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Airborne laser scan measurements of winter snow accumulation in high alpine catchments – hydrological implications and verification by ground penetrating radar at glacier surface

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The snow cover as storage of winter precipitation is a substantial source for runoff generation in high mountain catchments. Redistribution of solid precipitation, caused by wind and gravity, leads to a characteristic spatial distribution of snow accumulation which differs from simple model assumption of a homogenous snowpack increasing with altitude. Both, the distinct distribution of snow accumulation and the total amount of SWE stored in the snow cover, affect the magnitude and seasonality of melt water runoff. Complex relations exist between the spatial pattern of snow accumulation and the presence of glaciers and vice versa.

For proper hydrological modeling in high mountain catchments, knowledge about snow cover distribution is an important requirement. To date, to evaluate modeling results, spatially insufficient point data on snow depths and SWE are usually available. On catchment scale, optical space-borne remote sensing techniques deliver areal extent of snow cover, but no snow depths and hence no volume of snow cover. Multi-temporal airborne laser scanning (ALS) is an active remote sensing method to obtain elevation changes extensively even in inaccessible alpine terrain.

Before the start and at the end of accumulation season of winter 2010/2011, two airborne laser scan acquisitions were performed in the Ötztal Alps (Tirol, Austria). Differences of the respective digital elevation models were interpreted as snow depths and converted into SWE using a simple regression method between snow depths and snow density. Preferred snow accumulation areas were determined, e.g. wind sheltered depressions, the base of steep mountain walls and flat glacier surfaces. At catchment scale, solid precipitation is obviously redistributed from wind exposed mountain ridges to lower elevations, inducing characteristic elevations of maximum snow accumulation. Overall, catchment precipitation derived from snow accumulation is a valuable reference for precipitation approaches in hydrological modeling.

Due to ice dynamic processes, elevation changes observed by ALS at glacier surface can locally deviate from real snow depths. To account for these processes, two field campaigns were conducted along with the ALS flights to determine the snow depths utilizing ground penetrating radar (GPR), snow probing and snow pits. Geo-referenced GPR profiles were calibrated to measurements of snow depth at the snow pit locations and by snow probing data. Hence, the GPR measurements are a continuous source of snow depths along defined tracks. These data were compared to ALS obtained snow depths. Differences caused by ice dynamic processes are mainly located at higher glacier elevations. Close to the glacier tongue, variations between elevation changes of ALS and GPR determined snow depths are much smaller and irregularly distributed around zero.