Coupled Surface–Subsurface Modeling across a Range of Temporal and Spatial Scales

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A Blueprint for modeling fully integrated surface, subsurface, and land-surface processes that were originally put forth 40 years ago (Freeze and Harlan, 1969) is now becoming a reality. Although the first truly coupled terrestrial hydrologic and energy cycles. Updated numerical and computational technologies have enabled new approaches for modeling these coupled interactions. While these models all take different numerical, discretization, and even coupling approaches, they all share the common goal to rigorously, mathematically model the terrestrial hydrologic and energy cycle as an integrated system. Research addressing these issues encompasses a range of scales and includes a variety of processes. Papers in this special section present theoretical, process-description advancements to address some of the current research questions in coupled modeling.

This special section of Vadose Zone Journal is composed of five invited contributions, which were presented at the 17th Computational Methods in Water Resources 2008 Meeting held in San Francisco, CA (June 2008). The suite of papers highlights hydrologic modeling approaches and their use to understand and feedbacks of coupled processes across the land-surface interface. The contributions provide a cross-section of state-of-the-art physics-based modeling and include numerical studies that address the water and energy cycles in an integrated fashion over a wide range of time scales (diurnal to decades) and spatial scales (column to basin). Papers cover a range of subtopics, including watershed dynamics, interactions with the atmosphere.

These papers each address current challenges in coupled modeling: the disparate timescales between surface and subsurface systems, how to better integrate models and observations, inclusion of broader-reaching phenomena such as energy transport or human–water interactions, and expanding traditional approaches to be more mathematically accurate.

To better understand and represent the disparate timescales inherent in the surface–subsurface system, Park et al. (2009) present an implicit, adaptive, time-integration scheme for a fully integrated model (HydroGeoSphere). They use this scheme to decouple the time steps of the surface and subsurface components with a significant improvement in efficiency and minor loss of accuracy. To better couple model and observations Camporese et al. (2009) embed a fully integrated hydrologic model (CATHY) into a data-assimilation framework. They compare an ensemble Kalman filter (EnKF) to a Newtonian nudging (NN) technique for a small catchment in Belgium and demonstrate that the EnKF method outperforms the more straightforward NN approach.

Two articles expand the types of physics normally included in coupled modeling. Kollet et al. (2009) present a model of fully coupled water and energy balance (ParFlowE) that includes conductive and convective heat transport coupled to radiation balance at the land surface, something previously unexplored in integrated modeling. They compared their model simulations to observations collected from a field site in the Netherlands. These papers each address current challenges in coupled modeling: the disparate timescales between surface and subsurface systems, how to better integrate models and observations, inclusion of broader-reaching phenomena such as energy transport or human–water interactions, and expanding traditional approaches to be more mathematically accurate.

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