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Snow water equivalent assessment with low-cost GNSS sensors along a steep elevation gradient

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Snow water equivalent (SWE) is a key property of the seasonal snow cover. The water stored in the snowpack is a crucial contribution to the hydrological cycle in mountain areas. Estimating the spatial distribution and temporal evolution of SWE in mountain region is currently considered as one of the most important unsolved problems in snow hydrology. Direct measurements of SWE are still essential but are scarce and mostly non-continuous (manual measurements) or rather expensive (automatic scales or snow pillows). Recently, a novel in-situ measurement technique based on freely-available L-band Global Navigation Satellite Signals (GNSS) signals, like GPS signals, showed promising results in deriving SWE. This snow measurement technique is in general based on the combination of GNSS carrier phase measurements indicating signal time delay and GNSS signals strength information indicating signal attenuation within the snowpack. To derive the SWE, the signal time delay and attenuation are obtained from the signal differences between a GNSS antenna buried below the snowpack and a reference antenna above the snow cover. This method has been tested and validated at the high-alpine test site Weissfluhjoch (Eastern Swiss Alps, 2540 m asl.) and seems to work well for the snow conditions met at this elevation. However, the snow characteristics can vary considerably depending on location and elevation. At lower elevations the snow cover is normally shallower and is more frequently subject to melt-freeze cycles leading to faster snow aging and different snow densities. Moreover, it was not yet tested, if a rapid transition from dry to wet snow conditions is a challenge for deriving SWE by this GNSS method. To test these potential issues and aiming to improve our method, we installed four GNSS stations along a steep elevation gradient (820 m, 1185 m, 1510 m, and 2540 m asl.) within only a few kilometres in the Eastern Swiss Alps in autumn 2018. For validation purposes, the snow height is monitored continuously and automatically with additional sensors. SWE is measured at least biweekly at all locations. Moreover, at the two higher elevations, SWE is also measured continuously with snow scales. We present preliminary results from the ongoing season along this steep elevation gradient. The latest GNSS processing steps as well as our recent integration of Galileo besides GPS signals, which is particular useful to increase GNSS satellite visibility for valley sites, will be shown. Finally, we will assess whether the method is suitable for operational use at different elevations, in steep valley sites and under various snow conditions for deriving SWE continuously with reasonable costs.