Technical Project Report
„Innovation Projekt_LOR11 Network Coverage Test“

Final Projekt Report: **7.704.40001**

1 Summary

The project aims to gain a more accurate picture of the mobile network coverage within the AIRlabs test area LOR 11 Frauschereck. The project was successfully completed and provided numerous learning opportunities for all parties involved. Additionally, the created visualization of the network coverage supports AIRlabs in communication with customers and assists the cooperation partner Dimetor in optimizing its model.

2 Project Objectives

The AIRlabs test flight areas offer many innovative companies the opportunity to conduct tests in regions that are far from residential areas. The test flights were carried out in activated airspace with an operational approval in the SPECIFIC category.

For AIRlabs, understanding network coverage in their test areas is of utmost importance to provide reliable data to future customers.

Currently, relatively detailed data on network coverage is available in cities and along major transportation routes. However, in the air, coverage can vary significantly from that on the ground. In particular, larger differences can occur in forested areas outside of cities. Additionally, the received signal quality varies greatly depending on flight altitude. This is due to shielding and interference.

The cooperation partner Dimetor provides the mobile measurement device and the measurement program for the surveys. The goal of the project for Dimetor is to optimize their static model (based on terrestrial antennas) with data from drone flights.

A1 is a partner of both AIRlabs and Dimetor and provided the static data from A1 to supplement the algorithm with additional data.

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3 Project Implementation

3.1 Main Tools/Permits Used:

- Mobile phone + software: We used the device provided by Dimetor, specifically prepared for network coverage tests.
- AIRlabs operating permit: Since the test was to be conducted in BVLOS mode, the operation was carried out under the SPECIFIC operating permit of AIRlabs.
- A1/Drei SIM cards: Use of multiple SIM cards to obtain results from these mobile network providers.
- DJI M300: The test was conducted using AIRlabs' industrial drone. The mobile device was attached to the drone. (Figure 1)
- AIRborn RF software: The Dimetor platform, used to create the visualizations.

Figure 1: M300 RTK with Mobile phone

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3.2 Three phases of the Project:

3.2.1 Planning

In order to collect as much data as possible in a short amount of time, the flight had to be carefully planned. Preparations were made in case network coverage in the area did not allow for an internet connection. Therefore, the flight plan was created in advance. The drone's software offers the ability to use an offline map at a basic level. This was also downloaded so that the mission could be modified on-site if necessary.

The planning primarily considered the three takeoff and landing locations. The flight altitude was set at approximately 200 meters to ensure a sufficiently safe altitude while flying in BVLOS mode.

3.2.2 Test Flights

The flight was conducted under the AIRlabs operating permit in the LOR 11 test area. An RPIC (Remote Pilot in Command) and a VO (Visual Observer) were present. The pilot's task was to control the drone, start the software on the mobile device, and revise or modify the mission if necessary. The VO's task was to maintain radio contact with any potentially intruding aircraft in the airspace, continuously charge the batteries, and constantly monitor the surroundings. Both individuals supported each other with various information, particularly during the BVLOS flights.

At each takeoff and landing site, two types of missions were carried out. The first was a manual vertical flight, where the drone continuously ascended and descended above the takeoff and landing site.

The measurement device continuously collected data, aiming to gather as much data as possible, alternating between the A1 and Drei SIM cards.

This was followed by one or more pre-programmed BVLOS missions around the takeoff and landing sites, with defined grid patterns.

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Execution of the BVLOS Mission:

All missions were conducted by starting pre-programmed flights. One challenge was that, in many cases, trees or hills obstructed the area between the drone and the remote control, which increased the risk of signal loss. Care was continuously taken to minimize signal loss by occasionally adjusting the pre-programmed flight routes (it was helpful that the offline map had been downloaded to the controller during preparation), and the flight altitude was set at approximately 200 meters to ensure that the remote control remained in radio contact with the drone for as long as possible.

In 1-2 instances, there were signal losses, after which the drone safely returned to the starting point in accordance with the pre-set parameters.

3.2.3 Evaluation

3.2.3.1 Measurement Setup:

- Flights: A total of 11 flights were conducted in the Frauschereck area.
- Software: Azenqos
- Measured technology: LTE/LTEa
- Band lock: No LTE band lock was enforced.
- Measured MNOs: A1 (five flights) and Drei (six flights)
- Device: OnePlus 8
- Measured RF KPIs, etc.: Measurement samples were collected at a sampling rate of approximately 2 Hz. The following metrics were captured and imported into AirborneRF: coverage metrics (i.e., RSRP); signal quality metrics (i.e., SINR, RSRQ); delay metrics (latency measured by round-trip delay, measured via pings with a packet size of 1250 bytes). All KPIs were collected simultaneously through a pre-configured script running repeatedly on the device. The script for collecting latency samples was adjusted to simulate the C2 traffic model proposed in 3GPP TR 36.777.

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3.2.3.2 *Integration into AirborneRF:*

- All conducted measurements were uploaded to the respective MNO instances. First, AirborneRF converted the raw measurements from the Azenqos format into the AirborneRF (ARF.v2) format.
- During this process, the RF measurements were correlated with telemetry data (in this case, using GPS source data). The processed measurements were then used for model fitting, with only the measurement samples imported for which the cells were present in our database.

3.2.3.3 *Model Adjustment in AirborneRF:*

- After uploading the measurements, the 3D propagation models used in AirborneRF are adjusted through a combination of historical and current measurements. The network dataset is correlated with the measurements by using the cell identifiers collected through the measuring device. For each point along the flight route and a recorded measurement sample for that point, the corresponding network data (cell location, cell power, antenna alignment, antenna pattern, etc.) are selected, creating a sample point for the tuning process.
- It is crucial that the network data snapshot corresponds to the time when the measurement was conducted. In the web application, the performance of the prediction models is displayed in the form of "Model Performance" analyses, which show the difference between measured and predicted network analyses (for RSRP, SINR, RSRQ). The term "Model Performance" refers to the fact that in this analysis, the identified cell reference is used as input in the calculations—so the calculations for each communication link measurement sample are evaluated as cell-measurement.
- The analyses display the calculations before and after adjustment with the measurement. The differences between calculated and measured values are illustrated using various error statistics (mean, RMSE, STDE), percentiles, and charts along the flight path. Examples and screenshots are shown below.

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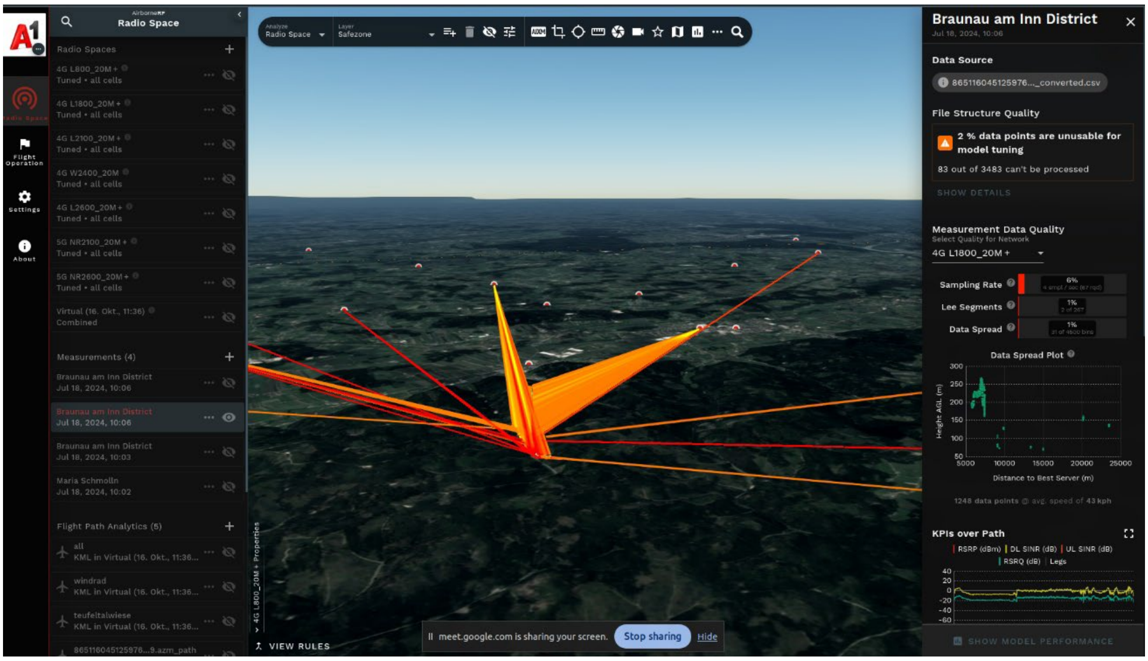
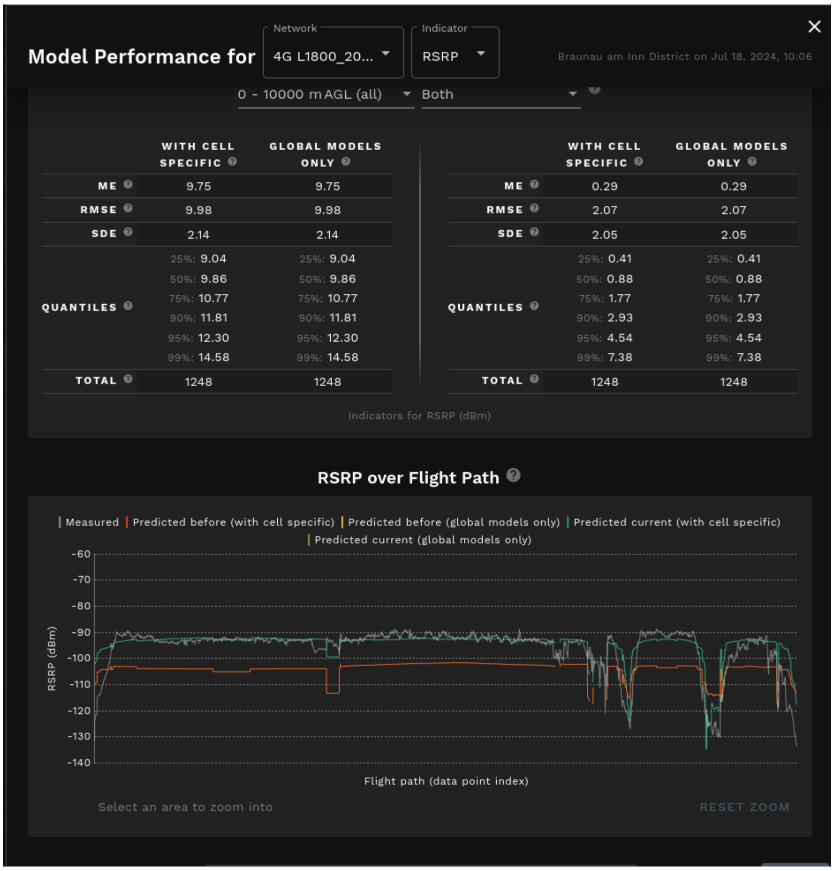


Figure 2



	WITH CELL SPECIFIC	GLOBAL MODELS ONLY
ME	9.75	9.75
RMSE	9.98	9.98
SDE	2.14	2.14
QUANTILES	25%: 9.04 50%: 9.86 75%: 10.77 90%: 11.81 95%: 12.30 99%: 14.58	25%: 9.04 50%: 9.86 75%: 10.77 90%: 11.81 95%: 12.30 99%: 14.58
TOTAL	1248	1248

	WITH CELL SPECIFIC	GLOBAL MODELS ONLY
ME	0.29	0.29
RMSE	2.07	2.07
SDE	2.05	2.05
QUANTILES	25%: 0.41 50%: 0.88 75%: 1.77 90%: 2.93 95%: 4.54 99%: 7.38	25%: 0.41 50%: 0.88 75%: 1.77 90%: 2.93 95%: 4.54 99%: 7.38
TOTAL	1248	1248

Figure 3

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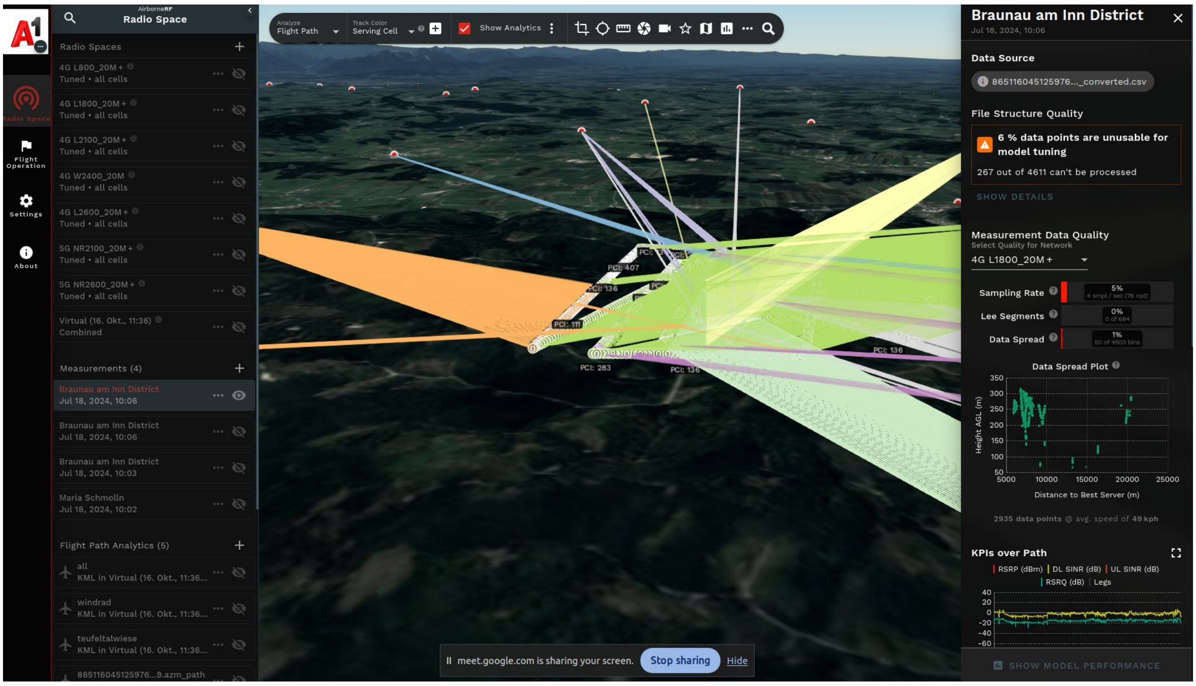

Figure 4

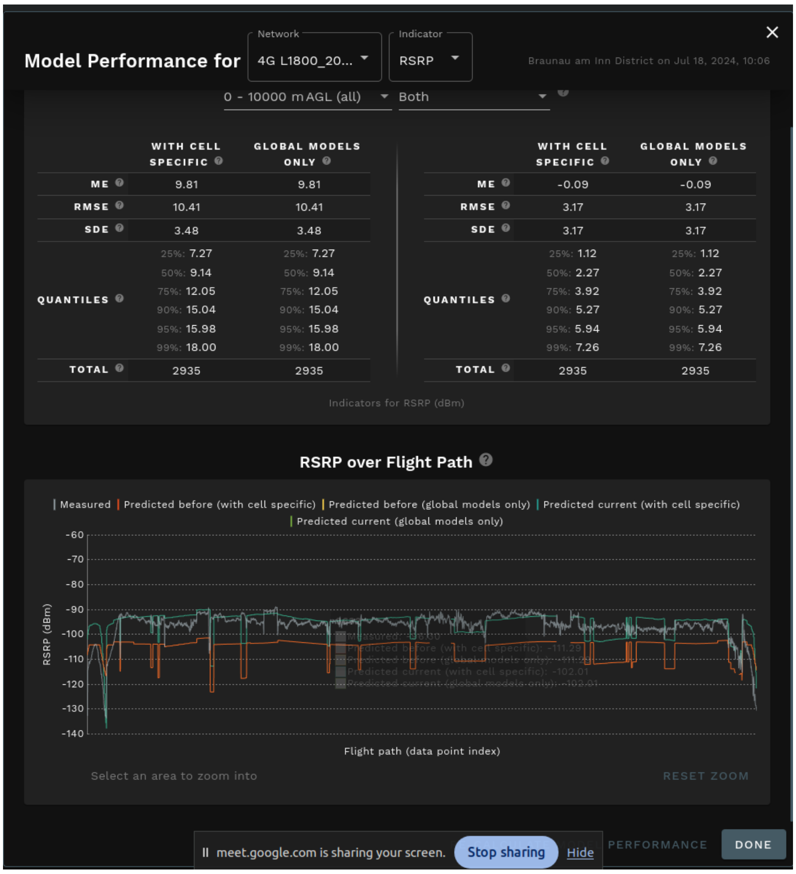

Figure 5

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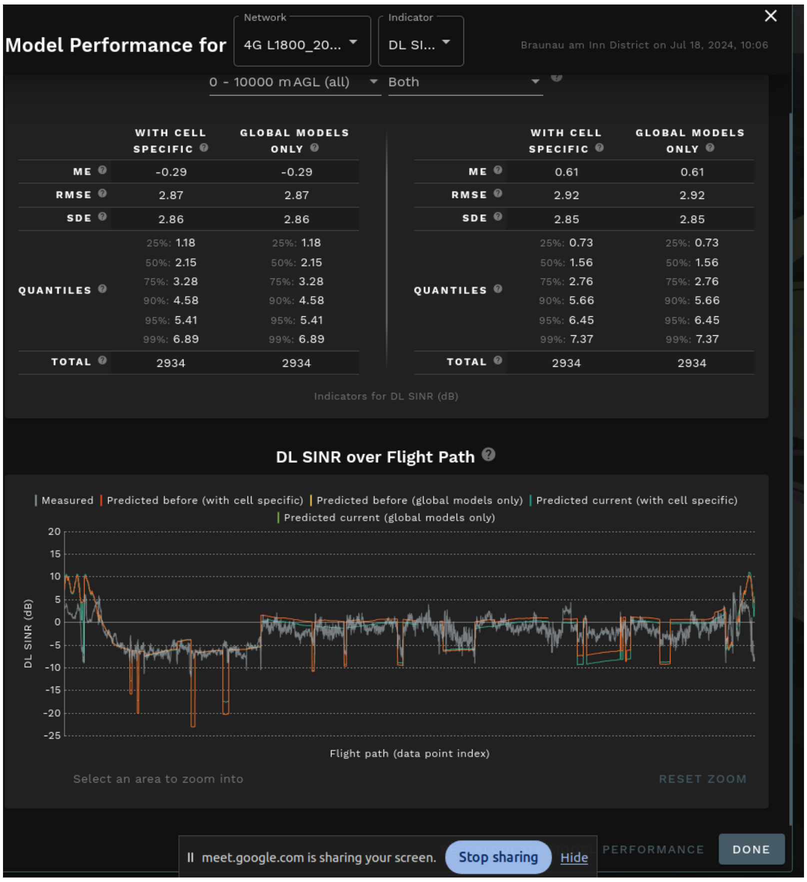

Figure 6

3.2.3.4 Visualization

The data was analyzed using Dimetor's specially developed system to determine the signal strength at different altitudes (10-30-60-90-120m).

The simulation was conducted by Dimetor on two different layers: at 800 MHz and 1800 MHz. (Table 1) It can be noted that the values at 800 MHz are significantly better.

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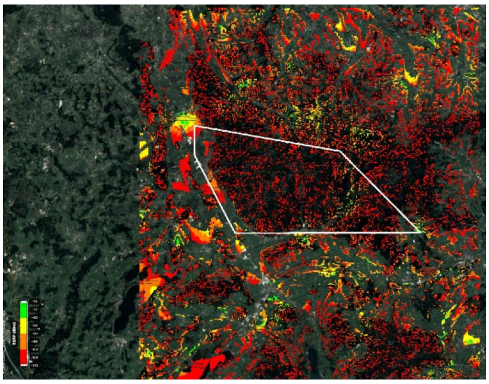
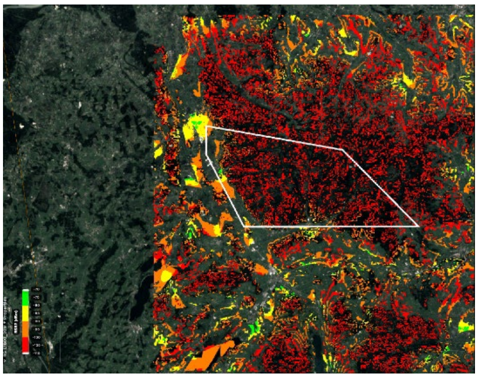
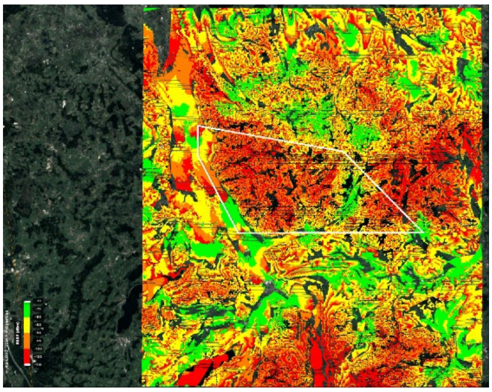
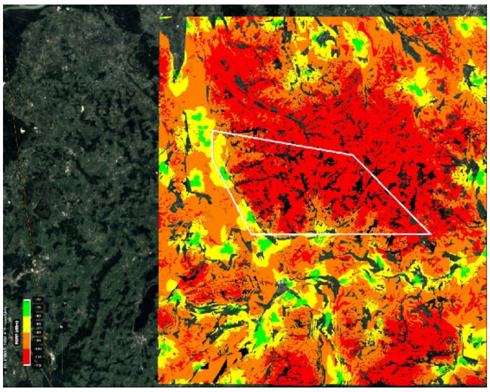
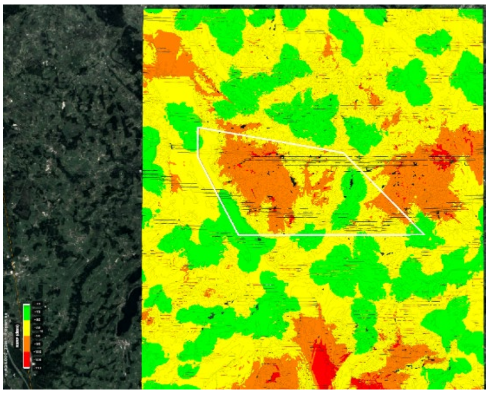
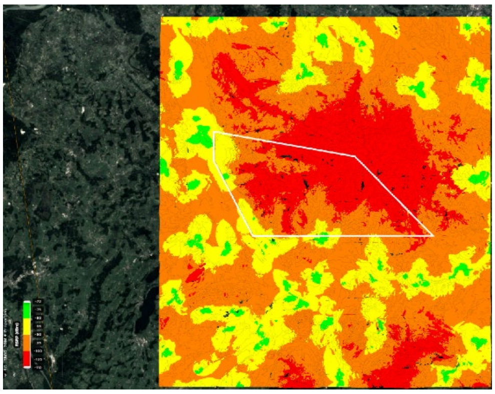
Table 1: Ergebnisse

AGL	800 MHz	1800 MHz
10m		
30m		
60m		

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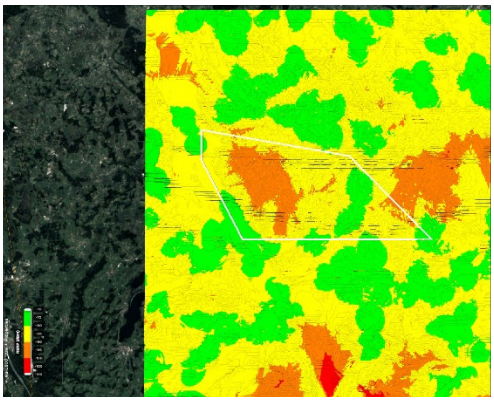
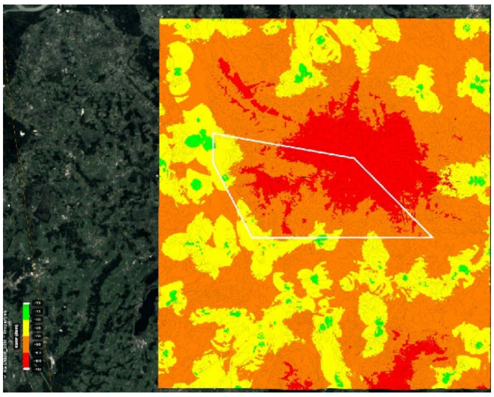
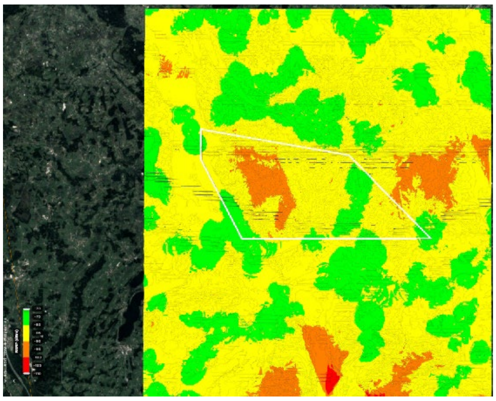
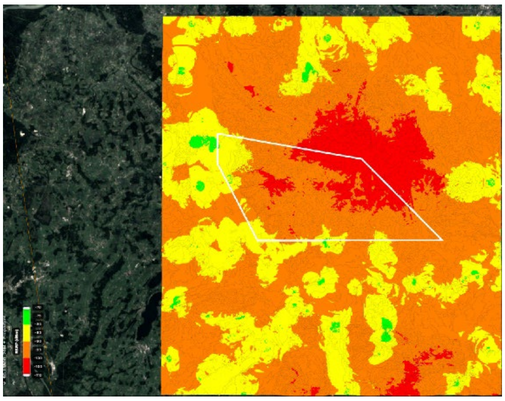
90m		
120m		

To determine the signal quality, the RSRP value (Reference Signal Received Power) was used (Table 2).

The evaluation shows that the higher the flight altitude, the better the signal quality.

		RSRP (dBm)
RF Conditions	Excellent	>=-80
	Good	-80 to -90
	Mid Cell	-90 to -100
	Cell Edge	<=-100

Table 2: RSRP Classification

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4 Conclusion/Outlook

In the future, more flights are planned in the area to collect additional real data and further improve the model. Another important goal for AIRlabs is to conduct such measurements in the other test areas as well.

The project also resulted in an internal AIRlabs "Lessons Learned" document for BVLOS flights.

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IMPRESSUM

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