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Simulating the carbon, water, energy budgets and greenhouse gas emissions of arctic soils with the ISBA land surface model

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Permafrost soils and boreal wetlands represent an important challenge for future climate simulations. Our aim is to be able to correctly represent the most important thermal, hydrologic and carbon cycle related processes in boreal areas with our land surface model ISBA (Masson et al, 2013). This is particularly important since ISBA is part of the CNRM-CM Climate Model (Voldoire et al, 2012), that is used for projections of future climate changes.

To achieve this goal, we replaced the one layer original soil carbon module based on the CENTURY model (Parton et al, 1987) by a multi-layer soil carbon module that represents C pools and fluxes (CO_2 and CH4), organic matter decomposition, gas diffusion (Khvorostyanov et al., 2008), CH4 ebullition and plant-mediated transport, and cryoturbation (Koven et al., 2009). The carbon budget of the new model is closed. The soil carbon module is tightly coupled to the ISBA energy and water budget module that solves the one-dimensional Fourier law and the mixed-form of the Richards equation explicitly to calculate the time evolution of the soil energy and water budgets (Boone et al., 2000; Decharme et al. 2011). The carbon, energy and water modules are solved using the same vertical discretization. Snowpack processes are represented by a multi-layer snow model (Decharme et al, 2016).

We test this new model on a pair of monitoring sites in Greenland, one in a permafrost area (Zackenberg Ecological Research Operations, Jensen et al, 2014) and the other in a region without permafrost (Nuuk Ecological Research Operations, Jensen et al, 2013); both sites are established within the GeoBasis part of the Greenland Ecosystem Monitoring (GEM) program. The site of Chokurdakh, in a permafrost area of Siberia is is our third studied site. We test the model's ability to represent the physical variables (soil temperature and water profiles, snow height), the energy and water fluxes as well as the carbon dioxyde and methane fluxes. We also test the model behaviour in the case of a flooded fen, hence giving a first insight of the sensitivity of greenhouse gas emissions with respect to surface hydrology. Comparing the model results on these three climatically distinct sites also gives a first insight on the model sensitivity to the forcing climate variables, and show that the model is generic enough to reasonably model methane and carbon dioxyde emission behaviour from different types of boreal ecosystems.