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Multiphysics ensemble-based modelling of an alpine snowpack

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Physically based multilayer snowpack models suffer from various modelling errors. It is necessary to quantify these errors in various applications including ensemble forecasting of snowpack conditions and ensemble assimilation of snowpack observations. We present here the new multi-physical ensemble system ESCROC (Ensemble System Crocus) which describes the uncertainties of snowpack modelling by new representations of different physical processes in the deterministic coupled multi-layer ground/snowpack model SURFEX/ISBA/Crocus, including 3 different options for snow metamorphism among others. This ensemble was driven and evaluated at Col de Porte (1325 m a.s.l., French alps) over 18 years with a high quality meteorological and snow dataset. 7776 simulations were evaluated separately accounting for the uncertainties of evaluation data. The ability of the ensemble to capture the uncertainty associated to modelling errors is assessed with probabilistic tools for snow depth, snow water equivalent, bulk density, albedo and surface temperature. Results show that optimal members of the ESCROC system are able to explain about 2/3 of the total simulation errors. The 3 different options of snow metamorphism can exhibit a similar skill for the evaluated variables, with a high dependency of results on the options chosen for the other physical processes (compaction, liquid water percolation, solar radiation absorption, turbulent fluxes, etc.). ESCROC is a promising system to integrate numerical snow modelling errors in ensemble forecasting and ensemble assimilation systems in support of avalanche hazard forecasting and other snowpack modelling applications. It may benefit of any future improvement in the uncertainty quantification about modelling of each specific physical process, such as snow metamorphism modelling.