A two-layer canopy model with thermal inertia for an improved snowpack energy-balance below needleleaf forest (model SNOWPACK, version 3.2.1, revision 741)

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Model: SNOWPACK version 3.2.1, revision 741

Abstract

A new, two-layer canopy module with thermal inertia as part of the detailed snow model SNOWPACK (version 3.2.1) is presented and evaluated. As a by-product of these new developments, an exhaustive description of the canopy module of the SNOWPACK model is provided, thereby filling a gap in the existing literature.

In its current form, the two-layer canopy module is suited for evergreen needleleaf forest, with or without snow-cover. It is designed to reproduce the difference in thermal response between leafy and woody canopy elements, and their impact on the underlying snowpack or ground surface energy balance. Given the number of processes resolved, the SNOWPACK model with its enhanced canopy module constitutes a sophisticated physics-based modelling chain of the continuum going from atmosphere to soil through the canopy and snow.

Comparisons of modelled sub-canopy thermal radiation to stand-scale observations at an Alpine site (Alptal, Switzerland) demonstrate improvements induced by the new canopy module. Both thermal heat mass and the two-layer canopy formulation contribute to reduce the daily amplitude of the modelled canopy temperature signal, in agreement with observations. Particularly striking is the attenuation of the night-time drop in canopy temperature, which was a key model bias. We specifically show that a single-layered canopy model is unable to produce this limited temperature drop correctly.

The impact of the new parameterizations on the modelled dynamics of the sub-canopy snowpack is analysed. The new canopy module yields consistent results but the frequent occurrence of mixed-precipitation events at Alptal prevents a conclusive assessment of model performance against snow data.

The new model is also successfully tested without specific tuning against measured tree temperature and biomass heat storage fluxes at the boreal site of Norunda (Sweden). This provides an independent assessment of its physical consistency and stresses the robustness and transferability of the chosen parameterizations.

The SNOWPACK code including the new canopy module is available under GPL license and upon creation of an account at https://models.slf.ch/.