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A dynamic model of bulk snow density, depth and mass content and its validation along an altitude gradient

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Many evidences are nowadays available of important modifications in the seasonal mass dynamics of snowpack due to climate change. Above all, decreasing solid inputs, earlier melting runoffs and decreasing SWE peaks have been measured both in the USA and in Europe starting from the second half of the twentieth century. Therefore, a reliable modeling of snowpack mass dynamics is of preeminent importance to predict the future availability of water and to assist decision-makers in natural resources management. Many reliable models are available to this purpose, which nonetheless need many input data and complex computational efforts. Besides, the scarcity of direct measures of snow water equivalent limits in many contexts the use of direct model for the characterization of this variable. As an alternative and simple approach, a one-dimensional model is presented for regional hydrology purposes which predicts snow water equivalent by means of the simulation of snow depth and bulk snow density, modeled both in dry and wet conditions. In the literature bulk snow density is often predicted with multiple regressions, and scarce attention has been paid to this state variable, principally because of its non-linear dynamics and its difficult measure. The model considers two constituent: the dry one and the wet one. It introduces as state variables the bulk density and the depth of the dry part, including the ice structure and pores, and the depth of the wet part. The input variables are precipitation (in liquid and solid forms) and air temperature. The wide availability of this kind of data let the model to be potentially adopted in many contexts, overcoming the paucity of SWE data. The model has been calibrated and validated along an altitude gradient against multi-year data series measured in the western United States by the SNOTEL network, with good values of the Nash-Sutcliffe parameters.