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The combination of MODIS cloud-free snow products and snow simulations to detect snow cover changes in low mountain ranges of Germany

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In the context of climate change, the dynamics of snow cover plays a crucial role in rebalancing the global energy and water budgets. Remote sensing, hydrological modeling and in situ observations are three techniques frequently utilized for snowpack investigations. However, each technique has its specific uncertainties. Our study aims at linking the three methods in order to better understand the spatial-temporal behavior of seasonal snow cover and snow cover changes as a consequence of temperature increase. Our study focusses on the southwest of Germany where a complex topography prevails, with small-scale differences in elevation between lowlands and several low mountain ranges (such as the Black Forest). The highest elevations are below 1500 m a.s.l. which makes the occurrence of snow vulnerable to the impact of climate change. Currently, typical values of mean annual snow duration range between less than 20 days at the lowest elevations and up to 160 in the highest parts of the mountains. Winter cloud coverage is usually high which makes it difficult to apply remote sensing methods to determine snow cover and snow duration.

In this study, a multistep method was developed to generate cloud-free MODIS daily snow cover products. A conditional probability interpolation was employed to reclassify the remaining cloud cover on MODIS snow maps based on in situ snow depth observations. Then we implemented a set of meteorological filters to minimize the misclassified snow in MODIS snow products. In a next step, the snow module of a hydrological model (TRAIN) was validated with in-situ snow observations and the improved MODIS data, indicating a well performance of the model. TRAIN was then applied over about 50 years to simulate snow water equivalent (SWE) and snow covered area on a 1 x 1 km raster covering the area under investigation. Trend tests for the simulated SWE as well as for recorded air temperature and precipitation were performed using Mann-Kendall (MK) trend test and Theil-Sen estimator, which showed significant SWE decline at the high elevations (December to March) and an intense warming trend in March during the study period of 1961-2008. Correlation analysis suggests temperature played a more important role than precipitation in affecting the snow recession in this area.