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ASSESSMENT OF ANNUAL MEAN SOIL TEMPERATURE DATA ON DIFFERENT HORIZONS IN THE YAMALO-NENETS AUTONOMOUS OKRUG USING OBSERVATIONAL DATA AND CMIP6 MODELS

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Rapid climate warming in the Arctic significantly affects permafrost stability, creating increasing risks for natural ecosystems and critical infrastructure. The Yamalo-Nenets Autonomous Okrug represents one of the key regions where rising air and soil temperatures contribute to ongoing degradation of permafrost. This study evaluates the ability of modern climate datasets and numerical models to reproduce long-term thermal conditions of soil horizons using observational records, ERA5 reanalysis data, and data from the CMIP6 climate model. The analysis covers the period from 1980 to 2020 and includes comparisons between meteorological station measurements, borehole observations, and gridded datasets. ERA5 reanalysis shows strong agreement with observational air temperature dynamics, confirming its applicability for regional climate assessments; however, its performance decreases when reproducing soil temperatures, particularly at greater depths, where systematic underestimation and reduced sensitivity to extreme events are observed. To assess model reliability, 45 CMIP6 climate models were evaluated using statistical performance metrics, including mean bias, root-mean-square error, and trend consistency relative to ERA5 data. Five models TaiESM1, GFDL-CM4, FGOALS-g3, GISS-E2-1-G-CC, and BCC-ESM1 satisfied the established selection criteria and were further analyzed for their capability to simulate soil thermal regimes across multiple depths. The comparison with borehole measurements revealed substantial spatial and depth-dependent variability in model performance. Model simulations demonstrate the highest agreement with observations near the surface, where indices of agreement reach 84–98%, while accuracy decreases within the active layer and deeper soil horizons. Among the evaluated models, GFDL-CM4 provides the most consistent reproduction of annual soil temperature cycles and long-term thermal gradients. Overall, the identified model performance differences are critical for improving projections of permafrost response to climate change and for assessing future risks to Arctic ecosystems and infrastructure systems in the Yamalo-Nenets Region.

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