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Meteorological conditions associated to high sublimation amounts in semiarid high-elevation Andes decrease the performance of empirical melt models

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Empirical melt (EM) models are often preferred to surface energy balance (SEB) models to calculate melt amounts of snow and ice in hydrological modelling of high-elevation catchments. The most common reasons to support this decision are that, in comparison to SEB models, EM models require lower levels of meteorological data, complexity and computational costs. However, EM models assume that melt can be characterized by means of a few index variables only, and their results strongly depend on the transferability in space and time of the calibrated empirical parameters. In addition, they are intrinsically limited in accounting for specific process components, the complexity of which cannot be easily reconciled with the empirical nature of the model. As an example of an EM model, in this study we use the Enhanced Temperature Index (ETI) model, which calculates melt amounts using air temperature and the shortwave radiation balance as index variables.
We evaluate the performance of the ETI model on dry high-elevation sites where sublimation amounts – that are not explicitly accounted for the EM model – represent a relevant percentage of total ablation (1.1 to 8.7%). We analyse a data set of four Automatic Weather Stations (AWS), which were collected during the ablation season 2013-14, at elevations between 3466 and 4775 m asl, on the glaciers El Tapado, San Francisco, Bello and El Yeso, which are located in the semiarid Andes of central Chile. We complement our analysis using data from past studies in Juncal Norte Glacier (Chile) and Haut Glacier d'Arolla (Switzerland), during the ablation seasons 2008-09 and 2006, respectively.
We use the results of a SEB model, applied to each study site, along the entire season, to calibrate the ETI model. The ETI model was not designed to calculate sublimation amounts, however, results show that their ability is low also to simulate melt amounts at sites where sublimation represents larger percentages of total ablation. In fact, we observed that Nash-Sutcliffe (NS) coefficients obtained by the ETI significantly change from 0.96 to 0.72 on sites were sublimation percentages vary from 1.1 to 8.7%, respectively. We think that the performance of the ETI model decrease because a large share of short and longwave radiation is required to balance the snowpack temperature decrease generated by the loss of energy from latent heat fluxes in areas with significant sublimation. We identify meteorological and environmental conditions under which the ETI model can be used to calculate melt at high elevation sites in arid environments, and when its use would result in errors that would affect their parameters and simulation of the water balance of such catchments.