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Climate reconstruction from boreholes: correcting for the influence of past temperature changes

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In recent years, geothermal logs have been used to reconstruct ground surface temperature histories (GSTH). The method is, however, not free of challenges and limitations. For instance, the temporal resolution of the reconstruction decreases drastically going back in time, where only time averages over periods of considerable length may be estimated; also 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 (e.g. on holocene or glacial time scales) that can nevertheless impact inferences on the climate of the last millenium.

In order to further characterize this bias, Monte Carlo simulations were employed, using simple subsurface models. For this purpose the forcing was parameterized by a piecewise constant function representing the surface temperature history of the last 100000 years 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 particular in its vertical gradient. This may lead to additional scatter of inferred temperature histories, if boreholes temperature profiles of different depths are combined.

If a broad knowledge of the regional temperature history is available, borehole temperature profiles from shallow boreholes may be corrected for the influence of holocene warming by subtracting a generalized temperature profile for the region, which is based on a forcing corresponding to the long-term temperature history.
Inversion of these reduced data leads to significantly better reconstructions and, when applied to data sets with largely varying borehole depth, to more consistent results. The use of corrected data will also ease the comparison with the outputs from climate models.

The conclusions of this work increase the potential for more accurate borehole reconstructions of the temperatures of the last millenium, and for improved knowledge of low-frequency variability through the last centuries.