OPERATIONAL EXPERIENCE WITH AUTOMATIC SNOW DEPTH SENSORS –
ULTRASONIC AND LASER PRINCIPLE

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ABSTRACT

The Austrian Central Institute for Meteorology and Geodynamics (ZAMG) operates a network of more than 250 automatic weather stations (AWS). Several are equipped with sensors for automatic snow depth measurement.

In order to evaluate the functionality and reliability of different sensors for automatic snow depth measurement, an intercomparison was carried out for a period of 5 months during winter 2006/07. All six tested sensors were of the same type based on ultrasonic technology. The result shows that only two of them are working reliably under all weather conditions.

In winter 2008/09 new sensors with laser distance measurement system were available. For evaluation we installed laser and ultrasonic instruments operated in simultaneous mode at two stations (Galzig 2080 m a.s.l. and Kanzelhöhe 1520 m a.s.l.). At station Kanzelhöhe also data from manual measurement of snow depth were available.

In this paper we present an overview of advantage and drawbacks of both sensor systems in contrast to manual measurement and under different meteorological conditions.

1. Introduction

A large part of the automatic weather stations (AWS) operated by the Austrian Central Institute for Meteorology and Geodynamics (ZAMG) are located in mountainous regions. For climatologic and touristic purposes there is a demand to equip them with systems for automatic snow depth measurements. Those sensor systems have to fulfil the main requirements shown in Tab. 1.

During two series of intercomparison performed in winter 2006/2007 and 2008/2009 we tested different sensor systems from various manufacturers. Some results are shown in this paper.

Table 1: Functional criteria for sensors for automatic snow depth measurement

A	Measurement range 0-300 cm, resolution < 1 cm
B	Automatic temperature compensation or heating of the measurement system if necessary
C	Reliable operation under all weather conditions on all sites
D	No maintenance required

2. Intercomparison of Ultrasonic Sensors Winter 2006/2007

In winter 2006/07 a specially installed test site (Fig.1) was set up for parallel operation of up to 5 sensors systems. The test site was situated at Eisenerz at 1030 m above sea level. During a test period of 5 months we tested 6 different sensors. In order to evaluate the meteorological conditions we installed an automatic weather station for measurement of temperature, humidity, precipitation, wind speed, wind direction and global radiation.

Fig.1 Test site Eisenerz for intercomparison of snow depth sensors winter 2006/07

A summary of the test results is shown in Table 2. Most of the sensors did not work properly during periods with frost and snow fall. Some were equipped with automatic temperature compensation, but nevertheless the sensors showed non realistic variation of snow depth depending on variation of ambient temperature. All sensors did not need any specific maintenance during the test period.

Table 2: Test results for ultrasonic sensors with regard to the operational requirements according to Table 1

Sensor	Requirement A	Requirement B	Requirement C	Requirement D
BRUSAG; Metnivis	-	+	-	+
JUDD; Snow Depth	+	-	-	+
SIAP+MICROS; TLU08-S	+	-	-	+
CAMPBELL; SR50 (out of production)	+	+	+	+
CAMPBELL; SR50AT	+	+	-	+
SOMMER; USH-8	+	-	+	+

As an example for illustration of the data quality of different sensor we show in Fig. 2 the result of measurement on a typical day with about 22 cm of snowfall within 24 hours. As a reference we used the cumulative precipitation amount. Average ambient temperature was between –2 °C and -3 °C.

All sensors except SOMMER USH-8 and CAMPBELL SR50 did not work properly during long periods.Based on the test results the manufacturer of the most promising sensors CAMPBELL SR50ATand SOMMER USH-8 improved the hard- and firmware of both sensors for further tests.

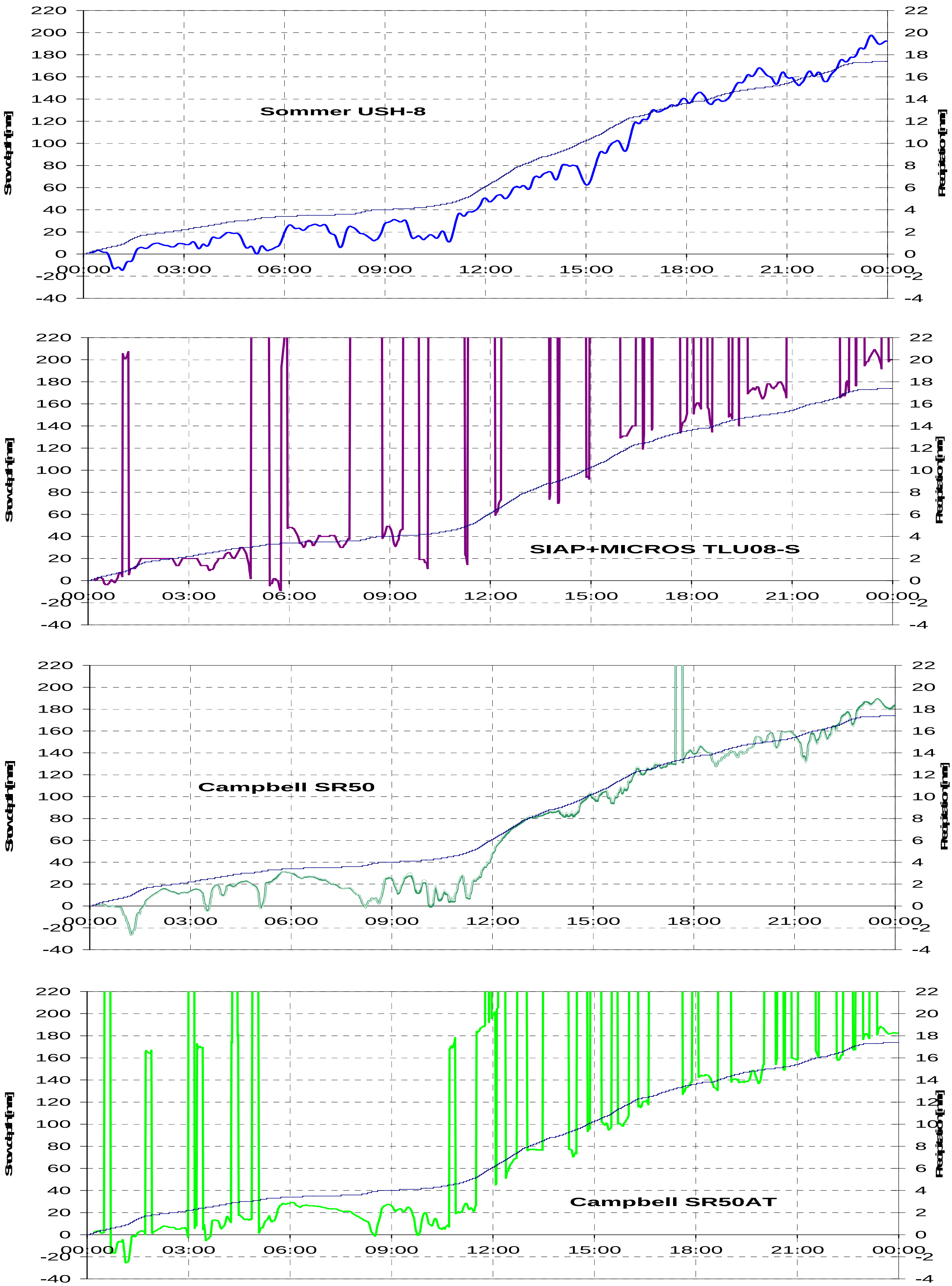

Fig.2: Snow depth measurement data from different sensors on 20.03.2007;
dark blue line – cumulative precipitation amount

2. Intercomparison of Ultrasonic and Laser Sensors Winter 2008/2009

For this test series a new sensor based on laser distance measurement technique (Jenoptik SHM30) was available. In order to evaluate the performance of this sensor in relation to the test results shown in Table 2 we set up two test sites for parallel operation of up to 3 snow depth sensors.

2.1. Test site Kanzelhöhe

This site is situated in the southern part of Austria (Fig. 3) at 1520 m above sea level at the Observatory Kanzelhöhe of the University of Graz. The staff of the observatory operate also an automatic weather station as well as manual snow depth measurement and other meteorological observations for ZAMG.
At this site we installed the following sensors for parallel operation:

- SOMMER USH-8
- JENOPTIK SHM30

Fig. 3 Test site Kanzelhöhe

The sensors for snow depth measurement were installed in January when the test site was already covered with approximately 80 cm of snow. In Fig. 4 we show the snow depth for the whole winter period on base of 10-minute average data. Snow depth of automatic measurement of both test sensors show a relative offset of 2-3 cm. This is caused by the inhomogeneity of the snow and the different area of measurement of both sensors. The daily performed manual measurement of human observer is in good agreement with the data reported by the test sensors. It has to be noted that also manual measurement by different observers (marked in Fig. 4 with different symbols) shows a certain variability.

Measurement data from SHM30 (Laser) sensor shows less variability as the data from ultrasonic sensor. This effect is even more significant during periods with large daily variation of snow depth e.g. during spring. In Fig. 5 even taking half-day average of snow depth the ultrasonic sensors show very noisy measurement data in contrast to the laser based sensor. The zero-level can not be determined with the ultrasonic sensor. The laser sensor shows an usable resolution of less than 1 cm.

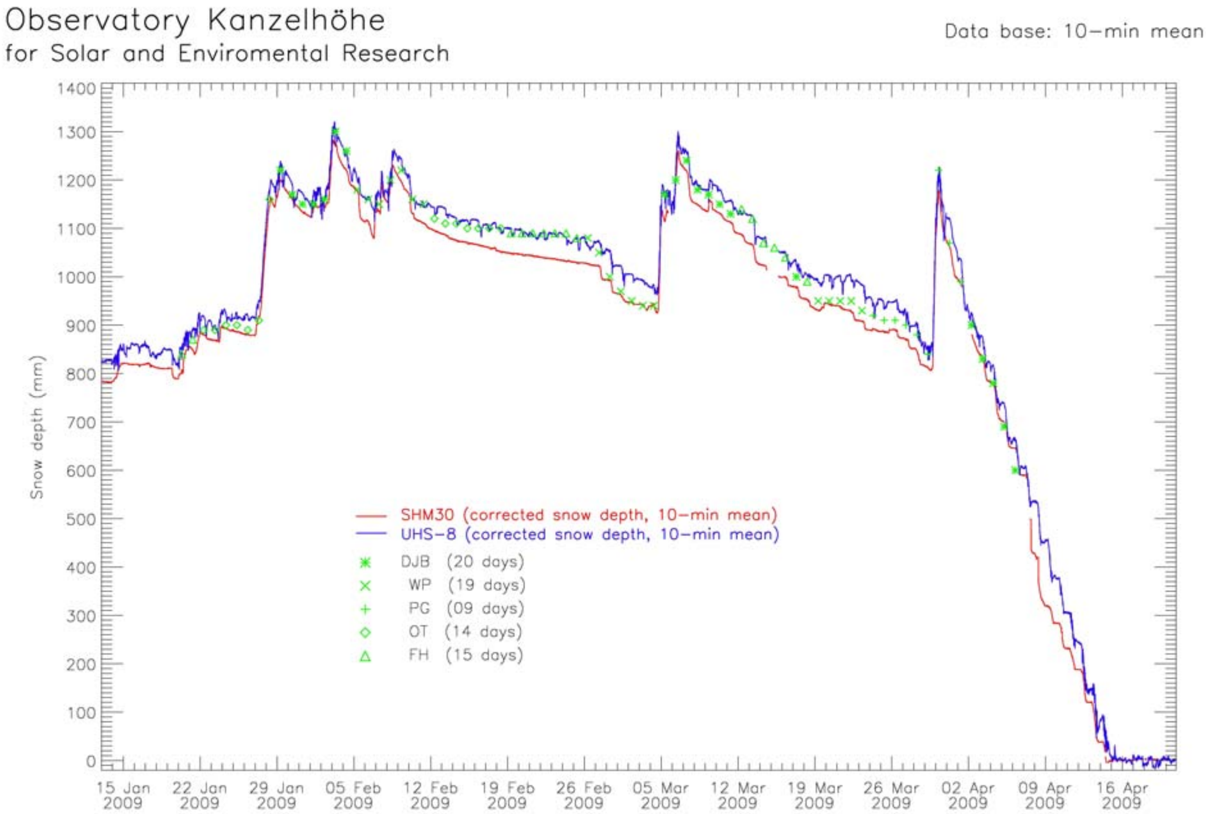

Fig. 4 Snow depth reported by ultrasonic USH-8 and Laser SHM30 sensors. The measurement data from human observer are indicated with green symbols

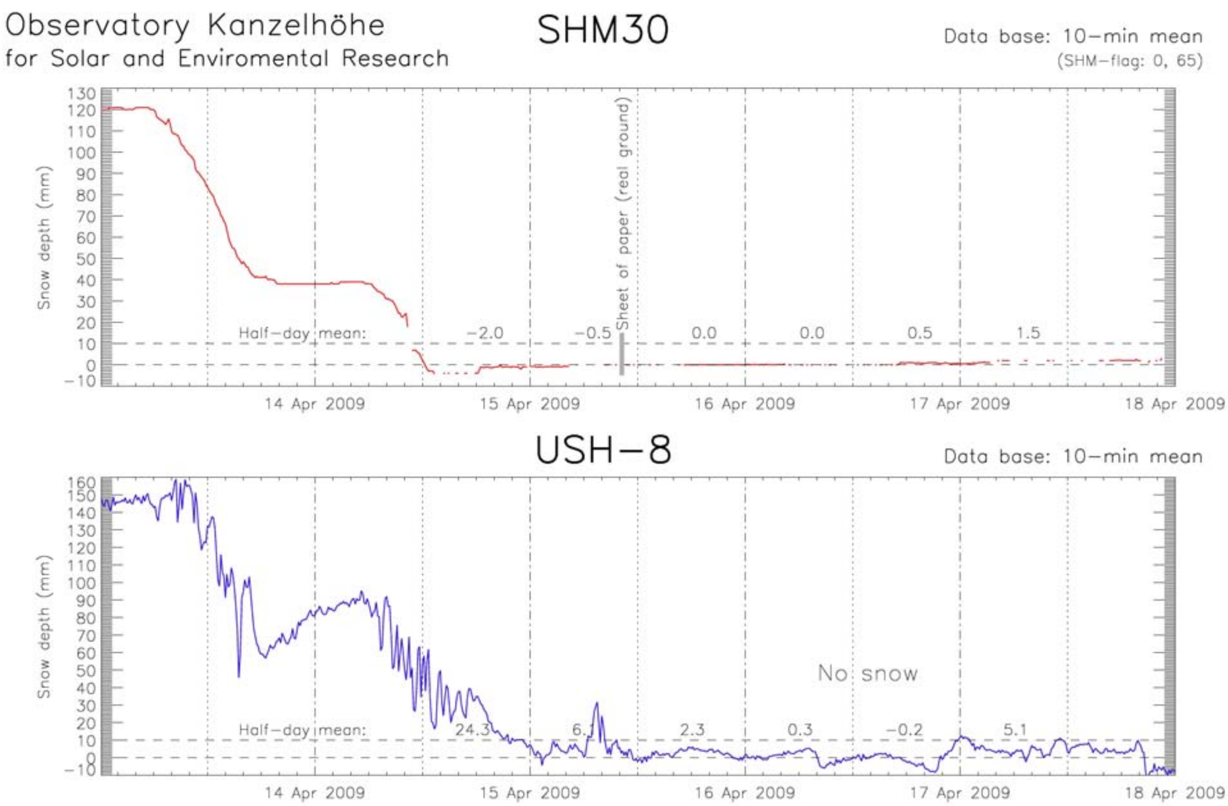

Fig. 5 Snow depth measurement data near the end of winter

The performance and reliability of both sensors during periods with precipitation is shown in an example in Fig. 6. Both sensors show similar measurement data. Completely different is the situation during periods without precipitation. The data from ultrasonic sensor USH-8 shows a non realistic daily variation of snow depth. The variation seems to be in good agreement with the variation of global radiation (Fig. 7).

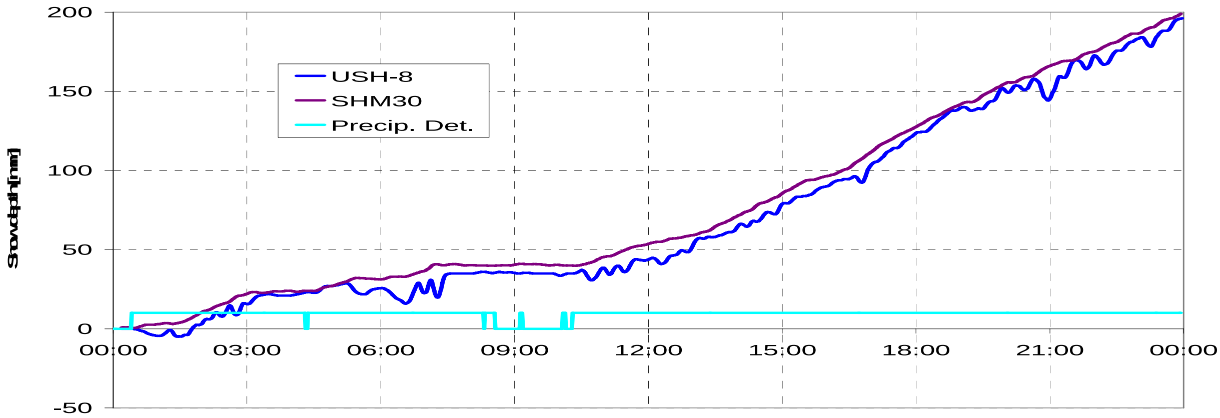

Fig. 6 Snow depth on 27.01.2009

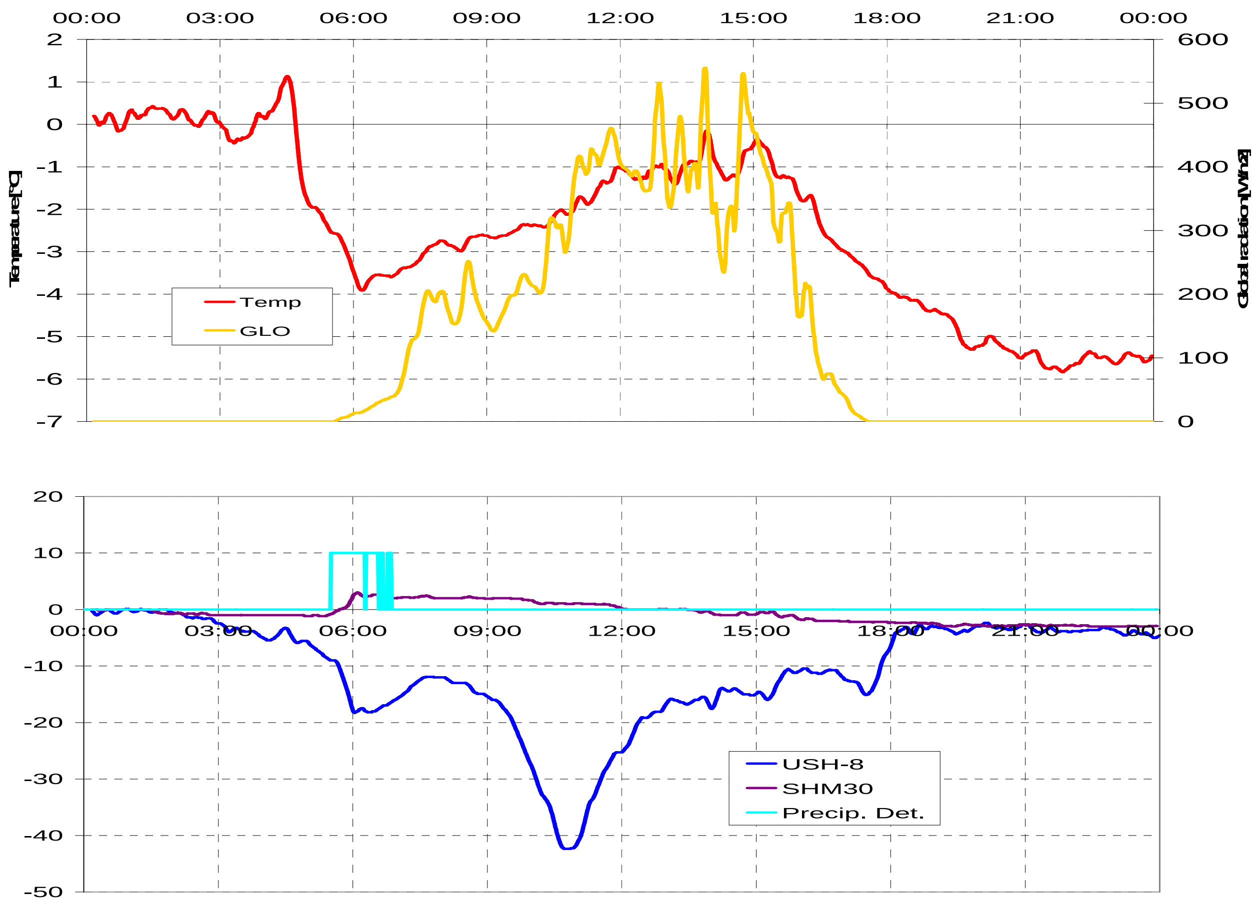

Fig.7 Snow depth data on 24.03.2009; the small amount of fresh snow at 6:00 is reported only by SHM30

2.2. Test site Galzig

This site is located in the western part of Austria (Fig. 8) at 2080 m above sea level there is also an automatic weather station installed near the test site. Unfortunately no professional observer for manual snow depth measurement is available. But due to frequent severe weather conditions especially during winter months this place is used for tests of all kind of meteorological sensors for several years.
At this site we installed the following sensors for parallel operation:

- CAMPBELL SR50AT
- SOMMER USH-8
- JENOPTIK SHM30

Fig.8 Test site Galzig

The measurement results at Galzig show similar results as those from Kanzelhöhe. During periods without precipitation the variation of snow depth reported only by USH-8 is even more significant. During periods with precipitation even at low temperatures and with high windspeed all three sensors work reliable. As an example in Fig. 9 we find good agreement of measurement data of all sensors, i.e. from both ultrasonic sensors as well as the laser sensor. Nevertheless the laser sensor shows less noise on the measurement data. Campbell SR50AT regularly stops measurement at temperatures below –10 °C. All three sensors are reporting variations of snow depth in the order of ±(100-150) mm within 10-20 minutes, caused by wind induced snow drift.

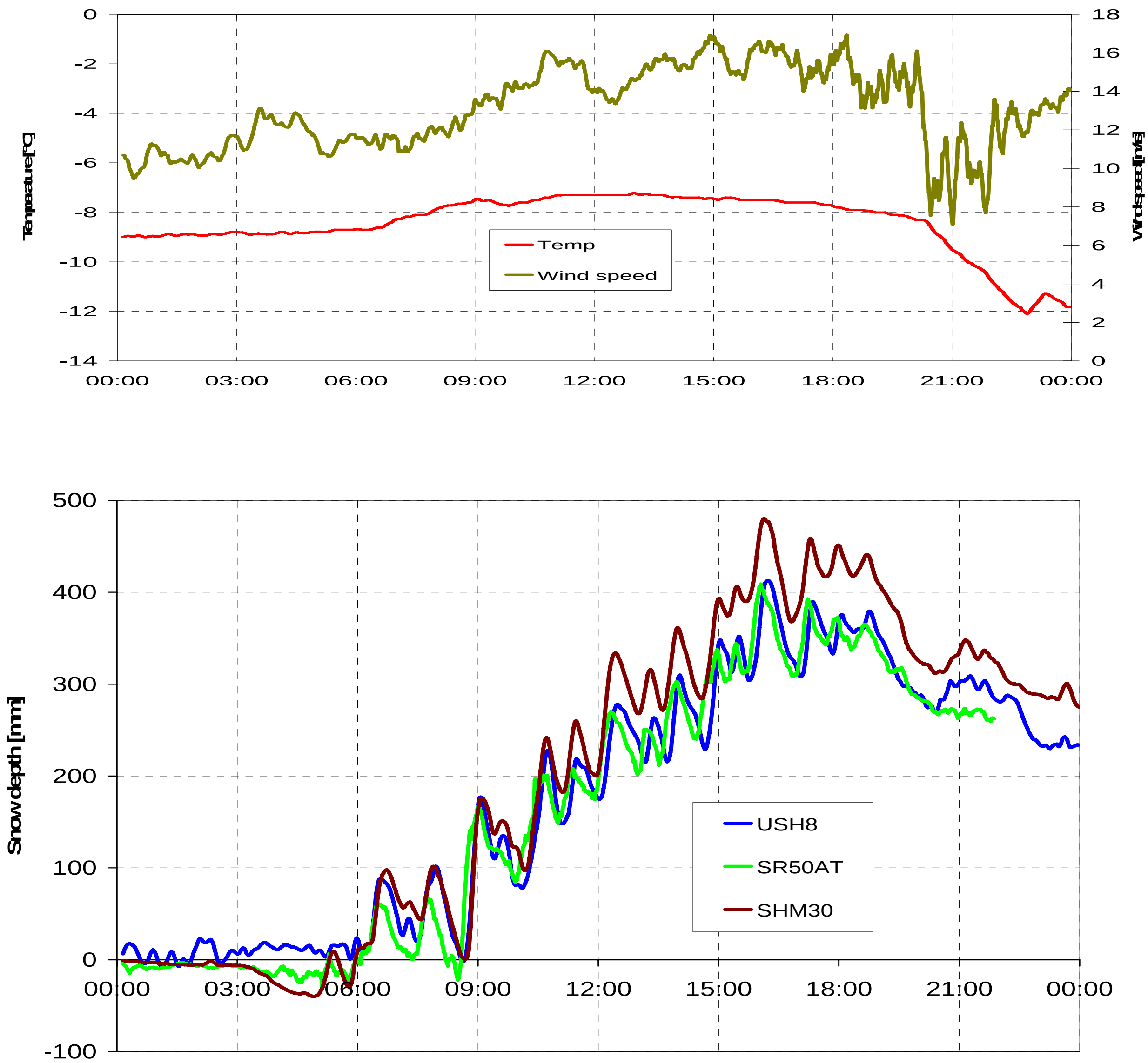

Fig. 9 Snow depth, temperature, and wind speed on 19.02.2009

3. Summary

As a result of parallel operation of ultrasonic and laser based sensors at two sites we found reliable operation of all sensors. Generally the laser sensors show less noisy signal and no variation of performance depending on ambient temperature or state of the snow surface. Especially during periods with low snow depth the laser sensor shows significantly better performance, because the measurement point is well defined whereas all ultrasonic sensors work on base of the reflected signal from a wide area which is varying depending on installation height and snow depth.