Comparison of Two Ground Temperature Measurement Techniques at an Interior Alaskan Permafrost Site

Charles M. Collins, Richard K. Haugen, and Timothy O. Horrigan

US Army Cold Regions Research and Engineering Laboratory
Hanover, New Hampshire 03755-1290

Two temperature measurement systems, a string of Chinese-fabricated mercury thermometers and a thermistor assembly, were installed in adjacent boreholes drilled in fine-grained, perennially frozen silt. The Chinese thermometers were provided by the Chinese Academy of Railway Sciences, Lanzhou. The thermometers read to 0.1 °C, and were supplied with correction tables also to 0.1 °C. The thermometers were assembled into a linear string to replicate, as closely as possible, the thermometer strings that are commonly used in China for monitoring ground temperatures. The sensors were installed at the Caribou-Poker Creeks Research Watershed in interior Alaska (65° 10' latitude, 147° 30' longitude). The thermometers were placed at the surface and at -0.6, -1.2, -2.1, -3.0, -4.5, -6.0, -9.0, and -10.0 m, with insulating spacers placed between each thermometer. The cable was suspended in air in a 5-cm-diameter casing installed in a 10-m-deep borehole. The thermometers were pulled from the hole periodically to obtain the temperature readings. The thermistor cable consisted of an assembly of YSI 4407 glass bead thermistors placed at the surface and at -0.3, -0.6, -0.9, -1.2, -1.5, -2.1, -3.0, -4.5, -6.0, -9.0, and -10.0 m. The assembly was inserted in a similar 5-cm-diameter casing installed in a 10-m borehole located 30 cm from the thermometer string. The pipe containing the thermistors was filled with silicon fluid and capped. The cable was extended some distance from the pipe to avoid surface disturbance. Simultaneous measurements were made on the thermometer string and the thermistor assembly over three years. The thermistor string remained undisturbed within the silicon fluid environment. The thermometer string, suspended in air with the insulating spacers, was removed each time a series of readings was made.

For statistical analysis, we grouped these depths into three zones: the upper 1.2 m, the middle range from 2.1 m down to 4.5 m, and the lower from 6.0 m down to 10.0 m. During the summer months of 1988 and 1989 (Fig. 1), the thermometers yielded higher readings (as much as 1.5 °C higher). Conversely, during the winter months, the thermometer readings were lower. The pattern of seasonal differences was not evident during the final year of the test evaluation (1990). In the middle zone (2.1 m through 4.5 m), the pattern was similar, warmer during the warmer months, and slightly cooler during the cooler months. The warmest period of the year at this zone occurs during the late fall. The thermometer readings for this middle zone are skewed upwards only during the warmer period (during the summer and fall) and not during the winter cooling period. Below 6.0 m (Fig. 3), the two time-series for the lower zone were almost parallel to each other. The thermometer readings were higher than the thermistor readings by an average of 0.17 °C, suggesting that the calibration of the thermometers was higher than that of the thermistors. (The average differential between thermometer and thermistor readings was 0.17 and 0.18 °C in the top and middle zones.) Figure 4 shows the time series of the differences between the thermometer and thermistor readings. The upper and middle zones show seasonal patterns of difference for most of the record; the lower zone is stable in this regard.

We attribute the minor differences in measured values between the two sensor types to an apparent difference of about 0.17°C in calibration between the two sensors, and a possible influence of ambient air temperature on the mercury thermom-

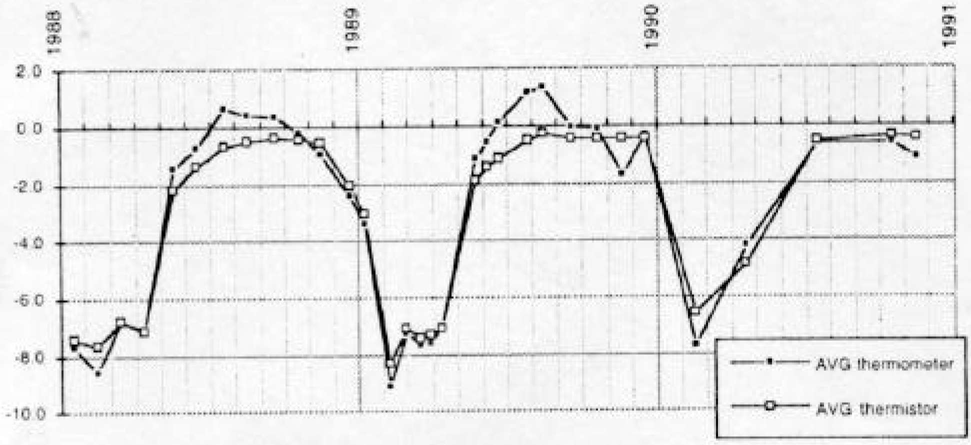

Figure 1. Average temperatures (°C), top 1.2 m, thermometer & thermistor methods.

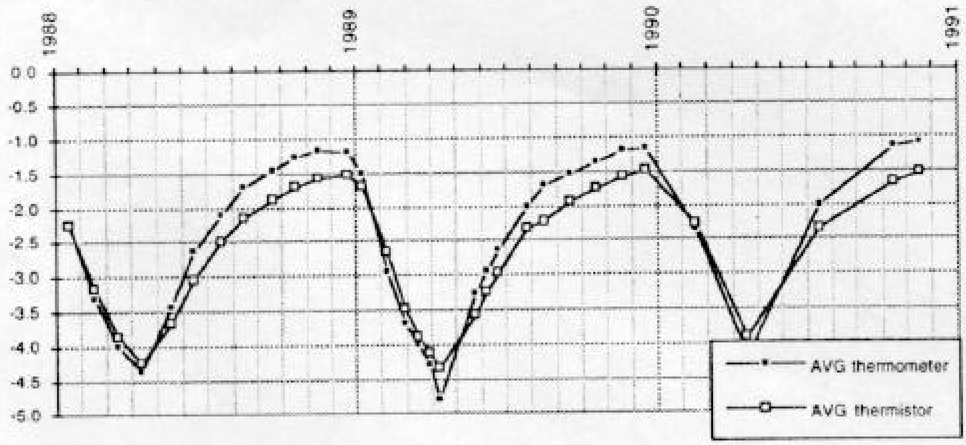

Figure 2. Average temperatures (°C), 2.1 through 4.5 m, thermometer & thermistor methods.

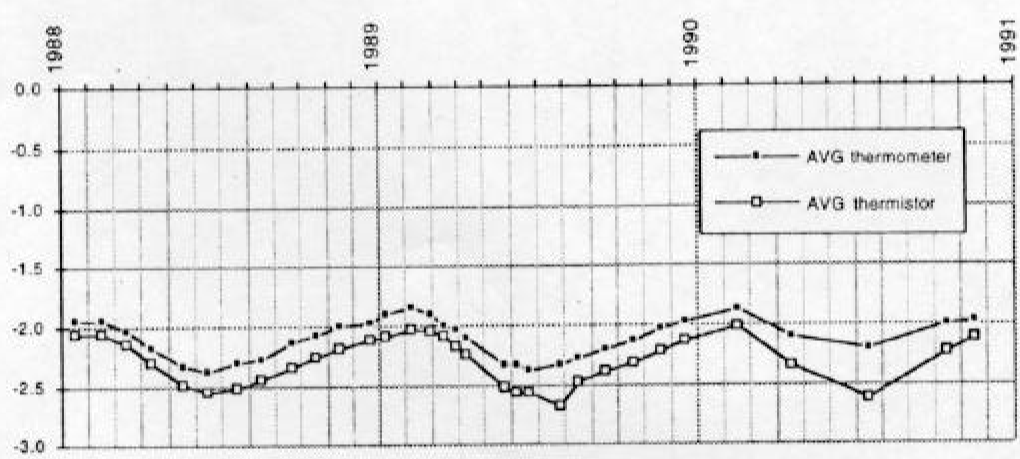

Figure 3. Average temperatures (°C), below 6.0 m, thermometer & thermistor methods.

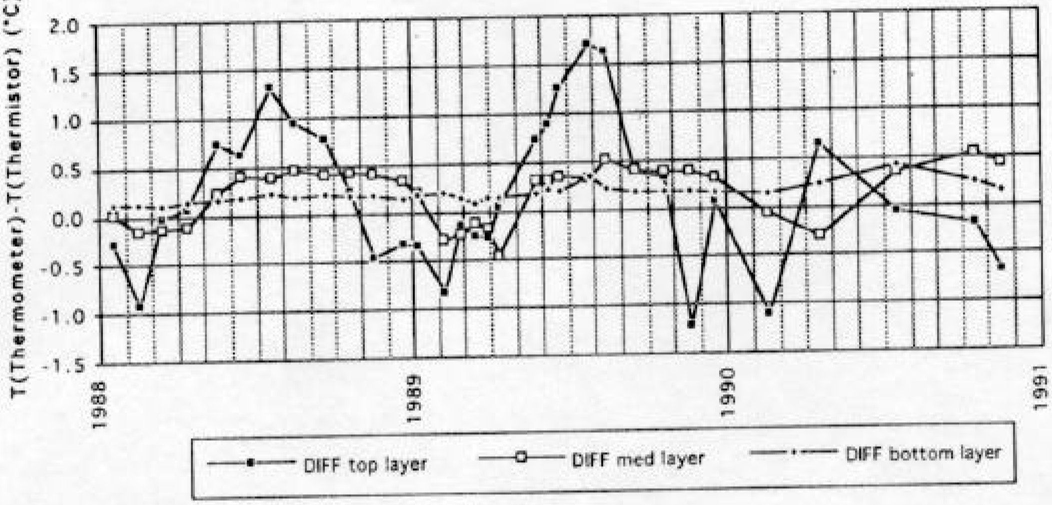

Figure 4. Difference between thermometer and thermistor readings.

eters at the time of reading. Average annual ground temperatures calculated based on the thermometers and the thermistors were within 0.01°C for all levels if the apparent calibration difference is taken into account. We conclude therefore that only minor differences exist between the two types of ground temperature measurements. Our Chinese colleague, Ding Jingkang, has obtained a similar set of data at the Fenghuoshan Permafrost Research Station on the Qunghai Xizang Plateau.