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Development of a Coupled 3D Groundwater-Vegetation Model for Coastal Wetlands

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Mangrove forests are mainly found in the intertidal zone. Their ability to live in saline water enables them to outcompete non-mangrove vegetation in harsh and specific coastal environment. Nevertheless, they can still be invaded by alien mangrove species in suitable hydrological conditions, possibly resulting in more fragile ecosystems. Subtropical mangrove ecosystem demonstrates high variability in mangrove growth and hydrological conditions. However, their interactions are not well-understood, especially for the mangrove interspecific competition in varying groundwater conditions. To address this issue, the present study developed a coupled three-dimensional groundwater-vegetation model based on MANTRA (MANHAM-SUTRA) to simultaneously simulate groundwater hydrodynamics and mangrove distribution. The developed model was then applied to a subtropical mangrove swamp invaded by Sonneratia spp. in Mai Po Nature Reserve, Hong Kong, China. Vegetation domain is updated yearly using the annual mangrove areas extracted from remote-sensing images from 2000 to 2018. Then, multidecadal simulations were performed to validate the model in simulating the interaction between groundwater and mangrove growth. For the piezometric head, all RMS errors are smaller than 0.2 m and the correlation coefficients are larger than 0.86, which proves the effectiveness of the model in groundwater level simulation within Mai Po. The seasonal variations in the groundwater salinity were also well captured in both the fringe forest and the mudflat. The simulated biomass of Sonneratia spp. is mainly distributed at the river outlets, which is also in good agreement with the historical measurements. The validated model can then be used to predict the invasion and the distribution of the exotic mangrove species in the context of future environmental changes for better management of mangrove swamps. Since Sonneratia is a common alien species in southern China, the model can also be used for regional management of mangrove invasion and conservation of native species. The insights obtained from this study may also provide references for other similar studies examining the interaction between coastal groundwater and vegetation.