Geophysical Research Abstracts
Vol. 12, EGU2010-3967, 2010
EGU General Assembly 2010

Modeling Hydrologic and Vegetation Responses in Freshwater Wetlands

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Wetlands constitute 6 – 7 % of the Earth's land surface and provide various critical ecosystem services such as purifying the air and water, mitigating floods and droughts, and supporting wildlife habitats. Despite the importance of wetlands, they are under threat of degradation by human-induced land use changes and climate change. Even if the value of wetlands is recognized, they are often not managed properly or restored successfully due to an inadequate understanding of the ecosystems and their responses to management scenarios. A better understanding of the main components of wetlands, namely the interdependent hydrologic and vegetation systems, and the sensitivity of their responses to engineering works and climate change, is crucial for the preservation of wetlands. To assess these potential impacts, a model is developed in this study for characterizing the coupled dynamics between soil moisture and plant biomass in wetland habitats. The hydrology component of the model is based on the Richards' equation and simulates spatially-varying groundwater movement and provides information on soil moisture at different depths. The plant growth component of the model is described through an equation of the Lotka-Volterra type modified for plant growth dynamics and is adapted from published literature. The two components are coupled via transpiration and ecosystem carrying capacity for plants. Transpiration is modeled for both unsaturated and saturated zones, while the carrying capacity describes limiting oxygen and subsequent nutrient availability in the soil column as a function of water table depth. Vegetation is represented by two species characteristic of mudflat herbaceous plants ranging from facultative wetland to upland plants. The model is first evaluated using a simplified domain and the hydrological information available in the RG2 site of the Everglades wetlands region. The modeled water table fluctuations in general are comparable to field data collected on-site, indicating the potential of the model in capturing soil moisture dynamics. Further application of the model for impact assessments demonstrates that drainage of wetlands resulting in groundwater drawdown is expected to produce appreciable effects on vegetation biomass response. The model developed in this study simulates the coupled and spatially-varying groundwater movement and plant growth dynamics, which allows researchers to better understand and protect the integrated hydrologic and vegetation systems of wetlands worldwide.