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Regional scale distribution of permafrost in Norway based on two equilibrium models.

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Previous regional permafrost mapping in Norway has exclusively been based on mean annual air temperature (MAAT). While MAAT is important when considering the climatic limitations and thus macro-scale distribution of permafrost, many other factors such as the timing and thickness of the snow cover, vegetation and thermal properties in the active layer are of decisive importance when considering regional/discontinuous (meso-scale) permafrost presence. Two established equilibrium models are used to determine the permafrost distribution in mainland Norway: (1) the empirically based TTOP-model (temperature at top of permafrost), by *Smith & Riseborough (1996)*, and (2) the Kudryavtsev approach, implemented in the GIPL-model (Geophysical Institute Permafrost Laboratory, University of Alaska, Fairbanks, *Sazonova & Romanovsky* (2003)). While both models define the top of permafrost from air temperatures, the TTOP-model includes seasonal n-factors derived from vegetation and snow cover distribution, and the conductivity ratio between frozen and thawed states in the active layer. Correspondingly, the Kudryavtsev approach utilizes a physical parameterization of snow- and vegetation cover and the soil in the active layer.

Block fields are known to represent a negative thermal anomaly. While these features are widespread in Norway, currently available digital sediment maps do not accurately represent observed block-field distribution. Therefore, block fields have been identified from Landsat images and have been considered in the models presented above. Petrophysical data such as bedrock density and thermal conductivity have been kindly provided by the Norwegian Geological Survey. Both models are implemented at 1km resolution for mainland Norway, and forced with operationally gridded temperature and snowdepth data from the period 1960-2010, provided by Norwegian Meteorological Institute and Norwegian Water and Energy Directorate.

The model results are validated against: (1) ground surface temperature from 140 miniature temperature data loggers distributed throughout Norway; (2) vertical temperature profiles measured in 20 boreholes; and (3) maps of palsa- and rock glacier distribution. The modelled permafrost distribution agrees relatively well with observations, and reproduces regional permafrost patterns. Compared to estimates based solely on MAAT, both the TTOP- and GIPL-models present a more accurate representation of the observed east-west gradient due to the consideration of snowdepth . Sporadic permafrost, which was not represented in previous regional modelling, is now reproduced, due to the incorporation of sediment conductivity data. Despite these improvements, topographic variation introduces challenges related to snow distribution and ground thermal properties. The largest sources of error in the TTOP-model relate to the freezing factors (n_f) for snow and the thermal regime in block field areas which is controlled by both convective and conductive heat transfer.

Sazonova, T and Romanovsky, V. 2003. A model for regional scale estimation of temporal and spatial variability of active layer thickness and mean annual ground temperatures. *Permafrost and Periglacial Processes* 14, 125-139.

Smith, M., & Riseborough, D. 1996. Permafrost Monitoring and Climate Change. *Permafrost and Periglacial Processes* (7). 301-307.