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Modelling distributed glacier ablation on Haut Glacier d'Arolla, Switzerland: a comparison of an energy-balance and an enhanced temperature-index model

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Modelling melt rates across alpine glaciers is an essential step for studying the interannual evolution of snow-cover and glacier ice and for estimation of the total runoff from glacierised basins. Two approaches are commonly used to compute melt: physically-based energy-balance models in which each of the relevant energy fluxes at the glacier-surface interface is computed using energy-balance equations and more empirical temperature-index models in which melt is calculated as a linear function of air temperature. The latter method has been recently improved by including additional variables, in order to bridge the gap between the two approaches and combine the lower data requirement of the latter with the higher accuracy of the former. Comparison between the two methods has been often conducted at the point scale, but very few such studies exist at the glacier wide-scale.

The main aim of this paper is to compare predictive skills and limitations of the two approaches at the distributed scale when input data from both on and off-glacier Automatic Weather Stations (AWSs) are used. For this purpose, we compute distributed ablation on Haut Glacier d'Arolla, Switzerland, by means of a physically-based energy-balance (EB) model and an enhanced temperature-index model (ETI), for the ablation seasons 2001 and 2006. Meteorological measurements from AWSs located on and off-glacier are extrapolated to the distributed glacier-wide scale using various extrapolation techniques. A parametric model that includes the effect of shading, atmospheric transmittance and reflection from slopes is used for modelling shortwave radiation. In the EB model, the longwave radiation flux is computed by means of Stefan-Boltzmann relationships and turbulent fluxes are calculated using the bulk aerodynamic method. Subsurface heat conduction are also included.

Hourly melt rates are validated against ablation observations derived from an ultrasonic depth gauge and ablation stakes (point scale) and the evolution of the snowline position is validated against georeferenced photos (distributed scale). We also conduct a thorough internal validation by comparing simulated values of gridded input variables, such as incoming shortwave and longwave radiation, albedo and surface temperature, with observations at various AWSs both on and around the glacier.

We show that differences between the EB and ETI models are not large in terms of cumulated total melt, especially when the models are forced by meteorological input data measured outside of the glacier boundary layer. Extrapolation of meteorological input variables, however, is a very large source of model uncertainty and it is more important than recalibration of the various model parameters.