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TOPODRONE DJI PHANTOM 4 PRO L1/L2 PPK

USER MANUAL

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1. Drone preparation

1.1 First steps before work

DJI Phantom 4 Pro Topodrone PPK – is a ready-to-fly geodetic survey solution based on DJI Phantom 4 Pro drone. It is strongly recommended to learn the DJI P4P manual first, you can find it on the official web-site: https://www.dji.com/ru/phantom-4-pro/info#downloads. Correct preparation of the drone means following exact rules to ensure flight safety and the best orthophoto or 3D-model quality. Flight safety is the main basis of our company.

1. **Checking.** All components of the drone must be in a condition: no damages, cracks or malfunctions. It is needed to carefully inspect blades, motormounts, motors, arms, gimbal, micro-SD cards, cables and connectors, especially if the drone has been in a public use. Always check your DJI Phantom 4 Pro Topodrone PPK before large orders and far business trips.

2. **Charging.** You should charge all batteries of the drone, the remote controller (RC) and the mobile device up to 100%. Never use a DJI Intelligent Battery charged lower than 90%, especially if the battery has started its storage discharging. It can cause premature termination of the flight mission.

3. **Exploring.** Before moving to the working area, explore locality in an on-line geo-service like DJI GEO, AirMap, and PilotHub, to provide yourself with more knowledge about the places and objects located nearby. It is not allowed to fly in No-Fly-Zones: airports, prisons, sports stadiums. Military bases, state institutions, objects of strategic importance (CHP, hydroelectric power plants, nuclear power plants, etc.) are particularly dangerous, but they are not marked at GEO-services. Electricity transmission lines, located at the place you need to capture, can cause radio and magnetic interference during the flight.

4. **Setting.** In the DJI Go 4[1] App set all parameters for comfort flying in a manual mode:
   1. Distance limit – “turn off” value is recommended
   2. Maximum Flight Altitude – 500 meters[2] value is recommended
   3. Return to home altitude – 100 meters or higher value is recommended. Anyway, it can be changed during the mission planning in other apps.
   4. RC MODE settings – set the axes of your sticks, value 2 is strongly recommended
   5. EXP tuning – allows you to control your drone more accurately, 0.10 value is recommended
   6. RC signal lost – an action that drone will make in case of RC signal loss. Value “Return to home” is recommended
   7. Low battery warning – set at the minimum, 30% value is recommended[3]

NOTICE 1. DJI Go 4 App is the basic application for DJI Drones. You may not be able to set several parameters via other apps. It is recommended to make manual flights using DJI Go 4 App.
NOTICE 2. In some countries the maximum allowed flight altitude for UAVs is 120 meters. Setting 500 meters value in maximum flight altitude menu makes your drone follow the terrain, flying higher than 120 meters with respect to the altitude of home point, but not to the terrain.
NOTICE 3. If the area of photographing is located far from you (more than 1 km), increase this value up to 40%
NOTICE 4. Camera settings are described in the paragraph 1.3 of this manual.

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1.2 Compass calibration.

As the basic model, on DJI Phantom 4 Pro Topodrone PPK needs the compass calibration (CC) each time you move to the new location. CC helps your drone to adapt to local magnetic field lines. During CC, the accelerometer and the compass of your drone make two rotations in different axes. After that, the drone makes an adjustment between the values of each sensor. To perform correct CC, follow the next steps:

1. CC is performed directly before the first flight at an open outdoor area. Making CC indoor is useless.
2. Remove the gimbal holder.

3. Turn on the drone and the RC, insert the mobile device.
4. Make sure that there are no large metal constructions or magnetic fields in 50 meters range.
5. Turn your drone into CC mode. At least there are two ways:
   a) In the DJI Go 4 app open MC Settings / Advanced settings / Sensors state / Compass / Calibrate compass / OK
   b) At the front left side of RC, rapidly move the slider to S and T positions not less than 4 times.

6. Ensure that rear LEDs of the drone lights are solid yellow.
7. Put the RC in the left arm and take the drone with your right arm. Hold drone from the top under the battery or like on the photo. Do not change the orientation of the drone!
8. Rotate your drone to the left side (counter-clock wise) in 380 degrees (a bit more than 1 turn). Stop when the rear LEDs will change their color from solid yellow to solid green.
9. Change the orientation of your drone, turning it in 90 degrees in a longitudinal axis.

10. Rotate the drone to the left side (counter-clock wise) in 380 degrees (a bit more than 1 turn). Stop when the rear LEDs will change their color from solid green to blinking green.
11. After using the 5a way entering CC mode, turn the Flight Mode slider to P (central position). This is especially important!
12. Compass calibration now is complete.

Before and after CC you can check the value of magnetic interference in the DJI Go 4 App – it should be at the green zone after CC. If the app notices that you have failed, the compass calibration (rear LEDs blinking red rapidly) – recalibrate the compass at another place nearby.

Notice 1: no magnetic or ferromagnetic objects on the pilot's body are allowed. For example: massive jewelry, metal inserts or magnets on the back plate of the iPad tablet etc. If you have some of these objects, even after successful CC, your drone will have "Compass Error" after taking off.

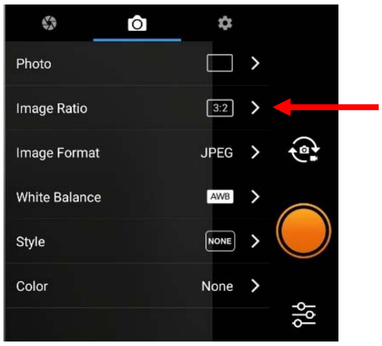
Notice 2: CC increases flight stability of the drone during the flight. But compass error can appear even after absolutely correct calibration. It is usually caused by different external interferences such as metal objects, large antennas, electricity transmission lines (ETL)

1.3. Camera calibration and settings

Before the shooting process will be started, you should calibrate the focus of your DJI Phantom 4 Pro PPK camera and set optimal image settings. It is recommended to use the next order.

1. You should determine your drone's working altitude. This value depends on many factors: scale of the final orthophoto map, properties of the lens, height of the obstacles, features of relief, etc. Usually, working altitude varies from 60 to 12 meters.

2. Set correct image ratio. Go to the image menu, tap the second tab. Use the Image Ratio 3:2 value, it allows to use all surface area of camera's matrix. Do not use 16:9 Ratio! Check other values of this menu – all defaults.

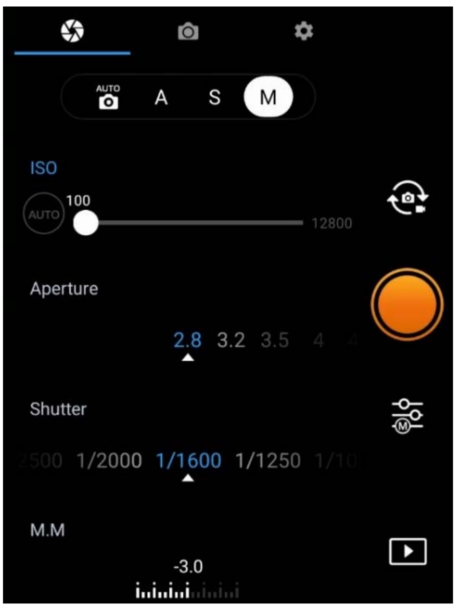


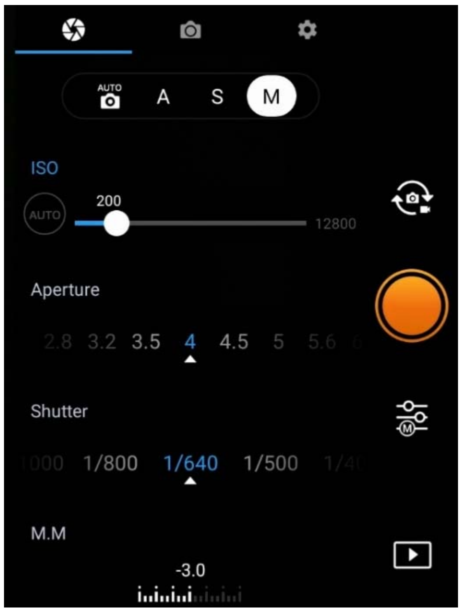
3. Lift off the drone to the working altitude and move the gimbal to 90 degrees (nadir). Ensure that the focusing method now is in the AF value. Then tap the center of the screen to let the camera focus at the surface. After that change the focusing method in the MF value - manual focus scale will appear. Do not touch it! Now your drone's camera is focused at the selected height value. It will not change in the future.

4. Now it is time to set the best camera settings. All parameters are set auto as default. In this case, your drone will change image brightness and smoothness during the flight. But this method is bad for triangulation image processing: the key points at different images will be different. To get the best image quality during the flight it is strongly recommended to set image params as follows:

   ISO: from <u>100</u> to <u>200</u>. Upper values increase image noise, and decrease ortophoto map quality
   Aperture: from <u>2.8</u> to <u>4</u>. Upper values decrease stream of light, so images will be darker
   Shutter: from <u>1/1600</u> to <u>1/640</u>**.** Upper values increase image motion blur**,** lower ones does not allow the camera to use mechanical shutter, so images will be distorted.

   Also using values upper than 1/1600 will not let writing GNSS marks correctly!





1.4. IMU calibration and settings

IMU calibration is needed very rarely. However, some things can affect the sensor states: falls and bumps, temperature changes and long stand by time. Because of using the additional module upper the shell of DJI Phantom 4 Pro PPK, the process of IMU calibration is not the same as the default. To calibrate IMU you need to do next:

1. Remove the props from the motors if needed
2. Remove the gimbal holder and turn on the drone and the remote controller
3. Prepare two tables, standing close to each other, or another flat surface with a hall: the horizon should be aligned with the bubble level
4. Start the IMU calibration process and make steps 1-5 as they are.
5. At the step 6 place the drone head over heels. Use the edge of two tables to make this step. Place your drone like at the photo below

6. When the step 7 is complete, rotate the drone and place it normally
7. IMU calibration now is now complete

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1.5. GNSS receiver settings

GNSS module is located in front of the drone in a special plastic shell. The receiver body has three holes in a row. The state of the receiver is shown by a single led. The signal led is located in the middle.

1. Dual frequency (L1/L2) antenna
2. Signal LED. Indicates power supply, GNSS state, Error.
3. Micro-SD slot.

LED State	Description
Blinks green/red	Satellite search mode
Solid green	The signal from the satellites is received
Blinks green	Flash card write mode (each interrupt means 4 KB of data is written)
Solid red	Micro-SD card error

4. GNSS cable, it should be plugged, do not touch it.

Each time the receiver is turned on, a new .ubx file is created in the folder with the date of the DD-mm-yy format and the name of the HH-mm-ss format. It is important that the time is recorded in UTC, and the file is created only after the GNSS receives the satellite signal.

It is forbidden to insert or remove the memory card "on hot". This process should only be performed when the power is turned off. It is allowed to use cards with a maximum capacity of 64 GB.

The standard configuration of the receiver is to record a UBX file with a frequency of 10 Hz and receive GPS and GLONASS satellites at L1 and L2 frequencies.

2. GNSS DATA POST PROCESSING AND IMAGES GEOTAGGING

2.1 Data preparation

- Remove the SD card with images from your drone and copy photos to your computer.
- Divide the whole image dataset into separate flights and store photos from each mission in separate folders. For example, Flight 1, Flight 2 etc.

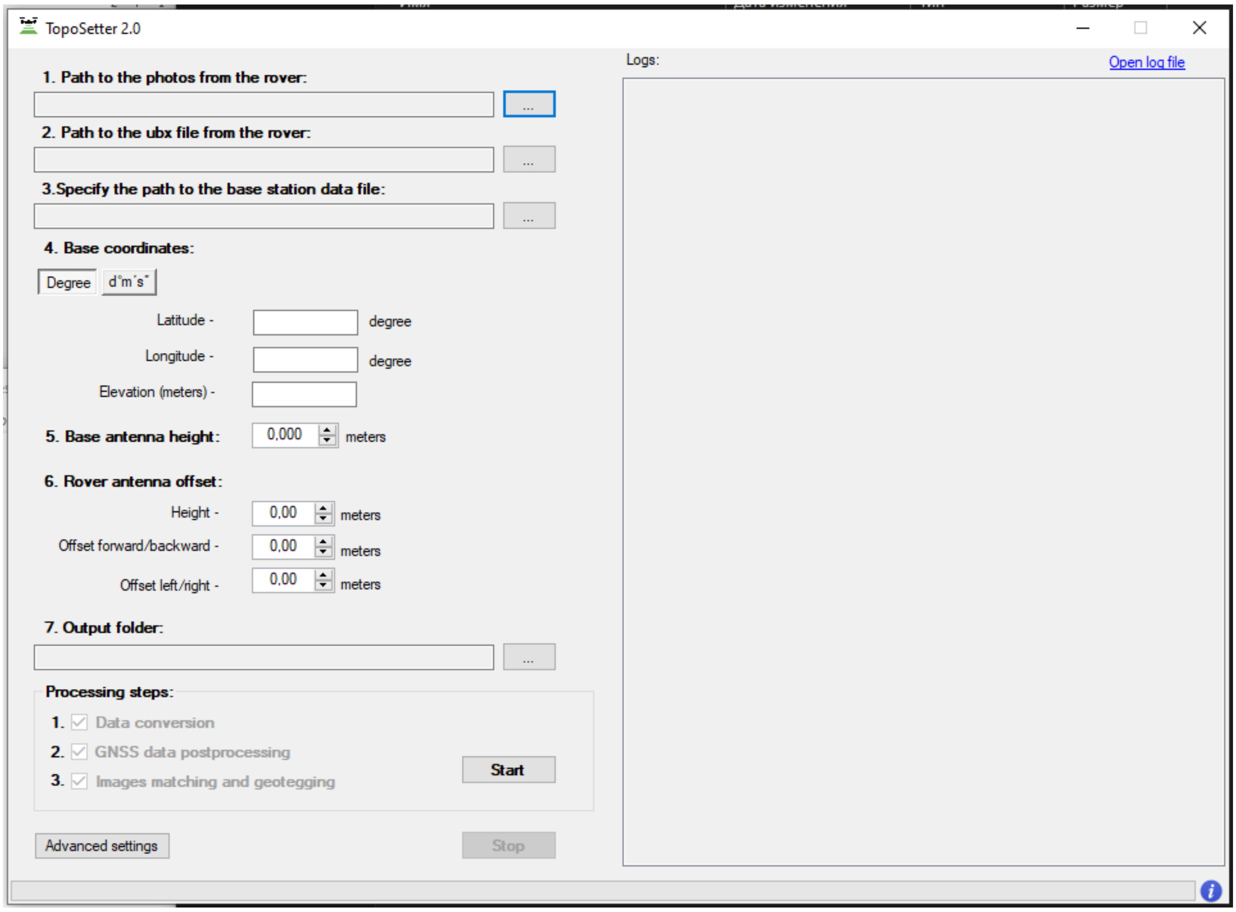
NOTICE. *Do not delete any images.*

- Remove the SD card from the GNSS receiver installed on the drone and copy ubx files to your computer to a folder ROVER (for example).
- Download GNSS static logs from the base station and convert them to Rinex format. Copy Rinex files to a folder BASE (for example)
- Measure coordinates of ground control points (GCPs) and coordinates of the base station.

NOTICE. *Coordinates of the base station should be in Latitude, Longitude, Ellipsoid high, WGS 84 coordinate system.*

2.2 GNSS data post processing

Step 1. Run TOPOSETTER 2.0 application



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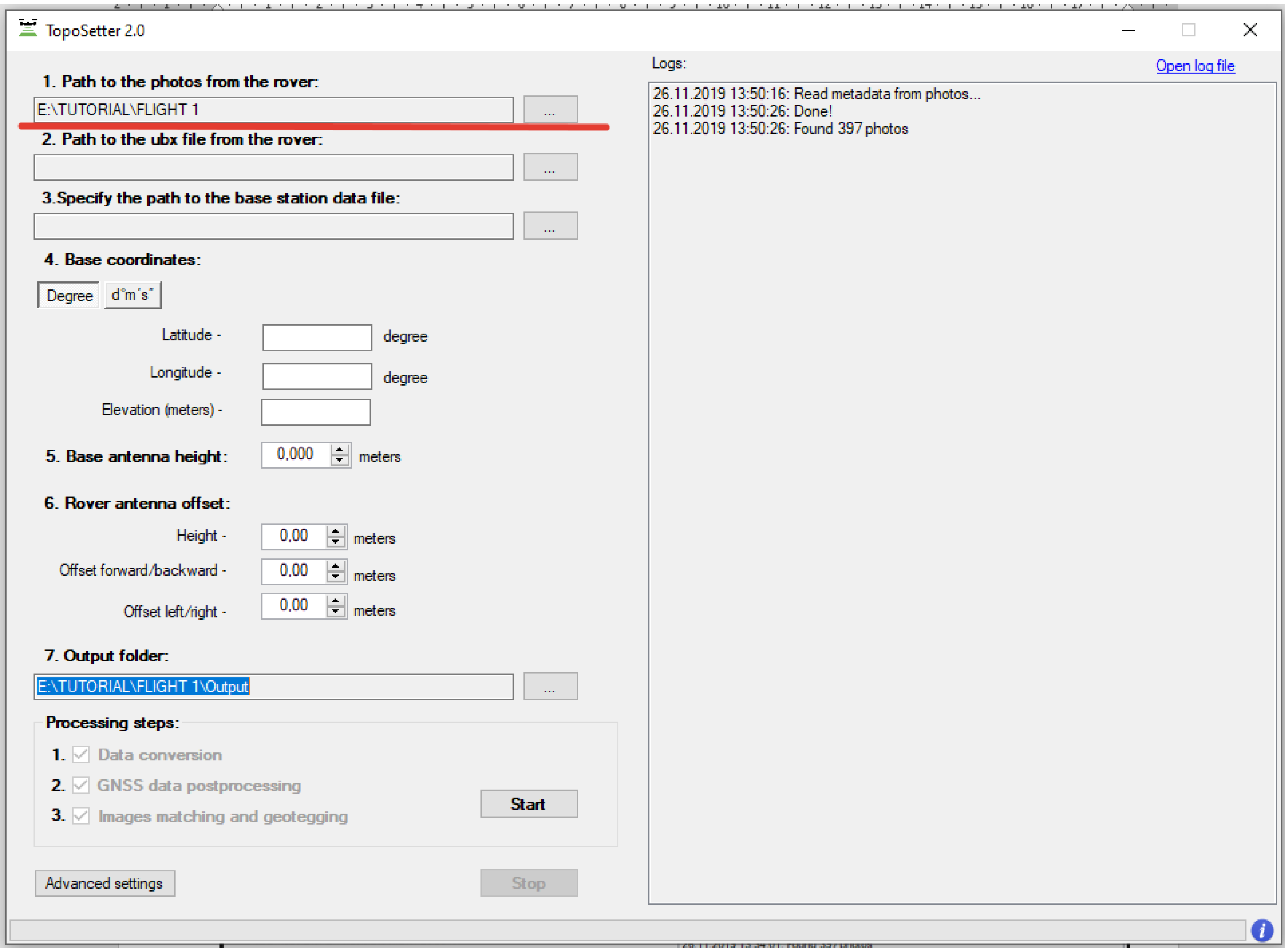
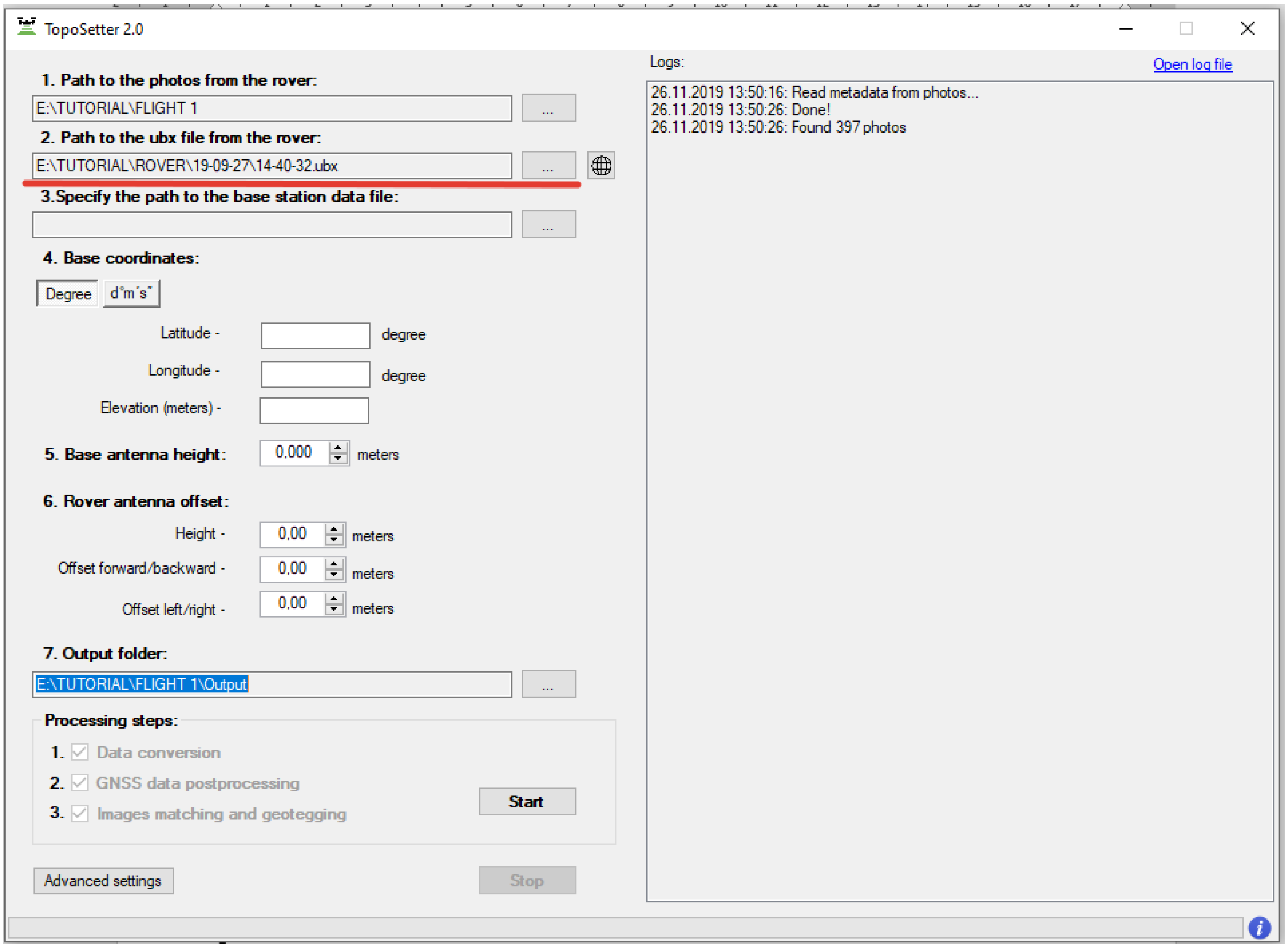
Step 2. Select a folder with photos



Step 3. Select a UBX file from a drone



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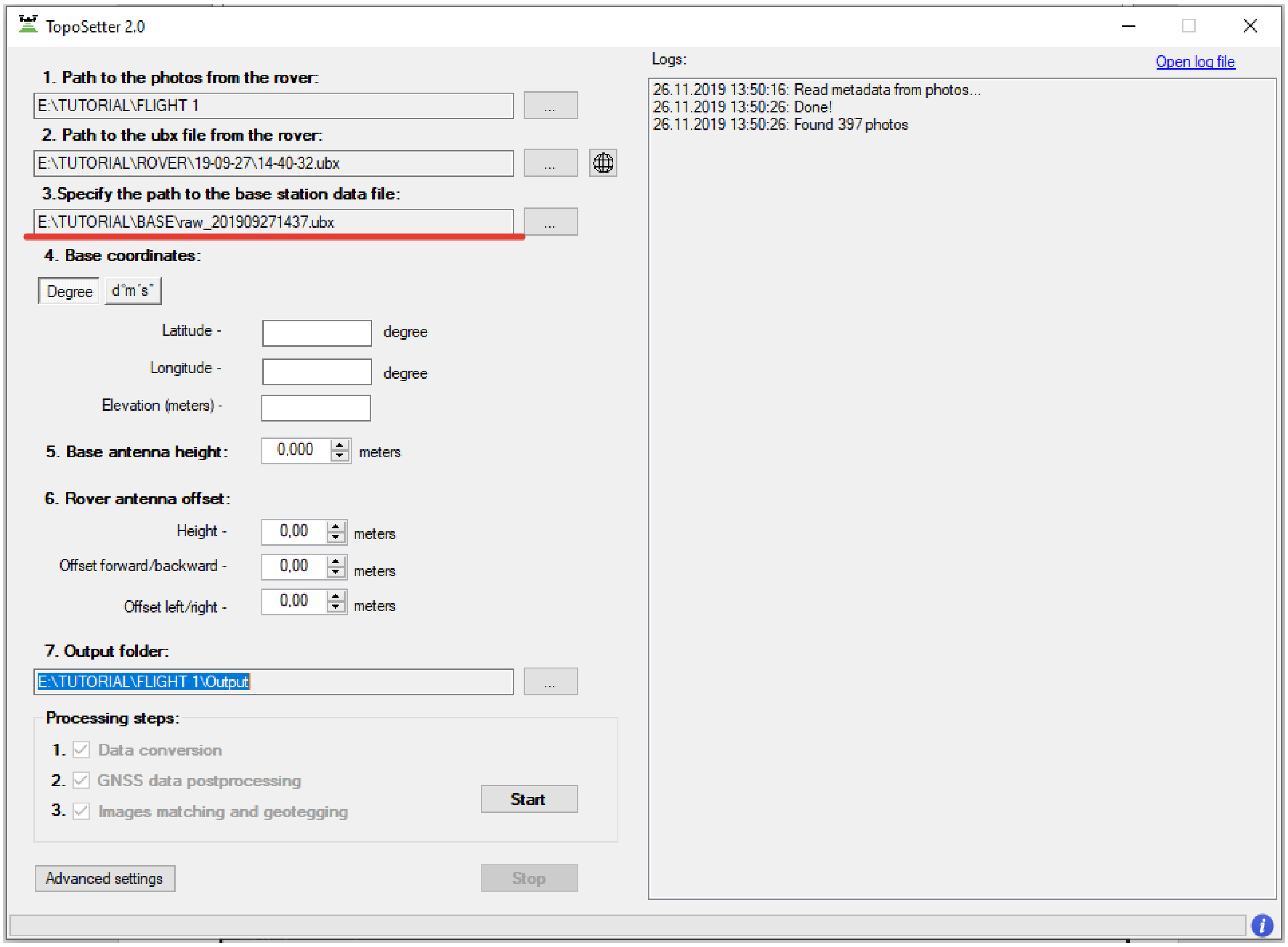
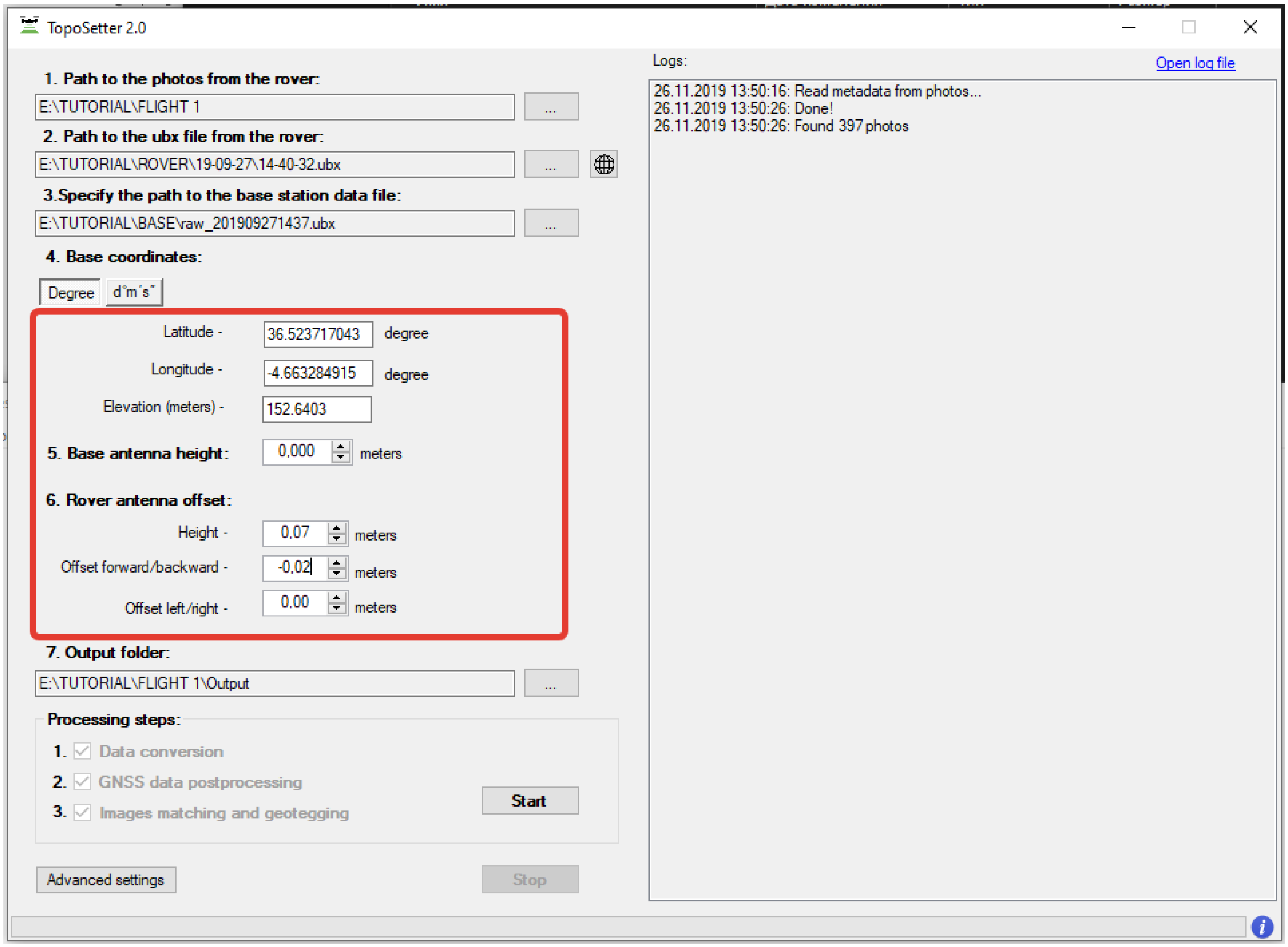
Step 4. Select a Rinex or UBX file from the base station



Step 5. Impute coordinates of the base station in WGS 84. Define antenna offset for the drone.



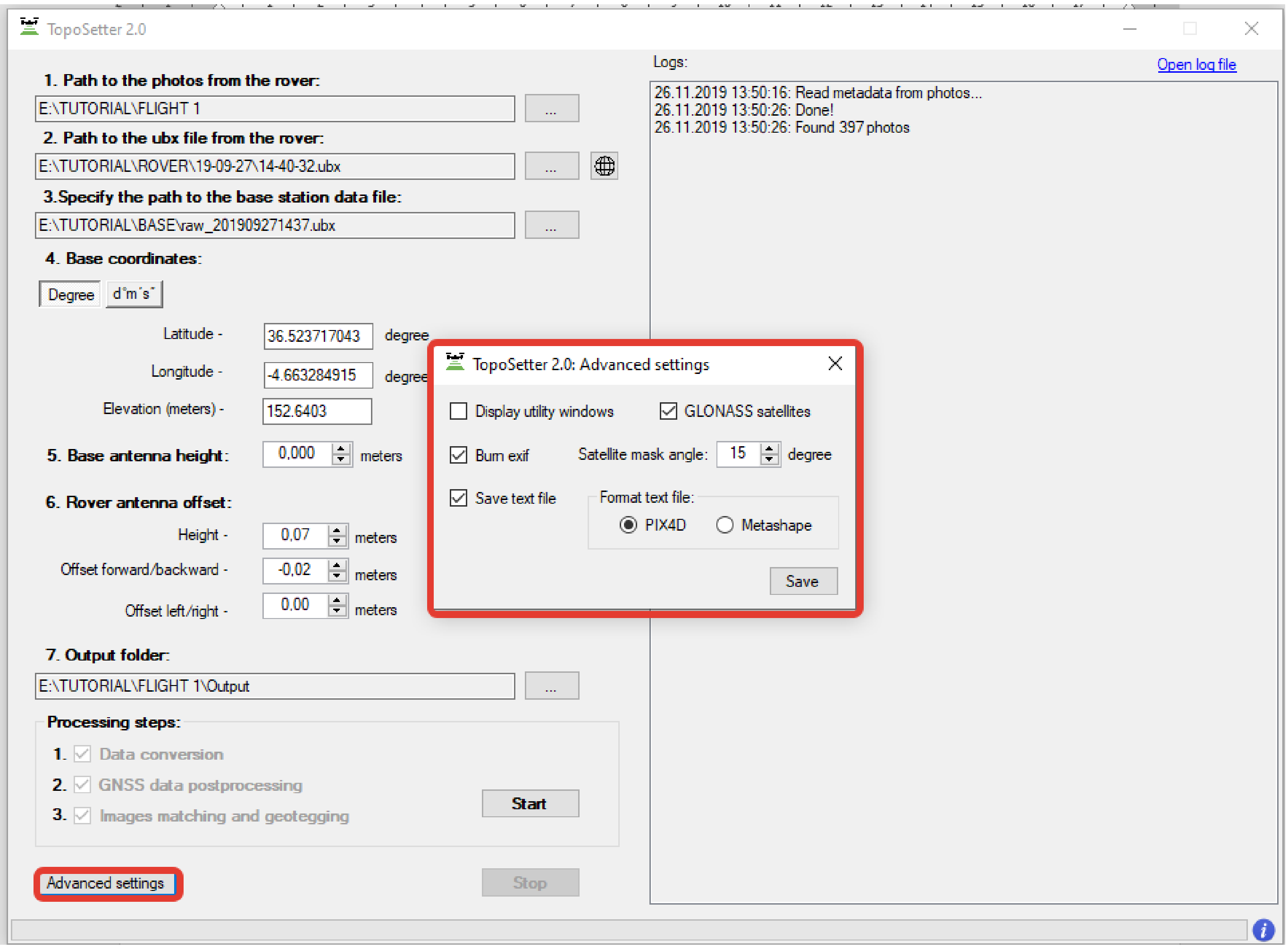
NOTICE.

FOR DJI MAVIC 2 PRO PPK use the following parameters
Height: 0.07
Offset forward/backward: -0.02

FOR DJI PHANTOM 4 PRO PPK use the following parameters
Height: 0.17

Step 6. Setup data processing setting. Click advanced setting. Advanced setting will appear. To embed precise coordinates to photos EXIF tags check Burn exif check box. This option may lead to increasing of the data processing time. To save the list of coordinates check Save text file check box. Select the format of the text file Pix4D or Metashape.

Click Save button.



NOTICE. *To look at data processing progress check Display utility windows option.*

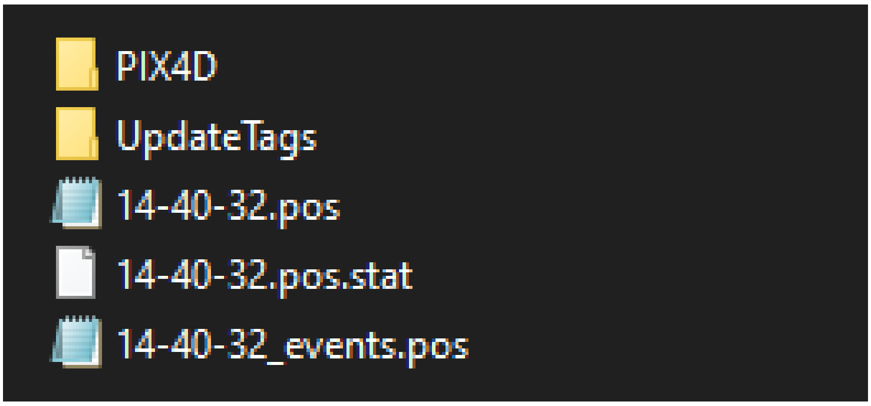
Click Start button

After finishing all steps of the data processing (data conversion, GNSS data post processing, images matching and geotagging) all results will be stored in the Output folder.

File Coordinates.txt is stored in the PIX4D or Metashape folder.

Photos with updated EXIF tags are stored in the UpdateTags folder.

Files with .pos extension are the results of the GNSS data postprocessing.



NOTICE. The *coordinate system is WGS84.*

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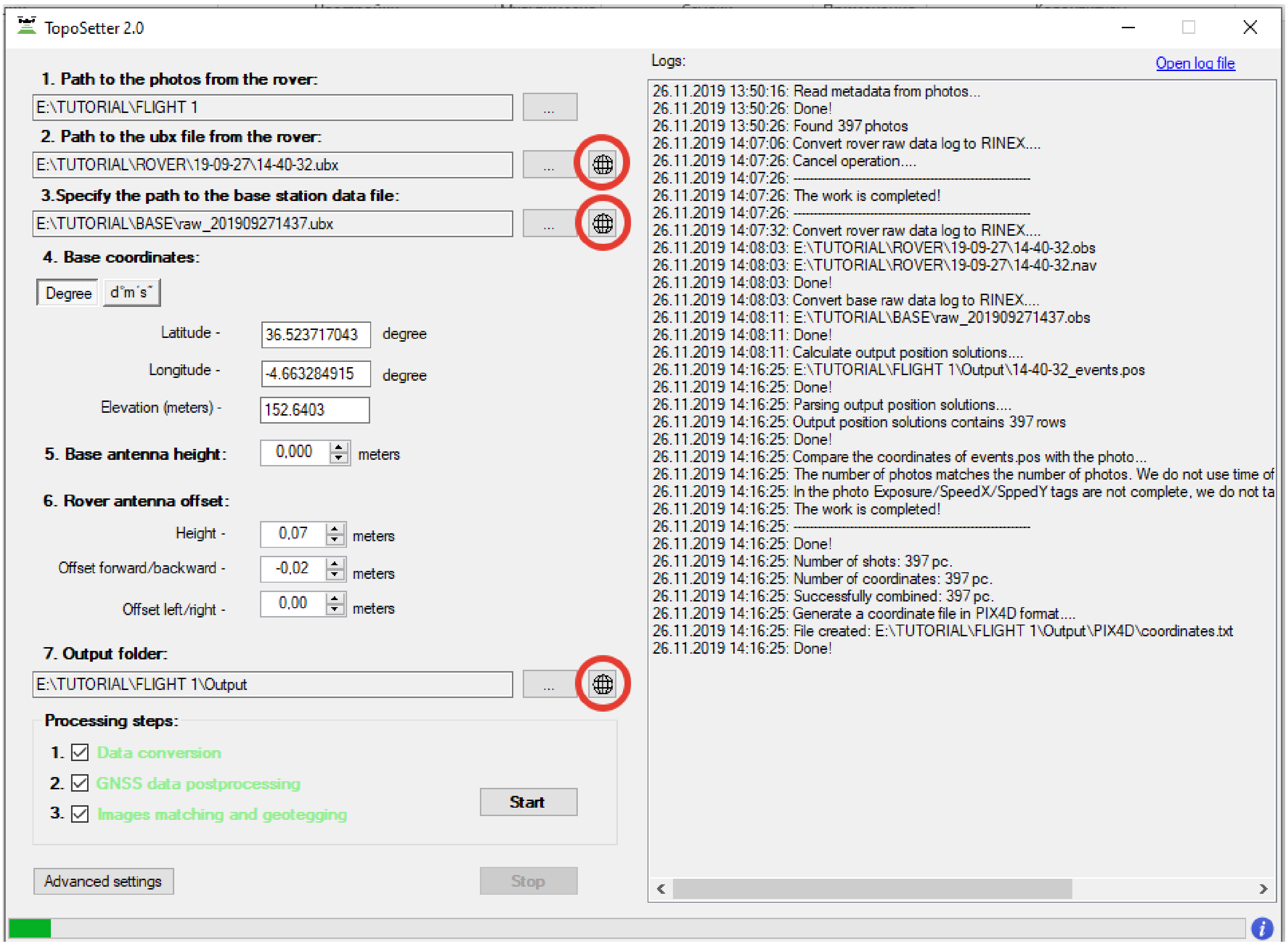
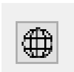
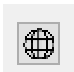
Step 7. Checking the processing results.

After the processing finishes, the following buttons will appear.

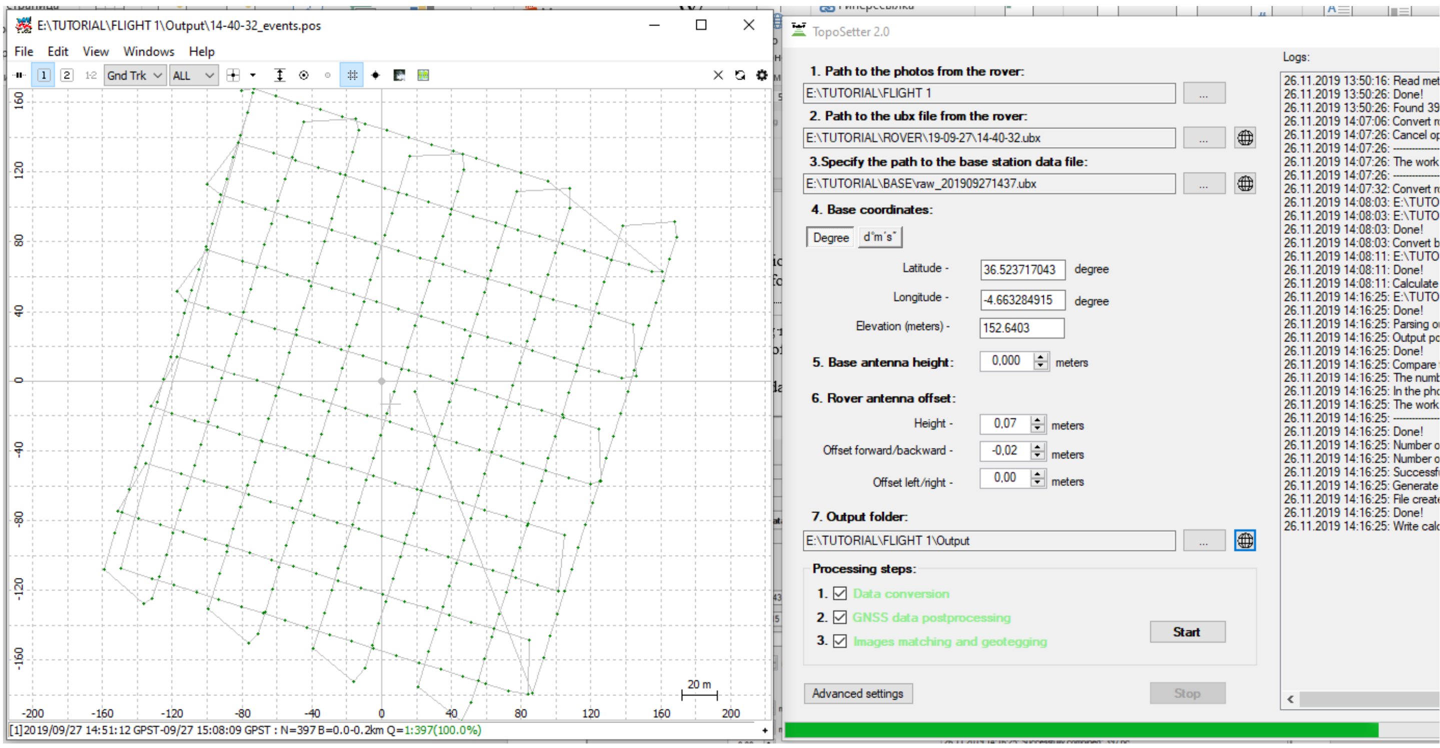


NOTICE.

Click  *buttons in front of the Rover or Base fields to open GNSS observation files and check the quality of GNSS signal.*

To check the quality of GNSS data postprocessing click  *button in front of output results.*

On the map you can see the results of the GNSS data postprocessing.
Green points of photos events stand for Fixed solution
Yellow points – Float solution
Red points – Single solution



NOTICE.

If there are only red points on the map it means that the GNSS data from the drone and the base station were not collected at the same time.
If there are only yellow points (float solution) you should check the coordinates of the base station or the quality of the signal. To remove noisy GNSS signal try increasing the satellite mask angle or excluding the GLONASS satellite system in Advanced setting menu.

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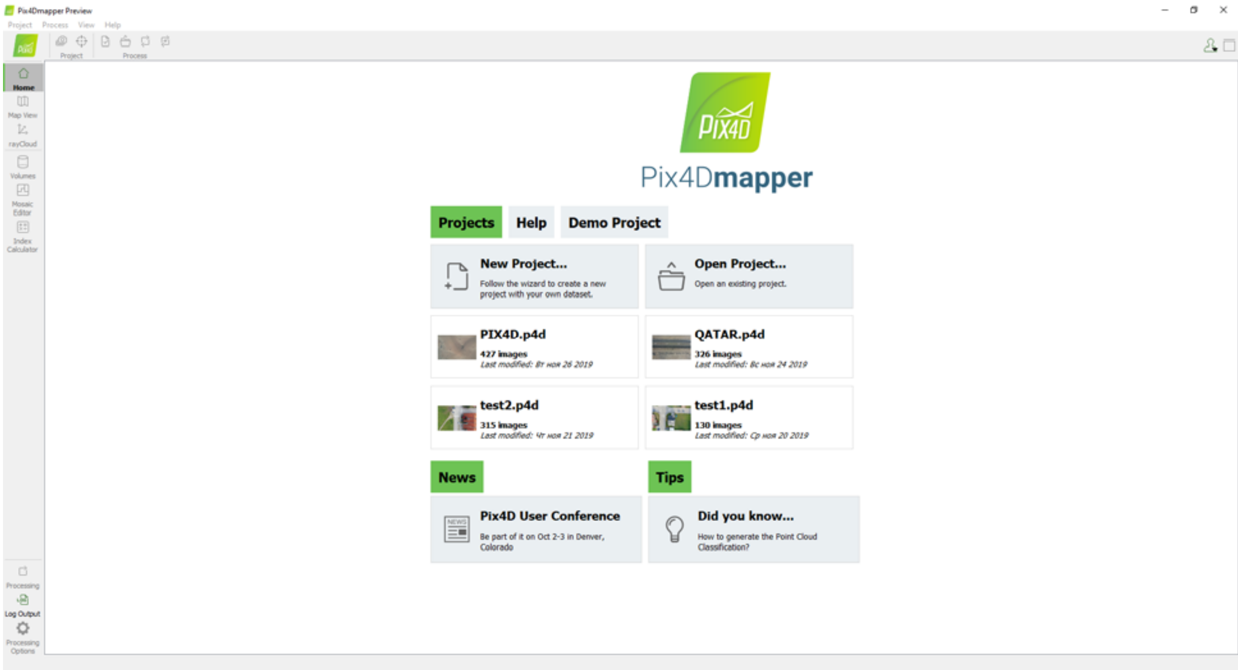
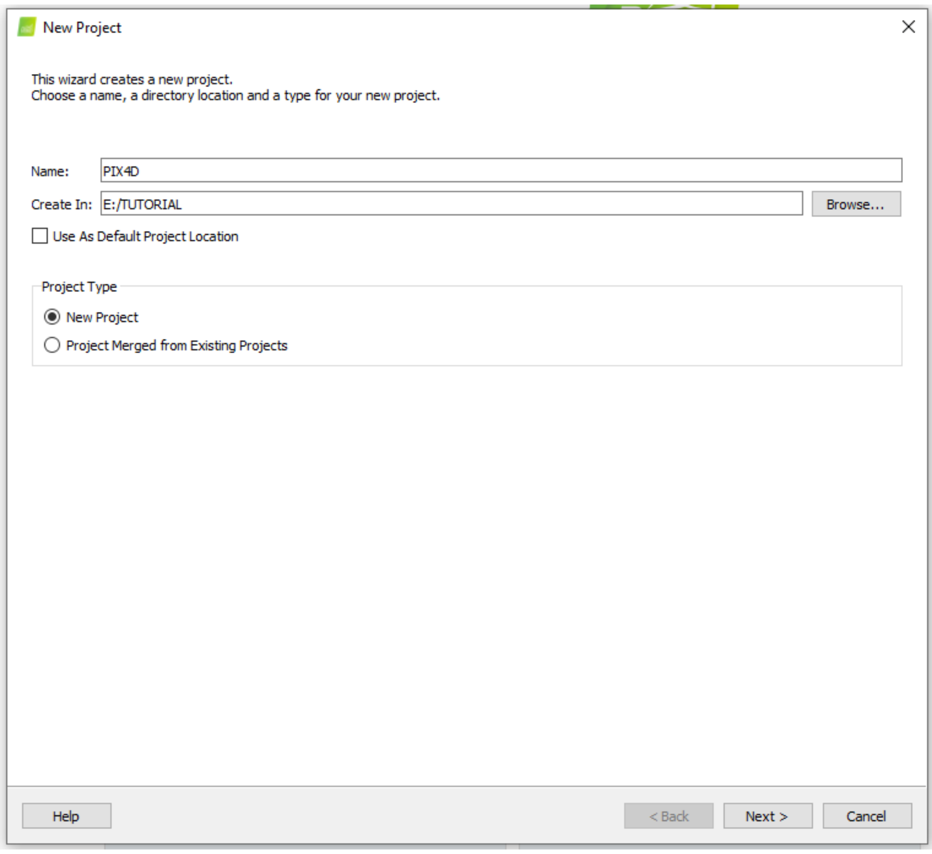
3. PHOTOGRAMMETRY PROCESSING IN PIX4D MAPPER SOFTWARE

3.1 Creating pix4d mapper project

Run PIX4D mapper application.



Click New Project. Select a project folder location. Click next



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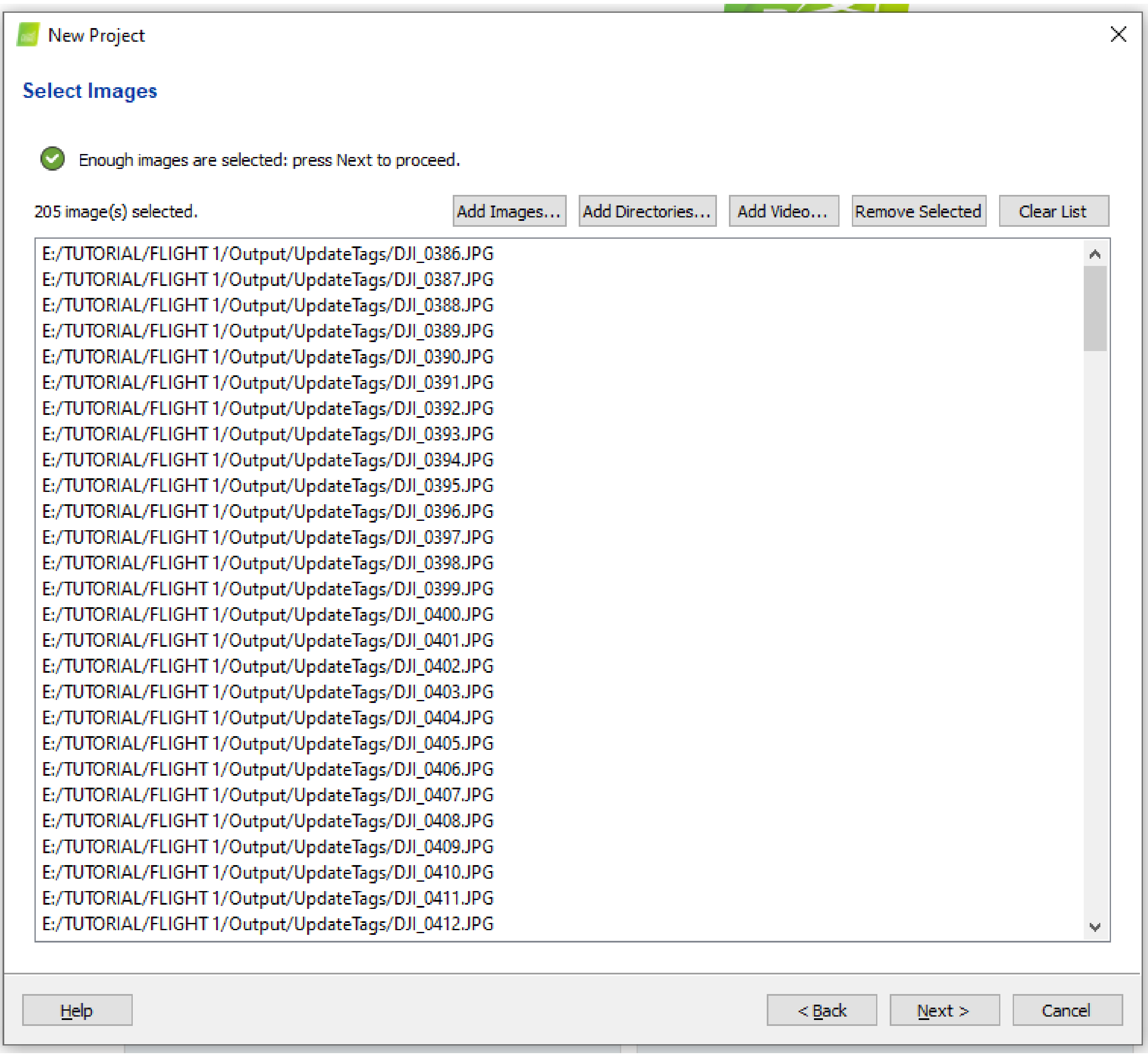
Select images to be processed from output\UpdateTags folder. Click next



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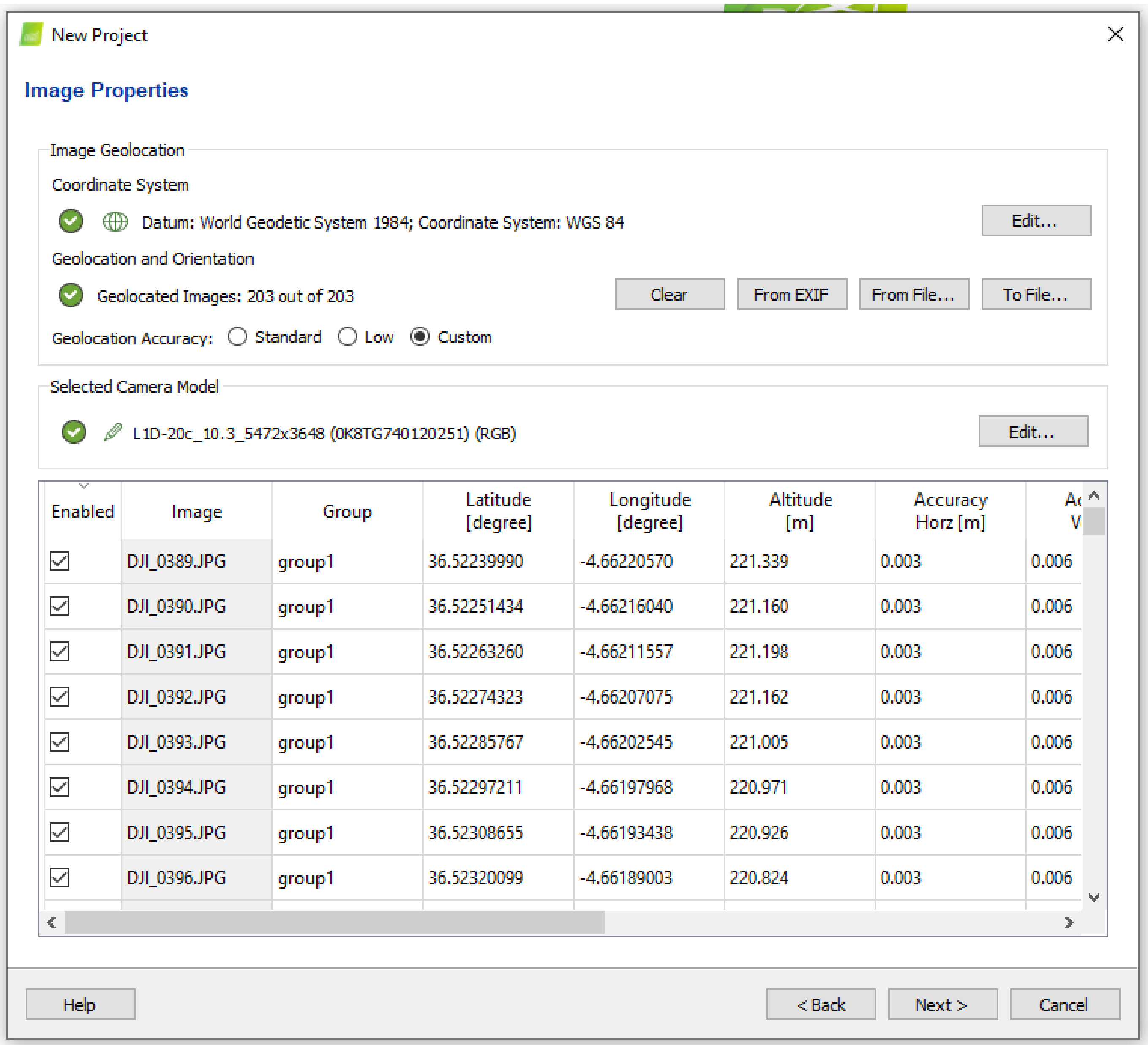
Software will read the precise coordinates of the images and the accuracy settings automatically. Click Next.



NOTICE. *It is possible to upload the coordinates from the .txt file. Click From File button and select the coordinates.txt file*

It is recommended to check the camera settings. Click Edit button and check if the Linear rolling shutter camera model is enabled if you have used a DJI MAVIC 2 PRO for survey.

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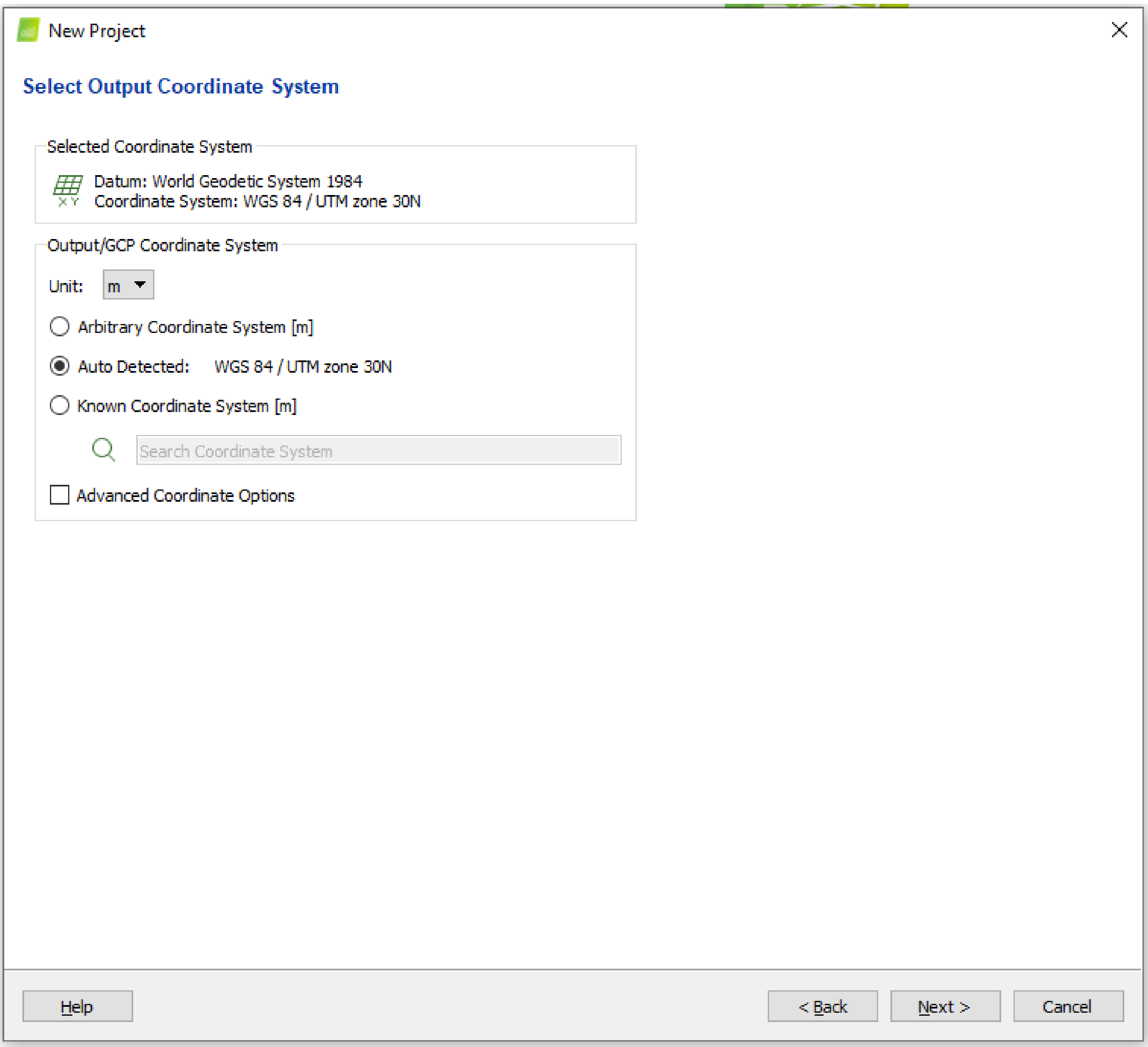
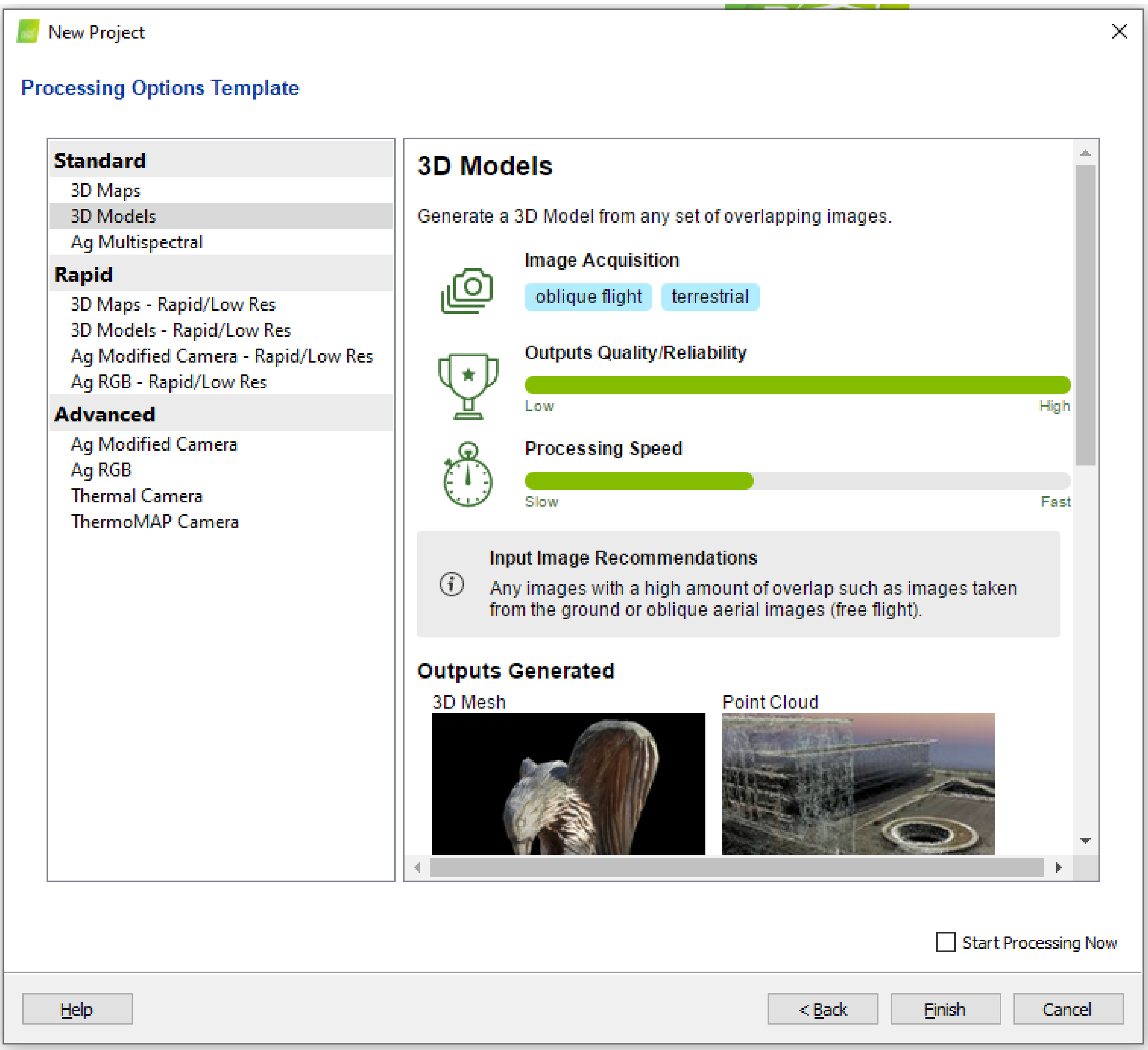
Select an output coordinate system and click Next.



Select a type of data processing options. Click Finish.



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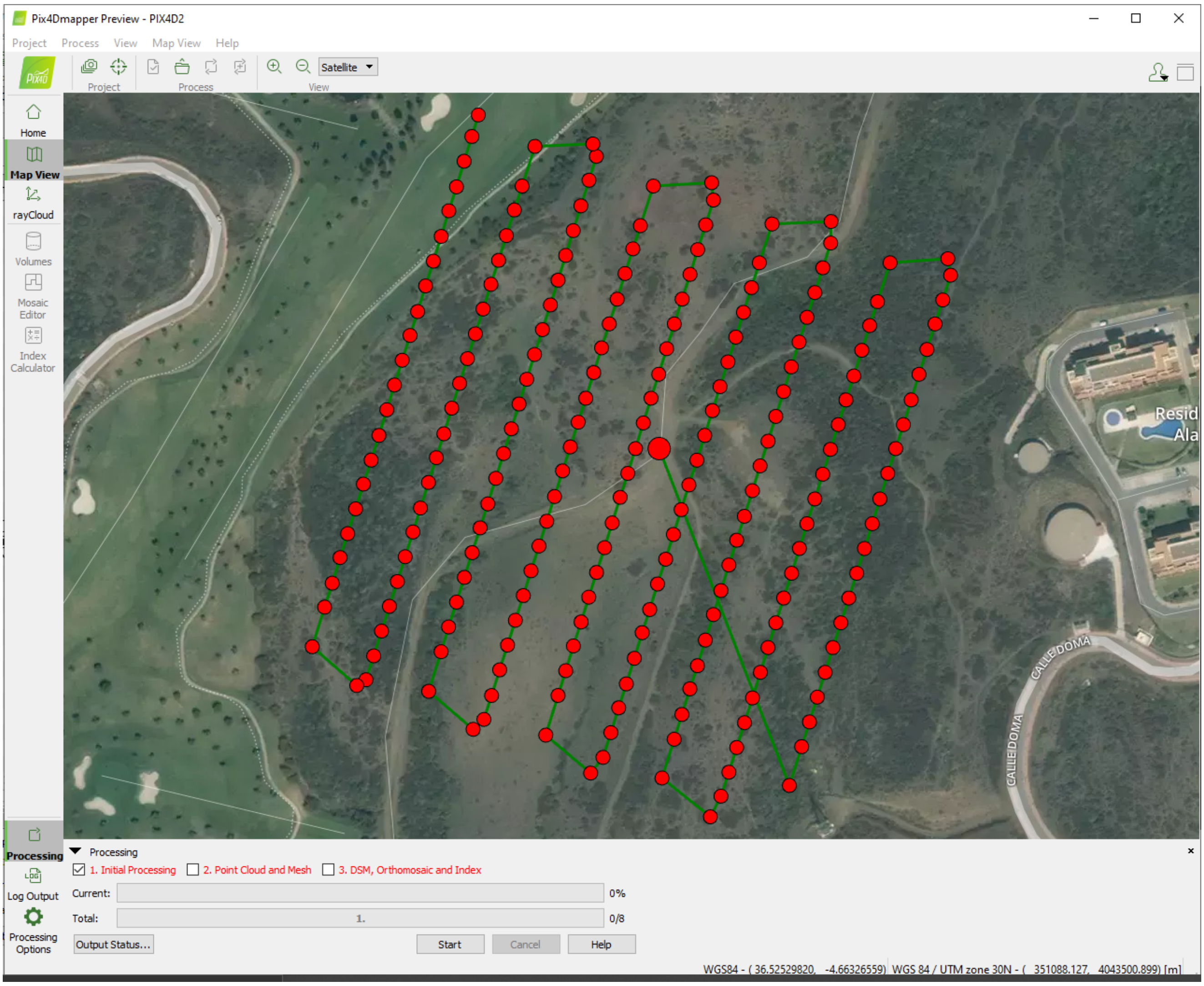
3.2 Initial aerial triangulation

Once the images with precise coordinates are loaded to the project, we can start the initial aerial triangulation. Select the initial processing checkbox and start processing.



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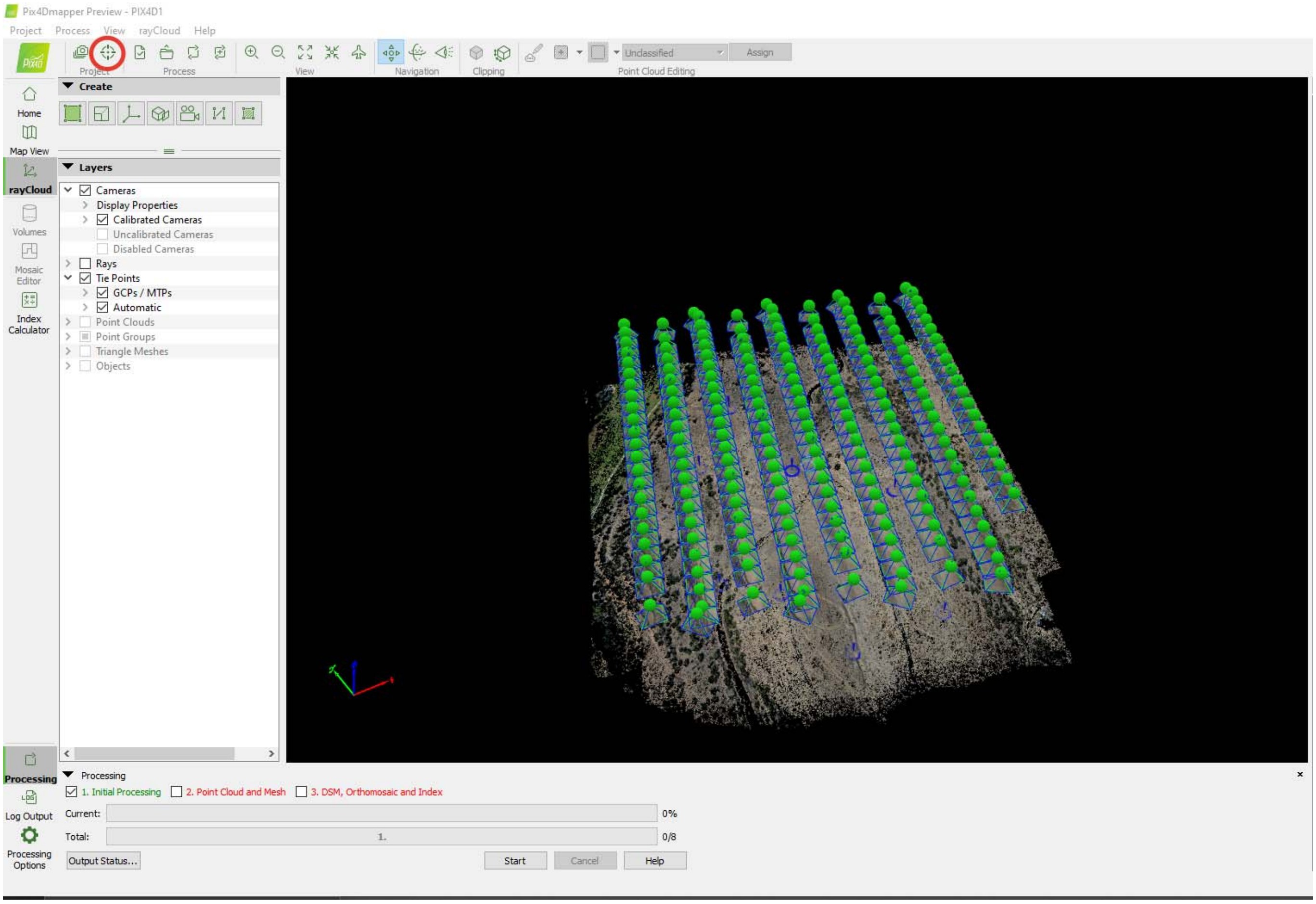
3.3. Camera calibration

In order to calibrate the focal length of the camera you need at least one GCP.

Click GCP/MTP button.



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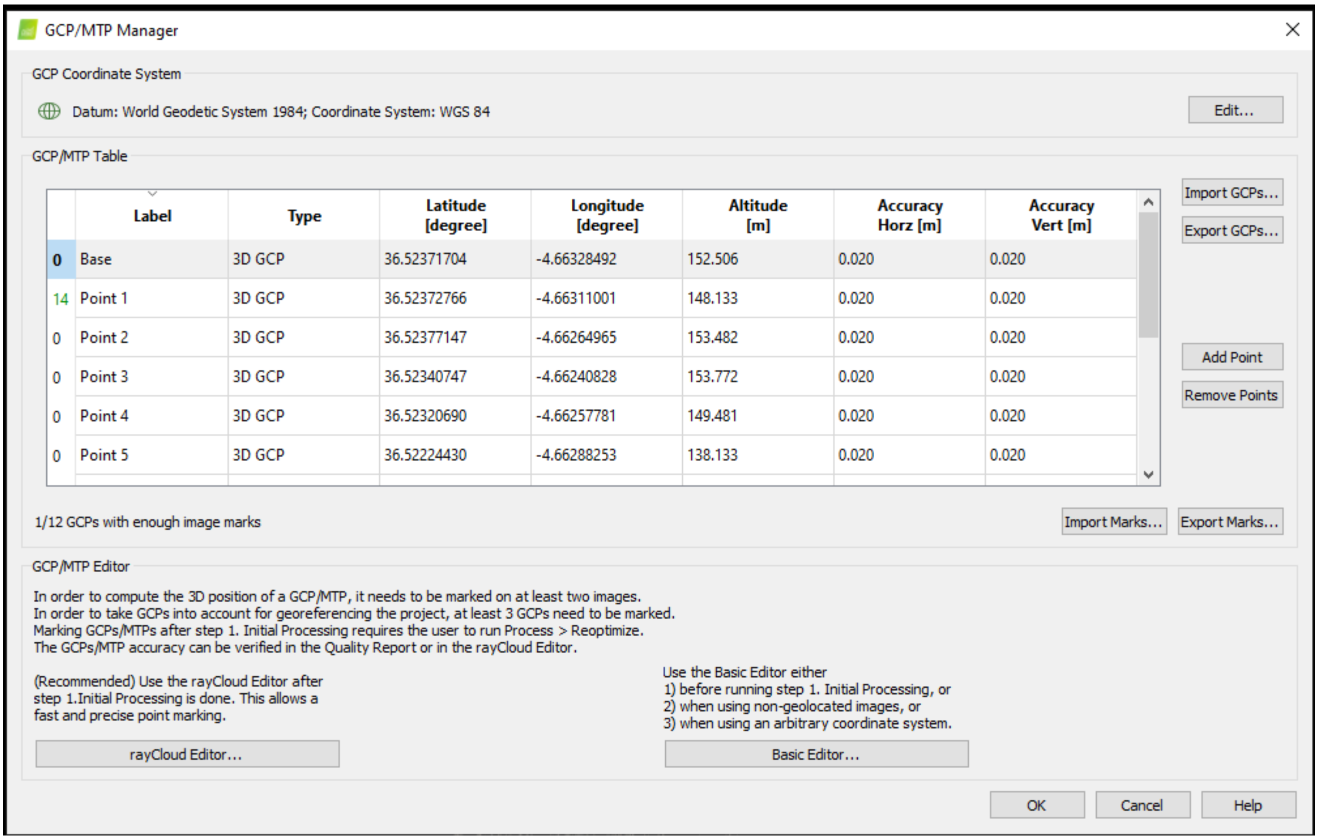
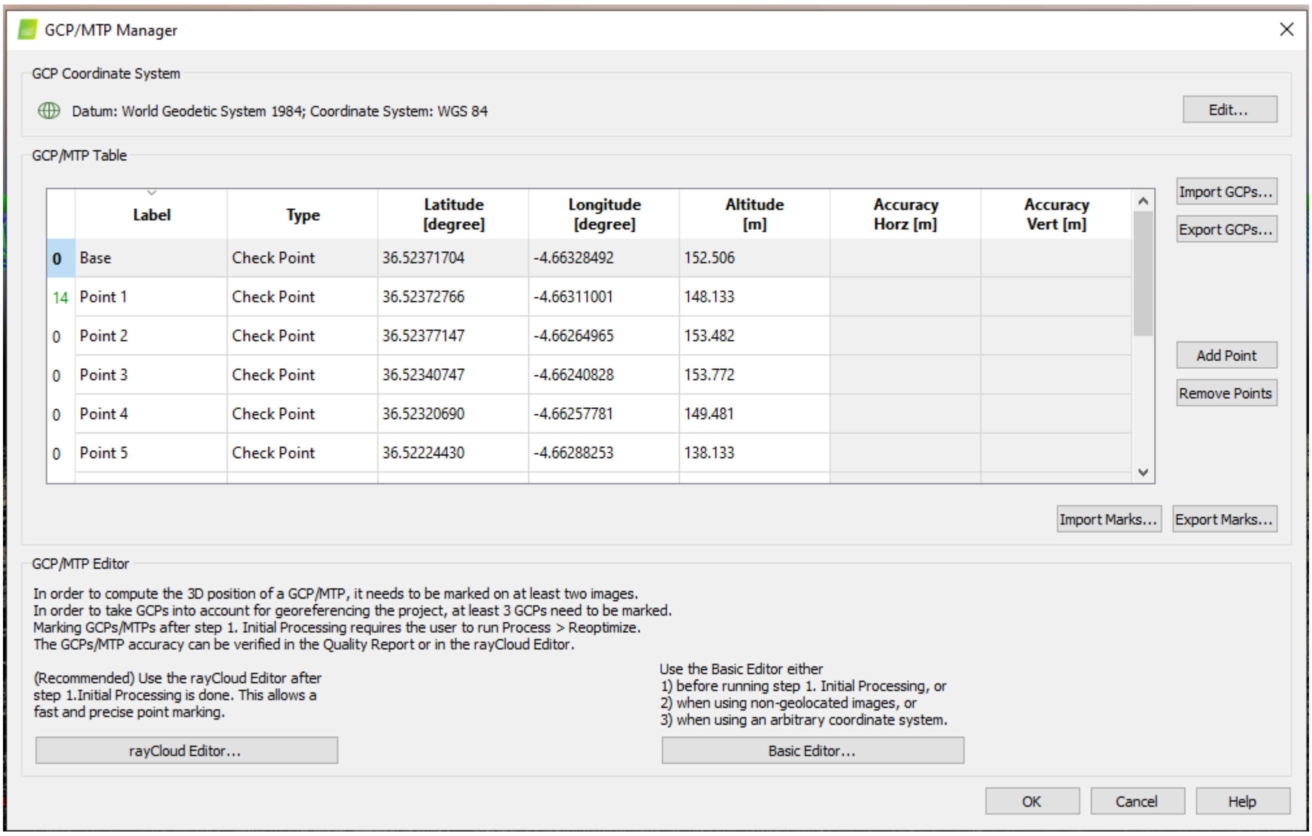
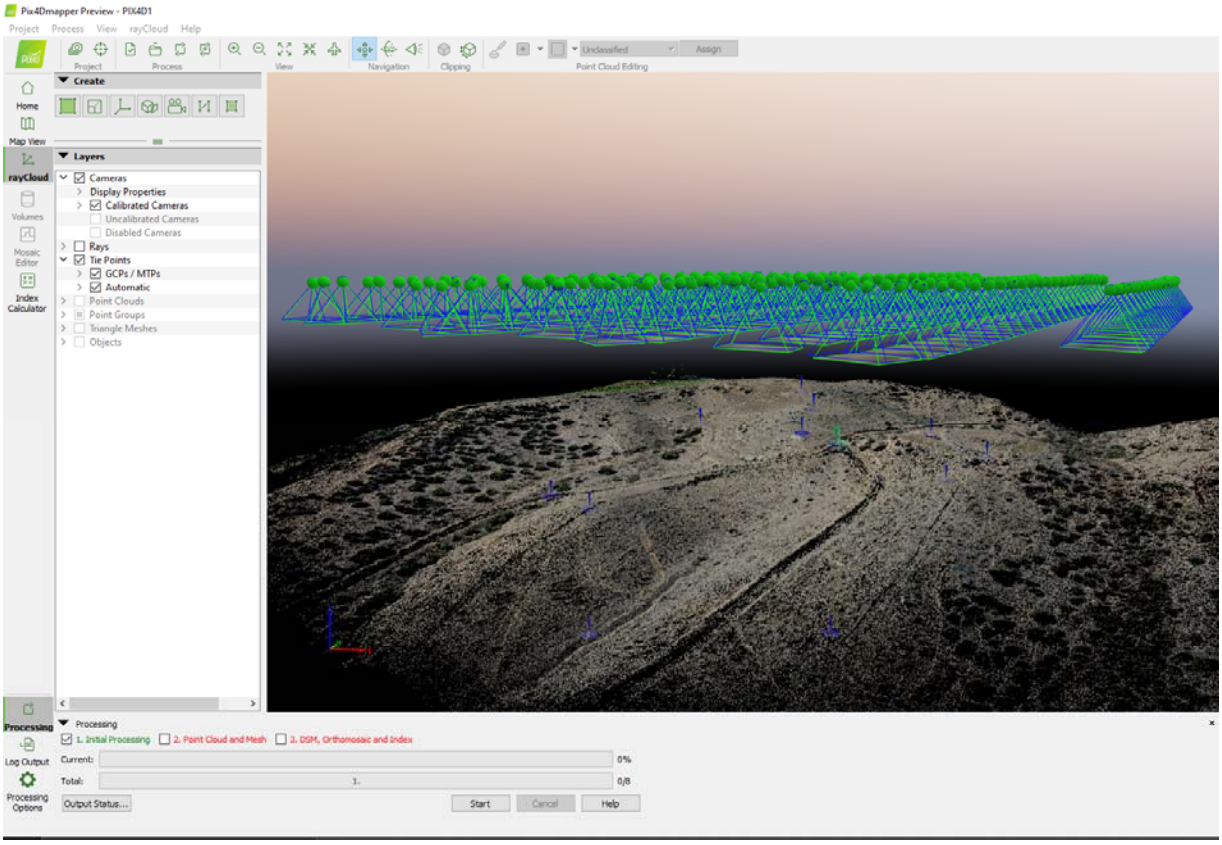
Select the coordinate system of ground control points and import GCPs. Click OK.



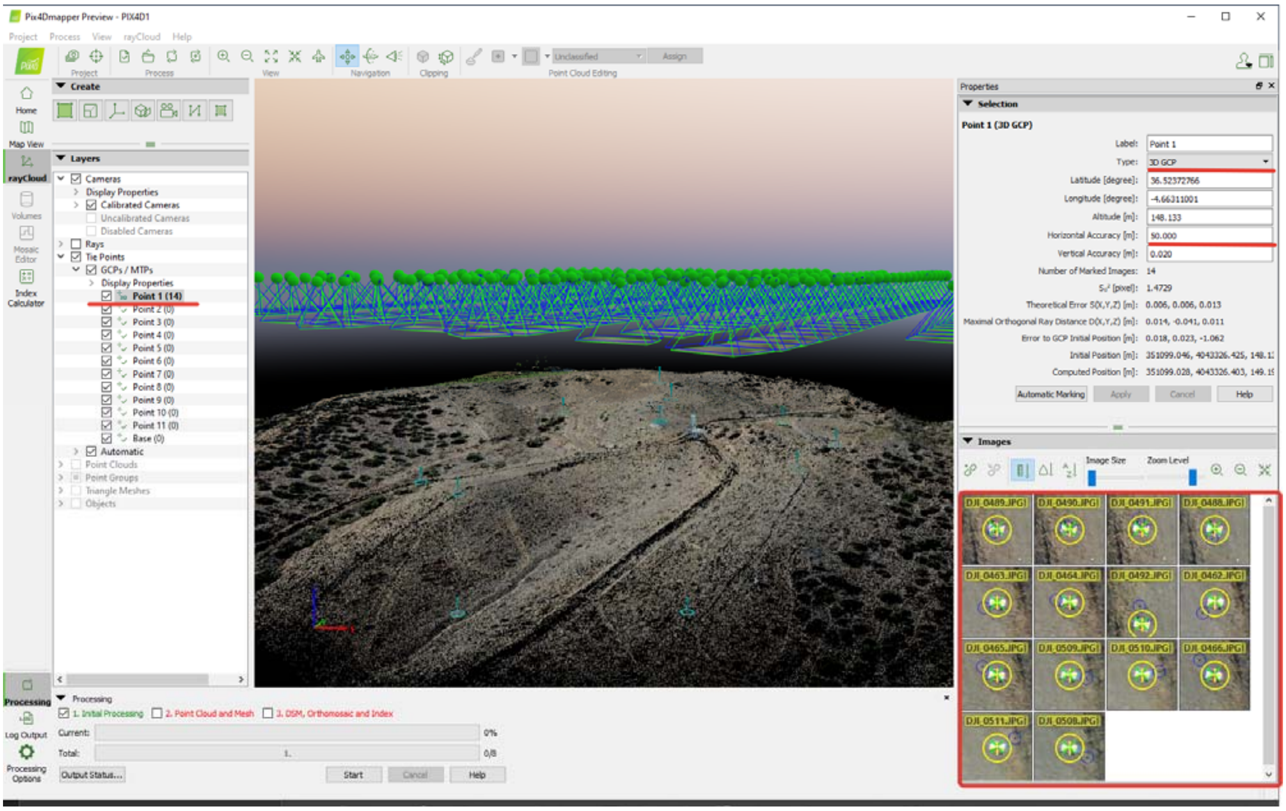
Change the GCP type to Check point.



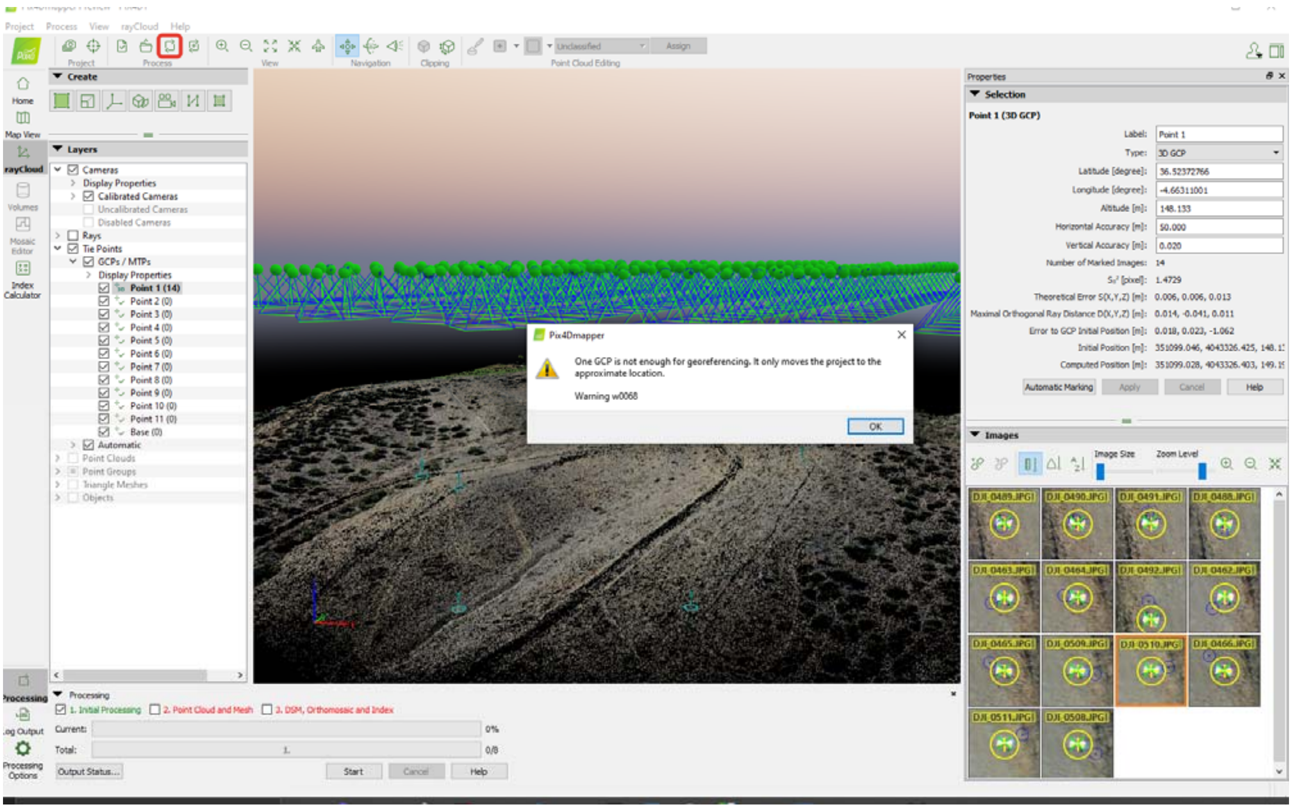
All GCPs will be shown on the map.



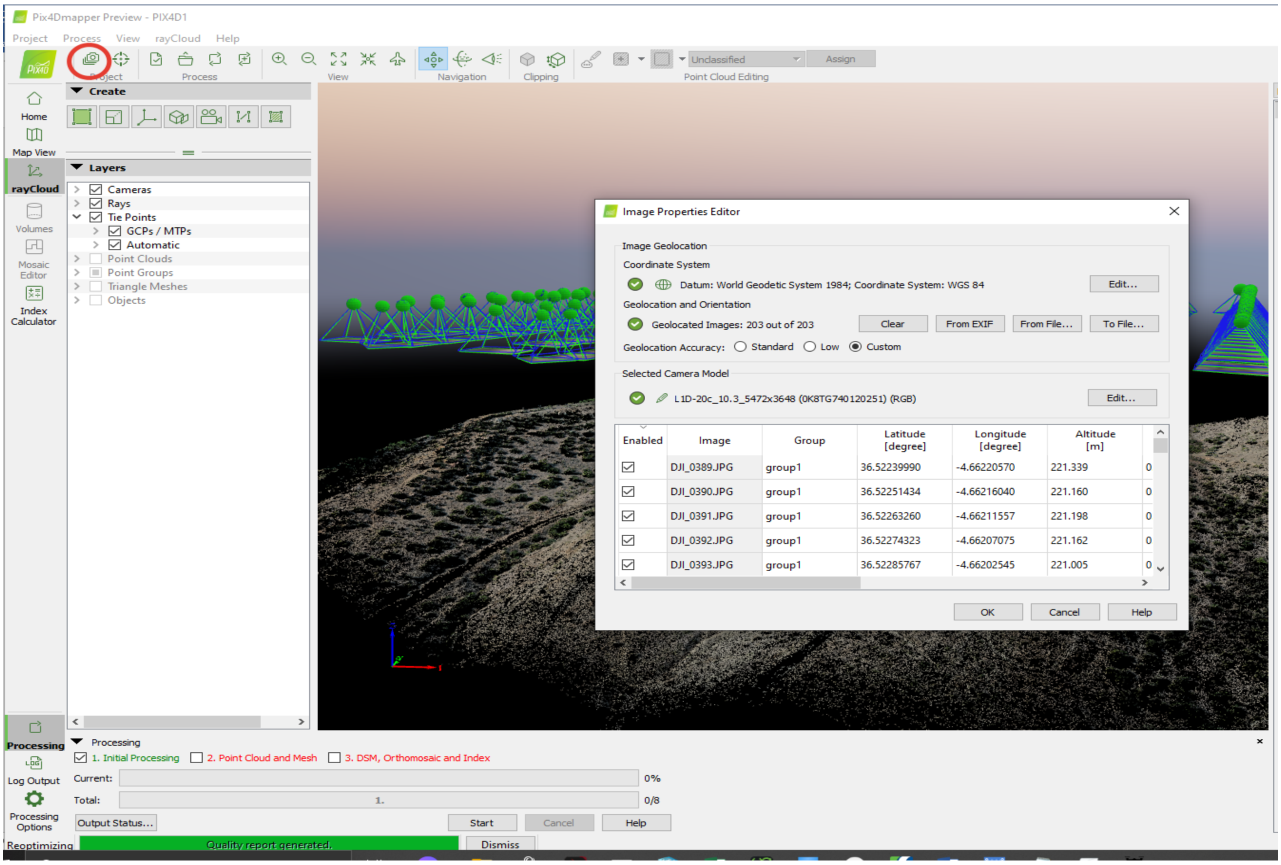
Select one GCP, define the position of the ground control point at each image, change the type of the selected(?) GCP to 3D and set the horizontal accuracy to 50 meters.



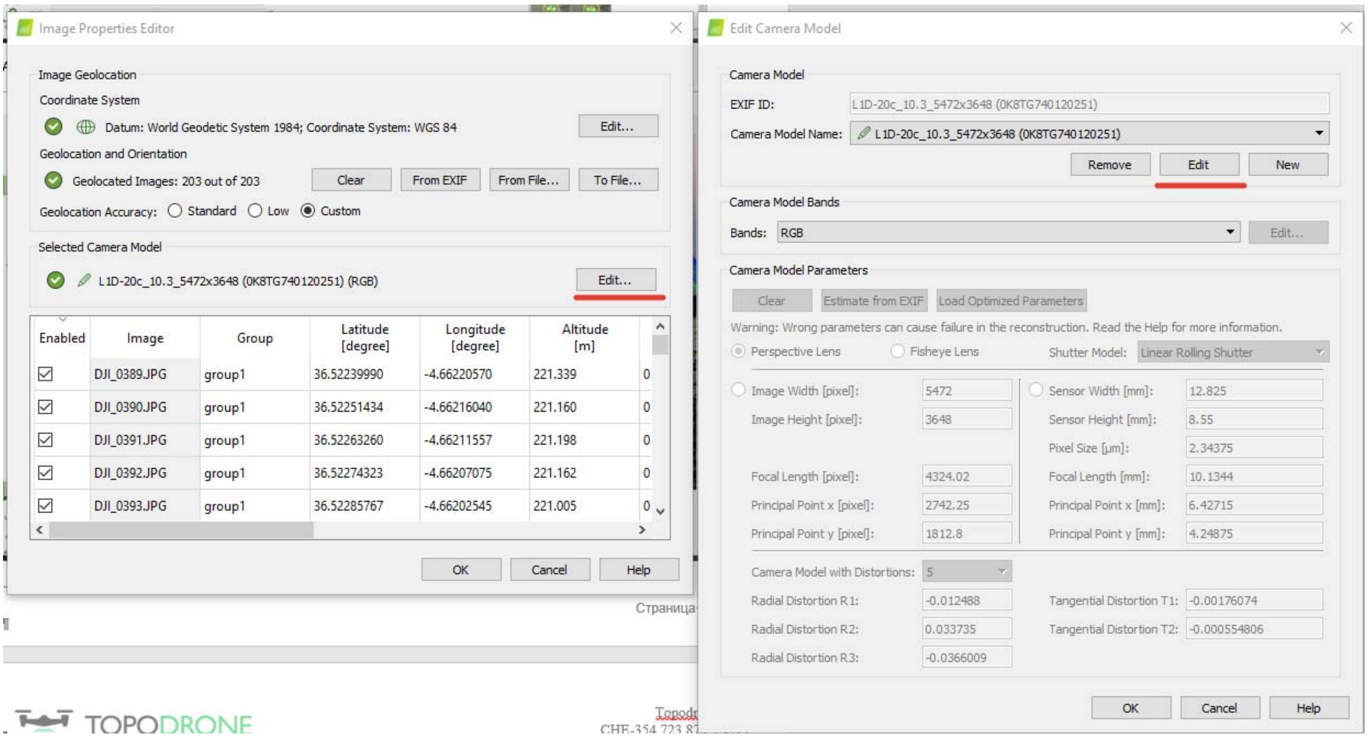
Click Reoptimize button. Click Ok on all warning messages.



After finishing the reoptimization process click the Image property editor button.



Click the Edit camera model buttons in the Image Properties Editor window and in the Edit Camera Model window



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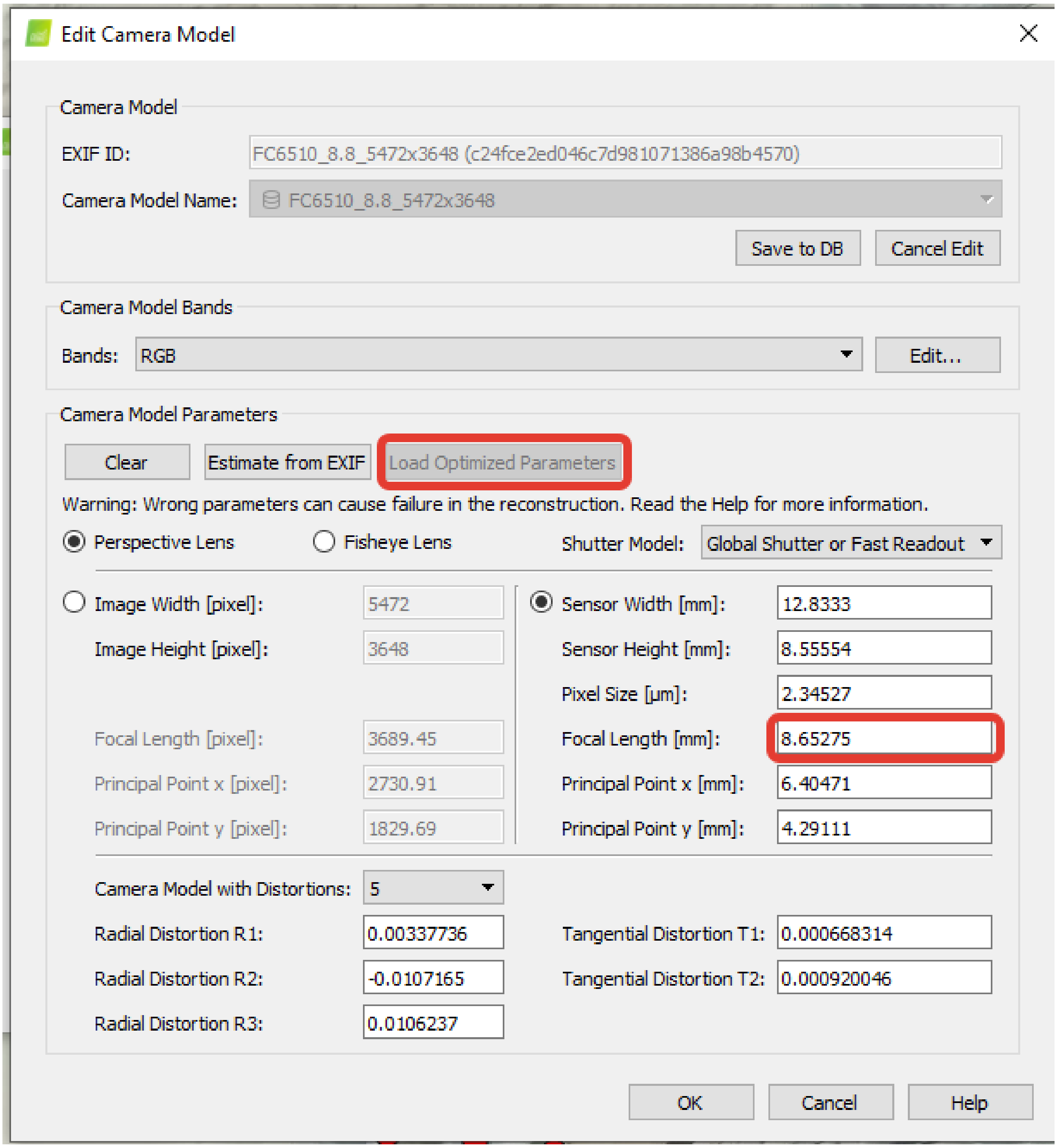
Click Load Optimized parameters. Copy the Focal Length value for the future work.



NOTICE. It will be possible to use the calibrated value of the focal length for the processing if you do not change your focus settings for the future flights.

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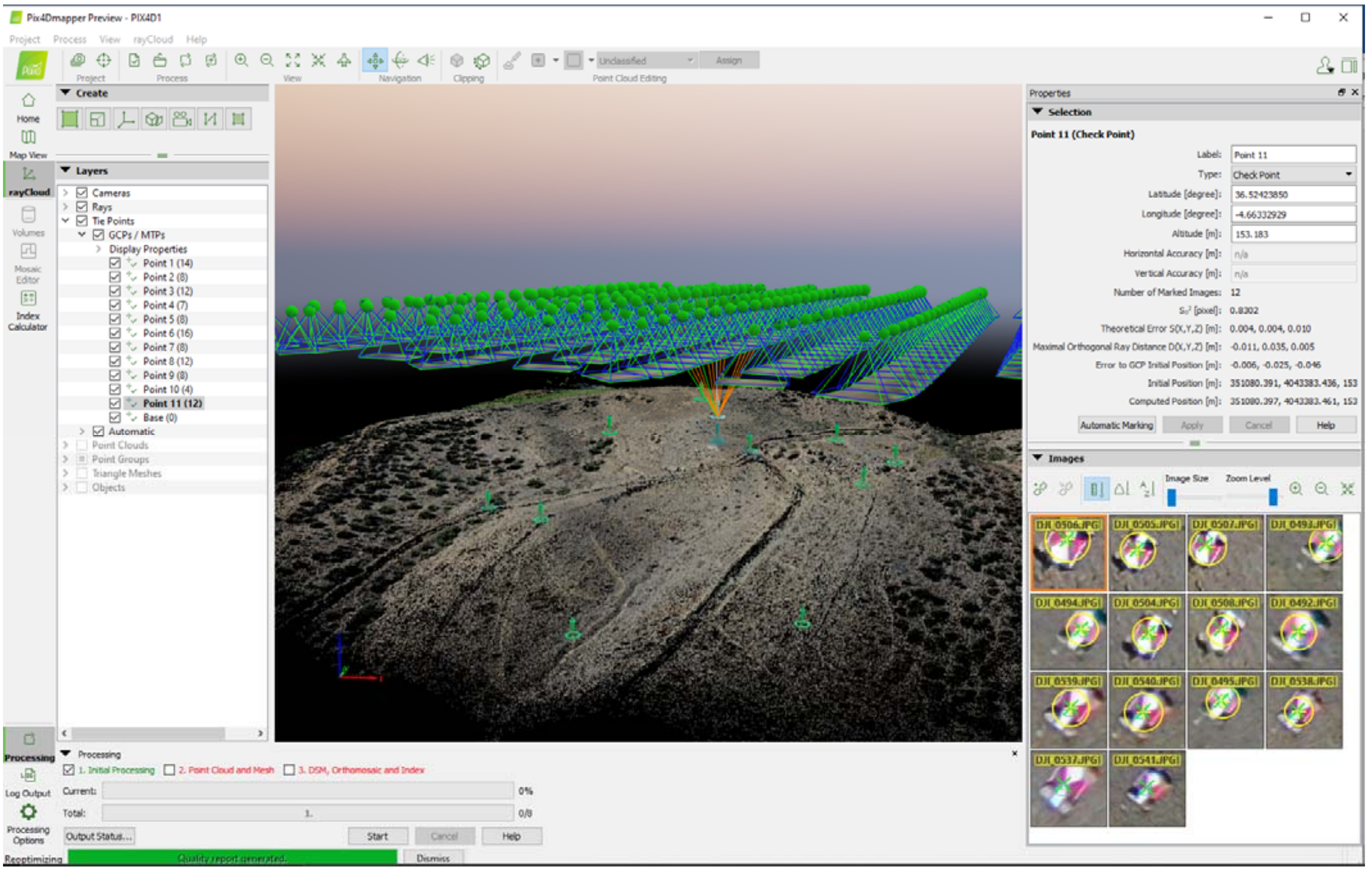
3.4 Accuracy estimating

Load the ground control points. Set them up as check points. Select position of all check points at images to check accuracy.



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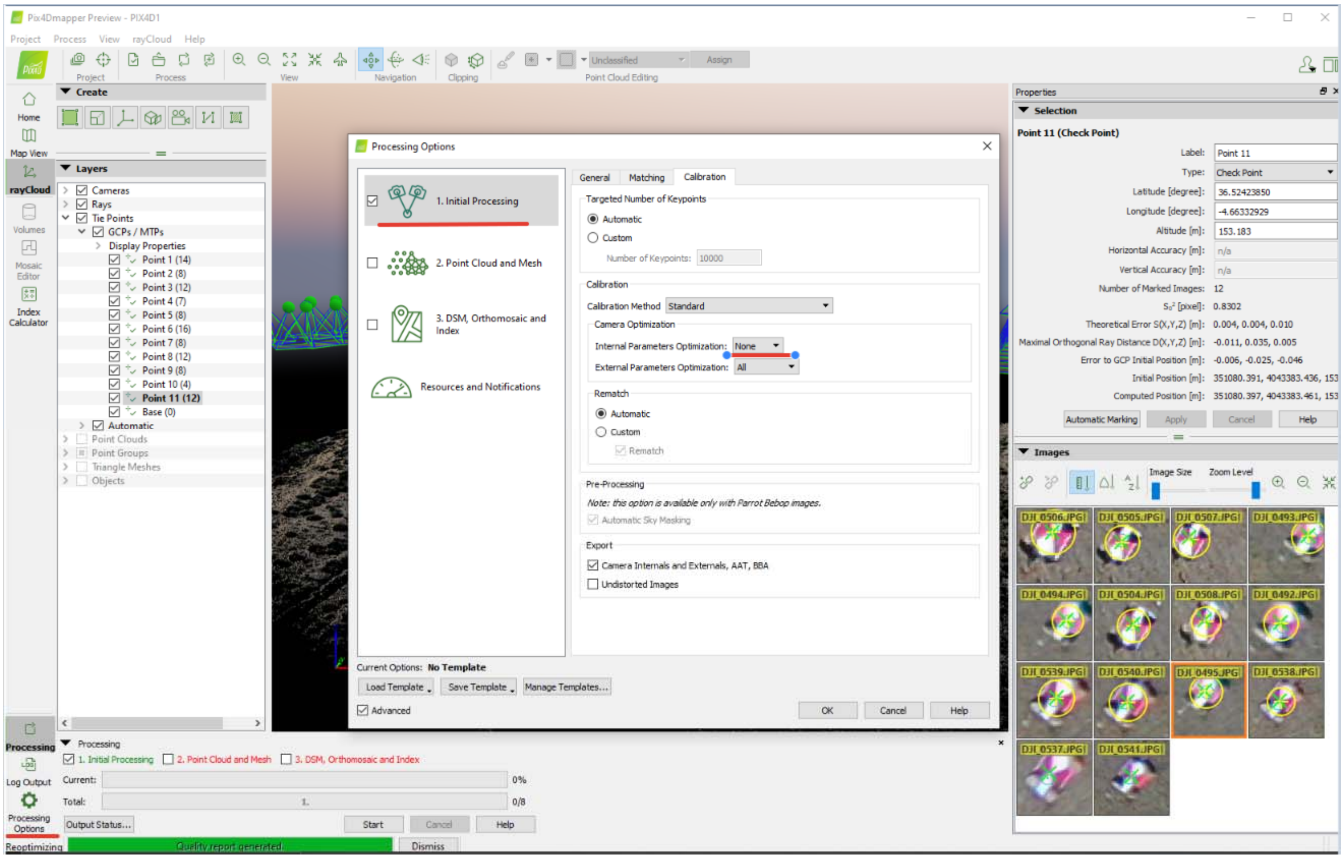
Go to the Processing options menu. Select None for Internal Parameters Optimization. Click Ok. Click Reoptimize.



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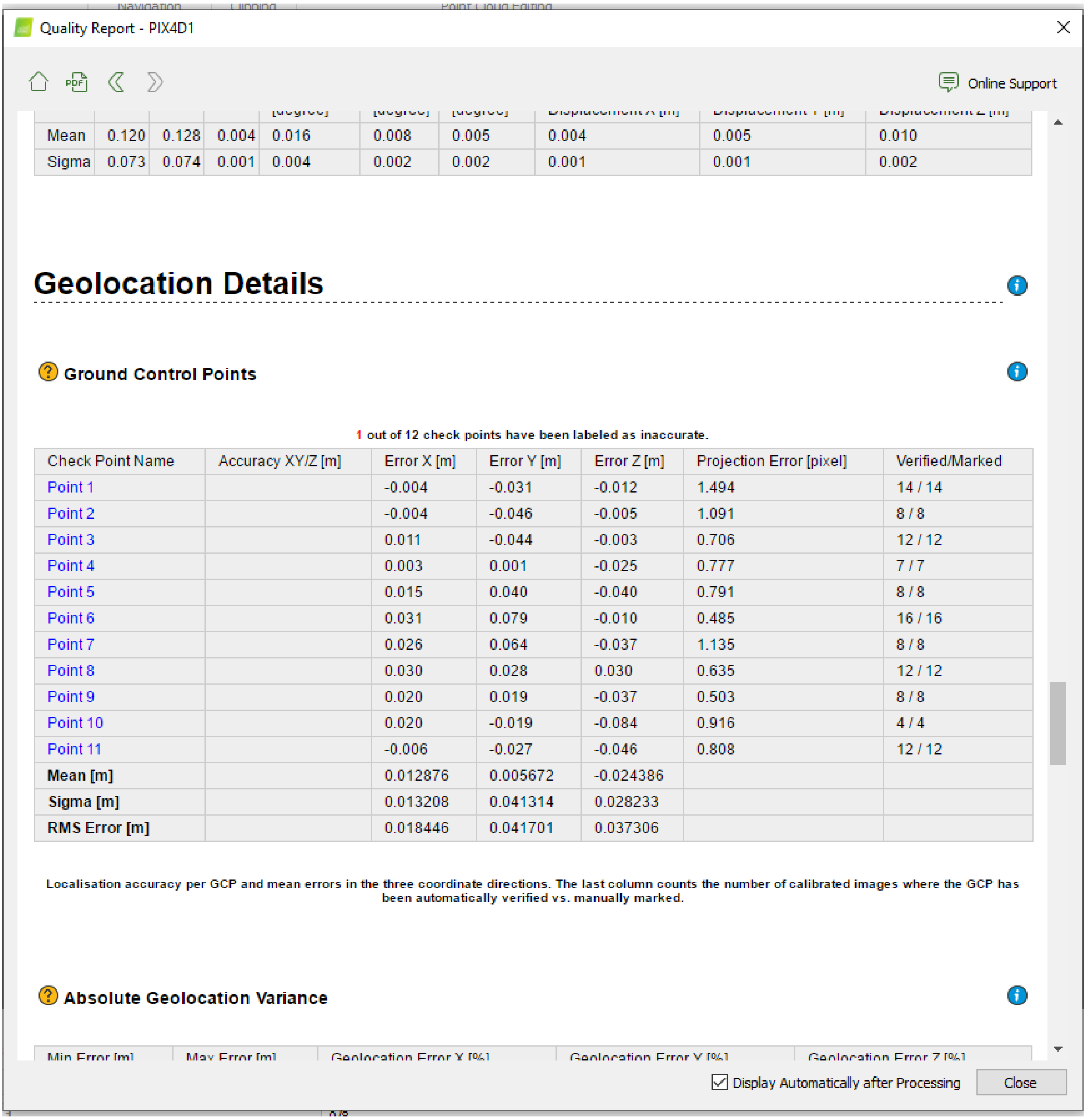
After finishing the optimization process go to Process Menu, click Generate quality report.

Data processing report will be generated. Go to Geolocation Details to estimate the accuracy of the project.


Quality Report - PIX4D1

Online Support

Mean	0.120	0.128	0.004	0.016	0.008	0.005	0.004	0.005	0.010
Sigma	0.073	0.074	0.001	0.004	0.002	0.002	0.001	0.001	0.002

Geolocation Details

Ground Control Points

1 out of 12 check points have been labeled as inaccurate.

Check Point Name	Accuracy XY/Z [m]	Error X [m]	Error Y [m]	Error Z [m]	Projection Error [pixel]	Verified/Marked
Point 1		-0.004	-0.031	-0.012	1.494	14 / 14
Point 2		-0.004	-0.046	-0.005	1.091	8 / 8
Point 3		0.011	-0.044	-0.003	0.706	12 / 12
Point 4		0.003	0.001	-0.025	0.777	7 / 7
Point 5		0.015	0.040	-0.040	0.791	8 / 8
Point 6		0.031	0.079	-0.010	0.485	16 / 16
Point 7		0.026	0.064	-0.037	1.135	8 / 8
Point 8		0.030	0.028	0.030	0.635	12 / 12
Point 9		0.020	0.019	-0.037	0.503	8 / 8
Point 10		0.020	-0.019	-0.084	0.916	4 / 4
Point 11		-0.006	-0.027	-0.046	0.808	12 / 12
Mean [m]		0.012876	0.005672	-0.024386		
Sigma [m]		0.013208	0.041314	0.028233		
RMS Error [m]		0.018446	0.041701	0.037306		

Localisation accuracy per GCP and mean errors in the three coordinate directions. The last column counts the number of calibrated images where the GCP has been automatically verified vs. manually marked.

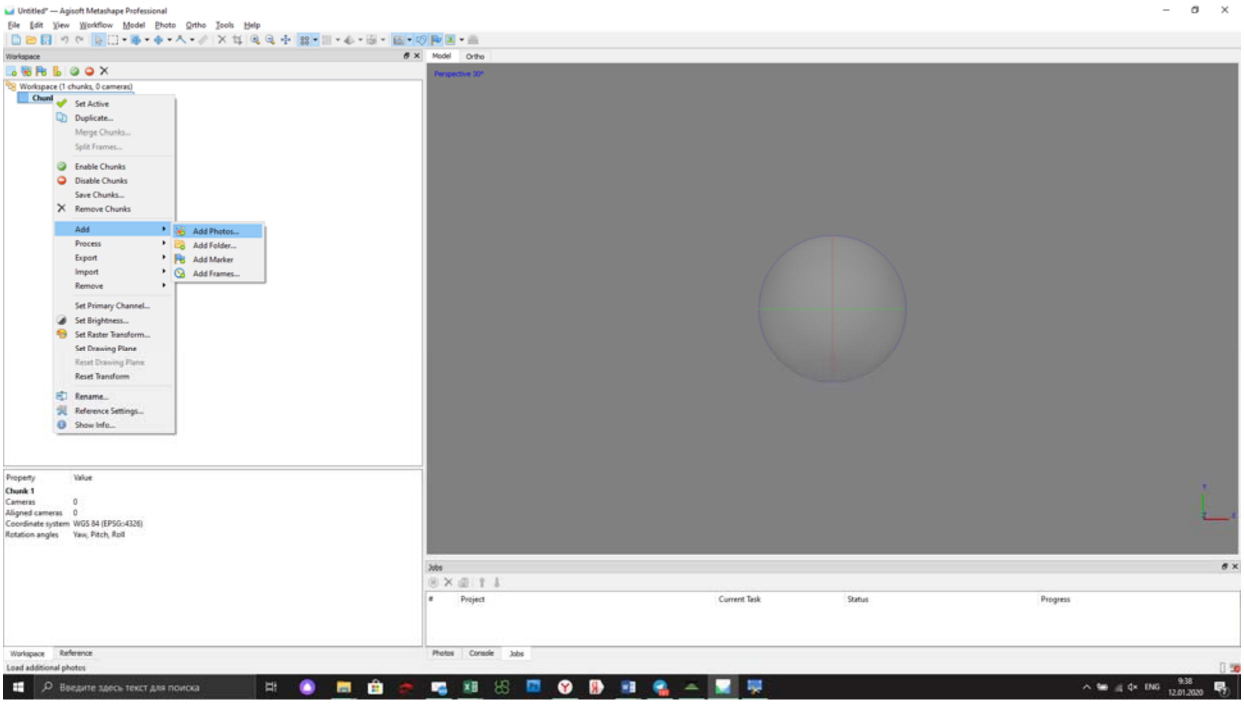
Absolute Geolocation Variance

Display Automatically after Processing Close

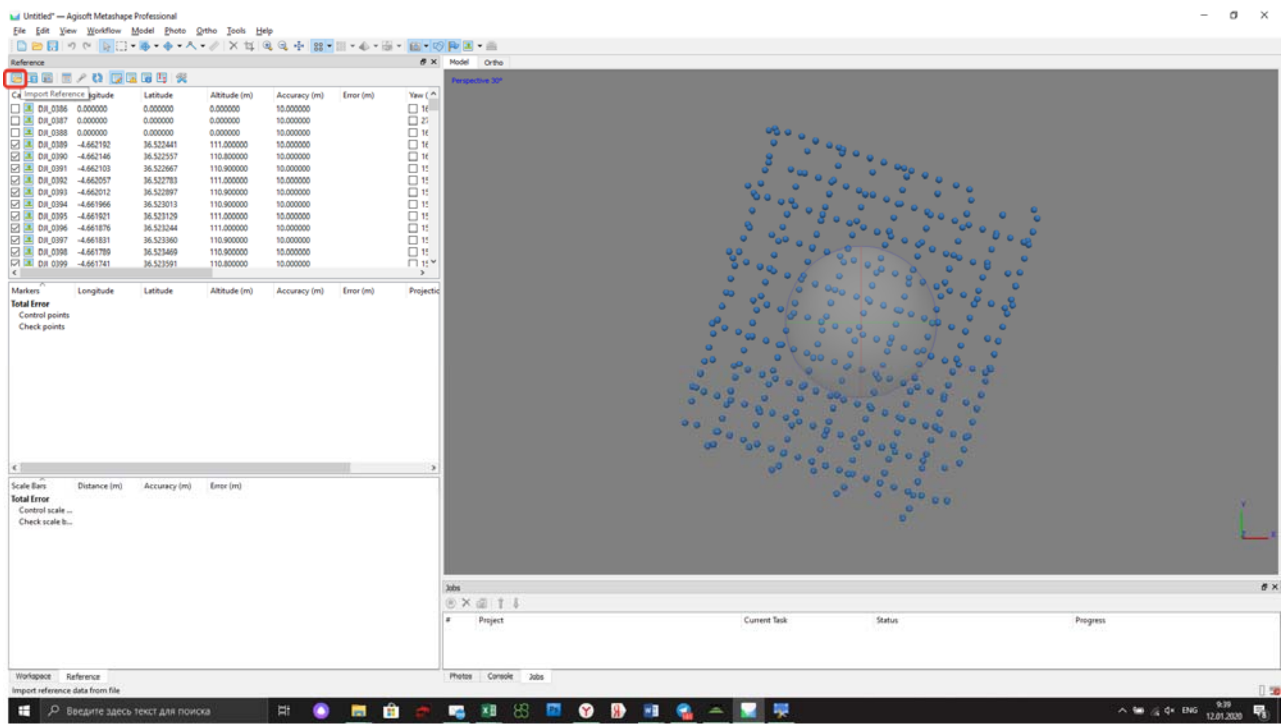
4. PHOTOGRAMMETRY PROCESSING IN AGISOFT METASHAPE SOFTWARE

4.1 Creating a project, photo alignment

The following process should be performed in the Agisoft Metashape software. Add photos to the project.



Import positions from the file coordinates.txt. Go to Reference. Click Import button, select coordinates.txt file from folder with photos



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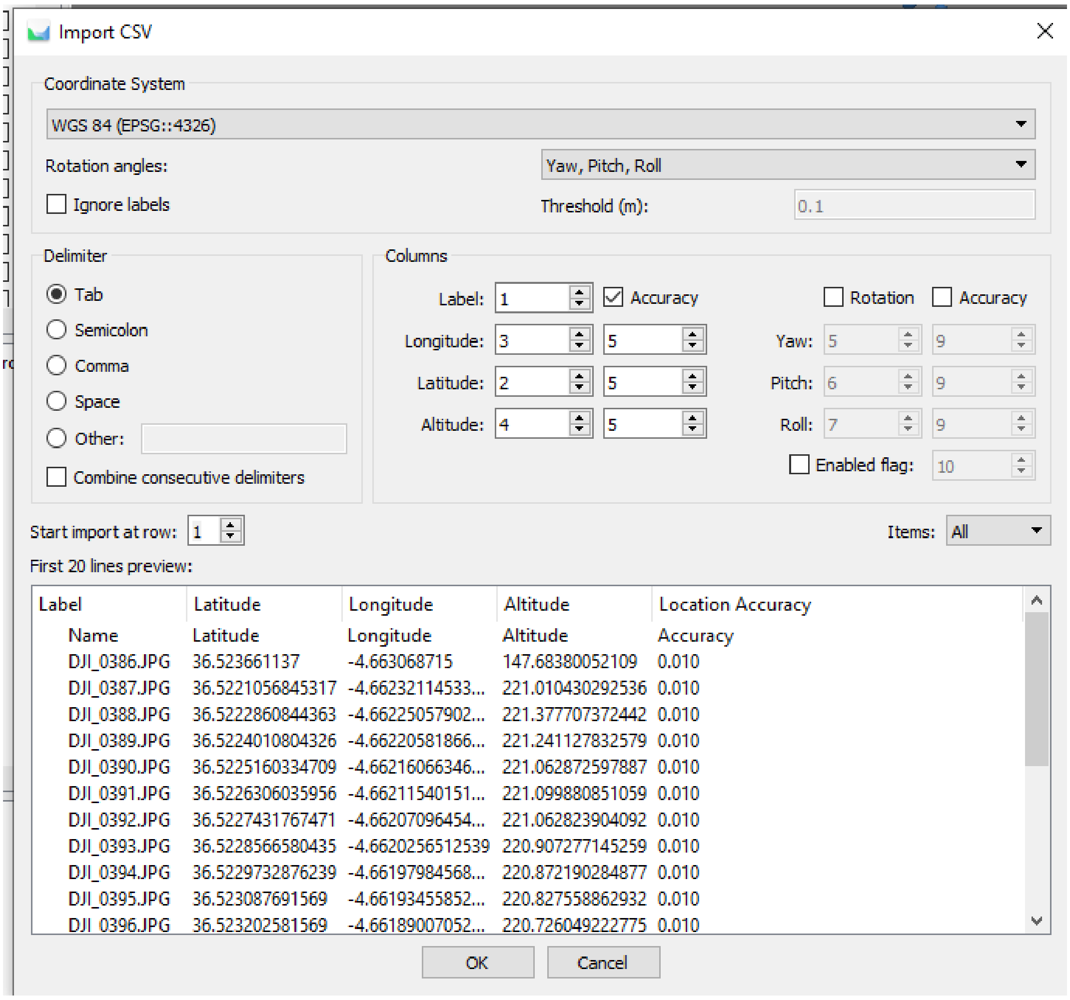
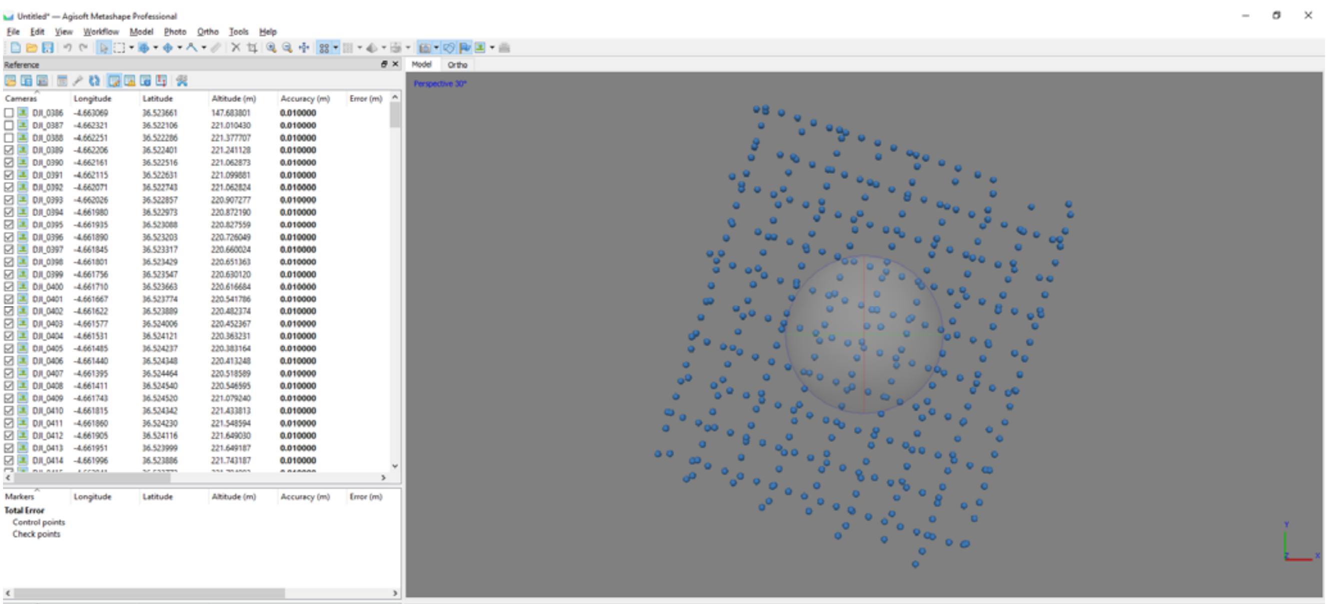
Select WGS 84 coordinate system, setup columns order 1,3,2,4, click Accuracy checkbox, select field 5, click OK



Accurate X,Y,Z coordinates and accuracy values will appear in the Reference window



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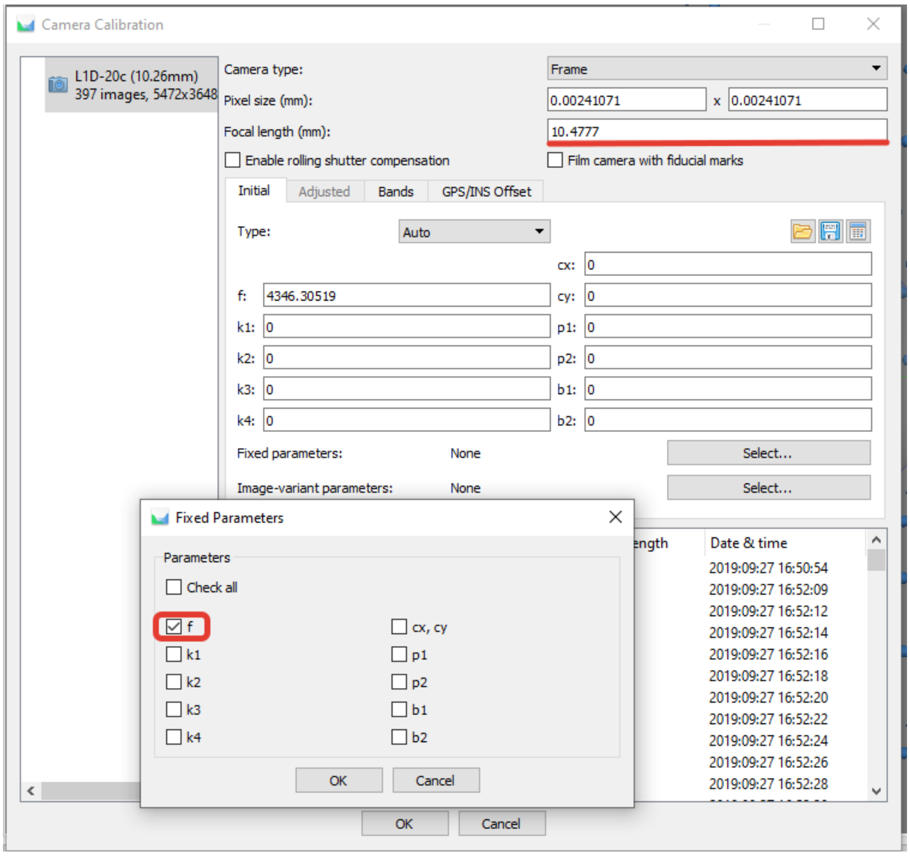
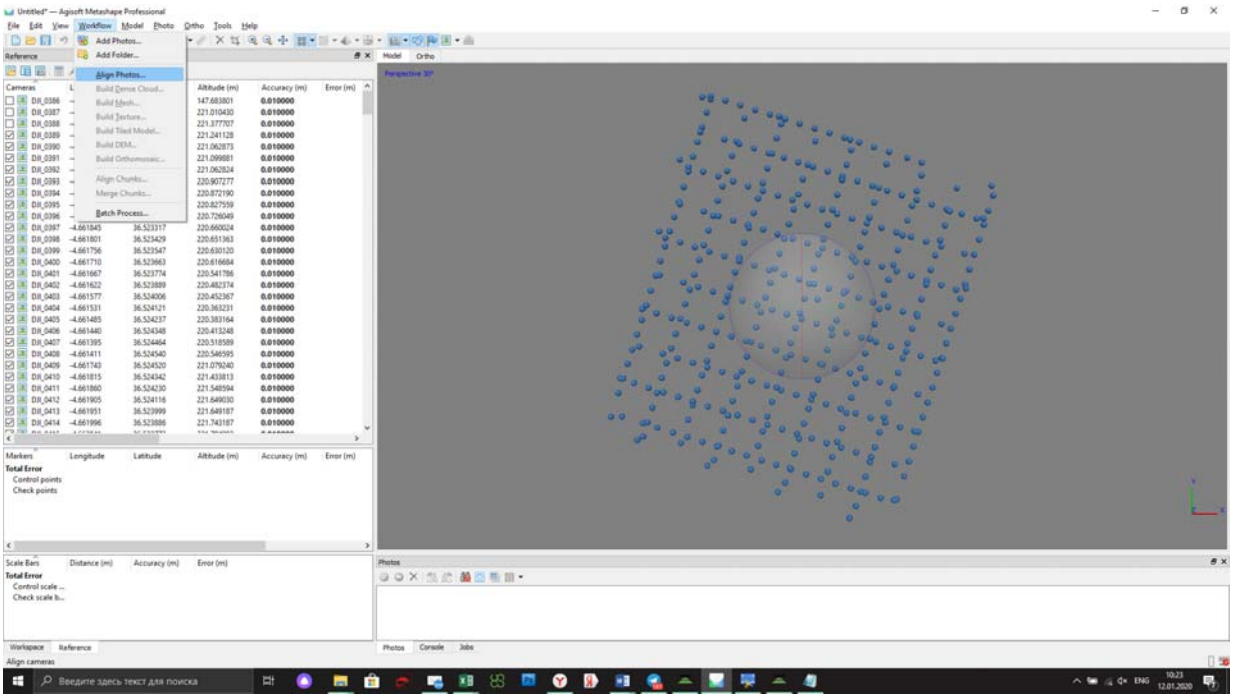
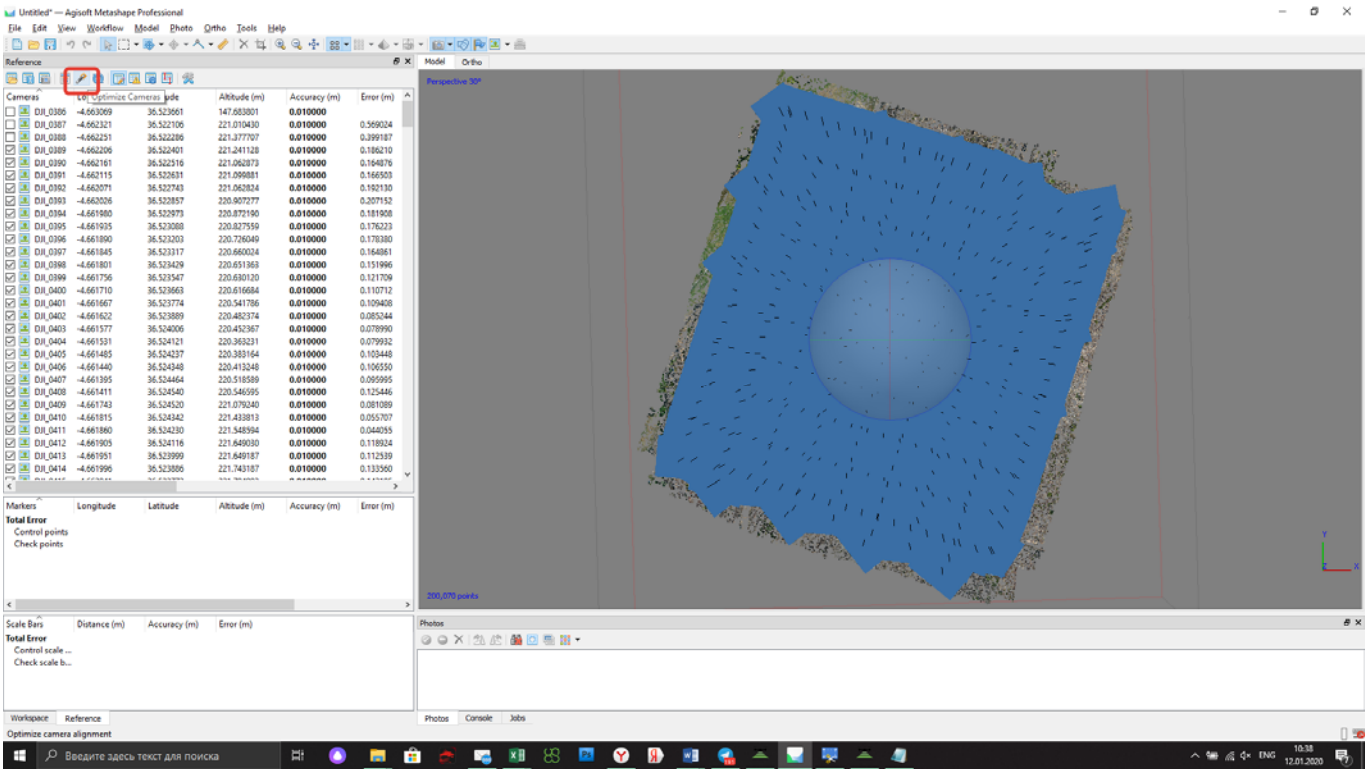
Go to Tools, click Camera calibration and input the calibrated parameter for focal length 10.4777, select fixed F parameter

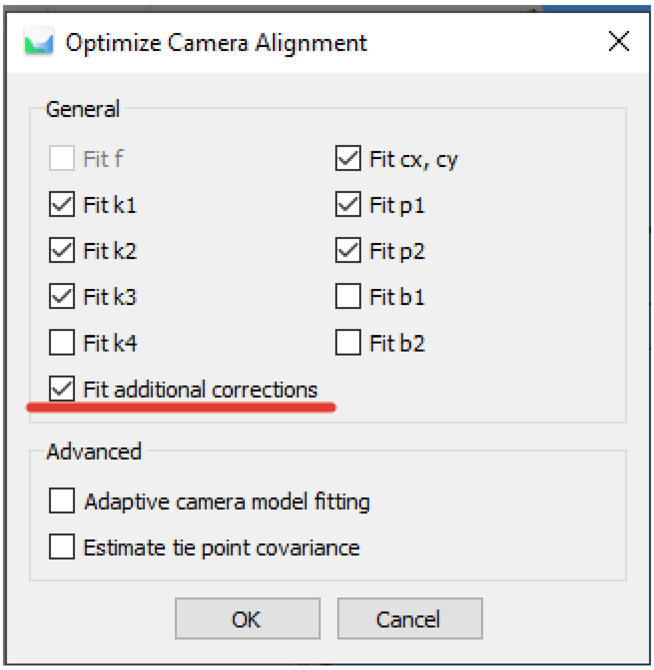


Go to Workflow and click Align Photos for aerial triangulations



After finishing the aerial triangulation go to the Reference, click "Optimize Camera Alignment" and click on Fit additional corrections check box. Click OK.





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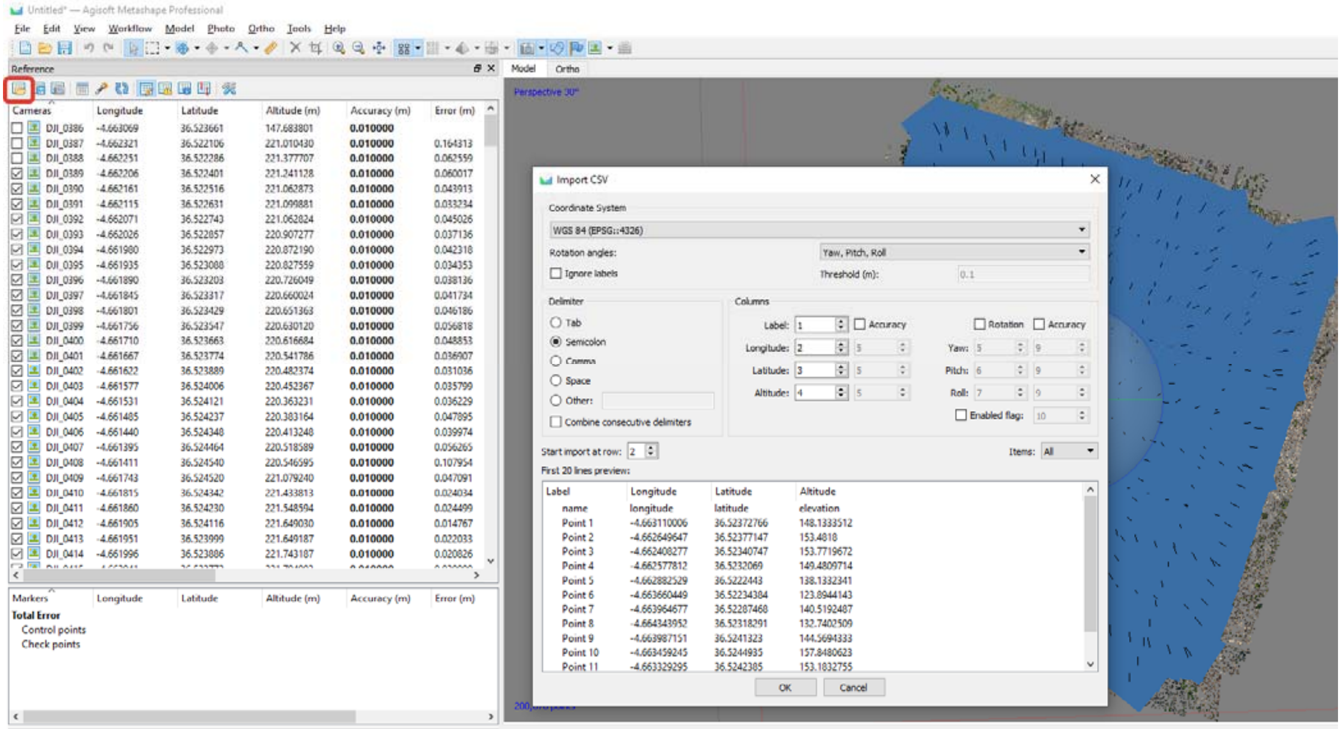
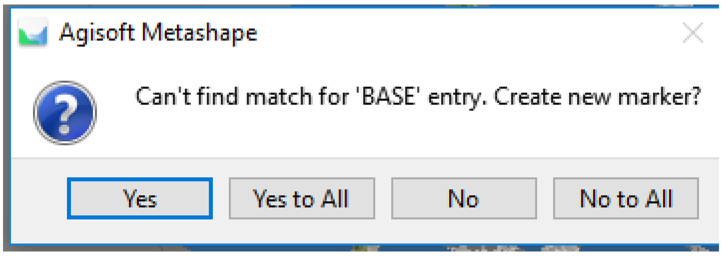
4.2 Accuracy estimating

After finishing the aerial triangulation go to the Reference, click "Import" and load the GCP.txt file. Use the following settings and click OK



Click «Yes to All» button. GCPs will be shown at the Model window.



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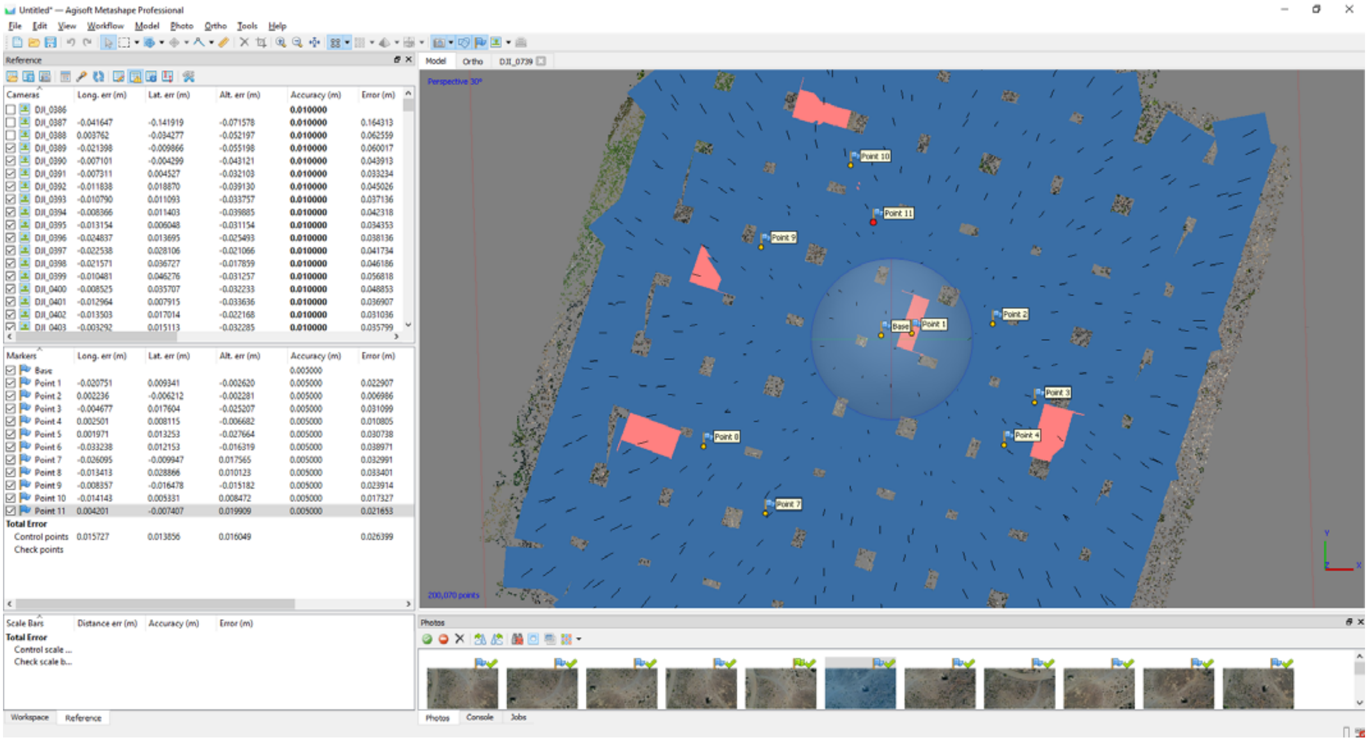
Select the locations of each GCP on photos and look at accuracy report



Markers	Long. err (m)	Lat. err (m)	Alt. err (m)	Accuracy (m)	Error (m)
Base				0.005000	
Point 1	-0.020751	0.009341	-0.002620	0.005000	0.022907
Point 2	0.002236	-0.006212	-0.002281	0.005000	0.006986
Point 3	-0.004677	0.017604	-0.025207	0.005000	0.031099
Point 4	0.002501	0.008115	-0.006682	0.005000	0.010805
Point 5	0.001971	0.013253	-0.027664	0.005000	0.030738
Point 6	-0.033238	0.012153	-0.016319	0.005000	0.038971
Point 7	-0.026095	-0.009947	0.017565	0.005000	0.032991
Point 8	-0.013413	0.028866	0.010123	0.005000	0.033401
Point 9	-0.008357	-0.016478	-0.015182	0.005000	0.023914
Point 10	-0.014143	0.005331	0.008472	0.005000	0.017327
Point 11	0.004201	-0.007407	0.019909	0.005000	0.021653
Total Error					
Control points	0.015727	0.013856	0.016049		0.026399
Check points					

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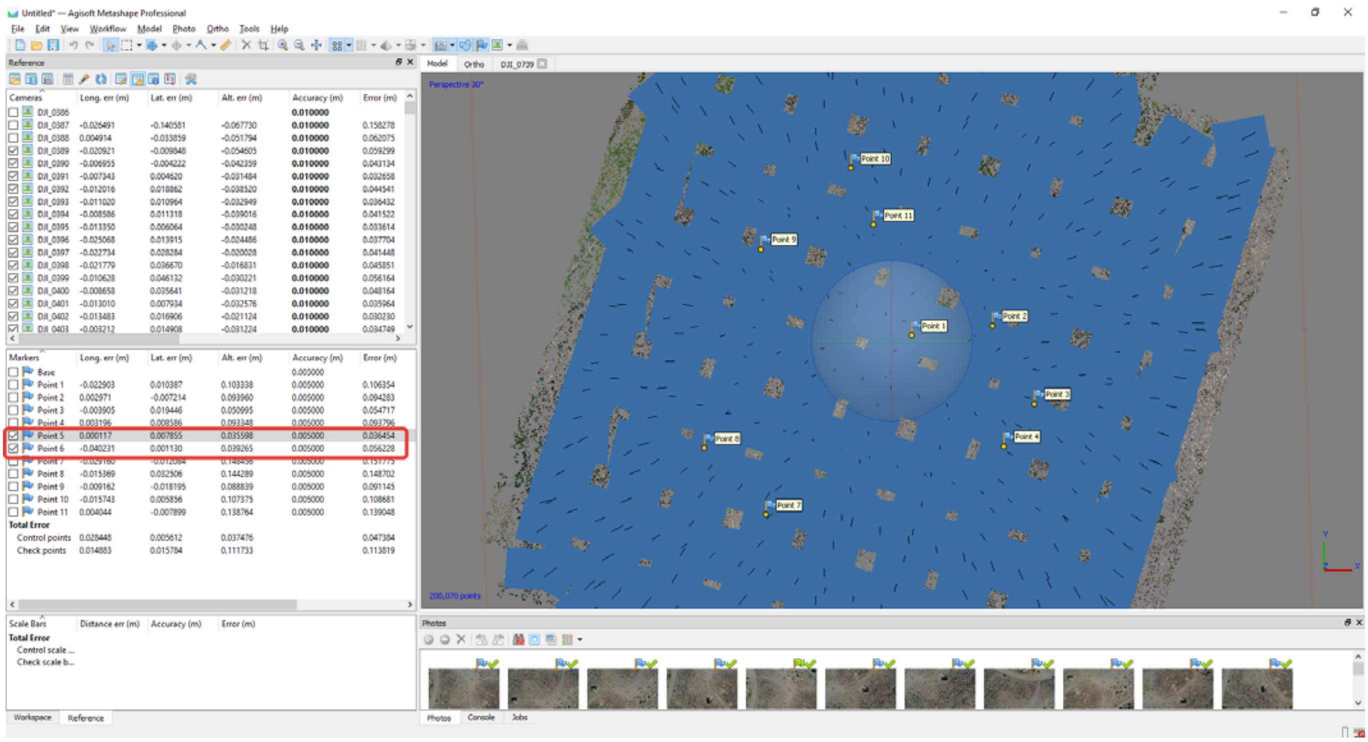
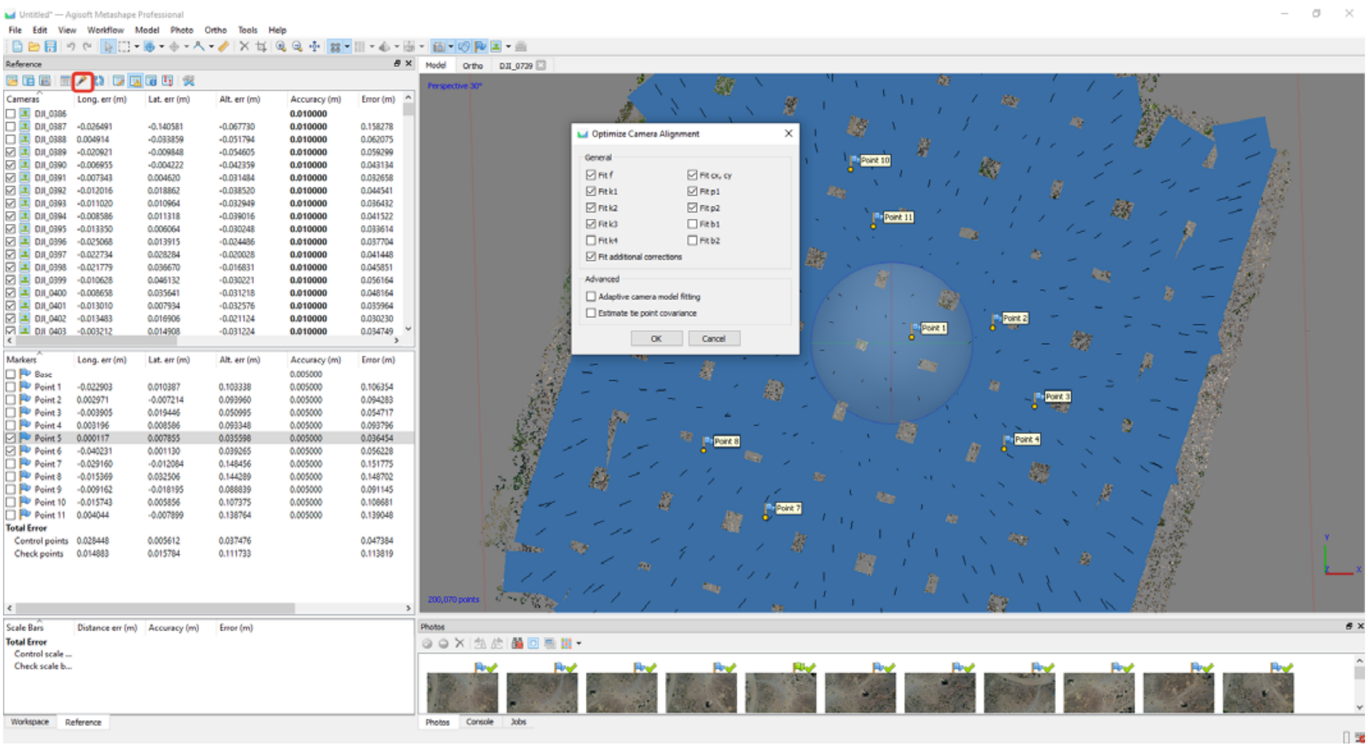
4.3. Camera calibration

To calibrate your camera focal length, load the images, import accurate coordinates of photos, perform the photo alignment (do not fix F parameter) and import the GCPs. Define the position of every marker on each photo. Select 2-3 markers.



Click Optimize camera Alignment, use the following settings and click OK



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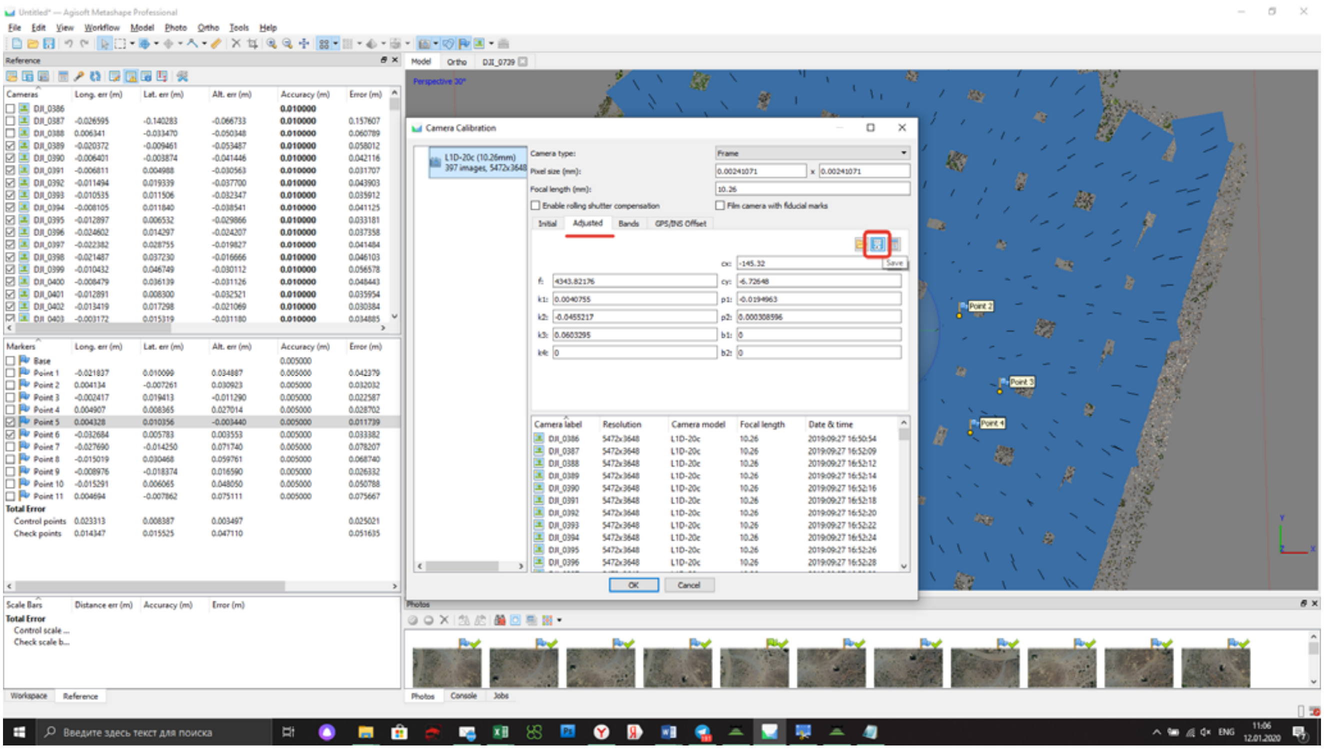
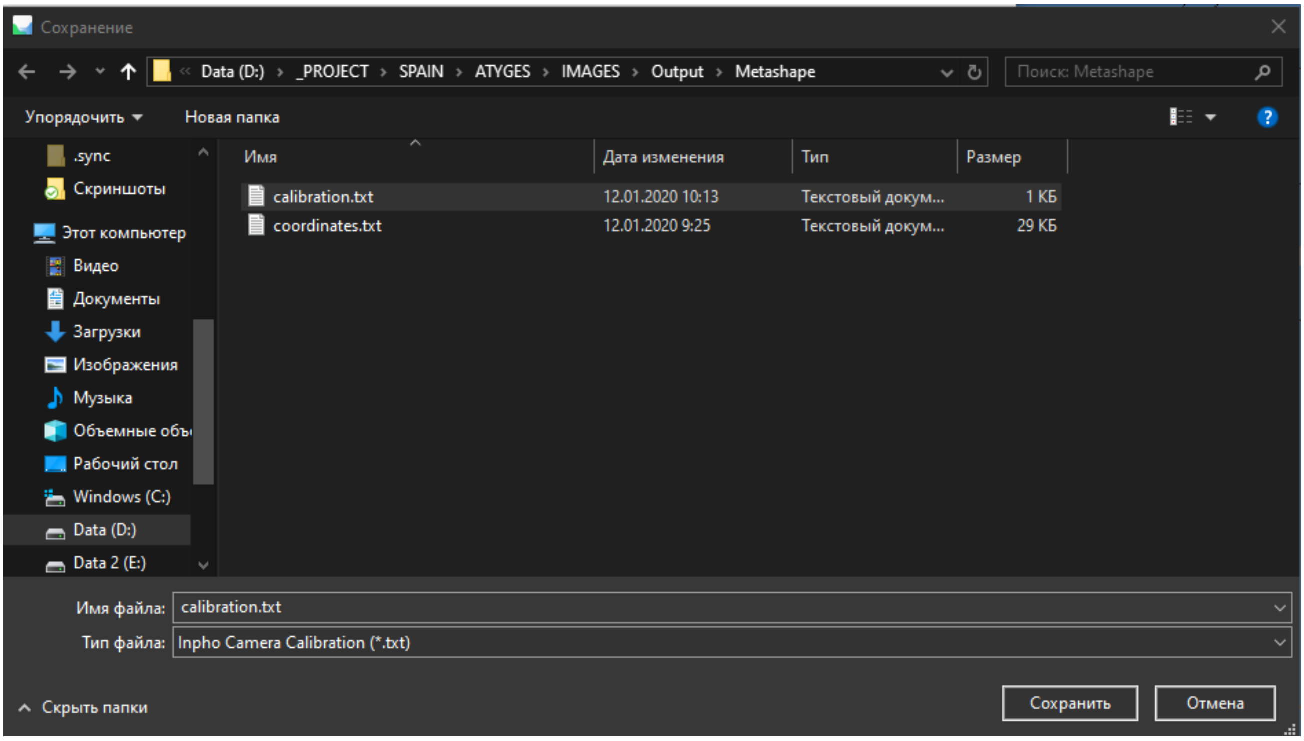
After finishing the aerial triangulation, go to Tools, click Camera calibration. Select adjusted and Save button.



Select Info Camera Calibration format and save file.



Open txt file and copy the focal length value

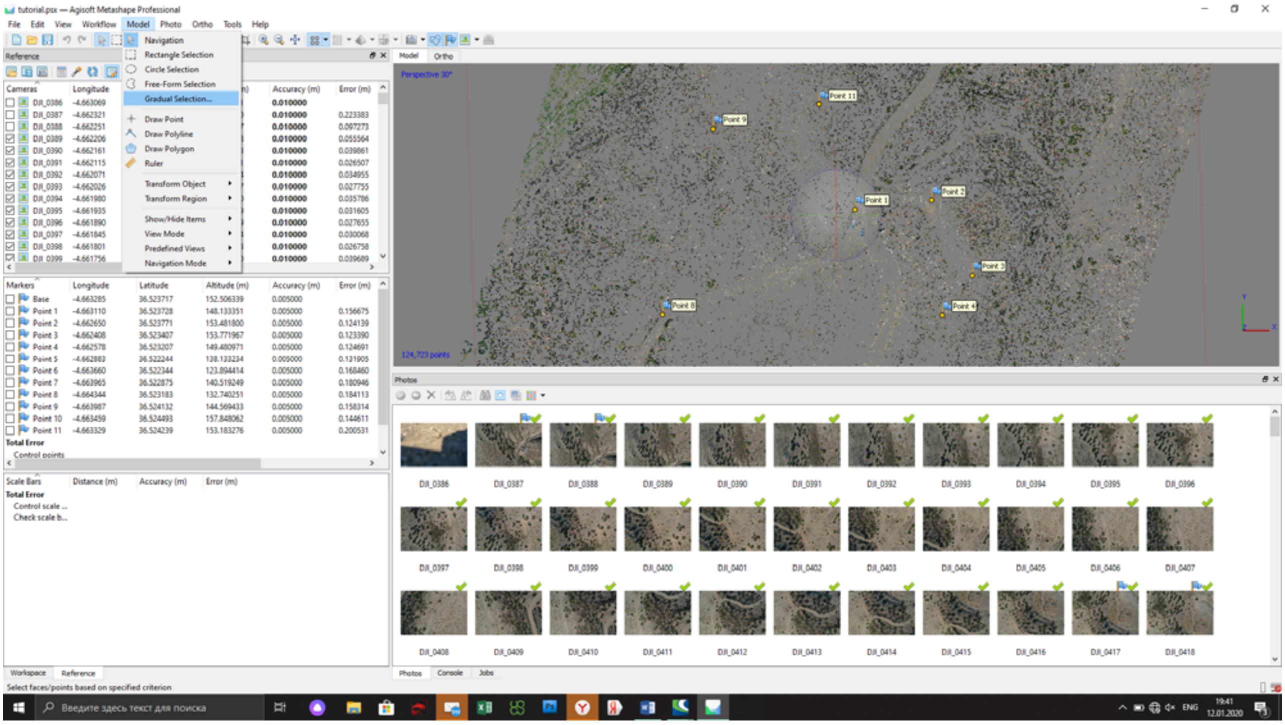
```
$CAMERA
  $TYPE : FC6510_(8.8mm)
  $DATE : 00:30:57 06/11/2019
  $BRAND : Custom
  $KIND : CCDFrame
  $CCD_INTERIOR_ORIENTATION :
     414.545       -0     2723.86
       0.0000000000    -414.545    1821.52
  $CCD_COLUMNS : 5472
  $CCD_ROWS : 3648
  $PIXEL_REFERENCE : CenterTopLeft
  $FOCAL_LENGTH :   8.81713
  $PRINCIPAL_POINT_PPA :     0.000000     0.000000
  $DISTORTION_TYPE :  Polynomial
  $RADIAL_COEFFS :
                    0             5.32009e-005                  -1.30922e-006                  1.72296e-008
                    -6.46663e-012                  0                  0                  0
  $DECENTRE_COEFFS :
                    -5.63946e-005                  5.98996e-008                  0                  0
  $GPS_ANTENNA_OFFSET :     0.000000     0.000000     0.000000
  $CAMERA_MOUNT_ROTATION :     0.000000
```

NOTICE. It will be possible to use the calibrated value of your camera's focal length for the processing in future, if you do not change your focus settings.

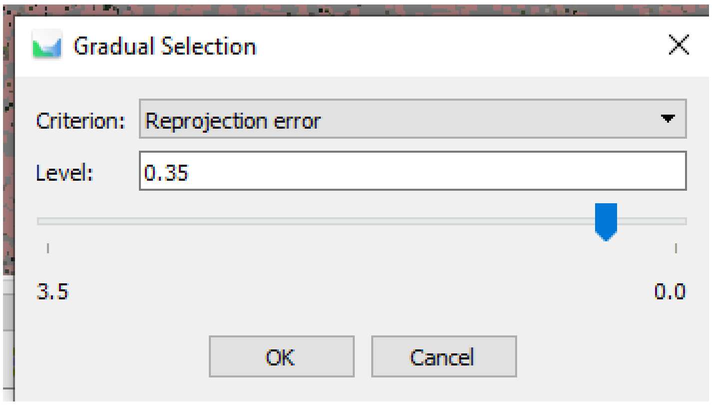
NOTICE. It is possible to use the calibrated value of your camera's focal length for the processing if you do not change focus settings for future flights.

4.4. Aerial triangulation accuracy improvement. Tie points filtering

In order to increase the accuracy of your model, we suggest filtering tie points with the Gradual Selection tool. Open Model menu, click Gradual Selection.



Select Gradual selection and input 0.35 value



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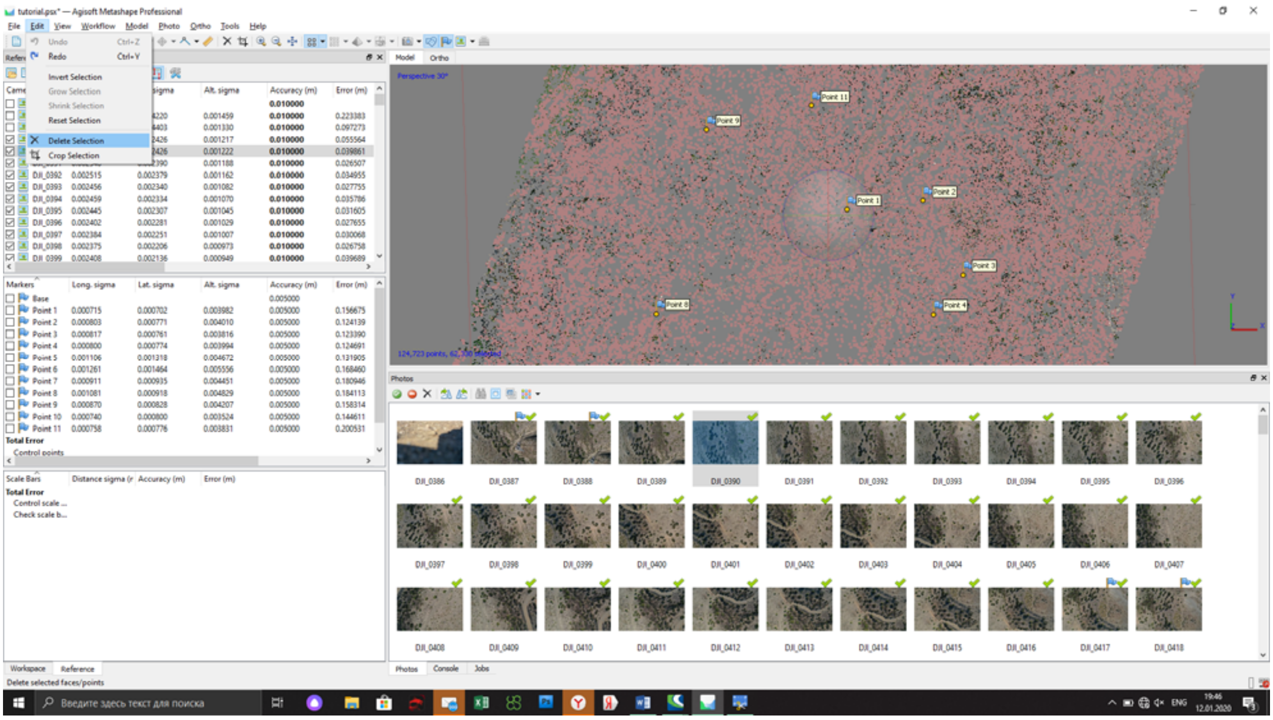
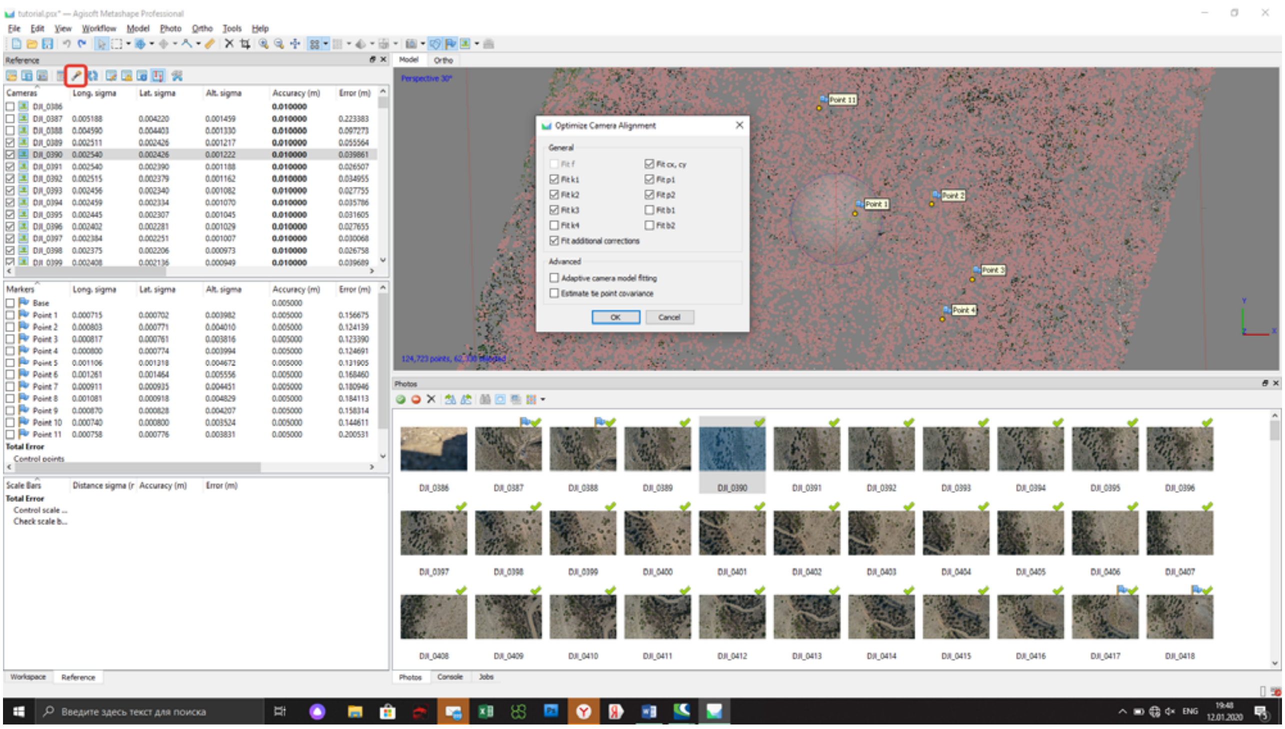
Go to Edit menu and delete the selected points



Click "Optimize Camera Alignment"



Check the accuracy and repeat the steps described above until the Reprojection error reaches 0.65-0.35 value.