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The impact of water management on watershed self-organization

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Temporal and spatial self-organization has been demonstrated for hydrologic variables including soil moisture, evapotranspiration and groundwater depth across many hydrologic catchments. Previous work has demonstrated that aquifers act as low pass filters, removing high frequency variability while allowing low frequency variability to pass through. While much research has focused on connections between water management and groundwater-surface water interactions, few studies have considered the impact of water management, specifically groundwater pumping and irrigation, on the scaling behavior of the natural system. We address this gap by simulating moisture dependent groundwater fed irrigation in the Little Washita Basin (Oklahoma, USA) using the fully integrated hydrologic model ParFlow-CLM. We present results from two simulations each spanning twenty years at hourly resolution, one with irrigated agriculture and one without. The model is forced with heterogeneous historical meteorological forcings and is populated with realistic land cover and subsurface units. Model results demonstrate scaling behavior for variables like latent heat flux and water table depth similar to other studies. Additionally, gridded model outputs allow for direct analysis of spatial patterns in temporal organization not possible with previous observational studies. Analysis shows clear spatial patterns in scaling. For example, water table depth and latent heat flux have the most similar scaling coefficients along the river, where groundwater and surface water are closely interacting. While scaling behavior is also observed in the irrigated agriculture scenario, there are notable differences in frequency behavior. Pumping and irrigation attenuate low frequency (inter-annual variability) while amplifying high frequency (intra-annual variability). Water management operations increase persistence in both groundwater and surface water systems and expand the spatial area where the two are closely connected. Results highlight potential impacts of managed agriculture on natural system dynamics that go beyond traditional considerations of water availability. Feedbacks between management operations and underlying system variability are an important consideration for water managers because system reliability is largely a function of natural variance.