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Improved simulation of the current state of high-latitude permafrost soils

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Changes in the high latitude environmental conditions have received much attention in recent years. Amplified atmospheric warming, increasing permafrost temperatures, deepening active layer thicknesses, accelerated melting of glaciers and changes in river runoff trends point to a wide scale alteration of the northern circum polar region climate system. These regions are underlain by 26 million km2 of permafrost soils where the organic matter is locked away in subzero conditions. Vast amounts of organic matter within these permafrost areas bring the threat of a prolonged climate forcing from the greenhouse gases that can be released from the thawed soils in case of permafrost degradation. The fate of the permafrost state and its effects on global biogeochemical cycles are not clear in model simulations due to complex feedback mechanisms and the lack of validation datasets. To clarify the future behavior of the permafrost regions under a changing climate, a new version of the JSBACH biogeochemical land surface model is developed to include cold regions specific processes and to better represent the physical conditions in permafrost areas. Improvements include: incorporating freeze/thaw processes, coupling thermal and hydrological calculations, defining a multi layer snow scheme and moss cover to provide the heat insulation for the soil. Multi scale validation of this process based land surface model is carried out and the model performance is elaborately presented. The comparisons with the observational datasets show that the new model version is able to capture the key processes in the permafrost regions. Site level tests demonstrate that the soil temperature profiles are accurately represented. On the global scale, a good match with the permafrost extent is observed. Comparisons with the active layer thickness (CALM) and deep soil temperature (borehole) datasets point to the robustness and some shortcomings of the model structure. Although the new model version can match the general patterns, there is a cold bias in the deep soil temperatures whereas deeper active layer thicknesses are simulated. However, these results are in accordance with other modeling results and reveal the need for further developments in the land surface schemes. Finally, the Arctic river runoff dynamics are compared with the model results and a discernible improvement is achieved in capturing the runoff values and their seasonal dynamics. All this validation work confirms the credibility of the new JSBACH model version and the importance of soil physics for a modeling tool to simulate the future response of the permafrost regions to the ongoing climate change.