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Shrubs covered by snow in the high Arctic cool down permafrost in winter by thermal bridging through frozen branches

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Warming-induced shrub expansion on Arctic tundra is generally thought to warm up permafrost, as shrubs trap blowing snow and increase the thermal insulation effect of snow, limiting permafrost winter cooling. We have monitored the thermal regime of permafrost on Bylot Island, 73°N in the Canadian high Arctic at nearby herb tundra and shrub tundra sites. Once adjusted for differences in air temperature, we find that shrubs actually cool permafrost by 0.6°C over November-March 2019, despite a snowpack twice as insulating in shrubs. By simulating the rate of propagation of thermal perturbations and using finite element calculations, we show that heat conduction through frozen shrub branches have a winter cooling effect of 1.5°C which compensates the warming effect induced by the more insulating snow in shrubs. In spring shrub branches under snow absorb solar radiation and accelerate permafrost warming. Over the whole snow season, simulations indicate that heat and radiation transfer through shrub branches result in a 0.3°C cooling effect. This is contrary to many previous studies, which concluded to a warming effect, sometimes based on environmental manipulations that may perturb the natural environment. The impact of shrubs on the permafrost thermal regime may need to be re-evaluated.