The value of tightly-integrated hydrologic and river-operations models on water resources planning and management

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Examples of hydrologic/river-operations modeling couplings found in the scientific literature have adopted a “feed-forward,” or explicit, approach. For these explicit coupling approaches, the hydrologic model passes information regarding groundwater/surface-water (GW-SW) fluxes to the river-operations model without considering feedbacks. However, nonlinear feedbacks between water operations and hydrology are significant, and explicit coupling can lead to large mass balance errors. Our recent published work relies on Implicit coupling between the water operations model MODSIM and the hydrology model MODFLOW using Picard nonlinear iteration and this approach provided convergence and near-zero mass balance errors. After the release of MODSIM-MODFLOW, integration of MODSIM with GSFLOW for enhanced surface water simulation capabilities relative to MODSIM-MODFLOW began. GSFLOW is the integration of MODFLOW with the Precipitation-Runoff Modeling System (PRMS). Through its integration with MODSIM, the physically-based distributed-parameter model GSFLOW can more readily simulate water resources planning and management in the context of reservoir operations, river diversions, and groundwater pumping for meeting water demands by agricultural, municipal, and other water-use sectors. MODSIM simulates complex administration of water-right and agreements in large-scale surface-water networks, such as the prior appropriation doctrine (i.e., “first in time, first in right”). Applications of MODSIM-GSFLOW to two western basins, including the Carson River Basin in California and Nevada, and the Deschutes River Basin in Oregon, have enabled direct exploration of groundwater management action on river-operations, and conversely, the impact of alternative surface-water management scenarios on groundwater sustainability and stream capture by wells. Moreover, presented results show the impact of projected climate warming on individual water-rights, including conjunctive use of surface water and groundwater. Although junior water rights experience the largest surface-water delivery shortfalls expressed as a percentage, the largest future shortfalls by volume are realized by mid-priority water rights, with some level of impact to the most senior water-righted land parcels.