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Estimation of snowpack matching ground-truth data and MODIS satellite-based observations by using regression kriging

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The estimation of Snow Water Equivalent (SWE) is essential for an appropriate assessment of the available water resources in Alpine catchment. The hydrologic regime in these areas is dominated by the storage of water in the snowpack, which is discharged to rivers throughout the melt season. An accurate estimation of the resources will be necessary for an appropriate analysis of the system operation alternatives using basin scale management models. In order to obtain an appropriate estimation of the SWE we need to know the spatial distribution snowpack and snow density within the Snow Cover Area (SCA). Data for these snow variables can be extracted from in-situ point measurements and air-borne/space-borne remote sensing observations. Different interpolation and simulation techniques have been employed for the estimation of the cited variables.

In this paper we propose to estimate snowpack from a reduced number of ground-truth data (1 or 2 campaigns per year with 23 observation point from 2000-2014) and MODIS satellite-based observations in the Sierra Nevada Mountain (Southern Spain). Regression based methodologies has been used to study snowpack distribution using different kind of explicative variables: geographic, topographic, climatic. 40 explicative variables were considered: the longitude, latitude, altitude, slope, eastness, northness, radiation, maximum upwind slope and some mathematical transformation of each of them [Ln(v), (v)ˆ-1; (v)ˆ2; (v)ˆ0.5). Eight different structure of regression models have been tested (combining 1, 2, 3 or 4 explicative variables). Y=B0+B1Xi (1); Y=B0+B1XiXj (2); Y=B0+B1Xi+B2Xj (3); Y=B0+B1Xi+B2XjXl (4); Y=B0+B1XiXk+B2XjXl (5); Y=B0+B1Xi+B2Xj+B3Xl (6); Y=B0+B1Xi+B2Xj+B3XlXk (7); Y=B0+B1Xi+B2Xj+B3Xl+B4Xk (8). Where: Y is the snow depth; (Xi, Xj, Xl, Xk) are the prediction variables (any of the 40 variables); (B0, B1, B2, B3) are the coefficients to be estimated. The ground data are employed to calibrate the multiple regressions. In order to assess the goodness of fit for the models (from 1 to 8) for each of the possible variables (from 1 to 40) the next indices have been selected: negative log-likelohood function; Correlation Coefficient; Adjusted Correlation Coefficient; Akaike information criterion; Bayesian information criterion; Kashyap information criterion. The last five of them take into account the parsimony of the models. A multi-objective analysis has been employed in order to identify the bets models and predictive variables in accordance with those indices. The "inferior" models in terms of goodness of fit were identified (dominated solutions, using the terminology of multi-objective analysis) and eliminated. A kriging of the residual has been also performed. The snow domain is constrained in accordance with the snow cover area deduced from MODIS data.

The Results obtained show that the model 7 is the only one that is not eliminated in any campaign. The main explicative variables in these models are: altitude (used in 91% of campaigns), northness (used in 72% of campaigns), latitude (used in 45% of campaigns) and longitude (used in 45% of campaigns).

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