Using SfM Photogrammetry to Estimate the Volume of a Sediment Deposit on the Ain River

Louis Rey

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1. Presentation of the study

1.1. Work environment

Metashape = https://www.agisoft.com/downloads/installer/

QGIS = https://qgis.org/fr/site/forusers/download.html

Open Metashape (Figure 1) and go into Tools>Preferences> GPU (check your GPU devices to use them) then still in Preferences go to General > Language (choose the one you need).

At this point, you should save your project: File > Save as… Give your project a name, ensuring that the 'save as type' box is 'PhotoScan project (*.psx)' (or *.psz if using an older version of PhotoScan).

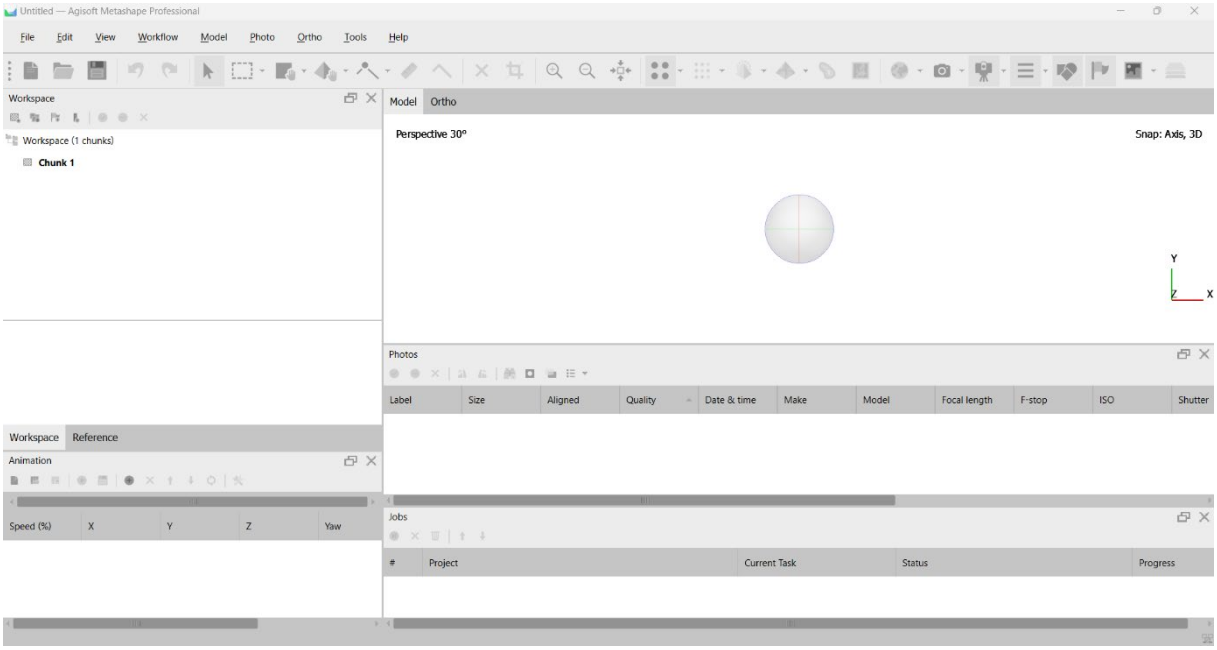


Figure 1 : Agisoft Metashape Pro environnment

To know:

1. Save your project regularly to prevent data loss.
2. Adjust parameters based on project specifics.
3. Remember that the quality of results depends on the input data quality and appropriate settings in Metashape.
4. Metashape documentation here: https://www.agisoft.com/pdf/metashape-pro_1_5_en.pdf or here in French: https://www.agisoft.com/pdf/manuals_other/metashape_pro_fr_1_5.pdf

1.2. Goal of this practical work

The Syndicat Rivière Ain Aval Affluents (SR3A) has deposited several cubic meters of sediment on the banks of the Ain, south of the village of Varambon, in order to compensate for a decrease in sediment inputs into the river. However, it is impossible to get hold of the document where the volume that was deposited was noted…

We ask you to find a way to estimate **as accurately as possible the volume of sediments depot** for the syndicat (Figure 2). Look at the picture of the terrain (Figure 3).

Look where is it, on Google Earth: https://earth.google.com/earth/d/1oszw_eheioh4IBu_iL-ml504gMGBc7IU?usp=sharing

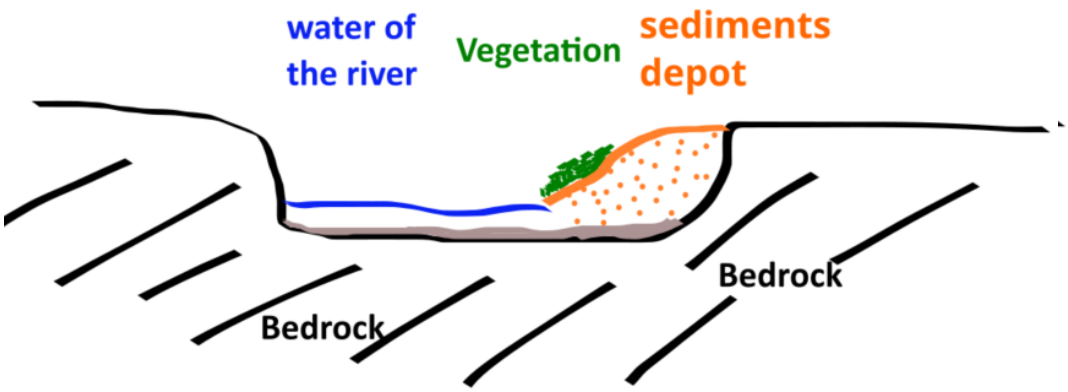


Figure 2 : Scheme of the study

Figure 3 : Area of study

1.3. Data acquisition

Capture Aerial or Ground Photos

Images have been captured with good coverage and sufficient overlap (70% overlap). Usually, we use an overlap of 70% in longitudinal and 70% in lateral.

Before the flight, the height is adjusted according to the camera parameters to get the spatial resolution you need for your project.

Collect GCP on the field

On-site, well-distributed Ground Controlling Points (GCP) are flashed. Record precise coordinates for each point (here it has been used GNSS Trimble R12). I advise you to import your points coordinates into a GIS as QGIS. Then choose which points will be used as GCP among all points and which will be used as check points.

2. Build tie cloud (nuage de points homologues)

Explanation below (Figure 4)(1)

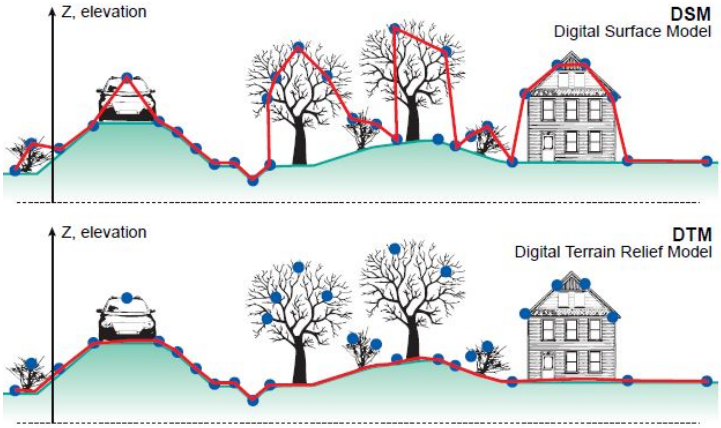


Figure 4 :Differences between DSM and DTM (CDEMA, 2014)

2.1. Import photos

Go to Workflow > Add Photos… or Add Folder…. You can choose to either add a selection of photos or add an entire folder. Select the folder where the photos are stored and all of them will be brought together. Alternatively, drag the image files directly into the Workspace pane.

If you have images with *EXIF* information you need to push the button indicates to collect coordinates information for each image (Figure 5). **Even though there is no EXIF information you could still have the coordinates in the image.**

"EXIF stands for 'Exchangeable Image File' or data exchange file. EXIF is a set of information relating to each photo and presented in a standardized format. This data is generated by the camera when shooting, automatically. They are stored in the image file for JPG, TIFF and RAW formats." (https://www.nikonpassion.com/qu-est-ce-que-donnees-exif-comment-lire-utiliser/).

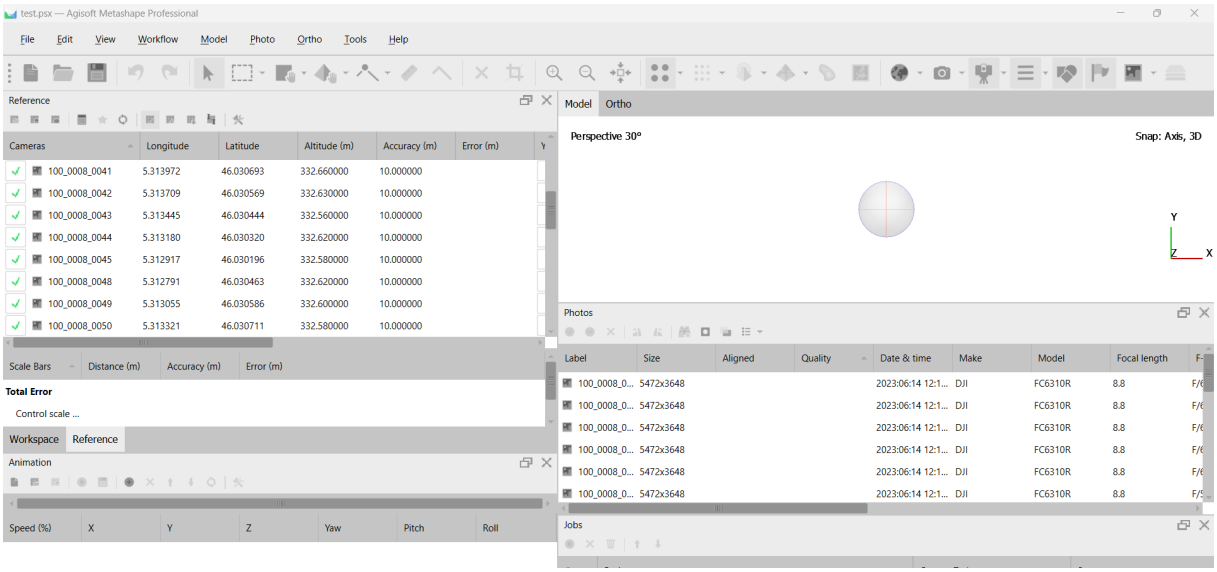


Figure 5 :On the left-up screen informations from camera acquisition for each image and on the right bottom screen information about each picture

When you import your images and the coordinates are not found by the software even though you have the coordinates into a file like .txt file there is a way to catch up the coordinates.

First of all, if you have a file with name of each image you need to add the extension format of the image. For instance, if the image is in .tif you need to add the information. Moreover, you need as well to have the separation of column right (Figure 7). **Be careful, to convert your coordinates into coordinates accepted by Metashape.**

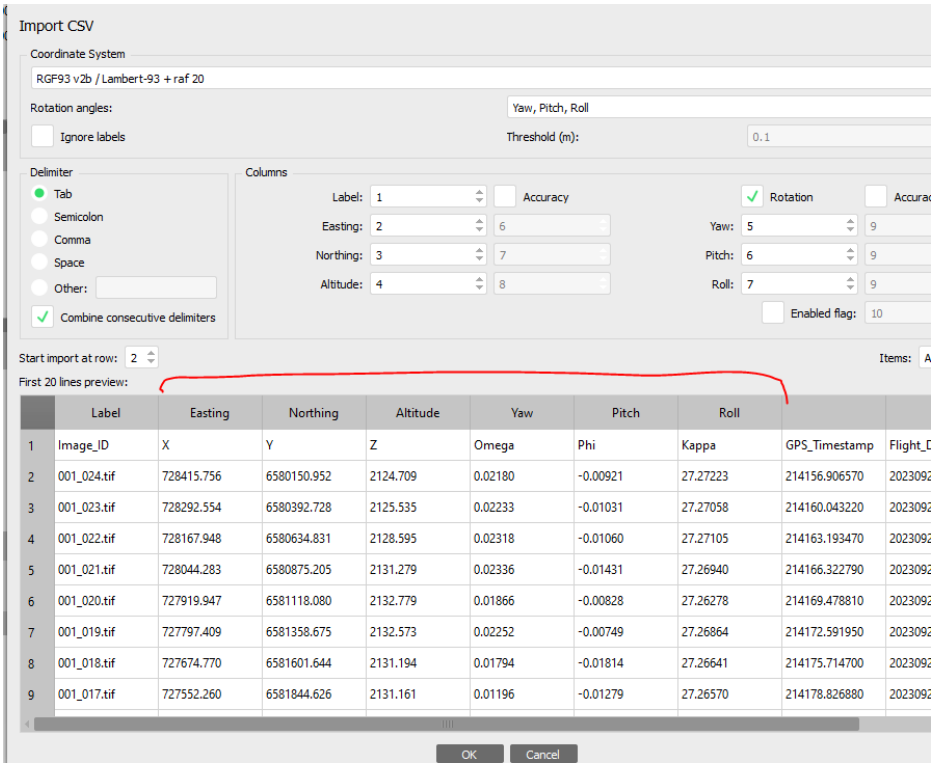
Then, when your file imported is ok, you must go to File>Import>Reference (Figure 6)

Trajecto_Val-Allier_20230926_L93_IGN69-RAF20_mise_en_forme_LouisREY - Bloc-notes

Fichier Edition Format Affichage Aide

Image_ID	X	Y	Z	Omega	Phi	Kappa	GPS_Timestamp	Fligh
001_024.tif	728415.756	6580150.952	2124.709	0.02180	-0.00921			
001_023.tif	728292.554	6580392.728	2125.535	0.02233	-0.01031			
001_022.tif	728167.948	6580634.831	2128.595	0.02318	-0.01060			
001_021.tif	728044.283	6580875.205	2131.279	0.02336	-0.01431			
001_020.tif	727919.947	6581118.080	2132.779	0.01866	-0.00828			
001_019.tif	727797.409	6581358.675	2132.573	0.02252	-0.00749			
001_018.tif	727674.770	6581601.644	2131.194	0.01794	-0.01814			
001_017.tif	727552.260	6581844.626	2131.161	0.01196	-0.01279			
001_016.tif	727428.786	6582085.956	2128.342	0.01793	-0.01128			
001_015.tif	727304.660	6582327.300	2124.150	0.01378	-0.01779			
001_014.tif	727180.246	6582568.958	2120.775	0.01234	-0.01237			
001_013.tif	727056.216	6582809.226	2119.270	0.01574	-0.01831			
001_012.tif	726932.499	6583051.595	2120.305	0.01854	-0.01577			
001_011.tif	726808.857	6583293.361	2122.035	0.01606	-0.02041			
001_010.tif	726685.801	6583533.959	2126.077	0.01267	-0.01490			
001_009.tif	726563.194	6583774.614	2130.035	0.01544	-0.01183			
001_008.tif	726439.156	6584018.910	2131.639	0.01705	-0.01670			
001_007.tif	726316.815	6584261.066	2131.457	0.01409	-0.01218			
001_006.tif	726193.761	6584501.596	2129.049	0.01914	-0.02117			

Figure 7 : coordinates of your images, taking from your .txt file



	Label	Easting	Northing	Altitude	Yaw	Pitch	Roll		
1	Image_ID	X	Y	Z	Omega	Phi	Kappa	GPS_Timestamp	Flight_D
2	001_024.tif	728415.756	6580150.952	2124.709	0.02180	-0.00921	27.27223	214156.906570	2023092
3	001_023.tif	728292.554	6580392.728	2125.535	0.02233	-0.01031	27.27058	214160.043220	2023092
4	001_022.tif	728167.948	6580634.831	2128.595	0.02318	-0.01060	27.27105	214163.193470	2023092
5	001_021.tif	728044.283	6580875.205	2131.279	0.02336	-0.01431	27.26940	214166.322790	2023092
6	001_020.tif	727919.947	6581118.080	2132.779	0.01866	-0.00828	27.26278	214169.478810	2023092
7	001_019.tif	727797.409	6581358.675	2132.573	0.02252	-0.00749	27.26864	214172.591950	2023092
8	001_018.tif	727674.770	6581601.644	2131.194	0.01794	-0.01814	27.26641	214175.714700	2023092
9	001_017.tif	727552.260	6581844.626	2131.161	0.01196	-0.01279	27.26570	214178.826880	2023092

Figure 6 : Import coordinates and information of IMU (yaw,pitch and Roll)

2.2. Observe metadata

Right click > Show infos

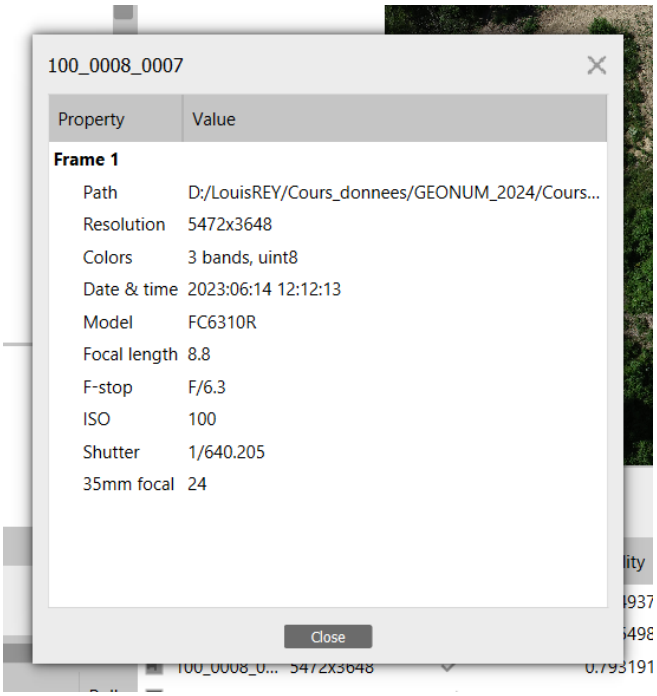


Figure 8 : metadata image

What do you see ? Que voyez-vous ? (Figure 8)

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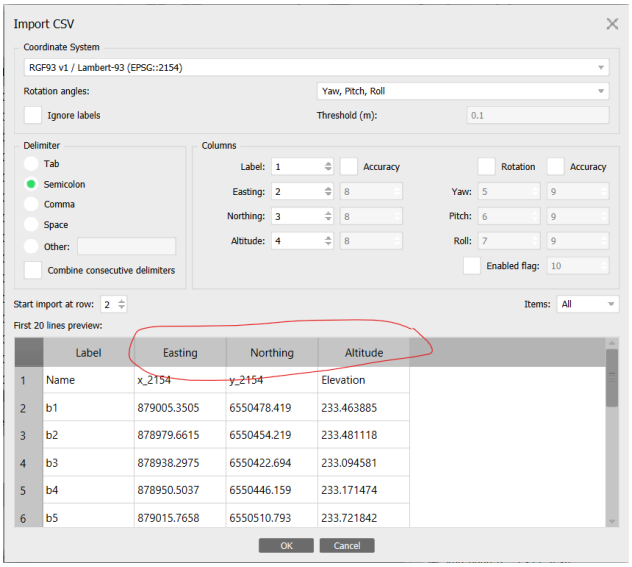
File>Import> Import Reference > GCP (check that your columns are correctly placed)



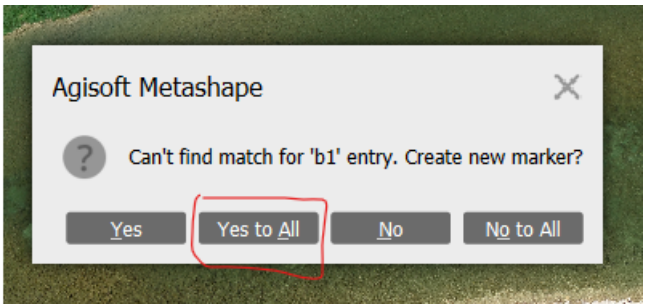


Figure 9 : Import ground points coordinates

Before continuing, go into reference Settings and put the good coordinate system for camera and marker reference.

The GCPs **allow you to convert your model in the desired coordinate system and/or adjust the altitude.**

2.3. Update coordinate system preferences

Now, you have to update coordinate preferences for project, camera and references (Figure 10).

Choose the coordinates system in the panel. If you use one with a geoid applied you maybe will need to import a geoid in Metashape Pro folders. Go at this link to get geoid file adapted for Metashape: https://www.agisoft.com/downloads/geoids/ . To know the process to do follow this link : https://agisoft.freshdesk.com/support/solutions/articles/31000148332-how-to-use-height-above-geoid-for-the-coordinate-system .

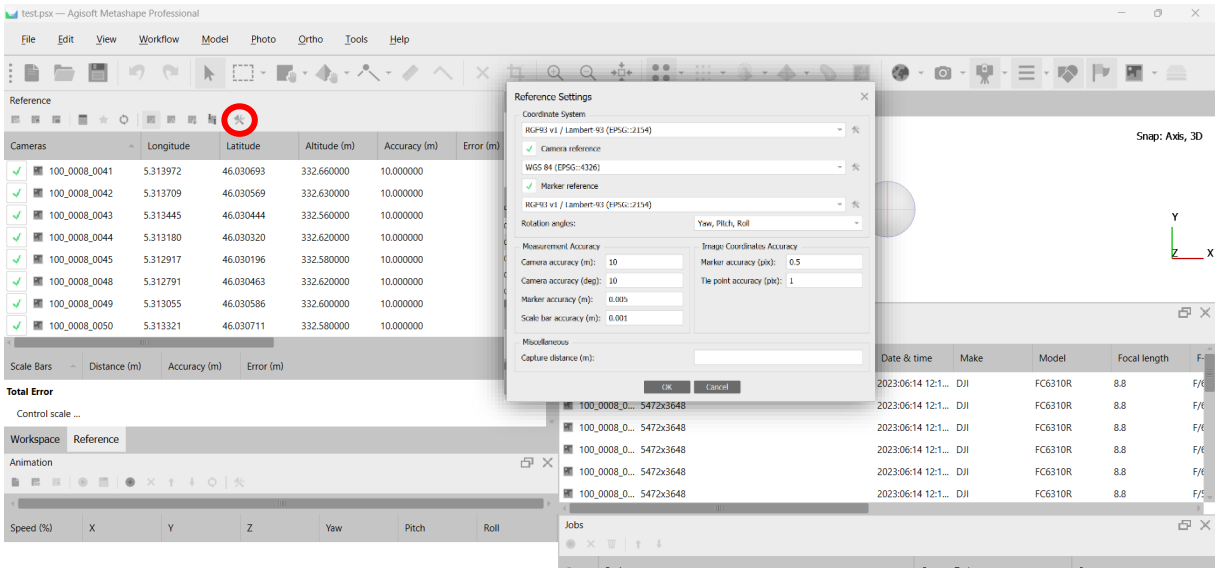


Figure 10 : Update coordinate system preferences

2.4. Image quality control

The aim of this step is to **eliminate any blurred, out-of-focus or unwanted photos** from your photoset. These images may obscure some of the features needed to match overlapping imagers and may decrease the accuracy of the final product.

If a photo appears blurred or a major portion of a photo appears blurred, remove it.

On the bottom screen “Photos” *right click on it > Estimate Image Quality>All images* (Figure 11). If your image quality **is below 0.7 you should remove it**. You can choose the threshold you would prefer according to the quality of data you have.

What do you see ? Que voyez-vous ? Figure 8 *(Figure 11)*

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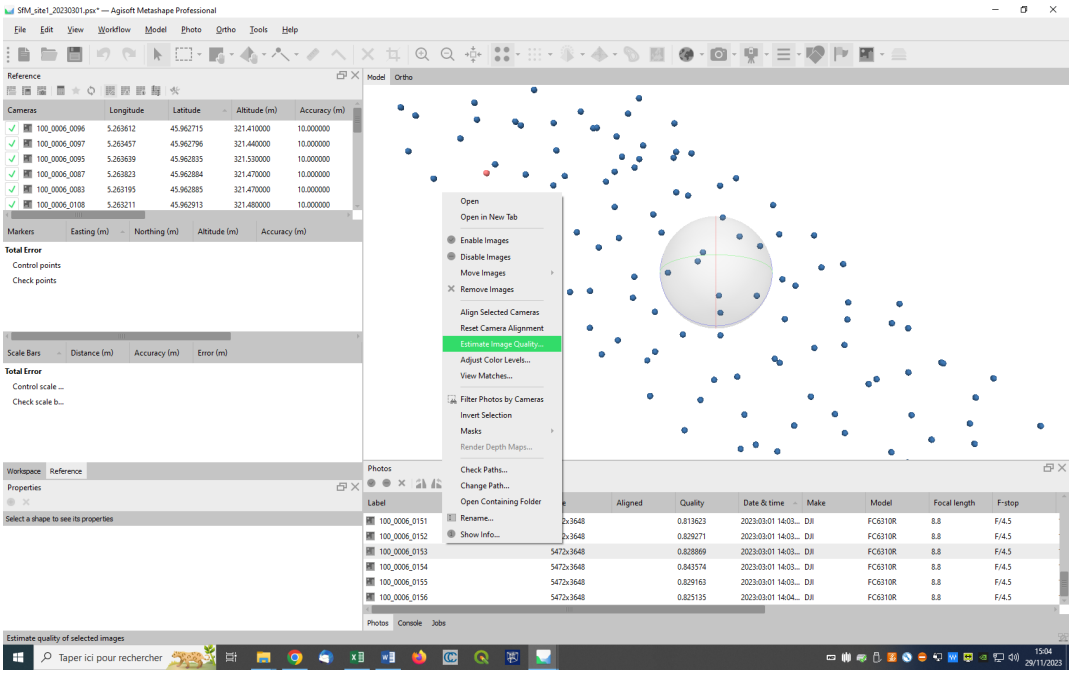

Figure 11 : Estimate Image Quality

2.5. Align images

The first step in the model generation process is to align the photos (Figure 12). This process results in a sparse point cloud, representing the ties points found between overlapping images, and the initial camera locations; both are found using the **SIFT** (Scale-Invariant Feature Transform) algorithm to **find matching point between overlapping images.**

Go to *Workflow > Align Photos (the virgule means thousand).*

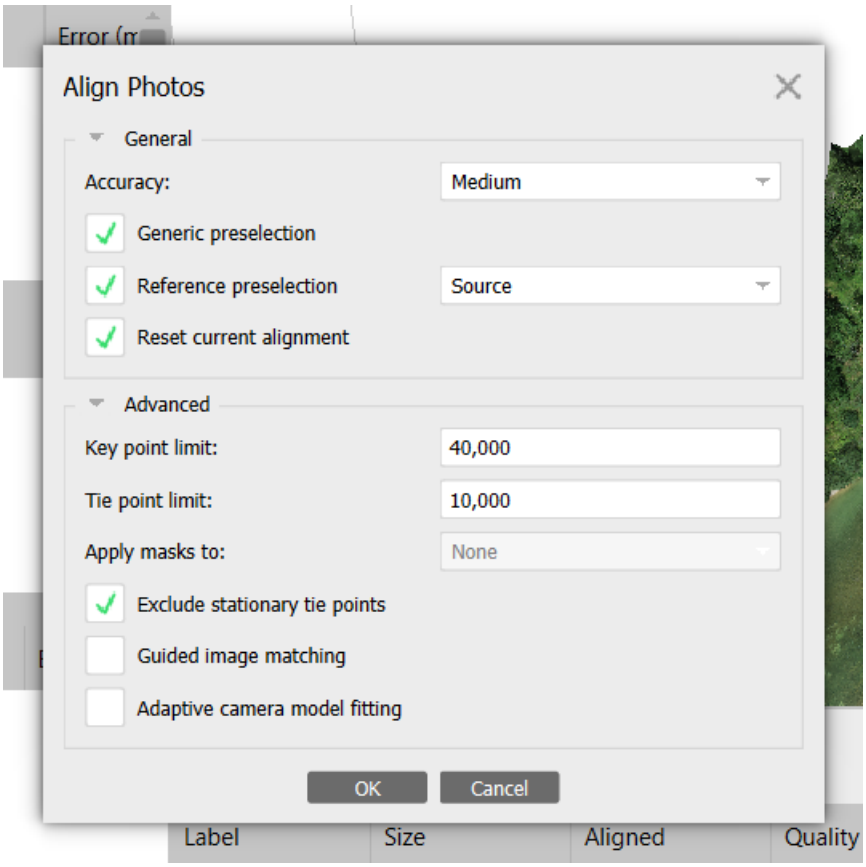

Figure 12 : Align Photos tools

Several parameters are required in the Align photos dialog, which are explained below (Figure 12).

Accuracy: Highest – High – [Medium] – Low - Lowest (the photos will not be down sampled - this

helps with later steps. lower accuracy setting can be used to get the rough camera positions in the shorter time)

Generic preselection: Disabled – [Enabled]. If disabled, processing is faster. Enable the option if you have issues aligning some photos.

Reference preselection: Disabled – [Enabled]. If your photos are geotagged, this will use the GPS positions to speed up camera alignment.

Key point limit: [40,000] is default. Lower number of key points can speed up processing, but increases the risks of lacking points for correct alignment.

Tie point limit: 4000 is default but [10000] is usually used. Sets the minimum number of ties needed to match images.

be set to 0 if images not aligning, but at the expense of lower accuracy.

Constrain features by mask: [Disabled] (Enabled in case any area has been masked prior to

processing).

You can change the size of the region of interest in going into Resize region

Through this, you will get in the view the photos aligned and you will get the tie points found.

2.6. Clean tie points

Tie points created, you can now clean them by hands in removing points which seem wrong, like the very low and high ones (Figure 14).

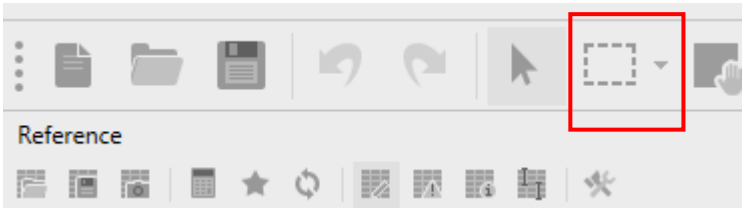

Figure 13 : Tool to select in the main panel

How is your tie points cloud ? Comment est votre nuage de points homologues ? Figure 8

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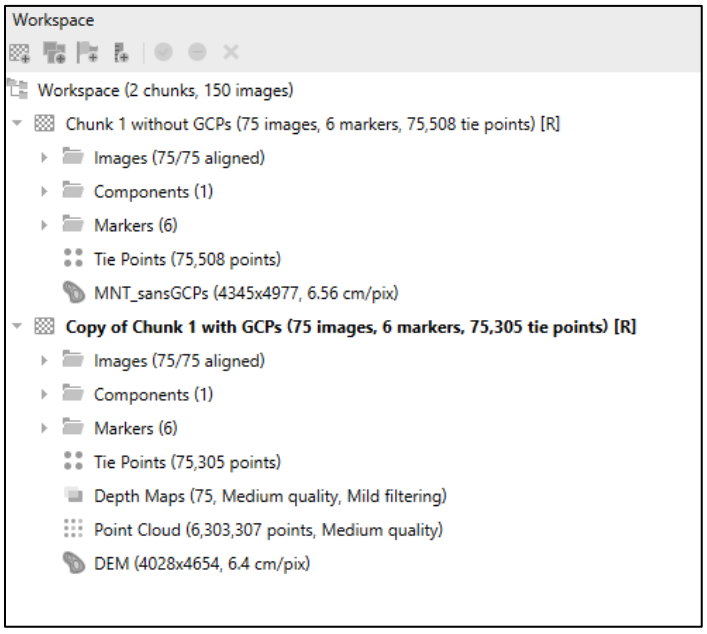
2.7. Create two chunks (projects)

You copy your project. Now, you have one named **without** GCPs and one **with** GCPs.



3. Create models with or without GCPs

3.1. Without GCPs

3.1.1. Optimized camera alignment

Click on Optimized camera alignment on reference bar (Figure 14).

The depth map will be removed.

This function takes into account:

(1) Internal parameters (camera intrinsics):
Focal length.
Principal point offset (cx, cy).
Lens distortion coefficients (e.g., radial and tangential distortion).
(2) External parameters (camera extrinsics):
Camera position (X, Y, Z).
Camera orientation (yaw, pitch, roll or rotation matrix)

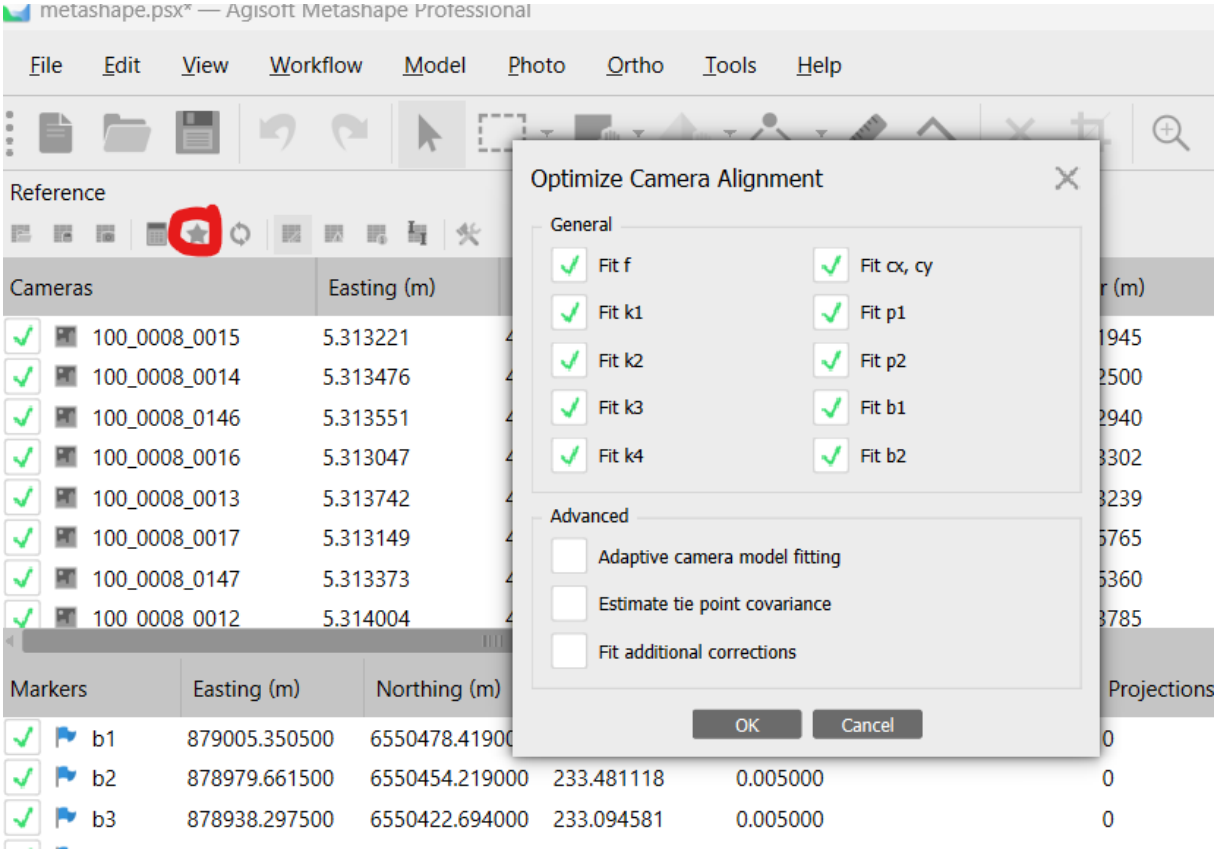


Figure 14 : Optimized camera alignment

3.1.2. Build dense cloud

In order to build the dense cloud, you need to have a depth map. After the step of Optimized Camera, you lose the depth map. That's why when you launch the tool Build dense cloud, the software builds automatically a depth map and then the dense cloud.

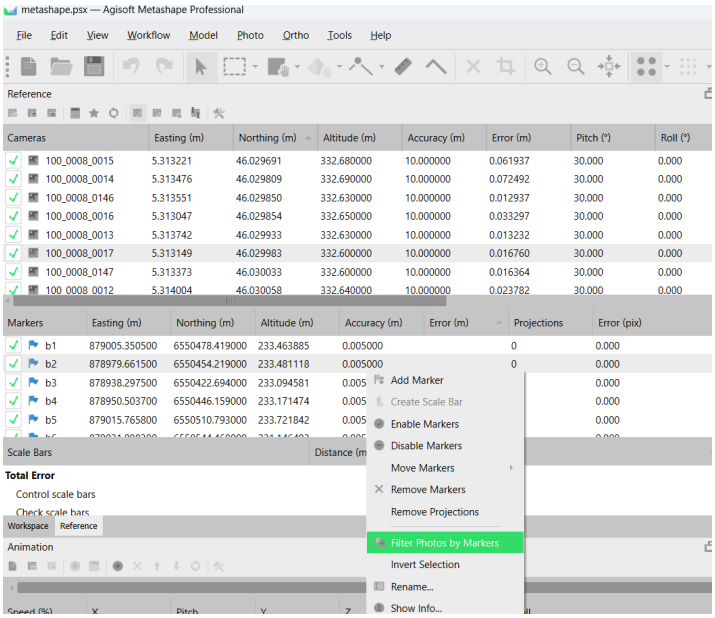


Figure 15 : Filter Photos by Marker

Once at least three markers are set, the software can estimate the location of all the remaining GCPs. Click the Update Transform button in the Reference pane (Figure 17).

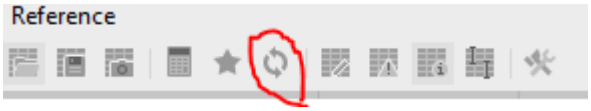


Figure 16 : Tool to refresh your model in the main panel

3.1.3. Create dense cloud

Based on the estimated camera positions, the program calculates depth information for each camera to be combined into a single dense point cloud. The dense point cloud operation fills in all the blank or empty areas in the sparse cloud and assigns colors values based on these photos. Dense point cloud generation is based on depth maps calculated using **dense stereo matching.** Go to *Workflow > Build Dense Cloud.* (Figure 19).

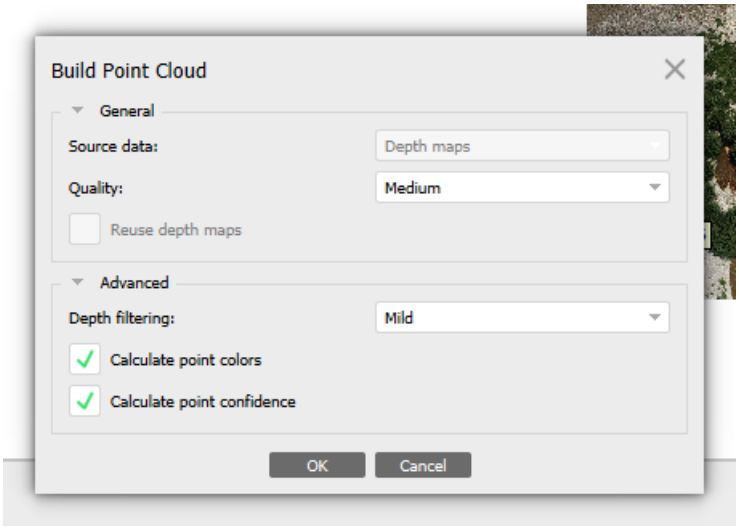


Figure 17 : Build Dense Cloud

Set the following recommended values for the parameters in the Build Dense Cloud dialog:

Quality: Ultra high – [High] – Medium – Low - Lowest: Uses original photos. Requires a large amount of memory, so recommended only for specific hardware setups. If small number of photos and/or high quality required, select Ultra high. Otherwise, High usually achieves good quality results or Medium if your computer is not adapted for heavy treatments.

- High: Photos are downsampled by a factor of 4. Recommended for smaller photosets.
- Medium: Photos are downsampled by an additional factor of 4. Recommended for larger photosets.
- Low: Photos are downsampled by an additional factor of 4. Not recommended.

Depth filtering: Disabled – Mild – Moderate – [Aggressive]: (if the geometry of the scene to be reconstructed is complex with numerous small details or untextured surfaces, like roofs, it is recommended to set Mild depth filtering mode, for important features not to be sorted out. If mild and aggressive options do not seem optimal for your data, select Moderate).

Reuse depth maps: disable

Calculate point confidence: = **important to clic here to clean dense cloud then**. Metashape assigns a confidence score to each point in the dense point cloud, based on various criteria such as the redundancy of a point's observations (how many photos it has been seen by).

After this step, a dense point cloud will appear.

3.1.4. Clean dense cloud

(1) Filter your points cloud by confidence

Before starting the cleaning, click on the button Show Markers and deselect the markers (Figure 20).

Confidence value can be used to perform additional filtering of low confidence points. For every point in a point cloud the number of contributing combined depth maps is recorded and stored as a confidence value.(2)

You can now, filter by confidence and remove the points with the lowest confidence.

Go into *Tools>Dense Cloud>Filter by Confidence* (Figure 21).

You have to increase the minimum value of confidence you want and test what is the better in your case. The idea is to remove the points with less confidence.

Then do the same process but between 0 and the minimum value of confidence. Now, all points with confidence you don't want are selected.

Delete them.

Tool>Dense Cloud>Reset Filter

Save project.

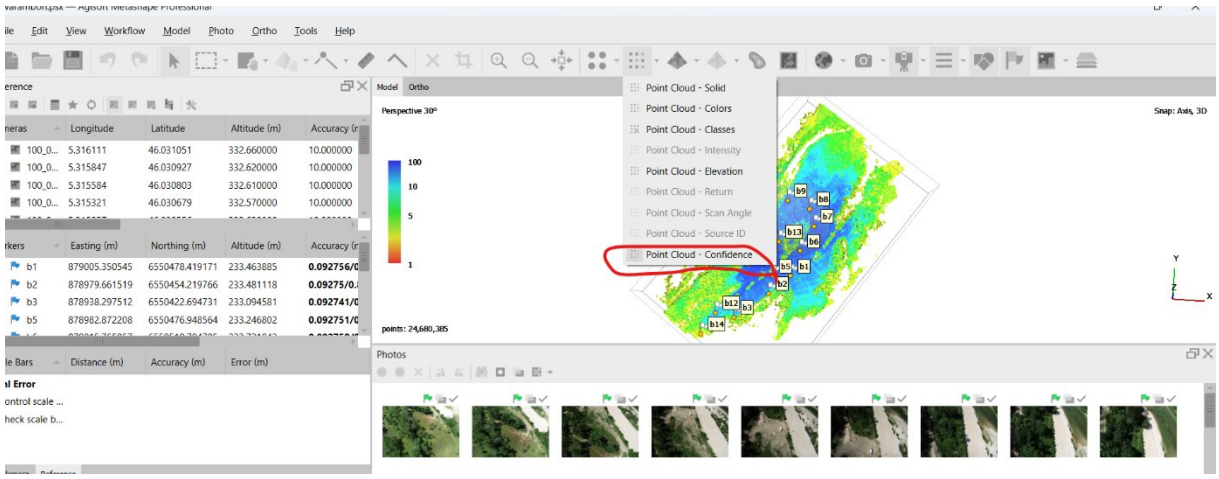


Figure 18 : Filter points by confidence

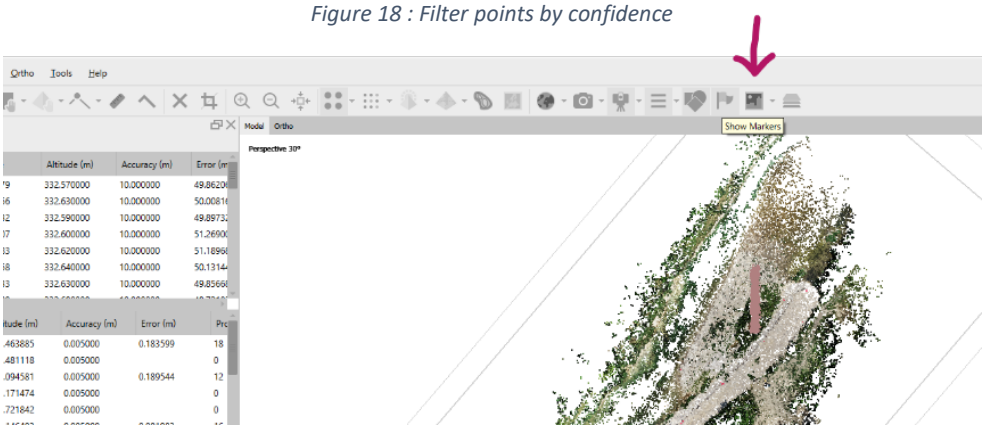


Figure 19 : Button Show Markers

(2) Filter incoherence by hands

When you look at your cloud points and if you still have points that are below sur surface or way above, you must remove them.

To do this, go to the icon Free-from Selection (Figure 22)

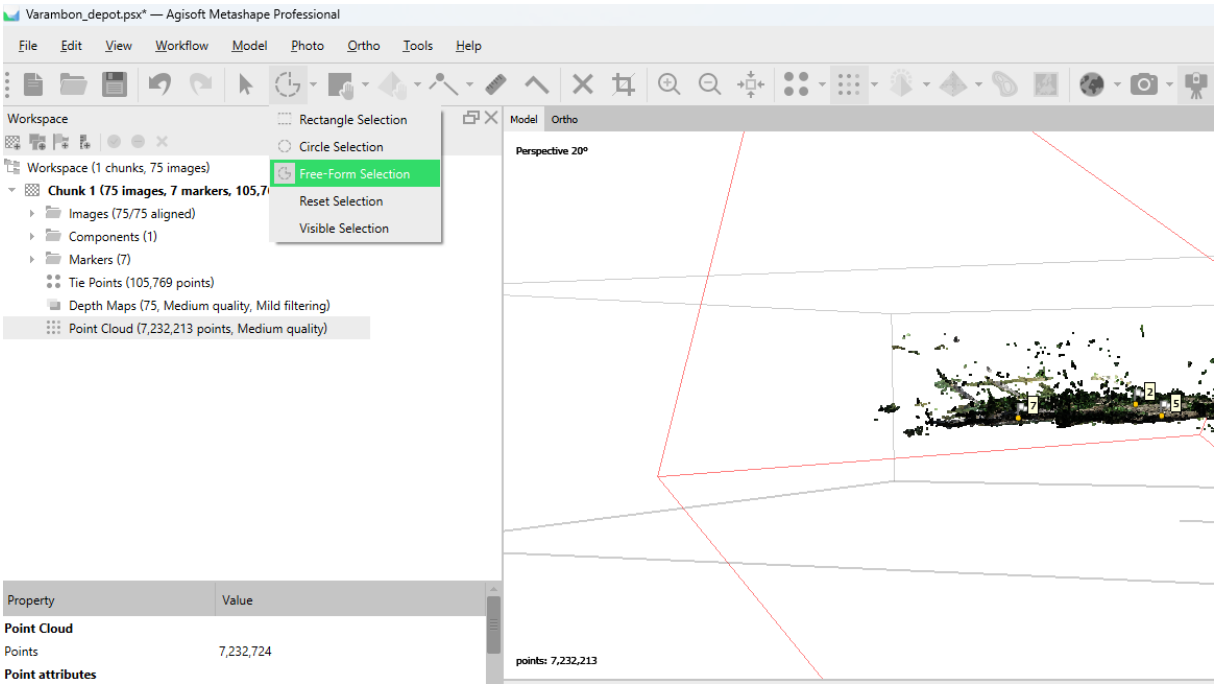


Figure 20 : Select by hands points

What does your dense point cloud look like? A quoi ressemble votre nuage de points dense ? Figure 8

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3.1.5. Class ground points

Tools>Dense cloud>Classifying ground points (Figure 23)

From: you can choose what class of points

Max angle (deg) : Determines one of the conditions to be checked while testing a point as a ground one, i.e. sets limitation for an angle between terrain model and the line to connect the point in question with a point from a Editing ground class. For nearly flat terrain it is recommended to use default value of 15 deg for the parameter. It is reasonable to set a higher value, if the terrain contains steep slopes.

Max distance (m) : Determines one of the conditions to be checked while testing a point as a ground one, i.e. sets limitation for a distance between the point in question and terrain model. In fact, this parameter determines the assumption for the maximum variation of the ground elevation at a time.

Cell size (m) : Determines the size of the cells for point cloud to be divided into as a preparatory step in ground points classification procedure. Cell size should be indicated with respect to the size of the largest area within the scene that does not contain any ground points, e. g.a building or a dense forest or a bridge.

Erosion radius (m): Determines the indentation (in meters) from unclassified points to create an additional area from the object, it is useful when classifying houses and trees to exclude the remaining "stumps" when building DTM

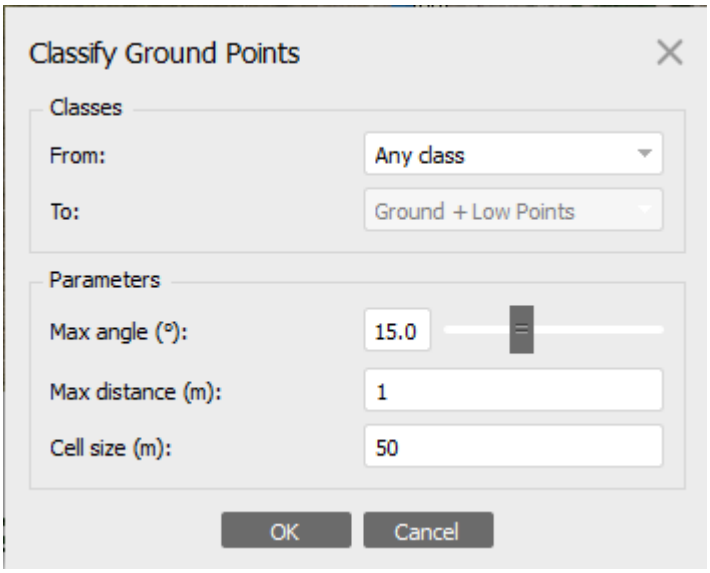

Figure 21 : Classify ground points

3.1.6. Build a DEM (here MNT)

Digital elevation model = DEM

With the points you classed you can build a DEM of ground or all points.

Go to *Workflow>Build DEM* (Figure 24). A dialog box will appear. Specify the coordinate system, source data, interpolation, and point classes to include. The coordinate system can be modified when the

DEM is exported. Be aware that DEM generation relies on sets of parameters that cannot be set in Metashape. For higher control on DEM creation parameters, it is advised to export model as Point Cloud and use other software (eg. ArcGIS, QGIS, Matlab, R, LASTools, CloudCompare, etc.).

Set the following recommended values for the parameters in the Build DEM dialog:

Projection type: [Geographic] – Planar – Cylindrical (if you used a projected or geographic coordinate system, you should select Geographic. Only use Planar if working in local coordinate system).

Projection: default (projection set in the Reference Settings is used. The coordinate system must be the same as coordinate system of GCPs).

Source data: Sparse cloud – [Dense cloud]

Interpolation: [Enabled](default) – Extrapolated.

Points classes: Use only « Ground »

The resolution is automatically defined by the software. You will be able to change this when you export it.

Think to export your DEM (MNT)

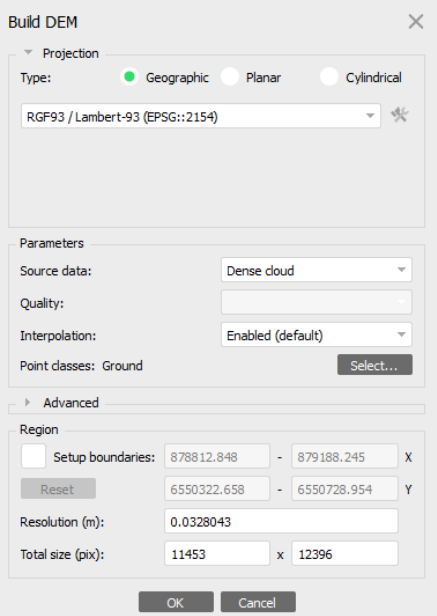

Figure 22 : Build DEM (en français MNT)

3.1.7. Build Orthomosaic (optional for the project)

You can build an orthomosaic with the DEM. However, you need a lot of rams Go (Figure 25).

Workflow>Build Orthomosaic

A dialog box will appear. A number of parameters may be set :

Projection type: Same as DEM (see above).

Projection: by default, the projection set in the Reference Settings is used.

Surface: DEM: **Best for aerial survey data and mesh + texture best for surfaces data as a building to have a smooth and detailed surface**

Blending mode: [Mosaic] – Average - Disabled (blends specific pixels from photo with best representation of feature with pixels from other images to avoid seams in the texture).

Enable back-face culling: Enabled – [Disabled]. (Option mostly important for non-vertical images).

Enable hole filling: [Enabled] –Disabled.

Pixel size (m): it is advised to choose the same pixel size as the one chosen for DEM generation. If no DEM was build, follow the same rules as above when choosing resolution: aim for orthogonality while keeping highest resolution possible.

Region: it is advised to choose the same boundaries as the ones picked for DEM building. If no DEM was built, select boundaries that are coherent with resolution and allow correct model orthogonality.

Total size (pix): will adjust automatically with resolution and boundaries.

Click OK button to start Orthomosaic generation.

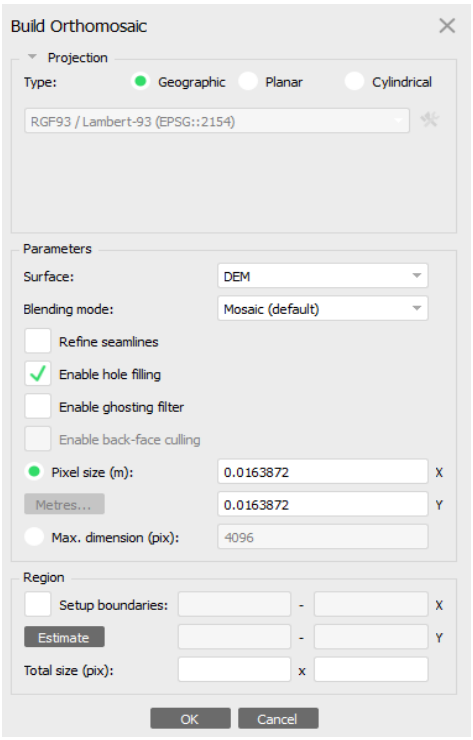

Figure 23 : Build orthomosaic

3.2. With GCPs

3.2.1. Import GCPs

GCPs should be surveyed prior to image acquisition using a dGNSS. These are necessary to georeferenced your model in a real-world coordinate system, **especially if your photos are not geotagged.** They can also be used to determine model accuracy, i.e. how confident you can be about the model. The number of GCPs required to generate accurate models depends on the camera used (distortion, resolution, etc.), local topography (high topography difference require more GCPs) and the purpose of the survey (e.g. detection of changes require high accuracy, hence a higher density of GCPs).

Import coordinates of points taken by DGNSS and only select the ones that you want to keep for the process (Figure 9). **Keep only the points: 8;6;5;1;4;12;9**. The others will be used later.

3.2.2. Georeferencing GCPs

I advise you to import your GCPs coordinates into a GIS as QGIS. Then chose which points will be used as GCP among all points. The step allows to correct the coordinates of your model and adding the altitude geoid correction (if the GCPs altitude have been corrected).

All points are represented by a **white flag on images randomly**, meaning that either the software or you have not placed the point.

When **the software has placed a point, the flag will be in blue**. When you move manually a point the flag go from white or blue to green. **Green flag means it has been verified by you.**

To associate the points with their locations manually click on each image and if you find the place of a GCP (Figure 15), **you have to move the point into the center of your marker (red square for example).**

Figure 24 : Red target

When a GCP is identified in at least two photographs, the software **is able to automatically estimate the location of that GCP in all aligned photos** (blue flag appears). Right-click on the marker in the Reference pane and choose **Filter Photos by Marker** (Figure 15) in the dropdown menu. Sort through these photos and place the marker accurately in each of them. If the GCP is not in the photo or inaccurately placed, right-click the flag that appears on the photo and choose Remove Marker from the dropdown menu that appears.

You have to use the tool Optimized camera alignment, in order to used the GCPs for corrections of of your model.

3.2.3. Repeat the steps from the part 3.1

Now, you can repeat the steps from 3.1.2(Build dense cloud) to 3.1.6(Build a DEM (here MNT))

4. Export products

4.1. Export DEM and orthomosaic

Export DEM and Orthomosaic : *File>Export>DEM and Orthomosaic* (Figure 26).

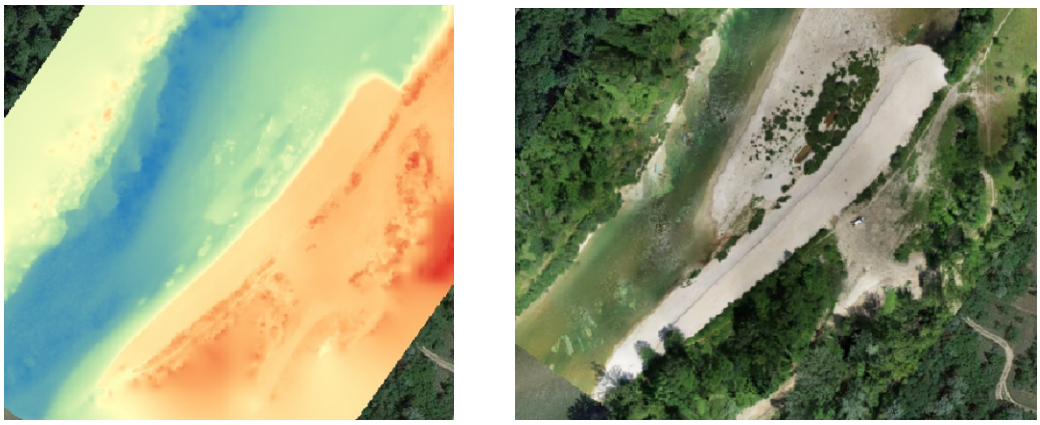

Figure 25 : DEM and Orthomosaic

4.2. Export the report of everything you did in Metashape

Export the report of all your treatments in order to know what you have done in Metashape (Figure 27). File>Export>Generate Report

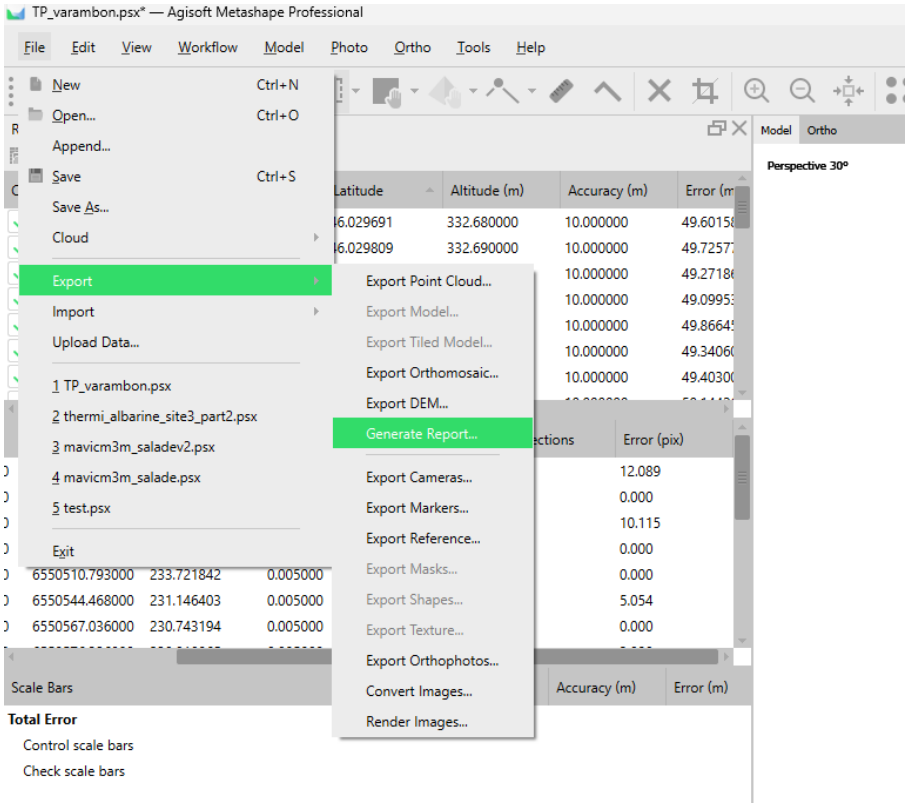

Figure 26 : Export the report of your workflow in Metashape

5. QGIS Calculate a volume from a DEM

5.1. Import your DEM of the terrain you made in last steps

Import your DEM (MNT) that you built in Metashape or another software.

And import the points of control (all of them).

What does your DEM (Surface and Soil) look like (visual quality)? A quoi ressemble votre MNS et MNT(qualité visuelle) ? Figure 8

……
……

5.2. Estimate difference of height between model and GNSS points GCP

It exists many ways to compared your DEM model with GCP that have been used.

In QGIS you can use *Point Sampling Tool* or "*Prélever des valeurs rasters*" in French .

Now, you have a table with the altitude from the DEM and from the GCP. You are able to know the differences of altitude between them.

Is there a significant difference between the altitudes of the DEM and the altitudes of the other points? Y a-t-il une différence significative entre les altitudes du MNT et les altitudes des autres points ?……
……

5.3. Cut you DEM by the limit of the sediment depot

Import the polygon from your folder Varambon_study\input\borders_depot.shp

Then cut you raster DEM by limits of the polygon.

5.4. Import water level points format .shp

Import the polygon from your folder Varambon_study\input\coordinates_GNSS\ water_level_.shp If

5.5. Create a raster from measured water level points with linear interpolation.

Tools box(Boîte à outils) >Interpolation IDW (Inverse Distance Weighted): In the IDW interpolation method, the sample points are weighted during interpolation such that the influence of one point relative to another declines with distance from the unknown point you want to create (Figure 29).

Take the same spatial resolution as the MNT and the the same coordinates system.

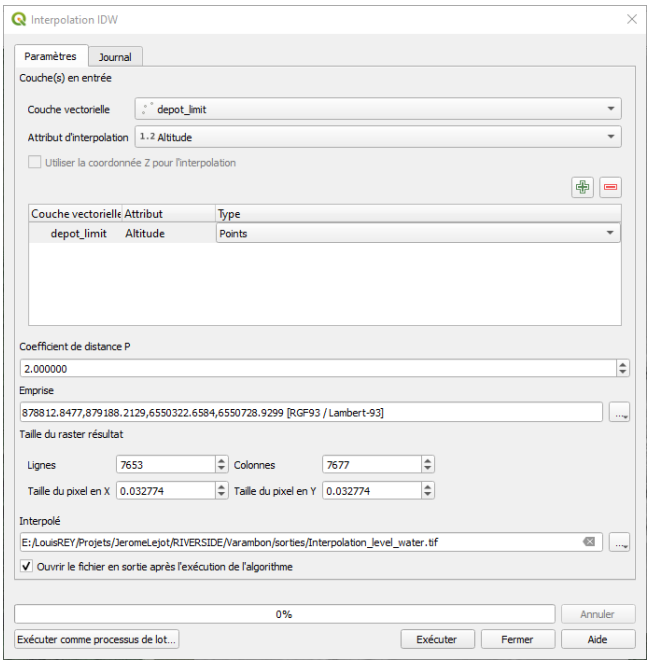

Figure 28 : Interpolation of your points layer to raster

If the layer doesn't work for the interpolation create a new point layer and fill the points with the altitude values (Figure 28).

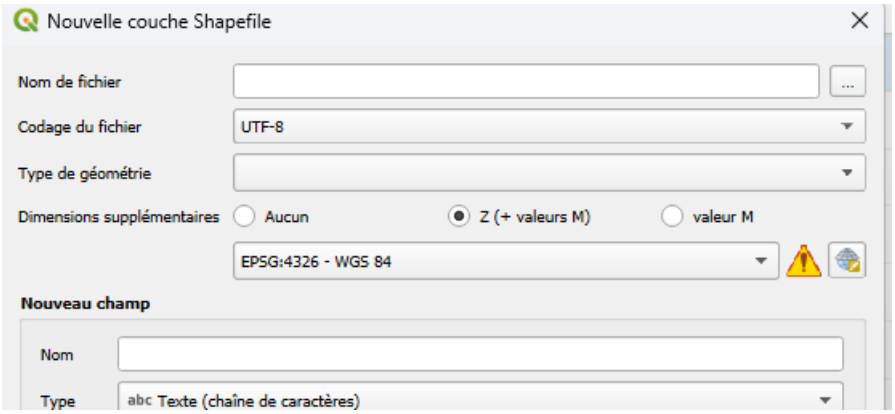

Figure 27 : Create a new point layer

5.6. Cut the peace of your DEM that you are interested to know the volume

Layer>Create a layer>New shapefile layer (edit your layer and draw the limits of your depot). In the folder input or output there is already a layer available of the limits.

Raster>Cut raster from a mask polygon (Figure 29)

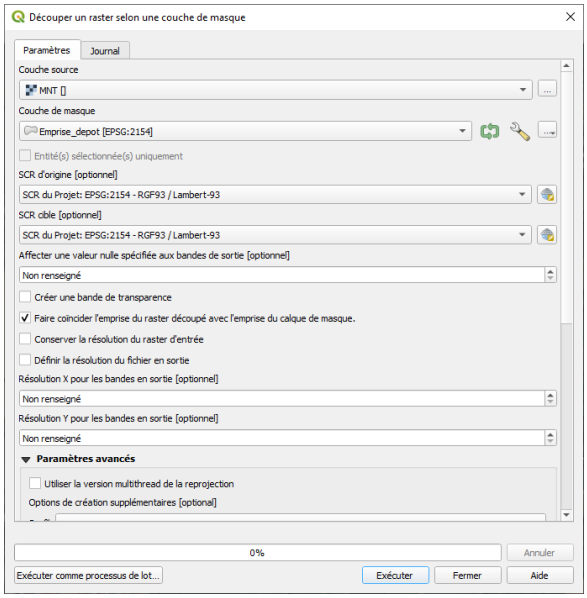

Figure 29 : Cut raster according to a mask

5.7. Subtract MNT with raster

Calculate Raster:

MNT_cut – raster interpolated

The new raster has only the difference of altitude. Pixels values will be small (between 0 and some meters). If the no-data are very big, no problem you will be able to precise in the next step.

5.8. Calculate the volume of the sediment depot

Tool>Raster Surface Volume

Method: Above base level

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1. User S. 3.2 Digital Elevation Models [Internet]. 2014 [cité 29 janv 2024]. Disponible sur: https://www.cdema.org/virtuallibrary/index.php/charim-hbook/data-management-book/3-base-data-collection/3-2-digital-elevation-models

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