Evaluation of the Stevens Hydra Probe's Temperature Measurements from -30 to 40 Degrees Celsius

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Abstract

Three prototype Stevens Hydra Probes were modified to accurately measure soil temperatures from -30^o to 40^o Celsius. The three prototype sensors were placed in an environmental chamber capable of maintaining constant temperatures in the range of interest. Temperature measurements were obtain by the three Hydra Probes at various temperatures within the range and compared to that of a standard thermistor. The Pearson correlation coefficient (R^2) was used to quantify the performance of the Hydra Probes' measurements in the selected range. The coefficient of variation (CV) and a 99% confidence interval were the statistical tools used to quantify the precision of the measurements. The R^2 values were found to be 0.99943 and the precision under a normal 99% confidence interval (1<CV) was +/- 0.26^o C.

Introduction

Soil temperature data down to -30^o Celsius is becoming more and more relevant to climate studies. While environmental issues fuel the development and the wide spread use of sophisticated environmental models, reliable input data is becoming essential for researchers and modelers. The soil temperature data collected by the Hydra Probe can be used in climate studies in artic regions, regional energy budget calculations, drought forecasting and heat fluxes. It is the intent of Stevens Water Monitoring Systems to provide the scientific community a reliable and cost effective soil temperature sensor to suit the needs of environmental researchers.

Sensor and Experimental Design

The Hydra Probe uses a thermistor powered by a 5 volt reference voltage (V_{ref})in series with a resistor to calculate the soil temperature from the V_5 parameter by the equation:

$$Rt = RV_5 / (V_{ref} - V_5) \qquad [1]$$

Where Rt is the temperature dependent resistance of the thermistor in ohms and R is the resistance of the resistor in series with the thermistor. With the resistance at 25 degrees Celsius (R_{25}) the temperature can be calculated from the fifth voltage (V_5) by

$$1/T=a+b(\text{Ln } Rt/R_{25})+c(\text{Ln } Rt/R_{25})^2+d(\text{Ln } Rt/R_{25})^3 \qquad [2]$$

Where a, b, c, and d are coefficients provided by the manufacture of the thermistor. From equations 1 and 2, the V_5 parameter on the Hydra Probe can be converted into temperature. This design will provide a working temperature range of -30° to 40° Celsius

In order to calculate the precision, and the accuracy of the probes, three probes were place in a temperature controlled environmental chamber with a calibrated accurate thermistor. The chamber was set to temperatures from -30° to 40° Celsius and incremented every 5 degrees Celsius. The Probe and the standard thermistor were allowed to equilibrate for one hour after a temperature change.

Materials

Three SDI-12 Digital Hydra Probes were retrofitted with 200 kΩ resistors in series with a Type F thermistor. The data collection platform was a Stevens DOT Logger. A LRE Tenney Environmental Chamber was used to maintain and manipulate the temperature range of interest and a calibrated Fluke 77 Series II Multi Metter with a 80t-150U Temperature probe was used as a reference thermometer.

Results and Discussion

The Pearson Correlation Coefficient (r^2) was used to quantify the accuracy the Hydra Probes compared to that of the thermistor. The confidence limit (CL) using a 99% confidence interval can be calculated by:

$$99\%CL = \mu \pm z\sigma / N^{1/2} \qquad [3]$$

Where z for a 99% confidence interval is 3.29, σ is the standard deviation of the population and N is the degrees of freedom. The CV Coefficient of variation can be defined as:

$$CV = \sigma/\mu \qquad [4]$$

Where μ is the mean. A CV value less than one is accepted as being low variance.

The r^2 for the entire range was found to be 0.99943. Table shows the precision results for the three Hydra Probes at three different temperature with six degrees of freedom. Figure 1 shows the plot for the entire range.

Reference Temperature	-29.4° C	20.8° C	-1.9° C
N	6	6	6
Sample Average	-29.89	20.28	-1.84
99% CL	+/- 0.19	+/- 0.26	+/-0.13
CV	<0.01	<0.01	<0.01

Table 1. 3 Hydra Probes measuring Temperature at 3 temperatures

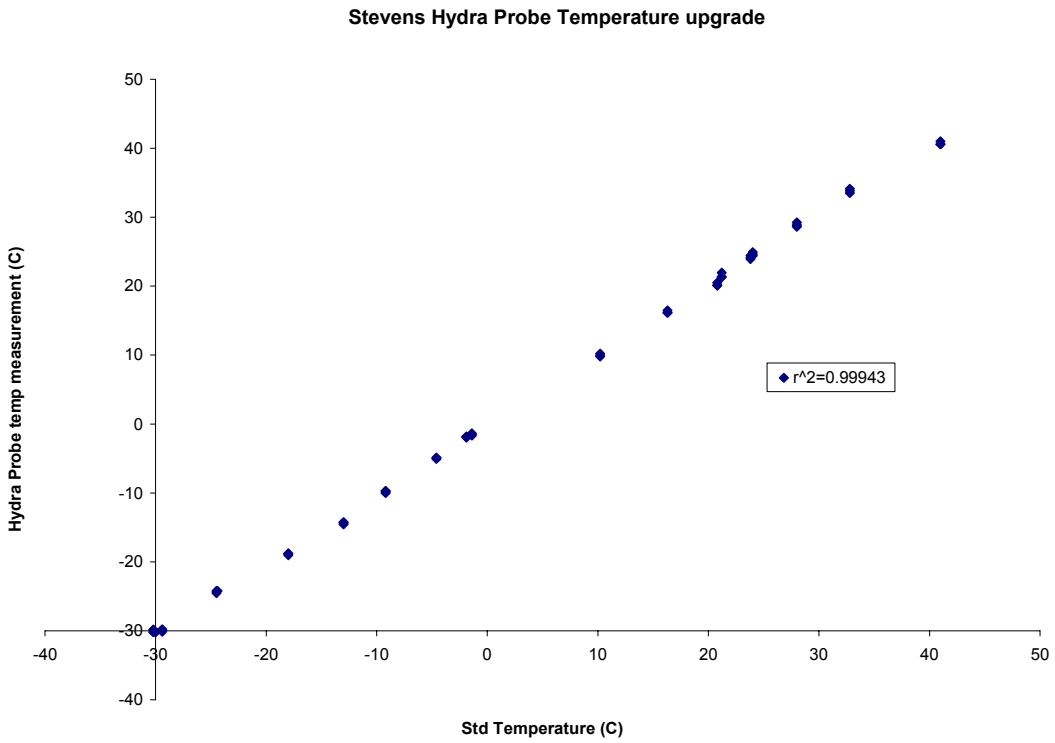

Figure 1. Plot of Hydra Probe Proto Type vs. a Standard thermistor.

Conclusion

This Stevens Hydra Probe prototype accurately measured temperatures from -30^{o} to +40^{o} C (CV>0.01) and was found to be +/- 0.26^{o} C under a normal 99% confidence interval. This proto type was found to have excellent correlation to that of a reference with an r^2 of 0.99943

References

Skoog, D. A., J. J. Leary. Priniples of Instrumental Analysis, 4th ed. 1992

Taylor, J. R., The Study of Uncertainties in Physical Measurements, An Introduction to Error Analysis. 1982