Distributed hydro-glaciological modeling of the Antisana massif in Ecuador during the 2005-2008 period

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In partial glacierized basins worldwide, the glacier recession driven by climatic factors has had a great impact on water availability for populations who depend directly on glacier melt water. Such is the case of Quito (2.2 million of habitants), the capital of Ecuador, which depends on a network of water intakes located at the Antisana massif (0˚28'S, 78˚09'W, 456 km^2) covered with moraine, páramo, and particularly with an icecap (15.1 km^2) on the summit of the Antisana volcano. This study aims to describe the peculiar precipitation pattern acting on the Antisana massif, its impacts on glacier mass balance profiles and stream flow generation using the Distributed Hydrology and Vegetation Model with Glacier Dynamics (DHSVM-GDM) over the 2005-2008 period. In order to quantify the hydro-glaciological response, an initial glacier ice thickness (max: 120 m) was derived from a digital elevation model using the average shear stress and it was compared with radar observations. A sensitivity analysis of the glaciological parameters albedo and rain/snow temperature threshold was conducted on the Glacier 15α (4850-5750 m a.s.l., 0.28 km^2) located on the northwestern side of the volcano. On the other hand, the hydrological parameters: lateral conductivity, exponential decrease of lateral conductivity and temperature lapse rate where calibrated in the Humboldt catchment (4010-5750 m a.s.l., 14.2 km^2, 14% glacierized) located on the southwestern side of the volcano. Due to unmonitored precipitation around the icecap, the Climatology Composite Product of the Tropical Rainfall Measurement Mission (TRMM-TCC) was used to compute precipitation interpolation weights over the entire massif. Furthermore, the simulated streamflow was evaluated through comparisons with observations at the hydrological station Humboldt (4010 m a.s.l.) on the Humboldt catchment using the Kling Gupta Efficiency (KGE).

The sensitivity to the rain/snow temperature threshold showed that setting this parameter at 1˚C provides annual glacier mass balance profiles and equilibrium line altitudes approximated to those observed with ablation stacks and accumulation pits. In addition, an underestimation in precipitation of 60% above 5000 m a.s.l. reported in the literature was confirmed in the Glacier 15α mass balance simulated profiles. However, the albedo parametrization must be improved in order to capture subdaily variations. In a first model test a KGE=0.5 was achieved between simulated and observed streamflow, the estimated evapotranspiration of the páramo was about of the 60% of the total precipitation amount and a glacier contribution to streamflow used in part by water intakes was of 23% approximately which is fairly considerable in water management under future scenarios of climate change.