Automatic Monitoring of Snow Depth

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ABSTRACT

This presentation is a review of the evolution of the measurement of snow depth using an acoustic (ultra sonic) sensor. Originally developed within the Hydrometeorology Division of the Canadian Atmospheric Environment Service, the sensor has undergone a series of design changes. Although the transducer has remained the same, the packaging and electronic design of the sensor is today quite different than the original sensor. Data from three sites will be presented to assist in showing the evolution and performance of the sensor. The data will show how the measurements produced by the sensor have improved and stabilized.

INTRODUCTION

In the early 1980's, the Atmospheric Environment Services of Environment Canada recognized the need for "a reliable, low cost automatic snow depth sensor" and developed this sensor (Goodison et al. 1984, Goodison et al., 1988). The ultra sonic wave reflection in air was used as the method for measuring snow depth, a technique initially presented by Caillet et al.(1979), and Gubler (1981). The sensor determines the distance to a target by sending out ultrasonic sound pulses and listening for the returning echoes from a target. The time from transmit to the return of the echo is the basis for obtaining the distance measurement. Once the initial design and verification were completed, a prototype sensor and technology was licensed to Campbell Scientific (Canada) Corp. (CSCC) for manufacturing.

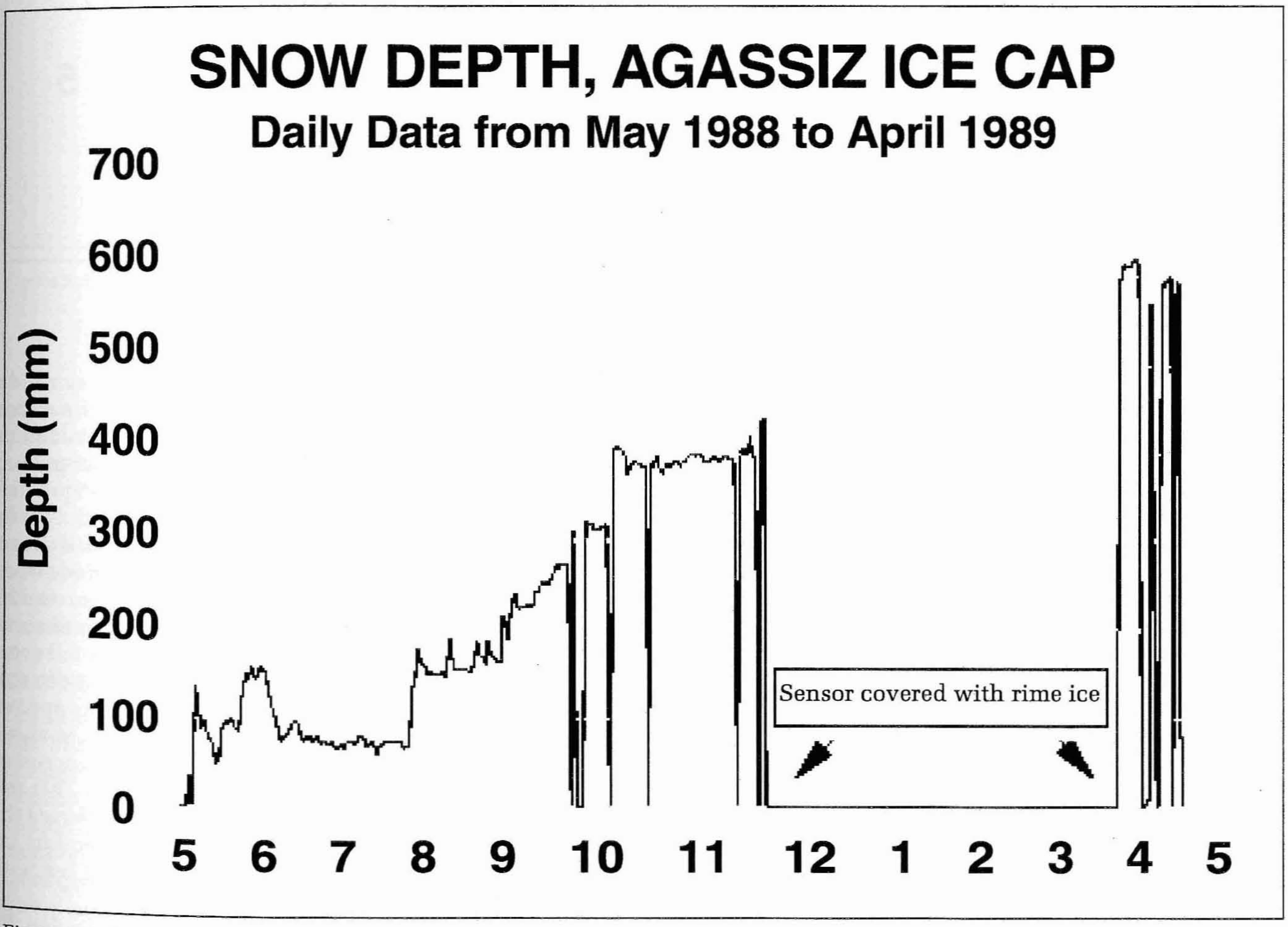

Figure 1. Daily snow depth data from Agassiz Ice Cap, Ellesmere Island, N.W.T.

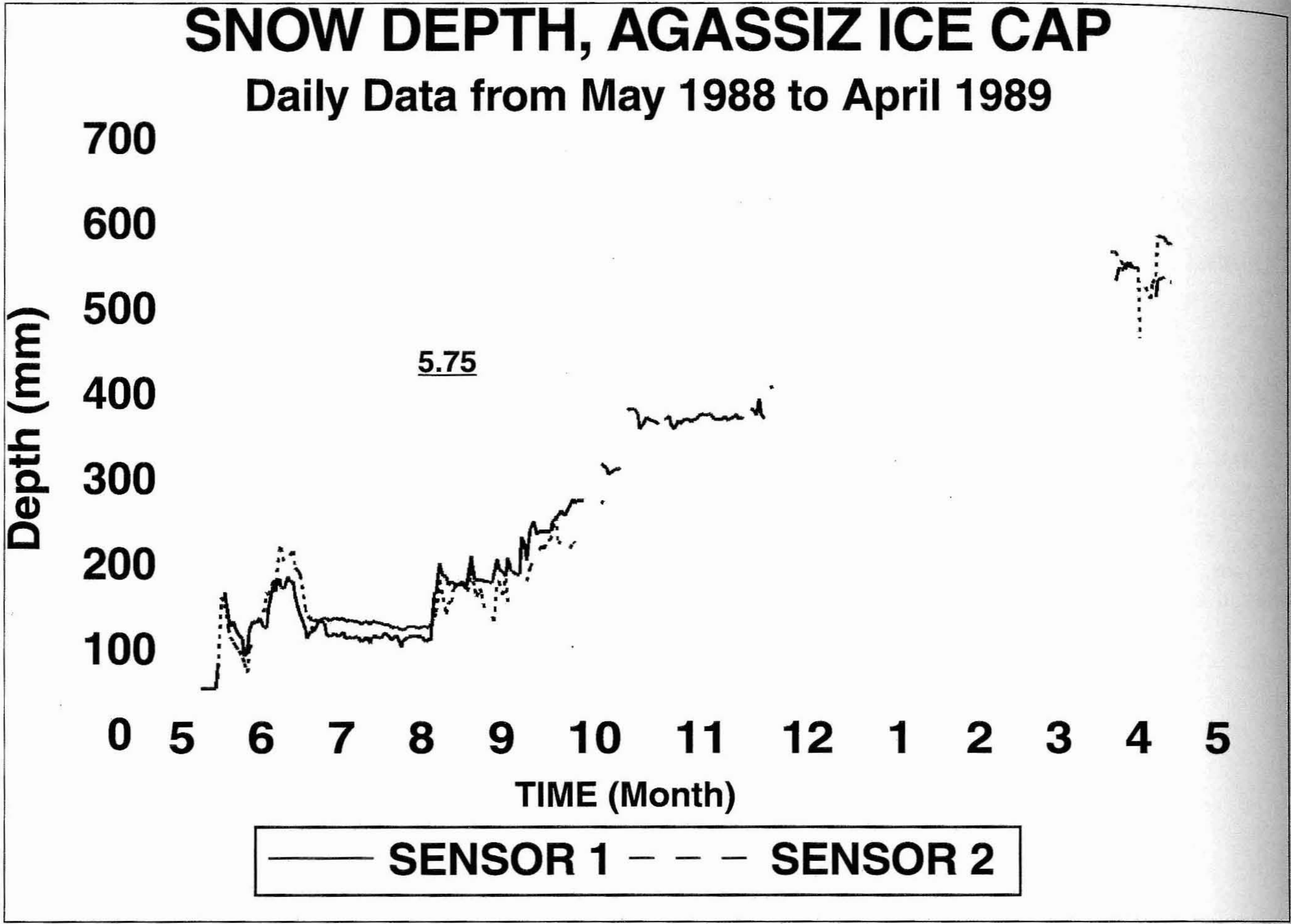

Figure 2. Cleaned daily snow depth data from Agassiz Ice Cap, Ellesmere Island, N.W.T.

Although the initial prototype worked well, there were some basic design changes which had to be incorporated in order to both improve the quality of the measured data and make the sensor operational in remote areas. Some of these changes were basic, involving power supply (from AC to DC operation), packaging and removal of a built it temperature sensor. The temperature measurement was required to adjust the velocity of sound for ambient temperature. It was difficult to build a reasonable radiation screen for the temperature sensor as part of the overall sensor. Furthermore, at most automatic stations where snow depth measurements are required, an air temperature measurement is usually available.

The first sensor designed and manufactured by CSCC had the model designation CSMAL01. Only a limited number of these sensors were built. They had the disadvantage of having the built in temperature sensor with a radiation shield, the power consumption was high and the sensor enclosure was inadequate for high humidity environments. The sensor subsequently had two major design changes, resulting in model designation UDG01 (Ultrasonic Depth Gauge) and most recently the SR50 (Sonic Ranger). In this presentation, only these two models will be discussed.

UDG01 SENSOR

This was the sensor resulting from the first major redesign of the ultrasonic sensor. The built in temperature sensor was removed as well as its associated radiation shield. This allowed a streamlining of the sensor packaging. Figure 1 is a graph showing the raw snow depth data for a sensor located on the Agassiz Ice Cap, on the northern region of Ellesmere Island. The data are daily readings from May 1988 to April 1989. There are periods when the sensor was not capable of making a proper reading and the resulting data value was zero. This would occur if the sensor was making a reading during a snow fall event or during periods of blowing snow. Under those circumstances, the sensor would receive multiple echoes and not be able to make a single determination. There is also a four month period when the sensor was totally encrusted with hoar frost and could not make a reading. This is a common problem with the site and it equally affected the performance of the anemometer and the temperature radiation shield. Figure 2, is for the same data set but with all the incorrect readings removed.

Figure 3 is snow depth data for the same site but for several years. The 1993–1994 season is incomplete because of missing data due to a severed communications

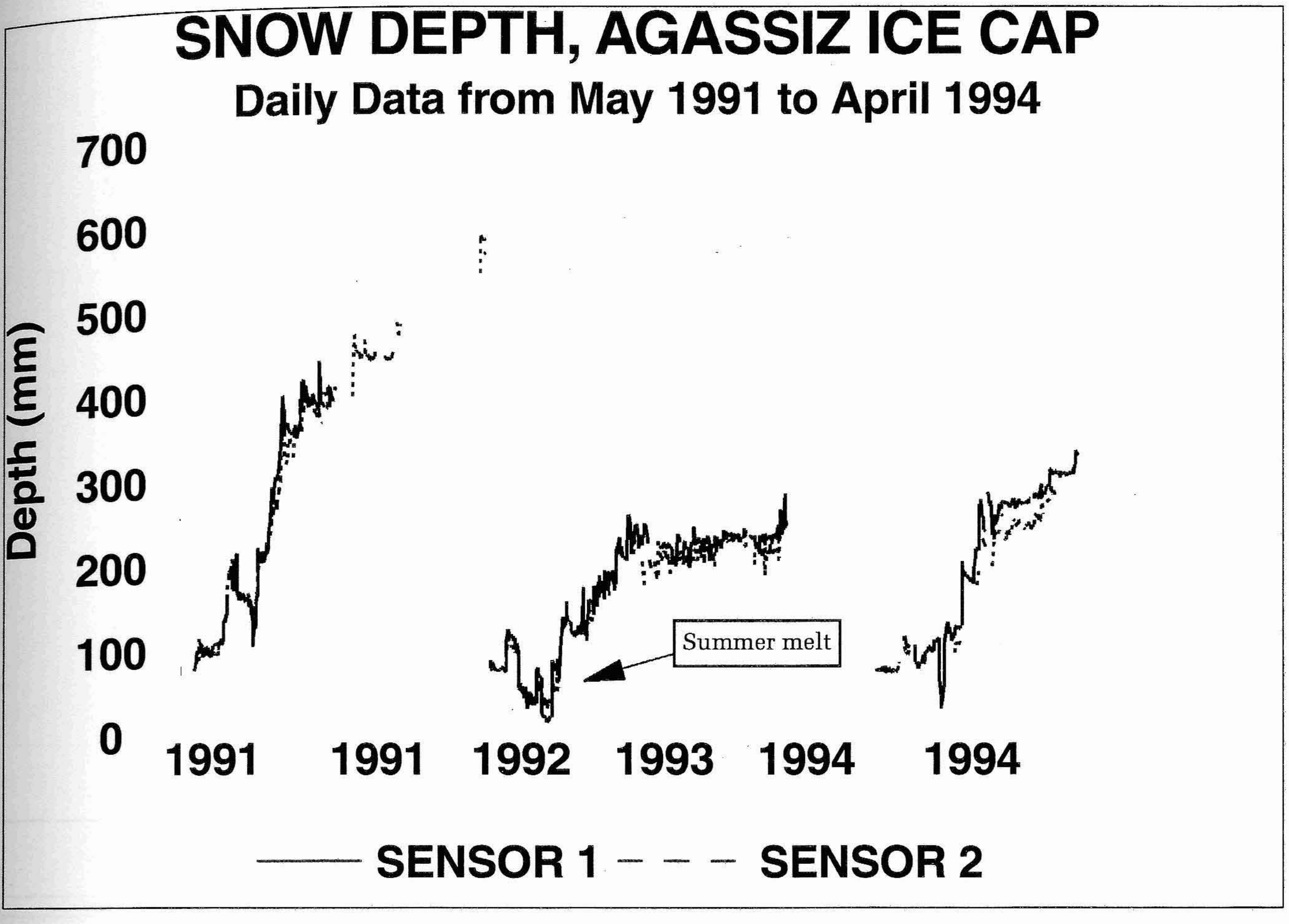

Figure 2. Daily snow depth data from Agassiz Ice Cap, Ellesmere Island, N.W.T. 1991 to 1995.

cable. This is the only existing data set for snow depth measurement from an Arctic Ice Cap. It is part of a collaborative project between CSCC and the Glaciology Division of Natural Resources Canada. It is the first time that the glaciologists have knowledge of the distribution of snowfall for the entire year, instead of once a year mass balance determination. In the summer of 1992, the snow depth measurements show a "negative depth" indicating a short period of summer melt.

SR50 SENSOR

The next and most recent version of the sensor is the SR50. The SR50 is capable of picking up small targets or targets that are highly absorptive to sound such as low density snow. The SR50 can measure multiple targets and it makes use of a unique echo processing algorithm to help ensure measurement reliability. If desired, the SR50 can output measurement quality numbers along with the distance measurement. The quality numbers have no units of measure but can vary from 162 to 600. Numbers lower than 210 are considered to be measurements of good quality. Numbers greater than 300, indicate that there is a degree of uncertainty in the measurement. A furthe r modification in the SR50 has given it the capability of having an SDI (Serial Device Interface) output. In Figure 4, the graph shows the distribution of SR50 quality numbers for this past winter at a test site at the Edmonton International Airport. There were only 14 occurrences of quality numbers with values greater than 300. For the period from November 1995 to May 1996, this is only .3% of all the hourly readings. Figure 5 is the actual snow depth data for the same site. Hourly readings from the SR50 are shown as well as manual readings from the nearby Atmospheric Environment Services weather station. Snow depth distribution at the site is not uniform which explains the discrepancy between the two readings.

Figure 5 also reminds us of the dynamic nature of snow depth, especially in areas with dry snow conditions. Invariably, each snow fall event is followed by a decrease in snow depth due to either settling of the snow or scouring and erosion by the wind.

Hourly snow depth data for a third site, Beaver Mountain, is shown in Figure 6. Beaver Mountain is located approximately 43 km. northeast of Logan, Utah. The station is located close to the 2200 meter level. The manual readings were taken at the very same site and the two readings compare favourably. The snow depth data for this site is much smoother than the previous site. The snow depth readings are the result of hourly average data based

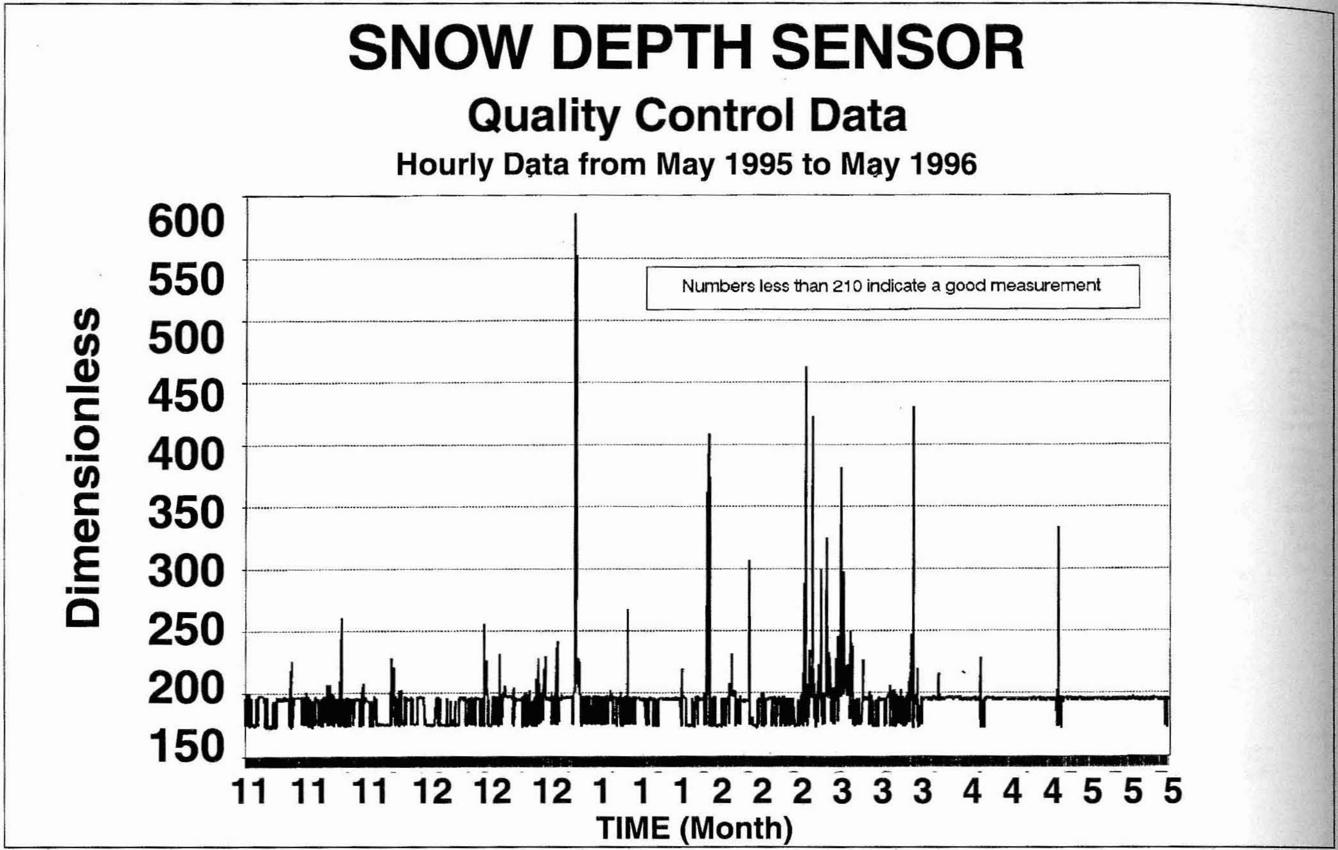

Figure 4. Snow depth sensor measument quality numbers.

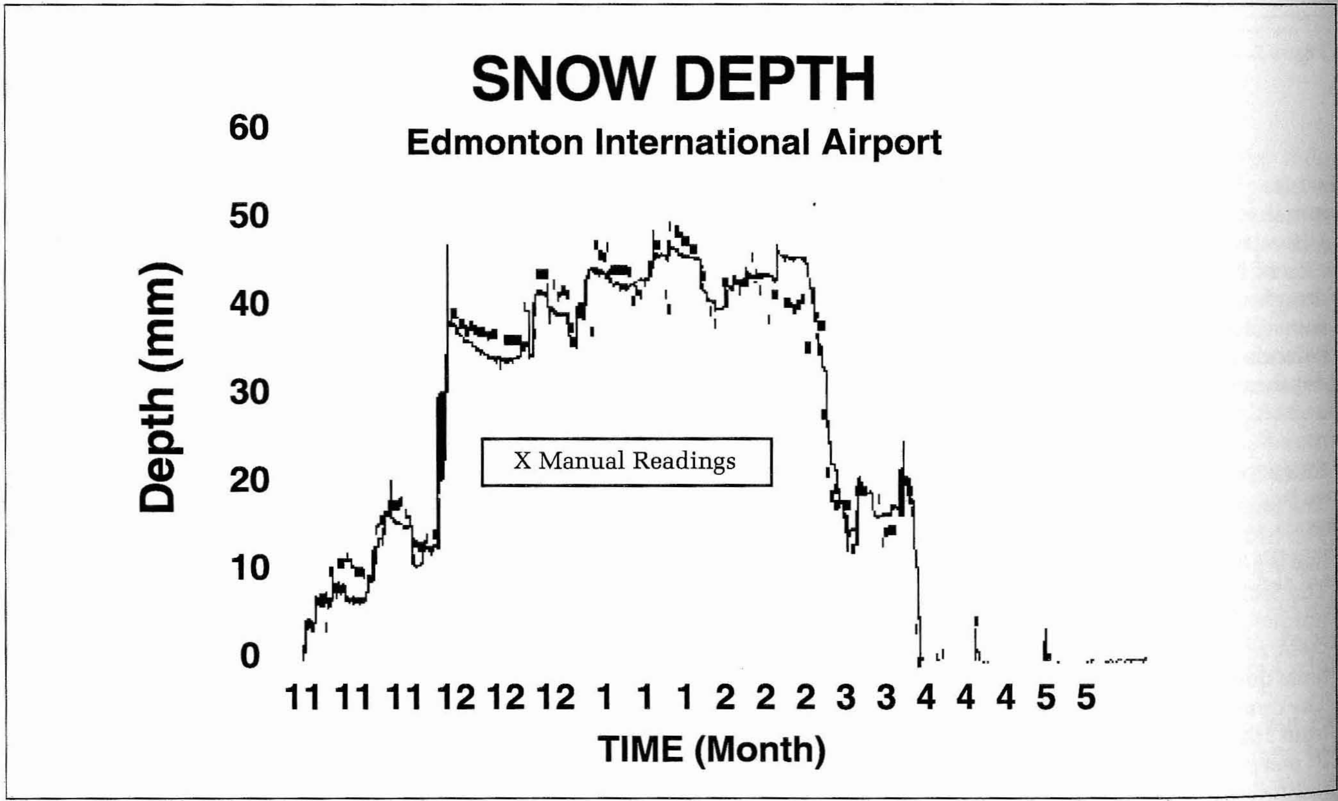

Figure 5. Hourly snow depth measurements from Edmonton International Airport.

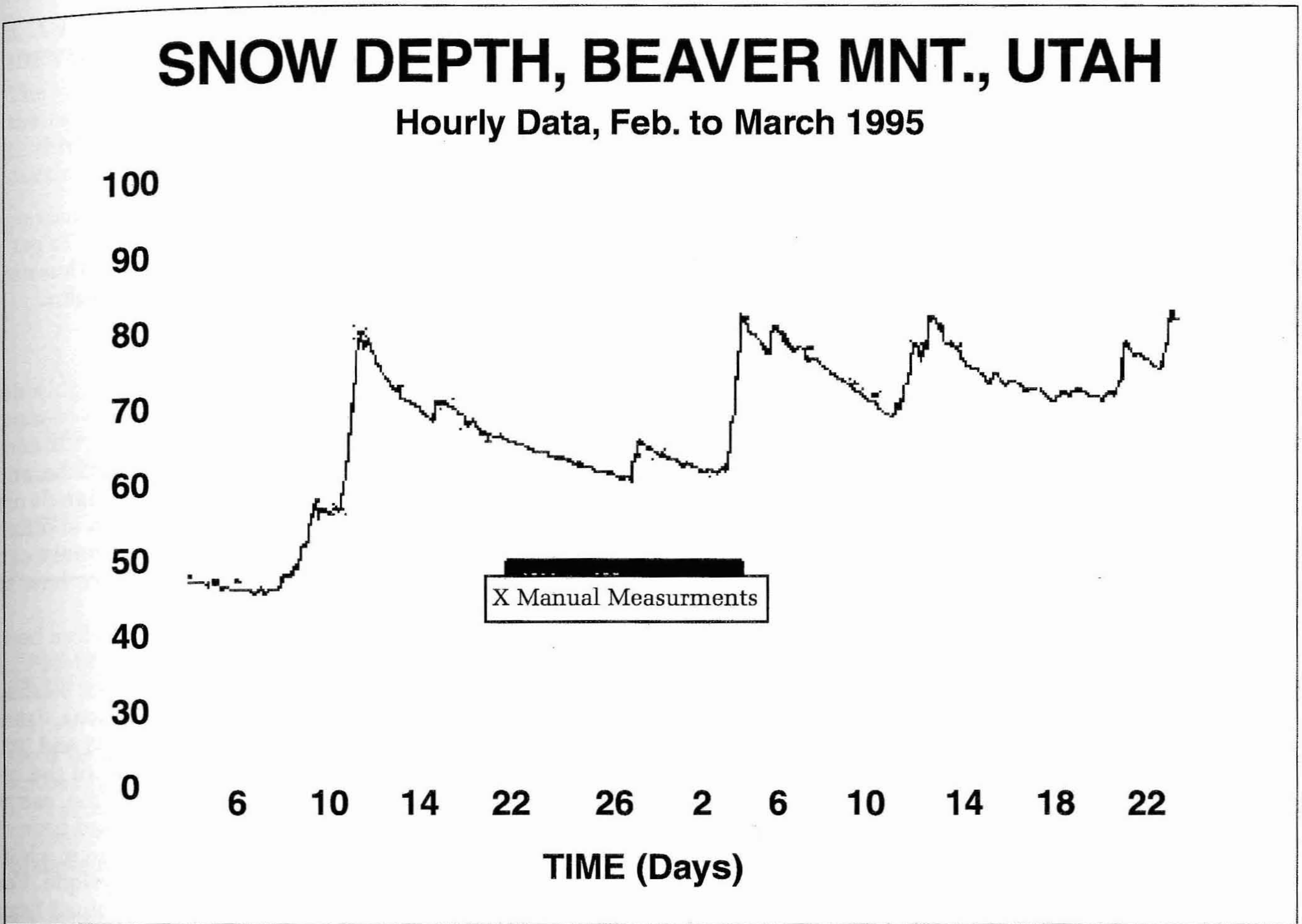

Figure 6. Hourly snow depth measurements from Beaver Mountaian, Utah.

on one minute readings. Furthermore, the snow would tend to have a greater density and be less subject to wind scouring and erosion. However, in this situation, the snow depth also gradually decreases after the initial snow fall, probably as a result of settling and compaction of the snow.

SUMMARY

The evolution of automatic snow depth measurement sensors based on ultra sonic measurements is discussed. Data are presented from the two most recent versions of the sensors and show how the measurement of snow depth has become more reliable under various conditions. Measurement quality indicator numbers are also now available from the sensor and are discussed.

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