CetTrack User Manual

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About this software

CetTrack was developed by Dr Michael Dähne (German Ocean Museum and Federal Agency for Nature Conservation) and Dr Mel Cosentino (Aarhus University) with financial support from the Danish Environmental Protection Agency, and the Independent Research Fund of Denmark as well as the Federal Agencya for Nature Conservation, Germany.

The programme can be used to track objects using footage collected with **DJI drones**.

It was developed in Matlab version 2023a, using the appdesigner environment.

Currently, CetTrack can be used with different drone types:

- Mini 2
- Air2S
- Mavic 3 Classic.

We will work in the near future to incorporate Phantom 4 and Mini 3. If you have another DJI drone, please get in touch with us and we will work to incorporate them.

This manual is for **version 1.87**

Acknowledgements

We are eternally thankful to everyone who helped us during the development of CetTrack (see Collaborators). Many people have contributed by testing CetTrack at different stages providing invaluable feedback. The feedback was used to find and correct errors, improve the look of CetTrack to make it more user-friendly, add or remove functionalities, etc.

Installation

The software is compiled and includes all the necessary Matlab tools to install and use it. The executable file can be downloaded on this page:

www.porpoiselady.org

Just run the installer on your computer and follow the instructions. The installation takes a while, as it has to install the necessary Matlab tools to run properly. You will see a progress bar as it instals it.

Prepare your files

In order to start using CetTrack, two previous steps are needed:

- The flight logs generated by the drones are encrypted and so they cannot be directly read into CetTrack, so they need to be decrypted first.
- Some drone types (e.g., Mini 2) do not generate independent subtitle files (SRT), but are embedded in the videos, and so need to be extracted first.

Flight logs

The DJI drones generate one flight log per flight, storing key information at (mostly) regular intervals, usually between 100 and 200 ms. These logs are saved as encrypted *.dat* files with names look like this:

EXPORT_FILE_2022-07-15_07-19-51.dat or *DJIFlightRecord_2021-11-05_[11-55-56]*

While DJI does not provide tools to decrypt the files, there are freely available options online, although the outputs vary. For CetTrack, we use the outputs generated by Airdata UAV. To convert the *.dat* files to *.csv* files using the Airdata UAV service, you need to create a free account here: Airdata UAV - Flight Data Analysis for Drones. Once you have an account, you can upload your flight logs and download them as *.csv* files.

NOTE

- Make sure you use **metres** not feet. The settings must be changed before you upload your files.
- While the name of the flight log has the local time, the time in the flight log itself is in UTC

The output file name looks like this:

Aug-28th-2022-08-55AM-Flight-Airdata.csv

The output is a table with 52 columns, with information about the drone (e.g., gimbal, speed), the battery (e.g., battery left), and the environment (e.g., height, coordinates). Only some of that information is used in CetTrack. See Table 1 for examples of column names and how they are used.

Table 1. Examples of columns in the flight logs generated by Airdata UAV

Column name	Description
time(millisecond)	As a cumulative number, starting at 0. This column is used to match the flight log and the video to the closest possible frame.
datetime(utc)	As text and in UTC, for example: 11/07/2022 11.21.11
latitude	In decimal degrees - input to estimate the real location of the object in the video footage.
longitude	In decimal degrees - input to estimate the real location of the object in the video footage.
height_above_takeoff(meters)	For the drone, the take-off height is always 0. The height above take off is the measured height, above take off.
zSpeed(m/s)	Height speed in metres per second
compass_heading(degrees)	Direction (e.g., North) the drone is pointing to, in degrees
isVideo	If a video is recorded, this column shows a 1 in all relevant rows, otherwise it shows a 0.
gimbal_heading(degrees)	Direction (e.g., North) the camera is pointing to, in degrees
gimbal_pitch(degrees)	Direction (in the vertical direction) the camera is pointing to, in degrees. 90 degrees is all the way downwards, 0 is towards the horizon

Videos subtitles (SRT files)

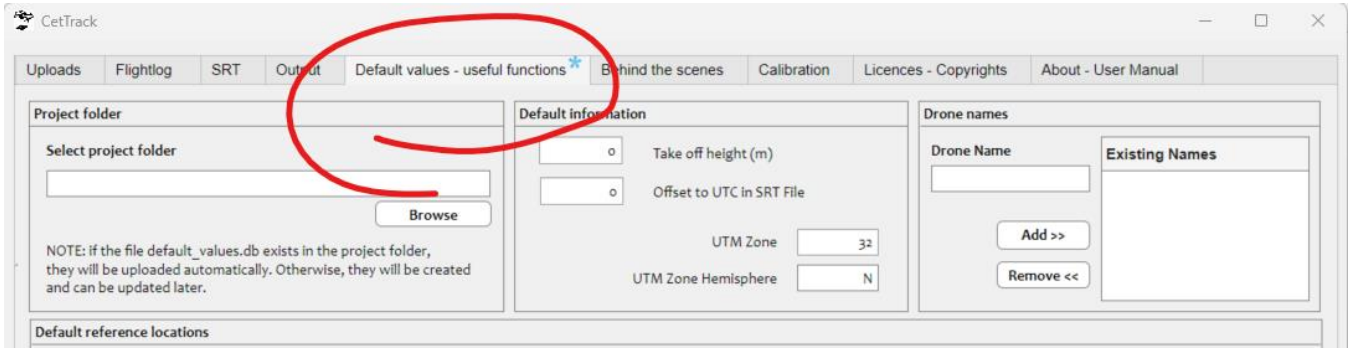
All DJI drone models have the option to generate subtitles (or captions). These can be embedded in the video file (e.g., Mini 2 and Phantom 4), or also saved separately as *.srt* files (e.g., Air2S and Mini 3), in which case they are generated for each video and have the same name. The subtitles consist of information logged at (mostly) regular intervals, including latitude and longitude as well as information about the camera settings, height, etc. (see image below).

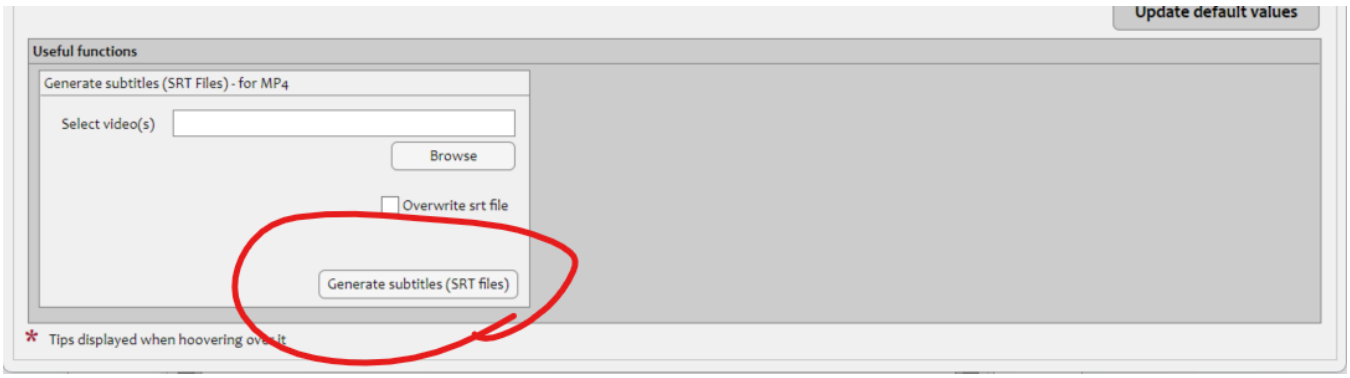
```
1
00:00:00,000 --> 00:00:00,016
<font size="28">FrameCnt: 1, DiffTime: 16ms
2023-07-28 09:55:11.550
[iso: 370] [shutter: 1/100.0] [fnum: 2.8] [ev: 0] [ct: 6417] [color_md : default] [focal_len: 24.00] [latitude: 55.45208] [longitude:
10.67257] [rel_alt: 17.700 abs_alt: 94.800] </font>

2
00:00:00,016 --> 00:00:00,032
<font size="28">FrameCnt: 2, DiffTime: 16ms
2023-07-28 09:55:11.565
[iso: 370] [shutter: 1/100.0] [fnum: 2.8] [ev: 0] [ct: 6418] [color_md : default] [focal_len: 24.00] [latitude: 55.45208] [longitude:
10.67257] [rel_alt: 17.700 abs_alt: 94.800] </font>
```

Not all subtitles consist of the same information and the format may also vary.

If your drone does not save the SRT files separately, you will have to generate them, as CetTrack uses them to match the video frames with the corresponding line in the flight log. The SRT files should have the same name as the video and have to be in the same folder.

There is a function in CetTrack specifically for this in the tab "Default values - Useful functions" (see image below). Just select your video and generate the subtitles.





NOTE

- The SRT files will not contain the date and time (as in the figure above) but the format will be similar.
- These SRT files can **only** be generated if the subtitles are embedded in the videos.

Structure and functionalities of CetTrack

Main screen - Uploads

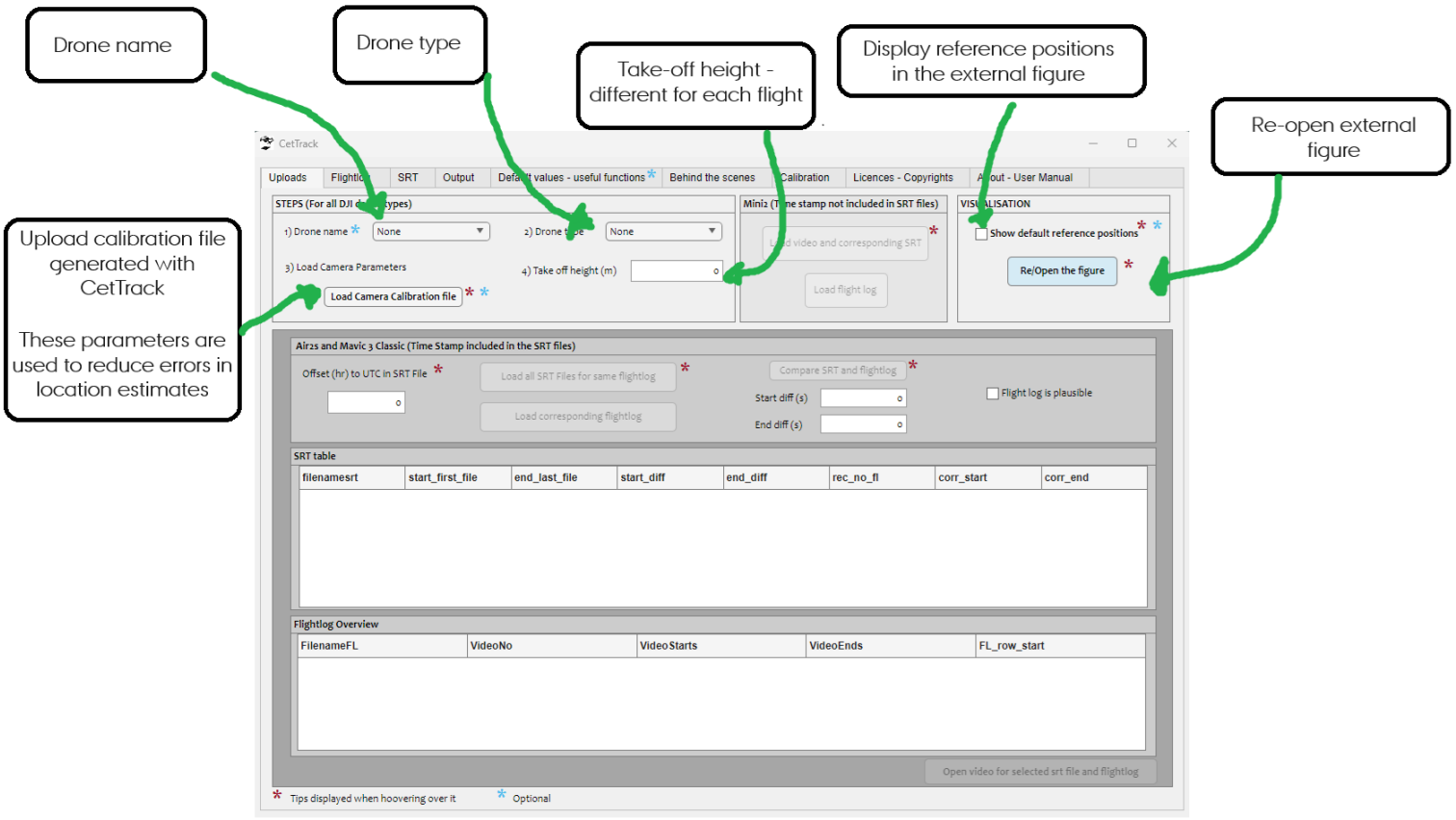


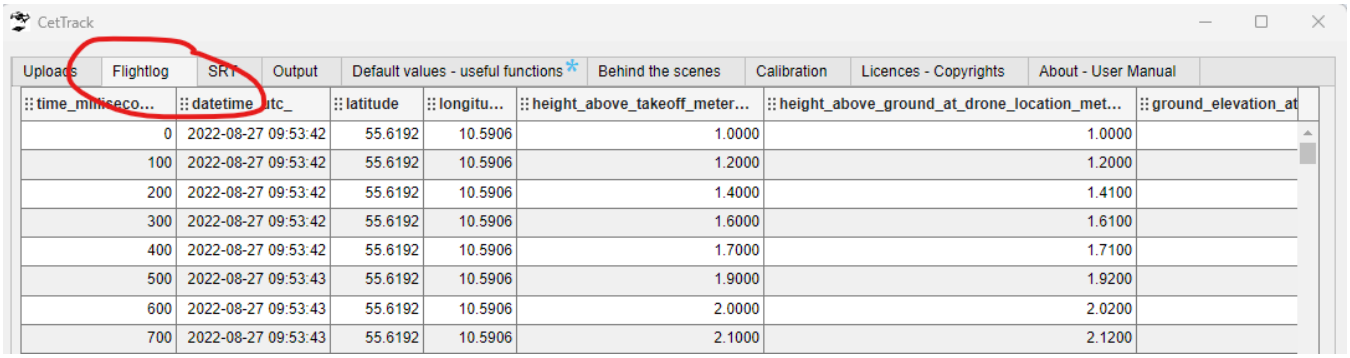
Figure 1: *Main display of CetTrack.*

Here, you can upload your videos, the corresponding SRT files, and the flight log. Once these files are uploaded and processed, an external figure will open, from where you can track your animals (See External figure - Tracking screen).

Also, if you close the external figure by mistake, you can reopen it from here. Lastly, you can decide whether to display reference positions or not.

Flightlog

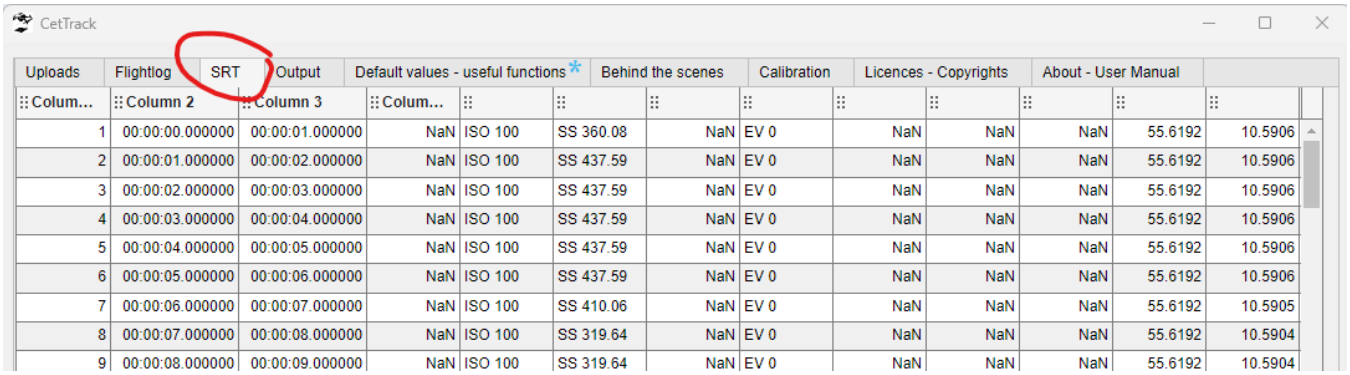
When the flight log is loaded, it is displayed here.



time_millisecо...	datetime_utc_	latitude	longitu...	height_above_takeoff_meter...	height_above_ground_at_drone_location_met...	ground_elevation_at
0	2022-08-27 09:53:42	55.6192	10.5906	1.0000	1.0000	
100	2022-08-27 09:53:42	55.6192	10.5906	1.2000	1.2000	
200	2022-08-27 09:53:42	55.6192	10.5906	1.4000	1.4100	
300	2022-08-27 09:53:42	55.6192	10.5906	1.6000	1.6100	
400	2022-08-27 09:53:42	55.6192	10.5906	1.7000	1.7100	
500	2022-08-27 09:53:43	55.6192	10.5906	1.9000	1.9200	
600	2022-08-27 09:53:43	55.6192	10.5906	2.0000	2.0200	
700	2022-08-27 09:53:43	55.6192	10.5906	2.1000	2.1200	

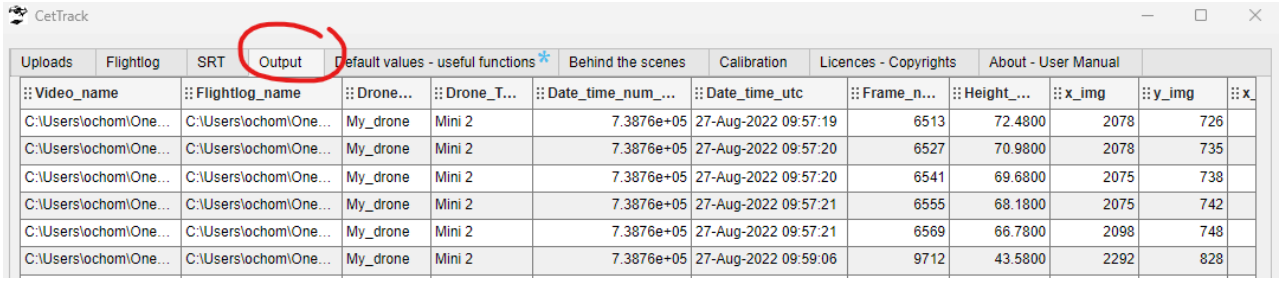
SRT

When the subtitles file (.srt) is loaded, it is displayed here.



Colum...	Column 2	Column 3	Colum...									
1	00:00:00.000000	00:00:01.000000	NaN	ISO 100	SS 360.08	NaN	EV 0	NaN	NaN	NaN	55.6192	10.5906
2	00:00:01.000000	00:00:02.000000	NaN	ISO 100	SS 437.59	NaN	EV 0	NaN	NaN	NaN	55.6192	10.5906
3	00:00:02.000000	00:00:03.000000	NaN	ISO 100	SS 437.59	NaN	EV 0	NaN	NaN	NaN	55.6192	10.5906
4	00:00:03.000000	00:00:04.000000	NaN	ISO 100	SS 437.59	NaN	EV 0	NaN	NaN	NaN	55.6192	10.5906
5	00:00:04.000000	00:00:05.000000	NaN	ISO 100	SS 437.59	NaN	EV 0	NaN	NaN	NaN	55.6192	10.5906
6	00:00:05.000000	00:00:06.000000	NaN	ISO 100	SS 437.59	NaN	EV 0	NaN	NaN	NaN	55.6192	10.5906
7	00:00:06.000000	00:00:07.000000	NaN	ISO 100	SS 410.06	NaN	EV 0	NaN	NaN	NaN	55.6192	10.5905
8	00:00:07.000000	00:00:08.000000	NaN	ISO 100	SS 319.64	NaN	EV 0	NaN	NaN	NaN	55.6192	10.5904
9	00:00:08.000000	00:00:09.000000	NaN	ISO 100	SS 319.64	NaN	EV 0	NaN	NaN	NaN	55.6192	10.5904

Output



Video_name	Flightlog_name	Drone...	Drone_T...	Date_time_num_...	Date_time_utc	Frame_n...	Height_...	x_img	y_img	x_
C:\Users\ochom\One...	C:\Users\ochom\One...	My_drone	Mini 2	7.3876e+05	27-Aug-2022 09:57:19	6513	72.4800	2078	726	
C:\Users\ochom\One...	C:\Users\ochom\One...	My_drone	Mini 2	7.3876e+05	27-Aug-2022 09:57:20	6527	70.9800	2078	735	
C:\Users\ochom\One...	C:\Users\ochom\One...	My_drone	Mini 2	7.3876e+05	27-Aug-2022 09:57:20	6541	69.6800	2075	738	
C:\Users\ochom\One...	C:\Users\ochom\One...	My_drone	Mini 2	7.3876e+05	27-Aug-2022 09:57:21	6555	68.1800	2075	742	
C:\Users\ochom\One...	C:\Users\ochom\One...	My_drone	Mini 2	7.3876e+05	27-Aug-2022 09:57:21	6569	66.7800	2098	748	
C:\Users\ochom\One...	C:\Users\ochom\One...	My_drone	Mini 2	7.3876e+05	27-Aug-2022 09:59:06	9712	43.5800	2292	828	

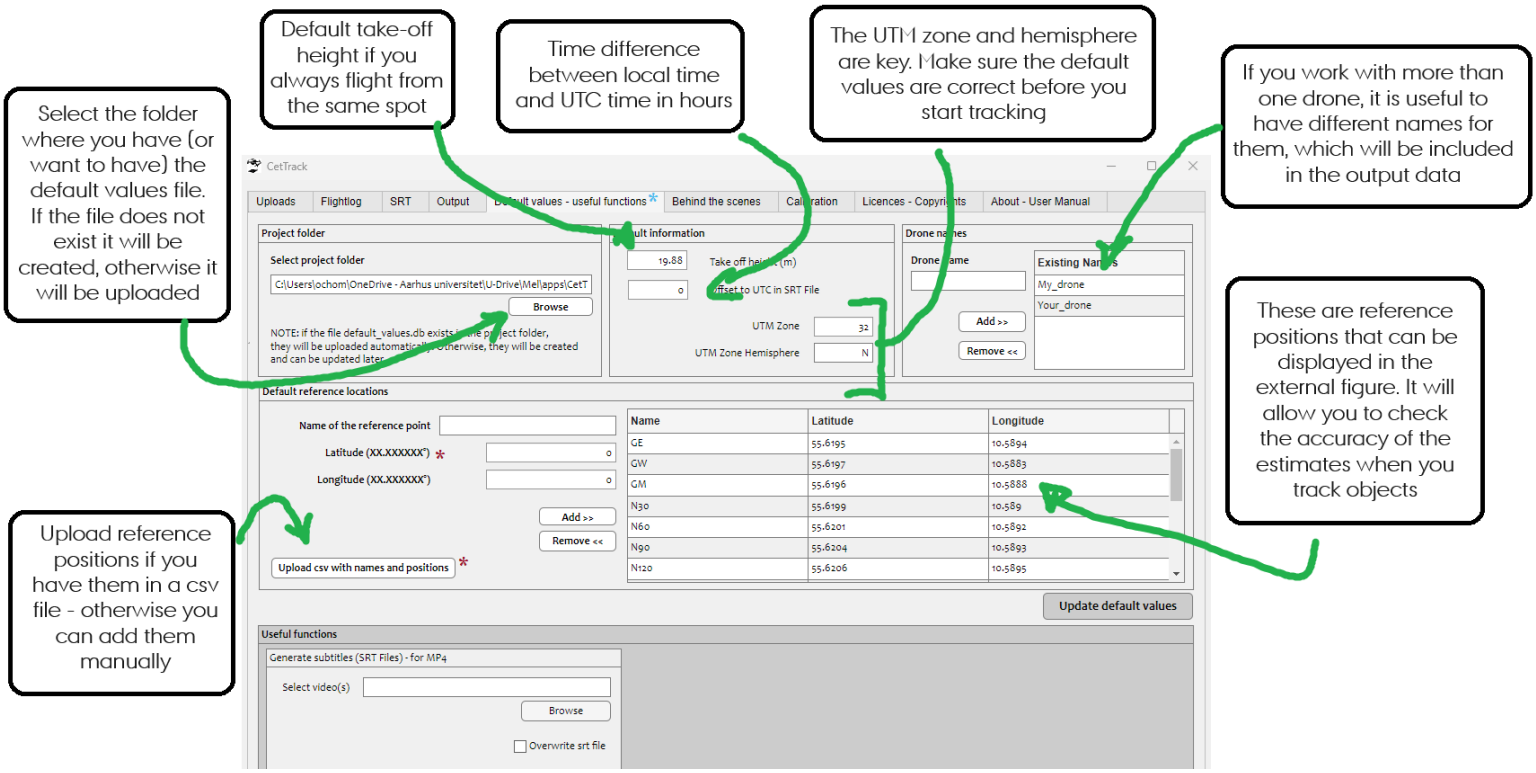
This tab contains a table where the track data as it is stored as it is generated.

The output include: video name, flight log name, drone name, drone type, date and time (UTC) in numeric and string format, frame number, corrected height of the drone, x and y selected in the image, coordinates of the drone and the object in decimal degrees as well as in UTM coordinates, drone and

gimbal heading in degrees, gimbal pitch, ID of the object (assigned automatically), and other information such as age class and behaviours.

Default values - Useful functions

When you open CetTrack, certain values will be defined by default and so before you start using the programme you need to make sure the values are correct for your purposes.



The current default values are:

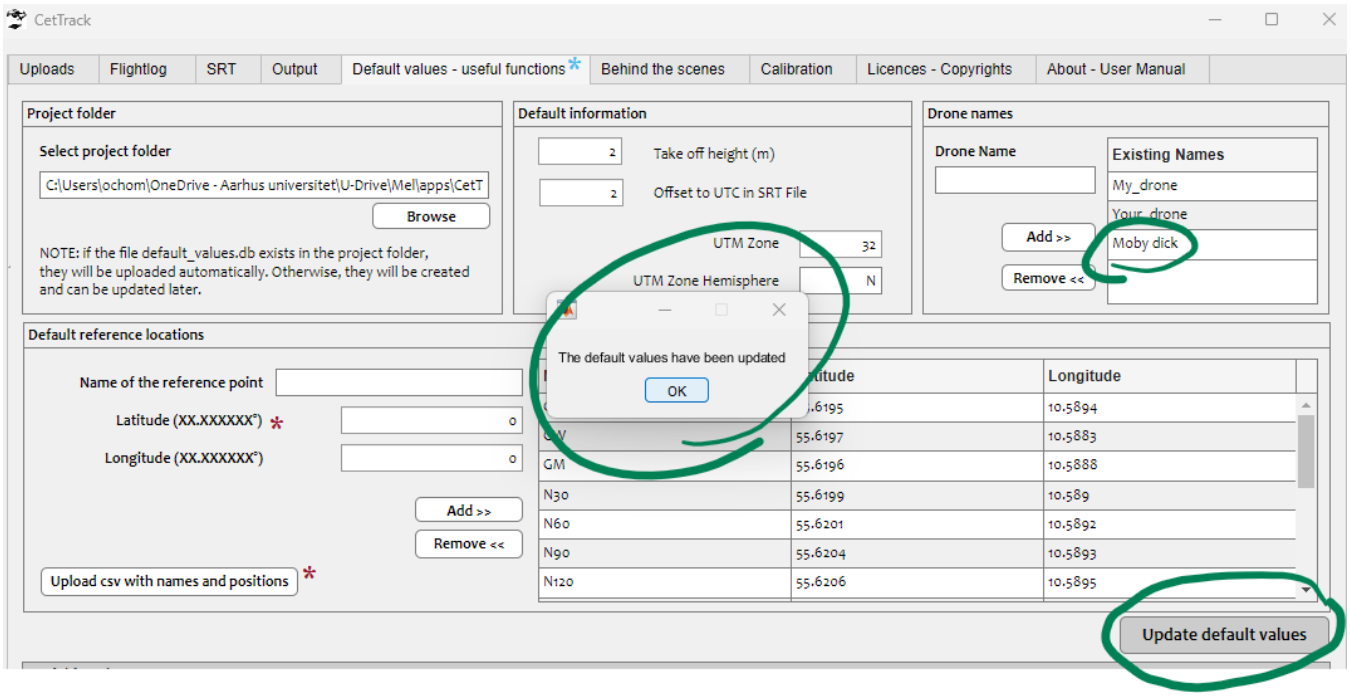
- Take off height (m): 0
- Offset to UTC in the SRT files: 0
- UTM zone: 32
- UTM hemisphere: “N” (north)
- Drone names: “None”
- No Reference points

CetTrack would work even if other default values are not defined (e.g., drone names, reference positions).

To create your own default values that can be reused in the future. The file is an SQLite database (.db) with 3 tables: drone_names, other_values, and reference_positions. If you have a project where there are default values (e.g., take-off height, reference positions, etc, we recommend that you create this database.

Steps to create a default values file:

1) Select a folder where you want the default values file to be saved for future use (default_values.db).
2) Update the default values with the values you want, for example adding a new drone name, then press "Update default values". You'll see a message that the default values have been updated.

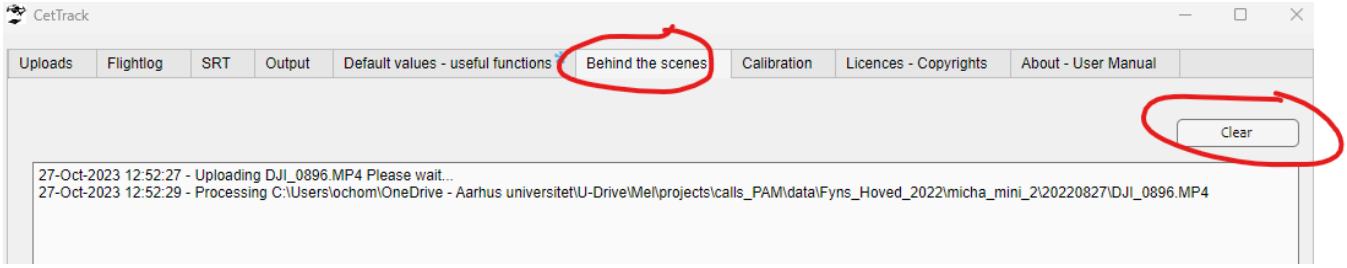


Uploading default values file:

Simply select the project folder where the default value file is saved and it will be uploaded automatically.

Behind the scenes

You will see information about what is happening in the background (e.g., when the video is being processed). This is complemented with pop up messages.

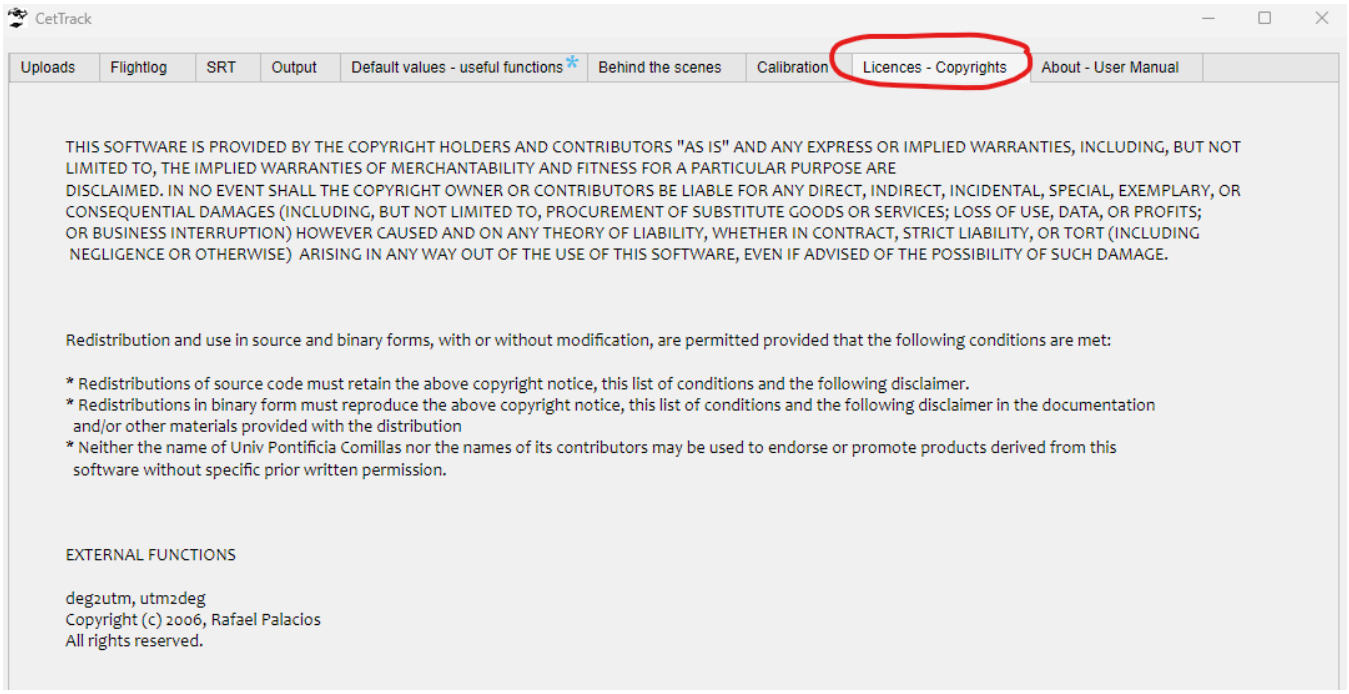


You can clear the displayed information by clicking on "Clear"

Calibration

Here, you can calibrate your drone to reduce errors in estimates. See Camera calibration - steps.

Licences - Copyrights



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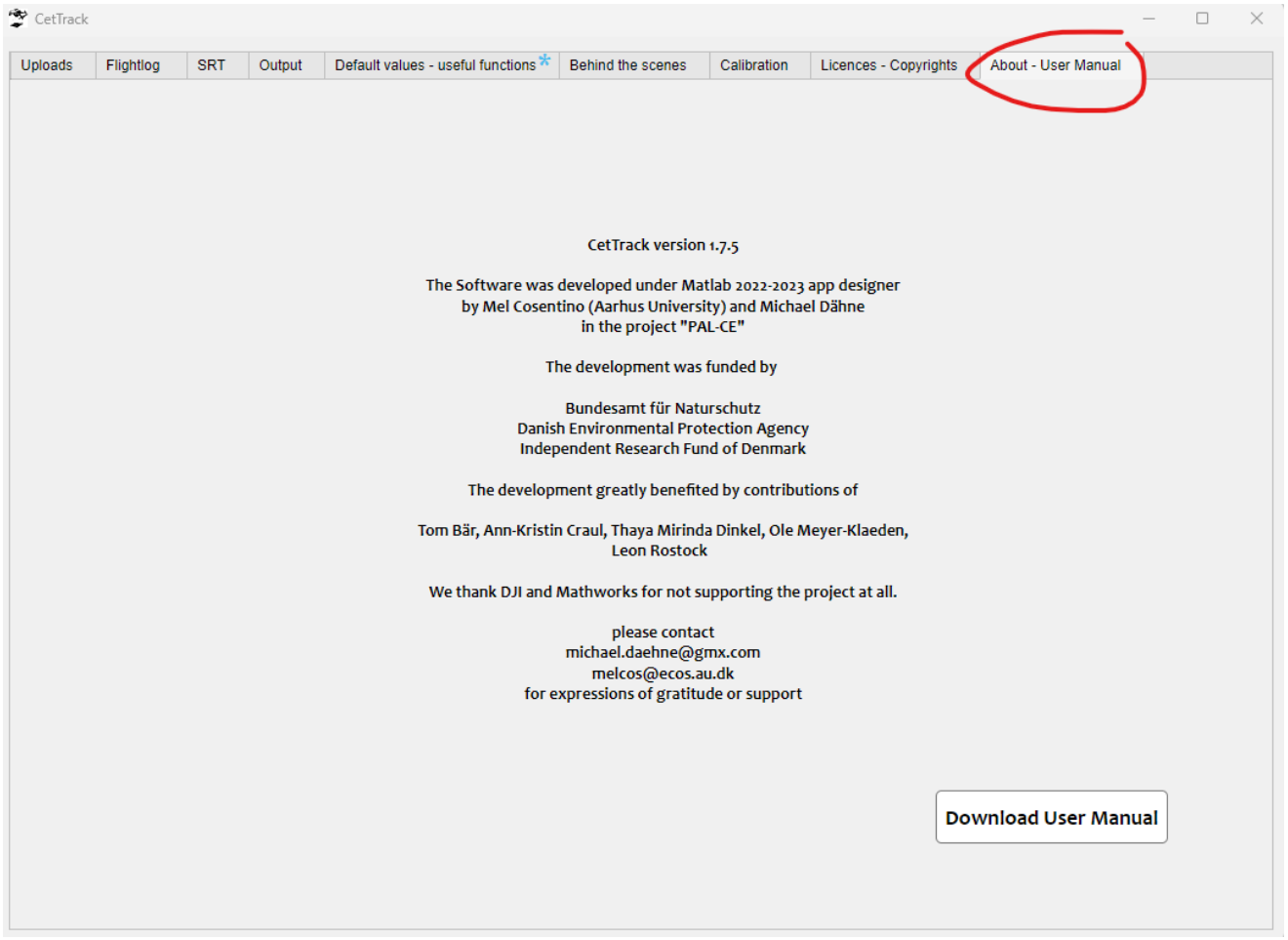


External figure - Tracking screen

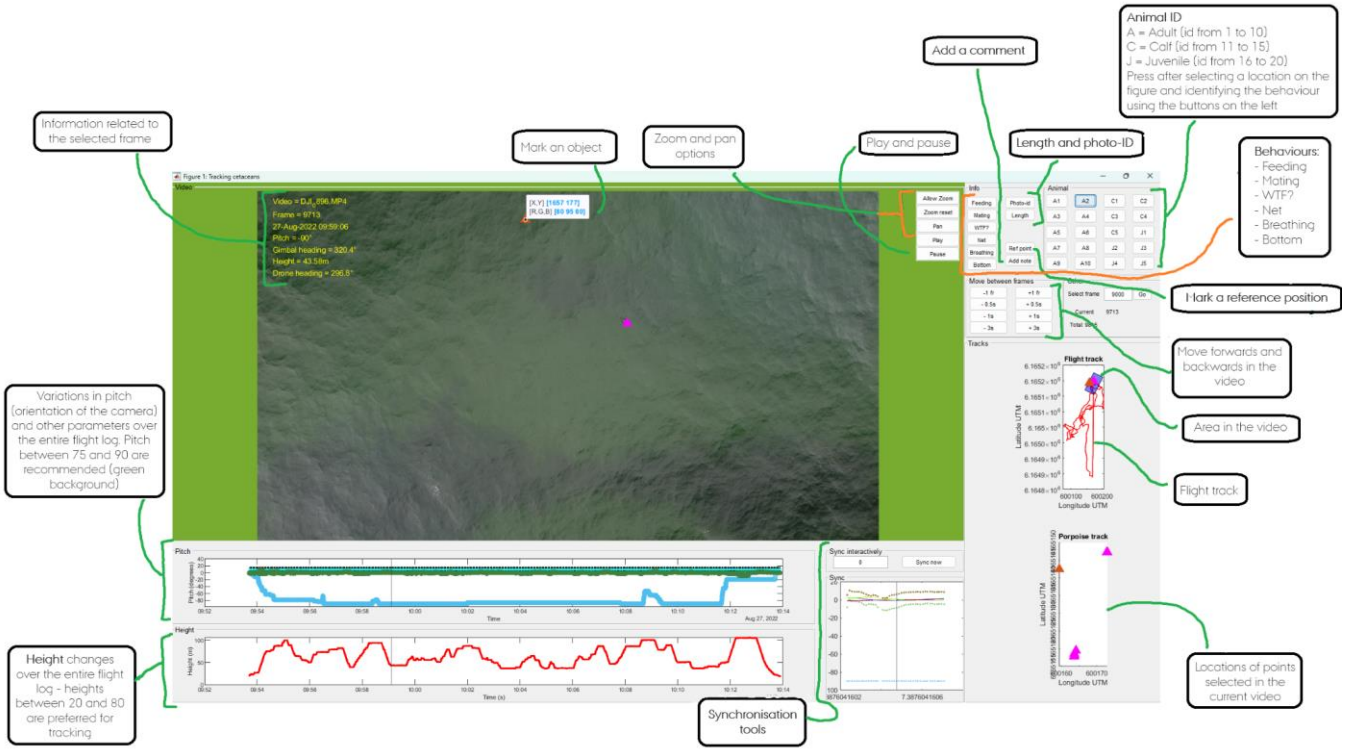
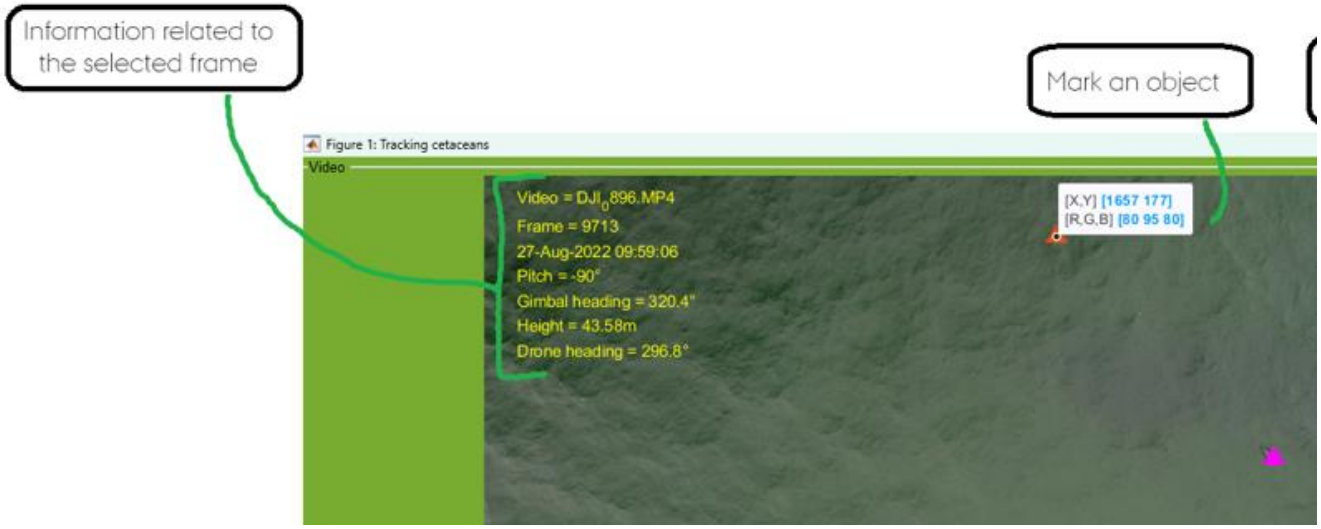


Figure 2: *Display of the Porpoise tracking figure.*

There are four panels in the pop up figure.

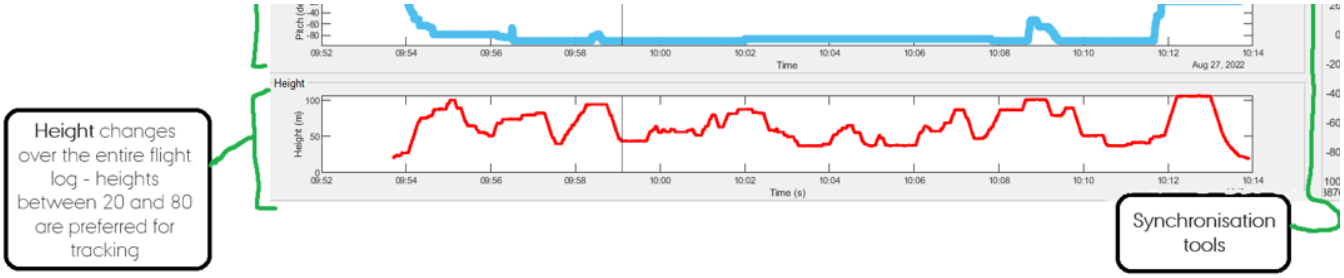
- Video:

Displays the video, with additional information including video name, date and time, and frame number.



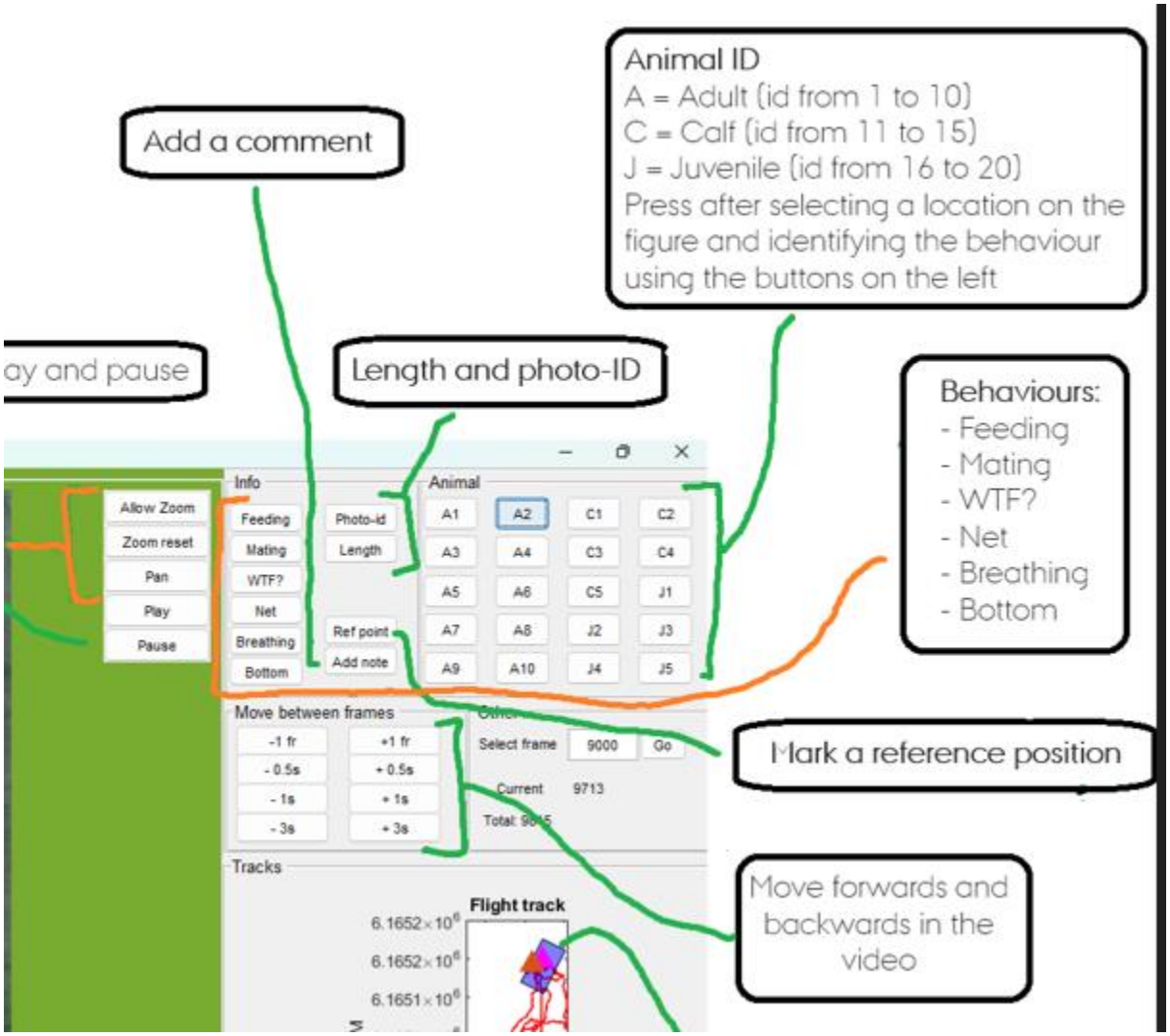
- Height

The corrected height (take-off plus height from take-off, in metres) is plotted over time for the entire flight log the video belongs to. When there is no log data the line is blue, otherwise it is red.



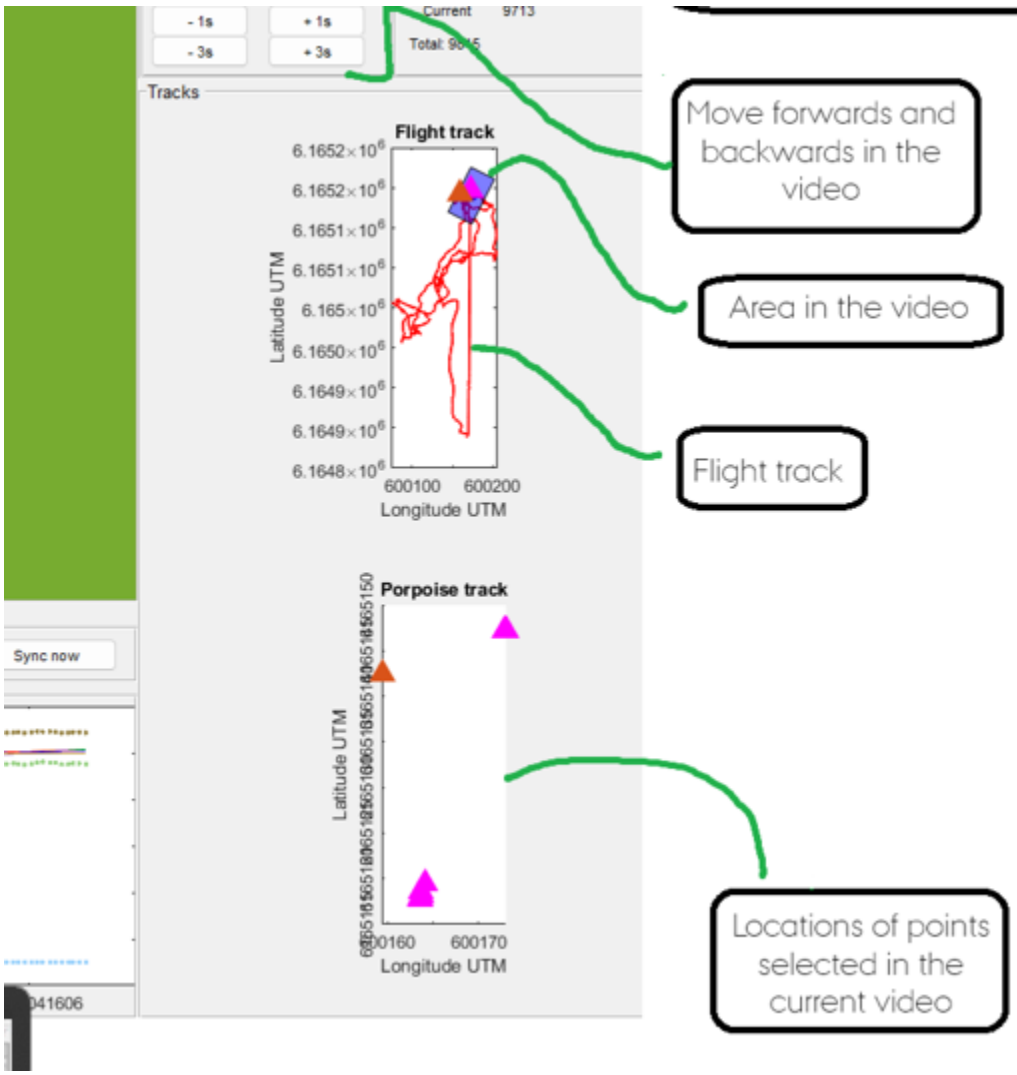
- Information – animal ID and more

This is the panel you will be using to track the animals. See Tracking - basics for details.



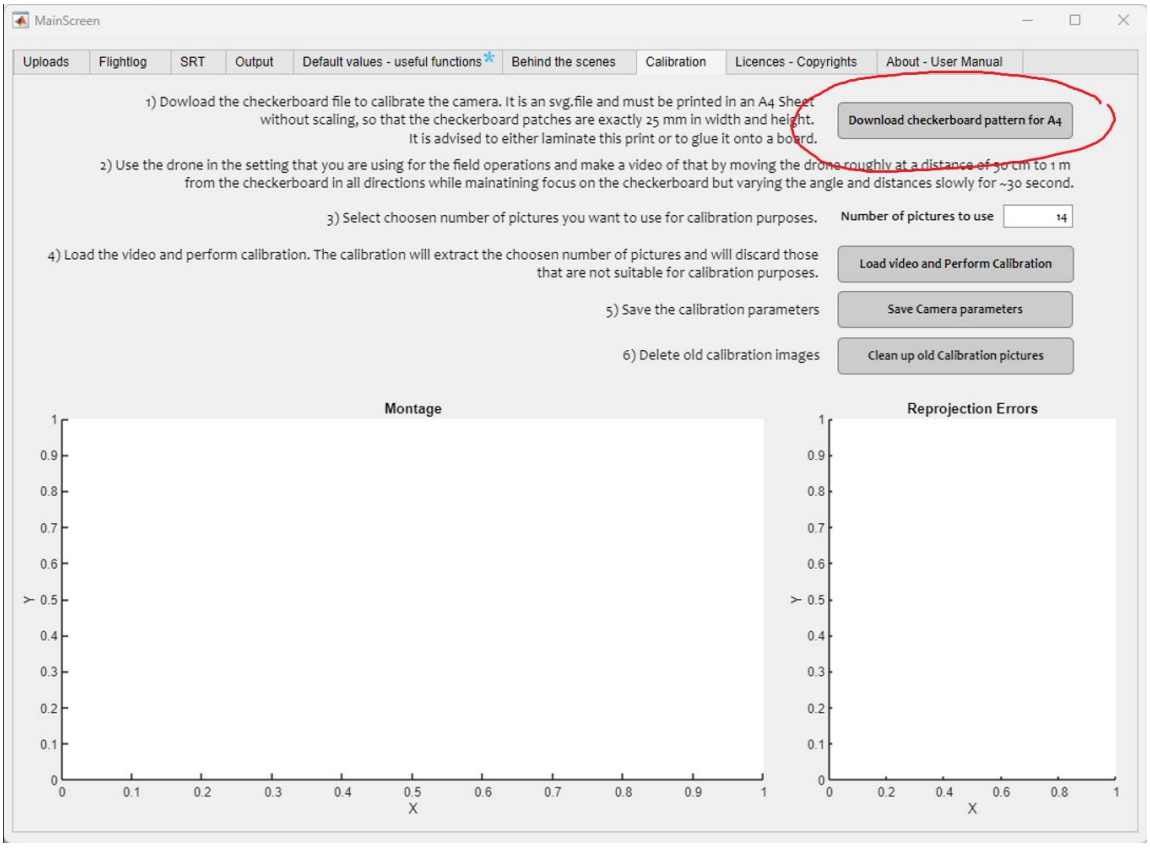
- Tracks

There are 2 axes: the bottom one shows the position of the animals that are being tracked. They will appear in different shapes (according to age class) and colours (according to ID number) and the top one shows the track of the drone and the area the camera is covering at any given time. The reference points can be plotted in these axes (black dots).

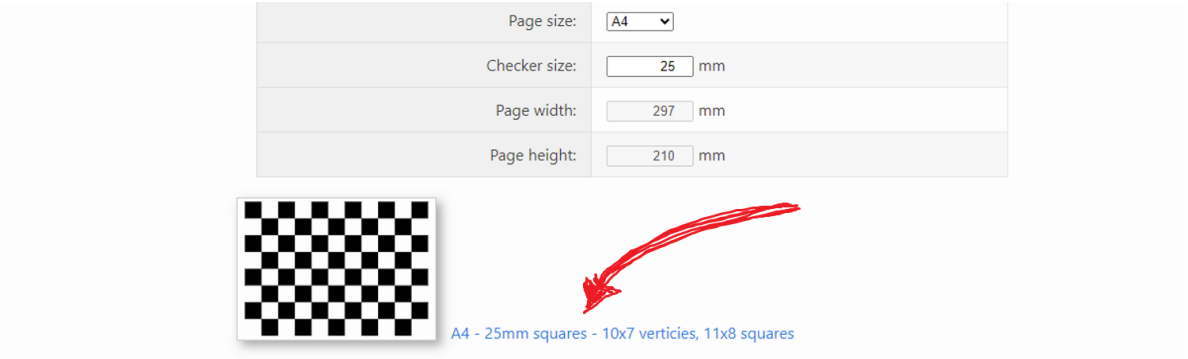

- 1s
+ 1s
- 3s
+ 3s
Current 9713
Total: 9845
Tracks
Flight track
Latitude UTM
Longitude UTM
600100
600200
Porpoise track
Latitude UTM
Longitude UTM
600160
600170
Sync now
Move forwards and backwards in the video
Area in the video
Flight track
Locations of points selected in the current video

Camera calibration - steps

1) Download the checkerboard

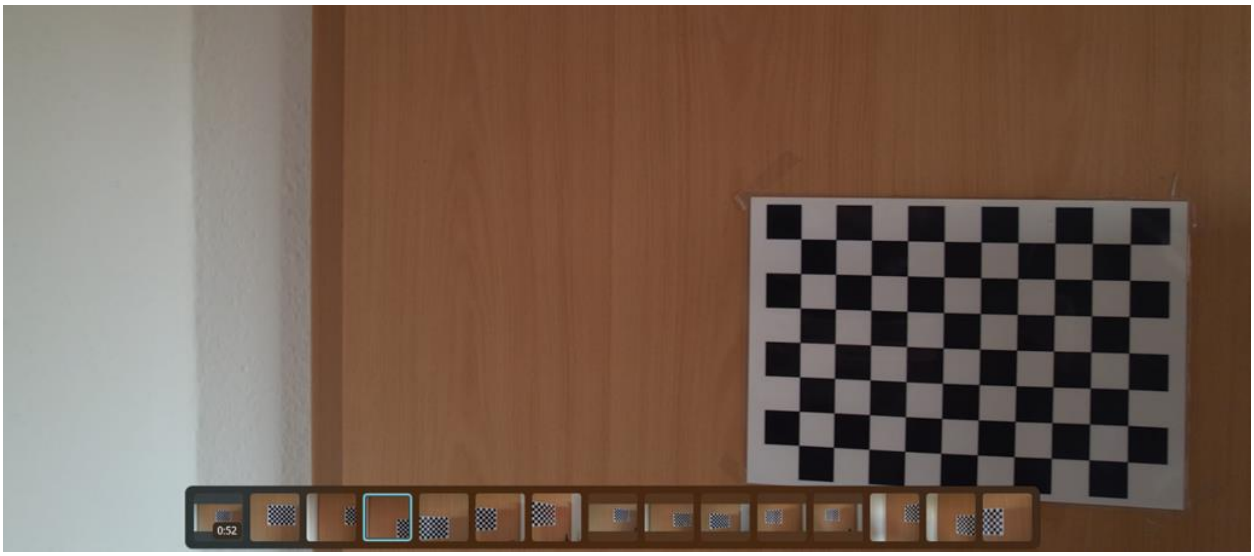


When pressing the button, you will be sent here: [Calibration Checkerboard Collection | Mark Hedley Jones](). Select the A4 checkerboard with 11 by 8 25-mm squares as shown in the image below:

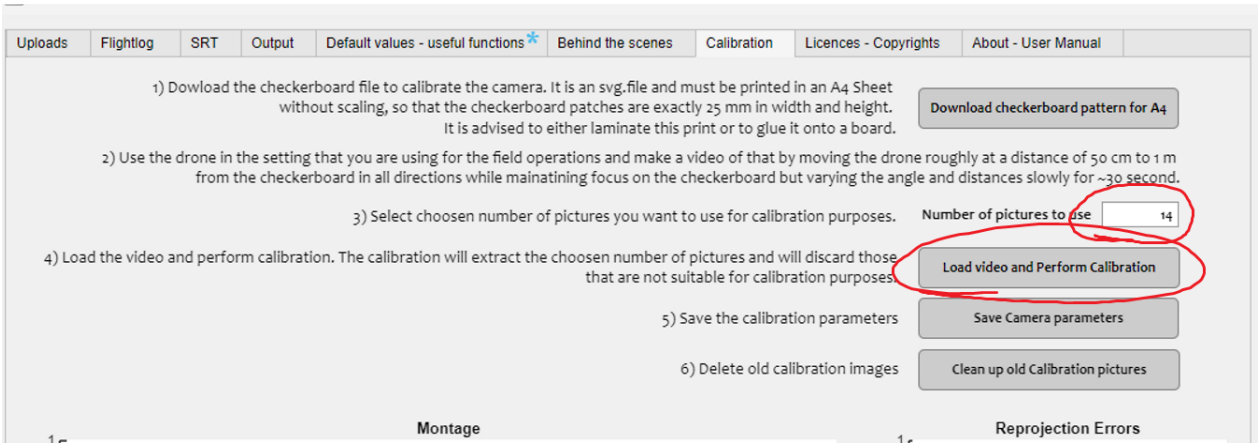


2) Print it on an A4 sheet, without figure margins, and unscaled(!!). Check with a ruler or measuring tape that each square is actually 25 mm in height and width before moving to the next steps.

3) Tape the board to a flat surface such as a closet door or a desk (preferred option) or laminate it (makes it difficult with reflections)
4) Make the drone ready and put it into the same mode (video image size and frame rate) that you used in the field
5) **With rotators off** - Hold the drone between 0.5 and 1.5 m from the checkerboard pointing towards it, start the recording and move the drone in such a fashion that it gets recordings from different angles as well as having the checkerboard in different parts of the screen (see images below). Do it slowly and stop in between otherwise the images will be blurry and cannot be used for calibration. The duration of the video should be between 30 and 90 seconds.



6) In CetTrack, go back to the tab named "Camera Calibration", indicate the number of images you would like to use for the calibration process (between 8 and 20 is preferred), and upload the video you just created.

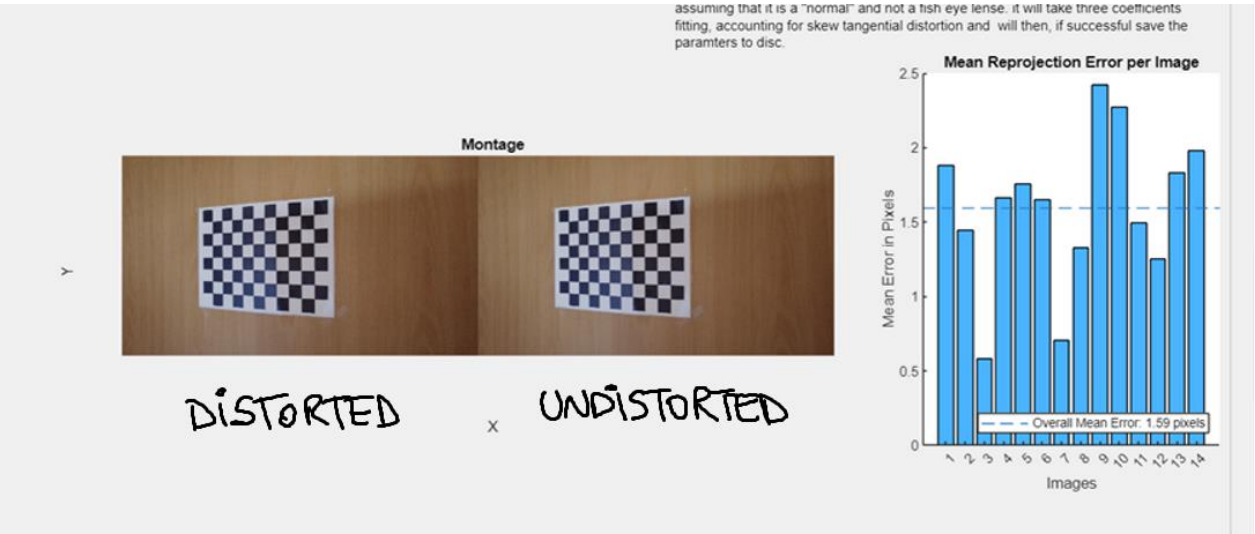


CetTrack will extract still images from the video (as much as you indicated) and perform the calibration. It takes 5-15 minutes - you will see a progress bar and will see a pop-up message when the calibration is ready.

The calibration consists of detecting the checkerboard in the pictures and place points onto the image where the checkerboard patches meet. It then calculates the camera parameters considering cushion-like distortion, and potentially misaligned axis of the camera and sensor.

When the calibration is ready, an image will open, where you can see the undistorted image. If you put a ruler onto your screen all lines that are straight in reality should now be straight on the picture as well. The image on the left (picture below) is the raw, distorted image, while the one on the right is the corrected, undistorted one. Errors for each extracted image are provided on the

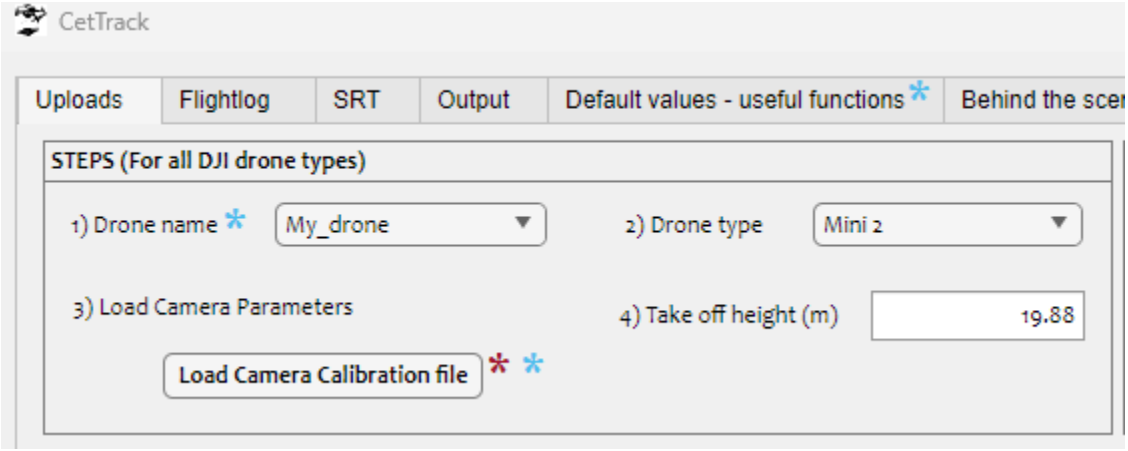
graph on the right side of the image below. The errors are usually very small, ranging below 2 pixels.



7) Now you can save the parameters and use them in the future.
8) If you would like to perform a new calibration, clean up the images first.

Tracking - best practices

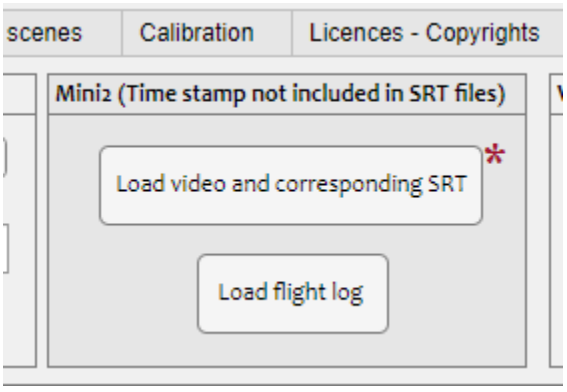
Steps for all drones



1) Drone name (optional): the default name is "None"
2) Drone type: There are currently three types of drones available: Mini 2, Mavic 3 Classic, and Air2S. When you select the drone type, the relevant buttons will be enabled.
3) Calibration file (optional): if you have, upload the calibration file generated by CetTrack.
4) Take-off height: The take-off height is the height to the object that will be tracked. In the case of small cetaceans, take-off height is the height difference to sea-level. If take-off does not take place from the same height (e.g., a cliff), it should be measured every flight. The wrong height leads to errors in estimates, especially when the drone is close to the object (below 20 m).

Mini 2 drones

Video and SRT files

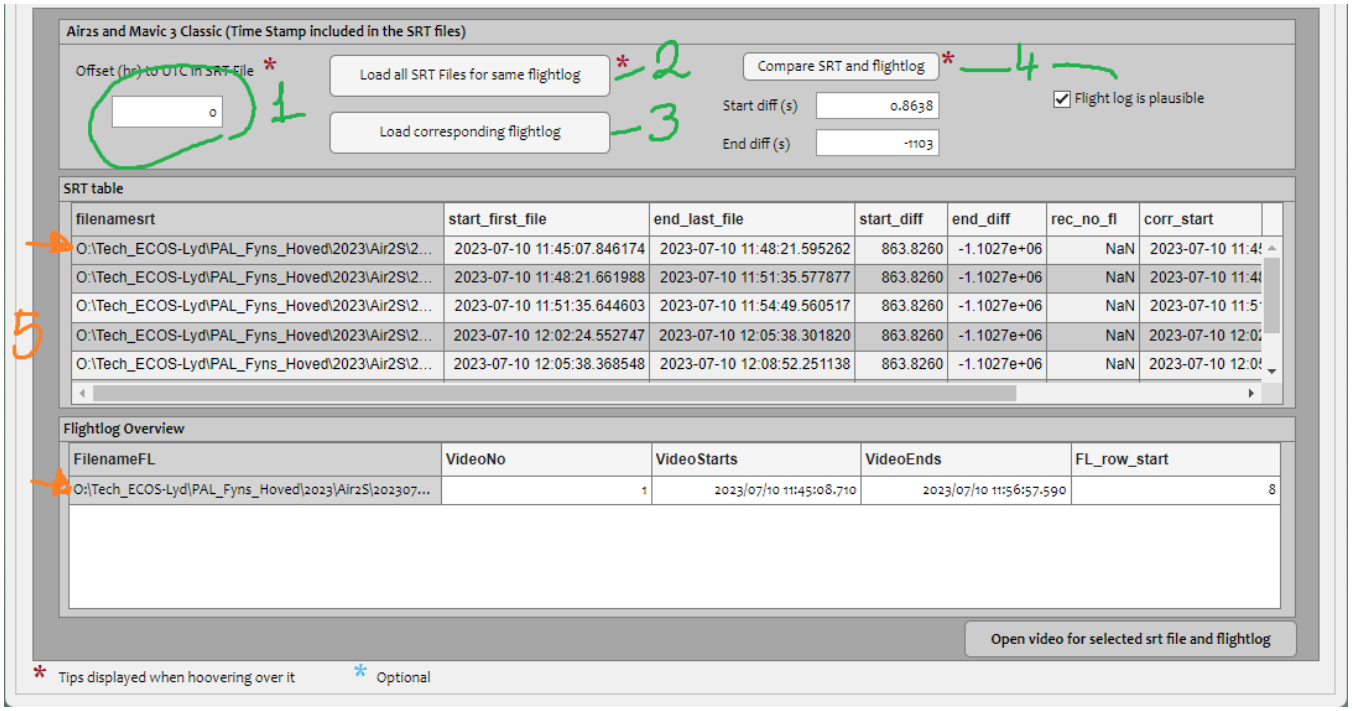


Make sure the SRT files are located in the same folder as the video files, and that they have the same name as the video it corresponds to.

Air2s and Mavic 3 Classic Drones

SRT files

1) Offset to UTC in SRT file – sometimes the SRT files are saved as local time, **not UTC**, so this may need to be corrected (an alert will appear if this is incorrect once the files have been uploaded). If SRT files are already in UTC, this can be left as 0, otherwise correct to UTC (-2hrs for instance = type in '2').



2) Select all the SRT files corresponding to the flight log of the video you would like to track. Make sure the SRT files are located in the same folder as the video files, and that they have the same name as the video it corresponds to.Because there is a time difference between the time in the SRT files and the flight log, it is necessary to upload all SRT files from the same flight log to identify the corresponding rows for accurately syncing the video and the flight log.
3) Load the corresponding flight log.
4) Generate comparison – there should also be a mark next to 'plausible'.
5) Select the first SRT file and the flight log, then click Open the figure for this SRTfile and flight log (may take a while to load).

Synchronising Data

Here you are matching the video footage with the recorded data to ensure that drone movements are completely synchronised.

1. Using the blue line in the top main graph, and the dotted blue line in the sync box (this is a 'zoomed in' view of the main graph) to identify an approximate point with a distinct change in camera pitch (like a tilt from 0 to 90 degrees).

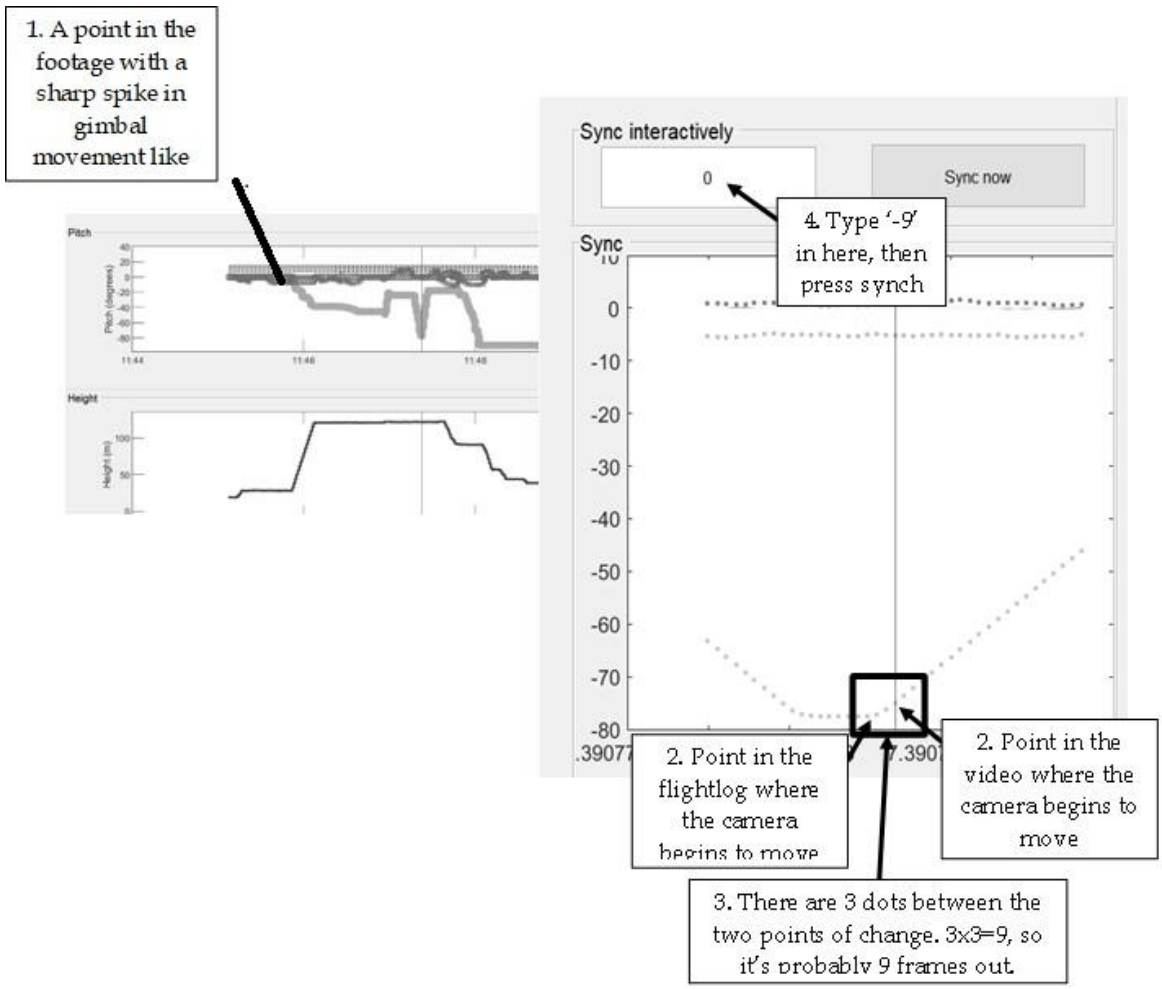
2. Watching the footage, identify where **in the footage** this distinct point occurs **(the frame where it changes)**. This may be before or after the change in pitch.

3. Using the synch interactively box to work out how out of synch the flight log is. Count the number of blue dots between the black vertical line (ie showing you where you are in the footage) and the point of change in pitch, then **multiply by** 3 as each dot represents 3 frames.

4. Type this number into the synch interactively box, then click synch now. Note that if the video footage is behind the flight log (i.e. the black line is to the right of the point of change on the blue line), then this number must be preceded by -.

5. You can double check that the footage is now in sync by repeating the process. It's also handy to record the sync number in the protocol spreadsheet now, to save time if something goes wrong!

Example


1. A point in the footage with a sharp spike in gimbal movement like
Pitch
Height
Sync interactively
0
Sync now
Sync
4. Type '-9' in here, then press synch
2. Point in the flightlog where the camera begins to move
2. Point in the video where the camera begins to move
3. There are 3 dots between the two points of change. 3x3=9, so it's probably 9 frames out.

Tracking - Basics

The external figure will open in the first frame when there is a good match between the information obtained from the SRT files and the flight log.

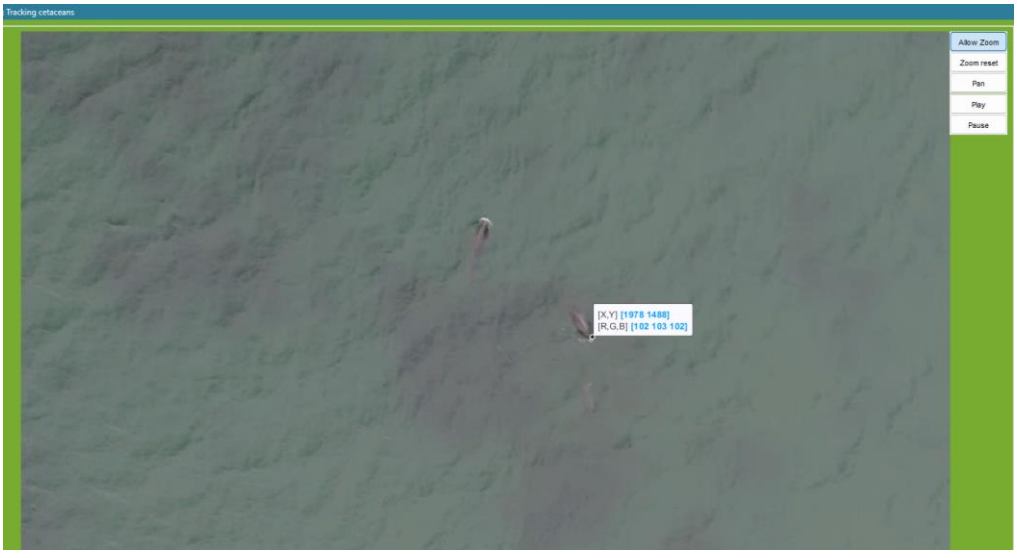
Marking and giving ID

1) Use the frames buttons to move through frames until you find your animal(s).
2) Make sure the background colour of the image is green when you track an animal. When the background is red it means the pitch (angle of the camera) is too small and the estimates will be wrong. The error will be smaller with orange but it is still not recommended.
3) Click on the animal(s) on the image, then select the relevant animal id (i.e. for 1st ind. select A1, for 2nd ind. select A2 etc).

   Use the same part of the body when marking an animal. We recommend using the beak (tip of the head) whenever possible, otherwise the middle (e.g., the dorsal fin). Each animal must keep the same ID number throughout the tracking period (and ideally throughout the entire flight log to avoid confusion further down the line).

   A message will appear showing X and Y values (pixels in the image) and RGB values (colour).

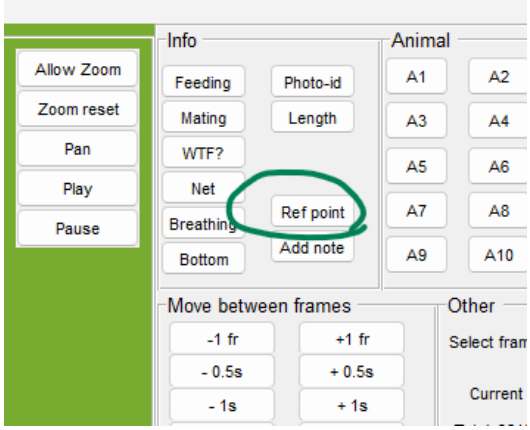
   Depending on the species you are working with and what your goals are, you can move frame by frame, or in periods of 0.5, 1 or 3 seconds.



NOTE

ID buttons with an A represent adults (will appear as ID numbers from 1-10 in the output table), with a C represent calves (IDs 11-15), and with J represent juveniles (IDs 16-20).

4) To note the location of any reference points by clicking on the image, then selecting "Ref point".



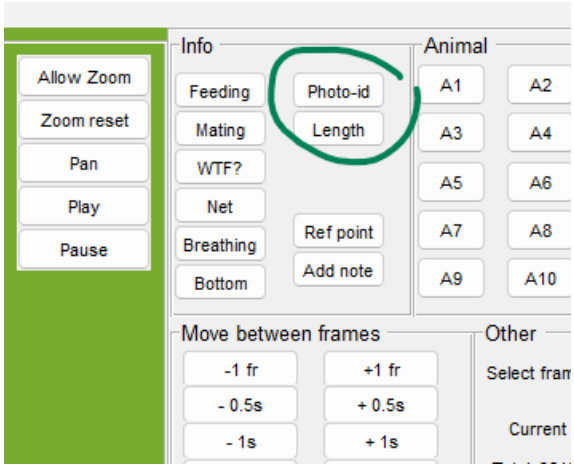
5) Move onto the next frame you wish to analyse (depending on the behaviour of the animal behaviour, you may skip more or less frames) and then repeat the process.
6) When you reach the end of the video, you must save this data before moving on to the next one.

Adding additional information

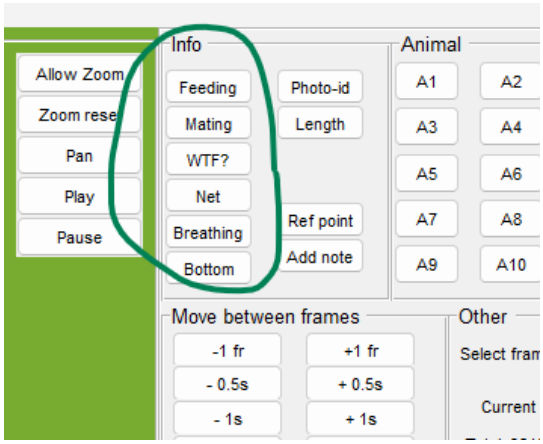
Additional information needs to be clicked **before** indicating the ID of the individual being tracked.

Photo-ID: Select to indicate whether the image could be used for photo-ID purposes. If pressed, a 1 will appear in the corresponding column of the output data. The default is 0.

Length: Select to indicate you have clicked on the animal for measuring the length (tip of the head and notch on the fluke). If pressed, a 1 will appear in the corresponding column of the output data. The default is 0.

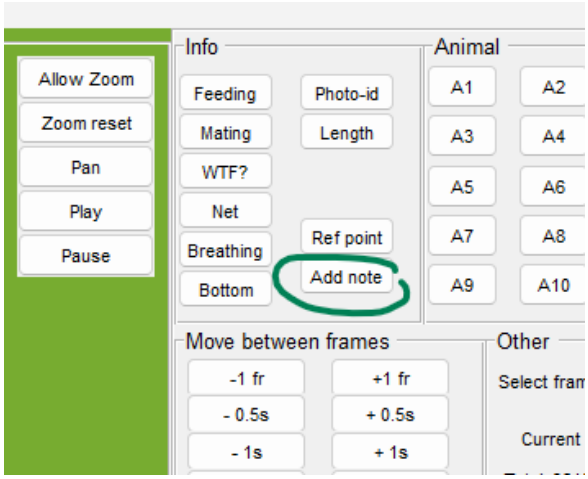


Behaviours: There are several behaviours available to select: Feeding, Mating, WTF?, Net, Breathing, and Bottom.



Click on the one that corresponds. If pressed, a 1 will appear in the corresponding column of the output data. The default is 0.

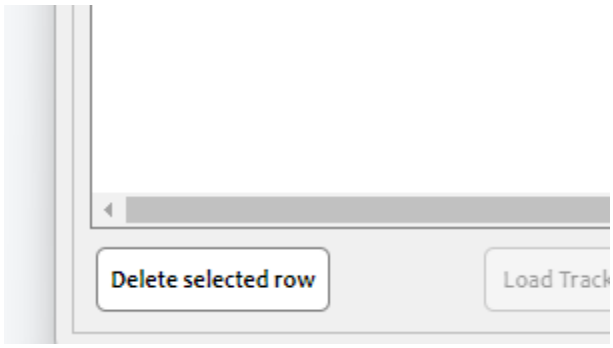
Notes: To add any comments or general remarks, you can use the notes button. **Note:** this must be selected **before** selecting a point in the image. Remember to also press save after typing your notes into the box that appears.



Skipping to specific frames

If you know your animal will not appear until later in the video, you can calculate which frame they approximately appear in and use the Actions box on the MainScreen to select this (type into the frame box, then click reopen the figure). The total number of frames in this particular video is also shown. Remember that the number of frames per second depends on the drone you used to record the footage. Normally it is either 29.97 or 59.94 frames per second.

Mistakes



Sometimes you will mistakenly select the wrong ID or add incorrect information for an individual, or other tracking issues that would require you to delete rows from the output data. In the Output tab, there is an option to do this. Just select the row to delete and click "Delete selected row". You will see it disappear from the table.

More animals than buttons

You can track up to 20 animals at the same time, by indicating the ID of the animal using the buttons in this panel. Two main issues can arise from this

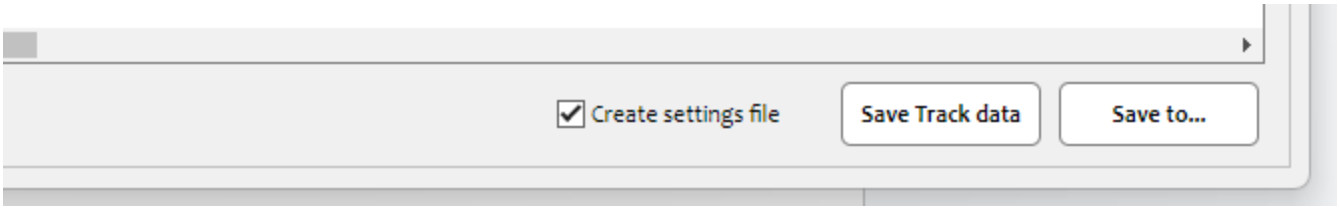
- More than 10 adults, 5 calves, or 5 juveniles. For example, you are tracking 12 adults but no other age classes. You can use a calf or juvenile button but add a note the first time so you know the ID corresponds to an adult.
- More than 20 animals overall. This would rarely happen but it can. We recommend tracking some animals in one go, and other animals in another go. The other option would be to assign the same ID to more than one animal (e.g., A1 to animal 21) but this could create many issues when analysing the outputs of not managed with care.

Saving the output

Return to the Main Screen and select the Output tab at the top of the screen. This is where you can view all the points you have selected (animals and reference points) and the information that is associated with each point.

You can either click on "Save Track data", which will save the output in the same folder where the videos are, or you can click "Save to…" that will allow you to select another destination.

The output is saved in the format of the flight log name, but adding the name of the video in front, e.g. 'DJI_0011.MP4_Jul-10th-2023-01-45PM-Flight-Airdata.csv'.



Output

The track data is saved as a csv, with the following columns

Table 2.

Column	Description
Video_name	
Flightlog_name	
Drone_ID	
Drone_Type	
Date_time_num_utc	Date and time in numerical format, in UTC
Date_time_utc	Date and time as text, in UTC time
Frame_num	Frame number of the track
Height_corr	Corrected height of the drone (take off height provided by the user + height from take-off provided in the flight log)
x_img	
y_img	
x_img_uncorrected	
y_img_uncorrected	
Drone_heading	
Gimbal_heading	

Gimbal_pitch	
x_utm_drone	Longitude (in UTM) of the drone
y_utm_drone	Latitude (in UTM) of the drone
Lat_drone	Latitude (in decimal degrees) of the drone (from the flight log)
Lon_drone	Longitude (in decimal degrees) of the drone (from the flight log)
Object_ID	ID of the animal (the same as in the buttons used to mark the animals)
x_utm_object	Estimated longitude (in UTM) of the object
y_utm_object	Estimated latitude (in UTM) of the object
Lat_object	Estimated latitude (in decimal degrees) of the object
Lon_object	Estimated longitude (in decimal degrees) of the object
Age_class	Adult, Calf, or Juvenile, depending on which button was used to track the animals: A, C, J
Breathing	The animal is breathing at the surface
Bottom	The animal is at the bottom of the sea. This is not when the animal is simply moving underwater, but when it is bottom grubbing (head towards the bottom).
Feeding	The animal is clearly foraging or feeding
Mating	There is a mating attempt
Net	The animal is near a fishing net

WTF	Who knows what the animal is doing?
Notes	

Terminology

SRT file: subtitles of the video files. For Air2S and Mavic 3 Classic, these are generated automatically for each video, while for Mini 2 drones, they have to be generated independently.

UMT region: The Universal Transverse Mercator (UTM) is a map projection system for assigning coordinates to locations on the surface of the Earth. It is a horizontal position representation and treats the earth surface as a perfect ellipsoid. However, it differs from global latitude/longitude in that it divides earth into 60 zones and projects each to the plane as a basis for its coordinates. You can find your UTM zone here: DMAP: UTM Grid Zones of the World.

UTC time: The Coordinated Universal Time is the primary time standard by which the world regulates clocks and time. It is the mean Greenwich time outside of the summer season, when the time is changed. For example, if the local time in Denmark is 15.26 during the summer months, the UTC time is 13.26 (two hours behind), while in winter, the time would be 14.26.

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