SPA - Snow Pack Analysing System

Reinhard Fiel[1], Wolfram Sommer[1] Thomas Rentsch[2]
[1] Sommer Mess-Systemtechnik, Koblach, Austria
[2] tytec AG, Ennenda, Switzerland

ABSTRACT: The Snow Pack Analysing System is an automatic in-situ measurement system to determine the characteristics of snow covers. Measurements of the complex impedance along flat ribbon sensors in combination with a snow depth sensor result in the snow density, the snow water equivalent and the contents of ice and liquid water in the snow. The data values are recorded during the complete snow cover cycle from the accumulation until the melt off.

KEYWORDS: Snow density, snow water equivalent, liquid water content, in-situ measurement.

1 INTRODUCTION

Obtaining information about snow by measurements is a difficult task. A multiplicity of parameters have to be registered to make reliable statements about the snow pack. Additionally, snow has an enormous variability in space and time. Up to now mainly punctual measurements are available for the relevant parameters. The Snow Pack Analysing System (SPA) constitutes a revolutionary innovation in snow measurement. It is a world unique system for automatic and continuous measurement of all the relevant snow parameters like snow depth, snow density, snow water equivalent and contents of liquid water and ice. The SPA offers a modern and highly time delayed data gathering. There are several possibilities to install the system, depending on demand. Moreover, the system helps to reduce dangerous and expensive adoption of human resources in the wintry area.

2 PRINCIPLES OF MEASUREMENT

Snow consists out of the three components ice, water and air. Referring to different measurement frequencies, these components show different dielectric constants. Measuring the complex impedance along a flat ribbon sensor (SPA-sensor) with at least two frequencies allows to estimate the volume contents of the individual components. These specific volume contents equate the liquid water, ice and air content in the snow pack, which consequently results in the snow density. Combining the snow density with the snow depth defines the snow water equivalent.

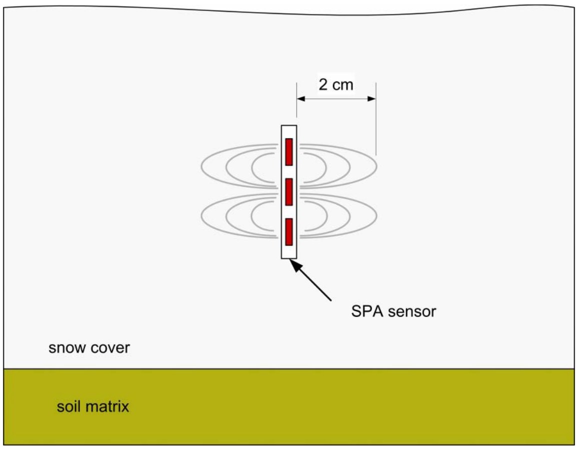

Figure 1. Principle of measurement of the SPA-sensor.

3 SYSTEM CONFIGURATION

The SPA-sensor is a 6 cm wide flat ribbon sensor including three copper wires. The length varies between 3 and 10 m. The sensor is installed with a suspension to ensure a tight and upright position. The snow depth sensor is based on transit-time measurements of an ultrasonic pulse between the sensor and the snow surface. Optional temperatures are measured at the ground level, at defined levels in the snow cover and the snow surface. A control unit performs all measurements, switches between multiply sensors and calculates the snow parameters. The data is transferred via a RS-232 interface fro example to a data logging device.

The SPA-system can operate with up to four SPA-sensors. Their quantity and assembly is related to the desired measurement demands. The sensors are either installed sloping through the complete snow cover, or they are spanned horizontally in the snow at defined levels.

Corresponding author address: Reinhard Fiel, Sommer Mess-Systemtechnik, Koblach, Austria; tel: +43 5523 55989; fax: +43 5523 55989-19; email: office@sommer.at

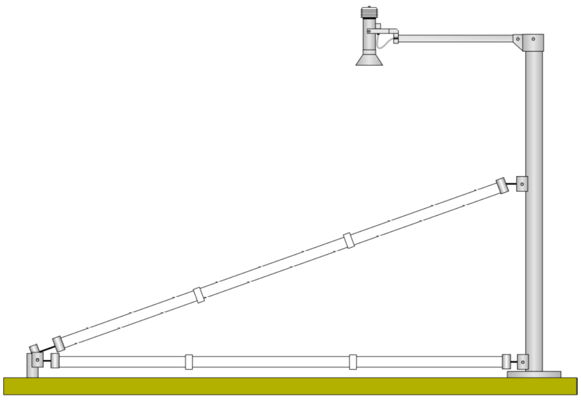

Figure 2. Combined assembly.

Combinations of sloping and horizontal sensors (Figure 2) increase the information content of the measurements. The sloping sensor determines the snow density, the snow water equivalent and the ice and liquid water contents of the complete snow cover. The horizontal sensor supplies additional information about the snow conditions close to the ground layer.

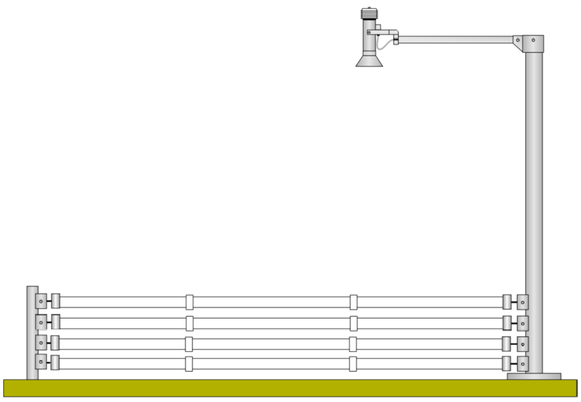

Figure 3. Profile assembly.

The horizontal installation of SPA-sensors with increasing levels (Figure 3) results in a profile of snow densities and liquid water contents. With this arrangement it is possible to detect the transit of snowmelt water through the snow pack and to generate a snow profile.

A further assembly is the installation of four sloping sensors in a star shape. The measurements of the individual sensors are averaged. This results in a high areal resolution, that corresponds to the pixel size of remote sensing data.

5 EXAMPLES

SPA-systems have been installed at various locations, including alpine sites in Switzerland, arctic sites in Sweden, and low mountain range sites in Germany. In the following examples of measurements are presented.

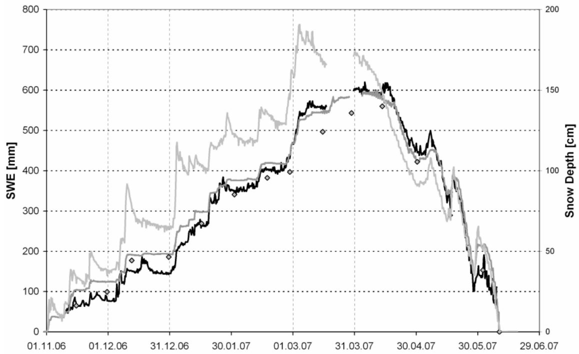

Figure 4. SWE of a 10 m sloping sensor, of a snow pillow and from manual probes at Weissfluhjoch test site (Switzerland) in the winter season 2006/2007.

In Figure 4 a comparison of different SWE measurements is shown. The black curve indicate the SWE data from the SPA-system and the dark gray curve SWE data from a 3x3 m snow pillow. The points are SWE samples from manual probes. For orientation the snow depth is displayed as a light gray curve. The SWE measured by the SPA-system shows a good correlation with the compared data during the complete snow cover cycle.

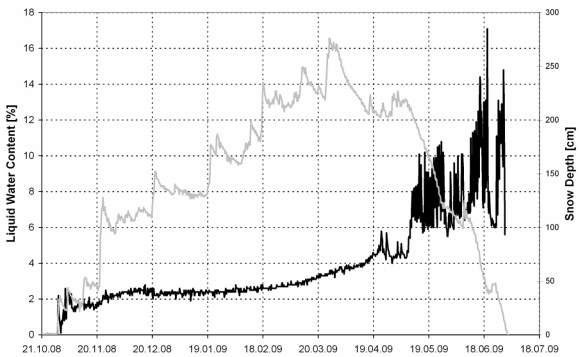

Figure 5. Liquid water content of a 5 m horizontal sensor situated in the ground layer at Weissfluhjoch test site (Switzerland) in the winter season 2008/2009.

The liquid water content in Figure 5 is an unique parameter of the SPA-system and represents the volume content of liquid water along the SPA-sensor in the snow cover. It has a significant increase at the beginning of the water run-off and can show a daily variation during the melting process.

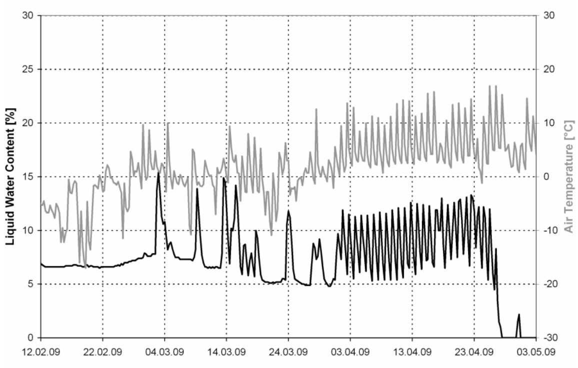

Figure 6. Liquid water content of a 5 m horizontal sensor at Hindelang test site (Germany) in the winter season 2008/2009.

The data of Figure 6 is from a low mountain range in Germany. The liquid water content is high at the beginning of March. A slight increase of the liquid water above saturation causes a sudden further rise of the liquid water, that is reduced by run-off. The daily variation in the melting period correlates with the daily temperature but the maximum has a slight shift into the evening.

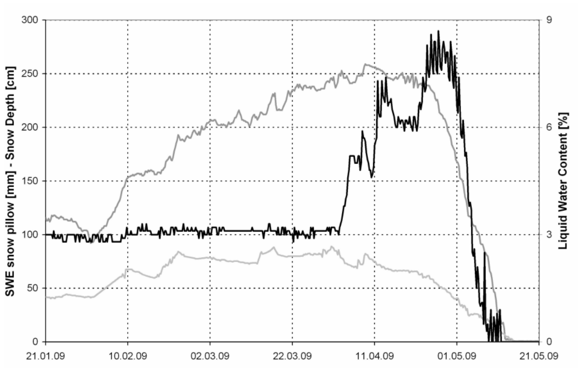

Figure 7. SWE of a snow pillow and liquid water content of a 5 m horizontal sensor at Korsvattnet test site (Sweden) in the winter season 2008/2009.

At the beginning of April the water content increases in Figure 7. The snow depth and the SWE of the snow pillow do not show significant changes at that time. The melting process has started. At a liquid water content of about 7-8 % the SWE starts to decrease, the run-off of the water from the snow cover has started.

In Figure 8 a compression of the snow occurs at the beginning of April while the SWE stays constant. The start of the run-off is defined by the decrease of the SWE. A significant increase of the liquid water content can be seen prior to the starting of the run-off. Therefore the liquid water content can provide a forecast of the point in time of the water run-off.

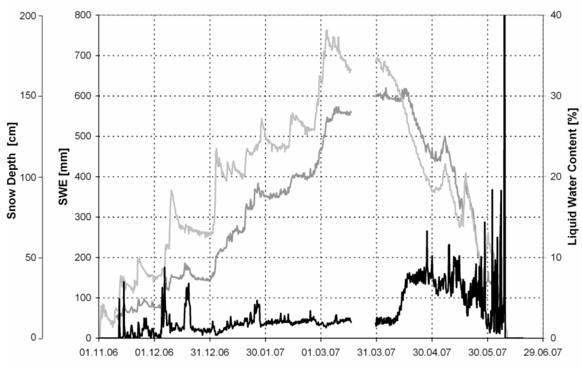

Figure 8. Liquid water content, SWE and snow depth of a 10 m sloping sensor at Weissfluhjoch test site (Switzerland) in the winter season 2006/2007.

5 FIELDS OF APPLICATION

For hydropower companies and flood prevention authorities the precise monitoring of water resources on catchment scales is indispensable for the prognosis of snowmelt run-off, which in return is relevant for flood prevention. In agriculture and mining estimations of the infiltration of melting water into the soil or underground are of basic interest. The information about the liquid water content of the snow pack makes it possible to estimate the point of saturation and snowmelt run-off. Thereby the system offers an important upgrading information for hydrological models. Furthermore these information is also important for snowmelt models, referring to remote-sensing data. The SPA can be a ground control for calibration. Snow density and liquid water content are fundamental parameters for the risk assessment of wet snow avalanches. The SPA helps to improve the quality and density of data for the responsible authorities. Thereby the systems contributes to increase the security of alpine villages and skiing-regions.

6 CONCLUSION

The SPA-system is an in-situ measurement system for snow density and snow water equivalent. The unique determination of the liquid water content enables a wide field of new applications. The possibility to arrange up to four SPA-sensors in sloping or horizontal installation enables to optimize the information depending on demands. The system can be simply installed even at hillsides and is not influenced by ice layers in the snow cover. The unique principle of measurement fulfils all the needs regarding to accuracy and reliability and will set new standards in the future.