A physically based distributed subsurface–surface flow dynamics model for forested mountainous catchments

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Abstract

This study was designed to develop a physically based hydrological model to describe the hydrological processes within forested mountainous river basins. The model describes the relationships between hydrological fluxes and catchment characteristics that are influenced by topography and land cover. Hydrological processes representative of temperate basins in steep terrain that are incorporated in the model include intercepted rainfall, evaporation, transpiration, infiltration into macropores, partitioning between preferential flow and soil matrix flow, percolation, capillary rise, surface flow (saturation-excess and return flow), subsurface flow (preferential subsurface flow and baseflow) and spatial water-table dynamics. The soil–vegetation–atmosphere transfer scheme used was the single-layer Penman–Monteith model, although a two-layer model was also provided. The catchment characteristics include topography (elevation, topographic indices), slope and contributing area, where a digital elevation model provided flow direction on the steepest gradient flow path. The hydrological fluxes and catchment characteristics are modelled based on the variable source-area concept, which defines the dynamics of the watershed response. Flow generated on land for each sub-basin is routed to the river channel by a kinematic wave model. In the river channel, the combined flows from sub-basins are routed by the Muskingum–Cunge model to the river outlet; these comprise inputs to the river downstream. The model was applied to the Hikimi river basin in Japan. Spatial decadal values of the normalized difference vegetation index and leaf area index were used for the yearly simulations. Results were satisfactory, as indicated by model efficiency criteria, and analysis showed that the rainfall input is not representative of the orographic lifting induced rainfall in the mountainous Hikimi river basin. Also, a simple representation of the effects of preferential flow within the soil matrix flow has a slight significance for soil moisture status, but is insignificant for river flow estimations.

Keywords:

Forest;

Mountainous terrain;

Macropores;

Runoff generation mechanisms;

Preferential subsurface flow;

Partitioning of vertical and horizontal (lateral) flow;

Physically based hydrological model