouse-click to switch to dynamic colouring. The graphic will update in real-time while adjusting the colourmap in the colourmap generator app (3rd button from the left on the top left of the viewing area).

Threshold

A percentage of height from min to max, below which the top pad of the spike/block will be coloured blue. Any spikes/blocks that exceed the threshold will be coloured according to the colourmap. If the user left clicks this button to disable the threshold, then it switches to a mode whereby any spikes/blocks that fall below the threshold will not be drawn at all

Marked events only

By default, this is disabled (value 0). Use the mouse-wheel to cycle this through values 1-9 in order to filter by data that has been marked with events values 1-9 either manually, or via the Behaviour Builder

View colourbar

This toggles the view of the colour-bar, showing the ***colour by*** channel name, and min/max limits currently being applied

Orientation sphere (o-sphere)

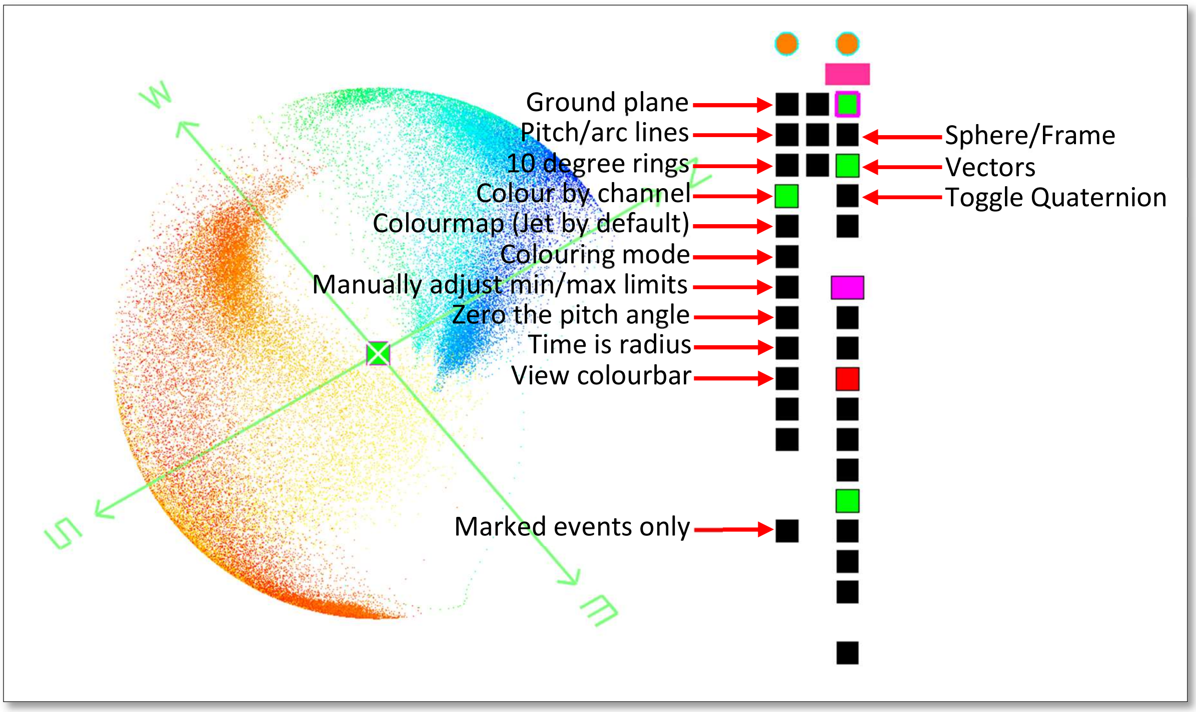


Figure 10.82 Orientation sphere data selection and visualisation options

Ground plane

This simply toggles the presence of a green square beneath the graphic

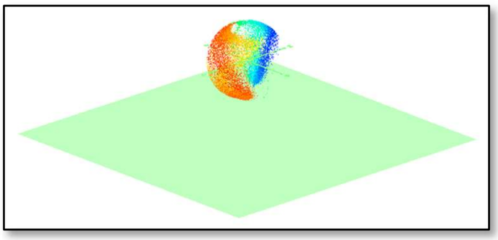


*Figure 10.83 Orientation-sphere with **ground plane** enabled*

Pitch/arc lines

Generates lines from the origin out to the sphere in 10-degree increments from +90 to -90 degrees. The heading vector that these all point at can be adjusted by using the mouse-wheel on this button to rotate through 0-360 degrees

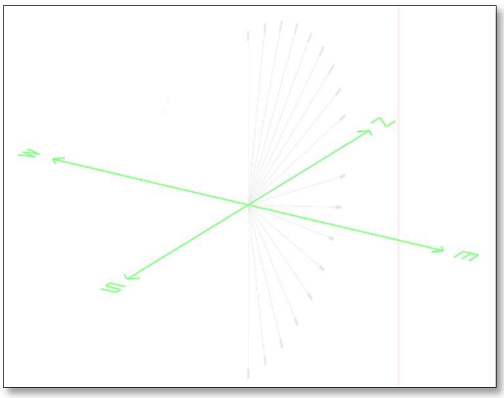


*Figure 10.84 Orientation-sphere with **pitch/arc lines** enabled*

10-degree rings

Generates circles at 10-degree increments from +90 to -90 degrees that draw around the full 360-degree heading.

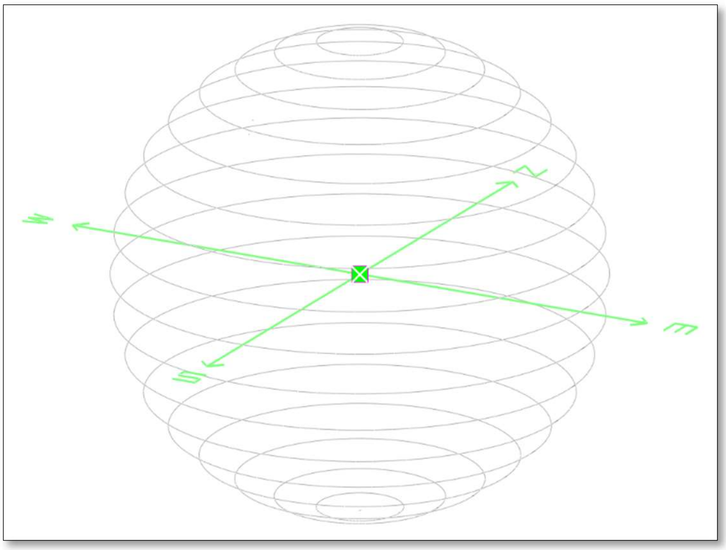


Figure 10.85 *Orientation-sphere with* ***10-degree rings*** *enabled to help locate pitch angles within the data*

Colour by channel

Select the data channel to be used to colour each data point

Colourmap

Select the colourmap to use via the mouse-wheel (only Jet available by default). Left mouse-click to switch to dynamic colouring. The graphic will update in real-time while adjusting the colourmap in the colourmap generator app (3rd button from the left on the top left of the viewing area).

Colouring mode

When ***Colour by select*** is using channel data to colour the data points, it can either use the colour limits as defined by the user in the above ***Manual adjustment of limits*** for the min/max colour values, or use floating limits i.e., scale the colour to the min/max values in the currently selected data

Manually adjust min/max limits

This manifests a control panel whereby the user can adjust the min/max limits of the colour channel. Hold down the shift key and mouse click/drag the above window around to better position it for viewing the values. Click on any of the ringed values to set the limits for the colour min/max values. A numeric touchpad will appear. Enter the required value and then click anyway else on the viewing area to accept this value, and the graphic will update (if the colour mode is set to ***user limits***).

Click the ***Manual adjustments of limits*** button again to hide this values panel

Zero the pitch angle

This reduces all pitch data to zero so that the visual is simply one of heading only. This button can be used together with the ***Time is radius*** button below

Time is radius

If selected, instead of the data always sitting on the surface of a sphere, it instead originates at the origin of the sphere, and radiating out to the sphere surface. This can be used with or without zeroing the pitch angle

View colourbar

This toggles the view of the colourbar, showing the ***colour by*** channel name, and min/max limits currently being applied

Marked events only

By default, this is disabled (value 0). Use the mouse-wheel to cycle this through values 1-9 in order to filter by data that has been marked with events values 1-9 either manually, or via the Behaviour Builder

Rose plot

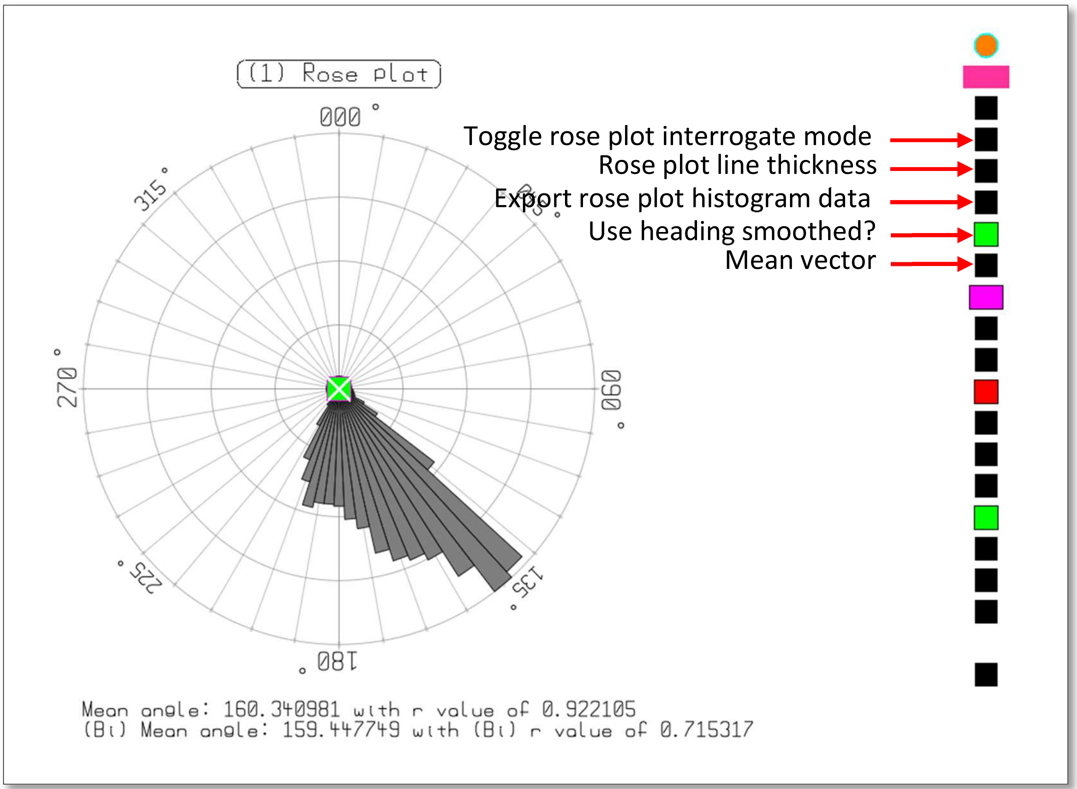


Figure 10.86 *Rose plot and associated options*

Toggle rose plot interrogate mode

Resets the orientation of the visual. Any mouse movements over the visual then shows the histogram value for that sector.

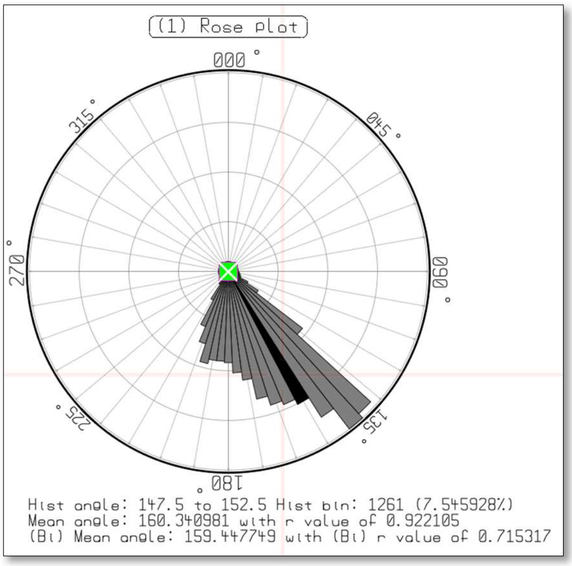


Figure 10.87 *Rose plot with interrogate mode enabled*

When *Interrogate mode* is selected, the user may hold down the ***Ctrl*** button, and left click on any bin on the plot's histogram, to ***Mark Events*** with the currently selected ***Marked Event*** value (use the mousewheel on this button to adjust from 0-9).

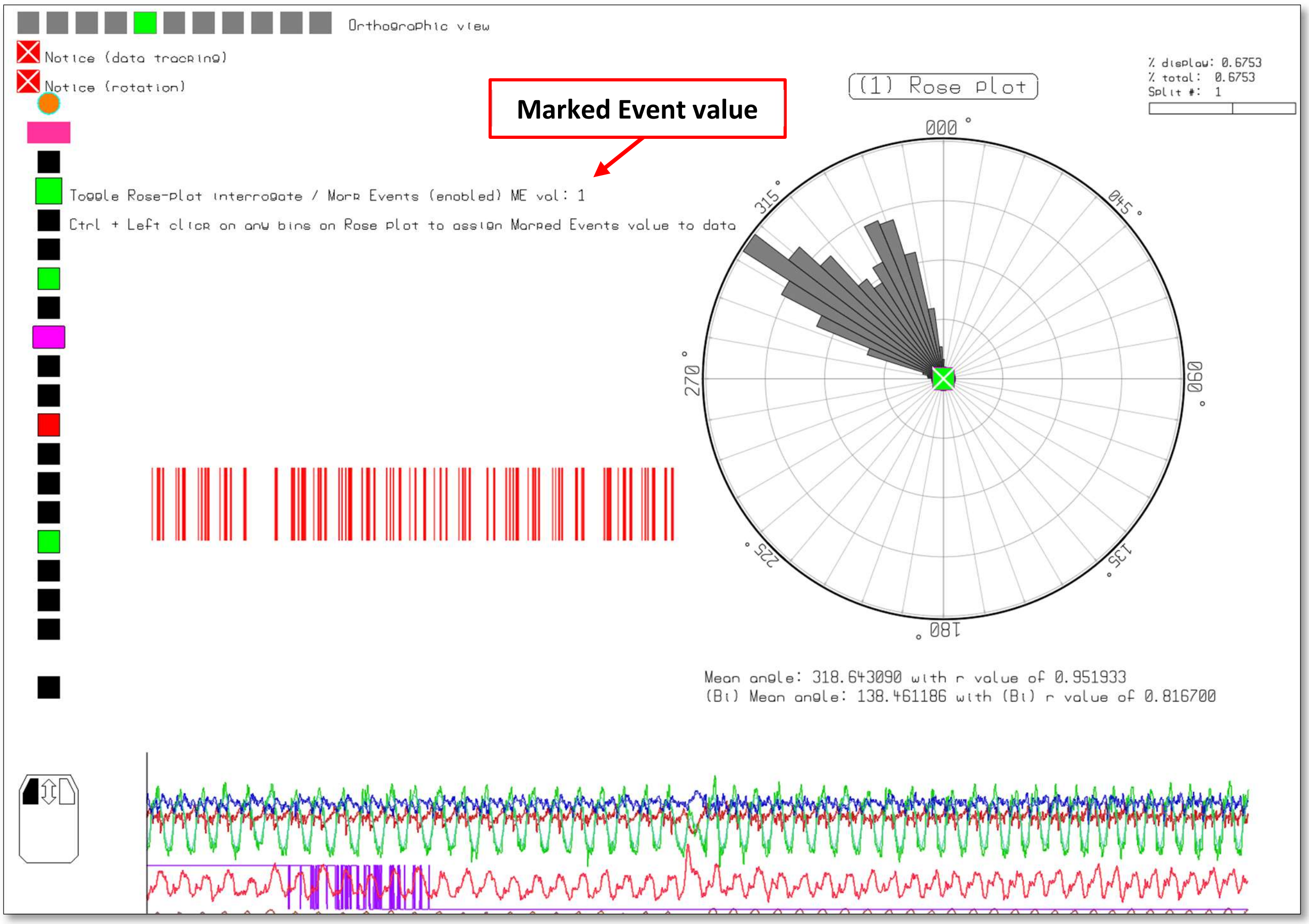


*Figure 10.88 Rose plot with interrogate mode enabled, and the user has held down **Ctrl** and left-clicked on one or more bins on the Rose plot, thereby highlighting which datapoints were at the selected binned angles*

Rose plot line thickness

Simply adjusts the line thickness of the graphic; sometimes necessary for screenshots and image-size reduction

Export rose plot histogram data

Creates a csv file containing the histogram data by sector

Use heading smoothed

Toggles between heading smoothed and raw heading channel data

Mean vector

Toggles the display of the mean heading vector. If ***Marked Events*** is enabled, ***1-9***, or, ***All***, then one or more mean vectors will be displayed, using the relevant ***Marked Event*** colour i.e., 1 = red, 2 = green etc. unless these default colours have been altered by the user. Example image using ***Marked Events = All***, with data selected with ***Marked Events*** = 1 and 2

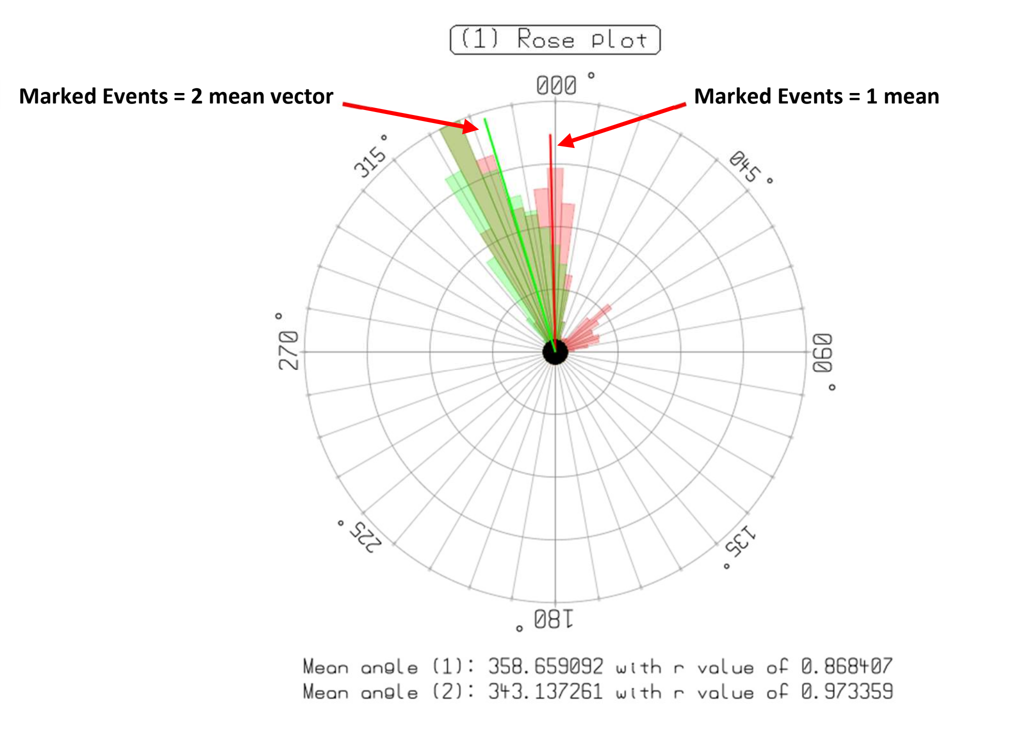


Figure 10.89 *Mean vectors for* ***Marked Events***

If ***Marked Events*** is selected, either **1-9**, or ***All***, then the roseplot will filter by this selection. If ***All*** is selected, then the roseplot will show multiple plots with transparency:

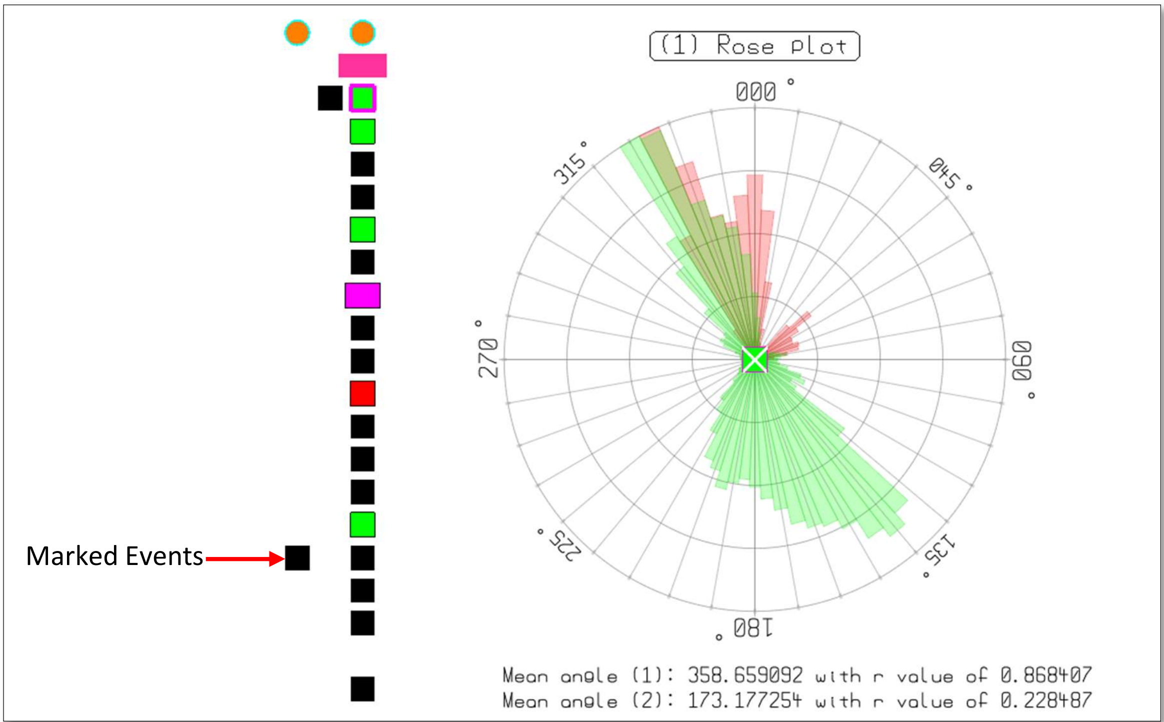


Figure 10.90 *Rose plot with* ***Marked Events*** *set to* ***All****, showing multiple plots with transparency*

3D histogram

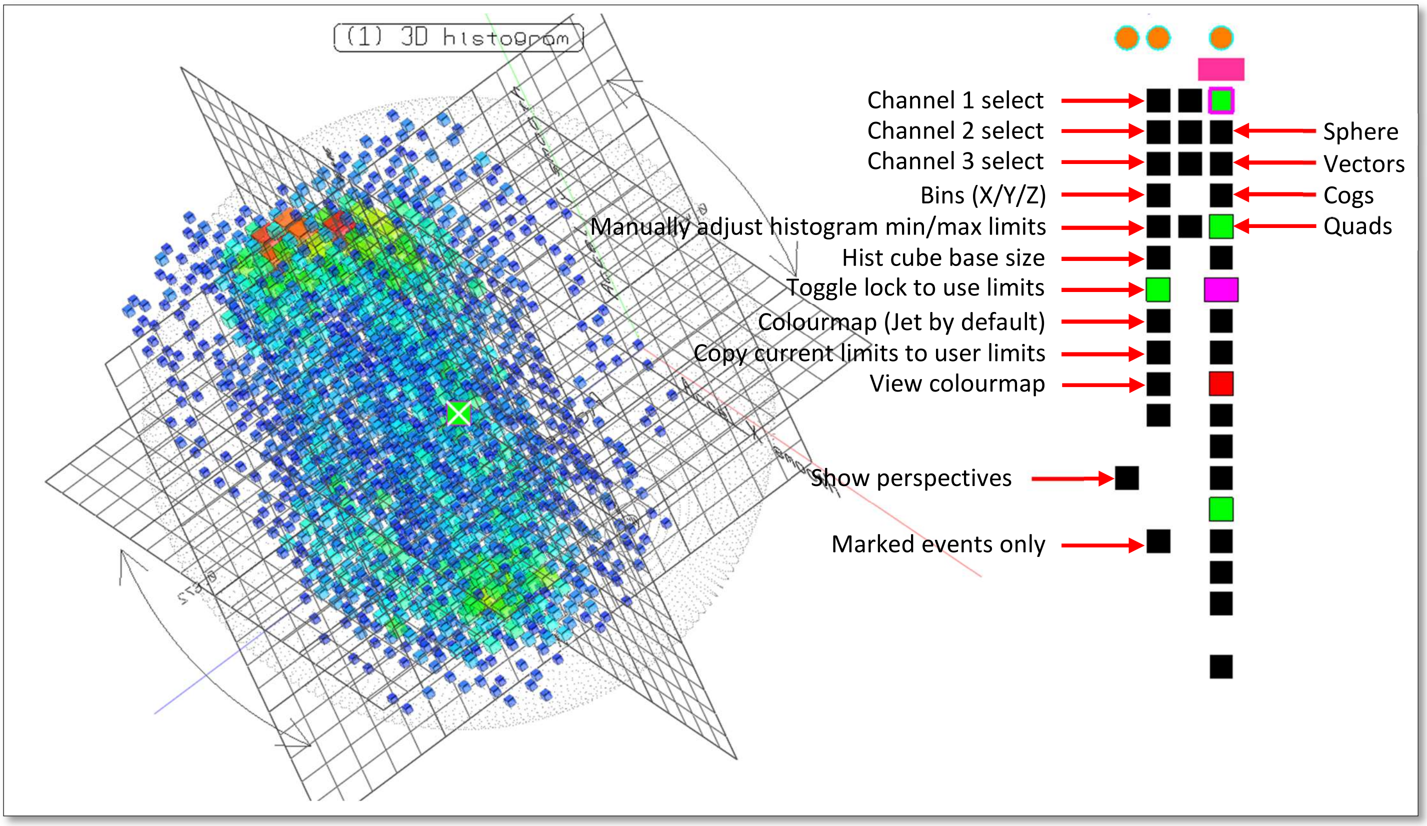


Figure 10.91 3D histogram with data selection and visualisation options

Channel 1 select

Use the mouse-wheel to select the appropriate data channel for the first axis

Channel 2 select

Use the mouse-wheel to select the appropriate data channel for the second axis

Channel 3 select

Use the mouse-wheel to select the appropriate data channel for the third axis

Bins (X/Y/Z)

Define the bin resolution of the histogram. All axes have the same number of bins. There is a 50-bin limit for each axis i.e. 50 x 50 x 50 (= 125,000) total bins

Manual adjustment histogram min/max limits

This manifests a control panel whereby the user can adjust the 1/2/3 channel limits of the histogram data.
There is also a small box, visible only when data is scaling to ‘user limits’ (see ***Toggle lock to use limits*** below), ticking this will double the values within the XYZ min/max user limits boxes. Alternatively, rolling the mouse-wheel while hovering over this tickbox will adjust up/down the values by 5%, thus scaling the data in view by this amount.

0

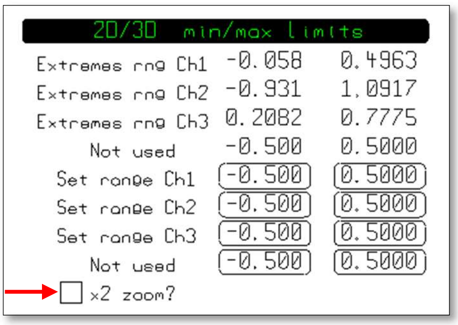


Figure 10.92 Setting min/max limits for 3D histograms

Hold down the shift key and use the mouse to click and drag the above window around to better position it for viewing the values. The top few rows of data indicate the currently selected channels’ min/max values. Click on any of the ringed values at the end of this list to set the limits for each axis. A numeric touchpad will appear. Enter the required value and then click anywhere else on the viewing area to accept this value, and the graphic will update (if ***Toggle lock to use user limits*** is set)

Click ***Manual adjustments of limits*** again to hide this values panel.

Hist cube base size

This defines the base size of the cubes, to which is added the value of the histogram bin. This ensures that small bin data is always visible

Toggle lock to use limits

This tells the visual to use the user-defined limits as set in ***the Manual adjustment histogram min/max limits***

Colourmap

Select the colourmap to use via the mouse-wheel (only Jet available by default). Left mouse-click to switch to dynamic colouring. The graphic will update in real-time while adjusting the colourmap in the colourmap generator app (3rd button from the left on the top left of the viewing area)

Copy current limits to user limits

This copies the values for the X, Y, and Z min/max extremes to the ***Set range Ch1/Ch2/Ch3*** user limits boxes (as shown in Figure 10.29)

View colourbar

This toggles the view of the colourbar, showing the min/max limits currently being applied

Marked events only

By default, this is disabled (value 0). Use the mouse-wheel to cycle this through values 1-9 to filter by data that has been marked with events values 1-9 either manually, or via the Behaviour Builder facility

Point compass

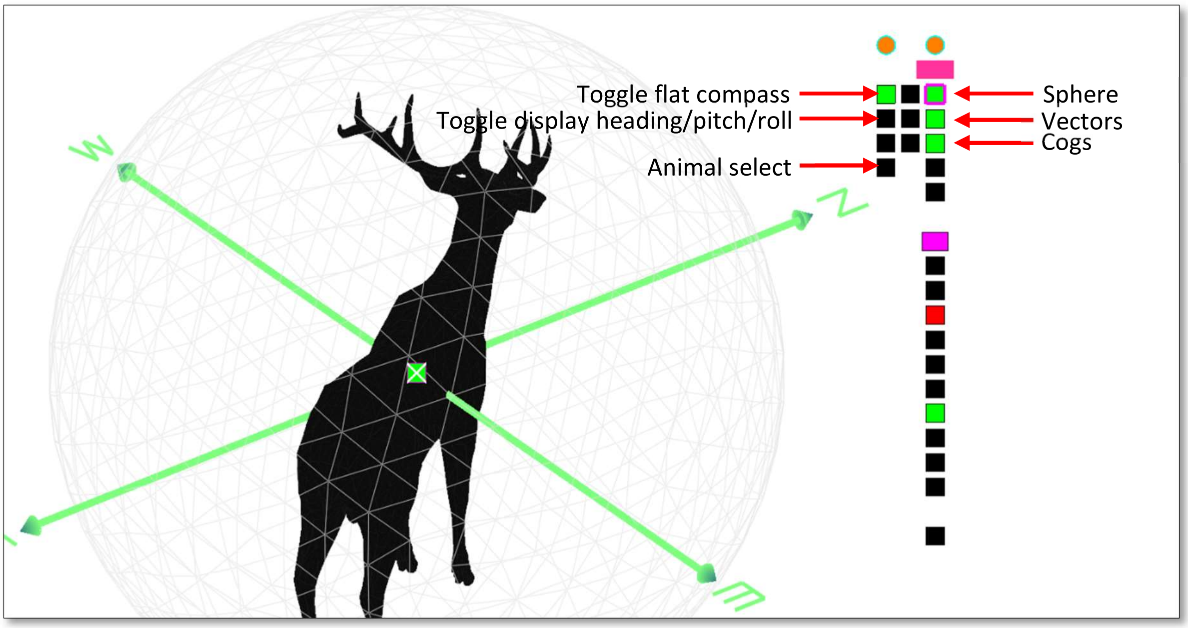


Figure 10.93 Point compass with visualisation options

Toggle flat compass

Normally the compass will tilt up/down by pitch value and rotate by heading. If flat compass is enabled, then pitch is always zero

Toggle display heading/pitch/roll

Display heading, pitch, and roll values for current left white line position

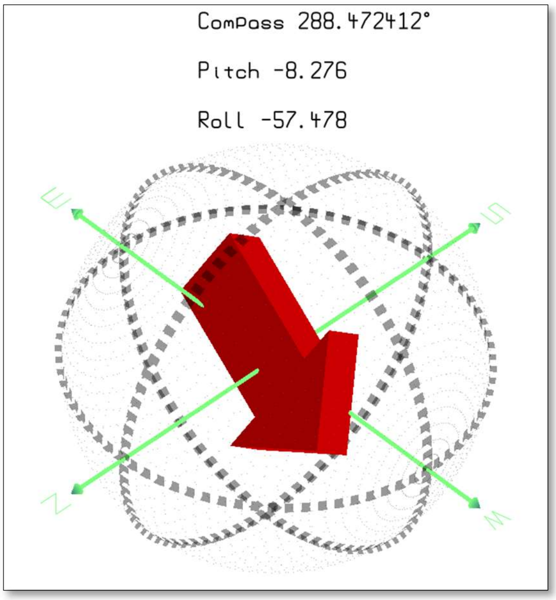


Figure 10.94 Point compass with display values enabled

Animal select Use the mousewheel to select from a small range of animals or the red 3D arrow (shown above)

Dead reckoning plot

The dead reckoning algorithm creates a 2- or 3-dimensional path, recreated using all or some of the sensor data presented to it.

Initially, it takes a combination of accelerometery and magnetometry data to derive heading, a technique known as a tilt-compensated compass. Together with heading information, pressure, or some other altimeter measure, can be used to determine the 3rd dimension. The quality of the path generated will be a function of the data and the way in which it is selectively applied by the user. A dead-reckoned path has a tendency to become more erroneous over time due to accumulation of errors in metrics such as speed, or incorrect association of behaviours to particular parts of data such as indicating that an animal is moving in an easterly direction whereas it is in fact stationary, and scratching. GPS data can be synchronised to the dataset to provide intermittent ground truthing, back correcting both range and bearing of data between fixes

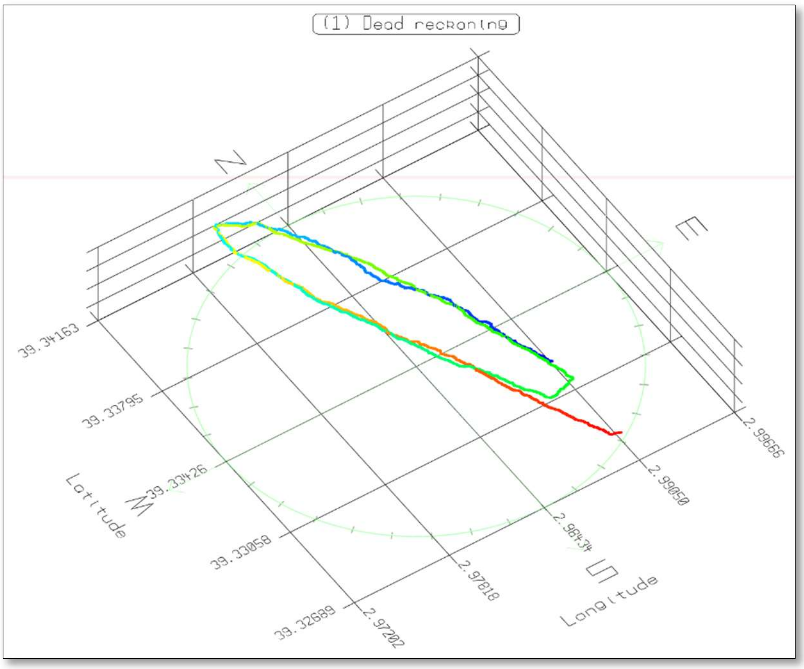


Figure 10.95 *Dead reckoning track*

In the above image we can see an oval track, circled twice. This was derived from heading data, with pressure (barometric) providing some height information

The controls for dead reckoning are (3rd column):

Figure 10.96 *3rd column menu for dead-reckoning visualisation*

…and (4th column):

Figure 10.97 *4td column menu for dead-reckoning visualisation*

Definitions for these controls are as follows:

Toggle 3D

Switches between dead reckoning on a flat plane, or including height/depth

Colour by altitude/depth/time

Toggle between colouring the track based on altitude or depth, or, on time

Toggle ground grid

Toggle view of a ground grid

Toggle solid ground grid

Toggle view of a solid ground grid

Toggle centralise on left white line

Centralise on the position of the left white line in the 2D graphing window

Dead-reckon using pressure, not pitch, for altitude change

By default, dead-reckoning is a 2D process, with the 3rd dimension filled in directly with smoothed pressure (/ depth). Left-clicking this button switches to using pitch angle to gain/lose altitude/depth. Mouse wheel inverts the vertical scale when direct smoothed pressure is the 3rd dimension (not pitch)

Pitch offset

When pitch angle is used to determine change in altitude (/depth), this button will appear that allows an offset to be added/subtracted to/from the pitch angle calculated for each data point within the dataset. This allows compensation for pitch due to the logger placement on the animal

Vertical scale

Adjust the vertical scaling of the visual with the mouse wheel

Toggle show left white line as white block

Show the position of the left white line in the track with a white block. Useful when determining where in the 2D data window something occurs in the dead reckoned track

View colourmap

Show the currently selected colourmap (currently redundant; cannot yet apply to the visual)

Toggle show vertical stack

Show the vertical stack – vertical lines from each point down to the lowest in the current track. Adjusting this button with the mouse-wheel switches vertical stack height to be a function of either altitude or VeDBA (smoothed)

VeDBA limit set

When dead reckoning using VeDBA as a proxy for step size, it is useful to provide a limit / cap to this variable. Let click to enable/disable. Mouse wheel to adjust limit

Set VeDBA movement threshold / coefficient

Here the user can check a box to use VeDBA as the step size for movement, and also provide a threshold value (VeDBA) which must be exceeded for movement to occur by an event, and a coefficient that is multiplied by the value of VeDBA that exceeds this threshold

i.e. *(VeDBA – Threshold) * Coefficient* is the distance moved in metres for that event (data point)

Alternatively, with “By VeDBA coeff?” deselected, a unit movement of *coefficient * 1.0* metres occurs for every event (data point) i.e. always moving, unless a data point is not selected due to a ***Marked Events*** filter (see below)
The user can either use the mouse wheel to adjust the threshold and coefficient, or click on the value and enter a new value using the keypad that appears

Switch graph modes

Clicking this button cycles the visual through having either one of the two graphs above, or none. The two graphs below represent either a linear scale, or proportional to the amount of movement, per unit time on the x axis.

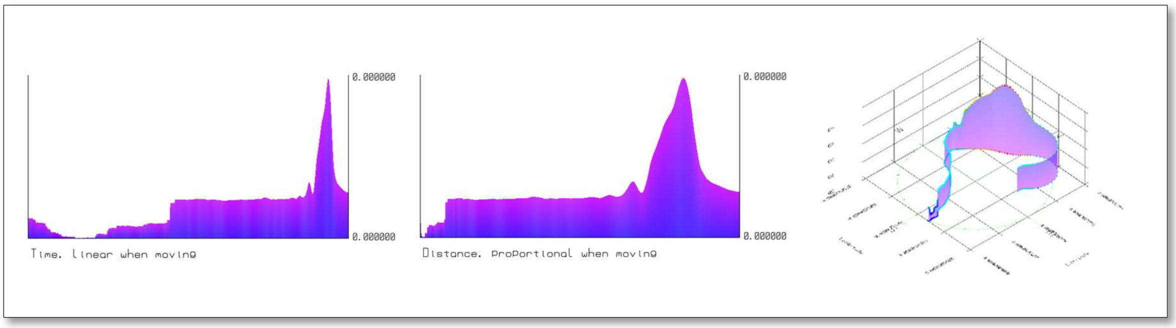


Figure 10.98 *Graph mode options, with time on the left and distance on the right*

Dead reckon by Marked events only

The dead reckoned track is generated from events selected by ***Marked Events*** only. Enabling this will modify the layout of the DR VeDBA Threshold / Coefficient settings panel:

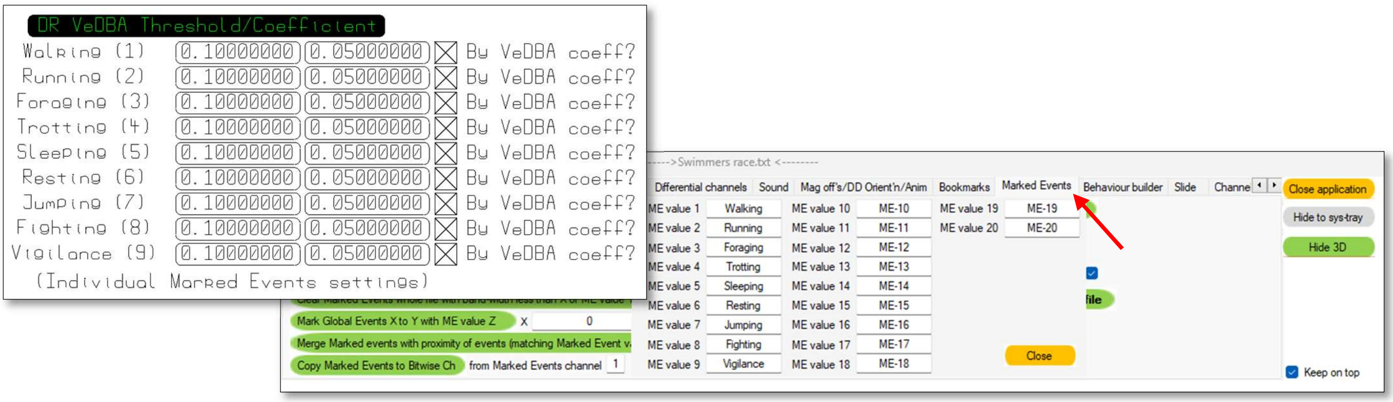


Figure 10.99 *Threshold / coefficient settings for **Marked Events***

Here, the ***Marked Events*** value (1-9) show their labels for values 1-9 i.e., Walking, Running, etc. Note that there are 20 labels shown above, but only the first 9 are currently available (future expansion). Now that “by ***Marked Events***” is selected for the movement step scale, the user can select different threshold and coefficient values for different categories of behaviours. As an example, the user might highlight a selection of data they believe is running and manually set this to ***Marked Events*** value 3 for *Running* , and another section of data to 1 for *Walking*. Which this ***Marked Events*** filter enabled, only those events that have ***Marked Events*** of a non-zero value will contribute to the dead reckoned track. The user would then “adjust up” the coefficient for the *Running* to perhaps 0.2, and “adjust down” the third coefficient to perhaps 0.1. Note that if there is data marked with different values (than 1 or 3 in this example), and the dead reckoned track should not move i.e., the animal is scratching, or sleeping (non-translational events), then set the coefficient to 0 (zero). The dead reckoned path is dynamically updated when a change is made to the track either by manually entering a value, or by adjustment with the mouse wheel

Export dead-reckoned track

Export the date/time/longitude/latitude/altitude data of the dead-reckoned track to a csv file

Set initial long/lat/alt coords

Set the starting longitude/latitude/altitude coordinates of the dead reckoned track. Click the yellow ringed values and use the numerical pad that appears to set each value. Click anywhere else in the 3D window to accept the value

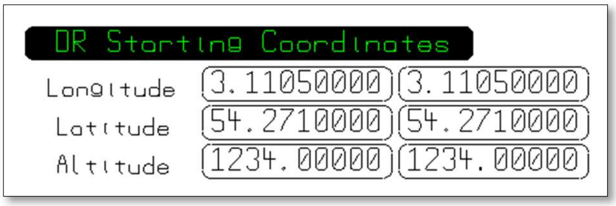


Figure 10.100 *Setting start point Longitude/Latitude/Altitude coordinates*

Toggle long/lat/alt coords

Toggle the view of the longitude/latitude/altitude min/max limits on the visual

Toggle vectors green ring/cross

Toggle the view of the green ring/central cross on the graphic as these might obscure the track

DR by smoothed or raw VeDBA

Left click to toggle between using raw or smoothed VeDBA as the step size for dead reckoned movement

Auto push DR data to main array

Enable this control to have the algorithm push the dead reckoned track to the system main array so that the DR longitude/latitude etc. is synchronised with the main sensor/timing data and can therefore be exported using the normal save/export functions. Under the ***What to save*** tab, there is an option to export these pseudo longitude/latitude/altitude data

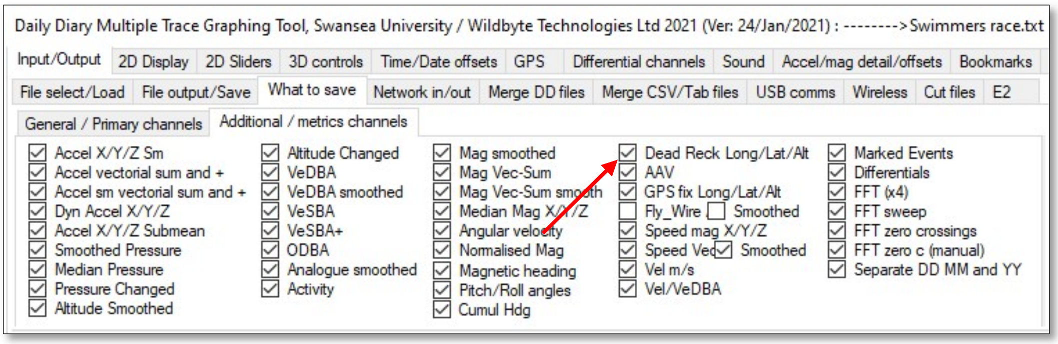


Figure 10.101 *Enabling dead-reckoning coordinate data for output in the* ***What-to-save*** *tab*

Clear DR main array

Clears the DR data in the main sensor/timing data array. If selected on the ***What to save*** tab, only zeros will be output

Overlay GPS onto DR trace

If GPS data has been preloaded into DDMT and synchronised timewise to the main array, then selecting this option will show the GPS coordinates within the time window selected in the ***2D graphing window***

Continuous calc of DR from this point and export to split 1

This enables a mechanism whereby the DR track on display export up to around 75% of the current split, and then load the next alternate split i.e., either even or odd, auto-generating the DR track, and will continue from 25% into the data, and export to the 75% point, alternating split to split. The last split it will export is that shown on the button label. The user can use the mouse wheel, while hovering on the button, to adjust this up or down. The minimum split value the user can select will be the current split. The data exported is determined by the user selection on the ***What to save*** tab. Separate files are output per split. These can either be merged later in R, or using the ***Merging csv / tab delimited files*** function, discussed in the first chapter, ***Importing and Exporting Data with DDMT***, to create a single large file for the total DR track

Heading correction value: xxx

This value synchronises with the ***Compass offset*** value on the ***Accel/mag detail/offsets / DD Orientation*** tab. It allows the user to manually account for any heading offset in the logger's magnetometer, possibly due to collar fitting issues. Any rotation correction will be redundant when using GPS for ground truthing, as heading errors are automatically corrected when the algorithm rotates DR data between GPS ground truthing fixes. The user can adjust this value using the mouse wheel while hovering over the button. The dead reckoned track (when not using GPS) will dynamically update

Altitude in metres

When enabled, the altitude values are in metres; disabled, the values are in pressure. The vertical scale, in either case, can be inverted (toggled) using the mouse wheel on the ***Dead-reckon using pressure, not pitch, for altitude change control*** (adjacent button in 3rd column)

Inherit starting GPS coords

When the user has selected the ***Overlay GPS onto DR trace*** control, selecting this control will force the dead reckoning to start from the first GPS (left most) fix in time, within the current time-window on the ***2D graphing window***. The first GPS coords (in time) will be loaded into the ***Set initial long/lat/alt coords*** boxes. Dead reckoning continues from these starting coordinates. This allows the GPS and dead reckoning data to be simultaneously displayed, else their coordinates may be too far apart to be viewed. Note that only the first GPS coordinates are used. Once this has been enabled, it is recommended that the user adjust any heading offsets, VeDBA thresholds/coefficients to achieve a best match of the dead reckoned path with the currently viewed GPS coordinates. Once this is done, the user can then enable the synchronisation of the remainder of the GPS coordinates with the ***GPS correction*** control below

GPS overlay colour

The user can adjust the colour of the GPS fixes using the mouse wheel

GPS undersample

When using high frequency GPS data, it might be desirable to under-sample the GPS data points i.e., 1 Hz GPS could be under-sampled to a point every 10 seconds, or every 10 minutes, by using the mouse wheel to set the interval in points here

GPS line thickness (incl. point size)

The GPS points' size, blue in the image below, are set to the "line thickness +2", so when the visual's points/lines mode is set to lines (2nd column, 3rd button down), the GPS points will be joined up with this line thickness

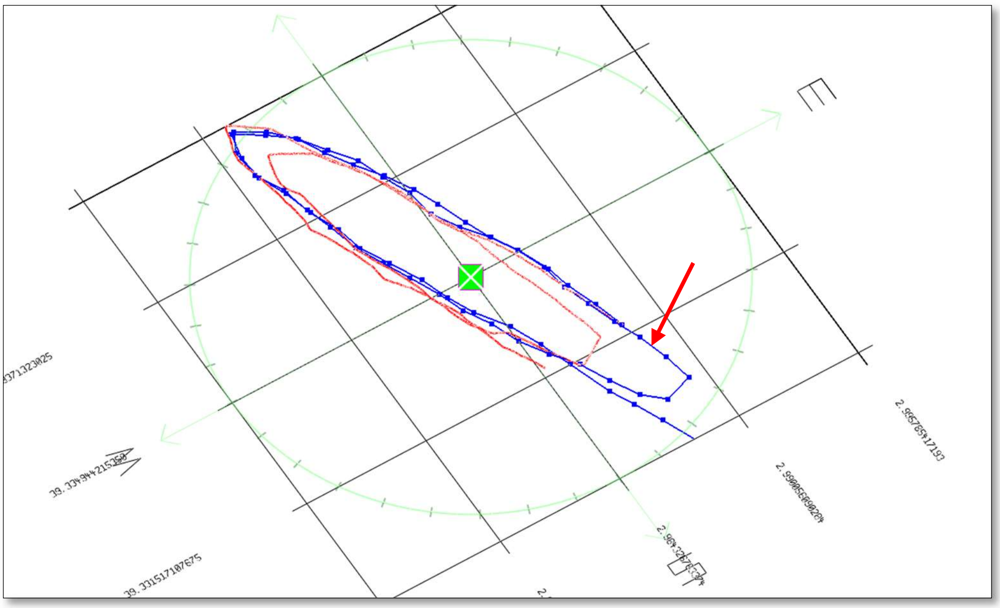


Figure 10.102 *Increasing the GPS line thickness – increasing a small amount will begin to join up the GPS points*

GPS correction

It my not be obvious in the image above, but the point marked with the red arrow is both the first GPS point, and the start of the DR track, due to the "***Inherit starting GPS coords***" option above. Selecting ***GPS correction*** reruns the dead reckoning algorithm and uses all available GPS fixes for ground truthing. See image below

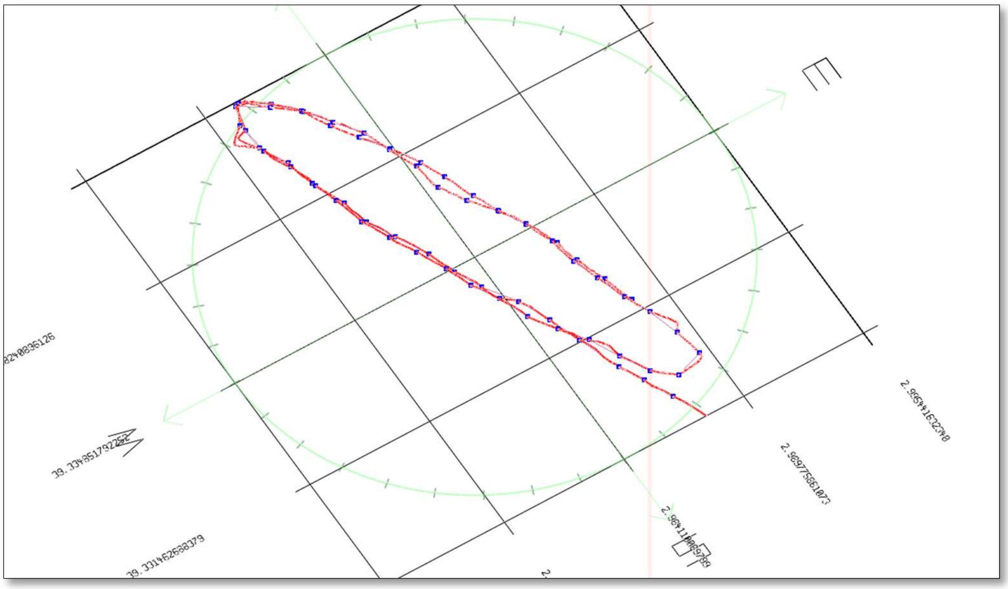


Figure 10.103 *Enable **GPS correction** will force the dead-reckoning algorithm to utilise the GPS coordinate information where available*

Show VeDBA vs GPS speed graph

Still in development

Scale bar

Implemented. When selected, a scale bar (m) will appear in the south-west corner of the plot. The mousewheel can be used to adjust the scale length on the graphic

Graph Bearing / Range error

Still in development

Apply wind vector

This option allows a constant vector to be applied to all data points used in the creation of the dead reckoned track.

The original track, without a wind vector applied, inset, and with the wind vector applied, main:

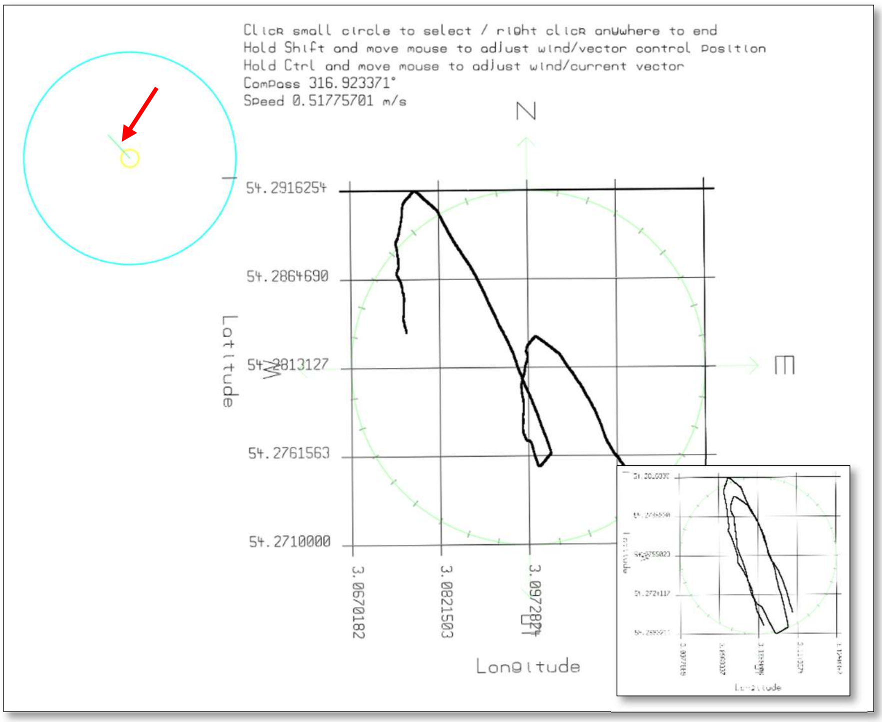


Figure 10.104 *Threshold / coefficient*

When the wind vector control is enabled, the button's label switches to ***Apply wind vector (enabled) Multiplier at :xx*** where xx is a coefficient. When enabled, there is no wind vector. The user must first click on the small circle, within the larger circle, top left of the above image. Then, by holding down the ***Ctrl*** button and moving the mouse around this larger circle, the bearing of the wind is determined, and the magnitude (multiplied by the button's coefficient) being the length of the vector from the centre of the circle, is the speed in m/s. In the above image (main), a vector has been applied in a northwest direction with a strength of approximately 5 m/s. This has caused the dead reckoned track to stretch in that direction. The dead reckoned track is updated dynamically with any change in the wind vector direction or magnitude. Note that with GPS ground truthing enabled, applying a wind vector may have limited results due to the autocorrection with the GPS fixes.

Dead reckon using first/last GPS points only

Still in development

Ground truth using GPS with Marked Events only

Still in development

DEM Digital Elevation Map – this is a work in progress; the DEM must be loaded prior to the data file. Updates to follow

Export as .kml This allows the current DR track to be exported as a *.kml* file for impot to Google Earth. Options include 'clamp to ground', pseudo altitude value etc.

Correction hairs This is a modification to the DR visual that shows 'hairs' between successive GPS points, that point in the direction of the DR track for that segment, prior to correction to the GPS bearing. The colour bar that appears can be moved by holding ***Ctrl*** and left clicking its new position. The length of the hairs, and their colour (as depicted on the colour bar scale) are a function of the absolute difference between DR segment distance and GPS segment distance

To begin - Using the dead reckoning algorithm

By default, when generating a dead reckoning visual in DDMT, the user is presented with a first approximation of a track using heading data, and step length per data point will be proportional to its VeDBA value.

Assuming the DD orientation settings are correct (see chapter 7) to generate heading data, along with pitch and roll from the accelerometer, then, if GPS data has been preloaded and synchronised with the DD data (see chapter 9), and the GPS data is believed to be low in positional error, it is recommended to enable the following, to bring GPS ground truthing into play:

GPS overlay

Inherit starting GPS coords (enabled automatically when ***GPS overlay*** enabled)

Do not enable GPS correction yet (this should be enabled later, once the VeDBA threshold(s) / coefficient(s) have been determined and applied)

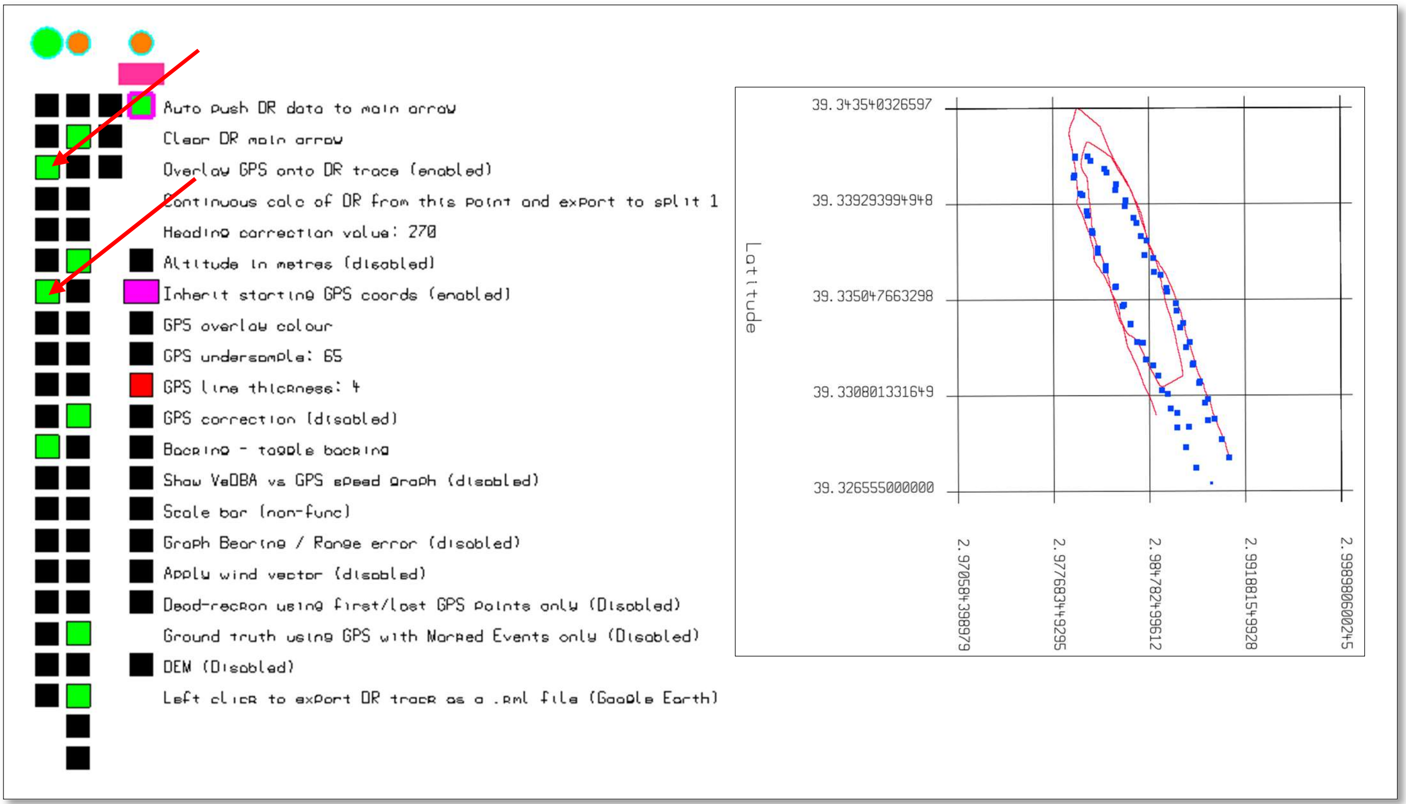


Figure 10.105 Enable ***GPS overlay*** and ***GPS correction***

The result of this is that the dead-reckoned track will now inherit the first GPS coordinates it finds in the timeline presented on the 2D graphing window, and so the start of the DR track and the GPS track will be collocated. In the image above, the red line represents the DR track, while the blue squares are the GPS data.

To take this to the next level we need to have the dead reckoned track develop / progress only for behaviours that warrant it. To allow the dead reckoned track to account for these different behaviours, the data needs to be marked per behaviour, by either manually applying ***Marked Events*** values, or use of the ***Behaviour Builder***. Sections of data where an animal is running would perhaps have a ***Marked Events*** value of 2, walking 1, sleeping or scratching (non-translational) 3 etc. In the image below, the first section has been "marked" with value 1 (red), the second with value 2 (green), and the third value 3 (blue), and the last value 1 (red). The other data before and after this *Marked* data, is value 0 i.e., "not marked" / ***Marked Events*** = 0. Let's pretend that the red data represents walking, green running, and blue stationary – scratching/sleeping etc. Only data that represents translational behaviours should generate movement / progression within a dead reckoned track.

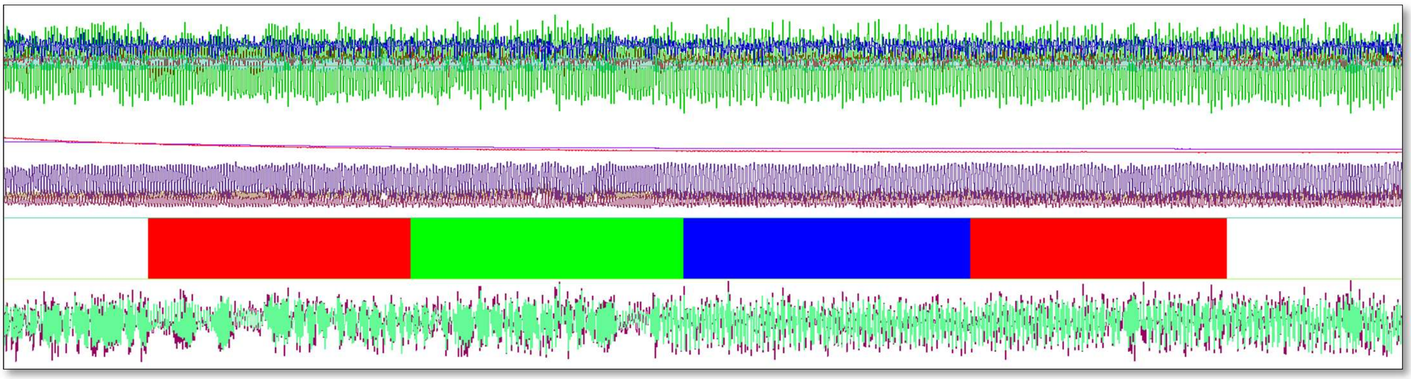


Figure 10.106 *Data marked with* ***Marked Events*** *value 1,2,3, and 1*

Enabling ***Dead reckon by Marked Events only*** (3rd column, near the bottom) and selecting ***Set VeDBA movement threshold / coefficient*** (2 buttons below this), the user should proceed to adjust the threshold and coefficient values for the various ***Marked Events*** values. In the settings below, the coefficient for ***Marked*** Events value 1 (red) has been set to 0.02, value 2 coefficient to 0.05, and value 3 to coefficient to 0.00. To change a value, simply left-click in one of the boxes and a numerical pad will appear. Enter the number and click away from the numbers and that value will be accepted. This grid of categories/coefficients etc. can be moved around by holding down the Ctrl key and left-clicking on the 3D area.

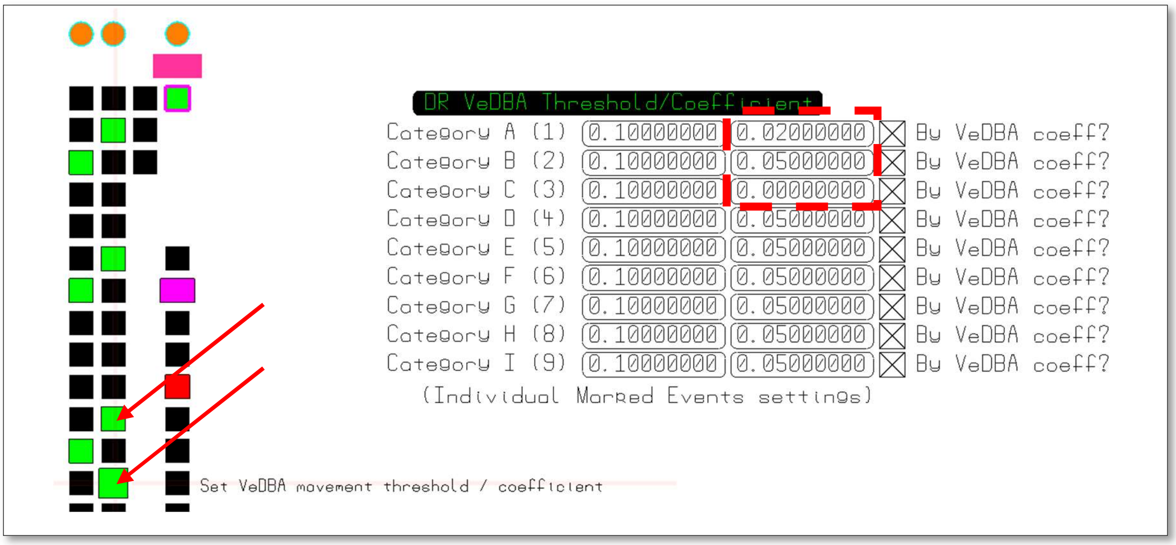


Figure 10.107 *Setting different coefficient values for different* ***Marked Events*** *values to simulate different speeds of translational movement*

There are two different calculations for step length with this dead reckoning algorithm, either by use of VeDBA, or not. The crossed box, adjacent to the ***By VeDBA*** in the image below, can be toggled on/off by left-clicking the mouse. If the cross is present, then the calculation is simply:

Metres moved in the direction of heading per data point = (VeDBA – Threshold) * coefficient

Or, if the box is not crossed, then the calculation is:

Metres moved in the direction of heading per data point = Coefficient

i.e., in the second case, speed is a constant for a given ***Marked Event*** value. If ***Dead reckon by Marked Events only*** is disabled, then all data generates the same step forward distance, but if ***Dead reckon by Marked Events*** is enabled, the stepping distance can at least be modulated by behaviour (***Marked Event*** value).

The threshold value is present to minimise movement at low VeDBA, but this could be set to zero, to truly enable movement as a function of VeDBA.

The dead reckoned track below has been generated using the VeDBA method. Only the red and green sections of data contribute to the track as the coefficient for the blue section is zero. Note that, even though all 4 sections contain approximately the same number of data points, the green section is 2.5x longer than either of the two red lengths as its coefficient is 2.5x greater. VeDBA does indeed factor in but has a relatively constant mean/variance for all 4 sections.

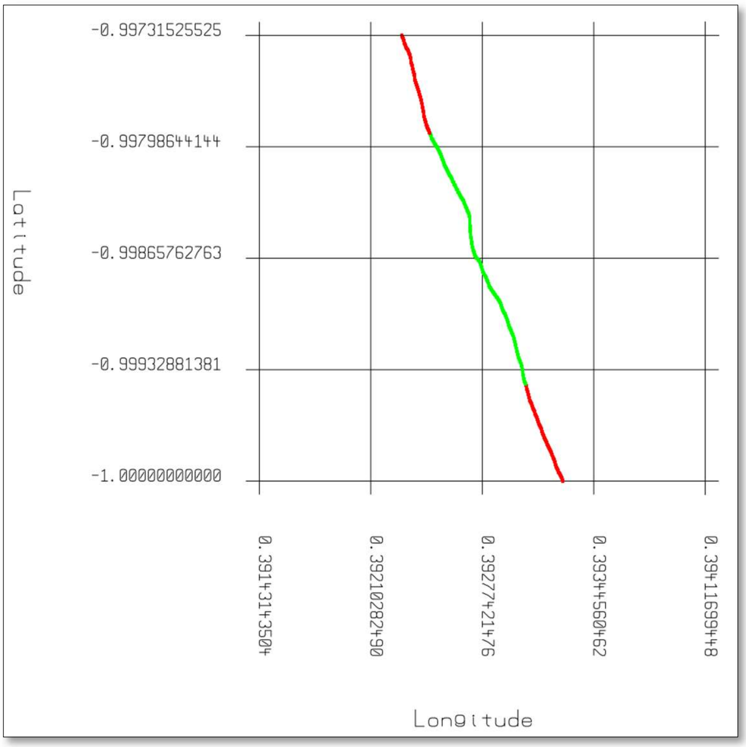


Figure 10.108 *Dead-reckoning tracks generated using different coefficient values for different* ***Marked Events*** *values. The track has also been coloured by the* ***Marked Events*** *value per data point*

The track above has been coloured by ***Marked Events*** by rolling the mouse wheel on this button; the selection is shown in brackets:

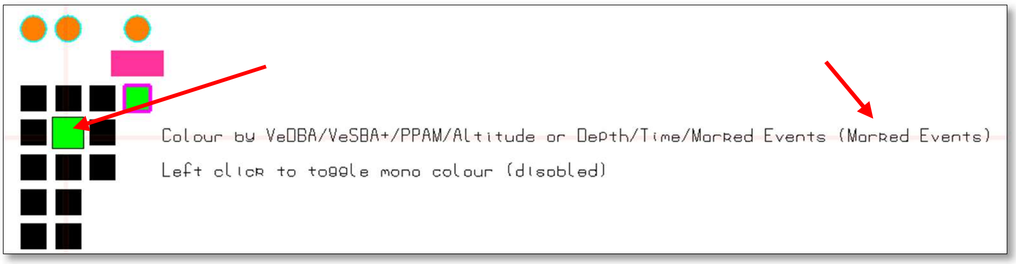


Figure 10.109*Adjusting the colour of the dead-reckoned track by different means*

The initial aim of using different coefficients is (1) to match the step length per data point, as best one can, to the true step length of each behaviour, while the overall aim is (2) to have the track closely match that of the GPS track.

When using VeDBA, there is a button (3rd column, 12th button down) that, disabled by default, limits any VeDBA values used in the algorithm to some value. The mousewheel on that button can be used to adjust this limit up/down.

In the image below, the coefficients have been set low, and then close to what they should be so that it closely matches the GPS track.

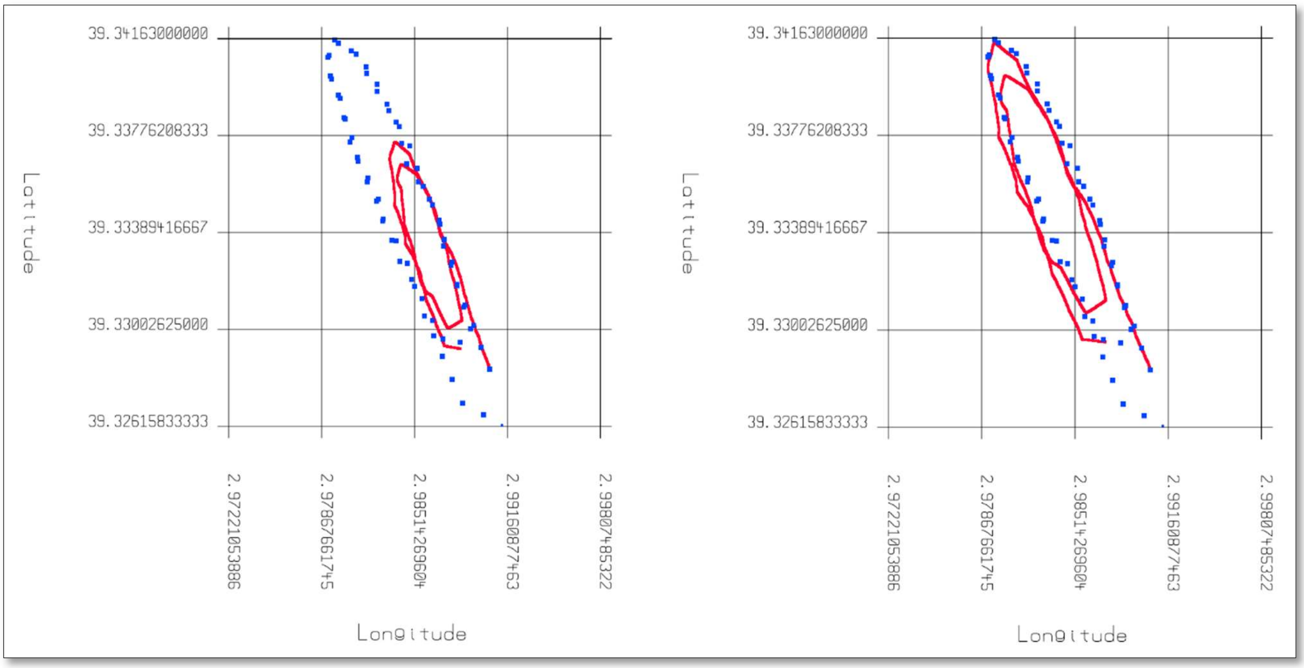


Figure 10.110 *Dead-reckoned tracks showing the result of different values of coefficients. The blue dots represent the GPS data, while the red track is the dead-reckoned track*

If no GPS data is present, but the coefficients are known, or can be calculated, then the starting longitude/latitude coordinates can be set here:

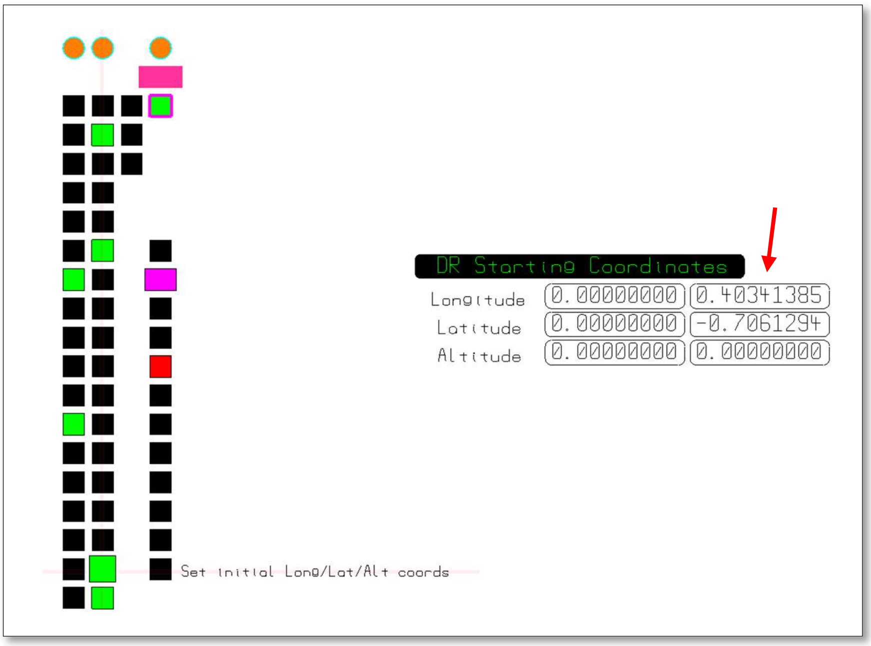


Figure 10.111 *Manually entering the startin Longitude/Latitude/Altitude coordinates*

Note that, entering a value into any of the three boxes on the right-side (indicated), will copy these 3 values into the left boxes, where they are read from at the start of the dead reckoning algorithm. When the algorithm is set to 'Inherit first GPS point', the GPS coordinates are loaded into these boxes, overwriting any manual entries.

It should be noted that when correcting the dead reckoned track with GPS data, the visual automatically switches to 2D i.e., no change in altitude. 3D can be switched back on by left-clicking the top button of the 3rd column. It is assumed, by default, that pressure (either barometric, or depth) then determines the height axis. The vertical axis can be flipped by this button:

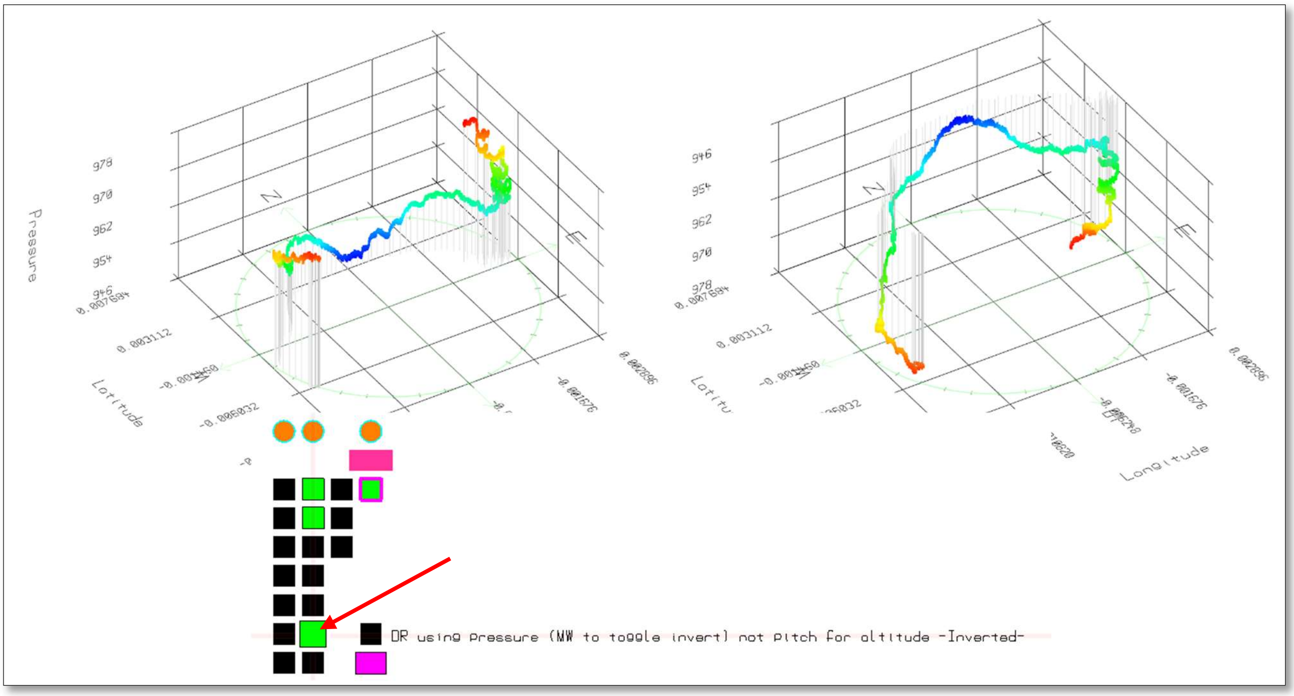


Figure 10.112 *Vertical scale inversion when using pressure / depth for height*

A compass ring can be enabled that shows the direction of *True North*, the height of which can be adjusted with the mouse-wheel on the same button. In the image below, the vertical scale has been set to 0%, so the track lays at the bottom of the visual.

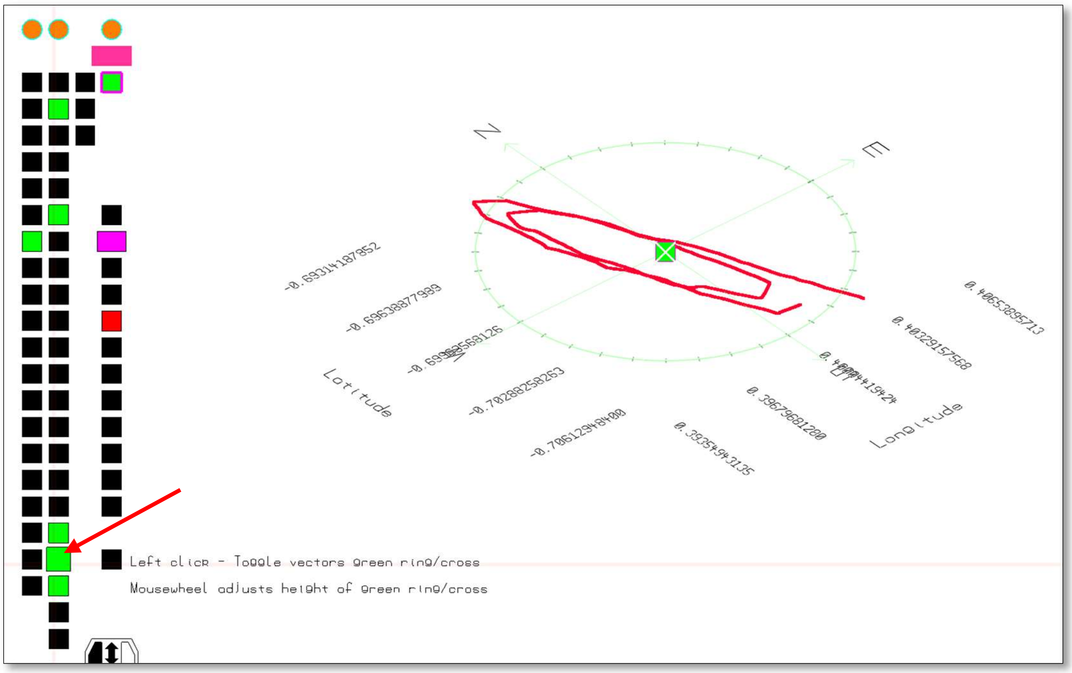


Figure 10.113 *Toggle the green ring compass*

Rolling the mouse-wheel on the top button of the third column toggles on a flat shadow of a 3D track. If the vertical height of the track is inverted, the flat shadow switches to the bottom/top (inset). This helps the user to visualise the 3D nature of the track on a 2D image/screen. The colour of this trace can be adjusted by holding the Ctrl key and rolling the mouse-wheel while hovering over this same button.

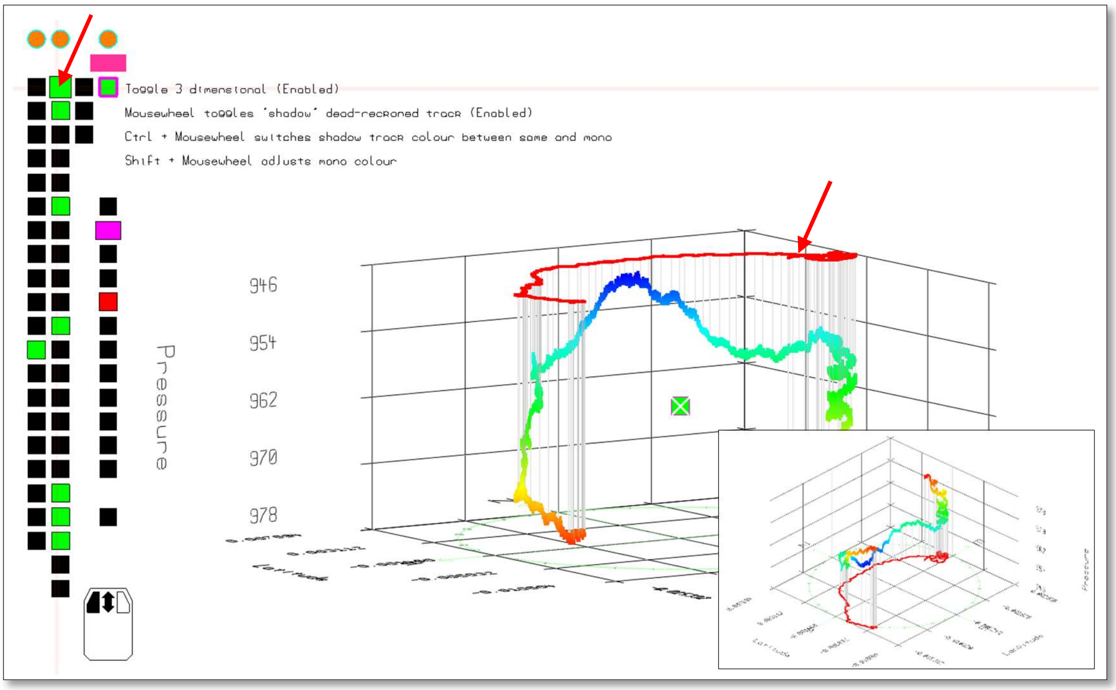


Figure 10.114 *Toggling the flat shadow track, and altering its colour from red through to blue on the* ***Jet*** *colour scheme*

To aid the user in determining distance travelled as a function of VeDBA, a side graph can be enabled. In the figure below, the top image shows pressure (red), and VeDBA (purple). The two images below this show the two modes for this distance travelled as a function of VeDBA.

The first (middle image) shows pressure over time, where the track 'progresses' such that each point that generates movement, shares an equal distance on the horizontal axis, i.e., linear with time.

The second (bottom image) shows pressure over distance travelled, where the track 'progresses' such that each point that generates movement, shares the proportional distance it moved on the horizontal axis, i.e., proportional with distance.

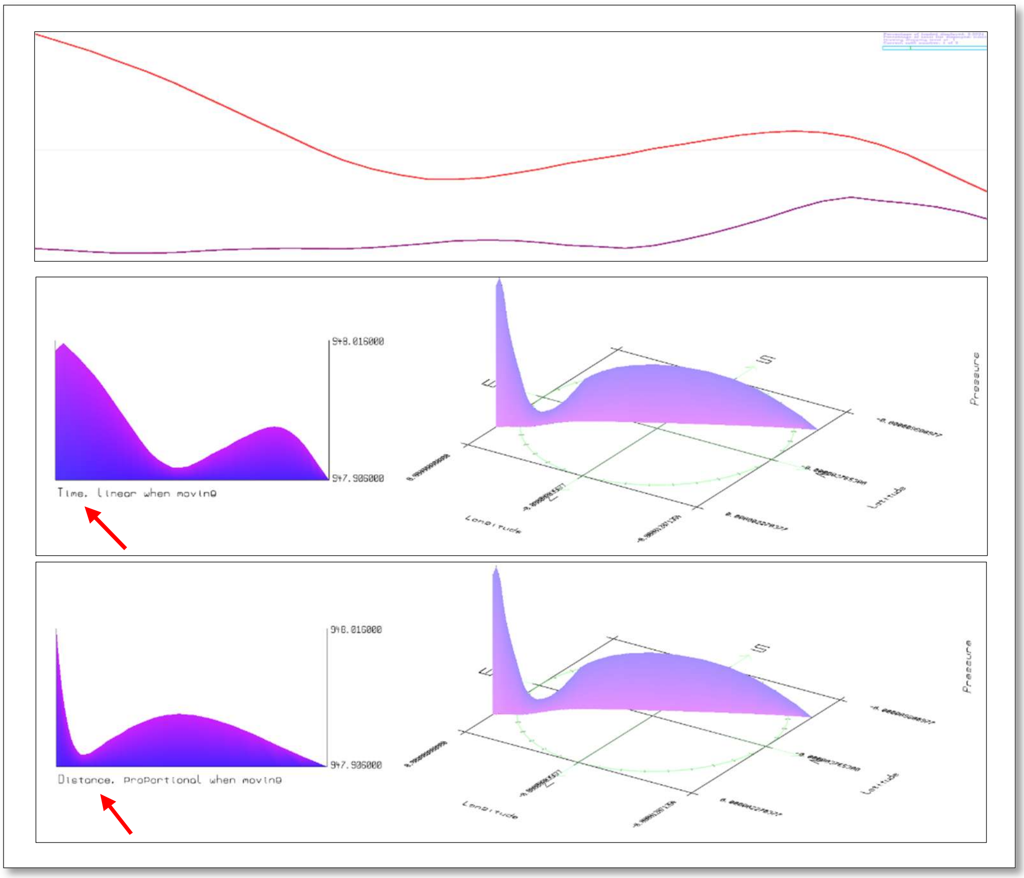


Figure 10.115 *Side graphs that show change in altitude over time*

Correcting heading bias where the logger was not lined up on the animal's back along the cranial axis, but instead skewed to the left or to the right

Heading correction is possible within the dead reckoning algorithm through simple addition or subtraction of a constant bearing value. This can either be entered on the ***DD Orientation*** tab, or it can be manually adjusted (and that on the ***DD Orientation*** tab will auto update to this value) by adjusting the mouse-wheel on this button (below):

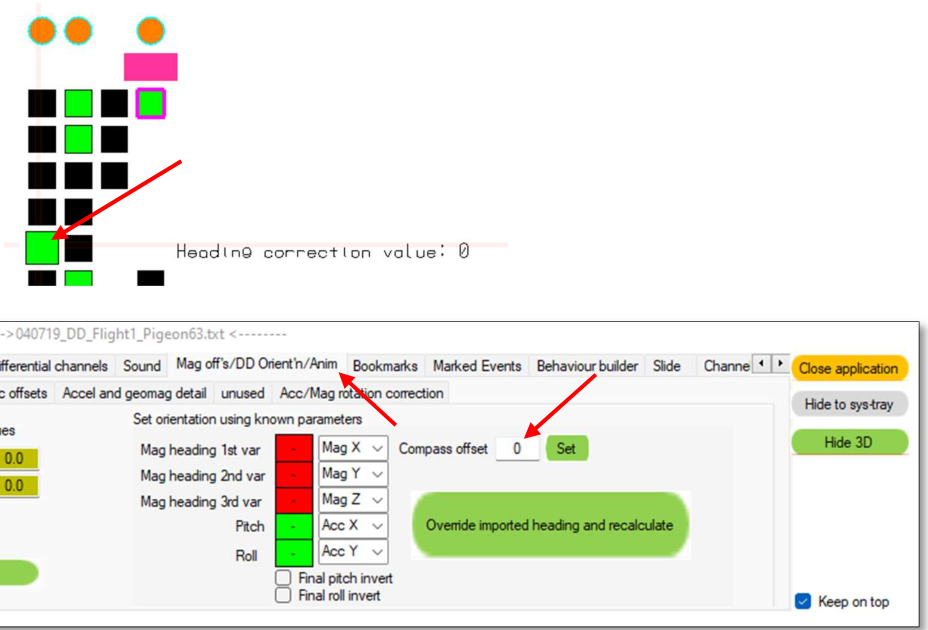


Figure 10.116 *Correcting heading bias for a dead-reckoned track*

If the two images below, the same track is shown for 0° bearing correction, and +45° bearing correction.

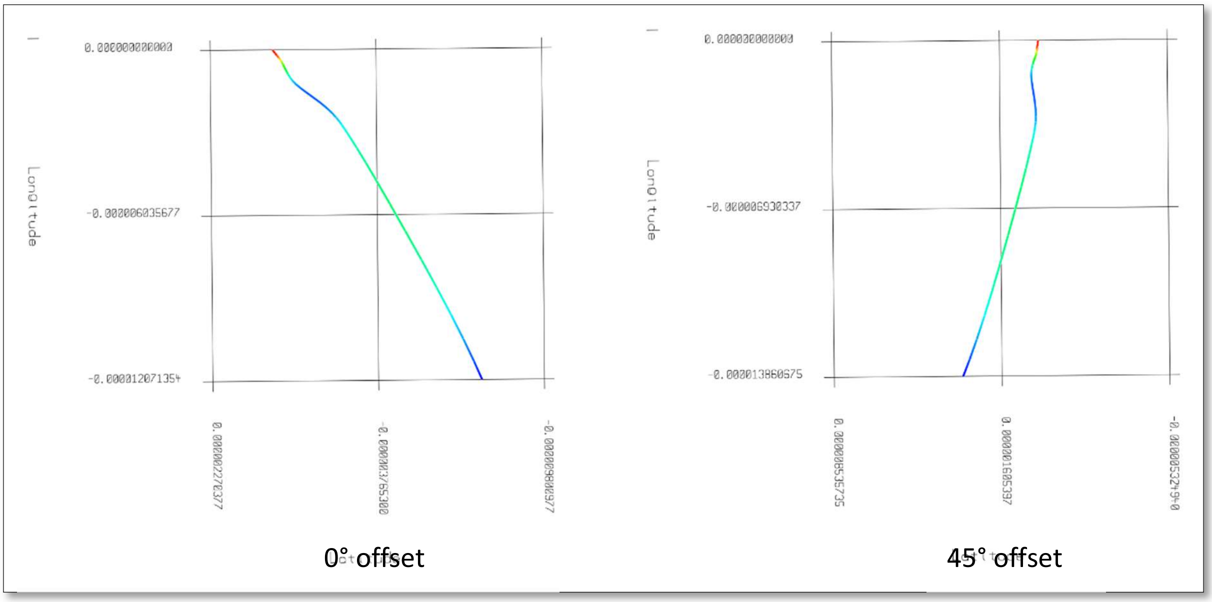


Figure 10.117 *Dead-reckoned tracks with 0 deg and 45 deg (clockwises) bearing bias*

Displaying correction hairs on the DR plot to indicate bearing error and distance error (for successive DR and GPS segments)

Clicking this button, enables the ***Correction hairs*** to be overlaid on the DR track. The direction is a function of

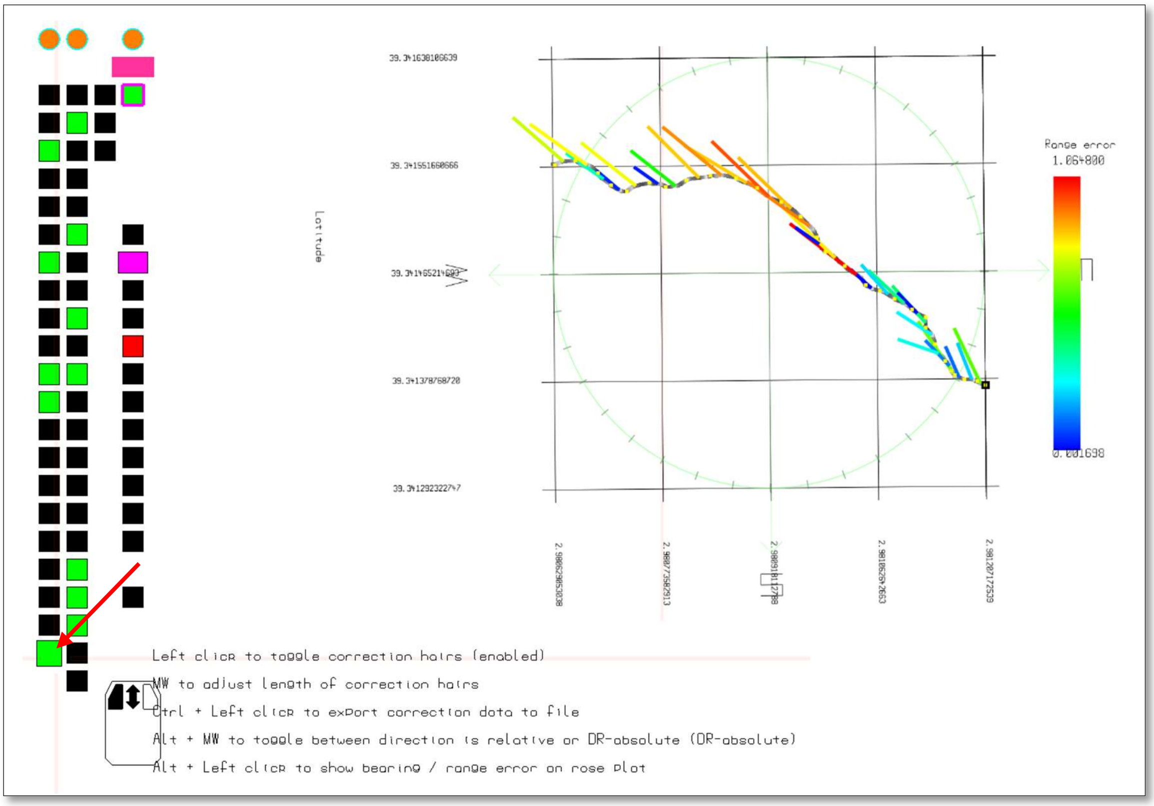


Figure 10.118 Correction hairs *that try to illustrate the dead-reckoning algorithms first guess on heading per segment (GPS-GPS set of data points) using both hair length (range error) and colour (range error); direction represents the DR headings segment direction*

This function can only be enabled when GPS is synchronised, and ***GPS overlay*** / ***GPS correction*** enabled on the DR visualisation, as it requires GPS correction to determine the DR-GPS bearing and DR-GPS range errors. The ***Correction Hair*** errors will consider ***Wind / current Vector*** if enabled/applied.

Colourmap Generator

Figure 10.119 Colourmap Generator

Store current map

Stores the current map using the set name (default is ***User defined name***) and makes it available to all visualisation types

Import colour map

Imports a .csv file containing colour map(s) and adds them to the list for all visualisation types

Export colour map

Exports all currently in-memory colour maps to a .csv file

Set map name

Reveals a virtual keyboard that the user can use to enter the name for the current dynamic colourmap.

Show custom maps

Under development

Figure 10.120 Adjusting the switching points for the different colours

Notice the 7x triple buttons. These are the red/green/blue components (top/middle/bottom, respectively). Positioning the mouse over one of these many smaller buttons will reveal a small tag showing the red/green/blue values for that "slider". The mouse-wheel can be used to adjust the value for these 3 component colours (0-255). Left click on any of the three small buttons for each of the middle 5 sliders, and its position will then track with the mouse. Left click again, and the slider's position will be released. In the above, several sliders have been adjusted horizontally

Important note – In order to interact with the colourmap generator, disconnect from all visualisations by holding down Ctrl and right-clicking on nothing in the 3D area i.e., turn a currently selected visual (green square at the centre of any currently generated visualisation to red)