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Do we need a dynamic snow depth threshold when comparing hydrological models with remote sensing products in mountain catchments?

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To assess the performance of simulated snow cover of hydrological models, it is common practice to compare simulated data with observed ones derived from satellite images such as MODIS. However, technical and methodological limitations such as data availability of MODIS products, its spatial resolution or difficulties in finding appropriate parameterisations of the model need to be solved previously. Another important assumption usually made is the threshold of minimum simulated snow depth, generally set to 10 mm of snow depth, to respect the MODIS detection thresholds for snow cover. But is such a constant threshold appropriate for complex alpine terrain? How important is the impact of different snow depth thresholds on the spatial and temporal distribution of the pixel-based overall accuracy (OA)?
To address this aspect, we compared the snow covered area (SCA) simulated by the GEOtop 2.0 snow model to the daily composite 250 m EURAC MODIS SCA in the upper Saldur basin (61 km^2, Eastern Italian Alps) during the period October 2011 – October 2013. Initially, we calibrated the snow model against snow depths and snow water equivalents at point scale, taken from measurements at different meteorological stations.
We applied different snow depth thresholds (0 mm, 10 mm, 50 mm, and 100 mm) to obtain the simulated snow cover and assessed the changes in OA both in time (during the entire evaluation period, accumulation and melting season) and space (entire catchment and specific areas of topographic characteristics such as elevation, slope, aspect, landcover, and roughness).
Results show remarkable spatial and temporal differences in OA with respect to different snow depth thresholds. Inaccuracies of simulated and observed SCA during the accumulation season September to November 2012 were located in areas with north-west aspect, slopes of 30° or little elevation differences at sub-pixel scale (-0.25 to 0 m). We obtained best agreements with MODIS SCA for a snow depth threshold of 100 mm, leading to increased OA (> 0.8) in 13‰ of the catchment area. SCA agreement in January 2012 and 2013 was slightly limited by MODIS sensor detection due to shading effects and low illumination in areas exposed north-west to north. On the contrary, during the melting season in April 2013 and after the September 2013 snowfall event seemed to depend more on parameterisation than on snow depth thresholds. In contrast, inaccuracies during the melting season March to June 2013 could hardly be attributed to topographic characteristics and different snow depth thresholds but rather on model parameterisation. We identified specific conditions (p.e. specific snowfall events in autumn 2012 and spring 2013) when either MODIS data or the hydrological model was less accurate, thus justifying the need for improvements of precision in the snow cover detection algorithms or in the model's process description.
In consequence, our study observations could support future snow cover evaluations in mountain areas, where spatially and temporally dynamic snow depth thresholds are transferred from the catchment scale to the regional scale.

Keywords: snow cover, snow modelling, MODIS, snow depth sensitivity, alpine catchment