A Watershed-Scale Groundwater-Land-Surface Model

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Motivation

Land Surface Models
- Ignore deep groundwater and lateral water flow

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Groundwater models
- Relatively simple evapo-transpiration scheme

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Coupled models of groundwater and land surface -may yield significant improvements in short-term climate and flood/drought forecasting

Model and data

- A land-surface module is incorporated into the Penn State Integrated Hydrologic Model or PIHM 2.0 (Kumar 2008)
  - Fully coupled surface water, groundwater, and land surface components
  - Land-surface scheme is mainly adapted from the Noah LSM (Ek et al. 2003)

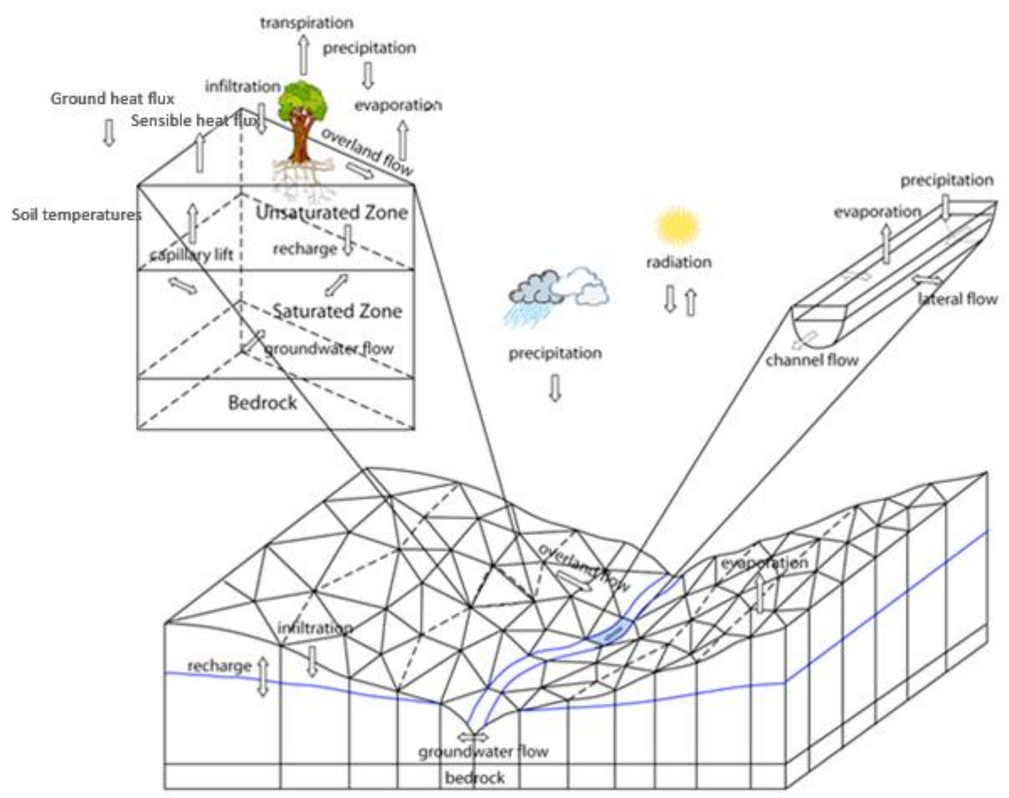

Figure 1 Schematic plot of new model illustrating unstructured grids and processes within each grid (adapted after Qu and Duffy 2007).

- Shale Hills Watershed in central Pennsylvania (0.08 km^2)
  - Shale Hills Critical Zone Observatory is a small-scale site for testing the theory with an array of land-surface and subsurface sensors.
  - 598 grids with an average grid size of 128 m^2

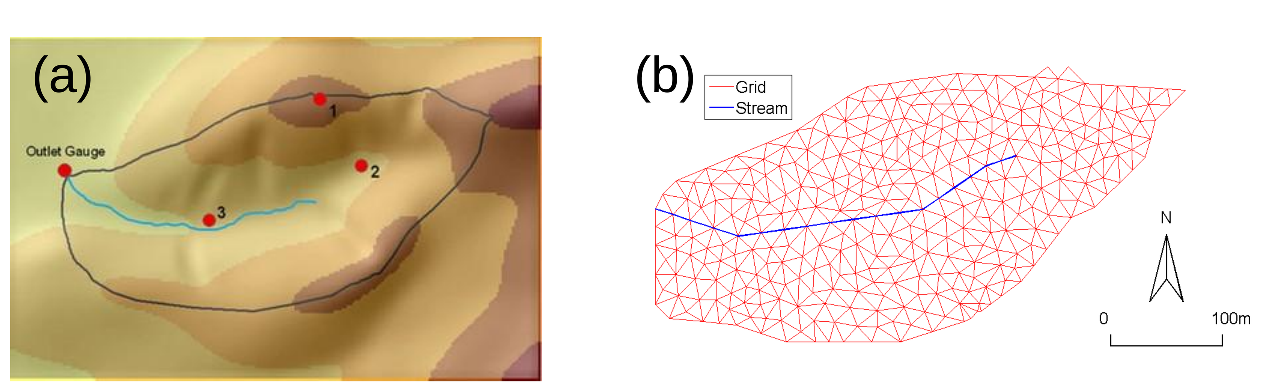

Figure 2 Map (a) and model grid setting (b) of Shale Hills Watershed. The locations of instrument arrays are labeled in (a).

- Uniform soil and land-cover distribution
- Driven by North American Regional Reanalysis (NARR)
- Simulation from 00 UTC 1 May to 00 UTC 1 June 2009

Results

Groundwater predictions

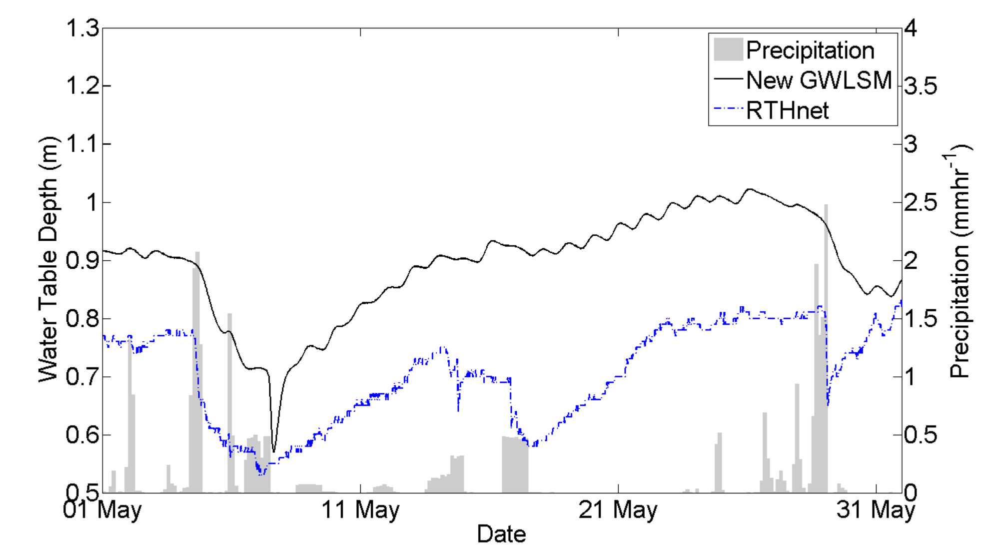

Figure 3 Comparison of water table depth (the distance from land surface to water table) between the GWLSM simulation and measurements of Real-Time Hydrologic monitoring network (RTHnet) groundwater level sensor at Instrument Array 3 (Figure 2).

- Model is insensitive to small amounts of precipitation
- Results could be improved by
  - Using more sophisticated hydrology (in development), and
  - Better optimization

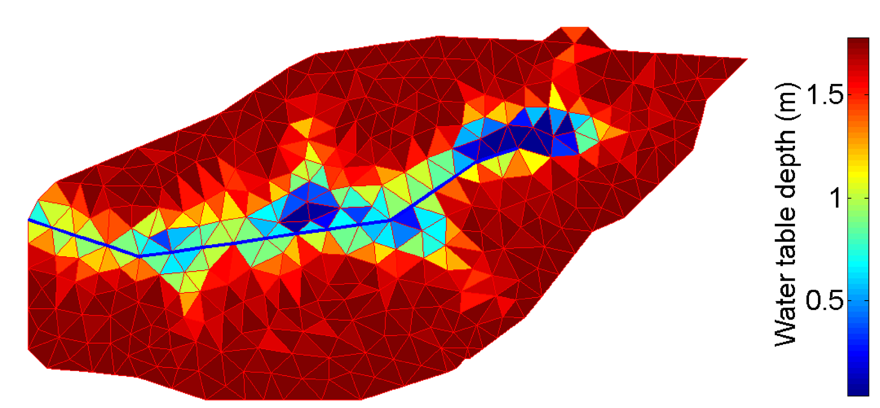

Figure 4 Spatial distribution of water table depths averaged over the entire simulation period.

Surface energy balance predictions

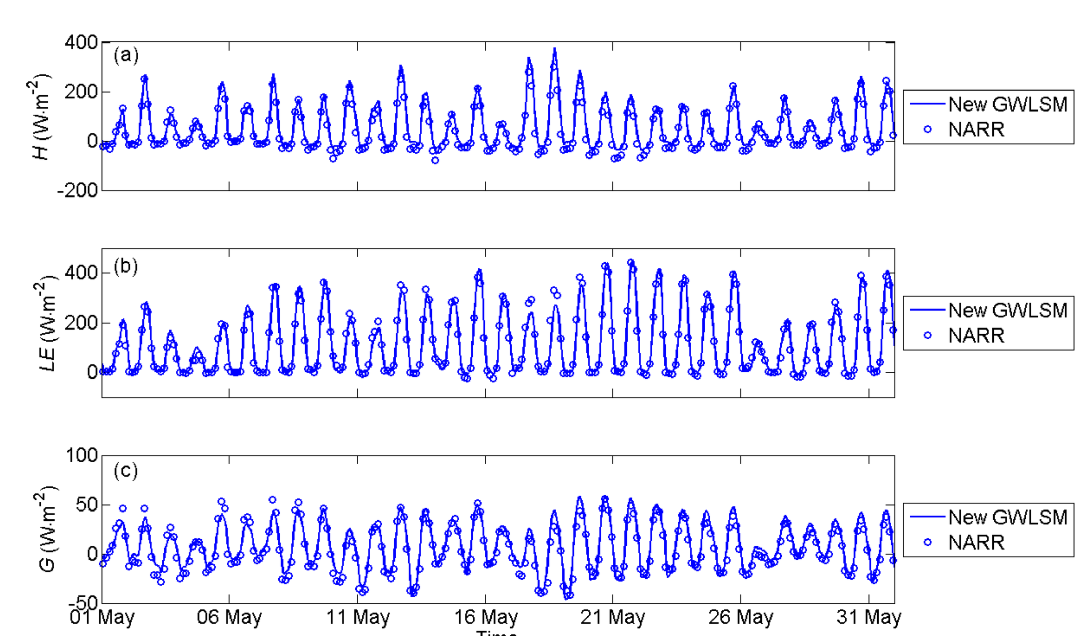

Figure 5 The comparison of (a) sensible heat fluxes, (b) latent heat fluxes, and (c) ground heat fluxes between new GWLSM simulation and NARR data. The heat fluxes are averaged spatially over the whole domain.

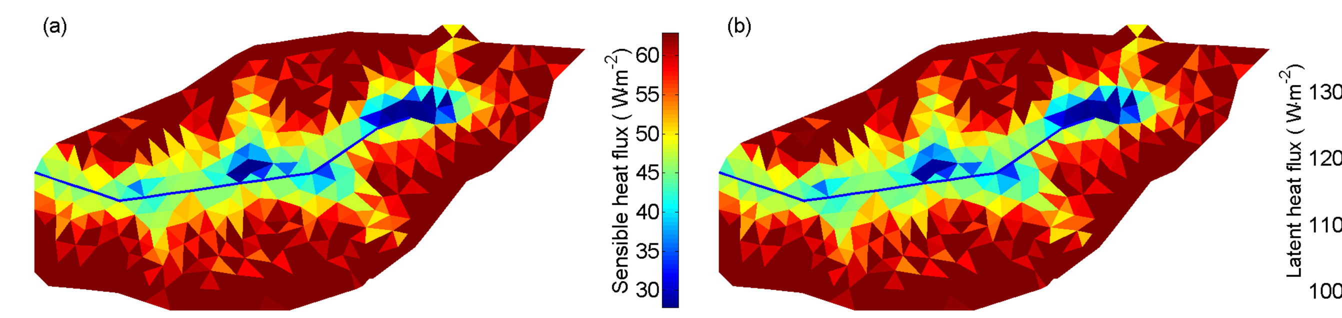

Figure 6 As in Figure 4, but for sensible heat flux (a) and latent heat flux (b).

Correlation between groundwater and land-surface variables

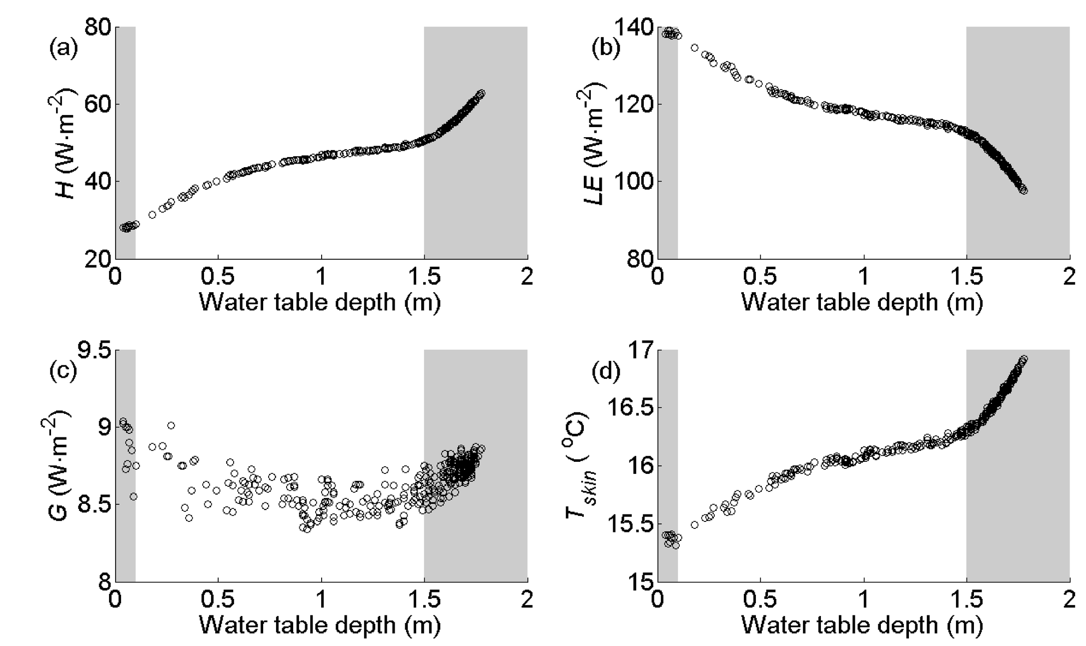

Figure 7 Simulated sensible heat flux (a), latent heat flux (b), ground heat flux (c), and skin temperature (d) as functions of water table depth. Each point represents a temporal average over the entire simulation period.

- Land surface variables are related to groundwater table, but in a complex way
- Land surface variables vary differently with water table depth in different water table depth ranges
- Results are different from prior work (e.g., Kollet and Maxwell 2008)

Future Work

- Compare model with eddy-covariance measurements
- Incorporate data assimilation module into model and test the assimilation of eddy-covariance and sap flux measurements, surface temperature, water table depth, and channel flow
- Test on different spatial scales
- Evaluate impact of model on flood/drought prediction at scales up to the Juniata River Basin (~8800 km^2)

Works Cited

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Kollet, S. J., and R. M. Maxwell. 2008. Capturing the influence of groundwater dynamics on land surface processes using an integrated, distributed watershed model. *Water Resour. Res.*, 44: W02402.

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