Supplement of:

Assessing spatially distributed snow simulations with MEB-Crocus in subalpine forests through modelling experiments

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Modifications to the canopy snow subroutines

Three major modifications were made to the MEB canopy snow scheme. They are based on extensive testing at the Col de Porte site, building on the datasets and work of Vincent et al. (2018) and Sicart et al. (2023). A publication documenting these changes and the data used to develop them is currently in preparation (Pauze et al., in prep.)

1. Interception and canopy snow fluxes are dependent on both LAI and canopy height

This change tries to better account for the three-dimensional structure of the canopy in determining intercepted snow load and turbulent fluxes associated with canopy snow. It was motivated by the fact that maximum interception loads based on the Hedstrom & Pomeroy (1999) scheme underestimated observations, especially for dense forests. We hypothesize that the impact of the much taller trees at Col de Porte (H ~ 35 m) compared to those considered for the development of the Hedstrom & Pomeroy model (H_{ref} ~ 10 m) is not sufficiently captured by LAI. For this reason, we propose to apply a scaling factor proportional to canopy height (H) to estimate an effective LAI (LAI_{eff}) controlling maximum interception capacity (W_{rn_max}, [kg m^{-2}]) and turbulent fluxes:

$$LAI_{eff} = \frac{H}{H_{eff}} \cdot LAI \qquad (1)$$

$$W_{rn\_max} = S_{n,v} \cdot LAI_{eff} \qquad (2)$$

Where $S_{n,v}$ [kg m^{-2}] is the maximum snow load per unit branch/leaf area depending on tree species and snow density (Boone et al., 2017).

This change entails an increase in interception loads and sublimation losses from canopy snow.

2. Change to the parametrization of snow unloading from the canopy

While the existing unloading scheme was a combination of linear unloading over time (Boone et al. 2017) and the parametrization by Roesch et al. (2001), we now apply the Roesch et al. scheme but with modified coefficients as proposed by Lundquist et al. (2021).

Unloading rate is computed as:

$$D = -W_{rn} \left(M_T \frac{\max(T_V - T_t, 0)}{C_T} + M_V \frac{U}{C_V} \right) \qquad (3)$$

Where D [kg m^{-2} s^{-1}] is canopy snow unloading rate, W_{rn} is the interception reservoir [kg m^{-2}], M_T and M_V are unitless calibration coefficients (both set to 0.25 here), C_T and C_V are unloading coefficients related to temperature and wind, respectively, and fixed to $C_T = 1.87 \cdot 10^5$ K·s and $C_V = 1.56 \cdot 10^5$ m, T_V and T_t [K] are vegetation temperature and a threshold temperature for temperature-driven unloading (T_t = 270.15 K), and U [m s^{-1}] is wind speed at top of canopy, derived from above-canopy wind speed as explained in Boone et al. (2017), Appendix D. Note that we use vegetation temperature instead of air temperature, as it better captures conditions encountered by the intercepted snow.

Overall, this scheme slows down unloading and increases residence time of snow on the branches, thus favoring melt and sublimation of canopy snow.

3. Change to the parametrization of canopy snow melt

The original formulation of melt of canopy snow follows a degree-day approach, using a degree-day factor of $5.56 \cdot 10^{-6}$ kg m^{-2} s^{-1} K^{-1}, yielding melt quantities of approximately 0.5 mm d^{-1} K^{-1}. This melting rate was increased using the formulation by Lundquist et al. (2021):

$$\phi_v = -M_f \cdot max(T_v - T_m, 0) \qquad (4)$$

Where [kg m^{-2} s^{-1}] is the melt rate of intercepted snow and T_v [K] is vegetation temperature. The degree-day factor M_f is set to $4.63 \cdot 10^{-5}$ kg m^{-2} s^{-1} K^{-1}, which corresponds to ~4 mm d^{-1} K^{-1}.

This formulation is a simplified version of the parametrization proposed by Raleigh and Lundquist (2012). Also here, we use vegetation temperature instead of air temperature. This change yields a phase change coefficient that is an order of magnitude larger than before and thus increases melt of canopy snow, consistent with observations at Col de Porte, where the canopy can lose all its snow in less than a day when conditions are well above freezing. Moreover, snow melt from the canopy was previously dependent on the amount of canopy snow, meaning that virtually no canopy snow melt occurred for small canopy snow amounts. With the implemented modifications, the mass of snow melting from the canopy is solely dependent on temperature (as long as there is snow to melt). Note that the opposite formulation is used to estimate refreezing of liquid interception, consistent with Boone et al. (2017).

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