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Water level observations from Unmanned Aerial Vehicles (UAVs) for improving probabilistic estimations of interaction between rivers and groundwater

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Integrated hydrological models are generally calibrated against observations of river discharge and piezometric head in groundwater aquifers. Integrated hydrological models are rarely calibrated against spatially distributed water level observations measured by either in-situ stations or spaceborne platforms. Indeed in-situ observations derived from ground-based stations are generally spaced too far apart to capture spatial patterns in the water surface. On the other hand spaceborne observations have limited spatial resolution. Additionally satellite observations have a temporal resolution which is not ideal for observing the temporal patterns of the hydrological variables during extreme events. UAVs (Unmanned Aerial Vehicles) offer several advantages: i) high spatial resolution; ii) tracking of the water body better than any satellite technology; iii) timing of the sampling merely depending on the operators. In this case study the Mølleåen river (Denmark) and its catchment have been simulated through an integrated hydrological model (MIKE 11-MIKE SHE). This model was initially calibrated against observations of river discharge retrieved by in-situ stations and against piezometric head of the aquifers. Subsequently the hydrological model has been calibrated against dense spatially distributed water level observations, which could potentially be retrieved by UAVs. Error characteristics of synthetic UAV water level observations were taken from a recent proof-of-concept study. Since the technology for ranging water level is under development, UAV synthetic water level observations were extracted from another model of the river with higher spatial resolution (cross sections located every 10 m). This model with high resolution is assumed to be absolute truth for the purpose of this work. The river model with the coarser resolution has been calibrated against the synthetic water level observations through Differential Evolution Adaptive Metropolis (DREAM) algorithm, an efficient global Markov Chain Monte Carlo (MCMC) in high-dimensional spaces. Calibration against water level has demonstrated a significant improvement of the estimation of the exchange flow between groundwater and river branch. Groundwater flux and direction are now better simulated. Reliability and sharpness of the probabilistic forecasts are assessed with the sharpness, the interval skill score (ISS) of the 95% confidence interval, and with the root mean square error (RMSE) of the maximum a posteriori probability (MAP). The binary outcome (either gaining or loosing stream) of the flow direction is assessed with Brier score (BS). After water level calibration the sharpness of the estimations is approximately doubled with respect to the model calibrated only against discharge, ISS has improved from 2.4^{-7} to 7.8^{-8} $\frac{m^3}{s \cdot m}$, RMSE from 9.2^{-8} to 2.4^{-8} $\frac{m^3}{s \cdot m}$ and BS is halved from 0.58 to 0.25.