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An Equivalent cross-section Framework for improving computational efficiency in Distributed Hydrologic Modelling

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While the potential uses and benefits of distributed catchment simulation models is undeniable, their practical usage is often hindered by the computational resources they demand. To reduce the computational time/effort in distributed hydrological modelling, a new approach of modelling over an equivalent cross-section is investigated where topographical and physiographic properties of first-order sub-basins are aggregated to constitute modelling elements. To formulate an equivalent cross-section, a homogenization test is conducted to assess the loss in accuracy when averaging topographic and physiographic variables, i.e. length, slope, soil depth and soil type. The homogenization test indicates that the accuracy lost in weighting the soil type is greatest, therefore it needs to be weighted in a systematic manner to formulate equivalent cross-sections. If the soil type remains the same within the sub-basin, a single equivalent cross-section is formulated for the entire sub-basin. If the soil type follows a specific pattern, i.e. different soil types near the centre of the river, middle of hillslope and ridge line, three equivalent cross-sections (left bank, right bank and head water) are required. If the soil types are complex and do not follow any specific pattern, multiple equivalent cross-sections are required based on the number of soil types. The equivalent cross-sections are formulated for a series of first order sub-basins by implementing different weighting methods of topographic and physiographic variables of landforms within the entire or part of a hillslope. The formulated equivalent cross-sections are then simulated using a 2-dimensional, Richards' equation based distributed hydrological model. The simulated fluxes are multiplied by the weighted area of each equivalent cross-section to calculate the total fluxes from the sub-basins. The simulated fluxes include horizontal flow, transpiration, soil evaporation, deep drainage and soil moisture.

To assess the accuracy of equivalent cross-section approach, the sub-basins are also divided into equally spaced multiple hillslope cross-sections. These cross-sections are simulated in a fully distributed settings using the 2-dimensional, Richards' equation based distributed hydrological model. The simulated fluxes are multiplied by the contributing area of each cross-section to get total fluxes from each sub-basin referred as reference fluxes. The equivalent cross-section approach is investigated for seven first order sub-basins of the McLaughlin catchment of the Snowy River, NSW, Australia, and evaluated in Wagga-Wagga experimental catchment. Our results show that the simulated fluxes using an equivalent cross-section approach are very close to the reference fluxes whereas computational time is reduced of the order of ~4 to ~22 times in comparison to the fully distributed settings. The transpiration and soil evaporation are the dominant fluxes and constitute ~85% of actual rainfall. Overall, the accuracy achieved in dominant fluxes is higher than the other fluxes.

The simulated soil moistures from equivalent cross-section approach are compared with the in-situ soil moisture observations in the Wagga-Wagga experimental catchment in NSW, and results found to be consistent. Our results illustrate that the equivalent cross-section approach reduces the computational time significantly while maintaining the same order of accuracy in predicting the hydrological fluxes. As a result, this approach provides a great potential for implementation of distributed hydrological models at regional scales.