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Reconstructing air temperature and permafrost attributes associated with past periglacial structures: a case study for sorted nets from the Krkonoše Mts., Czech Republic

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Many regions of the world host a number relict periglacial landforms that have been inherited from colder periods of the Quaternary. So far, these assemblages have been used to reconstruct former environmental conditions particularly in two basic manners. One is to search for a representative analogue in present-day periglacial environments. Second is based on present climatic context of active landforms (Ballantyne and Harris, 1994). Unfortunately, numerous problems arise with both approaches and therefore, the reconstructions are frequently considered as unreliable. Consequently, most periglacial phenomena have been widely accepted only as indicators of seasonally freezing or permafrost conditions and ground-ice presence, but this may also be dubious and rather tentative in some cases.

On the other hand, many theoretical, physically-based studies have emerged in the last few decades that aimed to explain the formation of some periglacial landforms, such as patterned ground. The investigations focused on patterned-ground formation have shown that the length scale of the patterns is more-or-less of the same size as the length scale that initiates the patterns, i.e. the frost depth in seasonally frozen regions and the thaw depth in permafrost areas, respectively. Importantly, the diameter-to-sorting depth ratio of the resulting patterns is constant, of c. 3.1 to 3.8 under subaerial conditions (Ray et al., 1983; Gleason et al., 1986; Hallet and Prestrud, 1986), and of the same value regardless of the formation mechanism as well. These findings clearly indicate direct coupling between patterned-ground geometry and both ground and air temperature conditions at the time when the pattern first developed (Peterson and Krantz, 2008). Hence, if these genetic rules are adopted then the temperature attributes during the pattern initiation can be inferred via the sorting depth, which closely approximates former frost or thaw depth, respectively.

In this contribution, we aim to infer the palaeo-temperature and palaeo-permafrost conditions associated with relict large-scale sorted nets in the Krkonoše Mts., Czech Republic. To achieve this, we employ a multi-disciplinary approach consisting of the Monte Carlo simulation based on a simple equilibrium thermal model, the Stefan equation, in an inverse form, driven by data obtained from remote sensing, geophysical soundings, and modern analogues from elsewhere. The results are subjected to a comprehensive uncertainty and sensitivity analysis. We introduce a robust, yet straightforward and easy-to-follow procedure to utilize these periglacial phenomena and other structures indicative of the base of palaeo-active layer to reconstruct former climate.

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