Numerical Model Development to Address the Effects of Climate Change on Coastal Hydrology and Ecology in Southern Florida

Eric D. Swain

U.S. Geological Survey, Florida Integrated Science Center, Ft. Lauderdale, FL, USA

Sea-level rise is an important climate change issue for coastal regions worldwide, affecting freshwater habitats, urban flooding, and saltwater intrusion in aquifers. The ability to predict how climate change affects ecosystems is complicated by environmental and hydrologic interactions that occur in urban, agricultural, and natural areas; as well as surface-water and ground-water connections, topographic variation, and other factors. All such interactions occur in southern Florida ecosystems, where complex hydrologic models have been developed to predict how restoration efforts will affect the Everglades. Model capabilities have steadily advanced in recent years, ranging from the coupling of dynamic surface-water and ground-water code to incorporating salinity and heat transport. The resulting computational tools are well suited to represent and predict how climate change may affect hydrologic and ecological systems.

The Flow and Transport in a Linked Overland/Aquifer Density-Dependent System (FTLOADDS) modeling code incorporates a two-dimensional hydrodynamic surface-water model coupled with a three-dimensional ground-water model to simulate the interconnectivity between the two hydrologic systems. Two primary concerns of global climate change are increased sea temperature and increased salinity induced by sea-level rise, both of which are simulated by FTLOADDS through heat and salt transport. The Intergovernmental Panel on Climate Change currently estimates that temperature will increase between 1.1 and 6.4 °C and sea-level will rise between 18 and 59 cm during the 21st century. By accurately simulating the complex hydrologic interactions resulting from these projected increases, the FTLOADDS code can be used to quantify local and regional effects on ecosystem-controlling parameters.

The FTLOADDS code is currently being used in several applications in southern Florida. One application, Tides and Inflows in the Mangroves of the Everglades (TIME), is currently being used to determine how different Comprehensive Everglades Restoration Plan (CERP) scenarios may affect Everglades National Park ecology and hydrology. TIME has been interfaced with the ALFISHES fish population dynamics model to examine how restoration-related hydrologic changes may affect fish abundance in the TIME domain. A FTLOADDS application to the coastal Biscayne Bay area is being connected with the TIME model to simulate hydrologic change along the entire southeastern coast of Florida, including interactions between undeveloped and urban areas. The westernmost application of FTLOADDS is in the Ten Thousands Islands (TTI) area. The TTI application is being used to examine potential restoration effects in the Picayune Strand area; specifically, the effects on Manatee refugia. The TTI application has been integrated with the Florida manatee individual-based ecological model. The relatively rapid and easily observed response of manatees to coastal changes in salinity, water temperature, and seagrass quality makes them a valuable indicator species. The manatee model, therefore, is an informative tool for addressing climate change and predicting possible effects to the ecosystem.

The applications presented herein can be used to provide insight into how sea-level rise and temperature change may affect hydroperiods, inundation patterns, inland salinities, and minimum/maximum water temperatures—all of which are factors that affect many plant and animal species. One of the first FTLOADDS applications used to examine the effects of sea level rise is the Southern Inland and Coastal Systems (SICS) application, the domain of which is located in the southeastern part of the TIME area. When a minor sea-level rise of 8 cm was applied to the SICS tidal boundary, salinity values at a number of coastal sites increased, but the temporal pattern of the salinity increase varied between locations. At the coastal Taylor River site, minimum salinities were about 5 psu higher than values without sea-level rise applied, although the peak salinities did not change substantially. A different pattern was observed farther east at West Highway Creek, which has a weaker hydraulic connection to the Everglades. At this site, minimum salinities were similar to corresponding minimum salinities without sea-level rise applied, but peak salinities increased by more than 5 psu. Circulation patterns and available freshwater primarily determined how sea-level rise affected salinity in the different areas.

The integration of the TTI application with the manatee model and the TIME application with the ALFISHES model provides an informative platform for predicting and assessing the collective effects of climate change and restoration efforts. Applying these techniques to other areas and species, and with different restoration, sea-level rise and temperature change scenarios will help resource managers, scientists, and policy makers effectively manage protected Everglades landscapes in the following ways:

- Southeastern Florida is threatened by sea-level rise and its effects on urban areas, flood control practices, water supplies, and undeveloped areas. Simulations can predict how climate change affects landscapes, species populations, and ecosystems in the region.
- The Greater Everglades is highly affected by human activity, and climate change will add uncertainty and complexity to restoration and management efforts in these landscapes. Simulations can predict how the effects of climate change differ under recently implemented and planned restoration scenarios as compared to current ecosystem conditions.
- Given that restoration implementation is in its early stages, the simulations provide insight into whether additional restoration scenarios not yet considered might best protect ecosystems and species against additional expected environmental stresses caused by climate change.

Contact Information: Eric Swain, U.S. Geological Survey, Florida Integrated Science Center, 3110 SW 9th Avenue, Fort Lauderdale, FL 33315 USA, TEL: 954-377-5925, Fax: 954-377-5901, Email: edswain@usgs.gov