Surface temperature reconstructions in the Lena River Delta and in the Western Laptev Sea, Russia, from borehole data

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Abstract:
Palaeotemperature reconstructions play an important role as palaeoclimate records, for our understanding of the climate system behavior as such, as well as being the basis for models identifying the impact of these climate conditions on specific processes in the past and future. Temperature records reconstructed from borehole logs have a more direct relationship to the historic temperature history than other proxy-based reconstructions such as tree-rings, pollen or isotope ratios in ice cores, which can include influences from other independent factors on those proxies.

At larger depths borehole temperatures are dominated by the geothermal heat flux and a rather uniform geothermal gradient in the profile. At shallower levels temperature variations at the surface propagate as heat waves into the ground. The further down, the more the temperature reflects influences of longer periods of surface variations due to the Earth's damping higher angular frequency periods first.

This study uses two inversion optimization methods previously applied to ice core sites (Roberts et al., 2013) to reconstruct the local surface temperature history at two shallow (100m and 65m deep) permafrost borehole sites: Sardakh Island in the Lena-Delta and Cape Mamontov Klyk in the Western Laptev Sea, Russia (Fig. 1). We employed a flux-conserving finite volume numerical soil model to calculate temperature-depth-profiles from surface temperature histories. Thermal properties of the sites were retrieved from either the observed temperature field or the sediment composition analysis of the borehole. Two inversion schemes that employ the forward soil model to optimize surface temperature history in a least square sense were used in the reconstruction: (i) the least square QR (LSQR) method and (ii) the particle swarm optimization (PSO) method. The latter resembles a Monte Carlo based approach (Ebbesen et al., 2012), the former is based on a generalized least-square solution of a linearized version of the problem as utilized by Orsi et al. (2012).

Recoverable time length for the surface temperature histories for the two borehole sites were found to be well above 400 years in both cases by frequency-dependent heat wave damping analysis.

The local surface soil temperature reconstructions for the two boreholes are discussed in comparison to other local as well as larger scale global temperature reconstructions to highlight important local and regional deviations.

Additionally, the reconstructions of both sites are compared on the basis that one (Mamontov Klyk) is situated away from any major river systems and the other (Sardakh) is situated in the Lena River Delta, possibly showing thermal influence by the river.

The local surface temperature history is important as a driving input factor in local permafrost models that assess the evolution, degradation and impact of permafrost in the high latitudes in the future climate system.

References:

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Figure 1: Location of shallow permafrost boreholes at Cape Mamontov Klyk and Sardakh Island.