Geophysical Research Abstracts
Vol. 21, EGU2019-3177, 2019
EGU General Assembly 2019

HydroCrowdMod – Rainfall-runoff-models can be calibrated using crowdsourced water level data

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Hydrological models are widely used to predict catchment runoff, but they require comprehensive (and expensive) discharge observations for model development and testing. For many catchments, particularly in less developed countries or in remote areas, such data is not available. Water levels can however be easily measured by citizens to collect data in catchments which would otherwise remain ungauged. The feasibility of calibrating hydrological models has not yet been tested using crowdsourced data although the concepts for using water levels instead of discharge data are described in literature.

Here we present a comparison between a rainfall-runoff-model calibrated against either automatically measured discharge data or water levels collected by citizens in a remote tropical catchment in Kenya. For this, Spearman-Rank-Coefficients between the measured water levels and the modelled discharge were calculated to identify the best 250 (CS250) and 50 (CS50) parameter sets out of 25,000 model runs in a Monte Carlo based framework. Crowdsourced water levels (n=271) and daily discharge from a one-year period starting on the 1th of April 2016 were used to calibrate a four-parameter lumped one-box model built with the Catchment Modelling Framework (CMF). For model validation, another one-year period of daily discharge data was used. In addition, we applied a simple water-balance-filter (F250 and F50) for bias reduction. In this case, we only accepted parameter sets in which modelled discharge agreed with the estimated discharge obtained from the water balance of precipitation minus actual evapotranspiration derived from MODIS data ($\pm$30% estimated uncertainty).

When calibrated against discharge, 199 parameter sets fulfilled the calibration criteria of a Nash-Sutcliffe-Efficiency (NSE) $\geq$ 0.8 and a Root Mean Square Error $\leq$ 0.5. The mean of all NSE in this case was 0.86. When calibrated against crowdsourced data only, we obtained a mean NSE of 0.51 for CS50 and 0.23 for CS250, when finally verifying the model with measured discharge. By including the water-balance-filter, NSEs were substantially improved to 0.87 and 0.86 for F50 and F250, respectively. Comparable trends were found for the validation period with efficiencies slightly reduced in relation to those found during calibration.

With this study, we demonstrate the value of crowdsourced water levels for rainfall-runoff-model calibration in data scarce regions. We emphasize the use of additional and easy to obtain spatial information on actual evapotranspiration to improve model credibility and the use of hydrological models to transfer crowdsourced water levels into a continuous discharge time series.