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Analysis of methodological and physical bias on borehole temperature reconstructions from a pseudo-proxy approach.

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The analysis of subsurface temperature measurements from boreholes is a well established approach for reconstructing last millennium (LM) surface air temperature (SAT). It is based on the assumption that SAT variations are strongly coupled to ground surface temperature (GST) variations and transferred to the subsurface by thermal conduction. We have evaluated the long-term SAT-GST coupling over the LM using an ensemble of both full- and single-forcing simulations form the Community Earth System Model-Last Millennium Ensemble (CESM-LME). Such a premise is explored by investigating the evolution of the long-term SAT–GST relationship. The results indicate that SAT–GST coupling is strong at global and above multi-decadal timescales in CESM-LME. However, at local to regional scales this relationship experiences considerable long-term changes mostly after the end of the 19th century. Land use land cover (LULC) changes stand as the main driver for locally and regionally decoupling SAT and GST, due to the changes in the energy fluxes at the surface. Snow cover feedbacks due to the influence of GHG forcing are also important for corrupting the long-term SAT–GST coupling. These processes may represent a source of bias for SAT reconstructions from GST borehole profiles. In light of these findings, we subsequently assessed the potential effects on SAT reconstructions from the borehole method in pseudo-proxy experiments that make use of the same set of simulations from the CESM-LME. First, a heat-conduction forward model has been used to estimate subsurface temperature-anomaly profiles using simulated GST as boundary conditions. Subsequently, singular value decomposition inversion (SVD) has been applied to reconstruct LM GST variations from the simulated profiles. We implemented and ideal scenario in which it is assumed the existence of borehole logs at every model grid point. Further, this scenario considers that all boreholes are logged homogenously at the same time. In addition, we implemented a more realistic approach in which the real-world spatio-temporal distribution of the global borehole network is considered. Results show that the SVD inversion is able to retrieve the long-term GST variations over the LM when an appropriated coverture of borehole logs is available. However, due to the limited spatio-temporal distribution of the actual borehole network, there is a lost in the accuracy to retrieve the simulated GST 20th century trends, with the temporal logging of the BTPs as the main sampling issue. Furthermore, in the surrogate reality of the CESM-LME the SAT-GST decoupling, due to the influence of LULC and

GHG forcings, leads to a slightly underestimation of SAT warming during the industrial period across the CESM-LME. The level of impact is, however, highly depended on the realization of internal variability.