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Calculation of new snow densities from sub-daily automated snow measurements

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In mountain regions there is an increasing demand for high-quality analysis, nowcasting and short-range forecasts of the spatial distribution of snowfall. Operational services, such as for avalanche warning, road maintenance and hydrology, as well as hydropower companies and ski resorts need reliable information on the depth of new snow (HN) and the corresponding water equivalent (HNW). However, the ratio of HNW to HN can vary from 1:3 to 1:30 because of the high variability of new snow density with respect to meteorological conditions. In the past, attempts were made to calculate new snow densities from meteorological parameters mainly using daily values of temperature and wind. Further complex statistical relationships have been used to calculate new snow densities on hourly to sub-hourly time intervals to drive multi-layer snow cover models. However, only a few long-term in-situ measurements of new snow density exist for sub-daily time intervals. Settling processes within the new snow due to loading and metamorphism need to be considered when computing new snow density. As the effect of these processes is more pronounced for long time intervals, a high temporal resolution of measurements is desirable.

Within the pluSnow project data of several automatic weather stations with simultaneous measurements of precipitation (pluviometers), snow water equivalent (SWE) using snow pillows and snow depth (HS) measurements using ultrasonic rangers were analysed. New snow densities were calculated for a set of data filtered on the basis of meteorological thresholds. The calculated new snow densities were compared to results from existing new snow density parameterizations. To account for effects of settling of the snow cover, a case study based on a multi-year data set using the snow cover model SNOWPACK at Weissfluhjoch was performed.

Measured median values of hourly new snow densities at the different stations range from 54 to 83 kgm-3. This is considerably lower than a 1:10 approximation (i.e. 100 kgm-3), which is mainly based on daily values in the Alps.
Variations in new snow density could not be explained in a satisfactory manner using meteorological data measured at the same location. Likewise, some of the tested parametrizations of new snow density, which primarily use air temperature as a proxy, result in median new snow densities close to the ones from automated measurements, but show only a low correlation between calculated and measured new snow densities. The case study on the influence of snow settling on HN resulted on average in an underestimation of HN by 17%, which corresponds to 2-3% of the cumulated HN from the previous 24 hours. Therefore, the mean hourly new snow densities may be overestimated by 14%.

The analysis in this study is especially limited with respect to the meteorological influence on the HS measurement using ultra-sonic rangers. Nevertheless, the reasonable mean values encourage calculating new snow densities from standard hydro-meteorological measurements using more precise observation devices such as optical snow depth sensors and more sensitive scales for SWE measurements also on sub-daily time-scales.