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Evaluation of surface runoff model hypothesis by multi-objective calibration using discharge and sediment data

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Conceptual hydrological models can move towards process-oriented modelling when addressing broader issues than flow modelling alone. For instance, water quality modelling generally requires understanding of pathways and travel times. However, conceptual modelling often relies on a calibration procedure of discharge at the outlet, which aggregates all processes at the catchment scale. As the number of parameters increases, such an approach can lead to model over-parametrisation issues. In this study we tested if adding a second kind of observation, specifically sediment data, can help distinguish surface runoff from total discharge. This new constraint relies on a hypothesis that in stream sediment concentrations are strongly influenced by surface runoff (through erosion and remobilisation). We tested our hypothesis by applying a multi-objective calibration (simulation performance on discharge and suspended sediment) to the World-Wide HYPE hydrological model (WWH) and we used this framework to evaluate new surface flow modelling routines. We gathered data for 111 catchments spread over the USA where both discharge and sediment observation were available at a daily step at locations suitable for WWH.

Results show that in comparison to a single-objective calibration on discharge this multi-objective calibration enables a significant improvement on the simulation performance of suspended sediments without a significant impact on the performance of discharge. This illustrates the benefits of multi-objective calibration rather than using two calibrations made one after the other. In addition, this evaluation framework highlights the advantage of a new process description for surface runoff in the WWH model that relates soil moisture conditions to surface runoff ratio. The new surface runoff routine resulted in similar discharge performances as the original one but with fewer parameters, which reduce equifinality and can prevent inadequate model complexity in data-poor areas.