

## DETECTING SNOWPACK WITH LOW-COST RADAR – CASE STUDY IN PYHÄTUNTURI, FINLAND

Lauri Nieminen<sup>1</sup>, Harri Valasma<sup>1</sup>, Saana Valasma<sup>1</sup>

<sup>1</sup> *Snower Oy, Finland*

**ABSTRACT:** Measuring snowpack and its qualities is a difficult task for snow scientists. Instrumentation is expensive and usually requires maintenance. The observation locations can be remote and often there are few possibilities to connect to the electrical grid and the internet network. A study was conducted to measure the snowpack with a low-cost IoT device. Device measures snow height with a radar, snow surface temperature, ambient temperature and relative humidity. Study area consisted of twelve sensors in the proximity of a ski resort. Additional four sensors were installed to the closest meteorological observation centre to compare the data with an official snow height observation location. The raw data was then manipulated with an algorithm to present the data from different snow types and scenarios. The results of this study showed that this method of using low-cost radar was reliable. The radars together with the algorithm were able to produce accurate readings throughout the winter season with different snow types. The usage of battery powered low-cost radar allows reliable data collection throughout the winter. Large meteorological datasets with small time intervals allows accurate data analyses and usage in other applications such as SNOWPACK. The small size and low-power usage allows data collection on remote locations and a possibility for a broad spatial coverage to get an overall understanding of the snowpack properties.

**KEYWORDS:** IoT, Radar, Instrumentation.

### 1. INTRODUCTION

Measuring snow and its qualities reliable has been a difficult task. Digging snow pits and making manual snow height measurements is time consuming and inefficient. Many widely used technologies are expensive and need electricity and other supporting infrastructure for the devices to work. With new technologies and methods snow measurements can be more accurate and more efficient due to automatization and network connectivity constant measuring. Radar technologies bring a new possibility to detect snow with cheaper and reliable instrumentation (Marshall and Koh, 2008).

A study was conducted to see how the sensors performed throughout the winter in cold environments. Highest measured winds in the area were 31 m/s and coldest recorded temperatures where below -34°C. Main goal of the study was to see how the sensors performed throughout the winter conditions with frequent measuring. Every sensor had a feature called “Quality of the service” (QoS), which is a parameter to detect how accurate and reliable each reading is. Maximum value for QoS was 1000 meaning that the reading is very reliable. A threshold for determining a reliable reading was set to 900.

The results showed that the sensor performed well throughout the winter and the quality of the service was reliable. The data that sensors produced can be utilized within the SNOWPACK model (Bartelt and Lehning, 2002)

### 2. MATERIALS AND METHODS

Twelve IoT-sensors were installed in the Pyhäntunturi, Pelkosenniemi region on the proximity of Kultakero fjell for the winter 2023—2024. Additional four sensors were installed to an official weather station nearby in Tähtelä, Sodankylä to compare the data of the sensors to an official weather station snow height sensor. Three of these sensors were installed to the same pole to measure at the same height while one was measuring in the official measurement area.

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\*Corresponding author address:  
Lauri Nieminen, Snower Oy, Finland  
tel: +358456512815  
email: lauri.nieminen@snower.fi

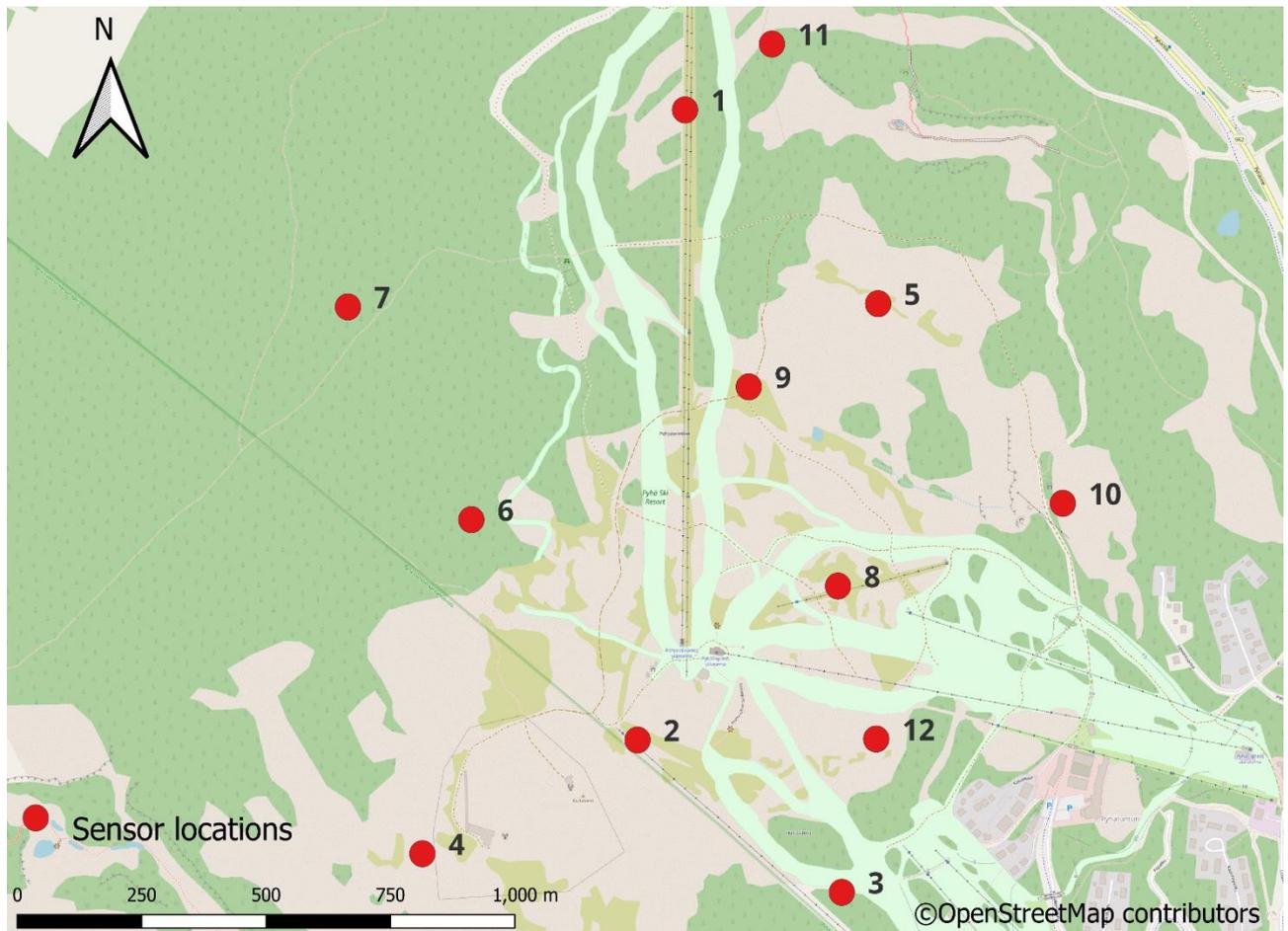


Figure 1. Study area in the Pyhätunturi region in Pelkosenniemi, Finland.

GIS-analysis was performed to determine the best locations for the sensors in the study area. Main goal of the GIS-analysis was to get a broad coverage of sensors on different aspects and elevations to gain information in variable conditions. Also, a terrain analysis was done to assure that the sensors were not placed in avalanche terrain and that the installations were done on relatively flat and representative environment (under 10-degree slope) to minimize the risk of wind loading.

The sensors were small battery powered devices which measured the snow height with a radar. The radar measured the distance between the sensor and snow surface. Additionally, there were sensors also to record ambient temperature, snow surface temperature and relative humidity. The data was then moved to cloud via network connection where it was processed to a XLSX format. Statistical analyses were performed to understand the performance of the measurements with the quality of the service.

Measuring interval was set to 30 minutes throughout the whole winter. Cold period of weather in

December and January made it first difficult to get best reflections from the snow with the radar. A decision was made to change the measuring profile from two to one to better get the snow reflection with radar also from the very light surface hoar that had formed widely across the study area.



Figure 2. Picture of the sensor

### 3. RESULTS

The sensors provided data throughout the whole winter starting from 4.10.2023 and ending at 17.5.2024. Total number of readings during the in Pyhäntunturi region during study period was 118 249. The average amount of readings produced by one sensor was 9854.

The quality of service varied throughout the winter. The measurement profile was changed gradually depending on the location. The change in measurement profile made it possible to detect snow with a higher QoS with an average increase of 10.95%. It was also noted that the sensor highest above the treeline had significantly lower QoS performance compared to other ones. Overall, the average quality of the service with values over 900 were 77,35%.

Table 1. Quality of service results from the winter 2023-2024 in Pyhäntunturi.

Sensor number	Quality of service above 900		
	Profile 2	Profile 1	Total
1	34,80 %	41,07 %	75,87 %
2	23,90 %	30,21 %	54,11 %
3	35,69 %	43,46 %	79,15 %
4	24,79 %	49,24 %	74,03 %
5	28,01 %	61,28 %	89,29 %
6	49,12 %	29,65 %	78,77 %
7	33,66 %	44,42 %	78,08 %
8	35,63 %	45,77 %	81,40 %
9	34,81 %	43,45 %	78,26 %
10	36,51 %	49,40 %	85,92 %
11	36,94 %	39,38 %	76,32 %
12	24,57 %	52,42 %	76,99 %
<b>Average</b>	<b>33,20 %</b>	<b>44,15 %</b>	<b>77,35 %</b>

The other test site in Tähtelä provided data throughout the winter. The results showed a deviation of +-1-2 cm in when results where compared with the public sensor. Similar results were also detected between the three sensors mounted to one pole.

### 4. CONCLUSIONS

The study was successful even though the cold early winter had produced a thick layer of surface hoar which was first hard to detect. The choice of changing the measuring profile from two to one

was later seen as a successful choice as the quality of the service became higher with the measurement profile number one. All the sensors where able to detect snow height in all winter conditions and even in very rapid snowmelts during springtime.

Even though the results where good, there is still place for improvement. There could be many reasons that still affect the QoS, one being changes in the weather. As the study showed the most wind affected sensor had the lowest QoS. Reasons to this could be the higher winds or a poor installation. A new study could be conducted to recognize the changes in QoS during snowfall or rain, which could improve the quality of the

These readings where accurate enough to produce data that can be used as inputs in snowpack modelling that could be utilized in better understanding the snow properties and the changes in the snowpack.

### REFERENCES

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