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Hybrid Modelling Approach to Prairie hydrology: Fusing Data-driven and Process-based Hydrological Models

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Modeling the hydrological response in prairie regions, characterized by flat and undulating terrain, and thus, large non-contributing areas, is a known challenge. The hydrological response (runoff) is the combination of the traditional runoff from the hydrologically contributing area and the occasional overflow from the non-contributing area. This study provides a unique opportunity to analyze the issue of fusing the Soil and Water Assessment Tool (SWAT) and Artificial Neural Networks (ANNs) in a hybrid structure to model the hydrological response in prairie regions. A hybrid SWAT-ANN model is proposed, where the SWAT component and the ANN module deal with the effective (contributing) area and the non-contributing area, respectively. The hybrid model is applied to the case study of Moose Jaw watershed, located in southern Saskatchewan, Canada. As an initial exploration, a comparison between ANN and SWAT models is established based on addressing the daily runoff (streamflow) prediction accuracy using multiple error measures. This is done to identify the merits and drawbacks of each modeling approach. It has been found out that the SWAT model has better performance during the low flow periods but with degraded efficiency during periods of high flows. The case is different for the ANN model as ANNs exhibit improved simulation during high flow periods but with biased estimates during low flow periods. The modelling results show that the new hybrid SWAT-ANN model is capable of exploiting the strengths of both SWAT and ANN models in an integrated framrwork. The new hybrid SWAT-ANN model simulates daily runoff quite satisfactorily with NSE measures of 0.80 and 0.83 during calibration and validation periods, respectively. Furthermore, an experimental assessment was performed to identify the effects of the ANN training method on the performance of the hybrid model as well as the parametric identifiability. Overall, the results obtained in this study suggest that the fusion of process-based and data driven models can provide an alternative modelling approach to prairie hydrology. The approach is capable of representing the highly non-linear nature of the hydrological processes and in particular, the challenging response originating from the hydrologically non-contributing areas.