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TOPODRONE DJI M200 L1/L2 PPK

USER MANUAL

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1. Drone preparation

1.1 First steps before work

Topodrone DJI Matrice 200 V2 L1/L2 PPK + X4S is a ready-to-fly geodetic survey solution which is based on DJI Matrice 200 V2. It is strongly recommended to learn DJI P4P manual first, you can find it on the official web-site: https://www.dji.com/matrice-200-series-v2/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 all our solution.

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 you had drone in a public use. Always check your Topodrone DJI Matrice 200 V2 L1/L2 RTK/PPK (+X4S) before large orders and far business trips.
2. **Зарядка.** You should charge all batteries of the drone (TB55), remote controller (WB37) and mobile device up to 100%. Never use DJI Intelligent Battery which is charged lower than 90%, especially if battery has started its storage discharging. It can cause premature termination of the flight mission.
3. **Exploring.** Before move to the working area, explore locality in the on-line geo-services like DJI GEO, AirMap, and PilotHub, to provide yourself more knowledge about 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 Pilot[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 changes during the mission planning in the other apps.
    4. RC MODE settings – changes axes of the sticks, value 2 is strongly recommended
    5. EXP tuning – provides you control drone more accurate, 0.10 value is recommended
    6. RC signal lost – action which drone would make if lost RC signal. Value “Return to home” is recommended
    7. Low battery warning – 30% value is recommended[3]

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

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1.2 Compass calibration.

As the basic model, Topodrone DJI Matrice 200 V2 L1/L2 RTK/PPK (+X4S) 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, accelerometer and compass makes two rotations in different axes. After that, drone makes adjustment between values of each sensors. To make correct CC follow next steps:

1. CC makes directly before flight at the open outdoor area. Making CC indoor is useless
2. It is allowed to make DJI M200 V2 compass calibration when the DJI X4S gimbal is removed.
3. Turn on the drone and RC, insert and plug the mobile device.
4. Make sure, there are no large metal constructions or magnetic fields sources in 50 meters.
5. Enter drone into CC mode. At least there are two ways:
   a) In the DJI Pilot 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 A positions not less than 4 times.

6. Ensure that rear LEDs of the drone lights solid yellow.
7. Put RC to the ground and take the drone with both hands. Hold drone for it's arms horizontally. Do not change the orientation of the drone!
8. Rotate drone to the left side (counter-clock wise) in 380 degrees (a bit more than 360 degrees). Stop when the rear LEDs will change color from solid yellow to solid green.
9. Change orientation of the drone, turning it in 90 degrees in a longitudinal axis.

10. Rotate drone to the left side (counter-clock wise) in 380 degrees (a bit more than 360 degrees). Stop when the rear LEDs will change color from solid green to blinking green.
11. If using 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 Pilot App – it should be at the green zone after CC. If the app notice you compass calibration failed (rear LEDs blinks red rapidly) – recalibrate compass at another place nearby.

Notice 1: no magnetic or ferromagnetic objects on the body of pilot are allowed. For example: massive jewelry, metal inserts or magnets in the end 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 increase flight stability of the drone during the flight. But compass error can appear even after absolutely correct calibration. It usually caused by different external interferences such are metal objects, large antennas, electricity transmission lines (ETL).

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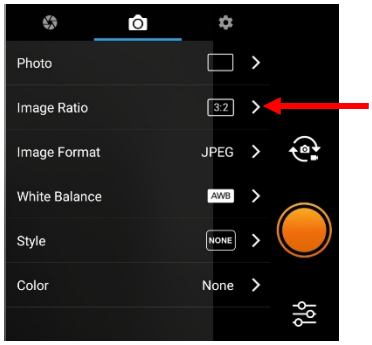
1.3. Camera calibration and settings

Before the shooting process will be started, you should calibrate focus of your DJI X4S camera and set optimal image settings. It is recommended to use next order.

Before the shooting process will be started, you should calibrate focus of your DJI X4S PPK camera and set optimal image settings. It is recommended to use next order.



1. You should determine 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 is from 60 to 120 meters.

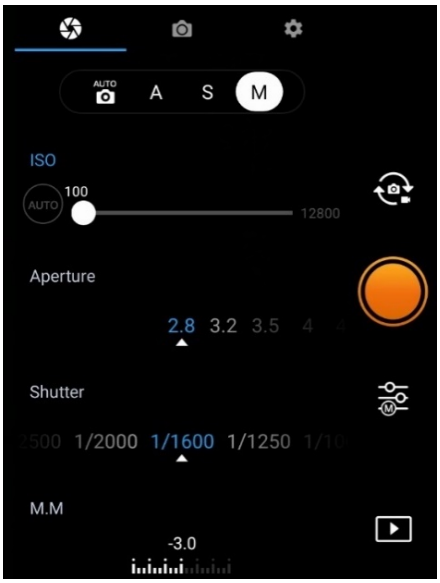
2. Set correct image ratio. Go to the image menu, tap the second tab. Use the Image Ratio 3:2 value, it allows to use all square of camera's matrix. Do not use 16:9 Ratio! Check another values of this menu – all defaults.

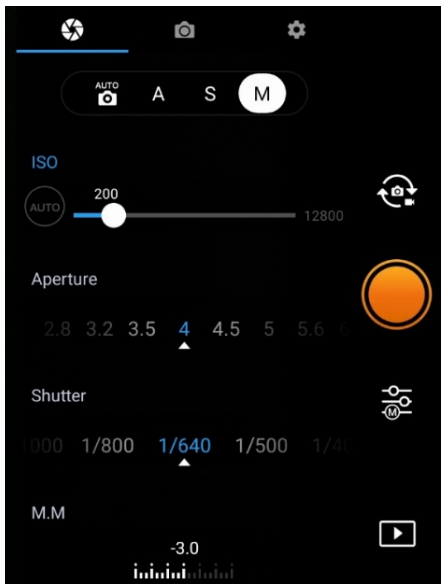
3. Lift off the drone to the working altitude and move gimbal to the 90 degrees (nadir). Ensure that focusing method now is in the AF value. Then tap to the center of the screen to let the camera focusing at the surface. After that change focusing method in the MF value - manual focus scale will appear.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

4. Now it's time to set the best camera settings. All parameters are at auto as default. In this case, drone will change image brightness, smoothness during the flight. But this way is bad for triangulation image processing: 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 100 to 200. Upper values increase image noise, and decrease ortophoto map quality
   Aperture: from 2.8 to 4. Upper values decrease stream of light, so images will be darker
   Shutter: from 1/1600 to 1/640**.** Upper values increase image motion blur**,** lower ones does not allow the camera to use mechanical shutter, so images will be distorced.

   Shutter value higher than 1/1600 will not allow to mark GNSS tags!!!





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1.4. IMU calibration and settings

IMU calibration needs very rarely. However, some things can affect the sensor states: falls and bumps, temperature changes and long stand by time. Because of use the additional module upper the shell of Topodrone DJI Matrice 200 V2 L1/L2 RTK/PPK, the process of IMU calibration is not the same as the default. To calibrate IMU you need to do next:

1. Remove props from the motors if needed
2. Remove gimbal from the drone (recommended)
3. Turn on the drone and the remote controller
4. Prepare a flat solid table, the horizon should be aligned to the bubble level
5. Start the IMU calibration process and make steps 1-5 as they are.
6. At step 6 you should place the drone head over heels. Fold the GNSS antenna to transport position. Place your drone like at the photo below (landing gears removed for a clarity)

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

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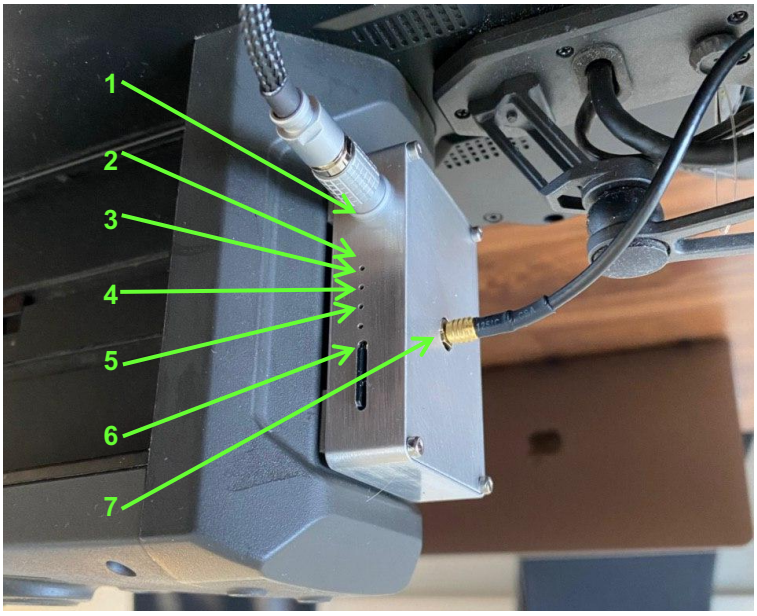
1.5. Устройство и настройки GNSS приемника

GNSS module locates in the front of the DJI M200 battery module in special metall shell. The receivers body has four LED indicators, two cable ports and micro-SD socket.



1. Cable of the GNSS receiver module and the modified DJI x4s suspension
2. Green LED. Notifies that the module has received power.
3. Orange LED. Shows the state of writing to the memory card. It blinks rapidly during recording. Each blink responds to a record of 4 KB of data.
4. Blue LED. Reports the quality of the GNSS antenna signal:

LED State	Description
Off	PDOP>10
Blinks slowly	3<PDOP<10
Blinks rapidly	2<PDOP<3
Solid	PDOP<2

5. Red LED. Shows the critical of errors in the system. If an error occurs, check the memory card. If replacing or reconnecting/formatting the micro-SD card does not solve the problem, contact customer support.
6. Micro-SD card socket.
7. Coaxial cable of the GNSS antenna.

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 creates only after GNSS catched 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.

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2. GNSS DATA POST PROCESSING AND IMAGES GEOTAGGING

2.1 Data preparation

Remove SD card with images from a drone and copy photos to your computer.
Divide a whole images dataset to 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 SD card from GNSS receiver installed on the drone and copy ubx files to your computer to a folder ROVER (for example).

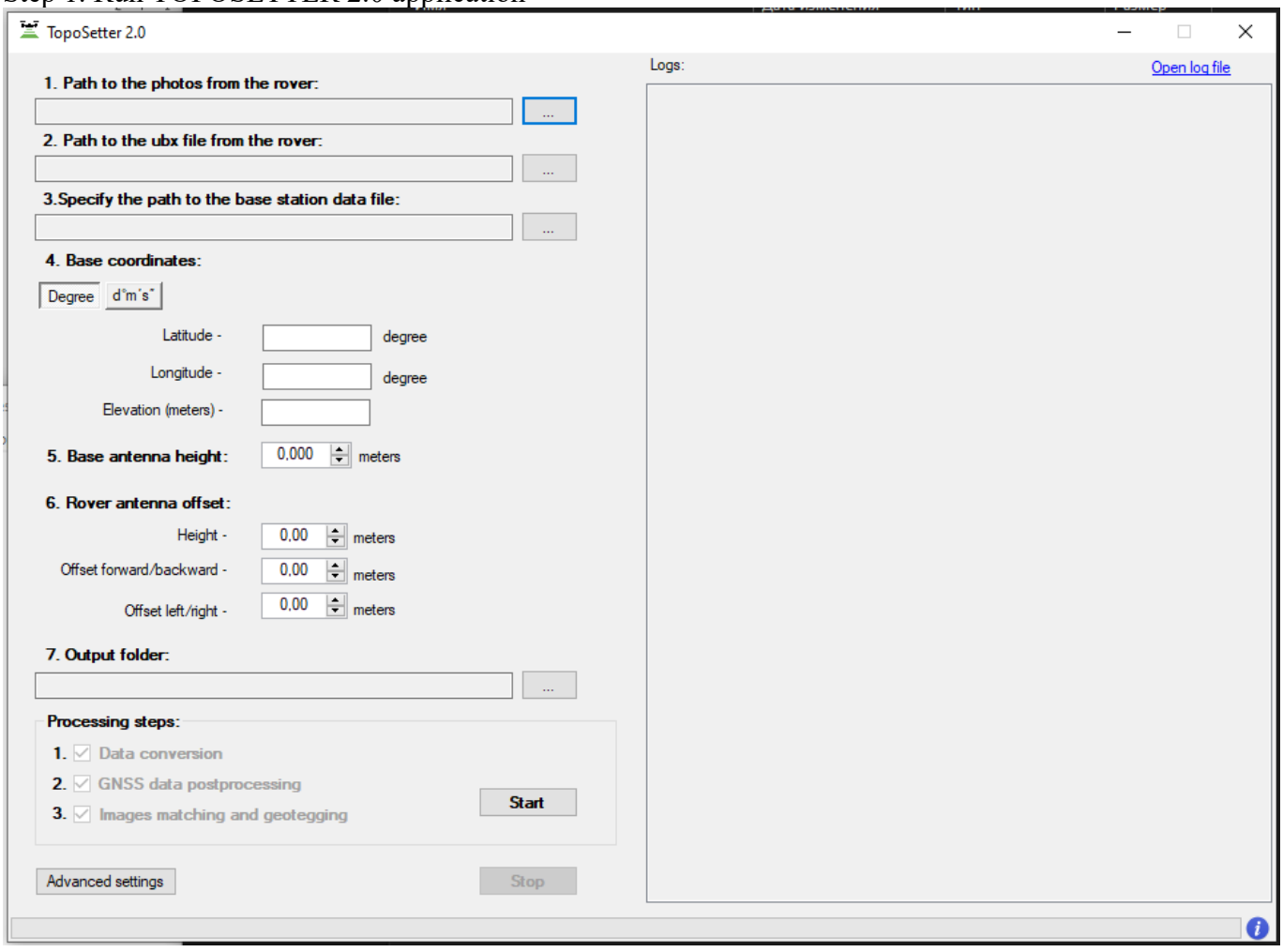
Download GNSS static logs from a base station and convert them to Rinex format. Copy Rinex files to a folder BASE (for example)

Mesure 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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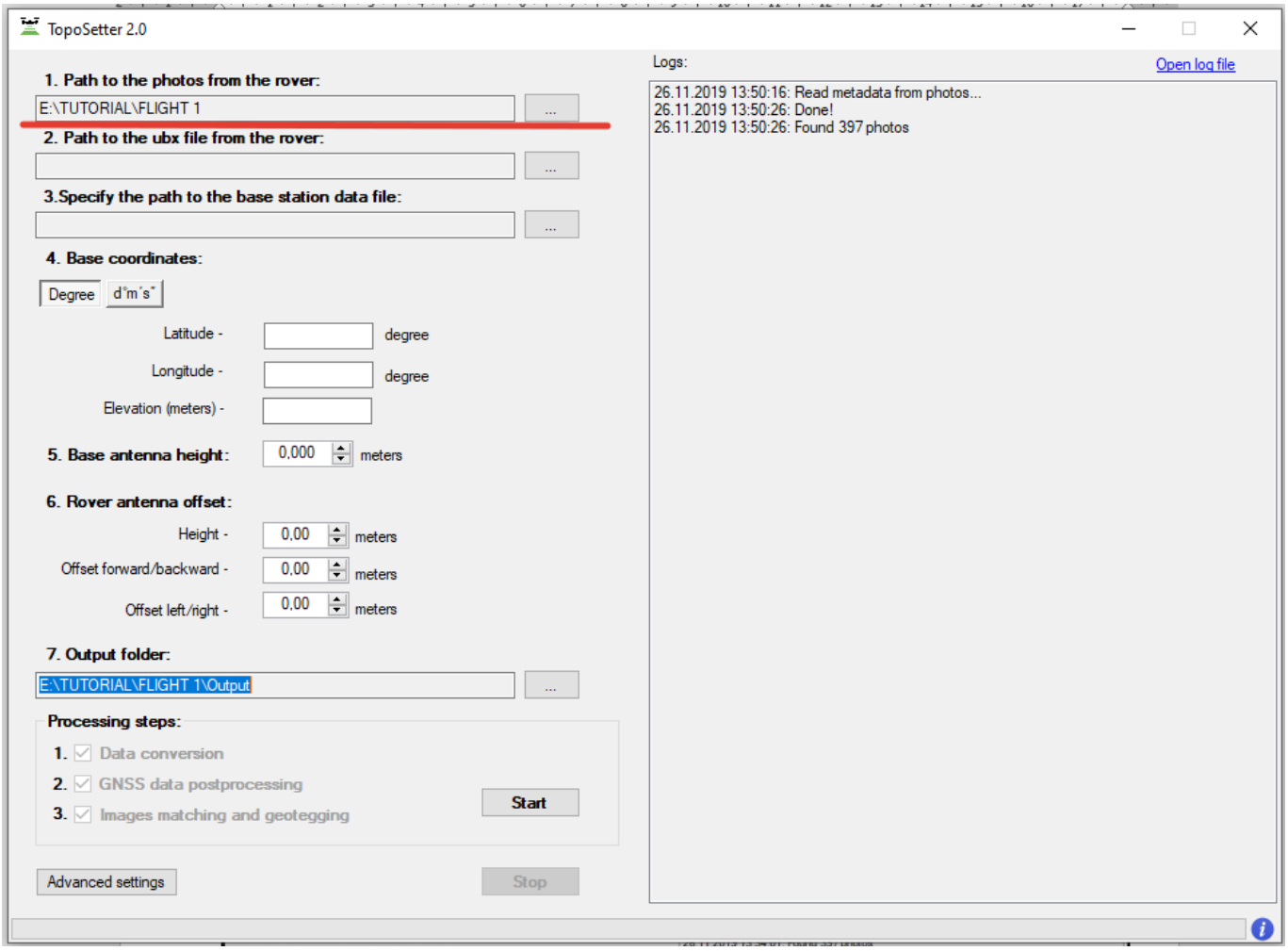
Step 2. Select folder with photos



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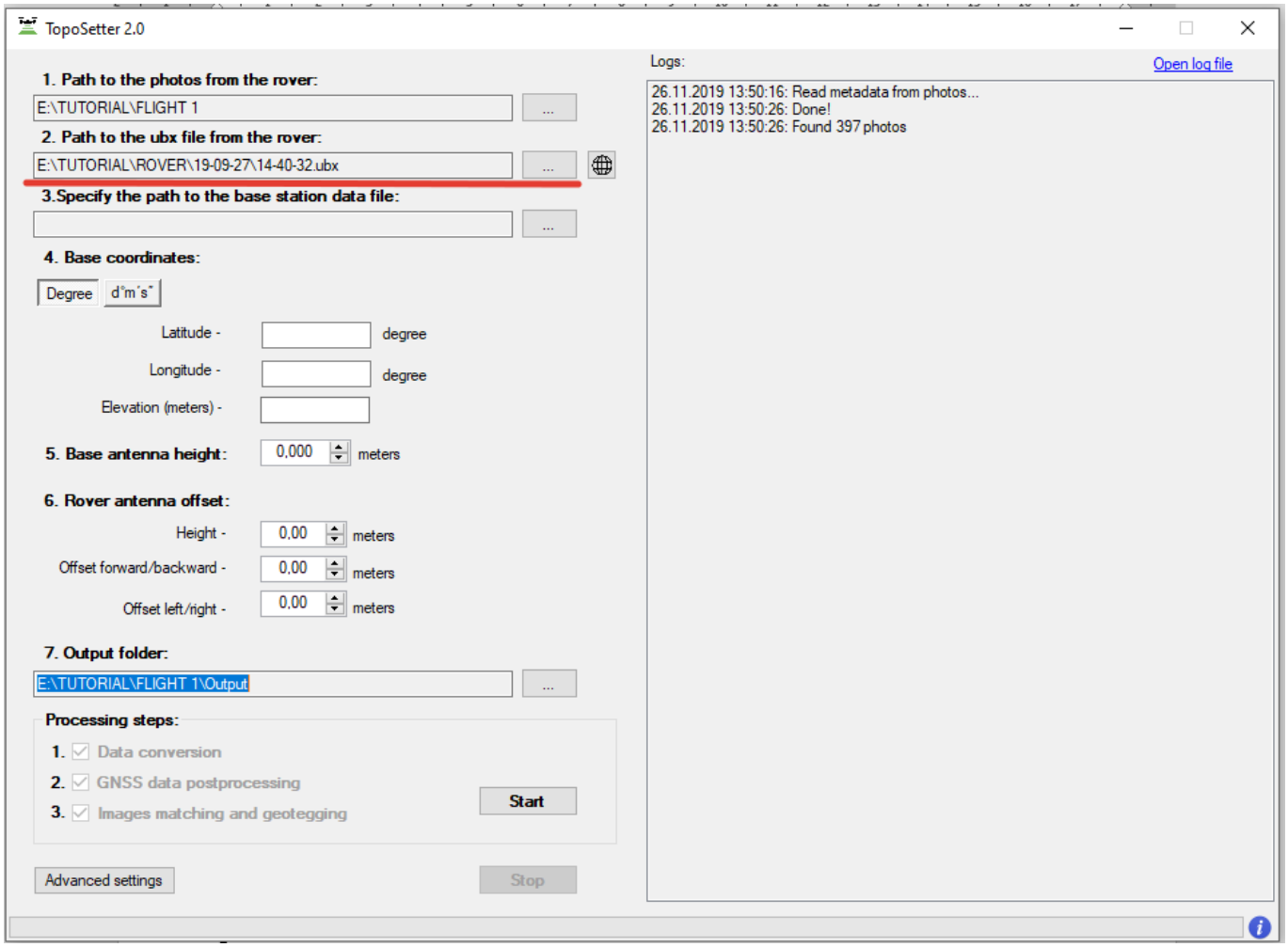
Step 3. Select UBX file from a drone



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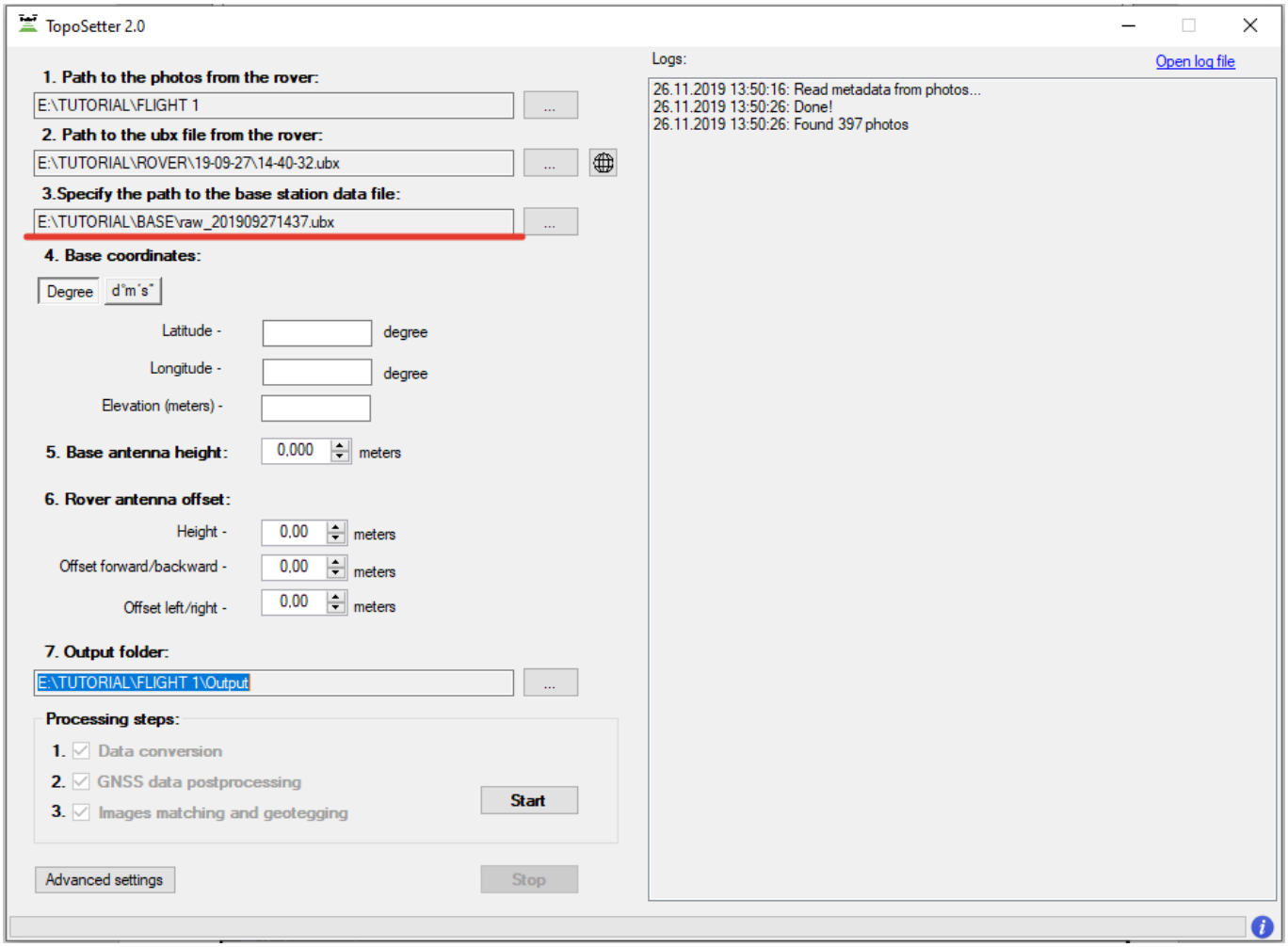
Step 4. Select Rinex or UBX file from a base station



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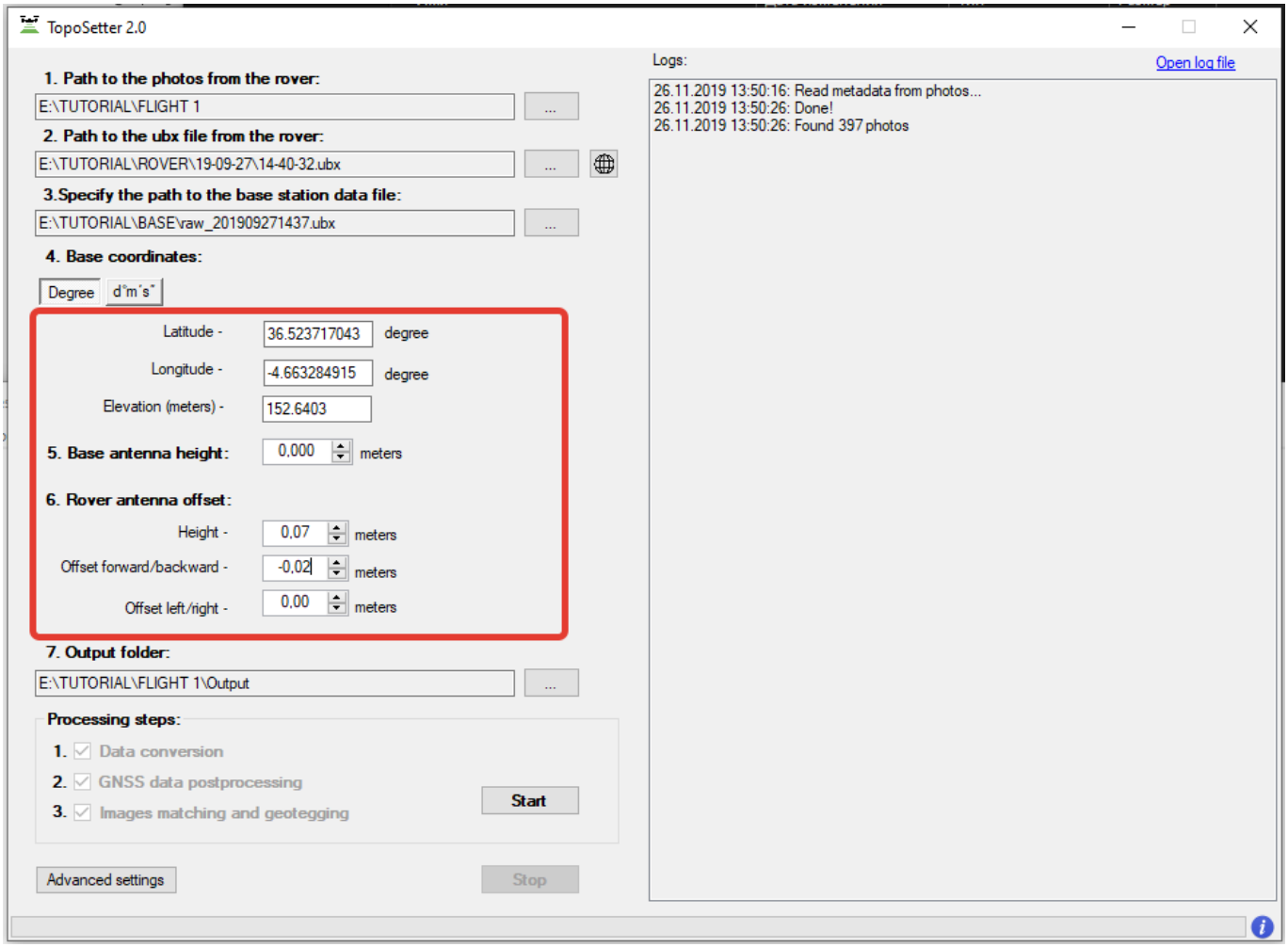
Step 5. Impute coordinates of the base station in WGS 84.
Define antenna offset for a drone.



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
FOR DJI M200 + X4S PPK use the following parameters
Height: 0.22

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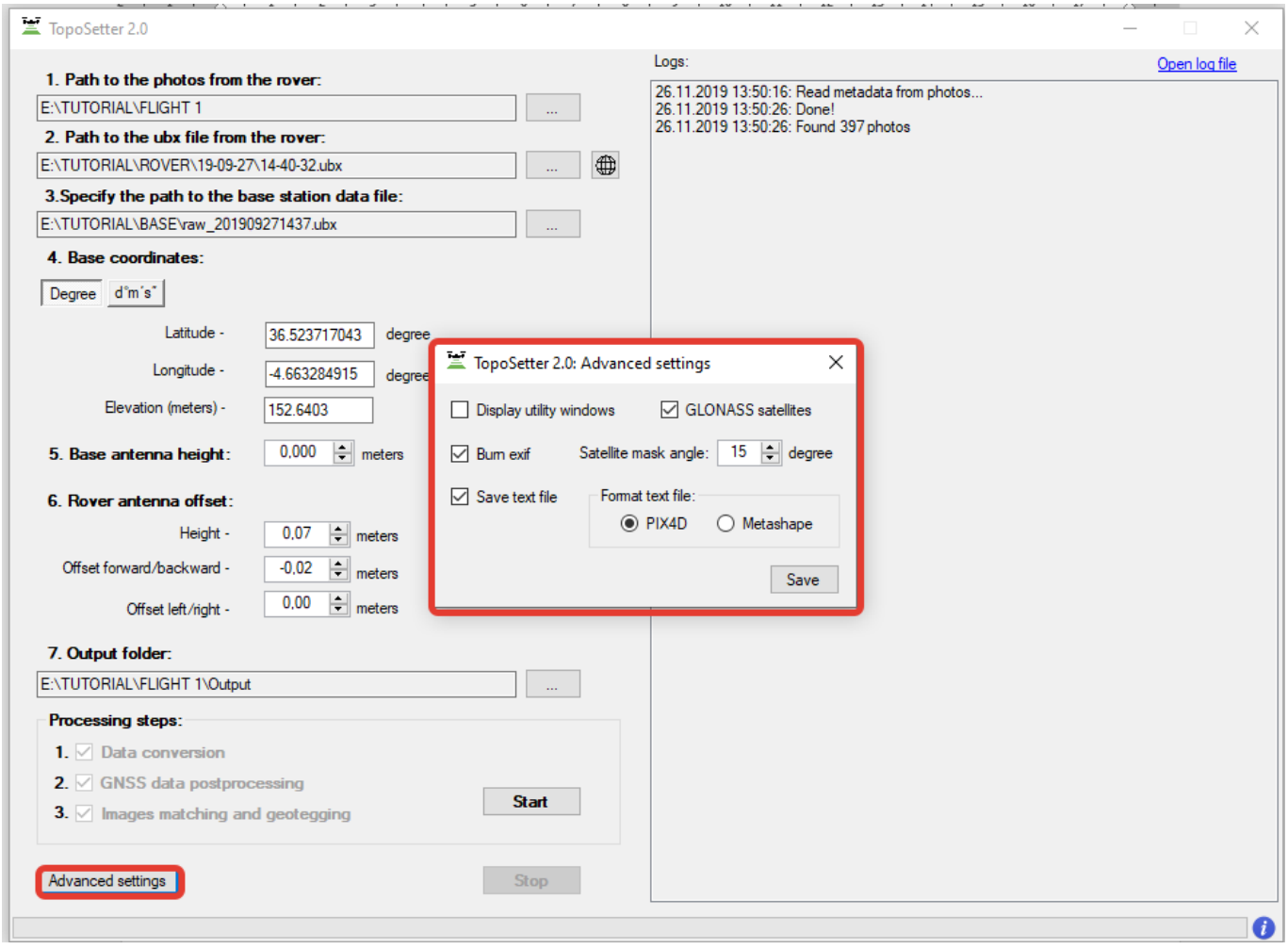
Step 6. Setup data processing setting. Click advanced setting. Advanced setting will appear.

To embed precise coordinates to photos EXIF tags check Burn exif check box. This option may lead increasing of data processing time.
To save list of coordinates check Save text file check box.
Select format of text file Pix4D or Metashape
Click Save button.



NOTICE. *To look at data processing performing switch on Display utility window option.*

Click Start button

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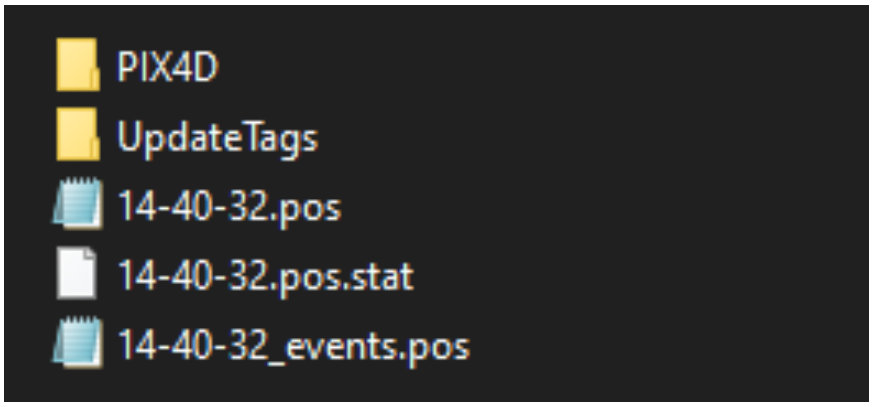
After finishing of all steps of data processing (data conversion, GNSS data post processing, images matching and geotagging) all results will be stored in Output folder.

File Coordinates.txt is stored in PIX4D or Metashape folder
Photos with updated EXIF tags are stored in UpdateTags folder
Files with .pos extension are results of GNSS data postrpocessing



NOTICE. *Coordinate system is WGS84.*

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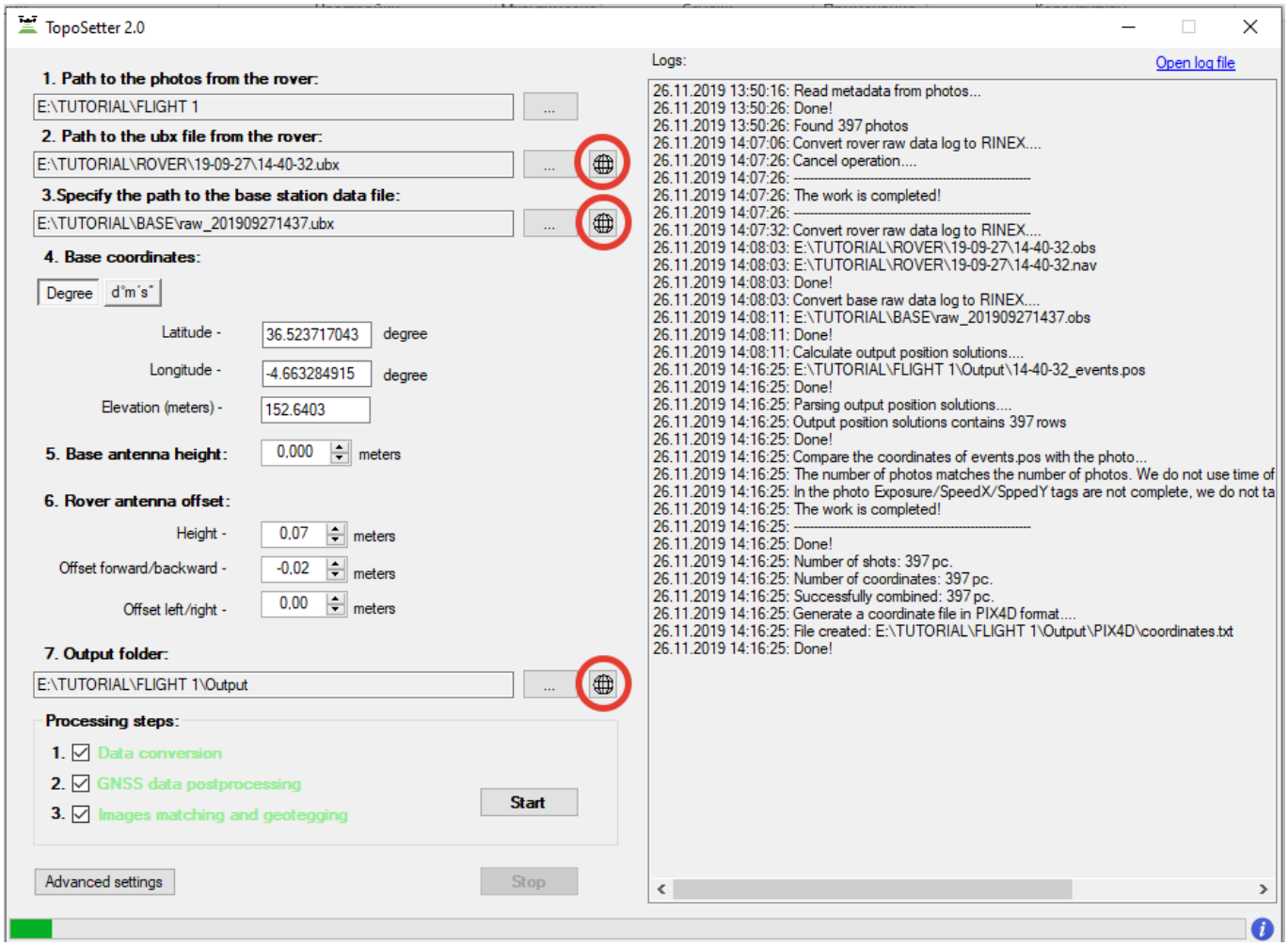
Step 7. Checking processing results.
After processing accomplishing, the following buttons will appear.



NOTICE.

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

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

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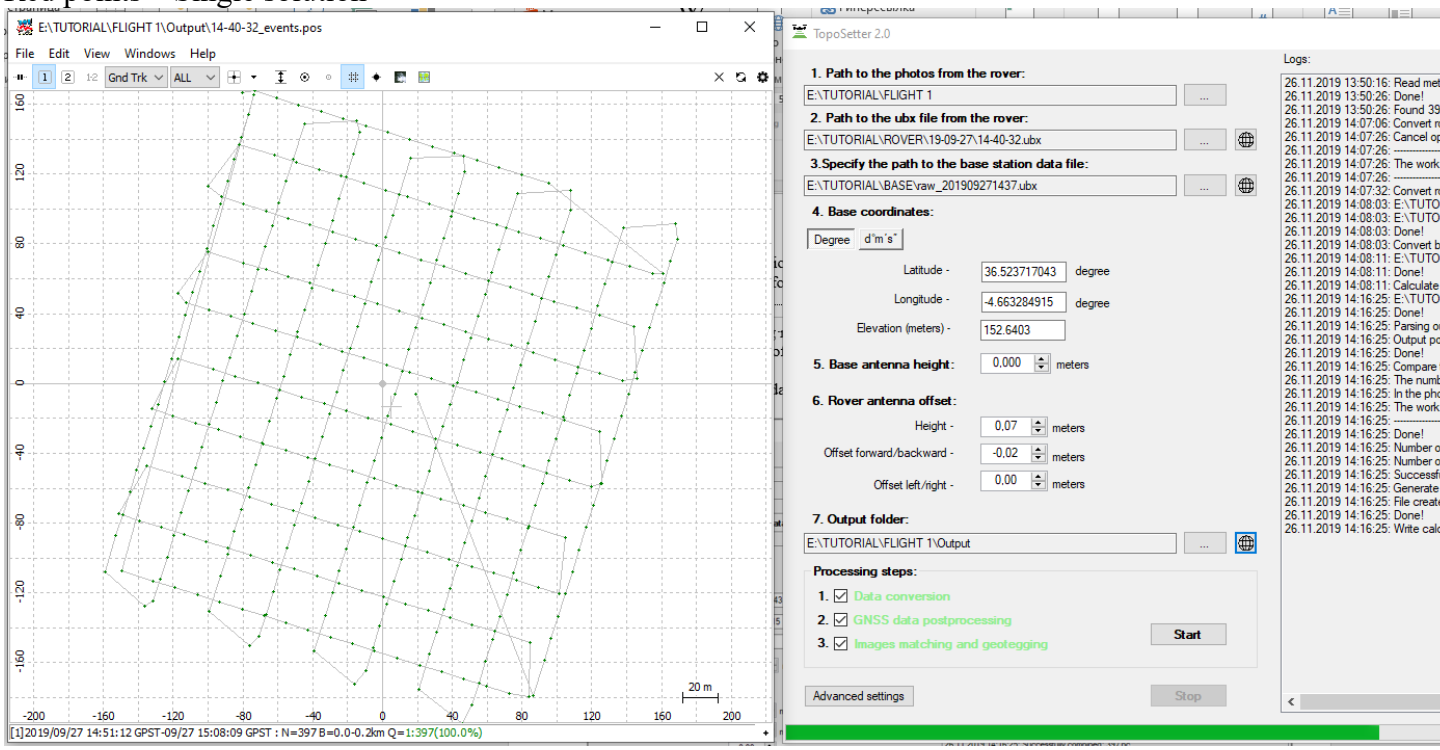
On the map you can see results of GNSS data postprocessing.
Green points of photos events – Fixed solution
Yellow points – Float solution
Red points – Single solution



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

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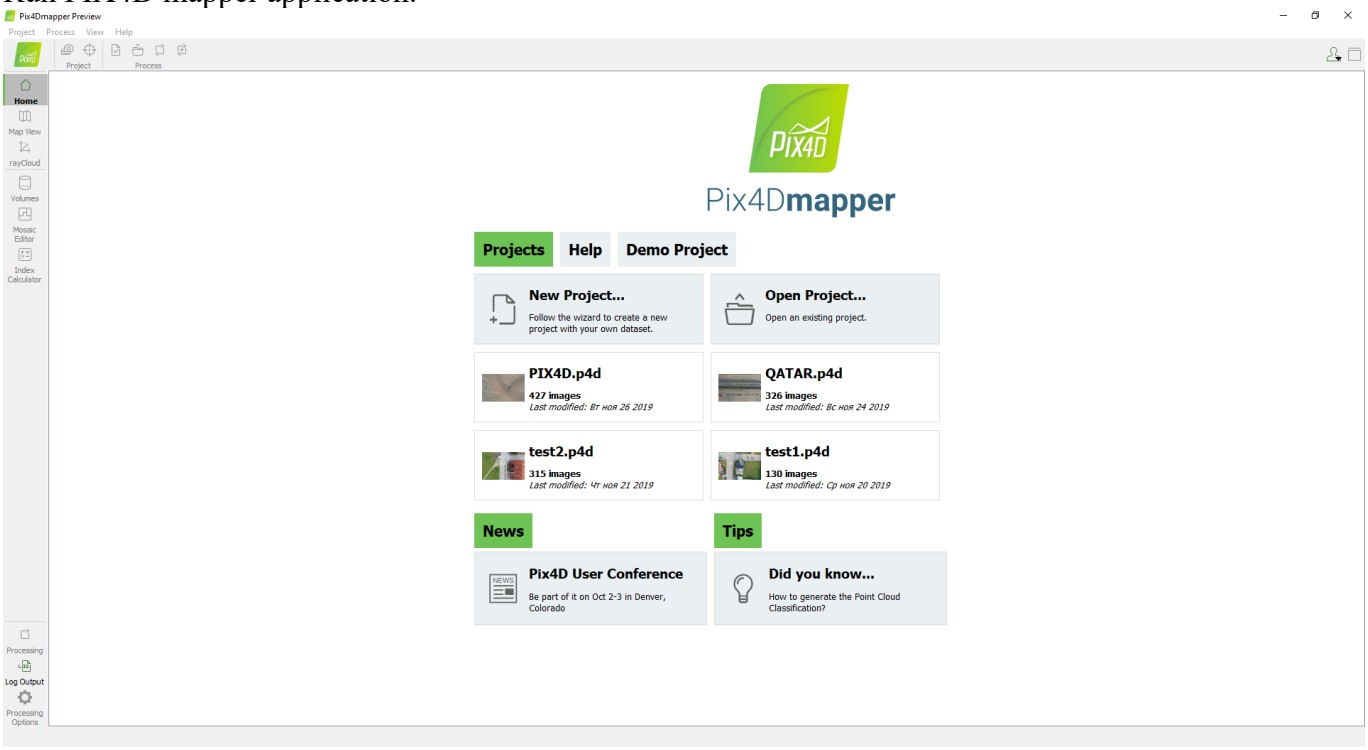
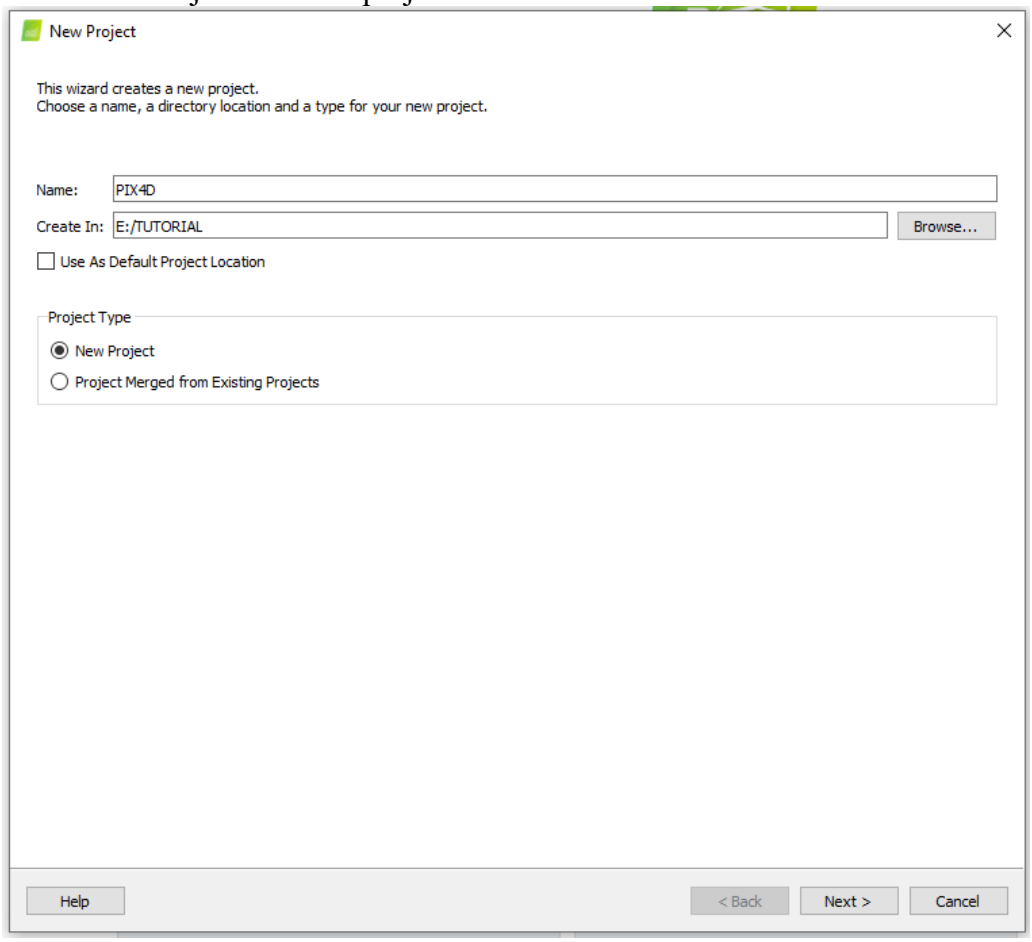
3. PHOTOGRAMMETRY PROCESSING IN PIX4D MAPPER SOFTWARE

3.1 Creating pix4d mapper project

Run PIX4D mapper application.



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



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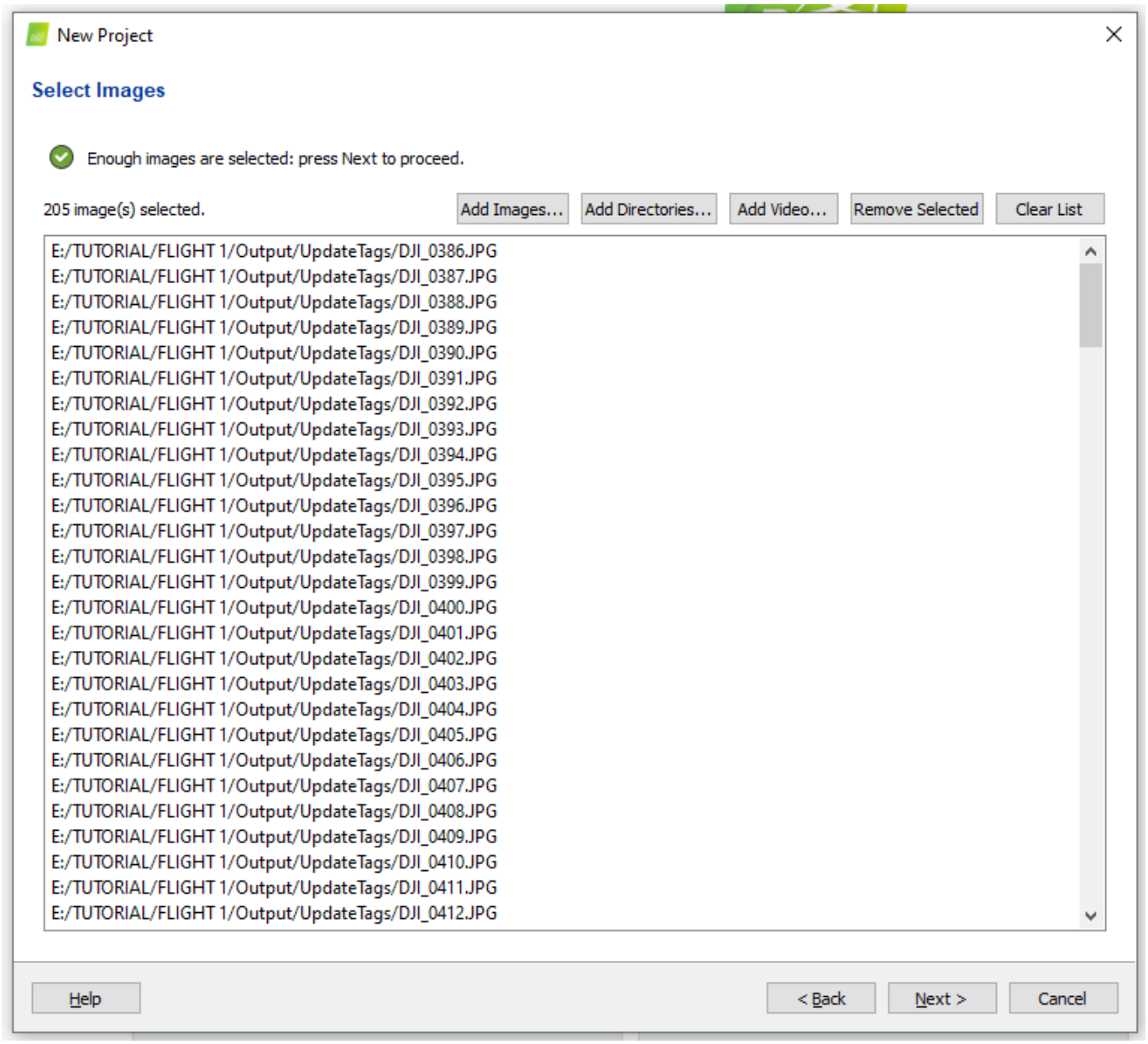
Select images to be processed from output\UpdateTags folder. Click next



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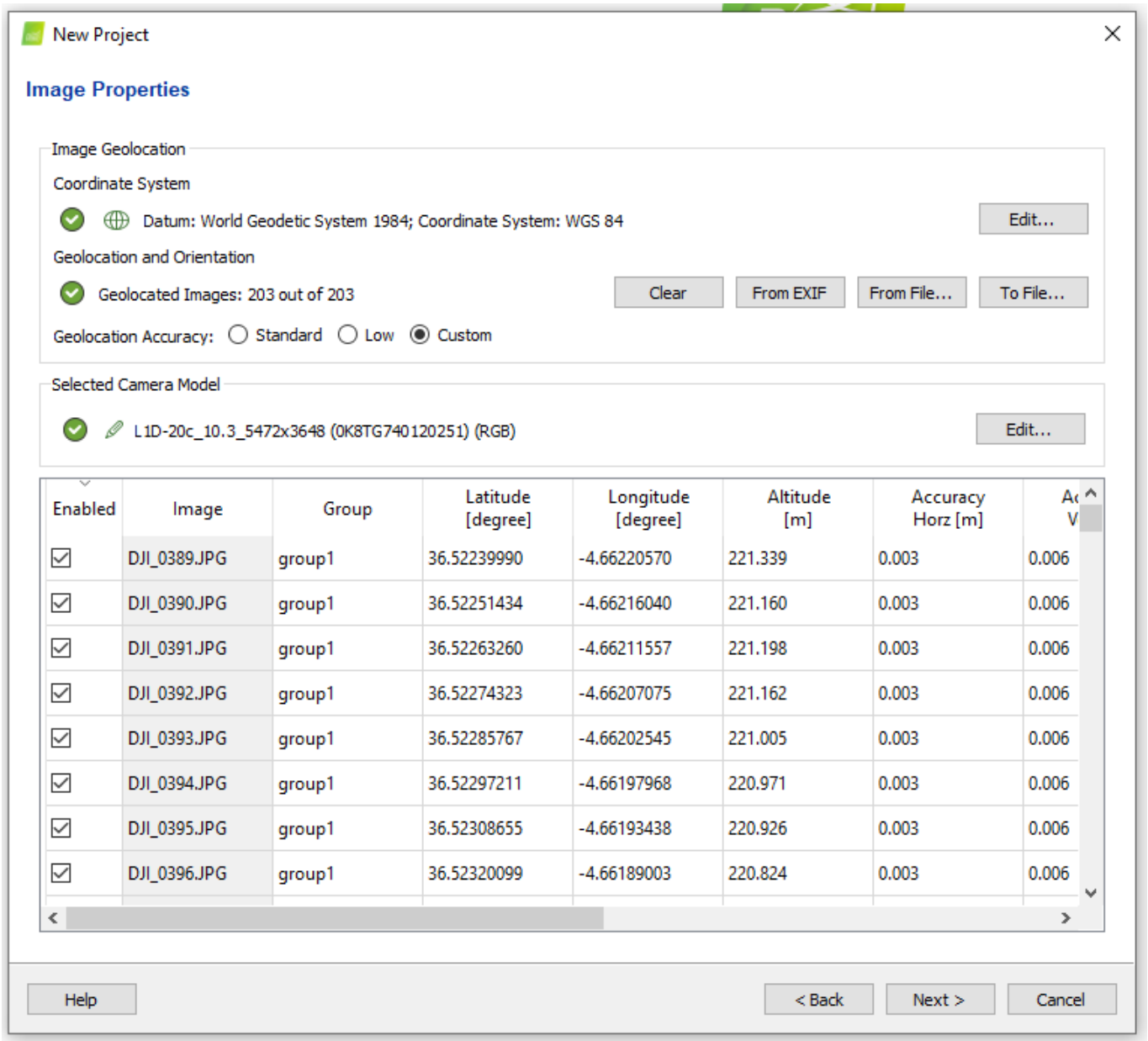
Software will read precise coordinates of images and accuracy setting automatically. Click Next.



Enabled	Image	Group	Latitude [degree]	Longitude [degree]	Altitude [m]	Accuracy Horz [m]	Ac V
☑	DJI_0389.JPG	group1	36.52239990	-4.66220570	221.339	0.003	0.006
☑	DJI_0390.JPG	group1	36.52251434	-4.66216040	221.160	0.003	0.006
☑	DJI_0391.JPG	group1	36.52263260	-4.66211557	221.198	0.003	0.006
☑	DJI_0392.JPG	group1	36.52274323	-4.66207075	221.162	0.003	0.006
☑	DJI_0393.JPG	group1	36.52285767	-4.66202545	221.005	0.003	0.006
☑	DJI_0394.JPG	group1	36.52297211	-4.66197968	220.971	0.003	0.006
☑	DJI_0395.JPG	group1	36.52308655	-4.66193438	220.926	0.003	0.006
☑	DJI_0396.JPG	group1	36.52320099	-4.66189003	220.824	0.003	0.006

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

It is recommended to check camera settings. Cilck Edit button and check if Linear rolling shutter camera model is enabled in case if DJI MAVIC 2 PRO was used for survey.

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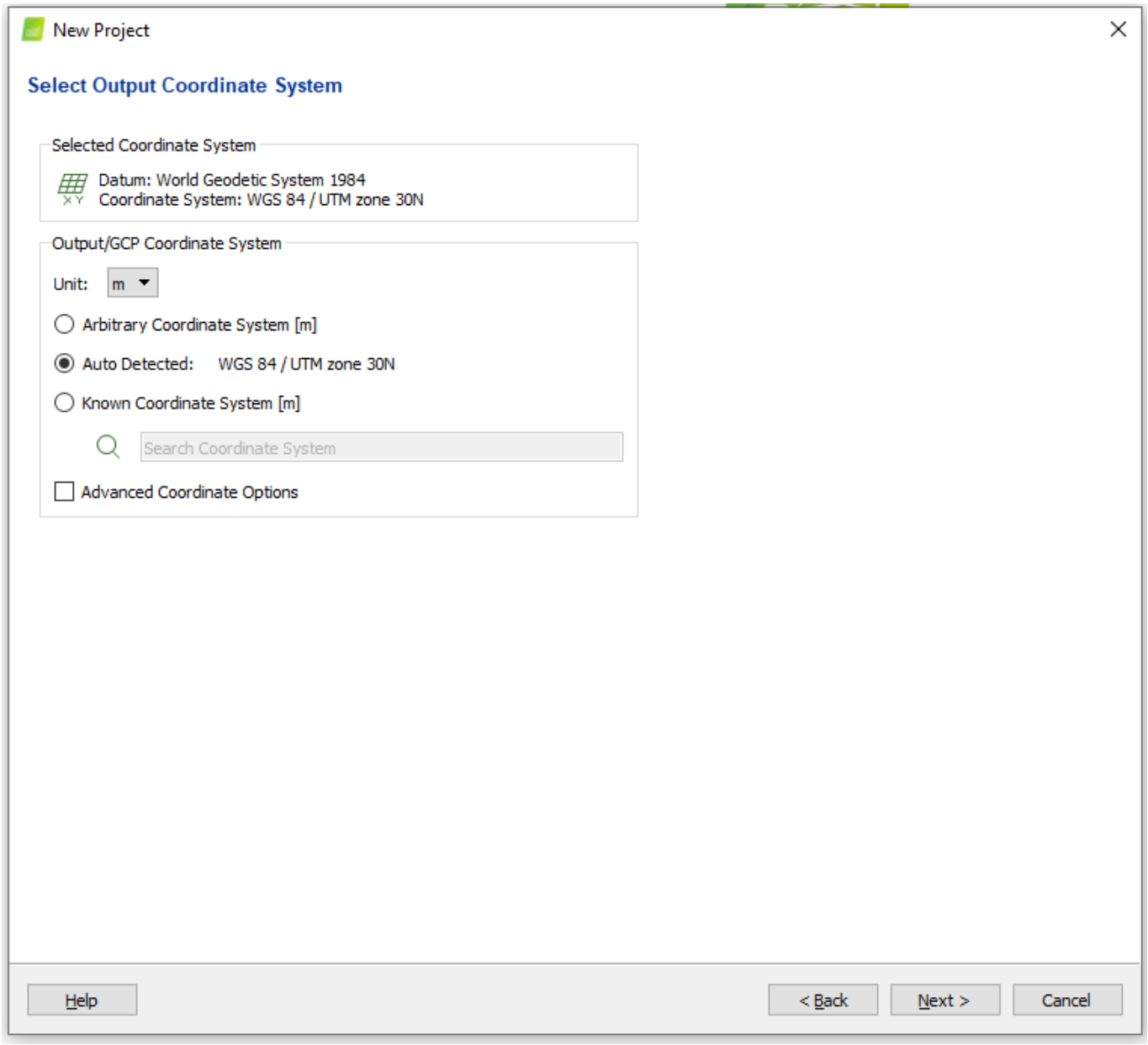
Select output coordinate system and click Next.



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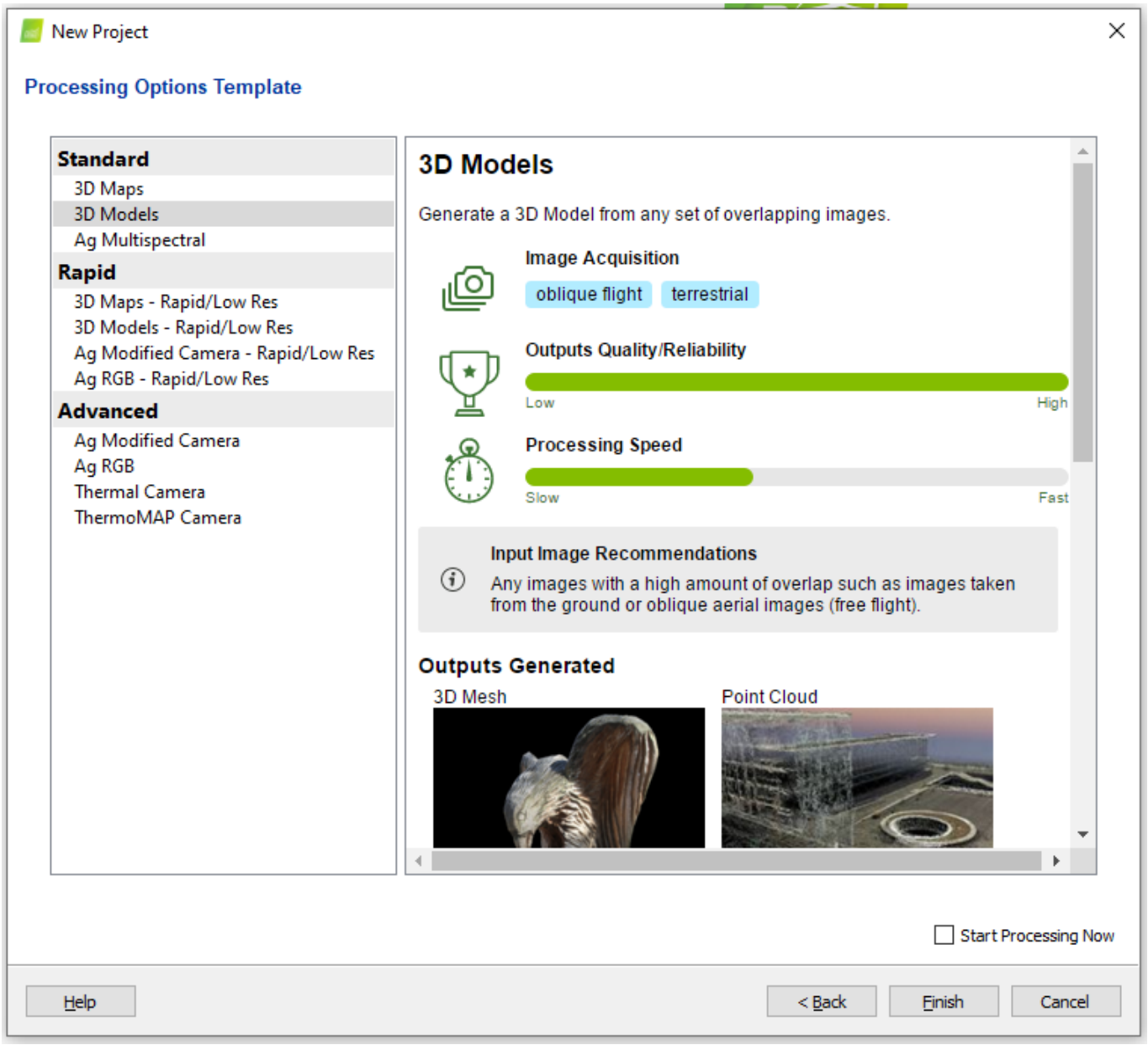
Select type of data processing options. Click Finish.



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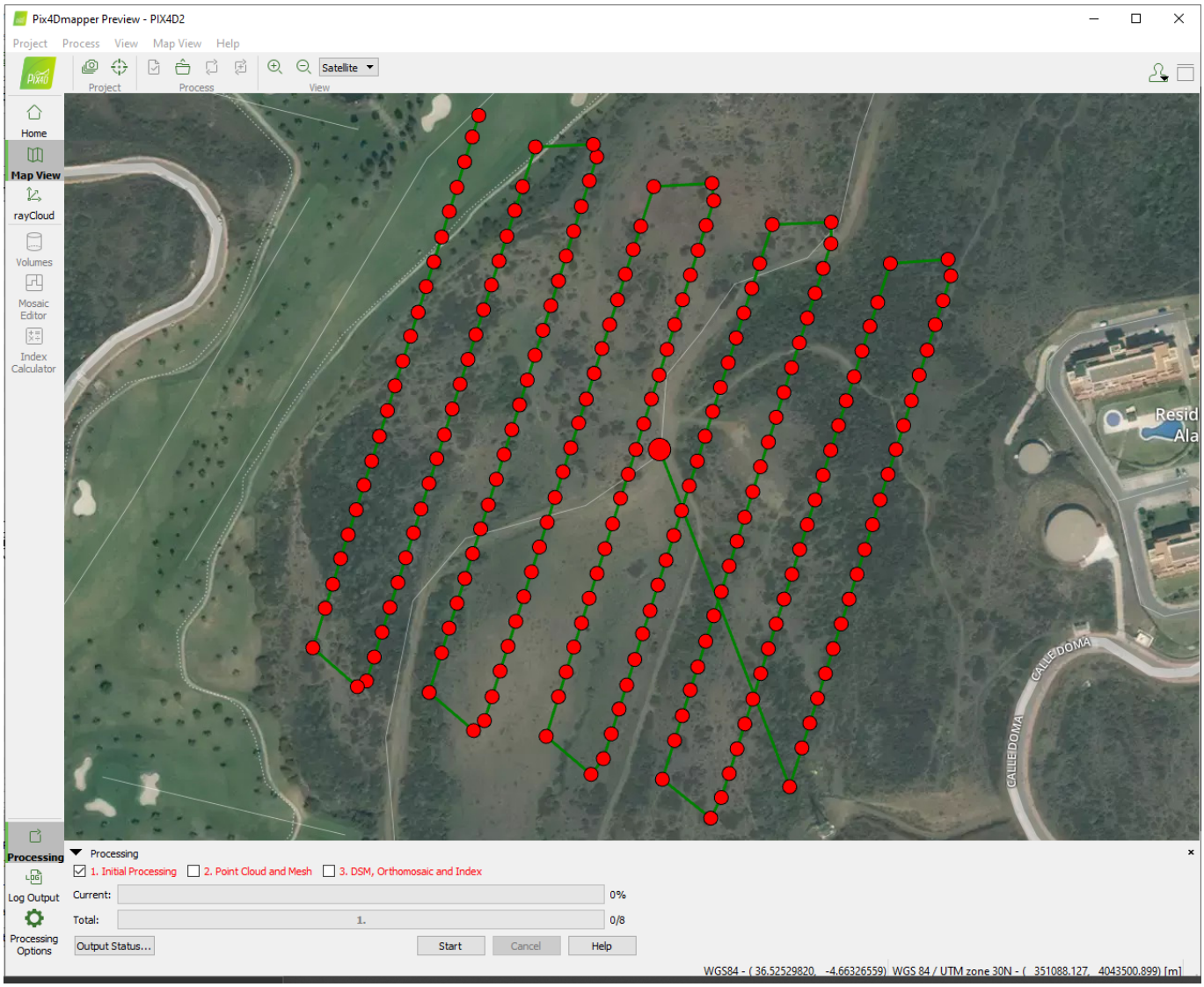
3.2 Initial aerial triangulation

As soon as images with precise coordinates were loaded to the project, we can start initial aerial triangulation. Select initial processing checkbox and start processing.



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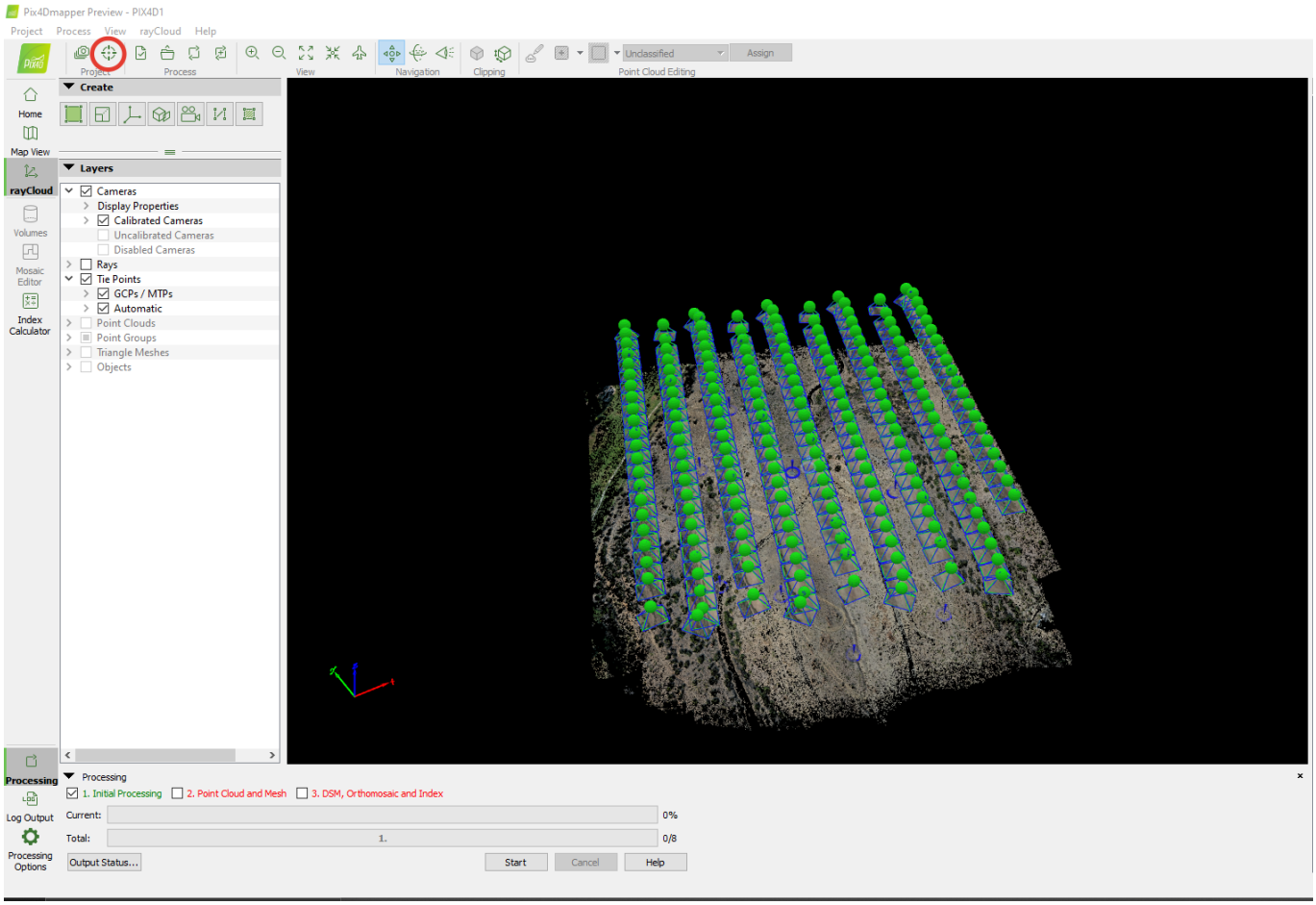
3.3. Camera calibration

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

Click GCP/MTP button.



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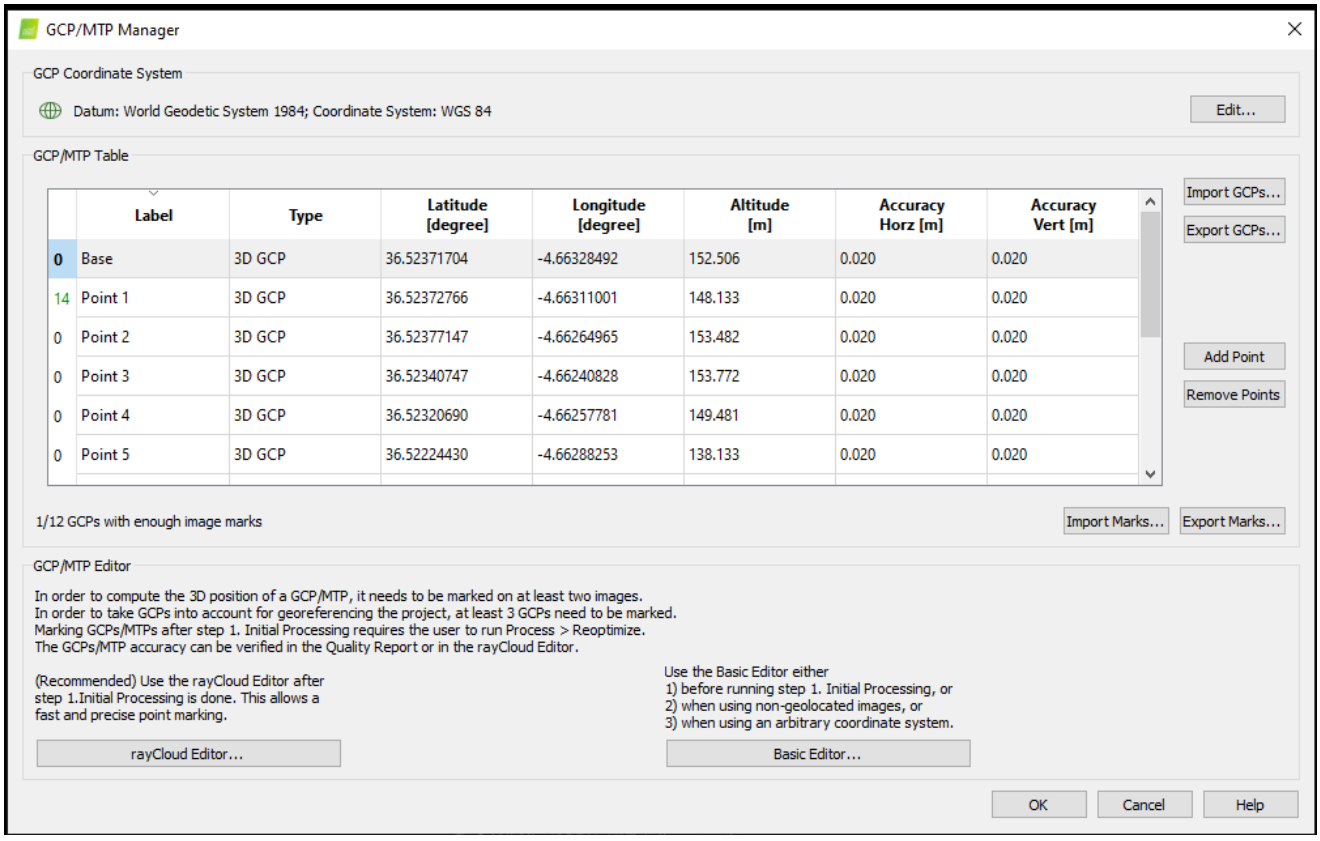
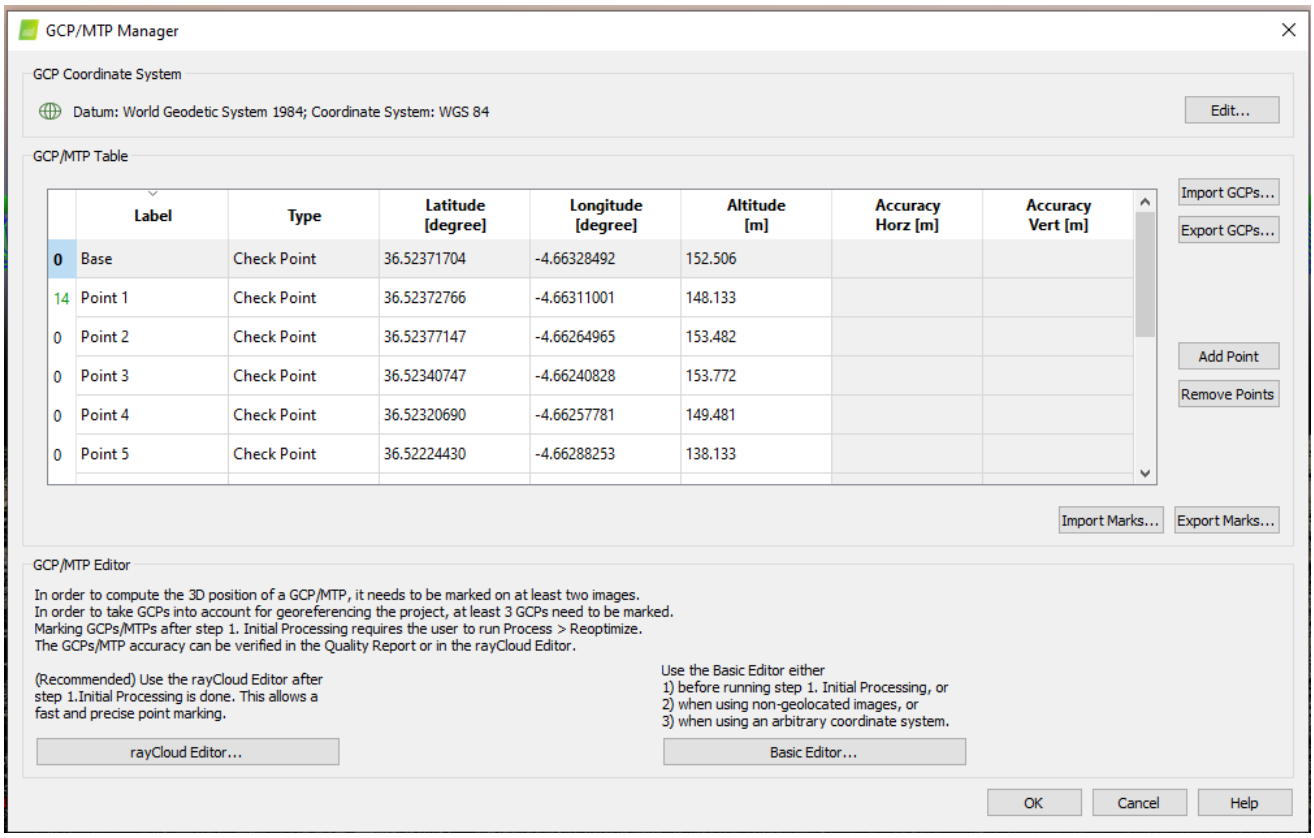
Select coordinate system of ground control points and import GCPs. Click OK.



Change GCPs type to Check point.



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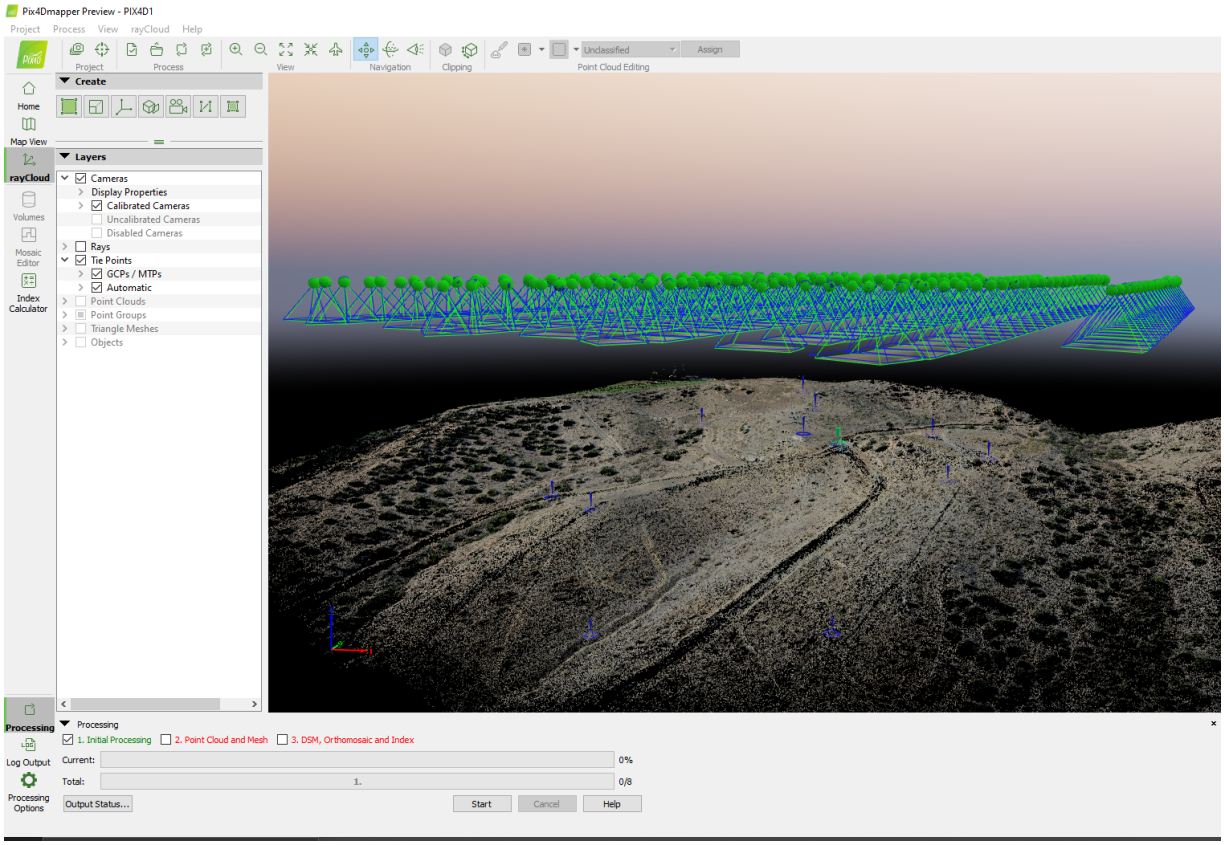
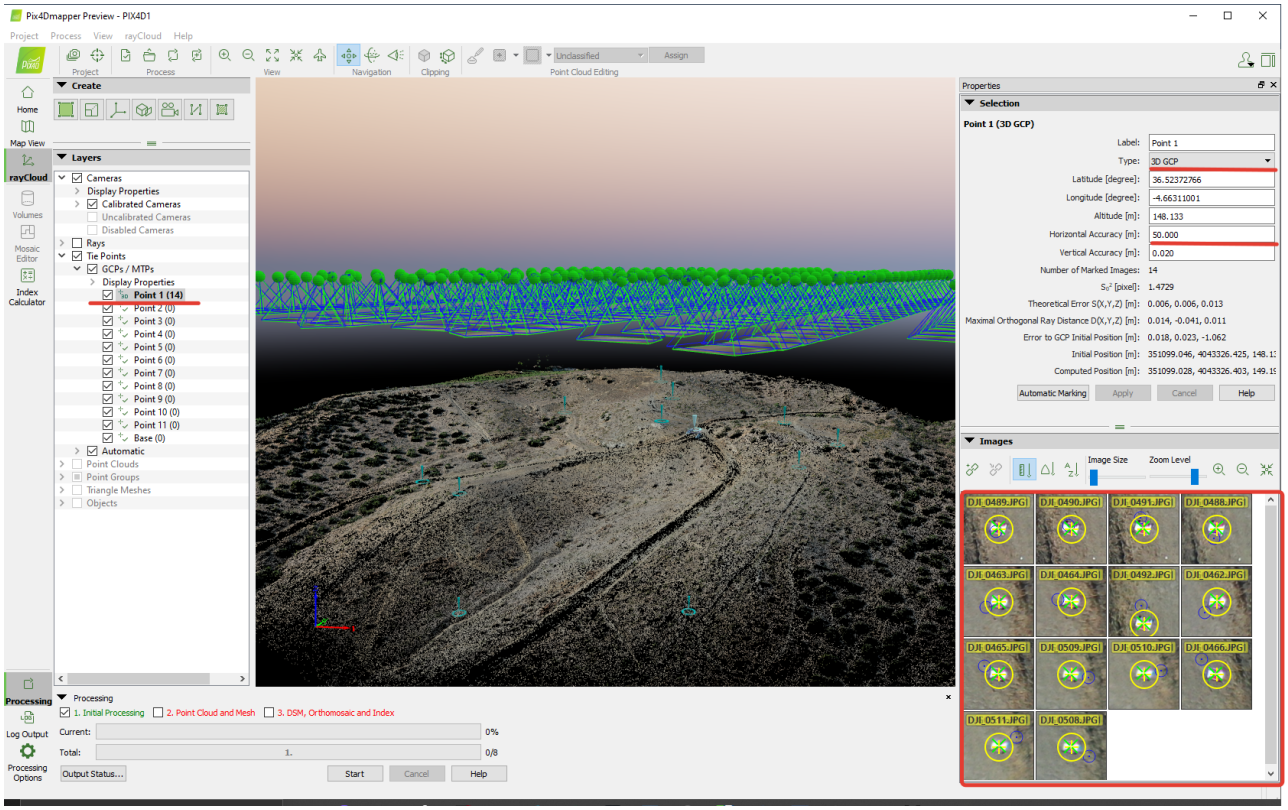
All GCPs will be shown on the map.



Select one GCP, define position of ground control point at each image, change type of GCP to 3D and setup horizontal accuracy to 50 meters.



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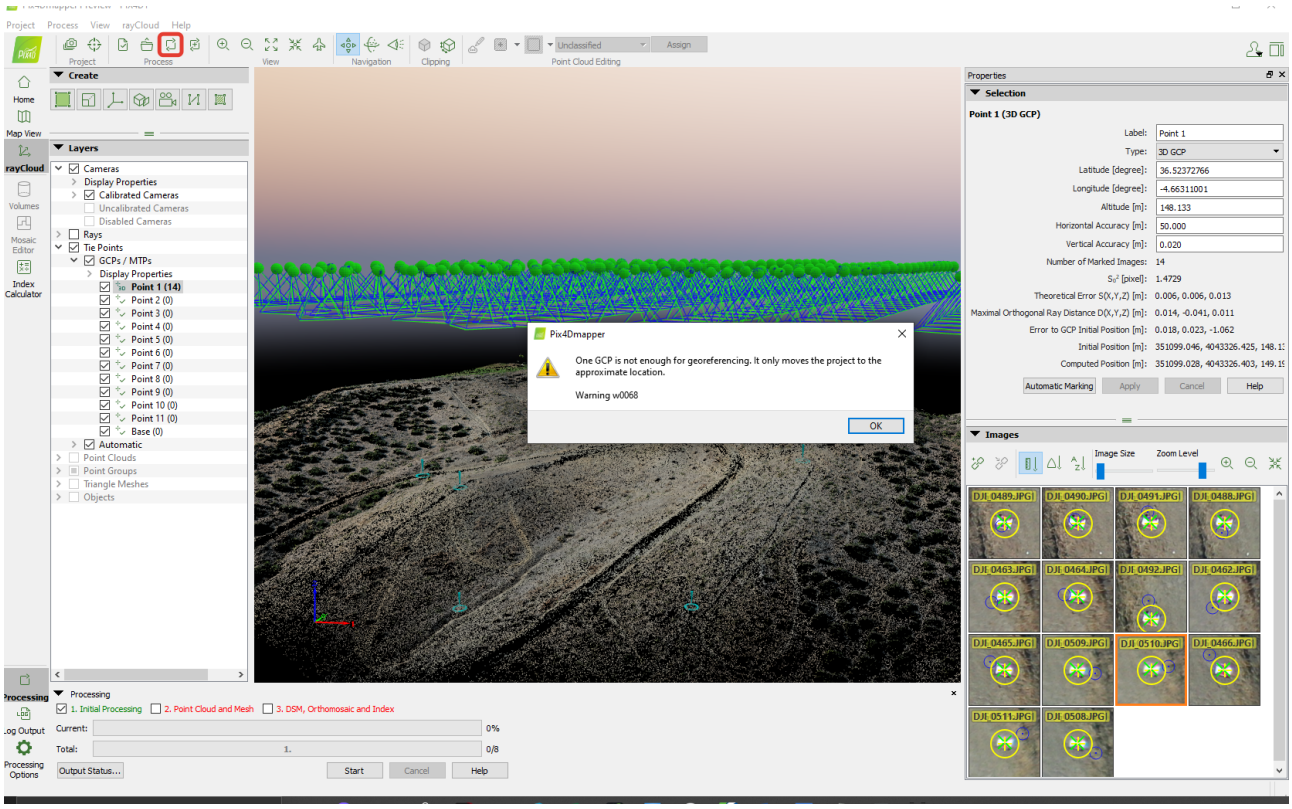
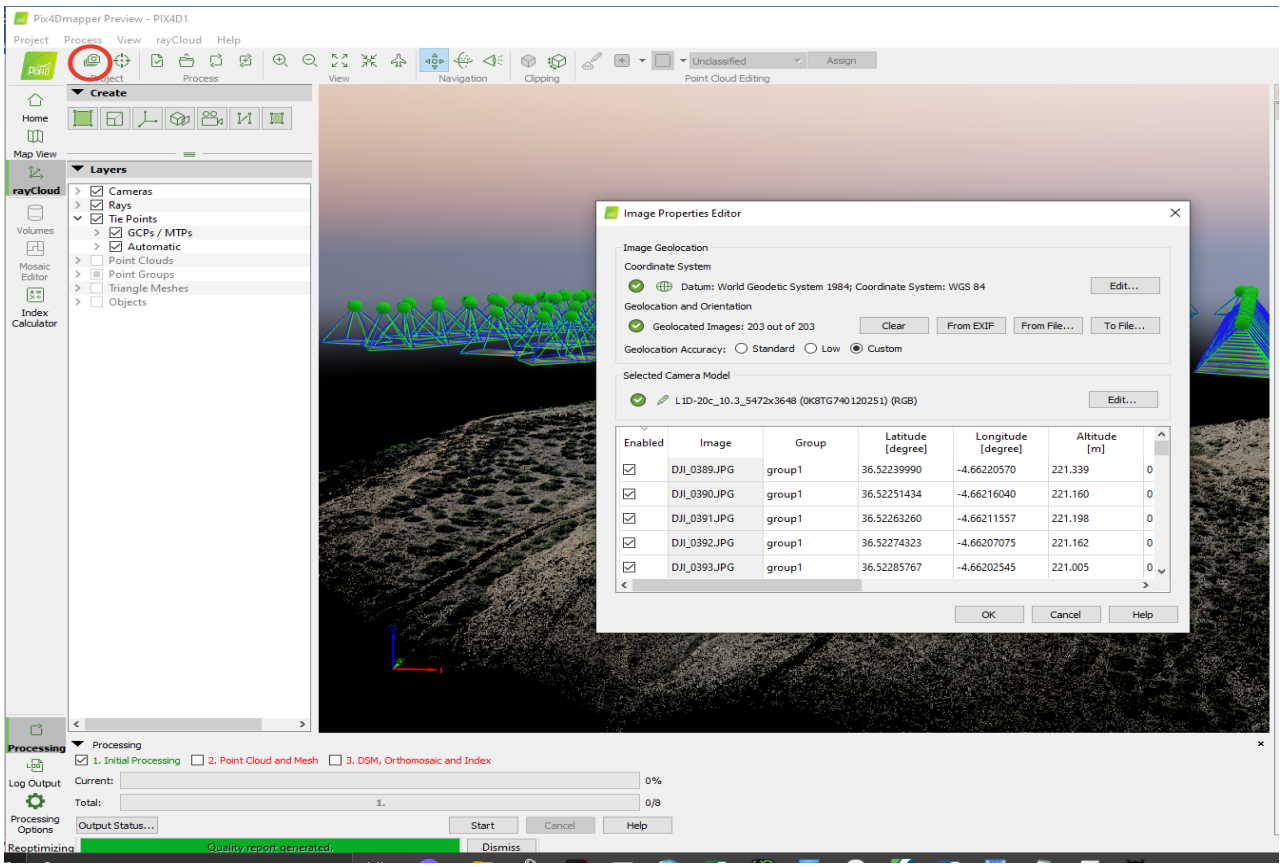
Click Reoptimize button. Click Ok on warning messages.



After finishing of reoptimizing process click Image property editor button.



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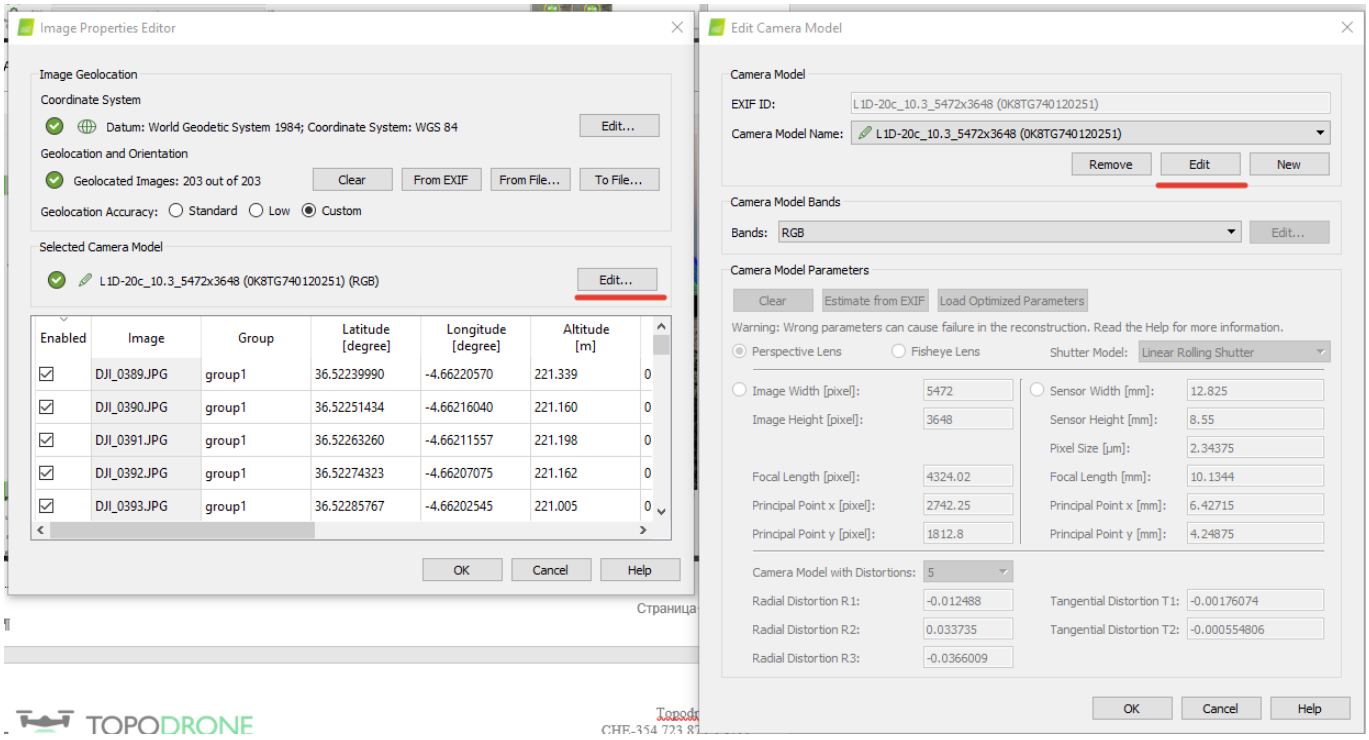
Click Edit camera model buttons in Image Properties Editor window and in Edit Camera Model window



Click Load Optimiezed parameters. Copy Focal Length value for future work.

NOTICE. It is possible to use the calibrated value of focal length for the processing If you don’t change focus settings for future flights.

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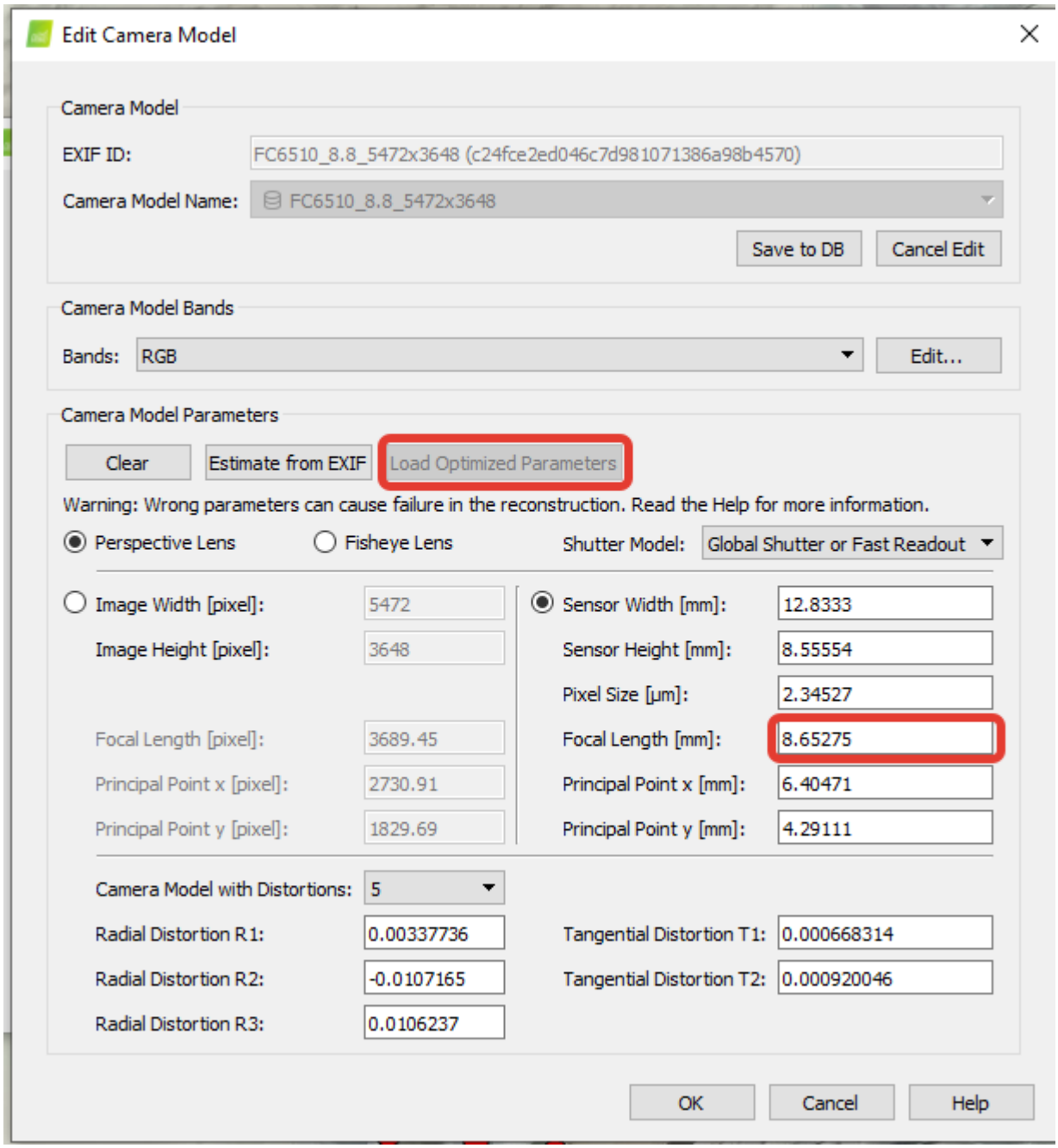

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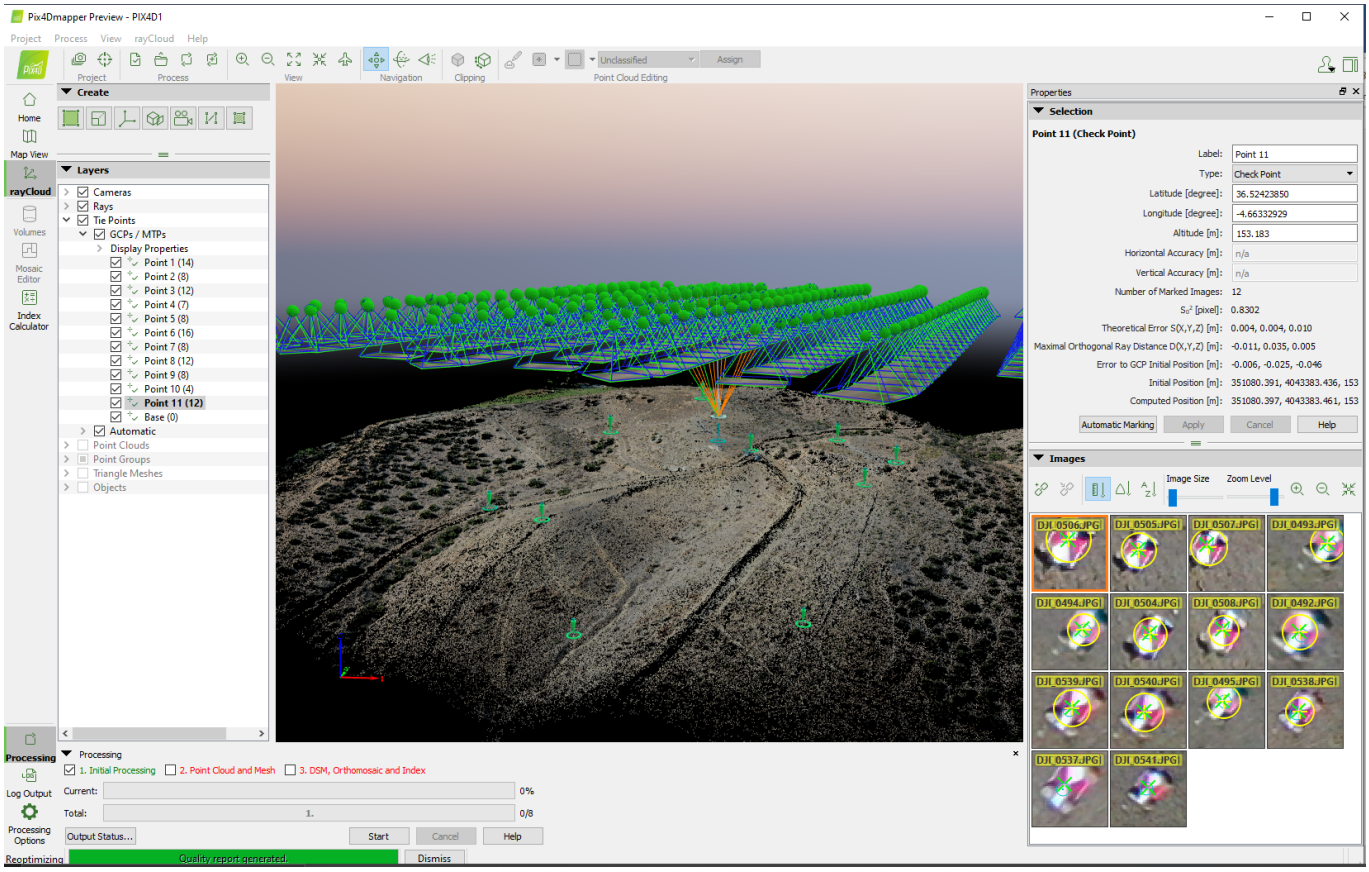
3.4 Accuracy estimating

Load ground control points. Set up as check points.

Select position of all check points at images to check accuracy.



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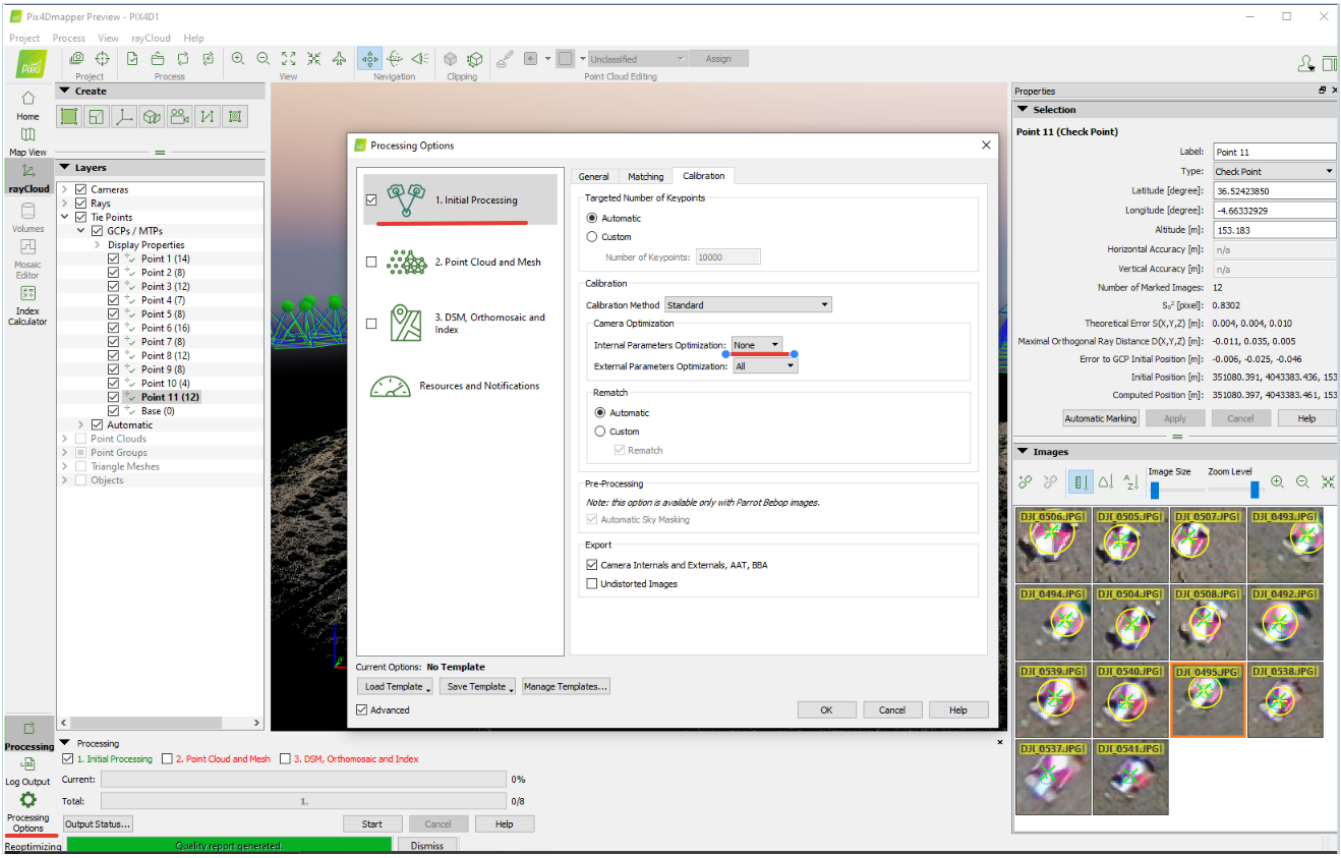
Go to Processing option. Select None for Internal Parameters Optimization. Click Ok.
Click Reoptimize.



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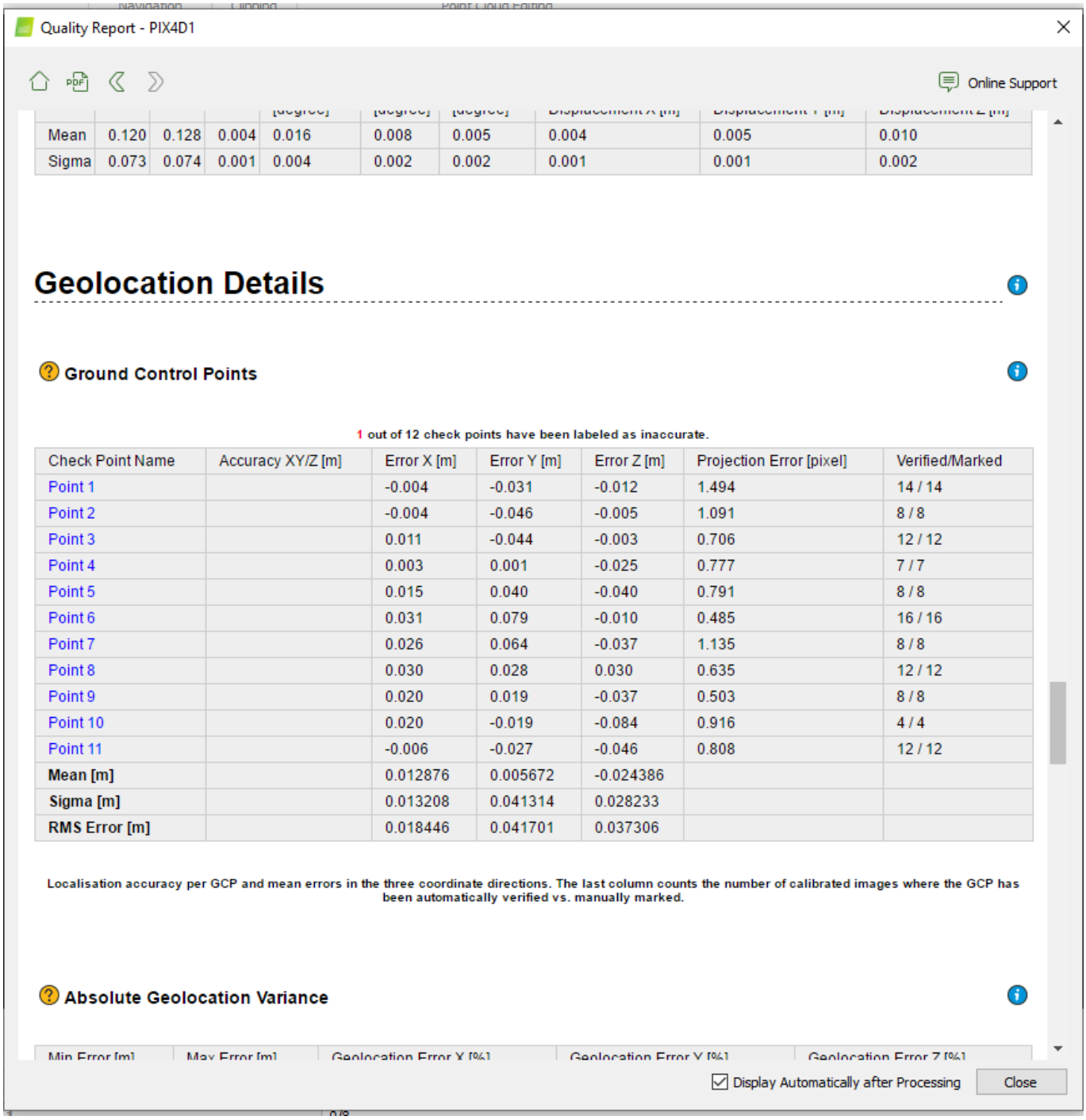
After finishing optimization process go to Process Menu, click Generate quality report.

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



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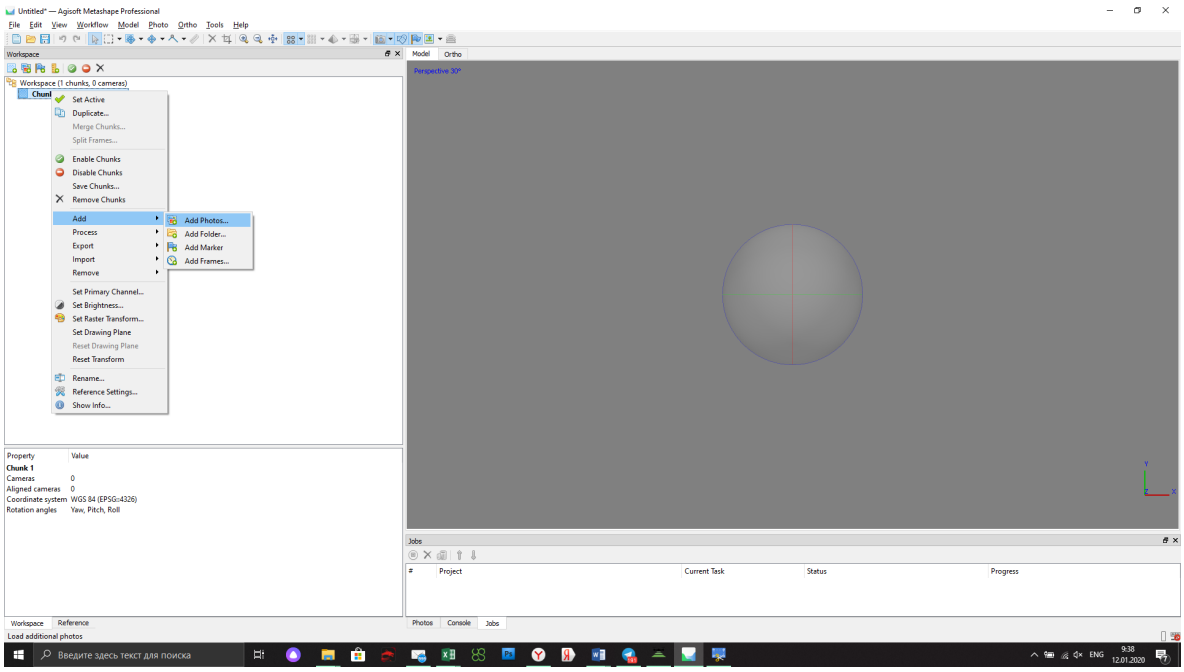
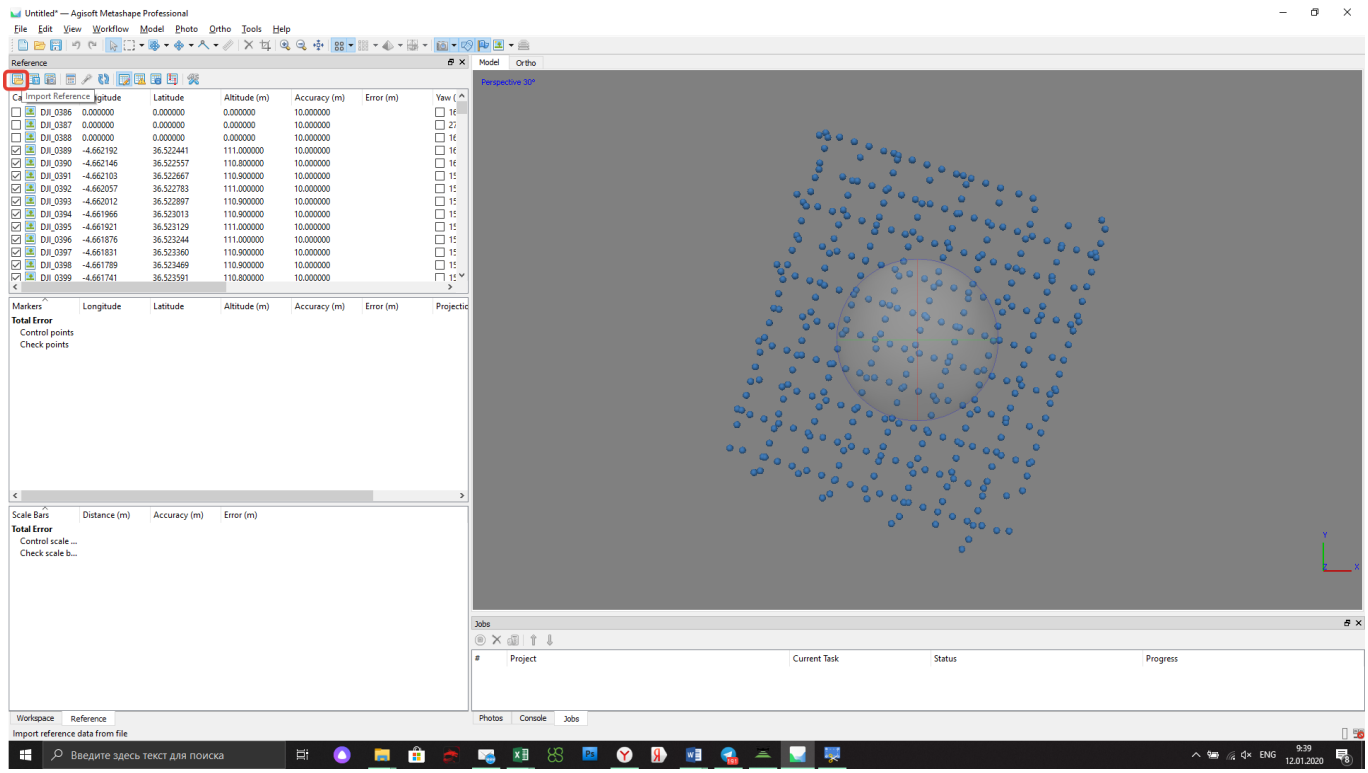
4. PHOTOGRAMMETRY PROCESSING IN AGISOFT METASHAPE SOFTWARE

4.1 Creating project, photos alignment

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



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



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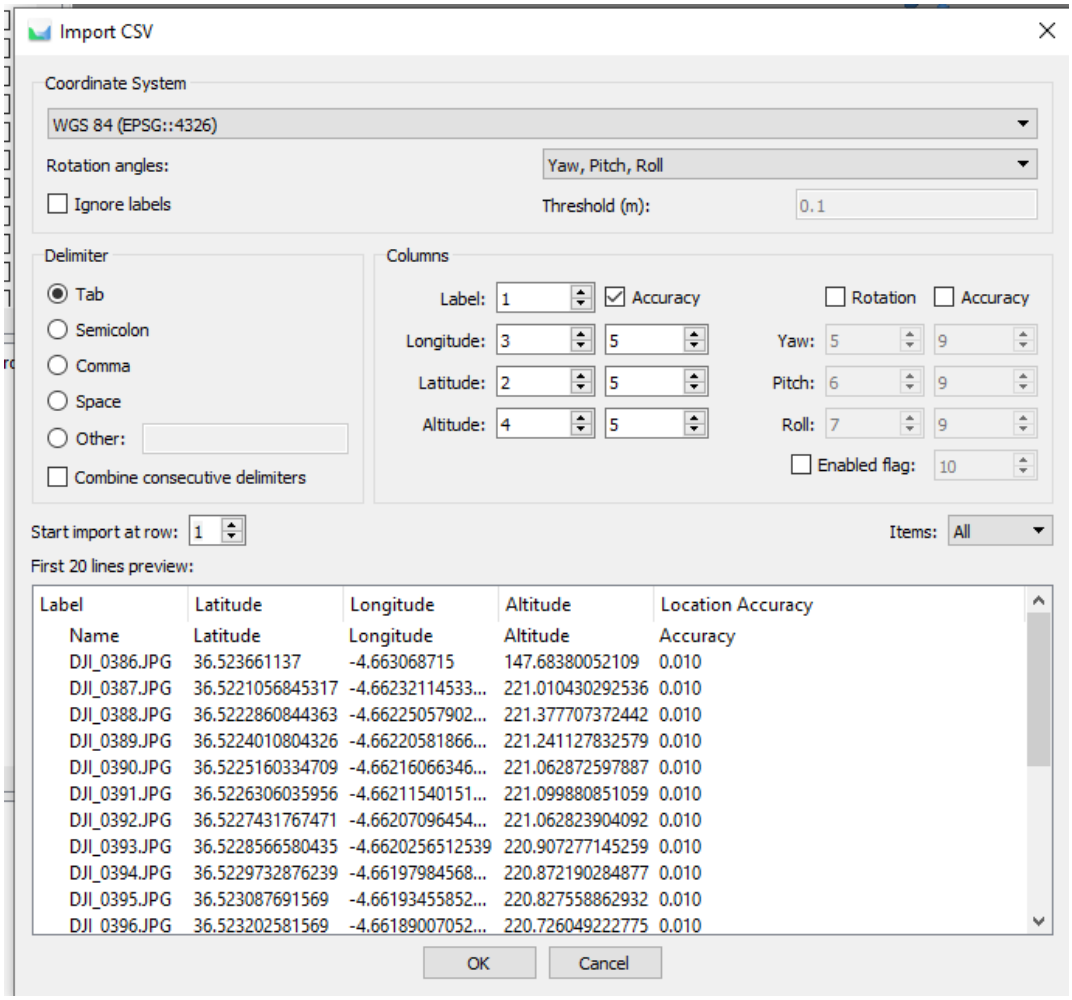
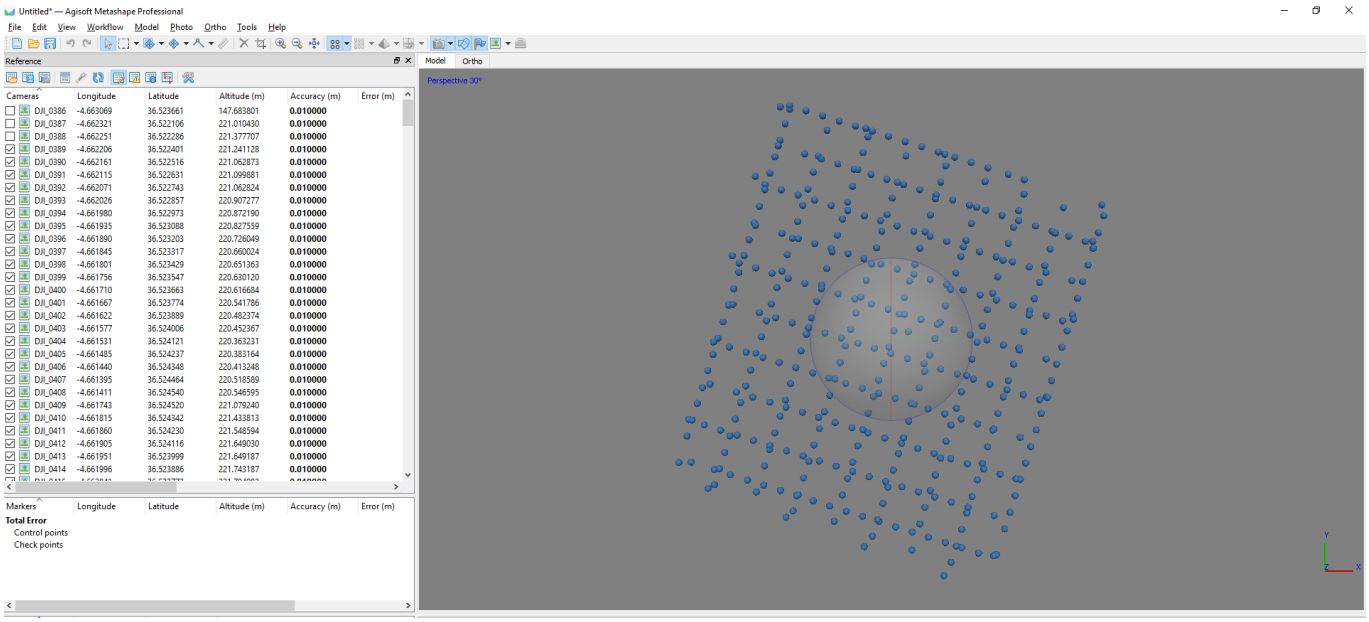
Select WGS 84 coordinate system, setup columns order 1,3,2,4, click Accuracy checkbox, select field 5, click OK



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



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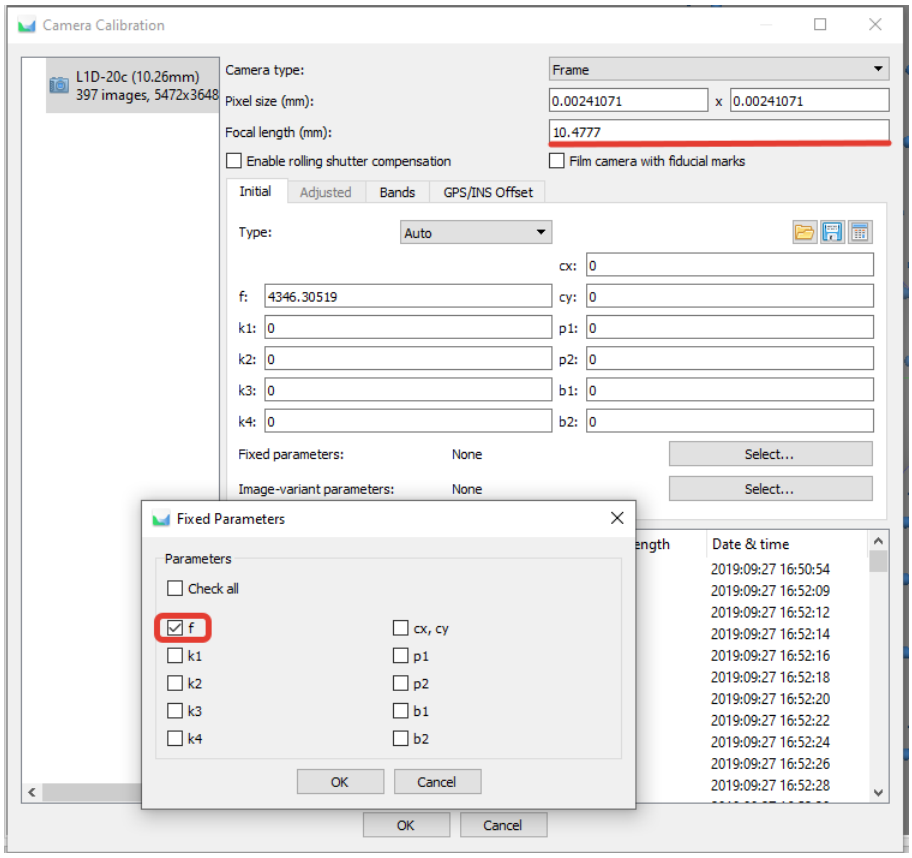
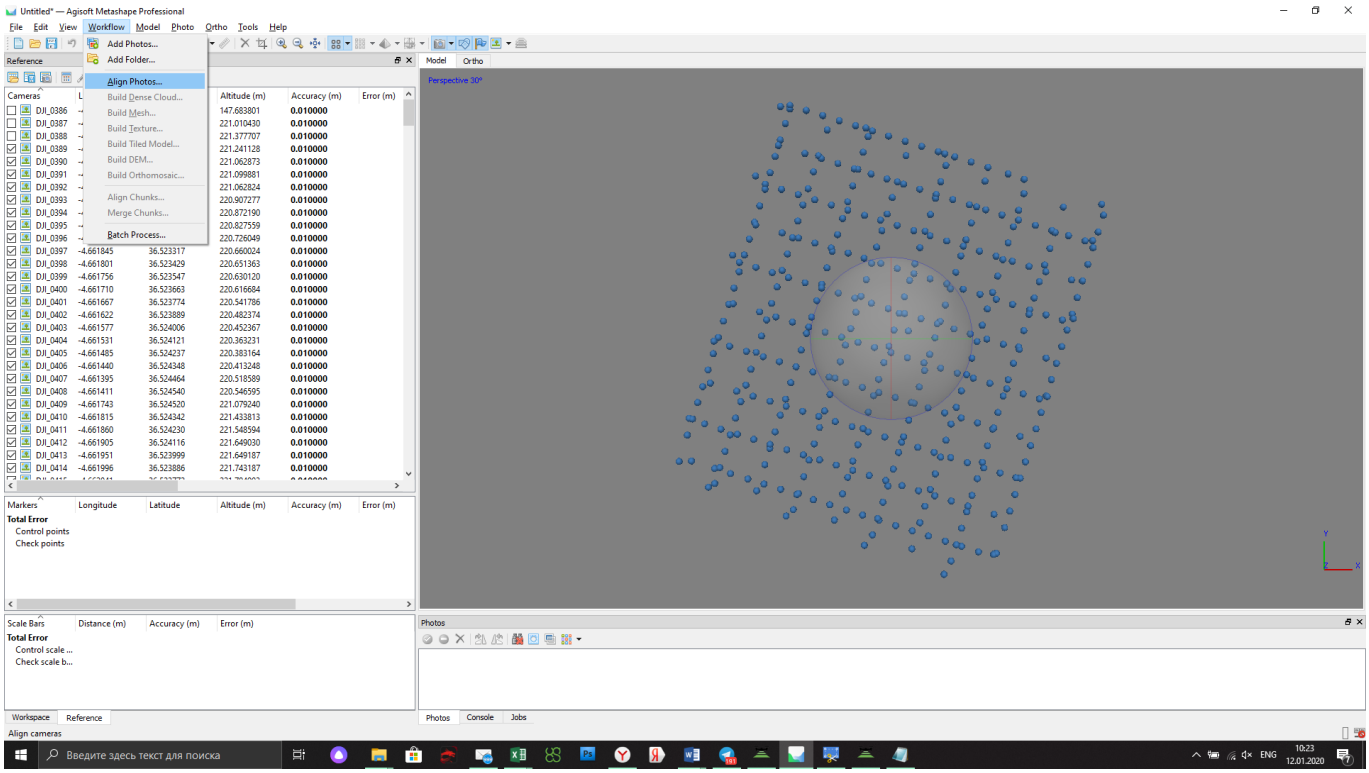
.Go to Tools, click Camera calibration and input calibrated parameter for focal length 10.4777, select fixed F parameter



Go to Workflow and click Align Photos for aerial triangulations



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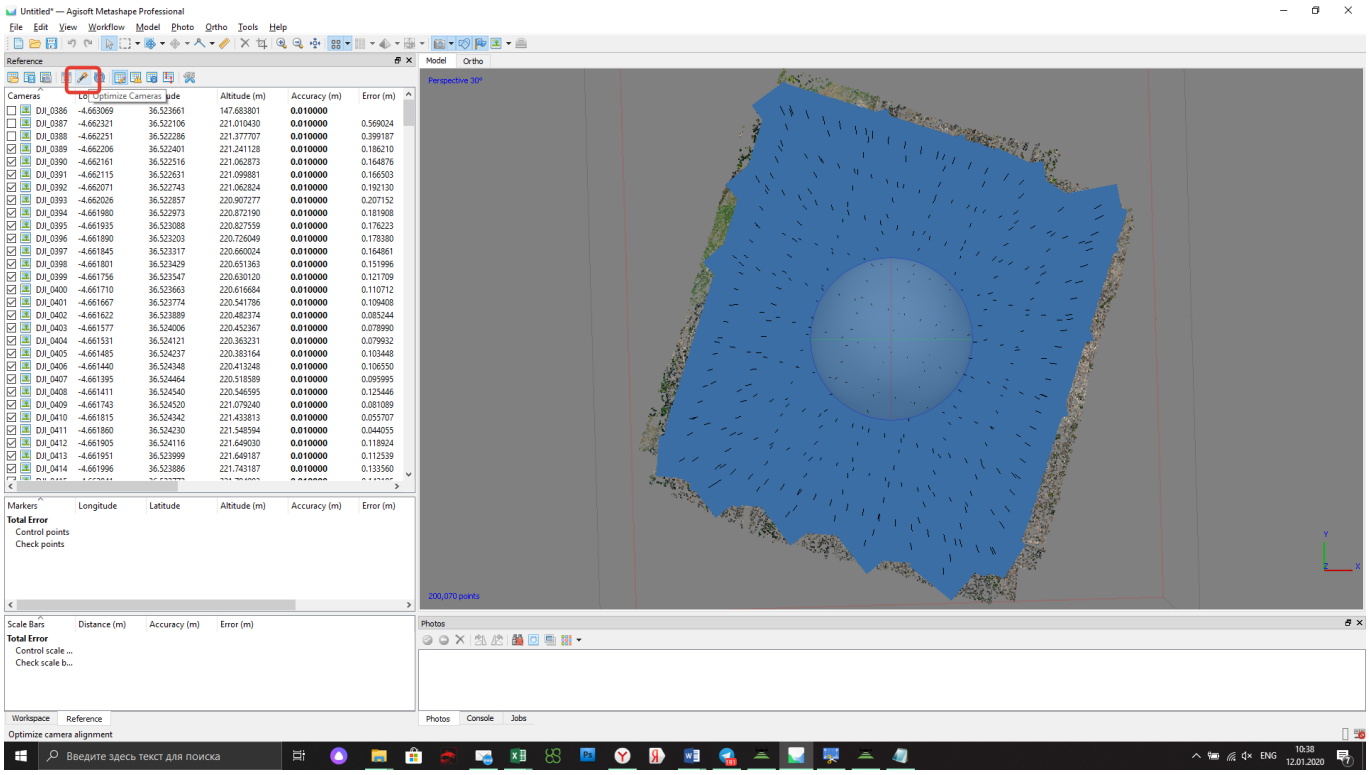
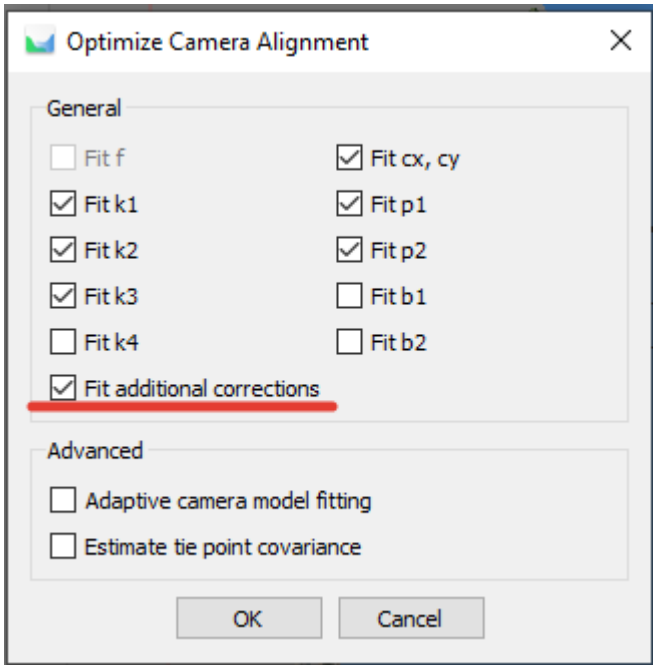
After finishing aerial triangulation go to Reference, click "Optimize Camera Alignment" and click on Fit additional corrections check box. Click OK





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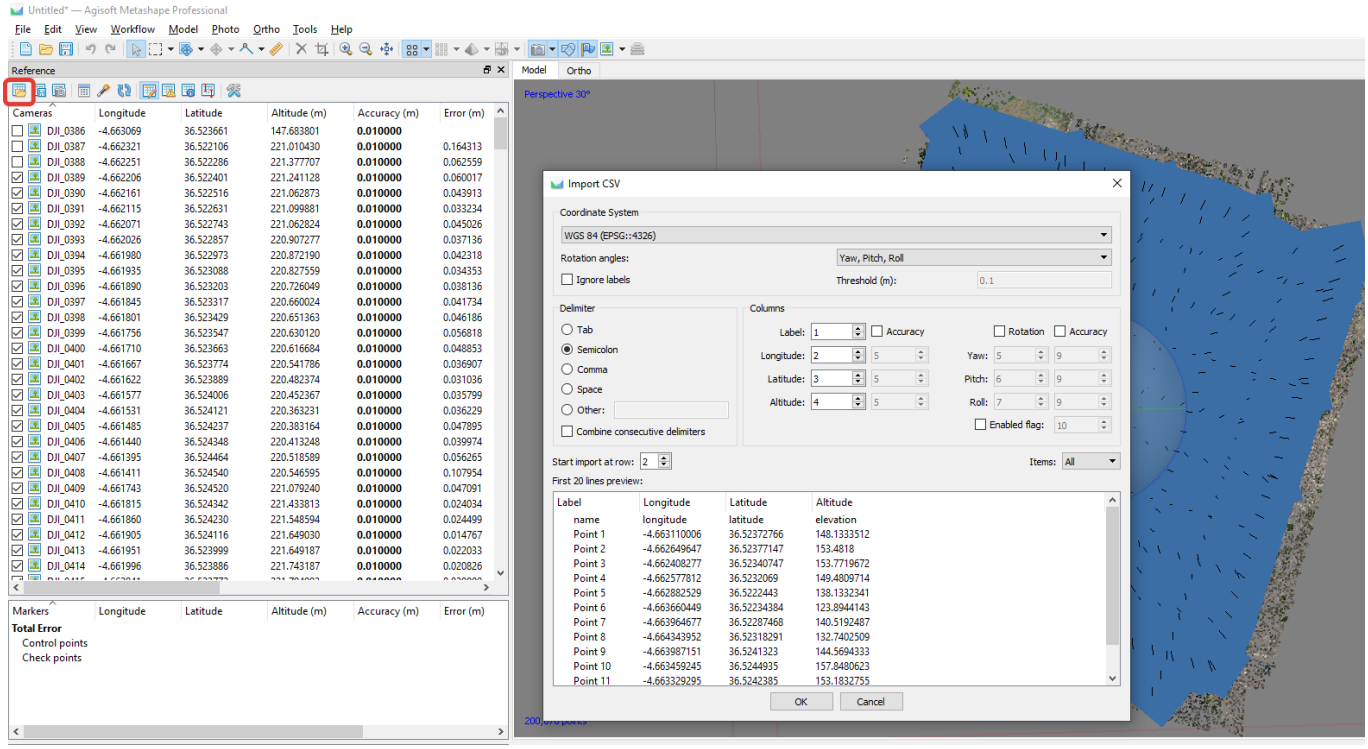
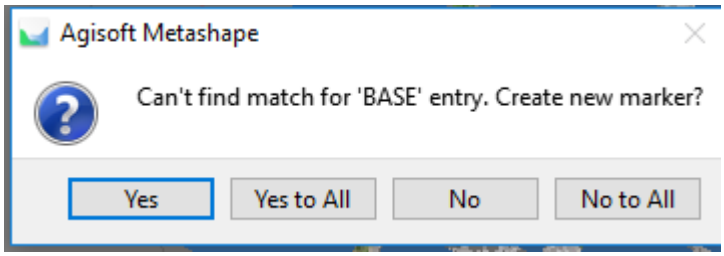
4.2 Accuracy estimating

After finishing aerial triangulation go to Reference, click "Import" and load GCP.txt file

Use the following settings and click OK



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



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

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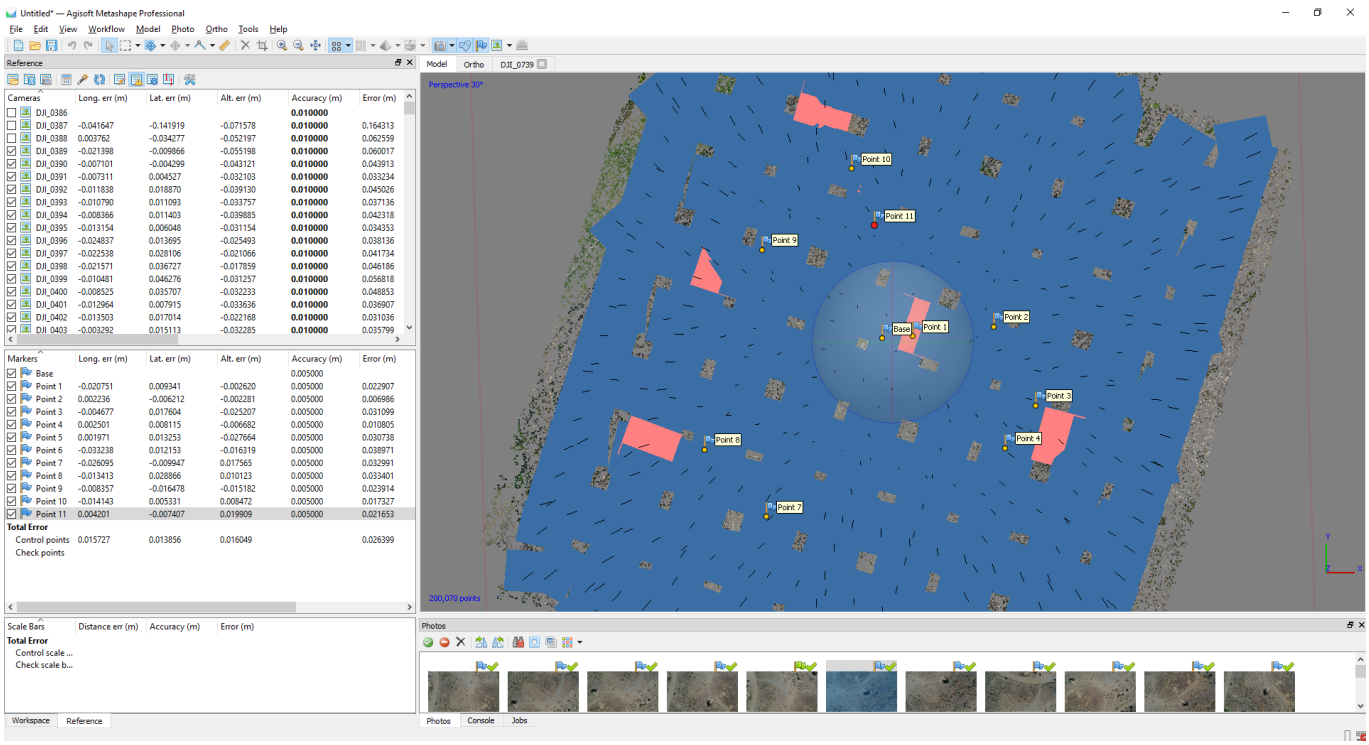

Markers	Long. err (m)	Lat. err (m)	Alt. err (m)	Accuracy (m)	Error (m)
Base				0.005000	
Point 1	-0.020751	0.009341	-0.002620	0.005000	0.022907
Point 2	0.002236	-0.006212	-0.002281	0.005000	0.006986
Point 3	-0.004677	0.017604	-0.025207	0.005000	0.031099
Point 4	0.002501	0.008115	-0.006682	0.005000	0.010805
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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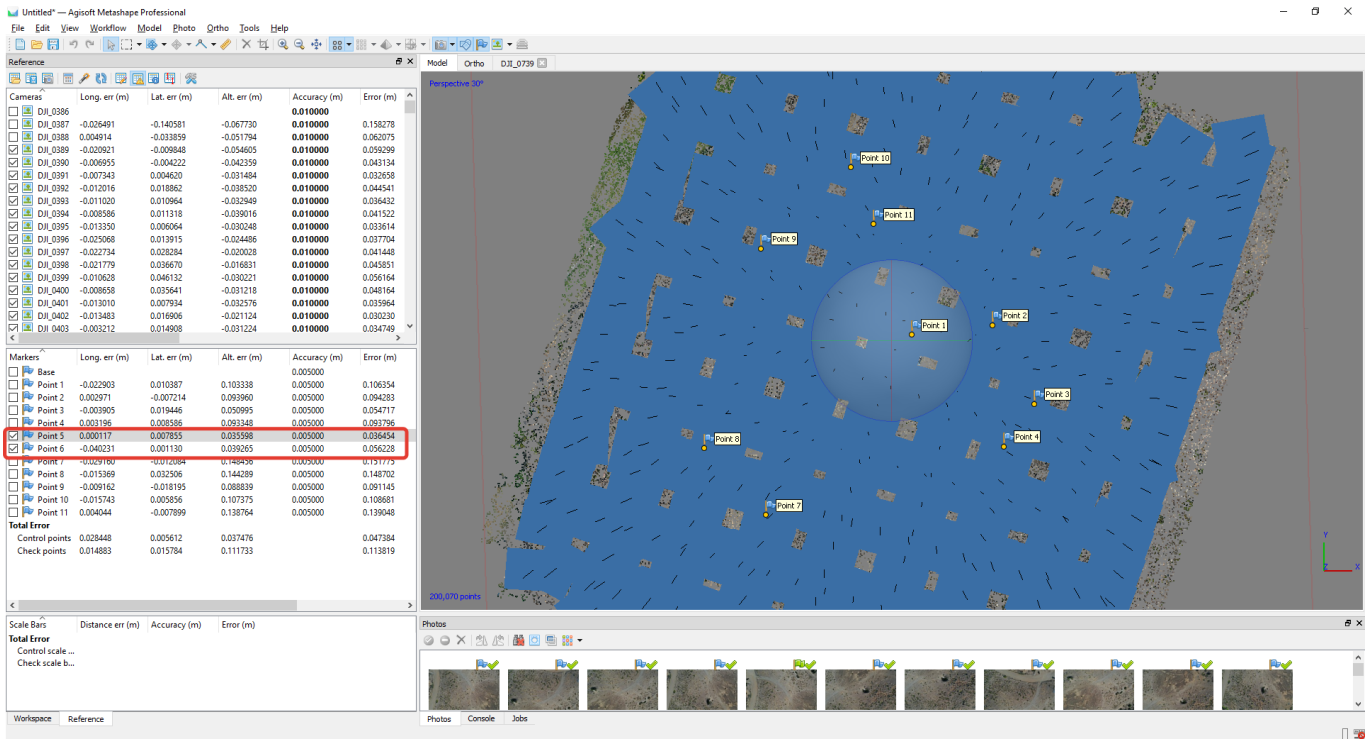
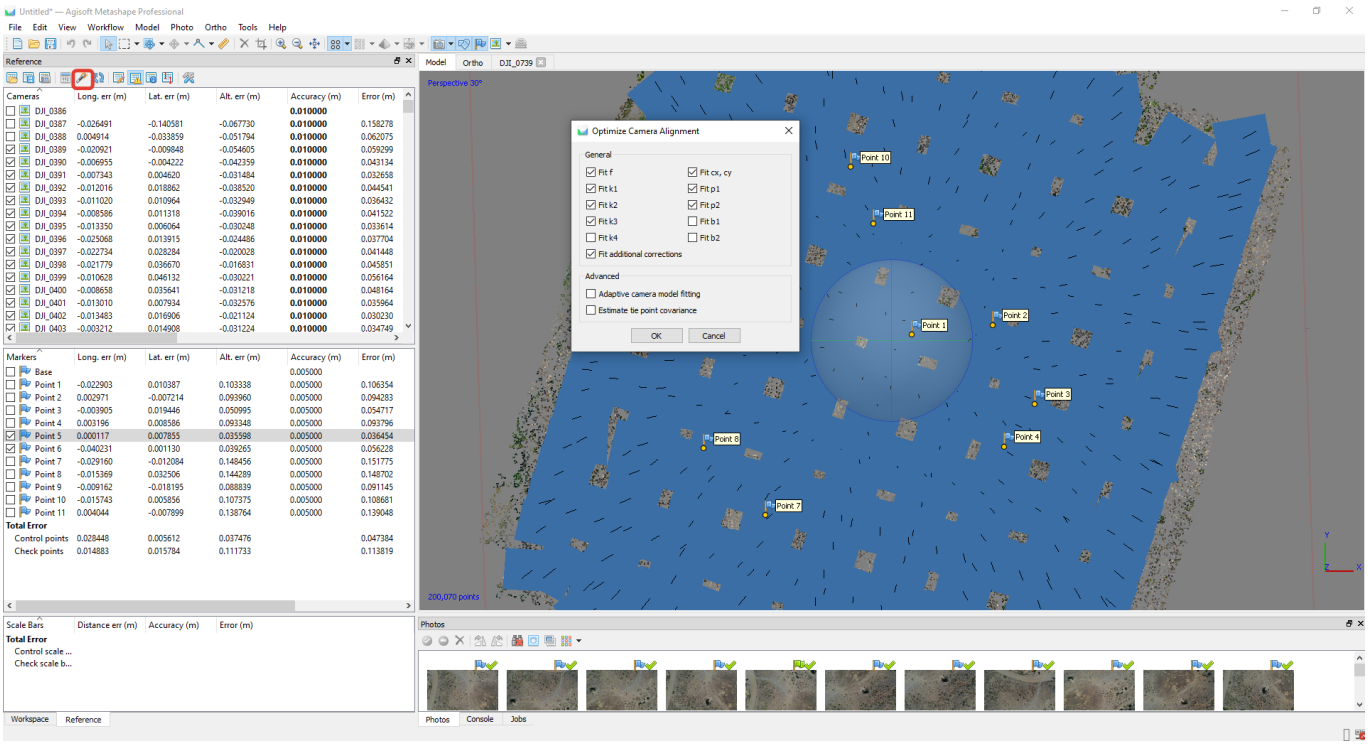
4.3. Camera calibration

To calibrate camera focal length, load images, import accurate coordinates of photos, perform phots alignment (don't fix F parameter) and import GCPs. Define position of markers on each photo. Select 2-3 markers



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



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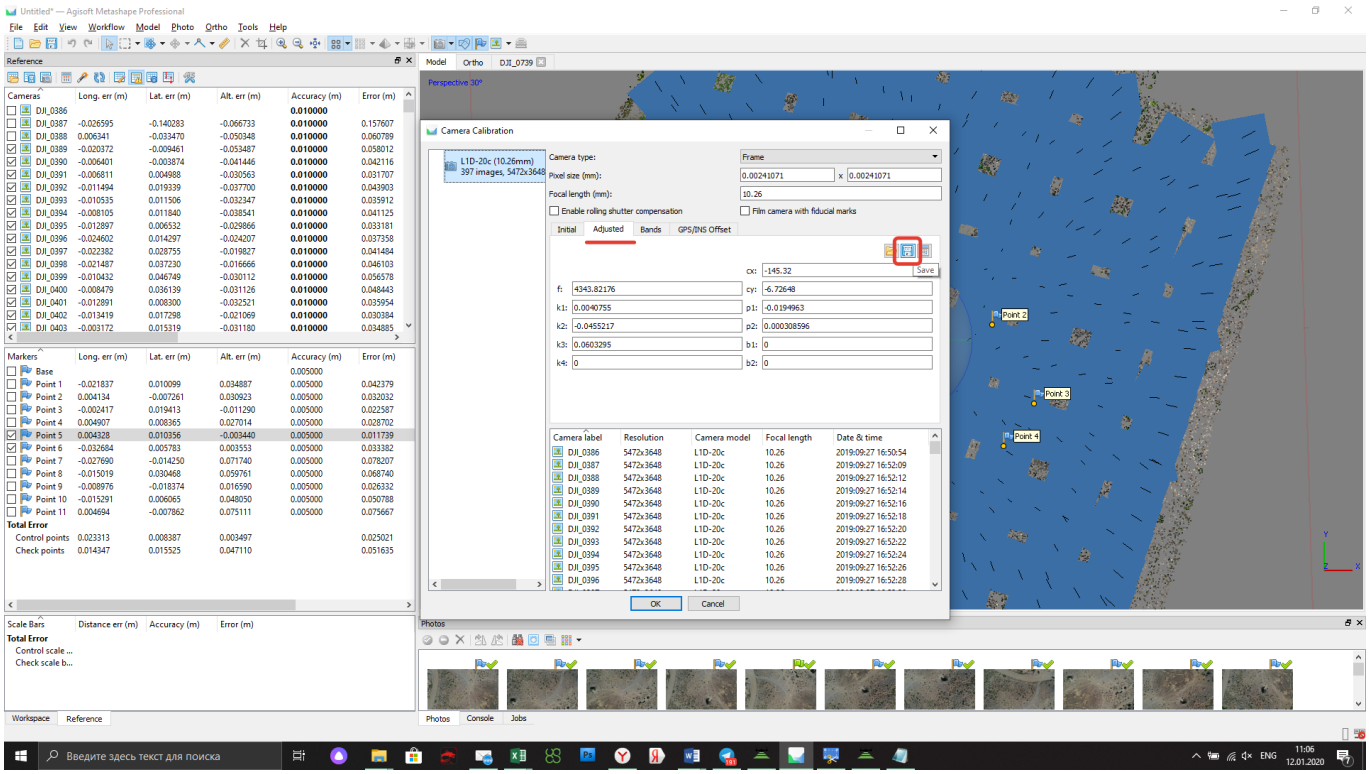
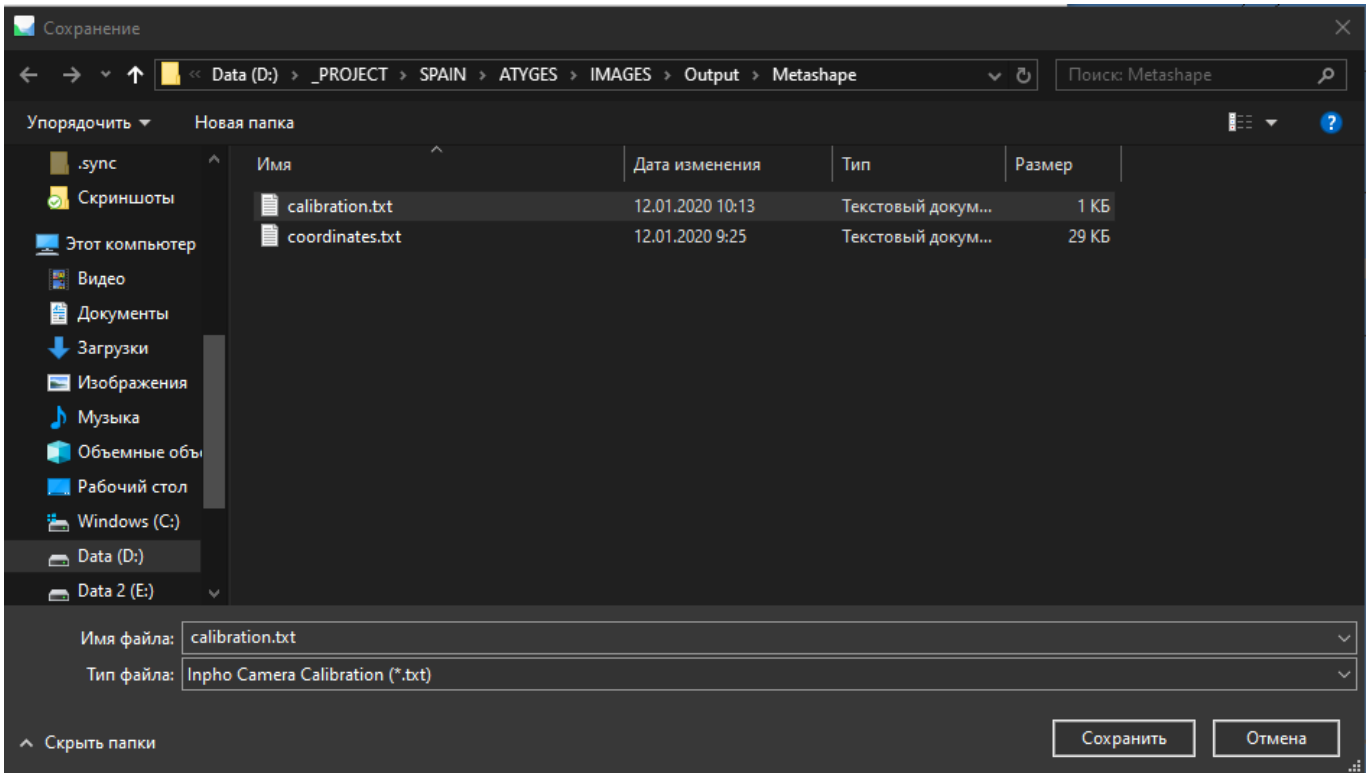
After finishing aerial triangulation, go to Tools, click Camera calibration. Select adjusted and Save button.



Select Info Camera Calibration format and save file.



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Open txt file and copy 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 is possible to use the calibrated value of focal length for the processing If you don’t change focus settings for future flights.

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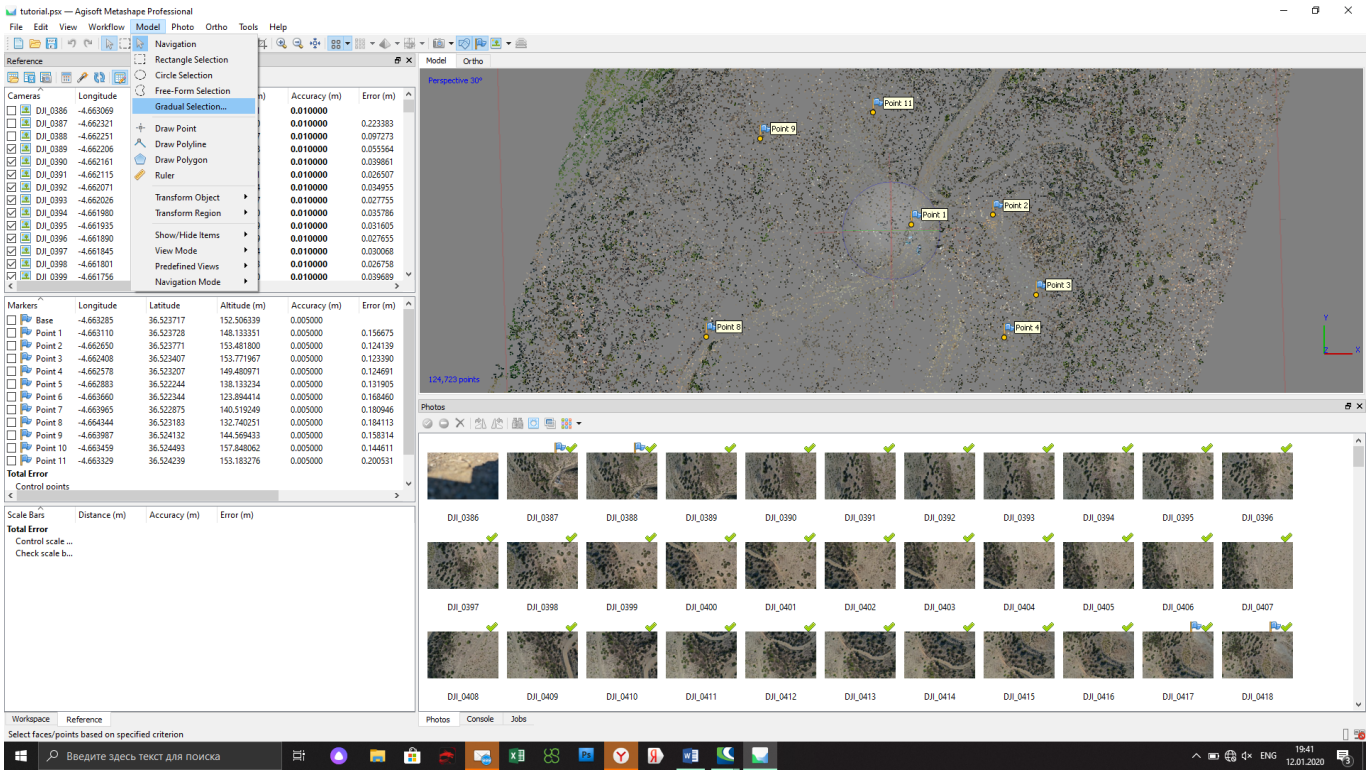
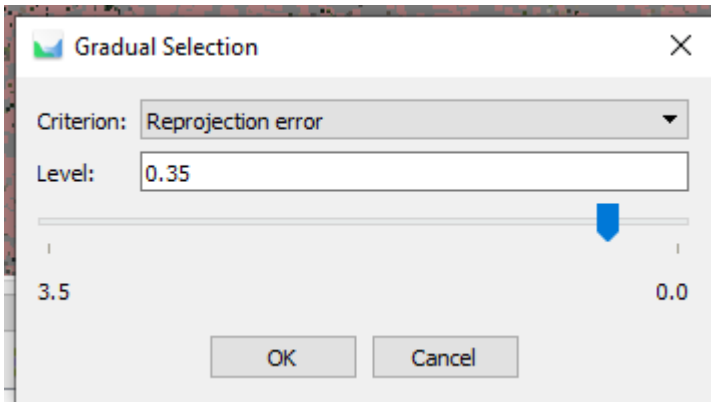
4.4. Aerial triangulation accuracy improvement. Tie points filtering

In order to increase an accuracy of your model, we would suggest to filter tie points using Gradual Selection tool. Open Model menu, click Gradual Selection.



Select Gradual selection and input 0.35 value



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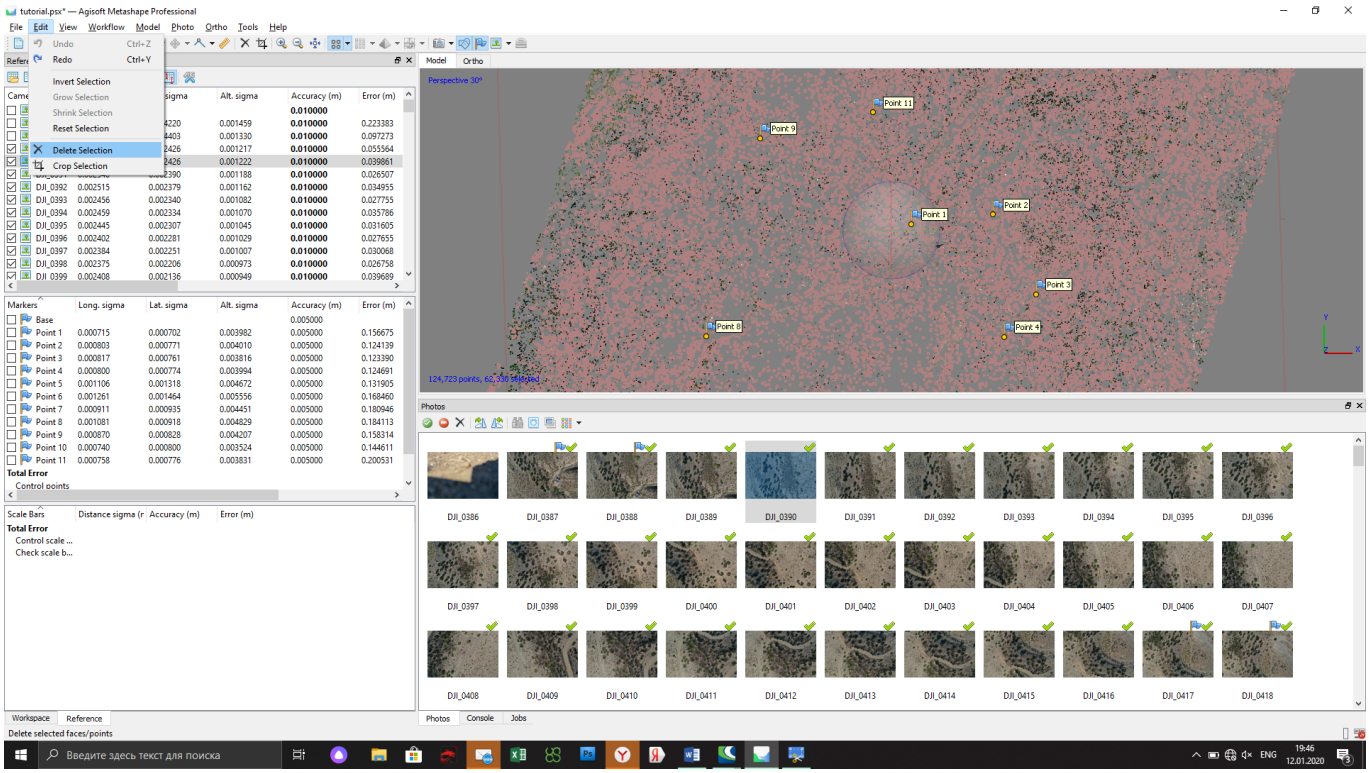
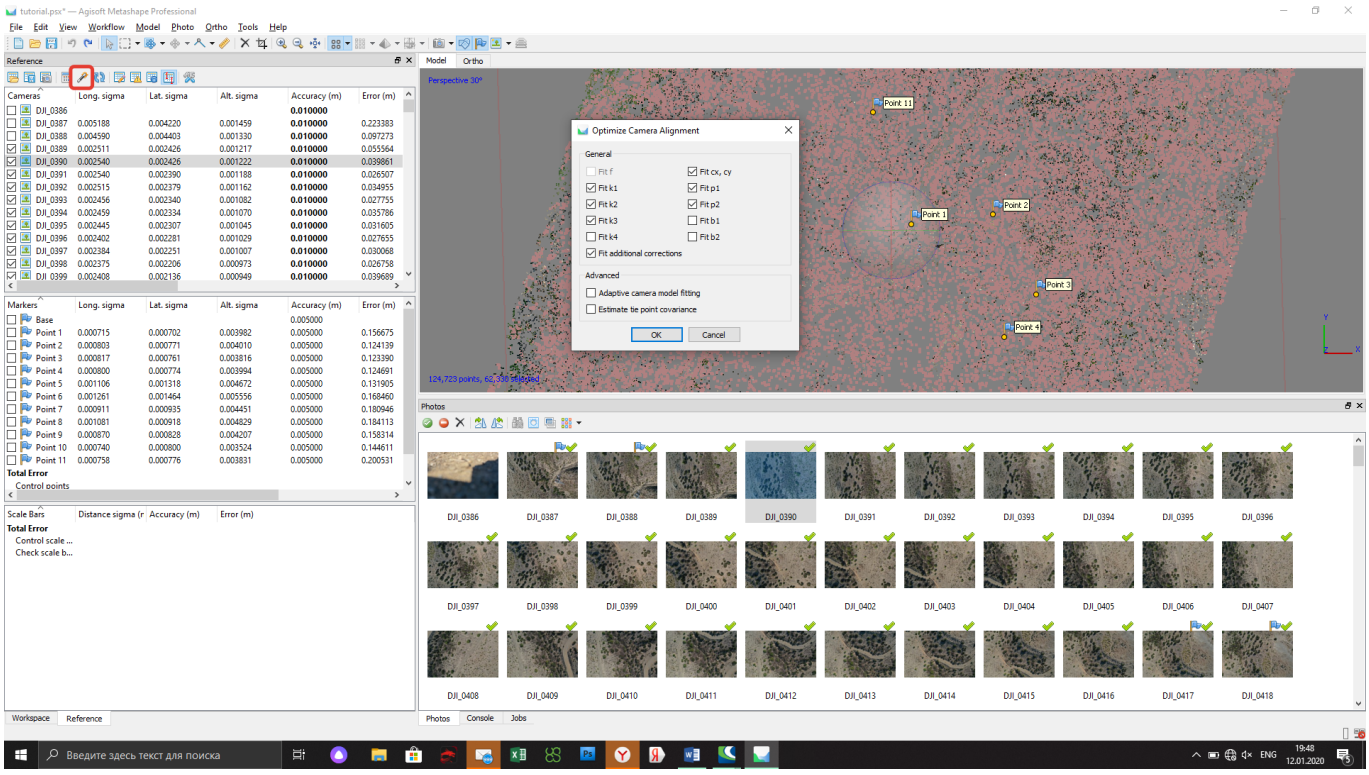
Go to Edit menu and delete selected points



Click "Optimize Camera Alignment"



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