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Numerical modelling of snow and frozen soil processes for a multi-layer atmosphere-soil-vegetation model

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Snowcover plays an important role in Earth's climate system because of its high albedo, low thermal conductivity, roughness length, and ability to store water. A sophisticated process-based snow model is useful for representing the complex snow physics. In the present study, an existing multi-layer atmosphere-SOiL-VEGetation model (SOLVEG) developed by the authors was modified to simulate snow and frozen soil processes. The schemes of a multi-layer snow structure for heat and liquid water transports in snow and freeze-thaw processes of soil moisture were incorporated into the model. In the snow scheme, the liquid water transfer in snow was modeled based on the processes of both capillary rise and gravitational drainage in order to accurately simulate water movement in unsaturated snow. The performance of the modified model was tested at the pre-alpine grassland site in TERestrial ENvironmental Observatories (TERENO) networks in Germany. The modified model overall reproduced the temporal changes in observations of surface energy fluxes, albedo, snow depth and surface temperature, and soil temperature and moisture. The measured increases of soil water content due to infiltration of melted snow to the soil were simulated by the modified model. The observed large negative sensible and positive latent heat fluxes associated with the typical south foehn, a warm and dry downslope wind of the Alps, were also reproduced in the simulation.