Linking GSSHA to SEDLIB: Improvements to in-stream sediment modeling

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Extended Abstract

The Gridded Surface Subsurface Hydrologic Analysis (GSSHA) model is a watershed analysis and management tool with the ability to simulate the movement of water, sediment, and associated constituents at the watershed-scale (Downer and Ogden, 2004). GSSHA provides the ability to explicitly simulate important watershed features such as streams, hydraulic structures, embankments, subsurface drainage systems, as well as reservoirs, lakes and detention basins, storm and tile drains.

When simulating a watershed, GSSHA utilizes an orthogonal mesh of 2D finite volumes to discretize the full domain. This mesh is used to compute all overland and groundwater flow and transport processes. Superimposed on this mesh, a link-node network of 1d finite volumes is used to describe the stream flow and transport processes. These two separate computational domains are linked dynamically at the time-step level, with fluxes that pass between them.

Heretofore, much of the development of sediment transport capability within GSSHA has focused on watershed processes, e.g.: raindrop and rill erosion, sheet flow transport processes, etc. (Downer et al., 2014). By contrast, the sediment transport processes developed for the stream flow network have been less rigorous. The stream flow network has been utilized primarily as a passive mechanism; whereby silt and clay sized sediment are represented as wash load emanating from the overland flow, and cannot interact with the sediment bed. The 1d channel network was developed to transport sand, but the sand transport model is an Exner-type equilibrium model, and is not capable of simulating any sand sorting or armoring processes within the streambed.

To introduce the ability to simulate dynamic sediment processes within the channel network, the in-stream module of GSSHA has been linked to the SEDLIB sediment transport library (Brown 2012). SEDLIB was developed at the Coastal and Hydraulics Laboratory (CHL) under the System Wide Water Resources Program (SWWRP) and Flood and Coastal (F&C) research program. SEDLIB is a fully generalized, multi-grain class, multi-bed layer, cohesive and cohesionless sediment transport module. It passes fluxes of sediment to and from the bed to the parent model (GSSHA), which then transports the sediments using the transport capabilities native to the parent model. SEDLIB was developed as a general in-stream sediment process library. In theory, SEDLIB can be linked to any H&H source code. SEDLIB has already been

linked with another ERDC H&H model, AdH (Adaptive Hydraulics). In this form, SEDLIB has been used broadly by many USACE engineers throughout the United States to simulate sediment transport processes at a variety of scales, from small watershed-scale streams to the largest rivers and estuaries.

The linkage between GSSHA and SEDLIB required a replacement of the existing in-stream sediment transport processes within GSSHA. The primary change that resulted was the introduction of a detailed description of the initial bed conditions within the channel network, which must be provided by the user. This initial condition describes the initial bed layers, and the grain class distribution of sediment within each layer.

When GSSHA is run with SEDLIB, the sediment bed in the 1d channel network becomes an additional source and/or sink of silt and clay sized sediment. Also, sediments that are buried at depth in the sediment bed can be exposed to erosion under very high shear stresses, and be introduced into the watershed. This capability can be used, for example, to investigate the likelihood of exposing buried contaminated sediments. The SEDLIB module also simulates the bed dynamics associated with sand and gravel sized sediments, including armoring, sorting and fining processes. Hence, SEDLIB provides a full suite of sediment bed dynamics that can be simulated in the channel network.

The linked GSSHA/SEDLIB model has been applied to simulate hydrodynamics and sediment transport for the USDA-ARS Goodwin Creek Experimental Watershed (GCEW). The GCEW is a rural 21.1 km^2 watershed near Batesville, Mississippi. The USDA-ARS has collected rainfall, runoff, and suspended sediment data in the watershed since 1986 at the basin outlet and the outlet of 12 sub-watersheds ranging in size from 0.17 to 17 km^2. A similarly dense precipitation data set has also been collected. Previous studies of this watershed using GSSHA (Downer et al., 2014) have revealed some deficiencies in the ability of the model to simulate peak sediment discharge, especially for the initial event, during storm events. These deficiencies were hypothesized to be associated with in-stream erosion of fines, which were not being simulated within the original GSSHA model. Hence, these results were revisited with the coupled GSSHA-SEDLIB model, to investigate this hypothesis numerically.

The new results confirm the plausibility of the hypothesis. The introduction of erodible fines with the numerical channel network increases the peak sediment discharges in a manner consistent with the observed discharges. Since there is insufficient data available to directly characterize the erosion rate of these fines, it is necessary to utilize a set of discharge data as a calibration data set, and then compare these concentrations to other events where no calibration adjustments are made, to validate the modeling quantitatively. The results of this modeling exercise demonstrate the added capability that is afforded to GSSHA with the introduction of SEDLIB to the model.

References

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