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Ground surface temperature history uncertainties from the determination of the quasi steady state in borehole climatology

Gurpreet Matharoo (1), Hugo Beltrami (1), and Jason Smerdon (2)

(1) Environmental Sciences Research Centre, St. Francis Xavier University, Antigonish, Canada (hugo@stfx.ca), (2) Lamont-Doherty Earth Observatory of Columbia University, New York, New York, USA.

Temperature changes at the Earth's surface propagate and are recorded underground as perturbations to the equilibrium thermal regime associated with the heat flow from the Earth's interior. Borehole climatology is concerned with the analysis and interpretation of these downward propagating subsurface temperature anomalies in terms of surface climate. As such, proper determination of the steady-state geothermal regime is crucial because it is the reference that determines the size and shape of the climate induced subsurface temperature anomalies. Here we examine the effects of data noise, of lithological or instrumental origin, on the determination of the steady-state geothermal regime of the subsurface and provide error bounds for a particular choice of ground surface temperature (GST) history. From a series of 1000 Monte Carlo experiments using Gaussian noise (mean = 0; standard devation = $\pm$0.02 K), a 100 m steady-state fitting interval, and a data sampling rate of 0.02 m, our results indicate that typical uncertainties for 50-year averages are on the order of $\pm$ 0.02 K for the most recent 100 year period. These uncertainties grow with decreasing sampling rate reaching about $\pm$ 0.1 K for a 10-m sampling rate under identical conditions and target period. Uncertainties increase for progressively older periods, reaching $\pm$0.2K at 500 year before present for a 10-m sampling rate. The uncertainties in reconstructed GST histories are also inversely proportional to the length of the fitting range used to estimate the reference steady-state thermal regime. We suggest that continuous logging should be the preferred approach when measuring geothermal data for climate reconstructions and that the steady-state geothermal gradient be estimated from a large depth range($>$100 m).