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SMART: A New Semi-distributed Hydrologic Modelling Framework for Soil Moisture and Runoff Simulations

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A new GIS-based semi-distributed hydrological modelling framework is developed based upon the delineation of contiguous and topologically connected Hydrologic Response Units (HRUs). The Soil Moisture and Runoff simulation Toolkit (SMART) performs topographic and geomorphic analysis of a catchment and delineates HRUs in each first order sub-basin. This HRU delineation approach maintains lateral flow dynamics in first order sub-basins and therefore it is suited for simulating runoff in upland catchments. Simulation elements in SMART are distributed cross sections or equivalent cross sections (ECS) in each first order sub-basin to represent hillslope hydrologic processes. Delineation of ECSs in SMART is performed by weighting the topographic and physiographic properties of the part or entire first-order sub-basin and has the advantage of reducing computational time/effort while maintaining reasonable accuracy in simulated hydrologic state and fluxes (e.g. soil moisture, evapotranspiration and runoff).
SMART workflow is written in MATLAB to automate the HRU and cross section delineations, model simulations across multiple cross sections, and post-processing of model outputs to visualize the results. The MATLAB Parallel Processing Toolbox is used for simultaneous simulations of cross sections and is further reduced computational time. SMART workflow tasks are: 1) delineation of first order sub-basins of a catchment using a digital elevation model, 2) hillslope delineation, 3) landform delineation in every first order sub-basin based on topographic and geomorphic properties of a group of sub-basins or the entire catchment, 4) formulation of cross sections as well as equivalent cross sections in every first order sub-basin, and 5) deriving vegetation and soil parameters from spatially distributed land cover and soil information. The current version of SMART uses a 2-d distributed hydrological model based on the Richards' equation. However, any hydrologic model can be incorporated in this framework. The post-processing tools generate time series of streamflow and evapotranspiration at the first order sub-basin scale and produce spatially distributed evapotranspiration and soil moisture across the catchment. SMART modelling framework and the automation procedures improve the toolkit application for large catchment scale simulations as they significantly reduce the model setup and computational times. Future work will focus on incorporating groundwater and vegetation dynamics in this framework.