Integrated Fieldwork 2022

WP 2: Three-Dimensional Reference Frame via GNSS Observations

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2 Three-dimensional Reference Frame via GNSS Observations

2.1 Brief Introduction

The main tasks of work package two are to establish the fundamental network in the fieldwork area and to determine the coordinates of the new survey points at the Hülben aerodrome. The coordinates of the points should be provided in the global WGS84 system and in UTM projection to other WP1,4,6.

The tasks can be allocated as follows:

• Selection of the points

• Design of the network

• Preparation of the session plan

• Observation according to the session plan

• Data processing with Leica Geo Office

To prepare the session plan the following constraints were considered:

• 7 available GNSS receivers

• At least 3 sessions per point in static GNSS mode

• 1 hour observation time per session

• Transportation time of one hour between consecutive sessions

• At least 4 non-obstructed satellites for every time point.

2.2 The process of fieldwork

During the fieldwork process, we selected 19, 53, 76, 105, 120, 150, 152, NP1 and NP2, nine points in total.

Every day is divided into two periods in the morning and afternoon, including 4 one-hour-time sessions per day. All groups arrive at the designated location by car and communicate with each other through the communication app to ensure that the measurement time covers a common one hour. After each measurement starts, our WP2 members determine the measurement end time and point change time and inform everyone.

In the measurement project, the height of the instrument is measured by a height hook, while the instrument on NP1 and NP2 was installed with the 3D-Tachy-prism, and use the tape to measure the height of the antenna and recorded in the fieldbook in time.

We will collect the fieldbook after the completion of the measurement work every day, complete the check of the antenna height after importing the data, and give feedback on the completion of the day's work.

2.3 The Problems Encountered

Most of the measurements were carried out successfully, but we still encountered a few problems, namely:

- Some groups are not familiar with the instrument operation.
- Inaccurate measurement of antenna height.
- The receiver did not shut down in time after completing the measurement.
- There are differences with the selection of the center of each point for every group.
- Some groups didn’t fill in the work sheet in time.

We recommend that next time to check the problems encountered.

2.4 Data Processing

We first check the measurements for errors and right antenna type and height measurement method (height-hook is for tripod and tape is for pillar used in 3D-Tachy-prism).

Then we processed the observations and LEICA Geo Office 8.4® software tried to fix the ambiguities in all baselines. Since it was not possible to fix the ambiguities a cut-off-angle of up to 19°. We choose 20° and choose just GPS-satellites for this processing, due to hot weather and so a disturbed lower atmosphere which makes this necessary this year.

But then all ambiguities could be fixed. Precision of all baselines was below 0.5mm (GPS-accuracy). The different measurements of points fits together better than 3cm, where you already see the 'terrestrial accuracy' of our observations. So, we fixed the known points as 'control' and do the adjustment with the given coordinates of state survey and came out with that table below.

To pass the F-Test we needed to set the a-priori factor to 50, which means 50 times 0.5mm (GPS-accuracy of baselines). This fits then to our average measurement's accuracy in this project of about 2.5cm.

The data are processed with LEICA Geo Office 8.4® software.

The network adjustment provides 3D-coordinates up to a suitable accuracy in the global system. The name of coordinate system name is ETRS89 and the projection used in the software is UTM-32-8.

Point	Type	East	North	Ellip Hgt	Ortho Hgt	Posn.Qlty	Sd East	Sd North	Hgt qlity
19	Adjusted	32529974.8110	5375217.7112	728.3620		0.0056	0.0034	0.0044	0.0131
53	Adjusted	32531086.8695	5371947.9670	506.1222		0.0107	0.0062	0.0087	0.0206
76	Control	32526328.6400	5373744.4300		421.2900	0.0141	0.0100	0.0100	0.0100
105	Control	32529618.0500	5375720.5400		720.8110	0.0144	0.0100	0.0100	0.0100
120	Control	32529004.6900	5377025.9800				0.0085	0.0116	
150	Adjusted	32526628.7963	5378546.3249	443.2912		0.0075	0.0045	0.0059	0.0158
152	Control	32531980.3800	5378673.4000		717.4365	0.0141	0.0100	0.0100	0.0100
NP1	Adjusted	32529520.4050	5375124.5797	720.1806		0.0106	0.0063	0.0085	0.0200
NP2	Adjusted	32529311.4574	5375146.3277	715.2550		0.0052	0.0031	0.0041	0.0128

Table 1: Adjusted Coordinates

2.5 Results and Discussions

During data analysis, we first selected four points as control points. Among them, 105 and 150 "Known in Position", while 19 and 76 Known in Position and Height. However, the result was not so good. To pass the F-Test we needed to set the a-priori factor to 150, which means 150 times 0.5mm (GPS-accuracy of baselines) was then our average measurements accuracy in this project (7.5cm). We checked from adjusted coordinates and found point 150 was 'tilted' too much to north direction. Everybody who measured on this point could prove that this stone was knocked over by a farmer’s tractor So we can’t use 150 as a “control” point. We set 120 instead as the benchmark to complete the which adjustment worked much better. The results obtained are in Figure 1 and 2:

It should be noted that for our data to pass the F-test, the Sigma a-priori (GPS) was set to 50 (the default setting for this data is 10), which increases the tolerance during data processing. It is a compromise for the poor quality of the data itself. It can be inferred that in the measurement work, we may have made many mistakes, including but not limited to the installation of the instrument, the filling error of the antenna height measurement. All of these would reduce accuracy of results.

Adjustment Results

Coordinates

Station		Coordinate	Corr	Sd	
105	Latitude	48° 32' 02.00994" N	0.0000 m	-	fixed
	Longitude	9° 24' 04.34220" E	0.0000 m	-	fixed
	Height	720.8345 m	0.0235 m	0.0093 m	
120	Latitude	48° 32' 44.39115" N	0.0000 m	-	fixed
	Longitude	9° 23' 34.75929" E	0.0000 m	-	fixed
	Height	475.4853 m	0.0000 m	0.0210 m	
150	Latitude	48° 33' 34.00856" N	0.0000 m	0.0059 m	
	Longitude	9° 21' 39.22316" E	0.0000 m	0.0045 m	
	Height	443.2912 m	0.0000 m	0.0158 m	
152	Latitude	48° 33' 37.22336" N	0.0000 m	-	fixed
	Longitude	9° 26' 00.35579" E	0.0000 m	-	fixed
	Height	717.4365 m	0.0000 m	-	fixed
19	Latitude	48° 31' 45.66431" N	0.0000 m	0.0044 m	
	Longitude	9° 24' 21.60922" E	0.0000 m	0.0034 m	
	Height	728.3620 m	0.0000 m	0.0131 m	
53	Latitude	48° 29' 59.57532" N	0.0000 m	0.0087 m	
	Longitude	9° 25' 14.95585" E	0.0000 m	0.0062 m	
	Height	506.1222 m	0.0000 m	0.0206 m	
76	Latitude	48° 30' 58.53906" N	0.0000 m	-	fixed
	Longitude	9° 21' 23.48629" E	0.0000 m	-	fixed
	Height	421.2900 m	0.0000 m	-	fixed
NP1	Latitude	48° 31' 42.72569" N	0.0000 m	0.0085 m	
	Longitude	9° 23' 59.42863" E	0.0000 m	0.0063 m	
	Height	720.1806 m	0.0000 m	0.0200 m	
NP2	Latitude	48° 31' 43.46528" N	0.0000 m	0.0041 m	
	Longitude	9° 23' 49.24602" E	0.0000 m	0.0031 m	
	Height	715.2550 m	0.0000 m	0.0128 m	

Figure1

General Information

Adjustment

Type:	Constrained		
Dimension:	3D		
Coordinate system:	WGS 1984		
Height mode:	Ellipsoidal		
Number of iterations:	1		
Maximum coord correction in last iteration:	0.0000 m	✓	(tolerance is met)

Stations

Number of (partly) known stations:	4
Number of unknown stations:	5
Total:	9

Observations

GPS coordinate differences:	72 (24 baselines)
Known coordinates:	10
Total:	82

Unknowns

Coordinates:	27
Total:	27

Degrees of freedom:	55

Testing

Alfa (multi dimensional):	0.5639		
Alfa 0 (one dimensional):	5.0 %		
Beta:	80.0 %		
Sigma a-priori (GPS):	50.0		
Critical value W-test:	1.96		
Critical value T-test (2-dimensional):	2.42		
Critical value T-test (3-dimensional):	1.89		
Critical value F-test:	0.96		
F-test:	0.88	✓	(accepted)

Results based on a-posteriori variance factor

Figure2

Integrated Fieldwork 2022

WP 3: Precision Levelling

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1. Introduction

The work package 3 is about delivering height information's for other work packages. The goal of the work package was to deliver the heights with a standard deviation of $\sigma_i \leq 2\ mm$. To achieve the goal, precision levelling was used. Therefore, 6 routes were made starting and ending at a benchmark point, where the heights are known. The plan was, to measure the six loops in 3 days and at the 4th day to measure loops which doesn't achieve the standard deviation. Because of problems while measuring, this plan couldn't comply with.

2. Progress of the measurements

The levelling should take place on 3 days, with three measurement teams on the first day and then always two teams on the following days. At day 4, it was planned to remeasure the loop which achieved the worst standard deviation. At the first day of levelling, there were some problems with the Leica level, so the measurement group couldn't finish their loop and only measured a line. The storage of the Leica instrument was full, so they had to delete some old measurements before the group could start. In addition to that the planned adjustment Method, the method of Näbauer, wasn't available, so the method of Förstner. The measurement team with the Leica instrument didn't measure till the planned GNSS point, because they would have to go through a corn field. On the next day, the first levelling team had to finish the loop of the group with the Leica instrument from the first day. Also at this day, the Trimble level broke, so the supervisors had to go back to the accommodation, to pick up the Leica level. The next team had to level with this instrument. The second measurement team on day two, also had problems with the height differences, so the measurement distances couldn't be constant and it took a lot of time to finish. As well, the weather changed, so the measurement team couldn't finish their line too. Their end was a nail, which the levelling supervisor has set at the beginning of the measurement. On the third day of measurement, the Trimble instrument was fixed and both teams can measure the planned loops. At day four the last loop was measured and everything went well.

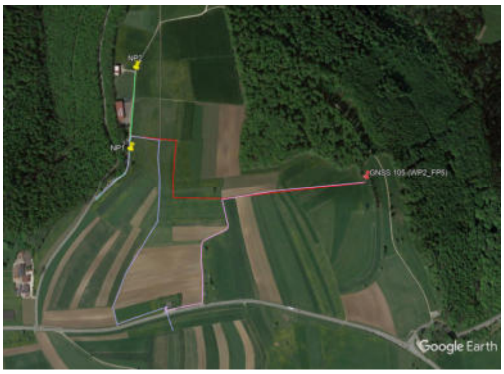


Figure 11: Loops at the airfield (selfmade in Google Earth Pro)

Figure 22: left loop Erkenbrechtsweiler, center loop Dettingen an der Erms, right loop near Neuffen (selfmade in Google Earth Pro)

The measuring teams, measured the following lines at the days:

Day 1:

Line 1: purple line (air field): FP7→FP8→FP2

Line 2: red line (air field): FP8→GNSS 105 (WP2_FP5)→FP8

Line 3: pink line (air field): FP2→GNSS 105 (WP2_FP5)→FP2

Day 2:

Line 1: purple line (air field):FP7→FP8→FP2→FP8→FP7

Line 4: Erkenbrechtsweiler: GNSS 152 (WP2_FP4)→FP 4 → GNSS 152 (WP2_FP4)

Day 3:

Line 5: Dettingen an der Erms: FP6→ GNSS 76 (WP2_FP2)→ FP6

Line 4: Erkenbrechtsweiler: GNSS 152 (WP2_FP4)→FP 4 → GNSS 152 (WP2_FP4)

Line 6: New line which includes NP1 and NP2:

FP7→FP8→NP1→NP2→NP1→FP8→FP7

Day 4:

Line 7: Line near Neuffen: FP5→GNSS 150 (WP2_FP3)→FP5

The following conclusion of the measurements are, that levelling takes significantly more time and brings more difficulties than thought. But if the teams are in the workflow, the measurements can be finished in an acceptable timeframe. All the teams learned a lot about the measurement and the problems that can occur.

3. Difficulties

Through the measuring, the measuring teams got some difficulties:

- The GNSS point 19 was unreachable, because of the vegetation,
- the weather was unsuitable because there was a lot of wind which influenced the levelling of the rods. There was a thunder storm which stopped the measurement for that day. As a solution for that, the measurement was postponed to the next day.
- The Trimble instrument broke, the thread of the tribrach screw came loose, but this problem could be fixed, so the Instrument could be used in the second week of measurements
- The storage of the Leica instrument was full, also the Näbauer adjustment didn't exist in the Leica instrument as indicated in the instruction
- The rods weren't kept on the stakes and on the frogs, till the measuring was finished

4. Analysis of the measurements

All of our analysing is based on the measurements we did. In the graphs shown below there are the starting points and the GNSS points marked.

GNSS152 – FP4:

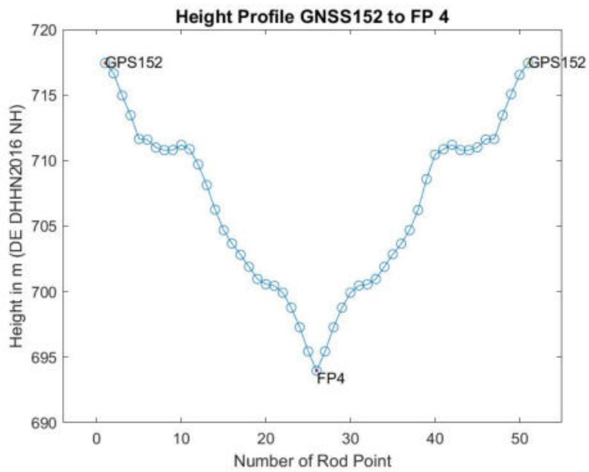


Figure 33: Loop Erkenbrechtsweiler (selfmade in Google Earth Pro and MATLAB)

FP5 – GNSS150:

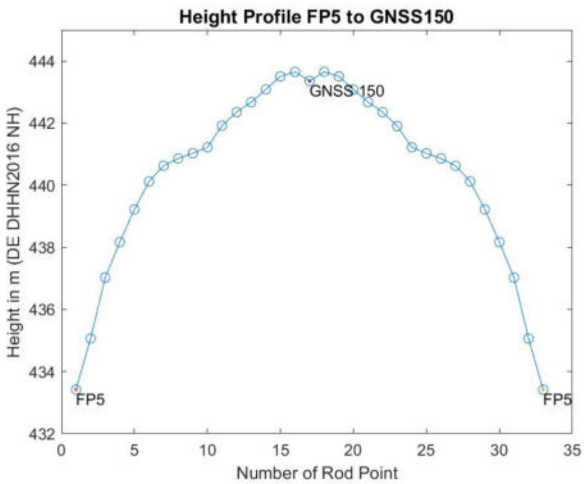


Figure 44: Loop Neuffen (selfmade in Google Earth Pro and MATLAB)

FP6 – GNSS76:

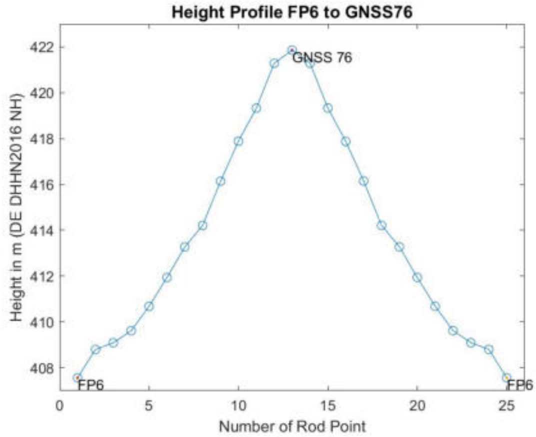


Figure 55: Loop Dettingen an der Erms (selfmade in Google Earth Pro and MATLAB)

FP8 – GNSS105:

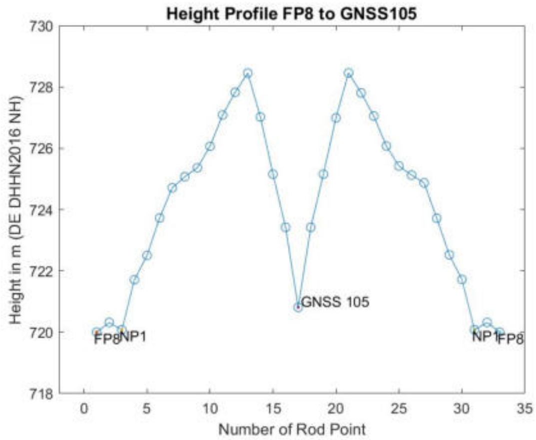
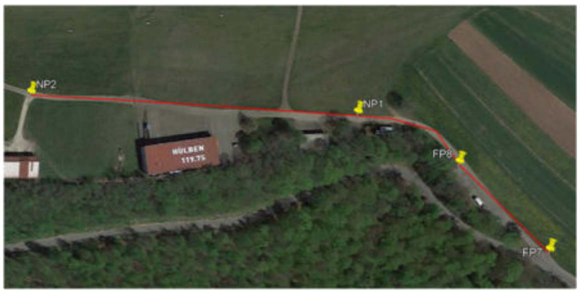


Figure 66: Red Loop at the Airfield Hülben (selfmade in Google Earth Pro and MATLAB)

FP7 – NP2:



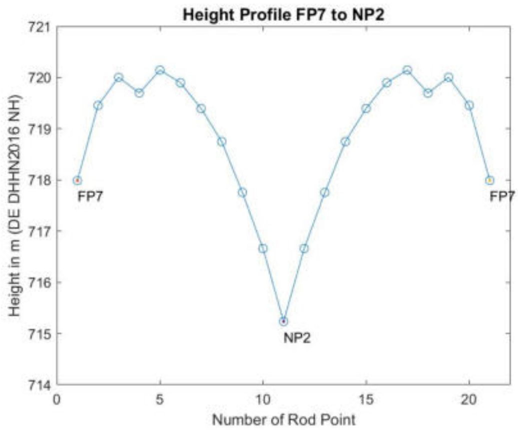


Figure 77: Loop of the New Line at the Airfield Hülben (selfmade in Google Earth Pro and MATLAB)

5. Results

The following table (Table 1) shows the heights that we measured. All heights are in the DE DHHN2016 NH height system.

Table 1: Measured Heights of GNSS Points

Point numbers	Measured Heights [m]	Heights from 2019 [m]	Loop Error [mm/km]	Loop Length [m]	Standard Deviation
GNSS 76	421.2898	421.2863	2.5	908.46	0.26
GNSS 105	720.8107	-	0.14	1647.56	0.11
GNSS 150	443.3570	443.3571	1.0	1961.40	0.71
GNSS 152	717.4365	717.4315	3.4	1179.58	0.31
NP1	720.1448	720.1465	1.5	644.70	0.19
NP2	715.2349	715.2322	1.5	644.70	0.19

Figure 88: GNSS Points in Google Earth Pro (Source: selfmade by using Google Earth)

The goal was to achieve a loop error $\sum \Delta h \leq 2\ mm$, this was not possible in some of the measurements. Under the given circumstances of the IP the measurements are good.

Integrated Fieldwork 2022

WP 4: Creation of 3D Network and surveying by Total Station

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4.1 Introduction

The purpose of WP4 is to create a terrestrial local 3D network at the airfield in Hülben, which will be used as a reference for all the future measurements, in the AOI (decollation area and hangar area). This network is based on the already existing points GNSS points NP1 and NP2. This network serves as a basis for further measurements at the airfield. This network was realized with the help of a robotic total Station from Leica (TS30).

4.2 Network planning

4.2.1 Points marking

The network was marked on the first day by team E. In total, the network included 14 points and among them, GNSS points NP1, andNP2 were already marked from last year. Some points were marked using the wooden poles because they were located on grass areas and other points were marked using the nails.

4.2.2 Measurements plan

a. 1st week

All the measurements that are related to the network creation were taken during the first week and they have been measured by all the teams. We set the total station at different stations in order have better error distribution and to different sight of view at each point.

b. 2nd week

For the second week, each team surveyed different part of the area each day .We also surveyed the boundaries, the land strips, the surrounding buildings and roads which you can see them in the 2D plan which is presented in the results. We also measured the terrain in order to have terrain model.

4.3 Data analysis

After we finished measurements, we will start with preparing the data in order to process it. The data is exported into a txt file which was edited in the Notepad++ text editor. Here we only select the observations for the adjustment in JAG3D and remove the not important information.
Now, after we finish editing our data, each data set is inserted individually in JAG3D in order to detect outliers more easily. If there are any observations that have bad effect on the results or it will lead to big error, we remove these observations.
Moreover, we can define the standard deviations for the observed directions, zenith angles, and slope distances.
After we adjust the data in JAG3D, the observations and the points are displayed graphically.
Below you can see the network measurement of all data set with result from the adjustment.

Enable	Point-Id	Code	y [m]	x [m]	z [m]	σy [mm]	σx [mm]	σz [mm]
✓	FP1	0	-77.9208	157.3710	2.2207	0.7	0.7	1.4
✓	FP2	0	-27.8413	267.2820	-0.4157	0.5	0.7	1.3
✓	FP3	0	7.5833	373.4176	-0.4023	0.9	0.4	2.3
✓	FP4	0	55.1921	373.2019	-1.4178	1.1	0.8	3.1
✓	FP5	0	35.0434	193.1107	-1.0510	0.4	0.4	1.3
✓	FP6	0	84.4084	64.2549	2.3997	0.5	0.4	1.3
✓	FP7	0	72.5790	-13.4237	6.5968	0.9	0.4	1.0
✓	FP8	0	58.8722	-115.3486	10.4879	0.5	0.4	1.0
✓	FP9	0	105.1592	-273.7599	15.3099	0.8	0.6	1.1
✓	FP10	0	32.8186	-308.4856	15.4332	0.6	0.4	1.2
✓	FP11	0	-43.1089	-330.6201	15.3725	0.8	0.6	1.3
✓	FP12	0	-77.9130	-61.7979	8.3222	0.6	0.5	1.1
✓	NP1	0	-66.8780	-137.4894	9.6716	0.6	0.5	1.3
✓	NP2	0	-34.9531	70.2617	4.7633	0.5	0.3	1.0

Fig 1: Point Results

Variance components estimation

Component	n	r	Ω	1 : σ²	Significant
Global adjustment	269	175.00	186.51	1.07	✓
Direction	94	56.00	59.72	1.07	☐
Direction σa	77	45.28	33.25	0.73	☐
Slope distance	92	62.97	67.14	1.07	☐
Slope distance σa	76	48.94	36.10	0.74	☐
Slope distance σc	76	1.51	1.22	0.81	☐
Zenith angle	83	56.04	59.65	1.06	☐
Zenith angle σa	67	44.71	39.39	0.88	☐

Fig 2: Variance Components

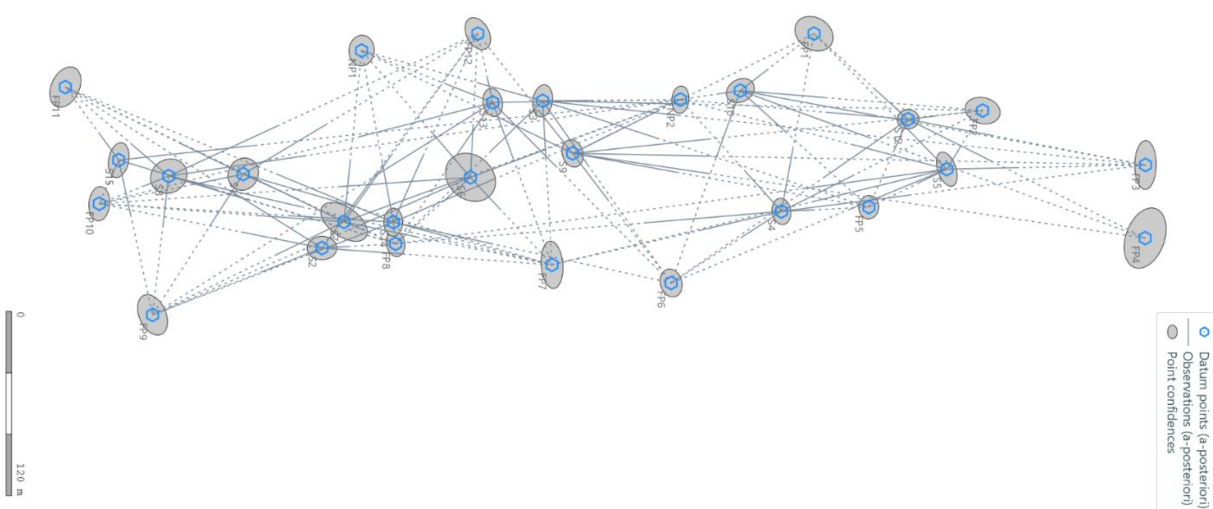

Fig 3: Network

After inserting the UTM-Coordinates received from WP2, I seemed like something is off. The difference in the distance between NP1 and NP2 was above 10 cm between the GNSS data and the Total Station Network. Therefore, only local coordinates were used.

4.4 Plotting

After we have collected our surveyed measurements, we exported the data by using a Matlab code in order to use just the observation coordinates in Autocad to build a 2D Plan for our measurements.
Figure below show our 2D Plan.

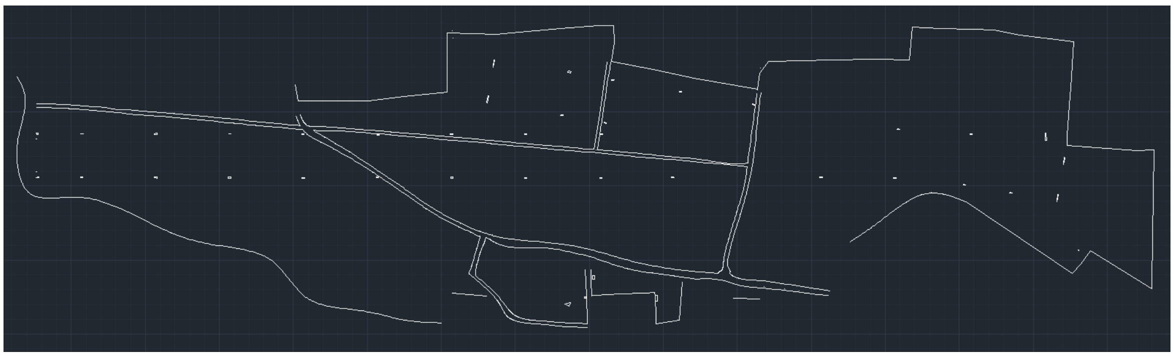

Fig4:2D Plan

4.5 Digital Terrain Model creation

DTM means digital terrain model, representing the terrain in several methods like TIN (Triangulated Irregular Network), contour lines or shadow maps. A DTM can be created by a cluster of raster points with height information. Our task contains not only to create the digital result, but also do the surveying measurement during the fieldwork. We used CloudCompare to build this terrain model.
The interest regions of our field work are the landing strips. We decide to measure every 10 meters and additionally, we need to measure the edge of the roads in the area. The steps of survey are simple and repetitively. At first we need the free station and total station set up. After we set the total station on a favorable position, we leveled it and introduced the pressure and temperature. We will establish a local coordinate system after we measure all the fixed points we chose.We cannot measure the whole region by one station because the further the target is,the worse the measurement will be due to refraction and measurement inaccuracy.Once we need a new station, all the set-up operations need to be done again.
After we finished measurements, all the measurements will be exported as a text file and then imported into the software.

The figure bellows shows us the digital terrain model.

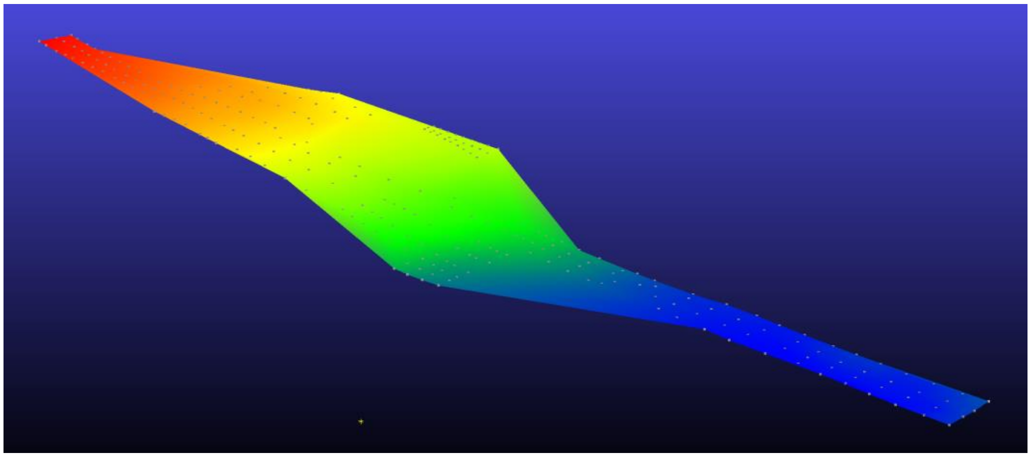

Fig 5: Terrain Model

4.6 Important remarks

We couldn't use the coordinates of the GNSS points of work package two (WP2)to transfer the whole network from the local coordinate system to the global UTM coordinate system.
Some measurements were deleted because of using wrong height reflectors.
Despite these errors the results obtained were satisfying and a 3D network was created and adjusted.

4.7 Conclusion

This fieldwork trains us a lot on survey, theory and many other aspects. We learned a lot about what we should do if we become an engineer and manage a project. The supervisor helped us a lot and taught us how and why a survey would be implemented. We also learned a lot from our teammates, and thanks for the members helping us obtain data.
To sum up, this integrating field was a very meaningful practice and experience which we will always remember these days. Thanks for all that helped us.

Integrated Fieldwork 2022

WP 5: Profile Measurements by Gravimetry

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Contents

1. Introduction

The objective in WP5 is to detect the signals of two caves of the Swabian Alb with gravimeter measurements. The approximate positions of these caves can be found with the help of cave plans and Google Earth. The main task is it to create measurement lines or grids along the surface from where a significant signal can be measured by the gravimeter. Afterwards the data has to be analyzed and it has to be evaluated, if the signal is significant.

2. The caves

The caves that we tried to detect were the Gustav-Jacob cave and the Falkensteiner cave. For the Falkensteiner we used two profiles. The main and an alternative one. On day one we measured the Gustav-Jacob cave in the second day the main and the alternative. After analyzing the data, it seemed better to only remeasure the alternative again, as the data at Gustav-Jacob and Falkensteiner main, weren’t so promising.

2.1.Corrections

To analyze the data, you first have to make the free-air and bouguer correction. The free-air correction eliminates the effect of the fact, that every point has a different height. The instrument height correction is similar to the free-air correction but instead of heights in general, the heights of the instrument get corrected. Formula (1) describes how the free-air correction is calculated with results in mGal:

$$corr_{FA} = -0.3 * \frac{m}{s^2} * h \tag{1}$$

The bouguer correction approximates the terrain by an infinite plate. The formula (2) describes the calculation.

$$corr_{BO} = -2\pi G\rho * h \tag{2}$$

The corrections are added to the measured values. After that the data is not influenced by height differences anymore.

The following example displays the impact of the corrections. The left figure shows the local height and the right one shows the gravity differences before the correction.

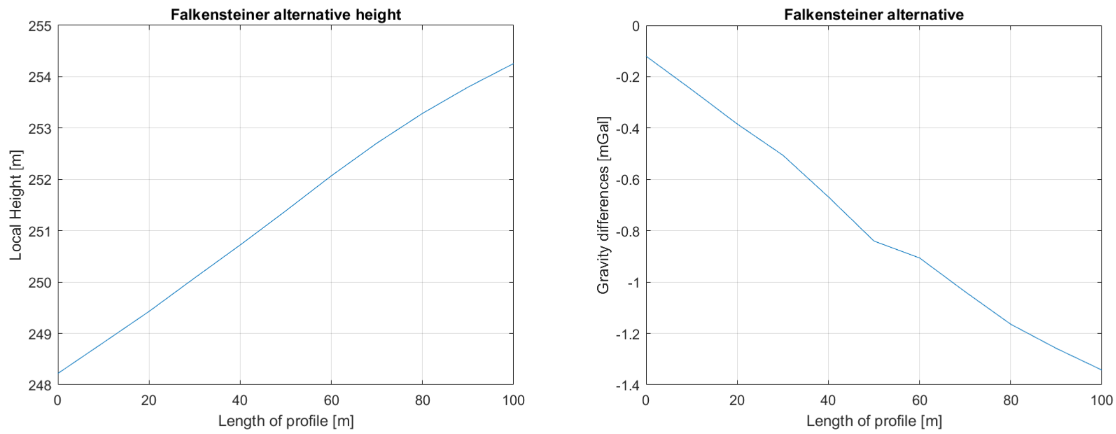

Figure 1: Height difference and gravity difference

It is visible that the values are strongly correlated to each other.

After the correction the values look like in Figure 2

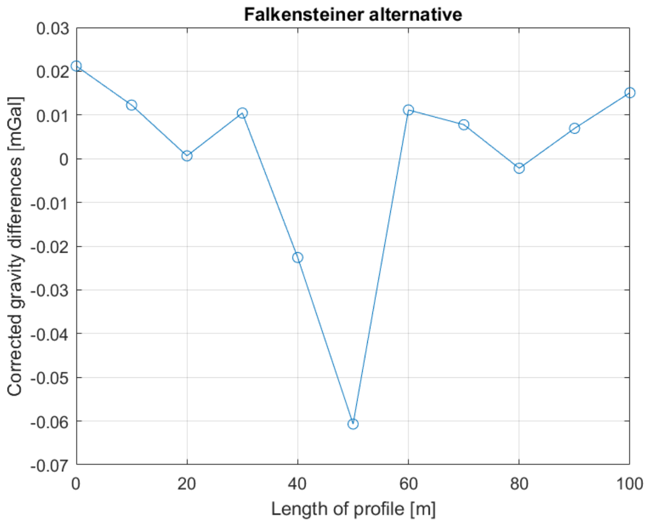

Figure 2: Falkensteiner cave with correction

In this example it gets visible, how the corrections work. The correlation between height and gravity is now corrected.

2.2.Gustav Jacob cave

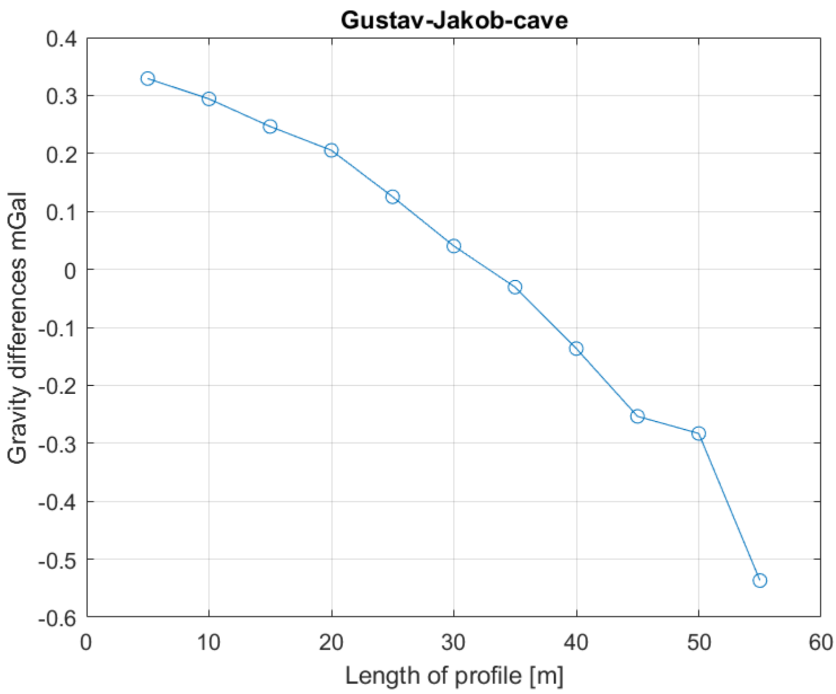

Figure 3: Gustav Jacob after correction

We measured the Gustav Jacob cave on 25/07/2022. In figure 3 you can see the gravity differences after the correction. As you can see there it wasn't possible to detect a cave signal.

We assume that the problem is that the topography close to the measurements area were too big, and it influenced the Gravimeter measurements.

Figure 4: Cave Plan of the Gustav Jakob cave with contour lines

It can be seen in the cave plan that there are big height differences nearby.

2.3.Falkensteiner cave

We planned two profiles for the Falkensteiner cave. In figure 5 the result of the first profile is shown.

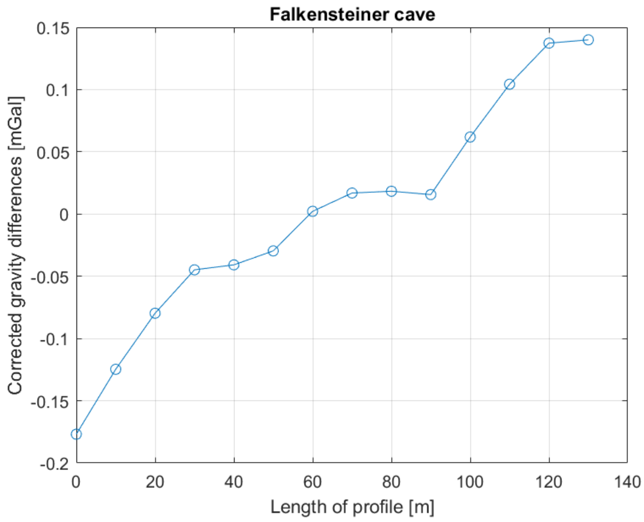

Figure 5: Gravity measurements Falkensteiner cave

It is visible that there is no anomaly detectable. We assume that this can also be explained with the topography differences in this area.

Figure 6: Falkensteiner cave with contour lines

2.4. Falkensteiner cave alternative

To classify the measurements, we insert the standard deviation into the graphic, so that the accuracy can be seen.

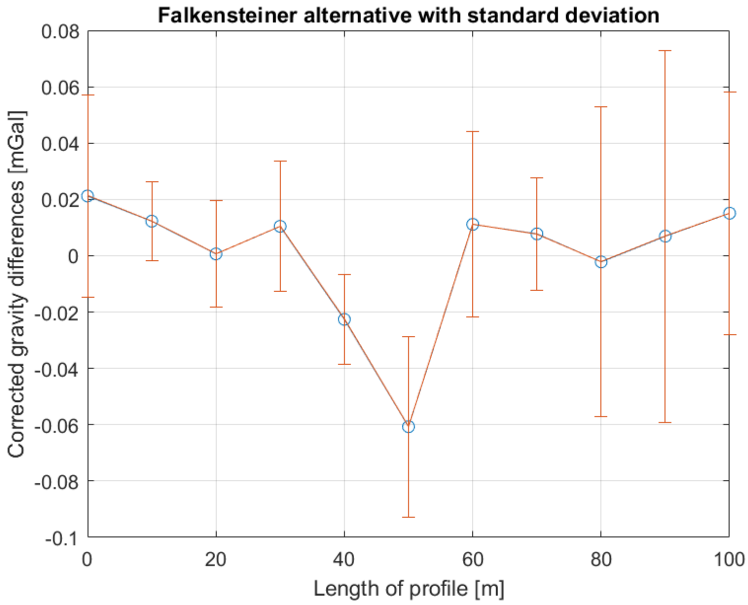

Figure 7: Falkensteiner cave alternative and standard deviation

The standard deviation is high, it could be because of the wind and vehicles passed nearby. As you can see in figure 8 there is an anomaly but it's not sure if it is the cave as the signal is too narrow in comparison with the model.

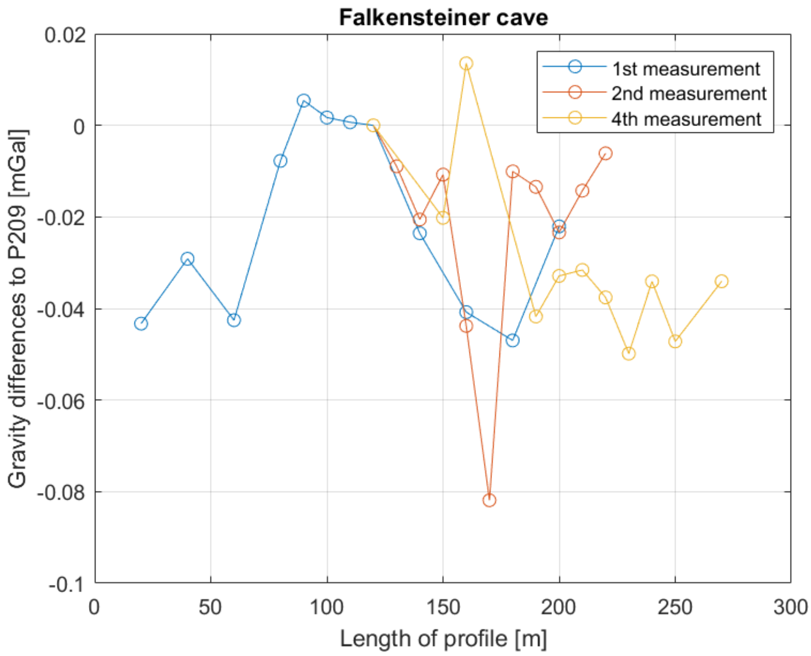

Figure 8: Falkensteiner cave all measurements

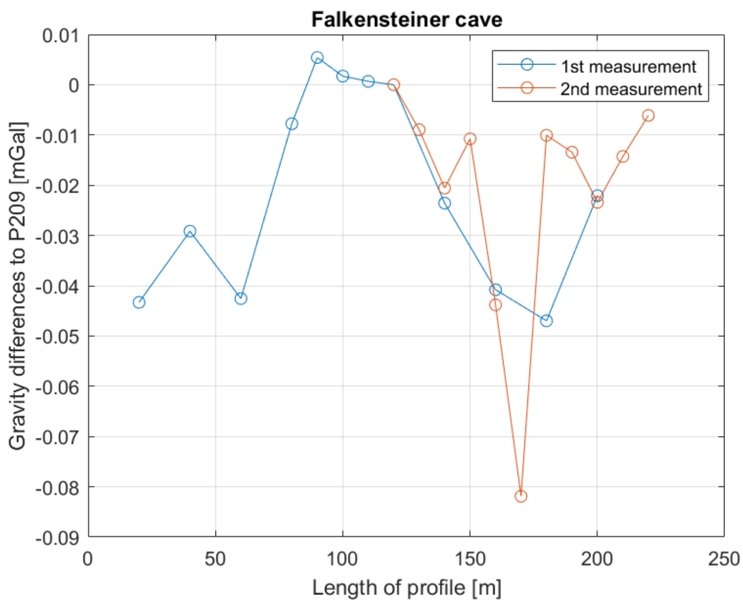

Figure 9: Falkensteiner cave alternative first two measurements

In figure 9 we can see that the first two measurements fit together, that's why we thought that beneath the area at 170 m of the profile there would be the cave and so we planned another 2 measurements to verify that. The values of the third measurement were not usable so we didn't used them in our plot. Another reason not being sure that the cave is under the area at 170m like in figure 5 is that in the fourth measurement there is no sign of the cave as the signal goes up.

We assume that under the ground there might be other holes that distort our signal. Another explanation might be that the signal of the cave is too small to be detectable by the gravimeter.

We had an additional measurement of the alternative of the Falkensteiner cave, but the values of this measurement are extremely different to the other measurements in the same area.

Figure 10: Failed measurement of the Falkensteiner cave

The gravity differences are too small to detect anything at this measurement. The only thing that is visible here is the noise.

2.5.Model

With the data we received, we try to model the Falkensteiner cave, but the measured anomaly is too narrow to find a fitting solution. The cave plans suppose that the cave is approximately 100 m below the surface. To get similar values, the cave needs to lie much closer to the surface than 100 m. This is the reason why the model is not really fitting.

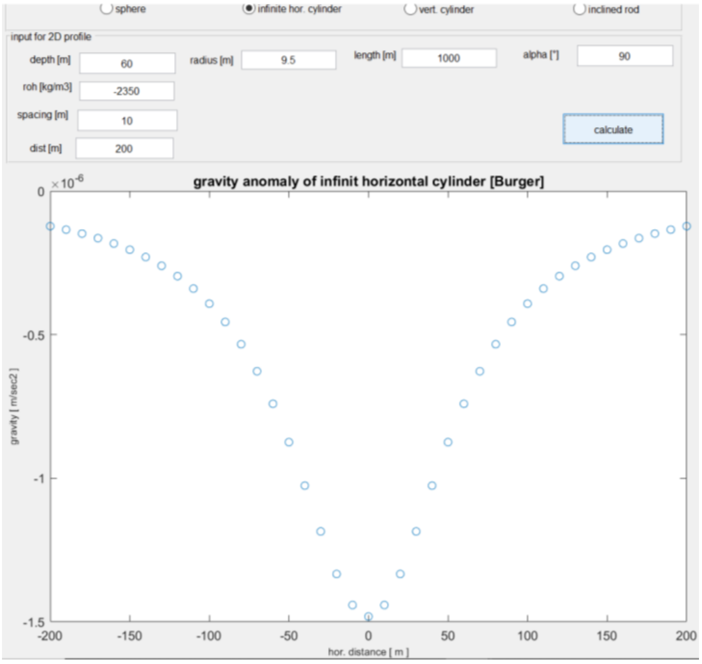

Figure 11: Model of the Falkensteiner cave

3. Conclusion

3.1 Falkensteiner cave (2nd Profile)

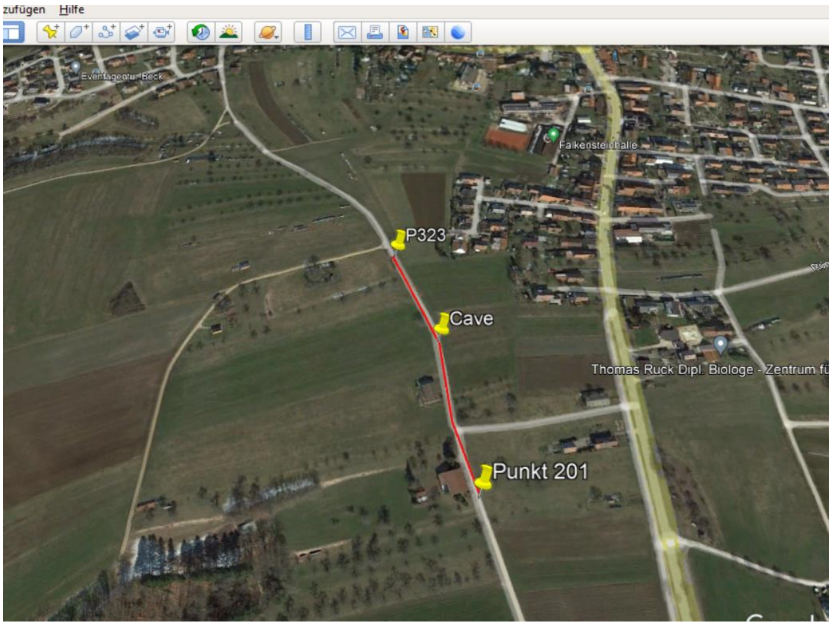

Figure 12: Coordinates of measurement

In this figure we see the start and end Point of the Alternative profile, and the path we measured. The measurement started at point 201 and ended at point 323. If the signal we received is really the cave, we assume that the cave intersects the road at the cave marker. The approximate coordinates can be found in table 1.

Table 1: Coordinates of the points Falkensteiner cave (Profile 2)

	East [m]	North [m]
Cave	32533898	5374132
201	32533932	5373977
323	32533854	5374233

3.2 Gustav-Jakob cave

Figure 13: Coordinates of measurement Gustav Jacob

Due to the topography of the area, it is not possible to find the signal of this cave. If in the future someone wants to detect the cave another area would suit better.

Table 2: Coordinates of the points Gustav/-Jakob cave

	East [m]	North [m]
Oben	32534977	5374378
Unten	32534990	5374332
Links	32534944	5374331
Rechts	32535010	5374364

3.3 Falkensteiner cave (1st Profile)

Figure 14: Coordinates of measurement Falkensteiner cave (Profile 1)

To find the Falkensteiner cave the 2nd profile is better than the 1st. As here the gravimeter didn't detect any signal that could be any kind of cave.

Table 3: Coordinates of the points Falkensteiner cave (Profile 1)

	East [m]	North [m]
Group B 01	32533660	5373906
Group B 15	32533658	5374096

Integrated Fieldwork 2022

WP 6: Kinematic Road Survey

Final Report

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Content

1. Introduction

The goal of Work Package 6 is to measure various roads, landing strips and paths, as well as the height profile of parts of the area with GNSS. Additionally, accuracy and availability of trajectories with degraded GNSS satellite visibility (for example in the forest) will be checked.

For the post-processing of the data the open-source software “RTKLib” is used. In the fieldwork the RC car equipped with a GNSS antenna and receiver is driven around the areas of interest as rover to take the measurements. To achieve higher precision a base station is set up to allow a differential GNSS post processing.

Figure 1. Remote Controlled car used as rover

2. Measurement in Field

During the measurement in the field each measurement group surveyed a certain part of the area as follows:

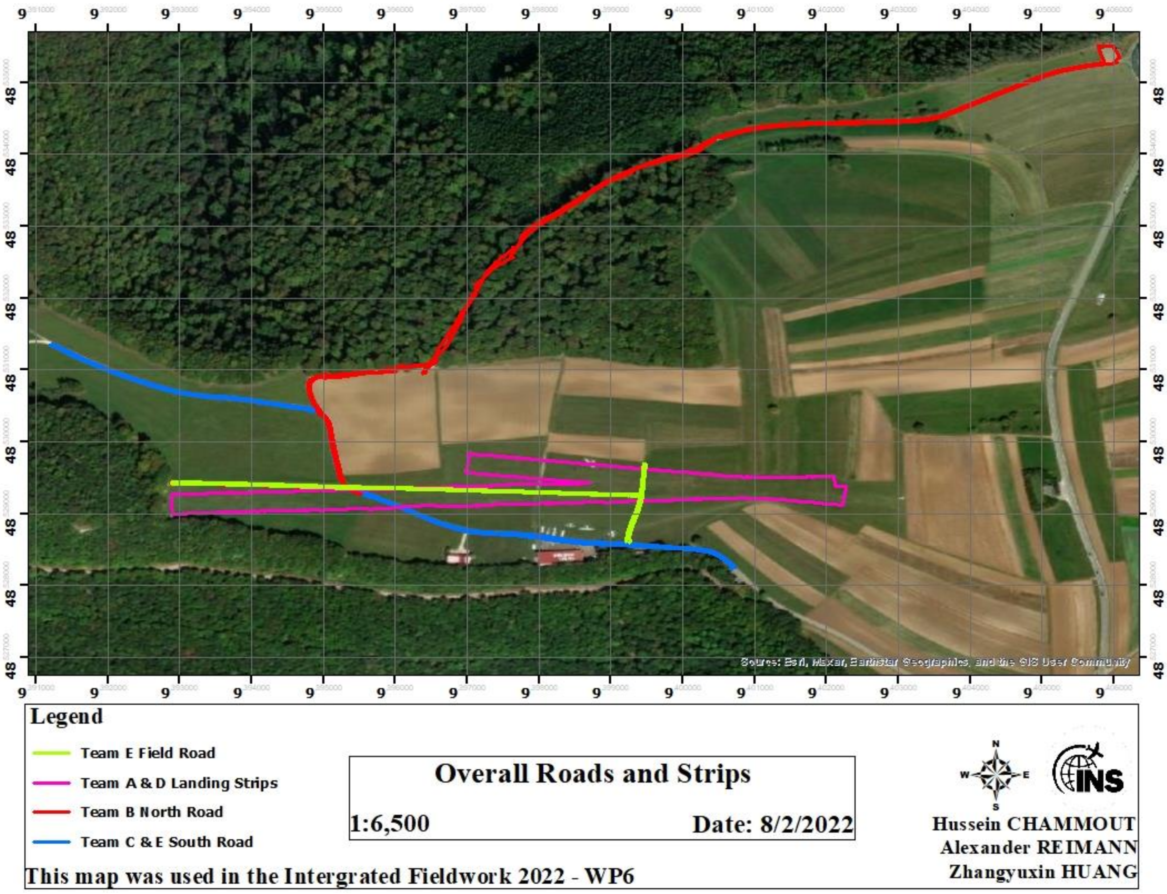


Figure 2. Overall Roads and Strips and Measurement groups

Here all the measured pre fieldwrokrk defined paths and lines can be seen including information which group was measuring which part.

Additionally, each group also measured some fix points to get a comparison with other WPs and drove around the area “for fun” to create a measurement of the surface of the areas of interest.

As reference station point a point temporally marked with an orange nail was used. Seen here:

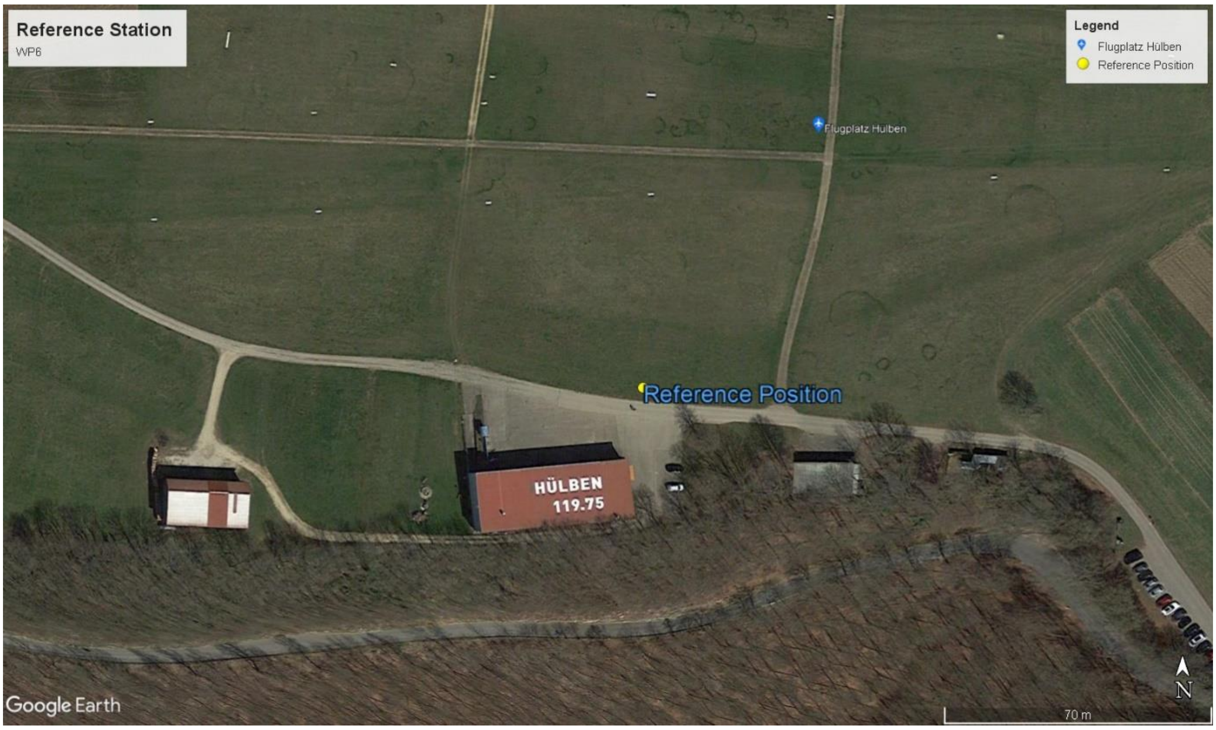


Figure 3. Fixed Reference Station

Before the measurement with the rover started the Base station measured its SPP position standalone averaged over 10 minutes. This position was also used in the post processing.

3. Post-Processing

In order to obtain the three- dimensional trajectories of the driven profile, the positions have to be calculated using RTKLib. The obtained WGS84 coordinates need to be transformed to fit the final project frame UTM32, thus it is possible to compare the precision and accuracy of the different approaches from the other work packages.

3.1. Post-Processing in RTKLib

The received data was organized and imported as raw data, observation files in RINEX format, to the RTKlib software with respect to the raw data of the base station, observation and navigation files in RINEX format. In addition, some settings in the software such as the elevation mask angle, SNR, base station position as well as the measurement mode “Kinematic or static”, depending on wether fixed points or roads/areas were measured, were adjusted. The measured rover and base station (antenna-) height was also used in the post processing.

Figure 4. Ground Track in RTKlib

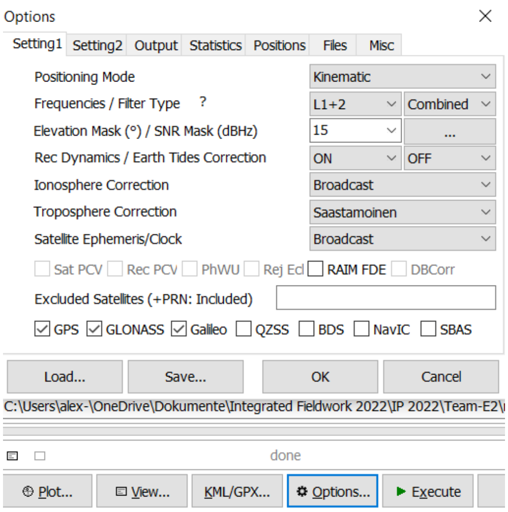


Figure 5. example for RTKlib settings

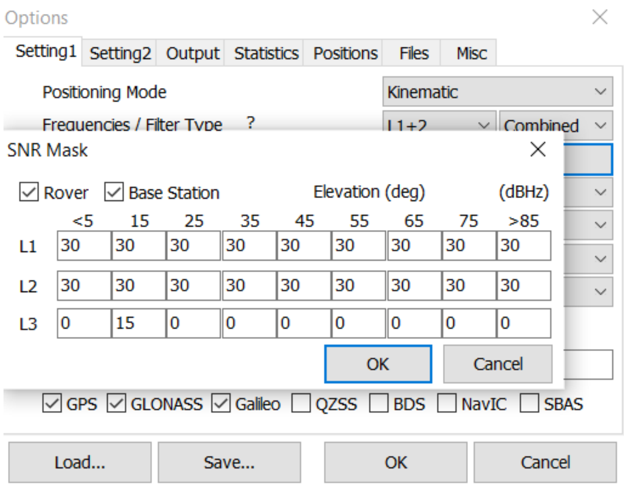


Figure 6. example for adjusting the SNR mask

3.2. Accuracy of the Measurements and Comparison to WP2

Solution of pre measured Base station position compared to Base position from raw data

While each measurement group wrote down the before mentioned SPP measured position, the base station was also recording raw data during the measurements with the rover. This data can also be used to get a SPP position:

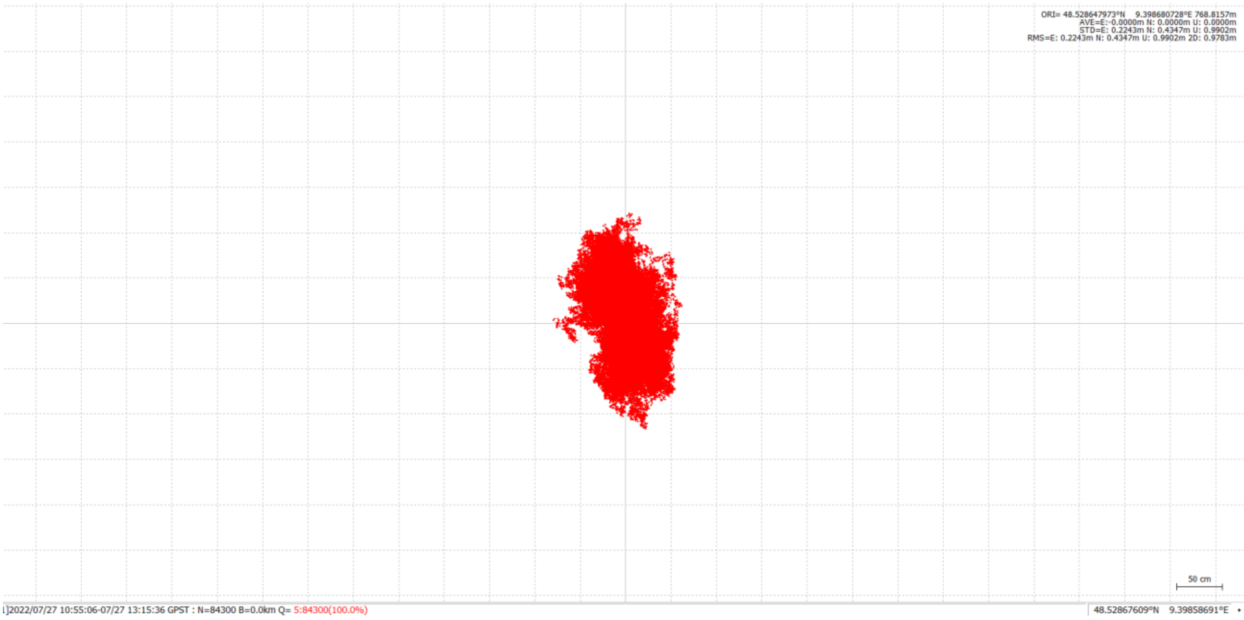


Figure 7. Example of Calculating SPP Positing

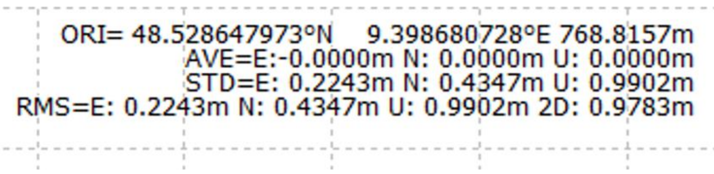


Figure 8. Top right corner of Fig. 7 zoomed in: Standard deviations of the point in ENU-System

Comparison between the results (in cartesian (GPS-) coordinates):

Base Station Group A:

	Field book (fb)	SPP with el = 5°	SPP with el = 15°	$\Delta_{SPPel=5-fb}$	$\Delta_{SPPel=15-fb}$
X [m]	4175547.0363	4175547.1475	4175547.3381	0.1112	0.3018
Y [m]	691158.1189	691159.8641	691157.8799	1.7451	-0.2391
Z [m]	4756585.2093	4756585.3066	4756585.1937	0.0973	-0.0156

Base Station Group B:

	Field book (fb)	SPP with el = 5°	SPP with el = 15°	$\Delta_{SPPel=5-fb}$	$\Delta_{SPPel=15-fb}$
X [m]	4175547.0242	4175546.6228	4175546.0834	-0.4014	-0.9408
Y [m]	691158.9727	691158.6492	691158.3923	-0.3235	-0.5804
Z [m]	4756584.3813	4756584.1071	4756583.9784	-0.2742	-0.4029

Base Station Group C:

	Field book (fb)	SPP with el = 5°	SPP with el = 15°	$\Delta_{SPPel=5-fb}$	$\Delta_{SPPel=15-fb}$
X [m]	4175547.1298	4175546.6063	4175546.6578	-0.5234	-0.4720
Y [m]	691158.4863	691158.8850	691159.0858	0.3987	0.5995
Z [m]	4756585.2523	4756584.6322	4756584.5828	-0.6201	-0.6695

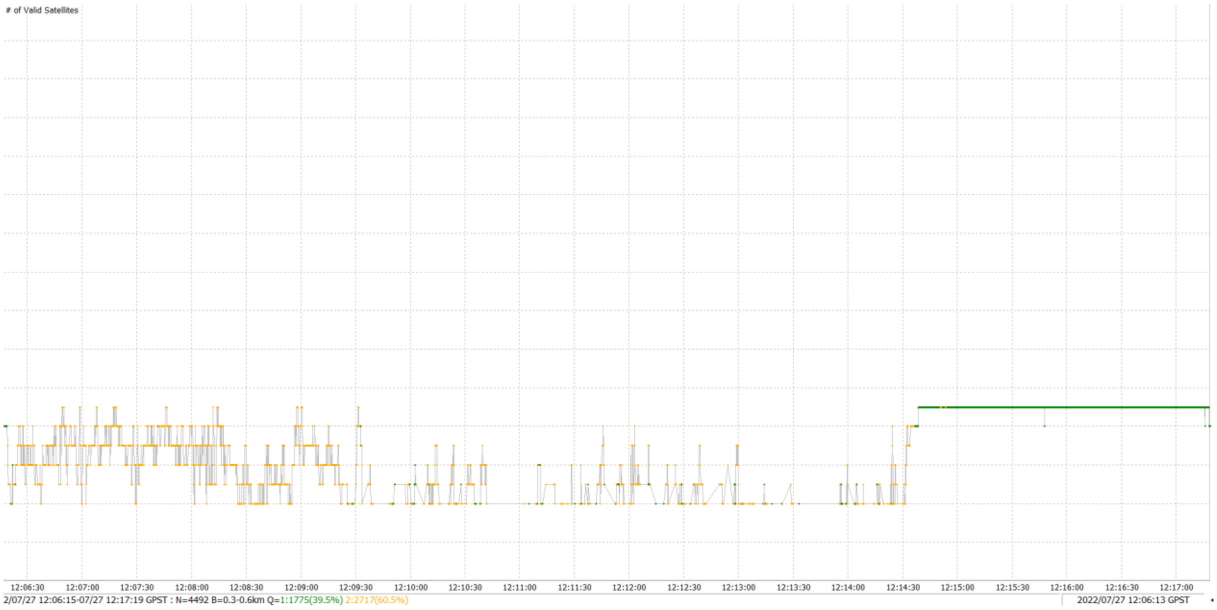
The position of the base station varies because the measured solution over 10 minutes averaged is supposedly not as precise as the SPP solution from the raw data with more than an hour time of logged data. Additionally, the settings were not the same. For the written positions in the field the elevation mask was set to 5°. For this reason, the differences between the SPP solution with an elevation mask of 5° for most parts differs slightly less to the written notes than the one with 15° (weird is Δ_Y of Group A). However, the still occurring differences could come from the overall longer measuring time or some sort of trend.

Accuracy of the Measurements with degraded satellite visibility

Figure 9. Measurement Inconsistency

The orange points mean there’s a float solution, the green points show a fixed solution. If the solution is fixed that means the software deciders within certain tolerances that it has chosen the correct intersection of wavelengths that the antenna was closest to. Float however means that the software does not have this certainty.

As seen in the picture above, as soon as the rover enters the forest the solution gets way worse while in the open it’s quite good. In the forest the number of valid Satellites decreases while Signal to Noise Ratio worsens (see below) hence the quality of the trajectory and fix percentage gets worse.



Fiure 10. Number of Visible Satellites inside and then outside the forest

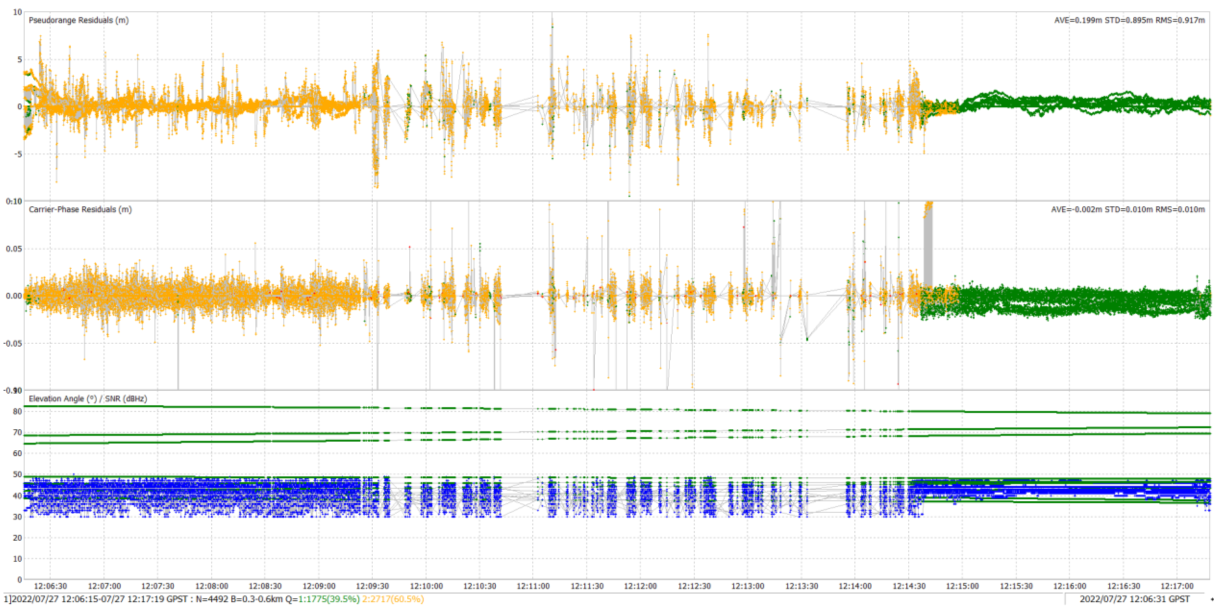


Figure 11. Residuals and SNR inside then outside the forest

Comparison of static measured points to WP2

Upon preparation of the work package one of the goals is to compare the coordinates to other work packages so we measured several points in static mode using our car equipped with the rover receiver. The results are shown in the following table after conversion of the coordinates into UTM projection.

Point ID	WP 6 static WGS 84 (GPS)	Standard deviations	WP 6 static UTM | H (DHHN2016)	WP2 UTM | H (DHHN2016)
NP 1	Lon: 9.399849428 ° Lat: 48.528543124 ° h: 771.4741 m	E: 0.0114 m N: 0.0040 m U: 0.0108 m	Y: 32 529521.001 m X: 5375125.495 m H: 722.975 m	Y: 32529520.4050 m X: 5375124.5797 m H: 720.1806 m
NP 2	Lon: 9.397016727 ° Lat: 48.5287466 ° h: 766.5364 m	E: 0.0006 m N: 0.0009 m U: 0.0049 m	Y: 32 529311.745 m X: 53 75147.023 m H: 718.40 m	Y: 32 529311.4574 m X: 53 75146.3277 m H: 715.2550 m
105	Lon: 9.401219245 ° Lat: 48.533895345 ° h: 771.319 m	E: 0.0794 m N: 0.0590 m U: 0.0260 m	Y: 32 529619.013 m X: 5375720.956 m H: 722.832 m	Y: 32 529618.0500 m X: 5375720.5400 m H: 720.8110 m

For X and Y, the difference varies around 0.5 to 1 m. in the heights however the difference is between 2 and 3 m, which is much higher than what the deviations let expect.

3.3. Autonomous Terrain Surveying

After manual driving of the car by the remote control for all measurements, we planned for an autonomous driving survey by planning the survey strips on the ground control station as shown in the map below and you will see the driving path of the car without any interference.

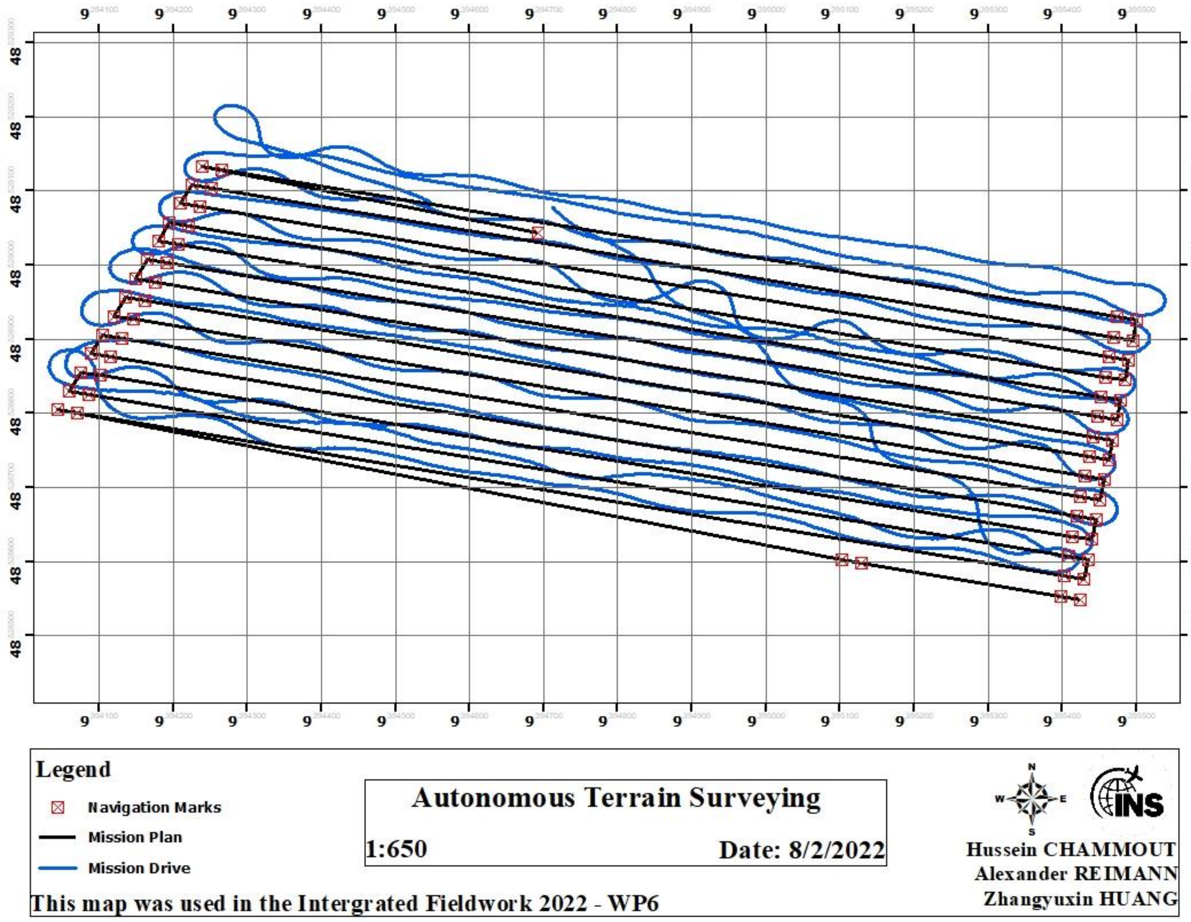


Figure 12. Planned survey mission

4. Problems and solutions

During the fieldwork the first day the car was equipped with the simleRTK3D pro as a GNSS receiver to save its own data logging on a mounted SD card board, luckily one of the groups was at the first day measurement and the board was not saving properly the data files after each measurement. The board was tested before but we felt that the other colleges will not use it smoothly and we have a risk for no data saving.

In the other hand after processing the first day data, one of the files was showing wrong or bad logging whereas the two other files where perfectly processed with RTKlib having an accuracy around 6 mm in stationary mode. However, due to this inconsistncy the receivers were unfortunately switched for the next day. This receiver however was more accurate than the Reach m2 receiver which replaced the on the first day used simpleRTK3D pro for the next days.

Integrated Fieldwork 2022

WP 7: Large Scale Airborne Data Acquisition with RGB and Multispectral Sensors

Supervisor

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Team Member

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Jessica Seemüller

Yi Chen Yang

Contents

1. Introduction

In working package 7, we focus on two main tasks:

a. RGB Point Cloud with the mesh, orthophoto and DSM
b. NDVI Map

There are three blocks of area we have chosen to do the flight:

i) Large scale campaign
ii) Cave Flight
iii) Smart Farming Flight.

During this fieldwork, we used the DJI Phantom 4 RTK drone to acquire images in our area of interest. There are two camera systems carried by the drone. One is the built-in Zenmuse camera, which is utilized to get RGB images. Another is a multispectral camera, the Parrot multispectral Sequoia camera, which helps us gather images from different wavebands. We used images from Zenmuse camera to create a RGB Point Cloud with the responding mesh, orthophoto and DSM. Then we used multispectral images to generate the NDVI Map.

We use the Metashape software (Agisoft) to generate a RGB Point Cloud, analyze precision, and create the DSM and Orthophoto.

Since we have a RTK system on DJI Phantom drone, we can generate georeferenced products (DSM, orthophoto, NDVI Map). To estimate the accuracy of our map, we compared our result with the 3D coordinates of ground control points (GCPs) derived from WP2 and WP4.

2. Plan

2.1. Workflow

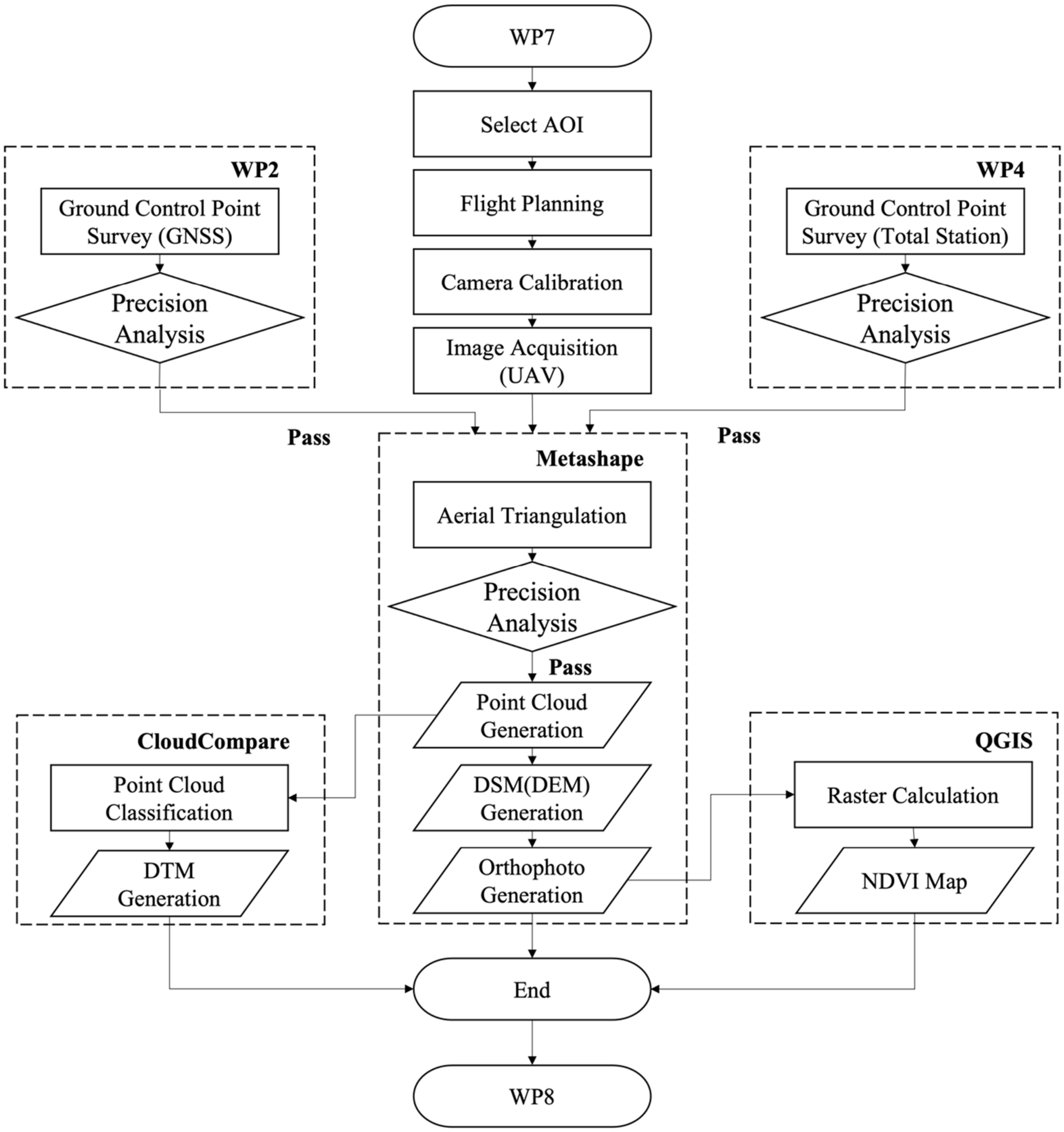


Figure 1: Workflow chart

2.2.Area of interest (AOI)

In this fieldwork, we have chosen three area of interest. The large-scale campaign (figure 2) is the main project. We did the calibration flight in a smaller part of the large-scale campaign flight (figure 3) to get the parameters of the camera. The points with the numbers from FP1-FP12 as well as NP1 and NP2 are points measured by WP2 and WP4 to get 3D coordinates. Additionally, the 2 blue boxes represent the landing strips from the airfield. In this area, we can check the accuracy of the data via the 3D coordinates of GCPs derived from WP2 & WP4. Also, we generate RGB point cloud, DSM and Mesh of the area. The cave flight (figure 4) is an additional project, as we want to get the approximate location of the cave underground and measure the terrain nearby the cave where WP5 did gravimetry measurements. Therefore, we produce the orthophoto and DSM of this area. The smart farming flight (figure 5) is a smaller project, which aims to get the vegetations information of the field next to the runway. The task in this area is to derive the NDVI map.

Figure 2: Large Scale Campaign

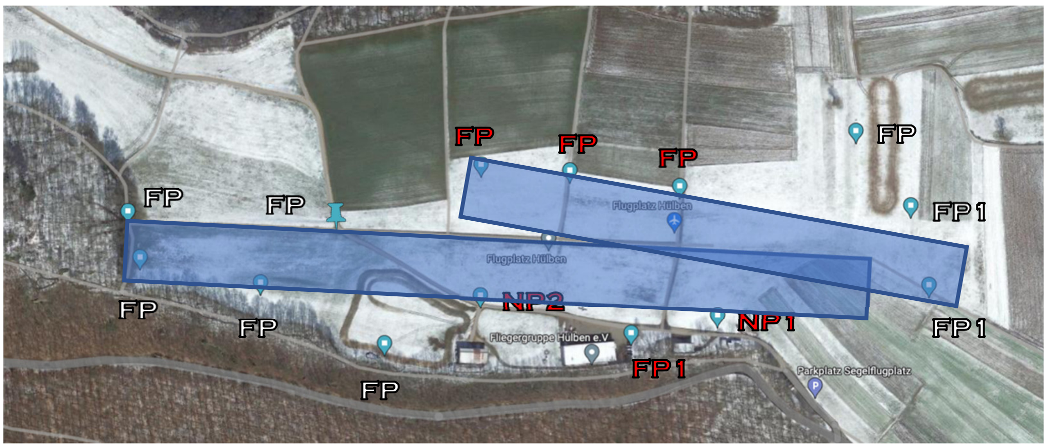


Figure 3: Area of calibration flight with Fix Points from WP2 and WP4

Figure 4: Cave Flight

Figure 5: Smart Farming Flight

2.3. Ground control points

Since we have high precision position information of every image from the RTK function, we don't need any Ground Control Points actually. However, in order to make our model more accurate and analyze accuracy, we set some Ground Control Points. Some Ground Control Points can be considered into bundle adjustment, other Ground Control Points can be used as checkpoints.

In total we had 14 Ground Control Points from WP4 which were evenly distributed in the area from the large-scale campaign. To identify them on the pictures, we used some markers (figure 8). Most importantly, we need to know the 3D coordinates of each Ground Control Point, which were be measured by WP2 and WP4.

3. Equipment

3.1. DJI Phantom 4 RTK drone

This drone has a built-in Zenmuse camera with 1 inch CMOS sensor and 5472*3648 pixels, with pixel size 2.4 µm. The color depth is 8 bits, which means it can record 256 different gray values. The lens undergoes a thorough calibration process, and the parameters recorded are stored in the metadata of each image so that our software can adapt them in post-processing. The RTK module has been integrated directly into this drone and offers centimeter-accurate position data.

Figure 6: DJI Phantom 4 RTK drone

3.2.Parrot multispectral Sequoia camera

This Parrot multispectral Sequoia camera will be attached on our drone. There are 5 cameras, including Green, Red, Near-Infrared, Red-edge, and a RGB camera.

Figure 7: Parrot multispectral Sequoia camera

Figure 8: Integrated system

3.3.Marker

We need some Checkerboard plates to mark the position of Ground Control Points.

Numbers of targets: 14

Type of targets:

Figure 9: Marker picture

4. Data Acquisition

4.1. Image Acquisition

After setting up the project, the app ‘DJI GO 4’ will make a flight planning automatically. It could be adjusted according to different situations (including front overlap rate, side overlap rate, flight height, etc.). We recommend the front overlap rate is at least 70% and the side overlap rate is at least 60%. For the RTK function, we use SAPOS so that we don't need to set our base station.

4.2. Ground Control Point Measurement

We got 3D coordinates data from WP2 and WP4. In Metashape six points were used as Ground Control Points: FP6, FP7, FP8, FP12, NP1, NP2, which where we set up out checkboard targets for the calibration flight. In the main project, FP1~FP12, NP1 and NP2 are regarded as GCPs and checkpoints when we are processing the data. To differentiate between Ground Control and Checkpoints, Checkpoints won’t have a check besides their number, as shown in figure 10.

Figure 10: Ground Control Points

5. Data Processing

5.1. RGB Point Cloud

We use Metashape to do the bundle adjustment and generate the sparse point cloud. There is no need to use all tie points computed by Metashape, we have different kinds of selection function in the software to eliminate most of the low-quality points.

5.2. DSM

We can build the dense point cloud and then build the DEM (Digital Elevation Model). Here the DEM in Metashape software is our DSM.

5.3.Orthophoto

We can use the Build Orthomosaic function to create the Orthophoto directly.

5.4.NDVI Map

Normalized Difference Vegetation Index (NDVI), which is used to indicate the presence of vegetation in an area and identify whether the vegetation is healthy or not. From the images of the Parrot multispectral Sequoia camera, we have information in different wavelengths. Then we can put these values into QGIS. The software can compute the function below by applying the raster calculate tool to generate the NDVI map. To do so, the following equation is used:

$$NDVI = \frac{NIR - Red}{NIR + Red} \tag{1}$$

6. Final Products

6.1. Large Scale Campaign

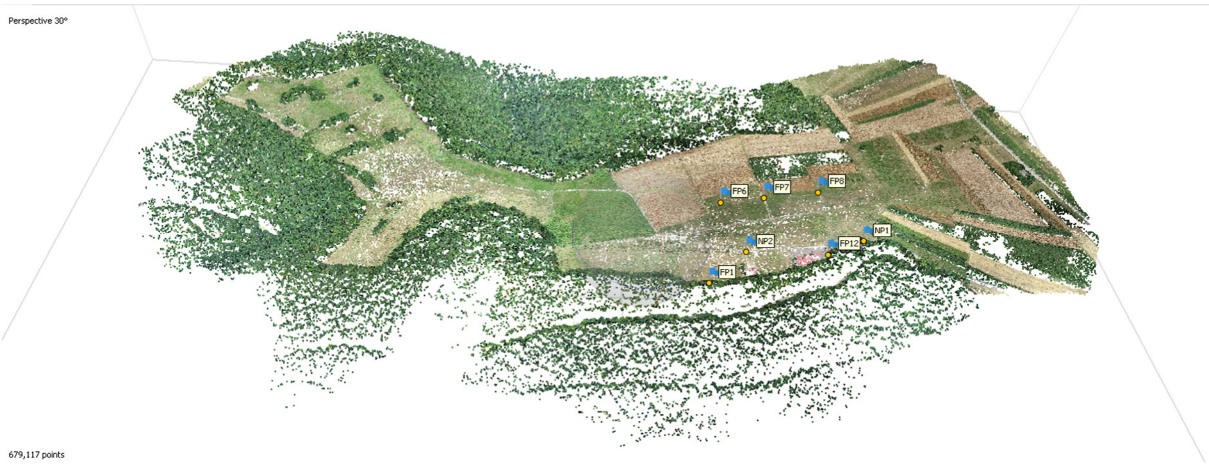


Figure 11: RGB Point Cloud

At the edge and on top of dense vegetation, you can see that there are some holes. This occurs at the edges and in the vegetation, because Metashape can’t compute many tie points because of missing corresponding points in the photos.

Figure 12: Orthophoto

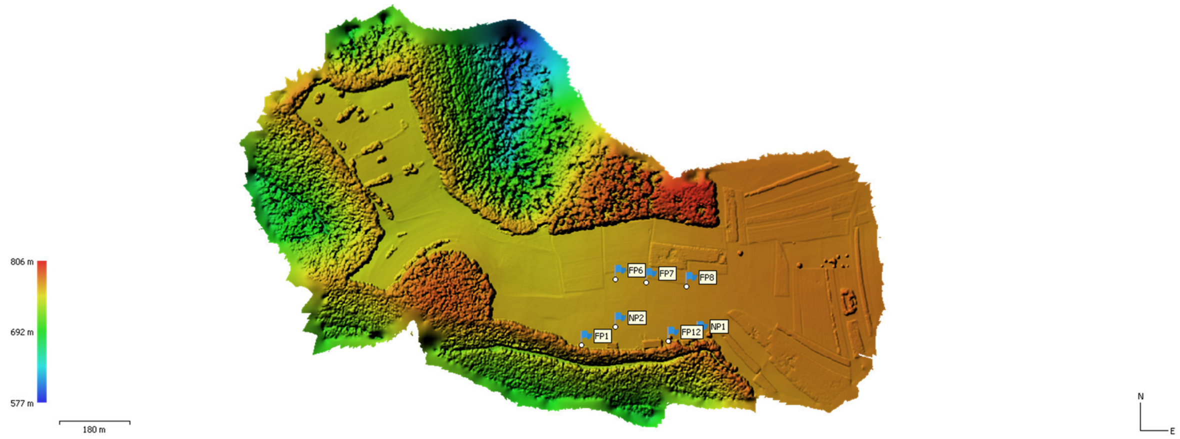


Figure 13: DSM

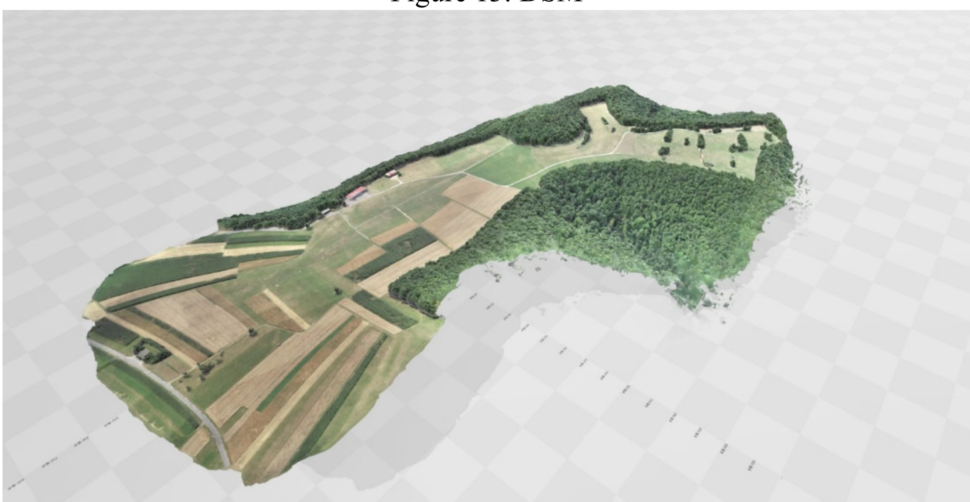
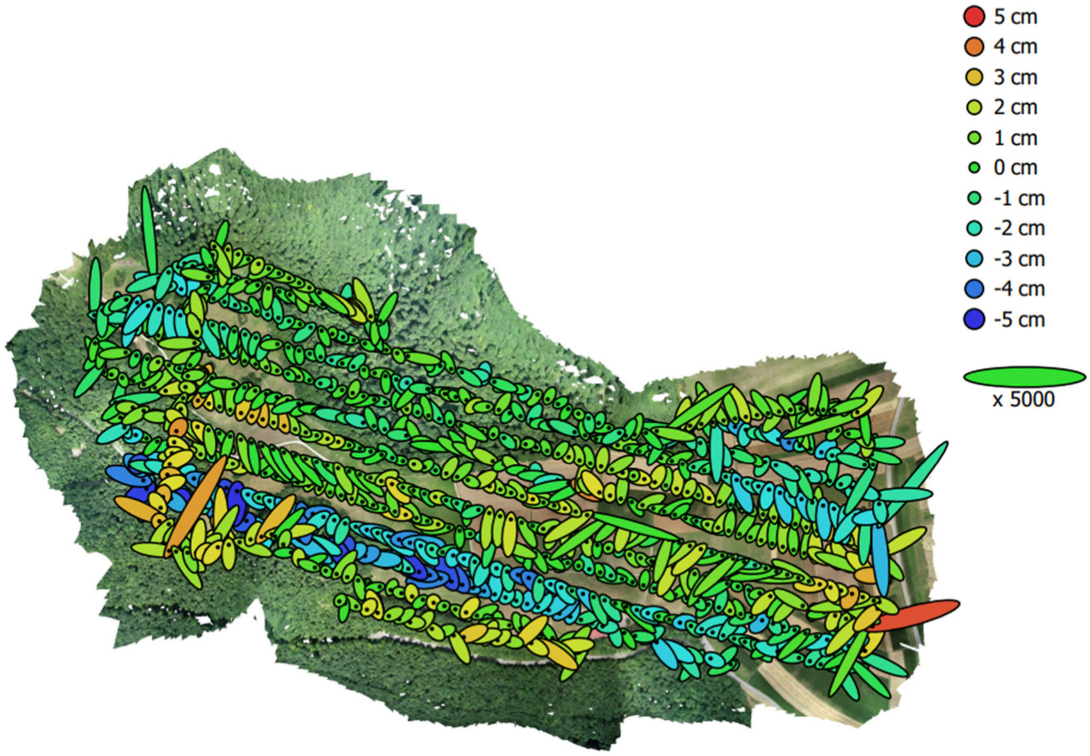


Figure 14: Mesh

Camera Locations



Z error is represented by ellipse color. X,Y errors are represented by ellipse shape.
Estimated camera locations are marked with a black dot.

X error (cm)	Y error (cm)	Z error (cm)	XY error (cm)	Total error (cm)
0.553526	0.535941	1.61432	0.77047	1.78875

Table 3. Average camera location error.
X - Easting, Y - Northing, Z - Altitude.

Figure 15: Camera Locations from the Metashape Report

As you can see, at the turning points of the flight, the error ellipses are larger than the ones during the straight stripes. Also, most of the error ellipses show random errors, because they point at different directions.

6.2. Cave Flight

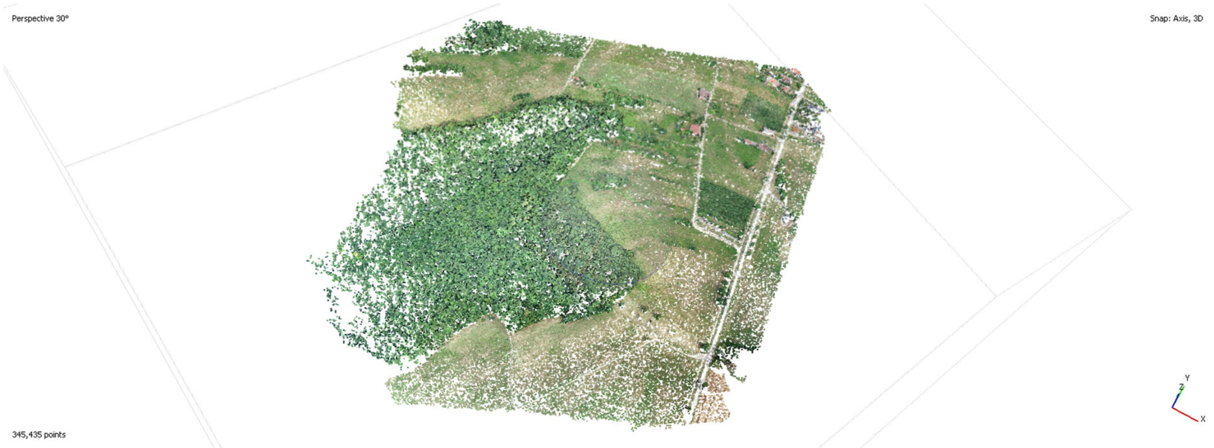


Figure 16: RGB Point Cloud

Figure 17: Orthophoto

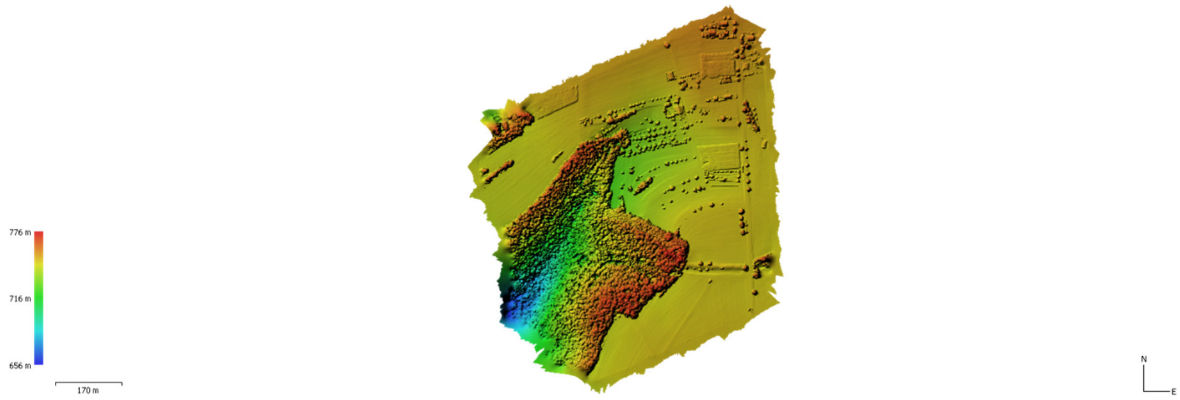


Figure 18: DSM

6.3. Smart Farming Flight

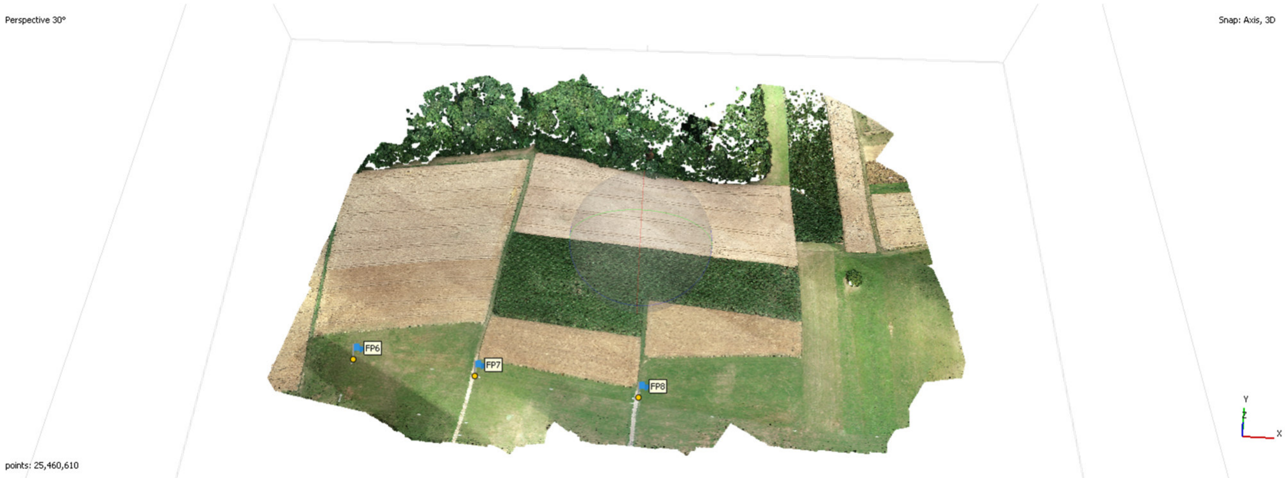


Figure 19: RGB Point Cloud

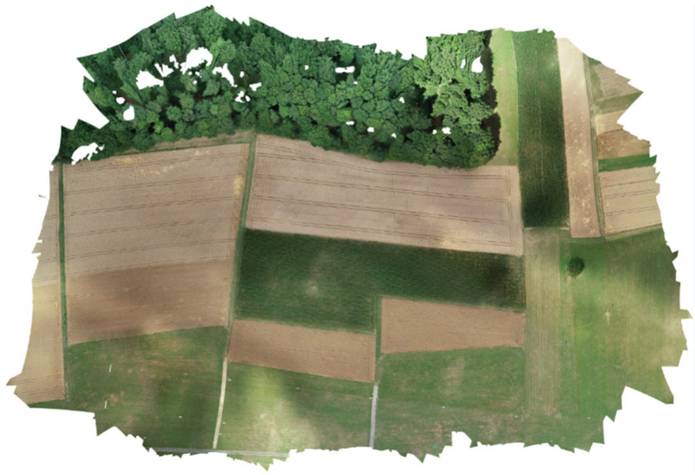


Figure 20: Orthophoto

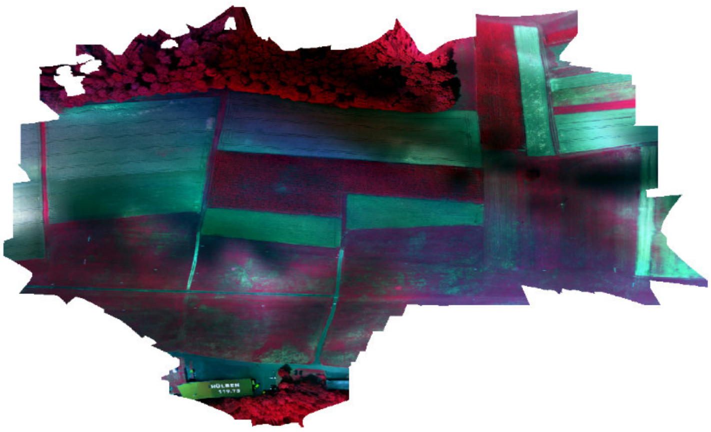


Figure 21: False color image

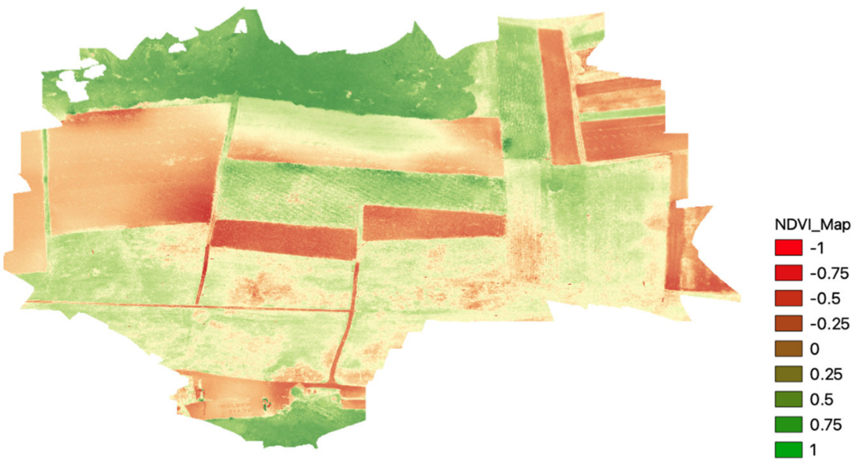


Figure 22: NDVI map

If you compare the NDVI map (figure 22) with the orthophoto you can clearly recognize the different fields on the airfield. To explain what can be seen, first, the legend will be explained.

The red parts indicate that there are no plants or non-healthy plants. You can compare that with the corresponding parts in the point cloud: Those are fields that are not green, because they were too dry are already harvested.

On the other hand represent green parts healthy vegetation, for example the green parts on top or the bottom which are forest parts.

This is also corresponding with the false color map (figure 21). Healthy plants reflect red light better as can be seen at the forests parts which are dark red. Additionally, fields that are blue or green are red in figure 22.

7. Appendix

7.1. Metashape

We use Metashape software to generate a RGB Point Cloud, analyze precision, and create the DSM and Orthophoto.

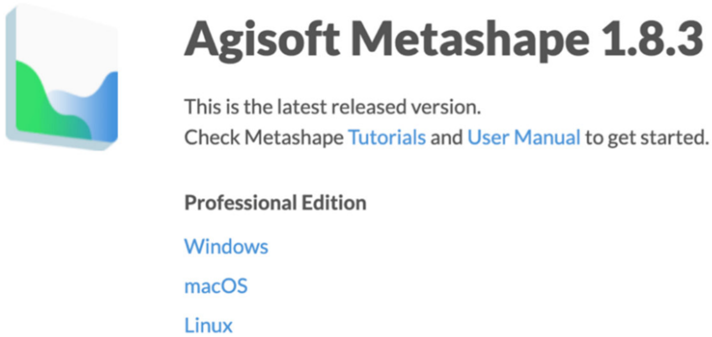


Figure 21: Metashape

(Source: https://www.agisoft.com/)

7.2.QGIS

We use QGIS to build the NDVI map.

QGIS

Figure 22: QGIS

(Source: https://qgis.org/ru/site/)

Report
Integrated
Fieldwork 2022

WP 8: Mobile Laser Scanning and Visualization of Multiple Point Clouds

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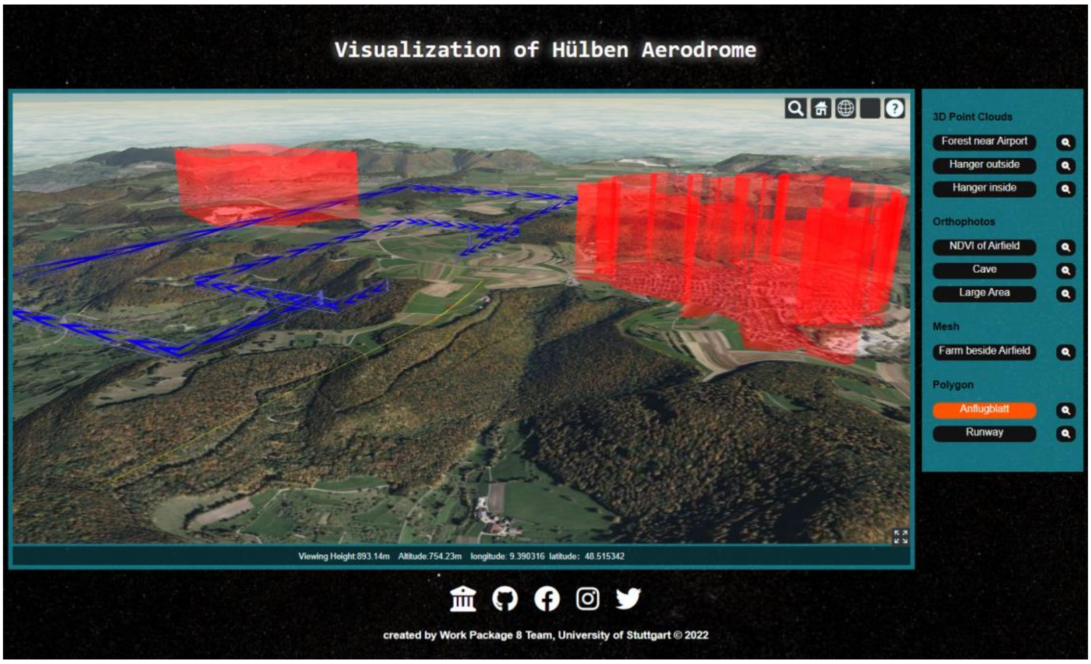
The main task of this work package was laser scanning with ZEB horizon laser scanner and creating an interactive website which displaying and visualizing the point cloud that obtained by laser scanner after processing the raw data and displaying product of other work packages especially Wp7.

During the past few months WP 8 were focusing on creating the website and designing it by using the Java Script, HTML, CSS and Cesium library.

Below you can find the interface and different sections of the website:

Runway:

Avoiding urban areas and Flight Track to important airports:

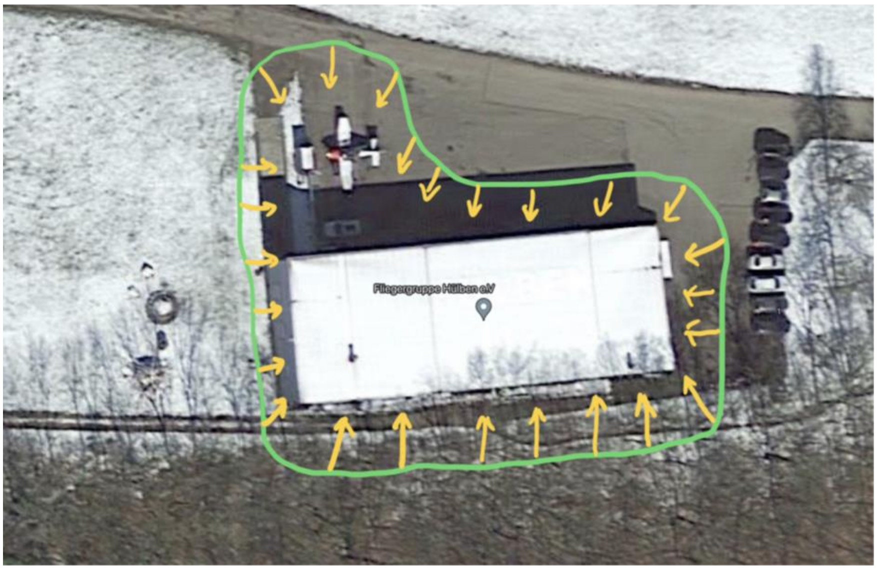


The location of the project was located at hülben aerodrome which is a hobby airport for light aircraft.

We had considered five routes for our laser scanning which include the outside/inside of the hanger, South Forest, West Forest, and forest near the cave, we scanned all the routes but skipped the processing of the fifth route (cave area) because of the shortage of time.

The considered routes images can be found below:

Route 1 & Route 2: Hanger outside & inside:



Route 3: South Forest:

Route 4: West Forest:

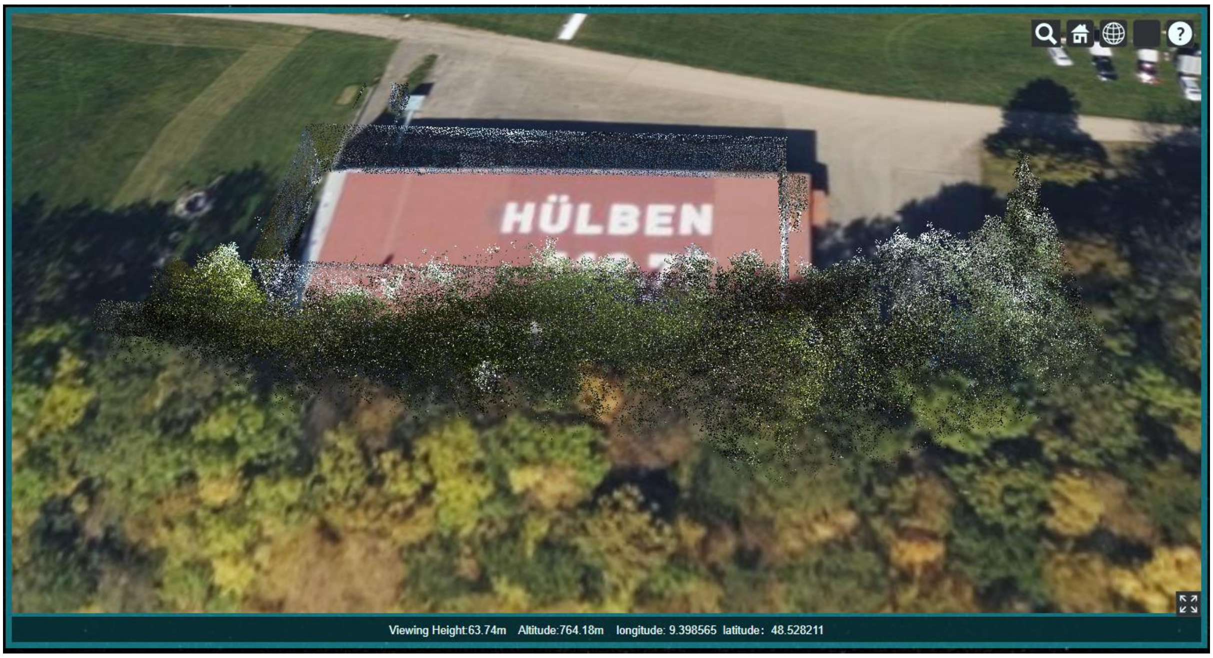
After the integrated field we processed the raw data of point clouds by Zeb hub and cloud compare so make them ready for displaying on the website. We also displayed the orthophoto that we received from WP7.

Below you can find the visualizations and different parts of the website that were created by WP8:

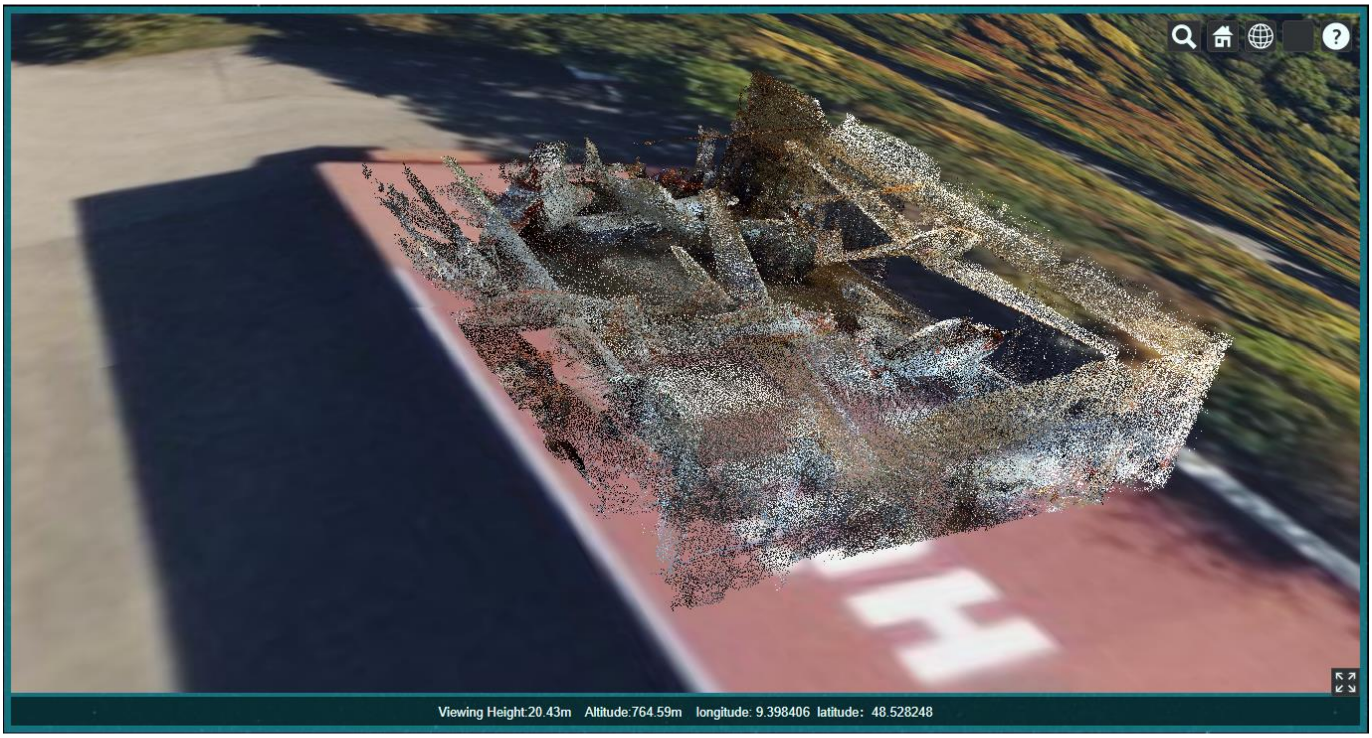
Forest near Airport:

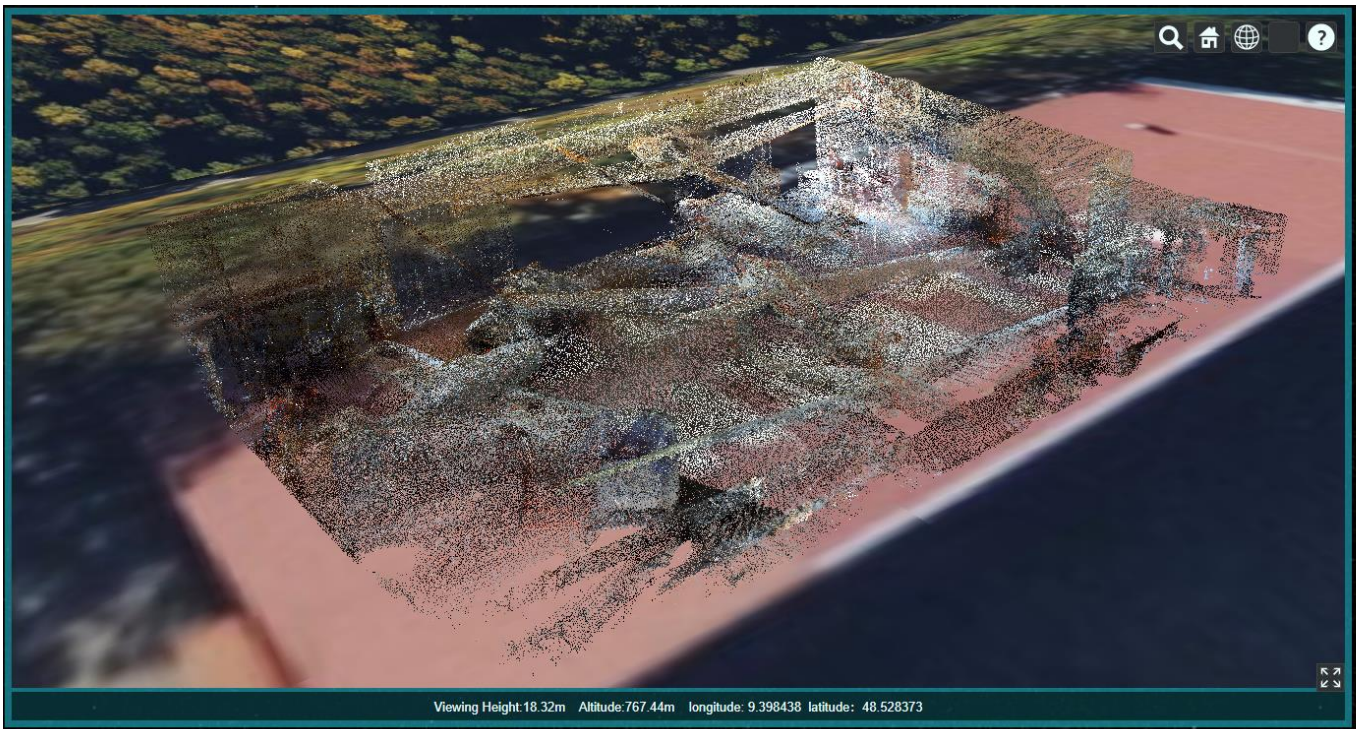
Hanger outside:


HÜLBEN
Viewing Height:21.60m Altitude:764.18m longitude: 9.398300 latitude: 48.528244

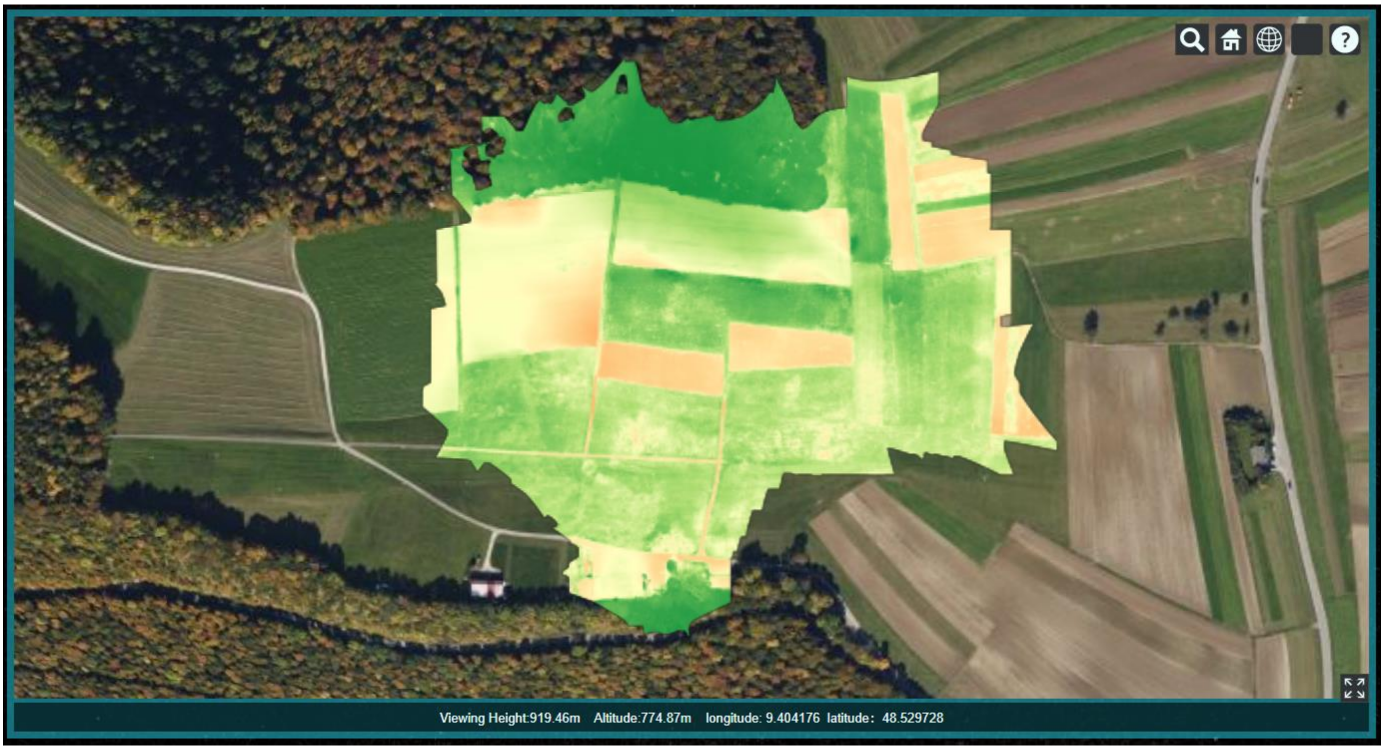

HÜLBEN
Viewing Height:63.74m Altitude:764.18m longitude: 9.398565 latitude: 48.528211

Hanger inside:





NDVI of the Airport:



Cave:

Mesh:

Farm beside Airfield: