Geophysical Research Abstracts
Vol. 20, EGU2018-18288, 2018
EGU General Assembly 2018

Improvements to Simulations of Canopy Longwave Radiation in Boreal Forests and their Impact on Seasonal Snow Cover

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The current generation of earth system models (ESMs) is known to underestimate the historical downward trend, and variability, in spring snow cover extent over northern hemisphere land. A substantial fraction of this area is covered by boreal forests, which impact the surface radiation budget by intercepting snowfall, shading the snow-covered ground, and enhancing downwelling longwave radiation from the trees to the surface (henceforth, longwave enhancement). Poor representation of longwave enhancement under boreal forests is a potential explanation for the deficiencies in ESM simulations of spring snow cover; however, to date its impact on snow cover in global land models has not been investigated. This study assesses sub-canopy longwave radiation and longwave enhancement in the NCAR Community Land Model version 4.5 (CLM4.5), the land component of the Community Earth System Model. The performance of the default single-layer canopy radiation scheme in CLM4.5 is compared to a more sophisticated two-layer scheme from the snow physics model called SNOWPACK. Comparisons are performed at a range of study sites with available measurements of sub-canopy longwave radiation from the Swiss alps, Finnish and Swedish arctic, and eastern Siberia, which represent the diversity of tree types found within boreal forests: evergreen needleleaf trees (ENT), deciduous needleleaf trees (DNT), and deciduous broadleaf trees (DBT). Our results show that CLM4.5 overestimates the diurnal cycle of sub-canopy longwave radiation, and consequently longwave enhancement, by approximately a factor of two at all study sites. The largest biases occur during clear-sky conditions, when the forest canopy in CLM4.5 absorbs too much shortwave radiation during the day, and produces too much longwave cooling at night. Taking inspiration from recent improvements to the canopy parameterisation in SNOWPACK, we introduce an improvement to the canopy radiation scheme in CLM4.5 that approximates the effects of a second canopy layer within the original single-layer parameterisation, and efficiently reduces the bias in longwave enhancement. The impacts of this improvement on the global snow cover simulation in CLM4.5 will be discussed.