THE CANADIAN AUTOMATIC SNOW DEPTH SENSOR
:A PERFORMANCE UPDATE

by

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INTRODUCTION

Snow depth data are important in many hydrological, agricultural and forestry applications, often being used as a substitute for snow water equivalent data. With automation of Canadian Atmospheric Environment Service (AES) observing stations and establishment of unmanned stations at remote locations, there is a requirement for an inexpensive automatic snow depth sensor, to replace manual ruler measurements, if snow depth observations are to be available.

AES has developed and tested an acoustic ranging device as an inexpensive automatic snow depth sensor which could be used at manned or remote stations (Goodison et al., 1984, 1985). The sensor has recently been redesigned and now has a 1.0 mm resolution.

SENSOR CONFIGURATION AND OPERATION

The primary components of the AES acoustic snow depth sensor are Polaroid Corporation's ultrasonic transducer (electro-static microphone) and Texas Instruments Sonar Ranging Module. These parts are combined with microprocessor based electronics to measure the distance from the sensor to the snow surface by timing the flight of an acoustic pulse from the transducer to the target and back again. Since the speed of sound in air is temperature dependent, a correction must be applied in the calculation of target distance to compensate for changes in speed related to changes in ambient air temperature. This is accomplished by referencing an external solid state temperature probe affixed to the snow depth sensor and using this in a look-up table in memory to determine the factor which is used to correct the distance to target measurement.

The resolution of the sensor is 1.0 mm. This improvement from earlier models was achieved by simple modifications to the time base oscillator and microprocessor software upgrades. The sensor is capable of measuring a "target" from 48-1000 cm from the transducer. The sensor operates on 12VDC (at 200 mA). Wilson (1986) and Goodison et al. (1988a, 1988b) describe the operation of the sensor in greater detail. Campbell Scientific Canada (Edmonton, Alberta) has been licensed to manufacture and distribute a sensor based on the AES acoustic snow depth sensor design.

PERFORMANCE TRIALS

Testing of the AES prototype ultrasonic snow depth measurement system developed by AES was first reported at the Western Snow Conference by Goodison et al. (1984). Subsequent modifications and improvements produced a sensor that provided reliable and reasonably accurate measurements (Goodison et al., 1985). Since that time, ten AES acoustic sensors with different output configurations have been installed and operated at various sites across Canada.

At Dorset, Ontario, daily ruler measurements at a nearby climate station were compared to hourly measurements from an acoustic sensor. A standard ruler measurement is the average of several snow depth readings over a representative area, whereas the acoustic sensor depth is a "point" measurement (e.g. a sensor mounted 300 cm above the snowpack integrates over a 45 cm diameter area). Measurements from the automatic snow depth sensor did replicate the time series of daily climate ruler values, at this site, with few inconsistencies. For the 1986-88 period at Dorset, (Fig. 1) the absolute mean difference for the 233 coincident measurements was 26.5 mm; on average the ruler measured 9.7 mm higher than the SDS. Anomalous measurements by the automatic sensor can occur during periods of snowfall and/or drifting or blowing snow events; however, these data are easily quality controlled using hourly trends and snowfall precipitation data. Similiar results were found at other sites (Goodison et al., 1988a, 1988b).

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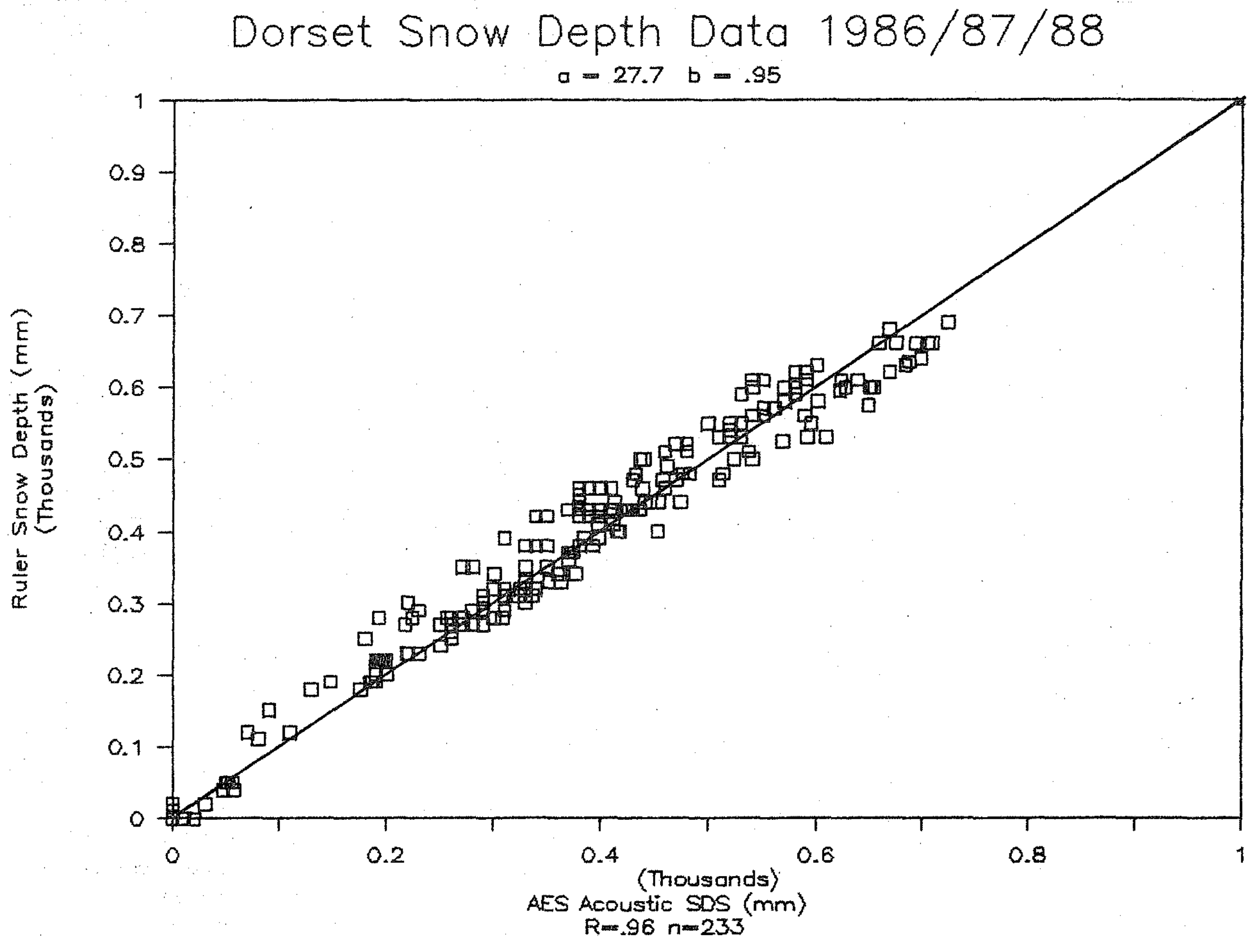

Fig. 1 Snow depth measurements from the AES SDS and snow ruler at Dorset, Ontario, Canada.

APPLICATIONS

Snow Depth Measurement at Remote Sites

The acoustic snow depth sensor is a viable method to obtain observations at Automatic Data Aquisition System (ADAS) sites. However, consideration will have to be given to proper siting since acoustic devices represent "point" measurements as opposed to a series of ruler measurements. At some open or windy sites an observer's estimation of areal average snow depth at the station is often used in-lieu of an actual measurement.

Figure 2 shows hourly data from an AES acoustic snow depth sensor (SDS) installed on a READAC ADAS at Winnipeg, Manitoba. The 1200Z snow depth observation taken at the Winnipeg airport station located within a few hundred metres of the ADAS installation is also shown. At times there was up to a 9 cm difference between the depth of snow under the sensor and the observers areal average snow depth at the station. On Dec. 19, the SDS measurement increased by 5 cm and on Dec. 31 it decreased by 4 cm where as little or no change occurred in the synoptic observation. The changes in SDS measurement were the result of snow drifting and scouring under the sensor. The observer, on the other hand, tended to smooth out any site irregularities, estimating rather than measuring snow depth.

Weekly snow course measurements are also taken at this station. The five individual point depths as well as the course mean are plotted on Fig. 2. It is obvious that there is a good deal of variability in snow depth at this airport site as seen in the difference among snow course points; for example, on Dec. 31 there was a 7 cm difference between the maximum and minimum depth (88% of the mean). The SDS measurements are generally closer to the mean depth of the snow course than is the observed synoptic depth, and in most cases they are within the scatter of the five snow course points. The synoptic observation of snow depth is always low.

Presently, Canadian standards call for snow depth on the ground to be measured to the nearest whole centimetre. It is extremely difficult to make accurate ruler snow depth measurements at exposed sites such as those found in the Canadian prairies and Arctic, or for that matter at airport locations like the Winnipeg station. The acoustic SDS does provide a reasonable measurement of snow depth at a station if it is properly sited.

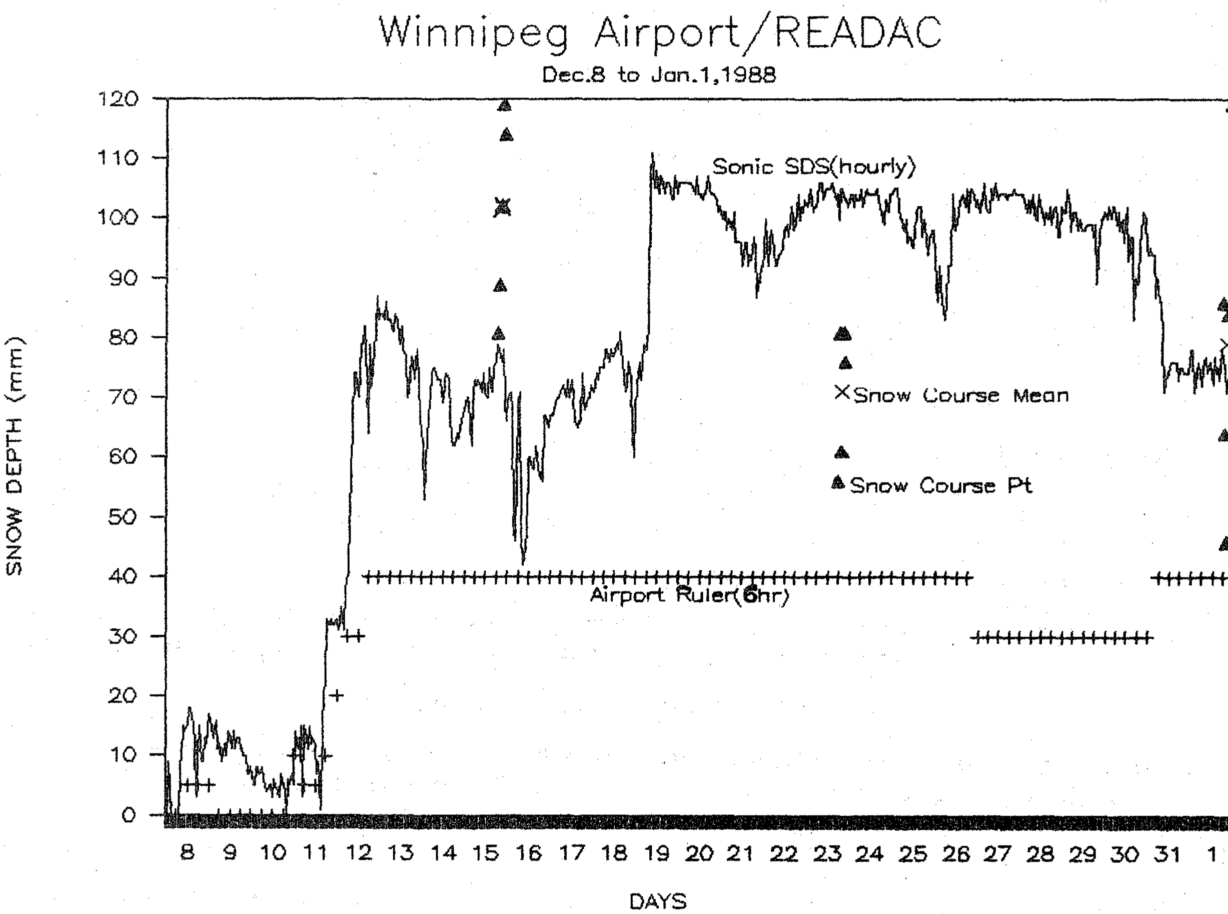

Fig. 2 Snow depth measurements from the AES Sonic Depth Sensor, snow course and airport ruler observations at Winnipeg, Manitoba, Canada.

Other Snowpack Properties

Snowpack water equivalent and density, in addition to depth, are properties of interest to users. With the steady reduction in the national snow survey network, agencies are relying more on snow water equivalent estimates based on precipitation data (Goodison et al. 1987). With increasing automation of observing stations and a reduction in measurements and comments by observers, there will be a strong desire to derive as much information as possible about the state of the snowpack. Goodison et al. (1988b) have found that a combination of hourly recording precipitation gauge and SDS measurements at unattended sites can be a very effective tool for determining precipitation totals, timing of snowfall events, assessing the type of precipitation and providing an indication of the state of the snowpack (melting/non-melting).

Figure 3 shows bi-monthly snow course measurements of mean snow water equivalent and depth in the Muskoka River watershed during the snow cover accumulation period. Daily snow depth from an AES SDS and accumulated precipitation (minus runoff from a lysimeter) from an ADAS located within the basin are plotted for comparison. Although runoff during the accumulation period is not normally available, a snow pillow or modelled runoff values could be used to compute snowpack water equivalent. A properly sited snow pillow or totalizing precipitation gauge co-located with several acoustic snow depth sensors could provide an acceptable estimate of snow pack water equivalent and density.

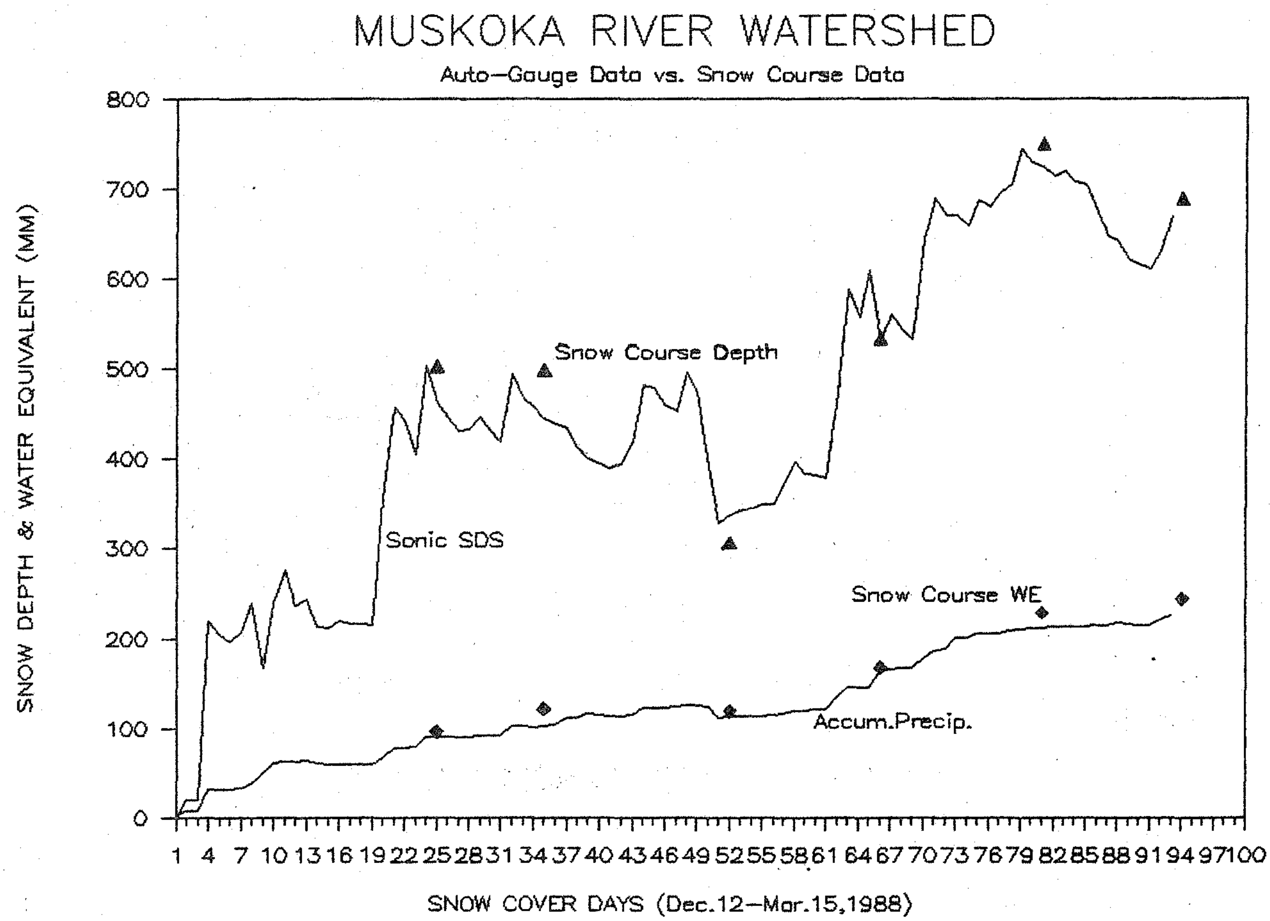

Fig. 3 Snow depth and water equivalent measurements from a snow course, SDS and according precipitation gauge in the Muskoka River Watershed.

CONCLUSIONS

Performance trials have demonstrated that the acoustic sensor can be used to measure snow depth at a site, under a variety of conditions with a root-mean-square error of less than 2.0 cm (Goodison et al., 1985). Goodison et al. (1988a) describe factors which can affect the accuracy of measurement including nature of the snow surface (e.g. low density, fluffy snow vs. ice), correction procedure for air temperature and falling snow at the time of the measurement. These factors, common to acoustic and other types of automatic snow depth sensors, mean that a 1.0 mm resolution should not be interpreted as 1.0 mm accuracy. An accuracy of +/-2.5 cm over a snow surface is more realistic using an acoustic ranging device.

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