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Simulation and inversion of borehole temperature profiles in surrogate climates: influence of SAT-GST decoupling processes in last millennium borehole temperature reconstructions

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The last millennium climate has experienced important variability at different timescales going from a relatively warmer period at the beginning of the last millennium (MCA; Medieval Climate Anomaly) to a colder period after the 15th century (LIA; Little Ice Age) that is interrupted by industrial warming in the 19th century. These past climate variations are known both from reconstruction methods that use proxy data as predictors and from simulations with climate models. Borehole reconstruction is a well established method to reconstruct past surface air temperature (SAT) based on the assumption that SAT changes are coupled to ground surface temperature (GST) changes and transferred to the subsurface by thermal conduction. However, some physical processes can impact this hypothesis since they decouple SAT and GST. Therefore borehole temperature reconstructions might be affected by such type of processes. Herein, the influence of these processes on SAT-GST coupling at long-time scales is specifically assessed in pseudo proxy experiments.

First, We have assessed the most important processes that impact the coupling between SAT and GST at local and regional scales in a set of simulations with the Community Earth System Model Last Millennium Ensemble (CESM-LME) by identifying their influences on the surface-ground heat transfer. Then, a heat-conduction forward model driven by simulated SAT and GST has been used to simulate global underground temperature perturbation profiles. Finally, a pseudo reality experiment has been developed in which an inversion approach has been applied to reconstruct the last millennium (850-2005 CE) SAT histories from the simulated temperature profiles and to compare them with climate model simulated SAT.

The results indicate that although some processes do have an impact on the SAT and GST coupling, they are important only at local or regional scales and at short-time scales. Consequently, they do not affect the global long-term coupling supporting the reliability of the borehole reconstruction technique in retrieving the low frequency past surface temperature variations.