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A permafrost distribution estimate for the Southern Alps, New Zealand, inferred from topoclimatic conditions at rock glacier sites

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The presence of numerous rock glaciers and perennial snow patches indicate the existence of discontinuous alpine permafrost in New Zealand's Southern Alps. However, research on the geographic extent of permafrost in the South Island has been limited. Existing estimates are restricted to single mountain ranges or focus on steep bedrock permafrost. A recent global-scale estimate has not been evaluated by local observations.

We present the results of a regional, spatially distributed permafrost estimate for the Southern Alps, focusing on debris-covered slopes. Permafrost distribution modelling was based on the statistical evaluation of 280 active and relict rock glaciers. Logistic regression identified characteristic topoclimatic conditions at the head area of presently active rock glaciers. Statistical relationships between permafrost presence, mean annual air temperature, and potential incoming solar radiation in snow-free months were subsequently used to calculate the spatially distributed probability of permafrost occurrence. The potential permafrost extent was delineated using a probability threshold of ≥ 0.6.

Model results suggest that topoclimatic conditions are favourable for permafrost occurrence above $\sim$ 2000 m a.s.l. in the central Southern Alps and above $\sim$ 2150 m a.s.l. in the northern ranges. This gradient in permafrost altitude reflects the warmer climate at lower latitudes.
Model results were locally validated by BTS (bottom temperature of snow cover) data derived from two-year continuous ground surface temperature (GST) measurements in the Ben Ohau Range, central Southern Alps. Applicability of BTS measurements for permafrost mapping had not been tested previously in the maritime setting of New Zealand, where common warm spells during winter can result in isothermal snow pack conditions, preventing the inference of late-winter equilibrium temperatures. BTS-indicated permafrost sites were in good agreement with modelled permafrost probabilities at the respective locations. The distribution of the perennial snow patches in the central Ben Ohau Range also suggested a reasonable model result, showing good agreement with the modelled permafrost extent on a regional scale.

The distribution of active rock glaciers in the Southern Alps and inferred potential permafrost limits suggest that the potential permafrost zone extends to lower elevations in New Zealand than in the European Alps despite comparable latitudes. Comparatively low summer temperature maxima, characteristic for maritime climates, might reduce ice loss during the warm season and thus facilitate the preservation of permafrost at significantly lower altitudes.