THE SM4 SNOWPACK TEMPERATURE AND SNOW DEPTH SENSOR

Örn Ingólfsson*
POLS Engineering, IS-400 Ísafjörður, ICELAND

Harpa Grímsdóttir
Icelandic Meteorological Office, Avalanche Research Center, IS-400 Ísafjörður, ICELAND

ABSTRACT: An instrument for measuring snow depth and snow temperature has been developed by POLS engineering in Iceland. The goal was to develop a simple, robust unit with a low operating cost that may be easily installed on steep hillsides. The snow sensor (SM4) consists of a series of digital thermistors mounted with a fixed interval on a pole that extends through the snowpack. Measurements from the thermistors are logged with a few minute interval to an internal memory chip and are transferred regularly to a central computer through a wireless connection.

The SM4 measures snow depth by identifying thermistors buried in the snow, based on the damping of temperature fluctuations that is caused by the snowpack, compared with temperature fluctuations in air. The temperature profile of the snowpack is obtained as additional information.

The Icelandic Meteorological Office (IMO) has operated SM4 sensors for two years in three avalanche starting areas, together with ultrasonic snow depth sensors. The results show that SM4 was able to measure snow depth with adequate accuracy, also during periods of snowdrift and icing, when the ultrasonic sensors stopped working.

KEYWORDS: snow depth sensor, avalanche monitoring, snowpack temperature

1. INTRODUCTION

Continuous monitoring of snowdepth in avalanche starting areas is valuable for avalanche forecasting. A few types of instruments have been developed for this purpose. Due to the nature of avalanche release areas, the instruments often need to be located at high elevation levels on steep hills where weather conditions can be harsh. Snowstorms and icing conditions occur frequently. Therefore, the operation reliability is often a problem and the operating cost can be high.

An instrument for measuring snow depth and snow temperature has been developed by POLS engineering in Ísafjörður. The goal was to develop a simple, robust unit with a low operating cost that may be easily installed on steep hillsides. The technical details of SM4 are explained in the first section.

Corresponding author address:
Örn Ingólfsson, POLS engineering
Urðarvegur 72, IS-400 Ísafjörður,
Iceland, phone: +354 892 3923,
e-mail: orn72@simnet.is

IMO operated SM4 sensors together with ultrasonic sensors in three different starting areas during the winters 2006/2007 and 2007/2008. Preliminary results are described in the second section.

2. THE INSTRUMENT

The snow sensor (SM4) consists of a series of digital thermistors mounted with a fixed interval on a pole that extends through the snowpack. Measurements from the thermistors are logged with a few minutes interval to an internal memory and are transferred regularly to a central computer through a wireless GSM telephone connection.

The SM4 measures snow depth by identifying thermistors buried in the snow based on the damping of temperature fluctuations that is caused by the snowpack compared with temperature fluctuations in air.

The IMO has located snowdepth poles in many starting areas above settlements. The purpose is to be able to measure the snow depth manually from below with a theodolite. Attaching SM4 to such poles has been an easy way of installing them.

Figure 1: SM4 attached to a snow depth pole.

3. PRELIMINARY RESULTS FROM THE FIRST WINTERS

The Icelandic Meteorological Office (IMO) has used ultrasonic snow depth sensors for some years for monitoring snow depth in avalanche starting zones. Those instruments provide important data for the avalanche warning service of the IMO. However, due to their sensitivity to icing and snowdrift they sometimes do not work for long periods, especially during avalanche cycles when reliable measurements are particularly important.

The SM4 snow sensor was installed together with an ultrasonic sensor in three starting areas in the fall of 2006. The SM4 unit was connected to the Campbell communication equipment within IMO's automatic weather stations. Also, the SM4 sensors send the data through the GSM system and to the Internet. In 2007, the SM4 was installed in two other areas as well without a connection to other instruments.

The results show that the SM4 was able to measure the snow depth with acceptable accuracy for avalanche forecasting. From the data, it is easy to distinguish the sensors buried in snow from the ones above the snow surface. Figure 2 shows the data from all the sensors in a SM4 unit in a graph. The graph shows very little temperature fluctuations for the sensors buried in snow, while the sensors above the surface experience greater fluctuations. Some thermistors are above the surface in the beginning of the period, but become covered by snow on March 6th.

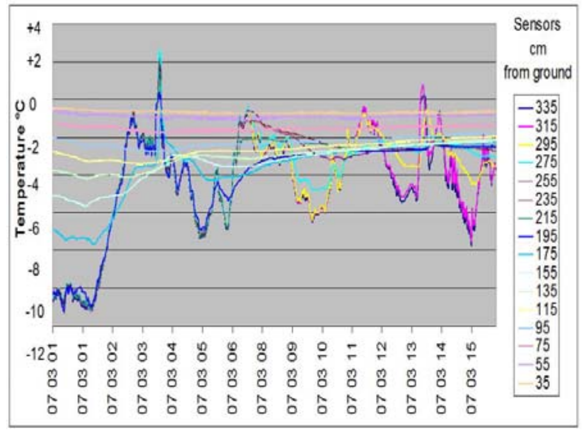

Figure 2: A graph showing data from individual thermistors on a SM4 snow depth sensor.

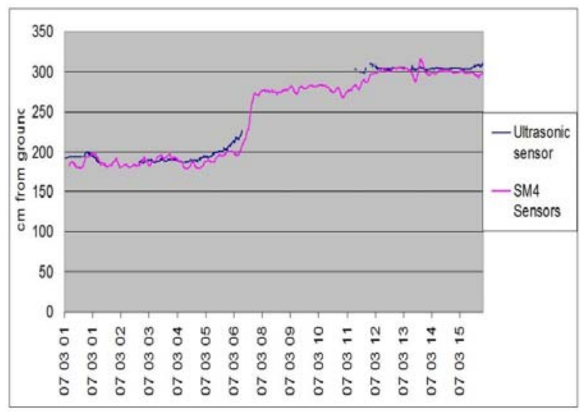

Figure 3: The calculated snow depth from SM4 using a preliminary algorithm compared to snow depth data from an ultrasonic sensor.

A development of an algorithm that calculates the snow depth has started, and gives promising results. Figure 3 shows the calculated snow depth and compares it to the snow depth data from the ultrasonic sensor (note that the timespan is the same as for Figure 2). The gap in the data from the ultrasonic sensor is considered to be due to icing. The challenge regarding the algorithm is greatest when the temperature of the atmosphere approaches the temperature of the snowpack, and it will be further developed.

The temperature gradient of the snow pack is obtained as additional information. Figures 4, 5 and 6 show temperature profiles on three days in a row from an SM4 sensor located in Kistufell by Ísafjörður. The snow depth is about 290 cm. The horizontal lines in the graphs show the temperature change observed by the thermistors for the last 6 hours. On the first day, the air temperature is low and the temperature gradient in the upper part of the snowpack is quite high, indicating the possibility of faceting. The next day, the air temperature has risen substantially and the uppermost 40 cm of the snowpack are starting to warm up. The snow temperature is still low at greater depth, however. On the third day the air temperature drops below 0°C again and the uppermost part of the snowpack is starting to cool down, causing a temperature profile with interesting undulations. Note that the span of the X axis is not the same for all the figures.

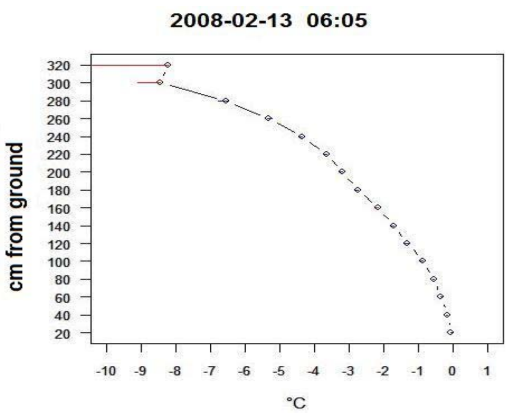

Figure 4: Cold air temperature and high temperature gradient in the upper part of the snowpack. The snow depth is about 290 cm.

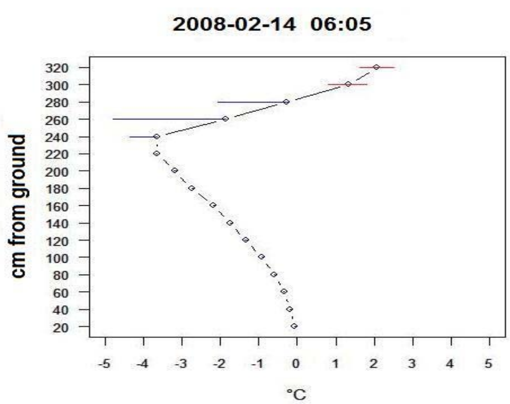

Figure 5: 24 hours after Figure 4. The air temperature has risen rapidly and the temperature in the uppermost 40 cm of the snow cover is rising.

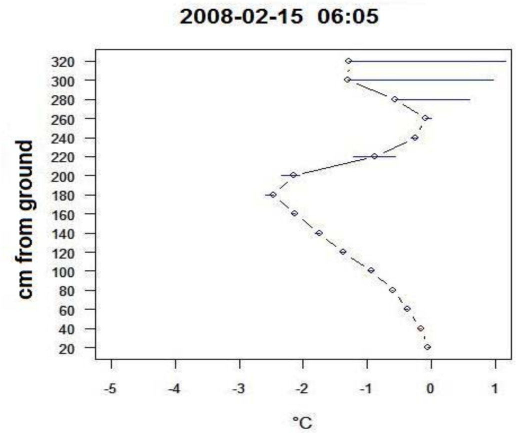

Figure 6: 24 hours after Figure 5. The air temperature is dropping; however, the uppermost part of the snow cover is still quite warm.

For the IMO, it is of special interest to test the reliability of SM4 during icing periods since the ultrasonic sensors do not work well under those circumstances. The following picture (Figure 7) was taken on December 9th and shows the instruments with an icing coat. The ultrasonic sensor had not been working in the days before, and it is considered very likely that the reason was icing. The data from the SM4 seems correct from those same days (Figure 8), and therefore, it can be concluded that icing of this magnitude does not interfere with the air temperature measurements of the SM4.

During the first winters of operation the instrument has been developed continuously in order to make it as robust as possible for the harsh conditions in Icelandic avalanche starting areas.

Figure 7: An ultrasonic sensor and a SM4 snow depth sensor covered with icing. The SM4 is attached to the upper stanchion. The sensors are located in Traðargil above Bolungarvík and the picture was taken on December 9th, 2007.

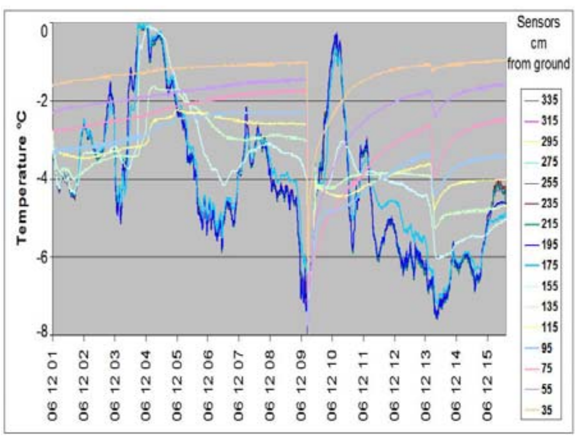

Figure 8: The data from the SM4 during a period of icing. On December 9th the instrument was dug up from the snow, which causes a disturbance in the graph.

4. CONCLUSIONS

In general, the first two winters of testing showed that the SM4 is a promising tool for continuous monitoring of snow depth. Furthermore, the temperature profile through the snow pack is obtained as additional information and may be useful for avalanche forecasting. The experience shows that the SM4 is able to operate during icing conditions when ultrasonic sensors stop working. The development of SM4 is being continued in order to increase the general robustness of the unit.

5. ACKNOWLEDGEMENT

The National Avalanche Fund and the Icelandic Road Administration are acknowledged for funding the project. Special thanks to Víðir G. Arnarson for his part in the technical development of the instrument. Tómas Jóhannesson at IMO has been involved in the project all along, and has given useful advice. Jóhann Hannibalsson, snow observer in Bolungarvík, has been of great help installing and fixing the instruments in the hillsides of Bolungarvík. Further thanks to all the volunteers who have helped bringing material up and down the mountains of the Westfjords during the test period of the SM4.

6. REFERENCES

Ingólfsson, Ö and H. Grímsdóttir, 2007. Snjómælir SM4 – Áfangaskýrsla. Samantekt reynslu frá vetrinum 2006-2007. Icelandic Meteorological Office, VSÖI/HG200701.