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Assimilation of multiscale terrestrial photography data into a physical model of snow processes

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Snow is an important component of hydrological, ecological, and climatic processes in mountain environments. The high heterogeneity of the spatial distribution of snow in Mediterranean areas usually poses a problem for the validation of GIS-based calculations of snowmelt/accumulation models due to non-negligible scale effects below the cell size. Many factors exert their influence on this irregular distribution: wind, topography, and atmospheric conditions. In the same way, many techniques can be used to predict the distribution process. Currently, the most popular techniques used in medium-large areas include satellite, aerial, or terrestrial images. The satellite and aerial photography data may have problems in adjusting to the significant scales associated with the spatial and temporal resolution of the process. They often operate with a fixed spatial and a low temporal resolution. In comparison, terrestrial photography is a powerful tool which allows one to work at high resolution scales with a relatively low cost.

In this work, we present a methodology for the use of georeferenced terrestrial photography in the validation of a snowmelt/accumulation model in Mediterranean areas (Herrero et al., 2009). Based on graphics design principles (Foley et al.,1990) and referencing with a digital elevation model (DEM) (Corripio et al.,2004), the proposed method includes an algorithm to detect snow automatically. This algorithm is also used to estimate the snow depth in a detailed photograph by a coloured ranging rod. The final results are snow masks with the pixels covered by snow in the photographed area for the study period, with a frequency ranging from 2 hours to 4 days and the spatial resolution of the DEM used. This technique has been evaluated at two different study sites in Sierra Nevada Natural Park (Southern Spain, with altitudes ranging from 1500 to 3500 m), to capture two different spatial scales for the size of the snow patches, O$\sim$1m (detail scale on a 0.1x0.1 m DEM) and O$\sim$100m (hillslope scale on a 10x10 m DEM).

The results of this image processing show that the methodology is valid for the two scales analyzed and provides an efficient high resolution tool for monitoring small mountain areas and also validating the results of snowmelt/accumulation models which operate on a distributed scale with a 30x30 cell size. At detailed scale, the snow masks are used to change the value of the windless transfer coefficient for the turbulence sensible heat flux proposed in Herrero et al. (2009), decreasing its value from 5 $Wm^{-2}K^{-1}$ (obtained for point calculations) to an effective value of 3 $Wm^{-2}K^{-1}$ for the cell area, and to define a new parameterization for the depletion curves, which extends the point scale equations results to distributed values. Also, the analysis of the results at hillslope scale identified the wind as the main driving factor of the snow distribution, and provided us with a basis to develop a wind interpolation algorithm to be included in the snowmelt/accumulation model by Herrero et al. (2011).