Snow level from post-processing of atmospheric model improves snowfall estimate and snowpack prediction in mountains

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In mountains, the precipitation phase greatly varies in space and time and affects the evolution of the snow cover and the hydrological response during rain-on-snow events. Snowpack models usually rely on precipitation-phase partitioning methods (PPMs) that use near-surface variables. These PPMs ignore atmospheric conditions in the vertical atmospheric profile, thus limiting their ability to predict the precipitation phase at the surface. In this study, the impact on snowpack simulations of atmospheric-based PPMs, incorporating upper atmospheric information, is tested using the detailed snowpack scheme Crocus. Crocus is run at 2.5-km grid spacing over the mountains of southwestern Canada and northwestern United States and is driven by atmospheric fields from a numerical weather prediction (NWP) system at the same resolution. Two atmospheric based PPMs were considered from the NWP system: the output from an advanced microphysics scheme and a post-processing algorithm determining the snow level and the associated precipitation phase. Two ground-based PPMs were also included as lower and upper benchmarks: a single air temperature threshold at 0°C and a PPM using wet-bulb temperature. Compared to the upper benchmark, the snow-level based PPM from NWP post-processing improved the estimation of snowfall occurrence by 5% and the simulation of snow water equivalent by 9% during the snow melting season. In contrast, the precipitation phase from the microphysics scheme decreased performances in phase estimate and SWE simulations compared to the upper benchmark. Manual and automatic observations of snow depth and snow density were also used to refine the analysis. The performances of the different PPMs and their impact on snowpack simulations were finally compared during the extreme flooding event in British Columbia in November 2021. Overall, our results highlight the benefits for mountain snow hydrology of using precipitation phase derived from post-processing of atmospheric models. The limitations to drive snowpack models at slope scale (<250 m) are also discussed.