# Monitoring of snow and ground temperature in the glide avalanche area at Trefall, Eksingadalen in Western Norway

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ABSTRACT: Glide avalanches represent a problem in Western Norway, with known areas where glides and glide avalanche problems arise towards the end of the winter season every year. However, in special winters with wet snow in the bottom of the snowpack, glide avalanches can occur throughout the whole winter.

One important question in relation to glide avalanches is to what extent the ground temperatures can affect the temperature/wetness in the bottom of the snowpack. In October 2017 two sensor strings for monitoring snow and ground temperature were installed in Trefall. The sensors were installed at the same elevation as the glide cracks normally appear in this area. The sensors were measuring ground temperatures more than 1 m down in the ground. During the winter, the sensors have also been inspected a few times, to register the snow depth around them and to document the snow conditions.

The Trefall area is suitable for monitoring glide avalanches because it is an area where glide cracks and glide avalanches occur every winter and it is in the same area where two web cameras (with time-lapse function) are already established, for monitoring the opening and expansion of glide cracks. Web cameras have been operating in Trefall from February 2015 for this purpose. The single road leading to the inner part of Eksingadalen is of vital importance to the local community there, and the monitoring will hopefully help to better understand the avalanche processes and better administrate the opening and closing of this road due to avalanche risk.

The preliminary results and experiences from the use of temperature sensors in combination with a web camera solution in studying glide cracks and glide avalanches during the first winter 2017/18 are presented, along with a discussion on the revised understanding of the processes of glide avalanche danger in the area.

KEYWORDS: Glide avalanche, time-lapse, The Norwegian Public Roads administration, Norway

## 1. INTRODUCTION

Norway is prone to glide avalanches due to its maritime snow climate. Winters in western Norway are for the most influenced by westerlies and thereby mild temperatures. The ground surface – snow cover bottom interface can be wet or moist throughout the winter, or become moist/wet early in the winter, as soon as the snow cover builds into depth. These observations are based on snow pits and our more than 10 years of experience observations of opening of glide cracks and glide avalanche activity on roads in western Norway.

In some years easterlies and cold conditions dominate the winter weather, leading to a frozen ground beneath the snow cover or dry snow conditions at the bottom of the snow. In this situation the opening of glide cracks and glide avalanche activity are believed to be much more defined from the first wetting of the ground surface – snow bottom interface. The winter of 2017/2018 was dominated by easterlies.

One purpose of the instrumentation is to learn more about whether the ground temperature or air temperature affects the conditions at the snow – ground interface. Further it is interesting to investigate how glide avalanches in our study area can be timed related to opening of glide cracks. Our preliminary results also suggest that even if a large potential release area show glide activity, the glide avalanches that reach the road, release from a smaller part of the glide area.

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## 2. INSTRUMENTATION

To webcameras are monitoring the site (Figure 1). One camera is a fixed time-lapse camera, and the other camera is a remotely controlled camera with zoom capability (Bjørlien et al. 2016).


Figure 1: The fixed time-lapse camera is an Axis P1357, and the remotely controlled camera is an Axis Q6045-E MkII. Data is transferred via the local mobile phone network.

Two SM4 temperature sensor strings are operating in the area since the 24th of October 2017 (Ingólfsson et al. 2012). The sensor strings are named Trefall 1 and Trefall 2. Trefall 1 (811 m a.s.l) has 6 temperature sensors under the ground down to 120 cm, and Trefall 2 (808 m a.s.l) has 10 temperature sensors under the ground down to 200 cm. Both sensor strings have 300 cm with sensors above ground situated in snow and air during the winter.

The bore holes are left open (Figure 2). The sensors log temperature at 10 minute intervals (Figure 3).

From the temperature readings the thickness of the snow cover is estimated. The data is available at www.snowsense.is/no.

The design with two measuring localities close to one another was to ensure the possibility of calibration between the sensors and offer redundancy if one of the two should fail.

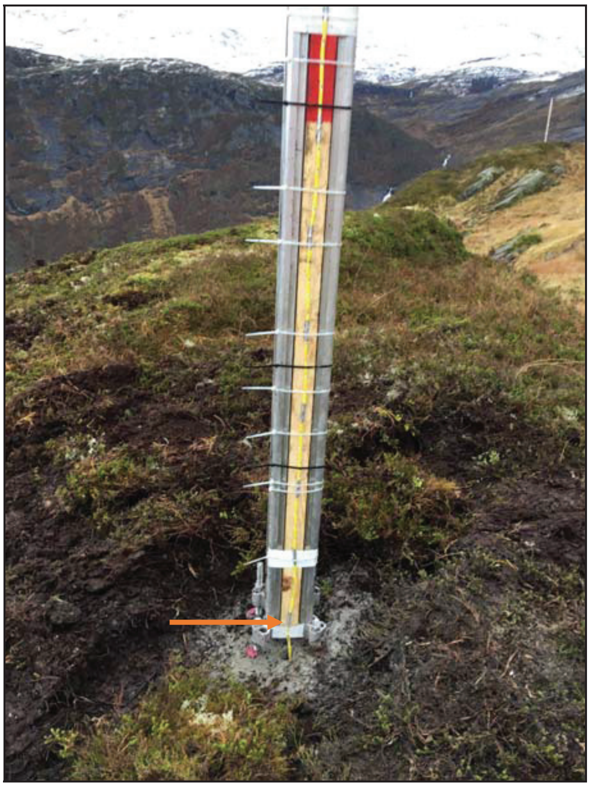

Figure 2: The temperature sensors are placed every 20 cm. The orange arrow points at the temperature sensor closest to the ground surface. The next temperature sensor below is placed beneath the ground surface. Picture is from Trefall 1.

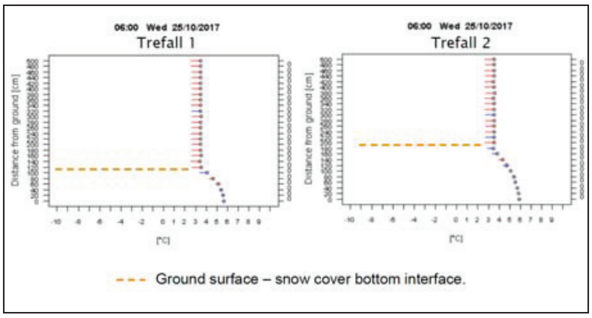


Figure 3: Temperature sensors showing temperature the day after installation. Temperature in the ground increases with depth Both Trefall 1 and Trefall 2 showed the same temperature (ca 5.5°C) at 120 cm depth.

## 3. RESULTS

The instruments were inspected three times during the winter. The first inspection was on the 1st of December 2017. The snow depth at the sensors was lower than average snow depth in the area. Trefall 1 had 25 cm of snow, and Trefall 2 had 20 cm of snow. Due to sun heating of the aluminium mast and the darker colour of the mast, snow had melted around the sensor string (Figure 4). A snow pit close to the sensors had 105 cm of snow. In the pit the ground surface – snow bottom interface was wet (Figure 5 and 6).

Figure 4: The instruments were inspected the 1st of December 2017.

Figure 5: Snow pit dug close to the sensor strings, 1st of December, 2017.

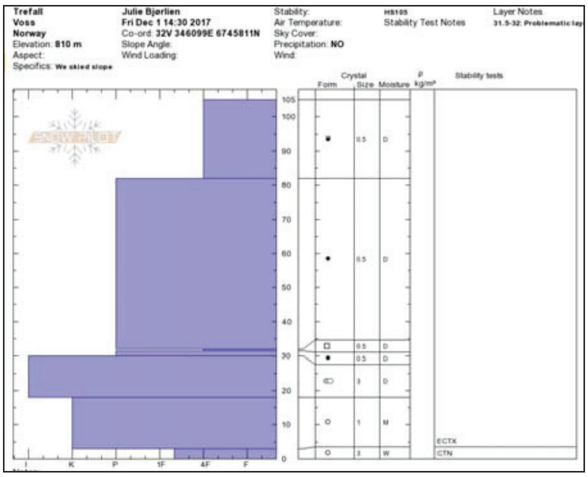

Figure 6: Snow pit profile close to the sensor strings registered 1st of December, 2017.

The second inspection took place the 12th of January. A snow pit from close to the temperature sensors indicate moist conditions in the lower part of the snowpack (Figure 7).

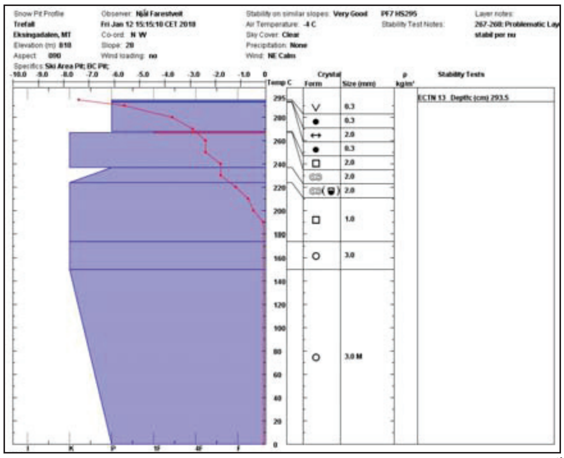

Figure 7 snow profile from Trefall January 12th 2018 show moist conditions in the lower 145 cm of the pit.

The third inspection took place 16th of March, 2018. This inspection was done by helicopter without landing. Accurate snow depth measurements from this inspection is therefore lacking. Estimated snow depth from picture analyses at Trefall 1 is ca 50 cm snow depth, and at Trefall 2 the snow depth is estimated to ca 30 cm. These are very rough estimates. It is possible to see from pictures that the snow had not melted around the sensors at this time, and no open glide cracks were observed (Figure 8).


Figure 8: Overview of the study area 16th of March, 2018. Glide cracks are not observed.

The winter of 2017/18 was more dominated by easterly winds and cold temperatures, except a rain on snow event to mountain top height on the 23rd of December. After this event there was only a few shorter periods with higher temperatures. Avalanche activity as wet loose snow avalanches up to size 2, started in the area around the 9th of April (Figure 9). From the 9th of April and into the 17th of April the area went through massive cracking, changing the characteristic of the area from having a smooth snow surface, into glide cracks over all (Figure 10).

Figure 9: The area shown 11th of April some days after glide cracks started to appear. A wet loose snow avalanche size 2 ran this day (orange arrow marks the starting point, and red arrow marks the end point for end of the run out zone).

Figure 10: The area shown 15th of April. Glide cracks have expanded much compared to the picture in Figure 9.

The 17th of April a glide avalanche size 1.5 stopped just before the road. The avalanche released between 05:40am and 05:50am. On the 18th of April, between 13:40pm and 14:00pm, a glide avalanche size 2.5 overran the road and covered the road for 40 metres (Figure 11). No damage happened, and the road was reopened the day after.

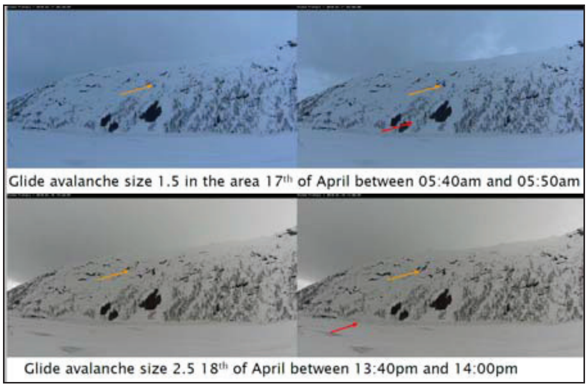


Figure 11: Glide avalanche activity started early morning the 17th of April. Left: “before” avalanche, right: “after” avalanche.

## 4. DISCUSSION

By looking at pictures taken the winter of 2016/ 2017, we found that the release area that produced the avalanche that overran the road in 2018, also released in 2017. Monitoring of this smaller release area, in combination with looking at the developing of glide cracks, could act as an indicator for when avalanche danger is high in the area (Figure 13).


Figure 13: The same release are seen in 2017 and in 2018.

The temperature profiles leading up to the avalanches the 17th and 18th of April indicate that the air temperature is the most important drive for the development of glide activity in April 2018 (Figure 14). The sensors closest to the snow – ground interface, respond quickly to the air temperature. Temperature sensor 11 (the lower most in the snow/air, above ground), indicate snow free conditions on this sensor from the 13th of April. Sensor 10 the uppermost underground has positive temperatures from the 15th of April, this indicates that the area around the sensor is snow free and the ground has begun melting from this date.

More glide cycles must be studied in this area to be able to determine if it is possible to use this to predict more precise timing for the avalanches hitting the road.

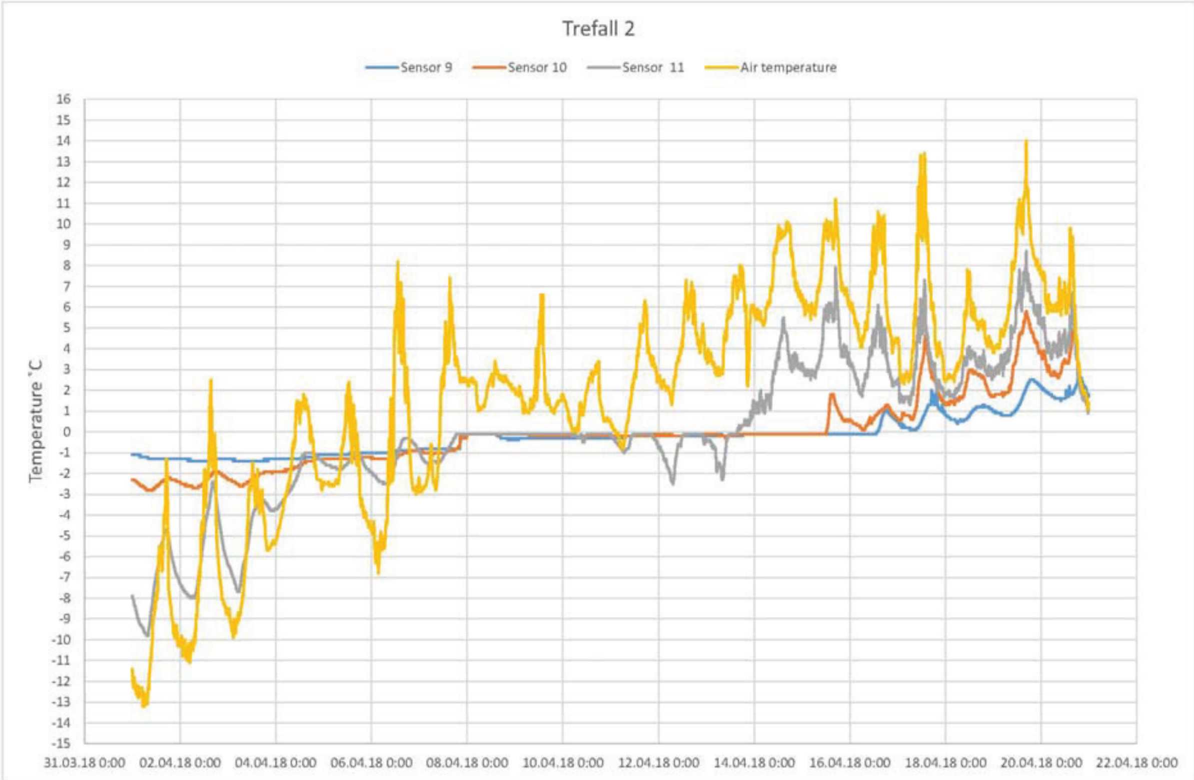


Figure 14: Air temperature, the sensor closest in the snow closest to the ground – sensor 11, sensor 10 – the upper most sensor in the ground and sensor 9 - 20 cm further down.

## 4 CONCLUSIONS AND FURTHER WORK

The instrumentation of the study area have operated well during the winter 2017/18. Trefall 1 and Trefall 2 have transmitted data throughout the entire season, as well as the cameras. There is an uncertainty about how well the temperature sensors display the real temperature in the snow cover, due to warming of the aluminium mast, and possible melting around the mast. This should be investigated further.

The position of the two sensor strings seems to be in an area that is somewhat exposed for wind erosion of the snow pack when easterly winds dominate. This is likely different for a winter with westerly winds dominating, and must be investigated further.

From our study just using the cameras to monitor the release areas most prone for glide avalanches (and only glide avalanches), we have managed to pin point a few smaller release areas. This is very helpful in an operational setting, and will be even more helpful as more data is recorded in the future.

Measurements will be continued 2018/19. Further analyses of the recorded temperatures with more analyses of the pictures from more glide cycles will be done after the next winters with instrumentation, contributing to better understanding of the processes in this area.

## 5. REFERENCES

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