SYSTEMS-BASED MODEL FOR SUBSURFACE AQUIFER RECHARGE AND IRRIGATION MANAGEMENT UNDER CONDITIONS OF UNCERTAINTY

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Climate drives the hydrological cycle and any change in climate will have consequential changes in the hydrological cycle. In semi-arid and arid regions, for example, precipitation, evapotranspiration, and aquifer recharge are often the key terms in the water balance of a catchment basin. The water balance will thus be sensitive to changes in temperature and precipitation associated with changes in regional and global climate. Because water retention is an important issue in such locations, groundwater recharge may be the most significant or lasting portion of the water balance. Natural groundwater recharge may be increased by irrigation and other artificial techniques involving water reuse, reinjection, and infiltration. The successful management and balance between all forms of recharge, withdrawals, and surface irrigation is important for the sustainable management of scarce water resources in such locations.

Because numerical simulations have become increasingly widespread, local, national and global policy-makers rely quite often on quantitative tools to frame and support water management decisions and strategies. However, numerical models typically have uncertainty associated with their inputs (parametric, conceptual and structural), leading to uncertainty in model outputs. Effective abstraction of model results for decision-making requires proper characterization, propagation, and analysis of that uncertainty. In the evolving sophistication of models in use today, propagation of uncertainty may require the interaction of various complex multiphysics model components that address, for instance, subsurface water flow, surface water runoff processes, land surface processes, and regional climate interactions. Although such models have been used to address the water resources problems with moderate successes, their application as drivers for uncertainty quantification will be correspondingly sophisticated and more computationally complex.

In this paper, we present a systems-based surrogate model that can handle for instance: 1) catchment flow, 2) wave propagation, 3) aquifer recharge and 4) water intakes and diversions for irrigation use and management. Based on systems analysis of surface and subsurface processes a set of equations were derived and numerically solved. These equations call for aggregate parameters that are site-specific and are inverted from specific observations. We also present a novel hybrid modeling scheme designed for propagating uncertainty and performing a global sensitivity analysis, while maintaining the quantitative rigor of the analysis by providing confidence intervals on predictions. The combined systems-based hydrological and uncertainty propagation model enables the assessment of uncertainty arising from endogenic variables, such as physical flow parameters, as well as that arising from exogenic variables that reflect, for example, climate change model predictions of precipitation and temperature. Outside of its more straightforward approach, such a model can also be used as precursor for further uncertainty exploration using more complex models. To illustrate its applicability, the model is used to assess the impact of irrigation by spreading on the recharge of the subsurface aquifer under different irrigation protocols and management conditions.

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