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Factors Influencing Snow Model Performance in Boreal Forests - Results from the ESM-SnowMIP Forest Site Simulations

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The site level component of the Earth System Model – Snow Model Intercomparison Project has 28 participating model variants. We summarize model performance at the Boreal Ecosystem Research and Monitoring Sites (BERMS) Old Aspen (OAS), Old Black Spruce (OBS) and Old Jack Pine (OJP) forests in Saskatchewan.

Many CMIP5 models have been previously shown to overestimate the winter albedo in the boreal forest due to errors in plant functional type (PFT) and leaf area index (LAI). In this project provided values for PFT and LAI were not implemented in a few models, but many models show a positive albedo bias in excess of 0.1 and some show a much larger positive bias. A larger positive albedo bias at OAS by some models suggests that snow masking by leafless trees requires attention. Average albedo bias from these off-line simulations, which lack atmospheric feedbacks, is not strongly related to bias in snowpack properties or the treatment or lack thereof of intercepted snow.

About half the models simulated snow water equivalent (SWE) with a RMSE smaller than the standard deviation of the observations. Snow depth was simulated slightly worse and only three models met this standard with respect to snowpack density. SWE was underestimated by just over half the models but the density of these sheltered snowpacks was overestimated by most models, resulting in snowpack depth being underestimated by an average 0.1 m. Models with multiple simplified surface parameterizations tend to show the greatest underestimation of SWE and depth and overestimation of density.

Biases in above-canopy radiative, snow surface and bulk snowpack temperatures are not consistent with respect to size and sign; many models show a combination of positive and negative biases. Radiative and snowpack surface temperatures are associated with trends in turbulent heat fluxes. Models with multiple simplified surface parameterizations (e.g. large or fixed density or thermal conductivity values, a composite snowpack, no organic soil) show more negative soil temperature biases and appear to be associated with a colder snowpack, but unfortunately, bulk snowpack temperature was not reported for many such models. Negative SWE

and depth biases are associated with colder winter soil temperatures and shorter snow seasons. Most models simulate snow thermal conductivity with one of many relationships with density. Soil temperature bias is highly sensitive to the choice of snow thermal conductivity parameterization.

Models with many snow layers tend to show smaller errors in snowpack properties and are less likely to show cold biases in the snowpack and soil compared with composite or single layer models. However, as found in previous SnowMIPs, some single-layer models occupy the same bias range as multi-layer models. Models employing a multi-layer snowpack tend not to employ multiple "simplified parameterizations" as described above whereas the models with a single snow layer employ surface parameterizations with a range of sophistication.

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