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Simple estimations of new and bulk snow density in the Italian Alps: Lessons from a decade of distributed observations

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The Snow Water Equivalent (SWE), combining the information of snow depth and snow density is a necessary variable for snow-hydrological studies and applications, as well as, for ecological function or avalanche forecasting. Direct automatics measurements of SWE requires an easy access to the monitoring site while manual measurements are costly and challenging. On the other hands, physically based models for snow density estimates require local meteorological data limiting their application in complex topography such as mountains areas. For this reason, different empirical regressions methods for the characterization of SWE and associated variability have been proposed for regional studies. In this study, we report our experience based on simple regression models able to characterize the new snow density and the snow bulk density at the scale of the entire Italian Alps, taking advantage of a decade of distributed observations. 12112 snowfall observations (2005-2015) gathered at 122 stations, ranging from 650 m to 2858 m a.s.l., have been analyzed to characterize the new snow density. 6078 snowpack depth and bulk density measurements (2009-2018) from 150 sites, ranging from 640 m to 3400 m a.s.l., have been collected to investigate the snow bulk density.

The mean air temperature of the 24 hours preceding the snowfall event, as a proxy of the transformation of freshly-fallen snow, has been found to be the best predictor of the new snow density, within 30% of uncertainty over the whole Italian Alps. While monthly regression allows considering part of the snow state variability through seasonality, the analysis of the associated residues suggests that, in the lack of local wind field information, the adoption of a local approach is not able to substantially increase the predictive capabilities of the model. The snow bulk density variability mainly responds to seasonality and can be estimated adopting the day of the year, as a proxy of the combined effect of compaction through seasonal snow accumulation and partial melting during the late season. Such approach enables a continuous (along the season) description of the SWE variation within 15% of uncertainty, similar to the within-site variability, presenting even better performances during the late season through the introduction of non-linearity. Differently from new snow density, regionalization performed considering separately those regions close to the sea improves the overall performances.

Although more performing models have already been proposed, the variables necessary to feed the proposed regressions (i.e. mean air temperature for new snow density and the day of the year for the bulk snow density) are easy to be acquired, making the proposed models valuable tools either in case of low instrumented watersheds or for past reconstruction. Finally, the low number of parameters to be calibrated makes the proposed regressions easy to be tested in other regions.