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Improving the representation of the prairie pothole dynamics in land surface models

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The hydrography of the prairie basins is complicated by the existence of numerous land depressions, known as prairie potholes, which can retain a substantial amount of surface runoff. Consequently, the runoff production in the prairies follows a fill, spill, and merging mechanism, which results in a dynamic contributing area that makes the streamflow simulation challenging. Existing approaches to represent the potholes' dynamics, in different hydrological models, use either a lumped or a series of reservoirs that contribute flow after exceeding a certain storage threshold. These approaches are simplified and do not represent the actual dynamics of the potholes nor their spatial water extents. Consequently, these approaches may not be useful in capturing the potholes' complexities and may not be able to accurately simulate the complex prairie streamflow. This study advances towards more accurate and physically-based streamflow simulation in the prairies by implanting a physically-based runoff generation algorithm (Prairie Region Inundation MApping, PRIMA model) within the MESH land surface model, and is referred to as MESH-PRIMA. PRIMA is a recently developed hydrological routing model that can simulate the lateral movement of water over prairie landscape using topographic data provided via DEMs. In MESH-PRIMA, MESH handles the vertical water balance calculations, whereas PRIMA routes the water and determines the amount of water storage and surface runoff. The streamflow simulations of MESH-PRIMA (using different DEM resolution as a topographic input) and MESH with its existing conceptual pothole dynamics algorithm are tested on a number of pothole-dominated watersheds within Saskatchewan, Canada, and compared against observed flows. MESH-PRIMA provides improved streamflow and peak flow simulation, compared to that of MESH with its conceptual pothole algorithm, based on the metrics evaluated for the simulations. MESH-PRIMA shows potential for simulating the actual pothole water extents when compared against water areas obtained from remote sensing data. The use of different DEM resolution changes the resulting pothole water extent, especially for the small potholes as they are not detected in the coarse DEM. MESH-PRIMA can be considered as a hydraulic-hydrologic model that can be used for better understanding and accurate representation of the complex prairie hydrology.