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ULTRASONIC SNOW DEPTH SENSORS FOR NATIONAL WEATHER SERVICE (NWS) SNOW MEASUREMENTS IN THE U.S.: EVALUATION OF OPERATIONAL READINESS

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1. INTRODUCTION

Over the past twenty years, the National Weather Service has worked to automate many aspects of surface weather observations. The replacement of human weather observers with automated sensors has advantages and disadvantages. Advantages include continuous real-time monitoring, high temporal resolution, objective uniformity and long-term cost and human resource savings. Negative aspects of automation include initial development costs, instrument performance problems, maintenance costs, discontinuities in long-term climate data, and the loss of integrative and interpretive inputs that manual observations provide. Until recently, the National Weather Service has not automated the measurements of snowfall and snow depth due to the complex properties and spatial variability in snow accumulation.

This paper briefly summarizes the results of an earlier study comparing ultrasonic snow depth measurements with traditional manual observations collected during the winter of 2004-2005. The results of this earlier study are now guiding an aggressive effort to test and evaluate ultrasonic snow depth measurement technology for use by the National Weather Service. This paper will describe plans, installation procedures and data collection schedules for the 2006-2007 snow season test of operational readiness.

2. BACKGROUND

During the 2004-2005 snow season, ultrasonic snow depth sensors from two manufacturers were tested at 14 ASOS and Cooperative observer sites across the U.S. The snow depth sensors utilize ultrasound to measure distance. The sensors transmit a 50 kHz pulse downward which reflects back from the snow surface. The time it takes to return from the target is corrected for the speed of sound in air and converted to a distance. It is then offset by the height of the sensor off the ground, resulting in a snow depth measurement. During the 2004-2005 test, traditional manual observations of snowfall, snow depth, snow water equivalent, gage precipitation and snow depth were taken every six hours and compared to the outputs from automated sensors (Brazenec, 2005).

The comparison of the sensor data to adjacent manual measurements of total depth of snow provided favorable results. Adjacent measurements of manual and automated snow depth typically were within ±1 cm when measured directly beneath the automated sensors. Comparisons with the manually observed total depth of snow on the ground (often an average of several measurements over a larger representative area) were typically within ± 2 cm. The difference between the two is attributed to spatial variability that was not captured by the point measurement of the electronic sensors (Brazenec, 2005).

As part of the 2004-2005 study, observers were asked to comment on any conditions present that may affect the performance of the sensors. As a qualitative tool, sensor failures (identified by large spikes in the data) were investigated using observer comments. The most commonly deduced causes of sensor failure included: low density snow crystals, presence of blowing/drifting snow, intense snowfall, high wind speeds, and uneven snow surface (Brazenec, 2005).

Depth sensors measure the total depth of both new and old snow on the ground immediately beneath the sensor. However, the most commonly used variable for reporting snow conditions has been “snowfall”, the accumulation of fresh snow over specified time intervals. Therefore a significant portion of the research to automate snow measurement involves the development of algorithms to derive six-hour and 24-hour snowfall from continuous measurements of snow depth. Two different snowfall algorithms were created, one using a 5 minute time step for change in snow depth and the other using a 60 minute time step. Temperature-based compaction routines were applied to the calculated 6 hour snowfall totals. The results of the snowfall algorithm were variable between sites, sensors and algorithm used and were also influenced by instrument siting, installation differences and the degree of variability in the output signal (Brazenec, 2005). Preliminary results favored the selection of the Campbell Scientific SR-50 to continue testing towards operational readiness, but revealed the need for further algorithm development, standardization of

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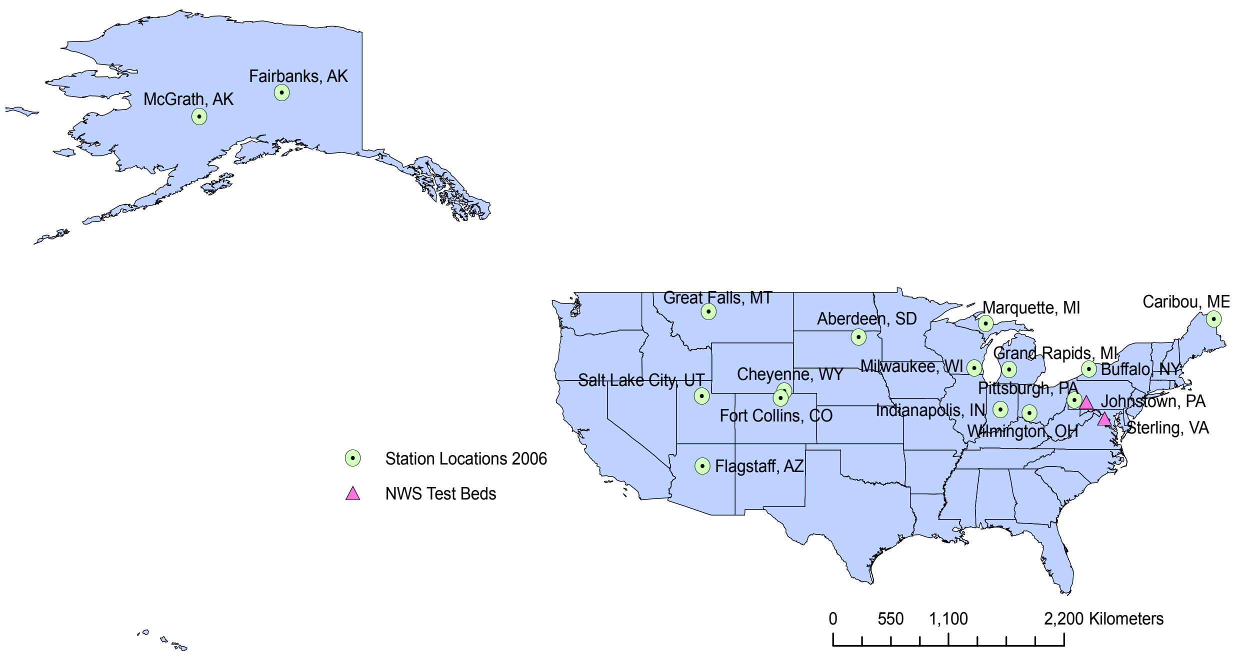


Figure 1: 2006-2007 snow research sites

instrument siting and installation, and better sensor output signal processing. This study concluded that further research was needed to understand the variable results obtained from the snowfall algorithms, and that verification of the snow compaction model used in the algorithm was needed. In addition, it was concluded that the 2004-2005 experiment did not adequately represent the Western U.S. climates including Alaska, where the snow season is long and variability in snow conditions from day to day can be extreme.

3. 2006-2007 SNOW SENSOR RESEARCH SEASON

3.1 *Site Locations*

The 2006-2007 snow season research effort consists of 18 sites representing various climates from Alaska to Arizona and Maine to Virginia (Figure 1), including both NWS test bed sites (Sterling, VA and Johnstown, PA). The sites were chosen based on average annual snowfall and variability of snow types and snow cover, proximity to an ASOS (Automated Surface Observing System), and the availability of trained and willing surface observers to take manual measurements. The proximity to ASOS is primarily to test the incorporation of various meteorological elements into the snowfall algorithm for improved results, in particular high temporal resolution precipitation measurements.

3.2 *Equipment and Installation*

Each site is equipped with three Campbell Scientific® SR-50 sonic ranging sensors and one temperature probe in a radiation shield. The reasons for using three sensors are: a) to capture spatial variability, b) to better support operational quality assurance/quality control, c) to provide redundancy in the case of potential instrument failure, and d) to improve snowfall algorithm performance and verification. Also, installing three sensors leaves the option of removing sensors from the analysis to test the effect of having fewer depth measurements. The SR-50's were arranged in a triangle 120º from one another with one sensor oriented to true North. Each leg of the triangle is 6.1 meters (20 feet) in length (Figures 2 and 3). The upright posts for the sensors were sunk in concrete to 0.9 meters (3 feet) or frost depth, whichever was greater. This was done in order to prevent frost heave of the sensors to ensure they remain level. The sensors were mounted at a height equal to the maximum observed snow depth at each site increased 25% to allow for larger than average events. The height was then increased by 0.5 meters which is the minimum height the sensor must be mounted above the surface in order to make a measurement. The temperature probe was installed in the center of the plot (Figures 2 and 3) at 75% of the sensor height off the ground. This height and position were chosen to best represent the average air temperature of the column of air between the sensor and the ground or snow surface for computing the speed of sound temperature correction. Expanded PVC snowboards were chosen as the target surface for the snow sensors. This is

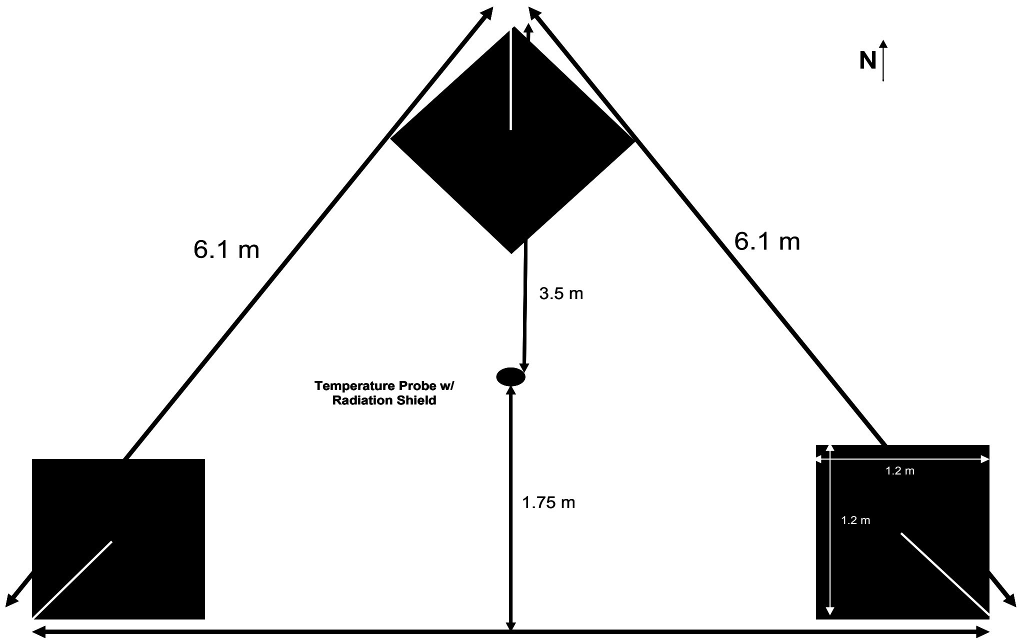
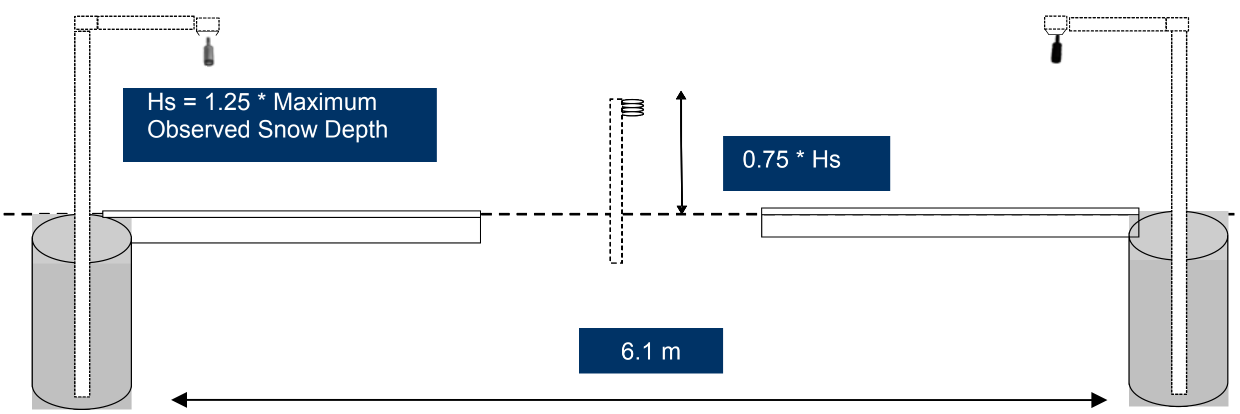


Figure 2: Snow Sensor Installation: Plan View

Figure 3: Snow sensor installation: Looking North (North sensor omitted for simplicity)



the same material utilized by the NWS for their snow measurement boards used for manual snowfall measurements. The boards were mounted onto either a wooden frame to prevent sagging, or if the area is prone to frost heave, the boards were attached to posts sunk to frost depth. The cross-arm for the sensors extended to the center of the snowboards. All elements (with the exception of the sensors) were painted white to reduce solar absorption and potential premature snow melt. Examples of several installations are shown in Figure 4.

3.3 *Data Collection*

Ultrasonic snow depth readings are collected every five minutes. The outputs for each SR-50 sensor include a five minute average snow depth computed from 10 second samples, a five minute snow depth sample coupled with a quality number (measure of the quality of the depth measurement), air temperature and battery voltage. The data are continuously logged on a PC and then automatically transfer to the snow sensor website for data archival and display.

Manual data collection consists of six and twenty-four hour snowfall, total snow depth on ground, number of total depth samples taken, gage precipitation, six and twenty-four hour snow board water equivalent core measurements, snow depth at each sensor (taken from measuring tape attached to each depth sensor mounting pole), once a day ground snow water equivalent and comments on snow conditions that may affect sensor performance. These data are entered by each participating station via a web interface. Manual and automated data are both accessible via the snow sensor website.

4.0 CONCLUSIONS

This paper has introduced the planned installation and data collection methods for the 2006-2007 snow sensor research project. The main goal of this project is to test six and twenty-four hour snowfall algorithms as well as total snow depth measurements toward operational usage. Preliminary results will be presented as data becomes available. The addition of automated snow measurements is promising and may provide long-needed improvements in the quality and availability of U.S. snow measurements.

5.0 ACKNOWLEDGEMENTS

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6.0 REFERENCES

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Figure 4: Site installation photos from top right (clockwise): Fairbanks, AK; Aberdeen, SD; Indianapolis, IN and McGrath, AK