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Insights into the effects of patchy ice layers on water balance heterogeneity in peatlands

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Peatlands in boreal and sub-arctic settings are characterised by a high degree of seasonality. During winter soils are frozen and snow covers the surface preventing peat moss growth. Conversely, in summer, soils unfreeze and rain and evapotranspiration drive moss productivity. Although advances have been made in understanding growing season water balance and moss dynamics in northern peatlands, there remains a gap in knowledge of inter-seasonal water balance as layers of ice break up during the spring thaw. Understanding the effects of ice layers on spring water balance is important as this coincides with periods of high wildfire risk, such as the devastating Fort McMurrary wildfire of May, 2016. We hypothesise that shallow layers of ice disconnect the growing surface of moss from a falling water table, and prevent water from being supplied from depth. A disconnect between the evaporating surface and deeper water storage will lead to the drying out of the surface layer of moss and a greater risk of severe spring wildfires. We utilise the unsaturated flow model Hydrus 2D to explore water balance in peat layers with an impermeable layer representing ice. Additionally we create models to represent the heterogeneous break up of ice layers observed in Canadian boreal peatlands; these models explore the ability of breaks in an ice layer to connect the evaporating surface to a deeper water table.

Results show that peatlands with slower rates of moss growth respond to dry periods by limiting evapotranspiration and thus maintain moist conditions in the sub-surface and a water table above the ice layer. Peatlands which are more productive continue to grow moss and evaporate during dry periods; this results in the near surface mosses drying out and the water table dropping below the level of the ice. Where there are breaks in the ice layer the evaporating surface is able to maintain contact with a falling water table, but connectivity is limited to above the breaks, with limited lateral transfer of water above the ice. Conceptually this means that peatlands which tend to have lower rates of growth are largely unaffected by the presence of a shallow ice layer in the early growing season, and are able to maintain moist sub-surface conditions in the absence of precipitation. They will thus be more resistant to severe wildfire. Conversely, peatlands which tend towards higher levels of moss productivity are able to maintain moss growth during dry periods. In the presence of an ice layer this greater productivity leads to a disconnection from deep water sources, extensive drying out of moss above the ice, and a greater susceptibility to severe wildfires.

Our study gives important insights into the mechanisms behind heterogeneity in burning and depth of burn in northern peatland wildfires, as well as into burn heterogeneity within peatland microtopography.