Geophysical Research Abstracts
Vol. 21, EGU2019-8134, 2019
EGU General Assembly 2019

GPS-based measurements of snow cover properties for snow-hydrological, risk and snow quality applications

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Continuous information on the snow water equivalent (SWE) is essential for diverse snow-hydrological and water resources management tasks. Additionally, knowledge on the volumetric liquid water content (LWC) supports assessing snow instability for avalanche forecasting and snow quality, e.g., for ski resort management. Hence, to simultaneously derive SWE and LWC, we developed a novel measurement setup based on freely-available signals of the Global Navigation System (GPS) using information on carrier phase measurements and signals strengths. This in-situ sensor setup is in general composed of two static low-cost GPS antennas and receivers, whereof one antenna is mounted on the ground and is covered with snow during the winter seasons. The other antenna is installed on a pole to be permanently above the snow cover. We derived the snow cover properties SWE, snow height and LWC continuously and non-destructively based on signal attenuation and time delay within the snowpack considering the varying dielectric properties of dry and wet snow. So far, the GPS-derived snow cover properties were validated at the high-alpine test site Weissfluhjoch, Switzerland (2540 m a.s.l.), and at a sub-arctic test site in Quebec, Canada. In a further step, we combined distributed measurements of self-designed and autonomous in-situ GPS stations with information from satellite-based Earth Observation (EO) and hydrological modelling within the ESA business applications demonstration project SnowSense (2015-2018) for the entire island of Newfoundland. Spatially distributed SWE and melt-onset maps as well as continuously assessed runoff information were of great interest for our two demonstration users, especially in view of improving flood forecasting and hydropower management for remote locations. Currently, SnowSense technology made the step towards a commercially modular snow-hydrological service. Apart from hydrological applications, we also aim to employ the GPS measurement technique in avalanche-prone slopes and for technical snow management in alpine skiing resorts, e.g. at Zugspitze, Germany. We provide a comprehensive overview on the in-situ sensor setup itself, the validation of the GPS-derived snow cover properties and the integrated runoff assessment as well as potential applications.