University of Fribourg / Faculty of Science and Medicine / Department of Geosciences

Towards improved spatio-temporal snow observations for glacierized high mountain regions by a multi-sensor approach

Rebecca Gugerli

The cryospheric elements of high mountain regions, i.e., seasonal snowpack, glaciers and permafrost are essential components of the hydrological system and highly sensitive to climate change. While changes in air temperature are fairly well understood, changes in precipitation are more uncertain, especially for high mountain regions during the winter season. To improve our understanding of changes in precipitation patterns and amounts as well as their impact on the cryospheric elements, reliable estimates of solid precipitation (snowfall) and snow accumulation are key. Yet, the challenges posed by the harsh environment, remoteness and complex topography limit the spatio-temporal resolution of snow observations. To address the lack of reliable and temporally continuous snow water equivalent (SWE) observations, i.e., the liquid equivalent of the snowpack, this thesis explores the performance of a cosmic ray sensor (CRS) on two Swiss glacier sites (Glacier de la Plaine Morte and Findelengletscher) and applications of its measurements with a focus on uncertainties within readily available precipitation products.

Validated with 17 manual SWE observations by means of snow cores and snow pits, the CRS shows a good performance and is thus considered a reliable and robust device to obtain temporally continuous SWE, and combined with a snow depth sensor, daily bulk snow density observations on glacierized sites.

The innovative combination of in-situ SWE obtained manually and by the CRS on glacierized sites with snowfall estimates from high-quality readily available precipitation products shows that all investigated products strongly underestimate SWE on Alpine glaciers. These products, which have a 1x1km grid and at least a daily resolution, are (i) based on interpolated gauge measurements, (ii) remotely sensed with weather radars that are merged with gauge measurements, and (iii) modelled with a numerical weather forecast model. Reasons for the strong underestimation include uncertainties in gauge observations, poor visibility of the weather radars and preferential deposition at glacier sites. By deriving a glacier-specific adjustment factor, the snow accumulation estimate is significantly improved.

The results presented outline the potential of the CRS and of precipitation products to provide accurate snow observations in cold and remote areas and bring us a step closer to improved spatio-temporal snow observations for glacierized high mountain regions.

Jury
Dr. Nadine Salzmann (supervisor)
Prof. Dr. Horst Machguth (internal expert)
Prof. Dr. Michael Lehning (external expert)
Prof. Dr. Ulrich Strasser (external expert)
Prof. Dr. Jessica Lundquist (external expert)
Prof. Dr. Martin Hoelze (president of the jury)