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Determining permafrost active layer thermal properties of the Qinghai–Tibet Plateau using field observations and numerical modelling

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Permafrost has become thermally instable as a result of surface warming, which has an uncertain impact on future hydrogeological conditions and the associated mobilisation of carbon and release into the atmosphere. Numerical modelling can provide insights into future permafrost spatial and temporal dynamics. However, crucial observational data of permafrost active-layer thermal properties; thermal conductivity and heat capacity are sparse, resulting in a large uncertainty in forecasts of the future development of the active layer. Therefore, our study aims to develop a methodology to numerically determine the permafrost thermal and soil properties from observations of temperature time-series in the subsurface, in order to reduce the current model uncertainty.

We used an ensemble of 786 numerical 1D permafrost models fitted against observed active layer temperature data from the Qinghai-Tibetan Plateau (QTP)[1] to find the optimal values for the soil thermal conductivity, heat capacity and porosity. Optimal parameter values are determined by finding the minimum RMSE, KGE and using the Russell error measure. We find optimized values for bulk volumetric heat capacity 1.3-1.85 $10^6 J/m^3 °C$, bulk thermal conductivity 0.9-1.1 $W/m\,°C$ and porosity between 0.25-0.35 (-), which are in agreement with typical ranges reported in literature for similar settings on the QTP. In a further sensitivity study, the 3 optimal parameter combinations were used to model the active layer thickness over a 100-year period with a gradual hypothetical air temperature increase of 5 $°C$. The results indicate a substantial difference in rate of thawing and increase in depth of the active layer for these models, with a maximum time-lag of roughly 15 years in before the models reach the same active layer thawing depth. The study shows how numerical models can be applied to determine active layer thermal properties without the need for field samples, opening up new possibility for in-situ permafrost temperature observation.

1. Luo, D. L., Jin, H. J., He, R. X., Wang, X. F., Muskett, R. R., Marchenko, S. S., & Romanovsky, V. E. (2018). Characteristics of water-heat exchanges and inconsistent surface temperature changes at an elevational permafrost site on the Qinghai-Tibet Plateau. *Journal of Geophysical Research: Atmospheres*, 123, 10,057–10,075. https://doi.org/10.1029/2018JD028298