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Modified soil hydro-thermodynamics cause large spread in projections of Arctic and subarctic climate

Norman Julius Steinert[1,2], Jésus Fidel González-Rouco[1], Philipp de Vrese[3], Elena García-Bustamante[4], Stefan Hagemann[5], Johann Jungclaus[3], Stephan Lorenz[3], Victor Brovkin[3], Camilo Andres Melo-Aguilar[1], Félix García-Pereira[1], and Jorge Navarro[4]

[1]Complutense University of Madrid, Department of Earth Physics and Astrophysics, Geosciences Institute IGEO (UCM-CSIC), Madrid, Spain

[2]NORCE Norwegian Research Centre, Climate and Environment, Bergen, Norway (nste@norceresearch.no)

[3]Max Planck Institute for Meteorology, Hamburg, Germany

[4]CIEMAT Center for Energy, Environment and Technology, Madrid, Spain

[5]Helmholtz-Zentrum Hereon, Geesthacht, Germany

The representation of the terrestrial thermal and hydrological states in current-generation climate models is crucial to have a realistic simulation of the subsurface physical processes and land-atmosphere coupling. This is particularly important for high-latitude permafrost regions since these areas are prone to the release of substantial amounts of carbon from degrading permafrost under climate-change conditions. Many current-generation climate models still have deficiencies in the representation of terrestrial structure and physical mechanisms, such as too shallow land depth or insufficient hydro-thermodynamic coupling. We therefore introduce a deeper bottom boundary into the JSBACH land surface model. The associated changes in the simulated terrestrial thermal state influence the near-surface hydroclimate when sufficient coupling between the thermodynamic and hydrological regimes is present. Hence, we also assess the influence of introducing various physical modifications for the representation of soil hydro-thermodynamic processes in climate projections of the 21st century. The results show significant impacts on terrestrial energy uptake, as well as changes in global near-surface ground temperatures when introducing the physical modifications. The resulting simulation of high-latitude permafrost extent is subject to large variations depending on the model configuration, reflecting the uncertainty of carbon release from permafrost degradation. We further use the modified model to assess the sensitivity of simulated high-latitude climate dynamics to different hydrological configurations in the coupled MPI-ESM. The differences in soil hydrological representation in permafrost regions could explain a large part of CMIP6 inter-model spread in simulated Arctic climate, with remote effects on subarctic dynamical systems.