JP1.33 SUITABILITY OF THE JUDD ULTRASONIC SNOW DEPTH SENSOR FOR ESTIMATING 6- AND 24-HOUR SNOWFALL AMOUNTS.

Douglas G. Cripe*
Department of Geography, Kent State University, Kent, Ohio
and
Nolan Doesken
Department of Atmospheric Science, Colorado State University, Fort Collins, Colorado

1. INTRODUCTION

When the U.S. National Weather Service (NWS) converted to the Automated Surface Observing System (ASOS) in the mid 1990s at airports around the country, observations of snowfall and snow depth were no longer reported on a regular basis. Until now, these variables required human participation if they were going to be reported at all (which is the case for only a handful of 1st order stations). This paucity of consistent, round-the-clock snow reporting in the context of ASOS has had an impact not only on the efficiency of airport operations, but also the quality of hydrological forecasts.

Our study examines the suitability of the Judd Ultrasonic Snow Depth Sensor as a potential solution to this problem. A key component of this study is to manually take collocated snowfall and snow depth measurements simultaneously with the automated sensor. In order to assess the instrument's reliability, such a comparison must be conducted in an area of light to moderate seasonal snowfall accumulations, which would be representative of most NWS airport locations around the US. Accordingly, the sensors have been deployed in 3 geographically and climatologically distinct locations: Flagstaff, AZ; Fort Collins, CO; and Brunswick, OH. Following reporting methods outlined by Doesken and Judson (1996), during periods of major snow events, manual observations of precipitation, snowfall, snow depth and total water equivalence were conducted every 6 hours, in conjunction with standard reporting intervals of the NWS (00z, 06z, 12z, 18z). If the instrument proves to be reliable, the NWS may elect to use it to supplement the ASOS network, enhance airport operations, and also improve hydrologic forecasts.

A further objective of the study is to incorporate our findings in a general analysis of spatial distribution of snowfall and snow depth while assessing the appropriateness of single-point measurements for these quantities. This analysis will be forthcoming.

2. JUDD ULTRASONIC DEPTH SENSOR

A few years ago, a new type of automated sensor was developed by Judd Communications of Salt Lake City, UT (www.juddcomm.com), which operates essentially as a sonar instrument. A transducer located on the bottom of the sensor sends out an ultrasonic pulse at 50kHz, and then measures the amount of time for that pulse to return to the transducer location (the transducer becomes a microphone during the return pulse). As with sonar, if the time elapsed between the emission of the pulse and the return of its reflection is known, the distance the pulse has traveled can be determined using the speed of sound. We can then infer the depth of snow on the ground, having initially calibrated the instrument while the ground is bare so that we have a baseline measurement to compare with. At the Brunswick, OH location, two sensors were mounted adjacent to each other for a side-by-side comparison. Each sensor has been separately mounted on a pole 1.25 m above a snow board painted white, measuring 60 cm by 120 cm. A shielded temperature sensor collocated with the transducer/sensor provides a speed correction to the computations since sound speed is proportional to temperature (Figure 1 shows a photograph of the Judd automated sensor). The sensor is promoted as having a 3 mm resolution and accuracy to 1 cm. An interesting feature of the sensor is that it can be programmed to sample snow depth on intervals of microseconds to hours through the use of a data logger. For increased accuracy, the sensor also sends out multiple echoes during a sampling interval and compares the results. If the computations agree within specified tolerances, then the measurement is reported to the data logger. Otherwise, if agreement cannot be reached within set tolerances, the observation is reported as missing.

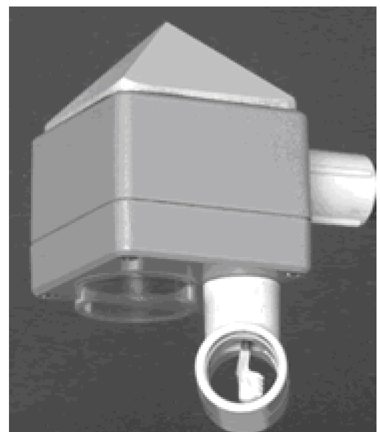

Figure 1: Judd ultrasonic snow depth sensor.

The Campbell Scientific CR510 data logger and associated computer software were used in conjunction with the sensors to monitor and record the data.

* *Corresponding author address:* Douglas G. Cripe, Kent State University, Dept. of Geography, Kent, OH, 44242; e-mail: dcripe@kent.edu

Table 1: Data collected during snow event at Brunswick, OH, February 26 – 28, 2002.

Time (UTC); Date	Precip. (mm)	Snow-fall (mm)	Snow depth (mm)	Snow depth (sensor 1, 2) (mm)	Air temp. (sensor 1, 2) (C)	6-hour snowfall (mm)	24-hour snowfall (mm)
1200; 2/26/02	4.8	0.0	0.0	7, 3	4.6, 5.1		
1800; 2/26/02	T	T	T	3, -3	-1.9, -1.0	0, 0	
0000; 2/27/02	2.3	10	10	13, 5	-3.0, -2.04	10, 8	
0600; 2/27/02	0.5	5	13	15, 10	-8.6, -7.6	2, 5	
1200; 2/27/02	T	T	10	15, 15	-10.2, -9.1	0, 5	12, 18
1800; 2/27/02	T	T	8	10, 8	-7.0, -6.3	0, 0	
0030; 2/28/02	2.0	25	28	23, 33	-7.6, -6.6	13, 25	
0600; 2/28/02	3.8	84	107	109, 114	-8.6, -7.6	86, 81	
1200; 2/28/02	T	T	99	89, 99	-11.1, -9.7	0, 0	99, 106

3. RESULTS

Since our study is still ongoing, the results presented in this paper are very preliminary. As an example of how the Judd sensor may be used to provide a reasonable estimate of snowfall, Table 1 outlines a snow event in Brunswick, OH that occurred February 26-28, 2002. Columns 2, 3, and 4 represent human observations of precipitation, snowfall and snow depth. Columns 5 and 6 represent 10-minute averages of sensor observations for snow depth and air temperature. Columns 7 and 8 show 6-hour and 24-hour estimates of snowfall, based on snow depth measurements from the sensors. For all computations, negative values are treated as zero. For the 6-hourly observations it has been assumed that snow fell only if the snow depth at a given observation was greater than the value reported at the previous 6-hour observation; otherwise no snowfall was reported for the interval. For the 24-hour snowfall computations, all 6-hour snowfall reports were summed. During the snow event, winds were initially from the north-northwest with sustained speeds of 15-20 mph, gusting to 30 mph, typical of lake-effect snow for the Cleveland area adjacent to Lake Erie. During the course of the storm, winds changed to southwesterly with sustained speeds of 20-25 mph, gusting to 35 mph, effectively shutting off the lake effect snow and bringing very cold air with only occasional flurries for the duration of the period.

4. DISCUSSION.

Preliminary results indicate that the sensors appear to provide reliable and realistic snow depth data. Both the snow depths and snowfall estimates based on sensor reports are in reasonable agreement with observed quantities. Further, the advertised accuracy and sensitivity of the sensors has been confirmed. A few caveats, however, are worth mentioning. First, in situations of high wind and/or heavy snow, which was the case periodically during the snow event, the sensors can give erroneous or negative readings. Lea and Lea (1999) reported similar problems in their investigation. The outliers produced in these instances are fairly obvious and could presumably be dealt with through simple data checking and linear interpolation. Second, the temperature sensors were often as much as 2°C different from each other, which contributed to variance in snow depth readings.

For a study such as this, the more human-obtained observational data correlating to these sampling times, the better, especially where analysis of the spatial distribution of snowfall is concerned. Additional surface meteorological variable measurements, such as temperature, moisture, precipitation, and wind speed/direction will also enhance our understanding of the general dynamics behind each snow event as well as verify our surface measurements. To complete our report, we will therefore be collecting meteorological data from NWS cooperative stations in proximity to our sensor sites as we further assess our findings.

5. REFERENCES

Doesken, N. J. and A. Judson, 1996. The snow booklet; A guide to the science, climatology, and measurement of snow in the United States. Colo. Climate Center, Dept. of Atmospheric Sciences.

Lea, J. K. and J. P. Lea, 1999. A study of new snow depth sensor data during a rain on snow event at Mt. Hood, Oregon. *Amer. Met. Soc.*, Preprints, 11th Conf on Applied Climatology, 227-233