Ground Temperature Measurement Frequency

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This presentation is based on

Riseborough, D.W. and M.M. Burgess, 1996. Measurement interval and the accurate assessment of ground temperature trends. *Permafrost and Periglacial Processes, v*ol 7 no 4, pp. 321-336.

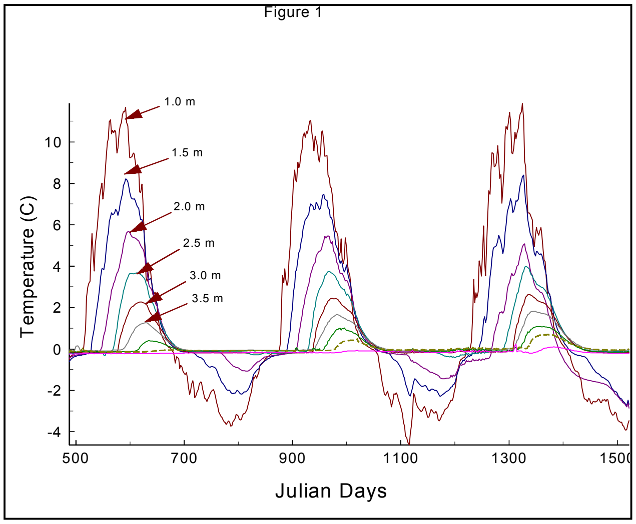
The increasing availability and decreasing cost of automatic data acquisition has mad the issue of measurement frequency less urgent in many situations: The cost of datalogger channels relative to the cost of sensors on temperature cables continues to decrease. An assessment of the relationship between measurement interval and the precision with which seasonal and mean annual temperatures can be specified remains important in at least three situations:

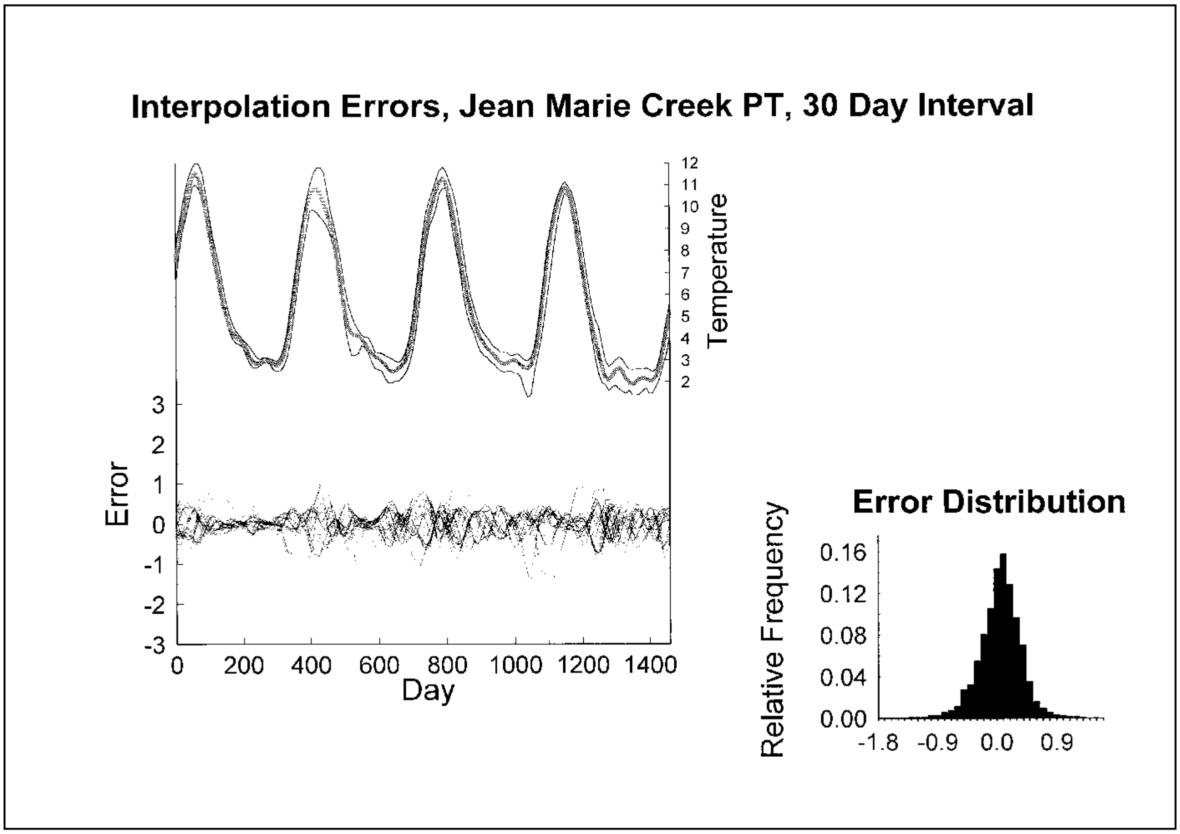
- when using existing long term monitoring records;
- in evaluating the effect of gaps in high frequency data due to failure of the data acquisition system; and
- when the design of a monitoring program makes the use of automatic data acquisition impractical (such as spatially dispersed sampling).

Between the depths of zero ***daily*** amplitude and zero ***annual*** amplitude, the filtering effect is strongly dependent on depth in the ground (Riseborough 1990), so that the reliability of the time series and of the mean annual temperatures derived from it increases with depth. The paper cited above demonstrated that the depth-reliability effect is reasonably predictable.

Test data were collected from a thermistor cable connected to a data acquisition system (64 channel Sea-Data logger Model 1250) as part of the Norman Wells Permafrost and Terrain Research and Monitoring Program at site 2A at Canyon Creek, 19 km from Norman Wells. Figure 1 shows the temperature data, characterized by a decreased temperature range and a smoother temperature trend at increasing depths, with an active layer extending over 4.5 m. The 1m and 1.5 m sensors exhibit significant short-term variation at time scales less than a month, while the deeper sensors show little short-term variability. Sensor calibration drift

Figure 1




Interpolation Errors, Jean Marie Creek PT, 30 Day Interval
Temperature
Error
Day
Error Distribution
Relative Frequency
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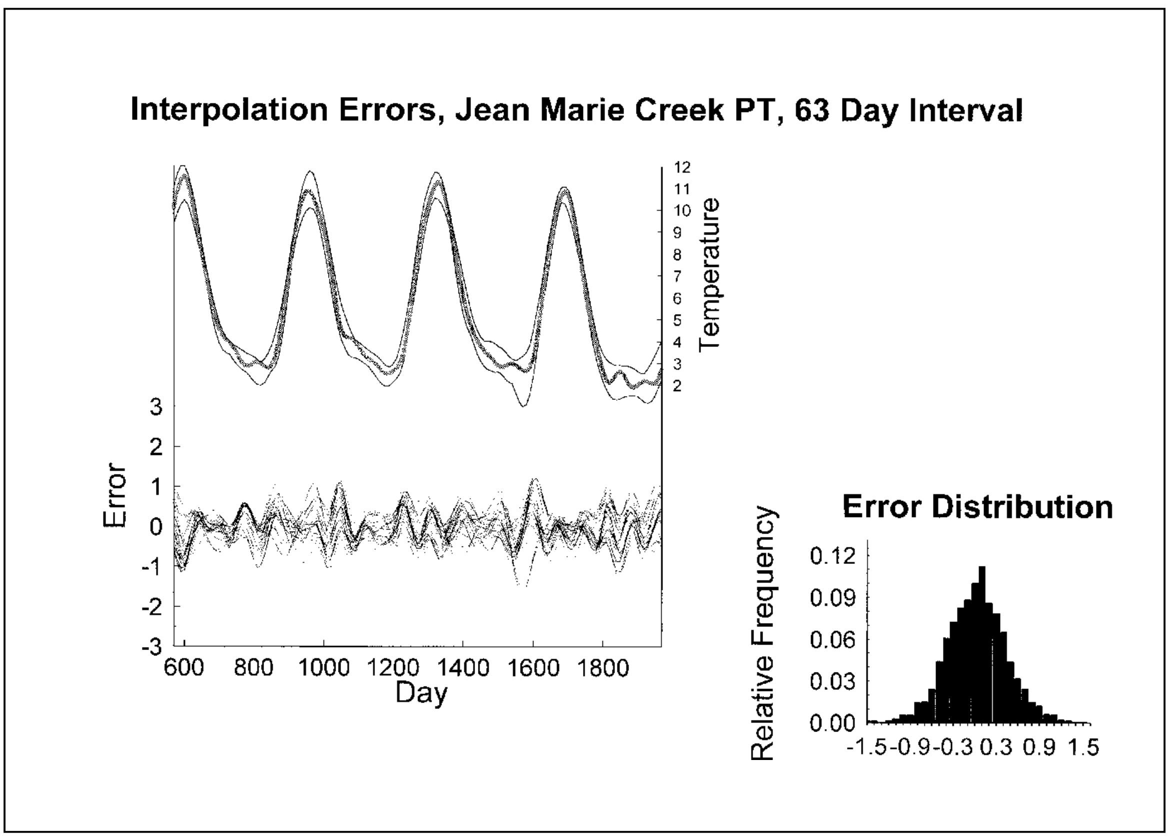
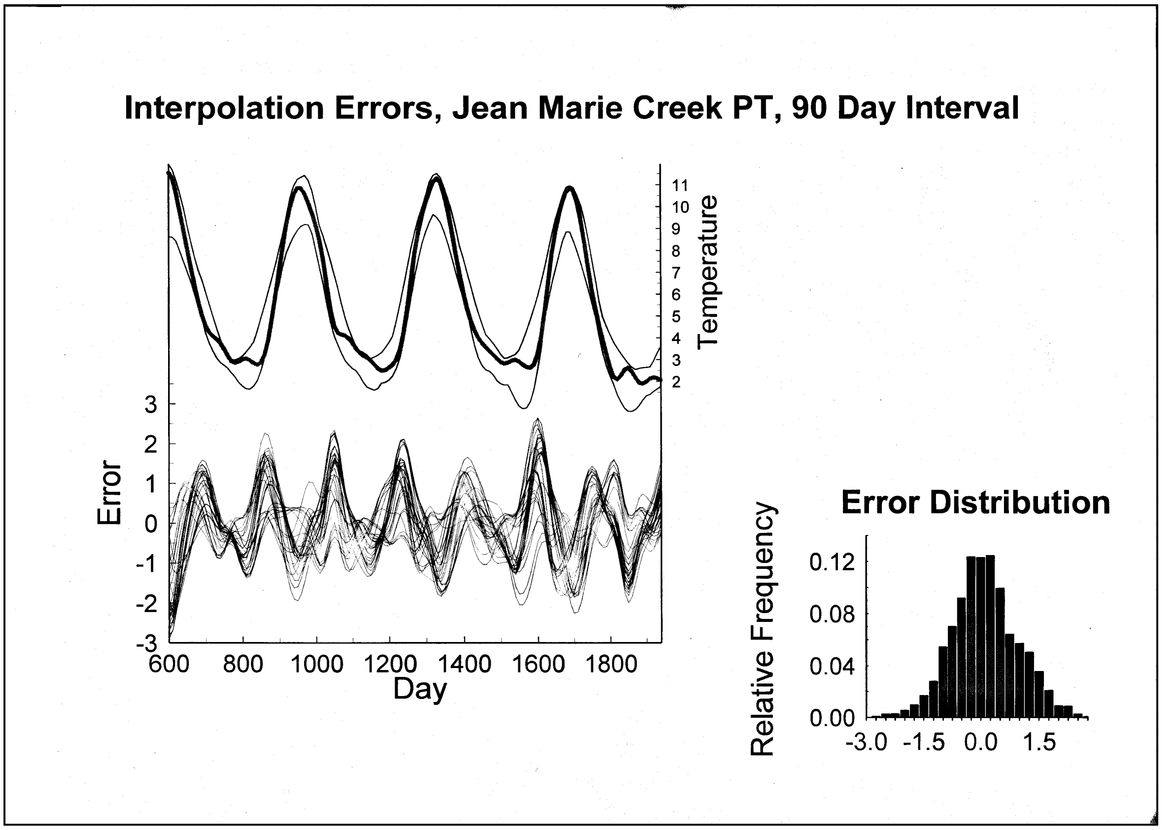
0.12
0.08
0.04
0.00
-1.8 -0.9 0.0 0.9


Interpolation Errors, Jean Marie Creek PT, 63 Day Interval
Temperature
Error
Day
Error Distribution
Relative Frequency
0.12
0.09
0.06
0.03
0.00
-1.5 -0.9 -0.3 0.3 0.9 1.5



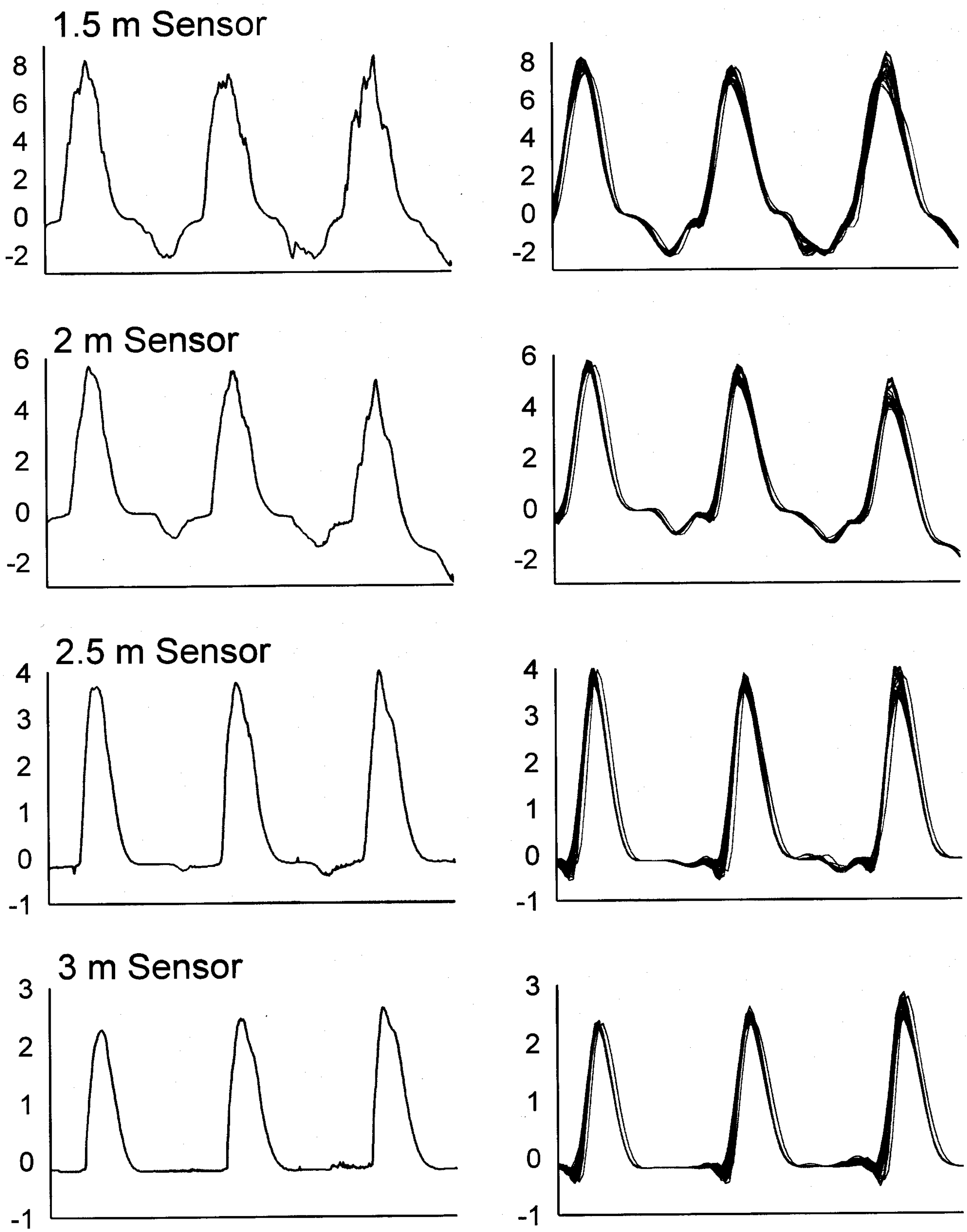
over time is apparent at 2 m depth as an increasing departure from the trends in neighbouring sensors.
The approach used was to create multiple sets of measurements at measurement frequencies of 28 to 90 days by sampling from the complete data logger record. Soil temperatures were then estimated between measurements using cubic spline interpolation and Mean annual temperatures were calculated from the coefficients of the spline equations. By repeatedly producing different low frequency subsets with a given (long term average) measurement interval, uncertainty and errors could be summarized using standard statistical measures (averages and standard deviations).

Figures 2-4 show typical results for one sensor at different intervals, while figure 5 shows results for several sensors at one interval. Some general features are evident:

- At all depths, the average uncertainty in the interpolated temperature curves (that is, the spread between the highest estimate and the lowest estimate at any point in time) is fairly constant as a proportion of the total temperature variation at each depth.

- The spread in uncertainty tends to be greatest where the change in curvature of the underlying temperature curve is greatest.

Canyon Creek Cable 2A-T1
30 Day Sampling Interval



- Short term temperature variations, due either to actual temperature change nearer the ground, or to datalogger "noise" have an erratic influence on the family of curves at each depth. Most "manual" measurement sets will miss these deviations from the long-term trend, but those that do include them are significantly different from the majority of the curves.

- The range between the highest and lowest temperatures for each sensor declines with depth, due to the increasing smoothness of the temperature wave as well as the decrease in the absolute magnitude of the temperature variation at each depth. These effects are consequences of the damping effect of soils with a finite thermal diffusivity on periodic variations at the soil surface.

Figure 6 shows the relationship between the standard deviation of temperature departures from the true values and sensor depth. As the original paper showed, this can be standardized by dividing by the sensor's temperature range. All-depth averages of this standardized value can then be plotted as a function of measurement interval (Figure 7). It isn't possible to discuss the details of the analysis in the time available here: however, the two main points that came out of the analysis were that:

- Errors decrease with depth, and increase as the measurement interval increases, in a fairly predictable way;
- There is no clear breakpoint in the relationship between uncertainty and measurement interval, with no obvious benfits or pitfalls in the range of intervals examined.