INSTRUCTION GUIDE
SCRIPT FOR RADIOMETRIC CALIBRATION OF ALS STRIPS
VERSION 3, 11 APRIL 2019

Introduction

This file describes the use of the script for radiometric calibration of ALS strips developed at the TU Wien for the Prospecting Boundaries* project (http://mazaro.univie.ac.at). It is designed to demonstrate relative calibration of reflectance data using a series of strip-adjusted ALS strips. The script itself is a basic interface for the OPALS software environment, a modular software system designed for various ALS data processing tasks. **Feel free to use this script with your own data, or to modify it as you see fit. When publishing, please cite the following papers:**

Sevara, C., Wieser, M, Doneus, M., and Pfeifer, N. 2019. Relative Radiometric Calibration of Airborne LiDAR Data for Archaeological Applications. Remote Sensing.

N. Pfeifer, G. Mandlburger, J. Otepka, W. Karel: OPALS - A framework for Airborne Laser Scanning data analysis. Computers, Environment and Urban Systems, 45 (2014), 125 - 136.
https://doi.org/10.1016/j.compenvurbsys.2013.11.002

The provided license key for opals is for scientific and academic use only. For enduring use in an commercial or governmental environment a license has to be obtained. You can find the OPALS License policy under https://opals.geo.tuwien.ac.at/html/stable/usr_licensing.html.

Prerequisites

This script is built around modules in the OPALS software system
https://opals.geo.tuwien.ac.at/html/stable/index.html . To run this script, you must first install OPALS on your computer. If you do not already have a recent version of OPALS installed, please register and download the **most recent build** at:
https://opals.geo.tuwien.ac.at/html/stable/php_download_overview.html . Users who do not have a license for processing data in OPALS may use the included limited license key file that unlocks the modules necessary for this script (**opals.key**). For ease of use, it is recommended that OPALS is installed in the root folder of a local drive (e.g. c:\OPALS). Follow the onscreen instructions for installation. After installation of OPALS, the license file (**opals.key**) should be placed in the **cfg** (e.g. c:\OPALS\cfg) directory of the OPALS installation folder.

In this guide, QGIS v.2.18 (https://www.qgis.org/en/site/forusers/download.html) is used for creation of shapefiles and visualization of results. Any GIS that supports such functions may be used instead, users may have to adapt the instructions in this document to suit their geospatial data processing environment of choice. This script is designed for use by people who already have some knowledge of geospatial/ALS data processing. A basic knowledge of how to navigate in a command-line environment will be helpful. A basic to intermediate level of GIS knowledge (coordinate system selection, creation of point and polygon shapefiles, generation of raster grids from point data) will be necessary, particularly if you would like to apply this script to your own data.

Sample data are provided in the file **Radcal_Script\ALS**. A trajectory file and trajectory format definition are also provided. Using these, the script can be run with the included ALS data. **If you wish to run this script**

with your own data set, you will need trajectory and definition files that correspond to your data set in addition to ALS strips that contain amplitude information for each point.

Installation & File Structure

Unzip the self-extracting file **Radcal_Script.exe** to a local drive, preferably in the root directory of the drive or in another easily accessible location (e.g. \OPALS**Radcal_Script**). The archive should contain the folder **Radcal_Script** and a number of subfolders. Please keep the relative file structure intact. The **Radcal_Script** folder should contain two subfolders, **ALS** and **SOFTWARE**, as well as example point, polygon and trajectory files. The **ALS** folder contains a series of ALS strips, in .laz format, which have not been radiometrically calibrated. The **SOFTWARE** folder contains the batch script and accompanying support files necessary to run the script. When results are generated, a **RESULTS** folder will be created in the **SOFTWARE** folder. You will find all of the data generated by the software here, including amplitude and reflectance rasters as well as LAS files containing calibrated reflectance data.

Running the Script – a walkthrough

The script contains step-by-step tasks that automatically execute various functions in OPALS with a minimum of user input. In order to generate a calibrated reflectance map using this script, the tasks 1 to 4 need to be run in order. If you are only interested in adding calibrated reflectance data to a point cloud & will use other software to generate a reflectance map, it is only necessary to run tasks 1 to 3.

Below is a step by step walkthrough of the script, using the supplied sample data.

Starting OPALS and Launching the Script

1) Start OPALS, e.g. by double-clicking on the **opalsShell.bat** file in the OPALS root directory. You should see the following command-line interface (the path to your OPALS installation may be different):
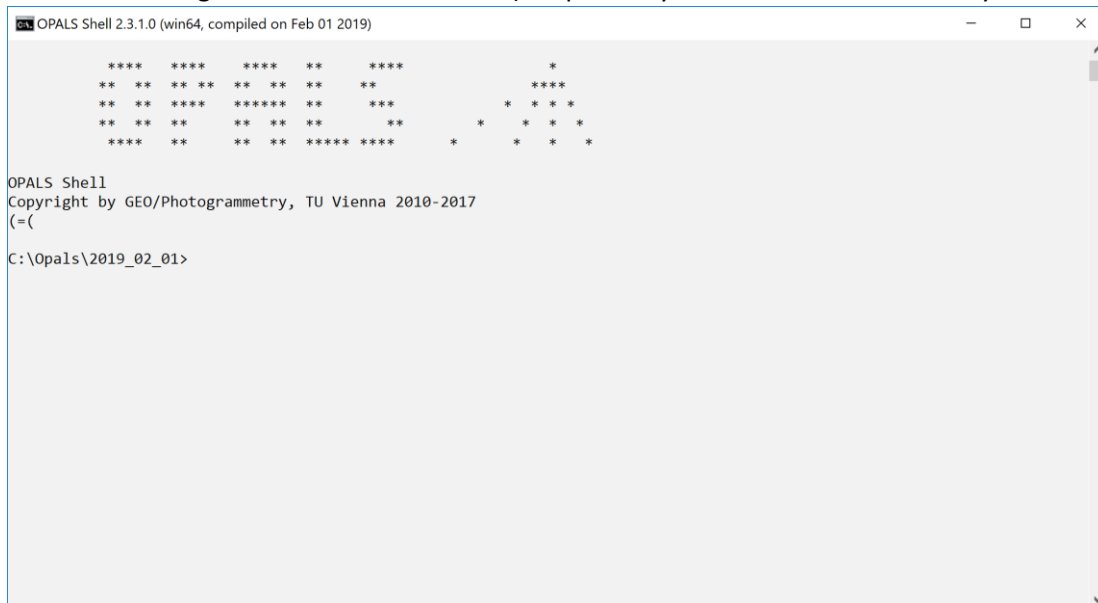
2) Change directories to the folder **Radcal_Script\SOFTWARE** and execute the script **RAD_BATCH_3rd.bat**. You can either type in the path, drag and drop the batch script to the command line window, or copy/paste the path using the right-click mouse button.

3) The script main menu should come up:

There are seven tasks that can be executed from within the script. Tasks 1-4 should be carried out in order and will be detailed below. Task 5 is a brief help file, and Task 6 can be used to clean temporary data out of the results folder when all processing steps are complete. This is recommended, as the script will generate data approximately three times the size of the source data set.

*Task 1 – Calculating bounding box and DSM hillshade.*

In this task, a bounding box, DSM, and hillshade are calculated from one ALS strip in order to check the coordinate system information. Additionally, a point shape file containing single points that will be used to generate local amplitude maps needs to be created for task 2. These amplitude maps will be used to digitize API polygons that will be used in Task 3, so the initial points should be in the vicinity of areas that contain objects made of relatively similar materials, such as asphalt roads.

In OPALS:

1) Select **task 1** from the list.
2) Type the full path of the strip location, or drag and drop the file from the folder containing the strips to the command prompt. Make sure the OPALS window is active and press ENTER. The DSM, hillshade, and bounding box will be calculated, and the script will notify you when the tasks are completed.

In GIS:

3) Open the single strip files (bound.shp (bounding box), DSM.tif (DSM) and DSM_shade.tif (hillshade)) in a GIS in order to check the coordinate system. Files are located in **Radcal_Script\SOFTWARE\RESULTS.**
4) Adding a satellite, aerial or other background image can be helpful to check the coordinate system and will also be needed to define calibration areas.
5) Check that the strip is located in the proper place, and note the **EPSG code** for the coordinate system (in the case of the sample data, this is **32633 (WGS84 UTM Zone 33N))**.
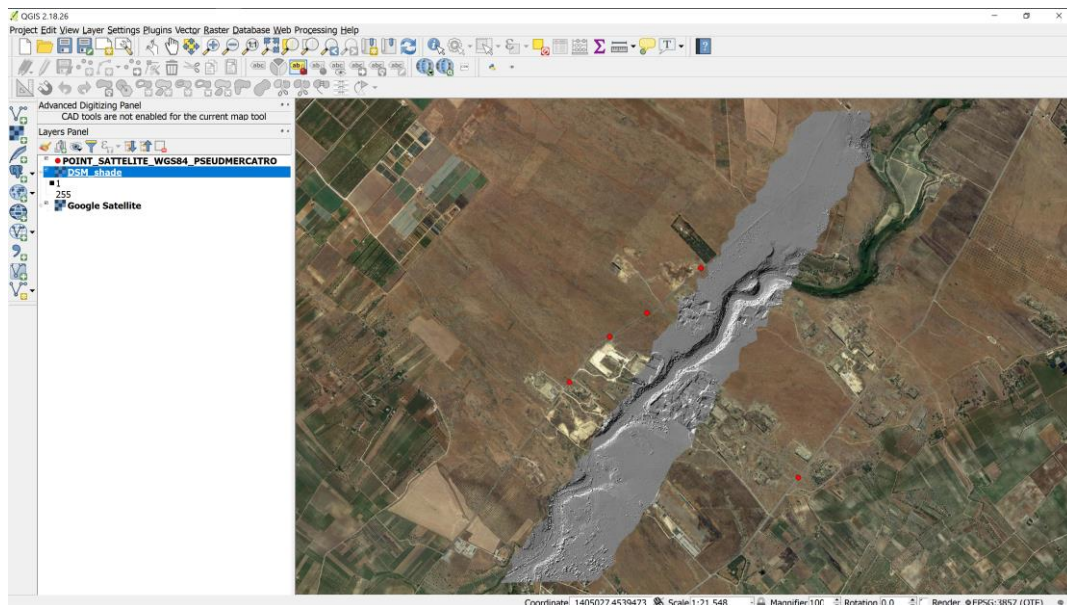
6) Create a **point shapefile** whose coordinate system corresponds to that of the ALS dataset and store it in the **Radcal_Script** folder (a sample point shapefile is located in the **Radcal_Script** folder). The point shapefile does not need to have any attributes beyond a unique ID. Make sure it has been added to your GIS and is ready for editing.
7) Create and pick points (red dots in figure) in the point shapefile at areas of known reflectance. In the case of the test data, worn asphalt surfaces are used. Create a number of points (in this example we use 5 points) at various locations within the bounds of the data set. Ensure that all points created are at areas of similar reflectance.
8) When finished creating points, stop editing and save the edits. Note the location of the point shapefile, as it will be used in Task 2.
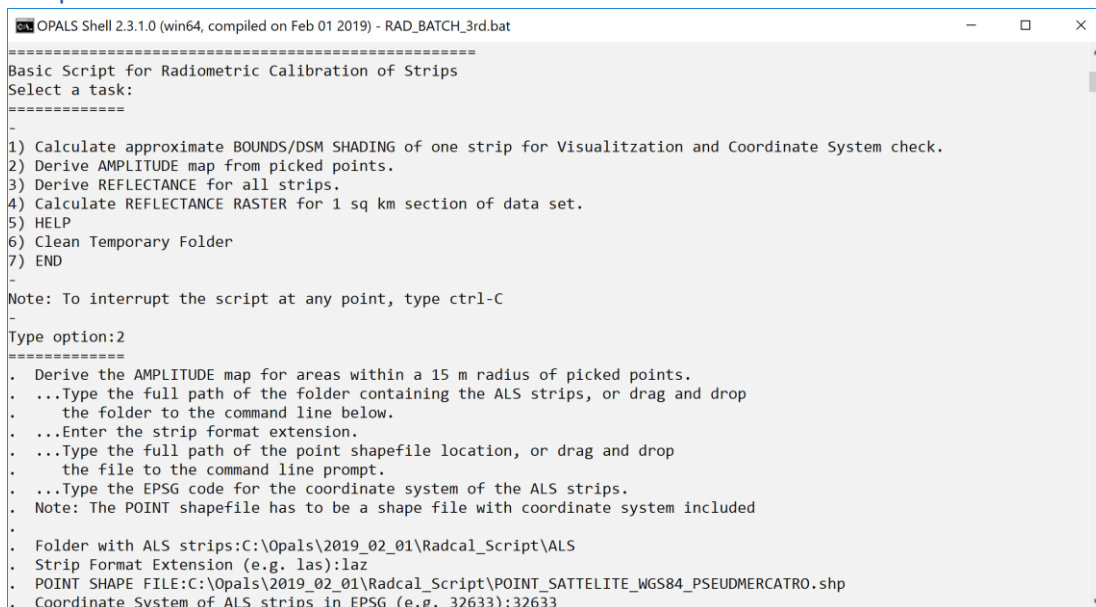
Note: Be sure that the picked points are within the total bounds of the ALS data set.

Task 2 – Derive AMPLITUDE map from picked points

In this task, the script derives amplitude rasters for areas within a 15 meter radius of the points created in Task 1. The resulting amplitude maps are used to digitize AOI polygons covering areas of known reflectance (again, in our example we use asphalt surfaces).

In OPALS:

1) In the OPALS shell window, run the **RAD _BATCH_3rd.bat** script again.
2) Select **task 2**.
3) Type the full path of the folder containing the ALS strips, or drag and drop the folder to the command prompt. Make sure the OPALS Shell window is active and press ENTER (test data are located in **Radcal_Script\ALS**).
4) Type the strip format extension without the preceding period (the test data are in **laz** format).
5) Type the full path or **drag and drop the pick point shapefile created in task 1** to the command prompt. Make sure the Opals shell window is active and press ENTER.
6) Type the EPSG code for the coordinate system at the command prompt (test data are in **EPSG 32633**) and press Enter.

```
OPALS Shell 2.3.1.0 (win64, compiled on Feb 01 2019) - RAD_BATCH_3rd.bat          –   □   ×
==================================================
Basic Script for Radiometric Calibration of Strips
Select a task:
=============
-
1) Calculate approximate BOUNDS/DSM SHADING of one strip for Visualitzation and Coordinate System check.
2) Derive AMPLITUDE map from picked points.
3) Derive REFLECTANCE for all strips.
4) Calculate REFLECTANCE RASTER for 1 sq km section of data set.
5) HELP
6) Clean Temporary Folder
7) END
-
Note: To interrupt the script at any point, type ctrl-C
-
Type option:2
=============
.   Derive the AMPLITUDE map for areas within a 15 m radius of picked points.
.   ...Type the full path of the folder containing the ALS strips, or drag and drop
.      the folder to the command line below.
.   ...Enter the strip format extension.
.   ...Type the full path of the point shapefile location, or drag and drop
.      the file to the command line prompt.
.   ...Type the EPSG code for the coordinate system of the ALS strips.
.   Note: The POINT shapefile has to be a shape file with coordinate system included
.
.   Folder with ALS strips:C:\Opals\2019_02_01\Radcal_Script\ALS
.   Strip Format Extension (e.g. las):laz
.   POINT SHAPE FILE:C:\Opals\2019_02_01\Radcal_Script\POINT_SATTELITE_WGS84_PSEUDMERCATRO.shp
.   Coordinate System of ALS strips in EPSG (e.g. 32633):32633_
```

The script will generate the amplitude maps and store them in the file **SOFTWARE\RESULTS\amplitude_BUFFERED.tif**

In GIS:

7) Load the **amplitude_BUFFERED.tif** file into the GIS. You should see a series of circular amplitude raster maps whose centers correspond to the points in the pick point shapefile, such as this one:
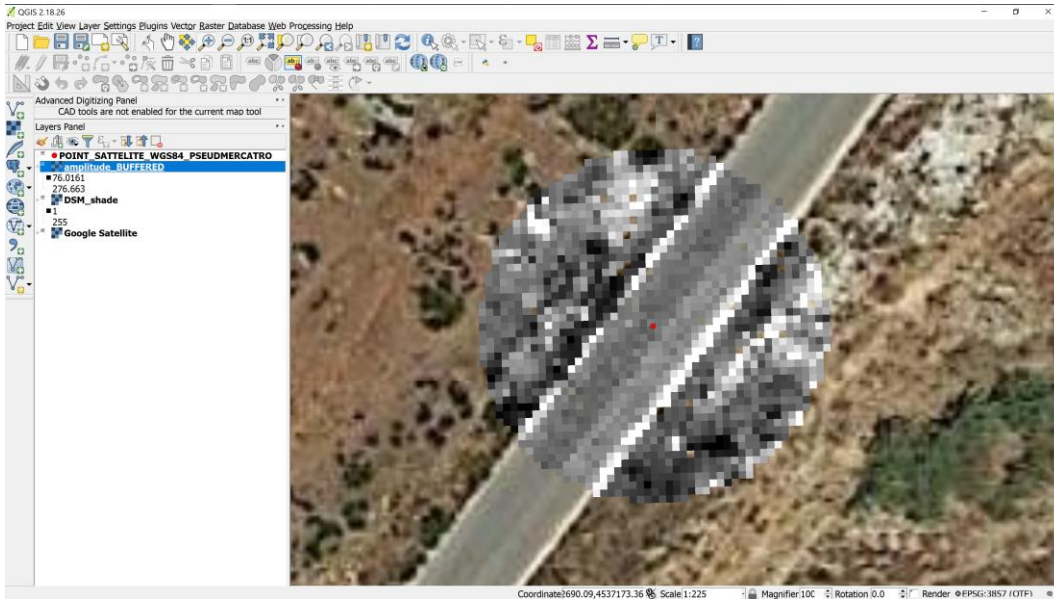
These amplitude maps can be used as a base for digitizing the AOI polygons needed for calculating the calibrated reflectance.

8) Create a **polygon shapefile** whose coordinate system corresponds to that of the ALS dataset. The shapefile must contain the fields **id (integer)** and **refl (double, length 5 precision 2)** (a sample polygon shapefile can be found in **Radcal_Script\REFLECTANCE_POLYGON_UTM33.shp**).

9) Make the polygon shapefile editable and digitize an API polygon for each amplitude map. Ensure that the polygon only covers a homogenous area of reflectance (in this example, parts of the asphalt road).
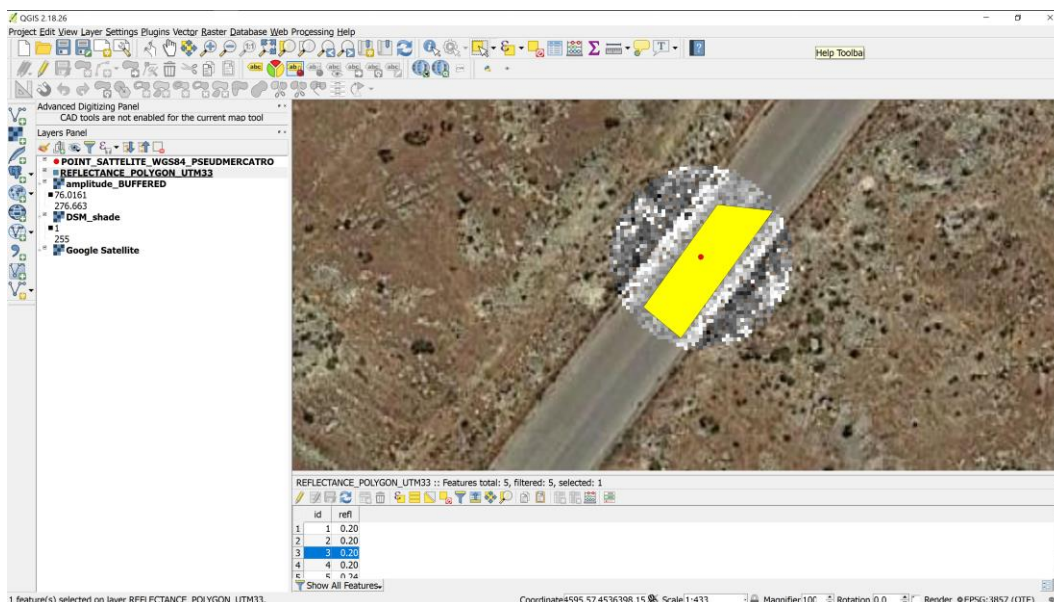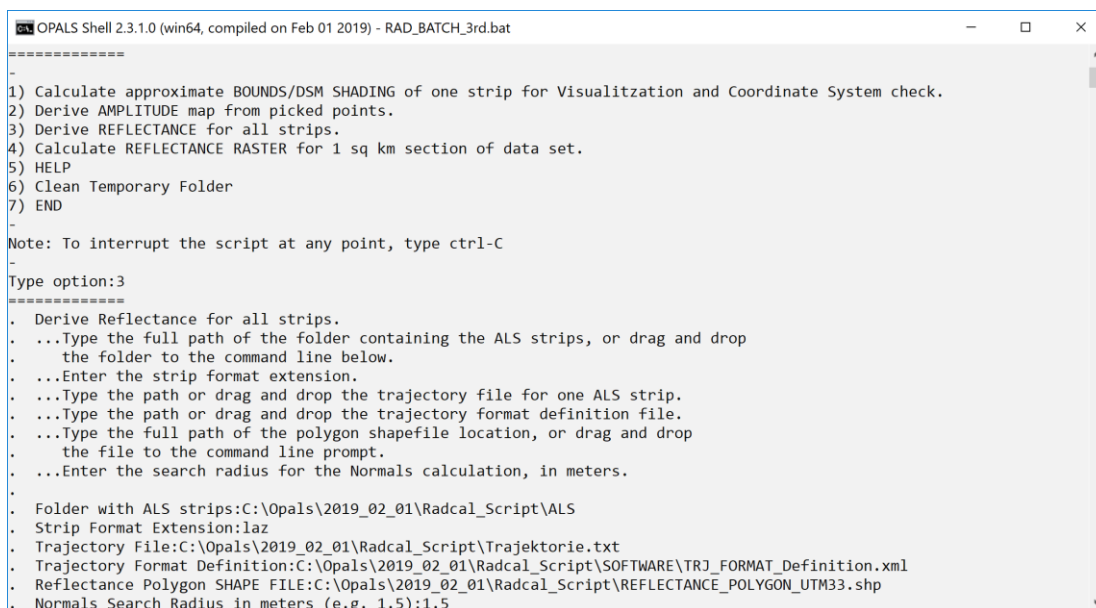

10) Enter the id # (id) and reflectance values (refl) for each digitized AOI. In the test data the asphalt surfaces used are given a reflectance of approximately 0.20.

11) When finished digitizing the AOIs, stop editing and save the edits. Note the location of the point shapefile, as it will be used in Task 3.

Task 3 – Derive REFLECTANCE for all strips

This task calculates the calibrated reflectance for all strips in the ALS data set using the polygon shapefile AOI and reflectance data stored in the shapefile attribute table. From these data and the trajectory information, a calibration constant is calculated which is subsequently applied to all strips. When this task is finished, every point in each strip in the ALS data set will contain calibrated reflectance values.

In OPALS:

1) In the OPALS shell window, run the **RAD _BATCH_3rd.bat** script again.
2) Select **task 3**.
3) Type the full path of the folder containing the ALS strips, or drag and drop the folder to the command prompt. Make sure the OPALS Shell window is active and press ENTER (test data are located in **Radcal_Script\ALS**).
4) Type the strip format extension without the preceding period (the test data are in **laz** format).
5) Type the full path or drag and drop the trajectory file for one ALS strip. Make sure the OPALS Shell window is active and press ENTER. (test data trajectory file is located at **Radcal_Script\Trajektorie.txt).**
6) Type the full path or drag and drop the trajectory format definition file. Make sure the OPALS Shell window is active and press ENTER. (test data trajectory format definition file is located at **Radcal_Script\SOFTWARE\TRJ_FORMAT_Definition.xml).**
7) Type the full path of the reflectance polygon shapefile created in task 2, or drag and drop the file to the command line prompt. Make sure the OPALS Shell window is active and press ENTER. (test data reflectance AOI polygon is located at **Radcal_Script\ REFLECTANCE_POLYGON_UTM33.shp).**
8) Enter the Normals search radius in meters and press ENTER.

The script will calculate the calibration constant (Ccal) and apply it to all strips. It will create new las files containing the calibrated reflectance values for each point in **SOFTWARE\RESULTS\LAS**. This can take some time, especially with a large data set.

Task 4 – Calculate REFLECTANCE RASTER for 1 km² of the data set

This task calculates a raster reflectance map for a 1 km² area around a center point, using the median reflectance values for each cell. Cellsize (in meters) and echo type (all or last) can also be selected.

In OPALS:

1) In the OPALS shell window, run the **RAD _BATCH_3rd.bat** script again.
2) Select **task 4**.
3) Type in the center x coordinate of the area to be calculated, in the ALS coordinate system and without decimal places. Press ENTER.
4) Type in the center y coordinate of the area to be calculated, in the ALS coordinate system and without decimal places. Press ENTER.
5) Choose the cell size of the output raster, in meters (for instance, 0.5 would equal 50 cm). Press ENTER.
6) Select whether or not the raster should be generated from the last echo only (selecting no uses all echos (returns)). Press ENTER:

The script will calculate a calibrated reflectance raster using the input specifications. When finished, the results can be found in **Radcal_Script\SOFTWARE\RESULTS\reflectance.tif.** These can be loaded into a GIS for evaluation and analysis:
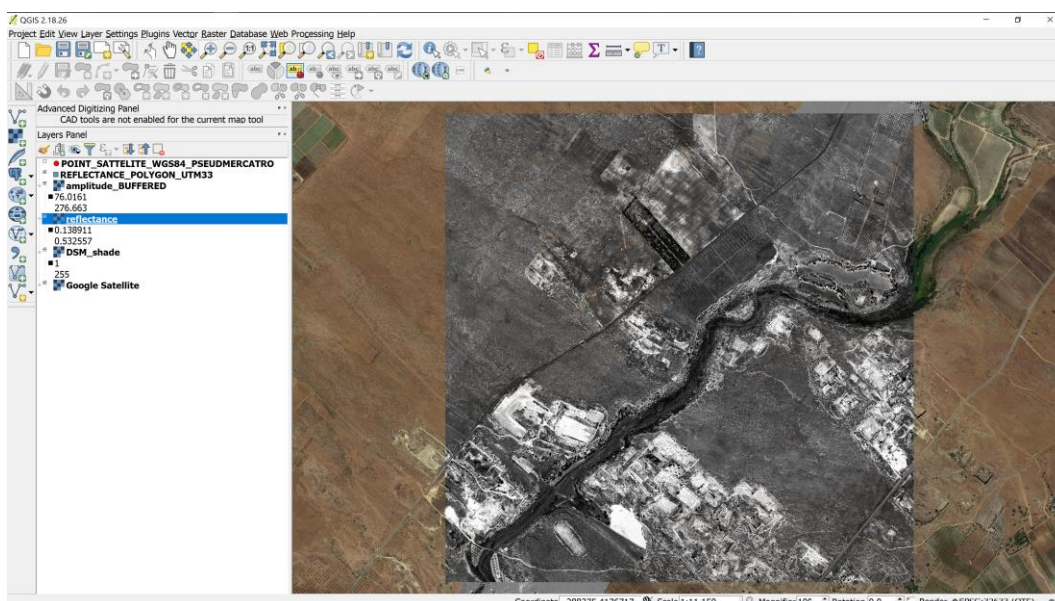
Note: This version of the software and supplied OPALS license key does not allow for building a reflectance map for areas of greater than 1 km^2. However, the calibrated reflectance is calculated for the entire ALS data set. If you would like to build a full reflectance raster from the calibrated ALS data, this can be done using the raster functions in your preferred spatial data processing software environment (e.g. in QGIS this could be done using the GRASS module v.to.rast, or LiDAR import modules), or with a full license of OPALS.

Task 5 – Help Menu

Brief information about the script and the results. For help with individual OPALS modules, please see the OPALS documentation (https://www.geo.tuwien.ac.at/opals/html/index.html).

Task 6 – Clean Temporary Folder

Selecting this cleans the temporary information stored in SOFTWARE\RESULTS\temp. Data in the RESULTS folder will not be deleted (amplitude, reflectance maps, LAS files). Use this only after you are finished generating reflectance rasters using the script, as it will delete some of the temporary files needed to run task 4.

Task 7 – END

Selecting this exits the script. The script may also be interrupted at any point by typing ctrl+C.

Location of Results

When results are generated, a **RESULTS** folder will be created in the **SOFTWARE** folder. As each task is completed, the resulting data will be stored here. You will find all the data generated by the software here, including amplitude and reflectance rasters, temporary files generated during processing, as well as LAS files containing calibrated reflectance data. If you are interested in the details of processing, they can be found within the script window.