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Climate reconstruction from boreholes: depth is not enough

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In recent years, geothermal logs have been used to reconstruct ground surface temperature histories (GSTH). There are, however, some serious problems with this method. Temporal resolution of the reconstruction decreases drastically going back in time, where only time averages over considerable periods may be estimated and the coupling of surface air temperature to ground temperature is still not well understood. Furthermore, a particular bias in GSTH inversions is produced by the choice of the basal heat flow which cannot easily be distinguished from the signature of earlier surface temperature variations.

In order to further characterize this bias, Monte Carlo simulations were employed. For this purpose the forcing was parameterized by a piecewise constant function representing the surface temperature history of the last 100000 a including the LGM and holocene warming. Jointly with this forcing function, also the thermal properties of the subsurface were taken into account, which were assumed to be constant or dependent on temperature. For the resulting set of 4 to 7 parameters, probable values, variances, or bounds were chosen. Both, uniform and normal independent distributions were adopted. From these configurations a large number of realizations and the corresponding synthetic borehole temperatures were generated. The results show, that the bias resulting from the holocene warming is significant, both in temperature and in heat flow. In order to obtain reliable heat flow estimates, borehole depths of at least 2000 m are required.

From those results one might conclude that the use deeper for GSTH may lead to less biased results results. However, the reduction of bias comes at the price of stronger influence of nonlinearities which often are not known accurately. These nonlinearities are particularly difficult to distinguish from the climate signal since they are comparably smooth. Additionally, the estimates from large depths display strong leverage because of geometric effects. This is demonstrated with synthetic and field data.