Geophysical Research Abstracts
Vol. 18, EGU2016-4826, 2016
EGU General Assembly 2016

The value of snow data assimilation for runoff modeling in alpine catchments

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Snowmelt provides a dominant contribution to runoff and groundwater storages in mountainous regions, where, therefore, modeling snow processes is crucial for resource management as well as for flood or drought forecasting. Erroneous simulations of snow accumulation can bias the amount and timing of snowmelt simulations and thus impact runoff modeling. In this study, we address the question, whether the performance of a runoff model can be enhanced by integrating data from a dedicated external snow monitoring system. As a framework for our tests we used the hydrological model HBV (in the version HBVlight), which originally follows a temperature index approach with time-invariant calibrated degree-day factors to represent snowmelt. We modified HBV to use snowmelt time series from an external and spatially distributed snow model as alternative model input. The external snow model integrates three-dimensional sequential assimilation of snow monitoring data with a snowmelt model also based on the temperature index approach, but uses a time-variant degree-day factor. The following three variations of this external snow model were applied: a) the full model with assimilation of observational snow data from a dense monitoring network, b) the same snow model but with data assimilation switched off, c) a downgraded version of the same snow model representing snowmelt with a time-invariant degree-day factor. Model runs were conducted for 20 catchments at different elevations within Switzerland for 15 years. Our results show that at low and mid elevations the performance of the runoff simulations did not vary considerably with the snow model version chosen. At higher elevations, however, best performance in terms of simulated runoff was obtained when using the snowmelt time series from the snow model which utilized data assimilation. Considerably higher performance metrics for snow-rich years than for years with low snow amounts were demonstrated. These findings suggest that with increasing elevation and correspondingly increased snow, the accurate estimation of snow accumulation and melt rates gains importance.