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Modelling basin-scale effects of shrub expansion on snow distribution, turbulent fluxes and soil temperature

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The interactions between shrubs, snow and soil are at the core of feedback loops affecting the water, energy and carbon budget at high latitude. Many studies, providing evidence from plot scale measurements to pan-Arctic satellite observations, have shown that shrubs are colonizing higher grounds, both latitudinally and altitudinally, in all countries circling the Arctic. It is therefore critical to understand how these changes may affect snow distribution, water equivalent and soil temperature. Given that shrubs colonize bare ground through the expansion of existing shrub patches, the potential effect of shrub expansion was investigated by selecting a site where shrubs are already in the landscape. Modelled snow distribution, water equivalent, turbulent fluxes and soil temperature under the current vegetation cover was compared to those of runs where cover was modified by 1/ removing all vegetation ("no-shrub") 2/ increasing shrub cover and height as a function of their respective neighbouring cell values ("shrub+"). The study was performed in the Granger Basin, Yukon Territory, Canada, which is situated within a sub-alpine ecozone and characterised by a shrub-tundra landscape. A distributed land surface model which calculates the energy balance over three sources (snow – shrub – ground) within each gridbox was used to investigate these processes. Although much of the snow distribution in the basin is topographically driven, increasing shrub cover and height reduced the spatial variability of snow depth and increased the snow cover fraction. Despite the heat advection from shrubs to snow patches, the basin became snow-free earlier in the control run than in the shrub+ run because of the shading effect of denser canopies. Removing shrubs caused higher latent heat fluxes across the basin both on snow and snow-free tiles whereas adding shrubs homogenized latent heat fluxes and soil temperatures across the basin, following the homogenization of the snow depth. The main difference between the control run and the shrub+ run occurred in the sensible heat fluxes from the surface to the atmosphere which are considerably higher with increased vegetation height. Therefore, although an increase in vegetation density homogenizes the landscape and allows soil temperature and latent heat fluxes during snowmelt to maintain equilibrium compared to the control run, the increase in vegetation height and, therefore, in vegetation protruding above the snowpack is expected to contribute to local atmospheric warming because of an increase in sensible heat fluxes.