SNOW DEPTH MEASUREMENT AT METEO-FRANCE

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ABSTRACT

METEO-FRANCE has just set up a snow depth measurement network in mid-mountain areas for avalanche forecasting. Eleven sensors SR50A from Campbell Scientific, like those already used in the French high-mountain network, have been installed in 2007-2008. An inter-comparison between manual and automated measures from the weather station of La Pesse in the Jura mountain is performed here.
A snow depth measurement experiment was also set up at the Col de Porte in the Alps during winter 2007/2008. One purpose of this experiment was to characterize the influence of precipitations, snowfalls in particular, on the quality of the SR50A measurement. Another aim of this experiment was to inter-compare snow depth measures of Campbell SR50A with those of a state of the ground sensor, SOLIA300 from Degréane-Horizon. This sensor, which will soon equip many airport and synoptic weather stations in France is able to measure snow depth ranging from a few mm up to 60 cm.

1. INTRODUCTION

Until recently, automatic snow depth measurement at METEO-FRANCE was carried out only in high-mountain sites, whose altitude is above 1500 m, in the Alps, the Pyrenees and in Corsica inside a special network named NIVOSE.
During winter 2007/2008, eleven ultrasonic snow depth sensors have been installed in the main operational surface network of METEO-FRANCE (RADOME), mainly in mid-mountain regions (Vosges, Jura in the North-East of France and Massif Central in the Centre region), in order to improve avalanches forecasts. Five other sensors will be installed next year.
As it was the first time we used this type of sensor in the main observational network, different studies have been carried out to improve the knowledge of this sensor in this operational context.
One sensor has been installed at the site of La Pesse in the Jura mountain, where an observer measures snow depth daily. This allowed performing comparisons between human and instrumental measures.
An experiment was also set up in the site of the "Col de Porte" (1326 m) near Grenoble, in the Alps. This site gets lots of snow from November to April. Two different sensors were installed : a Campbell SR50A and a SOLIA 300 from Degréane-Horizon, which is a state of ground sensor that is able to measure snow depth ranging from a few millimetres up to 60 cm. The aim of the experiment was on one hand to study the influence of precipitations on the quality of Campbell SR50A measurement and on the other hand to inter-compare the two snow depth sensors.

2. DESCRIPTION OF THE SNOW DEPTH SENSOR USED IN THE OPERATIONAL NETWORK AND THE DATA PROCESSING DONE TO OBTAIN RELIABLE DATA

The Campbell SR50A sensor determines the distance D (Figure 1) from the transmitter to a target (the reference surface or the snow surface) by emitting ultrasonic pulses in a 30 degrees beam angle and listening to the returning echoes that are reflected by the target. The distance is deduced from the transmission time between the emission and the reception of the echo. Since the speed of sound in air varies with temperature, an independent temperature measurement is also required. We use the measurement of the air temperature in a radiation screen.

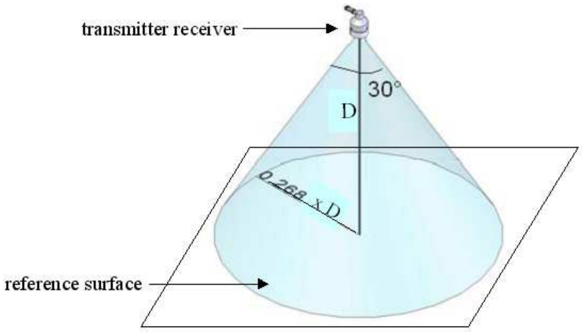

Figure 1 : Operation principle of the Campbell SR50A

In our stations, we have chosen to use a white board in expanded PVC as the reference surface, which is the same material that has been used so far for manual measurements of fresh snow. But as explained in section 3, this surface is not ideal.

SR50A outputs indicators of measurement quality. These data, named "quality numbers" have no units of measure. They vary from 162 to 600. Numbers lower than 210 are associated to measurements of good quality. A value of zero however, indicates that the measure was not obtained. Numbers greater than 300 indicate an uncertainty of the measure.

As shown in section 4, snow and rainfall events can disturb the ultrasonic signal and generate high quality numbers. To obtain reliable operational data, we perform therefore data processing using the quality number :

- the sensor is set up to give 20 measures per minute
- all the measures related to a quality number equal to 0 or above 300 are eliminated
- remaining values are sorted by ascending order
- the first distance D_i that verifies $D_{i-1} - D_i < 1$ cm and $D_{i+1} – D_i < 1$ cm is chosen to calculate the minute-snow depth measure. This supposes that we need at least 3 valid measures to calculate the minute-snow depth. If it is not the case, the minute-snow depth is not valid.

3. COMPARISON BETWEEN INSTRUMENTAL AND MANUAL MEASURE

A inter-comparison between manual and automatic snow depth measurements was performed at the weather station of La Pesse (altitude of 1133 m), in the Jura mountain. The Campbell SR50A sensor was installed 1.50 m above the ground. At this site, an observer came each morning during winter to measure snow depth with a graduated snow stick (Figure 2).

Figure 2 : Snow depth sensor Campbell SR50A and snow stick at the site of La Pesse. 17 January 2008.

Snow depth profiles that were measured during winter 2007/2008 are displayed on Figure 3. Both manual and automatic measures have a similar evolution. The ultrasonic sensor detects the increase of snow depth after snowfalls and measures a snow depth decrease during melting periods.

However, there are some significant differences between manual and automatic measures. The sensor often underestimates snow depth. The mean difference sensor measurement-manual observation is -2.64 cm (among the days with snow) and the maximum difference is -17 cm. In average, the sensor underestimates the manual measure by 15%. This underestimation is clearly illustrated on Figure 4 : all the points are below the line y=x.

This difference is not due to a measurement default of the sensor : observers have verified with a snow ruler that the sensor was measuring correctly snow depth above the reference surface. We can notice that the underestimation measured by the sensor increases with snow depth : the higher the manual snow depth measure is, the farther from the line y=x the points are. On the contrary there are a few points on the y-axis showing that snow was observed sometimes only over the reference board and not on the ground. This is illustrated on Figure 5.

The problem comes probably from the reference surface placed under the sensor, which is not representative of the ground. Next winter, we are planning to test artificial grass as a reference surface instead of the white board.

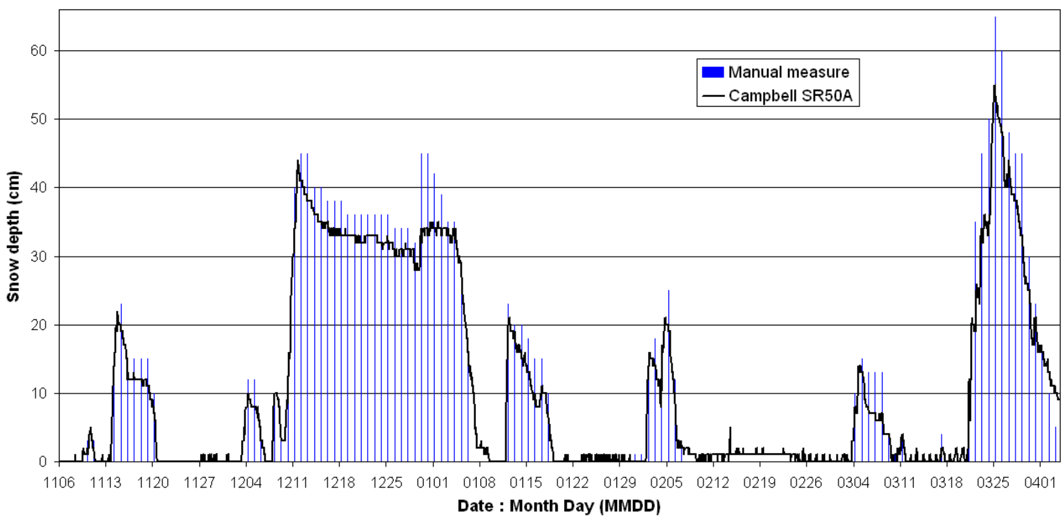

Figure 3 : Variation of the snow depth measured by the ultrasonic sensor Campbell SR50 and with a snow stick at La Pesse from 6 November 2007 to 3 April 2008.

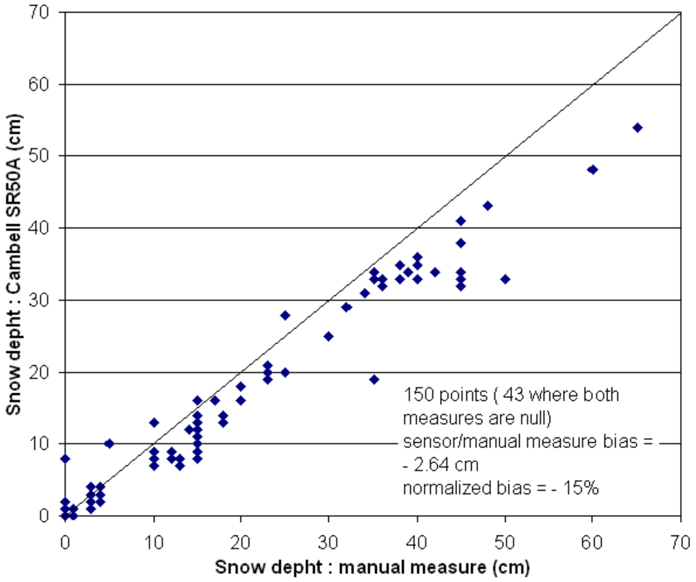

Figure 4 : Comparison between automatic and manual measurement

Figure 5 : Case with snow staying longer on the board than on the ground. St Sulpice site, 18 December 2007.

4. INFLUENCE OF THE PRECIPITATIONS ON THE QUALITY OF THE ULTRASONIC SENSOR CAMPBELL SR50A MEASUREMENTS

We have observed in our high-mountains network that ultrasonic measurement could be disturbed by precipitations and snowfalls in particular. Indeed, the ultrasonic waves emitted by the sensor can be reflected by snow flakes. The disturbing of the ultrasonic measurement is shown by the quality number increase. If it exceeds 300, the measure is not reliable. Figure 6 illustrates the fluctuation and the increase of the quality number during snowfalls.

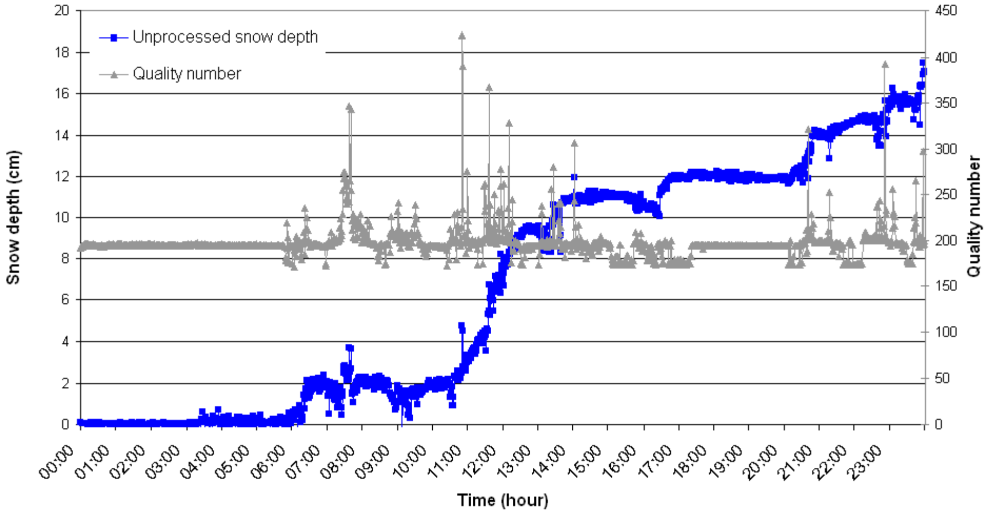

Figure 6 : Raw snow depth and quality number measured by the Campbell SR50A sensor during the snow event of 3 December 2007 at the Col de Porte.

To examine the link between the occurrence of precipitations and the increase of the quality number, we confront the number of measures in one hour having a quality number (QN) over 300 (among 60 measures) with the precipitation type (Table 1). This was done for the period from 7 January to 13 March 2008, with data from the instruments of the Col de Porte.

- The precipitation type was defined as follows :

- no precipitation : hourly accumulation equal to or lower than 0.2 mm
- rain : accumulation higher than 0.2 mm and snow accumulation lower than or equal to 1 cm
- snow : snow accumulation higher than 1 cm

- The quality number classes were defined so as to count enough observations in each class

Observed frequencies of hours with	Less than 3 QN exceeding 300	At least 3 QN exceeding 300	Total
no precipitation	1295	28	1323
rain	82	26	108
snow	20	75	95
Total	1397	129	1526

Table 1 : Contingency table confronting the type of precipitation observed in one hour with the number of measurements having a quality number (QN) exceeding 300 in this hour.

Table 1 shows that most of the hours without precipitation have less than 3 measurements of poor quality (associated with a QN over 300). On the contrary, the majority of hours with snow have more than 3 measurements of poor quality.

Using the chi-square method, the values of this table were compared with the theoretical frequencies that would have been obtained if the quality number was entirely independent of the occurrence of precipitation. The result of the chi-square test assessed that the number of QN exceeding 300 is linked with the type of precipitation with more than 99% chance.

Therefore, bad quality measurements can often be imputed to snow events. This emphasizes the necessity of filtering away the data associated with bad quality number and processing the data to ensure the consistency of the measurements. The filtering algorithm we are using in our network proved to work well during winter 2007/2008 : among 3599 hours of measurement at the station of La Pesse, only 14 hours had an invalid snow depth measurement, that is 0.4% of the cases.

5. COMPARISON BETWEEN CAMPBELL SR50A AND SOLIA 300 SENSORS

The operation principle of Solia 300 is very different from the Campbell one's. It is explained in details on F. Zanghi's poster (1 (34): State of the ground and snow depth measurement by SOLIA 300 sensor). A luminous source emits a slanting signal towards the snow surface. The calculation of snow depth is mainly based on the proportion of reflected signal against backscattered signal by snow.

During winter 2007/2008 Campbell SR50A and Solia 300 (from Degréane-Horizon) sensors have been installed at Col de Porte in order to inter-compare their measurements. Figure 7 shows the field with both sensors after the first snowfall.

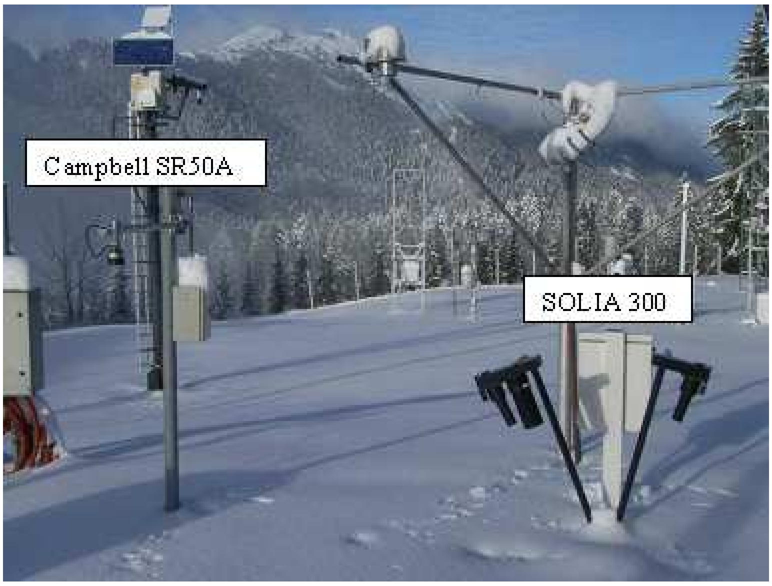

Figure 7 : Campbell SR50A and SOLIA 300 sensors at Col de Porte, 4 December 2007.

The evolution of snow depth measured by both sensors is shown on Figure 8.

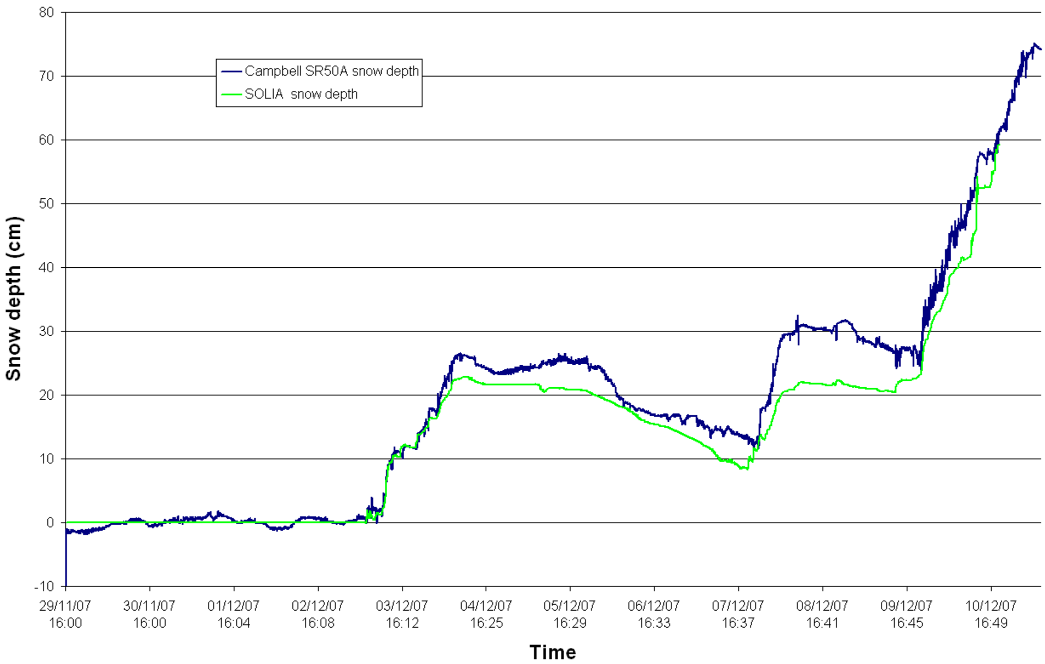

Figure 8 : Variation of snow depth during the first snowfalls (29 November to 12 December 2007) measured by the Campbell SR50A and SOLIA sensors.

Both snow depth measurements are rather close. At the beginning of the experiment, snow depth remained null for Solia 300 and varied between -1 and 1 cm for Campbell SR50A. These small variations correspond to the measurement uncertainty of the sensor. The first snowfall was well seen by both sensors : the profiles are very similar. After that, during melting periods and new snowfalls, the sensors were close but snow was not accumulated in the same way in the two different measure areas. Snow was probably melting faster on Solia 300 reference surface because of the vicinity of the black components of the sensor. Solia 300 stopped measuring snow depth as soon as it reached 60 cm. The sensor was later buried under snow (see Figure 9), which explains why the comparison stopped here.

Figure 9 : Campbell SR50A and SOLIA 300 (buried under the snow) at Col de Porte, 21January 2008.

The comparison started again on 8 April 2008 (see Figure 10). Both snow depth profiles have a consistent evolution. However, Solia 300 measured a snow depth that was, since the beginning, 40 cm lower than the one of Campbell SR50A. This difference was maintained until the end of the period. Although we did not have human measurements during this period, it is certain that snow depth was lower under Solia 300 because at the end of the period (around 25 April) the state of ground diagnostic of Solia 300 remained “dry”, whereas Campbell was still measuring a 30 cm high snow depth. The ground below Solia 300 sensor has therefore been dry earlier than below Campbell SR50. The accelerated snow melting under Solia 300 can probably be imputed to the contact of snow with the instruments. This emphasizes the fact that Solia 300 sensor was designed to measure small snow depth only and that Campbell SR50A is much more suitable for snow depth measurement in mountain regions.

Figure 10 also emphasizes abnormal null measures at the end of the period. These false values are due to a default of the sensor software. It has indeed difficulties to measure snow depth during melting. During this period, the sensors indicates a “dry” state of the ground during a few minutes only, before diagnosing a snow covered ground again. These defaults were mentioned to the manufacturer and improvements should be done.

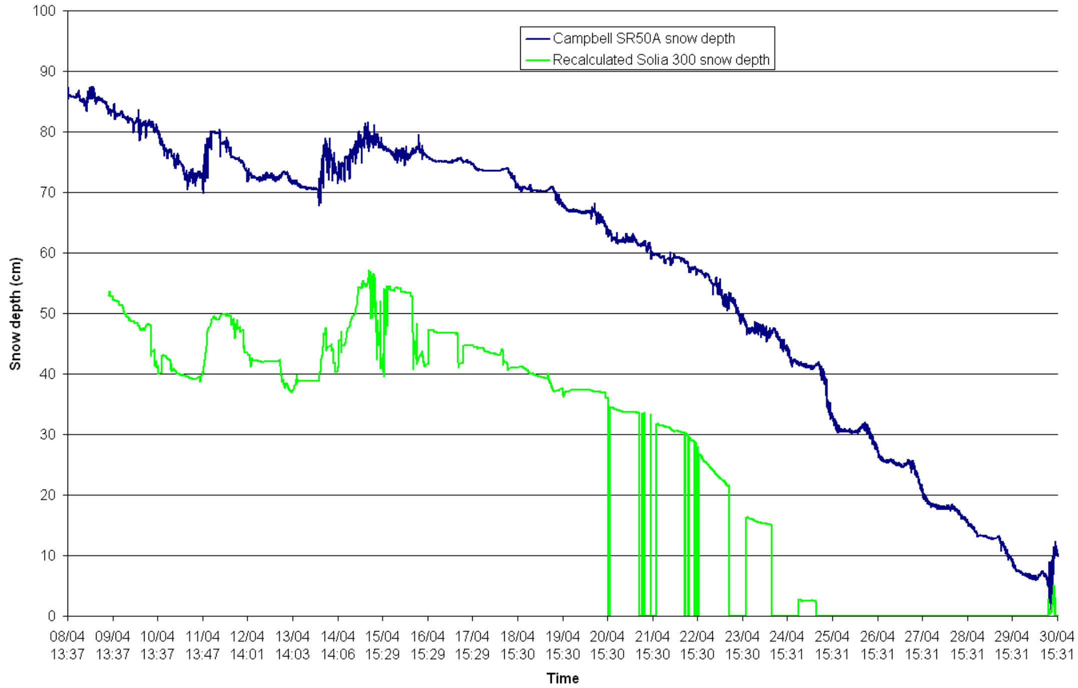

Figure 10 : Variation of snow depth during the melting period at the end of winter (8 to 30 April 2008) measured by the Campbell SR50A and SOLIA sensors.

6. CONCLUSIONS

The comparison performed at La Pesse between Campbell SR50A and manual snow depth measurement confirms that the automatic snow depth operational measurement is satisfactory. However, the study of the Col de Porte experiment data has shown that the ultrasonic measurement was significantly disturbed by precipitations and snowfall in particular. But thanks to the filtering used in the operational network, 99.6% of the hourly-measurements had a valid snow depth during winter 2007/2008.

The Col de Porte experiment also permitted to inter-compare the measurements of Campbell SR50A and Solia 300 sensors. The results are promising. Sensors measurements are particularly consistent during snowfalls. The operation principle of Solia 300 could therefore be validated although modifications in the Solia 300 software should be done to improve its diagnostic during melting periods.