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Towards Better Predictions of Snow Melt Runoffs: Measuring Snow Depth and Density Using Ground Penetrating Radar

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Snow melt runoff predictions by hydrological models are essential for efficient hydropower production in the Scandinavian countries, similar to many areas with a substantial amount of snow precipitation. Operational models in Sweden are currently based on precipitation and temperature as the main input variables and calibrated with runoff data, but there is an interest to make better use of new measurement systems for distributed snow data, especially the total amount of snow in the catchment area of interest. The main objective of our project is to investigate the potential improvements in runoff predictions in relation to the choice of model structure and measurement systems, as well as measurement accuracy. This involves comparing different methods for estimating the total amount of snow in a catchment area as well as improving their accuracy. Here we present the result of such comparison based on data from case studies conducted in Sweden. Our approach involves automated single point measurements over a long period in combination with high resolution distributed measurements over a large area during critical periods.

Stationary measurements are performed at a snow measurement station, with snow density and wetness estimated with a low-frequency impedance sensor band, snow depth measured using an ultrasonic depth gauge, and temperature measured at several (fixed) snow depths and at the snow surface. The station, located at Lake Korsvattnet in Swedish mountains, operates continuously during the whole winter season.

Measurements of snow depth and density over large lateral distances are performed using multi-offset ground penetrating radar (GPR) operated from a snow mobile. These measurements are conducted once a year, in late winter, when the amount of snow is expected to reach its maximum before snow melt begins. Since 2007 and during the duration of the project, yearly measurements have been and will be taken in two Swedish mountain basins important for hydropower, Lake Korsvattnet and Lake Kultsjön. The radar system used is a multi-channel RAMAC/GPR system with shielded 800 and 1600 MHz antennas. The antennas are attached to a snow mobile sledge forming an array, which allows us to use the common midpoint method to calculate both radar propagation velocity and two-way travel time of radar pulses. For dry snow this gives snow density and depth via an empirical formula establishing the relationship between electrical permittivity (i.e. propagation velocity) and snow density. Note that for wet snow additional information about liquid water content in snow is required, which can be estimated, for example, from radar wave attenuation. However, for the purpose of this presentation we assume that the snow is dry.

The results of GPR measurements taken from a snow mobile are compared with results obtained by two other methods. The first comparison is with manual measurements taken with traditional snow tubes along a 1000 m measurement profile at the area of Lake Korsvattnet. In this case a log-linear relationship between snow depth and density is used to interpret GPR data (note that this relationship is obtained from analysis of radar data itself). The other comparison is with GPR measurements taken from a helicopter along a 12 km transect in the area of Lake Kultsjön.