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Development of the subgrid excess ground ice framework in the Community Land Model

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An upgrade based on the Community Land Model (CLM, version 5.0) is developed to realize the excess ground ice physics in a sub-grid scale. Three more natural vegetation land unit types with different concentrations (low, mid, and high) of excess ice are added to the model source code. Surface data files are changed correspondingly to add information (area weights) of the above excess ice land unit types in model initialization. The excess ice physics in each column is from that in CLM4.5_EXICE (Lee et al., 2014). The finer vertical layers and dynamical soil layer depths in CLM5.0 compared to CLM4.5 supports the upgrade to deal with extremely high concentration excess ice (e.g. ice wedges) in a sub-grid scale.
Evaluation tests are conducted in a single-grid manner over with the continuous permafrost and relatively flat topography. Cases are initialized with the same concentration on average but different spatial distributions of excess ice, in addition to the control case without any excess ice. One-hundred-year spin-ups are forced by the 1900-1920 climate before test cases are computed over the periods of 1900-2005 and 2006-2300, forced respectively by the reanalysis and RCP8.5 atmospheric forcing. The result shows that the homogeneously-distributed excess ice is more sensitive to the warming climate, resulting in the earliest excess ice melt and surface subsidence compared to other cases in which the excess ice are distributed more concentrated. Correspondingly, the homogenous excess ice also leads to stronger changes in other variables including soil temperature, soil moisture, and surface runoff. Considering that excess ice in permafrost area is normally distributed in the small scale, while the spatial resolutions of CLM simulations are typically low (1 degree), such sub-grid scale excess ice physics offers the capability of modeling more realistic effects to the permafrost of excess ice and its melting. The Circum-Arctic Map of Permafrost and Ground-Ice Conditions (version 2) by National Snow & Ice Data Center (NSIDC), which has a 12.5 km spatial resolution, is upscaled to a 1-degree (f09) grid, serving as the surface data to a globally covered run in both the historical and projected periods. The sub-grid scale excess ice framework is able to better utilize such a high-resolution ground ice dataset as the input and simulate a more realistic excess ice effect to permafrost globally.