COMPARING A SNOTEL EXTENDED-RANGE AIR TEMPERATURE SENSOR AND EQUATIONS TO A NIST-CERTIFIED SENSOR IN AN ENVIRONMENTAL CHAMBER

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ABSTRACT

In the National Snow Survey program, air temperature is one of the parameters that is measured at a SNOTEL site. The original YSI air temperature sensor did not adequately measure the temperature range that was found throughout the network. Therefore, the extended-range YSI air temperature sensors were installed over time at all the telemetered stations. The new sensor required a different algorithm to convert the voltages (measured by the sensor) to degrees C. This conversion occurred in the server at the National Water and Climate Center. At the time, the algorithm used was developed at the center and was not the manufactured-recommended algorithm. Since the conversion, there has been some concerns that the algorithm or the sensor has overestimated the air temperature. To test for this, we installed 6 extended-range YSI temperature sensors and one certified Fluke sensor in an environmental chamber. The chamber was set to start at -50° C and then step 5° increments to +50° C. We then reversed the stepping from hot to cold in the same increments. The sensors were connected to a Campbell CR10X data logger and the millivolts from the sensor were recorded every 15 minutes. The measured millivolts were converted into degrees Celsius by the existing equation and the manufacturer-recommended algorithm. Both derived temperatures were compared to the certified sensor in the analysis. It was shown that the existing algorithm showed higher temperatures in the middle of the temperature profile. The manufacture's recommended algorithm did match more closely to the certified sensor throughout the profile. It was recommended that the data be remapped with the manufacturer-recommended algorithm or that a lookup table be developed to correct for the middle ranges of the air temperature profile. (KEYWORDS: SNOTEL air temperature, NRCS, air temperature, YSI extended range)

INTRODUCTION

The Natural Resources Conservation Service (NRCS) installs, operates and maintains an extensive, automated system called SNOTEL (an abbreviation for SNOw TELemetry). SNOTEL is designed to collect snowpack and related climatic data in the Western U.S. and Alaska. In 1935, the Soil Conservation Service (now NRCS) established the cooperative Snow Survey and Water Forecasting Program to conduct snow surveys and develop reliable water supply forecast. The program operates under the technical guidance of the National Water and Climate Center (NWCC). The modern SNOTEL network also provides data for climate studies, air and water quality investigations. The current parameters measured at a standard SNOTEL site are air temperature, precipitation, snow water equivalent, and snow depth (Figure 1).

The air temperature sensor that was used throughout the network before the 90's was the YSI standard temperature sensor (44230) with a range of -30 to + 50° C (Figure 2) and with a linearity deviation +/- 0.16° C. It was decided that the extended-range YSI sensor (44211A) would better cover the temperature range that is possible in the SNOTEL network. The range of the extended sensor is -55 to 85°C and the linearity deviation is +/- 1.1° C. Both sensors have an output in millivolts (mV) and then are converted by an algorithm. When the new extended-range sensors were installed, the data was converted to a temperature by a fitted equation using a linear least squares regression that was developed at the NWCC. The manufacture recommended equation was not implemented. There has been concern that the NWCC equation is incorrect and that the manufacturer's equation should be implemented. The purpose of this study was to obtain measured extended YSI data in a controlled environment and convert the raw millivolts using both the manufacturer-recommended equation and the NWCC equation. The results would then be compared to temperatures measured by an NIST-certified sensor (Figure 2).

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Figure 1. NRCS SNOTEL site with normal sensor deployment.

Figure 2. Fluke 1524 Reference Thermometer and
YSI Air Temperature Probe

METHODS

The air temperature sensor algorithm was evaluated thru the temperature profile range -50 to +50° C. A Cincinnati sub-zero environmental chamber (model ZP-32) was used (Figure 3). The chamber was set up to increment in 5° C every hour from -50 to +50° C. The temperature increments started at -50° C and then went to +50° C. To check the sensor behavior when heating up and cooling down, when the chamber temperature reached +50° C for an hour it was incremented down to -50° C using the same method. Since the temperature chamber regulation is not as precise as needed for this evaluation, the actual temperature was recorded by the reference thermometer. A Campbell scientific data logger was used in this comparison to collect data every 15 minutes. The logger used to collect data from the YSI sensors was mounted externally on the chamber. Sensor (YSI) wires were inserted into the chamber thru a sealed port. The logger was not subjected to the range of temperatures experienced

Figure 3. Cincinnati sub-zero ZP-32 Environmental Chamber.

Figure 4. Campbell CR10X Data Loggers and Sensor Wire.

by the sensors. The standard temperature was measured with a NIST-certified (B5A23017) Fluke 1524 reference thermometer. The logger collecting the Fluke data was mounted on the outside of the chamber and the thermometer inserted through the sealed port (Figure 4). The data logger was set to collect data every 15 minutes. Six YSI extended range sensors (44211A) were connected to the data logger thru the single-end inputs of the logger. The excitation of the sensors was 2500 mV for 0.0552 seconds. There was a 0.05 second delay between sensors measurements. Both the Fluke thermometer and the YSI sensors were mounted in the same location inside the chamber to account for possible differences within the chamber. The equations are in Table 1.

Table 1. The raw mV data is converted into degrees C by the following equations.

Current equation used in the SNOTEL server	Manufacture recommended equation for extended-range YSI sensors
Multiplier[×] of 77.80 Slope Coefficient of -65.929 Temp °C = (mV*0.0778)-65.929	Multiplier[×] of 78.92 Slope Coefficient of -67.30466 Temp °C = (mV*0.78.92)-67.3047

[×] Engineering Units from the data logger

RESULTS

The chamber never reached the true temperatures that were programmed into the controls. But the five degree increments were within 1 °C of the setting proposed. The chamber did reach a steady temperature every hour and the sensors did record that change.

The manufacturer-recommended equation showed that the chamber was colder than the Fluke sensor from +50° to +10° C (Table 2). The range or difference between the 6 sensors was 1° to 0.64° C in this higher temperature range. This occurred when the temperature was both decreasing and increasing. The YSI sensors ranged from 0.2° to 1.28° C cooler than the Fluke sensor at this higher temperature range.

The manufacturer-recommended equation showed that the chamber was warmer than the Fluke sensor from +5° to -25° C (Table 2). The range or difference between the 6 sensors in this temperature range was 0.64° C to 0.84° C. The same differences occurred as the chamber was cooling as well as warming. The YSI sensors ranged from 0.23° to 1.09° C warmer than the Fluke sensor at this lower temperature range.

The manufacturer-recommended equation showed that the chamber was cooler than the Fluke sensor from -49.70° to -28.91° C. The range or difference between the 6 sensors in this temperature range was 0.89° to 1.17° C. The same differences occurred as the chamber was cooling as well as warming. The YSI sensors ranged from 0.30° to 1.17° C cooler than the Fluke sensor at this lower temperature range.

The current YSI equation showed that the chamber was colder than the Fluke sensor from +50° to +15° C (Table 3). The range or difference between the 6 sensors was 0.45° to 1.01° C in this higher temperature range. This occurred when the temperature was both decreasing and increasing. The YSI sensors ranged from 0.02° to 1.25° C cooler than the Fluke sensor at this higher temperature range.

The current YSI equation showed that the chamber was warmer than the Fluke sensor from +10° to -50° C (Table 3). The range or difference between the 6 sensors in this temperature range was 0.25° to 0.46° C. The same differences occurred as the chamber was cooling as well as warming. The YSI sensors ranged from 0.02° to 1.56° C cooler than the Fluke sensor at this cooler temperature range. The YSI sensor shows at -39° to - 44.17° C that there is only 0.25° C difference between the standard and the current YSI.

Table 2. Results for Fluke versus current YSI using manufacturer's (MFG) equation. Six sensors were tested. Millivolts were converted using MFG equation. (Range MFG YSI = the range in variability between the 6 sensors; Diff = Fluke – average current YSI with MFG equation; Yellow marks average sensor temp that is higher (warmer) than the Fluke measurement.)

FLUKE VS CURRENT YSI WITH MFG EQUATION							
TEMPERATURE DECREASING				**TEMPERATURE INCREASING**			
Fluke Temp ℃	Ave MFG YSI ℃	Range MFG YSI ℃	Diff ℃	Fluke Temp ℃	Ave MFG YSI ℃	Range MFG YSI ℃	Diff ℃
49.27	48.85	1.00	0.42	-49.13	-49.70	1.17	0.57
44.55	43.78	0.94	0.77	-44.12	-45.21	1.11	1.09
39.81	38.77	0.86	1.04	-39.10	-40.23	1.05	1.13
35.19	33.97	0.78	1.21	-34.09	-34.91	0.97	0.82
30.28	29.00	0.77	1.28	-29.04	-29.34	0.89	0.30
25.25	24.07	0.73	1.18	-24.00	-23.77	0.84	-0.23
20.25	19.34	0.70	0.92	-18.99	-18.29	0.76	-0.69
15.56	14.96	0.69	0.60	-13.85	-12.85	0.69	-1.00
10.77	10.57	0.64	0.20	-8.77	-7.71	0.66	-1.07
5.91	6.14	0.68	-0.23	-3.67	-2.85	0.64	-0.82
0.97	1.62	0.65	-0.65	1.30	1.90	0.65	-0.61
-4.00	-3.06	0.62	-0.93	6.27	6.46	0.64	-0.19
-9.00	-7.94	0.66	-1.06	11.16	10.93	0.66	0.23
-13.92	-12.95	0.72	-0.98	16.00	15.36	0.68	0.63
-18.97	-18.28	0.77	-0.69	20.83	19.87	0.67	0.96
-23.96	-23.72	0.83	-0.23	25.72	24.52	0.75	1.20
-28.91	-29.26	0.90	0.35	30.63	29.36	0.76	1.28
-33.93	-34.76	0.95	0.83	35.54	34.33	0.83	1.21
-38.96	-40.13	1.03	1.17	40.38	39.35	0.89	1.03
-44.02	-45.14	1.10	1.12	45.14	44.42	0.96	0.71
-49.13	-49.70	1.17	0.57	49.96	49.61	1.02	0.34

Table 3. Results for Fluke versus current YSI using current SNOTEL equation. Six sensors were tested. Millivolts were converted using current SNOTEL equation. (Range MFG YSI = the range in variability between the 6 sensors; Diff = Fluke – average current YSI with current SNOTEL equation; Yellow marks average sensor temp that is higher (warmer) than the fluke measurement.)

FLUKE VS CURRENT YSI WITH CURRENT EQUATION							
TEMPERATURE DECREASING				TEMPERATURE INCREASING			
Fluke Temp ℃	Ave current YSI ℃	Range current YSI ℃	Diff ℃	Fluke Temp ℃	Ave current YSI ℃	Range current YSI ℃	Diff ℃
49.27	48.62	0.99	0.65	-49.13	-48.67	0.40	-0.46
44.55	43.63	0.92	0.92	-44.12	-44.24	0.43	0.12
39.81	38.68	0.84	1.13	-39.10	-39.32	0.45	0.22
35.19	35.17	0.81	0.02	-34.09	-34.06	0.41	-0.03
30.28	29.03	0.73	1.25	-29.04	-28.56	0.39	-0.48
25.25	24.16	0.62	1.09	-24.00	-23.06	0.34	-0.94
20.25	19.48	0.52	0.77	-18.99	-17.66	0.32	-1.33
15.56	15.17	0.48	0.39	-13.85	-12.28	0.25	-1.57
10.77	10.83	0.39	-0.06	-8.77	-7.21	0.26	-1.56
5.91	6.46	0.39	-0.55	-3.67	-2.42	0.27	-1.25
0.97	2.00	0.31	-1.03	1.30	2.28	0.34	-0.98
-4.00	-2.62	0.27	-1.38	6.27	6.78	0.37	-0.51
-9.00	-7.44	0.28	-1.56	11.16	11.19	0.42	-0.03
-13.92	-12.38	0.29	-1.54	16.00	15.57	0.45	0.43
-18.97	-17.64	0.32	-1.33	20.83	20.02	0.51	0.81
-23.96	-23.01	0.36	-0.95	25.72	24.60	0.64	1.12
-28.91	-28.48	0.36	-0.43	30.63	29.38	0.72	1.25
-33.93	-33.91	0.43	-0.02	35.54	34.29	0.81	1.25
-38.96	-39.21	0.46	0.25	40.38	39.25	0.88	1.13
-44.02	-44.17	0.42	0.15	45.14	44.25	0.95	0.89
-49.13	-48.67	0.40	-0.46	49.96	49.39	1.01	0.57

CONCLUSIONS

In this study, there is a difference in the output of the two equations for the YSI extended temperature range sensor. The manufacturer-recommended equation output has a maximum difference of 1.28° C from the Fluke calibrated standard. The current equation has a maximum difference from the fluke standard of 1.57° C. Both of these maximum differences occurred at the Fluke 0° C point. For some purposes, these deviations are not acceptable. A NRCS technical committee has been formed to address this issue. The desire is to increase accuracy and consistency by using another method, such as lookup tables, or have a series of equations that can better reflect the actual temperature.

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