Report for 2002FL4B: Application of a Multi-Scale, Multi-Process Hydrologic Model to the C-111 Basin in South Florida

- Other Publications:
  - Siqing Liu, S., Graham, W.D., and James, A. A hydrologic model coupling overland flow with flow in the unsaturated and saturated zones. American Geophysical Union 2002 Spring Meeting, 2002.
  - Liu, S., Graham, W.D., and Jacobs, J. The value of diurnal vs. daily climate forcings to capture soil water dynamics and actual evapotranspiration. In preparation.
  - Liu, S., Graham, W.D., and James, A. Monte Carlo simulation of coupled atmospheric, overland, and vadose zone flow processes. In preparation.
  - Liu, S., Graham, W.D., and James, A. Stochastic modeling of coupled overland and vadose zone flow. In preparation.

Report Follows:

Title: Application of a Multi-Scale, Multi-Process Hydrologic Model to the C-111 Basin in south Florida

Focus categories: HYDROL, MOD, WS

Keywords: Hydrologic models, ground water hydrology, watershed management.

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Congressional district: 5

Problems and Research Objectives:

Natural watersheds exhibit large degrees of spatial heterogeneity in topography, surface roughness, vegetation, and soil infiltration characteristics. This variability has significant influence on surface runoff, pollutant transport and soil erosion. Most existing studies of combined overland flow/infiltration studies have relied on coupling a simple one-dimensional kinematic wave model for overland flow with a simple infiltration model such as Green-Ampt infiltration equation, Phillip infiltration equation or the Smith-Parlange equation. In order to study coupled overland flow and infiltration processes, it was necessary to develop a physically based multidimensional model for the stochastic analysis of coupled surface and subsurface water flow.

Methodology:

As part of this study, a model was developed to couple overland flow with subsurface flow. The model includes three components to model hydrologic processes in different physical domains and two components that link flow between domains. The three physical domains in which flow is modeled are surficial, or overland, flow, subsurface (vadose and groundwater) flow, and evapotranspiration/precipitation. The linkages between domains incorporated into the model are transfer from overland flow and the unsaturated zone into the atmosphere, and infiltration from overland flow or precipitation into the subsurface. Monte Carlo and stochastic simulations were performed to determine how the variability of surface topography, surface roughness (through Manning's coefficient), and subsurface hydraulic conductivity affects runoff and infiltration.

Principal Findings and Significance:

Of the three parameters, variability in the saturated hydraulic conductivity has the most pronounced effect on runoff and infiltration, followed by surface roughness, and lastly surface topography.

High variability in subsurface conductivity, when compared to a uniform conductivity field, is manifested in the resulting surface runoff hydrograph in the following ways:

- Water begins to pond on the surface earlier as the degree of variability increases, and consequently runoff begins earlier.
- Runoff continues for a longer period of time as variability increases.

- The mean overland flow depth increases, particularly in the early stages of runoff.
- Total runoff volume increases as variability increases.
- The peak discharge of the hydrograph is lower compared with the uniform case.

Note that the earlier surface ponding time and the increase in total runoff volume imply that recharge to the saturated zone is lessened. This was confirmed during the simulations. The lower peak flow and increased total runoff volume were demonstrated in previous studies, and are reconfirmed here.

Variability in the Manning coefficient, affects the runoff hydrograph in the following ways:

- Surface runoff begins later for the random field.
- The mean ponding time is not significantly different between the random and uniform case.
- Runoff continues for a longer period of time as variability increases.
- The mean overland flow depth for the random field is not significantly different from the uniform case at early times (i.e., on the rising limb of the hydrograph), but depths are greater for the random field with increasing time. It was also found that the variability in water depth was higher as the degree of variability in Manning's coefficient increased.
- The peak discharge of the hydrograph is lower compared with the uniform case.
- Total runoff volume decreases as variability increases.

The lower total runoff volume indicated that recharge to the saturated zone increases as the surface roughness increases. The increase in mean overland flow depth indicates an increase in surface storage during a rainfall event, which in turn allows a greater period of time for infiltration to occur.

Variability in surface topography has the same effect on the hydrograph as variations in surface roughness. This result is not surprising, since variability in surface topography can be thought of as a larger scale expression of surface roughness.

Student Involvement:

One Ph.D. student was involved with this project for both 2001 – 2002 and 2002 – 2003.