Geophysical Research Abstracts
Vol. 18, EGU2016-3990, 2016
EGU General Assembly 2016

Soil frost-induced soil moisture precipitation feedback and effects on atmospheric states

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Permafrost or perennially frozen ground is an important part of the terrestrial cryosphere; roughly one quarter of Earth's land surface is underlain by permafrost. As it is a thermal phenomenon, its characteristics are highly dependent on climatic factors. The impact of the currently observed warming, which is projected to persist during the coming decades due to anthropogenic CO_2 input, certainly has effects for the vast permafrost areas of the high northern latitudes. The quantification of these effects, however, is scientifically still an open question. This is partly due to the complexity of the system, where several feedbacks are interacting between land and atmosphere, sometimes counterbalancing each other. Moreover, until recently, many global circulation models (GCMs) and Earth system models (ESMs) lacked the sufficient representation of permafrost physics in their land surface schemes. Within the European Union FP7 project PAGE21, the land surface scheme JSBACH of the Max-Planck-Institute for Meteorology ESM (MPI-ESM) has been equipped with the representation of relevant physical processes for permafrost studies. These processes include the effects of freezing and thawing of soil water for both energy and water cycles, thermal properties depending on soil water and ice contents, and soil moisture movement being influenced by the presence of soil ice. In the present study, it will be analysed how these permafrost relevant processes impact large-scale hydrology and climate over northern hemisphere high latitude land areas. For this analysis, the atmosphere-land part of MPI-ESM, ECHAM6-JSBACH, is driven by prescribed observed SST and sea ice in an AMIP2-type setup with and without the newly implemented permafrost processes. Results show a large improvement in the simulated discharge. On one hand this is related to an improved snowmelt peak of runoff due to frozen soil in spring. On the other hand a subsequent reduction of soil moisture leads to a positive land atmosphere feedback to precipitation over the high latitudes, which reduces the model's wet biases in precipitation and evapotranspiration during the summer. This is noteworthy as soil moisture – atmosphere feedbacks have previously not been in the research focus over the high latitudes. These results point out the importance of high latitude physical processes at the land surface for the regional climate.