Geophysical Research Abstracts
Vol. 12, EGU2010-10987, 2010
EGU General Assembly 2010

Simulation of glacier hydrology: how much information do we need?

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For the management of water resources as well as for climate change impact predictions, the hydrologic cycle of high mountainous catchments is frequently simulated with very simple precipitation-discharge models representing the snow accumulation and ablation behavior of a very complex environment with a set of lumped equations accounting only for altitudinal temperature and precipitation differences.

These models are often calibrated so that the model reproduces as closely as possible a series of observed discharge measurements. The question inevitably arises whether long term predictions of such a calibrated model are actually reliable, since knowing that a model performs well for historic situations does by no means imply that it will perform well for future, considerably modified catchment conditions. A first, although not sufficient step to answer this question, is investigating whether with such a model, we are “getting the right answers for the right reasons”. In glacierized catchments, this would for example imply that a precipitation-runoff model should not just mimic observed discharge but also reproduce the glacier mass balance.

In this study, we show how much observed information we need to reliably calibrate a hydrological model for a high mountainous catchment. Based on glacio-hydrological data from the Rhone glacier catchment, we analyze how well a simple conceptual precipitation-runoff model can reproduce seasonal glacier mass balance data and in a second step, how much information is required to achieve a reliable model calibration. Here, we focus on the question whether observed discharge is sufficient or whether we need annual or even seasonal glacier mass balance data.

For this particular catchment, a detailed reproduction of observed seasonal balances requires a modification of the snow accumulation and ablation module. The model only accounts for altitudinal differences of the meteorological conditions and e.g. not for wind drift or exposition. As our results show, introducing seasonal accumulation and ablation parameters is sufficient to enable this simple model to reproduce observed seasonal balances and annual net balances. Furthermore, our results suggest that calibrating the hydrological model exclusively on discharge can lead to wrong representations of the intra-annual accumulation and ablation processes and, thus, to a bias in long term glacier mass balance simulations. Adding only a few annual net balance observations considerably reduces this bias. Calibrating exclusively on annual net balance data can, in turn, lead to wrong seasonal mass balance simulations.

Even if these results are case study specific, our conclusions give valuable new insights into the benefit of different types of observations for snow modeling in high alpine catchments. The developed methods of model calibration on sparse data of snow accumulation and ice ablation can easily be transposed to similar modeling settings.