TRANSFORMATION OF THE SNOTEL TEMPERATURE RECORD – METHODOLOGY AND IMPLICATIONS

Chris R. Brown[1], Brian Domonkos[1], Troy Brosten[1], Tony DeMarco[1], and Alex Rebentisch[1]

ABSTRACT

SNOTEL (SNOw TELemetry) sites collect voltage output data from in-situ temperature sensors (along with other environmental sensors) and transmit these values to the National Water and Climate Center (NWCC) where they are calculated into temperature values using a prescribed algorithm. Beginning in the 1990s, the YSI 44019A thermistor with the 44211A thermilinear package (the extended range YSI temperature sensor) replaced the YSI 44230 temperature sensor as the default temperature sensor deployed at SNOTEL sites because of its broader temperature range. Temperature was calculated from output voltage using a linear least-squares regression developed at the NWCC. There is a step shift in SNOTEL temperature data beginning in the late 1990s, thought to be caused primarily by the switch to the extended-range YSI temperature sensor and the associated algorithm to calculate temperature at SNOTEL sites. A working group within the Natural Resources Conservation Service Snow Survey and Water Supply Forecasting Program conducted an empirical study to characterize the extended range YSI temperature sensor and develop a polynomial algorithm to better calculate temperature from output voltage. The working group has proposed transforming the historical SNOTEL extended-range YSI sensor temperature record and incoming values using this new algorithm. SNOTEL temperature data is used by many public and private entities in varying ways and transforming the dataset could affect products or management decisions that have already been made. The working group would like to gather feedback from users of SNOTEL temperature data on the implications of transforming the historical dataset and incoming data. (KEYWORDS: SNOTEL, temperature correction, instrumentation changes, temperature sensor, thermistor)

INTRODUCTION

The U.S. Department of Agriculture Natural Resources Conservation Service Snow Survey and Water Supply Forecasting Program (the Snow Program) operates and maintains the SNOTEL (SNOw TELemetry) network, a network of over 800 automated sites in the western United States and Alaska that collect and transmit hydroclimatic data used by myriad users in varying ways. SNOTEL sites collect voltage output data from in-situ temperature sensors (along with other environmental sensors) and transmit these values to the National Water and Climate Center (NWCC) in Portland, Oregon where they are calculated into temperature values using a prescribed algorithm (the SNOTEL algorithm) (Equation 1). Beginning in the 1990s, the YSI 44019A thermistor with the 44211A thermilinear package (the extended range YSI temperature sensor) replaced the YSI 44230 temperature sensor as the default temperature sensor deployed at SNOTEL sites because of its broader temperature range (YSI, 2001). Temperature was calculated from output voltage using a linear least-squares regression developed at the NWCC. There is a step shift in SNOTEL temperature data beginning in the late 1990s, thought to be caused primarily by the switch to the extended-range YSI temperature sensor and the associated algorithm to calculate temperature at SNOTEL sites (Julander and Beard, 2007; Harms, et al., 2016). The Snow Program formed a working group to characterize the bias in calculated temperature values caused by the SNOTEL algorithm. Herein, the empirical study conducted by the working group and the results from that study are described.

$$T = V * 77.78 - 65.929 \tag{1}$$

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[1]Chris R. Brown, NRCS Snow Survey and Water Supply Forecasting Program, Portland, OR, chris.r.brown@por.usda.gov
[1]Brian Domonkos, NRCS Snow Survey and Water Supply Forecasting Program, Denver, CO, Brian.Domonkos@co.usda.gov
[1]Troy Brosten, NRCS Snow Survey and Water Supply Forecasting Program, Salt Lake City, UT, troy.brosten@usda.gov
[1]Tony DeMarco, NRCS Snow Survey and Water Supply Forecasting Program, Palmer, AK, anthony.demarco@usda.gov
[1]Alex Rebentisch, NRCS Snow Survey and Water Supply Forecasting Program, Portland, OR, alexander.rebentisch@usda.gov

METHODS

An empirical test was designed and executed to compare the extended-range YSI thermistor to high-precision reference temperature in a laboratory setting. The effects of using the SNOTEL algorithm to calculate thermistor temperature were characterized.

Testing Procedures

Nineteen extended-range YSI thermistors were collected from four Snow Program data collection offices. The testing sample set included 7 new and 12 previously deployed thermistors with deployment durations for the latter ranging from ~6 years to ~16 years. The thermistors were tested in a dry-well calibrator in groups of five and compared to a high-precision platinum resistance thermometer (PRT) (Figure 1a&b). The PRT was used as the reference temperature for the calibrator and for comparison to the thermistors in test. The calibrator was programmed to ascend or descend in temperature in 2ºC increments from 50ºC to -56ºC, stabilizing for 20 minutes at each increment. Reference temperature and thermistor output voltage was collected on a data acquisition platform at each temperature increment (Figure 1a). Each thermistor was tested through the entire temperature range in three separate test iterations. Thermistor hysteresis was checked by recording output voltage during temperature ascension followed immediately by descension and comparing the output voltages from the same temperature setpoints. Self-heating in the excited thermistors was negligible in such a small, homogeneous testing chamber (Figure 1b).

Data Processing

Temperature was calculated from output voltage using the SNOTEL algorithm (Equation 1) and compared to the reference temperature. The relationship between thermistor output voltage and reference temperature was calculated as a polynomial function. A 5th-order polynomial was chosen for parsimony, as there is miniscule root mean squared error (RMSE) improvement with higher-order polynomials (Helsel and Hirsch, 2002).

a)  b) 

Figure 1. a) Temperature test setup: dry-well calibrator, platinum resistance thermometer, data acquisition hardware, thermistors in test. b) Close-up of dry-well calibrator test chamber and insert.

RESULTS

Thermistor temperature was calculated from output voltage using the SNOTEL algorithm and compared to the reference temperature (Figure 2). Temperature errors (reference minus calculated) ranged from ~ -3ºC to ~ +1.5ºC, with the largest errors existing along the temperature band around -56ºC, 15ºC, and 30ºC. Calculated root mean squared error (RMSE) for the entire empirical dataset (n = 3024) is 0.9996ºC. The relationship between the reference temperature and thermistor temperature calculated using the SNOTEL algorithm can be expressed by a polynomial function of this form:

$$T = 48.804367 * V^5 - 237.574607 * V^4 + 423.203863 * V^3 - 334.306517 * V^2 + 190.740828 * V - 79.098511 \quad (2)$$

T is calculated temperature and V is thermistor output voltage. A 5th-order polynomial function was chosen for the sake of parsimony, as the RMSE of the dataset was negligibly better using higher-order polynomial functions (Figure 3). Equation 2 can be used to calculated thermistor temperature from output voltage for the extended-range YSI thermistor. Recalculating temperature values for the historic SNOTEL temperature dataset would negate all data edits administered at the Snow Program Data Collection Office level. To maintain temperature data edits, a relationship between temperature calculated using Equation 2 and temperature calculated using the SNOTEL algorithm was created:

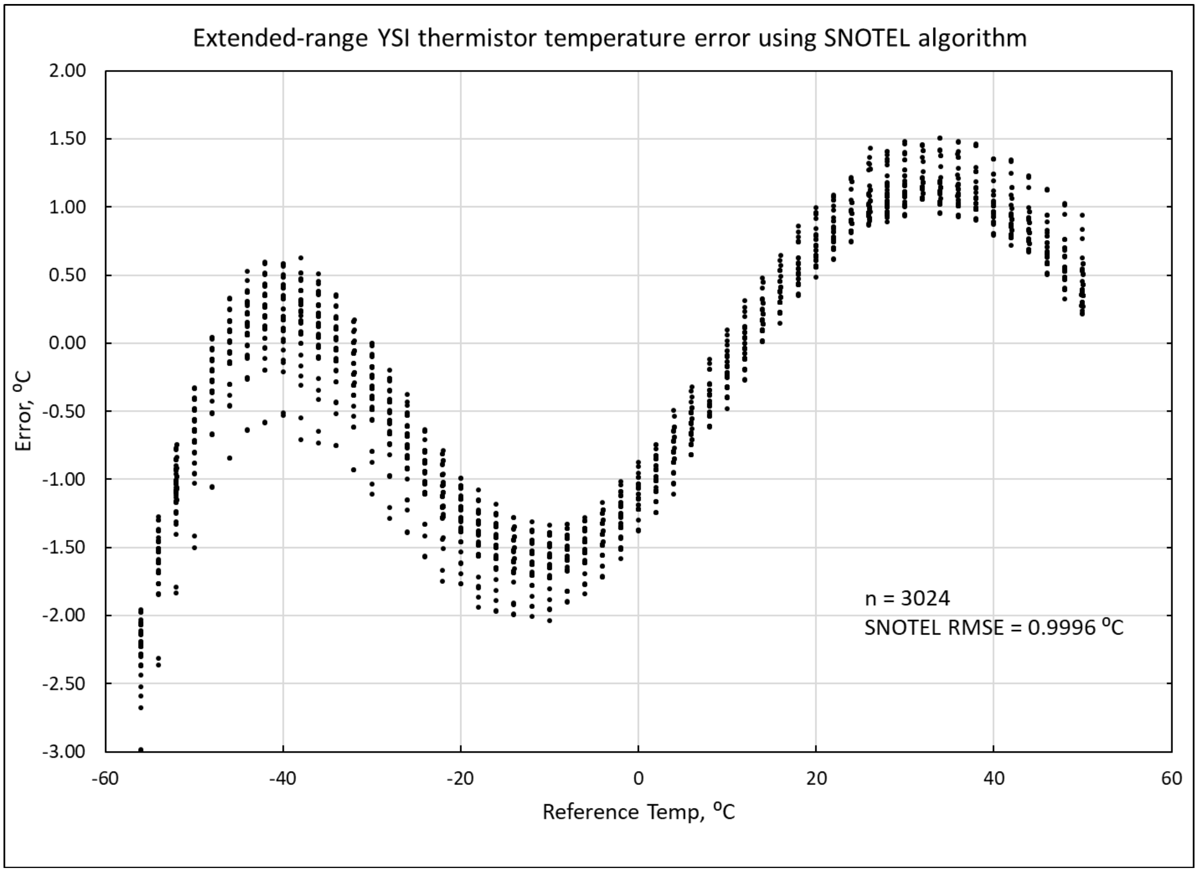

Figure 2. Difference between temperature calculated using the SNOTEL algorithm and the reference temperature.

$$T_C = 0.00000002 * T^5 - 0.00000084 * T^4 - 0.00006726 * T^3 + 0.00246670 * T^2 + 1.07255015 * T - 1.16329887 \quad (3)$$

T_C is the "corrected" calculated temperature and T is the historic SNOTEL temperature value (Figure 4). Using the polynomial function devised in this study brings the RMSE for the empirical dataset down to 0.1958ºC (Figure 5).

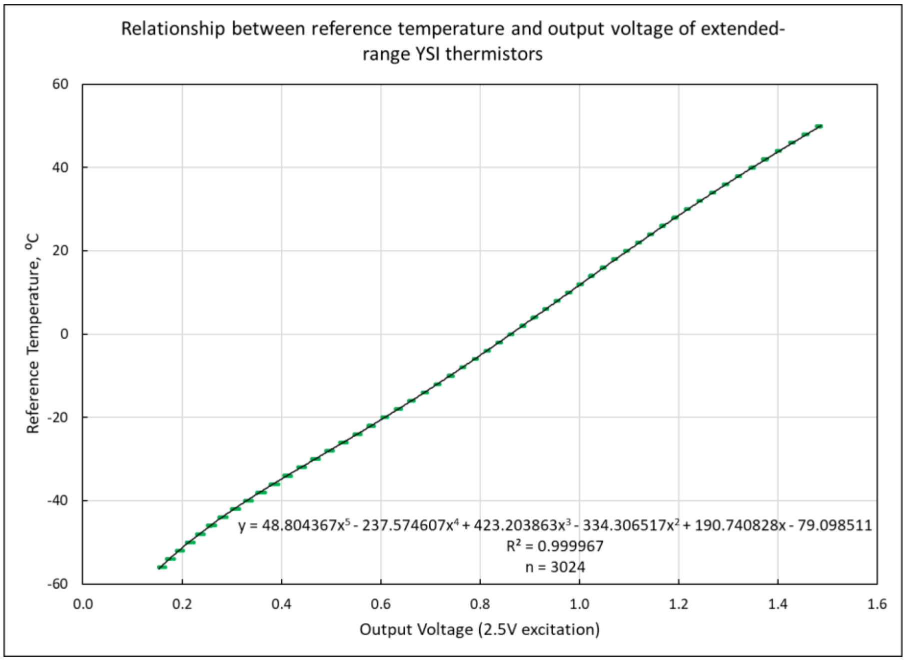

Figure 3. Relationship between the reference temperature and the output voltage of the extended-range YSI thermistors.

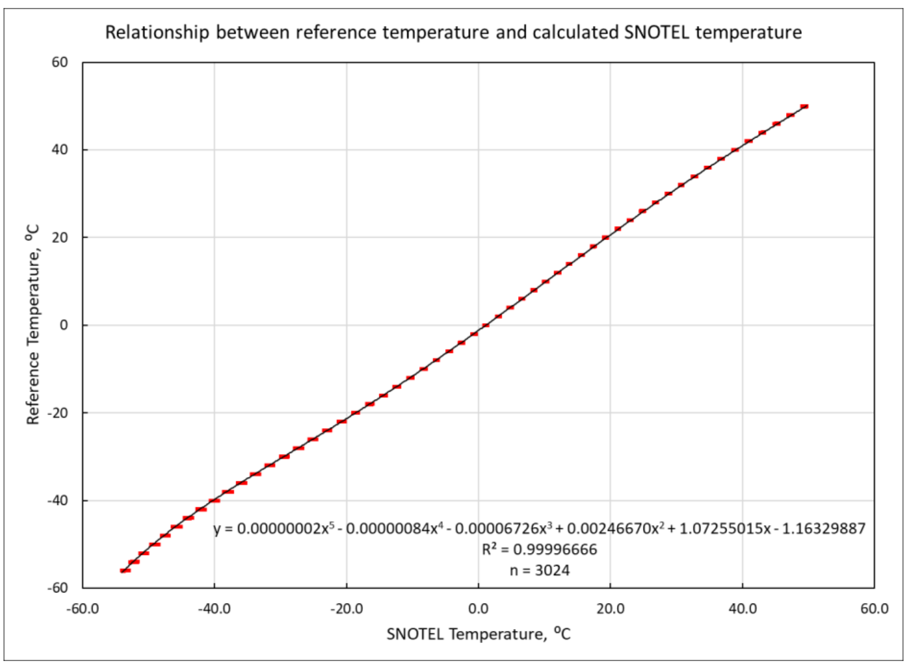

Figure 4. Relationship between the reference temperature and temperature calculated from thermistor output voltage using the SNOTEL algorithm.

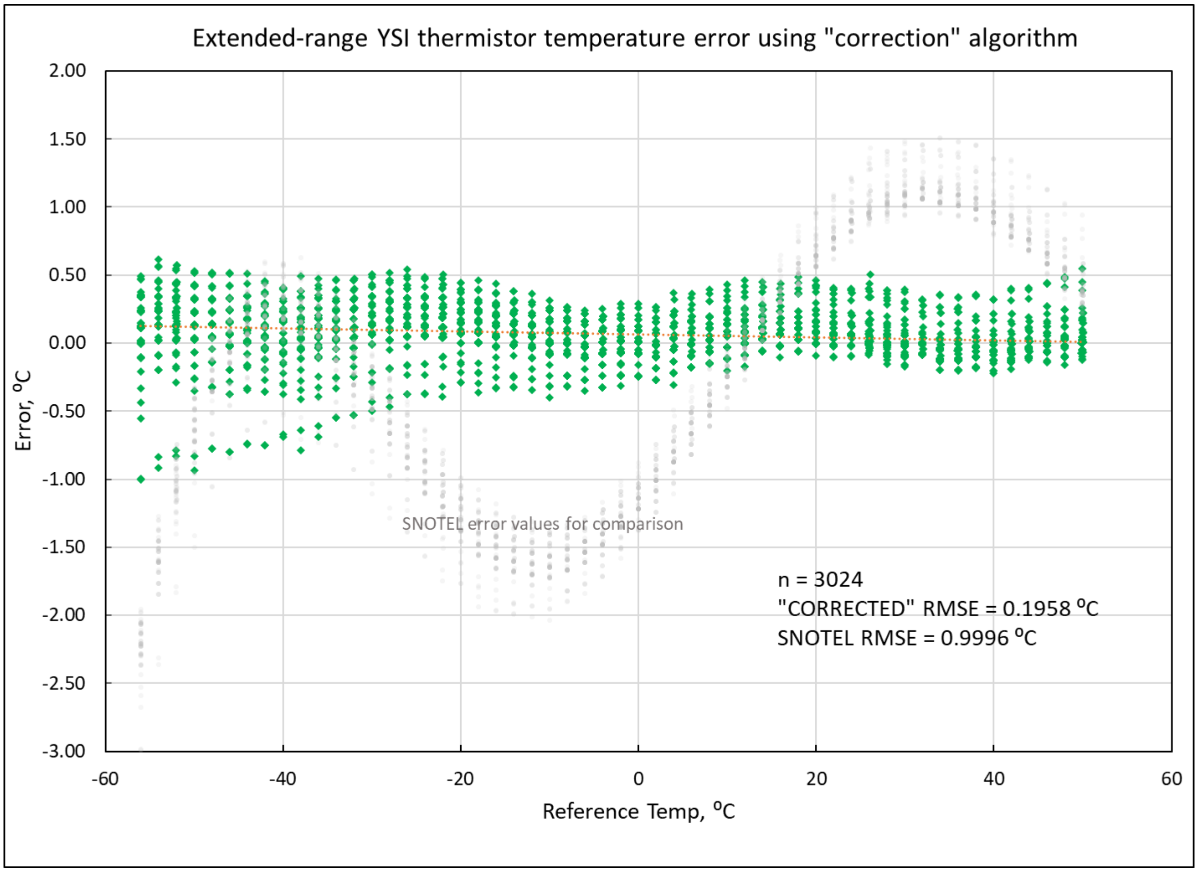

Figure 5. Difference between temperature calculated using the algorithm developed in this study and the reference temperature.

A random SNOTEL site was chosen (Whiskey Creek SNOTEL, 858) (Figure 6) and a portion of the historic extended-range YSI temperature data was transformed using Equation 3.

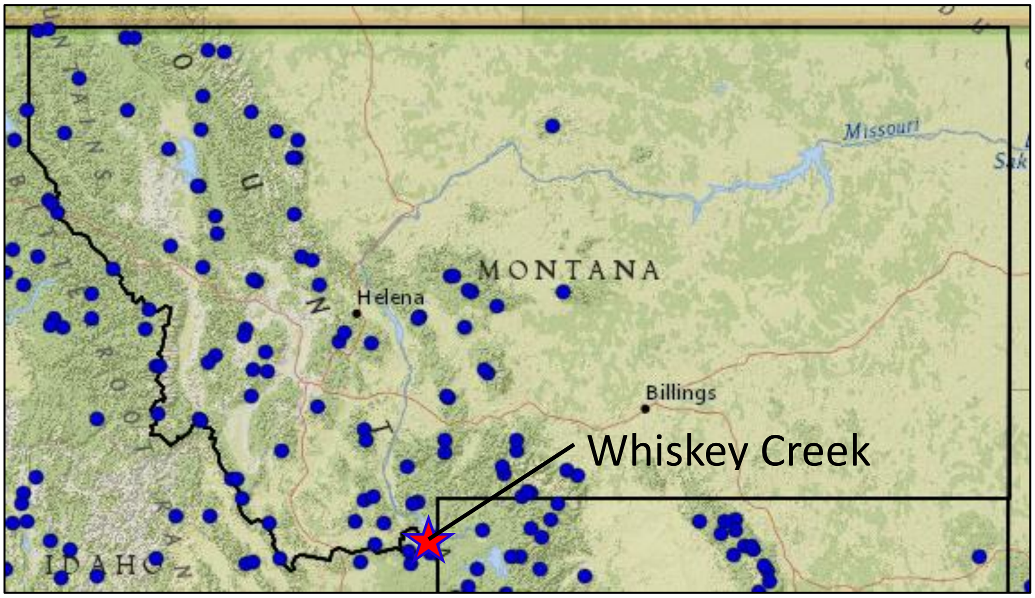

Figure 6. Map showing the location of the Whiskey Creek SNOTEL site within Montana.

Figures 7, 8 and 9 show historic temperature data at Whiskey Creek SNOTEL plotted concurrently with “corrected” temperature data calculated with using eq. 3. Depending on what part of the temperature band the data fall, the “corrected” temperature can be hotter or colder than the original value.

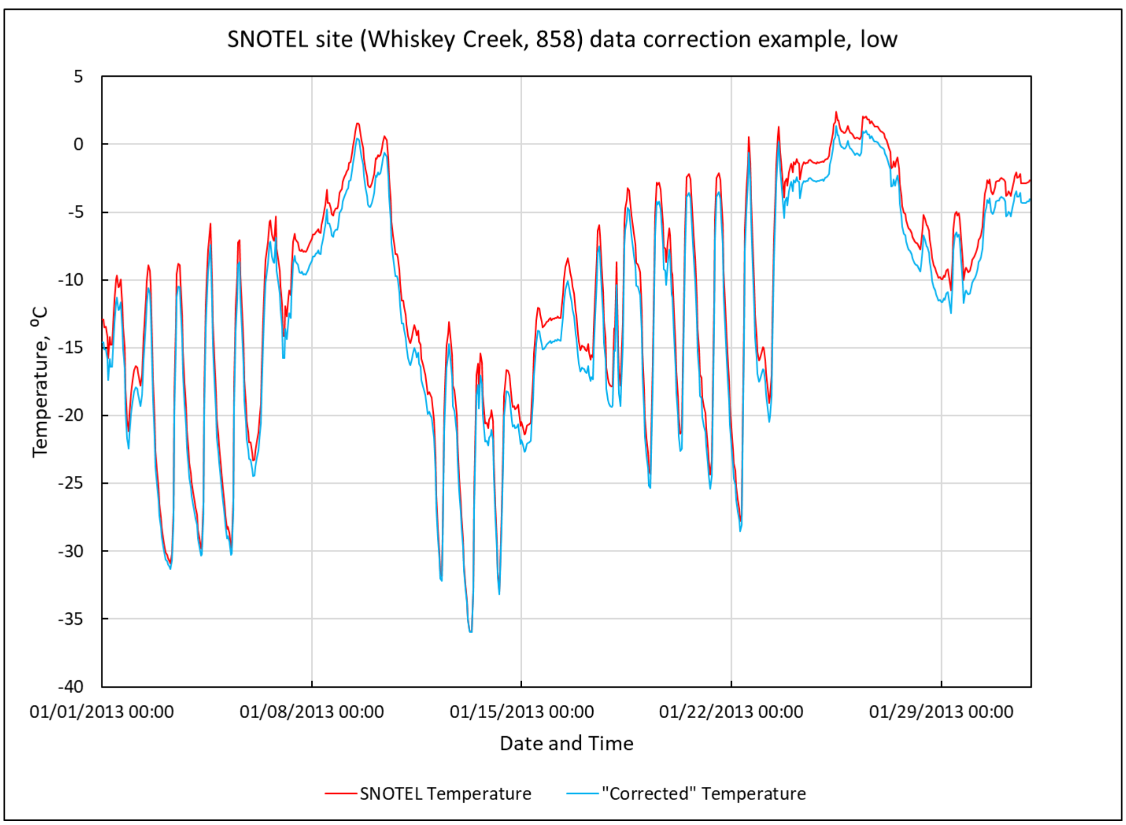

Figure 7. Transformation of historic temperature data from the Whiskey Creek SNOTEL site, low-range temperature values.

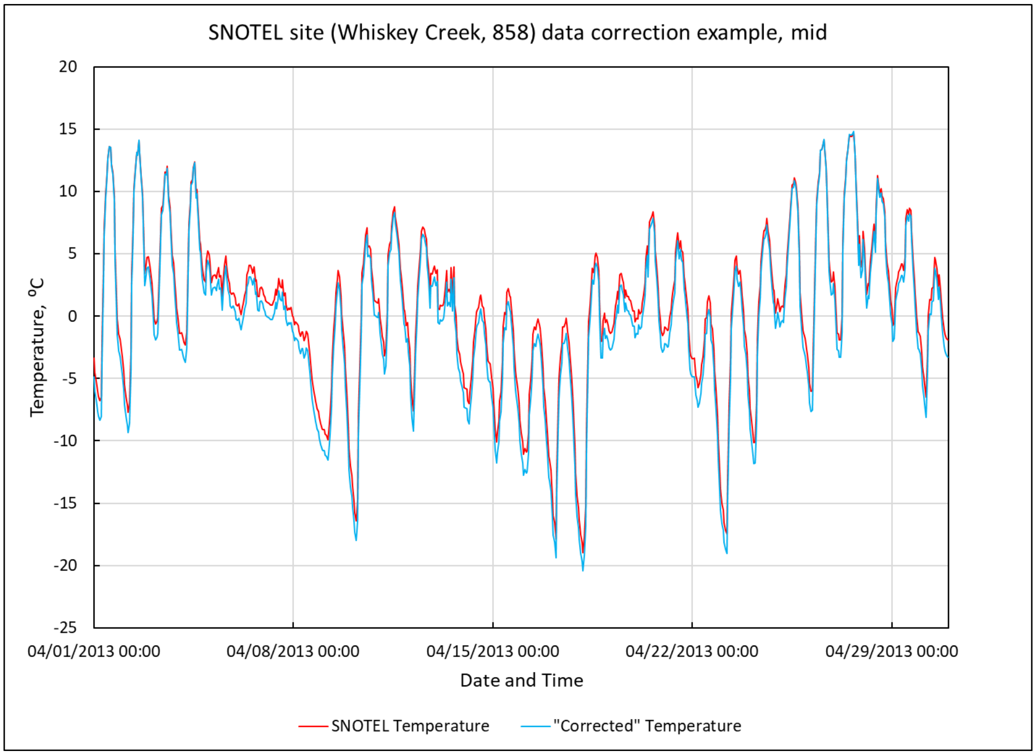

Figure 8. Transformation of historic temperature data from the Whiskey Creek SNOTEL site, mid-range temperature values.

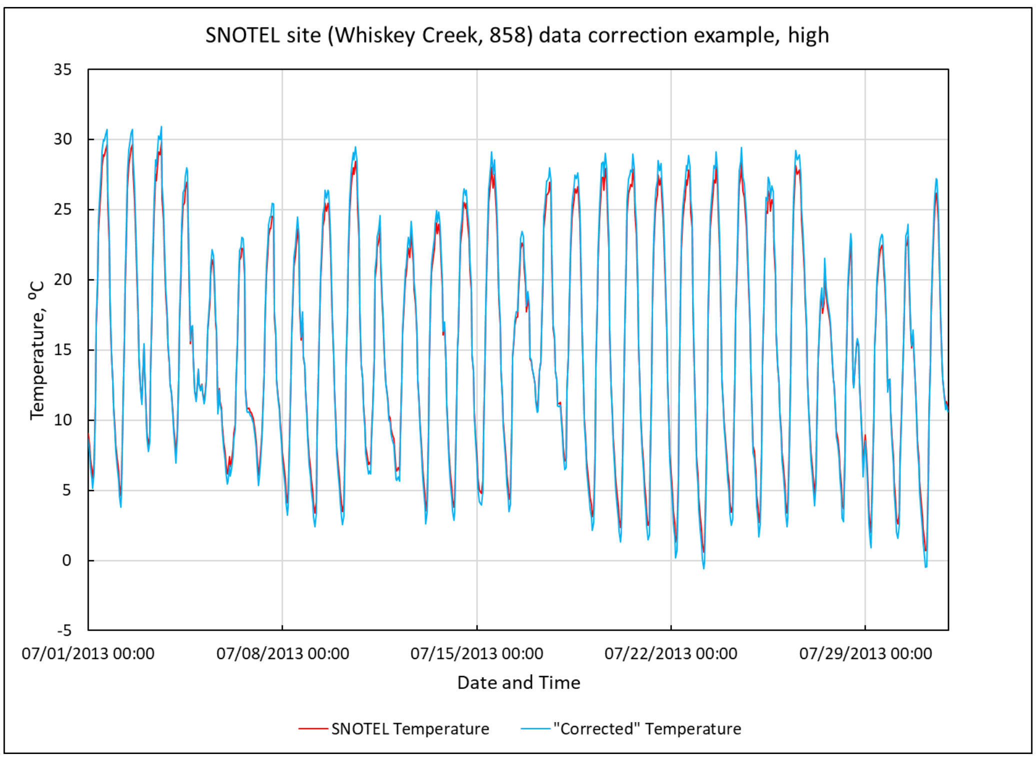

Figure 9. Transformation of historic temperature data from the Whiskey Creek SNOTEL site, high-range temperature values.

IMPLICATIONS AND CONCLUSIONS

A working group within the Snow Program conducted an empirical study to characterize the extended range YSI temperature sensor and develop a polynomial algorithm to better calculate temperature from output voltage (Equation 2). An algorithm to transform historical SNOTEL temperature values has also been developed (Equation 3). The working group has proposed transforming the historical SNOTEL extended-range YSI sensor temperature record and incoming values using this new algorithm. The new algorithm can be used only for transformation of temperature data from the extended-range YSI thermistor. Only the bias created by calculating temperature using the SNOTEL algorithm can be mitigated, differences in individual site physics, i.e., sensor placement, thermistor shield choice, effects from solar radiation, etc., were not addressed (USDA, 2010; USDA, 2015). SNOTEL temperature data is used by many public and private entities in varying ways and transforming the dataset could affect products or management decisions that have already been made. The working group would like to gather feedback from users of SNOTEL temperature data on the implications of transforming the historical dataset and incoming data.

REFERENCES

Harms, D.S., Seybold, C.A., Weeks, J., and Lea, Jolyne. 2016. Comparing a SNOTEL extended-range air temperature sensor and equations to a NIST-certified sensor in an environmental chamber, Proceedings of the 2016 Western Snow Conference, p. 123–128.

Helsel, D.R., and Hirsch, R.M. 2002. Statistical methods in water resources, Techniques of Water-Investigations of the USGS, Book 4, Chapter A#, 524 p.

Julander, R.P., Curtis, J., and Beard, A. 2007. The SNOTEL temperature dataset, Mountain Views: Newsletter of the Consortium for Integrated Climate Research in Western Montana, v. 1(2), p. 4–7.

U.S. Department of Agriculture, Natural Resources Conservation Service. 2010. National Engineering Handbook, Part 622, Snow Survey and Water Supply Forecasting, Chapter 2: Data Parameters, 18 p.

U.S. Department of Agriculture, Natural Resources Conservation Service. 2015. National Engineering Handbook, Part 622, Snow Survey and Water Supply Forecasting, Chapter 8: Standards and Specifications, 159 p.

YSI Integrated Systems and Services. 2001. <http://www.farnell.com/datasheets/169207.pdf>, accessed 12 April 2019.