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Estimation of the snow cover by application of a two-layered model of accumulation and snowmelt in the Sierra Nevada Natural Park (Spain)

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The Sierra Nevada Natural Park (Southern Spain), where the highest altitudes in Spain can be found (3482 m) just 40 km far from the seaside, is an example of high mountainous climate in a semi-arid Mediterranean environment. It is characterized by strong fluctuations in the energy fluxes that interact with the snowpack in a particular way due to the especial local weather conditions: intense daily cycles with high daytime incoming solar radiation, sudden night-time cooling under very clear skies, and a highly variable temperature regime during the snow season. The frequent presence of snow every year shows different cycles of accumulation and melting with very variable frequency, from days to months, as a result of the remarkable variability of rainfall and temperature in short periods of time. The snowmelt supplies and recharges the aquifers during periods of time when precipitation is not expected, and constitutes the main source of water flow during the summer especially in dry years
In the southern hillslopes of Sierra Nevada, Herrero et al. (2009) developed a physically based mass and energy balance snow model for a single snow layer under the hypothesis of homogeneous characteristic of the snow and with a new empirical expression for the atmospheric emissivity. Results by Herrero et al. (2009) showed excellent fits to the snow thickness measurements in the study area, improving the simulations obtained from previous existing models. This study looks now into the physical characterization of the snow layer dynamics in Mediterranean environments. To this purpose, a two-layered structure is added together with the consideration of density gradients along the snow column from the formulation of Marks et al. (1998), Link et al. (1999) and Marks et al. (1999). Finally, the analysis is extended to the whole area of Sierra Nevada Natural Park.
Input data to the model are meteorological variables (precipitation, temperature, solar radiation, humidity, wind speed, and long wave incoming radiation) measured at the weather stations located in the study area, as well as geographical and topographical data. Calibration data in terms of direct measurements of the snowpack thickness, consistency and hardness were obtained by field campaigns carried out between 2004 and 2007 as described in Herrero (2007). The results of applying the two-layered model in a distributed way in the Sierra Nevada Natural Park compared to the results obtained by the single layer model of Herrero et al. (2009) show that the two-layered model provides more realistic predictions of the evolution of the snow cover as well as the estimation of the evaporative and melting processes. The inclusion of a surface layer in the modelling of the snow dynamics improves the simulation of mass and energy transfer between the snowpack and the atmosphere, with results that estimate a total evaporation fraction from the snow up to a 38% and 19% , during the period 2004-2005 and 2006-2007, respectively, and an associated snowmelt fraction of 62% and 81%.