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Simulating effects of natural fire disturbance on soil carbon storage of boreal forest and tundra ecosystems in Alaska

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Boreal forest and tundra are the major ecosystems in the northern high latitudes and represent one of the largest reservoirs of carbon over terrestrial ecosystems in the world. Most of the carbon is stored in permafrost where frozen organic matter is protected from decomposition due to biotic activity in the underlying soil. The surface humus layers that should work as the protective layers insulate the permafrost soil far away from the effect of climate warming. Hence, the removal of protective layers by natural fire episodes increases the vulnerability of permafrost to thaw, and the carbon stored in permafrost to decomposition under climate warming in the near future. To elucidate effects of fire severity and temperature sensitivity on the soil carbon storage of boreal forest and tundra ecosystems in Alaska, we conducted simulations using the Physical and Biogeochemical Soil organic carbon Dynamics Model (PB-SDM), which consists of meteorologically-relevant land surface model and soil organic carbon dynamics model. The PB-SDM model of fire severity, designed from the analysis of the field observations, describes the effects of fire characteristics in frequency and size on the reduction of the soil organic layer. The simulation captured realistic annual variations in soil organic carbon storage and thickness in boreal forest and tundra ecosystems individually by finding optimal model parameters in terms of the frequency and size of fire events and temperature sensitivity. The result reveals that our model can be used for predicting soil carbon storage in boreal forest and tundra ecosystems at regional scales where fire regimes play a key role in the soil organic carbon storage as affected by climate warming.

Keywords: High-latitude soil, fire severity, Soil organic carbon, boreal forest, tundra